# Status of ILD Yoke Design

Uwe Schneekloth
DESY

ILD Meeting, Fukuoka
24.05.2012

# Outline

Conceptual design of ILD Yoke

Brief summary of

- End-cap design
- Barrel design
- Cryostat support
- Yoke assembly

Conclusions

Mainly report on progress at DESY

- K.Büsser, M.Lemke, B.Krause, C.Martens, A.Petrov, K.Sinram, U.S., R.Stromhagen (all part time)

# Function and Challenges of Iron Yoke

- Flux return
  - Field homogeneity in TPC
  - Stray field
  - Large magnetic forces

Determines total thickness of iron

- Muon identification and hadron rejection
  - Muon momentum measurement done with inner tracking detectors
  - Some muon ID with calorimeter, but need high purity and redundancy
  - Rejection of beam halo-muons
- Tail-catcher/backing calorimeter
- Main mechanical structure of detector
- Radiation shielding
  - Detector should be self-shielding
  - Study by T.Sanami presented in Warsaw, ECFA 2008

- Main challenges of yoke design
  - Reduce stray field to acceptable level
  - Huge magnetic forces on end-caps

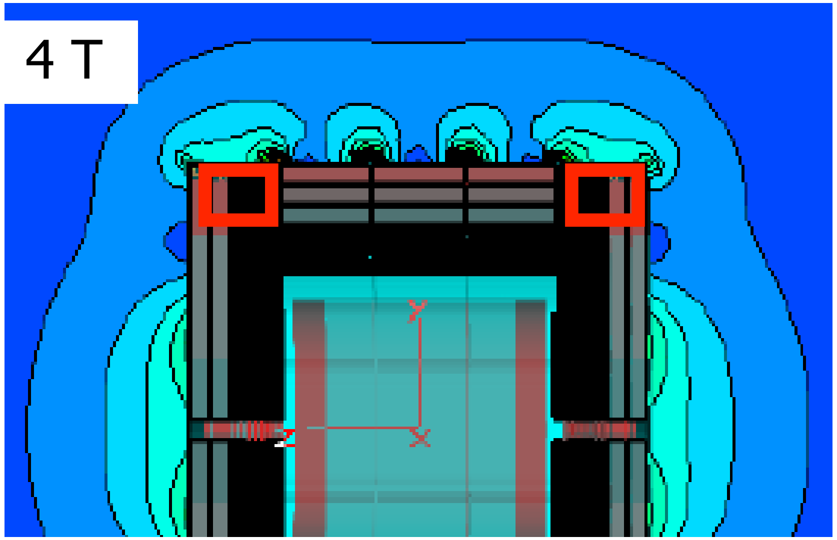
# ILD Parameters Reference Detector

- Segmentation of yoke
  - 100mm field shaping plate only end-cap
  - 10 x (100mm + 40mm gap)
  - n x (560mm + 40mm gap)
- Segmentation was fixed by steering group for good muon detection and tail catching. Detailed studies not available when decision made.

  Worst case in view of mechanical design. Thick plate design would be easier.
- Decision now confirmed by detailed muon study
  - However, fine segmentation may not be necessary at 'low' energy
  - Option
    - Could instrument every second layer
    - Install remaining layers for high energy upgrade

# Magnetic Stray Field

Did extensive field calculation for several geometries




iron thickness 2.68/2.12m

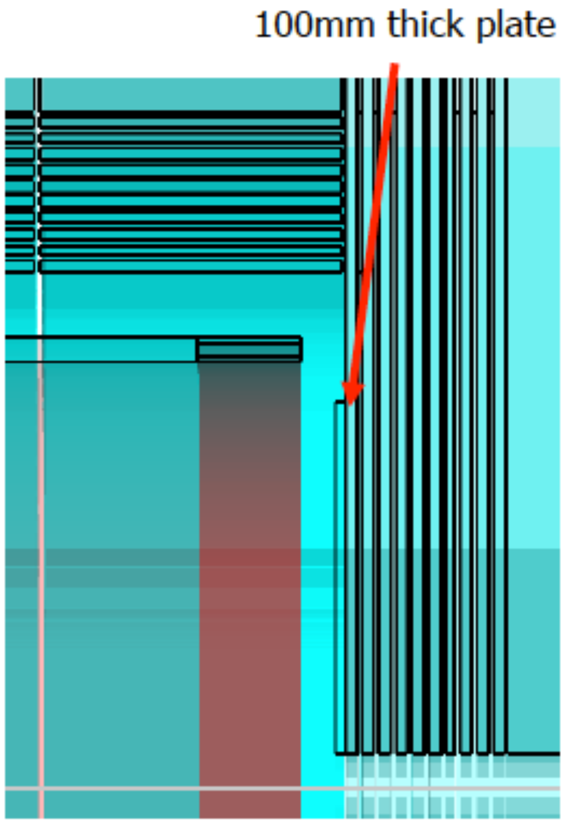
total thickness 3.16/2.56m

$r_{out}$ = 7.655m, z = 6.605m

- Achieved goal of < 50G at 15m from beam line for 4 T
- Thickness of iron and size of detector is determined by stray field requirements

# Field Shaping Plate

- FSP in front of end-cap was introduced for LOI to improve field quality in tracking volume.
- In principle no longer needed with relaxed field requirements
- FSP is part of part of 1st iron plate
- Strong magnetic forces acting on FSP. Without FSP, force would act on first plate. First plate less stiff. Probably no big effect on mechanical design (to be checked)
- FSP additional dead material in front of muon system/ tail catcher
- Options without FSP
  - End-cap cannot be moved in by 100mm
  - Could move CAL end-cap out by 100mm
    - Gain space in front of ECAL, worse acceptance in barrel EC transition
  - Could extend HCAL EC by 100mm. Expensive
  - Could use space for 1st muon/tail catcher layer
    - Would improve energy measurement



# End-Cap Forces and Deformation

End-cap design determined by large magnetic forces

ANSYS

- Force at each segment node

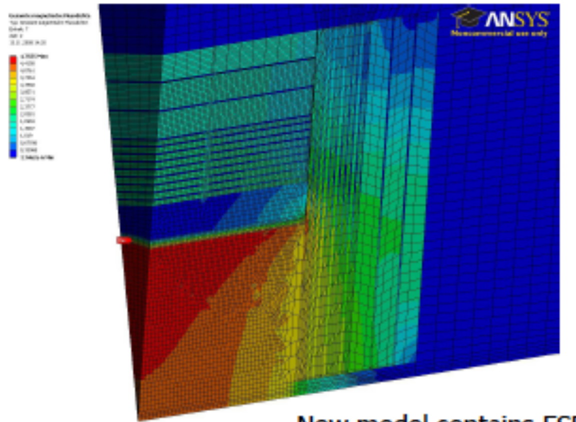
  Resulting force on hard stop

  → $F_z$ = 19000t for 3 thick EC plates

  $F_z$ = 18000t for 2 thick EC plates

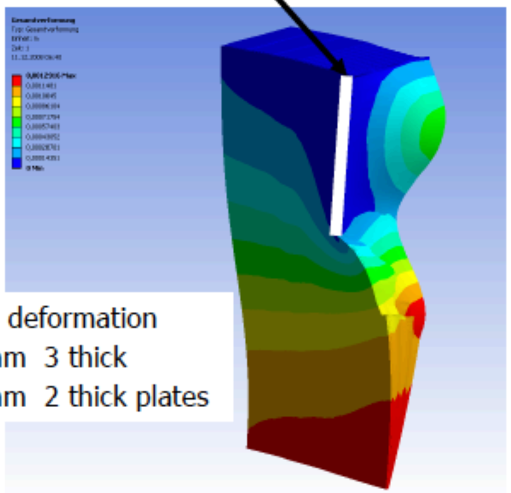
  Model with open gaps

ANSYS model B field



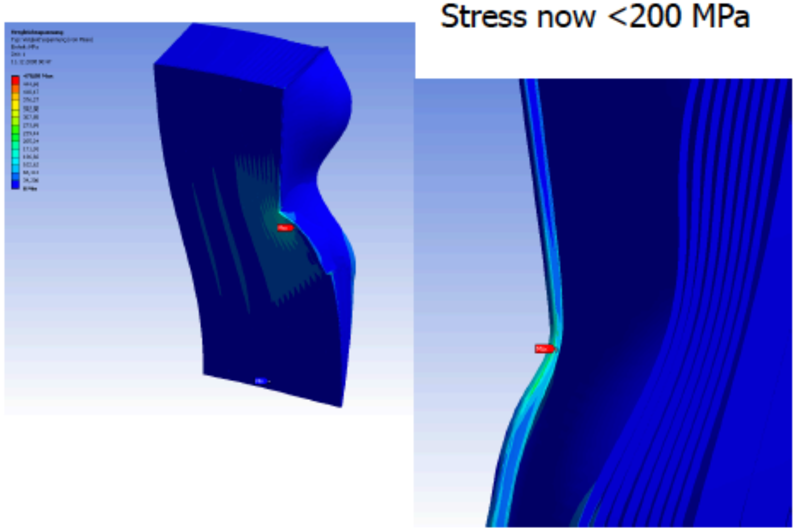
New model contains FSP

Same as previous page, but with modified hard stop
20cm wide, radially extending from first to last barrel iron plate



Max. deformation
1.3mm 3 thick
1.6mm 2 thick plates

Stress now <200 MPa

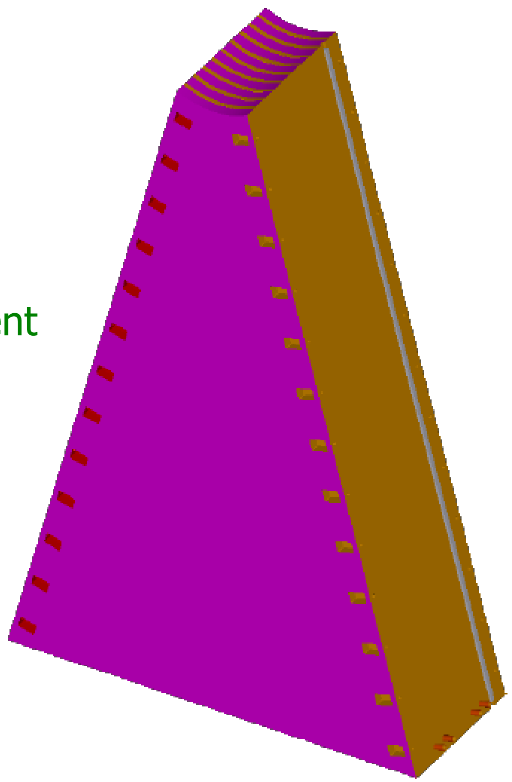


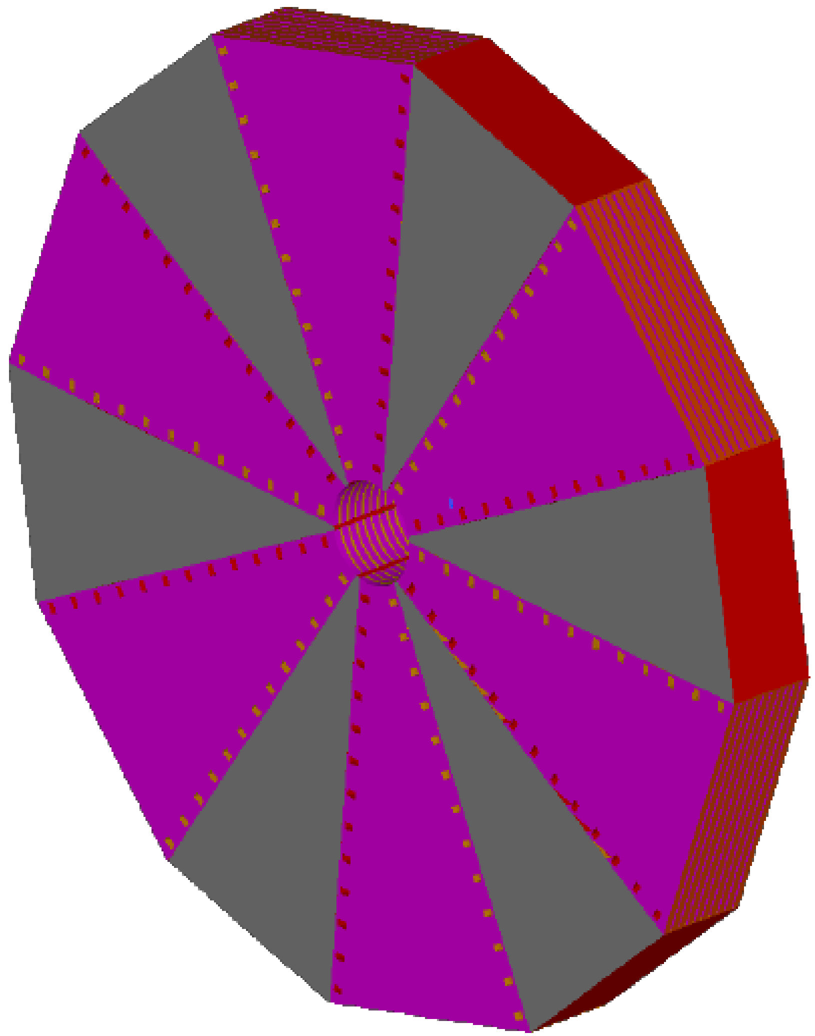
# Mechanical Design of End-Cap

R.Stromhagen/U.S.

Design with segments and welded plates.

