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FROM THE SYNERGY BETWEEN RESEARCH AND INDUSTRY: THE NEW SUPERCONDUCTIVE DIPOLES FOR HL-LHC

The High Luminosity LHC (HL-LHC) project is aimed at upgrading the LHC accelerator, the most powerful particle accelerator in the world, for a further improvement in its performance from 2026 onwards. With this goal, HL-LHC is exploring new configurations and advanced technologies in the fields of superconductivity, cryogenics, radiation shielding materials, electronics and remote handling. Launched in 2011 as a design studio under the European Commission's Seventh Framework Program (FP7), HL-LHC will be installed in the LHC tunnel during the Long Shutdown 3 (LS3), happening between 2025 and 2027, though installation of a few component of HL-LHC have been anticipated in Long Shutdown 2 (LS2), between 2019 and 2021. At the moment, CERN and INFN are collaborating for the procurement of models, prototypes and magnets, intensifying relations with companies that have built fundamental parts of the detectors and the accelerator itself. Among these, great part of the superconducting coils of the two magnets that are at the heart of the two ATLAS and CMS detectors, as well as a third around (450 magnets) of the superconducting dipoles of the LHC, were realized by the company ASG Superconductors of Genoa. Currently installed in a 27 km circumference tunnel, about 100 m deep underground, LHC accelerates and makes beams of protons collide, but also heavier ions up to lead, thanks to a design based on superconducting magnets cooled with superfluid helium at a temperature of -271 °C (about two degrees above absolute zero). In addition to the technological upgrade, HL-LHC will require a new technical structure including the construction of a cavern and an additional 300 m long gallery, along the region of insertion of the collision points 1 (where the ATLAS experiment is installed) and 5 (where the CMS experiment in installed). In its final configuration, HL-LHC will result in an increase in peak luminositys by a factor of five over the LHC's nominal value and will therefore be able to achieve an integrated luminosity level that is nearly ten times higher than that of LHC. To cope with the high intensity beam emitting in these extreme conditions, several magnets currently in use will need to be replaced. Among these, the superconducting dipoles that recombine the particles of the two proton beams around the interaction regions (D2 magnets), a type of magnets whose role is fundamental for achieving

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the performance expected from HL-LHC. The magnet design was developed by the INFN Genoa division in a collaboration framework with CERN. Then in 2019 ASG was awarded to build the D2 short dipole model (MBRDS1 - Main Bending Recombination Dipole Short Model 1) which was successfully tested at CERN in 2020, confirming the required performance at a temperature of -271 °C. More recently, in October 2021, the prototype full-scale magnet (MBRDP1 - Main Bending Recombination Dipole Prototype 1) was completed and delivered to CERN and the construction phase of six series of magnets was started, the realization of which was awarded to ASG in 2020. The MBRDP1 magnet is a double aperture magnet (each 105 mm in diameter), 8 meters long, which generates an integrated dipolar magnetic field of 35 T-m (Tesla x meter) in both apertures. with the same polarity. The magnet contains all components cooled by superfluid helium. Each dipole consists of the so-called active part, consisting of two coils with 105 mm diameter openings, contained in a mechanical structure of stainless steel collars, and an aluminum sleeve and an outer magnetic steel structure (the iron yoke). The mass of the dipole has an almost elliptical cross section with an overall length of 8,010 mm, a maximum diameter of 614 mm and an overall weight of 14.2 tons.

This milestone is a further step towards the realization of the Hi-Lumi LHC project at CERN, while the new magnets are a testimony of the fruitful relationship between the world of research and highly specialized industry, a collaboration that has already contributed to the achievement, in 2012, of an epoch-making milestone such as the discovery of the Higgs boson. ■