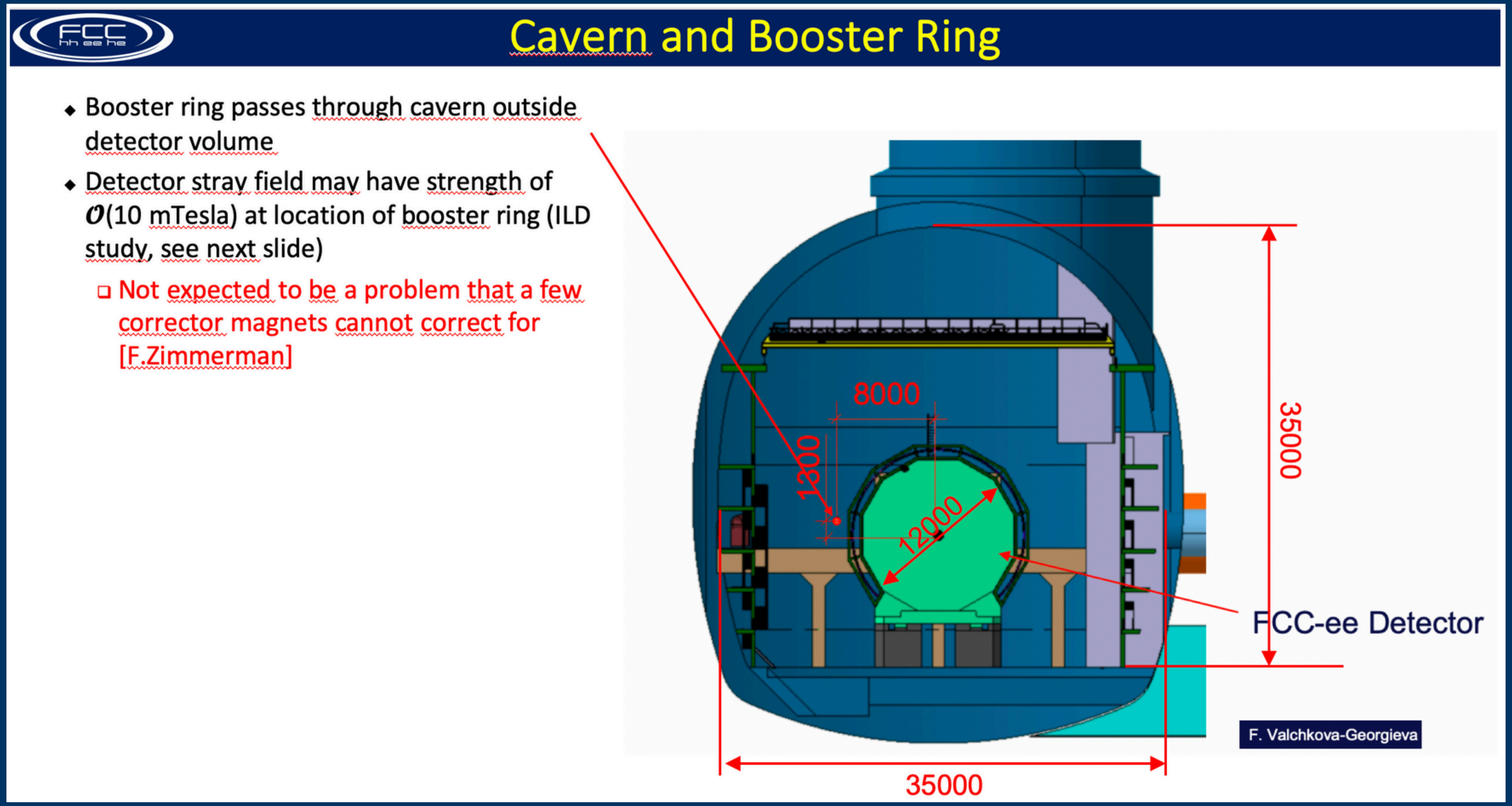
Magnetic Field Maps and Stray Field of the FCC-ee Detectors



Nikkie Deelen, Matthias Mentink, Alexey Dudarev, Benoit Curé - EP Magnet Team - 15.12.2022

