

ILD Yoke Design and Assembly

**LCWS 2015
Whistler**

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Outline

- > Requirements and boundary conditions
- > Present design
- > Yoke assembly
- > Alternative design of modules
- > Assembly of modules
- > Alternative assembly options
- > Conclusions

Work done in close collaboration with
R.Stromhagen, DESY

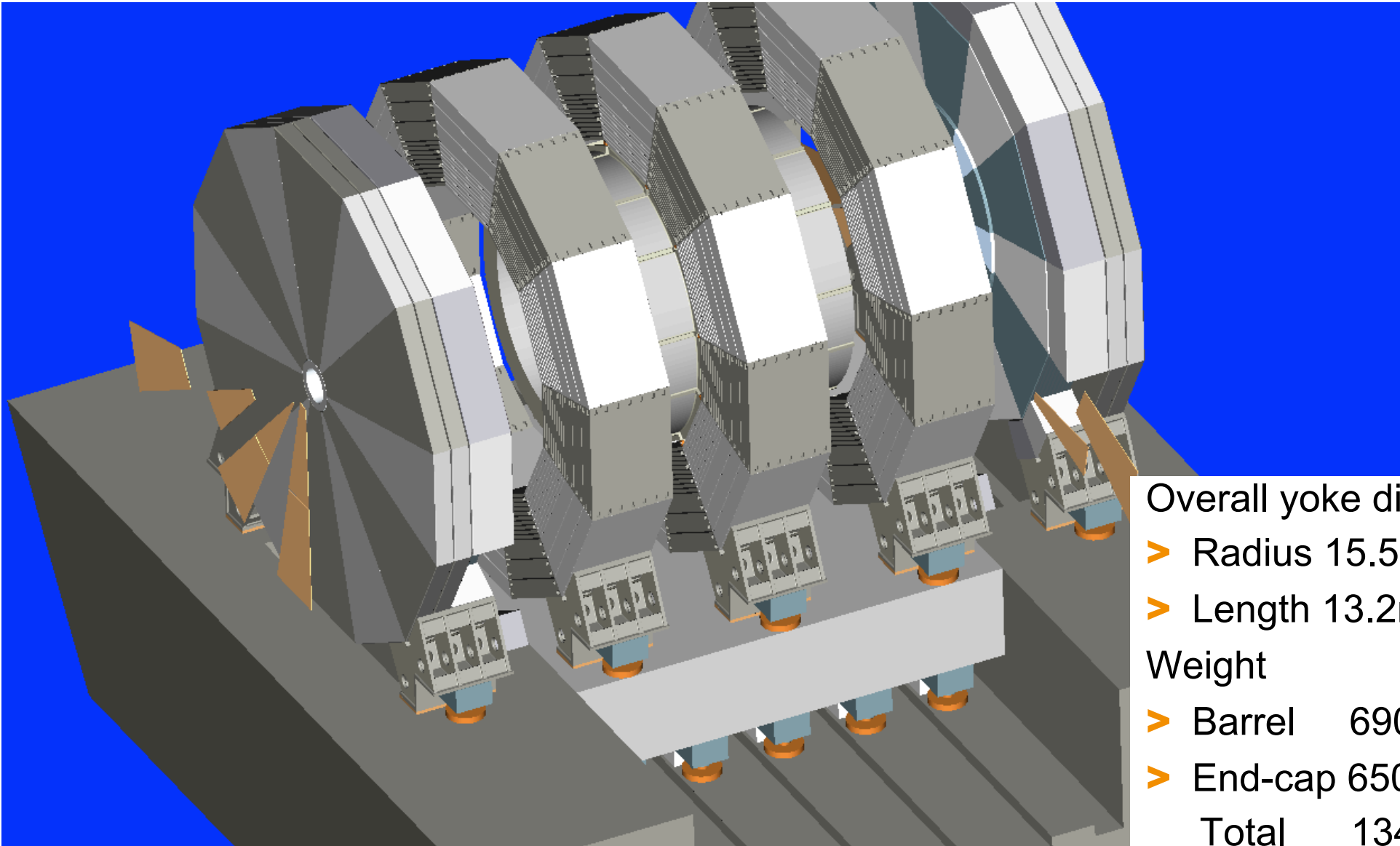


Design Challenges

- > Main mechanical structure of detector
- > Severe requirements on stray field determine thickness and cost of yoke
- > ILD cost/performance optimization in progress
 - Size might be reduced
- > At some point should reevaluate stray field requirements
 - Hope to reduce yoke thickness
- > Large magnetic forces on end caps
- > Transportation issues in Japan
- > Alternative design of yoke modules



