Hoisting procedure of the Mu2e Calorimeter

Marco Panichella

Final report

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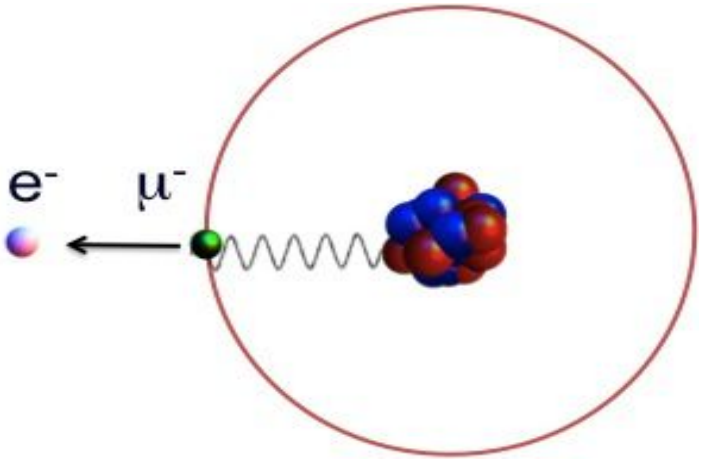
Overview

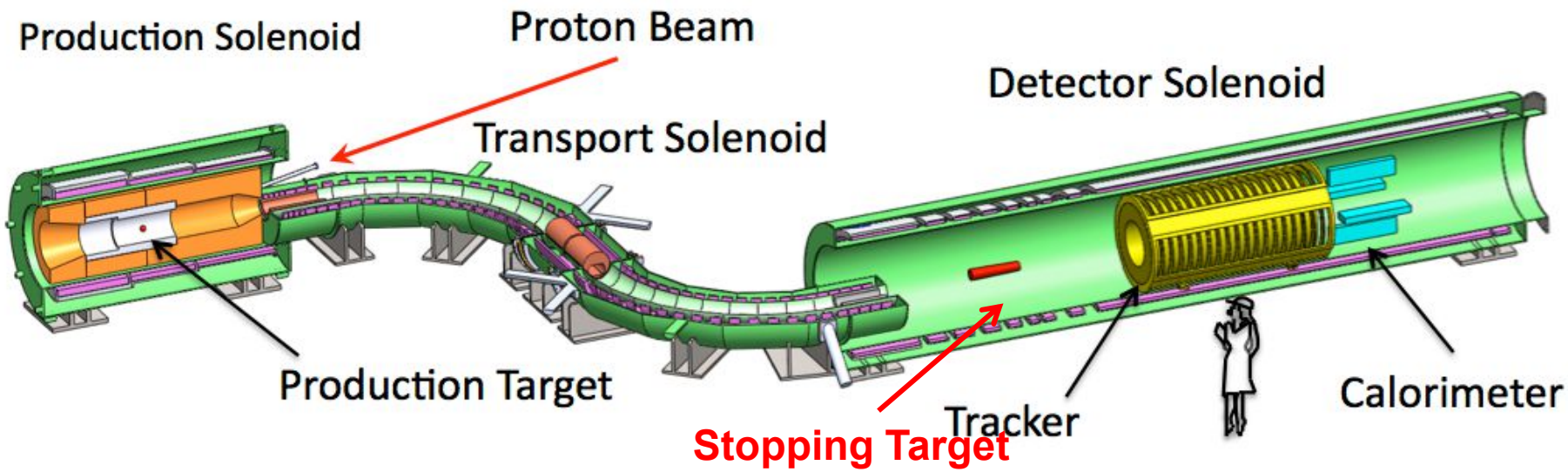
- Become familiar with the Mu2e experiment
- Become familiar with the Mu2e calorimeter
- Become familiar with the Mu2e building
- Design the lifting fixture
- Structural static test

Mu2e experiment

- Considering the muon an excited state of the electron, we look for muon-to-electron conversion in the coulomb field of a nucleus: $\mu^- Al \rightarrow e^- Al$ -> NEW PHYSICS
- We generate an intense beam of low momentum (p_T<100 MeV/c) negative μ
- Stop the muons in a target
  - Mu2e plans to use Aluminum
- Stopped muons are trapped in orbit around the nucleus
- Look for events consistent with $\mu N \rightarrow eN$
- Results in a monoenergetic electron of 104.97 MeV



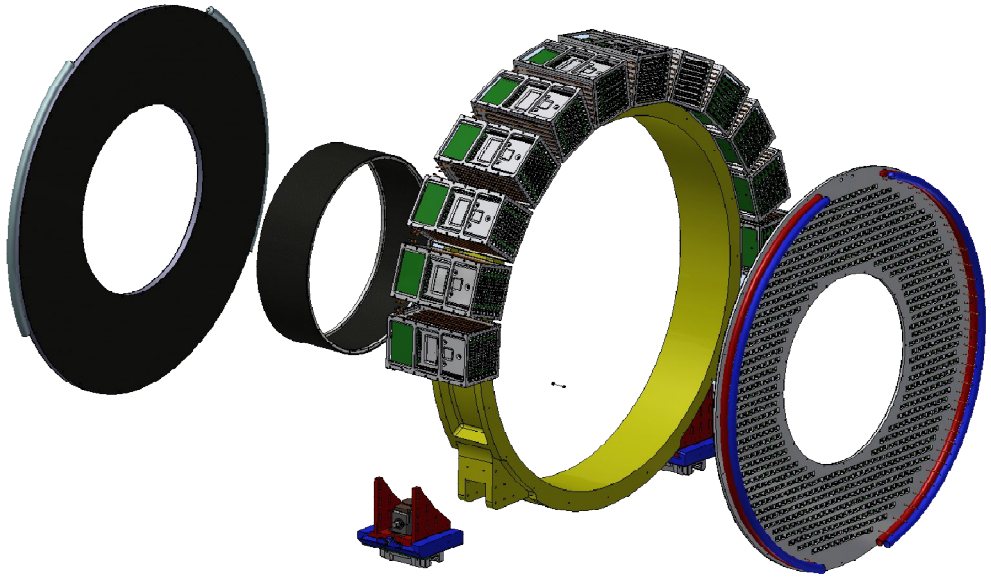
Mu2e solenoid system

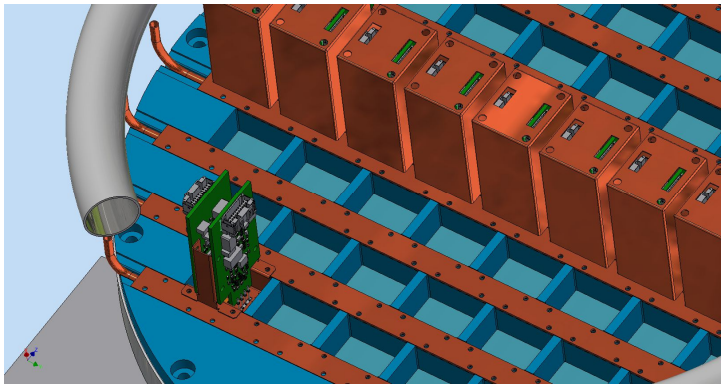


- Production Solenoid: $3x10^7$ protons per pulse coming from the delivery ring hit the tungsten target producing pions
- Pions decay into muons and are focused into the Transport Solenoid
- Only negative muons are sent to the Detector Solenoid where they hit the Aluminum Stopping target
- The electrons emerging are reconstructed by the two detectors: Tracker and Calorimeter that measure momentum and energy with high resolution

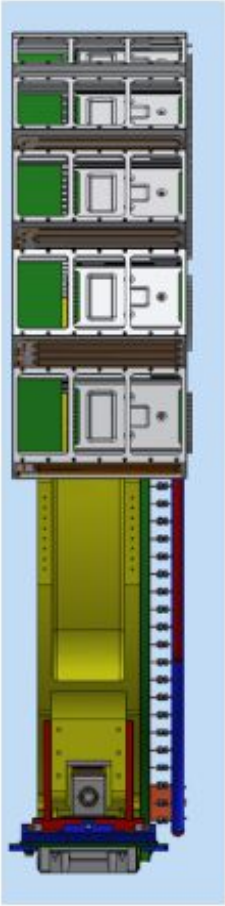
Mu2e calorimeter

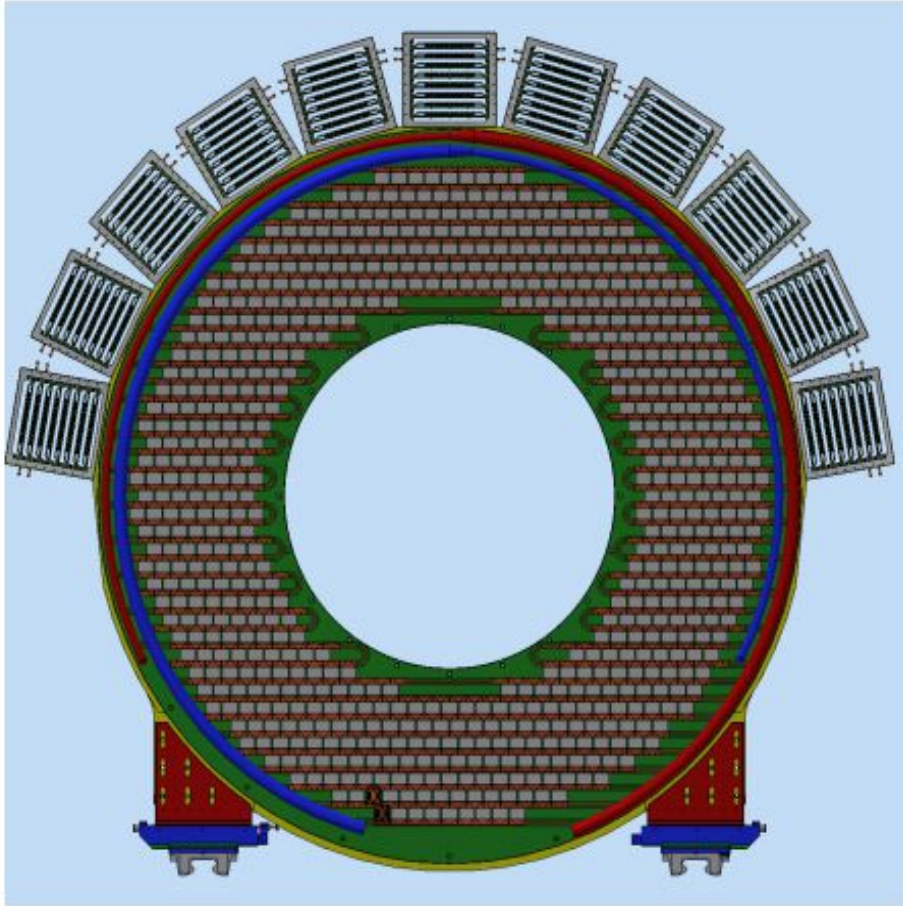
- The Mu2e calorimeter consists of two annuli filled by 674 CsI scintillating crystals each
- Each crystal's light is collected by Silicon Photomultiplier
- The mechanics has to be a support for the crystals, the electronics and its cooling system, the calibration system
- Each disk weighs ~1200 kg

