NEWSLETTER 17

Italian National Institute for Nuclear Physics

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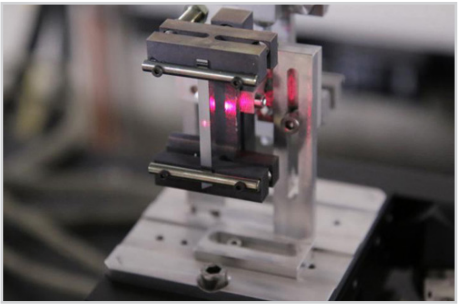
NEWS

INTERNATIONAL COLLABORATION
ITALY-ARGENTINA ALLIANCE STRENGTHENED FOR RESEARCH IN BASIC AND APPLIED PHYSICS

Two important steps taken in recent days by Italy and Argentina intensify the existing cooperation between the two countries in the field of nuclear and astroparticle physics.
In Buenos Aires, representatives of the Comisión Nacional de Energía Atómica (CNEA) and INFN have signed a cooperation agreement for research in nuclear, particle and astroparticle physics. The agreement envisages scientific and technological cooperation in basic and applied research activities and the development of technology transfer initiatives for advanced computing, the development and application of particle accelerators and nuclear medicine. In particular, the agreement will allow the fruitful cooperation in place between CNEA and INFN Pavia on research in the field of BNCT (Boron Neutron Capture Therapy) - for cancer therapy - to be intensified, facilitating the exchange of young researchers.
A second important commitment has been taken by INFN, and by the main research agencies and institutes worldwide, in the study of high energy cosmic rays. At the Pierre Auger Observatory in Malargue, the largest and most important cosmic ray observatory in the world, the refinancing of the project for the next ten years has been signed. The new operational phase of the observatory, renamed AugerPrime, has as its primary objective the investigation of the composition of cosmic rays produced at the highest energy levels of the entire visible universe. This will provide information on collisions between elementary particles at energy levels much higher than those achievable in large accelerators, such as the LHC. ■



RESEARCH
FROM ITALY THE BENT CRYSTALS THAT "CLEAN" THE BEAMS OF THE LHC

CERN in Geneva, UA9 international cooperation. Thanks to the use of innovative crystals, partly implemented in Italy by INFN and partly in Russia, at the Petersburg Nuclear Physics Institute (PNPI), the UA9 researchers have obtained a world record, "channelling" with a bent crystal a particle beam at 6.5 TeV, the energy at which protons are accelerated in the Large Hadron Collider (LHC). The aim of the research is to allow an increase in the number of particles accelerated in the LHC, developing an efficient beam "cleaning" technology, thanks to the collimation with crystals. The development of technologies useful in improving the performance of the LHC and, in particular, its luminosity (the density of colliding particles in the beams) is of great interest in the High Luminosity LHC (HiLumi) project, under development at CERN, with the goal of increasing the potential for discovery of experiments in operation at the accelerator.
The UA9 international cooperation includes, in addition to CERN and INFN, the LAL (*Laboratoire de l'Accélérateur Linéaire*) laboratory - Orsay Paris, the Imperial College London, the Russian laboratories PNPI, the IHEP (Institute for High Energy Physics) in Protvino and the JINR (Joint Institute for Nuclear Research) in Dubna. The implementation of the bent crystal in Italy is the result of a joint effort between the INFN and the Sensors and Semiconductors Laboratory of Ferrara University, dedicated to the development of advanced crystal processing techniques. The result was obtained in collaboration with the Large Hadron Collider (LHC) Collimation Group and the Engineering Sources, Targets and Interactions (EN-STI) Group at CERN ■

