The Large Hadron Collider (LHC) at CERN accelerates and collides beams of particles of various masses from single protons up to lead nucleii. It is installed in a 27 km circumference tunnel, about 100 m underground.

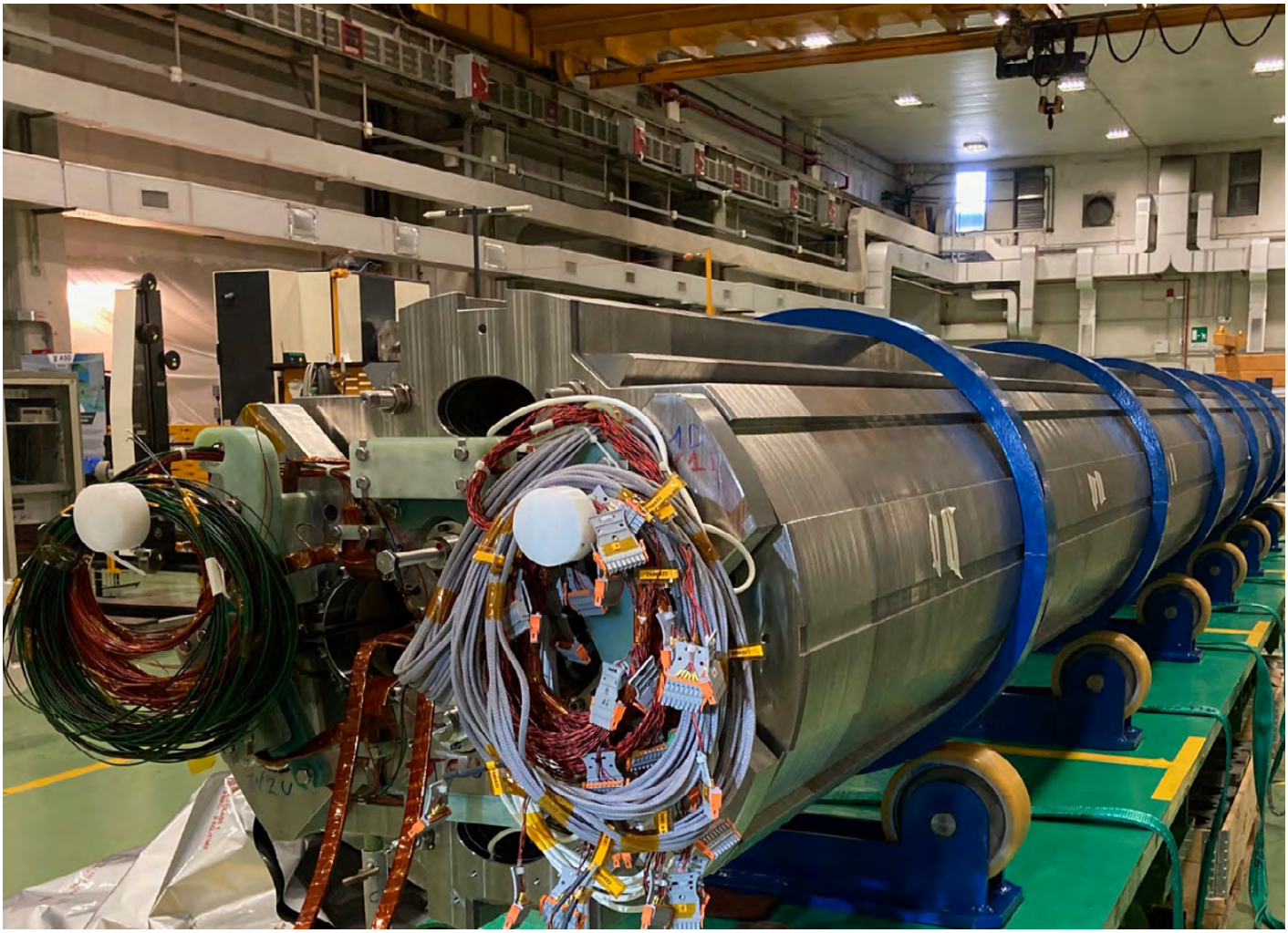
The High Luminosity LHC (HL-LHC) is exploring new beam configurations and the use of new advanced technologies in the domain of superconductivity.

In the HL-LHC an important role is played by the dipoles recombining and separating the particle of the two proton beams around the interaction regions.

ASG Superconductors is involved with INFN in the design and construction from the beginning of the project.

HI-LUMI: THE SUPERCONDUCTING D2 DIPOLE PROTOTYPE

Nicolò Valle



The High Luminosity LHC (HL-LHC) is a project aiming to upgrade the LHC collider after 2026 in order to maintain scientific progress and exploit its full capacity. The LHC is the most recent and powerful accelerator constructed on the CERN site. The LHC machine accelerates and collides proton beams but also heavier ions up to lead. It is installed in a 27 km circumference tunnel, about 100m underground. The LHC design is based on superconductive twin-aperture magnets which operate in superfluid helium at 1.9K (-271°C). By increasing its peak luminosity by a factor of five over the nominal value, it will be able to reach a higher level of integrated luminosity, nearly ten times the initial LHC design target. To this aim, HL-LHC is exploring new beam configurations and new advanced technologies in the domains of superconductivity, cryogenics, radiation hard materials, electronics and remote handling.

