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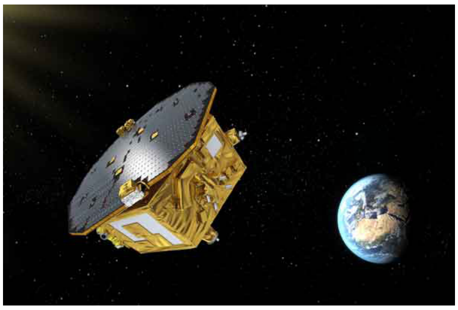
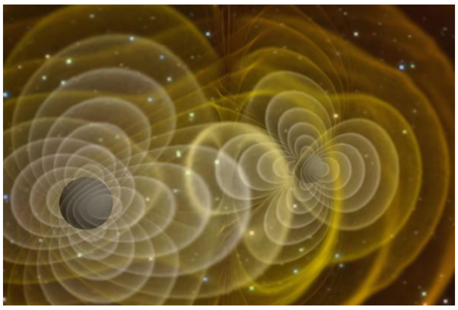
Italian National Institute for Nuclear Physics

NEWS



SPACE
LISA PATHFINDER SHOWS THE WAY

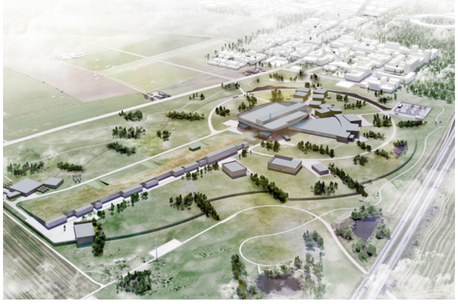
In orbit since January 2016, 1.5 million kilometres from Earth in the direction of the Sun, the LISA Pathfinder mission in just a few months has achieved its goal, demonstrating with an accuracy greater than expectations the technological feasibility of building a gravitational wave space observatory. The probe, built by ESA with the fundamental contribution of the Italian Space Agency (ASI), of INFN and of the University of Trento, was designed to test the technologies required for construction of the future eLISA observatory, a triangle of satellites connected by laser beams, 1 million km distant from each other and in orbit around the Sun, at 50 million km from Earth. The first two months of scientific activities of LISA Pathfinder show that the test masses on board the spacecraft, two 2 kg and 46 mm side gold-platinum cubes, are maintained in perfect free fall, undisturbed by other external forces, such as those due to solar wind or the Sun's radiation pressure. Substantially motionless with respect to each other, the two masses have a relative acceleration of less than ten millionths of a billionth (10^{-14}) of the acceleration of gravity on Earth. The results were published in June in the journal Physical Review Letters. ■



RESEARCH

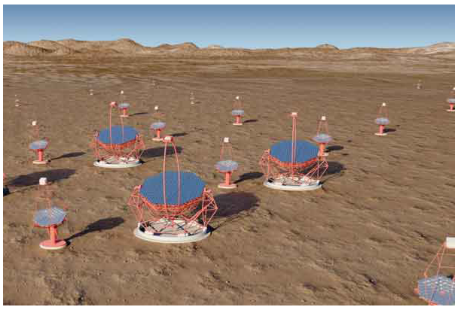
GRAVITATIONAL WAVES DETECTED FOR THE SECOND TIME

Observation of a second gravitational wave event was announced during a joint press conference by the scientists of the LIGO and VIRGO scientific collaborations, in which INFN is taking part. The tiny ripples in the spacetime fabric, predicted by the General Relativity of Albert Einstein a century ago, have been recorded for the second time, again during the first period of data acquisition, by the twin Advanced LIGO interferometers, in the United States. As with the first detection, these gravitational waves were produced by the merger of two blacks holes, a process that dates back to 1.4 billion years ago. This event nevertheless has different characteristics to the first because the black holes are lighter than those of the previous signal and therefore it was possible to follow the process for a longer period of time, well characterising the system. The waves measured in this second observation refer to the last 27 orbits that the black holes, of mass equal to 14 and 8 solar masses, made while "spiralling down" around each other before merging and forming a more massive single black hole, with mass equivalent to 21 solar masses. The energy released in the form of gravitational waves is therefore equivalent to approx. one solar mass. After opening new scientific horizons with the first historical gravitational wave observation, announced in Febraury 2016, this new measurement confirms that we have truly entered the era of gravitational astronomy. ■



