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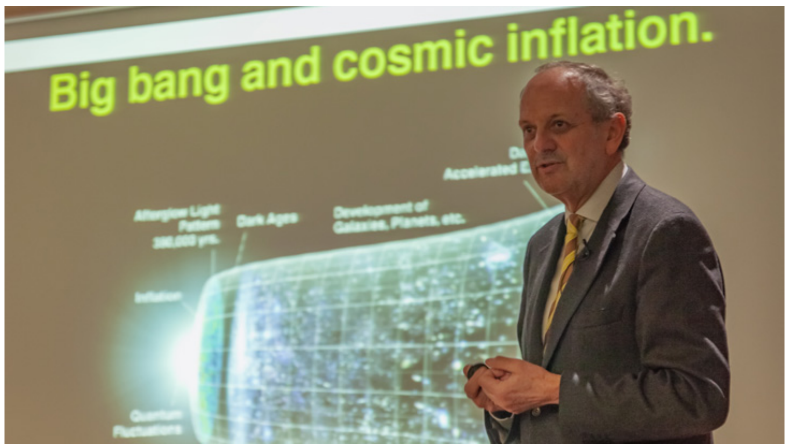
I Do not See Europe Aware of the Need to Lead in High Energy Physics



Interview with Italian physicist Guido Tonelli, one of the persons responsible for the discovery of the Higgs boson, on his visit to the UAB to give a conference at the Faculty of Sciences. Professor of Physics at the University of Pisa, Tonelli served as spokesperson of the CMS experiment at CERN, one of the two large international scientific collaborations, together with ATLAS, searching for experimental proof of the existence of the Higgs boson.

Guido Tonelli was present during the whole process of building the LHC accelerator up to the appearance of the first evidence of existence of the Higgs particle. His fundamental role in the discovery has earned him several awards, such as the Fundamental Physics Prize (2012) and the Enrico Fermi Prize of the Italian Society of Physics (2013). Presented by the director of the Institute of High Energy Physics (IFAE) Matteo Cavalli Sforza, Tonelli gave a conference entitled “The Imperfect Birth of Things” on 7 February at the UAB Faculty of Sciences.

Can we be sure that the Higgs boson really has been observed, or are there still other possibilities compatible with the experimental results?

On the one hand we are sure that there is a particle at 125 GeV, wich looks exactly like the Higgs boson. We are sure because we have seen this signal again in the new data that we have collected, so LHC has run at 7.8 TeV in 2010, 2011 and 2012, then it stopped for two years, and then we started again at 13 TeV, another energy. And the signal appeared again. That means that it will stay there, it will last forever. What is not clear, and this gives us perhaps the opportunity to discover new things, is if it is really elementary or not. The Standard Model foresees that the Higgs boson is an elementary particle, but if we discover in the future that there is an internal structure, this will open another world. This is what we are actually working very hard on.

So the Higgs boson is the ending but also the beginning of something in Physics.

Both. On one hand, it closes a hunt that lasted almost 50 years. So we have closed the chapter, we know that this is the mechanism that nature has chosen to break the symmetry between electromagnetic and weak interaction. Therefore, we know this particle is playing a big role in the composition, in the deep structure of our Universe. But now, this is history. Now we are focused on the future. With this new particle we have another powerful tool to investigate further mysteries of nature. The Higgs boson plays a special role in this game. It assigns mass to all known particles and also to particles that have not yet been discovered. So our secret hope is to be able to investigate the properties of the Higgs boson to such a level of detail, with such precision, that we might be able to understand and discover any anomaly. If we discover an anomaly in the properties of the Higgs boson, which are extremely well predicted by the Standard Model, the current theory of matter, that anomaly would mean that there is something else. So we might use the Higgs boson as a tool to make additional discoveries.

Is there any experimental evidence of “something else”, of New Physics?

With the discovery of the Higgs boson the Standard Model is complete. There is no other particle foreseen. But in nature, we observe phenomena which requires other particles or interactions. For example, the dark matter that keeps together our galaxy, and all galaxies, and that constitutes one quarter of the entire mass of the Universe, is made out of particles whose composition is not known. We don’t know what kind of particles form dark matter. So we are looking for new particles wich are not foreseen in the Standard Model that might explain this kind of phenomena. For the moment we have not discovered these particles yet. For example, supersymmetric particles would be good candidates to explain dark matter. Unfortunately, we have seen no sign of supersymmetric particles at LHC. What could this mean? The theory is wrong, this can be solution number one, and supersymmetry is not the right description of nature. Or, our energy is not large enough. We have not been able so far to discover new particles, namely supersymmetric particles, simply because the energy of the accelerator is not large enough to produce new particles, because they could be very massive, and being so massive we do not have enough energy to produce them. So from now on the hunt is open. We know that sooner or later there will be a young student, we don’t know where, we don’t know when, who will see something happening in the data. In that moment, the entire construction of which we are so proud, the Standard Model, will fall apart. And we will have to build a new construction, a new vision of nature and matter. We don’t know when this will happen, but we know it will happen. And we really think this could be the beauty of our work. We don’t know if it will happen next week or 50 years from now, and this is really what makes our research activity extremely challenging, emotionally involving, passionate. We don’t know what nature has in store for us.

