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NEWS

PHYSICS AND MEDICINE
CANCER: INSIDE SYSTEM SUCCESSFULLY TESTED FOR THE FIRST TIME ON A PATIENT

INSIDE (Innovative Solutions for Dosimetry in Hadrontherapy) has been tested for the first time on a patient. This innovative imaging system, which uses particle accelerators, was built by the INFN in Turin to further enhance the efficacy of hadron therapy, used for the treatment of localised tumours. INSIDE, which received a € 1 million grant under the PRIN (Relevant National Interest Projects) program, is the result of a research project coordinated by the University of Pisa in collaboration with the Universities the universities of Turin and Sapienza of Rome, Bari Polytechnic University and INFN. For the trial phase, INSIDE was tested on the patient at the Italian National Centre for Oncological Hadron Therapy (CNAO), in Pavia. INSIDE is an innovative monitoring system, which uses detector technology to obtain images of what happens inside the patient's body during the hadron therapy treatment. In more detail, this bimodal imaging system combines a positron emission tomography (PET) scanner with a tracking system for charged particle imaging and is capable of operating during radiation delivery to treat head and neck tumours. ■

NEW PROJECTS
CIPE ALLOCATES 4 MILLION EUROS TO THE ARIA PROJECT

The Italian Interministerial Committee on Economic Planning (CIPE) has approved funding for nine research projects considered to be of "strategic importance", one of which is the INFN's ARIA project. The projects will be funded through the Special Fund for Research (FISR). Led by the INFN with the collaboration of Princeton University (USA) and by Sardinia Regional Council through Carbosulcis S.p.A., ARIA will lead to the construction of an innovative research infrastructure in Sardinia, in the Monte Sinni mine in the Sulcis coalfield area. The aim of the project is to separate the atmosphere into its fundamental components to obtain elements that can be used in various areas of research and technology. One of these components, argon-40, is an extremely precious material that will be used in the DarkSide experiment to develop an innovative system for studying dark matter at the INFN's Gran Sasso National Laboratories (LNGS). ■

INFRASTRUCTURES
INAUGURATION OF THE SPES CYCLOTRON

The SPES (Selective Production of Exotic Species) project cyclotron was inaugurated at the Legnaro National Laboratories on 2 December.

The high-power SPES cyclotron is a circular accelerator capable of producing and accelerating protons at a rate of ten million billion of protons per second. Two proton beams will be extracted from the cyclotron: one will be used in nuclear astrophysics, the other for applications, especially in medicine, but also to study the properties of new materials, through neutrons radiation. Funds from the production of radioisotopes for clinical applications will be crucial for financing the SPES project, an aspect that will also guarantee its independence and continuity. SPES is part of a broader European project called Eurisol (European Isotope Separation On Line facility) on which European nuclear physicists are working to develop three radioactive ion beam facilities. A machine called SPIRAL2, with similar characteristics to the SPES ones, is currently being built in France and the existing ISOLDE (Isotope Separator On Line DEvice) facility at CERN is being upgraded. ■

RESEARCHERS
INFN HIRES 73 NEW RESEARCHERS

The INFN Directors Board has closed the year 2017 with a special session devoted to the approval of the list of winners of the competition for 73 new researchers positions, provided through the Italian Stability Law approved in 2015: a formal act which lays down the go-ahead to the next hiring. The new INFN researchers, 58 experimental physicists and 15 theoretical ones, will represent an overall increase of approximately 12% of the institute's permanent researchers. About 30% of the winners currently hold job positions outside the national borders and 7 researchers have a foreign passport.
1082 participation requests were addressed to INFN for the two competitions, one for theoretical physicists and the second for experimental ones, and 733 candidates took part in the selection (557 men and 176 women). The average age of the 73 winners's, among whom are 7 women, is around 33 years. Together with the 7 winners with a foreign passport (from Belgium, Georgia, Germany, Netherlands, Russia, Spain and Thailand) the Italians currently employed abroad (17) represent a third of the successful candidates. The new researchers will be free to choose the INFN division where they'll be assigned, without any constraint on the place or research project. ■

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WHEN RESEARCH IS BIG DATA AND COMPLEX COMPUTING

Interview with Antonio Zoccoli, vice president of INFN and responsible for the Computing and Networks division of the INFN's executive committee.

To enable epoch-making achievements like the discovery of the Higgs Boson and that of gravitational waves, but also to study the properties of cosmic rays and neutrinos, basic physics research handles enormous volumes of data and uses complex computing systems. For instance, in view of the huge amount of information produced by each collision between particle beams in the LHC accelerator at CERN, physicists have designed and developed a special infrastructure for the selection, storage and analysis of data. This continually evolving global infrastructure is a complex and organised system that incorporates different computing resources regardless of their geographical location or capacity. A worldwide computing network, known as the GRID, that harnesses the computing power and memory capacity of tens of thousands of different computers. The result is a computing power equal to that of 100,000 computers.

