Field Map Calculation of the Fundamental Mode for the Normal Conductive PITZ Gun

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Status Meeting
November 14, 2017
DESY, Hamburg

Outline

- Motivation
- Computational Model
  - Geometry and mesh information
- Simulation Results
  - Antenna and cavity tuning
  - Electromagnetic fields and Poynting vector
  - Electromagnetic fields in the vicinity of the cavity axis
- Summary / Outlook

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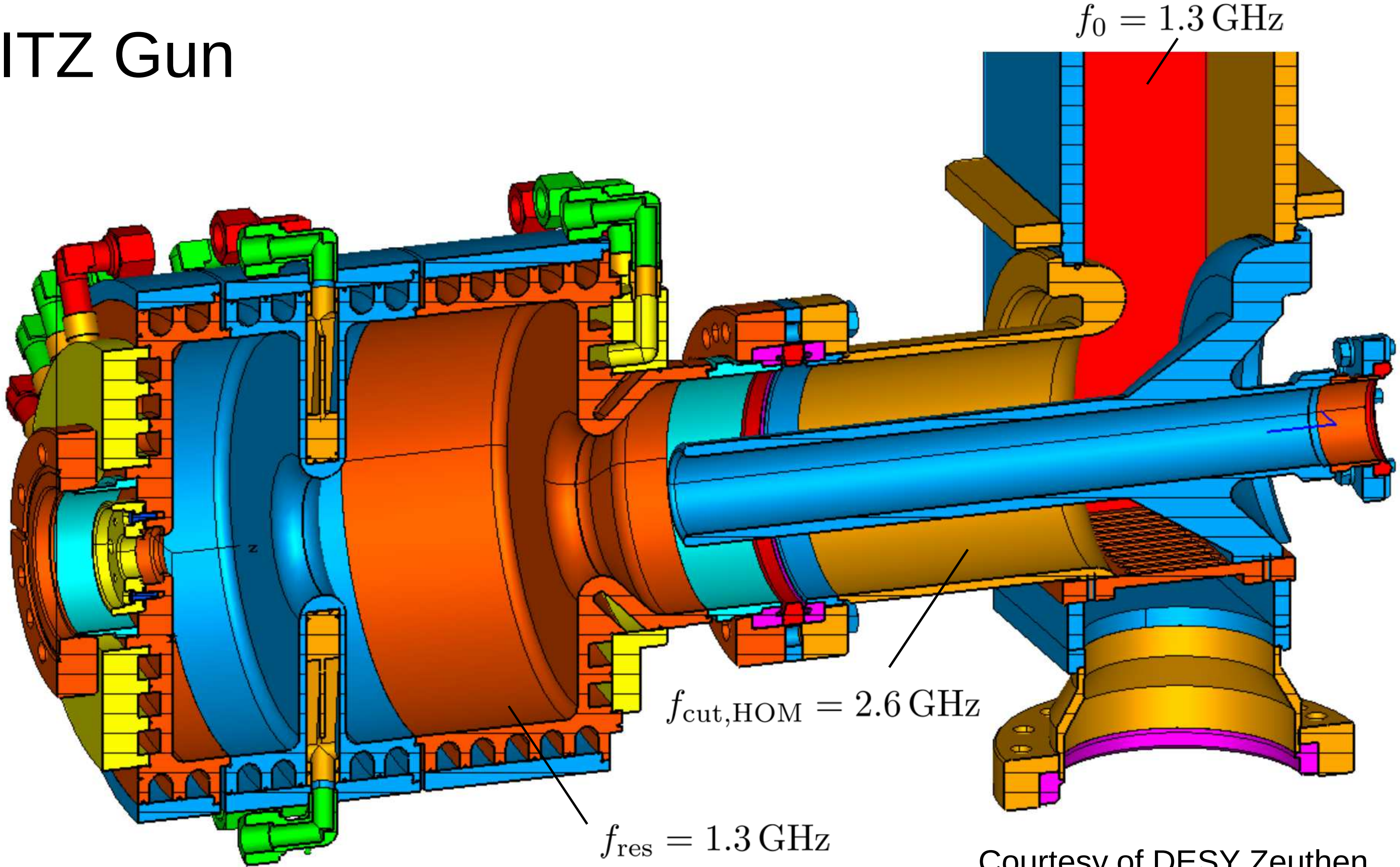
Motivation

- PITZ Gun



Courtesy of DESY Zeuthen

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Computational Model

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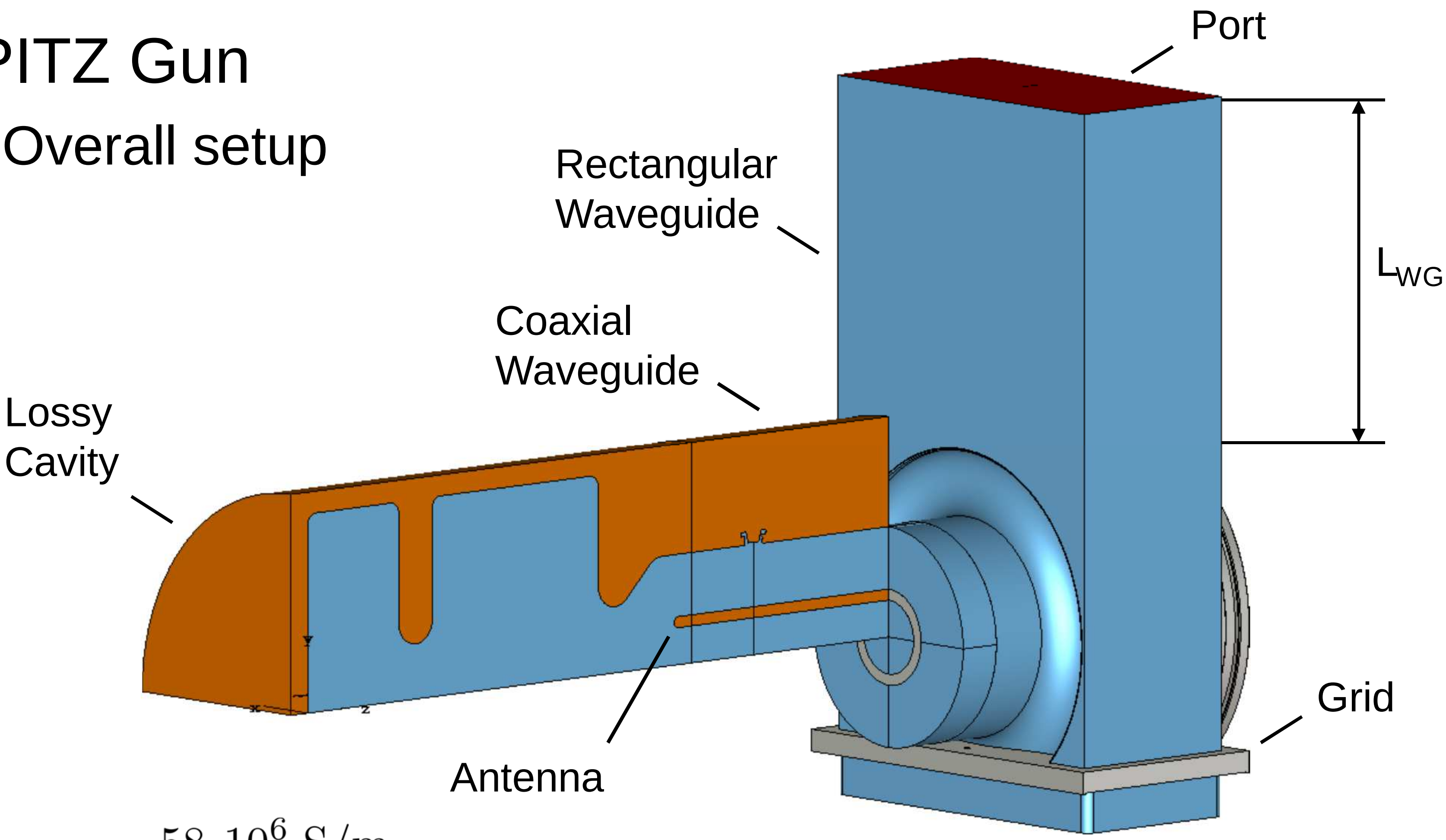
- Approach
  - Frequency domain (driven problem) ✓ → Ye Chen
    - Frequency and imposed mode magnitude fixed
    - Find antenna coupling such that reflection is minimal under the resonance condition in the cavity
  - Frequency domain (real eigenvalue with complex arithmetic) ✗
    - Determine magnitude of incident and reflected modes at the port interface
    - Find antenna coupling such that reflection is minimal
  - Frequency domain (complex eigenvalue) ✓
    - Change propagation direction of the fundamental port mode
    - Find antenna coupling such that $Q_{ext} = Q_{loss}$