Present Design



Overall yoke dimensions

> Radius 15.5m

> Length 13.2m

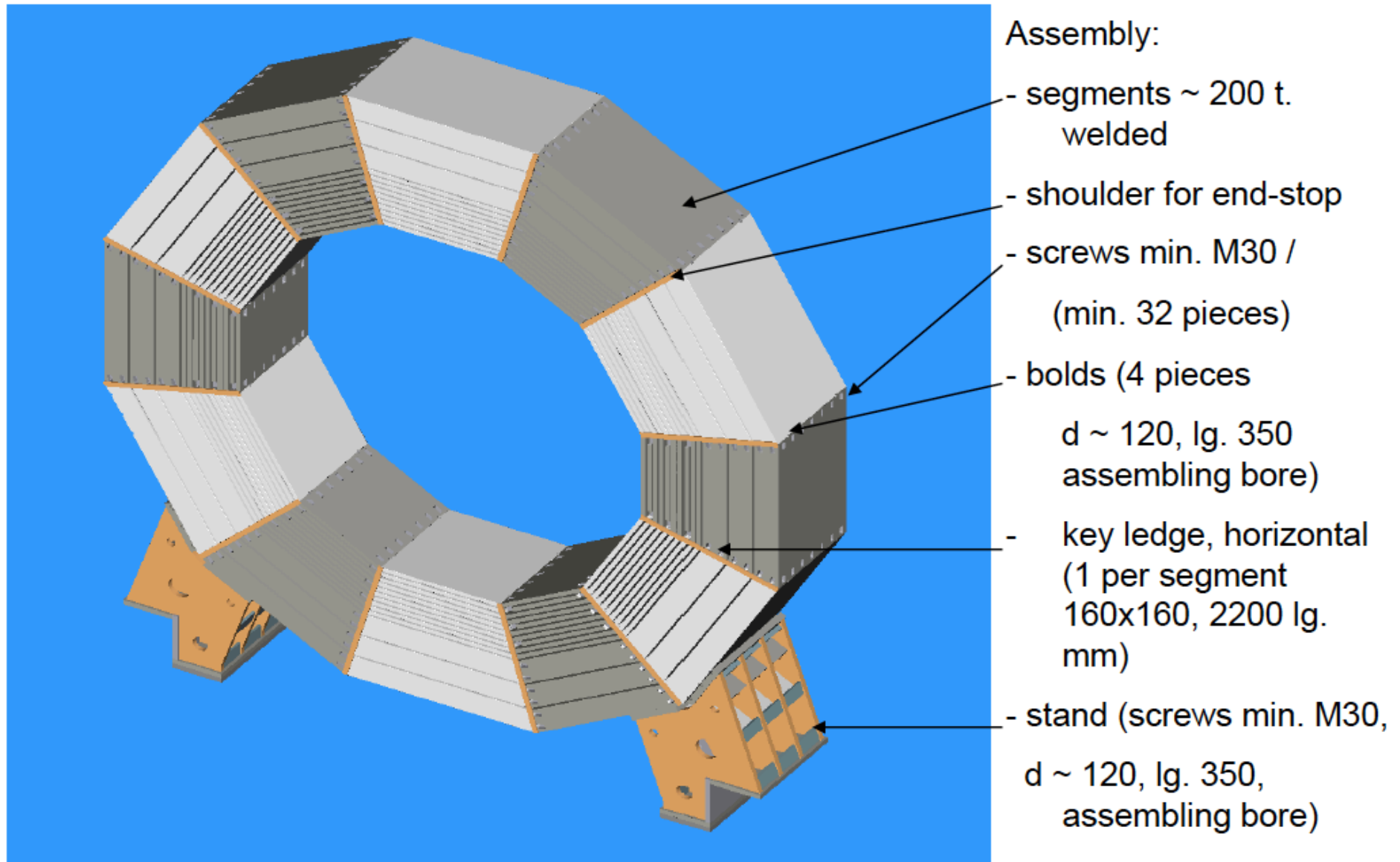
Weight

> Barrel 6900t

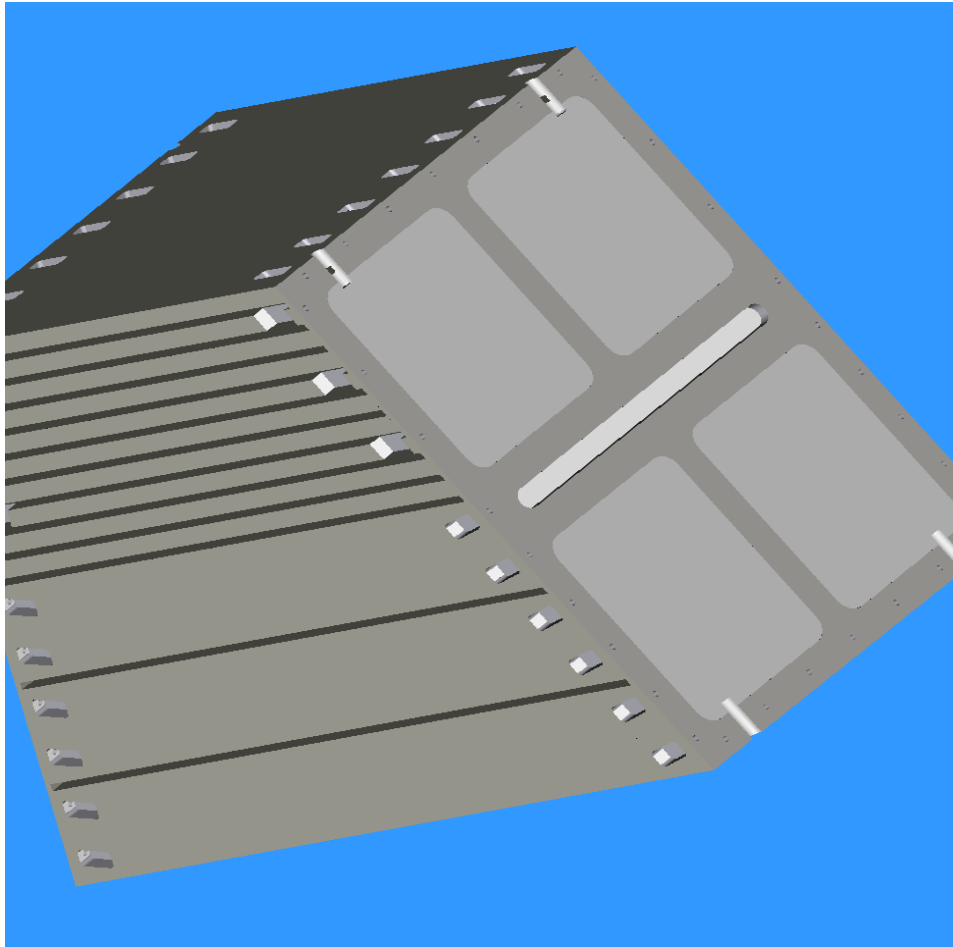
> End-cap 6500t

Total 13400t

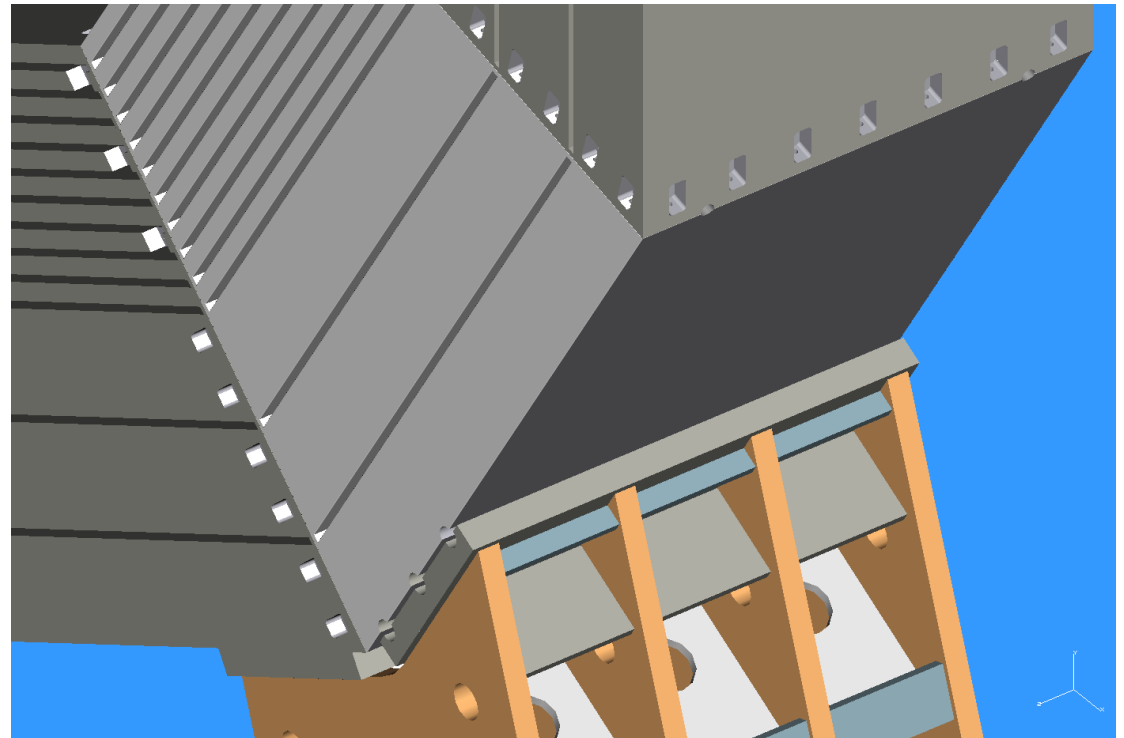
Barrel Design



Barrel Design



Module weight ~210 t



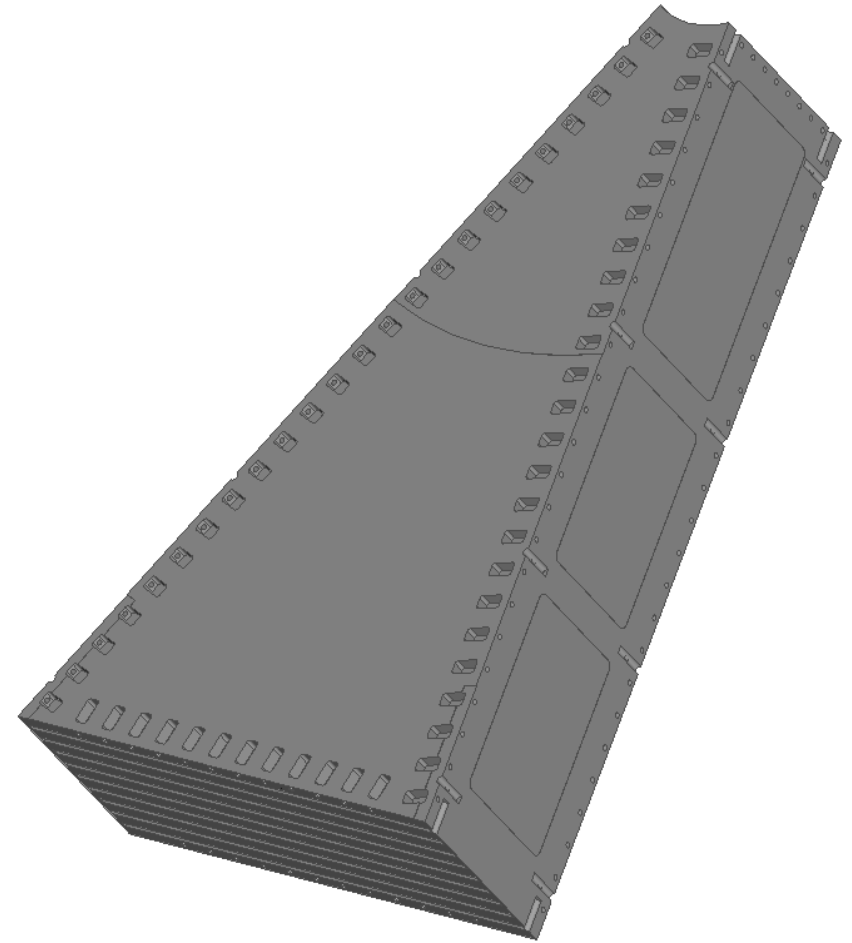
End-cap Design

Inner end-cap

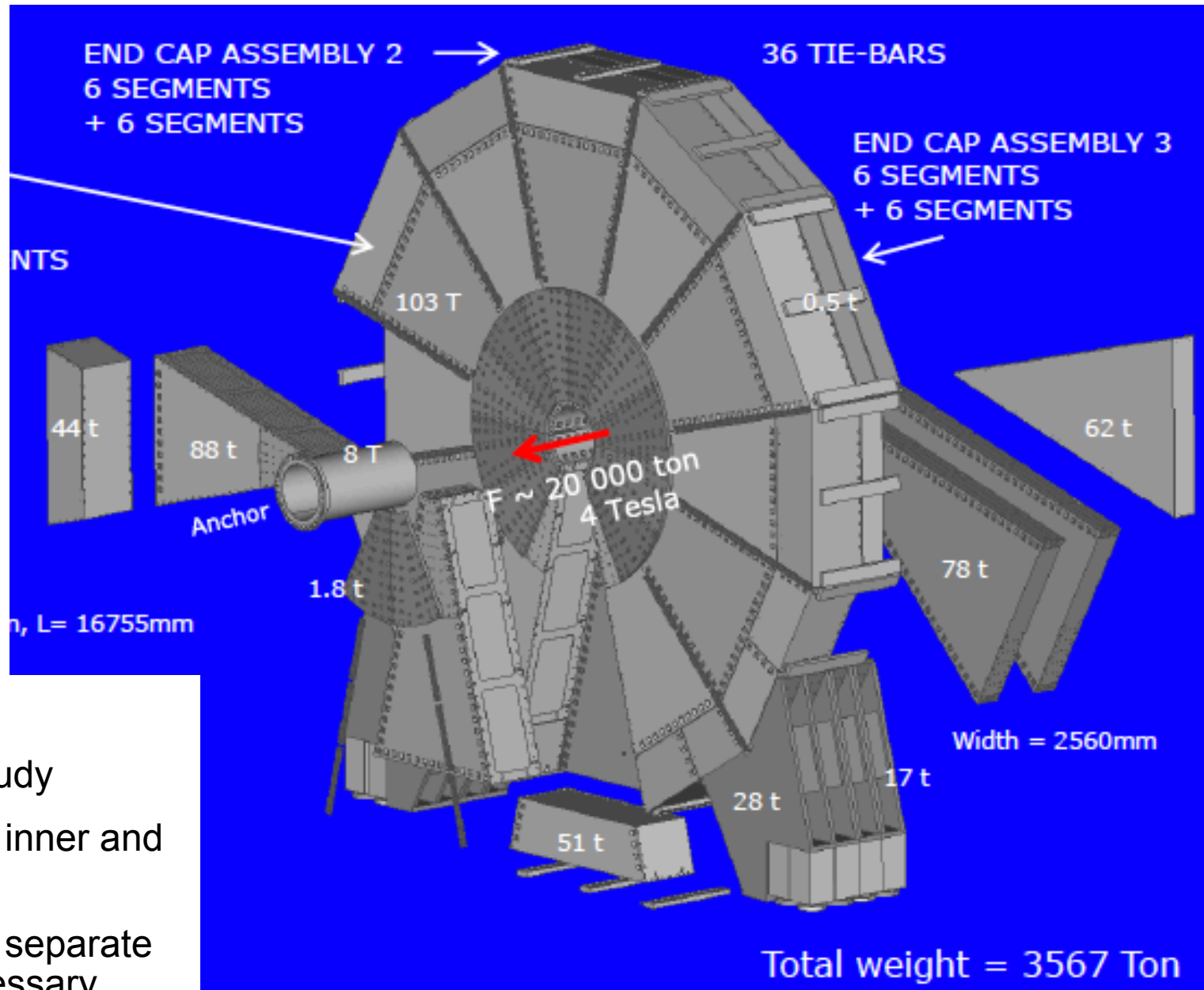
- Consisting of 12 wedge-shaped modules
- 10 100mm thick plates welded together
 - 25mm x 40mm spacers
- Modules bolted together using M36 screws
- Field shaping plate 100mm thick part of (or attached to) first plate
 - Welded, 200mm total thickness or
 - bolted to 1st plate (module overlap)

Outer end-caps