What are the essential requirements that guide the INFN's scientific calculations?
At the INFN we started performing scientific calculations when we had to analyse data from experiments in which we were taking part, so really it is something we have been doing ever since our first experiments. Right from the start, we recognised the importance of not just analysing data, but also of developing computing resources capable of performing Montecarlo simulations, a fundamental resource in scientific research. However, although scientific calculation was recognised as an important part of research activities, it was considered a secondary aspect in the planning and implementation of experiments until 20 or 30 years ago. Most experiments were designed irrespective of their computing needs: only later and depending on the circumstances were the computing instruments improved and the necessary infrastructure provided. There has definitely been a change of approach in recent years owing to the huge volumes of data produced by the LHC: the computing grid is now regarded as a

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fundamental part of the experiments, on a par with the detectors and the various scientific instruments. What we have witnessed in recent years is a real paradigm shift. Today it would be unthinkable to design an experiment without first knowing how much data will have to be handled or defining the appropriate procedure and infrastructure to analyse them. We will have to tackle this challenge over the coming years, since the LHC upgrade and subsequent HI-LUMI LHC project are two new experiments which are expected to generate 10 times more data than the LHC has done up until now.

The LHC is undoubtedly a driving force of development in computing resources for high energy physics. What are the specific research needs in this field and which solutions have been adopted?
The LHC has marked the turning point for computing infrastructure. Before it was designed, experiments could only rely on their own, extremely localised computing resources. With the start of the LHC project, instead, two goals were pursued right from the start. First: to provide enough computing capacity to analyse an unprecedented volume of data. Second: to allow all scientists participating in the experiments, based anywhere in the world, to access data so that calculations could be performed by the respective institutions. This meant the infrastructure had to be accessible from anywhere. The solution was the GRID, a worldwide computing infrastructure that literally encompasses the entire Planet. The name GRID comes from the analogy with the electricity grid. When you plug an electrical appliance in you certainly never have to think about having to build a electricity power station. Likewise, the GRID allows users to obtain a computer processing resource without having to know where it comes from. A network of computing sites connected via high-speed optical fibres and an interface that offers access to all users is no longer an infrastructure made up of individual resources, but a system. This is an entirely novel approach and the GRID is the first and only one of its kind in the world.

How has the INFN contributed?
The technological challenge has been addressed at a global level and the INFN has made a substantial contribution that has gone hand in hand with its participation in the LHC experiments. The challenge consisted in the need to allow the high energy scientific community to access the available resources and transmit massive data volumes in a very short time. With the problems associated with sharing data on such a large scale, such as authentication and data protection. In the end, we managed to develop the necessary hardware and software, with a significant contribution by the INFN in terms of manpower. The WLCG (Worldwide LHC Computing Grid) project is a collaboration of more than 170 computing centres in 42 countries. Its mission is to distribute and analyse the 50 Petabytes of data generated by the LHC in 2016 alone: a volume

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of data unparalleled in other disciplines and to which the term Big Data refers, not only for the huge volumes involved, but also to indicate their variability and the speed and flexibility with which they are transmitted and shared. The INFN has contributed with its researchers and specific skills to the implementation of the GRID and has been a key player in the process, concentrating most of its efforts between 2000 and 2010. In terms of scientific progress, this revolution produced its effects immediately. For the first time in the history of large experiments, scientific results can now be obtained just a few months after gathering data. The discovery of the Higgs Boson was the first tangible proof of this. As regards national resources, the process has led to the creation of a distributed computing grid in Italy in which the main centre, known as Tier1, is in Bologna and to which ten other Tier2 centres distributed nationwide are connected. This grid is part of the worldwide grid. It is connected to the Tier0 centre at CERN and to the other Tier1 and 2 centres around the world, in Europe, Asia, Japan, USA.

In addition to the LHC, the GRID supports experiments and collaborations in the field of data sharing and analysis. Which experiments benefit most?
At first the GRID was only used for analysing LHC data, the purpose for which it was originally developed. But then other experiments involving the analysis of large volumes of data, such as Belle II in Japan, and BES III in China, began to adopt the same approach. More and more experiments now rely on the GRID infrastructure, even in fields other than accelerator physics, such as large-scale international astroparticle physics research collaborations. In Italy, the Italian National Institute for Astrophysics (INAF) is the main body involved in such projects, in which the INFN also participates. I refer for instance to projects currently being developed such as the Cherenkov Telescope Array (CTA) or the Euclid satellite project. Then there is the Xenon experiment studying dark matter at the Gran Sasso National Laboratory of INFN. Given the significant increase in the volume of data to be analysed, researchers have asked to use the services of the LHC Tier1 and Tier2 sites. These experiments are rapidly expanding their scope and becoming increasingly international. Although they will continue to process less data than the LHC in the coming years, the GRID will still be an extremely valuable resource.

What are the prospects in Europe and worldwide?
We now face a double challenge. First, the infrastructure must move towards a new organisational model. The paradigm of GRID computing based on the connection of many CPUs via networks is no longer appropriate. Just to analyse the amounts of data generated by the next LHC upgrades we will need a larger infrastructure that uses Tier1 and Tier2 computing facilities, as well as machines with High Performance Computing capabilities. The infrastructure must be more general so that users within any branch of research can use it in the way most useful to them.