INTERNATIONAL COLLABORATION
INFN ON A VISIT TO CHINA WITH MINISTER GIANNINI

The China-Italy Science (CAS), Technology & Innovation Week was held in November. The Minister of Education, Universities and Research, Stefania Giannini, made stops in Beijing, Tianjin, Shanghai, Zhengzhou and Chongquin, accompanied by a delegation representing 160 research, university and national industry entities, including INFN and the Italian Space Agency (ASI). The purpose of the trip was to strengthen relations between the two countries in the fields of scientific research and technological innovation. In Beijing, in particular, the Minister visited IHEP (Institute of High Energy Physics), the Chinese counterpart of INFN, with which for decades there has been solid cooperation on projects of great scientific importance. Such as the BESIII experiment, funded by the European Union as part of Horizon 2020, the DAMPE satellite, to be launched by 2015, and the JUNO neutrino detector, under construction also thanks to the important Italian contribution. "All this is not only for the benefit of scientific research, of our understanding of the universe and of the laws that govern it, - underlined Minister Giannini - but also of the industrial and economic development of our two countries, thanks to the enormous potential to be exploited in current and future cooperation". The Minister's visit was also an opportunity to renew, in the headquarters of IHEP, the framework agreement between CAS and INFN, in order to strengthen the existing scientific cooperation and foster new initiatives. The mobility programme associated with the agreement will also allow a continuous two-way exchange of Chinese and Italian researchers between the two Institutes. ■

DISSEMINATION
THE GIFT OF MASS OF INFN TO THE ARTSCIENCE MUSEUM OF SINGAPORE

The *Gift of Mass*, the interactive installation stemming from the encounter between physics and video art, thanks to the INFN collaboration with Italian artists, will be at the *ArtScience Museum* of Singapore until February 14 next, together with the *Collider* exhibition of the London Science Museum, part of an exhibition that combines avant-garde art and scientific discoveries. The interactive *Gift of Mass* installation is a total-immersion work that accompanies the visitor in the discovery of the mechanism by which particles acquire mass, inspired by one of the most important achievements of contemporary physics, the discovery of the Higgs boson. As a leading thread of the show, the *Collider* exhibition then guides the audience in the LHC super-accelerator of CERN in Geneva, in an exciting journey in particle physics, with the tools and protagonists of scientific research. “This exhibition combines basic research, technological innovation and avant-garde art in such a way as to narrate some of the most fascinating aspects of the universe in an engaging manner which is accessible to different audiences”, said Honor Harger, Executive Director of the museum, at the inauguration. The *ArtScience Museum* in Marina Bay Sands is a first class cultural institution of South-East Asia, which explores the interrelation between art, science, technology and culture. With 21 galleries, the museum has staged major exhibitions of key artists of the twentieth century, including Salvador Dalì, Andy Warhol and Vincent Van Gogh, as well as major exhibitions that explore aspects of scientific history. ■

» INTERVIEW

THE BIGGEST DARK MATTER TRAP

Interview with Professor Elena Aprile, from Columbia University in New York, Spokesperson of the XENON1T experiment, inaugurated at the Gran Sasso National Laboratories (LNGS) of INFN

A new scientific endeavour, the XENON1T experiment, is starting at the Gran Sasso National Laboratories (LNGS) of INFN. The project is ambitious: understand what the universe still hides. About a quarter of what makes up the cosmos, in fact, is constituted by a type of matter, the nature of which is still unknown: dark matter. Physicists know that it exists, that it surrounds, for example, the Milky Way like a thick fog, but they do not know what it is made of. Like the explorers of the past, in search of an unknown continent, they are looking for it everywhere. First of all in space, with the Alpha Magnetic Spectrometer (AMS), the so-called Hubble of elementary particles, anchored to the International Space Station (ISS) like a lifeboat. But also at CERN in Geneva, with the Large Hadron Collider (LHC) super-accelerator. And in underground laboratories worldwide, starting with LNGS.
We asked Elena Aprile, from Columbia University in New York, the spokesperson of XENON1T, why the new experiment just inaugurated at LNGS has what it takes to succeed in this difficult task.

How did the idea of XENON1T come about and how does the experiment work?
The XENON project began in December 2002 and has evolved to a phase which will make it the most sensitive for the direct search of dark matter. XENON1T - hosted in the LNGS of INFN, under 1,400 metres of rock that shield the experiments from the incessant shower of cosmic rays - is the third in a series of detectors of the XENON project, after XENON10 and XENON100.
The detectors of the three XENON generations are dual-phase (liquid and gas) Xenon Time Projection Chambers (TPCs). When a particle releases energy in the liquid xenon, both excitation as well as ionization of the atoms is produced. The excitation generates a first luminous signal due to scintillation, while the ionization frees electrons that are brought by an appropriate electric field to the gaseous region, above the liquid, where they are accelerated to create a second luminous signal. Both signals are then detected by two groups of photomultipliers, 248 sensors in total, placed above and below the volume of xenon.

