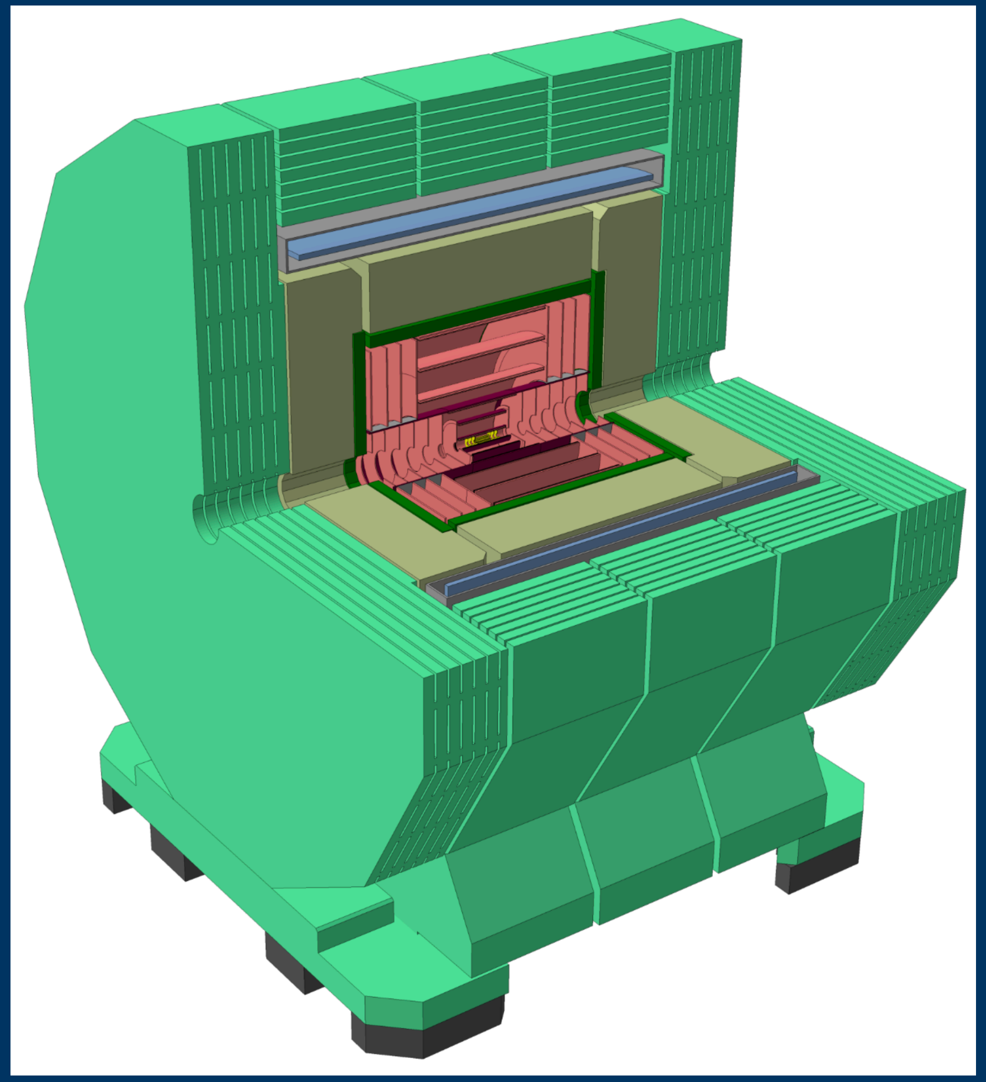
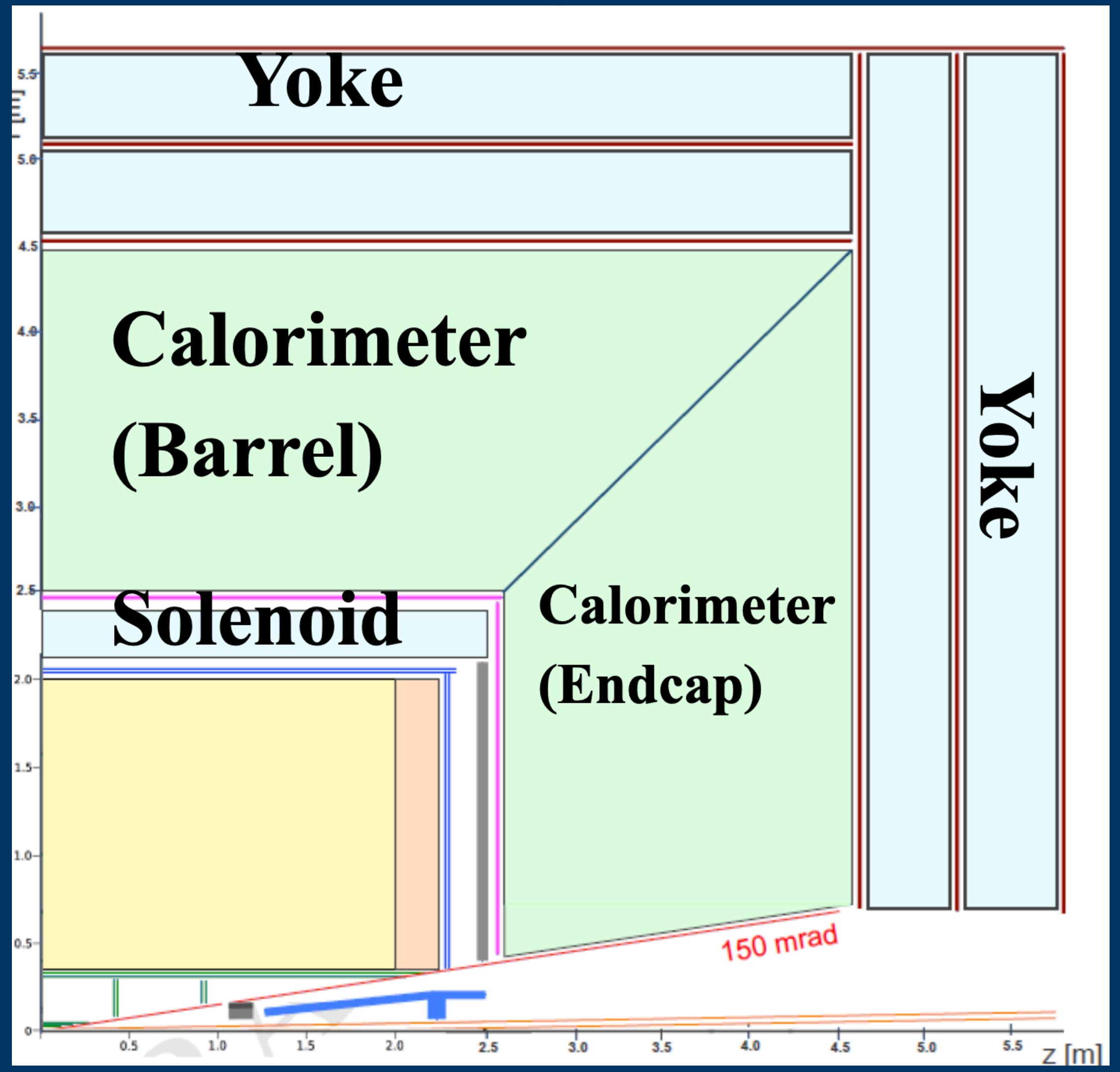
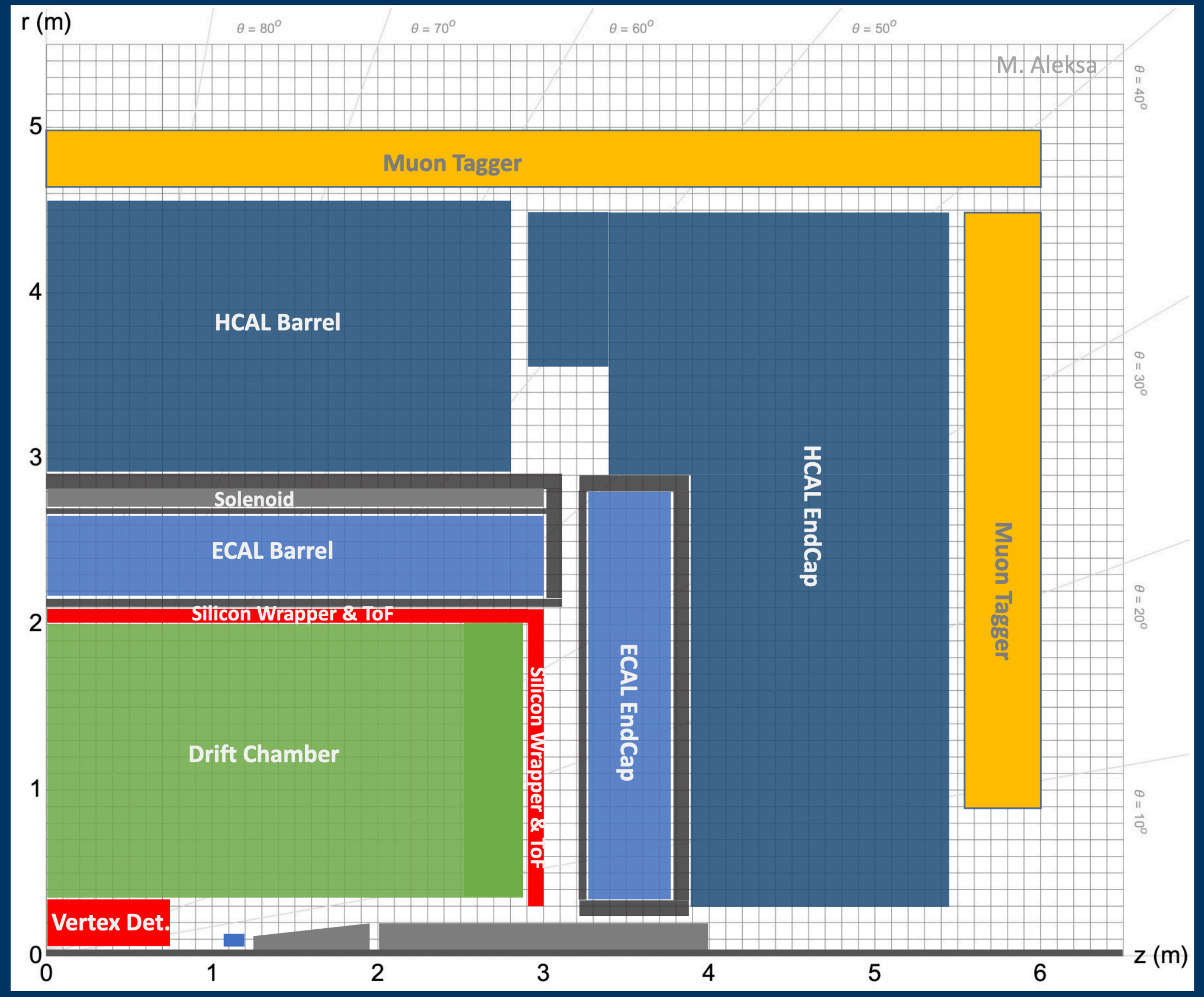
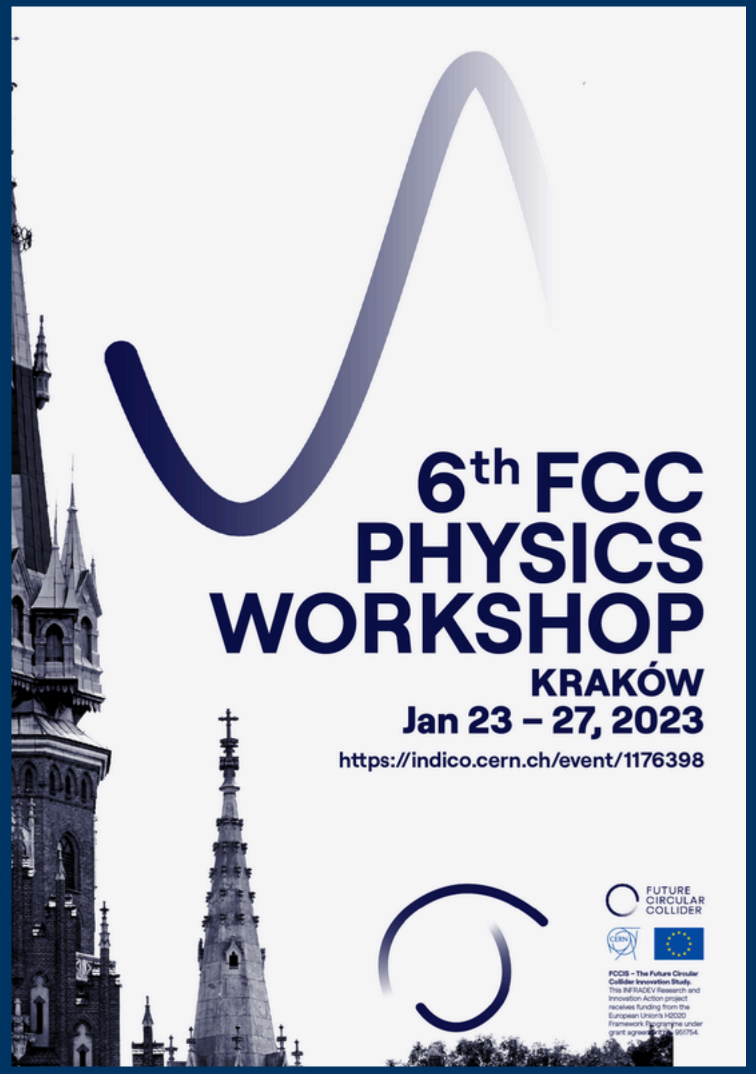
Detector Stray Magnetic Fields





