

Briefing 49 CERN's "Future Circular Collider" (FCC) Project

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Artistic representation of the Future Circular Collider tunnel
(credits: CERN)

Summary

- CERN is a European scientific organisation at the forefront of global research into high-energy physics. It is planning to build the world's largest particle collider, the FCC, on French and Swiss territory.
- CERN has carried out a feasibility study on the project's scientific relevance, technical characteristics and the impact of its construction.
- The aim of the FCC would be to carry out more exploratory fundamental research than is currently possible with existing facilities.
- The local and environmental issues involved calls for a deeper public debate.

Dominique Voynet, Member of the National Assembly

Anne-Catherine Loisiert, Senator

CERN¹ is an international organisation founded in 1954 with the aim of reviving European fundamental research in particle physics through a common project, following the interruption caused by World War II. The ideal of international scientific cooperation was one of its founding principles, which continues to this day.

CERN contributes to the advancement of theoretical research in particle physics and goes with it by building accelerators² and synchrotrons,³ instruments that can reach the very high energies needed to study the elementary constituents of matter.⁴ The LHC⁵ is currently the biggest particle collider in the world and CERN's flagship instrument, particularly since the discovery of the Higgs boson in 2012. The "Future Circular Collider" (FCC) project is part of this dynamic combining theory and experimentation, with the aim of taking over from the LHC in the 2040s and keeping Europe at the forefront of high-energy physics.

■ The FCC, the next flagship instrument in high-energy physics?

➤ The Standard Model of particle physics

Particle physics is the science that studies the **fundamental constituents of matter**. Discoveries from this field have made their mark on the 20th century and its pioneers have often been awarded the Nobel Prize. Particle physics enjoys particular prestige within the modern physical sciences, due to its theoretical complexity, the large instruments required and the scale of the international collaborations involved.

Research carried out in the 20th century led to the development of a general theoretical model, known as the **Standard Model of particle physics**. Formalised in the mid-1970s, it lists and categorises all the fundamental constituents of ordinary matter⁶ and describes their interactions.

In the Standard Model, the elementary particles at the origin of matter are electrons and quarks.⁷ Protons and neutrons are assemblies of quarks.⁸ They also join together to form the nucleus of atoms: the number of protons in the nucleus determines the chemical element; several versions of an element may exist, called isotopes, with different numbers of neutrons in the nucleus.

The Standard Model explains the interactions⁹ between these particles through the exchange of another type of particle, the bosons.¹⁰ One of them occupies a unique position in the model: **the Higgs boson**. This is what gives elementary particles their mass, through interaction with the Higgs field.¹¹

In the early 21st century, the Higgs boson was the last particle in the Standard Model whose existence had not been confirmed experimentally. In 2012, it was detected in the LHC, marking a major event: the completion of the Standard Model and the validation of the theoretical framework behind it.

➤ Particle accelerators

The accelerator is the flagship instrument of particle physics. It involves transmitting very high energies to beams of charged particles (protons or electrons), causing them to reach speeds close to the speed of

light.¹² This is achieved using electromagnetic fields¹³ to guide and accelerate the beams, successive packets of several million particles each, through a tunnel. At the observation points, they collide and the particles disintegrate, producing new particles. Since billions of collisions are needed to obtain significant results, accelerators produce very large quantities of data.¹⁴

The higher the energy of impact, the greater the mass of the particles produced. Accelerators make it possible to observe certain unstable particles that would otherwise be inaccessible.¹⁵

Particle accelerators¹⁶ are either circular, like the LHC and FCC, or linear, like the XFEL¹⁷ in Germany. Both types of accelerator coexist at CERN, where some small linear accelerators, such as Linac4, help produce the beams for the LHC.

The advantage of a circular accelerator over a linear one is that the same beam can interact millions of times, as it passes through the same experimental point each time it comes around. In a linear accelerator, on the other hand, the beam only travels in one direction and hits a single target at the end of the tunnel. Packets of particles must therefore be produced continuously to feed the accelerator. The disadvantage of a circular accelerator is that the particles lose energy as they travel,¹⁸ and this effect is greater the lower their mass: electrons are therefore affected more than protons. In practice, this limits the maximum energy reached. Since energy loss decreases as the radius of the ring increases, one solution to this is to increase the size of particle accelerators.

➤ Opening up a new experimental field?

Since the Standard Model was validated in its entirety, particle physics has entered a pivotal moment. Throughout its history, theoretical hypotheses have often preceded experimental confirmation by particle accelerators, sometimes by several decades. Fifty years passed between the postulation of the Higgs boson and its discovery. But today, the main theory of this field is complete, and there is no consensus on an exploratory model. Researchers must therefore rely on observations to guide their work.

The discovery of the Higgs boson in the LHC can therefore be seen not as the end of the story, but rather the beginning of a new science centred around the study of its characteristics, which are still poorly understood.¹⁹

The relatively small number of Higgs bosons created by the LHC makes it impossible to carry out precise analysis. This is why physicists are hoping to build a “Higgs factory”, which would allow for a much greater number of observations by increasing the energy of collisions. Its purpose would be not to validate the existence of a particle predicted by theory, like the LHC, but to study the precise characteristics of the Higgs boson and identify any discrepancies between the model and the results. Using higher energies than in the LHC would also open

up the possibility of discovering unknown particles. This remains highly conjectural.

