Ferrite HOM Load Surrounding a Ceramic Break

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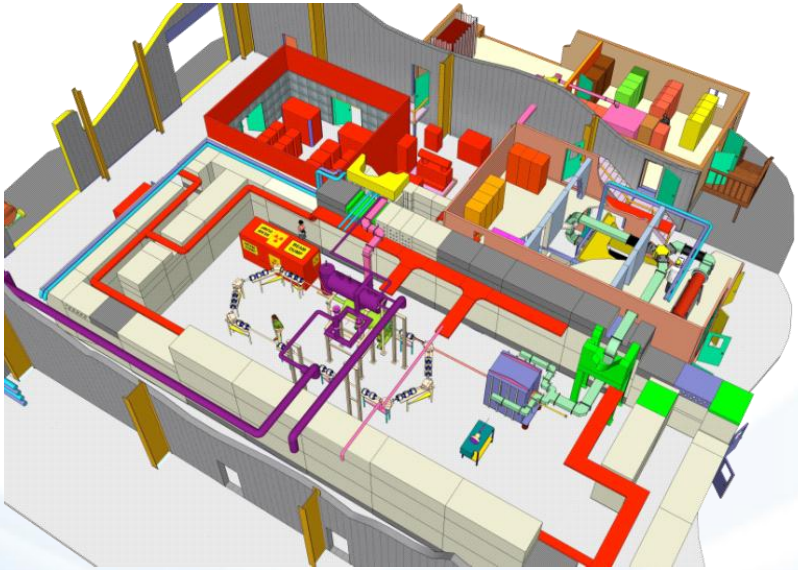
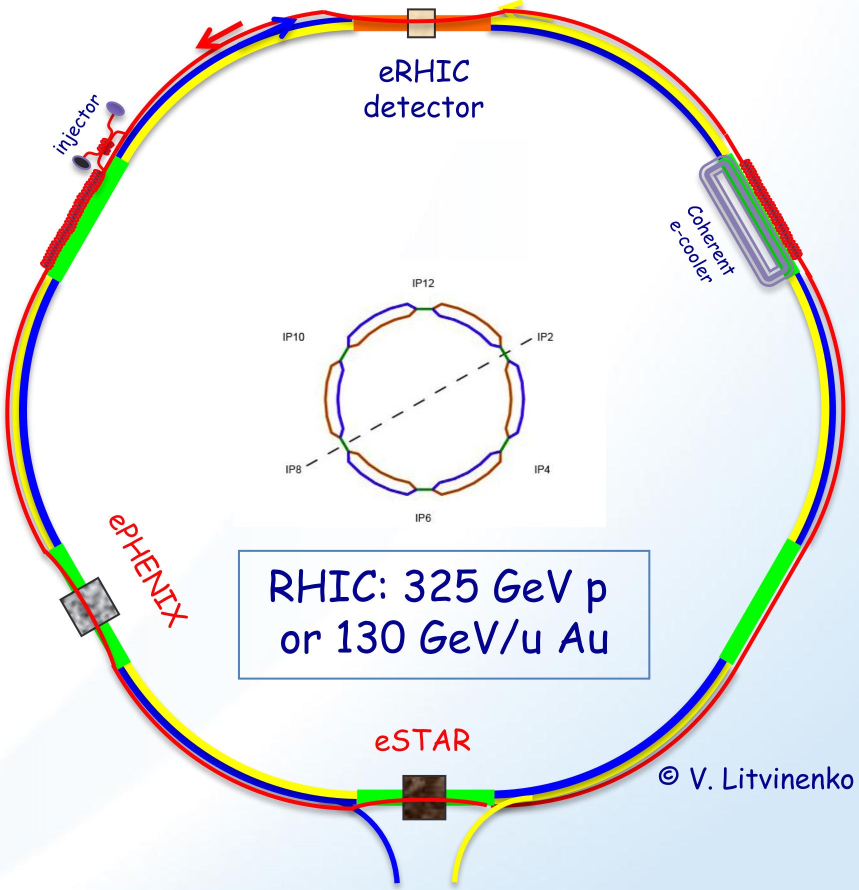
Effective HOM Absorber Development is Crucial to ERL and eRHIC

