Progress towards Yoke Design

Uwe Schneekloth

DESY

Towards Iron Yoke Design

- Need a somewhat realistic mechanic design of iron yoke in order to study stability/stiffness of yoke
  - With and without magnetic field
  - Opening and closing of endcaps
  - Push/pull

- Progress report

Iron Yoke – Thin vs. Thick plates

Thin iron plates (LEP, H1, ZEUS)

- Is momentum measurement necessary?
  - Done by TPC
  - Might be useful to improve muon purity
- Lower momentum cutoff (mainly determined by calorimeter + coil thickness)
- Backing calorimeter/tail catcher
  - Depends on thickness of calorimeter and coil (5 Λ + 2 Λ)

Thick iron plates (CMS)

- 4 chambers sufficient for momentum measurement
- Much less muon chambers
- Precision position measurements easier
- Better mechanical stiffness
  - Defection due to high magnetic field
  - Push/pull without platform
- Less support structures (rips)
  - Less holes in muon coverage

Iron Yoke – Welded vs. Bolted Assembly

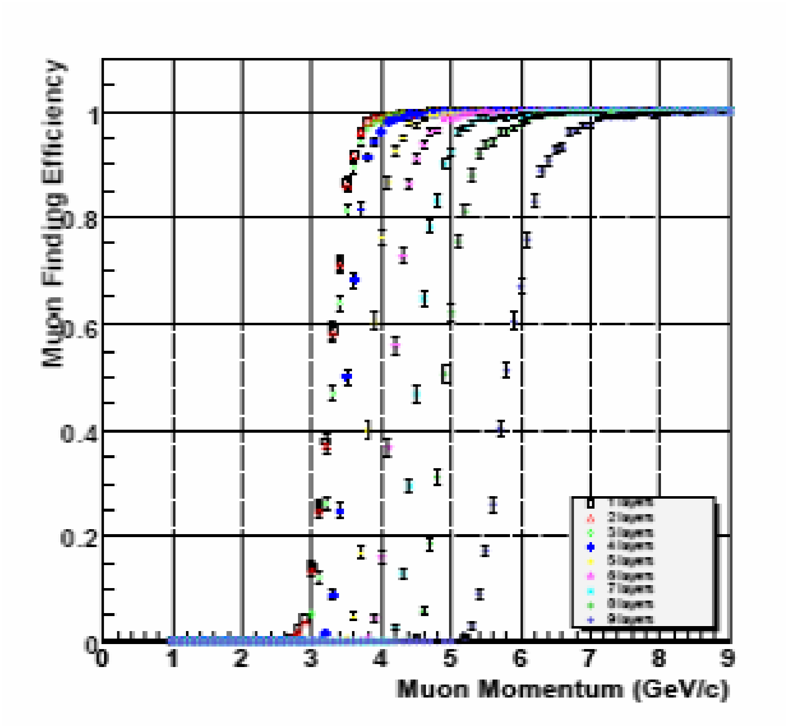
Welded assembly (H1, ZEUS)

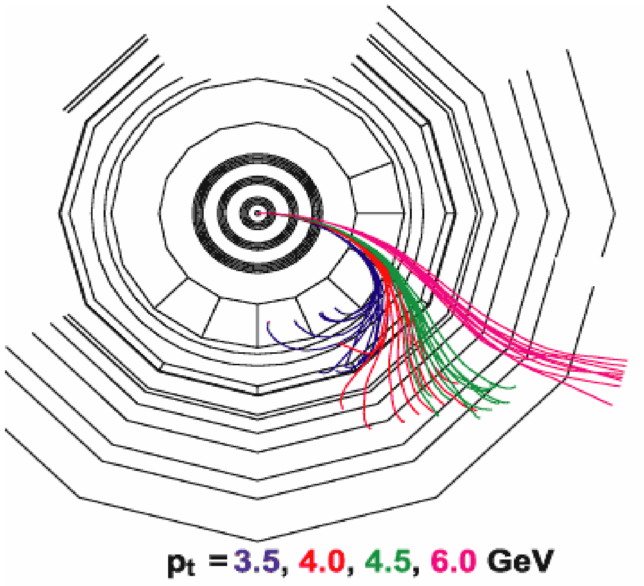
- Sections (octants, 12...) assembled and welded at manufacturer
- Sections very heavy (>100 t)
- Trial assembly at manufacturer difficult

Bolted assembly (CMS)

- “light” plates (<50 t)
- Trial assembly at manufacturer easier
- Easier to achieve high precision
- High precision not required for plates, only for connections
- Only machined at bolting points
- More vendors
- Transport and handling easier and cheaper

