HE-LHC magnets transport & installation

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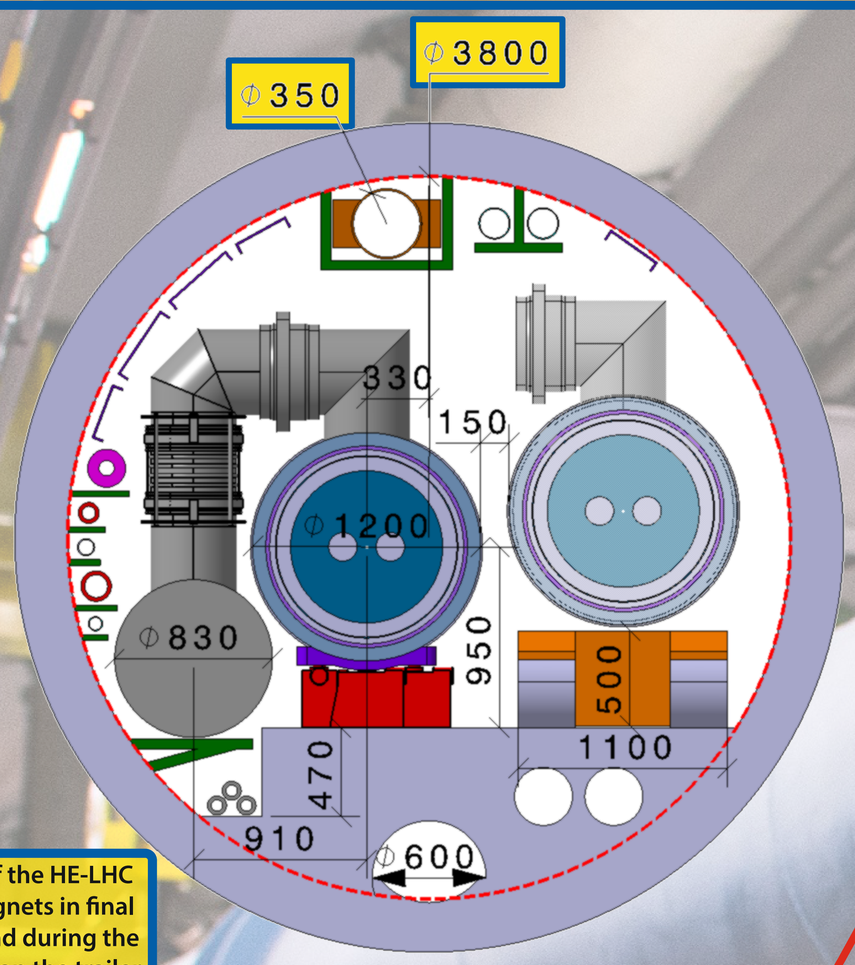
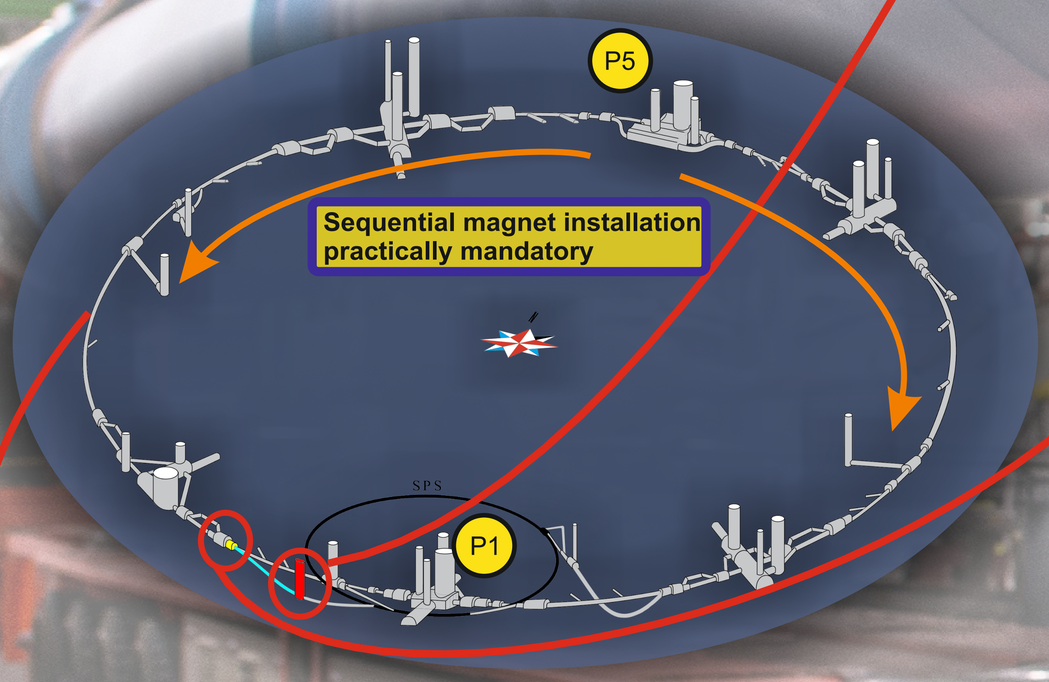
Introduction

