Newsletter Interview

SUPER-B FACTORY AND NEUTRINO PHYSICS: AN INSIGHT INTO THE KEK LABORATORIES IN JAPAN

Interview with Masanori Yamauchi, director general of KEK, the High Energy Accelerator Research Organization, in Japan

KEK is the Japanese High Energy Accelerator Research Organization. It is one of the world's leading accelerator science research laboratories, with which INFN has a strong collaboration mainly focusing on particle physics, with the Belle II experiment, and on neutrino physics with the experiment T2K (Tokai to Kamioka), the detector Super-Kamiokande and its future Hyper-Kamiokande.

We got the chance to visit the KEK main laboratory in Tsukuba for the collaboration meeting of Interactions, the network of science communicators working for the main particle physics laboratories worldwide. During our days there, we met Masanori Yamauchi, director general of KEK, and we asked him some questions about the organization he leads, its core projects and about the collaboration between KEK and INFN.

Could you introduce us to KEK and to its history?

KEK was established in 1971, 52 years ago, as a research laboratory focused on particle accelerators. At the time, we constructed a small proton synchrotron with a circumference of 300 meters: that's how we started our first particle and nuclear physics experiments.

Afterwards, in the 1980s, we started the construction of a collider, the first collider in Japan: it was an electron-positron collider, with a three kilometers circumference, and it was called TRISTAN. This machine has been the highest energy electron-positron collider in the world for a while, its peak energy was 64 GeV, which is far below the reach of the LEP at CERN, for example, but at the time it was the highest energy machine. We tried to find the Top Quark using TRISTAN, but unfortunately this was not possible because the energy of this accelerator was not high enough to produce a particle with the mass of the Top Quark.

After this experience, we transformed the TRISTAN ring into a new machine called "B factory", its name was KEKB and it started its operations in 1998. With KEKB, we started the study of CP violation phenomena in B mesons and in their decays and we started a very tough competition with another similar experiment at the SLAC laboratory in the United States, SLAC's PEP II B Factory. At the time, we were competing a lot also with INFN, which was one of the major contributors to the SLAC's experiment. This, of course, was a tough but friendly competition: we exchanged information, and we collaborated a lot.

Finally, in 2001, we discovered the CP violation in B mesons, and this discovery led to the Nobel Prize in Physics to Makoto Kobayashi and Toshihide Maskawa in 2008. This discovery was done at the same time and independently at KEK and SLAC, in Japan and in the US, on both sides of the Pacific Ocean, and pushed the award of the Nobel Prize to Kobayashi and Maskawa. A great moment!

What happened afterwards? KEK is now hosting a cutting-edge experiment for the study of B mesons. How did you get here?

After this great success, crowned with a Nobel Prize, we proposed to upgrade the B factory machine to a Super B factory, SuperKEKB. Actually, at the same time, the researchers working on the SLAC B factory proposed to build a SuperB factory in Italy, at INFN Frascati National Laboratories. We were hence looking forward to starting another collaborative competition between KEK and INFN in the era of SuperB factories.

This did not happen, because Italy decided not to go on with the SuperB factory, due to various reasons. So, after some time, we constructed the SuperB factory at KEK and we invited the Italian colleagues to join our activity on the SuperKEKB/Belle II program. This big experiment is now successfully going on. Now, it is actually paused due to some more minor upgrades of the accelerator and detector, but it is going to restart soon, in January 2024.

For this experiment, we have established a great collaboration with Italian researchers, from INFN laboratories and divisions. Their contribution is very valuable, as they bring to the experiment the experience they accumulated in the experiment at SLAC. We are very thankful for having such a good collaboration with the Italian scientists.

What are the other main scientific efforts KEK is engaged in?

