Integration and Push Pull

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DESY

ILD Meeting
Cambridge 11.09.2008

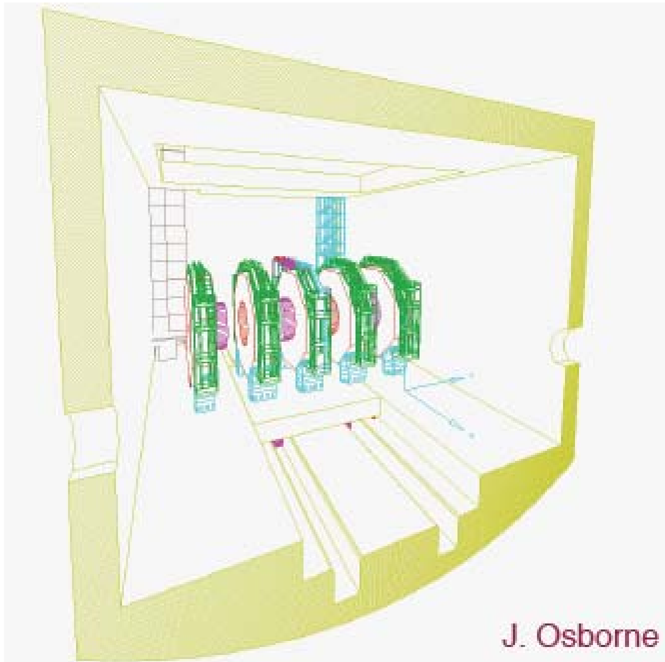
Outline

- Push Pull
- Iron Yoke
- Inner support tube
- Opening and movement of QF1
- Conclusions

Push Pull

- Platform
  - Would make movement of detector easier
  - Need ~2m deeper hall (quite expensive)
  - So far no work on-going within ILD
  - Preliminary work at SLAC on stability and strength of platform on hold
  - Will assume platform for LOI
  - Check whether detector design is compatible with no platform
- Concern by F. Kircher
  - Vibrations may destroy coil titanium support structures. Need careful design

    -> previous talk



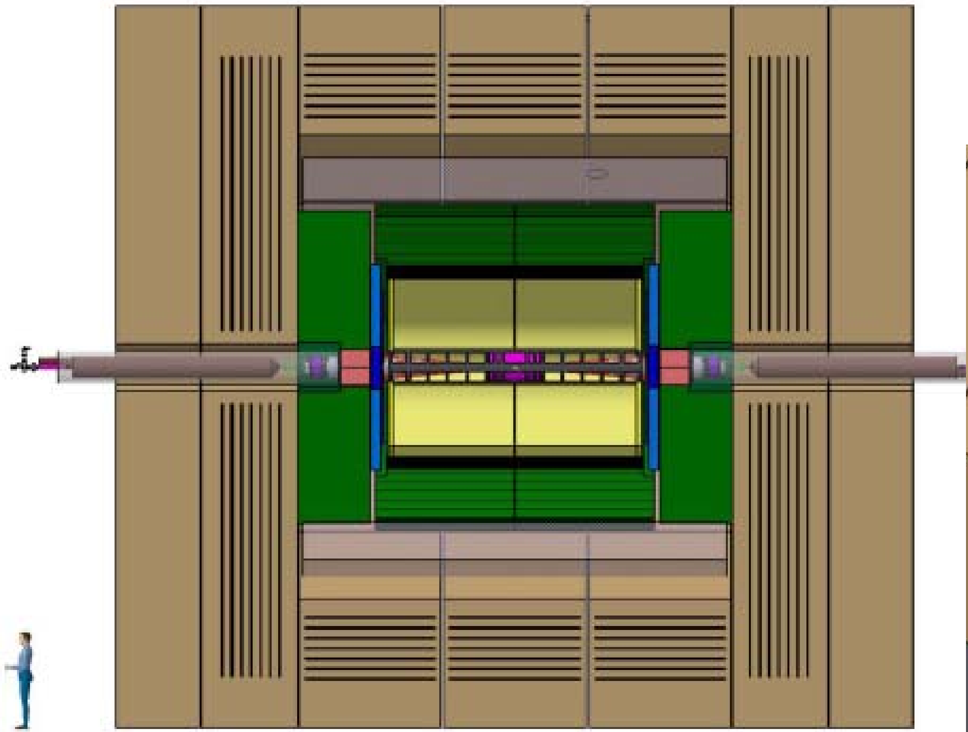
Function of Iron Yoke

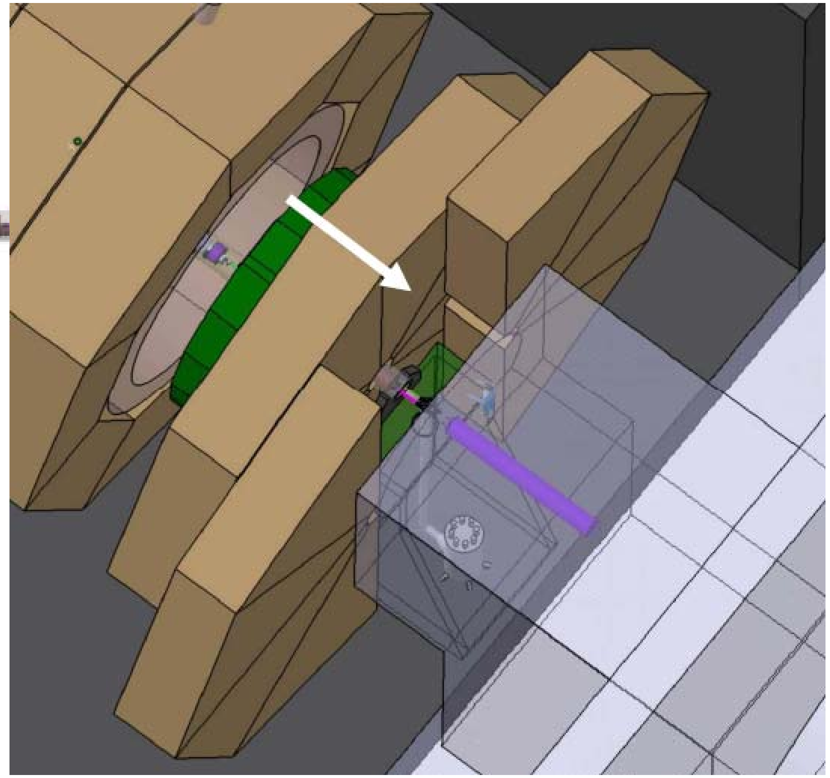
- Iron Yoke
  - Muon identification (and momentum measurement?)
  - Tail-catcher/backing calorimeter
  - Main mechanical support structure
  - Flux return
    - Stray field
    - Large magnetic forces
  - Radiation shielding
    - Detector should be self-shielding
    - Study by T.Sanami presented in Warsaw
  - Progress towards mechanical design

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 end-caps
  - Push/pull
- Previous and present studies:
  - LDC just rough structure. More details on end-caps. Opening and access.
  - GLD rough design. Estimate of end-cap deformation.
  - At Sendai agreed that DESY should get involved in yoke design, in particular end-cap design.
- Progress report

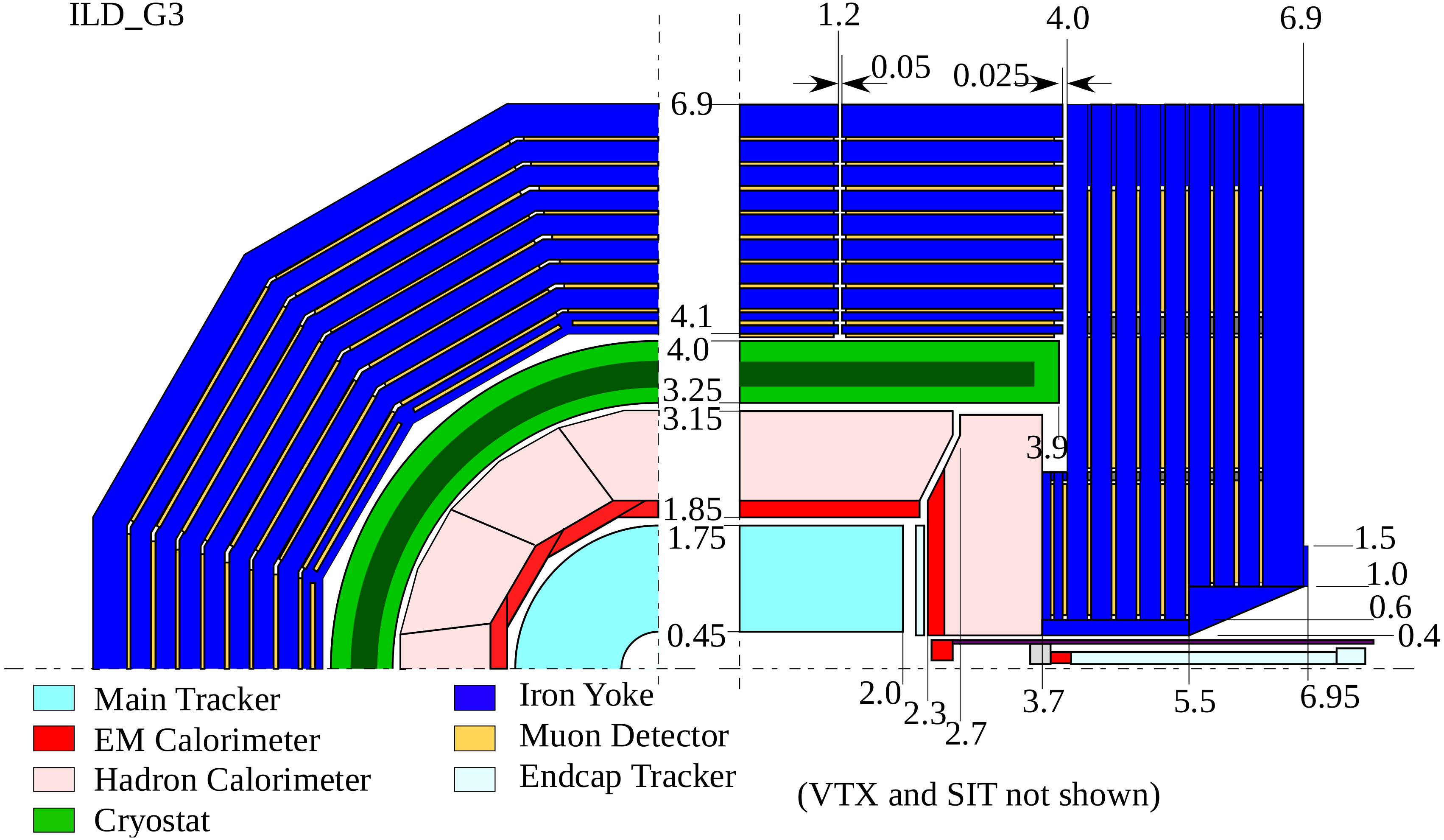
ILD2 Overview





ILD_G3 Overview

Y. Sugimoto



Yoke Design Considerations

Thin vs. Thick plates

Thin iron plates (LEP, H1, ZEUS)

