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

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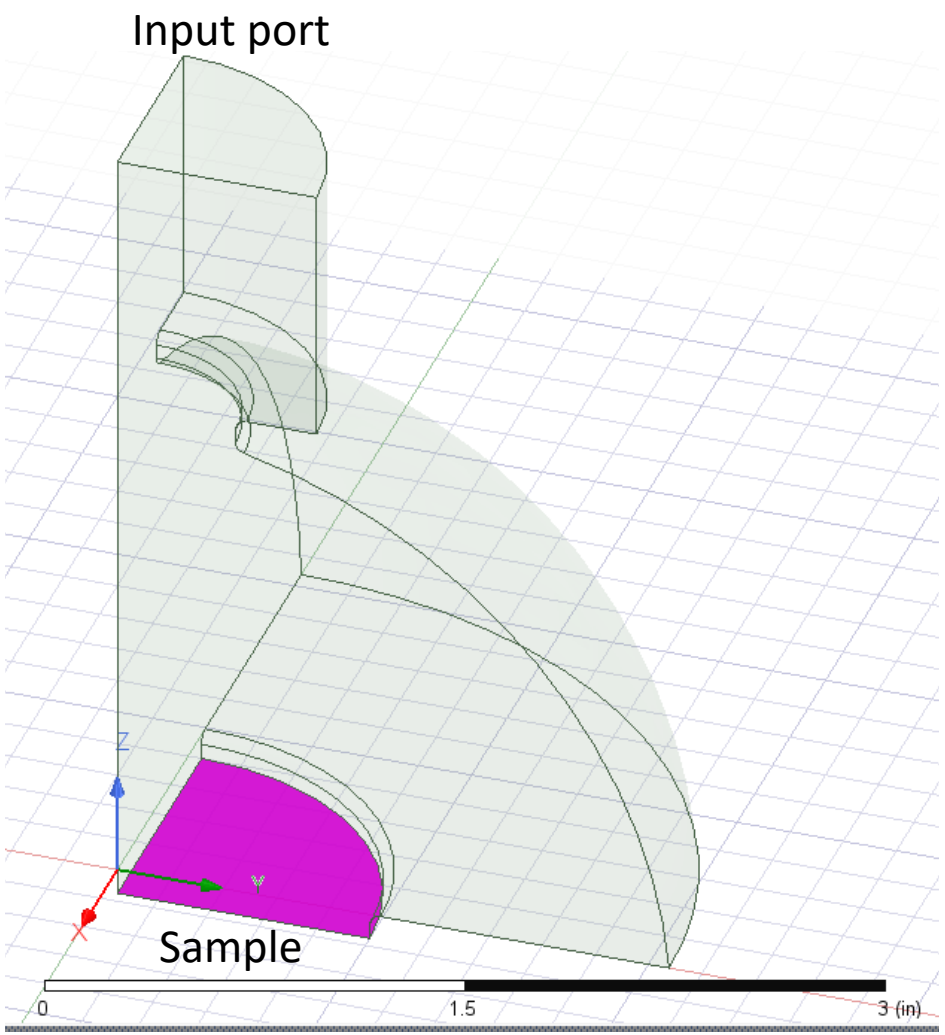
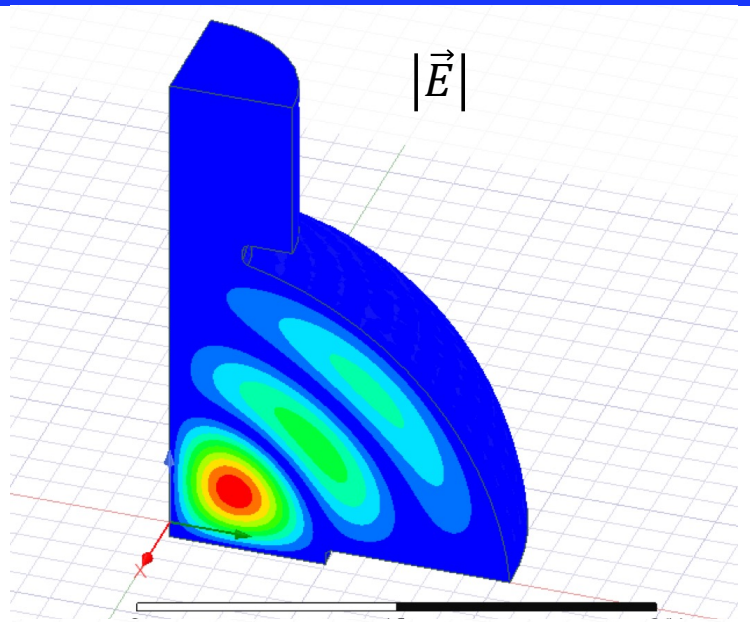
Outline

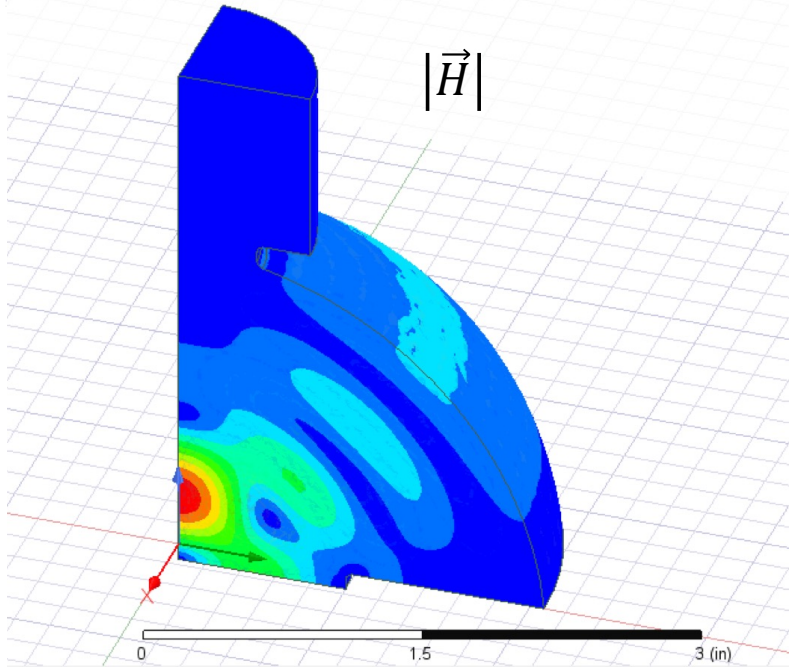
- ❑ Introduction
- ❑ Theoretical framework
- ❑ Preliminary studies
- ❑ Conclusions

