Fabrication Readiness Review: Overview, RF Design

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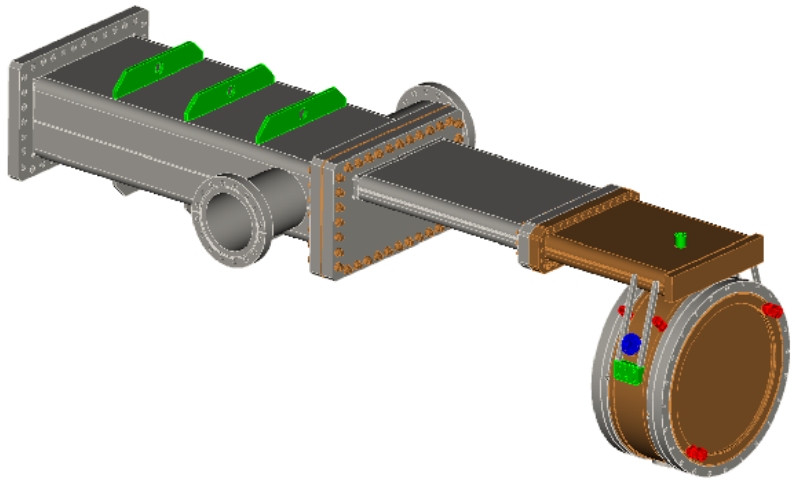
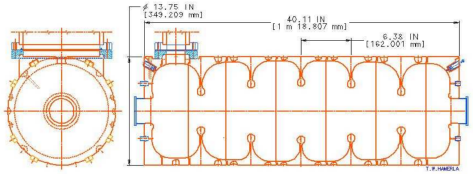
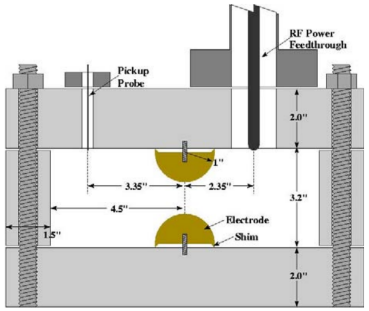
Overview

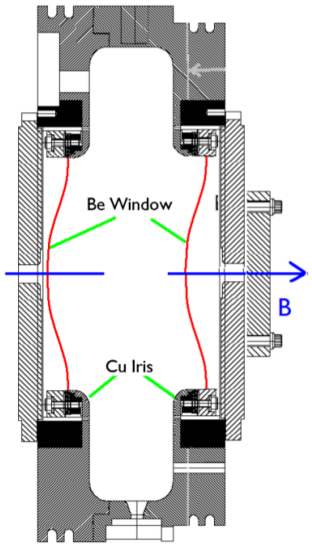


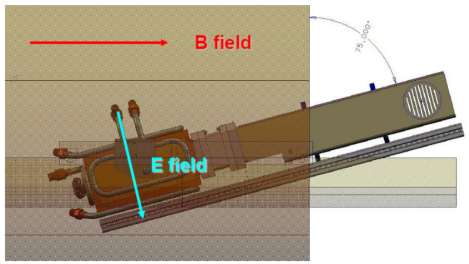
1. Experimental history
2. Design requirements
3. RF design
4. Hardware overview

805 MHz History

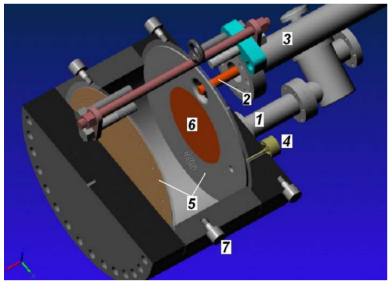






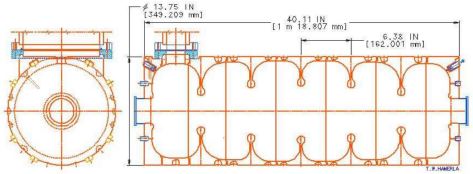


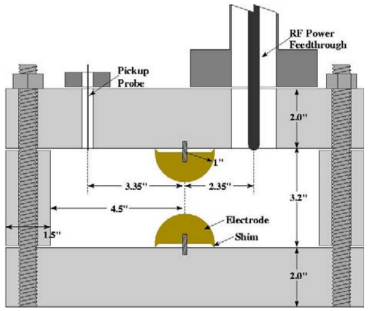
See A. Moretti's talk immediately following.

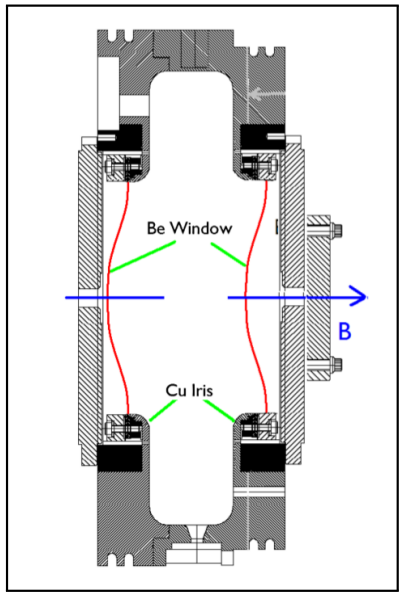


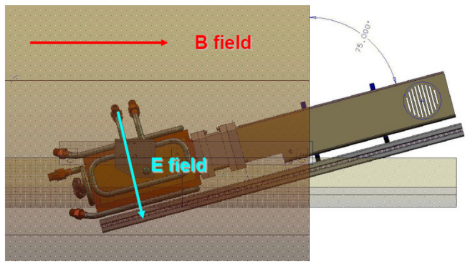
1. A. Moretti *et al.*, *RF cavities for the muon and neutrino factory collaboration study.* Proc. LINAC'00, Monterey CA, 2000.
2. R.B. Palmer *et al.*, *RF breakdown with external magnetic fields in 201 and 805 MHz cavities.* PRST-AB **12**, 031002 (2009).
3. M. Chung *et al.*, *Beam test of a high pressure cavity for a muon collider.* Proc. IPAC'10, Kyoto, Japan, 2010. WEPE066.
4. Y. Torun *et al.*, *Rectangular box cavity tests in magnetic field.* Proc. IPAC'10, Kyoto, Japan, 2010. THPEA054.
5. G. Kazakevich *et al.*, *Conditioning and future plans for a multi-purpose 805 MHz pillbox cavity for muon acceleration.* Proc. IPAC'12, New Orleans, LA, USA. 2012. THPPC032.

805 MHz History









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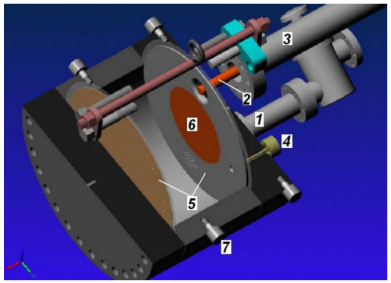

