Alternate design for DUNE Near Detector

Andrea Bersani

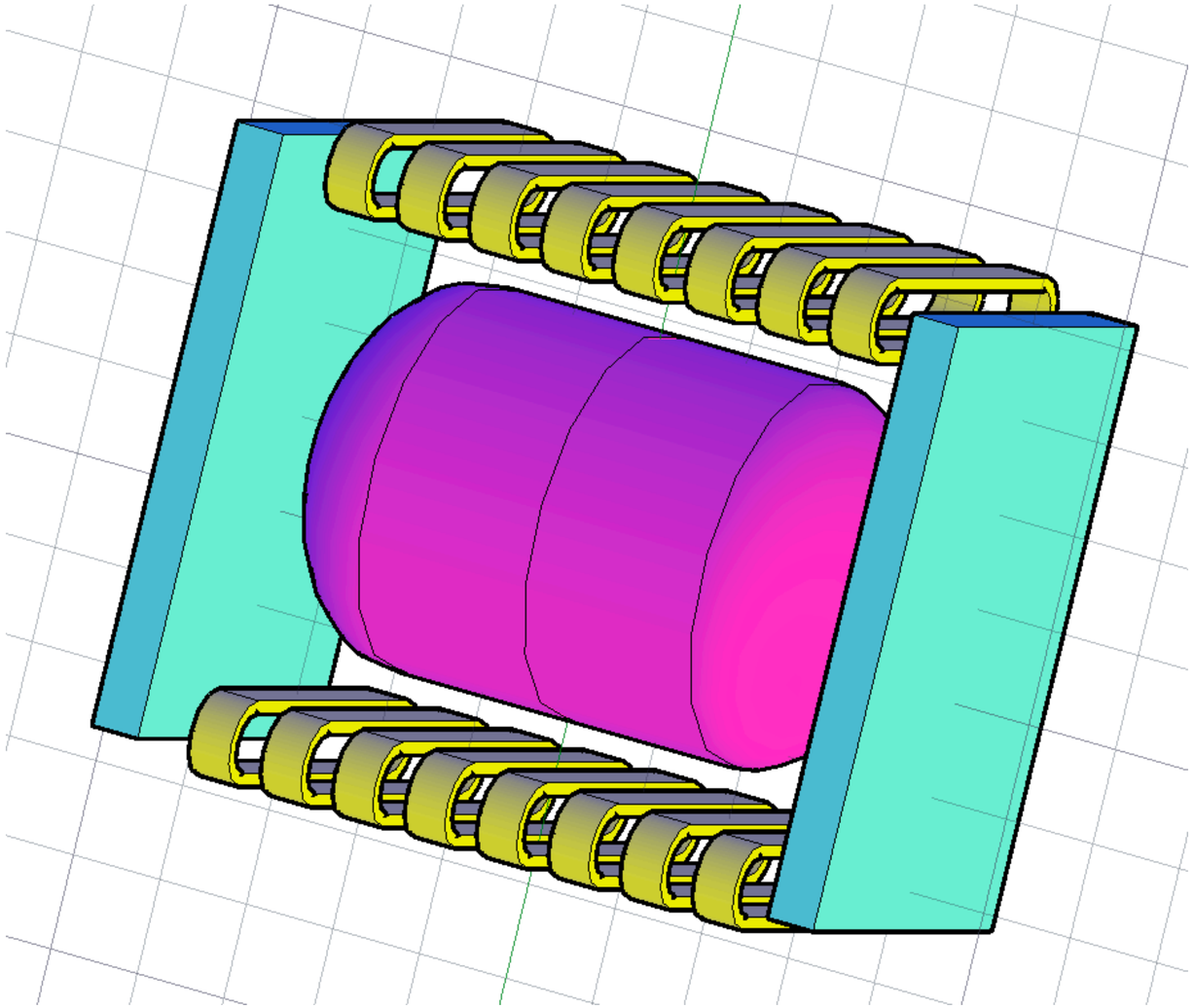
INFN Sezione di Genova
Istituto Nazionale di Fisica Nucleare

Magnet summary

- Must host a 5.27 m dia., 5 m long TPC + 60 cm thick calorimeter
  - pressure vessel design from BARC
- Must host a 60 cm thick 4**π** calorimeter
- Must be as thin as possible along the particle path
  - no material between calorimeter and HPArTPC
- Must provide 0.5 T ± 20% on the TPC
- Must minimise stray field *along the particle path*
- Must be movable
  - total wight w/o possible magnet iron: 400 – 500 metric tons

