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INTERVIEW

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LABEC: WORLD EXCELLENCE IN NUCLEAR TECHNIQUES FOR CULTURAL HERITAGE AND THE ENVIRONMENT

Interview with Massimo Chiari,
director of LABEC (Laboratory for the Environment and Cultural Heritage)

The Laboratory for the Environment and Cultural Heritage (LABEC) of the INFN, based in the Scientific Hub of the University of Florence, in Sesto Fiorentino, is the laboratory for nuclear techniques applied to the study of cultural heritage and environment, which has succeeded in acquiring a world leadership role in this sector over the years, by working in contact with prestigious national and international institutions. Besides being at the heart of the INFN network for cultural heritage, CHNet (Cultural Heritage Network), with the INFN sections in Genoa and Florence, the LABEC becomes part of a Joint Research Unit (JRU) known as Actris-Italia (Aerosols, Clouds and Trace gases Research Infrastructure), which aims to create an Italian network of national and international importance devoted to observing and studying the atmosphere, pollution and climate change.
Besides that, it has been the landmark laboratory for years in training young researchers originating from developing nations in the use of nuclear analysis techniques with accelerators, through programmes backed by IAEA, the International Atomic Energy Agency.
We asked its director, Massimo Chiari, about the main research dealt with so far and how the LABEC activities have evolved over the years.

What are the main lines of activity of the LABEC?
The LABEC laboratory was set up in 2003, in close cooperation between the INFN section in Florence and the University, mainly for applications of nuclear analysis techniques with accelerators in the area of cultural heritage and the environment, as its name suggests. The laboratory's interest, though, is also focused on applications of these techniques in other sectors, especially on testing detectors, study of geology, the sciences of materials, forensic science and on damage from radiation. So, the

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LABEC carries on extensive activity of research and development of new technologies in nuclear applications, with this activity financed by the INFN through the National Scientific Commission 5, which means it can maintain top international levels in these inter-disciplinary research areas.

What analyses are carried out at LABEC?
The LABEC activities are managed by the applied nuclear physics group of the INFN section of Florence and the University Department of Physics and Astronomy, a group which has focused on the development of nuclear techniques since the mid-1980s, using at that time a Van de Graaff electrostatic accelerator, set in the old centre of Arcetri, which is now the home of the National Centre of the INFN, the Galileo Galilei Institute (GGI). The main instrument used by LABEC nowadays is a Tandem electrostatic accelerator with 3 MV of terminal voltage, used to measure Ion Beam Analysis (IBA, to analyse, in an absolutely non-destructive manner, nor damaging in any way, the composition of a sample) and of Accelerator Mass Spectrometry (AMS, to measure the relative abundance of rare isotopes). Apart from the accelerator, though, the LABEC also consists of various ancillary facilities, such as the laboratory for preparing samples for AMS measurement, the laboratory specialising in research into atmospheric particulate matter and the laboratories for developing electronics, detectors and testing of components with ultra-high vacuum. At the moment, eleven people are stably working at LABEC, made up of researchers, technologists and technicians, both INFN and university staff, and the activities are carried on partly thanks to the vital contribution of research grant holders, Ph.D students and research fellows.

What techniques do you use for cultural heritage?
Knowledge of the composition of materials in the field of cultural heritage is of great interest to historians of art, conservator restorers and archaeologists. In this field, the experts are increasingly relying on techniques of analysis that are totally non-destructive and non-invasive, which are used both for the purpose of furthering knowledge of works of art and materials used, and in the stage of preliminary analysis before restoring and conservation operations.
At LABEC we apply IBA techniques, i.e. analysis with ion beams, in studying materials in the field of cultural heritage. The techniques of analysis with ion beams are efficient techniques for quantitative study of the composition of materials of interest in a non-destructive and non-invasive manner. The samples to be analysed are used as targets for a beam of accelerated ions (mainly protons and α-particles) generated by low energy particle accelerators and their composition and concentration profile in superficial layers are measured by analysing in energy the products of the interaction