Three concepts for FCC-ee detectors

Content of the talk

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

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

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

CLiC-Like Detector

1. CLD: important parameters

https://arxiv.org/abs/1911.12230

HCal is non-magnetic steel

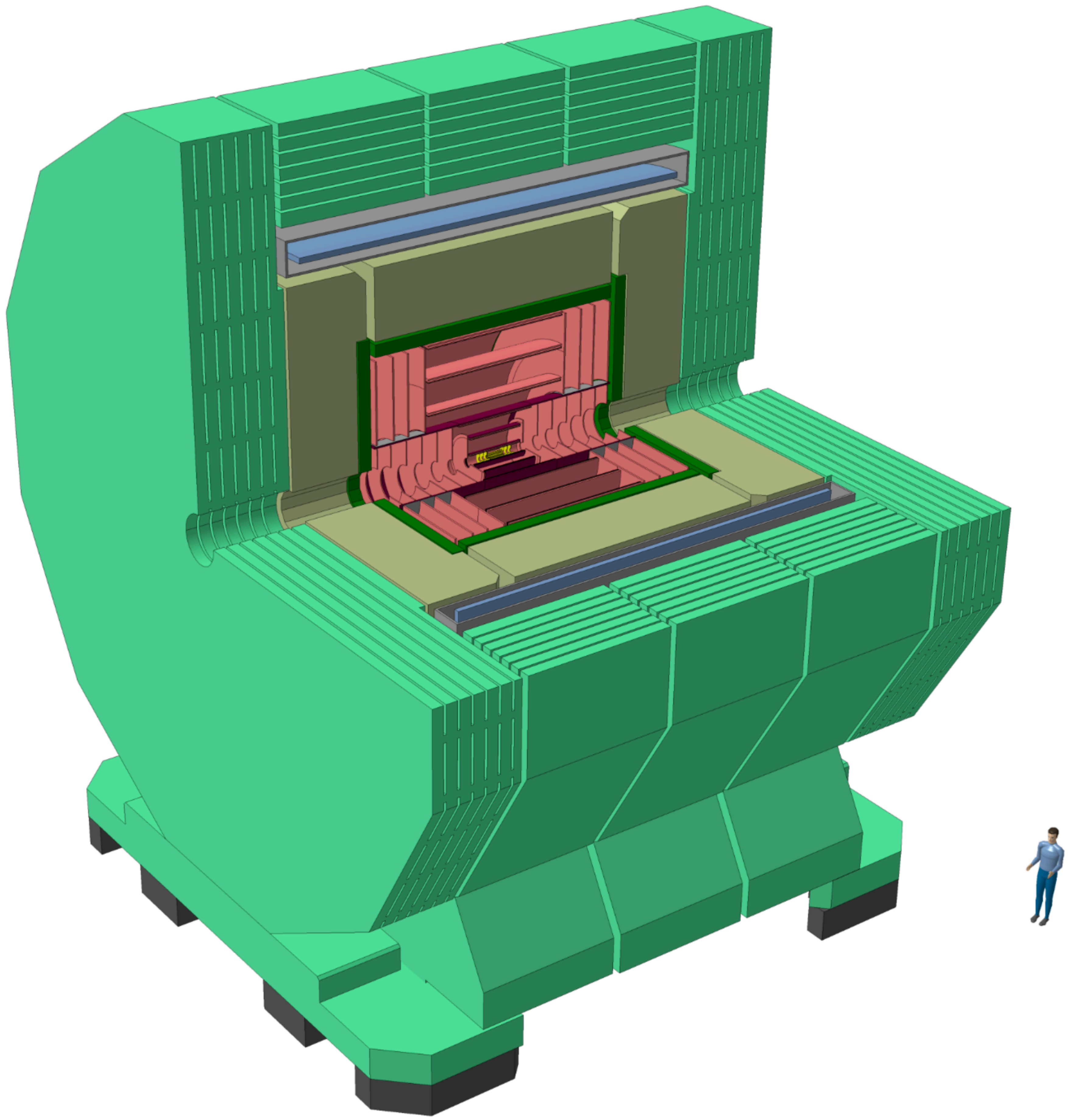


Figure 1: Isometric view of the CLD detector, with one quarter removed.

Table 1: Comparison of key parameters of CLD and CLICdet detector models. The inner radius of the calorimeters is given by the smallest distance of the calorimeter (dodecagon) to the main detector axis. 'HCAL ring' refers to the part of the HCAL endcap surrounding the ECAL endcap.

Concept	CLICdet	CLD
Vertex inner radius [mm]	31	17.5
Vertex outer radius [mm]	60	58
Tracker technology	Silicon	Silicon
Tracker half length [m]	2.2	2.2
Tracker inner radius [m]	0.127	0.127
Tracker outer radius [m]	1.5	2.1
Inner tracker support cylinder radius [m]	0.575	0.675
ECAL absorber	W	W
ECAL X_0	22	22
ECAL barrel r_{min} [m]	1.5	2.15
ECAL barrel Δr [mm]	202	202
ECAL endcap z_{min} [m]	2.31	2.31
ECAL endcap Δz [mm]	202	202
HCAL absorber	Fe	Fe
HCAL λ_{I}	7.5	5.5
HCAL barrel r_{min} [m]	1.74	2.40
HCAL barrel Δr [mm]	1590	1166
HCAL endcap z_{min} [m]	2.54	2.54
HCAL endcap z_{max} [m]	4.13	3.71
HCAL endcap r_{min} [mm]	250	340
HCAL endcap r_{max} [m]	3.25	3.57
HCAL ring z_{min} [m]	2.36	2.35
HCAL ring z_{max} [m]	2.54	2.54
HCAL ring r_{min} [m]	1.73	2.48
HCAL ring r_{max} [m]	3.25	3.57
Solenoid field [T]	4	2
Solenoid bore radius [m]	3.5	3.7
Solenoid length [m]	8.3	7.4
Overall height [m]	12.9	12.0
Overall length [m]	11.4	10.6

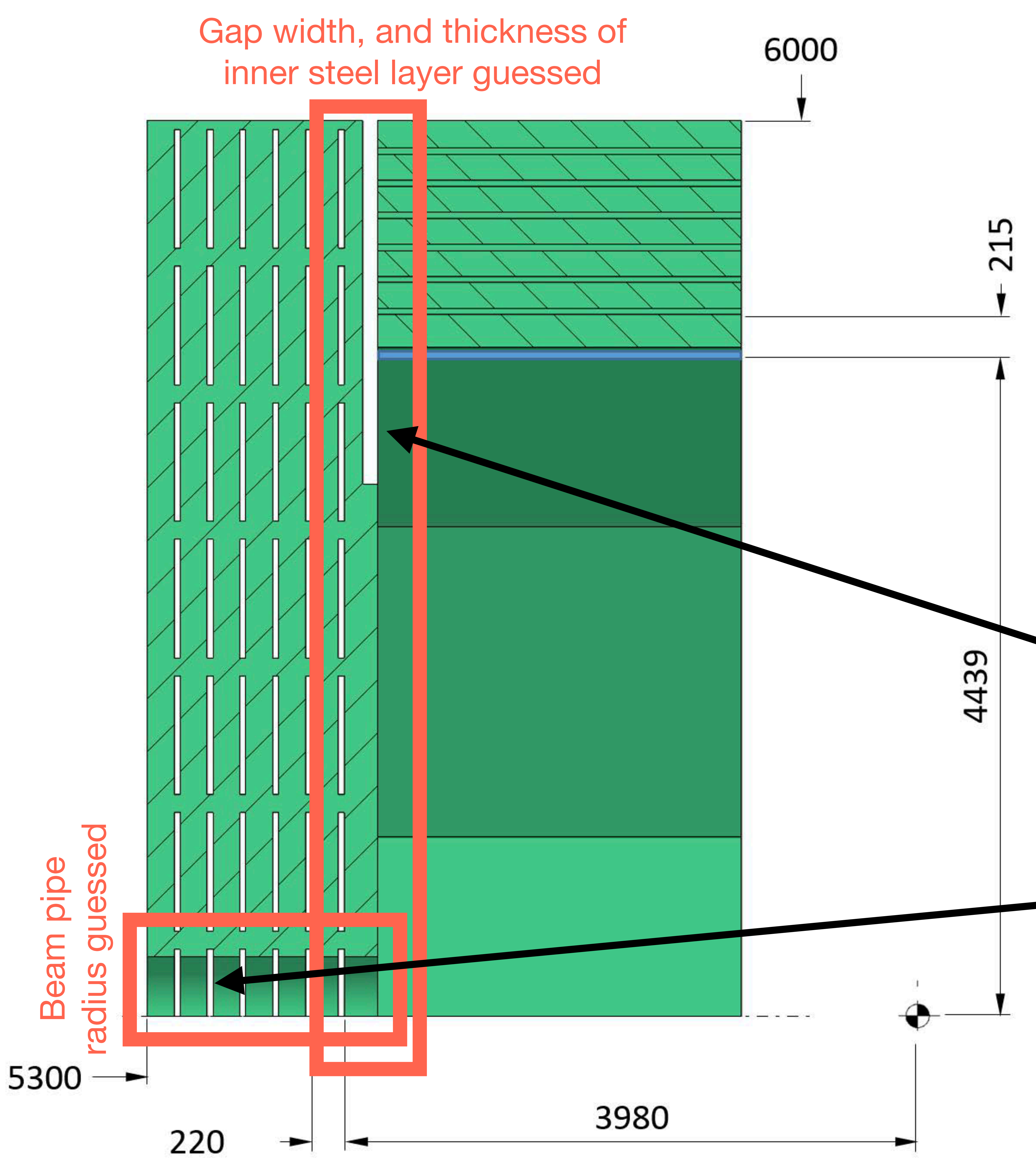
1.1 CLD: solenoid parameters (concept)

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

- Solenoid producing a **2T field in the center** of the detector volume
- Made with Al-stabilized 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 weigth of 52 t
- **Energy density of 11.6 kJ/kg**

