

# RESEARCH NETWORKS HELP THE LARGE HADRON COLLIDER (LHC) UNLOCK THE MYSTERIES OF THE UNIVERSE



RedIRIS transports massive amounts of LHC data, the biggest and most complex research project in history

## The LHC, the largest instrument in the world for studying the origin of the Universe

The Large Hadron Collider (LHC) is considered the largest and most complex scientific research project in history. It is a powerful particle accelerator and collider located at CERN (the European Organisation for Nuclear Research) on the Swiss-French border.

Nearly 10,000 physicists from around the world carry out experiments using the data produced by the LHC to learn about the origin of the universe: What is the origin of the mass of basic particles? How does the mass generation mechanism contribute to the expansion of the universe starting with the Big Bang? What is matter made of (we only know 5%)? What is dark matter? The first major discovery of the LHC was in 2012 when a new particle that matched the Higgs boson was identified; physical evidence corroborating the theory formulated in 1964 by Peter Higgs, François Englert and Robert Brout (+2011) on the origin of mass. The discovery earned Higgs and Englert the Nobel Prize in Physics and the Prince of Asturias honour (the latter together with CERN).

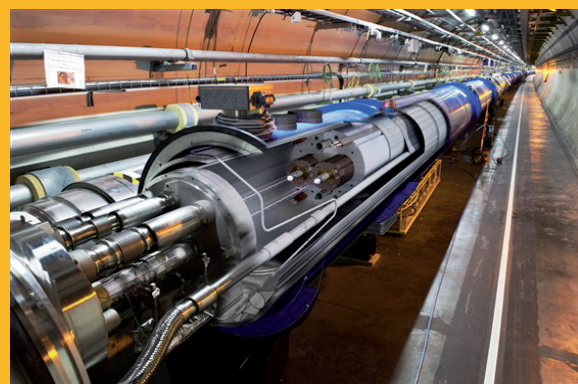
## A colossal engineering project to be used for research

The LHC is a huge project of innovative engineering that uses a circular 100-metre-deep tunnel with a circumference of 27 km. Over 2,000 physicists and engineers from 34 countries participated in its development, as well as hundreds of universities and laboratories. Its construction took about 15 years and it began operating in 2010.

Hadron beams circulate in the tunnel, each of which contains approximately 300 billion particles accelerated to almost the speed of light, thanks to the magnetic fields of 1600 superconducting magnets. This activity can generate up to 600 million collisions between particles per second.

## Billions of pieces of data generated

LHC collisions produce some 15 million gigabytes per year. Although only 1% of the data is selected, more than 25 petabytes/year are obtained, an unmanageable amount for traditional systems. CERN solved this problem by creating a distributed system, the Worldwide LHC Computing Grid (WLCG), which allows 170 centres in 36 countries to be connected to CERN via exclusive circuits implemented in academic networks, such as RedIRIS. The system processes 1.5 million daily tasks. If they were to be performed by a single computer, it would take over 600 years to complete them.



The Large Hadron Collider (LHC)

→ *"The role of RedIRIS is essential for the Galician research community to participate in such an ambitious project like the LHC, which demands top-level technology resources. RedIRIS provides us with the possibility of accessing the experiment under the same conditions as the most advanced centres in the world".*

Javier García Tobío, Director of the Supercomputing Centre of Galicia (CESGA)

→ *"The LHC experiments are essential to better understand the world around us. Given the range of generated results, the global collaboration among researchers is fundamental for their analysis. perfSONAR MDM, which combines ease of use with powerful capabilities, is essential in supporting our work as part of the LHC community".*

Josep Flix, Head of Tier1 at the Port d'Informació Científica (PIC)

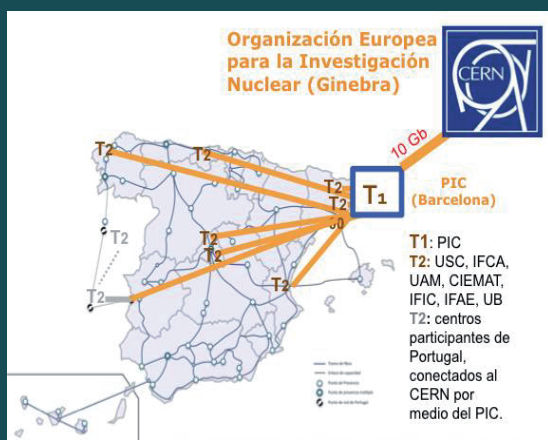
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A powerful network of centres connected to process all of the generated information

Analysis of these data requires a truly global collaboration, for which the pan-European scientific and academic network GÉANT and its national partners (NRENs), including RedIRIS, created the Large Hadron



Spain has seven Tier2 centres interconnected by RedIRIS: The University of Santiago de Compostela (USC), the Physics Institute of Cantabria (IFCA), the Autonomia University of Madrid (UAM), the Institute of Corpuscular Physics CSIC/UV (IFIC), the Institute of High Energy Physics (IFAE), The University of Barcelona (UB) and the Energy, Environment and Technology Research Centre (CIEMAT). Furthermore, the participating Portuguese centres are connected to CERN through PIC, thanks to RedIRIS and the Portuguese academic and research network (FCCN-FCT).



Spanish and Portuguese Tier Centres, connected to CERN through RedIRIS

Collider Optical Private Network (LHC OPN). Its aim is to support a distributed model based on four data storage and processing levels (Tiers).

In this model, the data generated by CERN (Tier0) are transmitted to 13 Tier1 centres, where they are refined and distributed to about 150 Tier2 centres (universities and other scientific institutions) and are then finally transferred to thousands of Tier3 terminals used by researchers.

Spain is one of the countries contributing at the highest level to the LHC as it has one of the thirteen Tier1 centres, the leading centre Port d'Informació Científica (PIC), maintained through the collaboration of IFAE and CIEMAT. Since its inception in 2003, the PIC processes and stores data from the LHC and distributes it to Tier2 centres in seven Spanish research institutions. In order for this to work, network infrastructures and the perfSONAR tool, provided by RedIRIS, are essential.

WLCG, through its participating centres, has collaborated on distributed processing projects such as the EGI (European Grid Initiative) and OSG (Open Science Grid in the US). In turn, these projects provide services that help manage WLCG using RedIRIS services. Such is the case of CESGA (Supercomputing Centre of Galicia), which develops software for high-level resource computing made available to the WLCG.

### Monitoring the performance of the LHC communications network

Several national academic and research networks, including RedIRIS, worked on the creation of the perfSONAR MDM (multidomain monitoring services) tool. RedIRIS, working closely with the PIC (Tier1) and two Tier2 centres (CIEMAT and IFAE), were pioneers in their implementation at a European level. perfSONAR MDM allows engineers to easily access all the information from the networks through just one screen. Its purpose is to transparently monitor, supervise and optimise data quality protocols from start to finish.