Iron Yoke – Thin vs. Thick plates





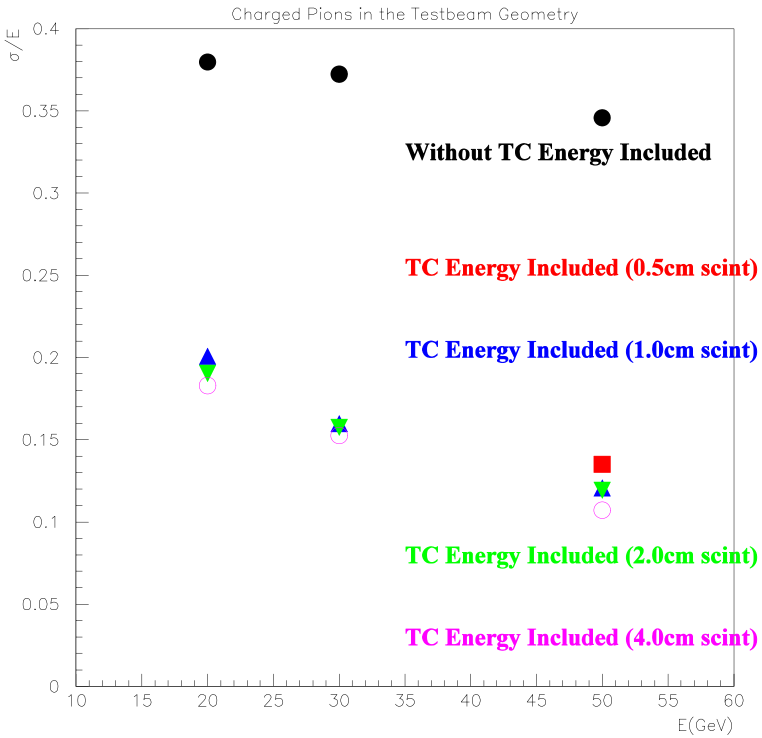
CMS (4 T)

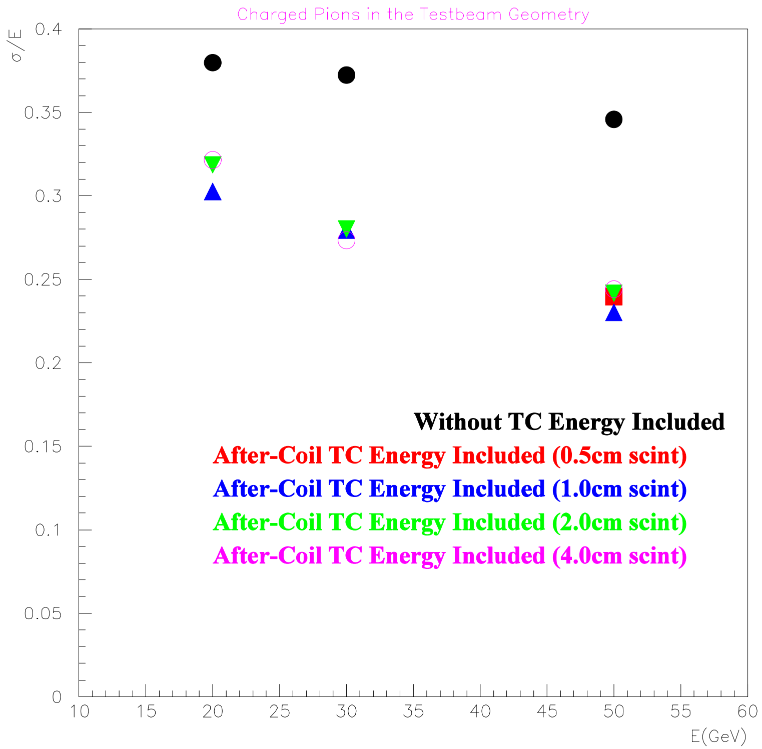
Only muons p > 4GeV reach muon chambers

Tail Catcher

Calice test beam study | N.Zutshi, NIU 2004

100mm thick absorber plates | including material of coil





Preliminary conclusion: need about five 10cm thick iron layers

Forces on Iron Yoke

4 T solenoid ➔ huge magnetic forces on endcap

- CMS total magnetic force on one endcap about 9000 t
- ILD
  - First, preliminary results of CST EM Studio calculations (A.Petrov) 24000 t.
- Very simple estimate of bending of 8m long steel plate with central force of 5000 t
  - Thickness 100mm (s = 4m) plate destroyed
  - Thickness 300mm s = 140mm
  - Thickness 600mm s = 18 mm (CMS observes 14mm)

Yoke Design Considerations

CMS yoke excellent design, coil very similar

Why not simply copy the yoke design?

CMS

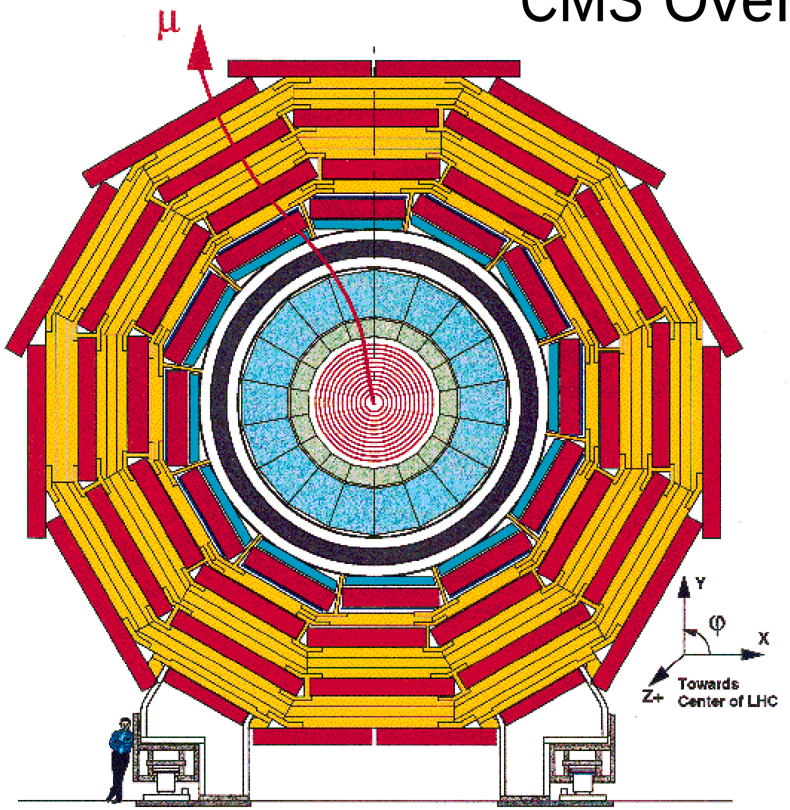
- Calorimeter 7 Λ (+ coil 2 Λ)
  - One tail catcher layer outside coil in central area
- Total iron thickness only 1.5m (endcap plates 600, 600 and 250mm)
- Stray field at 1m 1.2kG
- “High” radiation
- Hall is not accessible during operation

