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# RF mushroom cavity design for High Temperature Superconductor (HTS) material test

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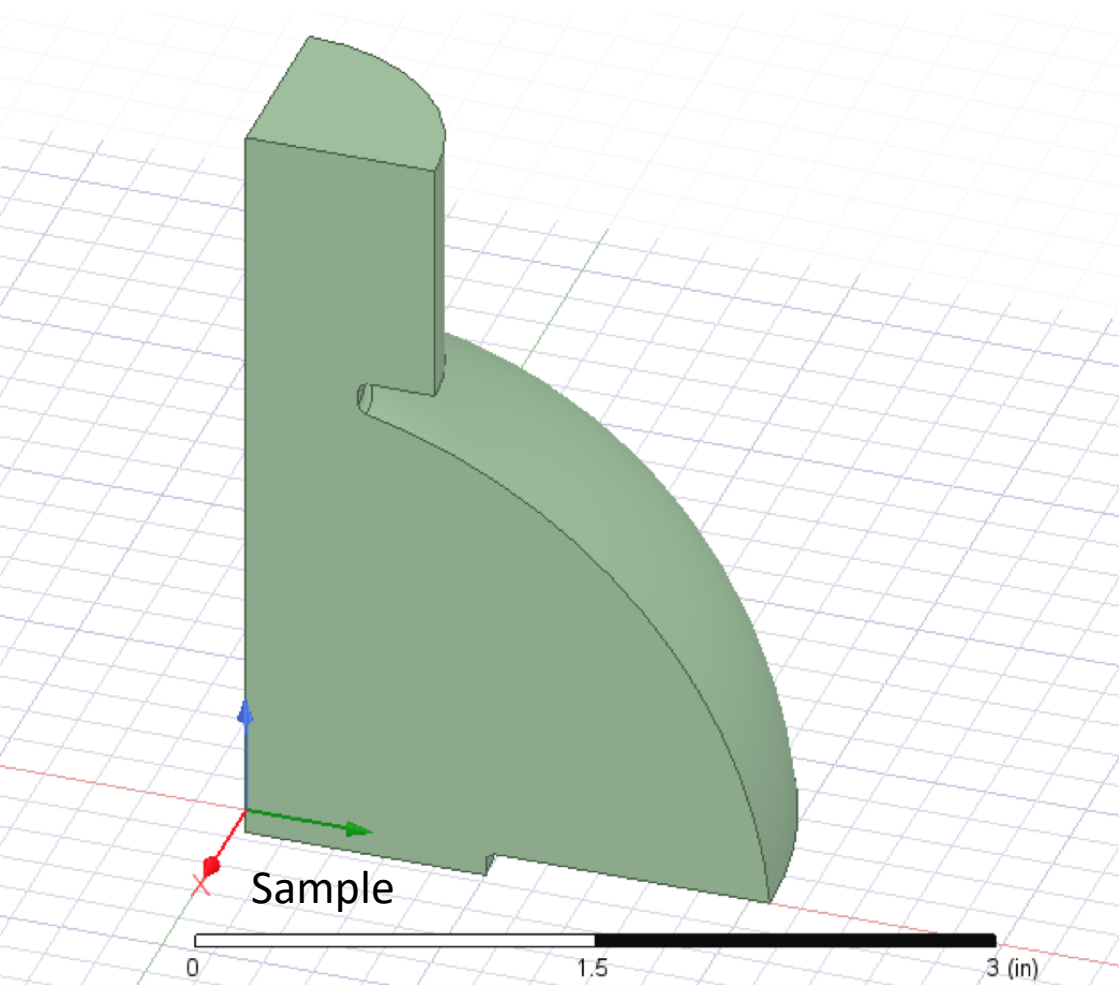
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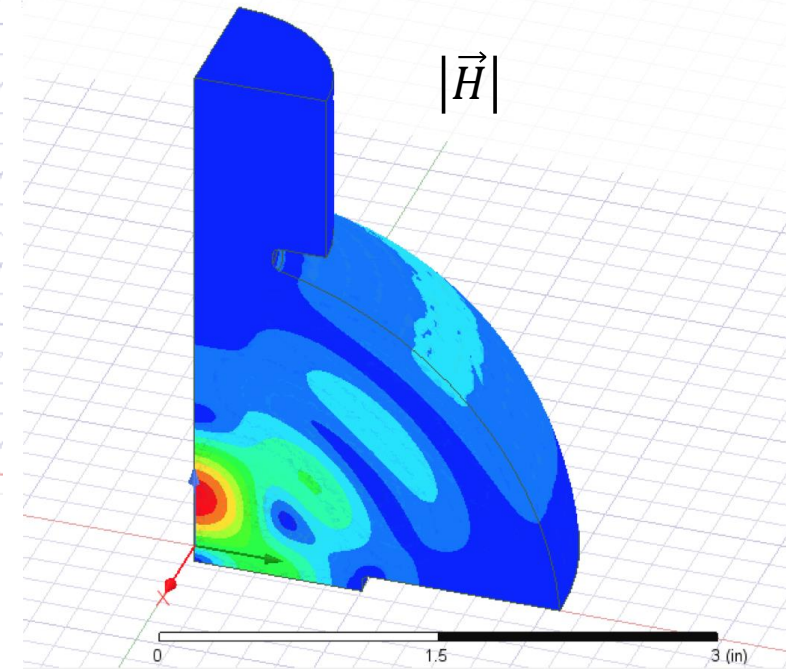
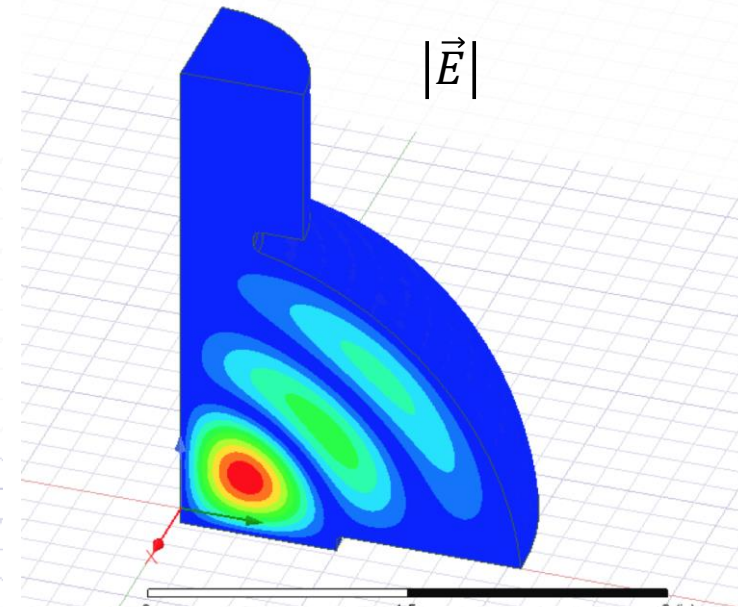
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# SLAC cavity

Input port



$f = 11.3995$  GHz



$TE_{320}$ -like mode in a “semispherical” cavity

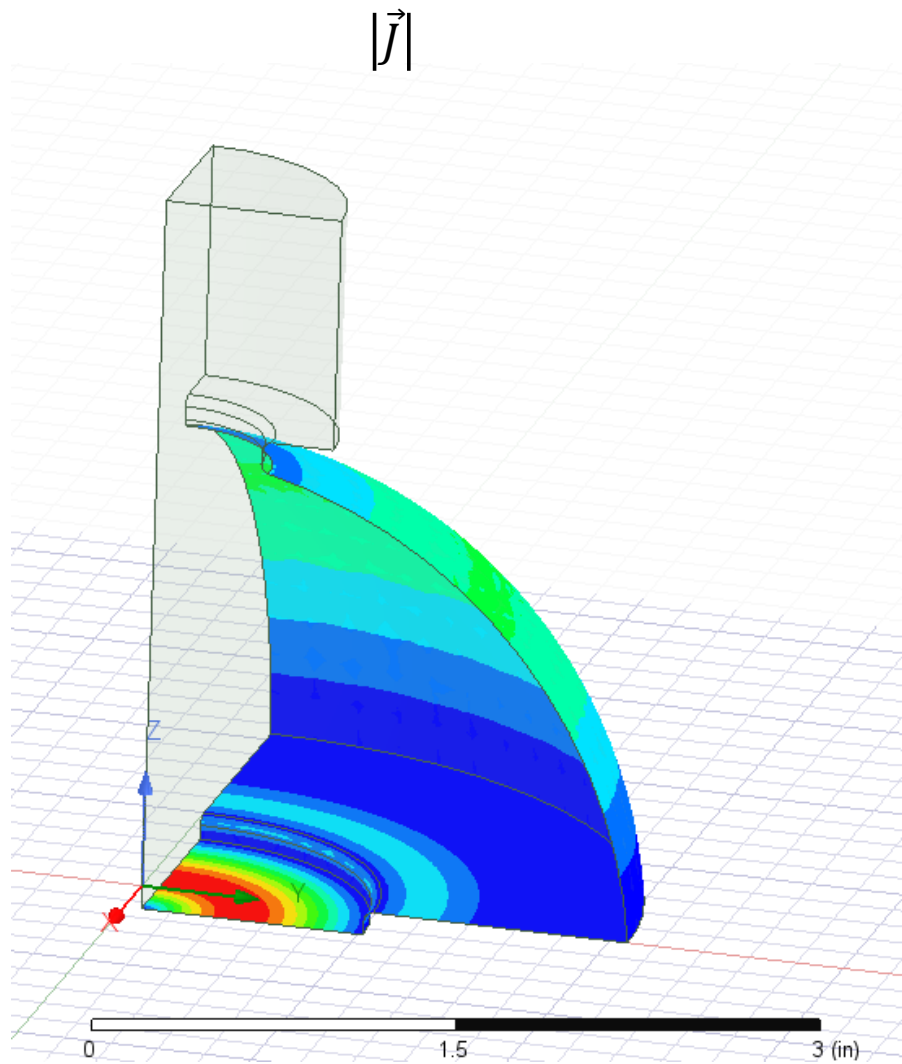
Test samples under high magnetic fields:

- High-Gradient material
- High temperature superconductor

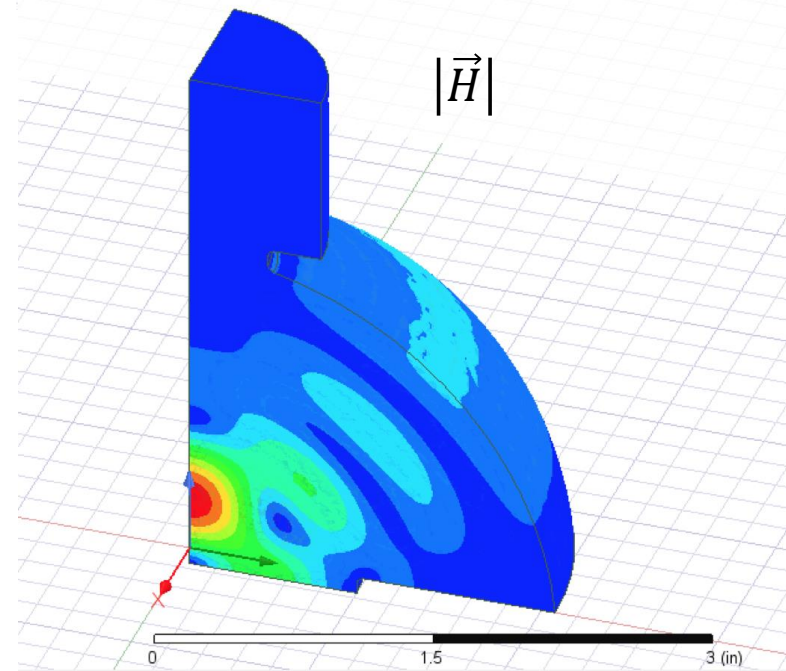
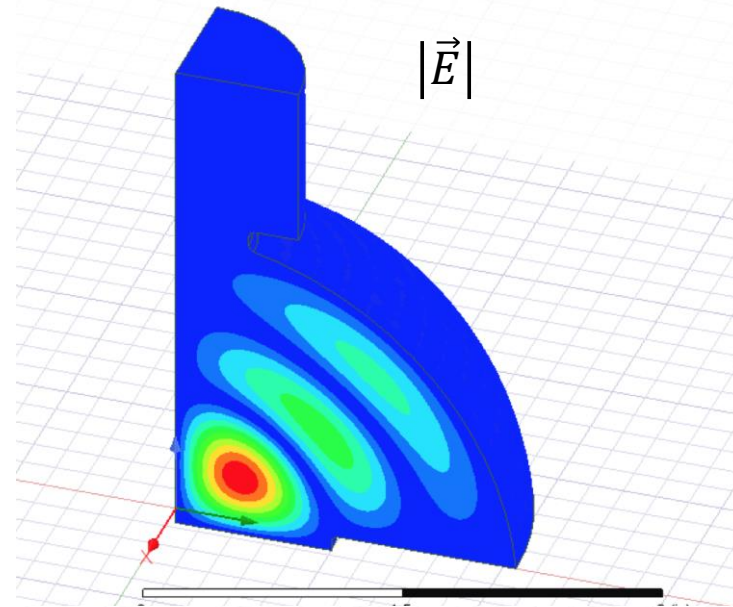
Test properties:

- No Electric field
- High Magnetic field
- No electric current on the edge

# SLAC cavity



$f = 11.3995$  GHz



$TE_{320}$ -like mode in a “semispherical” cavity

Test samples under high magnetic fields:

- High-Gradient material
- High temperature superconductor

Test properties:

- No Electric field
- High Magnetic field
- No electric current on the edge

# Solution approaches

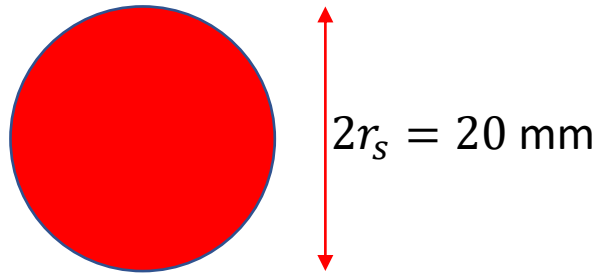
## Challenge:

- Radius = 0.95 in  $\sim$  24 mm
- HTS sample radius = 10 mm
- Same set up -> Same RF frequency

## Solutions:

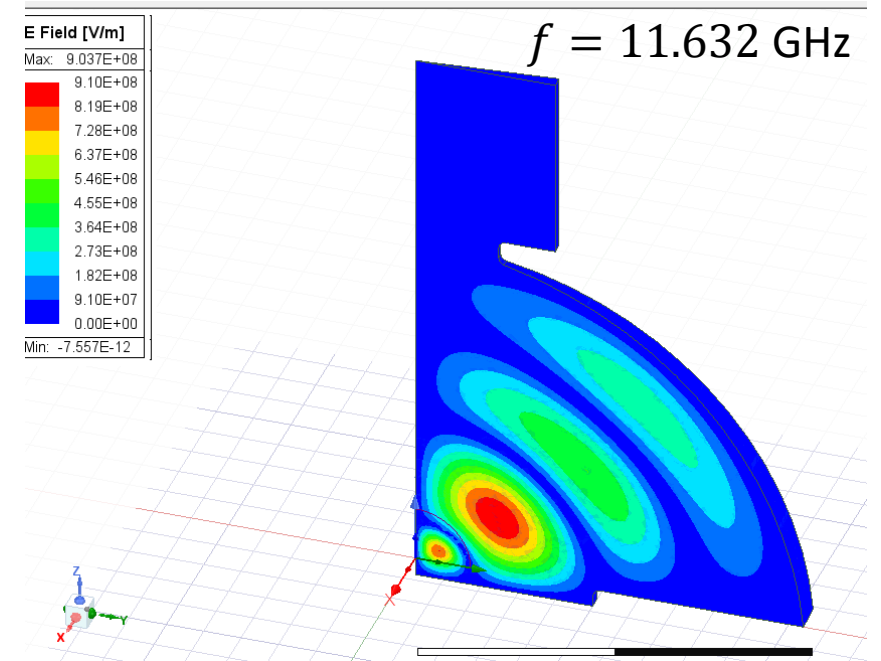
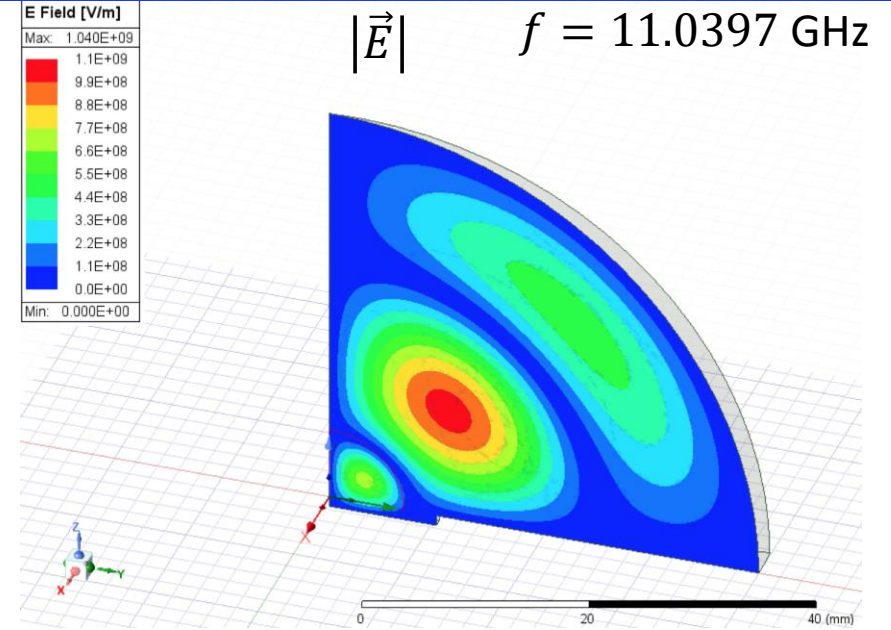
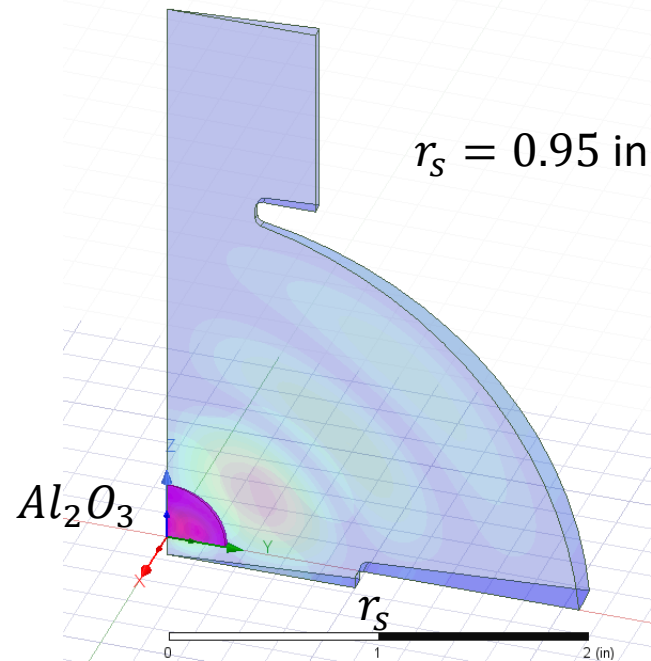
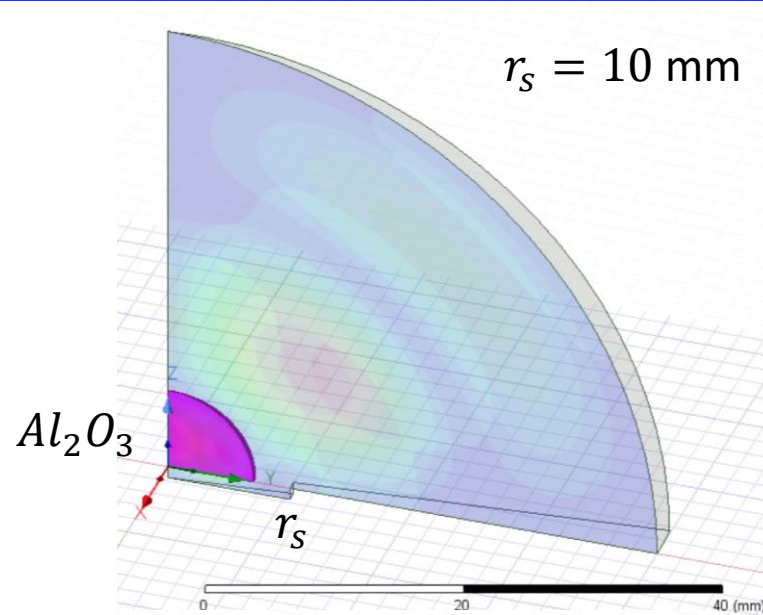
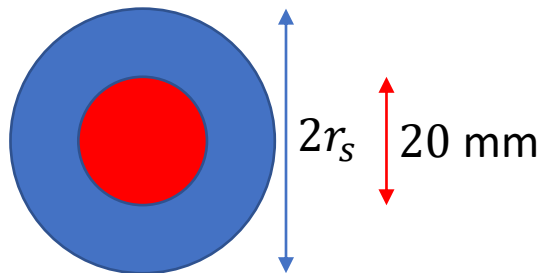
- Design a new cavity using dielectric.

HTS



- Next higher order mode with SLAC cavity using dielectric.