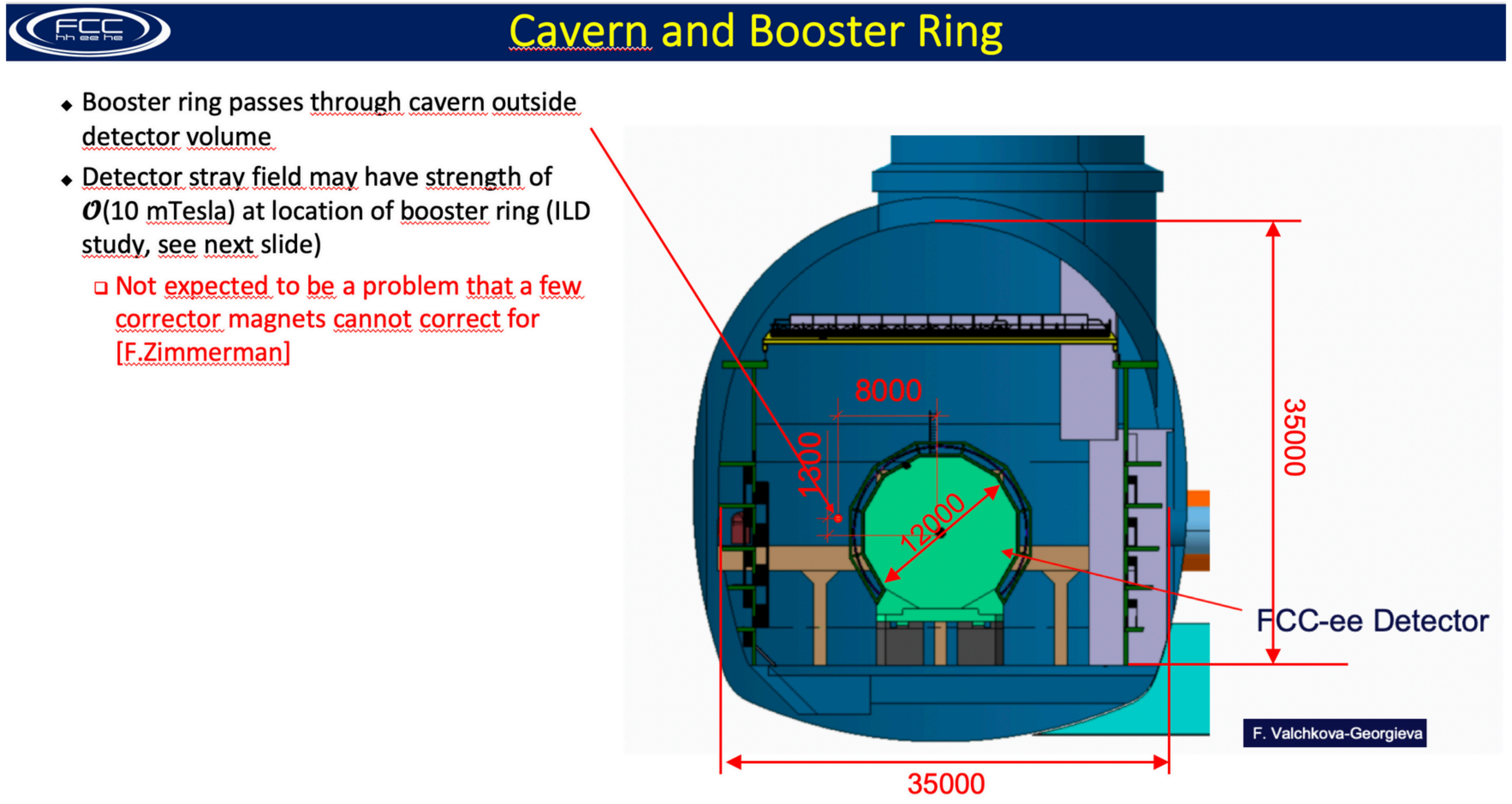




Benoit Curé, Nikkie Deelen, Alexey Dudarev, Matthias Mentink - EP Magnet Team - 25.01.2023

Introduction

- During feasibility study the position of the booster in IR is investigated
- At the booster position, the magnetic field in should not exceed 10 mT
- During this talk the B-field of the detector magnets is discussed, and the resulting stray field at the booster position:
  x,y = [8, 1.3] m / x,y = [7, 1.3] m



Three concepts for FCC-ee detectors

Content of the talk

1. CLiC-Like Design **(CLD):** Solenoid, steel in HCal, and iron yoke;

2. International Detector for Electron-positron Accelerators **(IDEA):** Solenoid, steel in HCal, iron yoke;

3. Liquid Calorimeter Design **(LCalo):** Solenoid, steel in HCal

1. CLiC-Like Detector

1.1 CLD solenoid concept

- Solenoid producing a **2T field in the center** of the detector volume
- Made with Al-stabilised NbTi conductor, in two layers of 300 turns
- Operating current is 20 kA, operating temperature is 4.5 K
- Stored energy of 600MJ, cold mass weight of 52 t
- **Energy density of 11.6 kJ/kg**

