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ESS: THE NEW EUROPEAN ACCELERATOR FOR FUNDAMENTAL AND APPLIED RESEARCH

Interview with Santo Gammino, Italian coordinator of the European Spallation Source (ESS) project and researcher at the INFN Southern National Laboratories.

The first high-tech components of the ESS (European Spallation Source) project, currently under construction at the Lund site, were inaugurated on 15 November, during the Italian State visit to Sweden, in the presence of the President of the Republic Sergio Mattarella, and the sovereigns of Sweden, King Karl XVI Gustaf and Queen Silvia. These components are the ion source of the future accelerator and of the Low-Energy Beam Transport line (LEBT), the approximately two and a half metres long section that couples the ion source to the subsequent sections of the accelerator under construction. The source and the LEBT were built at the INFN Southern National Laboratories (LNS). Delegations from both countries attended the inauguration ceremony. Among those present were the Swedish Minister of Higher Education and Research, Helene Hellmark Knutsson, Ricardo Antonio Merlo, Secretary of State of the Italian Ministry of Foreign Affairs and International Cooperation, representatives of the scientific community, including the Director-General of ESS, John Womersley, and the Vice President of INFN, Speranza Falciano, representing the two institutions involved in the event, who gave a presentation on the impact of ESS for European science.
We talked about the results achieved and, in general, about the ESS project with Santo Gammino, ESS coordinator for Italy and researcher at the INFN Southern National Laboratories.

What will the European Spallation Source be?
ESS will be a multidisciplinary research centre based on the most powerful high-intensity linear proton accelerator ever built, which will produce neutrons for use in cutting-edge scientific research in a variety of fields, from new materials to energy, from health to the environment, from life sciences to cultural heritage. ESS will therefore be an infrastructure for basic and applied research, which will benefit companies operating in various sectors, including mechanics, electronics, biomedicine and chemistry: observing matter with a truly extraordinary detail, as ESS will allow, will have a huge impact on safety

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and optimisation, to the benefit of both companies and consumers, maximising everyone's interests. ESS, which aspires to build the most powerful neutron source in the world by 2023, since 1 October 2015 is an ERIC: an infrastructure that falls within the cases contemplated by the European Research Infrastructure Consortium. ESS is also a landmark project of ESFRI, the European Strategy Forum on Research Infrastructure, which is committed to tackling the technological challenges posed mainly by Japan, China and the United States on the European front. For a transformation economy, such as the European one, it is only possible to address these challenges by keeping the level of innovation high. Research infrastructures that meet the needs of industry represent one of the pillars on which ESFRI is founded, and ESS fits perfectly in this context.

How does it work?

ESS will be like a very powerful microscope, thanks to which we will be able to study the behaviour of matter in real time from the microscopic level up to the dimensions of the atomic nucleus. In fact, neutrons will function as a probe to reveal the structure and processes of matter. ESS linear accelerator will provide a high intensity proton beam that will hit a target, thus producing the neutrons that will be used for scientific research. The process begins in the ion source, at the extremity of the accelerator furthest from the target, where, by heating up the electrons with electromagnetic fields, the plasma is produced (highly ionised matter, in which a large percentage of nuclei - protons in the case of hydrogen - are disconnected from the electrons that constituted the hydrogen atoms). The protons are extracted from this plasma thanks to a strong electric field and brought to the first part of the accelerator, the LEBT, where the particle beam is analysed, optimised and focused before the acceleration begins in the subsequent part of the machine, the radio frequency quadrupole (RFQ), which will be delivered by the French partner CEA in 2019. The proton beam accelerated almost to the speed of light then collides with the target, producing neutrons, through a process called 'spallation', hence the name European Spallation Source.

What are the neutrons used for?

Use of neutrons for research allows us to investigate the world around us and to develop new materials and processes with interesting repercussions for society. Neutrons are used, for example, in the development of new solutions for health, environment, clean energy, IT and much more. In fact, they can be used to study engineering materials and components, geological structures with their dynamics, as well as historical artefacts whose detailed study reveals important information to understand and preserve our cultural heritage. Moreover, they are used in research in life sciences, for the study of

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biological processes that occur from the cellular to the atomic scale, large macromolecular complexes, the function of water in enzymatic processes, the action mechanisms of drugs and the role of biological macromolecules. And they are also useful in materials science, from semiconductors to lasers, batteries and magnetic storage materials. The spectrum of use is therefore really broad.

What was inaugurated in Lund?

We inaugurated the ion source and the linear accelerator LEBT, the beam line. We can say that this is the culmination of approximately 30 years of investment in research and development on ion and plasma sources at the INFN Southern National Laboratories, which today has allowed our group to play a prominent role at the global level in this field. The main challenge in the implementation of the source concerned the optimisation of the beam characteristics that determine the reliability and costs of the entire accelerator: in particular, the "ripple" and the emittance of the proton beam (the ripple is the variation in current and must be as low as possible, as it happens for the emittance, which is a measure of the tendency of the beam to spread in its path along the accelerator). For these two parameters there were no previous experiences except with continuous beams over time. Here, on the other hand, a variation of the beam was required in the very short period, because the shorter the intervals, the greater the accuracy of the energy measurement of the single neutron which is used as a probe for the searches. We were confident that the beam characteristics required by the project could be achieved, but we also knew that this would be challenging: we managed to meet it thanks to the expertise and experience that we started to build from the late 90s with the TRASCO (TRAsmutazione SCOrie - waste transmutation) project, proposed by Nobel Prize winner Carlo Rubbia, together with colleagues from the Southern National Laboratories, in particular Giovanni Ciavola and Luigi Celona. The other major technological challenge was the neutralisation of the spatial charge: the high intensity protons are all positively charged, therefore they manifest a strong Coulomb repulsion: the "trick" to overcome this problem consists of getting protons out in the vacuum chamber at a higher pressure, so that, interacting with the residual gas (non-ionized hydrogen), they ionise it, counteracting the Coulomb repulsion: with an artistic simplification we can say that it is as if there were an electron sheath around the exit beam cylinder. In addition, I would like to underline another significant innovation with respect to similar sources built in the past: from the outset, the design of this source was based on its ease of assembly and operation. The source was assembled in Lund by six LNS colleagues (one physicist, two engineers and three technicians) in just 13 working days, following an operating scheme not unlike that of a pit stop in Formula 1. The preparation was so attentive to details that, after a few days, the Lund technicians were able to manage every aspect, with an efficient transfer of the necessary information.