SLAC cavity



$f = 11.3995$ GHz





TE_{320}-like mode in a "semispherical" cavity

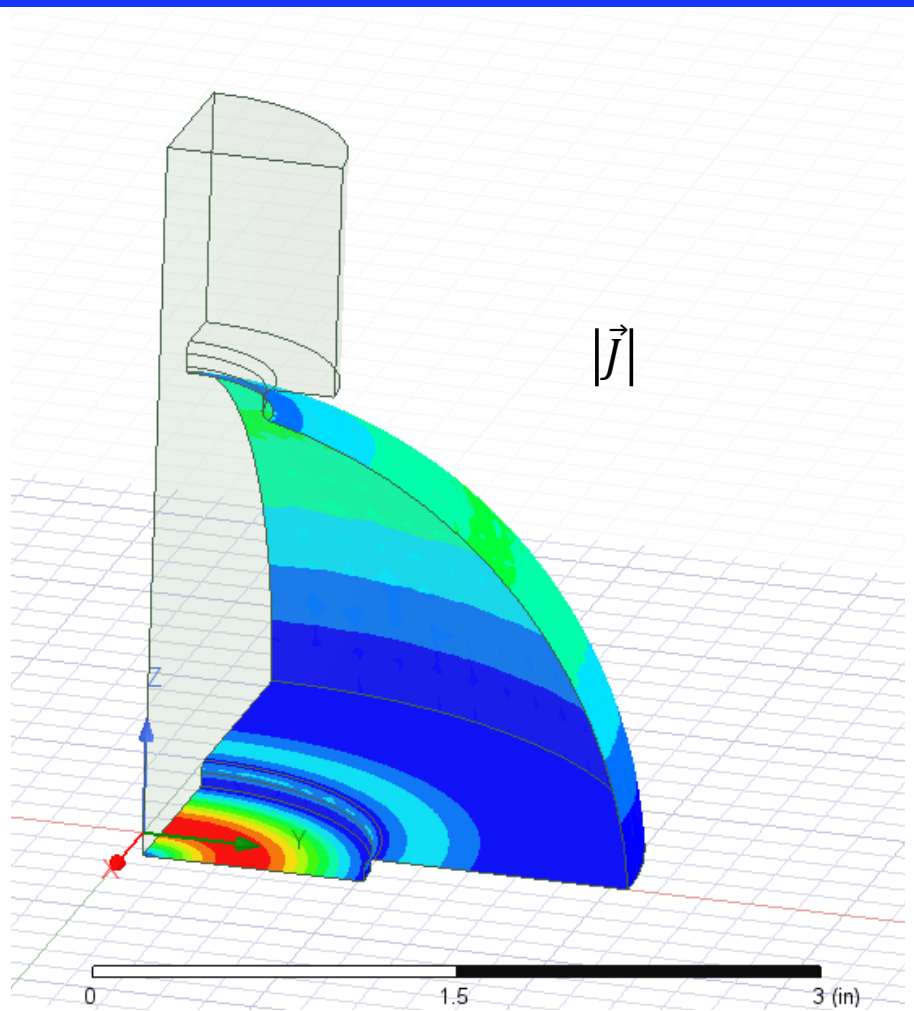
Test properties:

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

Test samples under high magnetic fields:

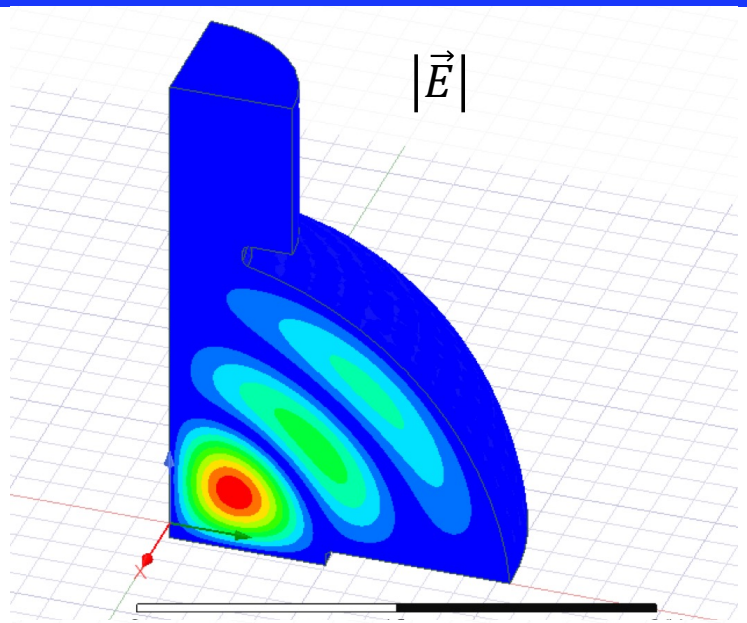
- High-Gradient material
- High Temperature Superconductor

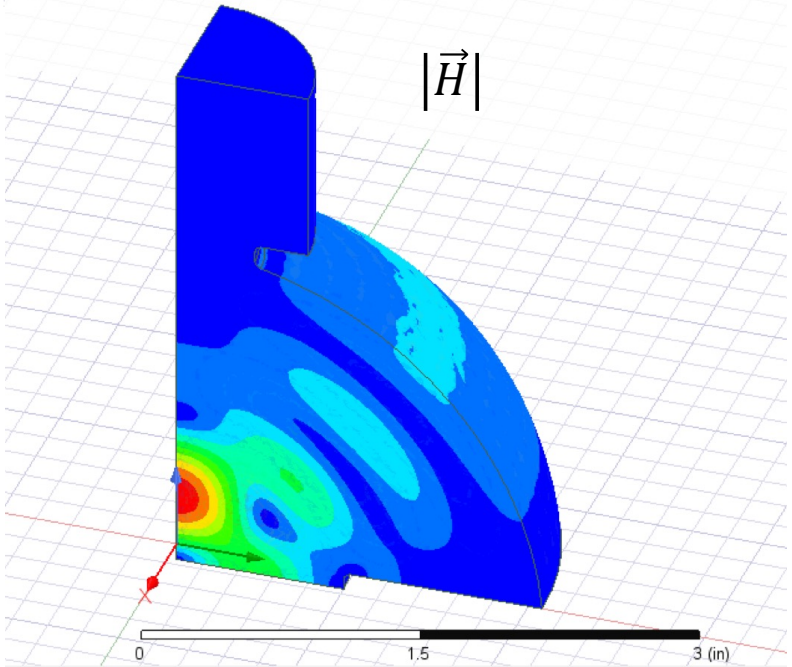
SLAC cavity



Challenge:

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





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Test properties:

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Solution approaches

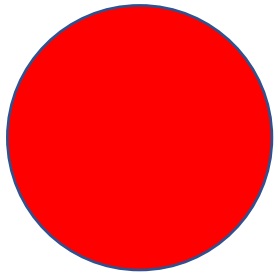
Challenge:

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

Solutions:

- ❑ Design a new cavity using dielectric.

