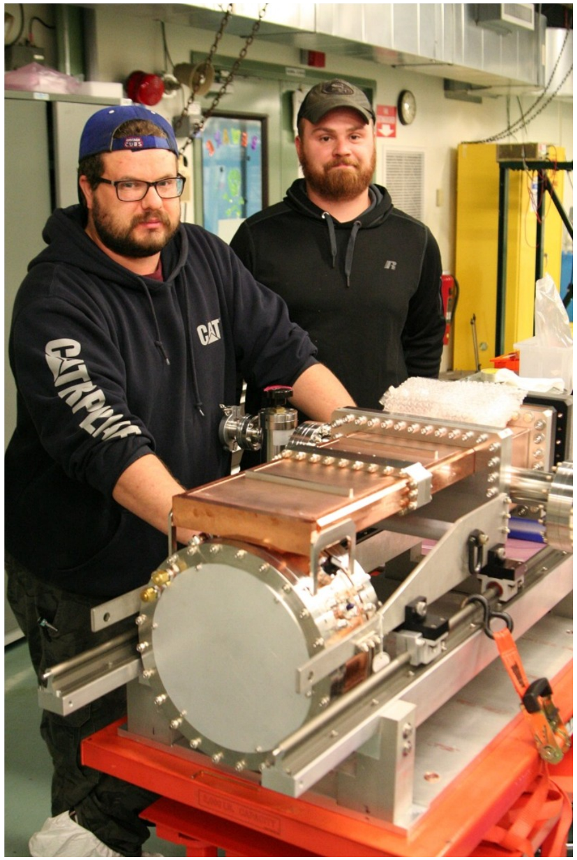
Overview of the 805 MHz Modular Cavity Project



MAP Spring Meeting

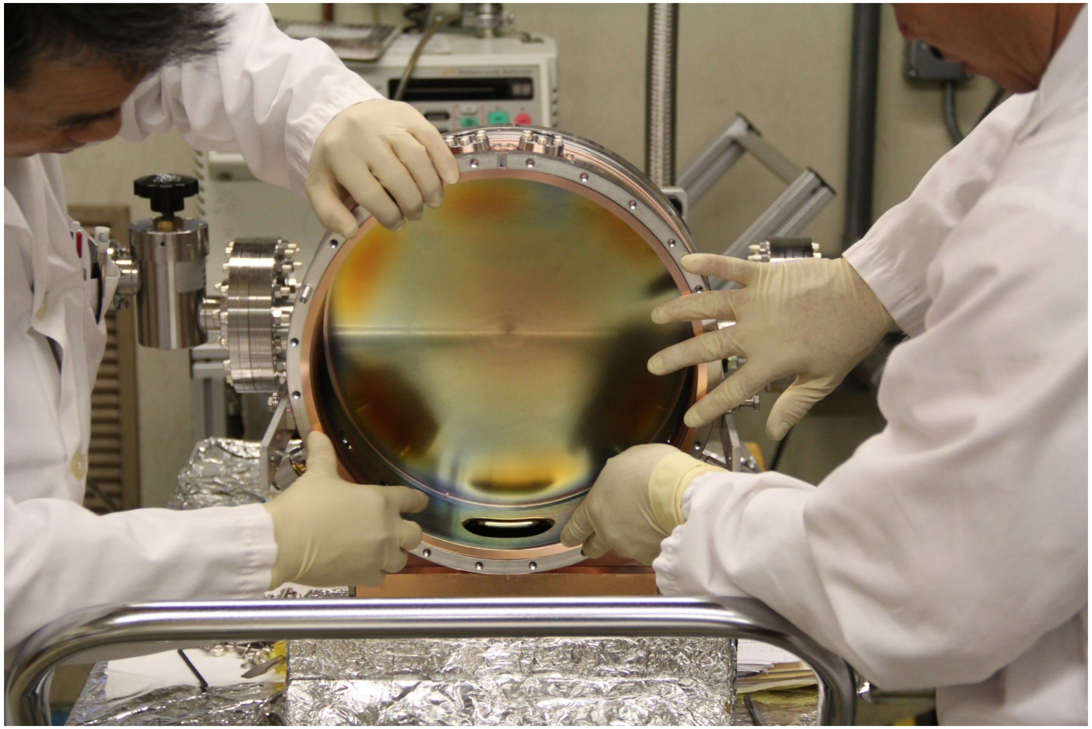
Daniel Bowring

FNAL

May 21, 2015

Overview

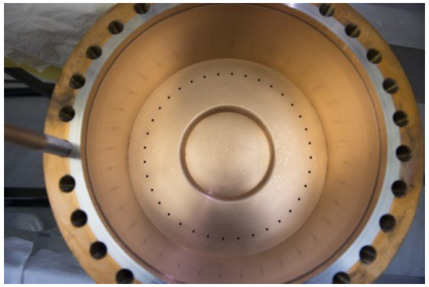
- Motivation for modular cavity program
- Program goals served by cavity's design features
- Recent activity
- Status
- Planned research