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(charged particles, X-rays and γ-rays). One peculiarity of IBA measurement that we carry out at LABEC is the use of ion beams extracted from the atmosphere: a technique introduced, precisely, by the applied nuclear physics group of Florence, which has since become a standard on the international level. There are various IBA techniques and each of them presents its own strong points, but also limitations, and often provides complementary information on composition, therefore synergistic use of several IBA techniques, which is called nowadays "Total IBA" measurement and which we do at LABEC, enables us to provide exhaustive information on the characteristics of the sample. The installation of the Tandem accelerator and the new line of measurement with AMS, accelerator mass spectrometry, has stimulated the interest of the community of archaeologists, restorers and geologists concerning the possibility of dating with ^{14}C. Over the years, this activity has become a very important component of the whole so-called machine-time of the LABEC.

At the LABEC you have analysed real masterpieces of art and culture...
Yes, the IBA techniques at LABEC have been used to analyse, just to name the most famous cases, masterpieces by Leonardo, Mantegna, the well-known painting "Trivulzio Portrait" by Antonello da Messina, by Giorgio Vasari, objects considered relics of Saint Francis and the inks on the papyrus of Artemidorus.
Obviously we, at LABEC, cannot analyse all works, for example unmovable works such as wall paintings or other works of large dimensions or which are particularly delicate, for which movement and transport to the laboratory is not advisable. Therefore, to increase the applicative potential of the laboratory, apart from the techniques requiring the use of an accelerator, we have also developed, within the INFN network CHNet devoted to cultural heritage, techniques for analysis of materials with portable instruments, for example a Fluorescence X-Ray (XRF) scanner, which can make measurements in situ.

You also carried out a particular analysis on a painting attributed to Fernand Léger, which established its non authenticity.
Yes, over recent years the dating activity at LABEC has moved towards concentrating on recent periods also, exploiting the particular trend of concentration of radiocarbon in the atmosphere post-1955 (the so-called Bomb Peak), to resolve problems of authenticity of modern and contemporary works of art. In fact, following the numerous tests conducted on nuclear arms in the atmosphere since the end of the Second World War, concentration of ^{14}C has increased abruptly, so much so that, in just ten years, from 1955 to 1965, it practically doubled. Later, starting from 1965, as a result

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of the Non-Proliferation Treaty, concentration of radiocarbon started to decline again, especially through the effect of dilution of carbon in the various terrestrial reservoirs, most of all the oceans. In recent years, then, the concentration of ^{14}C has varied from year to year, making it possible to date with great accuracy, which is very useful for unmasking a fake. By exploiting this effect, we at LABEC, precisely, dated a painting attributed to the painter Fernand Léger, by measuring the concentration of radiocarbon in a fragment of the canvas and placing the results in relation to the Bomb Peak. Owing to this comparison, used for assessing the authenticity of a painting for the first time, it was concluded with absolute certainty that the canvas the picture was painted on was produced after 1959, at least 4 years after the French artist's death, which occurred in 1955.

What analyses of impact on the environment are done at LABEC?
We have, for several years now, been dealing with the study of the composition and sources of fine powders present in the atmosphere: atmospheric particulate matter or aerosols. In spite of its minor concentrations in air, particulate matter has important effects both on human health, through inhalation of harmful substances, and on the environment, with alterations of the optical properties and influence on the climate. These effects depend on properties such as the dimensions of the particles, chemical composition, optical properties and concentrations in air and, in turn, these properties are linked to the sources of emission. In particular, measurement of the chemical composition combined with the use of statistical models makes it possible to identify the sources of pollution and quantify their impact. Techniques of analysis with ion beams have demonstrated that invaluable information can be furnished, especially, by high-sensitivity quantitative analysis of trace elements of specific components of atmospheric particulate matter, such as marine aerosols, mineral dusts and sulphates, or emission sources, such as biomass combustion, biogenic emissions, combustion of heavy oils, incinerators, traffic and industrial emissions. At LABEC we have developed methods of specific investigation, capable of determining the elemental composition of fine dusts in a few tenths of a second, and we process hundreds of data every day, making the laboratory a centre of international reference for this kind of analysis.
These techniques can also be applied to the analysis of samples of fine dust collected with high temporal resolution, on the hour scale, able, for example, to monitor emission sources of rapidly changing pollutants such as industrial ones.
Also, analysis with IBA techniques – thanks to its high sensitivity, but especially to the fact that, since no pre-treatment of the sample is needed, the chance of polluting the sample is reduced – has proved to be especially suitable for study of atmospheric particulate matter in “remote” areas,

