Cryomodule Concept for the ODU RF Dipole Crab Cavity

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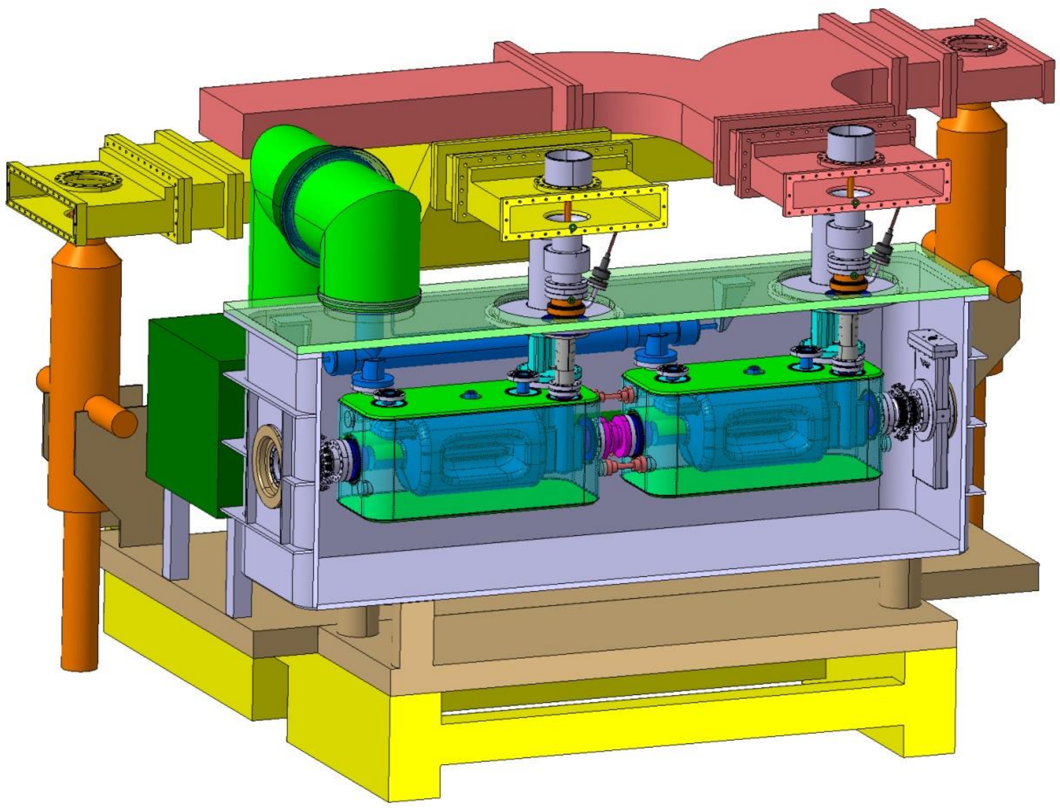
* With lots of help from HyeKyoung, Tom J, Shrikant, Ofelia, Luis, et al…

Still in the early stages

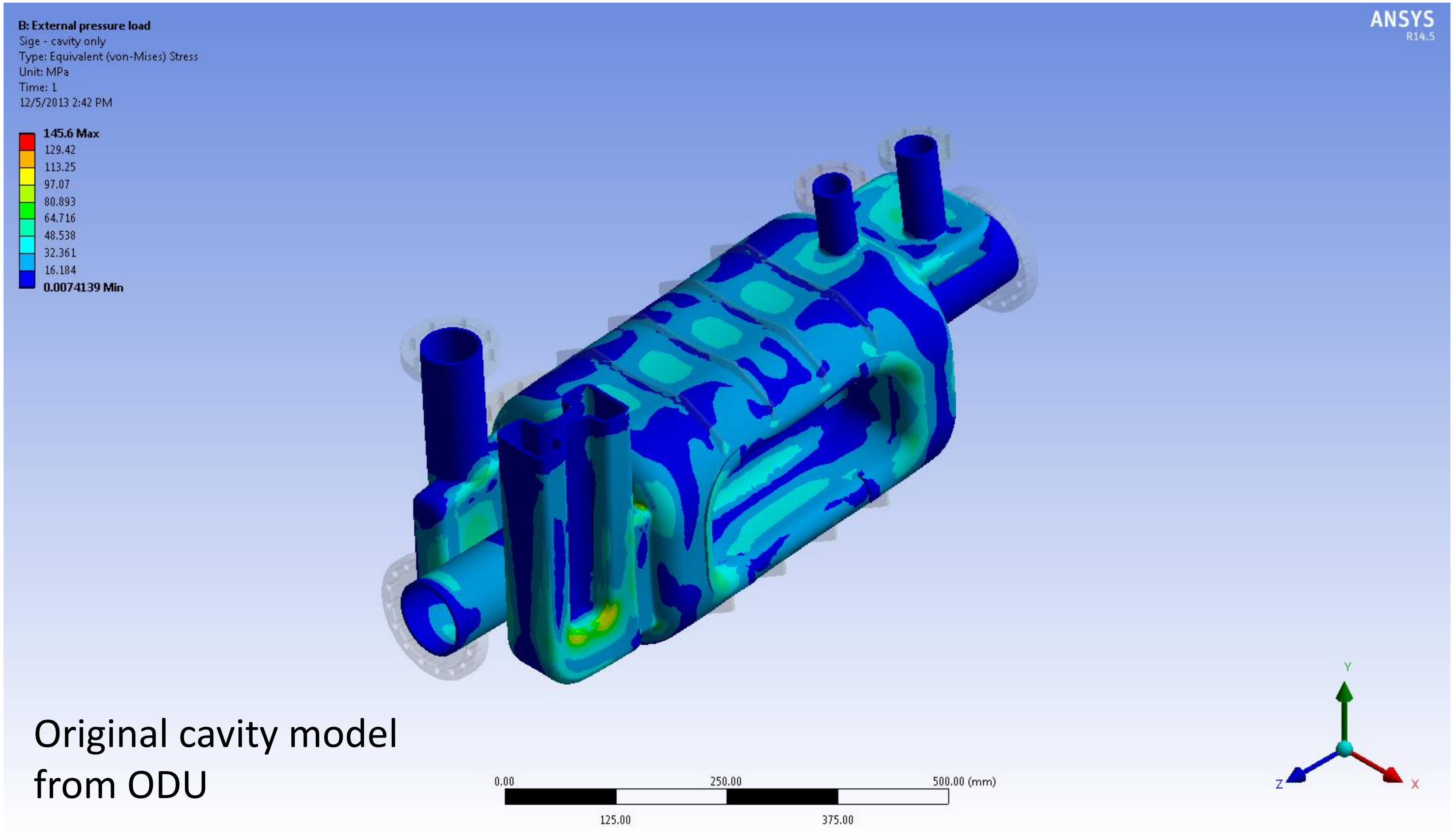
- Initial input from
  - Functional specification from CERN, especially integration into SPS
  - Cavity model from HyeKyoung
  - Presentation from Shrikant at November meeting
  - Meeting with Tom Jones at Fermilab
  - Integration solid models from CERN
  - Email correspondence with many
  - etc…

