ILD

Seismic design for ILD Detectors

ILD WebEx Integration Meeting – March 2nd 2012

Seismic Design

- **Installing the ILC and the associated detector(s) in Japan requires to take into account seismic hazard when designing the instruments**
  - Systems should be designed not to suffer any damage from minor earthquake, which are likely to occur during the lifespan of the instruments
  - Moderate earthquake should result in minor damages only
  - Recovery from a major earthquake should be possible

- **Systems should be design to resist vertically applied load (gravity) but also horizontal seismic loading**
  - Seismic load is dynamic and can induce forces with the same order of magnitude or higher than gravity in the horizontal direction
  - Even structures with high eigenfrequencies will have to withstand quasi-static loading

- **Any equipment, whether it is light or heavy, should have proper restrains, able to withstand loading in any direction**
  - Applies to subdetectors but also to ancillary systems: cables, services, electronic racks, tanks

Flexible vs. Rigid design

- **Two approaches: Rigid structure / Flexible structure**
  - Rigid design
    - Structure with high eigenfrequencies
    - Stiff connections able to withstand high stress levels
    - Limited displacements
  - Flexible design
    - Structure with low eigenfrequencies
    - Large displacements due to flexible connections to avoid stress concentration
    - Favored approach for buildings

- **Rigid design probably better suited for a HEP detector: small displacements are desirable**
  - Detector needs to be compact, with limited clearance between sub-detectors
  - Gaps are usually filled with cables and services

Design to Standards

- **Standards provides useful information to evaluate the seismic actions and design seismic resistant structures**
  - Mainly developed for buildings but cover also any equipment installed inside

- **ISO 3010 – Bases for Design of Structures - Seismic Actions on Structures**
- **EUROCODE 8 – Design of Structures for Earthquake Resistance**
- **National Standards or Building Codes**

- **In Japan**
  - Reference is the Building Standard Law
  - Non official documents but still acceptable: Recommendations from Architectural Institute of Japan (more frequently revised)
    - Released in 1993 updated in 2004
    - Specifications for T2K Neutrino experiment were based on AIJ 1993