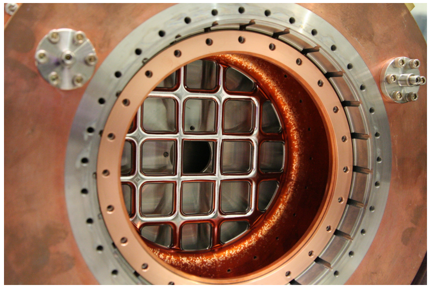


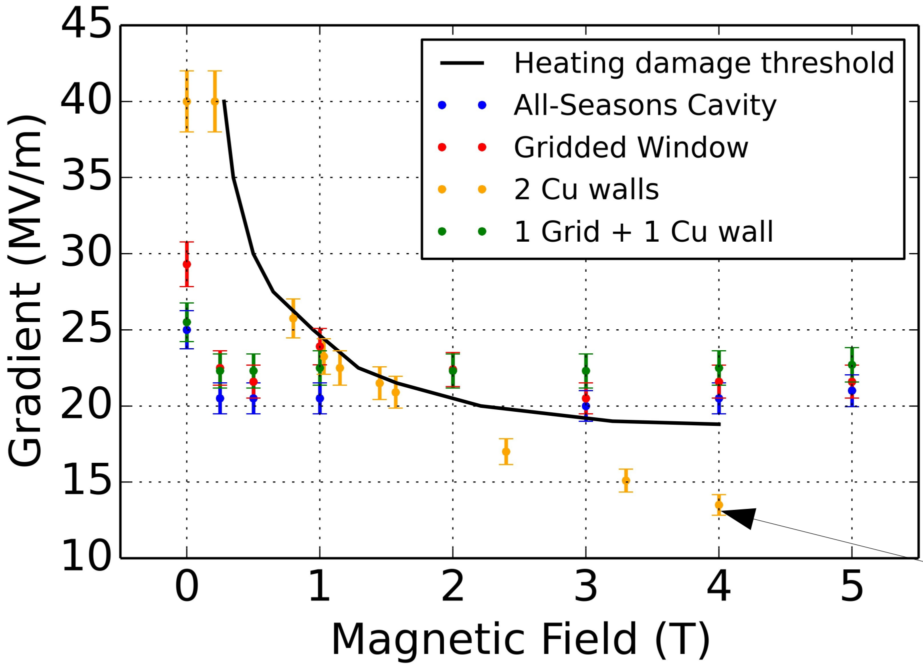
The modular cavity will give us the data we need to resolve important questions re: RF in B-fields.

1) How well does our model describe gradient limits due to breakdown?
2) Can SRF-style surface treatment give us the stability and performance we need?
3) Quantitatively, how much a performance boost do we get by using beryllium instead of copper?
4) How can be sure that our input couplers aren't limiting our performance?

(1) How well does our model describe gradient limits due to breakdown?



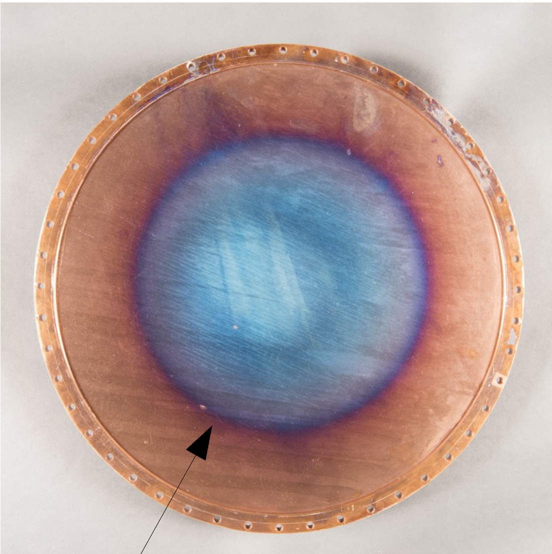


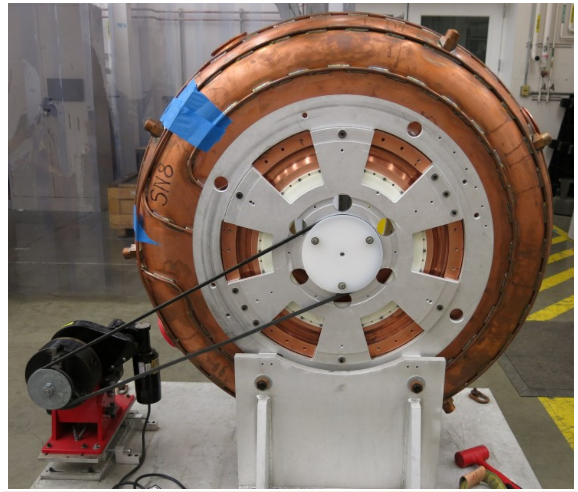


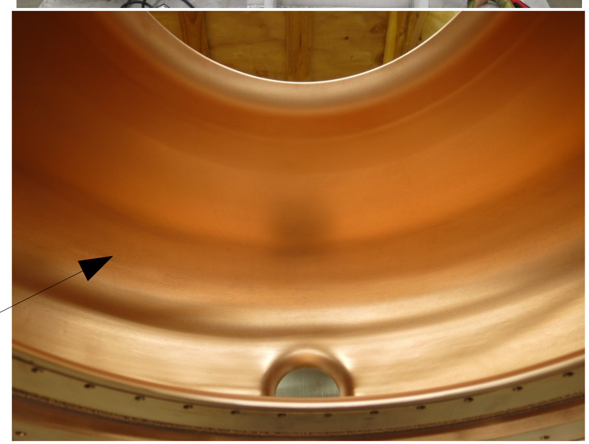
No surface prep for this cavity.

