Status of the 805 MHz Modular Cavity

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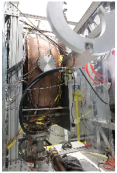
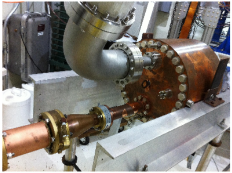
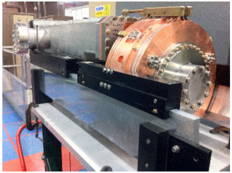
MAP 2013 Collaboration Meeting

Background







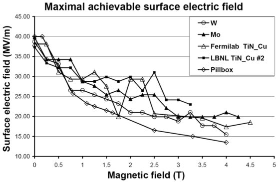
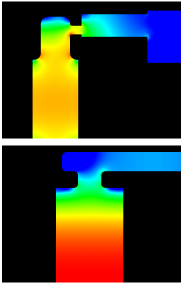


Figure: D. Huang *et al.*, PAC09, Vancouver, Canada, TU5PFP032.

- Strong magnetic fields reduce the maximum achievable surface electric field in vacuum RF cavities.
- RF breakdown → damaged cavities, reduced gradients.
- This is a challenge to building an ionization cooling channel.

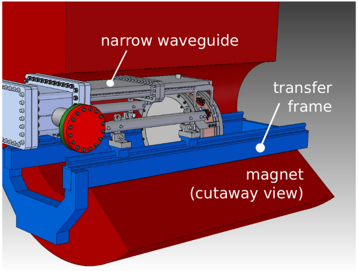
RF breakdown in magnetic fields: Open Questions

- Does pulsed heating / cyclic fatigue play a role?
- Can we mitigate this problem via clever material choices?
- What role does the coupler play?
- Does measurement order (0 T vs. 3 T) play a role?



The modular cavity addresses these questions. This talk presents the design and fabrication status of the modular cavity.

The 805 MHz modular cavity in one slide



- **End goal: A functioning ionization cooling channel.**
- $f = 805.00$ MHz, $Q_0 = 20500$, $\beta = 1.3$
- Power coupled in through the equator. Everything fits in the 44 cm diameter Lab G solenoid.
- Modular design: test different materials (Cu vs Be), surface treatments, gap lengths.
- **Under fabrication now.**
- **Delivered to MTA by the end of FY'13.**

21 people at 5 institutions are involved in this effort.

LBNL

- D. Bowring
- A.J. DeMello
- A.R. Lambert
- D. Li
- S. Virostek
- M. Zisman

BNL

- R.B. Palmer

FNAL

- A. Bross
- D. Kaplan
- A. Moretti
- M.A. Palmer
- R.J. Pasquinelli
- Y. Torun

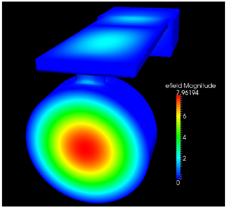
U. Miss.

- T. Luo
- D. Summers

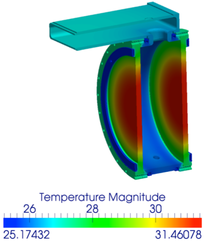
SLAC

- C. Adolphsen
- L. Ge
- A. Haase
- K. Lee
- Z. Li
- D.W. Martin

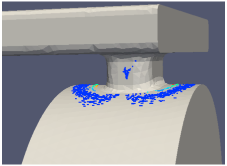
Zenghai Li has already discussed the simulation effort.



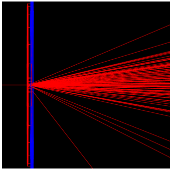
`Omega3P` eigenmode modeling.



`TEM3P` thermal analysis.

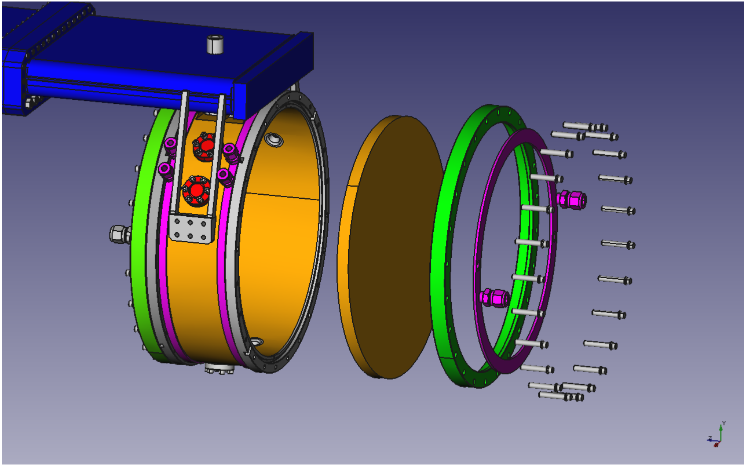


`Track3P` multipacting studies.



