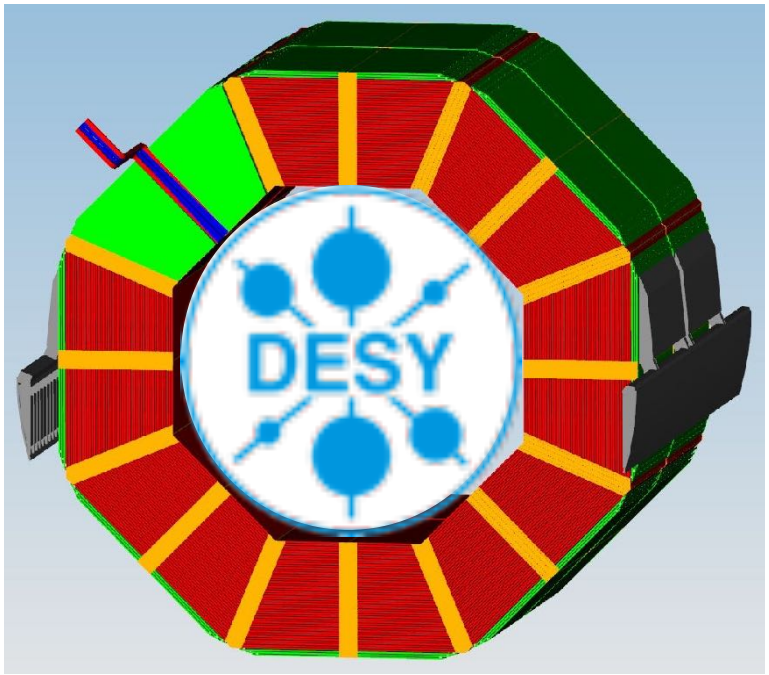
The AHCAL mechanical structure: some updates

Felix Sefkow



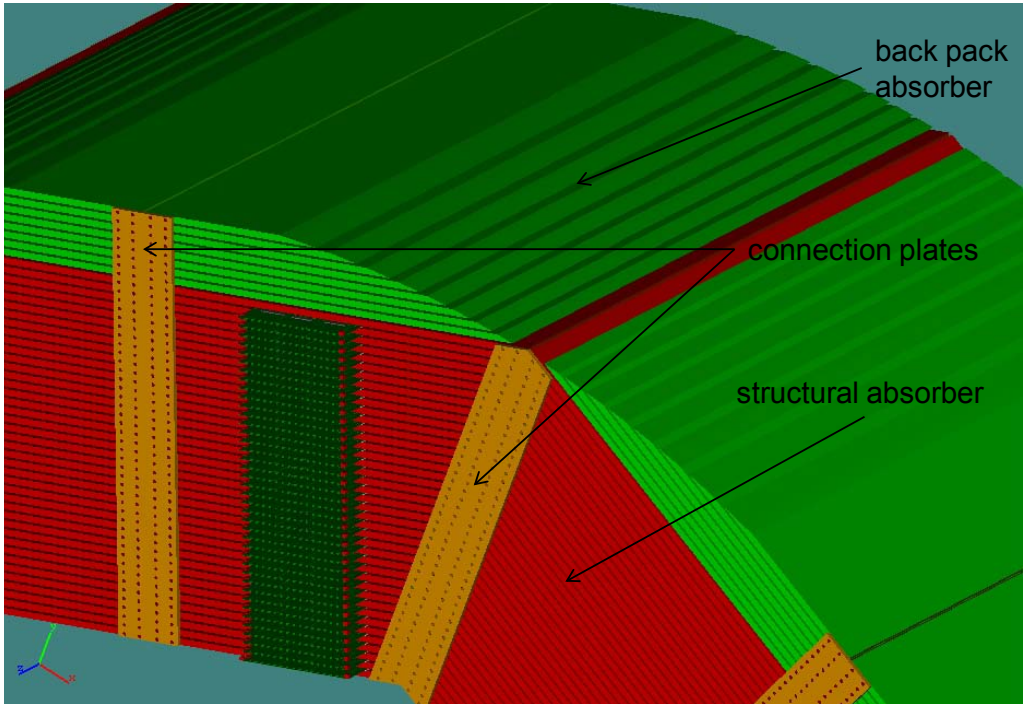
ILD Software and Technical Meeting Meeting, Lyon April 27, 2017

Outline

- Reminders
- Status of Finite Element computations
- Update on dead region study
- Update on signal and service routing

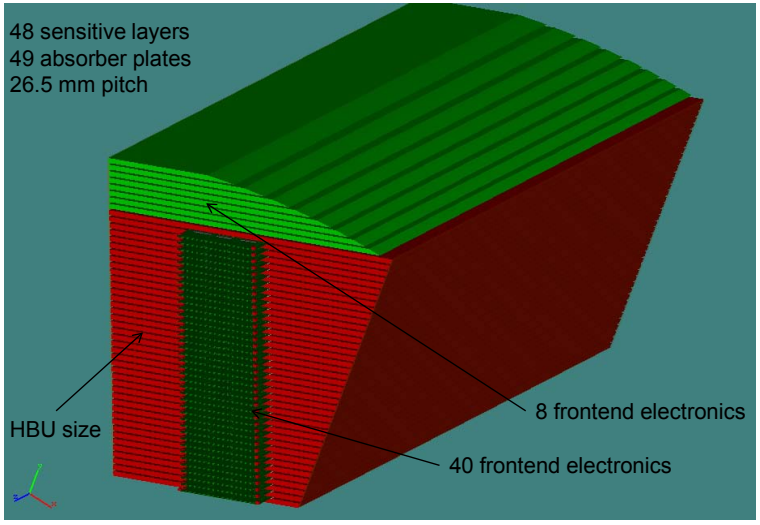
Design challenges

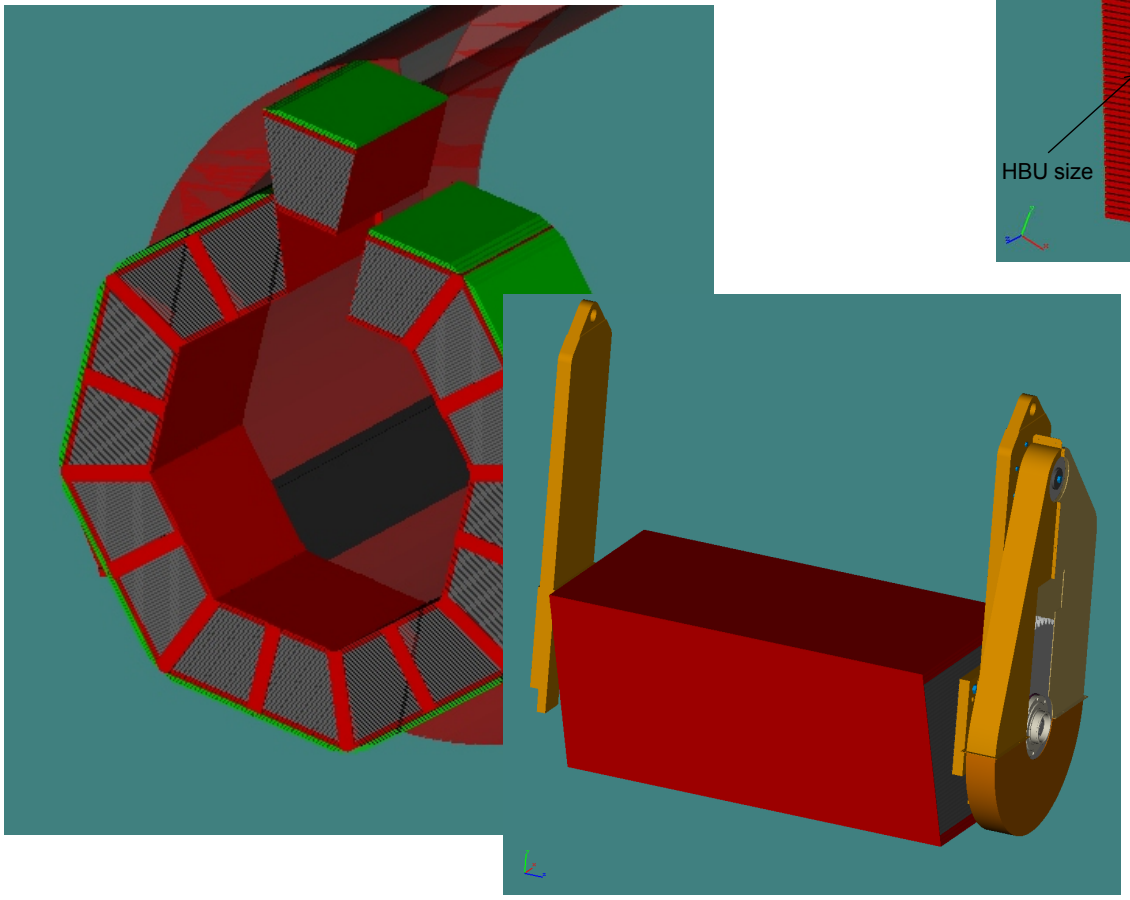
- Stainless steel
- Fine longitudinal sampling
  - 2cm plate thickness
- No cracks, minimal un-instrumented regions
- Inside coil radius:
  - compact design to maximise no. of hadronic interaction lengths
  - tight tolerances over large dimensions
- Accessible electronics
  - external: short access
  - internal: longer shutdown or upgrade
- Earth quake stability
  - computational challenge



Small modules

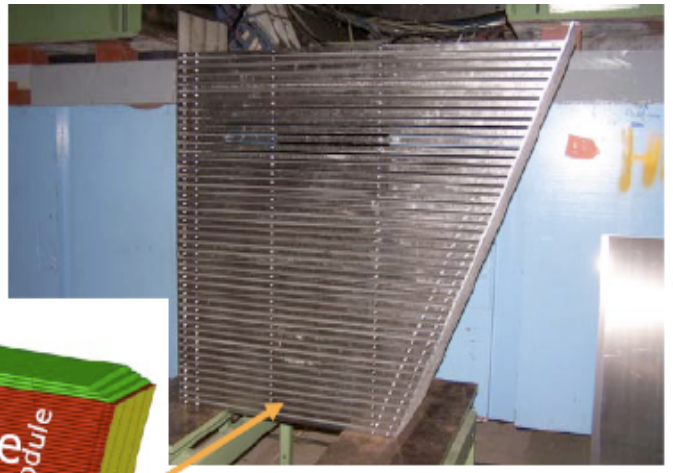
- Small sectors (<18t) for easy transport and assembly in situ





