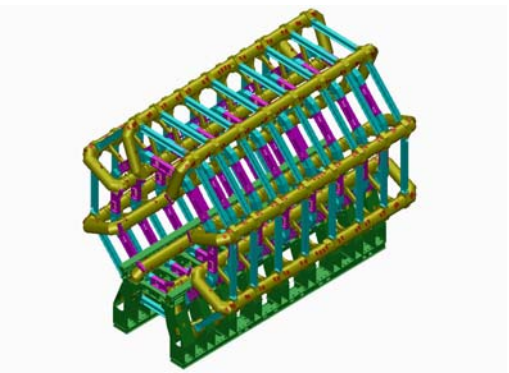
The ATLAS Toroid Magnet



SUN Zhihong

CEA Saclay DAPNIA/SIS

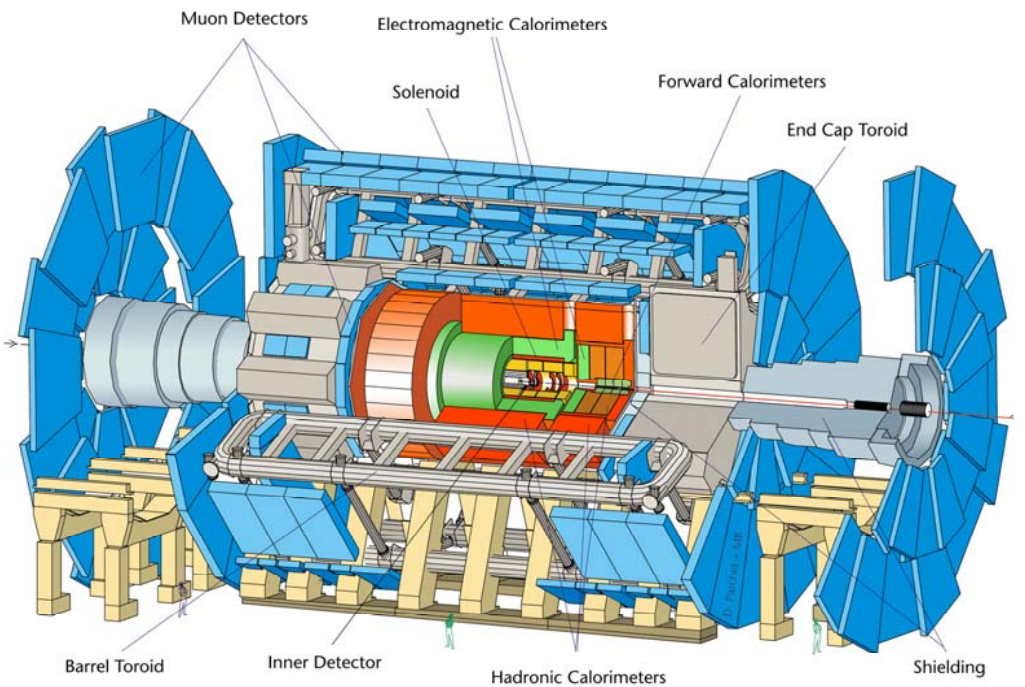
- The ATLAS Magnet System
- The ATLAS Barrel Toroid
- Mechanical computations on the Barrel Toroid structure
- Manufacturing and assembly of the Barrel Toroid
- The latest news: energizing of the Barrel Toroid
- Conclusion

The ATLAS Magnet System

The ATLAS Magnet System consists of the 4 magnets:
Barrel Toroid, End Cap Toroids and Central Solenoid.
It's a system of 4 magnets providing the magnetic field for inner detector and muon detector.

- 20.5 kA at 4 Tesla
- conduction cooled at 4.8 K
-170 t superconductor
- 700 t cold mass
-1.55 GJ stored energy

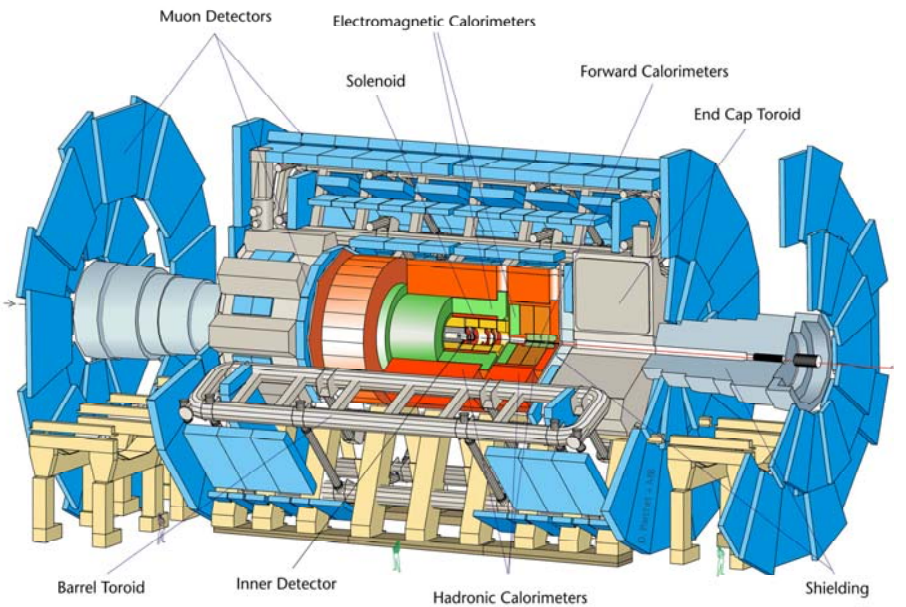
(1.10 GJ for the Barrel Toroid)



The ATLAS Barrel Toroid

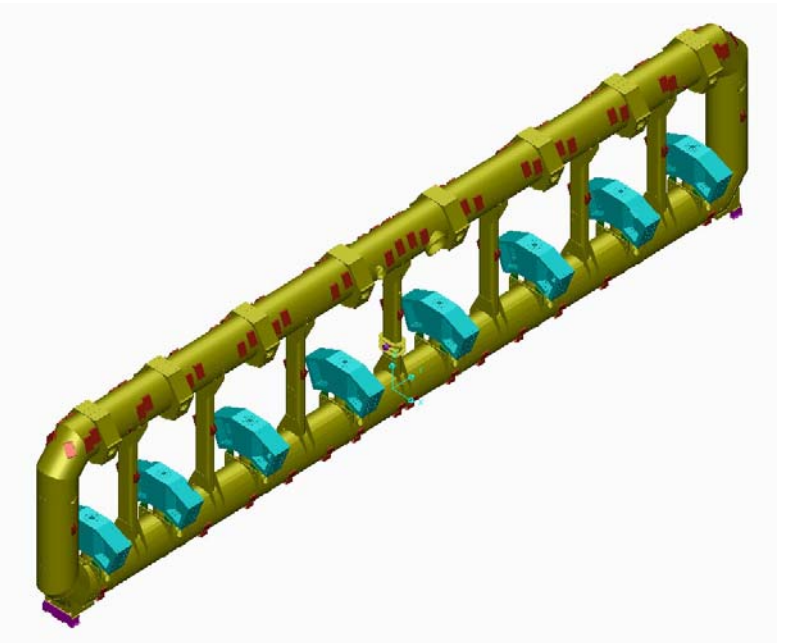
The ATLAS Barrel Toroid magnet is a large air-core toroid. It provides the magnetic field for the Muon detector. The barrel toroid structure is an open structure that the muon chambers are installed on and inside the toroid. The toroid structure supports the services of the ATLAS experiment, such as cables, cooling pipes and access, etc.

