SINGLE MODE CAVITY FOR 3^{rd} HARMONIC SYSTEM

Leon Kronshorst, Wolfgang Müller

DESY TEMF Collaboration Talks

CONTENT

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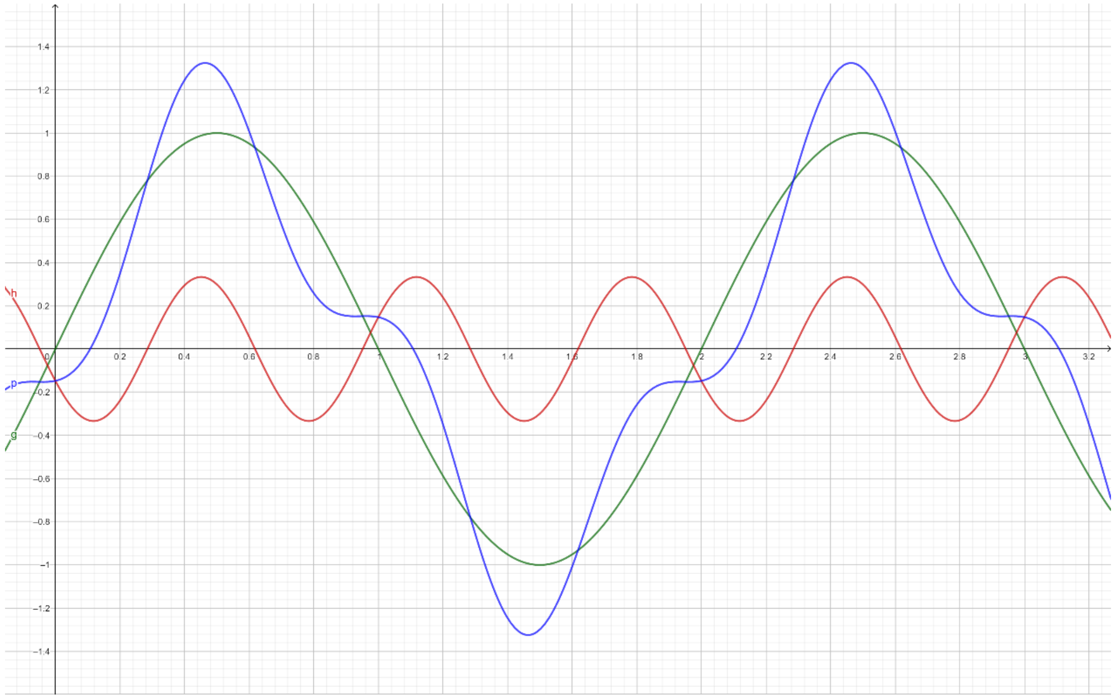
INTRODUCTION TO 3rd HARMONIC SYSTEMS

- Goal: Bunch lengthening
  - Achieves reduction of:
    - Toucheck Efffect
    - Intrabeam scattering

  - Longer Beam Lifetime
  - Lower Emittance



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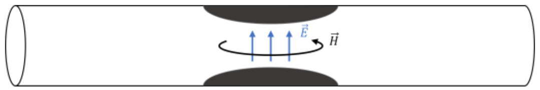
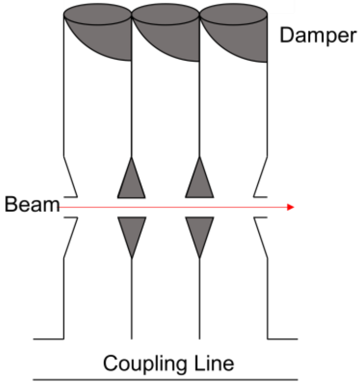
CAVITY DESIGN
PROGRESS