The High-Energy Large Hadron Collider is a future energy upgrade of the LHC. It shall provide proton-proton collisions at an energy of about 27 TeV in the centre of mass. The integrated luminosity of the HE-LHC over about 20 years of operation should exceed 10 ab−1. The target energy requires FCC dipole magnets with a field of 16 Tesla. The HE-LHC also incorporates novel elements from the HL-LHC, such as crab cavities and low-impedance collimators. The HE-LHC could accommodate two high-luminosity interaction-points (IPs) 1 and 5, at the locations of the present ATLAS and CMS experiments [1].

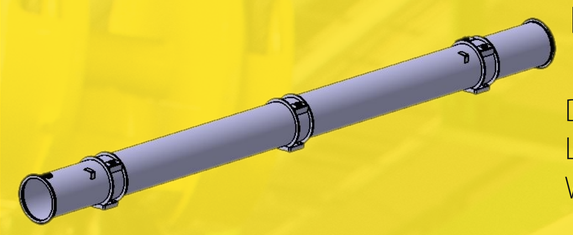


Cross-section of the HE-LHC tunnel with magnets in final position (left) and during the transport (right) on the trailer.



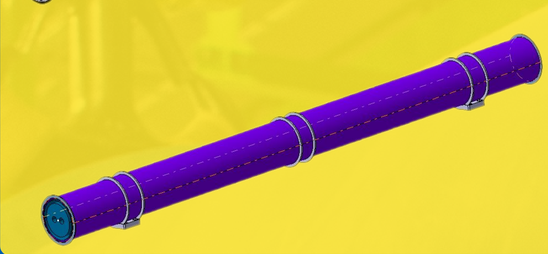
Magnets

The HE-LHC magnets must fit into the existing LHC tunnel with a diameter of 3.8 m. Therefore, they need to be compact, with a maximum outer diameter of 1.2 m. In addition, half-sector cooling is proposed to reduce the diameter of the cryogenics lines [1].



HE-LHC Magnet

Diameter: **1200 mm**
Lenght: 15 m
Weight: **60 t**



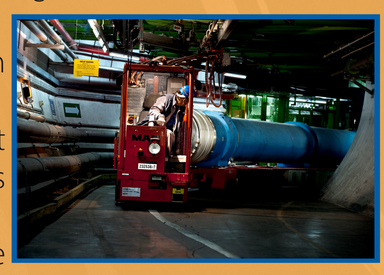
LHC Magnet

Diameter: **1055 mm**
Lenght: 15 m
Weight: **35 t**

Transport from surface to underground via PMI2 - TI2

The HE-LHC cryo-magnets will be lowered horizontally via a access shaft PMI2 and transported through a 1.9 km long transfer tunnel (TI2) to the 27 km long LHC ring tunnel.
The biggest challanges during the installation:

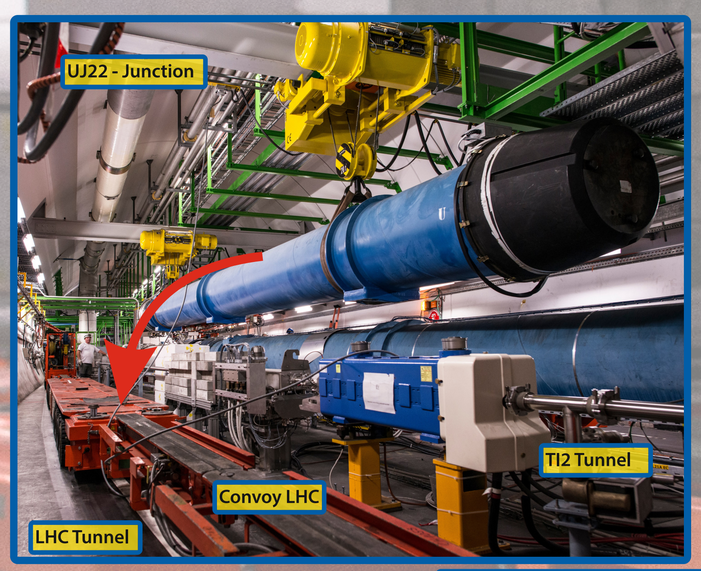
- **narrow** passages in the tunnels (close distance to the beam line in case of transport failure),
- **slopes** in the tunnel (the biggest in Ti2 tunnel - **up to 2.6 %**) - it is taken into consideration during the design phase of tractors and the trailer (new equipment needs to be developed),
- structural design of an attachment for the lifting unit on the ceiling of the tunnel:
  - **tight time constraints** between production, availability of the magnets and installation sequence,
  - **reversibility of the installation** sequence (in case of a defective magnet replacement),
  - PMI2 overhead **crane capacity** - currently 40 t (need for 70 t).