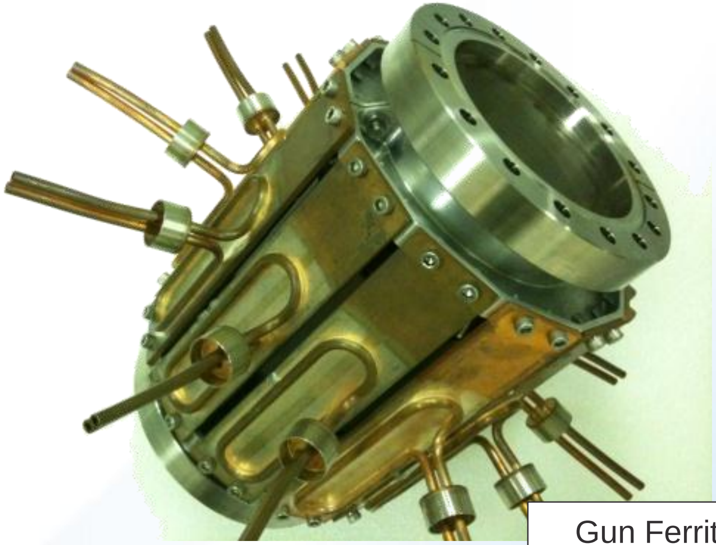
- ERL R & D facility with superconducting 5-cell cavity and ½-cell electron gun
- eRHIC





Ferrite Absorbers in the BNL ERL

- Beampipe absorbers for both superconducting structures used in the ERL
  - ½-cell electron gun
    - 703.75 MHz
    - 2.5 MeV injection energy
    - 1 MW power from klystron
    - Dual coupler ports