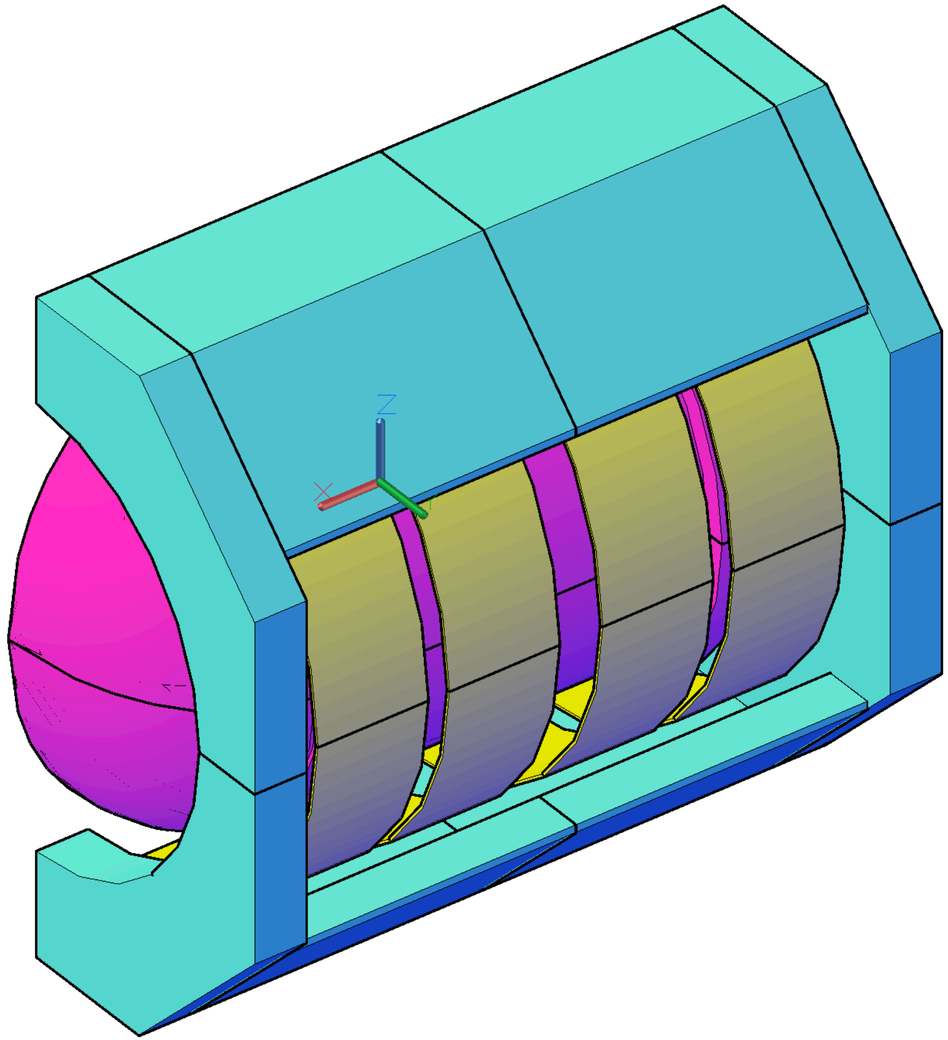
Double Dipole (DDDND)

- The original Genova group idea was a set of racetrack coils to be installed on the sides of the detector making a double dipole: the stray field is used on the detector
- Good for
  - no material in front of the detector
  - small coils
- Bad for
  - a lot of superconductor
  - hardly compatible with a so long pressure vessel



Solenoid with Partial Yoke (SPY@DND)

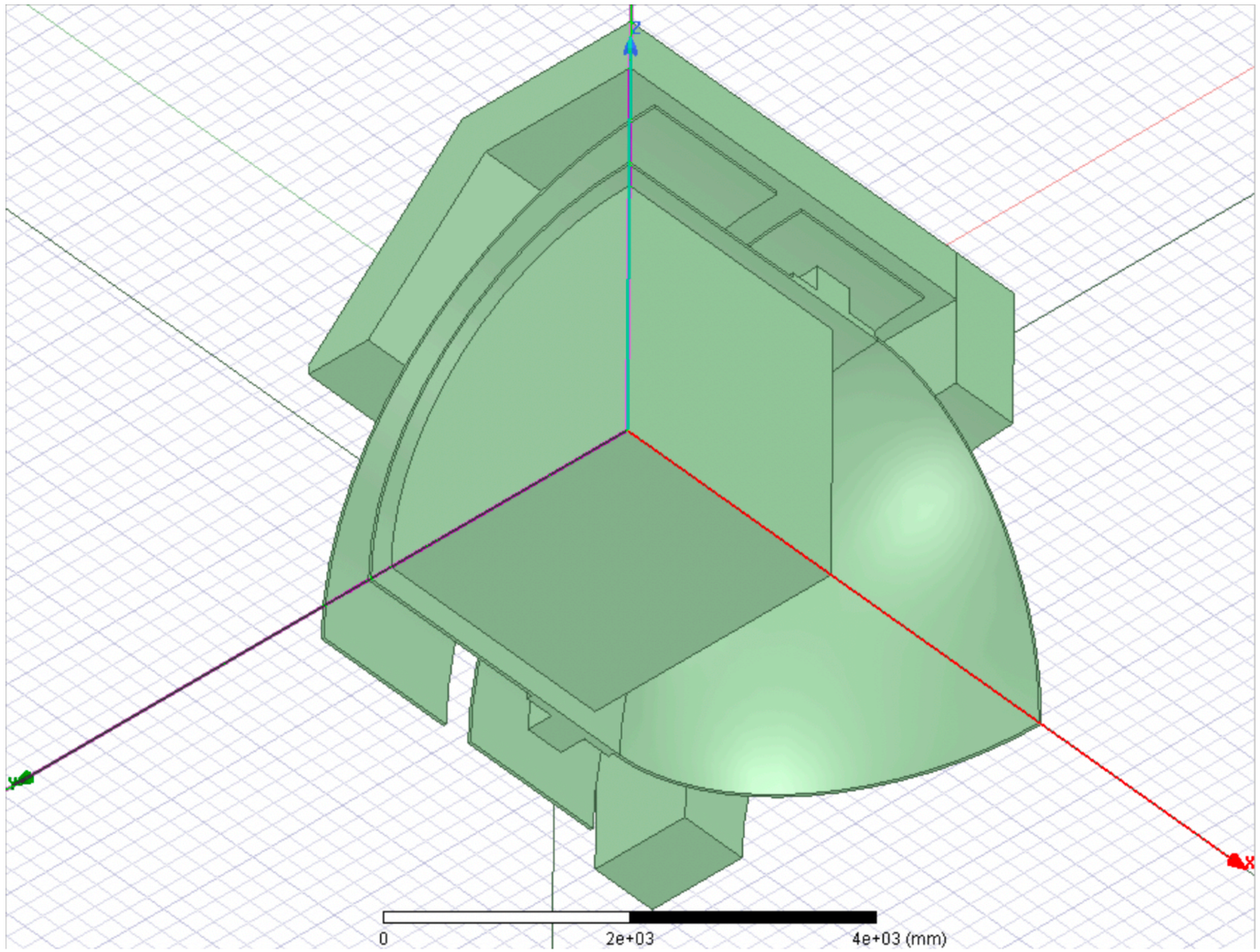
- Solenoid with a "window" in the yoke
  - closing the magnetic circuit where iron does not affect particles
- Good for
  - reducing stray field
  - reducing stored energy
  - having uniform material budget
- Bad for
  - heavier
  - ~10cm of aluminium along particles path (outside the calorimeter)



