Solenoid with Partial Yoke @ DND - an update

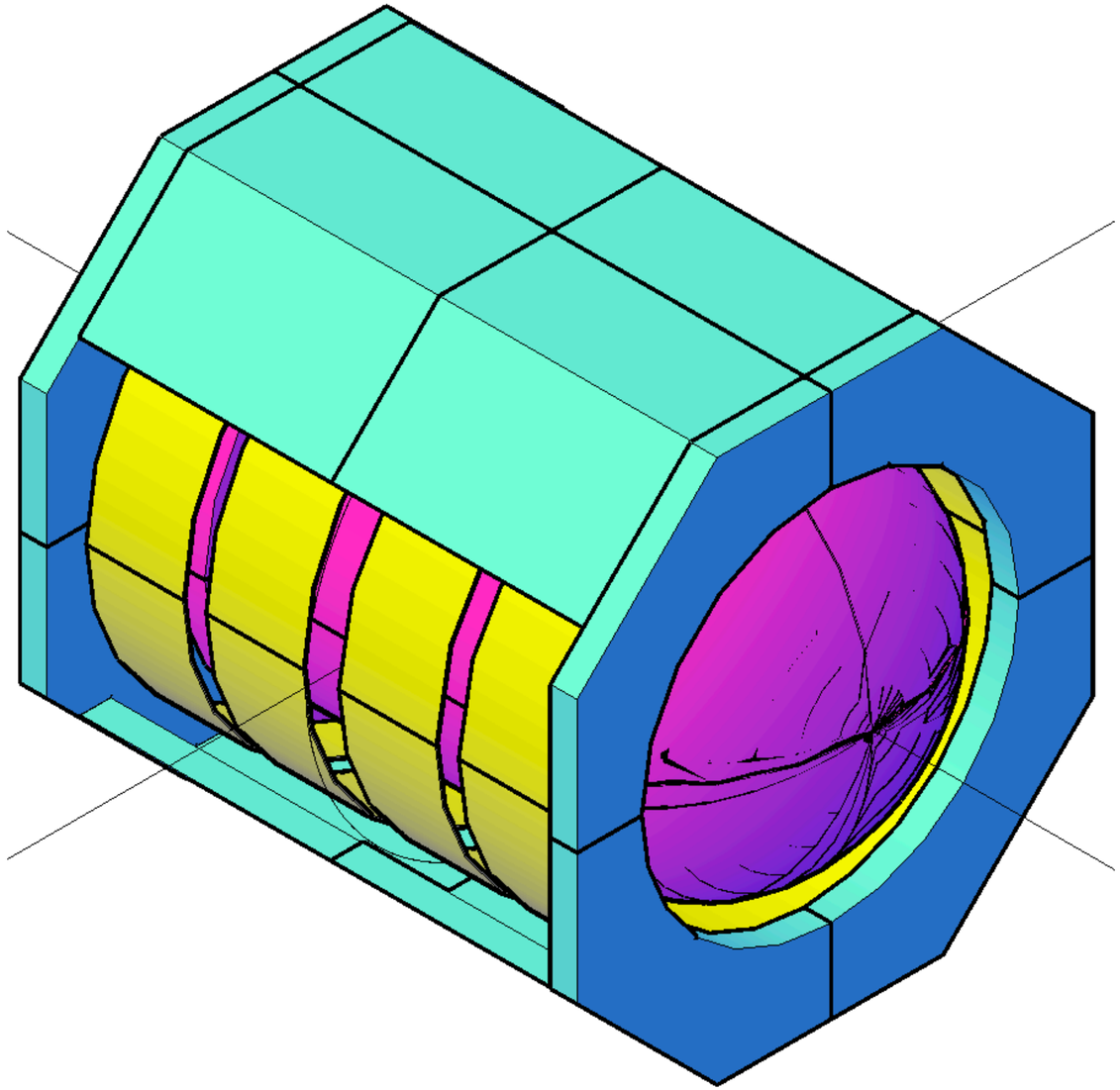
Andrea Bersani

INFN Sezione di Genova