Computational Model

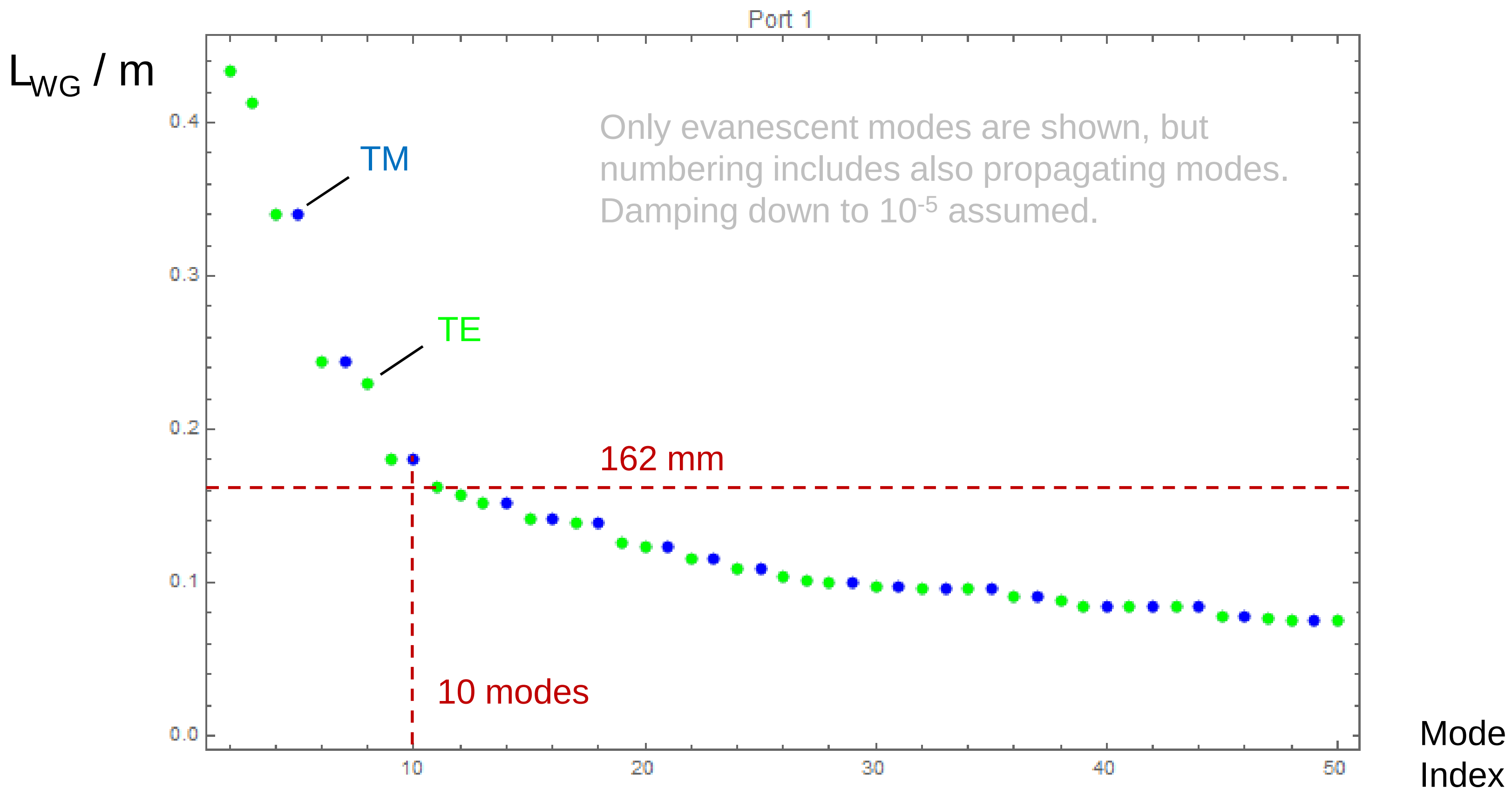
- PITZ Gun
  - Overall setup



$$\sigma_{\text{Copper}} = 58 \cdot 10^6 \ \text{S/m}$$

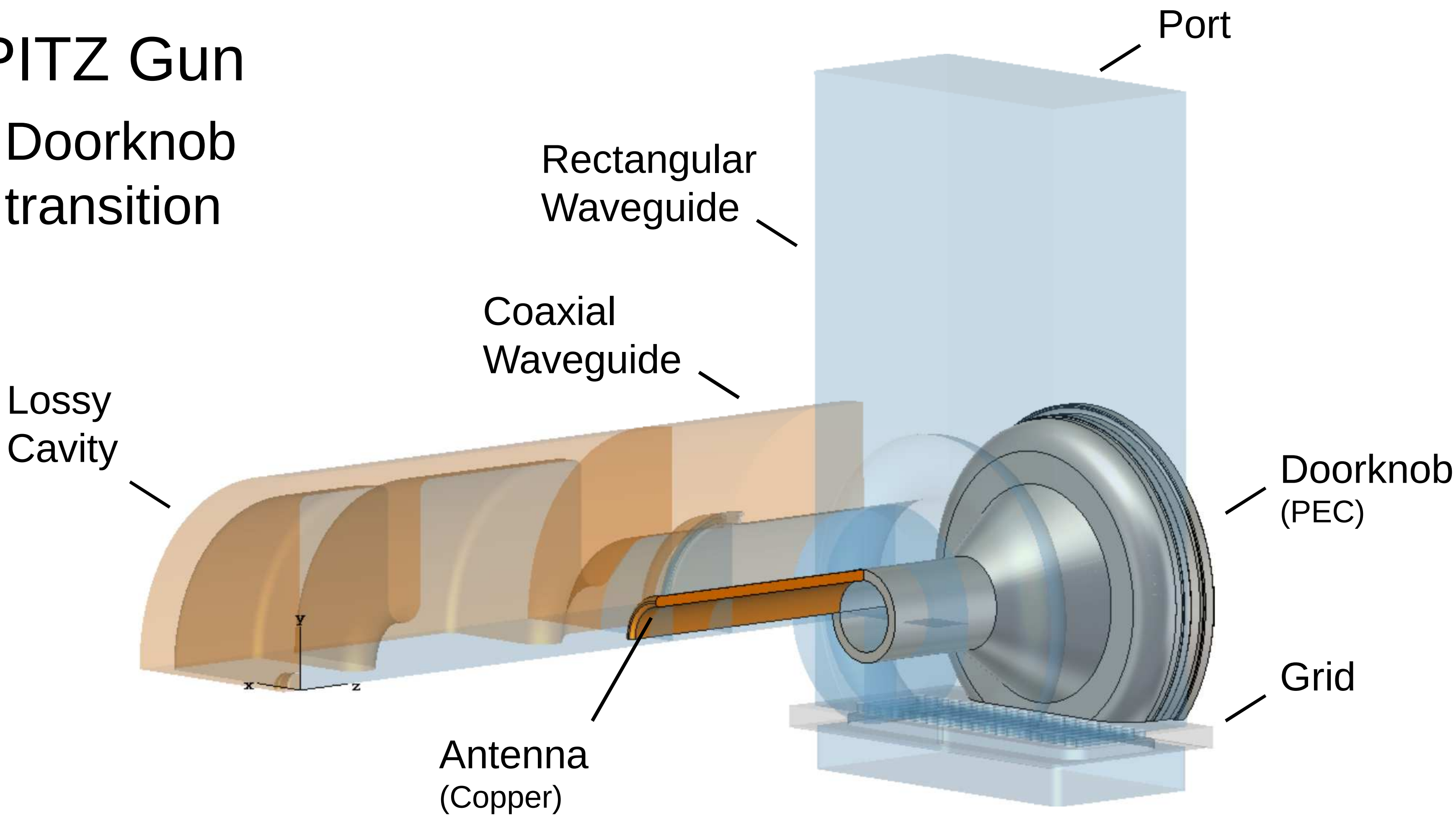
Computational Model

- PITZ Gun



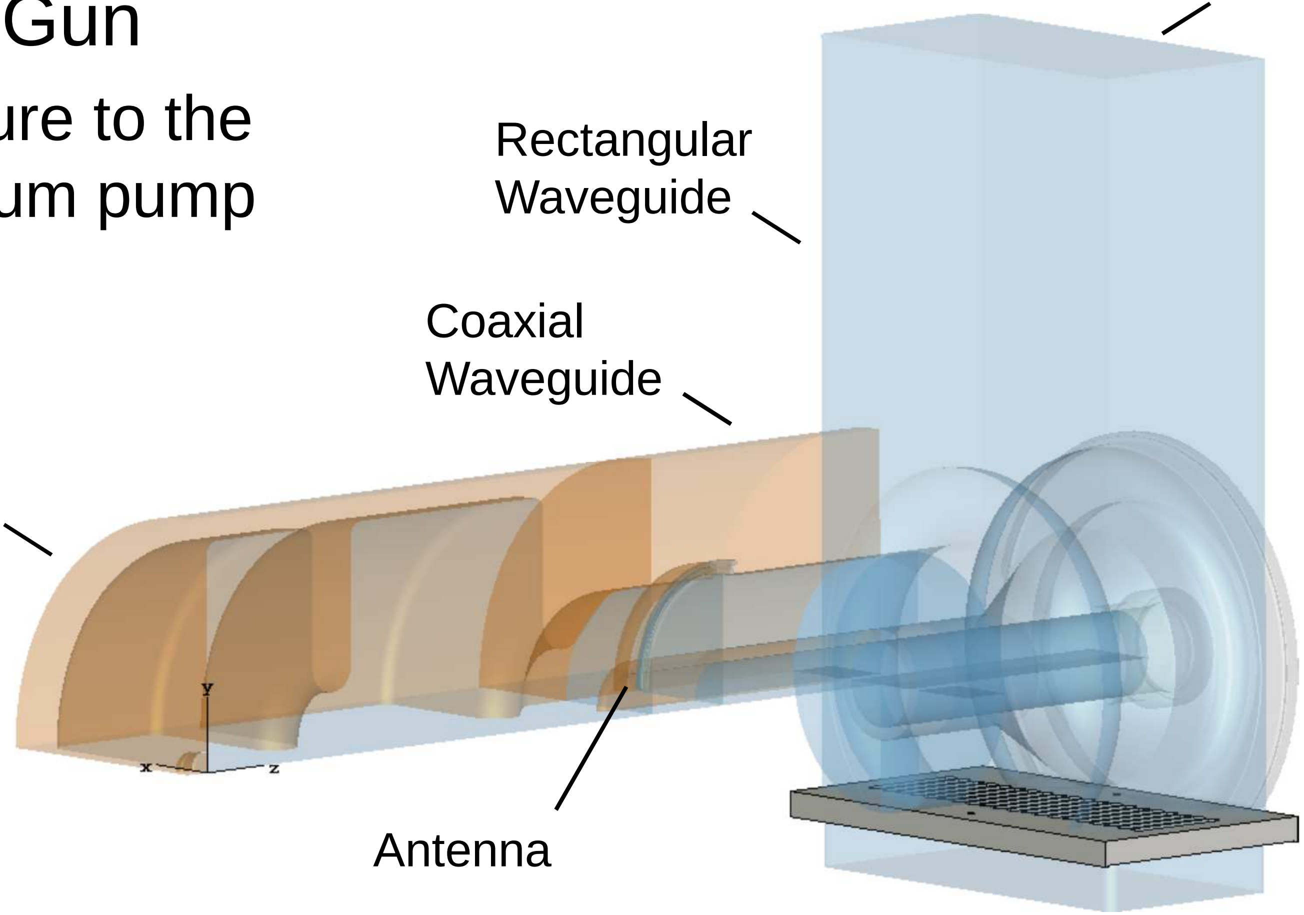
Computational Model

- PITZ Gun
  - Doorknob transition



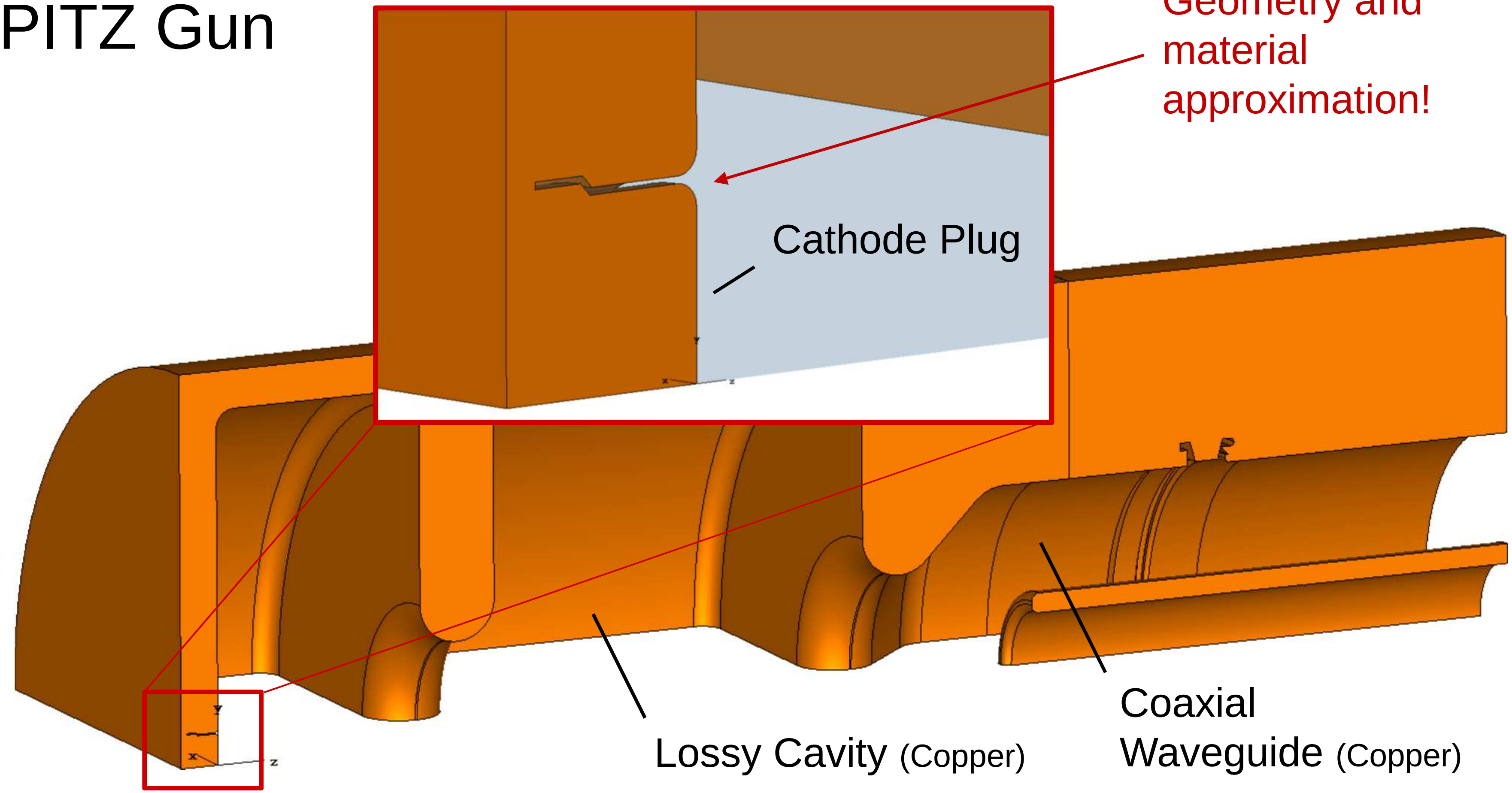