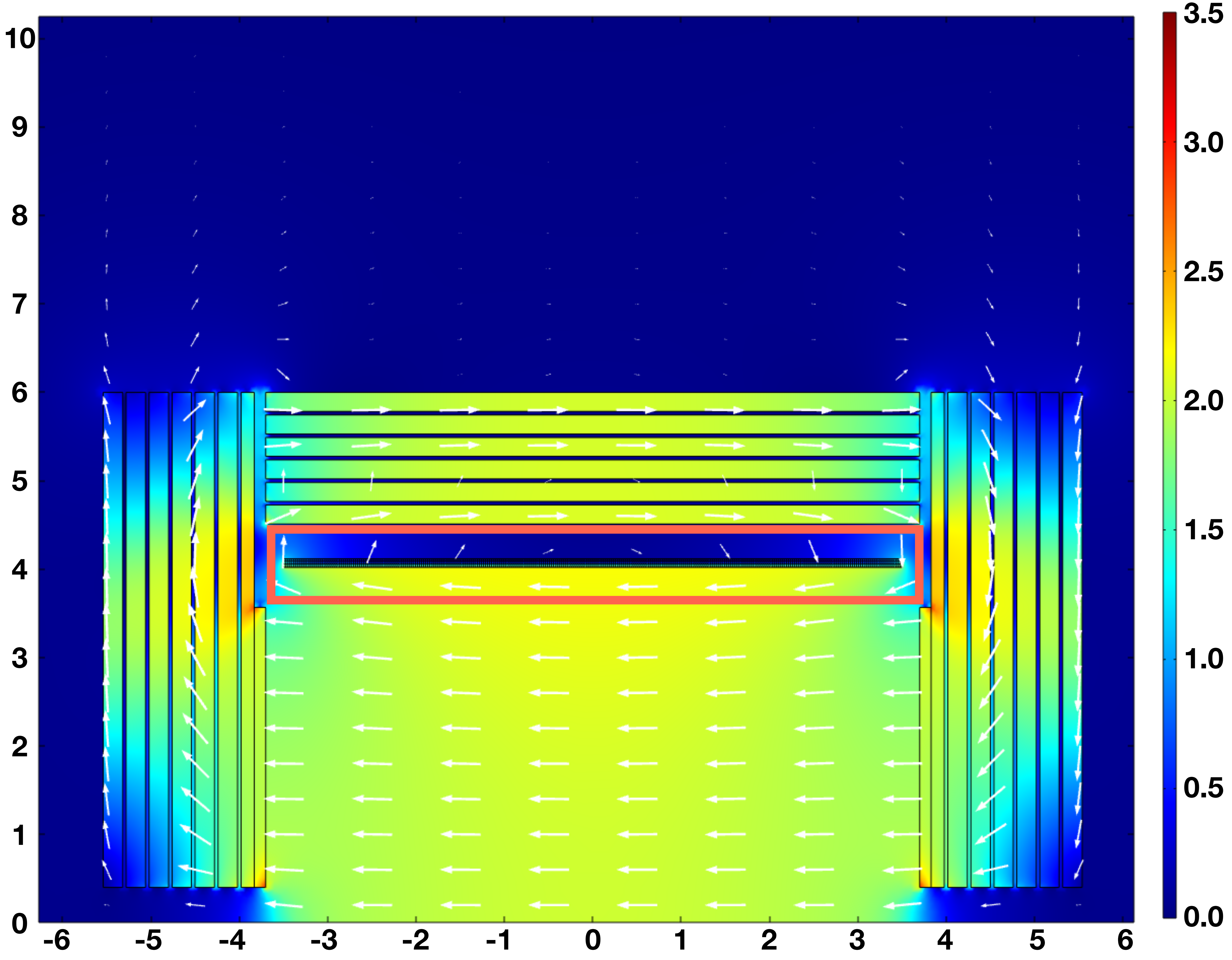
1.3 CLD: details on iron yoke

https://arxiv.org/abs/1911.12230



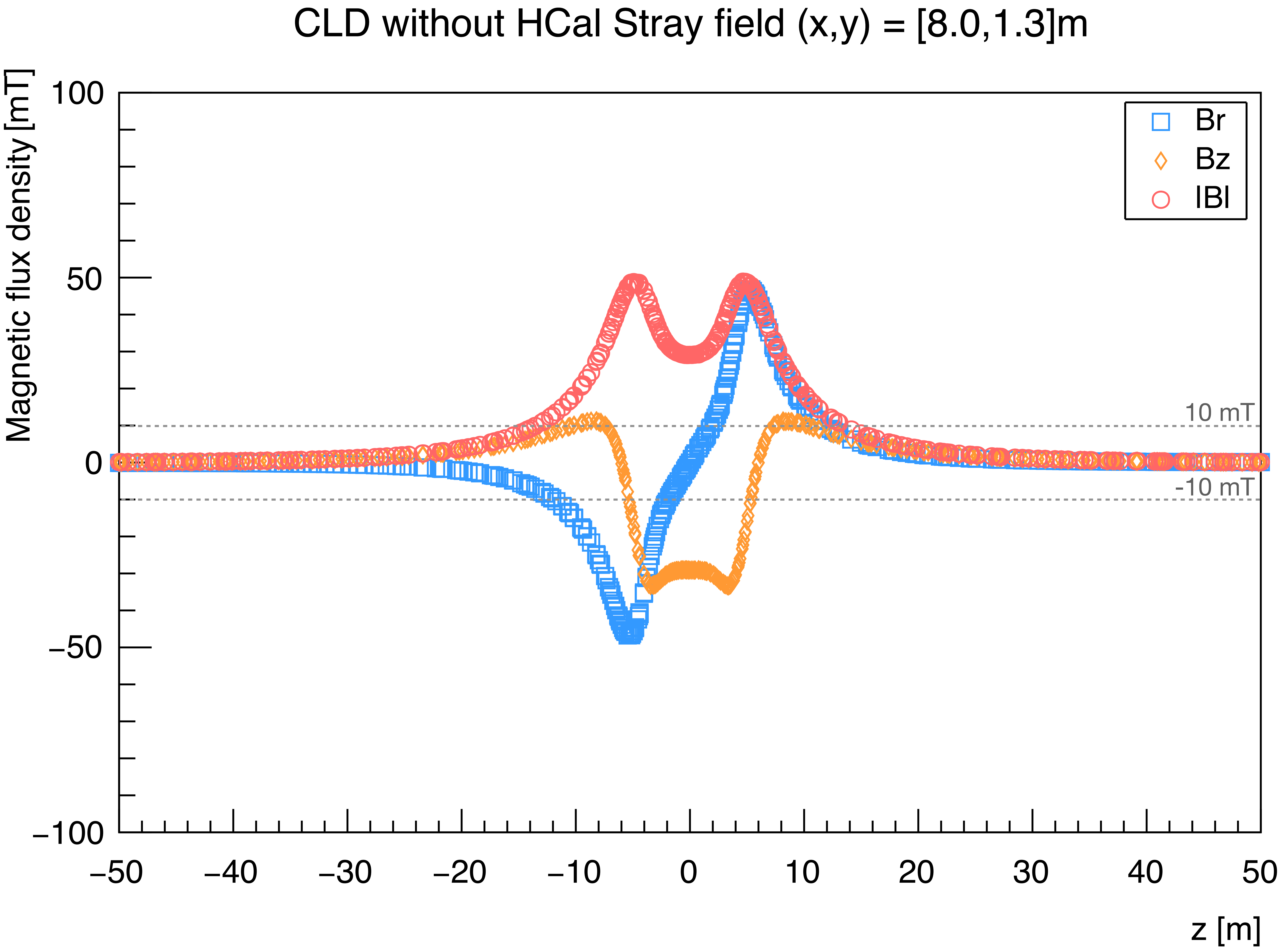
- 7 layers of steel
- In between 6 layers of RPC: 40 mm gap for each layer
- Barrel layers have 215 mm of steel, end-cap layers 220 mm
- Inner most layer of steel has gap at large R, seems thicker at small R than other layers
- Radius of hole for beam pipe guessed at end-cap locations