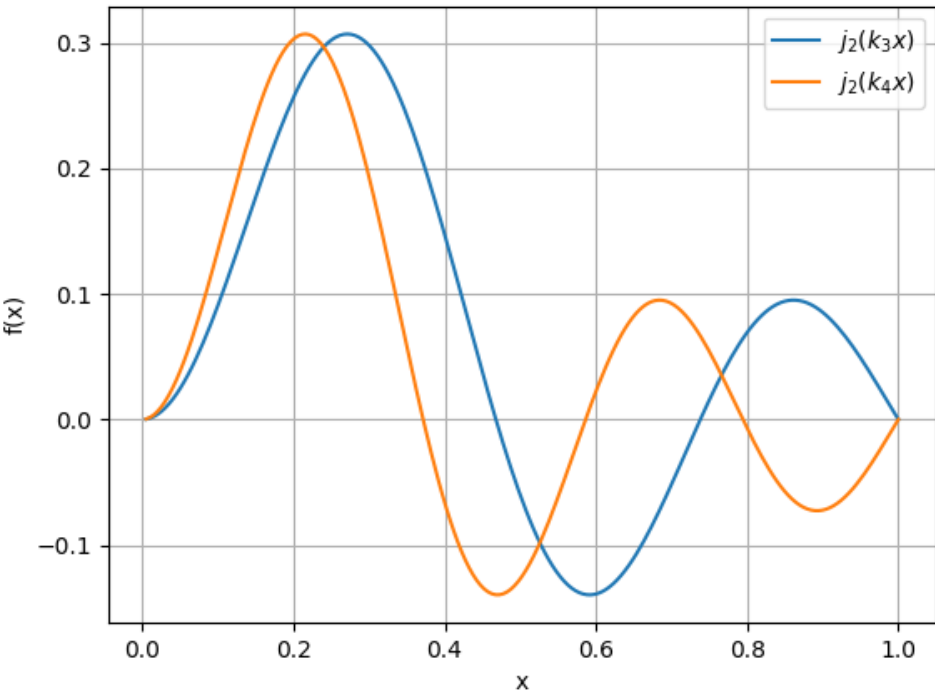
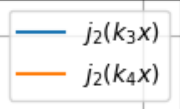
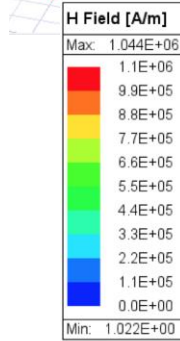
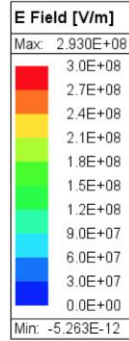
HTS



# Dielectric resonant cavity

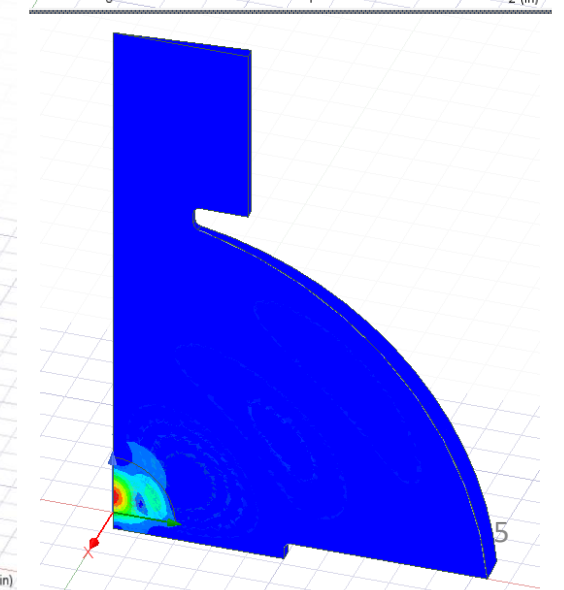
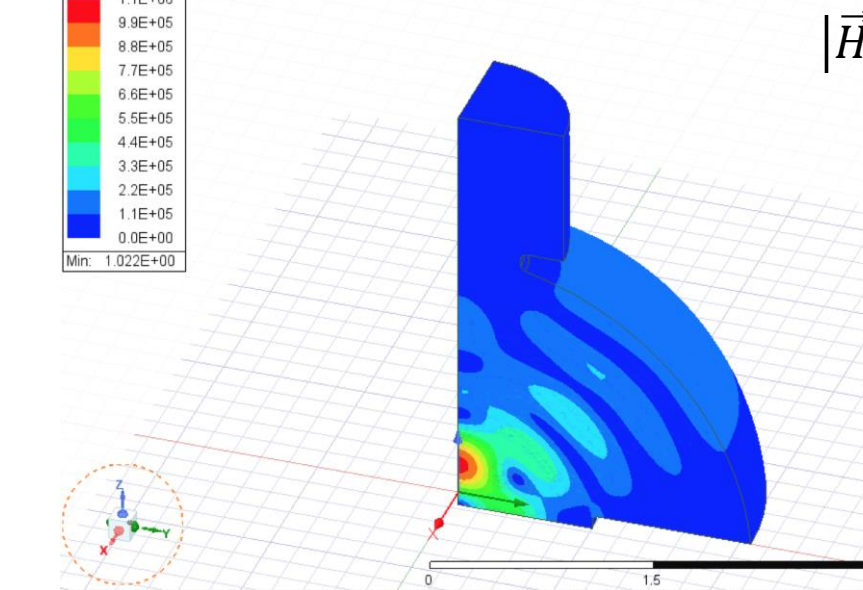
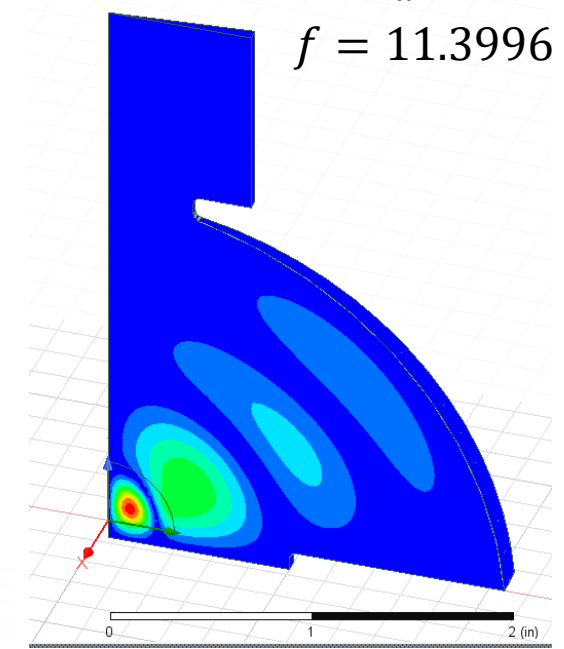
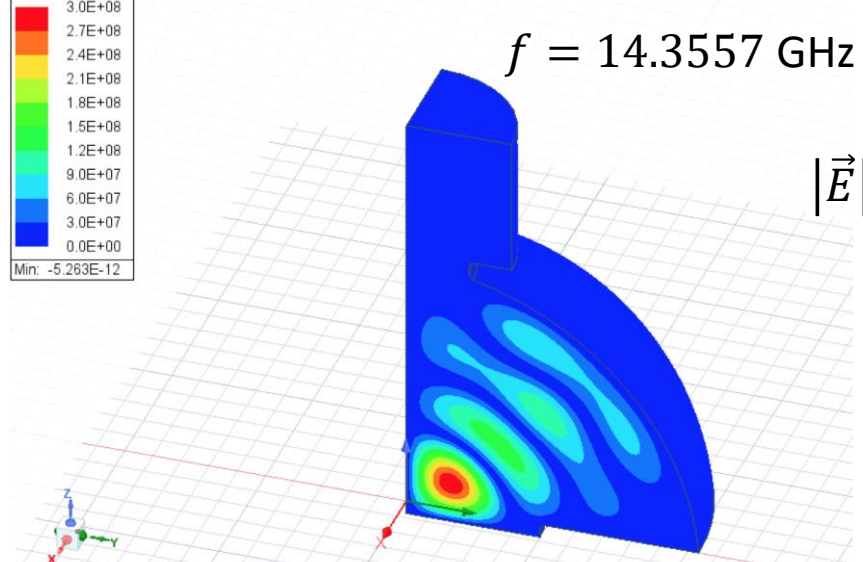
$$\omega_{m,n} = c \left( \frac{r_{mn}}{R} \right)$$