Istituto Nazionale di Fisica Nucleare

SPY@ND summary

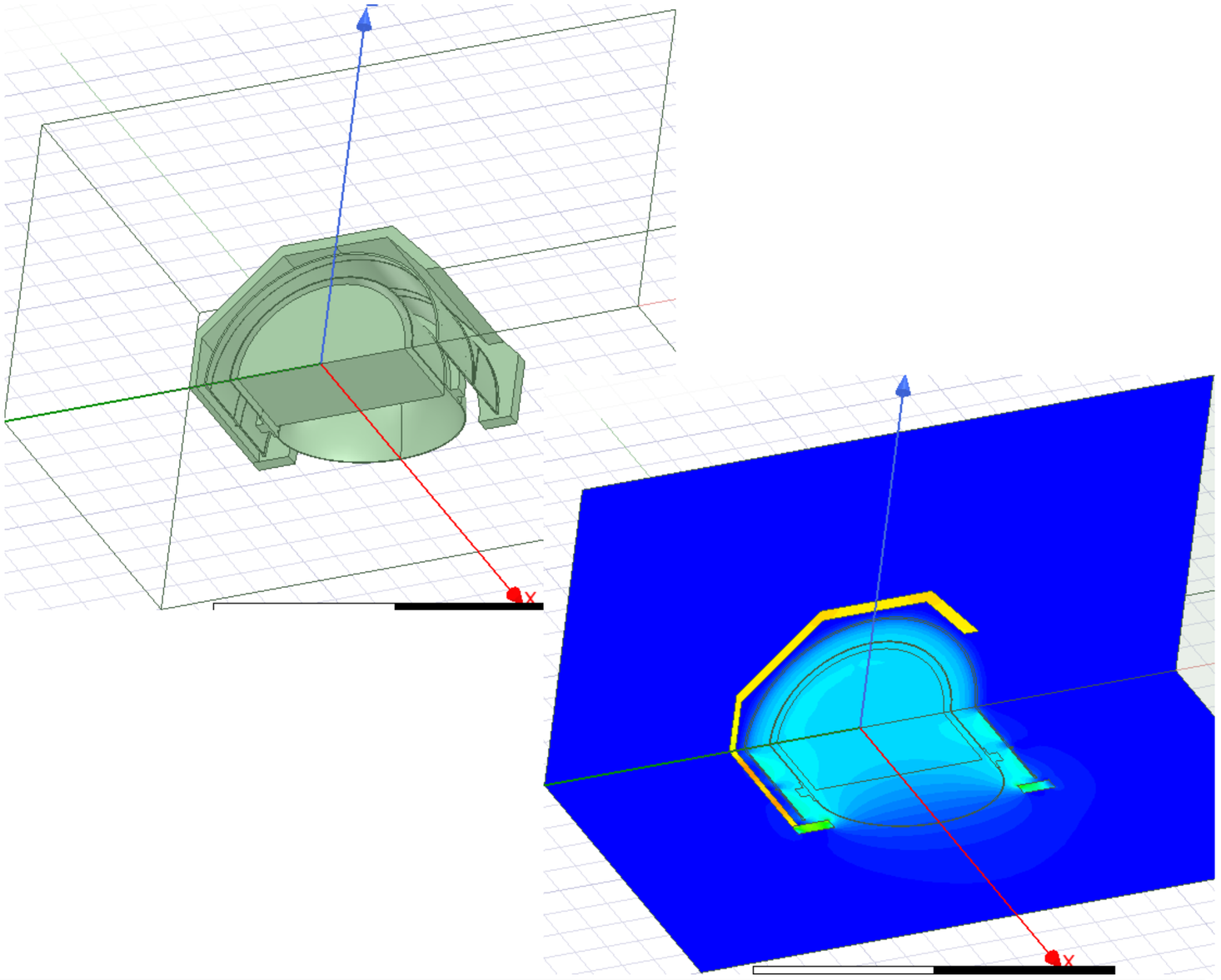
- Solenoid with Partial Yoke @ Dune Near Detector main features