Scientists are finding it difficult to convince non-specialists of the value of an in-depth study of the Higgs boson, not least because it is highly fundamental. Research in particle physics is then often promoted as being able to help answer the big questions of modern physics, which still resist the explanatory power of the Standard Model.

These enigmas lie at the intersection of cosmology and particle physics. Under the framework of current cosmological knowledge, observable matter in the Universe represents only 5% of the amount needed to explain its structure and behaviour. The missing portion is “dark matter”,²⁰ whose nature remains unknown, representing one of the major questions in modern-day physics. Similarly, we still do not know how to explain the preponderance of matter over antimatter,²¹ as the Big Bang should have produced similar quantities of both types.

It is conceivable that further experiments in particle physics will shed light on these very open questions. However, it is difficult to assess today what such exploratory work could contribute to our understanding of the fundamental laws of physics.

➤ The Future Circular Collider project

Particle physicists expressed their interest in a “Higgs factory” project in the “European Strategy for Particle Physics”,²² published in 2014. It asked CERN to outline a possible project for an instrument of this type. The Strategy that followed, published in 2020, made this a priority and tasked CERN with studying the project’s feasibility. The conclusions of the study were delivered in March 2025,²³ giving substance to the “**Future Circular Collider**” (FCC). The next European Strategy, scheduled for January 2026, is expected to validate the scientific importance of the project. A final decision will then be made in 2028.

The Feasibility Study recommends that the FCC accelerate particles to energies much higher than those reached in the LHC. It would therefore be capable of producing billions of Higgs bosons.²⁴

The plan for the FCC involves two successive phases. The first, FCC-ee, would be devoted to electron-positron collisions. This precision phase²⁵ will last around 15 years and serve to measure the characteristics of the Higgs boson. The instruments would then be in large part renewed; the tunnel having been designed from the outset with this in mind. The second half of the century will be devoted to proton-antiproton collisions. The purpose of this higher-energy phase, FCC-hh,²⁶ would be exploratory: by producing more heavy particles, it increases the chances of detecting rare events.²⁷

➤ Other particle accelerator projects around the world

In previous years, other particle accelerator projects have been contemplated in the rest of the world.²⁸ Since then, development of the ILC, a Japanese linear accelerator, seems to have come to a standstill. In any case, it would not perform as well on the precision criteria demanded for the FCC. The CLIC, CERN's linear accelerator project, has been relegated to second place behind the FCC, which is now one of the only projects that meets the expected level of scientific ambition.

On the other hand, a Chinese project for a circular accelerator similar to the FCC, the CEPC, is still underway and causing concern as a serious competitor.²⁹ However, China does not have the extensive expertise of CERN. Nor does it defend the principles of open science and international cooperation that characterise CERN and, just as much as its infrastructure, have enabled it to bring together the thousands of researchers who contribute to its influence and discoveries.

■ A project at the appraisal stage

➤ CERN, project owner

CERN brings together 25 Member States,³⁰ most of which are European. It is placed under the authority of the CERN Council, where each country is represented.³¹ **The Council will be the decision-making body for the FCC project in 2028**, by a qualified majority vote.³²

The FCC would certainly be one of the greatest technological, scientific and engineering challenges of the 21st century. It will take around ten years to build, at an estimated cost of 15 billion Swiss francs for the first phase (FCC-ee). This cost covers the construction of the tunnel and the entire accelerator infrastructure. Experiments would then be financed by international collaborations between research institutes, as for the LHC.³³

CERN has an annual budget of around 1.4 billion Swiss francs, financed by contributions from the Member States in proportion to their GDP. If approved, the FCC will require an increase in contributions, but the impact should be limited to around 10%. At this stage, some major contributors are showing reluctance, but no position has been taken yet.

Part of the amount (around 4 billion Swiss francs out of the 15 billion required) could be requested from the Observer States, including Japan and the United States, in return for the use of the facilities. CERN's operating principle is to provide the service, the tunnel and the collider, leaving funding and management of the experiments to international cooperation. The United States is one of the biggest contributors to the measurement instruments.³⁴ Another option would be to increase the European Union's contribution.³⁵ The participation of private sponsors is also being considered,³⁶ but their share of the FCC budget would probably remain very small.

The project's means of funding could have repercussions on its governance. If the Observer States were to increase their contribution, they could claim a greater role in the decision-making process. However, the French Ministry of Foreign Affairs defends CERN's European vocation and will be attentive to maintaining its centre of gravity in Europe.

➤ France, host country and committed partner

Along with Switzerland, France is one of CERN's two host countries, and as such has a particular interest in the project. CERN claims to provide France with a positive direct³⁷ and indirect economic return. The laboratory is an important factor in France's and Europe's scientific attractiveness, but it comes at a cost: the contribution to CERN is France's largest item of expenditure for Very Large Research Infrastructures (VLRIs), with a budget of €165.6 million.³⁸ Financing the FCC would place major constraints on France, both in absolute terms and in terms of balance with other VLRIs.

