Newsletter Interview

35 YEARS OF RESEARCH AT THE INFN GRAN SASSO NATIONAL LABORATORIES

Interview with Ezio Previtali, professor at the University of Milano-Bicocca and INFN researcher, director of the INFN Gran Sasso National Laboratories.

The celebrations for the 70th anniversary of the founding of INFN, which will end in September, provided the ideal setting to commemorate the foundation of many of the Divisions and Laboratories of the institute, spread throughout the country and branching out throughout the national university system. Among the structures that celebrated such milestones were the INFN Gran Sasso National Laboratories, a unique scientific reality and international benchmark for the field of neutrino physics and the search for dark matter, as well as a cutting-edge technology development center, which blew out 35 candles on 17 June.

Founded in the late 1970s from an idea of Antonino Zichichi, then President of INFN, the Gran Sasso National Laboratories were established in 1986, when, alongside the tunnel connecting the Teramo and Aquila sides of the Gran Sasso massif, excavation work on the three rooms that constitute its underground infrastructure was completed. The start of the centre's scientific activities, on the other hand, dates back to 1987. Thanks to the 1,400 metres of rock above them, capable of shielding natural radiation, the laboratories have hosted innovative experiments of high sensitivity, such as Borexino and OPERA, just to name the most well-known, which generated fundamental results, such as the observation of the major stellar nuclear processes taking place in the Sun and detection the neutrino oscillation.

After 35 years of activity and success, the Gran Sasso National Laboratories (LNGS) continue to fulfil their role as a privileged vantage point for rare physical phenomena, and are now preparing to welcome next-generation experiments through major maintenance and upgrade works. Coordinating this exciting transition phase is Ezio Previtali, head of LNGS since 15 October 2020.

What is the evaluation of the activities carried out by the Laboratories over the past two years and what do you think have been the main scientific and non-scientific achievements from the beginning of your office to date?

Even net of the latest success achieved by the Borexino experiment(see 'Borexino obtains the first experimental evidence of how massive stars shine' (https://home.infn.it/it/comunicati-stampa-full/comunicati-stampa-2020/4198-borexino-ottiene-la-prima-prova-sperimentale-di-come-brillano-le-stelle-massive?highlight=WyJib3JleGlubyIsImJvcmV4aW5vJ3MiXQ==), ed.), there has certainly been an important evolution of the experiments involving the direct search for dark matter, as demonstrated by the recent result of the XENON detector, which continues to be a global benchmark for research in this area. This latter result was particularly significant not only from a scientific point of view, but also because it showed that the Laboratories, despite the pandemic, which forced many research centres in other countries to close down, were able to complete the construction of the experiment, to commission it, and to get it started. A success therefore to be attributed certainly to the Xenon collaboration, but also to the ability of the LNGS to be able to manage a far from simple situation as the one determined by the health emergency. In parallel, we obtained significant results from the GERDA experiment, dedicated to the observation of neutrinoless double beta decay, which completed its analysis cycle, demonstrating that the technologies developed for the apparatus make it possible to reduce the background noise to an unprecedented level and to achieve a sensitivity: these results will be a benchmark for the future. The same goes for the other experiment focusing on the neutrinoless double beta decay, CUORE, which over the past two years has verified the capability of its sensors, the bolometers, to be able to obtain measurements over the long term in a stable and continuous manner. A result, also in this case, attributable to the responsible collaboration of CUORE, but in which the Laboratories certainly played a key role.

Another point worthy of mention for its technical significance is that in these two years, even with the pandemic, we were able to complete a whole series of experimental works that had somehow had problems in their genesis. Suffice it to mention: LUNA MV , dedicated to nuclear astrophysics, whose accelerator commissioning was completed in July, and which will begin acquiring data in January; COSINUS, for the study of dark matter, whose construction is almost complete; and the two smaller experiments VIP and LIME/CYGNUS, dedicated to dark matter and violation of the Pauli exclusion principle, respectively, whose construction has been completed. The last thing to add in the review of the activities of these last two years is the entire part of interventions involving infrastructure. Indeed, we are busy on a number of new facilities: the new laboratory for low radioactivity in tunnels, STELLA, the construction of which is expected to start soon, the infrastructure that will house DARK SIDE, NOA, Nuova Officina Assergi, a clean room, already set up at the external Laboratories, which will soon be operational, and the installations of the new 3D printers for the additive manufacturing laboratory.

