Crab Cavities Summary

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for the Crab Cavity Team

May. 13, 2015

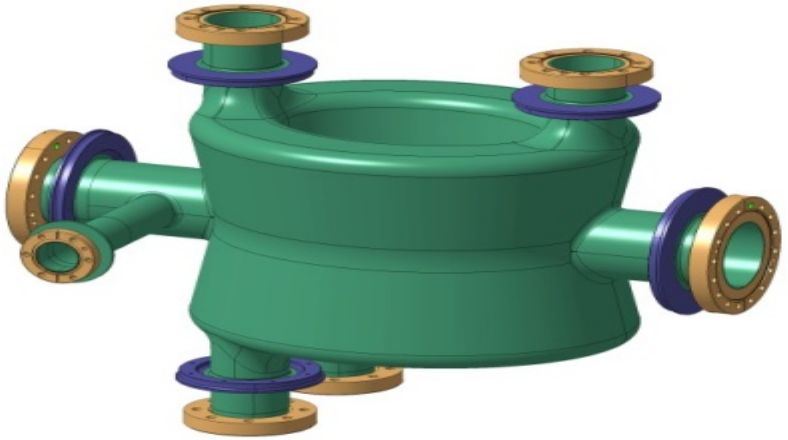
Outline

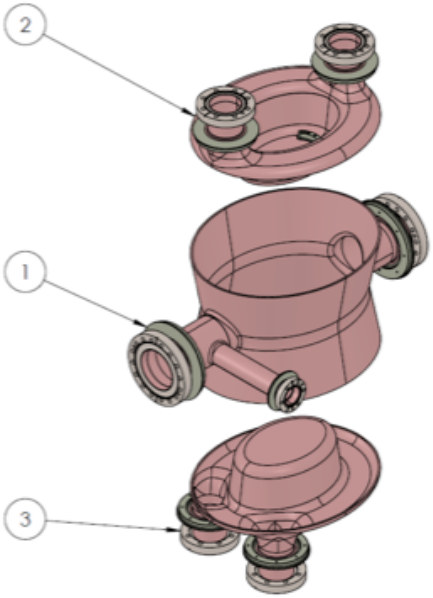
- Progress since KEK - highlights
- Cavity design update
  - Manufacturing tolerances sensitivity analysis
  - HOM damper optimization
  - Dressed cavity studies
- Cavity fabrication
- Open issues being resolved
  - Impedance budget
  - Losses
- Planning for SPS tests
  - Installation and location
  - MD proposal

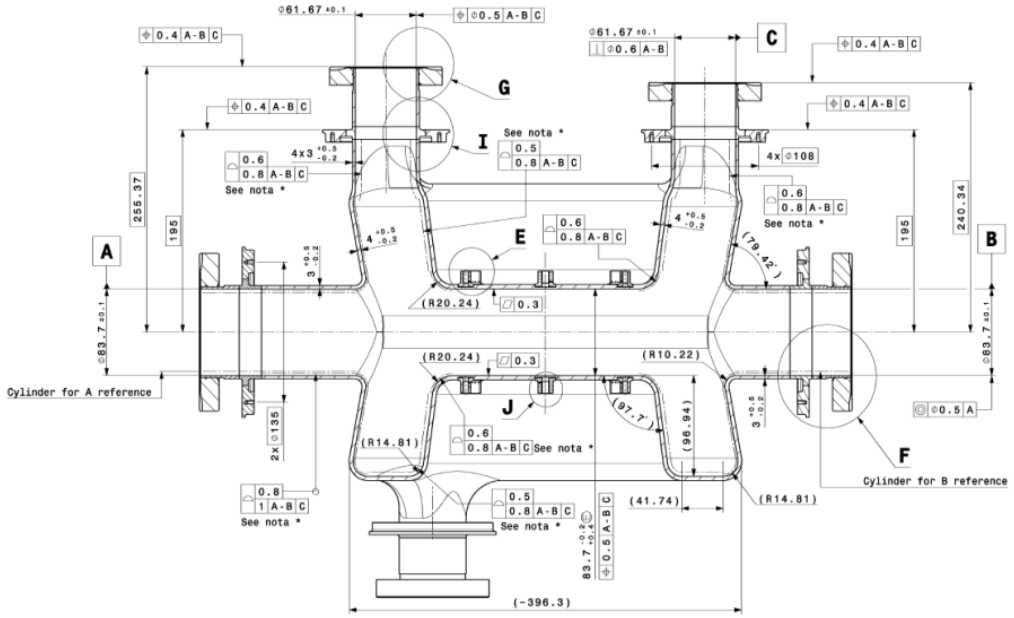
Cavity Development in Industry

- Most but not all documents in the manufacturing readiness list were delivered and accepted
- Tested all forming steps in Copper
  - Similar behavior to Nb
- Formed nearly all Nb parts
- Built test beam pipe assembly
  - Measured and tested at CERN
    - Some non compliances (being addressed)
- Beam pipe assemblies fabrication started
  - Working on acceptance plan

DQW – Assembly and Spec.







DQW – Outer Conductor

- Outer conductor halves
  - 4 halves etched, fixtured, and ready for weld

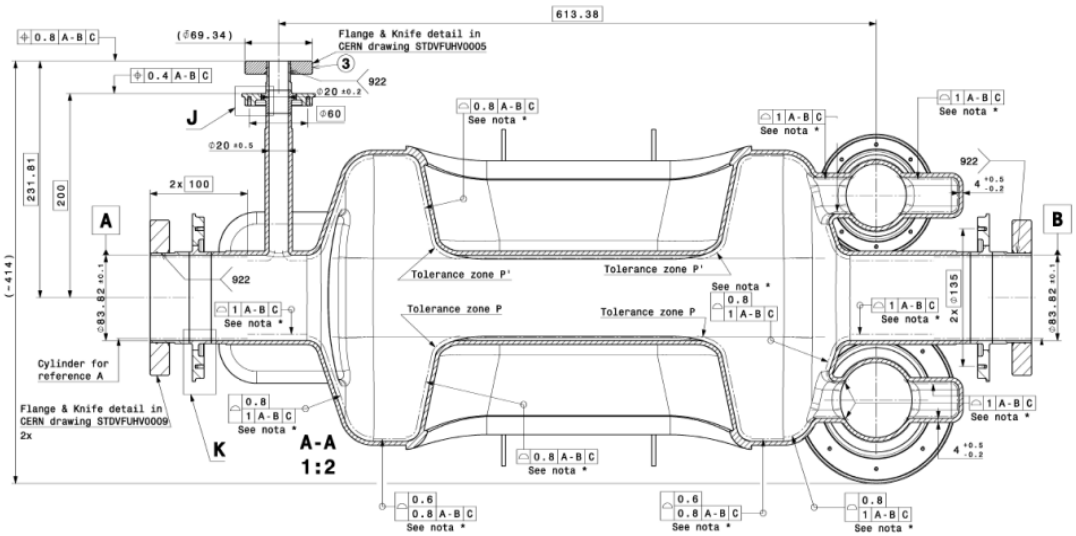
DQW - Cake pan assemblies

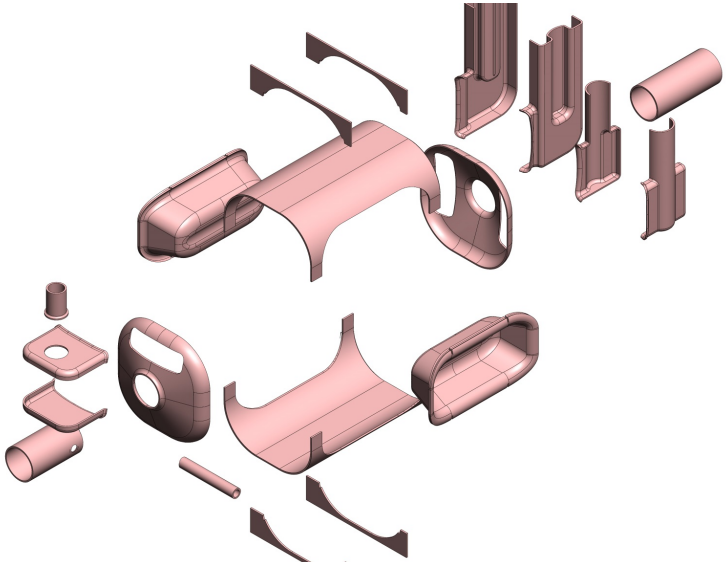
- Ready to weld

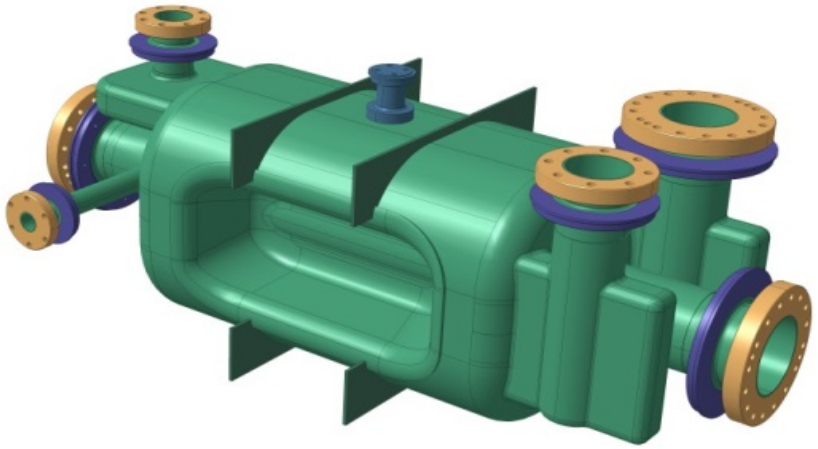
DQW – Inner Conductors

- "Bowls"
  - Complete
  - Etched, and ready for NbTi tuner attachment welds

RFD – Assembly and Spec.







RFD Stamped Parts

Fabrication Summary

- Nearly all Nb parts are stamped
  - Waiting for ¼" plates to finish stiffners for one RFD
    - Due next week
- All parts are measured at the factory
  - Variances addressed on a case-by-case basis
- DQW bodies ready to weld
- RFD bodies will be ready to weld in about one month
- Beam pipe assemblies fabrication underway
  - First welding cycle this week
- CC team will visit Niowave on Thursday
  - Inspect all parts that are ready and available

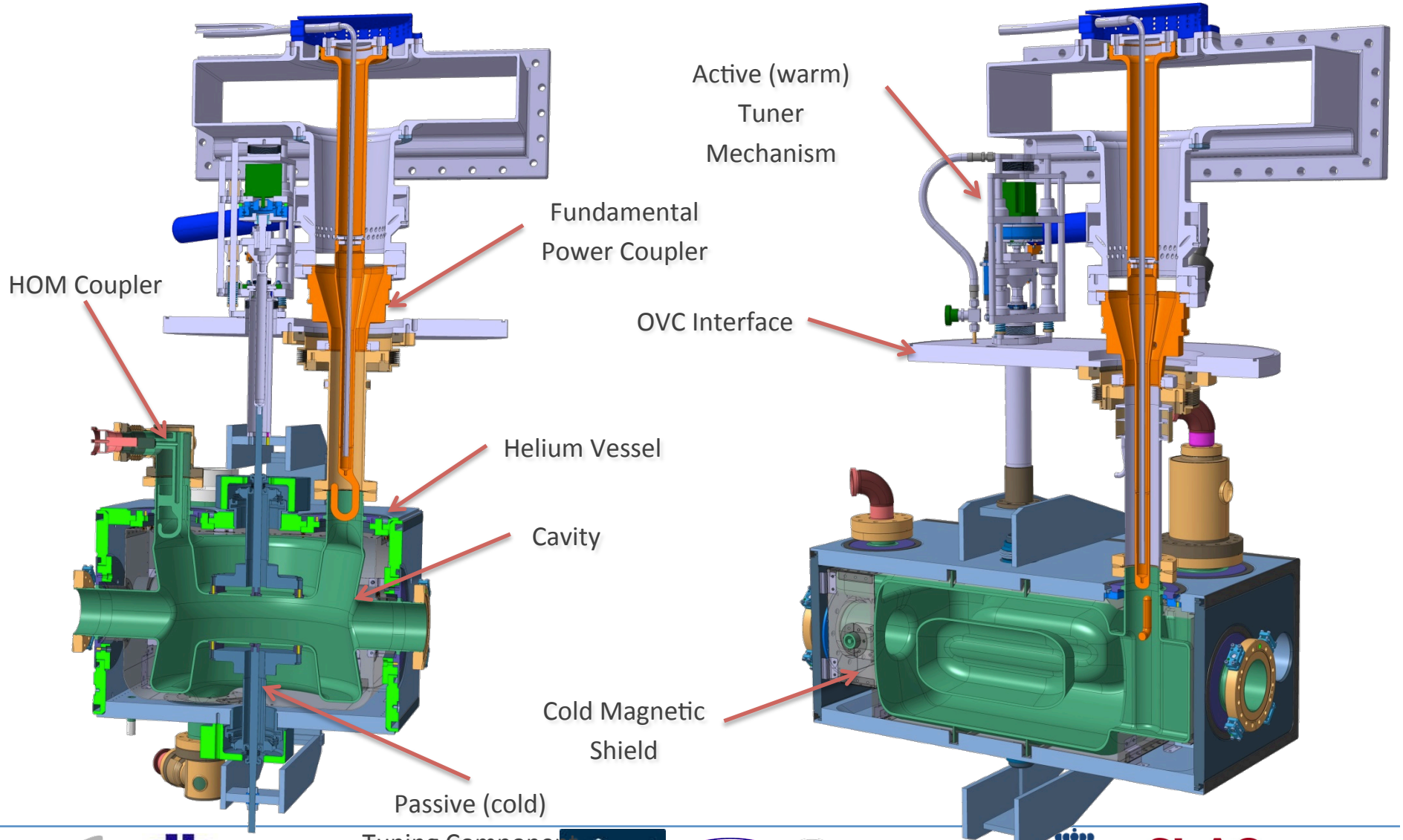
From Niowave

Cavity design

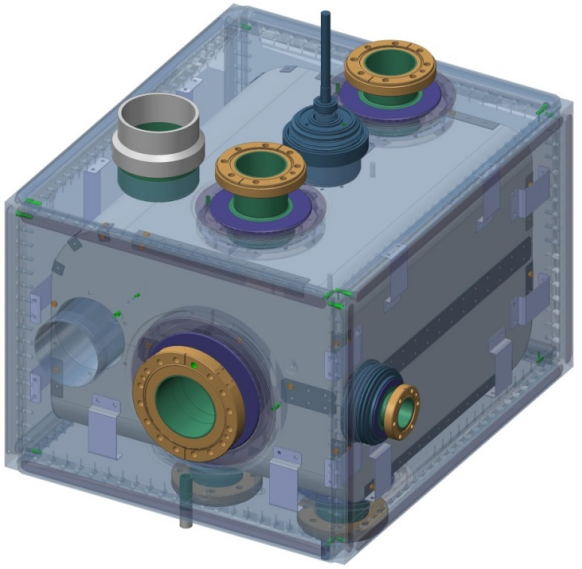
As fabrication of the core cavity is underway, progress in other areas:

- Magnetic shield and He vessel design
  - Review @ CERN on 6 May
  - Plan to complete both designs by June 2015
- Tuner Design
  - Discussed also at the 6 May review
- HOM optimization

Dressed Cavity Overview



Cold Magnetic Shielding

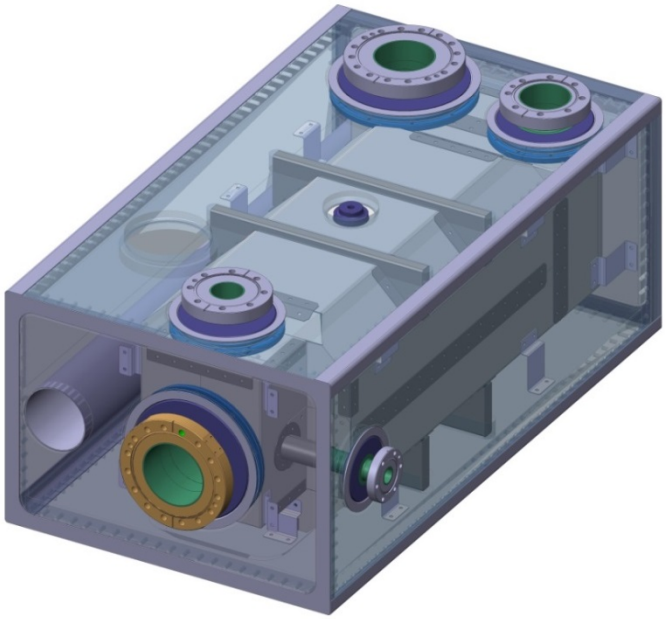


Specification

- <1μT on cavity surface
- To be achieved in conjunction with 3mm warm MuMetal shield

Constraints

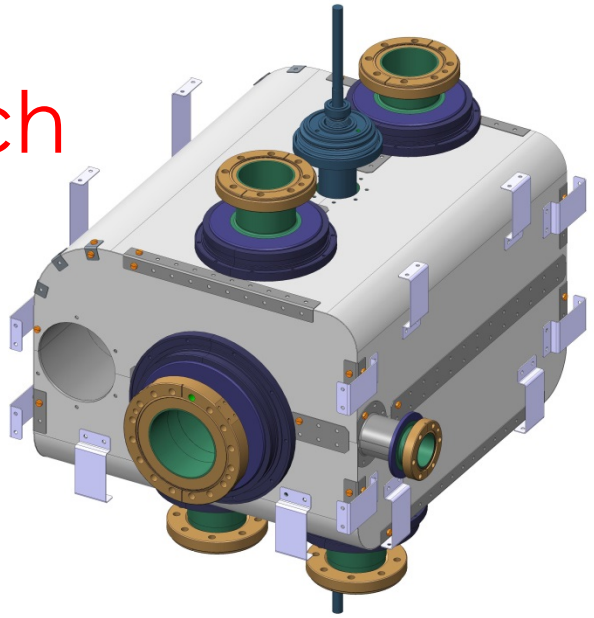
- Internal to Helium Tank
- Suspended in 2K Helium
- Mounted off Helium Tank – no cavity connection



Operating Conditions

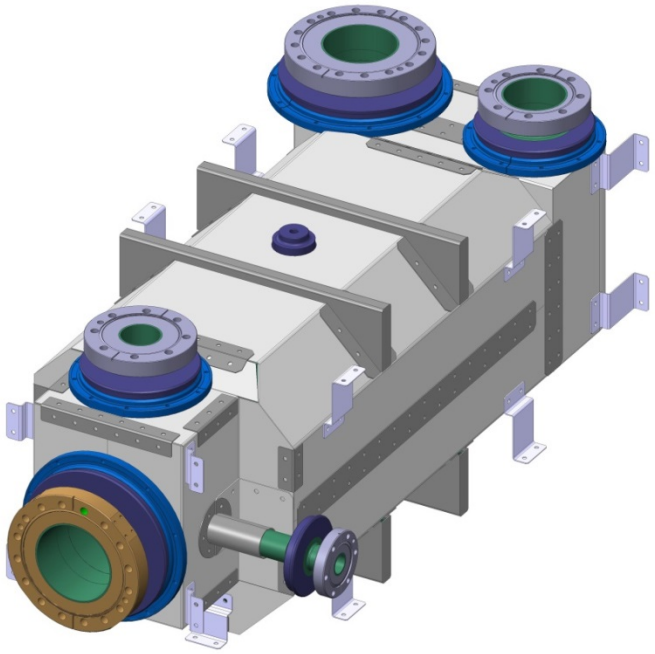
- >200μT – Earth's magnetic field + shielded local sources

Cold Shield Design Approach

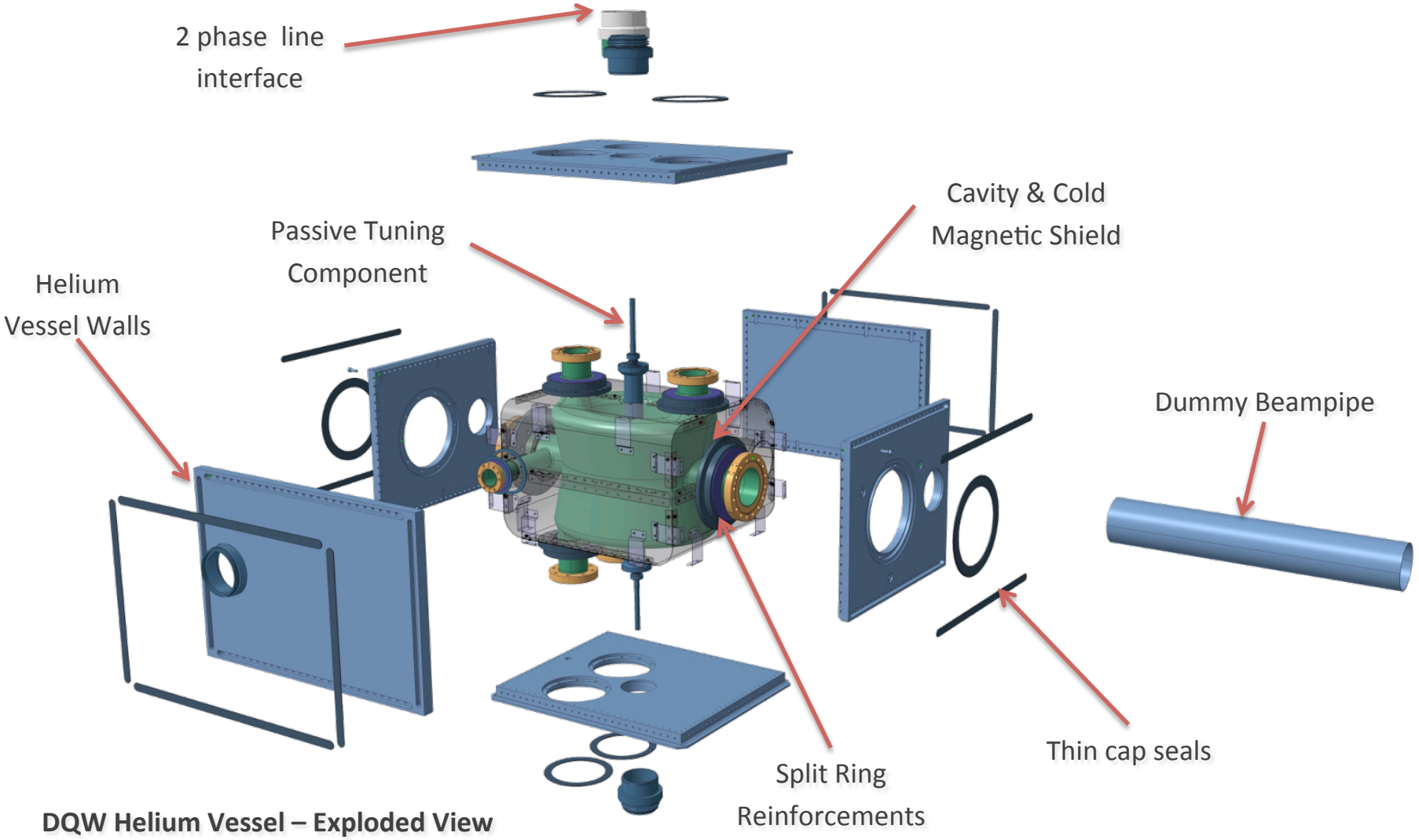


1. Minimise number & size of penetrations
2. Ease of manufacture & assembly
   - Minimise number of panels
   - Fabricated from Bent / Folded sheet
   - *Pressed panels possible future batch shield orders*
3. Maximise penetration attenuation
4. Maximise curvature