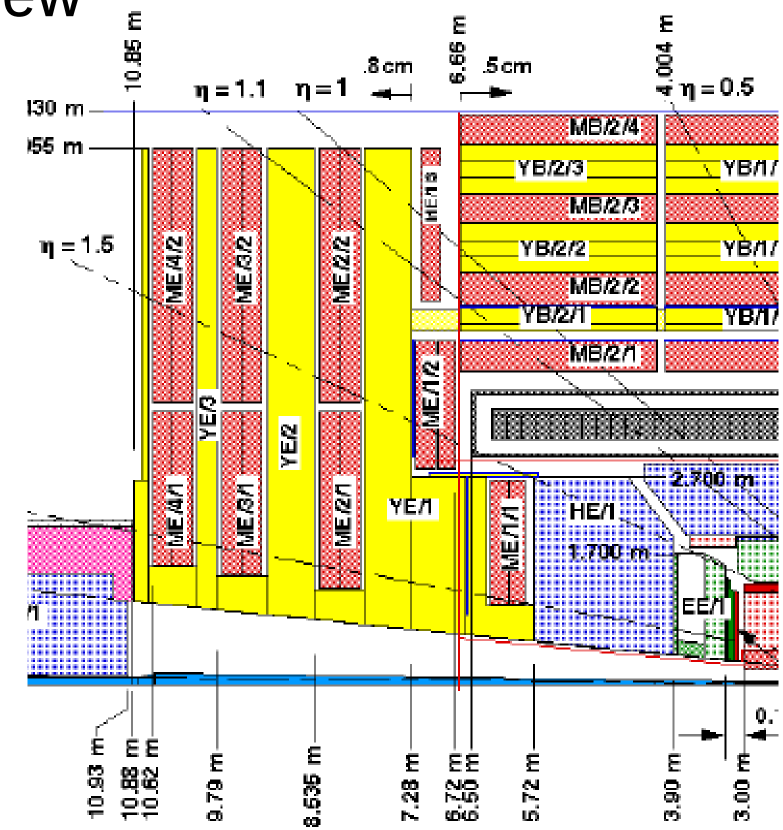
ILD

- Calorimeter only 5 Λ
  - Need tail catcher => thin inner iron plates
- Stray field should be 200G at 0.5m
- Self shielding

Yoke Design Considerations

CMS Overview





Thickness of iron plates (from IP)

Barrel: 295, 630, 630mm

Endcap: 600, 600, 250mm

Proposal for Yoke Segmentation

- Barrel
  - 4 100mm thick steel plates with 30mm gaps
  - 4 thick (about 400-500mm, depending on total iron thickness) with 30mm gaps
- Endcaps
  - 5 100mm thick steel plates with 30mm gaps

    Assuming a sufficiently stable mechanical design can be obtained
    - Thin plates not really needed in the barrel EC transition region
  - 4 thick (about 400-500mm, depending on total iron thickness) with 30mm gaps
- The exact size of the gap depends on the detector technology and whether different detectors will be used for energy and muon measurement

Shape of Iron Yoke

- Barrel
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  - 4 thick (about 400mm, depending on total iron thickness) with 30mm gaps
- Endcaps
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Shape of Iron Yoke

Octagonal vs. Dodecagonal (8 vs. 12)

- Should follow shape of calorimeter
  - Shower leakage and muon tracking easier

- Mechanical design

  Prefer 12
  - Individual sections smaller, weight ~2/3
  - Bending of iron plates ~ 0.3 (circumference)

