Dielectric Loaded HPRF Cavity Program Update

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Motivation

- To fit 325 and 650 MHz RF cavities in magnets required for Helical Cooling Channel, smaller radius than pure pillbox geometry required

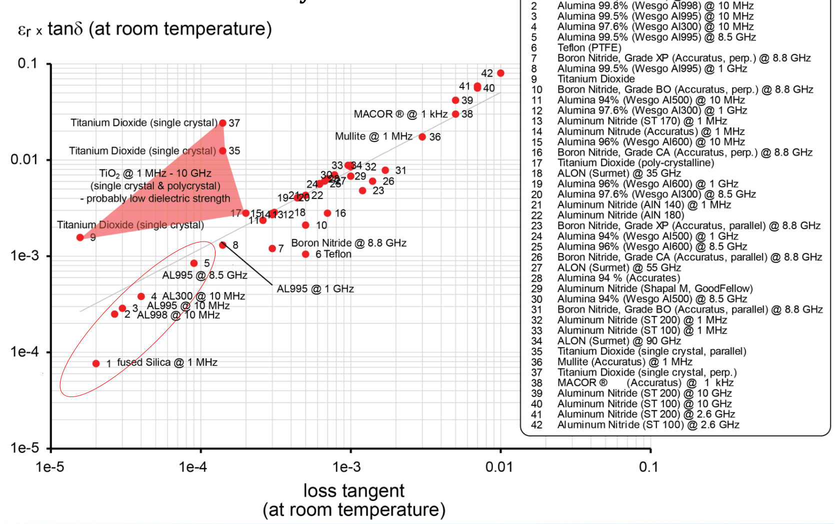
$$f_{nml} = \frac{c}{2\pi\sqrt{\mu_r \epsilon_r}} \sqrt{\left(\frac{p_{nm}}{R}\right)^2 + \left(\frac{l\pi}{L}\right)^2} \qquad f_{010} = \frac{c}{2\pi\sqrt{\mu_r \epsilon_r}} \frac{2.405}{R}$$

$R = cavity\ radius$
$L = cavity\ length$

- R_{325} = 35.3 cm, R_{650} = 17.7 cm (vacuum)
- From S. Kahn's talk on Wednesday:
  - $R_{IC\text{-}325}$ = 27.5 cm, $R_{IC\text{-}650}$ = 15.0 cm
- Accomplished by “loading” cavity with material with appropriate ϵ_r in appropriate geometry
- Loss tangent important in power considerations
- Al_2O_3 is attractive
- Appears to be some “trade off” in dielectric strength vs tan δ

$$P = \pi \cdot f \cdot \epsilon_0 \cdot (\epsilon_r \cdot \tan\delta) \cdot \int dV\ |E|^2$$

note: frequency may vary



Past Results

- L. Nash, et al., Proceedings of IPAC 2013, TUPFI068 summarizes past dielectric strength test for a 99.8% pure alumina rod (ε_r = 9.6, tan δ = 10^{-4})
- Vendor reports 16.7 MV/m
- Measurements indicate 14 MV/m

