# Dielectric Loaded HPRF Program

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ILLINOIS INSTITUTE OF TECHNOLOGY

Muon Accelerator Program

Muons, Inc.

# Introduction



- Two experimental programs: Low-powered material testing ("Sample Test"); High-powered insert testing ("High-Powered Test")
- Sample Test
  - Identify suitable candidate materials
  - Measure $\varepsilon_r$ and tan $\delta$
- High-Powered Test
  - Investigate "realistic" insert design
  - Measure dielectric strength vs. alumina purity
  - Beam test: study plasma-gas-dielectric interaction

# Past Work

- High-powered test of 99.8% alumina reported in IPAC '13 (TUPFI068)
- Measured dielectric strength of rod *on the axis* of the cavity

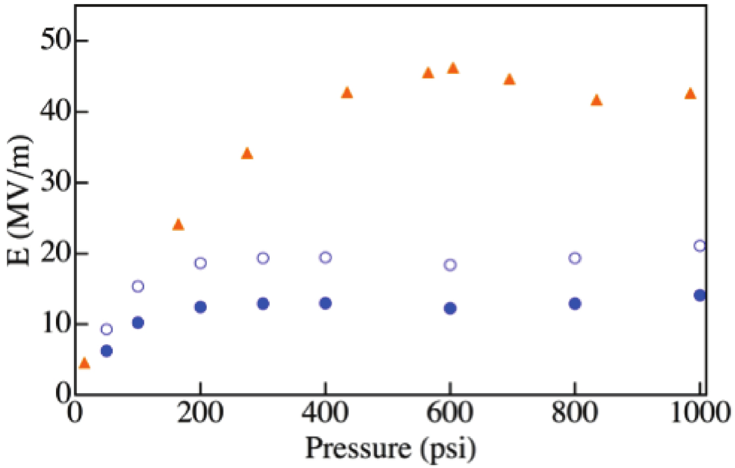


Figure 6: Measured maximum electric field as a function of N2 gas pressure. An orange point is taken in 2009 [7]. An open blue circle is the estimated peak electric field in the TC (protrude of copper electrode). A closed blue circle is the peak electric field on surface of the alumina rod.

# Sample Test Program

- Rods/tubes of alumina, aluminum nitride, cordierite, forsterite, and magnesium calcium titanate obtained from four vendors
- Modified cavity designed/built to accommodate easy insertion and removal of samples
- Low-powered RF measurements of *f* and Q taken
  - $\varepsilon_r$ and tan $\delta$ obtained by Superfish simulation
- Two undergrad summer students trained and utilized