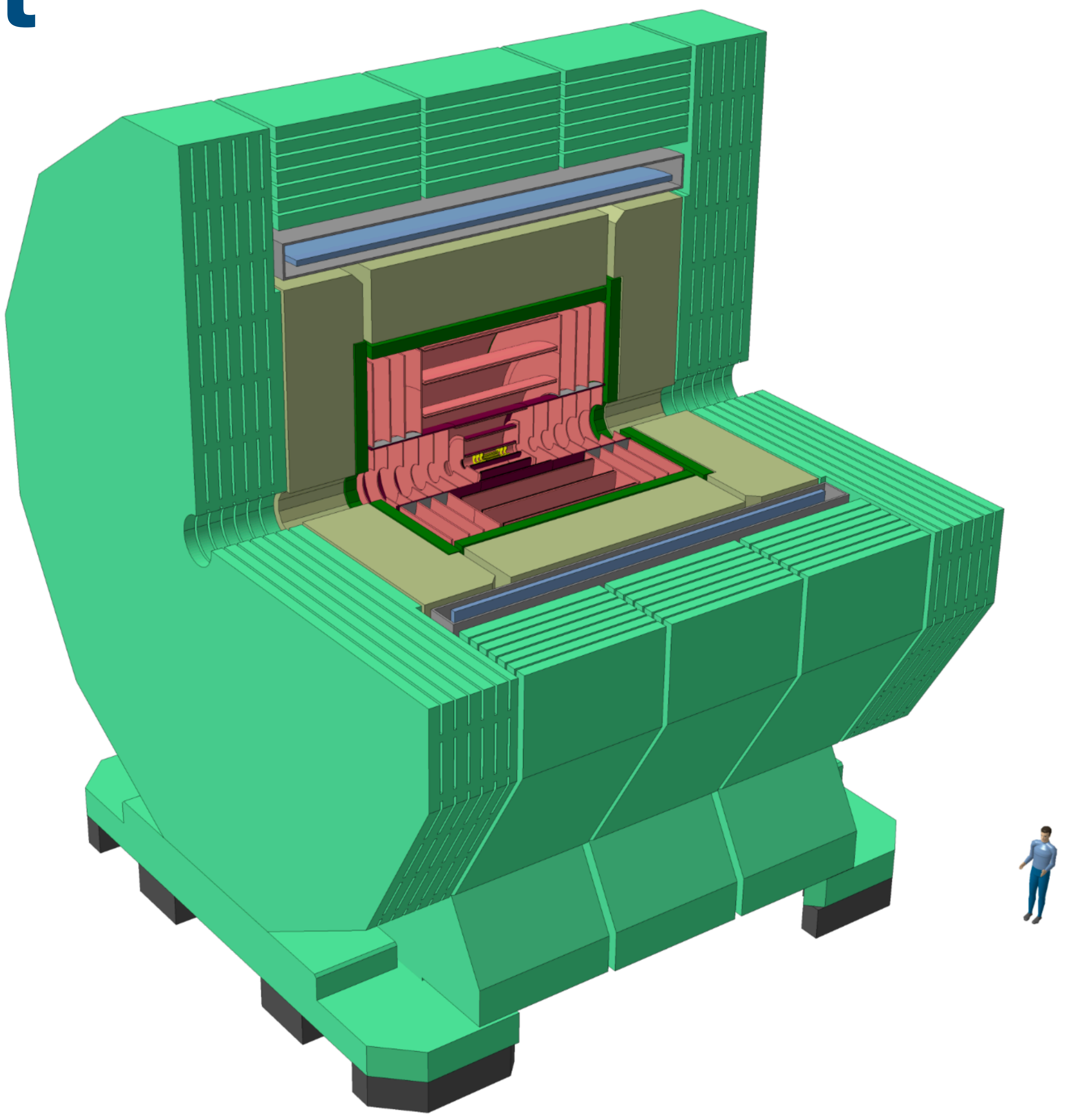
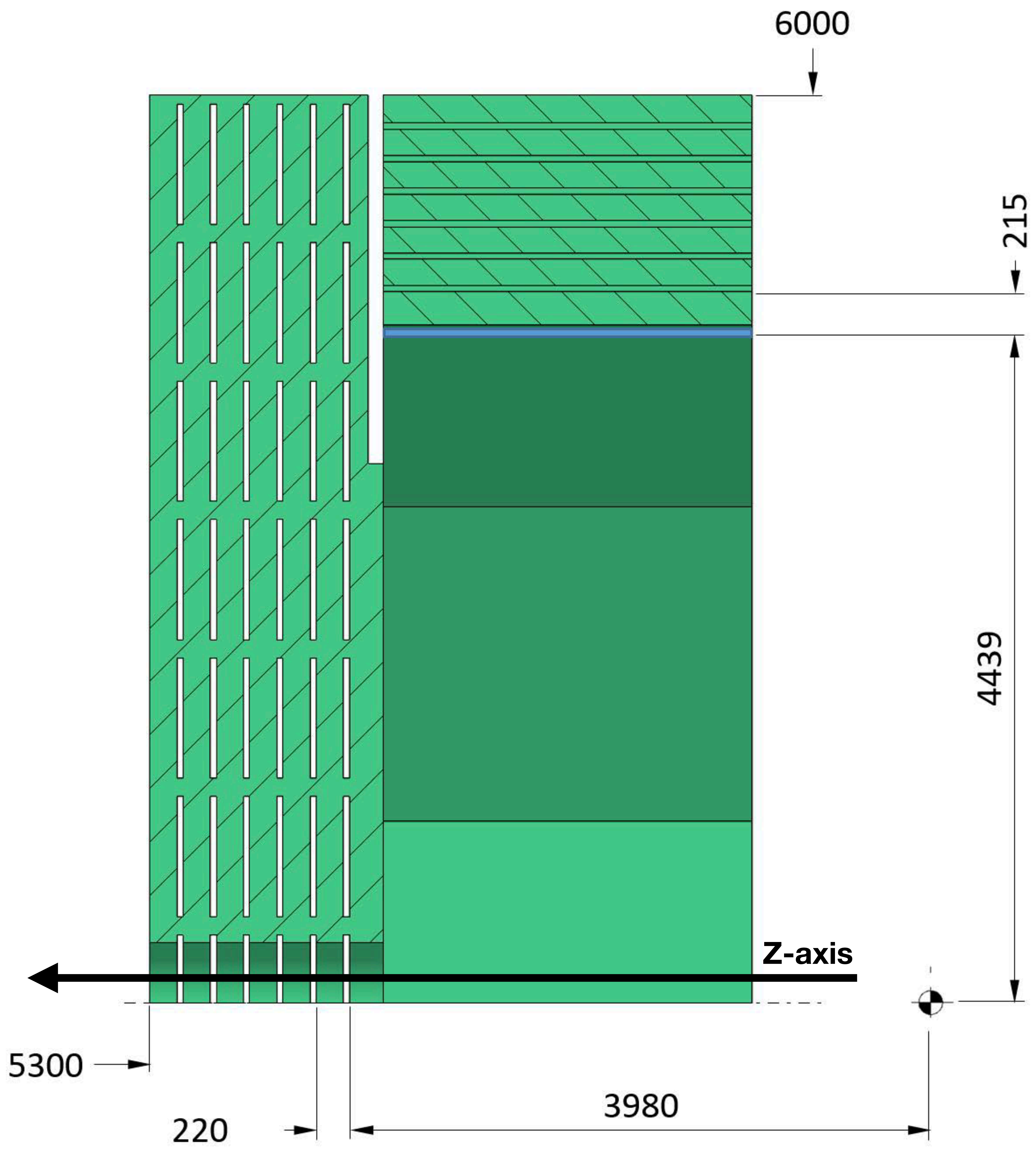


Figure 1: Isometric view of the CLD detector, with one quarter removed.

https://arxiv.org/abs/1911.12230

http://dx.doi.org/10.1109/TASC.2022.3149682

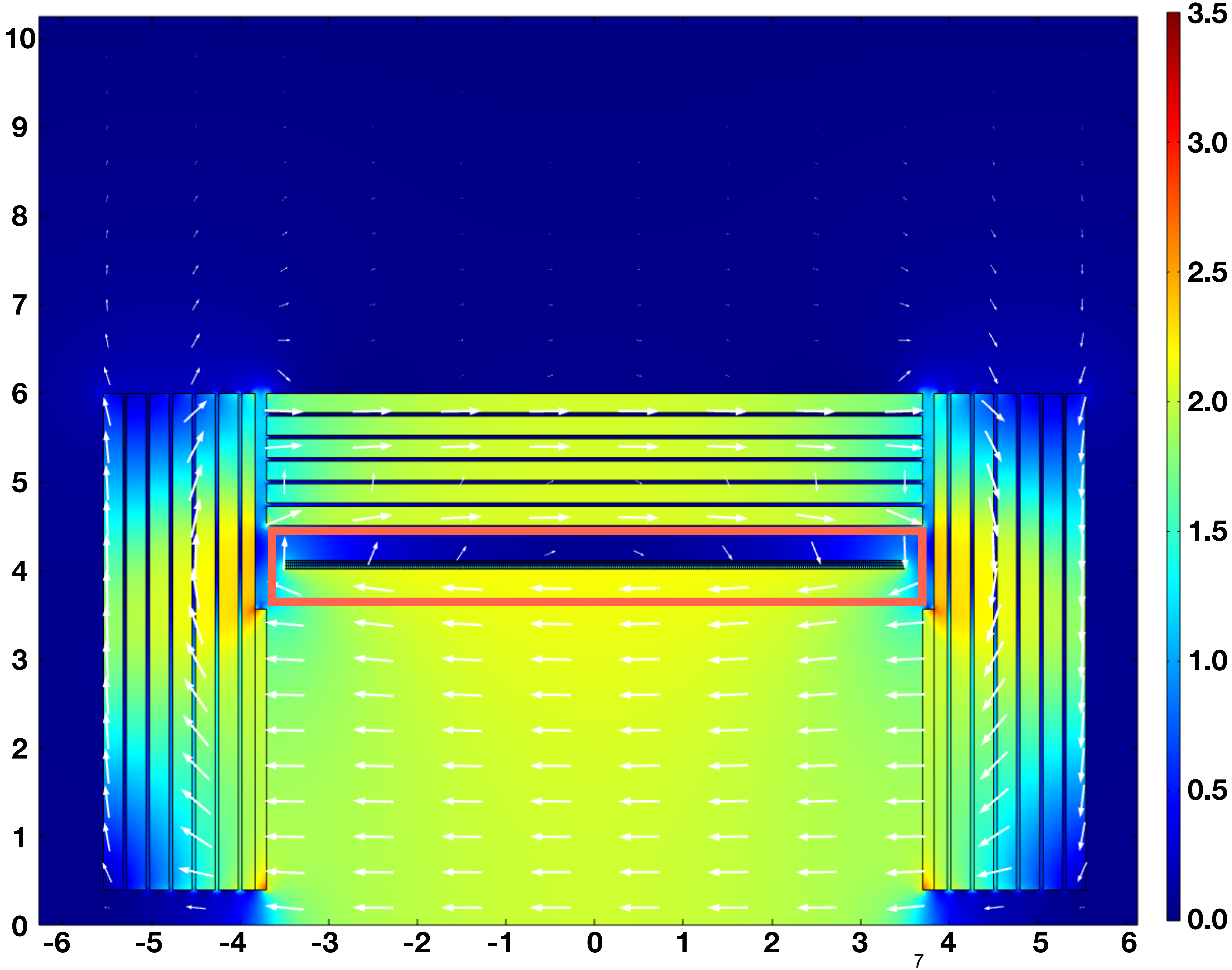
1.2 CLD: details on iron yoke



- 7 layers of **magnetic steel**
- In between 6 layers of RPC: **40 mm gap** for each layer
- Barrel layers have 177 mm of steel, end-cap layers 210 mm
- Weight **~ 4.5 kton**