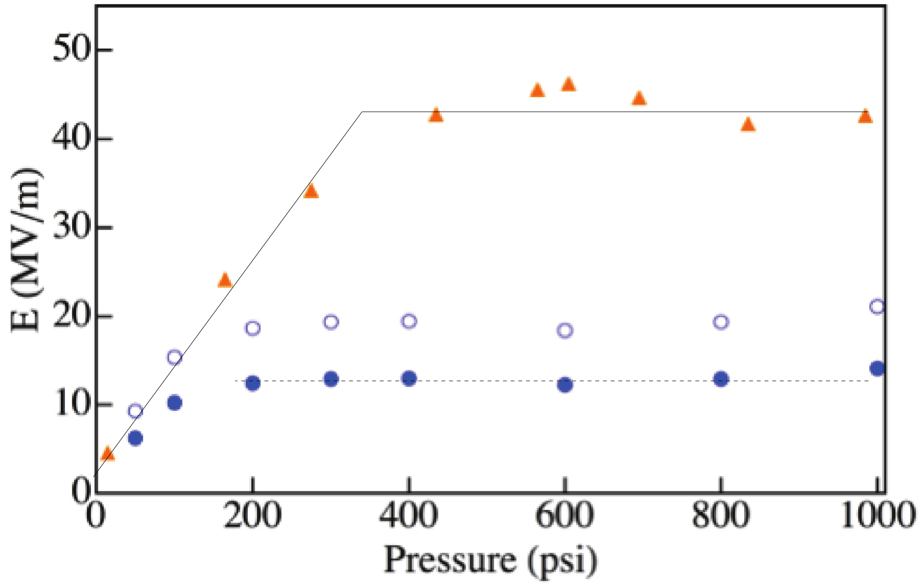
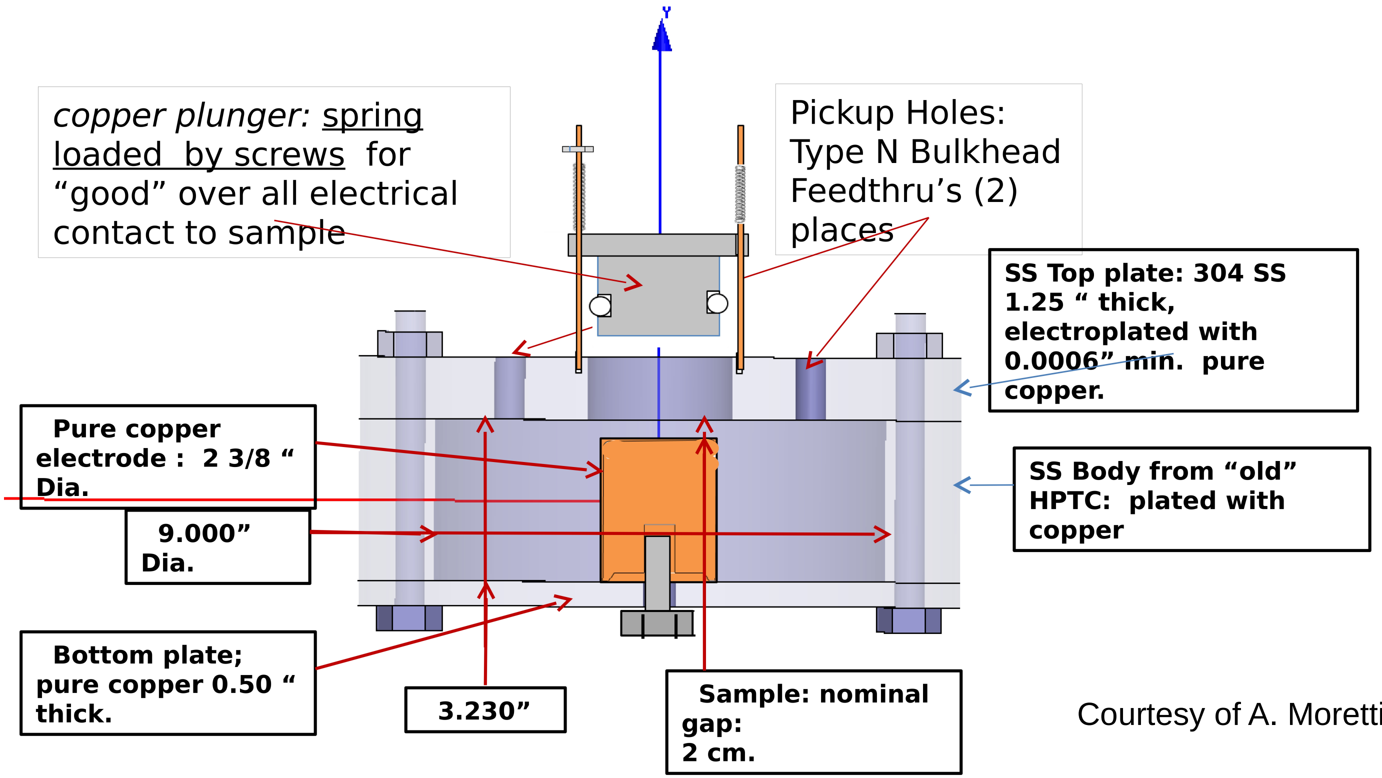


Figure 6: Measured maximum electric field as a function of N_2 gas pressure. An orange point is taken in 2009 [7]. An open blue circle is the estimated peak electric field in the TC (protrude of copper electrode). A closed blue circle is the peak electric field on surface of the alumina rod.

Dielectric Sample Test

- Goal: measure dielectric constant and loss tangent of various materials
  - Low power measurements with network analyzer
- Measurements made at atmosphere
- New sample test cell in fabrication to ease testing process