What can we expect from the LHC in the next few years?

The machine is working very well. We have to consider that we started operations only six or seven years ago. And this accelerator will last for another 20 years. So we are just at the beginning of this exploration. The plan is to produce millions, probably one hundred or two hundred millions of Higgs bosons, and for the discovery we produced just a handful of them. The goal is exactly the one I alluded before: to study in full detail all the properties of these new particles looking for an anomaly, something strange and not predicted by theory. Meanwile, with the high energy we have, and the high intensity that we are achieving these days – this year LHC has exceeded the record of luminosity, the intensity of the collisions - will probably have a factor of one hundred more statistics in respect to the statistics that has allowed us to discover the Higgs boson. So using this incredibly large amount of data we might have the luck of discovering something new directly, a new particle appearing in the data, now or 20 years from now; or we might discover New Physics indirectly through some anomaly in a known particle. In the Higgs boson properties, in the top quark properties, or in W and Z properties. All these heavy particles are extremely sensitive to New Physics. If there is a heavy particle around, they feel something, they act like an antenna. A very sensitive antenna to physics that we have not yet discovered. The hope that we have is that in one way or another, we are going to probably change our vision of nature and matter in the next 20 years. But this will require a lot of patience, and a lot of work.

What's next at CERN? Is there any plan for a future accelerator?

There is a worldwide discussion among the people working on high energy physics, on what will be the next step. When I was younger, we had the dream to build LHC and its detectors and it took 25 years. So the timescale of a new machine is about 20-30 years. So if you want a new accelerator in 2040, you need to start thinking and planning now. Those constructions require huge investments and new technology. This is what is happening today. We already have a collaboration of about 500 people, who are studying the new dream, the Future Circular Collider, or FCC. It is a machine with a circumference of 100, four times the 27km of LHC. Energy is 100 TeV, which is seven times the maximum energy we will have at LCH. The plan is directly to discover new particles in case we are not able to do it with LHC, and to study in detail the role of the Higgs boson at the beginning of our Universe. We have understood recently that the role that this special particle has played in our Universe might be even deeper in respect to what we thought. On one hand, it has been established that it is giving mass to elementary particles, and is breaking the symmetry between electromagnetic and weak interaction. On the other hand, there are theories that think that the assymmetry between matter and antimatter - one of the big questions we have, the fact that our world is a world of matter and that antimatter has dissapeared - has happened at a magic moment in which this boson established its field all over the universe. So we in some sense need to reconstruct this moment. But to do so, we need an energy which is factor five or ten higher in respect to LHC. This is why we are thinking on 100 TeV. With 100 TeV we could perturb the electroweak vacuum, the Higgs boson field, and try to see how it behaves, reproducing in laboratory what actually happened in our Universe at the magic moment which is one hundreth of a bilionth of a second after the Big Bang. This is the ambitious plan we have with the new accelerator and I see enthusiasm and new ideas. We are aware that we do not yet have the technology, we have to develop it. We need at least to spend 10 years to develop technology for the magnets, and the complex apparatus that will be needed, but I think and I hope that we are going to open a new big enterprise.

Is Europe leading experimental fundamental physics?

When I was young, to do high energy physics one had to take a plane and go to the United States. This was the situation in the 1970s and even early 1980s. Now the situation has changed. Now we have, at CERN, about 1,500 US scientists taking the plane the oposite way, from the United States to Europe, to do leading science. So Europe is leading the field, there is no question about it. The question I have is that if our governments, our political leaders, will be able to maintain this leadership. I see big plans for investments in this area, not from the US but mostly from China, Japan and Korea, eastern countries. China is trying to send men on the Moon, they have a spatial program and also a very agressive high energy physics programme. They want to build an accelerator of 70 Km, factor 3 in respect to LHC, and they plan to do it in the next 15 years. They want to attract the best brains in the world in this enterprise because they want to lead this field. The country that leads this field leads the tecnhnology. To develop new technologies has impact on the economy, on the political situation, and everywhere! I see in China, Japan and Korea that the political leadership is aware of this. They are aware that they need to invest in universities, in knowledge, in new facilities. And they are doing this very seriously. I don't see the same awareness in Europe. At least in the leadership of Europe, which is too divided and has no clear vision on what could be the role of Europe in the future world. A world where knowledge is the key component. So we have the leadership in this position, but I am a little bit worried if we want to maintain this leadership, because this would mean investing huge resources in this field.