- Two disks, 560mm thick plates
- Wedge-shaped modules bolted together
- In addition, iron pieces at outer radius to close gaps of inner end-cap plates (muon chambers)



End-cap Design



Comments

- Quite detailed study
- Should separate inner and outer EC again
- Unclear whether separate inner plates necessary

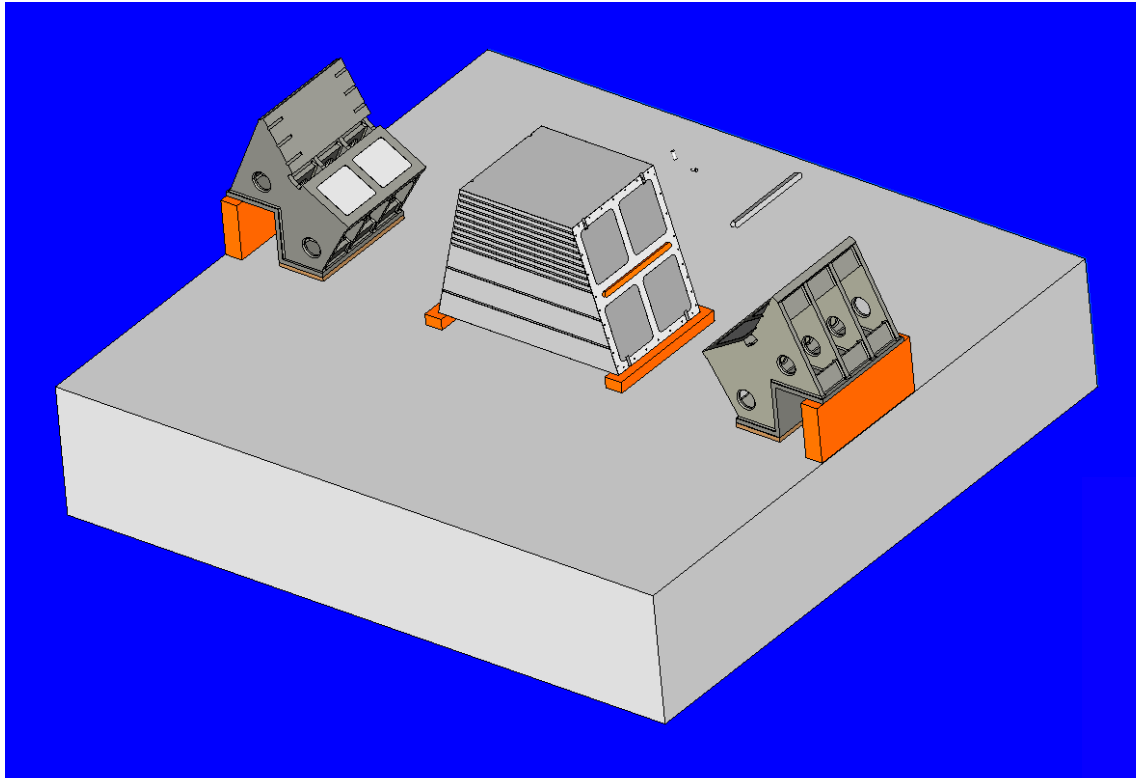
Yoke Fabrication and Assembly

General procedure

- > All machining done at fabrication site
- > Complete preassembly at fabrication site
- > Yoke disassembled
- > Modules shipped to ILD site
- > Barrel wheel and end-cap assembly in IR surface building
- > Installation of muon chambers, cabling, infrastructure,....
- > Wheels and end-caps lowered into IR hall

