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Accelerating Futures

Tracing expectations of a particle accelerator in the making

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Noah Münster, BA

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Abstract English

CERN (European organization for nuclear physics) has started investigating the feasibility of a next-generation particle accelerator: the Future Circular Collider (FCC). With an expected diameter of more than 100km and an estimated cost of more than 20 billion Euros, the project will require the support of many social, political, and technoscientific actors. The discourse surrounding the FCC is full of promises and expectations of novel epistemic insights, societal benefits, economic growth, and innovation. This thesis investigates the future making and justificatory narratives circulating around the FCC. Drawing on documents ranging from feasibility studies, public relation materials, and popular science magazines, I analyse the different orders of worth and the implicated politics of technoscientific futures surrounding the project. Doing so, I show how CERN's infrastructural upscaling is not just a technoscientific but also a social process. My research suggests that, with the FCC, CERN is narratively positioning itself as an institution that will not only produce excellent science but will also create benefits for society. By presenting the FCC as a project to foster technological innovations, European competitiveness in the knowledge economy, and a peaceful global collaboration in a fast-changing world, CERN is renegotiating the value of basic research and its relation to Europe.

Abstract German

CERN (Europäische Organisation für Kernphysik) hat damit begonnen, die Machbarkeit eines Teilchenbeschleunigers der nächsten Generation zu untersuchen: den Future Circular Collider (FCC). Mit einem voraussichtlichen Durchmesser von mehr als 100 km und geschätzten Kosten von mehr als 20 Milliarden Euro würde das Projekt die Unterstützung vieler gesellschaftlicher, politischer und technowissenschaftlicher Akteure erfordern. Der Diskurs um den FCC ist voll von Versprechungen und Erwartungen in Bezug auf neues Wissen, gesellschaftlichen Nutzen, Wirtschaftswachstum und Innovation. In dieser Masterarbeit werden jene zukunftsgestaltenden Narrative untersucht, die den FCC rechtfertigen. Anhand von Dokumenten, die von Machbarkeitsstudien über PR-Materialien bis hin zu populärwissenschaftlichen Zeitschriften reichen, analysiere ich die verschiedenen Wertesysteme und die damit verbundene Politik technowissenschaftlicher Zukünfte, die das Projekt umgeben. Auf diese Weise zeige ich, dass die infrastrukturelle Weiterentwicklung des CERN nicht nur ein technowissenschaftlicher, sondern auch ein sozialer Prozess ist. Meine Forschung legt nahe, dass sich CERN mit dem FCC diskursiv als eine Institution positioniert, die nicht nur exzellente Wissenschaft produziert, sondern auch Vorteile für die Gesellschaft schafft. Indem es den FCC als ein Projekt zur Förderung der technologischen Innovation, der europäischen Wettbewerbsfähigkeit in der wissensbasierten Wirtschaft und der friedlichen globalen Zusammenarbeit in einer sich schnell verändernden Welt präsentiert, verhandelt CERN den Wert der Grundlagenforschung und seine Beziehung zu Europa neu.

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Acronyms

ALICE	A Large Ion Collider Experiment
CEPC	Circular Electron-Positron Collider
CERN	European Organization for Nuclear Research
CLIC	Compact-Linear Collider
CMS	Compact Muon Solenoid Experiment
EC	European Comission
EU	European Union
ERA	European Research Area
ESPP	European Strategy for Particle Physics
FAQs	Frequently Asked Questions
HEP	High Energy Physics
ILC	International Linear Collider
LEP	Large Electron-Positron Collider
LHC	Large Hadron Collider
LHCb	Large Hadron Collider beauty experiment
FCC	Future Circular Collider
FCC-ee	electron-positron collider
FCC-hh	hadron collider
STS	Science and Technology Studies
TeV	Teraelectronvolt
YQA	Your Questions Answered

1. Introduction

CERN (Conseil Européen pour la Recherche Nucléaire) is considered one of science's biggest success stories. After the second world war, the idea emerged to create a peaceful collaboration in particle physics that would rival efforts by the most prestigious US science institutions and bring together a disintegrated Europe. Since its foundation in 1954, the European organization for particle physics has been valued for more than just its scientific contributions. As famously formulated by the French physicist Louis-Victor de Broglie in 1949 at the European cultural conference in Lausanne, the vision for CERN was to create an infrastructure "where it would be possible to do scientific work, but somehow beyond the framework of the different participating states". Such a European collaboration was imagined to be made possible by the "universal and very often disinterested nature of scientific research" (Cited in Maiani, 2004). Science, imagined as "neutral", was envisioned to enable a collaboration that transcends national differences.

Today, CERN has become the largest laboratory for High Energy Physics (HEP) in the world, involving more than 17000 people from over 110 countries in the use and maintenance of its infrastructure. Located between the border of France and Switzerland, about a 30-minute drive from the small town of Geneva, CERN seeks to investigate the constitution of nature on the smallest scales possible with the help of huge, complex machinery. The laboratory makes use of so-called particle accelerators that smash together particles with ever increasing energies and detector machines that capture and study the then occurring collisions in ever more detail. Currently, most of the research at CERN is done using the Large Hadron Collider (LHC), whose particle beams are directed to collide at the center of four particle detectors: ATLAS, CMS, ALICE and LHCb. The LHC's perhaps most prominent discovery was the so-called Higgs Boson in 2012, the fundamental particle to finally complete the standard model of particle physics (a theory to describe and classify the fundamental forces and particles that make up all known matter).

CERN is often portrayed as a place of immense scale. As Martin Beech (2010, p. viii) notes in his popular science book on CERN, the LHC is a machine that „can only be described in superlatives". This does not only apply to the enormous accelerator and detector technologies used to collide and study particles. It can also be seen in the scientific claims put forward by particle physicists. For instance, anthropologist Sophie Houdard (2015, p. 82) speaks of the LHC as a „high tech cosmogram devoted to commensurate the cosmos and particles, the infinitely big and the infinitely small". In many ways, CERN has become regarded as a quasi mythical place around which many fantastic stories are woven. In its efforts to study phenomena on incredibly small scales, particle physics puts forwards grand and universal assertions about nature, thereby bridging between particles, the fundamental constitution of matter, and questions about the origins of the universe. According to Sharon Traweek (1988, p. 2) particle physicists „bring news of another world: hidden but stable, coherent and incorruptible." For her, the "emotional power of cosmology" is a major source of legitimacy for High Energy Physics: "in times of bewildering and threatening change, this gospel, however esoteric, has a very deep appeal (p. 2). Western society is fascinated by these “promethean heroes in the search for truth”, who, taking on the roles previously held by priests, unravel the mysteries of the universe (p. 2).

To continue its quest to study the fundamental constitution of nature, CERN needs to continuously scale up its infrastructure, constructing particle accelerators that steadily increase in size and energy and building detectors that collect information in ever more sophisticated ways. As the historian of science John Krige (1996, p. 4) puts it: “the kind of physics one can do depends on the kind of machine that one has at one‘s disposal“. In the case of High Energy Physics, new scientific insights and technological innovations are thus closely correlated. But the currently active LHC’s capacity to produce new insights will soon reach its limits. The accelerator will stop its operation in 2036 when its energy range is estimated to have been sufficiently studied. But what does the end of the LHC mean for CERN and the field of particle physics more general? Particle physicists claim that there are still many unresolved questions beyond the standard model that urgently require answers and thus need further investment in large accelerator machines. In their view, the best way to study these questions is to go to even higher energies by constructing even bigger accelerators. In this thesis, I will investigate one such attempt to secure the future of High Energy Physics: CERN’s proposal to construct the Future Circular Collider (FCC) as post-LHC particle accelerator project. Specifically, I will look at the justificatory narratives circulating around the FCC. What kind of future(s) justify this new machine? What promises not only for science but also for society do such large research infrastructures come with? And how do proponents of the FCC craft plausible narratives that work with and address the multiple uncertainties that come with the project?

1.1. The Future Circular Collider

On June 19, the CERN Council released its 2020 update of the European Strategy for Particle Physics (ESPP). The ESPP, drafted by the European Strategy Group, is the major publication that sets the agenda for particle physics in Europe. Nearly seven years after the first strategy update (2013), the document gives clear insights into the desired European future in High Energy Physics. Setting the tone for particle physics after the LHC, it argues that for Europe to stay internationally competitive, there is a need for continuous investments into future projects at CERN. According to the strategy:

> *Europe, through CERN, has world leadership in accelerator-based particle physics and related technologies. The future of the field in Europe and beyond depends on the continuing ability of CERN and its community to realize compelling scientific projects. This strategy update should be implemented to ensure Europe’s continued scientific and technological leadership.* (European Strategy Group, 2020, p. 7)

The 2020 update of the ESPP emphasizes as "high-priority future initiative" to investigate the possibility of a next, bigger, particle accelerator at CERN that is able to reach even higher levels of energy: "Europe, together with its international partners, should investigate the technical and financial feasibility of a future hadron collider at CERN with a centre-of-mass energy of at least 100 TeV and with an electron-positron Higgs and electroweak factory as a possible first stage" (p. 8).

Following the European Strategy's recommendations, CERN has initiated a series of ongoing feasibility studies, proposing the FCC as a new particle accelerator that could potentially succeed the now active LHC. Partly funded by the European Commission, these studies look at the technical, epistemic, and financial feasibility of the collider. The FCC would be 100 kilometres in diameter, surpassing the scale of the LHC manyfold (25 kilometres). Imagined to be built in a tunnel below Lake Geneva, its construction would only be finished in 2040, with costs exceeding 25 billion Euros. The FCC promises to produce science until the end of the 21. Century and is intended to both study known physics in more detail and probe for new phenomena at higher energies.

Despite its long-term perspective, there is a sense of urgency around the project: even though the current LHC is still very much active and will not be decommissioned for another ten years, the temporalities of accelerator construction make it necessary to begin R&D efforts and feasibility studies already now. But whether the FCC will ever be constructed is still to be seen: the future of CERN and the field of High Energy Physics is still uncertain. The proposal for CERN's infrastructural upscaling comes with many technical, epistemic, socioeconomic and infrastructural challenges that first need to be addressed.

1.2. Justifying a new accelerator

In 2010, the year in which the LHC achieved its first collision, experimental particle physicist and collaborator in the Compact Muon Solenoid (CMS) experiment Tomasso Dorigo (2010) articulated his vision for the future of his field in a blog post titled „particle physics in 2020". He speculated that by 2020 particle physics might be „facing the specter of foreclosure: if no new physics is seen beyond the standard model at the scale of 14TEV [Teraelectronvolt], no expensive new project may be able to justify its existence". For Dorigo, this is the realistic but also most worrisome scenario. He actually hopes that he is wrong. Dorigo rather wishes that, in the next ten years, „the LHC - i.e. ATLAS and CMS, including myself together with the other 2500 collaborators in my experiment - will indeed soon stumble in a host of new particles, magically turning on our detectors as a Christmas tree. Wouldn't it be wonderful". Such fear that the LHC will lack new and interesting insights seemed to be a widely spread sentiment in particle physics. As Aripta Roy (2011) writes in her ethnographic study of CERN, particle physicists are „terrified that nothing but the Higgs will show up and conclude the Standard Model paradigm of particle physics. If physics today delivers on all the goals of explanation, then it would be dead" (p. 28). Today, in 2022, it seems like Dorigo's fearful predictions have come true. Besides the Higgs Boson, theorized already in the 1960s, no new particles and no new physics beyond the standard model have been discovered. There is uncertainty about what will come next (Hossenfelder, 2019). But is it really true that as a consequence, particle physics is "dead" and no new expensive project may justify its existence? If we take CERN's proposal to construct a new mega accelerator project seriously, the opposite seems to be the case. So how does a basic research project on such a scale justify itself in today's European scientific, sociopolitical and economic context?

The most obvious ground of justification is the idea that basic research justifies itself through its science alone. This understanding is firmly engrained in the narratives around High Energy Physics. For instance, in a renowned conversation, Bob Wilson, the first director of the US High Energy Physics laboratory Fermilab in Chicago, was asked: „what will your lab contribute to the defense of the US"?. His infamous response was; „Nothing, but it will make it worth defending" (Ouellette, 2011). In a similar manner, anthropologist Sharon Traweek (1988) claims that HEP stands outside of classical justificatory demands one would expect of a project on such a scale. As she puts it, „the extraordinary scale and costliness of much physics research if anything reinforces its cultural value. The great accelerators, for example, are like medieval cathedrals: free from the constraints of cost-benefit analysis." (p. 2).

But does this clear-cut separation between scientific and social concerns such as costs and benefits also hold true in the contemporary European context? If we follow one of science and technology studies' (STS) main insights, it is impossible to separate science and society. They are always co-produced (Jasanoff, 2004). This is only reaffirmed by historian of CERN John Krige (1996, p. 4), who argues that new accelerator machines are not only about doing better science but always also an „expressions of power and prestige: power to shape and to dominate the research frontier, power to compete effectively at the world level, power to raise money from governments". In other words, it is impossible to separate basic research from society and its interests, values, culture, economics and politics.

The entanglement of science and politics is also reflected in the history of CERN. In its early years, a variety of factors facilitated governments' support for the institution. Its prestige, Europe's competition with the US, the promise of novel technology and expertise, or more generally its political importance to foster international security and cooperation. But since the 1960s, even though experiencing a huge expansion, support for CERN „was no longer unconditional" (Krige, 1996, p. 13). Increasingly, not only epistemic but also technological returns in the form of spin offs for industry were demanded: „CERN was not to be an ‚ivory' tower surrounded by the protective moat of a cooperative Council. It was increasingly part of European scientific, technological, industrial and political integration" (p. 34). As such, from the 1970s onwards, the laboratory started to increasingly display its technological achievements. It also started to publish reports on the economic return of the member state's investments and on the medical and other applications the laboratory has produced. In other words, while CERN still justified itself by doing excellent research in High Energy Physics, it also needed to think of new forms of legitimacy.

But Krige and the CERN history team he was part of wrote their history of the institution more than 25 years ago. So how has the relationship between basic and applied research and between science and society changed since then? I believe such a question might best be approached by studying a basic research project that promises to be one of the biggest and most expensive scientific endeavors of all time. The debate around the (potential) construction of the FCC offers a unique opportunity for STS research as it lays bare the entanglements of scientific and sociopolitical processes. Moments of transformation in which new sociotechnical projects might emerge are full of uncertainties and controversies. As such, they reveal the social processes that are inevitably part of scientific projects. Interests and values suddenly become visible, actors make their opinions explicit, a project moves into the public arena, newspapers start to follow the events and policymakers get involved. As Galison and Helvey (1992, p. 2) argue, "the expansion of science has forced scientists to confront the world outside of their disciplines".

In this thesis, I am interested in how futures are constructed and used to legitimize the construction of the FCC. Specifically, I explore how the FCC's justification is co-produced with questions about CERN's (European) identity, culture, economy and geopolitics. Here I am attentive to how justificatory narratives deal with the multiple challenges and uncertainties that are perceived to accompany the new collider. These uncertainties revolve around the above-described lack of theoretical predictions for new scientific phenomena. But as my thesis will show, they are also about the FCC's socioeconomic worth, a global competition over the location of the next collider, and CERN's possible internationalisation as a response to the project's new demands on funding. By analysing the FCC's justificatory narratives, I show how CERN's infrastructural upscaling is not just a technoscientific but also a social process. The multiple uncertainties that get constructed around the FCC demand from the laboratory to demonstrate its worth in novel (scientific, socioeconomic, political and cultural) ways. My research suggests that, with the FCC, CERN is narratively positioning itself as an institution that will not only produce excellent science but will also create benefits for society. By presenting the FCC as a project to foster technological innovations, European competitiveness in the knowledge economy, and a peaceful global collaboration in a fast-changing world, CERN is renegotiating the value of basic research and its relation to Europe.

1.3. Assembling a thesis

This thesis has been written as part of a wider project on research infrastructures called METAFORIS (Making Europe trough and for its research infrastructures). In the project, a collaboration between STS TU Munich and STS Vienna, we set out to understand the co-productive relationship between European science and European integration. Comparing four different European research infrastructures that include the European Space Agency, Laser Labs Europe, the BBMRI-Eric biobanks, and CERN, we have been interested in how transnational research infrastructures shape and are being shaped by processes of European social, technical, political, and economic (dis)integration.

CERN is a case in point. In 2022, Kamiel Mobach and Ulrike Felt have published a first article "on the Entanglements of Science and Europe at CERN". In this paper, the authors pay attention to the temporal dynamics of co-production by studying how the relationship between CERN and Europe changed over time. Their historical approach makes explicit the laboratory's changing relationship with Europe, in which CERN has shifted from being an infrastructure that brings together Europe to being a European infrastructure for the world. Today, CERN is again at a turning point in which the worth of particle physics and its place in Europe needs to be renegotiated and relegitimized. As Roy (2011, p. 28) writes in her study of CERN: "to be alive and in business in the present it [particle physics] must constantly create futures that can be outclassed". The laboratory has to tell new stories, make innovative promises, and construct desirable futures to justify the construction of a new particle accelerator and thus to ensure the field's continuation.

To understand how CERN is (narratively) legitimizing, valuing, and situating itself with the FCC, I conducted a document analysis of PR materials connected to the project. CERN is putting a lot of effort into constructing futures in which a new collider is seen as valuable and desirable. The proposed FCC is accompanied by a scaled-up science communication effort that heavily utilizes digital media formats for PR work. Specifically, I analyse two types of documents: frequently asked questions (FAQs) and promotional videos on YouTube. The FAQ documents on CERN's new collider are interesting genre because they both problematize the project (questions) and at the same time provide a statement about why this is not a problem (answers). These carefully choreographed assemblages of questions and answers give their readers a broad overview of the FCC, covering not only its technical but also socioeconomic dimension. The FCC YouTube videos I analyse are a series of short introductions to the collider, variously giving insights into the personal lives of people working on the project, the scientific insights it promises, or its capacity to create a collaboration that will transcend national boundaries. From these documents, I then branch out to other sites, following the FCC and its narratives across conference proceedings and popular science articles. Doing so, I reveal the multiplicity of justificatory narratives around the FCC, how they travel, and how they are negotiated and transformed depending on the site of their performance.

To grasp these complex dynamics, I use a theoretical framework that brings together valuation studies, ontological politics, and an emphasis on narratives. This allows me to understand how the value of the FCC is brought into being, how multiple visions of the project are negotiated, and how these are coordinated through stories. Throughout the thesis, I thus demonstrate how the FCC variously becomes a European project, a global collaboration, a basic research infrastructure, and a motor for innovation and economic growth. I highlight how the multiple, complex, and sometimes competing futures around the collider are made coherent through narratives that assemble both scientific and social elements. These stories make sense of the FCC by aligning it to CERN's European past and a desired future of competitiveness and leadership in a global knowledge economy.

1.4. Overview

This thesis begins with a state of the art on the co-productive relationship between European science and society and the role of the future in novel technoscientific projects. I will then present in more detail my research question on the co-production of the FCC and Europe and give further insights into my theoretical and methodological approach, showing how I analysed PR documents by combining theory from valuation studies and post-ANT with a focus on narratives as justificatory and sense-making devices. The main part of my thesis then presents an analysis of my empirical materials over four chapters. The first chapter gives an overview of the wider context and actor constellations in which the FCC is situated, tracing its entanglements with multiple technical, social, political, and economic concerns and interests. In the second chapter, I discuss in detail the epistemic uncertainty currently haunting contemporary High Energy Physics. Specifically, I argue that narratives manage epistemic uncertainties by presenting them as potential for new science. The third chapter explores how CERN's infrastructural upscaling will necessarily make the FCC an international collaboration. The increase in size and cost of the accelerator will require new forms of organization and funding that go beyond the boundaries of Europe. In this context, I explore the tension between the FCC as a European and the FCC as a global project, showing how these two are managed through narratives that understand the FCC as a European laboratory for the world. In the fourth chapter, I show how the FCC is performed through a series of PR videos, assembling and reproducing in new ways many of the narratives analysed in the previous chapters. In the discussion, I draw together the insights of the different chapters to make a theoretical contribution to the role of narratives in legitimizing technoscientific innovation. I argue that narratives work as tools that manage and coordinate the FCC's uncertainties by rhetorically mobilizing the endless potential for innovation assumed to inhabit the unknown and by aligning epistemic with technological and sociopoltical concerns.

2. State of the Art

2.1. Making Europe through its research infrastructures

Work in STS has shown that to understand technoscientific developments it is necessary to also consider their entanglements with society. We cannot understand the FCC without the socio-political and historical context, as it is not simply the result of technical but also of social processes. The project is part of a general "knowledge culture" that shapes, sustains, or makes difficult certain epistemic practices (Karin-Knorr Cetina, 2007*)*. Big Science projects such as the CERN are inevitably embedded in the social: they both influence and are influenced by society (Disco & Beulen, 1998). Consequently, it becomes possible to argue that social and technoscientific orders are "co-produced". Using Sheila Jasanoff (2004, p. 2) idiom of co-production means considering how "the ways in which we know and represent the world (both nature and society) are inseparable from the ways in which we choose to live in it". As such, the creation and justification of the FCC is neither exclusively a technical nor a social process: it is "sociotechnical". Technoscientific artefacts are embedded in complex hybrid networks consisting of social and material elements. They both emerge out of and shape these networks. This means that the historical, socio-political, and institutional context matters when we think about CERN and the FCC. When looking at the FCC, it is thus important to consider how history, norms, culture, politics - "the building blocks of what we term the social" (Jasanoff, 2004, p. 3) - enable and constrain the expectations, narratives, discourses, and representations surrounding the FCC. The following will thus situate the proposed construction of the FCC in the (historical) context of shifting European science policies, European integration, the rise of Big Science, and the emergence of the European knowledge society.

Big Science research infrastructures such as CERN are always both technoscientific and political projects. They are situated in specific socio-political and historical contexts. This also means that, even though a project might appear technically feasible and scientifically valuable, this does not yet ensure that it will be realized (Riordan, Hoddeson & Kola, 2015). There are various and complex factors that contribute to the (non)building of novel Big Science projects. In other words, technoscientific processes are inherently political. As I will show, research infrastructures are essential to European science, technology, and innovation policies. They are key elements in fostering European integration, international collaboration, and diplomatic processes (Cramer et al., 2020). It is thus important to understand the current debate surrounding the FCC in light of larger macro social developments of Big Science and Europe (Hallonsten, 2016; Cramer, 2020; Cramer & Hallonsten 2020).

European scientific and technological collaboration is entangled with processes of European and economic and political integrations. European integration is not only a political but also a technical process. In this sense, technology has a central role in the making of Europe (Schipper & Schot, 2011; Halllonsten, 2012; Hallonsten, 2020). In their work on the "hidden" technical integration of Europe, Misa and Schott (2005) are interested the different ways in which Europe is done. Thus, instead of asking ‘what is Europe’, the authors understand Europe as an emerging entity that is assembled (but also disassembled) through a set of ongoing practices. More specifically, and against the standard understanding of European integration as a political process, Misa and Schott (2005) understand integration “as an emerging outcome of a set of practices that involve linking and delinking infrastructures, and the circulation and appropriation of knowledge and artifacts” (p. 8). Following this understanding, Europe is not a fixed category but rather made and unmade in ongoing and evolving sociotechnical processes. This shifts the focus on how European political integration is influenced by and relies on the creation of technoscientific networks and infrastructures as well as the circulation, sharing, and use of knowledge. Their view thus aligns with Andrew Barry’s (2006) understanding of European integration as enabled by the creation of „technological zones“. Technological zones are spaces in which „differences between technical practices, procedures and forms have been reduced or common standards have been established“ (Barry, 2006, p. 249). They are intrinsically political as they enable, constrain, and steer technoscientific developments. International collaborations and research infrastructures such as CERN are one way to create shared and standardized ‚zones‘ that enable different (national) actors to get together. More specifically, they can be understood as „infrastructural zones“ that align and internationalise different ways of doing research. Infrastructures, understood as “a bundle of heterogenous things (standards, technological objects, administrative procedures) […] which involves both organisation work as well as technology” (Slota & Bowker, 2017), bring together diverse technical and social elements. In the case of Europe, they also bring together different nation states, stabilising sociotechnical relations that become invisible and taken for granted over time. This makes explicit how international research infrastructures have a key role in processes of political integration in Europe. Here it is important to note that research infrastructures are not only material but also subject of the imagination. They not only stabilize and naturalise sociotechnical relations, they are also inscribed with various narratives, imaginaries and visions. As Larkin (2013, p. 329) argues, infrastructures also “emerge out of and store within them forms of desire and fantasy and can take on fetish-like aspects that sometimes can be wholly autonomous from their technical function”. As such, they are entangled with imaginaries of Europe and its future. European integration should thus be understood as a complex, emerging, and multi layered process that is always co-produced with different social, political, and technoscientific developments and imaginaries.

It is possible to trace the emergence of European Big Science research infrastructures to the years after the second world war (Cramer et al., 2020; Papon, 2004). This rise of large international science collaborations is connected to scientific, political, and economic rationales. Economic growth, national competitiveness and the role of science and technology during the war led to increased investments into scientific endeavours. Furthermore, since the early 20th century and driven by the US, experimental work has been slowly transforming (Krige 2003). Research in nuclear physics, high-energy physics, or space programs required ever larger technologies and thus also collaborations between different scientists and engineers. These increasingly massive experimental technologies needed huge financial support from governments. Due to these global scientific developments, the need to stay competitive, and a simultaneous scarcity of resources after the second world war, Europe's individual nations started to collaborate on large scientific projects. After the war, there have thus increasingly emerged instances of internationally financed research in Europe. Different nation states decided to cooperate in large scientific endeavours to work in expensive research fields that exceeded the funding of individual governments.

The increasing size of scientific research and the economic necessity for international cooperation was further accompanied by various sociopolitical, cultural, and foreign policy considerations (Trischler & Weinberger, 2005). For instance, in the context of the post-war years and an emerging Cold war, European (scientific) collaboration was considered as essential for lasting peace and unity. This shows how it is necessary to understand Big Science projects in a global context. Global developments and competition in science and technology are factors that influence national and European science policies and funding decisions. Large scale research infrastructures are not unaffected by global geopolitical developments.

CERN is a case in point. The foundation and development of CERN has to be considered in parallel with the end of the second world war as well as developments in the US and the Soviet Union. The 1954 establishment of CERN marked the creation of one of the first large scale, intergovernmental research infrastructures. As a major European collaboration on particle physics, it was understood as a mean to foster European integration in the post-war years, making it a scientific, cultural and political project. Science, understood as a neutral arbiter, was expected to bring together a fragmented post-war Europe. As Krige (2003, p. 904) put it: "paradoxically, just because it is seen as being a 'non-political' activity, scientific collaboration can be a particularly useful first and tentative step in a politically delicate context of alliance building". CERN's role as a diplomatic tool for cultural and political integration was accompanied by a narrative that attributed particle physics a distinct European cultural value. Mirroring the dominant European discourse on European cultural unity, "physics was presented as the common European language, and physics laboratories as arena suitable for the pursuit of political action towards greater integration" (Lalli, 2021, p. 111). Enacting basic research as a form of „Europeanness" further justified and promoted CERN to the wider public and policymakers. The language of cultural unity thus also served as a form of legitimation to the public. But CERN was not only considered a science diplomacy project for European cultural and political integration. In the context of the Cold War, CERN was also central to foreign policy (Krige, 2003). European technoscientific collaboration was understood to unite 'western' nations "in defence of the free world" (Krige, 2003, p. 902). Science was thus considered a foreign policy tool to secure national interests and to create international geopolitical stability and security. As Krige (2003, p. 900) puts it, international scientific collaboration can also be understood as „the pursuit of one's interest by other means". While perhaps framed in a language of altruism influenced by values of „universalism",

„Europeanism“ or „internationalism“, Krige argues that different governments and scientists essentially collaborate with each other because „they believe that it is to their competitive advantage to do so“ (p. 900). Within international scientific collaborations there can be witnessed a constant negotiation between different governments' attempts to pursue national interests. In this sense, CERN was not only a scientific but also a socio-political project. It is variously entangled and co-produced with global geopolitical developments, foreign policy and diplomatic goals, European integration and the imaginary of European cultural unity.

Furthermore, it is important to not how the development of European research infrastructures was accompanied by a gradual movement from basic research as separate from society towards an understanding of science in the service of society. Today, science has a fundamentally different role in society. Science is no longer a social good in itself but is instead understood as the main driver of economic growth, competitiveness and innovation.

Basic research projects after the Second World War relied on science policies that promoted science for its own sake. While science was associated with societal development, its freedom from both state and market (society so to say) was still celebrated as an intrinsic quality. Following a 'linear model of innovation', basic research was supposed to trickle down and provide wider societal benefits (Godin, 2006). Following this view, basic research was seen as a separate sphere that is clearly delaminated from society, governments, and industry. Science was understood as a good in itself that did not really have to justify itself to the public. The idea that science is outside of politics was famously promoted by Vannevar Bush; the director of the US Office of Scientific Research and Development at the end of the second world war. In a report to the US President Franklin Roosevelt, Bush (1945) notoriously described science as an "Endless Frontier". According to his vision of science, basic research was essential for progress, public wellbeing, and the flourishing of the nation. Bush proposed an ideal of science that, even though funded by the state, would be independent from public institutions and interests, only perusing its own goals. If there are enough public investments into basic research, this will inevitably have pay offs for society!

While this narrative is still prominent today, contemporary Big Science projects such as CERN serve a much wider array of purposes. In what Hallonsten (2016) calls a "transformed Big Science", there has occurred a shift from basic to applied and economically exploitable knowledge. This transformation has been variously labelled as the emergence of "Mode-2 science" part of the "knowledge society" or "innovation society" (Felt & Wynne et al., 2007). What these notions have in common is that they seek to describe a new relationship between science and society. Today, knowledge production is much more closely entangled with societal needs such as economic growth and innovation. This is accompanied with an understanding that economic growth and innovations emerge from the complex interaction between science, society and industry. Basic research is no longer an end in itself. Consequently, today's scientific projects are increasingly in need to justify their role to society. Big Science projects such as CERN need to actively contribute to innovation and economic growth. Publicly funded science is thus increasingly driven by promises and expectations of potential (future) innovations, commercial applications or societal benefits.

The gradual shift of the role of science in society is also reflected in the shifting narratives surrounding CERN. In the beginning, CERN was predominantly seen as a science diplomacy project that, by standing above ideology and politics, is able to strengthen Europe through basic research. Neutral science was supposed to participate in the recreation of a collaborative Europe. Today, High Energy Physics has to engage with shifting European visions of innovation and knowledge based economic growth. The laboratory has thus moved from making a peaceful collaboration in Europe to making Europe competitive in a global world, thereby bringing science, innovation, and economic growth together.

