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Istituto Nazionale di Fisica Nucleare

» INTERVIEW

ITALY-CHINA: A CONSOLIDATED SYNERGY FOR PARTICLE PHYSICS

Interview with Marco Maggiora, Director of the IHEP-INFN Joint Laboratory (I2JL), Professor of the University of Turin and INFN researcher.

INFN's scientific and technological collaboration with Chinese institutions has seen a quantum leap in the last decade, thanks to the collaborative effort of numerous Italian and Chinese researchers engaged in joint research projects. An effort also recognised during the eighth edition of the China-Italy Science, Technology & Innovation Week, the most important annual event in the context of Sino-Italian scientific and academic cooperation, recently concluded in Beijing, which this year brought together 750 representatives from research centres, universities, Italian spin-offs and companies and over 400 Chinese participants.
During the event, in the presence of the Italian Minister of Education, University and Research, Valeria Fedeli, and the Chinese Minister for Science and Technology, Wan Gang, the China-Italy Science and Technology Innovation Cooperation Contribution Award, awarded by the China International Technology Transfer Center Italy, was awarded to Marco Maggiora, Director of the IHEP-INFN Joint Laboratory (I2JL), Professor of the University of Turin and INFN researcher, for his contribution to the development of scientific and technological cooperation between Italy and China, through the continuous strengthening of the strategic collaboration between the INFN and the Institute of High Energy Physics (IHEP), a body of the Chinese Academy of Science (CAS) in Beijing.
We asked Marco Maggiora, an Italian scientist in China since 2009 and coordinator of the European H2020 project in China BESIIICGEM, to tell us how the Italy-China cooperation came about, how it has developed in the field of Particle Physics and about its technological repercussions.

When and how did the collaboration with China for particle physics research come about?
INFN activities on Particle Physics in China and/or with Chinese scientists range from Astroparticle Physics, inside and outside atmosphere, to particle Physics performed with accelerators, and to neutrino Physics.

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INFN started to successfully cooperate with Chinese Institutions since 1995 in AMS (Alpha Magnetic Spectrometer), a detector installed on the International Space Station to investigate antimatter in cosmic rays. But the first joint Collaboration in China was ARGO (Astrophysical Radiation with Ground-based Observatory). We are speaking here of the investigation of astroparticles with detectors in the atmosphere, namely in Tibet. The first joint activities in Tibet dates even to 1998, although data taking started in 2004. A long lasting partnership was emerging among the two institutions, INFN and IHEP, that are strikingly similar both as far as structure and scientific interests are concerned.
We have to wait for early 2009 for the first participation of INFN researchers to a Collaboration investigating Particle Physics with Accelerators: BESIII. I personally joined BESIII (BEijing Spectrometer) leading a small patrol of few researchers that later grew up to become one of the largest national communities within BESIII. This has been also the framework for the first joint H2020 European project, a RISE (Research and Innovation Staff Exchange) project I'm coordinator of, devoted to the construction of the new BESIII Inner Tracker and involving besides INFN and IHEP, German and Swedish Institutions as well.
Few years later the cooperation was extended also to neutrino Physics with JUNO, a Collaboration born in 2012 to which INFN joined in 2014.

What cutting-edge projects are INFN, IHEP and CAS involved in today?
IHEP and INFN cooperate today in DAMPE (DArk Matter Particle Explorer), the first Chinese Academy of Science (CAS) satellite to be launched in late 2015, hosting state of the art silicon detectors, exploiting Italian technology to investigate cosmic rays. An evolution on the same path will be HERD (High Energy Cosmic Radiation Detection); the IHEP-INFN Letter of Intents have been recently signed and the R&D and design stage of this new set of detectors on satellite has just begun.
CSES-Limadou (China Seismo Electromagnetic Satellite) is a synergy among several Chinese and Italian Institutions, aimed to monitor with a whole network of satellites electromagnetic field and waves, plasma and particles perturbations of the atmosphere, ionosphere and magnetosphere and their possible correlation with earthquakes. They want also to investigate low energy cosmic rays. The deployment of the first of these satellites in orbit is expected very soon, in early 2018.
JUNO, as we said, is the first joint IHEP-INFN collaboration on neutrinos. They aim to determine in an underground laboratory the neutrino mass hierarchy exploiting the neutrinos produced by a set of Chinese Nuclear plants.
Last but not least the BESIII spectrometer, that is hosted in the main IHEP campus in Beijing, will soon host the Cylindrical-GEM Inner Tracker we are building in the framework of the European Project BESIIICGEM. The BESIII Collaborations discovered two whole families of new particles, the Zc's. The discovery of the

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Zc(3900) at BESIII was selected as one of "China's Top Ten Scientific Advances 2013" and as one of American Physical Society "Highlights of the Year 2013".