Shield	No. Penetrations	No. Panels
DQW	11	7
RFD	7	10



Helium Tank Overview

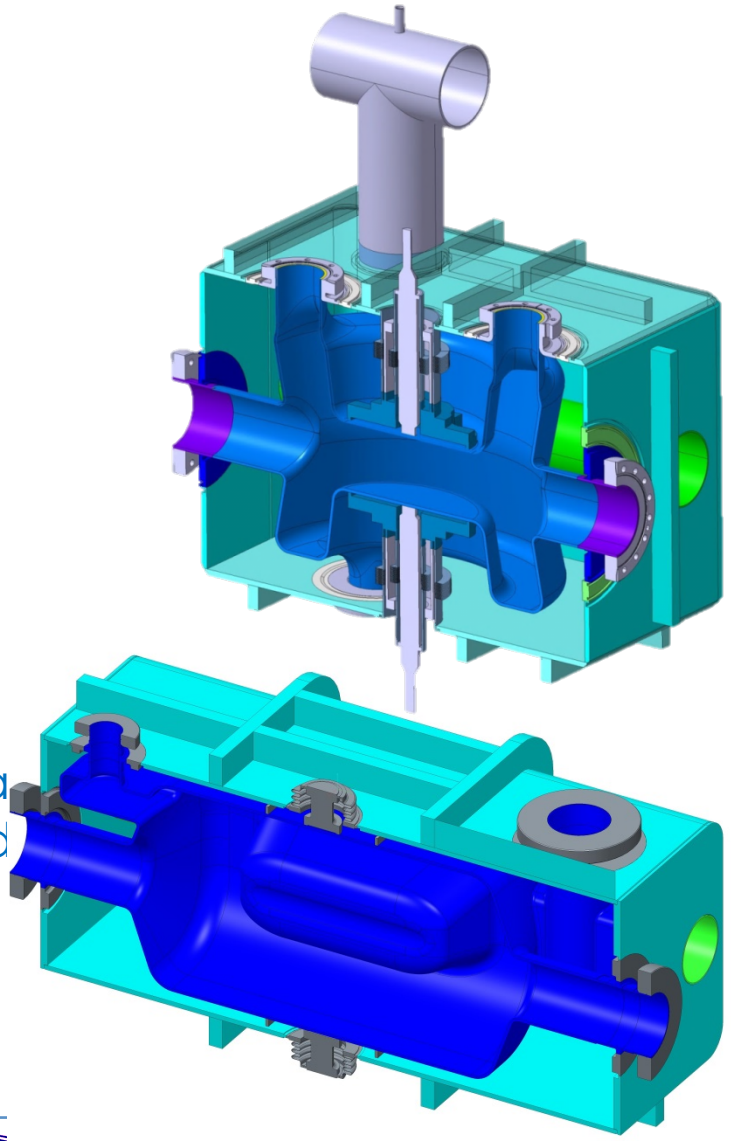


DQW Helium Vessel – Exploded View

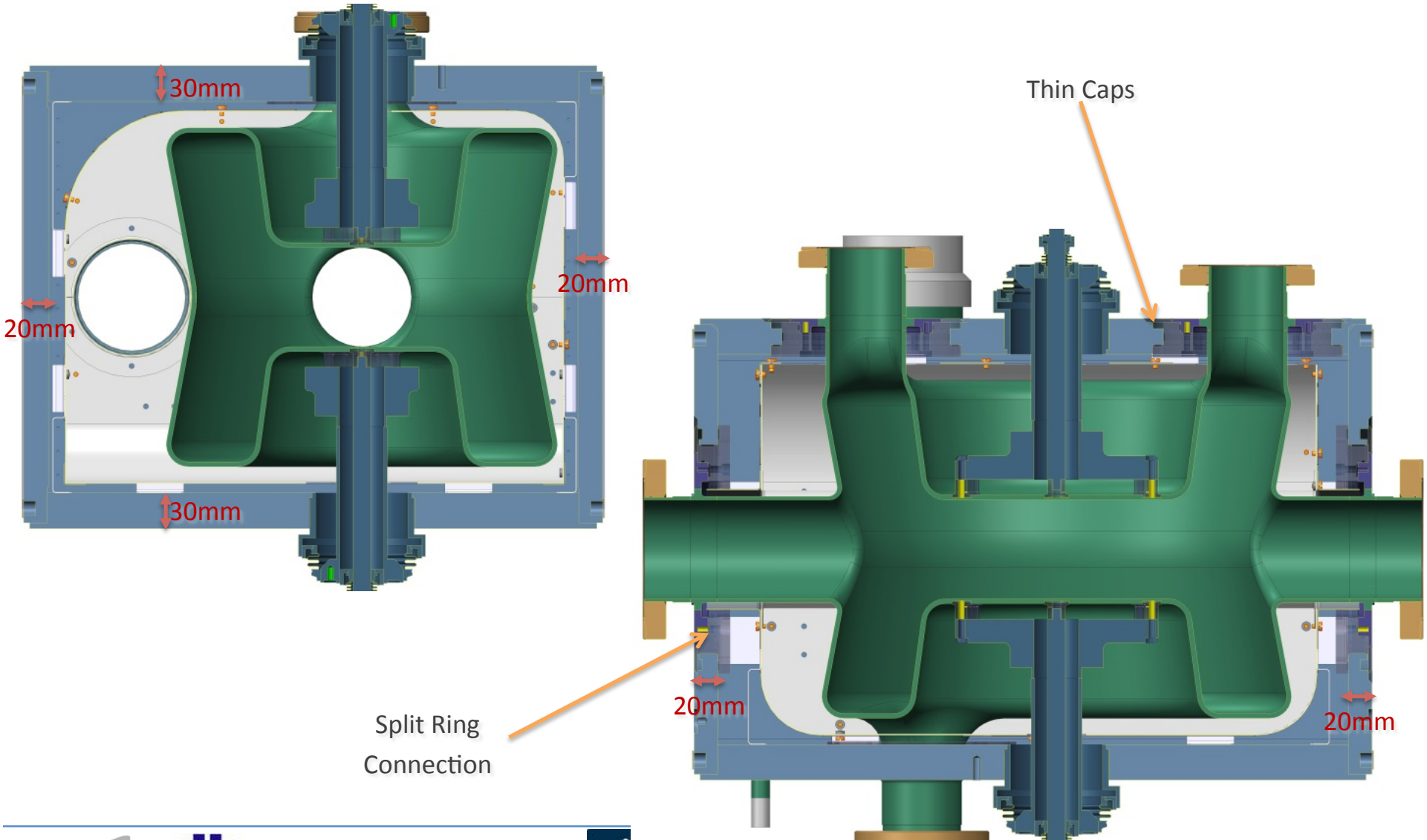
Dressed Cavity Engineering

Reasons for Bolted Helium Vessel

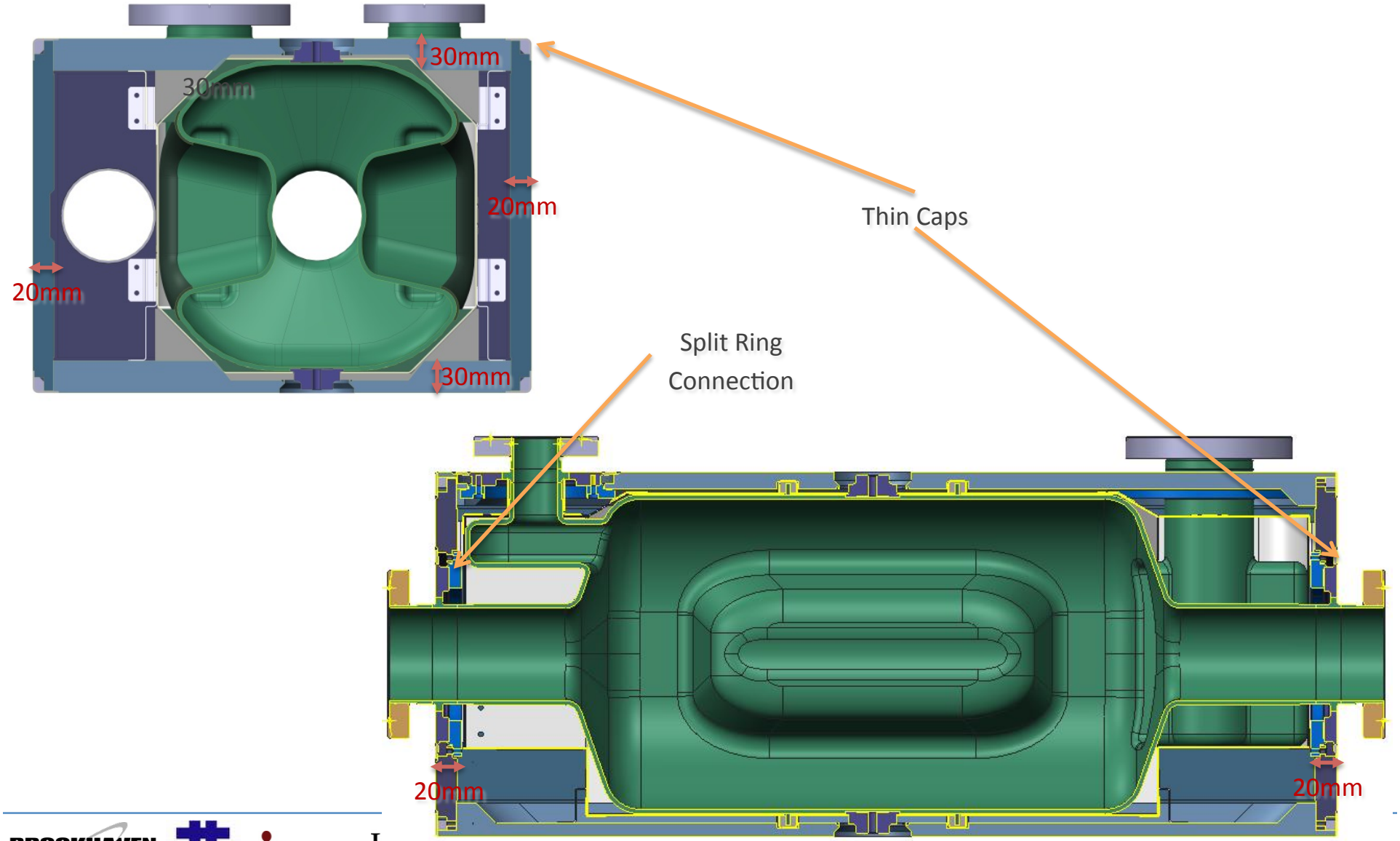
- Nature of compact crab cavity design requires a stiff helium tank for pressure testing and tuning.
- Thin walled vessel requires large number stiffening ribs.
- Manufacturers advised that thin walled design would result in large weld distortions.
- Weld distortions would be detrimental to cavity, thin walled design deemed too high risk.



Double Quarter Wave Helium Vessel



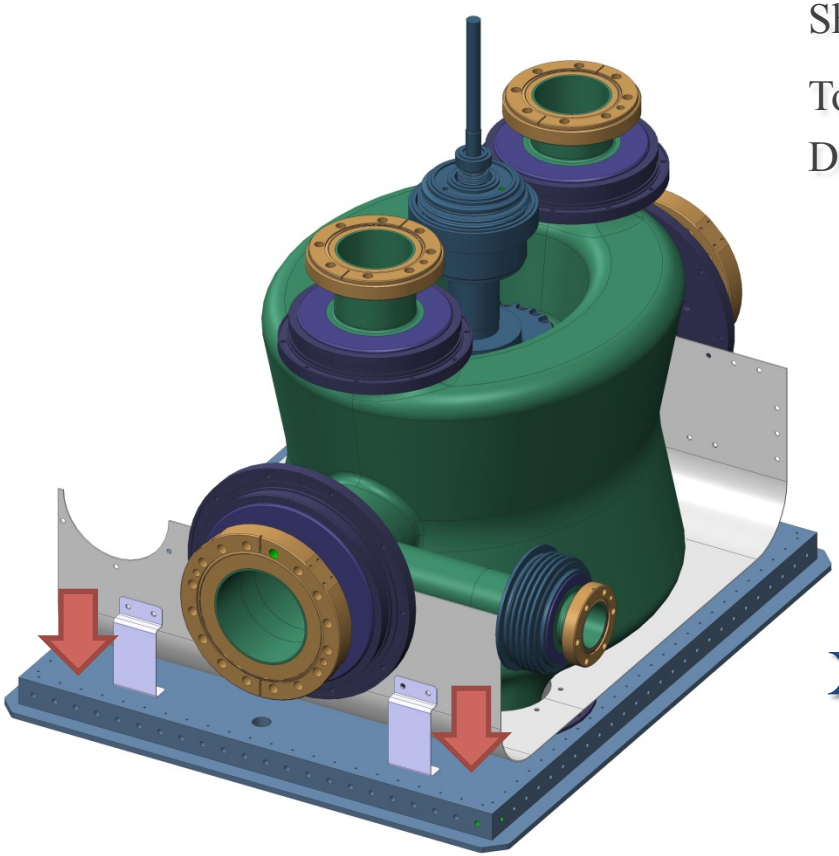
RF Dipole Helium Vessel

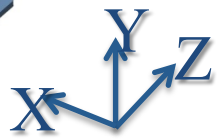


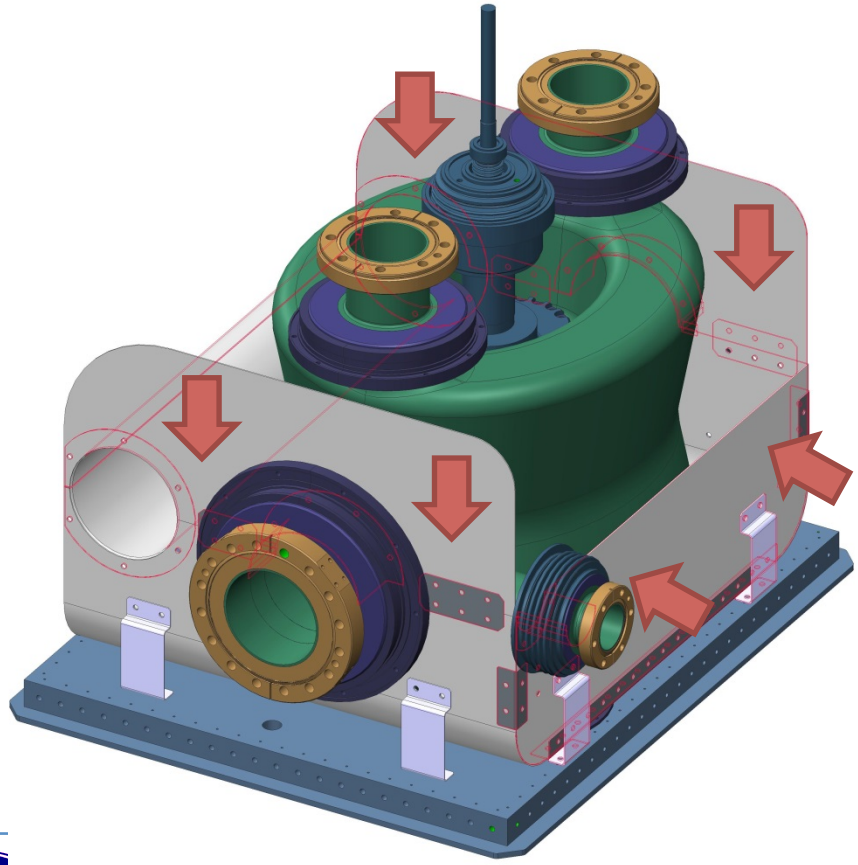
DQW Assembly Procedure

Shield & cavity mounted to base plate of the Helium Vessel

Top End caps are attached as well as bottom side panel and Dummy beam pipe attenuation sleeve.