RFD cryomodule in SPS



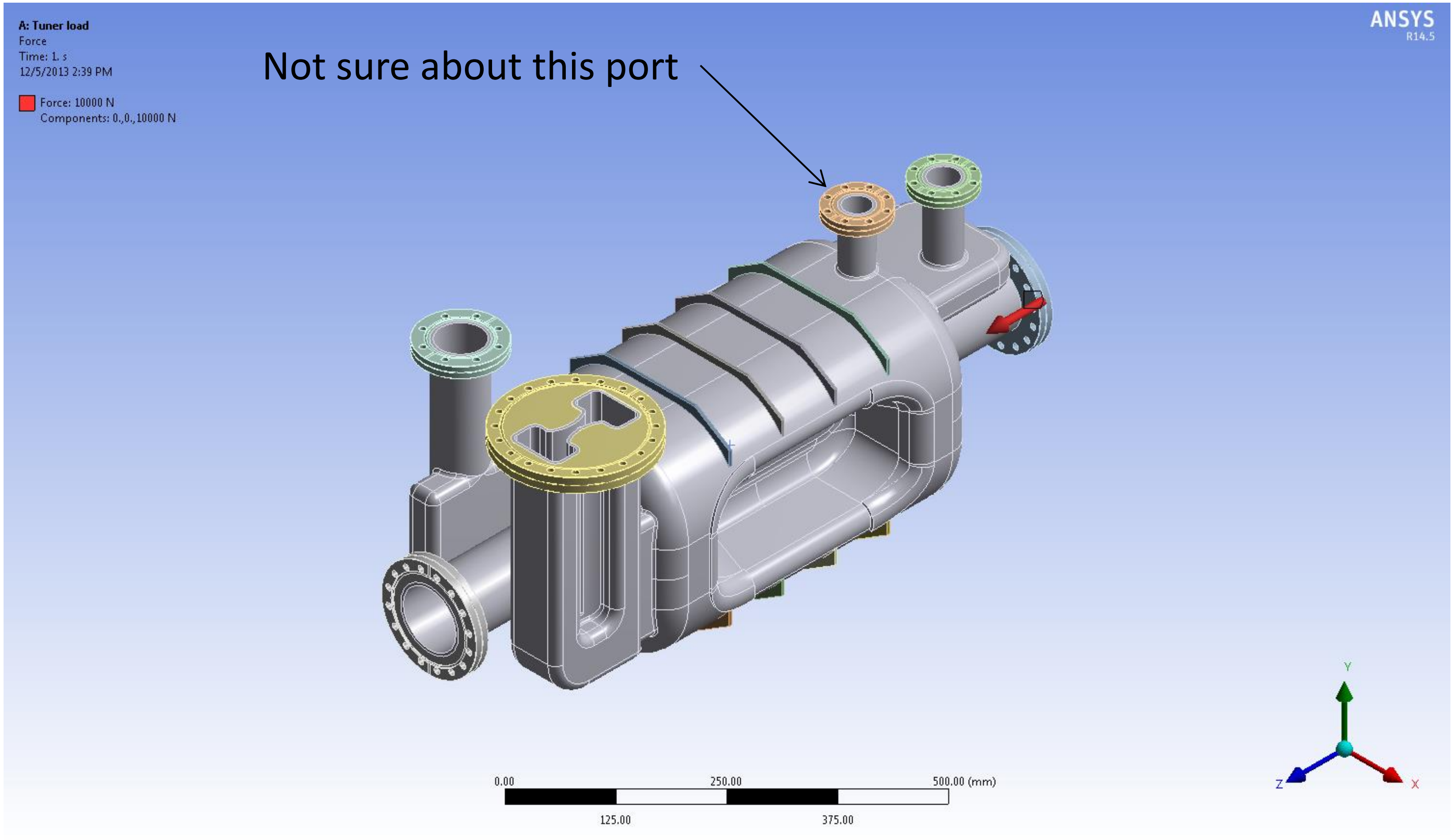
Cavity stress at 2.6 bar

Various cavity analyses to familiarize myself with the design

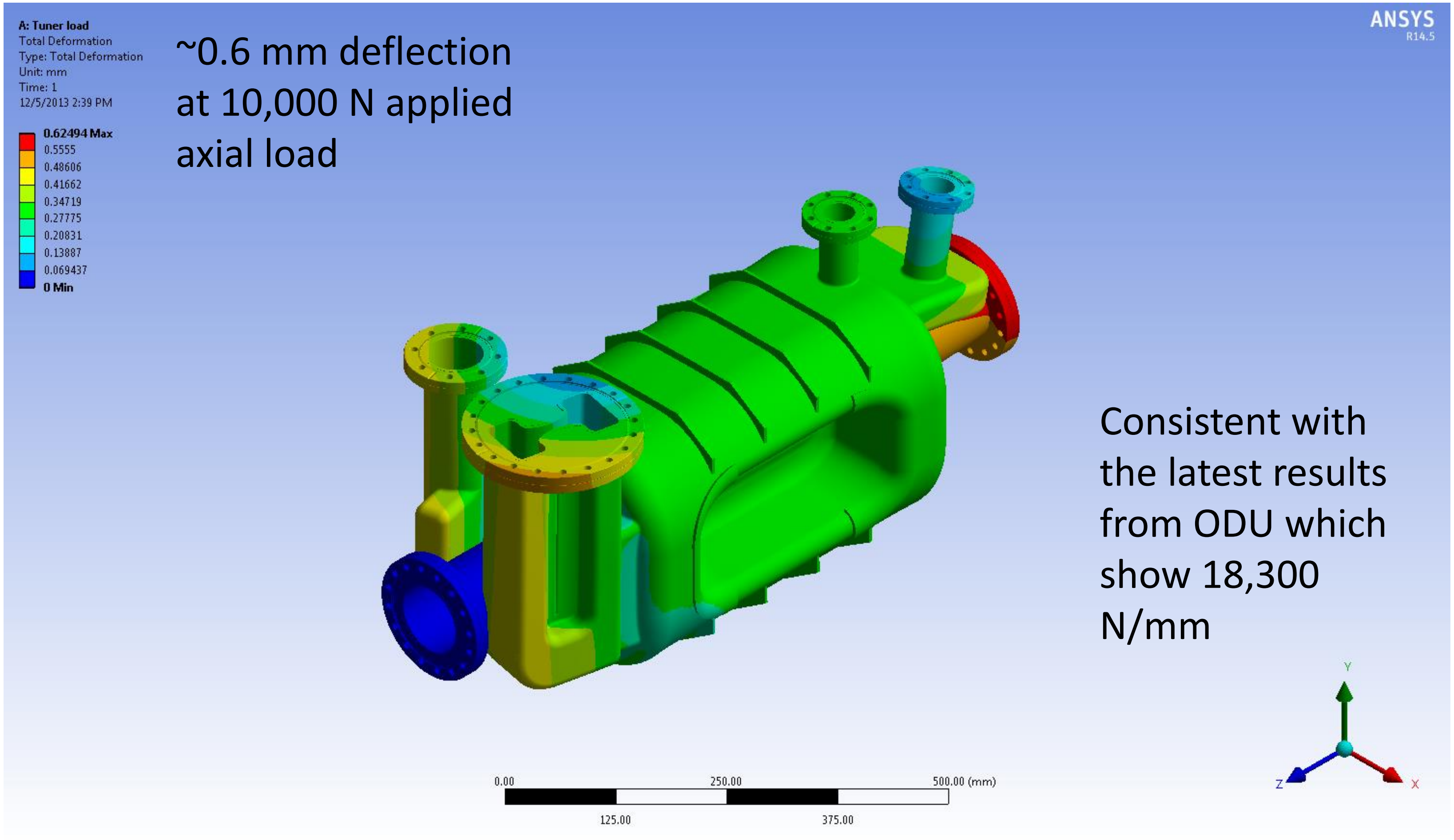


Original cavity model from ODU

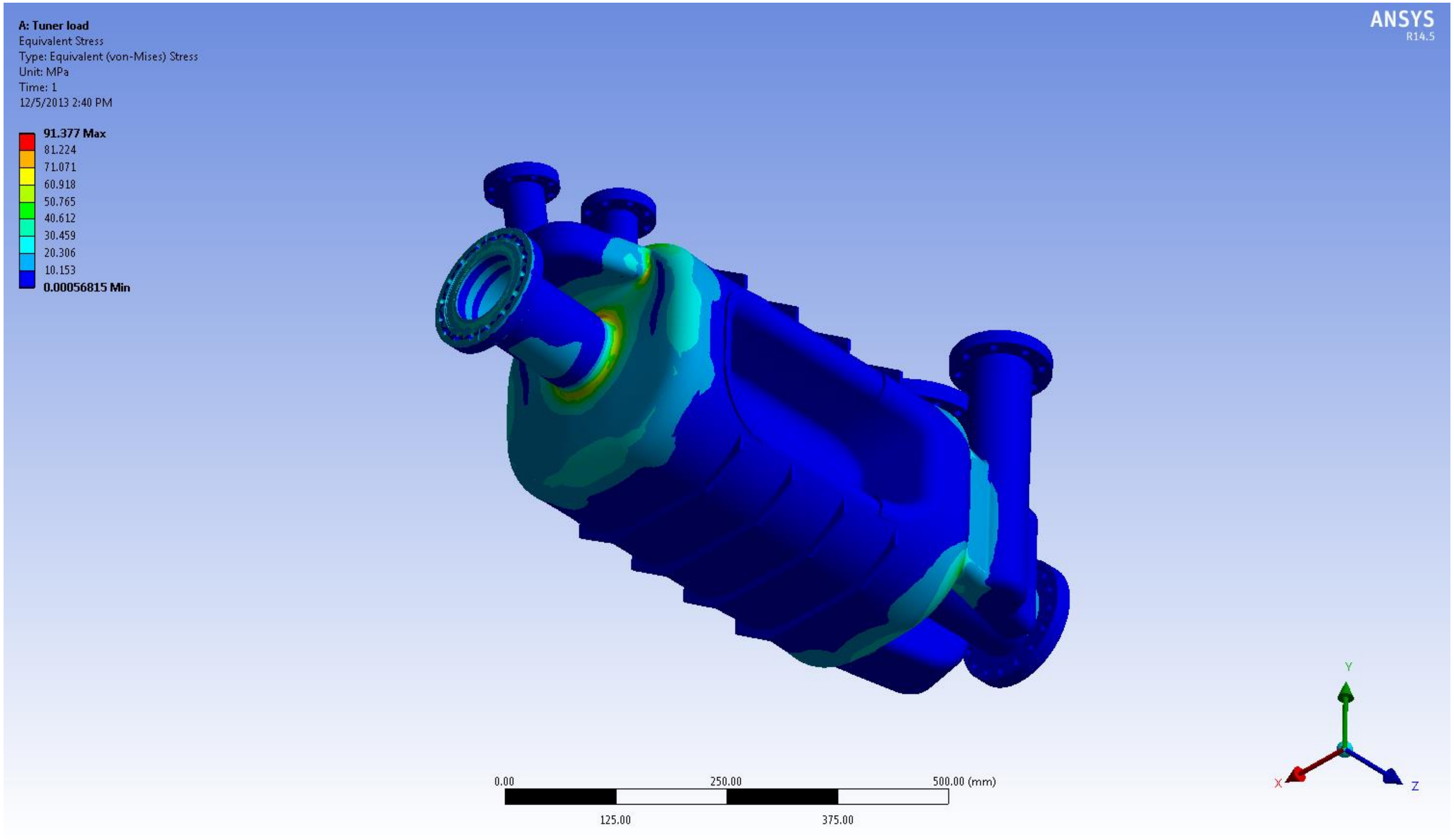
Cavity model – tuner load



Cavity displacement – tuner load



Cavity stress – tuner load



Example of ASME Code analysis

Protection against plastic collapse

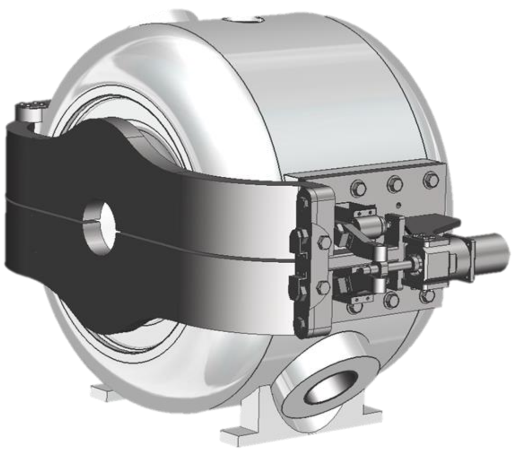
Protection against local failure

MAWP
>= 0.2 Mpa at 300 K
>= 0.4 Mpa at 2K

Protection against collapse from buckling

Protection against cycling loading (fatigue and ratcheting)

325 MHz spoke cavity at Fermilab



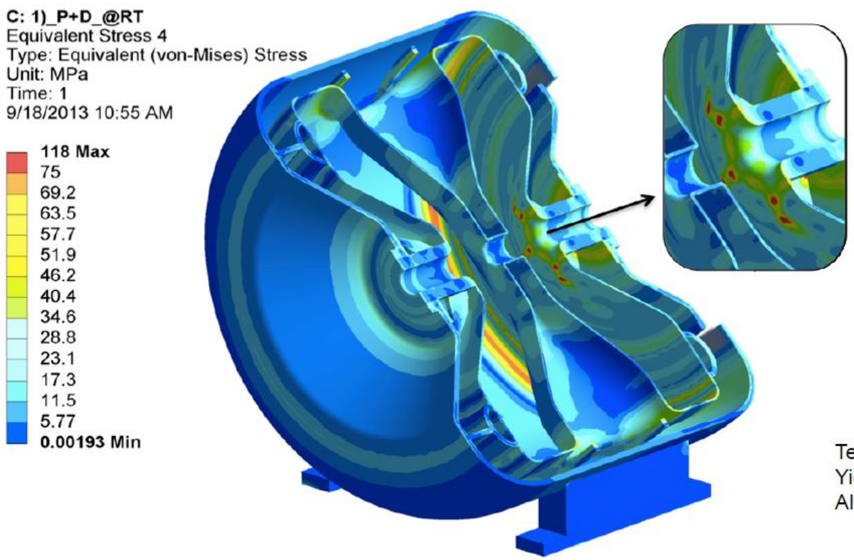
Actual results were:
0.24 Mpa at 300 K
0.90 Mpa at 2 K

SSR1 linear elastic stress plot

Thanks to Leonardo Ristori

Pressure Safety

- We designed spoke resonators to reach 2 bar (RT) and 4 bar (CT) meeting applicable US safety codes, ASME, B&PV, for complex shapes extensive FEA necessary
- Von Mises stresses may appear higher than yield in certain locations (see image), don't be scared, depending on the specific case, it may be OK!