To sum up, Big Science research infrastructures such as CERN have to be considered as co-produced with a wider socio-political and cultural context. Research in the history of technology has revealed the multiple and complex ways in which European technoscience is entangled with ways of making Europe. Research infrastructures such as CERN place Europe on the international scientific map while at the same time bringing together member states with shared projects, creating both an infrastructural and epistemic underpinning to European integration that is inscribed with certain normative, cultural, and political assumptions. There is a certain idea of Europe built into European Big Science research infrastructures. The recent proposal to construct a new particle accelerator at CERN thus needs to be understood as part of a long tradition of European cooperation in technoscientific projects. Furthermore, it also needs to be considered in the context of global scientific developments and competition as well as a changing relationship between science and society. As research in innovation studies has shown, there is an increasing focus on research as a means to foster economic growth and innovations. Science is increasingly in the need to contribute directly to society and safeguard a competitive (European) future.

2.2. Sociotechnical futures

Visions of the future are a driving force in contemporary technoscientific and societal processes (Felt, 2015). In a constant need for novelty, societies are dominated by the imperatives of progress, innovation, and change. As Adam and Groves (2007, p. 1) put it: “standing still means falling behind”. Futures have thus become both argument in and justification for contemporary technopolitics, thereby gaining authority in guiding the present.

According to Brown, Rappert and Webster (2000), the future has become a “contested object of social and material action” (p. 3). Actors are increasingly engaging in activities to realize or secure their desirable futures. In these attempts to ‘colonise’ the future (Adam & Groves, 2007), actors utilize a variety of rhetorical, discursive, organizational and material practices that invite sociological engagement. For instance, Brown, Rappert and Webster (2000) argue for a sociology of the future that, instead of attempting to predict the future, should analyse the various processes that enact different kinds of futures in the present. In other words, research should move from „looking into the future to looking at how the future as a temporal abstraction is constructed and managed“ (p. 4). Or as Barbara Adam (2000, p. xii) puts it: the aim of a sociology of the future is to „identify the field of contestation, show the intricate networks of interaction, establish the role of narratives, metaphors and ‚grammars of the future‘, disclose power relations and their effects on alternative futures“ (p. xiii).

In this context, I am interested in analysing the future-making practices surrounding the FCC. I want to investigate how different futures are performed to justify the construction of a new particle accelerator at CERN. To do so, I will pay special attention to expectations, understood as material and discursive practices of future making, and how these enact the FCC in specific ways. In the following sections I will thus take a closer look at the role of expectations in processes of technoscientific innovation and change. To do so, I will draw together literature from the sociology of expectation, a nascent sub-field in STS that investigates the role of expectation in technoscientific developments.

As I have shown above, in the knowledge society, technoscientific knowledge and innovations are increasingly considered as central to fostering economic growth, international competitiveness, and societal wellbeing (Felt, Wynne et al., 2007). In this context, large basic research infrastructures such as CERN need to convince society and policymakers of its value to secure continuous support and funding. For instance, large investments such as those necessary for the construction of the FCC are only prioritized if they are considered worthwhile. At the same time, the FCC is a technoscientific project whose (potential) value lies far in the future. Neither the epistemic nor the technological innovations it might produce can be predicted with certainty. It’s worth is inherently uncertain. This makes it a very interesting site to research the justifications, promises, and expectations that are evoked to enrol actors and mobilize public and political support.

Narratives about the future value of technoscience are increasingly important in science policy making (van Lente 2000; Michael, 2017). Because of the inherent uncertainty of the future, those institutions that tell better stories about their future benefits, will more likely receive support and funding. According to Borup et al. (2006), technoscientific innovation is a “future-oriented business” (p. 286). Imaginations, expectations, promises and visions not only shape but also help bring into being novel science and technology. As the authors put it, expectations are “generative”, that is, they “guide activities, provide structure and legitimation, attract interest and foster investment. (p. 285)”. Part of a wider “technoscientific economy of promises”, expectations justify, structure, and guide Big Science projects such as the FCC (Felt, Wynne et al., 2007; Joly, 2010).

Expectations play an especially important role in the early stages of technoscientific projects (Borup et al., 2006). This also holds true for novel Big Science infrastructures such as the FCC. Still under planning and highly visible, emerging research infrastructures have a heightened need to justify themselves to the wider public. Often, such projects are also subject to science policies that aim at securing innovations and economic growth from basic research. Thus, not only their potential future benefits are uncertain and under negotiation; there is often also a lack of common agreement on how to proceed and where to invest.

This shows that the successful creation of new technologies requires the coordination of many different actors. As Disco and Beulen (1998, p. 2) put it, "getting new technologies together also requires getting societal actors together". Expectations are one way to achieve and maintain the coordination of different actors. Inscribed with a script that attributes different roles to different actors, expectations structure processes by helping to coordinate different activities and create shared agendas (van Lente & Rip, 1998). Expectations thus work as "prospective structures". They function as "arrangements that do not yet exist, but are nonetheless forceful due to the perceived implications of the projected future" (van Lente & Rip, 1998, p. 206). By coordinating and structuring the present, expectations are thus able to link technical and social issues and "bridge or mediate across different boundaries and otherwise distinct (though overlapping) dimensions and levels" (Borup et al., 2006, p. 286). In other words, expectations, emerging from the interaction of diverse actors across various social arenas, are central to the governance of science and technology (Konrad, 2010).

It is important to note that expectations work at different scales. They occur on collective, institutional, or individual levels and can take on formal, informal, technical, scientific, or even philosophical forms. Expectations influence and are influenced by individual actors such as engineers and scientists but also work on the institutional, national, and supranational level. Frans Berkhout (2006, p.2) distinguishes between "private expectations" that are held by individuals and "collective expectations" that are widely communicated and shared. Other researchers frequently use the notion of 'sociotechnical imaginaries' to describe how collectively held visions of the future influence technoscientific developments (Mager & Katzenbach, 2021; Konrad & Böhle, 2019). Drawing on the seminal work of Jasanoff and Kim (2015), research on sociotechnical imaginaries shows how shared and culturally specific visions structure, shape and co-produce socio-technical futures. Such work provides insights into the ways imaginaries influence the governance and success of technoscientific projects (Felt, 2015)**.** Due to its focus on collectively held imaginaries, the concept is useful to grasp the role of future visions on the scale of institutions or nation-states. In contrast, work inspired by the sociology of expectations has attempted to show how different practices and assemblages construct and form specific sociotechnical futures and how these have a performative impact on the shaping of technoscientific processes. The multiple visions and expectations of the future, whether on the individual or collective scale, can run in parallel, interact or clash with each other. Individual actors can have multiple visions of the future that coexist with collective visions of the future. These can be reconciled with each other, but they can also remain contradictory. As Berkhout (2006, p. 12) puts it: "all societal actors contend with multiple visions of the future, each matched to different areas of their activities and belief". This shows that the future is not inevitable but contested.

As we have seen, expectations are central to the realisation of novel technoscientific projects. Shared expectations are powerful narratives able to coordinate but also constrain and structure the behaviour of different actors on various scales. In other words, expectations are performative. They are not neutral representations of the future; they do things in the world. Harro van Lente (2000) nicely demonstrates the performativity of expectations in his study of technoscientific promises. According to Van Lente, expectations can act as imperatives. As he puts it, "technological futures are forceful. […] Once defined as promise, action is required" (p. 60). This makes promises especially powerful tools to mobilise actors and guide actions. While something might start out as an option, it can be turned into a promise that acts as a necessity that should be achieved. Promises and expectations about the potential of a technology are thus at the same time also calls to realize it. Van Lente goes so far as to claim that expectations can turn into a "self-fulfilling prophecy". Promises can act as imperatives, bringing people to fulfil them with all their efforts, thereby eventually making them true. For instance, van Lente (2000) argues that Moore's law, the idea that computer chips double in power every couple of years, is not successful because it is true. Rather it becomes true because technologists actively try to realize it by using it as a guide for technological development.

Here it is important to note that expectations are not reducible to abstract narratives: they are inherently material. As Mike Michael (2000, p. 33) puts it, "the performativity of [future] representations does not take place in some abstracted, a-material domain. [They are] grounded in the material". According to him, expectations are not "a-material, ethereal bits of floating culture: they are substantiated, objectified on paper, verbally, on the screen, pictorially" (p. 23). This means expectations can have multiple shapes, embedded, or 'inscribed' into various texts, practices, or artifacts. Consequently, expectations can create "material and social path dependencies (lock-in or irreversibility)" that exclude alternative possible futures (Borup et al., 2006, p. 293). If there is already a lot of time and money invested in materializing expectations, considering alternatives becomes more difficult.

There has already been some attention on the role of expectation in the field of High Energy Physics (HEP). Karin Knorr-Cetina (1995) argues that the early stages of experiments in the field of HEP are characterized by processes of "consensus formation". For instance, this could be about finding agreement over the kind of accelerator that should be built next. According to Knorr-Cetina (1995, p. 39): "'Consensus' has been relocated into the beginning of an experiment, when the technology is still unsettled, the physics processes within reach unclear, and the protoexperiment is still in a fluid, unincorporated state". After consensus has been reached, that is a plan for a detector established and the necessary timeline mapped out, the experiment continues relatively uncontested. Now, the HEP experiment acts as a "superorganism, in which the goals and means are set, the stakes are aligned and what remains to be done is 'working things out'" (p. 141). In this sense, in the early stages of consensus finding, scientific and non-scientific actors need to be enrolled by convincing them that the experiment (in my case the FCC) is a project that should be further perused. According to Knorr-Cetina (1995, p. 138), in the phase of planning and coordinating an experiment in HEP, expectations are created and a future is constructed. As she puts it, in the early phases of an experiment, "reflexivity turns forward" - a future is anticipated and modelled, planned and simulated (p. 138). The future becomes obdurate through its repetition and inscription in material and textual form. In other words, "the future is captured in these simulation stories, and then slowly caught up with through being fed into the ongoing stories of actual instrument construction and use" (p. 138).

Looking at the formation of a Muon g-2 experiment in Upton, New York, Cornelis Disco (1998) similarly identifies expectations as central to the processes that lead to the construction and coordination of collaborative HEP projects. According to Disco (1998), HEP is guided and enabled by certain "frames" or "constructs". Functioning as "devices of summation and memory", frames are material and textual objects that coordinate, guide, and constrain subsequent action (p.11). Frames are ways to "freeze action, consolidate gains, mark progress, and attempt to establish predictable patterns of interaction on the basis of which they can proceed" (p. 111). Thus, Disco's frames work as forms of expectations that draw together diverse social actors to create and maintain cohesion between them. Just like expectations, they are used to guide, structure and coordinate action towards a shared goal.

Research in the tradition of the sociology of expectations has shown how enactments of possible futures take a central role in the development of novel technoscientific projects. If the future is still uncertain, those actors with the better promises will more likely receive political and financial support. But expectations are not only central to enrolling actors and mobilizing support: they also structure and guide action. As such, it is possible to argue that expectations are performative. They have a real influence on technoscientific processes and futures. Therefore, studying different material and discursive future making practices will give valuable insights into the ways contemporary societies make sense of and realize novel scientific and technological projects.

The FCC is a fascinating case to study 'expectations in action' (c.f. Latour, 1987). The particle accelerator's construction is supposed to start in 2030 and it is expected to be in operation by the mid 2040s. The whole project is likely to cost more than 20 billion euros. The investments needed for its realization make the FCC subject to different expectations. Narratives, representations, discourses, documents, status reports, conferences, prototypes, conceptual design studies, popular science magazines, feasibility studies or promotional YouTube videos – these are all future making practices that create expectations that enable and constrain further actions. Before it is possible to begin with the construction of the FCC, actors need to be enrolled and there needs to be a shared consensus on how to proceed. Only with some shared and fixed 'frames' can actors and future actions be coordinated towards the realization of the FCC.

The ongoing research into the FCC's feasibility are investments into creating and stabilizing expectations about the FCC. For instance, the FCC study's (2019) *Conceptual Design Report*, a document summarising research on the feasibility of the FCC, can be understood as a 'materialized' expectation. Guiding the 2020 ESPP decision to recommend the construction of the FCC, it has had a considerable influence on the future of HEP. But not only studies on technical and economic dimensions enact the FCC and guide its future. Expectations surrounding the FCC also materialize in the narratives and visual representations of promotional videos or social media posts. The FCC has started to engage with new technological infrastructures such as Instagram, Twitter and YouTube that enable novel (textual and audio-visual) possibilities to represent, tell stories and create visions of the FCC. These drastically change who can access and how people engage with knowledge about the project. The future of CERN is increasingly articulated and negotiated through social media.

3. Research Question

It becomes apparent that the FCC is a complex entity entangled with many different actors. Policymakers, the public, the European Commission, national governments, engineers, scientists, industry, private companies - all are involved in very different ways with the emerging FCC. As shown in my state of the art, expectations are a major mechanism to bring together and coordinate these heterogenous entities. But for the different actors involved, the FCC is not necessarily the same entity. Expectations are not always coherent; they understand and justify the FCC in multiple ways. In other words, there is not one FCC but many.

Consequently, my first research question is: h*ow do expectations justify the FCC?* This question explores the different ways expectations, here understood as material-discursive future making practices, enact the FCC as something valuable and desirable. For my research I draw from a variety of sources published on the CERN website and CERN database. The (future making) narratives and representations I engage with can be found in a diverse variety of materials such as policy documents, innovation and feasibility studies, PR materials, frequently answered questions documents, YouTube videos, power point presentations, annual reports, popular science magazines, or individual scientists. These all, although in different ways, create and materialize the FCC. They all enact the FCC. Consequently, I also analyse *how the different enactments of the FCC relate, co-exist, or compete.* With this question I look at the "ontological politics" surrounding the FCC and the different "coordination practices" that make it seem like a coherent object. How do the different expectations of the FCC relate to each other? How are the different expectations held together? How are they contested? And how do some expectations come to dominate over others?

My second research question is: *how are the different enactments of the FCC co-produced with different visions of Europe?* As I have shown, international research infrastructures such as CERN are closely entangled with wider (European) sociopolitical developments. Studying expectations around novel technoscientific projects makes the co-productive relationship between science and society explicit. Big Science projects such as the FCC need to convince a variety of scientific, public, and political actors to make them a reality. Expectations thus mobilize and enact the future in multiple ways, always shifting according to different circumstances and demands. Enrolling different actors and justifying action in the present, expectations are thus co-produced with wider societal concerns. As such, investigating expectations around the FCC not only tells us something about science, but also about (European) society more generally. In my project, I thus explore how different expectations of the FCC are entangled with different visions of Europe. As the FCC is part of a long standing tradition of European particle physics at CERN, I analyse how different understandings of „Europeanness" make their way into the expectations and narratives about the project. Here, Europe is not something fixed but should be understood as something that is continuously done or enacted. I do not want to impose Europe as a stable category, but rather understand how it is assembled (or disassembled) in different future-making practices.

4. Theoretical and conceptual considerations: enacting, valuing and storytelling

4.1. (E)valuation

In my state of the art, I have engaged with the central role of expectations in the development of novel technoscientific projects. Whether CERN's new particle accelerator will ever be constructed is still uncertain. To become reality, a variety of actors first need to be mobilised and convinced of the future value of the FCC. I want to understand how this is happening through the expectations put forward in the PR documents on the collider. Drawing on work in valuation studies, I will see these expectations as future making practices that enact the worth of the FCC.

Valuation studies has demonstrated that value is not given put done (Aspers & Beckert, 2011; Lamont, 2012). Valuation is happening in practice and takes place in specific situations that involve a heterogeneous assembly of human and nonhuman entities (Fourcade, 2011; Hutter & Stark, 2015). As such, value is socially and materially constructed. In this sense, expectations can be seen as forms of (e)valuation that perform the future worth of things. As Berkhout (2006, p. 3) argues, expectations are always "moralised". Visions of the future can be positive, negative, desirable, undesirable, utopian and dystopian. For Berkhout, attaching positive moral values to specific expectations enrols actors by making this future desirable. At the same time, not perusing this future would have negative consequences. But, understanding value only in moral terms (as opposed to economic value) is limited. As Stark reminds us (2009, p. 7), the established dichotomy between moral values (the subject of the sociologists) and economic value (the subject of the economists) does not hold and should be overcome. Instead, research should merge these two lines of inquiry to study the creation of "worth", thereby recognizing that "all economies have a moral component". As Aspert and Becker (2011, p. 6) argue, often "different forms of value are present simultaneously". In this sense, expectations' moral qualities are just one way evaluation that exists next to a plurality of other registers of valuing (Heuts & Mol, 2013).

In moments of contestation, dispute, and controversy practices of justification and their dynamics become visible. The current debate around the FCC is such a moment of controversy, in which the worth of a new particle accelerator at CERN is negotiated. To make sense of the discussions around the FCC, Boltanski and Thévenot's (1999, 2006) work is useful. The authors developed a framework to analyse how different societal actors justify their actions and claims for them to be considered legitimate. According to the Boltanski and Thévenot, there exists „a plurality of incomparable modes of justification", which means that disputes over valuations occur along different „orders of worth" (p. 359).There is not one universal truth according to which actors can justify themselves. Instead, orders of worth and modes of justification are multiple, each true in themselves. There are different understandings of the common good and thus also different ways to attribute worth and justify action. Actors shift between these, depending on the actor constellation they are in. A conversation between particle physicists on the potential of the FCC will likely involve very different arguments and justifications than a discussion between politicians and the local population living around CERN. One might revolve around the epistemic potential to learn about dark matter and the other focuses on the economic growth in the area. But this does not mean that one statement is more “true” than the other. The FCC is simply justified according to a different “order of worth”. Still, not anything goes. There are limits to the arguments actors can make (at least if they seriously try to convince others). They need to be recognizable and acceptable to their audience and be based on a shared understanding of what is ‘good’ or ‘valuable’. Consequently, to legitimize their position, actors need to ground their statements and actions in established and dominant „orders of worth“. It is likely difficult to justify the FCC to a politician by arguing that is simply fun to work there. Successful justifications (and valuations) have to follow „rules of general acceptability“ (p. 360). These rules of general acceptability are influenced by historically and socially contingent regimes of valuation that are materialized and objectified in different nonhuman devices and entities. This means that different actors are embedded in different „regimes of value“ (Appudarai, 1986) with different „orders of worth“ that enable and constrain valuations and justifications.

To make sense of valuation processes and their wider contexts Fochler, Felt, and Müller’s (2016) differentiation between „(e)valuative principles“ and „regimes of valuation“ is useful. Actors evaluate according to evaluative principles which are situated in and influenced by wider regimes of valuation. According to the authors, „(e)valuative principles denote how worth is ascribed and argued for in a concrete situation, and regimes of valuation point to the broader discursive, material and institutional background this concrete evaluation draws on“ (p. 180). Evaluative principles can thus be understood as “any logic or set of rules that [actors] explicitly or implicitly refer to when making a statement about worth in a particular situation“ (p. 179). In contrast, the notion of regimes of valuation points towards shared and stabilized evaluation principles to which individuals need to accompany their own evaluative practices. The concept thus sensitivities us to the wider institutional, national, supranational, social, political, cultural, and economic contexts in which the valuation of the FCC happens. Valuations are both situated in and part of larger developments and processes: they are co-produced with society. By looking at specific sites, moments, and practices of valuation it is thus also possible to get an understanding of the shared regimes in which they are embedded.

Waibel, Peetz, and Meier (2021) provide a useful conceptual language to make sense of the different actors, entities, rules, and infrastructures that are involved in valuation processes and influence or guide evaluative principles and their respective regimes of valuation. Their framework is helpful to disentangle the often invisible elements that enable and structure enactments of worth. According to the authors, valuation processes should be understood as a constellation that consists of positions and their relations, of rules of valuation, and of infrastructures of valuation. Together, these three elements make up what the authors call a „valuation constellation“. Because the different elements are entangled with each other, they have to be considered together to understand specific valuation practices. The authors further specify that processes of valuation consist of three different positions: the valuator (the one doing the valuation), the valuee (the one evaluated), and a respective audience observing, judging, taking up, or rejecting a valuation. The audience takes an essential role in the valuation constellation, as it either stabilizes or rejects the valuation. Only if the audience accepts a value judgment does the one valued have to accept and react to it. Next to the positions and their relationally, valuation infrastructures provide the material context of valuations and connect between different sites of valuation. As the authors put it, „they facilitate, transforms, stabilize, and distribute valuations" (p. 45). Finally, valuations are shaped by rules transcending a particular situation of valuation, thereby further influencing, enabling, and restricting enactments of worth. To sum up, the concept of valuation constellations with its many dimensions sensitives me to consider the multiplicity of heterogeneous actors, entities, rules, regulations, regimes, and infrastructures that influence processes of valuation.

Theory in (e)valuation studies will guide my analysis of how the FCC is valued and justified in practice. It will be used to make sense of the future making practices through which CERN attributes different kinds of (moral, economic, cultural, political) worth to the FCC. As such, valuation studies help me to conceptualize and make sense of the articulation, interaction and relationality of the different expectations surrounding the FCC. This will make explicit the mechanisms and evaluative principles through which the FCC is enacted as well as the wider regimes, constellations, arenas, and assemblages in which these are embedded in and co-produced with. Furthermore, it enables me to appreciate and be sensitive towards the (ontological) politics of multiple and heterogenous evaluations of the FCC.

4.2. Ontological Politics

Expectations and performances of value are implicated in politics and struggles over power. As Dussage, Helgesson, and Lee (2015, p. 275) argue: "enacting values is one way of producing stakes - i.e., matters of concern or care. What is supposed to be at stake, and what is at stake […] is the object of intense politics". This means that performances of the FCC's worth are neither innocent nor incontestable. Statements about the future value of the FCC do things in the world: they have political consequences. And in the question of whether to construct a new particle collider a variety of different interests and values are at stake. Whose values and concerns are these? Whose are neglected or made invisible? How are the multiple visions of the FCC coordinated with each other? In other words, what are the ontological politics surrounding the future collider?

Combining theory from valuation studies with post-ANT theory following the ontological turn, I will understand the multiple articulations and justifications of the FCC as a form of ontological politics. Critiquing commonplace assumptions assuming a singular reality that can be uncovered through sound scientific investigation, Actor-network theory and its material-semiotics have shown that the world does not have a stable and universal character. Instead, reality is always emerging, assembled through a variety of situated socio-material practices (Latour and Woolgar, 1986; Pickering, 1984). Instead of ontology, we are dealing with ontologies. Or in the words of Annemarie

Mol: (1999, p. 75) „if reality is done, if it is historically, culturally and materially located, then it is also multiple. Realities have become multiple" (p. 75). For instance, in her study of a Dutch hospital, Mol (2002) shows how atherosclerosis is enacted differently in different moments. She nicely demonstrates how a patient's understanding of atherosclerosis is drastically different from a pathologist's understanding of the disease, who observes it in human tissue using a microscope. In each case, very different practices render atherosclerosis real. In a similar sense, I am understanding the FCC not as a pre-existing thing but as an emergent feature of relational processes involving multiple actors and entities. This means that the nature of the FCC is not yet settled but rather continuously articulated and negotiated through expectations, narratives, representations, policy documents, or feasibility studies. Its qualities, usefulness, potential societal impact, scientific insights, or socioeconomic benefits are „up for grabs" (Woolgar & Lezaun, 2013). This implies that there no single answer to what is at stake in constructing a new particle accelerator. Rather, its value is something to be studied empirically.

As we can see, realities are multiple. But what to make out of this multiplicity? Does this mean we can choose between different realities? These are some of the questions Mol (1999) tries to answer in her article on the ontological politics of Anaemia. According to her ontological politics „have to do with the way in which ‚the real' is implicated in the ‚political' and vice versa" (p. 75). It suggests that „the conditions of possibility are not given" (p. 75). Here I want to emphasise that different enactments of an object are not simply multiple perspectives on the same thing: they are performative. In other words, enactments have reality effect. They bring with them normative and political implications (Mol, 2013), making a difference to how a patient is treated or whether and in what form the next particle collider will be constructed. A study of ontological politics is thus a study of the co-existence, negotiation, and coordination of multiple enactments of reality. It is also a study of how realities are held together. In midst of all this ontological multiplicity there are also instances of singularity. But this singularity is an achievement. Aligning disparate elements to create a coherent and commensurate world requires „coordination work" (Mol, 2002) or „choreography" (Thompson, 2005). As such, we need to be attentive to the practices that create singularity out of multiplicities, to the work that is necessary to maintain coherence.

In this thesis, I will thus explore the differences, multiplicities, and complexities of the FCC while remaining sensitive towards how these are held together or kept apart in practice. A sensitivity towards the ontological politics of the FCC made it possible to turn my attention to the multiplicities and complexities of the FCC, thereby challenging assumptions about a singular collider whose construction is assumed to be straightforward. They helped me to overcome a rigid separation between different, sometimes competing, regimes of value, instead showing me their negotiation, contestation, coordination, and entanglements. How do they relate, interact, compete with each other? In what moments are some values present and others absent? In what constellation does the FCC become what kind of infrastructure? And how are different narratives ultilised to highlight different aspects of the collider?

4.3. Narratives

In this thesis, I specifically focus on the narratives around the FCC and how these enact the (future) worth of the FCC. I understand narratives as ordering practices that bring into being, value, and justify the construction of the FCC. Narratives take a central role in innovation processes by constructing desirable (or undesirable) futures and guiding actions in the present. Studying the narratives repertoires around the collider will give insights into the regime of value, modes of justification, and promises and expectations through which the FCC is assembled and made sense of. It will also reveal the (ontological) politics of storytelling and how multiple visions of the FCC are negotiated and coordinated with each other.

Taking a closer look at FCC documents, I am following Woolgar and Leazaun (2013) claim that "the textual […] does not entail any lesser capacity for ontological enactment" (p. 333). According to them, to make sense of how texts enact realities, we need to be sensitive towards their "organization". Organization refers here to "the ways in which the text depicts the character of entities mentioned and, crucially, of the ways in which they relate to each other" (p. 331). Being sensitive to the organization of a text thus means paying attention to how entities are assembled, drawn together, depicted, and how they relate. We should analyze how text „makes available a cast of relevant characters, assigns attributes to each and depicts the network of rights and responsibilities that characterize the situation at hand." (p. 331). How does the text order actors, elements, and events into a coherent whole? What are the relevant actors, their characteristics and relations? What traits does it assign to the actors? What contexts are drawn on? In other words, what are the narratives (re)produced by the text? Narratives can be understood as a form of practice, that, in a repeated and routinised way, assemble heterogeneous elements into a coherent story, thereby (un)making realities. Put differently, narratives are ways of ordering reality (Czarniawska, 2004).

Narratives are central to the representation of the FCC. Especially in the PR documents I studied, we can observe a lot of grand narratives that bridge between science and society and between the secrets of the universe and far-reaching technological innovations. So how can we make sense of the narratives seemingly so important to the justification of technoscientific innovation? Bos et al. (2014, p. 151) argue that the new role of science in society has led to a reorientation towards "broad and generic goals" that involves the use of grand narratives or what they call "steering with big words". Referring to McGee's (1980) notion of the „ideograph", which describes a term that is unquestionably desirable while at the same time very flexible and open so that it can be applied in a variety of contexts, Bos et al. (2014, p. 152) define 'big words' as "encompassing concepts that are uncontested themselves, but that allow for multiple interpretations and specifications". Whether people believe in them or not, they still influence and structure research. For instance, van Lente and van Til

(2008) investigate the use of the big word “sustainability” in nanocoating research. According to the authors, sustainability is “not one, but many things”. Acquiring multiple meanings depending on the context of its enactment, references to sustainability become a practice of both "specification and legitimation". It is specified in some moments while serving as an overarching legitimation for the research practices in question. Big words thus share some similarities with the function of expectation, which acquire some of their force through their „interpretive flexibility“ (Berkhout, 2006). The more malleable a narrative, the more actors become enrolled in the network and act towards a particular future.

It is important to note that the narratives I will look at are not separate entities that exist in a void. As van Lente (2000, p. 43) puts it, „technological futures are embedded in well-established vocabularies“. He calls these overarching narratives that accompany sociotechnical processes „metadiscourses“. For instance, the narrative of „technical progress“ has become so firmly ingrained into our narrative repertoires that it now acts as such a metadiscourse. It has become a prominent „myth“ that legitimizes technological innovations by presenting them as inevitable. Drawing from the work of Deuten and Rip (2000) on product creation processes, Felt (2017) similarly shows how interconnected stories can form a „narrative infrastructures“, which can be defined as „a network of temporally stabilized narrative through which meanings and values of academic knowledge/work and its relation to society can be articulated, circulated across space and time“ (p. 5). In an organizational setting like CERN, stories get accumulated, stabilized, and materialized. Working as building blocks, they get taken up, transformed, and become accepted over time. These temporally stabilized narrative assemblages structure and guide technoscientific processes. Encoded with visions of how social and technical orders should relate, they both enable and constrain how we can tell stories about, think of, and thus also act towards emerging technoscience. Becoming part of a shared cultural repertoire, narratives can thus create irreversibilities and path dependencies, limiting what can be done by influencing expectations, justifications, and problem definitions. This means that narratives always produce and are produced by the dominant institutional structures, values, and norms, as well as the wider societal imaginary on the relationship between science and society. As such, they are both reflective of the prevailing assumptions about technoscience and actively reinforce them. The FCC can thus be understood as situated at the intersection of multiple narrative clusters that form a narrative infrastructure, which is influenced not only by institutional stories but also by policymakers and wider societal expectations and regimes of valuation. In the case of CERN’s next collider, science policymakers like the European Commission have a significant influence on defining the narratives that guide the project, posing a distinct vision of how the relationship between science and society should look like. Studying public relations materials thus makes explicit the intersection of institutional and societal narratives about the role of Big Science in Europe. Engaging with narratives will also give insights into the „coordination practices“ that create cohesion and give meaning in the context of novel, uncertain, and complex technoscientific developments. Narratives manage differences and uncertainties by ordering disparate elements and processes into a well-defined story. And as Dominque Pestre (1999, p. 205), a historian of CERN, writes: stories are „essential to the smooth functioning and perpetuation of scientific communities“.