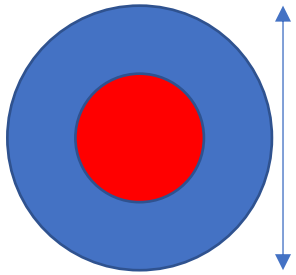
HTS



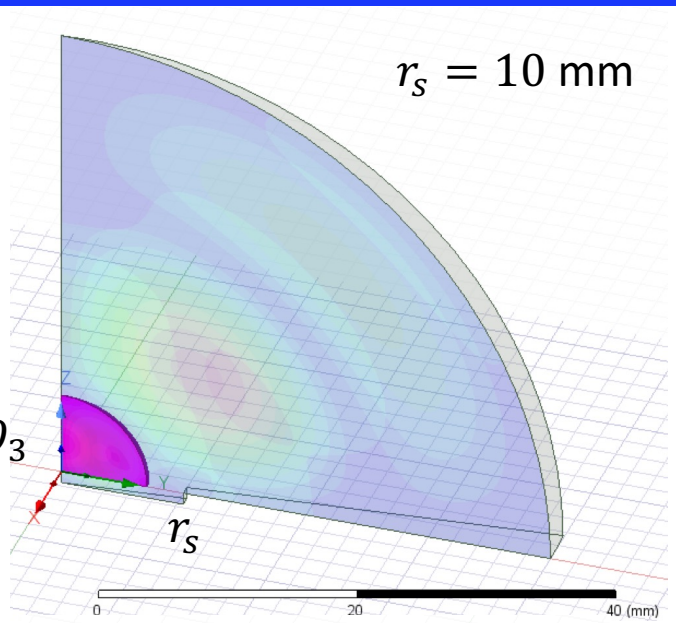
$2r_s = 20$ mm

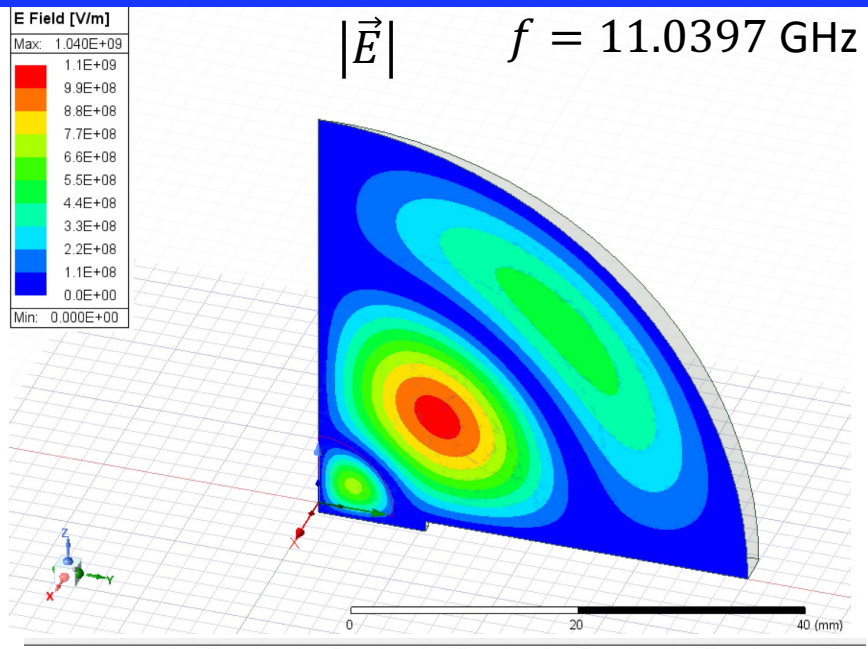
- ❑ Next higher order mode with SLAC cavity using dielectric.

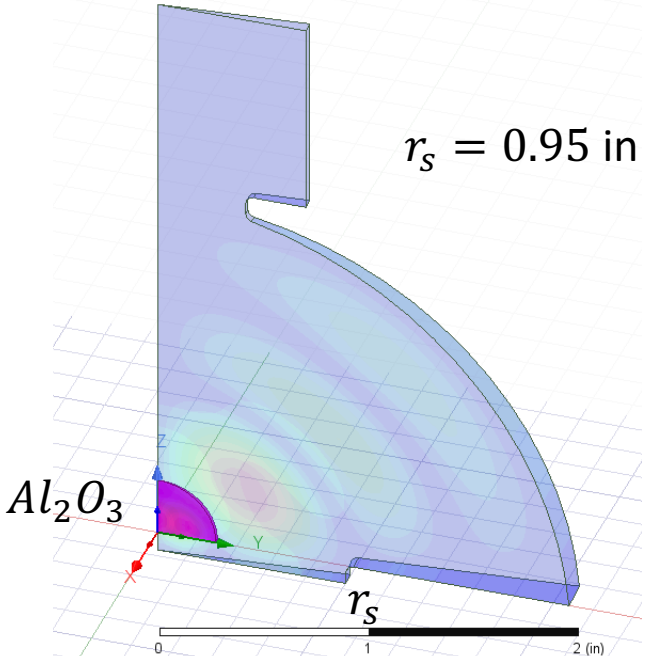
HTS

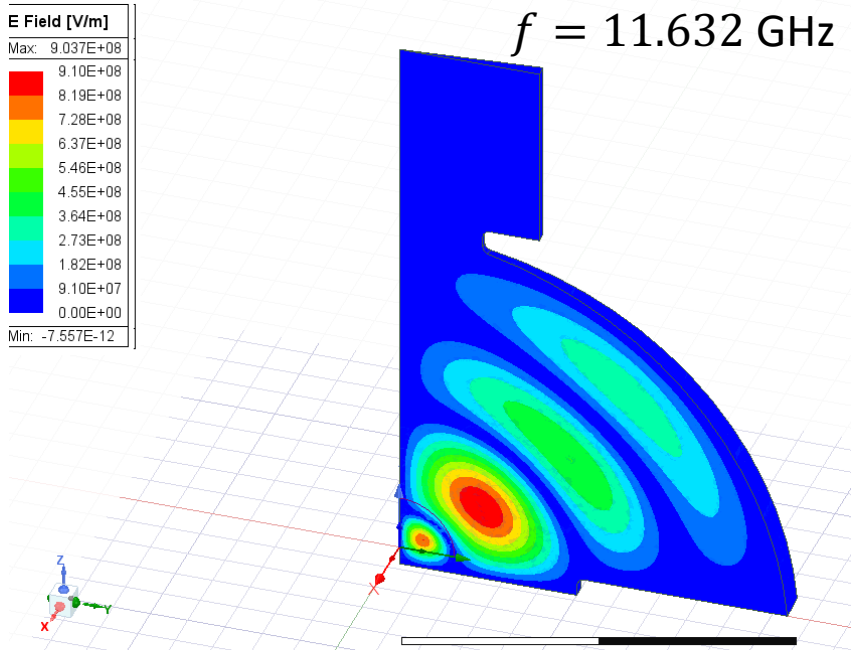


$2r_s$ 20 mm





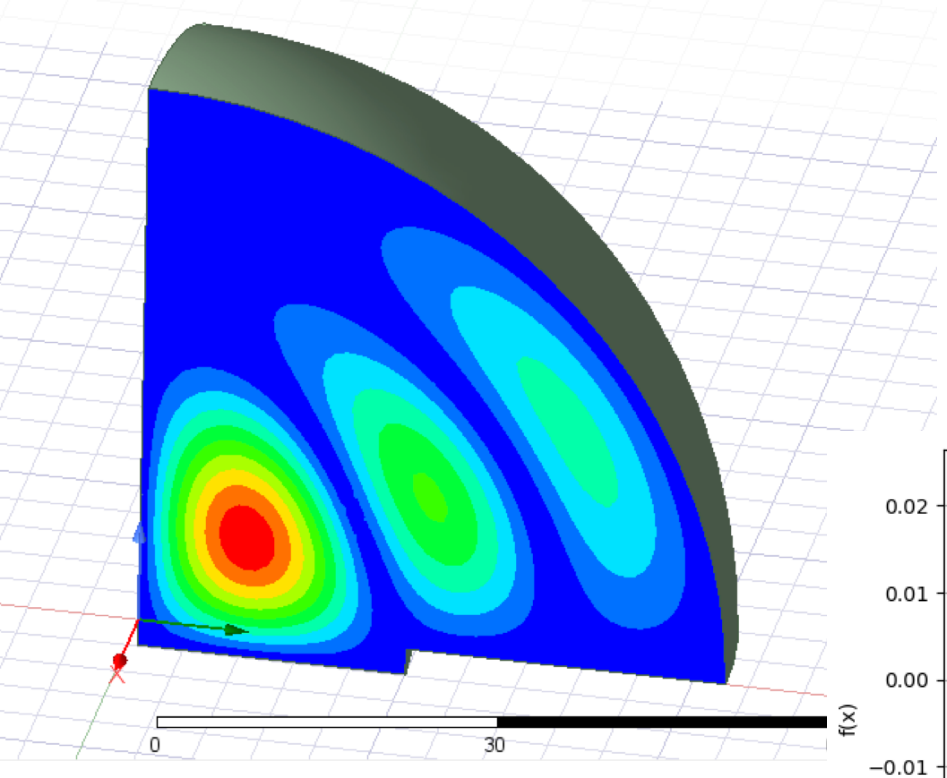




Resonant cavity: analytical study

TE_{320}-like mode in a "semispherical" cavity

$|E_\phi|$



$TE, \frac{\partial}{\partial \phi} = 0$ (axial symmetry)