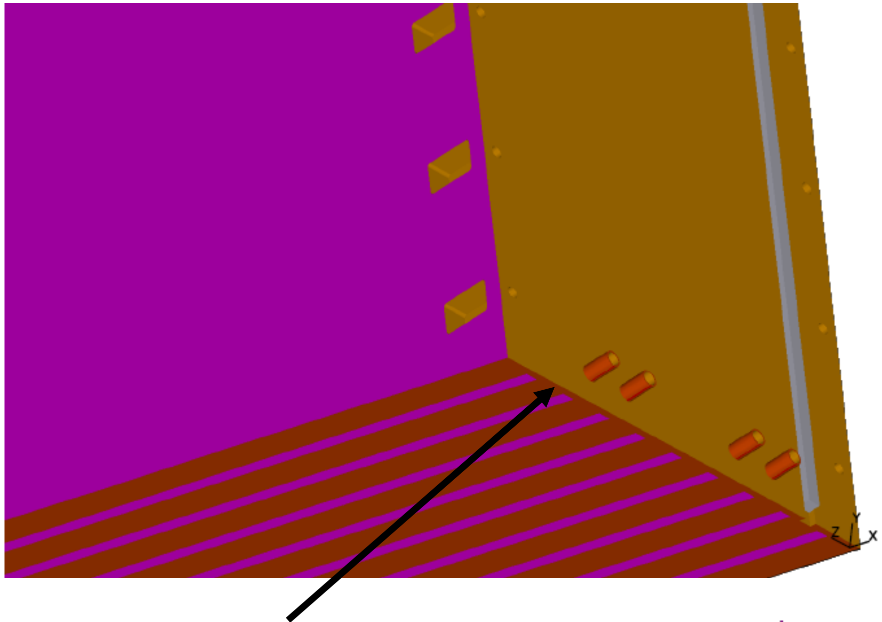
weight of segment about 90t





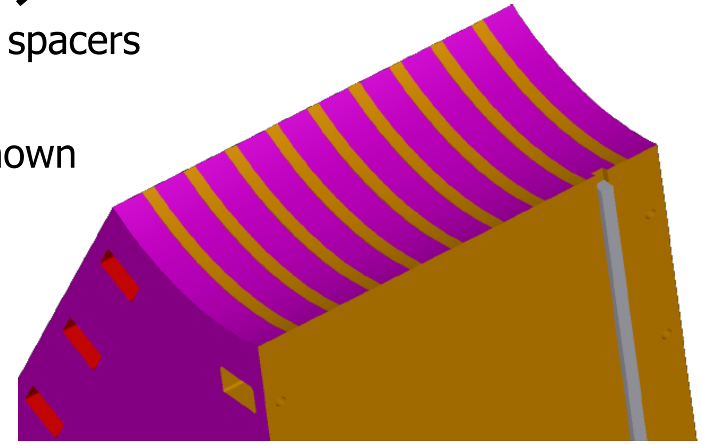
# Assembly of End-Cap Segments

Details of inner end-cap part



Plates welded to spacers

Inner ring not shown

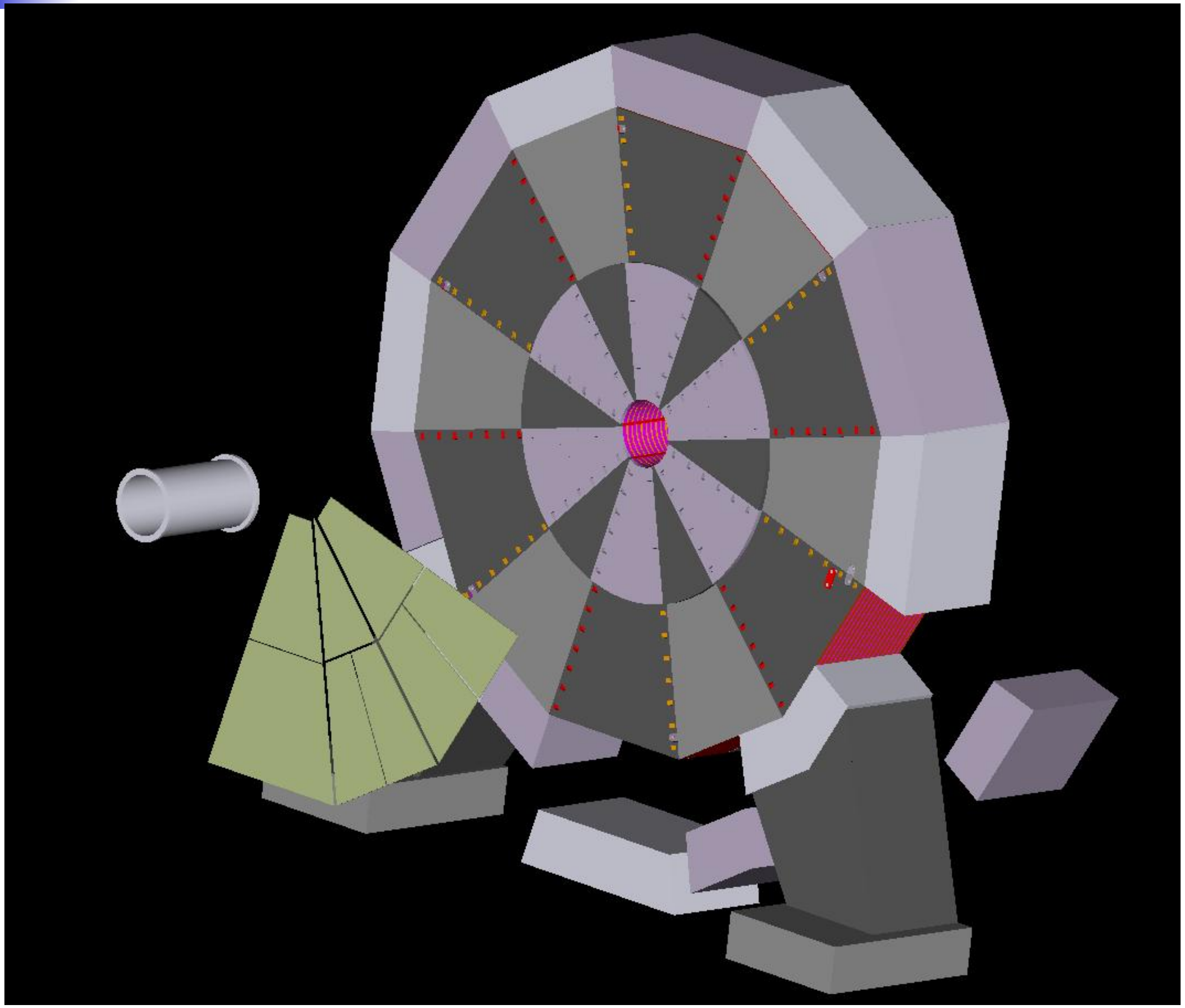


Segment assembly:

- Using shear keys and tension springs
- Segments connected by M30 bolts
- Using shear pins in FSP and first plate. Similar to proposal in CMS Magnet TDR.

Joining segments by welding not recommended

# Mechanical Design of End-Cap

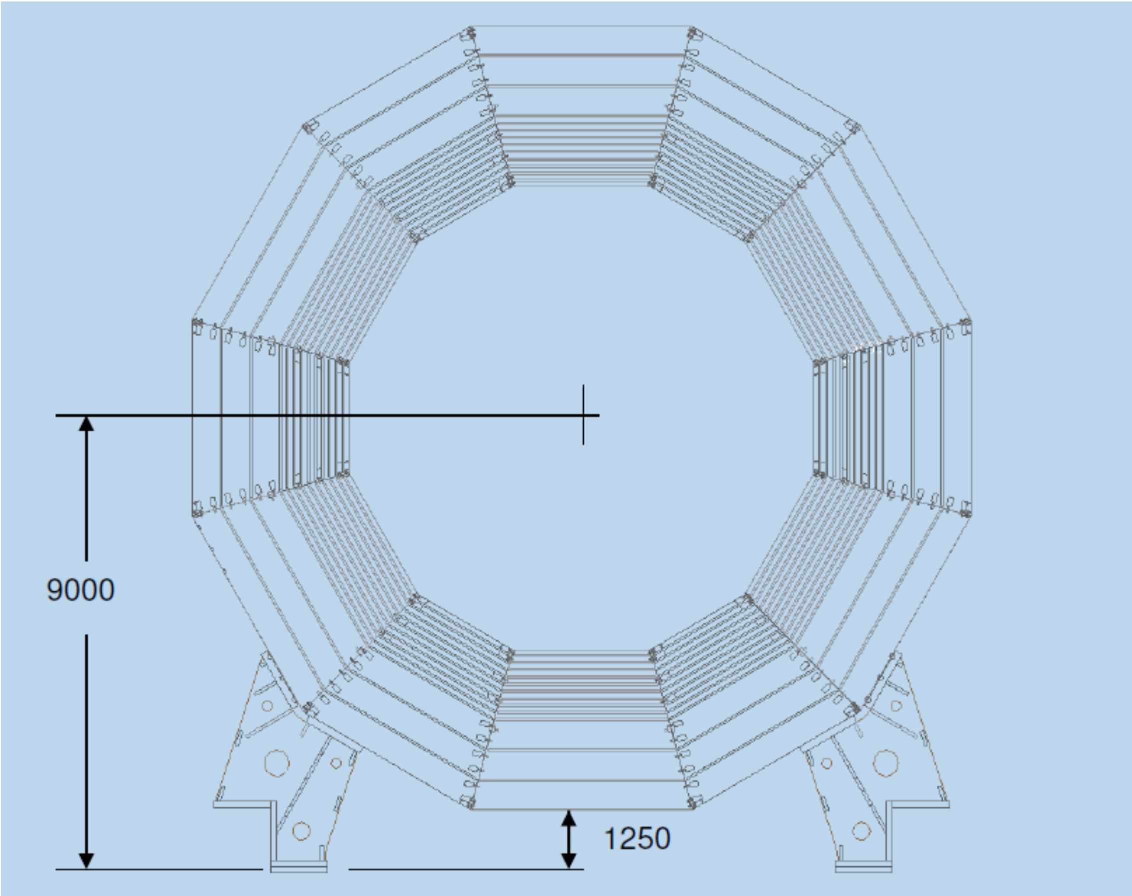


End-cap in one piece

- Also looked at split end-caps in case of opening in beam position
- Decided not to open in beam position

# Design of Barrel

R.Stromhagen/U.S.



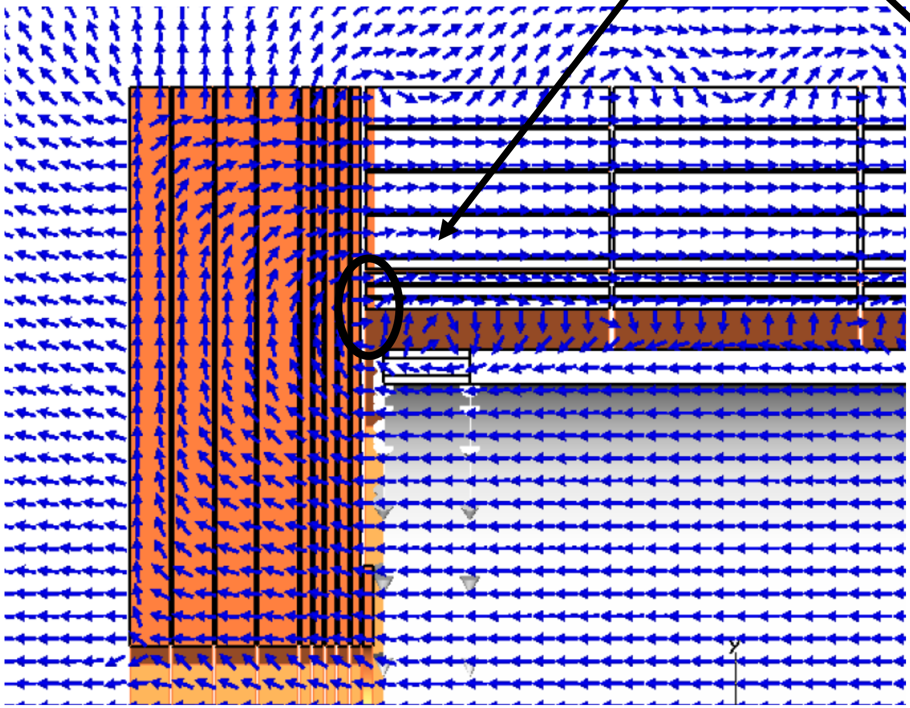

- Three barrel wheels, each consisting of 12 segments
  - Segment with welded plates
  - Segments could be split into inner and outer piece
- Same segmentation and plate thickness as for end-cap
  - Barrel design does not depend as much on segmentation and plate thickness as end-cap design
- Thickness of iron given by stray field requirements
- Radial iron thickness 2.68 m

# Forces on Barrel

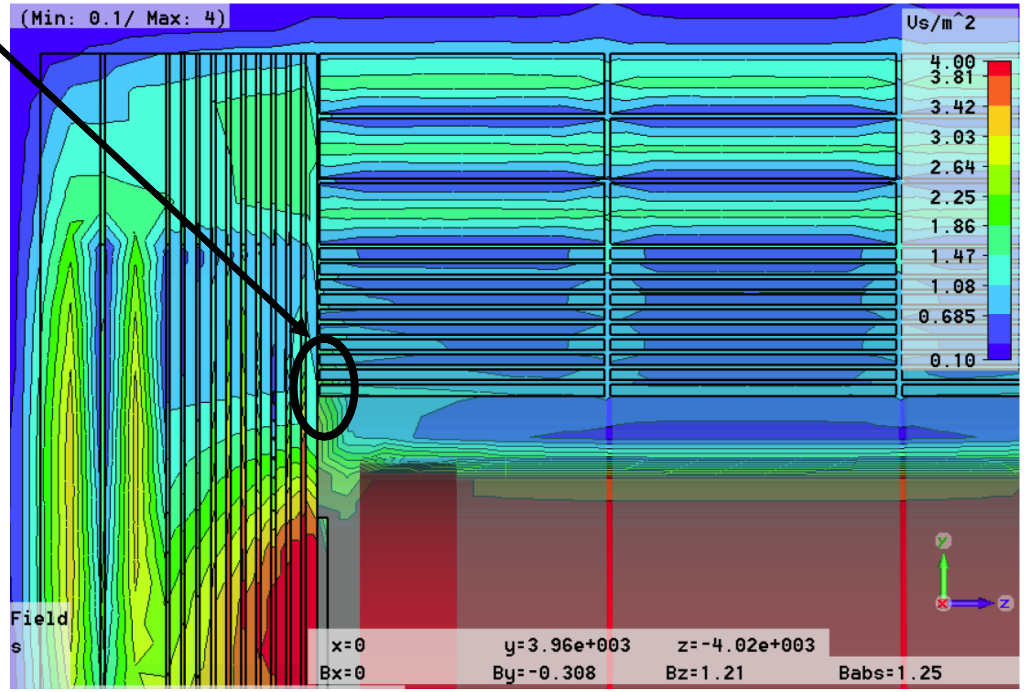
- Unlike end-cap, forces on barrel are mainly to due gravity
- Exception: magnetic force on innermost plate of outer wheels