Magnet features

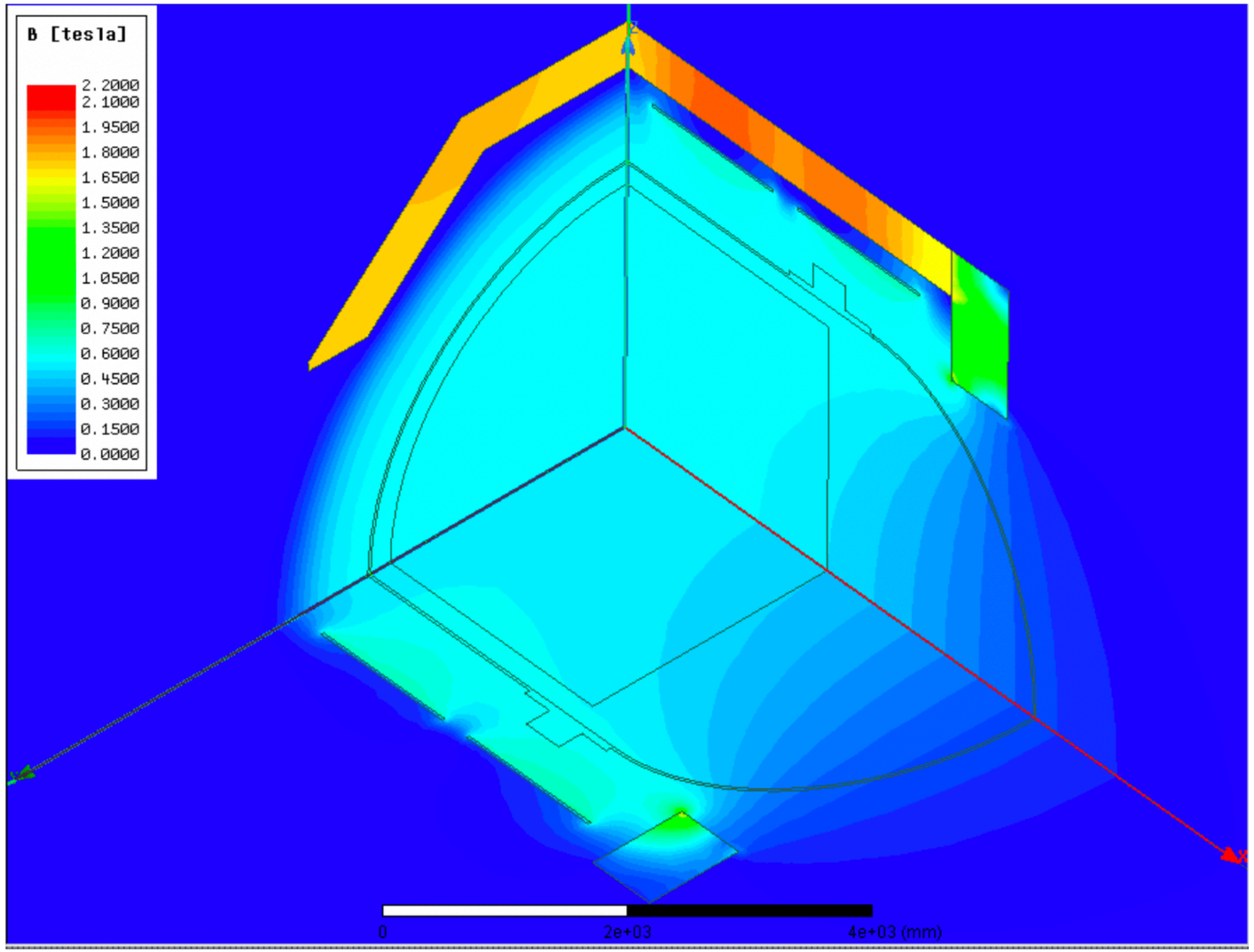
- Field on TPC: 0.51 T ± 12%
- Stored energy: 44 MJ
- Current density: 32 A/mm2
- Possible cable: 20 x 11 mm2
  - Total length: ~12.7 km
- Current: 7040 A
- Inductance: 1.8 H

- Magnetic calculations made on 1/8 3D model (Ansys Maxwell)



