Newsletter Interview

THE ITALIAN FUTURE OF ACCELERATORS - FROM FCC TO NRRP

Interview with Lucio Rossi, INFN researcher and professor at the University of Milan, coordinator of INFN Accelerators Committee

Right from their first appearance in the sector dedicated to studying the ultimate constituents of matter, particle accelerators have shown a profound propensity for finding a position, often central, in disciplinary fields other than fundamental physics. An emblematic case of this fertile transfer of technologies is surely the medical field that, from as early as the 1950s, has made use of accelerators in treating tumours. Examples of similar successes also punctuate the experience of INFN. These occur precisely in research aimed at promoting the transfer of technologies, created in the field of accelerator physics, towards the already mentioned medical sector and other ones too, such as those dedicated to the production and distribution of power and the preservation of the artistic heritage.

While remaining strategic for particle physics, the accelerator sector, as its history shows, is thus destined to hold an increasingly central role in external environments and also in the context of relaunching our country’s economy, especially in light of future challenges that it will be called upon to face. On the one hand, the physics of accelerators will need, in fact, to measure itself against the guidelines traced by the updating of the European Strategy for Particle Physics Update (ESPPU) for the post-LHC future, which involves developing innovative machines and technologies. On the other hand, it will need to implement and capitalise on the two projects led by INFN funded by Italy's National Recovery and Resilience Plan (NRRP) that promote research linked to the development of accelerators. For these reasons, starting from 2021, INFN set up an Accelerators Committee, which has the task of connecting communities of INFN's accelerator experts and its various institutes and laboratories. Lucio Rossi, professor at the University of Milan and researcher at the INFN Milan Division - LASA Laboratory - and former head of the High Luminosity LHC project at CERN, will coordinate the committee.

How was the Accelerators Committee created? What are its tasks and its contact people within the INFN community?

The committee was born from the need to draw together our community of accelerators. This derives from the peculiarities that distinguish INFN, an organisation that is distributed across all of Italy. While in other European countries research in the area of accelerators is concentrated in one or two centres, in Italy INFN has three dedicated national laboratories, those in Frascati, the Southern National Laboratories (in Catania), and Legnaro. The Gran Sasso National Laboratories, which are equipped with a new, small accelerator for studying nuclear reactions of interest to astrophysics, have also recently been added to this list. A vast series of activities in this same sector is, in any case, hosted in many

other INFN facilities, such as, for example, the Laboratory of Accelerators and Applied Superconductivity (LASA) and the Milan, Genoa, Naples, Rome, Rome Tor Vergata, Bari, and Ferrara divisions. The goal of the committee, which replaced the earlier ACcelerator TEcnhology COmmitee (ACTECO), set up with the specific purpose of coordinating efforts in the context of the European I.Fast programme, is precisely that of not wasting this expertise, which would otherwise run the risk of remaining isolated. Thus, the committee performs its task by helping the community access funding programmes that are provided at a European and national level and providing INFN leadership with consultancy and support in the choice of strategic lines to adopt.

Speaking of the European programmes dedicated to accelerator physics, to which INFN will contribute, what are their purposes and which fields of application do they refer to?

Promoting European programmes and supporting the INFN community in taking part in these initiatives are among the committee's tasks, and our work is concentrated on important projects that have taken off in 2021 and in the present year. Among these, only one, the Muon Collider, for a particle collider that is an alternative to the current ones and able to accelerate muons and make them collide, has purposes strictly linked to basic research. All the others, I.FAST, HITRI plus, and EUROLABS, respectively oriented at developing new technologies for accelerators, the identification of solutions for the treatment of tumours via heavy ions and the creation of a European network of shared infrastructure, have a strong applied character, demonstrating the ever-greater presence of accelerators in crucial fields like the medical one. Today, the accelerators sector can, in fact, be described as a sector that rests on two distinct legs: one consisting of fundamental physics, still the main promoter of progress in accelerators, and the other of the activities in which these tools find space, first of all the medical ones, but also those connected to energy and preserving the artistic heritage.

The medical applications have, historically, represented a privileged outlet for accelerator physics. This is one line of research of which INFN is, today, the undisputed leader. What are the projects that straddle medicine and accelerators in which INFN is today engaged?

With reference to research directed at using accelerators in the medical field, with specific reference to the treatment of tumours, INFN has two important lines open. The first one is dedicated to so-called FLASH therapy, which involves the use of electrons, and compact accelerators able to produce them with higher energies compared to conventional radiotherapy. The second, which is part of the HITRI plus programme, and, in part, I.FAST, instead concentrates on work that aims to expand the potential for therapies that use ions, delivered today in Italy by CNAO (the National Centre for Oncological Hadrontherapy). Although they have a greater treatment capacity in the case of specific tumours, the ions are, in fact, difficult to accurately dose. To overcome these difficulties, INFN is currently engaged, together with CNAO, in a project to create a system, called ”gantry”, for the effective distribution of ions when treating patients. We must also mention the effort to produce protons and ions for medical purposes using flash lasers on solid targets, pursued by various Divisions, including the Milan-LASA one and, above all, the Southern National Laboratories (I-LUCE project). As mentioned, the applied outlets, both European-wide and nationally, of INFN accelerator research are not, in any case, only directed at the medical division. One example above all concerns the energy sector, today more than ever called upon to provide alternative solutions that could make energy production and distribution efficient. INFN, thanks to its expertise, is, in fact, often called to assist the industry in projects for incinerating radioactive waste using accelerators, a process that can, in turn, produce energy and it is also involved with the Legnaro and Southern National Laboratories and the INFN Turin, Padua, and Bari Divisions, in studying the creation of fusion accelerators.