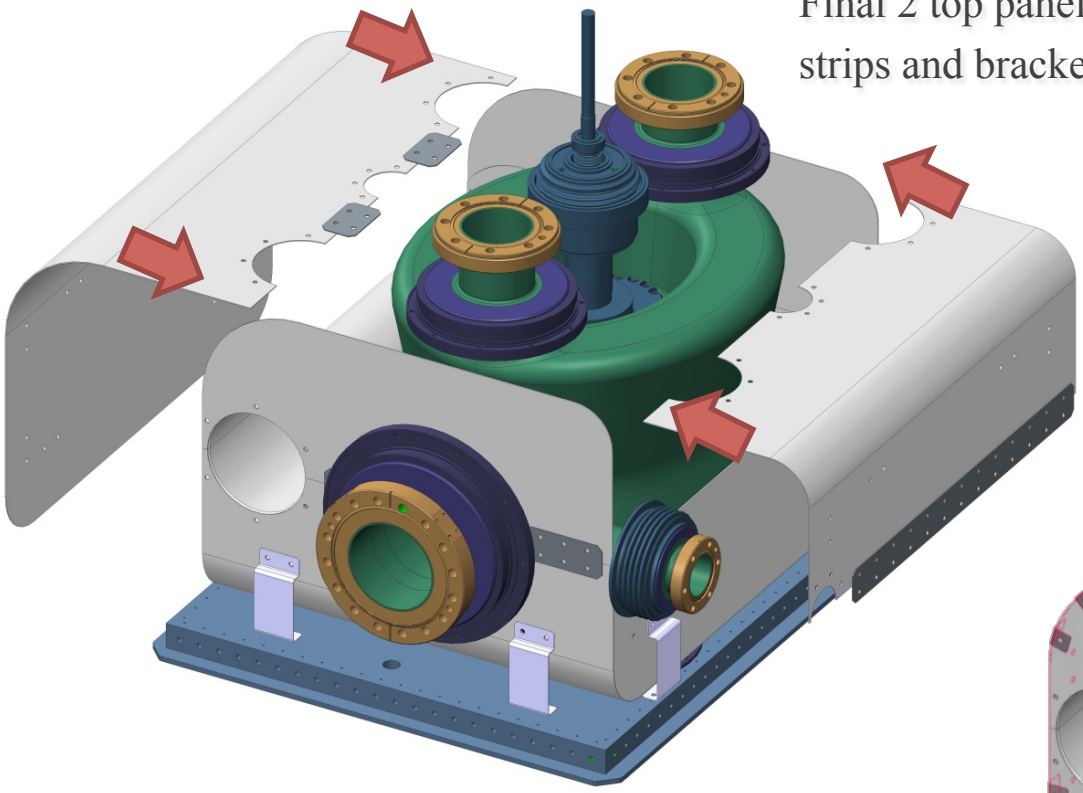


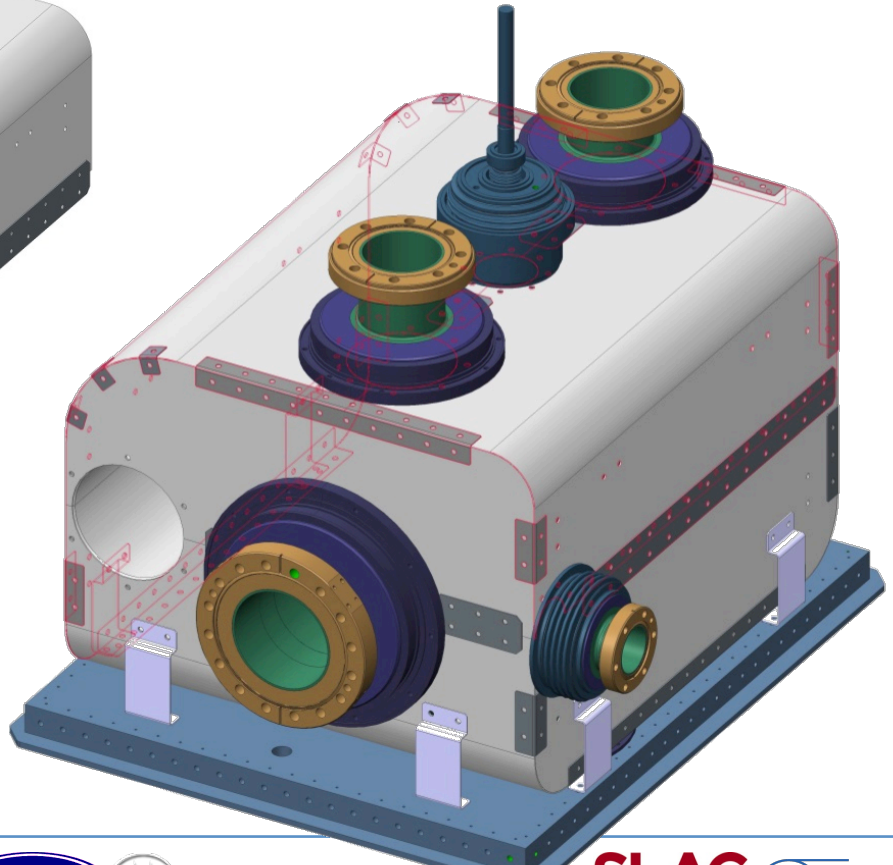




DQW Assembly Procedure

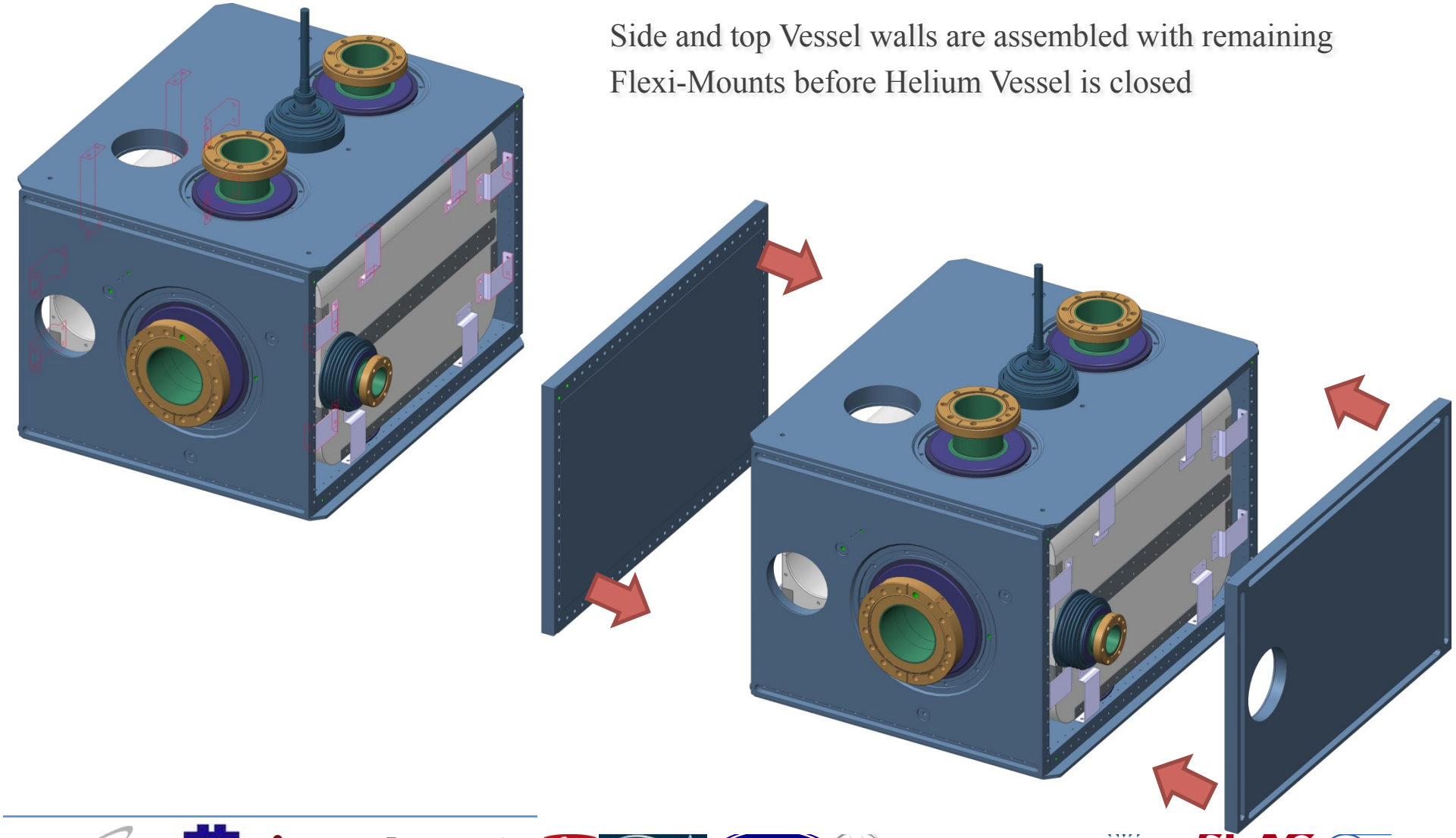
Final 2 top panels are brought into place and remaining cover strips and brackets are fastened



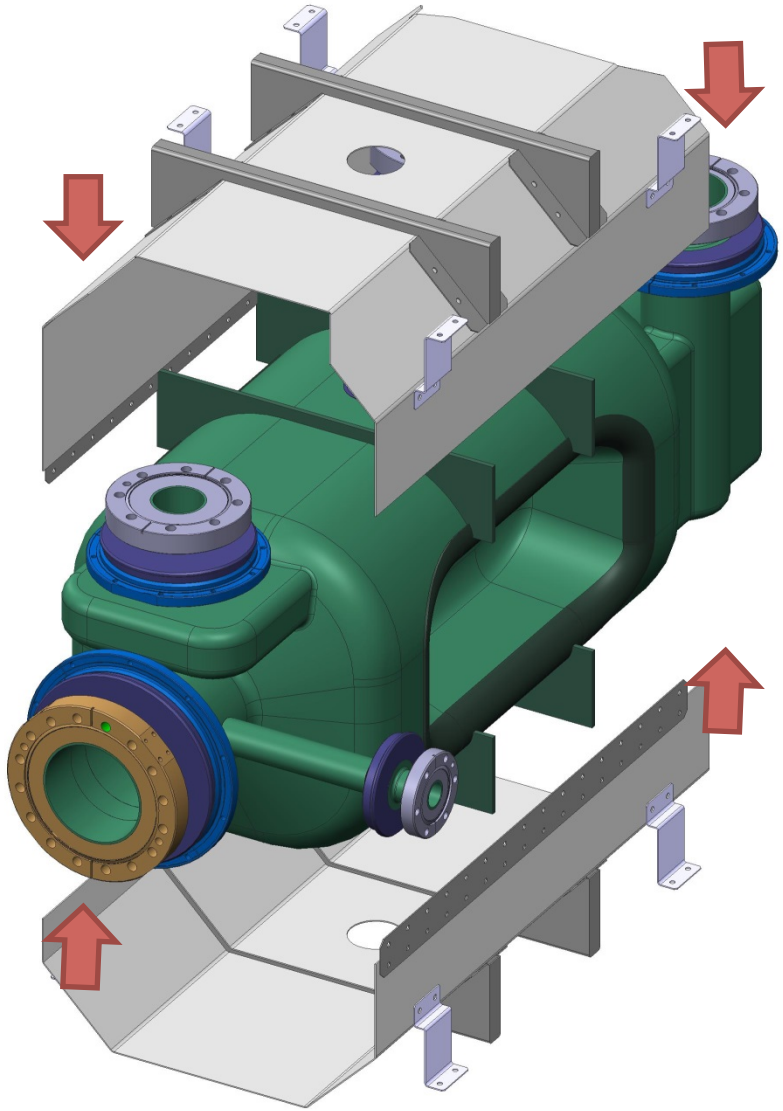


DQW Assembly Procedure

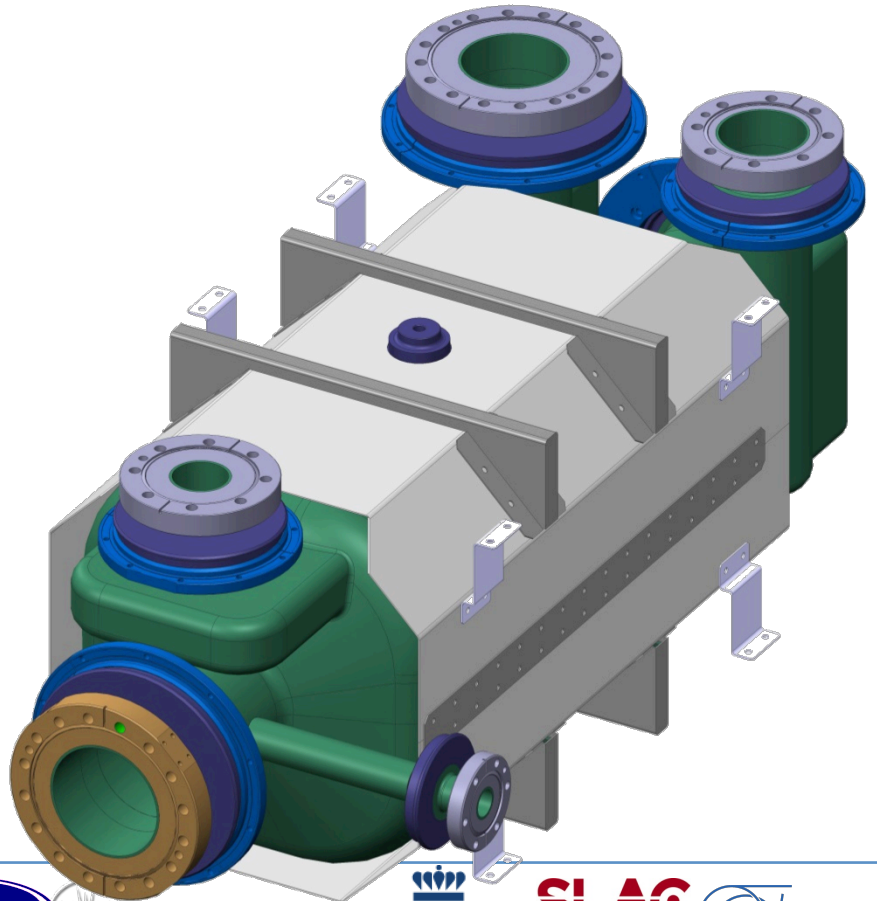
Side and top Vessel walls are assembled with remaining Flexi-Mounts before Helium Vessel is closed



