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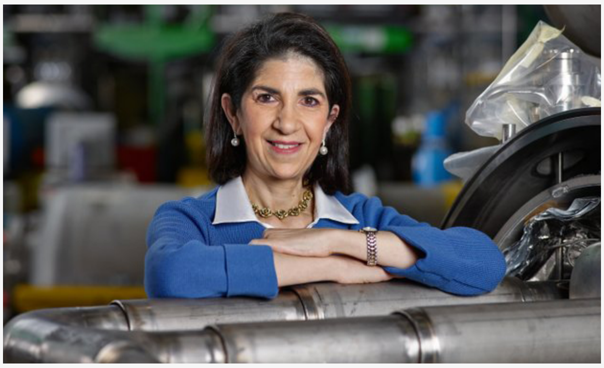

CERN IN THE 70 YEARS OF INFN

Interview with Fabiola Gianotti, director-general of CERN

From the founding of the Italian Institute for Nuclear Physics, on 8 August 1951, to today, the history of research into fundamental physics in Italy has known seventy years of excellence that led to historic results and discoveries. Rooted in the intertwining of two research currents, the physics of atomic nuclei and the study of cosmic particles, INFN was set up a short time after the founding of particle physics, constituting, right from the start, a solid base for the scientific successes that followed in subsequent years, in Italy and in the context of increasingly wide international collaborations. Three years after the founding of INFN, Europe joined its forces focusing on a single research goal: founding an international research centre for high-energy physics. CERN was, thus, founded in Geneva in 1954. From that moment, it accompanied the whole INFN research path in the field of high-energy physics, with extraordinary results, up to the most recent, in 2012: the discovery of the Higgs boson, which was awarded a Nobel Prize.

The protagonists of the opening event celebrating 70 years of INFN, "70 years of understanding the universe", which was held at the Auditorium Parco della Musica in Rome on 29 September 2021, included the director-general of CERN, Fabiola Gianotti. She re-traced the fundamental steps in the adventure that led to the discovery of the Higgs boson and that, today, paves the way for research into new frontiers of science and technology in the field of fundamental physics.

Below is the transcription of the whole interview.

Almost ten years ago, in 2012, you were head of the ATLAS experiment that, alongside the CMS experiment, announced the discovery of the Higgs boson. How did we get there?

It took 30 years. This is the time that passed from the very first ideas about the Large Hadron Collider in 1984 to the discovery of the Higgs boson in 2012. In my opinion, this discovery is emblematic of the way in which the scientific community works in our field. It was the result of the virtuous union between research, with its push towards exploration and the ambition to answer open questions, and technology, which finds its greatest expression in the relationship with industry and global collaboration. The research adventure always starts from an idea that is often trying to answer a crucial question: this was the case with the electroweak symmetry breaking, which could be explained by the Brout-Englert-Higgs mechanisms and then by the existence of the Higgs boson or, perhaps, by something else. Secondly, the following point is to ask themselves what tools are needed to answer the question

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that was posed. At the time of the first discussions on the LHC, there still weren't the data from the LEP, the previous CERN accelerator, and, therefore, there were no limits on the mass of the Higgs boson, which could make us think of a light particle. Generally, the mass of the Higgs boson could have been up to 1 TeV, so we needed a very powerful accelerator, capable of accelerating protons to energies of a few teraelectronvolts and producing very intense particle beams, since the Higgs boson production is a weak interaction process. The creation of the accelerator thus required very complex and cutting edge technologies, in particular in terms of high-field superconducting magnets. Furthermore, we knew that such a powerful accelerator would lead to very harsh conditions for the detectors. Thus, the detectors would need to ensure, not only high performance, but also the ability to operate in an extremely complex environment, resulting from the energies and intensities of the collisions. Hence a new need arose: to develop new technologies and tools that would be up to a challenge that, at the start, seemed impossible. But telling physicists or engineers that "the undertaking is impossible" is the best way to push them to find the solution to the problem.