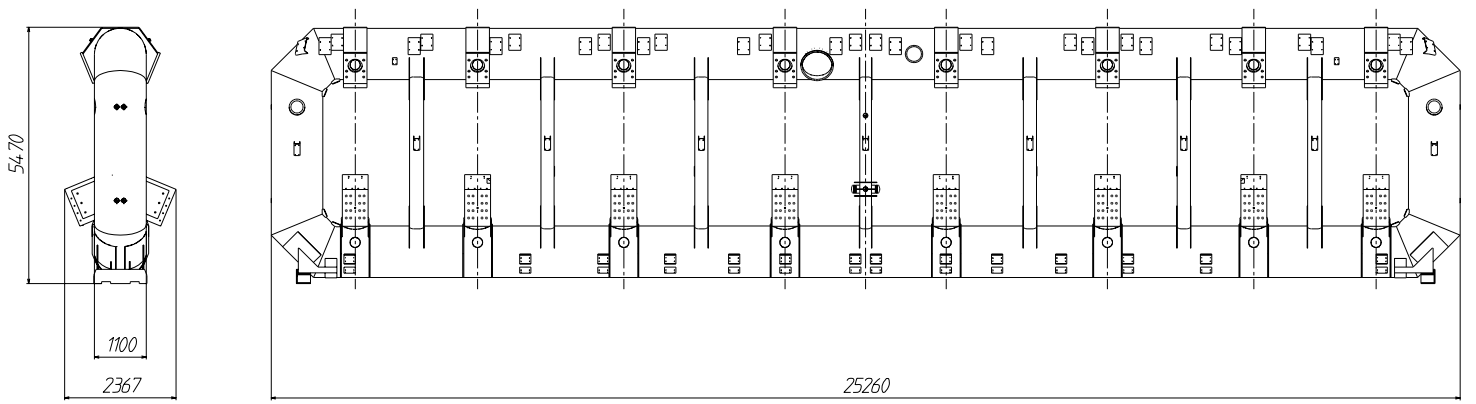
The Barrel Toroid consists of eight superconducting coils which are evenly positioned around the beam axis with an outer diameter of 20 m.



Each coil is inside a vacuum vessel with dimensions of 26 m x 5 m x 1 m.

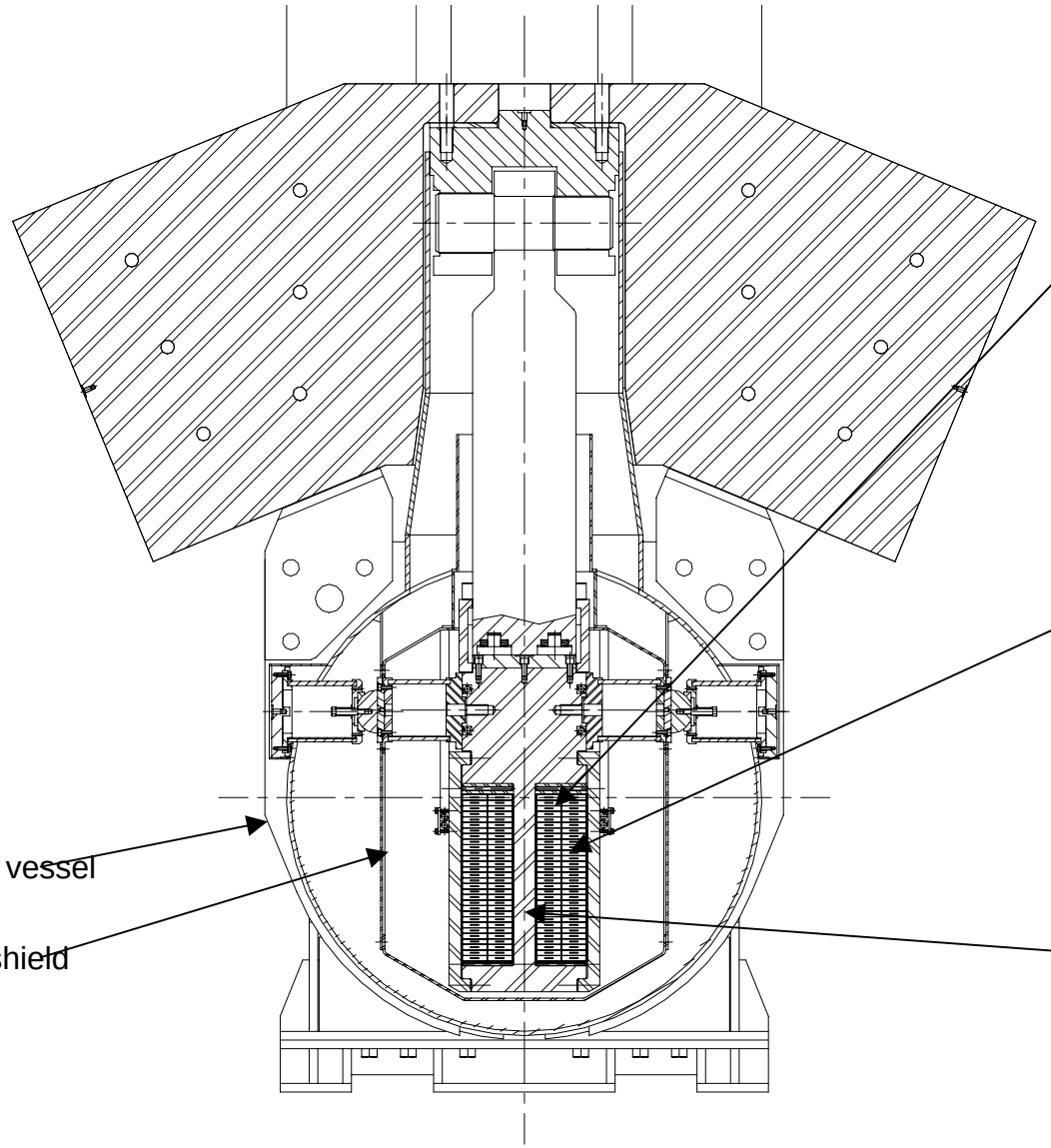
The weight of one coil is about 85 tons.