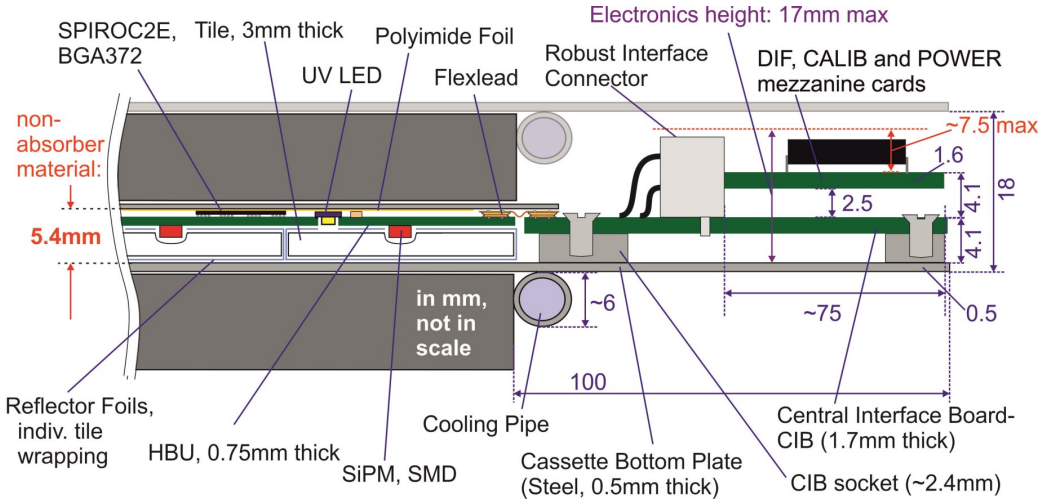
Design features

- Uniform sampling along shower axis
- Structure is made from rolled steel plates
  - flatness with roller levelling within 1mm verified
  - no machining: cost effective
- Assembly with screws
  - moderate tolerances
  - damping oscillations
- Thin side walls (5mm)
- 16 phi sectors, 2 rings
- Flexible structure, matched to flexibility of scintillator cassettes
- Varying layer width no problem for scintillator

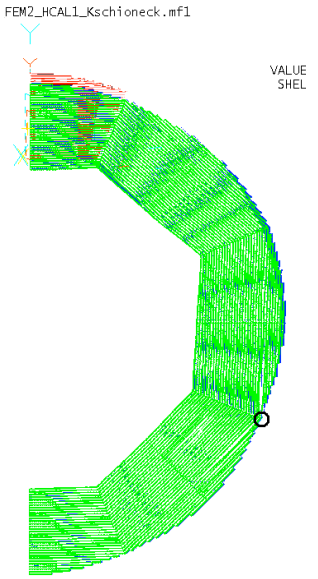


Cassettes

- Housing the scintillator and electronics active layers
- Made from stainless steel and contributes to absorbing material
- Sum of absorber plate and cassette thickness = 20 m / layer
  - for both AHCAL and SDHCAL
  - material in absorber plate contributes to rigidity of structure
  - material in cassette contributes to load on structure
- AHCAL Physics prototype and early designs had 16 + 2x2 mm
- Present design and new prototype have 19 + 2x0.5 mm
- Weight is 17 kg /m2
  - cf SDHCAL 48 kg / m2 with 2x 2.5 mm cassette

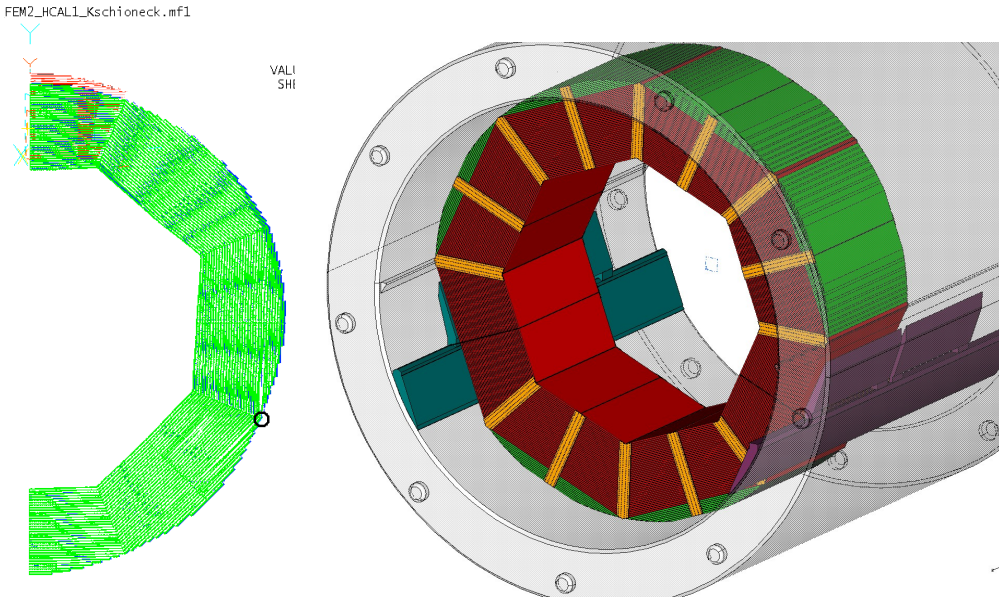


Orientation



- Earlier studies have shown that the “roman arc” structure shows less deformation with a tip at the top than with a flat top
- However, this leads to a conflict with ECAL endcap module structure and square insert

Orientation



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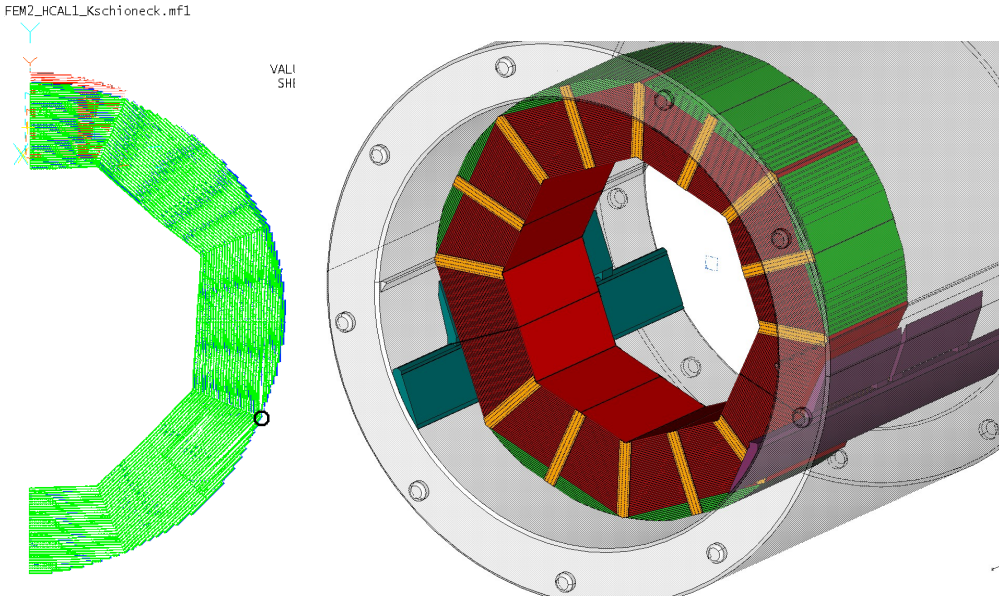

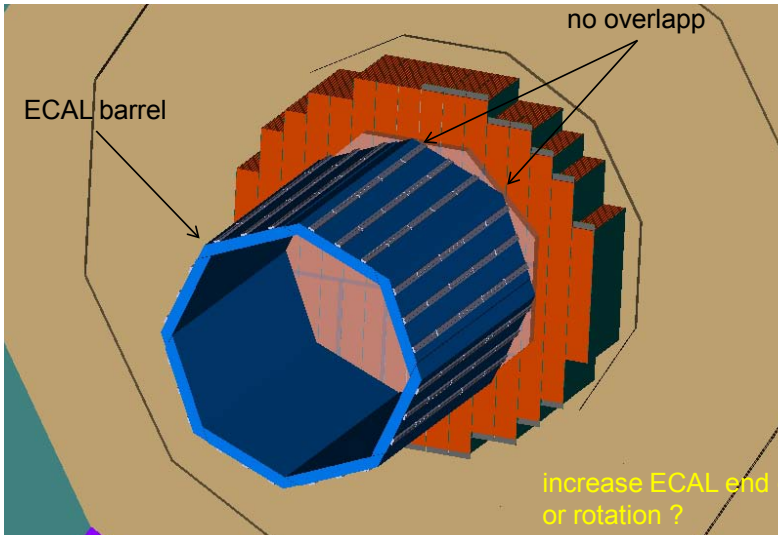

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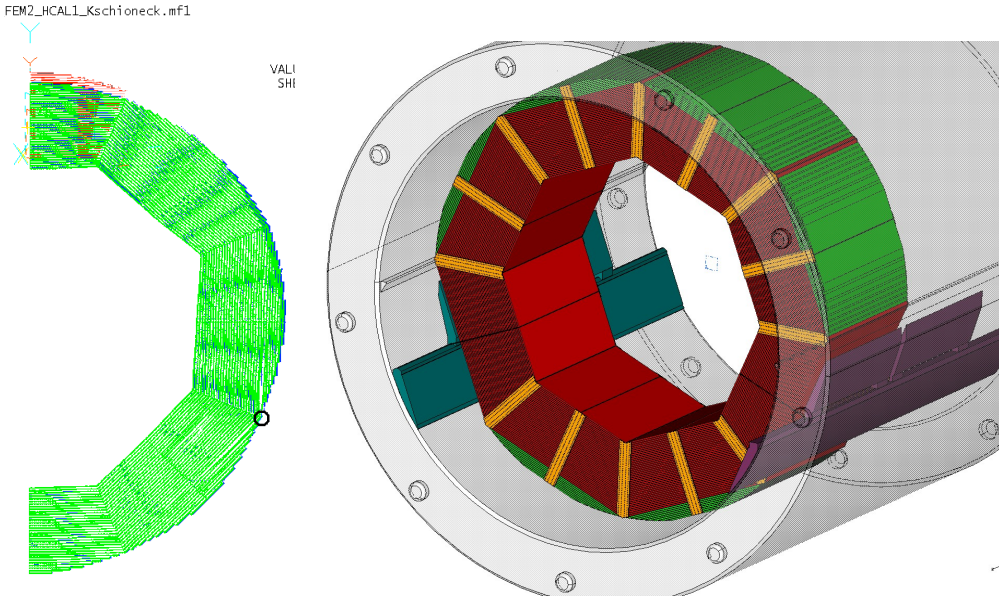

