NEWSLETTER 16

Italian National Institute for Nuclear Physics

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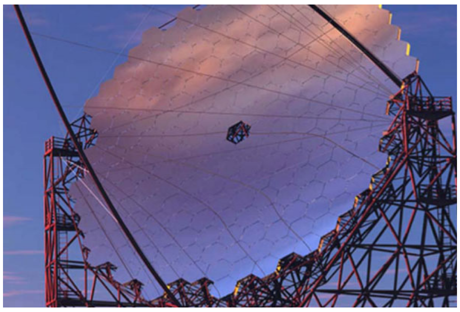
NEWS

RESEARCH
THE 2015 NOBEL PRIZE IN PHYSICS FOR NEUTRINOS

The 2015 Nobel Prize in Physics has been awarded to Takaaki Kajita from Japan and Arthur B. McDonald from Canada, for their key contributions to the SuperKamiokande experiment in Japan and Sudbury Neutrino Observatory (SNO) in Canada, which demonstrated that neutrinos oscillate. Neutrinos are in fact chameleon-like particles, switching between three different types that physicists call "flavours": electron, muon and tau neutrinos. Contrary to that predicted by the Standard Model, this metamorphosis requires that neutrinos have mass. The discovery has changed our understanding of the innermost workings of matter.
The neutrino Nobel Prize is another extraordinary achievement in the field of particle physics after the discovery of the Higgs boson, which received the Nobel Prize in 2013, and is one of the most promising keys to unlocking the mysteries of the Universe. A particle, the neutrino, that speaks good Italian. Starting from its name, jokingly coined by Enrico Fermi to distinguish it from the neutron which also has no electric charge, but a much greater mass. Then there was Bruno Pontecorvo who first hypothesized that neutrinos might oscillate also suggesting how to observe them in an experiment with nuclear reactors. And then the INFN's Gran Sasso National Laboratory, where the MACRO, Gallex/GNO, BOREXINO and OPERA experiments are helping to shed light on all the various aspects of such oscillations. The INFN Gran Sasso National Laboratories are currently working to solve the dilemma of the nature of this particle, as suggested by Ettore Majorana. ■



INFRASTRUCTURES
FOUNDATION STONE LAYING CEREMONY FOR THE CTA-NORTH TELESCOPE

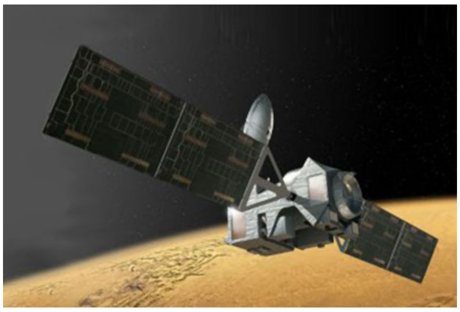
The construction of the Large Size Telescope (LST) prototype, one of the hyper-technological eyes of the Cherenkov Telescope Array (CTA) North, has officially started. Takaaki Kajita, who was recently awarded the Nobel Prize in Physics, attended the opening ceremony on 9 October, on the island of La Palma (Canary Islands). The CTA-North is one of the two structures that will make up the biggest gamma ray observatory ever built. The CTA-North will be built at the Roque de los Muchachos Observatory of the Instituto de Astrofisica de Canarias (IAC) at an altitude of 2,200 metres above sea level, on the island of La Palma in the Spanish Canary Islands. The European Southern Observatory (ESO) in Paranal, Chile has been chosen as the site for constructing the CTA-South, in the southern hemisphere. The project involves the construction of over 100 new-generation telescopes to study high and very high-energy photons from galactic and extra-galactic sources. Italy is involved in the CTA project through the Italian Institute for Astrophysics (INAF), the INFN and a consortium of universities led by the University of Padua. ■

