# **INFN NEWSLETTER 74** Istituto Nazionale di Fisica Nucleare

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## » INTERVIEW



#### FRASCATI NATIONAL LABORATORIES: FROM HIGH ENERGY PHYSICS TO INTERDISCIPLINARY RESEARCH

Interview with Fabio Bossi, newly elected director of Frascati National Laboratories and former director of the INFN division in Lecce.

The Frascati National Laboratories (LNF) complex is the first, in terms of size and age, of the four INFN National Laboratories. It has taken on the role of forerunner in particle collider research worldwide since its inception, with the pioneering Ada and Adone, also sowing the seeds for the development of the large colliders at CERN in Geneva, which saw the laying of the foundation stone in the same years. Since 2000, LNF has hosted DAFNE, the collider, still operating, that holds the world record for low energy instantaneous brightness.

The technical and scientific expertise of the LNF in the field of accelerators is unique in Italy and competitive in Europe. Thanks to the broad spectrum of expertise put in place to pursue fundamental physics objectives, activities complementary to research in high energy physics have grown, including the study of condensed matter, the study of new detectors, medical and space applications, radiation dosimetry and environmental control, computer network management and the construction of advanced computing centres. A vital part of the Laboratories is the the SPARC free-electron laser, built in collaboration with ENEA and CNR, and the very high-power FLAME laser for the study of innovative particle acceleration techniques.

Fabio Bossi, former director of the INFN division in Lecce, has been appointed as the new director of the Frascati National Laboratories, taking over from Pierluigi Campana who has managed the structure since 2015 and who, at the beginning of 2020, was appointed as a supervisory member of the Ministry of Education, Universities and Research, on the INFN Executive Board.

Fabio Bossi, from Rome, is an elementary particle experimental physicist. He has worked at CERN and LNF on electron-positron collision experiments. He has also been involved in precision measurements of the Standard Model, flavour physics and light dark matter research. He was head of the KLOE-2 collaboration at the LNF Dafne accelerator and head of the Research Division of the Laboratories themselves. We asked him, as the newly appointed director, to tell us how he sees the LNF in the near future.



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# How does it feel to move from managing the INFN division in Lecce to managing the largest of the INFN laboratories?

Beyond the human aspect, which was extraordinary, the four-year period in Lecce was an excellent training ground for me to understand many aspects of the management of the Institute that I only partially knew. Certainly, the big step towards LNF is a great challenge not only because of the size of the structure, but also because running a National Laboratory also means steering and supervising its scientific production and ensuring it meets the highest possible quality standards. In addition, LNF plays a central role in INFN, because it has skills that in certain cases are unique in the institute, skills that under no circumstances must be lost. Managing it, therefore, is a great responsibility.

# The historical tradition of LNF is an important legacy. How can the unique skills of the laboratories be best developed, projecting their qualities in the near future? Through which scientific and/or technological challenges?

Our subject, Particle Physics, is experiencing an epochal turning point. We need to take a conceptual and technological leap forward in our ability to accelerate particles at increasingly higher energies. We also need to build more refined detectors to detect phenomena that are hitherto still mysterious. LNF has the necessary skills to tackle these challenges as a protagonist. It also has very ambitious development programmes in these fields; I am thinking mainly, but not exclusively, of the Eupraxia (European Plasma Research Accelerator with eXcellence In Applications), the European project for the development of a plasma accelerator. Apart from the technical issues, however, I believe that the of the process to develop innovative instruments and technologies is strongly linked to our ability to train and grow a new generation of researchers, engineers, technicians and staff with administrative and management skills) who will have to manage the development of research in the years to come. I believe that investing in the younger generation is a key strategic task.

At the beginning of your career, the results achieved in recent years, with the discovery of the Higgs boson at CERN, also thanks to many LNF researchers, and the discovery of gravitational waves, in the search for which LNF has played an important role since the 1980s with the Nautilus experiment? A new research path is now opening, perhaps less marked than the previous one... When you are young you are always optimistic and full of hope. So, I have to say yes, I thought and hoped so. In fact, I must admit that I was hoping that we could open an even more important window on New Physics, beyond the Standard Model. We have learned that this enterprise is more



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to be just as exciting and full of good results as the past ones.

# For several years, you were the spokesperson for the KLOE-2 collaboration at LNF, contributing to publications on the research of dark photons, particles potentially related to dark matter. In this context you are among the founders of the PADME collaboration at LNF for the search for dark photons and light dark matter. What does it involve?

