Newsletter Interview

THE GREAT CHALLENGES OF THE FUTURE CIRCULAR COLLIDER

Interview with Michael Benedikt, accelerator physicist at CERN and coordinator of the Feasibility Study for FCC

The Italian national workshop "INFN and the European Strategy for Particle Physics" was held on May 6 and 7 in Rome and was well attended by the scientific community, including young researchers. The purpose of the meeting was to introduce the work that various INFN research groups are conducting to meet the goals recommended by the latest edition of the Update of the European Strategy for Particle Physics (ESPPU) and to start the discussion on the preparation of the next update of the European Strategy for Particle Physics, a crucial milestone for the future of high-energy physics. We talked about the status of work on the Future Circular Collider (FCC), a project at the heart of the Strategy update, and the upcoming major challenges, with Michael Benedikt, accelerator physicist at CERN, who is coordinating the FCC feasibility study.

What will the FCC be, how will it be different from the LHC and why will it be a good Higgs factory?

The FCC will be a circular collider based on a 90-kilometer-long tunnel, that would be roughly 200 m underground in the area between Switzerland and France. In this tunnel infrastructure, a lepton collider will be installed, based on normal conducting magnets, equipped with large superconducting radio frequency cavities to accelerate the particles, and to compensate the synchrotron radiation losses. The FCC-ee will be able to accelerate and collide electrons and positrons, whereas in the LHC only protons are colliding. The big difference between protons and electrons is that electrons have much more radiation losses, and this means that we need a big radio frequency system to compensate for these synchrotron radiation losses in the electron collider. So, the key technology is the superconducting radiofrequency system, and an important topic is to make this system as energy efficient as possible to create a sustainable collider.

What technologies beyond the state of art will the FCC need?

The FCC will house two colliders. In the first stage there will be a lepton collider, FCC-ee: the key technology for the lepton collider is the superconducting radiofrequency system. The big effort is to make this system more efficient in terms of technical performance and in terms of energy efficiency and electrical consumption. And this requires optimization of the cavity materials, of the cavity coatings and of the superconducting technologies. And it also requires the optimization of the radiofrequency power consumption devices to have them work at much higher efficiency than today.

In the second stage, the FCC-hh will house a hadron collider. Here, the key technology are superconducting magnets at very high fields. We are aiming at a factor two higher than the LHC collider. And for these we also need to do research on high temperature superconducting materials with the goal of developing efficient magnets that could be operated at higher temperature than the LHC magnets.

You are now leading the feasibility study for the FCC. What are the main tasks of this study?

The feasibility study needs to address all the aspects necessary to design and to decide on the project of such a new, huge collider, including the aspects concerning integrating and placing such a huge 90-kilometer infrastructure in the local region, which covers also socio-economical aspects and of societal acceptance. It also needs to cover, the question of the feasibility of civil engineering, so it needs to understand how you can construct the 90-kilometer-long tunnel, where you can build the access sites on the surface, how many shafts you need until you technically realize this tunnel infrastructure. It must cover all the aspects of the technological development of the colliders, and of the infrastructure cooling, ventilation and cryogenic supports, and it has to cover the detector and the experiment concepts, as well. A complete feasibility study and picture of such a future facility must be available by the end of the feasibility study, so that the decision makers can have an informed discussion on the feasibility, on the cost, and on all aspects of realization of such a future collider.

What stage is your work at? What are the next steps? When is the feasibility study expected to be completed?

We have just completed a mid-term review, delivered to the CERN Council, that looked at the general advancement of the feasibility study. The key goals for the next few months are to complete the technical work for the feasibility study by the end of this year, to prepare the documentation, to update the cost estimate and to provide this input for the European Strategy for Particle Physics. Actually, the feasibility study will be completed by March 2025, and then it will be available as input for the next Update of the European Strategy for Particle Physics that will start immediately afterwards.

If the feasibility study and the whole process are successful, how long will it take to build the FCC and when is it expected to start running?

