Thermo-mechanical Studies of the “D1 Mask” (name to be defined)

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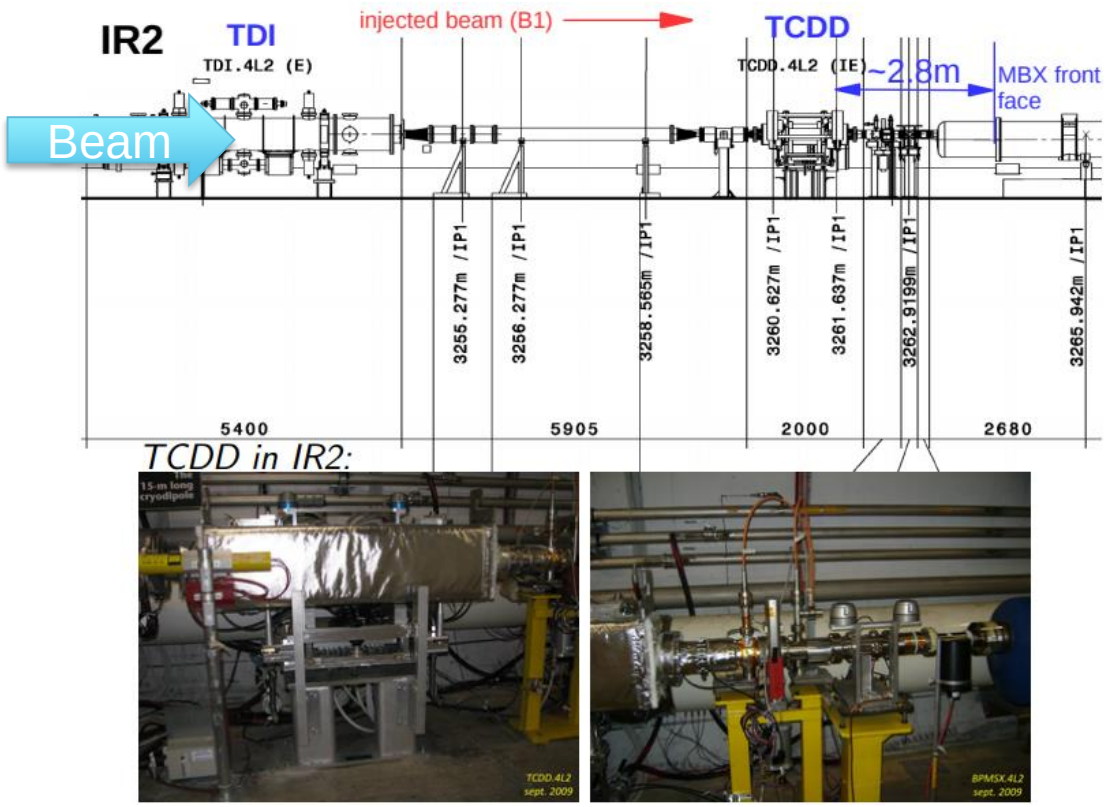
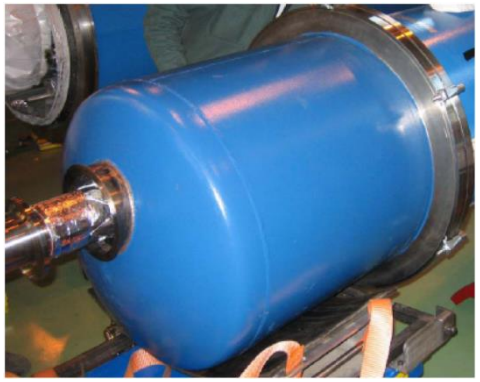
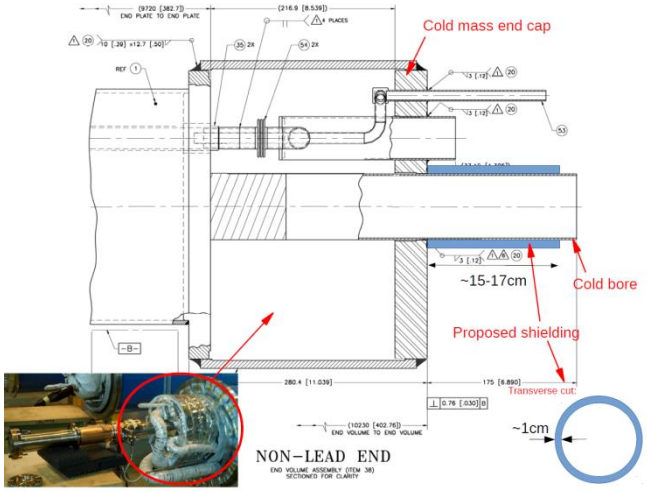
Agenda