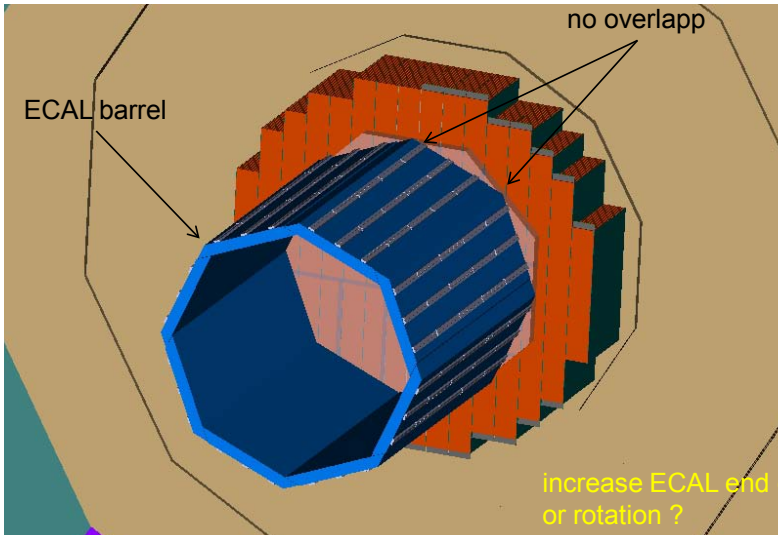

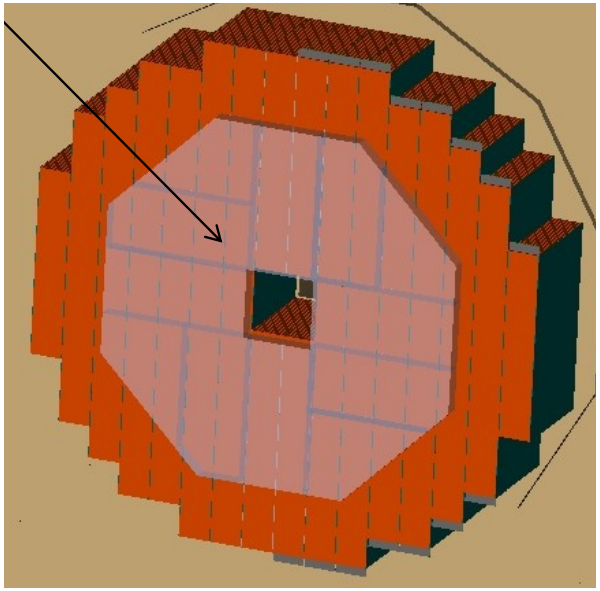

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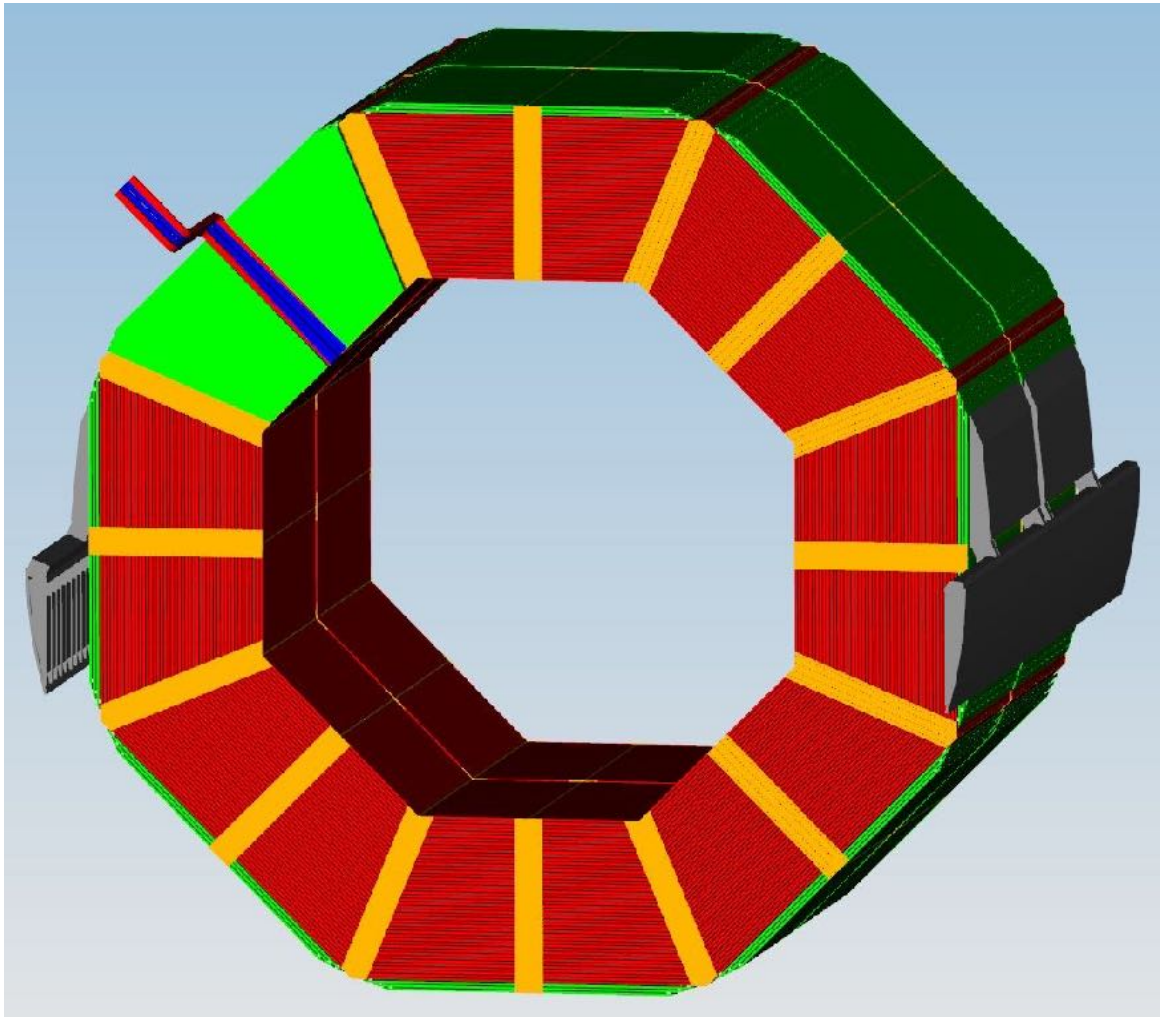
Alternative

- Integration into cryostat OK
- Stability calculation to be re-done
  - with smaller radius
  - possibly thicker plates



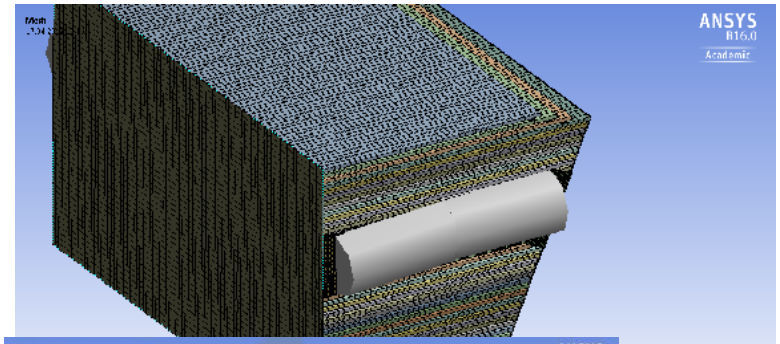
Stability

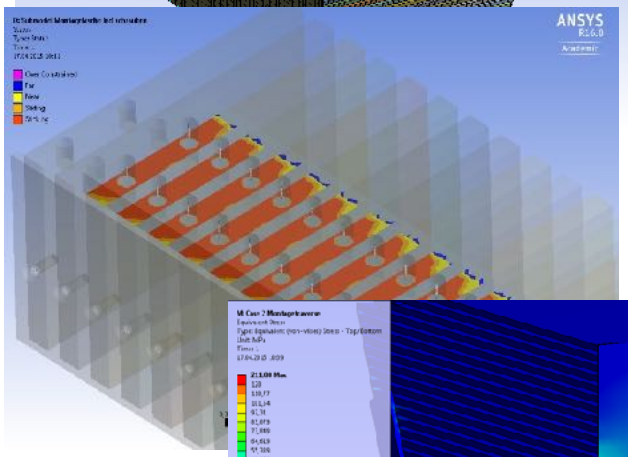
- Stability of modules for transportation and handling
- Stability of barrel structure - static
- Stability of barrel structure - dynamic

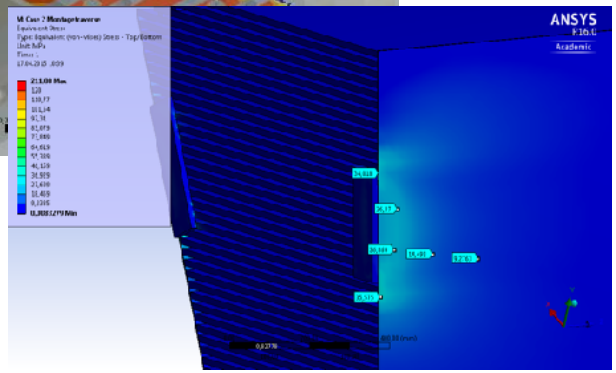
ANSYS model

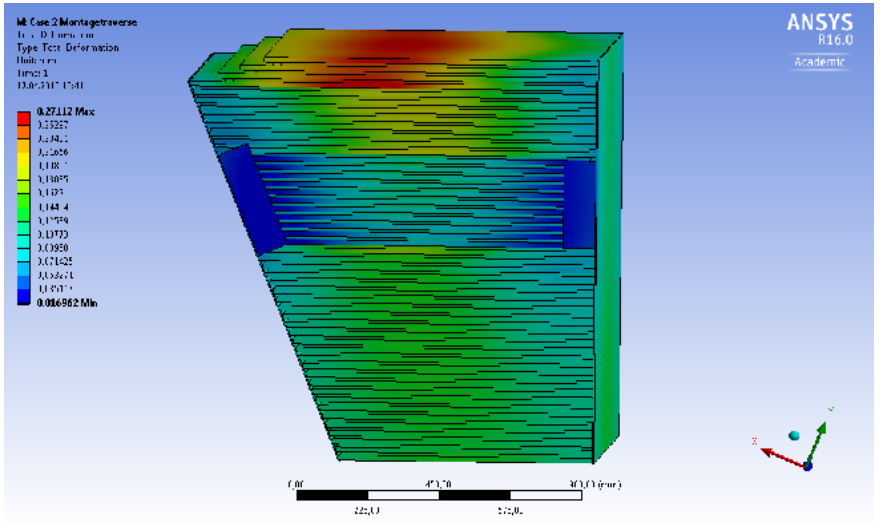
- Parameters for submodule validations:
- Mesh types:
  - shell bodies for all plates
  - solid bodies for transportation and assembly brackets
- Mesh statistics:
  - ~ 575.000 nodes, 295.000 elements
  - refined local sub-models: 1.5M nodes, 870k elements
- Contacts:
  - bonded contacts (all DOF fixed) on lines and faces of shell bodies
  - bolts modelled as spring elements in refined sub-model in case of high load concentrations