- Starting Point: Design ideas from Herminghaus

  - Circular cylindrical waveguide with indentations



  - Stacking multiple cells together and damping in the Waveguide



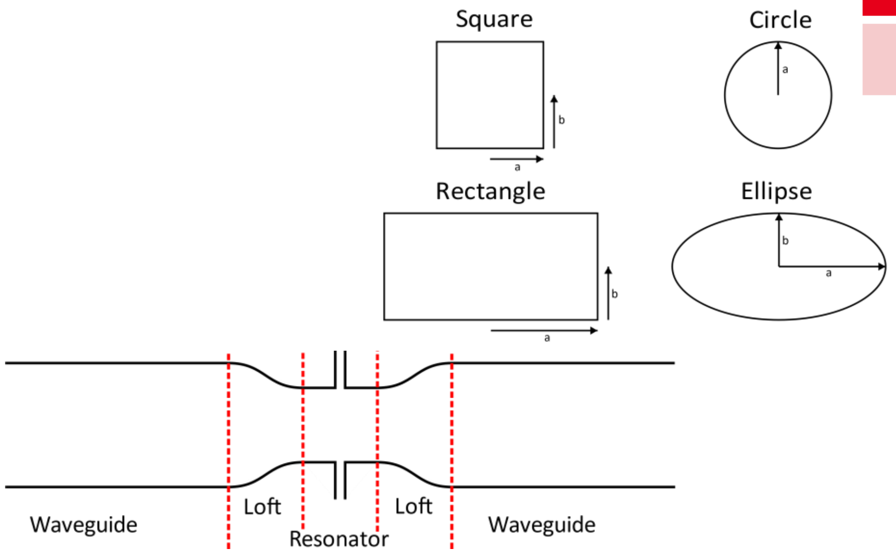
  - Approx. figures of merit

Q_0	15000
R_s	44.58 MΩ

CAVITY DESIGN
PROGRESS

- Next step: Geometry investigation

- Combining different crossections for waveguide and resonator section



- Approx. figures of merit

Q_0	16000
R_s	1.82 MΩ

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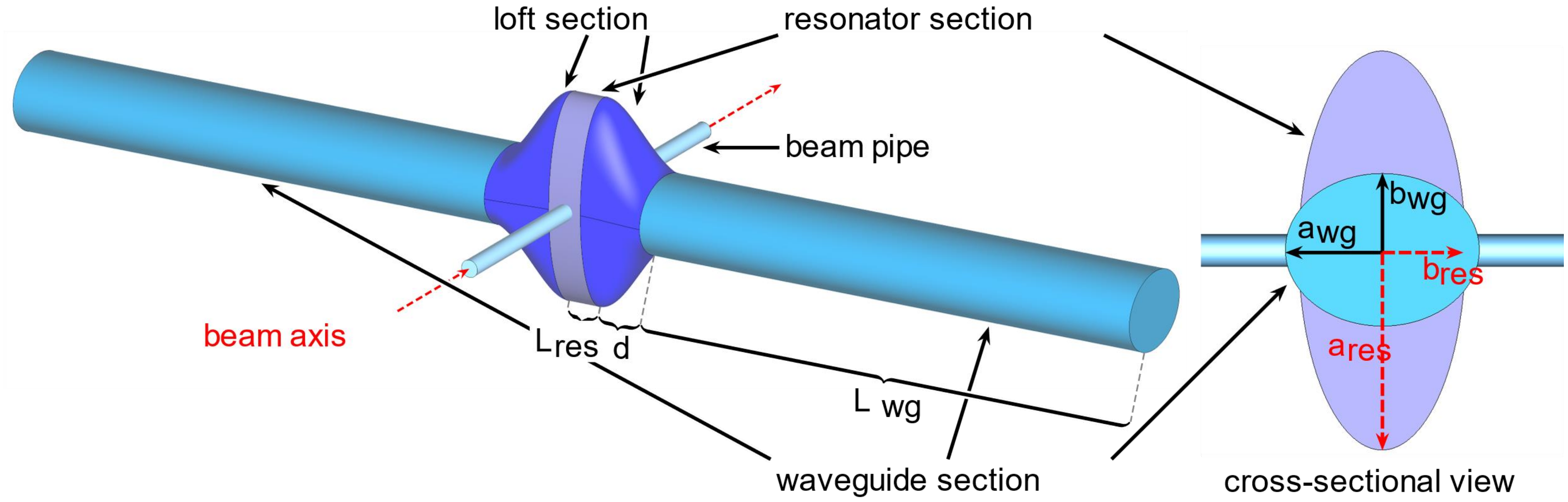
CAVITY DESIGN
CURRENT STATE



- Reasoning
  - Strong decoupling between waveguide and resonator
  - No sharp edges

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REGIONAL SENSITIVITY ANALYSIS

- Many valid parameter combinations
  - Difficult task for common optimizer
  - How to obtain needed knowledge?

➢ Sensitivity Analysis (SA)
  - Estimating influences of individual parameters on the model result through sampling
  - Understand the influence of parameter combinations

- Regional Sensitivity Analysis (RSA)
  - Type of SA
  - Only 100 - 1000 x M samples necessary
    - M – number of parameters
  - Map the input space to different regions of interest
    - Typically, desired $y \in Y_b$ and not desired $y \in Y_{nb}$