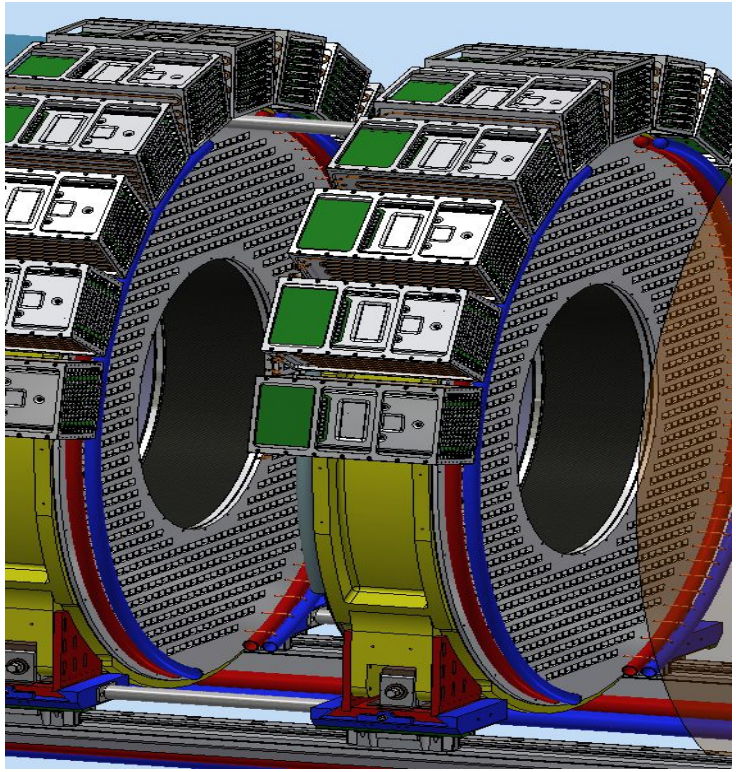




Mu2e Calorimeter

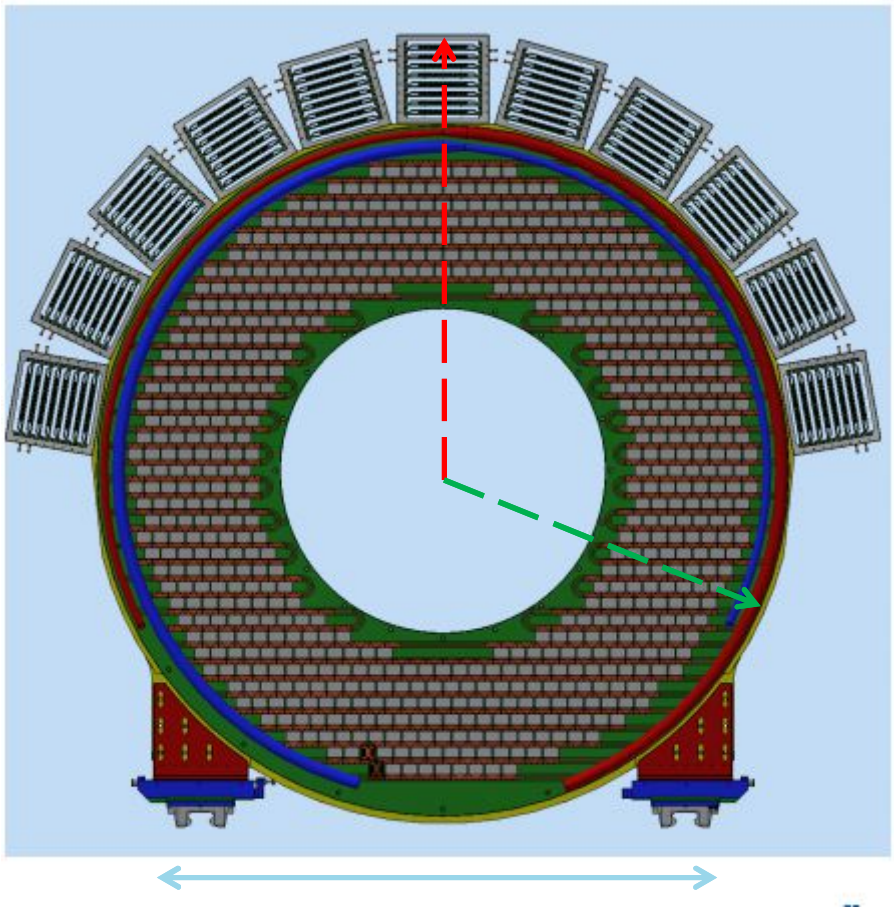




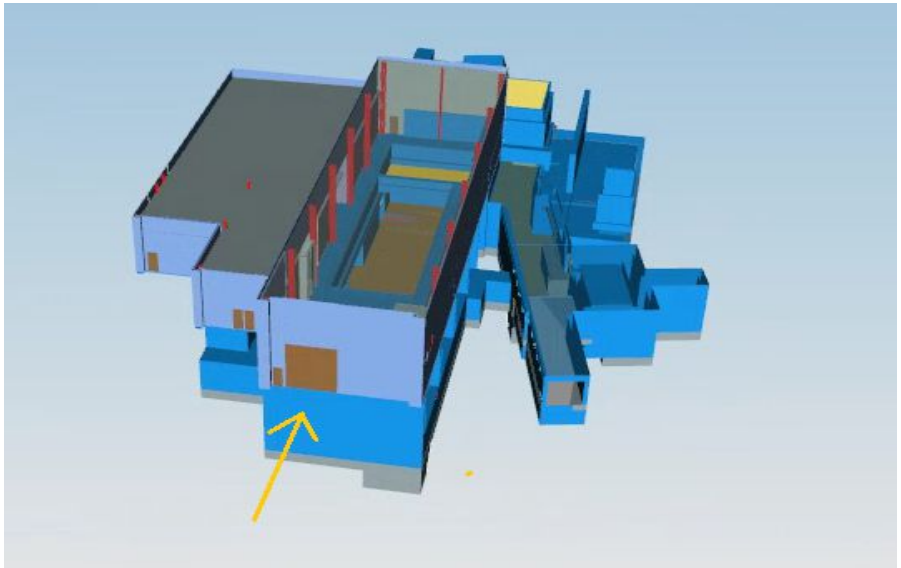


Calorimeter's features

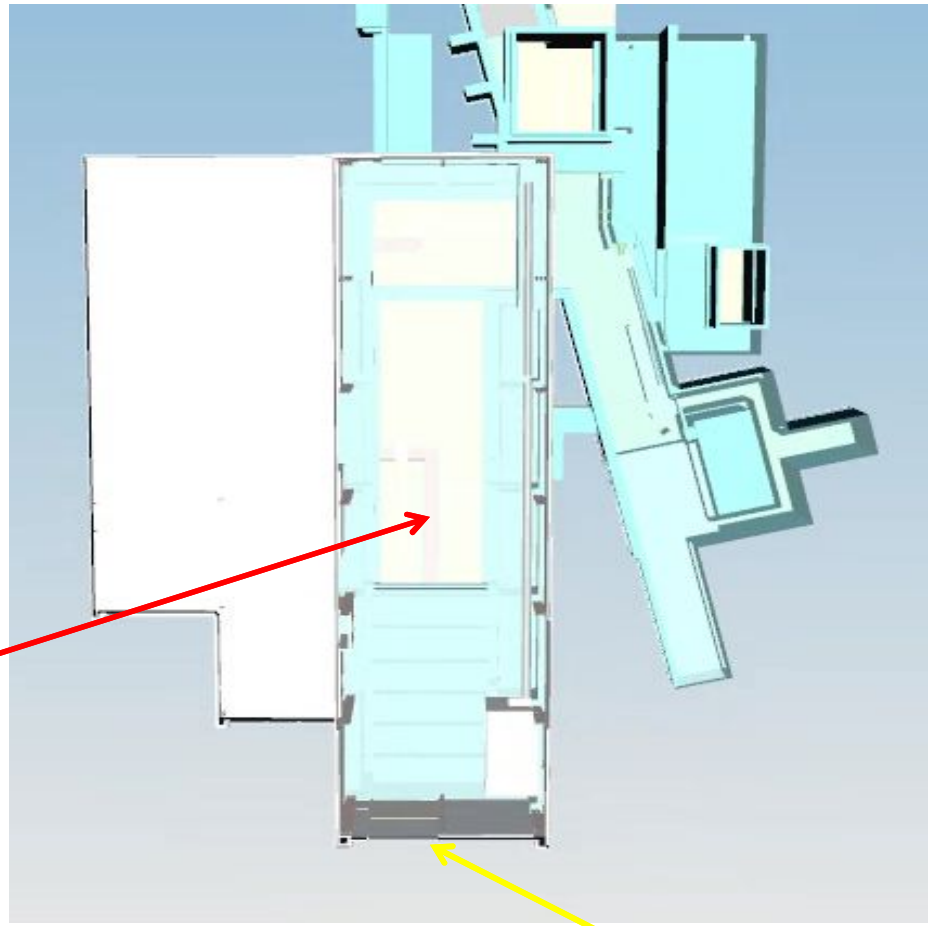
- 2 discs of aluminium
- 11 crates with electronic devices
- 674 crystals
- External radius: 910 mm
- Internal radius: 785 mm
- Distance between feet: 1200 mm
- Total weight: 1200 Kg
- Thickness of each disc: 350 mm

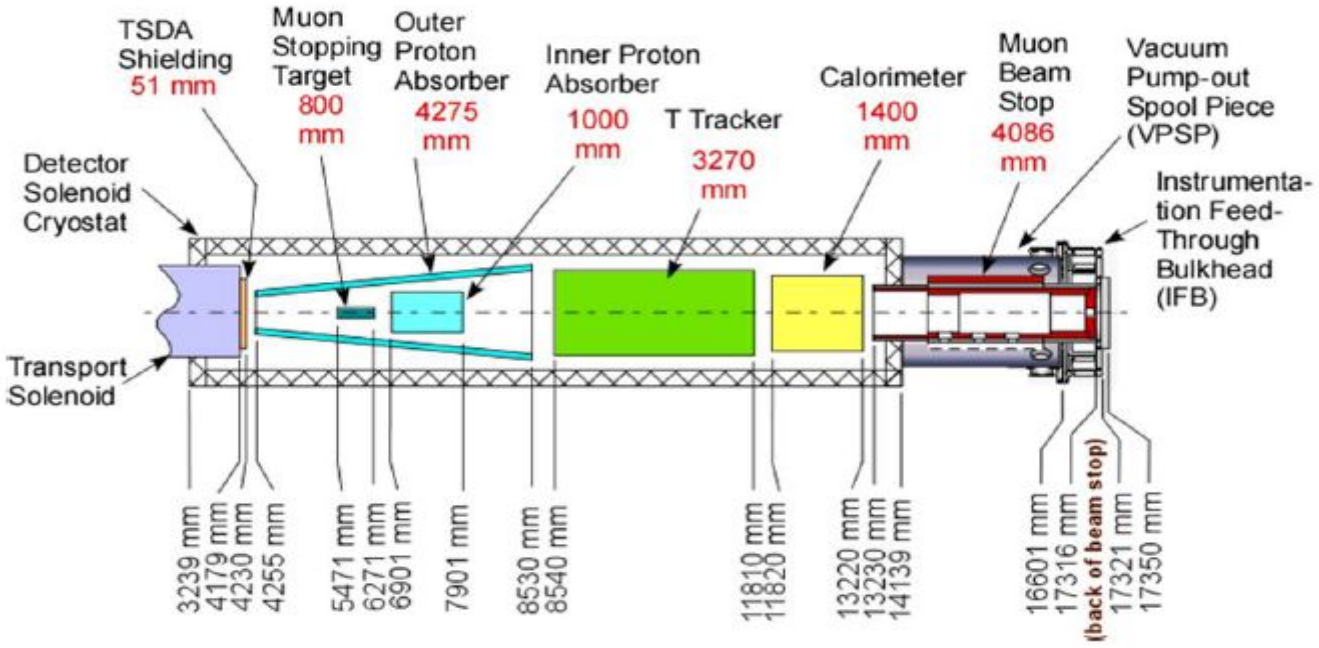


Building



- The calorimeter has to be transported after its assembly by truck into the Mu2e building to be placed with the other components over the detector rail
- The yellow arrow shows the entrance of the building
- Garage's door dimensions: 13' (width) x 16' (height)

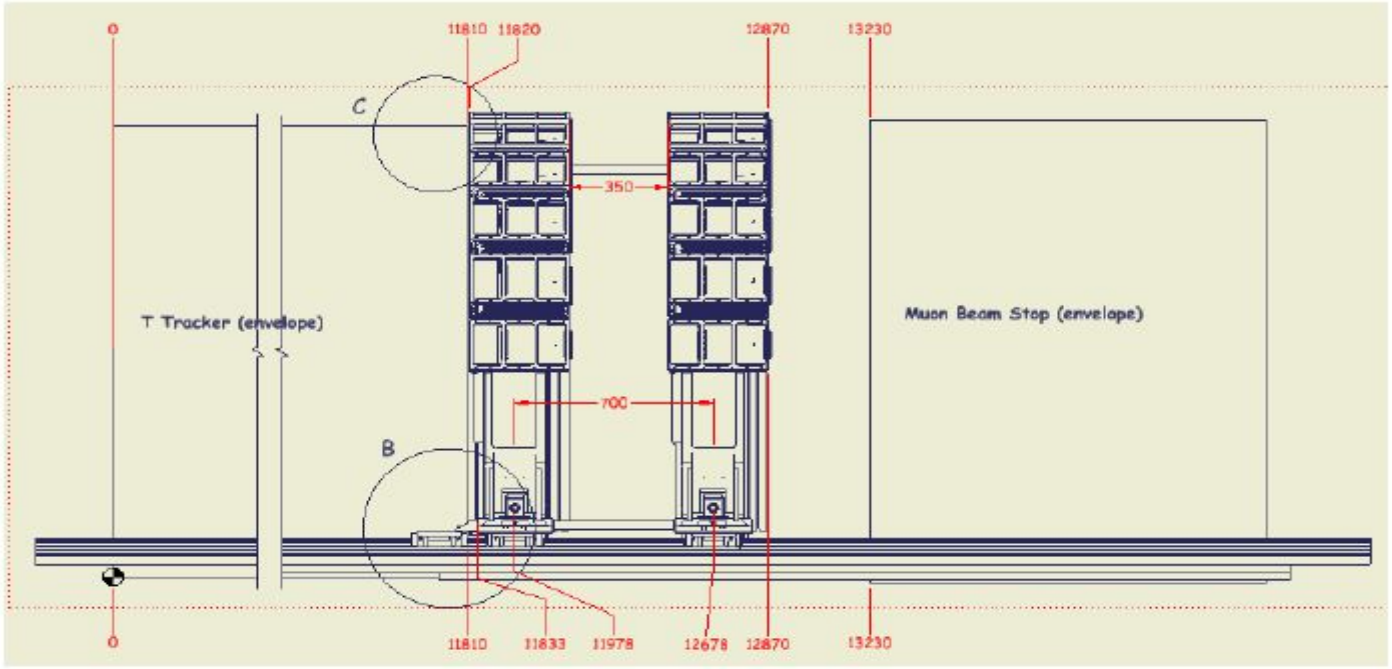

hatch to place
the calorimeter
Garage entrance



- The calorimeter has to be collocated over the detector rail, between the Tracker and the Muon Beam Stop

- Available longitudinal space to place both the disks and to remove the structure after the hoisting procedure: 1400 mm