- Started on mechanical design of octagonal shape
  - More difficult case

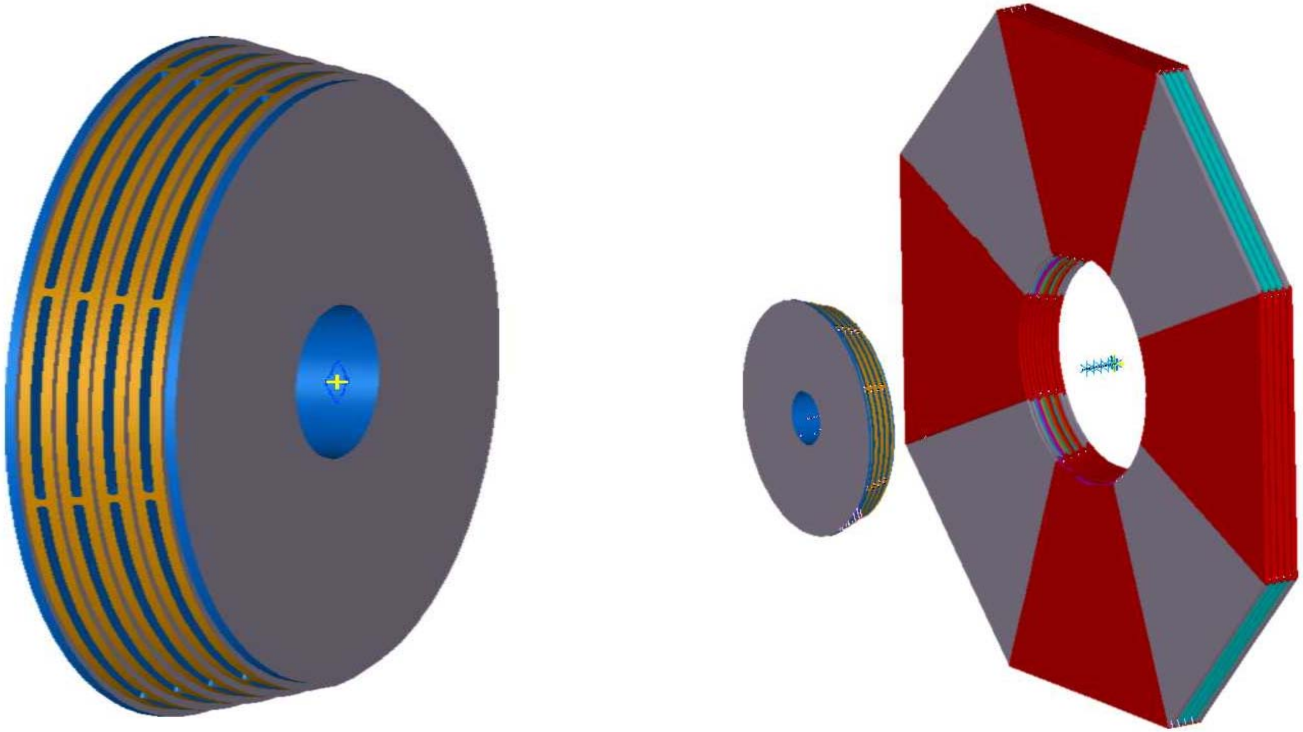
Yoke Design Considerations

Endcap design more challenging than barrel design due to huge magnetic forces

- Propose radial supports (rips) in radial direction for inner endcap section
- Tensile strength of support rips determined by welding seams or bolts
  - Looking into cast iron design

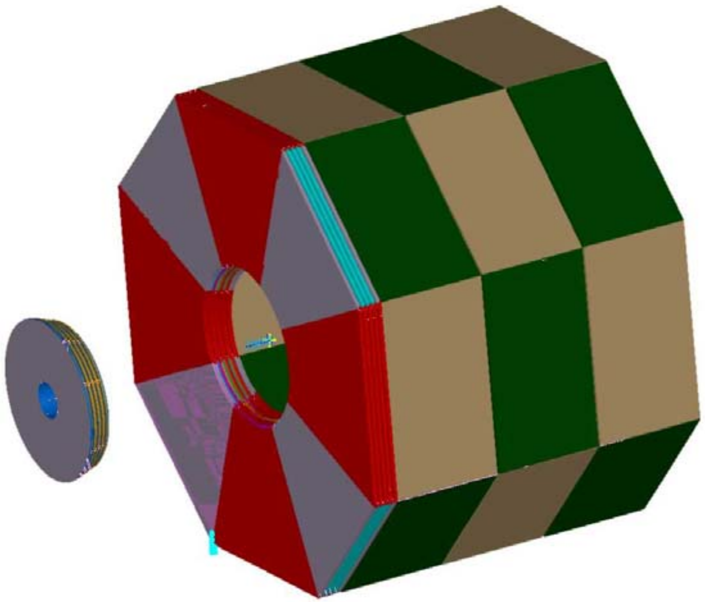
Endcap Design Proposal

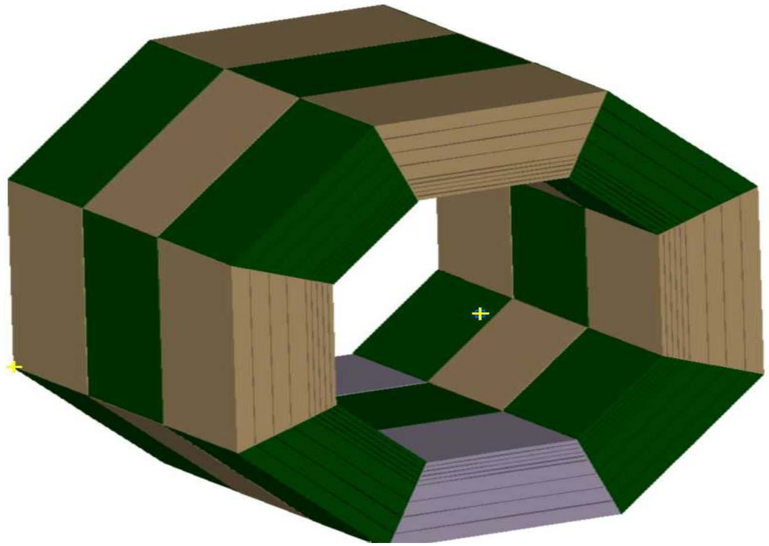
Endcap cast iron proposal (R.Stromhagen)

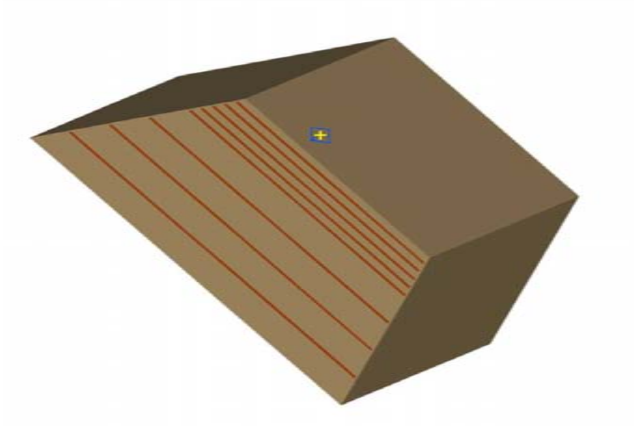


Very rough estimate of bending assuming central force of 5000t and unsupported diameter of 8m: 10 mm