$$E_\phi \propto j_2(k_{42}r)$$



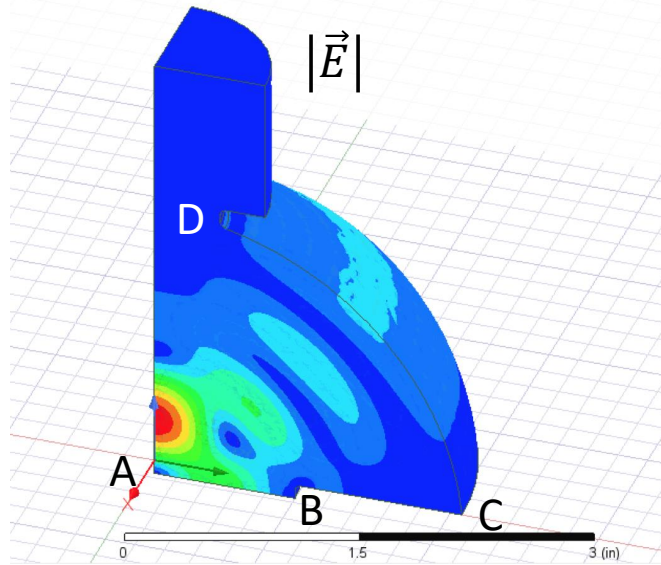
No dielectric  
 $f = 14.3557$  GHz

Dielectric  $r_d = 8.79$  mm  
 $f = 11.3996$  GHz



# Dielectric resonant cavity

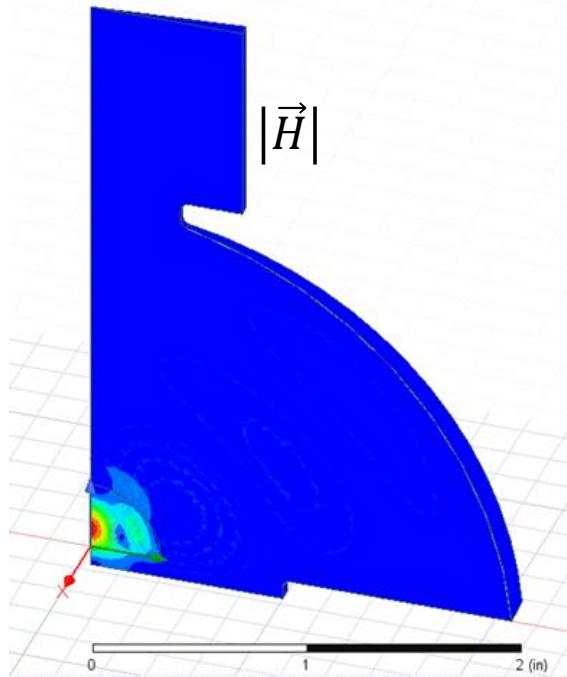
$$E_\phi \propto j_2(k_{42}r)$$



$$r_d = 8.79 \text{ mm}$$

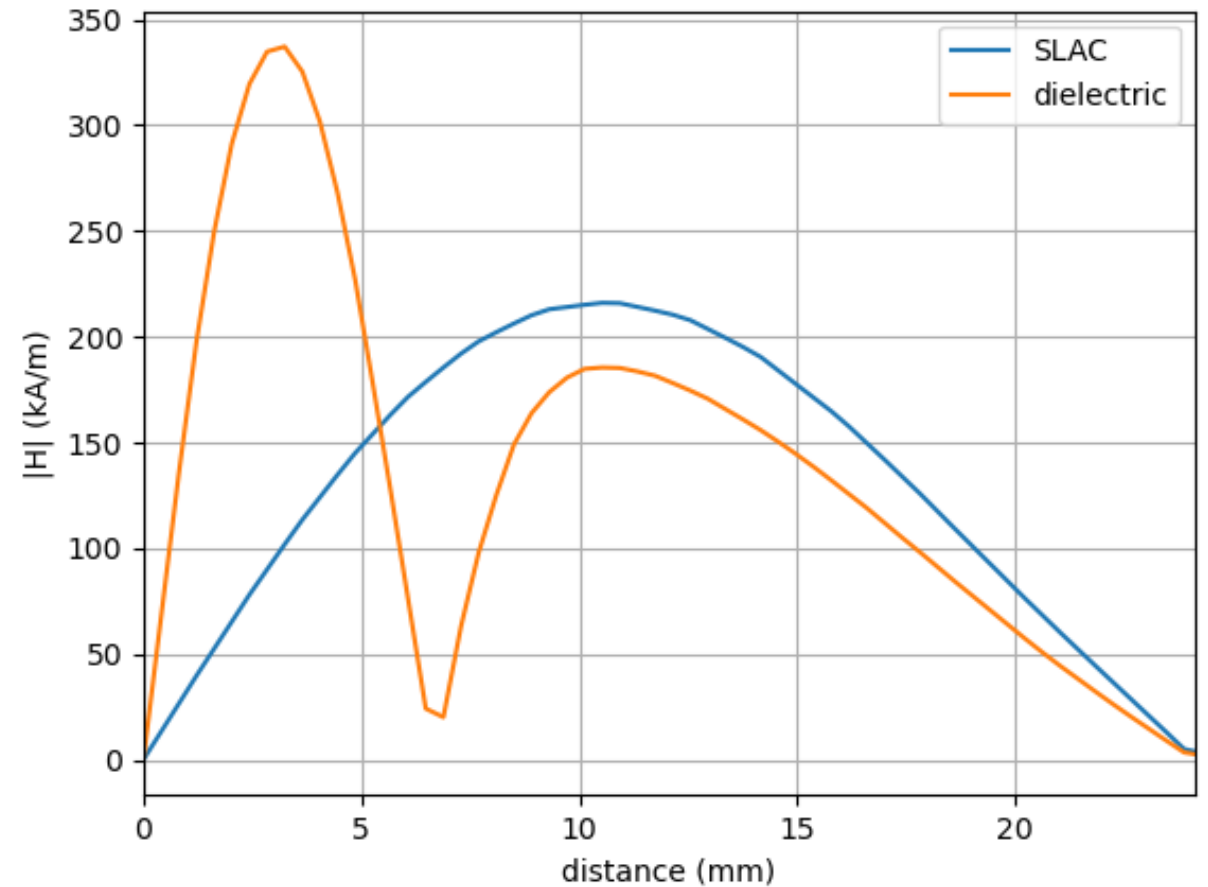
$$f = 11.3995 \text{ GHz}$$

$$\beta = 0.13$$



Surface magnetic field along  $\overline{AD}$

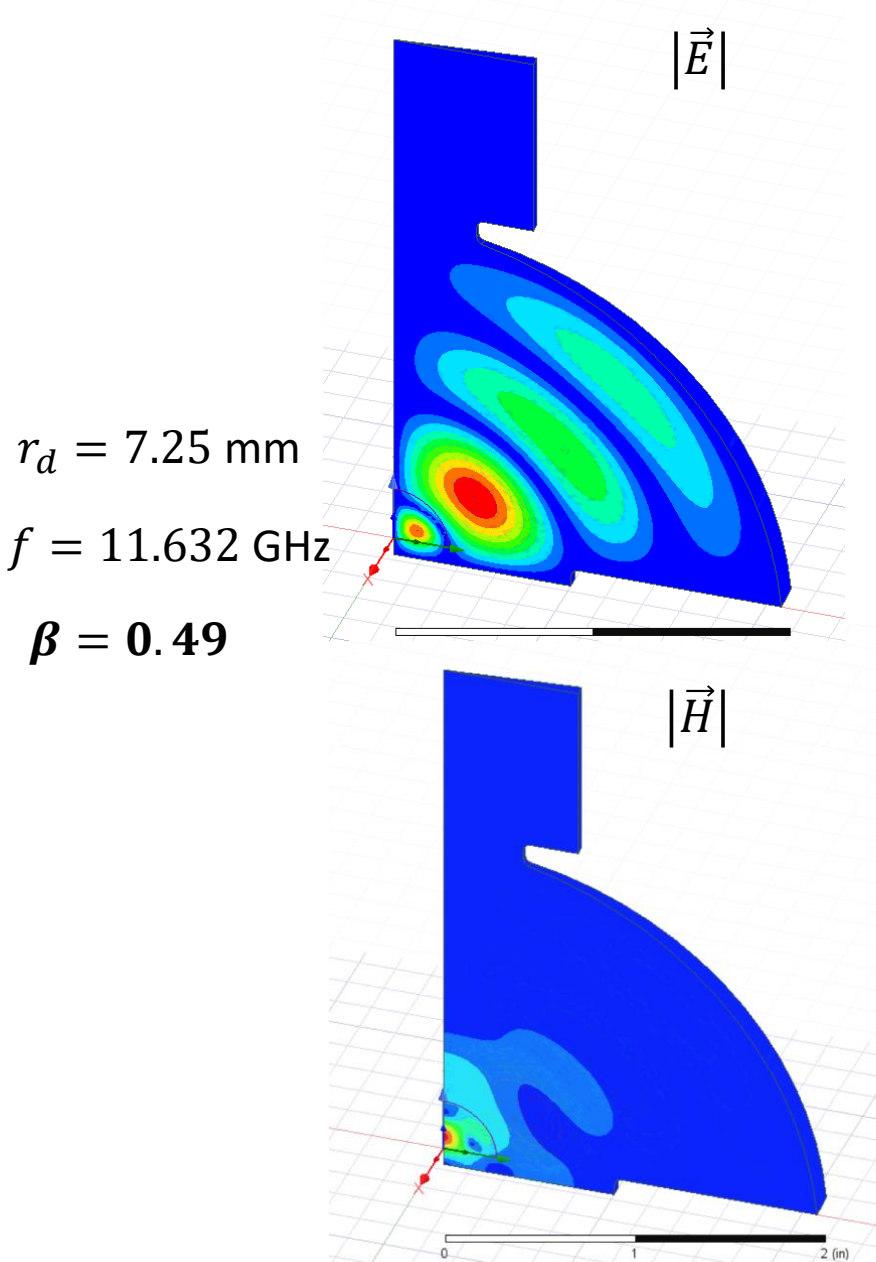
- Field normalization:  $W = 1 \text{ J}$  in the full cavity



