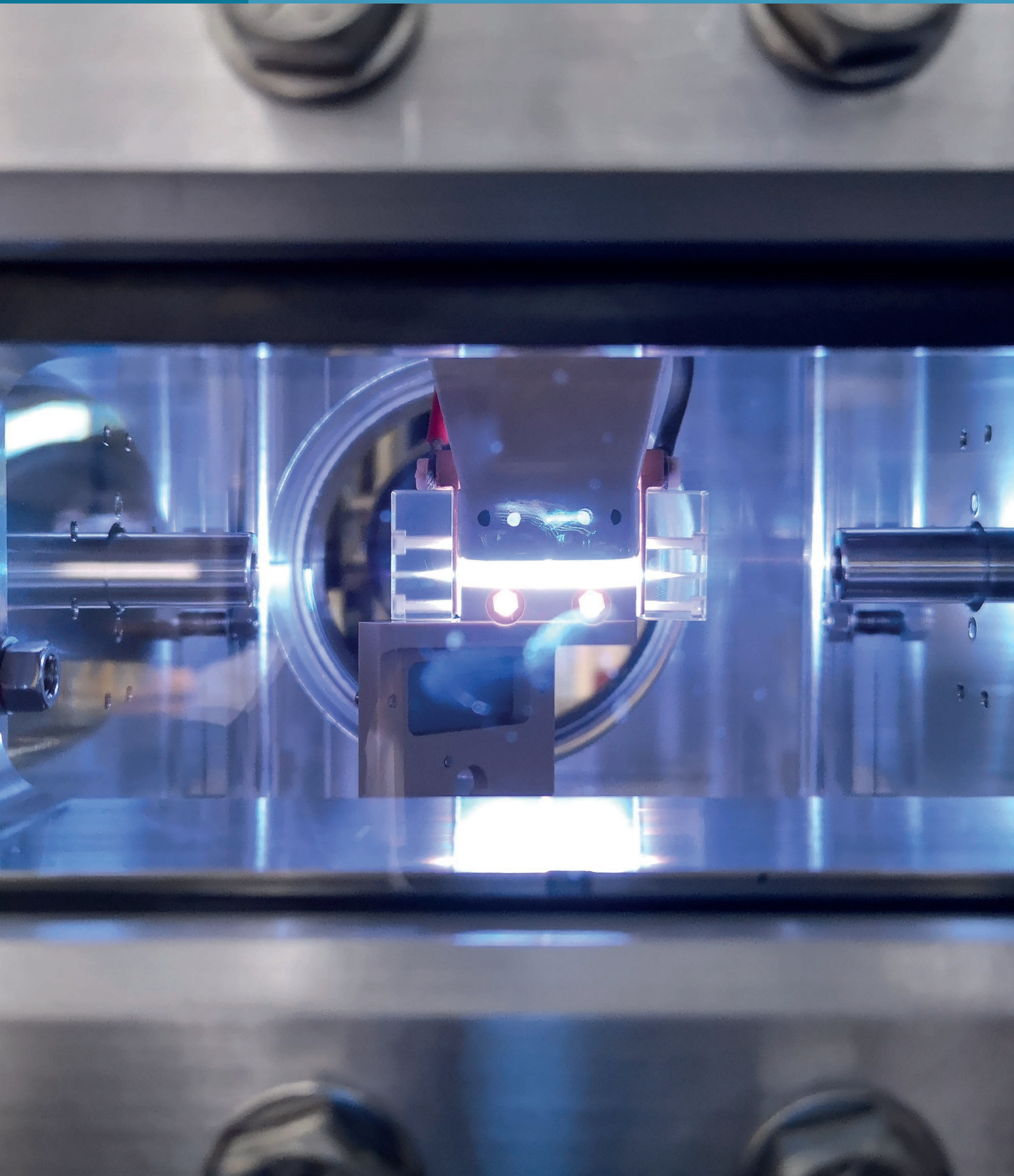
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

ONE YEAR OF RESEARCH AT LNF

LNF HIGHLIGHTS 2022



Some LNF achievements during 2022

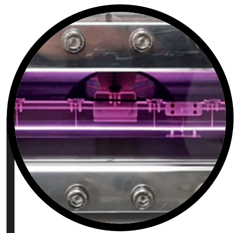
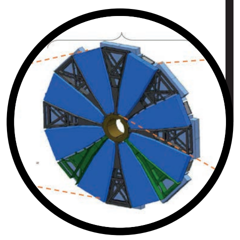


Image acquired during the plasma formation within a gas-filled discharge capillary with a length of 400 mm and diameter of 2 mm.

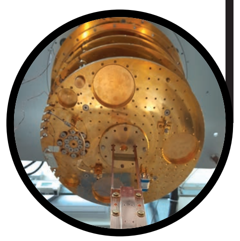
Participants at the EuPRAXIAPP kick-off meeting.

View of the experimental hall with the PADME detector.



The ATLAS Detector at the LHC showing the position of the NSWs

The readout system as seen from the photonmultiplier tube side.



The resonant cavity of the Haloscope connected to the coldest plate of the dilution refrigerator.

In this photo it is shown the HEP scape room installation while people are playing at this science game.

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FOREWORD

Year 2022 has seen important progress for EuPRAXIA, the flagship project of our Laboratory. On the one hand, the first prototype of the plasma accelerating module of the EUPRAXIA@SPARC_LAB facility has been built and succesfully tested in the PLASMA Laboratory. On the other hand, the large community that is participating in the project has been granted funding for several multi-million euro initiatives by the European Commission. This testifies, if needed, the enormous interest of the scientific community around the construction of this plasma-acceleration based facility that will drive the Laboratory towards a bright future.

In the fall, the BTF facility has delivered a dedicated beam to the PADME experiment with the purpose of finding evidence for the existence of a hypothetical new particle, dubbed as "X17". If PADME will observe signals of the X17, this will be the first incontrovertible evidence for new phenomena that cannot be explained by the currently accepted Standard Model of Particle Physics. For this reason, the analysis of the data has to be carried out with special care: the first results are expected to come by the end of 2023. In the meanwhile, large detectors developed and built in Frascati have been succesfully installed in major laboratories around the world, a further demonstration of the special and internationally recognized competences of our reasearchers, engineers and technicians.

After two years in stand-by due to the Covid-19 pandemics, the Laboratory has opened the doors to the general public for the traditional "Open Labs" happening. More than 2000 visitors have joint our personnel in a full day of visits to the research infrastructures, seminars and scientific demonstrations dedicated to people of all ages. It is amazing to see how big is the demand for a deeper understanding of science issues by the average citizen; as scientist we are absolutely happy and willing to satisfy this request.

Fabio Bossi / LNF Director

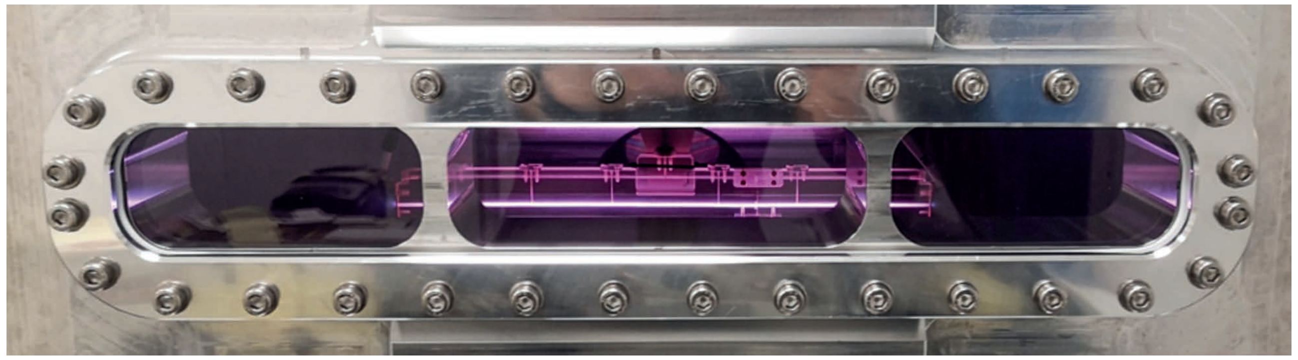
THE FIRST DISCHARGE IN THE EuPRAXIA@SPARC_LAB, PLASMA ACCELERATION MODULE

The testing of the first prototype of the plasma accelerating module of the EuPRAXIA @ SPARC_LAB project has been successfully carried out in the Plasma_LAB laboratory.

Unlike the previous tests, which were performed with discharge capillaries of a few cm in length, in this case it has been demonstrated the possibility of creating a capillary of nominal length, 400 mm as foreseen in the Conceptual Design Report of the project, capable of supporting a uniform discharge along the entire structure.

