INFN - Laboratori Nazionali di Frascati
Annual Report 2024

Figure 1: *Aerial view of the Frascati laboratory.*

The Laboratori Nazionali di Frascati (LNF) is the largest (for number of employees) and the first built among the INFN national laboratories. INFN was funded, in the fifties of last century, to give Italy its first particle accelerator, and the site to locate this infrastructure was chosen to be Frascati. Since these early days, the LNF has always been involved in two main activities: building and operating particle accelerators, designing and constructing particle detectors. The LNF site stands on a surface of 135 178 m^2, 25 000 of which are indoor and include offices, laboratories, and workshops. At LNF the following facilities are hosted:

- DAΦNE, an e^+e^- collider operating at the Φ energy (1020 MeV), able to deliver instantaneous luminosities of up to 2×10^{32} $cm^{-2}s^{-1}$, a world record at this energy.
- A synchrotron radiation facility, DAFNE Light, with lines in the X, UV, and infrared regions, extracted in parasitic or dedicated mode from the intense photon emission of DAΦNE.
- A Beam Test Facility (BTF), with two beam lines providing electron/positron or photon beams, for detector test and calibration purposes, and for small-size fundamental physics

experiments.

- SPARC_ LAB, a facility that combines a linear accelerator (SPARC) and a 200 TW laser (FLAME). This is an infrastructure for R&D in the field of new technologies for particle acceleration like Free Electron Laser (FEL), Plasma WakeField Acceleration (PWFA), and Terahertz radiation. SPARC_ LAB is the seed for the new large accelerator infrastructure which will be built in Frascati, EUPRAXIA@SPARC_ LAB.
- SCF LAB, a laboratory equipped for space simulation. It is used to characterize devices that are to be sent in space missions.
- DDG-Lab, the infrastructure of the Detector Development Group, that since 1985 has been performing R&D, design, and construction of classical and innovative gas detectors for large high energy physic experiments.
- COLD (CryOgenic Laboratory for Detectors), the site where research is conducted on superconductors, magnetic materials and related systems using magnetic and electric transport tools with cryogenic equipments able to study the dynamic behavior of these materials under conditions of extreme temperature and magnetic field.
- Assembly halls, mechanical workshops, a computer center, and an electronics laboratory suited for complex and challenging enterprises in many fields of fundamental research.
- Eight clean rooms (class ISO 6 and 8), three connected to DAFNE Light, SPARC_ LAB and SCF LAB, and the others equipped for the construction of different kind of particle detectors, for a total area of 400 m^2.

1 One year of research at LNF

During 2024 many important results have been accomplished by the LNF research teams in Frascati and in other laboratories around the world.

To start with, the LNF flagship project, EUPRAXIA@SPARC_ LAB, at the end of 2024 obtained additional funding from the Lazio Region to create a second line for users. The international collaboration is presently completing the design phase, with a TDR due in the next months. The construction of the research infrastructure will start in 2026. At the same time, the ancillary facilities of the project (EuAPS, TEX, SABINA), thanks to the funds provided under the aegis of the PNRR projects, have achieved important scientific and technological results. Among these, SPARC_ LAB team implemented a novel method for deflecting and guiding relativistic electron beams along curved paths using magnetic fields generated within plasma-discharge capillaries. This pioneering approach, which follows previous studies on straight active-plasma lenses, shows that the same working principle can be applied to curved geometries, and promises to significantly mitigate the chromatic dispersion effects commonly encountered with conventional bending magnets, marking a substantial leap forward in the field. A major milestone of 2024 was also the high-power RF test of the first X-band accelerating structure prototype for EUPRAXIA@SPARC_ LAB. This was achieved at TEX facility, which is equipped for development and test of the high-gradient X-band RF technology, and has become an international reference point for advanced linear accelerator research.