Computational Model

- PITZ Gun
  - Closure to the vacuum pump



Computational Model

- PITZ Gun



M. Otevrel, „Report on Gun Conditioning Activities at PITZ in 2013"

Computational Model

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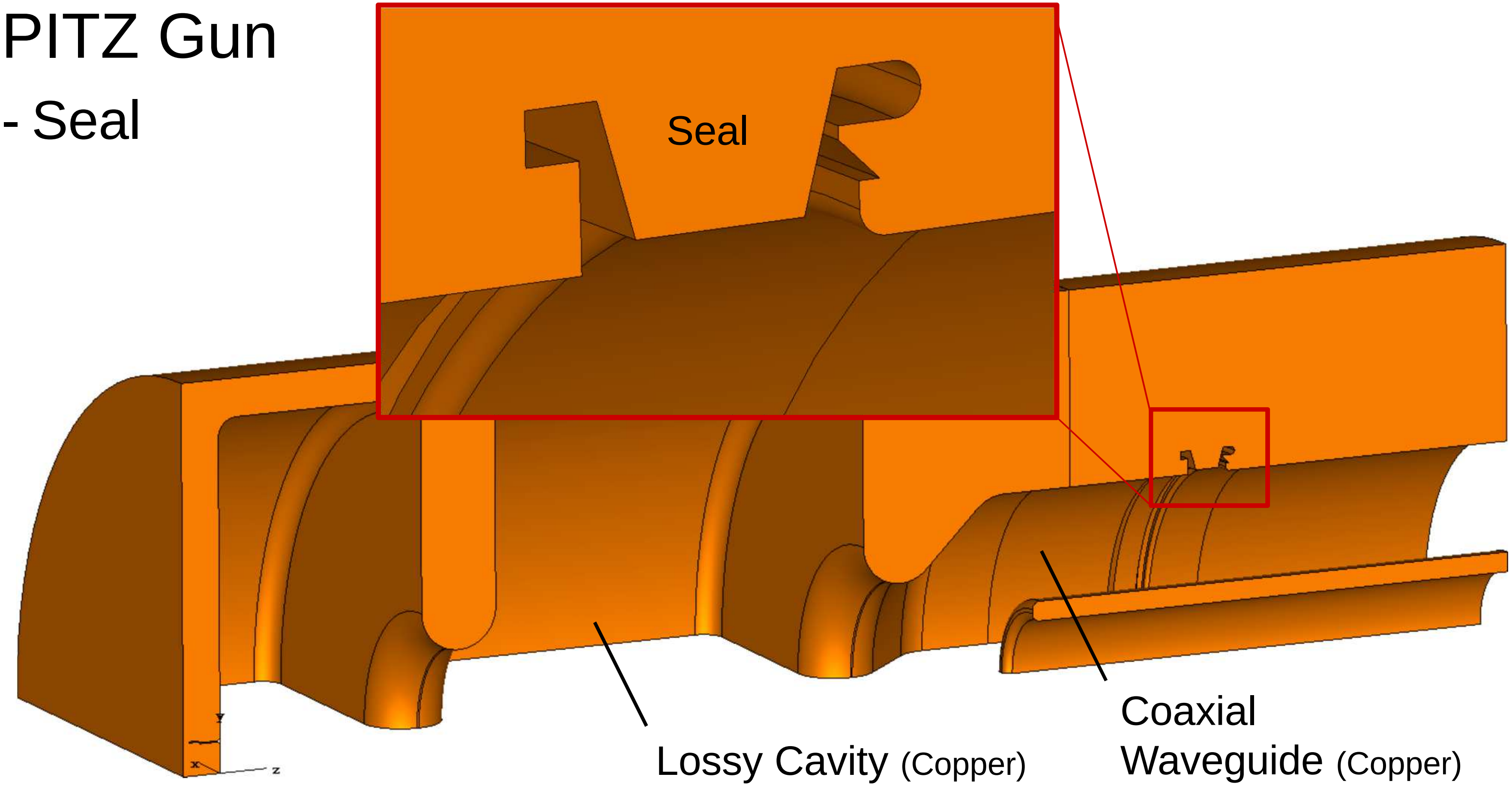
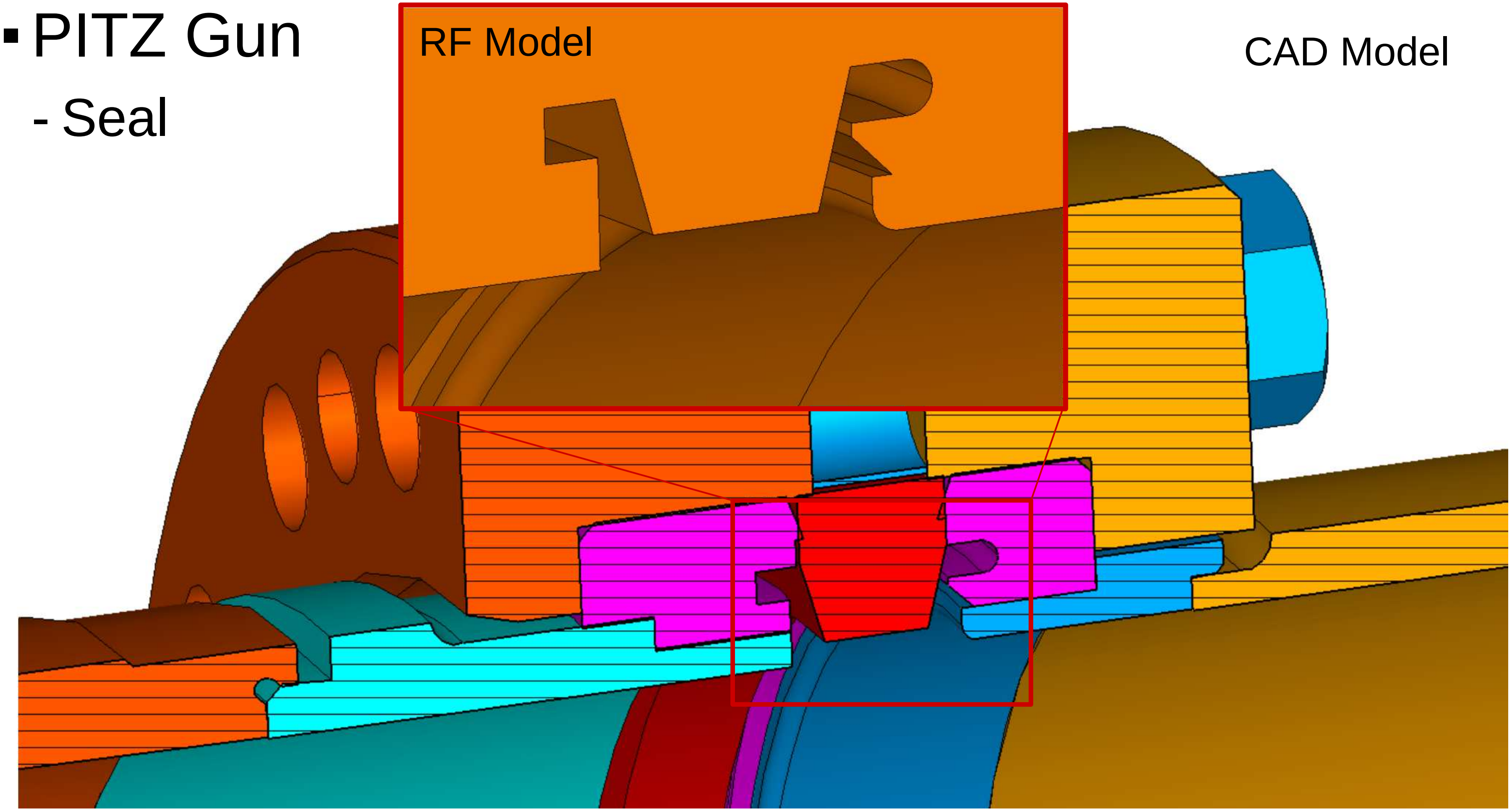
- PITZ Gun
  - Seal