Longitudinal interferences



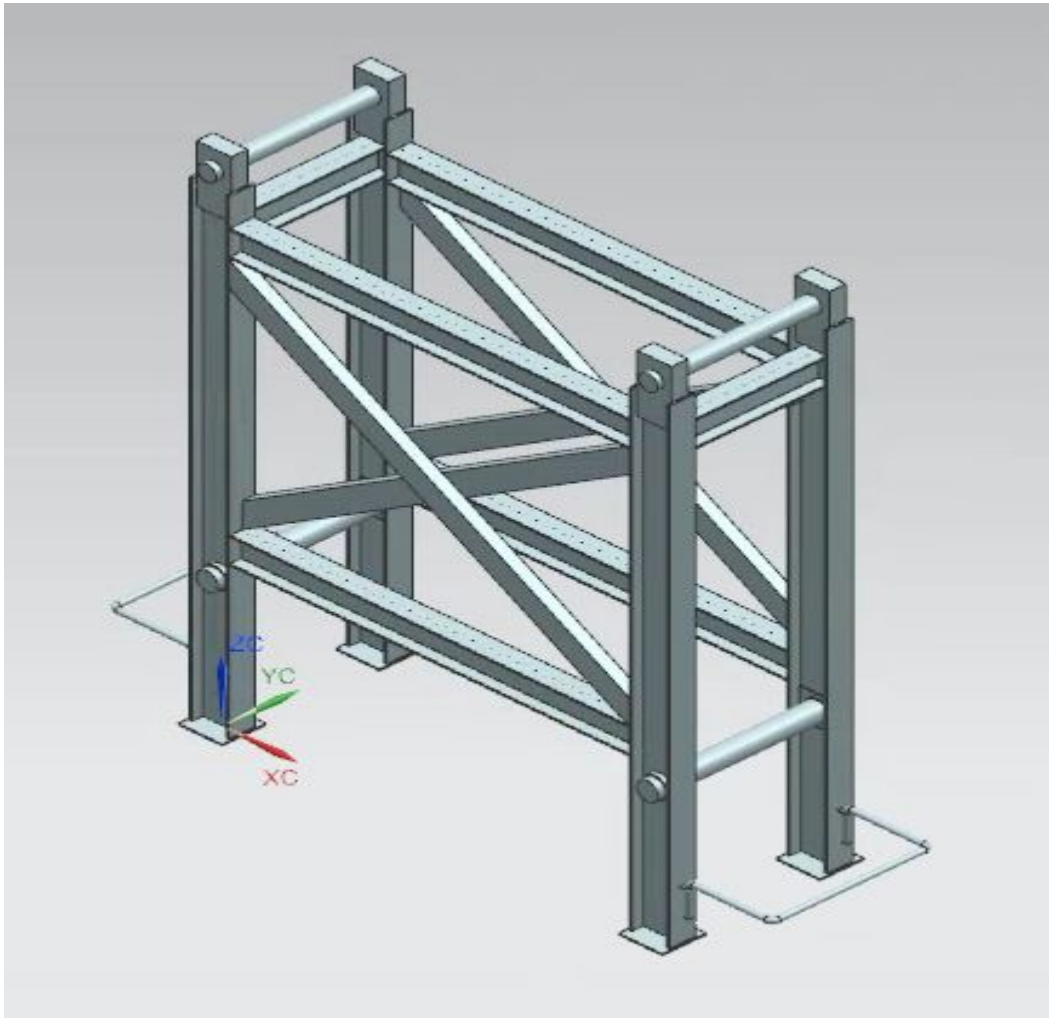
- Distance between the two discs of aluminium in the space: 350 mm
- Possible problems of space to place the second disc in the hatch and remove the lifting structure

Hoisting structure

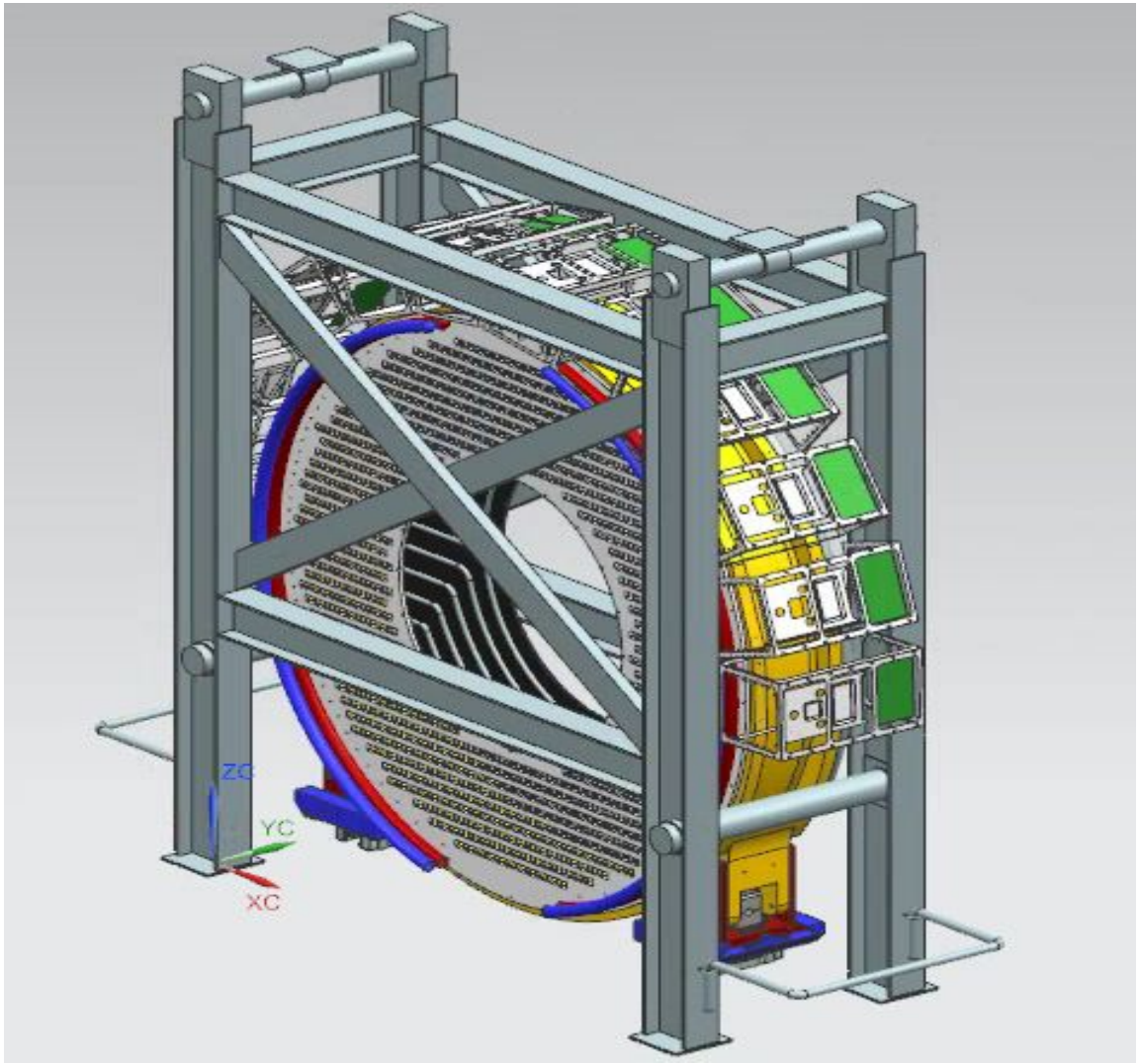
Features to fulfill:

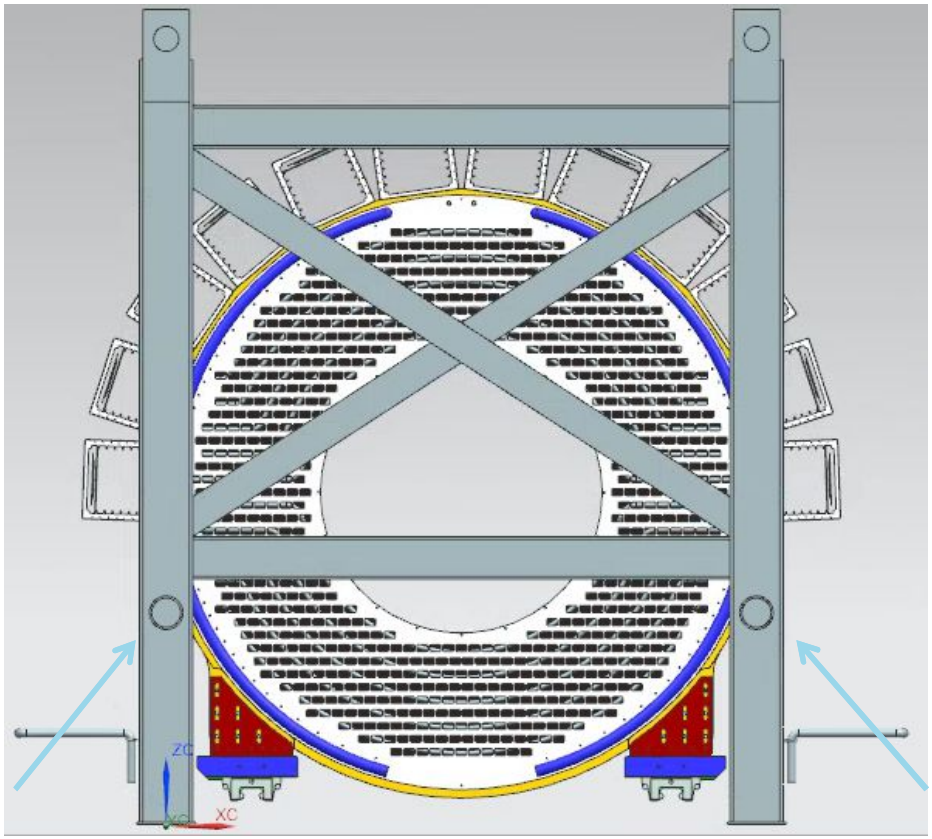
- Need to pick up the calorimeter from points close to its feet
- Do not compromise the stability of the disk
- Be sure to assure the vertical position of the calorimeter during the hoisting procedure
- Necessity to have available room to remove the device

Hoisting structure: 3D model



Assembly





- The idea is to pick up the disc using two cylindrical beams. These two beams have to be lined up and are external to the calorimeter's feet.

Hoisting structure advantages

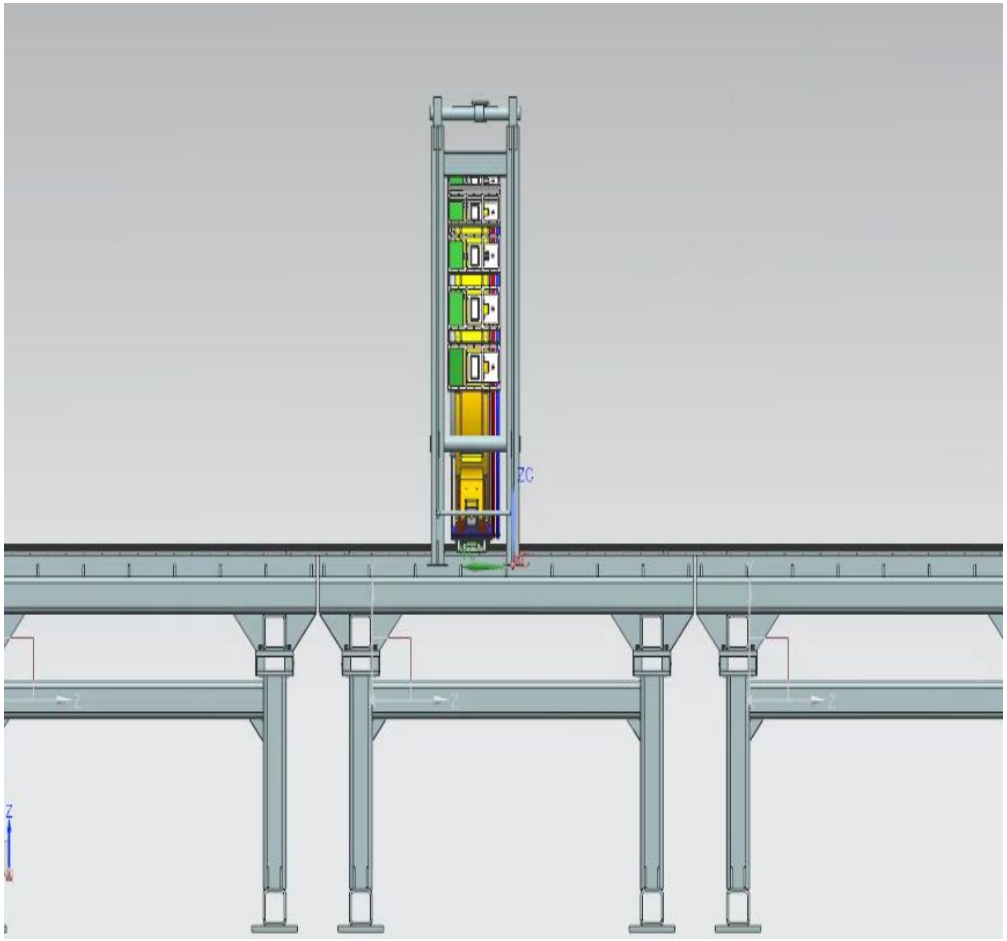
- The lifting device and the calorimeter symmetry are such that the two barycenters are lined up along “x” direction
- The hoisting structure has its own feet, so it can be built around the calorimeter after each disk is assembled
- The feet of the structure are external to the detector rail, so there will not be interference problems during the hoisting procedure
- Facility to remove the cilindrical beams once the disk is placed over the rail, respecting the hatch constrains

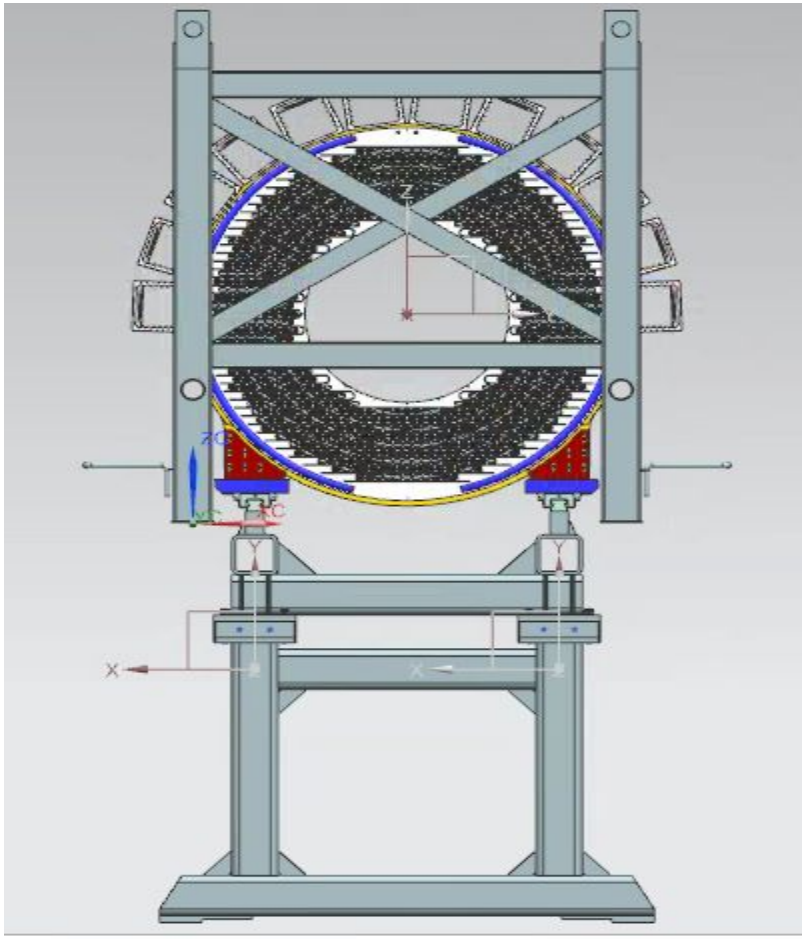
Hoisting procedure

- Step 1: set up the calorimeter disk
- Step 2: assemble the lifting device around the calorimeter disk
- Step 3: roll out the whole assembly
- Step 4: transport the whole structure by truck to the Mu2e building where the calorimeter will be placed in the hatch.