The EuPRAXIA@SPARC_LAB project, intended to put forward LNF as host of the EuPRAXIA European Facility and recently included in ESFRI (European Strategy Forum on Research Infrastructures), provides, for an electron beam injected into the plasma at 500 MeV, the achievement of a final energy of 1.1 GeV through the use of a plasma section capable of ensuring an accelerating gradient of 1.5 GV/m. During these first tests, a stable and reproducible plasma with an electron density of the order of 10^{16} cm^{-3} has been created and confined within a capillary 400 mm in length

Figure 1.
Image acquired during the plasma formation within a gas-filled discharge capillary with a length of 400 mm and diameter of 2 mm, which is mounted inside a vacuum chamber expressly created to house large plasma sources. The applied voltage pulse is 9 kV and the peak current reaches about 500 A.



and 2 mm in diameter. The plasma source has been entirely designed and built at the LNF.
The plasma formation technique is based on the use of high-voltage pulses (between 10 and 25 kV, with current peaks up to 2 kA and duration around 600 ns) to ionize a homogeneous gaseous hydrogen column produced between two electrodes.
The synchronization between the gas injection into the longitudinal capillary's channel, obtained by means of 6 vertical inlets, and the instant for supplying the high-voltage pulse represents a crucial point to achieve stable and uniform plasmas suitable for producing high-quality accelerated beams.
Given the considerable size of the plasma source and the impossibility of making it in a single piece by using common 3D-printers, two sections are printed and then later joined by means of a die-casting technique, which provides gas losses of the order of 1010 mbar.
The systematic characterization of the plasma behavior during the gas discharge has just begun, but its first ignition represents a very important milestone for the EuPRAXIA project and in any case a novelty on the world scene.

EUPRAXIA PREPARATORY PHASE KICK-OFF MEETING

The European plasma accelerator community has received a major impulse for the development of a user-ready plasma accelerator facility with the funding of several multi-million euro initiatives under the umbrella of the EuPRAXIA project. These are EuPRAXIA Preparatory Phase, EuPRAXIA Doctoral Network, and EuPRAXIA Advanced Photon Sources, as well as funding for the construction of one of the sites of EuPRAXIA in Frascati.
The EuPRAXIA project aims at the construction of an innovative electron accelerator using laser- and electron-beam-driven plasma wakefield acceleration that offers a significant reduction in size and possible savings in cost over current state-of-the-art radiofrequency-based accelerators.
The EuPRAXIA project started with a Design Study, which was funded under the EU Horizon 2020 programme, and culminated at the end of 2019 with the publication of the worldwide first Conceptual Design Report for a plasma accelerator facility. EuPRAXIA was then included in 2021 in the European Strategy Forum on Research Infrastructures (ESFRI) Roadmap, which identifies those research facilities of pan-European importance that correspond to the long-term needs of the European research communities.

Figure 1.
Projected building for the particle-driven plasma accelerator of EuPRAXIA in Frascati. Credit: INFN & Mythos – consorzio stabile s.c.a.r.l.

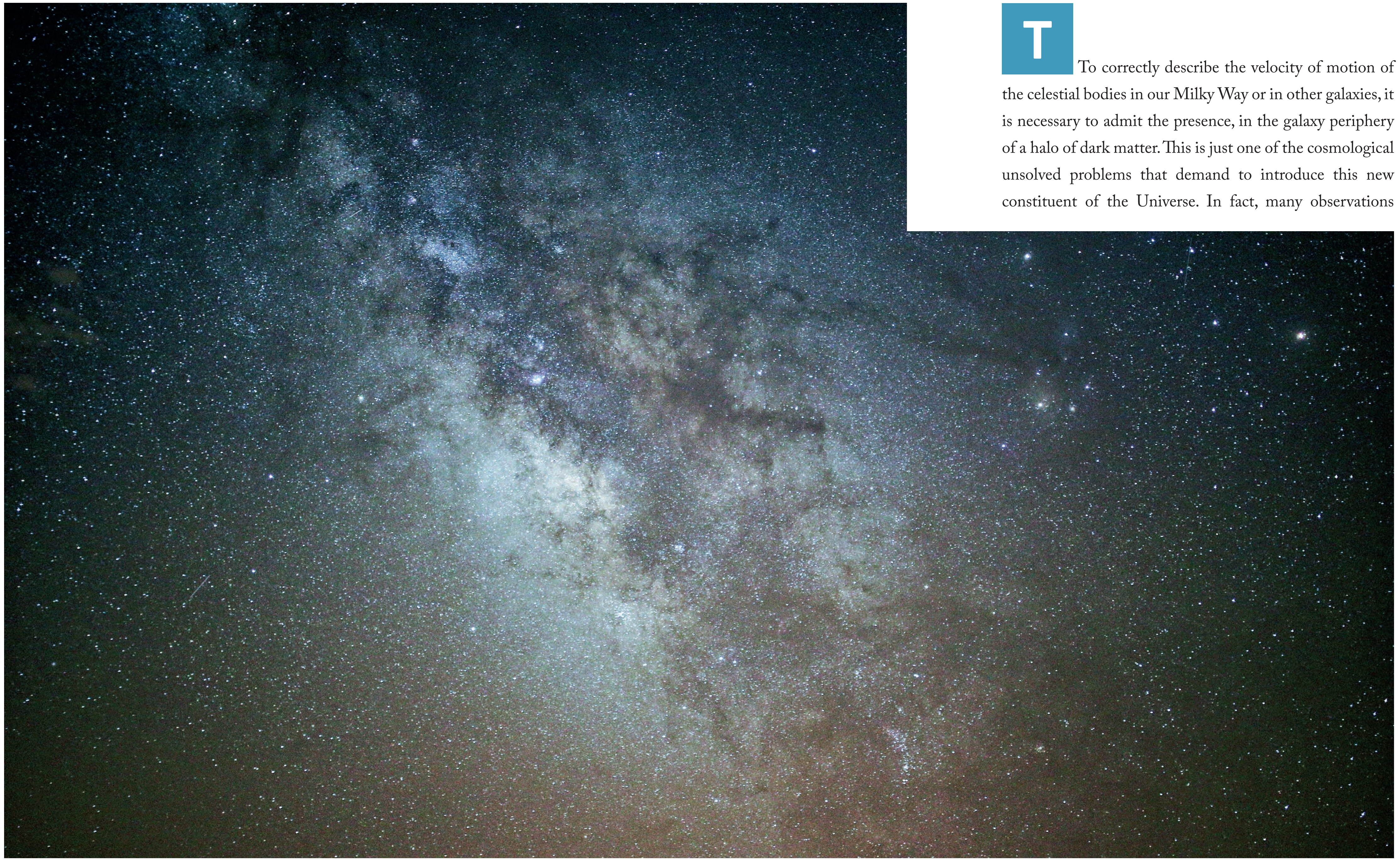
Figure 2.
Participants at the EuPRAXIA-PP kick-off meeting.

Now the the 3.69M€ EuPRAXIA Preparatory Phase project started with a kick-off meeting on 24/25 November 2022 in Frascati, that brought together 115 representatives from all 34 participating institutes, from Italy, Czech Republic, France, Germany, Greece, Hungary, Israel, Portugal, Spain, Switzerland, United Kingdom, USA and CERN as International Organization. EuPRAXIA-PP is a project designed to develop the organizational, legal, financial and technological aspects of the EuPRAXIA facility – an innovative laser- and electron-beam-driven plasma wakefield accelerator – following the recommendations of the European Strategy Forum on Research Infrastructures (ESFRI). This Preparatory Phase project will give the consortium a unique chance to prepare over the next four years the full implementation and realisation of EuPRAXIA as a new, distributed ESFRI Research Infrastructure for Europe. The meeting was hosted by Massimo Ferrario and Ralph Assmann, who coordinates the network at the Italian National Institute for Nuclear Physics – INFN in Frascati. Fabio Bossi, director of Laboratorio Nazionale di Frascati (LNF) welcomed the participants, giving an overview of the LNF facilities and their role in the EuPRAXIA project. All work package leaders had the opportunity to introduce and discuss the plans for their respective areas of responsibility, from the organizational to the technical tasks, finalizing with a round-table discussion.

On the following day, the management team explained the administrative aspects of the project; Carsten Welsch and Massimo Ferrario presented the EuPRAXIA Doctoral Network and the EuPRAXIA Advanced Photon Sources respectively, and the first meetings of the EuPRAXIA-PP and EuPRAXIA-ESFRI Collaboration Boards took place. The participants were offered a tour of SPARC_LAB and the EuPRAXIA@SPARC_LAB site, which will host the beam-driven accelerator of EuPRAXIA.

The kick-off meeting was a testament to the growing international interest in plasma accelerators in general and EuPRAXIA in particular, as the world-first facility implementing this technology.

THE PADME EXPERIMENT NON-CONVENTIONAL SEARCH FOR DARK MATTER AT ACCELERATOR



To correctly describe the velocity of motion of the celestial bodies in our Milky Way or in other galaxies, it is necessary to admit the presence, in the galaxy periphery of a halo of dark matter. This is just one of the cosmological unsolved problems that demand to introduce this new constituent of the Universe. In fact, many observations are pointing in the direction that only a tiny fraction of the matter in our Universe is made of the fundamental particles that obey to the rules of the Standard Model. Understanding what the rest is, its nature and interactions, it is one of the most urgent questions of modern physics.

Among the experiments involved in this challenge, we distinguish two complementary categories: experiments trying to detect galactic dark matter underground or in the outer space, and those trying to produce dark matter at accelerators. The Positron Annihilation into Dark Matter Experiment (PADME) ongoing at LNF is ascribed to the second category.

Some theoretical models postulate the existence of a new force bridging our world with that of dark matter [1-2]. This "fifth force" would require a mediator particle with a non-zero mass, a dark photon, similar to the ordinary one that mediate the electromagnetic force.

