LNF

The National Laboratory of Frascati of the INFN

Accelerating the Future

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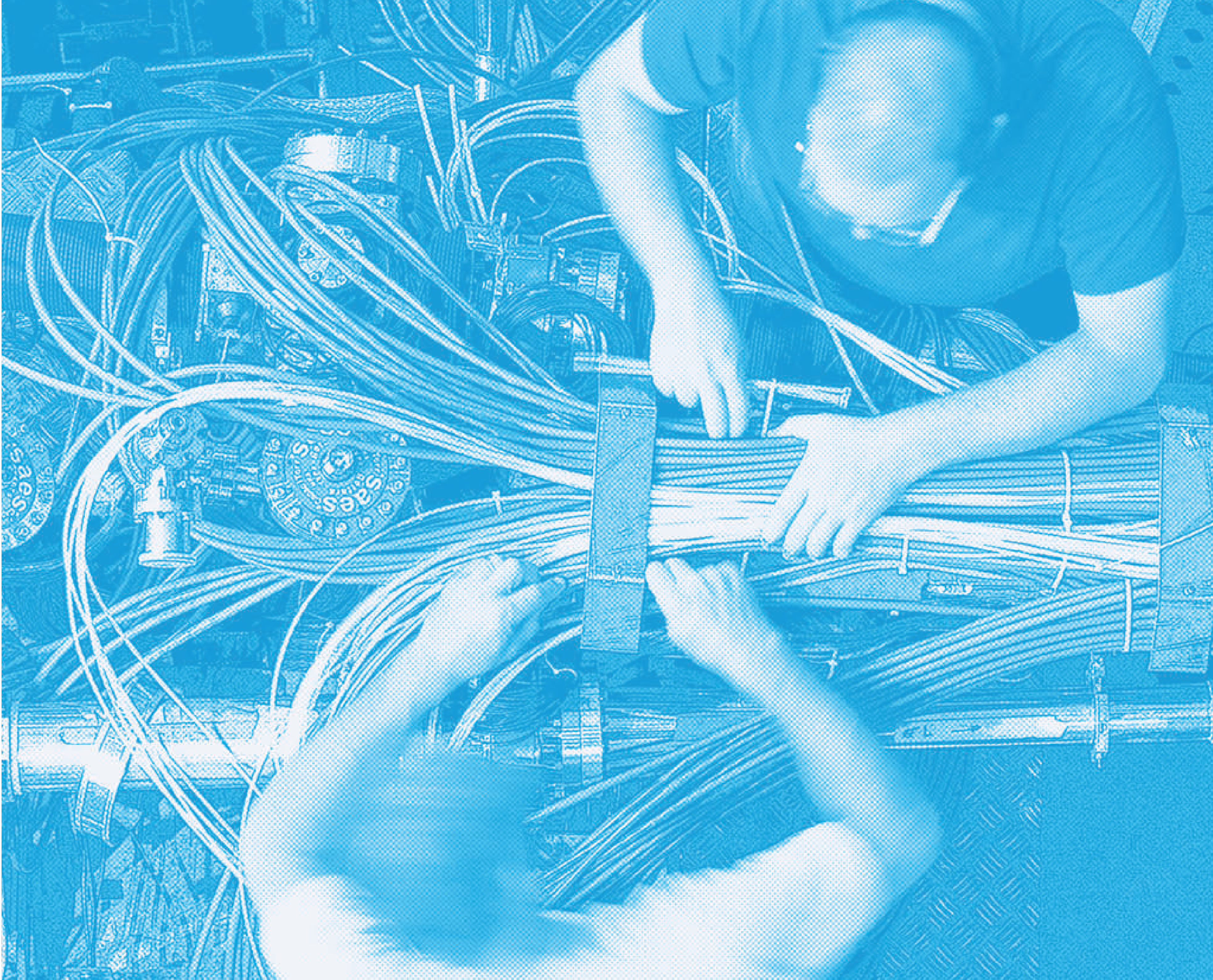
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati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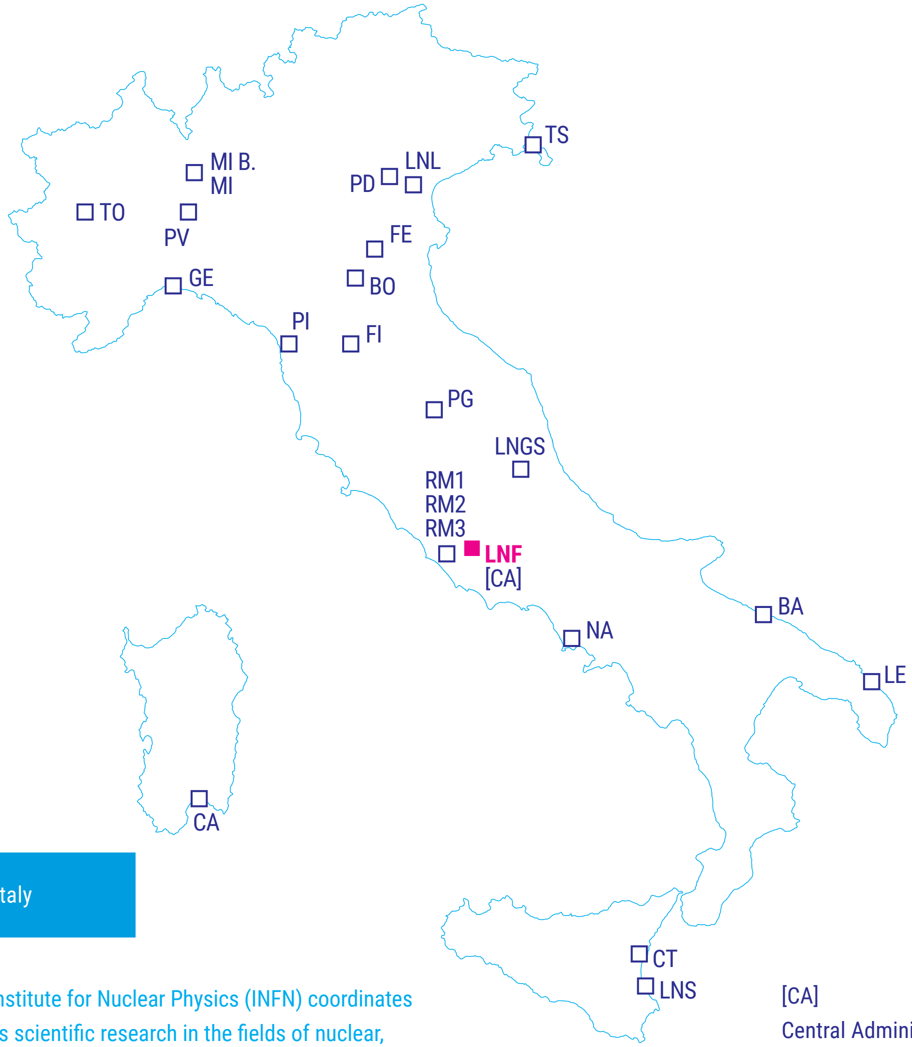
Istituto Nazionale di Fisica Nucleare

INFN - The Frascati National Laboratories

Accelerating the Future

// Index

On the road to knowledge
Italian excellence in accelerator physics, fundamental research, and innovation



INFN sites in Italy

The National Institute for Nuclear Physics (INFN) coordinates and undertakes scientific research in the fields of nuclear, subnuclear and astroparticle physics and physics of the fundamental interactions, as well as the research and technological development relevant to activities in those sectors

[CA]
Central Administration

Particle accelerators are designed and built to answer some of the most important questions about Nature's workings. The Frascati National Laboratories were the first Italian research institute devoted to the study of nuclear and subnuclear physics with accelerating machines.

Aerial view of LNF

The Frascati National Laboratories (LNF) are protagonists in all research sectors of the Italian National Institute for Nuclear Physics (INFN). The Laboratories are continuously committed to putting cutting-edge technical and scientific expertise at the service of research and society.

In addition to performing experiments on site, LNF contributes significantly to the implementation of national and international projects, in collaboration with other research centres, universities and companies. These goals are achieved by significant investment in human resources, with a staff of 500 people including employees, associated personnel and students. The Laboratories have always been active in spreading scientific culture through outreach programs addressed to schools and the general public.

The activities of LNF, which are closely integrated into a network of national and foreign centres, contribute to the overall objective of extending the boundaries of knowledge. The quality of the scientific and technological program guarantees the continuous growth and interest of new generations.

The main entrance of the laboratories just after their inauguration, in the 1950's. During the years of the Italian economic miracle, the foundations for scientific development and progress were laid down, with large investments in research

The building hosting the DAΦNE accelerator

The evolution of the Frascati National Laboratories

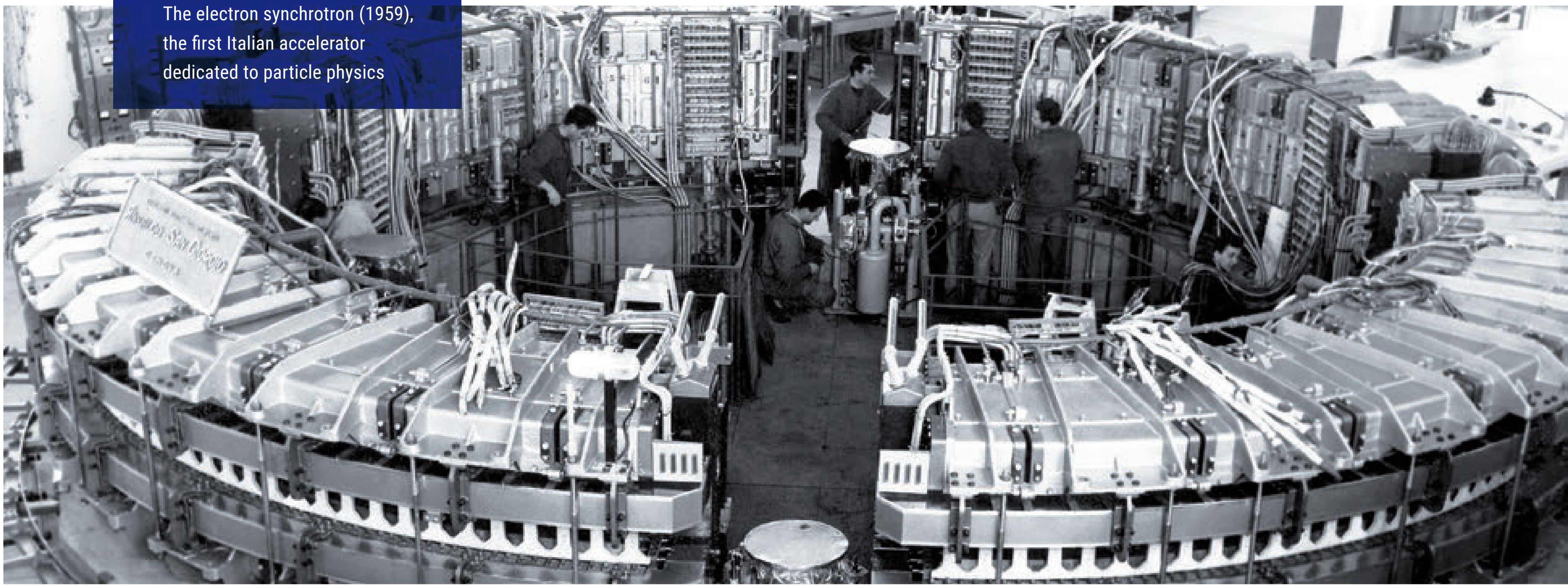
A repository of knowledge for both accelerator and particle detector physics

The story of the Frascati National Laboratories is closely linked to the construction and use of its particle accelerators, machines built to produce and study particle physics phenomena, on the basis of advice and requests from the experimental physics community.