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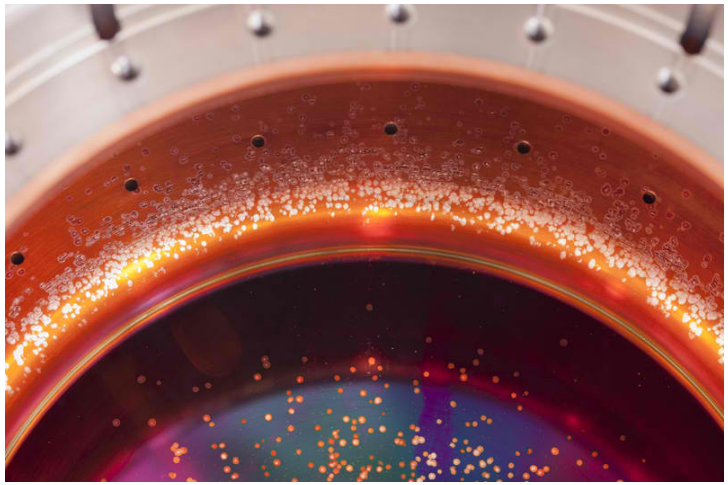
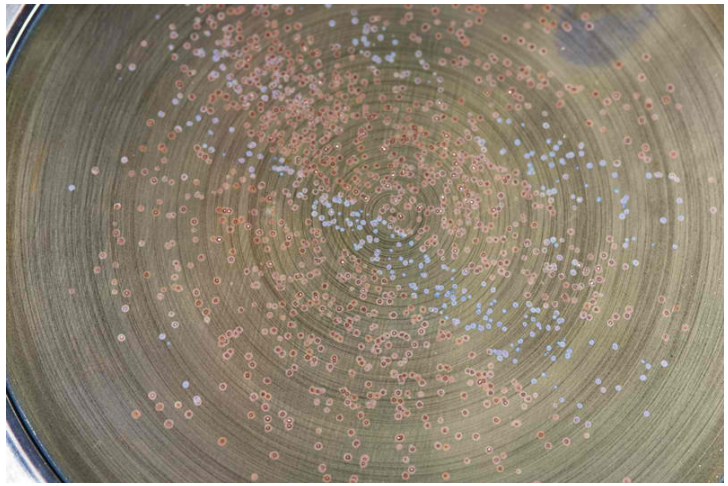
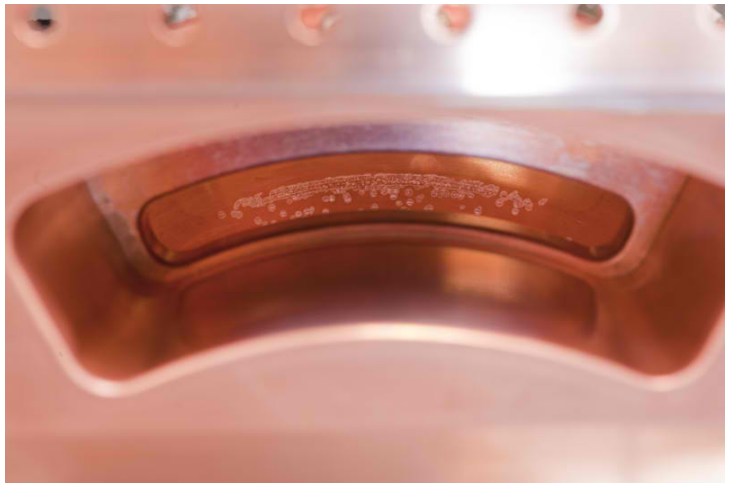
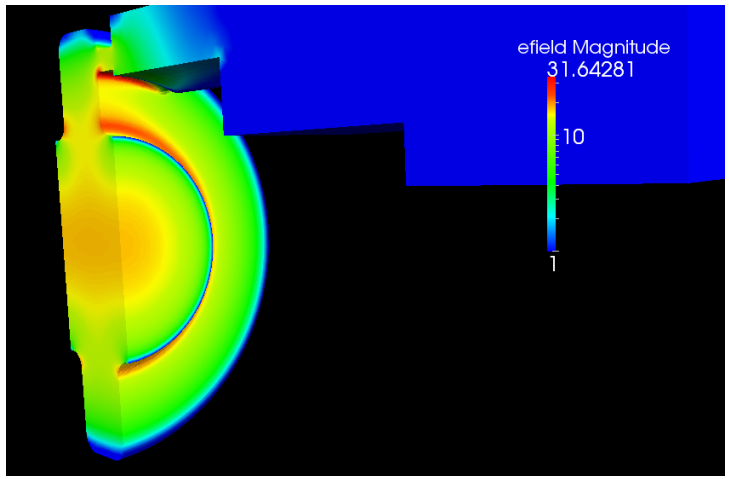
Pillbox with flat windows: extensive breakdown damage.









Erratic button data: Try for greater field enhancement.

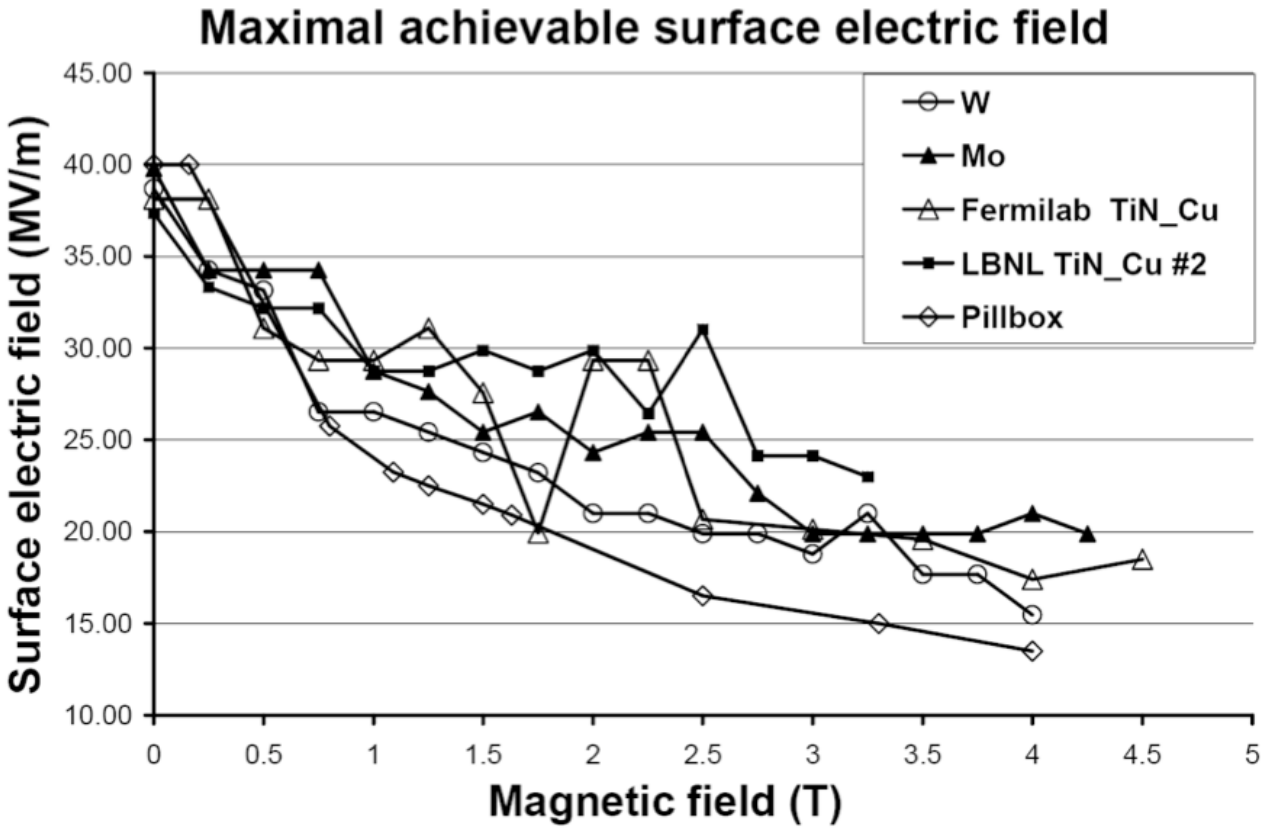


Figure: D. Huang *et al.*, *RF studies at Fermilab MuCool Test Area*, PAC09, Vancouver, May 2009, TU5PFP032, p. 888 (2009), http://www.JACoW.org.

Open Questions

Results of the 805 MHz R&D program have uncovered some interesting questions. These questions should be resolved before moving forward with ionization cooling designs.

- How do strong magnetic fields limit the maximum achievable gradient of Cu cavities?
- Is this behavior affected by material choice? Do materials other than Cu mitigate it?
- To what extent is this anomalous breakdown behavior due to erratic coupler behavior?

These questions can all be addressed directly, quickly, and clearly by this new modular cavity design.

Some indication that Be endplates would ameliorate these problems.