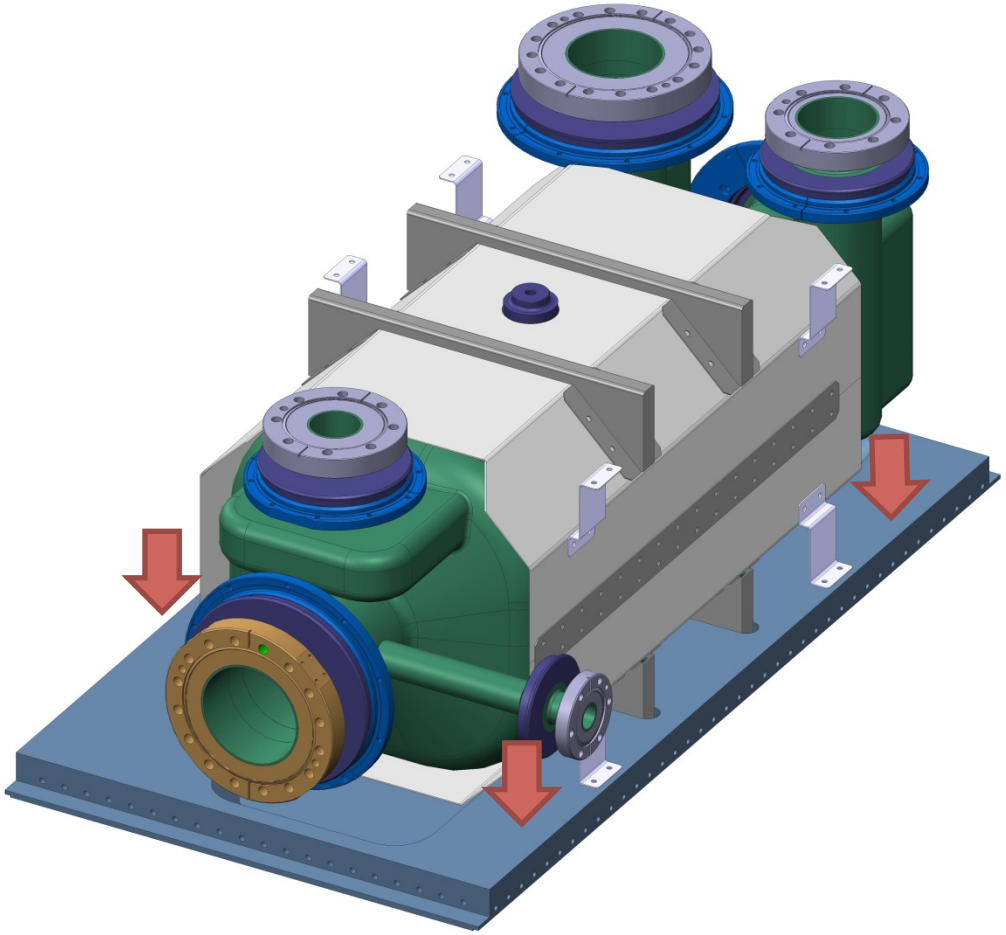
RFD Assembly Procedure



Pre-assembled shield body is assembled Top and Bottom



RFD Assembly Procedure

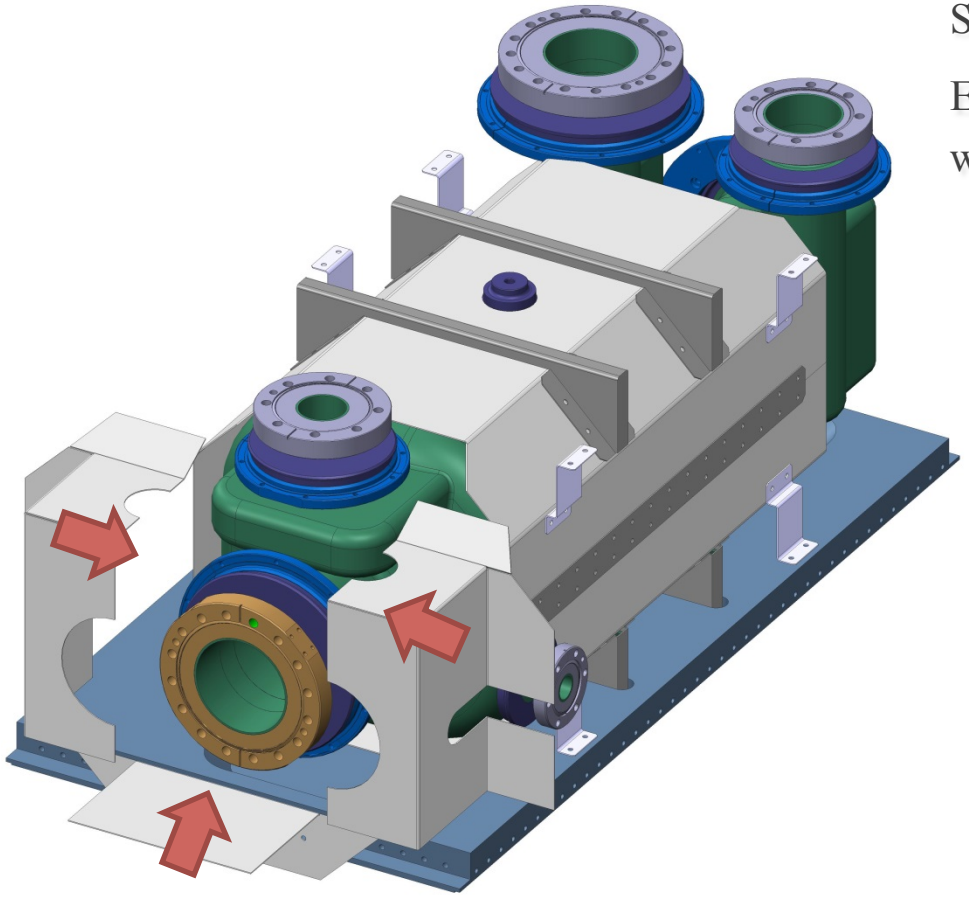


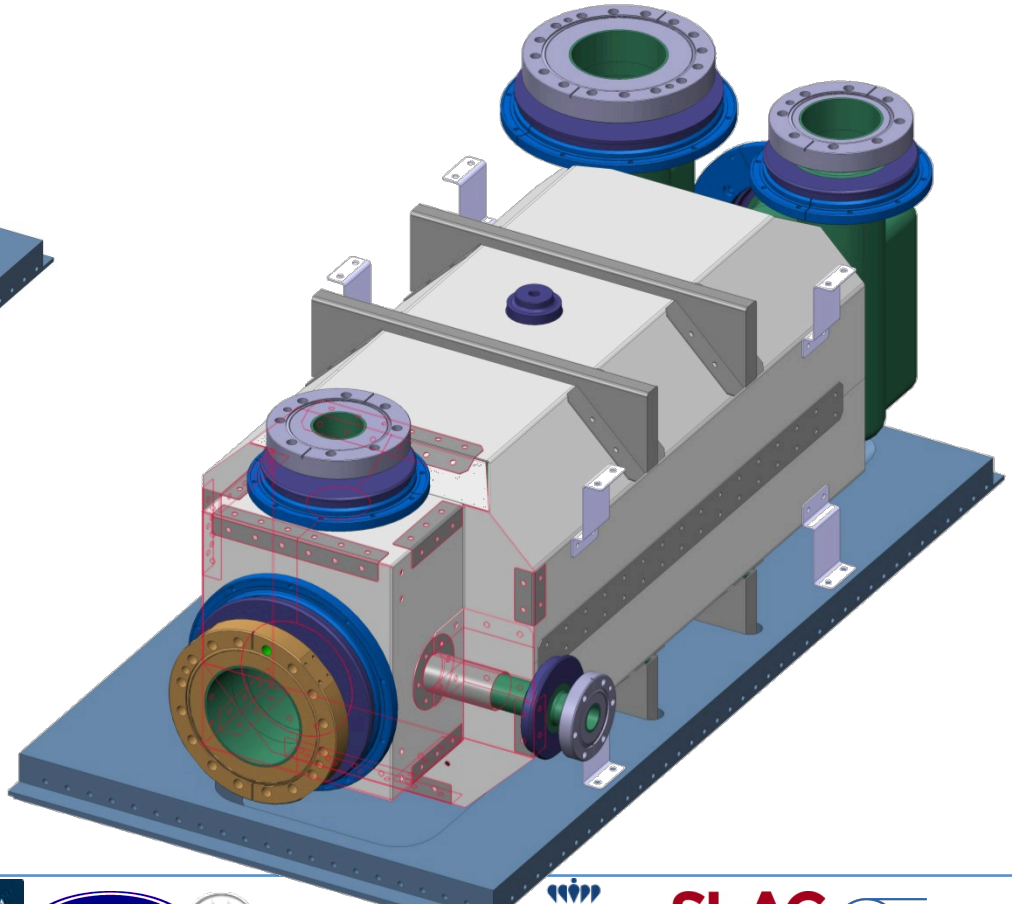
Shield body is mounted to Helium Vessel base

RFD Assembly Procedure

Split folded-end panels are assembled around 3 ports

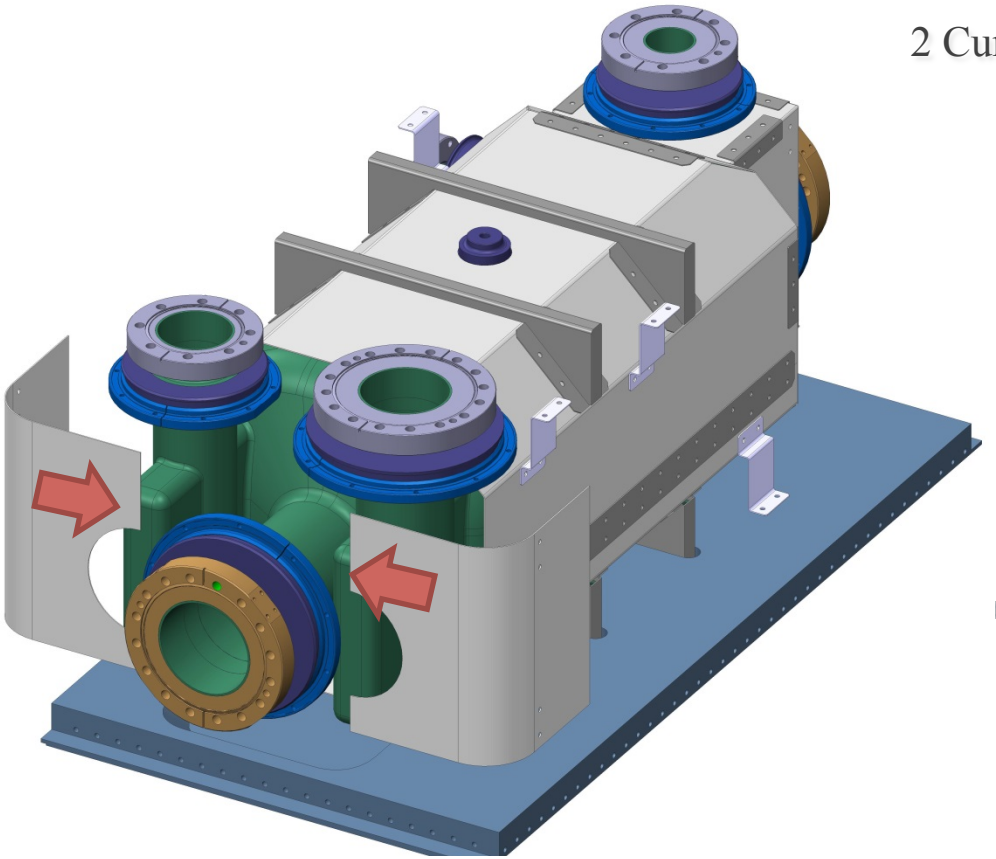
End Cover is assembled to main body and fastened with cover panels and brackets