The Italian-Chinese synergy spans from the Earth to space, from the study of neutrinos to dark matter. In which sectors does Italy make the biggest contributions?

INFN is leader in the investigation of cosmic rays, inside and outside the atmosphere, since late 80's. This is generally recognized within the scientific community, in particular in China.
The expertise in building particle detectors, and in particular silicon detectors, has been extended bringing these detectors from ground laboratories to satellites, as for DAMPE or CSES. The core of these silicon detectors is Italian technology, originally developed within the PAMELA, FERMI and AMS Collaborations. Moreover INFN is moving to space also other kind of detectors, as the CALOCUBE calorimeter developed for HERD.
The Italian contribution is essential in JUNO as well, profiting of the previous experience from BOREXINO at Gran Sasso INFN Laboratory, and providing the purification system of the JUNO scintillators. In BESIII the new CGEM Inner Tracker, evolving the original Italian technology developed within KLOE-2, will allow for unprecedented detection resolutions even in large magnetic fields. Within the BESIIICGEM project INFN has contributed innovative solutions in cloud computing, allowing for a significant simplification of the access to cloud technologies. IHEP and INFN have jointly organized doctoral summer schools in China on these issues. Finally, future experiments with next generation accelerators require new concepts and pose new challenges. INFN can contribute an unique expertise on many different types of detectors, as well as on accelerator, vacuum and magnetic technologies.

Have INFN research programs undergone changes since the cooperation with China has become relevant? And, vice versa, has Italy influenced Chinese research policy in the field common to INFN and IHEP?
INFN have contributed tremendous efforts to the scientific cooperation with China: in technology sharing, in manpower, and of course with in kind contributions as well. Such resources have been provided, according to the different cases, by the National Commissions or directly by the INFN Executive Board. We are speaking of several millions of Euro, if we add up the INFN contributions to all the Collaborations I quoted before. When a similar amount of resources is provided to support a strategic partnership, choices are needed and priorities must be set. I can safely say that INFN has provided in the last years growing attention and support to the activities jointly performed in China with IHEP and CAS. The cooperation with China has been

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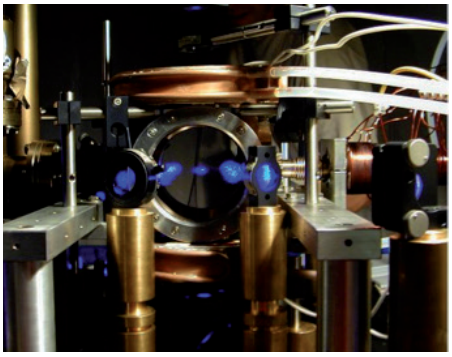
added aside to previously existing strategic international partnerships of INFN, the main one being the synergy with CERN, and has become one of the INFN priorities.
This is possible of course also considering how wide is the set of research fields involved by these Collaborations. And let me also say that it is an investment in the future, of INFN and of its scientific community.
On the other hand, in order to exploit the Italian technology, CAS has decided to fund the design and construction of the DAMPE silicon tracker. This is an example of how the Chinese research policies have been adapted as well in order to include the Italian community and its technologies. This is true also for JUNO: the expertise from BOREXINO has strongly influenced the JUNO concept and design.