INTERNATIONAL COLLABORATION
BILATERAL MEETING IN PISA BETWEEN THE INFN AND JINR FROM DUBNA

The INFN and JINR (Joint Institute for Nuclear Research) based in Dubna held a bilateral meeting on 12 and 13 October at the Rector's office of the University of Pisa to discuss their respective research activities and explore potential areas of common interest with a view to expanding their collaboration. Russia and Italy have a long history of scientific collaboration. Physicists at the INFN and JINR are currently working together on several projects, specifically the Borexino, SOX, DarkSide and GERDA experiments at the Gran Sasso National Laboratory (LNGS), the JUNO project in China and the mu2e and CDF (Collider Detector at Fermilab) experiments at Fermilab in Chicago.
During their two-day annual meeting, the INFN and JINR also attended a series of conferences on history and science focused on the legacy of Bruno Pontecorvo, one of the "Via Panisperna Boys", who carried out some of his research into neutrinos in Dubna. In 1957 this Pisa-born physicist had the brilliant idea that neutrinos might oscillate and, just a few days prior to the bilateral meeting, the 2015 Nobel Prize in Physics was awarded to the physicists who experimentally demonstrated of such a phenomenon. ■

DISSEMINATION
INFN AT THE MAKER FAIRE ROME 2015 WITH HOMEMADE DETECTORS

As from this year, the INFN has joined the list of partners for the Maker Faire, the important exhibition for new digital artisans. The Italy 2015 edition was hosted by the Sapienza University in Rome. Makers from the INFN showed the public how to build a homemade particle detector, using simple ingredients. The instruments presented at the event, a cosmic ray detector and accelerated particle beam scanner, were built using "ArduSiPM" Arduino Shield software and board, developed for research purposes by the INFN's Rome division.
With the addition of a few electronic components, it was possible to build a particle detector data acquisition and control system, creating a small-scale replica of the large physics experiments built by the INFN.
The homemade detector is very similar to the larger versions used for instance in the LHC accelerator at CERN, but its very low production costs mean it has numerous applications in education.
As well as presenting the work of its makers, the INFN also took part in the Maker Faire Rome 2015 with a contribution to the exhibition called "La Scienza illumina" (Science illuminates), the aim of which was to raise awareness among people of all ages about sustainability and energy saving. The exhibition was designed and realized by the Sapienza University in Rome. ■



SPACE
AN ITALIAN INSTRUMENT BY ASI AND INFN ON BOARD EXOMARS

Europe is preparing to land on the Red Planet in 2016 with the robotic ExoMars mission by the European Space Agency (ESA). A mission in which Italy is playing a key role, that will be becoming increasingly important in the next few days, as the INRRI (INstrument for landing-Roving laser Retroreflector Investigations) laser micro-reflector developed by ASI together with INFN, with scientific direction by Simone Dell'Agnello, physicist from the INFN's National Laboratories of Frascati (LNF), is loaded on board.
After passing all the necessary tests, the instrument was delivered in record time and has just been installed on the martian descent module ExoMars EDM (Entry, descent and landing Demonstrator Module) named Schiaparelli after Italian astronomer Giovanni Schiaparelli, who drew the first map of the Red Planet.
INRRI will be the first passive laser reflector on the surface of Mars and the first to go further than the Moon. It should also be the first of a series of micro-reflectors carried on board future landers or rovers, that will go together to form a Mars Geophysical Network (MGN): a network of reference points for taking geodesic measurements and conducting General Relativity tests on Mars. In the long term, MGN could become a precision positioning network similar to that created using laser retro-reflectors on the Apollo and Lunokhod moon missions. Lastly, the INRRI could possibly be used as a new primary precision geodetic reference point on Mars: a sort of martian Greenwich. ■

» INTERVIEW

THE INFN-LED WAVESCALES CONSORTIUM WILL PARTICIPATE IN THE HUMAN BRAIN PROJECT

Interview with Pier Stanislao Paolucci, researcher at the INFN and head of the WAVESCALES project

The INFN will participate in the European Commission's international Human Brain Project (HBP). It will lead the WAVESCALES (WAVE SCALing Experiments and Simulations) Consortium, one of the 4 winning projects selected from among the 57 proposals submitted in response to the Call for Expressions of Interest (CEoI) launched by the HBP. The WAVESCALES Consortium will be coordinated by Pier Stanislao Paolucci, a researcher at the INFN. We asked him what this achievement means and to tell us about the winning project.

What is the Human Brain Project (HBP)?