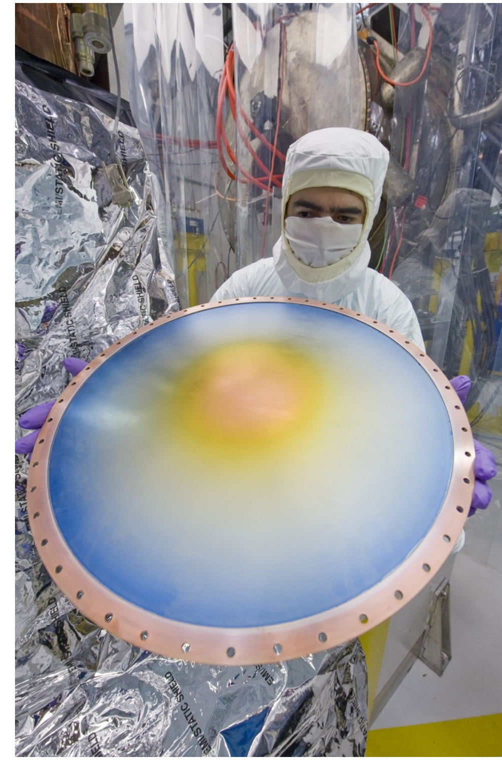
- **> 20 MV/m at 5 T for 2+1 cavities.**
- Black line indicates threshold for plastic deformation from cyclic beamlet heating.
- Fit quality affected by conditioning history, coupler effects.

(2) Can SRF-style surface treatment give us the stability and performance we need?