- Is momentum measurement necessary?
  - Done by TPC
  - Might be useful to improve muon purity
- In principle, lower momentum cutoff (mainly determined by calorimeter + coil thickness)
- Backing calorimeter/tail-catcher
  - Depends on thickness of calorimeter and coil (6 Λ + 2 Λ)

Thick iron plates (CMS)

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

Yoke Design Considerations

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

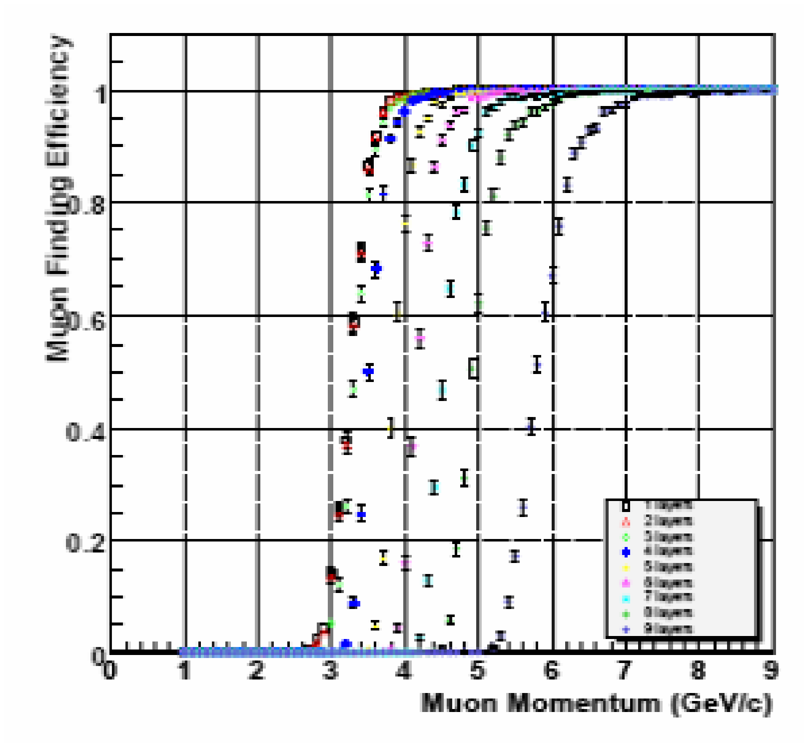
Bolted assembly (CMS)

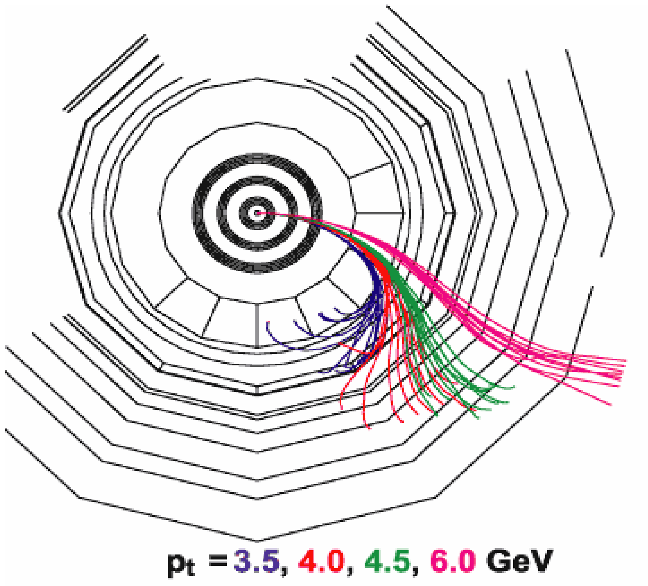
- “light” plates (<50 t)
- Trial assembly at manufacturer easier
- Easier to achieve high precision
- High precision not required for plates, only for connections
- Only machined at bolting points
- More vendors
- Transport and handling easier and cheaper

Iron Yoke – Thin vs. Thick plates

GLD study

Muon finding efficiency at 90deg





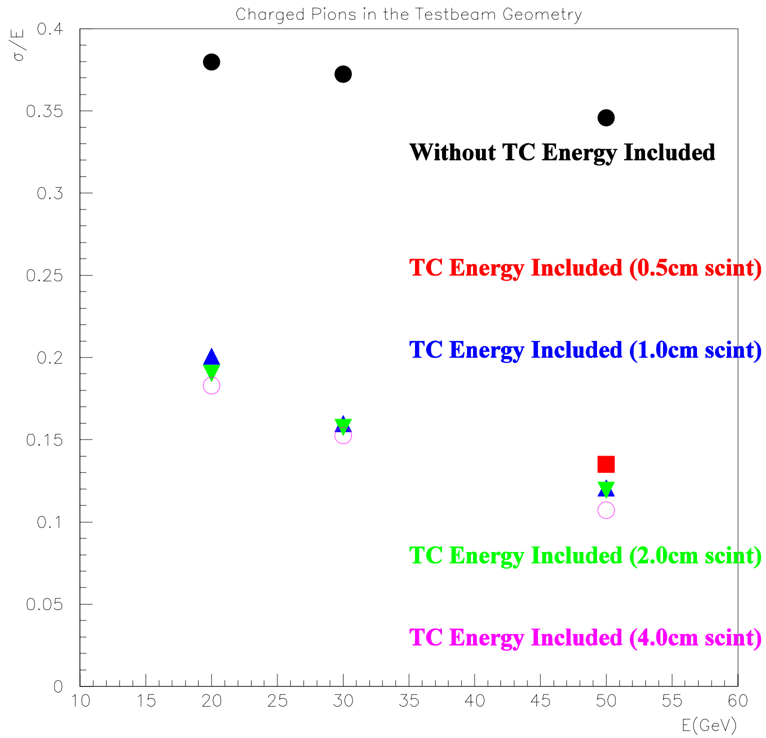
CMS (4 T)

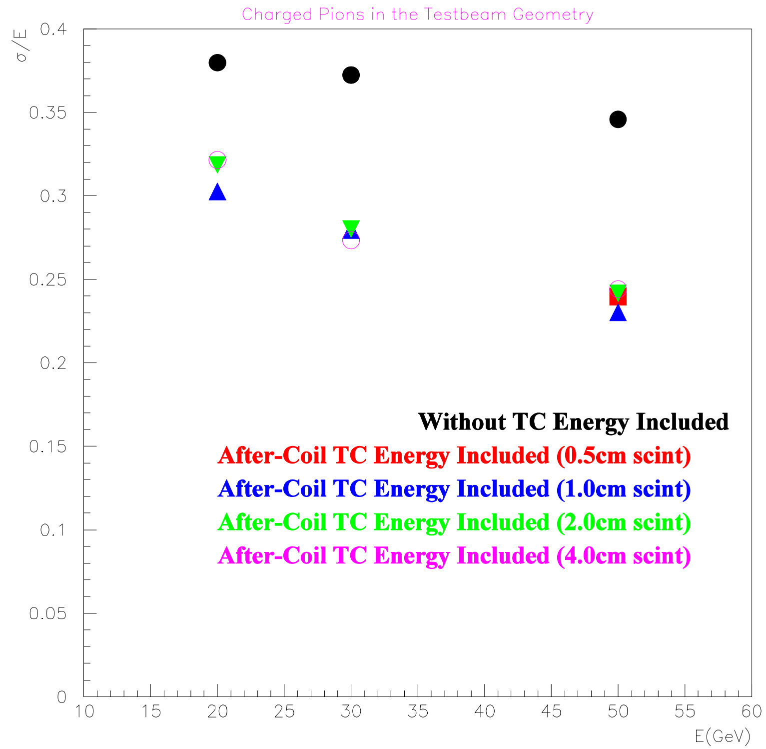
Only muons p > 4GeV reach muon chambers

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 end-cap

- CMS total magnetic force on one end-cap about 9000 t
- ILD
  - First, preliminary results of CST EM Studio calculations (A.Petrov) 24000 t.

- Simple estimate of deformation of 8m diameter circu-lar steel plate with central distributed force of 5000 t
  - Thickness 100mm (s = 0.8m) plate destroyed
  - Thickness 300mm s = 30mm
  - Thickness 600mm s = 4 mm

Yoke Design Considerations

CMS yoke excellent design, coil very similar

Why not simply copy the yoke design?

CMS

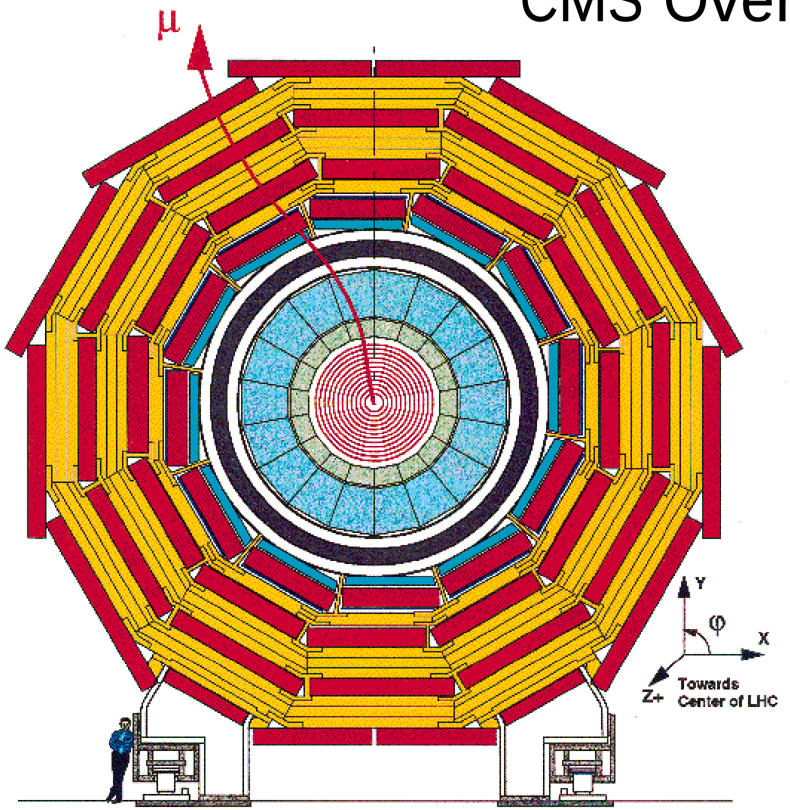
- Calorimeter 7 Λ (+ coil 2 Λ)
  - One tail catcher layer outside coil in central area
- Total iron thickness only 1.5m (end-cap plates 600, 600 and 250mm)
- Stray field at 1m 1.2kG
- “High” radiation
- Hall is not accessible during operation