An interministerial committee led by the DGRI³⁹ will monitor the Feasibility Study and examine the project. The prefecture of the Auvergne-Rhône-Alpes region, which is a member of this committee, is coordinating the territorial aspect.⁴⁰

France's position on the FCC has not yet been determined. It will be based on the project's scientific and financial relevance in particular. The scale of its environmental impact will be another determining factor.

➤ Preparing the public debate

The FCC project will be the subject of public debate in France, in accordance with the procedure applicable to any project with an impact on the environment.⁴¹ The debate will take place at local and national level and be coordinated by the National Commission for Public Debate (CNDP), which has carried out an advisory mission for CERN in preparation for the referral. This concluded with recommendations aimed at ensuring the quality of the debate.⁴² The CNDP's guarantors recommend organising the public debate as quickly as possible, before the project moves too far ahead. It has since been decided that the debate will open in 2026, to allow sufficient time before the 2028 deadline. Another important recommendation highlights *"the need to keep the debate open around the appropriateness of the project"*,⁴³ to allow for genuine public participation.

This is all the more important as information on the future project has already started to be communicated via various channels, in parallel with the Feasibility Study. On this note, the CNDP notes that the idea of a project that is already "a done deal" is widespread among the general public and certain local elected representatives.

■ Local and environmental issues

The FCC tunnel would have a circumference of 90.6 km, three times that of the LHC.⁴⁴ Excavated to an average depth of 240 m,⁴⁵ it would cover Ain, Haute-Savoie and

Switzerland,⁴⁶ with a section under Lake Geneva. Beyond the issues of fundamental research and global scientific competition, the FCC is above all a major infrastructure project.

➤ A project anchored in its region

CERN is a major local player alongside other important international organisations based in Geneva, contributing to the region's economic prosperity through its influence and attractiveness. In an international context that is weakening the position of most of Geneva's institutions, the FCC would guarantee CERN's future for several decades.

The CNDP's advisory mission highlights this unique local context. It also notes that, while Ain residents are used to the presence of the LHC and see CERN as a source of dynamism, this is not the case in Haute-Savoie, which currently has few connections with CERN. The CNDP also points out that there are a number of constraints that are cause for concern. In particular, the construction work and potential creation of new jobs could exacerbate the pressure on transport and infrastructure in a region that is already saturated.⁴⁷ This is a major concern expressed by local elected representatives. They are also concerned about the distribution of efforts and economic benefits in a context marked by strong demographic and economic pressure, linked to the proximity of Switzerland.

As the accelerator is mainly underground, its surface footprint is relatively small. Efforts have been made to reduce it from the initial plan. The project features eight sites,⁴⁸ requiring approximately 40 ha.⁴⁹ Avoiding agricultural land and proximity to transport networks were priority criteria in choosing their locations. CERN estimates that less than 3 km of new roads would be needed to connect the site to the road network.⁵⁰

One of the most sensitive issues relates to excavated material. CERN estimates that 16.4 million tonnes of molasse will need to be excavated.⁵¹ In comparison, 37 million tonnes will be extracted for the Lyon-Turin railway tunnel, located in the same region. The means of storing this excavated material will be an important factor in the project's local acceptability.

➤ Environmental issues at the heart of the debate

The project's environmental impact has already begun to be debated, with local associations⁵² and national newspapers⁵³ challenging the plans. One of the main points of concern is electricity consumption. The FCC would require between 1.1 and 1.8 TWh per year, which is roughly equivalent to the consumption of a city with a population of 200,000.⁵⁴ CERN has stated that it intends to use low-carbon electricity to power the accelerator, and to optimise the recovery of waste heat. Two new connections to the French 400kV grid, managed by RTE, will be required.⁵⁵

At a more local level, the impact on water resources is also a cause for concern. Most of the tunnel would pass

through molasse and avoid groundwater, but one of its sections would be located in a karstic area, where it could affect the circulation of groundwater. In addition, requirements for cooling water are estimated at 1 million m³ per year for the first few years of the experiments, rising to a maximum of 3 million m³ per year.

■ Conclusion

CERN was somewhat late in launching the public information process. Despite the communication efforts currently underway,⁵⁶ it may have given the impression that it had not fully grasped the societal expectations surrounding the project. The scientific foundations of the project require further explanation, important technical questions remain unanswered, the consequences for water resources should be clarified, the impact of climate change needs to be studied, and the integration of the planned infrastructure into the region is a matter of local concern. The success of the project will be determined by its acceptability. More comprehensive information needs to be provided to all local stakeholders.

The public authorities will be called upon to define France's position on the benefits of committing to the FCC project. However, in the field of high-energy physics, expertise is highly concentrated among the very players who may have an interest in the project's success. While it may not be completely justified to say that there is a "monopoly on expertise", the situation does put the authorities in a vulnerable position. OPECST therefore draws attention to the need for the administration to build up a pool of scientific and technical experts from a variety of backgrounds, capable of providing independent advice to political decision-makers.