Let's talk about the future. Which will be the main lines of research on which the Laboratories will focus in the coming years?

In perspective, the main lines of research that will be pursued, and in which the Laboratories are already directly engaged, are those involving dark matter and neutrinoless double beta decay, with the goal of continuing to maintain leadership in both areas. In this regard, we are applying to host two of the three large next-generation experiments that will be expressly implemented for the observation of double beta decay, CUPID and LEGEND 1000, and we are also working so that the evolution of XENON, the DARWIN experiment, can also be carried out here. In addition to this, we also continue to work on research topics related to biology and geology. With respect to the latter, we have an agreement with INGV within the framework of the study of seismic events that involves the installation of a network of underground detectors. We are also discussing the possibility of using and making available our infrastructure for the needs of centres engaged in R&D activities developed in the fields of supercomputing and quantum computing. Finally, we are also involved in the aerospace sector, for which we will build an external laboratory, where we will work with Leonardo and Thales Alenia Space, which are interested in acquiring some of the material production techniques we have adopted.

From what you have said, it is clear that LNGS is considered an international benchmark technology development centre, not only for the world of physics research, but also for companies in various sectors. Which are the particular skills in which the Laboratories excel?

As far as research is concerned, I would start with cryogenics, the super cold technology, because I believe that in cryogenics, at least in the context of particle physics, the Laboratories represent a reference with expertise - exploited both in the field of dark matter research through bolometers and in that related to double beta decay - that has always been internationally recognised. The other aspect that the Laboratories excel in, and makes them a benchmark centre, is the one related to the measurement and management of radioactivity. Indeed, the ability to make measurements and develop instruments for spectroscopy makes us the world leader in radioactivity measurements. This is in addition to all the activity concerning mass spectroscopy, in which the Laboratories have developed capabilities also used in applied technology. The other area that is becoming increasingly important and in which the Laboratories are playing a leading role is that concerning the development of specific instrumentation for the experiments that need a low-level radioactivity. A case in point is the work we are doing for DARK SIDE, among the leading experiments for the study of dark matter, and which was carried out together with the Nuova Officina Assergi. Indeed, we already have several requests from other centres to work on the instrumentation and to develop other experiments elsewhere. Also setting us apart internationally is our experience in handling ultra-clean materials. On the other hand, with regards to what we can call indirect products, which are not linked to particle physics and which have been acquired as a consequence of concentration in the Laboratories of the skills mentioned above, there is certainly the activity of developing technologies for quantum computing, for which the cryogenic skills and infrastructure and the limited radioactivity guaranteed by the Laboratories are indispensable in order to try to improve the performance of qubits by increasing their latency. This is precisely where the agreement with the Fermilab *Superconducting Quantum Materials and Systems Center* (SQMSC) and the interest shown by other international entities comes in. Lastly, I would like to mention the increasing presence of the Laboratories in the field of additive manufacturing, within which we are pursuing a pioneering activity involving the use of copper, an unusual material, for 3D printing. A rather interesting development in my view, since the use of copper could

have technologically significant advantages both in the production of certain experimental components and in other areas, where copper is widely used. For this reason, we are currently expanding the 3D printing lab while waiting for new machines.

Among the major LNGS experiments is BOREXINO, which finished data acquisition in October 2021. What did BOREXINO achieve? And what will the future after BOREXINO be?