The PADME detector was conceived to search for a dark photon *A'* weakly interacting with leptons and then accessible via the annihilation process $e^+e^- \rightarrow \gamma A'$ [3]. The existence of an *A'* would be highlighted studying the missing mass of events with a single photon in the final

Figure 1.
A picture of our galaxy: the Milky Way. According to observed gravitational effects, a halo of dark matter should be present in the galaxy periphery.

state and requiring a peak in the distribution of this quantity. This approach just makes few requirements on the dark photon nature and therefore is extremely unbiased.

The opportunity of studying this process at LNF is something unique in the panorama of particle physics and it is possible thanks to the availability of the high intensity positron beam of the Beam Test Facility (BTF) of the DAΦNE complex. This beam, whose energy is precisely tunable up to 550 MeV, exhibits also excellent features in terms of spot size and energy resolution.

Despite of the pandemic, PADME had in 2019 and 2020 two periods of data taking: Run I and Run II. The first one was mainly devoted to the commissioning of both the detector and the beam line. This last required an intense tuning work by the BTF staff. In fact, the nominal conditions of the positron beam delivered by the LINAC are not ideal for the experiment. In particular, the duration of the positron pulses is too short (~ 10 ns). The bunch length was then stretched up to ~ 300 ns to reduce the possibility of multiple positron interactions in the target. On a parallel line, the separation between the accelerator vacuum and that of the detector had to be refurbished to reduce the background coming from the beam halo interacting with the beam line materials (beam-induced background).

Thanks to all the optimization performed, during Run II the quality of the collected data was excellent, allowing their use for a first physics measurement: the evaluation of the cross-section of the process $e^+e^- \rightarrow \gamma\gamma(\gamma)$ *at* $\sqrt{s}$=20 MeV. This is a scientific result per se, since there were no previous measurements done with a precision better than 20%. Furthermore, the existing measurements date back to the '50s and since they were performed with bubble-chambers, they were actually measuring $e^+e^- \rightarrow$ *not charged particles*. The result obtained by PADME is in agreements with NLO QED calculations within 5% [4].

This measurement has also implications for the dark matter search: any new physics phenomena (i.e. production of new particles) in this energy range should have a coupling to e^+e^- constrained by this value. The measurement was also the necessary preliminary step to optimize the detector response before attacking the study of single photon final states. The result of the analysis for the search of the *A'* is proceeding and will be published soon.

Starting form 2016, a Hungarian collaboration of the Atomki Institute of Debrecem, while studying several light nuclei de-excitation via internal pairs creation (^{8}Be, ^{4}He, ^{12}C) reported an anomalous behavior that can be interpreted with the creation and subsequent decay into e^+e^- of a particle of mass ~ 17 MeV now called the X17 [5-7] (see Fig. 3).

This unexpected result triggered theoretical speculations and experimental attempts to confirm or disprove the existence of such a new particle.

PADME stands in the unique position of trying to directly form the X17, since there are no other positron beams of the needed energy all over the world. By properly tuning the energy of the incident positrons, PADME may produce the resonance in the annihilation with the electrons of the target. After several studies to evaluate the sensitivity and the background sources, some modifications of the experimental setup were performed, and in the second half

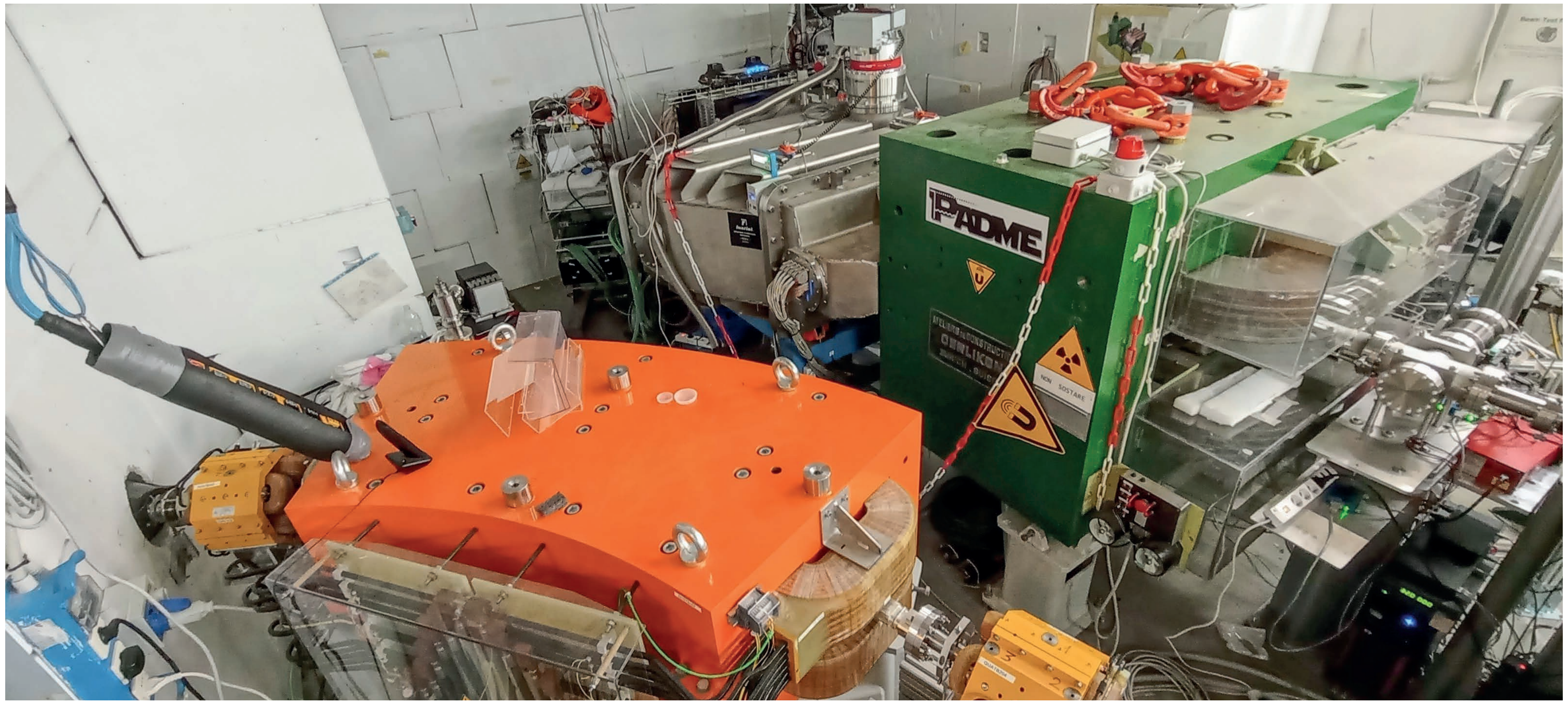


Figure 2.
View of the experimental hall with the PADME detector.

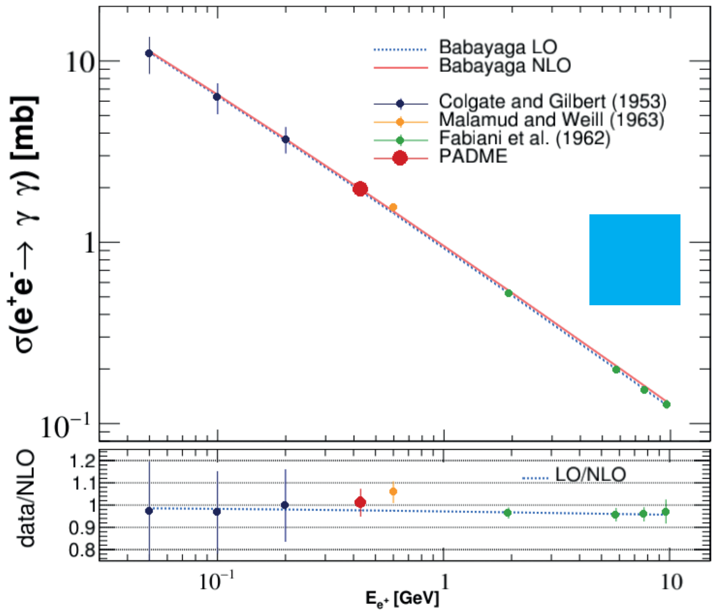
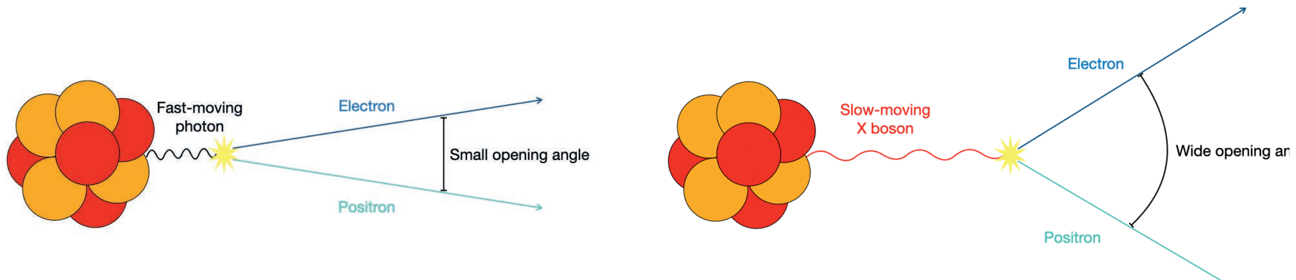


Figure 3.
Experimental measurements of the positron annihilation cross-section in flight at different positron energies (points) compared with theoretical predictions (lines).

of 2022 a dedicated data taking was taking place (Run III). It consisted in an energy scan around the center of mass value of the particle plus some other points collected off-resonance to calibrate the analysis procedure.