The Laboratories were founded in 1954 to host a 1.1 GeV electron synchrotron, the first Italian particle accelerator dedicated to fundamental research. This machine was constructed under the direction of Giorgio Salvini, and in 1959 it started to generate electron and gamma-ray beams that made it possible to perform numerous experiments carried out by INFN researchers in collaboration with various Italian universities.

In 1960, during a memorable seminar, Bruno Touschek suggested injecting both electron and positron beams circulating in opposite directions into the same vacuum chamber to analyze their collisions. This idea set in motion the construction of the storage ring AdA (Anello di Accumulazione), a small accelerator made of an electromagnet with a diameter of a little less than 2 meters, in which the radio frequency field accelerated the beams to an energy of 250 MeV. In AdA, the first artificial collisions between electrons and positrons in the world took place.

The electron synchrotron (1959), the first Italian accelerator dedicated to particle physics



The purpose of the AdA accelerator was to prove that the construction of a matter-antimatter collider was possible. When this goal was achieved, the design and construction of an electron-positron collider with higher energy and luminosity was started: ADONE, which would have reached the energy of 3 GeV, enabling four experiments to be performed simultaneously. ADONE began to produce collisions in 1969 and ran until it was decommissioned in 1993. During this long period, the experiments performed at ADONE allowed studies on quantum electrodynamics and the behavior of light quarks, helping to lay the foundations of our understanding of subnuclear matter. ADONE also operated as a source for synchrotron light, the electromagnetic radiation emitted by charged particles while passing through a magnetic field. Its unique characteristics in terms of intensity and frequency made it a powerful tool for investigations in sectors such as materials science, biology, and preservation of cultural goods.

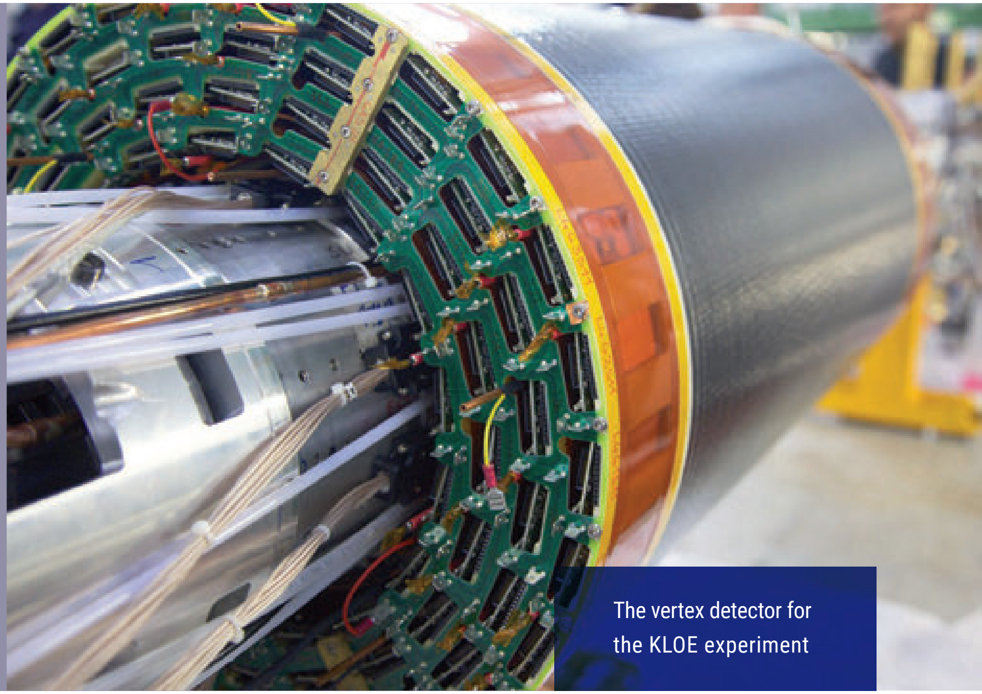
In 1999, in the same building that had hosted ADONE, a new collider, DAΦNE, with a collision energy of just over 1 GeV, came into operation. DAΦNE is a newly designed particle accelerator whose primary objective is to provide high luminosity, making it possible to study rare phenomena. DAΦNE was conceived to produce the Φ resonance, an unstable particle which decays mainly into particles called K mesons, or "kaons". DAΦNE is therefore a high-intensity source of kaons, both charged and neutral, enabling various topics in fundamental physics to be studied. The kaon flux generated at DAΦNE has been used by different experiments: KLOE, which investigates the matter-antimatter asymmetry and the rules which bind the lightest quarks of matter together; FINUDA, which carried out measurements and analysis on hypernuclei; DEAR and SIDDHARTA, which studied kaonic atoms.

The DAΦNE complex is a powerful and flexible infrastructure which also includes a Beam Test Facility (BTF) where electron/positron beams with variable energy and intensity are available for testing prototypes and equipment. In addition, in the synchrotron light lab DAΦNE-Luce, synchrotron radiation beams with wavelengths from infrared to X-rays are used for interdisciplinary studies. Synchrotron light activities are, by their nature, a meeting point between fundamental physics and the industrial and technological world, essential to promote and increase innovation and industrial partnerships.

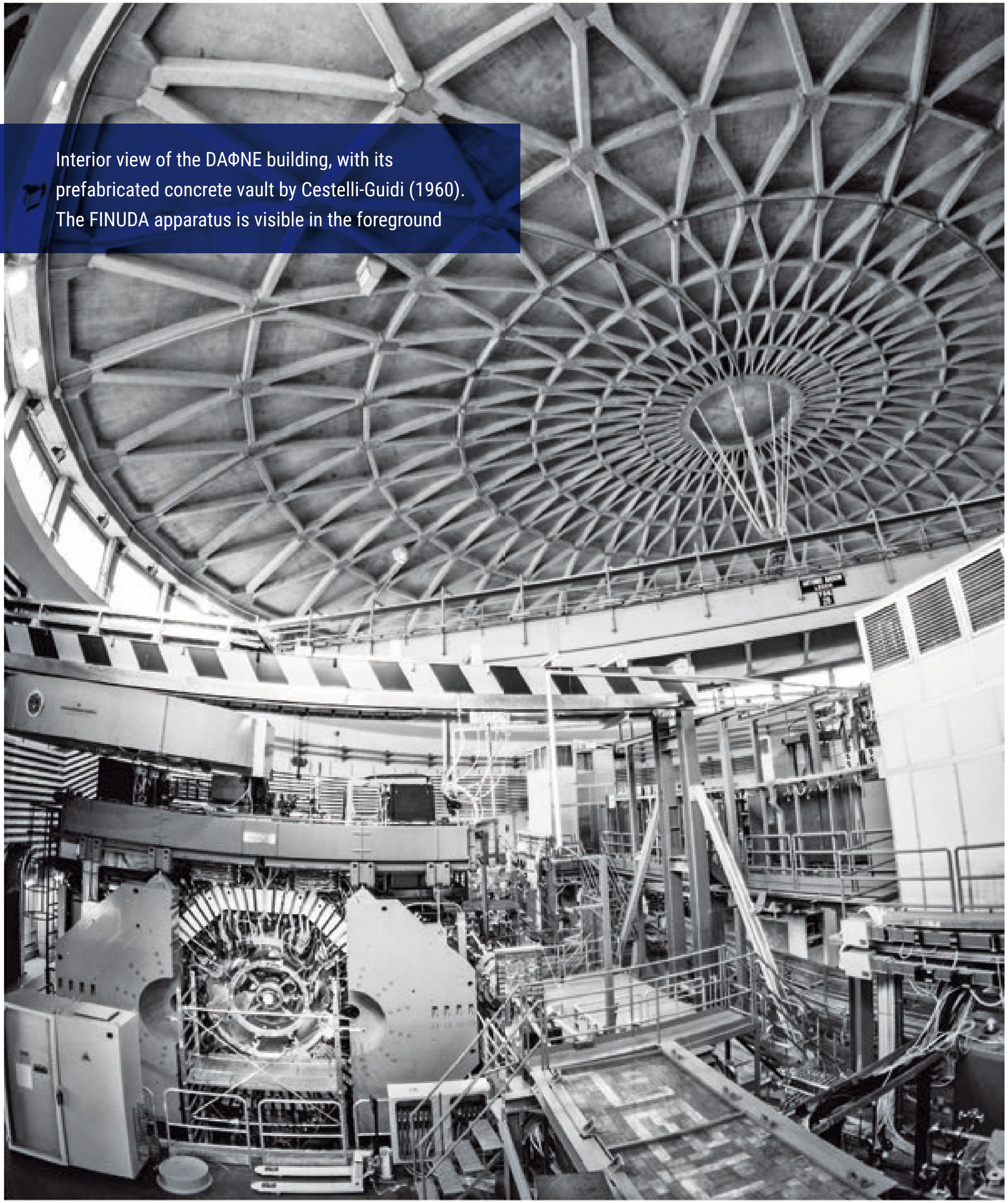
Giorgio Salvini

[Milan 1920 - Rome 2015]

As one of the big players in post-war Italian physics, Salvini was the guiding force behind the construction of the Frascati National Laboratories starting in 1953. From 1966 to 1970 he was president of INFN and later dedicated himself to his experimental activities at CERN. He was President of the Accademia Nazionale dei Lincei from 1990 to 1994. In 1995 he was appointed Minister of Universities and Research. Also remembered as an appreciated and passionate teacher, he maintained a privileged relationship with the Laboratories throughout his life. He is is considered to be the founding father of the Frascati National Laboratories.