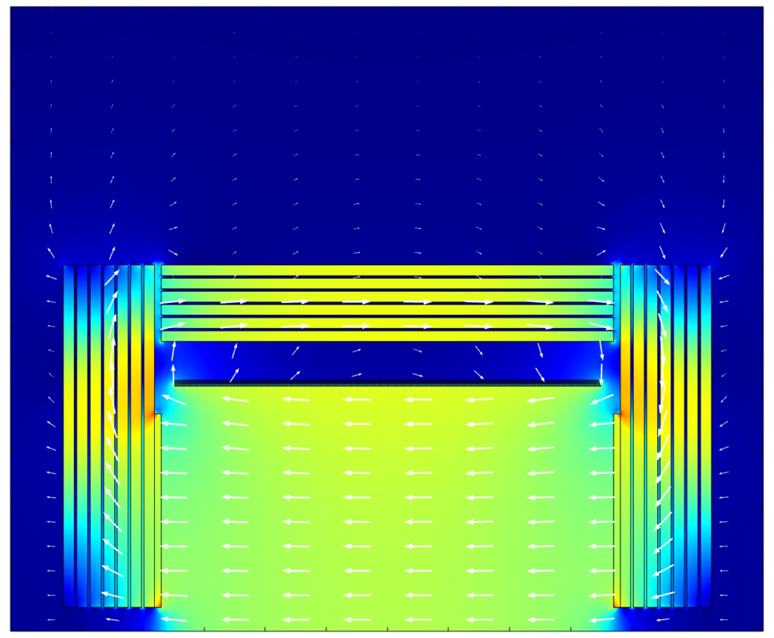
https://arxiv.org/abs/1911.12230

1.3 CLD Field Map

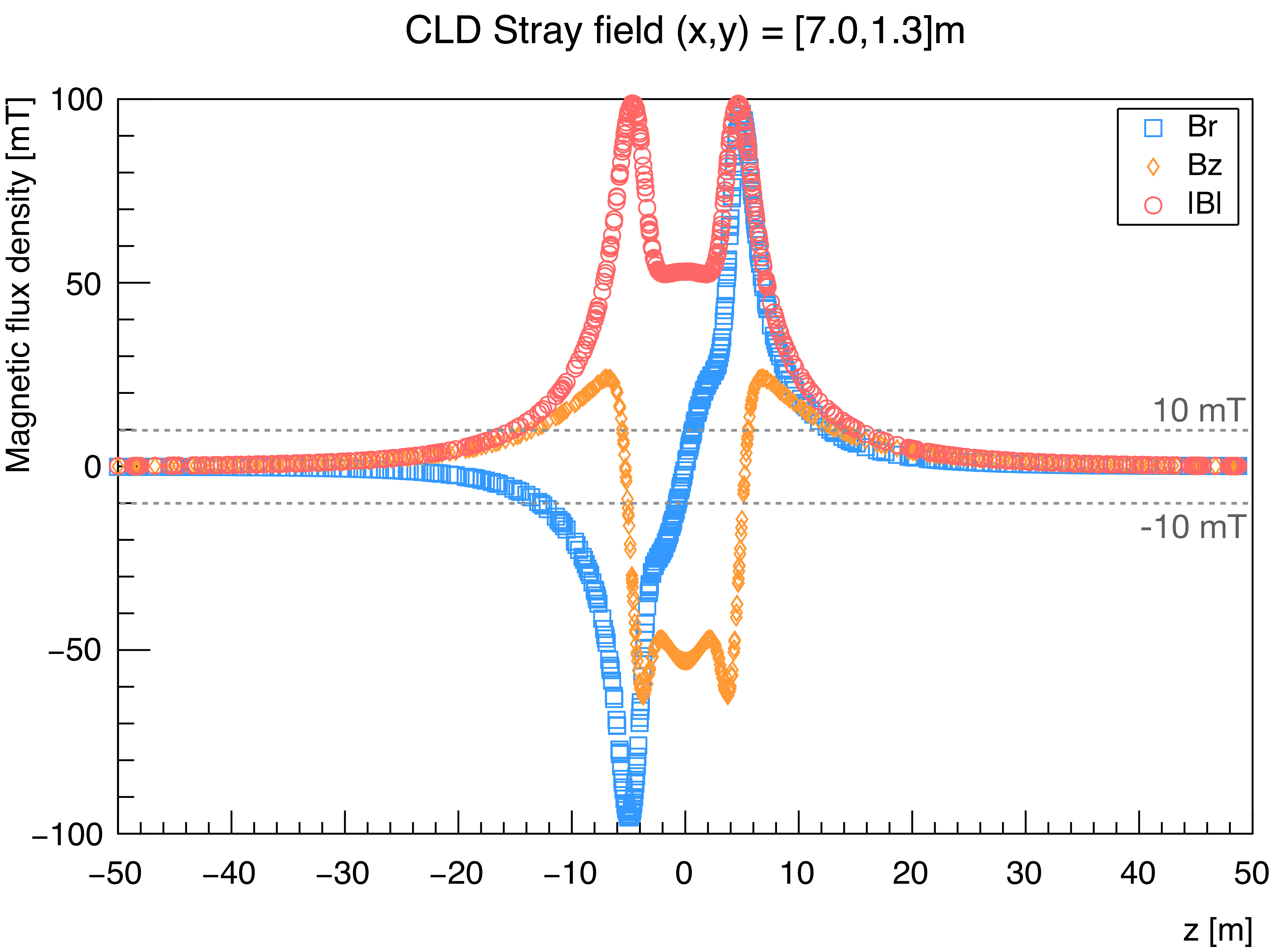


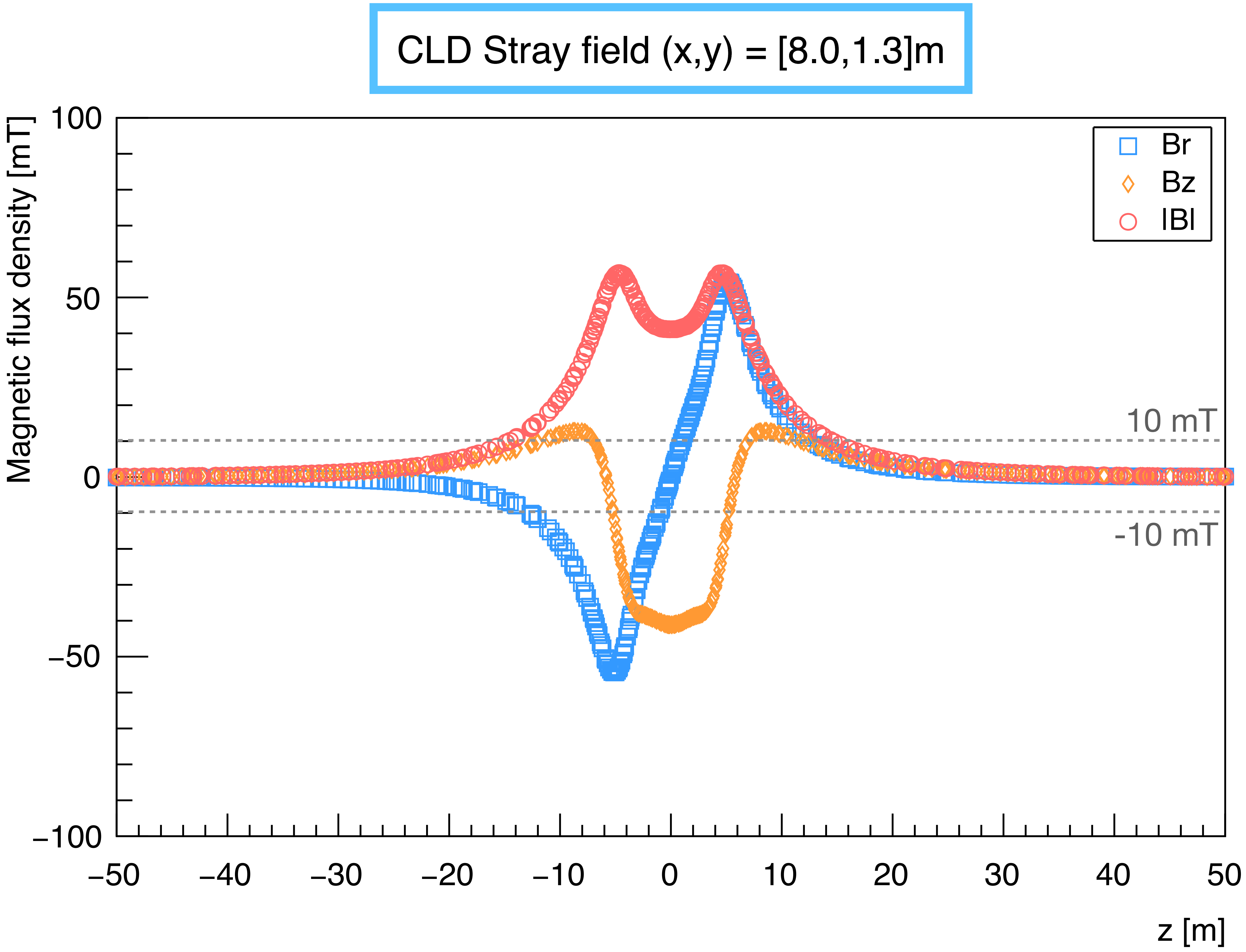
- Axisymmetric model in COMSOL®
- Only solenoid and magnetic steel are modelled for the purpose of the (stray) field calculation

1.4 CLD Stray field



- Stray field calculated at 8 m and 7 m for different booster positions, parallel to the z-axis



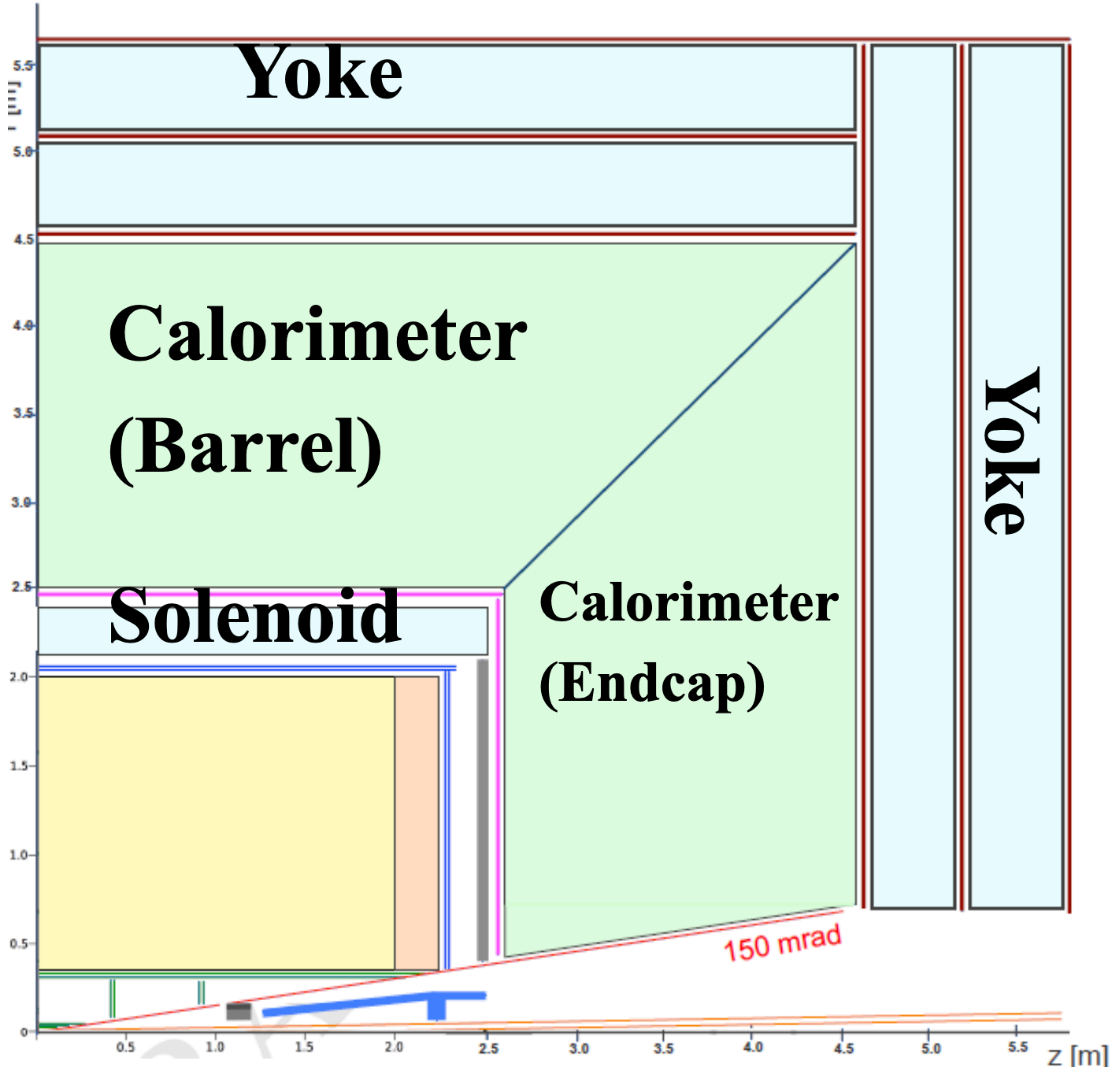


2. International Detector for Electron-positron Accelerators

2.1 IDEA: solenoid parameters (concept)

http://dx.doi.org/10.1109/TASC.2022.3149682

- Solenoid producing a **2T field in the center** of the detector volume
- Made with Al-stabilised NbTi conductor, in one layers of **436 turns**
- Operating current is 20 kA, operating temperature is 4.5 K
- **Energy density of 12.3 kJ/kg**
- Two yoke layers, **500 mm thick,** weight ~ 3.9 kton
- Dual readout calorimeter with **55 % steel,** weight ~ 1.5 kton