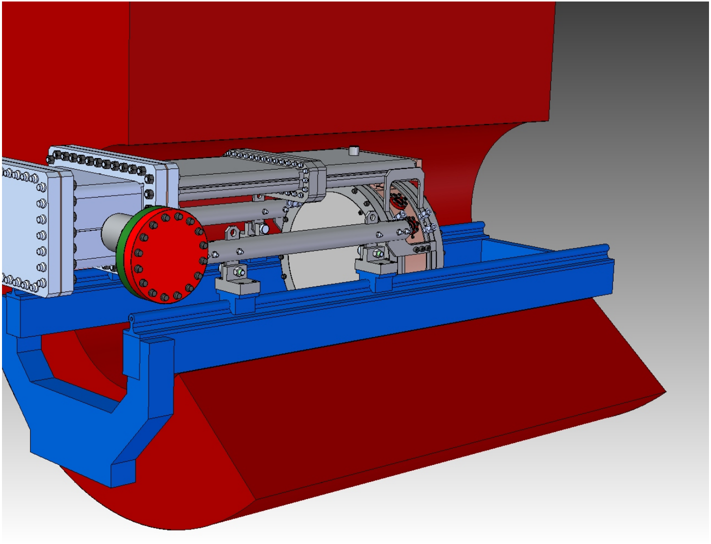
`G4beamline` simulation of scattering in Be.

Exploded view of the modular cavity

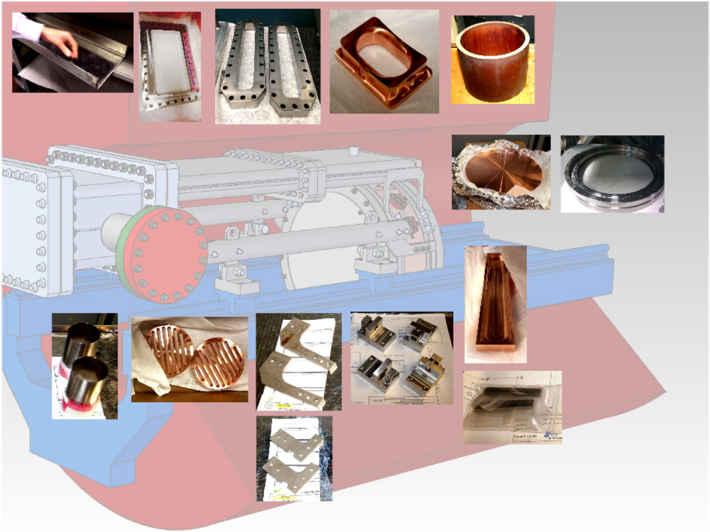


Copper components, narrow waveguide, retaining rings, coolant channels, instrumentation ports.

Working on the assembly now.



Working on the assembly now.

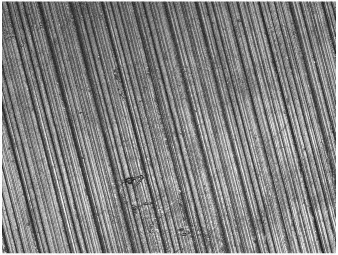


Parts fabrication is almost done. **Assembly has begun!**

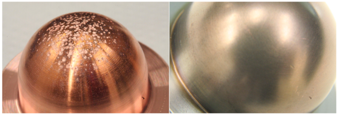
Timeline

Task	When?
All parts at SLAC for final assembly	mid-July
Assembly / cold testing	July & August
Final assembly	August
Ship to FNAL	September
Unpacking, inspection	FY'13
High-power testing	October 2013

We'll test different surface finishes, materials.



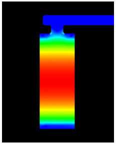
Cu surface at 10X magnification, no surface treatment. What emitter density can we expect from this surface?



Buttons from 805 MHz pillbox. Be may be more resistant than Cu to breakdown damage.

- Compare different Cu surface treatments: as-received, baked, chemically polished.
- Cu vs. Be walls: Be has longer radiation length, higher melting point.