In total ~ 5×10^{11} events were collected at 47 different energies of the incident positrons. Now the collaboration is performing the analysis of these data and a preliminary result is expected within 2023.



HYPOTHETICAL NUCLEUS DE-EXCITATION

EXPECTED NUCLEUS DE-EXCITATION

Figure 4.
Cartoon of the de-excitation mechanism of a nucleus (left).
Cartoon of the hypothetical creation of a X17 boson (right).

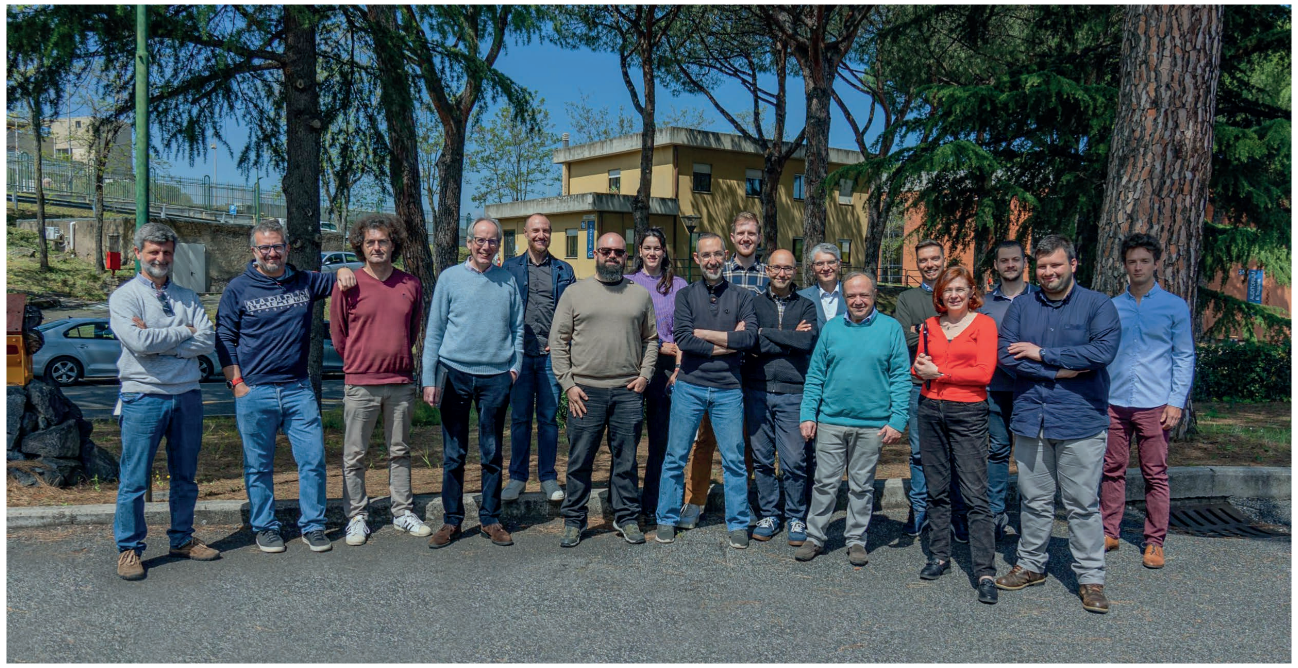


Figure 5.
Some members of the PADME collaboration

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THE ATLAS NEW SMALL WHEEL IS READY FOR LHC RUN III

A

ATLAS [1] is the largest experiment at the Large Hadron Collider (LHC) [2] and is undergoing the Phase 1 upgrade. An improvement in the performances was required in the ATLAS forward Spectrometer (New Small Wheel, NSW) both for the trigger and the track reconstruction to cope with the higher luminosity foreseen for the future LHC Runs (up to 5-7 x 10^{34} cm^{-2} s^{-1}).

Micromegas (MM) [3] and small Thin Gap Chambers (sTGCs) were chosen as fast detectors able to perform precision tracking (~100 µm per plane with an efficiency > 90%) and to cope with the increasing background particle flux as the luminosity increases (up to 20 kHz/cm^2) while rejecting fake triggers.

The ATLAS MM and sTGC detectors have a trapezoidal shape, to match with the wheel structure of the NSW as shown in Figure 1.

Resistive Micromegas chambers are frontier Micro-Pattern Gas Detectors produced for the first time on large dimensions ($O(m^2)$) with a planar geometry operating in a gas mixture of $Ar:CO_2:IsoC_4H_{10}$ (93:5:2).

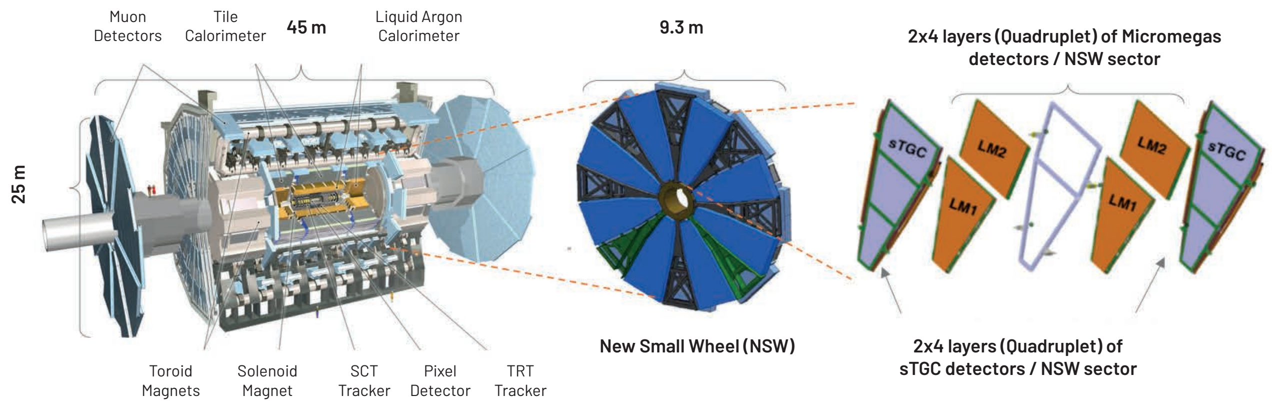


Figure 1.
The ATLAS Detector at the LHC showing the position of the NSWs with their sector structure and the composition of each sector out of sTGC and MM quadruplet modules.

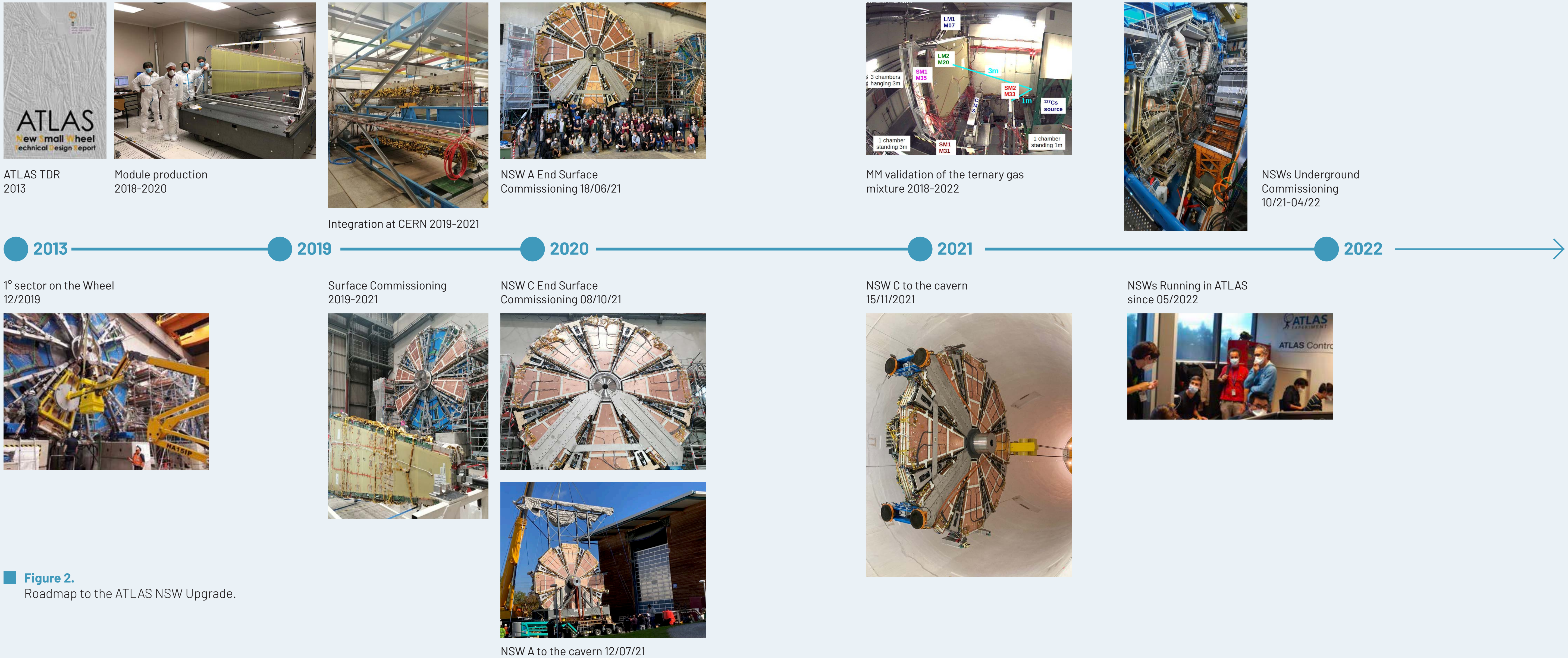


Figure 2.
Roadmap to the ATLAS NSW Upgrade.