The Human Brain Project is an international research effort funded by the European Union with a budget of about € 500 million between 2013 and 2023. It is one of the two Future and Emerging Technology (FET) Flagship projects that will run for the next ten years. The other FET Flagship project is Graphene. The project's ultimate goal is to improve our understanding of the human brain, and to build and simulate the first model of its cognitive capabilities. The HBP is running in synergy - but also scientifically competing - with other research collaborations, such as the Allen Institute for Brain Science and the BRAIN Initiatives of the National Institutes of Health (NIH), both in the US. The specific mission of the HBP is to construct an "information technology infrastructure", integrating data obtained from experiments in the fields of neuroscience and medicine with instruments that simulate the human brain, and the brains of mice.

Can you tell us what the WAVESCALES project, which won the international call launched by the HBP, consists of?

The WAVESCALES Consortium, led by the INFN, is a team of five research institutes. Three of the partners are specialised in experiments on the human brain and the brains of rodents, the other two will

» INTERVIEW

concentrate on developing theoretical models and computer simulations. The INFN's Array Processor Experiment laboratory (APE lab) will develop the neural network simulator, which will mimic the behaviour generated by several tens of billions of nerve cell connections, or synapses. The partners in the experiment will measure the slow cerebral waves propagated in the cortex during deep sleep and the waking state, and observe the cortical response to localised spatio-temporal perturbations. The experimental techniques used will include non-invasive observations in humans, such as high resolution electroencephalographic response to transcranial magnetic stimulation, performed by the team led by Marcello Massimini at the University of Milan. And electrophysiological measurements on rodents in response to opto-pharmacological stimulations, conducted by teams led by Maria Victòria Sánchez-Vives, from the *Institut D'Investigacions Biomèdiques August Pi i Sunyer* (IDIBAPS) in Barcelona, and by Pau Gorostiza, from the *Institut de BioEnginyeria de Catalunya* (IBEC), also in Barcelona. The theoretical models will be developed by the Italian Institute of Health (ISS - *Istituto Superiore di Sanità*), under the direction of Maurizio Mattia and Paolo Del Giudice.

The project makes reference to neural networks: can you explain what these are?

The human brain is an extremely complex system. We believe it has about 90 billion neurons and several hundred thousand billion (that's a number with 14 noughts) synapses and neural connections. Using an extremely simplified model, we can say that the neurons perform computations using the information transmitted by the synapses, on the basis of which they decide whether to switch from around a resting state - like the zero in a binary system - to a spiking state - like the unit in the binary system - which lasts about one millisecond. Typically, each neuron produces a few tens of potentials, or spikes, per second. The incredible thing is that if a single neuron performs a different computation, the brain can significantly change its global state and objectives, within less than a second. Therefore, to understand the principles underlying the brain's computational activities, we need to simulate the activity of a relatively extensive network of neurons.

What is the INFN's contribution in terms of skills and technology in a field like neuroscience, which is apparently so different?

A single computer could not perform simulations of large scale neural networks. We need computers that work in parallel, that process data simultaneously and in a coordinated way, and a series of dedicated parallel algorithms. Here at the INFN we have long-established traditions that will offer a key contribution to research into the human brain. One strategic asset is the APE lab, set up by Nicola Cabibbo and Giorgio Parisi, central figures in the fields of numerical simulation and complex systems.

» INTERVIEW

Since 1984, the APE lab has been one of the key centres for research on parallel computing. Over the years the INFN has developed several generations of computers and algorithms that work in parallel, as well as dedicated interconnection systems. The activities of the APE lab originally focused on simulations in subnuclear physics, especially Quantum-Chromo Dynamics (QCD). Over the years we have developed specific expertise that we have also applied to various other fields where high data processing efficiency is required, such as simulations of neural networks. We should also remember that one of the pioneers in theoretical and computational neuroscience was Daniel Amit, who worked at the INFN and founded a school in Rome of scientists with expertise in this field.

Why is studying the brain so important?

In Europe the cost of brain disorders and traumatic brain injury was estimated at € 798 billion in 2010. Given the ageing population, this cost is likely to increase unless we make real progress in gaining a better understanding of the brain. Moreover, understanding how the human brain works has always been regarded as a major intellectual challenge. Now, especially by harnessing information technology to new experimental techniques, Brain Research is emerging as a new quantitative science, with a potentially huge impact.

Where will the INFN's participation in the HBP lead to in the future?

