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## **STUDYING THE UNIVERSE, FROM NUCLEI TO STARS**

Interview with Eugenio Nappi, member of the Executive Board of INFN and its representative for research projects in experimental nuclear physics.

Experimental nuclear physics represents the link between the study of the primordial stages of the universe, carried out with the aid of large particle accelerators, and research into star, galaxy and galaxy cluster formation mechanisms, with experiments on nuclei stability and exotic nuclei production. At INFN, research activities in this field are carried out in the four national laboratories, at TIFPA (Trento Institute for Fundamental Physics Applications) and in several divisions, with important repercussions in various fields other than fundamental research, such as medical physics, physics for the cultural heritage, energy research and development of new materials and technologies for nuclear safety.

## The INFN is engaged in several projects on experimental nuclear physics, ranging from fundamental physics to medical applications. How are the various activities coordinated in the Institute?

The coordination of experimental nuclear physics research activities in INFN is carried out by the third National Scientific Commission (CSN3) which establishes the priorities and funding of individual projects. But the broad spectrum of research activities in this field doesn't end with CSN3.

Since 2006, following the signing of a collaboration agreement between INFN and Ansaldo Nucleare, the development of skills and instruments in the field of nuclear physics applications in the energy sector, with particular attention to safety issues, is coordinated by the INFN-E strategic project. Since 2012, INFN-E has an annual budget of 200.000 euros. Also to be listed are the many nuclear physics activities related to the fifth National Scientific Board (CSN5), dedicated to technological developments. Among these, a very important role is played by medical applications that, in the development of diagnostic systems and the related simulation and analysis software, are rooted in a tradition of excellence of INFN. With the appointment of Marco Durante, an internationally renowned expert in hadron-therapy, as Director of TIFPA,



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we wanted to give a strong impetus to activities in the field of particle beam therapy techniques. Again within the scope of CSN5, the activities related to nuclear physics applied to the cultural heritage, environmental pollution monitoring and detector and accelerator development are of great importance.

### How does the INFN's strategy fit into the European scenario?

Priorities in funding nuclear physics activities are established by CSN3 in complete harmony with the guidelines of NuPECC, the European Coordinating Committee, which recently completed the work of drafting the Long Range Plan, the European roadmap for nuclear physics, whose conclusions will be presented on 27 November in Brussels. In particular, INFN's nuclear physics projects, following international nomenclature, belong to two major research branches: nuclear structure and hadronic physics. In the first case, the aim is the study of the nucleus as a composite system, to investigate the characteristics of radioactive vs stable atoms, the evolution of the universe and the formation of stars. Internationally, major investments are in progress to implement research infrastructures that accelerate exotic radioactive nuclear beams. In this context, the project on which the Institute is focussing is SPES (Selective Production of Exotic Species) at the Legnaro National Laboratories. In parallel with fundamental research, SPES will allow new radiopharmaceuticals to be synthesised for medical diagnostics.

The second branch, hadronic physics, is closer to the objectives and experimental techniques of research in high energy physics, coordinated in the Institute by CSN1. Hadronic physics represents the link between elementary particle physics and nuclear structure physics. In other words, hadronic physics aims to study the mechanisms by which the fundamental constituents of nucleons, quarks and gluons contribute to defining the actual properties of the nucleus. The most wide-ranging international hadronic physics initiatives in which the Institute is participating are ALICE, at CERN, and the experiments in progress at the Jefferson lab in the US and, in perspective, those that will be implemented at the EIC-Electron Ion Collider currently being designed in the United States (at the Brookhaven National Laboratory or at Jlab).

### What are the objectives of the strategic INFN-E project?

The activities of INFN-E focus in particular on the following two lines of action. The first concerns the dismantling of nuclear sites, management of radioactive material repositories, personnel protection at nuclear sites and security. The second deals with contacts with organisations dedicated to energy issues, such as Ansaldo Nucleare, ASG Superconductors, CAEN, Gilardoni and the Euratom-Ispra Joint Research Center. In these areas, INFN-E acts as both an incubator for the development of products to be offered to industries and other entities, as well as an initiative centre for forms of external financing.



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### What is the institute's involvement in experimental nuclear physics at the international level?