$$E_\phi(r,\theta) = E_0 j_n(k_{mn} r) \frac{d}{d\theta} L_n^0(\cos\theta)$$

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

$$\vec{H} = H_r \hat{r} + H_\theta \hat{\theta}$$

$$\vec{E} = E_\phi \hat{\phi}$$

$L_n^0(x)$: Legendre polynomial

$j_n(r)$: spherical Bessel function

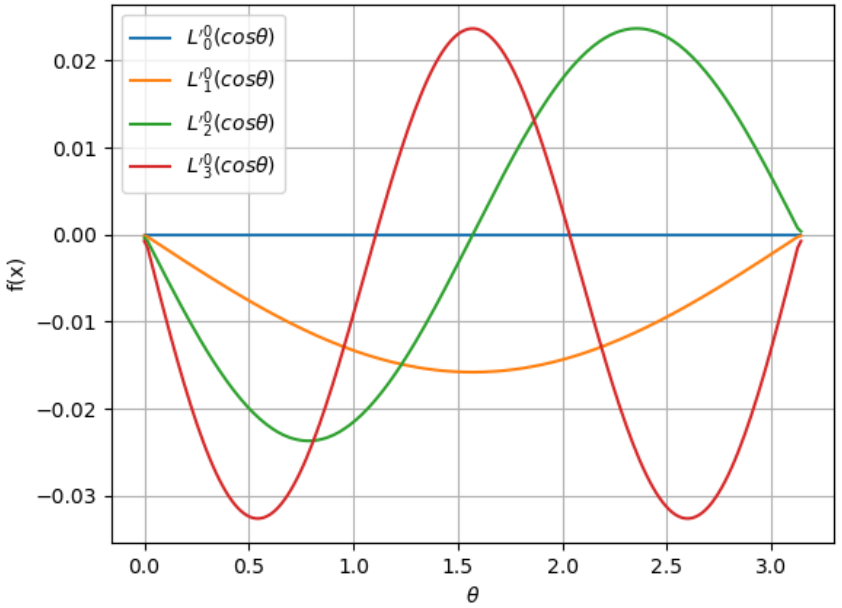
r_{mn}: n-th zero of the m-th spherical Bessel function

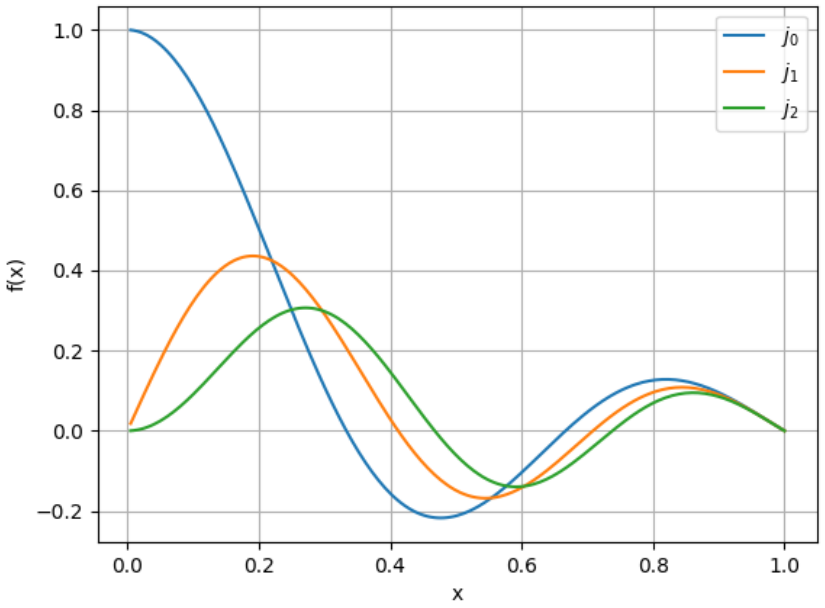
$$j_n(r) = \sqrt{\frac{\pi}{2r}} J_{n+\frac{1}{2}}(r)$$

$$\boldsymbol{E_\phi = E_0 j_2(k_{32} r) L_2^0(\cos\theta)}$$

Zeros of $j_2(x)$

5.76346	9.09501	12.3229	15.5146





Solution I

$$\omega_{m,n} = c\left(\frac{r_{mn}}{R}\right) \qquad \boldsymbol{E_\phi \propto j_2(k_{32}r)}$$

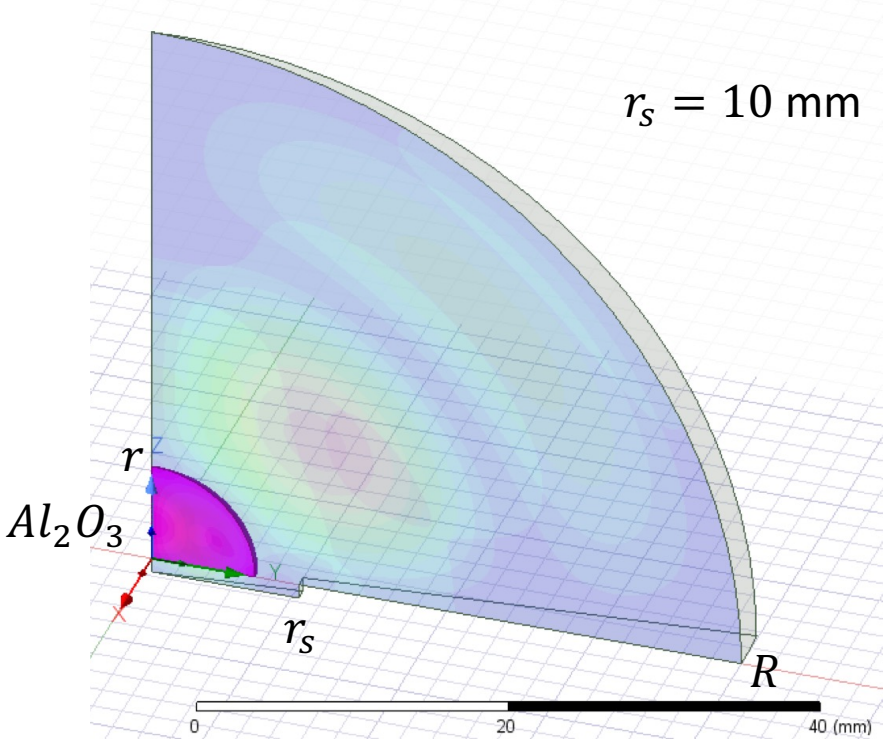
$$\lambda_d = \frac{\lambda_0}{\sqrt{\epsilon_r}}$$

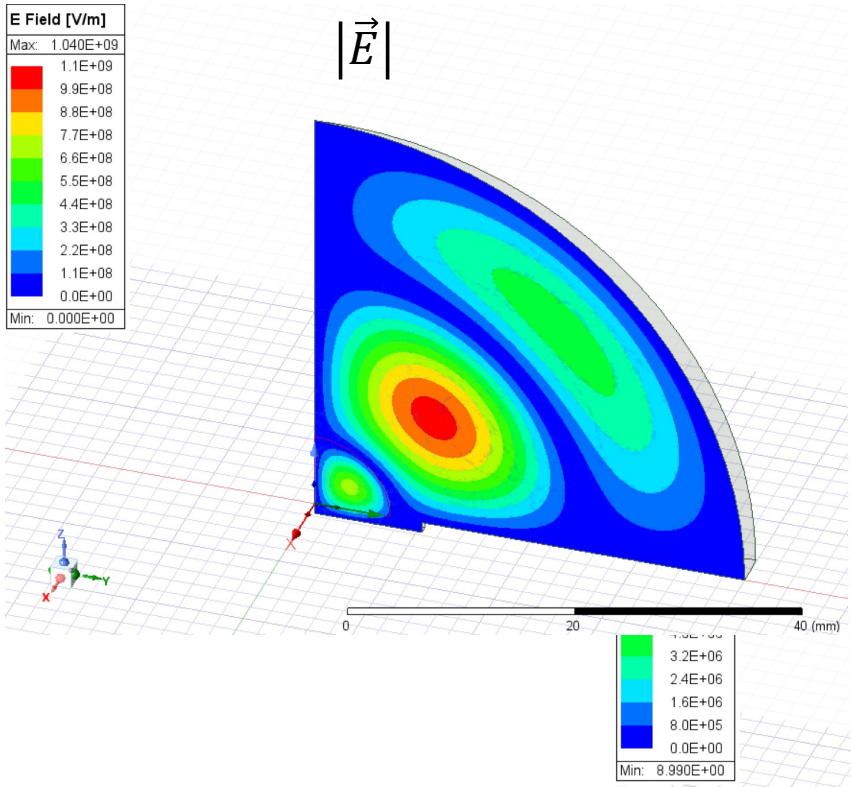
λ_0 must be the same to keep frequency constant