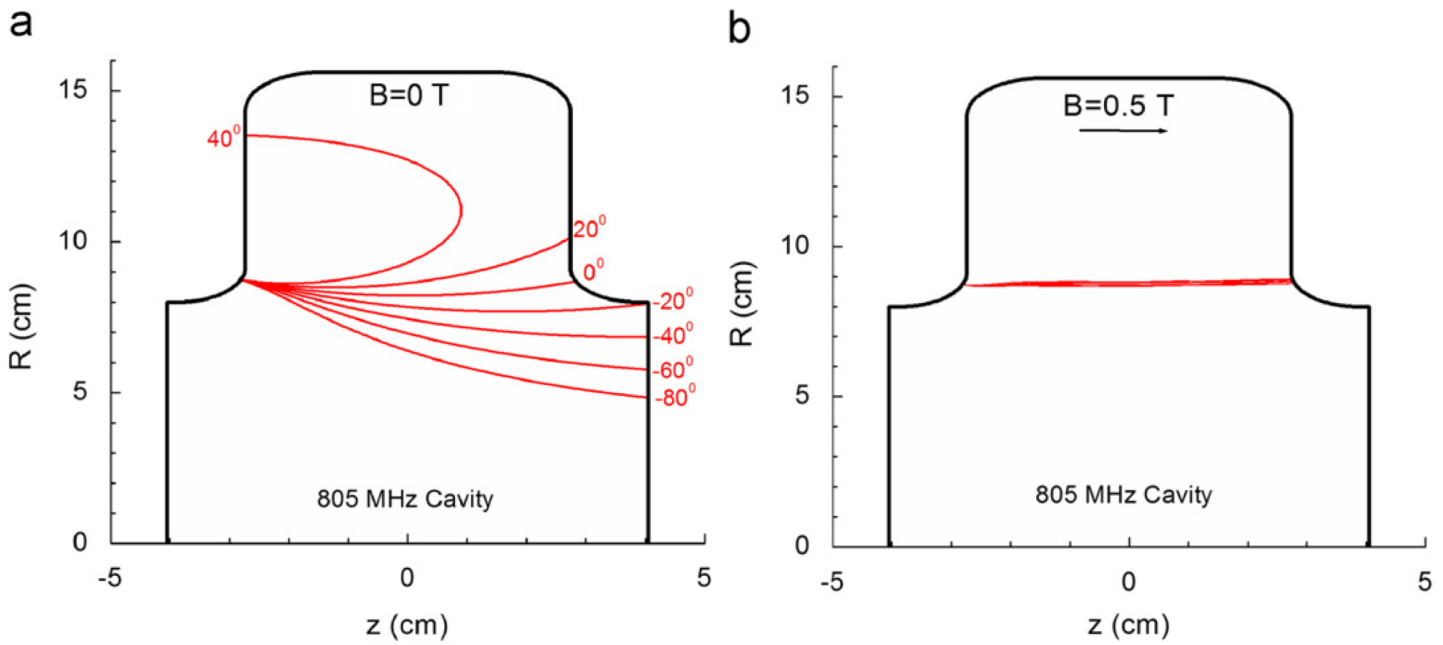


Figure: Stratakis *et al.*, Nucl. Inst. Meth. A 620 (2010) 147-154.

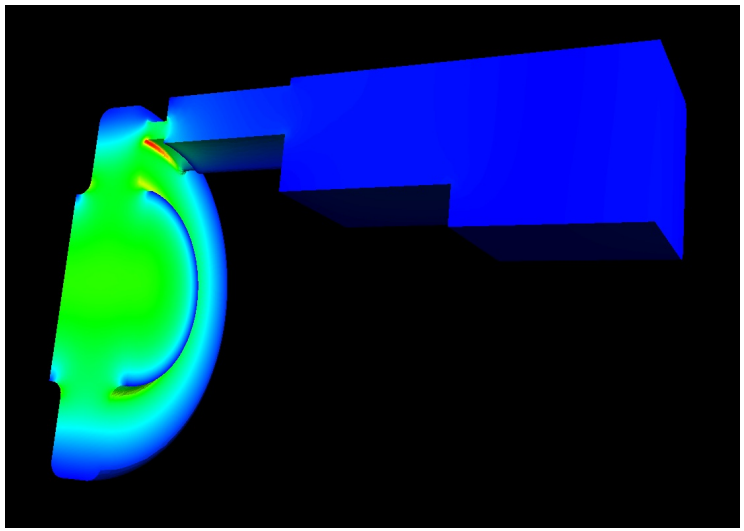
Be has longer radiation length than Cu. Less pronounced pulsed heating effects may mean more stable high-gradient operation in strong B-fields.

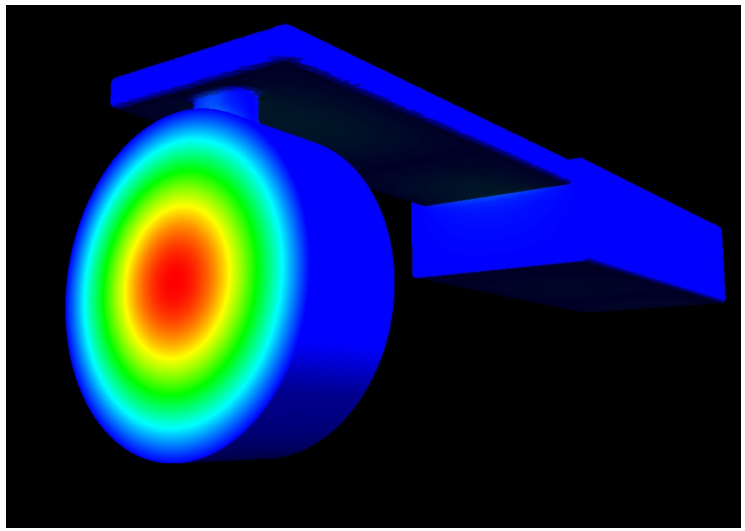
Goals for the new cavity design

1. **Fix coupler issues.** Eliminate uncertainty in breakdown location.
2. **Scaled version of a "real" cooling channel cavity.** (Geometry, coupling strategy.)
3. **Modular design.** Fast turnaround, cheap component repair/replacement, simplified damage analysis, simplified materials comparison.

Fix coupler issues.

Surface E-field in old, new cavity designs (ACE3P).

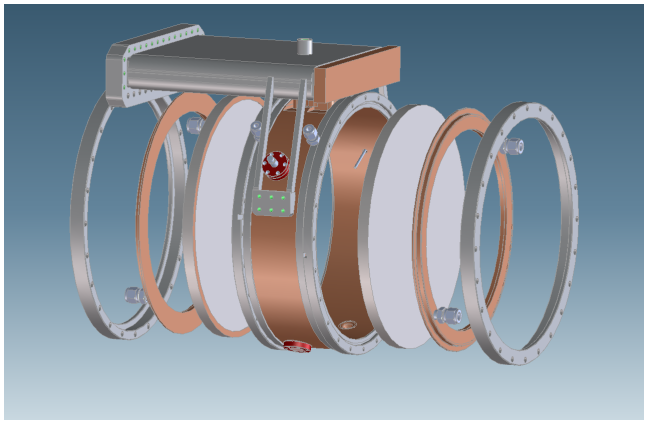




Old 805 MHz cavity design: Field at coupler is roughly twice as large as that on the longitudinal axis.

New modular cavity design: Field at coupler is roughly three times smaller than that on the longitudinal axis.