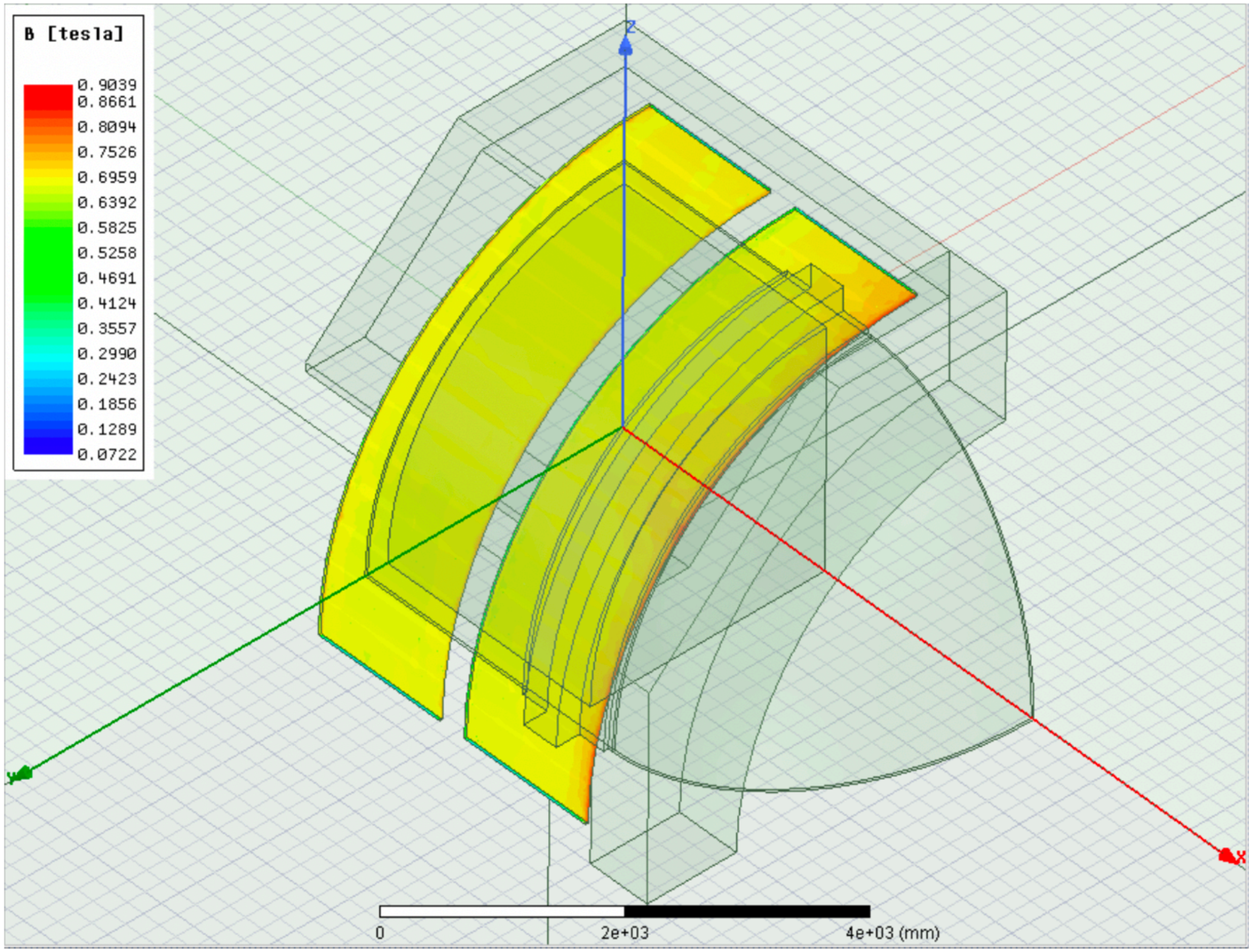
Field overview

- Max field in iron: 2.1 T
- Max field on cable: 0.9 T
- Force on end caps: 100 t
- Force on yoke segments: 120 t
- Yoke mass: 520 t
- End caps mass: 370 t (possibly this can be reduced)



