Newsletter Interview

LHCB: ON THE TRACKS OF NEW PHYSICS

Interview with Vincenzo Vagnoni, INFN researcher, spokesperson of the international Scientific Collaboration of the LHCb experiment at the CERN Large Hadron Collider

There has a been a change at the top of one of the main scientific collaborations that operate at the CERN Large Hadron Collider, the LHCb collaboration, responsible for the construction and operation of the detector with the same name, as well as the scientific analysis of data acquired by the large experimental apparatus. After his election at the start of the year, Vincenzo Vagnoni, researcher at the INFN Bologna Division, succeeded on 1 July Chris Parkes, who held the role since 2020. Vagnoni will now lead the LHCb international collaboration, becoming the new head of a community that today counts over 1500 scientists, engineers, and technicians. The passing of the baton occurs in a phase of intense scientific activity for the LHCb collaboration, currently engaged in the detector's third period of data acquisition (Run3). This run can benefit from a substantial increase in the detector's sensitivity, the result of the upgrade it underwent between 2018 and 2022 during the long shutdown of the LHC (Long Shutdown2). The appointment of Vagnoni is a new proof of the significant role played by Italy and INFN over the years within the LHCb collaboration. The latter relies on over 200 Italian researchers, who have substantially contributed to the project, both in terms of science and coordination. Vagnoni will ensure the continuation of the LHCb scientific programme, which is focused on precise measurements of rare decay phenomena. These could provide clues to the presence of new physics beyond the Standard Model of elementary particles, also thanks to the detailed study of "asymmetries" in the behaviour of matter and antimatter particles. Over the next three years, he will have the task of coordinating all the activities that involve the LHCb collaboration, including those for planning additional upgrades in view of the experiment's future data acquisition cycles. Such cycles will be characterised by greater intensities than those happening today as the result of works planned as part of the High-luminosity LHC project. INFN researcher at the Bologna Division since 2005, Vincenzo Vagnoni has been the physics coordinator of the LHCb international collaboration from 2016 to 2018. He is the author of more than 700 articles published in international journals in the field of particle physics. These range from precise measurements of asymmetries in matter-antimatter behaviour to the study of the dynamics of particles consisting of so-called heavy quarks.

The history of the LHCb collaboration is characterised by a strong Italian contribution, whose activity is coordinated by INFN. When was the collaboration born and what contribution does INFN provide?
The collaboration was born at the end of the 1990s. Right from the start, the INFN component was central to the experiment, constituting the most numerous community, along with that of the United Kingdom. At the moment, INFN is participating in the experiment with around 15 facilities (Bari, Bologna, Cagliari, CNAF, Ferrara, Florence, Genoa, Frascati National Laboratories, Milan, Milano Bicocca, Padua, Perugia, Pisa, Roma Sapienza

and Roma Tor Vergata), with primary responsibilities in various major activities regarding detectors, software, data analysis, and coordination.

Over the last two years, the collaboration has been engaged in the LHCb upgrades in view of the LHC Run3, which started in April 2022. What actions were undertaken?
After the end of Run2, the LHCb collaboration undertook an upgrade of the detector, to increase the data acquisition speed by a factor of between 5 and 10, depending on the physics processes of interest to the experiment. Thus, during Run3, in just one year the experiment will be able to accumulate a quantity of data equivalent to 5-10 years compared to the two previous ones, Run1 and Run2. The experimental equipment was almost entirely renovated, constructing a new silicon pixel detector around the proton collision point of the LHC, replacing the charged particle tracking system with new technologies, updating the photosensors and electronics of the two Cherenkov light detectors needed to identify pions, kaons, and protons, and replacing the muon detector electronics for reading data. In addition, the online acquisition system was upgraded and is now entirely based on software, using the most recent technologies - for example reconstructing events using professional Graphics Processing Units (GPU) and latest-generation Field Programmable Gate Arrays (FPGA).