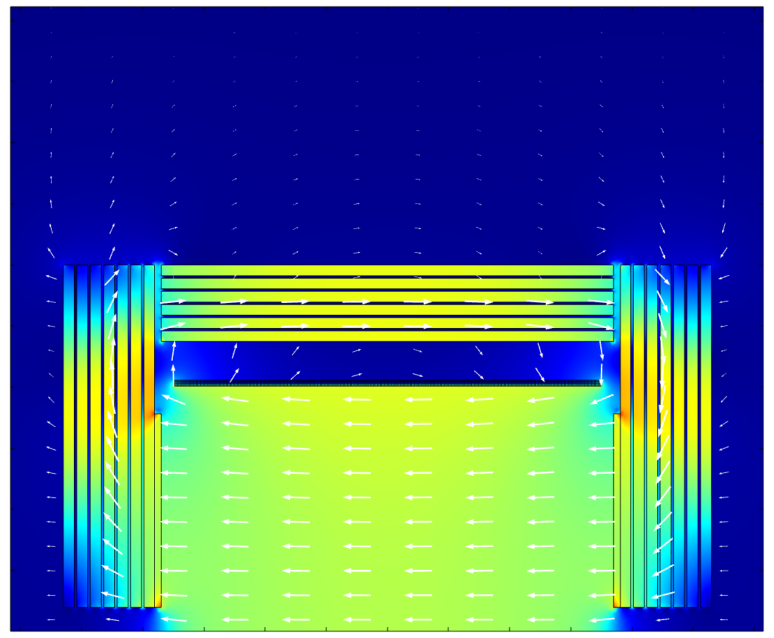
1.6 CLD Field Map



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

1.7 CLD Stray field - No HCal

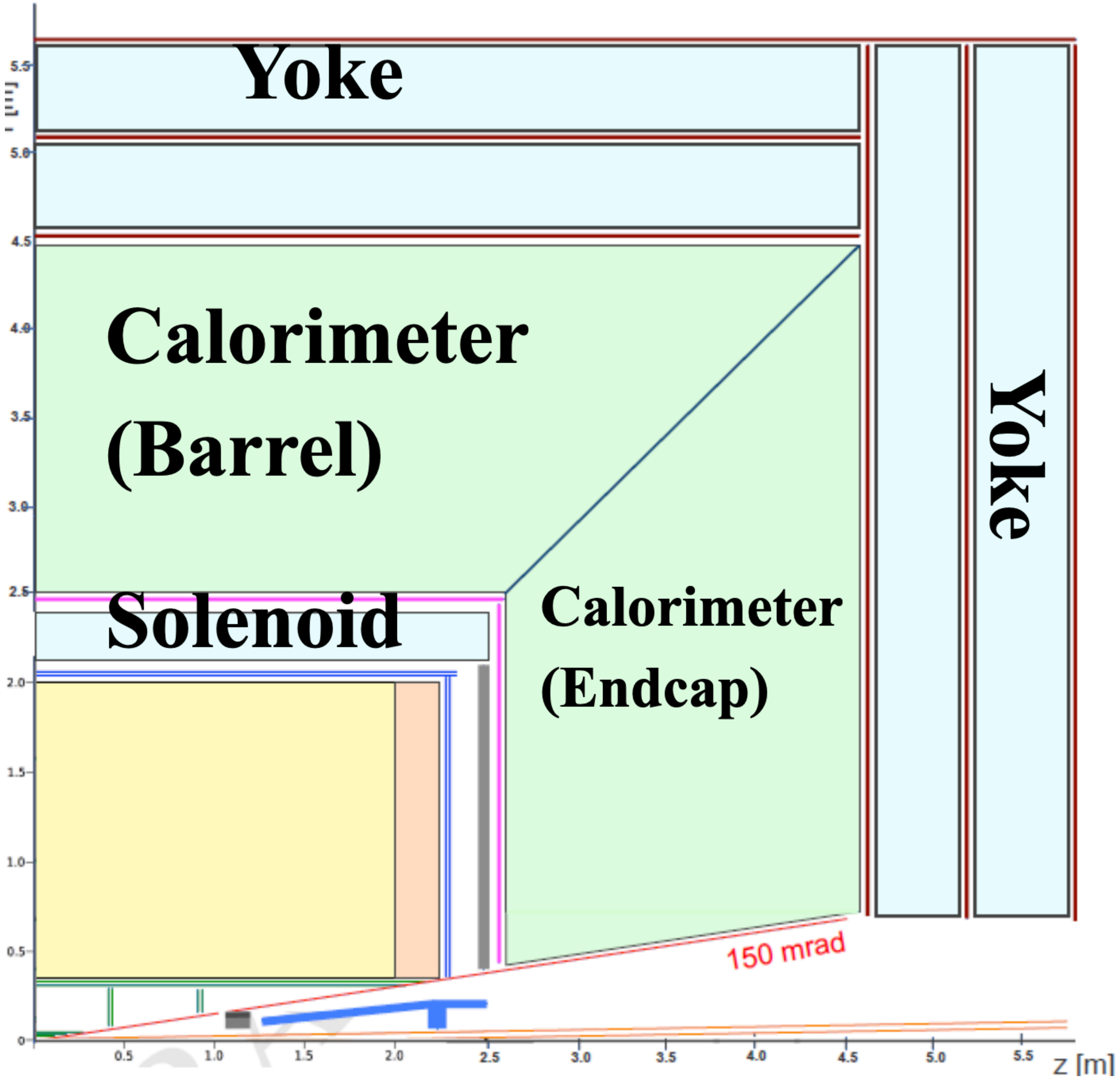




International Detector for Electron-positron Accelarators

2. IDEA: important parameters

Franco Bedeschi, “Solenoid field study”



- Two yoke layers, **500 mm thick**
- Muon gap: 100mm **(?)**
- Dual readout calorimeter with **55 % steel**

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-stabilized NbTi conductor, in one layers of 436 turns
- Operating current is 20 kA, operating temperature is 4.5 K
- Stored energy of 130MJ, cold mass weigth of 10.5 t
- **Energy density of 12.3 kJ/kg**