They have a 5 mm conversion (drift) gap (cathode at -300 V), a floating mesh embedded in the drift panel structure and a 128 μm wide amplification gap between the read-out (RO) PCBs and the mesh (supported by insulating pillars of millimetric diameter), which is grounded. The PCBs are produced by industries, with 300 μm wide strips and a pitch of 425-450 μm. Resistive strips are superimposed to the copper signal strips to mitigate the intensity of discharges [4]. The detector, in this fashion, is really compact with a high electric field (~ 45 kV/cm) on a surface of (O(m²)) in the amplification gap (anode at ~500 V), high transparency and with fast ions evacuation (~100 ns). Each MM chamber is a quadruplet formed by 5 stiff panels needed to form 4 gaps when coupled: 2 RO panels, and 3 drift panels composed by cathode PCBs and the meshes. Two out of four layers have strips inclided by ± 1.5° in order to reconstruct the 2nd coordinate (stereo layers), while the other two aim for precision coordinate reconstruction (eta layers).

NSW MM were constructed with some peculiarities with respect to the status of the art of the pre-esistent MM technology[5][6]:

- screen printed resistive strips capacitively coupled to copper read-out strips, in order to cope with the high flux expected in view of the HL-LHC future Runs. Equidistant interconnections are made on the resistive circuit to have uniform resistance across the pcb (~10 MΩ/cm).
- mesh at ground potential in order to allow for separation of the anode in separate HV sections, which was required by the fact that industries had limitations in dimensions of the PCBs.
- mechanically "floating"mesh, which is integrated in the drift panel structure and not embedded in the anodic structure (as it was for the bulk MM[5]). This is necessary for large area detectors and allows for chamber re-opening in case of intervention.

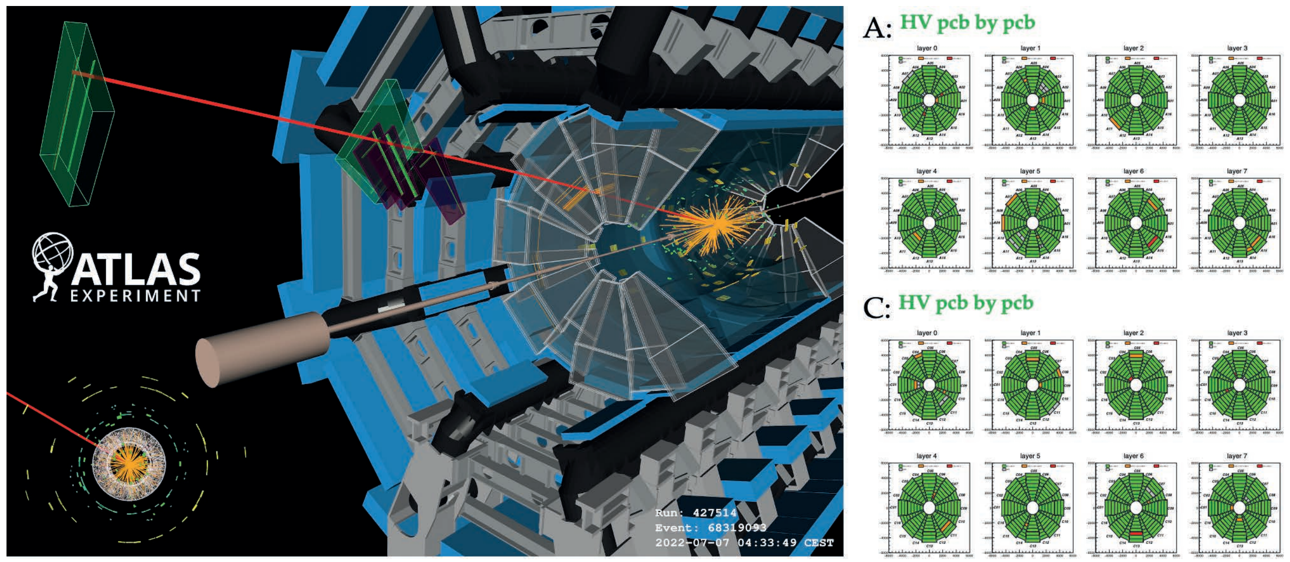
It has been a long way to the integration of the NSW in the ATLAS cavern starting from NSW Technical Design Report (TDR) describing the project, passing through the single Modules assembly, and the integration and commissioning steps at CERN. The Frascati team has played a leading role in this effort in all the steps bringing the project to a full success. Figure 2 summarizes the main steps toward the NSW completion.

Preliminary results are available to test the NSW performances with the Early Run III data. Figure 3 shows on the left an event diplay of a muon interacting with the NSWs during the early Run III data-taking and on the right, the HV behavior of the 2 NSWs (A side and C side). HV preliminary performances are shown, for each HV section (i.e. one pcb) showing that ~ 97% of the channels at nominal HV.

This picture is only preliminary since effort are ongoing to optimize In conclusion, the New Small Wheel is the largest ATLAS Phase-I upgrade project and it aims at improving Level-1 muon trigger and tracking in the ATLAS forward region towards HL-LHC runs. With all the knowledge acquired in the past years we managed to address the main issues affecting the MM detectors.

Detectors have been fully commissioned and installed in the ATLAS cavern. This huge achievement has been possible thanks to the commitment and dedicated effort of hundreds of people but still intense and continuous efforts are ongoing to understand and improve the performance of the system.

Figure 3.
(left) Event display involving the NSWs. (right) HV status of the A and C NSWs.



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THE RING IMAGING CHERENKOV DETECTOR OF THE CLAS12 SPECTROMETER, JEFFERSON LABORATORY, USA

In June 2022, the second module of the Ring Imaging Cherenkov (RICH) detector on the CLAS12 spectrometer of the Hall B at the Jefferson Laboratory (JLab) in Newport News (Virginia, USA) has been successfully accomplished. This result concluded a project initiated more than 10 years ago by INFN researchers of the LNF and Ferrara, who proposed the construction of a detector that allowed the clear identification of strange mesons in a kinematical regime not otherwise reachable by CLAS12, opening a new way to the study of the internal structure on the nucleons and on the role played by quarks and gluons in explaining their basic properties like the mass or the spin.

The detector exploits the Cherenkov effects, i.e. the emission of highly directional visible and UV light by high energy particles crossing transparent materials and traveling at a speed higher than that of the light. Particles with different speeds emit Cherenkov light in cones with different opening angles, thus the measurement of the emission angle allows the determination of their speed and, ultimately, to identify them.

The design of the detector has been challenging in many aspects. Its large dimensions, about 4.3 m height and 4.1 m width, are unusual for such a kind of detector, and required a detailed simulation study to minimize the area instrumented with photon detectors and therefore to reduce the costs. The result is a hybrid geometry, in which the photons are detected either directly after the emission or after one or more reflections on the mirror system. In addition, the detector must be light, to minimize the impact on the downstream components of CLAS12, but also extremely rigid to guarantee the necessary angular resolution in the detection of the photons. This has been achieved by extensively using light materials, aluminum and carbon fiber, and the sandwich technique, in which two thin layers of material are glued on a honeycomb core, obtaining a highly rigidity even on large dimensions.

The construction of the detector has been a joined effort lead by physicists, engineers and technicians of various INF Sections, with the support of the Jefferson Laboratory and the contribution of several European and American Institutions. It also involved various Italian companies for the production of the mechanical structure, the mirrors and the electronics.

The chosen Cherenkov radiator is silica aerogel, produced in large tiles of 20x20 cm^2 and thickness of 20 or 30 mm, the largest ever used in nuclear physics experiments. The mirror system is composed of 10 spherical mirrors in carbon fiber and 7 planar glass mirrors covering several square meters. Special systems to hold the aerogel tiles in place and to align the mirrors have been designed at LNF.

