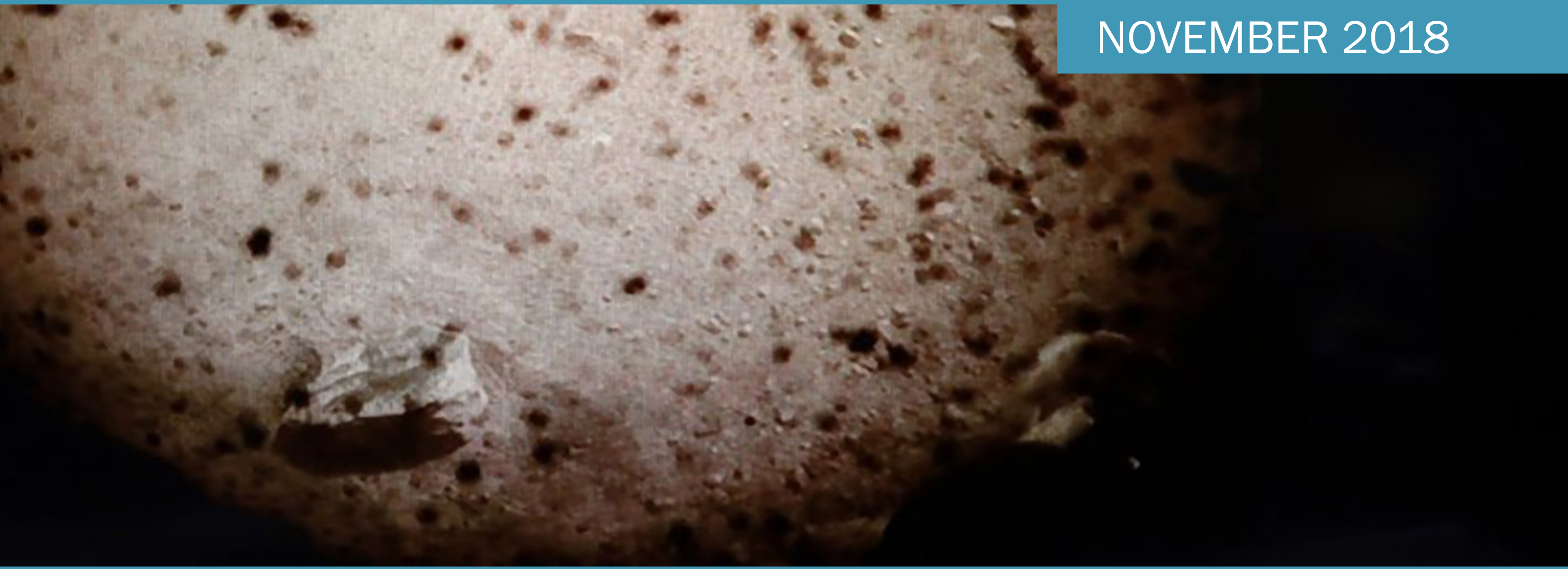

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Istituto Nazionale di Fisica Nucleare

INTERVIEW

NEWS

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» INTERVIEW

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

» INTERVIEW

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

» INTERVIEW

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.

» INTERVIEW

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.

» INTERVIEW

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.

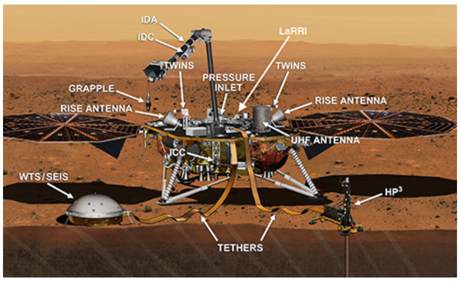
Another important aspect is the partnership model with industry: we have worked with industry, we have not only assigned tasks. Our engineers participated in and followed individual production aspects. We could say that we worked in an industrial-like way: the production was clearly not mass production,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

» INTERVIEW

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. ■



SPACE

THERE'S ALSO THE ITALIAN INSTRUMENTS LARRI ON MARS

On 26 November at 8:54 pm, the NASA lander Insight landed on Martian soil, taking a bit of Italy to the Red Planet. On board, in fact, there is LaRRI (Laser Retro-Reflector for Insight), a laser micro-reflector developed by the INFN Frascati National Laboratories with the support of the Italian Space Agency (ASI).