So how do the narratives around technoscience typically look like? Narratives surrounding novel technoscientific projects frequently refer to both the past and the future. As Helga Nowotny (2008) puts it: “The new must be brought into the familiar world and enter into exchange with prior experiences. It must be given meaning and evaluated” (p. 2). Not only expectations about the future but also past experiences are constructed and drawn on to make sense of science and technology in the present. As Brown, Rapper, and Webster (2000, p. 5) argue, „the manufacturing of ‚the future‘ is no different from discourses about ‚the past‘ - not least, the history of science and technology itself“. As the quote indicates, the separation between past and future is not as clear as one might think. In a sense, both are narratives that influence decisions in the present. Future expectations and past achievements both serve as proof that an investment is worthwhile. History is thus read and utilized as proof of (inevitable) technological progress (van Lente, 2000, p. 46). As such, retrospective stories about successful innovations are often presented as a linear narrative (Deuten and Rip, 2000, p. 65). Such linear narratives make it seem as if innovations would be the logical outcome of a linear and straightforward process, thereby simplifying its actual complexity full of struggles and controversies. Retrospective accounts of successful technologies thus neglect the highly uncertain aspects of their creation. Uncertainty as well as possible alternative pathways are underplayed, thus making it seem as if the success of a technology was inevitable.

To conclude, narratives, full of promises and expectations, serve as a justification for CERN’s next collider project. As these narratives have a significant influence on any decision on the future of CERN, they invite close scrutiny. The narratives I will engage with take multiple forms and are utilized differently in different contexts. Such assemblages of different expectations can form narrative infrastructures or meta discourses. This means that there are a couple of shared expectations that form a ready-made repertoire that policymakers or scientists can tap into to justify the (future) technoscientific project. This thesis will thus engage with the different narratives around the FCC and their production, circulation, transformation and contestation. Furthermore, I will give a detailed analysis of how these give meaning to the FCC and its relationship to (European) society.

5. Methodological approach

5.1. Document analysis

This thesis is based on a document analysis of materials surrounding the FCC. Documents such as feasibility studies, policy reports, funding strategies, coordination papers, YouTube videos, newspaper articles and Facebook posts all bring the FCC into being. They help to create new realities by erasing disagreements, simplifying events, and creating linear storylines. As such, documents bring together a wide range of disparate elements into a single space and coherent narrative. According to Shankar, Hakken & Østerlund (2017) a document is "any artefact that includes substantial references to the social processes through which it was produced and reproduced" (p. 59). In other words, documents are artefacts that document (p. 61). This also means that it does not make sense to separate the document from where it was produced and the text from the practices that it describes. Documents not only represent and perform the FCC in a certain way; they can also give insights into the practices, settings, actors, organisations, rules, or values that produced them (Stark, 2012). As such, the documents surrounding the FCC are an interesting site to study valuation processes, the enactment of worth, and the implicated ontological politics. Following Asdal (2015), I understand documents as "lively value agents". Acting as sociotechnical "devices", they assemble and coordinate various entities and resources, making them central to processes of value creation and the enactment of worth.

Following Hilgartner's (2000) dramaturgical perspective on written documents, I was attentive to CERN's practices of "information control", that is, the strategic control of information in documents. As documents often conceal their messy processes of production, we need to consider how documents are created, who has access to them, and also what information is absent from them. According to Hilgartner, information is controlled in various ways: „performers actively reveal some information to their intended audience by displaying it in written text; they actively conceal other information from the intended audience by omitting it from the text; and they create nonaudiences by restricting access to the document, preventing unwanted persons from reading it at all" (p. 17). So how does CERN "manage" its stage and regulate what its audience perceives? CERN does not only control information through confidential documents or by omitting the practices that are going on in the „backstage" of the laboratory like the ongoing deliberations, uncertainties, and controversies we cannot find in the FCC's materials. Access to information is also regulated by the sheer amount of data available on the CERN database and the complexity of much of the materials on the FCC. The collider is the subject of long documents and technical language, making it difficult makes for people without the necessary expertise to make sense of them.

As I am interested in how the FCC is justified, I thus started my research by coding and analysing documents on the FCC that are publicly available on the CERN website or the CERN database. I further limited my research to materials addressing a more general audience, as this helped me to avoid getting lost in documents that exclusively refer to scientific and technical details. Thus, for my focus on how the FCC, and hereby also Europe, are enacted through visual and discursive narratives, representations, and expectations, I was especially interested in the "frontstage" of the FCC: those clean and polished representations of the FCC that are designated for an external audience. Many of the materials I analysed were created with the explicit intention to disseminate information about the FCC to a broad audience. Such documents necessary often reduce the complexities and contradictions of the underlying and informal discussions of the FCC, thereby making explicit the expectations, promises, and visions of the FCC.

My research thus draws on a diverse range of materials that range from conceptual design reports to feasibility studies, press materials, promotional YouTube videos, frequently answered questions documents (FAQs), and the FCC's new logo. Studying them helped me to understand how a complex and abstract technoscientific project like the FCC is translated and communicated to a wider audience. As these documents address different audiences, from policy makers, to funding agencies, or an interested public on YouTube, they also draw on diverse narratives, representations and expectations that enact the FCC differently. By downplaying, or as I will argue "managing", the uncertainties around the collider, the documents serve as a justification for action in the present. Studying the FCC's self-representation thus gave me unique insights into how European Big Science projects present, market, and justify themselves in order to mobilise public and political support. Specifically, it showed me CERN's vision of the FCC, Europe, and the relationship between science and society.

Many of the PR documents I looked at were produced as part of the "FCC Study", which is a major feasibility study on a post-LHC circular collider project at CERN (for a more detailed discussion see Chapter 1). Initiated in 2014 and finalised in 2019, the FCC Study formed the basis of the 2020 update of the ESPP and can thus be considered of central importance to the enactment of the FCC. It has a major role in constructing and thereby guiding the future of CERN. The FCC study, drawing on the expertise of a diverse array of scientists and engineers, has produced a detailed four-volume Conceptual Design Report with around 100 pages each. Widely referenced and quoted, the report can be understood as an important and ‚authoritative' account of the feasibility and desirability of the FCC. The FCC study has also produced various documents that remediate the insights of the Conceptual Design Report to a "lay" audience. This includes various press materials, FAQ's, visualisations, PR videos or summaries of the study, all readily available on CERN's website. The document assemblage around the FCC study has been a valuable site to better understand the justification of the proposed collider. The practices of engineers, experimental and theoretical particle physicists, social scientists, politicians, and communication experts all inform the FCC study, getting assembled, ordered, and narrated in specific way. The insights are also translated into a variety of mediums and addressed at a multiplicity of audiences, always constructing and materialising a specific perspective on the FCC. As a consequence, the FCC study documents do not only describe the collider's scientific and technical details but also emphasise the socioeconomic benefits it will generate.

Given the large amount of material published withing the study, I had to necessarily be selective. For my first round of coding, I focused on the FCC study's major publications (Conceptual Design Report 1 – 4; European Strategy Update Documents), conference recordings of the yearly FCC Week, as well as material designated for a lay audience (FAQ documents, press materials, PR videos). This enabled me to get a broad overview of the different narratives that revolve around the FCC. But, for an in-depth analysis, this was still too much material. As such, for my second round of coding, I focused specifically on two genres of documents: FAQ documents and PR videos on the collider project. These two document types have been at the heart of my empirical analysis (Chapter 1 – 4). Limiting my material to these two genres enabled me to do close readings to them, paying attention to both structure and content. Taking them as the base of my analysis, I branched out to other sites and documents in which the FCC is discussed. These included science policies from the European Commission, the CERN convention, or poplar sciences articles in newspapers like the CERN Courier. Doing so, I was able to show how the FCC is articulated differently at different sites and how these multiplicities are narratively coordinated.

I should also note that my research has been accompanied by a four-day field visit to CERN. During those days I had the chance to talk to a series of scientists either working at the LHC collaborations, involved with smaller CERN experiments, or directly engaged with the FCC and its feasibility studies or communication efforts. As I am specifically interested in how public documents justify the FCC, I do not explicitly refer to the interviews and fieldnotes in my analysis. Nonetheless, they have been essential to make sense of and contextualize my material.

5.2. Coding

Following Clarke's (2005) situational analysis, I started with a conceptual informed coding of materials. This means that, guided by my research question and theoretical framework, I inductively coded and attributed meaning to my data using words or short sentences. While Coding, I was especially sensitive towards expectations and valuations of the FCC as well as reoccurring rhetorical or narrative strategies. The codes were later classified and grouped into similar clusters or categories (which were then attributed to different regimes, orders or registers of worth) (Rivas, 2018). Constructing larger categories enabled me to identify patterns, thereby sensitising me towards similarities, differences, and relationalities in my data. It helped me see how the codes relate, interact, influence or depend on each other. Coding and categorisation were accompanied by memos, creating a continuous interpretation and reflection on my research processes and material. In this recursive and open-ended process, I remained open for new potential interesting data to emerge, thus continuously moving between reading, coding, and analysing my data.

From early on in my research I was creating abstract "situational maps" that lay out the major human, nonhuman, cultural, political, historical, or discursive elements involved in the research situation (Clarke, 2005). Situational maps helped me get an overview of, make sense of, and analyse the “situation” of the FCC. I started by describing and laying out what appear to me the major human and nonhuman entities in my research interest. Following Clarke (p. 87), I continuously asked: “Who and what are in this situation? Who and what matters in this situation? What elements “make a difference” in this situation?”. Mapping my research situation thus helped me gain some clarity about relevant actors and relations as well as the future direction of data collection. The maps visualised how heterogeneous elements such as national governments, industrial actors, and the international particle physics community are all entangled with the FCC in complex ways. They revealed some of the stakeholders in the FCC study, the dominant narrative registers drawn on, as well as elements present and absent from representational practices. The maps were continuously adapted and changed with the emergence of new data and insights. The following chapter is based on these situational maps and will give an overview of the multiplicity of entities, interests, discourses around the FCC, while remaining sensitive towards how they relate.

6. Findings

6.1. Situating the FCC

How does a new technoscientific project such as the FCC become reality? What are the social, technical, and political processes that lead to the (non) construction of a particle accelerator? How does a research tradition such as HEP, requiring a lot of resources, ensure its continuation? These are questions that cannot be easily answered. HEP is variously described as driven by theory, by experiments, by „Nature", or, as work in the sociology of scientific knowledge argues, by social processes. Some scientists might contend that despite the lack of theory or the large cost of the infrastructure, basic research in particle physics should continue no matter what. Investigating Nature is here often understood as an inherent desire of the rational human being. To this a politician might respond that, while this might be a nice ideal, investing huge amounts of money into research without any societal or economic benefit is not really feasibly. Consequently, they might be more interested in the socioeconomic spillovers that come from such a project. Similarly, the European Commission, with its attempt to foster cultural, political, and infrastructural integration across Europe, might see a very different value in the FCC. Others again might argue that basic research has no place in contemporary society; we have much more stressing issues to deal with than study the fundamental constitution of nature in ever more detail.

This clearly shows that we cannot reduce the question over the construction of the FCC to either an epistemic, technical, social or political issues. Science and society are always inextricably intertwined. Before I begin a more detailed analysis of the FCC's justificatory narratives, this chapter thus gives insights into the wider context in which the proposed construction of the collider is situated. The FCC is a large sociotechnical project that is part of multiple networks and actor constellations that reach from the European Commission to the citizens living around CERN. By following the FCC and its traversal across and entanglement with various arenas, I now provide an overview of the different, often overlapping, sites, constellations, processes, and human and nonhuman actors involved in the imagination and possible construction of the FCC. By doing so, I give insights into the assemblages in which the project is made sense of and the multiplicity of issues, concerns, and interests that are at stake. The FCC is not a free-floating entity but has to be considered as situated in and entangled with a multiplicity of entities that all shape what kind of thing the accelerator can become. Instead of giving easy answers and simplifying the question over the FCC's construction, the following seeks to show the messiness and complexity of technoscientific innovation.

6.1.1. Governing CERN

To begin, we can ask who decides over the construction of a new particle accelerator at CERN. What are the formal processes through which the FCC could become reality? In principle, the CERN council decides over the future of CERN (for a discussion of the role of the CERN Council in its early years, see Chapter „the Early history of CERN" by Pestre and Krige (1992) in „Big Science".

The CERN Council, supported by a Scientific Policy Committee and Finance Committee, has the main decision-making authority at CERN. It is made up by delegates from CERN's twenty-three member states. According to the Council's (n.d.) mission statement, it „determines the organization's policy in scientific, technical and administrative matters, defines its strategic programs, sets and follows up its annual goals, and approves its budget". Furthermore, the Council appoints CERN's Director General, who acts as the chief executive and representative of the organisation. Since 2016 this is the experimental particle physicist Fabiola Gianotti. National countries' institutional participation and representation in the governing bodies of CERN is limited by their membership status. For instance, full membership at CERN comes with a significant contribution to the institution's operating cost and thus also participation in decisions over its future activities and preferential treatment in procurement or knowledge and technology exchange programs. While full membership status is in principle open to countries regardless of their geographical location since 2010, with the exception of Israel it is still exclusively attributed to European states. In contrast to states with full membership, associate member-states, with a reduced contribution to CERN's budget, have no voting rights in the decision of the CERN Council. In exchange for significant contributions to CERN, states can also be awarded observer status. Today, this includes Japan, the United States, and Russia but also the EU. Finally, states and national organisations can take part at CERN through non-institutional participation which is made possible through international cooperation agreements and a so called „Memorandum of Understanding" that sets the conditions of the collaboration. This already shows some of the complexity of the governance of CERN. It is a huge, international organisation that includes actors from all over the world with different levels of involvement and participation.

But then who decides over the next particle accelerator? Even though the Council has the authority to make decisions over the future of CERN, its members also represent the interests of their respective national governments. It is not only what's best for particle physics and CERN, but also what's best for the collaborating national (member) states. This can make negotiations over new accelerators very difficult. As Chris Llewellyn Smith (2007) nicely shows in his discussion of the controversy over the construction of the LHC, national governments have a lot of influence over the future of CERN. In the end, their nonparticipation could bring an end to a successful scientific collaboration. Usually, member states clash over their respective financial contribution to CERN. For instance, in the 1990s the construction of the LHC was nearly hindered by the United Kingdom and Germany's reluctance to accept CERN's budgetary conditions. In light of this, funding and governing a mega project such as the FCC will likely be a major challenge. Given the project's increase in size and cost over previous accelerator programs, it will be essential that CERN extends its collaboration partners even further, securing resources from all over the world. Simply the huge cost of a next generation particle collider will make it an international project. As Ursula Bassler (2021), current president of the CERN Council, insists:

> *Neither the implementation of the technology roadmaps nor the FCC feasibility study, and far less its construction, can be carried out by CERN alone. Without a tight network of collaboration and exchanges it will not be possible to find the brains, the hands and the financial resources to ensure that CERN continues to thrive in the long term. The collaboration and support from laboratories and institutes in CERN's Member and Associate Member States and beyond are crucial.*

While the LHC was still, besides some non-member contributions by the US or Japan, predominately funded by CERN's member states and constant budget, the cost of the FCC will make this increasingly difficult. Thus, even though still located in Europe, one of the major challenges in realizing the FCC will likely be convincing global scientific and political actors to invest in the machine. This will certainly be complicated negotiations, as benefits from the project are geographically unequally distributed. Who will get the contracts to do the R&D necessary for the FCC? What (national) companies will be involved in the development and manufacturing of detector components? Who will be involved in the planning and execution of the tunnelling work? What kind of organizational model is suitable for such an endeavour? And how would CERN change if it would transform from a European to a global research infrastructure? These are some of the questions that have to be negotiated when it comes to the construction of the FCC, making explicit that there is not only epistemic but also economic, social, and pollical interest in the project.

6.1.2. The European Union

As hinted at above, also supranational institutions such as the European Union (EU) have a stake in Big Science project, reflecting an increased demand on science to contribute directly to society (Felt & Wynne et al., 2007). In recent years, the EU has started to show increasing interest in transnational European research infrastructures, making them subjects of its various science policies and funding programs. With its mission to create the European Research Area (ERA) to advance Europe's global competitiveness, economic growth, and innovation, the EU is entangled with the FCC in interesting ways.

Before I describe the EU's concrete involvement in the FCC, it makes sense to look at the institution's history of science policies. This might give some insights into the rationales behind the EU's support of CERN. After World War II, European collaboration was limited to the European Coal and Steel Community (ECSC) and later the Common Market and the European Atomic Energy Community (Cramer et al., 2020). Only with the establishment of the European Economic Community (EEC) in the 1970s were science and technology explicitly mentioned in policy programs. The first Framework Program for Research and Technological Development in 1984 was another important development towards developing a clear European research agenda. With the framework program, the EEC (today the EU/EC) started to actively steer the direction of technoscientific developments by funding specific research projects. In the early 2000s, the EU then created the European Research Area (ERA) and the European Strategy Forum on Research Infrastructures (ESFRI). This marks another milestone towards a common European policy on science and technology, increasingly aimed at fostering innovation, economic growth, and Europe's international competitiveness in a global knowledge-based economy. The ERA is about promoting European research institutions and innovation. For the realisation of the ERA, international collaboration through research infrastructures is considered of central importance. According to (Cramer et al., 2020, p. 6), this move towards improving Europe's global role in science and technology was accompanied by the emergence of an "innovation union" that aims to create the conditions for innovation through a more systemic understanding of science, society, and industry relations.

With this context in mind, it is not surprising that the EU is interwoven with CERN in many different ways. In line with the Horizon 2020 program, the EC's 2014 Framework Program, CERN is receiving funding in over 90 different projects (CERN, n.d.-a). Some of these EU funded projects explicitly aim at making the FCC reality. For instance, the EU has contributed 3 million euros to the European Circular Energy-Frontier Collider Study (EuroCircCol) (2015 – 2019). The project is a conceptual design study that looks into the feasibility of a post-LHC research infrastructure in Europe. Mirroring the language of Horizon 2020, EuroCirCol aims at strengthening the ERA and thereby Europe's competitiveness through global research cooperation. As the project descriptions put it, the research will form "the foundation of subsequent infrastructure development actions that will strengthen the ERA as a focal point of global research cooperation and as a leader in frontier knowledge and technologies over the next decades" (European Commission, n.d.-a). Similarly, the EU is contributing 3 million euros to the ongoing Future Circular Collider Innovation Study (FCCIS) that will run from 2020 until 2024. The study aims to create a "conceptual design and an application plan" for the FCC in order to "strengthen Europe's leadership in excellent science for many decades" (European Commission, n.d.-b).

So why does the EU show such a particular interest in CERN? If we consider the values, norms, and goals materialized in Horizon 2020, the support of the FCC makes a lot of sense. Horizon 2020, the eighth European framework program running from 2014 until 2020, aims at securing Europe's global competitiveness, driving economic growth and developing the ERA through science and innovation. It is thus exemplary of the EU's vision of the relationship between technoscience and society - solving societal challenges through innovation, economic growth, and global competitiveness (Ulnicane, 2015). It also exemplifies European integration through the creation of „technological zones" (Barry, 2001), in which the EU attempts to strengthen its social, political, and economic position in the world by creating shared research infrastructure projects and the ERA. The EU's expectation toward a future accelerator becomes even more explicit when we take a look at the description of the specific funding program that supports the study of the FCC. The EuroCircCol and the FCCIS are both funded under the H2020 rubric on „Excellent Science - Research Infrastructures"

(H2020-EU.14.). The program states as its objective to "endow Europe with world-class research infrastructures which are accessible to all researchers in Europe and beyond and which fully exploit their potential for scientific advance and innovation" (European Commission, n.d.-c). This is important because, at least according to the EC, „Research infrastructures are key determinants of Europe's competitiveness across the full breadth of scientific domains and essential to science-based innovation".

The EU understands itself as having a very particular role in the development of the ERA and Big Science Research infrastructures. It is not directly involved in funding infrastructures themselves, but rather about creating favourable conditions for them. As the EC (n.d.-c) puts it: "while the role of Member States remains central in developing and financing research infrastructures, the Union plays an important part in supporting infrastructure at European level such as encouraging co-ordination of European research infrastructures, by fostering the emergence of new and integrated facilities."

The EU's support of „the emergence of new and integrated facilities" is thus key to understanding its involvement in the FCC. While the EU might not be a major contributor to CERN's budget and consequently the construction and maintenance of the FCC, funding conceptual design and feasibility studies has an indirect influence on the future of CERN and particle physics in Europe. Funding schemes might thus be understood as "soft power", that is, instruments to keep Europe's leading role in experiments in high energy particle physics. It serves as a way for Europe to maintain competitiveness in the global knowledge economy. Funding research on the FCC can thus also be seen as a "future making" practice. By funding research on the FCC, the EU is indirectly setting the future for particle physics in Europe. Without directly funding the project, it clearly sets the agenda for what is supposed to come next. This vision of the future goes beyond CERN. It is co-produced with a wider imaginary of an EU that is globally competitive and innovative through its Research infrastructures.

6.1.3. The European Strategy for Particle Physics

So far, I have engaged with some of the national and supranational actors implicated in the realization of the FCC. Now I want to proceed to discuss some of the formal processes and feasibility studies in which the details of the accelerator are deliberated and materialized. One of the major publications guiding the future of CERN is the European Strategy for Particle Physics (ESPP). At least referenced once in most documents on the FCC, the strategy serves as a legitimization for present and future research into the feasibility of a new collider. Based on the input of the (European) scientific community, the strategy's main goal is to create a publication that plans, coordinates, and sets the agenda for the future direction of the field. It acts as a guideline for CERN and aims to create a coherent science policy for European particle physics. In the language of actor network theory, we can understand the ESPP as an obligatory passage point (Callon, 1986). To become reality, the FCC first needs to be recommended by the strategy and the people involved in its creation. This makes it a central stage in which the future of CERN and European particle physics more general is negotiated and performed. In its own words, the ESPP aims to create:

> *a clear prioritization of European ambitions in advancing the science of particle physics. It takes into account the worldwide particle physics landscape and developments in related fields, and is initiated by the CERN Council to coordinate activities across a large, international's and fast-moving community with the aim of maximizing scientific returns. (CERN, n.d.-b)*

The strategy is created through multiple steps in which many different scientific actors are able to participate and voice their visions and expectations for the field of particle physics. The European Strategy Group, a temporary body made up of representatives of CERN member and associate member states, observer states, CERN's director-general, and others, coordinates and drafts the strategy update, which then has to be approved by the CERN Council. Collaboration with the particle scientific community is ensured through an open symposium, in which particle physics are invited to give their input to the strategy.

To this day, there exist a 2013 and a 2020 strategy update. Both had an influential role in the processes towards the emergence of the FCC as a project of interest. One could argue that everything started with the 2013 strategy's proposal to begin research into possible post-LHC accelerators for the following strategy update in 2020. As the 2013 strategy put it:

> *to stay at the forefront of particle physics, Europe needs to be in a position to propose an ambitious post-LHC accelerator project at CERN by the time of the next Strategy update, when physics results from the LHC running at 14 TeV will be available.*
>
> *CERN should undertake design studies for accelerator projects in a global context, with emphasis on proton-proton and electron-positron high-energy frontier machines. These design studies should be coupled to a vigorous accelerator R&D programme, including high-field magnets and high-gradient accelerating structures, in collaboration with national institutes, laboratories and universities worldwide. (p. 1)*

To inform the 2020 strategy on the feasibility of a new circular collider, CERN thus initiated the *FCC study* in 2014. The study roughly marks the emergence of the next collider as a coherent object that from then on would be addressed as the Future Circular Collider or FCC. A European particle accelerator for the post-LHC area suddenly became a real possibility. The 2013 strategy update and the subsequent feasibility study brought the FCC into existence. It was now an object that could be talked about and studied. So in a sense, the FCC can be seen as the materialization of the desires and expectations of the 2013 strategy. Feasibility studies bring expectations into being. The more resources that are invested in them, the more likely they are to become reality: they create path dependencies that exclude alternative futures (Borup et al., 2006). This makes them interesting sites to witness a variety of different narratives and expectations in action.

6.1.4. The FCC study

So who is involved in the FCC study? How is it governed and coordinated? Who is its audience? And what is its influence on the future of the FCC? Led by accelerator physicist Michael Benedikt, the FCC study understands itself as an international collaboration that, by involving national institutes, laboratories, universities and industry, aims to investigate the possibility of a successor to the LHC. At the centre of the study, there is a steering committee**,** which in close interaction with the FCC study coordination group, represents its main governing body. Then there is a collaboration board, representing the actors collaborating with the study and an advisory community that reviews the progress and makes recommendations. The study is accompanied by an annual conference called the FCC Week, in which the scientific community comes together to discuss its progress and further steps to be taken. Collaboration is based on a memorandum of understanding that sets the rules for collaboration. Already the organization of the FCC study reflects the increasing internationalization of. While historically, CERN planned and developed its accelerators internally, the FCC study actively seeks relationships with the global particle physics community. By establishing collaborative structures with actors all over the world, the study already sets the stage for the construction and maintenance of the FCC. Open to academia and industry, the collaboration thus involves 136 institutes, 32 companies, 34 countries, and the European Union.

Informed by the FCC study, the 2020 strategy recommended the further investigation of the technical and financial feasibility of the FCC. As the strategy is the major site in which the future of the field is decided, this was a huge relief for the particle physics community, worrying whether the further study of the FCC will be recommended by CERN. In the words of the editor of the CERN Courier Matthew Chalmers (2020), the strategy proposed „an ambitious program to carry the field deep into the 21st century". Consequently, in June 2021, the FCC Feasibility Study (FCC FS) was approved by the CERN Council. Finalized in 2025, the FCC FS is distributed over five pillars: Physics, Experiments and Detectors, Accelerators, Technical Infrastructures, Civil Engineering and Host State Processes, and Organisation and Funding. The feasibility study aims at „demonstrating" the geological, technical, environmental and administrative feasibility of the tunnel. It will further prepare the administrative process for the approval of the project, look into a sustainable operational model, make a cost estimate, create a funding and organizational model, and identify resources from outside of CERN's budget. At the time of writing, the study has only just commenced. This means that there are not yet any documents available for analysis. The further development of the FCC thus needs to be the subject of future research, and will not be further addressed in this thesis.

As we have seen, the strategy's recommendation to investigate the feasibility of the FCC marked an important moment for the future of the field of particle physics. It started various initiatives that investigate the feasibility of such an endeavour, and expressed a clear interest to construct the next accelerator machine at CERN. The strategy was not only a symbolic proposal, it also led to the start of two very concrete studies into its feasibility. But here it is important to note that CERN's interest into a new particle accelerator alone is not enough to make it a reality. There can be a perfect conceptual design report that clearly lays out the feasibility and construction plan for the machine. But technical feasibility and the desire of the scientific community alone are not enough to ensure the success of a techno-scientific project. As Riordan, Hoddeson, and Kolb (2015) nicely show with their historical analysis of the failed construction of the Superconducting Super Collider in the US, technical feasibility and epistemic interest do not yet ensure that a particle accelerator will in the end also be built. There are many social, political, cultural, and economic factors involved in the planning and construction of Big Science projects. Even though the FCC studies mostly focus on the technical feasibility and epistemic relevance of the FCC, society is still always present in the reports. So what are some of the social, political, and economic aspects entangled with the construction of the FCC?

A quick look at the FCC's study section on the feasibility and possible placement of the future infrastructure reveals how the project is not only technical but also natural, social, economic, and ecological. Before the FCC can be constructed, there need to be extensive studies on the place in which the tunnel for the accelerator could be situated. For instance, there needs to be a lot of attention to the geophysical composition of the environment in which the collider will be located. What soil, rock, or lake formations might make tunnelling difficult? In contrast to other tunnels, the FCC needs to be perfectly straight, making placement even more challenging. But then, the construction might also interfere with local flora and fauna, potentially attracting local environmental groups. Here we move from the realm of the technical and natural into the social and political. The construction might interfere with local laws protecting the environment or with densely populated areas, in which inhabitants might be opposed to the construction of the FCC. It is thus essential that the local French and Swiss public understands the value of another, bigger collider. The population living around CERN and the future FCC are the most impacted by its construction and operation. Without their approval, it will be very difficult to realise the project. Big science infrastructures interfere with the lives of the local population in many ways. The FCC will not be built in some empty desert but in a fairly populated area around Geneva crossed by various smaller rural and agricultural towns. The tunnel might pass through environmentally protected areas, provoking the concerns of local environmental groups. There might be worries about the creation of black holes and potential negative health effects caused by the FCC's radiation, the construction might interfere with private property rights, or there might be fears about turning local communities into industrial centres. Transporting the molasses created through the tunnelling will certainly require a lot of effort, involving thousands of trucks moving the excavated materials across the countryside. Caravans of huge machinery will have to drive across small roads and pass through local towns, which is likely to provoke responses from the local population. It will require the construction of new roads and other transport infrastructures, producing a lot of noise and unpleasant views.

These were just some examples of the difficulties that need to be considered when studying the feasibility of the FCC. By describing the different aspects interwoven with the construction of the FCC I want to emphasise that Big Science projects are not just a technical issue. There are a multiplicity of different legitimate concerns about the construction of a new accelerator at CERN. Not only the technical feasibility and epistemic desirability, but also the high cost, environmental impact, or influence on local communities are of issue. This means that the FCC needs to be justified to all of the concerned actors. If not, this can have negative implications for the future of CERN. It is thus widely acknowledged that demonstrating the epistemic potential and feasibility of engineering is not enough to realize the FCC. CERN is not an autonomous entity that can simply decide whether to construct a new particle accelerator or not. It is much more complex than that. Not only epistemic, but also social, economic, political, and cultural factors play a role. It is a complex sociotechnical assemblage. Potential international collaboration needs to be established. Universities and scientific institutes from all over the world are invited to participate. The epistemic desire of the particle physics community needs to be there. Similarly, industrial actors need to be interested. As such, the FCC is at the centre of various actors and discourse that reach from scientists and engineers to national governments and supranational institutions. Different concerns, values, and desires become visible. But not only the study itself, but also its (re)mediation outside of CERN become sites for discussion and contestation. Picked up by newspapers and popular science magazines, the FCC is also moved into the public discourse.