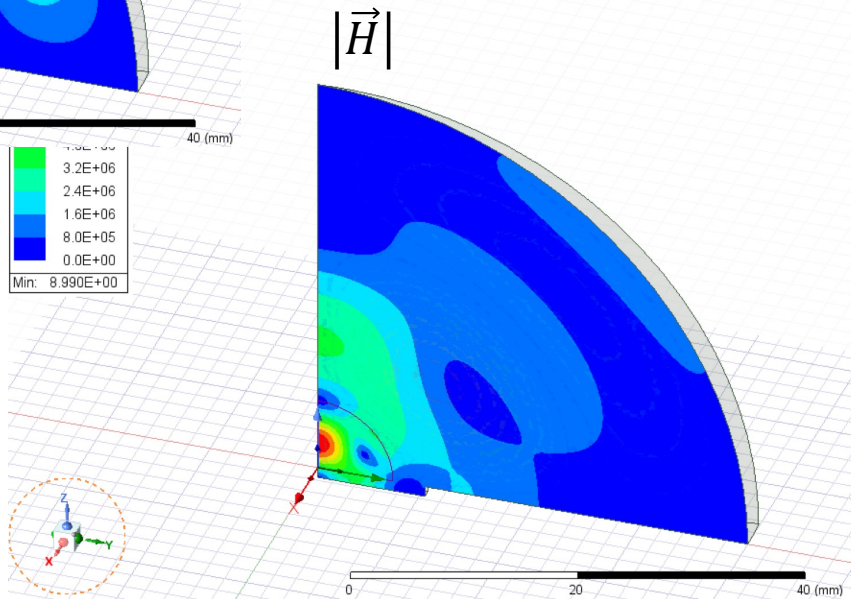
λ_{12}	0.46*R
λ_{22}	0.27*R
λ_{32}	0.27*R