- Niobium Titanium Rutherford cable stabilised in aluminium
- Four single layer coil forming a quasi-continuous solenoid
- ~10 cm of equivalent aluminium along particle path - homogeneous
- Iron yoke featuring a front window to allow particles coming from the Argon Cube to enter the HPArTPC with no degradation
- Possibility to host muon chambers in the yoke lamination



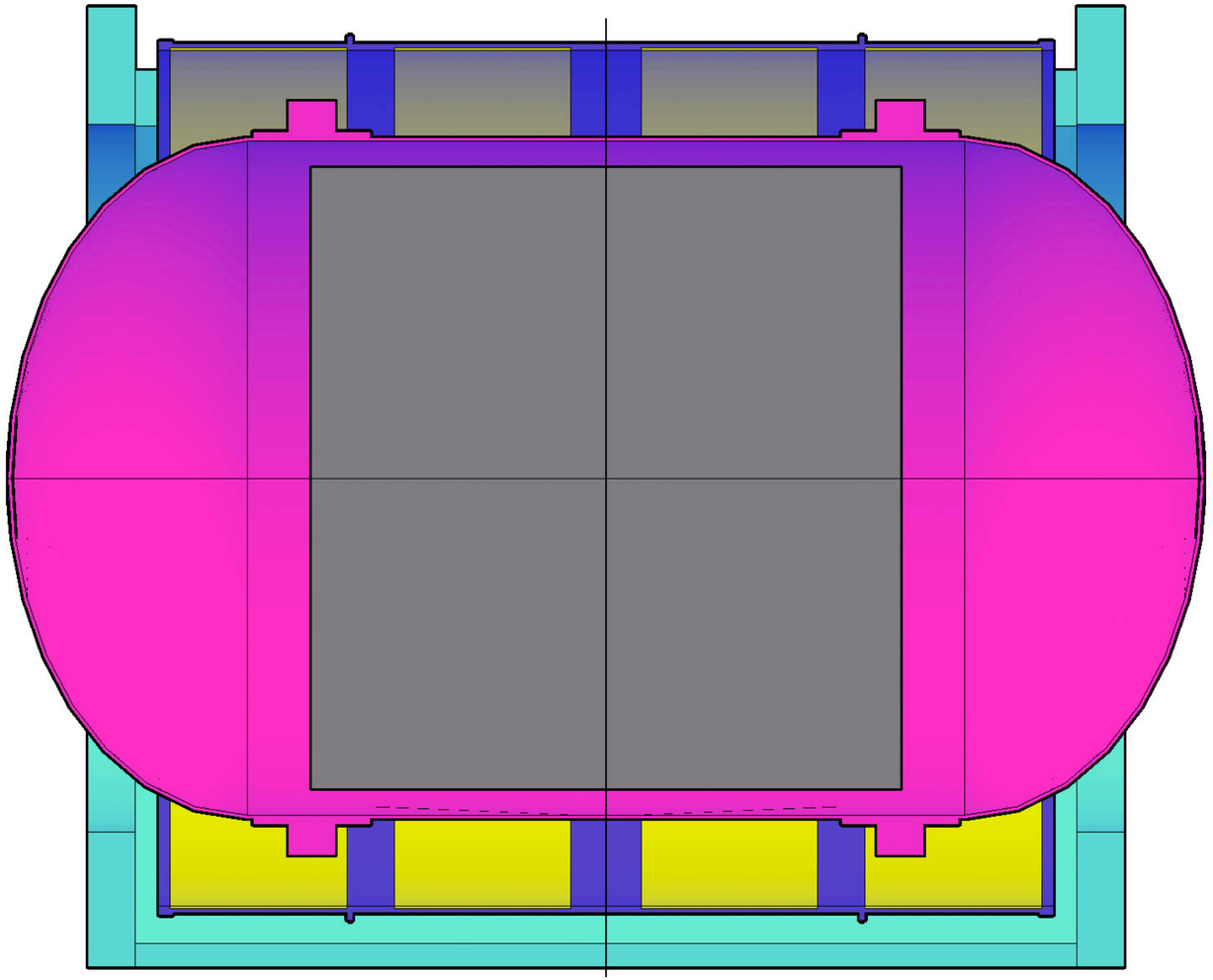
SPY@DND before CERN meeting

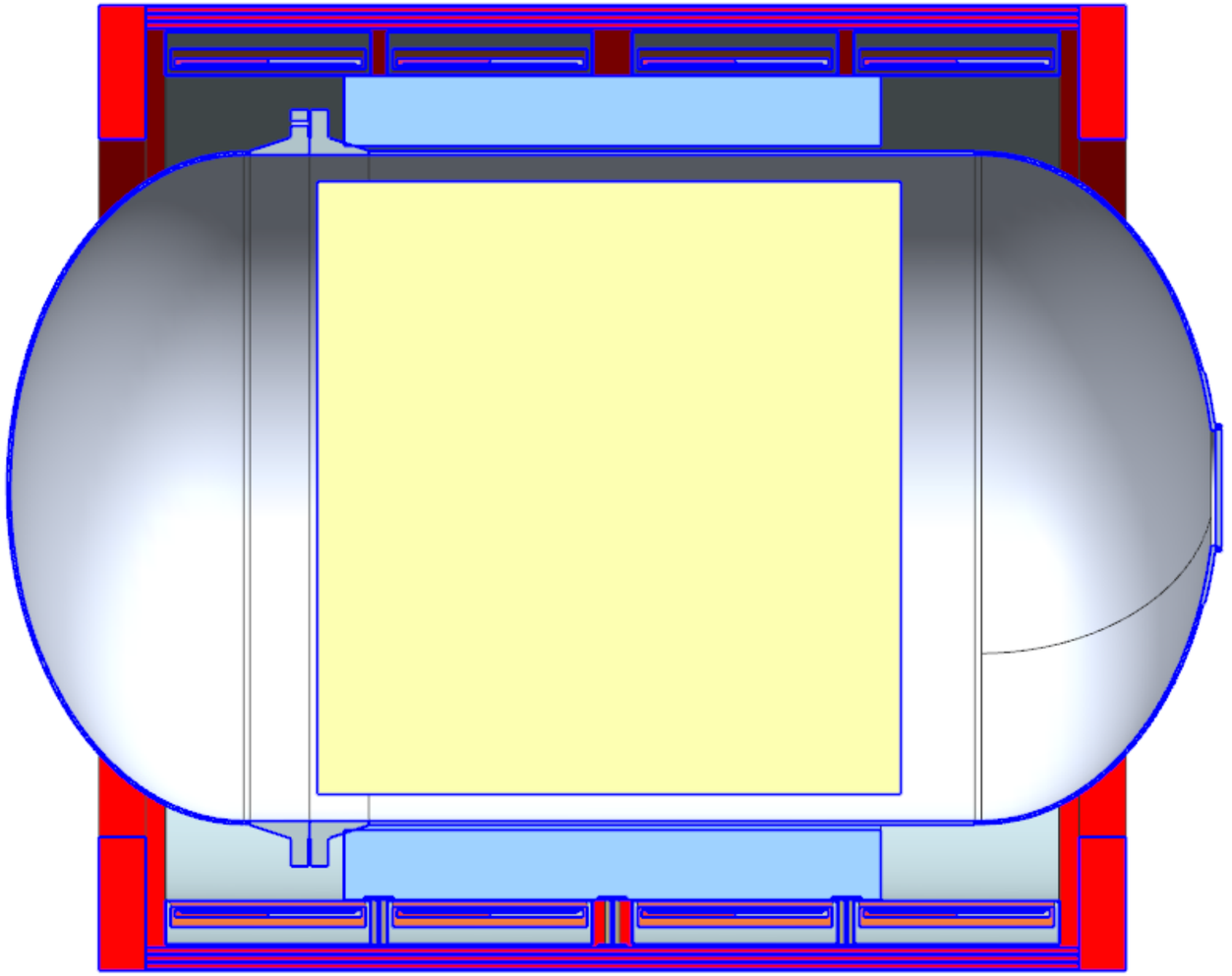
- Current density: < 35 A/mm2
  - lower than most SC magnets for HEP experiments
- Field in the TPC: 0.46 - 0.57 T
  - on 90% of the volume: ±8%
- Significant non symmetric forces on the coils
  - true for every partial yoke