2.2 IDEA: the dual-readout calorimeter

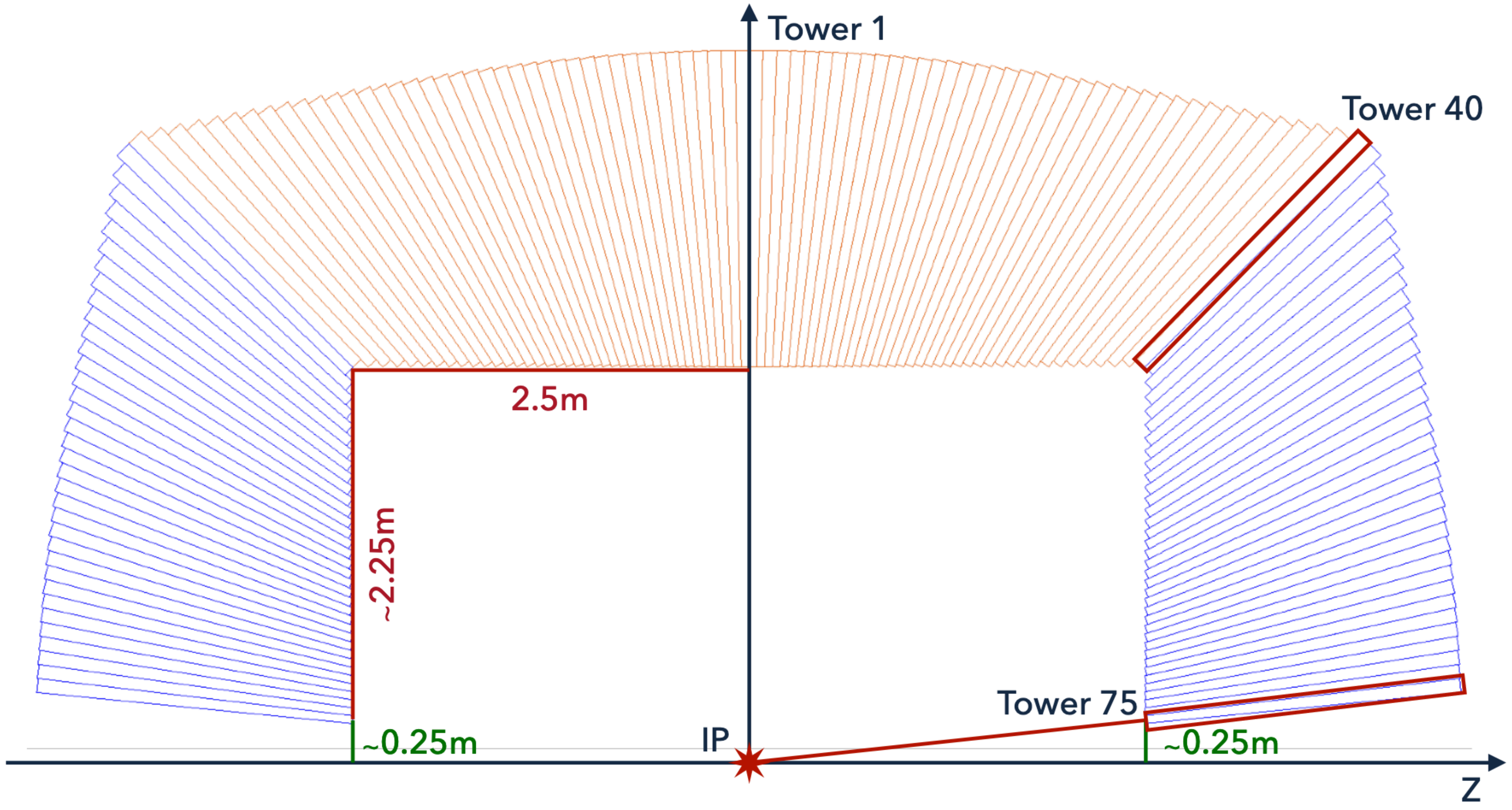
M. Antonello, L. Pezzotti, E. Prosperio, "DR calorimeter full simulation geometry", Bologna - June 2019

Slice details

Each *slice* has ***150*** towers: **Δϑ = *1.125°*** (0.0196 rad) - Tower height ***2m.***

Barrel: 40*2 = 80 towers - Inner length: 2.5m.

Endcap: 35*2 = 70 towers - Inner length: 2.25m - up to ~***0.100 rad.***

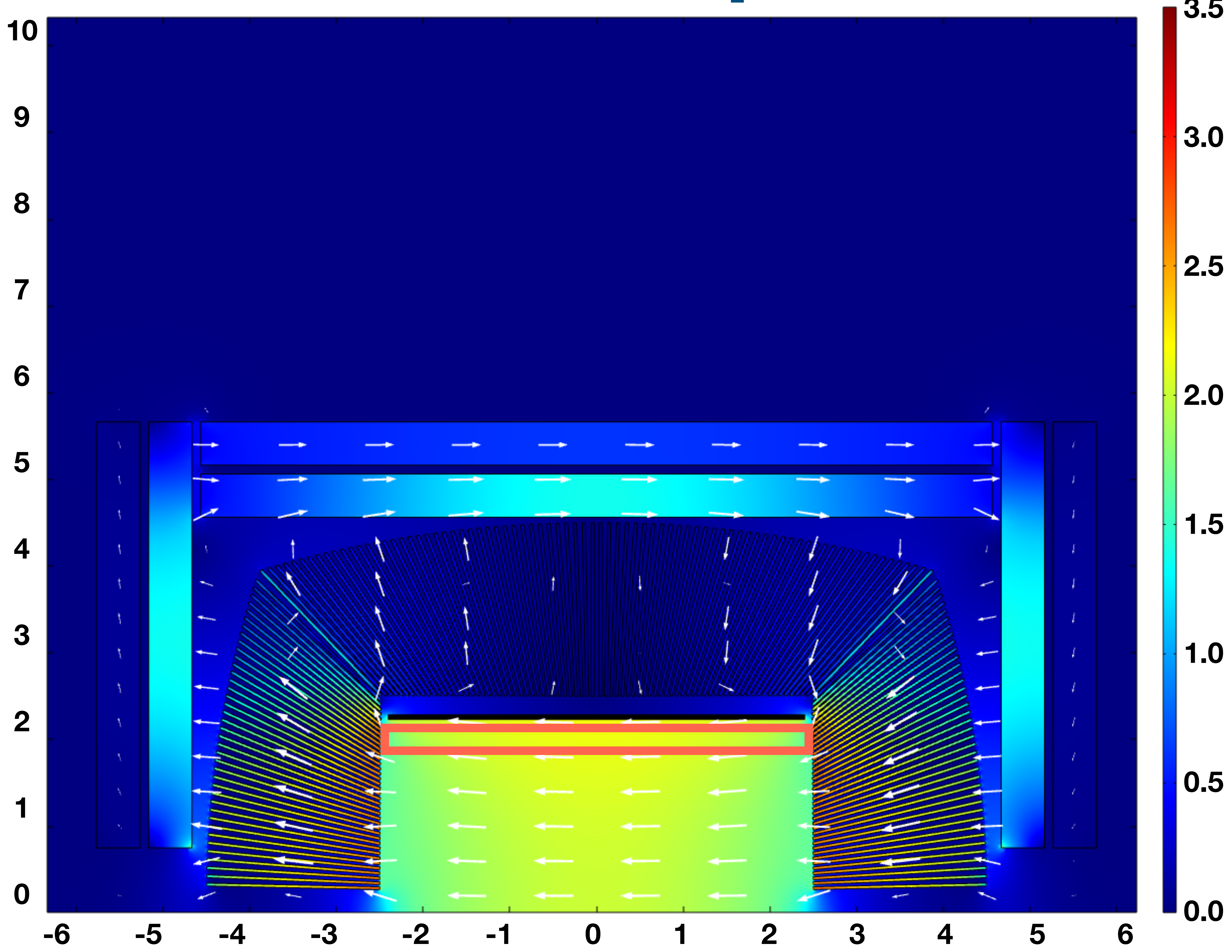


- 55 % fill-factor assumed **(55 % magnetic steel)** for the (stray) field calculations

Assumptions:

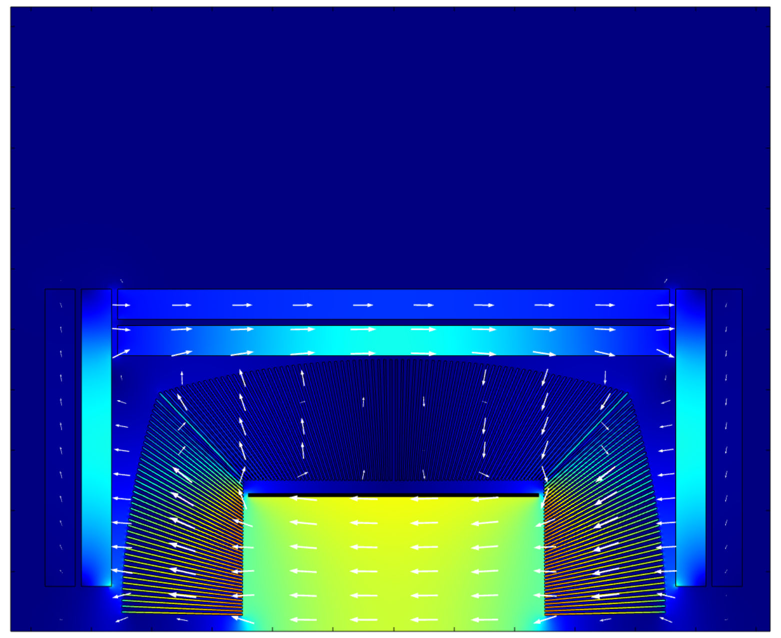
- Iron layer thickness barrel: **34 mm** (28 mm gap)
- Iron layer thickness end-cap: **35 mm** (29 mm gap)