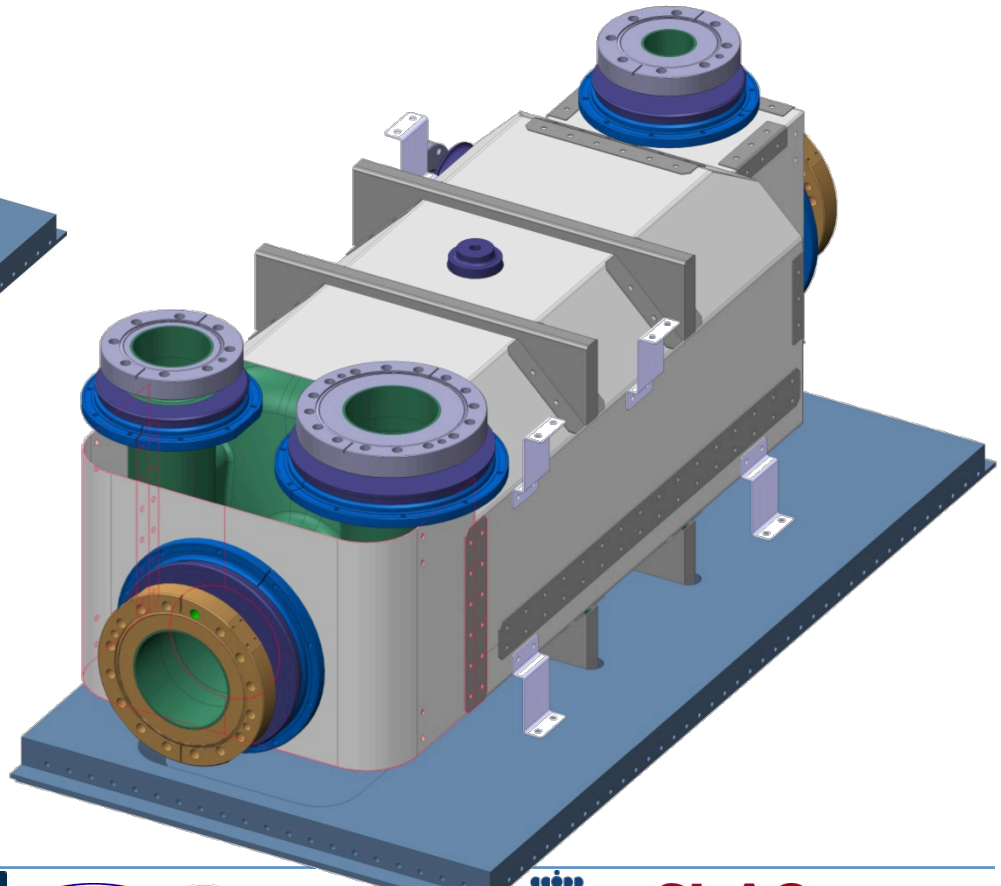




RFD Assembly Procedure

2 Curved-End panels are assembled around Beam Pipe

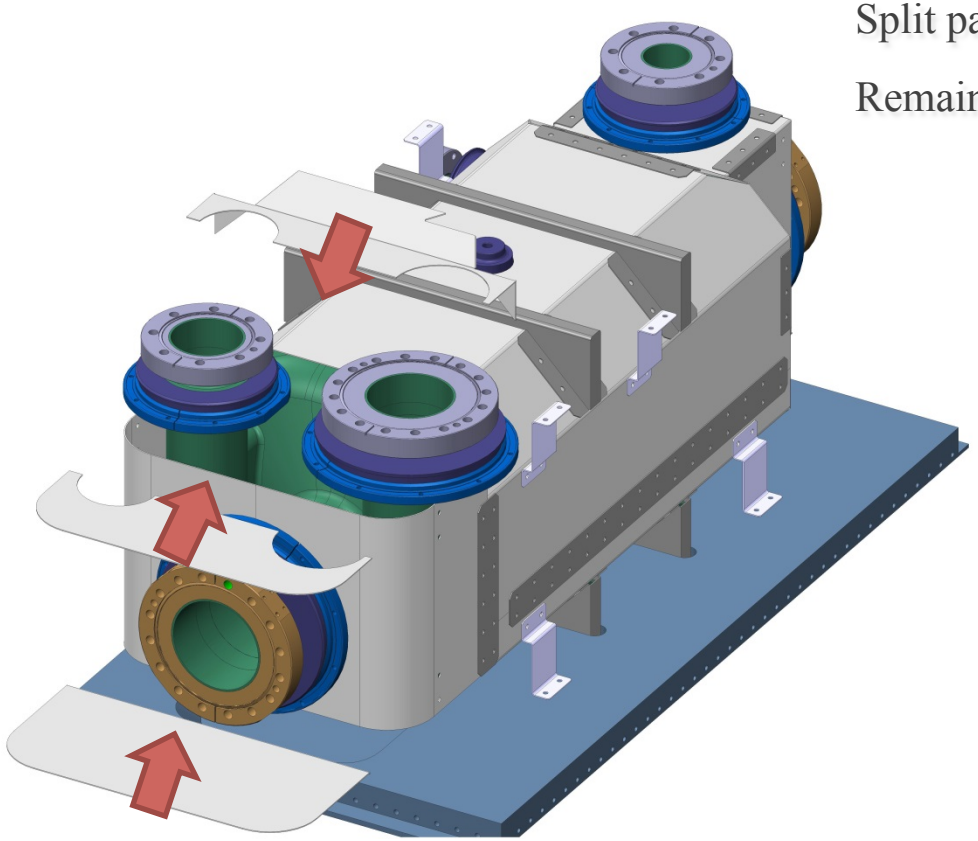


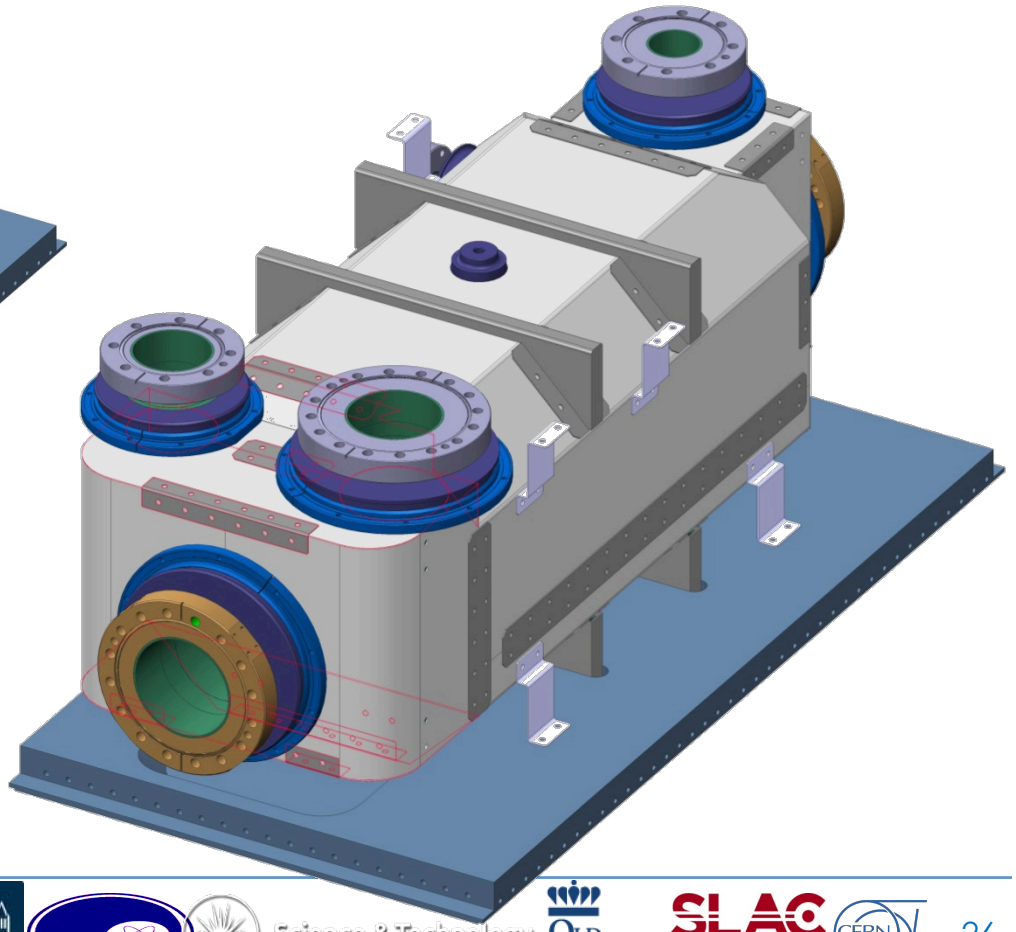


RFD Assembly Procedure

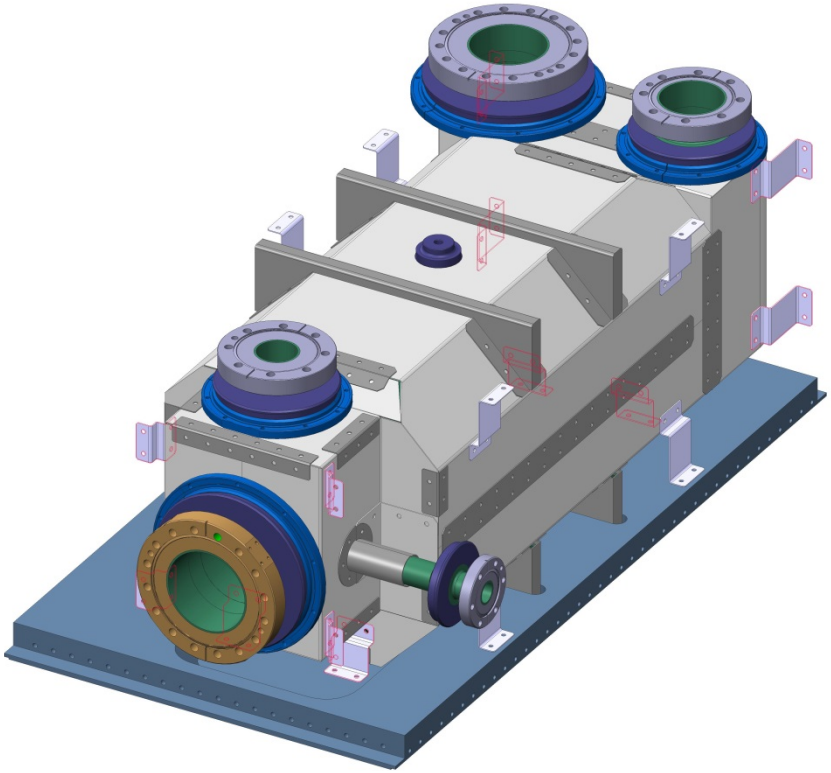
Split panels complete the Shield at the FPC & HOM Ports

Remaining cover strips are assembled

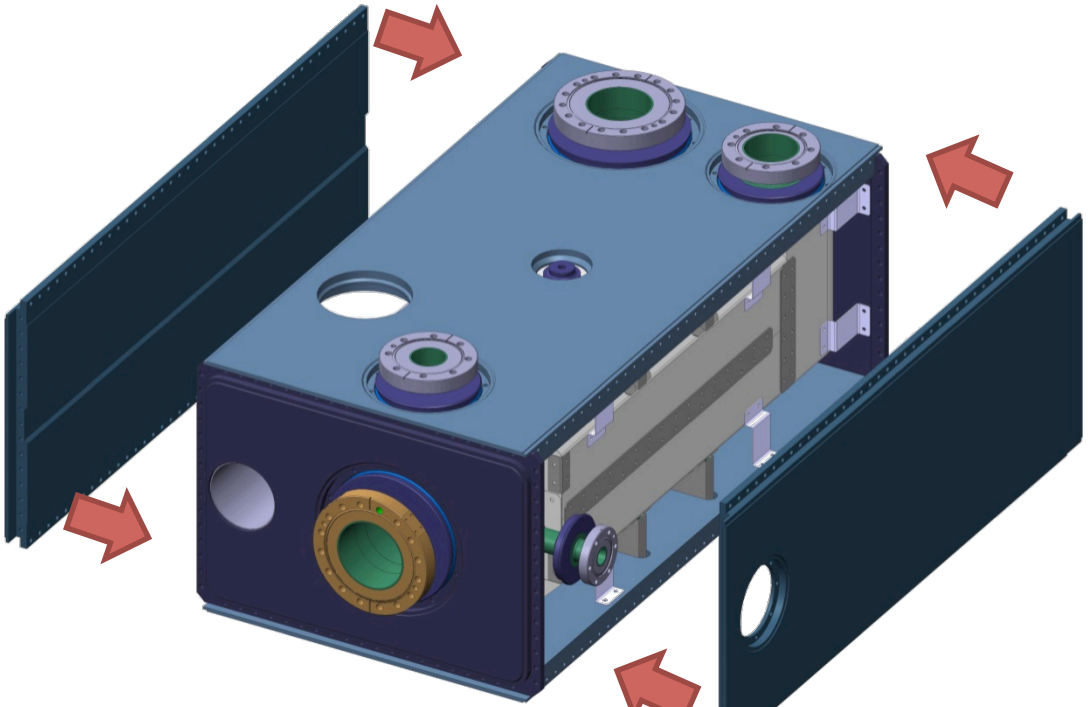




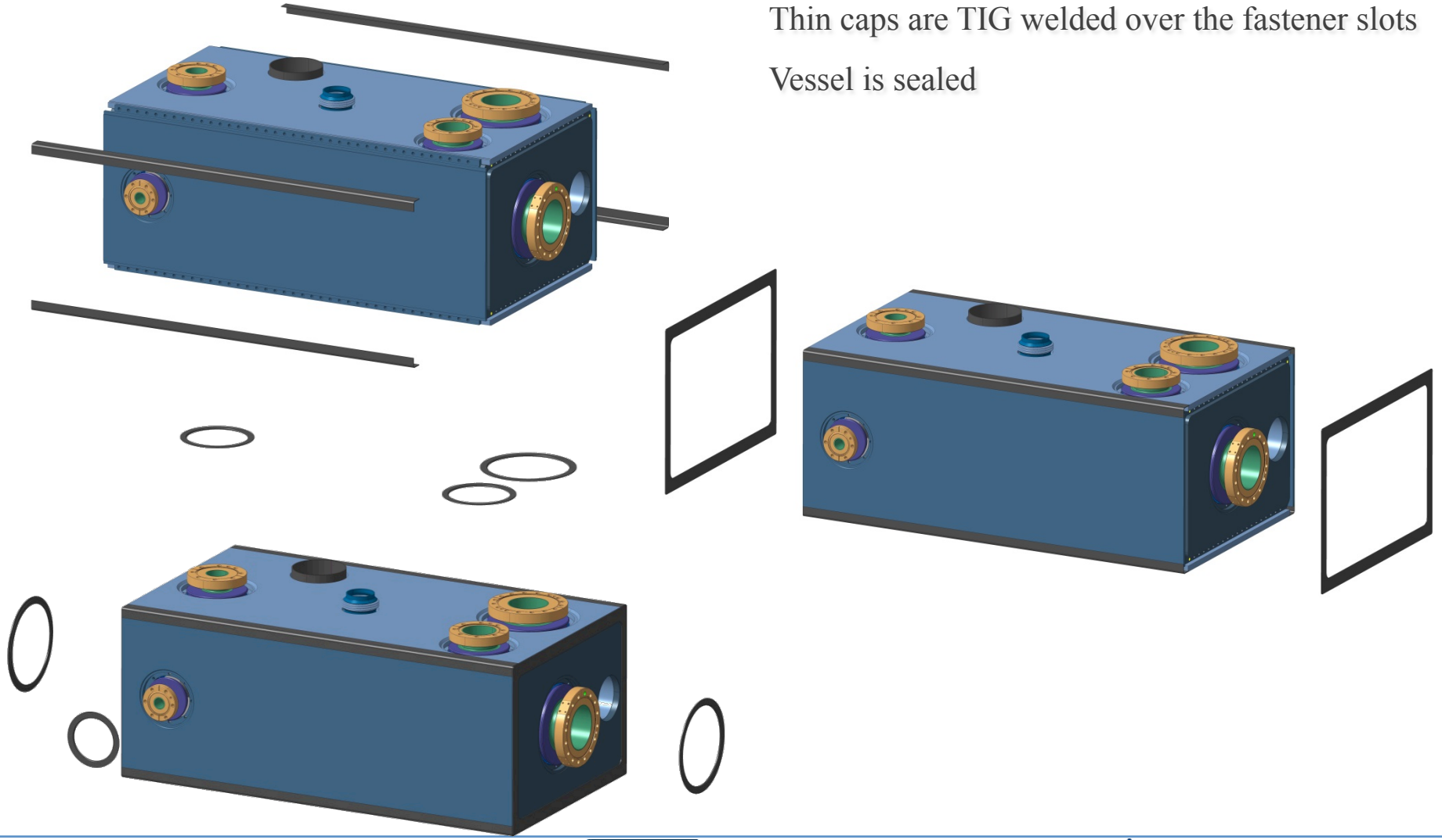
RFD Assembly Procedure



Flexi-mounts are connected and Helium Vessel is assembled



RFD Assembly Procedure



Thin caps are TIG welded over the fastener slots

Vessel is sealed

Impedance of Crab cavities

- Crab cavities in LHC are a worry for the impedance team due to:
  - The very large transverse beta functions at their planned location (~4 km)
  - The large number of cavities (16 in the final stage)
  - The large number of HOMs and their high Q if undamped.
  - The already optimized LHC impedance to reach high brightness beams.