2.2 IDEA: details on the HCal

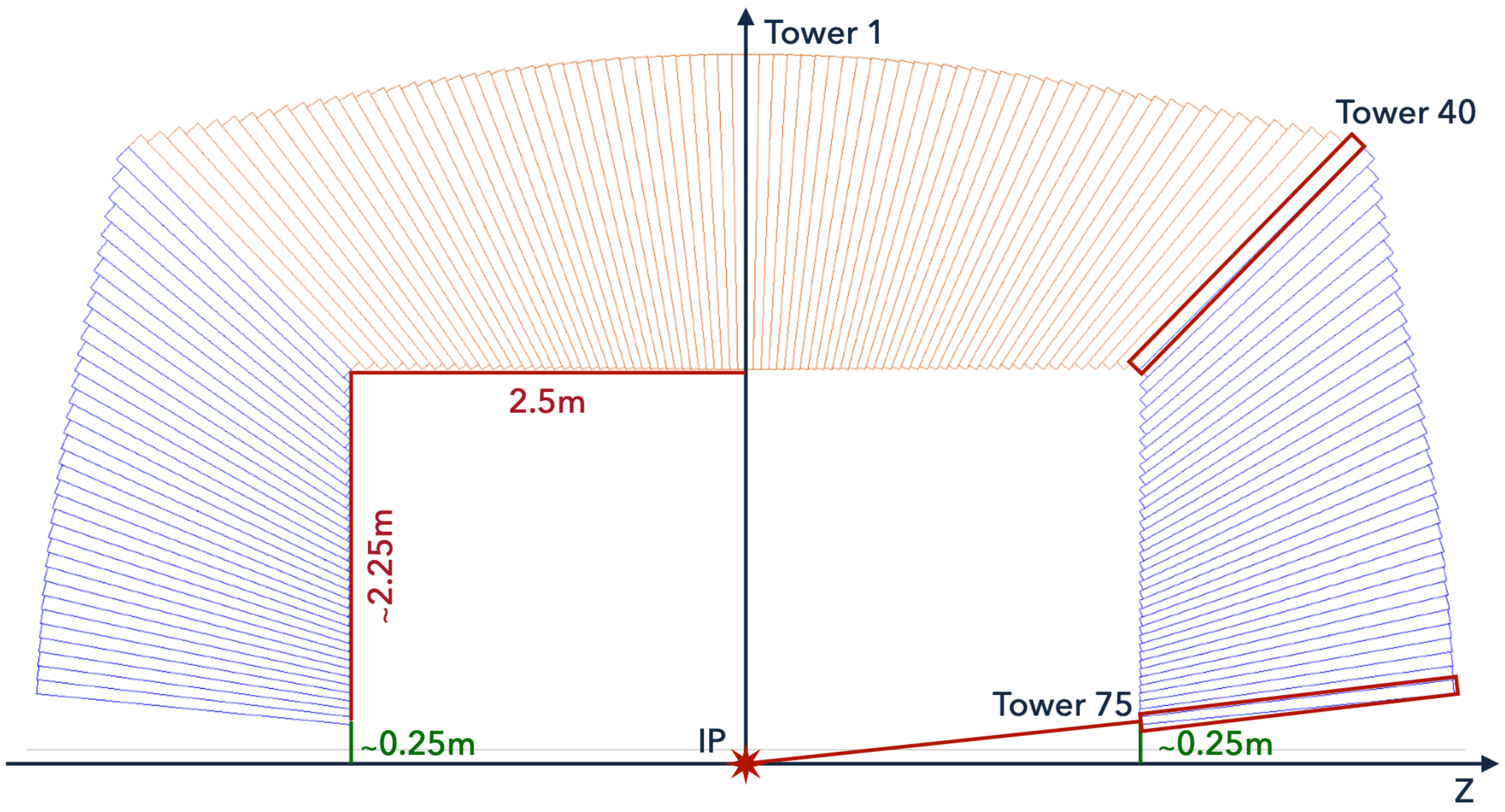
M. Antonello, Pezzotti, E. Prosperio, “DR calorimeter full simulation geometry”

Slice details

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

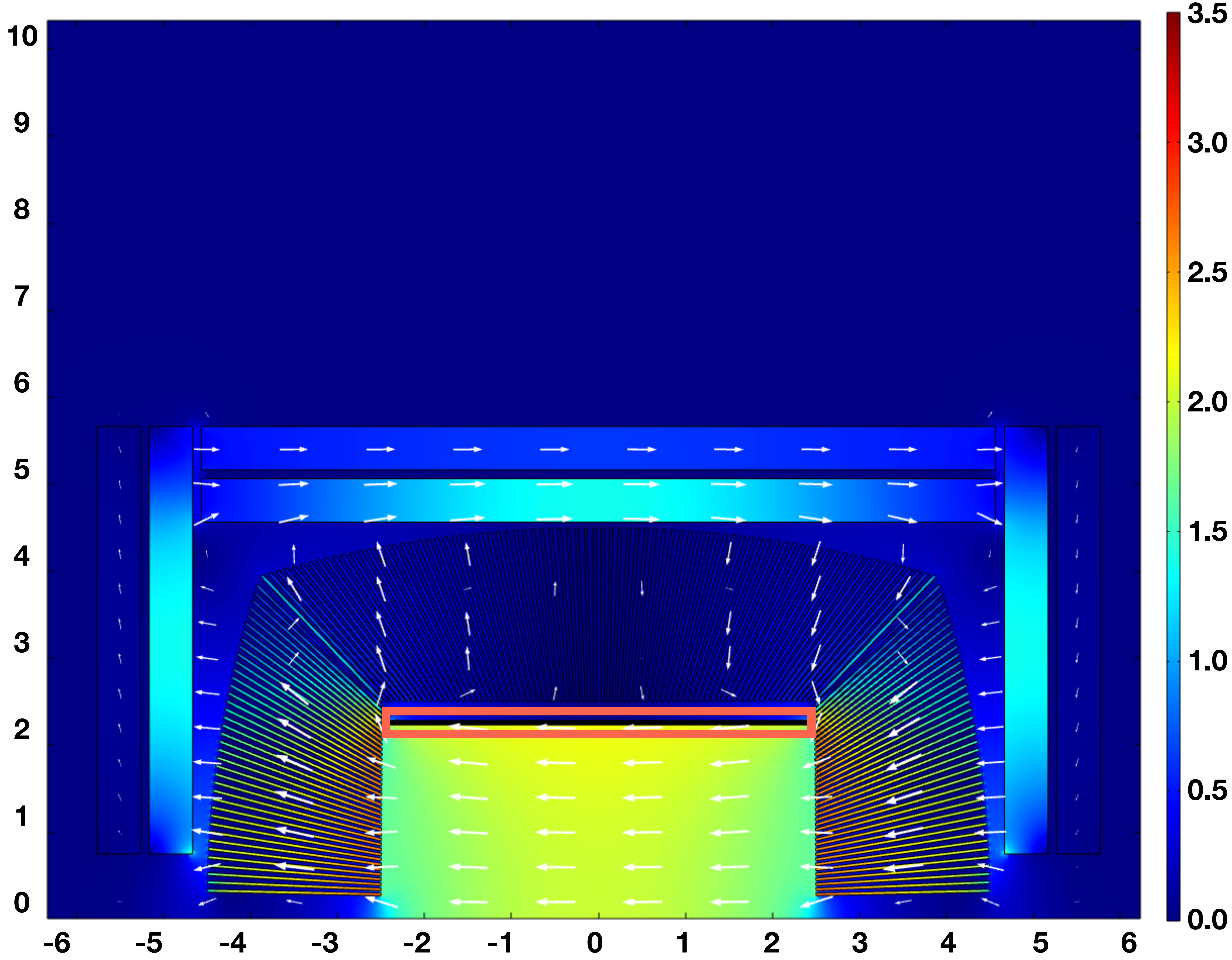
Barrel: 40*2 = 80 towers - Inner length: 2.5m.