Future work: Vary cavity length to study dark current impact energy



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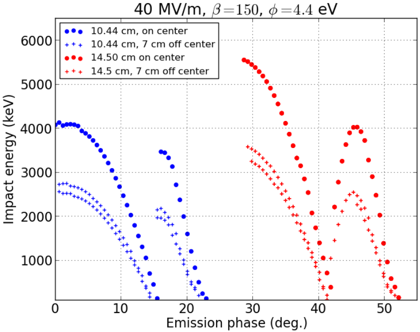
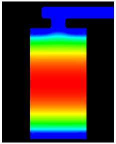
10.44 cm





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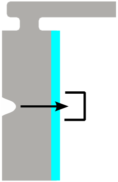
14.50 cm

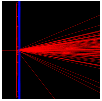
- What effects from cavity length?
  - Transit time factor affects FE impact energy.
  - Stored energy may influence BD damage extent.
- Modular cavity is 10.44 cm long. We can test a 14.5 cm version to evaluate these effects.

Future work: Button variations

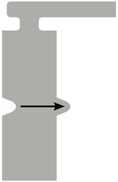
1. Induce field emission



- Measure FE currents.

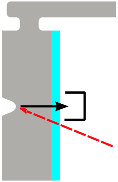


2. Button/anti-button tests



- Decouple cyclic fatigue, FE.

3. Photoemission tests



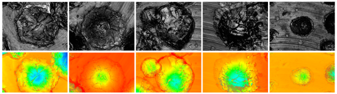
- Map local variations of β, ϕ.

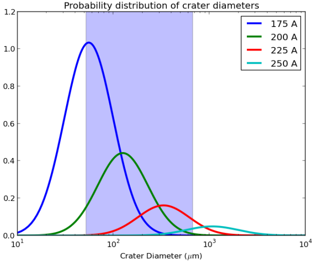
Thanks for your attention!

- We expect to begin high-power testing of the modular cavity in the MTA in October 2103.
- With Cu and Be end plates + variations, we expect to address most of the open questions involving RF breakdown in magnetic fields.

Supplemental Slides

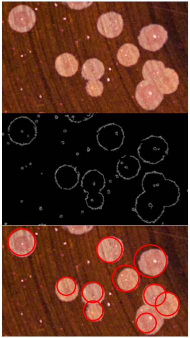
Damage Analysis





Damage spot size distribution may describe breakdown current density.

J.E. Daalder, IEEE Trans. Power. App. Syst. 93 (1974) p. 747.



We're developing computer vision tools to automate cavity surface inspection. Red circles (above) are 1 mm breakdown spots tagged by computer.

Field Emission

Considering the Fowler-Nordheim equation:

$$\langle j \rangle = \frac{5.7 \times 10^{-12} \cdot 10^{4.52\phi^{-0.5}}}{\phi^{1.75}} (\beta E_s)^{2.5} \exp\left(-\frac{6.53 \times 10^{9} \cdot \phi^{1.5}}{\beta E_s}\right)$$

- ϕ is the work function of the metal, measured in eV.
- β is the geometric field enhancement factor of an emitting surface feature. Very roughly, $\beta \sim h/r$.
- For Cu, $\phi \approx 4.5$ eV on average.
- Recent work suggests that variations in ϕ are important for FE analysis. See H. Chen *et al.*, PRL **109** 204802 (2012).

$\langle j \rangle$ vs. ϕ

The average work function of copper is ≈ 4.5 eV.

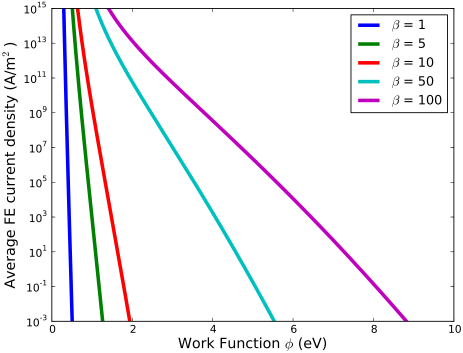


Figure: Average FE current for varying work function, using five different values of β. $E = 50$ MV/m.

Photoemission studies to map β, ϕ on cathode surface

PRL **109**, 204802 (2012) PHYSICAL REVIEW LETTERS week ending 16 NOVEMBER 2012

Surface-Emission Studies in a High-Field RF Gun based on Measurements of Field Emission and Schottky-Enabled Photoemission

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(Received 6 June 2012; published 14 November 2012)