A.Petrov

B field direction



B field

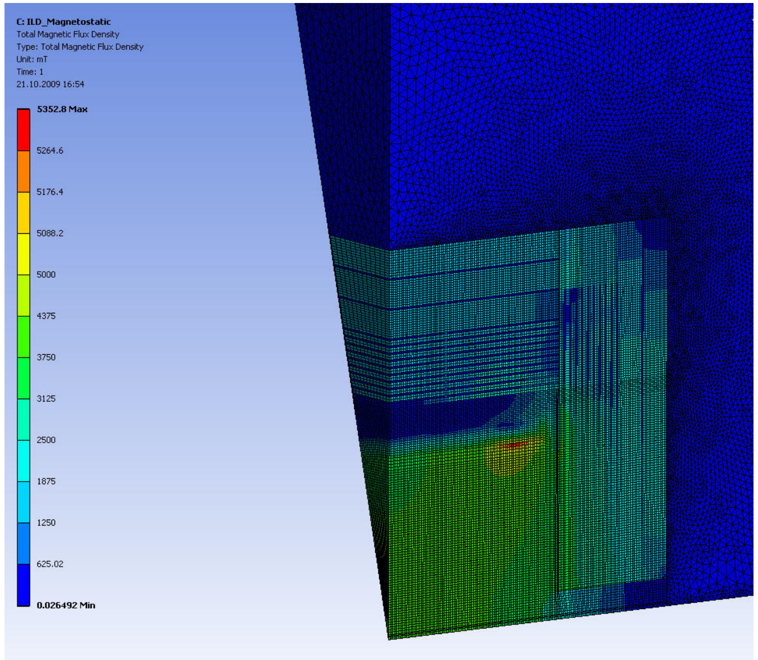


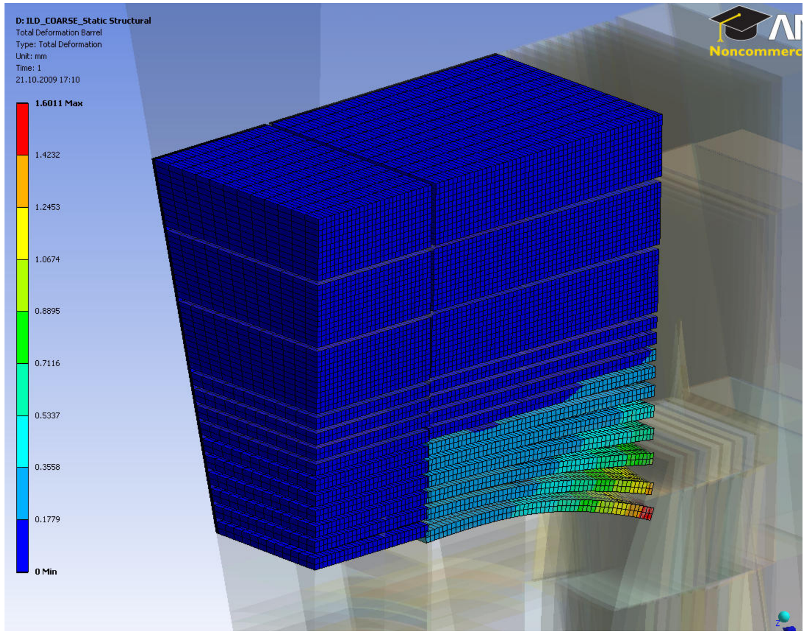
# Magnetic Forces on Barrel

Forces much weaker than for end-cap

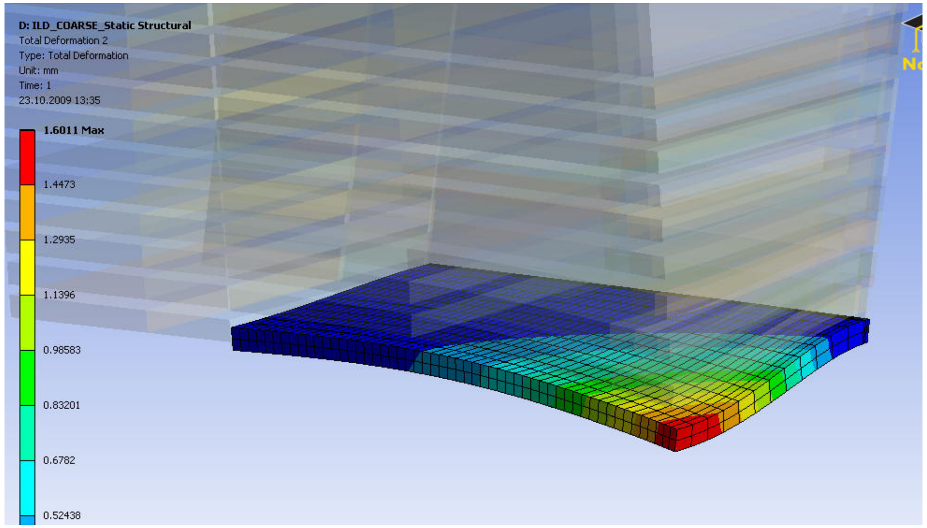
M.Harz

B field




Deformation due to magnetic forces



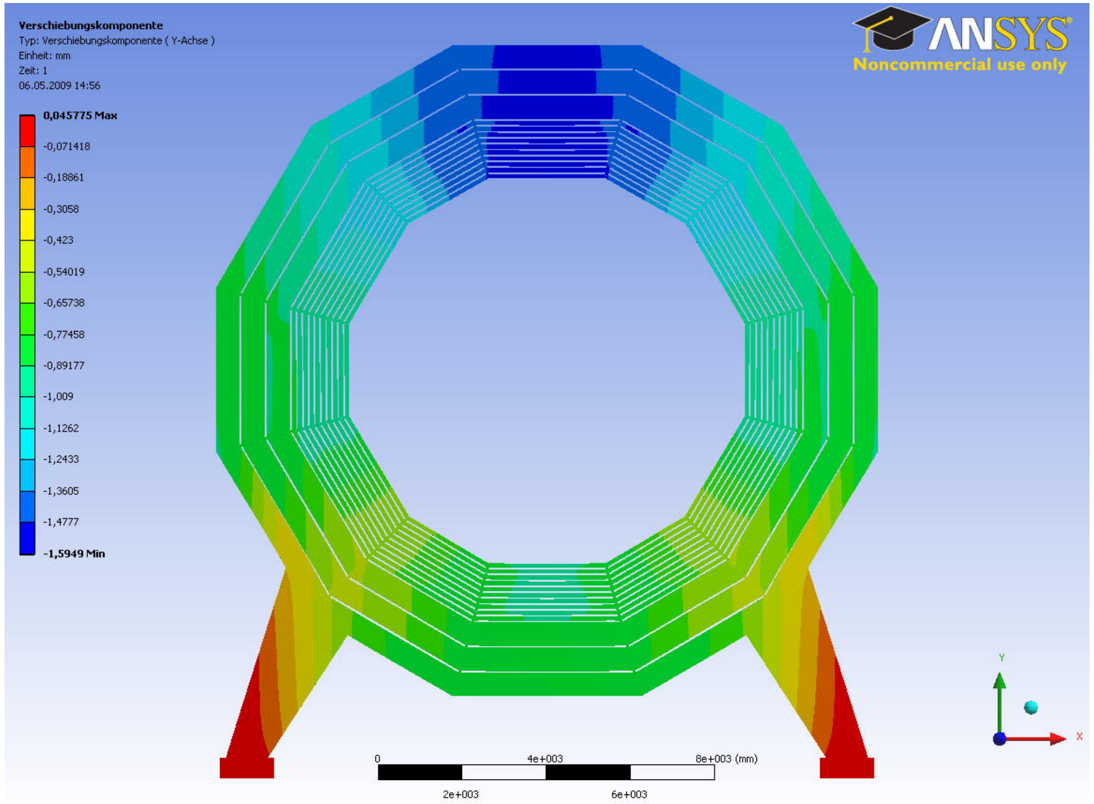

Deformation of inner plate of outer wheel 1.5mm

# Deformation due Gravitational Load

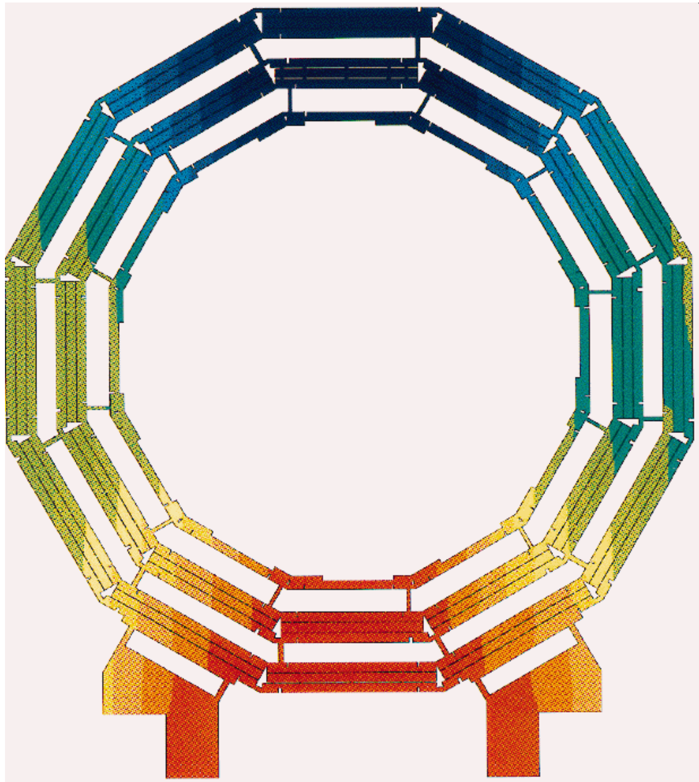
Vertical deformation of outer wheel

- Assuming solid connection between segments
- Max. deformation 1.6mm

  (Support feet too small, simplified)