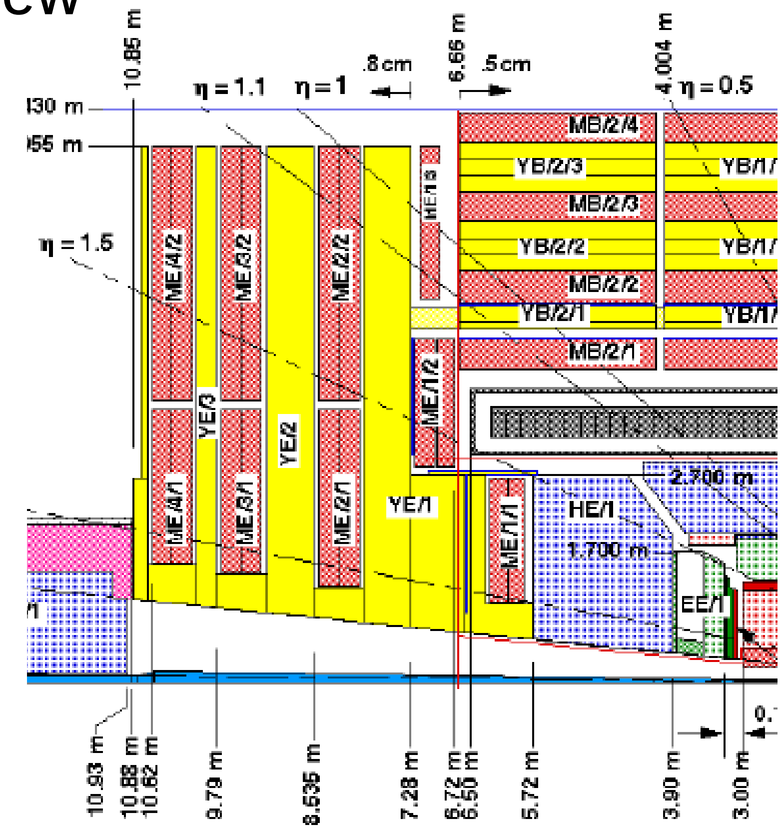
ILD

- Calorimeter only 6 Λ (+ coil 2 Λ)
  - Need tail catcher => thin inner iron plates
- Stray field should be 200G at 0.5m
- Self shielding
- Move in/out beam position

Yoke Design Considerations

CMS Overview





Thickness of iron plates (from IP)

Barrel: 295, 630, 630mm

End-cap: 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
- End-caps
  - 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.
- Thicker (>100mm) plates can of course be used, if tail-catcher not needed.

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 sided
  - Individual sections smaller, weight ~2/3
    - Present assumption hall crane 100t
  - Bending of iron plates ~ 0.3 (circumference)
  - Smaller distance between supports (~2/3)

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

Yoke Design Considerations

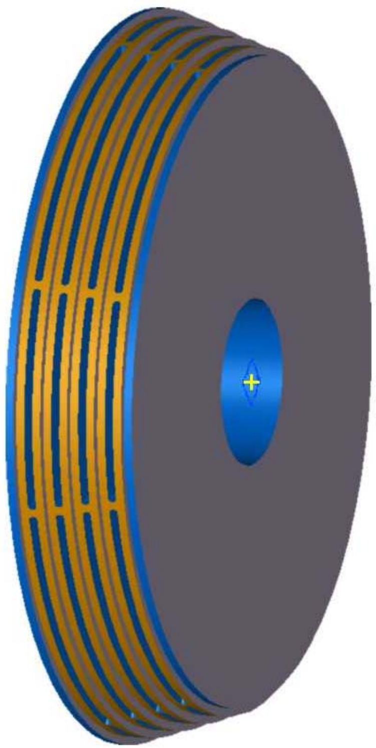
End-cap design more challenging than barrel design due to huge magnetic forces

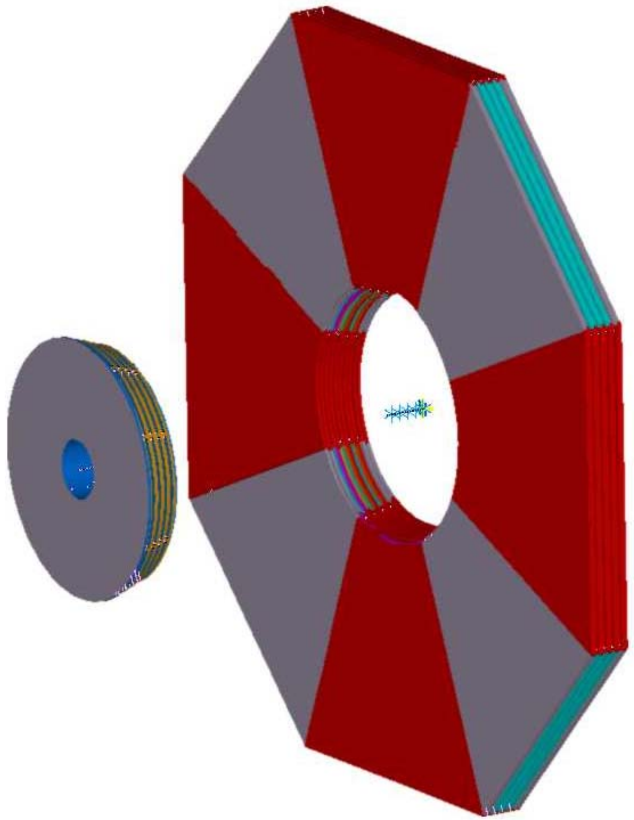
- Propose radial supports (rips) in radial direction for inner end-cap section in order to minimize deformation and mechanical stress.
- Tensile strength of support rips determined by welding seams or bolts
  - Looking into spheroidal cast iron design
  - Solid rips much better tensile strength than bolts

Need detailed mechanical study

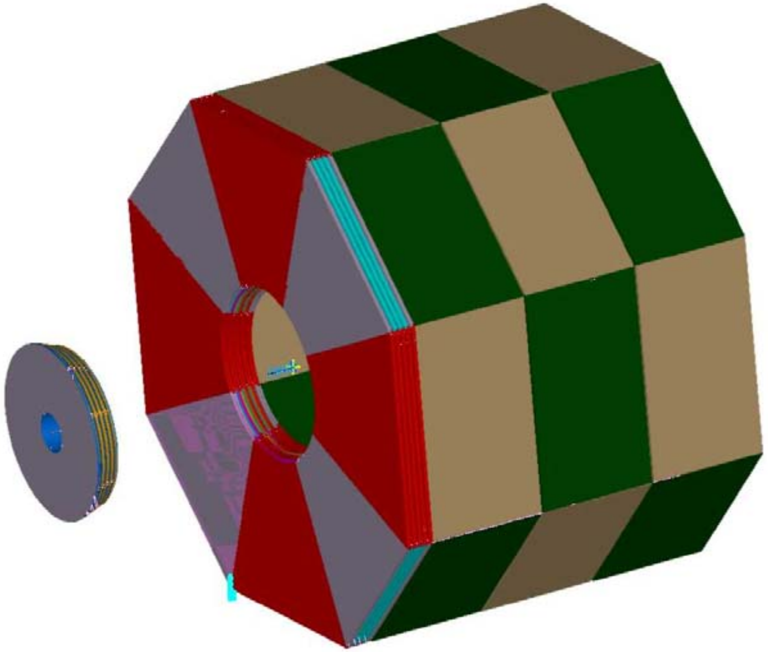
End-cap Design Proposal

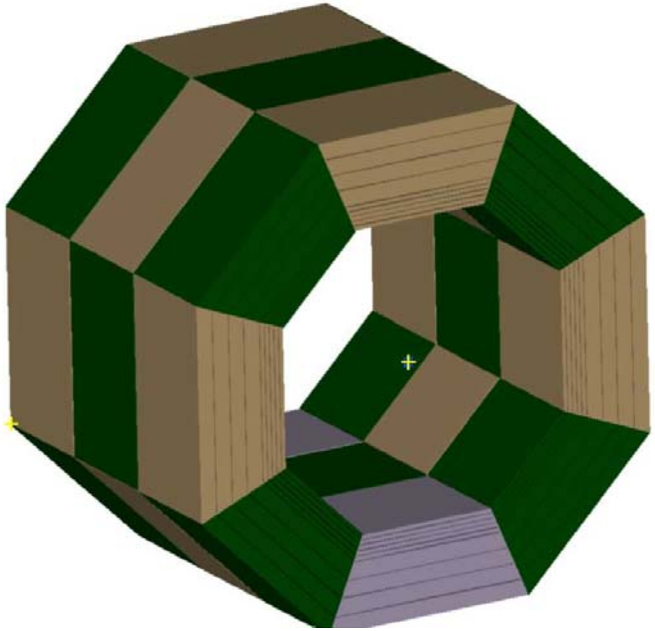
Proposal: End-cap out of spheroidal cast iron (R.Stromhagen)