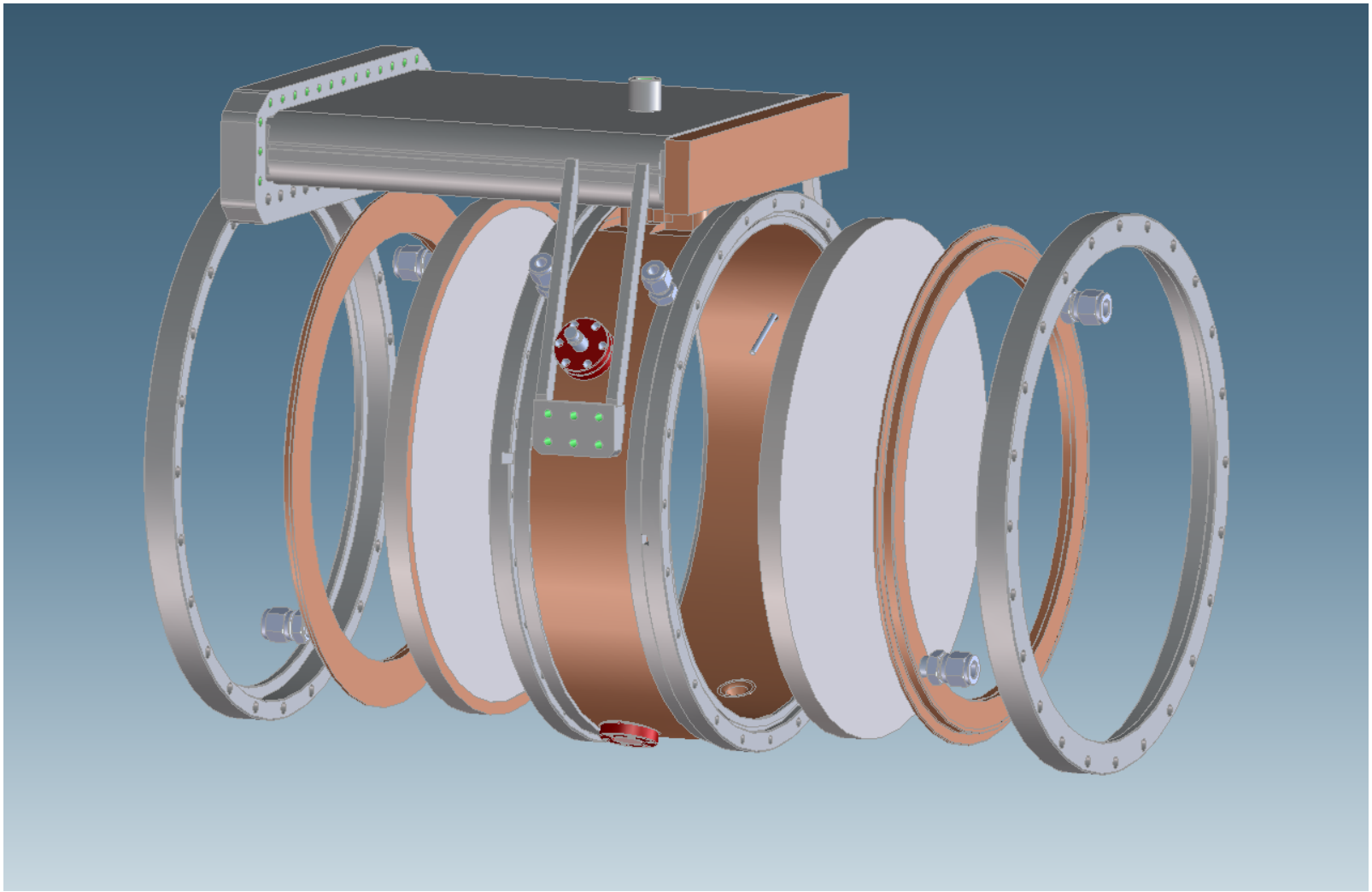
R&D goals aided by modular cavity design.



See next slide for a larger image.

- Demountable endplates: **compare Cu vs. Be** vs. [other materials, pending $ availability].
- **Quick experimental turnaround:** by design, plus simplified flanges, gaskets, and off-the-shelf instrumentation ports.
- **Easier experimental analysis:** Easier open/close + all interior surfaces visible for easy inspection.
- **Any damage more simply repaired/replaced.**

R&D goals aided by modular cavity design.



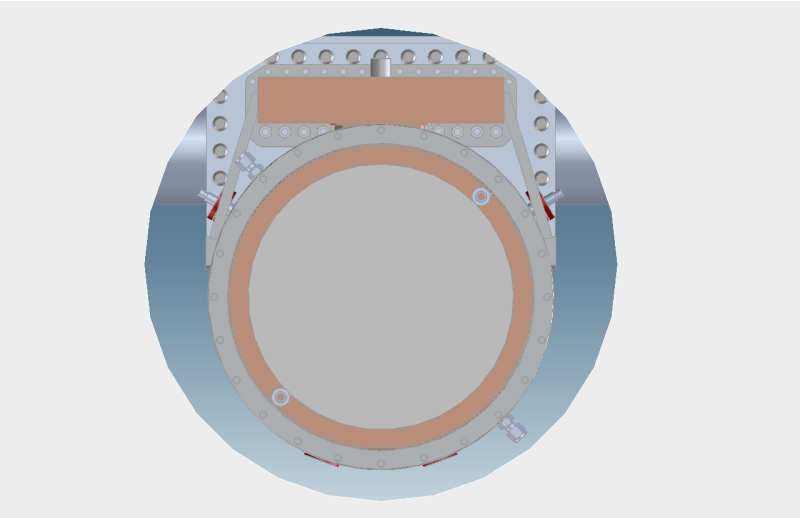
RF Design Goals: Scaling a 201 MHz MICE cavity

- $f = 805$ MHz.
- Gap length $= 10.44$ cm.
- Over-coupling: $\beta = 1.3$ to account for losses at clamped endplates (per past MTA experience).
- In an actual cooling channel, RF power will be coupled in from a *radial* direction, rather than longitudinally as in the old 805 MHz cavity.

In the long term, we plan to test a **15 cm gap length as well**, in order to evaluate transit time and stored energy effects on the breakdown phenomenon.

RF Design Goals: Radial Coupling

- **Magnetic coupling at the pillbox equator.** This will be the coupling strategy in any eventual cooling channel design.
- Equatorial coupling presents interesting challenges: how to fit such a cavity inside the Lab-G solenoid? (44 cm warm bore diameter.)



(Min. clearance here is ~ 6 mm.)

Fitting the cavity in the magnet: Does vertical offset matter?

