The design of the new LHC connection cryostats

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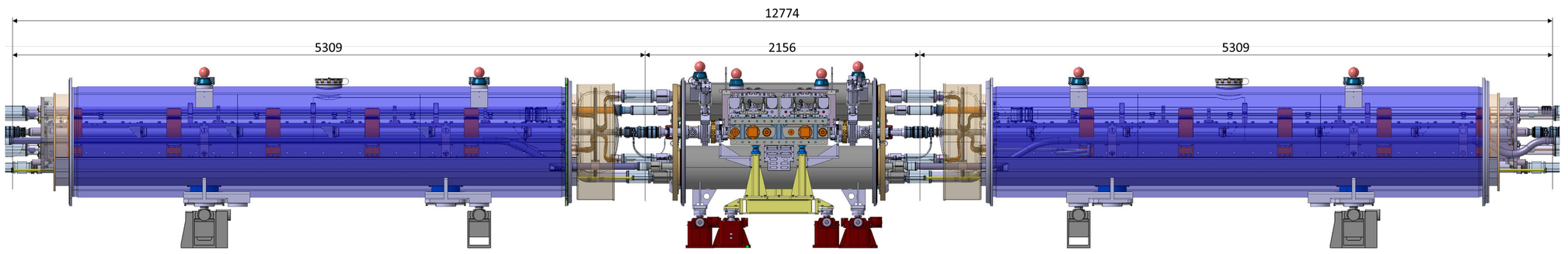
Abstract

In the frame of the High Luminosity upgrade of the LHC, improved collimation schemes are needed to cope with the superconducting magnet quench limitations due to the increasing beam intensities and particle debris produced in the collision points. Two new TCLD collimators have to be installed on either side of the ALICE experiment to intercept heavy-ion particle debris. Beam optics solutions were found to place these collimators in the continuous cryostat of the machine, in the locations where connection cryostats, bridging a gap of about 13 m between adjacent magnets, are already present. It is therefore planned to replace these connection cryostats with two new shorter ones separated by a bypass cryostat allowing the collimators to be placed close to the beam pipes. The connection cryostats, of a new design when compared to the existing ones, will still have to ensure the continuity of the technical systems of the machine cryostat (i.e. beam lines, cryogenic and electrical circuits, insulation vacuum). This paper describes the functionalities and the design solutions implemented, as well as the plans for their construction.

Layout

- Install collimators in LHC IR2 (Alice experiment) left and right
- Bypass cryostat to create room temperature space for installation of collimator
- Replace one existing connection cryostat (12.7 m) with two shorter ones and a bypass cryostat
- Ensure continuity of the cryogenic, vacuum and powering systems

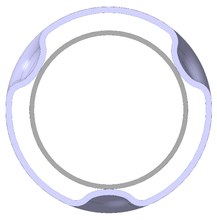


Cold mass

Beam line to V' supporting

Requirements
- Vertical positioning : +/- 0.5 over full length
- Horizontal positioning: +/- 0.8 mm over full length

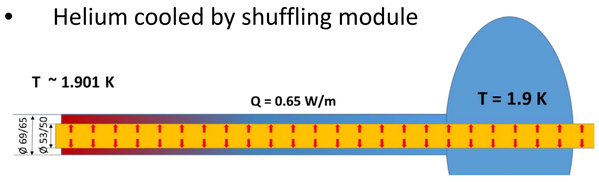
Solution
- Guide cold bore to V' cooling tube every 750 mm
- Indenting V' line in three positions spaced at 120 degrees
- Radial gap < 0.1 mm



V' cooling tube

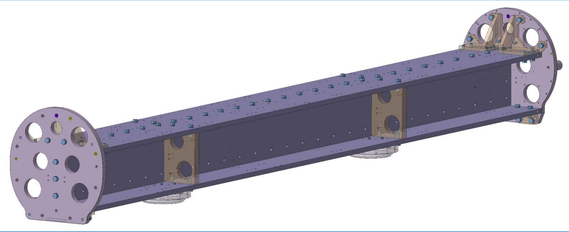
Requirements
- Beam line heat load = 0.65 W/m
- Cold bore below 2.7 K

Solution
- Cold bore inside concentric tube
- Interspace filled with superfluid helium
- Helium cooled by shuffling module



Supporting structure

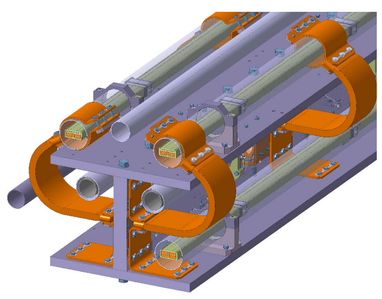
- Ease access during assembly
- Machined stainless steel plates
- Bolted, no welds to avoid stress/deformation
- Stress relieved for geometrical stability



Thermalisation

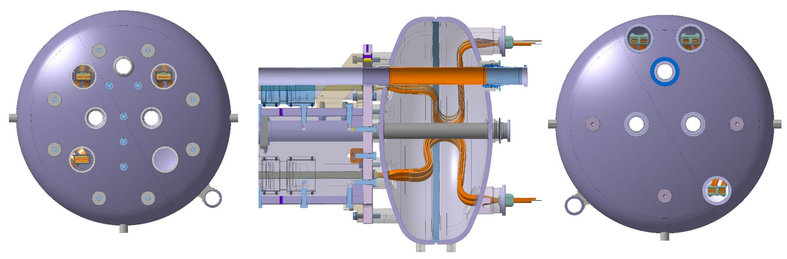
Requirements
- Homogeneous cool-down of the support structure
- Cool-down to 80 K in one week