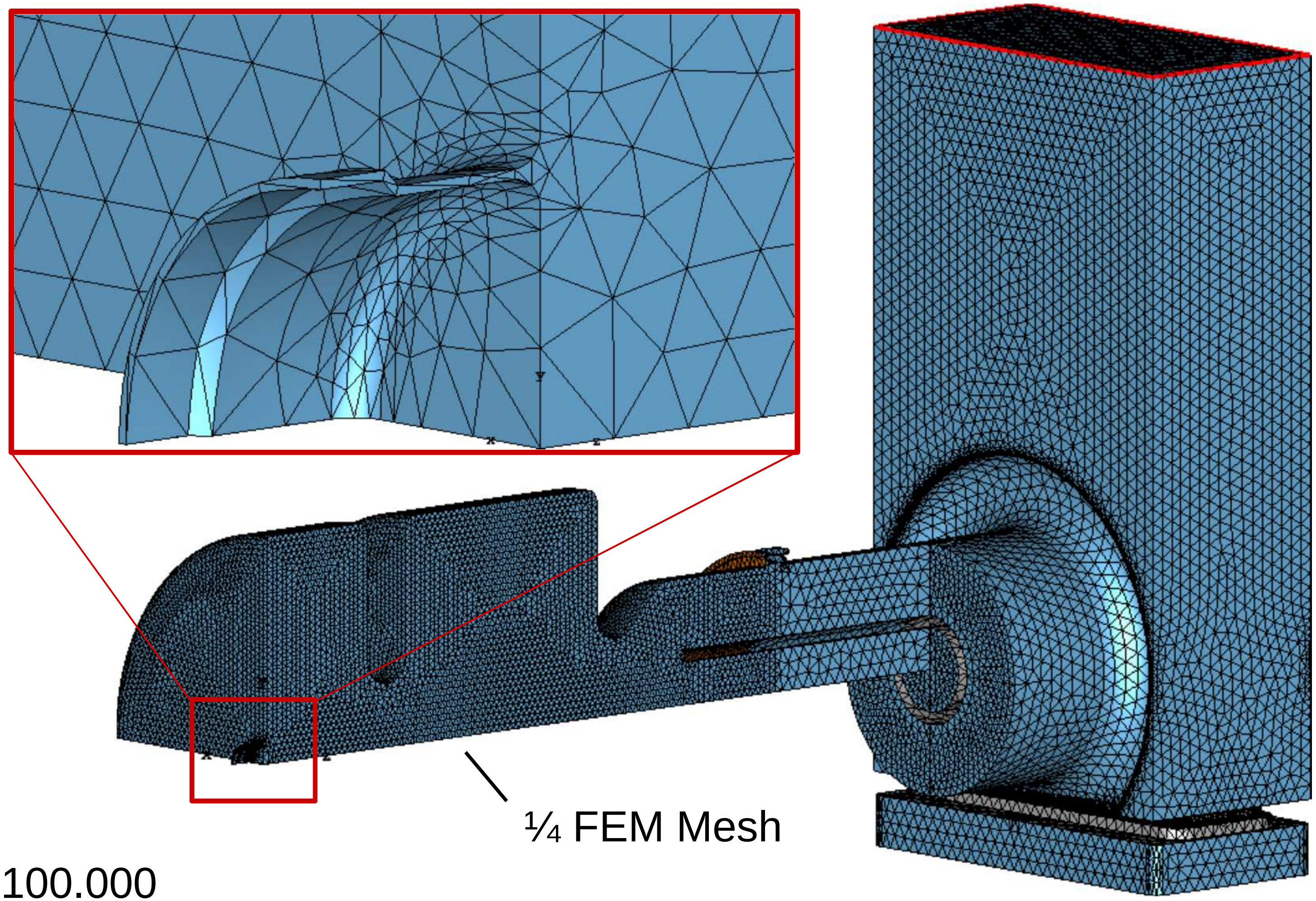
Computational Model

- PITZ Gun
  - Seal



Computational Model

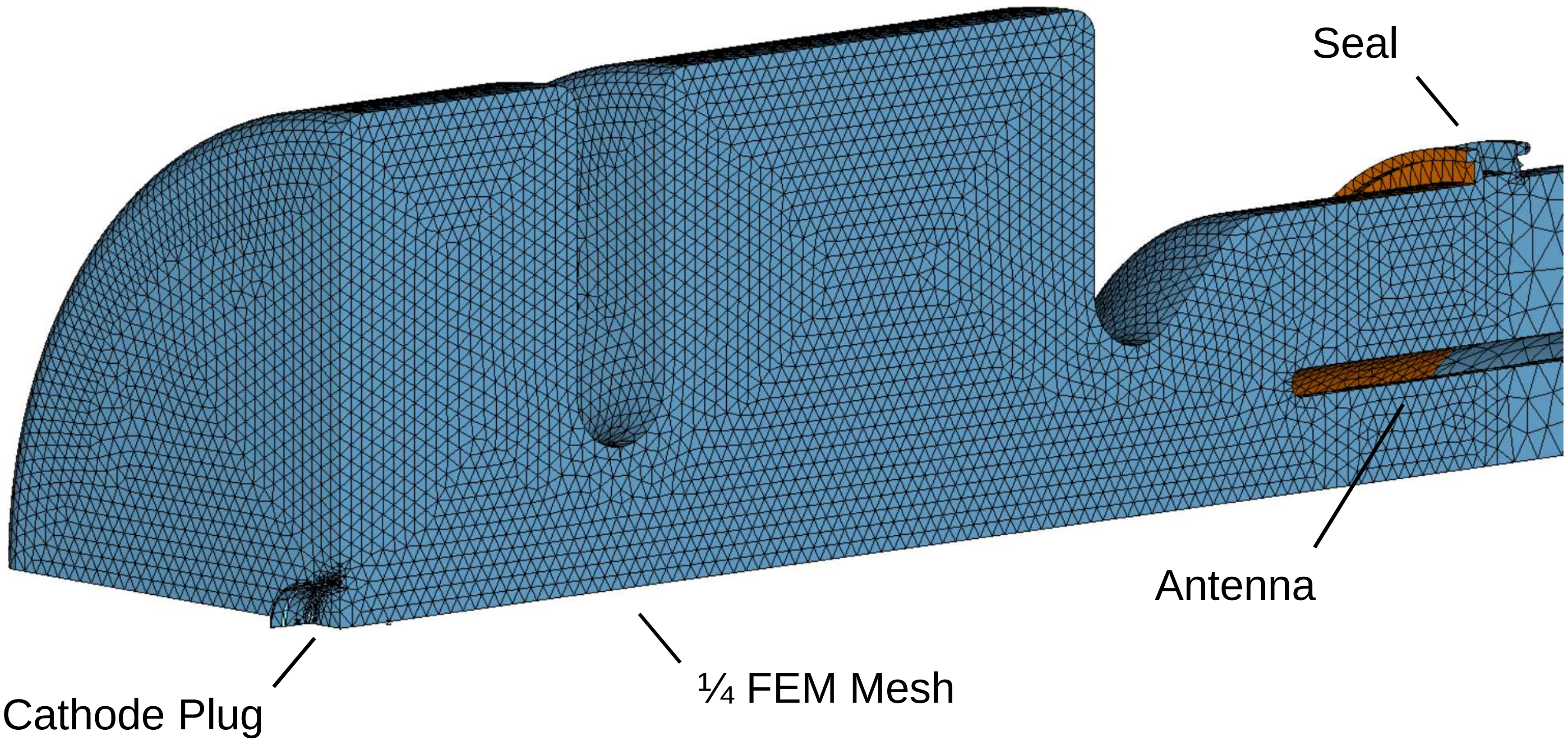
- Gun



$N_{tetra} \approx 2.100.000$

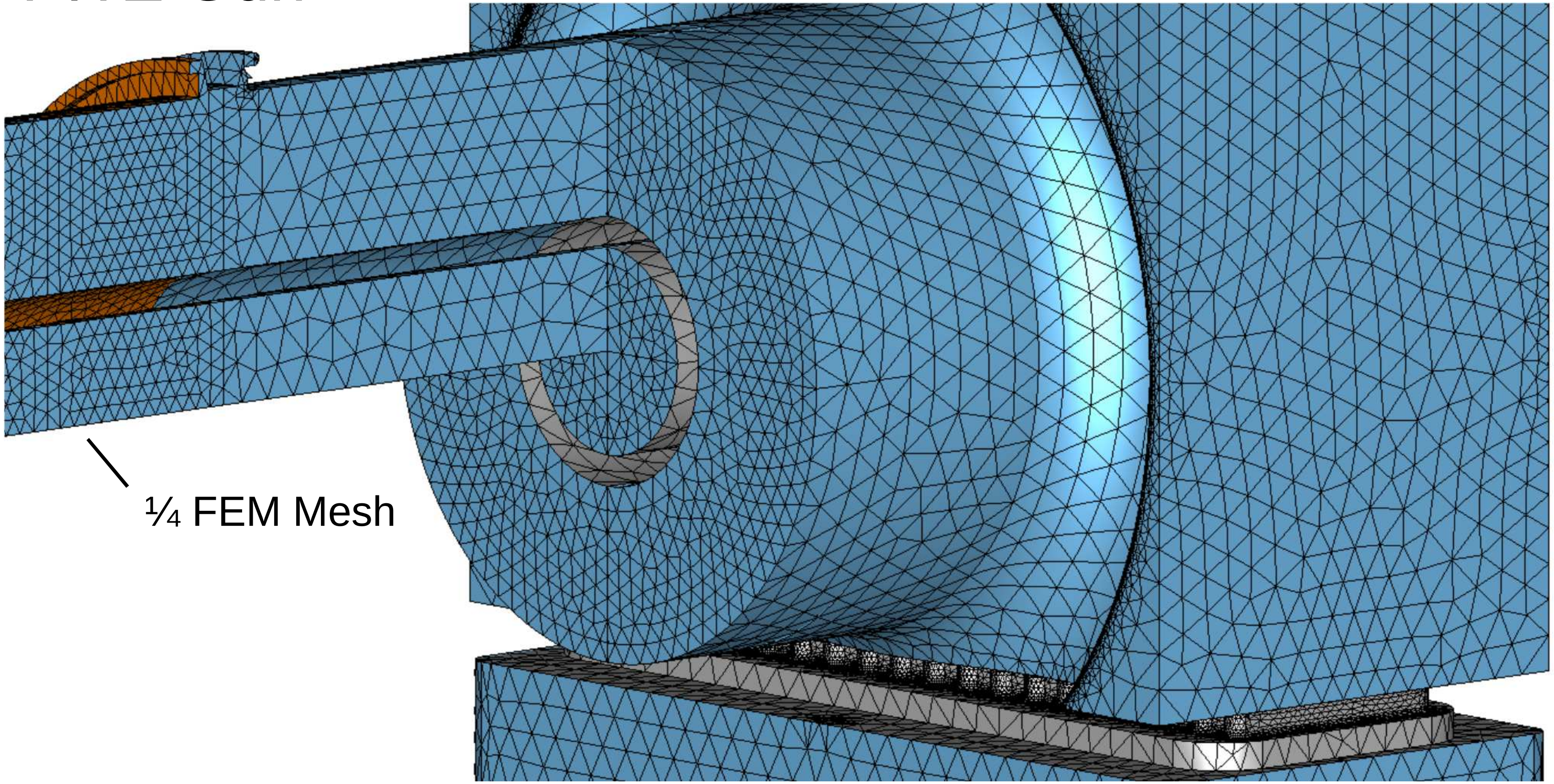
Computational Model

- PITZ Gun



Computational Model

- PITZ Gun



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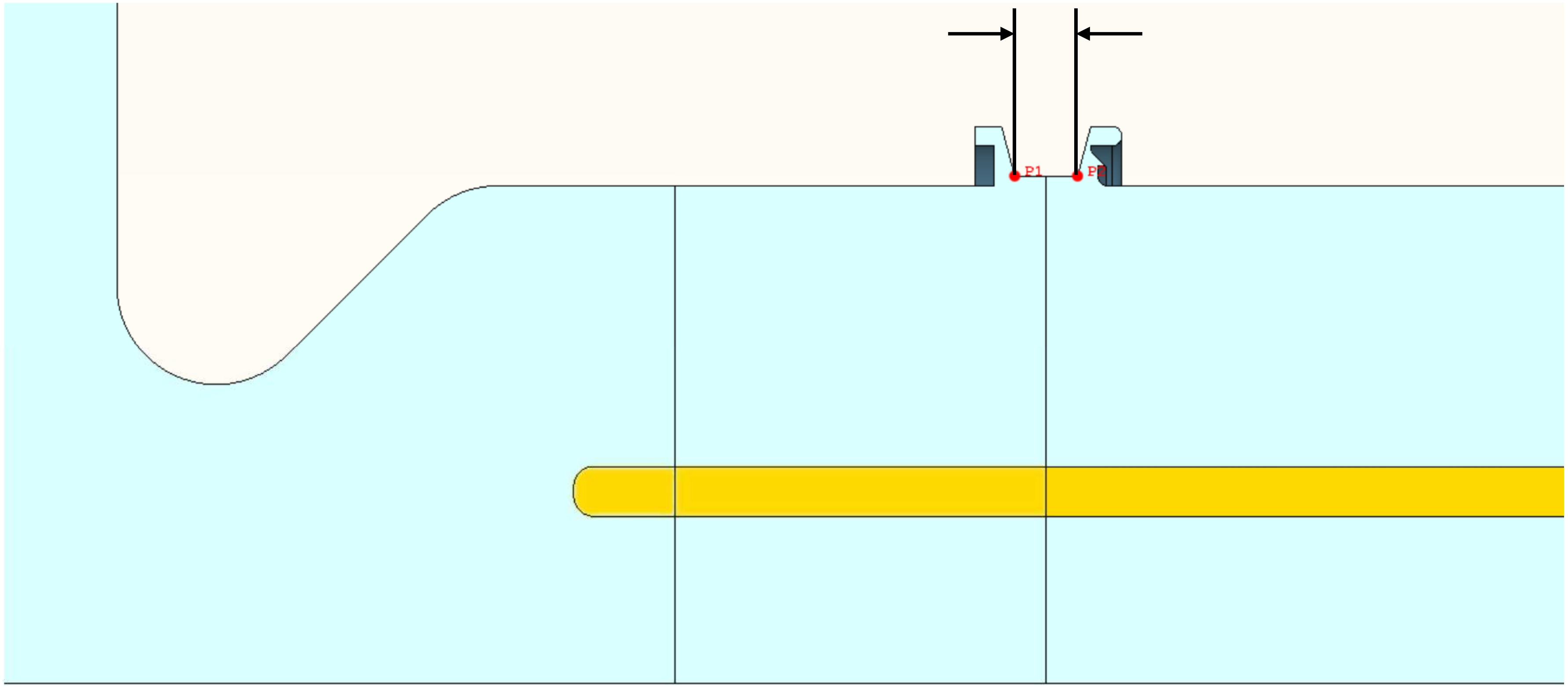
Simulation Results

- Antenna Tuning

Parameter: Seal Thickness

$6.32\,\mathrm{mm} + L_{\mathrm{coax}}$



Simulation Results

- Antenna Tuning (symmetric model without waveguide)
  - Untuned Cavity (half-cell and full-cell radii according to CAD model)

	L_coax	F	Q	Q_ext	Q_loss
1	-4.	1.30249×10^9	-151187.	-20003.4	23053.6
2	-3.	1.30249×10^9	-316441.	-21489.2	23054.9
3	-2.	1.30249×10^9	6.44473×10^7	-23060.	23051.7
4	-1.	1.30249×10^9	337582.	-24748.4	23058.
5	0.	1.30249×10^9	173397.	-26571.7	23040.9
6	1.	1.30249×10^9	109268.	-29213.8	23051.
7	2.	1.3025×10^9	81910.9	-32089.	23056.5
8	3.	1.3025×10^9	66614.2	-35247.3	23050.6
9	4.	1.3025×10^9	56970.	-38716.	23050.9
10	5.	1.3025×10^9	50325.7	-42529.5	23050.2

untuned (F column)

$N_{tetra} \approx 580.000$

Simulation Results

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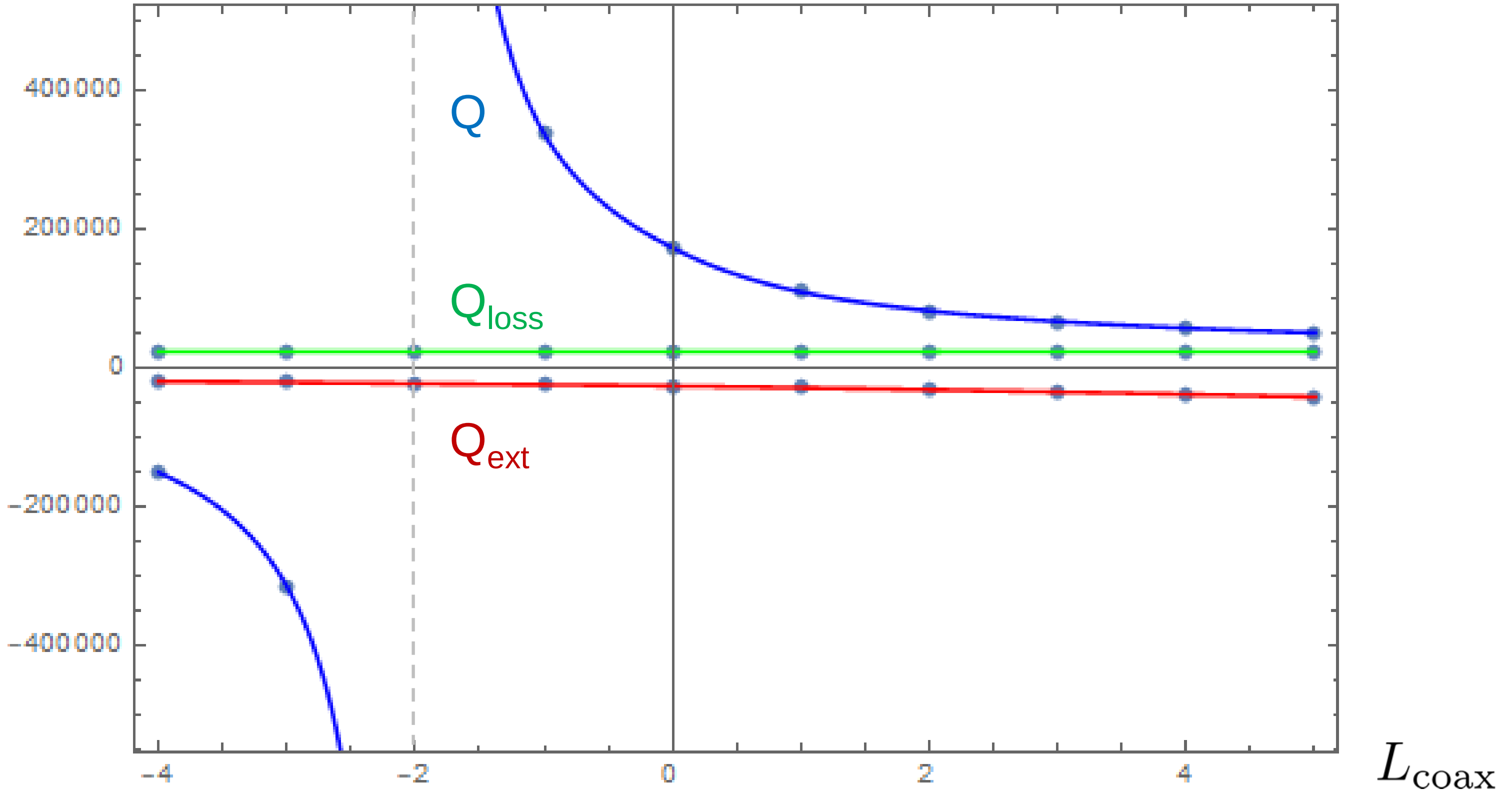
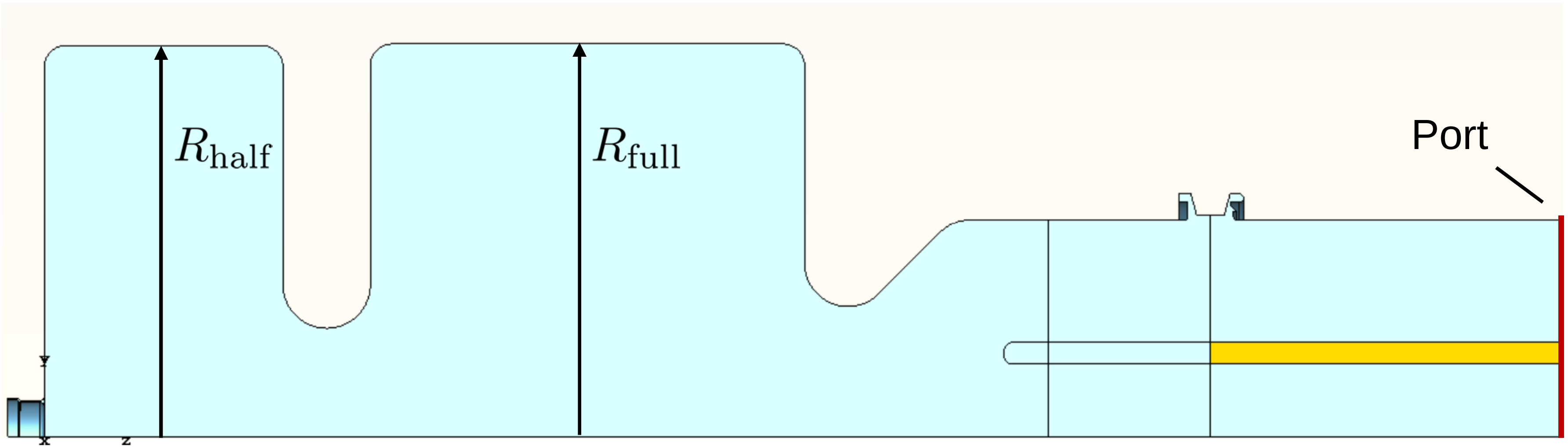
- Antenna Tuning (symmetric model without waveguide)
  - Untuned Cavity (half-cell and full-cell radii according to CAD model)