The WAVESCALES project will study the brain's overall response to localized perturbations in its simplest state, deep sleep, and during waking. If we manage to develop a theory that faithfully mimics these responses by simulating a large-scale neural network, that will mean we have discovered some fundamental elements in the overall architecture of the brain. But the human brain contains far more computational elements than our simulations will ever be able to mimic in the coming years. Research involving simulations of the brain using parallel processors and dedicated calculation systems will therefore be fundamental for many decades.

We will also need to develop experimental methods with increasing numbers of acquisition channels and higher temporal and spatial resolutions. The INFN will definitely be able to contribute and also play a central role in the experimental field, drawing on decades of experience in the construction of some of the most complex experimental equipment in the world. This equipment provides much higher temporal and spatial resolutions than the apparatus currently used in the field of neuroscience. ■

» FOCUS ON

A ROMAN SHIELD FOR THE CUORE EXPERIMENT

In October work began on assembling the shield of the cryostat of the CUORE (Cryogenic Underground Observatory for Rare Events) experiment at the Gran Sasso National Laboratory (LNGS). CUORE is an experiment designed to study the properties of neutrinos and, specifically, to look at a rare process called neutrino-less double-beta decay. This process has never been observed before and requires an extraordinary low level of radioactivity in order to be successful. To protect the CUORE experiment, researchers have come up with a truly original solution, which was proposed by Ettore Fiorini, carried on by the University and the INFN division of Milano Bicocca and realized under the supervision of LNGS. Ancient Roman lead ingots salvaged from a shipwreck that occurred more than 2000 years ago off the coast of Sardinia have been melted down to create a shield. The use of this shielding material will protect the detectors used in the experiment against environmental radioactivity. Lead is a very dense material with a high atomic number, which makes it ideal for shielding. "Ordinary" lead contains a radioactive isotope (lead-210), which has a half-life of about 22 years: thus, the Roman lead, produced 2000 years ago, does not contain lead-210 anymore.
The Gran Sasso National Laboratory and the Sovrintendenza ai Beni Culturali (Cultural Heritage Authority) in Cagliari worked in collaboration to recover the lead ingots from the bottom of the sea. They were then studied in Cagliari and taken to the LNGS to be preserved and prepared. As agreed upon with the Cultural Heritage Authority, the parts of archaeological interest, namely the inscriptions on the top of each ingot, were removed and taken back to Cagliari for preservation. The 230 ingots were then cryoblasted to remove all surface contamination. This process, which causes no radioactive contamination, consists of bombarding the surfaces with a pressurised stream of dry ice. The ingots were then melted down to obtain the segments and panels required to assemble the shield for the experiment. This work, which was carried out at the German MTH Metall-Technik Halsbrücke GmbH & Co KG took more than two months. The shielding of the CUORE experiment will be

» FOCUS ON

cup-shaped and comprise 26 rings plus a base disk assembled within a copper supporting structure. Each ring is composed of 6 segments and the base disk is divided into 20 panels. This lead shielding will be 6 centimetres thick and weigh 5 tonnes. It will be cooled to a temperature of approximately 4 kelvin (-269 °C).
This original solution for the shielding of the experiment was dictated by the fact that the scientific goals of CUORE are really ambitious. Neutrinoless double-beta decay is an extremely rare event, so rare that it has never been detected before. If researchers are able to observe and thus demonstrate the existence of this process, they will be able to measure the mass of neutrinos, and also determine whether or not they are Majorana particles, thus offering a possible interpretation of the prevalence of matter over antimatter in the Universe. Double-beta decay is a process by which two neutrons in a nucleus are converted into two protons, emitting two electrons and two antineutrinos. In neutrinoless double-beta decay no neutrinos are emitted, because one of the antineutrinos is converted, in the nucleus, into a neutrino. According to the Standard Model, neutrinos are not involved in this transformation. However if, according to the model proposed in the 1930s by Italian physicist Ettore Majorana, neutrinos are actually their own antiparticles, like the two faces of a coin, the transition between matter and antimatter would be possible. This event, though extremely rare, may have occurred frequently in the primordial Universe immediately after the Big Bang and determined the prevalence of matter over antimatter. CUORE is an international collaboration involving some 157 scientists from thirty organisations in Italy, the USA, China, Spain and France. The INFN is taking part through its Milan-Bicocca, Bologna, Genoa, Padua and Rome La Sapienza divisions, and its Gran Sasso, Frascati and Legnaro National Laboratories. ■

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