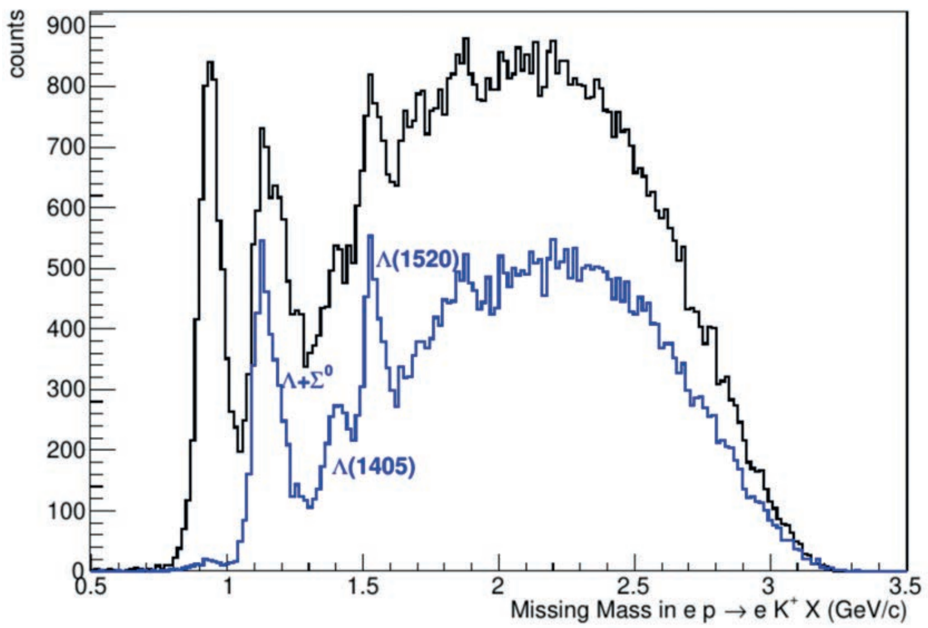
The photons are detected by an array of 391 Multi-Anode Photomultipliers Tubes, each one composed by a 8x8 matrix with a 6 mm pixel size. The total number of readout channels is 25024 per module. The front-end electronics, installed just on the back of the detector, is based on the MAROC3 chip, which provides a fast binary line with a highly configurable shaper and adjustable gains and thresholds. A specially designed FPGA is used to configure and read out the chip and is optically linked to the data acquisition system.

The first RICH module has been installed in January 2018, just before the beginning of the data taking of the CLAS12 experiment and successfully operated since then. During the 4 years of data taking, a major effort was devoted to the understanding of the performance of the detector. In particular, a detailed study was devoted to the alignment of the mirrors, a crucial point to obtain the required angular resolution in the photon detection.

The quality of the best performance reached so far is demonstrated in the Fig. 1, where the missing mass of the e p → e K$^+$ X events is presented, with the kaons identified in CLAS12 either without (black histogram) or with (blue histogram) the RICH. The signal-to-background ratio of the peaks corresponding to the various Lambda and Sigma resonances is greatly enhanced when using the RICH, with a marginal loss of events. In addition, the pronounced fake peak in the nucleon mass region in the black histogram basically disappears in the RICH histogram, indicating that the overall reduction of events in that case is mostly due to rejection of pions misidentified as kaons.

The construction of the second module was delayed by the pandemic crisis, but finally started at the beginning of 2022 and was carried on in three sessions of work by INFN personnel of LNF and Ferrara with the support of JLab technicians and physicists. The progresses in the assembly work are documented next: the readout system (Fig. 2),

Figure 1.
Missing mass in e p → e K$^+$ X events measured in CLAS12 without (black histogram) or with (blue histogram) the RICH information.



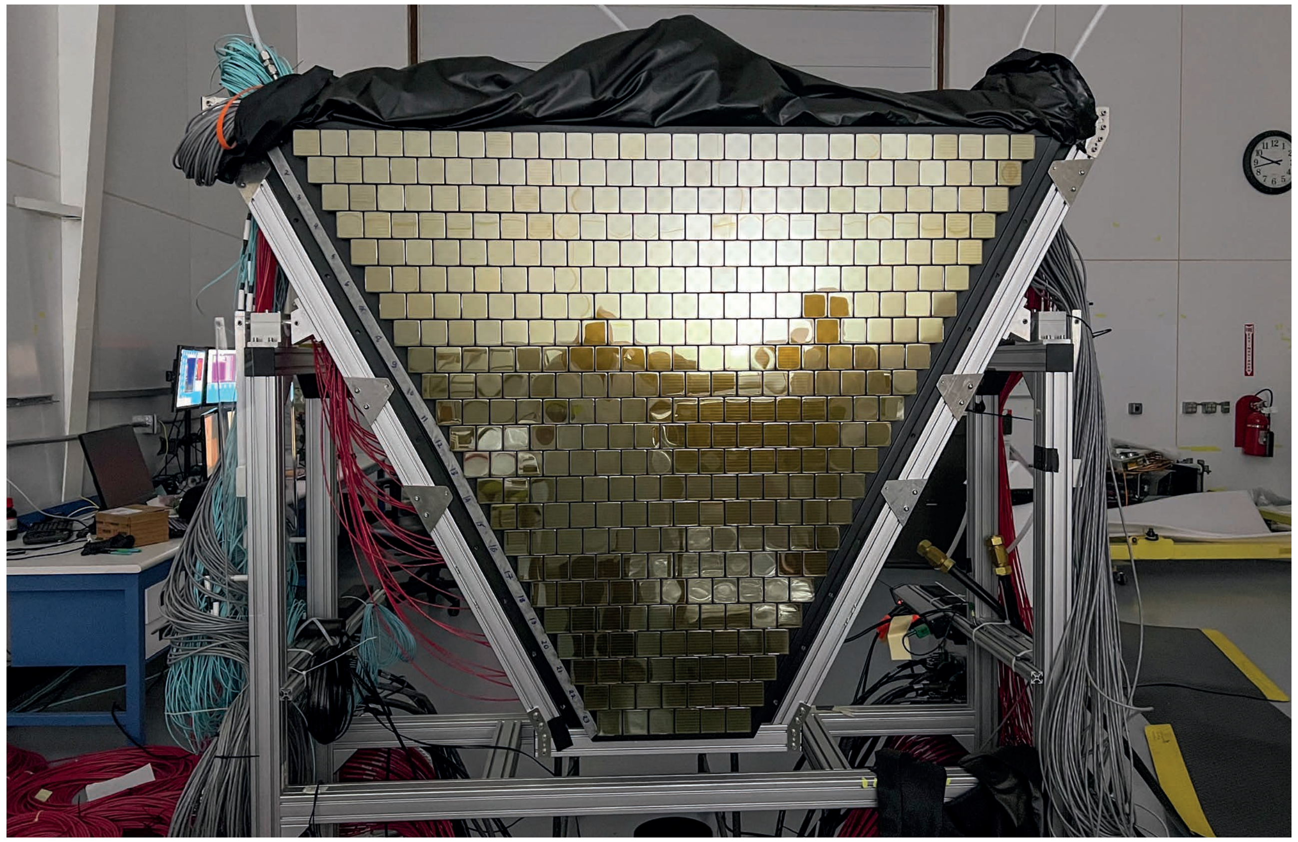


Figure 2.
The readout system as seen from the photonmultiplier tube side.

Figure 3.
The mirror system.

the mirror system (Fig. 3).

The CLAS12 spectrometer with the two RICH modules installed is shown in Fig. 4 After few days of commissioning, by mid of June the second module was also fully operative. The availability of two RICH modules in symmetric positions with respect to the beam axis not only will double the statistics collected, but it is also a crucial point for the measurements with polarized targets that are now the main goal of the CLAS12 experiment.

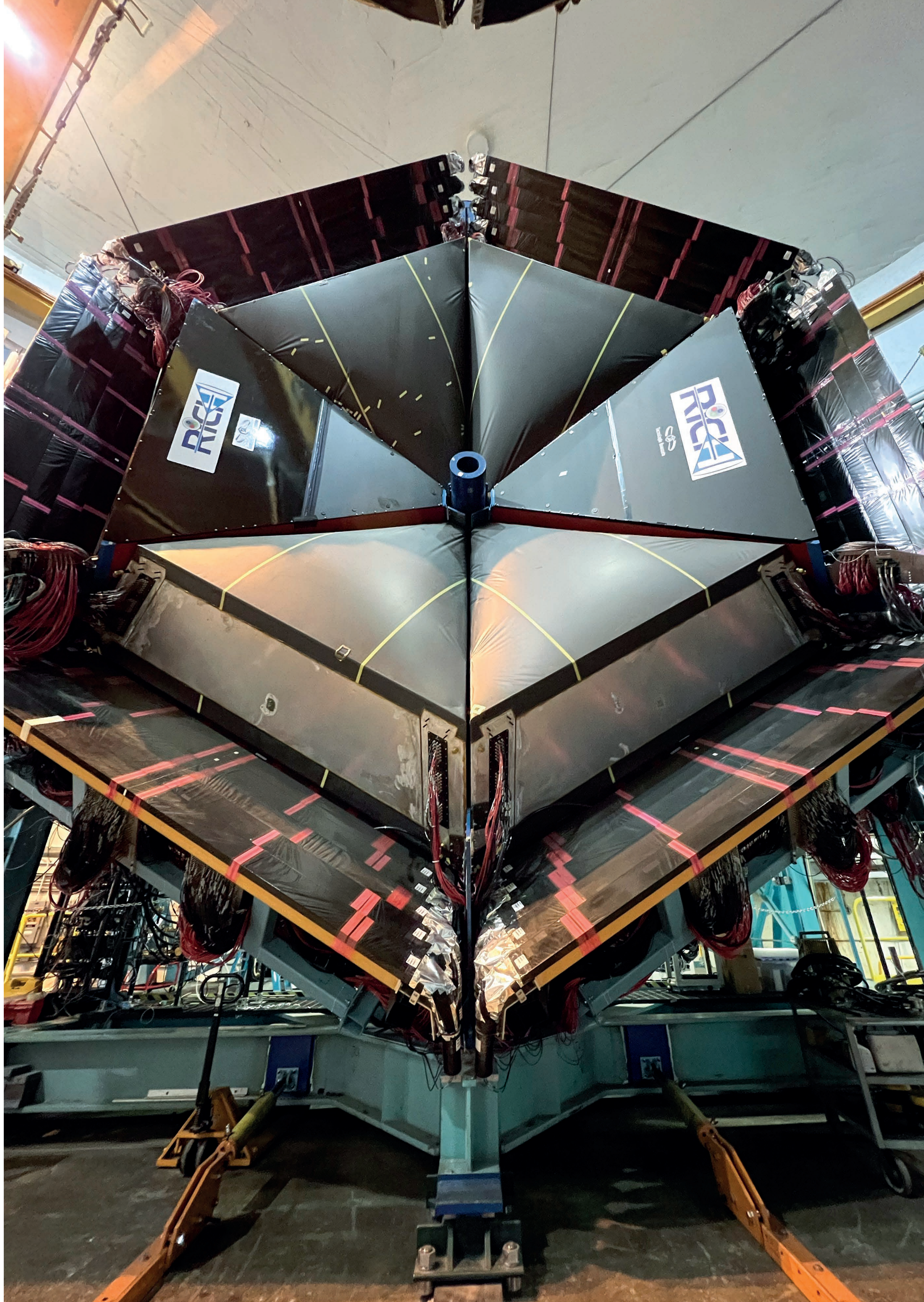


Figure 4.
The CLAS12 spectrometer
with the two RICH modules installed.