Simulation Results

- Cavity Tuning
  - Rotationally symmetric model

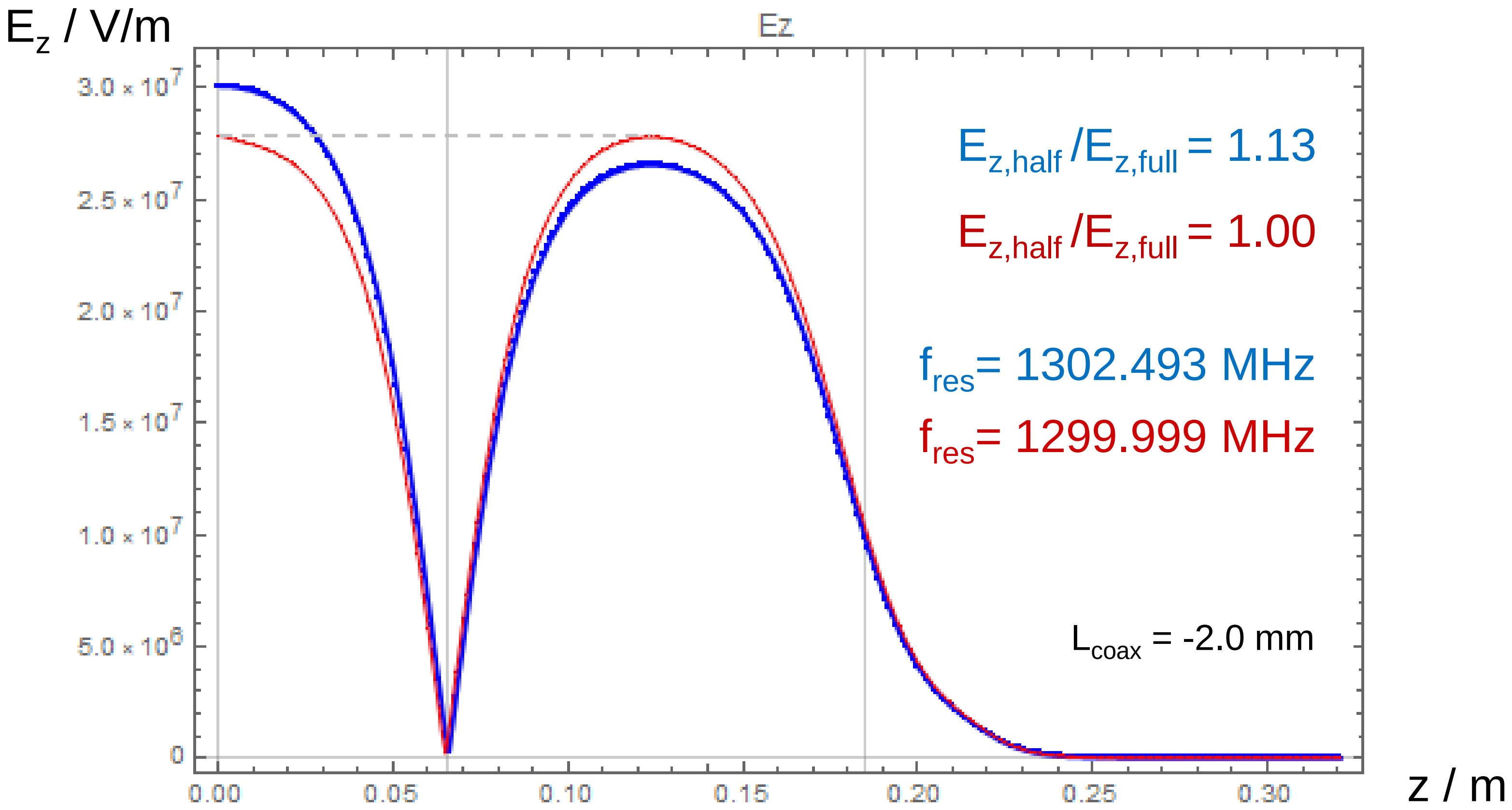


Simulation Results

- Cavity Tuning

R_{half} = (89.95+0.234-0.048+0.012) mm = 90.148 mm

R_{full} = (90.32+0.172-0.021+0.002) mm = 90.473 mm



Simulation Results

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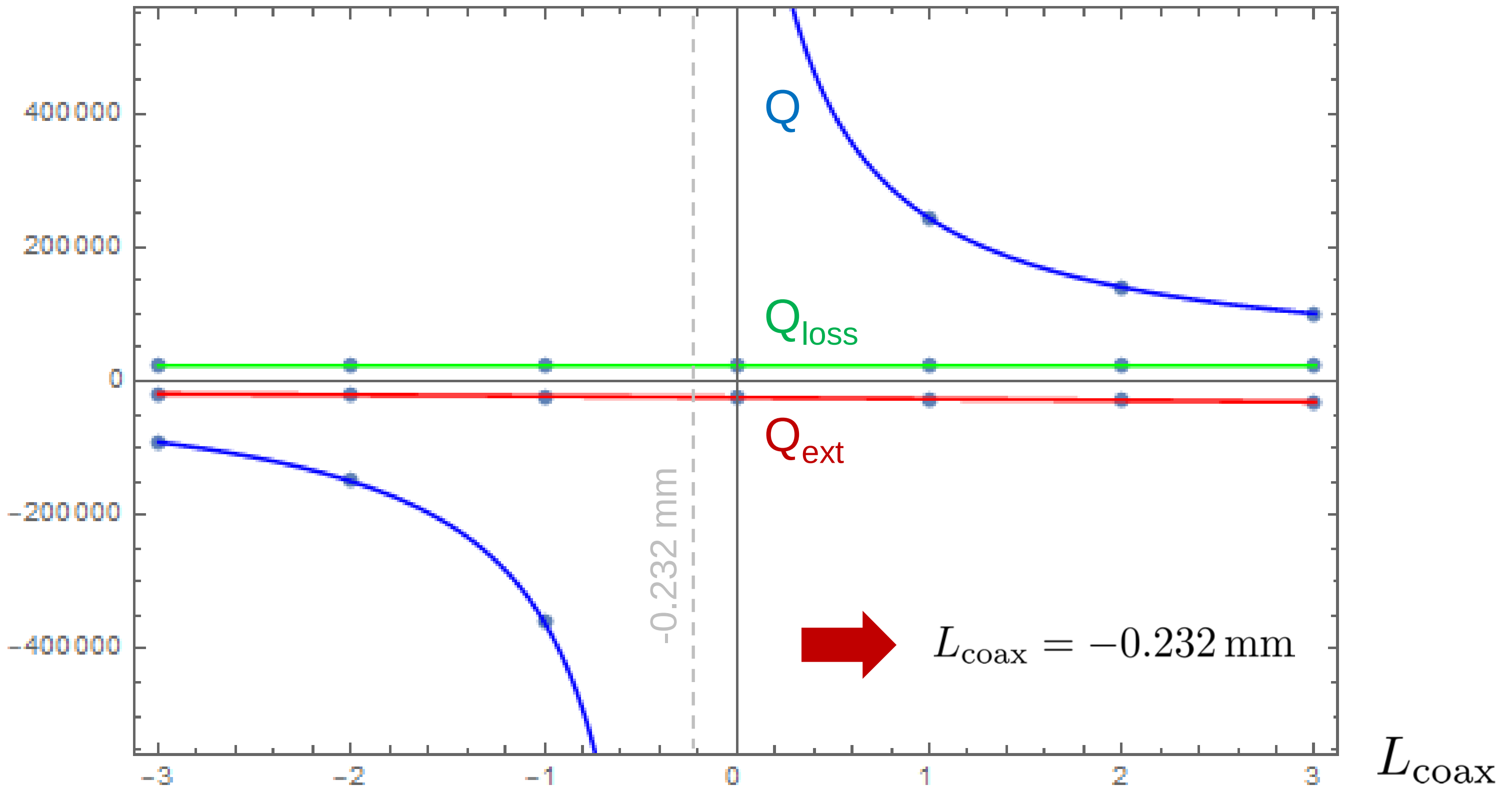
- Antenna Tuning
  - Tuned Cavity (R_{half} = 90.148 mm, R_{full} = 90.473 mm)

	L_coax	F	Q	Q_ext	Q_loss
1	-3.	1.3×10^9	-91023.3	-18714.7	23558.4
2	-2.	1.3×10^9	-149064.	-20344.5	23560.
3	-1.	1.3×10^9	-358763.	-22109.9	23562.
4	0.	1.3×10^9	1.23961×10^6	-24020.	23563.4
5	1.	1.3×10^9	243383.	-26088.5	23562.8
6	2.	1.3×10^9	140128.	-28325.6	23562.6
7	3.	1.3×10^9	100848.	-30746.8	23562.9

$N_{tetra} \approx 2.100.000$

Simulation Results

- Antenna Tuning
  - Untuned Cavity (half-cell and full-cell radii according to CAD model)