The first design iteration

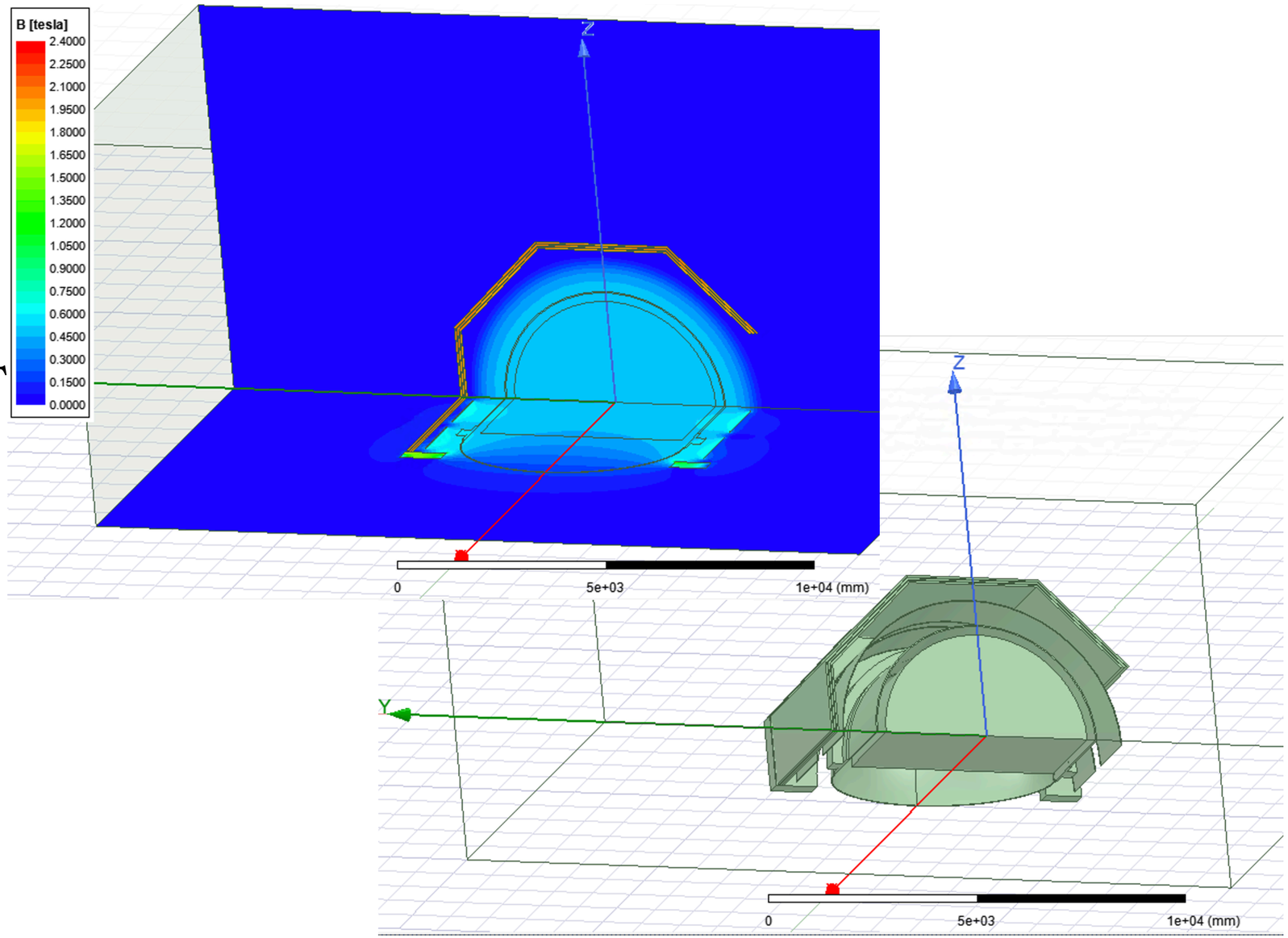
- INFN design has been shared with FNAL and we had a first iteration (thanks Don Mitchell)