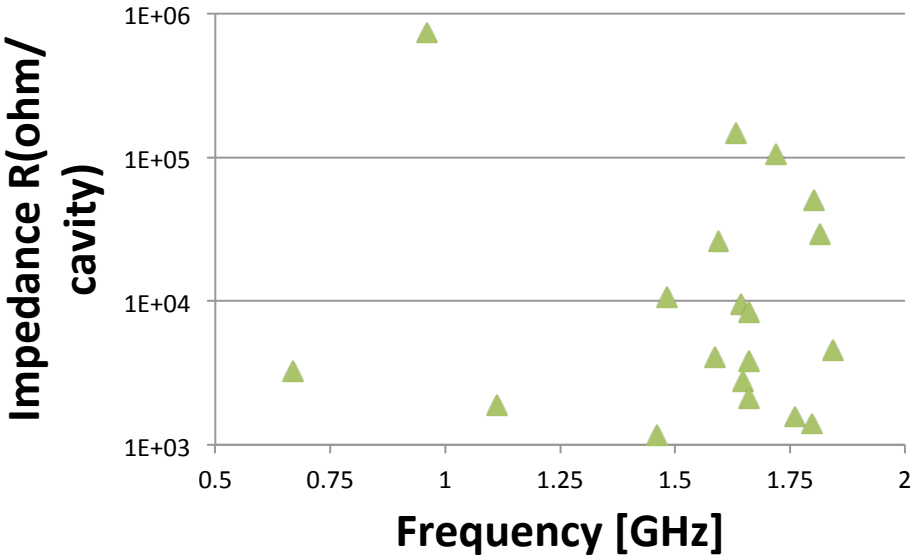
- In the SPS, however:
  - The beta function can not be very high.
  - There are only 2 cavities.
  - The large number of HOMs and their high Q if undamped.
  - The SPS impedance is large compared to LHC, in particular in the longitudinal plane.

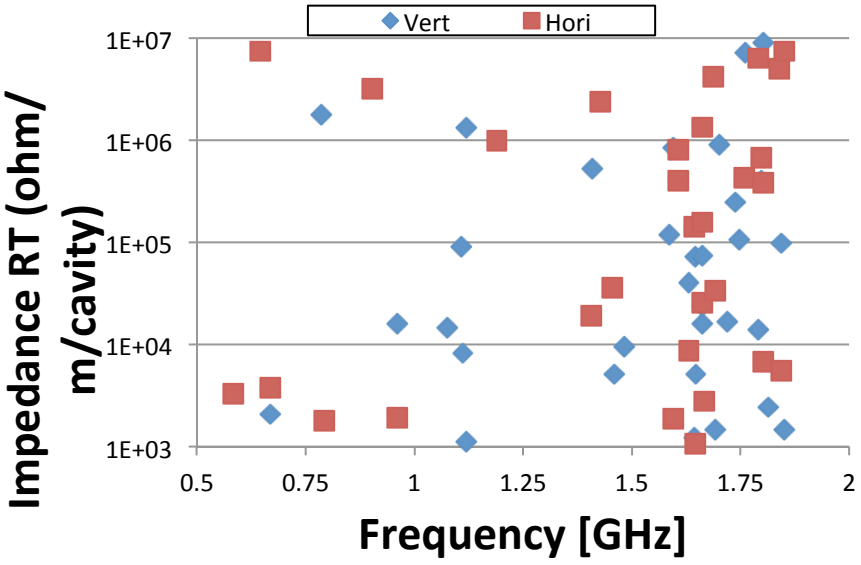
HOM Damper Design

- Two reviews since KEK meeting
  - Electromagnetic design
  - Mechanical design
- Major progress
- Reducing worse offending modes
- Review outcome
  - > ready to build NOW

DQW – HOM impedance

Results above 1.75GHz are not accurate as the modes started to leak out from the beam pipe.



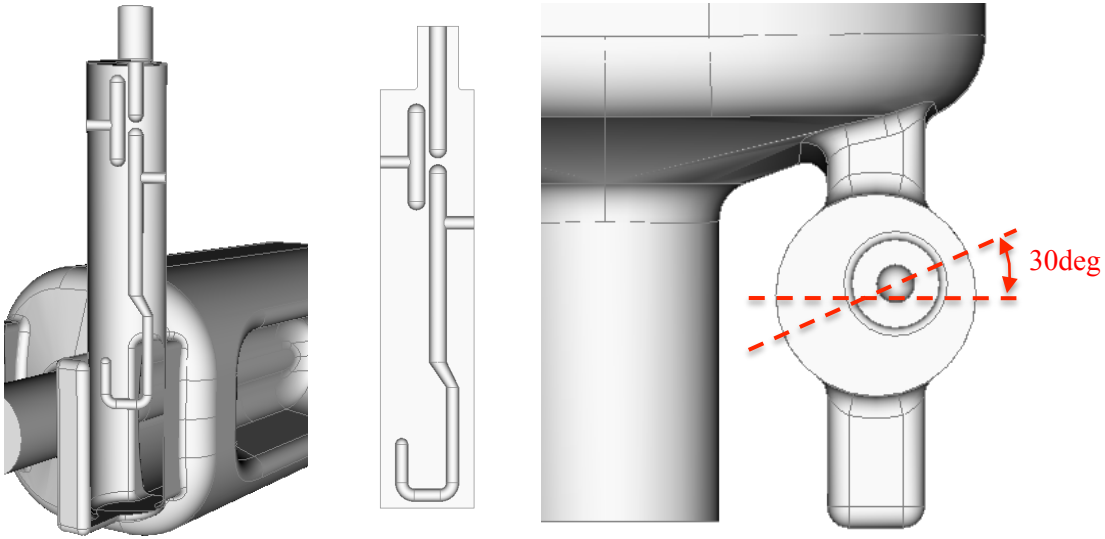


By inserting the most recent version of HOM filters to the **100mm aperture cavity**, the HOM longitudinal and transverse impedances were calculated. There are a few modes need to be optimized. It is a good starting point.

Improved HOM Damping

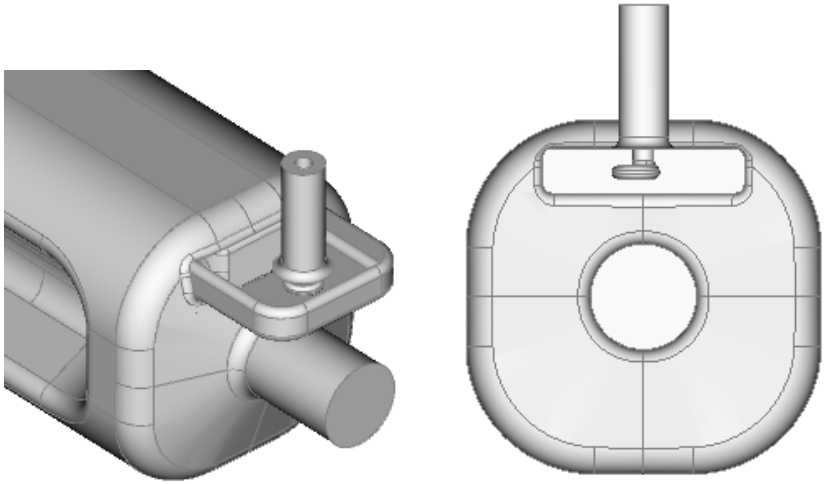
Horizontal HOM Coupler

- Coupling hook optimized
- 30 degree hook orientation
- No change in filter elements

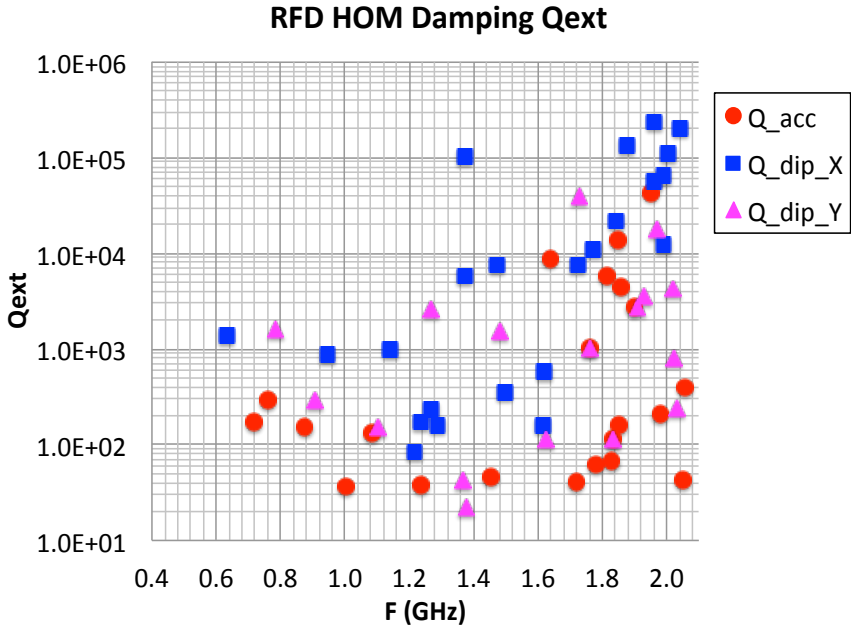


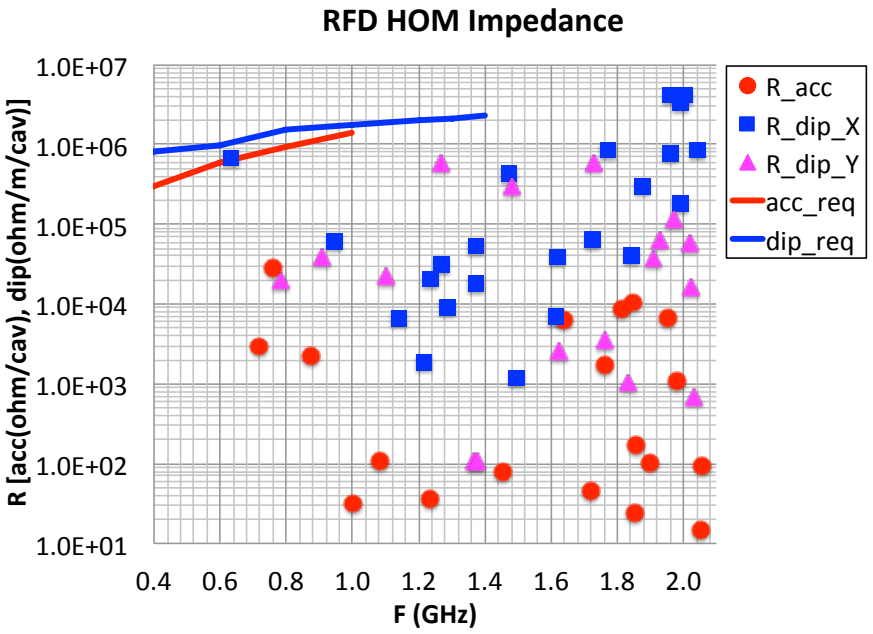
Vertical HOM Coupler

- 7 mm offset incorporated into the pickup tip to enhance coupling to the dipole modes at around 2GHz
- Small RF power leakage through the coupler, ~1.5W, due to asymmetry



HOM Damping and Impedance





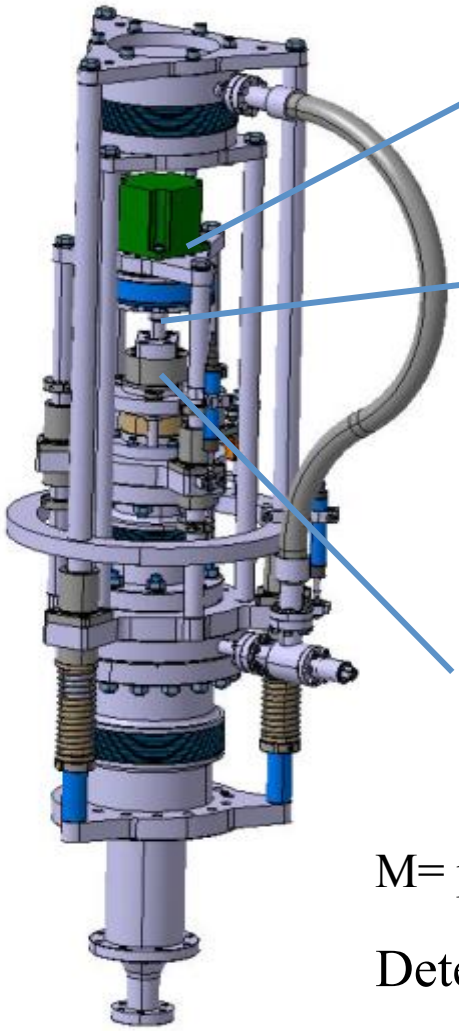
- Q_{ext} calculated using Omega3P for modes up to 2 GHz
- Solid lines are the impedance budget for dipole HOMs (blue) and accelerating HOMs (red) respectively