Hoisting procedure

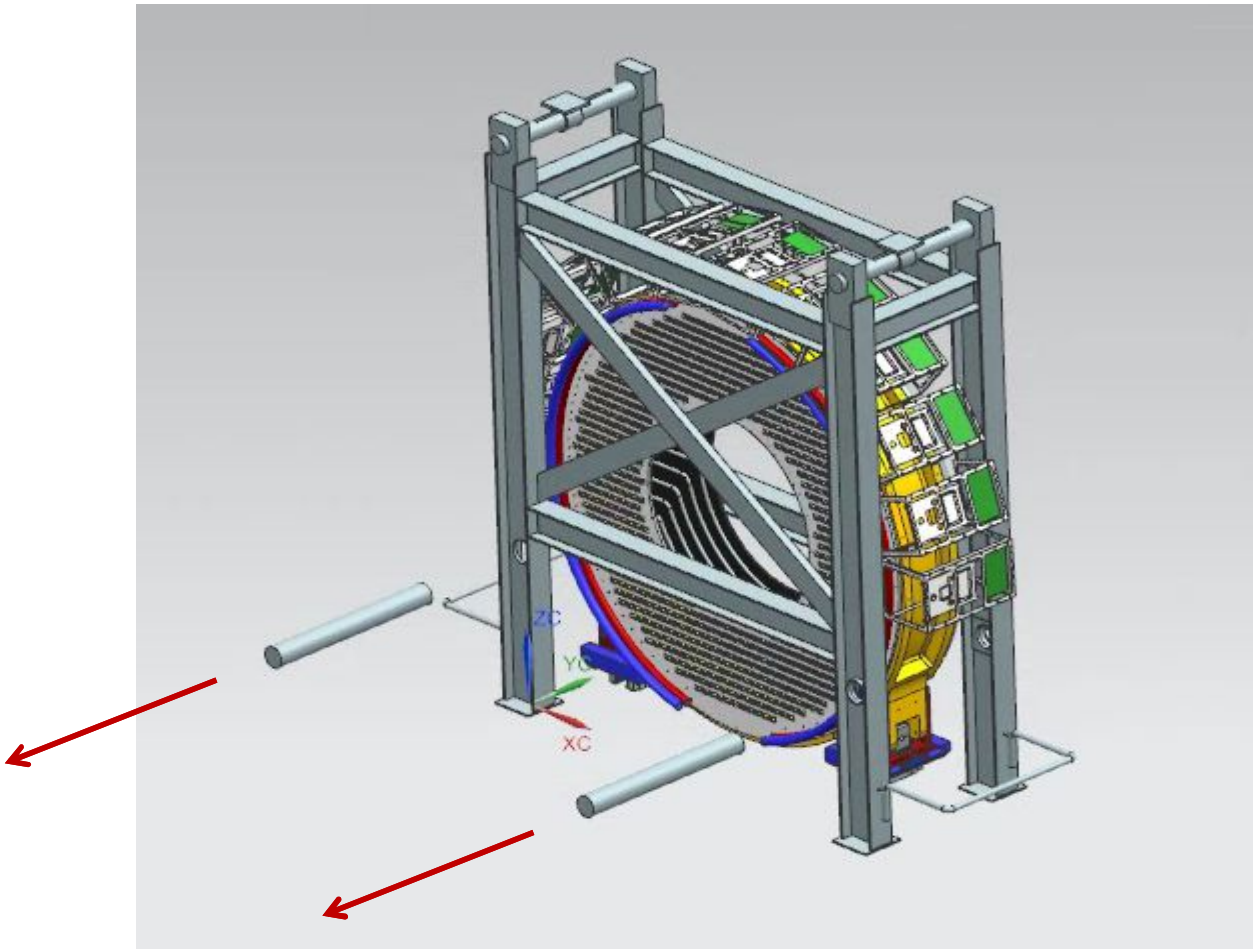
- Step 5: pick up the structure using some straps and place the calorimeter over the detector rail