OPECST websites:

<http://www.assemblee-nationale.fr/commissions/opepst-index.asp>

<http://www.senat.fr/opepst>

People consulted

People interviewed

- A delegation from the CO-CERNés collective:
 - Jean-Bernard Billeter, member of the Noé 21 association
 - Elisabeth Charmot, member of EELV Savoie and the Association for Consultation and Proposals on Planning and Transport (Acpat)
 - Félix Danlang, member of the Noé 21 association
 - Thierry Lemmel
- A delegation from the National Commission for Public Debate (CNDP)
 - Marc Papinutti, Chairman
 - Ilaria Casillo, Vice-Chairwoman
 - Brigitte Fargevieille and Jonas Frossard, guarantors for the Feasibility Study for CERN's Future Circular Collider project
- A delegation from the Ministry of Foreign Affairs and Europe
 - Frédéric Jung, Deputy Director for the United Nations, International Organisations, Human Rights and Francophonie (NUOI),
 - Valérie Brisset, Deputy Director for Cultural, Educational, University and Scientific Diplomacy
 - Jérémie Petit, Head of Economic Affairs and Global Issues, Sub-Directorate for Global Issues and Governance of International Organisations (NUOI/EG)
- In their capacity as institutional players
 - Karen Amram, Head of the Large Research Infrastructures Department at the Directorate-General for Research and Innovation (DGRI), and head of the interministerial committee on the CERN Future Circular Collider project
 - Michel Guidal, Chairman of the Very Large Research Infrastructure (VLRI) Committee at the CNRS
- In their capacity as academics
 - Laurent Vacavant, Deputy Scientific Director for Particle Physics at the National Institute of Nuclear Physics and Particle Physics (IN2P3) at the CNRS
 - Nathalie Besson, particle physicist at the CEA, Head of the Particle Physics Department at the Institute of Research into the Fundamental Laws of the Universe (IRFU)
- In his capacity as former rapporteur for the OPECST Science and Technology Briefing on Large Particle Accelerators
 - Cédric Villani, former Member of the National Assembly, former Chairman of the Parliamentary Office for Scientific and Technological Assessment
- In his capacity as an association member
 - Laurent Husson, Director of Research in Earth Sciences at the Institute of Earth Sciences (ISTerre) in Grenoble under the CNRS, member of Scientifiques en Rébellion

Visit of CERN on 10 April 2025

- Giovanni Anelli, Head of the Knowledge Transfer Group
- Raphaël Bello, Director of Finance and Human Resources
- Michael Benedikt, Head of the Feasibility Study for the Future Circular Collider (FCC)
- François Briard, Group Leader ad interim, Science Portal
- Mar Capeans, Head of the Site and Civil Engineering Department
- Pierre Cardon, Head of the Site Asset Management Group, Site and Civil Engineering Department
- Manuela Cirilli, Medical Applications Adviser, Technology Transfer Group
- Roberto Corsini, Technical Coordinator, CERN Linear Electron Accelerator for Research - CLEAR
- Benoît Delille, Head of the Occupational Health & Safety and Environmental Protection Unit
- Fabiola Gianotti, Managing Director
- Grégoire Guillot, Heat Recovery Systems at CERN, Site and Civil Engineering Department
- Susana Izquierdo, Magnets, Superconductors and Cryostats, Technology Department
- Mr Yann Léchevin, Feasibility Study for the Future Circular Collider (FCC)
- Philippe Magnano, Project Manager, construction of the Prévessin data centre, Site and Civil Engineering Department

- *Malika Meddahi, Deputy Director of Accelerators and Technology*
- *Emma Sanders, Head of the Exhibition Section*
- *Matteo Solfaroli, Head of the LHC Operations Section, Beams Department*
- *Charlotte Warakaulle, Director of International Relations*

Meeting with the Permanent Representation of France to the United Nations in Geneva and International Organisations in Switzerland, 11 April 2025

- *Claire Thuaudet, Chargée d'Affaires*
- *Louis Belmont, CERN Advisor*
- *Thibault Le Gonidec, Global Affairs Advisor*

Visit to local elected representatives in Ain and Haute-Savoie on 11 April 2025

- *At Ferney-Voltaire Town Hall*
 - *Daniel Raphoz, Mayor of Ferney-Voltaire*
- *The French Genevois Metropolitan Cluster*
 - *Christian Dupessey, President of the Cluster, Mayor of Annemasse*
 - *Vincent Scattolin, Vice-Chairman of Pays de Gex Agglo, Mayor of Divonne-les-Bains*
 - *Carole Vincent, Mayor of Neydens*
 - *Pierrick Ducimetièrre, Mayor of La Roche-sur-Foron*
 - *Florent Benoit, President of the Genevois Community of Municipalities, Mayor of Vulbens*
 - *Julien Bouchet, Vice-Chairman of the Genevois Community of Municipalities, First Deputy of Saint-Julien-en-Genevois*
 - *Sébastien Javogues, Chairman of the Arve et Salève Community of Municipalities*
 - *David Ratsimba, Mayor of Eteaux, President of the Pays Rochois Community of Municipalities, Haute-Savoie Departmental Councillor*
- *To the Pays de Cruseilles Community of Municipalities (CCPC)*
 - *Jérémie Courlet, Mayor of Minzier*
 - *Jean-Marc Bouchet, CCPC Councillor for the Ecological Transition and Mayor of Villy-le-Bouveret*
 - *Patrice Primault, Mayor of Cercier*
 - *Brigitte Nanche, Mayor of Allonzier-la-Caille*

References

¹ CERN, often referred to as the European Laboratory for Particle Physics, takes its acronym from its original name: the "Conseil Européen pour la Recherche Nucléaire", or the European Council for Nuclear Research. Thanks to advances in research, the particles it studies are now much smaller than the nuclei of atoms, which is why its original name is hardly ever used nowadays.