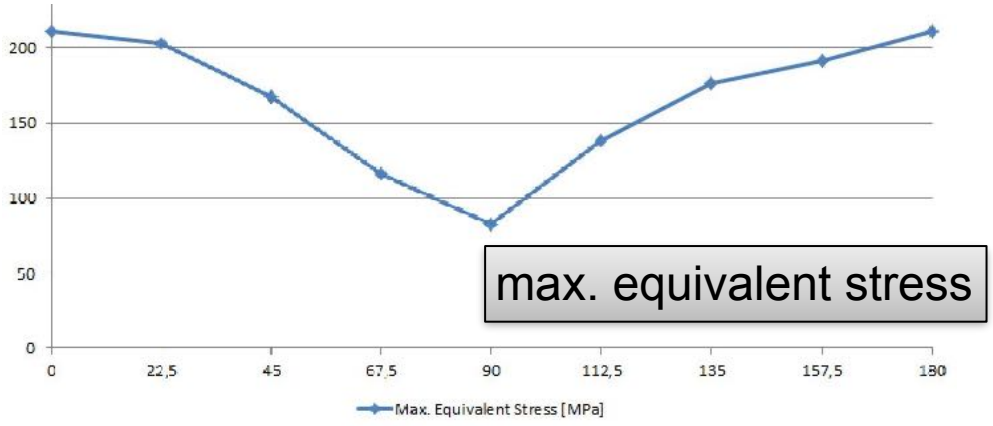
Module installation







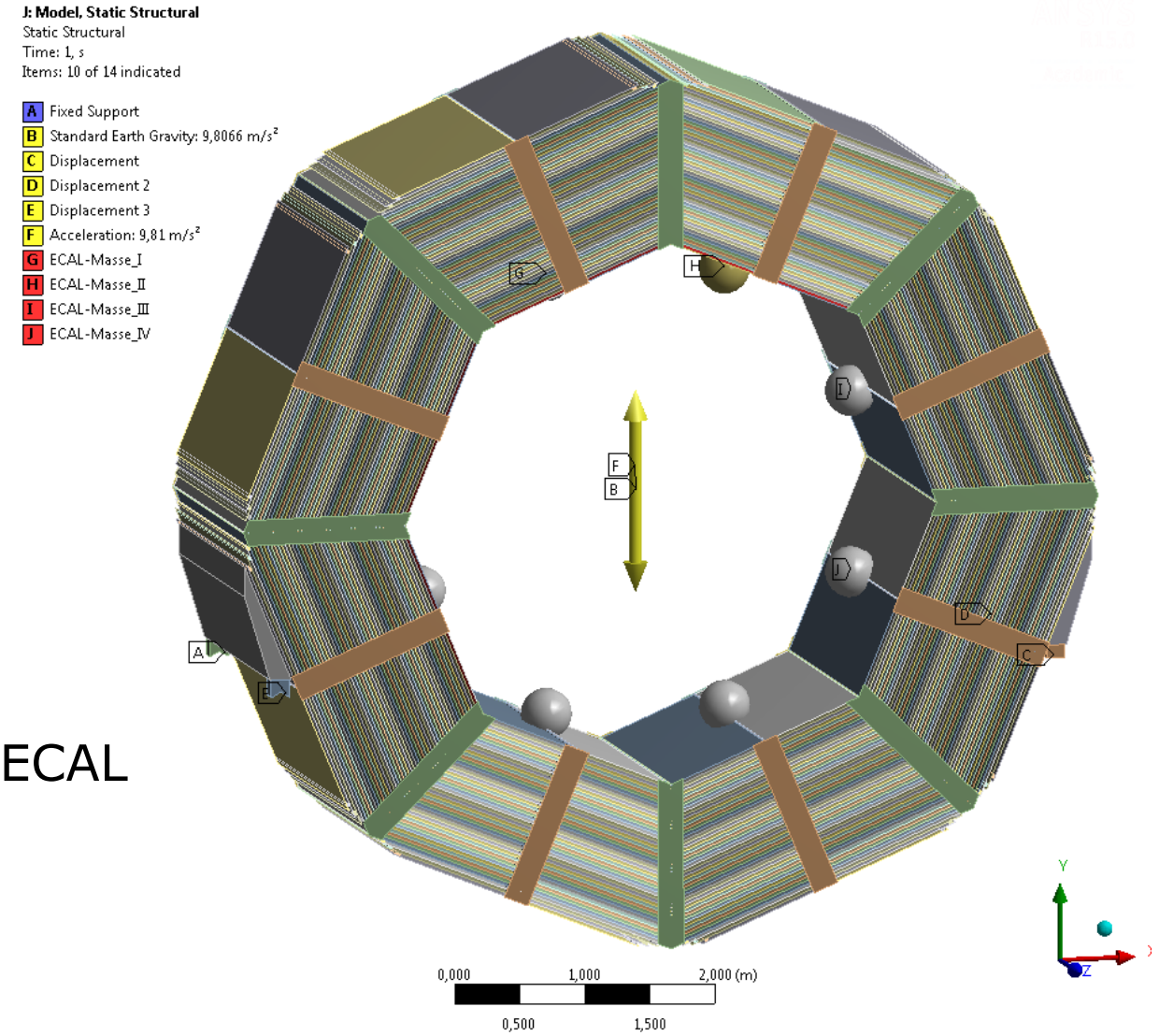




max. equivalent stress

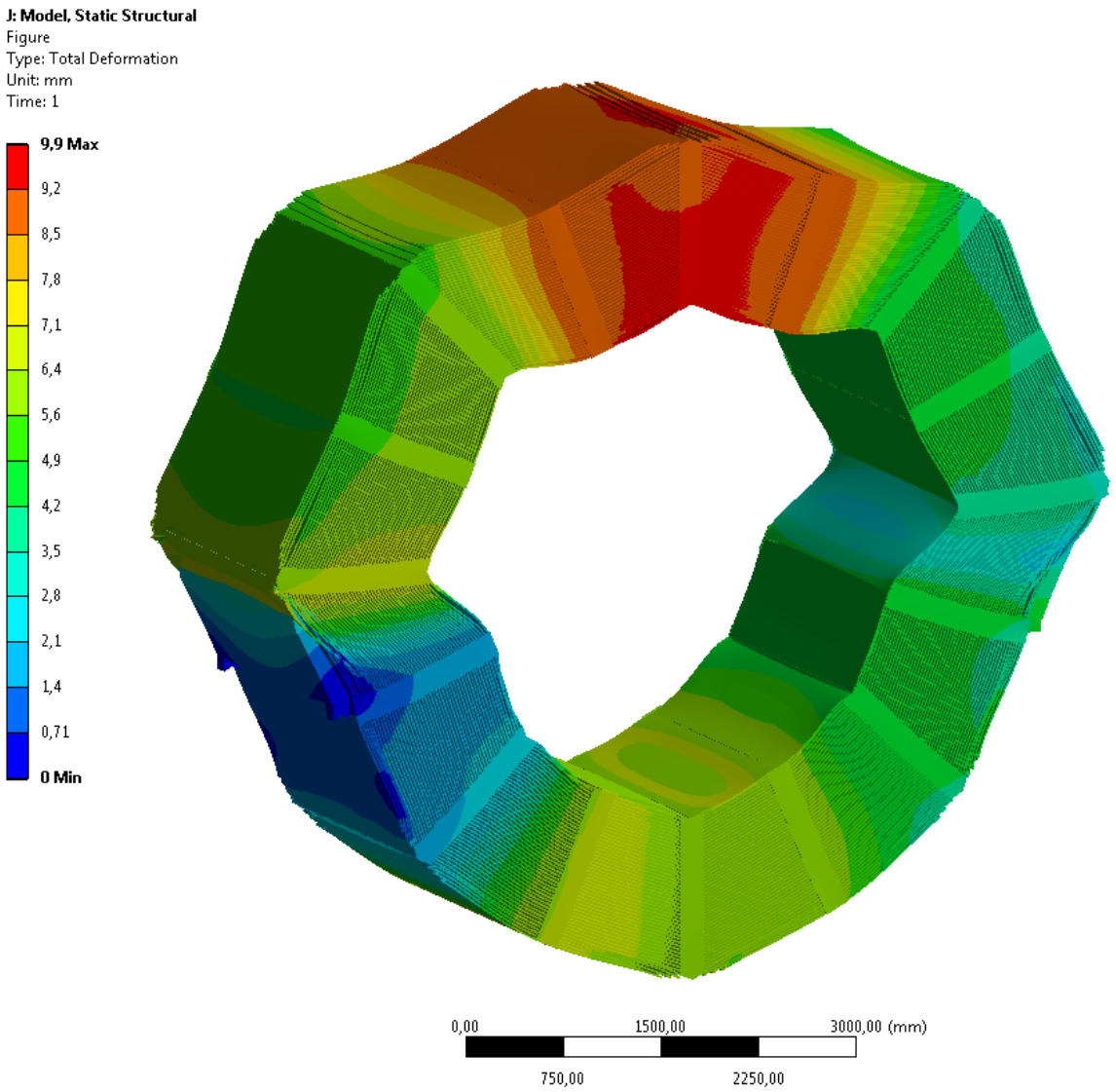
- need some modification of module connection pates

