Status of the Dielectric Loaded HPRF Test Program

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Running in Place...

- Content of this talk very similar to that I gave at the collaboration meeting in December
- Testament to the amount of work trying to be crammed into a short time at the MTA
- Remarkable progress with 201 MHz cavity and Modular Cavity
- I look forward to running the HPRF cavity again (sometime soon!)

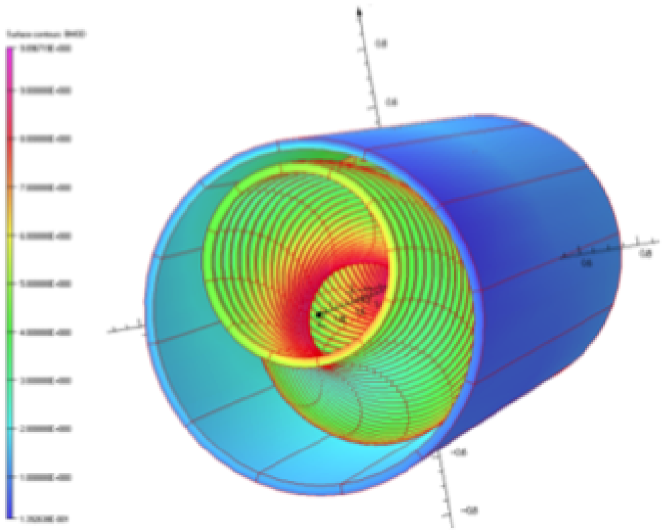
Motivation

- High field solenoid magnets have small bores
- Resonant frequency of pillbox cavity related to radius by:

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

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

- Hydrogen ε_r = 1.03718 @ 160 atm
  - R_{325} = 34.7 cm, R_{650} = 17.3 cm
- From Katsuya's talk on Wednesday:
  - $R_{IC\text{-}325}$ = 21.7 cm, $R_{IC\text{-}650}$ = 10.0 cm

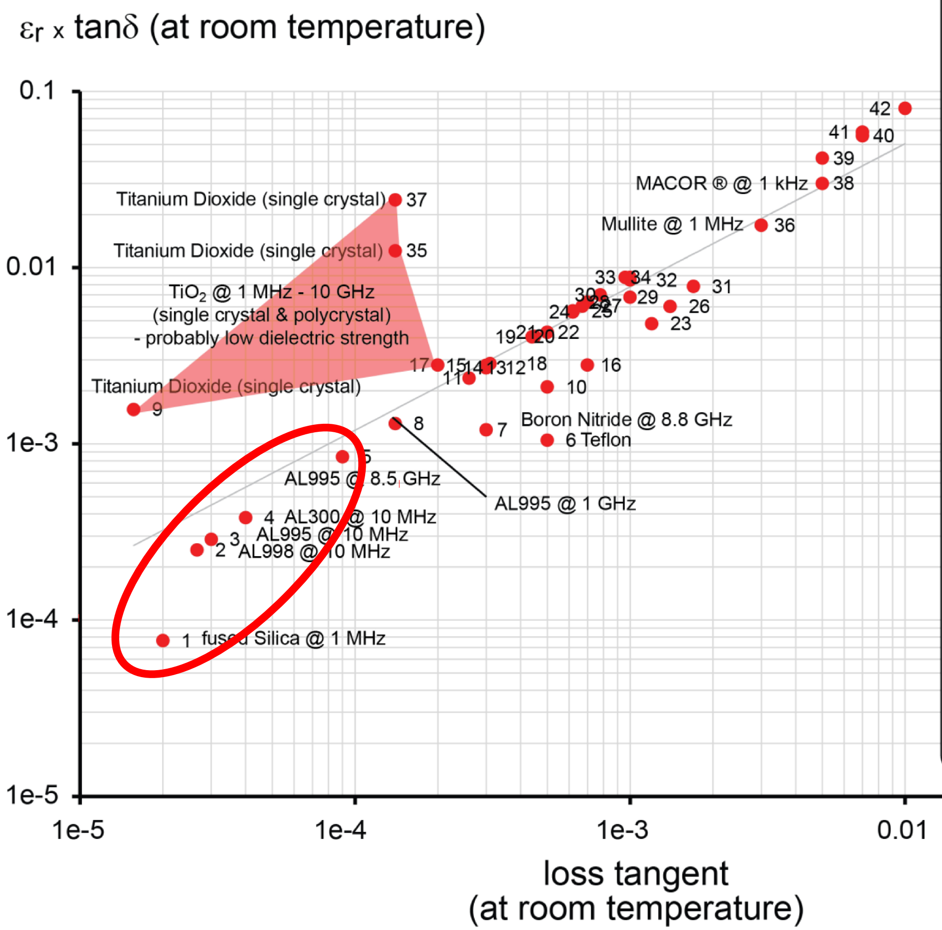


- For R = 10.0 cm and completely filling cavity with dielectric, ε_r = 3.12
- Target $\varepsilon_r \geq 9.0$