INTERNATIONAL COLLABORATION
FROM THE SOUTHERN NATIONAL LABORATORIES THE FIRST PLASMA FOR ESS

The first plasma in the proton source for the *European Spallation Source* (ESS), which is under construction in Lund, Sweden, has been produced. The result was achieved at the INFN LNS Southern National Laboratories, which from the outset have occupied an important role in the European partnership engaged in the project and have become the leader in the implementation of the Warm Linac, the first component of the heart of the ESS particle accelerator. The *European Spallation Source* will be a multidisciplinary research centre (from life sciences to energy, from environmental technologies to cultural heritage and fundamental physics) based on the most powerful neutron source in the world. It represents one of the largest research projects at the international level, both in terms of financial investment (over 1.8 billion euros), as well as number of scientists and engineers involved. ESS involves 17 European countries, including Italy. INFN is participating, as well as with LNS, also with LNL Legnaro National Laboratories, the Turin section and the LASA (Accelerator and Applied Superconductivity Laboratory) in Milan. ■



INFRASTRUCTURES
ITALY, WITH BOLOGNA, AWARDED THE HEADQUARTERS OF CTA

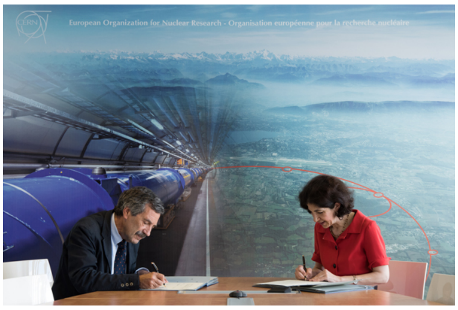
Bologna has been chosen as the headquarters of the Cherenkov Telescope Array Observatory (CTA Observatory), and Berlin as the headquarters of the Science Data Management Centre (SDMC). CTA is part of the ESFRI roadmap indicating the research infrastructures of primary interest for Europe, and this is the first time that Italy has been awarded the headquarters of an ESFRI project. The decision was taken by the CTA Board on the basis of evaluation criteria that included infrastructures, services and accessibility. The headquarters will be on the premises of INAF, the National Institute of Astrophysics, in a new building shared with the Department of Physics and Astronomy of the University of Bologna. SDMC, on the other hand, will be located in a newly built complex on the campus of the Deutsches Elektronen-Synchrotron (DESY), in Zeuthen, near Berlin. CTA is the project for the construction of the largest gamma ray telescope in the world. Italy is participating with INAF and, since 2013, with INFN. ■

SPACE

FERMI WILL CONTINUE TO OBSERVE THE SKY UNTIL 2018

The Fermi gamma ray space observatory, in orbit since 2008 and built and led by a large international collaboration in which Italy is participating with the Italian Space Agency (ASI), INFN and the National Institute of Astrophysics (INAF), will continue its exploration of the universe until 2018, with a scientific program that reinforces the issues of astroparticle physics and joint observations with other observatories. NASA announced so on 9 June at the conclusion of the Senior Review 2016, the procedure for the assessment of space missions in activity. The data collected by Fermi over the years has revolutionised our understanding of high energy cosmic radiation, bringing us information on some of the most turbulent and complex systems in the universe, capable of accelerating particles to ultra-relativistic energies in extreme gravity and magnetic field conditions.

The possibility of performing multi-messenger astronomy represent a key point of the proposed extension of the operations presented by the Fermi group and approved by NASA. The goal is implementing simultaneous observations of gamma radiation with Fermi and of other cosmic messengers with the most recent charged radiation observatories, such as AMS-02, DAMPE, neutrino observatories, such as IceCube and KM3NeT, and gravitational wave observatories, such as LIGO and VIRGO. ■



INNOVATION
CERN-INFN AGREEMENT FOR A NETWORK OF BUSINESS INCUBATION CENTRES (BICs)

CERN and INFN have signed an agreement for the development of an Italian network of *Business Incubation Centres* (BIC), coordinated by INFN, which will have the objective of creating new business opportunities starting from the technologies developed by physicists and engineers at CERN. The agreement was signed in Geneva on 16 June by Fabiola Gianotti, Director General of CERN, and Fernando Ferroni, President of INFN. The Italian network is part of the new international network promoted by CERN which to date involves 9 countries and supports 12 incubators, with applications ranging from biotechnology to energy and materials science. The Italian BIC network will be called *Research to Innovation* (R2I) and was created with the intent of supporting technology transfer in Italy, promoting the development of innovative products and services, starting with frontier technologies stemming from fundamental research in high-energy physics. Recipients of the initiative are businesses, spin-offs and young hi-tech companies willing to focus on innovation and technology to accelerate their business. ■

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THE GLOBAL EFFORT TO STUDY ARTIFICIAL NEUTRINOS RESTARTS IN THE USA

Interview with Sergio Bertolucci, from 2008 to 2015 director of research at CERN, today INFN coordinator of DUNE (Deep Underground Neutrino Experiment)

