

Viewpoint

The HL-LHC: a bright vision

Pushing the boundaries of current technology to extend the discovery potential of the LHC.

CERN



The High-Luminosity LHC project was under the spotlight during the 2015 International Year of Light.

By Lucio Rossi

The LHC is one of the world's largest and most complex scientific instruments. Its design and construction required more than 20 years of hard work and the unique expertise of a number of experts. Following on from the discovery of the Higgs boson in 2012, the machine continues to run at unprecedented energy to give physicists access to phenomena that have so far remained out of reach.

The full exploitation of the LHC and its high-luminosity upgrade programme, the High Luminosity LHC (HL-LHC), have been identified as one of Europe's highest priorities for the next decade in the European Strategy for Particle Physics (CERN Courier July/August 2013 p9) adopted by CERN Council in the special session held in Brussels on 30 May 2013. The HL-LHC was also recently selected as one of the 29 landmark projects of the European Strategy Forum on Research Infrastructures (ESFRI) 2016 Roadmap.

Although it concerns only about 5% of the current machine, the HL-LHC is a major upgrade programme requiring a number of key innovative technologies, each one an exceptional technological challenge that involves several institutes around the world.

At the heart of the new configuration are the powerful magnets – both dipoles and quadrupoles – that will have to operate at unprecedented field values: 11 and 12 T, respectively. In particular, the quadrupoles, also called “inner triplets”, which will be installed on both sides of the collision points, are crucial components to obtain the designed leap in the integrated luminosity: from the 300 fb^{-1} of the LHC by the end of its initial run to the 3000 fb^{-1} of the HL-LHC. Their aperture will be more than double that of the current triplets – a requirement that would scare many magnet experts, because the stored energy goes with the square of the magnetic field and the magnet aperture.

The overall increase of luminosity cannot be reached without revolutionising the superconducting technologies currently used in particle accelerators. The new magnets rely on niobium-tin (Nb_3Sn) superconducting cables, instead of the LHC's niobium-titanium alloy. The first model, with full-size cross-section and shorter length than the actual magnet (1 m long compared with the final 4.2 or 7 m), has just proven that the technology works well, even beyond expectation. Similarly good results were reached in January by the experts dealing with the 11 T dipoles that will house the new collimation system for the Dispersion Suppressor, which is being entirely redesigned (see p31 in this issue).

Another key element of the new machine is the crab cavities. Unlike standard radiofrequency cavities, crab cavities produce a rotation of the beam by providing a transverse deflection of the bunches. This is used to increase the luminosity at the collision points and to reduce the beam–beam parasitic effects that limit the collision efficiency of the accelerator. The crab-cavity concept was explored by the KEKB machine, but it will be implemented for the first time at the HL-LHC for a proton collider.

The current operation of the LHC is often disrupted by the machine powering system breaking down. This also happens because of high levels of radiation caused by the high-energy and high-intensity circulating beams. With even higher luminosity, this problem could prevent the accelerator from performing reliably. New magnesium-diboride-based (MgB_2) superconducting cables capable of transporting electrical currents of 20 to 100 kA have already proven their capability for such large current transport, at a convenient 20 K temperature. In this way, it will be possible to move the power converters from the LHC tunnel to a new service gallery, thereby facilitating technical and maintenance operations and reducing the radiation dose to personnel.

All in all, more than 1.2 km of the current ring will need to be replaced with new components. Using cutting-edge technologies, it will be possible for scientists to significantly extend the discovery potential of the LHC (e.g. providing about a 30% higher mass reach for new particles) without replacing the full ring. This is also a challenge for the experiments, which will have to upgrade their inner detectors and other components to face the higher collision rate (CERN Courier January/February 2016 p26).

Based on innovative technological solutions, the HL-LHC will also allow physicists to study in depth the properties of the Higgs boson and any possible new particles that the LHC may discover in future runs. In addition, it will play a decisive role in the future of experimental particle physics because it is the ideal test bed for both technology demonstration and for the design of future accelerators beyond the LHC.

The promising results obtained so far have been possible thanks to the collaborative effort of several institutes in Europe and around the world. It is indeed amazing to realise that since its inception, the HL-LHC has brought together more than 250 scientists from 25 countries. This is confirmation that, today, no big scientific endeavour, however bright and smart it might be, can actually be pursued without the contribution of the whole community.



Since 2010, Lucio Rossi has been head of the High-Luminosity Project at CERN.

Rossi joined CERN in 2001, and led the Magnet, Superconductor and Cryostat Group for the LHC Project until 2011. In 2007, he received the IEEE Council of Superconductivity Award for sustained contributions to applied superconductivity. He has authored more than 150 publications in international journals and reviews.

Subnanometre positioning in a vacuum

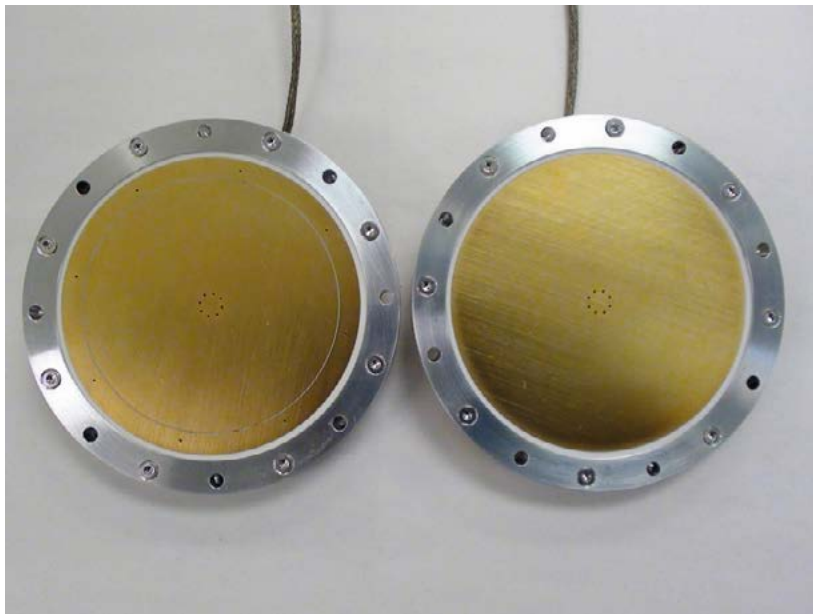
Queensgate Instruments, an Elektron Technology brand, specialize in creating nanopositioning and sensing solutions for high-tech industries, with variants for precision measurement in vacuum, radiation and cryogenic environments. The company was founded in 1978 as a spin-off from Imperial College, London, and pioneered the use of capacitive metrology for nanopositioning. With deep roots in academia, Queensgate has stayed firmly involved in cutting-edge research and development, and has a range of market-leading products.

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Our standard range of capacitive sensors, the NX series, are metal plate sensors. The standard models are constructed in aluminium, with the option of Super Invar for superior thermal stability. They are available in a variety of shapes and sizes to suit the application.



Image: NX capacitive sensor.



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