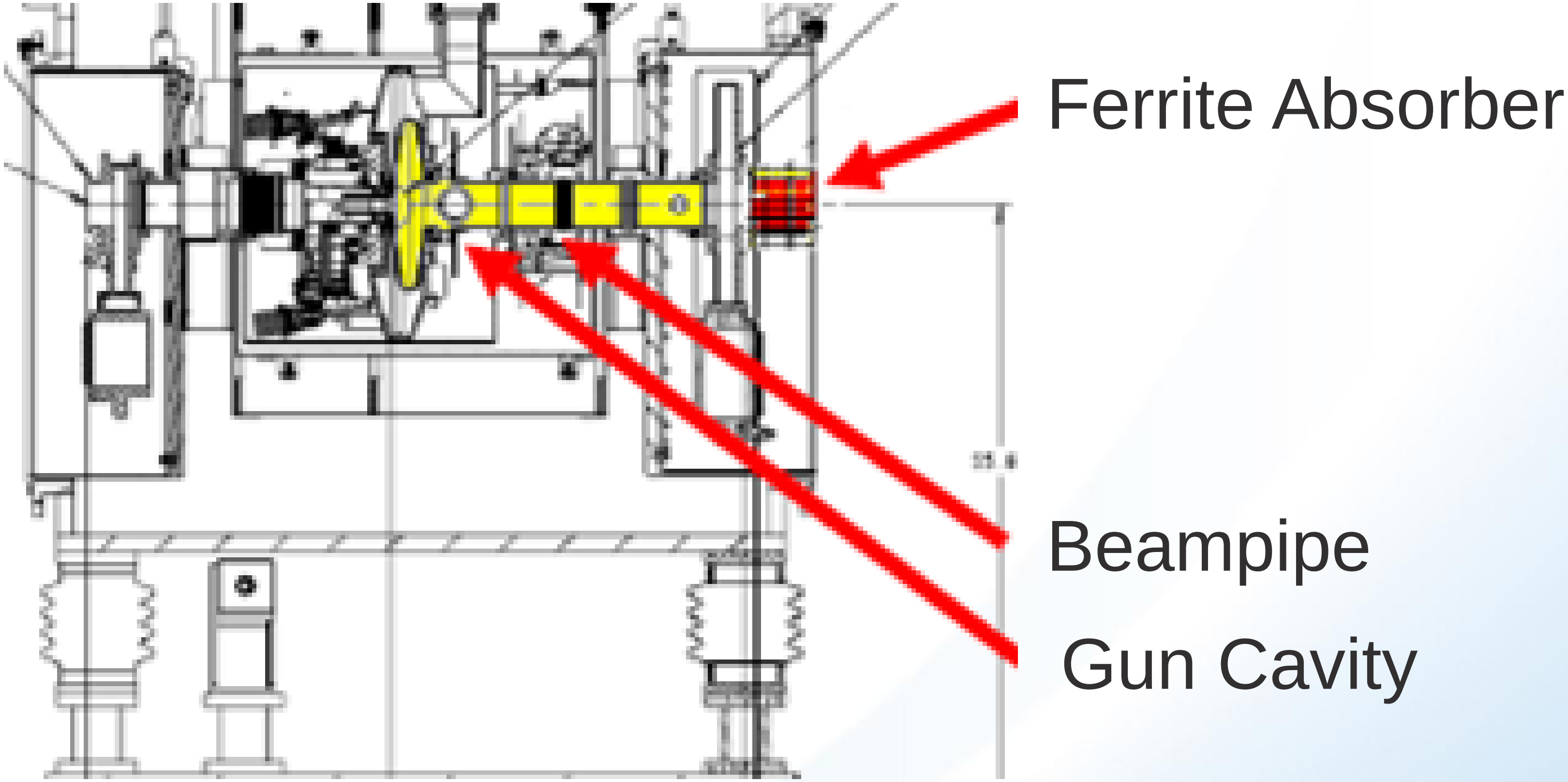
Gun Ferrite Damper

Superconducting Gun

Development of a Gun Absorber

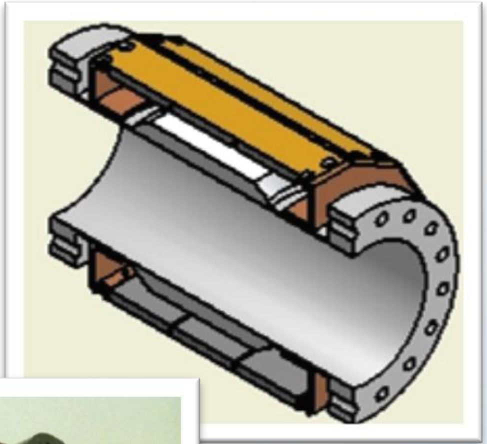
- High current along with high bunch charge beams dissipate large power in HOMs
  - Approximately 0.5 KW for 500 mA beam current and 1.4 nC bunch charge
  - Must be extracted outside cryogenic environment
- Beampipe ferrite absorbers placed in warm section to absorb HOM power
  - Only effective for modes beyond cutoff of beampipe
    - Cutoff: ~2.2 GHz
- Concerns:
  - Protection of superconducting cavity from damage to ferrites