Ring structure



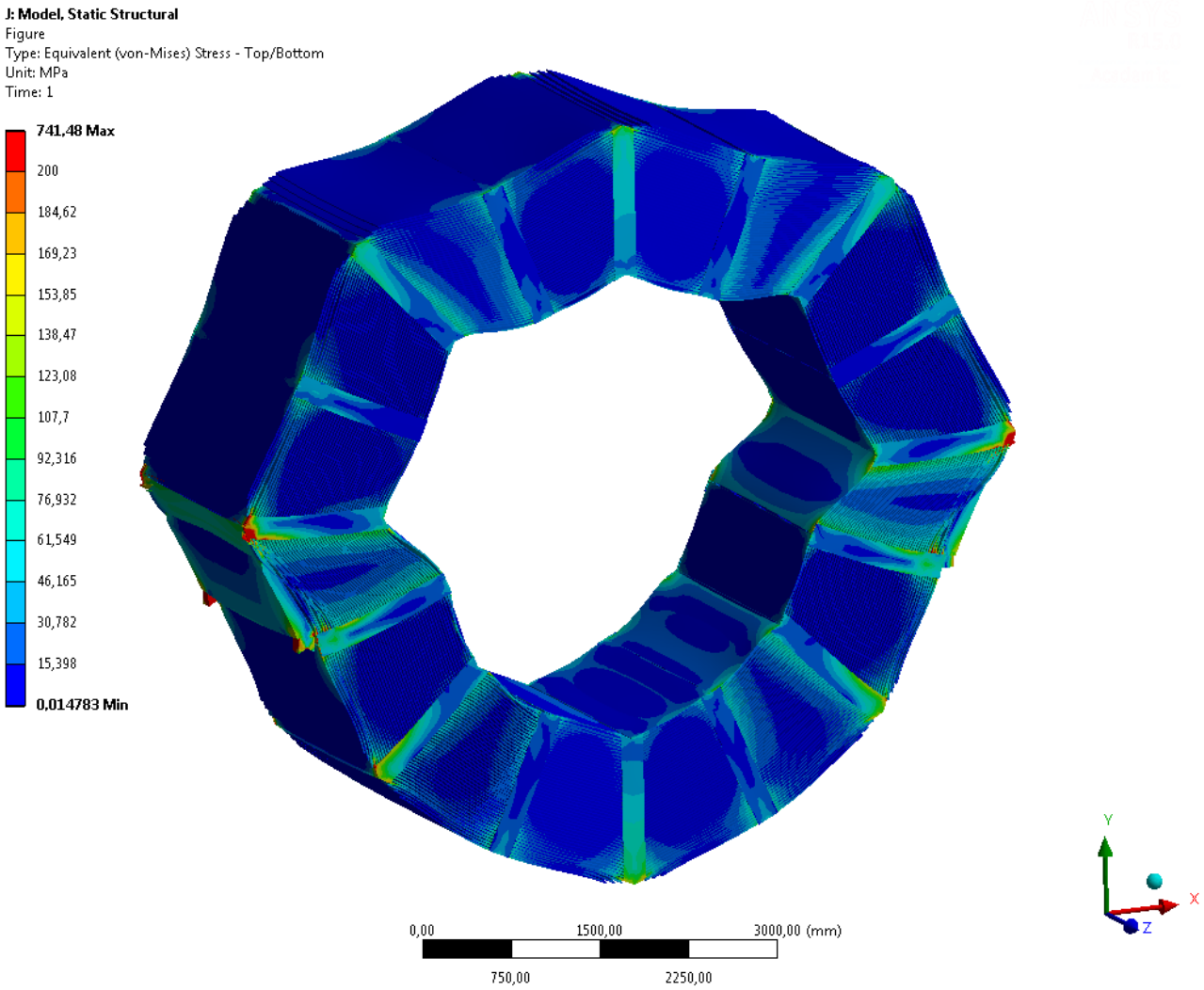
- model includes ECAL masses

Ring deformation



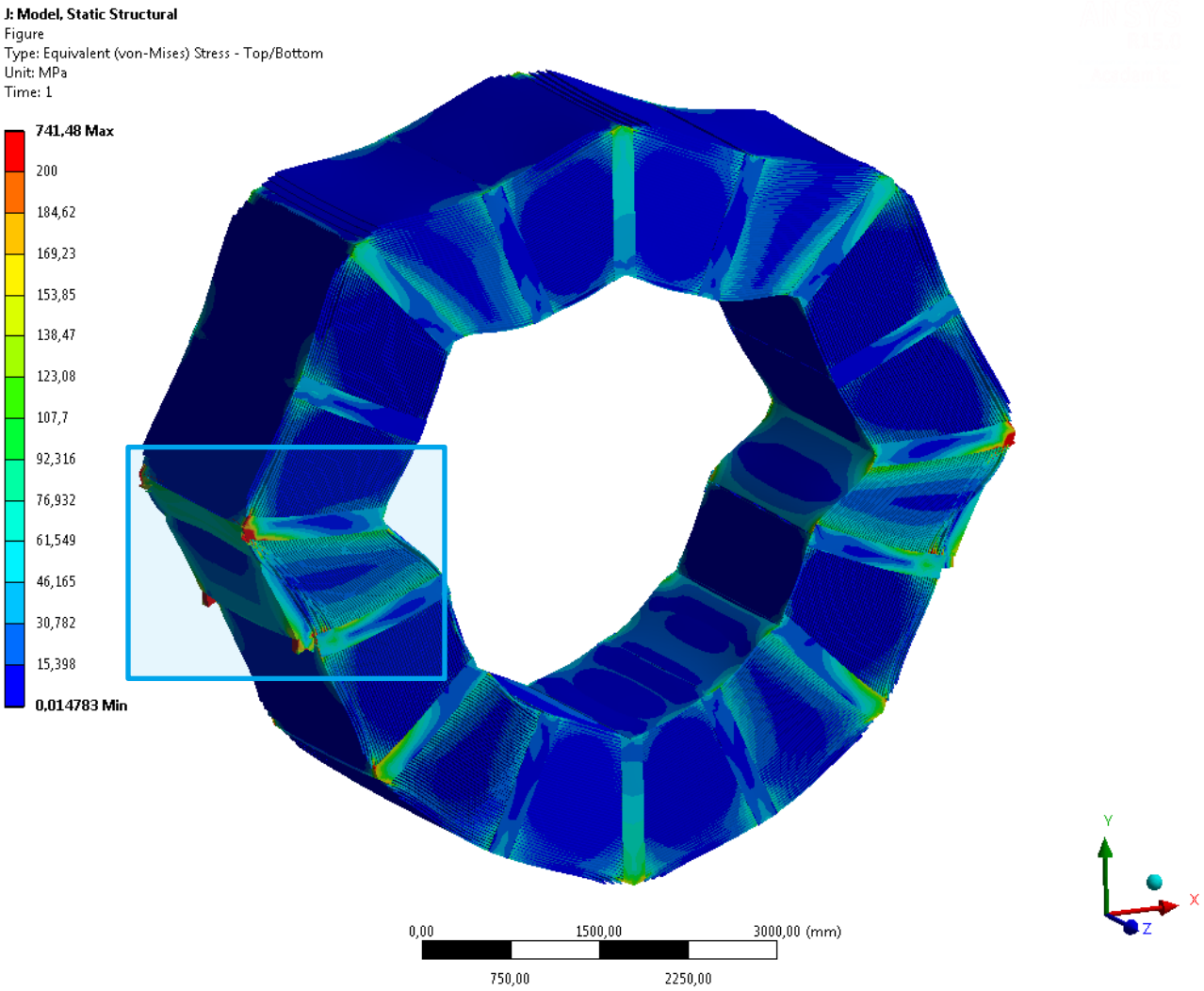
- max 10 mm

Local stress peaks



- max tension 360 N/mm^2 - safe

Local stress peaks



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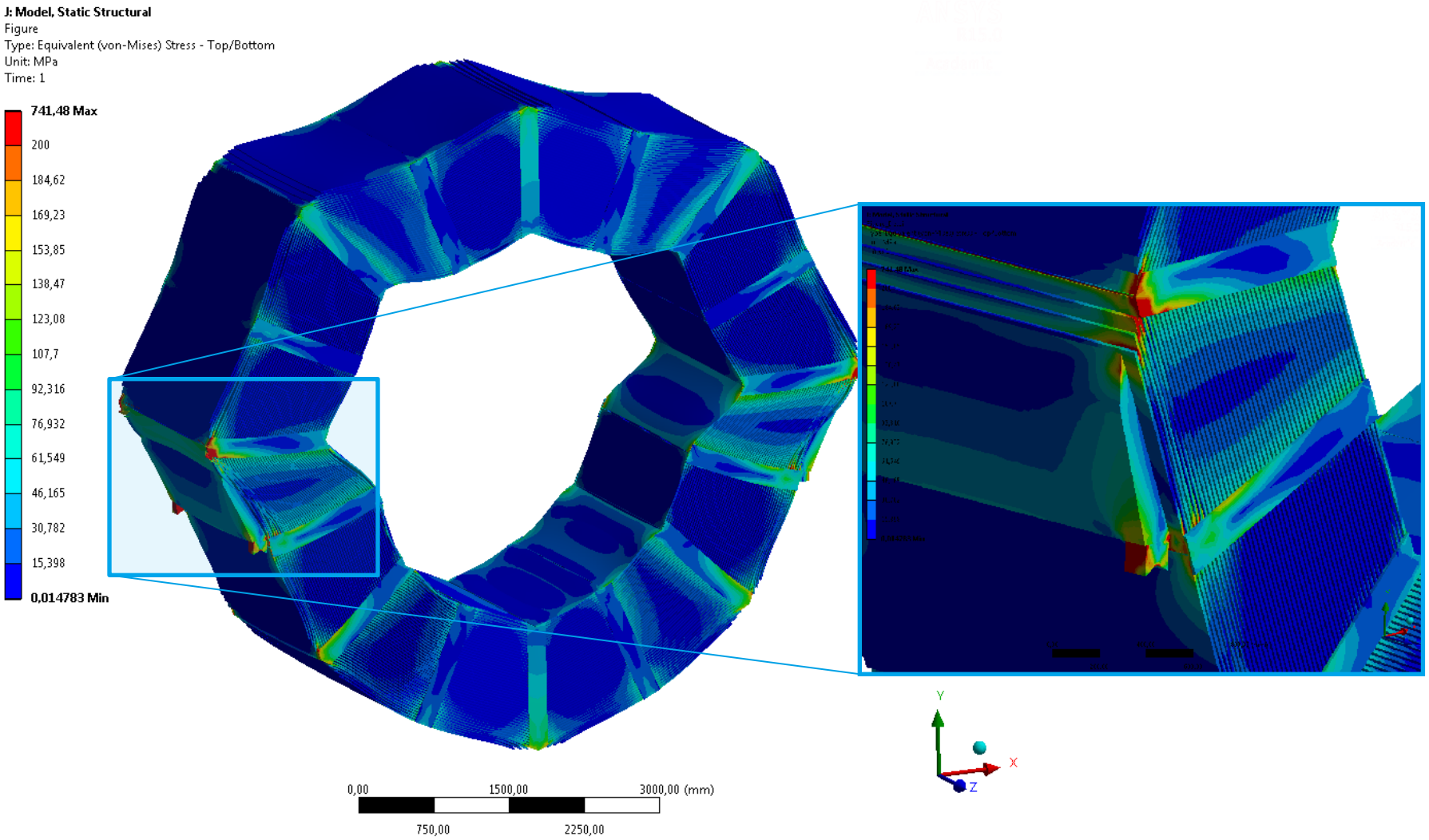
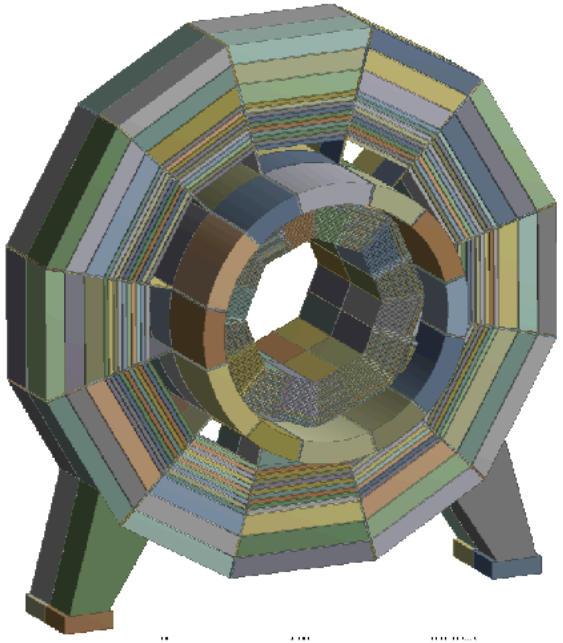
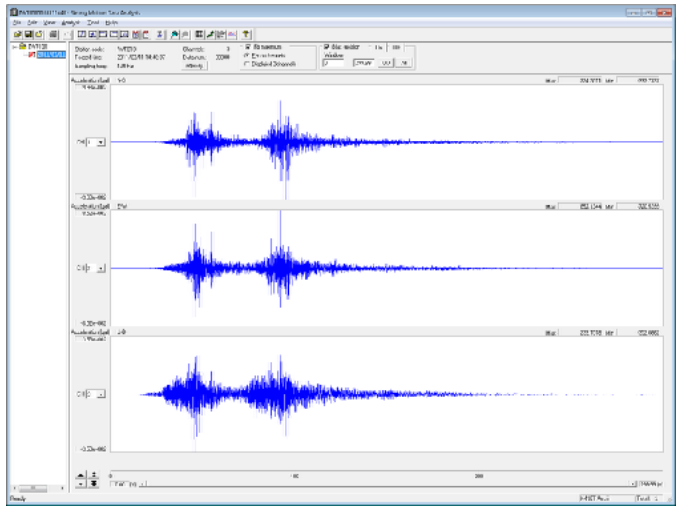