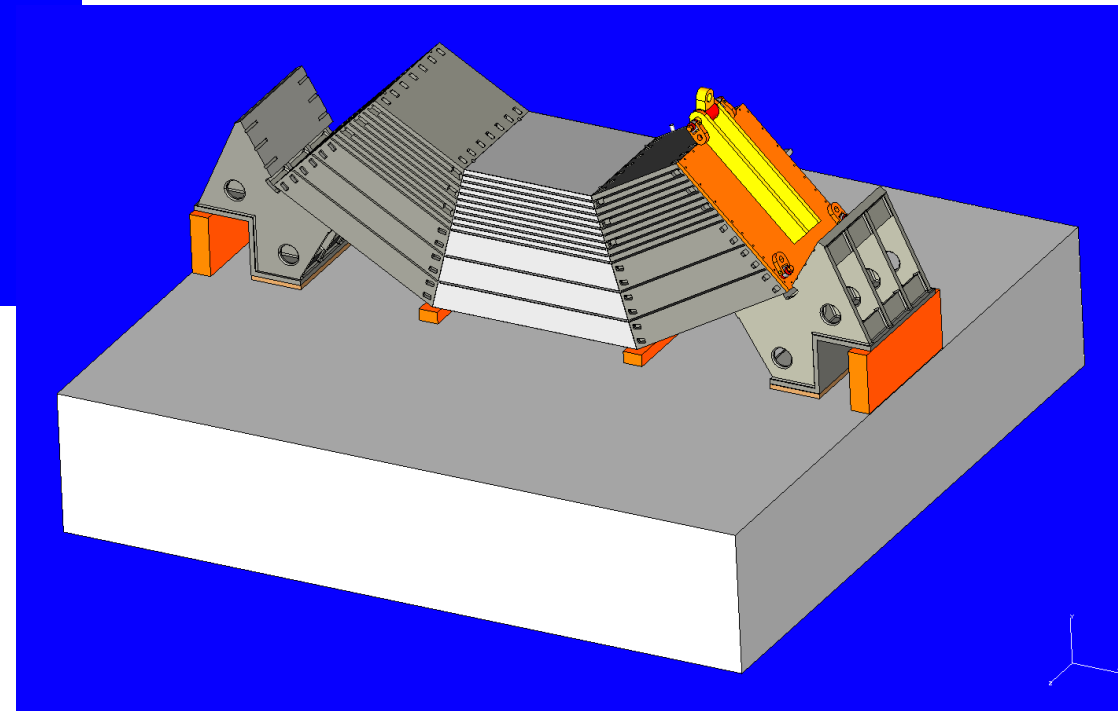


Barrel Wheel Assembly

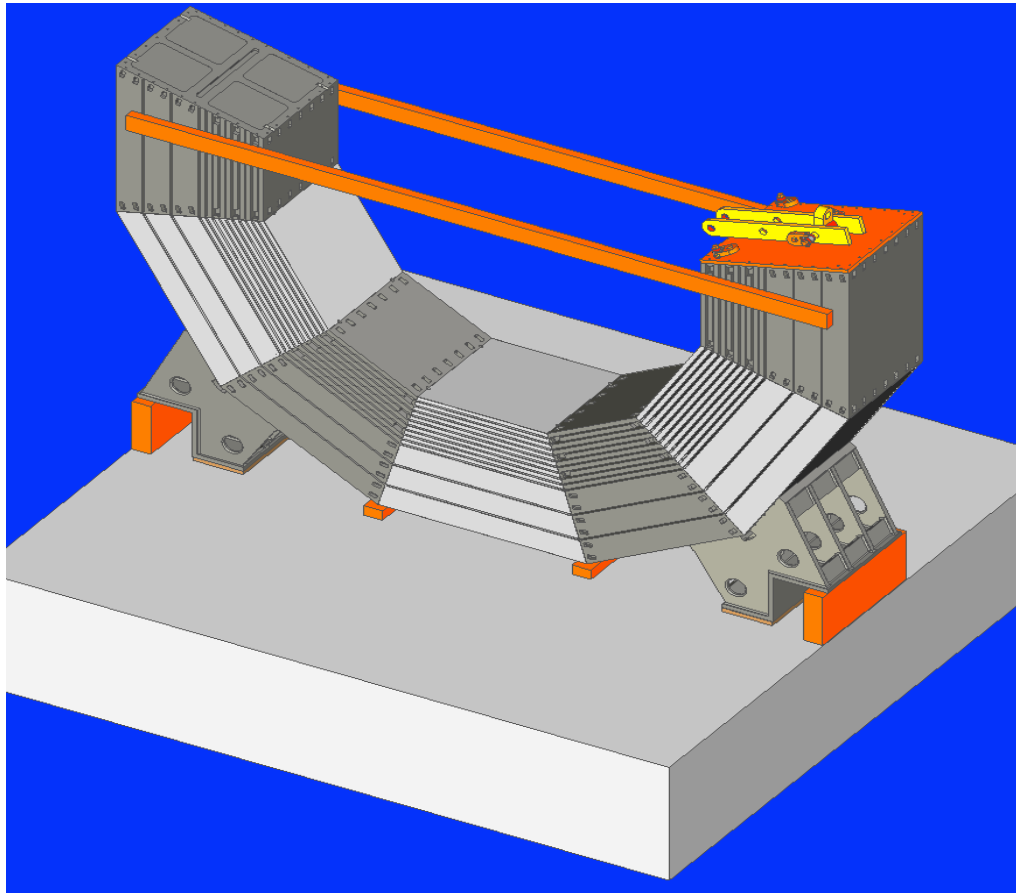


Tools needed:

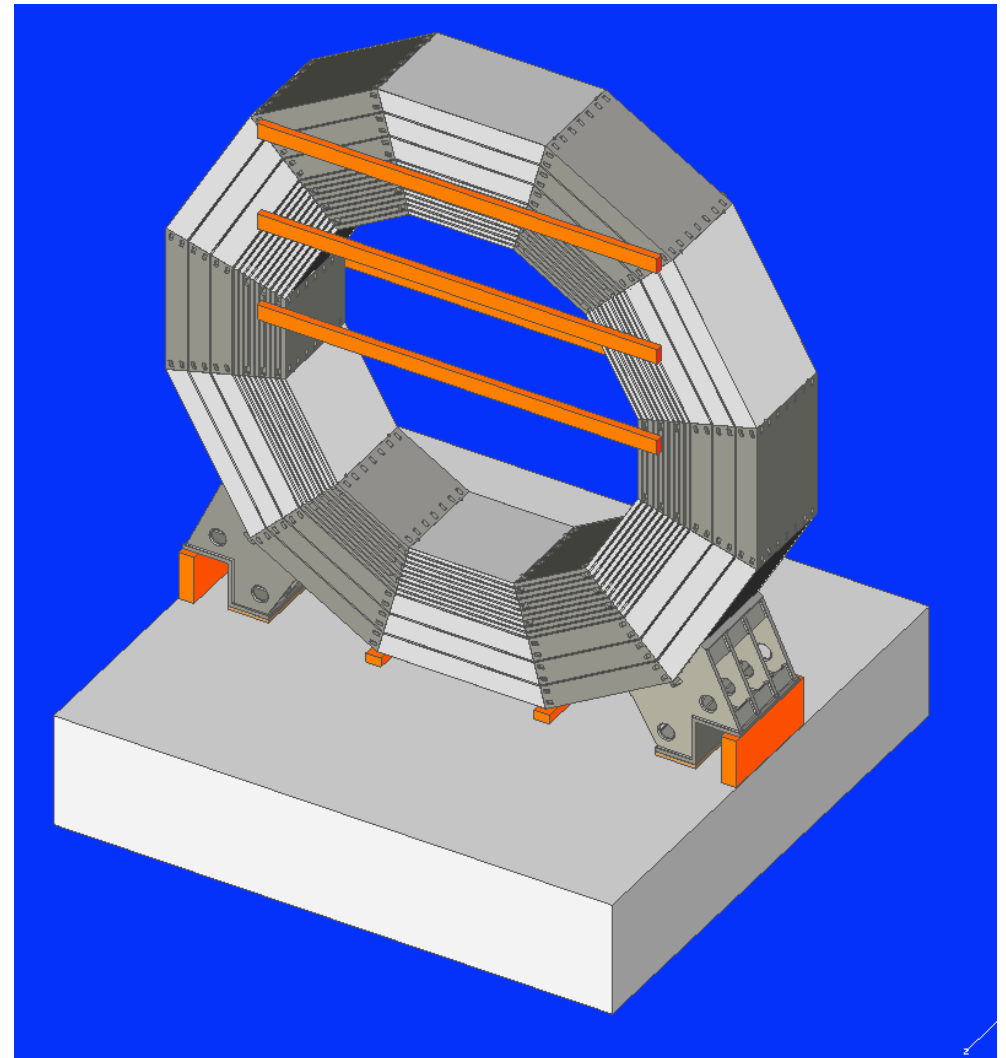
- > 250t crane
- > Lifting gears
- > Support structures
- > Survey