2.3 IDEA Field Map

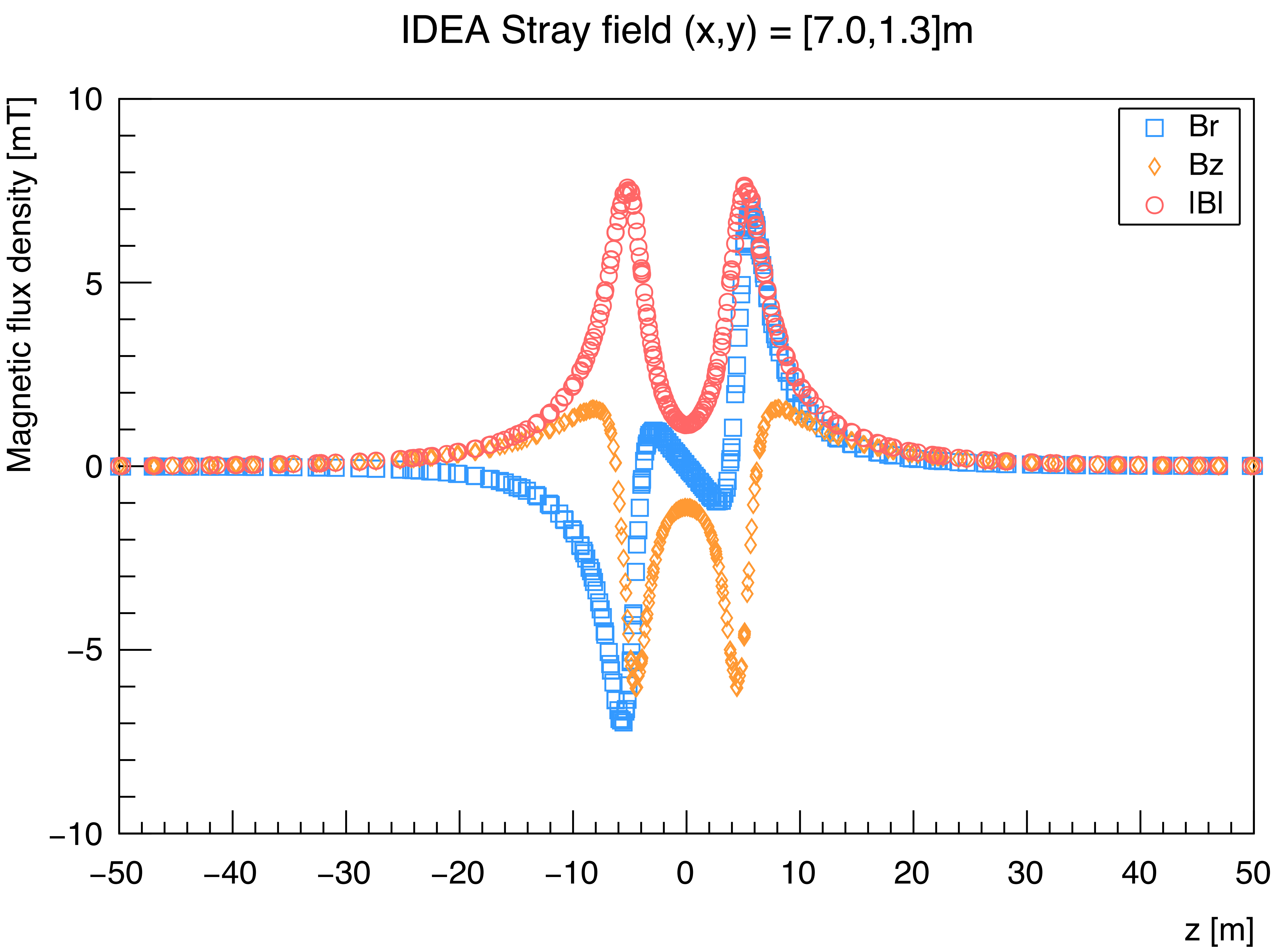


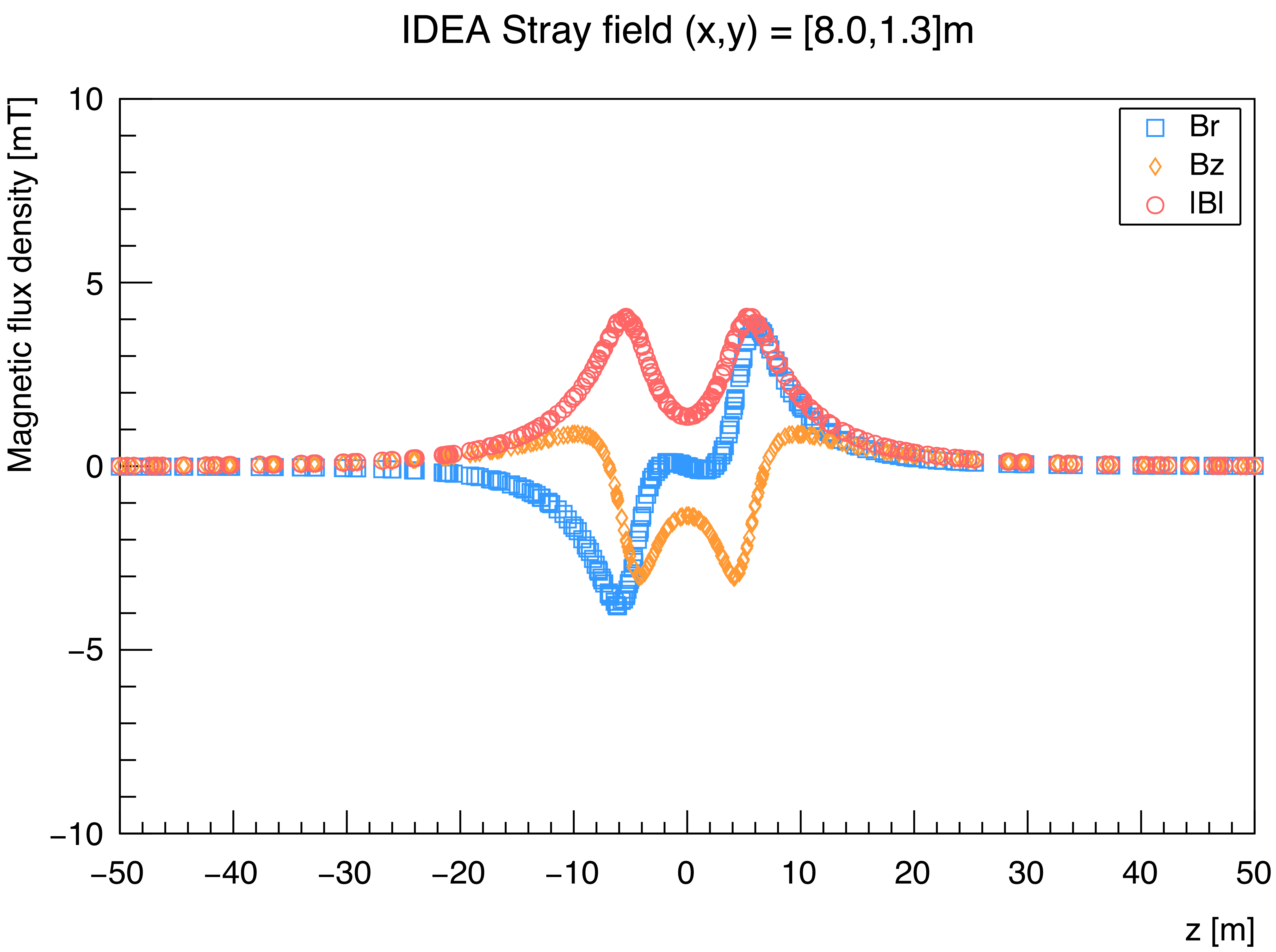
- Axisymmetric model in COMSOL®
- Only solenoid and magnetic steel are modelled for the purpose of the (stray) field calculation

2.4 IDEA Stray Field



- Stray field calculated at 8 m and 7 m for different booster positions, parallel to the z-axis