From a scientific point of view, BOREXINO certainly represented a milestone, since it provided a number of decisive results in the field of neutrinos. In my opinion, BOREXINO was in some ways the chapter that closed the story, which began 50 years ago, of the evolution of solar neutrino experiments. This does not mean, of course, that solar neutrino measurements are finished. However, BOREXINO provided and arranged the last missing building blocks to arrive at an understanding of the spectrum of stellar mechanisms responsible for solar neutrino emission, most recently the CNO cycle, the first observation of which was announced by the collaboration of the experiment in November 2020. In addition to these achievements, BOREXINO represented a fundamental technological milestone, since it must be remembered that the experiment, in its final phase, achieved levels of radio purity that were initially unimaginable, which will be a challenge for the future, since currently no one would be able to achieve such standards. BOREXINO closed its cycle in October 2021 and was emptied of the hydrocarbon used as the scintillator liquid, pseudocumene, during the first six months of this year. For the future, the Laboratories are moving in the direction of developing “green” experiments based on non-hydrocarbon technologies such as scintillators. The BOREXINO infrastructure remains an important laboratory facility, so we are already working to convert it to accommodate next-generation experiments, such as LEGEND 1000 or DARWIN. We also do not have a short-term plan at this time to contemplate solar neutrino experiments. With BOREXINO, and subsequently GALLEX and GNO, the era of the Gran Sasso Laboratories as a site dedicated to solar neutrino studies comes to an end.

Returning to the subject of the future, LNGS is involved both as a leader and partner and as a direct recipient of funds in many of the projects funded by the PNRR. Can you tell us what they envisage and what the contribution of the Laboratories will be?

Within the scope of the funds earmarked for research infrastructure, the already approved funding available to the Laboratories will be used for a substantial modernization of the underground experimental are. The strategic goal of the interventions will be to make the infrastructure suitable for hosting next-generation experiments. Works will also be carried out on the infrastructure outside Assergi.

Thanks to these resources, we would also like to work on a sustainable renovation of the common areas, developing the electricity supply part from renewable sources, optimising the insulation of the outdoor Laboratories, and taking action on the conference rooms and visitor center. In parallel with this, we will be busy with the project of the new national centre for supercomputing and quantum computing, ICSC, devisied and led by INFN, from which we will receive funds for the installation of the node dedicated to natural disasters, which will be hostesd at LNGS and on which we are already working. In addition to these main sources of funding, other funds are expected to come from two projects that are in the process of being approved: the first related to technology transfer in additive manufacturing, which will allow us to create a hub where external companies

or interested users can find advanced manufacturing methodologies on the one hand, and a place to carry out training on the other; the second expressly earmarked for the reconfiguration of the BOREXINO infrastructure for the installation of a new experiment.

LNGS turned 35 years old this year. An important milestone that demonstrates the success of the project from an international scientific perspective. On the other hand, what is the role of the laboratories at the local level and what kind of relationships bind them to the territory?

Regarding the territorial dimension, the laboratories are well recognized and acknowledged. Indeed, my experience over the past two years allows me to say that on average the laboratories, both at the level of institutions and at the level of local populations, are accepted as an important territorial reality. This depends, in my view, on those functions, which the laboratories fulfill, that have spillover effects on the territory. The first ones concern activities that have a direct impact resulting from the fact that we are solicited by the communities themselves to provide services. To give an example, we are involved in training activities through agreements with schools in L'Aquila and Teramo of various levels, to which we provide scientific and educational support. This commitment produces benefits of a different kind, because it allows us on the one hand to interact with the territory, involving and training those young people who are interested in working with us, and on the other hand to provide help to the schools that request it. In this regard, in the past year alone we have signed many agreements, and today we are actively working with several schools. On the other hand, in a context that we can define as more institutional, from what I have been able to find, the laboratories are recognized for their ability to be proactive on projects. In fact, we are often contacted by the territory, with requests also coming from Molise and Marche, to be active participants in development processes in various sectors, providing, for example, support to companies in the electronics field. Finally, based on the recent experience inherent to “Perdonanza”, an event with great symbolic value, not only religious for L'Aquila and the people of L'Aquila, I can say that the laboratories are classified as an important reality of the territory. In fact, the labs participate in an active form in the Perdonanza parade, alongside other scientific and cultural realities in the area such as universities.