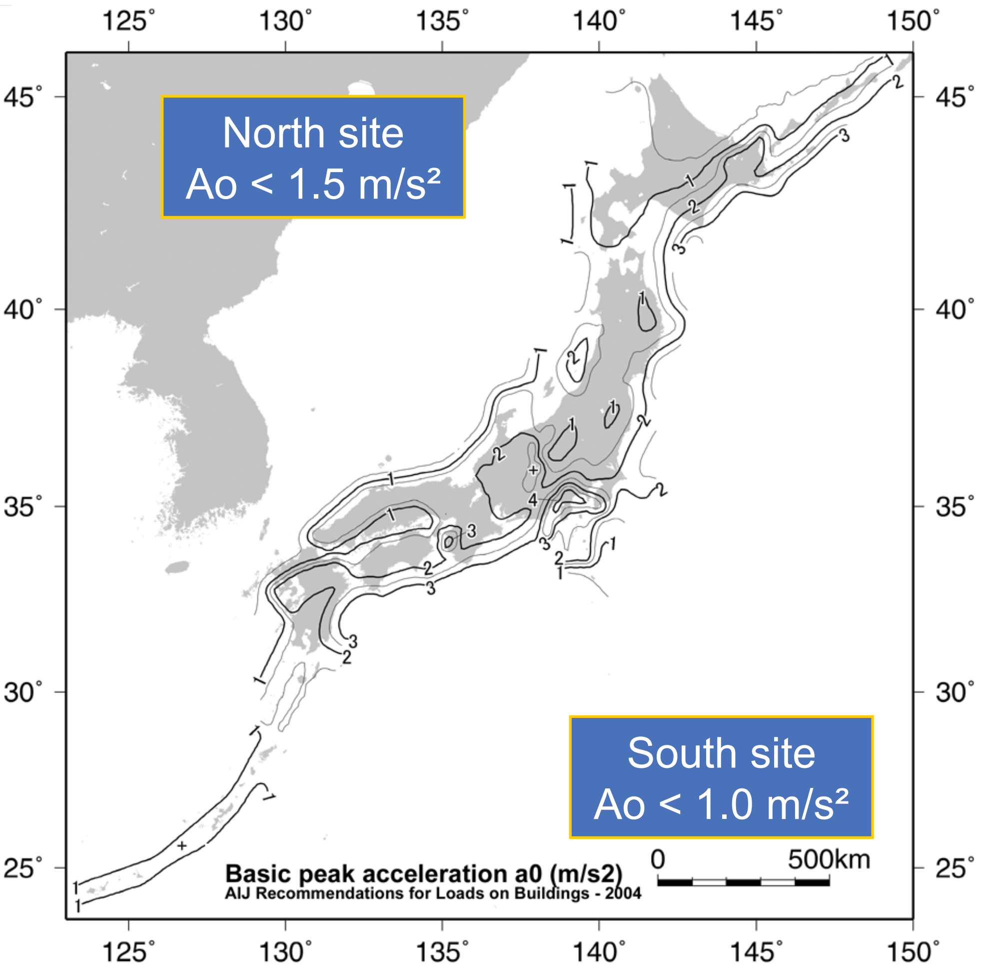
Analysis Procedure

- **Response spectrum analysis for linear structures**
  - Define a site specific acceleration response spectrum
  - Calculate the eigenfrequencies, enough to account for at least 90% of the participating mass of the structure
  - Combine the modal contributions with CQC method
  - Combine spatial components (X, Y, Z) with SRSS method

- **Time history method for non linear structures**
  - Requires sets of ground motion records to be used as load input