The nature of dark matter is surely one of the unsolved mysteries of physics. To date, we have no definite indication in this regard, but we can only put forward reasonable hypotheses to be tested experimentally. One of these hypotheses envisages that dark Matter is subjected to a new type of interaction whose mediator is similar to the photon of electromagnetism but is endowed with a mass, albeit small: the dark photon. This particle can be generated in electron-positron collisions at relatively low energies, such as those achievable with LNF's accelerators. When, ten years ago or so, together with other colleagues, we realised that our laboratory could be the protagonist of this research, we jumped headlong into the enterprise and published a series of experimental works on the subject. Unfortunately, to date we have not obtained any evidence of the existence of this particle, but as is well known, this is the nature of science: searching does not necessarily always translate into finding something, but also important information can be drawn from this "not finding".

# LNF also played an important role in the creation of CNAO, the oncological Hadrontherapy Centre in Pavia. How did the vocation of LNF in interdisciplinary research and applied physics arise?

The awareness that our research can, sometimes unexpectedly, find applications in areas other than fundamental research has been growing over the years, and now an important part of our scientific programme is specifically dedicated to this type of issue. Certainly, the development of accelerators and detectors for oncological Hadrontherapy is a reality which we are very proud of, but today we are designing and building facilities that also have an impact in other areas, for example in cultural heritage or aerospace. Furthermore, lines of contact with the business world are opening up, in particular through the SABINA (Source of Advanced Beam Imaging for Novel Applications) e LATINO (A Laboratory in Advanced Technologies for INnOvation) projects which aim to transfer our technical-scientific skills to regional and national industries. I believe that this virtuous circle: "fundamental research, applied research, transfer to industry" is a significant key to understanding the central role that INFN plays in the development of our country.





#### RESEARCH

INFN IN THE \$115 MILLION US QUANTUM COMPUTING PROJECT

The funding allocated by the U.S. Department of Energy (DOE) to the Superconducting Quantum Materials and Systems Center (SQMS),

at the Fermi National Accelerator Laboratory (Fermilab) in Chicago, amounts to \$115 million. Headed by Anna Grassellino, researcher who took her first steps at INFN, SQMS will have the task of developing a revolutionary quantum computer based on superconducting technologies. INFN is the only non-US partner of the project and will receive a contribution from the DOE of approximately \$1.5 million. INFN is contributing to the project with a globally competitive know-how in quantum theory, superconductive and cryogenic technologies and detectors development. The use of the quantum devices implemented by SQMS will allow INFN to develop more sensitive detectors for the detection of "exotic" particles, such as dark matter. Of great importance within SQMS is the implementation of a facility for measurement, testing and validation of quantum devices at INFN Gran Sasso National Laboratories, a unique place worldwide for research with very low environmental radioactivity.

At the centre of the American race for the efficiency in quantum computing, which has a parallel in Europe with the Horizon 2020 Quantum Flagship, lies one of the most urgent problems in quantum information science today: the time of "quantum coherence", the period of time in which a qubit, the basic element of a quantum computer, can keep information unchanged. Understanding and mitigating sources of decoherence, which limit the performance of quantum devices, is critical to the engineering of next-generation computers and quantum sensors.

In addition to INFN and Fermilab, about 20 partners are participating in the SQMS project, more than 80 American research centres, universities and companies, as well as Rigetti Computing, one of the most important quantum computing industrial companies worldwide.





#### RESEARCH

# CMS AND ATLAS HAVE ANNOUNCED NEW RESULTS ON THE HIGGS BOSON'S PROPERTIES

CERN'S CMS and ATLAS experiments have announced new results indicating that the Higgs boson decays into two muons: second

generation elementary particles, similar to electrons but heavier. The work was presented at the International High Energy Physics Conference ICHEP 2020. Following the discovery of the Higgs boson, announced at CERN in 2012, physicists have studied this particle, generated in the collisions of the LHC accelerator, through the particles generated by its decay. In this case, the CMS and ATLAS researchers observed the rare decay of the Higgs boson into two muons, with a significance that reached 3 sigma for the CMS experiment, the standard to announce experimental evidence. Obtained by studying a rare phenomenon involving only one Higgs boson out of 5000, these results for the first time indicate that the Higgs boson interacts with second generation elementary particles, in accordance with the prediction of the Standard Model: a result that will be further refined with the data collected in the next series of collisions. The threshold of experimental evidence of this important process was reached by the CMS experiment also thanks to the use of Deep Learning tools, i.e. techniques developed in the field of Artificial Intelligence and commonly used by the IT giants in our mobile phones or self-driven cars.