Suitable Materials

- Power & heating considerations at forefront
  - Small loss tangent

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

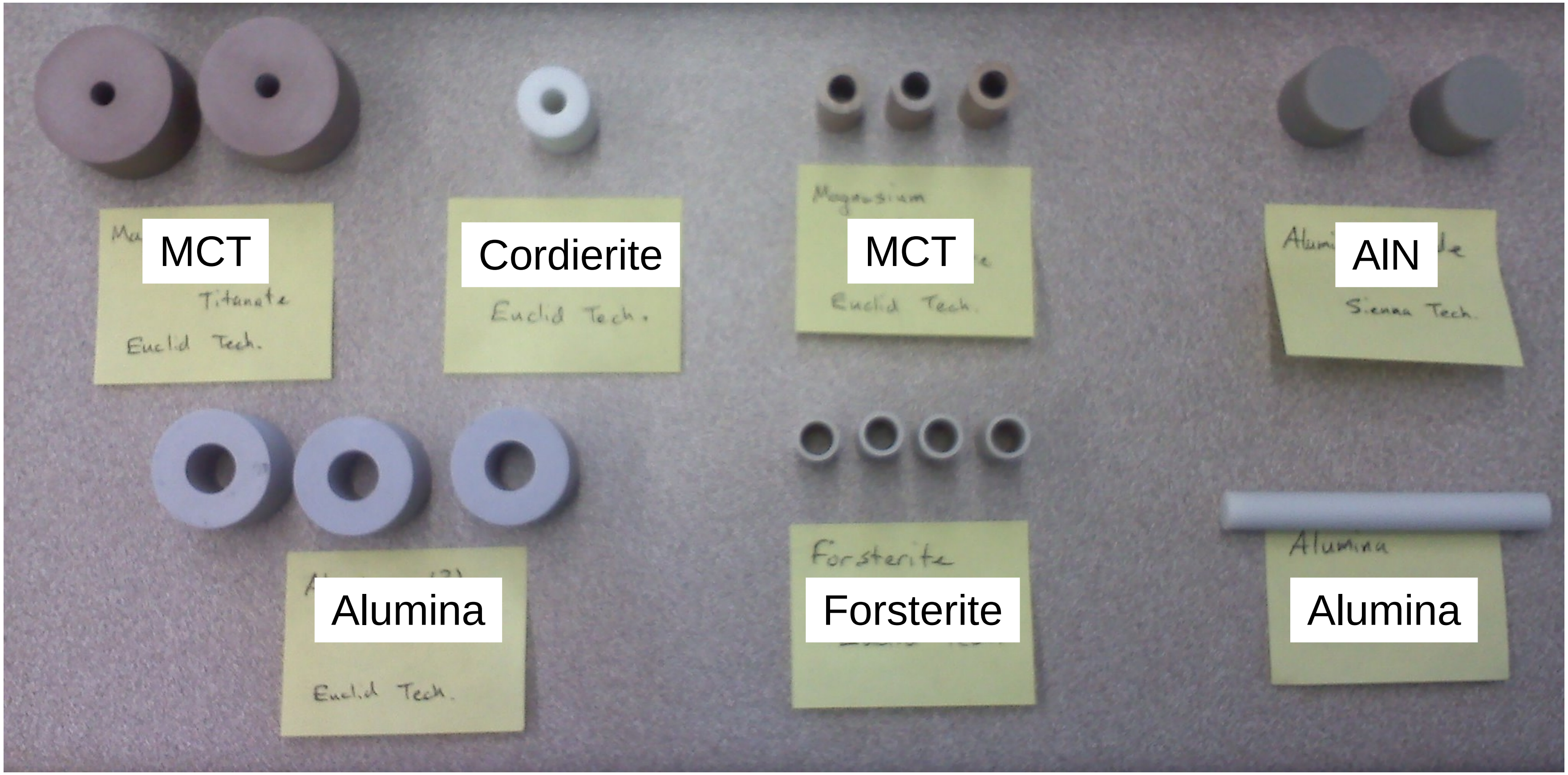


note: frequency may vary

1 fused Silica (Accuratus) @ 1 MHz
2 Alumina 99.8% (Wesgo Al998) @ 10 MHz
3 Alumina 99.5% (Wesgo Al995) @ 10 MHz
4 Alumina 97.6% (Wesgo Al300) @ 10 MHz
5 Alumina 99.5% (Wesgo Al995) @ 8.5 GHz
6 Teflon (PTFE)
7 Boron Nitride, Grade XP (Accuratus, perp.) @ 8.8 GHz
8 Alumina 99.5% (Wesgo Al995) @ 1 GHz
9 Titanium Dioxide
10 Boron Nitride, Grade BO (Accuratus, perp.) @ 8.8 GHz
11 Alumina 94% (Wesgo Al500) @ 10 MHz
12 Alumina 97.6% (Wesgo Al300) @ 1 GHz
13 Aluminum Nitride (ST 170) @ 1 MHz
14 Aluminum Nitrude (Accuratus) @ 1 MHz
15 Alumina 96% (Wesgo Al600) @ 10 MHz
16 Boron Nitride, Grade CA (Accuratus, perp.) @ 8.8 GHz
17 Titanium Dioxide (poly-crystalline)
18 ALON (Surmet) @ 35 GHz
19 Alumina 96% (Wesgo Al600) @ 1 GHz
20 Alumina 97.6% (Wesgo Al300) @ 8.5 GHz
21 Aluminum Nitride (AlN 140) @ 1 MHz