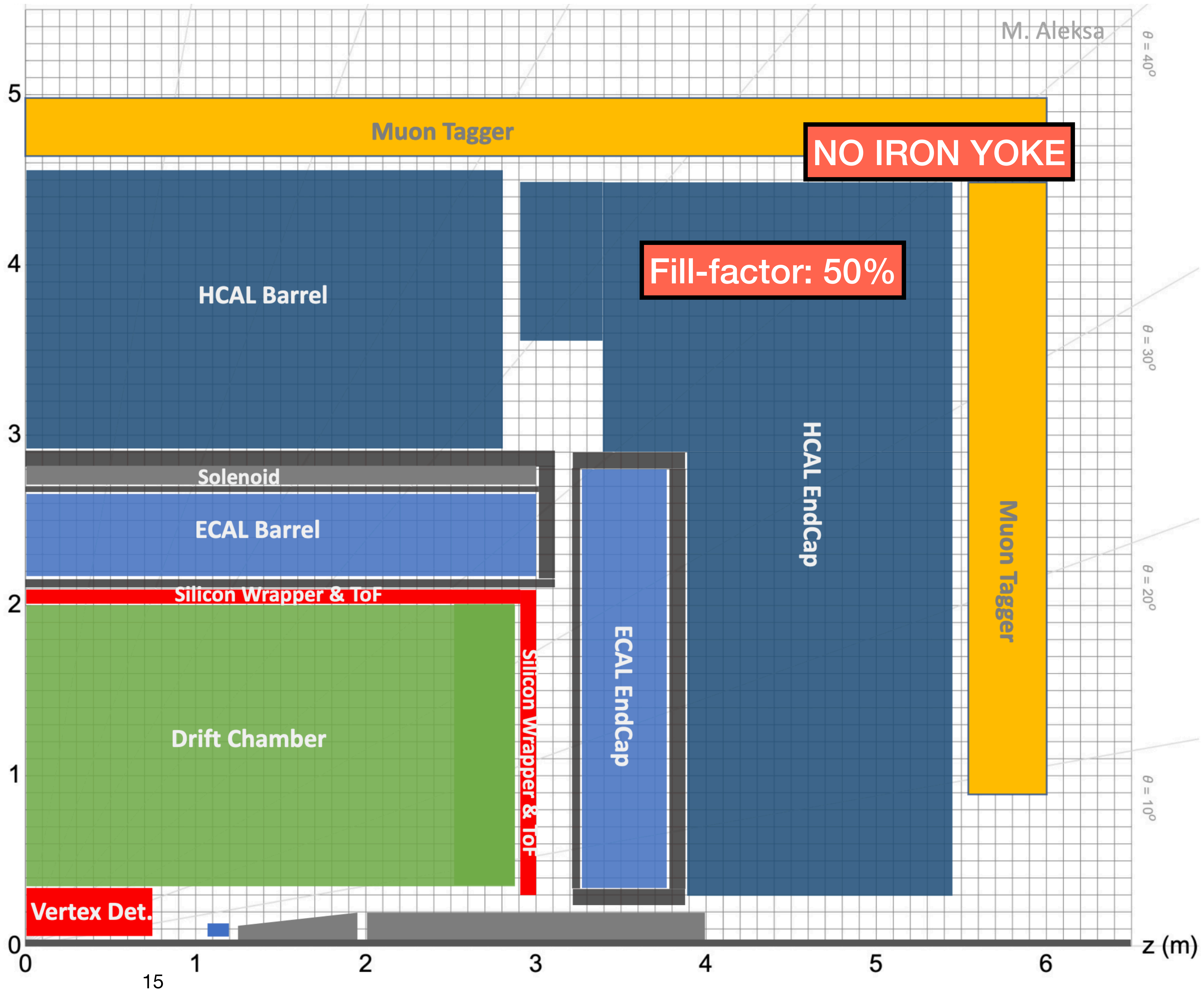


3. Liquid Calorimeter design

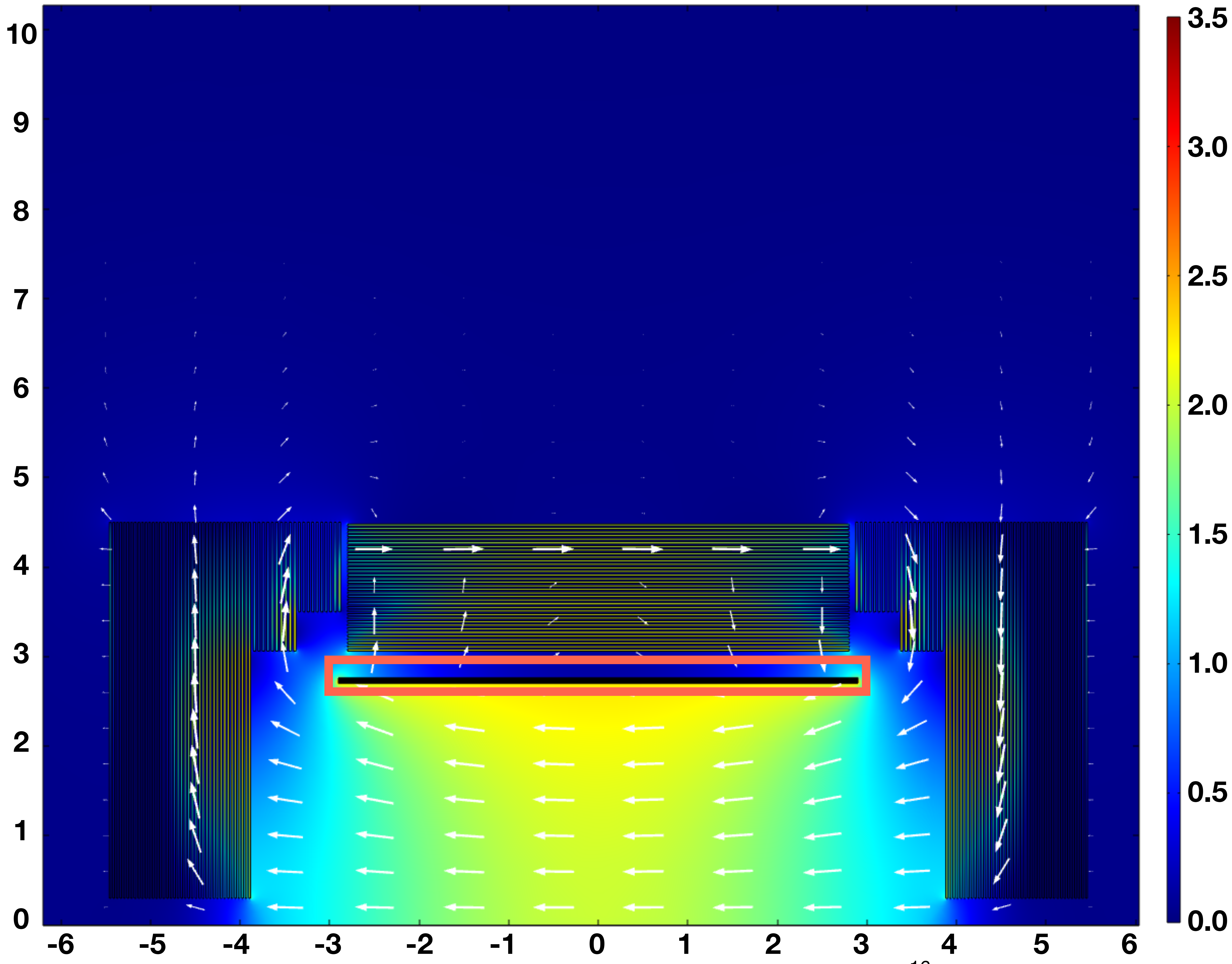
3.1 LCalo Design: important parameters

Magnet CONCEPT:

- Solenoid @ R = 2.7 m producing a **2T field in the center** of the detector
- Made with Al-stabilised NbTi conductor, one layer, 562 turns
- Operating current 20 kA, operating temperature 4.5 K
- *Stored energy of ~250MJ, cold mass weight of ~20 t*
- **No yoke,** iron in HCal with **fill-factor 50%,** weight ~ 1.8 kton