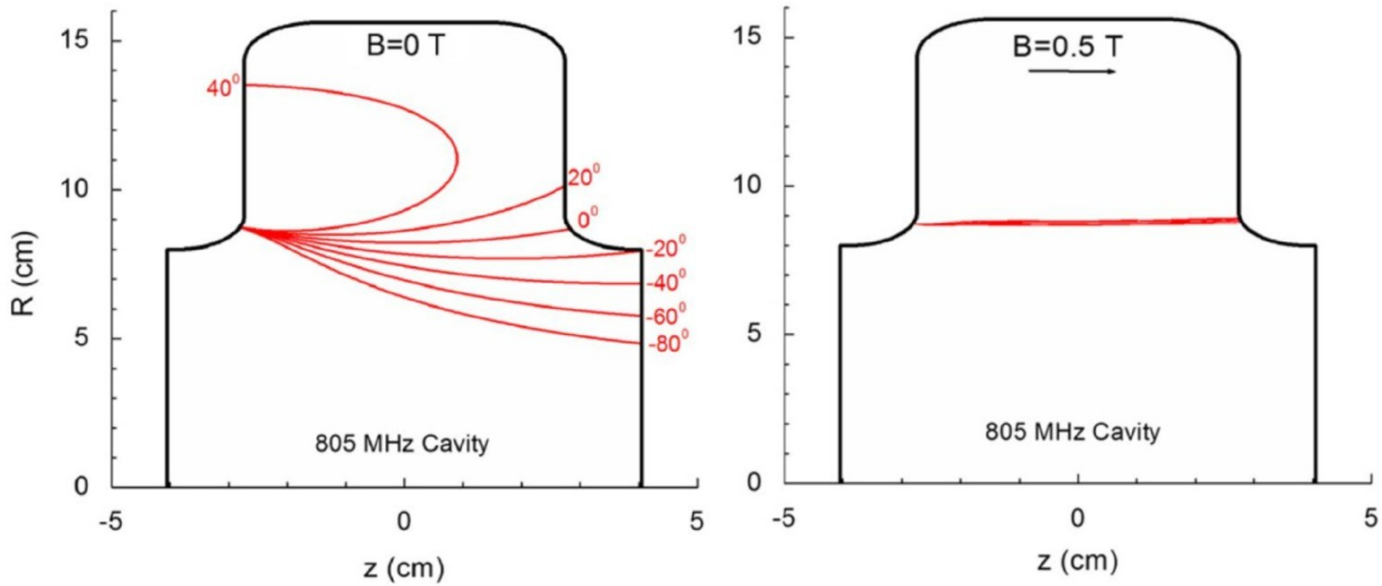






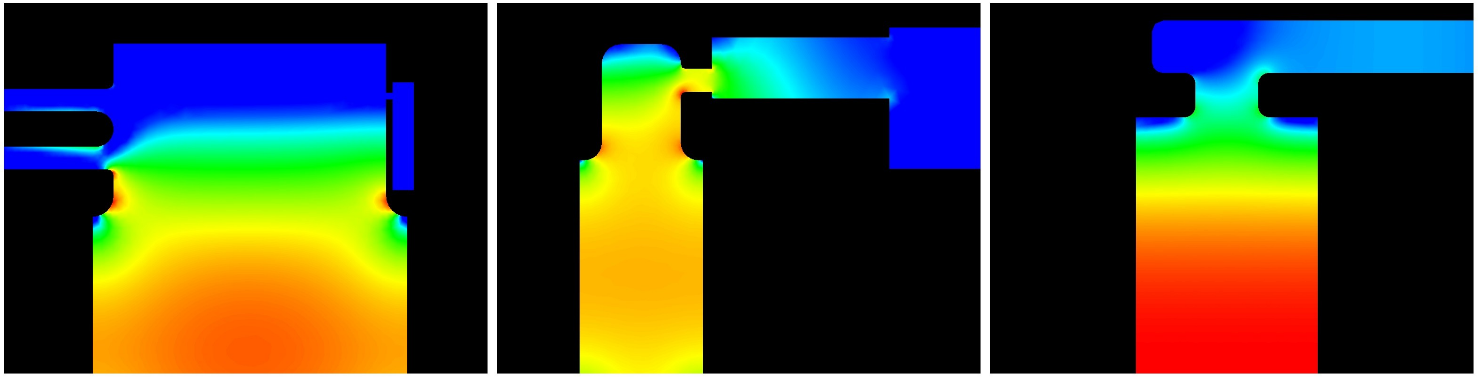
- “Unprepared” surfaces break down & conditioning is interesting.
- Electropolished surfaces fare better! No evidence of breakdown on EP'd Cu.
- Be surfaces similarly well-behaved.

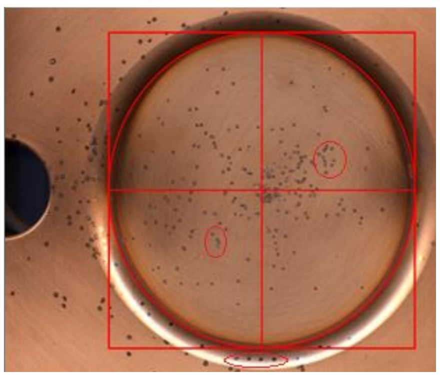
(3) Quantitatively, how much a performance boost do we get by using beryllium instead of copper?

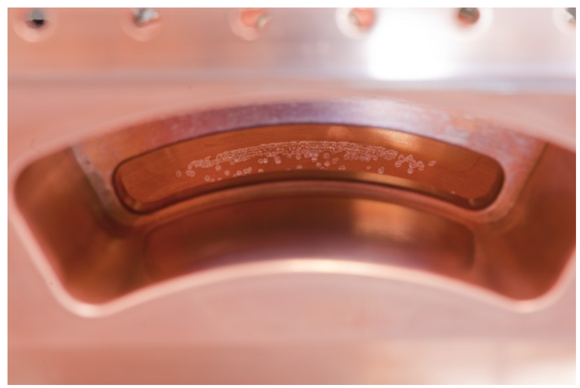


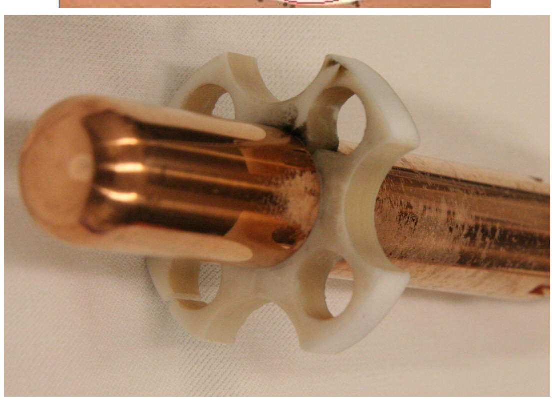
- D. Stratakis, *et al.*, NIMA **620**, 2010, pp147-154.
- Reducing dE/dx reduces energy deposited on cavity surfaces.
- (Harder surfaces may also be effective here, as they're more resistant to damage. But with limited time and resources...)

(4) How can be sure that our input couplers aren't limiting our performance?



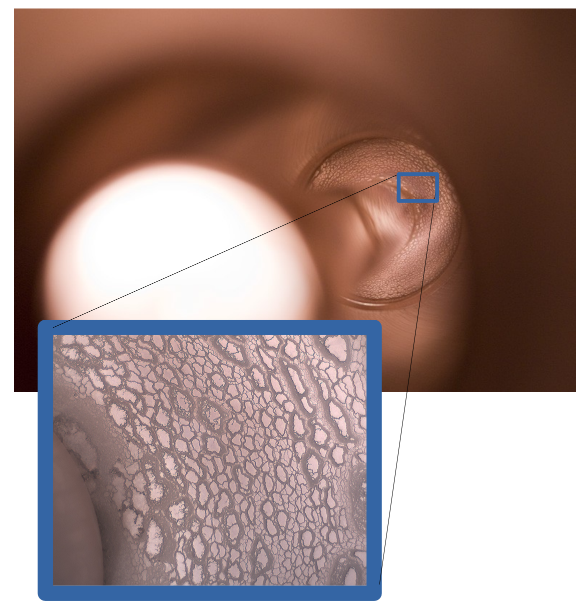






- Hard to fit 805 MHz cavities in the solenoid, so couplers are very constrained.
- Want to avoid surface E-field enhancement.