You have been collaborating in Sino-Italian projects since 2009 and are today the Director of the joint IHEP-INFN laboratory. Which are the main advantages of the collaboration between two very different cultures and which are the main difficulties?
Let me start from the difficulties. What I love of China is that it is a land of opportunities. You are right, our cultures are remarkably different, but characterized by a widespread mutual respect. In our joint Collaborations, no sooner have the difficulties appeared than people have started talking and looking for possible solutions, acceptable by everyone.
It is important to define, for any project, and as soon as possible, joint management structures, where two researchers, one from each Country, jointly take care of each role. This makes the collaboration effective and profitable, since it exploits the different approaches of the two cultures.
This is an unique opportunity for the training of the youngest as well! I always have as guests or with temporary positions in my group in Turin some Chinese students, post-docs or professors. Letting them work together with my students and colleagues is profitable for everyone: each culture learns from the other. And for the same reason, thanks also to the European funds of my project, I try to encourage even extended stays of my students and colleagues in Beijing at IHEP. Besides, it is also a fact that Chinese people and Government have an effective vision and planning of scientific research, with a good fraction of their GDP devoted to these activities. The strategic collaboration with IHEP and CAS, and in the future hopefully with NSFC as well, gives INFN access to a set of funds and opportunities wider with respect to those that can be found in Italy or even in Europe. Last but not least, bringing cutting edge Italian technology in China within high profile projects, provides an excellent showcase for our Country and for our industries. ■



RESEARCH

RELATIVITY MEASUREMENTS WITH PRECISION BEYOND THE LIMITS

From quantum physics arrive two results that exceed the limits reached so far in sensitivity and precision in the measurements of the phenomena related to General Relativity and to gravitational physics. The results, published in Physical Review Letters were obtained in two atomic interferometry experiments by a team of researchers from the University of Florence and of INFN. At the base of the two experiments are atomic interferometry apparatuses, built in Florence, and based on the use of "atomic fountains" created with a laser.

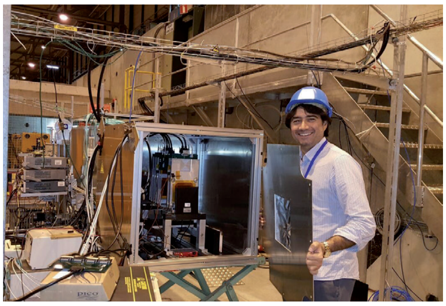
In the first experiment, carried out within the scope of the MAGIA Advanced project, the researchers developed a method that will allow testing of the validity of Einstein's equivalence principle with unprecedented accuracy. By cooling the rubidium atoms down to almost absolute zero with a laser and launching them upwards in a vacuum system, the conditions to measure the fall of weights were created by eliminating the effects due to the variation of the earth's gravity, which influence any classical measurement.

Then, using strontium atoms, the researchers built a second experiment that proved to be valid for future measurement experiments, on a quantum scale, of low-frequency gravitational waves, with even higher sensitivities than those obtained by the LIGO and VIRGO interferometers. This second experiment thus opens the way to the construction of high precision atomic interferometry instruments to study gravitational waves in a region of frequency that cannot be observed with current terrestrial optical interferometers, instruments also useful for future spatial experiments in collaboration with the European Space Agency (ESA) and the Italian Space Agency (ASI). ■

INSTITUTIONS

MINISTER VALERIA FEDELI VISITS CERN

On 18 December, the Minister of Education, University and Research, Valeria Fedeli, went to CERN to visit the most important particle physics laboratory in the world, where there is so much Italy, with its physicists coordinated by INFN, and with the cutting-edge technologies developed by the national industry. The Minister, accompanied by CERN's Director General Fabiola Gianotti, and by INFN President Fernando Ferroni, leading the Italian delegation, visited the high technology laboratories and the ATLAS experiment at LHC and met the Italian community working at CERN at the Globe. Only three days earlier, at the end of the CERN Council meeting, the 25th anniversary of the LHC scientific program, started in 1992: indeed, when the previous LEP accelerator had just begun to "do physics" the new accelerator program was launche, had been celebrated. Since then, a lot of progress has been made and many important scientific and technological achievements have been made, including the historical discovery of the Higgs boson in 2012, earning the Nobel Prize for physics for Higgs and Englert the following year. The anniversary just celebrated testifies the extraordinary ability to plan the future, a characteristic of particle physics: even today, while the LHC, thanks to its very high performance, continues to churn out an impressive amount of valuable data, the physics community is working on its upgrade, the High Luminosity LHC, coordinated by the Italian Lucio Rossi, and is already studying the design of future of accelerator machines. ■