The J-PARC is a high-intensity proton accelerator complex and is now being operated by a collaboration between KEK and another institution, the Japan Atomic Energy Agency (JAEA). Another core business here at KEK are neutrinos. At J-PARC we produce neutrino beams, and we make them travel for 300 km downstream, to the Super-Kamiokande site. In this facility, we hence study the nature of neutrino. A neutrino is a very special particle that can penetrate anything, almost everything. Even the Earth can be penetrated by a neutrino without making any interactions. So, capturing a neutrino or studying the nature of neutrinos is very difficult because no matter how many neutrinos you can produce, they just penetrate the detectors without doing anything. Therefore, we use a very big detector constructed by the Institute of Cosmic Ray Research (ICRR) of the University of Tokyo, called Super-Kamiokande. It is a large water tank, weighing 50,000 tons, installed in the mountain of Kamioka, where we wait for the neutrino beams coming from our accelerator at the J-PARC Laboratory, in Tokai, which is 60 or 70 kilometers north from the KEK Main Laboratory, here in Tsukuba. Hence the name of the T2K experiment, Tokai to Kamioka.

The ICRR is now also working on the upgrade of the Super-Kamiokande detector, Hyper-Kamiokande, a new generation neutrino experiment with a much higher sensitivity. Super-Kamiokande, Hyper-Kamionde and T2K, as well, are very large international collaborations consisting of 500 researchers coming all over the world and, also for these projects, the collaboration and contribution of INFN researchers are extremely valuable.

So, on neutrino physics, the future KEK’s large effort will be Hyper-Kamiokande. What about the future of accelerator physics? What will be KEK’s main enterprise?

While we continue working with SuperKEKB and the Belle II experiment for the next ten years or so, and on a possible future of this collider experiment, we are now considering building a linear collider, the International Linear Collider accelerator (ILC). This is very big project for the construction of a 20-kilometer-long linear accelerator, where electrons and positrons are accelerated in opposite directions and collide in an interaction point.

The idea of the ILC was proposed over 20 years ago by the international high energy physics community: it is a large-scale project, and it is very expensive. Such a big project can be developed only as a global project, not only by KEK or by the Japanese government. So, we must collaborate with as many governments and institutions as possible, and we are now proposing people to get together to discuss how we can do this. This is very challenging because all the different actors have their own ideas on the future of particle physics and it's hence very difficult to get together and have a common direction. We are still having a difficult time. However, I strongly believe that the next generation particle physics experiments can be developed only within large international scientific collaborations.

Big science and big physics can also lead to the development of new cutting-edge technologies that can find useful applications in the everyday life for people and for society. On which technological applications are you working here at KEK?

Here at KEK, we have SuperKEKB but also a smaller accelerator, called compact ERL, and we also have a R&D facility for ILC. What’s common among these facilities is the superconducting accelerator technique.

We developed a good expertise in superconducting accelerators which can have various industrial and medical applications. One example is that using high intensity electron beams from superconducting accelerators, we can produce technetium 99 that is a very important element for medical diagnosis, for example to look into the bones and detect a cancer in the very early stages. So far, the technetium 99, used for this kind of diagnosis, has been produced in large power reactors. However, the number of power reactors in the world is decreasing and it is now difficult to produce a sufficient amount of technetium 99 only with the reactor method. Therefore, we are now developing a new method to create technetium 99 using particle accelerators, with high intensity electron machines. We have now achieved some early-stage success and we are hence planning to further increase the intensity of to produce sufficient amount of technetium to meet the needs of medical diagnosis.

Another example is we are now working on an EUV FEL, an extreme ultraviolet free electron laser: this is a sort of a laser based on an accelerator emitting very short wavelength light in the region of extreme ultraviolet. This FEL can be used in next generation lithography, when developing a next generation very high density semiconductor chip. The semiconductor industry needs a very intense light source in the EUV region and only accelerators can produce this very intense EUV light.

There are also some more examples I could list, but I focused on superconducting radio-frequency accelerators because we believe that they can have various industrial and medical applications, and we are making big efforts in this direction. Particle physics research develops cutting edge technologies to discover the secrets of the universe and often these technologies have unexpected and impactful effects on our everyday life.