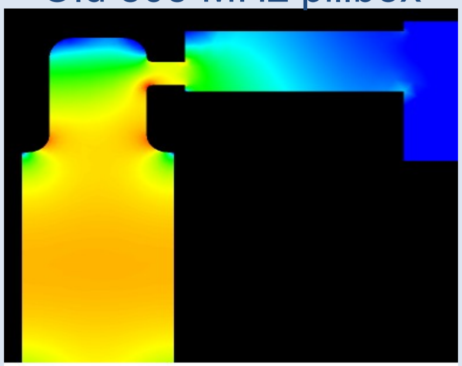
- Old 201 MHz coupler damage:

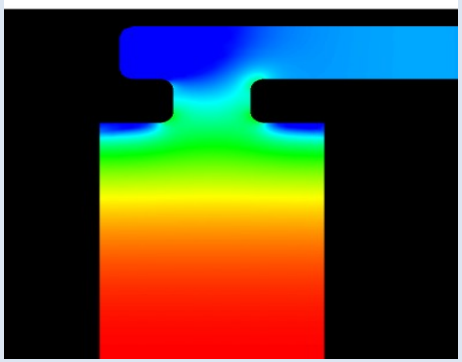


The 805 MHz “Modular Cavity” directly addresses the issues of conditioning history & coupler effects.

Surface E-field at couplers is < 1/5 that at cavity axis.

Old 805 MHz pillbox

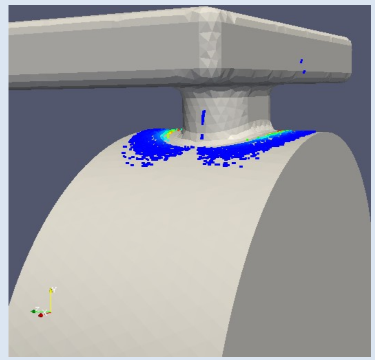


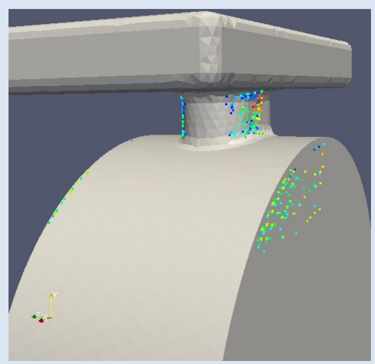


Modular cavity

Multipacting is optimized over a range of *B*-field values.

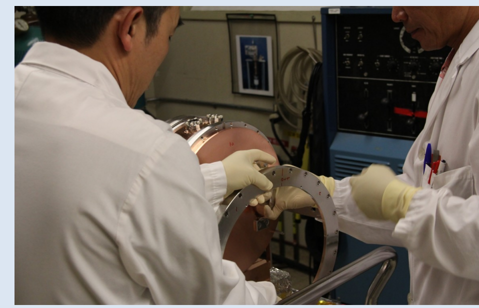
B = 0 Tesla

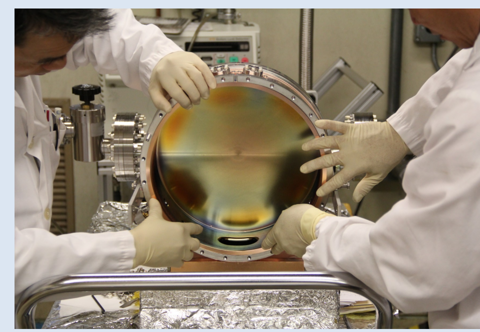




B = 3 Tesla

End walls easily removed for inspection, materials studies.