The vertex detector for the KLOE experiment



Interior view of the DAΦNE building, with its prefabricated concrete vault by Cestelli-Guidi (1960). The FINUDA apparatus is visible in the foreground

There are more than 35.000 accelerators in operation throughout the world today, with only few dedicated to pure research. Accelerators perform diverse tasks: in hospitals they cure tumours and produce radioactive tracers; in industry they help to study and develop new materials and kill bacteria causing food spoilage. The Laboratories are undoubtedly the headquarters of Italian accelerator physics, making available extensive expertise in the sector, in a process of continuing innovation and development.

Accelerators at Frascati
Little machines grow

The Frascati Laboratories are at the forefront of accelerator physics and technology. Shortly after the construction of the electron synchrotron, the first large Italian machine for high energy physics research, right here in Frascati, the first steps in the glorious history of colliders were taken. In the early 1960s Bruno Touschek proposed to collide and annihilate two beams of oppositely charged particles circulating in opposite directions within the same vacuum chamber. This elegant and original idea was quickly recognized by the international scientific community to be a turning point in experimental high energy physics.

AdA

The first storage ring in the world, AdA, designed and built in 1961 to experimentally verify Touschek's idea, was a great success. The pioneering work on AdA opened the way to over half a century of physics discoveries which were made possible by successive generations of circular colliders constructed around the world. In recognition of its historical role, AdA is still hosted at LNF, which was recognized as a historic site of the European Physical Society in 2013.

AdA: the first matter-antimatter collider

Bruno Touschek

[Wien 1921 - Innsbruck 1978]

A physicist of Austrian origin, Touschek was recruited in 1952 to work at the nascent INFN National Laboratories. An expert in accelerator physics, he was the creator of the first matter-antimatter collider in the world (AdA 1961). Even now, one of the effects on particle dynamics within an accelerator bears his name (Touschek effect) since he was the first to explain and describe it in rigorous mathematical terms.

ADONE

In the wake of AdA's great scientific success, ADONE, a larger storage ring dedicated to the study of fundamental physics, was constructed. The two colliding beams could reach an energy six times higher than AdA's in a toroidal vacuum chamber about 100 m long. ADONE operated for 24 years, providing vast amounts of events for particle physics experiments, while the synchrotron radiation emitted by its curving beams was used for applied physics experiments.

During ADONE's period of activity many other storage rings of various types and sizes were constructed around the world. The success of the experiments performed with these machines led to impressive growth in the knowledge of fundamental physics, as well as a large number of discoveries, some of which received the Nobel Prize.

DAΦNE

Frascati's tradition in the field of storage rings has continued and today is more alive than ever thanks to DAΦNE, a modern accelerator belonging to the generation of the so-called *factories*. This name refers to relatively compact machines that explore the frontier of luminosity, a measure of the rate at which collisions are generated. In terms of luminosity and intensity of the stored currents, DAΦNE is the highest performance low/medium energy collider ever built.

In order to serve a broad and demanding experimental physics community, DAΦNE had to face a large number of technological challenges. The high luminosity required can only be obtained using very dense and intense beams subject to different forms of instability that must be prevented through the careful design of each component and cured by powerful and sophisticated control systems.

An innovative and original collision scheme known as *crab waist* was proposed in 2006 and successfully tested at DAΦNE to reduce the effects of perturbations induced by the electromagnetic interaction between the beams. The crab waist is an important contribution to the progress of circular collider physics and has been adopted by several accelerators currently being designed or built in Japan (SuperKEKB B-factory), Russia (SuperC-Tau factory), at CERN (Future Circular Collider FCC-ee), and in China (Higgs Factory CEPC).

SPARC_LAB

Free electron lasers are establishing themselves in many laboratories as the microscopes of the 21st century. There is an increasing interest in using terahertz (THz) radiation for its unexplored and peculiar characteristics. The generation of monochromatic X and gamma rays derived from the Compton interaction of photons and electrons is of the greatest interest for applications ranging from biology to nuclear physics. The use of ultra-high-powered lasers to accelerate or interact with beams of charged particles is a rapidly developing sector. Plasma acceleration techniques are being studied worldwide to decisively increase acceleration fields and far exceed the limits of standard techniques based on radiofrequency devices.

This is being investigated at SPARC_LAB, an inter-disciplinary research facility at the Frascati Laboratories based on two pillars: the linear accelerator SPARC, able to produce high-quality electron beams, and the ultra-high powered laser FLAME, for generation of very short and extremely intense pulses in the infra-red range. SPARC and FLAME are used for various experimental activities, both individually and in concert. The combined use of these technologies will allow electron acceleration by plasma waves in very confined spaces.

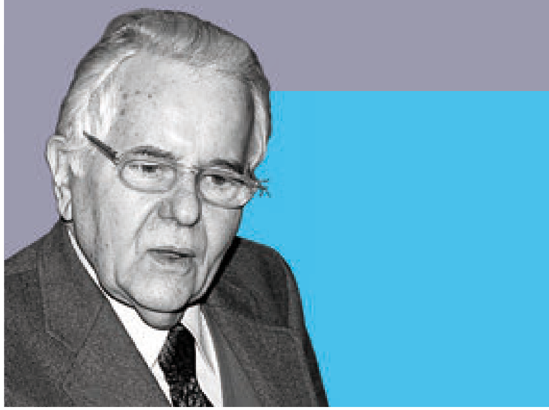
The activity on acceleration techniques at SPARC_LAB enables the Laboratories to contribute to research for the future of particle accelerators.

Nicola Cabibbo

[Rome 1935 - Rome 2010]

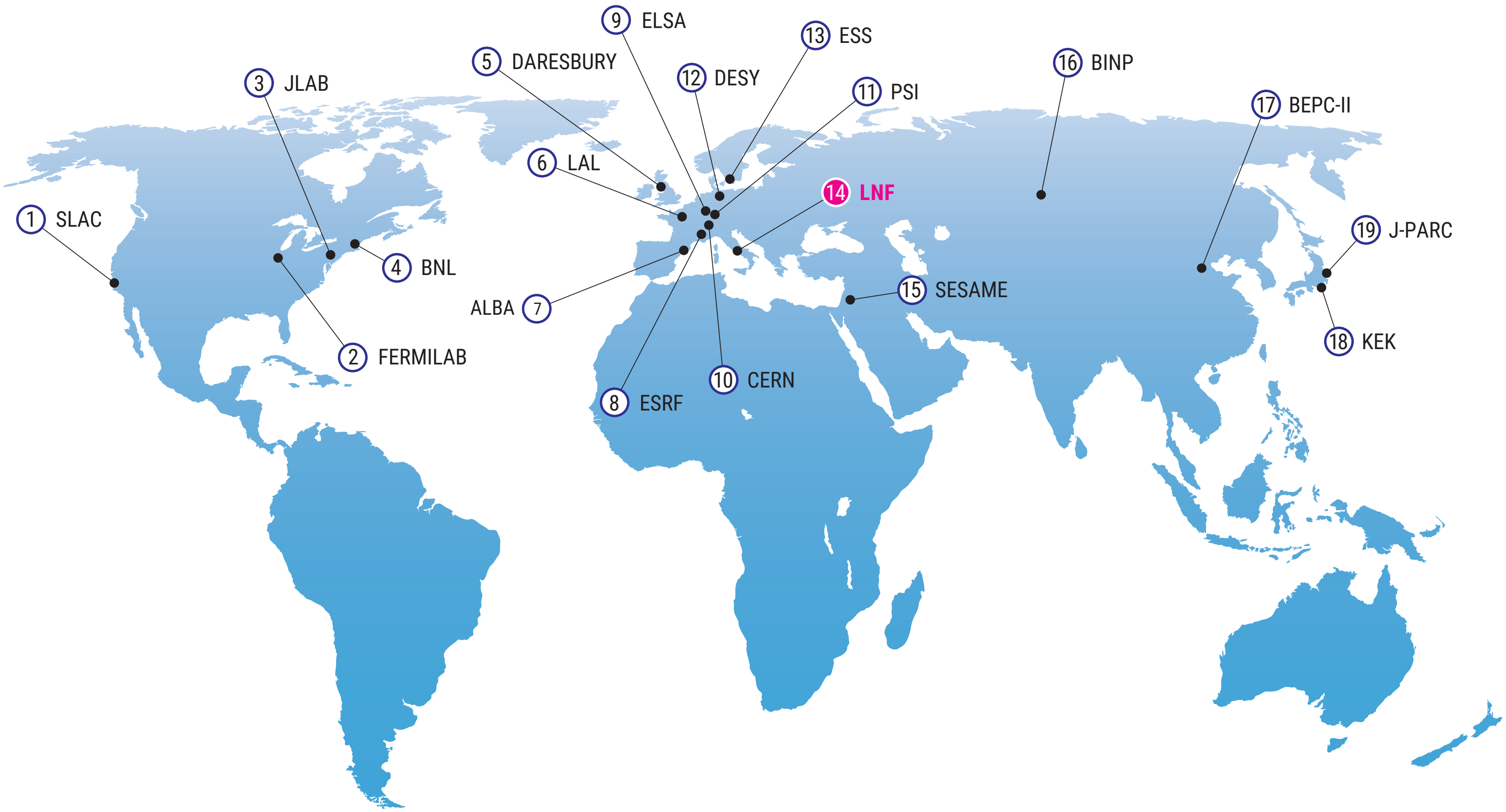
Cabibbo was one of the most brilliant post-war theoretical physicists in the 1960s, he formulated a theory of weak interactions between elementary particles in processes characterized by the violation of the strangeness quantum number, introducing a parameter called the **Cabibbo angle**. His scientific ideas had great international impact, and he was fundamental to the rebirth of theoretical physics in Italy.

Cabibbo was a student of Touschek and he created the Rome school for theoretical physics, first working at the Frascati National Laboratories and then at Sapienza Univeristy of Rome. He was president of INFN (1983-1992) and ENEA (1993-1998) and played a crucial part in the decision to construct the DAΦNE accelerator.