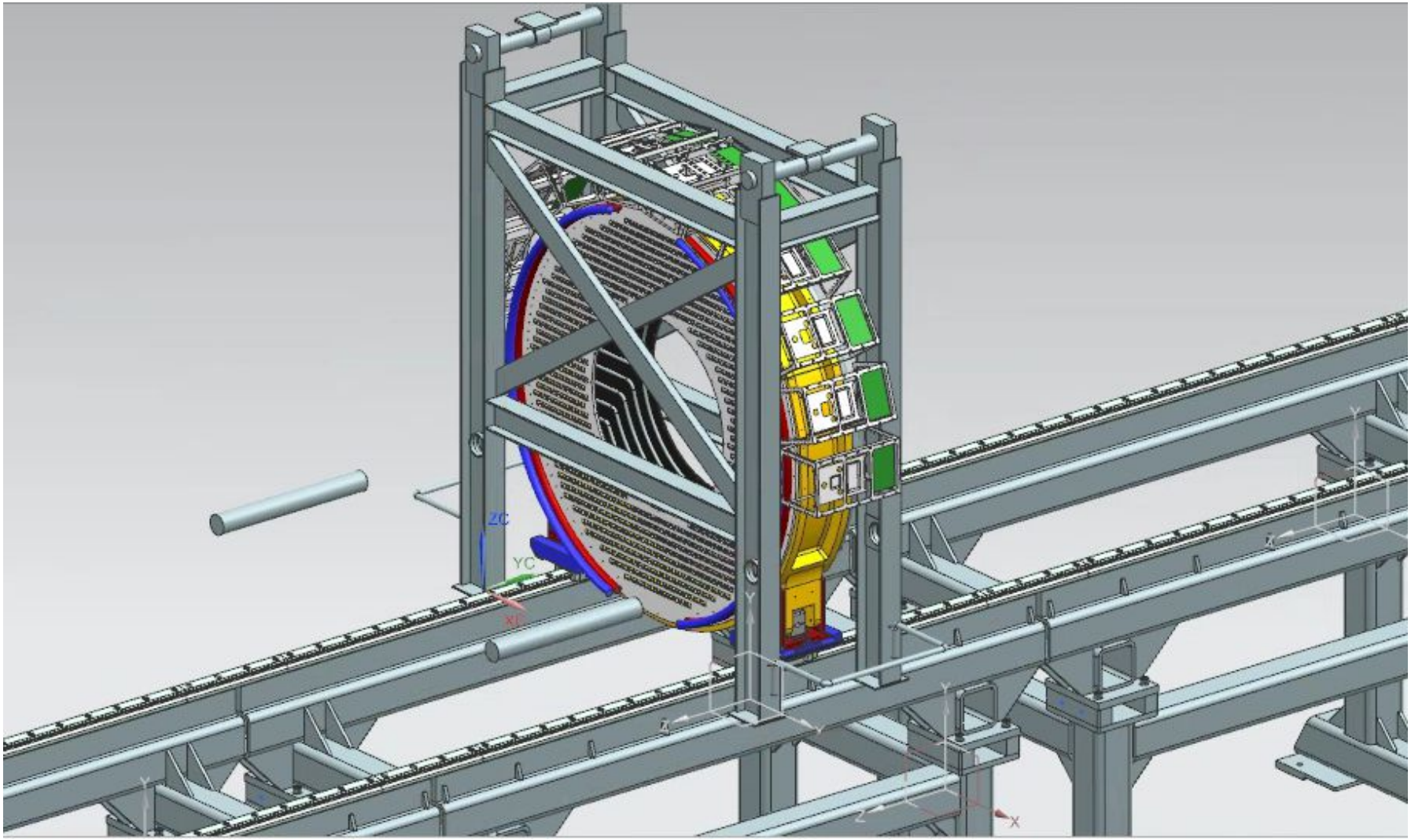


Hoisting procedure

- Step 6: remove the rods (20 Kg each) in order to remove the lifting structure



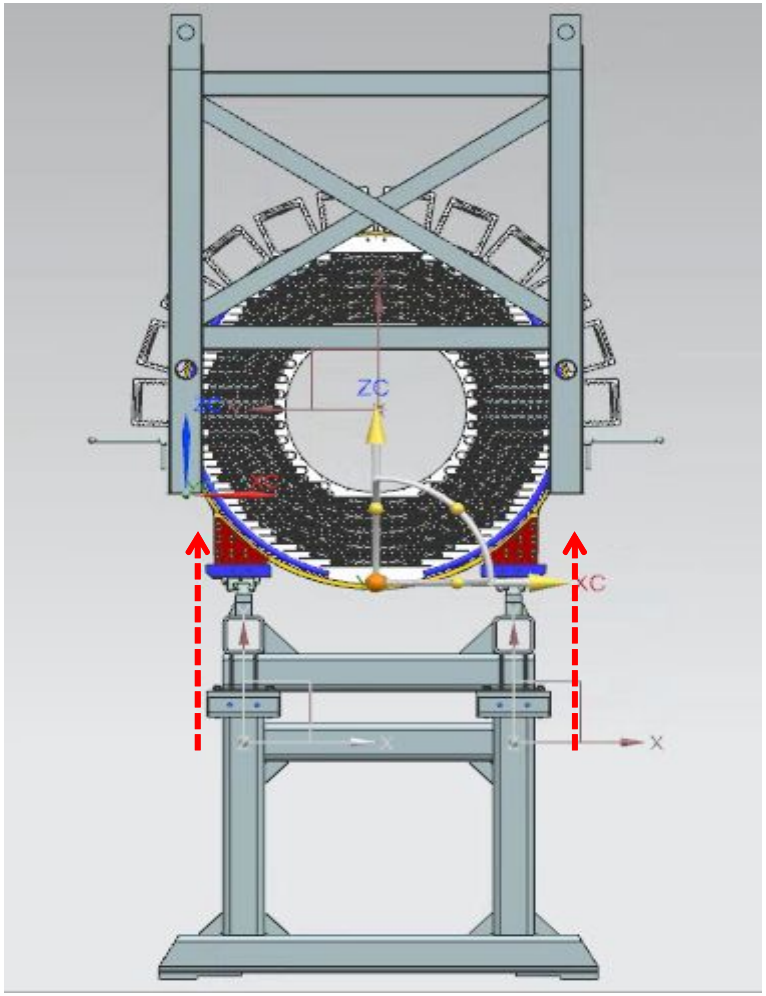
Hoisting procedure

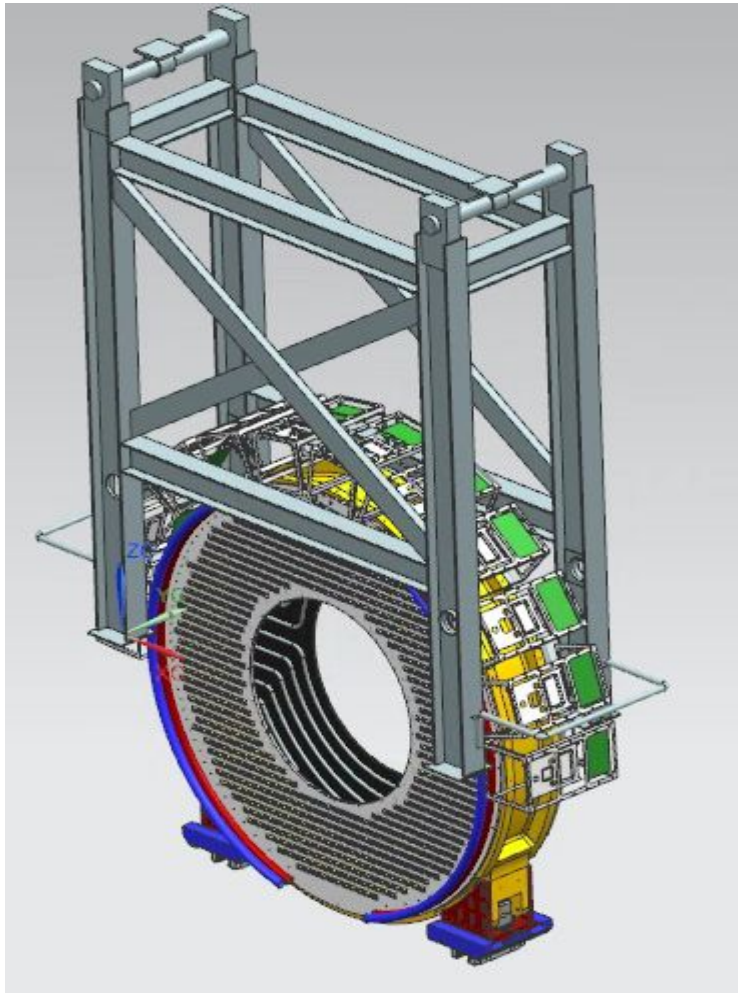


Fermilab

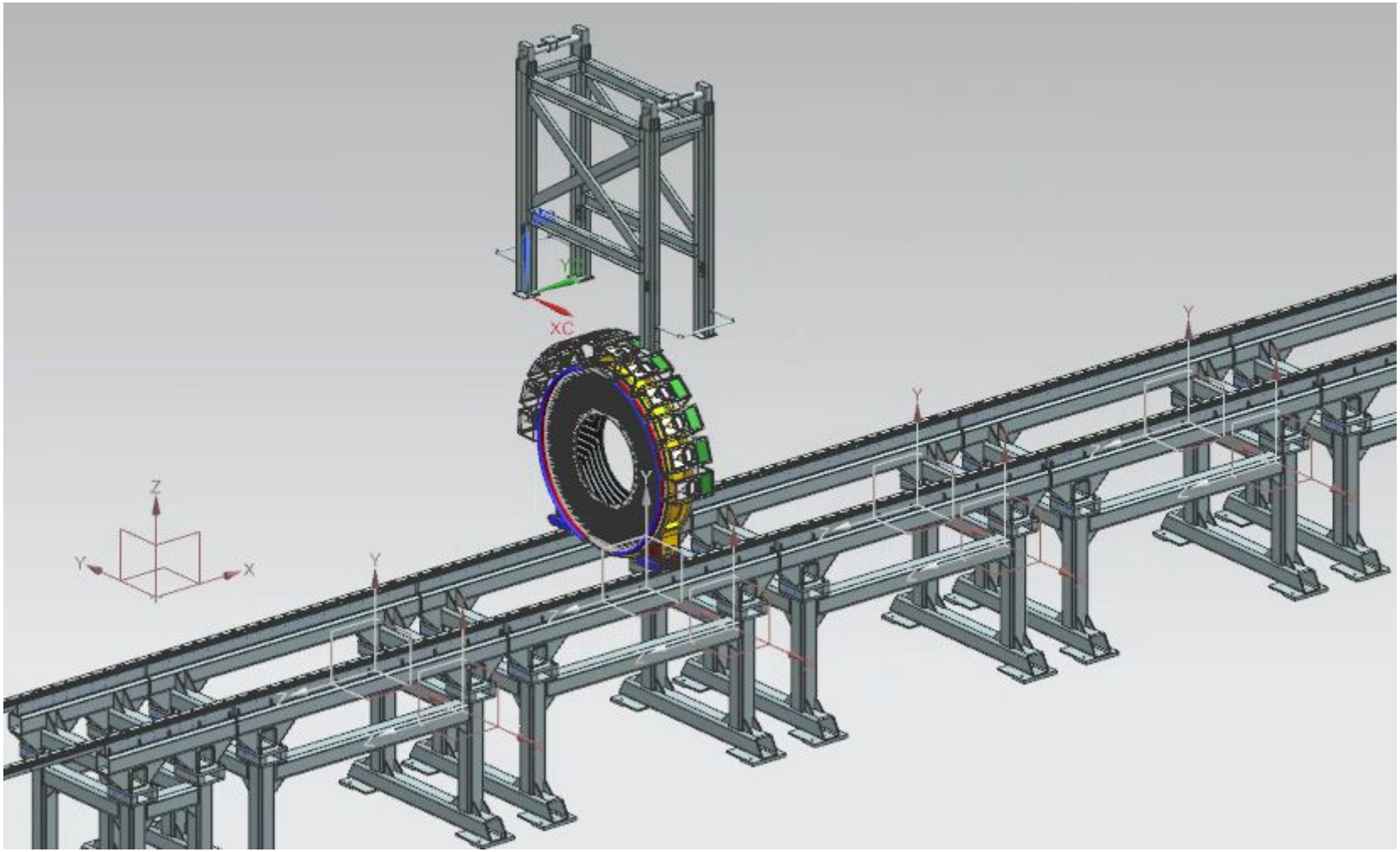
Hoisting procedure

- Step 7: lift up the lifting fixture



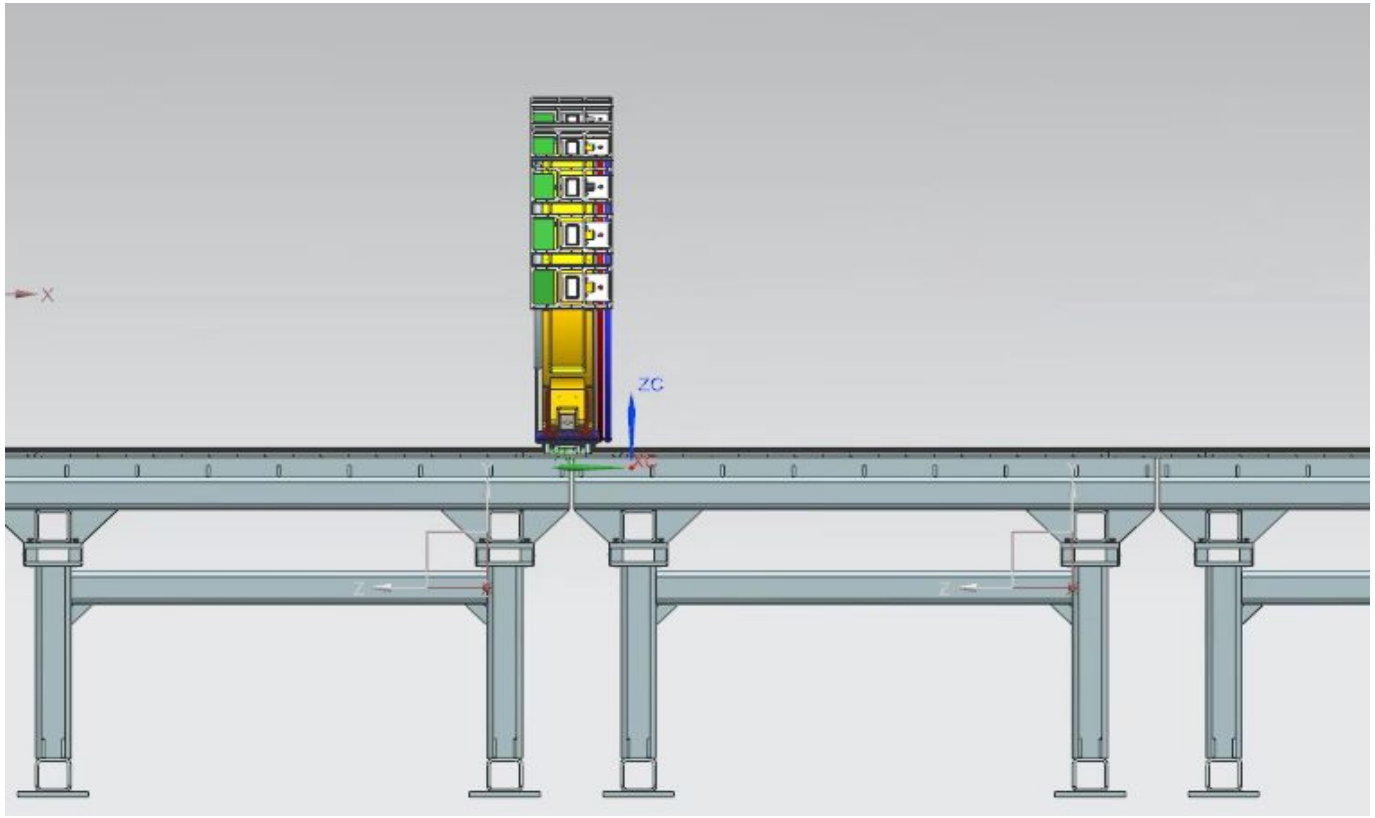


Hoisting procedure

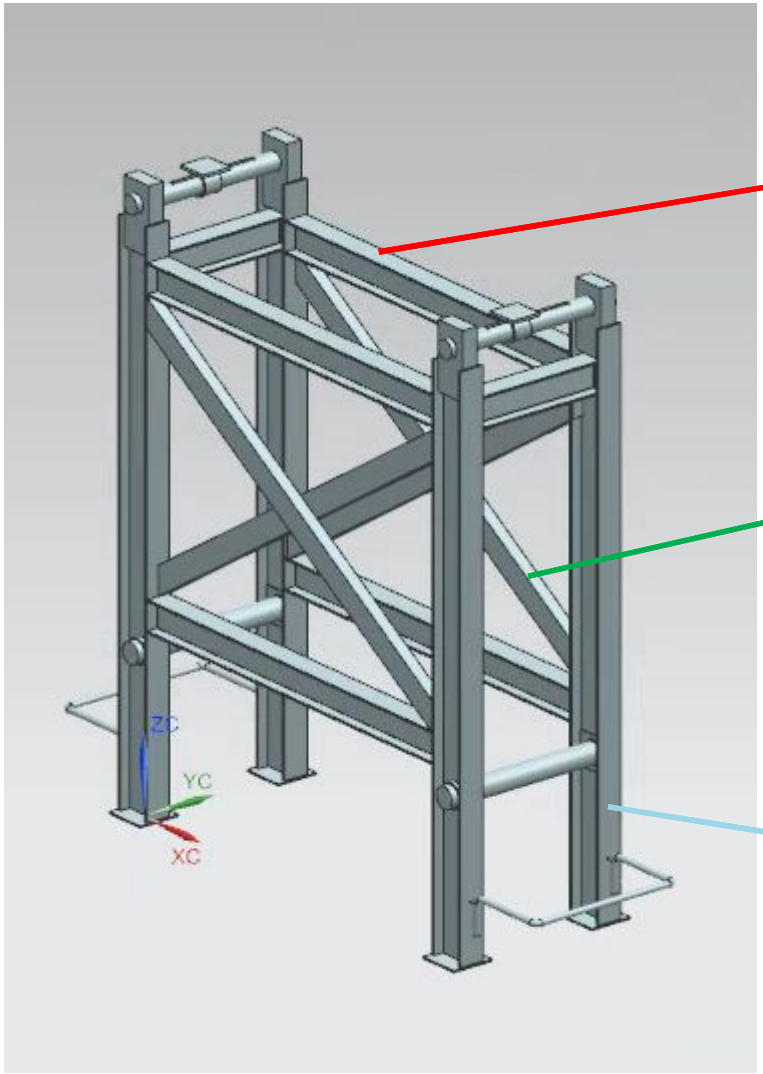


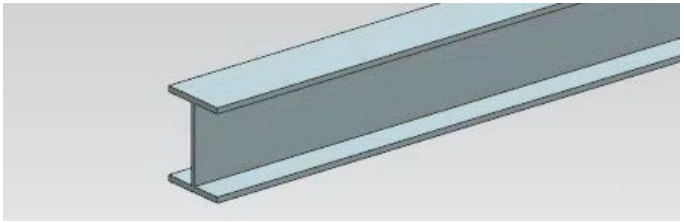
Hoisting procedure

- Step 8: move the calorimeter over the rail in order to place it in the required position and repeat the same procedure for the second disk

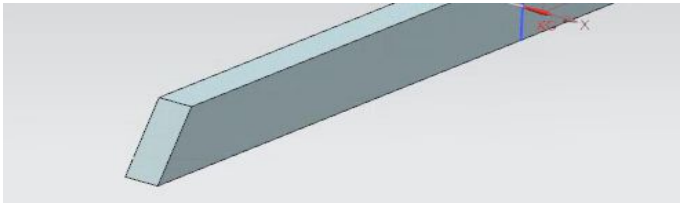


Lifting fixture components

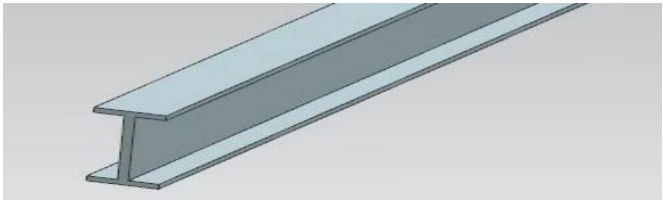




"I" steel profile: 4' x 0.170' x 3' x 0.25'



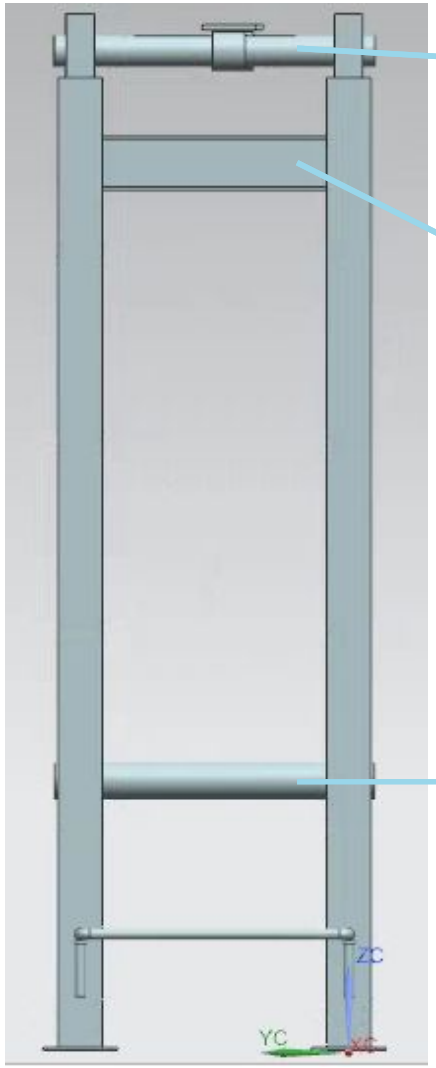
Steel rectangles: 1' ½ x 3'

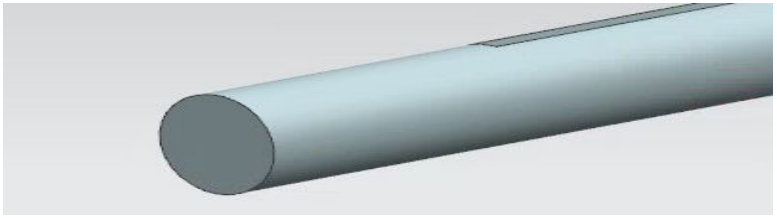


S beam standard: 5' x 0,316' x 3,824' x 0,494

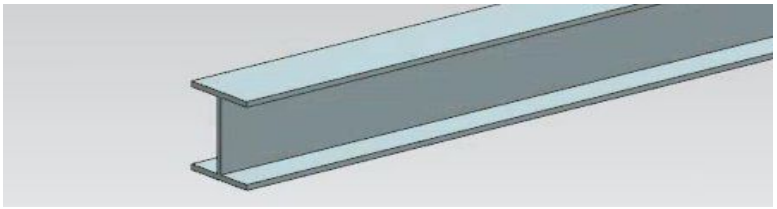
Fermilab

Lifting device components

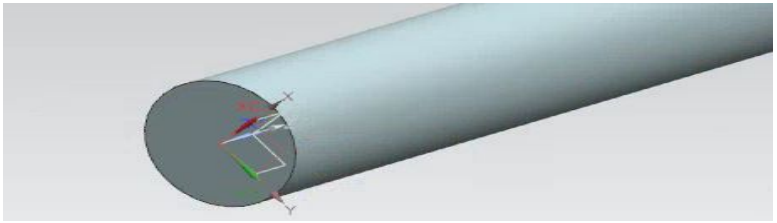




Steel rounds: 2.375’