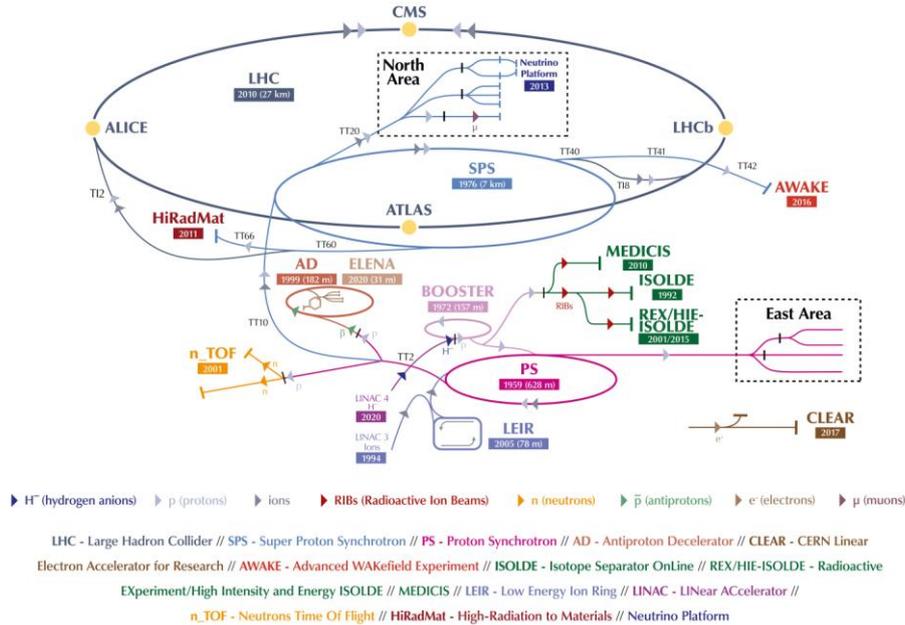
² OPECST Science and Technology Briefing 12 - Large Particle Accelerators, February 2019, Mr. Cédric Villani, Member of the National Assembly.

³ A synchrotron is a circular accelerator designed to study the radiation emitted by charged particles in circular motion, fittingly known as synchrotron radiation.

⁴ The CERN accelerator complex has been built up over many years and is extremely intricate. Before arriving at the LHC, a beam is created in Linac4, then passes through a booster, then the PS and finally the SPS. Some of these beams stop before the LHC to be observed by intermediate instruments.

A diagram of the complex is shown below (source: CERN - <https://home.cern/science/accelerators/accelerator-complex>):

The CERN accelerator complex Complexe des accélérateurs du CERN

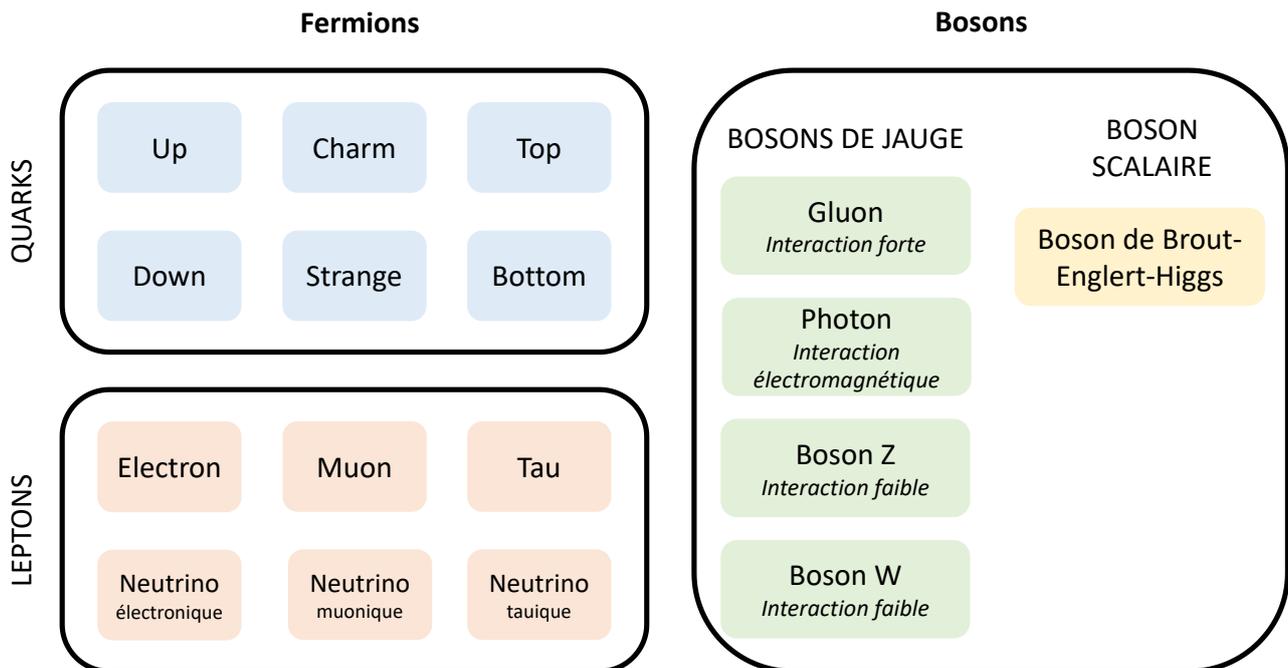


⁵ Large Hadron Collider; particle accelerator that produces collisions between protons and antiprotons.