Work inside a magnet in the 1960s, demonstrating that research is not just an intellectual activity

In a global research network
Where everything and everyone is connected



1 SLAC, National Accelerator Laboratory
(Stanford, USA)

2 FERMILAB, Fermi National Accelerator Laboratory
(Batavia, USA)

3 JLAB, Thomas Jefferson National Accelerator Facility
(Newport News, USA)

4 BNL, Brookhaven National Laboratory
(Upton, USA)

5 DARESBURY Laboratory
(Daresbury, UK)

6 LAL, Laboratoire de l'Accélérateur Linéaire
(Paris-Orsay, France)

7 ALBA Synchrotron
(Barcelona, Spain)

8 ESRF, European Synchrotron Radiation Facility
(Grenoble, France)

9 ELSA, Elektronen-Stretcher-Anlage
(Bonn, Germany)

10 CERN, European Organization for Nuclear Research
(Geneva, Switzerland)

11 PSI, Paul Scherrer Institute
(Zurich, Switzerland)

12 DESY, Deutsches Elektronen-Synchrotron
(Hamburg, Germany)

13 ESS, European Spallation Source
(Lund, Sweden)

14 **LNF, Frascati National Laboratories**
(Frascati, Italy)

15 SESAME, Synchrotron-light for Experimental Science and Applications in the Middle East
(Allan, Jordan)

16 BINP, Budker Institute of Nuclear Physics
(Novosibirsk, Russia)

17 BEPC-II, Beijing Electron-Positron Collider II
(Beijing, China)

18 KEK, Kō Energī Kasokuki Kenkyū Kikō
(Tsukuba, Japan)

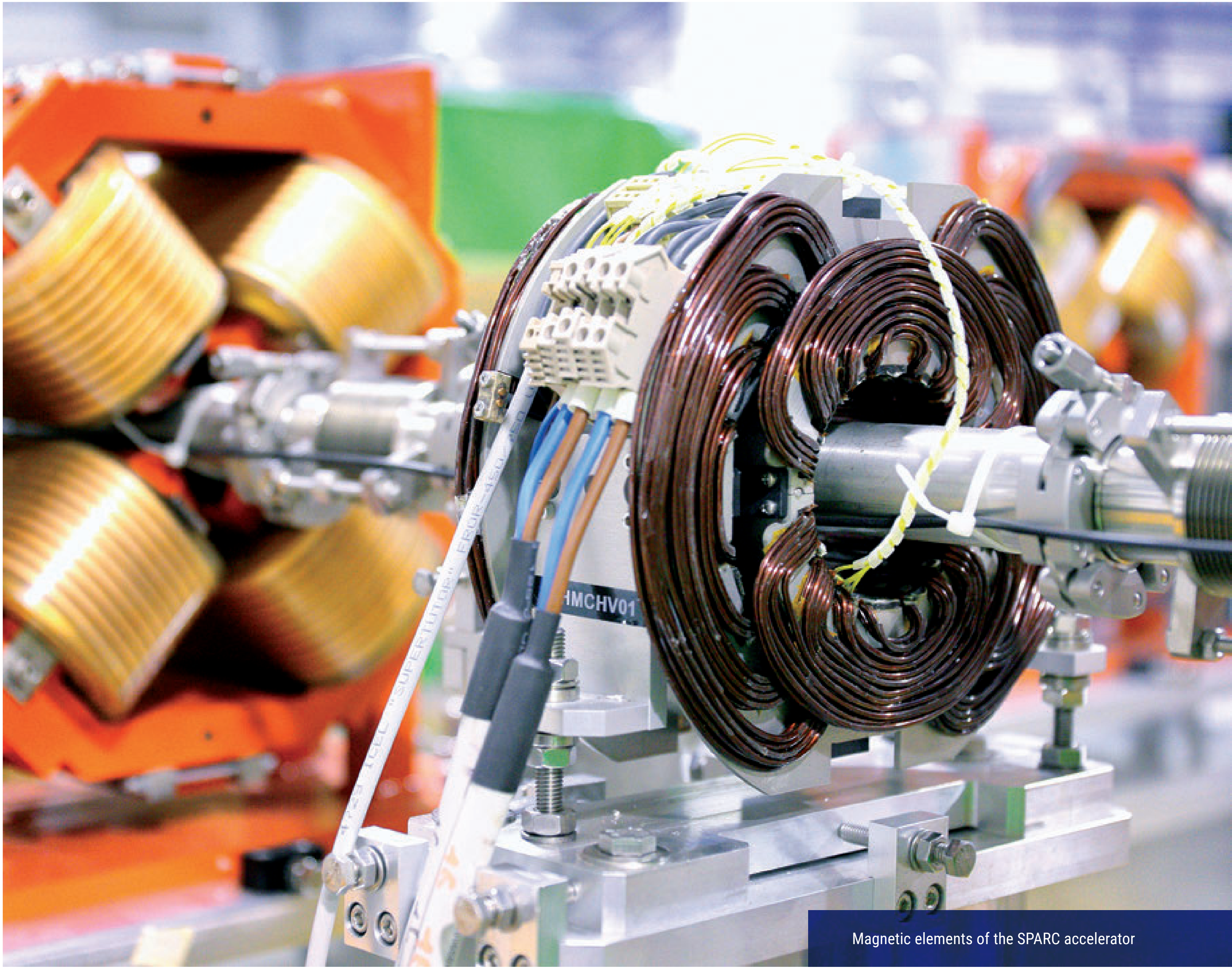
19 J-PARC, Japan Proton Accelerator Research Complex
(Tokai, Japan)

Research in experimental particle physics has for many years been a scientific undertaking that requires investments of a scale and complexity that are no longer within the reach of a single country, and which therefore requires multilateral contributions, international collaborations, and multi-year programming. Our researchers often work in foreign laboratories hosting the accelerators and equipment necessary for their studies. Correspondingly, the Frascati Laboratories host scientists interested in using the unique facilities available on site. Over time, LNF researchers have taken on leading roles in a dense network of collaborations connecting centres for fundamental physics around the world.

The complex equipment constructed at LNF is often sent to facilities abroad, where it is installed and used by researchers, engineers and technicians at the biggest foreign laboratories. The latest examples include the experiments at the LHC (CERN), FERMILAB (US), KEK (Japan), JLab (US), and BEPC (China). The Laboratories host a broad community of both Italian and foreign users participating in experiments and activities carried out on site.

The map at the left shows the extensive network of relationships and collaborations of which LNF is a part.

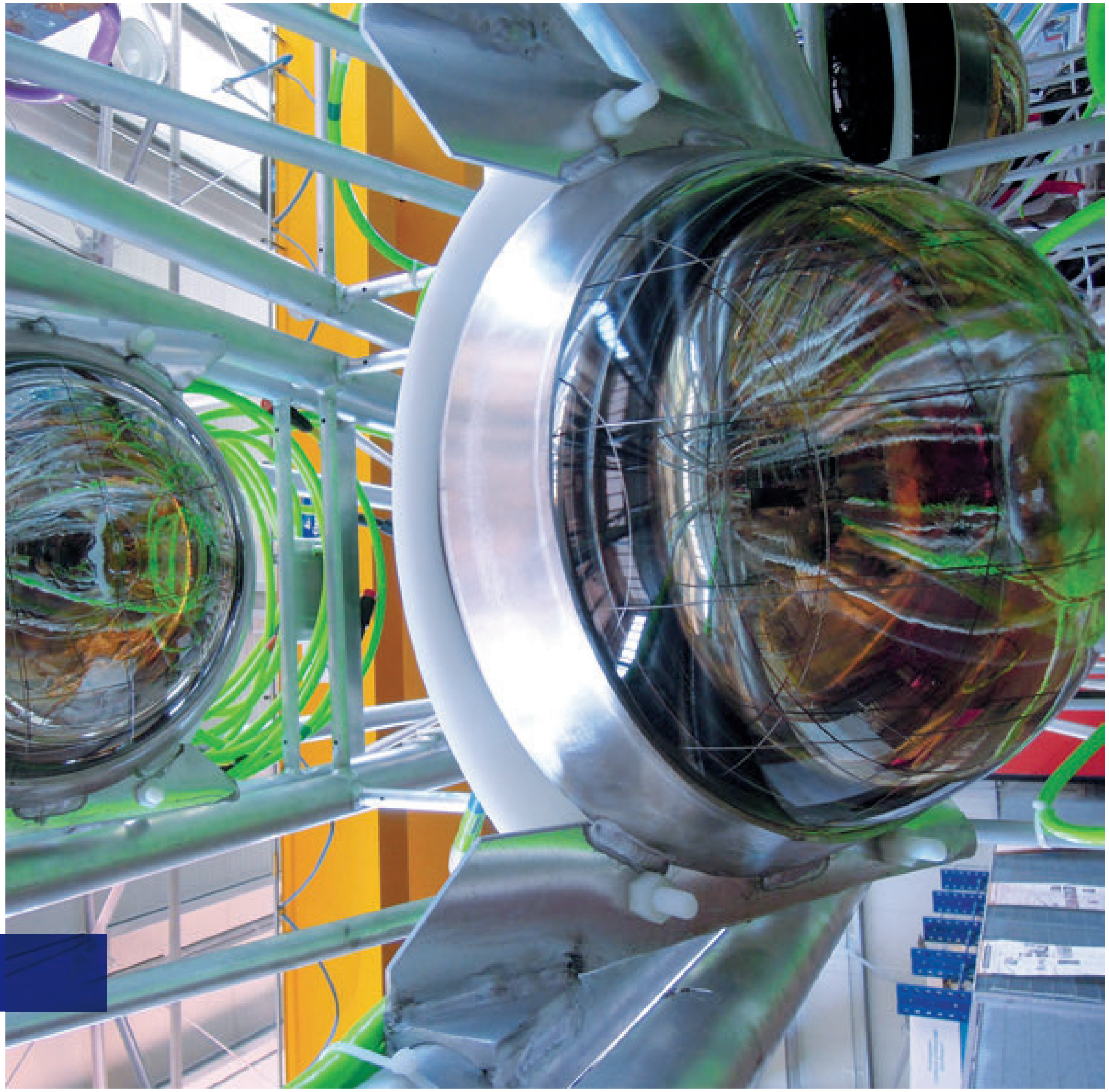
Technicians in a clean room working on the construction of a detector for CERN



Magnetic elements of the SPARC accelerator

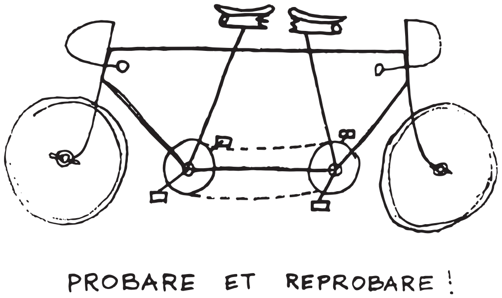
Fundamental research
Understanding the workings of the Universe

Fundamental research is a cultural endeavor aimed at improving and extending our knowledge of Nature, its constituents, and the forces ruling their interactions. The Frascati National Laboratories' founding mission is to carry out this kind of research in the field of particle, nuclear and astroparticle physics.