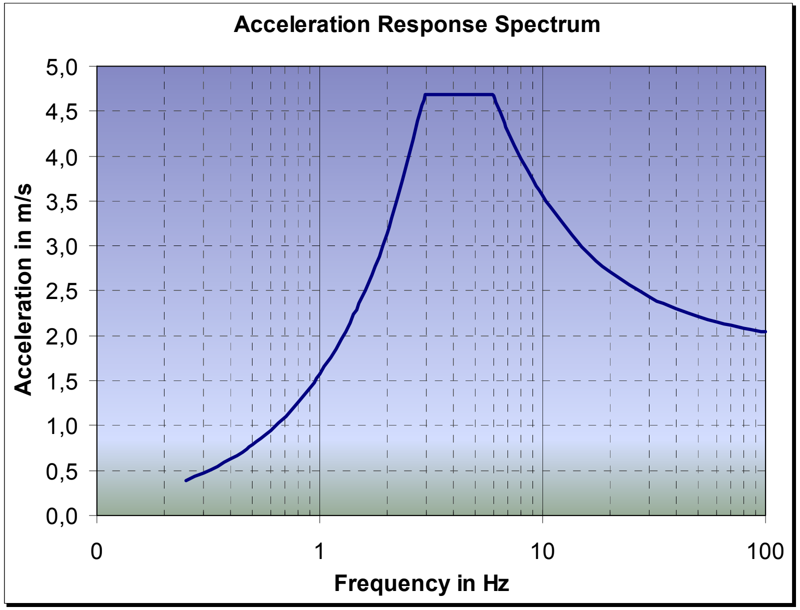
Response Spectrum

Spectrum based on AIJ - 1993



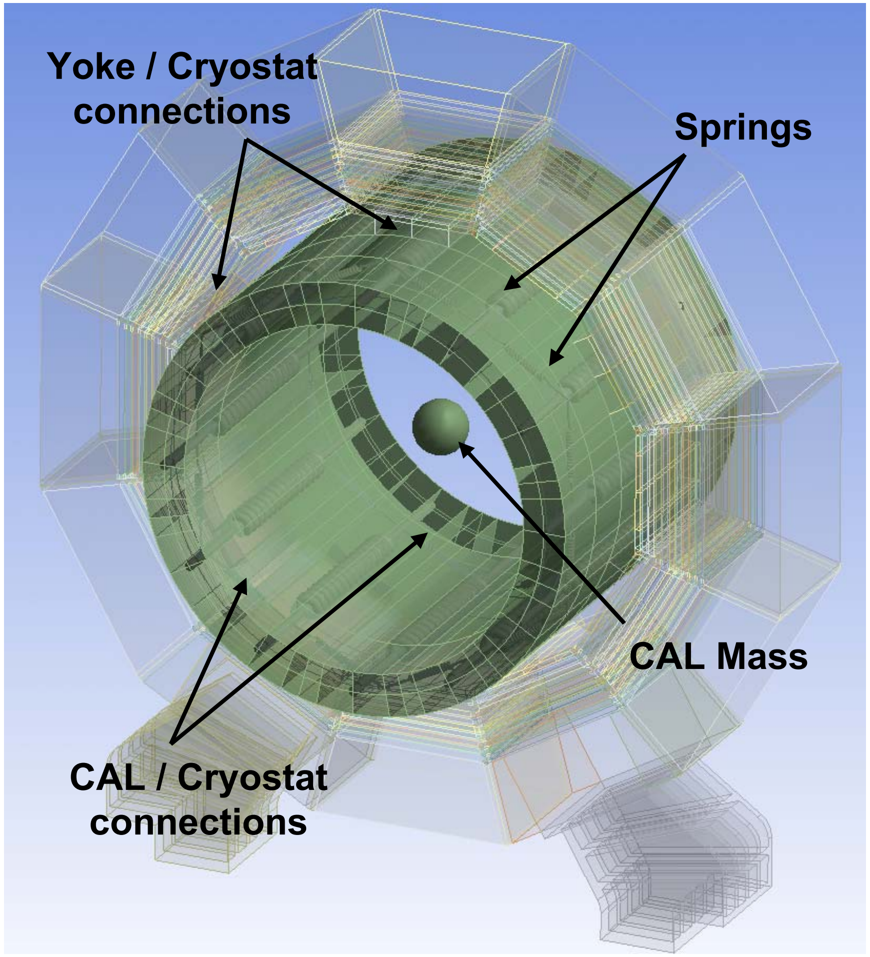
Parameters for acceleration spectrum

- Peak Ground Acceleration: 1.5 m/s²
- Damping ratio for steel structure: 2%
- Soil type: hard soil



Preliminary Analysis Results

- **Model: very limited engineering input**
  - Central yoke ring with supporting feet, cryostat with coil
  - Calorimeters as nodal mass
  - ILD dimensions and weights
  - CMS type design
- **Interfaces**
  - Coil attached to the cryostat with springs
  - Radial connections between the cryostat and yoke at the front and the back
  - Radial connections between the CAL mass and the inside shell of the cryostat
- **Loads**
  - Vacuum inside the cryostat
  - Gravity
  - Seismic load