InSight (Interior exploration using Seismic Investigations, Geodesy and Heat Transport) is a mission that has the task of exploring the depths of Mars to understand how more than four billion years ago rocky planets, like the Earth, were formed. It was launched on 5 May last from the American base in Vandenberg (California) and will also measure the tectonic activity and the heat flow of the planet, as well as meteorite impacts. The Italian LaRRI instrument will provide the accurate position of the Insight lander during its exploration and will help to test Einstein's general relativity: it will be one of the first nodes of a future Martian network for geophysical and physical measurements, and will help to obtain a more accurate measurement of the 0 Meridian of Mars (a sort of "Mars Greenwich"). Designed by the SCF_Lab group of the INFN Frascati National Laboratories, within the scope of research addressed to the Moon and Mars, in joint activities with ASI-Matera, LaRRI weighs 25 g, has a diameter and a height of 54 and 19 mm respectively, and consists of laser micro-reflectors made of a material suitable for the space environment. It is also a passive instrument that does not need maintenance and will work in space for many decades.

In 2020, two more micro-reflectors are planned to be launched towards the red planet: one on board Mars 2020, the new-generation NASA Rover (called LaRA, Laser Retroreflector Array) and another on the Russian Landing Platform of the ESA ExoMars 2020 Rover mission (called INRRI, Instrument for landing-Roving laser retroreflector Investigations). ■

INFRASTRUCTURES

ELIMED: THE FUTURE OF HADRON THERAPY IS BEING TESTED IN PRAGUE

Treating tumours with accelerated particle (ion and proton) beams using non-conventional high-power lasers and plasma technology: this is the scientific and technological challenge that will test the ELIMAIA (ELI Multidisciplinary Applications of Laser-Ion Acceleration) infrastructure inaugurated on 27 November in Prague, along with its key component: ELIMED (ELI-Beamlines Medical and multidisciplinary applications), an experimental room that houses a beamline dedicated to the transport, selection and diagnostics of proton and ion beams, accelerated using high power lasers, which will be used for hadron therapy and radiobiological applications. The scientific objective is to verify the possibility of using protons produced by an unconventional laser source in the treatment of tumours. In fact, the Prague Centre will differ from current ones due to the production of particle beams that will be accelerated in plasma, rather than by particle accelerators, exploiting the interaction between laser and matter.

The implementation of ELIMED was made possible thanks to the experience acquired at the INFN Sothern National Laboratories, where since 2002 the first Italian proton therapy centre (CATANA) is active and thanks to the skills developed in medical physics and in particular in hadron therapy by INFN researchers. The collaboration between LNS and the Czech Academy of Sciences dates back more than a decade and has been strengthened through the ELI consortium and the implementation of the ELIMED line. In 2014, INFN won the public tender for the construction of the room, successfully completing the supply of one of the most technologically advanced points of the entire infrastructure.

ELIMAIA will be fully operational starting from 2019 when it will open the doors to the international scientific community for multidisciplinary experiments in the fields of biology, medicine, chemistry, materials science, engineering and archaeology. ■

OPEN ACCESS

PLAN S, FROM PRINCIPLES TO IMPLEMENTATION

After the launch of Plan S last September, now cOalition S published the guidance for its implementation by 2020. The guidance serves to clarify the Plan S provisions and describes implementation modalities. It also provides responses to questions and comments arising from online discussions and debates on Plan S.
Plan S is an initiative for Open Access publishing supported by cOAlition S, an international consortium of research funders, to which the INFN has signed up. Plan S requires that, from 2020, scientific publications that result from research funded by public grants must be published in compliant Open Access journals or platforms.
Plan S aims for a system of scholarly publications that is more transparent, efficient and fair. It also aims to foster a culture that ensures all scholars, and in particular early career researchers, have the opportunity to excel and advance their careers.
To achieve this, Plan S identifies three main paths to follow: publication in Open Access journals or platforms, deposit of Versions of Record (VoR) or Author Accepted Manuscript (AAM) in Open Access repositories without embargo, as *www.openaccessrepository.it*, and publication in 'hybrid' journals only under transformative agreements.
The guidance presented provides information and technical requirements on the three roads to Plan S compliance and gives indication of the policies that the cOALition S funders intend to put in place. cOAlition S welcomes feedback on the implementation guidance, in particular to identify specific areas of the Plan S implementation that require further clarification. ■