FIRST OPERATION OF A HALOSCOPE AT LNF

In July 2022 a Haloscope was put in operation at LNF for the first time.

A Haloscope is a cryogenic antenna able to convert axions, hypothetical light particles that may constitute the Dark Matter in our galaxy, into a faint electromagnetic signal by means of a strong magnetic field. Observing an axion would solve two problems at the same time, the nature of Dark Matter and the absence of the violation of the charge-parity symmetry in the Strong interactions (the Strong CP problem).

It was just a short data taking run of about two hours but an important milestone on the road for preparing a longer run in 2023. In fact, it marked the completion of the first phase of the installation that the LNF team of the QUAX experiment is carrying on at the COLD laboratory of LNF, the CryOgenic Laboratory for Detectors.

During this first phase, a resonator, made of high-purity copper, designed and fabricated at LNF and chemically polished at the National Laboratory of INFN in Legnaro (LNL), was thermally anchored to the coldest plate of a dilution refrigerator able to reach temperatures down to 10 mK, ten thousandths of a degree above absolute zero (Fig. 1). The resonator is able to amplify an axion signal by a factor 10^5 at a frequency of 8.5 GHz.

Figure 1.
The resonant cavity of the Haloscope connected to the coldest plate of the dilution refrigerator

The magnetic field was provided by a superconducting magnet inserted in the cryostat of the refrigerator (Fig.2). The magnet is designed to reach 9 Tesla of peak magnetic field when a current of about 90 Ampere is circulating in its coil. This circulating current introduces a large thermal input in the cryogenic system, and only recently we upgraded the refrigerator to fully stand it. Therefore, during this run the magnetic field was kept to a lower value of about 2.5 Tesla.

Once the cryostat was closed, the resonator was located inside the coil of the magnet, fully immersed in its magnetic field. The signal generated in the resonator was amplified, down-converted to low frequencies, further amplified and finally digitized and stored on disk. One of the goals of this run was also to set up the data acquisition software, the calibration procedure and the data analysis. Even with this lower field, in two hours run we were able to search for dark matter axions with values of mass never probed before.

During the second phase of the installation, besides improving the sensitivity by operating the magnet at full current, we will add a tuning system that will allow to change the resonator frequency and probe the existence of axions of several mass values. The final improvement will require using a superconducting amplifier able to add the minimum noise allowed by quantum mechanics, currently under test at the COLD lab.

After that, the LNF Haloscope will be ready to join the first QUAX Haloscope, already operating in LNL, in the search for galactic axions.

Figure 2. Insertion of the 9T magnet inside the cryostat of the dilution refrigerator.

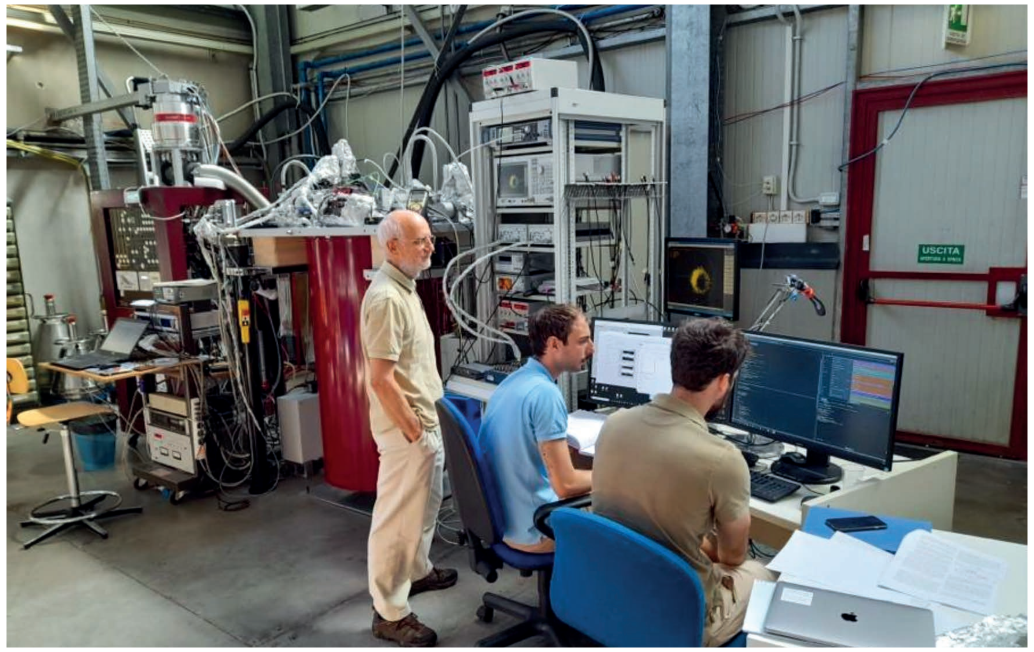


Figure 3. A Preliminary signal analysis during data taking.

RE-OPENLABS 2022

T open day, Open Labs, represents the most important popularization of science activity carried out in the framework of the public outreach program.

The open day is a traditional one-day event addressed to the general audience and dedicated to science and to people who animate science. LNF opens its laboratories and facilities to showcase the manifold leading research areas and technology developments conducted either inside or outside LNF, engaging participants in a large number of initiatives. The aims are to present the latest issues of modern physics directly in the environment where the research takes place, to share the implications of scientific results and technology-based outcomes for the benefit of the society and to inspire young people with science.

After two years, the 2022 edition was held in person again on Saturday, the 28th of May. More than 2200 participants attended this edition. The event gathers many colleagues from LNF, INFN Central Administration and other INFN units, universities (University of Ferrara, Sapienza University of Rome) and research centres (ENEA, FBK).

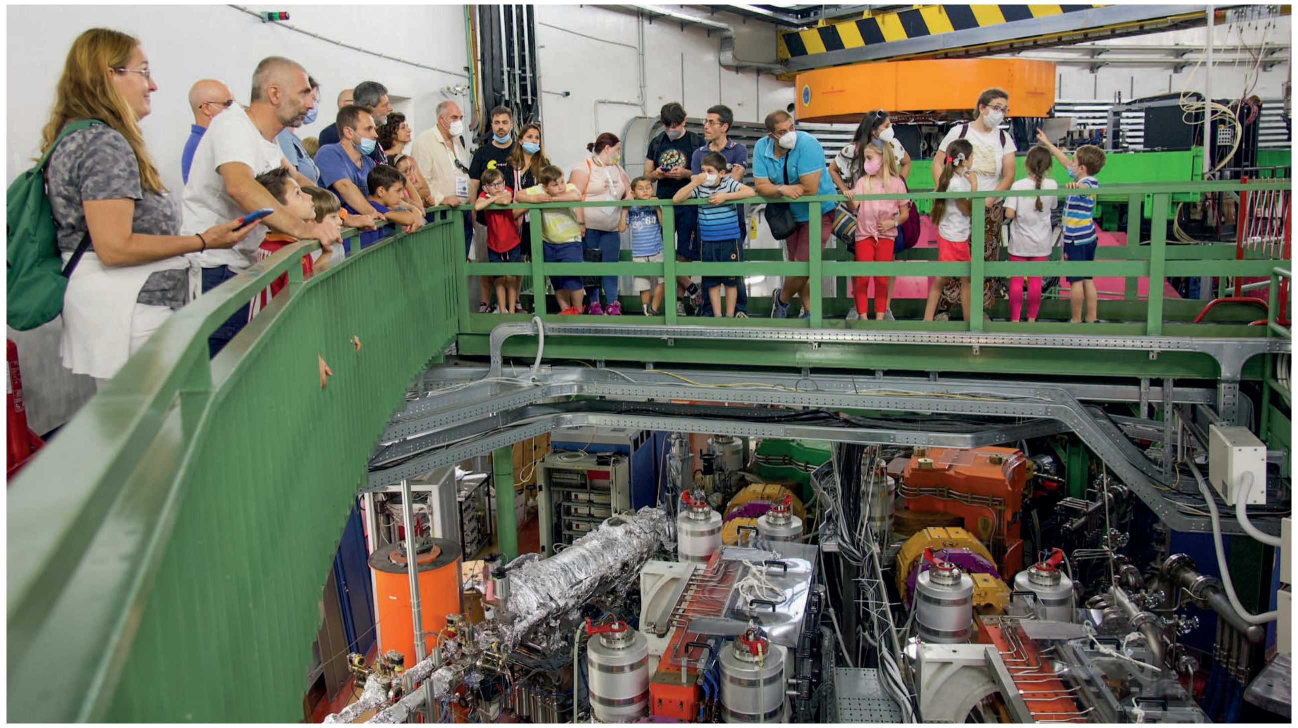


Figure 1. A picture taken during the guided tours at the DAΦNE accelerator.