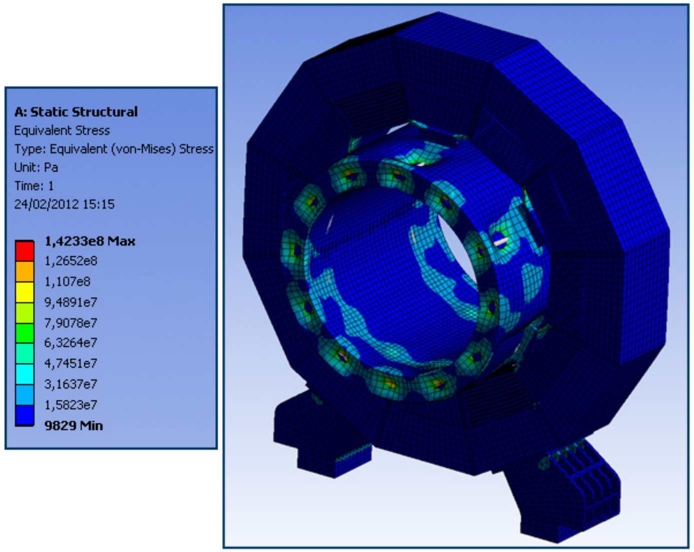


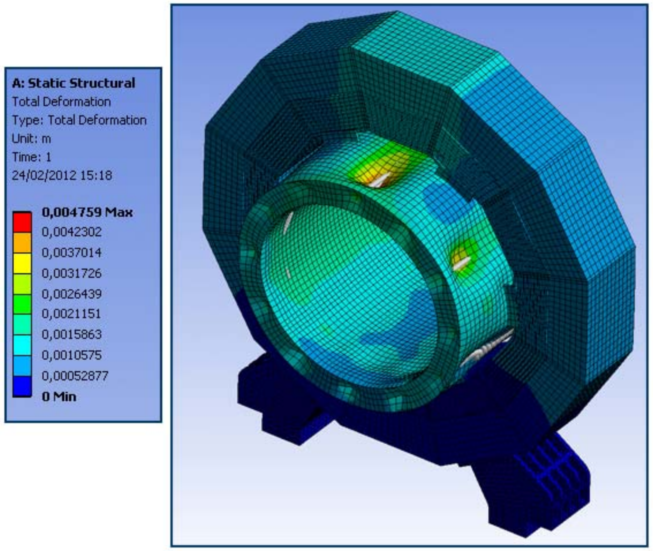
Preliminary results / Static

- **Static analysis to evaluate the effect of the gravity (vacuum inside cryostat included)**

- **Peak stress 142 MPa, but very local at the interface between the cryostat and the springs supporting the coil**
  - Not really relevant, better, more detailed model is required

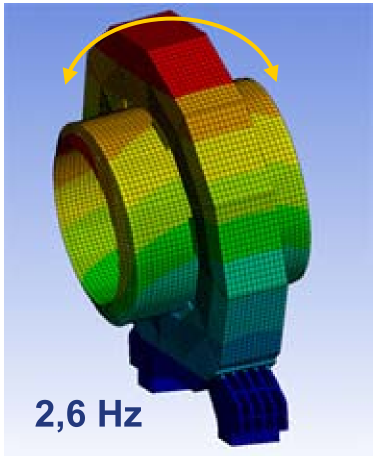
- **Max displacement 4,7 mm, again at the interface between the coil and cryostat**