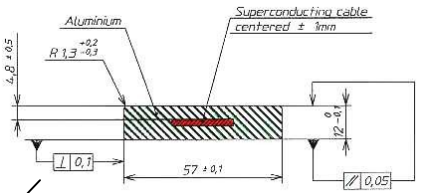




The ATLAS Barrel Toroid

Coil



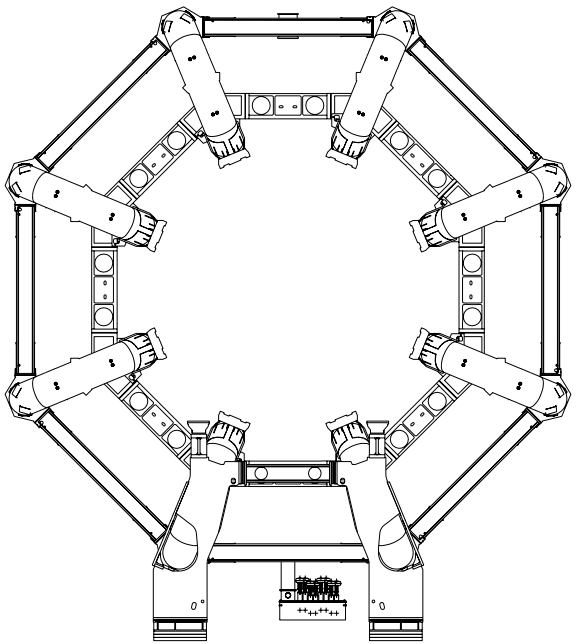


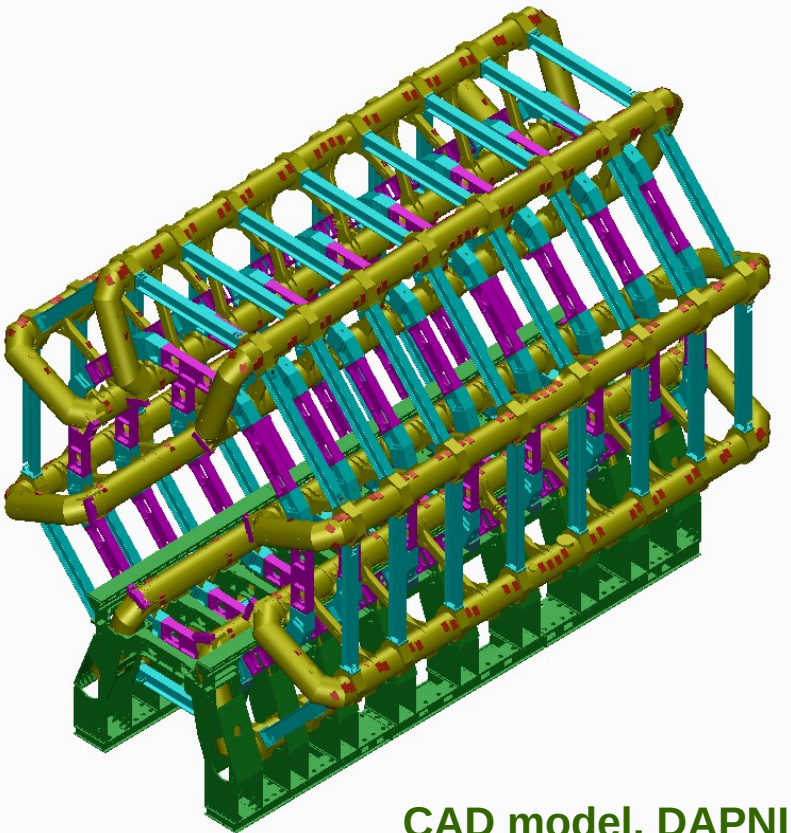
Section of conductor

Coil

Coil casing

The barrel toroid structure holds the eight coils in space. The structure works in the room temperature. With respect to the superconducting coil that works at 4.8 k, the structure is named as the warm structure.





CAD model, DAPNIA/SIS

Physics requirements

The more the structure is ‘transparent’ to the particles, the better it is for the resolution of the muon detector.

→ The quantities of the materials used in the warm structure must be minimized.

To ensure the precision of the muon chamber positioning,

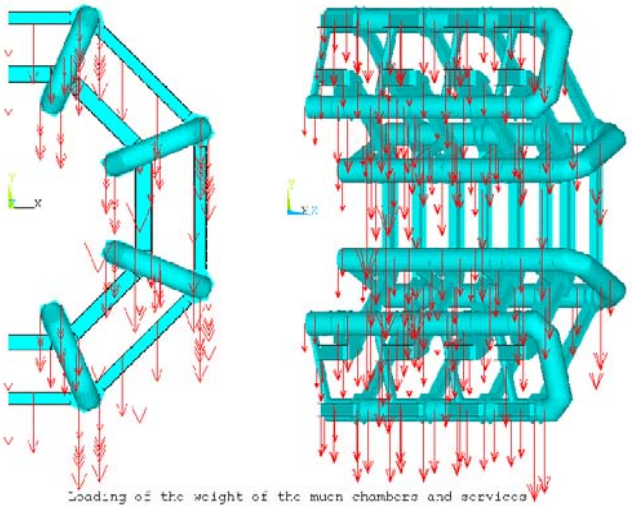
→ the deformation of the overall structure should be less than 30 mm.

To reproduce the experimental measurements, the muon chambers must stay stable with or without the magnetic fields.

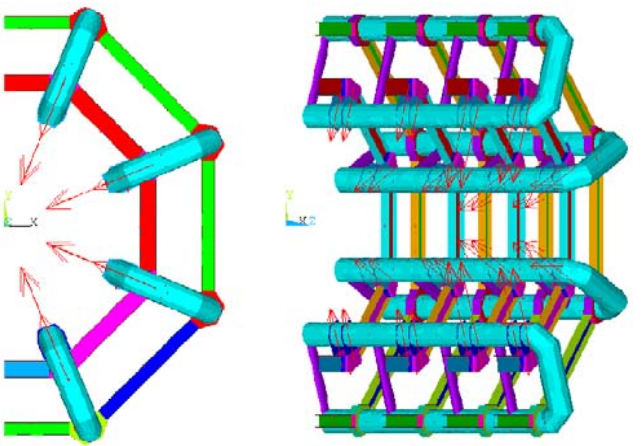
→ The deformation of the structure should be controlled in all the different situations.

Challenge on the mechanical design

- The loads on the structure: 1400 tons
- With or without the magnetic forces:
  - radial forces: 1100 tons / coil
  - axial forces: 240 tons / each side
- Atmospheric pressure
- Thermal deformation and stress
- Bolting assembly
- Accidental conditions



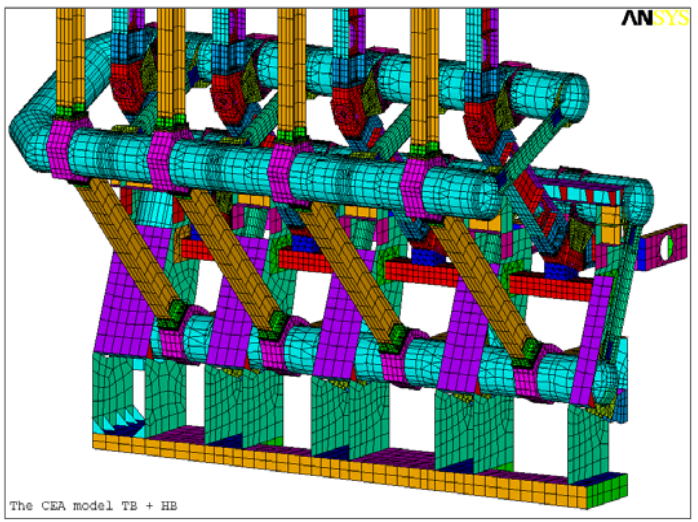
Loads



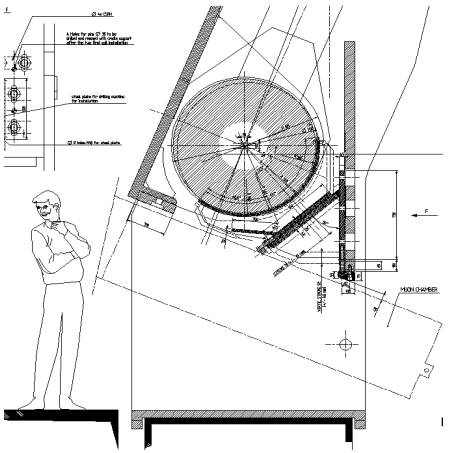
Magnetic forces

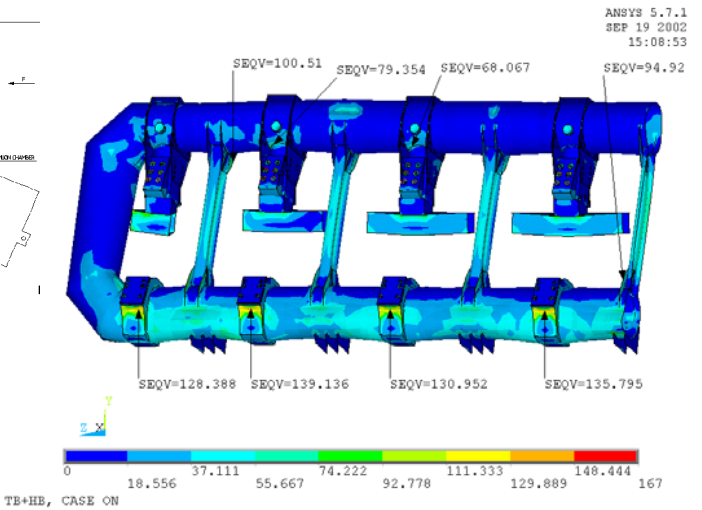
Mechanical computations on the Barrel Toroid structure

The design optimization has been achieved through extensive finite element analyses (FEA).