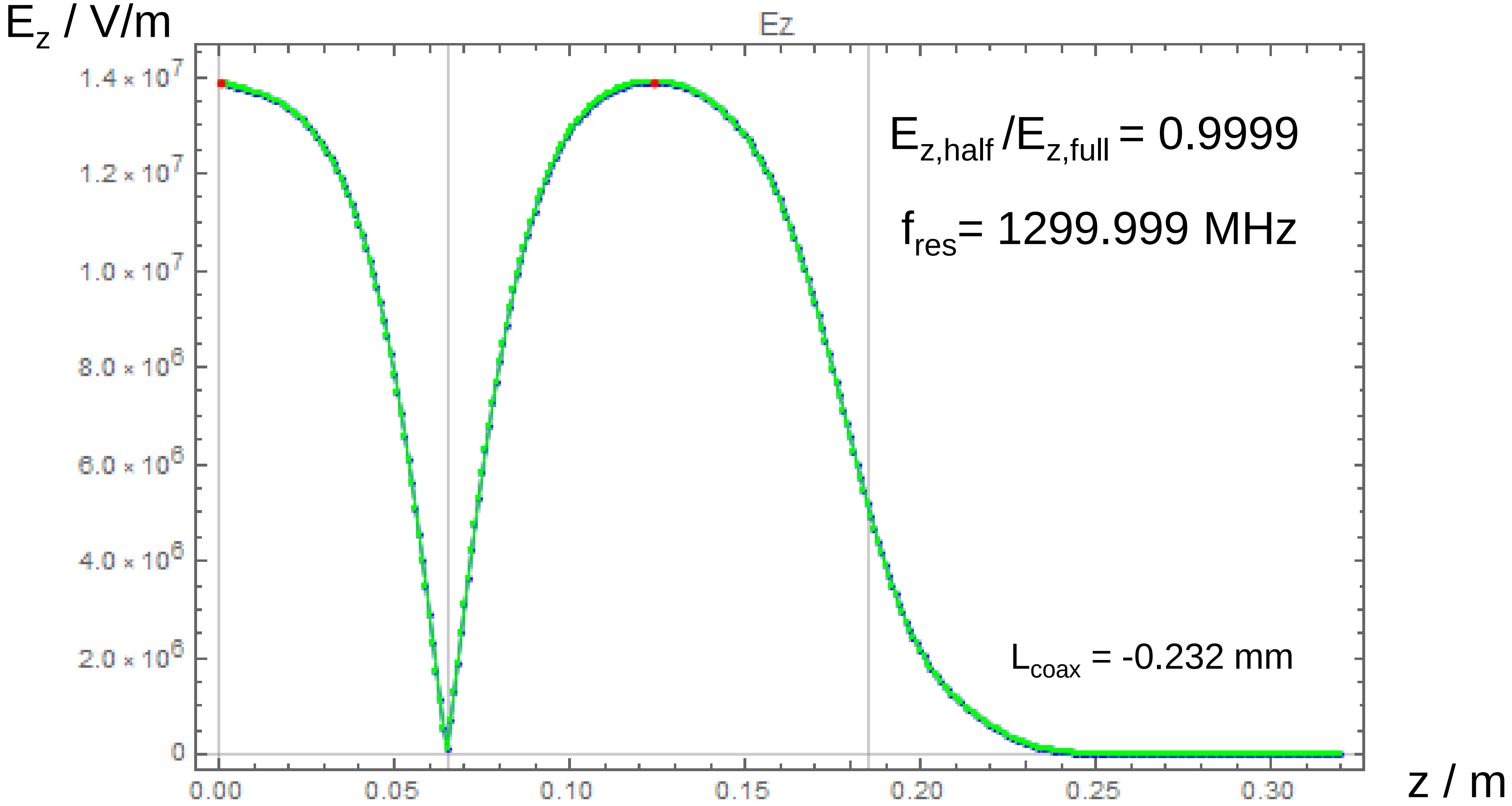


Simulation Results

- Cavity Tuning

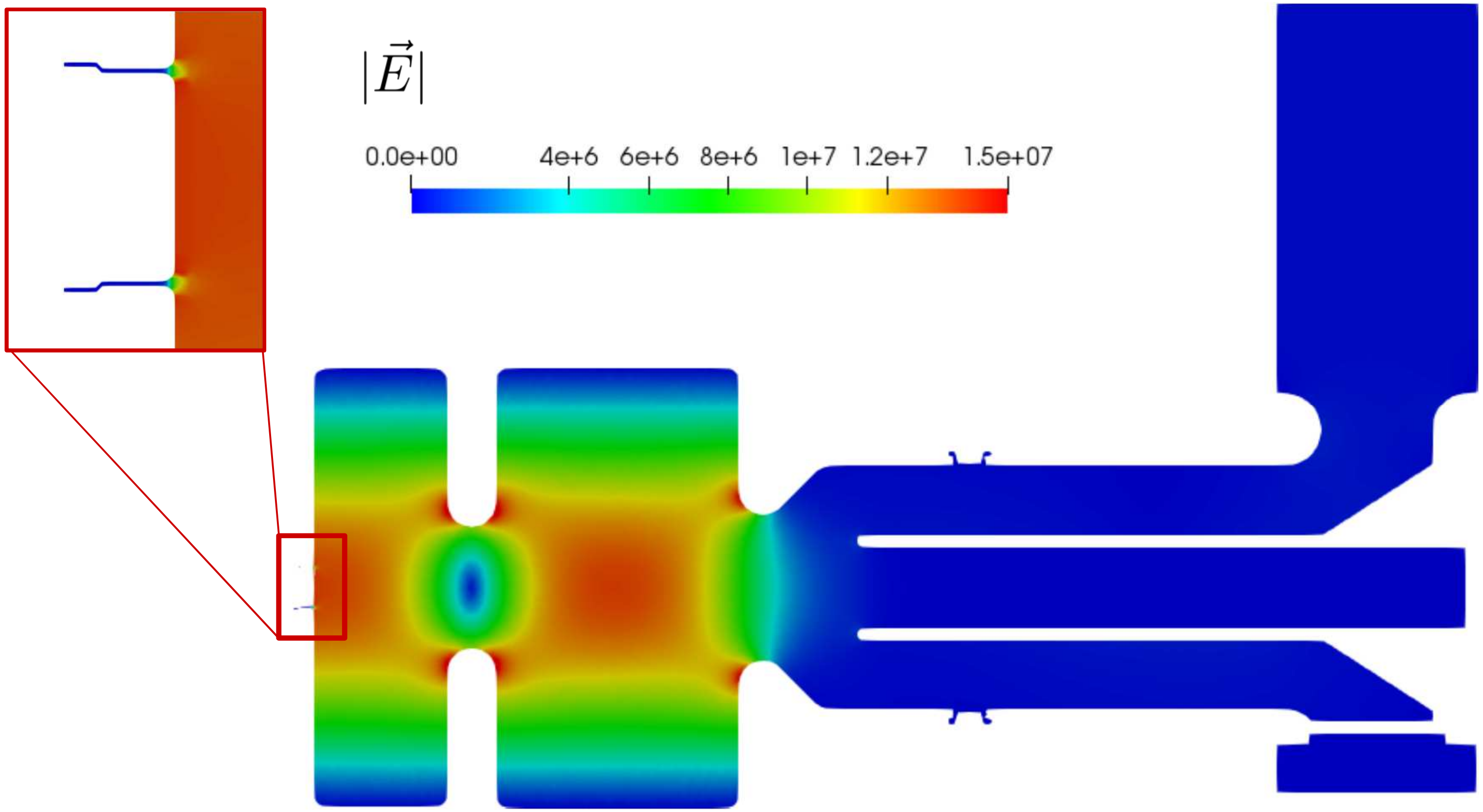
R_{half} = (90.148 + 0.000) mm

R_{full} = (90.473 + 0.000) mm



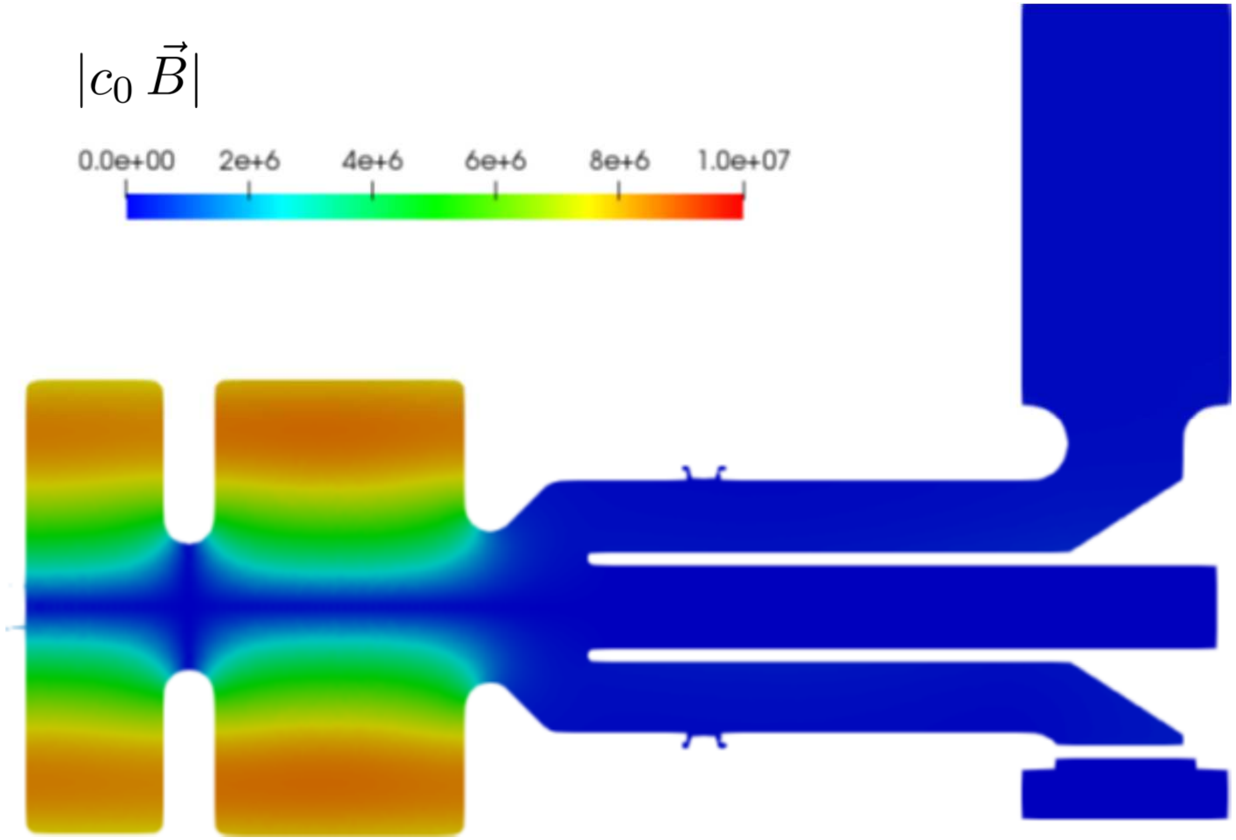
Simulation Results

- Electric Field Strength $|\vec{E}| = \sqrt{\vec{E} \cdot \vec{E}^*}$



Simulation Results

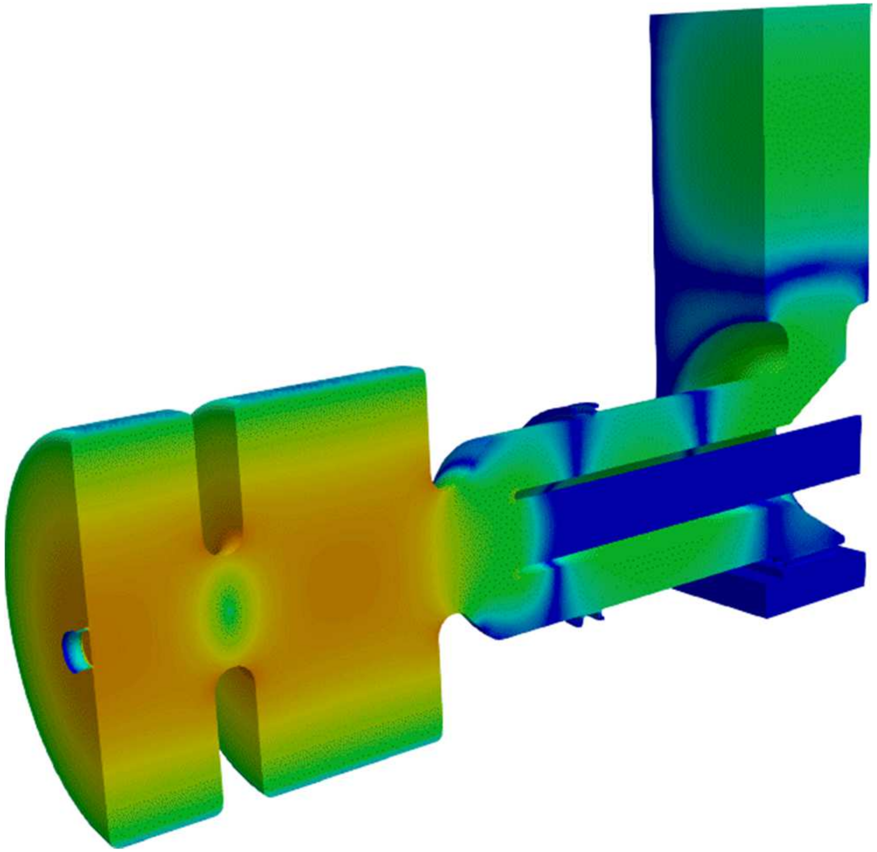
- Magnetic Flux Density $|\vec{B}| = \sqrt{\vec{B} \cdot \vec{B}^*}$



Simulation Results

- Electric Field Strength $\vec{E}(t) = \mathrm{Re}(\vec{E} \cdot e^{i\omega t})$

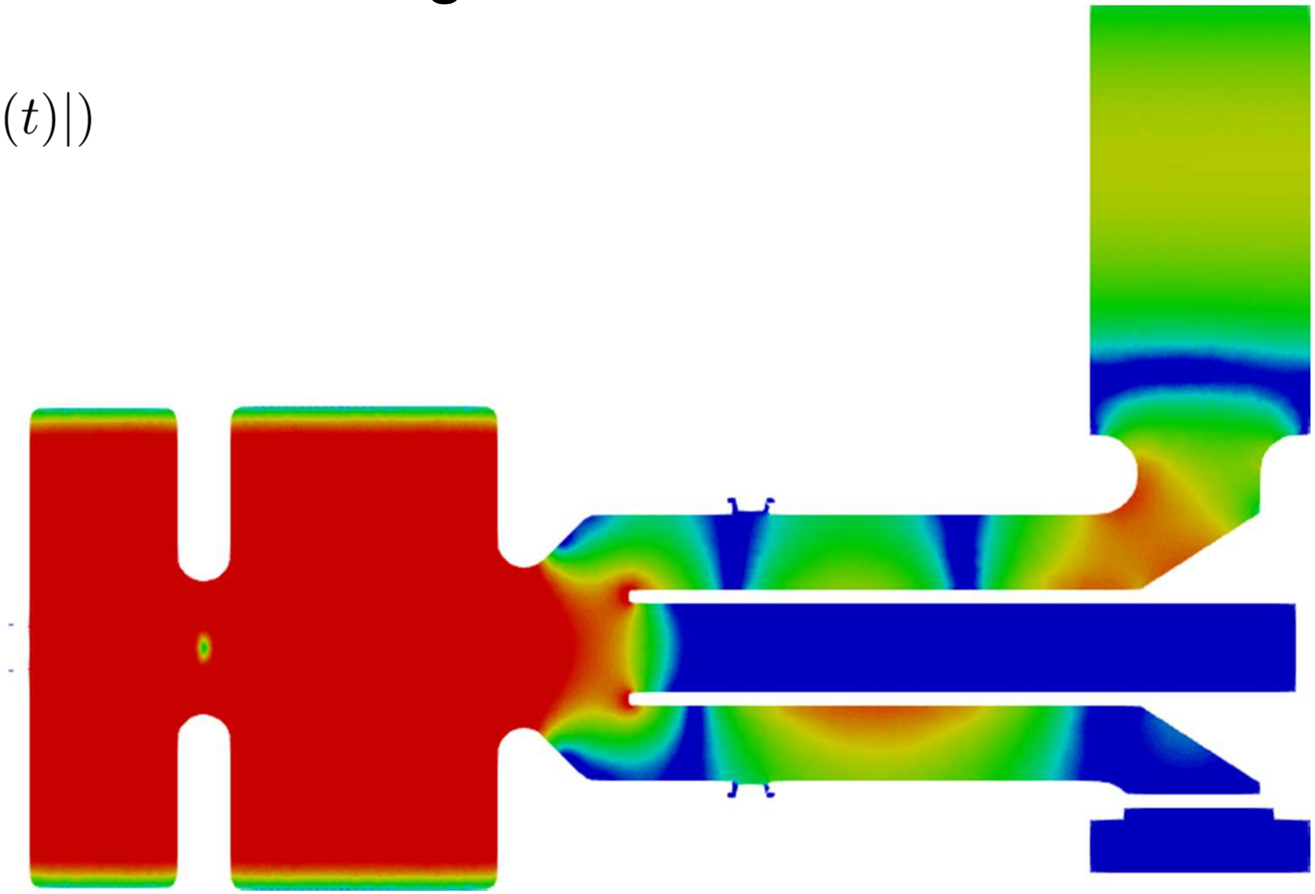
$\mathrm{Log}(|\vec{E}(t)|)$



Simulation Results

- Electric Field Strength $\vec{E}(t) = \mathrm{Re}(\vec{E} \cdot e^{i\omega t})$