CMS

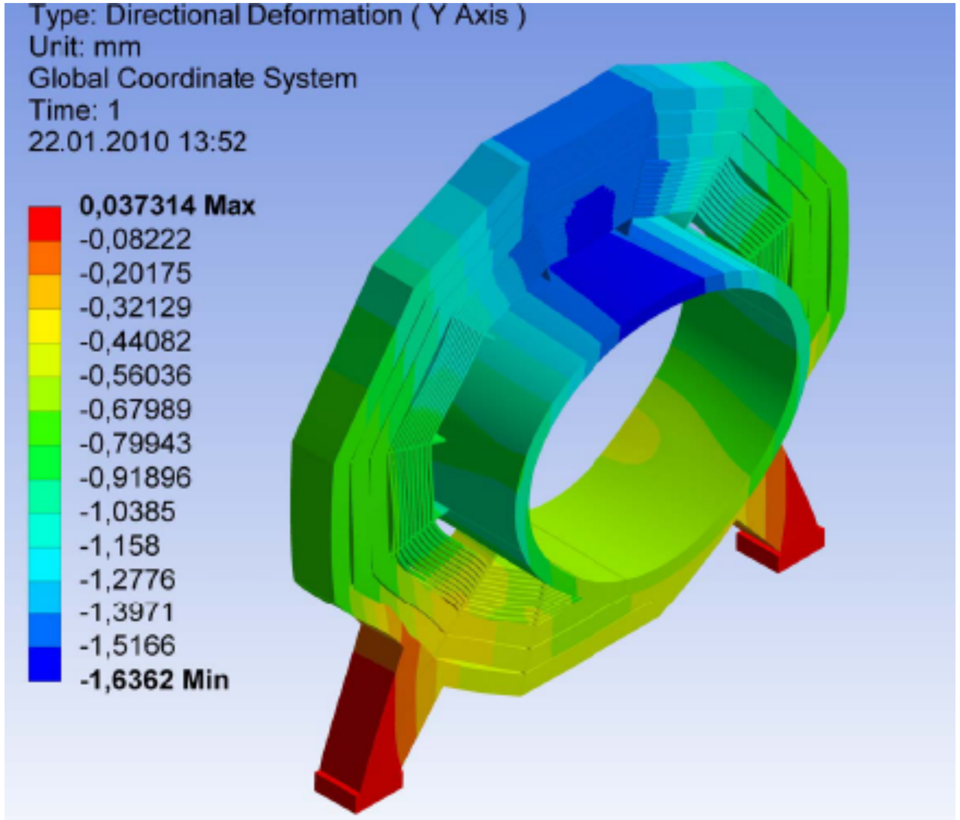


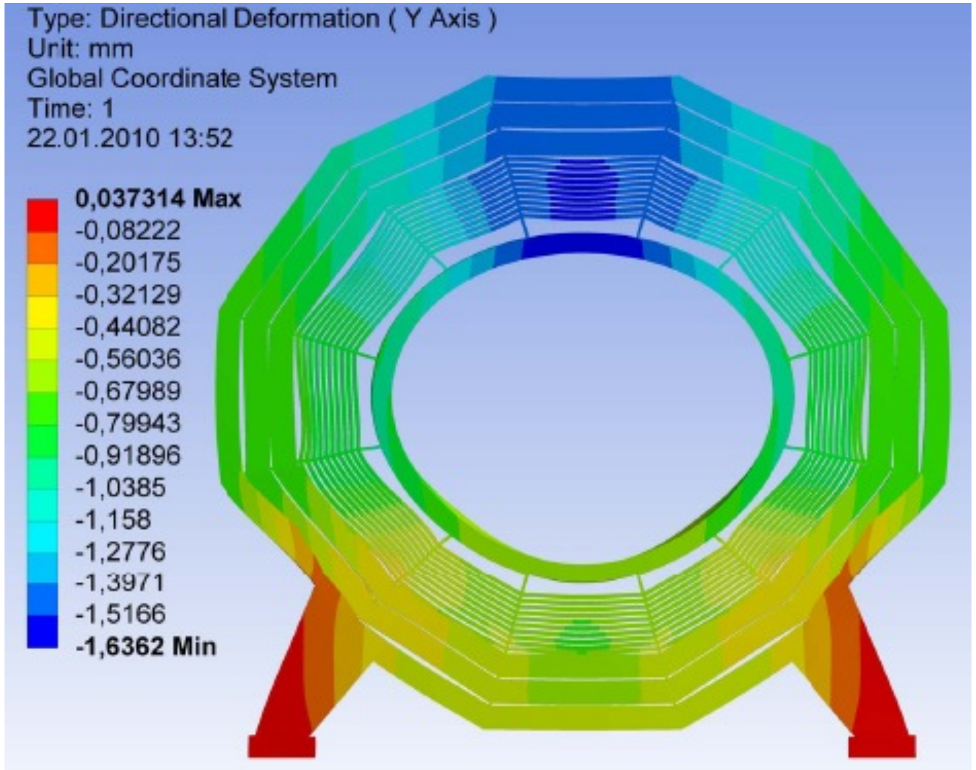
Max. vertical deformation 4.1mm

# Deformation Gravitational Load

3D calculation  M.Harz

Vertical deformation of central wheel
Caveat: cryostat too stiff in this model

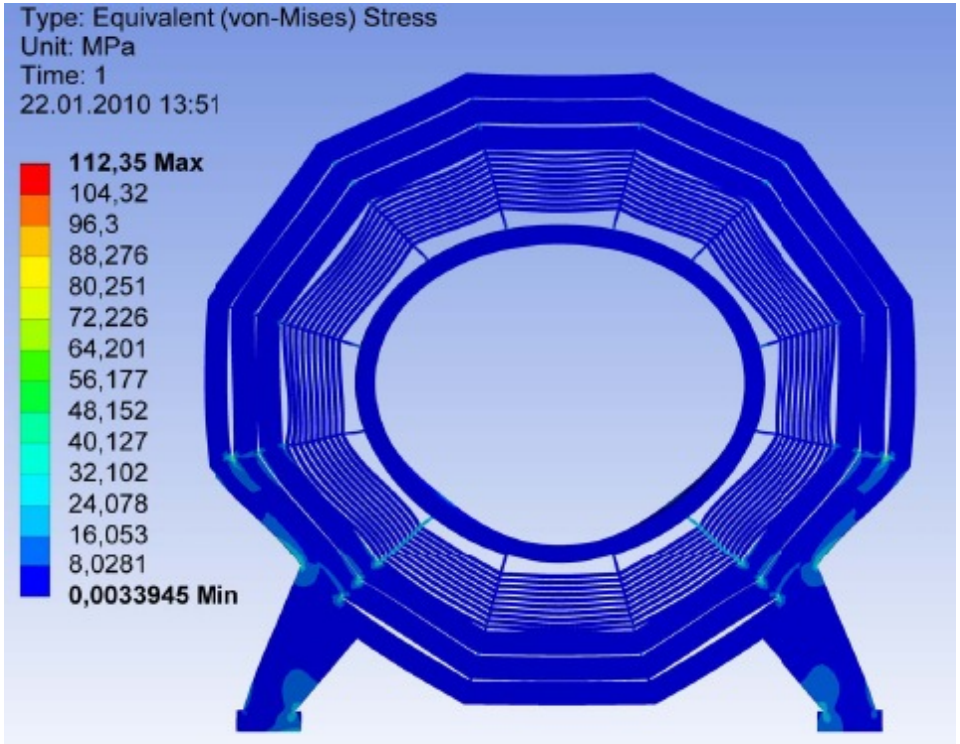


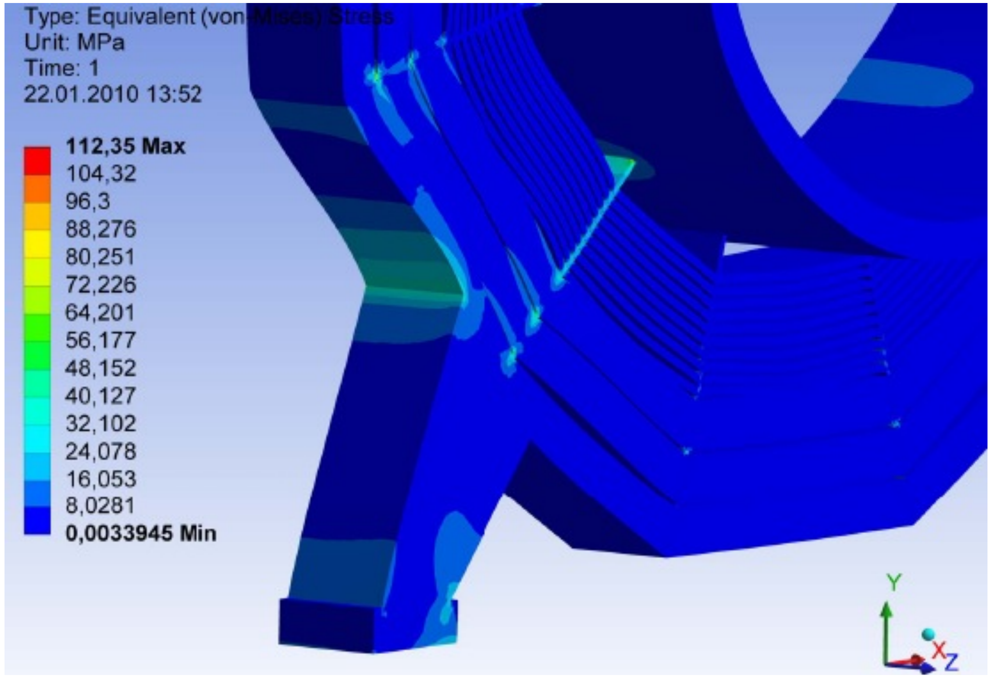



# Stress due to Gravitational Load

3D calculation M.Harz

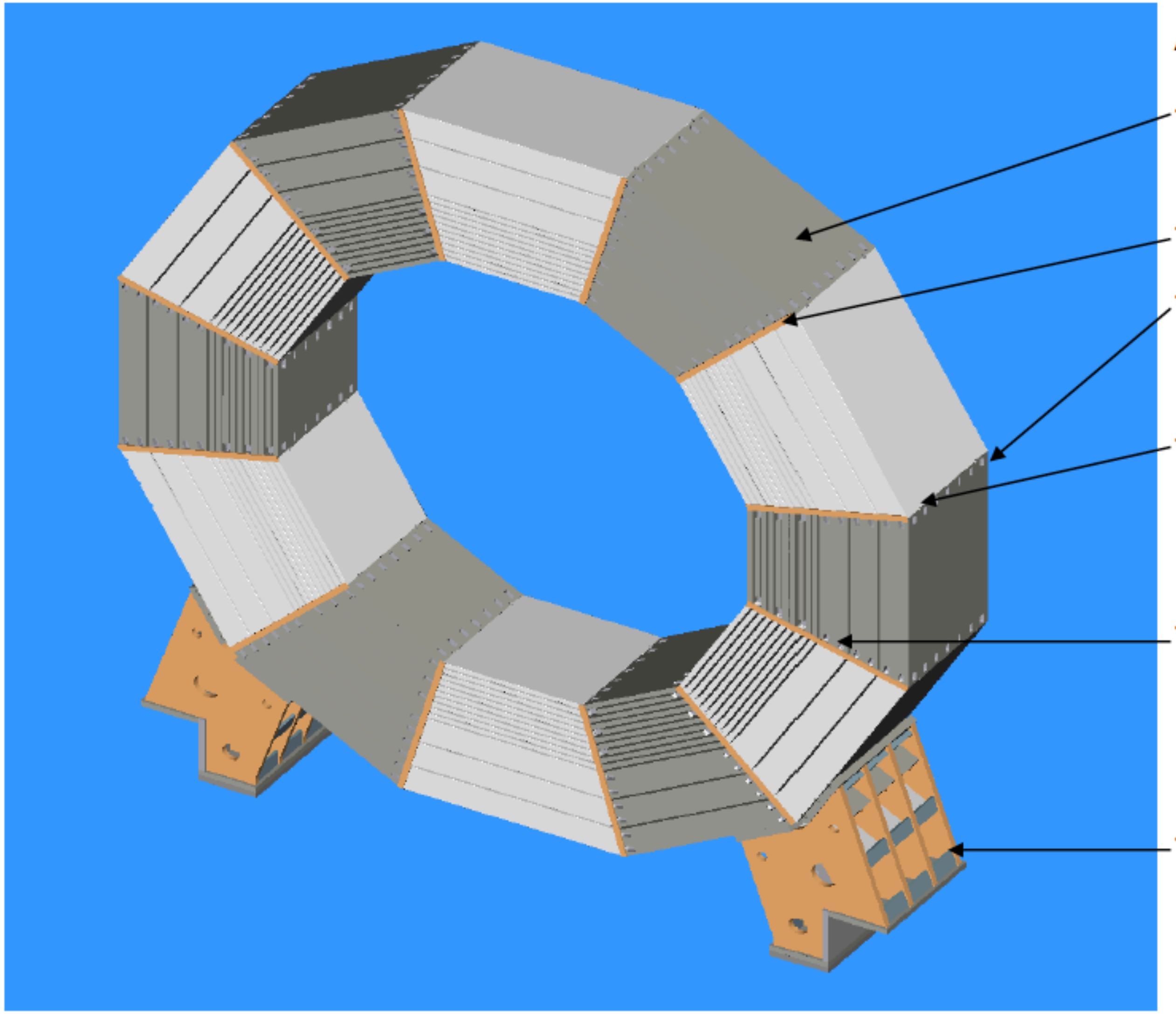
Stress of central wheel
Caveat: cryostat too stiff in this model



# Barrel Design

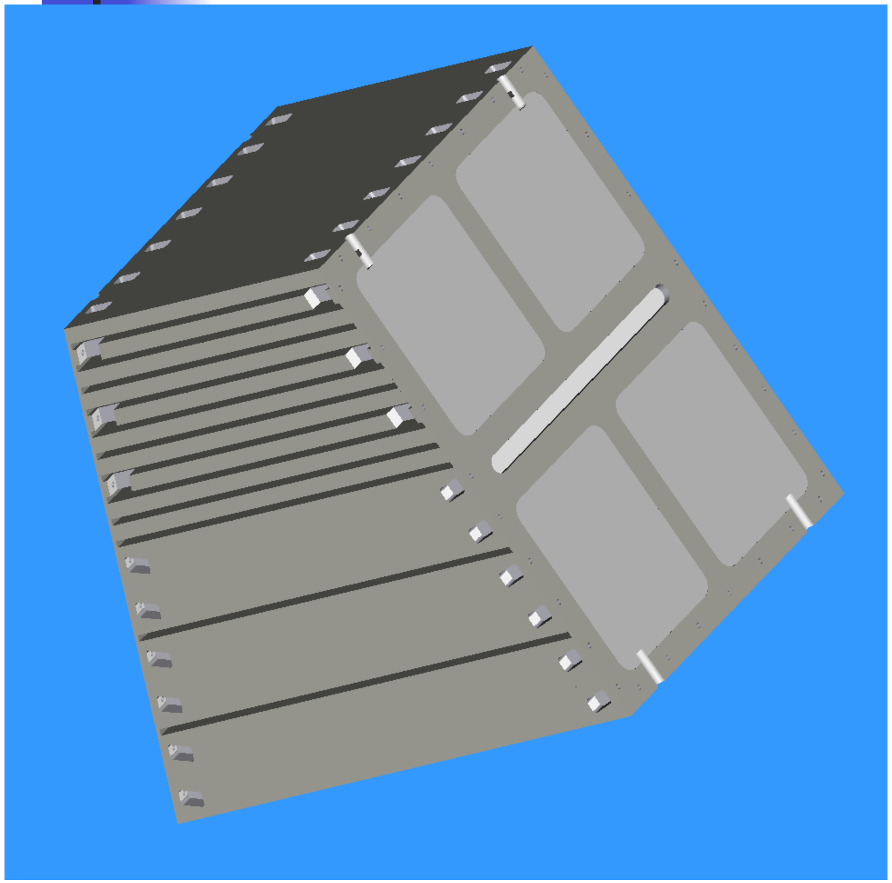
R. Stromhagen



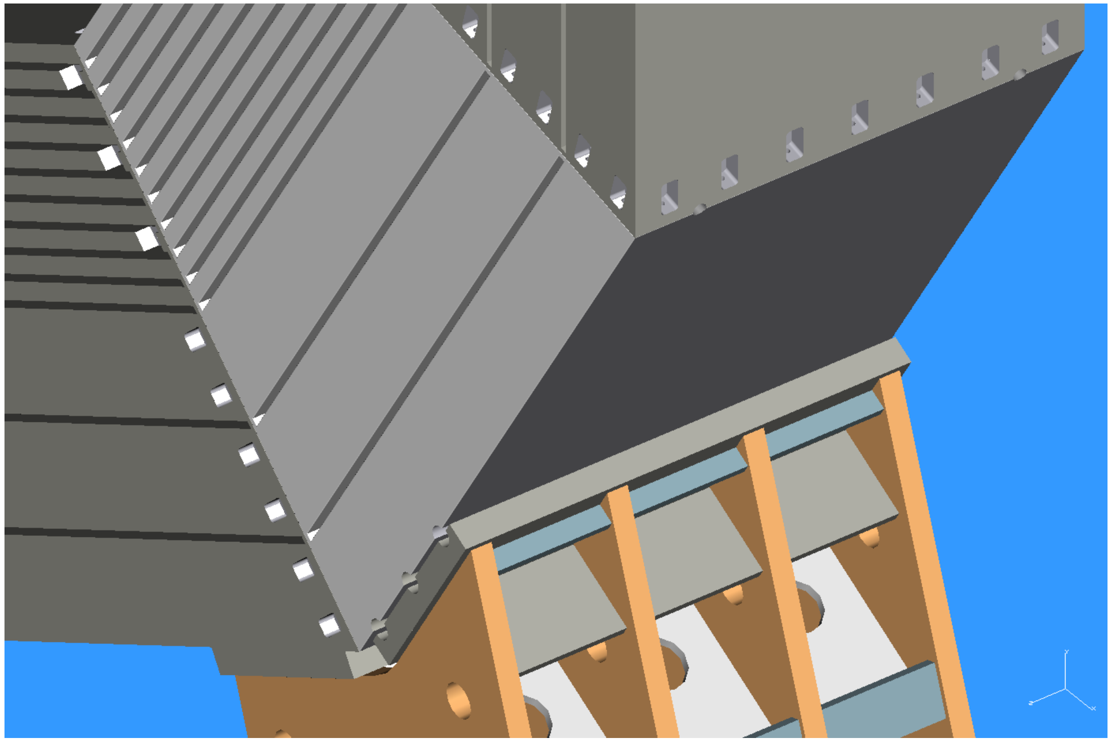
Assembly:

- segments ~ 200 t. welded
- shoulder for end-stop
- screws min. M30 / (min. 32 pieces)
- bolds (4 pieces d ~ 120, lg. 350 assembling bore)
- key ledge, horizontal (1 per segment 160x160, 2200 lg. mm)
- stand (screws min. M30, d ~ 120, lg. 350, assembling bore)

# Barrel Design

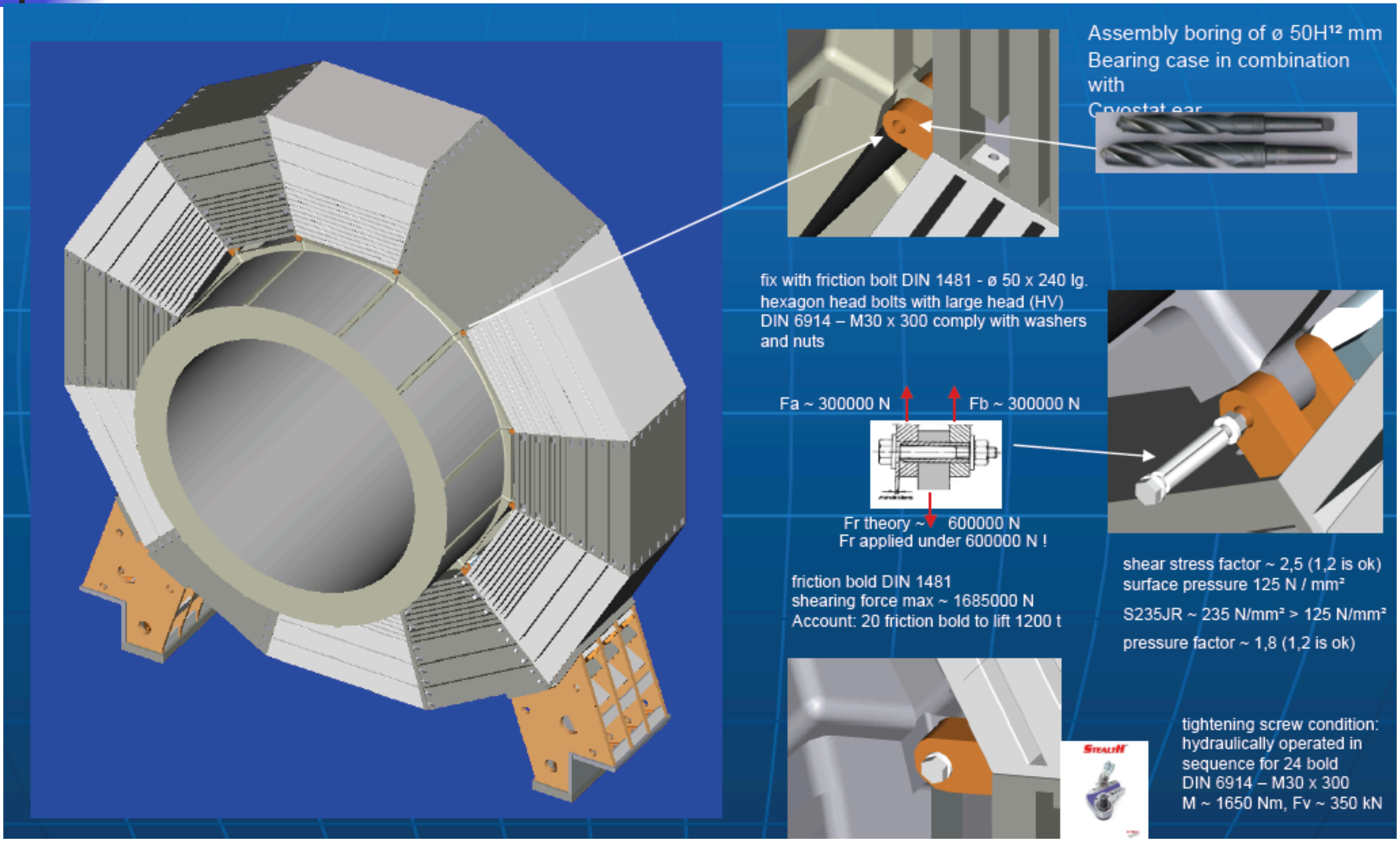


Segment weight ~200 t



# Central Barrel Coil Support

R. Stromhagen



# Yoke Assembly

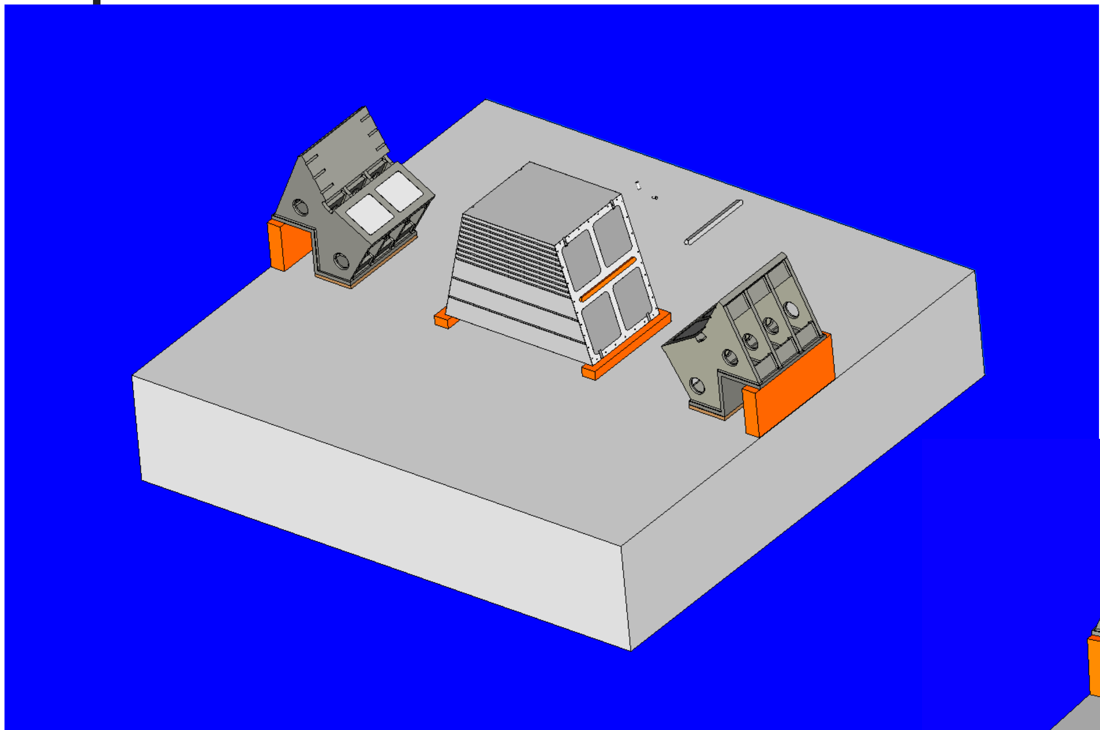
In principle, yoke design and assembly based on CMS assembly

- Barrel consists of 3 large wheels (CMS 5)
  - Barrel segments form a rigid structure
  - No “mandrel” or Ferris wheel needed for assembly
- Each end-cap consists of 1 (or 2) large large disk (CMS 3)
  - Similar shape and assembly

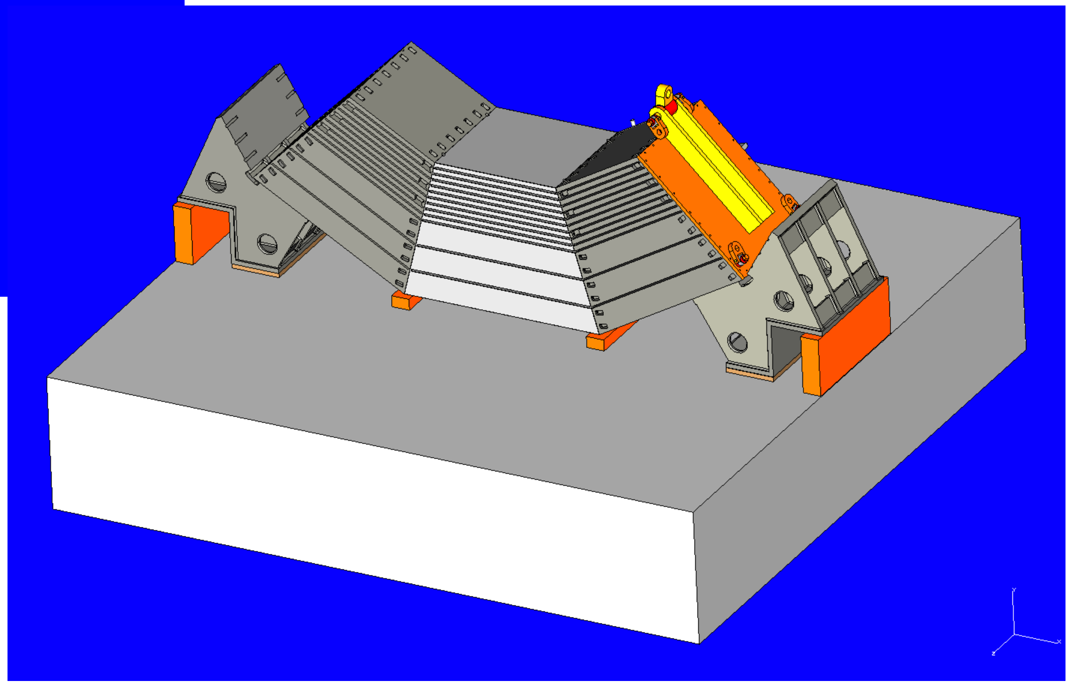
- Original CMS-style assembly (vertical access)
  - Assemble wheels and disks in surface building
  - Lower wheels/disks into IR hall
- Recent study, mountain site IR hall (horizontal access)
  - Yoke design unchanged
  - Size of items mainly limited by weight and crane capacity in IR hall (200 t)
  - Assembled segments (max. weight 200t) moved to IR hall
  - Wheels and disks assembled in IR hall