Endcap Design Proposal

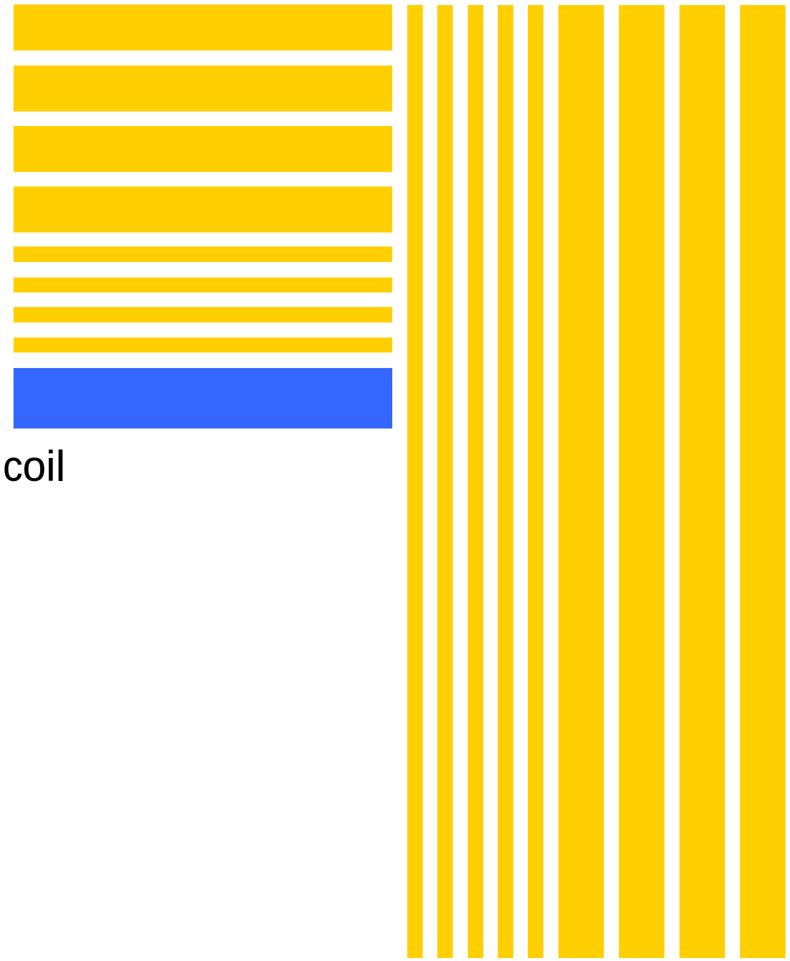






Only inner, thin plate endcap shown

Endcap Design Proposal

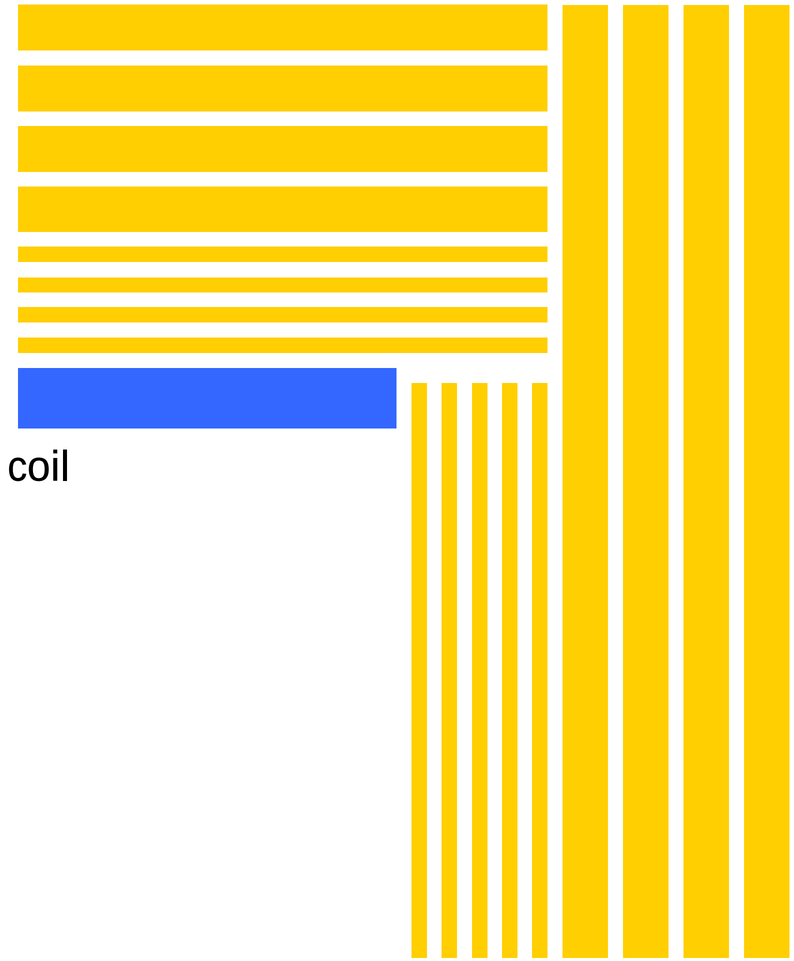


Fine (100mm) segmentation in barrel endcap overlap region not realy needed.