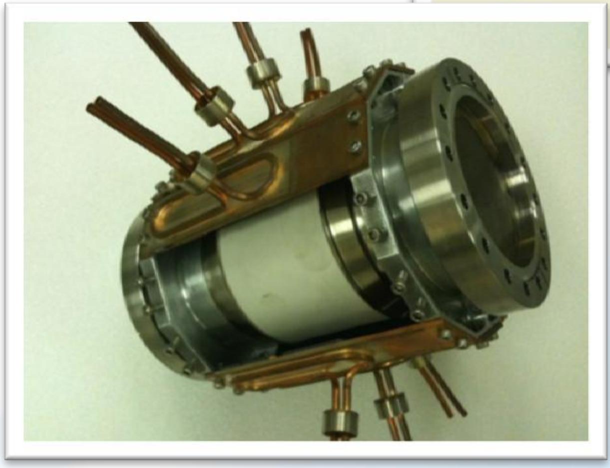
Gun Cavity and Ferrite Absorber



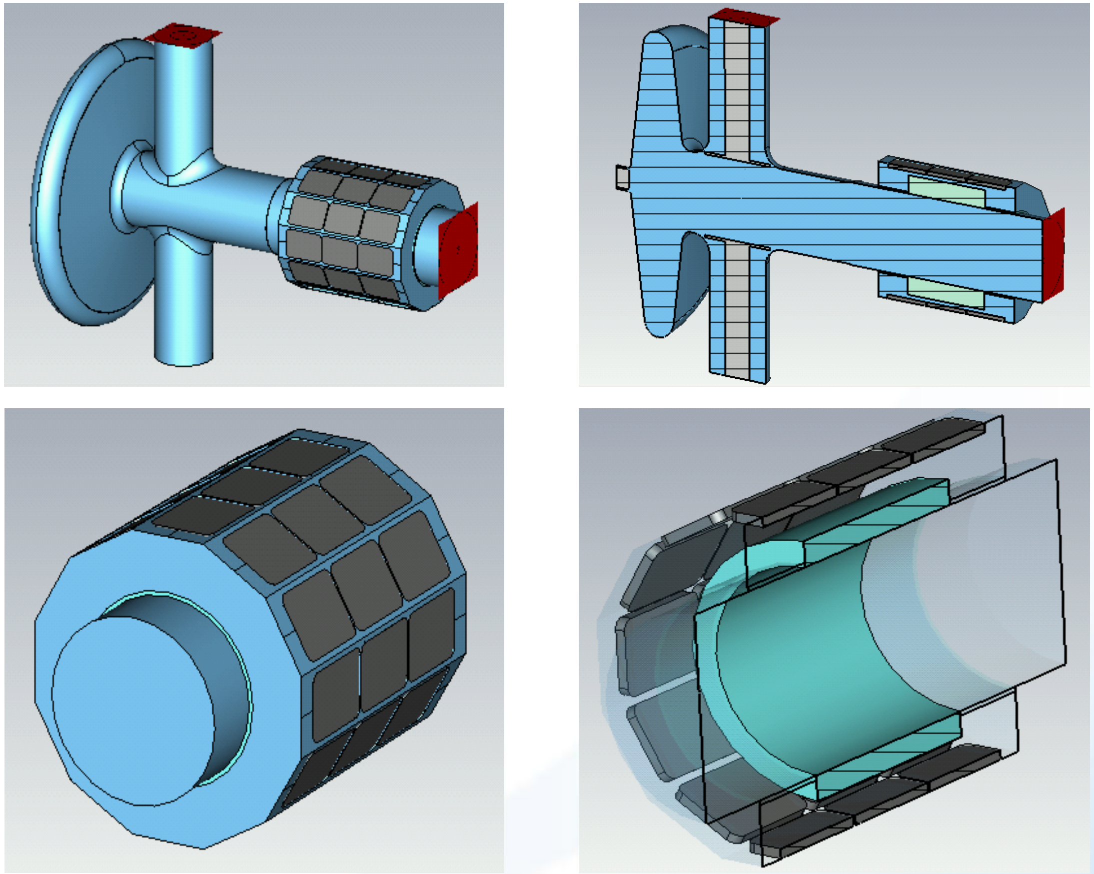
HOM Absorber Surrounding Ceramic Break

- Ferrite tiles surrounding a ceramic break
  - Beampipe inner radius: 5.08 cm
  - Ceramic parameters
    - Alumina
    - Thickness: 1.9 cm
    - $\varepsilon = 9$
    - $\tan \delta = 10^{-4}$