Following the closure of the SLAC (Stanford Linear Accelerator) PEP-II and Chicago Fermilab (Fermi National Accelerator Laboratory) Tevatron accelerators - resulting in the confluence of many American physicists towards the LHC accelerator at CERN - the US has redefined its particle physics research strategy. The research programme, scheduled until 2024, is included in the P5 (Particle Physics Project Prioritization Panel) Report and envisages the assignment of high priority to neutrino physics and re-launch of the Fermilab in Chicago, home of the most intense neutrino beam in the world.
With the Sanford Underground Research Facility, in South Dakota, Fermilab is one of the two infrastructures on which the LNBF (Long Baseline Neutrino Facility)/DUNE project is based and whose overall character is well represented by the number of countries, 27, involved in its design. The giant underground LNBF laboratory will be built to house DUNE, the world's largest experiment with international governance to study the properties of neutrinos. Presented for the first time in January 2014 to the Fermilab Committee by the then director of research at CERN, Sergio Bertolucci, LNBF/DUNE envisages laying the foundation stone by 2017 and the start of experimentation in 2024. In 2015 Italy, represented by INFN, through the Ministry of Education, Universities and Research, signed a technical cooperation agreement with the DOE for research at Fermilab. Bertolucci is currently coordinating the Italian physicists, belonging to INFN, engaged with DUNE in neutrino research.

What is the basis for this ambitious global neutrino programme?
The main point of contact between the American P5 Report and the global strategy for particle physics is the recognition that particle physics is the most globalised field of science currently in existence. The global strategy in this research area is in fact based on two considerations which represent the current situation: no geographical region in the world can imagine doing particle

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physics research without contemplating collaboration with other regions; it is also necessary that each region focuses on a flagship project with international involvement.

CERN has played a key role in the genesis of the LNBF/DUNE project.
The great innovation introduced by the LNBF/DUNE programme is that, for the first time, the US has adopted a modus operandi, which is typical of CERN. CERN has always acted as a host laboratory and collaborated with other European and worldwide research institutions, basically providing the infrastructure, but the experiments are independent entities whose governance does not depend on CERN. For the first time in the history of American research, the US has agreed to make available the infrastructure for an experiment with international governance in which the DOE is taking part but is not the main leader. CERN, on its part, has decided to cooperate and support Fermilab in the implementation of the infrastructure part, providing, for example, the giant cryostats for the underground laboratory, for the design and construction of which it has a European patent. Two years ago, CERN also launched a prototype engineering platform, the neutrino platform, which will be a point of reference for the European community engaged in neutrino research, for all the detector prototype construction and testing activities. The project has led to the creation of a gigantic experimental area: here the cryogenic technology and the detector prototypes (single-phase and two-phase), which will constitute the four DUNE detectors, will be tested.

Is it currently worthwhile focussing on neutrino research? Is it a field that can compete with the high-energy physics?
We have still understood very little about neutrinos. Until a few years ago, for example, we thought that they had no mass, then we discovered that they oscillate and, therefore, must have mass. We still do not understand precisely their nature: they could be Majorana neutrinos, coinciding with their antiparticle, or Dirac particles, distinct from their antimatter counterpart. And neutrinos could in fact be the origin of the asymmetry between matter and antimatter in the universe. Studying the mixing mechanisms of neutrino masses is also essential to complete our knowledge of particles. For example, we know in all probability that it is not the Higgs Boson that gives mass to neutrinos. One of the fields in which the Standard Model, the current theory of particles and their interactions, has been put to the test and presents critical issues is precisely neutrino physics, a complementary aspect, therefore, to the physics that we study with the LHC accelerator.

What are the scientific objectives of LNBF/DUNE? How can its results open a path on new physics?
The programme basically envisages two main goals: measuring the neutrino mass hierarchy and measuring the violation of symmetry between matter and antimatter (CP violation). As regards the mass of neutrinos, we only know that the second stage of neutrinos is heavier than the first. But

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we do not know if the third is the lightest or the heaviest of the three (normal or inverted hierarchy). This has many implications and can give important indications on the scale of CP violation, on the neutrino mixing mechanism.
Measuring CP violation, on the other hand, helps us to understand how the original matter-antimatter asymmetry was produced. As in the case of quarks with the CKM (Cabibbo-Kobaiashi-Mascawa) matrix, mixing of neutrinos is described by the PNMS (Pontecorvo–Maki–Nakagawa–Sakata) matrix, an equivalent which provides the transformation probability density. In the terms of both these matrices there are terms that indicate a CP violation and while in the case of quarks the violation is too small to justify the asymmetry between matter and antimatter, in the case of neutrinos, if this violation is large enough, it could account for the asymmetry. Calculation of the parameters of this matrix, moreover, could reveal information on new physics, on the existence of new particles, such as sterile neutrinos.