Photomultiplier tubes for the KM3 experiment being tested

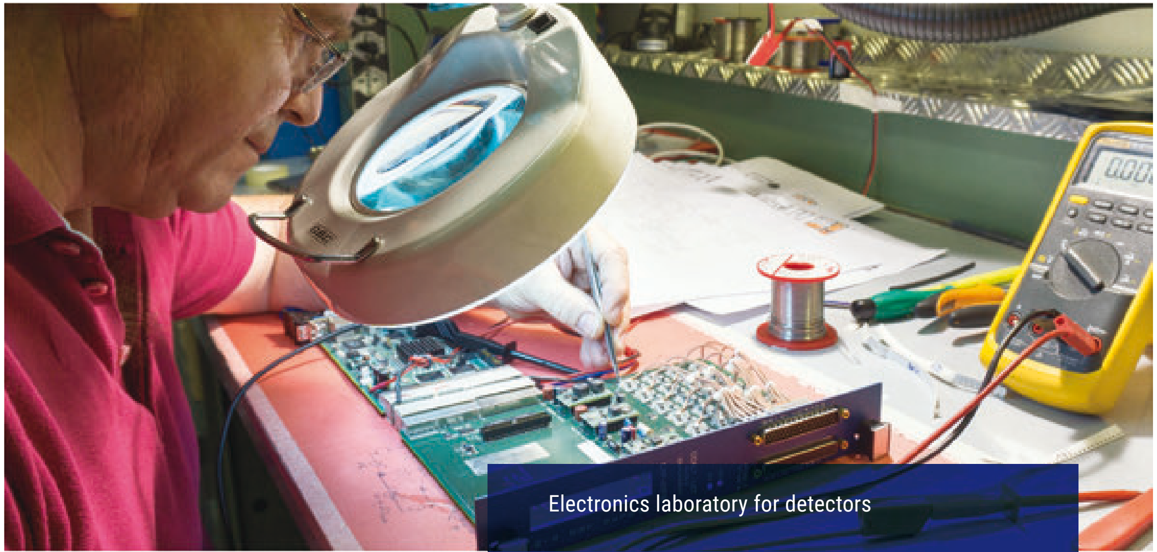
The motivations behind fundamental research are purely intellectual. However, the by-products of this kind of activity can be surprising, with numerous practical applications that significantly improve the quality of life. The full range of modern medical diagnostic tools, for example, results from fundamental research in the fields of radiation, particle detectors, and nuclear physics.



Drawing by Bruno Touschek

The Laboratories have a long tradition in fundamental research, with their participation in important experiments on site and in the main laboratories of the world. The confirmation of the existence of the charm quark at ADONE, the study of CP violation at DAΦNE and SLAC, the search for gravitational waves with the resonant-bar antenna NAUTILUS, the measurements of cosmic rays and neutrinos from CERN performed at the Gran Sasso Laboratories, and the verifications of the Standard Model at the large colliders of LEP at CERN and the Tevatron at Fermilab, are just a few examples of this commitment.

Frascati researchers collaborate as protagonists in the experiments at the LHC, having had leading roles in the discovery of the Higgs boson (ATLAS and CMS), the study of ultra-rare decays in heavy quark physics (LHCb), and the study of matter in the first moments after the big-bang (ALICE).



Electronics laboratory for detectors

Technicians and researchers during the installation of a component of the KLOE detector in the DAΦNE hall

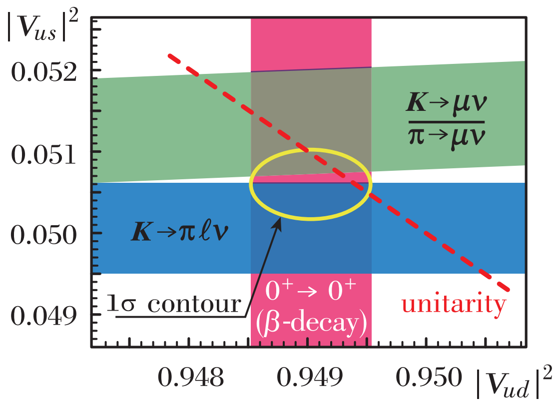
The expertise and facilities available at the Laboratories has enabled them to make important contributions to both fundamental research and the development of particle detectors, including most recently the construction of sophisticated gas detectors (especially the KLOE drift chamber, the largest ever built), the development of crystal and scintillator detectors, and the demanding manufacturing of silicon and micro-pattern devices to upgrade the experiments at LHC. These detection techniques are eventually applied to make everyday life better: for medical imaging and radiotherapy dosage, non-invasive analysis of cultural artifacts, security, and the science of materials.

Theoretical research at LNF, carried out in close cooperation with experimental researchers, has also played a crucial role from the earliest years of the Laboratories. The contributions of Raoul Gatto and Nicola Cabibbo are particularly noteworthy. In the early 1960s they laid the foundations for what would later become the *Standard Model of Fundamental Interactions*.

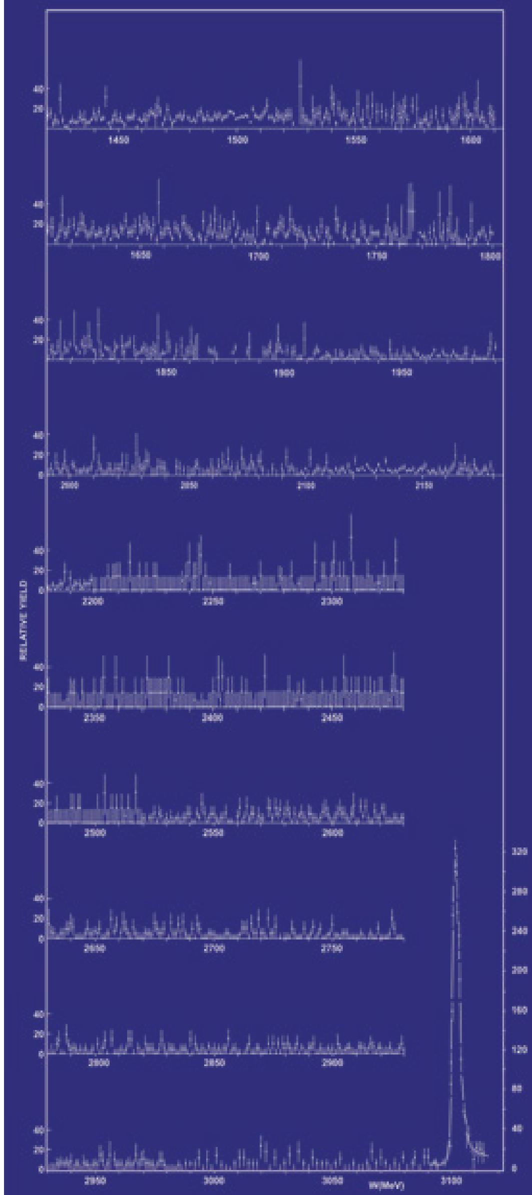
In those years, concurrently with the experimentation at ADONE, a strong theoretical physics group was born at LNF, a team that would study the phenomenology of electron-positron collisions.

More recently, theoretical research includes a wide range of activities: from string and supergravity theories to the pheonomenology of the fundamental interactions, from the quark-gluon plasma to models aimed at explaining dark matter, from field theory methods to their applications to condensed-matter systems.

Drawing by Bruno Touschek



An important result from the KLOE experiment at the DAΦNE accelerator. The element V_{us} of the Cabibbo-Kobayashi-Maskawa matrix (*Cabibbo angle*), a fundamental parameter of the Standard Model, has been measured by two different techniques (green and blue bands). If combined with the V_{ud} parameter obtained from measurements of radioactive β decay (red band), a very accurate test of the theoretical prediction of the existing relation between V_{us} and V_{ud} (dotted line) is achieved, providing a high-precision test of the Standard Model



Original diagram of the J/ψ resonance, measured at LNF, one of the first confirmations of the Standard Model

Technological and applied research
Not just fundamental physics

Each generation of accelerators and particle detectors has allowed us to make new discoveries that have broadened our basic knowledge, opening doors to the development of new technologies that led to genuine revolutions.

A system of laser retroreflectors for precision space telemetry

Elementary particle physics provides numerous examples of technologies that were developed for fundamental research, but which later found application in other fields, including the superconducting wires now used to wind the magnets for MRI scanners, the crystals developed for LHC detectors now used for PET imaging, and the World Wide Web, which was invented at CERN. At the Frascati Laboratories technologies under development with potential for broader applications include those related to synchrotron light, the development of new detectors, superconductivity, nanotechnologies, space research, and lenses for X-rays, in addition to accelerator technology.

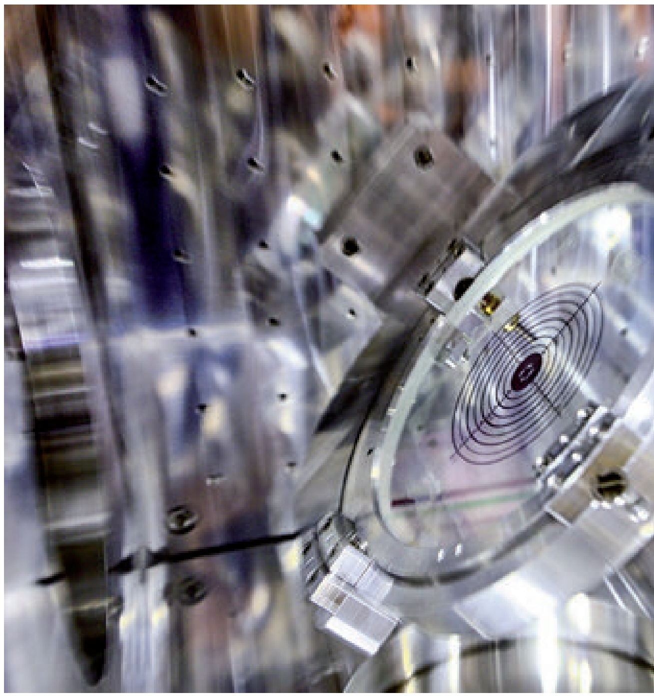
DAΦNE-Luce, a facility equipped with four high-intensity beamlines with high resolving power with wave-length from infrared to X-rays, is available to researchers from Italy and abroad, belonging to both the academic and industrial sectors. The activities carried out in this laboratory include micro-imaging, spectroscopy for materials science, radiobiology, the in-vivo study of cells, the analysis of cultural goods, and geophysical research.

New high-spatial-resolution and radiation-resistant micro-pattern gas detectors, silicon detector arrays, and crystals with excellent spatial and energy precision are all under development for future accelerating machines and medical applications.

Research on superconducting materials is carried out at the LAMPS laboratory. Here, both equipment with high-field cryogenic magnets and modern magnetic sensors are designed and constructed.

The SCF_LAB tests research equipment in collaboration with the Italian Space Agency. The conditions of outer space can be reproduced using tools such as a cryostat, a solar simulator, and vacuum chambers. Several laser retroreflectors used in space telemetry have been assembled and characterized, including one that will be mounted

Mirror for the transfer of ultra-high intensity infrared laser radiation



aboard the InSight lander constructed by NASA for the exploration of Mars.