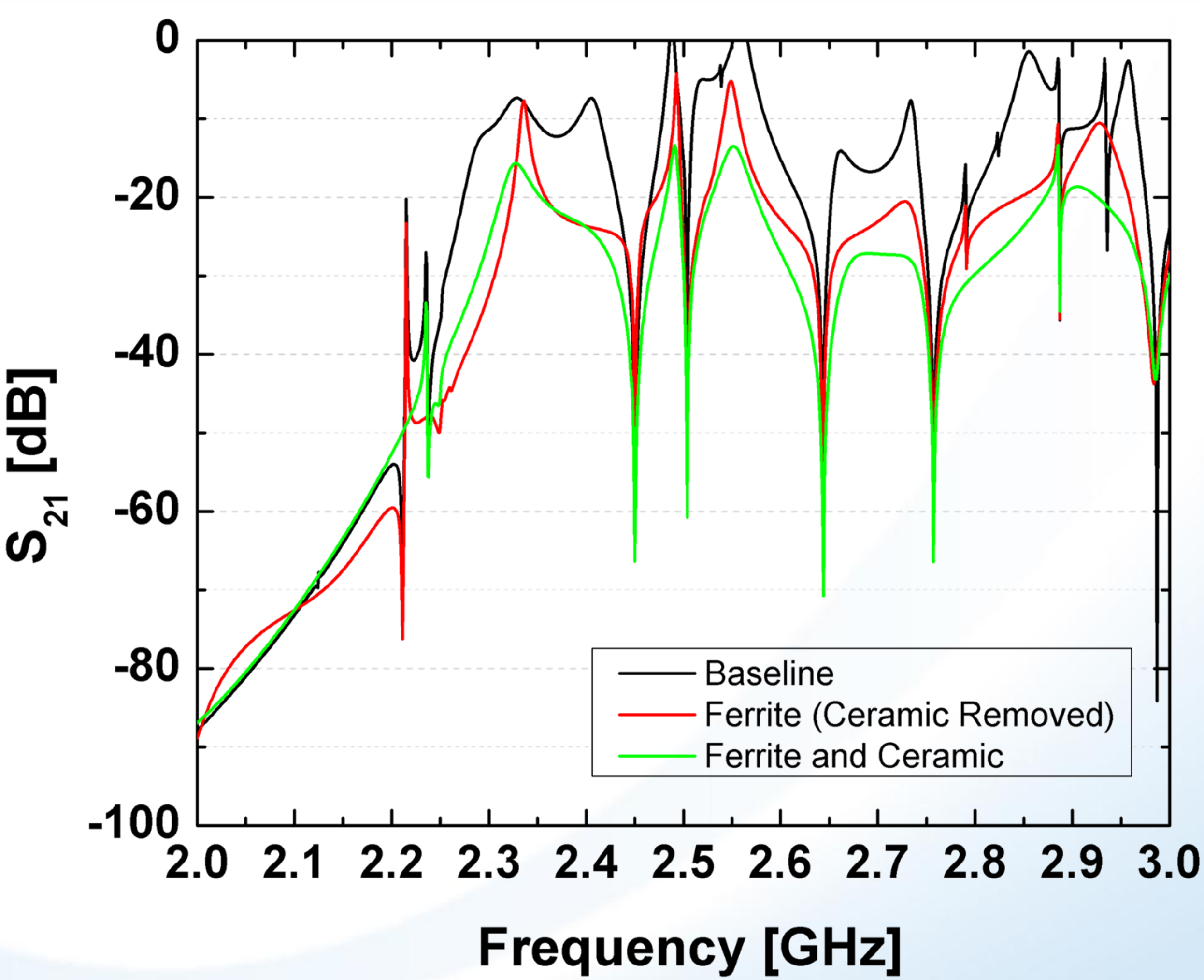




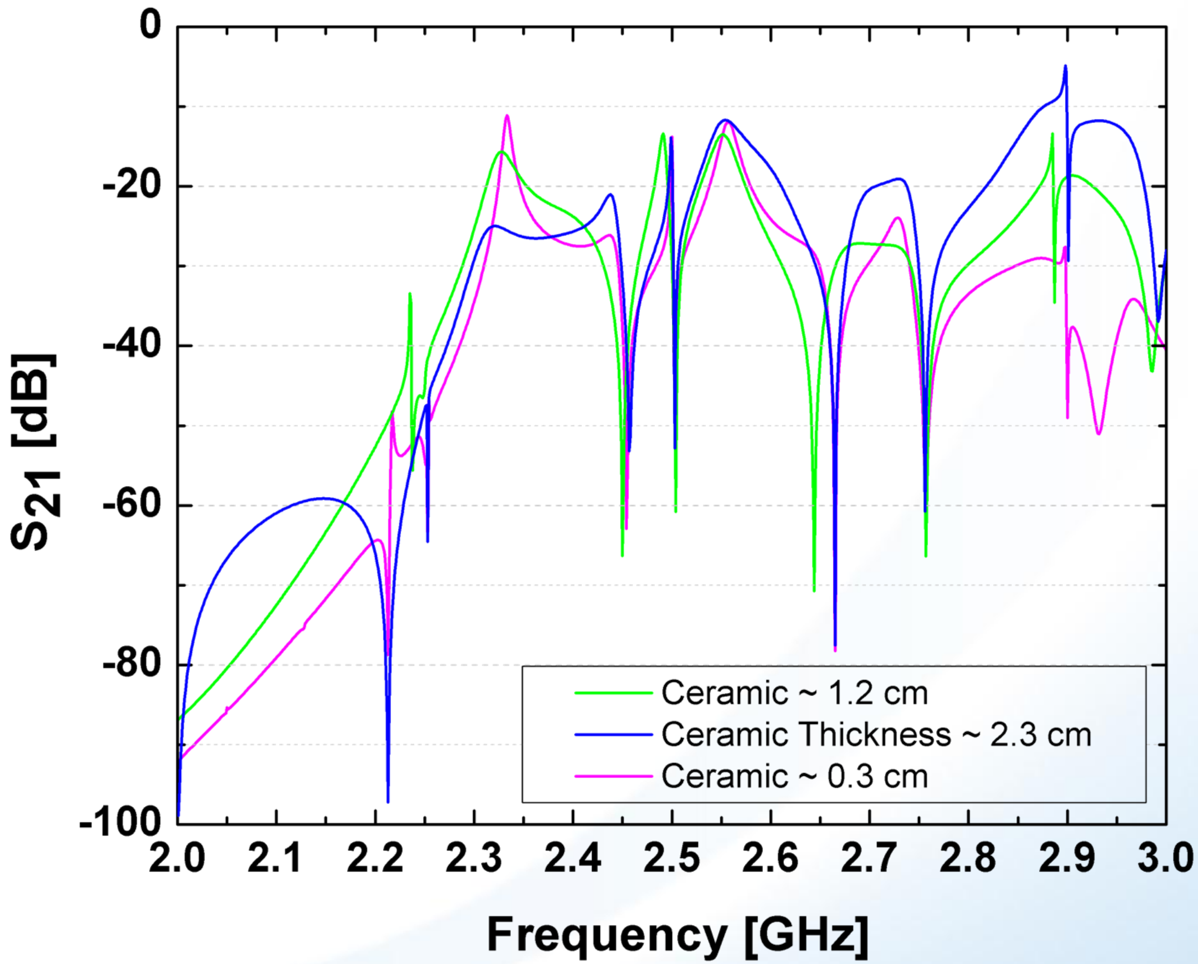
Gun and Damper Simulation



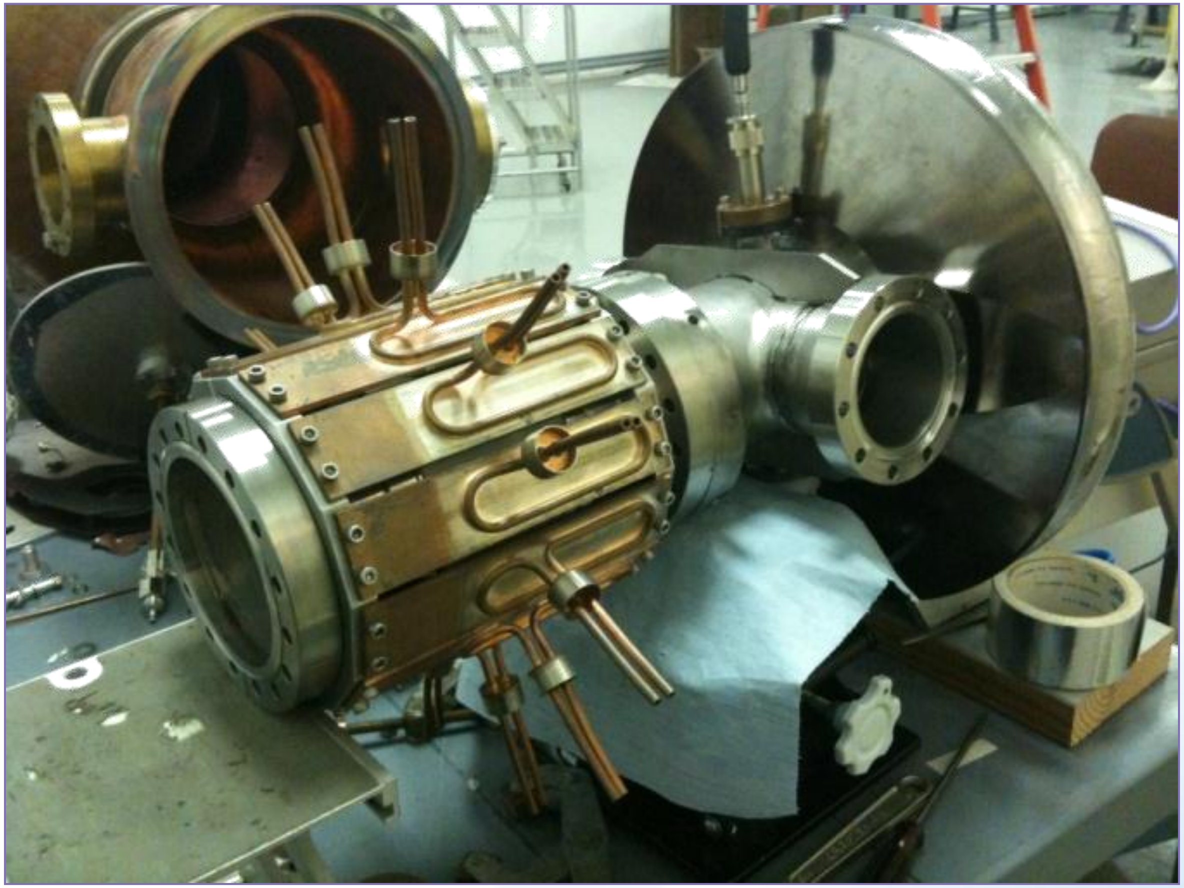
Simulation Results



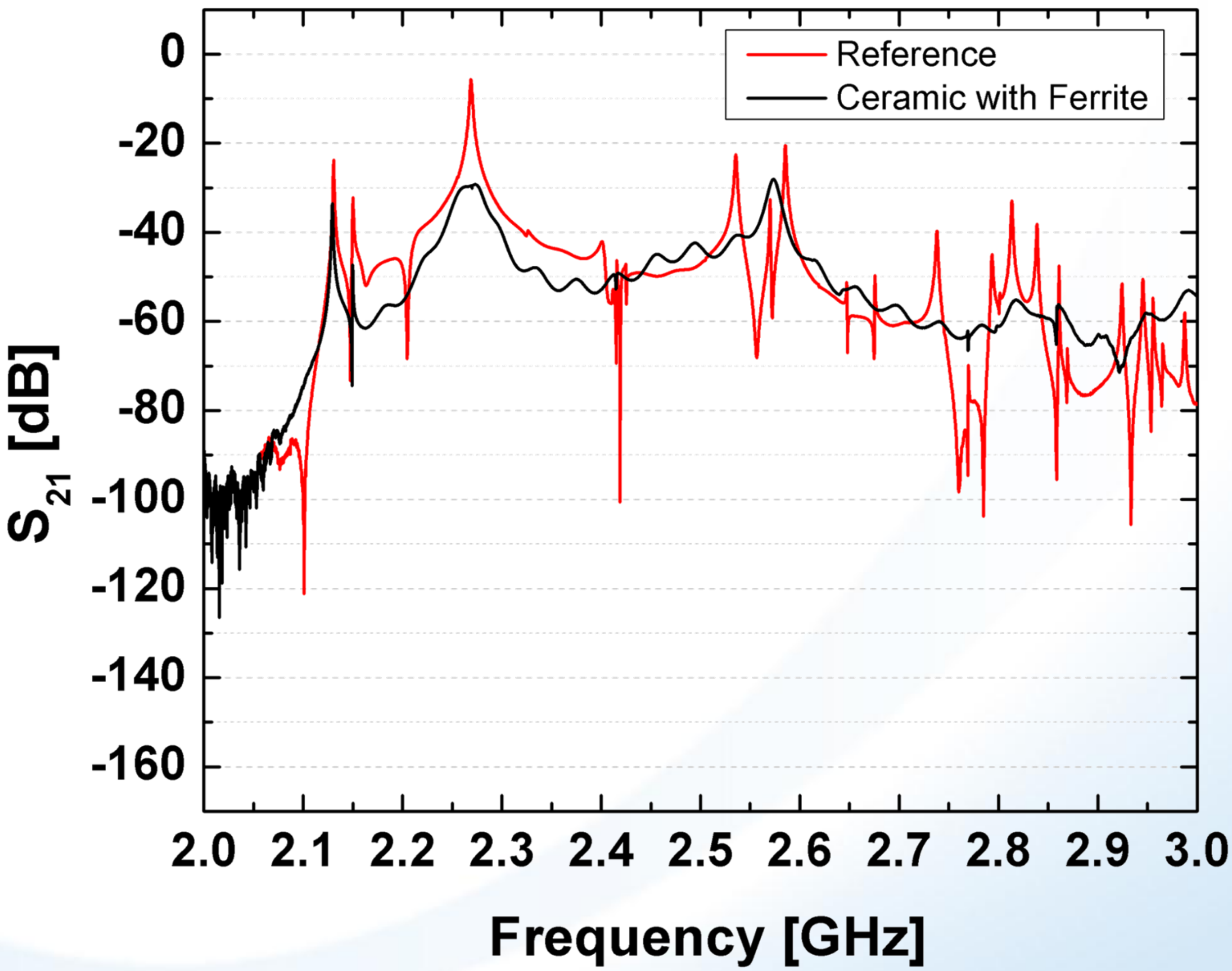
Varying Ceramic Thickness



Measurement of HOM Damping



Comparison of Ceramic Damper to Baseline Cavity



Ceramic Coating

- **Coating required to prevent electron accumulation**
  - Coating required to be in good contact with beam tube
  - Damping effectiveness depends critically on coating thickness