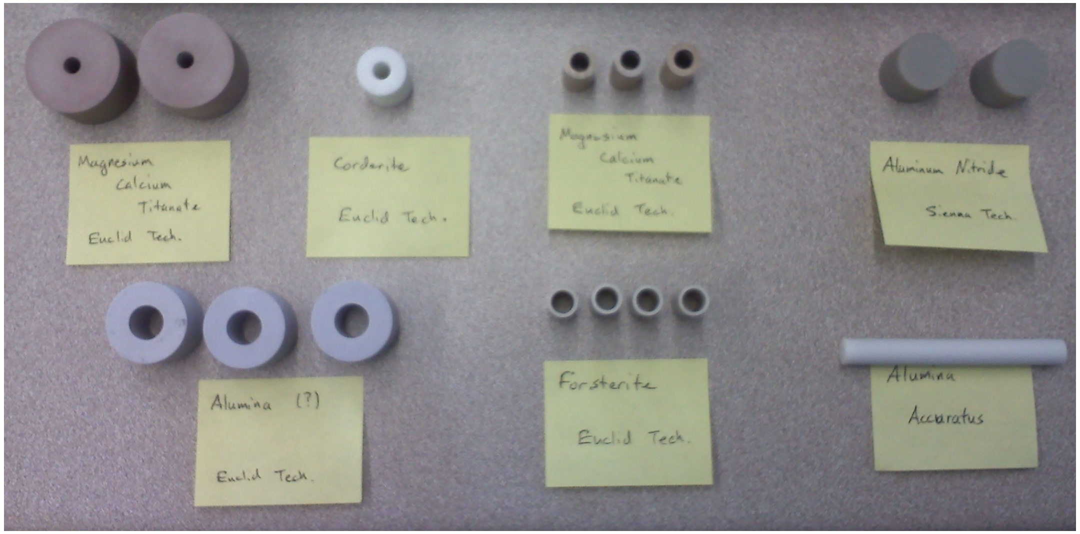


Courtesy of A. Moretti

Dielectric Samples

Material	Purity (%)	ε_r	tan δ	Geometry	Outer Diameter (cm)	Inner Diameter (cm)
Alumina	97.6	9.0	0.0003	Rod	0.81	N/A
Alumina	94.0	9.0	0.00062	Rod	1.54	N/A
Alumina	96.0	9.2	0.00044	Rod	2.11	N/A
Alumina	97.6	9.0	0.0003	Rod	1.40	N/A
Alumina	99.5	9.3	0.00014	Rod	2.53	N/A
MCT	N/A	35	<0.001	Tube	1.03	0.60
MCT	N/A	20	<0.001	Tube	2.93	0.54
Alumina (?)	N/A	9.7	<0.001	Tube	2.40	1.03
Forsterite	N/A	6.64	<0.001	Tube	0.90	0.70
Corderite	N/A	4.6	<0.001	Tube	1.50	0.55

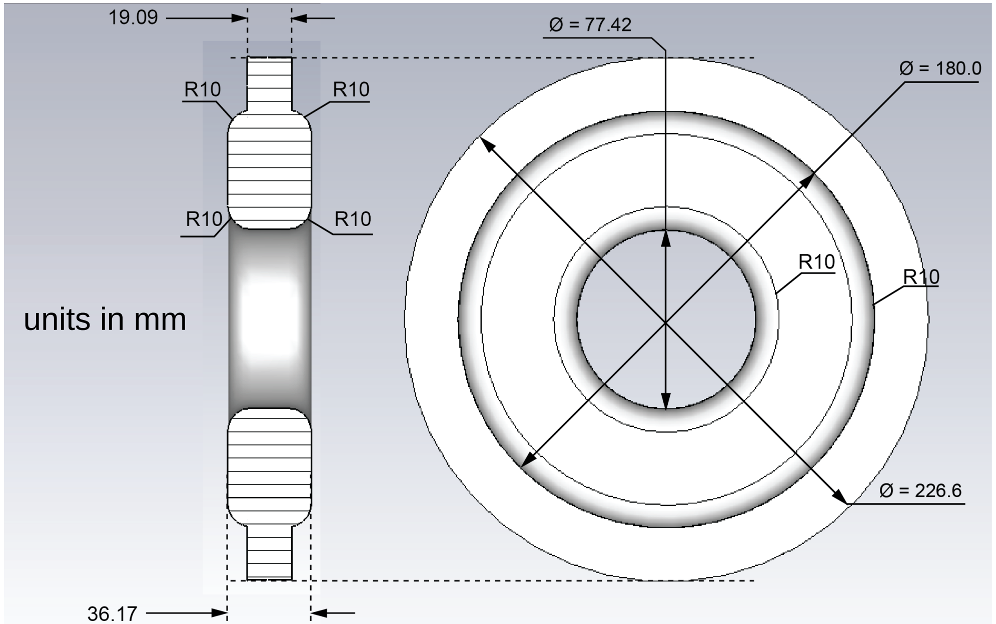
- Many purities of alumina ordered (one in hand)
- Tubes of other candidates also in hand
- Multiple samples of each material add statistics