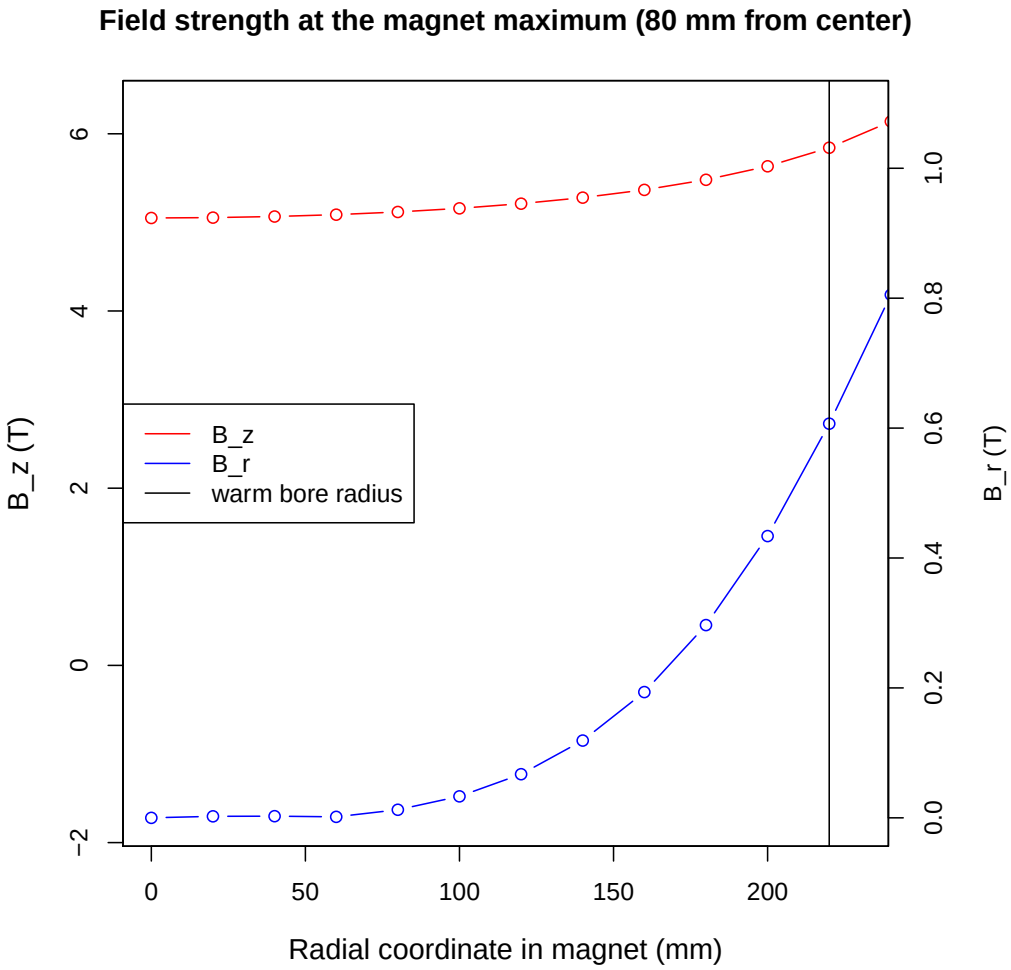
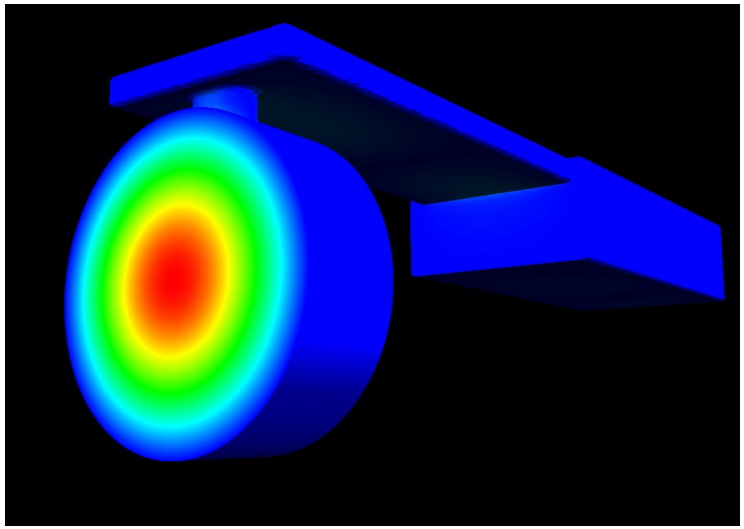
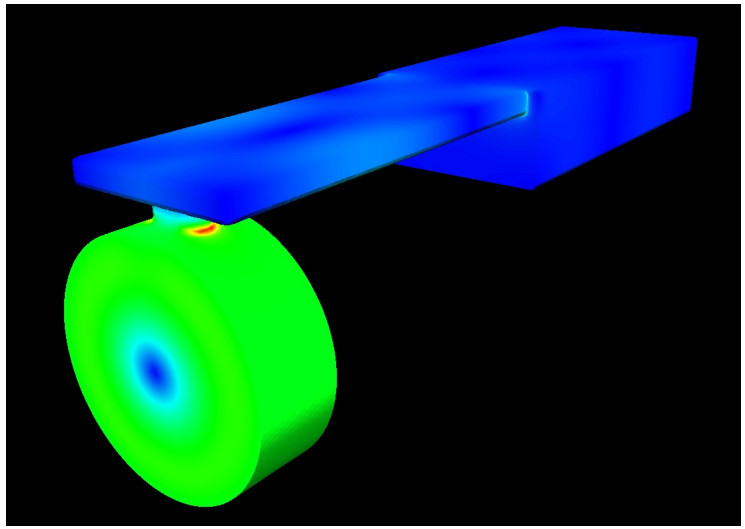


Figure: Measured B-field in Lab-G solenoid.

- Cavity is 30 mm lower than longitudinal magnet axis, in order to make room for coupling waveguide.
- Coupling waveguide is as narrow as possible without problematic mode cutoff.
- Longitudinal B-field uniform to within 2% at cavity edge. $\longrightarrow$ offset is acceptable.

ACE3P Field Simulations



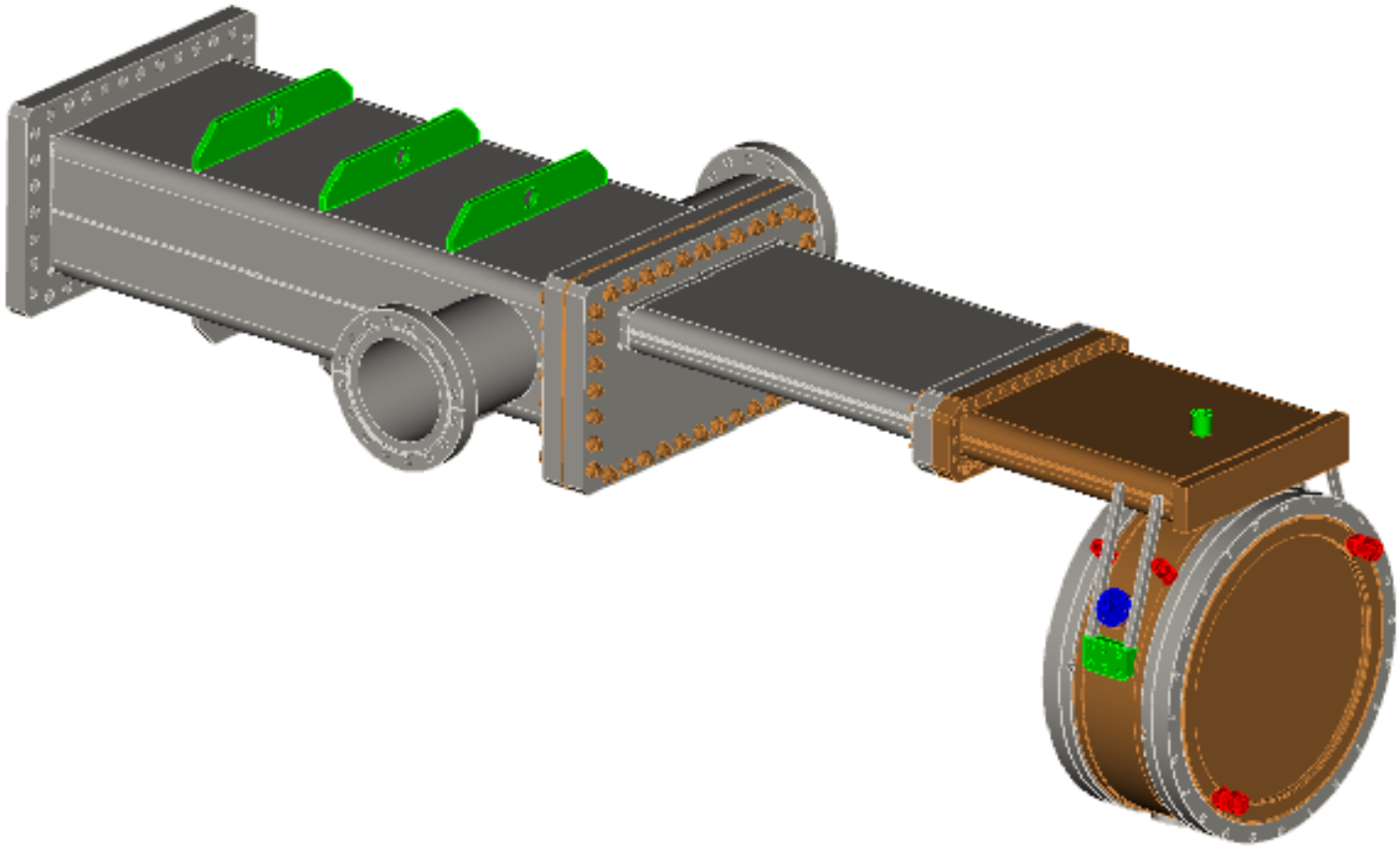


Simulations of electric (left) and magnetic (right) fields in the new modular cavity. E-field is strongest on axis by a factor of ~ 5. (Note location of strongest B-field. c.f. Zenghai's MP discussion.) **Automated simulation scripting $\rightarrow$ cavity geometry optimization.**