MULTIDISCIPLINARY REARCH

CHANGES DETECTED IN THE BEHAVIOUR OF THE GRAN SASSO AQUIFER IN CONJUNCTION WITH THE AMATRICE 2016 EARTHQUAKE

Research within the scope of the study of the interactions between the Gran Sasso aquifer of the and seismic phenomena - conducted by INGV, National Institute for Geophysics and Volcanology, in collaboration with the INFN Gran Sasso National Laboratories and the Department of Civil and Environmental Engineering, Building and Architecture (DICEAA) of the University of L'Aquila - has found changes in certain physical parameters of the underground waters of the Gran Sasso massif, in conjunction with the seismic event that struck Amatrice in August 2016.
The study, recently published in the Scientific Reports journal by Nature, is based on continuous high sampling measurements (20 measurements per second) of hydraulic pressure, temperature and electrical conductivity of the water, measurements taken, from May 2015, on a horizontal drilling, called S13, made in the late '80s during the excavation work, and located near the motorway tunnel and the Gran Sasso Laboratories. The presence of S13 provided a unique opportunity to investigate the deepest part of the Gran Sasso calcareous aquifer, located in the seismically active area of the central Apennines. The data acquired, starting from May 2015, showed clear and interesting signals before, during and after the earthquake that occurred on 24 August 2016 (01:36:32 UT) with epicentre approximately 39 km away from the study site. Within the scope of the measurements taken, the researchers therefore focused their analysis on data relating to anomalies in hydraulic pressure starting from 19 August 2016, five days before the event, finding large and asymmetrical fluctuations: negative micropulsations, which had not been detected in the previous data and which continued until the end of August 2016. Now, further exploration of the relationship between earthquakes and changes in groundwater parameters in the vicinity of large seismogenic faults is needed for a full understanding of pre-seismic, co-seismic and post-seismic processes. ■

COMPUTING

OPEN SCIENCE: GRANT AGREEMENT FOR ESCAPE SIGNED

It is called ESCAPE, European Science Cluster of Astronomy & Particle physics ESFRI research infrastructures: it is the project put in place to address the Open Science challenges shared by both the ESFRI (European Strategy Forum for Research Infrastructure) research infrastructures such as SKA, CTA, KM3NeT, EST, ELT, HL-LHC, FAIR, and other major European infrastructures, such as CERN, ESO, JIVE, operating in the fields of astrophysics, particle and astroparticle physics. The 16 million euros European funding agreement has just been signed and the project will start next February. ESCAPE, led by CNRS in consortium with 31 partners, including INFN with European funding of almost 900,000 euros, is one of five cluster projects that will collaborate on the implementation of the European Open Science Cloud (EOSC), an initiative for a European research computing cloud that allows universal access to data through a single online platform. The strategy chosen by the member states of the European Union, aware of the great challenge that research of excellence implies in the management of big data, is to federate resources in national centres and research infrastructures, so that both researchers and citizens can have access to and use scientific data, a quantity of data equal to many Exabytes (billions of Gigabytes).

INFN will contribute to the development of the future infrastructure by providing the knowledge and expertise in the field of distributed scientific computing, acquired from the projects for the creation of the European Grid and the WLCG computing network and the recent successes in being awarded EOSC implementation projects, such as INDIGO-DataCloud, eXtreme DataCloud and EOSChub. ■

AWARDS

RINALDO SANTONICO HAS WON THE APS DPF INSTRUMENTATION PRIZE

The American Physical Society (APS) has awarded the 2018 DPF (Division of Particles and Fields) Instrumentation Award to Rinaldo Santonico, Honorary Professor at the University of Rome Tor Vergata and researcher at INFN, for the development of Resistive Plate Chambers (RPC, fast single gas gap detectors) and their application in a wide variety of experiments, from LHC to cosmic ray physics.