Zoom of one FEA model

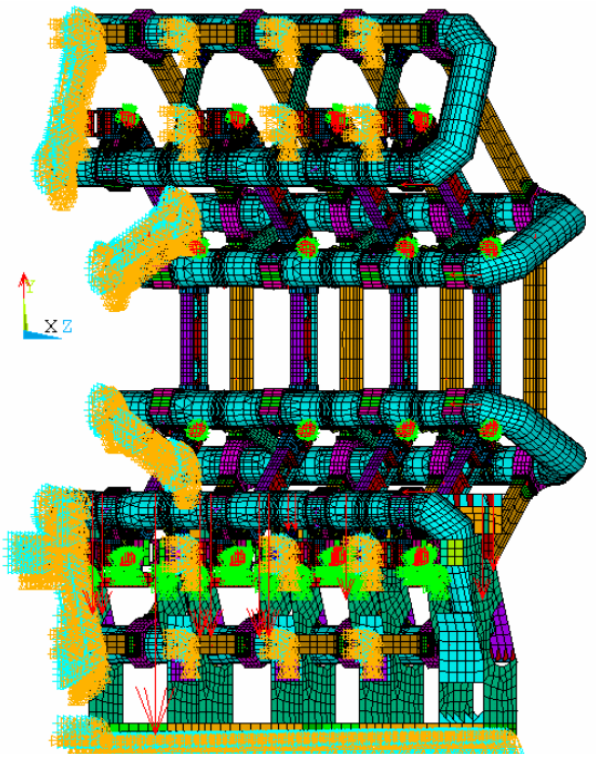




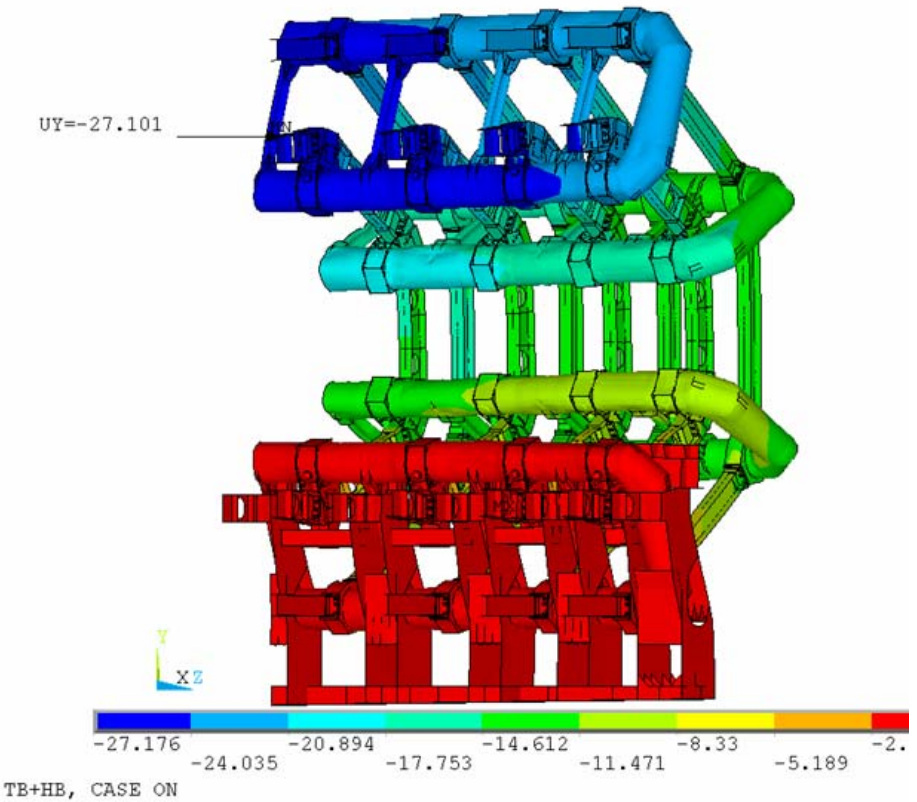
Stress contour

Mechanical computations on the Barrel Toroid structure

The ANSYS main model

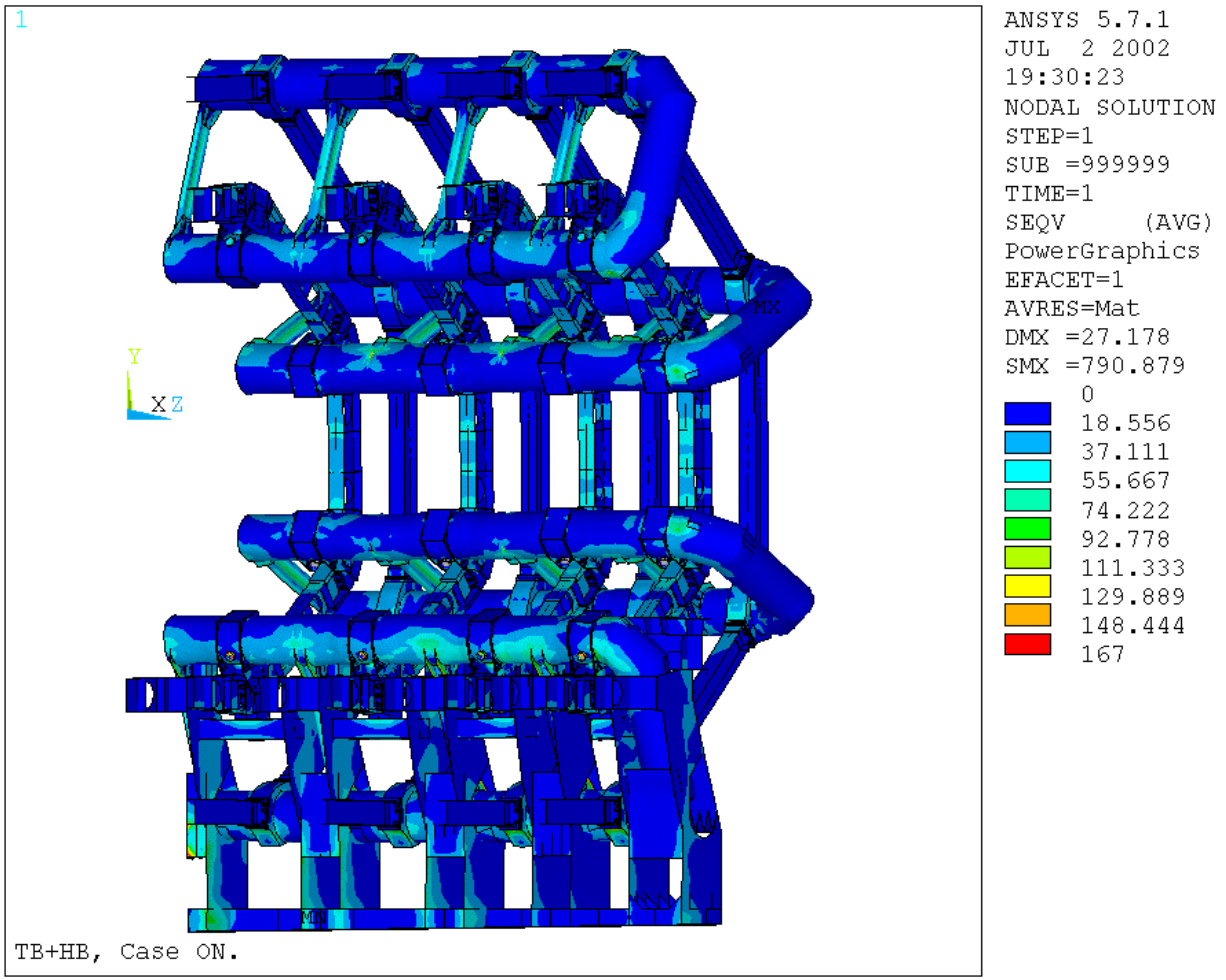


The model



The deformation contour

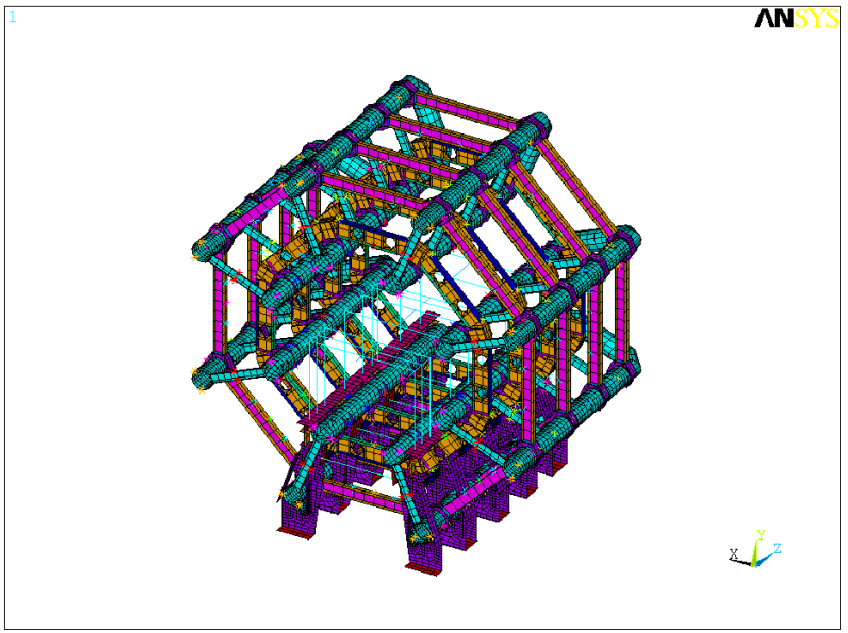
Mechanical computations on the Barrel Toroid structure