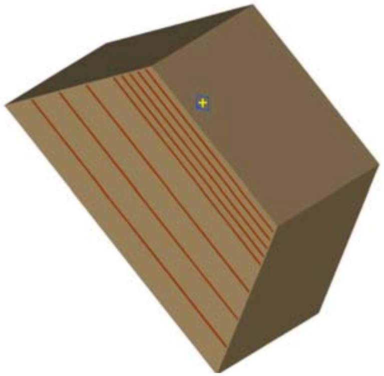




End-cap Design Proposal

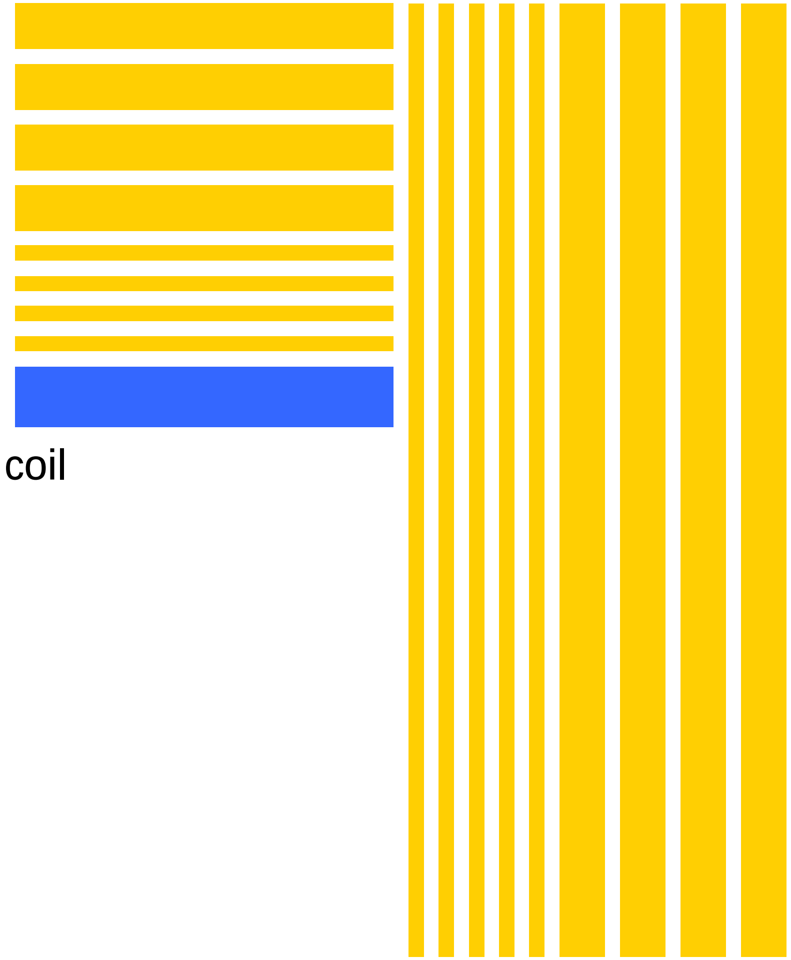






Only inner, thin plate end-cap shown

End-cap Design Proposal

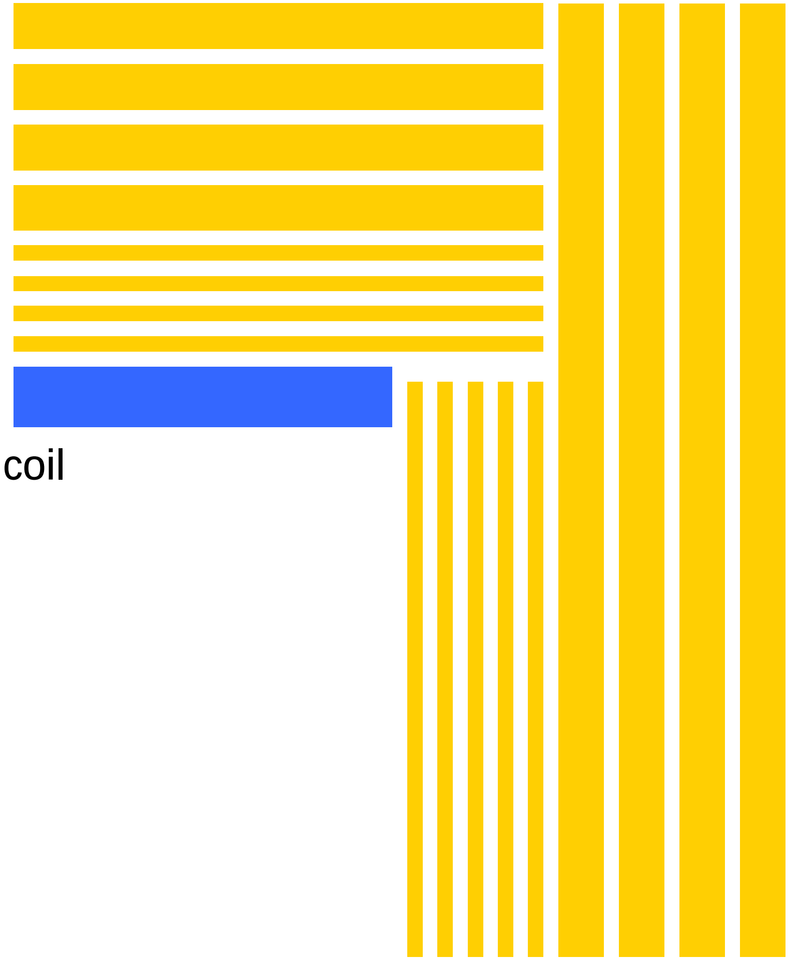


Fine (100mm) segmentation in barrel end-cap overlap region not realy needed.

Problems:

- Mechanical strength of thin plates
- Installation and access of end-cap detectors in case of radial rips. In particular for bottom detectors

End-cap Design Proposal



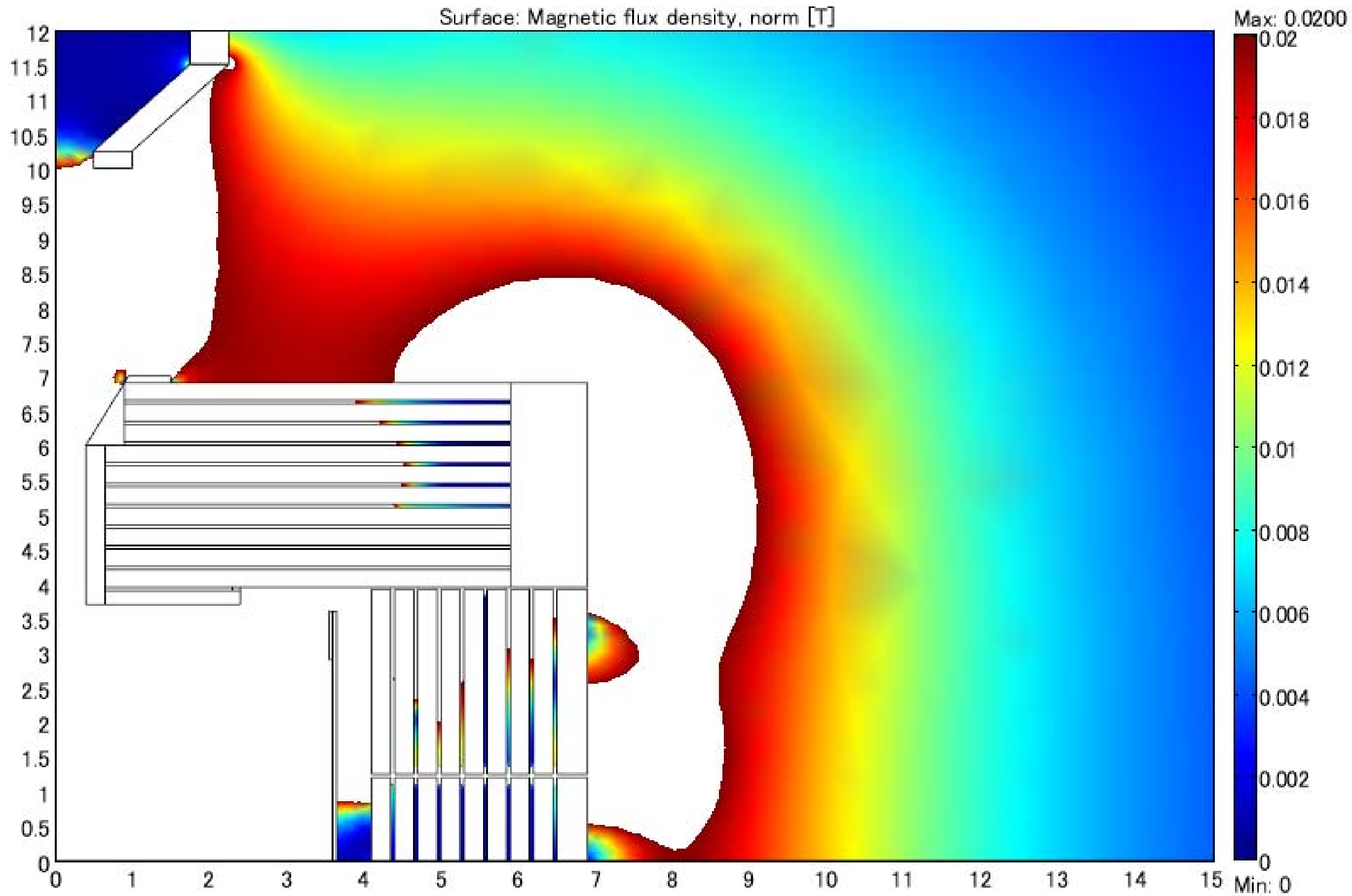
Slightly longer barrel

- Better mechanical design of end-cap
- Better installation and access of end-cap detectors in case of radial rips
- More difficult access when end-cap open. To be looked into.

Magnetic Field Calculations

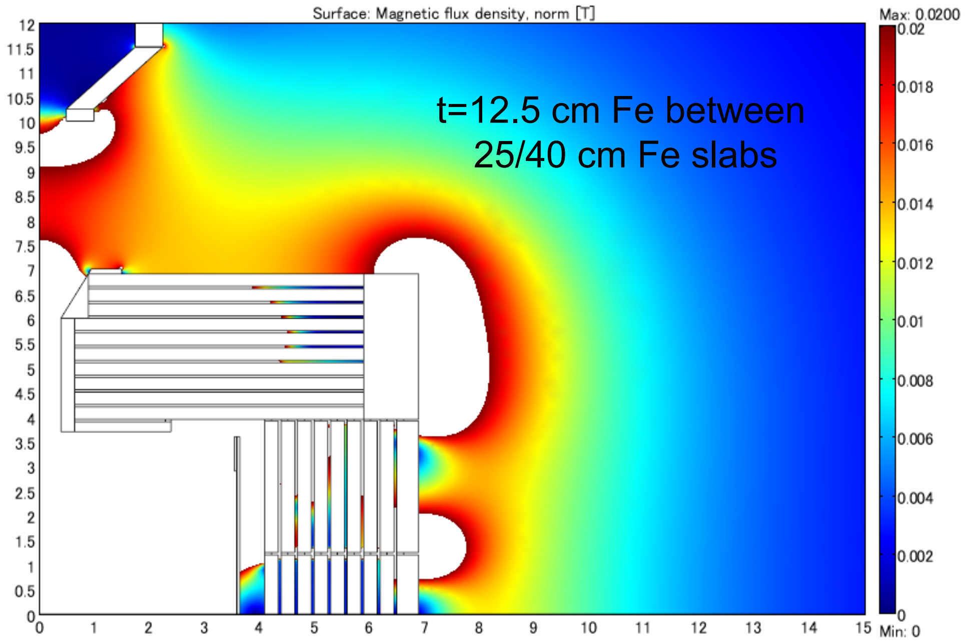
GLDc 2 D calculations, B = 3.5T

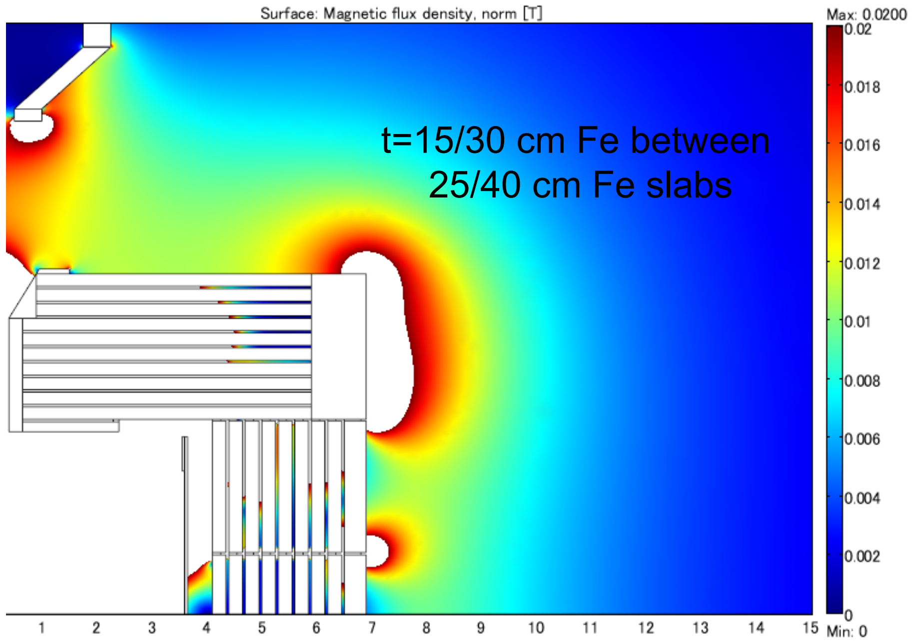
Y.Sugimoto



Magnetic Field Calculations

B = 3.5 T   Gap partially filled with Fe   Y.Sugimoto





In order to achieve the required stray field of <200 G at 0.5m (thickness 2.5m)