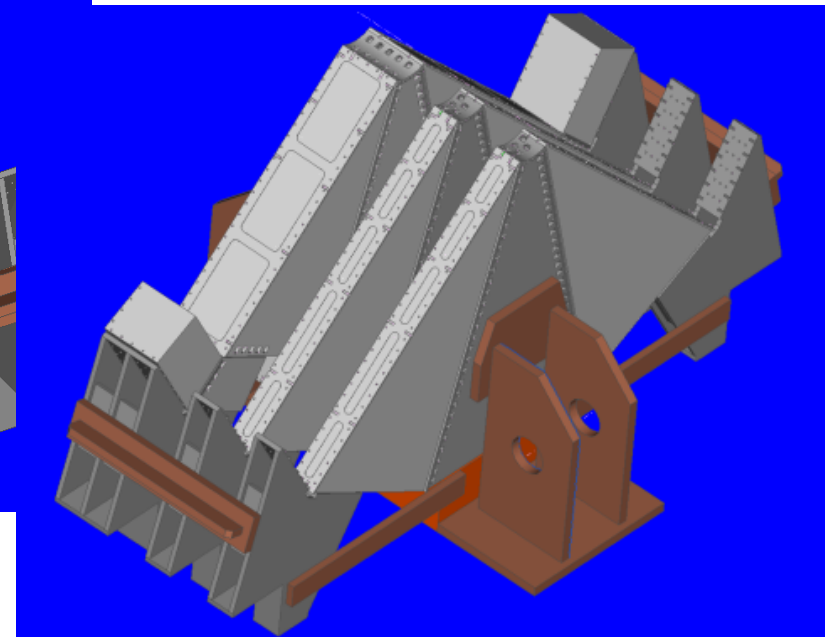
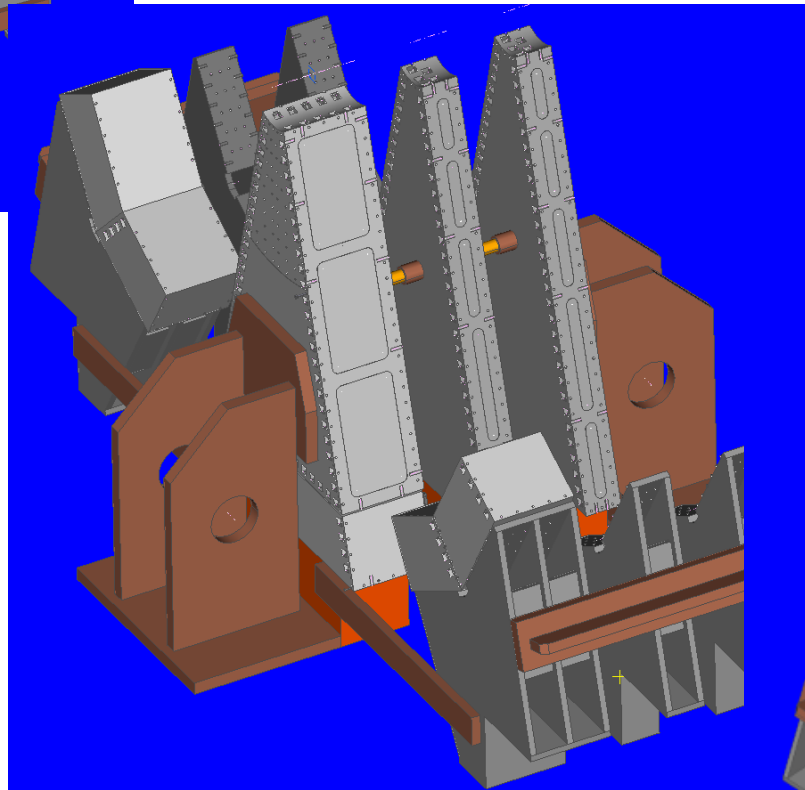
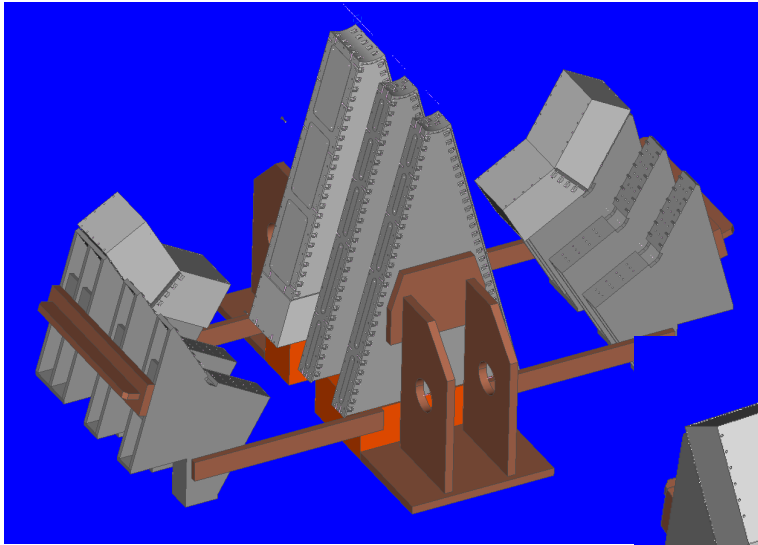
Barrel Wheel Assembly



Schematic support structures

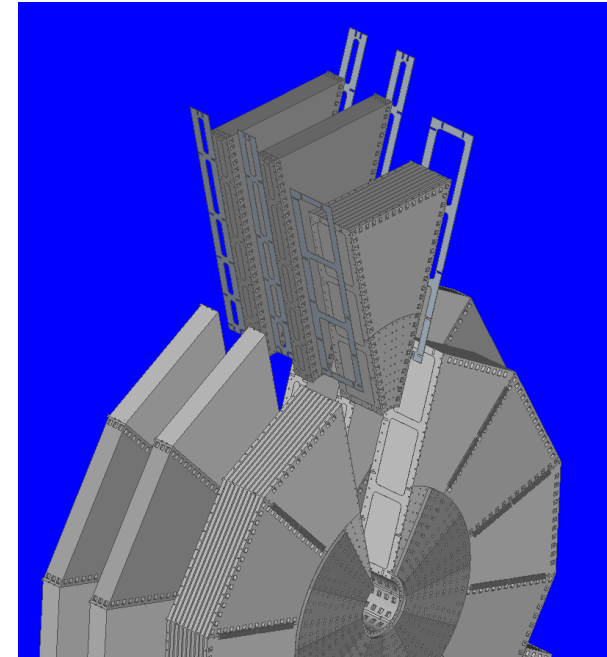
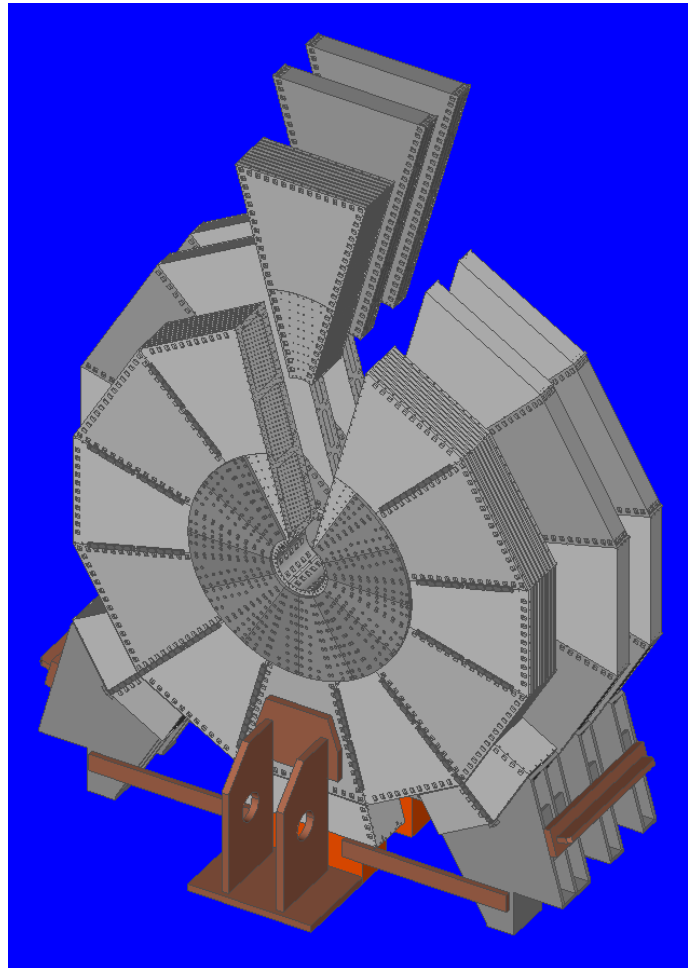
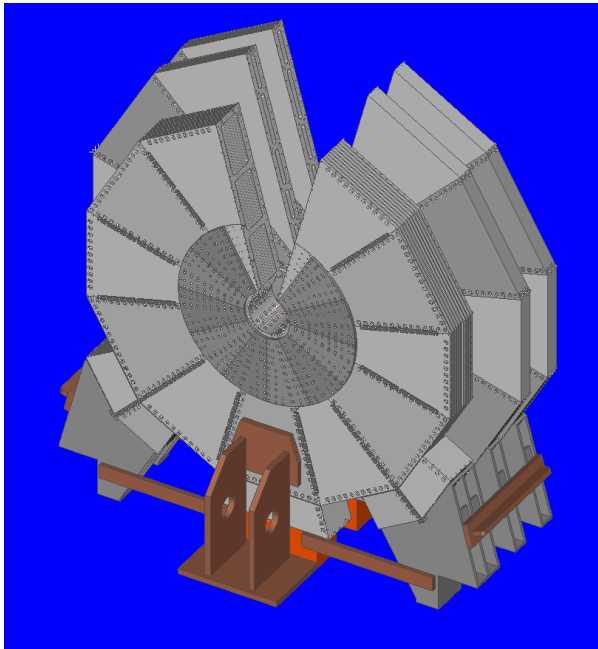
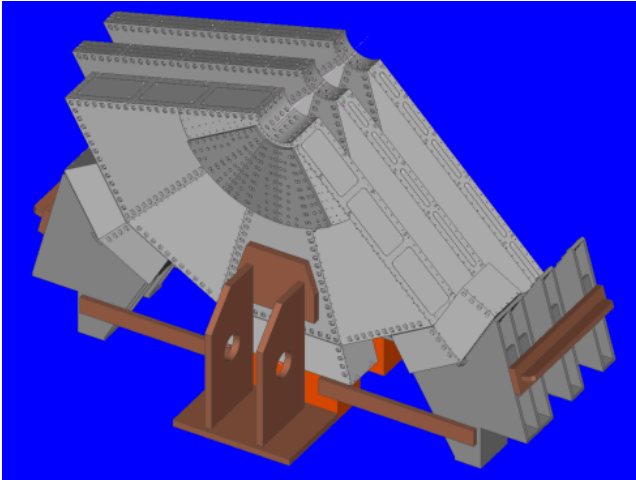