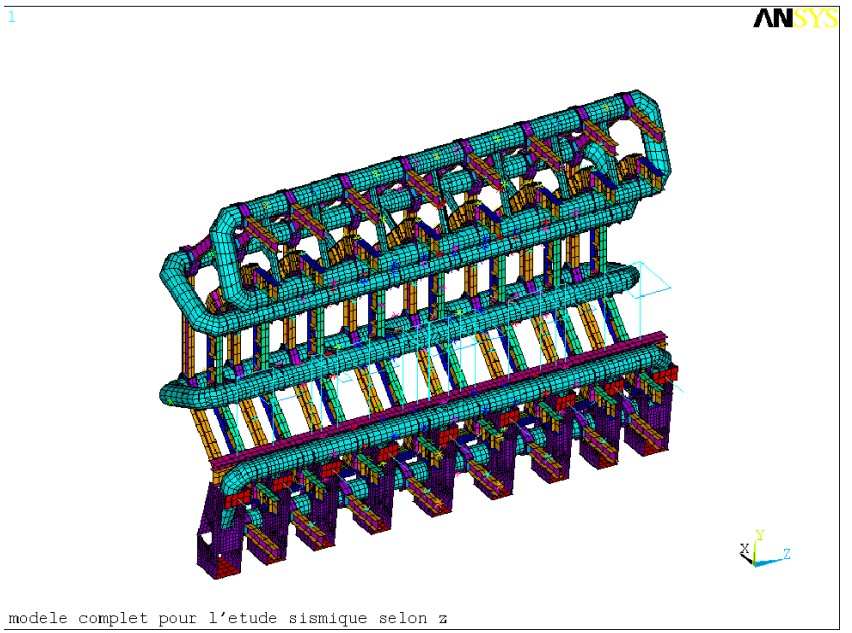


The stress contour

Mechanical computations on the Barrel Toroid structure

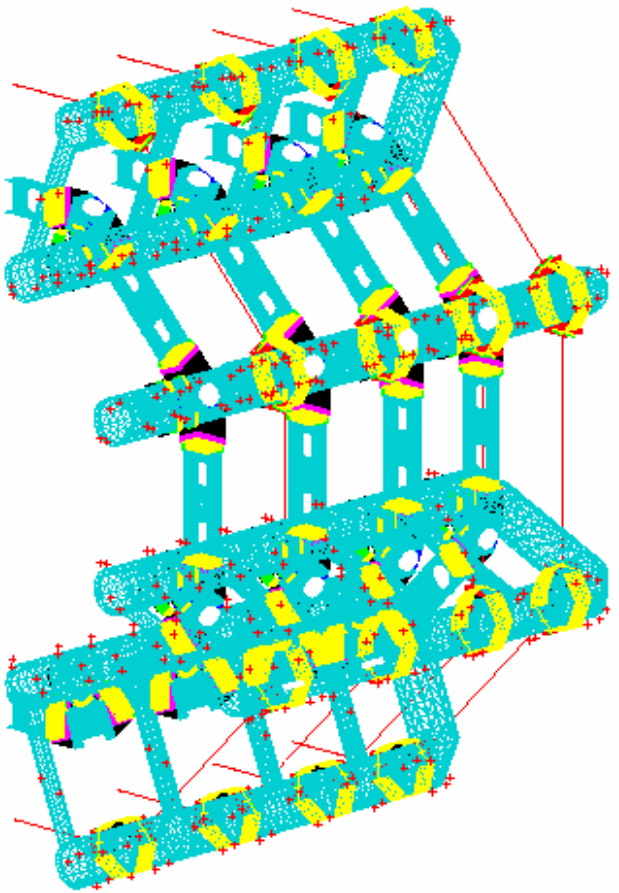
Models for seismic studies

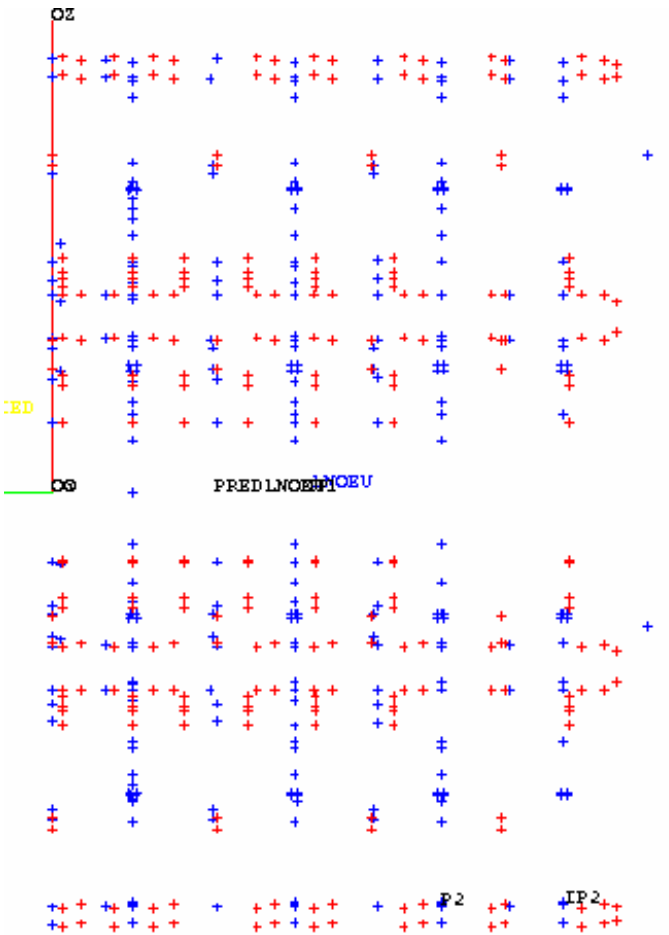




Mechanical computations on the Barrel Toroid structure

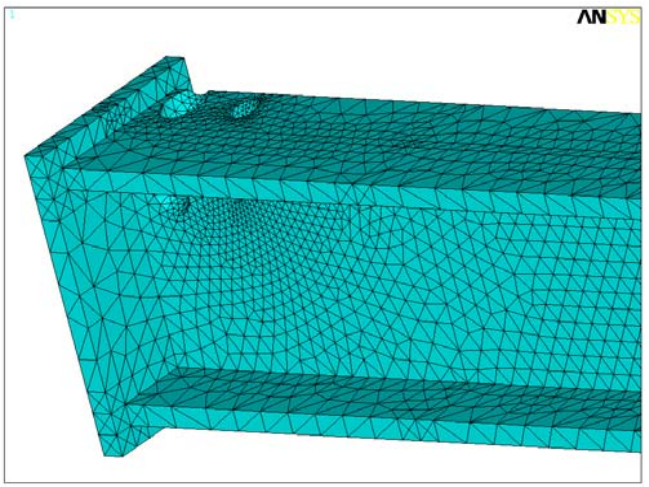
CASTEM model

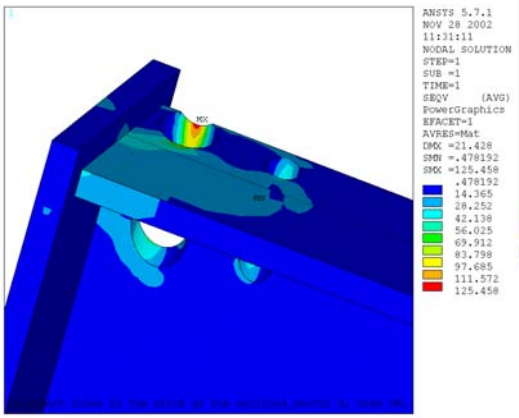