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Why use xenon? What makes this element suitable for searching for dark matter?
Xenon is a noble gas, and as such is easily separable from the contamination of other radioactive elements. Furthermore, in the liquid state it is three times denser than water, and this allows it to be effectively used as a shield against external radiation. Finally, it has excellent characteristics as a detector medium, because it has among the best scintillation - emission of light when excited by a release of energy - as well as ionisation properties among all noble gases.

Many people are searching for dark matter: in what way does XENON1T differ from other experiments, at CERN or on board the ISS?

It is certainly a very exciting time for the search for dark matter, in light of the various experiments dedicated to detecting it. It is important to search for dark matter in different ways which complement each other. With experiments such as XENON1T, in fact, we use the so-called direct method to observe the interaction of dark matter WIMPs (Weakly Interactive Massive Particles) - name by which physicists indicate one of the leading candidates for dark matter - with the nuclei of materials in terrestrial detectors. AMS, placed on the ISS, on the other hand, looks for signs of anti-particles generated in the annihilation of WIMPs in the galaxy. In particle accelerators, such as the LHC at CERN, the search is via the collision of very high energy protons in order to observe the production of new particles that meet the characteristics of dark matter.

What are, on the other hand, the differences with the predecessors XENON10 and XENON100?
The main difference concerns the size of the detector and, consequently, also the mass of xenon present inside it. This increase - by about a factor of 10 for each phase of the XENON project - allows the target mass for WIMP interaction to be increased, but also the background level must be decreased, since the most dangerous radiation comes from external materials. So with a larger detector, the external radiation is shielded by a thicker layer of xenon.

How do the LNGS physicists look for something that we still do not know what it looks like, such as dark matter? Isn't a bit like groping in the dark?
It's true that we do not know the details of the particles that constitute dark matter, but the various experimental indications that come from cosmology and astrophysics allow us to clearly outline the general characteristics of these particles: they must have mass and only interact weakly. In addition, also their abundance is well known. The experiments are, therefore, designed to detect particles with these characteristics. We know we are looking for a weak and rare signal, a veritable needle in a haystack, but we are also hoping to be able to overcome this challenge.

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What exactly do you expect to find with XENON1T? And what if the experiment doesn't see anything?
The most commonly searched for candidate is the WIMP, which produces an interaction with the nuclei of the detector. In XENON it is possible to distinguish between nuclear interactions, representing the signal, and electromagnetic interactions, which are instead a background. The interaction of a WIMP is, therefore, recognisable with a good probability. There are, however, some models suggesting that dark matter may also have interactions with xenon electrons. Also in this case, with XENON1T the search is possible, thanks to the very low background in the central part of the detector.
If we were to detect nothing, we will still have precisely defined which are the properties that dark matter does not possess, for example, placing an upper limit on their interaction cross section. The XENON1T experiment could provide a range of mass for WIMPs not yet accessible to accelerators. In this sense, even not observing anything would still be a result.

When will XENON1T data collection begin? What is the future of the experiment?
Assembly of the detector was recently completed. Now the commissioning phase begins, in which all the components, which have already been tested separately, will be tested in the final configuration. Within a few months, therefore, we will be ready for the actual scientific run. With a week of data we will be able to reach the sensitivity of current experiments, while we will need approximately two years of data to reach the design sensitivity of the experiment, which is two orders of magnitude better than that achieved with XENON100. We are, however, already prepared to further increase the size of the detector, using almost completely all the auxiliary structures developed for XENON1T, in order to expand it to almost twice the amount of xenon. The new detector will be called XENONnT. With the XENON project we would like to be the first to understand what the universe is hiding from us. ■

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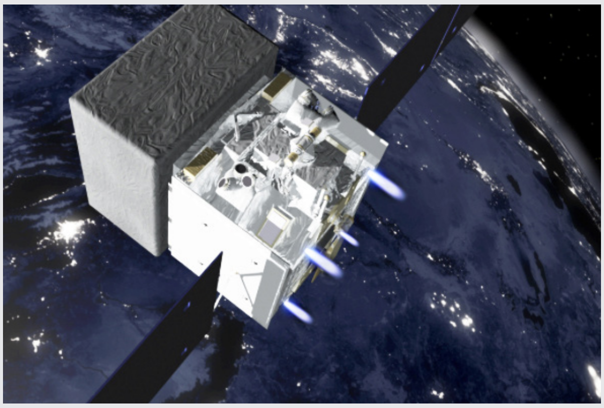