End-Cap Assembly



End-Cap Assembly

Final module:
precision machined
or adjusted with shims



Yoke Transportation

Present design

- > Barrel: 36 modules ~200t each (without heavy load truck)
- > End-caps:
 - Inner EC: 24 segments ~90t each
 - Outer EC 48 segments ~60t each plus outer radius pieces

Severe road transportation limits in Japan, although only ~25km distance from harbor

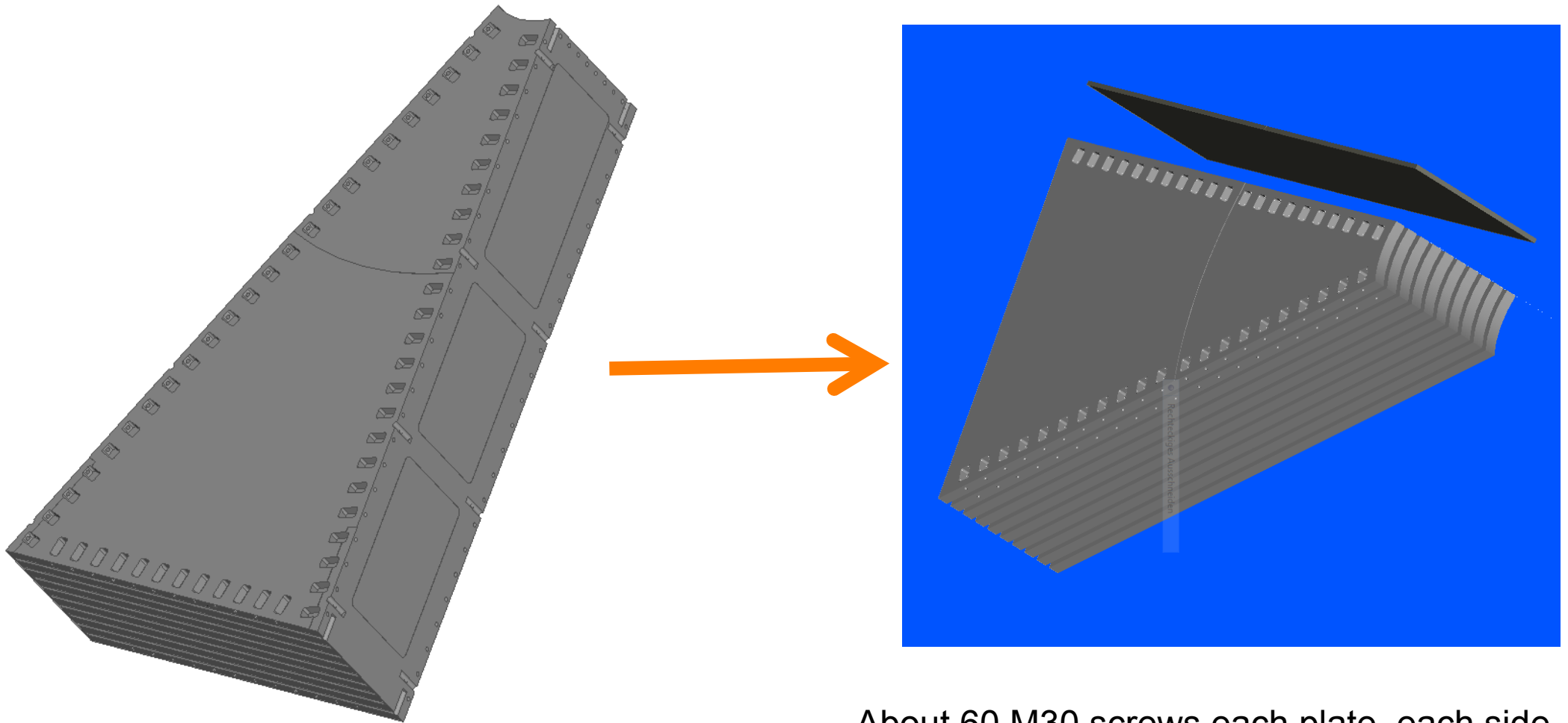
- > Maximum load 44t including truck (24t net weight)