22 Aluminum Nitride (AlN 180)
23 Boron Nitride, Grade XP (Accuratus, parallel) @ 8.8 GHz
24 Alumina 94% (Wesgo Al500) @ 1 GHz
25 Alumina 96% (Wesgo Al600) @ 8.5 GHz
26 Boron Nitride, Grade CA (Accuratus, parallel) @ 8.8 GHz
27 ALON (Surmet) @ 55 GHz
28 Alumina 94 % (Accurates)
29 Aluminum Nitride (Shapal M, GoodFellow)
30 Alumina 94% (Wesgo Al500) @ 8.5 GHz
31 Boron Nitride, Grade BO (Accuratus, parallel) @ 8.8 GHz
32 Aluminum Nitride (ST 200) @ 1 MHz
33 Aluminum Nitride (ST 100) @ 1 MHz
34 ALON (Surmet) @ 90 GHz
35 Titanium Dioxide (single crystal, parallel)
36 Mullite (Accuratus) @ 1 MHz
37 Titanium Dioxide (single crystal, perp.)
38 MACOR ® (Accuratus) @ 1 kHz
39 Aluminum Nitride (ST 200) @ 10 GHz
40 Aluminum Nitride (ST 100) @ 10 GHz
41 Aluminum Nitride (ST 200) @ 2.6 GHz
42 Aluminum Nitride (ST 100) @ 2.6 GHz

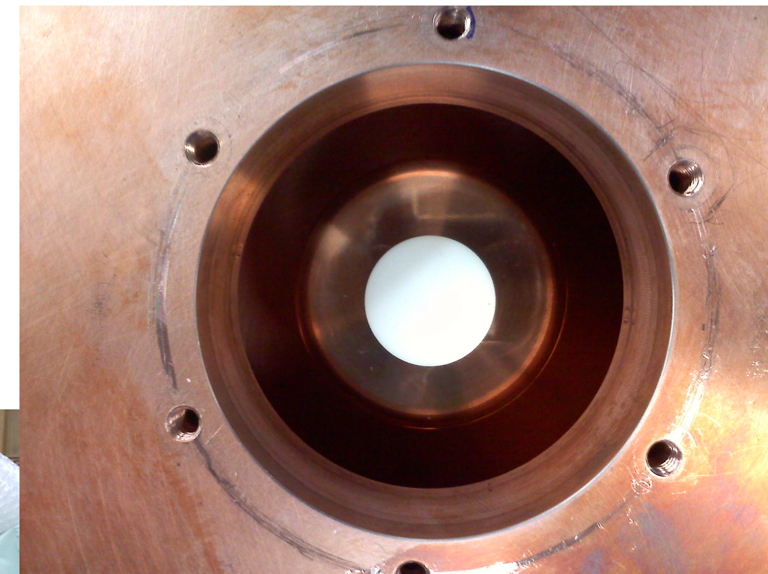
Dielectric Samples

- Rods/tubes of:
  - 94, 96, 97.6, 99.5% Alumina
  - Aluminum Nitride
  - Cordierite
  - Forsterite
  - Magnesium Calcium Titanate