- Overview
- Thermal and Mechanical Studies
- Summary

Overview



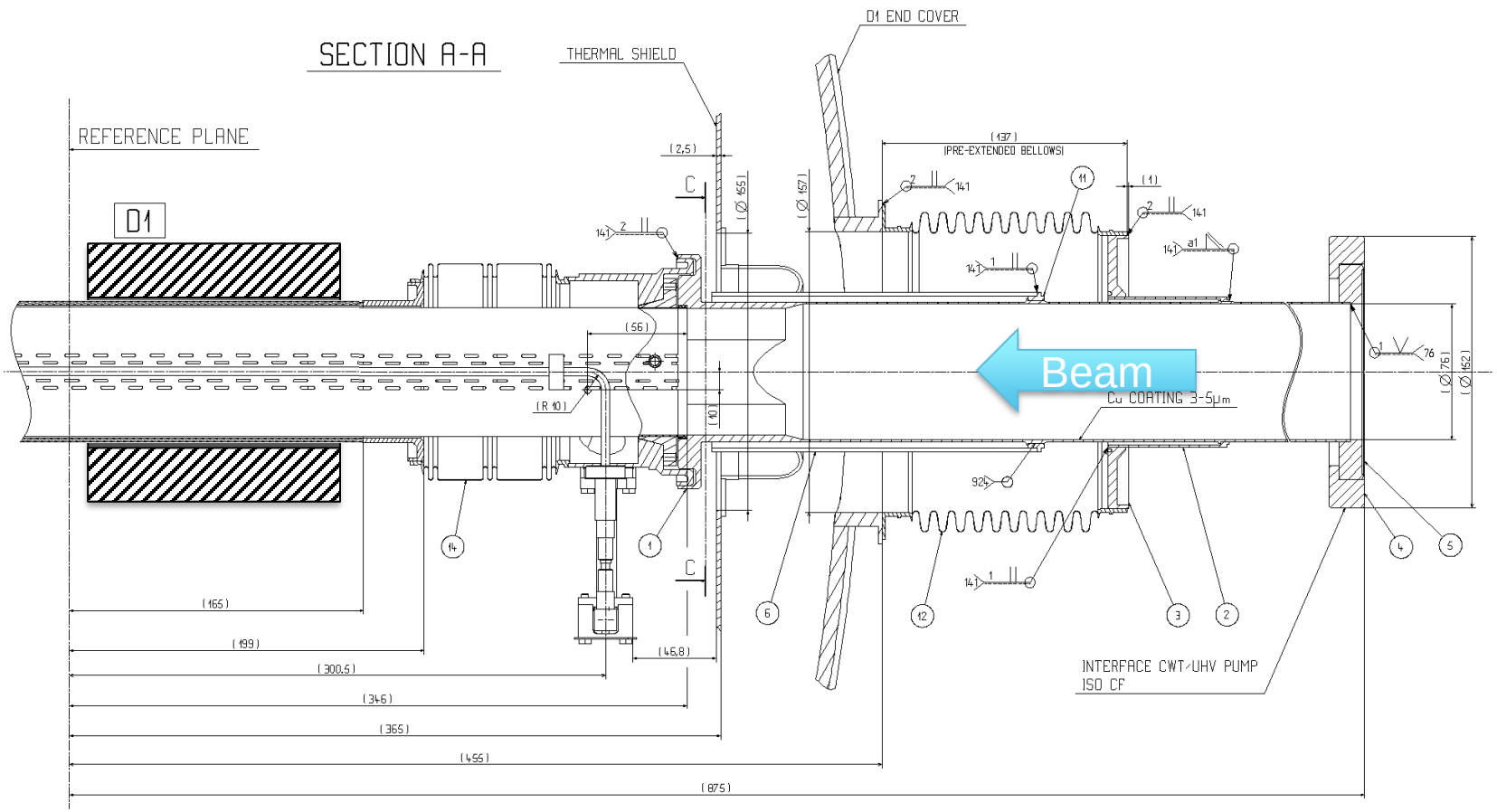




Objective is to prevent the D1 magnet coil from permanent destruction in Run3

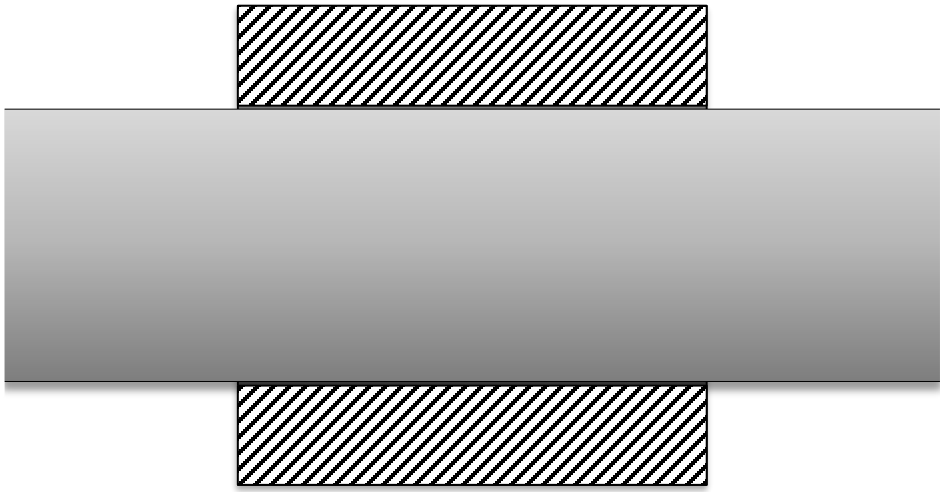
Source of figures: “D1 shielding in case of LHC injection failures” from M. Frankl and A. Lechner
https://indico.cern.ch/event/632532/contributions/2557807/attachments/1448641/2232822/2017_04_25_wp14protstudies.pdf

Overview