  - Currently planning on use of Titanium Stabilized High-Gradient Steel (TSHGS) coating
    - Thickness: ~10 – 20 Å
    - Conductivity: $2.08 \times 10^{6}\ \Omega^{-1}\ m^{-1}$

Calculation of Surface Impedance

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Matrix solution for the wall impedance of infinitely long multilayer circular beam tubes

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$$M(b, r_0) = M^{I}(b, r_1) \cdot M^{II}(r_1, r_2) \cdots M^{III}(r_{0-1}, r_o)$$

$$\begin{pmatrix} E_z(r) \\ H_\varphi(r) \end{pmatrix} = M(r, r_0) \begin{pmatrix} E_z(r) \\ H_\varphi(r) \end{pmatrix} = \begin{bmatrix} m_{ee}(r, r_0) & m_{eh}(r, r_0) \\ m_{he}(r, r_0) & m_{hh}(r, r_0) \end{bmatrix} \begin{pmatrix} E_z(r_0) \\ H_\varphi(r_0) \end{pmatrix}$$

$$m_{ee}(r, r_0) = \kappa r_0 [K_0(\kappa r) I_1(\kappa r_0) + I_0(\kappa r) K_1(\kappa r_0)$$

$$m_{eh}(r, r_0) = j \frac{\kappa^2 r_0}{\varepsilon_S k} [K_0(\kappa r) I_0(\kappa r_0) - I_0(\kappa r_0) - I_0(\kappa r) K_0(\kappa r_0)$$