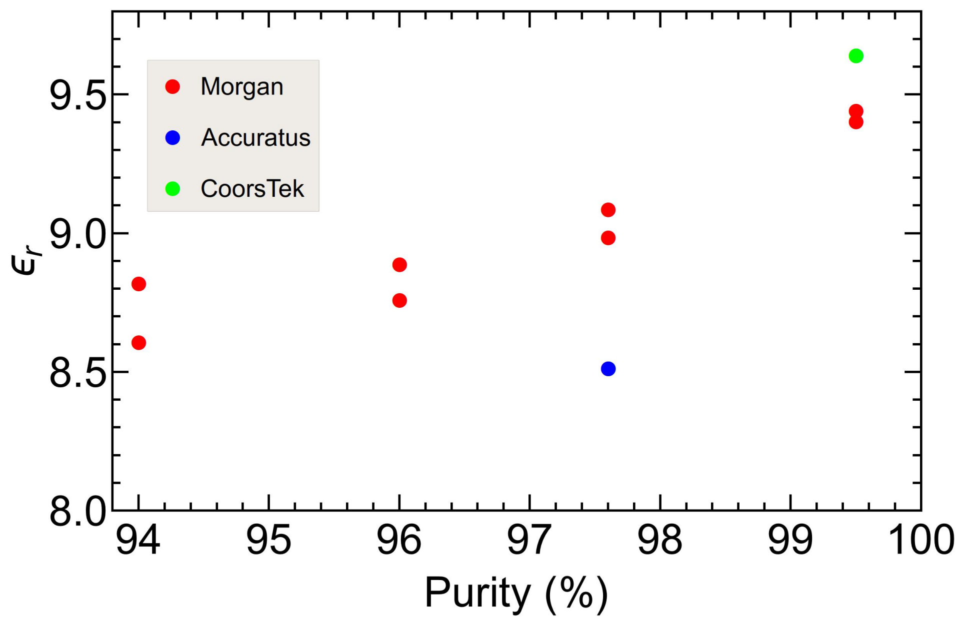


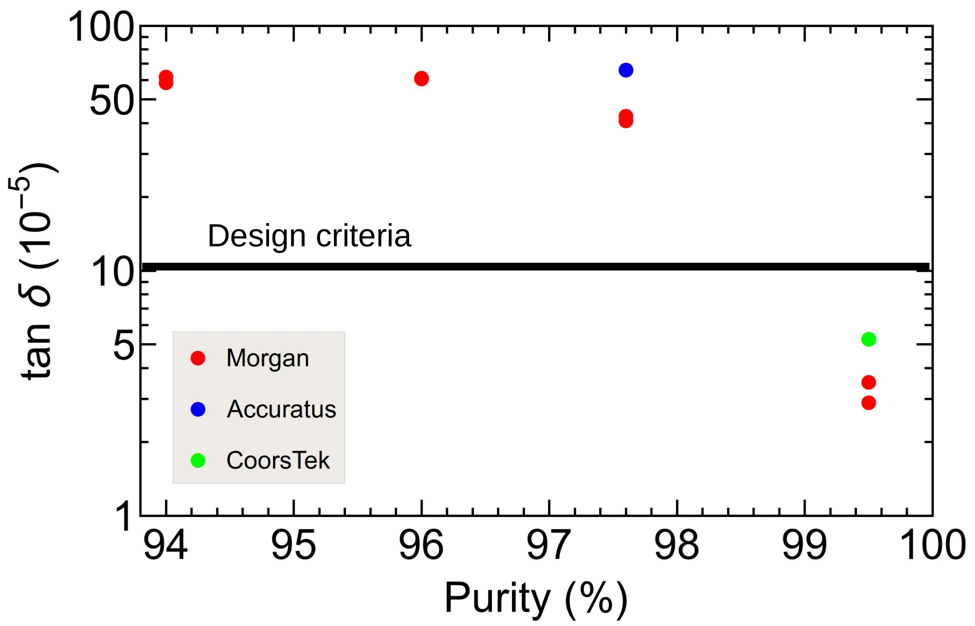
Sample Test Cavity

- Copper end plates bolted to copper coated stainless steel body
- Copper electrode and copper plunger for inserting and holding samples