GRANT

THE SELDOM PROJECT OF NICOLA NERI HAS BEEN AWARDED AN ERC TO DISCOVER THE SECRETS OF ANTIMATTER

Nicola Neri, a researcher at the INFN section in Milan, has been awarded one of the prestigious grants of the European Research Council (ERC) of almost 2 million euros with his SELDOM project, to be developed at the LHCb experiment at CERN's Large Hadron Collider, to investigate why our universe is made of matter rather than antimatter. The SELDOM project proposes a new experimental method to investigate the asymmetry between matter and antimatter, through the study of certain particular particles: heavy baryons. The distribution of the electrical charge of these particles has a spherical symmetry and their electric dipole moment - which measures the separation of electric charges of opposite sign - is predicted to be zero. One of the possible causes of the asymmetry between matter and antimatter in the universe could be linked to the not perfectly spherical shape of these particles, highlighted by the non-zero electric dipole moment. SELDOM is a competitive project at the international level: it is in fact part of an intense experimental research program of the electric dipole moment of the neutron, of the proton and of leptons, in progress worldwide, adding the new possibility of studying baryons containing heavy quarks, thanks to a new fixed target experiment, in which heavy baryons will be produced and then channelled into curved silicon and germanium crystals. This research could prove important because the eventual discovery of the electric dipole moment of a fundamental particle would represent clear evidence of physics beyond the Standard Model, i.e. of a new physics that goes beyond our current theories, and could tell us how it is possible that the universe exists, us included. ■

APPLICATIONS

SMALL, PRECISE AND POWERFUL: MACHINA, THE ACCELERATOR FOR THE CULTURAL HERITAGE, IS HERE

A next-generation accelerator resulting from the collaboration between INFN and CERN, entirely dedicated to the cultural heritage. This is the identity card of the MACHINA (Movable Accelerator for Cultural Heritage In-situ Non-destructive Analysis) project for the construction, at the laboratories of the Opificio delle Pietre Dure (OPD) in Florence, of a compact, transportable accelerator to be dedicated full-time to non-invasive diagnostic studies for the restoration and study of materials of historical finds and works of art. In recent years, diagnostic techniques for the study of the cultural heritage have undergone significant development that has led to an increase in the demand for scientific support by art historians, archaeologists, restorers, curators and other cultural heritage experts. In parallel, the national INFN-CHNet (Cultural Heritage Network) has been established at INFN which brings together over 15 research teams specialised in this field. Among these, the Laboratory for Nuclear Techniques for the Cultural Heritage and the Environment (LABEC) in Florence where, since 2004, a particle accelerator has been used also for analysis of the cultural heritage, with which, thanks to the collaboration with OPD, many works of art and finds have been studied, including masterpieces by Leonardo, Mantegna, Antonello da Messina and many more. MACHINA will be implemented with technology developed at CERN for biomedical applications, called radio frequency quadrupole technology (HF-RFQ), that will allow a high precision and small size (approx. 2 metres long and weighing 300 kg) accelerator to be built, thus allowing it to be transported in places large or immovable works, as frescoes, or works which cannot be transported due to their fragile preservation conditions are preserved. ■

NOMINATION

MARICA BRANCHESI IS AMONG THE 10 PERSONALITIES OF THE YEAR FOR THE JOURNAL NATURE

Marica Branchesi, a scientist of the VIRGO collaboration, Associate Professor at the Gran Sasso Science Institute (GSSI) and associate researcher at INFN, has been included by the journal Nature in the 2017 ranking of the 10 personalties who have made the most significant contribution in the world of science.
With the role of coordination between the LIGO and VIRGO interferometers and the electromagnetic telescopes network, Branchesi is one of the protagonists of the historic result announced jointly by the two collaborations, on 16 October 2017, of the first detection of gravitational waves from the fusion of two neutron stars: Branchesi was among the scientists who presented the result during the LIGO and VIRGO conference in Washington at the National Science Foundation (NSF), at the same time as many other conferences worldwide, including that in Italy of the INFN, of the National Institute of Astrophysics (INAF) and of the Italian Space Agency (ASI), in collaboration with the Ministry of Education, University and Research (MIUR). The observation of a gravitational wave signal from the fusion of two neutron stars, which took place simultaneously with the observation of the electromagnetic counterpart of this source, marked a historic change in our way of studying the universe with the beginning of the era of multi-messenger astronomy.
Marica Branchesi is also chair of the gravitational wave commission of the International Astronomical Union and member of the Gravitational Wave International Committee. ■