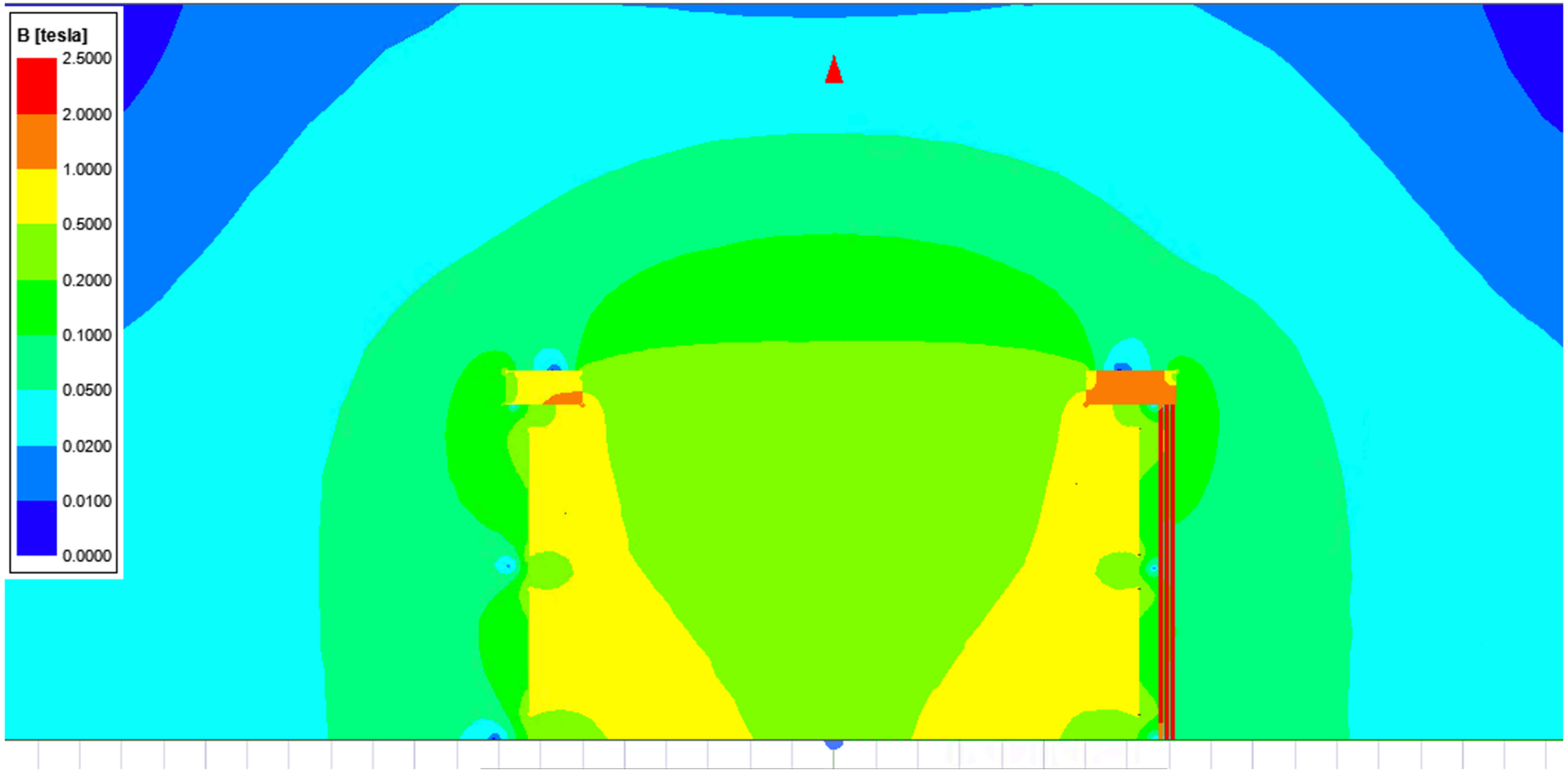
New design performances

- Current density unchanged
  - can be increased a little
- Field in the TPC: 0.425 - 0.535 T
  - lower than in previous design