The project also requires a new technical structure with a cavern and a 300m long tunnel along the insertion region of IP1 (ATLAS) and IP5 (CMS). The cold-masses of these two magnets (ATLAS and CMS) have been realized by ASG Superconductors in Genoa as well as 450 (one third) of the LHC cold masses. The project began in 2011 as the European Commission FP7 Design study called “HiLumi LHC” and the main installation in the LHC tunnel will take place during the Long Shutdown 3 (LS3) in 2024-2026.

CERN and INFN (Italian Institute for Nuclear Physics) are developing a collaboration activity for HL-LHC for the procurement of models, prototypes and magnets. In the frame of the first Contract, ASG realized the MBRDP1 Short Model during 2019 that has been successfully tested at 1,9K at the CERN Lab during 2020. At present (October 2021) the Prototype Full Scale Magnet has been completed and delivered to CERN and the construction phase of six series magnets awarded to ASG in 2020 has been started.

Figure 1 (cover) MBRDP1 – Prototype.

The Magnet

In the HL-LHC an important role is played by the dipoles recombining and separating the particles of the two proton beams around the interaction regions. In particular the MBRDP1 realized by ASG is an 8 meters long twin aperture (Φ 105 mm) magnet with a separation between apertures at 1,9K of 188 mm, generating in both apertures an integrated magnetic dipolar field of 35 Tm with the same polarity. The cross-section of the dipole, which contains all the components cooled by superfluid helium, is shown below. Each dipole consists of the so-called active part, made of two coils with 105 mm diameter apertures in a mechanical structure of stainless steel collars and an aluminium sleeve, with an outer magnetic steel structure (the iron yoke). The dipole cold mass has a quasi-elliptic cross section with an overall length of 8010 mm, a maximum diameter of 614 mm and an overall weight of 14,2 tons.

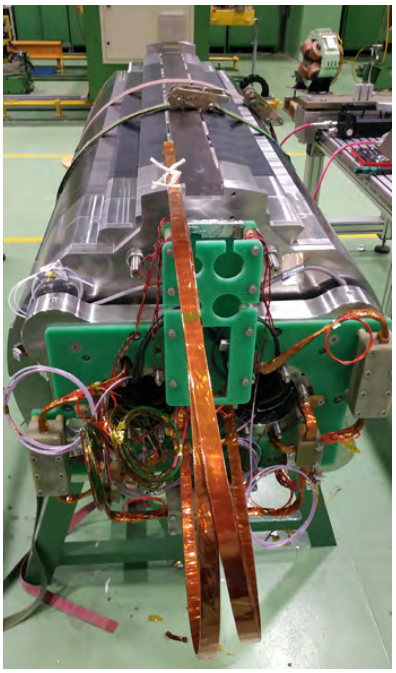


Figure 2 MBRDP1 – Short Model.

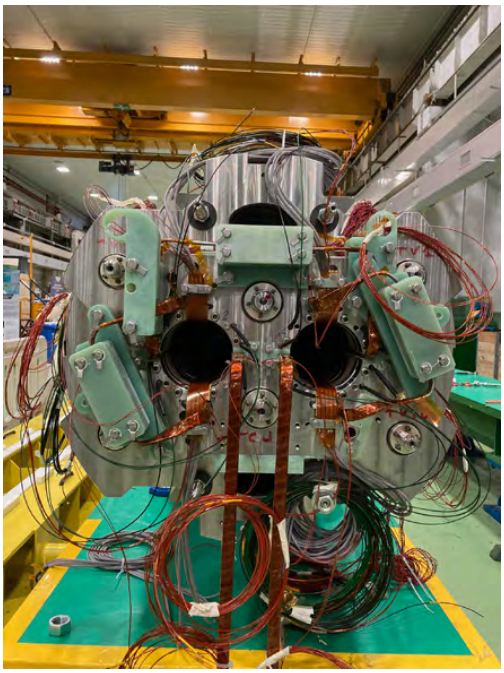


Figure 3 MBRDP1 – Detail of the LC Side Head.

Here below are reported the MBRDP1 – Prototype main parameters:

MBRDP1 Prototype Main Parameters	Unit	Value
Aperture diameter	mm	105
Number of apertures per magnet	No.	2
Distance between the two apertures (cold/warm)	mm	188,0/188,7
Cold mass outer diameter (min/max of the iron yoke)	mm	550/614
Coil Length	mm	8010
Magnetic length	mm	7778
Bore Field	T	4,5
Peak Field	T	5,2
Operating Current	kA	12,340
Operating Temperature	K	1,9
Overall current density	A/mm2	478
Stored Energy	MJ	220
Superconductor Type	-	NbTi Rutherford
Strand Diameter	mm	0,825
Number of strands per cable	No.	36
Coil Turns	No.	31
Cold-mass overall weight	Tons	14,2

Figure 4 D2 dipole ready for shipment in ASG premises.

For High Luminosity LHC, the future configuration of the Large Hadron Collider at CERN several new magnets are needed to have the proper acceptance to cope with the high intensity beams emittances.
The recombination dipoles (D2) are one of the magnet that will be replaced. ASG is involved with INFN in the design and construction from the beginning of the project.

Many thanks to INFN and all our colleagues at ASG for this important achievement. This milestone is a further step towards the accomplishment of CERN's HI-Lumi LHC project, whereas our magnets are a testimony to the ASG's legacy of partnership and service to the needs of the research Institutions. A legacy that has proven conducive, in the past, to have contributed to reaching important scientific goals, like – for example – the discovery of the Higgs Boson in 2012.