The benefits of the collider need to be communicated and justified to policy makers, funding agencies, politicians, policy makers, and the public from the very beginning of the project. As Ursula Bassler (2021), president of the CERN Council, put it quite strikingly in her reflections on the future of CERN:

> *We must clearly and carefully explain the case for continued exploration at the energy frontier. To other scientists: we all benefit from mutual exchange and stimulation. To teachers and educators: we can contribute to making science fascinating and help attract young people into STEM subjects. To society: we can help increase scientific literacy, which is crucial for democracies to distinguish sense from, well, nonsense. Twenty-five years is not long. And no matter our individual roles at CERN, we each have our work cut out. Together, we need to stand behind this unique laboratory, be proud of its past achievements, and embrace the changes necessary to build its – and our – future.*

As we can see, communication and outreach activities are seen as essential to the success of the FCC. The quote above makes explicit how CERN imagines the project's different audiences and interests. Consequently, it is important to take a closer look at the various ways through which the FCC is communicated and justified to society. The following chapters will thus closely engage with two documents aiming to communicate the FCC. In line with the FCC study there were created a variety of FAQ documents and PR videos that cover, imagine and perform the next collider at CERN in very different ways. I use these two types of documents to give insights into the multiplicity of epistemic, economic, social, cultural, and political concerns around the FCC. I show how these concerns are articulated, addressed, and "managed" within these documents and other sites. Doing so I trace the narratives around the FCC across space and time, showing how they assemble old and new things, always emerging and transforming depending on the site of their enactment.

6.2. Epistemic uncertainty

Particles, the smallest constitutes of our world, have been the subject of the imagination for a very long time. Many fantastic stories have been woven around them. Hopes, desires, fears, and entire philosophies have become entangled with particles and the machinery that produces them. From ancient India to ancient Greece, the composition of the world has occupied the minds of philosophers and scientists for centuries (Traweek, 1988, p. 46). Only over the last decades, the understanding of what makes up matter has continuously changed. As Andrew Pickering (1984, p. ix) puts it: „Etched into the history of twentieth-century physics are cycles of atomism. First came atomic physics, then nuclear physics and finally elementary-particle physics. Each was thought of as a journey deeper into the fine structure of matter“. For a long time, the atom, consisting of a positively charged nucleus that is surrounded by negatively charged electrons, was understood to be the fundamental part from which all elements were made up. A bit later in the history of particle physics, the atoms' nucleus was considered to be constituted by even smaller particles: protons (positively charged particles) and neutrons (electrically neutral particles). Together, protons, neutrons, and electrons, the so called „elementary particles“, were understood as the fundamental building blocks of nature. In the post-war years, there were then discovered a couple more particles. Suddenly, atoms, protons and neutrons were no longer the elementary particles. As Pickering (1984) nicely shows, from the 1960s onwards, physicists increasingly started to consider quarks as the newest smallest entities making up the world, forming composite parts of protons and neutrons. In this context, we can situate the field in physics that tries to study and understand these small constituents of our matter: so-called elementary particle physics, or in reference to the experimental machinery it uses, High Energy Physics.

Today, CERN's LHC is the major particle accelerator that probes for new physics in the high energy ranges. After the 2013 discovery of the Higgs Boson at CERN, the so-called standard model of particle physics is considered complete. Nonetheless, there still appear to be many open questions bothering particle physicists: what are the properties of dark matter, what to make of the mater-antimatter asymmetry, or more generally, „what are the fundamental laws of nature“ (CERN, n.d.-c)

But, different to past discussions over the need for bigger particle accelerators, today some people argue that there exists a distinct lack of theoretical predictions that would justify the construction of the FCC. In contrast to the LHC, a bigger hadron collider will not (dis)prove any major theoretical claims or predictions such as the (non)existence of the Higgs. After the discovery of the Higgs Boson and the completion of the standard model, there is no more concrete energy range to reach in the search for new phenomena. In a sense, the FCC can be seen as a blind search with the hope of discovering something unknown or out of the ordinary. In the discussions around the collider, a frequent concern thus appears to be the epistemic uncertainty that comes with the construction of such a mega project: we don't know where to look and what to find.

This argument against the FCC is most famously articulated by theoretical physicist Sabine Hossenfelder. As a popular science writer who runs a blog as well as an educational YouTube channel, she is one of the more visible and prominent particle physicists today. Hossenfelder's criticism of CERN's proposal to construct the FCC has probably reached its peak in 2019, when she wrote an article about the topic for the New York Times, sparking wide discussion in the particle physics community and beyond. In the 2019 article, Hossenfelder writes about the „uncertain future of particle physics". Her argument comes down to this. The scientific case for a bigger accelerator is small: there are too many uncertainties involved. It is not very likely that a new particle collider will bring answers to the remaining open questions in physics. As such, money would be better spent elsewhere, either in multiple small and medium sized basic research projects or for research with a concrete societal value such as the mitigation of climate change. According to Hossenfelder, not even the LHC has fulfilled the many theoretical promises originally circulating around the project. Besides the discovery of the (already predicted) Higgs and the thereby completion of the standard model, the epistemic value of the LHC has been a disappointment. Theory had many more interesting predictions, for instance about the nature of dark matter, supersymmetry, or more new particles, but in the end, none of these could be discovered. And if we look at the FCC, this is even more so the case. While it is not impossible that a bigger collider will find something, there is no real reason to think it will. The inherent uncertainty of the project simply does not justify its huge price. As she puts it: „if particle physicists have only guesses, maybe we should wait until they have better reasons for why a large collider might find something new" (Hossenfelder, 2019). In the future, better theoretical prediction might reduce epistemic uncertainty or technological innovations might reduce projects costs drastically, thereby justifying the construction of the FCC.

6.2.1. Constructing uncertainty

CERN does not deny the epistemic uncertainty haunting contemporary particle physicists. As acknowledged in a FCC study document that informs the European strategy about the feasibility a new hadron collider: „Today High Energy Physics lacks unambiguous and guaranteed discovery targets" (Benedikt et al., 2019a, p. 2). Or put differently, there exists no substantiated theoretical prediction that the FCC will discover anything new. One might think that uncertainty about the potential epistemic insights of the FCC would be an argument against spending more than 20 billion Euros on such a mega project. If we do not know what insights we can generate from the project, why even bother building it? Are there no better ways to spend public money? And indeed, as I have shown above, these concerns do exist. Interestingly though, uncertainty is not always constructed as something negative that needs to be avoided. Frequently, epistemic uncertainty is mobilized as an argument in favour of constructing a new collider. CERN's narrative goes something like this: because there are no good theoretical predictions about what could be discovered at higher energies, we need to construct a bigger and better machine even more urgently.

In an article for the CERN Courier, Michelangelo Mangano and some colleagues (2017) very explicitly put forward the claim that a lack of theory should not hinder the construction of the FCC.

Against the critique that the LHC has not discovered many of the phenomena earlier promised, they argue that this does not mean that physicists should stop looking for them:

> *That no new particles beyond the Higgs have yet been found, or any significant deviations from theory detected, does not mean that these questions have somehow evaporated. Rather, it shows that any expectations for early discoveries beyond the SM at the LHC – often based on theoretical, and in some cases aesthetic, arguments – were misguided.*

In a sense, the authors' opinion aligns with Hossenfelder's claim about the failure or lack of theoretical predictions for physics beyond the standard model. Earlier (theoretical) expectations of the epistemic potential of the LHC „were misguided" and failed to materialize. But, and here their argument starts to differ, they also claim that this should not stop us from constructing the next generation of particle accelerators. Instead, the lack of theoretical predictions is evidence of the urgent need for the FCC.

> *In times like this, when theoretical guidance is called into question, we must pursue experimental answers as vigorously as possible. [...] There are numerous instances in which the answer nature has offered was not a reply to the question first posed. For example, Michelson and Moreley's experiment designed to study the properties of the ether ended up disproving the existence of ether and led to Einstein's theory of special relativity.*

If there exists uncertainty in theory, experiments need to create certainty. Just because there are no predictions for phenomena at higher energies this does not mean that nature could not still hide there. Even more so, the past has shown that experiments have discovered physics even though theory predicted something else entirely. We can thus witness how this argument for the epistemic worth of the FCC implicitly draws a boundary between theoretical and experimental physics. While theory appears to be mere speculation, experiments are able to uncover the secrets of nature that are supposed to pre-exist somewhere out there. Theory is not the driver of new physics; experiments are. And as the FCC is a large experimental endeavour, the lack of theoretical predictions should not be a concern. We simply cannot predict where nature hides. The authors go on to write:

> *The possibility of unknown unknowns does not diminish the importance of an experiment's scientific goals. [...] This is true of all expeditions into the unknown. We should not forget that Columbus set sail to find a westerly passage to Asia. Without this goal, he would not have discovered the Americas.* (Mangano et al., 2017)

This narrative implies that epistemic uncertainties or „unknown unknowns“ are an inherent part of scientific activity. Science is in part about the exploration of the unknown. As such, theoretical predictions are not the only aspect through which new science is discovered. Even more so, theoretical predictions are frequently false. There can never be certainty that what is intended to be found will also be what one discovers in the end. But this does not diminish the epistemic potential of experiments. Even if theory is wrong or non-existent, experiments can still provide (unpredicted) insights into nature. More so, in this story uncertainties and the experiments to investigate them are the main drivers of new knowledge. Uncertainties in science are what turns novel experiments into a productive and innovative force. Simply because we cannot know what there is, this does not mean that nothing could be hiding there. Uncertainty about what to find also means that anything can be found. The most fantastic and world changing, science could be discovered in higher energy ranges. The only way to find out and gain certainty is by constructing the FCC.

This narrative is powerful because it always holds true. There are theoretical predictions for phenomena at the FCC-hh energy range? Let's build the collider to see whether they are true! There are no theoretical predictions for phenomena? Even more so a reason to construct it! No matter the circumstances, the FCC would always be the logical next step. It is always justifiable, at least from an epistemic point of view. This makes a critique of the epistemic potential of the FCC incredibly difficult. Both the existence of theory and the lack of theory can be used as an argument for the construction of experiments. Uncertainty as intrinsic to scientific progress becomes an very powerful narrative to justify the FCC and its epistemic worth.

6.2.2. Exploring the endless frontier

As we can see, narratives construct epistemic uncertainty as potential for new scientific insights. By stepping into the unknown we can, at least if we are lucky, find new physics. As the FCC Q&A (2019, p. 5) writes: „the proposal of a 100 TEV pp collider stems from the bold leap into the completely uncharted new territory that it offers, probing energy scales, where fundamental new physics principles might be at play“. In this narrative, the FCC becomes presented as a brave venture into uncharted new territory, an explorative endeavour that will bring upredictable epistemic insights. Interestingly, overcoming uncertainties is here no longer only about doing science. It is also about being "brave". As I will show now, in the stories around the FCC, uncertainty becomes embedded in a mythical narrative that celebrates the exploration of the unknown. Paralleled with colonial and space exploration, the FCC is promised to extract value from the endless frontier of science, which will inevitably drive human progress. This is how the argument goes: great actions by great people, venturing into the unknown driven by nothing besides their curiosity, benefit the whole of humanity. Here, exploration is a significant part of what it means to be human. This story is entangled with a moral argument: the exploration of the secrets of nature is the moral duty of humanity, or as Fabiola

Gianotti, CERN's current Director General, puts it in an interview with the new scientist: „Its the duty and the right of humanity to understand how nature works" (New Scientist, 2019).

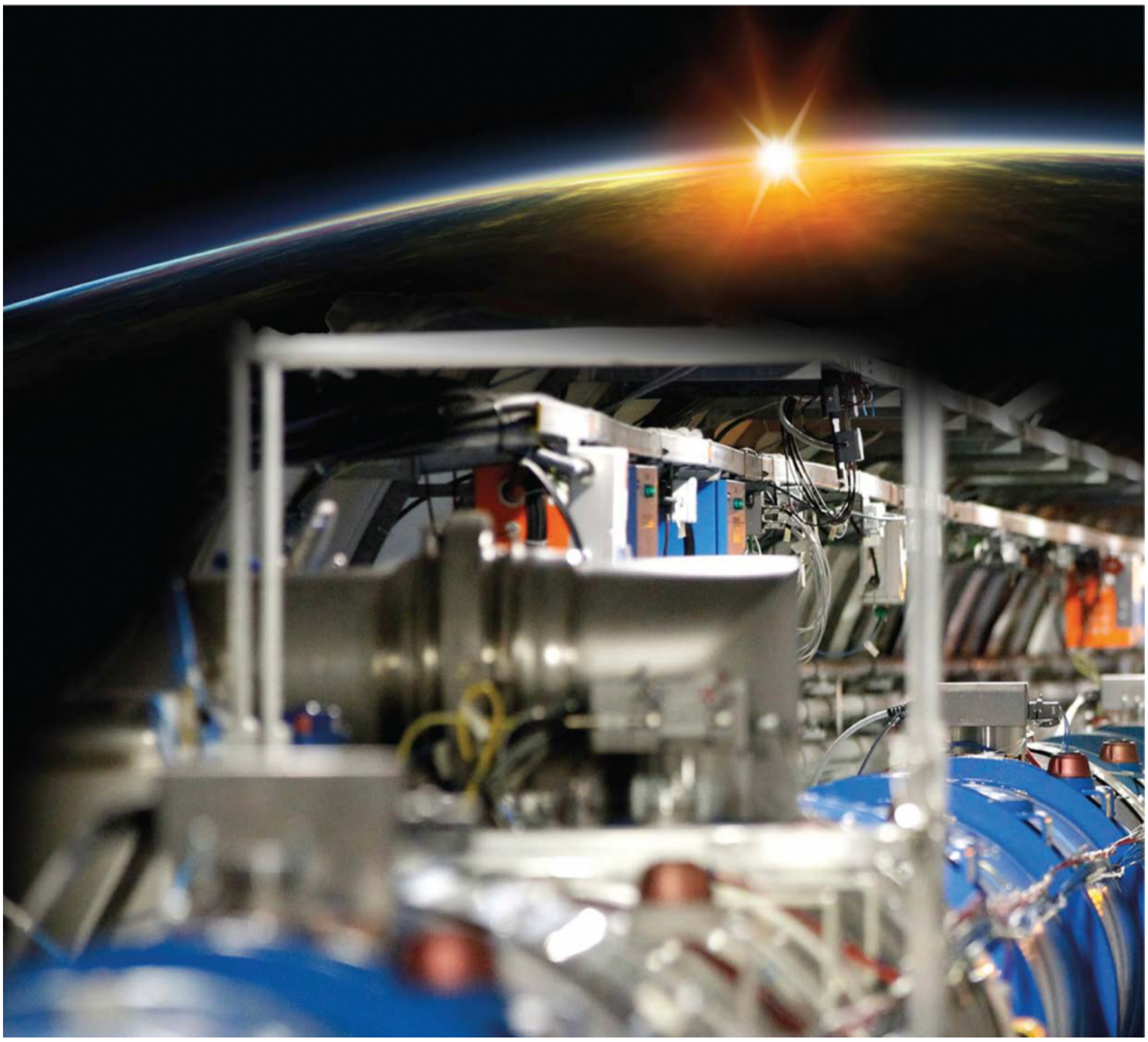
This narrative becomes even more explicitly if we take a look at Gianotti's opening address of the 2019 FCC Week in Brussels. Here she emphasises that, even though the FCC project might seem daunting or impossible, „the only way for Humanity to push back the limit of knowledge and to make great progress is through difficult, challenging, and brave initiatives. The knowledge of humanity needs brave projects and brave people". Gianotti continues her speech with a story about a past visit to the London science museum, in which she reflects on her encounter with the there exhibited capsule of the Apollo 10 mission that brought three people into space. Gianotti uses space exploration as an analogy to CERN's next collider project. The FCC, similarly to Apollo 10, is an exploration into the unknown. But her story also exemplifies a narrative in which bravery is needed to advance "humankind" and create "progress". Overcoming uncertainty and discovering the unknown, even though a difficult achievement, is how "humanity moves forward".

Gianotti's speech seems to be part of a wider narrative in which single, brave, and monumental actions, done by a couple of extraordinary people, advance knowledge for the benefit of all. In this narrative, the exploration of the unknown is how society progresses. By references to Columbus' colonial undertakings, ventures into the final frontier of space, or the endless frontier of particle physics, the exploration of the unknown is presented as an intrinsic part of what it means to be human. Moreover, it is only by making brave, bold and revolutionary leaps into the unknown that epistemic, technological, and societal innovation becomes possible. And the FCC is exactly such a bold venture into uncertain territory.

The different stories come nicely together in an image used for a 2017 article in Europhysics news. Written by Michael Benedikt and Frank Zimmermann, the two leaders of the FCC study, the article introduces CERN's new collider project. On the first page of the article and under the words „designing a future circular collider is a next step in humanity's question to explain the world" the reader is faced with an image visualizing the FCC juxtaposed with a picture of a rising sun over the horizon of the Earth (Image 1). The dawn of light over the planet signifies the dawn of a new era in particle physics. Not different to text, the image is inscribed with visions and imaginations of the FCC. Godlike, the viewer gazes from out space down onto the earth. The collider, shown in its full complexity, is floating freely above the planet. This juxtaposition of the FCC with a visualisation of the globe brings together vast scales. Human ingenuity has conquered space. Now it is time to move towards the smallest constituents of our universe: particles. Both the exploration of the final frontier of space and the final frontier of particle physics requires the use of huge machinery. Both are seen as brave accomplishments, celebrated as great human achievements.

Image 1

The FCC in space



Note. Benedikt & Zimermann (2017), Can you afford to wait? Designing the collider of the future, Europhysics News

But the references to space exploration do not stop with the image. The refences are not only analogical and metaphorical. There has also been a proposal to construct a future collider on the moon. The vision of ever bigger machines with ever higher energies to counter epistemic uncertainty is exemplified by a 2021 article that proposes the construction of a particle accelerator in space. James Beacham and Frank Zimmerman, two CERN scientists involved in the construction of the FCC, make the case for a "(next-to-)next-to-next-generation discovery machine" on the Moon (p. 1). In a way, the article is representative of the current state of High Energy Physics as criticized by Hossenfelder. It makes explicit the community's desire for big machines that permeate the discussions around the FCC. There is a kind of fetishization of new particle accelerators, celebrated for their size and complexity. Before the construction of the FCC has even been accepted, let alone started, there is already talk of the next accelerator project, 100 times larger than the FCC. The future is already the past. Of course, the article is meant as a joke, a kind of speculative thought experiment of what the future could hold.

Nonetheless, it is surprising how much it tells us about the current discourse around the FCC. Accelerators are continuously getting bigger, energies are getting higher: from the LHC, to the FCC, to the Moon. Mirroring the techno-fantasies of Silicon Valley billionaires, not even the sky is the limit. There is always one machine bigger and better: progress never stops. As the authors write: „ A CCM (Circular Collider on the Moon) could be a natural successor to next-generation machines, such as the proposed Future Circular Collider at CERN" (p. 2). This makes the current expectations and desires, and urge for novel, bigger, and more powerful machines explicit. There will always be one more and one bigger. Exploring the unknown with frontier machines at the endless frontier of science.

Epistemic uncertainty and lack of theoretical predictions again are driving forces for the construction of bigger machines: there are "multiple unsolved mysteries of physics, but few (or no) hints as to the mass scale of new particles or phenomena, that, if discovered, could help solve these" (p. 2). The authors acknowledge that currently, HEP is not driven by any theoretical motivations that predict new particles and phenomena at higher Energy levels. "New particles could appear at any energy up to the Planck energy, 10^16 TeV. The future of collider physics is exploratory and experimental, irrespective of specific theory motivation" (p.2). In other words, different from the LHC, the future collider will not be driven by theory but through exploration and experimentations. This happens "irrespective of specific theory motivations". This shows that epistemic uncertainty, used as a justification for the construction of bigger experiments, always holds true. In principle, there will never be a moment in which it does not make sense to construct another accelerator. There can always be something there! As such, the sheer size of colliders, whether it is the 100km FCC or the even bigger collider on the moon, serves as a major argument against the lack of theoretical predictions. Accelerators ever increasing in size have made possible insights in the past and will thus also drive future endeavours in HEP. Without any sound theoretical predictions, particle physics has become an exploratory and experimental science, which thus even more relies on big machinery. HEP become defined through its accelerators. If you take away the accelerator, the field seizes to exist.

As we could see, representations of the FCC are interwoven with an abundance of colonial metaphors and references to space flight. The FCC will enable research at „the frontier of knowledge". The collider is a „frontier machine" searching at the „precision" or „energy frontier". As such, the narratives position the collider next to figures such as Christopher Columbus who, exploring, colonizing, and enslaving the unknown „new world", pushed further the frontiers of Europe. It is also compared with endeavours in space flight that explore the „final frontier" of humanity, which comes together in a vision of a particle accelerators on the moon. What these different (colonial, spaceflight, and accelerator) stories have in common is that they are all entangled with stories of human greatness, progress, and the exploration of the unknown. They work so well together because, at least in the dominant western narratives, they are all constructed as outstanding human achievements in which a couple of great people have conquered uncertainty for the benefit of all. Stories about the exploration of an unknown frontier make up an established narrative repertoire that representations of the FCC can mobilize to make sense of the next collider. Flink and Peter (2018) understand the metaphor of the "frontier" as a "traveling concept" that changes its meaning over time and space. Moving from the US into the European context, references to "frontier" research can be increasingly found in contemporary science policies. According to the authors, the frontier metaphor has two rationales. First, it is geopolitical, implying urgency to discover new science before other actors do so. Second, it ensures independence of scientists from society, as there is no model for how to explore the unknown. Pushing back the frontier of science is justification enough, as it is assumed to be beneficial for society as a whole. Both rationales can also be visible in the discussion around the FCC. As I will explore further in Chapter 3, Europe is presented as involved in a race for new knowledge, and the FCC becomes a way to remain leading in an international competition with China. In addition, the exploration of the unknown is presented as an inherent feature of particle physics and thus a good in itself, which will inevitably bring benefits for science and beyond. But as I have argued, the frontier narrative also acquires a very specific function that is unique to the case of CERN. Through the frontier narrative uncertainty is managed and overcome. It is mobilised to turn uncertain futures into open futures full of potential for new technoscientific innovation. As we cannot know what phenomena might be hiding at higher energies, this becomes and endless and inexhaustible justificatory repertoire for the next big accelerator project. Uncertainty, coupled with the endless potential of the endless frontier of particle, physics, enables promises for grand scientific insights.

6.2.3. Too big to fail

So far, I have shown some of the dominant narratives through which particle physicists manage (but also critique) the epistemic uncertainties revolving around the FCC. Here, uncertainty is not only seen as intrinsic to scientific research but is also considered as a driving force for epistemic innovation. New knowledge is created by taking bold steps to explore the unknown secrets of nature. But this is not the only way through which narratives coordinate and manage the uncertainties around the FCC.

In a 2014 interview ex-Director General and Nobel prize winning particle physicist Carlo Rubbia says:

> *I do not know what the next page will be and I would prefer to let nature decide what we physicists will find next. But one thing is clear: with 96% of the universe still to be fathomed, we are faced with an absolutely extraordinary situation (...) The problem is, you never know where the next discovery will come from! Our field is made of surprises, and only a broad-band physics programme can guarantee the future of CERN.* (Catapano, 2014)

Rubbia also draws on a frontier narrative in which epistemic uncertainty is of key concern. We are in an "absolutely extraordinary situation". It is impossible to know what will be discovered next and humans have no real agency in this question. In the end, it is nature that will make this decision. But of course, if we follow the “science as endless frontier” story, we are always in an extraordinary situation. There are always more uncertainties to explore. Interestingly though, not everything in current physics seems to be uncertain. At least there is certainty that there are still many things to be discovered: 96% of the universe is still unexplored. This is a narrative that is frequently deployed to justify the FCC. What sounds like an oxymoron is a powerful rhetorical to convey a sense of urgency. We can be certain - „one thing is clear“ - that there are still many uncertainties: most of the secrets of the universe are still unknown to us. They thus need to be explored. Certainty and uncertainty, the known and the unknown, and an unchangeable nature are drawn together, together making a strong argument for further research in fundamental physics. Only uncertainty would be paralyzing. The same is true for too much certainty: why should we investigate further if everything is already known. But assembled together, the two mutually reinforce each other. The only problem, the big uncertainty in the exploration of the unknown, is where to look next. Are the unexplainable 96 percent of the universe really hiding at the energy scales reachable by the FCC? We simply cannot know. So how should we go on to explore the unknown secrets of nature? Why do we need such an expensive and huge accelerator to explore the unknown? As Rubbia argues, in light of these uncertainties, „only a broadband physics program can guarantee the future of CERN“. The best way forward is a broad and versatile program. And, as I will show next, CERN promises that the FCC will be exactly this: a broad, versatile, and far-reaching approach that will secure the future of particle physics. I will argue that the FCC’s broad approach is presented as the best way to deal with epistemic uncertainties.

The FCC study’s *Your Questions Answered* introductory paragraph is exemplary of this argument.

> *Particle physics has indeed arrived at an important moment in its history. The discovery of the Higgs boson with a mass of 125GeV opens a new era, clearing the decks for a new phase of exploration of physics beyond the Standard Model. For the first time since the Fermi theory, there is no clear guide what form this may take. Several fundamental experimental facts, however, remain unexplained, such as the abundance of matter over antimatter, the evidence for dark matter, and the non-zero neutrino masses. Many theoretical issues also require physics beyond the present Standard Model (BSM). Particle physics must continue its investigations, in the broadest possible way, with a mix of radical improvements in sensitivity, precision, and energy range* (Blondel et al., 2019, p. 5).

From the passage above we learn that particle physics is currently at a unique moment. After the discovery of the Higgs and the completion of the standard model „there is no clear guide what form [future exploration] may take“. But this uncertainty is nothing that should hinder further research using particle accelerators. Indeed, it rather „opens a new era“ of exploration full of potential for new discoveries and physics. Do not despair over the lack of theoretical guidance, the future of particle physics is bright! There are still many things to do and phenomena to be explained. And exactly because we are at such an uncertain and indeterminate point in HEP, more than ever there exists the need to invest in future projects. Furthermore, given the epistemic uncertainty of future research, particle physics must continue „in the broadest possible way". In this case, this is ensured through technical innovations to improve sensitivity, precision, and energy range. In other words, uncertainty can be overcome through more of the same. As could be seen with the Higgs, smashing particles was a great success in the past, and will thus also be a success in the future. Following this narrative, the FCC, with its broad range and ability to reach unprecedented energies and precisions, is presented as the perfect solution to the uncertainty of current research in particle physics and the lack of clear guidance for further exploration. Again, uncertainty becomes a productive force to justify the construction of a bigger, more powerful, and more expensive accelerator. More specifically, uncertainty becomes an argument in constructing a collider on a massive scale like the FCC. Because there is no precise target to look for there needs to be an even bigger machine with even more sensitivity, better precision, and higher energies.

Let us look a bit closer at the claim that, because of its „broad" approach, the FCC will be the best way for the field to move forward. The argument comes down to this. First, the FCC offers „the broadest discovery potential" (Benedikt et al., 2019a, p. 3). Second, the FCC is „complementary to other ongoing research activities and leverages crossdisciplinary synergies to expand our understanding of the universe" (Benedikt et al., 2019b, p. 1). The FCC as a „broad" approach that offers many „synergies" and „complementarities" comes up in every document of the feasibility study. As I will argue, it is this flexibility and versatility associated with the FCC that makes it seem well adapted to the many uncertainties that come with the project. The collider's sheer scale makes it inevitable that at least some (epistemic) value will be generated.

For instance, the FCC is argued to offer a broad approach because it will host both an electron and a hadron collider in an "integrated programme".

> *As the most powerful of all e+e- collider projects at the electroweak scale, it proposes, with centre-of-mass energies from 88 to 365 GeV and in a coherent research programme of about 15 years, a multifaceted exploration to maximise opportunities for major discoveries. Guided by the findings, high-energy physics will require direct access to the energy frontier. The 100 km infrastructure is designed to subsequently host a hadron collider with a centre-of-mass energy of at least 100 TeV, expanding the physics reach with multiple synergies and complementarities, allowing for the broadest and most versatile field of research, and providing the most ambitious future for CERN and for fundamental physics, for many years to come.* (Benedikt et al., 2019c, p. 2)

The FCC will be constructed in two steps. First, the tunnel will house an electron collider (FCC-ee) to study phenomena with high precision. In a second step, the same tunnel will host a hadron collider (FCC-hh) to probe for new phenomena at higher energy ranges. In a sense, the same infrastructure would host two different colliders, each promising their own unique scientific insights. The two-step approach makes the project very broad and versatile. The two machines work very well together, having multiple complementarities and synergies. For instance, the insights gained from the electron collider will inform the research done at the hadron collider

A very similar narrative can be found in documents on the individual FCC collider projects. As the FCC study writes about the hadron collider:

> *High-energy physics requires a powerful, sustainable and versatile hadron collider at the energy frontier. A 100 km circular collider that extends the current accelerator complex at CERN, with four interaction points, the possibility to operate with protons and with heavy ions and with the potential to include an electron-hadron interaction point, meets that need. This scenario permits multifaceted exploration and maximises the possibilities for major discoveries in a rich physics programme. Such a machine would expand the physics reach with multiple synergies and complementarities for the worldwide fundamental physics research community, until the end of the 21st century. (*Benedikt et al., 2019a, p. 5)

While an electron collider promises the study of phenomena occurring at relatively low energies but with high precision, the hadron collider will reach much higher energies, thus having the potential to explore new phenomena that were previously impossible to be detected. But my interest here is not so much in listing the broad range of physics that can be investigated with the FCC. Instead, I want to draw attention to the frequently recurring words and narratives in the descriptions of the FCC. Again, particle physics is constructed as in the need of a „powerful, sustainable, and versatile“ collider. The FCC is all these things. It can collide electrons with electrons, protons with protons, and potentially even electrons and hadrons, using four different interaction points. As such, this „multifaceted exploration“ speaks to many different epistemic desires. The FCC seems to be an answer to all the open questions in fundamental physics, thus bringing the worldwide physics community into its argumentation. In other words, the FCC not only promises a broad approach because of its two-step collider program (FCC-ee and FCC-hh) and the multiple physics that can be done with this. It is also broad because it promises „multiple synergies and complementarities“ with researchers outside of the field of particle physics. The FCC's worth for the general physics community is frequently emphasized. The collider is *„*complementary to other on-going research activities (e.g. long-baseline neutrino experiments in the US and Japan) and leverages cross-disciplinary synergies to expand our understanding of the universe (e.g. dark matter searches complementing astro-particle physics research projects)*“ (*Benedikt et al., 2019a, p.6).

Interestingly, the FCC's "broad approach" is not only presented as the solution to the epistemic uncertainty but also the technological uncertainty around the project. Should a post-LHC accelerator programme include a linear or a circular collider? And if we would decide on the more expensive circular FCC, will its R&D have progressed enough to realize the collider's challenging detector and accelerator technologies? I will now show how both these questions are (narratively) resolved by referring to the FCC's scale.