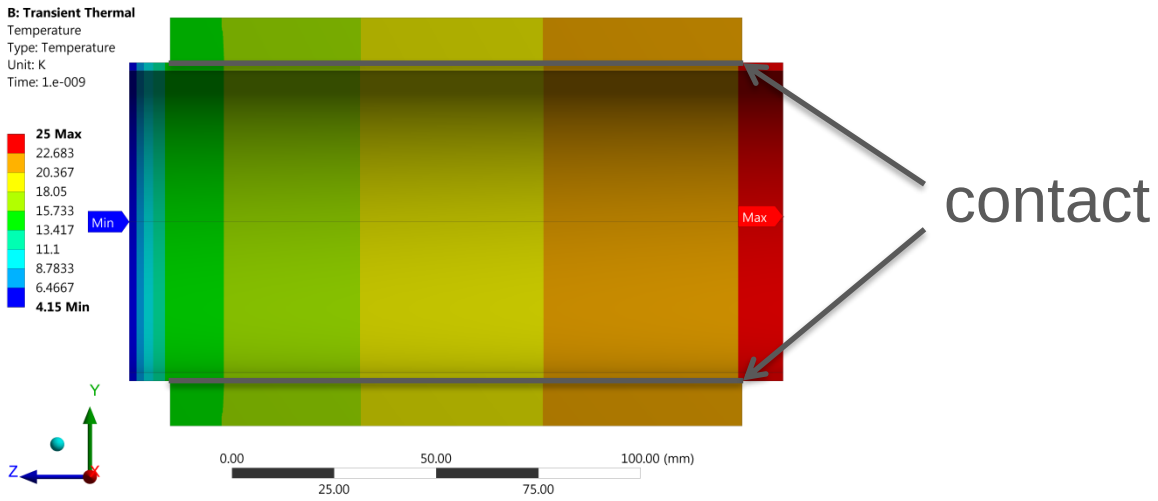
Source: "LHCVST__0062 - C/W TRANSITION CBDIA. 74 FOR D1 - ASSEMBLY & WELDINGS"
https://edms.cern.ch/document/397536/0

Overview



- SS316LN vacuum chamber has a outer diameter of 78 mm, with a tolerance of ± 0.15 mm)
  https://edms.cern.ch/document/334961/1.3, https://edms.cern.ch/document/107723/0
- SS316LN Mask dimensions: Outer diameter of 100 mm, thickness 11 mm and a length of 140 mm
- Contact to vacuum chamber to prevent relative movement