⁶ "Ordinary" as opposed to "dark matter", discussed below.

⁷ The Standard Model is detailed in its entirety in the table below. The particles that make up ordinary matter are known as **fermions**. **Quarks** are classified into three families of increasing energy: up/down, charm/strange, and top/bottom. Assemblies of **quarks** are called **hadrons** (which includes protons and neutrons). Electrons belong to another type of fermion, **leptons**. Unlike quarks, they are not sensitive to strong interaction and do not bind together. **Bosons** are particles that enable interactions between other particles. The **Higgs boson** occupies a special position within the boson category. Finally, each particle has a corresponding symmetrical **antiparticle** (see footnote 21), which are not shown in this table (for example, electron/positron, quark/antiquark, etc.). For a more detailed theoretical introduction, see for example André Rougé, *Introduction à la physique subatomique* (Palaiseau: Editions de l'Ecole polytechnique, February 2014).

Modèle Standard de la physique des particules



⁸ Since quarks are unstable elementary particles, a lot of energy is needed to create them in an experimental facility. The branch of particle physics that studies them is called very-high-energy physics.

⁹ The forces described by the Standard Model are electromagnetic interaction, which is well-known, strong interaction, which binds quarks and ensures the cohesion of the nucleus, and weak interaction, which is responsible for beta decay.

¹⁰ Photons are the particle that carries light and the boson responsible for electromagnetic interaction. There are other bosons, such as those associated with weak interaction, known as the W and Z bosons. They were discovered at CERN.

¹¹ Note here that the mass of an assembly of elementary particles is less than the sum of the masses of its constituents. The difference, known as “mass defect”, is equivalent to the energy required to completely break the assembly apart, known as “nuclear binding energy”. This is linked to interactions other than the Higgs mechanism.

¹² The conceptual framework applicable here is special relativity, in which the notion of energy is more relevant than that of speed, as it is always very close to the speed of light. The LHC accelerates beams to an energy of 6.5 Teraelectron volt (TeV), a unit of energy widely used in particle physics (<https://home.cern/science/accelerators/accelerator-complex>). The FCC-hh is expected to reach energies of around 100 TeV (<https://home.cern/news/news/accelerators/cern-council-reviews-progress-feasibility-study-next-generation-collider>).

¹³ Electric fields accelerate charged particles, while magnetic fields confine and guide them. The operations of particle accelerators are described in more detail in OPECST Science and Technology Briefing 12.

¹⁴ The LHC, for example, saw 2,400 million million collisions per experiment in 2016 (<https://home.cern/news/news/accelerators/lhc-report-lhc-smashes-old-collision-records>).

¹⁵ In the Standard Model, there are three families of increasingly heavy particles, as shown in the diagram in footnote 7. Obtaining particles of a heavier family from a lighter family is difficult, because it involves transmitting a great deal of energy to the lighter particles. Some families are made up of unstable particles, which do not exist outside conditions such as those found in accelerators. Particles from all the families in the Standard Model have been detected.

¹⁶ Colliders are a category of particle accelerators that create collisions between particles.

¹⁷ The European X-ray Free-Electron Laser (European XFEL) is a research instrument comprising an X-ray laser produced by a 3.4 km long linear particle accelerator.

¹⁸ A beam of particles spinning inside a circular collider is constantly undergoing centripetal acceleration. Any charged particle that is accelerated emits radiation (this is the principle of synchrotrons), which causes it to lose energy.

¹⁹ The value of the mass of the Higgs boson, for example, remains highly uncertain.

²⁰ This type of matter is known as “dark” because it is not subject to electromagnetic interaction, so it is impossible to “see” it with astronomical instruments. The only other type of interaction with long-range effects is gravitational interaction, which means that dark matter can only be detected indirectly, through its gravitational effects: its mass distorts the space-time around it (according to the theory of general relativity), which modifies the trajectory of light from galaxies behind it. By observing distortion in images of objects in the background, we can infer the presence of this otherwise invisible matter. This is known as the gravitational lens effect (<https://www.cea.fr/comprendre/Pages/matiere-univers/essentiel-sur-matiere-noire.aspx>).

²¹ The Standard Model allows for the existence of two types of matter: “ordinary” matter, the kind that surrounds us, and antimatter, which is made up of particles with properties that are the opposite of ordinary particles; each ordinary particle therefore has a corresponding antiparticle. An antiparticle can interact with other antiparticles in the same way that an ordinary particle can interact with other ordinary particles; but the meeting of a particle and its antiparticle must result in their mutual annihilation; they cannot coexist for long. There is nothing in the Standard Model to justify the predominance of one type of matter over the other; similarly, the cosmological model of the Big Bang predicts that, at the very beginning of the Universe, the quantities of matter and antimatter should have been equal. Yet, antimatter is only present in minute quantities in the observable Universe.