CMS <u>https://cms.cern/news/cms-sees-evidence-higgs-boson-decaying-muons</u> ATLAS <u>https://atlas.cern/updates/physics-briefing/new-search-rare-higgs-decays-muons</u>





#### RESEARCH

# ATLAS HAS OBSERVED A RARE PHENOMENON WITH PROMISING DEVELOPMENTS FOR THE FUTURE OF LHC

At the beginning of August, at the international high-energy physics conference ICHEP 2020 - held in virtual form from Prague - CERN's

ATLAS scientific collaboration presented new results that pave the way for a new way of using the LHC accelerator as a high-energy photon collider. The experiment announced the first observation of photoninduced production of a pair of W bosons, weak force mediating particles. This is the observation of a very rare phenomenon in which the two photons interact with each other to produce two W bosons of opposite electrical charge, through the direct interaction of four mediators of two different forces, the electromagnetic force and the weak force. The result has a very high significance of 8.4 sigma, which rules out the possibility that it is due to a statistical fluctuation. While what ATLAS observed confirms one of the main predictions of the electroweak theory, it also provides a new way, through the study of photon collisions, of testing the Standard Model and probing the New Physics, to reach a deeper understanding of our universe. The observation of photon-induced production of W boson pairs is a further fundamental step forward in our understanding of electro-weak interactions, following the measurement in 2017 of the light-by-light interaction process in which photon pairs are generated in photon interactions.



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# NA62 EXPERIMENT AT CERN TACKLES A VERY RARE PROCESS

A very rare process has been observed with an excellent level of statistical confidence and with unprecedented accuracy by the NA62 experiment at CERN. We are speaking of a particle decay that sees a charged kaon turning into a charged pion with a neutrino and an antineutrino. The new results were presented on July 28 during the International Conference on High Energy Physics 2020 (ICHEP 2020) by the collaboration of researchers working on the experiment, which includes INFN physicists and technologists. The detailed study of this process could allow us to find signs of New Physics, that's the physics that we do not yet know and that could extend our current theories. Indeed, the objective of NA62 is to find in this process something not foreseen by the Standard Model, the theory that today gives us the best description of the world of elementary particles and their interactions.

NA62 is an experiment consisting of several particle detectors using a proton beam extracted from CERN's Super Proton Synchrotron (SPS) accelerator. The protons are made to collide on a beryllium target to generate an intense secondary beam with a significant percentage of kaons, the particles that are the subject of the experiment. Unlike the experiments that have studied this rare decay to date, such as E787 and E949 of the Brookhaven National Laboratory in the United States, NA62 studies kaons "in flight", within a volume, over 60 meters long, in which a vacuum has been created. This approach makes it possible to increase the total number of observable decays. In the data collected in 2018, obtained from more than two billion proton collisions on a beryllium target, NA62 was able to record 17 events that could correspond to this particular decay of the kaon, if added to the three events identified in the data collected between 2016 and 2017, these events provide a great level of statistical confidence (3.5 sigma), making it possible to announce evidence of this very rare decay, which physicists have been searching for over 50 years.



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Analysis of the data proved to be a major challenge: signal events must be extracted from the sea of events that constitute the "background noise", a number one trillion times greater than the number of events to be observed. In these cases, it is important not to be influenced by the data but to define their analysis criteria before the analysis phase itself, based on preliminary studies. This is what was done by applying so-called blind analysis: only after having definitively decided the analysis criteria did the researchers observe the data and find the signal events.

The NA62 collaboration, led by the Italian Cristina Lazzeroni from the University of Birmingham, involves approximately 200 physicists from Europe, the United States, Canada, Mexico and Russia. INFN's commitment stands out with approximately one third of the participants: over 70 physicists and technologists from the Frascati National Laboratories and eight INFN Divisions - Ferrara, Florence, Naples, Perugia, Pisa, Rome1, Rome2 and Turin - are making a decisive contribution to the success of the experiment with important responsibilities, both on the detector (with the development of the highly advanced beam tracking system, the veto system for photon and charged particle backgrounds, and the pioneer detection system) and on the complex data acquisition system of the experiment.



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Quantum laboratory at Fermilab. © Fermilab

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