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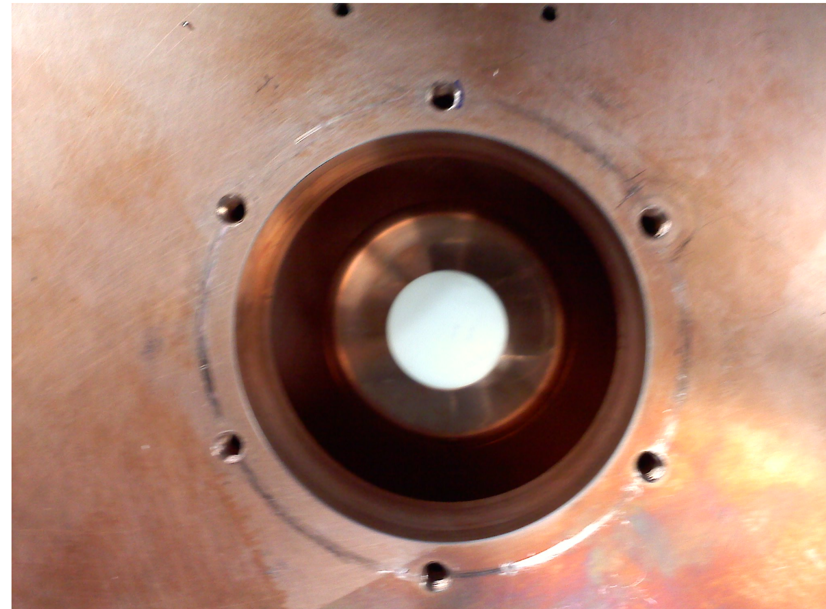
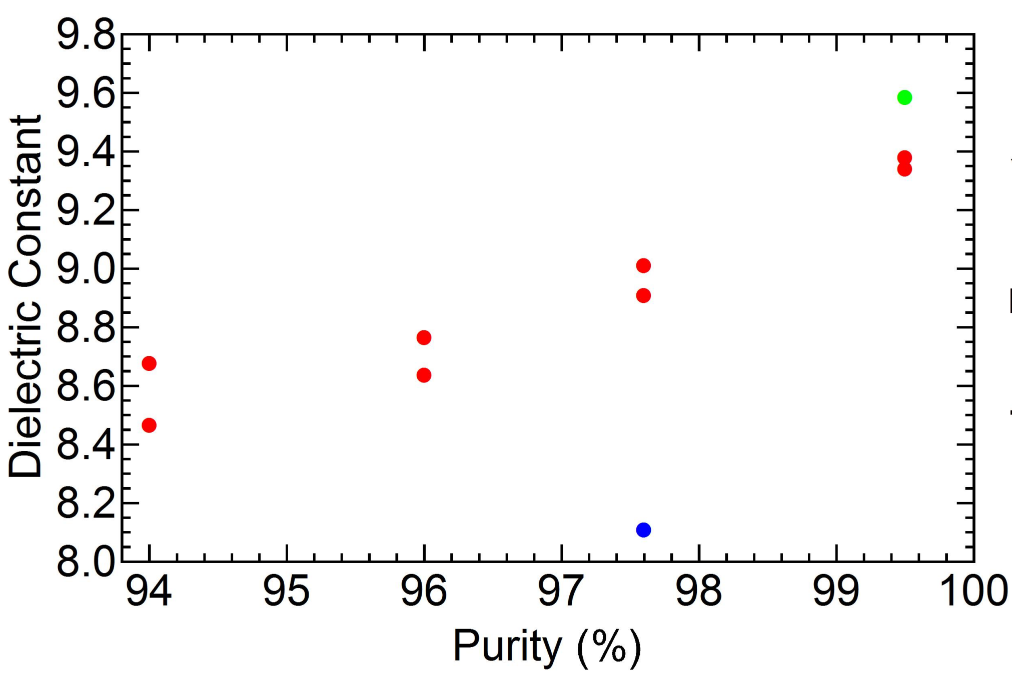
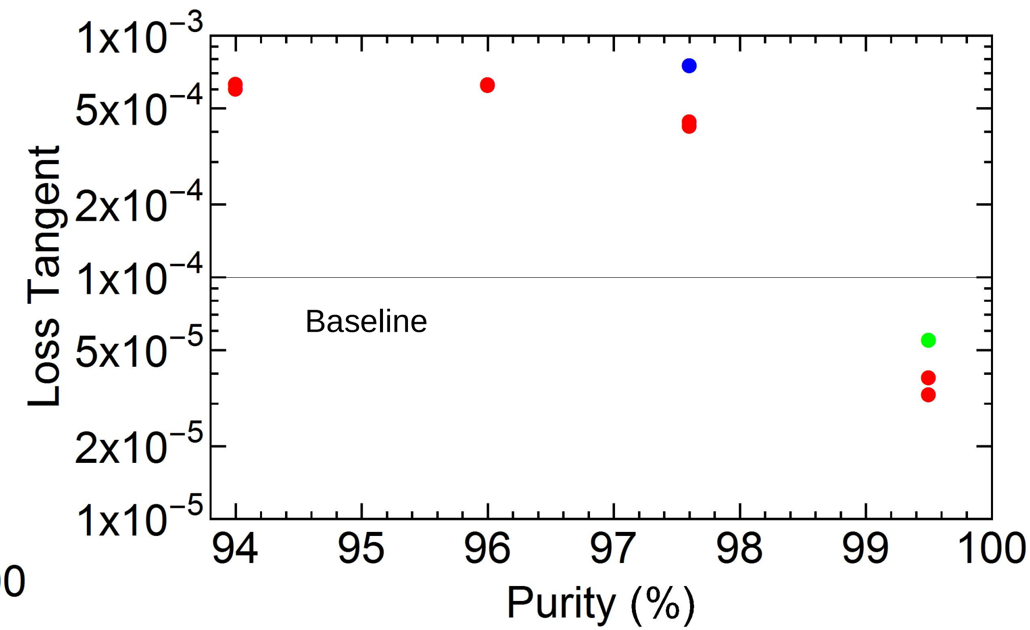
# Sample Test Cavity