²² The European Strategy for Particle Physics is the result of a consultation of European scientists, coordinated by CERN, on needs around research infrastructure. The latest was published in 2020 (<https://cds.cern.ch/record/2721370/files/CERN-ESU-015-2020%20Update%20European%20Strategy.pdf>).

²³ The Feasibility Study is available at <https://home.cern/news/news/accelerators/cern-releases-report-feasibility-possible-future-circular-collider>.

²⁴ Like the LHC, it would have 4 shafts, each housing an experiment. Their two-by-two symmetry means that the results can be verified by redundancy – which is not possible in a linear accelerator.

²⁵ Collisions involving protons can generate heavier products than those involving electrons, which can lead to the discovery of new particles. This is the energy frontier. Electrons allow for more precise measurement of collision parameters. This is the intensity frontier. In both cases, collisions occur between particles and their antiparticles (protons and antiprotons, electrons and positrons). The particle beam travels in one direction through the accelerator, while the antiparticle beam travels in the opposite direction, until they reach the collision point.

²⁶ “hh” stands for “hadron-hadron”, the hadrons in question being mainly protons and antiprotons.

²⁷ In particular, the self-coupling of the Higgs boson is of great interest (<https://www.in2p3.cnrs.fr/fr/cnrsinfo/letau-se-resserme-sur-la-valeur-de-lauto-couplage-du-boson-de-higgs>). It is a very rare occurrence, hence the interest in producing a very high number of Higgs bosons to increase the chances of observing it. It is also possible that particles not predicted by the model could be produced in energy ranges that are not yet accessible in experiments.

²⁸ They are mentioned in OPECST Science and Technology Briefing 12 and the 2020 European Strategy for Particle Physics.

²⁹ CEPC stands for Circular Electron Positron Collider. As with the FCC, this would be the first phase of an instrument designed to evolve into the Super Proton-Proton Collider.

³⁰ Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Israel, Italy, the Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom. CERN also has 9 Associate

Member States: Cyprus, Brazil, Croatia, India, Latvia, Lithuania, Pakistan, Turkey and Ukraine. Lastly, the United States and Japan hold Observer status with regard to the LHC.

³¹ France's two representatives are the General Administrator of the CEA and the Permanent Representative of France to the United Nations Office in Geneva and International Organisations in Switzerland.

³² The CERN Council also appoints the Organisation's Director-General. Fabiola Gianotti, who has held the post since 2016, will be replaced in early 2026 by Mark Thomson, who has already expressed a favourable opinion on the FCC (<https://www.mediapart.fr/journal/fil-dactualites/071124/le-nouveau-patron-du-cern-dit-son-engagement-en-faveur-du-futur-super-accelereur>).

³³ More specifically, this amount of 15 billion Swiss francs includes CERN's investment in the FCC-ee, as well as a 10 % contribution to the funding of the four experiments. Operating costs for CERN are estimated at around 650 million Swiss francs per year, including electricity.

³⁴ Although the science policy of the current US administration does not appear to favour international cooperation, the United States has shown an interest in the project in the past. Furthermore, as the project is long-term, it is not necessary to obtain a commitment from the US right away.

³⁵ At this stage, this is just an avenue to explore. However, the European Union is aware of CERN's central role. The President of the Commission defended CERN's importance for Europe during her speech at the organisation's 70th anniversary in 2024, echoing the Draghi report on European competitiveness, which mentions CERN as a European success story.

³⁶ For example, the Science Portal, CERN's education and communication hub for the general public, was financed by private funds.

³⁷ CERN obtains its electricity mainly from the French grid.

³⁸ Within the budget of the Ministry of Higher Education and Research. This is not the total cost, as public research bodies also cover certain CERN-related activities in their own budgets. By comparison, ITER, the second largest VLRI budget item, cost €155 million in 2023. Apart from international organisations, in the category of "RI*" (which includes research infrastructures that are part of a national policy and covered under ministerial budgets), the infrastructure with the most funding is the French oceanographic fleet (FOF) with €69.3 million.

³⁹ Directorate-General for Research and Innovation, attached to the Ministry of Research.

⁴⁰ The members of the interministerial committee are

- for the Ministry of Research: the Directorate-General for Research and Innovation;
- for the Ministry of Finance: the General Secretariat for Investment and the Budget Directorate;
- for the Ministry of the Environment: the General Commission for Sustainable Development;
- for the Ministry of Foreign Affairs: the Directorate-General for Political and Security Affairs, with the support of the Directorate for Cultural, Educational, University and Scientific Diplomacy;
- for the Ministry of the Interior: the Prefecture of the Auvergne-Rhône-Alpes region.

Observers are present in a support role: the project team from the Ministry of Higher Education and Research, as well as the French delegates to the CERN Council and their advisors (CEA, CNRS and the Permanent Representation to the UN and OSI in Geneva). Lastly, experts are invited to attend open sessions, as and when required, depending on the agenda.

