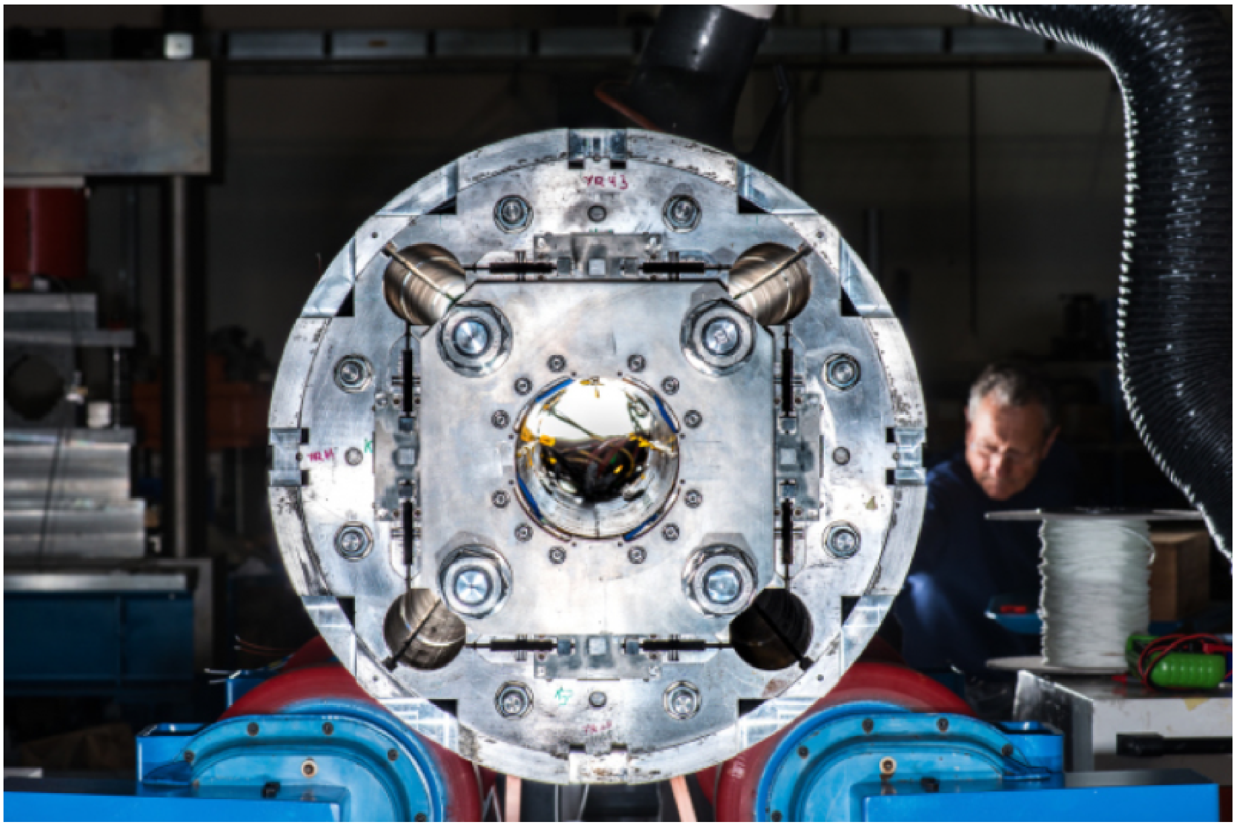
The crown jewel of the HL-LHC magnets

June 26 2017, by Stefania Pandolfi



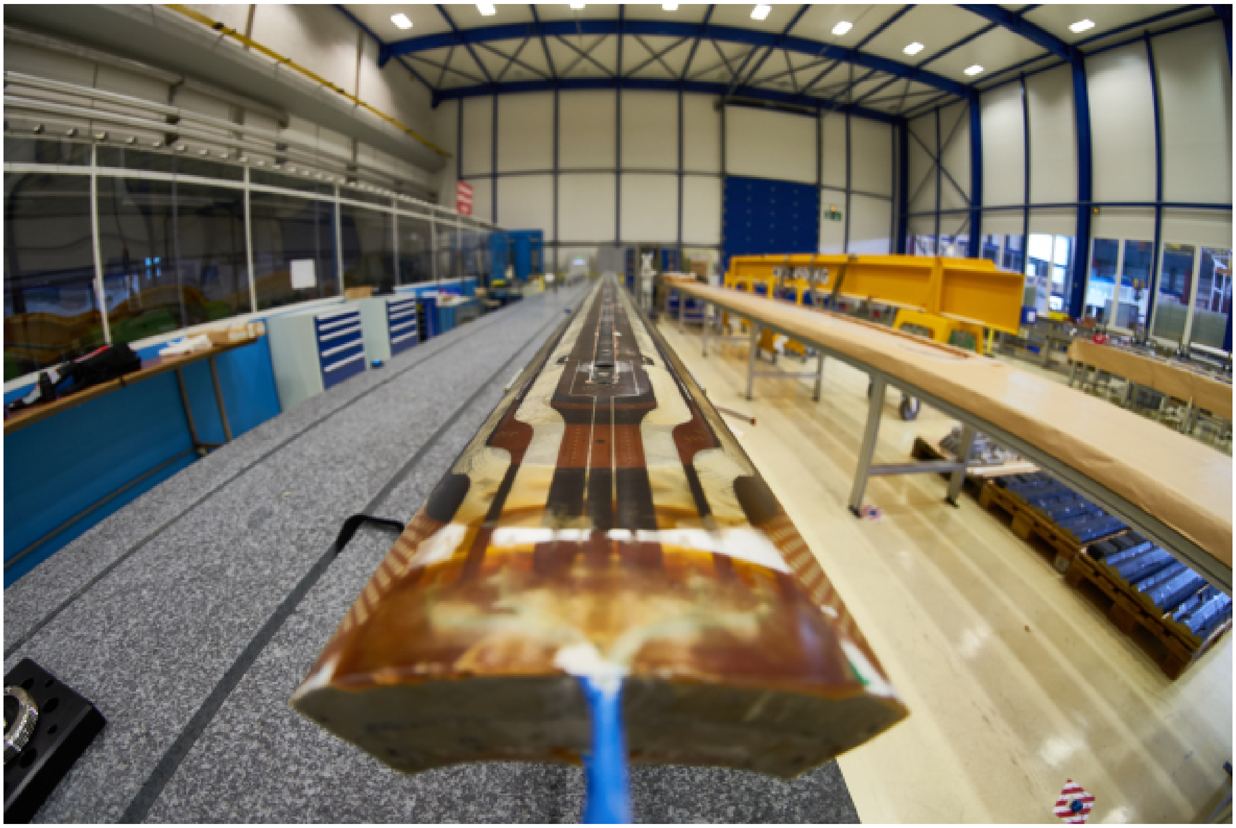
View of the cross-section of a short-model magnet for the High Luminosity LHC quadrupole, with three coils manufactured at CERN and one coil made in the US. Credit: Robert Hradil, Monika Majer/ProStudio22.ch

While the LHC is at the start of a new season of data taking, scientists and engineers around the world are working hard to develop brand new magnets for the LHC upgrade, the High-Luminosity LHC (HL-LHC).

Indeed, for this upgrade, more than one kilometer of the LHC machine needs to be replaced. Installation will start in 2024, and there will be about 100 magnets of 11 new types: four types of main magnets (dipole and quadrupole magnets which bend and focus the beams), and seven different types of correcting magnets.

In particular, the new main quadrupole magnets, that will sit in the insertion regions on either side of the ATLAS and CMS detectors, exploit a key innovative technology providing fields beyond 10 Tesla. They are built from niobium-tin (Nb3Sn), using a unique design that allows the peak magnetic field strength to be increased by around 50% compared with the current LHC dipoles, bringing it from about eight to about 12 tesla (T). They will squeeze the beams before collisions, replacing the quadrupoles in the LHC's triplets. These magnets will contribute to increasing the HL-LHC integrated luminosity – the total number of collisions – up to a factor of 10 beyond the LHC's design value.

The new quadrupole magnets are being developed in the framework of a collaboration between CERN and the LHC-AUP (LHC Accelerator Upgrade Project) consortium, which involves three US laboratories. Two types of these new quadrupole magnets of two different lengths (4.5 metres in US and 7.5 metres at CERN) are being developed.



The new 7.15-metre-long coils for the Nb3Sn quadrupoles for HL-LHC, in the Large Magnet Facility building. Credit: M. Brice/CERN