Tensile tests on Nb batch
Yield limit 75 MPa
Allowable 47 MPa

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Established material properties for dressed cavities

From FESHM guidelines for dressed cavity fabrication – part of FESHM Chapter 5031.6

Material	Property					
	Elastic Modulus (psi) and GPa	Yield Strength (psi) and MPa		Ultimate Strength (psi) and MPa		Integrated Thermal Contraction 293K to 1.88K (in/in)
		293K	1.88 K	293K	1.88 K	
Niobium	15.2E+06 104	5,500 38	46,000 317	16,600 114	87,000 600	0.0014
55Ti-45Nb	9.0E+06 62	69,000 476	79,000 545	N/A	N/A	0.0019
Titanium, Gr. 2	15.5E+06 107	40,000 276	121,000 834	50,000 345	162,000 1,117	0.0015

Testing matrix for cavity materials

Material									
Batch ID									

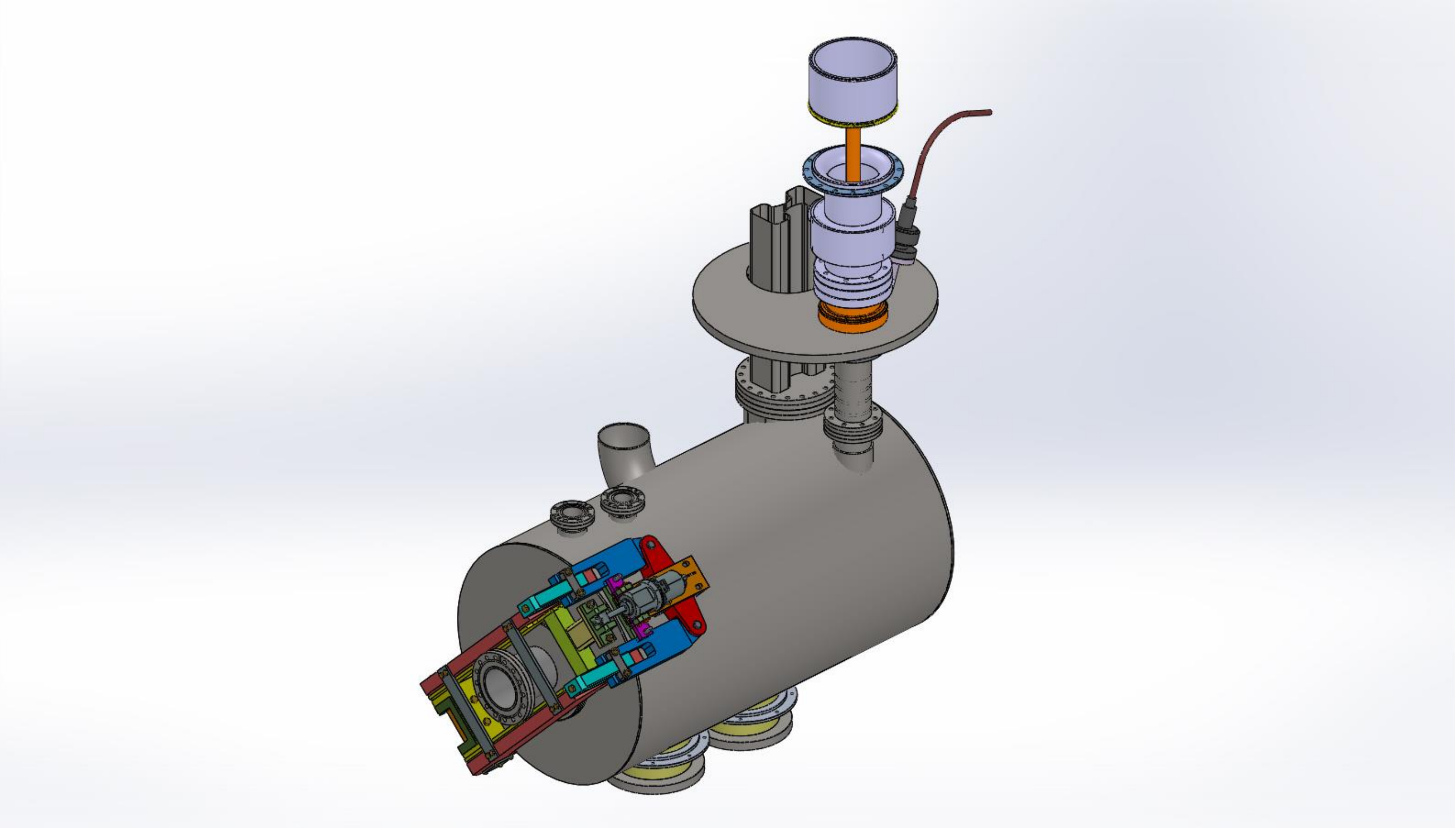
	Room temperature			77 K			4.5 K		
Sample ID	Yield	Ultimate	Charpy	Yield	Ultimate	Charpy	Yield	Ultimate	Charpy
Trans-1									
Trans-2									
Trans-3									
Trans avg									
Long-1									
Long-2									
Long-3									
Long avg									

Elastic modulus										
Chemical content										

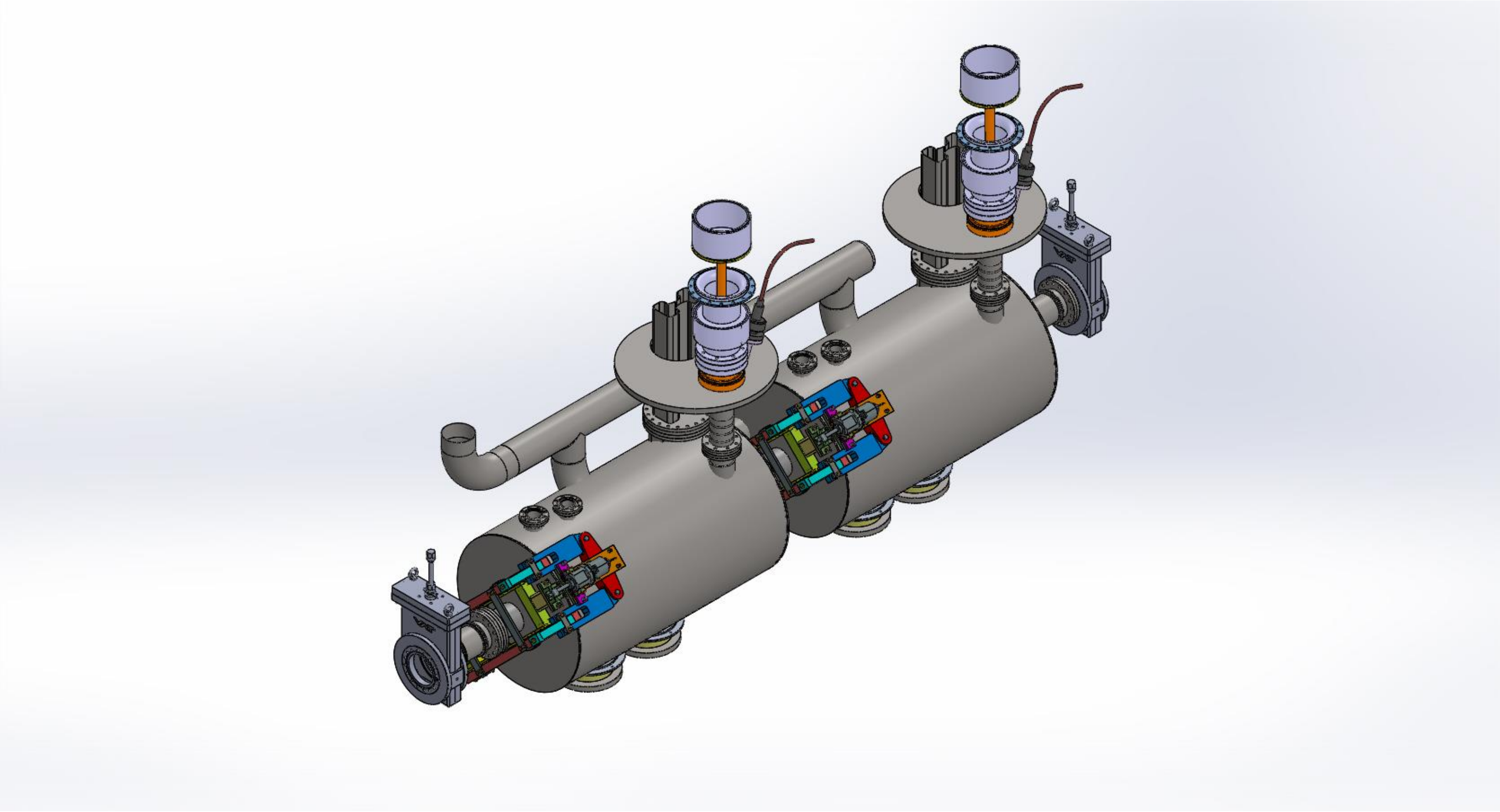
Initial design features

- Incorporate all fixed constraints, i.e. pipe sizes, locations, etc., initially focused on SPS requirements
- Dressed cavities supported from the bottom
- Adapt an end-lever tuner from Saclay or 650 MHz elliptical cavities at Fermilab
- Still undecided about helium vessel material (more analysis needed)
- Bottom-up assembly similar to FRIB cryomodules
- Really wanted a round vacuum vessel, but it just isn't a good fit to the current requirements