  - on 90% of the volume: ±8%
- Significant non symmetric forces on the coils
  - true for every partial yoke



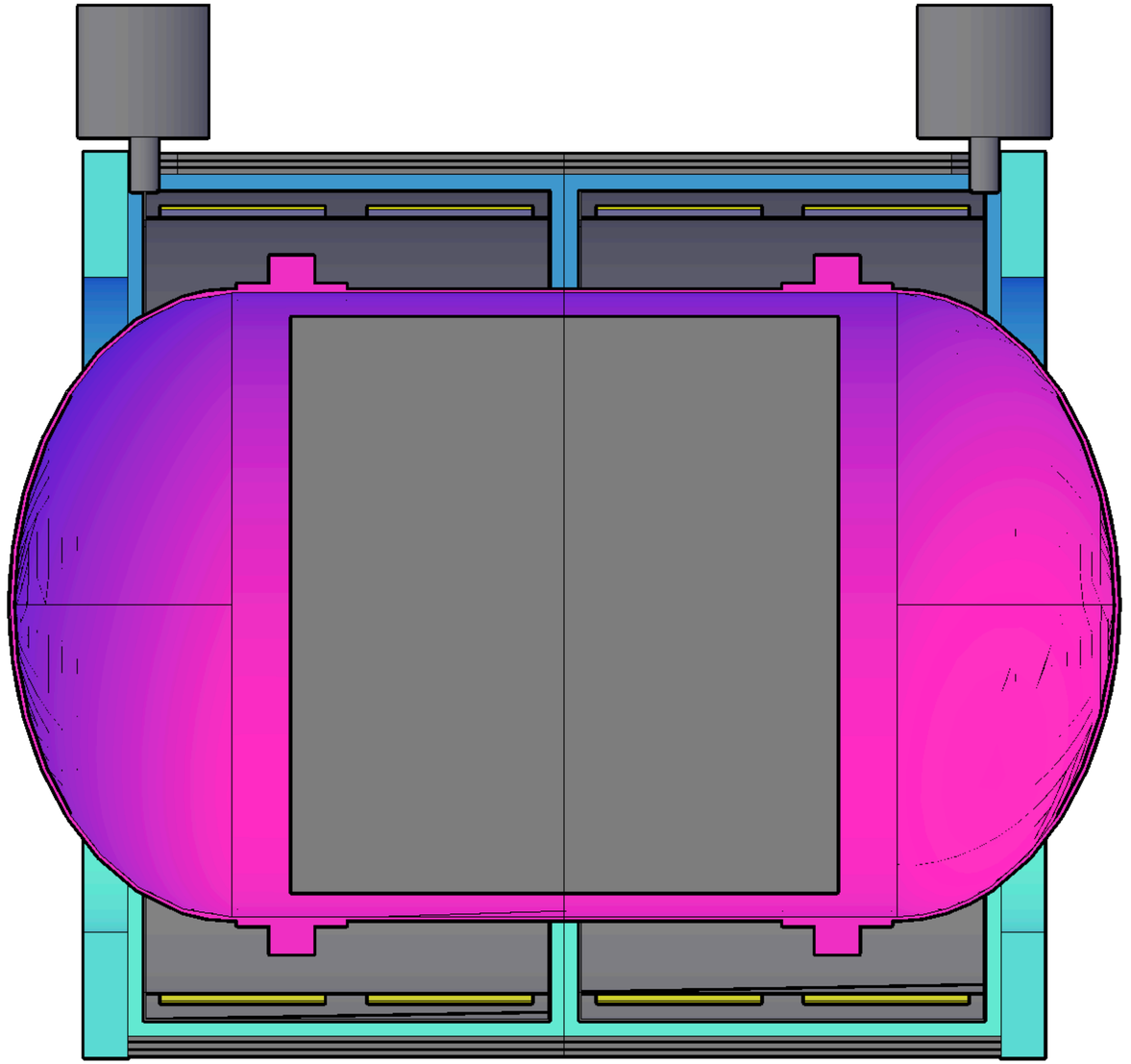
Stray field (preliminary)