$f = 11.0397$ GHz $\quad r = 7$ mm $\quad R = 40$ mm

$r_s = 10$ mm

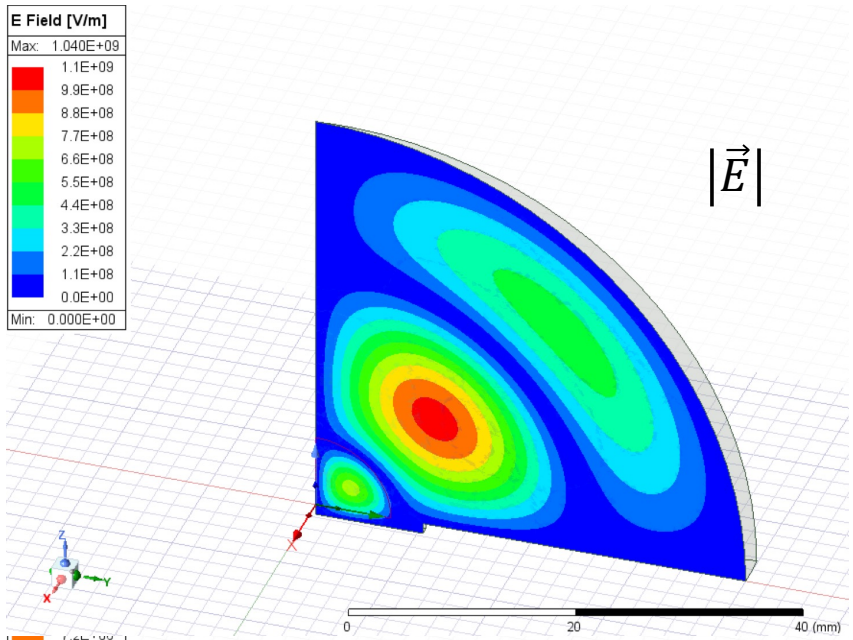


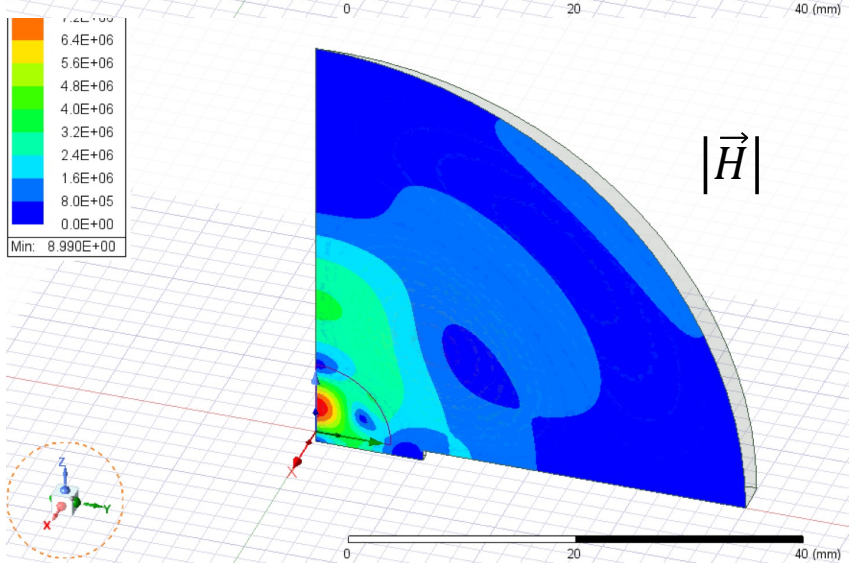




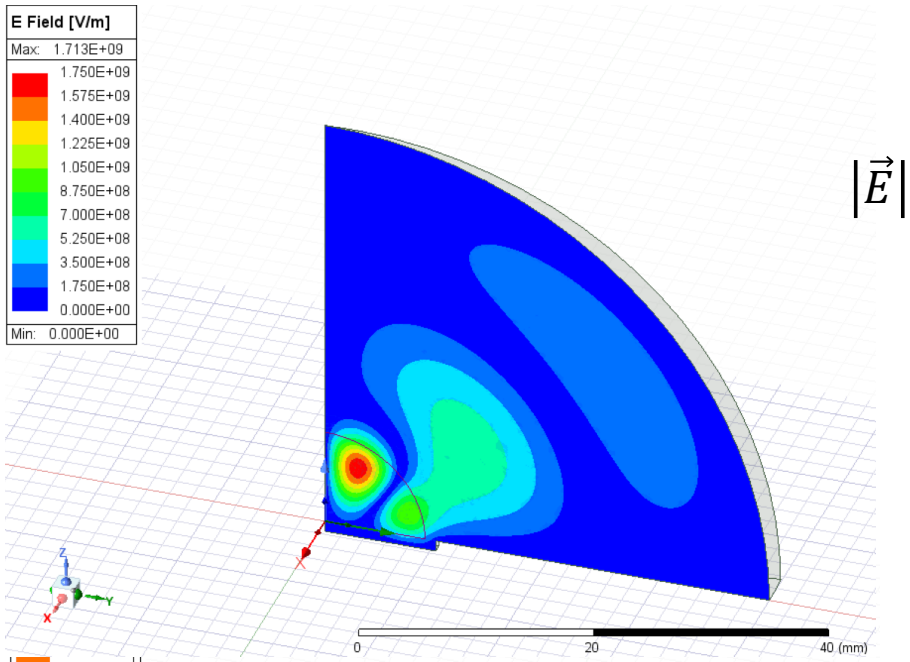
Solution I

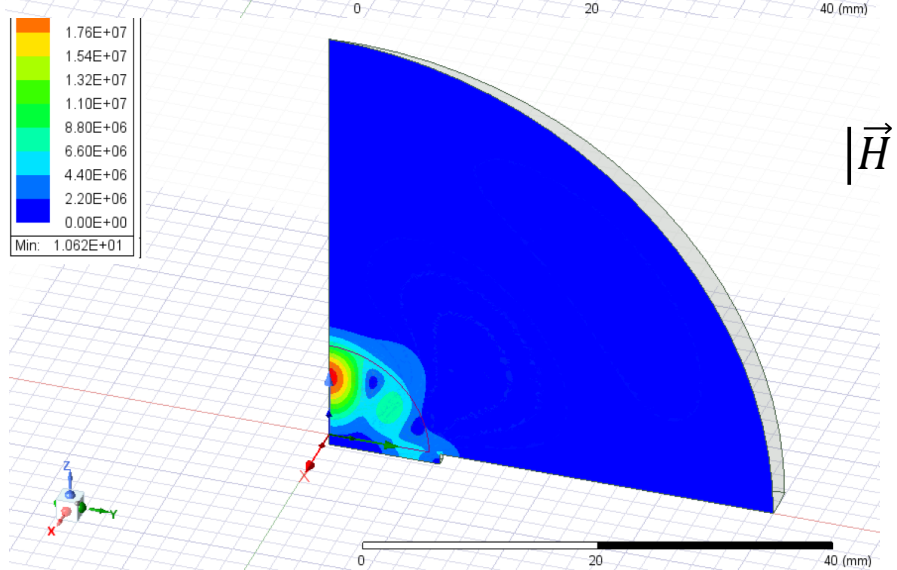
$f = 11.0397$ GHz $r = 7$ mm $R = 40$ mm





$f = 11.128$ GHz $r = 9$ mm $R = 40$ mm

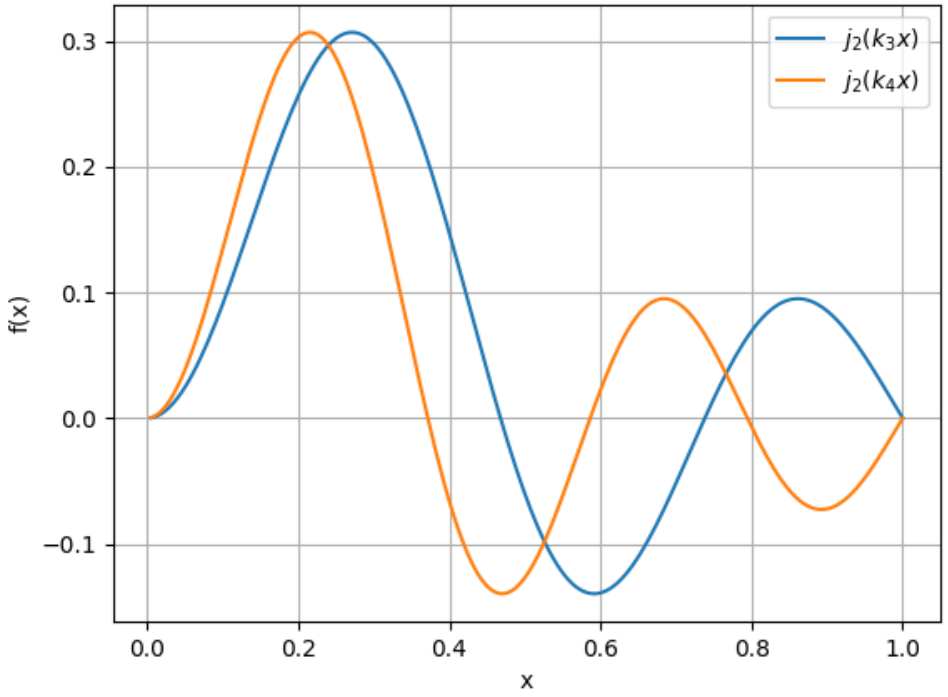


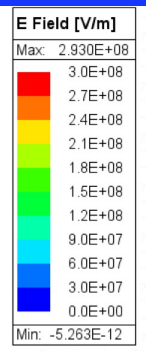


Dielectric resonant cavity

$$\omega_{m,n} = c\left(\frac{r_{mn}}{R}\right) \qquad \boldsymbol{E_\phi \propto j_2(k_{42}r)}$$