# Sample Test Results - Alumina

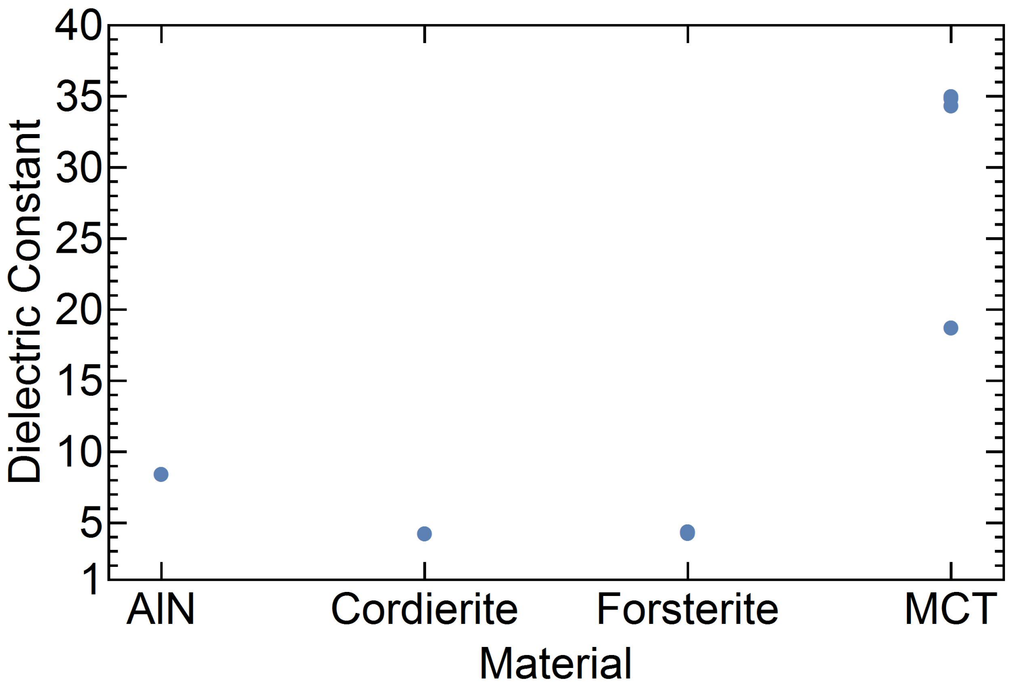
- Alumina samples tested:
  - 94, 96, 97.6, 99.5%
  - Morgan, CoorsTek, Accuratus