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in other words not directly impacted by sources of an anthropic nature, such as the Arctic and Antarctic, for the purpose of studying aerosols of a natural origin (mineral dust and marine aerosol) and transportation of particulate matter over a long distance. In the polar regions, the studies concern sampling and analysis of atmospheric particulate matter currently present in those areas, considered the most sensitive to climate change, as well as analysis of samples extracted with cores of ice and marine sediments.

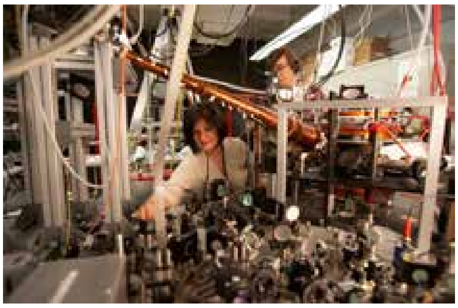
The European AIRUSE project, to which the LABEC has made a decisive contribution with a crucial role, was recently given an award as the best project in the LIFE+ 2016-2017 program, in the category of green city.

AIRUSE is a project that had the aim of identifying the sources of ambient particulate matter (PM), of testing certain measures of mitigation and suggesting effective strategies for reducing particulate matter in the cities of Southern Europe, where scarcity of rainfall, compared to the North, means that the atmosphere does not clean itself and the particles remain in suspension for long periods. For three years ambient PM was sampled and analysed with chemical-physics techniques in Athens, Barcelona, Porto, Milan and Florence. The results obtained show that the main sources of atmospheric pollution are, apart from the most obvious ones like traffic or industry, also emissions from ports and shipping, construction work, local dusts or that coming from the Sahara, marine spray, activities associated with agriculture and intensive animal farming and combustion (especially biomass). It also emerges clearly that a part of the dusts (secondary aerosols) forms in the atmosphere from pollutants of a gaseous nature, emitted even at a considerable distance from the sampling site. Not everyone knows, for example, that combustion of biomass is also an important source of PM, for example in Florence and Milan, but not in Barcelona, where residential heating fuelled by biomass is non-existent. In periods of highest pollution levels, this source makes a contribution comparable to that of the traffic. The project results are summarised in a publication entitled “Measures for improving air quality in urban areas”. ■

INFRASTRUCTURES

NEW LIGHT FOR NEW PHYSICS: LAYING THE FIRST STONE OF HILUMI LHC AT CERN

It is a priority of the European strategy in particle physics and it's going to be the biggest physics project of the next 10 years. It's High Luminosity LHC, also known as HiLumi LHC, which on the 15 June, at CERN, celebrated the laying of its first stone, with the start of the civil engineering work. The HiLumi LHC project, in which Italy is in the front line with the INFN, will boost CERN's superaccelerator to increase its luminosity, one of the main indicators of performance of a particle accelerator, in other words the number of potential collisions per unit of surface in a given time interval. The large detectors positioned along the LHC 27 km superconductor ring at the collision points of the particle beams also have to be uprated, in view of the machine's new performance. The LHC HiLumi project will make a contribution to explaining the properties of the Higgs boson more accurately and will thus describe in greater detail how it is produced, decays and interacts with other particles. Besides that, scenarios beyond the Standard Model will be put to the test, for example, supersymmetry (SUSY), the theories with extra dimensions, the structure of quarks and much more. The LHC HiLumi project is the fruit of a major international undertaking, involving 29 Institutes from 13 Countries. ■



AWARD

ELENA APRILE TO RECEIVE 2019 BERKELEY PRIZE FOR THE RESULTS OF XENON1T AT THE NATIONAL LABORATORIES OF GRAN SASSO

The leader of the most sensitive dark-matter experiment conducted to date will receive the 2019 Lancelot M. Berkeley – New York Community Trust Prize for Meritorious Work in Astronomy. The Berkeley prize is bestowed annually since 2011 by the American Astronomical Society (AAS) and supported by a grant from the New York Community Trust. Elena Aprile will give her prize lecture on Thursday afternoon, 10 January 2019, during the 233rd AAS meeting at the Washington State Convention & Trade Center in downtown Seattle.