Final simulated cavity RF properties

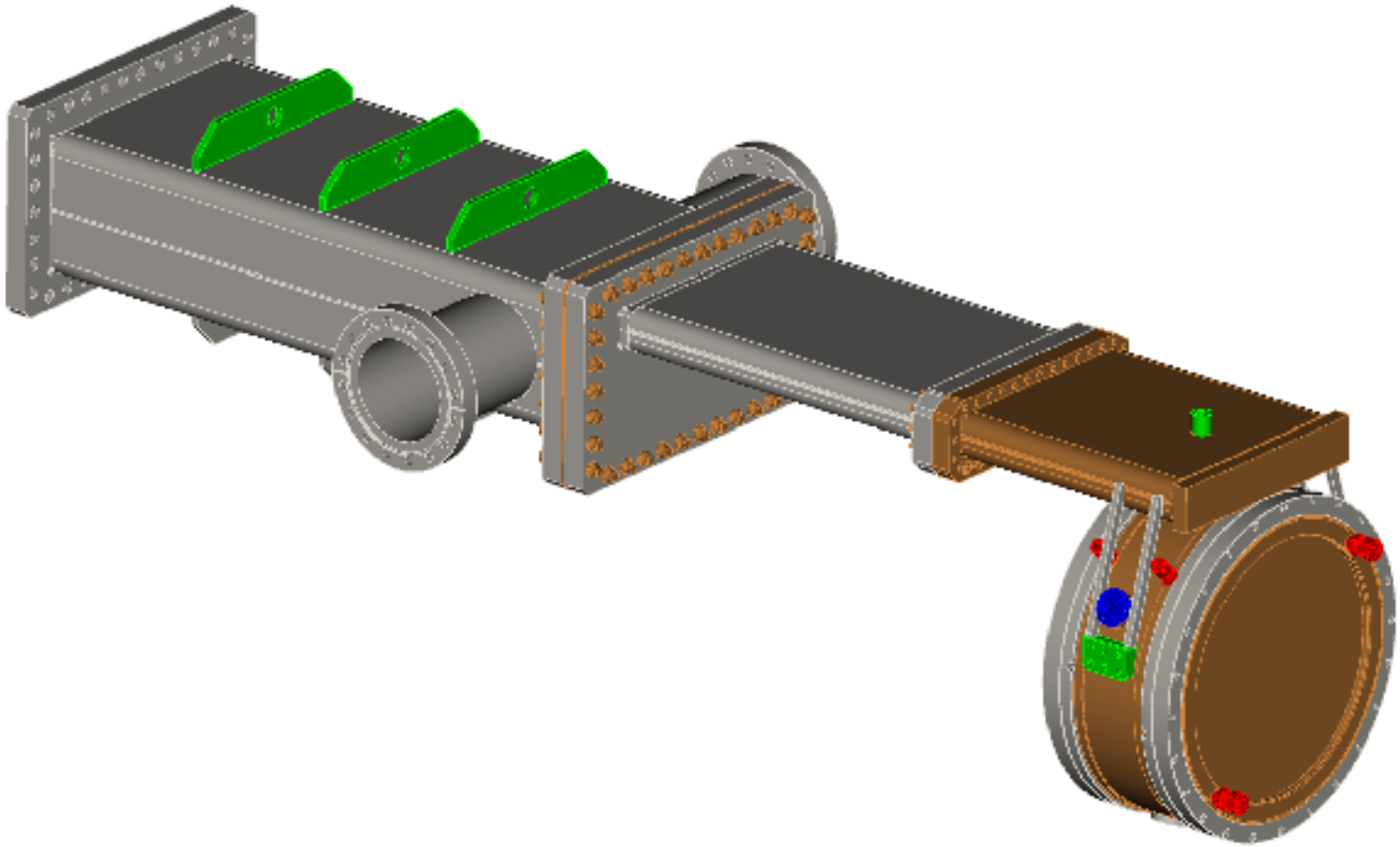
- $f = 804.99$ MHz
- $\beta = 1.3$
- Field ratio ≈ 5.

Design Features: Coolant channels on Cu "ring" and endplates.



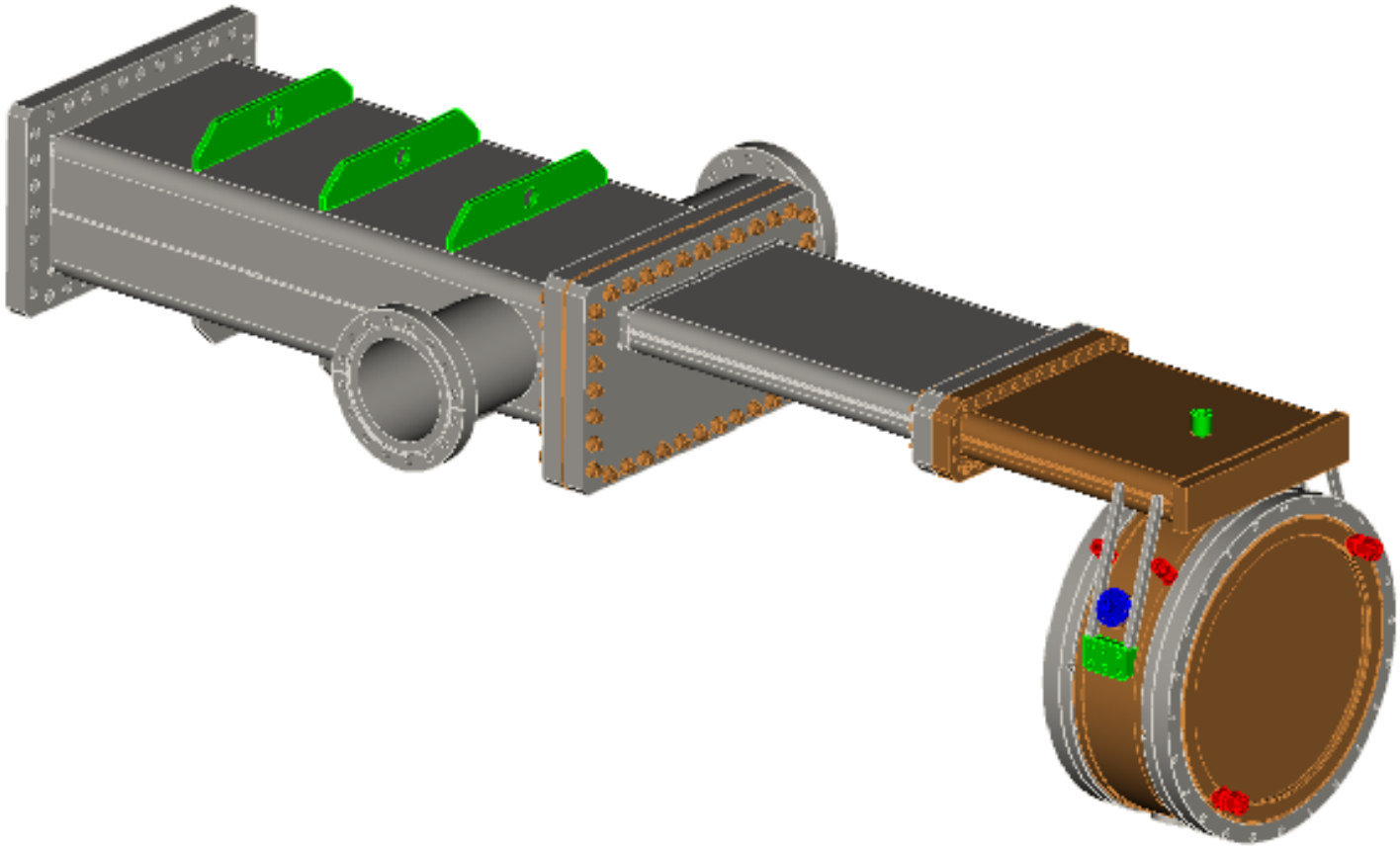
Compression fittings for coolant coupling shown in red. c.f. Zenghai's talk.