As I have previously mentioned, a major uncertainty around CERN's next big project has been about the kind of accelerator that should be constructed next. Next to the FCC, CERN has also started to investigate the feasibility of a much cheaper but also less powerful linear collider CLIC. A linear collider would enable precision measurements of the Higgs Boson through electron-positron collisions. Proponents of the machine might argue that it is a more feasible, less risky, and less expensive option to move forward the field. Right now, also due to the uncertainty around possible physics at higher energies, CERN's main focus should be to study the Higgs in all its details. But, one of the major downsides of a linear collider is that it cannot be upgraded to a hadron-hadron collider. In contrast to the circular FCC, it is thus unable to probe for new phenomena at the energy frontier. Even though there is no sound theoretical base on where to look next, there is still the potential to find something new and interesting. As such, the FCC's integrated programme is presented as the much better way to solve some of the open questions in particle physics: "the sequential implementation (first FCC-ee, then FCC-hh) maximizes the physics reach at the precision and the energy frontiers far beyond that of any linear collider project, taking advantage of the multiple complementarities and synergies of FCC-ee and FCC-hh" (Blondel et al., 2019, p. 31) As we can see, the FCC's broad approach, its capacity to be upgraded to a hadron collider, gives it better chances to discover new science. Here both, epistemic uncertainties and uncertainties over the type of accelerator that should be constructed are addressed. Given the uncertainty of what will come next, we need an approach that is as broad as possible, and this is something that a linear collider simply cannot provide. As such, only the circular collider will make it possible to secure the future of CERN.

So what about the second form of technological uncertainty. How is the FCC's broad approach mobilized to addresses questions about whether the project will have the necessary technological innovations for its successful operation? Often, demonstrating technological feasibility is a question of numbers. Feasibility is calculated, measured, and quantified, serving as a convincing argument that the project is technologically sound . But, if we take a look at the document for the FCC-hh feasibility study, it appears as if much of the technologies necessary for its construction are not yet developed (Benedikt et al., 2019a*)*. Technical feasibility is not (yet) there. With such a complex project, not all of the required R&D is finished. The document gives a whole list of uncertainties and challenges, mentioning things like: "particle detection technologies do not meet the performance, reliability and cost needs" or "electrical peak power requirement too high", or "superconducting Nb3Sn wire performance not attainable in time" (p. 10). While the FCC study details the resolution to each of them, their proposed solutions basically come down to this: future R&D and innovations will resolve all uncertainties. The wires are too expensive? innovate. Performance not attainable? Innovate. Inefficient magnets? Innovate. Or in their words: "this project entails a limited set of uncertainties that could adversely impact its implementation. They can all be addressed through a well-focused R&D programme and with an early start of the project preparatory phase" (p. 10). This R&D program is promised to make the FCC technically feasible sometime in the future. Future feasibility and the work that is necessary to realize it is not something that can be easily expressed in numbers. It is inherently uncertain whether the FCC will have the necessary future innovations to become reality. So in this case, narratives are important again. If we do not know what kind of accelerator/detector/magnet technologies will be ready in the future, how does CERN (narratively) manage this uncertainty.

It is fascinating to see is how in this case, we can witness yet another instance in which the FCC's scale, this time its long-time scales, is mobilized as an argument for its construction. The construction of the FCC's integrated program would take a very long time. Built in two steps, the hadron collider could only start its operation sometime in the 2040s. But this is not a problem. Instead, the FCC's long-time scales are a potential for innovation for an even better collider.

As the FCC YQA writes:

> *The FCC-ee will not delay FCC-hh: instead, it will make it a realizable dream, and will maximize the significance of its physics results. What appears to be additional time can be used to investigate newer, more ambitious technologies, with the possible result of a more affordable 100TeV collider, or even a higher-energy collider (150 TeV or more?)* (Blondel et al., 2019, p. 31).

In the paragraph, the future is mobilized to address concerns about the FCC's technological uncertainties. Again, an uncertain future is turned into a resource for potential innovations. The future is on our side: the long temporalities of the FCC construction and the many uncertainties that this entails are presented as full of potential to make an even better accelerator. Future innovations might make the FCC even cheaper and more powerful. We can thus witness how the FCC's "scale" is not only presented as a way to deal with the epistemic but also the technological uncertainties around the project. In a sense, the FCC's integrated programme and the long timescales that this entails make the hadron collider "a realizable dream" in the first place, maximizing the project's scientific potential. Through the FCC's "broad" approach, operating on large scales and temporalties, we have the possibility to construct a powerful, cheap, and sustainable accelerator, which can only be improved in the future. The FCC is presented as so big, requiring so many years to construct, that it will not only have all R&D ready for its construction, but that it might even surpass all current expectations. As such, narratives mobilizing the FCC's scale address both questions over the kind of accelerator that should be constructed next and questions on whether we have the technological innovations prepared to realize such a challenging project.

Note how the passages I cited, even though from different documents and talking about different things, draw on a similar narrative. They all refer to the scale of the FCC to demonstrate its capacity to create value for CERN and beyond. What makes the FCC a project that is worth pursuing is its broad with many synergies and complementarities. Because of its size, integrated programme, and long timescales, the collider(s) will bring valuable insights for a variety of different epistemic questions and disciplines. Arguments for a broad approach as an answer to a broad variety of (epistemic) concerns thus also serve as a justification to construct a bigger, more expensive circular collider. Interestingly, the temporalties the project are then even mobilized to appease concerns about technical feasibility, presenting the future as full of potential to even further improve the FCC through R&D and innovations. So, in a sense, there happens a clever rhetorical shift; what is frequently used as an argument against the FCC becomes a justification for its construction. The FCC size, often manifesting in criticism against its construction (it is too expensive! it will take too long! the technology is not good enough!) is turned into a story about synergies and complementarities. Only by constructing such a big machine can we ensure to address the many uncertainties of current particle physics. The FCC will be too big to fail.

6.2.4. Managing uncertainty

I have started this chapter by looking at a common criticism posed against the construction of the FCC: its epistemic uncertainty. There are no good theoretical predictions for phenomena at higher energy ranges that would justify the construction of such a big machine. From there, I have engaged with some of the popular responses against the fear of epistemic uncertainty. Uncertainty is here constructed as an inherent part of scientific exploration. In this story, uncertainty becomes the driver of contemporary physics. In its essence, the FCC is about the exploration of the unknown. Given the FCC's many uncertainties, I wanted to understand how these are shaped, constructed, and mobilized in justificatory narratives. By alternating between opposing voices of the FCC and CERN's own perspective on the project, I was able to show how proponents of the FCC integrate, address, and transform concerns about epistemic uncertainty in their arguments for the next accelerator.

I now want to argue that in the justifications around the FCC, narratives work as tools to manage uncertainties. By actively embracing uncertainties, narratives turn them into powerful justificatory devices. Above, I have detailed two such managerial narratives. First, there is a narrative that presents uncertainty as the driving force of technoscientific progress. By referring to research in particle physics as the exploration of an endless frontier, the FCC is presented as having the capacity to create epistemic innovations whose impact we cannot even imagine. Second, there is a narrative in which the FCC is presented as too big to fail. In this argument, a broad approach is necessary to deal with uncertainties. Here, uncertainties are managed by referring the sheer scale of the project. The

FCC will be such a big project, with so many synergies and complementarities, that it is sure to bring some benefits. Due to its broad approach, the project will be able to address multiple open questions, epistemic concerns, and technological uncertainties. As such, references to uncertainties and to the scale of the FCC work well together: because the future is uncertain, we need a broad approach to make the most out of its potential. Furthermore, the FCC's long-time scales are mobilized to promise innovations that will resolve present technological uncertainties in the future. Again, uncertainty is not a problem but rather potential to improve the FCC even more in the future.

The argument that narratives work as managerial devices is nothing new. Deuten and Rip (2000) similarly argue that stories work as "management tools" that are used to address uncertainties and reduce complexities in product creation processes. According to them, uncertainties are managed through narratives that create shared frames of reference that guide collective action in large heterogeneous groups. While in their case, uncertainty might be recognized, "the idea is to reduce it rather than embrace it" (p. 70). In the case of the FCC, narratives manage uncertainties slightly different. Rather than reducing uncertainties, they actively embrace them. As such, the case stands in contrast to dominant framings of technoscientific innovation, in which the unknown is played down or controlled. Next to Deuten and Rip, other STS scholars have also paid attention to the uncertainties part of and produced through technoscientific processes. For instance, Adam and Grooves (2007) speak of a paradox in which "efforts to control, manage, and engineer the future produce unprecedented uncertainties" (p. 77). As the future is emptied and opened to endless possibilities, "non intended consequences mushroom and planned outcomes become ever more elusive" (p. 77). In other words, the more we colonise the future, the more unintended consequences proliferate. As such, STS has frequently critiqued any claims to certainty. For Jasanoff (2013), it is "hubris" to think that we can control all uncertainties that come with novel technoscience. So in a sense, it seems like CERN is aware and even capitalising on the fact that we cannot know the future. While often, uncertainties are avoided or played down, in the case of the FCC we can witness the opposite. Uncertainties are made bigger, which enables grand promises to emerge in the first place. Uncertain futures are not a problem but on the contrary a resource that is mobilised to accelerate the construction of the FCC. As such, they enable a complex economy of technoscientific promises to emerge (Joly, 2010). This economy of promises is not limited by any theoretical predictions, which means it can put forward claims to find the most fantastic science.

But (possible) epistemic insights and technological feasibility are not the only way through which the FCC has to demonstrate its worth. Sure, a new particle accelerator should provide new insights for particle physics. And as I have shown, narratives are a powerful tool to show that this will also be the case. A broad, exploratory approach to tackling the open questions and uncertainties in particle physics makes sense. But taken on its own, this argument does not hold. There are much more than just technoscientific uncertainties in a project on such a scale. As such, the narratives that I have presented above do not yet justify, at least in today's socio-political context, the large resources that need to be invested into the project. What kind of socioeconomic benefits does the FCC bring? How to scale up, fund, and organize a bigger and more expensive CERN? What does the implicated internationalisation do to a European organization? The question thus becomes how narratives manage these other uncertainties around the collider. How do they demonstrate the project's social, economic, political, and cultural worth? In this sense, the following chapter will analyse how the justificatory narratives around CERN's next collider go beyond possible scientific insights, situating the project within todays European and global context. Specifically, I will explore how CERN's material and infrastructural expansion is accompanied by an expansion of imaginaries around the project and how these are co-produced with an understand of Europe and its place in an accelerated and competitive the world.

6.3. (Un)making Europe

We can understand the history of HEP as an history of particle accelerators continuously increasing in size and complexity: from CERN's first accelerator the Synchrotron-Cyclotron in 1957 (only 16 meters in circumference), to the Super Proton Synchrotron in 1976 (already 6.9 km in circumference), the currently active LHC (26,7 km) and now the FCC (100 km). But such infrastructural upscaling is not an easy endeavour. Every new and scaled up accelerator project requires novel collaborative, organizational and funding structures. If we take a broad view on the history of CERN, we can witness an increasing internationalization of the institution that accompanies its infrastructural upscaling. After the second world war, CERN was an organization in which different European states came together to collaborate. With novel material demands from bigger collider infrastructures and wider sociopolitical developments such as the dissolution of the Soviet Union, also the size of CERN's collaboration and the geographical distribution of its users expanded. As such, CERN has been increasingly becoming a global research infrastructure. For instance, the construction of the LHC was partly funded through in-kind contributions by countries such as Japan, India, Israel or the United States, which meant that CERN was receiving substantial sums of money from states outside of Europe (Riordan, Hoddeson & Kola, 2015, p. 276). With the construction of the LHC and the cancellation of the Superconducting Super Collider (SSC) in the US, CERN experienced an influx of user from all over the world. When the SSC failed, there was no more real international competition, and CERN became the biggest laboratory for particle physics in the world. The institution acquired its singularity. There is one place to do experiments at the energy frontier and this is in Europe, which meant that people from all over the world had to come there. As such, while in the beginning, CERN was about bringing researchers from a European context together by offering them an infrastructure, the institution is now increasingly repositioning itself in a wider international context (Mobach & Felt, 2022). This is accompanied by institutional changes such the opening up of the CERN membership status to states outside of Europe. In 2010, the CERN Council changed the laboratory's membership policy, enabling geographical enlargement and full membership to states independent of their geographical location. 'Associate membership' was introduced as an official status, which should ideally be an intermediary step towards full membership. For, Voss and Tsesmelis (2014), CERN's new membership policy for geographical enlargement is driven by two rationales. On the one hand, the globalization of particle physics is driven by the increase in size of particle accelerators. Bigger accelerators require bigger collaborations which attracts scientists from all over the world. On the other hand, it can be seen as „a first step in preparing CERN's membership and governance for the post-LHC future". According to the particle physicists Voss and Tsesmelis, it is inconceivable that future research infrastructures at CERN „could be approved and built within the same membership, governance and funding structures that worked 20 years ago". But enlargement is not as straightforward as it may sound. There are difficulties bound to emerge in the processes of CERN's continuous globalisation: „in the long term, broadening the institutional base without sacrificing the traditional values of European co-operation that have been a key ingredient in CERN's past successes is likely to emerge as the true challenge of the enlargement process." From the perspective of the two scientists, CERN's inevitable globalisation, driven by the material requirements of future collider infrastructures, has to stay true to the institutions (European) values. It is assumed that with CERN's globalisation also comes the integration of new actors that might not ascribe to its established values and norms. This shows how discussions about CERN's enlargement are not only questions about new technologies and funding. They are also negotiations between the institution's European origins and identity and an emerging sociomaterial context that requires global collaboration.

This fascinating relationship between Europe and the world is exemplified in a 2016 article by CERN's current director for international relations Charlotte Warakaulle. Reflecting on the role of CERN in today's global context, Warakaulle writes:

> *Enlargement is part of a process that recognizes CERN's inherently global nature, encourages emerging physics communities and allows us to thrive in an ever-changing world. It is targeted to benefit all players in particle physics, is conducted in a gradual manner, and will not change the way we work. We remain a global laboratory with a European heart.*
>
> *The world is in flux, and enlargement helps us to play our part in shaping developments, rather than allowing ourselves to be swept along by the winds of change. The enlargement process reacts to new developments in our world, and it has given us new tools to react with. But it builds on a long and proud tradition of inclusiveness and openness, key principles that have for over 60 years been at the heart of our scientific work.*

The quote captures the essence of CERN's dominant narrative about enlargement. It picks up many of the themes that I will explore in this chapter. For instance, Warakaulle sees CERN as "inherently" global. For her, enlargement is in line with an intrinsic globality of CERN. This could refer to CERN's origin story as an institution that facilitated international collaboration after the world war. As I will show later, it could also refer to a universal and placeless quality that is associated with particle physics. But CERN is not only inherently global; apparently it also needs to become more global through enlargement. CERN needs to be global as a response to a rapidly changing world. It is a way to cope with or adapt to a changing social, political, and economic context. A global institution is a necessary response to a global world, which is inevitable if one wants to avoid „to be swept away by the winds of change". So CERN is both inherently global and becoming more global. But in its essence, it is also European. It is a global infrastructure with a „European heart". What Warakaulle means by that we learn in the second paragraph. No matter how global CERN will become, it will stay true to its (European) values such as openness and inclusiveness. European is not defined by European member states or European collaboration. CERN is European because of its long-standing values.

The tensions between CERN as a European research infrastructure and its increasing internationalization, hinted at above, is something that I want to further explore in the chapter. It is also at the heart of the current discussion around the FCC. As I have shown, it is widely acknowledged that the next big particle collider will have to be a truly global collaboration. For the FCC, enlargement is no longer a choice. Constructing the collider will require novel forms of organization and funding that will go beyond the boundaries of Europe. As such, the globalisation of CERN is of central concern in the discussion around the FCC**.** How CERN will be reorganized to accommodate the next particle accelerator only the future can tell. Such details are still discussed and negotiated in the ongoing FCC feasibility studies. But infrastructural enlargement not only requires novel organizational and funding models. It also requires novel narratives. This chapter is concerned with how infrastructural uncertainties, emerging or co-constructed with CERN's (imagined) upscaling, are managed through novel narratives. It will explore the FCC's tension between the local and the global, analysing how different enactments of the FCC both make and unmake Europe. How is the FCC's global/European nature constructed? How is a possible material and infrastructural expansion accompanied by an expansion of imaginaries around CERN? How is the FCC embedded within and made sense of through existing and novel narratives about CERN, particle physics, nature, and Europe? What kind of collaboration will the FCC be? Is CERN still a European institution? Or is it already an inherently global project?

6.3.1. A laboratory for the world

In February 2014, experts in particle physics and accelerator technologies from all over the world came together at the University of Geneva to initiate the *FCC Study*. Sponsored by the EU commission funded EuCARD-2 project for enhanced European coordination in accelerator research & development, the event presented and discussed publicly the possibility, scope, and organization of a new particle accelerator at CERN. It was the day in which the FCC started to take shaped. In his opening address of the conference, CERN's then active director-general Rolf Heuer (2014a) introduced the study by arguing for the urgent need to „go beyond the present energy frontier". Despite existing conceptual design reports on parallel colliders such as the ILC in Japan or the CEPC in China, he emphasizes the necessity of a global collaborative project, which, hosted at CERN, should investigate the feasibility of the FCC. In his talk, Heuer repeatedly makes the point that worldwide collaboration is essential to the realisation of a new hadron collider with energies of up to 100 TEV. According to him, such a big project has to be global in scale.

This emphasis on not only the need but also desire for global collaboration becomes again explicit in Heuer's (2014b) closing remarks of the conference. Here, he stresses that safeguarding the future of High Energy Physics (HEP) and building the FCC are the main priorities of the global particle physics community. As he writes on his slide: „there is broad acknowledgment that any future collider will need to be a global enterprise, requiring resources (financial, human) from across the board“. Understanding research in particle physics as beyond politics, he stresses that the scientific community should „work for its dream“ independent of the next collider’s location. The only important thing is that HEP will have a future.

To accentuate his argument, Heuer reuses the summary slide of a prior talk by his colleague Yifang Wang from the Institute of High Energy Physics in Beijing, who presented China’s plans for the future of High Energy Physics. Reinterpreting Wang’s slide, stating that „Even if it [the FCC] is not in China, it is still very beneficial to our field and the Chinese HEP & Science community“, he argues that „independent from where it is, it is very beneficial to our field and the HEP and Science community in general“. To understand the significance Heuer’s speech, we need to shortly move away from the conference and consider the wider international developments in particle physics. In 2018, China has proposed a similar accelerator project to the FCC – the Circular Electron Positron Collider (CEPC). This is now the main competitor to CERN’s future accelerator project. The reinterpretation of Wang’s slide is thus a highly symbolic gesture, implying that the physics community is predominantly concerned with the production of knowledge and that the location of the next collider is of no importance. While acknowledging parallel developments and political deliberations around alternative future collider projects outside of CERN, what matters most is that particle physics will continue to flourish. Europe as a scientific and economic competitor to China, part of global struggles in the knowledge economy and over the future of particle physics, is thus rendered absent. International competition over technoscientific futures has no room in Heuer’s idealistic talk about the universal striving for new knowledge. What counts in the end is that the global community works together and collaborates on the project. This narrative reflects an idealised vision of particle physics as a placeless and neutral science that investigates a universal nature. In this story, science is detached from any geographical location or politics. It is about the creation of knowledge for the benefit of all.

In a way, Heuer’s emphasis on the global nature of the FCC serves as an argument for and legitimization of the proposal to construct the collider in Europe. If the global scientific community is only interested in advancing knowledge, if in the end, all they want is a new accelerator, why not just build it in Europe? Science and the creation of knowledge, today a necessary global endeavour, become goals in themselves. As such, the construction of a new particle accelerator, understood as unanimously supported by the global scientific community, is presented as the logical next step for particle physics. And if the community’s priority is the construction of a bigger collider, if geopolitical and economic concerns are just distractions to the true goals of science, then it only makes sense to fully support CERN’s plan to construct the FCC.

Despite Heuer’s efforts to describe the FCC as a truly global collaboration, the place of the next collider still matters. Heuer still presented his speech at a conference in Geneva, initiating a large-scale feasibility study to construct the next particle accelerator in Europe. Similarly, Yifang Wang’s presentation of China’s plans to construct the CEPC as a post-LHC project that geography is important. Although played down by Heuer, there is an ongoing competition between China and

Europe over the location of the next collider. As I will show later, in some situations, references to the geographical location of the FCC are made much more explicit. Here, the FCC is suddenly central to a geopolitical struggle in which European leadership is at stake. The project appears to be both global and European: it both transcends space and is a continuation of a particle physics tradition at CERN. It is both located in Europe and the desire of a global particle physics community

Documents from the *FCC study* also emphasise that the next collider will be a global endeavour that is only realisable through an international collaboration. The sheer size and cost of the project makes it an impossible task for European countries alone. For instance, the FCC Q&A (2019) asks: "Why an international collaboration is needed"? (p. 10). This is an interesting formulation. Whether we need an international collaboration is no longer a question. It is a requirement for the next facility. The only thing that remains to be is answered is why it is needed. The FCC Q&A (p. 10) responds to its question by stating that:

> *the future of any type of post LHC facility is set in a global context. Think for example that the construction of the LHC, presently the world's largest scientific instrument, is the collaborative result of more than 70 000 scientists coming from 60 countries. To develop a post-LHC project reaching energies ten times of magnitude higher means that this tradition should be continued and further endorsed.*

The Q&A thus emphasises that the FCC will be a global project. Already the LHC is a collaboration that spans over the whole world. As such, the next collider will inevitably continue the trend of the globalisation of particle physics. This ideal is already practiced within the *FCC study*: "

> *The FCC study hosted by CERN is an international collaboration of more than 70 institutes from all over the world. This prepares the ground for geographically well-balanced contributions, leveraging the competencies of world experts in the numerous areas concerned. It also ensures that the entire worldwide scientific community is involved from the very start of the endeavour.* (Panagiotis & Gutleber, 2016)

Here, the FCC's ‚global character' becomes a value in its own right. The FCC, as an international collaboration, is expected to benefit the whole world. It something inherently desirable. Interestingly, in the Q&A document never explicitly mentions Europe. The FCC is enacted as beyond a particular location. Its „Europeanness" completely disappears. From the beginning, the „entire worldwide scientific community" will participate for a „geographically well-balanced" distribution of expertise. Internationalism is valued as a way to „leverage" the knowledge and competencies of „world experts". Global collaboration means that everyone can participate while at the same time bringing the best experts in the world to CERN.

6.3.2. Openness for a global collaboration

The ideal of an international collaboration is connected to a narrative that stresses the FCC's "openness". As the Q&A puts it:

> *A core value of the FCC-study is its openness: universities and research institutes as well as companies from all over the world are welcome to join this effort. Adopting an inclusive approach, the study embraces the worldwide science and technology community both in an open and incremental participation process. (Q&A, p. 10)*

The FCC is all about „openness“. It will include technoscientific actors from all over the world in a collective effort to plan the new collider. Here, the emphasis is on „participation“ and an „inclusive approach“. The FCC is valued as an international collaboration that is open to and will thus bring together a wide range of actors to participate in and profit from the project. Similarly to my earlier discussion of Heuer's remarks on the inauguration event of the *FCC study*, the passages above enacts the FCC as detached from CERN's European context. It is valued as an intrinsically global collaboration. But, slightly different from Heuer, in this case it is not a universally shared striving towards new knowledge assumed to be intrinsic to science that lays the foundation for a global collaboration in particle physics. Instead, „participation“ and „openness“ are values in their own right. The FCC project becomes a global project, not because science always transcends locality, but because international collaboration is a quality that is actively sought after. The collider will be global not because of any qualities intrinsic to science, but through the many different actors that are actively invited to come together and work on it. We can witness different kinds of openness. One has to do with scientific norms (Merton, 1973). Science should be practiced in an open way as good epistemic practice. But science should also be open to extract value from global expertise or to bring people and nations together. In the discussions around the FCC, these different kinds of "openness" come together and get intermixed with each other. But the emphasis on openness is not only present in the Q&A documents can also be found in other representations like the FCC's new logo.

CERN has created a new logo to give the FCC a „visual identity“. The logo is used in documents and public presentations of the collider. Official representations of the FCC draw on it as a form of branding. As such, it makes sense to take a closer look at the logo's (visual) narrative.

Image 2

The FCC logo

Note. CERN (n.d-d), FCC Visual Identity*,* from https://twiki.cern.ch/twiki/bin/view/FCC/LogoDesign

Image 3

The FCC logo in motion

Note. CERN (n.d-d), FCC Visual Identity*,* from https://twiki.cern.ch/twiki/bin/view/FCC/LogoDesign

On a dark blue background, there is depicted a minimalistic white circle (Image 2). The circle is not completely closed. One end is gradually fading, implying an ongoing transformation. Indeed, the logo is variously also depicted as an animated clip (Image 3). Here, the shape transforms from a closed circle, into a spiral or wave that appear to represent traces of particles collisions. In a continuous movement, the logo changes its shape: from a circle, to a spiral, to a wave, and back. There are some similarities with CERN's current logo - a white abstraction of two particle accelerators juxtaposed over each other. The logo thus implies both continuity and novelty. It is clearly situated within the scientific tradition at CERN but also something novel and exciting. While remaining firmly grounded in the past, it portrays a stylish and innovative future for particle physics. The FCC is doing cutting edge and visionary research at the forefront of knowledge production to explore uncharted territories. From CERN's website (n.d.-d) we can learn that „the goal of the FCC visual identity is to support the efforts that FCC becomes reality". The visual branding of the FCC thus appears to be something that is considered detrimental to the realization of the project. The collider needs to be recognizable, clearly associated with a visual identity that implies change and innovation. Scrolling a bit further on the website that presents the FCC logo, we can also gain insights the values the visualization is supposed to portray. The circular shape is based on the projects „core values": the so called „3 O's". Signifying openness, the three core values are „open innovation", „open science", and „open to the world". So in a sense, the FCC logo's ever transforming (open) circle is understood to be representative of the values driving the project. Again, we are faced with the notion of "openness". Openness is a nice ideal that implies that everyone can participate and consequently also profit from a new collider. But of course, simply calling something open does not actually make it so.

CERN's emphasis on openness does not simply emerge with the FCC. It has an intellectual history that can be traced across space to the European Commission and across time to CERN's foundation and its convention.

For instance, the FCC logo's 3 O's (open innovation, open science, open to the world) do not have their origins with the collider. The emphasis on these three kinds of openness are also key commitments of the European Commission, and can be traced back to a speech by Carlos Moedas (2015), its current commissioner for research, science, and innovation. The 3O's, turned into a report in 2016 that goes into detail for each of them, have become a normative ideal driving European science polices (European Comission, 2016). As such, the FCC's is performed in line with the EC's values and commitments. So even though the emphasis on openness implies that the FCC will be a global collaboration, through an alignment of narratives and language, there remain traces of Europe.

But the FCC's emphasis on openness should not only be attributed to the Commission's influence on the project. Stories about openness can also be traced back to the beginning of CERN. Strasser (2009) connects the narrative of openness to Switzerland's role in founding CERN. To participate in the project, Switzerland demanded that CERN would not be subject of any political or military endeavors. Thus, in line with the Swizz national identity as a "neutral country", there was set a nonnegotiable condition for its participation: CERN must be open to all European nations, which includes Eastern Europe, and its research cannot be secret and should be focused seclusively on scientific and civilian goals. Strasser thus shows how CERN's identity as an open and neutral institution was not given but an achievement. After the second world war, and especially in the US, science was closely interwoven with national political, economic, and military interests. Here, science was neither neutral nor open. Pursued in secret, science was intrinsic to (national) geopolitical goals. In line with its identity as a neutral state, Switzerland thus demanded openness, transparency and the inclusions of easter countries as a prerequisite for its participation. This would ensure that CERN would neither be seen as an American nor a military project. In the words of Strasser: "neutral science and neutral state had been efficiently coproduced" (p. 176). But CERN's commitment to openness remained an ideal, never fully realized. While in principle CERN was open to anyone, in practice this was very unlikely, as every member state reserved the right for a veto. This also resolved the dilemma over the inclusion of communist states. As John Krige put it, this approach "preserve the appearance of openness while masking the reality of exclusivity" (Krige, 1987, as cited in Strasser, 2009, p. 175). It becomes apparent that openness is not a novel narrative that only emerged with the proposal of the FCC. It has a long history that can be traced back to the foundation of CERN. While its implementation remains ambiguous, reinterpreted and aligned to emerging sociotechnical developments, the ideal of openness has becomes part of CERN's institutional identity.

To see this, we only have to take a look at the CERN convention, the institution's foundational document. The convention states the purpose, goal, identity and form of governance of CERN. This means that any changes within the institution have to be in line with what is written in its convention. As such, the document also played an important role in the discussion about CERN's enlargement beyond Europe. Reinterpreting the convention enabled CERN to adapt to novel social, material and political developments, in this case opening up membership to non-European states. It provided "for the leeway that is necessary to adapt the organization to a changing political environment, and to new scientific and technological challenges" (Voss & Tsesmelis, 2014). Such interpretative flexibility is important for Big Science infrastructures like CERN, enabling them to survive and change over the decades. But I do not want to discuss in more detail the re-interpretation of the convention that made possible CERN's geographical extension. While this is certainly an interesting topic that invites further research, I refer to the convention for another reason. It is fascinating to see how the narratives inscribed into the document are also used to make sense of the FCC. While the convention is not always explicitly mentioned, we can still see a continuation between it and the current discussions around the next collider. While written in a different context, its statements about CERN as an open and peaceful collaboration are also prominent today. To make sense of the narratives around the FCC, it is thus helpful to take a closer look at the CERN convention.