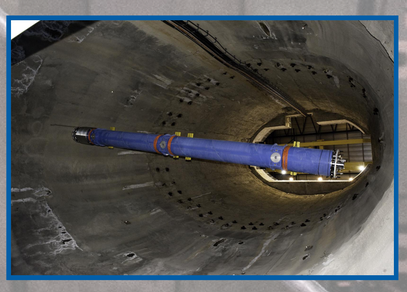
Transfer in UJ22

There are two scenarios during UJ22 to LHC transfer:

- installation of the new magnets - convoy transfer between the two tunnels on the ground (no obstacles),
- maintenance after the HE-LHC is fully assembled (e.g. exchange of the magnets) - need to transfer over connected LHC cryo-dipoles (see picture below).

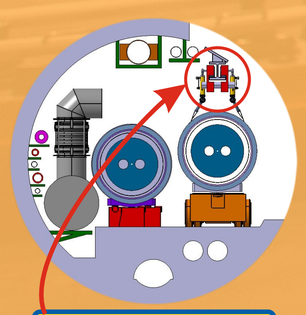


LHC magnet transfer in UJ22



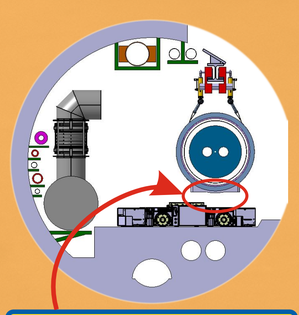
Installation in LHC

The sequential installation is practically mandatory which means that the HE-LHC magnets will be installed from the furthest point in LHC (figure above) after reaching it from both sides (two at a time).
The magnet is then lifted from both sides by **hydraulic cylinders** that are installed respectively moving along on the continuous rail. The trailer can then be removed from under the magnet.
Two transfer tables can then be positioned under the magnet. They handle the cryo-magnets with 6 degrees of freedom and high precision (0.5 mm). It takes over the cryo-magnet from the unloading equipment and aligns it with respect to the magnet support jacks. The magnet is then **transferred horizontally** at a height allowing the passage of the magnet interconnects and finally lowered onto the support jacks[2].
The cryo-magnets will be installed on support jacks fitted with spherical bearings.



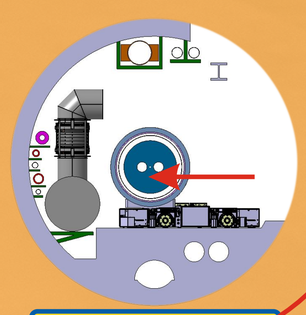
Magnet lifting

- Hydraulic Jacks mounted on the mechanical trolley allow to lift the magnet by 30mm in order to retreat the trailer.



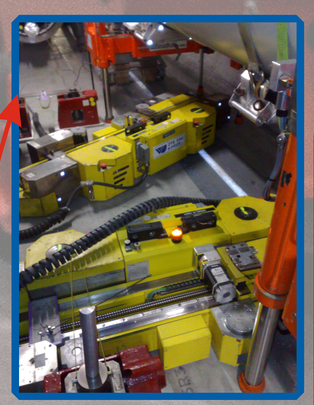
Placement on the transfer table

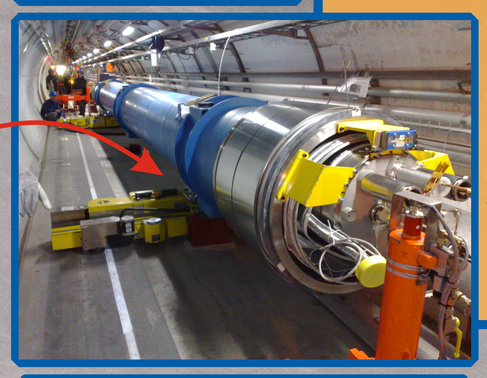
- When the trailer is left, the hydraulic jacks can lower the magnet (~200 mm down).
- Each hydraulic jack has capacity of minimum 15 tons and minimum stroke of 200 mm.



Final position

- Transfer tables, placed on both sides of the magnet is capable of moving it laterally onto the final position.
- It can lift and lower the magnet from and on the jacks.





Transfer table with LHC magnets

Studies

All the requirements mentioned above can be met by using different transport methods and means. The biggest challenge is to design such systems (transport vehicles, lifting units, transfer tables) that will be able to perform all the logistics from the surface to the final position in the existing LHC tunnel, taking into account heave and fragile equipment.
Further studies will have to be carried out in for different types of cryo-magnets (SSS and LSS).
Such solutions are taken into account and an appropriate studies are being carried out to determine their feasibility.

References:
[1] F. Zimmermann. CERN. HIGH-ENERGY LHC DESIGN.
[2] K. Artoos, O. Capatina, K. Kershaw. CERN. TRANSPORT AND INSTALLATION OF CRYO-MAGNETS IN CERN'S LARGE HADRON COLLIDER TUNNEL.

Acknowledgements:
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