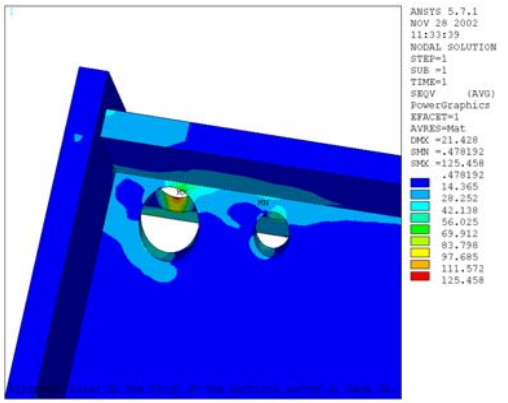


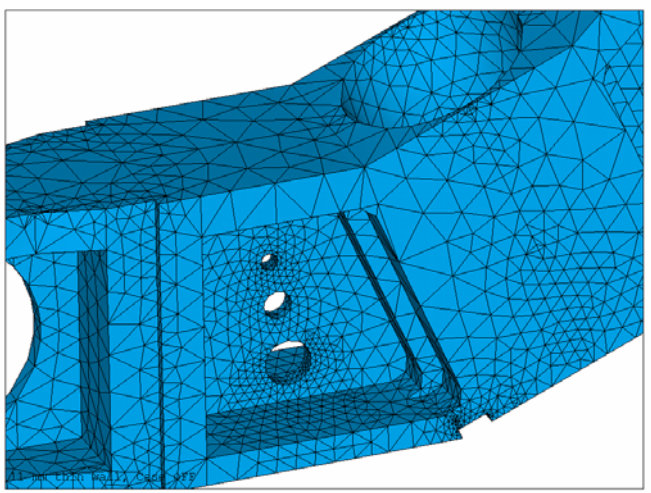
Mechanical computations on the Barrel Toroid structure

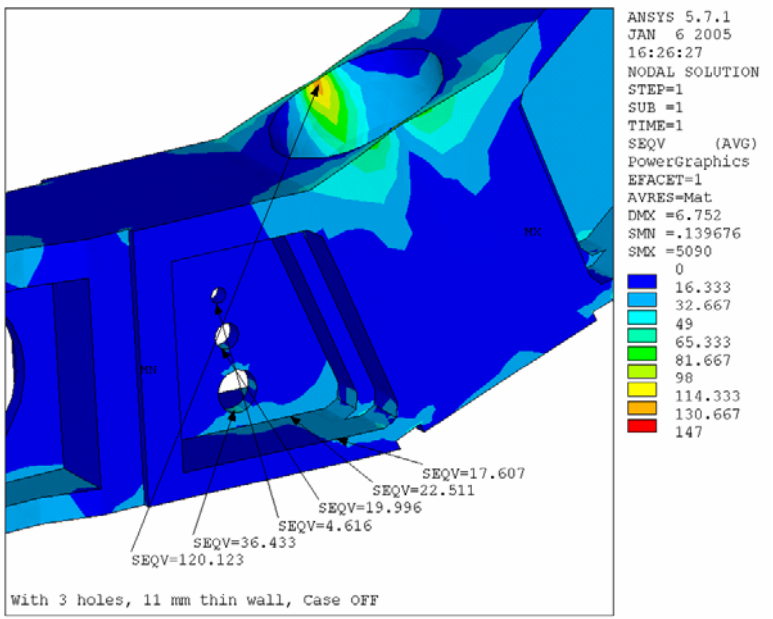
Local analyses:



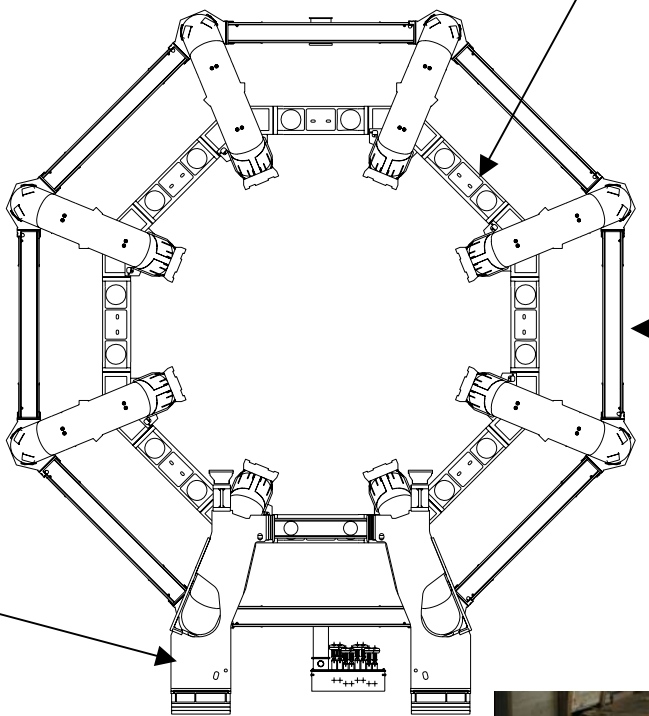








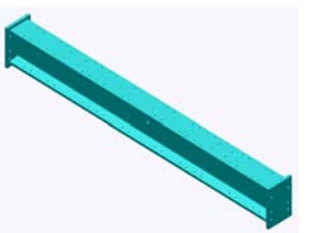
Manufacturing and the assembly of the Barrel Toroid



