Dielectric RF Cavities

Addressing the challenges of a Muon collider

Katheryn Decker French

Fermilab: Lee Teng program

August 9, 2010

Constraints for Muon acceleration

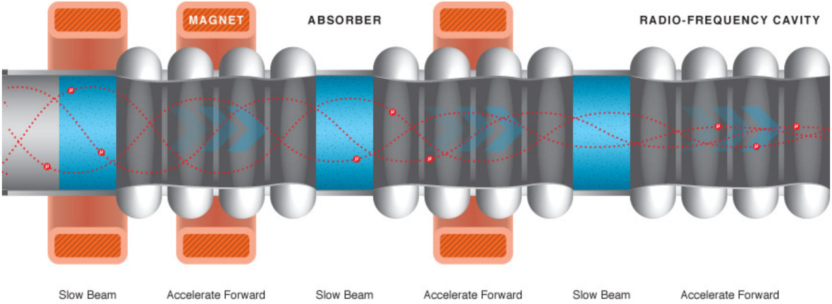


Image source: fnal.gov

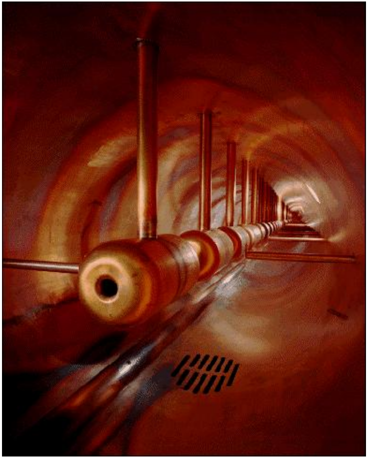
Muon Acceleration

- Muons have a short lifetime
- Ionization cooling lowers momentum in all directions
- RF power is used to accelerate longitudinally

Constraints on accelerating RF cavities

- Must fit inside solenoids
- Use existing RF power supply
- Prevent breakdown

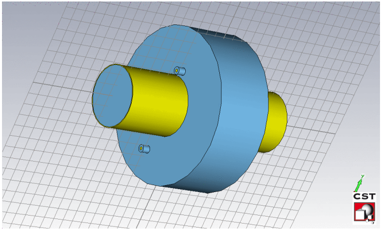
RF Cavities

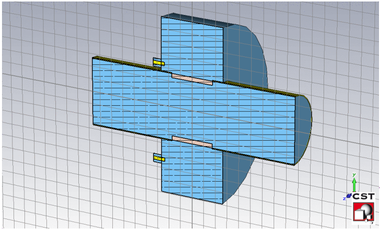


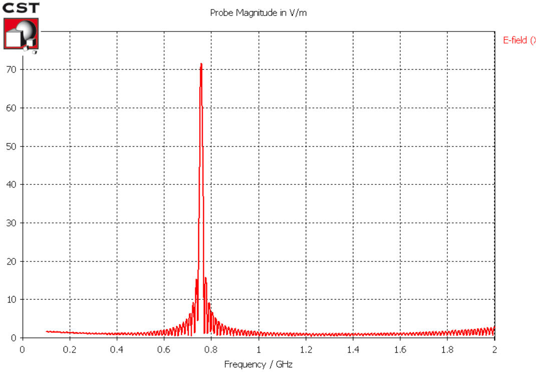
Fermilab linac. Image source: www-bd.fnal.gov

- Radio frequency power used to accelerate charged particles
- Frequency depends on geometry of cavity and the properties of the materials within cavity
- For a basic pillbox cavity: $f = \frac{2.405c}{2\pi R\sqrt{\epsilon\mu}}$
- Increasing ϵ allows for a smaller cavity to operate at a lower resonant frequency

Simulations
Using dielectrics to reduce frequency of cavities



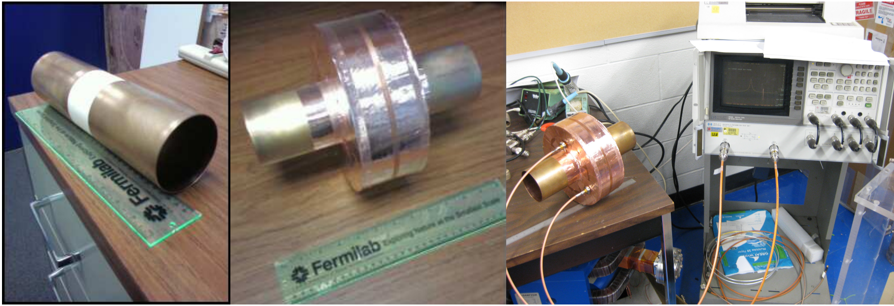




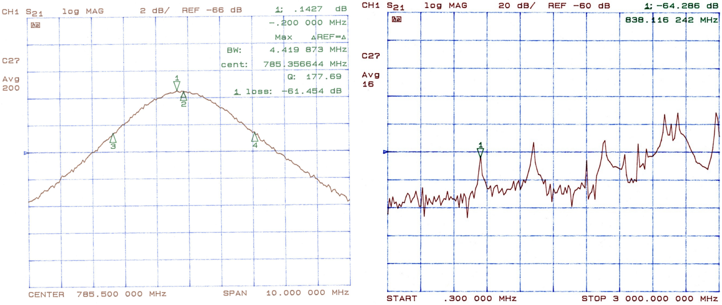
The resonant frequency, quality factor, and response to power inputs can be simulated.

Prototype Cavity

Construction and Network Analyzer Measurements



- Cavity was constructed around copper pipe with ceramic cylinder inset
- Power was input through antennas in the side of the cavity
- The resonant frequency was measured using a network analyzer



- The resonant frequency occurs when the transmitted power is at a maximum

Simulations and Measurements for three cavity designs

Build	Width (mm)	f_{sim} (MHz)	f_{obs} (MHz)	ϵ
1	79	789	836	7.4
2	91	740	785	7.5
3	86	756	807	7.3

Table: Results from Microwave Studio simulation of the resonant mode frequencies for the three cavities, assuming $\epsilon = 9.7$ and $\tan\delta = 0.0004$, from observations, and the values of ϵ required to reconcile these discrepancies.

Results & Conclusions

- Discrepancy between simulated and observed frequencies
  - Relative dielectric constant of ceramic from manufacturer is $\epsilon = 9.7$ at $f = 1$ MHz
  - Measurements were at $f \sim 800$ MHz
  - Using three different cavity sizes, the relative dielectric constant of the ceramic at $f \sim 800$ MHz is $\epsilon = 7.4 \pm 0.1$.
- Finding the right material will be a key step in further development of this technology.