Newsletter Interview

THE LHC RESTART AND NEW PROSPECTS

Interview with Roberto Tenchini, president of the INFN National Scientific Committee 1, which coordinates the institute's activities in the particle physics sector, and researcher with the INFN Pisa Division.

Last 22 April, the whole international particle physics community welcomed with interest and enthusiasm the news coming from CERN where two proton beams, each with an energy of 450 billion electronvolts (450 GeV), were injected in opposite directions inside the 27-kilometre underground ring of the Large Hadron Collider (LHC), the biggest and most powerful particle accelerator ever created. The restart of the LHC, which comes after a stop of almost three years, during which the machine and the four big experiments installed at the beam collision points underwent maintenance and upgrade works, was, in fact, the first step towards fully restarting scientific activities of the third data acquisition period (Run 3). Thanks to this new phase of operations in the collider's life, the start date for which is planned for July, particle physicists of the large experimental collaborations hope, in the next four years, to shed light on the properties of the Higgs boson and on the anomalies encountered during Run 2 that, if confirmed, could also lead to a new physics beyond the Standard Model.
It's precisely these prospects that made the update and upgrade works necessary. These works will significantly increase the performance of the accelerator and of the experiments, and were carried out, during the long break just concluded (Long Shutdown 2) on the LHC and on the ATLAS, CMS, LHCb, and ALICE detectors – and, subsequently to the FASER and SND@LHC experiments. Italy has decisively contributed to this effort thanks to INFN, which is in charge of developing and producing a significant part of the experimental components that were substituted. We spoke about the upgrade of the LHC and its experiments and the future scientific prospects with Roberto Tenchini, president of the INFN National Scientific Committee 1, which coordinates the institute's activities in particle physics, and researcher at the INFN Pisa Division.

On 22 April, LHC was restarted with the injection of the first two proton beams. What does this initial switching-on stage of the LHC entail and how long will it last?

The LHC is a complex machine, a particle collider with a 27 km ring with a large number of components. Just to give an example: only the magnetic dipoles, which "bend" the beams, are 1232. The LHC itself receives the beams from the CERN accelerator complex. After a period of three years in which improvements were made and repairs carried out, we need to verify that each of its parts operates perfectly, increasing, step by step, the intensity of the packets of protons, the number of packets themselves, and their energy. We expect to have

stable beams with an energy of 6.8 TeV by early July. An important operation to do in June concerns the so-called “scrubbing”, i.e. using the beam itself to clean the walls of the vacuum tube in which the beam circulates, removing impurities that would form “electron clouds” that would degrade its performance.

What performance will the LHC be able to offer during Run 3 and what will be the differences compared to the past?

During Run 3, the collider will function with a greater energy in the centre-of-mass, increasing from 13.0 TeV to 13.6 TeV. It will also have a higher luminosity, making it possible to double the number of proton-proton collisions for experiments in the 2022-2025 period compared to previous periods (2010-2018).

What works and upgrades did the accelerator undergo?

The LHC is a particle collider that makes extensive use of superconductivity, with liquid helium at a temperature of 1.9 kelvin, to make very intense currents circulate in the magnets. The sudden passage from the superconductive state to the normal resistive state of electrical conductivity, the so-called “quench”, is a phenomenon that occurs with little notice and needs suitable protection to dissipate the stored energy. These protections were considerably improved. Improvements and repairs were also carried out on various cryogenic systems.

The maintenance and upgrade activities did not just involve the LHC, but also the chain of machines for pre-accelerating beams before they are injected into the LHC. Which machines were involved and what were the improvements made?

The most important improvement, which makes it possible to reach higher beam intensities during Run 3, concerns not the collider itself, but the proton injection system that consists of a new linear accelerator (LINAC 4). This new injector reaches higher energies and twice the intensity. In addition, the Super Proton Synchrotron (SPC), the ring that accelerates the protons in the second-to-last stage, i.e. before the LHC, was equipped with new radiofrequency systems.

How will the increase in the LHC’s performance influence the activities of the four big detectors installed at proton beams collision points?

The experiments have been significantly improved, especially for the detection of muons from now on, and one of these, LHCb, was completely reconstructed. The machine’s performance increase, coupled with the improvements made to the equipment, will enable “general purpose” experiments, like ATLAS and CMS, to triple the data collected, and it will allow the LHCb experiment, dedicated to the study of “flavour” physics, to increase the data available by a factor of more than five. The ALICE experiment will, finally, be able to further refine the study of heavy ion collisions.

What are the main scientific goals that will be pursued during Run 3 and how long will this data acquisition period last?

A very important goal concerns studying the Higgs boson properties. The Higgs boson was discovered 10 years ago right at the LHC. In this sector, measurements with significantly higher statistics will be possible, extending, at the same time, the territory explored in the search for new phenomena. The LHC should also

significantly solidify the data on anomalies observed in the decay of the quark b during Run 2, definitively excluding or confirming them.

LHC is a complex and monumental tool that required an extraordinary technological effort, to which Italy also contributed. What role has our country played in constructing the accelerator and in the activities conducted during the last shutdown?

Italian companies contributed substantially to the construction of the machine, for example a third of the superconducting dipole magnets, mentioned earlier, were produced in Italy. INFN researchers and technicians also designed and produced a considerable part of the key detectors of all four big experiments: ALICE, ATLAS, CMS, and LHCb, and contributed to their improvements during these difficult, pandemic times.

What will be the future of the LHC, once Run 3 has reached its end?

Run 3 will be followed by three years of additional improvements to pass to the High-Luminosity LHC phase with a collider able to provide a quantity of data six to nine times higher during the final data acquisition periods, expected to end in 2038. In this phase, the potential of the LHC will be fully exploited, before passing the baton to future investigative tools.