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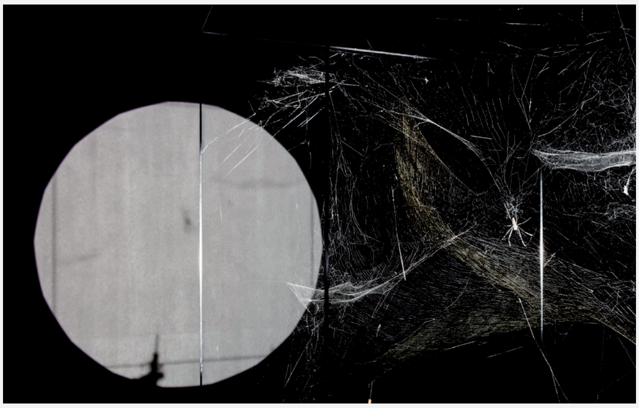

THE EXHIBITION "GRAVITY" IMAGINES THE UNIVERSE AFTER EINSTEIN

It is not wrong to consider the exhibition *Gravity. Imagining the Universe after Einstein*, conceived by MAXXI, 21st Century Art Museum in Rome, together with INFN and the Italian Space Agency (ASI), as an unexpected side effect of the recent discovery of gravitational waves. A discovery which, in addition to constituting a historic scientific result, has had such global repercussions as to also capture and focus the attention of artists, intellectuals and the world of culture in general on our ability to know the cosmos. Gravity effectively accepts the challenge of creating dialogue between contemporary art and science on this issue: a dialogue whose outcome is by no means to be taken for granted. The exhibition is divided into three thematic areas - Spacetime, Crises and Boundaries - that have at the centre as many crucial stages of the theoretical vision developed by Albert Einstein, father of the Theory of Relativity that led the German physicist, among other things, to predict the existence of gravitational waves a century before their discovery. More generally, Einstein's theory revolutionised our vision of the universe, rethinking the categories of space and time and providing us with powerful new tools to describe cosmic phenomena, as well as fundamental particle physics. And it is this radical change in our perspective on the world which dialogues in the exhibition with the visions of a number of important contemporary artists.

The almost dark space of the exhibition is pervaded by the sounds of the *Cosmic Concert* of the Spanish artist Thomas Saraceno, which derive from a 'sonification' of digital signals, generated by very different phenomena and on incommensurable cosmic scales. The data, transformed into sounds, is generated, for example, by the 'noises' of deep space and the imperceptible vibrations made by a spider on a large spider's web; by the steps of the visitors in the exhibition and by the imperceptible deformations produced in the gravitational antennas by the fusion of two black holes; or by the signals of the KM3Net submarine

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experiment, able to detect the passage of cosmic neutrinos, but also to record the ultrasounds emitted by dolphins and sperm whales. The sounds of Saraceno create harmonies and dissonances, alluding to the inextricable network of actions and reactions, which regulates natural phenomena, interrelating - with a poetic vision - cosmic scales with the microscopic tremors of a spider. Perfectly integrated in this work is the model, a thousand times smaller, of the Virgo gravitational interferometer, near Cascina, capable of capturing and detecting in real time all the acoustic and mechanical vibrations of the Cosmic Concert, which thus become a perceptible metaphor of gravitational waves.
The scientific story and the artistic suggestion are intertwined in the same way in the *Horn* work by the French artist Laurent Grasso: a reproduction, almost full-scale, of the radio telescope, with which Arno Penzias and Robert Wilson, in the mid-1960s, detected microwave cosmic background radiation. The antenna of Penzias and Wilson, surrounded by the echoes of a forest, becomes a mysterious object, which makes us reflect on our ability to listen to nature and the cosmos, and to decipher the most remote signals. The aesthetic fascination of works of art is balanced by the equally powerful visual impact of a number of original scientific findings, such as the original mirror of the VIRGO gravitational wave interferometer or the antenna of the Cassini-Huyghens probe, orbiting for ten years around the planet Saturn. Yet another element is constituted by the interactive installations, curated by INFN, which allow us to play with dark matter or to curve spacetime, letting us approach the ideas and discoveries of contemporary research in a playful way. And thus in *Gravity*, art and science meet, in an apparently natural way, recognising themselves in the same attitude to listen and scrutinise the cosmos and encouraging us to constantly rethink and change the perspective with which we look at the world.

The exhibition *Gravity*, conceived and implemented by MAXXI, INFN and ASI, is open until 29 April 2017 at the MAXXI museum in Rome. ■

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Cover

An image of *Gravity. Imaging the Universe after Einstein* at the MAXXI Museum, Rome