- Stray field worsens
  - 0.05 T at 6m along particle path
  - it was contained downstream, 5m upstream



Possible iteration

- Don proposed 4 separate cryostats
- We can check the possibility yo have two cryostats, symmetric
  - almost identical
  - compatible with the shaft
  - high force between the coils (650t)
    - axial, attractive
  - current leads can be warm on the outside
- Can accomodate a support at the centre of the vessel



Why 2 is better than 4

- 4 cryostats need 4 independent axial suspensions vs. 2
- 4 cryostats need 4 cryogenic turrets for current leads and LHe vs. 2
  - iron yoke lamination becomes significantly complicated
  - 2 cryo turrets can be routed through slots at the end of the yoke
- 2 cryostats mean a single electrical link between the turrets easily feasible outside the yoke
- The envelope of the cryostat can be ~ 4 x 8 x 8 metres (compatible with the shaft)
- The force between the cryostats can be transferred to the yoke and compensated by spacers between the cryostats
- 3 points (ends + centre) are sufficient for the path load of the pressure vessel and calorimeter?

On the iron yoke

- The reduction of the effective section of the yoke poses several problems:
  - B containment is less effective
  - the average thickness of the yoke should be ~ 400 mm*
    - presently is ~ 120 mm
    - in previous design was ~ 240

- Adding iron on top and bottom?
  - costs and weight

* area of the solenoid ~ $(3.5\text{m})^2 \times \pi = 38.5\ \text{m}^2$
field is 0.5 T, saturation of iron occurs at ~ 2 T, iron yoke is at ~ 4 m from the magnet centre
area of iron ~ $38.5\text{m}^2 / (4 \times 8\text{m} \times \pi) = 0.4$ m
where 4 comes from 2T / 0.5T and 8m is the average diameter of the yoke

Some data for magnet fans (no news)

- 4 identical coils, single layer
- ~1500 x 20 mm^2 each
- ~3660 mm radius
- 45 MJ of stored energy
- ~100 t force w.r.t. the end caps
- Field on cable: < 1 T
- Field in iron: up to 2.1 T

- Furukawa showed interest for this cable

- NbTi SC Rutherford in pure aluminium
- SC/Cu ratio: 1:1
- Strand diameter: 0.8 mm
- Number of strands: 16
- Stabilised cable size: 20 x 11 mm^2
- Cable length: 12.7 km
- Inductance: 1.8 H
- Current: 7040 A
- Time constant on 0.1 Ohm: 18 s
- Maximum voltage: ~ 700 V

Next steps

- Iterate the work on the iron yoke
- Check the cable feasibility
- Evaluate the different schemas for the criostats
- Start a study on the construction sequence
- A dedicated meeting will be announced

Possible magnet meeting

- We would like to host a magnet meeting in Genova
- The meeting is intended to be very technical
- A visit at ASG Superconductors is possible
- A possible time slot for this meeting is 22 - 25 of April 2020
  - two complete days for discussion
  - a day for visiting ASG premises both in Genova and in La Spezia