Beyond those aspects linked to technology transfer, research into fundamental physics, for which accelerators are an essential tool, remains the main mission of INFN. What will be the future of accelerators in this sector?

In recent years, INFN has aligned itself with the research recommendations identified by the latest update to the European strategy for particle physics, which has obviously also provided suggestions on the shared prospects to be pursued in the accelerators sector. The document has defined, as a priority, the study of the Future Circular Collider (FCC), the 100-kilometre diameter collider that should represent the future after the LHC. INFN is, thus, concentrating on this project, which could involve a first phase using electrons (FCC-ee), thanks to which it could test the operation of the machine and carry out precision physics. This will be followed by the acceleration of hadrons (FCC-hh), like protons, at much higher energies than those which can be obtained at CERN today. Our community is currently involved, in the front line, both in studying the FCC-ee and in researching and developing the new magnets needed for the FCC-hh, which promises to be very long. In the eventuality that the FCC project is not realised due to too-high costs or its complexity, the European strategy has also clearly indicated that the Muon Collider is a possible alternative. In this case too, we're talking about a very difficult machine to produce due to the technological challenges that it poses. Europe is engaged in carrying out a feasibility study for this device within the next four years. To this end, a design project was approved for understanding whether it is possible to create a muon collider and in what time frame. INFN will participate in this activity with a leading role together with CERN, so as to be among the promoters of a proposal for studying and constructing a facility in which to develop the most significant components, i.e. those necessary to produce and "capture" muons, which must be very rapidly cooled to obtain a coherent beam of particles.

In addition to the guidelines outlined by the European strategy for particle physics, INFN is conducting, in the context of the Eupraxia project, research into an alternative acceleration system based on plasma. At what point is the research into plasma and what kind of future will this technology have?

Research into plasma, a state of matter composed of ionised gas, is one of the development lines adopted by INFN for the accelerators sector which has its main site at the Frascati National Laboratories, leader of the EUPRAXIA project, which gathers the centres working on the plasma accelerators technology Europe-wide. In this context, the results already obtained are important: recently, the same group of researchers engaged at the Frascati National Laboratories on these activities demonstrated the ability to produce coherent radiation by accelerating a beam of electrons using plasma. Over the next few years, it will be necessary to improve its capacity to exploit the full potential of plasma to transform them into accelerators able to produce useful beams. Now, the possible outlets for this technology concern the research and industrial sectors that make use of so-called Free-Electron Lasers (FEL), which could, thus, exploit compact accelerators with reduced costs. In any case, the full development of the plasma accelerators could enable their use in medicine and fundamental physics in the future. The interest that is forming around this line of research, leader of one of the five projects led by INFN that will be funded by the NRRP with a grant of € 22.3 million, derives from this. Eupraxia Advanced Photon Sources (EuAPS): this is the name of the project that aims to produce a distributed user facility (Frascati National Laboratories, Southern National Laboratories, Tor Vergata University, and CNR-INO [National Research Council-National Institute of Optics] of Pisa), to provide groups of users with sources of radiation and advanced particles based on different types of plasma acceleration.

Staying with the NRRP, INFN is both the proponent and the leader of another important project dedicated to accelerator technology: IRIS. What are its goals and what type of benefits might it bring to the fields it addresses?

Like EuAPS, the IRIS (Innovative Research Infrastructure for applied Superconductivity) project has the goal of creating distributed infrastructure, sharing already existing research centres, starting from LASA of the INFN Milan Division, before passing to the INFN Genoa and Naples Divisions, the affiliated groups in Salerno and Lecce, and the Frascati National Laboratories, which will also be updated with new buildings based on the project's needs. Each of these poles, which will also see the participation of local universities (Milan, Genoa, Naples, Salerno, and Salento) and, in Genoa, Naples, and Salerno, the National Research Council's SuPerconducting and other INnovative materials and devices institute (CNR-

SPIN), will specialise in one of the activities that will characterise IRIS which will comprise all the research and development areas linked to producing superconducting magnets and cables dedicated to accelerators. IRIS is funded with € 60 million and, in addition to the creation of a distributed infrastructure of laboratories, also has the purpose of developing two important technological demonstrators. First, there is a magnet intended for basic physics, which will have the purpose of demonstrating the possibility of obtaining strong magnetic fields at higher temperatures than those necessary today in the LHC. The FCC project could also draw an enormous advantage in terms of energy savings from this. The second is a superconducting transmission line, similar to that envisaged for the transfer of current from the High Luminosity (LHC) project, able to transport and distribute large quantities of power (up to 1 GW) efficiently via small buried cables.

In short, the accelerators sector is very active, and its scientific community is working, at the same time, on several fronts, on diversified research and development projects for innovative machines, with very promising prospects, both for basic research and for its beneficial uses for society.