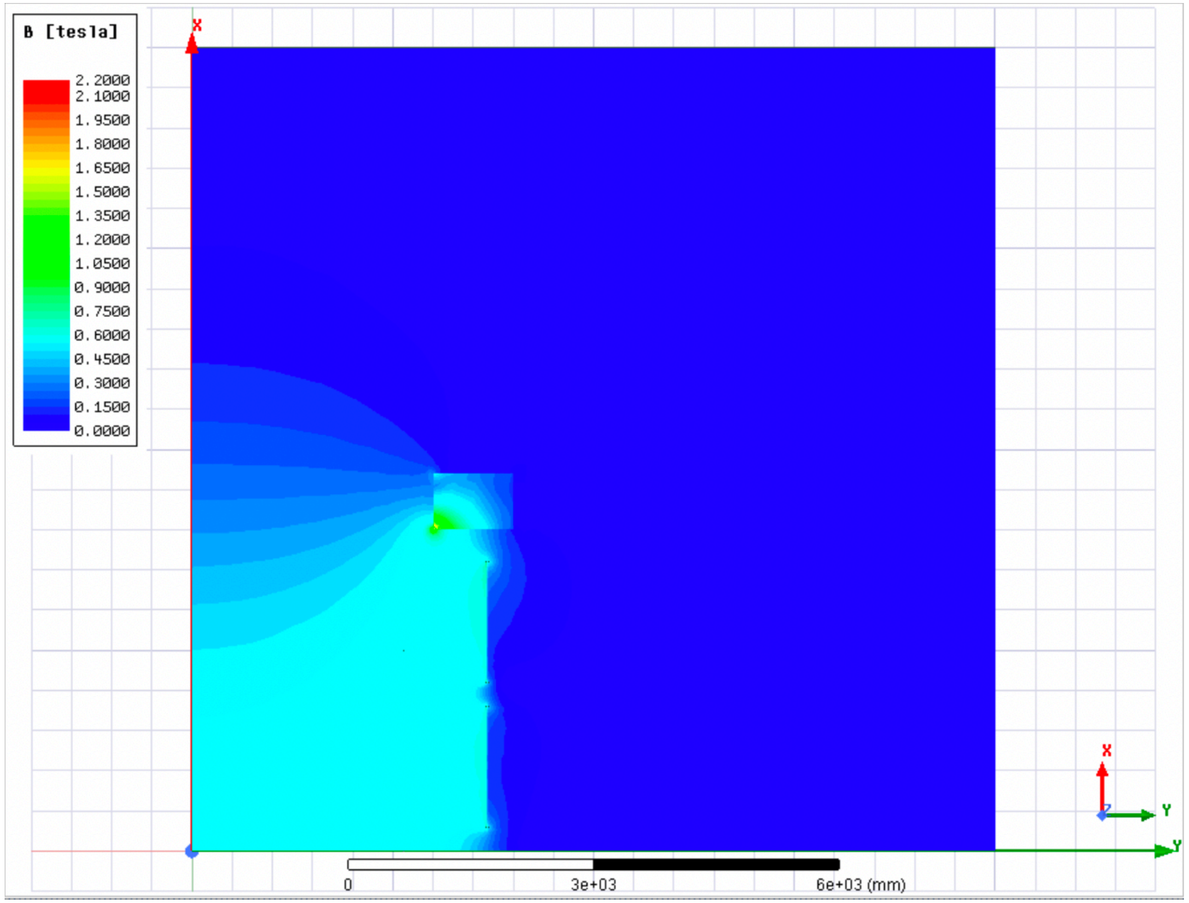
Coils features

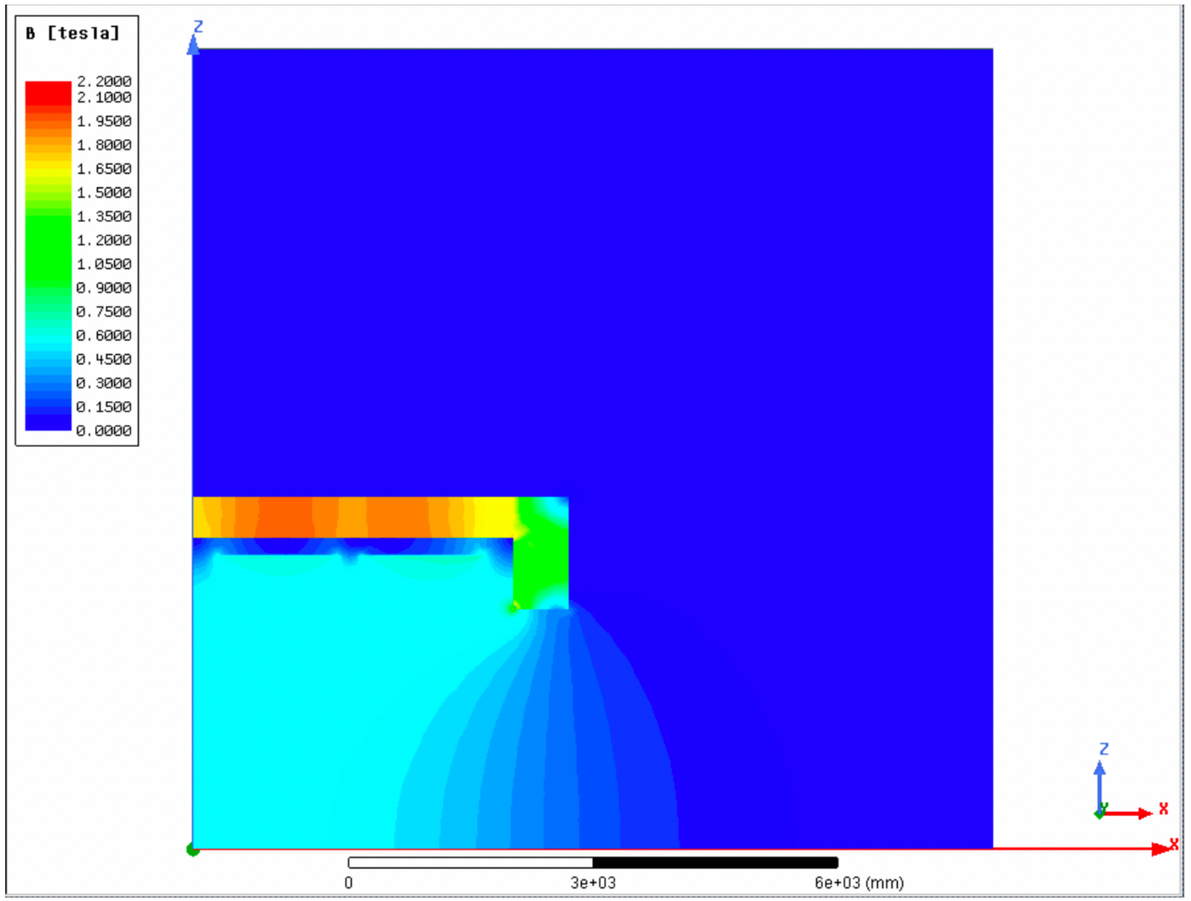
- 4 identical single layer coils
- 1500 x 20 mm2 section
- ~3660 mm radius
- Can be built independently and assembled and integrated in the experimental hall
- Total width (along particles path): ~8000 mm
- Total height: 8800 mm (without wheels)