➢ Allows for targeted optimization and parameter space reduction

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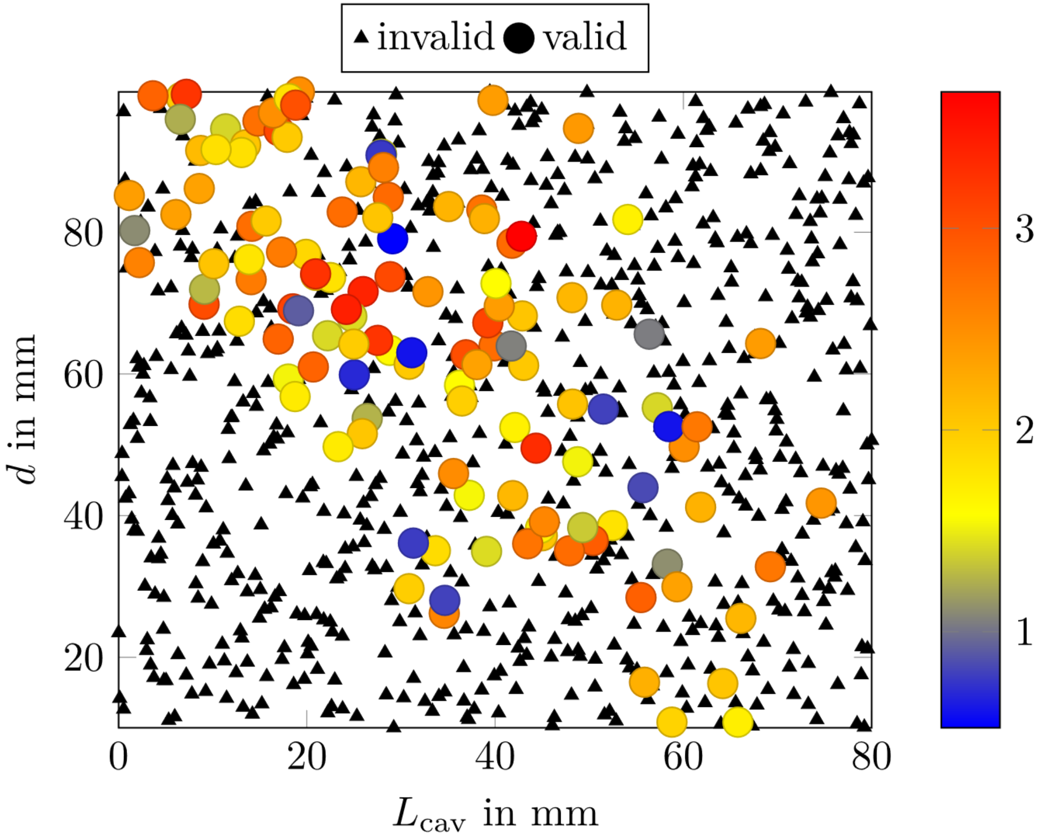
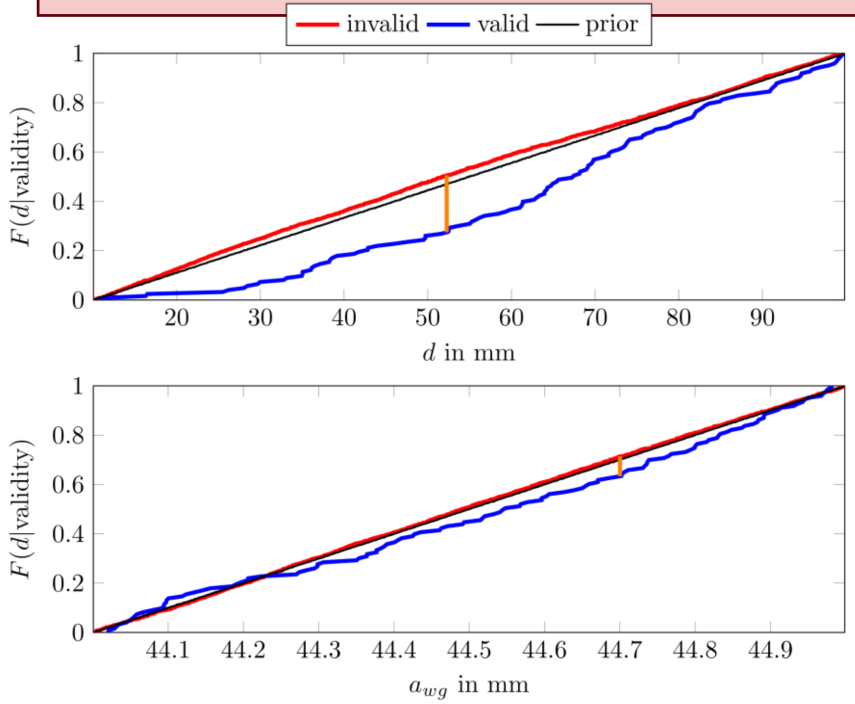
REGIONAL SENSITIVITY ANALYSIS

1. Visual RSA



2. Statisitcal RSA using Kolmogorov-Smirnov statistic

$$S_i = \max_{x_i} \left| F_{(x_i|y_b)}(x_i|y \in Y_b) - F_{(x_i|y_{nb})}(x_i|y \in Y_{nb}) \right|$$