INFN contributes at the international level to all the most important initiatives in the field, with top level presence in the main European and global management committees. At the European level, Angela Bracco, from the University and INFN Milan Section, is in his second term as Chairman of NuPECC. Nicola Bianchi from the Frascati National Laboratories is head of the EPS-NPB (European Physical Society – Nuclear Physics Board) since 1 January 2017. I myself have for three years been a member of the IUPAP C12 (International Union of Pure and Applied Physics – Nuclear Physics) and of the ICFA panel

for the development of new detectors.

Paolo Giubellino, from the INFN Turin division, formerly spokesperson of ALICE, was appointed a few months ago as Scientific Director of FAIR in Darmstadt, Germany, a new research infrastructure, under construction, which from 2020 will become the most important German nuclear physics laboratory. Since the beginning of the present year, another INFN researcher is spokesperson of the ALICE experiment at CERN. From September 2017, Raffaella De Vita, from the INFN Genoa Section, will take on the role of spokesperson of the CLAS12 experiment at Jlab (of which Patrizia Rossi, LNF, has been deputy director for about 5 years). Recently, an Italian researcher from the Frascati National Laboratories, Catalina Curceanu, received the EPS "Emma Noether Distinction" Prize for women who have proven to be excellent in nuclear physics research at the European level.

### Which are the main future nuclear physics research initiatives in Italy?

At the Legnaro National Laboratories, the SPES project, starting in 2019, is currently being installed. At the Southern Laboratories, the NUMEN (NUclear Matrix Elements of Neutrinoless double beta decay) project has important implications in astroparticle physics, in particular for the study of neutrinos and dark matter.

At the Gran Sasso National Laboratories, the most ambitious project is LUNA MV (Laboratory for Underground Nuclear Astrophysics-Mega Volts), an experiment in nuclear astrophysics which is expected to start within a couple of years, consisting of a research infrastructure able to study the formation of nuclei using an accelerator capable of producing nuclear reactions at energies comparable to those that occur in the stars. In 2018 SIDDHARTA - intended for fundamental research in nuclear physics - will enter into operation at the Frascati Laboratories, at the end of the KLOE (K-LOng Experiment experiment), currently in progress at the Dafne accelerator. In Trento, the TIFPA is engaged in the application of and research on oncological hadron-therapy, not only for treating patients but also for the study of therapy optimisation techniques.



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### AWARD OF STARTUP GRANTS FOR NEW RECRUITS

INFN has awarded a start-up grant of 20 thousand euros to each of the 73 researchers recently recruited, thanks to the Stability Law, to implement their own research project. Overall, INFN will

allocate nearly 1.5 million euros (to be precise, 1.460.000 euros) promoting young people's initiative, enterprise and creativity in research. This is a start-up grant, personally awarded to new recruits for the enrichment of their curriculum, regardless of the structure to which they belong or of the experiment that they are collaborating in, also envisaging the participation in international calls. Projects funded with the start-up grants must be submitted by the end of 2017 and must start on 1 August 2018. The person responsible will have two to three years to implement the project, which, at the end of such period, will be subject to a final assessment by an INFN committee consisting of the Chairmen of the National Scientific Committees.



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### RESEARCH ASTRI SEES THE FIRST LIGHT

The ASTRI telescope has seen the first glimmers of Cherenkov light from the astronomical site of Serra la Nave on Mount Etna. ASTRI, a project led by the National Institute of Astrophysics (INAF), and

implemented in collaboration with INFN, a number of Italian universities, the University of São Paulo in Brazil and the North-West University in South Africa, is the prototype telescope developed for the future CTA (Cherenkov Telescope Array) device, which will be the largest and most sensitive gamma ray observatory in the world.

This first light comes shortly after last November's confirmation of the validity of the newly developed optical technology, based on the Schwarzschild Couder dual mirror configuration, proposed for the CTA project. Despite the camera had not been fully configured, it was possible to detect the first signals of astrophysical origin in Cherenkov light and thus produce the images of the shower produced in the atmosphere by cosmic rays. The scientific and technical development of CTA, a project included in the ESFRI (European Strategy Forum on Research Infrastructures) 2008 roadmap and funded within the scope of Horizon 2020, involves more than 1350 scientists and engineers from 32 countries. The observatory will detect with unprecedented accuracy high energy radiation reaching the Earth; the sensitivity of the measurements will be 10 times greater than that provided by the instruments currently in use and will allow a new understanding of the universe's most extreme events.