- Much more iron is needed or
- Gaps between rings should be partially (>50%) filled with iron, however need space for cables, cooling,... (2 D calculation)

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
- Used currents from F. Kircher as starting point. Slightly adjusted when iron geometry changed
- Inner field uniformity not optimized

Programs being used

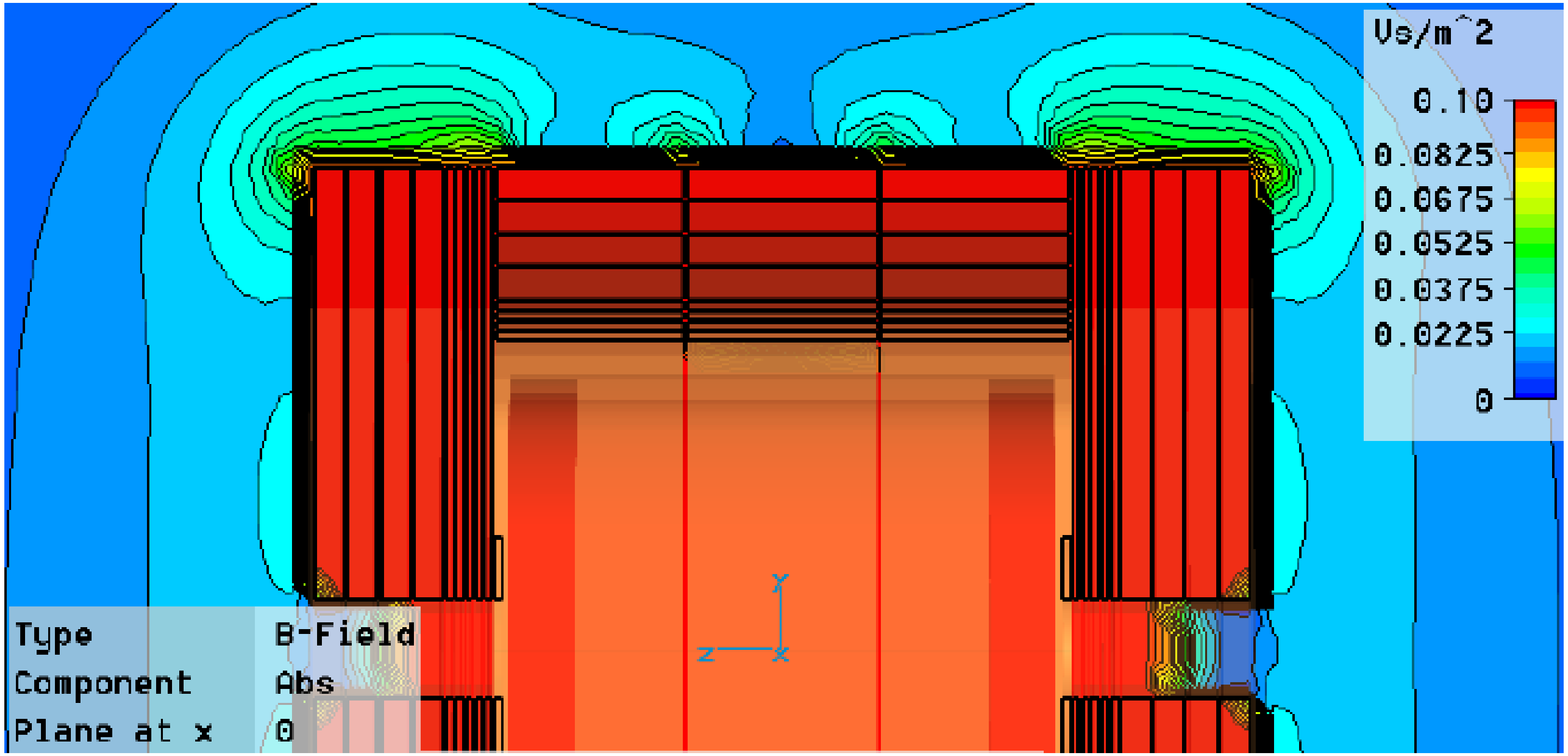
- CST EM Studio (A.Petrov, B.Krause)
  - First results available
- ANSYS (C.Martens)
  - First results this week