$$E_p = 183.4 \text{ MV/m}$$

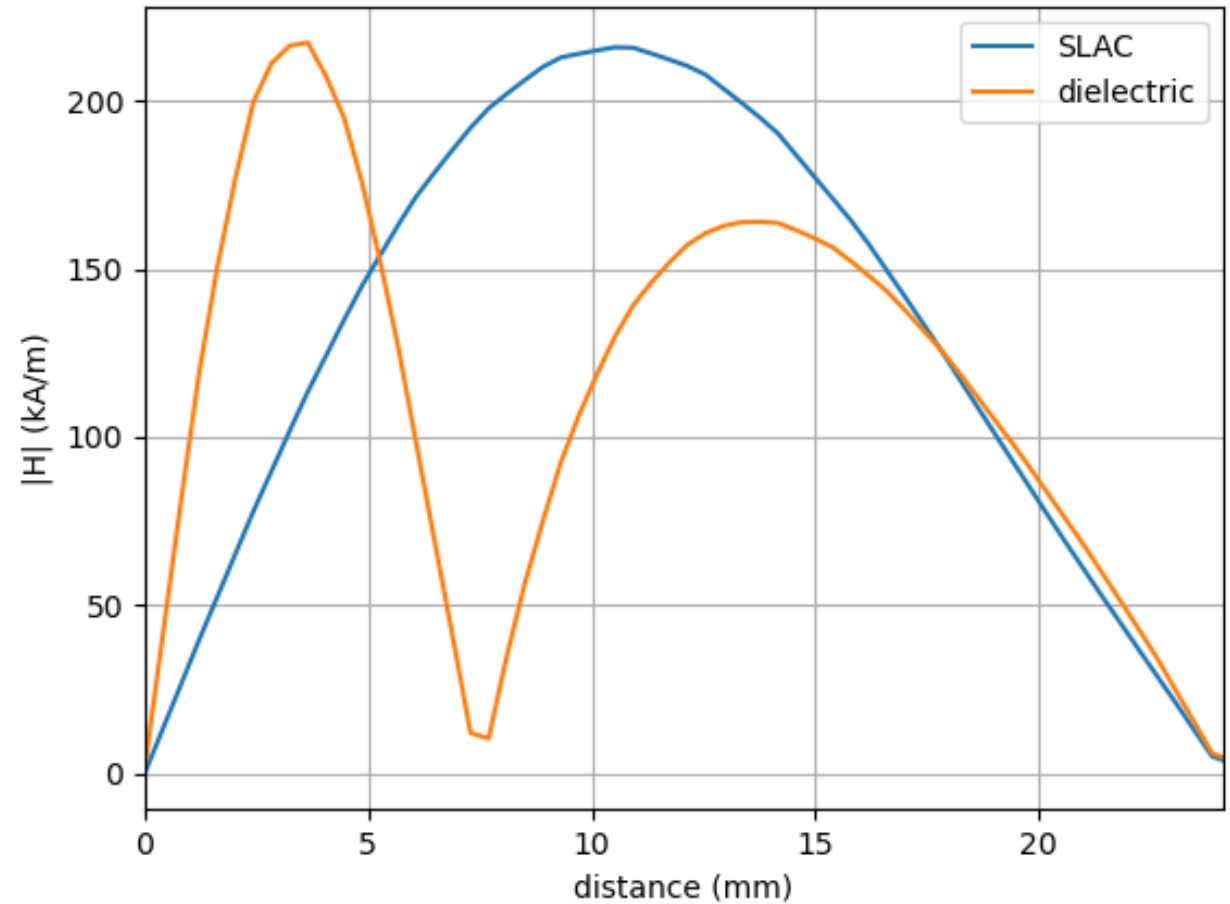
$$H_p = 2238 \text{ kA/m}$$

# Dielectric resonant cavity



Surface magnetic field along  $\overline{AD}$

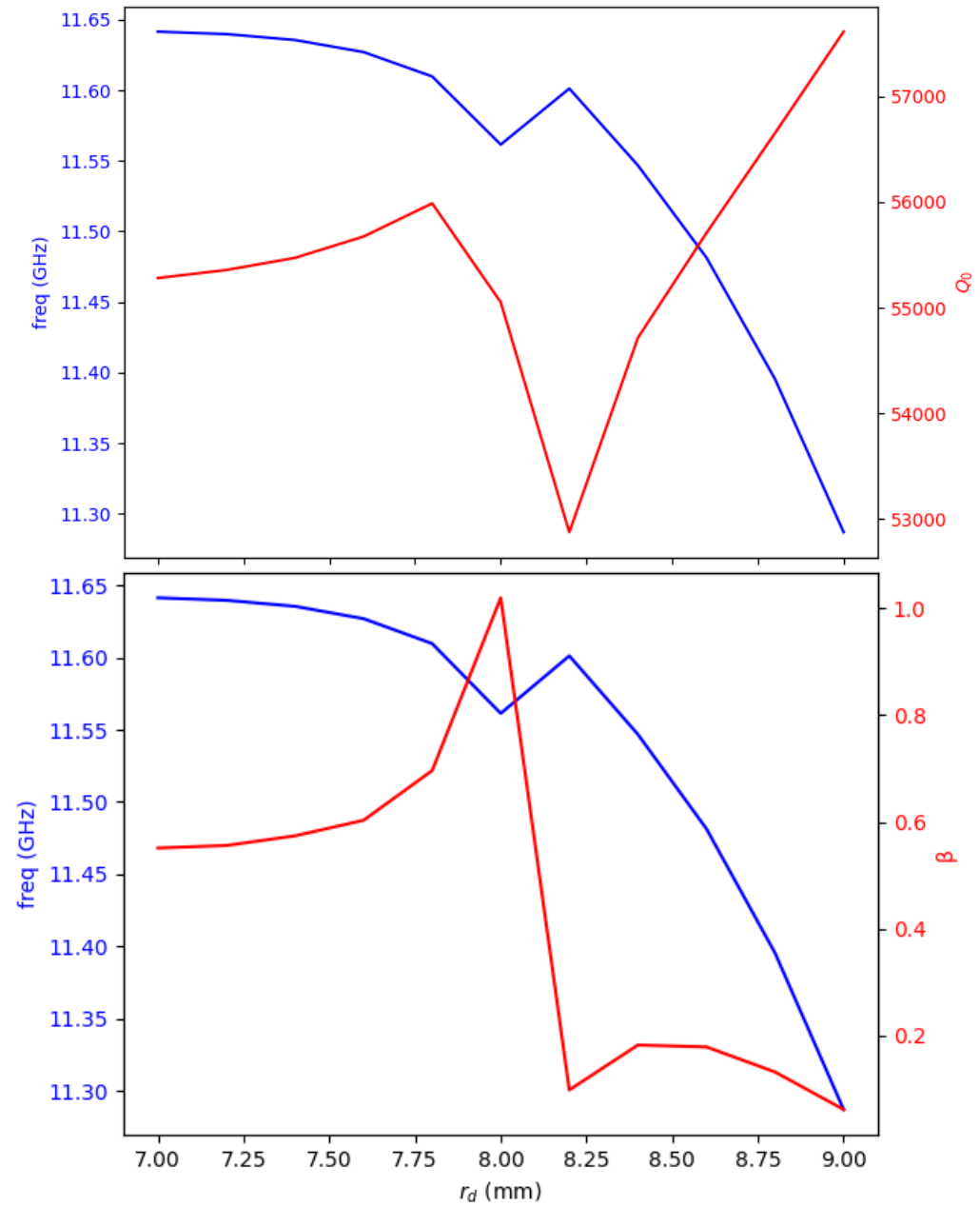
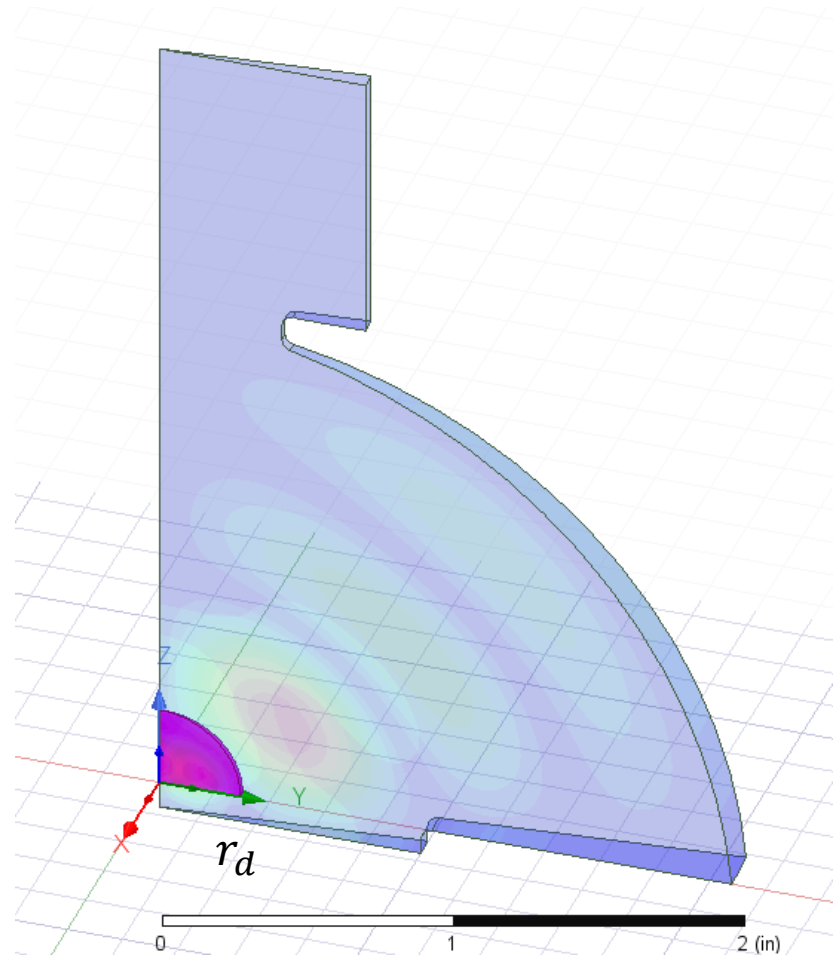
- Field normalization:  $W = 1 \text{ J}$  in the full cavity



$$E_p = 107.1 \text{ MV/m}$$

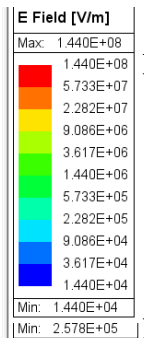
$$H_p = 1025 \text{ kA/m}$$

# Dielectric resonant cavity





# Dielectric resonant cavity



$|\vec{E}|$

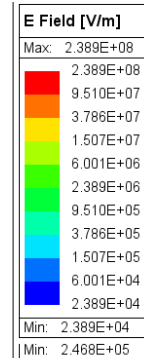
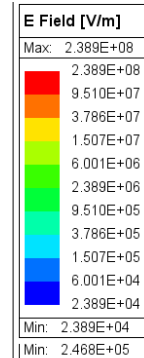
Dielectric  $r_d = 8$  mm

$$f = 11.5615 \text{ GHz}$$

$$Q_0 = 55051$$

$$Q_{ext} = 53979$$

$$\beta = 1.02$$

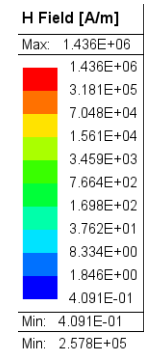


$$f = 11.7075 \text{ GHz}$$

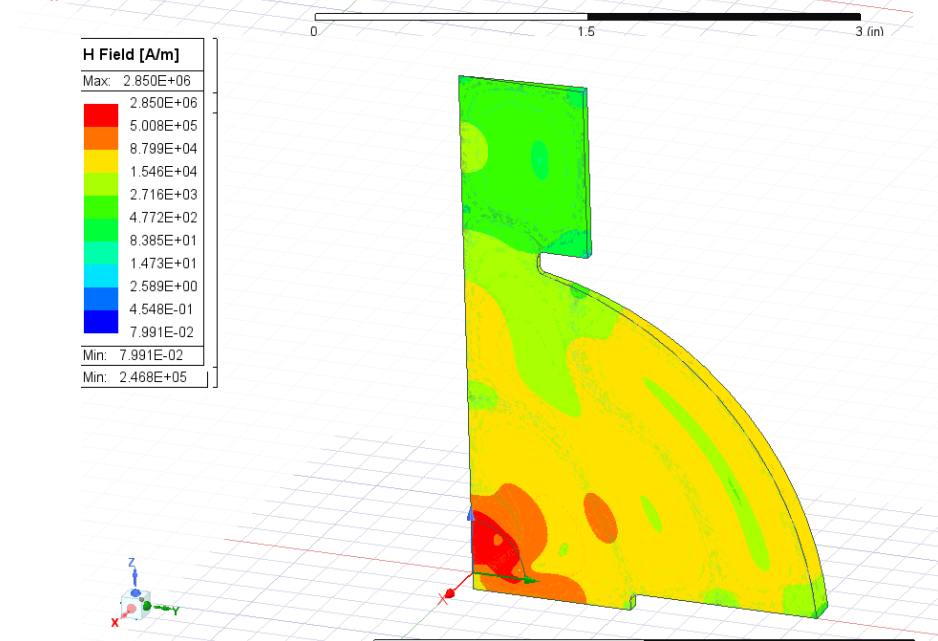
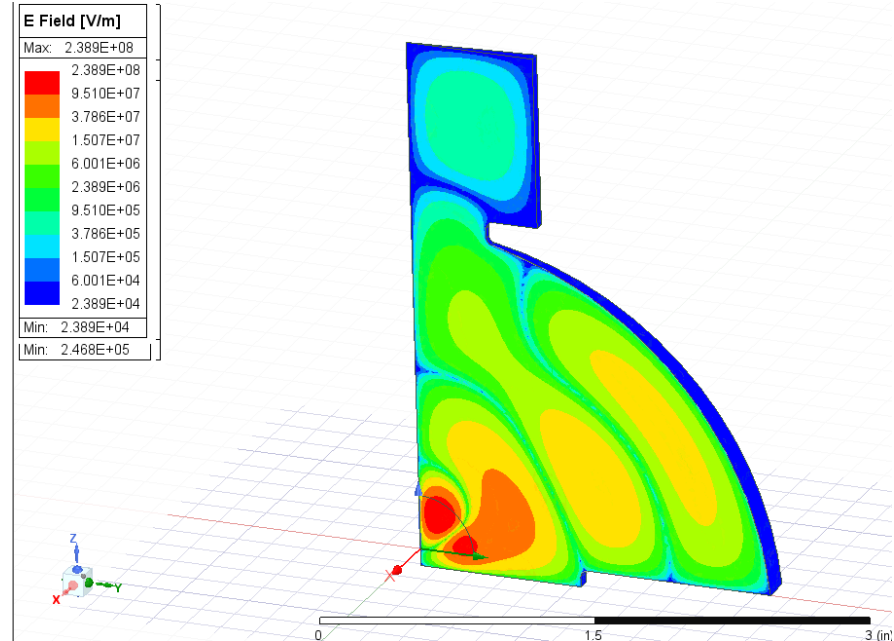
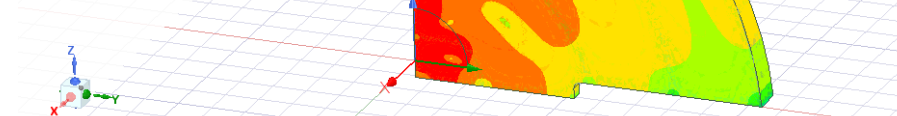
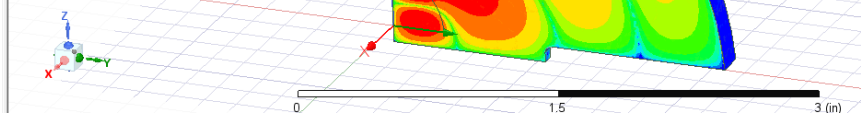
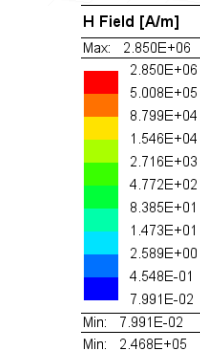
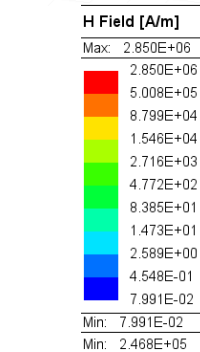
$$Q_0 = 47482$$