- max tension 360 N/mm^2 - safe

Dynamic stability

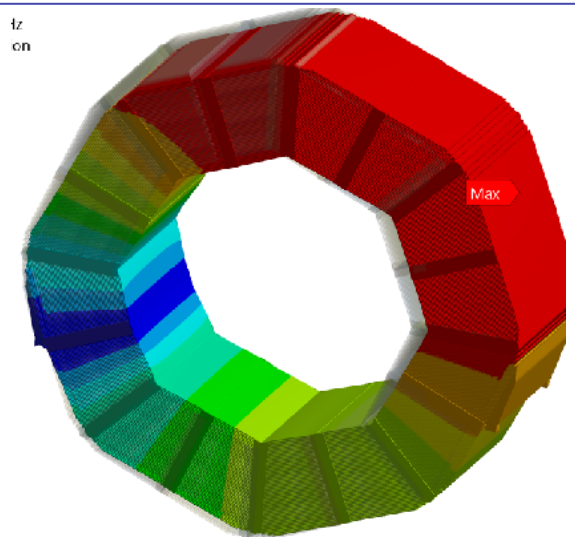
- In principe one needs to study the entire system of yoke, cryostat and HCAL
- Not enough details known: assume rigid transmission of excitation forces to HCAL and study HCAL alone
- Steps:
  - eigen mode analysis
  - response spectrum (with damping)
  - excitation with real earth quake wave form
    - East-West 0,36 g
    - North-South: 1,02 g
    - Vertical: 0,36 g

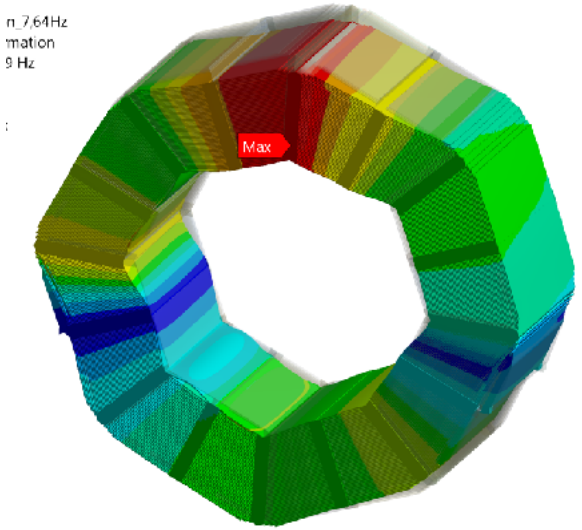


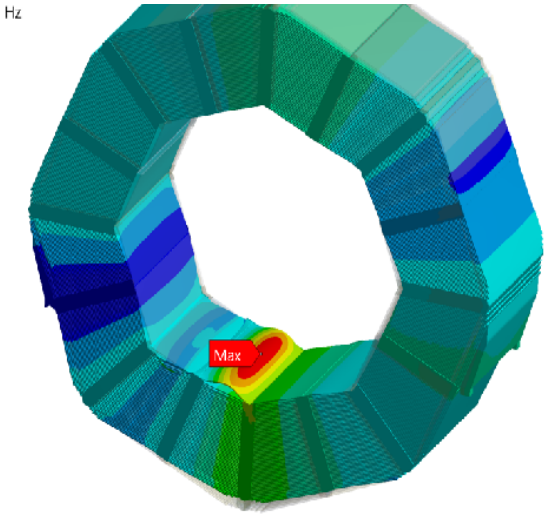


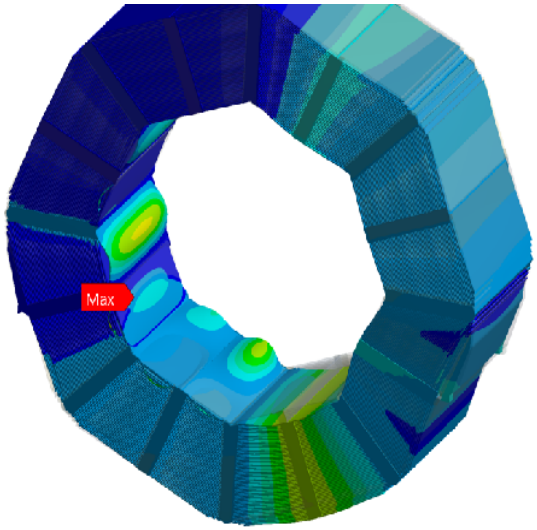
Eigen modes

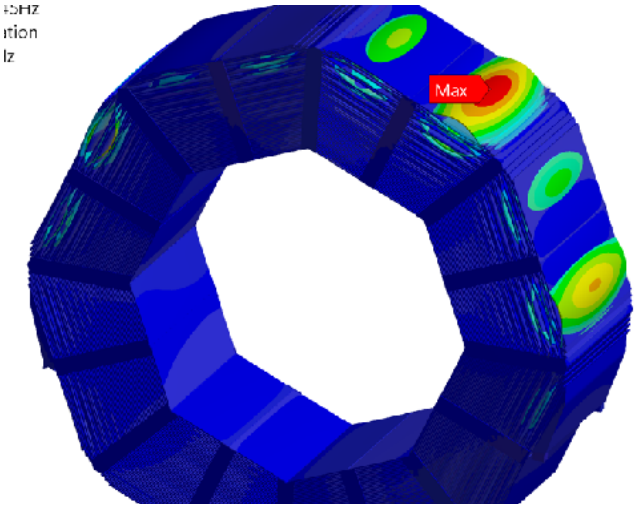
- Swinging barrel: 3Hz
- Swinging module: 8Hz
- Swinging plate: 6Hz
- Higher modes: 15 Hz
- Several plates: 45 Hz





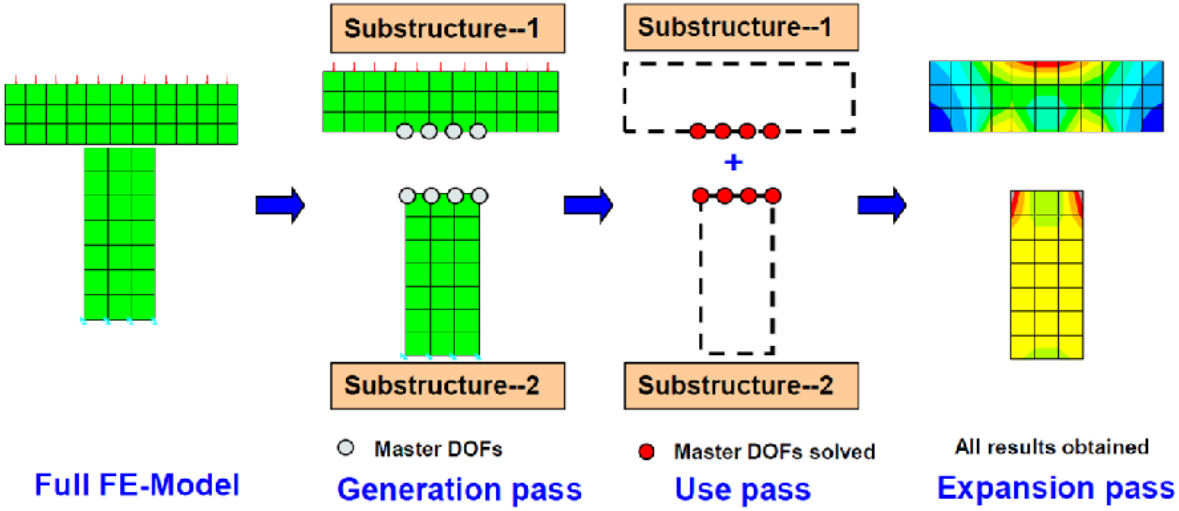






Status

- Calculations with full model are time-consuming and produce large data volumes
- Alternative approach: sub-structuring
  - CMS: component mode synthesis
- Status 4/2016: validated against full shell model for deformations and eigen-modes
- Resumed fall 2016. following parental leave of key engineer
  - common project with DESY central mechanics service



Ongoing activity and plans

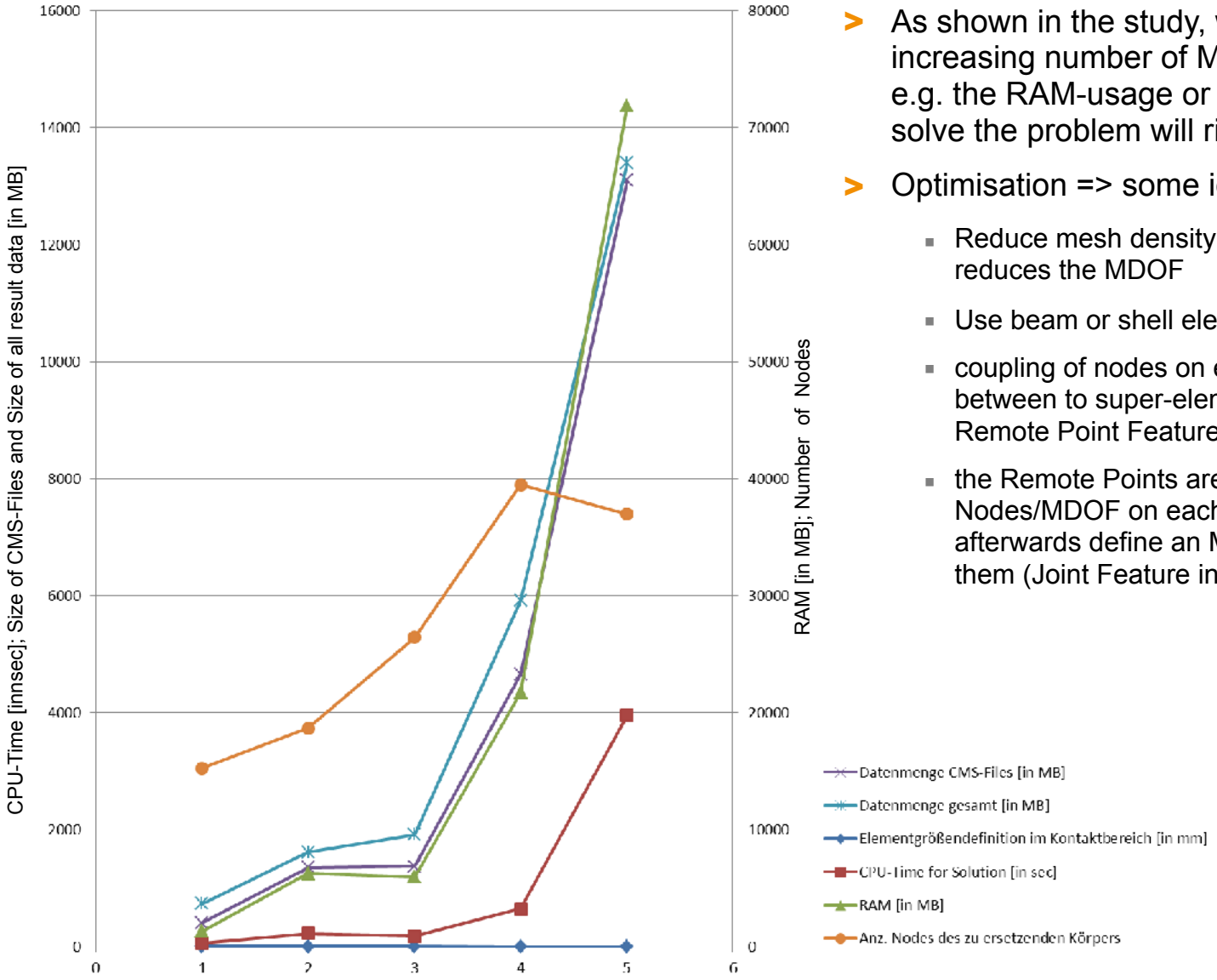
- Substructure approach validated with simple toy model
- Code and data handling have been re-organised
- Collected lots of experience
- Currently being tested on a wheel-type toy model
  - optimisation of connecting nodes
- Hope to return to full HCAL structure soon