They have been very exciting and very difficult years. The 1990s were engaged in developing technologies and tools - accelerators, detectors and computing infrastructures - that would allow us to observe the Higgs boson and explore a new energy frontier. And when you work at the limit of technology, the road to travel isn't downhill, nor is it flat, it's an uphill road: you take three steps forward, two backwards and one to the side, so you need a lot of tenacity, a lot of determination. Industry played a very important role. In general, the way in which CERN and the other facilities dedicated to research in our field, like the INFN Gran Sasso National Laboratories, work with industry is not a standard method, based on a classic customer-supplier relationship. We don't sign a cheque so that industry, for example, is charged with producing the 1232 magnetic dipoles for the LHC. We work together from the beginning. The prototypes are constructed in the laboratory, together with the most promising industrial partners. Then, when the technology is mature, the production is transferred to industry for the construction on a large scale of magnets or other components of accelerators and detectors. In this way, industry quickly became part of the LHC adventure. Furthermore, the LHC challenge was shared with the international scientific community and this common effort had a fundamental role. Large-scale international cooperation is a distinctive feature of our research field and can effectively represent an example of how humanity should and can work collectively to pursue noble goals. Incidentally, the need for a global collaboration to overcome societal challenges is one of the main lessons we have learned from the pandemic.
The discovery of the Higgs boson occurred relatively quickly. In reality, we weren't expecting to find it so quickly: we thought we would discover other particles before, for example the supersymmetric ones, which then weren't found to be present in nature, at least at the energies explored up until now. Already in 2011, only one year and a half after the LHC was switched on, when we passed to 7 TeV energy, we saw some indications at a given mass of about 125 GeV and then, in 2012, the signal of the Higgs boson manifested itself in all its intensity and beauty. We could then announce the discovery.

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The two big discoveries of the last decade, the ones of the Higgs boson and of gravitational waves, took a lot of time, much determination, and enormous vision. If I'm not mistaken, there's a new challenge knocking on the door, is that right?

Yes, luckily, there are new challenges. If there weren't, we wouldn't move forward along the path towards knowledge, which is a very long one. If there is one certainty in fundamental physics today, it is that there are many open questions that we cannot answer. Some of these questions have been identified and understood, even if we don't have the answers yet. These are what we call the known unknowns, for example, dark matter, the problem of the Higgs boson mass, the mass of neutrinos, etc. Then, there are the so-called unknown unknowns, that is the mysteries of which we are not yet aware. Progressing along the path of knowledge, also means understanding the right questions to pose.

Another important thing to highlight is that these open questions probably have solutions that are related to one another. Understanding, for example, the issue of the Higgs mass could also give us some indication about dark matter and vice versa. These are very complex questions and there isn't, as of today, a tool that allows us to answer everything. The best strategy, therefore, is to put into practice all the most promising experimental approaches that particle physics and astroparticle physics have developed in the last decades, also thanks to the extraordinary advancement in the technologies of particle accelerators and detectors and of the instrumentation in general. These approaches include the physics of accelerators, the underground experiments that study particles coming from the cosmos, the experiments installed on satellites, etcetera.

Historically, particle accelerators have been our main tool, from the experimental point of view, for building the Standard Model, since they replaced, in the middle of last century, the study of cosmic rays to studying elementary particles. And accelerators will continue to play a very important role in the future as well. It's impossible to think of answering the open questions without the contribution of accelerators. And, therefore, we need to start thinking about the next particle collider after LHC. As we know, the European community of particle physicists has identified the project called Future Circular Collider (FCC) as the most promising one from the scientific point of view. FCC is the project of a 90-100 km ring that would allow, first, electrons-positrons collisions and, then, would evolve in a hadron machine. The physics reason to pursue this enterprise comes mainly from the Higgs boson, which can only be studied with accelerators. And the Higgs boson is a special particle: it has very different characteristics from all the other elementary particles discovered to date and it interacts with a different force; we therefore believe that it may be the key to answering some of the open questions.

To study the Higgs boson in detail, we need a bigger and more powerful accelerator. FCC is a very ambitious project and, once again, as in the case of LHC, the undertaking seems impossible, but I'm sure that if we decide to move forward in this direction, we will achieve it.

About this, I'd like to highlight another important aspect. In the case of the LHC and its experiments, as with the experiments for the detection of gravitational waves, in the end, and despite their complexity and the difficulties that needed to be faced in constructing them, the performance exceeded the most rosy and optimistic of expectations,

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singnificantly. This means that our research field, our scientific community can carry out very complex and ambitious projects, respecting the set budget, fully achieving, or even exceeding expectations. And this is a milestone in view of even more ambitious future projects.

The whole recording of the event: “70 years’ knowledge of the Universe” can be found *here*.■