The improvement in LHC performance, with the increase in energy and luminosity obtained by the machine, could pave the way to new discoveries soon. What is the scientific programme that the LHCb collaboration is carrying forward in this phase and what are you expecting?
The LHCb experiment has a peculiar feature compared to the other LHC experiments, having a “forward” configuration that makes it possible to cover a small-angle region highly efficiently in relation to the LHC proton collision direction. In this region, you can gather events containing particles composed of beauty, charm, and strange quarks, with greater probability, that are very interesting for precisely studying asymmetries in behaviour between matter and antimatter and rare decays. The LHCb collaboration proposes, therefore, to significantly increase the statistics of these events to detect possible discrepancies compared to the Standard Model predictions. This may open new horizons in physics and outline the direction for future-generation experiments. Obviously, the hope is to find effects of new physics that are still unknown, which are able to explain some of the mysteries that still surround the sub-atomic world, despite the great progress made in recent decades. Whether this is possible or not, only nature can say. However, we are trying our best.

The pause due to the long shutdown 2 hasn't prevented the LHCb collaboration from moving forward with its scientific research. What are your most recent scientific and technological results?
During the detector upgrade carried out in the last long shutdown scheduled for the LHC between Run2 and Run3, the collaboration continued to actively work on analysing Run1 and Run2 data. At the moment, the collaboration has published 674 scientific articles in international journals only using the data from the first two Runs. For example, the collaboration recently published the most precise measurement in the world of matter-antimatter asymmetry (violation of CP symmetry, in technical terms) in the decays of B mesons in a pair of particles called J/y (consisting of a charm quark-antiquark pair) and short-lived neutral kaon (consisting of a strange and down quark-antiquark pair). The previous most precise measurement had been made by the BaBar and Belle experiments and, using the LHCb data, it was possible to significantly improve the precision. At the moment, discrepancies in relation to the Standard Model have not emerged yet, but there is still much room for improvement. The LHCb experiment’s life is not yet halfway through; it is expected to collect data, including future upgrades, until the 2040s.

Another activity that has already engaged the LHCb collaboration, as well as the other three large LHC experiments, is the planning of the upgrades the detector must undertake in view of the High Luminosity LHC project, which is scheduled to begin in 2028. What solutions will the LHCb adopt to get ready to the increased performance of the LHC?

Unlike the ATLAS and CMS experiments, which scheduled their upgrades for the high-luminosity phase for the LHC Run4, the LHCb experiment (like the ALICE experiment) scheduled a new upgrade for Run5. The additional upgrade of the LHCb proposes raising the data acquisition speed by an additional factor of 10 compared to Run3 and Run4. This will make it possible to obtain all the physics possible from the LHC during the last phase of life of the accelerator before starting with the next big CERN project, the Future Circular Collider (FCC). The future LHCb upgrade, the so-called LHCb Upgrade II, is an unprecedented technological challenge in the context of particle physics, with the need to associate a new dimension with the measurements of various sub-detectors: time. Briefly, the detector will be upgraded to provide temporal measurements of the passage of particles with extreme precision, in the order of 10 thousandths of a billionth of a second. This will make it possible to reduce the complexity of the events, using the temporal separation of multiple LHC proton collisions.

You are asked to lead a collaboration of over 1,500 people coming from all over the world. What will your responsibilities be? What will the main challenges be?

Collaborations of this size constitute a big sociological experiment as well. At the moment, the LHCb collaboration includes researchers, technologists, and technicians coming from 20 countries and around one hundred research institutes from every corner of the world. My role is head of operations for all the experiment activities, including interaction with CERN, with the various institutions involved and with the outside world. The two main challenges for the next three years will be conducting the current detector towards maximum efficiency, launching the publication phase for the Run3 data, and preparing the work for the next upgrade of the Run5 experiment. All the preparatory work will need to be completed over the next three years, so as to then start with the phase of constructing the new measurement equipment. Without doubt, it’s a difficult undertaking and an ambitious one, but I’m not alone in bringing it to completion. I have many close collaborators at my side. In particular, the great strength of INFN gives us, as Italians working at the frontier of science and technology, extraordinary courage. The great strength of INFN in particular gives us, as Italians working at the frontier of science and technology, extraordinary courage.