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



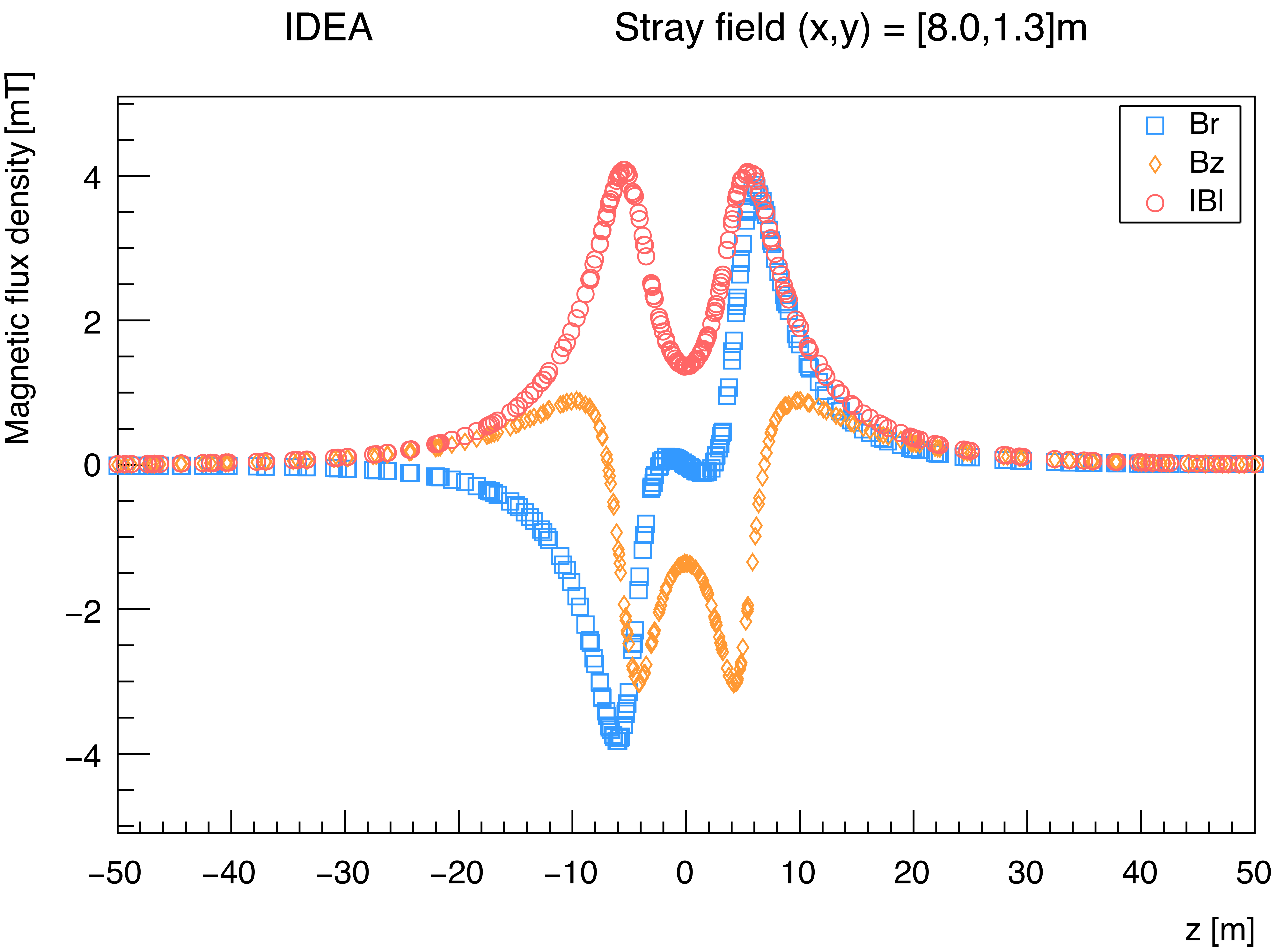
- 55 % fill-factor assumed **(55 % steel)** for the stray field calculations
- Iron layer thickness barrel: **34 mm** (28 mm gap)
- Iron layer thickness end-cap: **35 mm** (29 mm gap)