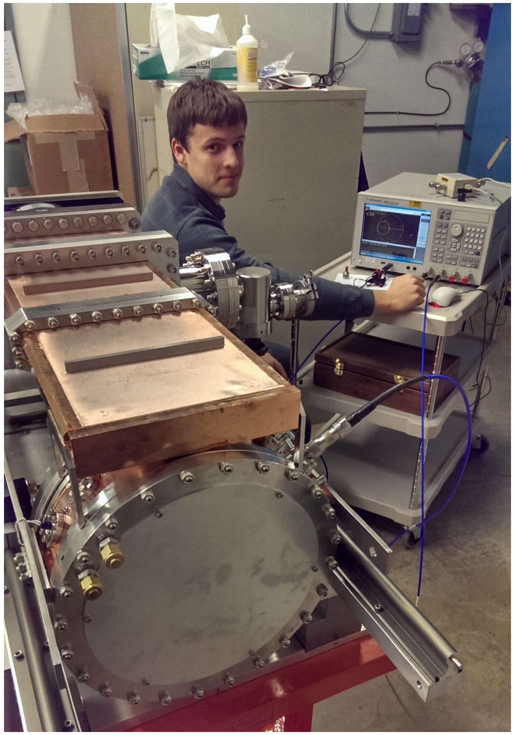




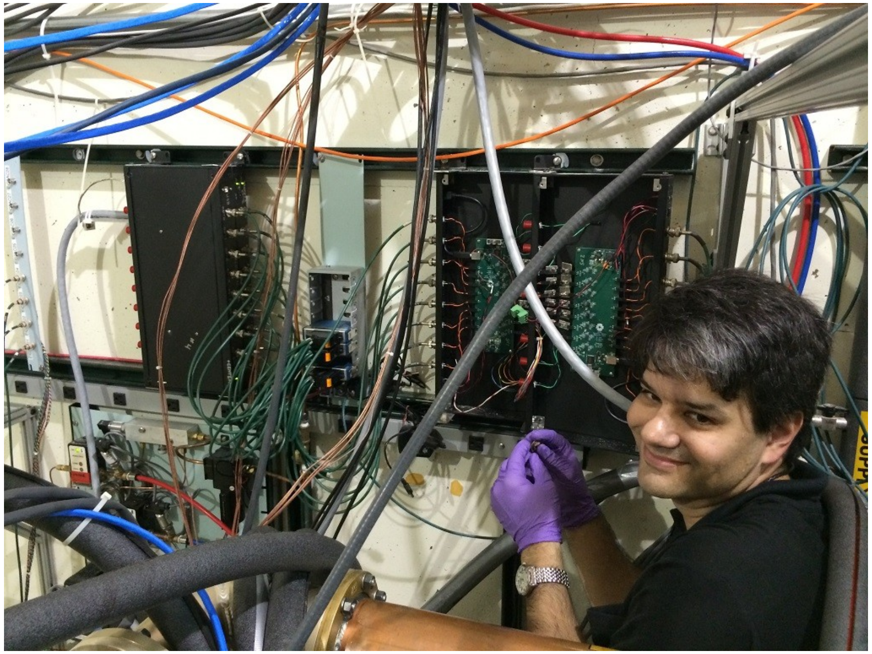
Chemically polished to minimize surface roughness.

Not shown: Extensive instrumentation (e.g. Faraday cup), cooling circuits. Improved DAQ.

The modular cavity program is fertile ground for two PhD theses.

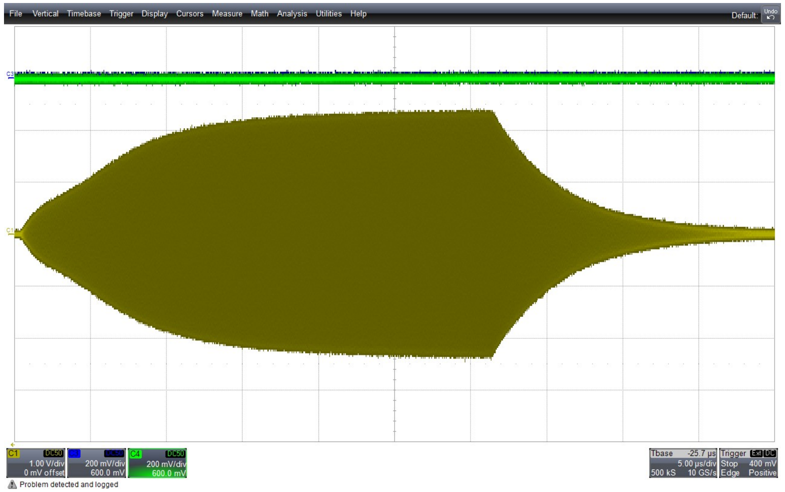


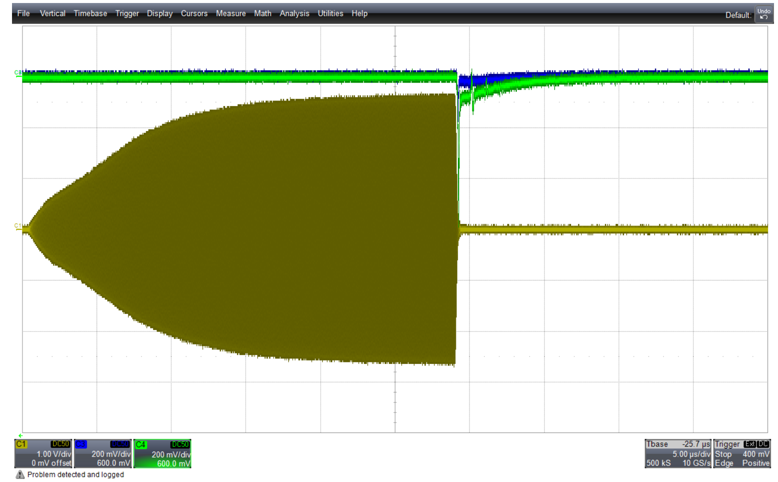
Alexey Kochemirovskiy (U. Chicago) on RF breakdown in strong magnetic fields



Peter Lane (IIT) on the use of acoustic sensors for spark localization in cavities

The modular cavity had its first high-power run in April. A great success!