$S_d = 0.2304$

$S_{a_{wg}} = 0.0808$

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CAVITY OPTIMIZATION

REQUIREMENTS & GOALS

- Resonant frequency $f_1 = 1.5 \text{ GHz}$
  - it being a qTE111,even-mode
- Waveguide cutoff-frequency $f_c \approx 2 \text{ GHz}$
- 2nd Eigenmode resonant frequency $f_2 > f_c$

- Mitigate all relevant Higher Order Modes
- Maximize:
  - Q_0 - unloaded Quality Factor
  - R_s - Shuntimpedance
  - λ_{TTF} - Transit Time Factor

❑ ε - Efficiency

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CAVITY OPTIMIZATION
EFFICIENCY

- Proposed figure of merit:

Efficiency $\boldsymbol{\varepsilon} \coloneqq \frac{\Delta \mathrm{U}}{P_e}$

- $\Delta\mathrm{U}$ - is the energy gain of the particle per cavity passage
- $\mathrm{P_e}$ - is the required externally supplied power

- With:
  - $\Delta U = -Q\underline{V}_{\mathrm{acc}} = Q \int_{-\frac{L}{2}}^{\frac{L}{2}} \underline{\vec{E}} e^{-j\omega\frac{z}{\beta c}} \cdot \mathrm{d}\vec{z}$
  - $P_e = P_{\mathrm{couple\ loss}} + P_{\mathrm{cavity\ loss}} + P_{\Delta U}$
- And
  - $P_{\mathrm{couple\ loss}} + P_{\Delta U} \ll P_{\mathrm{cavity\ loss}}$

$$\boldsymbol{\varepsilon} \propto \frac{\underline{\boldsymbol{V}}_{\boldsymbol{acc}}}{\boldsymbol{P}_{\mathbf{cavity}\ \boldsymbol{loss}}}$$

Possibly better choice than individually optimizing for:

$$R_S, Q, \frac{R_S}{Q} \ or \ \lambda_{\mathrm{TTR}}$$

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CAVITY OPTIMIZATION
PROCESS

1. Performing RSA
   - Enabling the adjustment of parameter ranges
   - Provide a starting point for further optimization
     - i.e. a parameter set with a high efficiency ε

2. Optimizing for f_1
   - Reaching target of $1.5\ \mathrm{GHz}$
   - Maintaining $f_2 > f_c$ and a high ε

3. Optimizing for ε
   - Final increment in ε
   - Maintaining $\mathrm{f}_1 = 1.5\ \mathrm{GHz}$ and $f_2 > f_c$

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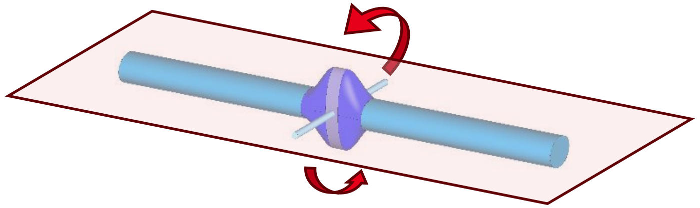
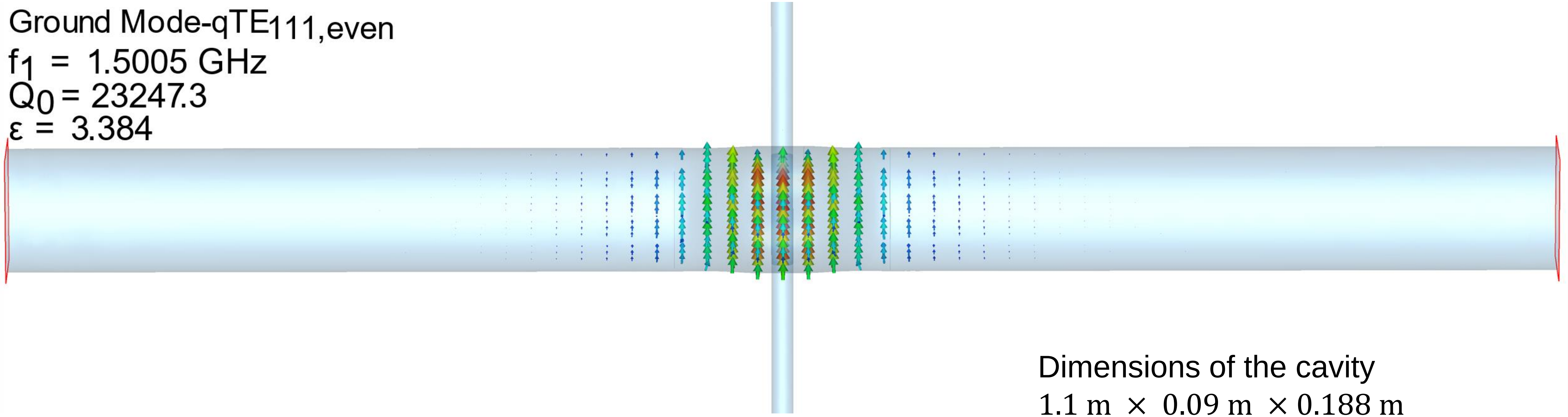
CAVITY OPTIMIZATION
RESULTS