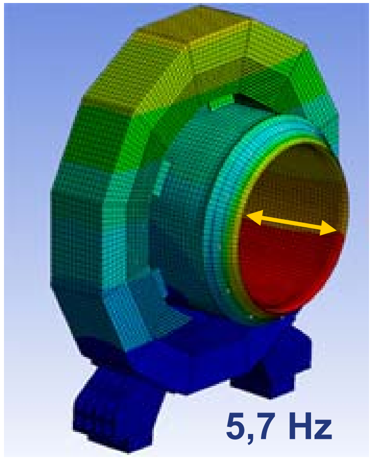


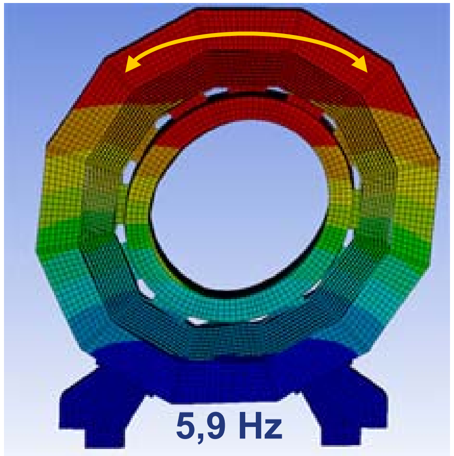


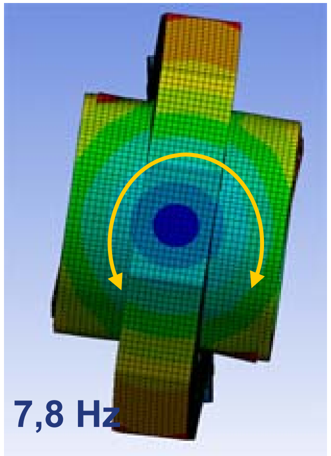
Preliminary results / Eigen Modes

Global modes

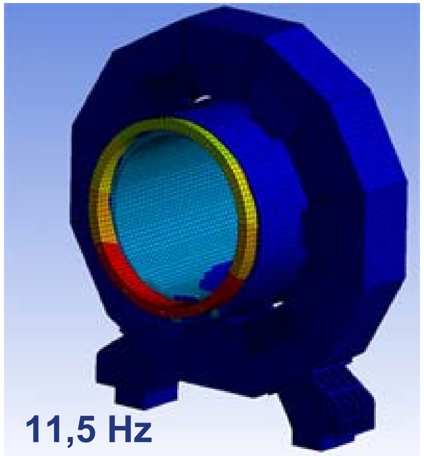

2,6 Hz

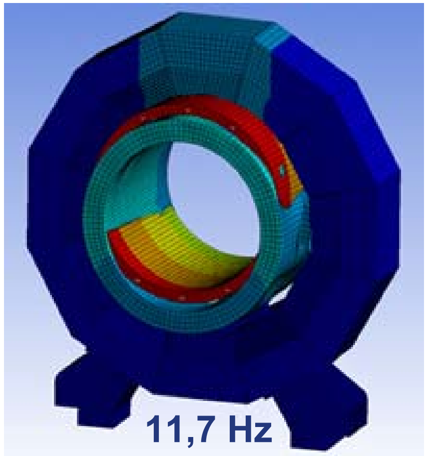

5,7 Hz

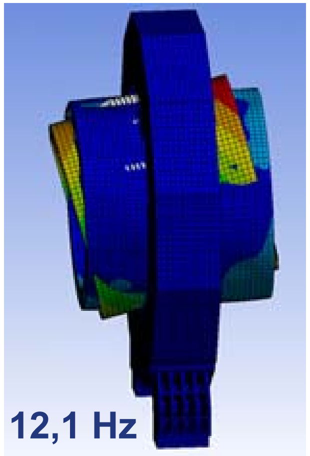

5,9 Hz

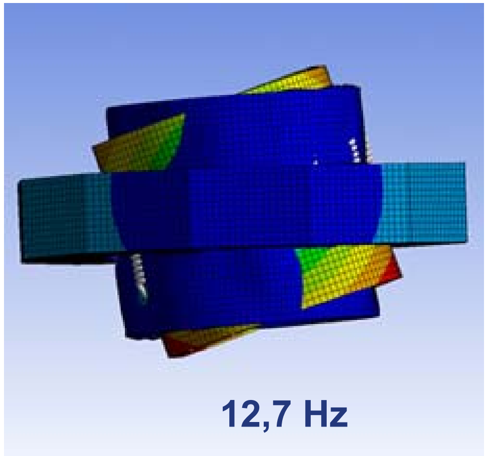

7,8 Hz

Modes associated with the coil


11,5 Hz

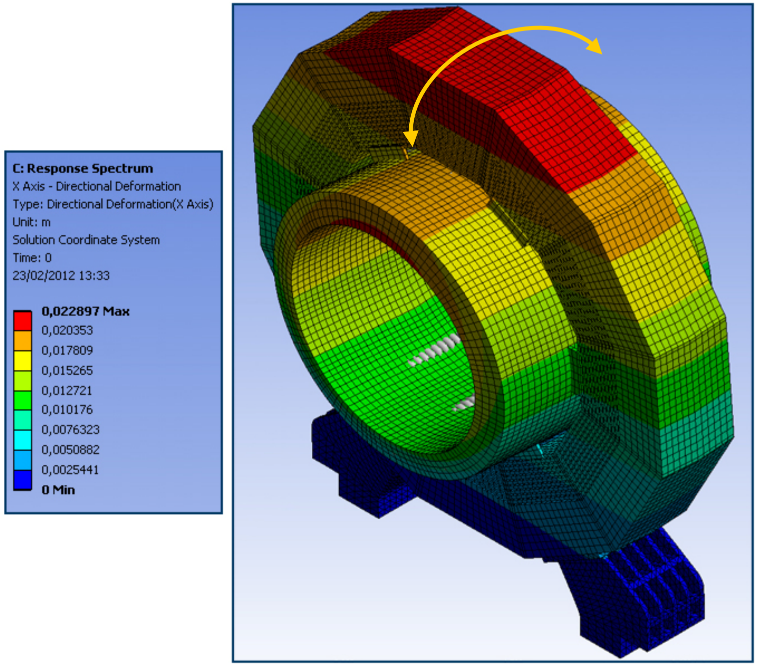

11,7 Hz

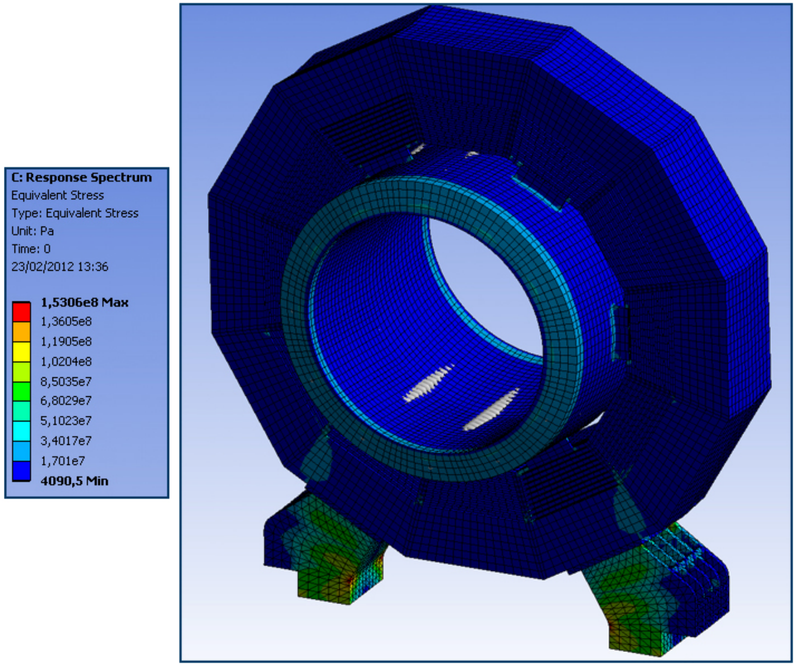

12,1 Hz


12,7 Hz

RS Analysis Results

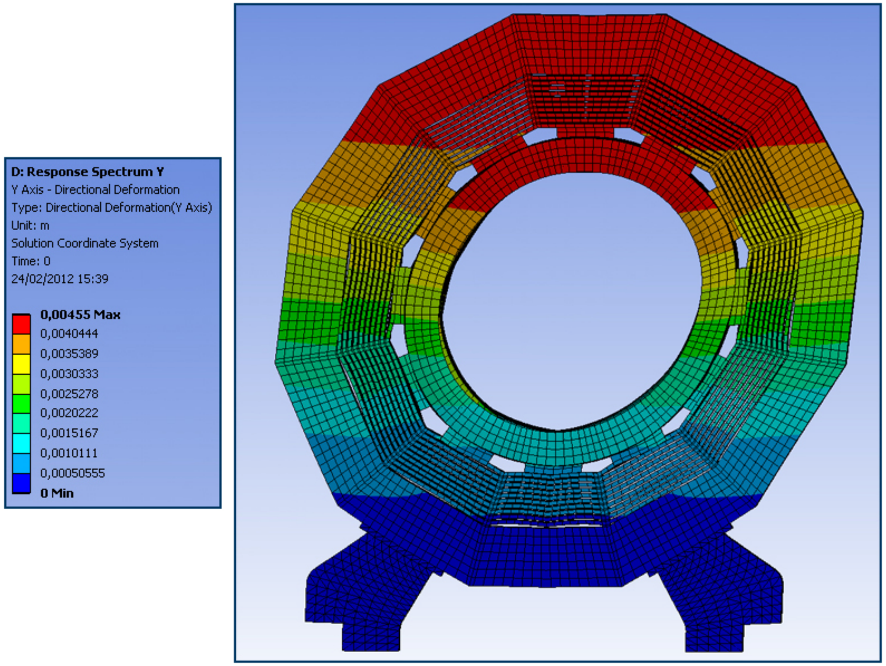
- **With the acceleration response spectrum applied along the detector axis, the fundamental mode of the structure dominates: back and forth motion of the yoke ring**