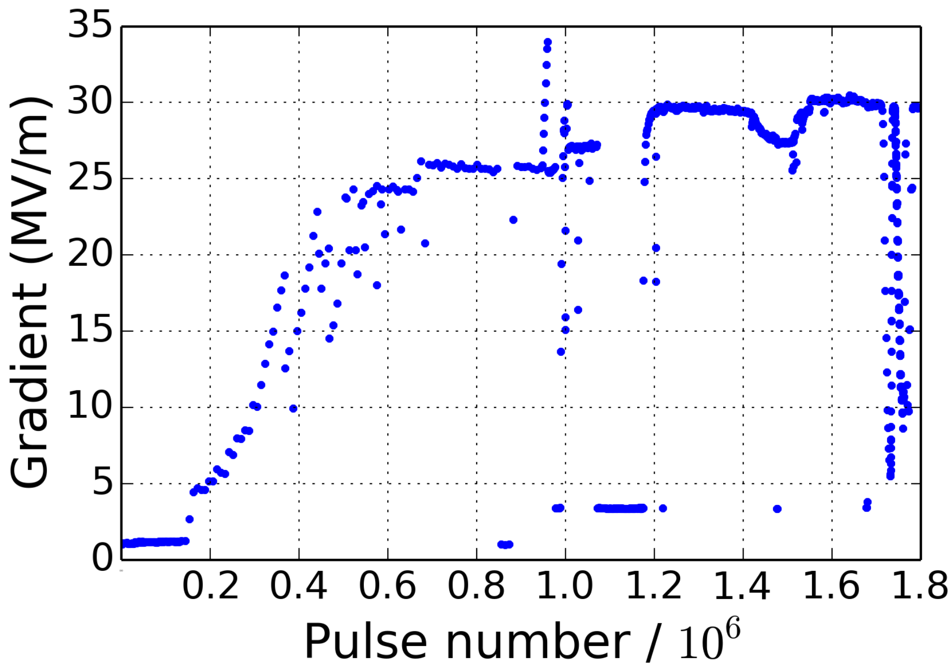


- Conditioned up to 30 MV/m with ~15 sparks.
- Vacuum, water systems, instrumentation, detectors all performed well.
- Spark detection system worked well. OS-related problems were found and diagnosed.
- Klystron instability limited max. power. More on this in a bit.

DAQ channels for MC run, April 16-21

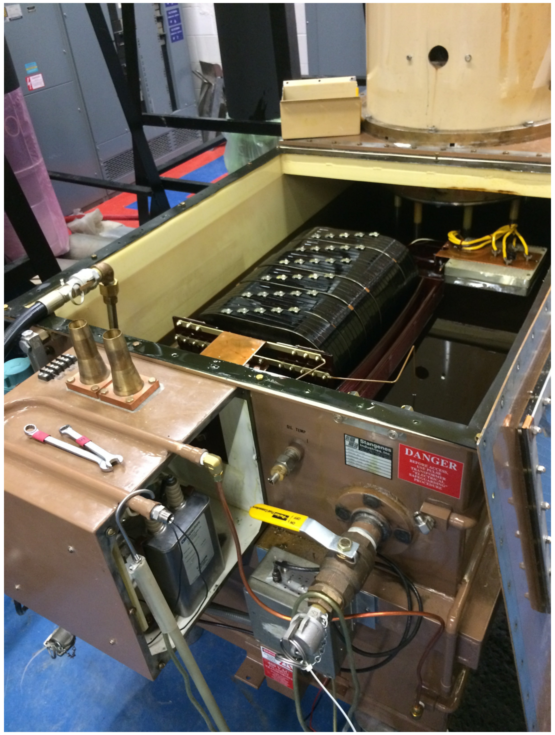
- DAQ apparatus reconfigured, optimized for heavy running of 3 cavities during the next several months.
- Data channels for MC run:
  - 2 x RF pickup loops
  - 2 x “cavity light”: optical fibers coupled to PMTs
  - Forward, reflected power @ MTA waveguide
  - Forward, reflected power @ klystron
  - NaI detector
  - Acoustic sensors (c.f. Peter Lane's talk following this one.)
  - Much “slower” instrumentation: water temperature & flow, vacuum pressure, etc., detailed here:
    - http://mice.iit.edu/cgi-bin/mta/acnetize?Config=ModularShift

Conditioning summary, April 16-21.



- 100% shift coverage, 24/7 operation
- 5 Hz operation, 18000 pulses per hour
- DAQ cuts power by 3 dB when a spark is detected. Source trips are even more obvious on this plot.

Klystron maintenance is underway.