The purpose of CERN as a fundamental research institution is stated in Article 2 of the Convention (1953):

> *The Organization shall provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto. The Organization shall have no concern with work for military requirements and the results of its experimental and theoretical work shall be published or otherwise made generally available. (p. 6.*

> Also relevant for my research is Article 2.2.b, specifying as one of CERN's main activities *"the organization and sponsoring of international co-operation in nuclear research" (CERN, 1953, p. 8)*

The passages above lay the groundwork for CERN's self-image as an institution that not only does science but that also brings different nations together in a neutral collaboration. It explicitly excludes any military activity as one of the first articles of the convention. This means that CERN pursues scientific research that is not driven by national or private interests. As such, the sentences materialize the idea that CERN is able to bring stability and peace through neutral science. For many, CERN has become a symbol or model "for what Europe can do when it unites, bridging nationalities and bringing different cultures tighter to work towards a common goal" (Heuer, 2014c*).* In the convention we can also see traces of the previously discussed notion of openness so frequently emphasized in discussion around the FCC. The document explicitly states that CERN should make the results of its work available to the public. Thus, we can find the origins the narrative performing the FCC as an open and collaborative effort in the very founding document of CERN. Over the years, the ideals of peaceful collaboration and openness have experienced continuous re-articulations and re-mediations, both as a narrative in CERN's documents or practiced in its collaborations and open data portal. In the words of Heuer (2014c) - "times have changed, but the spirit of openness and peaceful collaboration enshrined in the visionary words of the convention continues to shape CERN to this day". Despite CERN's many transformations and enlargements, the original spirit is still believed to be strongly anchored in the institution, now not only uniting Europe but the whole world. Today, narratives about openness and peaceful collaboration beyond borders are used to make sense of CERN's globalization through the FCC. Through a slight adaptation, "collaboration among European States" has become "collaboration among the world". In the discussions around CERN's infrastructural enlargement, stable narratives are used to make sense of changing material circumstances. The new is understood through the old and the future is understood through the present. The same story that once understood CERN as an institution that brings Europe together has now become a story about uniting the world. In other words, the (potential) infrastructural extension that promises to bring CERN into the future is accompanied by a narrative extension that adapts the past for the future.

As I have shown, the FCC is understood through a narrative that stresses its openness. The FCC will produce open science, it will be open to industry, it will be open to global collaboration, and it will be open to the public. Openness thus remains an incredibly vague notion. Everything seems to be open, ranging from abstract values inscribed into scientific practice, to concrete open science policies, and participatory practices and transparency. I want to note that openness, as an institutional value, requires some of its rhetorical strength through its close association with the modern liberal-democratic state. Open access to science and innovation, participation by the scientific community, and transparency and insights into its practices all give the institution legitimacy and hold it accountable to a public.

6.3.3. A laboratory for Europe

So far, Europe has been more or less absent in my discussion of the representation of the FCC. In the passages I looked at, the emphasis is placed on the open and international nature of the next collider. But the FCC is not always a global project. It is also valued as something uniquely European. For instance, the 2013 update of the ESPP explicitly presents the FCC as a European project: „to stay at the forefront of particle physics, Europe needs to be in a position to propose an ambitious post-LHC accelerator project at CERN“ (European Strategy Group, 2013, p. 1). Following the ESPP, the FCC is a European project that is competing with parallel global developments in particle physics. Europe (and CERN) appear to be one actor out of many that struggle over the „forefront of particle physics“. Or as the Conceptual Design Report writes on its website: „the race is on for new physics that lies beyond the Standard Model“ (CERN, n.d.-c).

The quotes above emphasise that the FCC is a European project, implicated in wider developments in the knowledge economy. Europe becomes an entity that needs to act to remain competitive in a race over the future of particle physics. By looking in more detail at the *Your Questions Answered* (YQA) document, the following will make explicit how the FCC is implicated in a discourse about Europe (Blondel et al., 2019). Specifically, I will look in more detail at two parts at the end of the document that exemplify how the FCC becomes constructed as a project in and for Europe: their subheadings are “Should we leave FCC-ee to China?” and “Why do we want FCC in Europe. By answering these two questions, the FCC’s YQA very explicitly frames parallel developments in particle physics as potentially threatening Europe’s leadership in the field. Drawing on a discourse about basic research as a driver of modern socioeconomic worth, in the document scientific advances and knowledge production are no longer a value in itself, but rather part of a wider geopolitical competition in the global knowledge economy. The FCC is here no longer simply the ‘logical’ next step for research in particle physics: it becomes a strategic actor in a highly competitive global environment struggling over the location of the next big particle collider. The FCC is European because it serves European economic, scientific, and political goals.

The FCC Study's YQA asks the question: "Should we leave FCC-ee to China?" (Blondel et al., 2019, p. 37). To answer its own question, the document goes on to write:

> *The integrated FCC programme is reflected in a similar proposal in China under the name CEPC-SppC, with a rapid technical schedule that foresees physics starting in 2029, under the assumption of an ideal funding scenario. The consequence for particle physics in Europe of the realisation of this project would be considerable. All the technical and scientific qualities of FCC would be shared by this essentially identical project which has thus the broadest, most encompassing physics discovery reach, with respect to which it would be extremely difficult to maintain leadership. (p. 37)*

Here the reader is introduced to China's proposal to construct an "essentially identical" collider to the FCC. Expected to begin with experiments already in 2029, the CEPC-SppC would be finished significantly before the FCC. Due to the close similarity of the two collider projects, the construction of the CEPC-SppC is presented as the (potential) end to Europe's leading role in particle physics. Because of the many resources necessary to construct a 100TeV accelerator and the near-identical design of the two proposals, it would not make sense to construct two facilities. There can only be one future accelerator. In contrast to earlier smaller experiments, with the FCC it is all or nothing. Instead of spreading particle research over multiple smaller high precision accelerators, all the money is put into another massive collider that will occupy the scientific community for a couple of decades. In this sense, there emerges a competition over the geographical location of the next collider. Even though the project will inevitably be international (Europe will not be able to fund the project alone), it will still be bound to a physical location. The question thus becomes who will be the first to construct the next generation collider. In this sense, China's proposal to construct a particle collider serves as a dual legitimation for the project: not only is it proof that the FCC is worthwhile, it also implies that Europe has to act quickly to be first and maintain leadership. Here, the FCC becomes an asset that needs to be capitalized on in order for Europe to stay internationally competitive. This narrative implies inevitability. It is inevitable that a novel particle accelerator will be constructed. The question is thus not whether to build the FCC but rather who will construct it.

A paragraph later, the document goes on to argue that:

> *The European Particle Physics community has a chance to decide on its own future independently, and to remain at the forefront of high-energy physics, without being pre-emoted by putative scenarios of future plans in other regions. […]. This decision should be based on the scientific judgment of what is best for the future of HEP from the European perspective. […]. The appearance of an ambitious alternative makes it essential for the ESPP to express in 2020 a firm recommendation for the FCC at CERN. In its absence, CERN's future becomes a*

> *hostage to fortune and Europe may have to fall back on a less powerful instrument, with the risk of losing very rapidly the leadership in High Energy Physics that it presently enjoys. On the contrary, a clear European position would constitute a focus for a worldwide collaboration.* (Blondel et al., 2019, p. 37)

According to the paragraph, Europe has now the chance to decide on its future and to remain competitive in high-energy physics. The choice is clear: either the FCC is constructed in Europe or elsewhere. This decision should be based on a “scientific judgment” of, in this case not what is the best for HEP in general, but what is best for HEP “from a European perspective”. To remain competitive in the global technoscientific environment, Europe needs to urgently express a clear recommendation for the FCC. In case CERN would fail to construct the FCC, the institution would become “a hostage to fortune” and Europe might “fall back” and lose its current leadership in HEP. The reference to fortune as a consequence of an absent recommendation for the FCC is an interesting formulation. To avoid becoming a “hostage” to luck, there is a need to act now. In a sense, this implies that the future is malleable. Europe can take its future into its own hand, as long as it starts to act now. If not, Europe will regress to inferior experimental technology. Thus, failure to construct the FCC now implies a movement back in time to a moment in which European particle physicists stood in the shadows of their global competition. Interestingly though, “a clear European position would constitute a focus for a worldwide collaboration”. In other words, if Europe would decide to construct the FCC this would enable a global collaboration in particle physics. In this last sentence, the narrative changes from a focus on CERN as a European project to CERN as facilitator of a global project. The passage shifts from European competitiveness to worldwide collaboration. Constructing a novel accelerator at CERN would enable Europe to keep its leading position in the global race for new physics while at the same time also enabling a collaborative project in which the whole world is involved. Thus, the FCC is enacted as both a European and a global project. In case the FCC would not be built, Europe (and thus also the world) would lose massively. On the other hand, if the FCC would be constructed in Europe, everyone would benefit. This reflects an interesting duality, in which Europe is understood as the stage that enables global collaboration. Is the FCC a European project that needs to be constructed before the international competition does so? Or is it a global project result of a worldwide effort? As I will show at the end of this chapter, these two aspects are not necessarily contradictory: the FCC can be both.

After making explicit that the next collider ‘should not be left to China’ the next and final question of the FCC YQA document asks: “Why do we want FCC in Europe” (Blondel et al.,2019, p. 38). The document thus moves from discussing global competition with China to the collider’s benefits for Europe. Interestingly, the FCC’s epistemic potential is here no longer the most important aspect of the next collider. The final passage of the YQA document explicitly addresses the social, economic and cultural benefits the FCC will generate for Europe. Moreover, it emphasises the central role of (European) qualities to make the project possible. This, in turn, implies that if the next collider would be constructed in China, Europe would not only lose out on the many benefits the FCC will bring, it would also mean that the project would lack the values necessary for its realization.

So "Why do we want FCC in Europe?" (p. 38). To this question, the YQA document promptly gives us an answer:

> *Over the past 65 years, step by step and exploiting synergies between successive accelerators, Europe has developed a laboratory, CERN, that is now leading the field. With its demonstrated extraordinary competence, its international membership, its built-in cooperation among countries sharing common ideals of freedom and democracy, and the existing infrastructures (accelerator and injector complex, cryogenics, mechanics, electronics, workshops, and its many competences), CERN is the best place for a challenging enterprise such as FCC. (p. 38)*

In the passage, the FCC should be constructed at CERN because of past achievements. Europe has managed to successfully establish CERN as a leading laboratory in the field of particle physics. It demonstrated its competence to create excellent science and should thus continue to do so in the future. There is not only a material but also a cultural base on which the FCC can be constructed. CERN not only has the technology and expertise but also the values to make the next collider a reality. So, on the one hand, there is an existing infrastructure made up of technologies, people, and their expertise. On the other hand, there are values or ideals of freedom and democracy that make possible a global collaboration. We want the FCC in Europe because there we have the material and cultural fundament, implying seamless continuity from the past to the future. But arguments for the FCC in Europe are not only grounded in the past. As the YQA continues:

> *The FCC CDR makes a compelling list of the benefits for all CERN member states, and more generally for all participating countries, of hosting the FCC project at CERN. Such benefits encompass technological and industrial applications in fields that range from information technology to fast electronics, particle accelerator and detector technologies and know-how, which in turn are put into practice in communications, medicine, health, and many other sciences or day-to-day use. […]. It is therefore, not only for the physics, but also from a socio-economic point of view, an unbeatable scenario. To lead in the race to knowledge and discovery is a tremendous motor for ingenuity and excellence, that permeates the whole of society, particularly young people (p. 38)*

We are now in the realm of the future. The FCC promises many socioeconomic benefits to Europe and beyond. As discussed before, the collider is seen as a way for Europe to remain competitive and lead in the race towards knowledge. The infrastructure is a "motor" to generate novel technologies, innovations, expertise, and excellence from which not only scientist but the whole of society will benefit. This is not an argument that is exclusive to the YQA. We only have to take a look at an article for *Europhysicsnews* written by Michael Benedikt and Frank Zimmermann (2017), the two leaders of the FCC study. Asking "can we afford to wait?", the authors argue that "Investment in frontier research will reinforce and revive European competitiveness, employment, and prosperity, while preparing the next generation of accelerators." (p. 16). Or a bit later, they claim that "to remain a key player in science and innovation, in a world that is becoming ever more competitive, Europe should try to secure its current pole position in high-energy physics. […]. The future is ours to shape!" (p. 16). Again, we can find the same argument about the FCC as a way for Europe to stay competitive and create far reaching socioeconomic benefits. In this case, Europe not only has something to gain by constructing the FCC. Failing to do so would also be a huge setback, losing its competitive edge over the rest of the world. The choice is ours to make.

As we can see, there are multiple reasons why Europe should want the FCC. In the first place, it is a way for Europe to remain competitive in its pursuit of science. This is close related to the idea that the project will produce innovations, expertise, and other socioeconomic spillovers that are of strategic importance. But there is another argument to construct it in Europe: values. Already hinted at above, a prominent narrative understands abstract values such as openness, freedom, or democracy as central to the FCC. Not only the existing material infrastructure and expertise but also certain values need to be present to realize the project. And interestingly, these values are frequently associated with Europe.

6.3.4. European values

CERN not only understands the FCC as a project that will bring Europe social and economic benefits. The FCC is also represented as closely connected to a form of „Europeanness". In this story CERN's efforts in particle physics are enacted as a uniquely European phenomenon that reflects European culture and values. As the FCC YQA (2019) puts it in its last paragraph:

> *The physics we do today, hand in hand with cosmology, astrophysics and many other fields, addresses questions – How was the Universe born and how does it work? – that have fascinated humanity and raised enthusiasm for a very long time. The existence in Europe of the fulcrum of a large community of scientists from all continents, genders, cultures, and religions, working together to address to these fundamental questions, with explanations based on facts, in a language that is universal, is a tremendous hope for education, world harmony, and peace. Progress in knowledge has no price.*
>
> *As Europeans, we can be proud that Europe hosts such a place and we should strive to keep it at the forefront of the worldwide effort. (Blondel et al., 2019, p. 38)*

Instead of directly mentioning the FCC, the paragraph inserts the project in a grand narrative that celebrates science as a value in itself. As a continuation of the (European) enlightenment tradition, the FCC is valued as a symbol for rational thought and scientific progress. Physics is representative of an ancient fascination of and search for questions about the nature of the universe that have "fascinated humanity […] for a very long time". Europe, with CERN, is understood as at the heart of a scientific tradition that, speaking in a „universal" language based on „facts", transcends all "continents, genders, cultures, and religions". Here, CERN and particle physics are representative of a European narrative about rationality, equality, secular liberalism, democracy, and progress. Europe is at the "fulcrum" of a worldwide effort in particle physics. Assembling Europe and the universal values of science into a single narrative shows the similarity between the two: European values are paralleled with scientific values. The discourse on universalism and rationality as a „tremendous hope for education, world harmony, and peace" is commonly used to discuss both Europe and science. In other words, CERN, particle physics, and thus also the FCC, are phenomena representative of European values. Both Science and Europe are understood as guardians of knowledge, progress, and world harmony. The last sentence makes this connection explicit: "As Europeans, we can be proud that Europe hosts such a place". Interestingly, even though elsewhere celebrated as an international collaboration, the reader is directly addressed as being "European". Who is imagined as "we"? Who is understood as European?. In a sense, everyone who supports the above-described values of universalism and scientific progress. Europeans should be "proud that Europe hosts such a place". The European citizen, subscribing to "a language that is universal, "explanations that are based on facts" and a striving towards "education, world harmony, and peace" has a moral obligation to support the next generation particle accelerator. If they would be opposed to the FCC, they would also be opposed to progress and all the other values associated with the project. Particle Physics are thus ascribed a series of intrinsic values. In this case, the intrinsic values of science are enacted as a form of „Europeanness". Universalism, rationality, the desire for new knowledge, are all understood as European qualities. Europeans should be proud to have CERN - a symbol for these values - in Europe.

This narrative can also be recognized in Fabiola Gianotti's (CERN's current director general) speech at the 2019 FCC Week in Brussels. In contrast to Rolf Heuer's (2014a) speech, who argued that the FCC will be beneficial to the science community „independent from where it is", Gianotti (2019) emphasizes the advantages of constructing the novel particle collider in Europe. As she puts it: *"*If we look at the FCC, without being too arrogant, I think that the best place to realize it is at CERN and in Europe. Of course, with a strong collaboration of partners from all over the world." She goes on to ask:

> *So why at CERN in Europe? Because in Europe we have the expertise developed over years of activities in this field, we have the knowledge, we have the infrastructure, […] but also because we have the values. We have the values of open science accessible to everybody, we*

> *have the values of sharing knowledge, and we have the values of global collaboration, and we have been trained with working with these values for decades.*

Here, Gianotti argues that Europe is not only suitable to host the FCC because of its expertise, knowledge, and existing infrastructure, but also because of its „values". Proper values are considered an essential feature of scientific research: they make international collaboration possible. Open science, sharing knowledge, and global collaboration are all understood as uniquely European values that are inscribed into CERN and that have been practiced for decades. To further make her point, Gianotti goes on to refer back to the origins of CERN to emphasize how European values have been part of the infrastructure since the day of its foundation. CERN's founders knew that

> *science and research is the foundation of economic development, progress, and peaceful collaboration. [...] The founding fathers would be proud if they could see what CERN has become 60 years later. Promoting peace not only in Europe but also to actors in the world, bringing together people from all countries.*

Again, European values contribute to prosperity and peace; they make it possible for a wide variety of actors to overcome their difference and unite under European leadership at CERN. As such, it is essential that Europe remains with a „prominent role in fundamental science and a prominent role in the values of humanity" (Gianotti, 2019). Europe, as guardian of the „values of humanity" will make successful international collaboration at the FCC possible.

The passages above associates Enlightenment values with CERN. Representations of the FCC enact it as a symbol of rationalism that, producing facts and speaking in a universal language, will bring progress, peace and democracy to the world. In itself, this narrative is nothing new. There is a long history in which values like openness, participation, democracy have been linked to scientific practice. For instance, in *the Republic of Science,* Michael Polany (1962, p. 54) argues that there is a close interrelation between a liberal democratic society and the organization of science: „in the free cooperation of independent scientists we shall find a highly simplified model of a free society". As such, the best organization of science and of society are imagined as closely linked - both are made up of free rational individuals interacting with each other. I mention Polany here to draw attention to an established imaginary that compares the functioning of science with the (ideal) functioning of western society. As such, it is not out of the ordinary that the values of CERN (rational, open, democratic, transparent, participatory, etc.) are envisioned to coincide with the values of scientific practices and the values of (western) liberal democracy. For instance, Ezrahi (2012, p. 49), goes so far as to argue that there exists a "sociohistorical correspondence […] between the imaginaries of scientific community and the liberal democratic society as aggregates of free rational individuals. In both contexts, this imaginary of the community as voluntary association of autonomous individuals legitimates knowledge and politics as their respective products.” The removal of personalities, scientific subjects, and politics of the processes of knowledge production, presenting its insights as a transcendental mirror of nature, made science an essential resource in the construction of democratic order (Ezrahi, 2004). Interestingly, while the qualities of science give legitimacy to the democratic organization of CERN/Europe, the values of democracy now also give legitimacy to construct the FCC in Europe. There thus occurs a kind of reversal of Ezrahi’s argument. It is no longer just science for democracy but also democracy for science. But the YQA document not only use democratic values to argue for the FCC. They also understand these as a particular European quality. CERN’s values are also European values. This becomes explicit when it is about the location of the next collider. After introducing Chinese competition, the YQA makes explicit that we should construct the FCC in Europe because of its values. Similarly, Gianotti argues to construct the FCC in Europe „because we have the values“. In both cases, (democratic) values are used as an argument to construct the FCC in Europe. As such, this narrative not only associates European values with CERN. It also sees these values as the foundation to make a global collaboration possible. We can thus observe how the values of science, liberal democracy, and Europe have become (narratively) entangled, converging, overlapping, and reinforcing each other in interesting ways. Together, they make the case to construct the next collider at CERN.

Throughout this chapter, I have shown how the FCC is variously enacted as a European and as a global project. The collider is both a way for Europe to stay internationally competitive and a way to bring the whole world together through an international collaboration. These stories are closely connected to uncertainties about CERN’s scaling (how to fund the project and who to involve) and questions about the FCC’s socioeconomic benefits for Europe, placing the project in a peculiar position between internationalization and Europeanization. Interestingly, the tension between the local and the global, between Europe and the world, and implicitly also between international competition and cooperation, is resolved through a narrative that emphasizes CERN as a facilitator of international collaboration based in Europe. Following this narrative, the FCC will become a global project in Europe. As the YQA puts it: „CERN is the home of European particle physicists, and it is also the radiating center of an intense worldwide collaboration“ (Blondel et al., 2019, p. 38). CERN is both European and international. And as I have shown above, both are reconciled with each other by referring to CERN’s (European) values. CERN’s “Europeaness” is what makes possible a truly open and international collaboration. It is why the FCC, as a global project, should be constructed in Europe. Following Mobach and Felt (2022), we can understand CERN’s narrative of global scientific collaboration as based on a vision of „Europeans as universalist culture, a collaborative spirit of scientific rationality, and a heart made of openness and diversity“ (p. 15). Collaboration is open to the world to anyone who wants to contribute and subscribes to European values. In other words, CERN is performing „a stabilized Europe from which global science can be shaped“ (p. 16).

6.4. Communicating the FCC

Science communication efforts are central to the FCC, informing the public about CERN's plans to construct a new collider. In this chapter I will take a closer look at some of the public relations materials created within the FCC study to better understand how these present the FCC as something valuable. CERN has started to create an active social media presence for its new collider. Frequently posting on all big social media platforms under designated FCC accounts (Facebook, YouTube, Instagram and Twitter) CERN puts a lot of effort into establishing the project as something that is talked about not only by experts but also by a public audience. From discussing articles in popular science magazine, feasibility studies, conference proceedings, and FAQs we now move into the realm of science communication and public relations work. Specifically, I will engage with short introductory clips and promotional audio-visual videos uploaded to YouTube. In 2016, CERN has created a YouTube channel to promote the FCC called „Future Circular Collider Study". On its description we can read that „the YouTube channel of the Future Circular Collider study aims to share with you the latest advancements and news from our collaboration and introduce you to the scientists and engineers who work to explore different designs of circular colliders for the post-LHC era" (FCC Study, n.d.). If we scroll through the collection of videos that have so far been shared on the channel, we can find a mix of re-uploads from past conference proceedings and interviews that either discuss or promote the FCC. In addition, there is a variety of videos are produced especially for the YouTube Channel. For instance, in 2021, the FCC study has hired the Austrian PR company „Terra Mater Factual Studies" to create a professionally produced short series called *collider diaries: young CERN scientists up close and personal*. Further, the are two promotional videos with high production value: *After the LHC: designing the Future Circular Collider* (2018) and *Science knows no borders* (2018). In the following, I will move through each of these to analyse how they, although in very different styles, enact the FCC as the best future for particle physics. Specifically, I will show how, by assembling and reproducing some of the narratives I have discussed in the previous chapters, the FCC is performed as a global collaboration.

6.4.1. The collider diaries

The collider diaries, a series separated into six episodes, introduces the lives of a couple of young researchers currently involved in the research and development of the FCC. The series is part of the EU funded EASITrain project working on superconductor and cryogenic technology R&D. The collider diaries are presented as a „v-log", mimicking many of its stylistic elements. They show the scientists narrating what they do and how they feel. Both the titles and the content within the videos make use of an abundance of emojies, both contributing to very personal and informal style. Using footage that seems to be created with a smartphone, the videos are made to appear as if they were shot by your average blogger who also incidentally happens to work at CERN as a part of the FCC study.

The collider diaries give the viewer a very personal insight into the lives, experience, and daily routine of the people working on the FCC. As the name of the series indicates, the videos are small diaries of researchers working on the realization of a novel particle collider. The viewer gets to know how the scientists live, what their work looks like, what food they love to eat, the hobbies they have, or the books they currently read. We learn how they spend their days, that they like to jog, do photography, or tend to plants in their spare time. We are told that Dorothea likes to act, that Vanessa has recently become a vegetarian, and that Aisha likes to write poetry in her native langue Urdu while doing her phd on thallium based high temperature superconductors. So in a sense, the videos move between morning routines, extremely complex scientific work, the mistakes making this work difficult, and the worries that keep the researchers up at night. In other words, we learn „what drives them, how they live, and what they do when they're not working on what could become the world's largest particle accelerator" (FCC study, 2021a).

Researchers as subjects with dreams, hopes and fears, usually hidden in representations of scientific work, are put at the centre of the videos. Oftentimes, stories about scientific work make invisible the people that produce knowledge. It thus appears as if scientific knowledge would be created independently from the persons involved in its production. Usually, when we talk about the achievements of CERN, these are about science's many successes, the machinery used to create them, or the genius of a couple of individuals such as Peter Higgs. But only rarely does one get to know the figures involved in science personally. What Peter Higgs had for breakfast or what plants he tends to is not really anything anyone talks about. Science and the insights it creates are usually separated from the people that produce it. As such, the collider diaries create a very interesting image of particle physics and its scientists. The new collider, although always present and hinted at, fades into the background. This places it in stark contrast to the other promotion videos I will discuss below, which focus on the FCC's more abstract scientific promises detached from the people that will create them. The collider diaries offer a very personal accounts of the people working on project. Researchers are here no longer eccentric figures that, detached from earthly needs and concerns, work on incomprehensible sciences in their ivory tower, perhaps best exemplified by representations of scientists in white lab coats. Science is no longer this depersonalized, sublime, abstract and untouchable thing: it becomes something relatable and tangible. In the collider diaries, CERN researchers are presented as average people. Like many of us, they wake up every morning, drink their coffee, and then go to work, all the while dealing with personal issues and anxieties.

Even though the focus is on the mundane lives of scientists, the collider diaries still frequently reference the FCC and the scientific insights and societal benefits it promises to bring. While not at the centre of the videos, the FCC and its justifications are still very present. The videos implicitly draw on similarly justificatory repertoires as the FAQ documents I have previously discussed. Stories about innovations, societal benefits, and a human striving for knowledge about the secrets of the universe still make it into the videos. This happens through funny vignettes, accounts by the scientists, and the visual materials inserted into the footage.

For instance, in one of the videos the experimental physicist Dorothea is asked whether it is true that bananas are radioactive (FCC study, 2021b). In the scene, the viewer is informed that something incredibly banal such as a banana is actually a radioactive object. It contains pattsium, a naturally occurring element that, when decaying over time, is transformed, thereby emitting particles, energies, and thus also radioactivity. But the viewer is immediately told that this is nothing to worry about: „it is nothing scary, it is something natural, we shouldn't be scared of what we don't know. We only need to understand it better" (FCC study, 2021b). The video reminds of the many fears that revolve around new particle accelerators and other scientific advances. There are many stories about the possible creation of black holes at CERN that might bring the end of the world or the harmful radioactivity it might produce. In any case, the story about the radioactive banana is a subtle and humorous argument for a new collider, addressing some of the fears and uncertainties that come with the project. It implies that viewer should not be scared of what they don't know. In contrast, the only way to overcome uncertainties and the unknown is to study and thus understand them better. Basic research is neither scary nor unnecessary. Instead, it is presented as essential to understand the world around us and reduce the many anxieties and uncertainties that we face every day. Just as science has made it possible to make sense of the secrets of the banana, a new collider will help us make sense of the secrets of the universe. And as we learn from Vanessa in another video, it is in human nature to investigate nature: „people are thirsty for knowledge. And I think FCC in general is a little bit a part of that human curiosity of going further and further" (FCC study, 2021c). Here, the FCC is a manifestation of humanity's inherent curiosity and drive to better understand the world. It is a human thirst for knowledge and a desire for progress that drives the project. The collider diaries thus tap into similar justificatory narratives to those I have discussed in Chapter 2, presenting (epistemic) uncertainties as the driver of the FCC's construction.

Furthermore, the young scientists also let the viewer know that their work is not only about their own curiosity. They also do something for other scientific fields and society. „It's something for humanity. It's not only just for me". Watching images of the LHC collider being disassembled that could be straight out of a science fiction movie, the viewer is told that:

> *We scientists are eager to know more about the nature, about the universe. But, of course, what we are doing is not only related to this huge machine, which will hopefully be built, it's also something that might be useful, which will be useful, in other fields.* (FCC study, 2021d)

Further, the FCC will also create innovations and transform society at large:

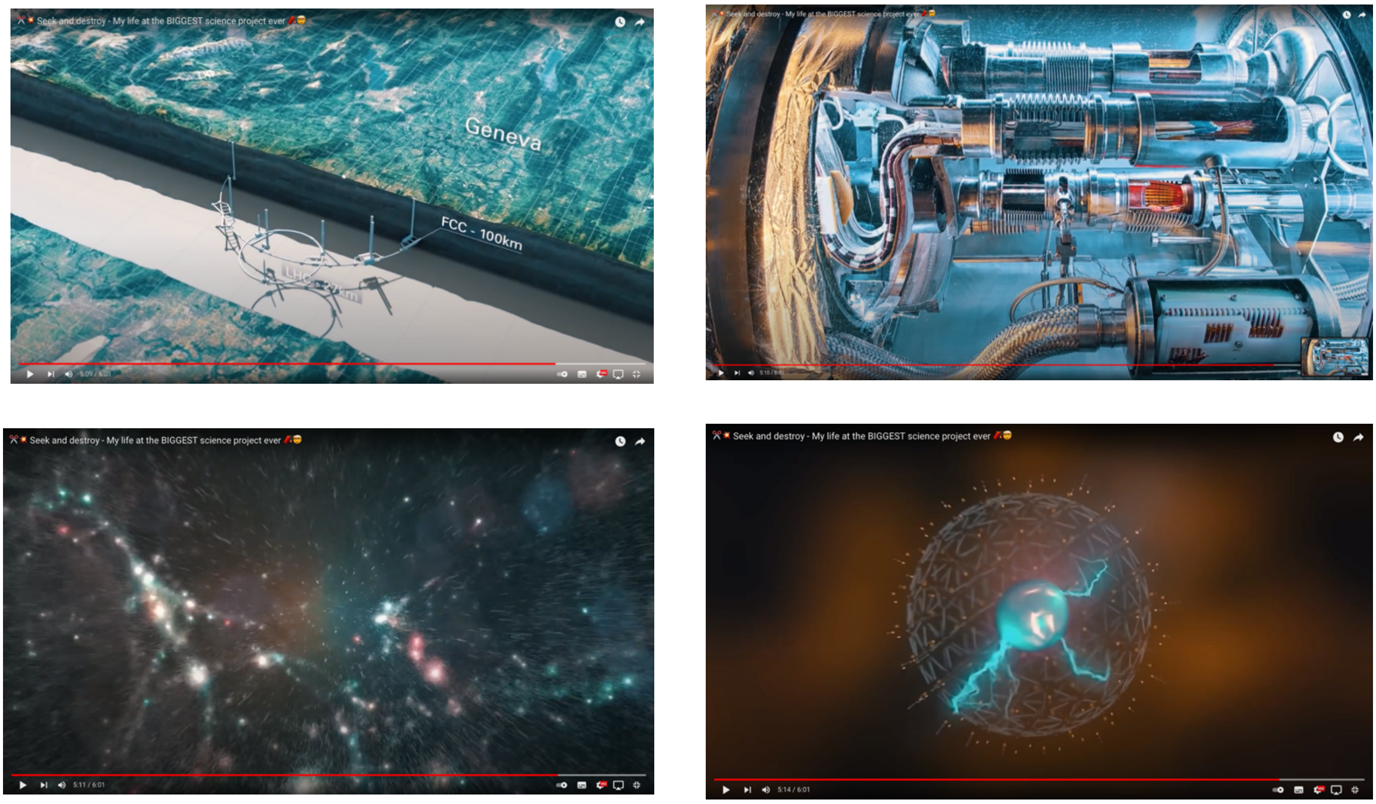
> *My work has an impact on society. Not an immediate impact on society, because for basic research it usually takes years, sometimes decades, to get to the point that it finds its application on everyday life. But it will eventual find it and like many other technologies that come from discoveries that have been done in basic research, in fundamental research, it will change our lives in some way that we don't know yet. But this is basically the meaning of fundamental research. (FCC study, 2021b.)*

In other words, the video claims that the FCC and the knowledge it creates will eventually create societal benefits. While this might take some time, it is certain to change our lives at some point in the future. As a consequence, uncertainty about the FCC's impact on society becomes normalized. The uncertainty is presented as an inherent quality of basic research, which places the FCC outside of demand for societal benefits. This again shows parallels with the narratives discussed in Chapter 3, similarly promising (unpredictable) social and economic benefits from the FCC. But while the FAQ materials present the socioeconomic benefits by listing them in a document, the same promises are here made by a passionate scientist talking directly to the camera and by extension to the public.