- Once method is established, study Roman orientation and variants of overall detector radius, etc

- Will probably have to wait until then for quantitative comparison with LLR results

- Progress is slow (< 0.2 FTE)

Tested: Optimisation by reducing MDOF on interfaces



- As shown in the study, with linear increasing number of MDOF on Interfaces e.g. the RAM-usage or the CPU-Time to solve the problem will rise exponentially
- Optimisation => some ideas:
  - Reduce mesh density on interfaces directly reduces the MDOF
  - Use beam or shell elements to reduce nodes
  - coupling of nodes on each contact face between to super-elements with the help of Remote Point Feature in ANSYS
  - the Remote Points are used to create Master Nodes/MDOF on each contact site and afterwards define an MPC-contact to couple them (Joint Feature in ANSYS WB)

News – Modelling techniques

- in a previous study it is shown, that the number of defined Master DOF has a significant influence in model size and solution times
- Nodes-Coupling of common face with the use of ANSYS-Workbench features:
  - user defined coordinate systems for each face, on which the nodes have to be coupled => The position of COS depends on the underlying geometric face. Therefore geometric changes/updates are easier to manage
  - Remote-Point Feature in ANSYS Workbench is used to couple the nodes on one common face – internally a surface to node contact is built
  - the Joint Feature (fix joint) is used to couple the adjacent remote points of two superelements – internally a MPC-Formulation is used (MPC = Multi Point Constraint)

News – Result data management

- in past analyses we had problems with huge result files (for Modal Analysis up to 400 GB)
- one part of the problem is the number of Master DOF in an analysis
- a second part is the type of result data, which is needed to do an appropriate post processing of dynamic FE-Models
- a simple test model shows the influence on requested result type in the analysis set up
- the following table shows different result file sizes of the test model

	Only Displacement	Nodal Forces, border	Nodal Forces, all
Static	9 MB	36 MB (+300%)	42 MB (+366.7%)
Modal	6 MB	23 MB (+283.3%)	40 MB (+ 66.7%)
Harmonic	213 MB	872 MB (+309.4%)	1 GB (+ 369.5%)

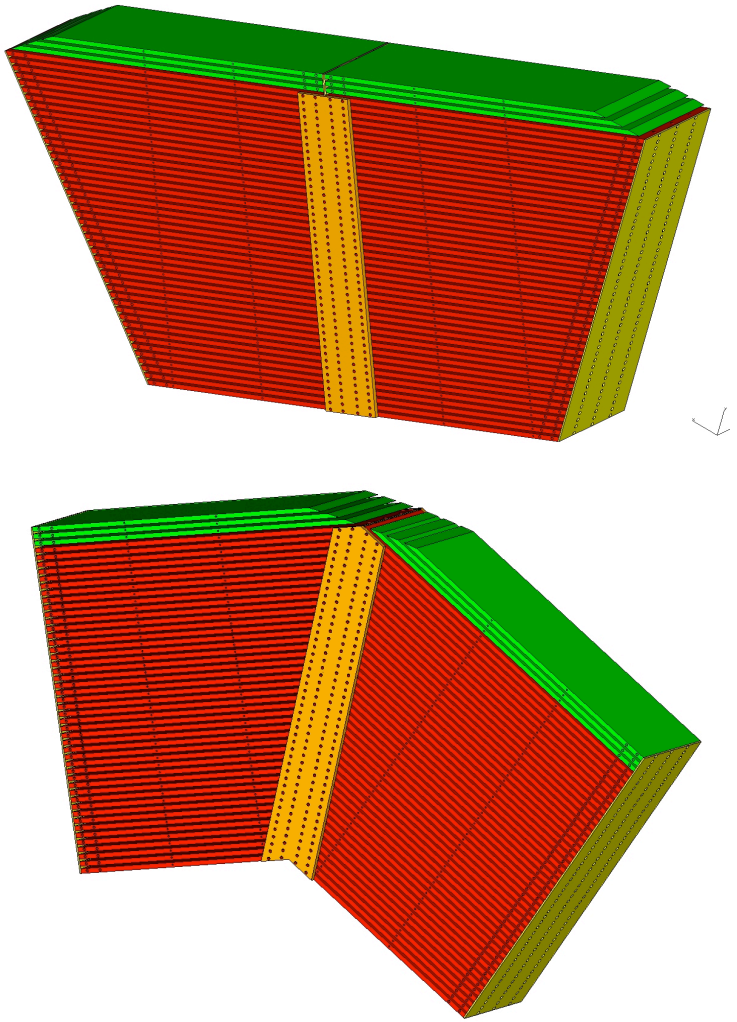
- Ideal plan: solve the dynamic models of the AHCAL-Structure only with the displacement results stored
- with the help of displacement results on supports, parts, contacts, more detailed FE-Models can be built (e.g. only few segments) to study the stresses/strains in the structures (sub-modelling technique, too)

Summary (calculations)

- The AHCAL structure has evolved considerably from the old TESLA design
- Optimised for scintillator
  - access to electronics and power interfaces
  - small units for transport and assembly
  - cost-effective
  - small un-instrumented regions
- Integration with ECAL on the way
- Improved stability with smaller radius and possibly thicker plates expected
- Dynamic stability evaluation on-going, no show-stoppers so far, but challenging and time-consuming

Possible test configurations

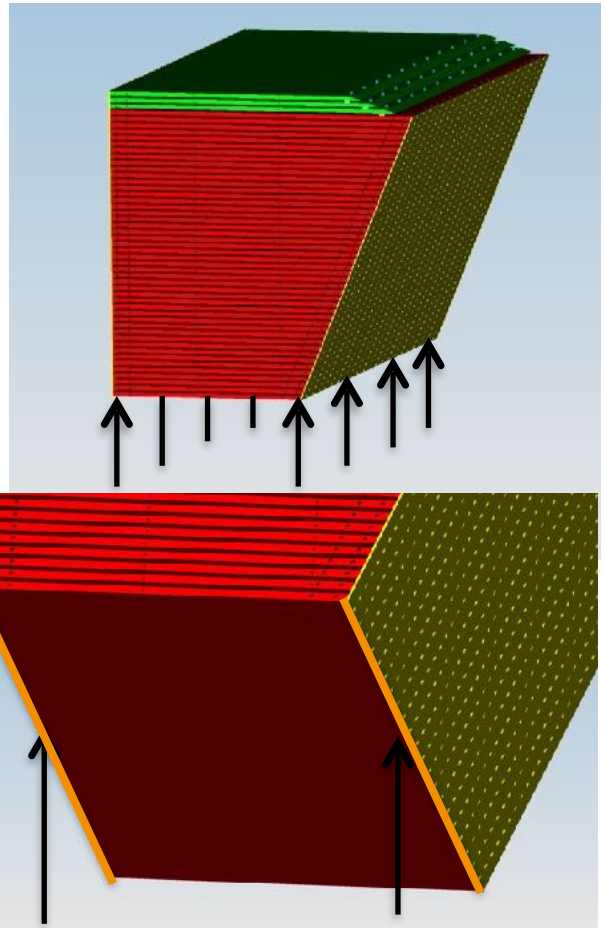
- For dynamical stability studies
- For test beam validation of dead material corrections

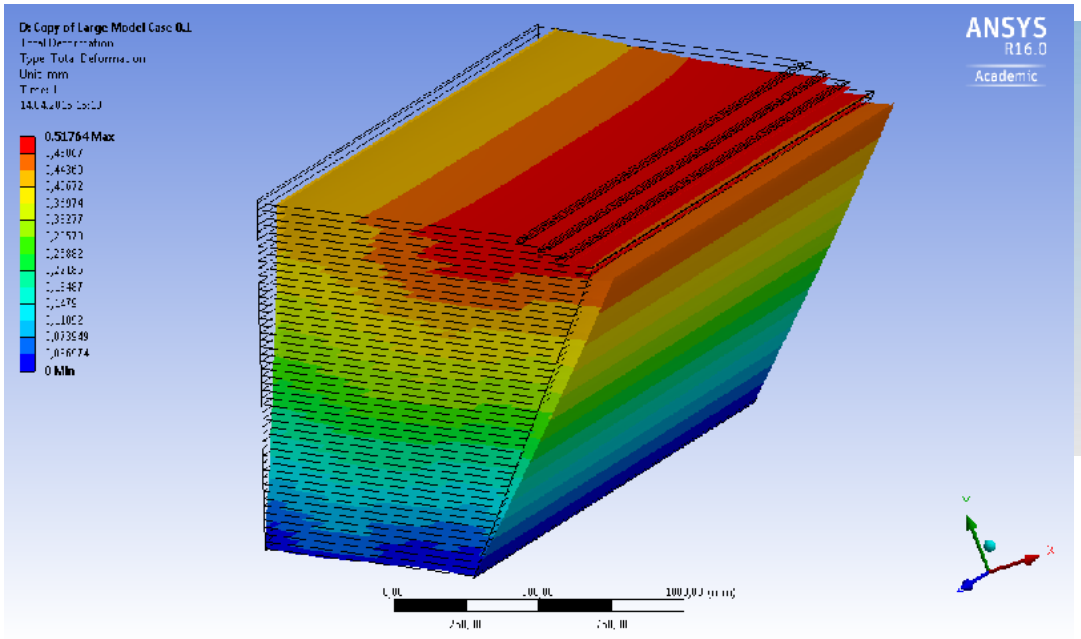


Backup

Module support

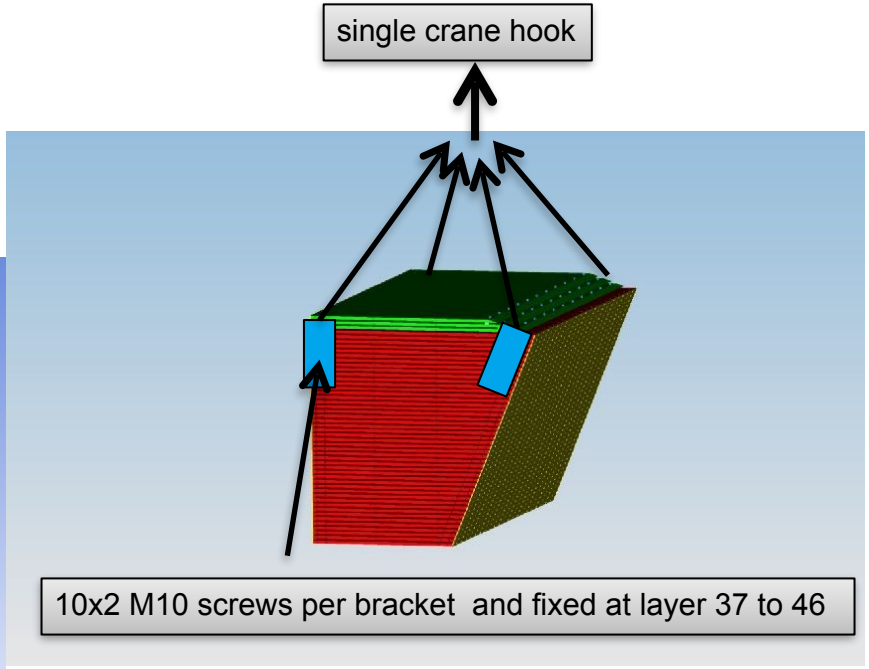
- During assembly and active layer integration
- Prefer support at the side plates
  - foresee overlap of 3mm for safety