Now the design phase has been completed, the main magnets are in the prototype phase. Given the high cost of the magnets' materials, tests are done on shorter models (1.5 metres) to assess the stability of the design and the mechanical structure. One of the main issues of the Nb3Sn magnets is the management of the thermal contractions, because the materials that make up the magnet have to undergo harsh changes, from being heated to 650 °C to make the superconductor, and then cooled-down to cryogenic temperatures – needed by the magnets to work in a superconducting state.

Last year, a 1.5 metre-long short model quadrupole, made of two coils from the LARP (LHC Accelerator Research Program) consortium and two from CERN, was tested in the United States, reaching a peak magnetic field of 13 T. Another short model, with three coils made at CERN and one in the US, was also tested at CERN later in the year, to verify the performance reproducibility. It reached a peak field of 12.2 T, above nominal magnetic field, but a few tenths of a tesla below the target of ultimate performance. Another iteration of the assembly will be done in the second part of the year. A third short model of the triplets on either side of ATLAS and CMS, and the first one with a homogeneous set of coils, will soon be tested at CERN. It will be an important test to validate many features of the quadrupole design.

In January 2017, a full-length 4.5 metre-long coil – a world-record-breaking length, for a Nb3Sn magnet in an accelerator – has been tested at the US Brookhaven National Laboratory and reached the nominal field value of 13.4 T.

Meanwhile at CERN, the winding of 7.15-metre-long coils already started in the Large Magnet Facility building. "Scaling from one to seven metres is absolutely not a trivial task, and it is one of the main technological challenges of this project," says Ezio Todesco, a physicist in the SC Magnet Design and Technology section, in the Magnets, Superconductors and Cryostats group of the Technology department, who is leading the work for the HL-LHC project dealing with magnets for the insertion regions. "Between the end of this year and the end of next year, we will test the first full length prototypes. We will have then the confirmation that they perform as expected, and see whether some design iteration is needed," he adds.

Provided by CERN