The collider diaries not only use the physicists' narration to construct the expectations, promises, and imaginaries of the FCC. The informal blog-like clips are intermixed with imagery that shows current CERN technology like the LHC collider and detectors or speculative design concepts of the FCC. These short insertions of collider related imagery are of vast scale and complexity; the polished high tech leaves the viewer in wonder and amazement. Let us look at the role of visual images in the collider in a bit more detail, focusing especially on how they take part in constructing and reproducing dominant narratives of the FCC. In the scene I want to discuss, the viewer is told by a young CERN scientist that she hopes that she will work at the FCC at some point in the future (FCC study, 2021e). In the meantime, the scene quickly changes from showing the researcher in her living room to images from underground tunnelling work and then to an animated conceptualization of the FCC that, floating between the Geneva region sliced in half, portrays a sense of the collider's massive scale (Image 5). Two seconds later, the camera cuts to a complex looking shiny silver technology, after which the viewer is suddenly catapulted into outer space, flying across the galaxy between millions of stars and through a flaming sun, until the shot ends on an animation of an atom, its constituting forces visualized as flashing lighting bolds (Image 6 - 8). Now we are beyond space and time, in the all-encompassing, universal, and placeless realm of science. Then the image fades into black and in big white letters there emerges the question: „doesn't humanity have more pressing problems to solve these days?“ To this, the young CERN scientist responds: „we only progress when we keep looking. What is coming and how to handle these things we can only know when we know how to progress in the future“.

Image 5 – 8

Visualisations used in the collider diaries



Note. Future Circular Collider Study (2021e), Seek and destroy - My life at the BIGGEST science project ever 🧨🤯, YouTube, https://www.youtube.com/watch?v=VWphloMnfQk

As we can see, the video moves from the researcher's home to an underground tunnel, a speculative design of the collider, the endlessness of space, and ends at the atom, one of the smallest constituents of matter. We move from the personal and situated lives of CERN scientists to an understanding of science as universal and placeless, creating absolute truths about nature. The collider diaries' images thus enact the FCC as both the result of the work of individual scientists and an engineering achievement using complex technologies. The images used are all iconic references to the achievements of science becoming symbols of a western imaginary of progress. As the scientist in the video affirms, the FCC is a way to progress into the future, not only for the individual researchers but for humanity as a whole. Progress and a better understanding of humanity and its place in the world can only be secured through more science. Uncertainty, stagnation, slowing down, these are issues that concern all of us - „we only progress when we keep looking".

As such, the videos discussed above present a complex choreography that moves from the very personal life of researchers involved in the FCC to major ontological claims about science and the world we live in. There is a constant change between the personal, the technological and the scientific. Stories of eating breakfasts and watering plants become interwoven and juxtaposed with imageries of large technologies and the vastness of the universe. In an interplay of images and stories that move between the intimate and the scientific, between subjectivity and objectivity, between the mundane and the high technological, and between living rooms, the smallest matter, and the endless vastness of the universe, relatable and sympathetic young scientists tell the viewers that their work is not just theoretical speculation but affects and benefits all of us. This juxtaposition of the mundane lives and works of scientists working on the FCC and the mythical narratives and fantasies woven around it serves as a powerful justification for the next collider. It gives the grand narratives of particle physics credibility by connecting them to the very real lives of the people working on the FCC.

The collider diaries' vision of the FCC is not limited to justificatory narratives about the project's scientific insights and societal benefits. It also performs an imaginary of particle physics as enabling international collaboration in Europe, reproducing some of the narratives I have previously discussed. In the videos, the FCC is enacted as an international collaboration that, while based in Europe, will bring together scientists from all over the world.

At the beginning of every video, there appears a small frame providing some personal details about the scientists. Specifically, the viewer is told where the researchers are from, the place they are currently working at, and what their current research interests are. This is the only information that we learn about every single scientist across the six videos. Why are details about national origin and geographical location of the workplace considered such important information that they are mentioned in all videos? These categories are arbitrary and could just as easily be about the scientists' eye colour or taste in music. Still, they are in the videos, performing a specific form of scientific collaboration in which place is of importance. Specifically, we learn that Vanessa, originally from Los Teques in Venezuela is currently working in Padova in Italy. We also learn that Maxime, a French accelerator engineer, is currently based in Stuttgart, that Vanessa from Genova, Italy is currently working in Vienna, and that Aisha moved from Pakistan to Italy to take part in the FCC study. But these different national identities are not only performed in the information window at the beginning of every video. The scientists proudly tell us about their culture. We see plates of traditional Venezuelan food, we get to read a poem in Urdu, and we are told that Vannessa, the Italian experimental physicist, thinks that Viennese coffee is nearly as good as the one in her native country. So we see that formal and informal national identity matters to the FCC collaboration.

The videos perform the FCC study as a diverse and global collaboration in which researchers with different socio-cultural backgrounds, interests, and scientific expertise come together to work on the same project. While looking at the visualization of a global research network (image 9), the viewer is reminded by one of the scientists that the FCC study „is a huge, massive effort towards the next, big particle accelerator, that hopefully, will be built at CERN and this will require the collaboration of an enormous amount of countries and researchers from all over the world. Physics, like it's never done before“ (FCC study, 2021b).

Image 9

Visualisation of the FCC's global research network

Note. Future Circular Collider Study (2021b), Unvarnished diaries of a CERN scientist, YouTube, https://www.youtube.com/watch?v=K0NqsgHNQnc

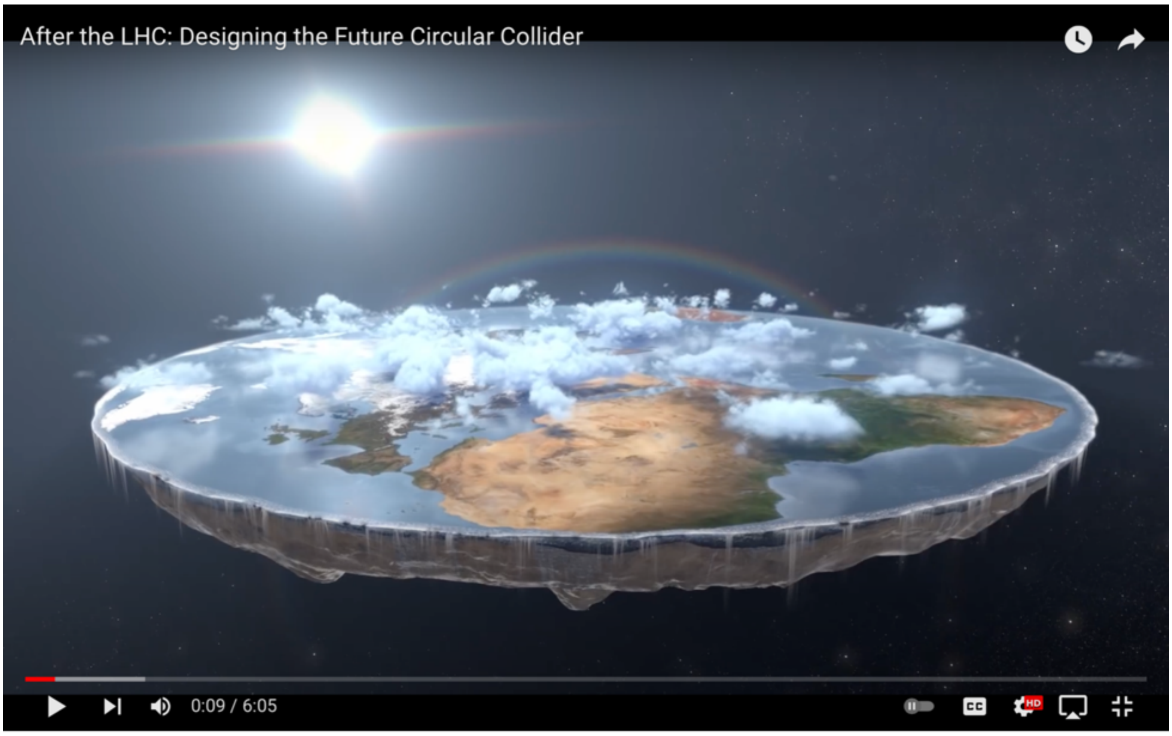
As we can see, the endeavour to realize a new accelerator is understood as a truly global collaboration, in which people from all over the world come together. More specifically, the different nationalities and cultures become united through a single European project in particle physics. Even though the videos emphasise that the researchers have very different national backgrounds, they are all working on the FCC at European universities and laboratories. This is reinforced by the previously mentioned visualization of the global collaboration: most of the lines symbolizing scientific exchange end in Europe. In other words, the whole world comes together and is united in Europe. So what is it that brings these people together in Europe? Despite their cultural differences, all researchers are united through their work in and passion for particle physics. They all speak the "universal language of scienc"'. Here, just like the narratives discussed in Chapter 3, it is universal science, based in Europe, that makes global collaboration possible. The FCC is both European and global, both localized and placeless. Going back to my earlier discussion of the collider diaries' visual narrative (see Image 5 – 8), we can see how images contribute to the imaginary of a universal science. Visualisations (of particles, the universe, or complex technologies) all depict things that are considered placeless, beyond society and culture. They are assumed to hold true wherever you go. As such, while acknowledging the cultural particularities of the researchers, the science they practice is considered as universal. The videos thus reproduce and naturalize a vision of science as placeless and as motivated by a shared striving for universal truths – both qualities that appear to bring together the scientists despite their cultural differences. It is science's assumed universality that makes an diverse and international collaboration (in Europe) possible.

6.4.2. After the LHC: designing the Future Circular Collider

Next to the collider diaries, there are two other videos created to promote the FCC to the public. One is called „After the LHC: designing the Future Circular Collider" and the other „Science knows no borders". While the former focuses on the FCC and its potential epistemic insights, the latter promotes a vision of the collider a collaboration that transcends cultural boundaries. As these two videos are at the centre of CERN's communication strategy, it is worth describing them in some detail to see how they relate to but also differ from the collider diaries. Doing so, I give insights into how these represent the FCC in different ways, while at the same sharing some commonalities, like an understanding of the FCC as global.

Image 9

Visualisation of a flat earth



Note. Future Circular Collider Study (2018a), After the LHC: Designing the Future Circular Collider, YouTube, https://www.youtube.com/watch?v=habsQbdEc0A

The „designing the Future Circular Collider" video (FCC study, 2018a) begins with the camera slowly moving over the surface of an animated earth. There are huge landmasses and oceans. But suddenly we reach its end. The earth turns out to be flat, visualized as a free-floating disk, its oceans gradually flowing over the edge (Image 10). At a closer look, another peculiarity becomes noticeable. Against current scientific consensus, the flat earth is circling around the sun. Then, slowly, the shape of the earth is transforming into a sphere, and the sun becomes the centre of all movement. The viewer can relax, everything is in order again. The animated images coincide with the current understanding of the world. What a shock, to be catapulted back in time, when uneducated and irrational people did not yet know what the world really looks like. How must it have been, back then, without modern science? What horrible fate, to live in such uncertainty, without the enlightening knowledge of science. Then the camera moves away from earth, into the vastness of the universe. Images of planets, lines indicating their path around the sun, remind us of the many achievements and insights science has brought to humanity since the dark ages in which the earth was still assumed to be a disc. From there, the camera cuts to an image of CERN and the LHC.

The visual imagery is accompanied by a narration, which tells us that:

> *At one point we thought the world was flat until explorers pushed into the unknown. At one point in time we thought the sun orbits around the earth. That was our whole universe. Until we looked further. It's all about explorers pushing into the unknown. Scientists are like these explorers. People who discover things that we didn't think that we needed to know. Without explorative science we wouldn't know what we know today. That all our modelling makes up only five percent of the known universe.*

Just like the visual narrative, the spoken word moves from a past of uncertainty into a present guided by science. Scientific knowledge has continuously progressed, revealing ever more of the secrets of the universe and humanity's place in it. The metaphor of the scientist as an explorer is utilized. Science is about pushing into the unknown, discovering things that no one could predict. Certainly, this can be read as a response to the criticism the FCC faces due to a lack of theoretical predictions. Similar to the FAQ document discussed in Chapter 2, the video presents epistemic uncertainty as nothing to worry about. Uncertainty is inherent to the very nature of scientific work. What is more, the narrative celebrates science's many tremendous achievements and insights, not only in the past but with the FCC also in the future. In the words of the narrator: „without explorative science we wouldn't know what we know today" - which is, in this case, that we only understand „five percent of the known universe". This implies that, even though science's huge achievements in the past, there is still much more to discover. Thus, the passage not only celebrates past achievements, but it also describes an epistemic problem that needs to be studied further in the future. There are still many uncertainties and unknowns that require urgent scientific investigation. And that this investigation will eventually drastically change how we view the world, science as already proven numerous times. According to the video, the FCC should thus be seen the next step in humanity's quest to explore nature.   And that this will eventually be worth it, science has already proven numerous times.

Now I want to look a bit closer at how the video presents the FCC as the future for particle physics. As mentioned above, science is frequently described as an exploration of the unknown. The viewer is told that „there is no clear hint on where nature could hide its secrets.“ Future discoveries are an intrinsically uncertain endeavour. But does that mean we should stop looking? While it is uncertain what we will find next, one thing is clear to the scientists in the video: „If we stopped exploring then basically we stopped evolving. The question isn't should we explore, it’s how should we explore.“ In this narrative, scientific exploration is seen as essential to human progress. We need to explore; it is human nature. The only question is how. And to this question, the viewer is immediately presented with an answer: „the future circular Collider FCC will be the next instrument that we have to build if we want to continue to be in the path of discovery.“ The narrator further specifies the reasons that drive scientific exploration and continued discovery: „the motivation for what we are doing is basically curiosity. There is a lot more to learn still and we have.“ Next to curiosity and learning, the FCC is also promised to provide very specific insights: „the FCC will be a tool for high-energy physics for discovering new particles, for maybe discovering new laws of nature.“

As we can see, the video fluidly moves from grand stories about the exploration of the secrets of the universe, to stories about curiosity and progress, bringing them together in an argument for the FCC. CERN’s next collider becomes presented as the logical next step towards further scientific insights. Interestingly, science and the fascination it creates is very much at the centre of the video. There are no mentions of innovations, societal spillovers, economic growth, or competitiveness in the knowledge economy. Instead the videos focuses on curiosity driven fundamental research, presenting it as a symbol of progress that influences how we understand nature. While there are no immediate societal benefits from exploring the unknown**,** it has still provided many fundamental insights, revolutionizing humanity’s understanding of itself.

In the latter half of the video, the emphasis shifts away from science as a bringer of knowledge towards science’s ability to bring the world together. Again, as already discussed numerous times before, the focus becomes the global nature of the FCC. As the viewer is told:

> *We will need all the people of CERN but all the people also worldwide. Such a project can only be realized as an international global effort. You can no longer do such science alone. Science knows no borders. […] The questions that we are starting to ask in science are questions that only humanity acting together can hope to answer***.**

As I have already discussed this narrative at length, I will not go into much detail into the vision of science that is here reproduced. It is enough to note that this is more or less the same narrative I have discussed before (see also Chapter 3). On the one hand, science is already inherently global: it knows no borders. On the other hand, the increase in size of the FCC requires a global collaboration: it can only be realized if the whole world works together. As such, the argument that science is inherently global justifies the increase in size of the FCC. Science was always global, and it should continue to be so in the future. And the FCC is the way to realize such truly global collaboration.

Interestingly, the video also implicitly performs the FCC as an international collaboration. Not only what is said but also how it is said enacts the project as global. The story of the FCC is told through a patchwork of different voices. It is an assemblage of different scientists working at CERN, their voices intermixed to create a coherent narrative and form a complete whole. If one is paying attention, it is possible to discern voices by people such as CERN Director-General Fabiola Gianotti, FCC study leader Michael Benedikt, or Nobel laureate Peter Higgs. One scientist begins a sentence, and the next continues it seamlessly. Intermixing these voices implies that the FCC is backed by a diverse but united scientific community. The scientists of CERN, in the name of past and future scientific achievements, unanimously support the construction of a new circular collider. This assemblage of people implies unity but also diversity, bringing together diverse actors in the name of science. They speak united in favour of a new collider at CERN. The video also makes explicit that this is a highly international community. It ends on a variety of scientists that, speaking in different languages, tell the viewer what insights they hope the FCC will make possible. Changing from English to French, German, or Japanese, we are presented with hopes of a better understanding of dark matter, pf new technologies and innovations, of an experiment that makes it possible to explain the four fundamental forces with one theory, or, as one scientist puts it: „with the FCC, I hope one day we might know where we come from". This is a powerful way to not only tell but also show the international nature of the collaboration. Scientists from all over the world, speaking a variety of different languages, can come together to dream about science. Moreover, the scene presents the viewer with many fantastically sounding insights that the FCC could potentially produce. As the narrator tells the audience: „you have to think that nothing is impossible. From time to time the success will be tremendous." Or in Peter Higgs's encouraging words concluding the video, „we only scratched the surface, we have clearly much more to discover".

6.4.3. Science knows no borders

As we have seen above, the FCC's potential epistemic insights, its global collaborative nature, and its value for humanity have become entangled with each other, together making a powerful argument for the FCC. I already showed how the FCC is implicitly enacted as global by showing diverse scientists coming together to collaborate in the name of science. In the following, I am interested in how collaboration is performed in the „science knows no borders" video, in which, as the name already indicates, an understanding of the FCC as global is at the centre (FCC study, 2018b).

In the video, former CERN Director General Rolf Heuer explains to the audience why science knows no borders. His story revolves around CERN's European origins, why the laboratory is now a global endeavour, and its benefits for future generation scientists and humanity in general. The video begins with Heuer, who, sitting in a huge and empty lecture room, argues that „ it [the FCC] cannot be done by a single nation“. To make this claim, he draws on a narrative that is frequently used to justify the FCC: CERN's origin story. We learn that shortly after the second world war, visionary diplomats and scientists came together to found CERN. Going beyond their national differences, they were able to convince twelve nations to take part in a European collaboration. As such, from its very foundation, CERN is driven by a vision: „we cannot do it alone, we have to go beyond our borders“. This story about CERN's origin has become a kind of myth that is continuously reproduced in the narratives around the FCC. As Heuer continues:

> *CERN started as a European collaboration but globally used. Science is global. Today, we are going beyond the borders of Europe. More than 100 nationalities working at CERN, agreements with institutions from around the world, from the north to the south from the east to the west.* (FCC study, 2018b)

This story implies a kind of linear continuation from CERN's foundation to the contemporary deliberations on the next accelerator. As we learn from the video description, „CERN was born on 29 September 1954, with a dual mandate to provide excellent science, and to bring nations together”. Thus**,** not dissimilar to the historical moment in which European nations came together to participate in an international collaboration, we are today again confronted with an important decision. Again, there is the possibility to decide in favour of an international project. The stakes are just as high, this time not only bringing Europe together, but the whole world. The FCC is a kind of new beginning. A crucial moment in the history of CERN, in which a novel, even bigger collider would make possible collaboration even beyond the boundaries of Europe. With the FCC, deeply rooted in the institutional past of CERN, history can be made another time, moving from national, to European, and now to global science. In other words, CERN is bringing together different nations, not only in the past but also in the future. Again, this is assumed to be enabled by the universality of particle physics that transcends national differences.

Heuer's narration is accompanied by visual images that show an old globe in the middle of a library. In a closeup, the video shows the turning globe, in which the different cities collaborating with CERN are indicated (Image 11). Here, the viewer gets a sense of the scale of the institution's collaborations. Looking at the spinning globe, it becomes clear that the FCC will be truly global, involving the whole world. Again, such international collaboration is assumed to be made possible by the universality of particle physics. Collaboration, transcending cultural differences, is enabled through the scientific method. As Heuer puts it: „There is a single language at CERN, and that's science“. He goes on to specify that: „collaboration means you get your ideas together with the others, you develop things together, independent of culture, independent of age, independent of experience.“

Image 11

Visualisation of a spinning globe

Note. Future Circular Collider Study, (2018b), Science knows no borders, YouTube, https://www.youtube.com/watch?v=HUGEWoGM_1U

Interestingly, CERN's global collaboration is not only an ideal to be realized with the FCC. CERN is already actively practicing it. After learning how science enables people to come together to collaborate despite their differences, the viewer is told that everything CERN produces is open to everyone. In the words of Heuer: „we have one secret at CERN, this is that we don't have a secret. All science, everything we do here, all our results is open". Open science nicely ties in with the FCC's vision of global collaboration. In a sense, CERN's open data policy is a form of lived global collaboration that, at least in principle, is open to everyone. Thus, CERN is open to the world, not only inside of the institution, but also far beyond its boundaries. Science knows no borders, not only because of an idealistic and intrinsic universal quality, but also because this ideal is already actively practiced by CERN, providing its data open to everyone. As such, narratives about science as openly practiced and science as a universal language reinforce each other. Openness is both intrinsic to science and actively pursued. The FCC and its vision of global collaboration thus perfectly aligns with the nature of science and the ideal of openness. Openness, as a value, both enables and reflect CERN's, and for that matter science's, collaborative nature. The FCC will both be open to the world to participate but also open to the world to use the data it produced. It is not entirely clear whether science as open/global is descriptive or normative. Is it an intrinsic feature of particle physics? Or is it a moral ideal that, also prominent in European science policy discourse, should be actively achieved?

In the speech of Heuer, the two come seamlessly together, creating a powerful argument in favour of the FCC. The particle accelerator and its global collaboration is the logical next steps in line with CERN's founding moment and the inherent universality of science.

As I have shown, in the video different narratives about science, openness, and European collaboration after the second world war are woven together, each reinforcing a vision of particle physics as beyond borders. If we believe Heuer, this has another, unintended consequence: „There is definitely a stability in science, because we are talking science and we are not talking politics. […] You can no longer do science alone, and that may help to make the world a little bit better." The science practiced at the FCC is promised to bring stability in a rapidly changing world. In contrast to politics, science is a stable entity. It is not driven by interests and beliefs but hard facts about the world. And as particle physics, practiced at the scale of the FCC, will facilitate a global collaboration in the name of this ‚neutral' science, it might make the world a better place. The FCC will show that, despite national differences, global collaboration is indeed possible. In this context, the FCC's slogan shown at the end of the video(s), „Designing the Future Circular Collider - expanding our horizons", acquires multiple meaning. The accelerator is promised to go both beyond the boundaries of current knowledge and the boundaries of Europe. But there is also implicated a third boundary crossing. Science knows no borders, not only in its geographical distribution, but also in the impact it has on society. Outside of the borders of CERN, even society will benefit, making the world a bit better. Both epistemically and societally, the FCC is seen as a way beyond current limitations. The world is increasingly global and HEP has become so big that it requires global collaboration. As such, the FCC is seen as an infrastructure perfectly suitable to our current globalized world. Globality becomes both a requirement and a normative statement. Not only do we need global collaboration to make the FCC possible. We also need the FCC to make global collaboration possible, thereby not only opening up the potential for better scientific insights but also providing stability in a rapidly changing world.

6.4.4. Performing global collaboration

What can we learn from discussing the FCC's promotional videos? How do they enact CERN's next particle accelerator? The PR videos analysed above tie in with many of the themes I have discussed in previous chapters. As discussed at length in Chapter 2, the discussion of the FCC happens at a time in which particle physics experiencing a sense of epistemic uncertainty about what will come next. After the discovery of the Higgs, there is no longer a clear theoretical prediction of what to find at high energy ranges. This is reflected in the videos' epistemic promises, all remaining rather vague. They mostly describe potential insights into vague questions such as the nature of „dark matter" or „the origins of the universe". These are things that, at least to the lay public, do not mean anything: the missing 95% of the universe could be everything and nothing. Given this lack of theoretical predictions, it makes sense that videos portray particle physics as an explorative endeavour, which closely aligns with my previous findings. And because of no, or at least no easily articulated epistemic benefits, the FCC's justification moves into alternative registers of worth. For instance, the collider diaries quite explicitly speak of the societal benefits that come from fundamental research in HEP: satisfying human curiosity, creating innovations, and enabling progress. In contrast to the FAQ documents discussed in the previous chapters, the videos convey their messages through a much more personal and affective aesthetic. Instead of questions and answers listed in a document in which any authorship is erased, in the videos it is the scientists themselves, both established and young, who give us promises of the FCC's ´scientific and societal benefits.

One of the above analysis' most interesting finding is that all three videos more or less explicitly perform the FCC as a global collaboration. This relates to my insights of Chapter 3, in which I described how the FCC's increase in size and funding sparked a debate about CERN's internationalisation and expansion beyond the boundaries of Europe. There seems to be a broad acknowledgment that to realize the FCC, the whole world needs to be involved not only in scientific collaborations but even in CERN's governance. The European laboratory has to now become a truly global laboratory. Within the videos, this narrative is presented through fantastic stories about the universal language of science, values of openness, and CERN's origin story and institutional identity as a unifying force in the European post-war years. Globality, whether intrinsic to science, a normative ideal, a historical achievement, something actively practiced, or a requirement for the FCC, finds its way in every video. In the end, although with very different approaches, they all make the same argument: the FCC will bring the world together.

The collider diaries portray the lives of young researchers working on the FCC, giving a very personal insight into their mundane daily routines. Here, the emphasis is on showing scientists as situated subjects. In the diaries, culture matters. Each scientist has a very different social background. But while the videos clearly emphasise the scientists' many cultural differences, it also shows how, in the name of science, they can all come together and collaborate. Science, in its striving for universal knowledge about nature, makes possible global collaboration, while also leaving room for cultural differences. Similarly, in the „designing the Future Circular Collider" video, international collaboration is only implicitly present. While mostly focusing on science's past and future achievements, the necessity of exploration, and the benefits this will bring to humanity, the FCC's global nature is made visible through a narration that is made-up of different scientists that, speaking in various languages, together create a coherent narrative. Thus, not dissimilar from the collider diaries, the FCC becomes global not only by telling but also by showing the viewer that it is an international collaboration. But still, there is a profound difference between the two videos. While the former focus on the personal life of scientists, the latter leaves no space for the individual. Cultural differences and the scientific subjects are transcended. The different scientists have become absorbed into a complete whole: the institution of CERN. They have all become one, speaking unanimously and in a single voice. They all speak the universal language of science. Science is here not the achievement of individuals but of a collective particle physics community. In this narrative, there is no room for personalities, identities, subjectivities, or emotions. While the collider diaries emphasise collaboration despite culture, it is now collaboration without culture. The „science knows no borders" video similarly emphasises particle physics as universal, neutral, and placeless. And as Rolf Heuer tells the viewer, it is these qualities in which the success and emancipatory potential of science lies. It makes it possible to go beyond differences, boundaries, and borders, open and accessible to everyone. Science is a symbol of the rational humanist ideal; through science the world can come together and be united despite political uncertainties. Thus, the FCC, as a global collaboration, is also a moral and normative project. In today's unstable world, there is the necessity to foster international collaborations and create stability. And the FCC, in the spirit of CERN's founding moment after the second world war, will make this possible. Global collaboration is thus not only intrinsic to science, but also ingrained into the institutional identity of CERN. From its foundation, CERN was not only about making science but also transcending borders, and it should continue to do so in the future.

Thus, what unites the different representations of the FCC and what, in each case, enables the argument for a global collaboration, is an assumed intrinsic quality of science. The imaginary of particle physics as universal, placeless, and thus global collaboration closely aligns with Traweek's (1988) study of the epistemic culture of particle physicists. According to her, high energy physicist „construct their world and represent it to themselves as free of their own agency". It is an „extreme culture of objectivity: a culture of no culture, which longs passionately for a world without loose ends, without temperament, gender, nationalism, or other sources of disorder - for a world outside human space and time" (p. 162). What is here significant is how this understanding of science has appeared to make its way in the promotion of the FCC. As I have shown, it is mobilised in multiple different ways, reinforcing an image of the FCC as a global collaboration.

7. Discussion

In my thesis, I have considered the FCC's epistemic uncertainty, the projects ambivalent place between Europeanisation and globalisation, and how these concerns are played out in PR videos. But so far, I have treated these different aspects of the FCC separately. In this final chapter, I bring into conversation the insights of the previous chapters, synthesise some of my key results, connect these to a broader academic conversation, and make an argument about the role of narratives in the justification of the FCC. In the following I will recapitulate how CERN (narratively) justifies the construction of a new particle accelerator, how the laboratory acquires legitimacy in contemporary Europe, and how this played out in an increasingly medialized environment. Specifically, I make explicit how the FCC's PR materials construct narratives to manage the project's multiple uncertainties, transforming these into desirable futures of both scientific and societal benefits.

7.1. Uncertainties

Uncertainty is a major actor in the discussion around the FCC. Even though the FCC is subject to meticulous planning within a series of feasibility study, uncertainty is still a central part of the project. While further studies will certainly give details into the technical feasibility of the project, some questions will likely remain uncertain until the machine is constructed. One simply cannot know what the future will bring. As I have demonstrated throughout my thesis, we should thus understand the FCC as a site of multiple uncertainties. From my analysis of PR documents, I can identify three major uncertainties that were addressed across all the materials: epistemic uncertainty, socioeconomic uncertainty, and infrastructural uncertainty. These uncertainties don't just exist but they are actively shaped, constructed, and strategically mobilized in the discourses around the FCC.