A SPACE EYE ON THE HIGH ENERGY UNIVERSE

In October, Science magazine reported the first detection of an intense flux of gamma rays coming from a pulsar, a neutron star in rapid rotation, outside of the Galaxy. The bright gamma source is located within the Large Magellanic Cloud, a satellite galaxy of the Milky Way. The result was achieved by the international collaboration of the NASA Fermi satellite, in which Italy is participating with the Italian Space Agency (ASI), the INFN and the National Institute for Astrophysics (INAF). Since 11 June 2008, when it was launched with a Delta II rocket from the Kennedy Space Center in Cape Canaveral, Florida, the Fermi satellite has been orbiting the Earth at an altitude of 550 km. Since then, it has continued to provide highly detailed photographs of the sky, seen under a particular radiation – the gamma radiation – constituted by high and very high energy photons. In particular, Fermi has two instruments: the LAT (Large Area Telescope) sensitive to very high energy gamma radiation (from 20 MeV to the TeV), and the GBM (Gamma-ray Burst Monitor), for the study of relatively lower energy phenomena (between 8 keV and 40 MeV).
The satellite, originally called GLAST, was then renamed by NASA, in August 2008, the Fermi Gamma-ray Space Telescope in honour of Enrico Fermi. The great Italian scientist was in fact a multifaceted figure, pioneer in the study of high-energy particles and among other things, was the first to postulate the physical mechanism of acceleration of cosmic rays that pervade our Galaxy, reaching even us. The data that Fermi satellite has provided us over the years has proved invaluable for the study of our universe. Some of the most catastrophic astrophysical phenomena, such as binary systems of neutron stars, black holes, pulsars and active galactic nuclei, in fact, cause intense emissions of gamma rays, which arrive directly as far as us, bringing us information on the sources that generated them and on the interstellar space they passed through. Very high energy photons, unlike the photons that constitute visible light, when interacting with matter, produce electron-positron (antielectron) pairs. Reconstruction of the tracks of these particles therefore allows the direction of the primary

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photon that produced them to be identified and thus their characteristics to be studied. This process is the basis, in particular, of the structure of the LAT instrument - a structure similar to the detectors used in high energy physics, for particle accelerators - for the implementation of which INFN made a significant contribution.

Among the most interesting results published by Fermi is the first evidence of an excess of very high energy electrons and positrons recorded in 2009. This result, together with the excess of cosmic positrons measured by the Pamela and AMS (Alpha Magnetic Spectrometer) satellites, can be explained by two alternative mechanisms, both of considerable interest. The firts one is the emission by an astrophysical source of particularly high energy particles, such as a pulsar, close to us, but still unknown, the second is a signal of dark matter, which in the process of annihilation or decay produces ordinary matter, including electrons and positrons. Fermi has collected millions of electron events, and ongoing studies on the angular distribution of these particles will help us to understand the dominant scenario.

Today the activity of the Fermi satellite is projected towards the completion of its tenth year, in 2018, with a significant improvement in its observational capabilities, thanks to a new software, called Pass 8, providing researchers with a more accurate reconstruction of the events detected and a significant increase in the sensitivity of the telescope, also beyond the energies so far explored. The new generation of algorithms, in fact, allows the energy and direction of each gamma photon passing through the telescope to be measured with high accuracy, allowing the most complex structures of extensive gamma sources to be optimally identified and weak sources thus far not detectable with the previous generation of algorithms to be seen.

It is therefore now possible to isolate sources with exceptional characteristics, such as the pulsar recently observed, and to verify, therefore, our understanding of cosmic ray acceleration and propagation mechanisms, observing a galaxy which, although close to us, is nevertheless different from ours. ■

ITALIAN NATIONAL INSTITUTE FOR NUCLEAR PHYSICS

CONTACTS

Communications Office
comunicazione@presid.infn.it
+ 39 06 6868162

EU INFN Office – Brussels
euoffice@presid.infn.it

Valerio Vercesi - Delegate to European Institutions
Alessia D'Orazio - Scientific Officer
+32 2 2902 274