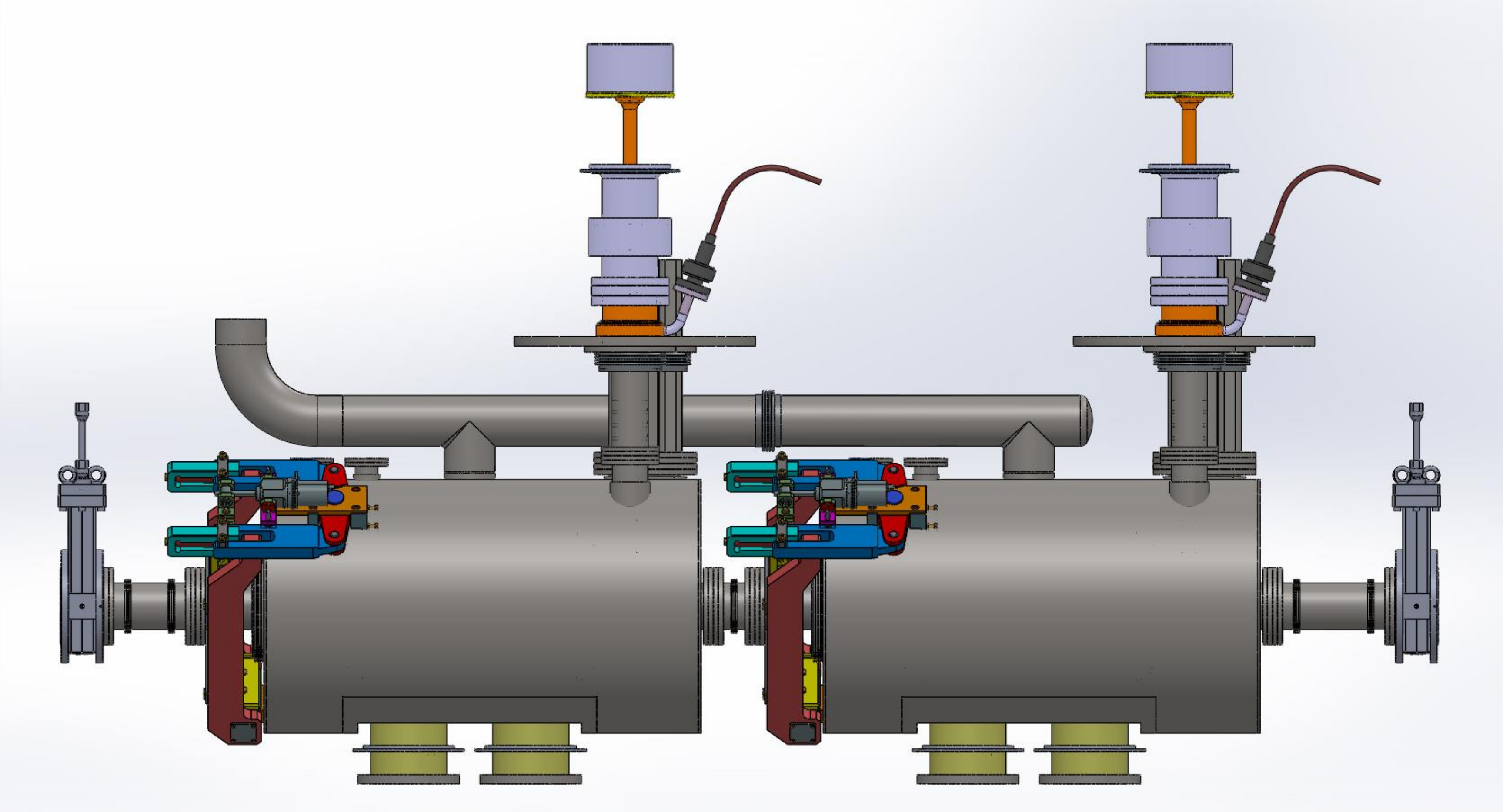
RFD dressed cavity



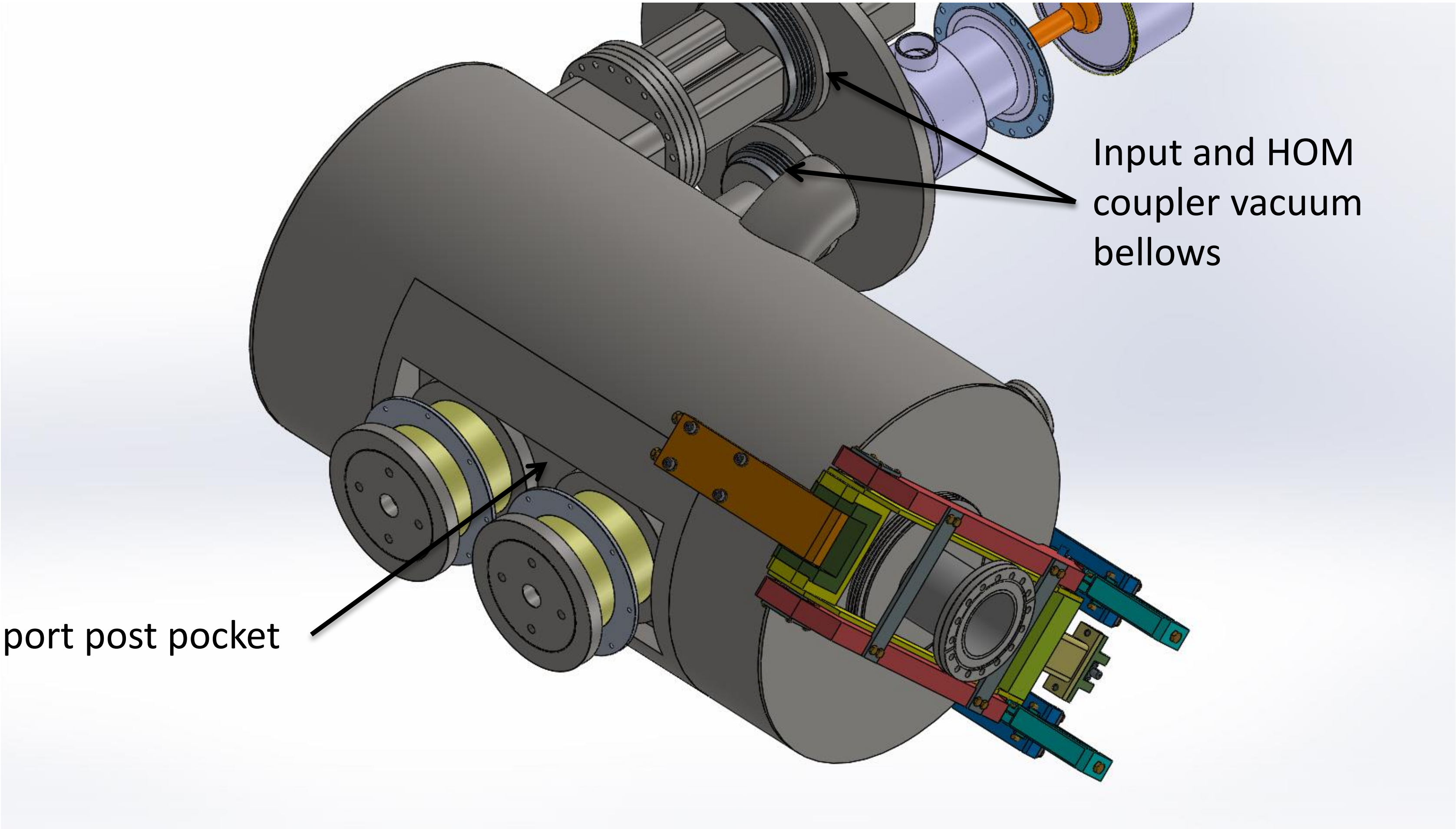
RFD cold mass assembly



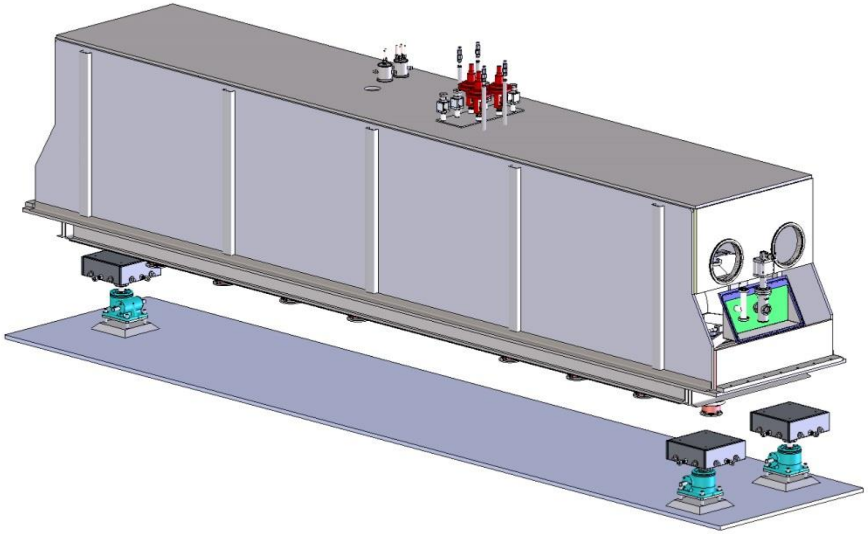
RFD cold mass assembly

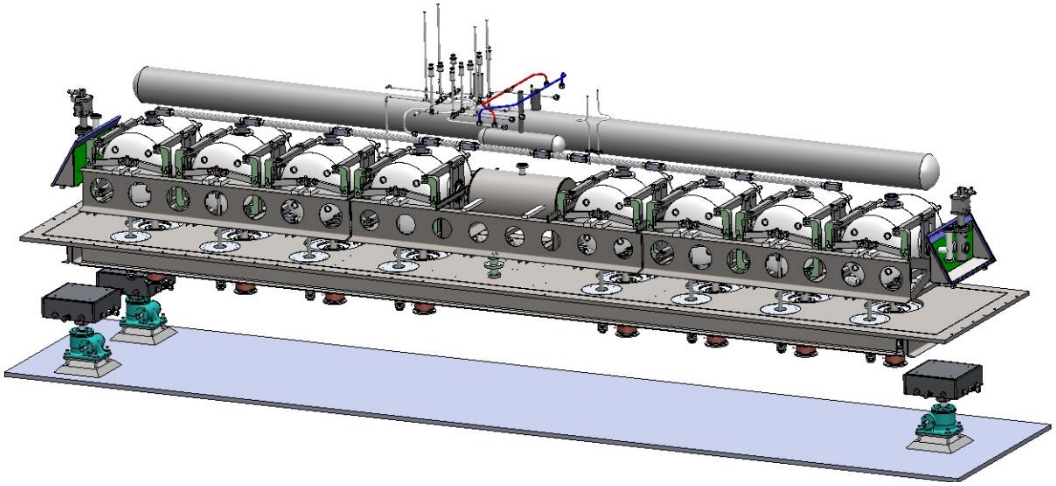


RFD cold mass assembly

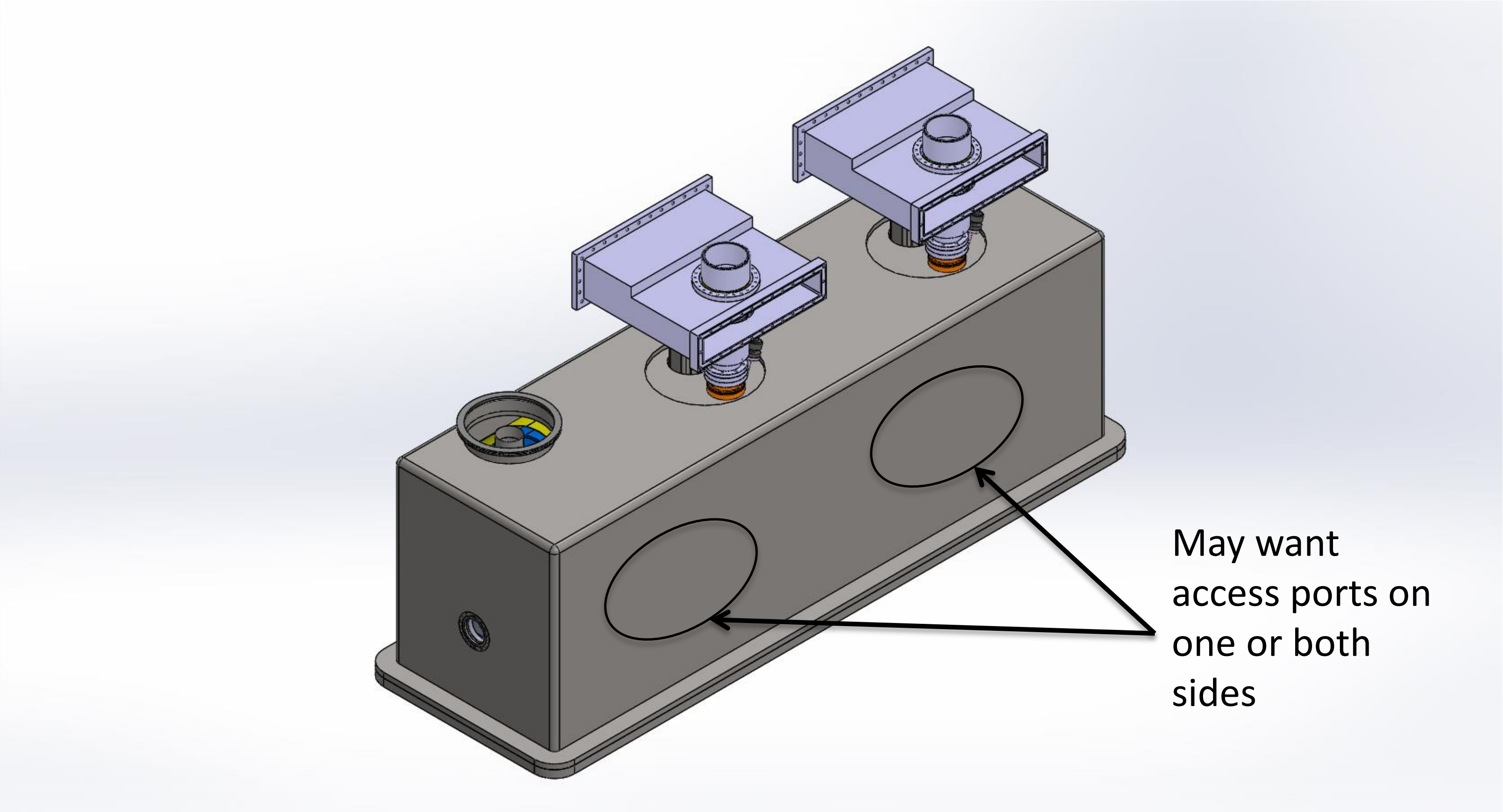


FRIB cryomodule

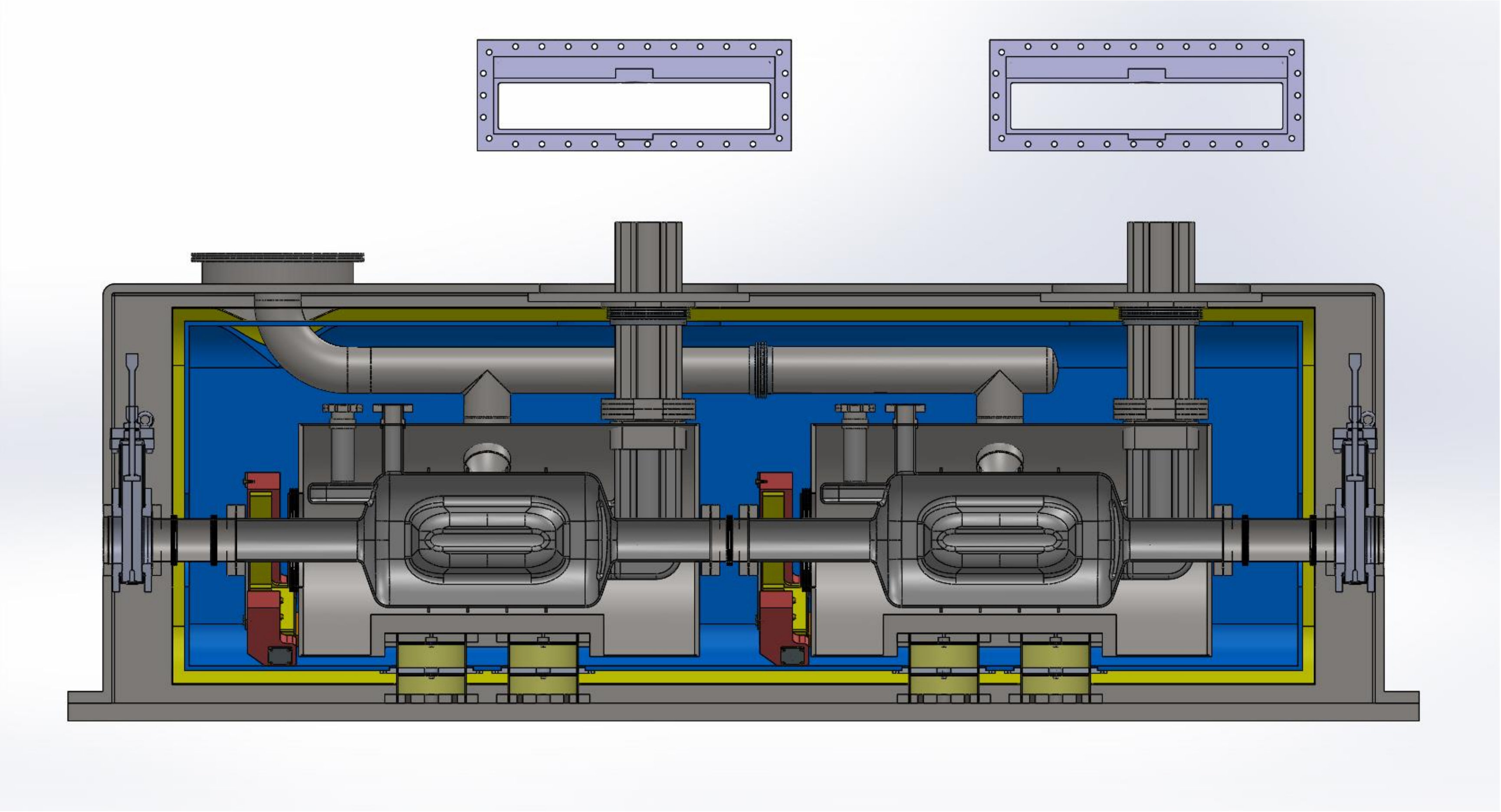




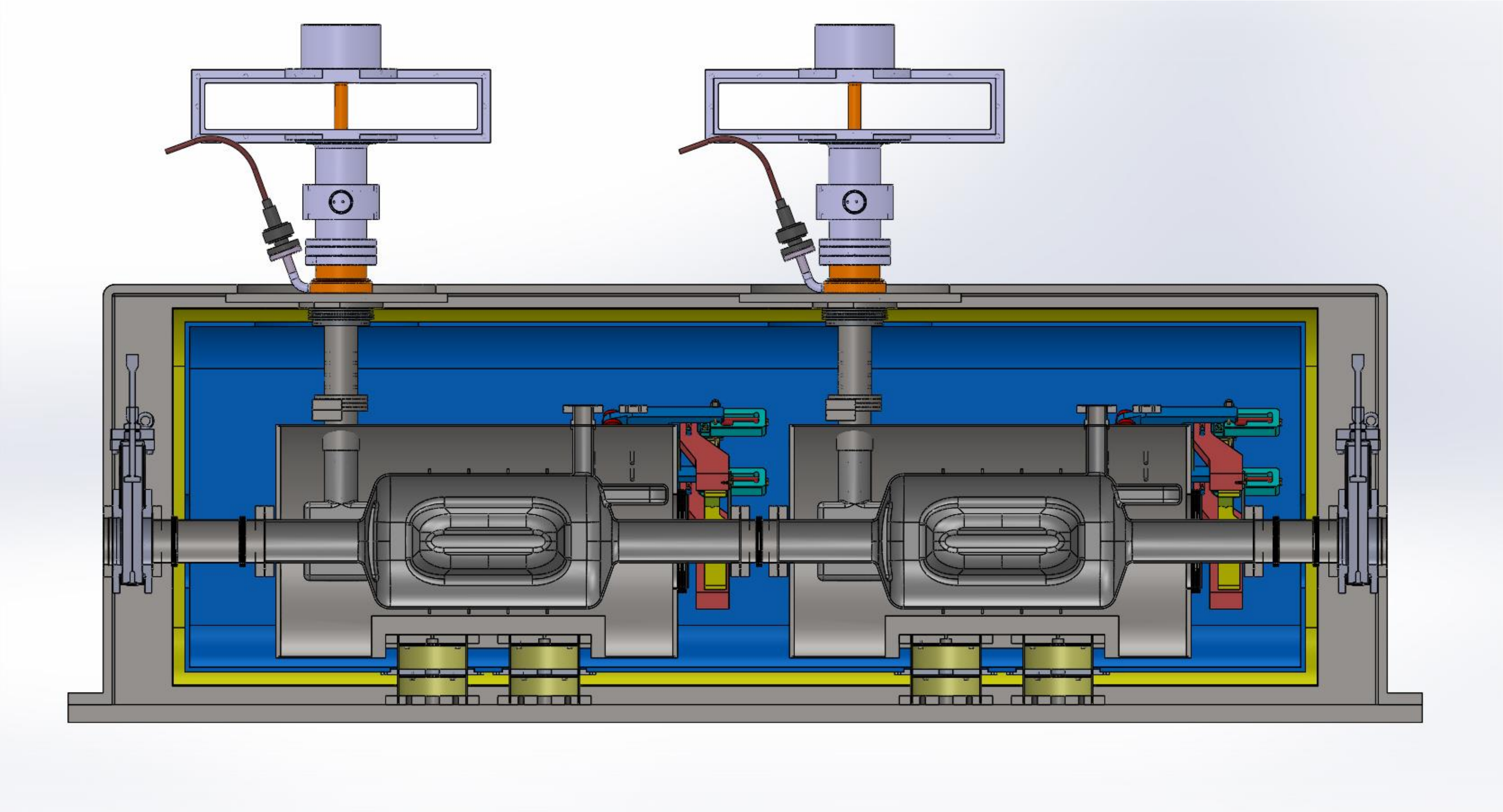
RFD cryomodule



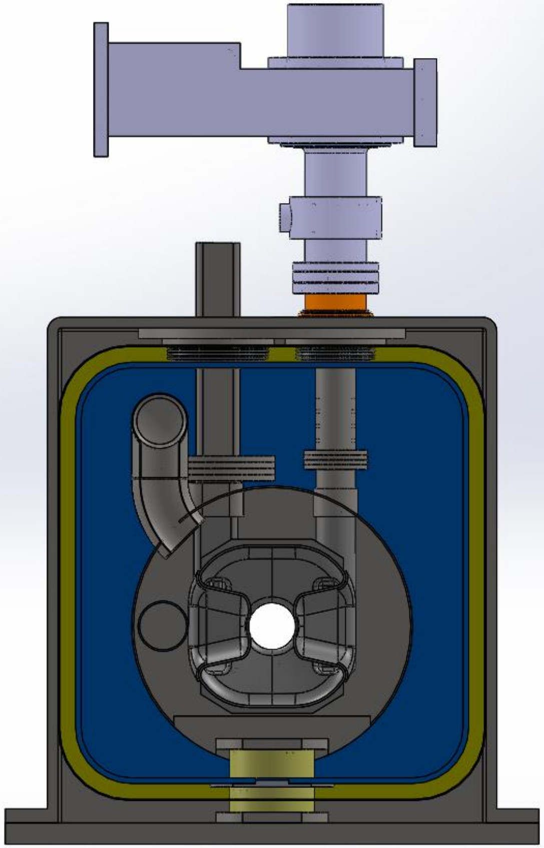
RFD cryomodule – aisle side



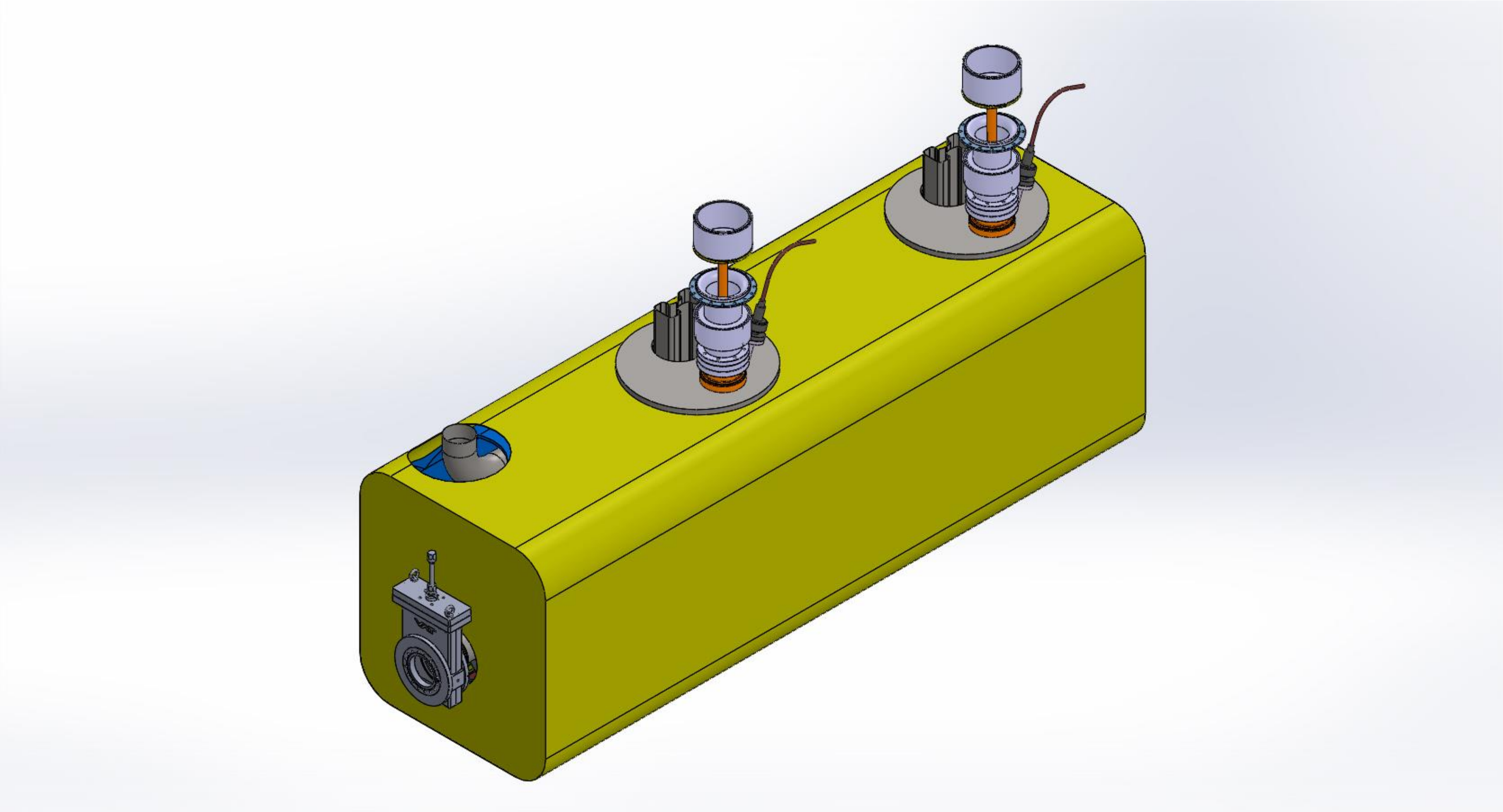
RFDcryomodule – wall side