Problems:

- Mechanical strength of thin plates
- Installation and access of endcap detectors in case of radial rips

Endcap Design Proposal



Slightly longer barrel

- Better mechanical design of endcap
- Better installation and access of endcap detectors in case of radial rips

Preferred geometry

Magnetic Field Calculations

Recently started 3 D magnetic field calculations at DESY

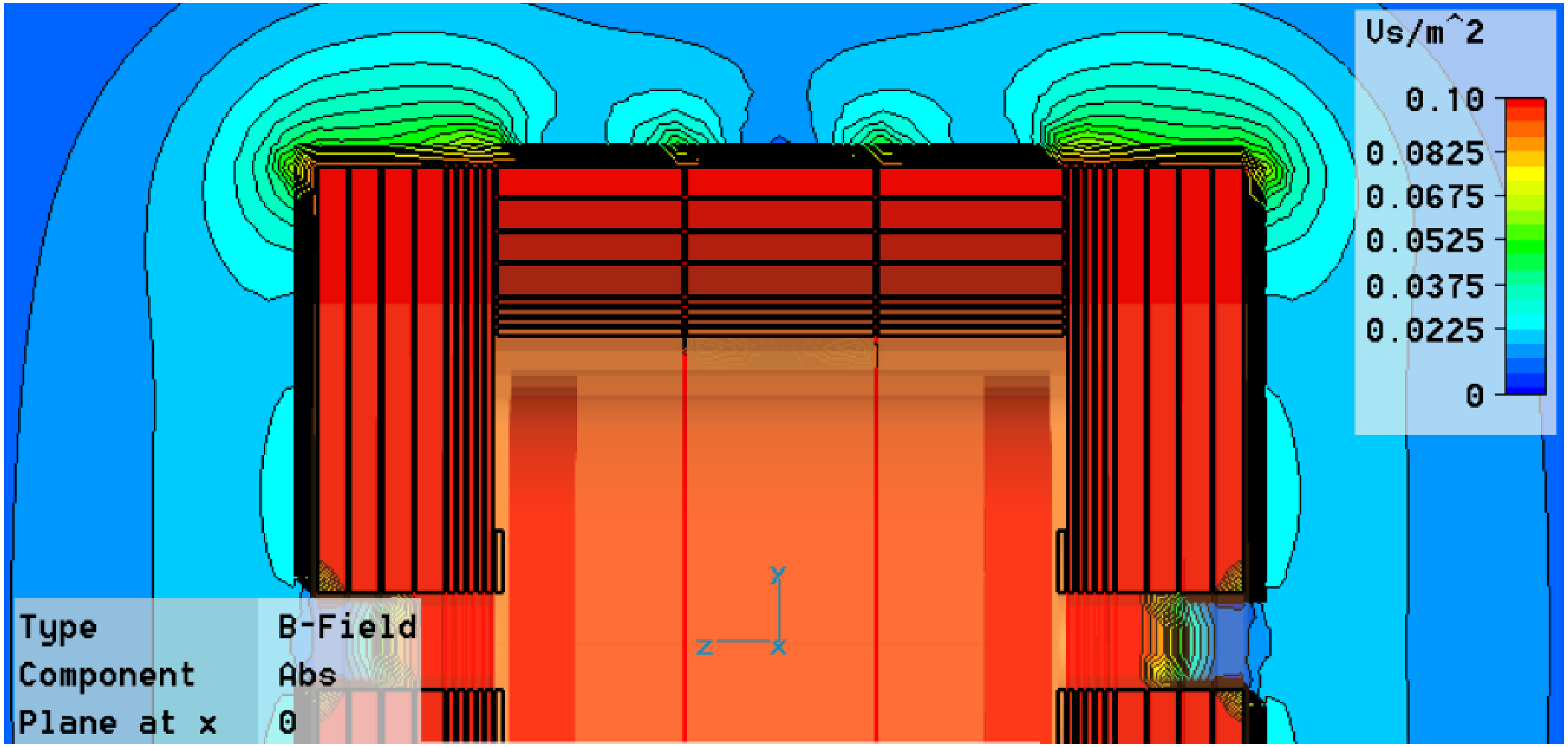
- Determine total iron thickness to achieve stray field of 200 G at 0.5m
- Determine magnetic forces on iron yoke

- Programs being used
  - CST EM Studio (A.Petrov, B.Krause)
    First results available
  - ANSYS (C.Martens)
    First results hopefully this week