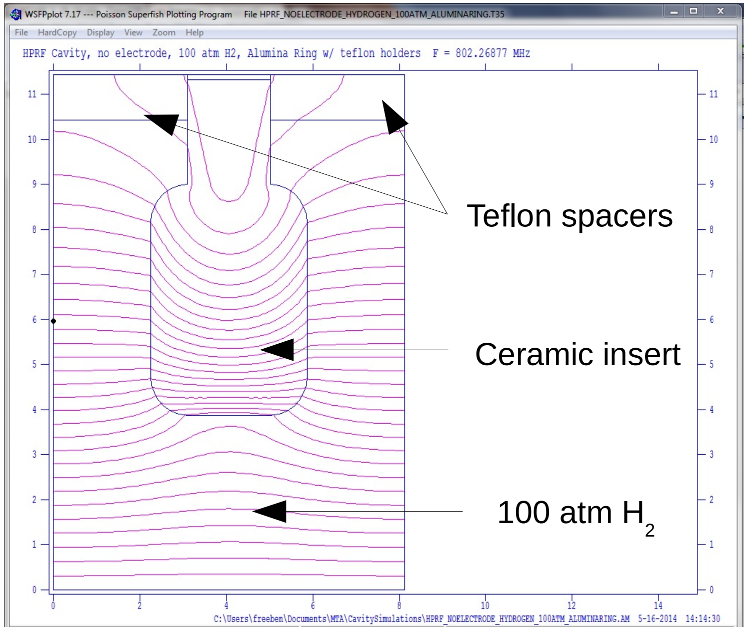


High Power / Beam Tests

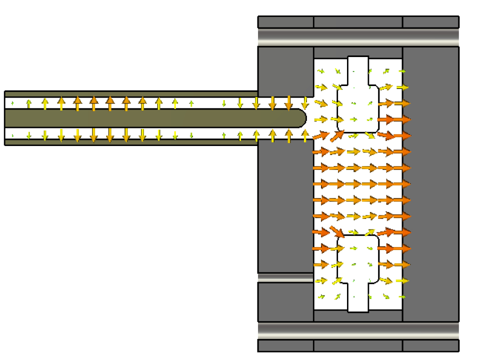
- HPRF cavity used in beam tests of 2011-2012 to be refit for high power test of select “donut” inserts with and without beam
- Electrodes used in beam test removed
  - 100 atm H_2 gas with appropriate insert geometry achieves required frequency
- To be studied:
  - Charge up of ceramic
  - Interaction of ceramic – gas
  - Interaction of ceramic – gas – beam – plasma
  - Physical considerations (heating/expansion of ceramic, RF contact, …)
  - Dielectric strength (?)
- Alumina (possibly multiple purities, cost restricted) and teflon inserts will be tested
- F. Marhauser, Muons, Inc. responsible for alumina insert design
- A. Moretti, FNAL, responsible for teflon insert design

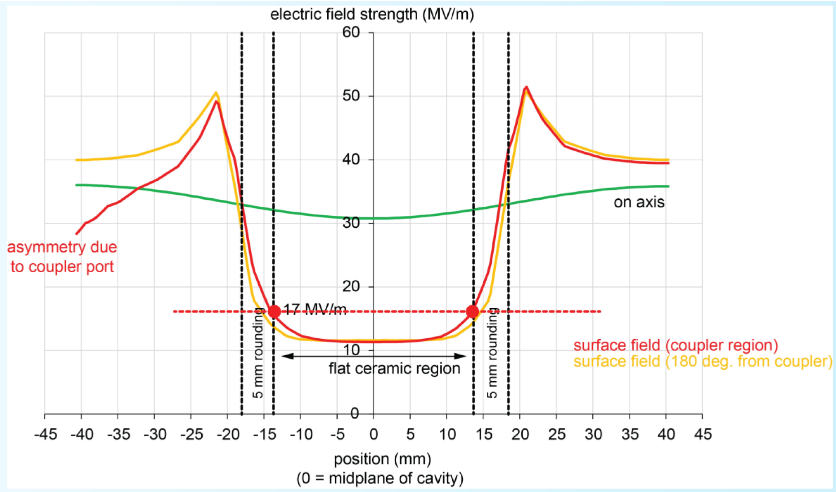
Alumina Insert





- Dimensions not final – to be determined from sample test results
- The ring will be held in place with spacers
  - Teflon leading candidate





Insert Considerations

- In finalizing design of ceramic inserts, one must consider:
  - Spacer dimensions
  - Relative expansion of ceramic/spacer and tensile strength of each
  - Sufficient RF contact between insert and cavity body
- Additionally, heating/expansion of insert may limit RF rep. rate and E field

Schedule

- Independent of MTA schedule:
  - Assemble and measure Q of sample cavity: June (end plates arrive in ~ 2 weeks)
  - Measure samples: July
  - Finalize design of inserts and select vendor: July
- MTA schedule dependent*:
  - Assemble and measure Q of beam test cavity with insert(s): September
  - High power tests in Station II: September
  - Beam test: October

* There is a priority for test programs in the MTA, in which MICE cavity > modular cavity > dielectric loaded cavity