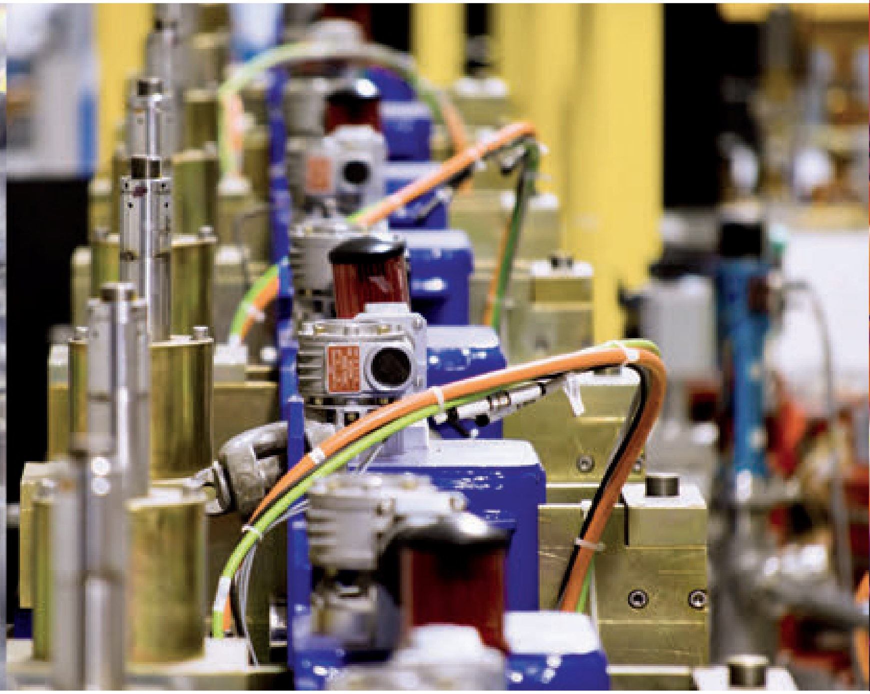
NEXT is the LNF nanoscience laboratory, with a wealth of expertise in the synthesis and engineering of carbon nanostructured materials, such as nanotubes, graphene nanoplates, and foils of woven nanotubes (*buckypapers*).

The XLab facility offers the possibility to perform experiments with X-rays for tomography, diffractometry, and fluorescence using glass polycapillaries, with interesting applications to techniques for biology, cultural preservation and industry.

A laboratory dedicated to advanced techniques for the construction and testing of accelerating cavity modules and for performing measurements on magnetic elements allows the construction of compact accelerators, not only for fundamental physics, but also for medical and industrial applications.

Experimental study of laser-induced condensation in the atmosphere

Set of vacuum pumps mounted on a section of an accelerator



Benefits and by-products for society

How scientific research affects everyday life

The aim of fundamental scientific research is the advancement of knowledge. However, the concepts, techniques, and instruments developed by researchers to face the challenges encountered in their activities sometimes turn out to be useful and applicable to various aspects of daily life. The benefits involve sectors such as information technology, networking, medical diagnostics, preservation and dating of artistic and archeological heritage, and technology transfer. Thus, research has a dual value for society: it both expands knowledge and produces new technologies that improve the quality of life.

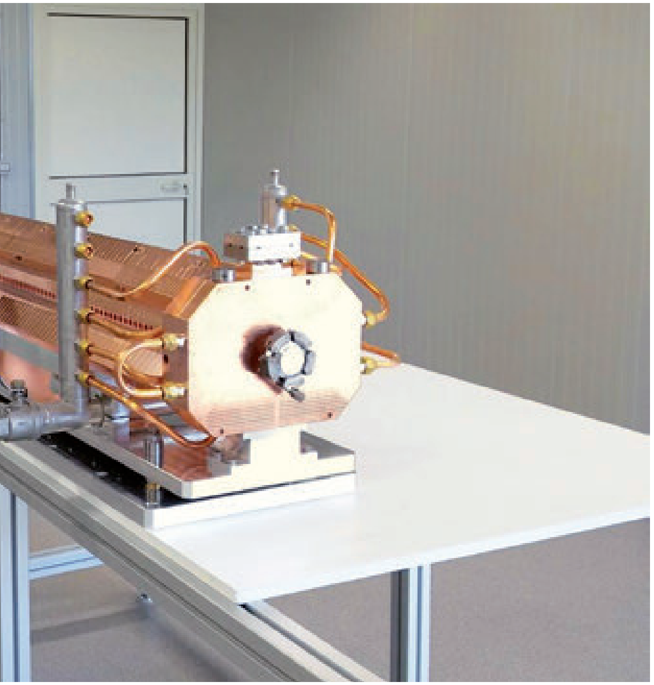
Technology Transfer

Passionate study, hard work and a touch of creativity are the ingredients researchers combine to deal with the everyday challenges of experimentation at the frontier of knowledge. This constant effort often leads to the development and subsequent industrialization of original technical solutions in areas such as precision mechanics, materials science, ultra-high vacuum technology, microelectronics, and computer science. The acquisition of know-how allows the industries involved to innovate, improve the quality of their products, and open up to new markets. Here are a few examples of technology transfer successes achieved at LNF.

CNAO

The Centro Nazionale di Adroterapia Oncologica (National Centre of Oncological Particle Therapy) is a large-scale facility built at San Matteo General Hospital in Pavia to treat radio-resistant or unresectable tumours by the use of carbon ions and protons accelerated by a synchrotron. Patients are exposed to beams of accelerated particles, which lose the greater part of their energy only at a certain depth, destroying the DNA of cancer cells while limiting biological damage to the surrounding tissue. The Frascati Laboratories were a key partner in the construction and commissioning of CNAO, a successful undertaking in which the INFN's expertise in accelerators was put to use for the benefit of society.

Section of an accelerator designed at LNF under construction by a company in the Rome area



!CHAOS

A software environment for control of experimental devices, designed and developed at LNF, !CHAOS can also be used in areas other than scientific research, thanks to its extreme versatility and scalability. !CHAOS is of interest to industry, as demonstrated by a pilot project in collaboration with and co-financed by an important partner, a global leader in the field of automatic machines for processing and packaging of products. Possible applications of !CHAOS include distributed sensor networks, smart traffic lights, and other large-scale, real-time activities.

GRID

One of the computer centres making up WLCG (the Worldwide LHC Computing Grid), the largest computer grid dedicated to the analysis of the large body of data coming from LHC, is located at LNF. The Grid is used every day by scientists from all over the world who can access data in real time. Moreover, the Laboratories host an advanced facility for computing and data storage for the KLOE experiment and participate in programs to develop cloud computing techniques to provide Big Data service infrastructure to other scientific communities as well.

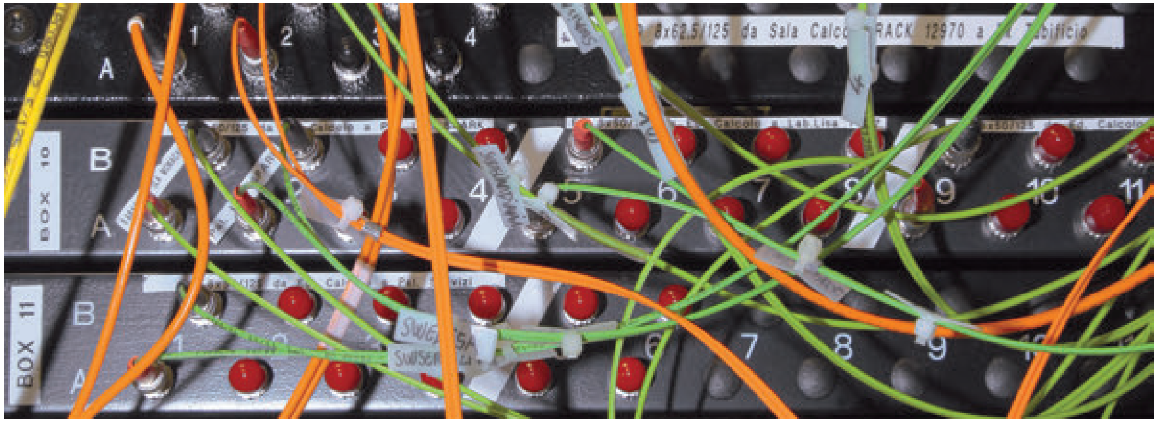
Irradiation of samples at the BTF

The Beam-Test Facility is a nearly unique infrastructure in the panorama of particle accelerator applications. The strong radiation to which electronic components for space-bound objects (satellites, orbiting stations, ships) are exposed to can quickly cause these components to fail. At the BTF, such components, in particular, for applications in future space missions for planetary observation, can be irradiated with electron beams. Through exposure to the particle beam for a period ranging from a few minutes to a few

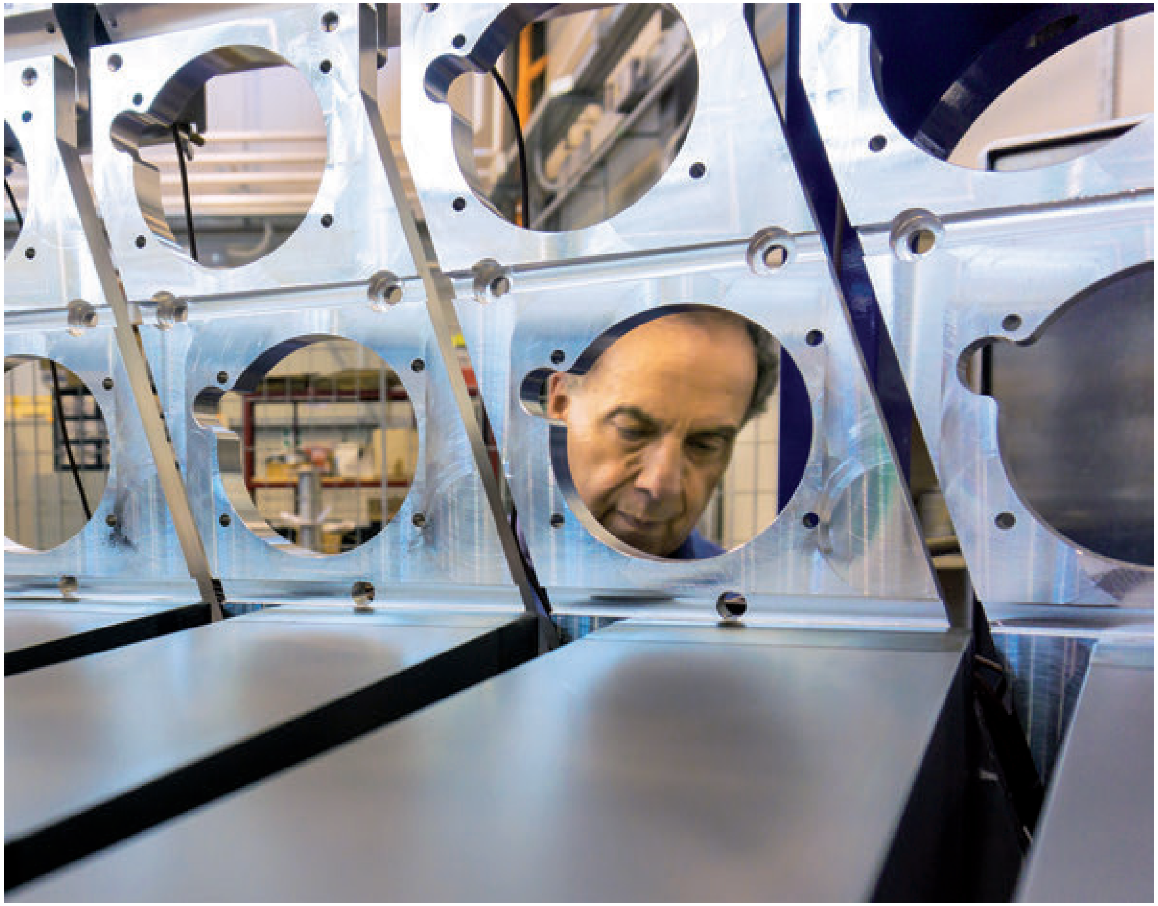
days, the behavior that the electronic components would have in space over several years of activity is simulated, so that their characteristics can be studied and improved.

