# NEWSLETTER 14

*Italian* National Institute for Nuclear Physics

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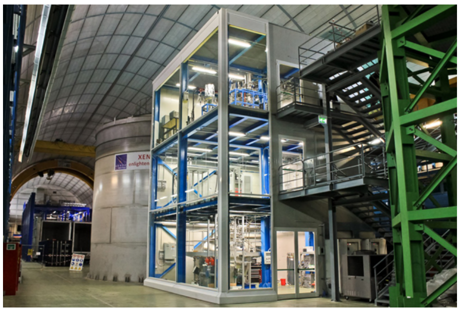
## NEWS







## RESEARCH
# XENON100 IS CLOSING IN ON DARK MATTER

For the first time, new results from the XENON100 international experiment at the Gran Sasso Laboratory of the Italian Institute for Nuclear Physics (INFN) have raised questions about a variety of models previously thought to be a possible explanation for dark matter. The study has been recently published in *Science* and the XENON100 results are soon to be published in *Physical Review Letters*.

Among the models excluded by XENON100 are some of those developed as an explanation of the signal that was first detected in 1998 and subsequently confirmed at the Gran Sasso Laboratory by the DAMA/LIBRA (DArk MAtter/Large sodium Iodide Bulk for RAre processes) experiment and interpreted as the signal of particles of dark matter. The signal detected by DAMA/LIBRA, with a seasonal modulation that is consistent with the presence of dark matter, has still not been confirmed by any experiments currently underway. To alleviate the conflict, theorists have postulated that dark matter particles preferentially interact with the electrons, a type of interaction that previous experiments were not sensitive enough to detect.

To verify this hypothesis, scientists working on the XENON100 experiment have developed a new method for analysing the data obtained and, for the first time, started looking for dark matter interactions with the electrons of the liquid xenon used as a detector. The new method of analysis should be able to detect a very clear signal of dark matter interactions with the electrons, but none have been detected.

On the other hand, the existence of dark matter, as claimed more than ten years ago, is currently the only explanation for the seasonal modulation of the signal observed by DAMA/LIBRA. In view of the results of XENON100, the search will now move beyond the traditional horizon of study in this field.

The experiment will therefore continue using a new-generation detector called XENONIT, 20 times bigger and designed to be 100 times more sensitive than XENON100, which will be ready by the end of this year. ■

## RESEARCH
## SAME MASS FOR NUCLEI OF MATTER AND ANTIMATTER

A team of physicists from the INFN working on ALICE (A Large Ion Collider Experiment), have confirmed with unprecedented precision the symmetry of a fundamental property of the nuclei of matter and antimatter: their mass. The study has been published in *Nature Physics*, the first time this journal has dedicated an article to ALICE. In the ALICE experiment, researchers were able to select a sample of one million antideuteron nuclei and thousands of nuclei of the light antihelium isotope. They then measured the difference in their mass compared to the corresponding nuclei of matter. This difference, allowing for experimental uncertainty, was found to be equal to zero.
This measurement by ALICE comes 50 years after the experiment at CERN by a group of scientists led by Antonino Zichichi. It represents a significant improvement on existing measurements of the mass difference between nuclei and anti-nuclei with a precision of 1/10000 for the anti-deuteron and 1/1000 for anti-helium.
To perform this high-precision measurement, physicists at the INFN built a detector that represents the new frontier of technology. The TOF (Time Of Flight) detector is like a giant chronometer that measures the time it takes for a particle produced in a collision to reach the detector, about 4 m away. The TOF detector determined this arrival time with a resolution of 80 picoseconds (80 thousandths of a billionth of a second). Besides confirming the existence of states of aggregate antimatter, first discovered 50 years ago, this experiment also shows that it behaves like ordinary matter. ■