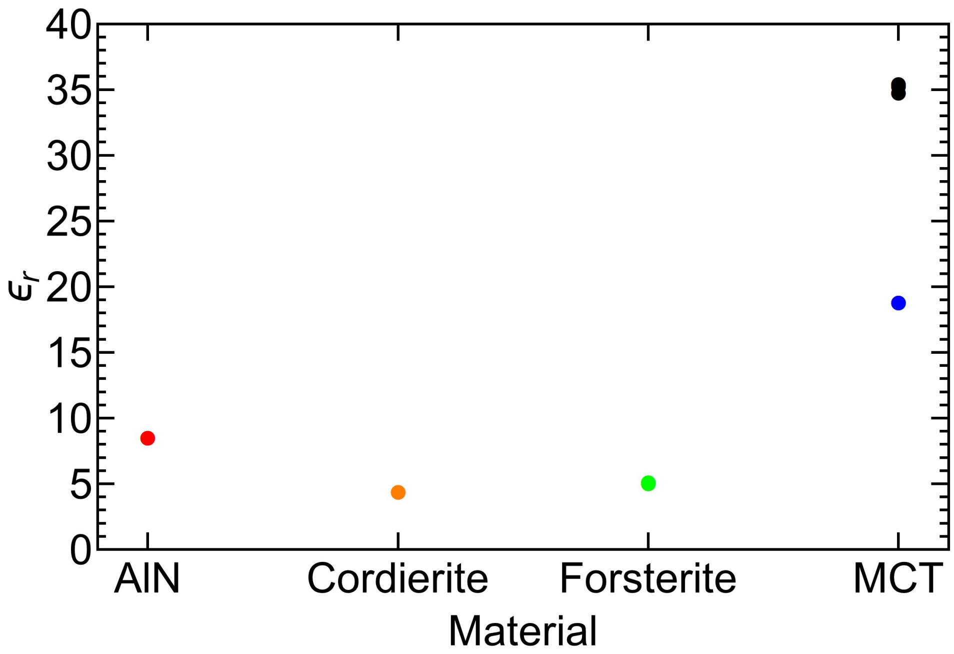
Results – Alumina

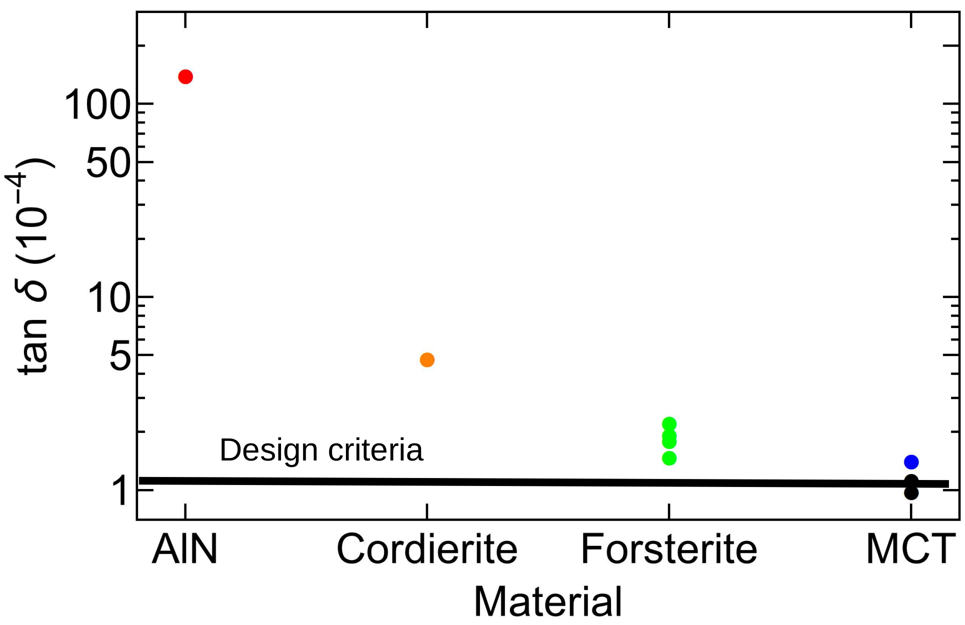




- Only 99.5% met loss tangent requirement