# Barrel Assembly

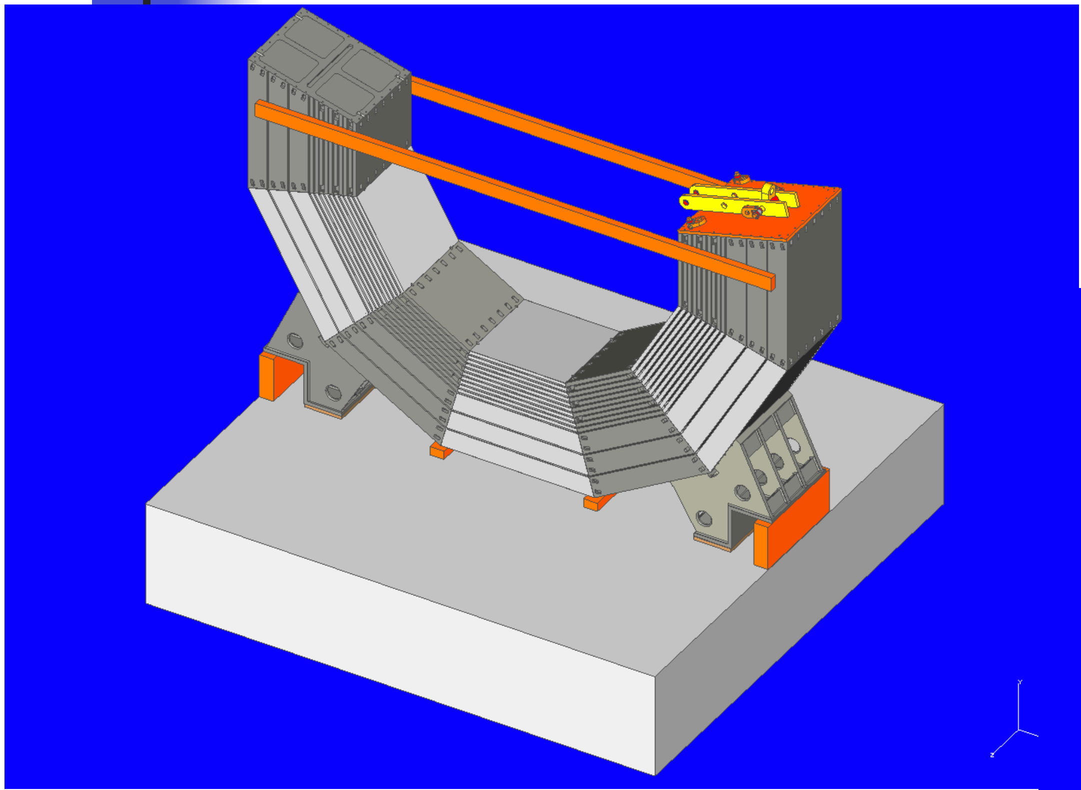
R.Stromhagen

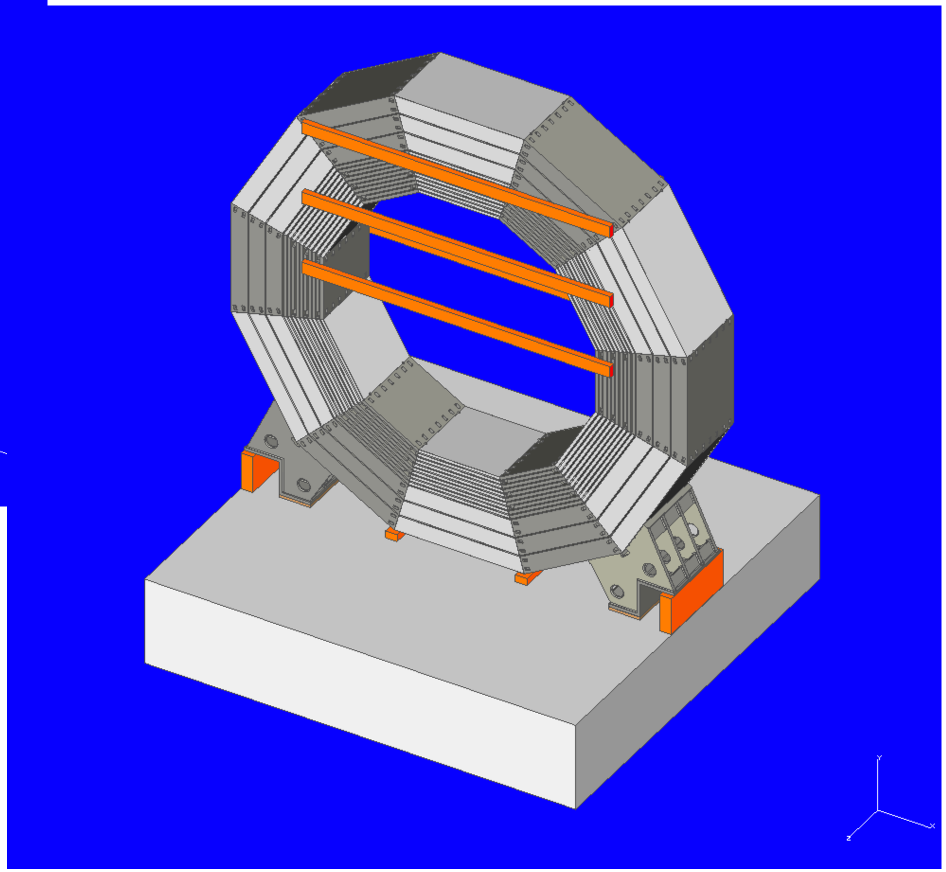


Tools needed:
- 200 t crane
- Hoists
- Support structures
- Survey



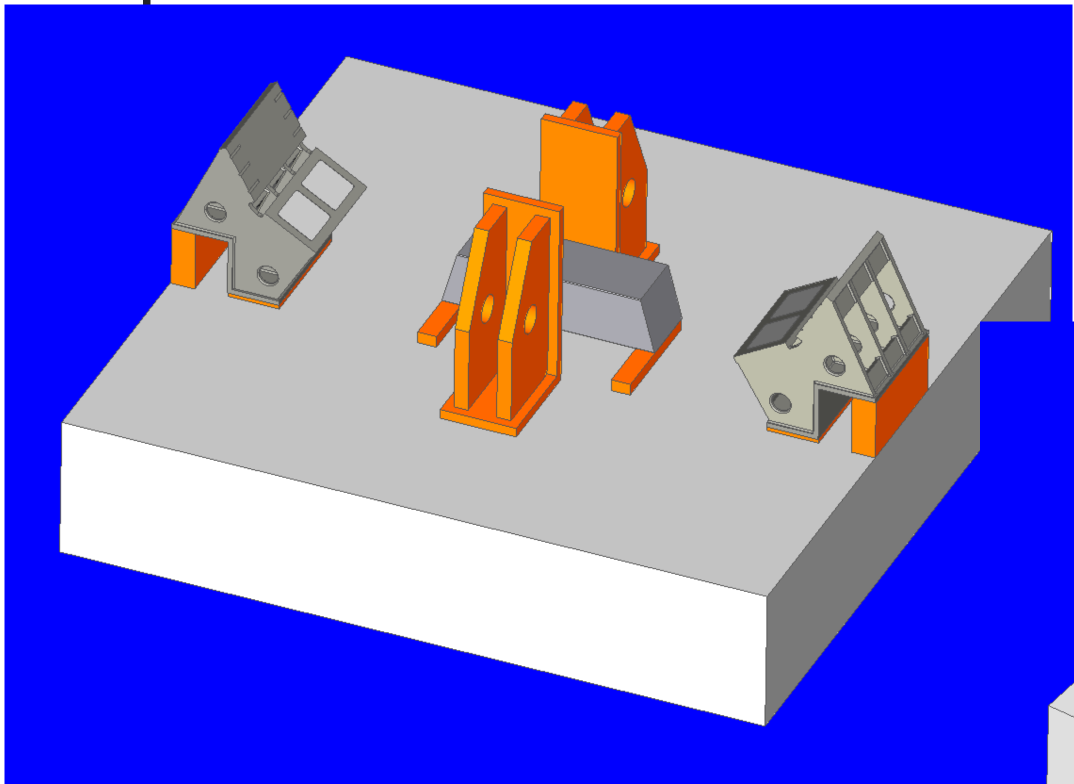
# Barrel Assembly

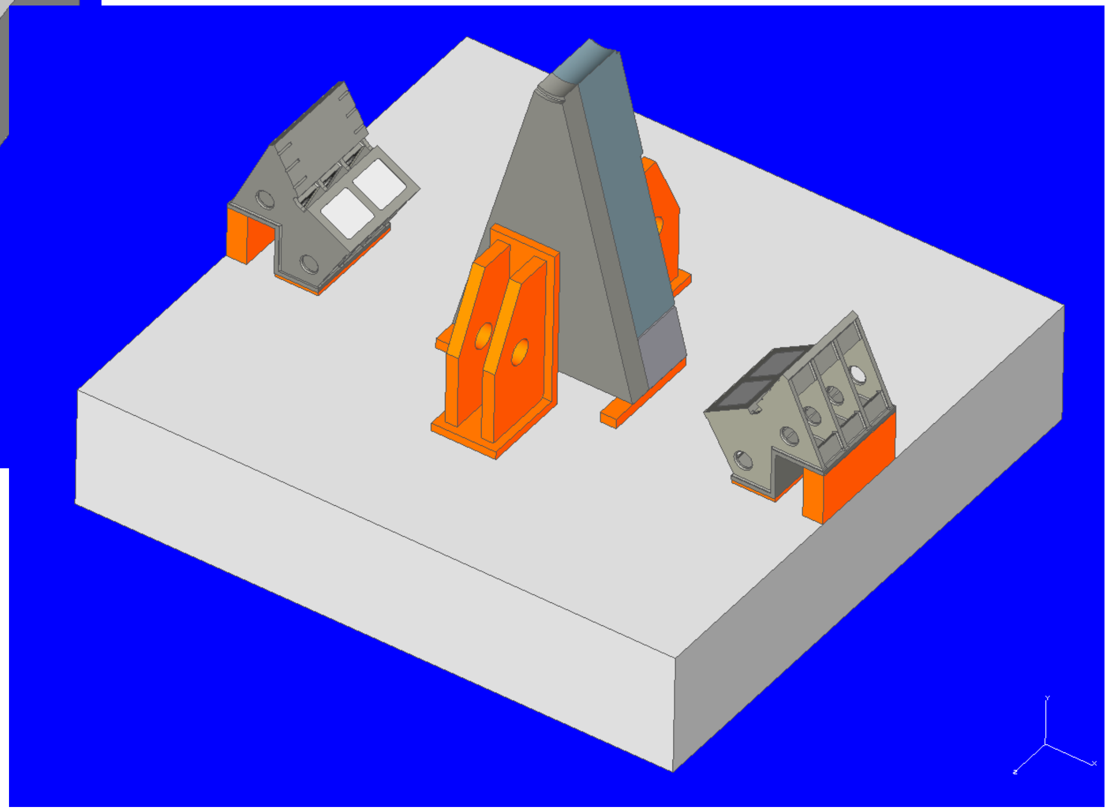




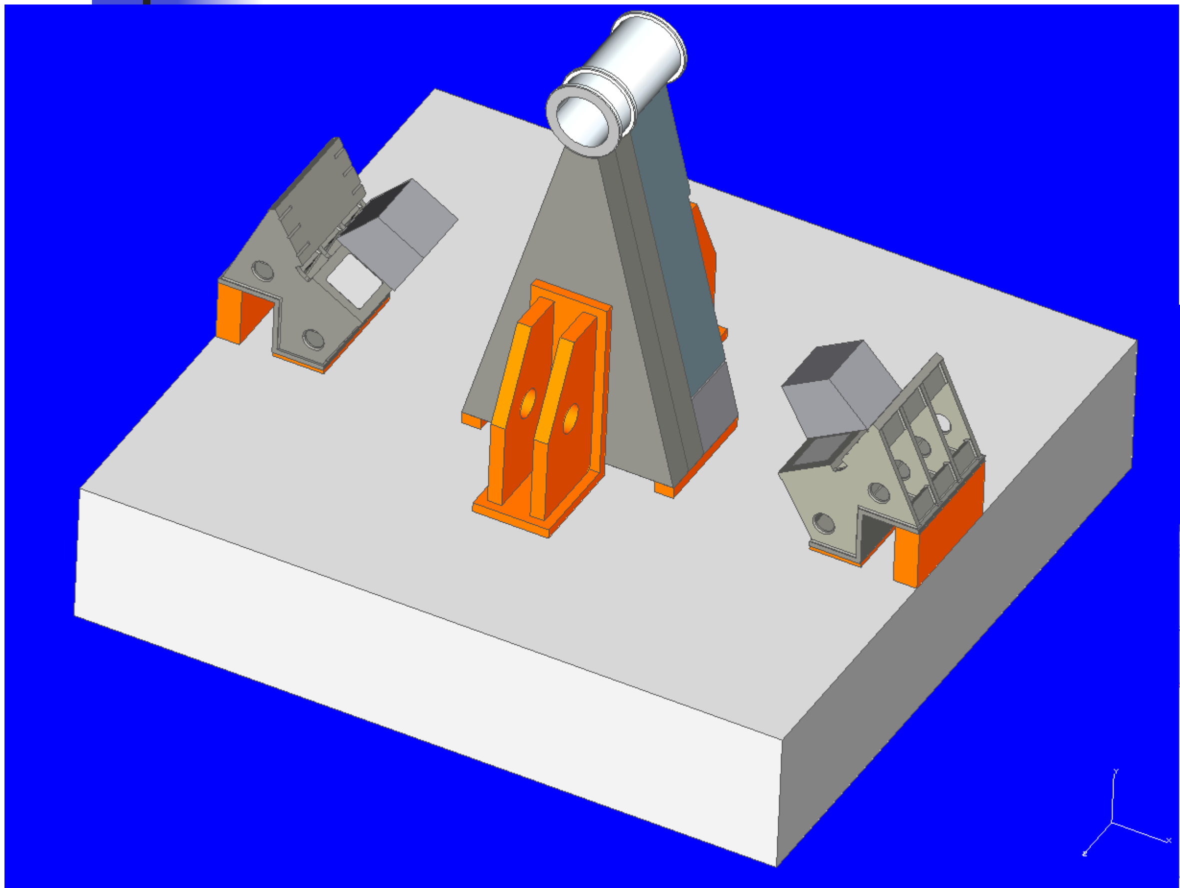
Rough time estimate 60 working days per wheel