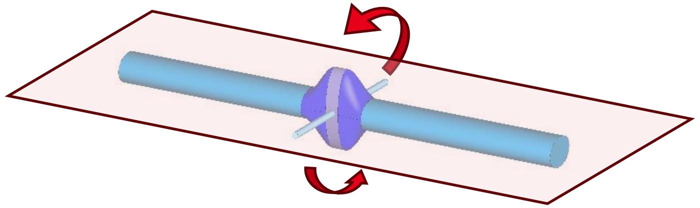


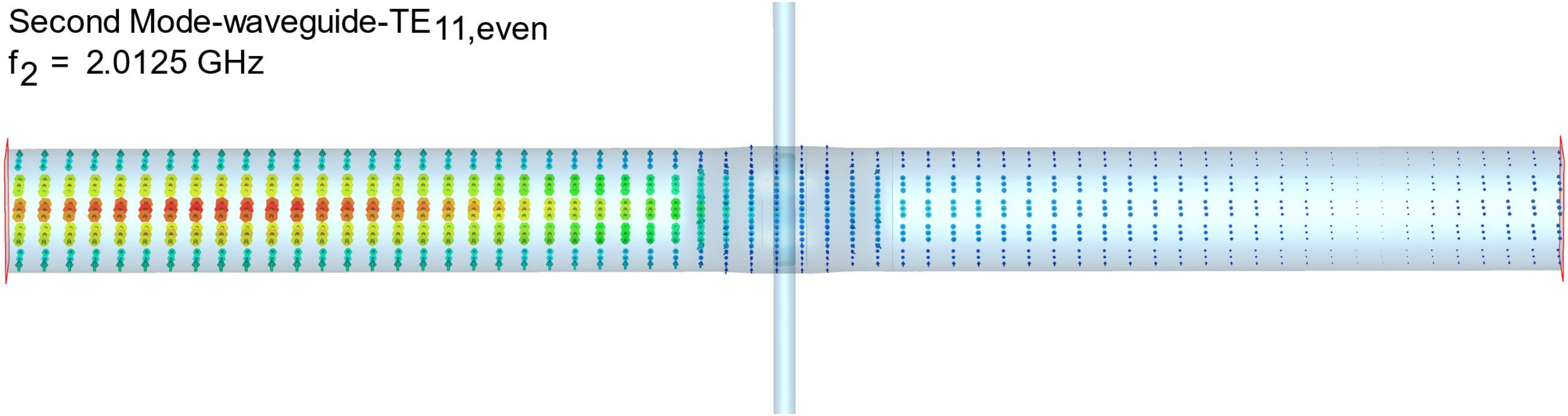


Dimensions of the cavity

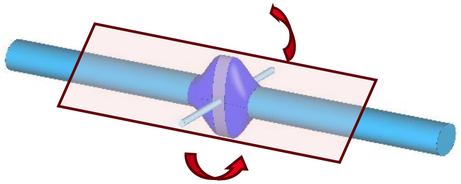
$1.1\ \text{m} \times 0.09\ \text{m} \times 0.188\ \text{m}$