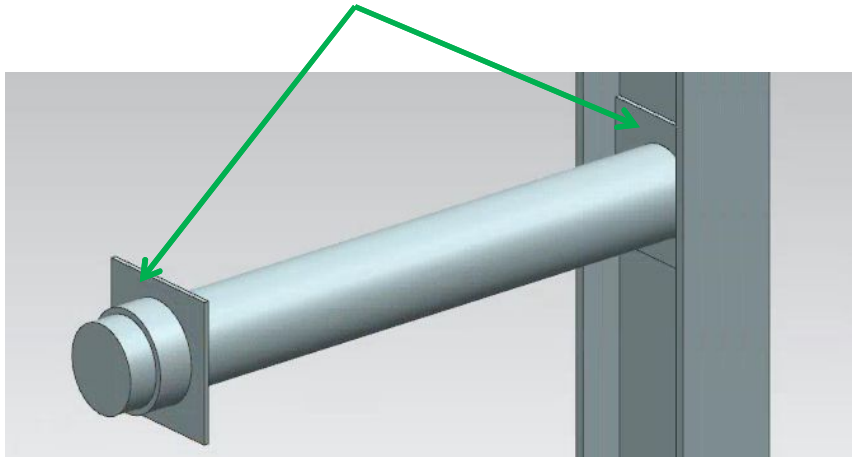
“I” steel profile: 4’ x 0.170’ x 3’ x 0.25’



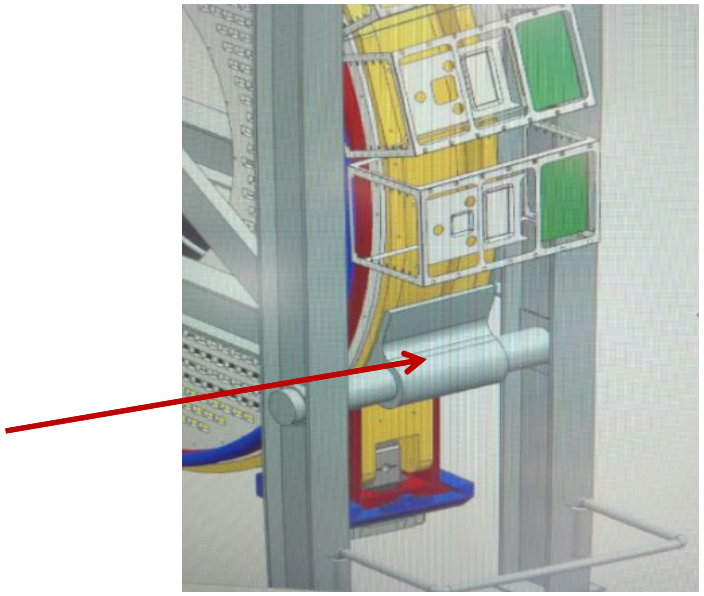
Steel rounds: 2’ ¾

Connection elements

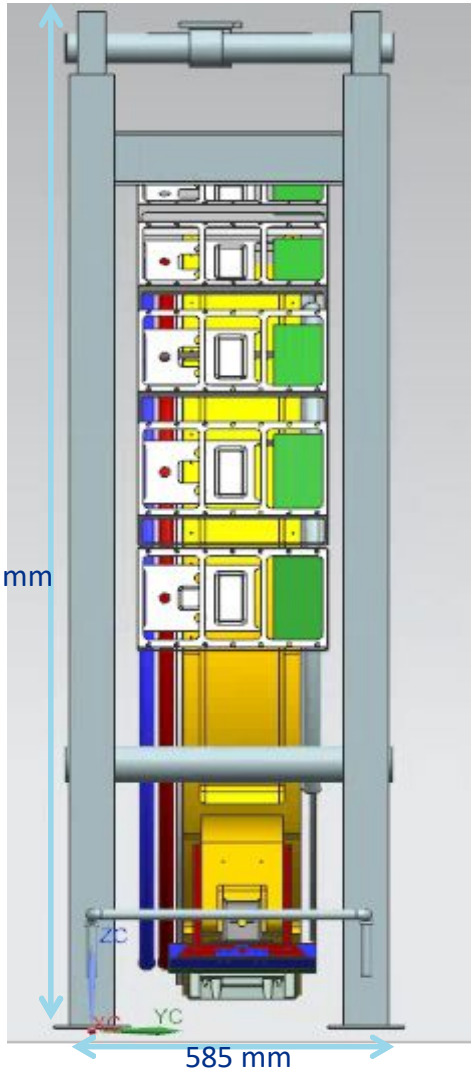
- Strengthening of the contact area between the feet and the rods

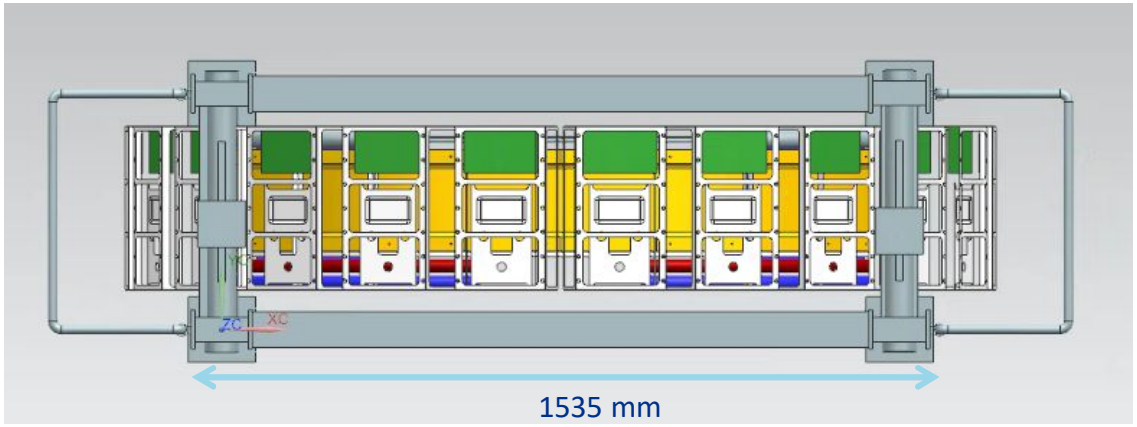


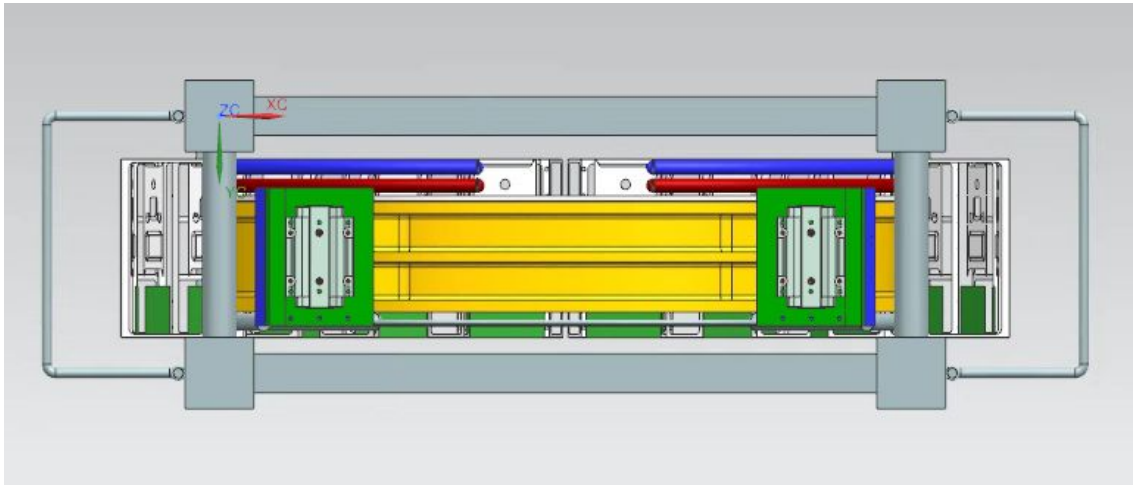
- Support elements in order to ensure a better connection between the aluminum disc and the rods
- These elements are not included in the following ansys simulation



Lifting device dimensions



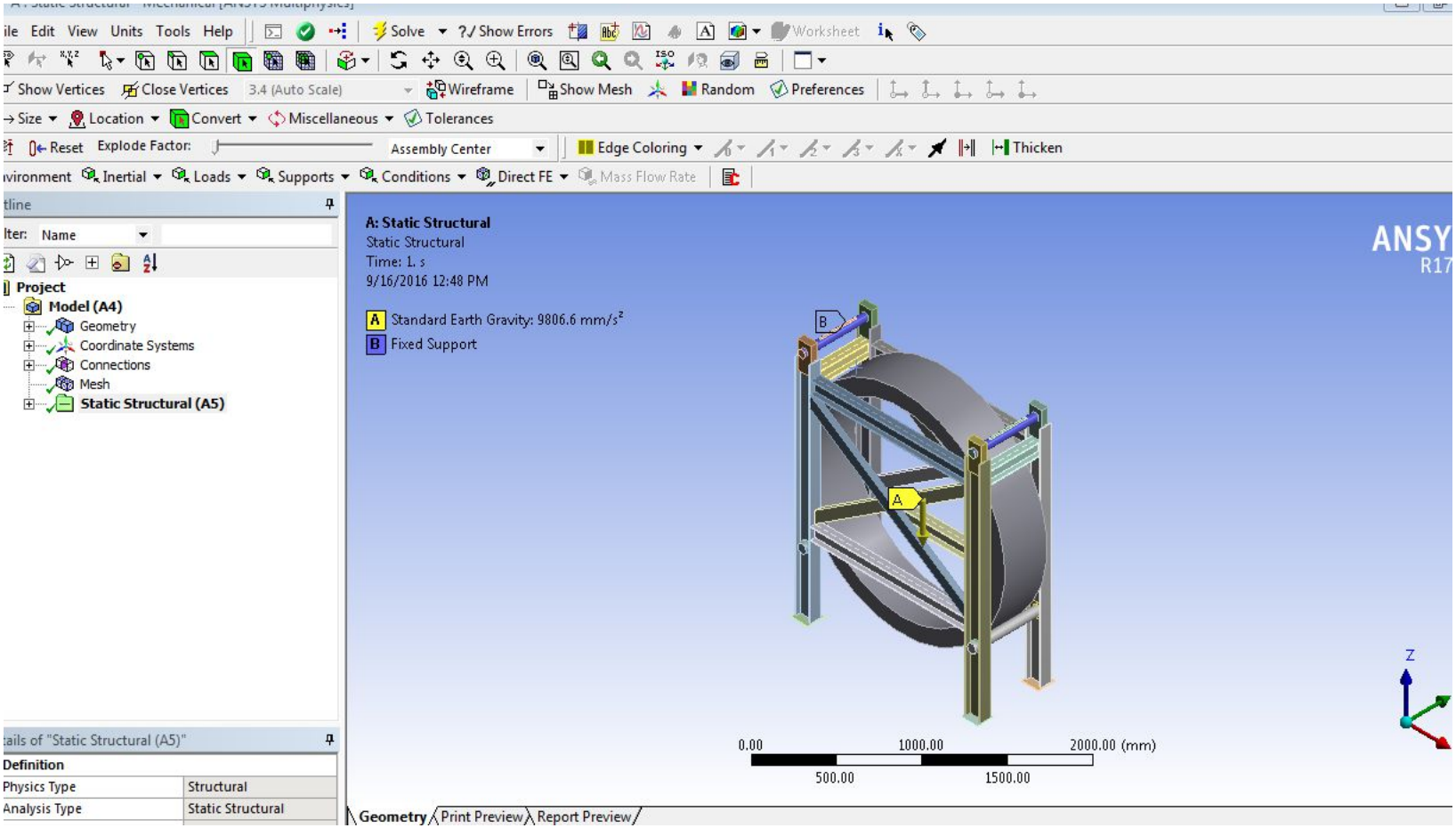




Lifting device features

- Total lenght: 1535 mm
- Total height: 1945 mm
- Total thickness: 585mm
- Lifting structure weight: 480 kg
- Material: structural steel