Results – Other Materials





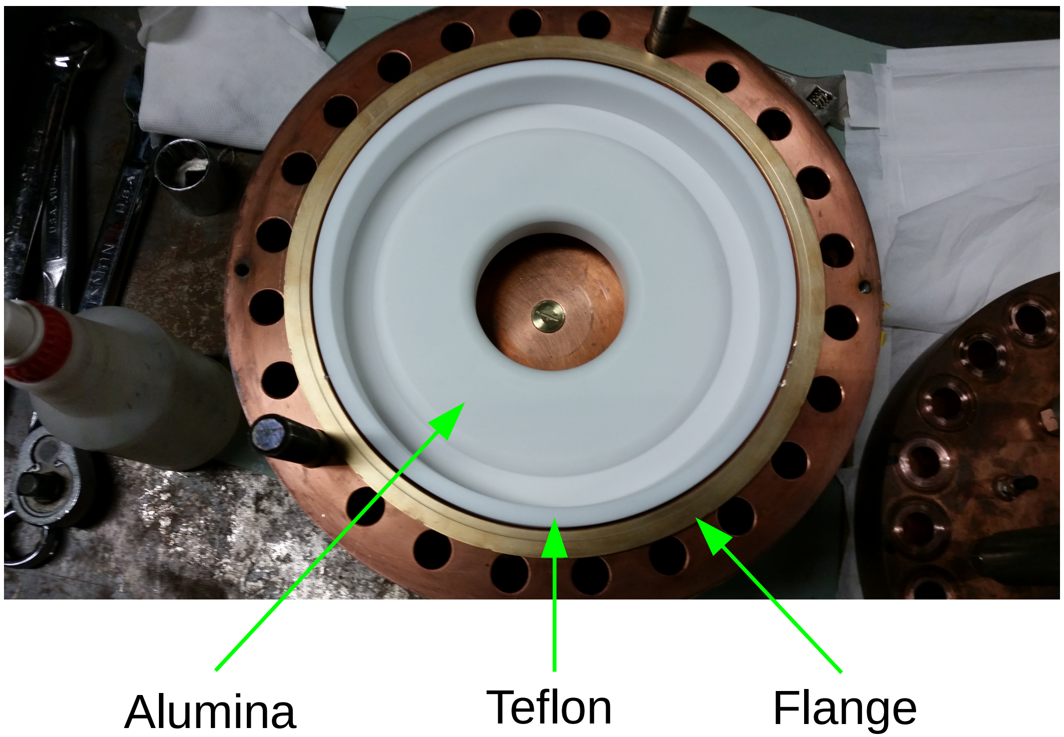
- Only magnesium calcium titanate met loss tangent requirement