Field calculations in agreement

B Field Calculations

3 D calculations B = 4 T

A.Petrov, B.Krause

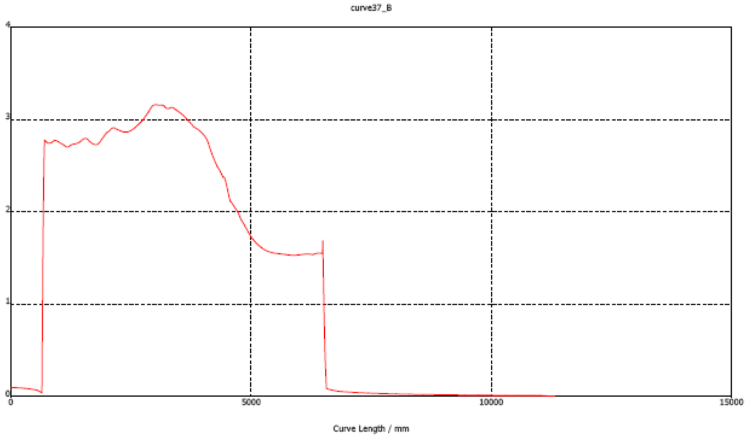


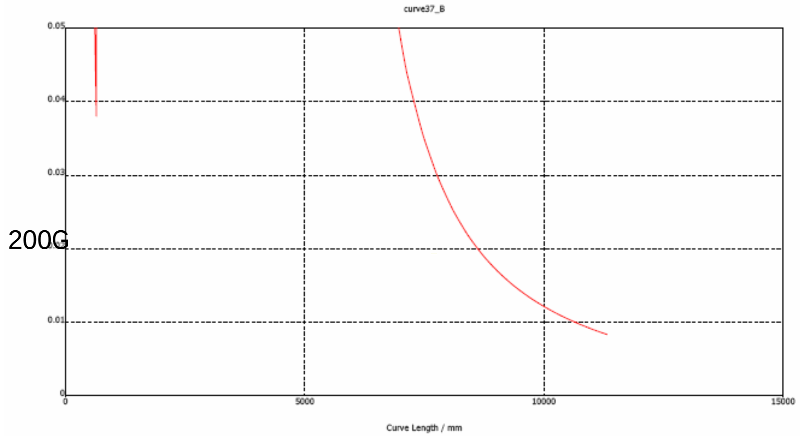
iron thickness 2.16m

B Field Calculations

B field vs r at end-cap, bounding box 15m

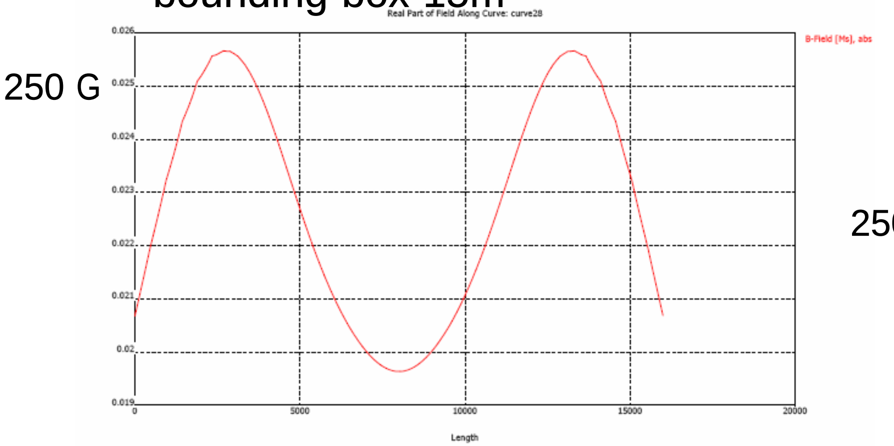
A.Petrov, B.Krause



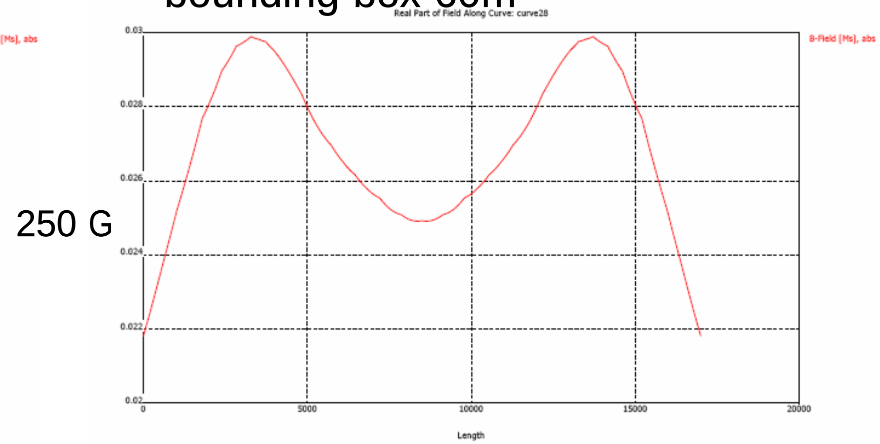


B field vs. z at x = 10m

bounding box 15m

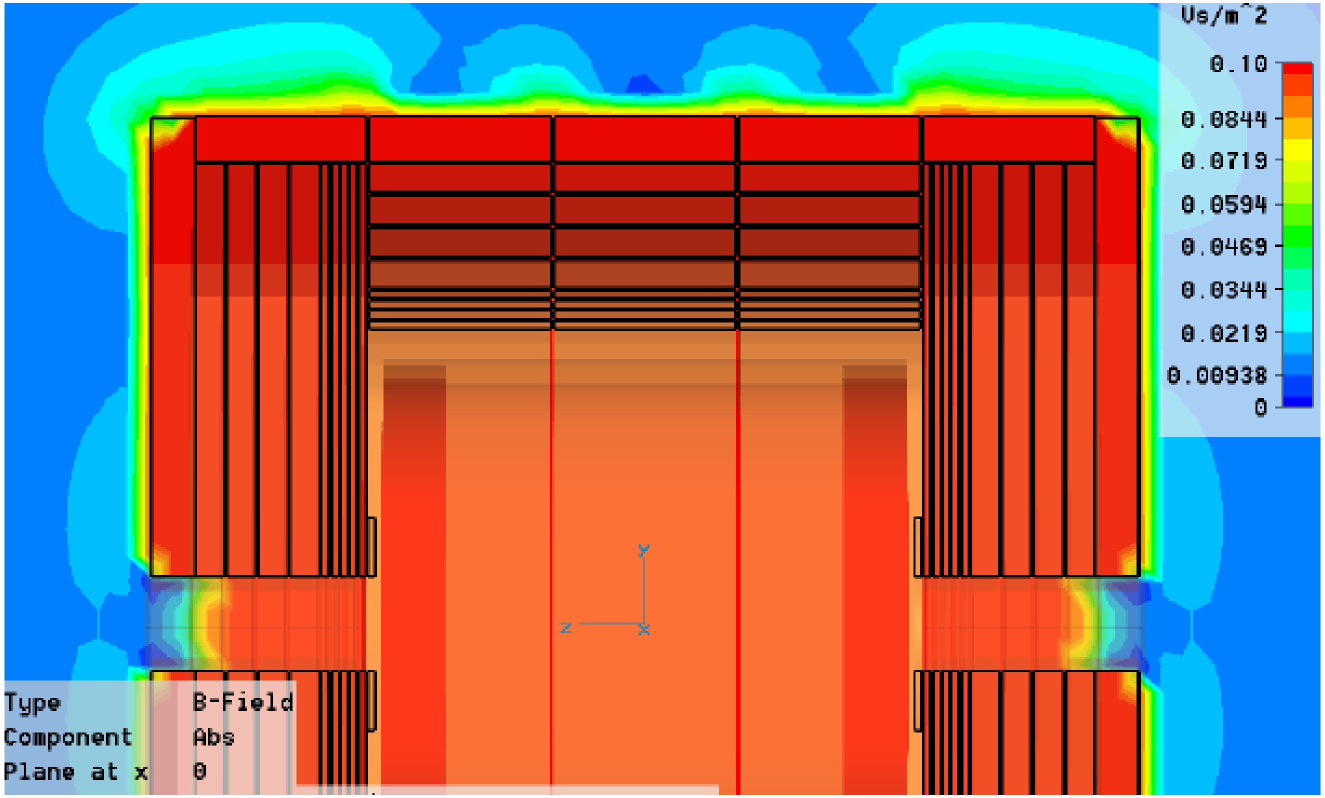


bounding box 60m



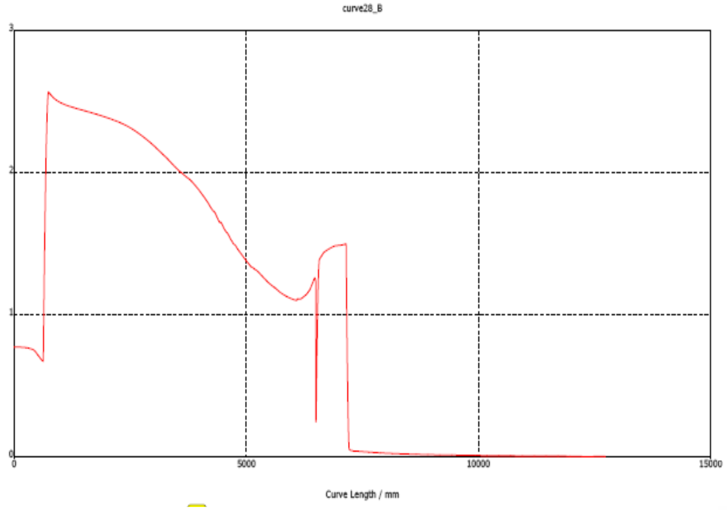
B Field Calculations

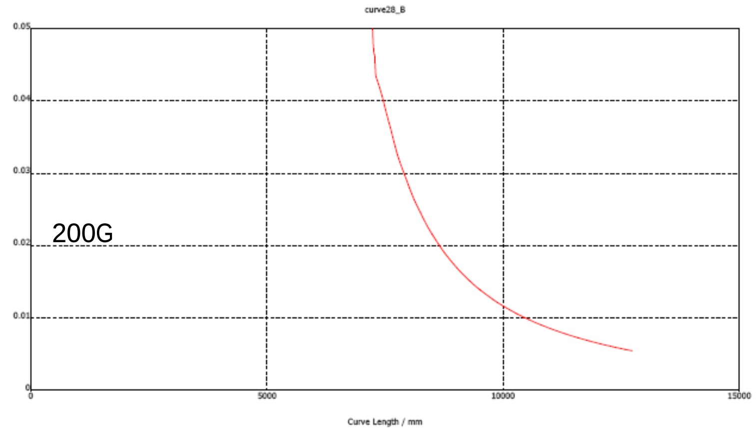
Added 60cm of iron to reduce stray field, bounding box 15m



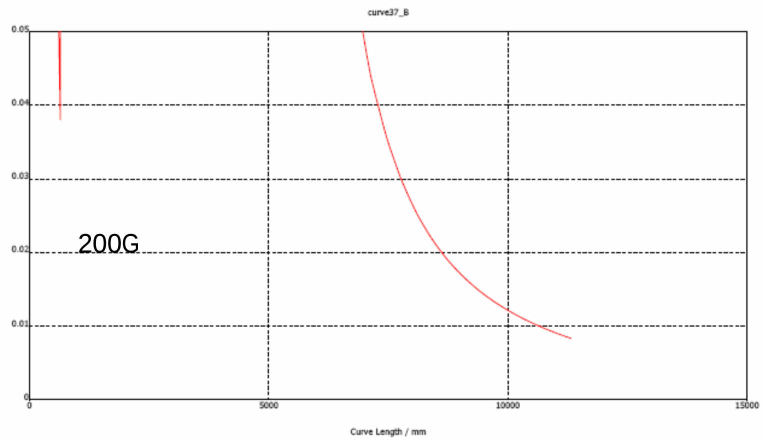
B Field Calculations

B field vs r at end-cap, +60cm iron, bb 15m





Previous plot, no additional iron



200 G reached at about:

- 2m from iron
- 1.5m for +60cm iron

The projection is close to the maximum

B Field Calculations

Conclusion of first results

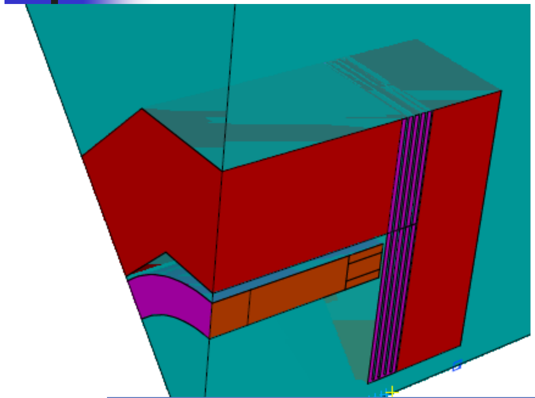
- Maximum stray field barrel
  - Geometry 1: 260G at x=10m ~3.5m from iron (bounding box 15m)
  - Geometry 1: 300G at x=10m (bounding box 60m)
- Very challenging to achieve 200 G at 0.5m

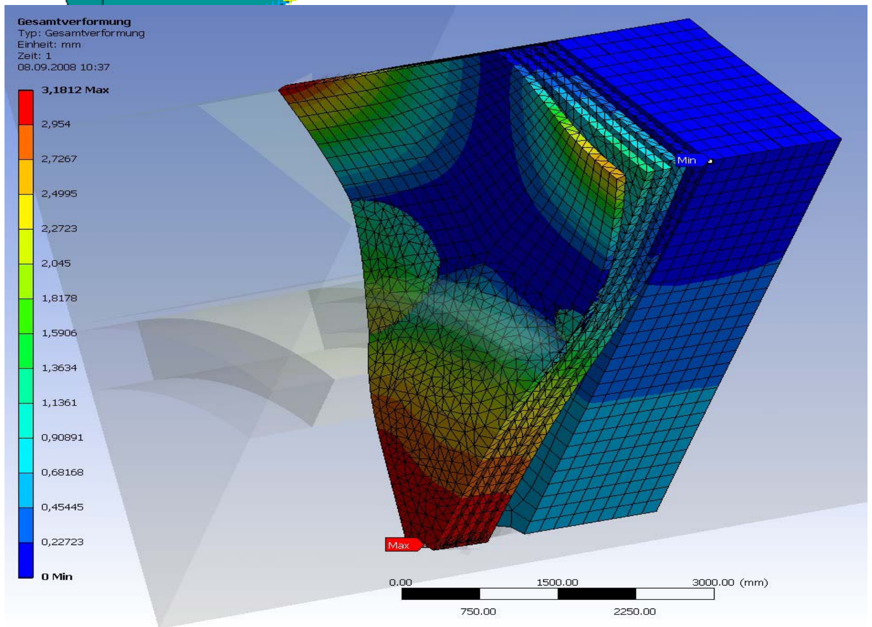
- Is 200 G really fixed?