Elena Aprile, Professor of Physics at Columbia University in New York City, is being honored with the 2019 Berkeley prize for her leadership of the XENON project and its groundbreaking search for the weakly interacting massive particles ("WIMPs") thought to make up the mysterious dark matter that appears to provide most of the universe's gravitational pull.

With its multiton liquid-xenon detector, XENON1T - at the Gran Sasso National Laboratory, LNGS in Italy, which is operated by the INFN - is currently the world's most sensitive direct experimental search for dark matter. Aprile and her colleagues are narrowing the range of allowable particle masses and interaction strengths. WIMPs have almost nowhere left to hide, causing physicists and astronomers to rethink the nature of dark matter and to wonder if the particles might be much less massive than originally thought.

Elena Aprile founded the XENON Dark Matter Collaboration in 2002 and has served as its scientific spokesperson ever since; her international team includes more than 165 scientists and students representing 24 nationalities and 21 institutions. ■

SPACE
HAPPY BIRTHDAY FERMI!

The 10th birthday for the Fermi Gamma-ray Space Telescope, the NASA satellite operating in the field of high energy astrophysics, dedicated to detecting gamma-rays. Fermi is a NASA mission which counts on a fundamental Italian involvement, with the contributions of the INFN, the Italian Space Agency (ASI), and the National Institute of Astrophysics (INAF).

In the ten years of its activity, the telescope has produced important scientific results, rewarded with prestigious international recognition. One of the main instruments on board the satellite, the Large Area Telescope (LAT), counts on an important Italian contribution. The LAT analyses the sky every three hours and has observed more than 5,000 individual sources of gamma rays, including an event known as GRB 130427A, the most powerful burst of gamma-rays ever detected by the scientific community. Moreover, with the Gamma-ray Burst Monitor (GBM), the secondary instrument of Fermi, the burst of gamma-rays was observed on 17 August 2017, produced with the gravitational wave that was detected by the LIGO and VIRGO observatories, emitted by the fusion of two neutron stars. Fermi has been awarded, on no less than four occasions, the Bruno Rossi Prize from the High Energy Astrophysics Division, the most sought after honour in the field of high energy astrophysics, which is awarded in recognition of results of major significance. ■

CULTURAL HERITAGE

THE MYSTERY OF THE GIRL HIDDEN IN THE PAINTING OF "THE PASTON TREASURE"

Something that was hidden in a painting for almost four centuries has now become visible for the first time and this is partly thanks to a special X-ray scanner called LANDIS-X, built by researchers from the INFN and the National Research Council (CNR). What was hidden was a female figure, painted then removed, probably a member of the family shown in the picture "The Paston Treasure", an important work of painting in the history of English art. An exhibition dedicated to this painting opened on 23 June at the Norwich Castle Museum, in England, which the work belongs to and where the analyses were carried out. The discovery is credited to a team of researchers from the INFN Southern National Laboratories and the Institute for archaeological and monumental heritage (IBAM) of the CNR. The researchers photographed "The Paston Treasure" with the innovative LANDIS-X scanner, designed and developed in the laboratory for non-destructive analysis (LANDIS) of the INFN Southern National Laboratories, which it is named after, in synergy with the CNR; the LANDIS laboratory is part of the network of the INFN, which is dedicated to applications for cultural heritage, CHNeT (Cultural Heritage Network).
The images provided by the researchers made it possible to completely reconstruct all the pictorial layers and restore the work to its original composition. ■

RESEARCH

CUPID-0 ON THE TRAIL OF THE SLOWEST DECAY IN THE UNIVERSE

The CUPID-0 (CUORE Upgrade with Particle IDentification), installed in the INFN National Laboratories of the Gran Sasso (LNGS), has published its first results in Physical Review Letters.