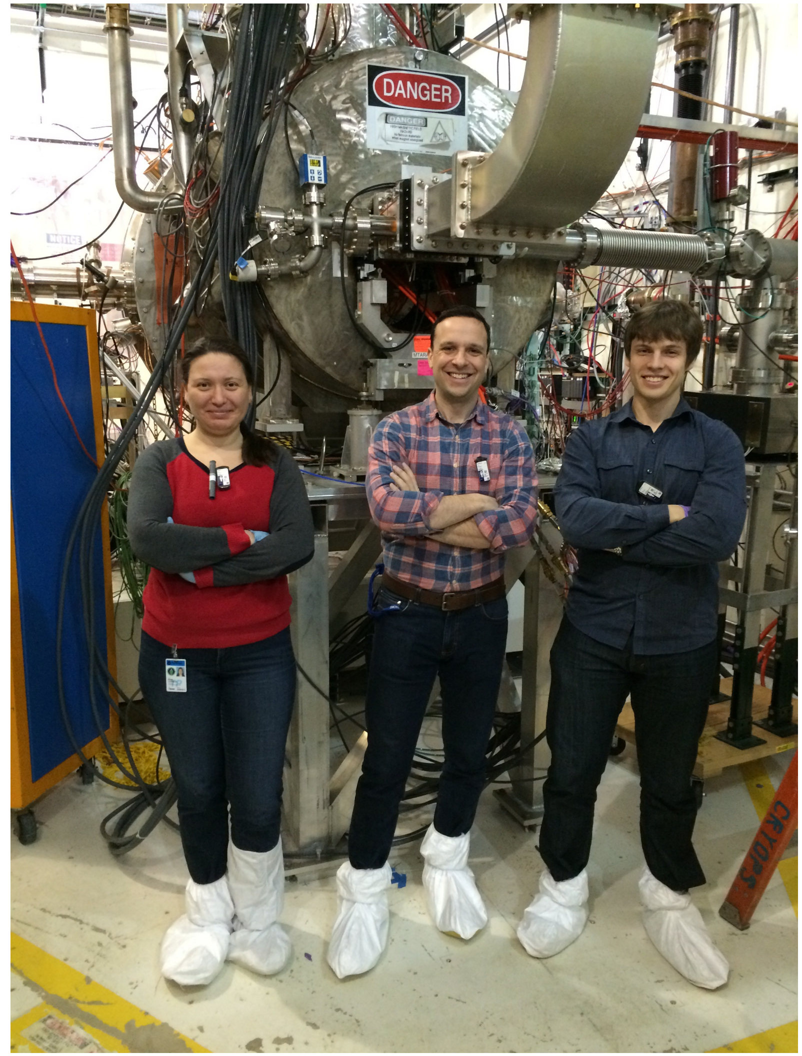


- Source was delicate. During this run, we got no more than 1.8 MW, limiting gradient to 30 MV/m. (Plus not-infrequent trips.)
- Maintenance underway, several weeks of down-time are required. We hope to run once the current MICE work is complete. (c.f. Yagmur's talk.)
- This RF station is a “hot spare” for the Linac. Repairs are not low priority.

We have a *very* aggressive experimental program planned for the next N months.

Modular cavity tests planned:

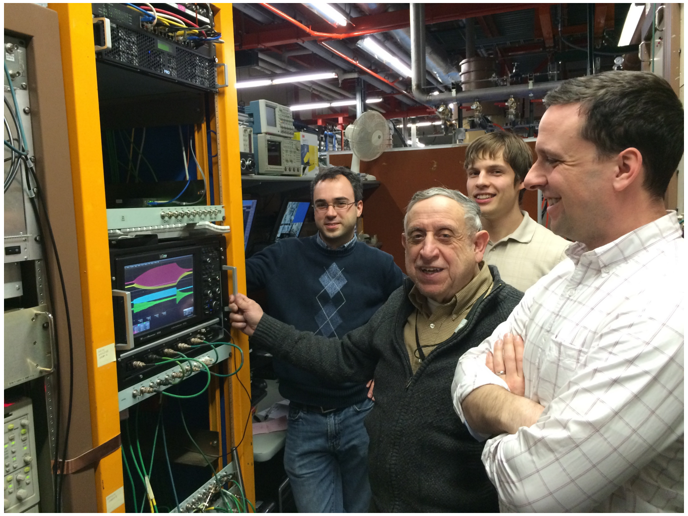
- Determine maximum gradient for $0 < B < 5$ T with Cu and Be walls. (Be walls permit detailed x-ray, dark current measurements.)
- Establish “lifetime” of Cu surface: observe spark rate over millions of pulses for $B >$ 0.
- Beam tests w/ Be walls.
- c.f. Alexey Kochemirovskiy's talk for discussion of the surface inspection system, which will be used regularly.

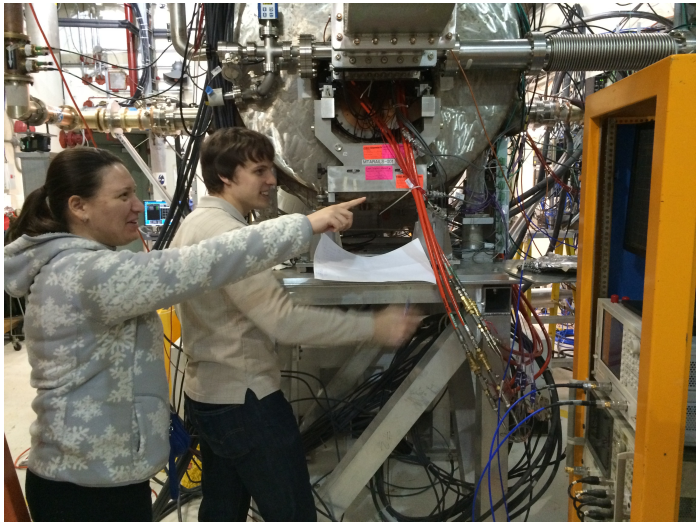


Conclusions

1) The modular cavity program will provide data which is critical for the design of ionization cooling channels:
    - Maximum achievable gradient vs magnetic field
    - Control over systematic errors is much improved.
2) The cavity performs as designed. All instrumentation and DAQ infrastructure is characterized and functioning.
3) Running will resume ASAP once MICE prototype run is complete.
4) Lots of hard work, solid results planned for this year.

Thanks for your attention!





- Thanks especially to those who helped during recent data-taking :

Michael Backfish
Ben Freemire
Alexey Kochemirovskiy
Peter Lane
Maria Leonova
Al Moretti
Dave Peterson

Thanks also to Fernanda Garcia and the Linac crew, who were available at all hours to support this experimental run.