# INFN

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### RESEARCH IN SEARCH OF THE MUON ANOMALY

The Muon g-2 experiment studying the magnetic moment of the muon is celebrating a milestone. The first muon beams produced by the Fermilab accelerator have circulated in the large superconducting

magnet: this marks the beginning of a fascinating challenge to confirm or deny an anomaly measured at the beginning of the 2000's by the first experiment of this type. INFN is participating in the experiment with researchers from the Frascati National Laboratories and from the INFN Sections of Lecce, Naples, Pisa, Rome Tor Vergata, Trieste and the associated group of Udine. At the beginning of 2000's, physicists at the Brookhaven National Laboratory, measuring the anomalous magnetic moment of the muon (a property of this particle) found that the probability that the measured value was consistent with the predictions of the standard model was less than 1/1000. The result was not sufficient to constitute a discovery but worth investigating further. This discrepancy could, in fact, be explained by the contribution to the muon anomaly of still unknown particles, such as supersymmetric particles, or other new particles that could explain dark matter. The final solution to this enigma is now entrusted to the Muon g-2 experiment, that will measure the muon anomaly with a precision hitherto never achieved (140 parts per billion). Over the next year the first physics results are expected.



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### SPACE INFN-ASI AGREEMENT FOR THE NEW IXPE MISSION

The agreement between INFN and the Italian Space Agency (ASI) has been signed for the launch of innovative detectors capable of measuring the polarization of the X-ray radiation of the astrophysical

sources: so far a property only observed in the brilliant Crab Nebula in 1972, due to the lack of sufficiently sensitive instrumentation. This property is expected in many sources, and it is essential to understand, for instance, the geometry and magnetic field of black holes and neutron stars. The unique feature of the new GPD (Gas Pixel Detectors) is the combined use of a gas detector and a high resolution reading integrated circuit. The three GPDs, designed and built in the INFN laboratories in Pisa, will be the eyes of the Imaging X-ray Polarimetry Explorer (IXPE) telescope, the next mission of the Small Mission EXplorers (SMEX) program, whose launch is scheduled for the end of 2020. For over ten years, INFN, the National Institute of Astrophysics (INAF) and ASI have been perfecting GPDs for applications in polarization measures for their use on dedicated satellites: every photon that arrives on the detector develops in the gas of the GPD a track whose direction, rebuilt thanks to the pixel sampling, is bound to the properties of polarization of the radiation. IXPE will provide for the first time a simultaneous measurement of source image, time and energy development of their X-ray emissions and polarization properties.



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## TOP PHYSICISTS GATHERING IN VENICE

One of the most prestigious physics conferences worldwide, the European Physical Society (EPS) conference on High Energy Physics (HEP), is coming back to Italy after over thirty years. The EPS HEP 2017 edition is organised by the Italian Institute for Nuclear Physics (INFN) Padua Division and by the University of Padua Department of Physics and Astronomy "Galileo Galilei". It will take place at Lido island in Venice, which will hence become the gathering point for the international top physicists.

The conference will deal with some of the most fascinating themes in physics research: from the origin of our Universe to the Higgs Boson identikit, from the hunt for dark matter to the properties of the elusive neutrino, from New Physics to gravitational waves whose historic discovery was announced in 2016. All of these topics and many more will be discussed during the conference, where many cutting edge results and updates will be presented. The scientific subjects will be organized in thirteen topics: astroparticle physics, cosmology, dark energy and gravitational waves, dark matter, neutrino physics, heavy ion physics, flavour physics and fundamental summetries, Higgs and new physics, QCD and hadronic physics, detector R&D and data handling, accelerators for HEP, quantum field and string theory, outreach, education and diversity. The subjects will be proposed during 900 presentations, including plenary and parallel talks, and scientific posters session. A thousand researchers are coming to Venice from about fifty countries in all continents. More than 400 scientific institutions worldwide will be represented.

During the conference, the ceremony of the prestigious 2017 awards of the High Energy and Particle Physics Division of EPS will be held: High Energy and Particle Physics Prize, Giuseppe and Vanna Cocconi Prize, Young Experimental Physicist Prize, Gribov Medal, Outreach Prize and one Special Prize.

EPS-HEP 2017 will not only be about meaningful scientific results: it also offers a rich cultural program involving high school students and the general public: exhibitions, science shows and concerts.



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The EPS-HEP Conference 2017 has also been rewarded with the prestigious acknowledgment of the Medal of the President of the Italian Republic. ■



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Venice will host EPS HEP 2017