B Field Calculations

Recently started B field calculations at DESY

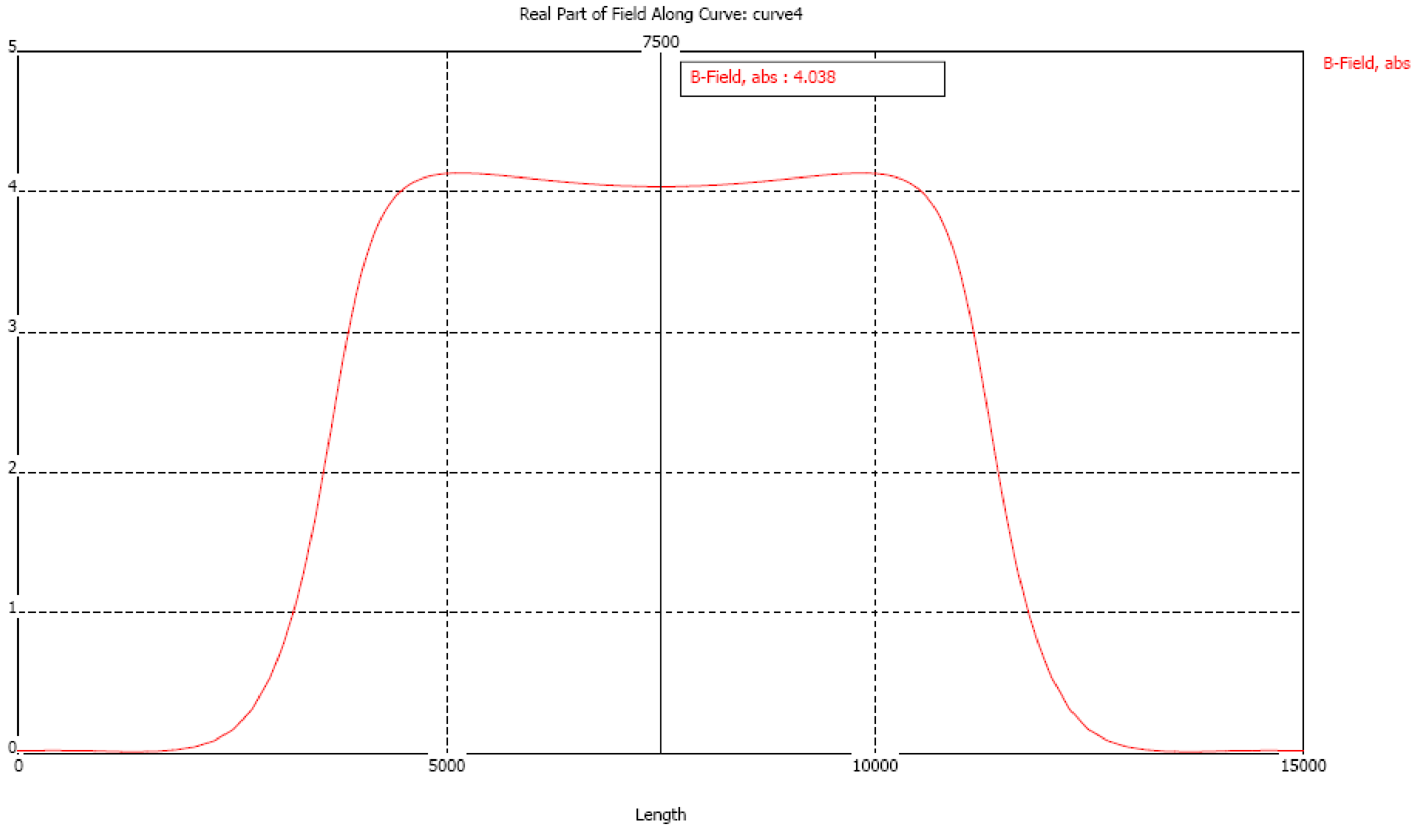
Coil: r_{in} = 3.4m, r_{out} = 3.75m, l = 7.35m, B =4T