CAVITY OPTIMIZATION
RESULTS

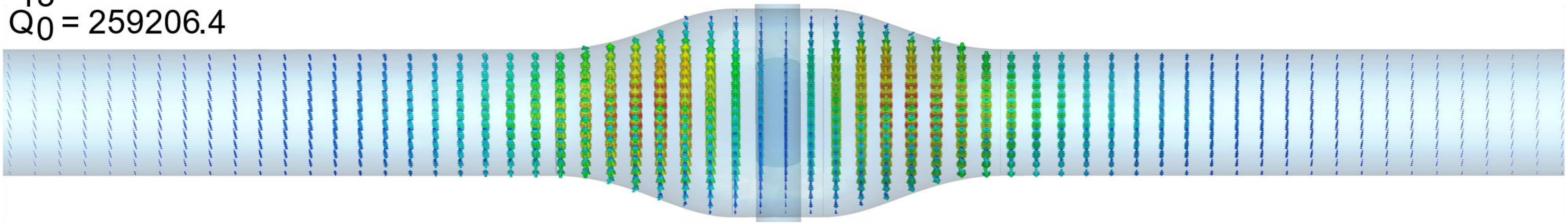




HIGHER ORDER MODES INVESTIGATION



$qTE_{112,even}$
$f_{13} = 2.2499$ GHz
$Q_0 = 259206.4$



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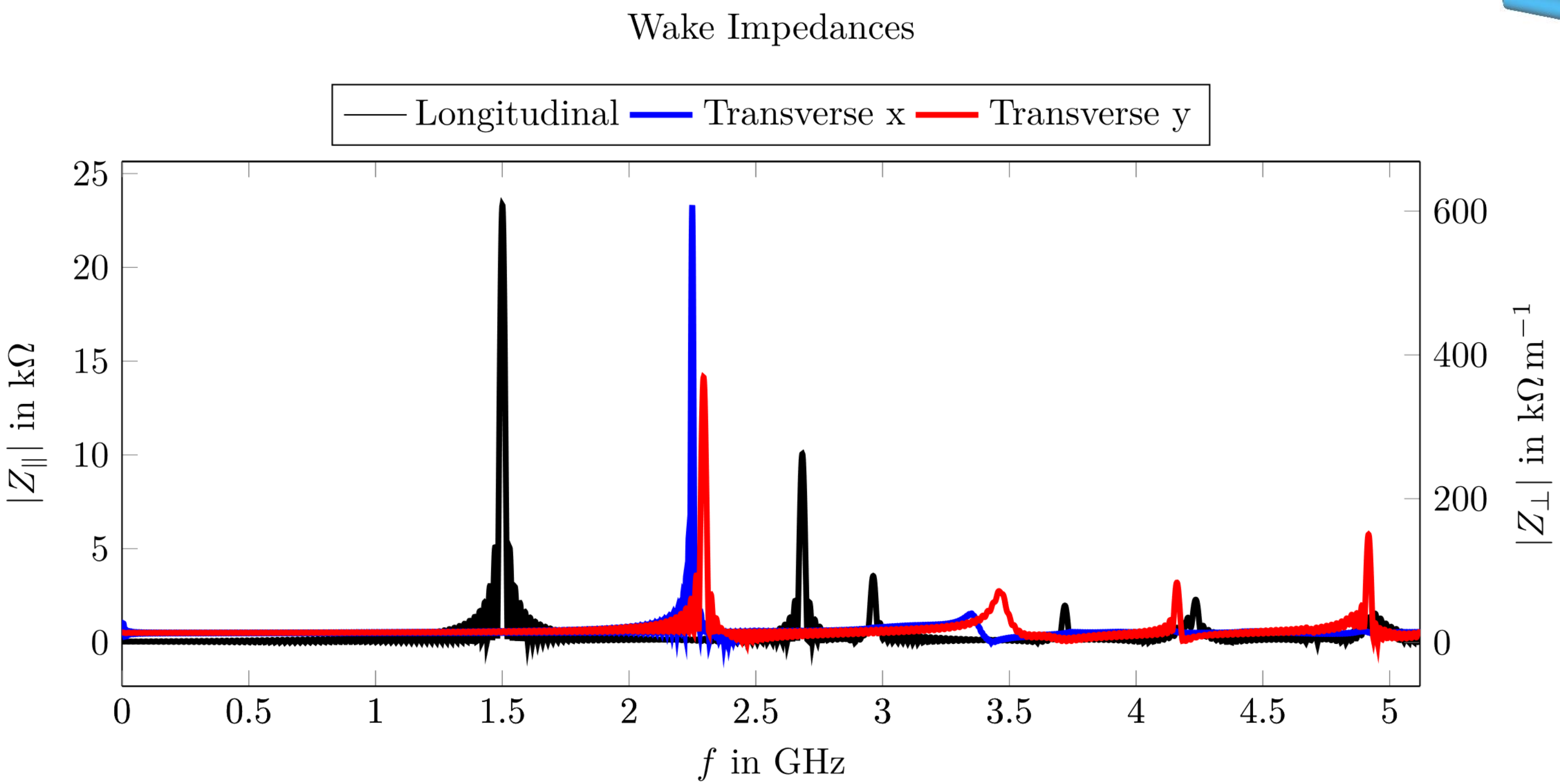
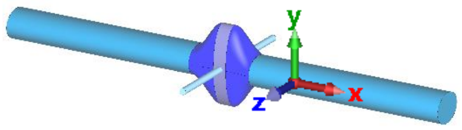
TEMF