CHNet

Interest in techniques for the analysis and preservation of artistic and cultural artifacts has greatly increased in recent years. As a participant in the framework of CHNet, a network of laboratories devoted to cultural preservation, LNF has specialized in diagnostic spectroscopy techniques, such as X-ray fluorescence (XRF), and developed a portable device capable of analyzing a wide range of artworks. The technique has been used for studies of Roman imperial coins, a medieval cross, and a Byzantine codex, among other items.



Optical fibres at the LNF Computing Centre



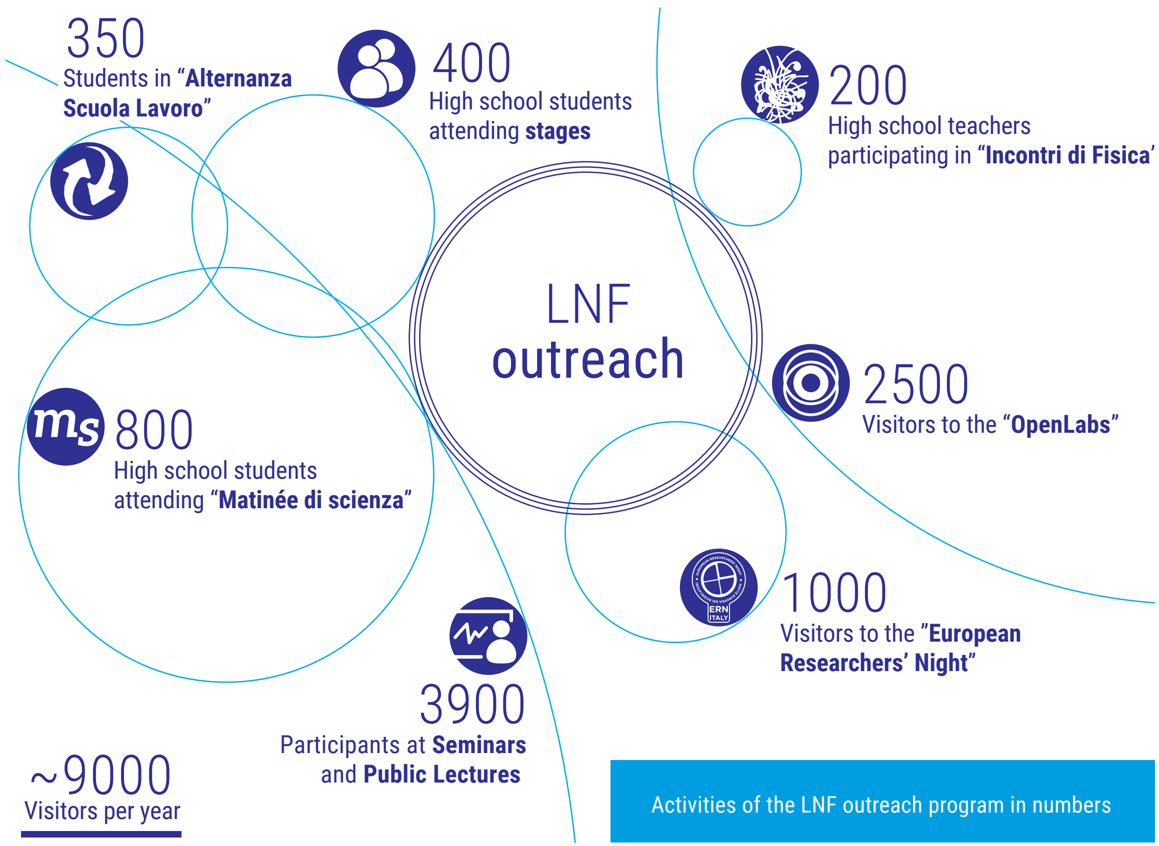
Metallic structure to host crystals for an experiment at CERN

The synchrotron at CNAO (National Centre for Oncological Hadron Therapy), built at the San Matteo General Hospital of Pavia in collaboration with LNF


LNF is open

Informing and engaging
Involving young people and the general public in the passion for research

Inventiveness, passion, and ability are essential for communicating scientific progress with the broader public. With this in mind, the Frascati National Laboratories commit themselves daily to promoting the diffusion of science at the national and international levels, bringing the general public closer to subjects that might seem beyond the reach of understanding, but which actually find important applications in everyday life.



Activities of the LNF outreach program in numbers

In addition to carrying out research and training the next generation of scientists, LNF's "third mission" is to familiarize society with its research programs and their results. With their specialized infrastructure and privileged relations with the surrounding community, the Laboratories carry out a unique role.

Special emphasis is placed on creating opportunities for young people to express their potential, encouraging them to pursue scientific careers and studies in science at the university level. The pillars of LNF's third mission are institutional communication, up-to-date multimedia content, a rich outreach program, and event organization.

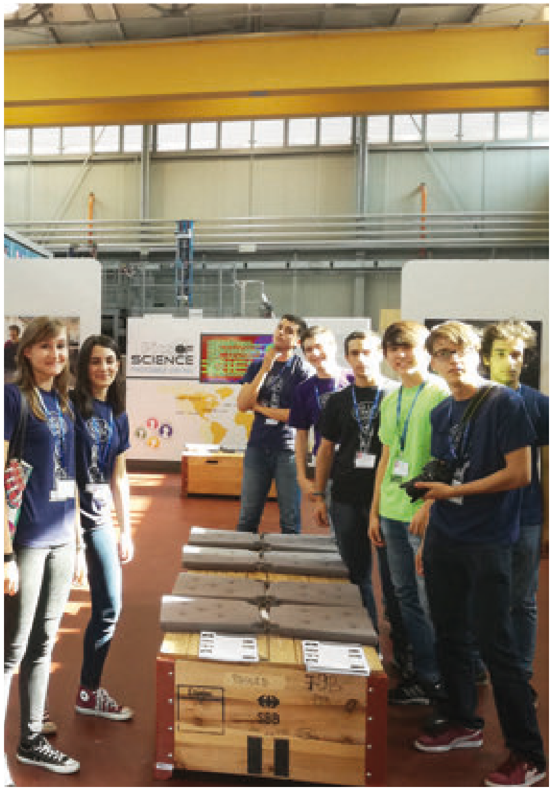
Students of all ages, teachers, and members of the general public are involved in dedicated initiatives. Students can attend stages, physics lectures, and guided tours of the Laboratories tailored to their courses of study, as well work-related learning activities. The students, from Italy and abroad, are selected by their teachers on the basis of their course of study, personal inclinations, and motivations.

Students participating in stages are introduced to research activity at the Laboratories and spend a period of time in close contact with experimental groups, learning how to apply scientific methods and the use of cutting-edge techniques and equipment under the guidance of researchers, technologists and technicians. They learn how to work in a team, acquire and analyze data, and present their work in front of an audience. Particular attention is paid to the issue of gender equality and to motivating girls to pursue a scientific career. Educational workshops and special tours are organized for children (*edu-kids*).

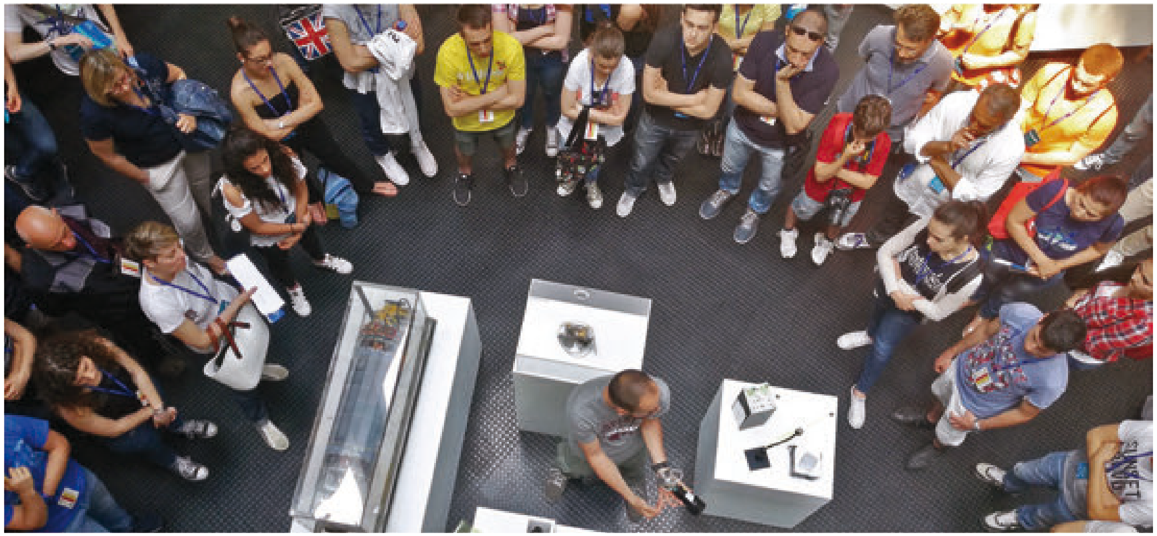
These programs represent a unique experience for students to study in the open environment of an international research laboratory, as well as an opportunity for university and career orientation.

The INFN is considered a qualified entity for the training of school personnel and its courses are recognized by the Ministry of Education, Universities and Research (MIUR). As such, the Laboratories prioritize and promote refresher courses for teachers, so that science education and innovation go hand in hand. High-school teachers from all over Italy participate in these refresher courses, which provide opportunities to meet LNF researchers, establish an environment for the exchange of knowledge and experience, and help teachers to keep up with the MIUR curriculum in modern physics, from the theory of relativity and quantum mechanics, up to recent discoveries such as the Higgs boson and gravitational waves.