During the day, participants had the chance to visit the electron-positron collider Dafne, (fig 1 Visit Dafne) the SPARC_Lab facility, many laboratories, the KLOE experiment's hangar, enriched by the art installation "The perfect asymmetry" and the Bruno Touschek Visitor Centre; interactive exhibits were displaced in the Maker Lab to show people cutting-edge technologies and the working principles of devices used in research; public seminars were organized to illustrate the main research topics in particle physics, astrophysics and nuclear fusion. Moreover the program included a kids area where different initiatives, hands-on and science demos, were conducted by the staff of INFN Kids (fig 2 INFN Kids) to engage young people with science to explore some physics phenomena and their applications in everyday life. As usual, the science show "Il Wow della Fisica!" was held in the main Auditorium. The show is designed to involve the audience in the discovery of the most attractive Physics topics. An escape room based on High Energy Physics, "HEPscape", designed and run by the INFN Roma 1 unit's colleagues, was an interactive activity proposed to our participants to play the role of researchers in a simulated experiment. One of the most popular activity has been the small train (fig 3 The small train), Science Express, that carried our visitors

Figure 2.
One of the interactive science demos to engage young people with science.

Figure 3.
In this photo it is shown the HEPscape room installation while people are playing at this science game.

in the different LNF sites and was also the scene for science talks presented by researchers while the train was running. The event has been a unique opportunity to visit LNF, to discover the science conducted by INFN, universities and other research centres and a great occasion to bridge science and society.

OpenLabs website: http://www.lnf.infn.it/openlabs

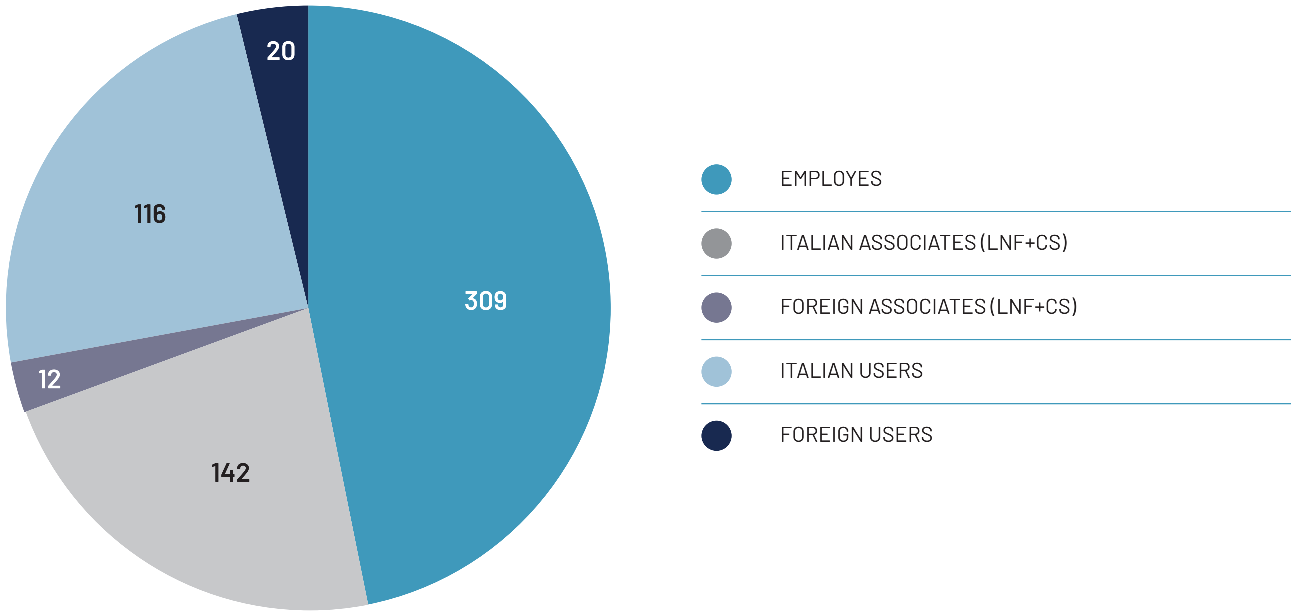
Figure 4.
The Science Express activity in which researchers gave public seminar on the latest issues of modern Physics on train travelling through the LNF area.

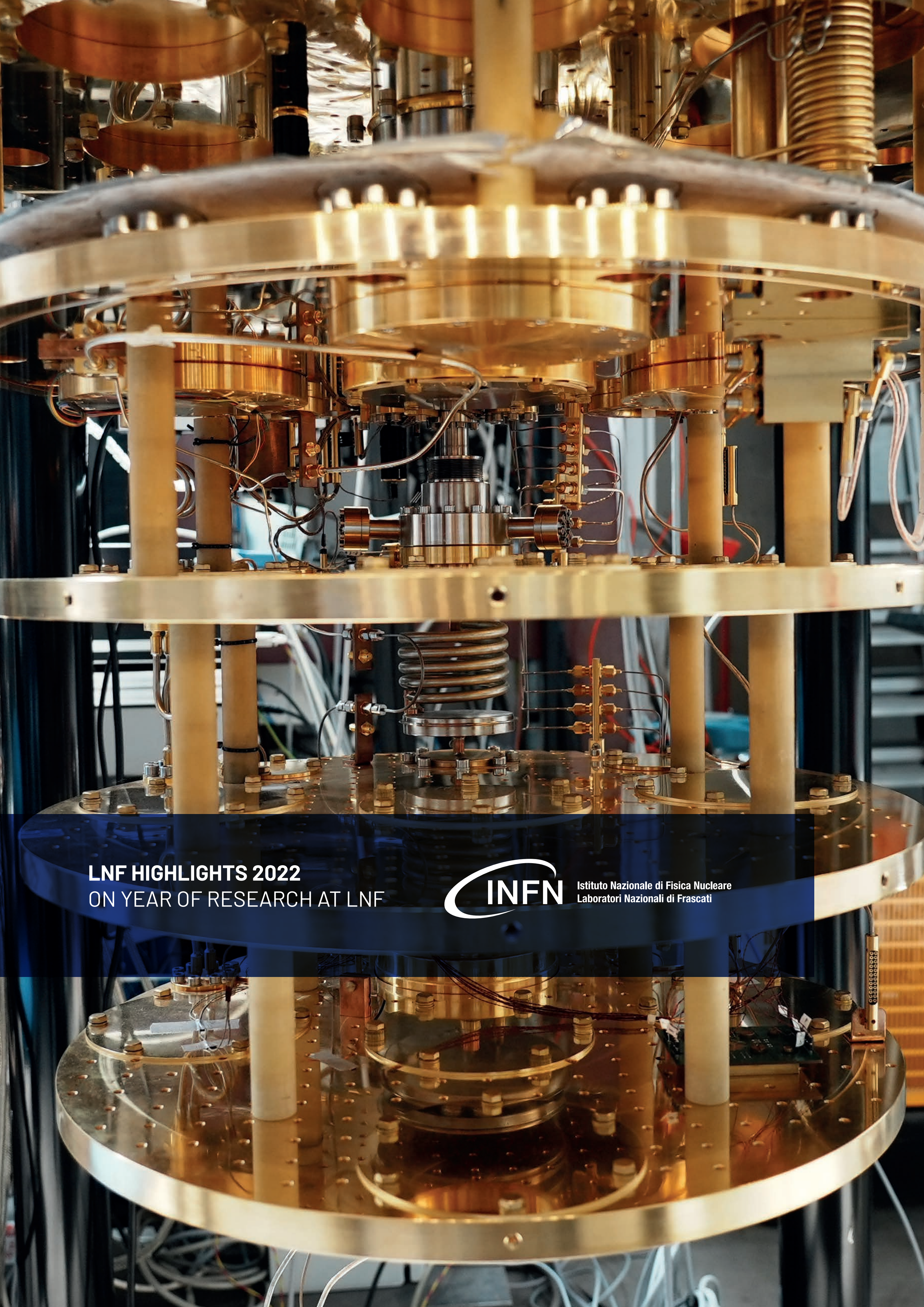
LNF IN NUMBERS

The LNF personnel, at the end of 2022, consists of 309 units, including 29 with a fixed term contract, plus 154 associate members. Among these, there are university and PhD students, young post-Docs and employees from universities or other research institutions. Associate members work alongside staff members and likewise take part in the Laboratory's activities. Tab. 1 shows the division of the LNF personnel among the different profiles.

	STAFF	TEMP.	TOT.
RESEARCHER	71	0	71
ENGINEER	73	5	78
ADMINISTRATIVE	34	10	44
TECHNICIAN	102	14	116
TOT.	280	29	309

Table 1.
Snapshot of the LNF personnel at December 2022.





LNF HIGHLIGHTS 2022
ON YEAR OF RESEARCH AT LNF

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