Thermal Studies
- Assumptions -

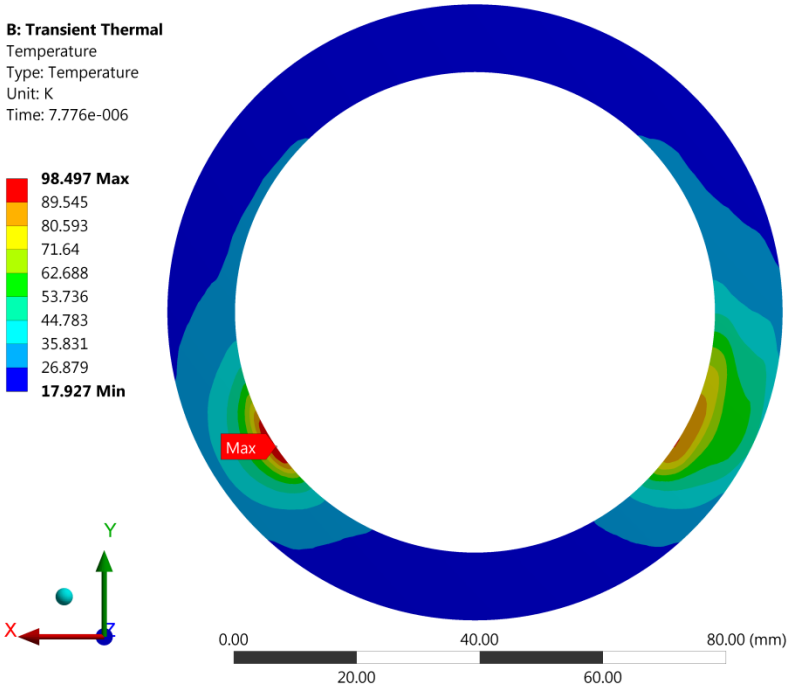


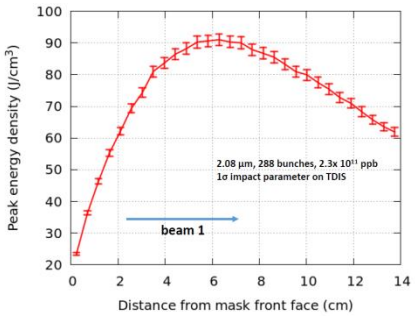
- 4 K at the cold side, because of the availability of data
- 25 K at the warm side to be conservative with the temperature gradient (removed in transient simulation)
- Contact is “bonded” (maximum possible stresses)
- Thermal resistance of the contact plays a minor role (long period of cooling before and after the impact)

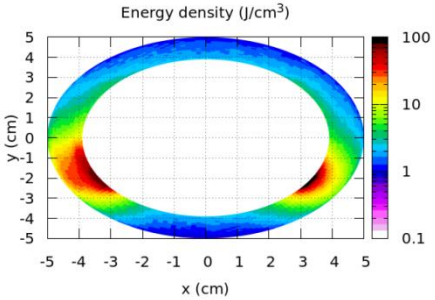
Thermal Studies
- Considered Load -

- HL-LHC STANDARD beam train (288 bunches)
- impact on the TDIS with an impact parameter of 1 sigma
- STD beam emittance: 2.08 µmrad
- Number of bunches per pulse: 288
- Total pulse intensity: 288 x 2.3E11 = 6.624E13
- Total pulse time: 7.775 µsec
- Repetition rate: Single failure

Thermal Studies
- Results -



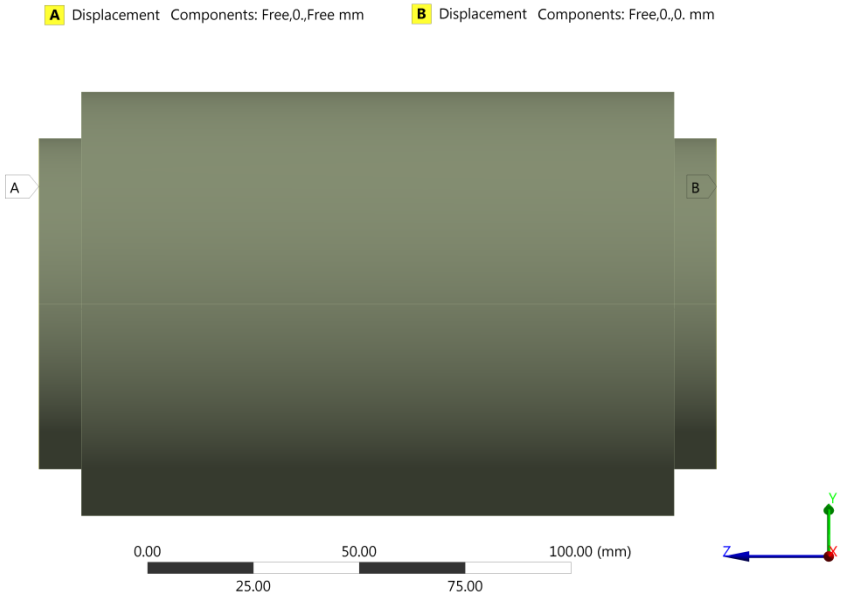




- Peak deposited energy density: 90 J/cm^3
- Expected maximum Temperature: 99 K
- Numerical result: 98.50 K