Structural static analysis: equivalent model used in ansys

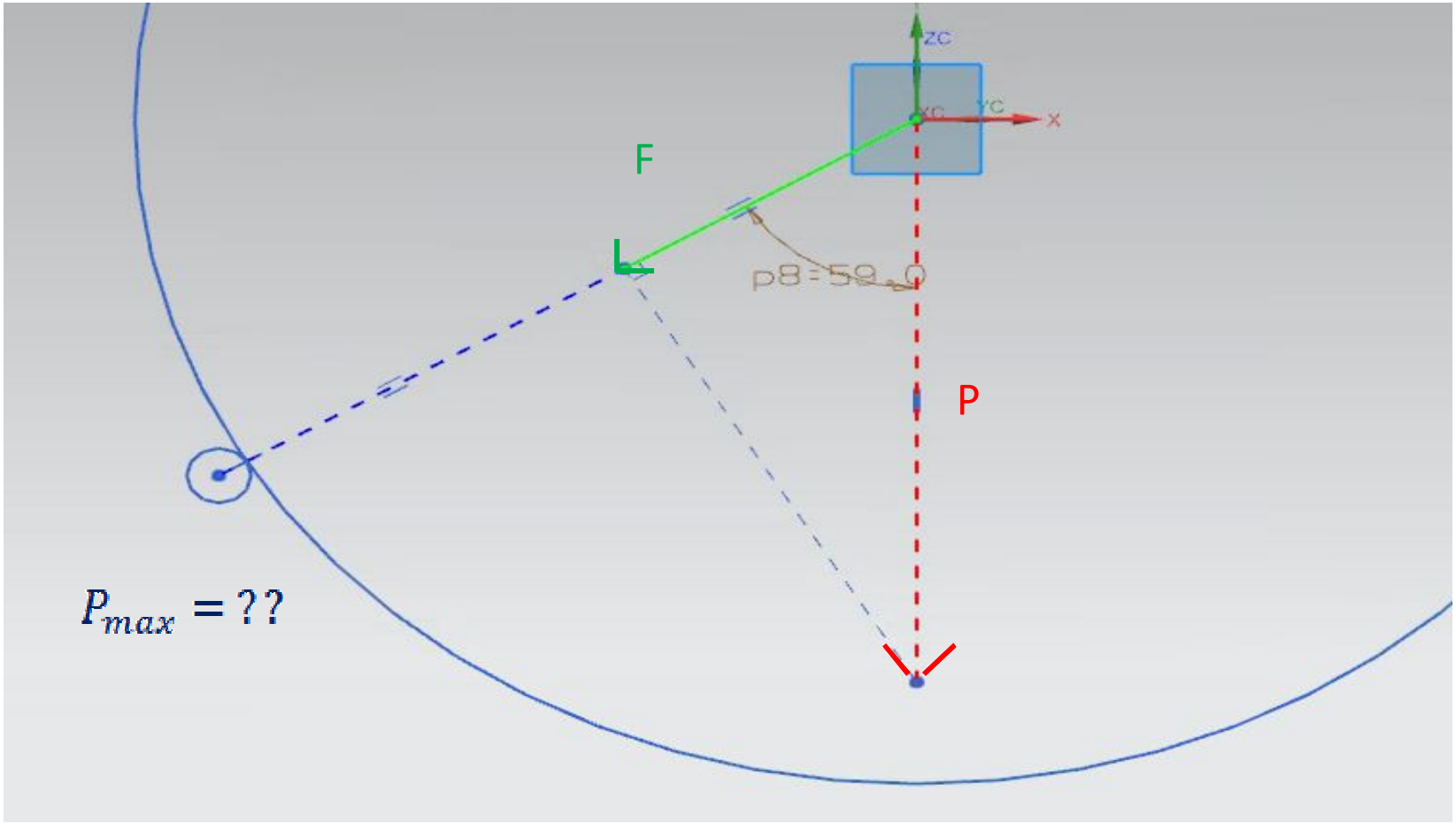


Fermilab

Equivalent model features

- Standard earth gravity
- Fixed supports: upper rods
- The diameter of the disk used for the ansys analysis is equal to the diameter of the calorimeter
- Same weight of the calorimeter disk

Hertz theory



$$F = {}^{P}/_{2} * \cos(59°)$$

Hertz theory

$$F = {}^{P}/_{2} * \cos(59°)$$

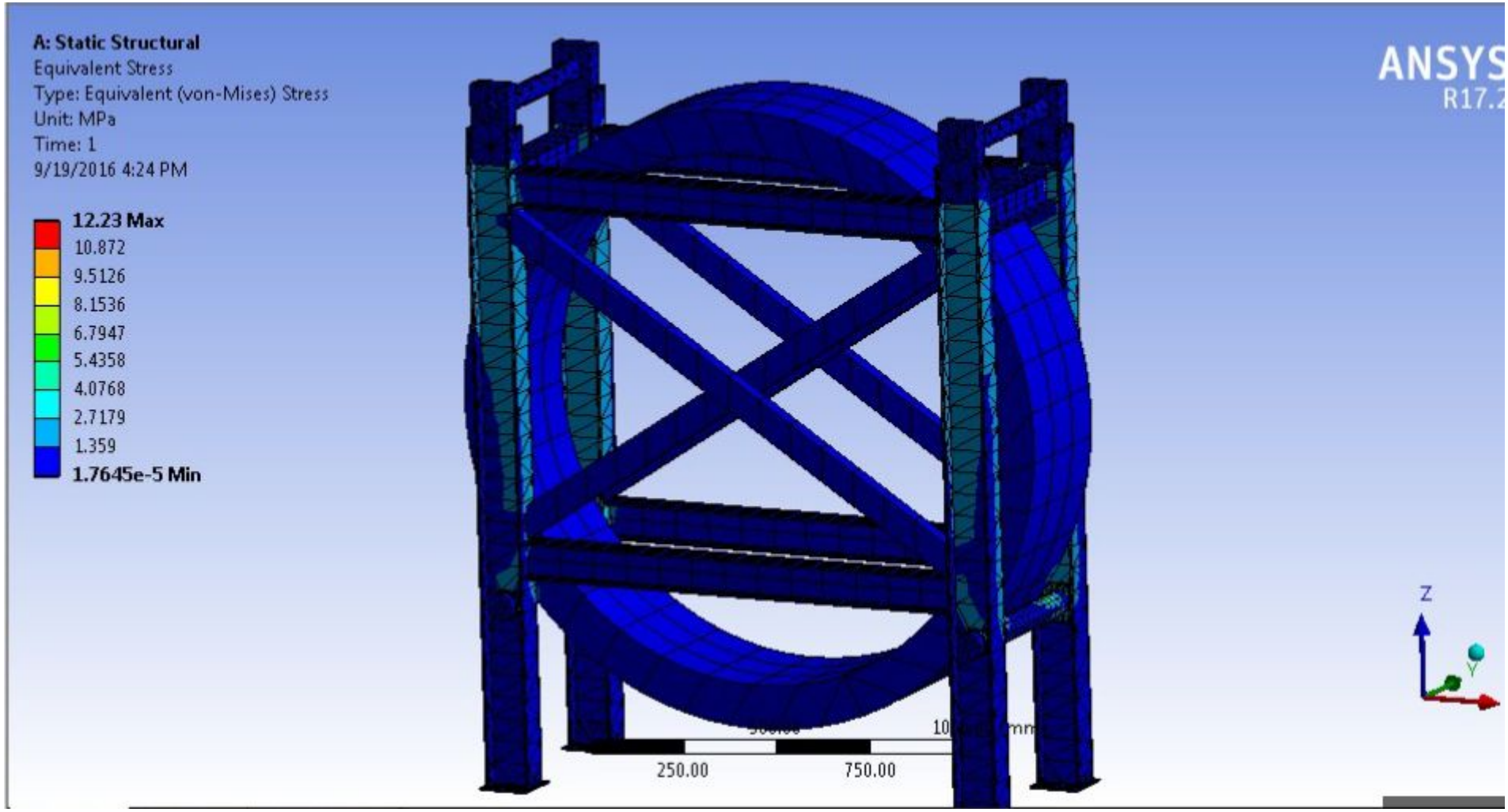
$$P_{max} = 0{,}64 * \frac{q}{a}$$

$$q = \frac{F}{l}$$

$$a = \sqrt{q * \frac{4}{\pi} * \frac{\rho}{\Delta}}$$

$$\longrightarrow \quad P_{max} = 90\ MPa$$

Ansys structural static test: equivalent Von-Mises stress



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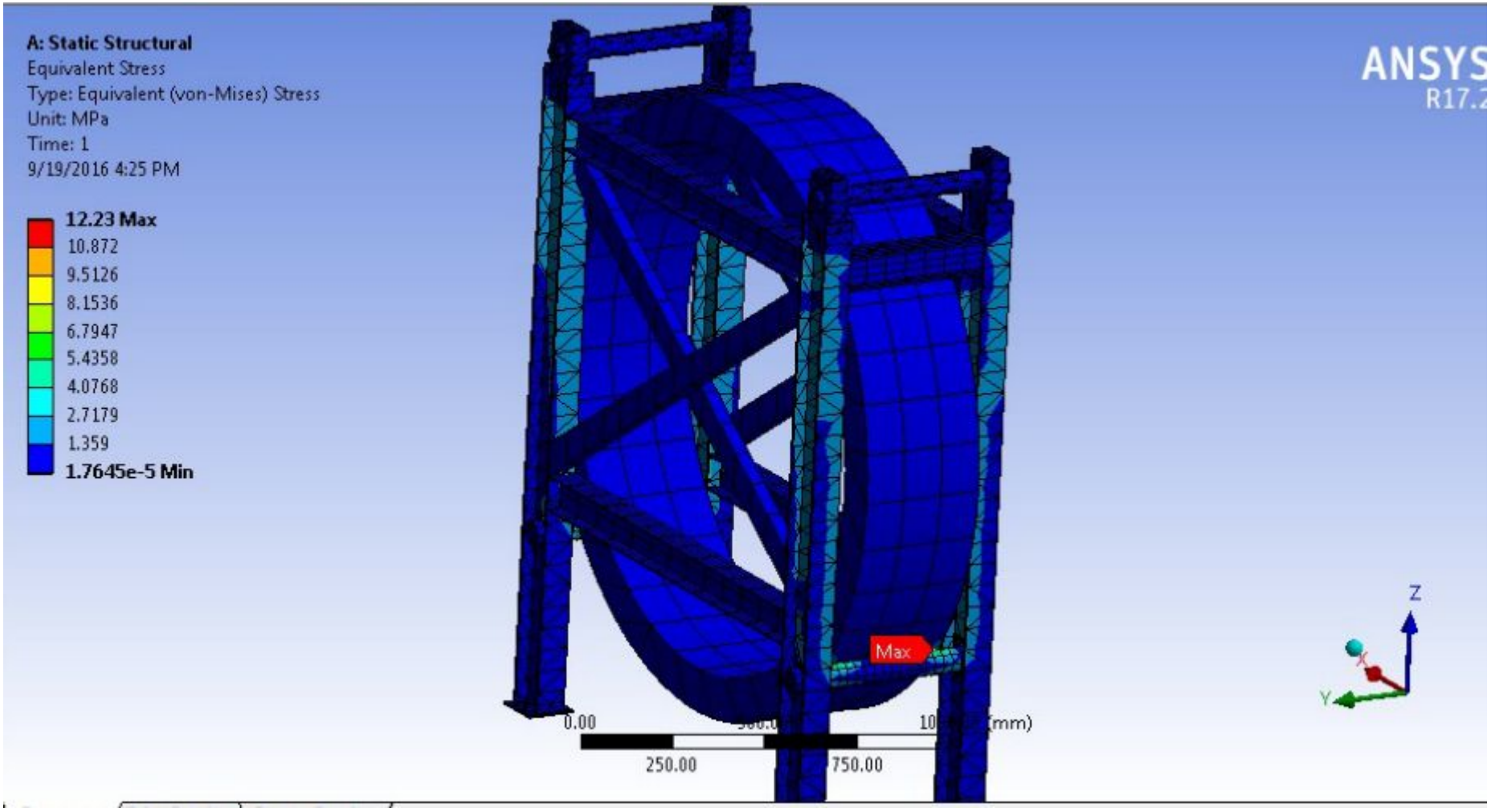
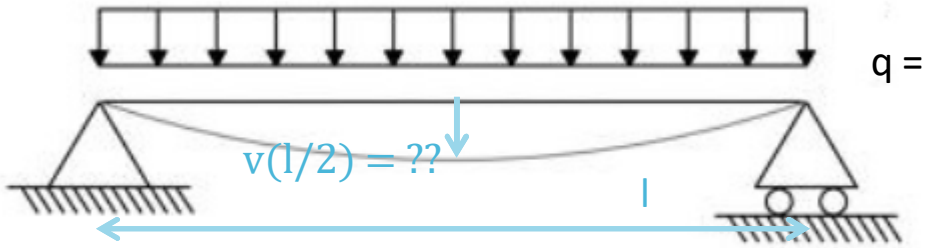
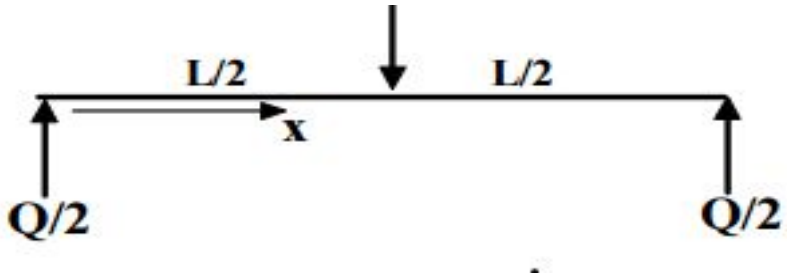