  Interface document, similar to CERN Safety Rules
  - Surface of 'on-beamline' detector < 2kG (limit for working day)
  - Non-restricted area (including 'off-beamline' detector) < 100G
- Adding lots of additional iron will
  - be very expensive
    - Very rough estimate using CMS yoke cost/ton (1997): +60cm barrel and EC additional 8 M€
  - reduce available space when end-cap is opened

- (Argument for reducing field to 3.5 or 3 T, if 200G is kept as the limit)

Deformation due to Magnetic Forces





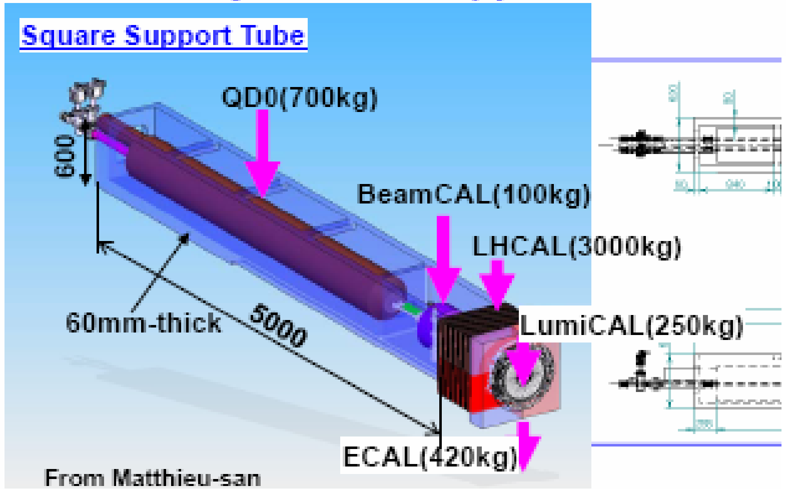
C.Martens

Deformation of inner thin end-cap section with radial rips

- So far not connected to outer end-cap
- Plates connected at inner tube
- Very preliminary results max. deformation
  - 3mm at 3T
  - 4.5mm at 4T

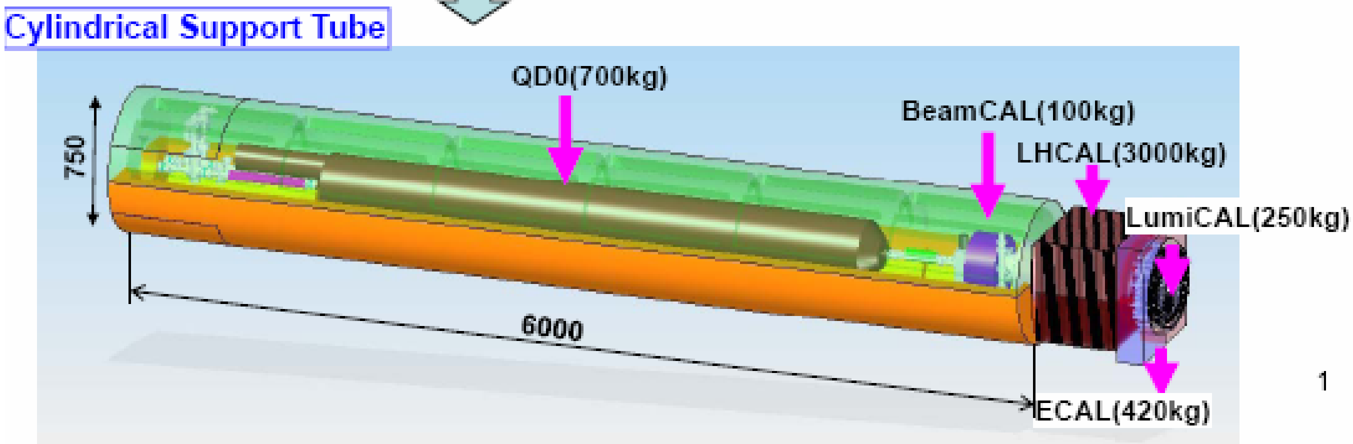
Confident that a ‘thin’ plate inner end-cap can be built

Cylindrical Support Tube Design



Design of square support tube in progress M.Joré

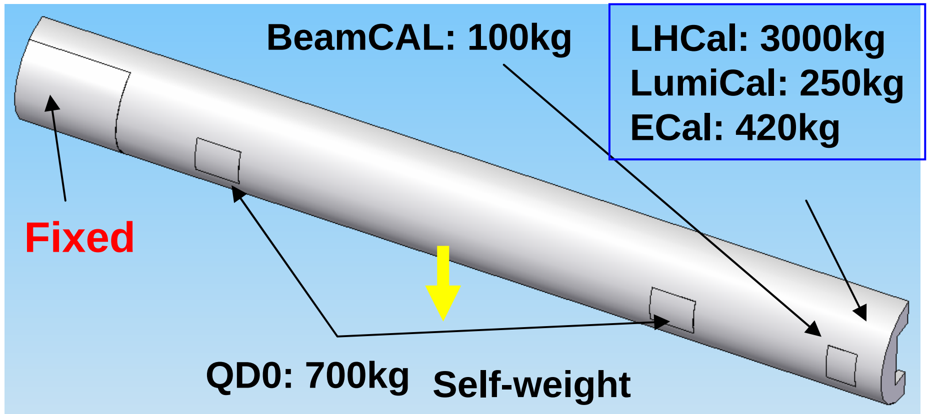
Detailed design of cyclindircal support tube H. Yamaoka

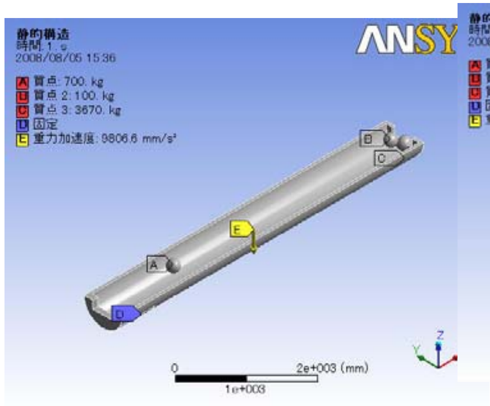


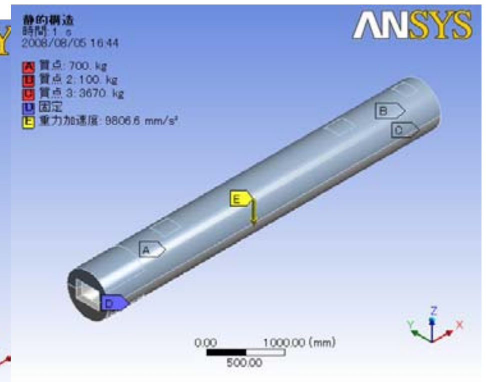
Cylindrical Support Tube Design

H. Yamaoka

- **Materials**
  - Stainless steel
  - Aluminum
- **Load condition**
  - See: right-upper
- **Constraints**
  - Only cylinder-end.
  - Not constraint on the middle position
- **Models**
  - Half-Cylinder
  - Full-Cylinder
  - Half-cylinder with reinforcement rips
- **Analyses**
  - Static analysis
  - Modal analysis
  - Dynamic analysis due to grand motion

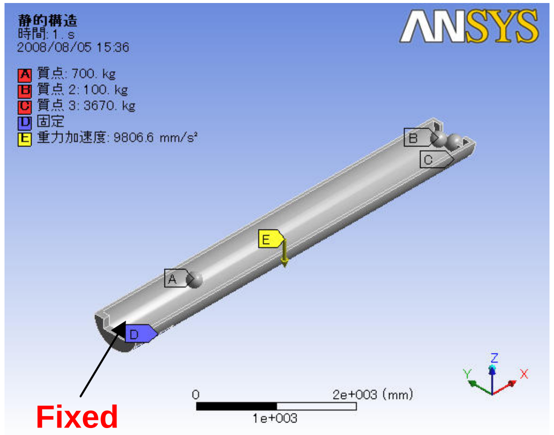


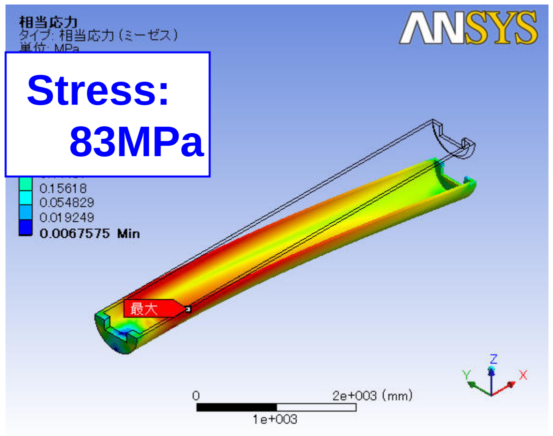


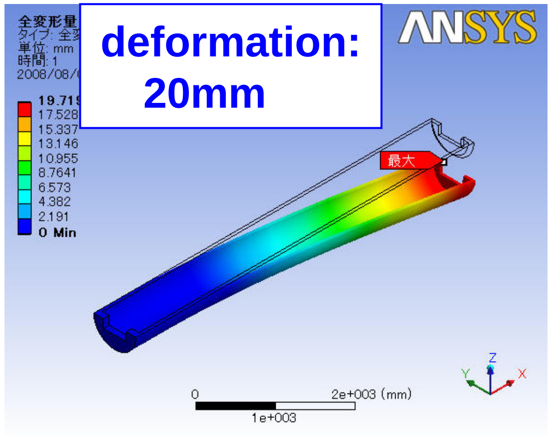


Cylindrical Support Tube Design

- Half-cylinder
- Stainless-steel
- 50mm-thick
- Each detector weight +Self-weight







Cylindrical Support Tube Design

Additional studies H. Yamaoka

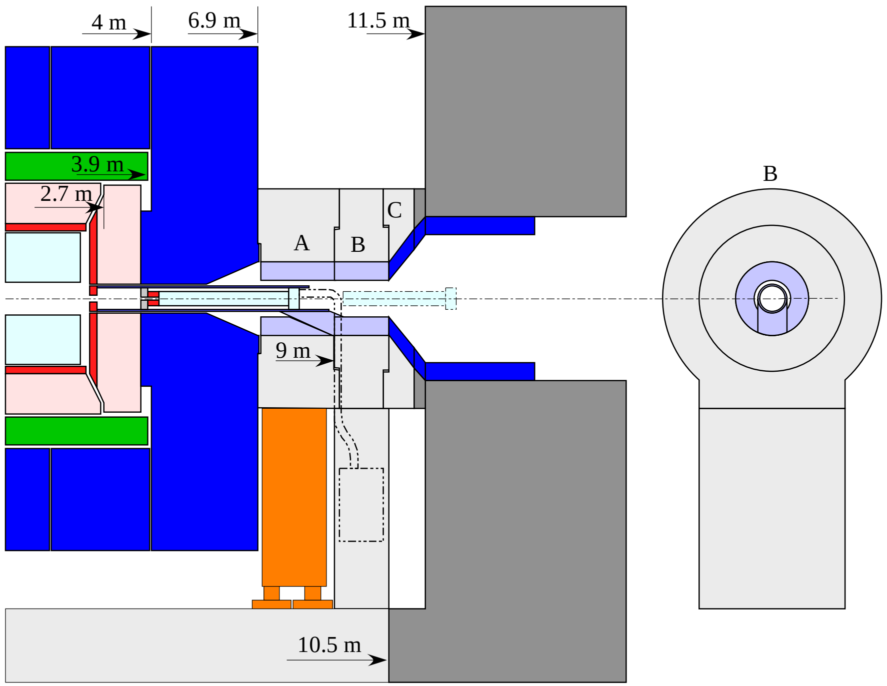
- Natural frequencies
- Amplitude due to ground motion
  - Used KEK ATF measurements
  - ➔ max. amplitude 8nm at 4Hz