⁴¹ However, the situation is unique because of CERN's legal status as an international organisation. According to the CNDP's advisory mission, CERN considered that it was indeed possible to refer the matter to the CNDP in this context, which was confirmed by the Ministry of Foreign Affairs.

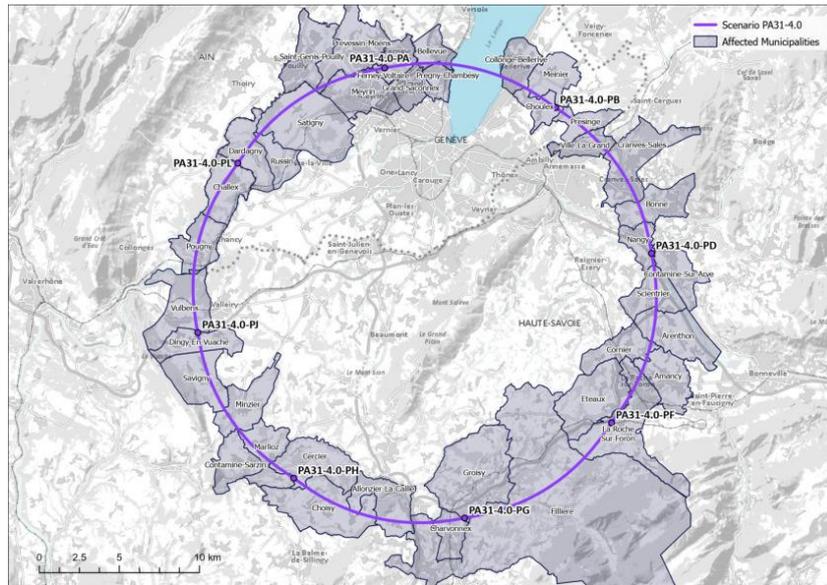
⁴² The CNDP's opinion and recommendations are available at <https://www.debatpublic.fr/projet-de-futur-collisionneur-circulaire-fcc-daccelerateur-de-particules-5952>.

⁴³ Since the project is cross-border, the public debate will be partly organised in conjunction with Switzerland. However, national specificities will remain. In particular, the question of the merits of the project will be an integral part of the public debate in France, as required by law, unlike the public debate in Switzerland, which will leave this subject out of the discussions.

⁴⁴ The LHC is a ring 27 km in circumference between Switzerland and France, mainly in Pays de Gex (Ain).

⁴⁵ The deepest access shaft would reach a depth of 400 m below the surface.

⁴⁶ The reference scenario for the tunnel location, proposed by the CERN Feasibility Study, is PA31-4.0. A map of this scenario is shown in the figure below (source: CERN). An interactive version is available on the CERN website: <https://cern.ch/fcc-overview>



⁴⁷ The local context is detailed in chapter 2.2 of the CNDP's *Bilan de la mission de Conseil* (28 February 2025), "Réalisation d'une étude de contexte".

⁴⁸ Corresponding to the four shafts housing scientific experiments and the four technical shafts used for construction and maintenance.

⁴⁹ CERN states that it has reduced the area required from the initial 110 ha (<https://home.cern/science/cern/fcc-study-media-kit>).

⁵⁰ Volume 3 of the Feasibility Study details the local characteristics of each surface site (<http://cds.cern.ch/record/2928194/?ln=fr>).

⁵¹ CERN is conducting research into how to recycle these excavated materials, with the *Mining the Future* project. However, it is likely that most of the molasse extracted from the ground will not be able to be reused.

⁵² Including several associations grouped together in the Co-Cernés collective.

⁵³ An article signed by scientists opposing the project appeared in *Libération* on 25 February 2025: "Il faut renoncer au futur méga-collisionneur de particules du Cern, par 400 scientifiques" (https://www.liberation.fr/idees-et-debats/tribunes/il-faut-renoncer-au-futur-mega-collisionneur-de-particules-du-cern-par-400-scientifiques-20250225_5XHFW4JKRNFPDJTH52UF3B5PR4/). This was followed by a response from other scientists in favour of the project, on 11 March in the same newspaper: "Pourquoi l'Europe devrait approuver la construction du futur collisionneur de particules du Cern" (https://www.liberation.fr/idees-et-debats/tribunes/pourquoi-leurope-devrait-approuver-la-construction-du-futur-collisionneur-de-particules-du-cern-20250311_PQ4BBOMIX5CDDDNJNYEKXFREY/).

⁵⁴ This is comparable to the 1.3 TWh currently used each year by CERN, with 600 GWh for the LHC alone.

⁵⁵ An upgrade to a third existing connection at Prévessin, involving a link to a surface site at Ferney-Voltaire (around 4 km away), will also be required. RTE has confirmed that no grid upgrades or modifications will be required as a result of the FCC project. The new "connections" mentioned therefore correspond to local connections to the existing grid, without any reinforcement or modification to the main grid. As part of this process, RTE will work with CERN to consult the CNDP in preparation for the public debate. In addition, electrical connections provided by Enedis for six surface sites and by Énergie de Seyssel for the seventh surface site in France will be needed, to guarantee the power supply during the construction phase.

⁵⁶ This effort includes organising public meetings and constituency offices in municipalities in the region (L'actualité de l'étude FCC, Lettre des Territoires, 9th edition – October 2025).