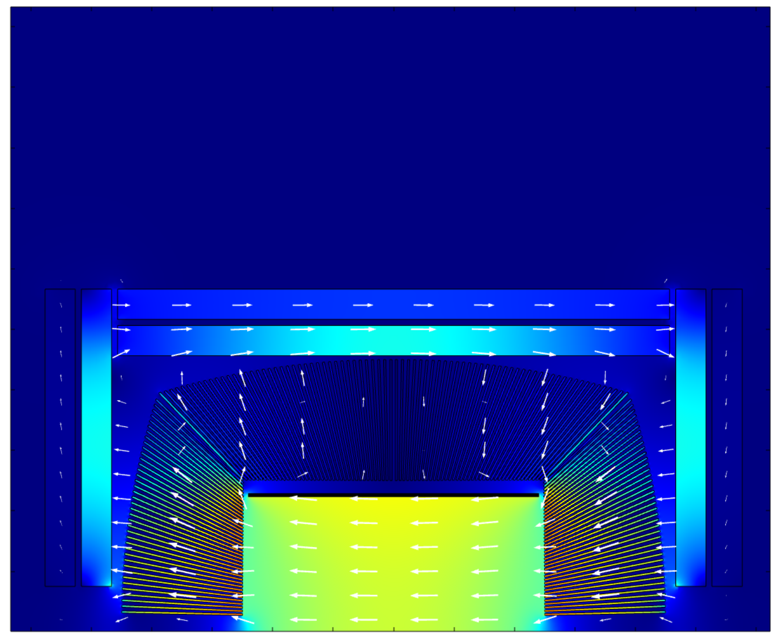
2.3 IDEA Field Map



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

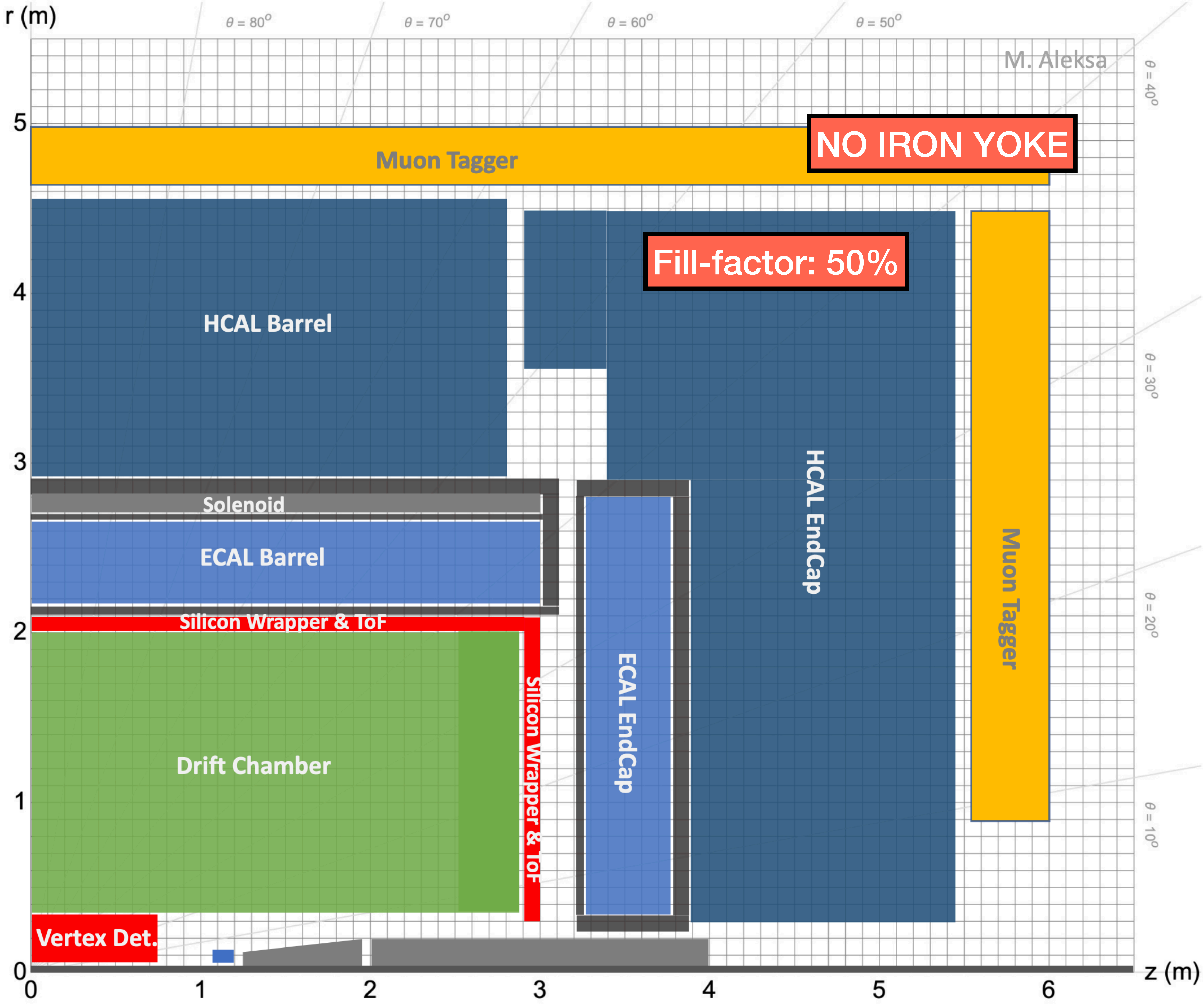
2.4 IDEA Stray Field





Liquid Calorimeter design

3. LCalo Design: important parameters



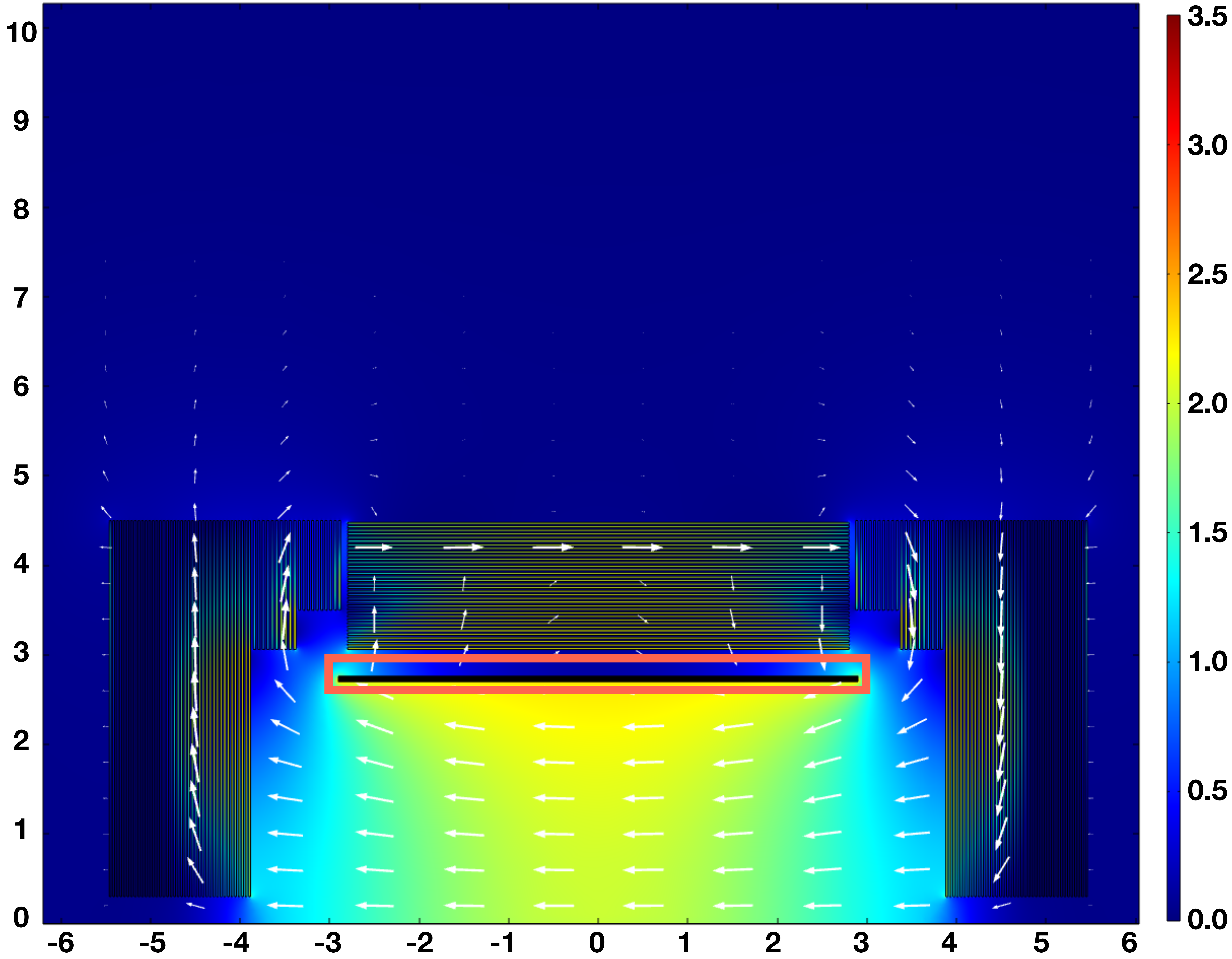
Detector Concept 1a

- Vertex Detector:
  - MAPS or DMAPS possibly with timing layer (LGAD)
  - Possibly ALICE 3 like?
- Drift Chamber (±2.5m active)
- Silicon Wrapper + ToF:
  - MAPS or DMAPS possibly with timing layer (LGAD)
- Solenoid B=2T, sharing cryostat with ECAL, outside ECAL
- High Granularity ECAL:
  - Noble liquid + Pb or W
- High Granularity HCAL / Iron Yoke:
  - Scintillator + Iron
    - SiPMs directly on Scintillator or
    - TileCal: WS fibres, SiPMs outside
- Muon Tagger:
  - Drift chambers, RPC, MicroMegas