Impedance Summary

- CC impedance is a concern in the LHC
  - On the other hand, we may not be able to even notice their presence in the SPS
- Studies are underway both in beam physics (WP2) and RF design (WP4)to find a suitable solution

[Note: dedicated MD time in the SPS is tight]

Status SM18 p.o.p. tuner



Design: **P. Minginette**

Motor 1.3 Nm Bipolar Nema 23 (1.8 deg/step)

HD HFUS-20-100-2SO

Ratio i : 0.01 ,
repeat. peak Torque 82 Nm, average torque 49 Nm
Accuracy < 1 arcmin, precision <0.1 arcmin
Fa Dyn 7.7 kN, η=~0.80 (grease, 20 °C)

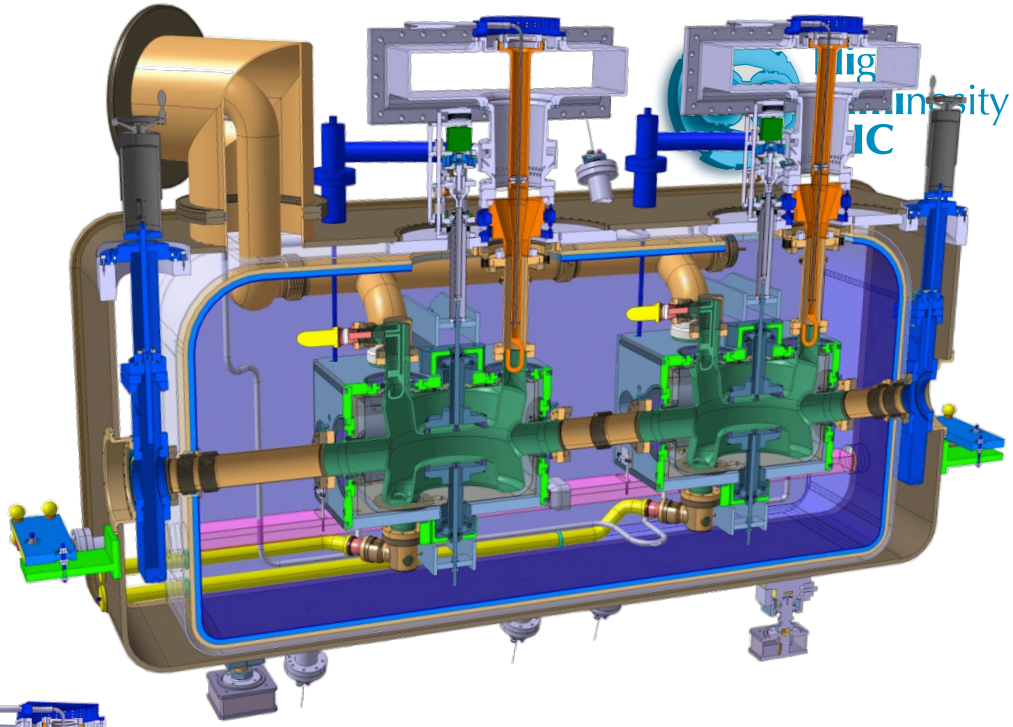
Roller screw Rollvis RV 12 x 1
η=0.79 , static load capacity 17 kN

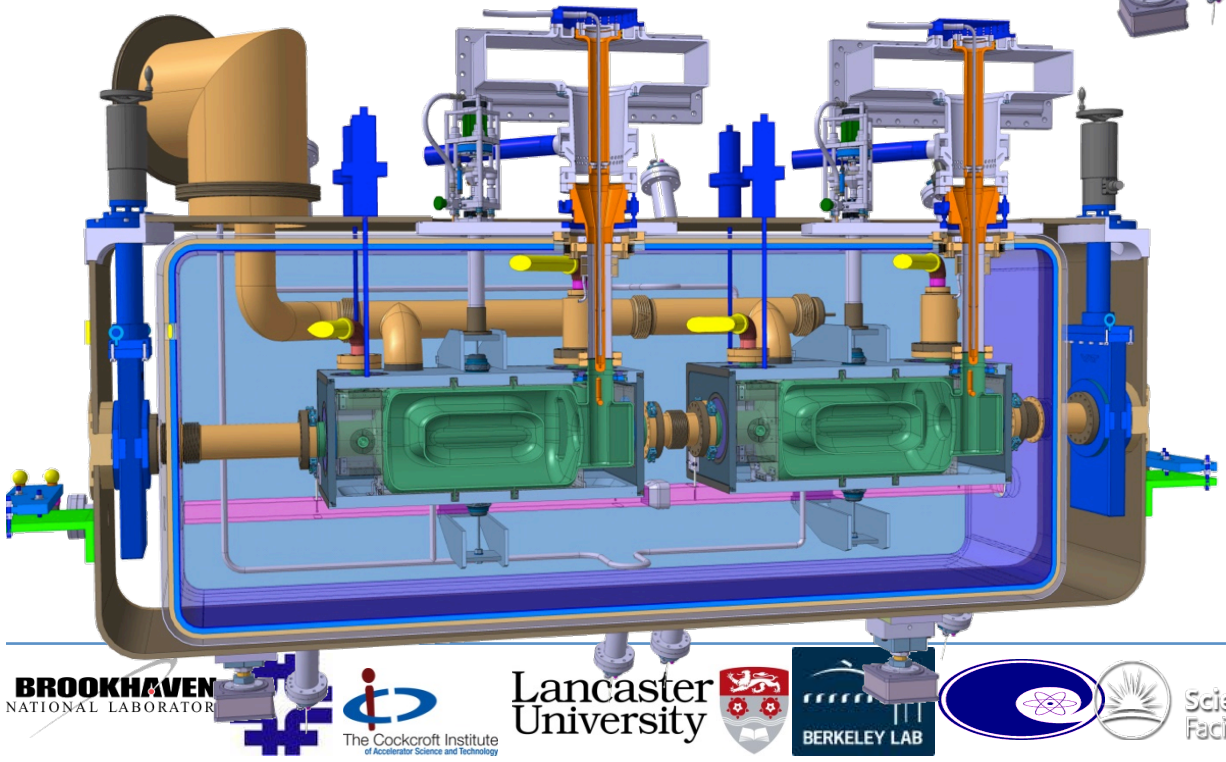
$M = p\, i\, F/2000\, \pi\, \eta = 0.01$ Nm F= 4 kN, p= 1

Detend torque 0.017 Nm, self locking

Cryomodules

Double Quarter Wave, Vertical Deflection

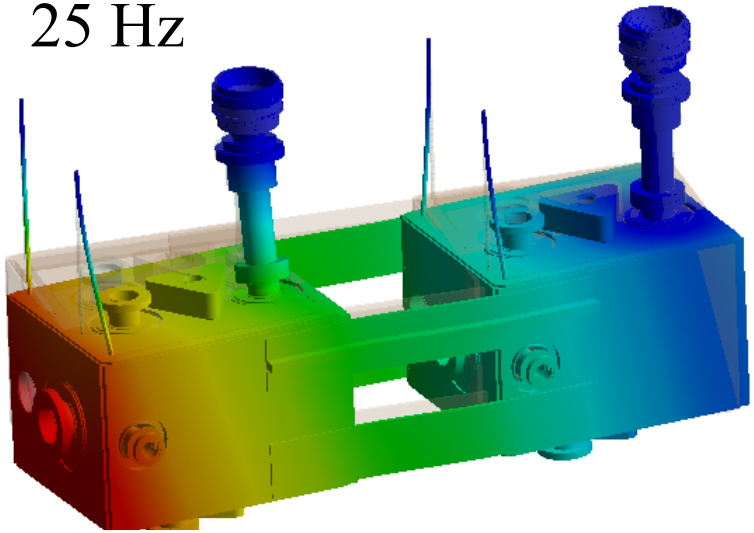




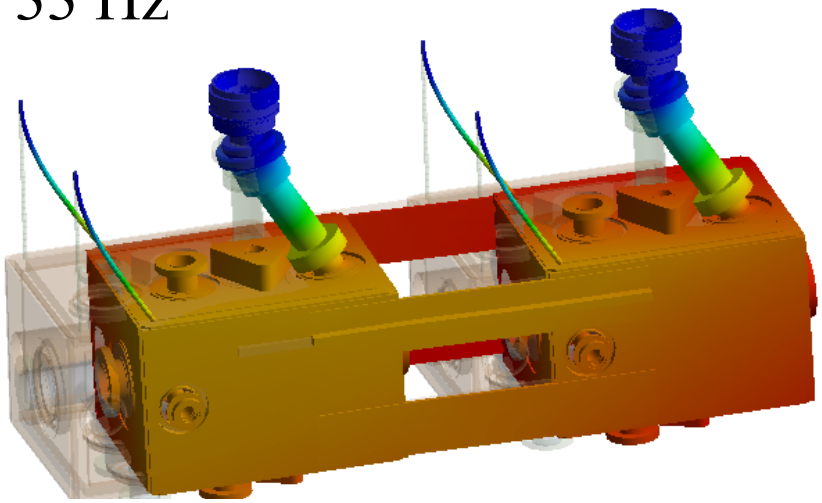
RF Dipole, Horizontal Deflection

Supporting system - Vertical Rods and Inter-cavity Link

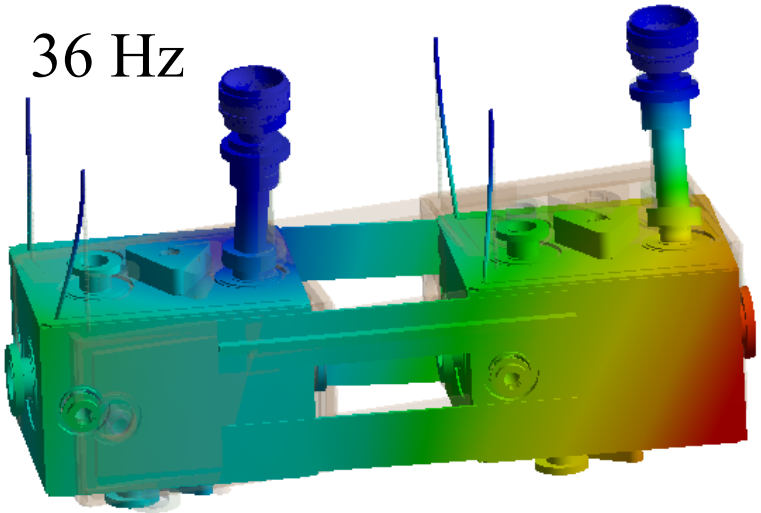
25 Hz



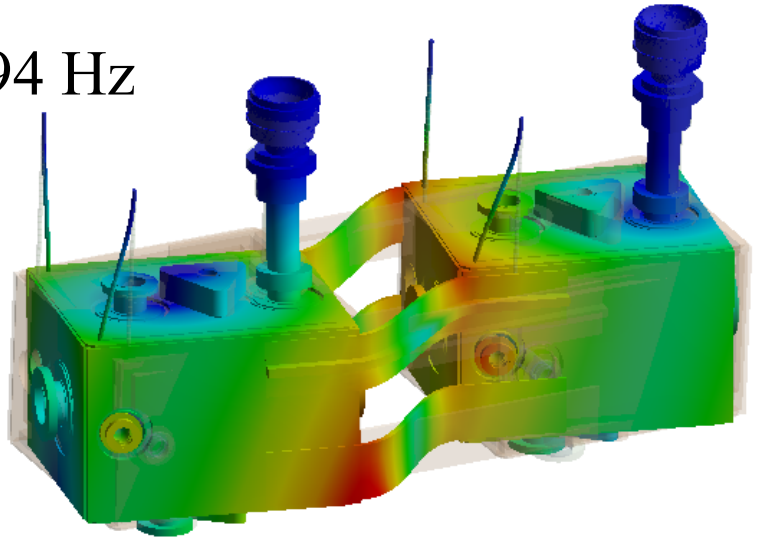
33 Hz



36 Hz



94 Hz



Summary – Cavity and CM integration

- Lots of progress and lots of work ahead of us in preparation for the SPS test
  - Need to freeze He vessel design very soon
    - Successful review of 6 May is a key step forward
  - Magnetic shield and He Vessel
  - Tuner prototype underway

- Finalizing the cryomodule design will be next, if we want to be ready at the end of 2016
  - Studies also in progress

Conclusions

- Major progress across the board
  - Cavity production of both cavity designs is underway at our US industrial partner
  - Finalizing dressed cavity and He vessel design
- Working on other major aspects of the design
  - Impedance and machine protection
- Planning for SPS test
  - A decision is needed soon
  - Schedule remains tight
- Active contributions from all collaborators

Acknowledgments – The Team

- Contributions to this presentation came from the whole collaboration

  - BNL – S. Belomestnykh, S. Verdu-Andres, Q. Wu, B. Xiao
  - CERN – L. Alberty, R. Calaga, O. Capatina, T. Capelli, M. Garlasche, C. Zanoni (and more)
  - FNAL – T. Nicol
  - LBNL – A. Ratti
  - Niowave – J. Hollister, T. Grimm, S. Klass, E. Maddock, J. Yancey,
  - ODU – J. Delayen, H. Park, R. Olave, S. da Silva
  - LU/STFC – G. Burt, B. Hall, T. Jones, S. Pattalwar, N. Templeton
  - SLAC – Z. Li

  And I'm sure there are more…

Questions