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What is the Italian contribution to ESS?

ESS is a pan-European project, worth a total of 1,843 million euros, which will be implemented thanks to the contributions, both in kind and financial, of 20 Institutes in 8 countries: Czech Republic, Denmark, Estonia, France, Germany, Italy, Norway, Poland, Spain, Sweden, Switzerland, United Kingdom and Hungary. Italy, which is one of the founding countries, is in the project with INFN, which coordinates the national participation, and is the representative entity of the Ministry of Education of the University and Research (MIUR), and with Elettra Sincrotrone Trieste and the National Research Council (CNR). Our total contribution is 110 million euros (equal to approximately 6% of the overall budget), of which 83 million in kind. In particular, the in-kind value provided by INFN will be over 33 million euros. A favourable condition for Italy: in fact, while other countries have made agreements for an in-kind and financial contribution of 70% and 30%, respectively, Italy, with France, has had better conditions with over 80% of in-kind contribution. This was possible because we possess the essential know-how to build machines based on high power proton accelerators.

In detail, in addition to the proton source, whose design began at the LNS in 2012, and the LEBT already delivered and just inaugurated, the INFN will provide a spare source, which will also be used for accelerator tests and training of the personnel that will operate the machine, a Drift Tube Linac that will accelerate the beam from 3.6 to 90 MeV, and the superconducting cavities of the mid-beta section that will accelerate it from 200 to 571 MeV. All these components will be built at the INFN Southern and Legnaro National Laboratories, and LASA (Laboratory of Accelerators and Applied Superconductivity) of the Milan division and the INFN Turin and Bologna divisons.

Elettra Sincrotrone Trieste contributes with various parts of the linear accelerator. One of the most important contributions concerns the supply of the 26 power stations that supply the 'spoke' cavities. It has also designed and is overseeing the construction of the magnets, more than 200 of different types, to guide and confine the protons along the desired trajectory in the superconductive linac and in the high-energy beam transport line. The implementation of the magnets will be accompanied by the supply of the related power converters. Elettra's contribution is completed with the design and construction of the acquisition systems, including the development of dedicated firmware and software for the 'wire scanner', a diagnostic element for measuring the characteristics of the proton beam.

CNR has started its research and development activity aimed at creating tools for spectroscopic techniques based on neutron-matter interaction: VESPA, T–REX and LOKI. These are analysis techniques that open new horizons in the exploration of advanced technological materials and processes in a very wide range of applications.

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What does contributing in kind mean to a large research infrastructure?

The collaboration with the partners involved has been excellent, especially with Elettra, which has a similar way of working to ours. A great deal of coordination was clearly needed, especially for tender management: it is not easy to coordinate two bureaucratic machines, but we have succeeded and this has allowed us to respect the project timing. And the collaboration with industry was also effective: since these were very specialised orders, the fact that often several companies joined forces to meet our requests was decisive. An initiative that proved to be very useful to encourage the participation of national companies was the Industry Day, promoted by the INFN ILO (International Liaison Office) in Bologna and followed by a specific workshop on ESS contracts, carried out at the LNS in Catania a month later, in July 2015. It is in fact strategic to develop a critical mass on projects that require significant investments over short periods, in order to create alliances that increase production capacity and reduce the risk, to the benefit of both companies and the Public Research Bodies. These temporary company groupings are, in fact, effective both for the supply of products and for job management. For example, they represent a guarantee for respecting execution times: if one industrial partner is lacking technical personnel, there is another company that can promptly step in. It is therefore an effective risk mitigation method.

Another important aspect is the partnership model with industry: we have worked with industry, we have not only assigned tasks. Our engineers participated in and followed individual production aspects. We could say that we worked in an industrial-like way: the production was clearly not mass production, but we tried to adapt good industrial practices to our case.

What does it mean to work in the high-tech components supply chain for large-scale basic research projects?

This is also an aspect that concerns both Public Research Bodies and industrial partner. Working at the frontier of technology forces you to do everything optimally. We had to adapt our know-how to the specific objectives of ESS. When we started the project in 2011, we were not able to build a source like the one that is now installed at the Lund site. And its implementation would not have been possible without the very flexible companies that have followed us step by step in the development of the project, sometimes renouncing profit margins, because they understood that earning a bit less today, while learning to implement something completely new, could have opened up important opportunities for future profits. It is a long-term investment: an intrinsic fact for us who are engaged in fundamental frontier research, but a company that has to make profit may not have or cannot afford this foresight.

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We know that the supply chain of cutting-edge technologies is an opportunity for the industrial world, we have already seen, in many cases, companies that have invested in working on prototypes subsequently acquiring other important orders. The construction of the LHC and its experiments at CERN is a lesson, and ESS is the second largest European project in the field of accelerators after LHC. We therefore expect an equally important impact in terms of generating value for our industrial ecosystem. ■