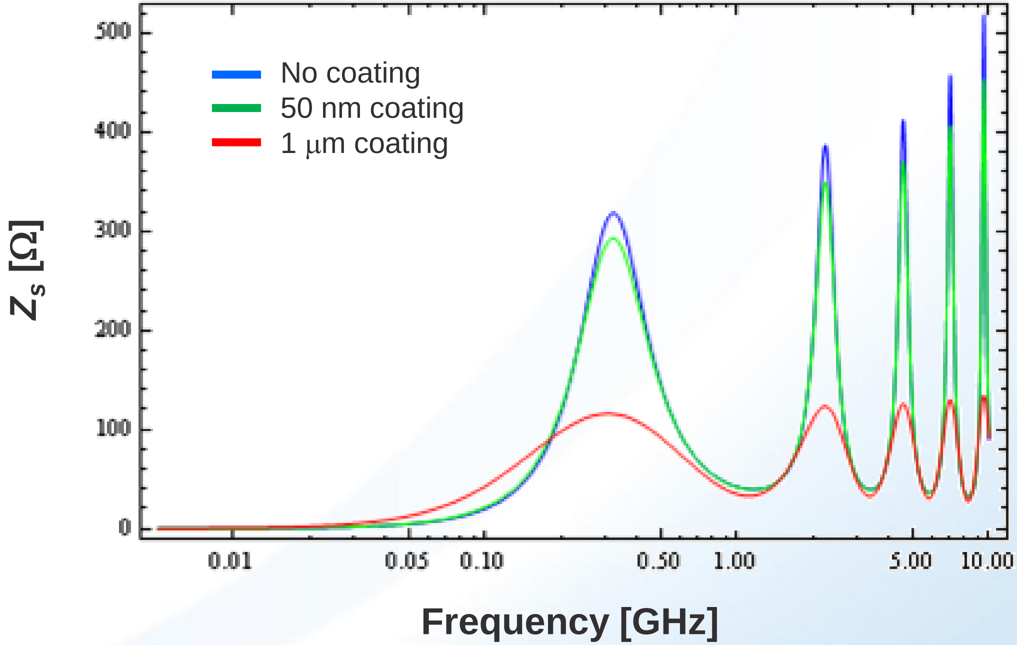
$$m_{he}(r, r_0) = -j \varepsilon_S k r_0 [K_1(\kappa r) I_1(\kappa r_0) - I_1(\kappa r) K_1(\kappa r_0)$$

$$m_{hh}(r, r_0) = \kappa r_0 [K_1(\kappa r) I_0(\kappa r_0) + I_1(\kappa r) K_0(\kappa r_0)$$

Surface Impedance

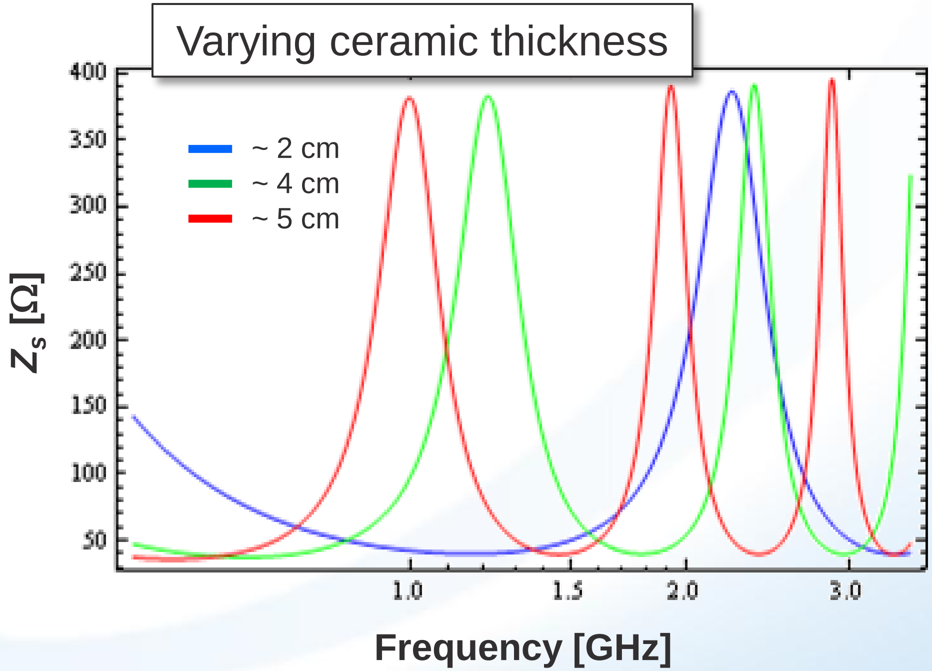
- Power dissipation in wall is characterized by the surface resistance:

$$\frac{dP}{ds} = \frac{1}{2} R_s |\mathbf{H}|^2$$



Reconfiguring Damper Parameters

- Frequency response depends on of ceramic thickness as well as ferrite thickness and material
- Choosing thickness allows frequency response to be adjusted to the cavity



Conclusions

- HOM load surrounding ceramic damper can effectively damp higher order modes
- Ceramic break offers important advantages:
  - Superconducting cavity is protected from damage to ferrite tiles
  - Arrangement of ferrites and ceramic allows for exploration of damping materials
  - Ceramic break concept allows for simple reconfiguration of design to meet various bandwidth and damping requirements