$$Q_{ext} = 662120$$

$$\beta = 0.07$$



$|\vec{H}|$



# Dielectric resonant cavity

$|\vec{E}|$

Dielectric  $r_d = 8.2$  mm

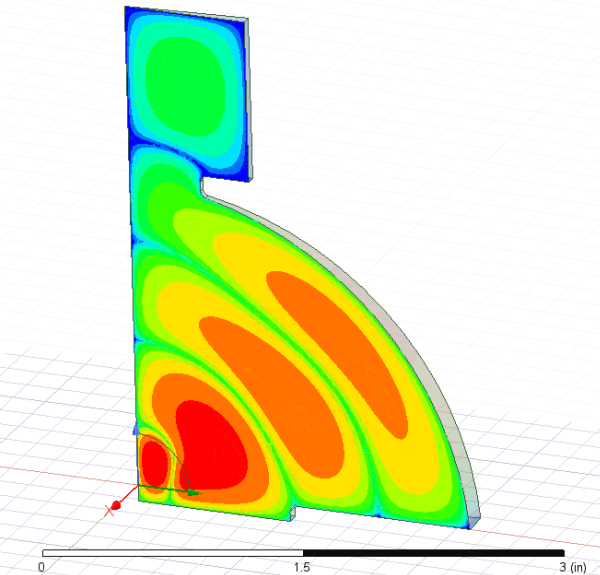
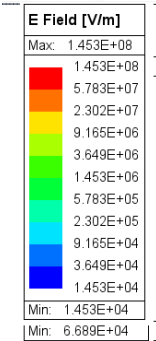
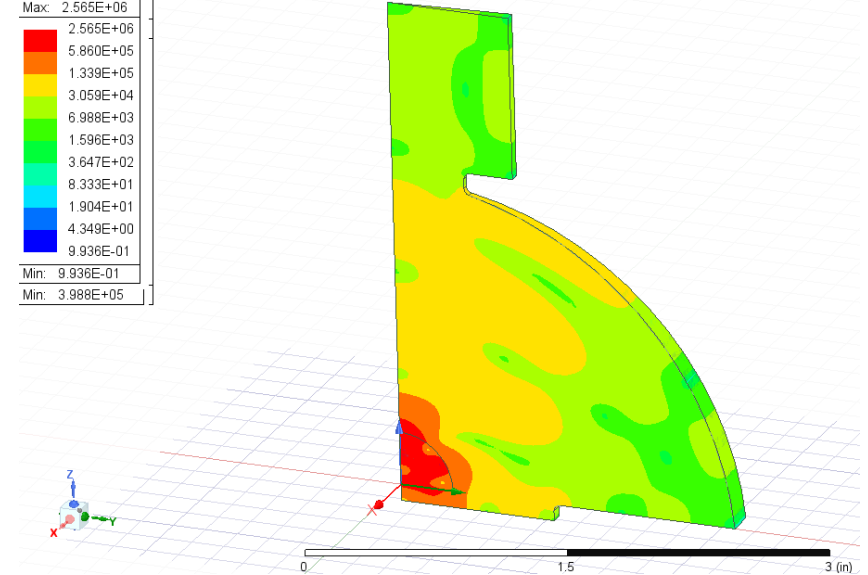
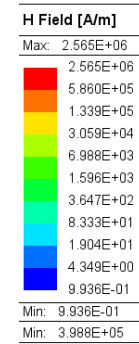
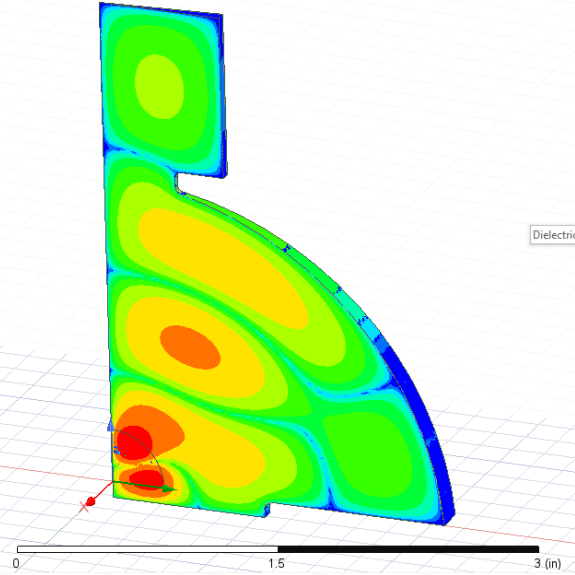
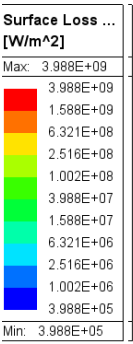
$|\vec{H}|$

$$f = 11.3928 \text{ GHz}$$

$$Q_0 = 49362$$

$$Q_{ext} = 38389$$

$$\beta = 1.29$$

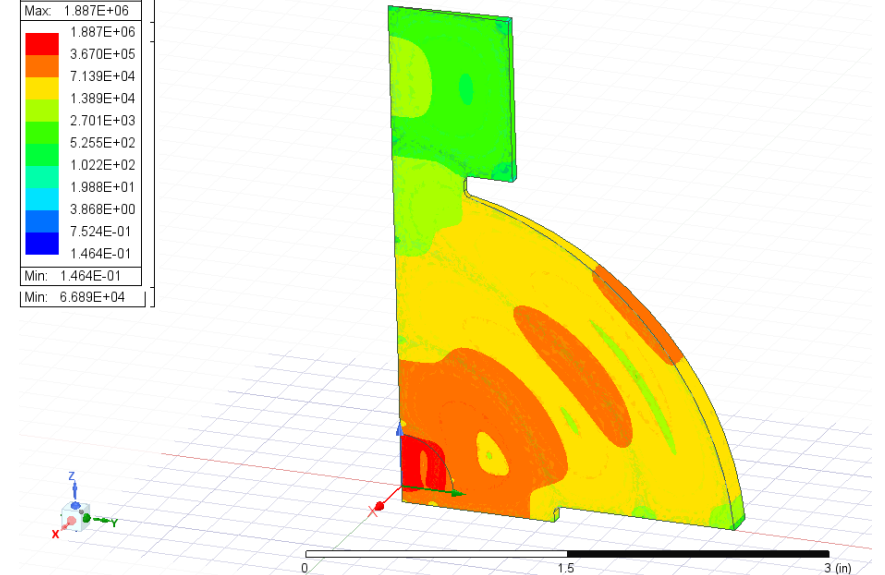
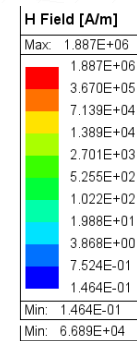


$$f = 11.6011 \text{ GHz}$$

$$Q_0 = 52876$$

$$Q_{ext} = 538150$$

$$\beta = 0.10$$

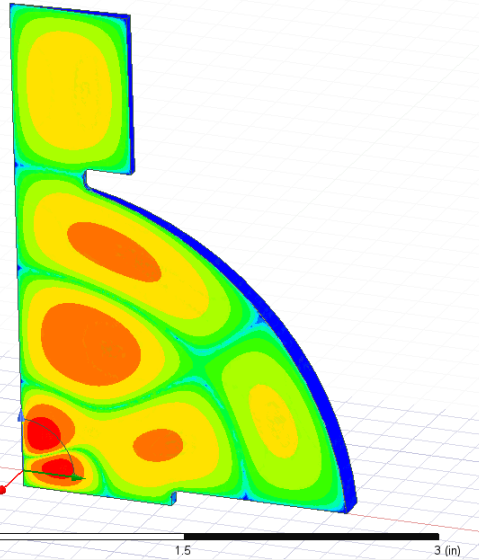
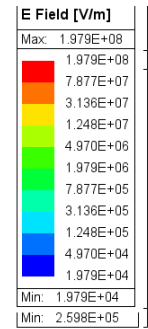