Solution
- 1200 mm2 copper braids between bus-bars line and support structure every 833 mm



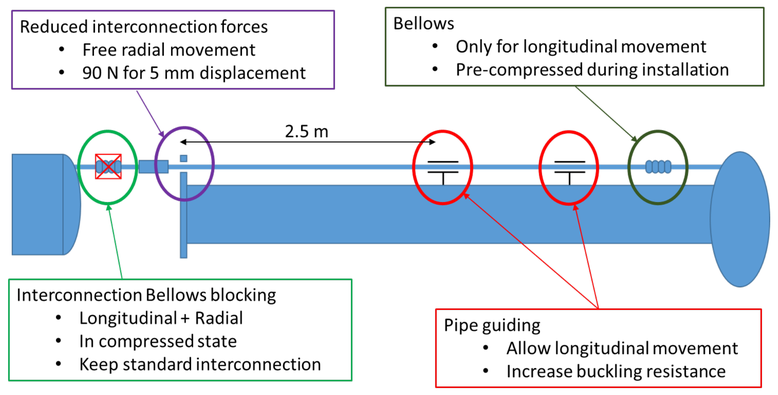
Shuffling module

- Composed of two dished ends welded back to back
- Create space for bus-bars flexible sections
- Houses copper bayonet heat exchanger
- Transition between standard LHC interconnect layout and bypass cryostat layout



Flexible busbars lines

Reduce interconnection transversal forces from 2920 N to 300 N



Negligible deformation of cold mass
(<< 0.1 mm deformation due to weight)

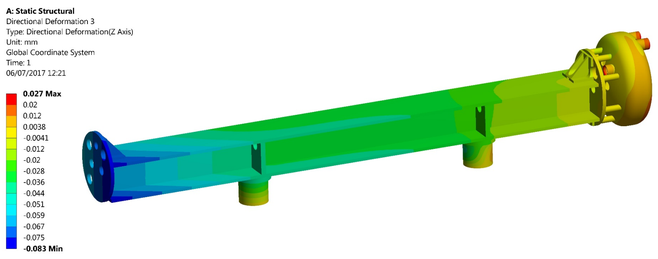
Structural studies

Case A : operational conditions

Loading
- Nominal pressure (1.3 bar)
- Self weight

Requirement
- Maximum deformation ≤ 0.1 mm

Result
- 0.08 mm deformation at magnet end side



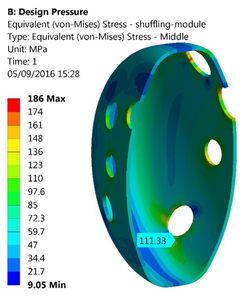
Vertical deformation of cold mass under operational conditions

Case B : quench conditions

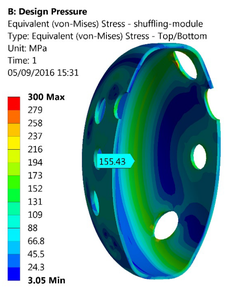
Loading
- Design pressure (20 bar)
- Self weight

Requirement
- Stress ≤ requirement of EN 13445-3 Annex C

Result
- Within requirement of standards
  2.2 safety factor on membrane stress
  4.6 safety factor on membrane + bending stress



Membrane stress in shuffling module in quench conditions



Membrane + bending stress in shuffling module in quench conditions

Thermal studies

Case A : Maximum cooling

Loading:
- 50 K at end of copper braids

Requirement :
- No plastic deformation
- No large deformation (< 1 mm)

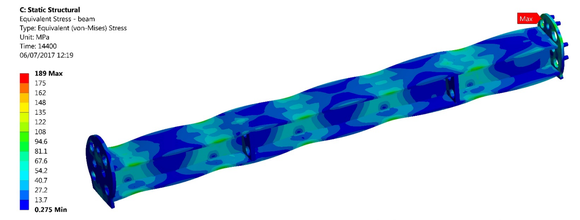
Results
- Negligible deformation
- Maximum stress = 100 MPa (240 MPa allowed)

Case B : Real conditions

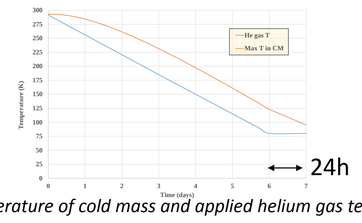
Loading
- Calculated heat transfer coefficient between helium gas and pipe wall
- Linear temperature/time gradient

Requirement
- 24 h maximum delay between gas temperature and cold mass temperature

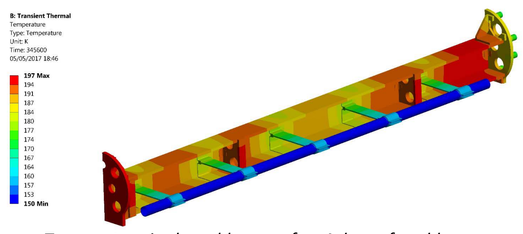
Results
- 24 h delay to reach uniform stable conditions



Maximum thermal stress in the support structure (after 4 hours of cooldown)



Maximum temperature of cold mass and applied helium gas temperature



Temperature in the cold mass after 4 days of cooldown