$\mathrm{Log}(|\vec{E}(t)|)$

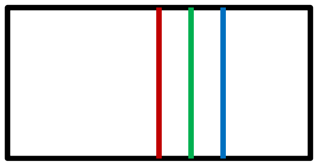


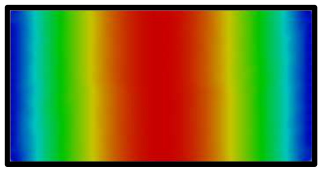
Simulation Results

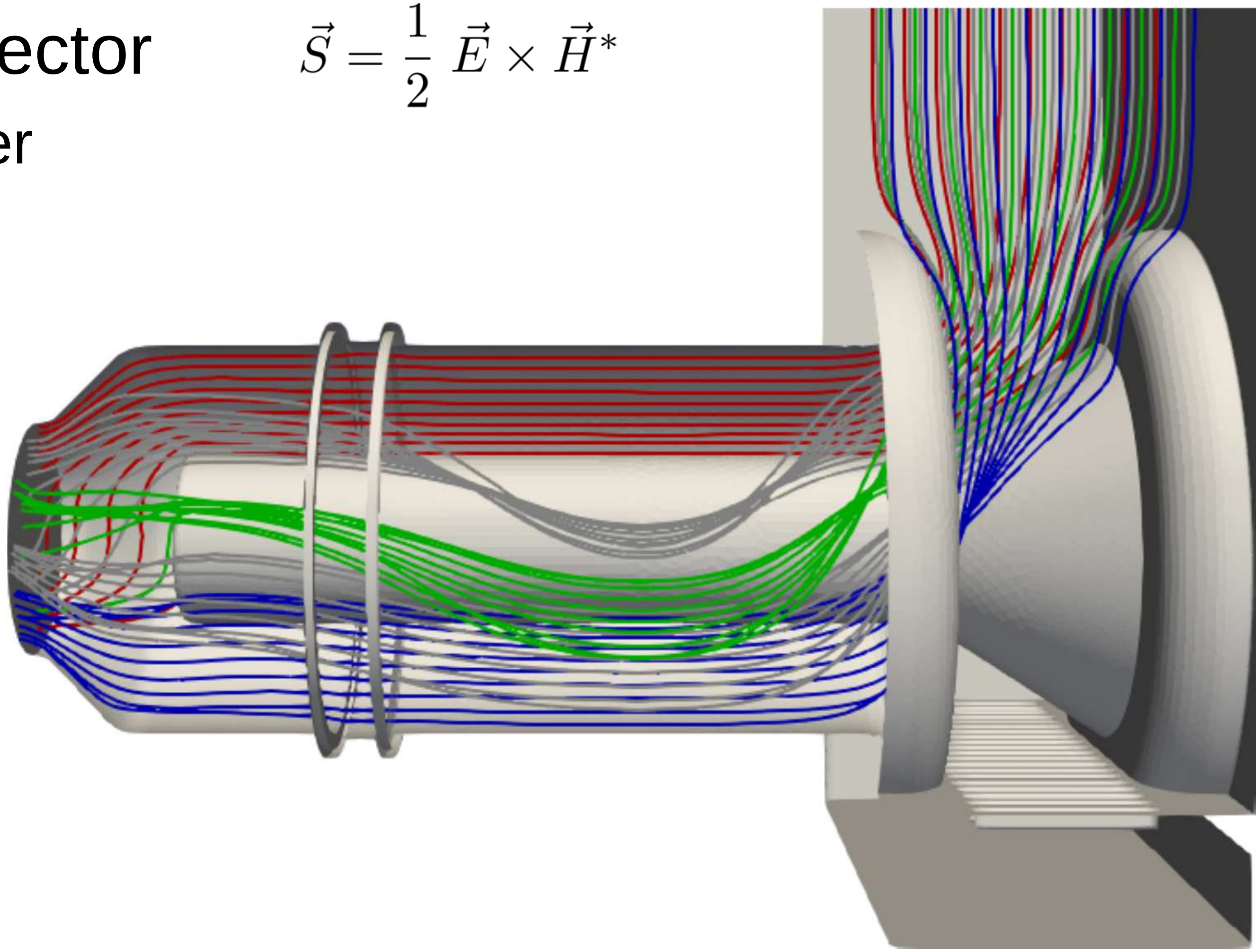
- Poynting Vector
  - Active power

$$\vec{S} = \frac{1}{2}\,\vec{E} \times \vec{H}^*$$

$$\mathrm{Re}(\vec{S}\,)$$



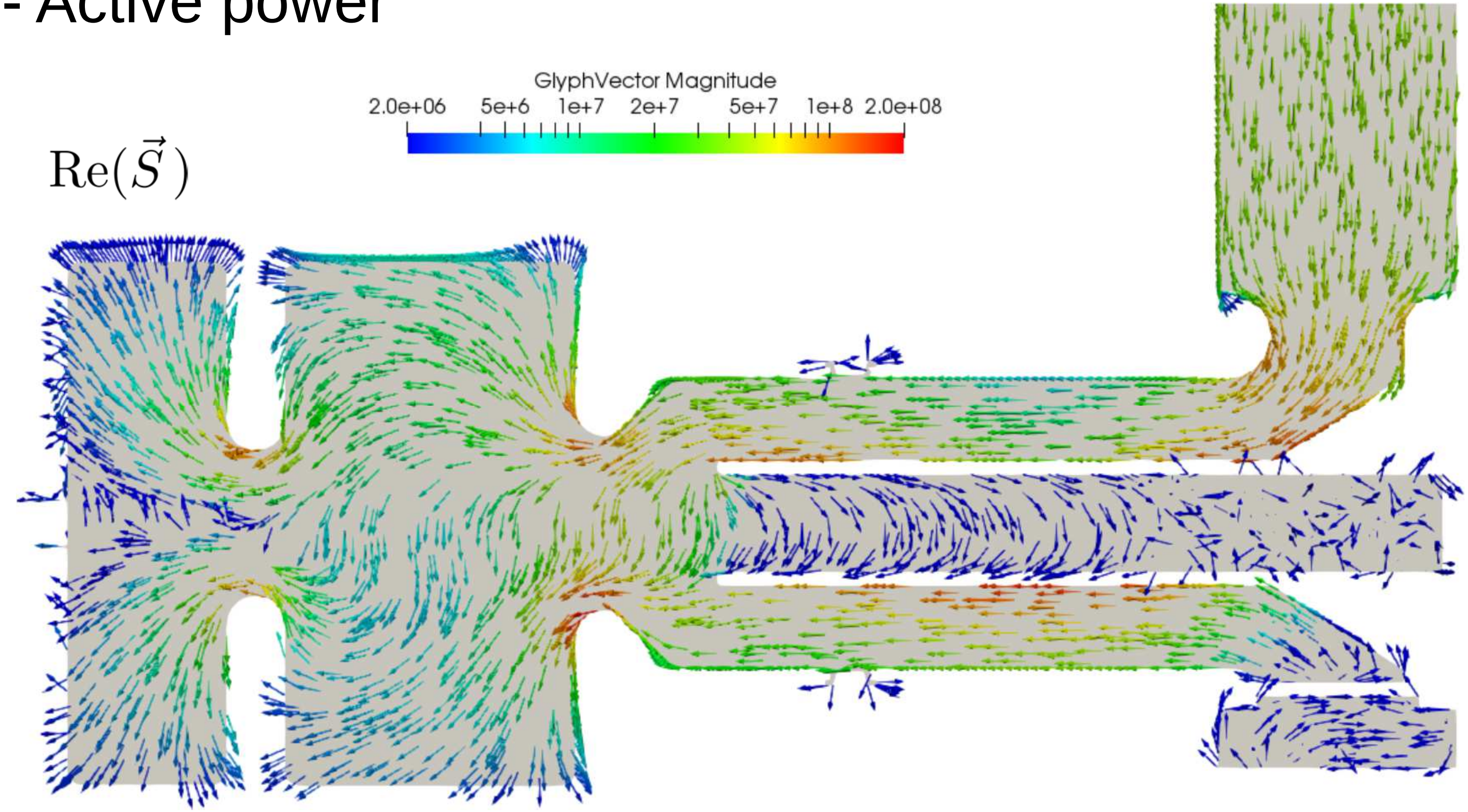




Simulation Results

- Poynting Vector $\vec{S} = \frac{1}{2}\,\vec{E} \times \vec{H}^*$
  - Active power

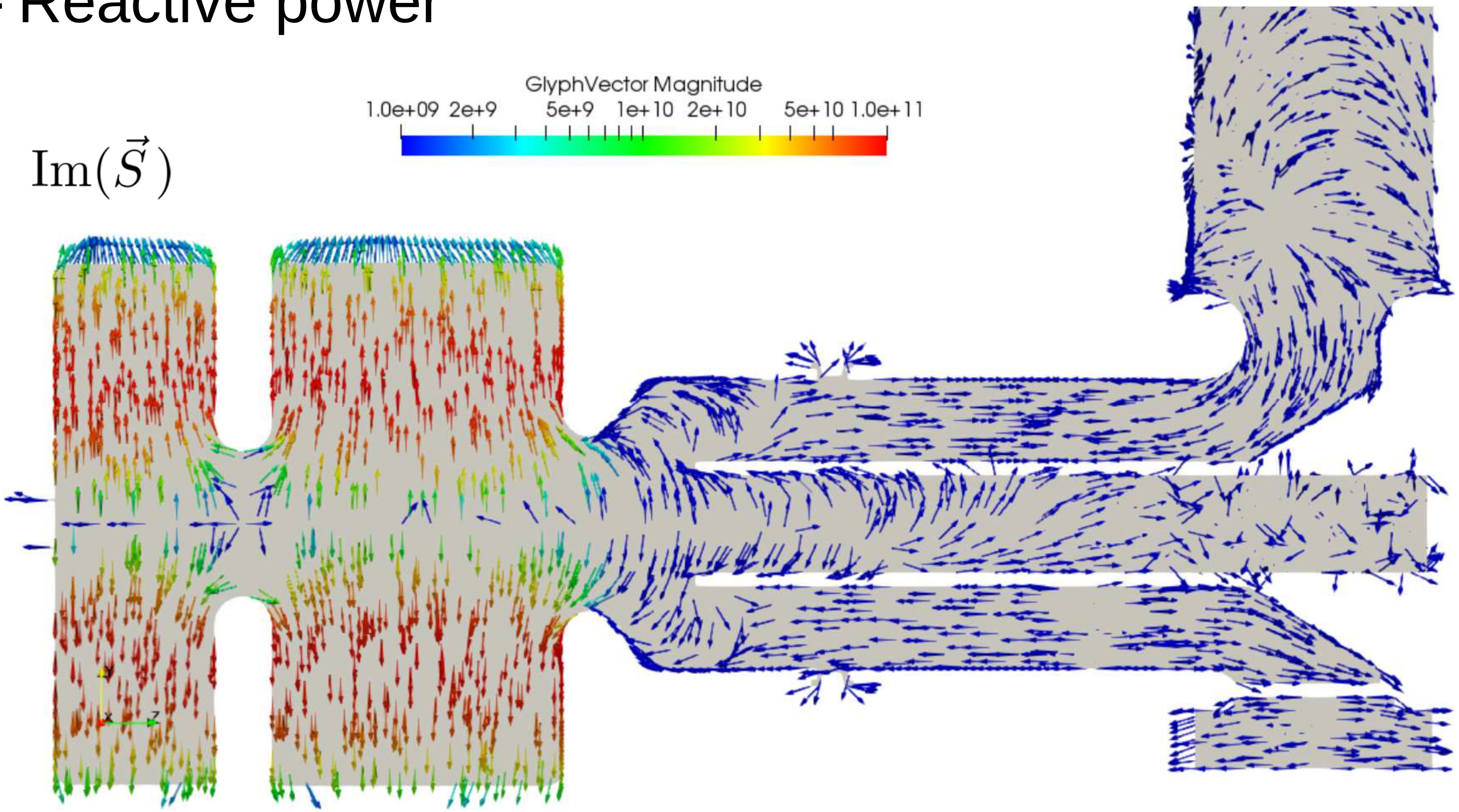
$\mathrm{Re}(\vec{S}\,)$



Simulation Results

- Poynting Vector $\vec{S} = \frac{1}{2}\,\vec{E} \times \vec{H}^*$
  - Reactive power

$\mathrm{Im}(\vec{S})$



Simulation Results

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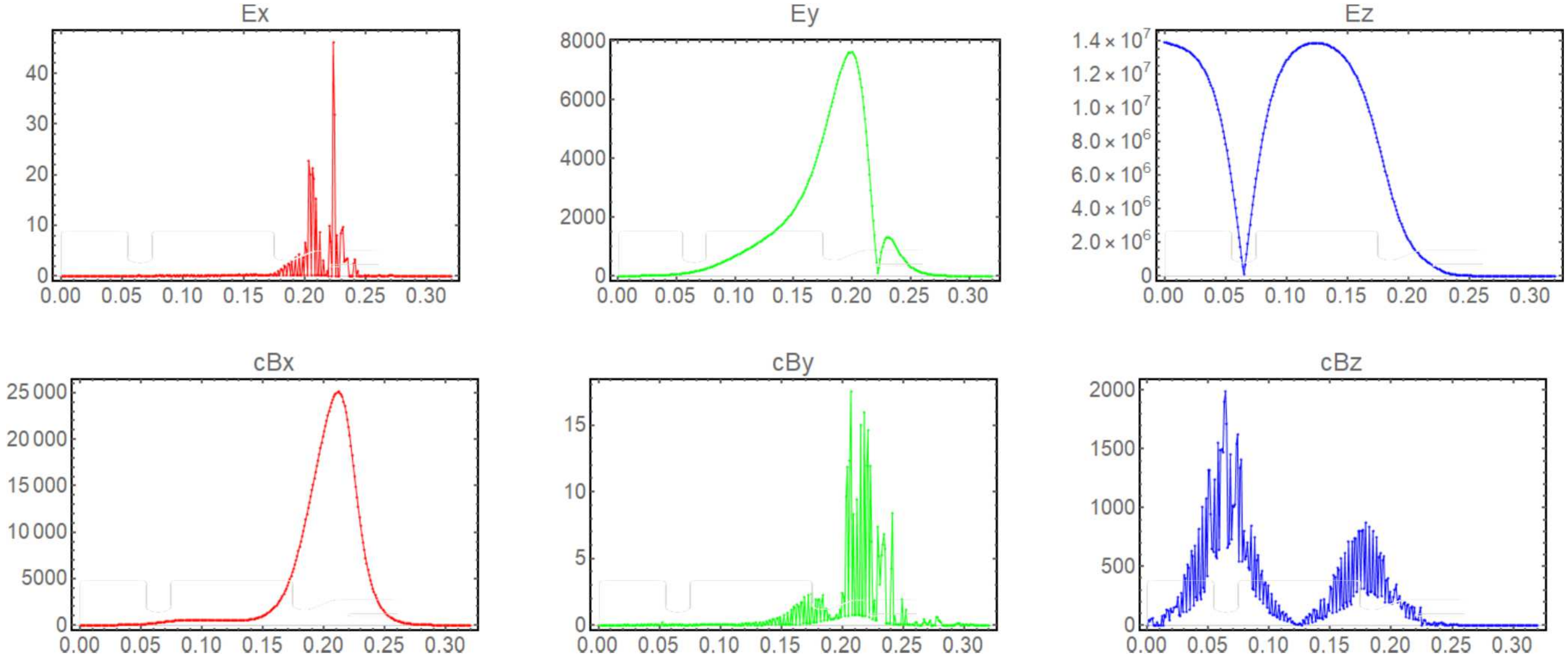
- Cavity Fields along the Axis
  - FEM

z in m
E in V/m
cB in V/m



Simulation Results

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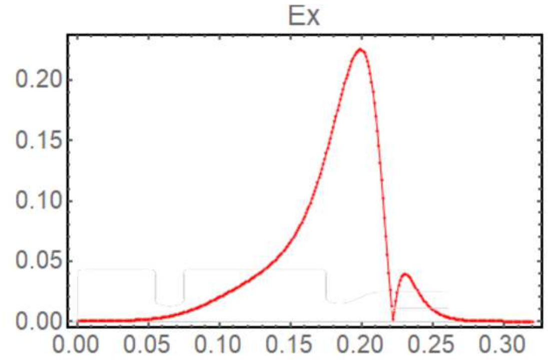
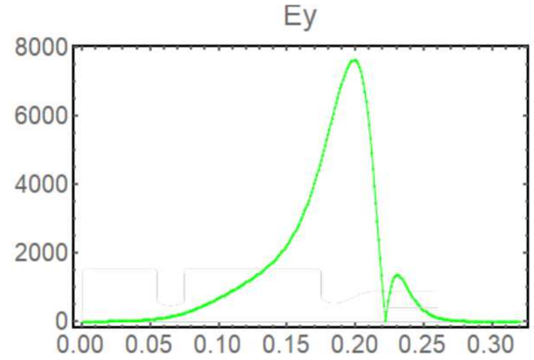
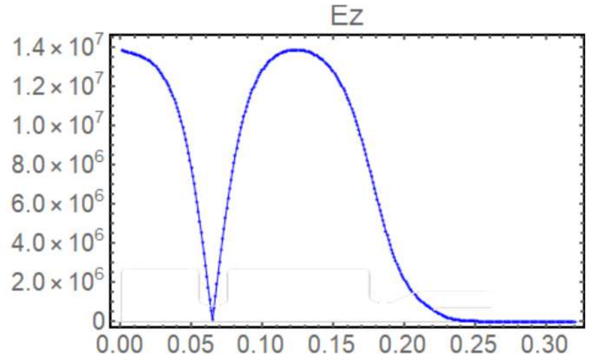
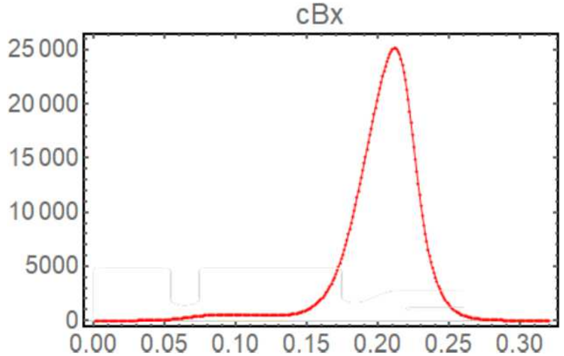
- Cavity Fields along the Axis
  - Kirchhoff