Design Features: mini-CF instrumentation ports



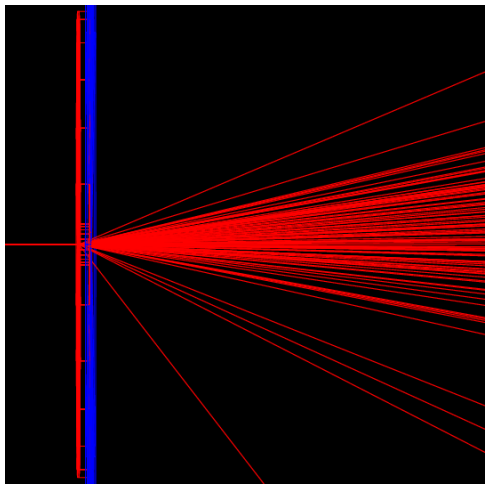
Mini-conflat ports for RF pickups, optical ports (blue).

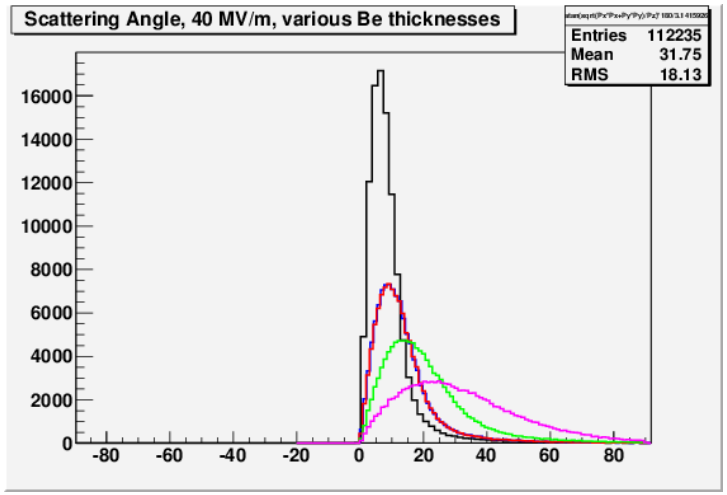
Design Features: mini-CF instrumentation ports

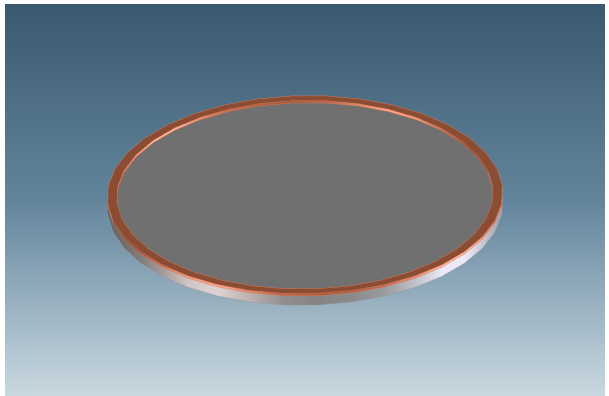


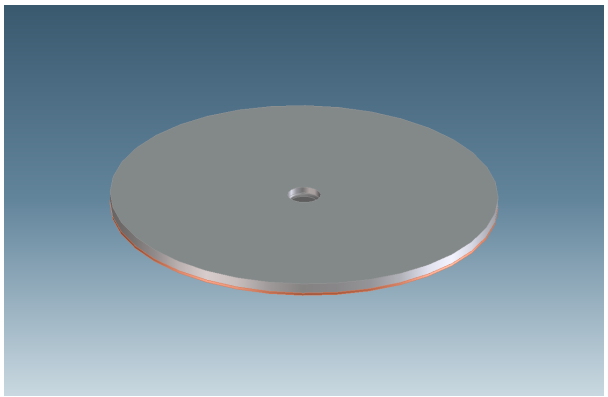
Mechanical supports for hoisting, rail mounts (green).