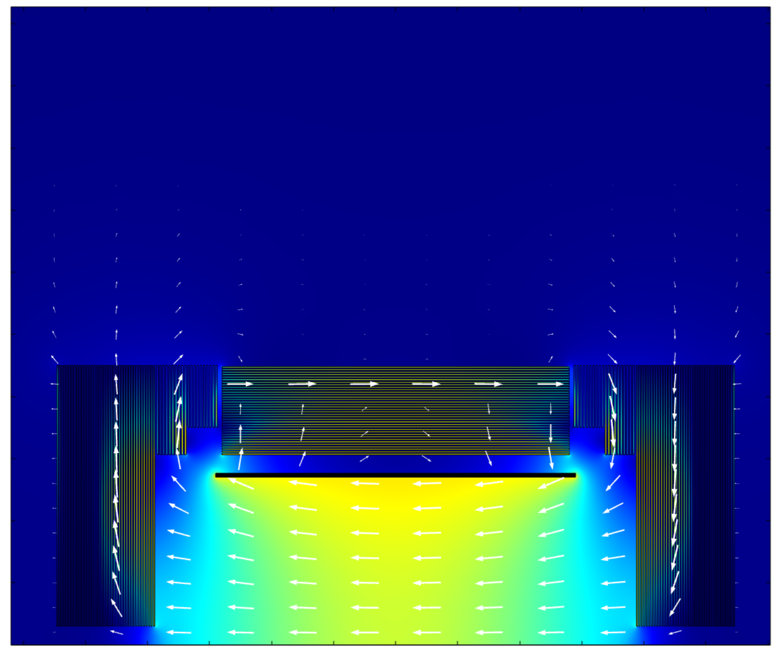


3.2 Lcalo Field Map

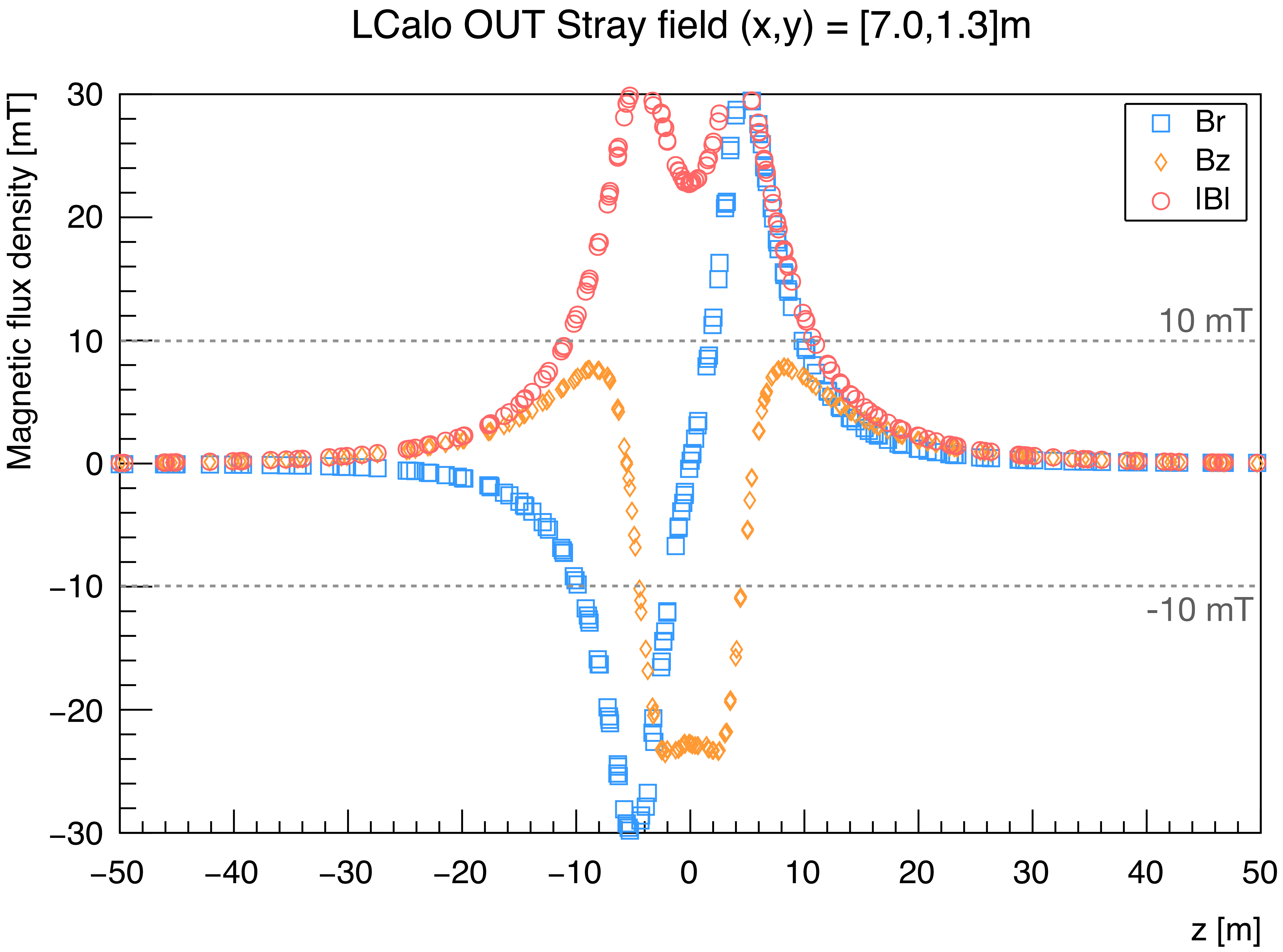


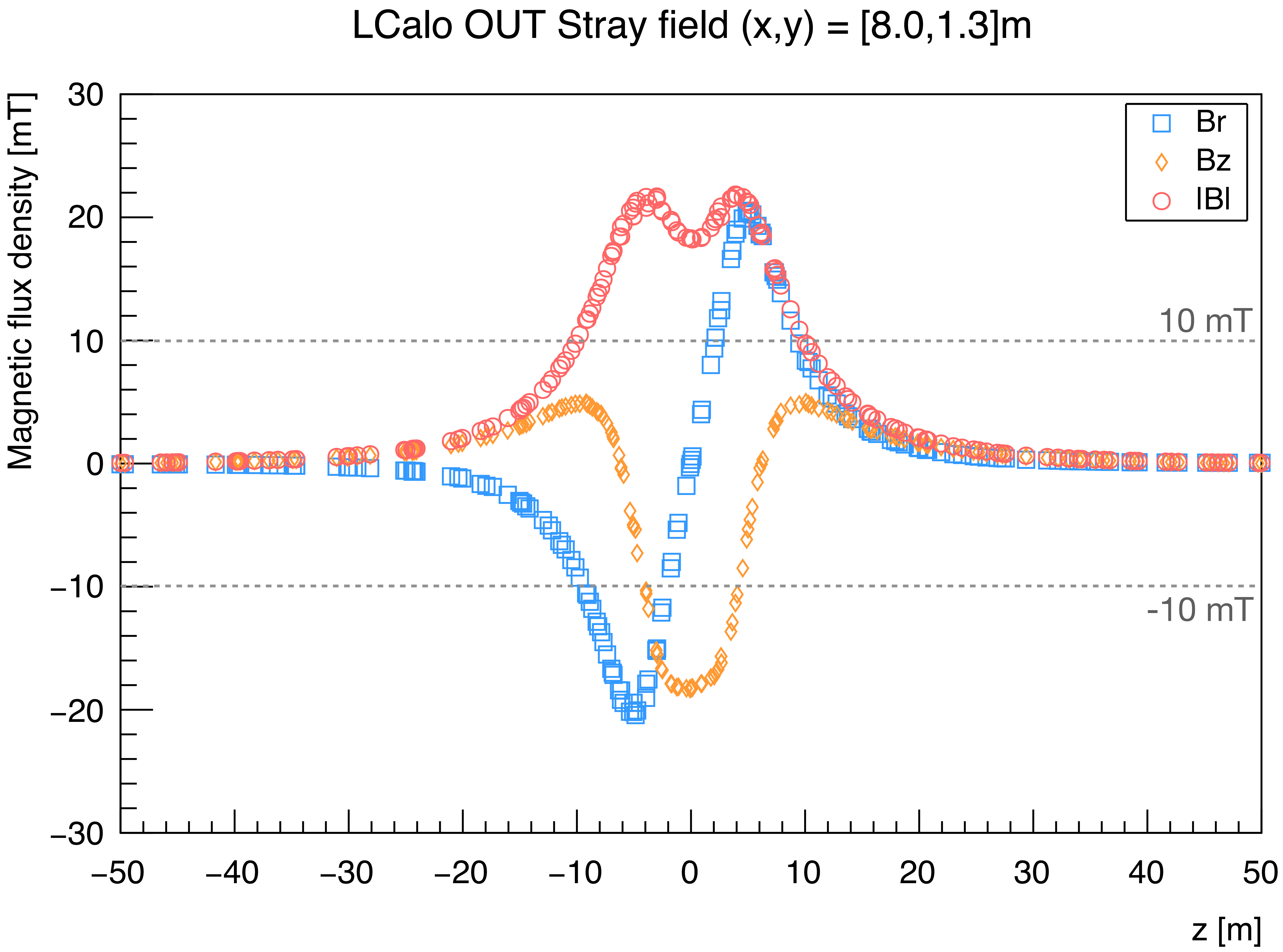
- Axisymmetric model in COMSOL®
- Only solenoid and steel are modelled for the purpose of the stray field calculation
- Assumed **36** steel layers in barrel, **20 mm thick** with 20 mm gap
- Assumed **25 mm thick** layers in end-cap with 25 mm gap
- **NLayers** small ring: 10, big ring 10, end-cap 40

3.3 LCalo Design Stray field



- Stray field calculated at 8 m and 7 m for different booster positions, parallel to the z-axis



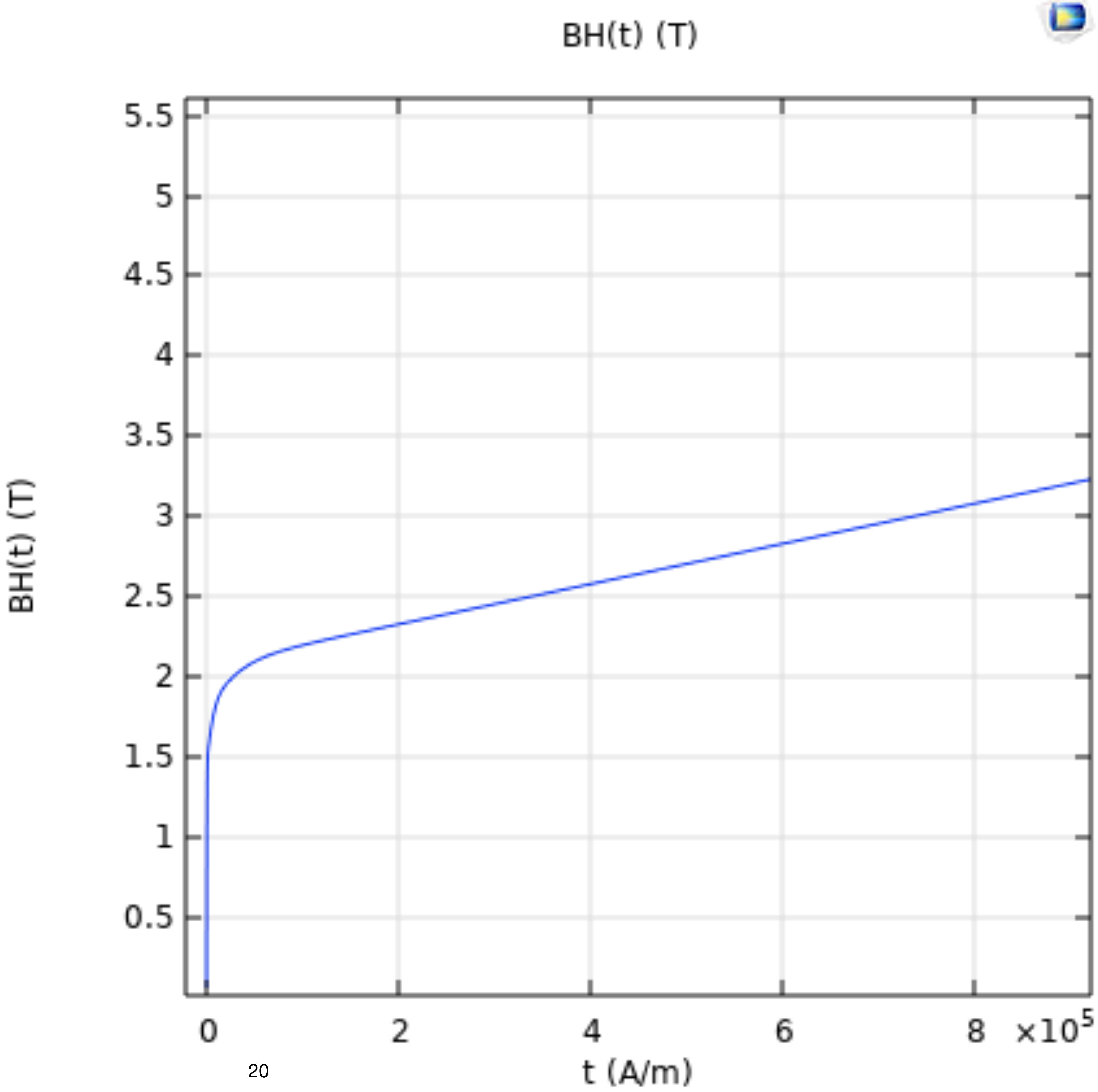


Conclusions

- Maximum stray field for CLD is almost 4-5 x higher than 10 mT @ x = 8 m. Magnet has largest bore, and highest magnetic flux.
- IDEA maximum stray field is ~5 mT, well below 10 mT @ 8 m, and below 10 mT @ 7 m as well.
- LCalo Design stray field ~20 mT @ 8 m, but there is no iron yoke.
- Compensation solenoids in the interaction region are not included yet, design of those magnets is ongoing by M. Koratzinos.

Back-up slides

Back-up: HB-curve



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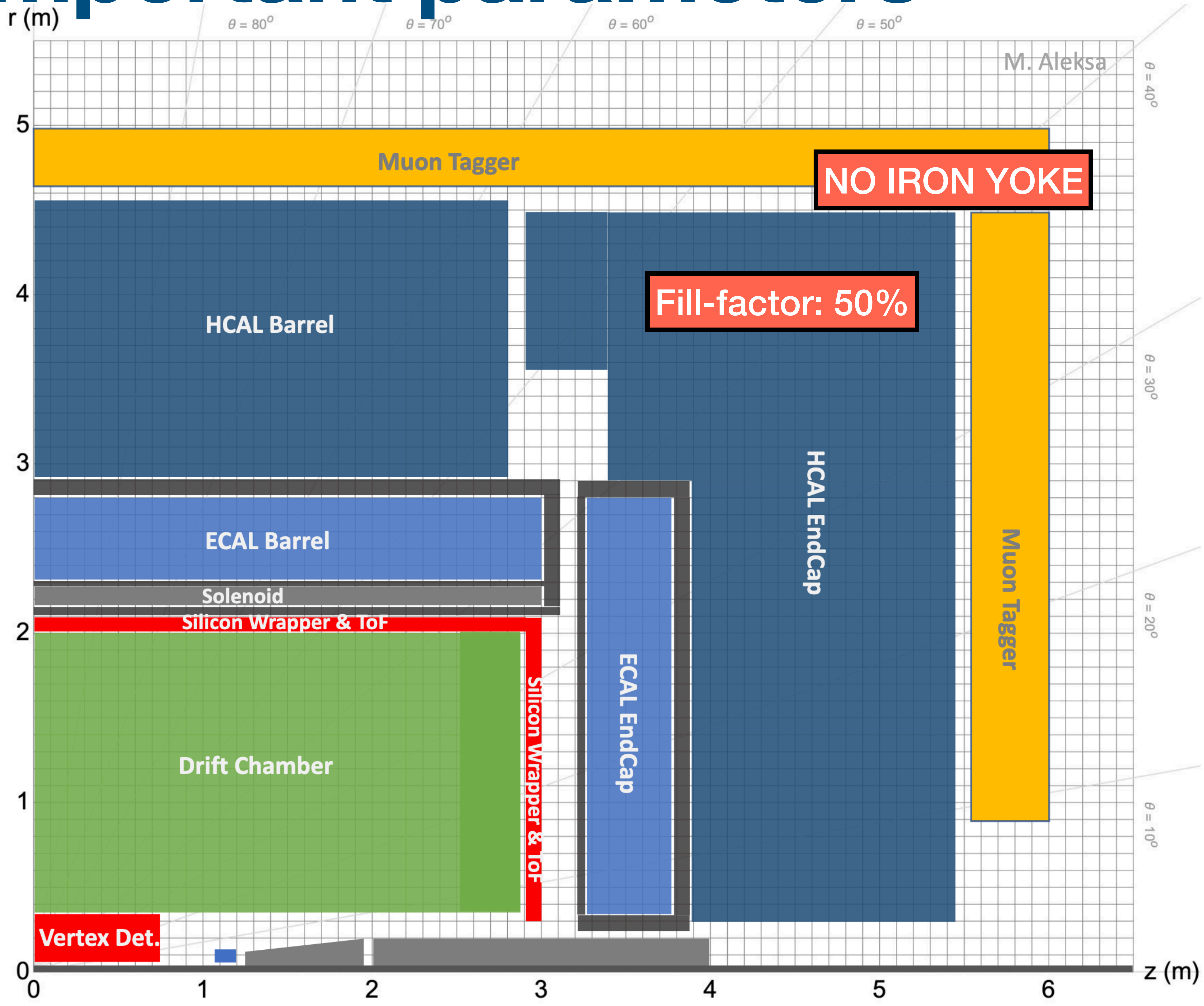
- Made with Al-stabilised NbTi conductor, one layer, 562 turns
- Operating current 20 kA, operating temperature 4.5 K
- Stored energy of ~250MJ, cold mass weight of ~20 t
- **No yoke, iron in HCal with fill-factor 50%**



3.3 LCalo Design Stray field, solenoid inside

- Stray field calculated at 8 m and 7 m for different booster positions, parallel to the z-axis