First, I have described epistemic uncertainty (Chapter 2 & 4) relating to the fact that scientists don't know if the FCC will produce interesting new insights. Critics of the FCC's epistemic vision speak of a crisis in High Energy Physics (Hossenfelder, 2019). After the discovery of the Higgs, no new particles and no physics beyond the standard model have been discovered. Insights about dark matter, supersymmetry, or possible new particles remain speculations. In contrast to earlier colliders, there is no longer a clear theoretical prediction for revolutionary new insights at the FCC's energy range, which means the new science is entirely driven by experiments.

The second uncertainty is what I identify as socioeconomic uncertainty (Chapter 1, 3 & 4). For a long time, HEP stood outside of the requirements of cost-benefit analysis (Traweek, 1988). In this view, basic research stands apart from societal demands. Epistemic insights are justification enough, its technological innovation assumed to eventually trickle down and bring benefits to society (Krige, 1996). But in the last decades, an increased demand has emerged on science to not only return epistemic insights, but also technological innovations that will benefit both the economy and society (Felt & Wynne et al., 2007, Hallonsten, 2016). CERN is not separate from society but inextricably intertwined with it. As I have shown, this is reflected the European Commission's active interest in the realisation of the FCC, emphasising its underlying goal to foster innovation and economic growth. But, and this is the big uncertainty, it is unclear what socioeconomic benefits the FCC will bring. The potential technological innovations the FCC will create and the impact these have on society simply cannot be known. The FCC's future value is inherently uncertain because it is impossible to predict the societal and economic effect the collider might have.

Finally, I recognize what I call infrastructural uncertainty (Chapter 3 & 4). Scaling up CERN leads to questions about its organizational and funding model. The increased cost of the FCC would require increased support from non-European states. The FCC study thus makes explicit that the next generation circular collider would need to be a global collaboration. As I have shown, CERN is currently in a position between internationalization and Europeanization. While needing to grow to get support, funding, and expertise, it simultaneously tries to position itself as a European institution. This tension produces uncertainties, opening questions about whether the FCC will be too big to be European or whether it is possible to retain a European essence while opening up to the world. It also raises concerns on how the FCC should be organized and funded, what countries should be involved in the project, and to what extent these should partake in the governance of CERN.

These uncertainties are by no means conclusive. There are many other open questions and challenges around the project. One of the most important ones revolves around the FCC's sustainability, which is likely to play a much bigger role in future discussions around the collider. The absence of such other uncertainties in my analysis does not mean that these are not important or talked about. Rather, it indicates that these issues found no or only little space in the documents I have analysed.

7.2. Managerial narratives

In my thesis I paid attention to how CERN is using PR documents to demonstrate the worth of the FCC and justify its construction. Doing so, I have given insights into the many ways narratives are utilised to coordinate the uncertainties and open questions around the FCC. Following Mol (2002), I showed how narratives take part in "coordination work". Narratives assemble, draw together, and relate various different entities into a coherent story. In the process, they coordinate, negotiate and manage the multiple uncertainties and inconsistencies around the collider. This alignment work is necessary to create cohesion: narratives are the glue that holds together the FCC, justifying its construction by turning it into a project full of future potential. Specifically, I claim that the project, is justified through what I call "managerial narratives", that is, narratives that work as tools to frame, manage, and overcome uncertainties. I have identified four such managerial narratives that work to justify the FCC, coordinate its uncertainties, and align the institution to changing social, political, and infrastructural contexts and current material and socioeconomic demands

Managerial narrative 1: Too big to fail

The PR documents present the FCC as a project that does multiple different things, with many synergies and complementarities. The FCC follows a versatile and broad approach, which means it can be both precise and reach high energies. From precision measurements studying the Higgs in detail, experiments in untried energy ranges probing for novel physics, the generation of insights for other epistemic fields like astrophysics or computer science, to also being complementary to societal and industrial needs: the FCC can do it all. I argue that this narrative presents the FCC as "too big to fail". Managing uncertainties through narratives means performing the collider as a project of such breadth and scale that it will inevitably bring benefits to science and beyond. The narrative in which the FCC is "too big to fail" is utilized as response to both the project's epistemic and its socioeconomic uncertainty. On the one hand, the FCC's "broad approach" is presented as having the most potential for discovery in a time of theoretical uncertainty. But the FCC's broad approach, its multiple complementarities, are not exclusively epistemic. On the other hand, the FCC's scale is thus also used to justify the collider despite the impossibility to predict its socioeconomic impact. The FAQ documents promise that the project will have synergies with industry, the EU's attempt to establish the European Research Area, the goal to educate the public about science, and goals to stay competitive in the knowledge economy. Because of the FCC's scale, versatility, and multiplicity, uncertainties are managed and overcome. Multiple concerns about the future are united, coordinated, and made coherent through an FCC multiple. It is precise (FCC-ee), reaches high energies (FCC-hh), brings benefits to society (economic growth and innovation) and makes Europe internationally competitive. In other words, the size of the FCC, (also its biggest critique, as this is what makes it so expensive) becomes an argument for its construction. The project is so big, it reaches in so many scientific, social, and political areas, no matter what, it will always be worth it. While a frequently asked question is: has Big Science become too big? I have shown that it is not only the size and costs of projects that have increased. Also, the futures from which they derive their justification are scaled up. Big Science is full of big expectations, having to promise much more than just epistemic insights.

Managerial narrative 2: Exploring the endless frontier

The second managerial narrative responds to questions about the FCC's future value by constructing a story about scientific exploration as having limitless potential for innovation. This narrative presents the FCC as a tool to explore and profit from the endless frontier of science. The frontier can be seen as the line between the explored and the unexplored, between the known and the unknown, in which the latter is continuously explored, exploited, and overcome through colonialization and expansion (Flink and Peter, 2018). But the frontier also has a utopian quality, in which the unknown becomes a projection for desires and wishes, for potential and endless profits, and as in the case of the FCC, for technoscientific innovation. In the justificatory narratives of the FCC, the literal frontier has thus become a powerful metaphor. The colonist is exchanged with the astronaut who is replaced by the particle physicist, all exploring and exploiting the unknown in the name of the promise of endless potential for the benefit of everyone. This narrative is representative of what Adam and Groves (2007, p. 88) term “frontier spirit”, which is about exploring, taming, and profiting from the unknown. The FCC seeks to colonise and conquer the future in the endless pursuit of epistemic progress and economic growth. As I have shown with my discussion of the Q&A documents, understanding the FCC as a form of exploration and science as an endless frontier makes the project unchallengeable. Even though it is impossible to know what will come there, moving further into the unknown has no end: something new can always be discovered. Following a similar narrative, the FCC’s PR videos use imagery of the vastness of space. Scientists compare particle physicists to figures like Christoph Columbus. By drawing parallels to colonial and space exploration they thus give a sense of the potential that comes with ventures into the unknown. Similar to Europe’s colonial frontier, science’s endless frontier holds not only new knowledge but also immense socioeconomic riches, in this case in the form of technological spill overs. Basic research and technological developments thus follow a similar pattern: they are the results of brave and bold steps into uncertainty, their greatest achievements unpredictable. Following Sarewitz (1996, p. 17), we can describe these narratives as perpetuating the “myth of infinite benefit” (more science will inevitably bring more benefits to society) and the “myth of unfettered research” (both scientific findings and its societal spillovers are unpredictable). These two myths work closely together and form a coalition in which the former suggests that the FCC will always lead to societal benefits and the latter implies that all basic research has the same capacity to lead to applications. Uncertainties are managed through frontier narratives implying that the construction of the FCC will always be worth it: there is endless potential for new and revolutionary epistemic and or technological innovation.

Managerial narrative 3: Colliding pasts and futures

The third managerial narrative I identified overcomes uncertainties by grounding the new collider both in a successful, fixed past and in an open future full of potential. In the analysed documents, the FCC is imagined as both a continuation of a (European) particle physics tradition and something entirely new, situated in a realm between continuity and novelty, between past achievements and future promises, and between mythical histories and disruptive possibilities. This posits the FCC as a continuation of a long tradition of excellent science and innovation, implying a linear trajectory towards future benefits.

On the one hand, the FCC is frequently portrayed as a continuation of CERN’s existing expertise and infrastructure; it is part of a decades long research tradition investigating the fundamental constituency of nature and is embedded in an institutional culture and value order. The PR documents emphasise the technical continuity between past accelerator projects and the FCC. They present the project as just another particle collider, part of a long history of experimentation at CERN. The FCC is based on decades of accumulated know-how, using a long tested and matured approach to do science. It will continue to do particle physics, an epistemic field that has already shown its worth numerous times. And as chapter 3 has shown, the Q&A documents also emphasise the collider's cultural continuity with an epistemic culture cherishing European enlightenment values like rationalism, democracy, and openness. As such, CERN is presented as having not only the material but also the "cultural" infrastructure to make a new collider project reality. Not only technology and expertise but also values are seen as necessary for a successful scientific project.

But the FCC is not simply a continuation of the past. Narratives are also future oriented, presenting the collider as something entirely novel. CERN's infrastructural upscaling is thus accompanied by an upscaling of the imagination. Drawing on imagery of complex machinery, the PR videos present the FCC as an engineering achievement like we have never seen before, another immense accomplishment of human ingenuity. Similarly, they promise that the project will bring new physics and insights into dark matter, supersymmetry, and the origins of the universe that have the potential to revolutionize humanity's understanding of itself and the world we live in. The FCC will bring progress in technologies like accelerators or superconductors, with the potential to have far reaching effects not only on science but also on society more broadly. It will make Europe competitive in the knowledge economy, create socioeconomic value, enable leadership in a global geopolitical race over science and technology, and simultaneously also bring a fractured world together in a peaceful and global collaboration. Science done on an entirely new scale is expected to foster a truly international collaboration between different nations, in which CERN is reorienting itself towards the world.

The narratives promoting the FCC traverse the old and the new, the material and the cultural, moving from mythical pasts to desirable futures. New stories emerge, old ones are transformed and adapted to today's problems and concerns. As such, the FCC is both grounded in the past and orientated towards the future. Novelty alone can be scary. Continuity alone can be unexciting, especially in today's hyper accelerated world. But taken together, the two make a good case for a new collider. The past is mobilized to show that future potential is actually there. The narrative links an open and uncertain future to a past of certainty. Once something is established as an achievement (e.g. the invention of the world wide web, the LHC, the discovery of the Higgs Boson, or CERN's capacity to unite Europe after the second world war), it can be utilized as a justification for future projects. Functioning as "invented traditions" (Hobsbawm & Ranger, 1983), past historical achievements are used, drawn on, or referred to in order to give urgency to the FCC. These „origin stories" selectively highlight some aspects and events while neglecting others, thereby reducing uncertainties and enacting linear stories (Law, 2004; Deuten and Rip, 2000). This creates a kind of historicist argument that implies continuous and linear progress from past to future technoscientific achievements (van Lente, 2000). The argument is that given CERN was so successful in the past, not only scientifically but also by fostering European integration, innovation, and international competitiveness, the FCC is expected to become a similar success story.

Managerial narrative 4: A European project for the world

The fourth managerial narrative coordinates CERN's European identity and its internationalisation by presenting the FCC as a European project for the world. Responding to uncertainties around CERN's globalisation, the narrative presents the FCC as a continuation of CERN's European origins and values: the collider will be a world laboratory in Europe and after a European model. It achieves this by constructing a specific relationship between scientific and European values which, embodied by CERN, is supposed to enable a truly global collaboration in particle physics. Scientific values (neutral, universal), closely aligning with CERN's European values (openness, democracy), are assumed to make possible an open and international project. In this story, only at CERN in Europe can universal and neutral science be practiced on a large scale, thus also resolving the question of whether the FCC should be constructed in Europe or elsewhere

Both the FAQ documents and the YouTube videos refer to intrinsic qualities of particle physics, variously imagined to be universal, placeless, or neutral, to frame and make sense of the FCC's extension beyond the boundaries of Europe. Particle physics, seen as placeless science that produces universal truths articulated in the universal language of science, knows no borders. The FCC, a project in which the whole world can participate, is thus presented as the logical consequence of a universal science that exists outside of culture and that transcends national differences. Furthermore, the FCC's global collaboration is in line with CERN's institutional identity as an organization that stands outside of politics: an impartial force that enables collaboration between different nations. As Strasser (2009) shows, in the early 20th century, science was still closely related to national militaristic and geopolitical goals (nuclear weapons, etc). The imaginary of CERN as neutral, only emerging because of Switzerland's insistence to keep the laboratory's goals purely scientific, has become naturalised and institutionalised. Neutrality, inscribed into the CERN convention, is reproduced in the institution's origin story (science uniting Europe after the war), spinoff projects such as SESAME (science uniting countries in the Middle East) and now also in the discussions around the FCC. Here, a global collaboration is presented as in line with CERN's vision to bring nations together under neutral science, moving from uniting Europe to uniting the world (Lalli, 2021). As such, the FCC, a truly international project, becomes a normative argument. As my analysis of the FCC week conference (2014) and the science knows no borders video (2019) has shown, CERN's next collider is presented as a step to fulfil the Enlightenment vision of a united world. By enabling neutral and universal science to be practiced on a scale never seen before, the FCC is framed as a cosmopolitan force that will bring stability and unity in an uncertain and nationalist world. CERN's internationalisation is thus not only a step towards better science but also a better world, making the FCC both a global collaboration for science and a scientific project for global collaboration. While CERN's origin story emphasises that science's neutrality was able to bring Europe together after the second world war, it is now CERN's European values that are assumed to make open and global scientific collaboration possible**.** This narrative feeds on a peculiar association between CERN's values and "European" values, which becomes explicit in discussions about alternative locations for a future collider. For instance, the FAQ documents claim that the FCC should be constructed in Europe because of shared ideals like freedom and democracy. This implies that if China would construct the next collider, presented as Europe's main competitor, the project would lose its (universal, neutral, and open) qualities, which are understood to make good scientific practice and international collaboration possible. There thus appears to be a tension between the ideal of science and how it is then actually practiced: China's values are assumed to misalign with the values of science. In contrast, Europe's enlightenment values (universalism, liberal democracy, participation, openness, and transparency) are all compatible with scientific values. As such, the narrative claims that only in Europe can the scientific value of universalism and neutrality fully flourish to make possible an open and global collaboration. Thus, only at CERN can and should an international project like the FCC be realised.

7.3. Accelerating Futures

As we can see, the sociotechnical uncertainties around the FCC are managed through narratives: they are essential tools to justify and enact the (future) worth of the project. These managerial narratives are powerful because they transform uncertainties into open futures and in the process align scientific with social, political, and economic concerns. The PR documents present uncertain futures as potential whose exploration is promised to accelerate both scientific and societal progress. As indicated by the title of the thesis, we can thus speak of "accelerating futures" that drive and are driven by the FCC.

In the FCC's PR documents uncertain futures become a resource that is (narratively) managed and mobilized to accelerate the construction of the FCC. As Adam and Groves (2007, p. 79) remind us, "future potential is the impetus that moves us to innovate and invent, control and colonise, transform and traverse". In my case, uncertainties, whether epistemic, socioeconomic, or infrastructural, become presented as potential that drives innovation. Uncertainties are transformed into promises: the promise of new science, technological innovations, European competitiveness, and a truly global collaboration at CERN. The narratives are thus constructing a future of endless possibility from which can be extracted immense value. Not knowing what comes next means anything can come. We only need to act courageously to reap its benefits. McGoey (2012) speaks of "strategic unknowns" as a challenge to the idea that power thrives only on information. From this perspective, ignorance and non-knowledge are often actively produced, cultivated, and exploited as a resource and a strategy. In a related way, in the discussions around the FCC, the inherent uncertainty of the future, also a form of non-knowledge, serves as a generative force. Uncertainty enables the construction of an economy of technoscientific promises that drives the justification of the FCC (Joly, 2010). It is unclear what phenomena the project might find and what technological innovations it will bring. But in CERN's narratives, something is sure to emerge, if only we try. Even though it is impossible to know for certain what value the machine will create, at some point in the future it is sure to produce some benefits. Without risk, there is no reward. Or in this case, without the FCC, we will never know what revolutionary science we might have discovered, what technologies we might have invented, and how a conflicted world might have been united through a global collaboration. I would even speculate that, if there were concrete goals (theoretical predictions/technological innovations) driving the construction of the FCC, the justification of the project would look very different. While uncertainties open up potential, certainties narrow the discussion towards cost and benefit analysis of a specific vision. If there are no certainties, anything and everything can be (imagined to be) possible.

But the managerial narratives deployed by the FCC not only turn uncertainty into future potential, they also coordinate epistemic with social, political and economic concerns. They acquire their force by fluidly traversing natural and social order, aligning the FCC with other sociotechnical questions. In the process CERN's new collider is posited as the solution to problems that go beyond the immediate concerns of the project's construction, enrolling actors outside of the physics community. In other words, my thesis has shown how the FCC is a site at which particle physics and "society" are co-produced (Jasanoff, 2004). For instance, in the collider diaries young particle physicists speak about their curiosity of the world, which aligns the FCC's epistemic uncertainty with a story about humanity's relentless drive to explore the "secrets of the universe". In this narrative, the exploration of the unknown, not knowing what will come next, is a deeply human endeavour. Here, fundamental research has an inherent value: to satisfy humanity's thirst for knowledge. In a similar manner, the Q&A documents align the FCC's socioeconomic uncertainty with a story about basic research as the driver of technological innovation. As scholars like Cramer et al., (2020) have argued, (European) society is increasingly asking for a return for its investments in scientific endeavours. And in CERN's story, the FCC will be able to achieve exactly this: it will bring innovation, socioeconomic benefits, and competitiveness in the knowledge economy, able to extract immense value from an uncertain/open future. This becomes even more explicit through the alignment of the FCC's language with the language of the European Commission, who now share many common goals like the fostering of socioeconomic value through research infrastructures. It is also visible in the FCC's alignment to a story about Europe's international competition with China, in which the collider becomes an actor in the race over leadership in science and technology. This creates a sense of urgency to begin the construction of CERN's next collider soon. If Europe does not act now, it will lose its leading position in particle physics and fall behind in the global quest towards technoscientfic innovation. Finally, the FCC's infrastructural uncertainty is aligned to a story about global collaboration as a normative ideal. Funding and organizing the collider in a way that includes actors beyond the boundaries of Europe is not a problem. As Rolf Heuer (2019) emphasises in his interview on the FCC, international collaboration should be actively pursued. In our fragmented world, global collaboration will not only produce good science but will also bring together nations in a peaceful collaboration beyond cultural and political differences.

Following Boltanski and Thévenot (2006), my analysis revealed how the FCC is justified within different "orders of worth" (e.g. an epistemic, socioeconomic, and geopolitical order). This was even reflected in the composition of the materials I have looked at. For instance, the Q&A documents, going through the different questions around the project, seamlessly transition between scientific and social issues. We can thus witness how the FCC is demonstrating its epistemic value to produce new science, its cultural value to revolutionize humanity's understanding of the universe they inhabit, its socioeconomic value to create innovations, expertise, and technologies for industry and society, and its geopolitical value to secure Europe's leadership and competitiveness for the future to come. But the FCC's narratives do more than simply justify the project within a distinct order of worth. Specifically, narratives connect, bridge between, and make commensurable the natural and social order. Epistemic and societal concerns become indistinguishable, coming together in the question over CERN's next collider. The uncertainties around the FCC's future worth are thus coordinated, justified and managed through narratives that fluidly traverse between a multiplicity of orders of worth. Narratives legitimise the FCC by turning uncertainties into open futures and by aligning disparate social and technoscientific questions with each other, presenting the collider as the answer to both.

7.4. Infrastructuring justifications

The FCC's justificatory narratives are always both stable and fluid, drawing together entities and stories into complex assemblages or "narrative infrastructures" (Felt, 2014). Branching out from Q&A documents and PR videos to other sites like the European Commission or the CERN Convention showed how these narratives traverse time and space, always materializing with slight altercations. The narratives' mutability but also standardization and solidification make them suitable repertoires to legitimize the FCC. Similarly, to material infrastructures, these narratives become firmly established and taken for granted, "managing" and justifying novel technoscientific developments like the FCC. Understanding managerial narratives as infrastructures draws attention to the fact that they do not spontaneously emerge together with the new collider. Instead, I have shown that they have histories; their origins and travel can be traced across different contexts. The narratives I have looked at can be followed both across sites (the European Commission, conferences, feasibility studies, or popular science magazines) and across time (back to the foundation of CERN). Stories do not stay the same. Moving between sites, they get transformed and adapted, assembling other actors, and coordinating novel uncertainties. Narratives are thus an important force to bring "society" into the discussion around the FCC. For instance, the FCC is interwoven with institutions like the EU, forming novel (narrative) connections in unexpected ways. Some of the notions circulating around the FCC (e.g. open science, open innovation, and open to the world) are taken directly out of the European Commission's agenda. Some visions of science and CERN, like the ideal of a peaceful collaboration to bring together nations, have become firmly institutionalized, bringing stories from CERN's founding moment (convention) into the present and future. Beyond the scope of Europe, the FCC is also drawing on grand narratives that drive western society. Endless progress through science, technology and innovation are central myths around the next collider. Parallels with space flight and colonial exploration evoke images of individuals doing great deeds for the whole of humankind.

Managerial narratives gain legitimacy by drawing on and contributing to existing narrative infrastructures. Their continuous repetition turns them into a stable argumentative repertoire to overcome uncertainties and justify the construction of the FCC, guiding how science can and should be justified in today's Europe. This means that managerial narratives can gain a certain trajectory, making them difficult to change and even more difficult to challenge. Any critique of the FCC would also need to contest the established and widely shared narratives that from the firm sediment on which the projects justification rests. Managerial narratives are thus not dissimilar to what Bos et al. (2014) call "big words". They are "big stories": unchallengeable, inherently positive, and applicable in a variety of contexts through slight altercation. Both stable and fluid, the narratives I have described are the motor that drives the economy of promises around the FCC, giving the project both plausibility and credibility.

8. Conclusion

CERN is a mythical place, producing fantastic cosmologies that connect matter on the smallest possible scales with stories about the origins of the universe. The stories told by particle physicists have long fascinated philosophers, anthropologists, and the public. In many ways, my own study of CERN has also engaged with the mythical narratives surrounding the work of particle physics. Analysing FAQ documents and YouTube videos on CERN's proposal to construct the FCC has led me on a journey from the origins of the universe microseconds after the Big Bang to visions of potentially lifesaving innovations in medical equipment and a global geopolitical competition over the location of the next collider. My thesis has shown that legitimizing a new High Energy Physics project requires narratives that go beyond the study of particles and the uncovering of fundamental truths about the world. To the language of cosmology has been added the language of economic growth, international competitiveness, and technological innovation. These stories are not less mythical, fluidly bridging between nature, technology, society, and Europe. As we could see, CERN does no longer position itself as separate from society. With the FCC, the laboratory is narratively reinventing itself to accommodate the challenges Europe faces in the present. Science's mission to venture into the unknown, to be open to surprise, has to become coordinated with the necessity of making the project worthwhile to society. In the process, the value of fundamental science and CERN's place in Europe is renegotiated. My thesis thereby contributes to ongoing debates in STS on the co-production of science and Europe (Cramer, 2020; Mobach & Felt, 2022), the place of Big Science in society (Lalli, 2021; Krige, 2003), and the role of narratives, promises, and futures in the making and justification of novel technoscience (Felt, 2015; Adam & Groves, 2007; Borup, et al., 2006). To conclude, I want to present some key takeaways from my thesis.

Using a co-productive lens to understand the justification of the FCC has given insights into the multiple ways in which technoscientific and sociopolitical orders are shaping each other, contributing to discussions on the role of research infrastructures in processes of European integration and international collaboration (Cramer et al., 2020). My analysis has revealed how the FCC is narratively negotiating its place between Europeanisation and internationalization, which reflects a tension between CERN's European history and culture and a demand to open up to the world.

On the one hand, my research has shown how the FCC is presented as a global project. Discussions on the FCC emphasize that the project can no longer be funded by its current member states alone and consequently needs to integrate actors from beyond the boundaries of Europe. With the FCC, CERN is thus resituating itself as a laboratory for the world that will facilitate a truly global collaboration. As shown in Chapters 3 and 4, globality takes on multiple forms. Globality becomes a requirement for the FCC, something intrinsic to science, and a normative ideal. Narratives thus bring together references to CERN's historical capacity to unite Europe in an international collaboration, the FCC's necessary globalization, and particle physics' placeless, neutral and universal nature to make sense of the new accelerator project. In this vision, the FCC becomes presented as a global collaboration that goes beyond cultural differences, transcends national boundaries, and thus realizes the cosmopolitan ideal of a united world.

On the other hand, I have shown how Europe has a central role in the justification of the FCC. I have given insights into how Europe takes on multiple shapes and forms, variously becoming a place, a culture, or a geopolitical actor. The debate surrounding the next collider thus reveals itself as being not only about the future of CERN but also about the future of Europe more generally. CERN and Europe are always co-developing, sharing a long history and (possibly also) future. With my analysis, I thus made explicit how the discussion of the FCC can only be understood by considering macro-social developments in Europe and the world. Global geopolitical processes, international competition in the knowledge economy, and Europe's science policies are all factors that influence the discussion of the FCC. For instance, I have shown how the European Commission has become central to financing the FCC's feasibility studies, making the project subject to its agenda to create the European Research Area and foster integration through science and technology. I have also shown how Europe becomes an important category when it is about the location of the next collider. The PR documents present China's proposed accelerator project as a direct competition to Europe's FCC. In this story, the FCC becomes an essential project to secure Europe's leading role in the knowledge economy by making it a key player in science and innovation in a competitive world. This makes explicit how science is not neutral but inherently political.

My analysis of the FCC has further contributed to an understanding of the role of narratives in the justification of emerging technoscientific projects. Specifically, I have shown how CERN is justifying the FCC by constructing sophisticated narratives that create, embrace, transform, and manage uncertainties to redefine them as open futures full of potential for innovation. As shown in my discussion, these "managerial narratives" present the FCC as too big to fail, as a way to explore the endless frontier of science, as situated between past achievements and future possibilities, and as a European project for the world. These narratives transform concerns over the FCC's epistemic uncertainty and lack of theoretical predictions into potential for new physics. Uncertainties over the FCC's socioeconomic worth become endless possibility for technological innovation and societal spillovers. Similarly, infrastructural uncertainties on how to organize and fund the FCC are turned into promises for a truly global collaboration that will bring together a conflicted world. In other words, even though an inherently uncertain project, justificatory narratives present the FCC as delivering on multiple innovation promises with benefits for both science and society. Narratives demonstrate the FCC's future worth by presenting the basic research project as accelerating us towards epistemic novelty, socioeconomic benefits, a competitive Europe, and a peaceful global collaboration.

Analysing these narratives has given insights into the work that goes into justifying the FCC. The narratives draw together heterogenous elements into a narrative infrastructure. These justificatory assemblages form a stable repertoire that enrols a diverse set of actors by bridging between scientific and societal concerns. From CERN's origin myth (bringing together Europe after the second world war) to stories about basic research as endless resource for socioeconomic value, established and shared narratives are utilised to align the FCC to current sociopoltical concerns and to demonstrate its continuous relevance in today's world. The FCC, presented as both an epistemic and a sociopoltical project, has become inseparable from global geopolitics, foreign policy goals, and processes of European integration. By studying justificatory narratives, I have thus brought "society" back into the discussion of the FCC, making explicit the assumptions values, norms, and futures driving the project.

Interestingly, the promises around the FCC, whether epistemic or socioeconomic, all tap into an imaginary of linear and limitless growth. Any concerns about the FCC's uncertain worth are "managed" through stories about endless future potential yet to be realized. As a consequence, any reflections about possible alternative pathways into the future are sidelined from the beginning. Unchallengeable narratives about continuous progress make the case for the next collider and justify continuing like before. Scaling up CERN promises to enable further exploration and exploitation of the unknown for the benefit of both science and society. In the narratives around the FCC, the idea of expansion has become naturalized, seen as necessary for endless improvement and wellbeing. As such, CERN's path towards ever bigger accelerator machines appears to be inevitable, depoliticising the question about the laboratory's future. But this imaginary of scaling, so explicit in the narratives driving the construction of the FCC, is also a form of "future taking" that leaves no room for alternative visions. Barbara Adam and Chris Groves (2007) argue that "when we traverse time and colonize the 'not yet' (….) the future is eliminated and transformed into an ever-expanding present" (p. 104). In a similar manner, the narratives I studied portray a single future for a scaled-up CERN: the only way forward is through another even bigger accelerator. In these narratives, the future is moved into the present, making it difficult to act responsibly as there is less time for reflection. The decision on the FCC is presented as urgent; actions need to be taken now to save time and money. While the decision to construct the FCC will have implications long into the future, timeframes for thinking about alternatives are shortened.

CERN has started to increasingly identify itself through its big accelerators. But maybe, there are also other ways forward. Absent in the PR documents are the views and perspectives of scientists currently working at CERN. There exist alternative visions of scaling, emphasizing diversification instead of expansion. Instead of "more of the same", some voices argue for a broadening of methods and experiments, either as an alternative to the FCC or to bridge the time until technological and theoretical innovations make its construction more targeted. What kind of place could CERN become if it would decide against the FCC? Are there other ways of doing science that can also benefit from CERN's unique and international research environment? CERN's next project is not yet fixed, there are still ongoing deliberations about the laboratory's future. However, such alternative visions for CERN, these could be about a diversified infrastructure or something else entirely, are all rendered invisible in the PR documents. I thus would like to conclude this thesis with a call to reflect on what futures are enabled by the FCC and what alternatives are made invisible. Perhaps, instead of referring to trajectorial narratives of inevitability, limitless growth, and expansion, we should slow down and try to open up spaces to think about alternative futures. This might enable us to talk about uncertainties in a new way. Instead of endless potential, we might see them as what they really are: uncertain futures. Instead of silencing or "managing" uncertainties, this would make it possible to proactively discuss and shape them. Accepting uncertainties as uncertain futures would also place the conversation about the FCC in a new light. Acknowledging that it is simply impossible to know whether the FCC will bring any specific scientific or social benefits, that inherent in science lies the immanent possibility for failure, debate on whether the machine should be constructed could take place on different, more transparent and perhaps also inclusive terms.

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