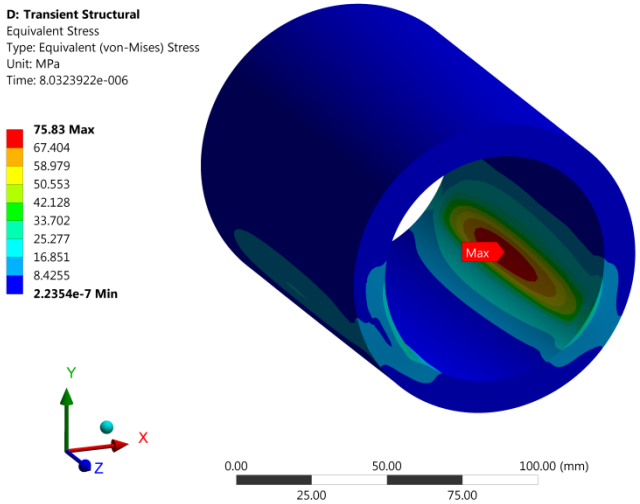
Mechanical Studies
- Assumptions -

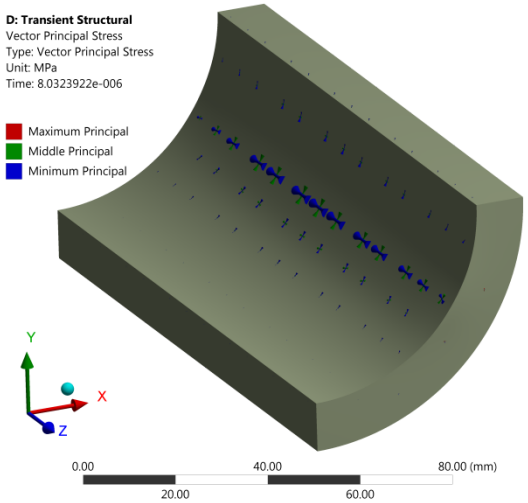
- Chamber is free to expand axial and radial

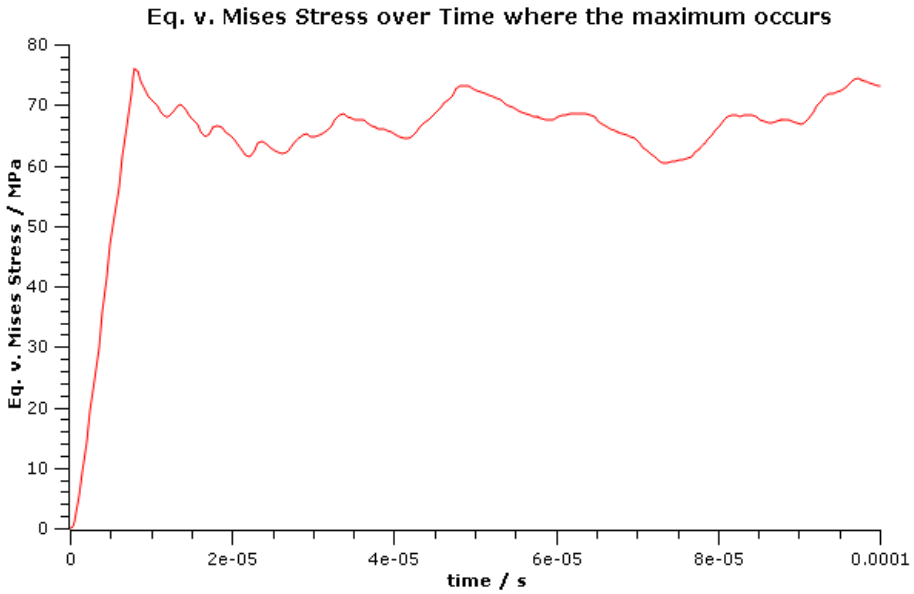


- The mask is “glued” to the chamber everywhere
- The maximum of stresses occurs within 1e-4 s after the impact

Mechanical Studies
- Results -







Yield Strength at 100 K: 830 MPa

$$S_{yield} = \frac{R_{yield}}{\sigma_{Eq,max}} = \frac{830\ \text{MPa}}{75.83\ \text{MPa}} = 10.9$$

Source: K. Nohara et al. “Cryogenic Properties of Austenitic Stainless Steel for Superconducting Magnet” in “Austenitic Steels at Low Temperautres”

Summary

- Big margin against permanent deformation
- Maximum directional deformation of the vacuum chamber is <10 µm
- All reasonable designs of the connection between the vacuum chamber and the mask are considered
- The next step is the detailed design of the device

Thanks to Matthias Frankl for the FLUKA simulations!