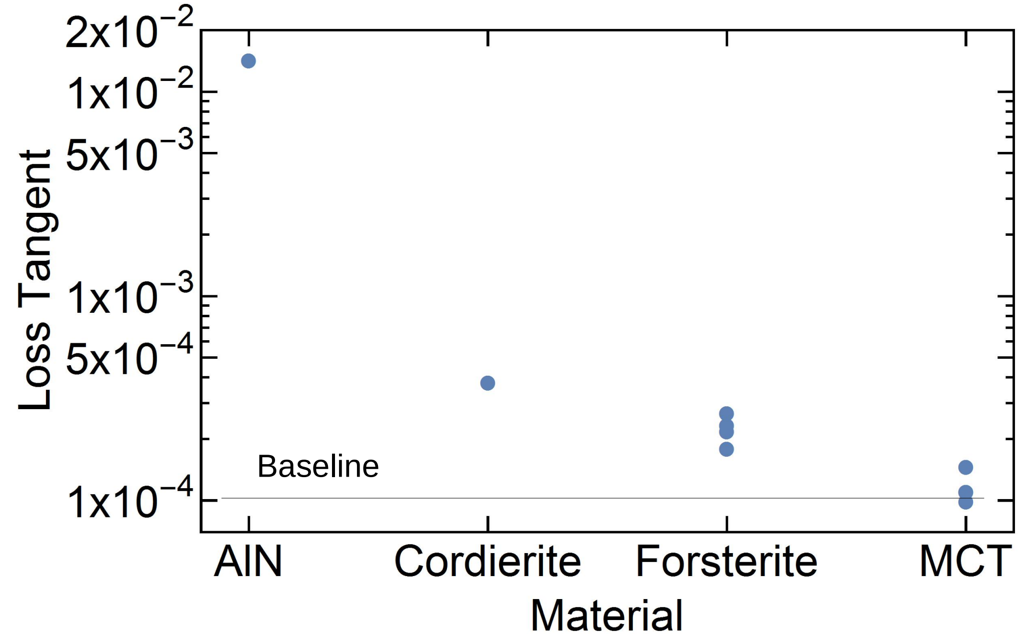


# Sample Test Results - Other Materials

- Aluminum nitride, cordierite, forsterite, magnesium calcium titanate (two purities) tested