Events for the general public are designed to satisfy the curiosity of enthusiasts of all ages. The wide-ranging offerings of the Laboratories include a program of open seminars with special guests on various scientific topics; *OpenLabs*, the Laboratories' open day, which has become an institutional rendezvous; and a broad collection of recorded lessons available on the LNF *YouTube* channel.



Open Day at the Laboratories




Sala Controllo DAΦNE
9
DAΦNE

The Laboratories in numbers
Data and statistics on LNF activities and programs

2
number of interaction points in the DAΦNE collider

96
length of the DAΦNE collider in meters

172
kilometers of wire in the KLOE drift chamber, the largest in the world

267
scholarships awarded to young people in the last 10 years

400
people using the Laboratories for their research activity per year

470
articles published by LNF researchers in a year

500
researchers, technologists, scholars, associates, technicians, and administrative staff working at the Laboratories

6150
hours of machine time per year available to users of the DAΦNE and BTF complexes

77850
meals served at the LNF canteen per year

131000
surface area of the Laboratories in square meters

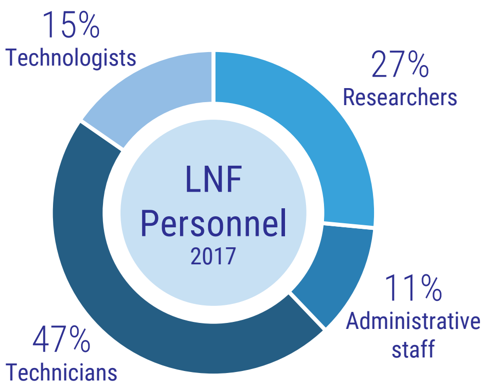
30 million
Φ mesons produced at DAΦNE in one day

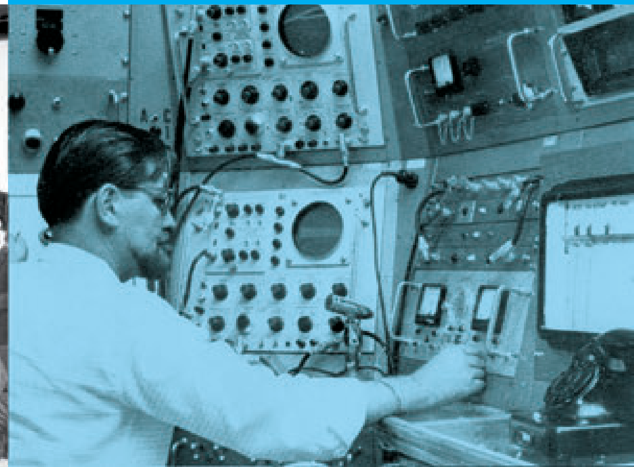
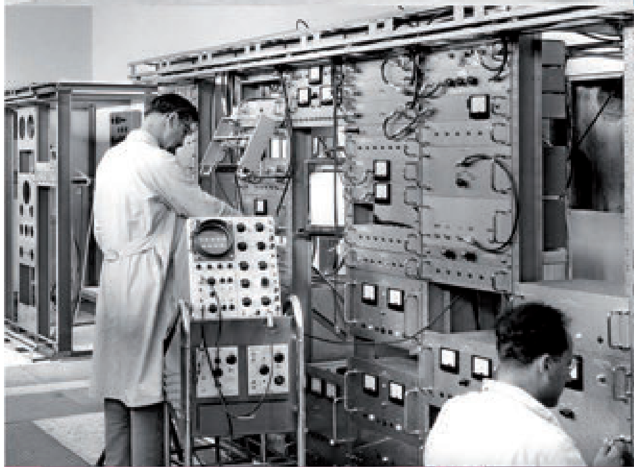
20 billion
electrons in a packet injected into the DAΦNE accelerator

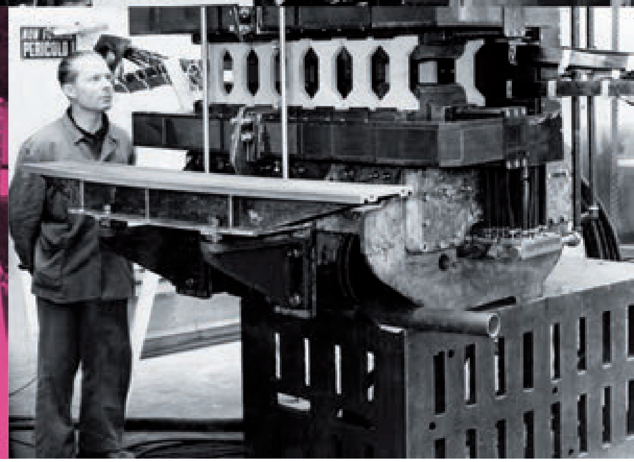
LNF is the biggest of the INFN laboratories, with a total staff of over 320 permanent and fixed-term employees accompanied by about 200 scholars and associates, employees from other institutes and universities who carry out their activity mainly at LNF. Master's and PhD students play a special role. These students work in LNF research groups and then continue their training through scholarships at cutting-edge facilities both inside and outside of the laboratory, gaining experience at the interational level in preparation for their careers. External users represent an important part of the laboratory community. These

Distribution of the various categories of personnel working at LNF in 2017 are users from other institutes in Italy and abroad who work at the facilities available at the Laboratories. About one third of the more than 400 users are foreign.

The LNF staff is organized into three divisions, Research, Accelerators, and Technical, as well as general services that answer directly to the laboratory director: Administration, Personnel, Safety, Health and Radiation Protection, Knowledge Transfer.



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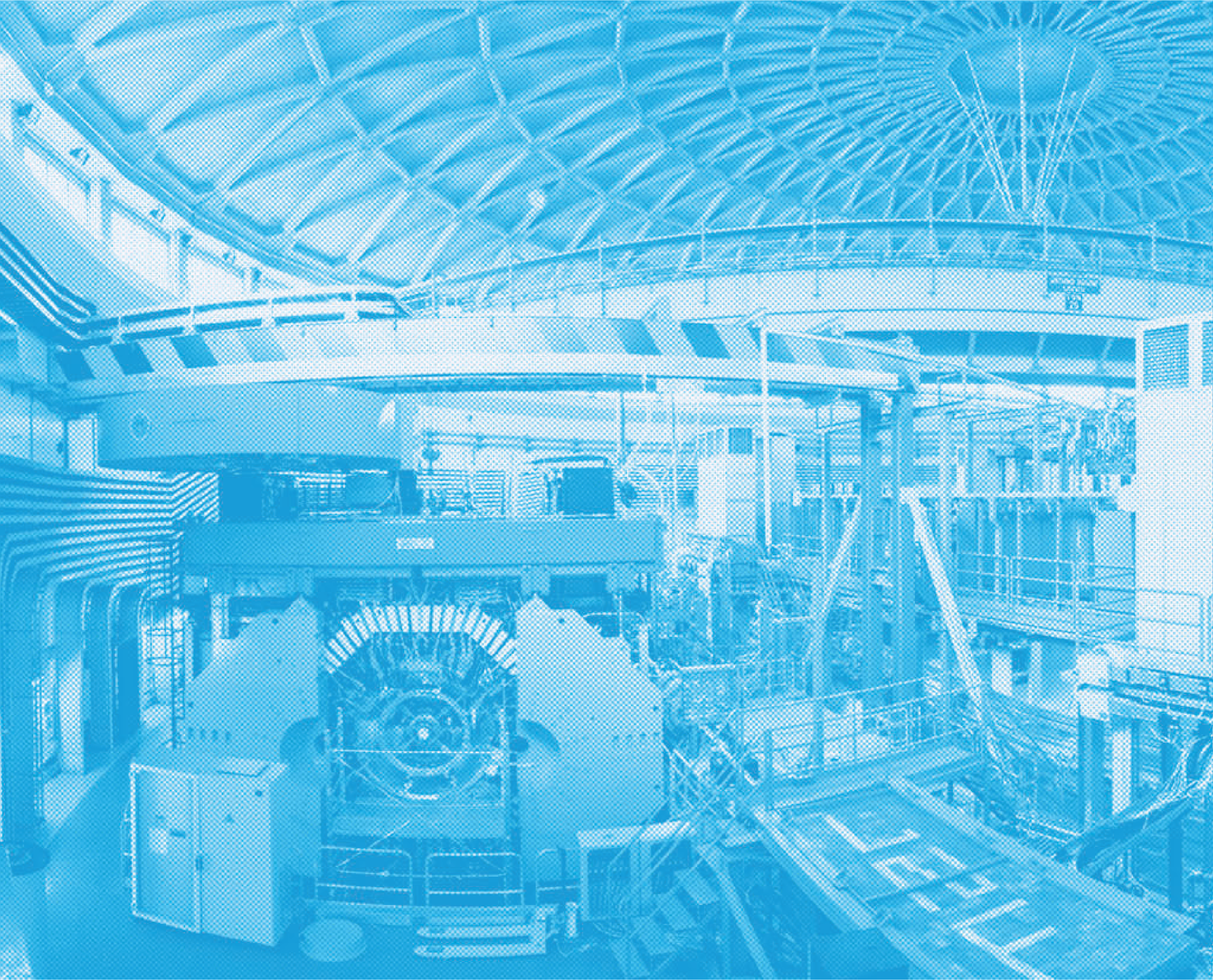

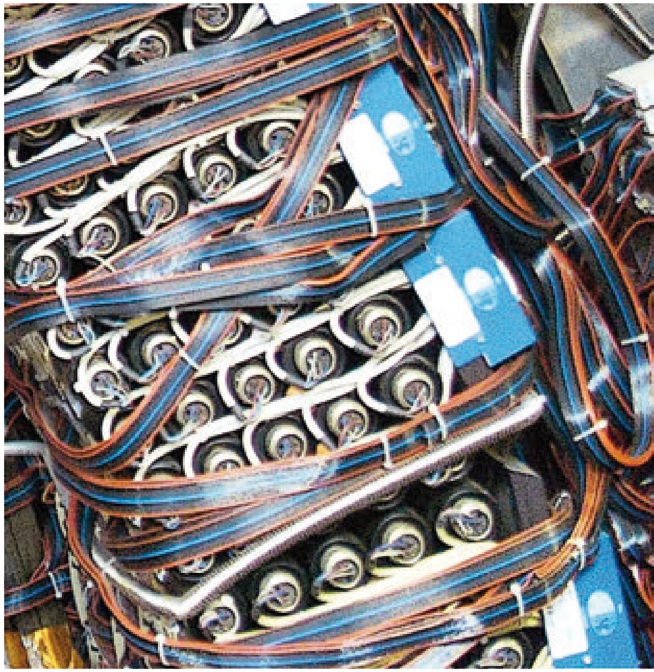

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