Stray field

- 0.04 T at 5 m from the magnet centre along the particle path – higher on sides



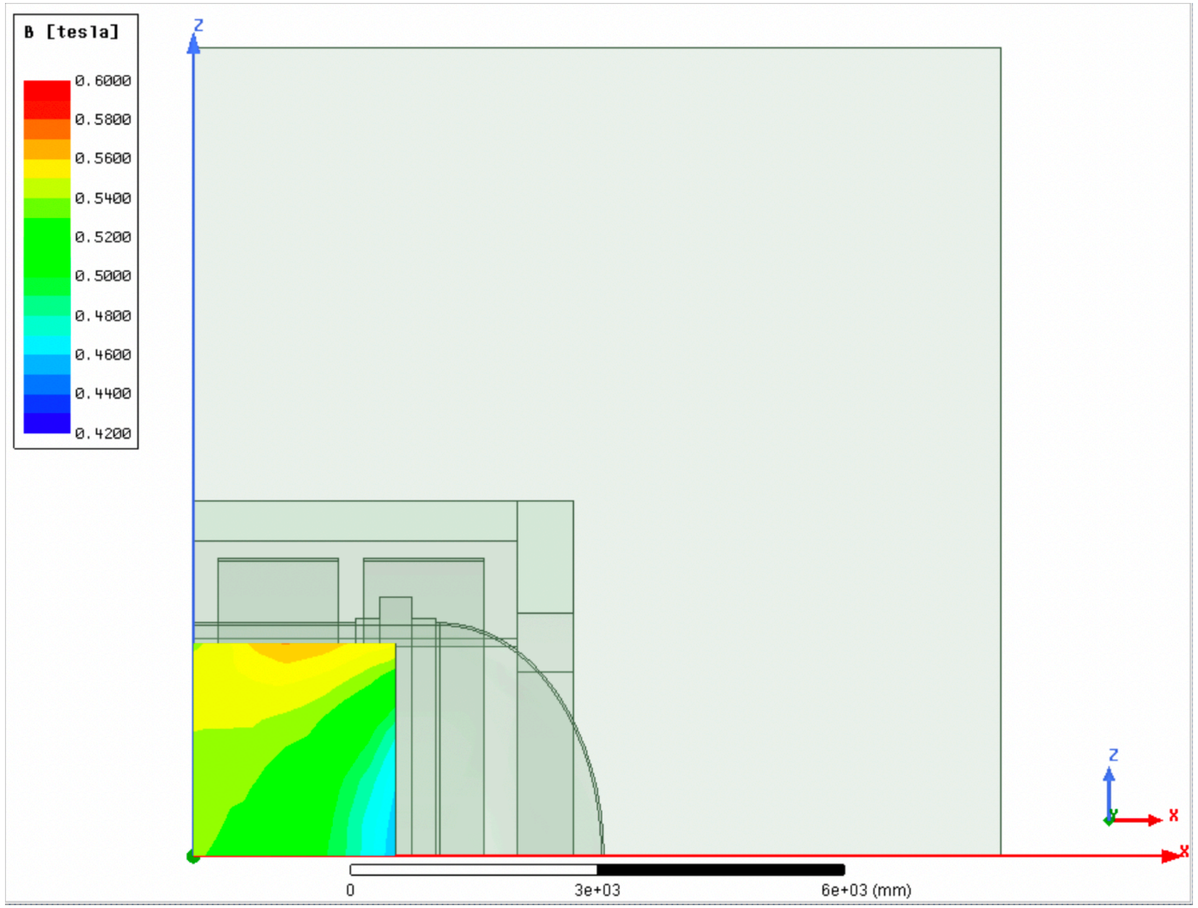


Field on TPC

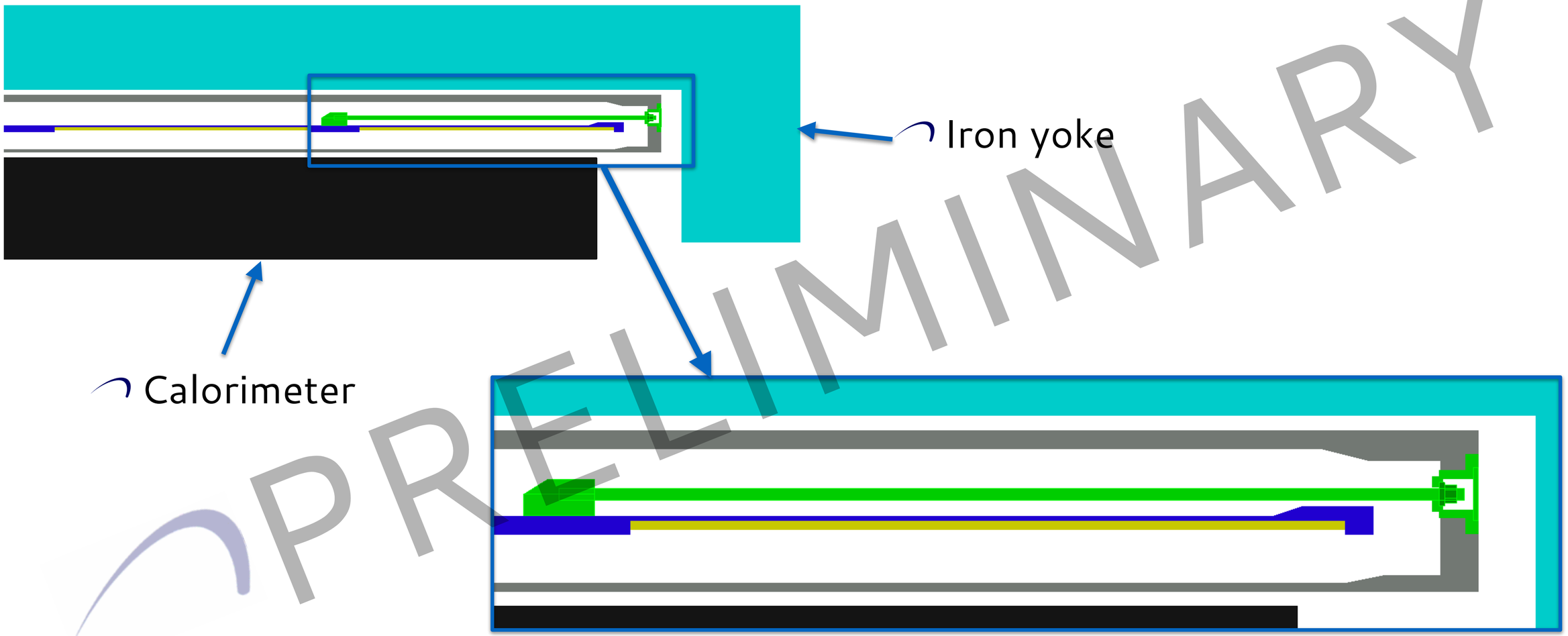
- 0.51 T ± 12% on the whole TPC
- 0.51 T ± 8% on ~90% of the TPC

- Requirements on radial field?
- Further optimisation is useful?

- Field on calorimeter?