Voussoir after forging

Strut before machining

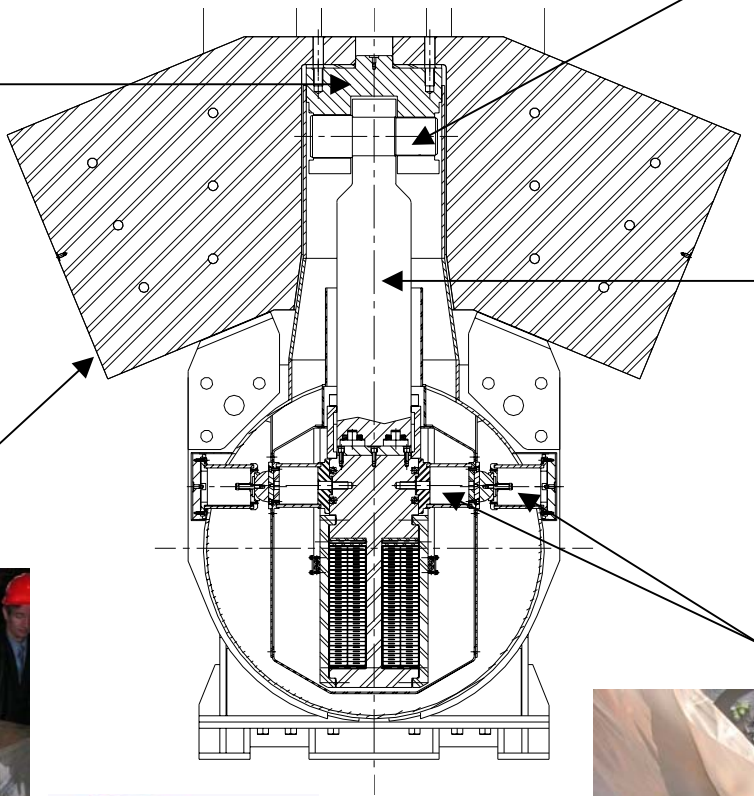
Profil of strut



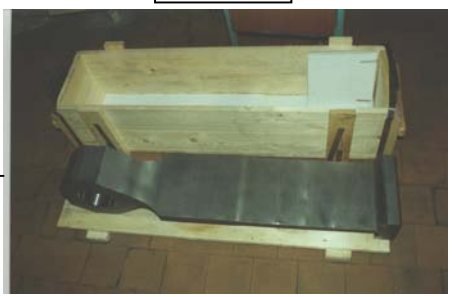
Manufacturing and the assembly of the Barrel Toroid

Chape

axis

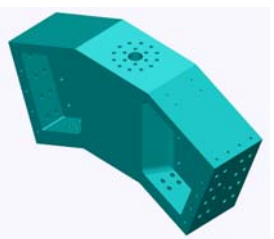


Tie rod

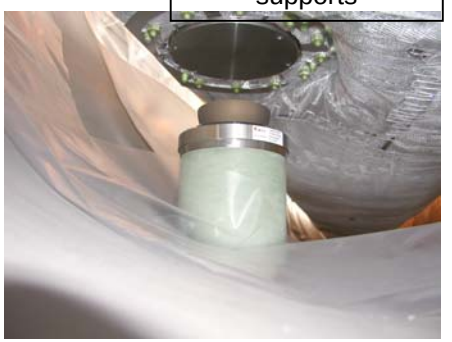


Connection box

Half connection box after forging



Cold to warm supports

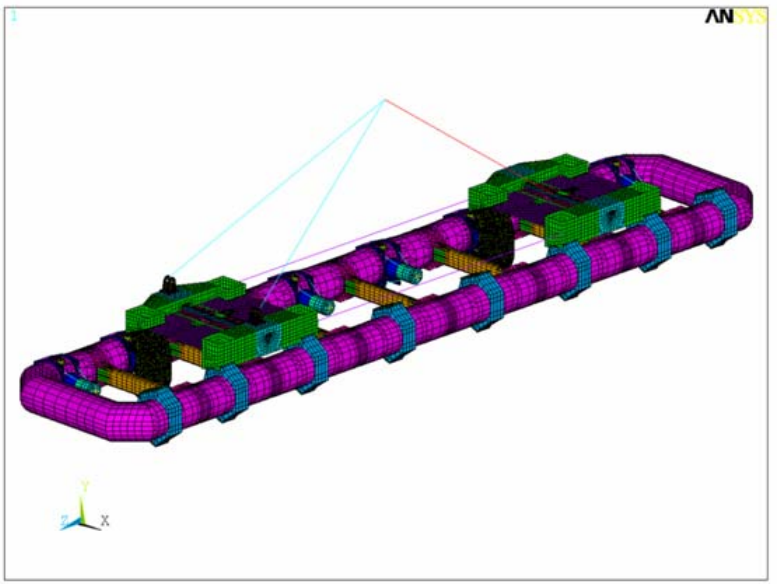


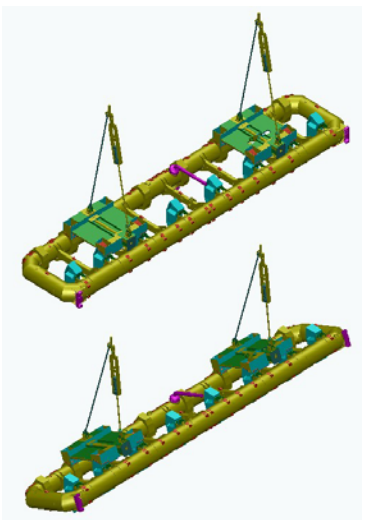
Warm part

Cold part

Manufacturing and the assembly of the Barrel Toroid

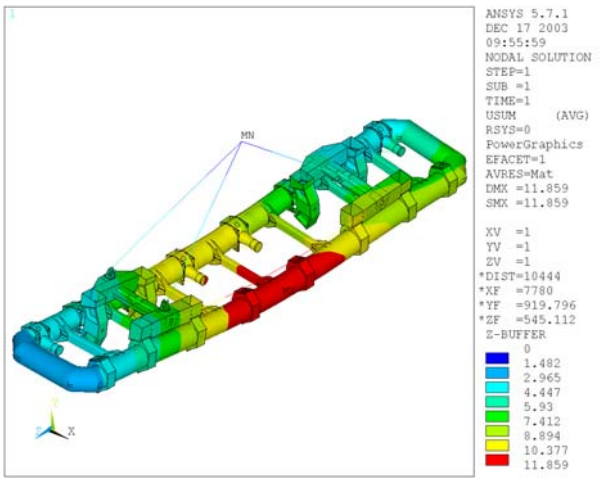
Assembly tooling design





Manufacturing and the assembly of the Barrel Toroid

Deformations during the coil handling



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ZV =1
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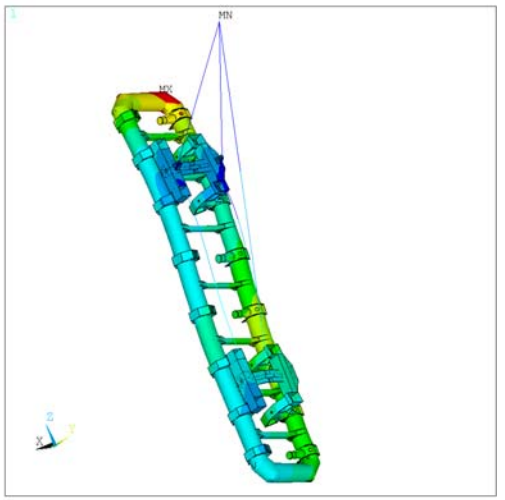
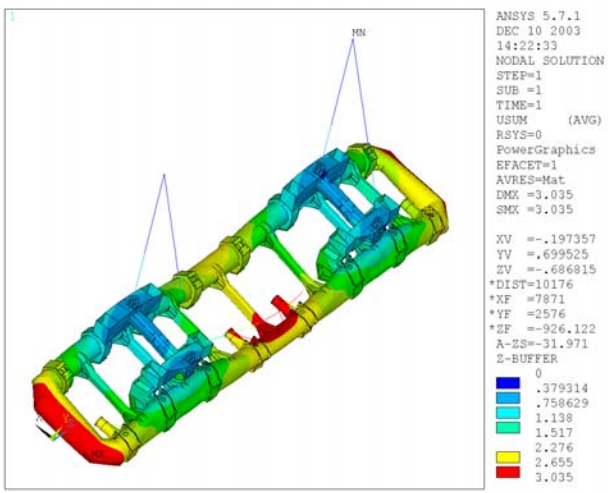
4.447
5.93
7.412
8.894
10.377
11.859