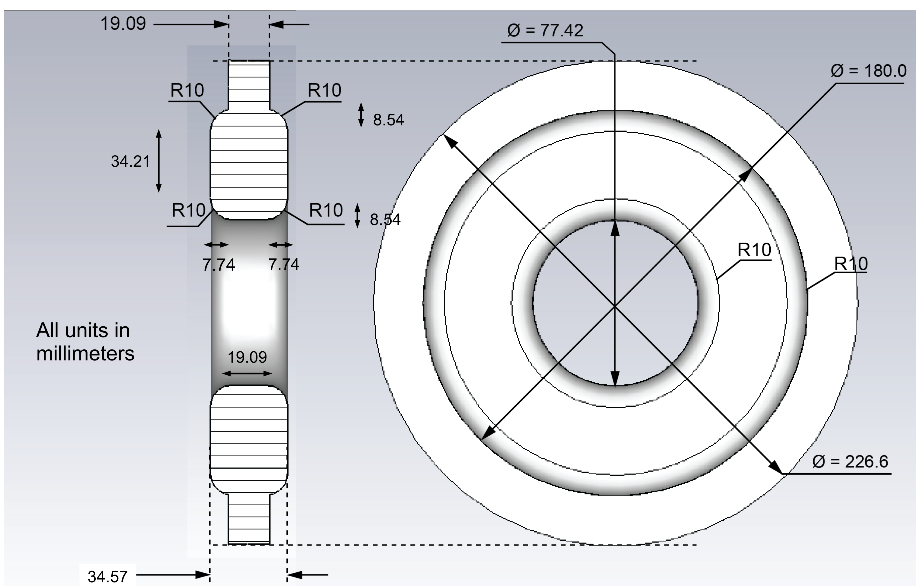



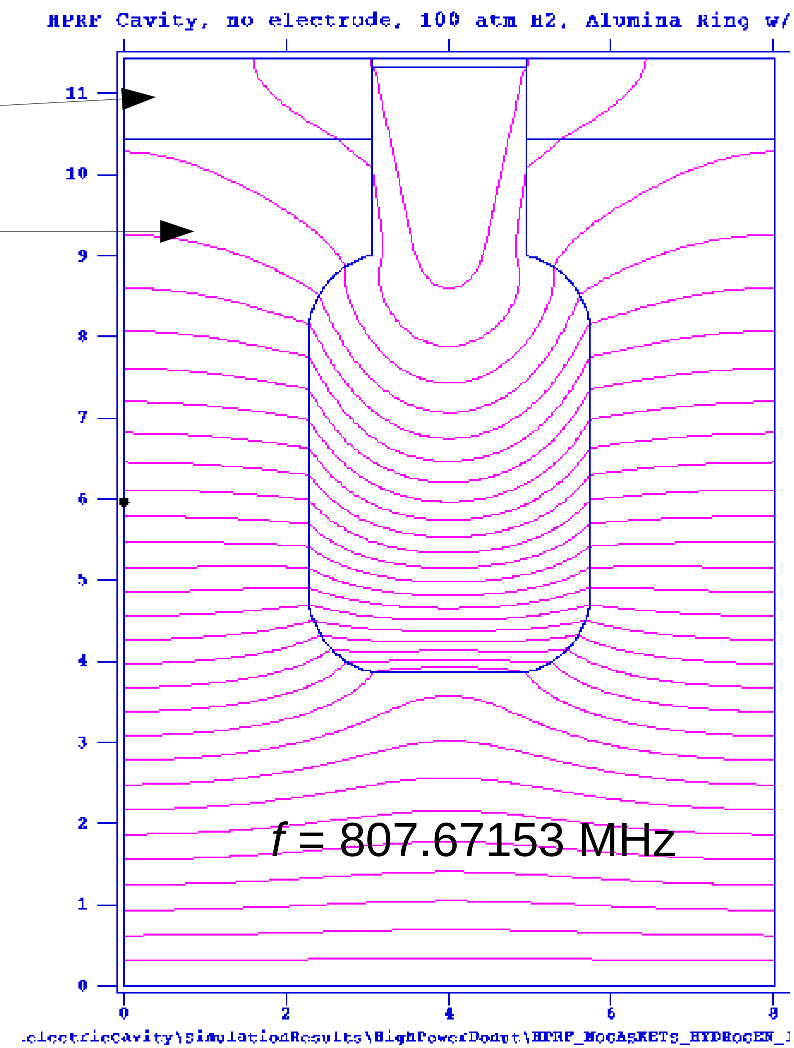
# High-Powered Test Program

- Four alumina inserts ordered: 96, 98.5, 99.5, & 99.8%
  - All same design
- Two experimental goals:
  - Measure dielectric strength (no beam)
  - Study plasma-gas-dielectric interaction & influence on cavity (*with* beam)

# Insert Design

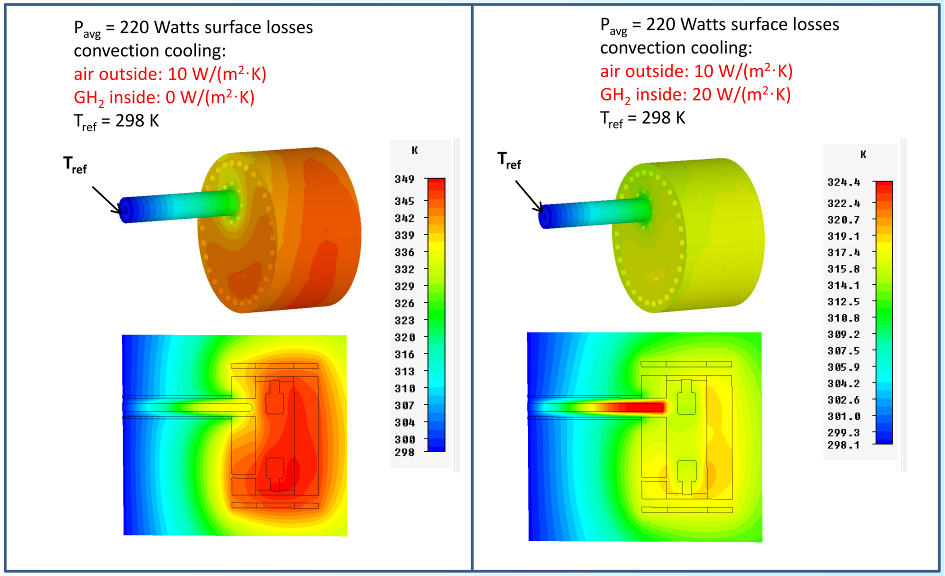
- Measured $\varepsilon_r$ from sample test used to design insert for modified "beam test" HPRF cavity
  - Alumina "donut"
  - Teflon spacers
  - $N_2$ or $H_2$ gas (up to 100 atm)
  - Designed to be resonant "too high"
    - small electrodes on axis bring *f* down