Ever since the initial idea in 1981, Santonico and his group have continued to develop and improve this technology for over 30 years. The excellent temporal resolution, good spatial resolution, and a relatively low cost per unit area have made RPC detectors an interesting technology, both in high energy physics for muon tracking and in astroparticle physics for covering large areas for charged particle tracking. Through the definition of detailed procedures for the production of large quantities of RPCs and the transfer of this technology to industry, Rinaldo Santonico has allowed many other research teams to use them in a wide range of international applications, both in research and in industry. ■

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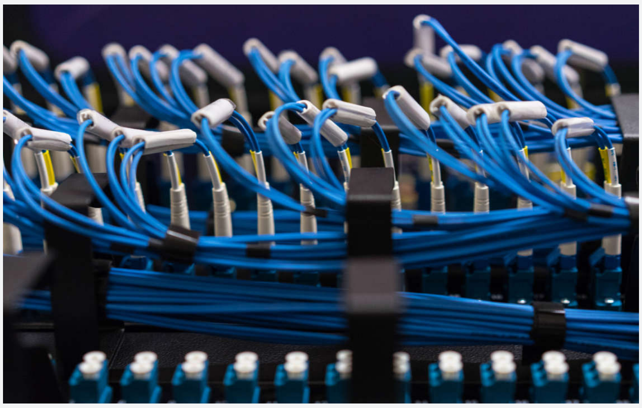

CNAF IS IN THE GLOBAL RESEARCH NETWORK AT 200 GBPS

With an unprecedented speed of 200 Gigabits per second (Gbps), CNAF, the INFN national computing centre, is the first site in Italy to have a connection to the global geographical network, thanks to the GARR research network. The link now allows CNAF to be interconnected with the entire global system of research networks, in particular with CERN in Geneva, where the enormous amount of data from the LHC accelerator is produced, and with the other national centres where the scientific data produced by the experiments is distributed and analysed. In the case of CERN, we are talking about a volume of data exchanged in 2018, to date, equal to 61 PBs, so much as to require a 200 Gbps link, i.e. a capacity over 200 thousand times higher than the average capacity - calculated on the basis of data from the DESI (Digital Economy and Society Index) Report 2018 - of an Internet connection in Italy.

The result is the crowning glory of a series of enhancement interventions which concerned, on the one hand, the national GARR network and, on the other, the availability of storage space and computing power by the INFN. The work on the GARR network has made it possible to create a backbone that currently reaches a total capacity of approximately 3 Tbps, thanks to the doubling of capacity in the connections of its main nodes located in the cities of Milan, Bologna and Rome, nodes that, alone, can now count on a total capacity of 800 Gbps. This was achieved by exploiting the results of the GARR experiment on "alien lambda". The technique is named so because it allows the transport of light signals on an optical platform different from the one that generated them and allows different devices to talk to each other, maximising performance. A technique that has allowed the capacity of the network to be increased in a short time, and with marginal costs, since it has not required the updating of all the equipment along the infrastructure.

At the same time, INFN has enhanced its overall computing and big data management capabilities by making available to its scientific users, in particular CERN's LHC experiments, more than 60,000 cores of

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computational power and approximately 150 PBs of experimental data storage capacity, divided between fast access systems (disks) and slow storage systems (tapes).
The 200 Gigabit per second link to the national scientific computing networks means that CNAF is now able to make full use of its computing and storage resources internationally, thus facilitating the development of high-performance distributed computing models on a global scale. A result that allows CNAF to be increasingly closely integrated with CERN and places it, in terms of connectivity, at the same level as the most important American scientific computing centres, such as Fermilab and the Brookhaven National Laboratory.
The synergy in terms of technological innovation between GARR and INFN does not end with this important result and has already moved to the next step, foreseeing for the near future the doubling of the international connection with CERN and the creation of the so-called "data lake", data storage distributed on a geographical scale where data can be "fished", regardless of the place where it will be processed. ■

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Cover
InSight's First Image from Mars. Credit: NASA/JPL-CalTech