## INFRASTRUCTURES
## EUROPE FOCUSES ON ESS

ESS (European Spallation Source), the multi-disciplinary research centre based on the most powerful neutron source in the world, has been recently established as an European Consortium ERIC (European Research Infrastructure Consortium). The completion of this important milestone, recently approved by the European Commission, will guarantee a more agile management of the infrastructure construction and a lower cost realization. Already included among the strategic projects in the European Strategy Forum on Research Infrastructures (ESFRI) roadmap, ESS will enhance new areas of research and application in the fields of fundamental physics, life sciences, energy, environmental technology and cultural heritage.
The construction of ESS, recently started, involves 17 countries, with Sweden and Denmark host nations. The two countries will be respectively the base of the research centre and the supercomputing facility, this last designed to manage the large amount of produced data.
Italy participates in ESS with the Ministry of Education, University and Research (MIUR) and with INFN, holding the role of Italy coordinator, the National Research Council (CNR) and Elettra Synchrotron Trieste.
The total planned investment amounts to 1.84 billion euro, the 6% of which will be from Italy, mainly (80%) as an in-kind contribution through the provision of machine parts. As for other countries, ESS will have for Italy a double strategic value: on one hand, it provides a unique opportunity for scientific research, whether basic or applied; on the other hand, a strong R&D effort will involve high technology industries, making of ESS an economic driver for the whole of Europe. ■

## DISSEMINATION
## PHOTOWALK: INTERNATIONAL COMPETITION FOR THE BEST SCIENTIFIC IMAGES

This year's edition of the international photography competition, Photowalk 2015, will be staged in September. Hundreds of photographers will have the rare opportunity to walk round physics labs around the world and take pictures of accelerators, particle detectors, high-intensity lasers, the instruments used and scientists at work. The research facilities taking part in this year's edition, organised by the InterActions collaboration, include CERN in Geneva, SLAC in California, FERMILAB in Chicago, KEK in Japan, COEPP in Australia and TRIUMPH in Canada. In Italy the competition will be held on 25 September, in conjunction with European Researchers' Night, in the unique setting of the INFN Frascati National Laboratory. A regional panel of judges will evaluate the photos taken during the laboratory walks and the winners of the national contests will then take part in the international competition. The winning entry in the Italian contest will be published in Le Scienze and on the nationalgeographic.it website. The winner of the international competition will be published in Cern Courier.
Gallery of the winning entries of the previous edition http://www.infn.it/...
For further information please write to comedu@lnf.infn.it. Terms and conditions of the competition will be published at the beginning of September on www.infn.it/comunicazione and on http://w3.lnf.infn.it. ■

# » INTERVIEW

## HILUMI, AT CERN THE BIGGEST PARTICLE PHYSICS PROJECT OVER THE NEXT DECADE

*Interview with Lucio Rossi, High Luminosity LHC project coordinator*

High Luminosity (HiLumi) LHC is the name of the ongoing project to make the Large Hadron Collider at CERN even more powerful. The aim is to extend the discovery potential of the LHC and its experiments. To do this, scientists are working to increase its luminosity to make it capable of producing even more collisions per second. HiLumi also represents a technological challenge and the project will take at least ten years to complete. We spoke about it with Lucio Rossi, the project manager.

**What is HiLumi LHC?**

The project consists of upgrading the LHC. Its aim is to increase the peak luminosity, in other words, the number of events produced per second, by a factor of 5, and its integrated luminosity, meaning the total amount of data obtained by the experiments, by a factor of 10. In technical terms, the machine and detectors are designed to produce 300 inverse femtobarns (the unit of measurement of integrated luminosity). With HiLumi we will produce 3000. This cannot be achieved simply by upgrading the machine. The experiments will also need to be greatly improved. You cannot observe something merely by producing light. The eyes must be efficient too, otherwise it's like when someone shines a torch straight in your face: you can't see anything. We are therefore working on a substantial upgrade of both the accelerator and the detectors.
Most of the work on the accelerator will be funded by CERN. The cost of upgrading the experiments will mainly be borne by associated bodies, such as the INFN, although CERN will also contribute to these.

**What stage is the project at now and what are the next steps?**

The design study is almost complete and will be ready by the end of this year. It was approved in 2011 and partially financed by the EU: HiLumi is in fact named after the European project. As well as the technical work to complete the design study, we have also started to produce the first prototypes. From now until 2017 we will work on the hardware, especially on the prototypes of the new 12 TeV magnets: these Niobium-3-

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Tin superconducting magnets will allow us to improve the LHC magnet performance by 40-50% around the collision point. Along with the magnets, another important component are the so-called crab cavities: superconducting cavities that are very special because they manipulate the beam in the transverse plane and, with the magnets, make it possible to increase the luminosity. A third fundamental element is the new generation of collimators, similar to those currently used but made of new materials. These innovative devices may also use electron beams to collimate the LHC's primary proton beam halo. Lastly, another important component are the superconducting links: high amperage superconducting cables carrying up to 100 kA so that the magnet power converters can be moved away from the tunnel to avoid radiation damage.