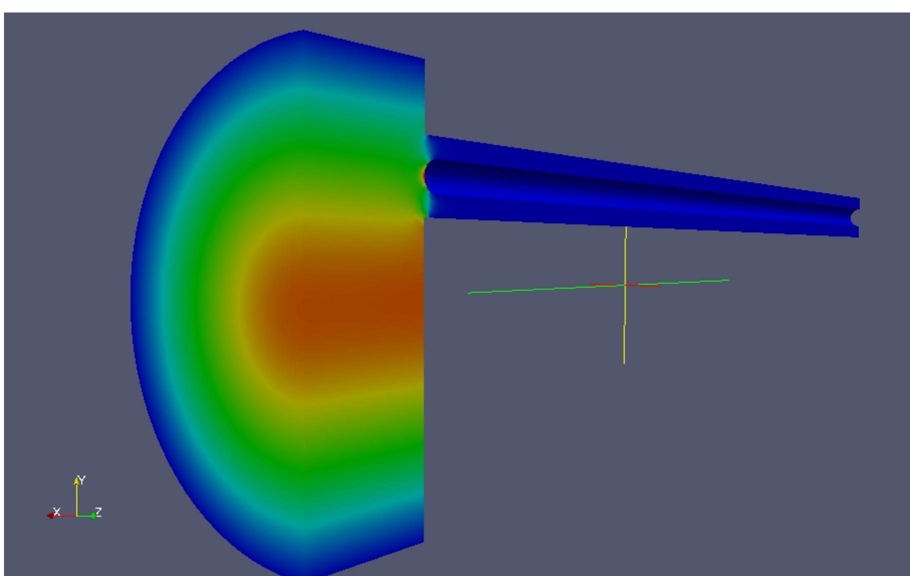
# Simulation Model

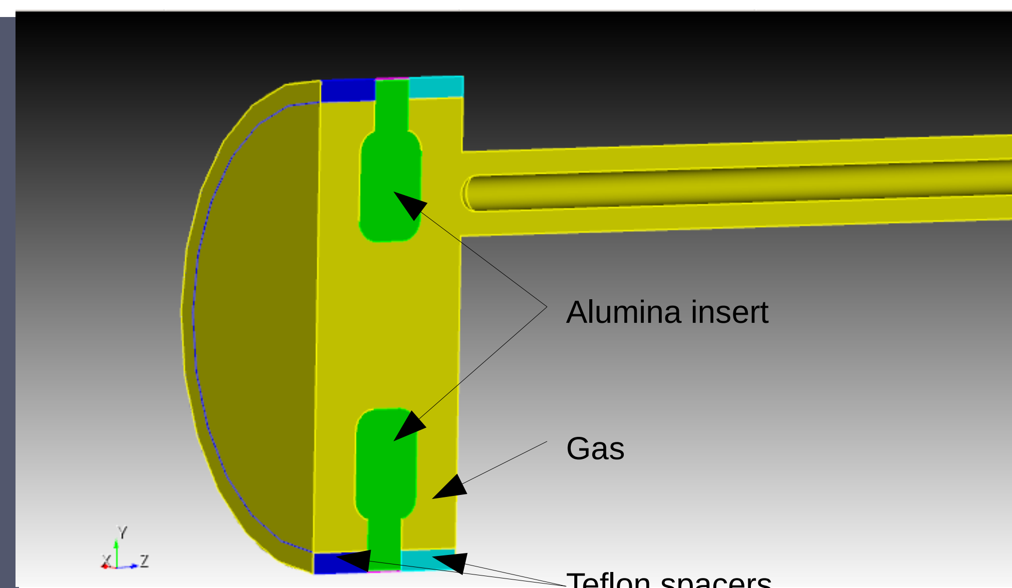
- Superfish was used in sample test for analysis
- Concern about dielectric heating necessitates thermal model
  - Possibly limit RF repetition rate
- Preliminary modeling done by F. Marhauser using CST
- ACE3P model being developed



# ACE3P Model Validation

- Measurement of the "empty" HPRF cavity agrees well with simulation
  - $f_{meas}$ = 1004.3451 MHz, $f_{sim}$ = 1004.2773 MHz
- Full simulation of cavity with gas/insert/spacers progressing





# Program Plan

- Assemble cavity with insert/spacers
- Perform low-powered RF measurements
  - Frequency ($\varepsilon_r$) and Q ($\tan\delta$)
- Pressurize cavity and run gradient up to a “reasonable” value (~20 MV/m)
- Send beam through the cavity
- Move cavity to RF station 2 and ramp up gradient to determine dielectric strength
- Repeat measurements at station 2 for other purity inserts

# Summary

- Numerous materials have been tested and identified as potential candidates for DL-HPRF cavities
- "Realistic" dielectric insert designed and ordered
- High-powered tests, including beam, scheduled for 2015
  - Results will steer future design of HCC