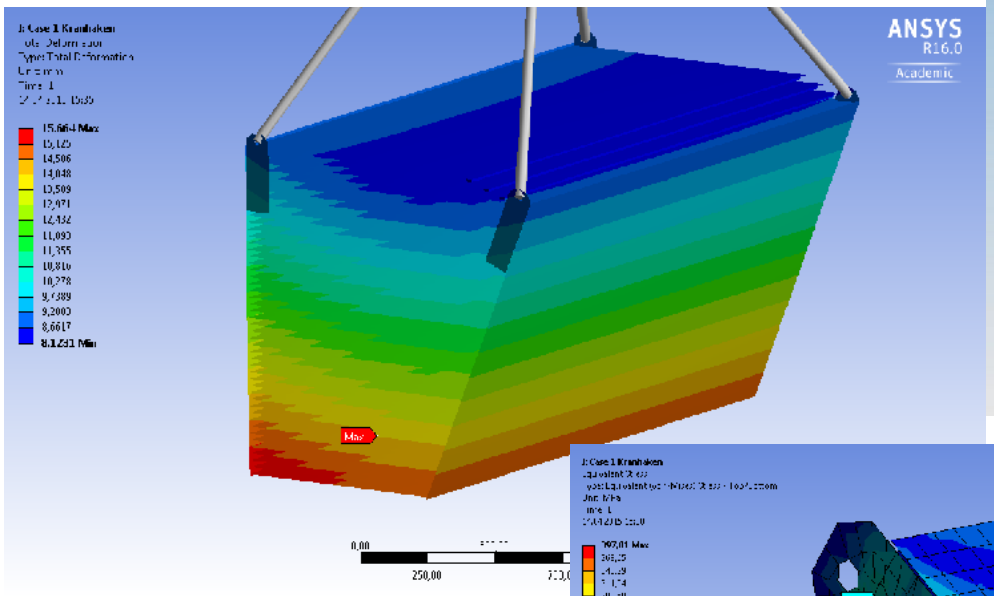


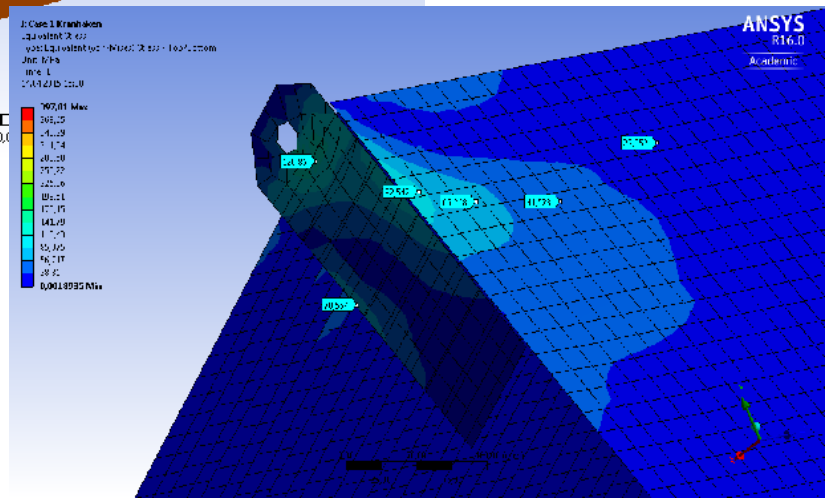


Module transport

- possible with single crane hook

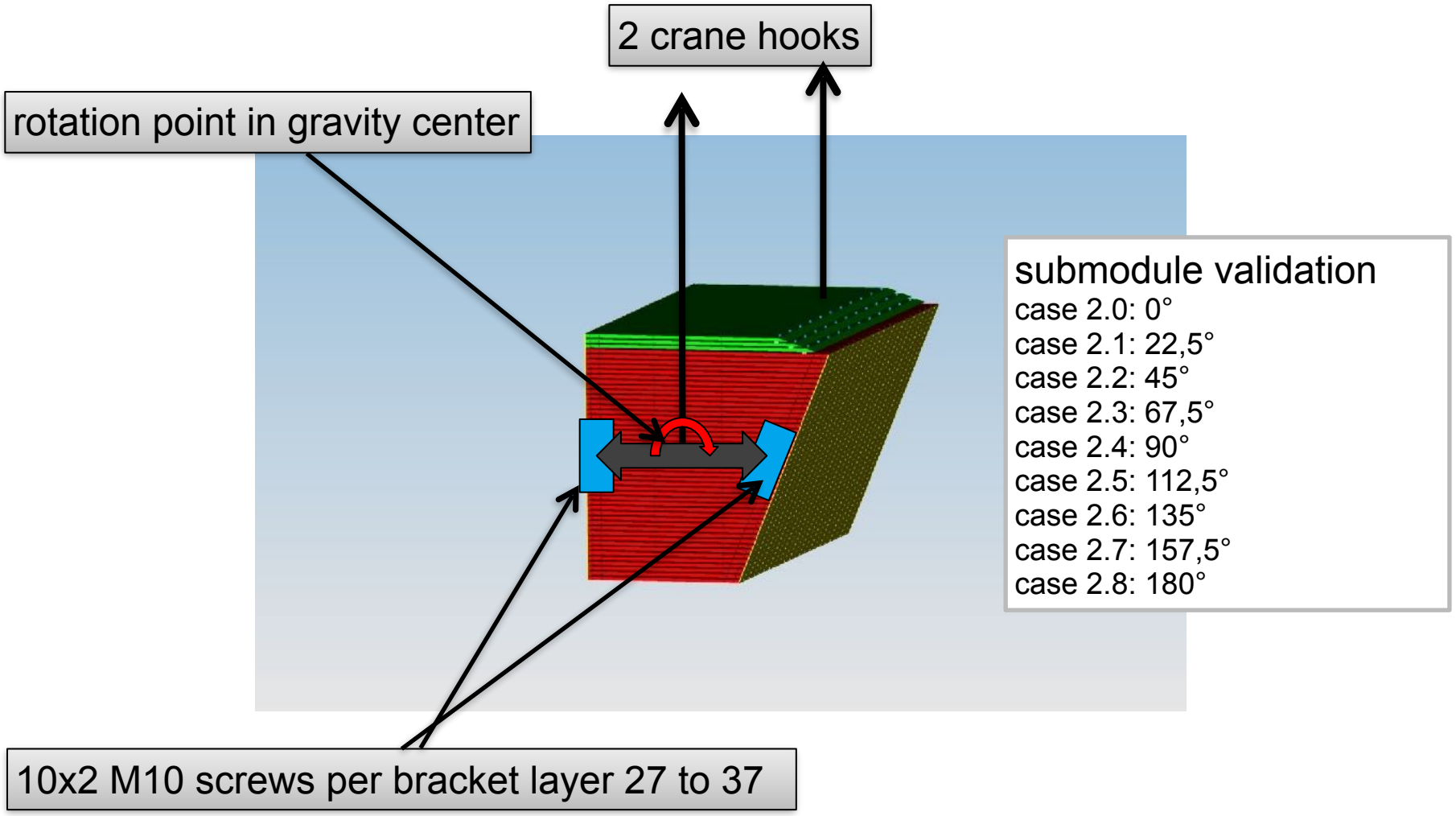


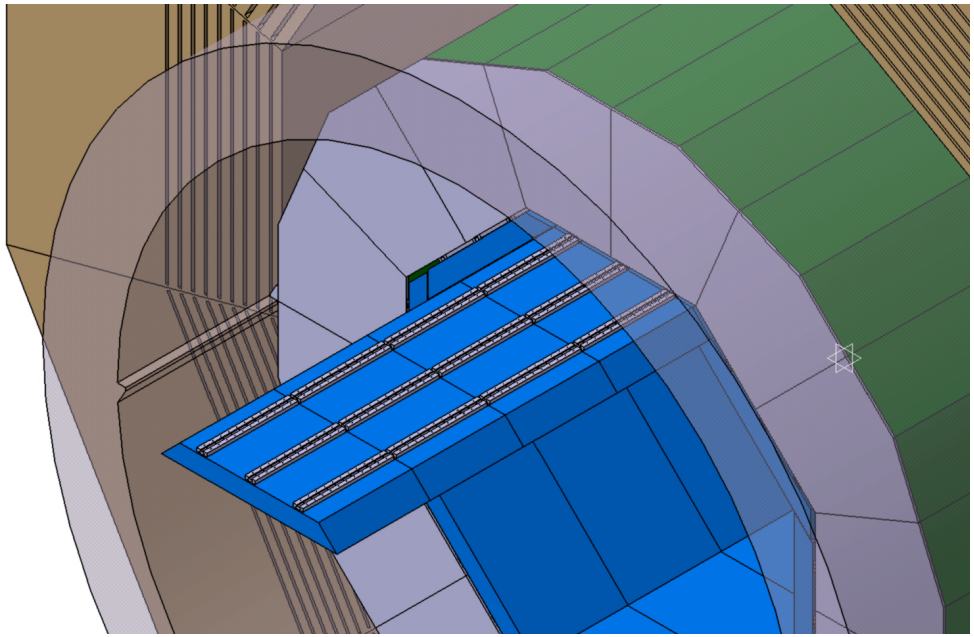




Module installation

- stable under rotation with mounting tool



ECAL HCAL barrel integration

- Weight of the ECAL is included in the stability calculations
- Plan to exchange ANSYS models to include ECAL substructure and details of fixation rails
- Depending on results, stiffness of HCAL front layers can be improved
  - spacers in first few layers, minimal impact on performance expected