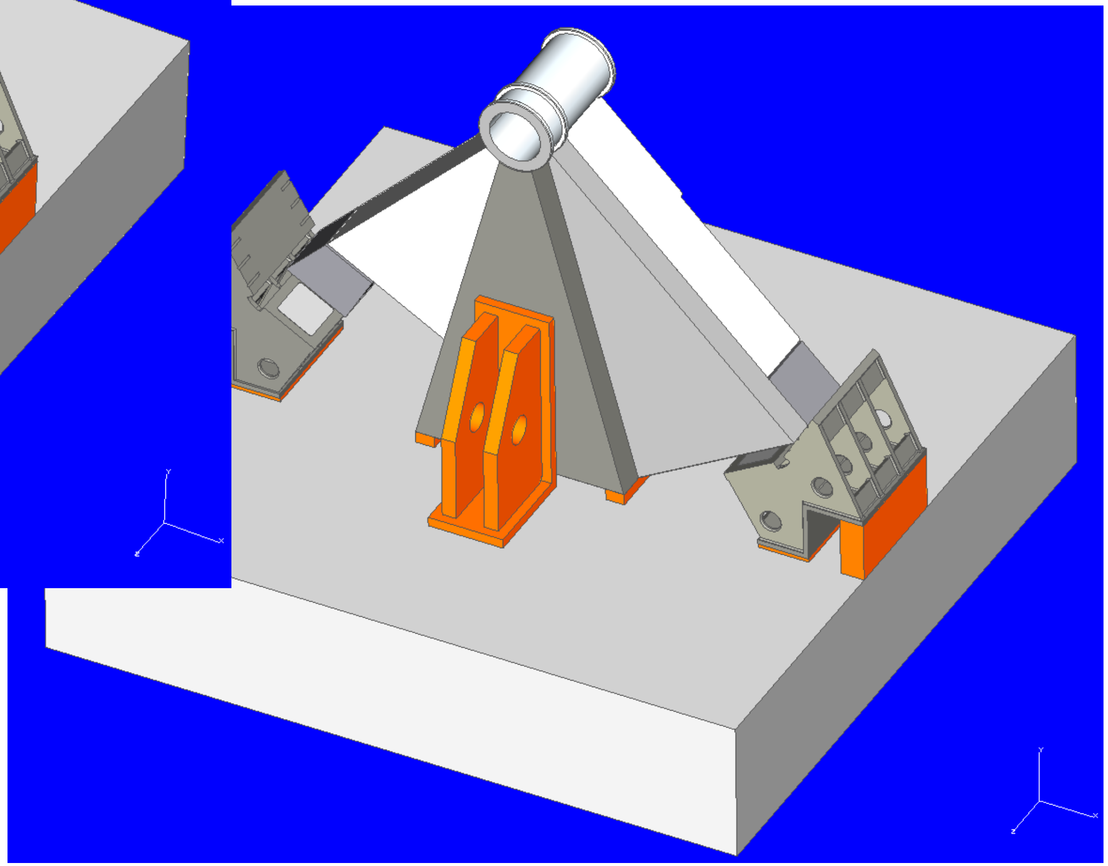
# End-cap Assembly



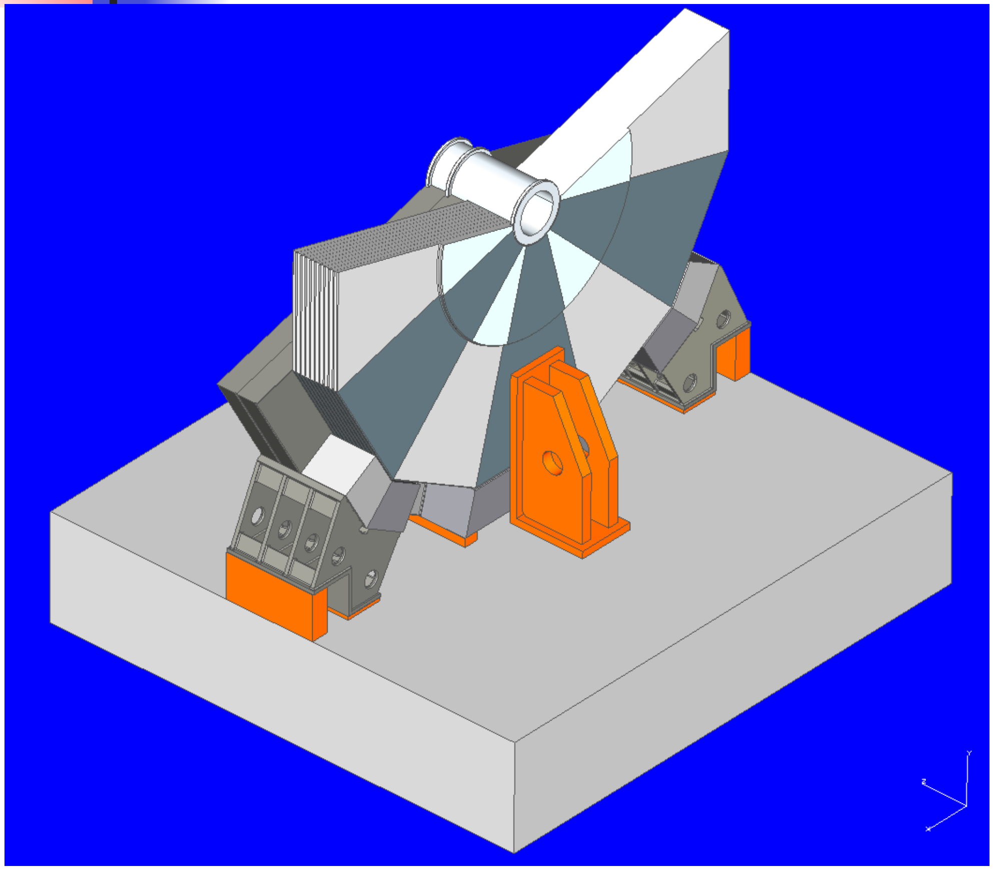


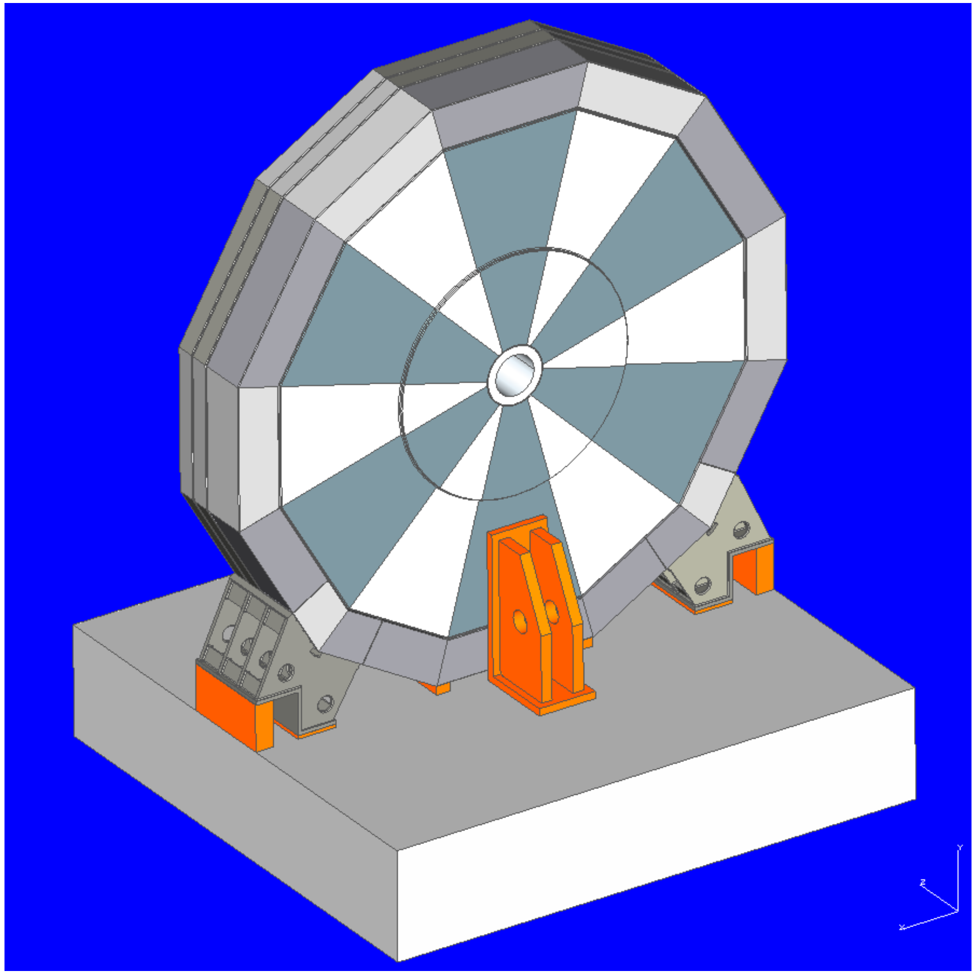
# End-cap Assembly





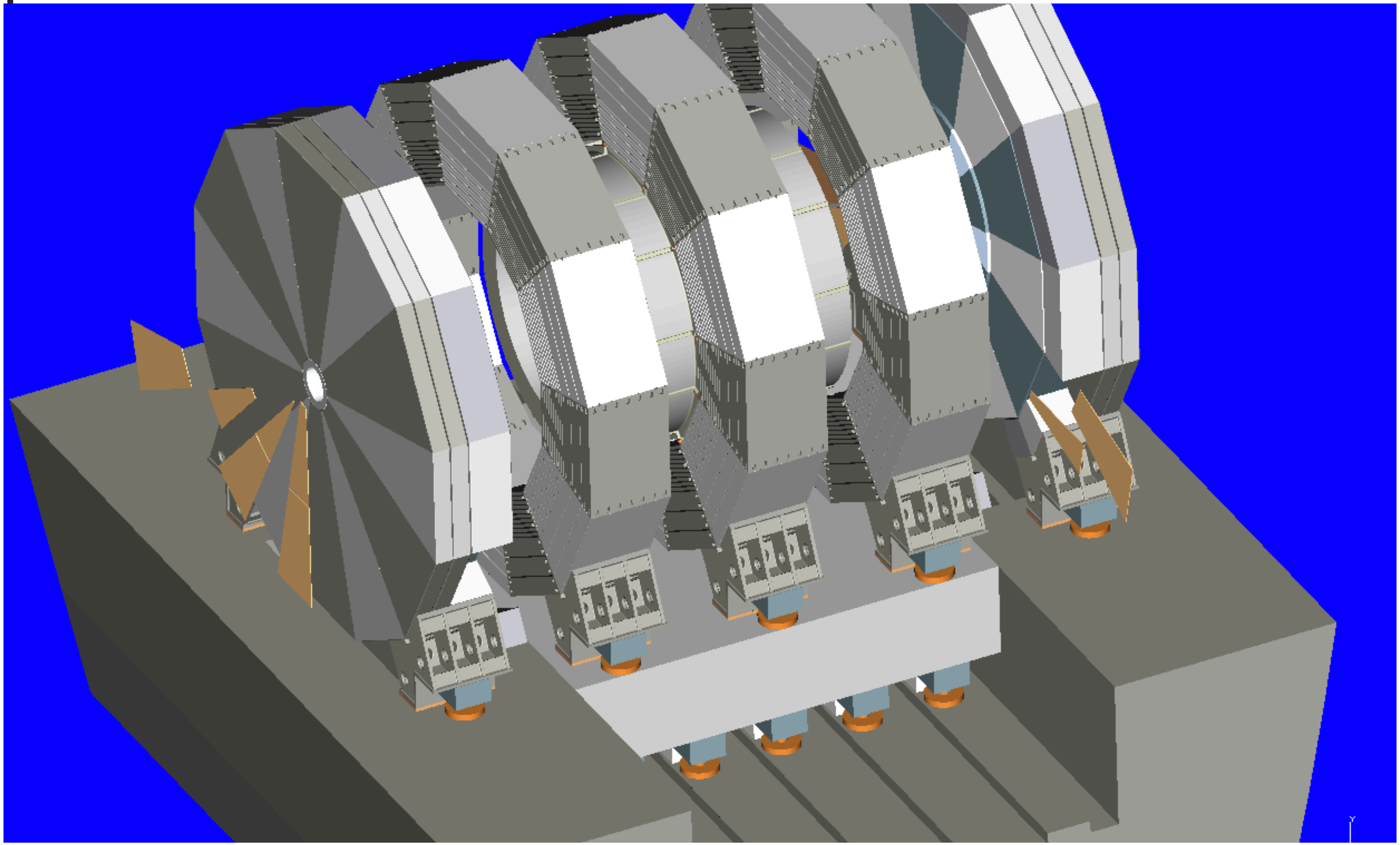
# End-cap Assembly





Rough time estimate 60 working days per end-cap

# Assembled Iron Yoke

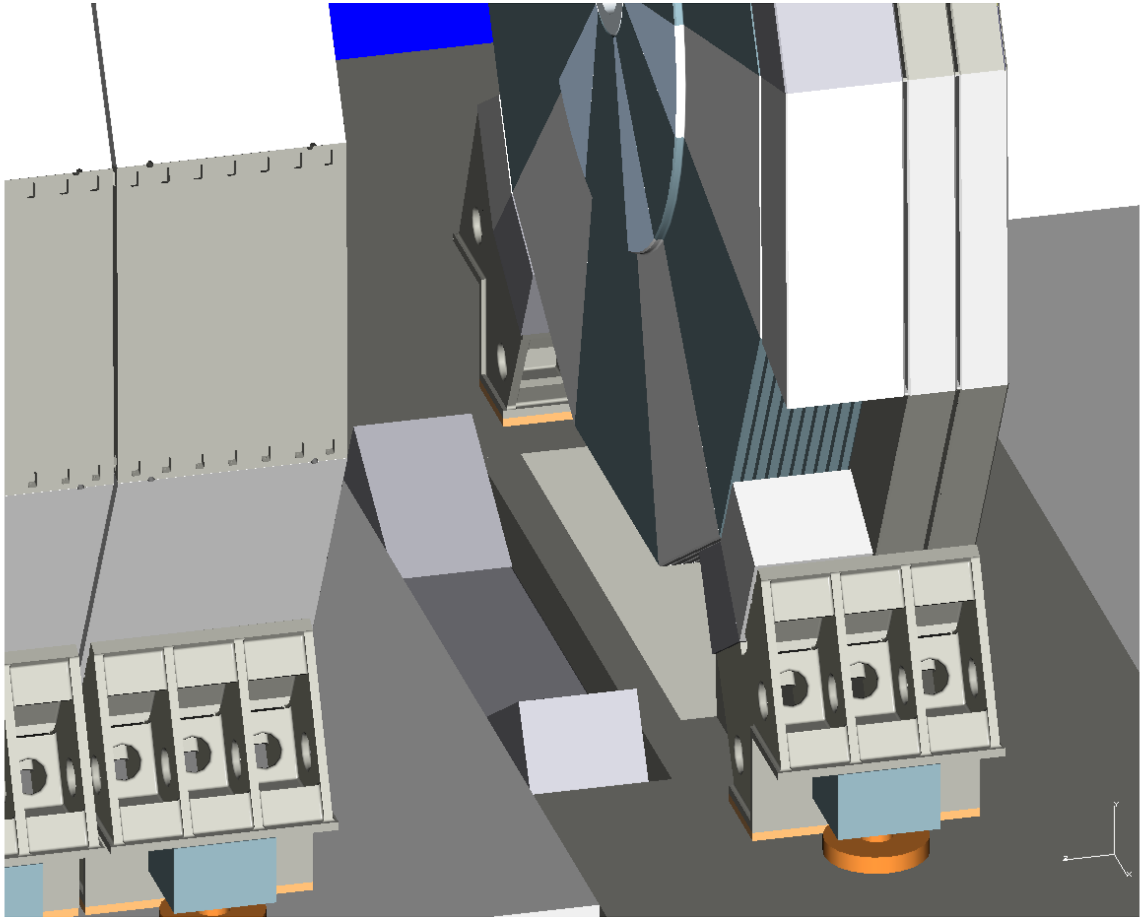


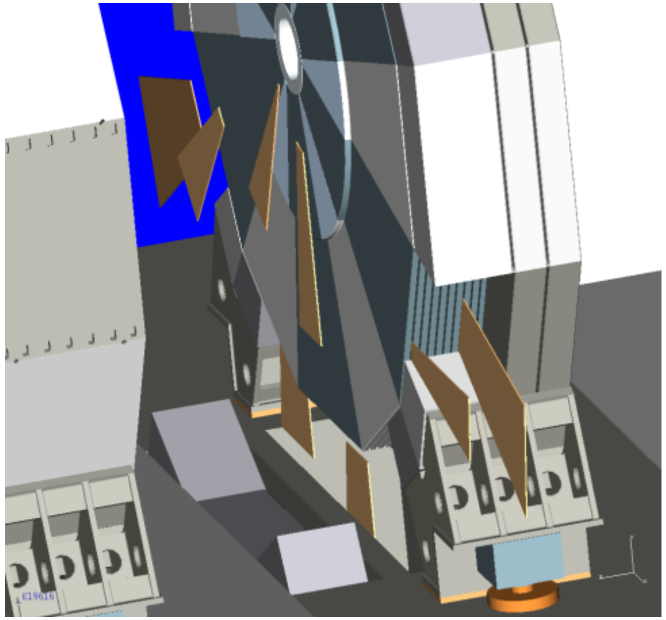
# Conclusions

- Conceptual mechanical design of barrel and end-caps quite advanced
- Design of Cryostat support
- Looked at assembly of barrel and end-caps