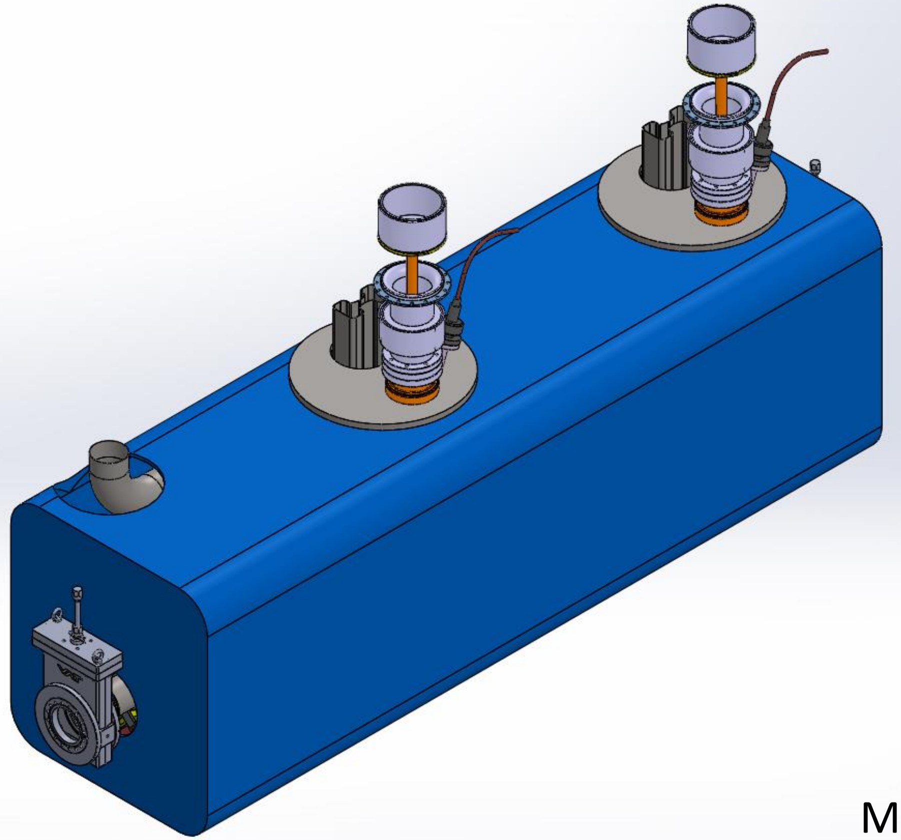
RFD cryomodule – end view



RFD – magnetic shield

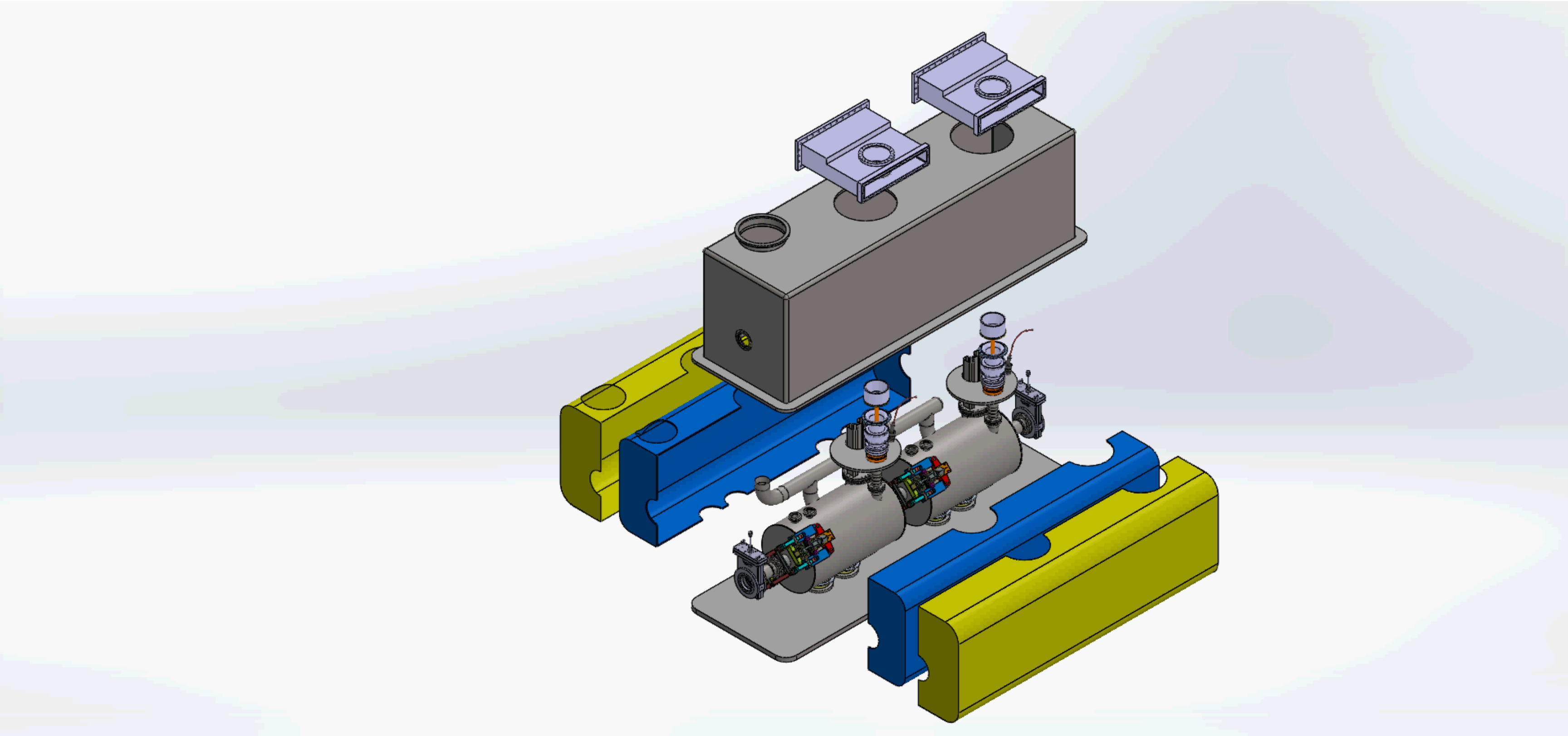


RFD thermal shield

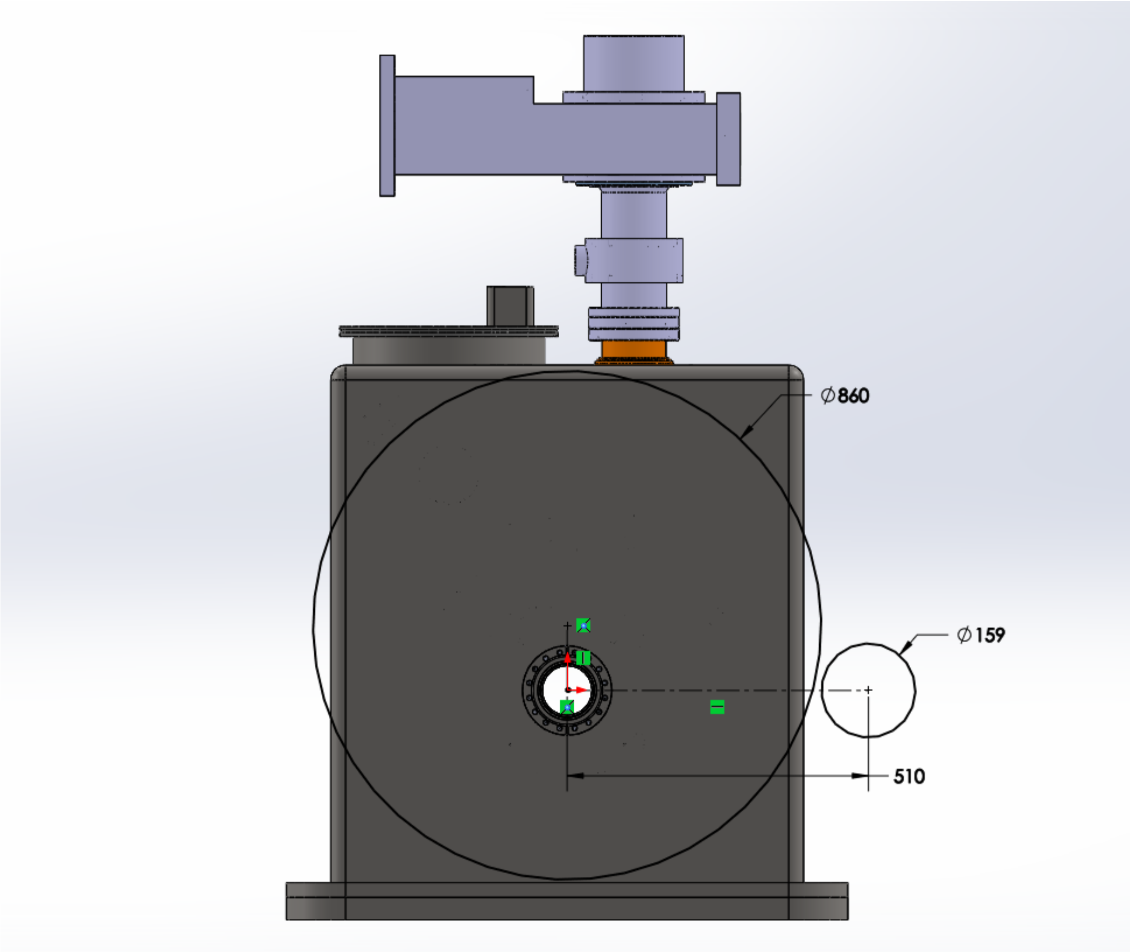


MLI not shown

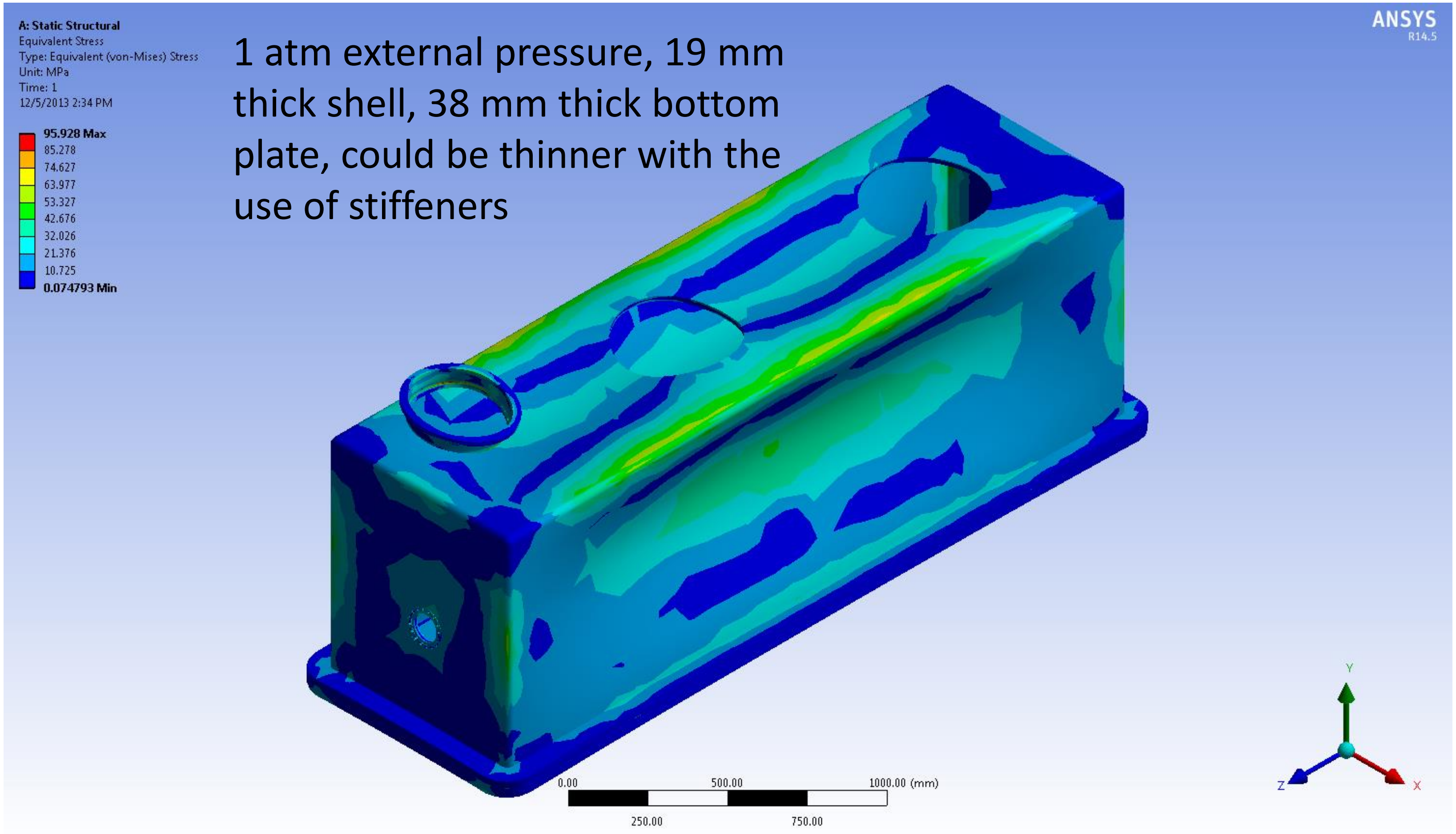
Assembly sequence



Bypass beamline location

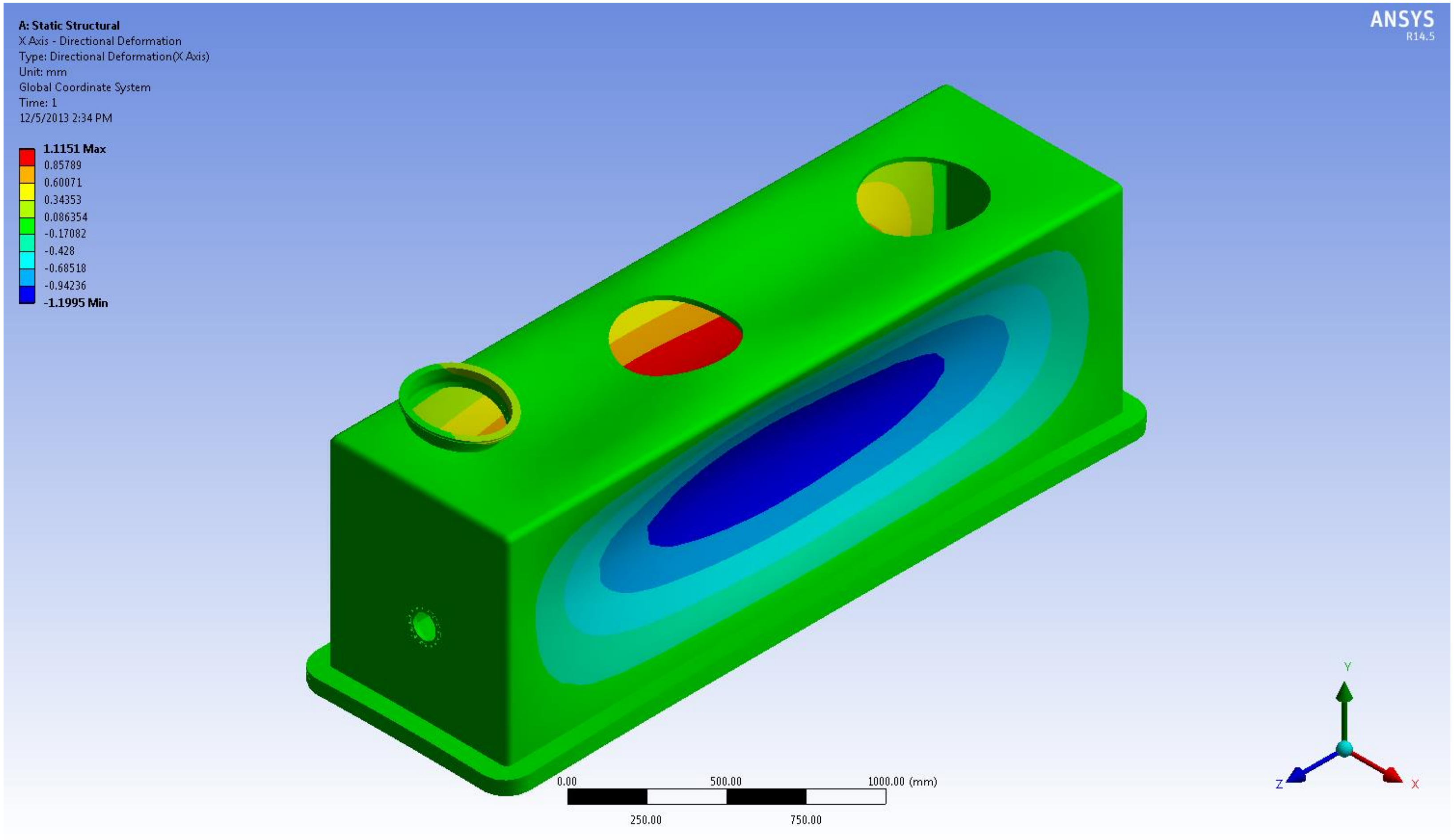


Vacuum vessel stress

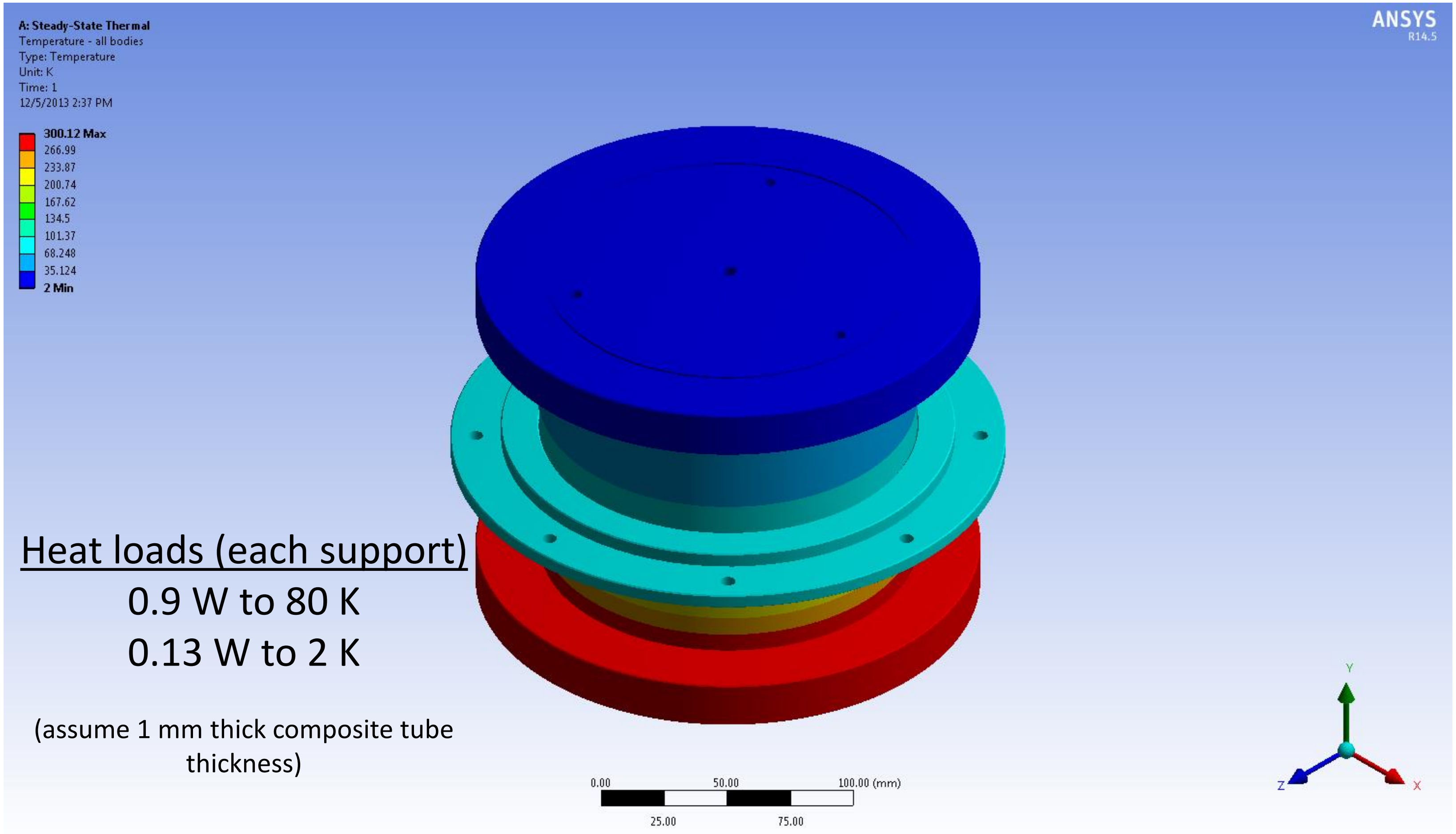


1 atm external pressure, 19 mm thick shell, 38 mm thick bottom plate, could be thinner with the use of stiffeners

Vacuum vessel displacement



Support post analysis



<u>Heat loads (each support)</u>