Fermilab

Cylindrical beam deformation

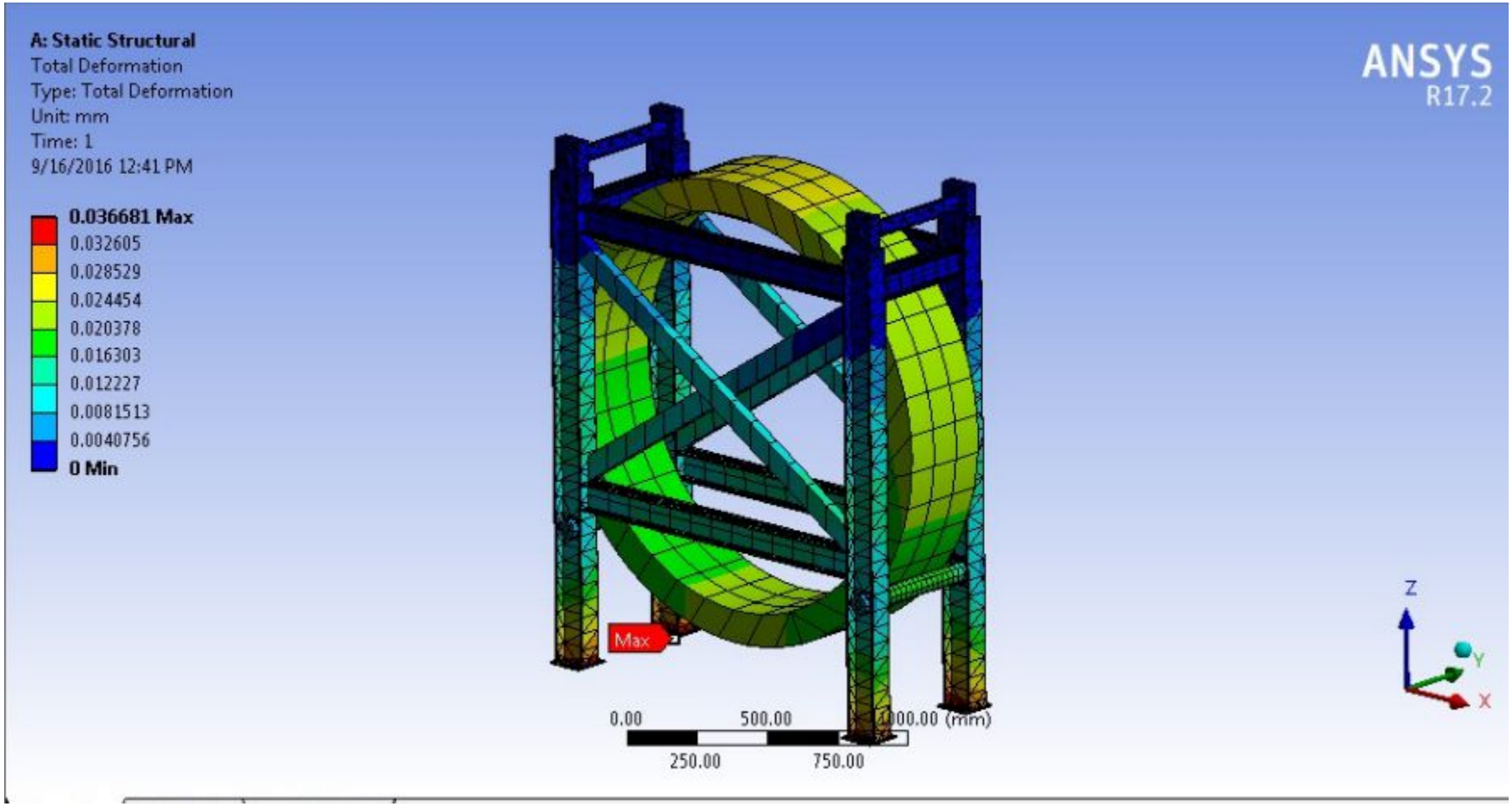




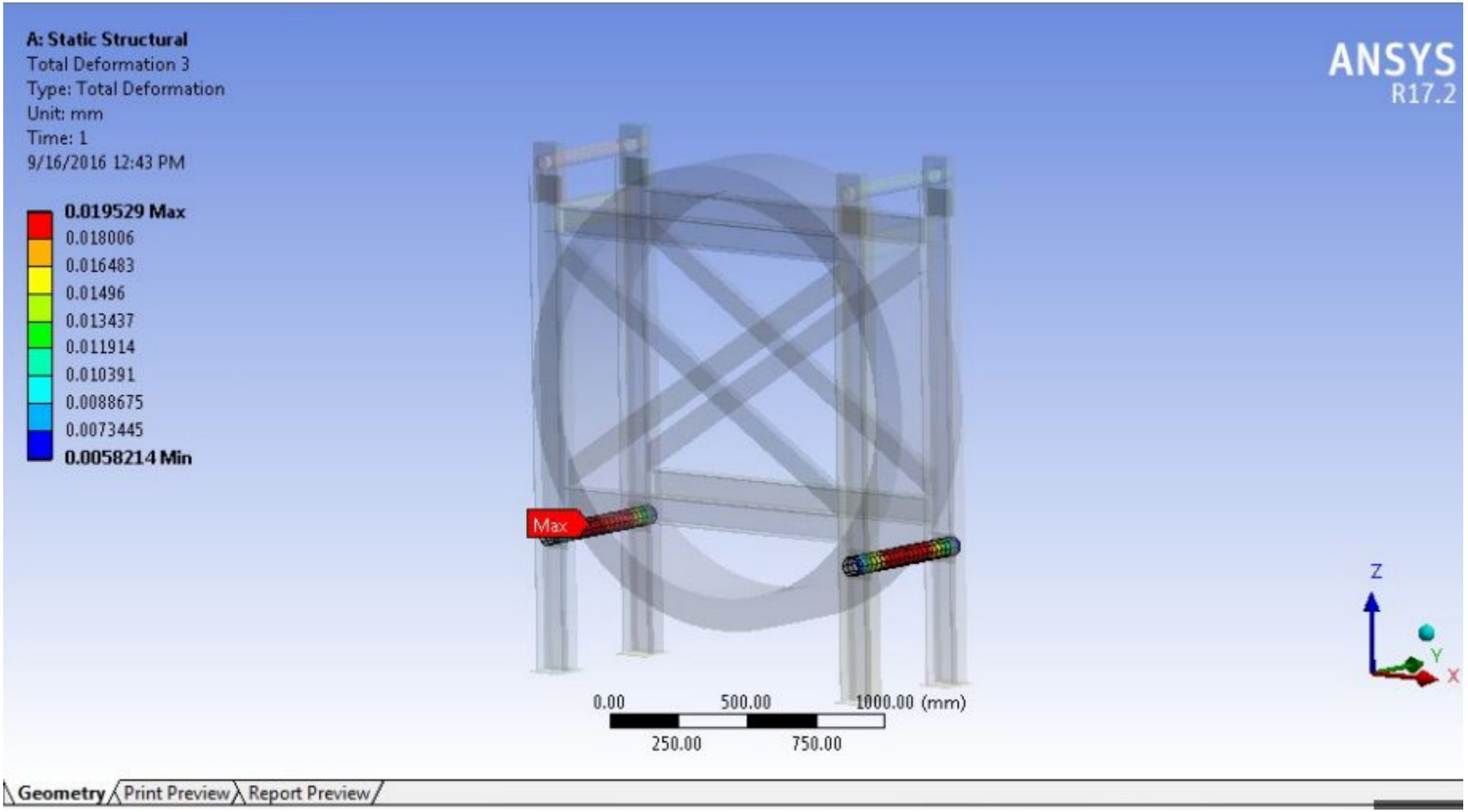
$$v''(x) = \frac{M(x)}{E * I} \longrightarrow v''(x) = \frac{\left(\frac{Q}{2} * x\right) - \left(q * \frac{x^2}{2}\right)}{E * I}$$

$$\longrightarrow v\left(\frac{l}{2}\right) = 0.01\ mm$$

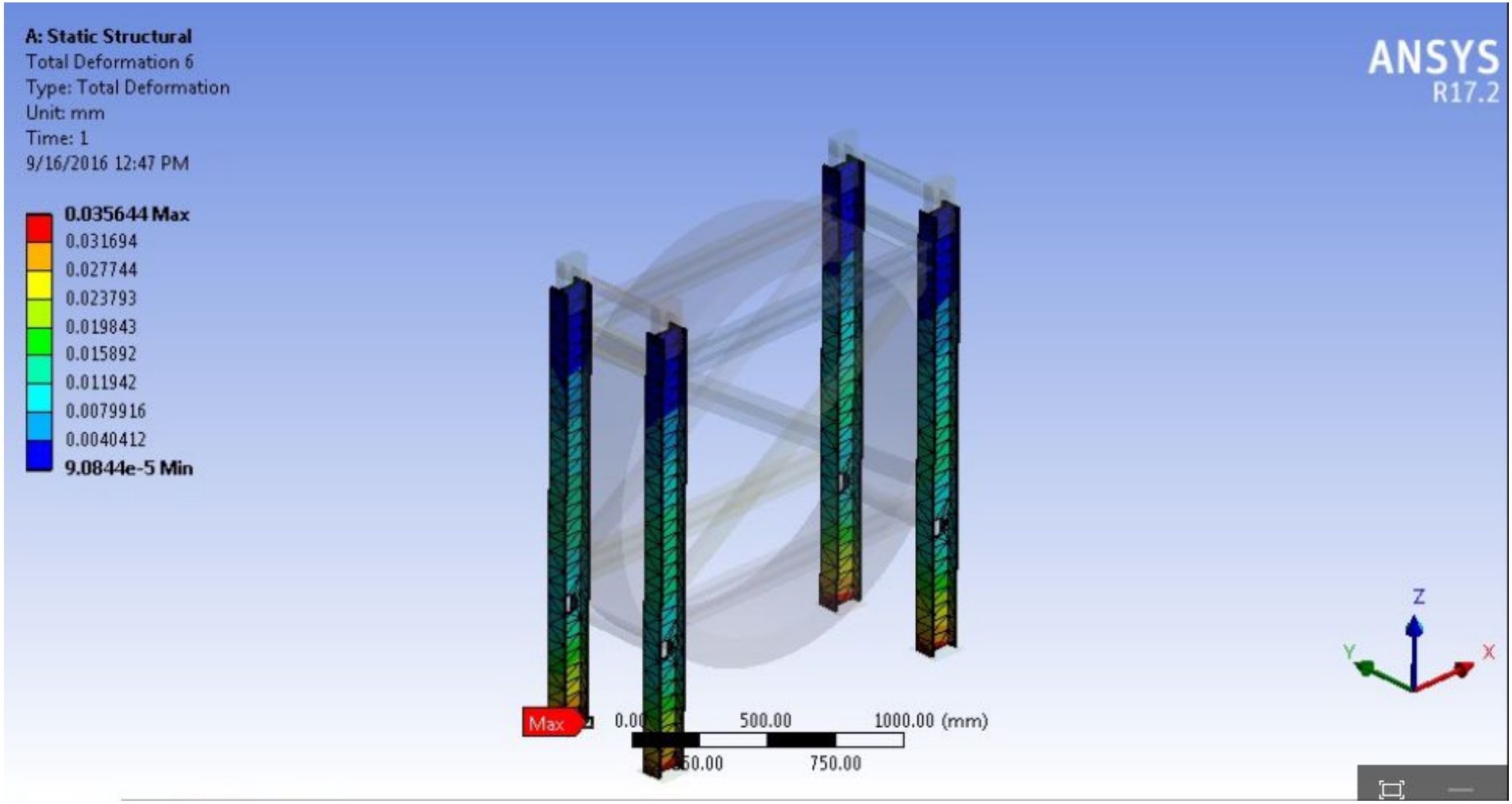
Ansys structural static test: total deformation



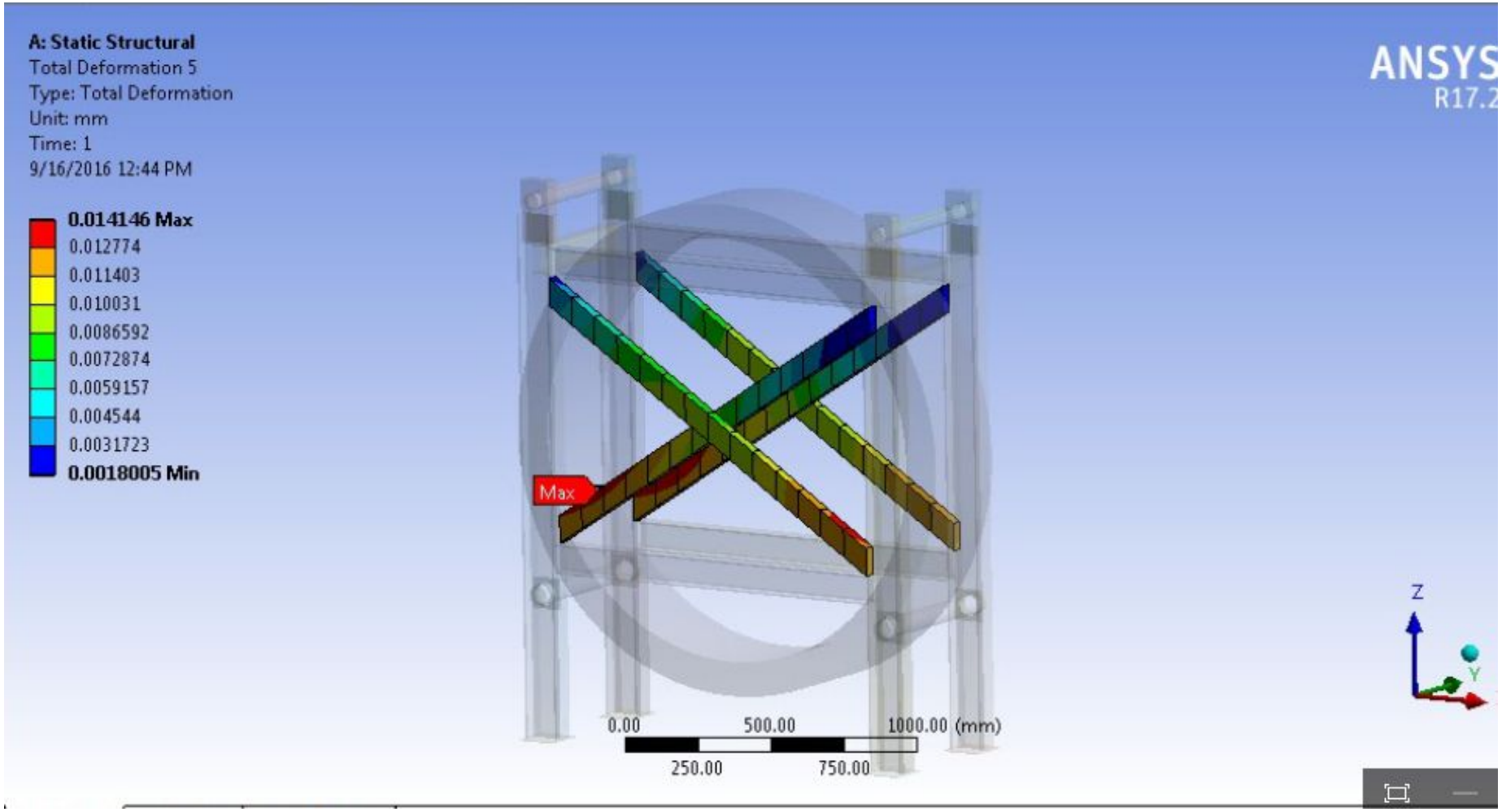
Ansys structural static test:cylindrical beams deformation



Ansys structural static test: other elements deformation



Ansys structural static test: other elements deformation



Summary

- Acquired all the details and constraints of the calorimeter structure and Mu2e building clearances
- Modeled a concept for the Mu2e calorimeter lifting fixture using Cad NX 9.0
- Preliminary static structural analysys using Ansys
- I really enjoyed working with people at Fermilab!
- GRAZIE