3.1 LCalo Detector Design: solenoid parameters (CONCEPT)

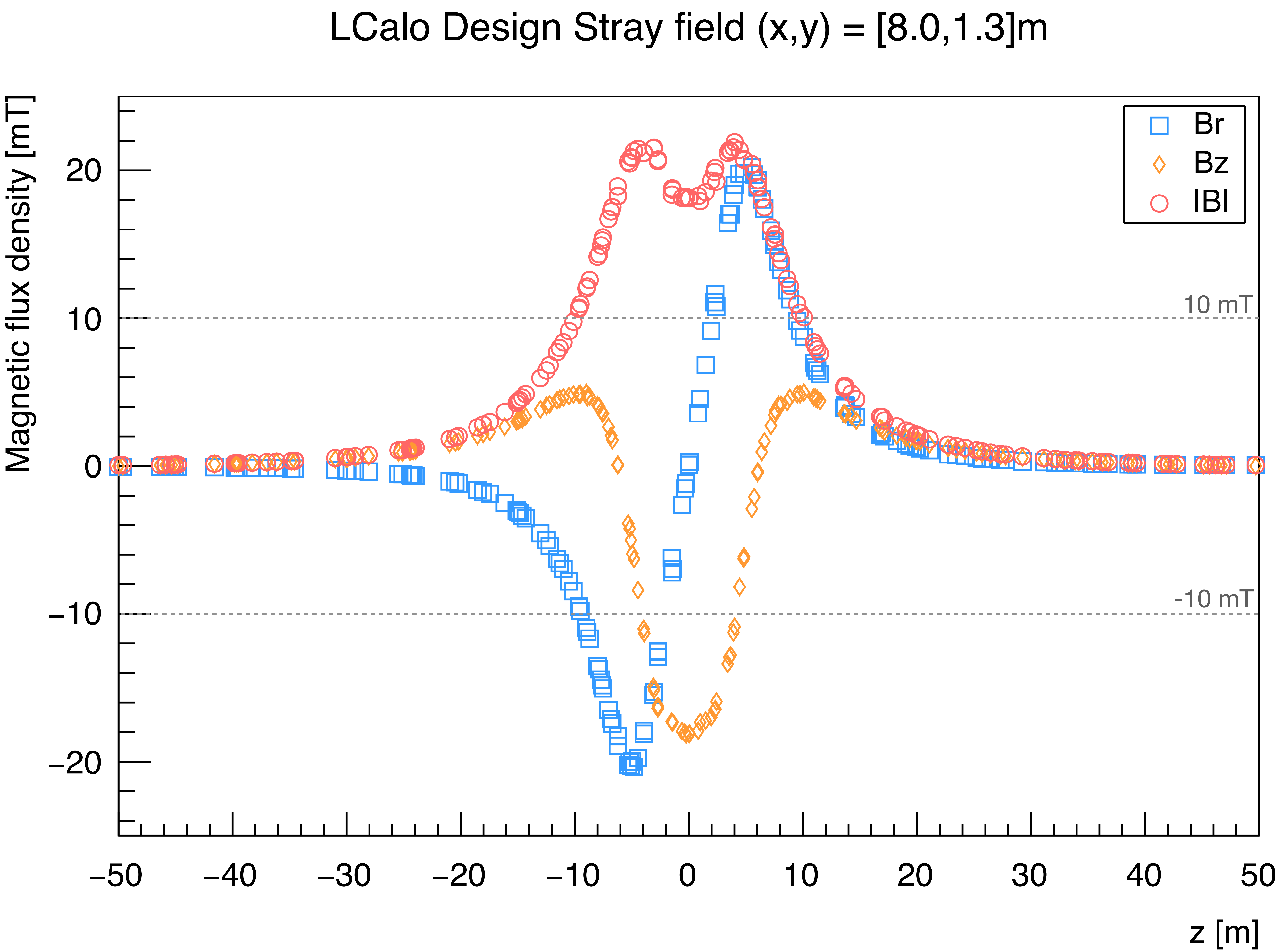
- Solenoid producing a **2T field in the center** of the detector volume
- Made with Al-stabilized NbTi conductor, in one layer of 562 turns
- Operating current is 20 kA, operating temperature is 4.5 K
- Stored energy of ~250MJ, cold mass weigth of ~20 t

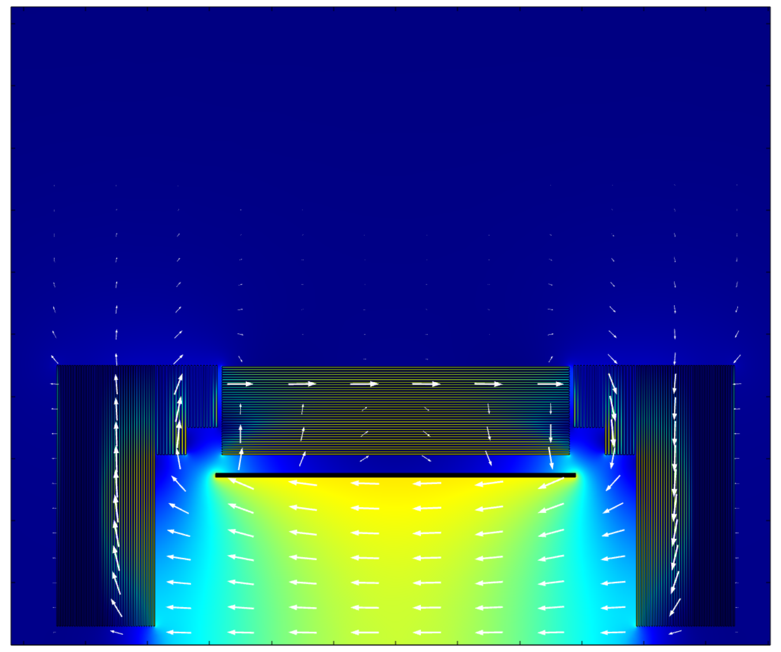
3.2 Lcalo Field Map



- 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





Conclusions

- Maximum stray field for CLD is almost 4-5 x higher then 10 mT
- IDEA maximum stray field is ~5 mT, well below 10 mT
- LCalo Design stray field ~20 mT, but there is no iron yoke
- Compensation solenoids in the interection region are not included
- Stray field will also be calculated at 7m from the interaction point

Back-up: HB-curve