- **The max displacement is around 23mm, which is quite high**
- **The peak stress is located in the feet. The level seems acceptable but the results need to be checked with a proper design and model**
- **Attaching the 3 rings together is probably the way to go to increase the overall stiffness and reduce the peak displacement**

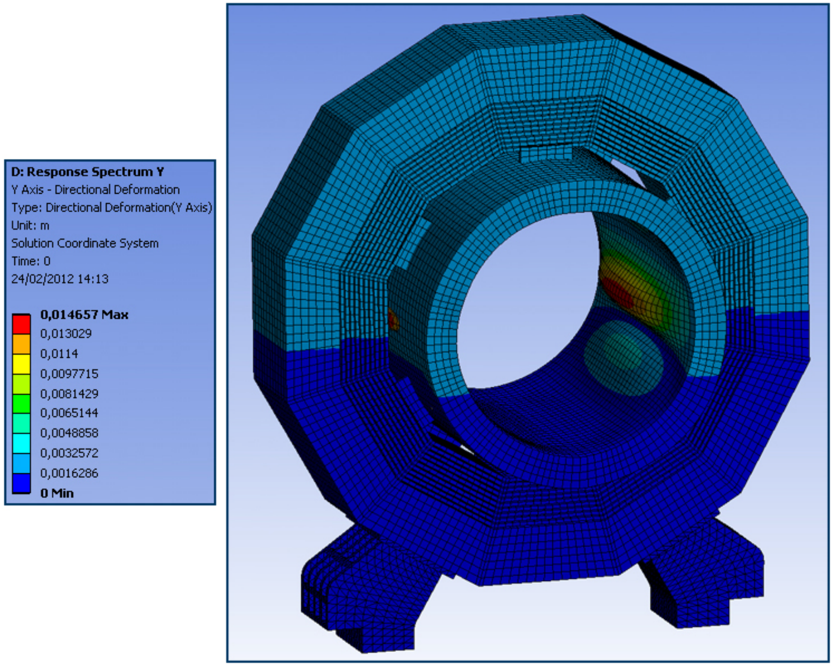




RS Analysis Results

- **With the acceleration spectrum applied perpendicular to the detector axis, the displacement are significantly lower (less than 5 mm).**
  - Due to its geometry, the yoke ring offers a good resistance to side loading
  - The effect is still not negligible
- **With a rail type support, the effect is local: it affects only the calorimeters. The peak displacement increased to around 15 mm**





Conclusion

- Seismic load is a major load case that needs to be taken into account when designing instruments to be installed in Japan

- Detectors and ancillary systems should be designed to be seismic resistant

- It is desirable to take into account those aspects as soon as possible in the design phase of the instruments

- Additional and stronger mechanical connections are needed to resist loading from various direction, which significantly impacts the assembly procedure of the detector