HIGHER ORDER MODES INVESTIGATION





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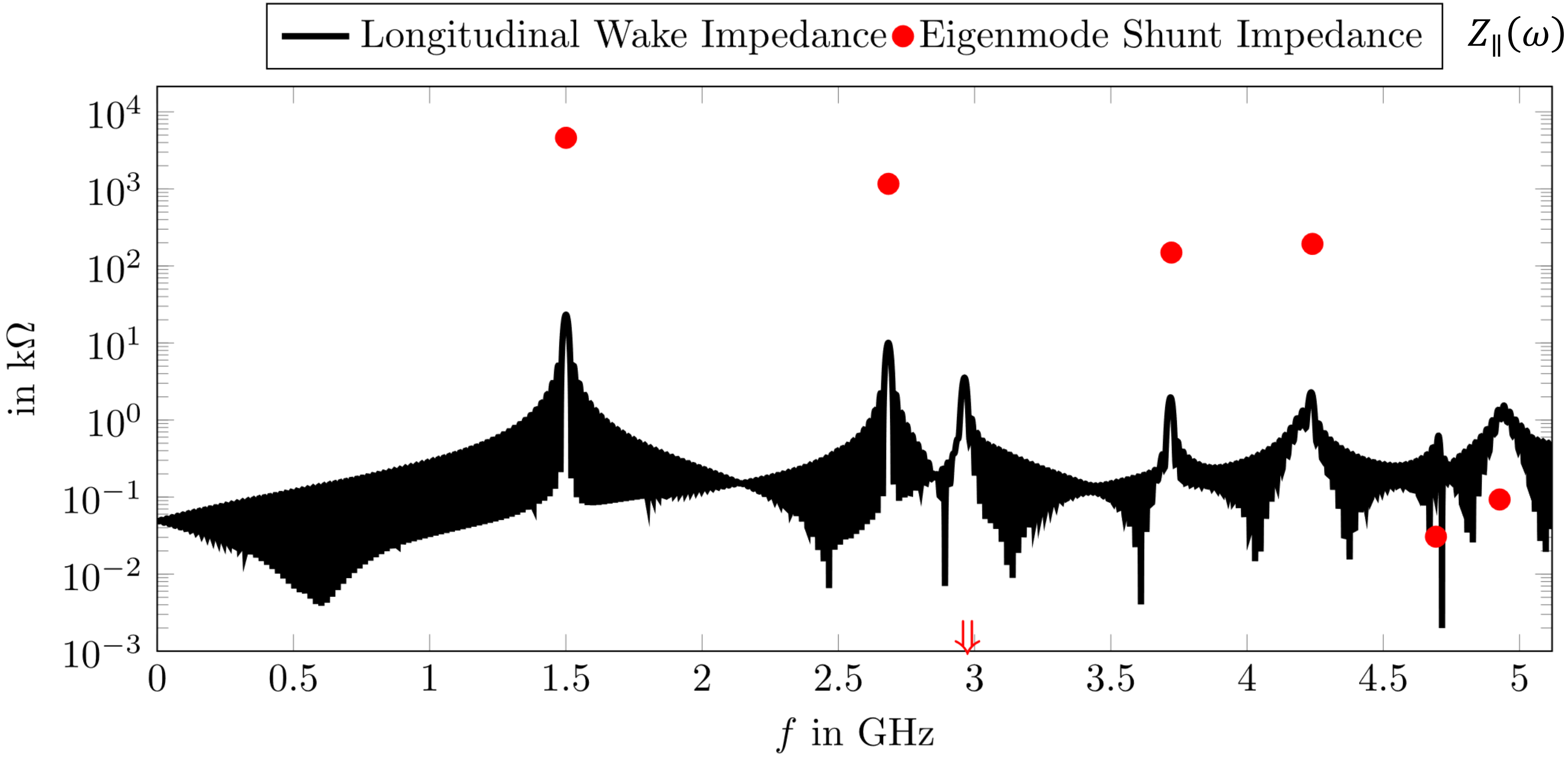
WAKE IMPEDANCES
LONGITUDINAL