Design features: "Window" in Be endplates for dark current measurements

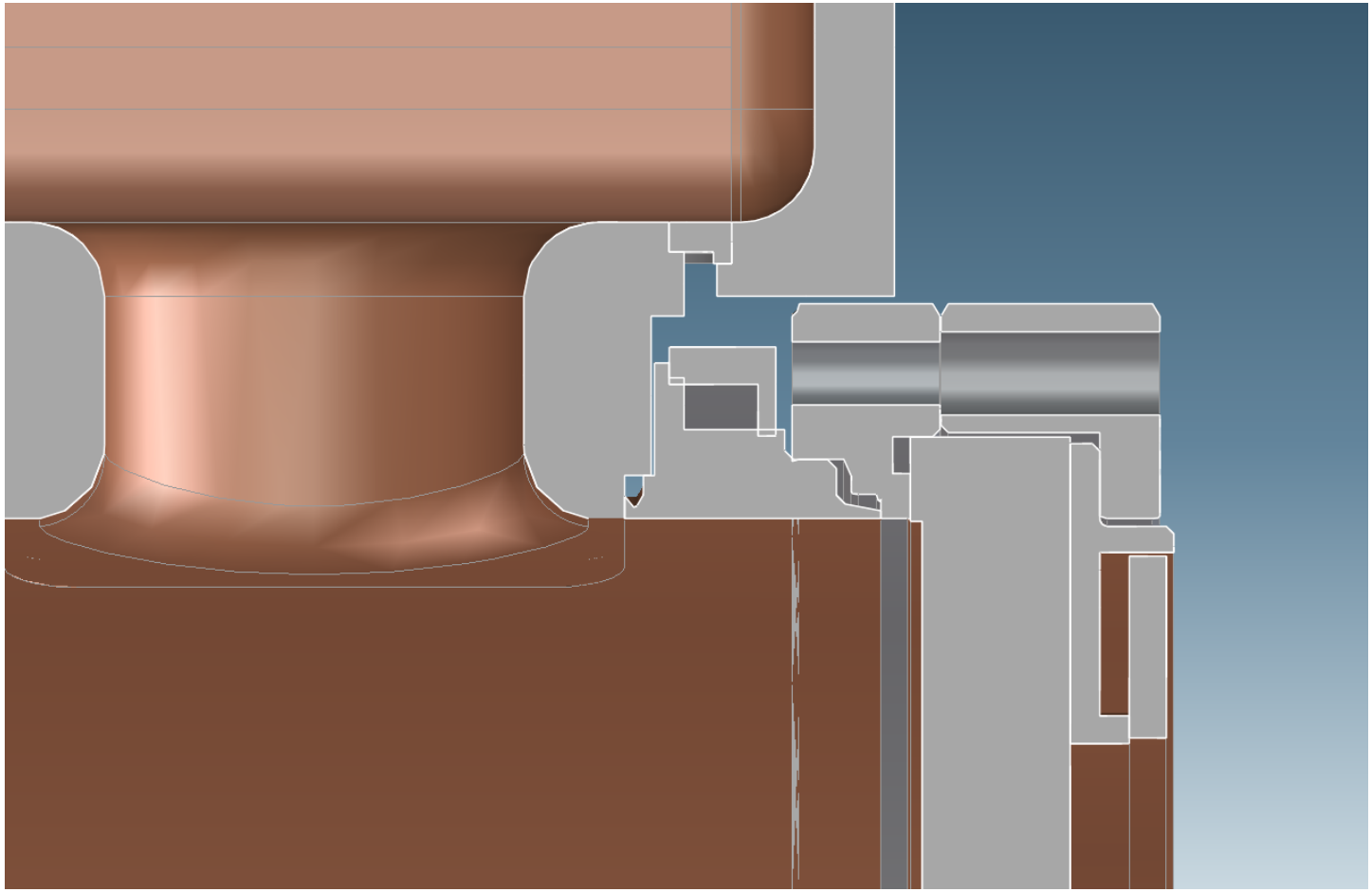






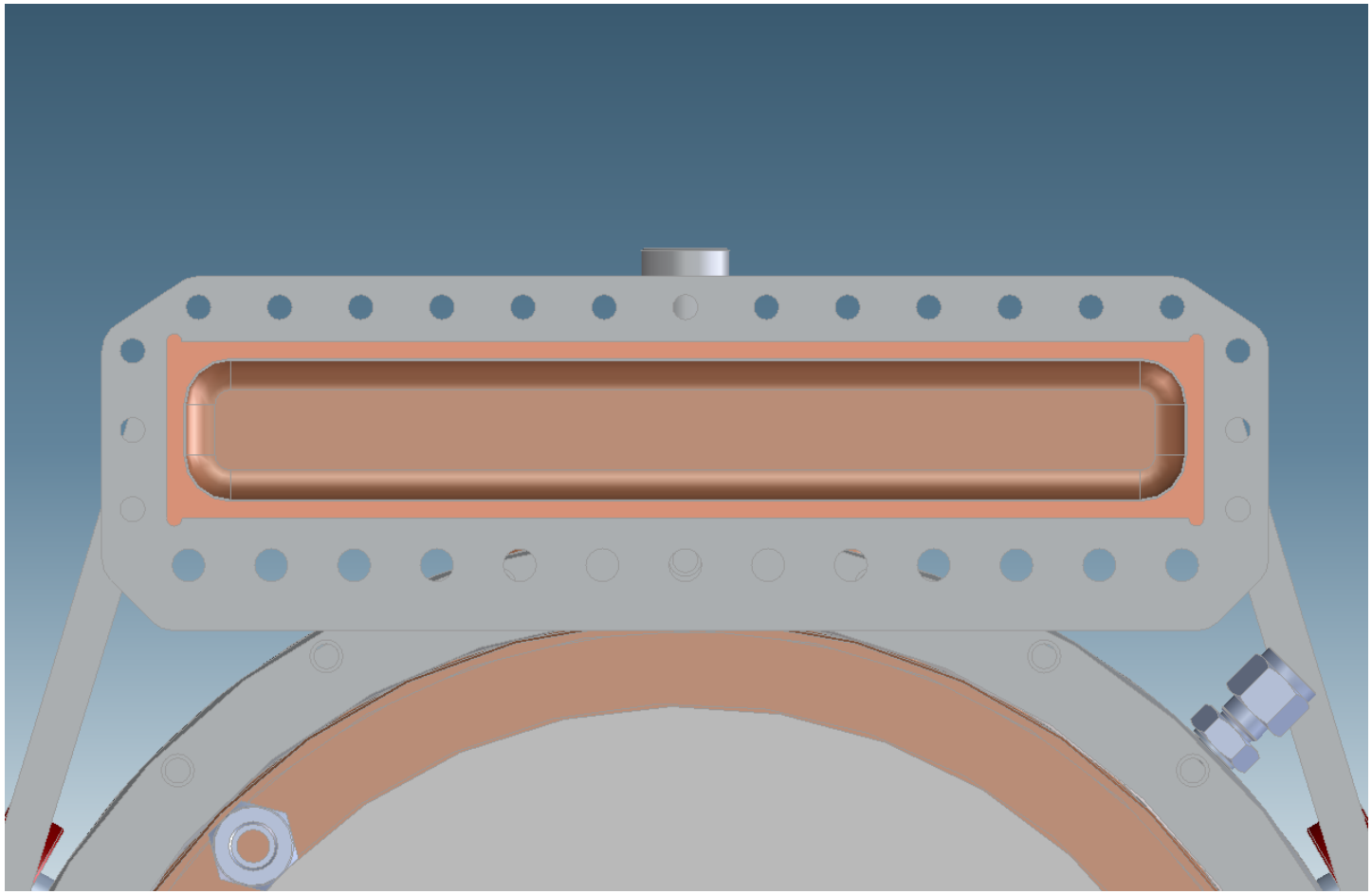


Design features: Cut view of "neck" region.

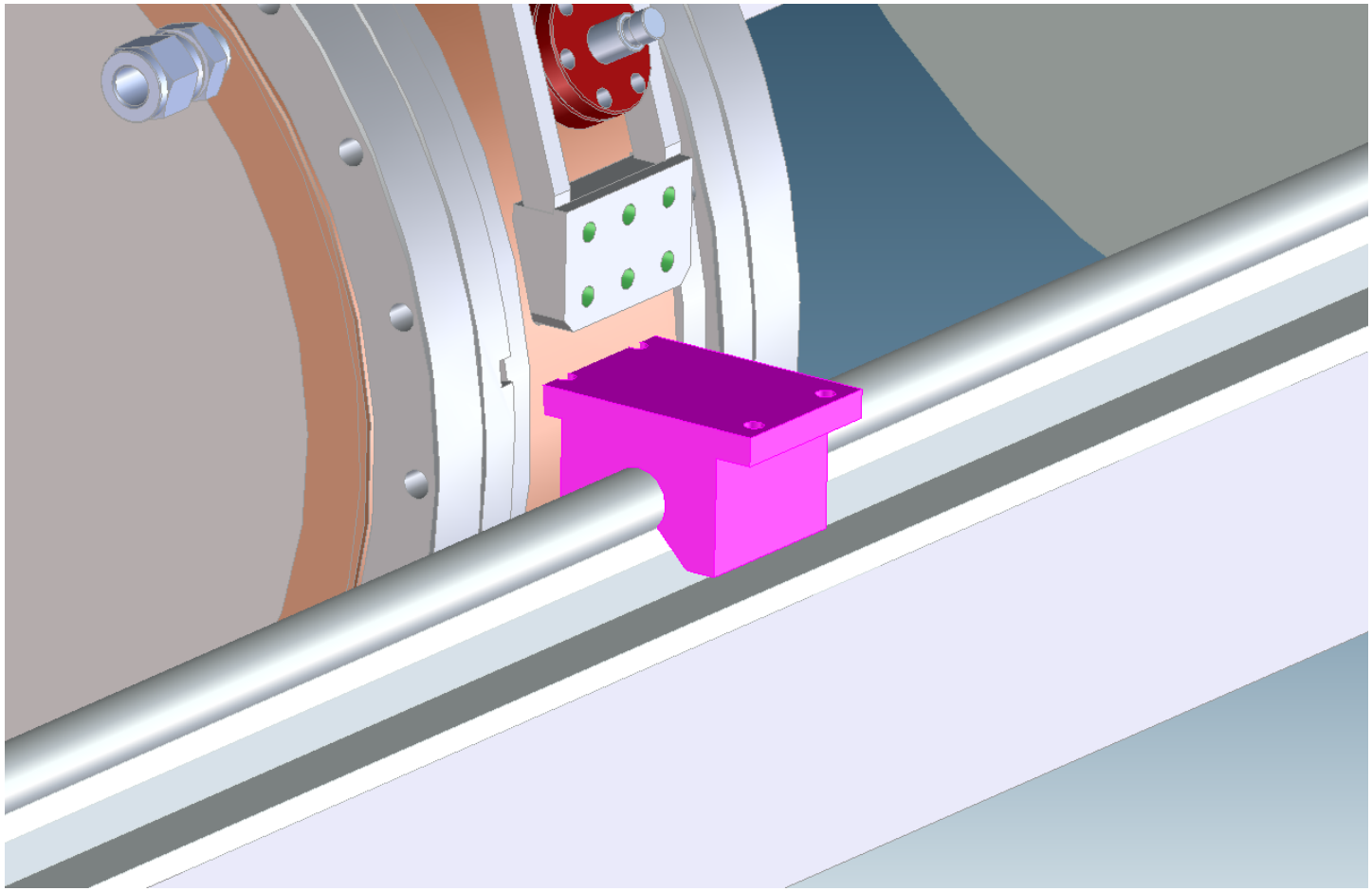


Axial coolant lines limit minimum "neck" height, further complicating the problem of fitting the cavity in the magnet. Note RF/vacuum gasket location.

Design features: Magnet constraints influence flange design.



Design features: Mounting the cavity on the magnet rail system.



Mounting hardware design is straightforward, will be based on measurements of the actual rails, cavity.

Further Review Topics

- **Zenghai Li:** multipacting, thermal/mechanical strain analysis.
- **Tianhuan Luo:** EP capabilities at LBNL.
- **Yagmur Torun:** MTA installation, commissioning, run plan.
- **Lunch**
- **David Martin:** Mechanical design.
- **Andy Haase:** QA, fabrication milestones.

Other cavity views are possible. Thanks for your attention.