Some mechanical considerations

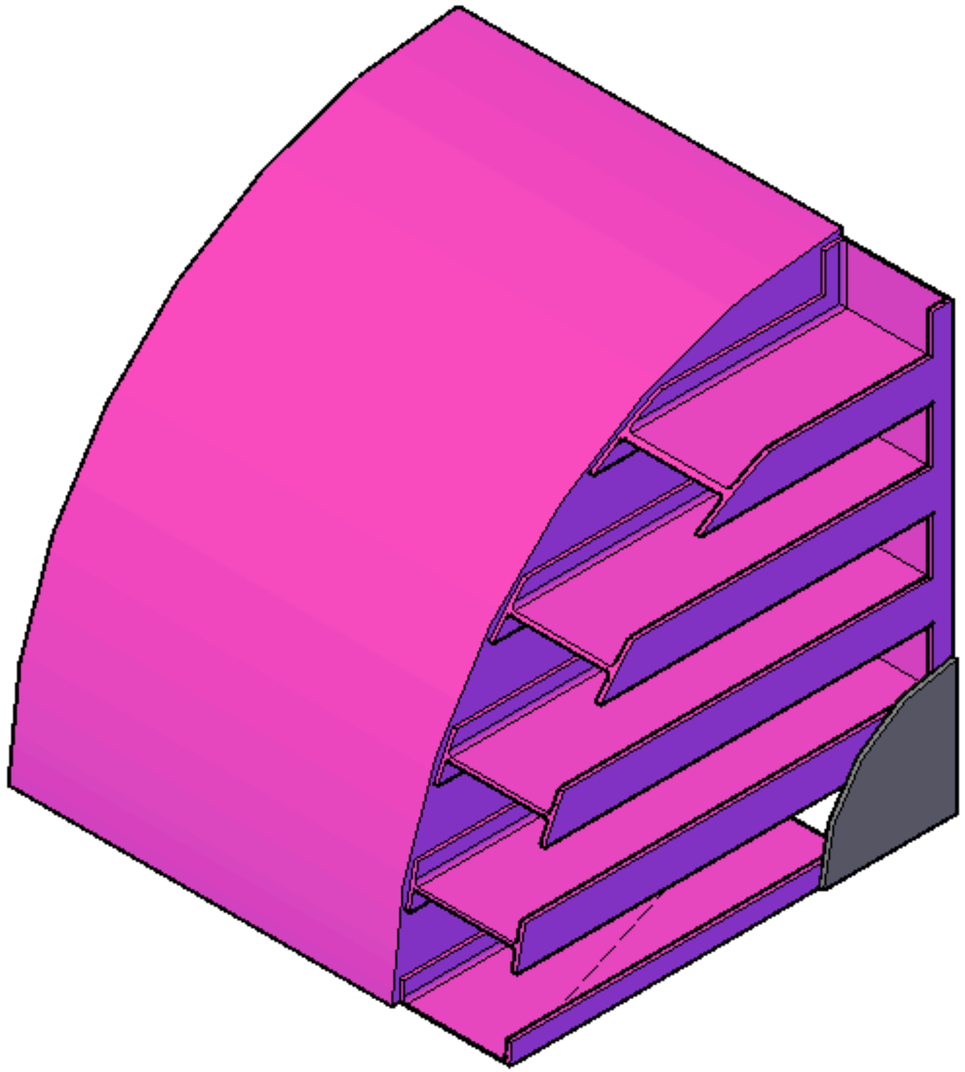


Possible suggestion for the TPC vessel

- Based on Alan's suggestion

- Reinforcing the vessel ends to reduce the size
- Ideally, flat ends with I-beams
  - IPE 750 based – actually non standard
- To be evaluated if this structure can host the calorimeter
- Design is very preliminary and not yet satisfactory