# Back-up Slides

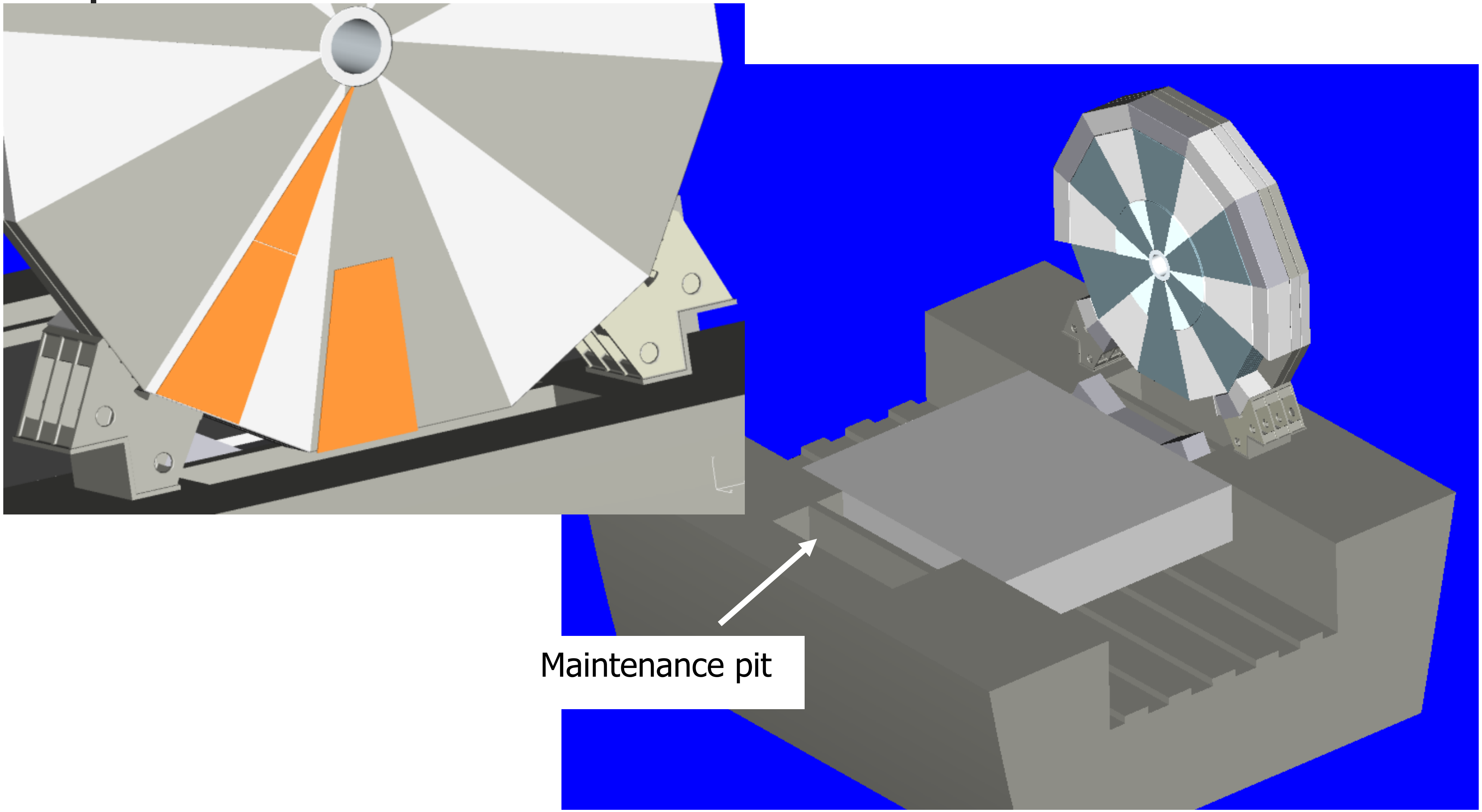
# Muon Chamber Installation





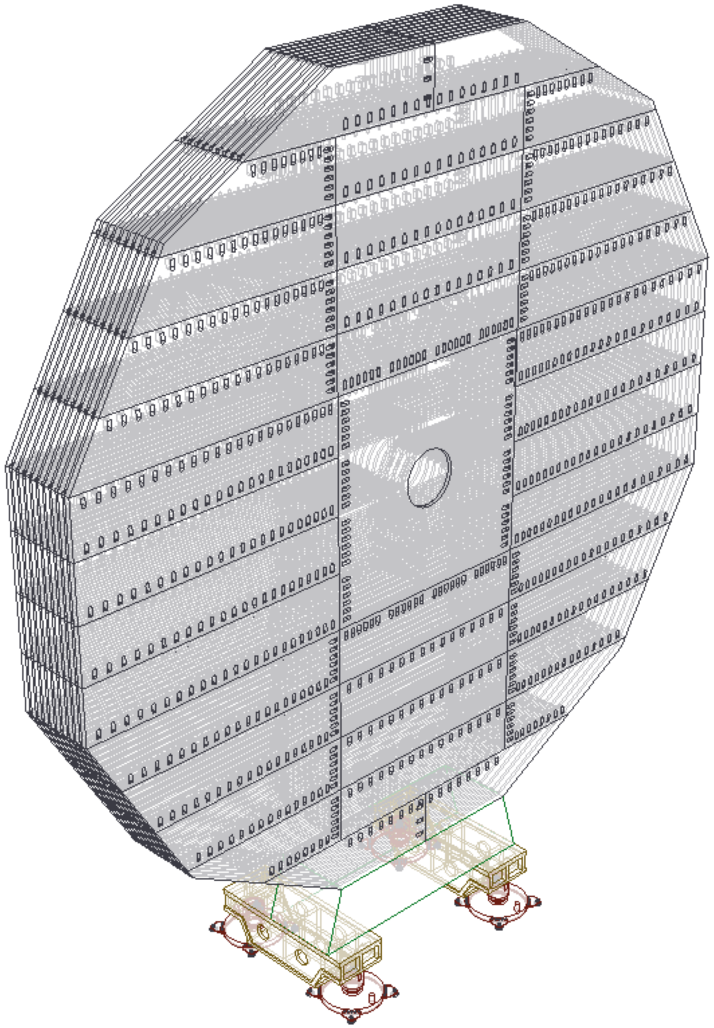
- Remove outer iron
- Pull up chambers from maintenance pit

# Muon Chamber Installation

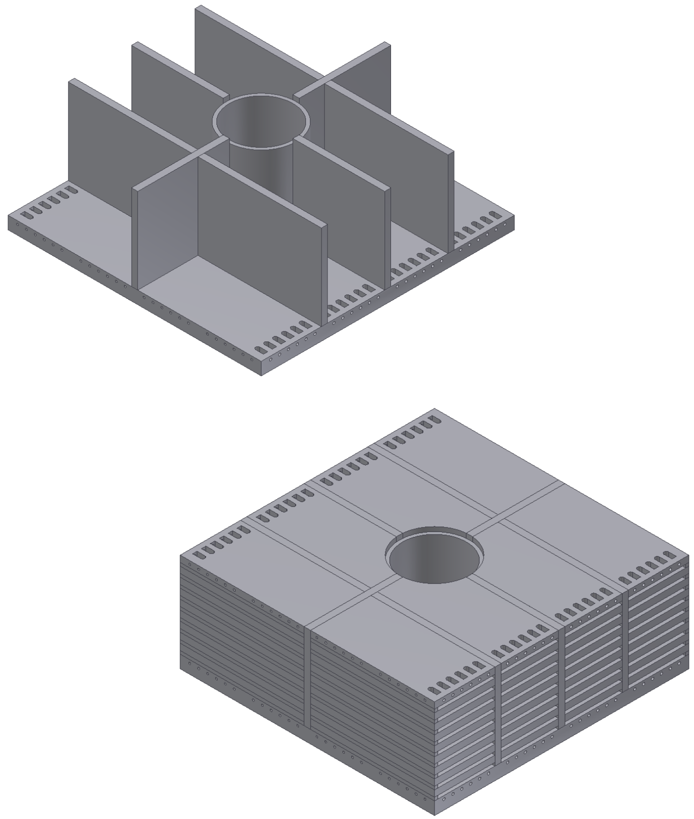


# Alternative End-Cap Design

Design by Hubert Gerwig and Nicolas Siegrist, CMS/CERN



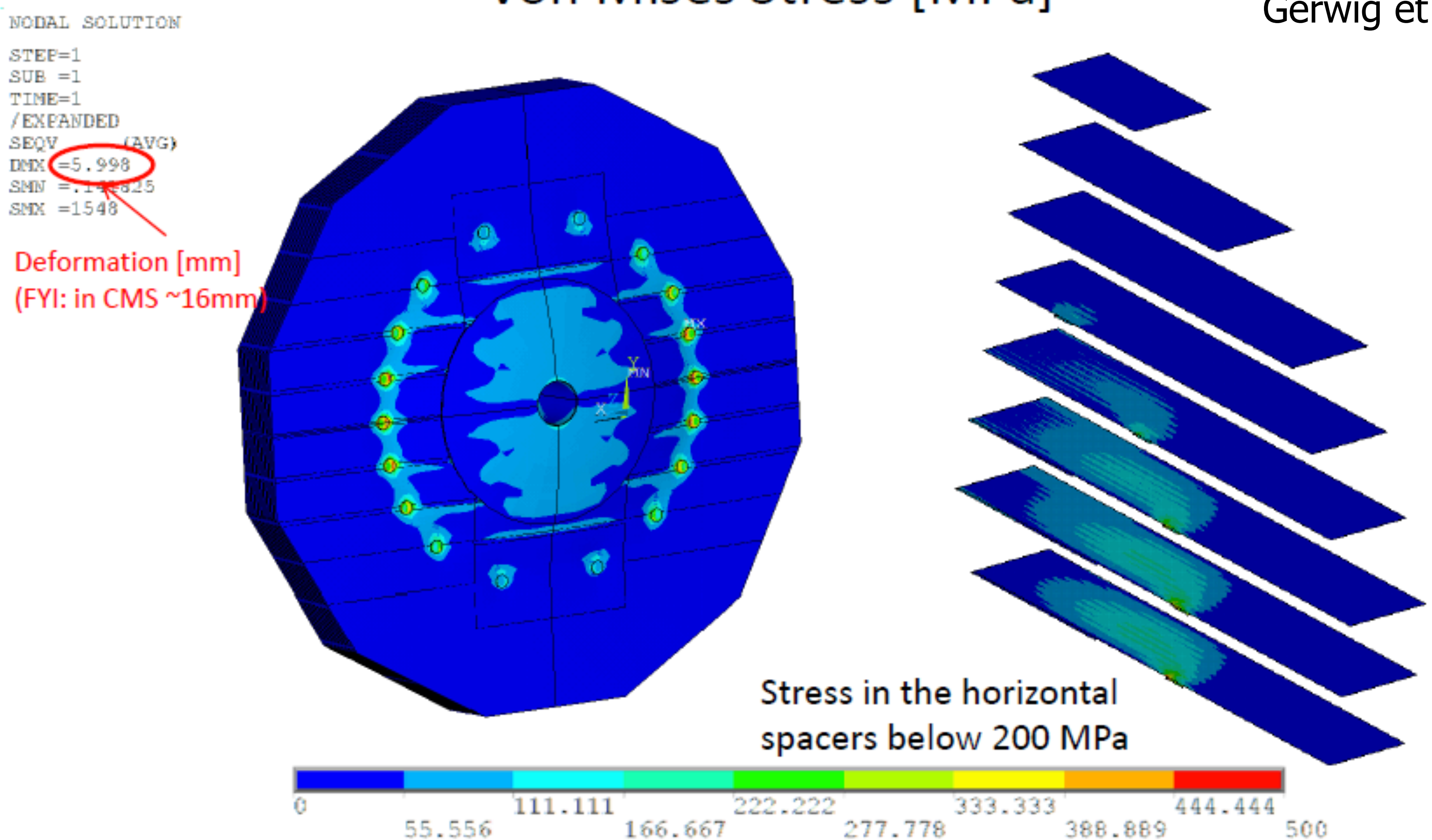
Central part (120t)



# End-Cap Design Horizontal Supports

CLIC note 2010-10
Gerwig et al.

Von Mises Stress [MPa]




Considering to use better quality steel

# Comparison of Inner End-cap Designs

- Radial reinforcement design
  - $\phi$ symmetric deformation and stress
  - Iron and magnetic field $\phi$ symmetric
  - Hard stops straight forward
  - Symmetric forces acting on barrel
  - 12 segments plus small inner support tube
  - Fewer surfaces to be machined precisely
  - Half as much reinforcement (and dead space)
- Horizontal reinforcement design
  - Deformation and stress somewhat higher
  - 36 segments segments plus big central piece
  - Assembly somewhat easier
  - Installation of muon chambers easier