**Will the structure of the accelerator ring and underground experimental halls remain unchanged?**
Certainly not. HiLumi is not just a huge technological enterprise, it is also an important civil engineering project. New tunnels and new underground halls will have to be built near the ATLAS and CMS experiments. The increased use of cryogenics will require new infrastructure to house more cryogenic equipment. The new side tunnels will be about 300 metres long and will house the cryogenic systems as well as the electric and power supply plants. To give you an idea of the scale of the work involved, the civil engineering work for HiLumi amounts to 25% of that for the LHC project. These factors. considered as a whole, make HiLumi LHC the biggest particle physics project over the next decade.

**What will be the overall cost of HiLumi?**
CERN approved the project in 2014 and integrated it into the Medium Term Plan, although only three-quarters of the budget was covered. Now, in the new Medium Term Plan for 2016-2020, published in 2015, the project has been fully funded up until 2020 and the remaining funding to complete the project in 2026 has been specified. In September CERN is expected to approve the structure of the funding of the whole HiLumi project, in its five-year plan.
The total cost of the project is CHF 958 million (just over EUR 900 million). This has been calculated based on European rather than American parameters, which means the cost of materials is included but not staff expenditure (approx. 1600 man-years). The costs of the HiLumi project have been validated by a panel of auditors: in March an international board of independent reviewers accountable to CERN, not to the project management team, conducted an in-depth review of the costs and planning. The remarks we received, based on this review, have been taken on board and incorporated into the Medium Term Plan.

**What is Italy's contribution to HiLumi?**
The INFN has made an important contribution to the magnet design study, in particular through the LASA Laboratory in Milan. Scientists at the INFN Frascati National Laboratory have also contributed to the physics of the machine. The INFN and CERN have signed agreements for the new corrector magnets, the realization

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of wich is being undertaken in collaboration with the LASA Laboratory. INFN-Genoa has signed an agreement to carry out design and prototyping on the D2 dipole magnet, which is a particularly complex component to develop. Other forms of collaboration are currently being discussed.
Italian industries have also made a significant contribution, especially two companies based in Genoa, ASG Superconductors and Columbus. Columbus is in pole position to build the superconducting links, which will use a new superconducting material, magnesium diboride (MgB2). It is the only company capable of producing this material on an adequate scale to meet our requirements. ASG is already involved in the construction of the new magnet technology, in partnership with other companies: engineers and technicians at ASG are working at CERN laboratories in order to learn about the technology (and in turn contribute with their important know-how). This will allow them to acquire the necessary skills in order to take part in tenders. Then there is Tosti, based at Castel del Piano near Grosseto, which supplies specially profiled composite materials for use in the construction of the magnets. Tosti is also investing in new technologies for superconducting radio-frequency cavities. Several other firms are on track to build other components of HiLumi.
Italy is the third-largest contributor, after the UK, which did not take part in the LHC project, and France. The UK has invested a great deal in the HiLumi design study, which has seen the participation of five British universities. When research institutes commit resources to a project, industry always follows close behind. The INFN is a good example of this mechanism. The INFN is regarded as a major partner in the development of both the detectors and the accelerator: having facilities spread across the country, as in the case of the INFN, fosters differentiation, and this is the real strength of the INFN.

**What does the future hold for HiLumi?**
HiLumi has two goals: one physical, and one technological. In other words it is a project to exploit the full capacity of the LHC: in practice, it will extend its life with expenditure accounting for 25% of the LHC budget. The second goal of a project like HiLumi is to develop new technologies. The LHC has completed the technological developments initiated by the Tevatron programme. In HiLumi, we are using Niobium-3-Tin something new and never used so far in accelerators: we need to build 40 large magnets, which will represent 2-3% of all the LHC's magnets and will be about one kilometre long. Unlike the LHC, which was a large-scale project, this one is medium-sized, leaving us room to "experiment" (always within margins of safety, as with any machine that must "produce"): with HiLumi we hope to achieve a technological leap forward.
The new components will be installed in 2024 and it will take two years to complete the work: then HiLumi LHC will work for about ten years, until the mid 2030s and will probably continue to be operational until 2040. It is a perfect bridge-project, conceived to last 25 years, until we have built the big new next-generation accelerator, which we have already been discussing for some time. Short-sightedness gets you nowhere in this sector. We have to be far-sighted. These are the timescales involved in high-energy physics, major basic research projects of the type that eventually revolutionise science and technology. ■