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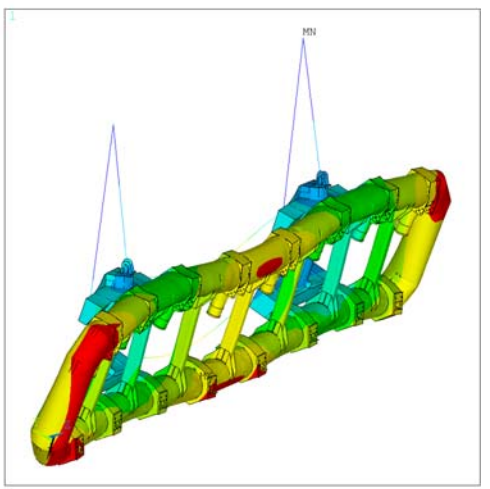


Manufacturing and the assembly of the Barrel Toroid

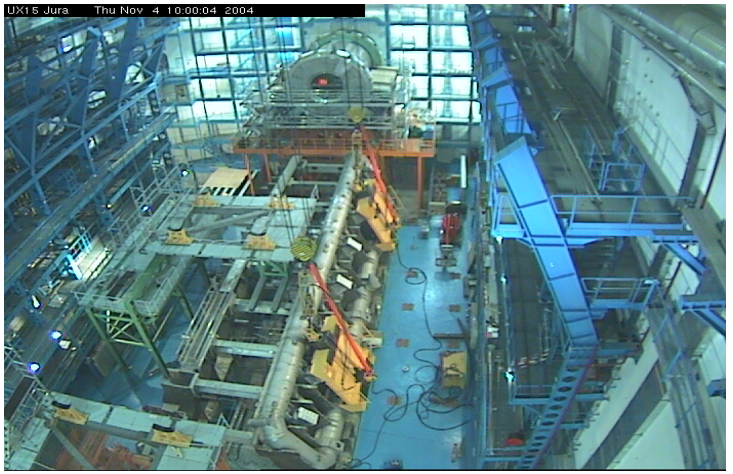
Lowering down the coil to the ATLAS cavern

Manufacturing and the assembly of the Barrel Toroid

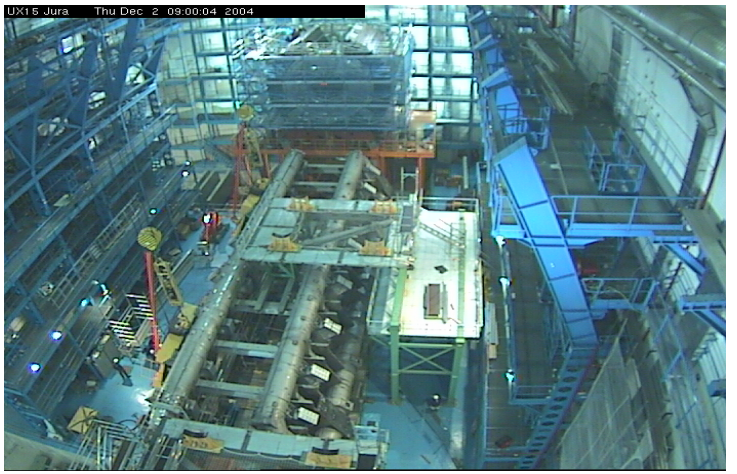
Coil inclination

Manufacturing and the assembly of the Barrel Toroid

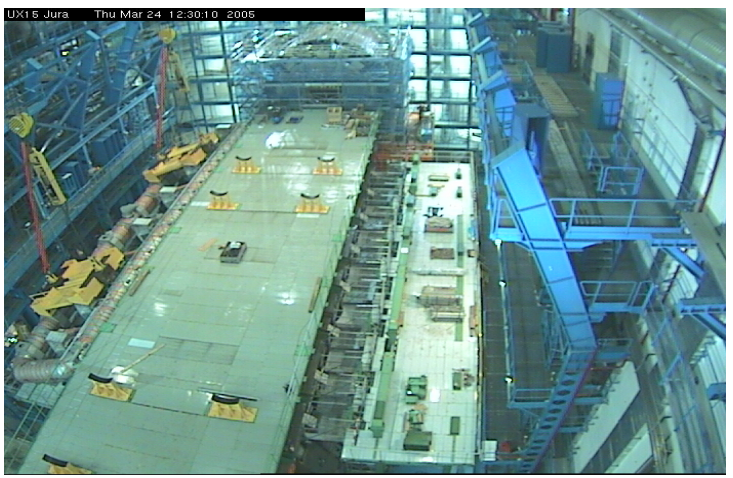
Installation of the coils



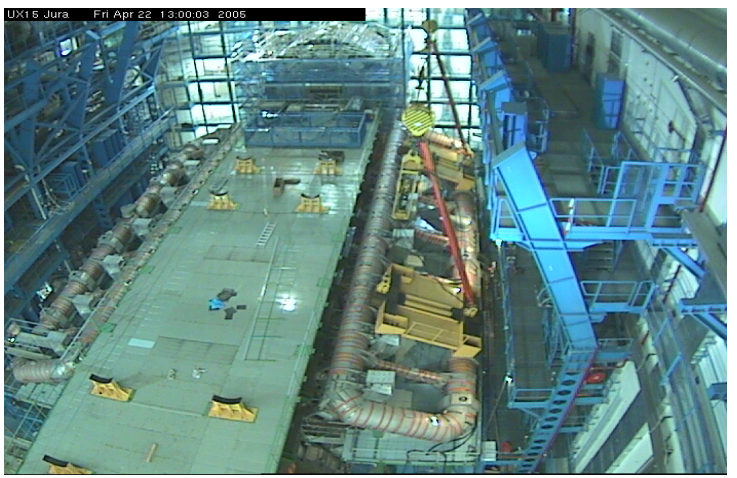
The 1st coil installed 4th Nov 2004.



The 2nd coil installed 2nd Dec 2004.



The 3rd coil installed 24th March 2005



The 4th coil installed 22th april 2005

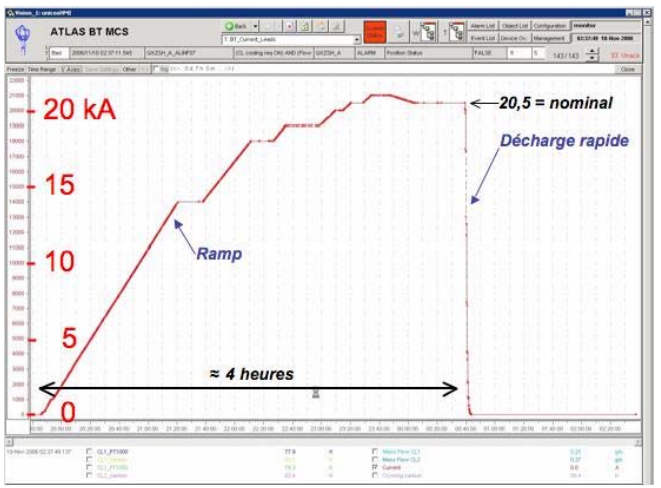
Manufacturing and the assembly of the Barrel Toroid

“During the summer of 2005 the last coils of the Barrel Toroid were installed in the cavern and the warm structure was completed. In October the top supports, which were used to hold up the coils in position during toroid assembly were removed. The top of the Barrel Toroid came down by about 18 mm under its own weight. With the installation of muon chambers and detector services, the top of the Toroid will go down by another 7 mm or so. The toroid then changed from the "egg" shape during installation to an (almost) circular shape. **Remarkably the deflection observed is within the mm as predicted by calculation.”**

The latest news

The first test of the Barrel Toroid at full current is successful.

"After a few weeks of testing up to intermediate currents, finally, in the evening 9 November 2006, the current in the Barrel Toroid was pushed up to its nominal value of 20500 A and even 500 A beyond this value to prove that we have some margin. It went surprisingly well."



"On this occasion several detector groups tested their response to the magnetic field as well and the first beautiful curved traces were shown to us by the muon team working one floor below us to master their system as well."

Conclusion

On the occasion of this 1st Chinese – French Workshop on LHC Physics, we look for collaborations with IHEP on the mechanical computations and the magnetic field computations for the future projects of high energy physics.