In the last 7 years you played the strategic role of director of research and computing at CERN. What benefits can the largest particle physics laboratory in the world derive from the collaboration in neutrino research?
First of all, the advantage is cultural. A mistake not to made in fundamental research is to believe that the road you are following is the right one. It is not possible to determine a priori which is the right road and it is always necessary to keep several paths alive.
There are at least two other reasons of interest. One is to maintain, within the community, a high ability to study different things. The other is a matter of research policy: if we were not to help the American researchers, we would force the United States to focus solely on their line of research and we would no longer be able to rely on the US contribution to the LHC. In general, it is very dangerous to concentrate all research in one place; only in turn supporting the American programme can we achieve a fruitful balance.

With INFN and the experiments at the Gran Sasso National Laboratories, Italy has a long tradition of experimental research on neutrinos. Among the big detectors playing a role in this field is ICARUS, a instrument that will be soon installed at Fermilab. Is it still a cutting edge technology today?
What we are exporting with ICARUS is liquid argon technology, the same that will be used for DUNE, but with much larger detectors. DUNE will in fact be hosted in a former gold mine with more than 550 km of tunnels, up to 2500 m deep. The laboratory will be built at a depth of 1550 m and will consist of 5 large rooms, one of which dedicated to hosting the service infrastructures, while the other 4 will each host a 10,000 active ton liquid argon detector, equivalent to 17,000 actual tons. ICARUS is smaller: it's a 600 ton detector, now being updated at CERN, before being sent to Fermilab. Here, meanwhile implementing the LNBF laboratory and the DUNE detectors, ICARUS will

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be used for a short baseline experiment with a neutrino beam produced by the Fermilab booster ring: an experiment entirely contained in the laboratory to verify the anomaly observer by the Liquid Scintillator Neutrino Detector experiment, at Los Alamos (LSND anomay). The phenomenon, not yet been explained, may be attributable to experimental errors or to the existence of sterile neutrinos. Thanks to ICARUS, the experiment will be repeated in order to remove any possible systematic errors. Experimentation with ICARUS at Fermilab will also be a training ground for young physicists and for development of the software of the new experimental technologies useful for the construction and management of DUNE. ■

» FOCUS ON

PAMELA: COSMIC RAYS OBSERVED FROM SPACE

15 June 2016 marked the tenth anniversary of the PAMELA (*Payload for Antimatter Exploration and Light-nuclei Astrophysics*) satellite detector, the space observatory for the study of cosmic rays, currently in orbit at 560 km above the Earth. Launched in 2006 with a Soyuz rocket from the Baikonur base in Kazakhstan, included on board the Russian satellite Resurs-DK1, for all this time PAMELA has been acquiring data and obtaining fundamental results. The result of an Italo-Russian collaboration also involving Germany and Sweden, the mission is led by INFN and supported by the Italian Space Agency (ASI).
Certainly among the most significant and promising scientific contributions of the mission, the first measurement of high-energy positron and antiproton streams has over the years enabled a new field of investigation on dark matter to be opened. Great interest was aroused, in particular, by the excess of positrons detected by PAMELA and published in Nature in the first half of 2009. Various explanations have been advanced by theoretical physicists in the more than 1,400 articles subsequently published. Contributions from the annihilation of dark matter or from pulsars, or changes in the propagation models of cosmic rays in the Galaxy have been postulated. Noteworthy were also the results of the measurements performed on proton and helium nuclei streams, i.e. almost all cosmic radiation, up to one billion MeV and published in Science in 2011. PAMELA for the first time demonstrated that these particles have slightly different energy spectra between the two species and have a change of slope at high energies. This data has shed new light on the mechanisms of production, acceleration and propagation of cosmic rays in our Galaxy. Among the results that have aroused great interest, also outside the scientific community, is the unexpected discovery of an antiproton belt around the Earth. Finally, the latest experiment data, published in Physical Review Letters on 13 June last, demonstrate for the first time with extreme clarity the effects of solar activity and the magnetic polarity of the Sun on cosmic rays, also providing unique information on heliosphere mechanisms.

» FOCUS ON

PAMELA is conducted by an international team, led by INFN and with the support of the Italian Space Agency, consisting of the INFN Sections and Departments of Physics of Trieste, Florence, Rome Tor Vergata, Naples and Bari, the Frascati National Laboratories, the IFAC Institute of the CNR, the NRNU MEPhI and the Fian Lebedev in Moscow, the Joffe Institute in St. Petersburg, the University of Siegen in Germany and the *Royal Technical Institute* in Stockholm. The Russian Space Agency also built the Resurs-DK1 satellite and the Soyuz rocket. The individual parts of the instrument were built in the various laboratories with the support of numerous companies, especially Italian. Iintegration of the instrument prior to launch took place in the laboratories of the INFN section and Department of Physics of Rome Tor Vergata. ■

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