Newsletter Interview

PRESENT AND FUTURE OF ENERGY FROM NUCLEAR FUSION AND INFN CONTRIBUTION TO RESEARCH IN THIS FIELD

Interview with Marco Ripani, researcher of the INFN Genoa Division, who has been working on energy-related topics for some years and is involved in the INFN-Energia strategic project

Having a clean and unlimited source of energy, by reproducing in the laboratory the same nuclear reactions that fuel the stars: this is the goal of scientific research on nuclear fusion, which has seen increasing global investments and initiatives in recent decades. This has given rise to ambitious international projects, such as ITER, which is expected to lead to the construction of a demonstrator for a fusion reactor in Europe by 2025. Another ambitious project is the one carried out in the United States, at the National Ignition Facility of the Lawrence Livermore National Laboratory in Berkley, California, which has just obtained an important result, unveiled last December 13 by the US Department of Energy (DoE), during a live streamed press conference, followed all over the world. The researchers of the Livermore Laboratories have succeeded in the enterprise of obtaining net energy from a nuclear fusion process, with the technique of inertial confinement using two isotopes of hydrogen, deuterium and tritium, as fuel. Unlike the system that ITER will use to ignite nuclear reactions, based on the heating of large volumes of confined plasma composed of deuterium and tritium by means of intense magnetic fields, the experiment conducted in the Livermore laboratory used powerful lasers to compress and heat a capsule containing the fuel to the point of triggering the fusion process which produced, in a very short time, more energy than that carried by the laser pulses themselves. A diversity of approach that demonstrates the great R&D work carried out on several fronts in this sector, to which INFN also contributes thanks to the skills and initiatives supported by the INFN-Energia strategic project, in which Marco Ripani, researcher of INFN Geova Division, participates.

What is the impact of the recent result obtained at the Lawrence Livermore National Laboratory? For many years, efforts have been made to achieve nuclear fusion in the laboratory. In recent years, the process has been obtained from various experiments, thanks to which, by resorting to external systems, it has been possible to produce the conditions necessary to trigger the reaction, which can take place in the presence of high density in very short times (inertial fusion) or of low density over longer times (magnetic confinement), in any case, reaching extremely high temperatures. However, before the experiment conducted in the Livermore laboratory, the fusion reactions obtained had never released more energy than that provided by the systems used to ignite them. The confirmation by the DoE of the net energy production by an inertial fusion process therefore represents a very important result, which however does not solve the many problems that will have to be overcome before obtaining truly usable fusion energy. Indeed, it is necessary to consider the total energy balance, which includes the energy consumed to operate the lasers and the energy derived from the process itself, which, moreover, must be transformed into electricity.

What are the differences between the fusion reaction trigger system used by the scientists at the Ignition Facility of the Livermore laboratory and the one that will be used by ITER?

The goal of every controlled fusion process - and therefore of all the systems used to induce the nuclear reaction - is to exceed certain values of the so-called "triple product", i.e. the product between the density of the plasma (the ionized gas composed of deuterium and tritium which plays the role of fuel in the fusion process), the typical time for the plasma to cool (known as the “energy confinement time” - usually very short), and the temperature. This is needed to obtain the ignition of a useful plasma, or even a plasma in which the fusion reactions are self-sustaining, a goal that is still very distant. In the case of magnetic confinement, the system which ITER will use, the triple product values to be achieved are obtained through low densities, long cooling times and high temperatures, reached by increasing the plasma temperature thanks to the injection of neutral atoms and radio frequency electromagnetic energy in very large plasma volumes. In inertial confinement, on the other hand, the aim is to achieve the ignition of the fusion reaction with very high densities, very short cooling times (infinitesimal fractions of a second), in very small volumes, always in the presence of high temperatures. In fact, the configuration of the experiments conducted in the Livermore laboratory involves the use of small capsules, called pellets, filled with fuel, which are compressed and heated thanks to the laser pulses, thus starting the fusion reaction. In this case the process is extremely rapid, as the pellet is destroyed when the energy produced by the reaction is released.

How does INFN contribute to nuclear fusion research activities?

INFN is not directly involved in the ITER project, which envisages the construction of a fusion reactor using the plasma magnetic confinement system by 2025. However, INFN is a member of the executive board of Fusion for Energy, the European agency promoting all the activities related to ITER, where, together with ENEA, it represents Italy. Furthermore, INFN is engaged in research and development work to support fusion, contributing to the development of facilities for testing the materials that will be used by ITER's successor, DEMO, which, reaching a higher power, will require components capable of withstanding an increased neutron bombardment. This is the goal of the IFMIF project, which envisages the construction of a facility equipped with an ion accelerator and a liquid metal source capable of producing a flux of neutrons with an intensity and an energy distribution similar to the one of the fusion machines. The work done so far under the project has led to the construction of a prototype accelerator, called EVEDA, installed in Japan, which will deliver the same ion current expected for IFMIF but with a lower energy. INFN provided the radiofrequency quadrupole, one of the main components of EVEDA. Under the umbrella of the activities promoted by Eurofusion, the European consortium headed by Euratom, and which coordinates the activities dedicated to nuclear fusion, INFN also participates in the R&D of the second accelerator foreseen in context of IFMIF, DONES, which will be installed near Granada, Spain. As far as ITER is concerned, INFN is finally involved as a member of the RFX consortium, based in Padua, in collaboration with which the Institute conducted a study on the sources for the neutral atom injectors used to heat the plasma. RFX plays an important role in the implementation of ITER, hosting the construction and testing of the reactor injectors, which involves two distinct devices: the SPIDER source, which is currently being commissioned, and the MITICA injector, a replica of the devices that will be installed in ITER, currently underway. Last but not least, I want to mention that INFN Commission 5, which is in charge of coordinating activities related to research and technology transfer, has recently approved the FUSION project, which will see precisely the development of innovative techniques to support inertial fusion, in collaboration with ENEA and various universities.

As for DEMO, the successor of ITER, INFN is involved in another Italian-led project which involves the construction of a demonstrator, the Divertor Tokamak Test (DTT) in the ENEA laboratories in Frascati. What will be the INFN contribution?

INFN is a member of the Italian company responsible for the creation of DTT. DTT’s objective will be to study the behavior of the divertor, which can be defined as the “exhaust pipe” of the fusion reactors, because it absorbs excess heat from the plasma. INFN participates with various Divisions and National Laboratories in various activities, including the development of the acceleration part of the neutral atom injector, one of the plasma heating systems, a very important component for which we are responsible, and in which we are also applying the innovative technique of additive manufacturing (also known as 3D printing). The Institute also collaborates in the creation of radiofrequency systems, elements that are also crucial for obtaining the temperatures necessary to trigger fusion in the plasma, and in the development of some diagnostics, systems used to verify the physical behavior of the plasma. For radio frequencies and diagnostics, we benefit from the great experience developed in experiments such as PANDORA, which aims to study nuclear reactions in plasma.

INFN activities on nuclear fusion are also supported by INFN-Energia. What does this line of research deal with and what are its aims?

Conceived by Roberto Petronzio and born under his presidency, INFN-Energia is part of the Institute's special projects. An initiative considered of strategic interest for the INFN's potential in the field of problems related to nuclear energy. Although it does not possess specific skills in the field of fission or fusion engineering, INFN can certainly make its technological capabilities available developing and building diagnostic systems, detectors, beam sources and accelerators. The primary objective of INFN-Energia is therefore to develop and support activities in nuclear energy sector, from fusion to fission, to radioactive waste management and radiation monitoring.