CUPID-0 studies neutrinoless double beta decay, an extremely rare phenomenon which, if detected, would mean that neutrino and antineutrino are Majorana particles, i.e. that particle and antiparticle coincide. One year on from the start of data collection, started in March 2017, the scientists from the joint project have reached a new limit, around ten times greater than the previous one, for neutrinoless double beta decay in an isotope of selenium. With a view to future developments of the experiment, CUPID-0 is testing scintillating calorimetry (bolometry) based on zinc selenide crystals, developed with the help of financing from the European Research Council (ERC, Advanced Grant) of the LUCIFER (Low-background Underground Cryogenic Installation for Elusive Rates) project. This technology will then be used in the CUPID project, which is a major third generation experiment to be built at the LNGS over the next decade.

CUPID-0 involves the INFN sections in Genoa, Rome 1, Milan Bicocca and the National Laboratories of Legnaro and of Gran Sasso, which are hosting the experiment. ■

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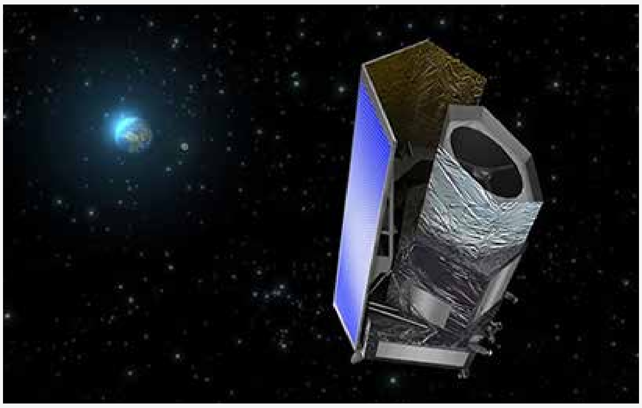

FULL SPEED AHEAD EUCLID: TOWARDS THE STUDY OF THE DARK UNIVERSE

On 14 June in the ThalesAlenia Space facility in Turin, the avionic model (AVM) of the Near Infrared Spectro Photometer (NISP) was delivered, the "eye" in the infrared, which will join the one in the visible (VIS) in helping the EUCLID space mission of the European Space Agency (ESA) to study the Dark Universe with levels of precision never reached before. The aim of EUCLID is to create a super-detailed map of the distribution and the evolution of dark matter and dark energy in the Universe.
AVM is the first fully functioning system of the electronic part of the NISP and it makes it possible to check that the instrument is working properly, starting from commands sent from Earth, down to receiving scientific data, after processing by the on-board computer and by the two software systems. The AVM is completely "made in Italy" and Italy is involved in the EUCLID mission under numerous aspects: both with making the subsystems of the on-board instruments and with responsibility for management of the Earth Segment and the survey, but also with important roles in managing technical and scientific aspects of the mission. Whit the support of the Italian Space Agency (ASI), more than two hundred Italian scientists are involved in EUCLID, coming from the INAF (National Institute of Astrophysics), INFN and several Universities.
The avionic model AVM, delivered in mid-June, consists of various instruments. Apart from the series of simulators of the detectors, motors and the thermal control system of the NISP, the system includes two control units, with software created by INAF installed: the Instrument Control Unit (ICU) and the control and management unit of the data from the detectors, the Data Processing Unit (DPU), made by the Italian company OHB and financed by the ASI. The AVM model of NISP was assembled in the INFN laboratories and those of the University of Padua, with the involvement of the whole INAF and INFN team. The subsystems were then tested, thanks to software developed by INFN research groups, with

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the support of CNAF, the INFN national center for research and developement in INFN information and communication technologies. After successful completion of the testing, the ESA has approved the delivery of the first working model to Thales Alenia Space of Turin, who are responsible for producing the EUCLID satellite, which will use it for verifying communications between the satellite itself and the NISP instrument. ■

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

Cover
Analysis at LABEC on Painting “Trivulzio Portrait” by Antonello da Messina © INFN