- Indeed, the advantage could be great

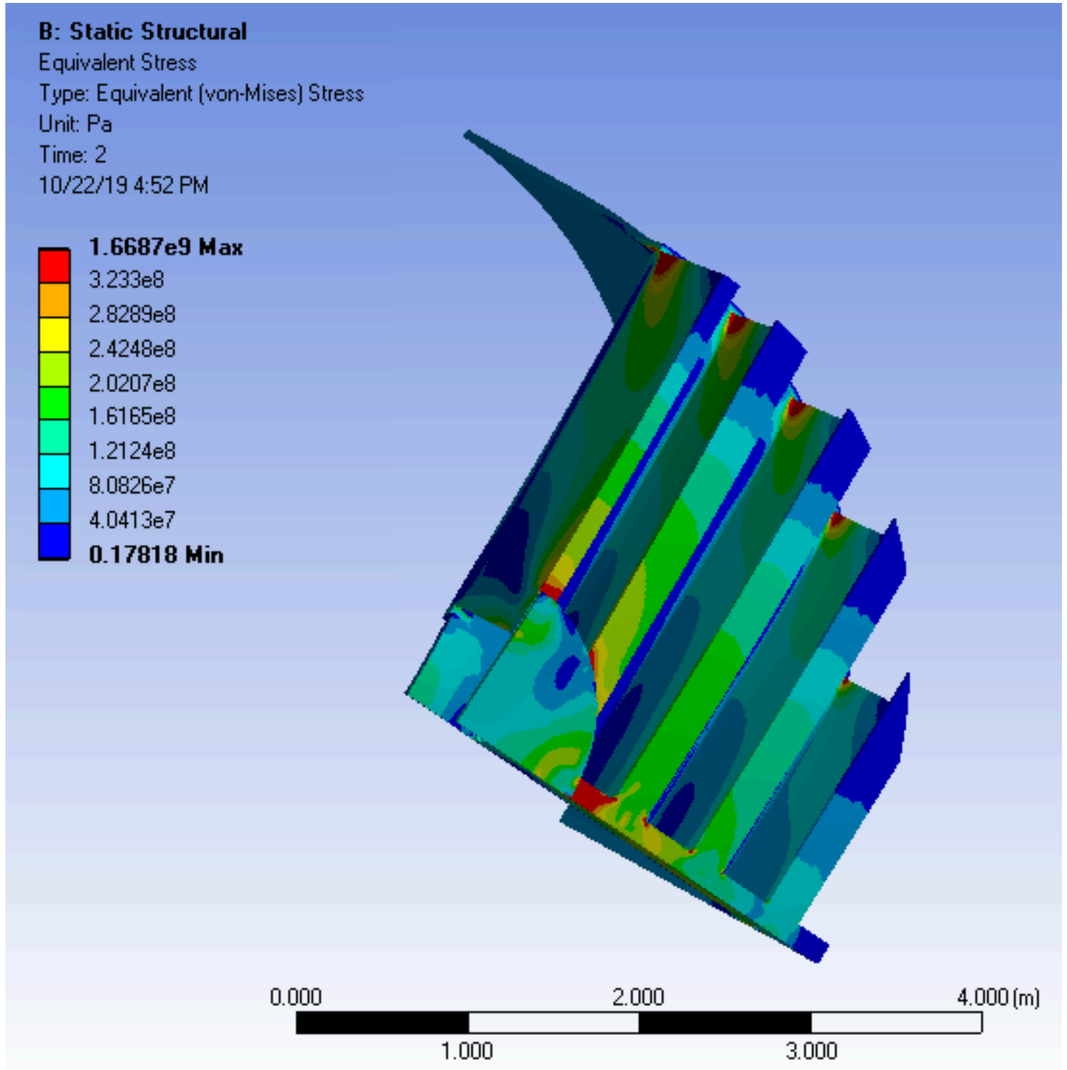


Preliminary analysis

- Maximum stress exceeds 300 MPa
  - in fact, in few spots
- Weak optimisation has been performed
- Possibly a slightly non flat vessel end is the best compromise

- Length reduction can be ~ 3 m

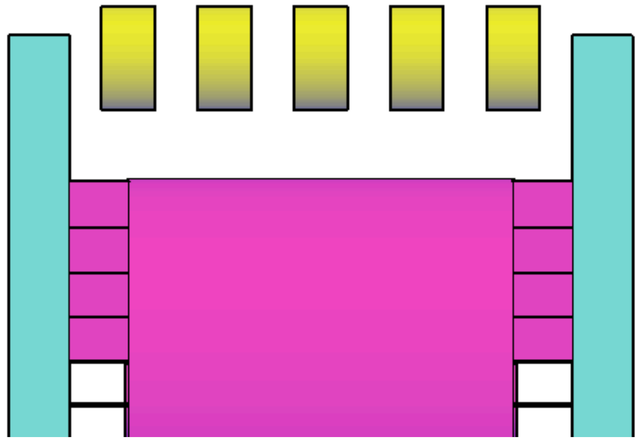
- Compatible with but not needed by SPY@DND

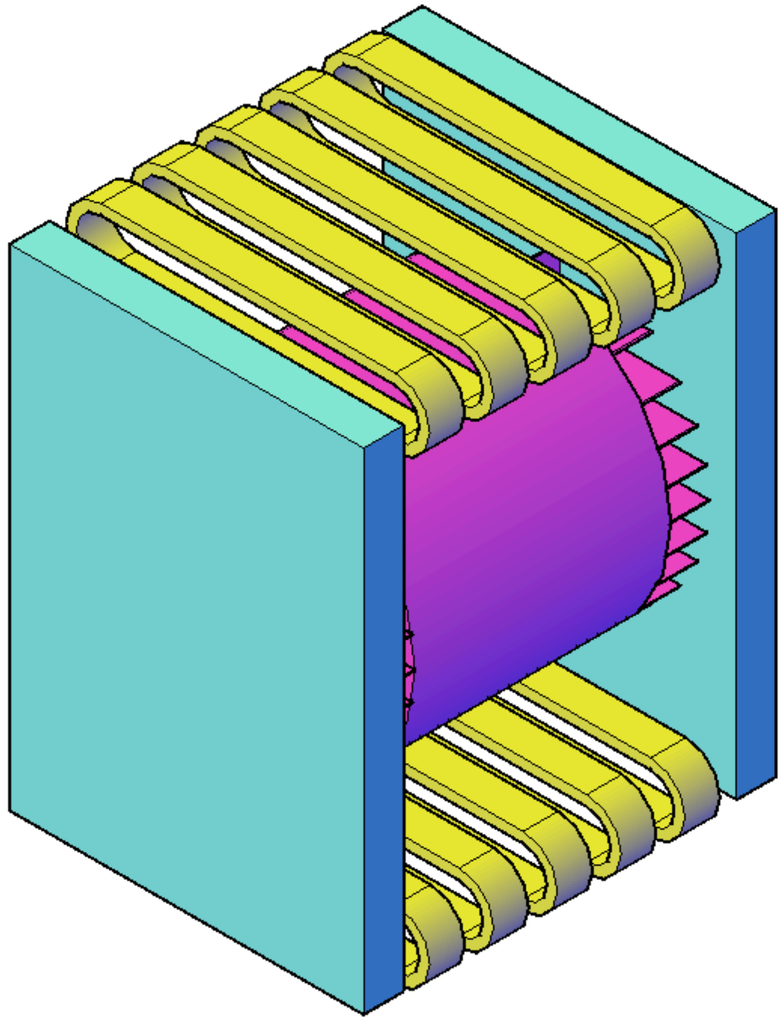


Possible evolution of DDDND

- With shorter vessel, DDDND solves part of the issues
- Less coils
- Less stray field
- More compact design

- … anyhow, I would recommend SPY@DND





Further steps

- SPY@DND validation by the collaboration is needed
- Magneto-mechanical design
  - forces on coil with misalignments and displacement
- Detailed mechanical design of coil, coil former and vessel
  - minimisation of material
  - optimisation of volumes
  - optimisation of parts for installation in experimental hall
  - integration of vacuum chamber in iron yoke
- Iron yoke detailed design
  - support structure
  - moving platform
  - services and supplies integration