

» INTERVIEW



AN EYE FOCUSED ON ANTIMATTER

Interview with Giovanni Passaleva, INFN researcher, since July spokesperson of the LHCb international collaboration at CERN.

Designed to measure the behavioural differences between matter and antimatter at LHC energy levels, the LHCb experiment at CERN records the decay of B mesons, unstable particles containing a b antiquark and a quark of another type (up, down, strange or charm), produced in large quantities in high energy collisions between LHC beam protons. In particular, LHCb investigates the reasons for the absence of antimatter particles in the current universe that are thought to have been very abundant shortly after the Big Bang. Physicists believe in fact that by studying and comparing the decays of B mesons and of the corresponding B anti-mesons, it is possible to obtain important information on the differences between matter and antimatter.

Among the challenges taken up by the international head of the experiment, Giovanni Passaleva, is also the one of taking LHCb to its next upgrade, a performance improvement of the detector, starting in 2019, which will allow phenomena that could pave the way for new discoveries to be explored with even more extreme precision.

LHCb was created with a defined objective, even though the scope of the experiment is very broad. A fascinating and difficult objective: reveal the mystery of the current asymmetry between matter and antimatter. What are the hypotheses underlying the LHCb research program?

According to what we know today about the elementary particles and the forces with which they interact with one another, we can say that in the first moments of the life of the universe after the Big Bang, there was perfect symmetry between matter and antimatter. This symmetry disappeared during the evolution of the universe, so much so that today it consists almost exclusively of matter, while antimatter is produced only for brief moments in nuclear reactions or particle collisions in accelerators or in cosmic

» INTERVIEW

rays.

In the 1960s, it was discovered that nature is not perfectly symmetrical between matter and antimatter, but there is a very small difference that manifests itself in certain weak force driven decays. Violation of the matter-antimatter symmetry goes by the name of "CP symmetry violation", CP being a mathematical operation ("symmetry") that transforms a particle into its corresponding antiparticle. "CP violation" is now a well-known and well-studied phenomenon but, based on cosmological considerations, we know that the CP violation effects we observe are not sufficient to explain the level of matter-antimatter asymmetry in the current universe. There must therefore be other sources of asymmetry related to physical phenomena which are currently unknown which, once identified, could tell us many things about the big issues still open in modern physics. LHCb was designed precisely to search for these phenomena and ultimately explain why the universe has evolved as we know it today.

To date, what pieces have you been able to put in the puzzle to explain the absence of antimatter in our universe?

Matter-antimatter asymmetry has been observed and studied in many different particle decays such as those of K mesons or B mesons, and the theory of elementary particles, the Standard Model, is able to accurately explain, in a coherent theoretical context, all the experimental observations. Nevertheless, as I explained earlier, this is not sufficient to explain the current structure of the universe. LHCb is seeking in many different ways to highlight possible new sources of asymmetry, for example by comparing many different decays or looking for CP violation in phenomena where it is not predicted by the theory, such as in the decay of the charm quark.

The search for "new physics", for phenomena that are not described by the current elementary particle theory, the Standard Model, is among the goal of all LHC experiments. How is it going?

The absence of clear evidence of new particles in the numerous analyses carried out by the ATLAS and CMS experiments makes the search for new physics difficult but, at the same time, increasingly fascinating. We know that there must be something new and unexpected, since the Standard Model cannot explain very significant phenomena such as dark matter or matter-antimatter asymmetry, but we do not have a clear reference theoretical framework. This opens up a phase of great scientific creativity where new technologies, new experimental techniques and increasingly refined data analysis methods are combined with new theoretical models. Compared to the recent past in which theory drove experiments, leading, for example, to the discovery of Z and W particles or the Higgs boson, now the situation is reversed and large experiments are exploring a wide spectrum of possible signs of new

» INTERVIEW

physics.

LHCb, for its part, is contributing to this "creative phase" by studying decays and extremely rare processes with ever greater accuracy, in search of some small clues revealing the presence of something new and unexpected.

What are the main differences between LHCb and the other LHC experiments?

The first obvious difference is the structure of the detector. While ATLAS and CMS are large cylinders consisting of subsequent layers of detectors coaxial with the LHC beam, LHCb has the typical structure of a "fixed target" experiment, with the detectors positioned perpendicularly and very close to the proton beam. This particular geometry is due to the fact that the particles containing b and c quarks, the main study subjects of LHCb, are produced in collisions between protons at an angle, on average, very small in relation to the beam direction.

The second significant difference is that, while ATLAS and CMS attempt to observe new particles directly, LHCb studies the effect they may have on physical quantities such as decay ratios or the matter-antimatter asymmetries in particularly rare B meson decays. This indirect research method exploits the fact that, in accordance with quantum mechanics, in the decay of a B meson particles even heavier than the meson itself can be created and re-absorbed in very short time ("virtual" particles) these particles, although not directly visible, affect the value of the physical quantities related to the decays we are studying. When the measured value and the theoretical value of one or more of these quantities differ significantly, there is clear evidence of the presence of new particles. The indirect method provides sensitivity to the presence of new particles with a mass even higher than that accessible to direct observation.

At the beginning of July, the discovery of X_{cc}^{++} , a particle known but never observed before, was announced. Does it open any new perspectives?

Observation of the new X_{cc}^{++} particle has had significant resonance not only in the media but also, and above all, in the scientific community. Particles in which two or more "heavy" (b or c) quarks bind together allow very accurate theoretical predictions of properties such as their mass or average life. The main instrument for these predictions is the study of strong interactions which link quarks together, for example in protons and neutrons, and which are therefore the basis of the building blocks constituting atomic nuclei and hence the world as we know it on a daily basis. The various theoretical models that describe how quarks and gluons are bound together to form so-called hadrons (such as, for example, neutrons and protons) can be tested very accurately by comparing the predictions of the characteristics

» INTERVIEW

of particles such as the Xicc++ with experimental observations.

The observation of a particle like the Xicc++ paves the way for an entire research area in which many other "sister" particles of the Xicc++, or other similar particles that contain a b quark, can be observed and studied, allowing a very strict comparison with the theoretical models, confirming some and confuting others.

Simplifying somewhat, we can say that the Xicc++ and other similar particles will constitute an exceptional laboratory for studying strong interactions.

What does the role of head of a broad and culturally diverse international collaboration such as that of LHC experiments require?

Having just started, I still have many things to learn. Nevertheless, I believe that there are at least two fundamental things to keep in mind when leading a large international collaboration. First of all, the word "collaboration" indicates a work method that requires shared intentions and the desire to work together to achieve important results. Those who lead a scientific collaboration have the responsibility to maintain this spirit and to harmonise the work of all colleagues, taking into account the peculiarities of each. The other responsibility I believe to be fundamental, especially in the scientific sphere, is that of promoting and facilitating the development of new ideas as much as possible: this means having utmost respect for all collaborators and promoting a climate in which even the slightest form of discrimination based on gender, age, cultural or ethnic background, etc. is banned. I believe that the ability to listen to people and to understand and enhance the peculiarities and expectations of each, especially of the younger ones, are the main requirements for those who lead a large collaboration like LHCb. ■