If the feasibility study is successful and if the European Strategy for Particle Physics recommends the project, then the CERN Council and potential other financing partners could discuss and take a project decision possibly around the end of 2027, beginning of 2028. That would be the moment where we would start the civil engineering design work, and the tender of the civil engineering contracts. This would allow to start the construction at the beginning of the 2030s. The construction would be completed by 2040, and followed by the installation of technical infrastructure, accelerator and detectors, and then commissioning and operation could start from middle of the 2040s onwards.

Are there other potential Higgs factories under evaluation?

There are various studies. There is the Chinese project that is, in all its parameters, in its performance and its plans, similar and comparable to the FCC-ee. There are also other projects, which are the linear colliders, in particular the ILC, that was proposed in Japan, that differs significantly in terms of number of experiments on a single collision point and also it is significantly different in several other parameters.

Are the FCC civil works compatible with High Luminosity LHC?

Yes, Hi-Lumi LHC can run during the civil engineering works of the new facility. The FCC ring will be roughly 100 meters below the LHC ring, and most of it is in a different geographical site, thus there's no problem of compatibility between the LHC operation and the FCC construction.

How many different countries are working on the feasibility studies and how is your work organized?

The feasibility study is organized as a global collaboration. There is a memorandum of understanding that provides the legal framework. And individual partners can join by signing this memorandum and by concluding individual agreements, which we call addenda, to provide specific contributions. In total, today, there are about 150 institutes working on the feasibility study from 33 countries. We have about the equivalent of 50 full time persons working at CERN, considering that overall 150 people are engaged in the feasibility study. Then we have about 50 PhD students and postdocs working directly at CERN, and about the same number is also coming from the collaboration. So, in total we have about 50 to 60 full time equivalent persons and about 50 to 60 students. We usually have one large collaboration meeting week per year, that is called the FCC week, that this year will take place in San Francisco, California, very shortly, in June.

What is the role of Italy and INFN?

INFN and Italy have been very strong partners from the very first moment, not just in the feasibility study, but also in the conceptual design phase started in 2014. INFN was always accompanying the development of the project, and it is clearly extremely important to have long term stability and the competence that comes with INFN as partner.

In the future, also the Italian industries could contribute to the project, in particular, in the high field magnet technology, in superconducting radiofrequency, where there is a significant experience, and in other accelerator technologies, since Italy is a country where accelerators and accelerator based research centers are widely spread, thanks to INFN; there places where the know-how and the technologies have been developed in collaboration with industries.

How will the FCC deal with environmental challenges, both concerning its construction and its operation?

For the design of the facility, from the very first moment, we have used the principle “Avoid, Reduce, Compensate” for the development of the project. This principle is in the French law and it is also mentioned in the Swiss law, and it means that already in the very initial design phase, you should try to avoid any environmental incompatibilities. Only if you cannot avoid them, you try to reduce, and only if you cannot reduce anymore, you must think about compensation measures. And that's why we have studied a hundred different variants, different circumferences, different layouts, different locations, to make it compatible with the surface constraints, such as protected zones, groundwater reservoirs, humanistic aspects, existing transport, outdoor routes, existing electrical grid distribution networks and other aspects. At the same time, you have to study the geology to make the tunnel construction low risk and feasible. And, of course, the performance of the machine. So, this is a key ingredient as the first step. And then, on the technical side, we are looking at the optimization of individual technical assistance, like increasing the efficiency of a superconducting radiofrequency system, increasing the electrical efficiency of the radiofrequency power production, reducing the power consumption of the magnets by introducing new designs, and other developments.

Then there are the aspects of energy supply to the future facility. We know that the average consumption of the FCC-ee will be 1.3 to 1.4 terawatt hours per year, while the present energy consumption of CERN plus the LHC is 1.2 terawatt hours per year. So, we have studied, modern opportunities of buying and purchasing electricity from renewable sources, these elements are called power purchase agreements: they allow you to build up a mix of renewable energy sources from which you can get your energy supply. And this would allow to base the future operation of the facility to large extent on renewable sources. Then, there is a fourth component: we are trying to reuse as much as possible, for example, the heat produced by the cooling of magnets, in the sense of heat recovery and reusing it, for example, to heat local districts, to heat hospitals, to heat schools. Such kind of synergies are possible because ours is a long-term project. FCC would be operational in 2040, and you can integrate these services in the long-term urban planning in the region. This makes it interesting for the region as well.