B Field Calculations

B field vs z

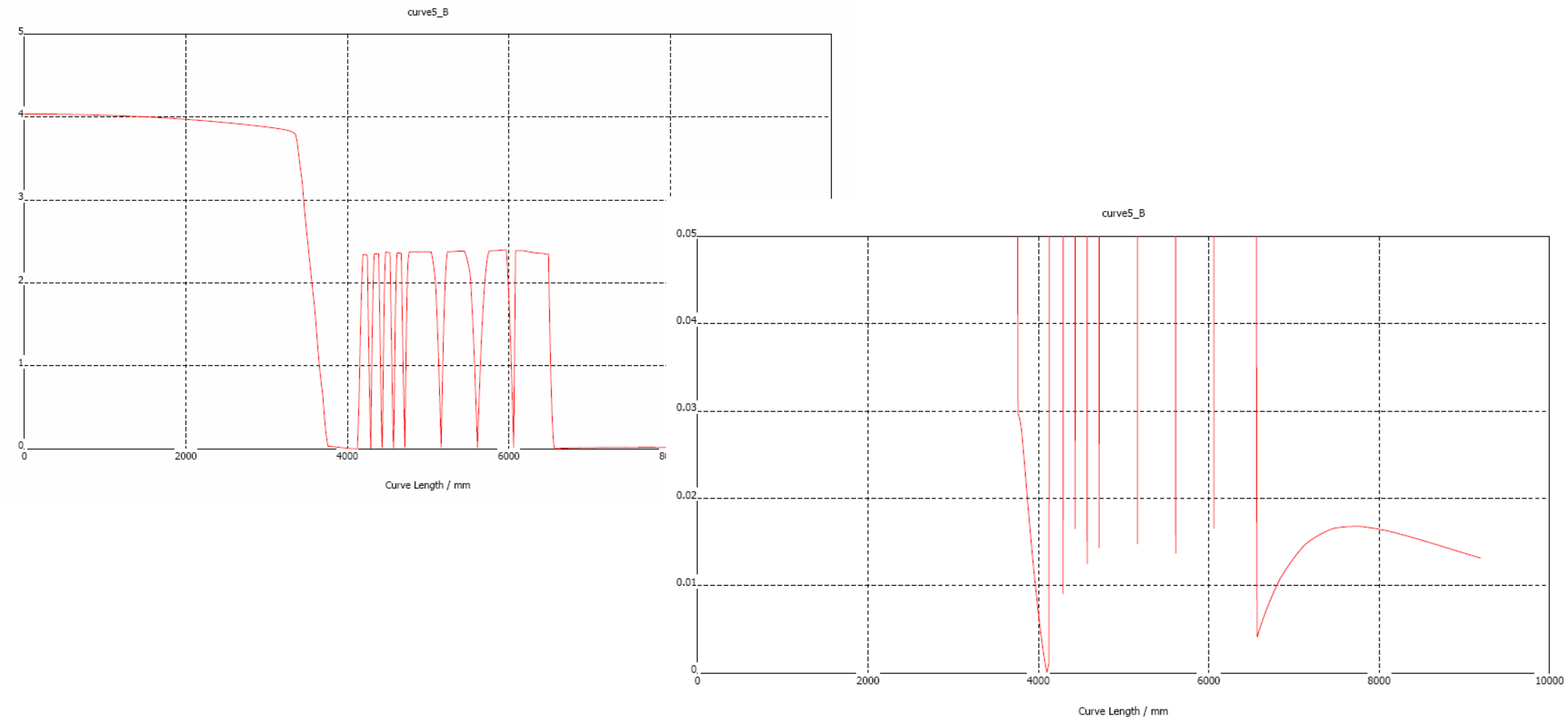
A.Petrov, B.Krause



B Field Calculations

B field vs r at z=0

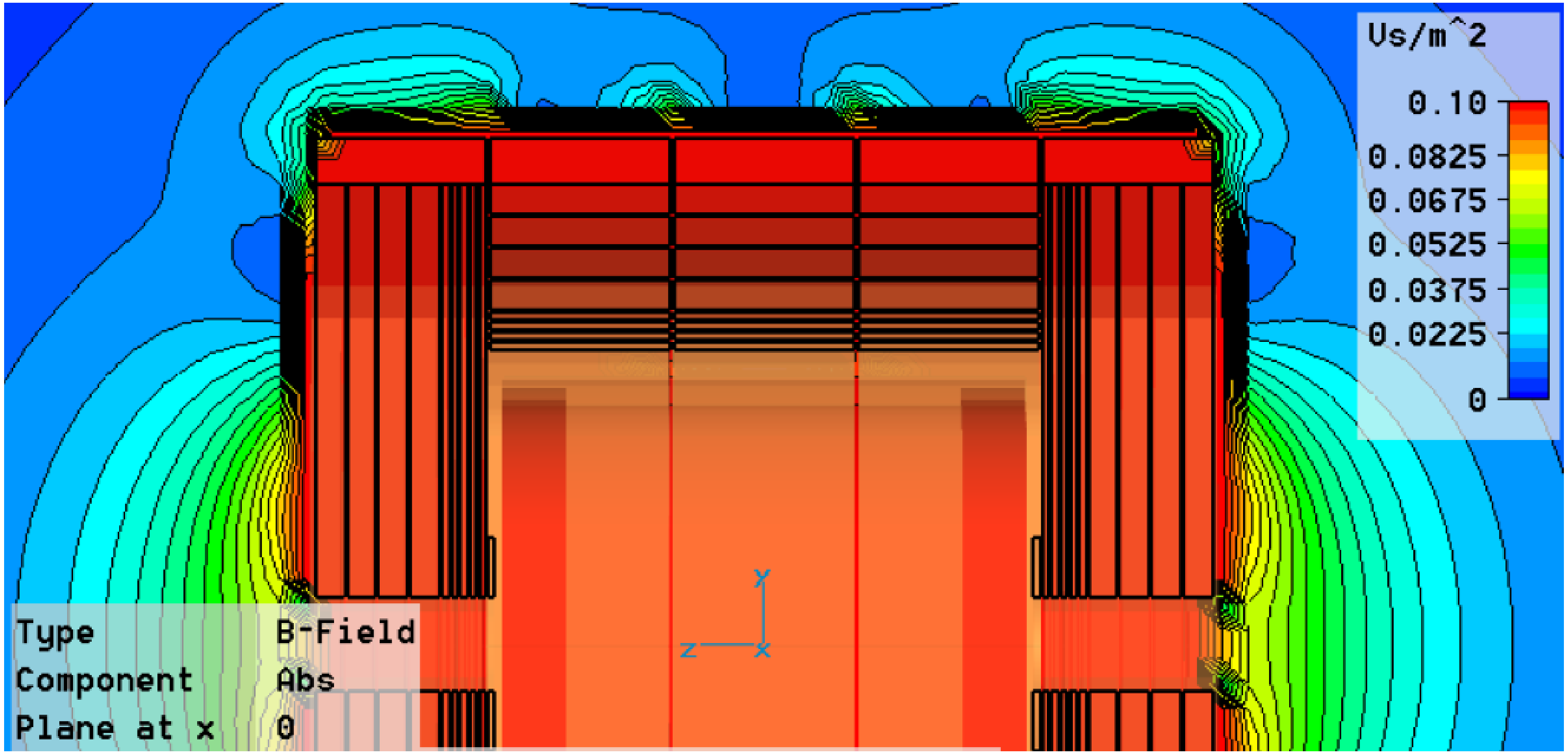
A.Petrov, B.Krause



B Field Calculations

B Field Calculations

Added 60cm of iron to reduce stray field



B Field Calculations

Conclusion of first results

- Difficult to achieve 200 G at 0.5m
- Is 200 G really fixed?
- Adding lots of additional iron will be very expensive, will reduce available space when endcap is opened

- Should compare with recent simulations by O.Delferriere

- Argument for reducing field to 3.5 or 3 T

Conclusions

- Need a somewhat realistic mechanic design of iron yoke in order to study stability
  - With and without magnetic field
  - Opening and closing of endcaps
  - Push/pull
- Have to fix
  - Size of iron yoke
    - total iron thickness mainly driven by stray field
  - Segmentation of iron (thin, thick plates)
  - Yoke shape (8 vs. 12)

- Need detail simulations of magnetic forces in order to proceed with mechanical design (stress, bending,...)