Started looking at alternative design with bolted plates



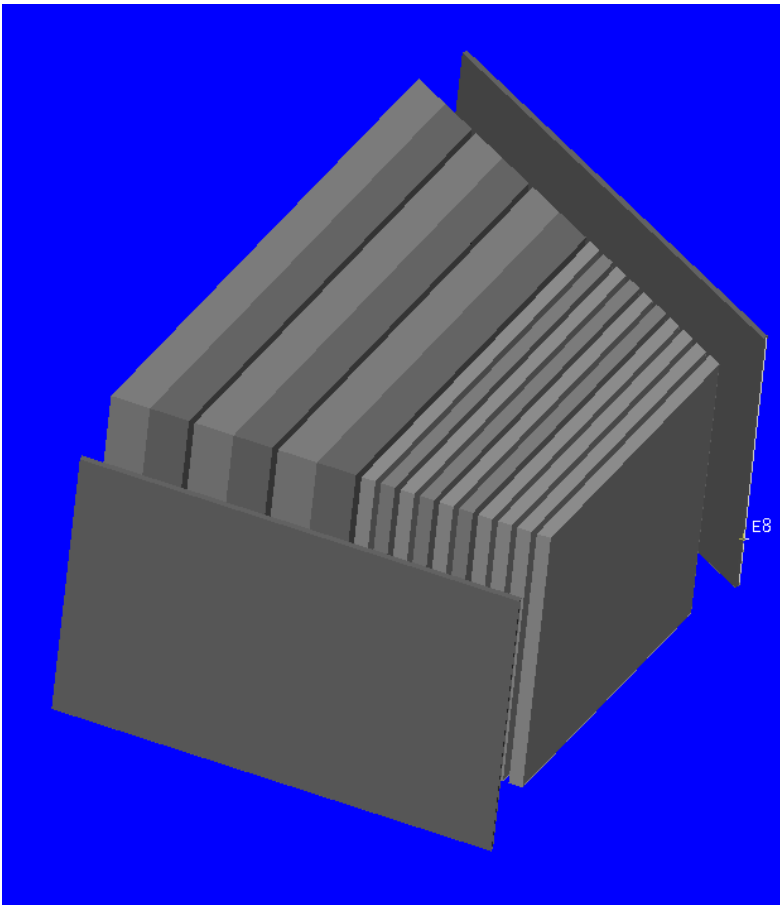
Alternative Module Design

Going from welded structure to plates bolted to side plates

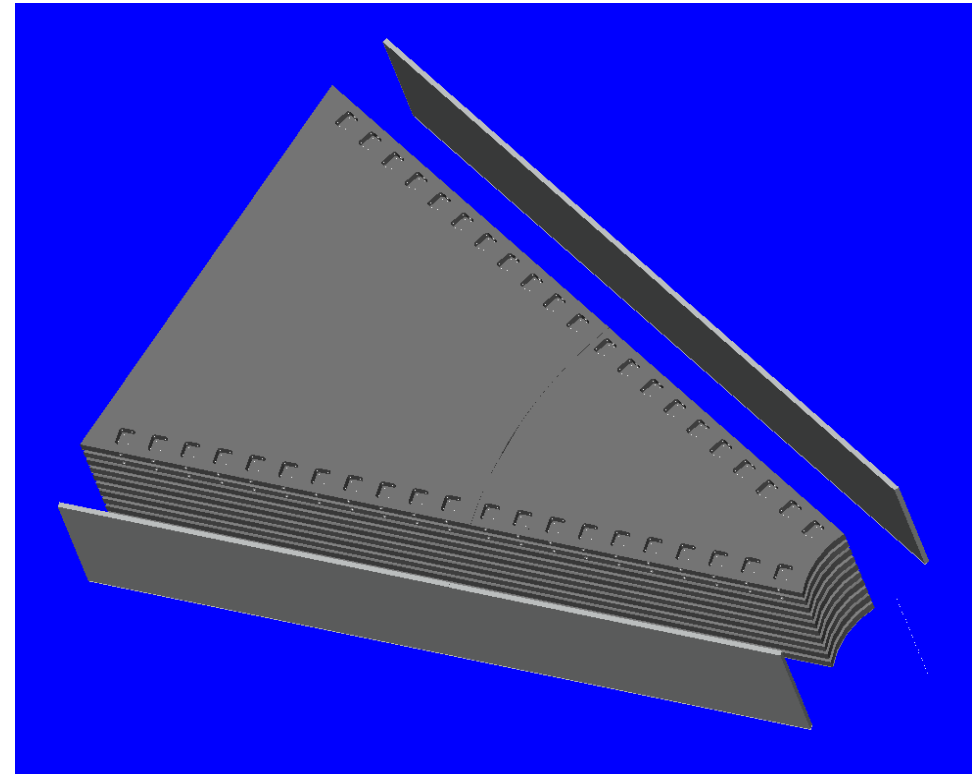


About 60 M30 screws each plate, each side
plus sheer bolts

Alternative Module Design



Barrel wheels straightforward,
no big forces



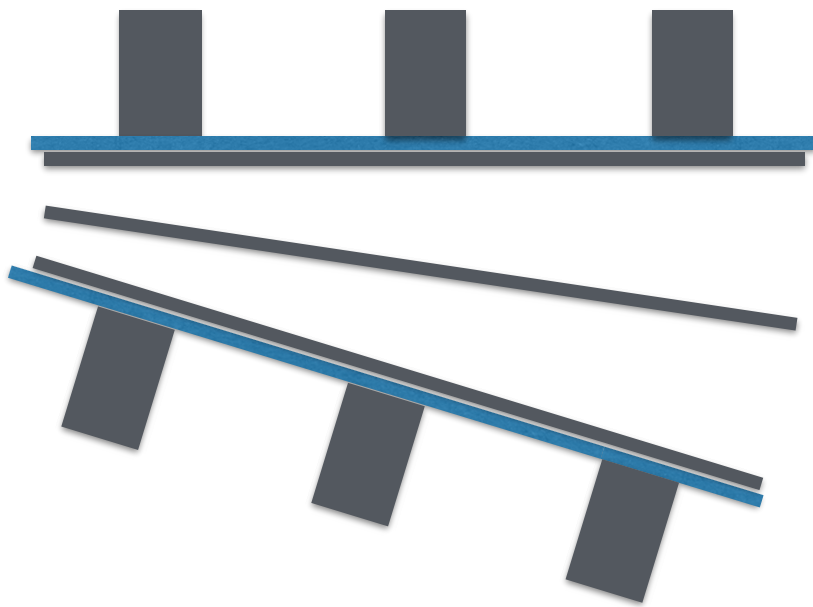
End-caps

- > Plates 2-10 and outer plates straightforward
- > FSP/1st plate large magnetic forces, may need higher quality steel.
- > Work in progress