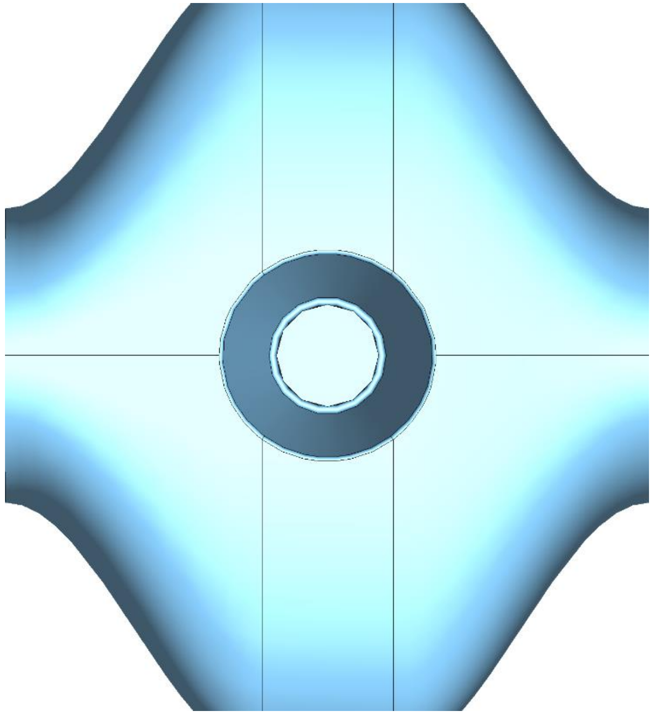


$$Z_{\parallel}(\omega) = \frac{R_s}{1 + jQ_r(\omega/\omega_r - \omega_r/\omega)}$$

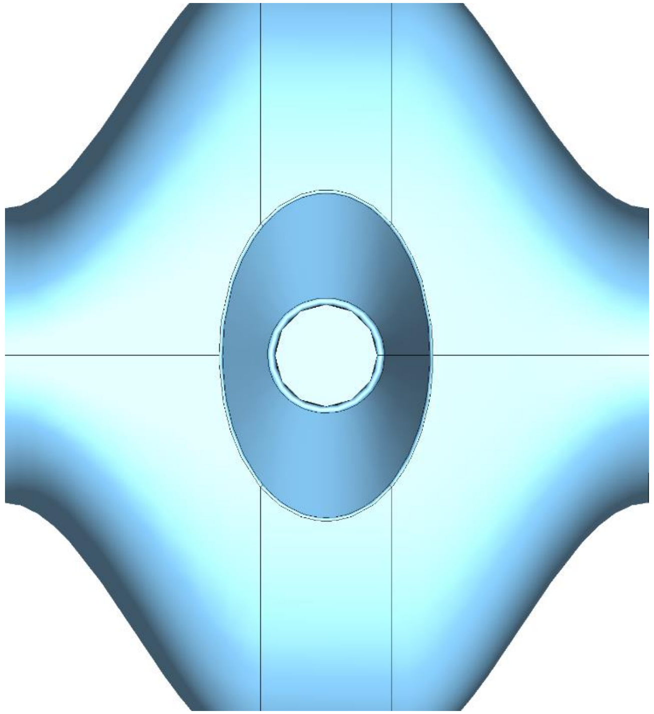
$$\Rightarrow Z_{\parallel}(\omega_r) = R_S$$

ADDITION OF NOSECONES

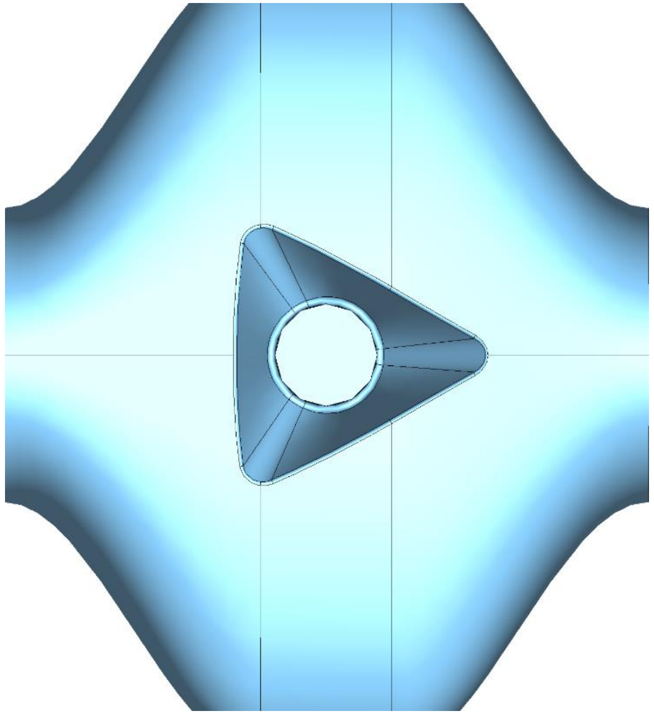
1. Regular Nosecone



2. Elliptical Nosecone



3. Triangular Nosecone



None of the designs led to the desired reduction

OUTLOOK

- Promising results for ground mode and general functioning of cavity
- HOM's need further investigation
  1. Convergence study of the wake impedance using the wakefield solver
  2. Calculating the transverse shunt impedance from eigenmode results
  3. Changing the 2 waveguides to lead to asymmetries in resonator section
  4. Adding 2 more waveguides
- Additional possible work
  - Investigating the efficiency ε of known and build cavities
  - Further sensitivity analysis using variance-based methods
  - Comparing the optimization ansatz to popular methods