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### LASA, EXCELLENCE IN THE TECHNOLOGIES FOR ACCELERATORS AND APPLIED SUPERCONDUCTIVITY

The INFN LASA (Laboratory of Accelerators and Applied Superconductivity) facility in Segrate, near Milan, was established almost 30 years ago and is an internationally recognised centre of excellence for particle accelerator technology. The first Italian superconducting cyclotron, first in Europe and third in the world, was built at LASA: since 1994 it has been committed to the Southern National Laboratories of INFN in research and important applications to medicine. In developing advanced technology for superconductivity, radiofrequency systems, cryogenics and high-intensity magnetic fields production, the laboratory has become a centre of outstanding expertise in the field of accelerators, its expertise being channelled into studying innovative technology for major international particle physics projects. In this frame, the primary mission of LASA is the development of superconducting systems for particle acceleration (radio frequency cavity) and for steering the beams (magnets).
Fundamental is the contribution to the success of the LHC. Thanks to LASA's activities, the first prototypes of the accelerator's dipole superconductors and the toroidal magnet of the ATLAS experiment (the LHC's biggest detector) were developed. The laboratory also supplied and certified 50% of the superconducting cable and made the superconducting coils for the experiment. Now, with the MAGIX (Innovative MAGnets for future accelerators) project, LASA stands at the forefront in the development of technologies for future LHC projects. MAGIX involves the design, construction and cryogenic testing of prototypes of superconducting magnets for interaction points under the HiLumi project, the future high-luminosity accelerator that will follow the LHC's final phase of activity.
Among the research efforts in which LASA is involved, the study of superconducting radio-frequency (SRF) cavities for accelerators is certainly one of the most promising. The laboratory coordinates the Italian participation in XFEL (European X Free Electron Laser), the European infrastructure based on a powerful X-ray source (nowadays in an advanced construction phase) which will be operative in Hamburg starting from 2017, available to scientists worldwide for research activities and applications,

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in physics, biology, medicine, material science and other fields. Jointly with the national industry, LASA is responsible for the implementation of half of the 800 superconducting accelerator cavities for electrons, almost the half part of the cryogenic modules containing them and the charge control system to increase the current of the beam. Indeed, also in the production of coherent X-radiation, the research group on SRF cavities is an international reference point for the production of photo-cathodes for electron beams sources with very high brightness, which are provided to the major infrastructure active worldwide in this field.

LASA has also a fundamental role in the design and development of the superconducting cavities for protons beams acceleration, for the European project ESS (European Spallation Source), the most powerful neutron source for basic and applied research in the world, under construction in Lund, Sweden, to be operative in 2019.

Over the years, the skills acquired have led LASA to the development of many applied physics and technology transfer activities. Among these, its worthwhile to list the development of linear compact accelerators (3 GHz) for medical applications (the first prototype, called LIBO, is exposed at the Globe of Science and Innovation, at CERN) and the collaboration in the design and construction of the accelerator cavities for the National Centre for Oncological Hadrontherapy (CNAO), in Pavia.

At present, as a partner of the European project ELI (Extreme Light Infrastructure), LASA deals with the application of laser accelerators to medicine, nuclear physics, inertial fusion, as well as to the advanced diagnostics of materials, through the development and characterization of proton beams produces by high power lasers.

Collaborations are also effective in the field of radionuclides, for the commissioning of the high intensity cyclotron SPES (Selective Production of Exotic Species), currently being installed at the INFN National Laboratory of Legnaro. The same laboratory also collaborates with the radiochemistry laboratory of LASA in the application of particle accelerators to the medical diagnostics and the metabolic radiotherapy.

Moreover, LASA carries out nano-toxicological studies on the environmental pollutants, in collaboration with the Applied Nuclear Energy Laboratory (LENA) at the University of Pavia.

In conjunction with the Scientific Degrees Project of the Italian Ministry of University and Research, LASA is finally involved in dissemination activities about the environmental radioactivity, through the installation of radioactivity measurements laboratories in schools. ■

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