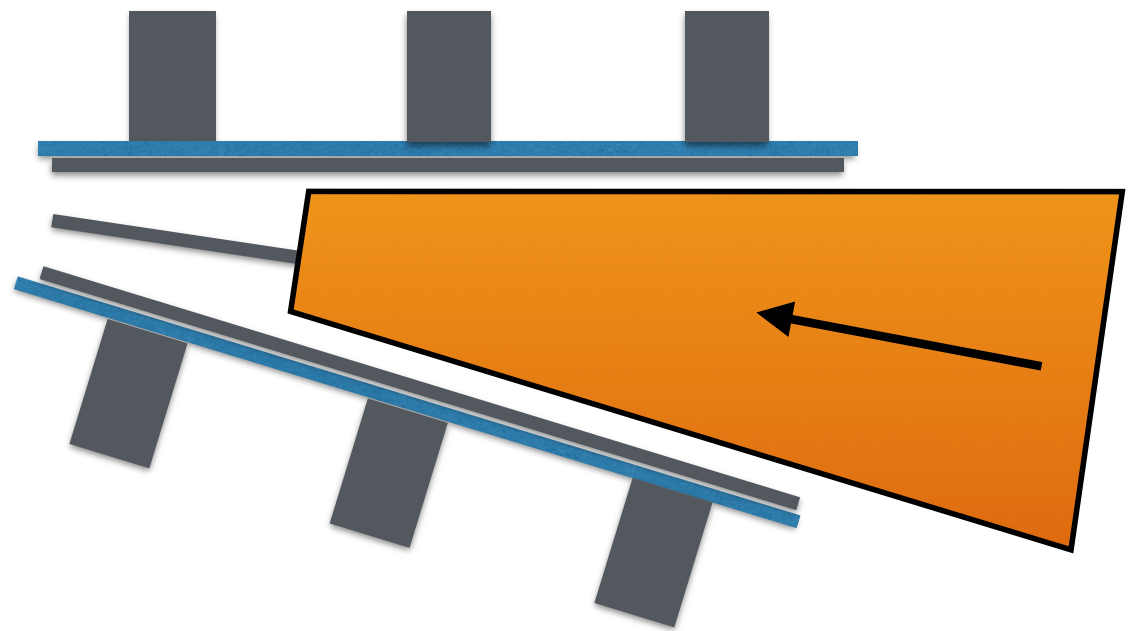
Alternative Design – Module Assembly

Inner End-cap

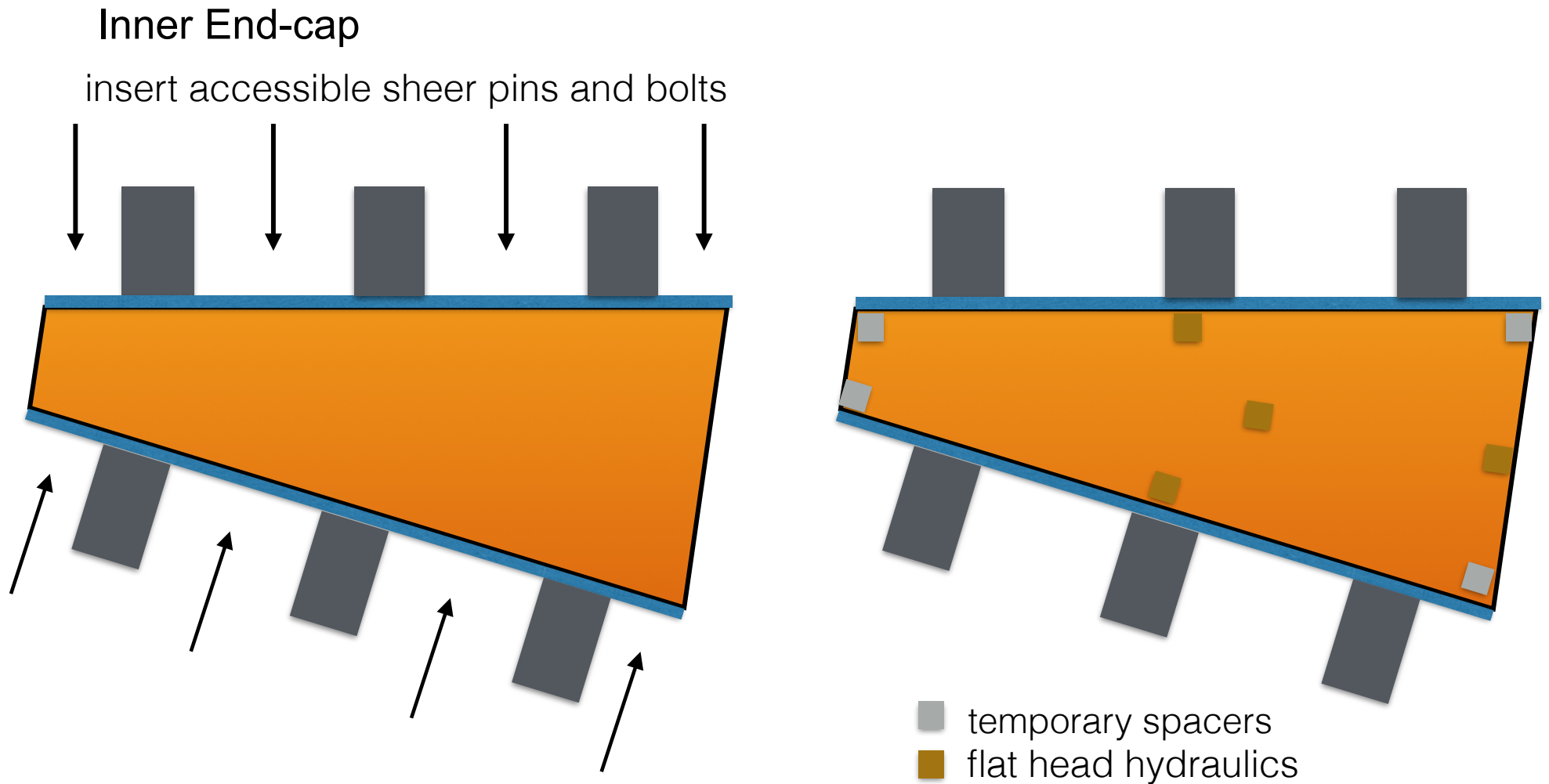
Support fixture and side plates



Crane in first plate

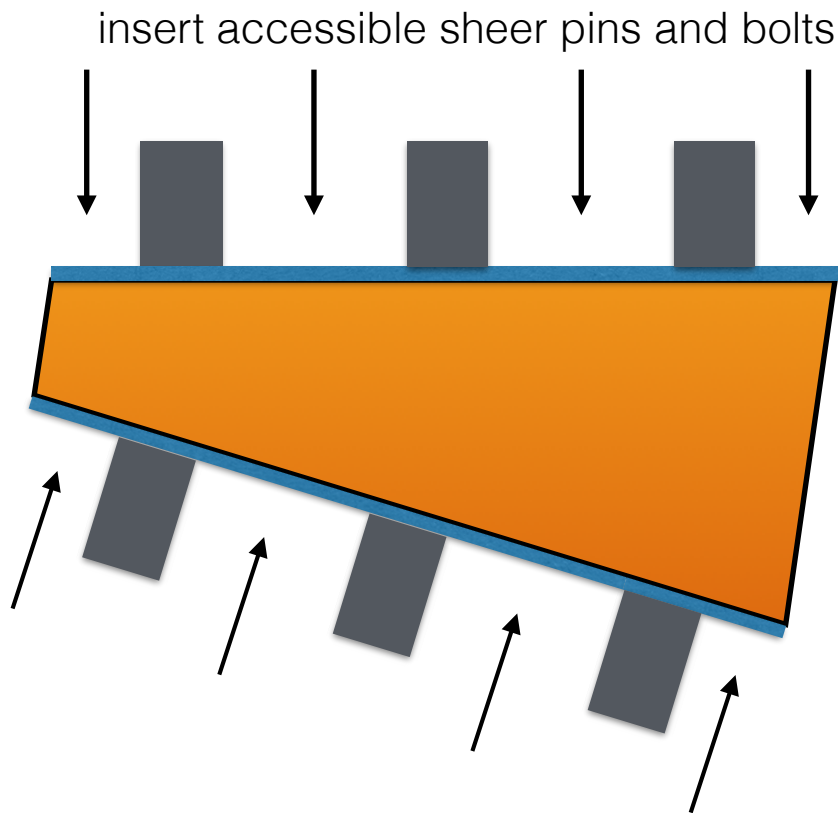


Alternative Design – Module Assembly

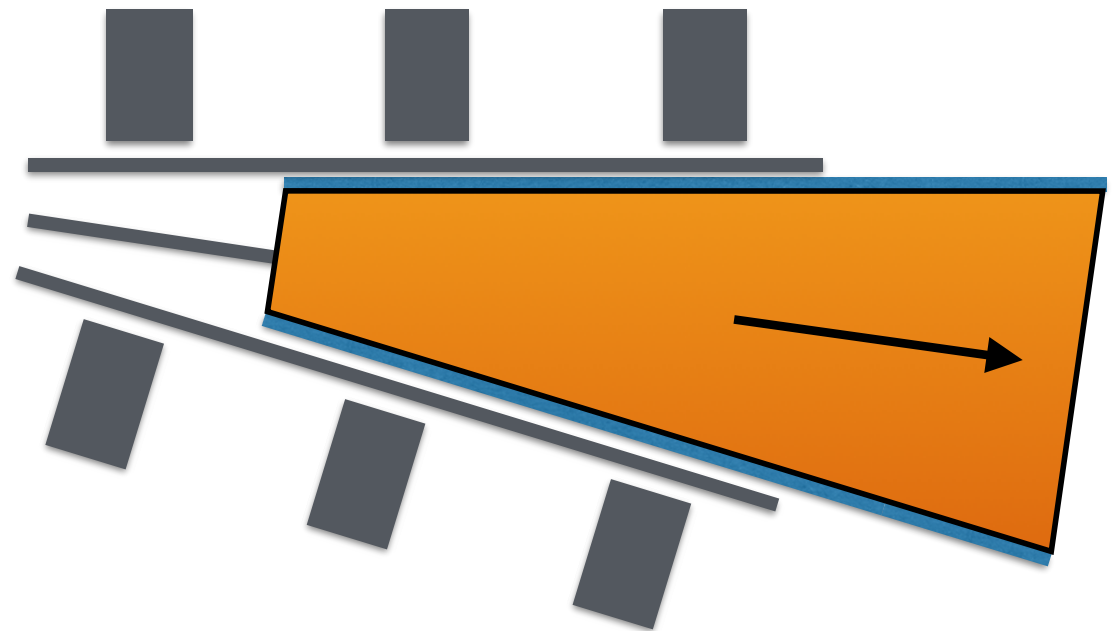


Alternative Design – Module Assembly

Inner End-cap



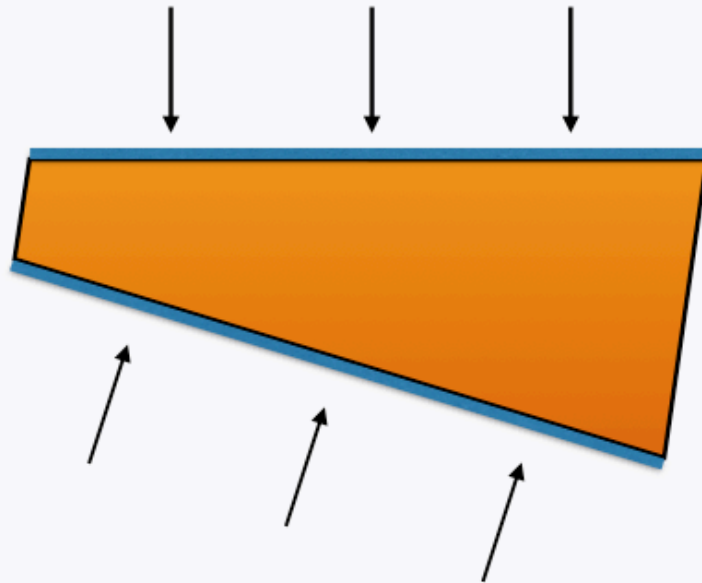
Move out complete segment



Alternative Design – Module Assembly

Inner End-cap

Insert remaining shear pins and bolts
Survey complete segment



Floor space 10 x 10m²

Module Assembly – Rough Schedule

Inner end-cap

- > Check (survey), prepare support structure and side plates: ½ d
- > Move in and connect 10 plates: 2d
 - Screw in bolts (2 steps) and put in shear pins where accessible
- > Move out module, insert remaining screws: 1d
 - Screw in bolts (2 steps) and put in shear pins
- > Repeat pre-tensioning of screws: 1d
- > Final quality assurance (survey): ½ d
- > Time estimate: 5 days (1week) for 1 inner EC module
- > 24 inner modules → 120 days (24 weeks)

- > Man-power: 4 technicians, 1 head technician, 3 crane people, 2 survey techs



Module Assembly – Rough Schedule

Outer end-caps

- > Single modules too heavy for transport, to be divided into 3 pieces
- > 4 days per modules
- > In total 48 modules → 192 days
- > Outer radial pieces (to be completed)
- > End-caps: in total 312 days (without outer radial pieces)

Barrel wheels

- > Inner barrel 10 plates
 - > Outer barrel 3 thick plates, each to be divide into 2 pieces: 6 thick plates
 - > 9 days per module
 - > 36 modules → 324 days
-
- > Man-power: 4 technicians, 1 head technician, 3 crane people, 2 survey techs



Module Assembly – Schedule and Hall

> Preliminary schedule

- End-caps: 312 days (without outer radial pieces)
- Barrel wheels 324 days (without support feet),
- In total about 2 years, ~1 year in case of two assembly lines

> Module assembly hall

Storage area for 1 end-cap

- ~1400m² (with 40t crane) without space for moving plates and assembled modules or
- ~900m² with 250t crane
- Assuming plates are delivered in containers, could store incoming containers on outside “parking lot” to reduce required hall space
- Assembly area 20m x 10m → 200m², 2 assembly lines → 400m²
- Need 2 ~40t cranes + moving system for assembled modules (or ~250t crane)

> Work to be done at fabrication site

- Module assembly, barrel and end-cap assembly, complete disassembly of yoke and modules

> Assuming max. shipping load of 25t → at least 540 truck transports



Alternatives

Module assembly very time consuming due to trial assembly at company

- Assuming two assembly lines, ~ 1½ year additional time for yoke fabrication and assembly

Alternatives

- Yoke fabrication done by company **on ILC site**, not at company
 - Set up heavy fabrication workshop on site
 - Welded option preferred, since less expensive
 - Need floor space for welding, machining, surface preparation, painting, quality assurance and storage in one hall (if possible)
 - Would probably reduce number of fabrication companies to Japanese firms
- Yoke fabrication still done at company, but **without** trial assembly
 - Rely on quality assurance
 - Might require machining of top modules. Could be made slightly smaller, use shim plates if necessary



Conclusions

- > Started looking at alternative yoke module design
 - Bolted instead of welded plates (more expensive)
- > Barrel should be straightforward
- > End-cap plates 2 – 12 (in z-direction) should be straightforward
- > End- cap FSP/1st plate somewhat problematic due to large magnetic forces
 - May need higher quality steel for FSP/1st plate, work in progress
- > Module assembly quite time consuming
 - Assuming two assembly lines, ~ 1½ year additional time for yoke fabrication and assembly
- > Storage of 1 end-cap requires ~1300m² (~250t crane) or ~2300m² (~40t crane) module assembly hall with cranes and moving systems, less if containers are stored outside
- > Possible Alternatives
 - No trial assembly at fabrication site
 - Fabrication near ILC exp. Hall, welded option preferred