λ_{12}	0.37*R
λ_{22}	0.215*R
λ_{32}	0.208*R
λ_{42}	0.207*R

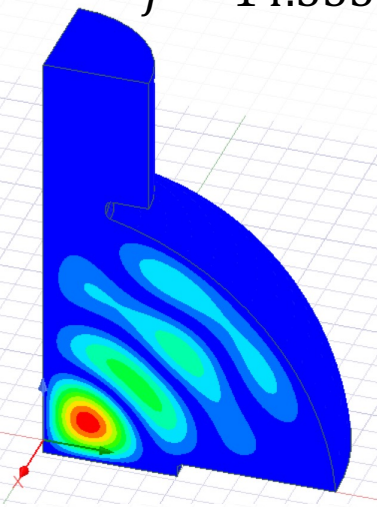




No dielectric

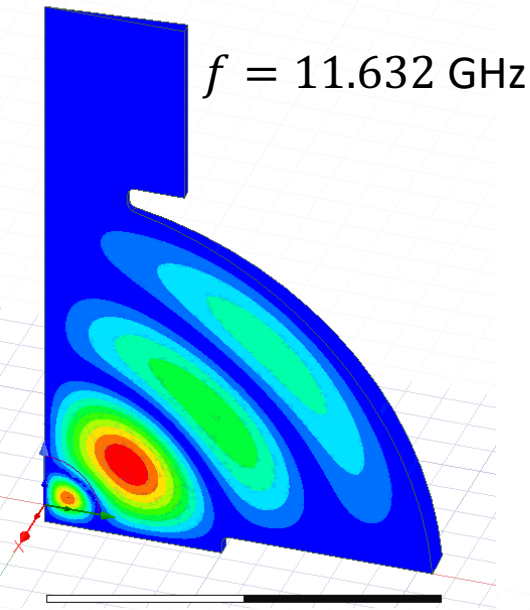
$f = 14.3557$ GHz

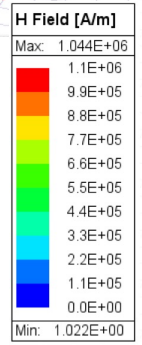
$|\vec{E}|$



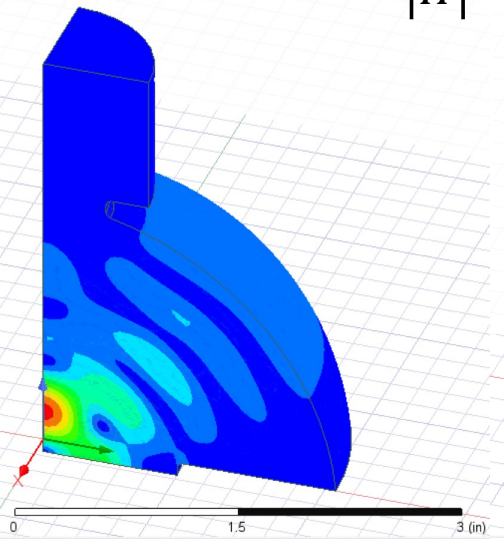
Dielectric

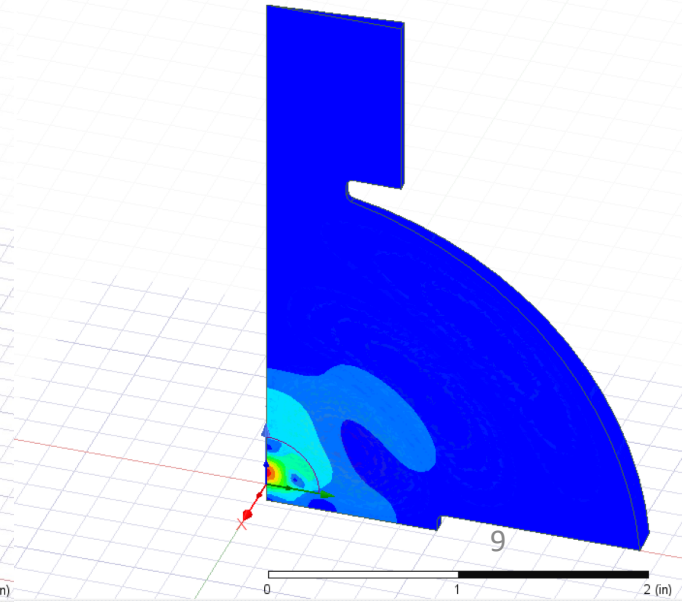
$f = 11.632$ GHz





$|\vec{H}|$





Conclusions

RF Mushroom cavity update for HTS measurements at SLAC set up.

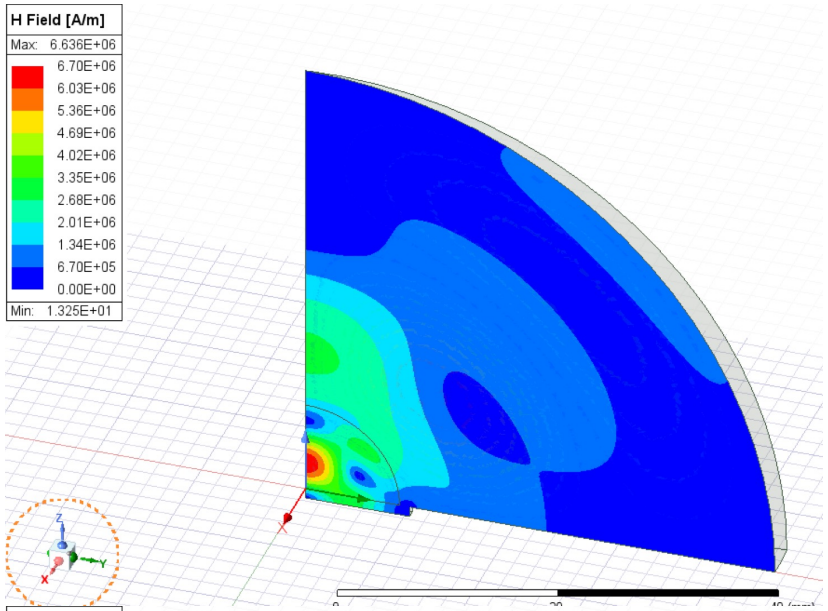
- ❑ Smaller cavity with dielectric:
  -  ○ More freedom in the design.
  -  ○ Need of fabrication
- ❑ Same cavity with dielectric and higher order mode:
  -  ○ No need of fabrication.
  -  ○ More constraints to the design