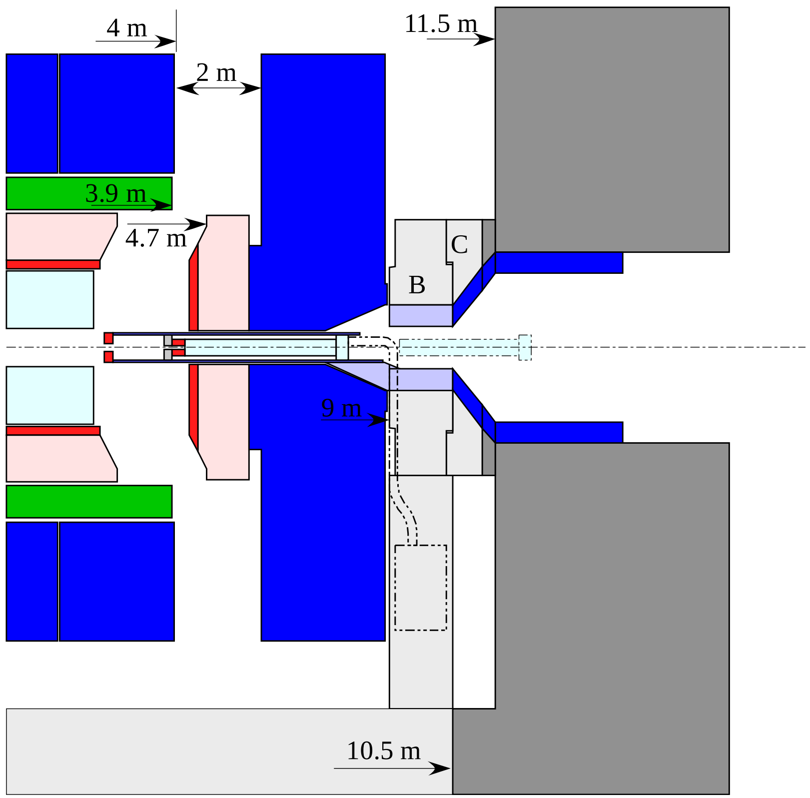
Results

- Half-cylinder too large deformation (stainless steel 20mm) /stress
  Should be full-cylinder (deformation 3.2mm)
- Stainless steel is the best material for support tube
  Smaller deformation/stress than aluminum case (def. 6.7mm)
- Additional support is probably not necessary
  - Amplitude due to grand motion is acceptable (few nm)

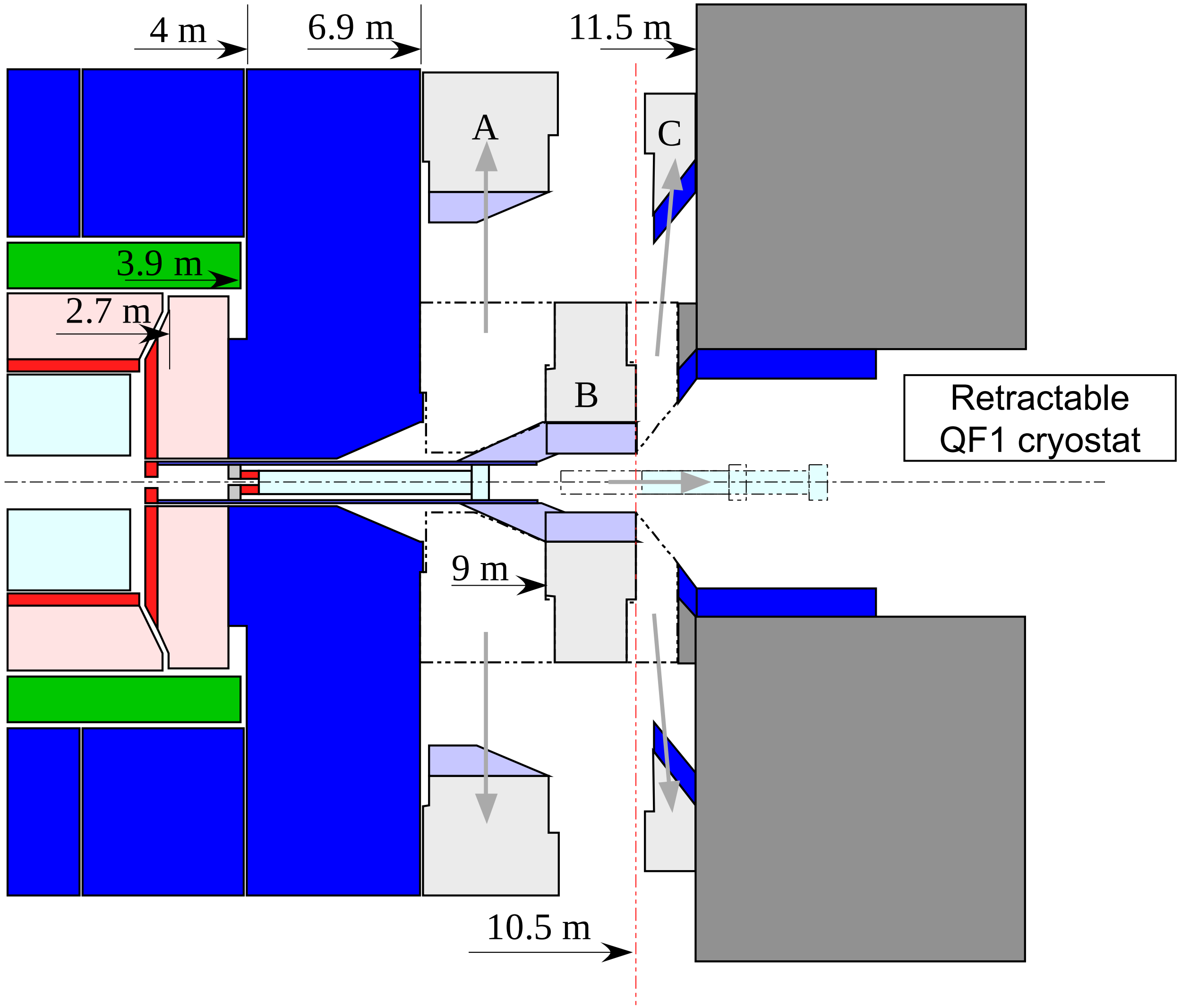
ILD_G3 End-cap Opening

Y.Sugimoto

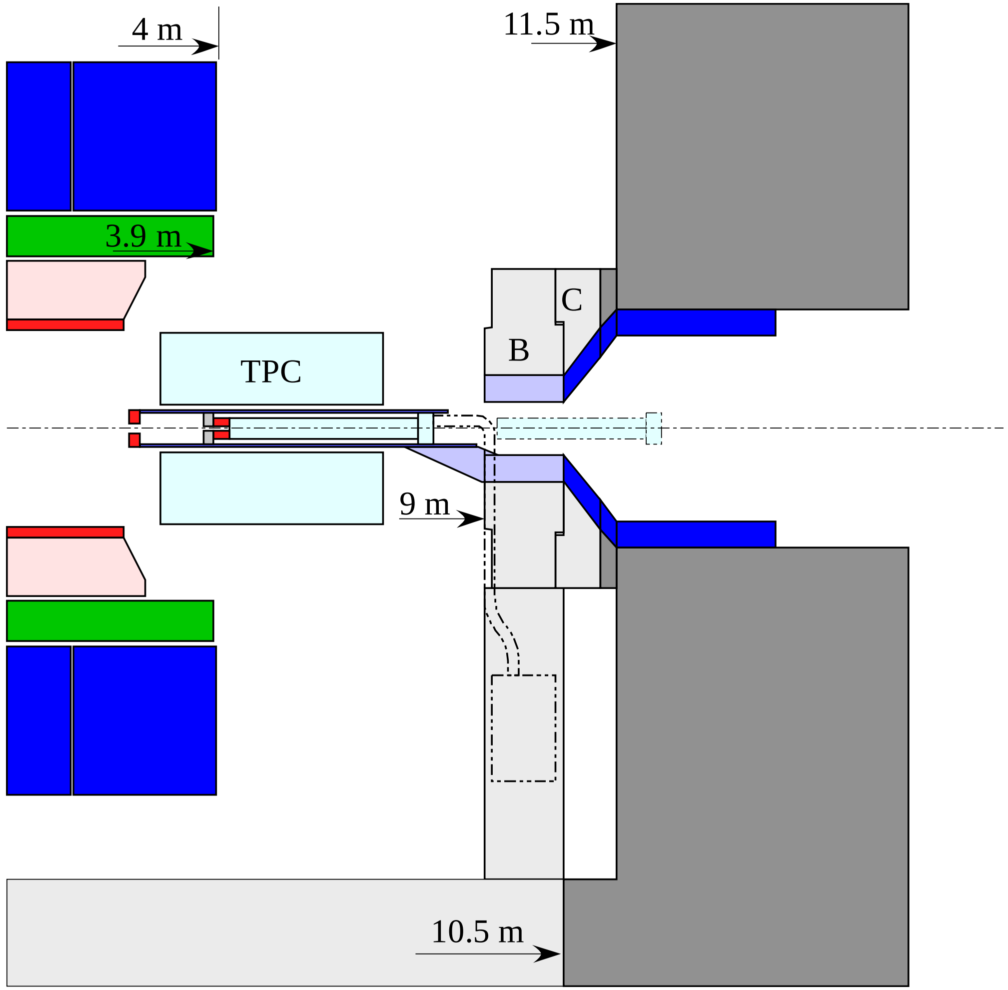




ILD_G3 End-cap Push-pull Operation



ILD_G3 Access to Inner Tracker



Conclusions

Need performance vs. cost optimization

- Decide on magnetic field
- Size and total thickness of iron yoke
  - Main problem outside stray field
  - Adding iron -> significant cost increase
  - Thickness of end-cap determines available space for access
    -> Propose not to use 200G as limit
- Segmentation of iron yoke
  - Is tail-catcher needed?
    - If yes, probably five layers (100mm iron plates)
    - Thickness of gaps (30mm)
  - Muon detector
    - Is fine segmentation needed?
    - Few outer layers should be sufficient
    - Do we need momentum measurement? Improve purity?
    - Detector choice? Gap thickness?

Conclusions

- Yoke shape (8 vs. 12 sided)
  - Propose to follow calorimeter design
    - Dodecagon is preferred from mechanical point of view
    - Easier transport and handling
    - Less deformation
- Started on somewhat realistic mechanical design of iron yoke in order to study stability
  - With and without magnetic field
  - Opening and closing of end-caps
  - Push/pull
- Detailed simulations of magnetic forces in order to proceed with mechanical design (stress, deformation) in progress
- Compare different yoke designs

Conclusions

- Push Pull
  - Will assume platform for LOI
  - Check whether detector design is compatible without platform
  - Mechanical design of coil support critical (F. Kircher's talk)

Good progress on

- Support tube design
- Re-commissioning after push (not reported)
- Beam pipe design (not reported)
  - Higher order mode losses
  - Deformation and stress