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If I need to perform data analysis that also involves the use of computing capacity, I must expand the opportunities offered by the infrastructure. Second, we will have to abandon the GRID approach and move towards CLOUD computing, a more flexible system in which resources can be used by users with different needs. Other experiments and research topics that are not necessarily relevant to the INFN must be able to access the infrastructure. The INAF, for instance, with which we are involved in ongoing experiments, but also the Italian Space Agency (ASI), and the Long Baseline Science sector that is currently particularly active in China.
For this process to be effective we must continue to develop the GRID for the future of the LHC. From the outset, we had to decide whether it is worth generalising the infrastructure to make it more flexible and integrated in a system, so that it is available to Italian research centres other than the INFN. We have the expertise needed to take this step and, with the support of the institutions, it would definitely be worthwhile in order to avoid the unnecessary dissipation of efforts and resources which would lead to fragmentation of the interests of the different scientific communities. This is exactly what happened before with the GRID, which was set up for us and is now a common asset.

» FOCUS

THE FIRST FIVE YEARS OF AMS ON THE ISS

In five years, the Alpha Magnetic Spectrometer (AMS) has observed more than 90 billion cosmic particles, including over a million rare antimatter particles, and undertaken a systematic study of all the nuclear species in cosmic rays, discovering surprising information about the characteristics of the spectra of protons, helium and lithium. The great antimatter hunter has thus opened up a new era of high-precision measurements for particle physics research in space and new and more in-depth theories are now required to explain these observations. The Nobel Prize winner Samuel C.C. Ting from the MIT provided a summary of these first results at a seminar at CERN in December.
AMS is an international collaboration, led by Mr. Ting, with participating institutions from 15 countries across three continents. Italy has made a fundamental contribution: most of the detectors on board AMS were built in this country by teams at the INFN and the Universities involved (Bologna, Milan, Perugia, Rome Sapienza, Trento) and with the contribution of the main Italian aerospace companies, coordinated by the Italian Space Agency (ASI). AMS was carried into orbit in May 2011 by the STS-134 mission of the space shuttle Endeavour and installed on the ISS under an agreement between NASA and the DoE (Department of Energy). The experiment is run by collaboration members at the Payload Operations Control Centre at CERN, who work in close partnership with the NASA support team at the Johnson Space Centre. All data obtained by the experiment are sent to the National Computing Centre (CNAF) of the INFN to be analysed before being forwarded to the ASI Science Data Centre (ASDC).
The mission's main purpose is to study antimatter particles: AMS studies the spectral shape of cosmic ray positrons and antiprotons in an unexplored energy range.
Extremely small amounts of antimatter particles may be created as cosmic ray particles collide with interstellar dust, but it is possible that the excess of antimatter particles observed, compared to that expected from a "standard" production, might be linked to the presence of new exotic sources, such as annihilations of dark matter particles. This represents a huge experimental challenge: 10,000 protons,

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1,000 helium nuclei and 100 electrons have to be "rejected" to observe one antiproton. This was made possible by simultaneously using several detection techniques developed via high energy physics experiments in particle accelerators. AMS has measured antiprotons and positrons fluxes in a wide energy range never previously achieved, and studied the characteristics of their spectra and their differences from the corresponding particle spectrum. An excess was detected in both channels compared to the expected rate, confirming the observations of Pamela (Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics) in 2009, but to a higher degree of precision and in a wider energy range. New sources of antimatter particles and/or new processes for generating these antimatter particles in the interstellar medium are required to explain these observations. Alternatively, astrophysical sources, such as pulsars, represent a "conventional" source that could explain the observations of AMS.
Another mystery surrounding antimatter being investigated by AMS concerns the origins of the universe: according to the Big Bang theory, matter and antimatter should have been created in equal amounts, but the universe as we know it is made of matter, and we have yet to understand why. Observing even just one antimatter nucleus in the cosmic rays, such as antihelium or anticarbon, would thus be extremely important. In the case of antihelium, for example, the signal (antihelium) to background (helium) ratio is extremely small in these observations, around 1/1 billion: to fully understand these events it is hence fundamental to comprehend and take into account the influences of instrumental effects. AMS has also begun a systematic study of all the nuclear species in cosmic rays - ranging from the lightest, such as protons, helium and lithium, to heavier nuclei up to iron - presenting its results up to oxygen nuclei. The large amount of statistical data collected and the precision of AMS detectors have provided unexpected information about the characteristics of the spectra of proton, helium and lithium, and the different behaviour of "primary" species, produced by sources, and "secondary" ones mainly produced in collisions with the interstellar medium. The interpretation of these measurements is directly linked to the mechanisms that produce cosmic rays and the processes that affect their path as they travel through the Galaxy and define the length of their journey according to the flux ratios between the different species.
If we are to fully understand the phenomena observed by AMS in the field of cosmic ray physics, distinguish between the different scenarios to account for the excesses of antimatter particles observed and confirm the possible antihelium candidates, the experiment must continue to gather data in the coming years, for as long as the ISS stays in orbit. ■

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Immagine di copertina
The Alpha Magnetic Spectrometer (AMS) on the International Space Station (ISS) (©NASA)