Back up

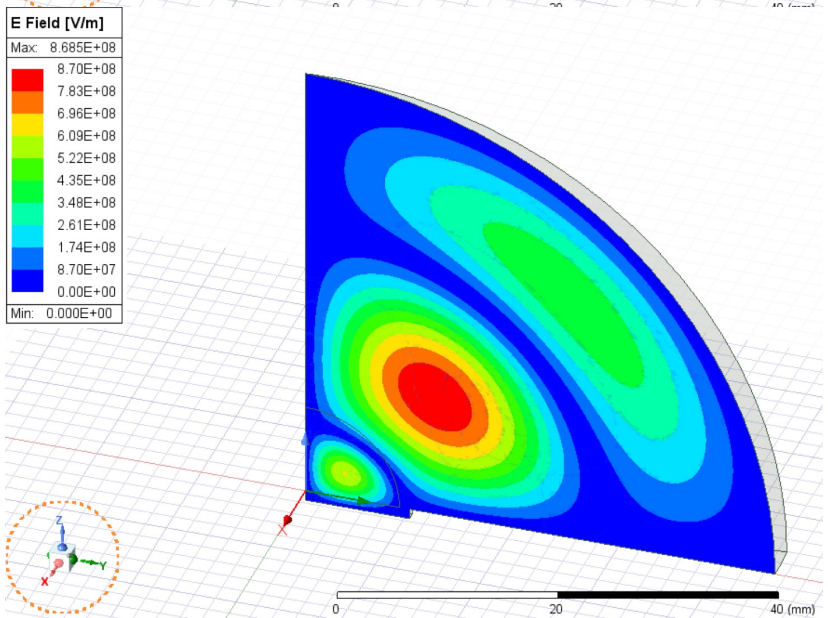
Dielectric resonant cavity I

$R = 45$ mm $r = 9$ mm $f = 9.81$ GHz

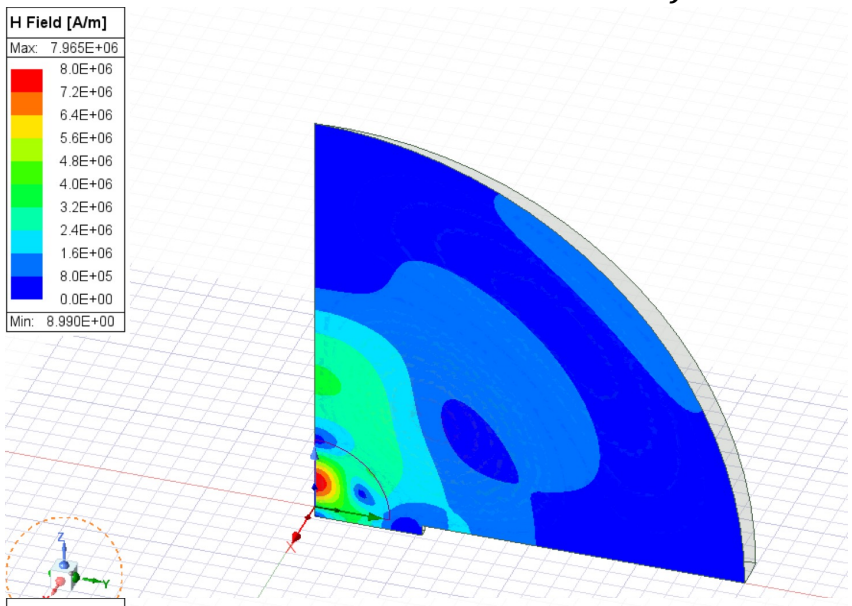
$|\vec{H}|$

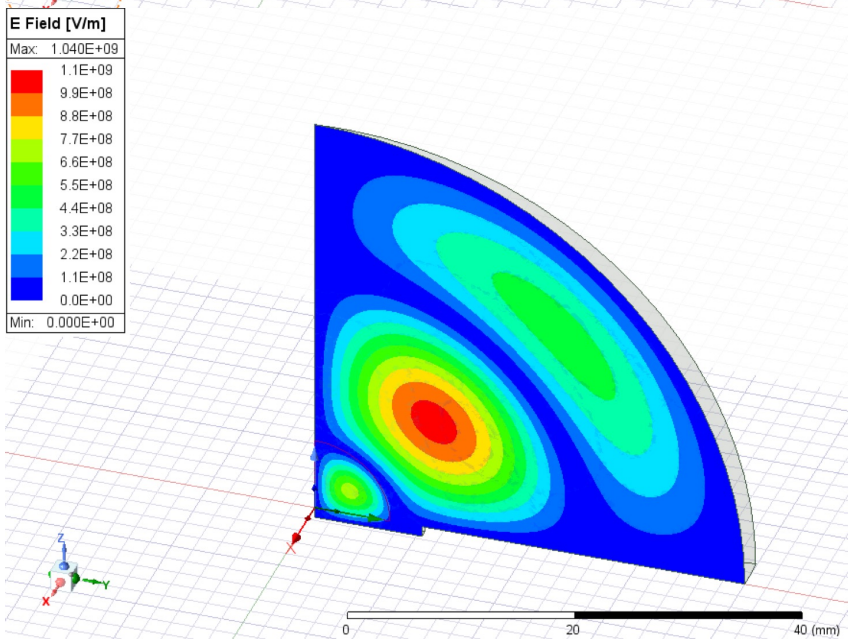


$|\vec{E}|$



$R = 40$ mm $r = 7$ mm $f = 11.0397$ GHz



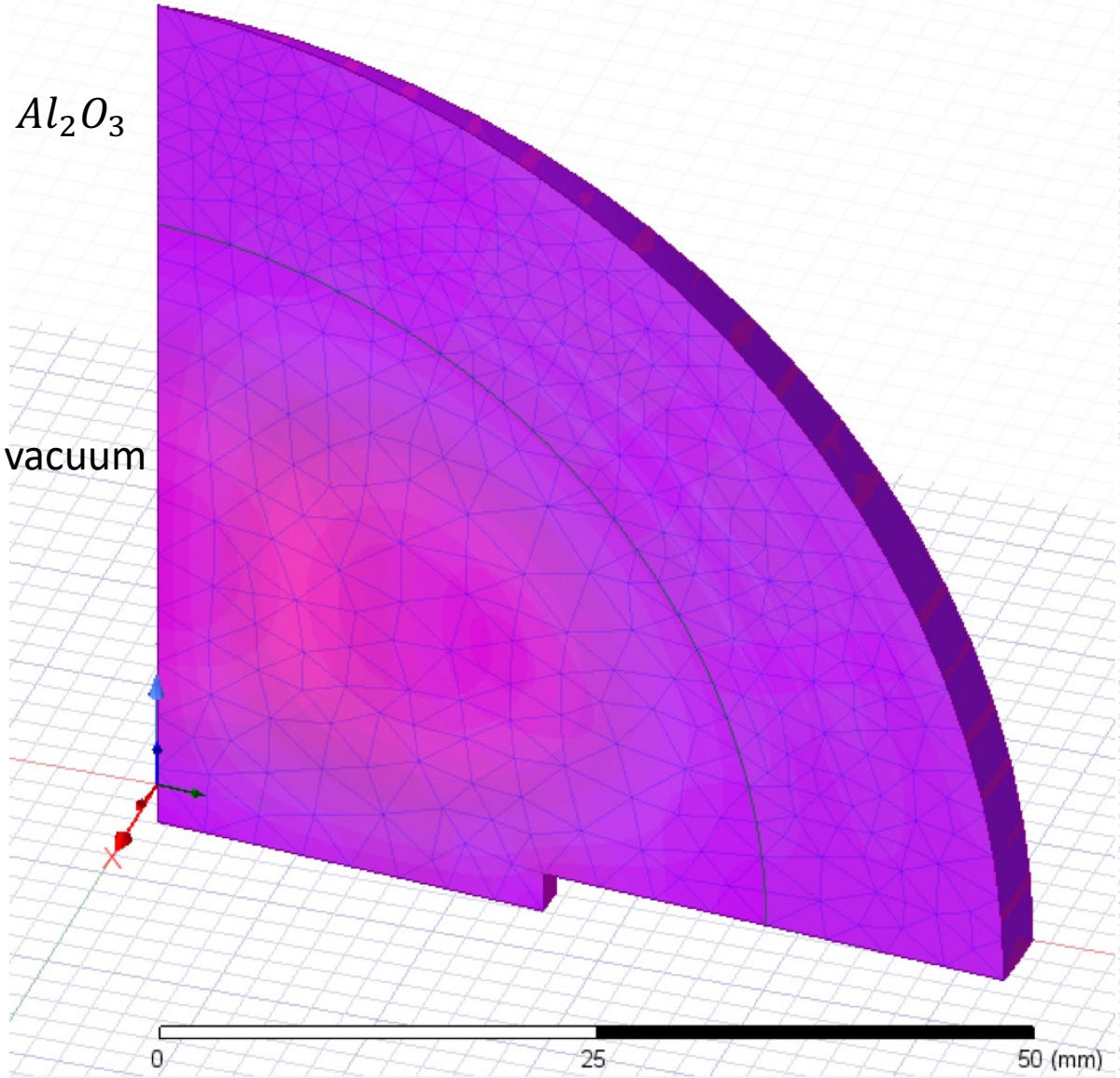


Dielectric resonant cavity II

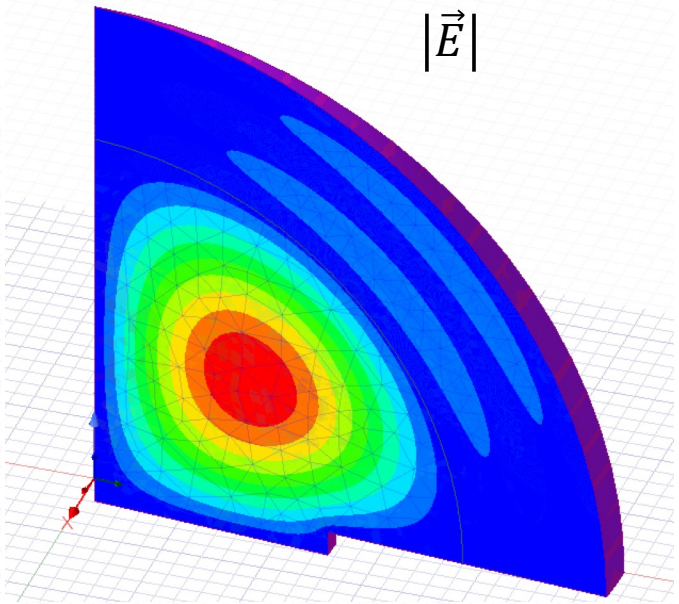
$f = 6.8949$ GHz

Al_2O_3

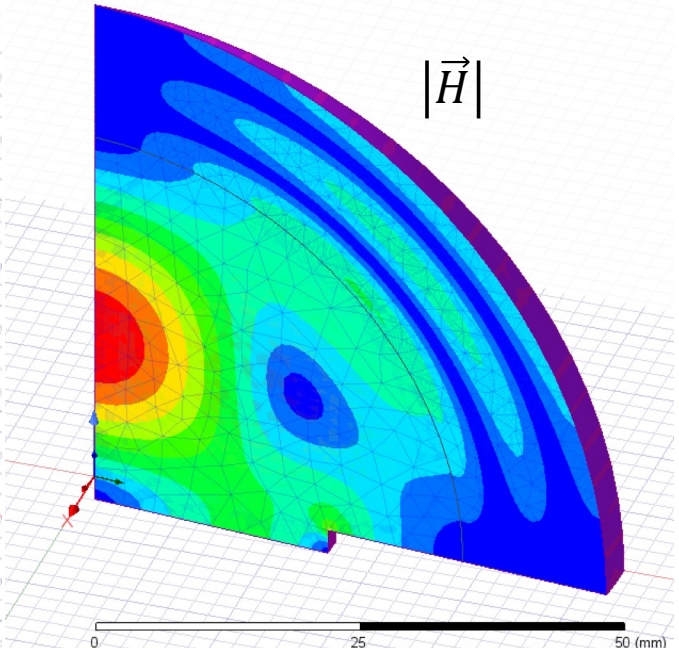
vacuum



$|\vec{E}|$



$|\vec{H}|$



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