The LNF researchers' commitments have always been divided between on-site activities and international collaborations at major laboratories around the world, and primarily at CERN. Besides a very important involvement in all of the four LHC experiments (ATLAS, CMS, ALICE and LHCb), this year's major achievement by the LNF teams working at CERN consists in the first observation of the very rare decay $K^+ \to \pi^+ \nu\overline{\nu}$ by the NA62 experiment, at a rate $\sim 2\sigma$ in excess

of the Standard Model prediction. To reach this result, a critical contribution was given by the LNF team, who built in the past years the experiment Large Angle Veto (LAV) calorimeter system. This detector, which is made of 12 separate ring-shaped detectors with diameters ranging from 2 to 3 m each, and each weighing between 8 and 20 tons, was used to reject with extremely high efficiency the π^0 from the dominant $K^+ \to \pi^+\pi^0$ background. A larger data sample is now being acquired by the experiment, that will tell us whether new physics signals will appear in the kaon sector, or not. To confirm the very advanced expertise of our teams of researchers, engineers and technicians (with the invaluable support of the administratives) in designing and constructing large detectors, another achievement to be celebrated this year is the completion of the electromagnetic calorimeter of the Mu2e experiment. This experiment is in preparation at Fermilab, and has the goal of reaching unprecedented sensitivities in the quest for Lepton Flavour Violation processes, via the search of muon to electron neutrino-less conversions in the Coulomb field of aluminum. The Mu2e LNF team coordinated the design and construction of the calorimeter, which is made of two anular rings to be operated in vacuum, each composed by 674 CsI crystals, readout by twice as many SiPMs.

Among the on-site activities, for some years now, the LNF has also been involved in fundamental physics research using the haloscope devices, which are built by the COLD lab team. These devices, consisting of microwave cavities cooled down to cryogenic temperatures and placed inside a superconducting magnet, were in particular used for axion dark matter search. In 2024, the same team, together with other three european institutes, has been awarded by the European Council with a 10-million-euro Synergy Grant, to implement a global network of cryogenic detectors, called GravNet. This network will extend the observational campaign to investigate the uncharted territory of high-frequency gravitational waves. The LNF will contribute the project with two haloscopes. The first is already in operation within the QUAX experiment for axion search, while the second, FLASH, will be constructed recycling the 3m-bore magnet of the FINUDA experiment. In addition, the LNF team of the COLD lab will develop new superconducting devices to increase the sensitivity of the detectors.

At LNF, dark matter is also searched with the PADME experiment at the BTF facility. The research is conducted by studying the products of positron, produced by the DAΦNE LINAC, annihilating with the electrons of a very thin diamond target. In 2022, special data were collected to verify the existence of a new particle with a mass of 17 MeV/c^2, which was hypothesized to explain some anomalies highlighted by a nuclear physics experiment conducted at the ATOMKI laboratory in Debrecen, Hungary, and named "X17". Thanks to over 500 billion acquired events, analyzed using advanced statistical techniques, the PADME researchers have identified a $\sim 2\sigma$ excess corresponding to the mass indicated by the ATOMKI experiment. This important result, demonstrating the very goog sensitivity achieved by PADME in this search, will pave the way for a thourough data taking campaign, with the whole scientific community now looking at Frascati for a clarification of the experimental picture.

From the above, it is clear that 2024 was a very fruitful year for the LNF, with many more results and activities discussed in the following chapters of this report. The success and impact of the laboratory activity is also testified by the large community of people (students, general public) reached by our Education and Public Outreach Service, which exceeded 30k in 2024.

2 Organization

2024 has been a year of changes also from the point of view of the organization. Since August, Paola Gianotti took office as the first female director of LNF. On behalf of all of the laboratory employees and users, we warmly welcome Paola in this role, anticipating that she will prove herself up to the very high standards of this role. A heartfelt thank you to her predecessor Fabio Bossi,

who was capable to lead the laboratory with wisdom and scientific vision during his entire mandate, in a very crucial period for the laboratory future evolution.

The LNF personnel slightly increased with respect to previous year, and, as of the end of 2024, consists of 349 units, including 47 with a fixed term contract. This is shown in Tab. 1, where also the numbers in each profile are given. In addition to LNF personnel, 140 associate members

Table 1: *Snapshot of LNF personnel, both staff and temporary, at the end of 2024.*

	Staff	Temporary	Total
Researcher	70	0	70
Engineer	78	22	100
Administrative	48	4	52
Technician	106	21	127
Total	302	47	349

are also part of the research teams. Among these, there are master and PhD students, young postdocs and employees from universities or other research institutions. The number of associated members once again demonstrates,if there was any need, the relevance of the laboratory research activity, and its impact on the local and national scientific community.

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