# Dielectric resonant cavity

$|\vec{E}|$

Dielectric  $r_d = 8.4$  mm

$|\vec{H}|$

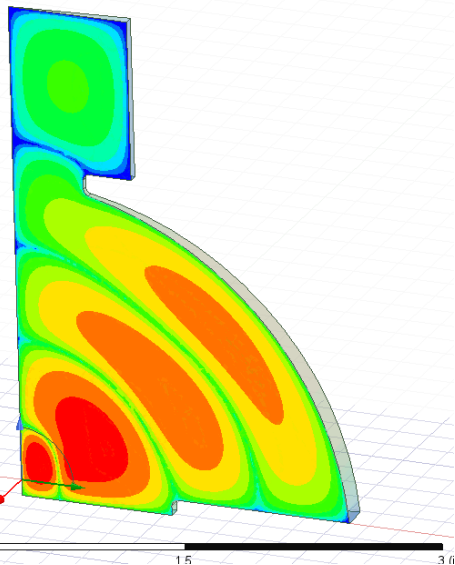
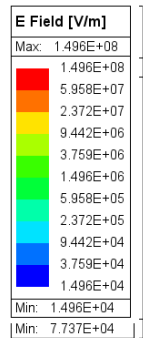
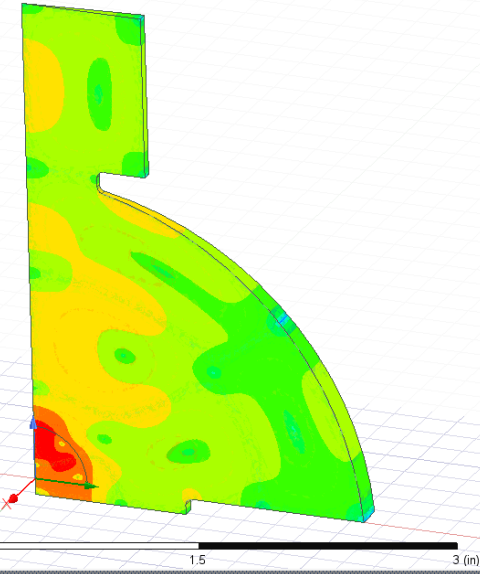
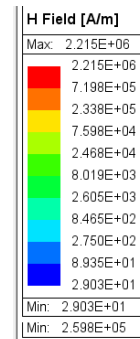


$$f = 11.2073 \text{ GHz}$$

$$Q_0 = 48346$$

$$Q_{ext} = 18600$$

$$\beta = 2.60$$

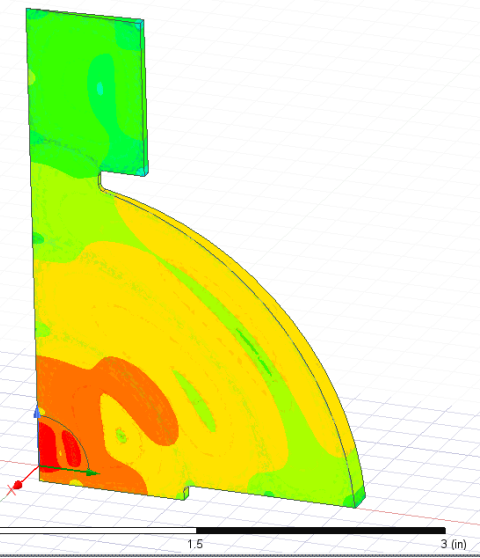
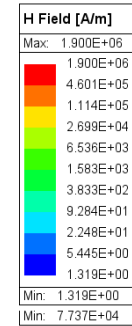


$$f = 11.5467 \text{ GHz}$$

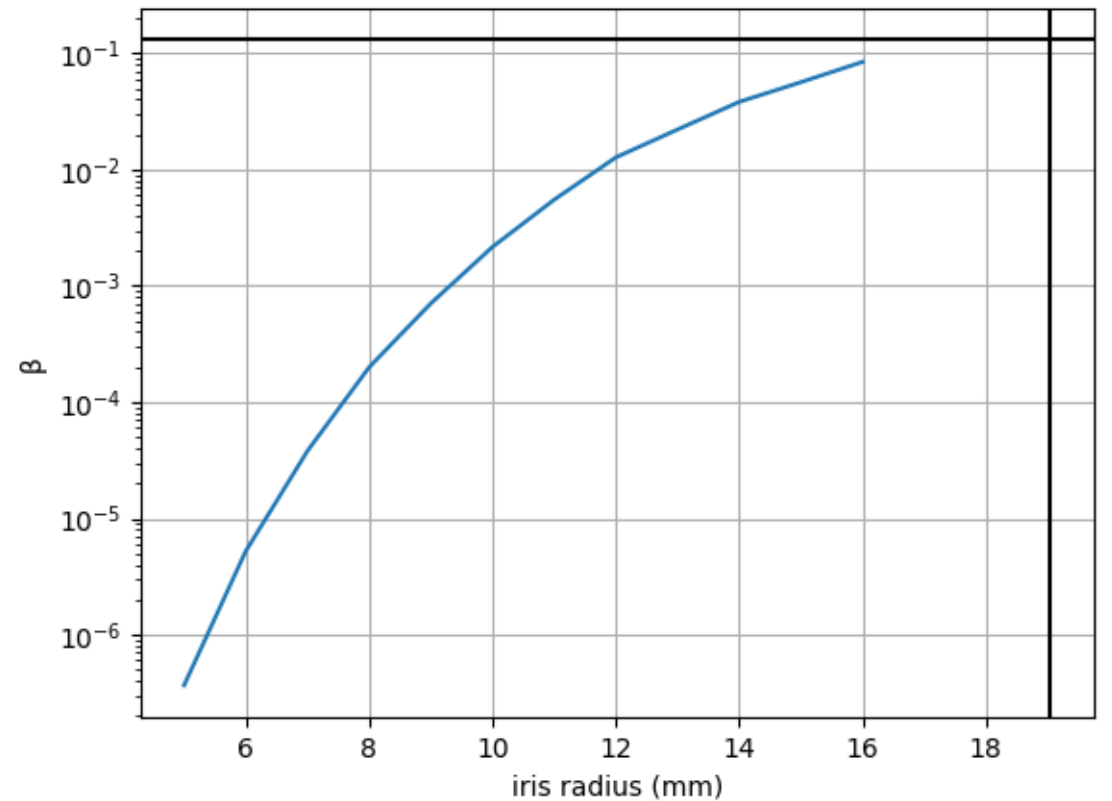
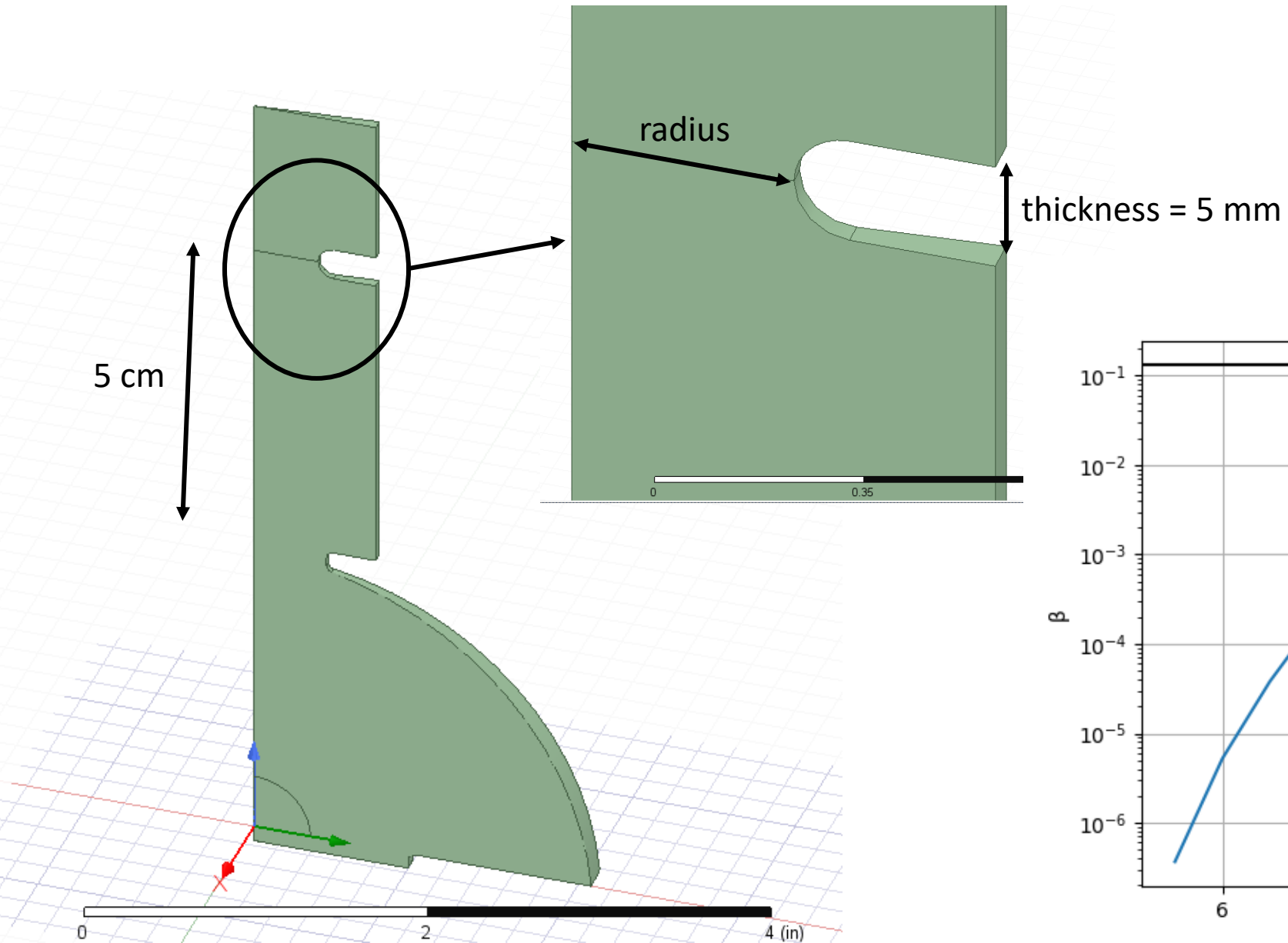
$$Q_0 = 54715$$