0.9 W to 80 K

0.13 W to 2 K

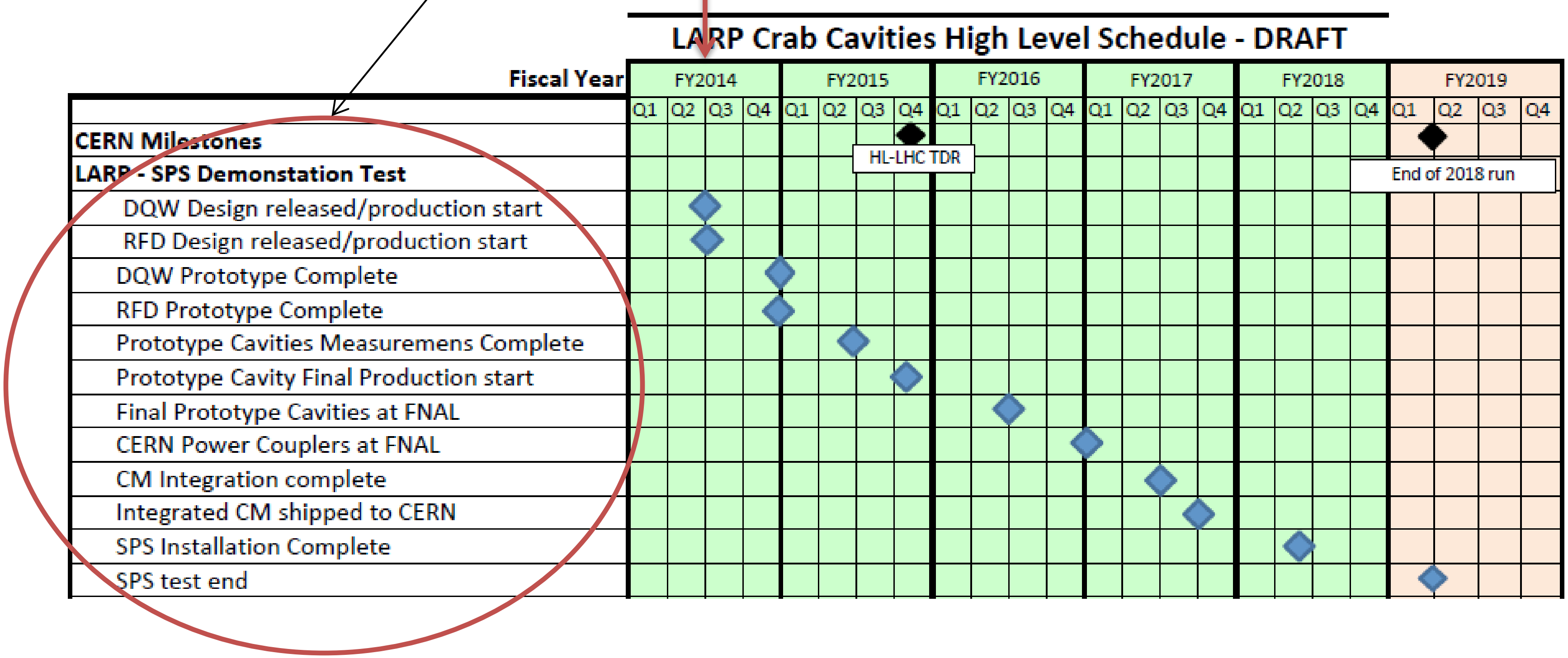
(assume 1 mm thick composite tube thickness)

Still much to do on the design…

- Look into switching the positions of the input and HOM couplers
- Develop tuner details and ensure compatibility with tuning requirements
- Look at cooldown stresses and interaction between the helium vessel and cavity
- Integrate the remaining cryogenic piping, including coupler cooling
- …

High level schedule – Dec 2013

Each of these steps implies a lot of other steps



Technical steps (to name a few)

- Determine safety requirements for involved labs
- Finalize tuning requirements including df/dp
- Decide on helium vessel material
- Decide on vacuum sealing technology, e.g. Conflats vs. aluminum diamond seals
- Integrate devices from others, e.g. couplers and tuners
- Verify heat load compliance
- Ensure cavity is compatible with cleaning requirements
- Determine method for in-process frequency adjustment
- …

Project requirements (to name a few)

- Functional Requirements Specification
- Engineering Risk Assessment (to determine extent of following steps)
- Statement of Work
- Project Management Plan
- Technical Requirements Specification
- Design Process
- Design Review(s)
- Safety Review(s)
- Procurement Process
- Performance Acceptance Test
- …

Summary

- We have resources that can be allocated to cryomodule design and analysis
- We have some capability to help with safety analysis if needed
- Continue working on the conceptual and detailed cryomodule design
- Work closely with the cavity designers and assist where needed
- Provide oversight of dressed cavity fabrication as needed
- Continue filling in more of the details implied by the high level schedule