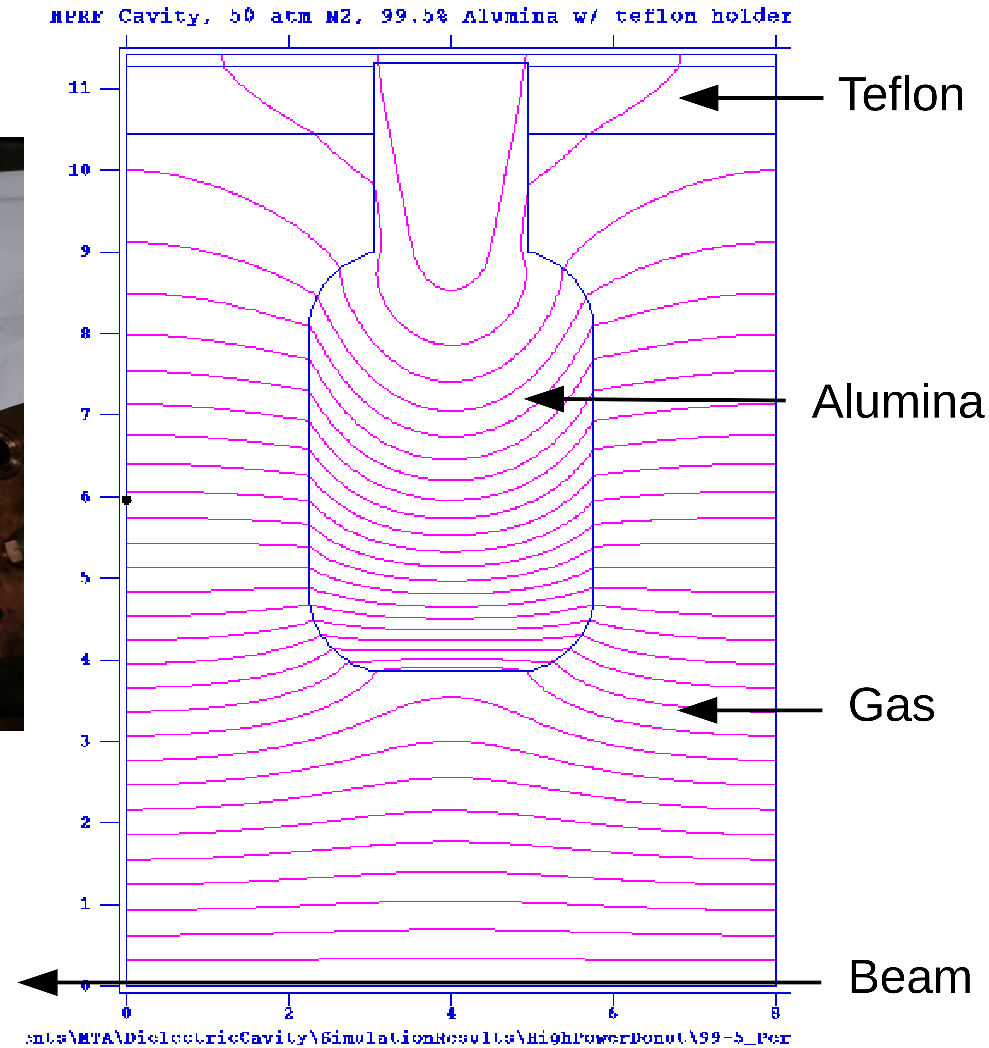
Sample Test Conclusion

- 99.5% alumina and MCT measured tan δ ≤ 0.0001
- Alumina pursued due to ease of machining and cost
- Four inserts were designed based on the sample test results
  - 99.8, 99.5, 98.5 & 96%
  - All in hand
  - All but 99.8% measured with low level RF
  - 99.5% assembled in cavity
- A set of teflon spacers fabricated
  - Three more to be fabricated

High Powered Test Cavity

- “Donut” shaped alumina inserts held in place by teflon spacers





Sealing the Cavity – Progress!

- After many iterations of assembling and disassembling the cavity, there was difficulty maintaining pressure
- Solution: thicker, hand-polished gaskets

Updated Safety Documentation

- Result of new gaskets:
  - Update safety documentation
  - Lower Maximum Allowable Working Pressure (MAWP)
  - New/recalibrated pressure relief valve
  - Pressure test
- Safety documentation complete
- New relief valve in the works
  - Pressure test pending

Experimental Plan

- Measure dielectric strength of each insert outside magnet using nitrogen and nitrogen + oxygen

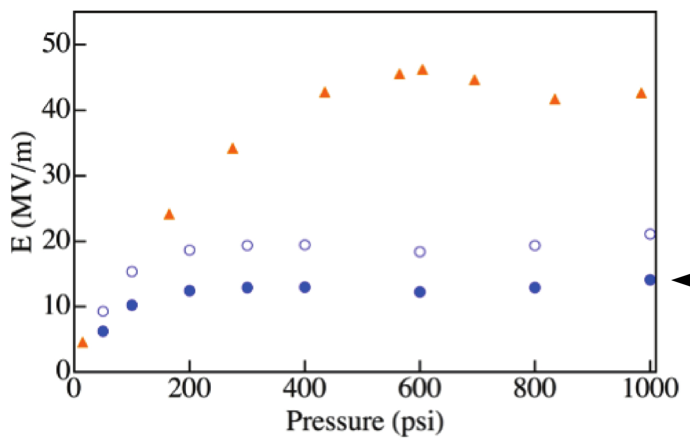


Figure 6: Measured maximum electric field as a function of N2 gas pressure. An orange point is taken in 2009 [7]. An open blue circle is the estimated peak electric field in the TC (protrude of copper electrode). A closed blue circle is the peak electric field on surface of the alumina rod.

CoorsTek published dielectric strengths

Purity (%)	96	98.5	99.5	99.8
Dielectric Strength (MV/m)	8.3	8.7	8.7	8.7

- 2013 measurement of 99.8% Alumina from Accuratus
  - Rod on cavity axis
  - 14 MV/m

- Beam test using hydrogen and hydrogen + oxygen with one insert