$$Q_{ext} = 300075$$

$$\beta = 0.18$$



# Dielectric resonant cavity

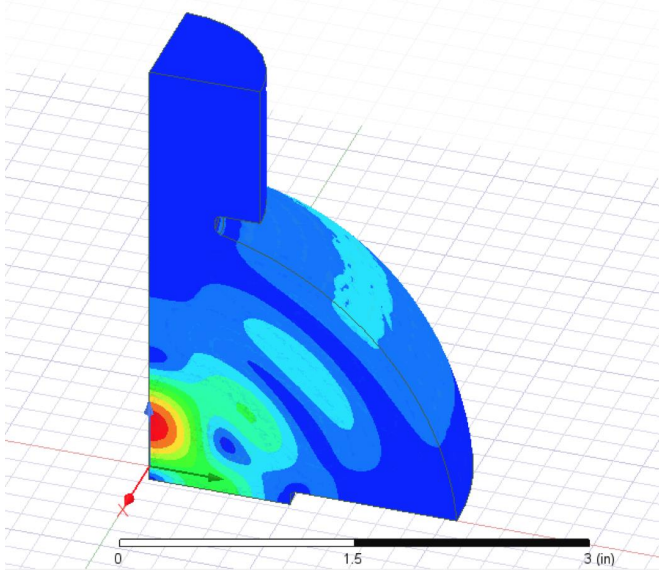


Back up

# Dielectric resonant cavity

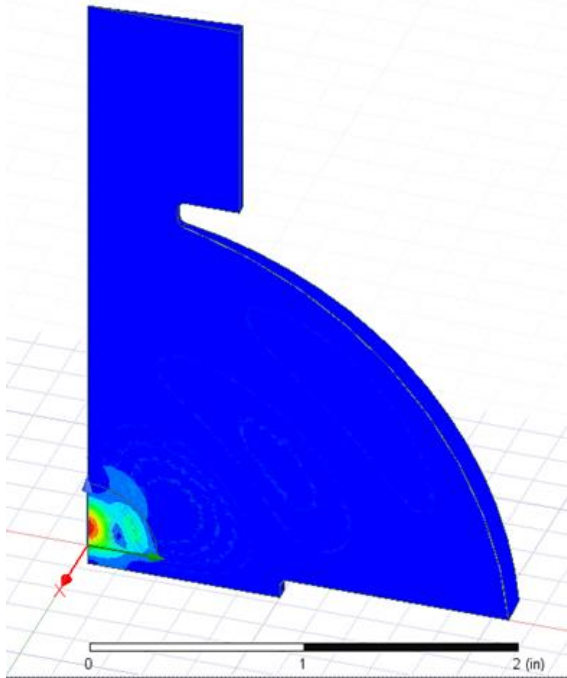
$$E_\phi \propto j_2(k_{32}r)$$

$$f = 11.3995 \text{ GHz}$$

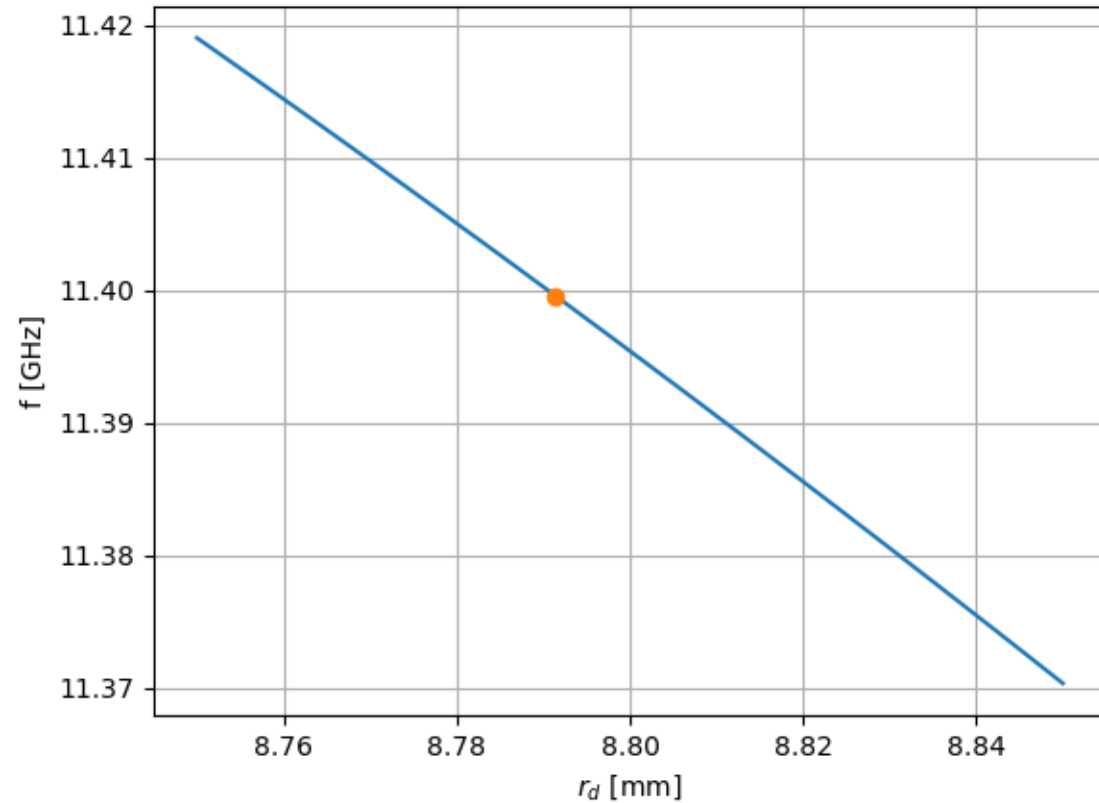


$$E_\phi \propto j_2(k_{42}r)$$

$$f = 11.3996 \text{ GHz}$$



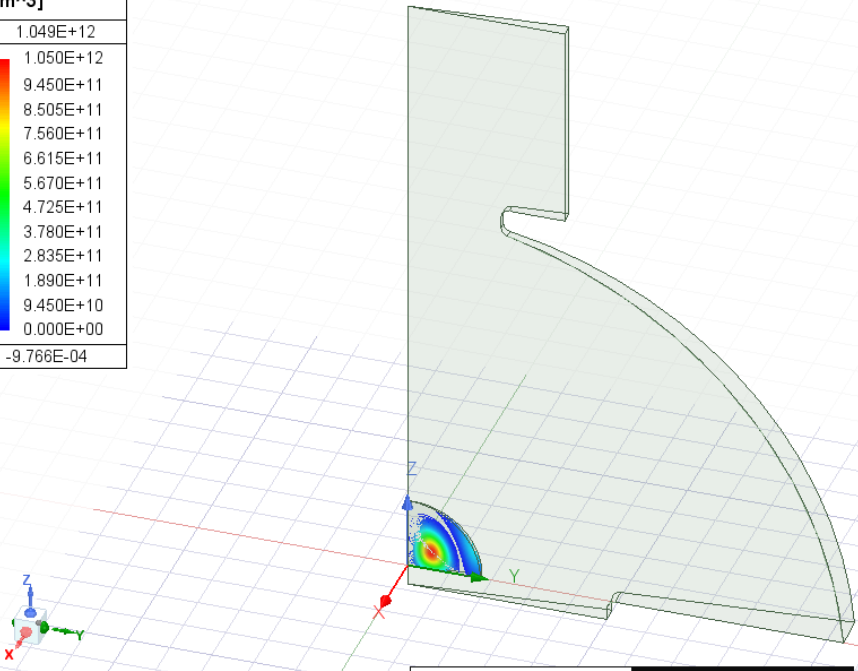
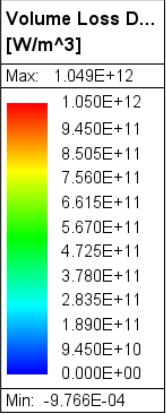
Tolerance study



$$\frac{df}{dr_d} = -482 \left[ \frac{\text{GHz}}{\text{m}} \right] = -482 \left[ \frac{\text{kHz}}{\mu\text{m}} \right]$$

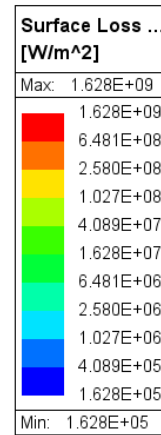
How is the cavity tuned?

# Dielectric resonant cavity

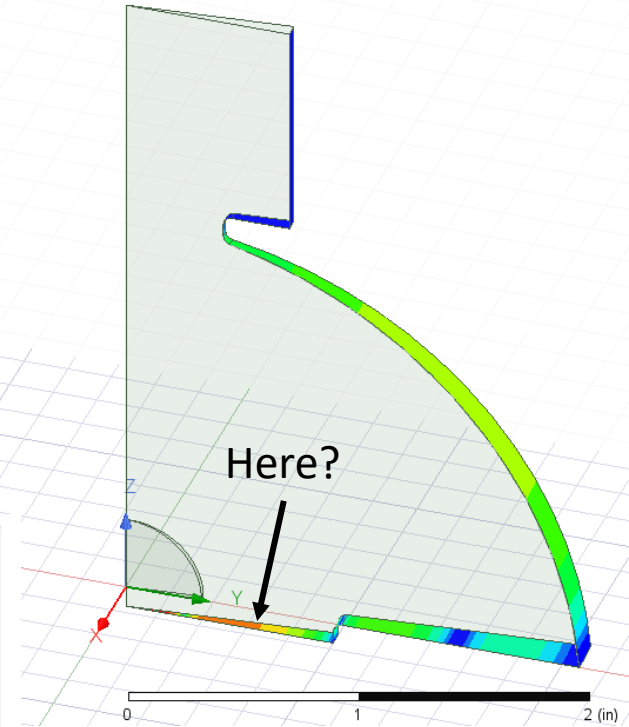


$$f = 11.3996 \text{ GHz}$$

$$Q_0 = \omega \frac{W}{P}$$

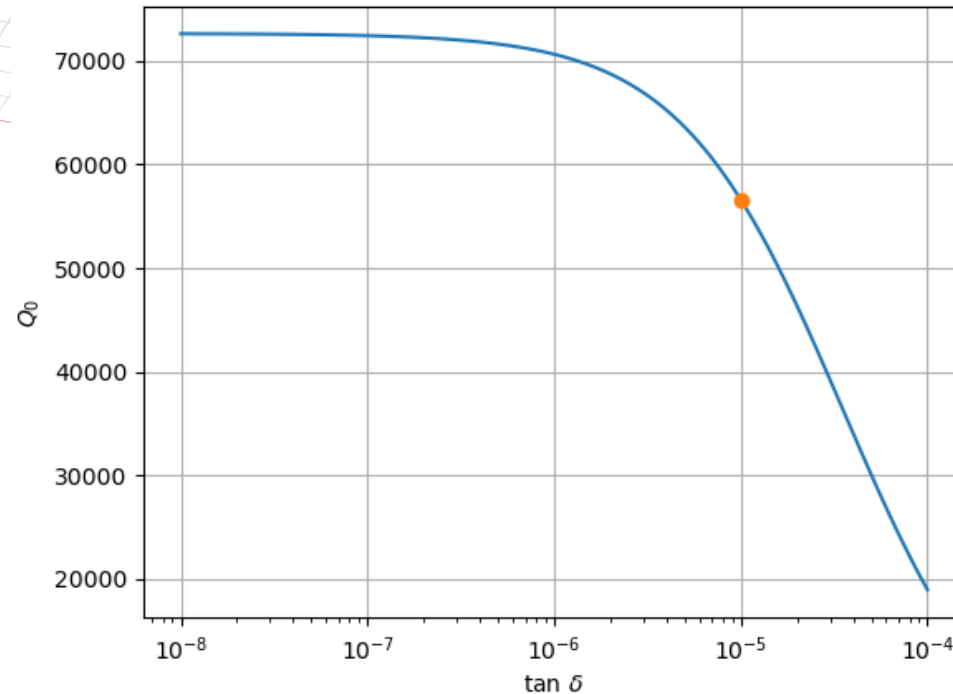


Log scale



$$P_d = \frac{1}{2} \omega \tan \delta \epsilon_0 \epsilon_r \int |\mathbf{E}|^2 dV$$

$$Q_0 = \omega \frac{W}{P} = \frac{\omega W}{P_c + P_d}$$



$$P_c = \frac{R_s}{2} \int |\mathbf{n} \times \mathbf{H}|^2 dS$$