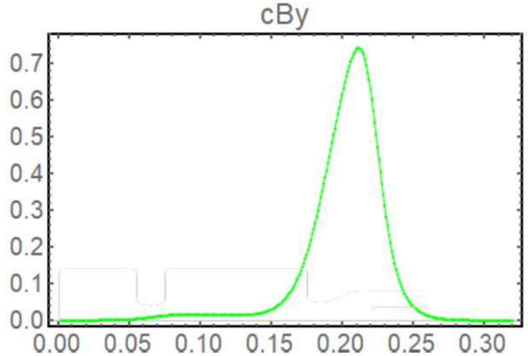
z in m
E in V/m
cB in V/m

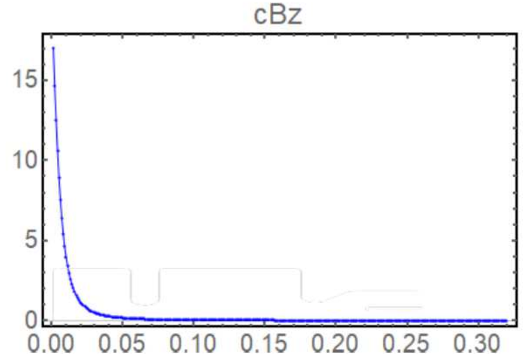






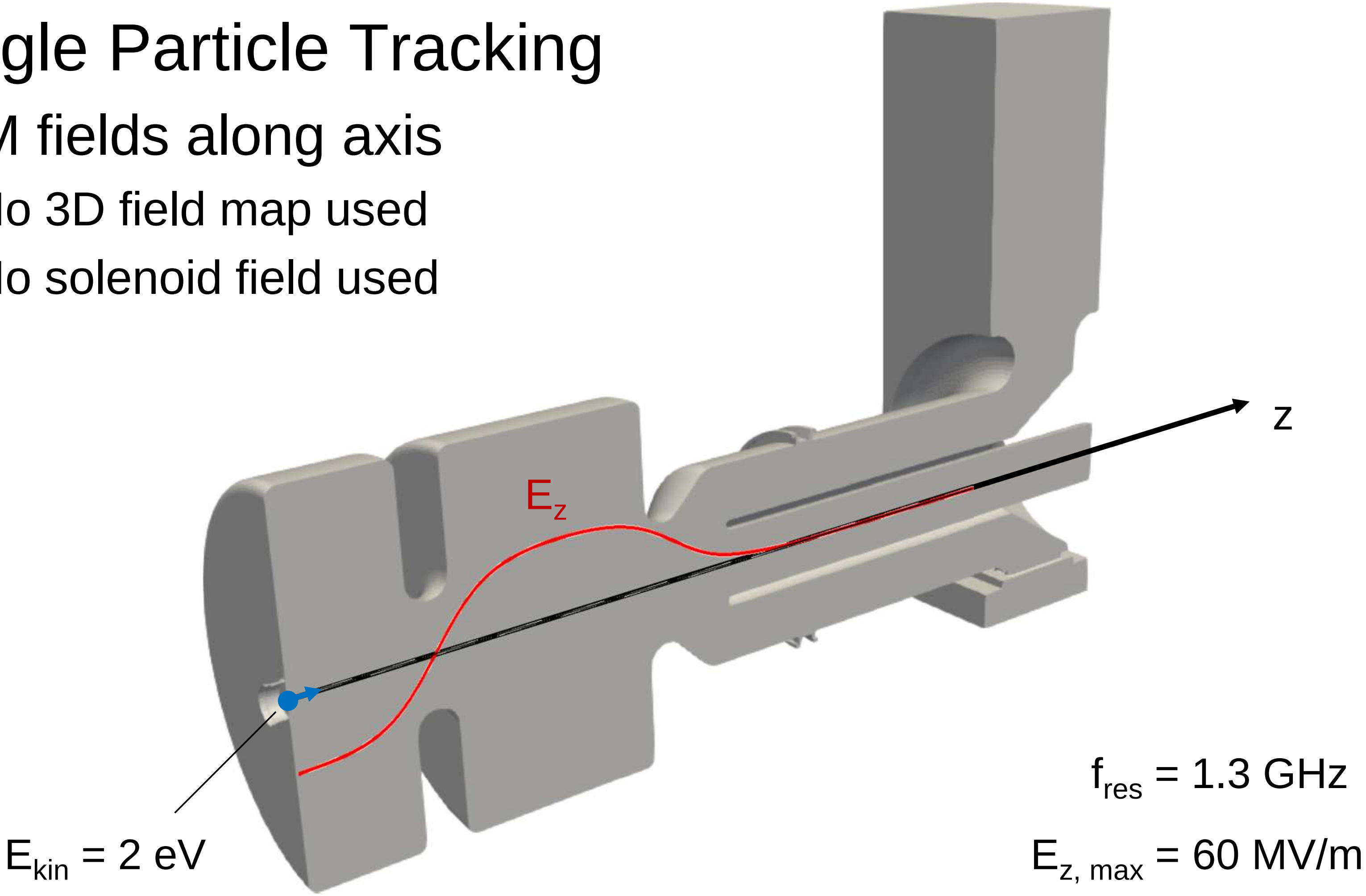






Simulation Results

- Single Particle Tracking
  - EM fields along axis
    - No 3D field map used
    - No solenoid field used



Simulation Results

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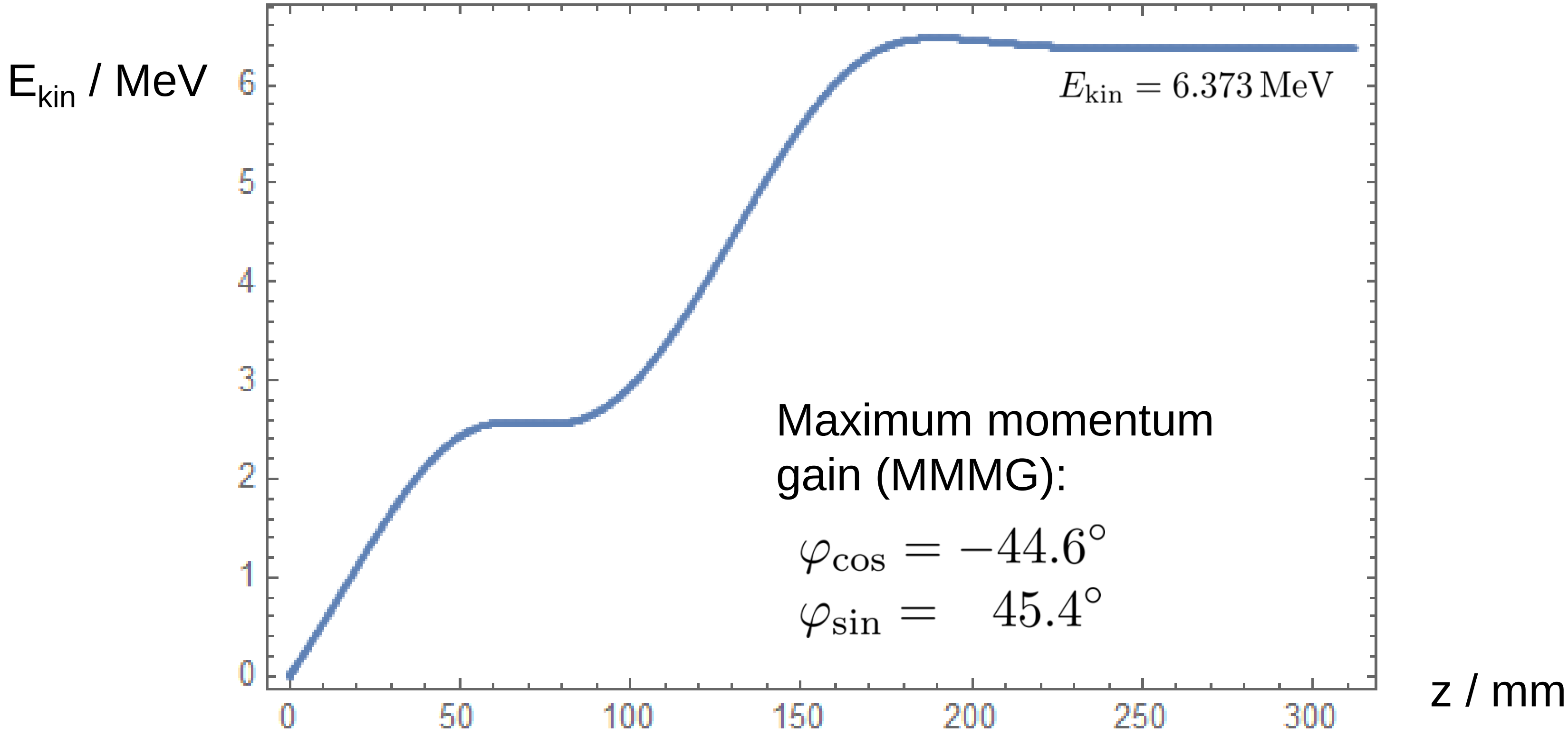
- Single Particle Tracking
  - Phase scan and energy gain



Simulation Results

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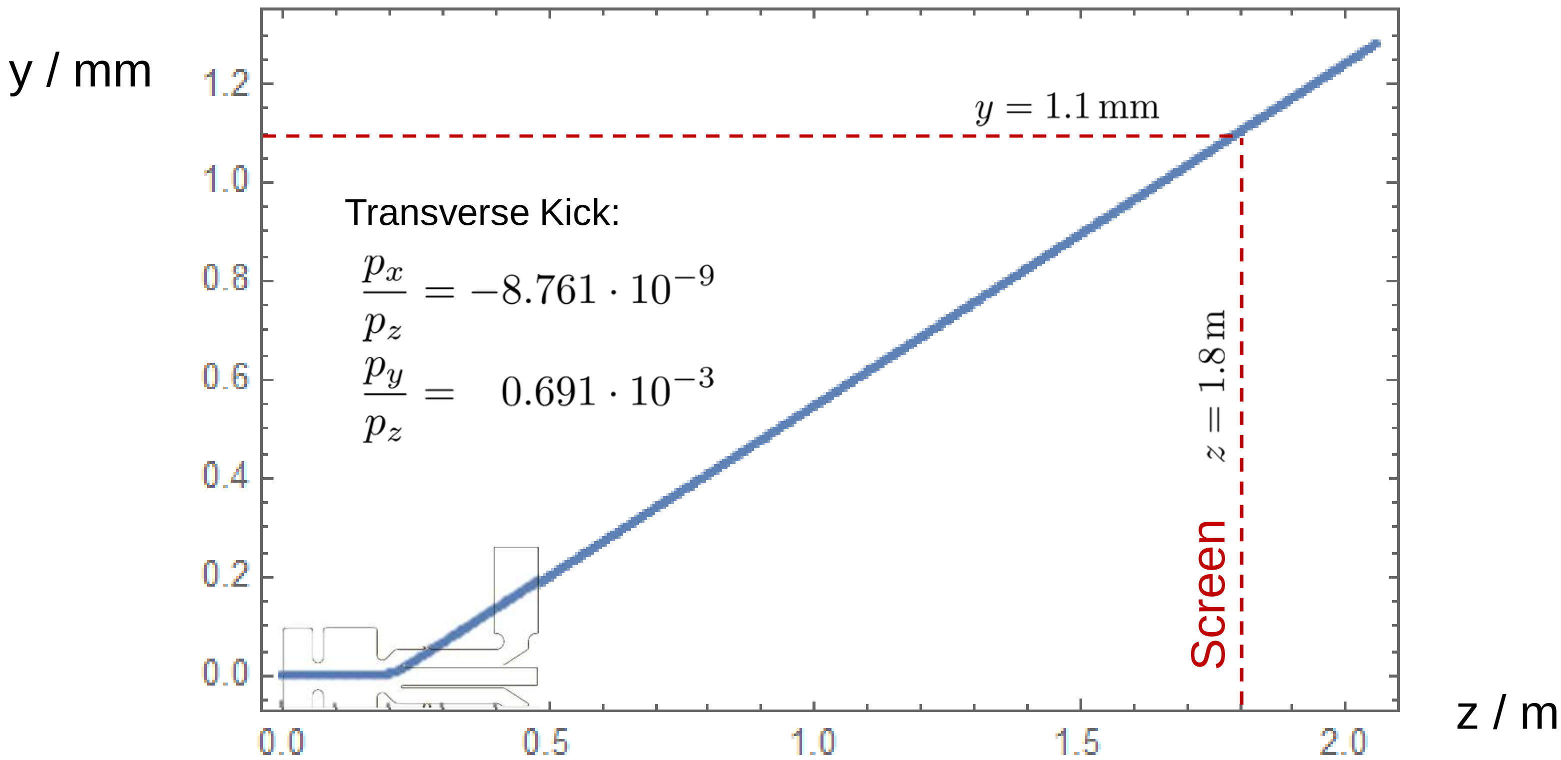
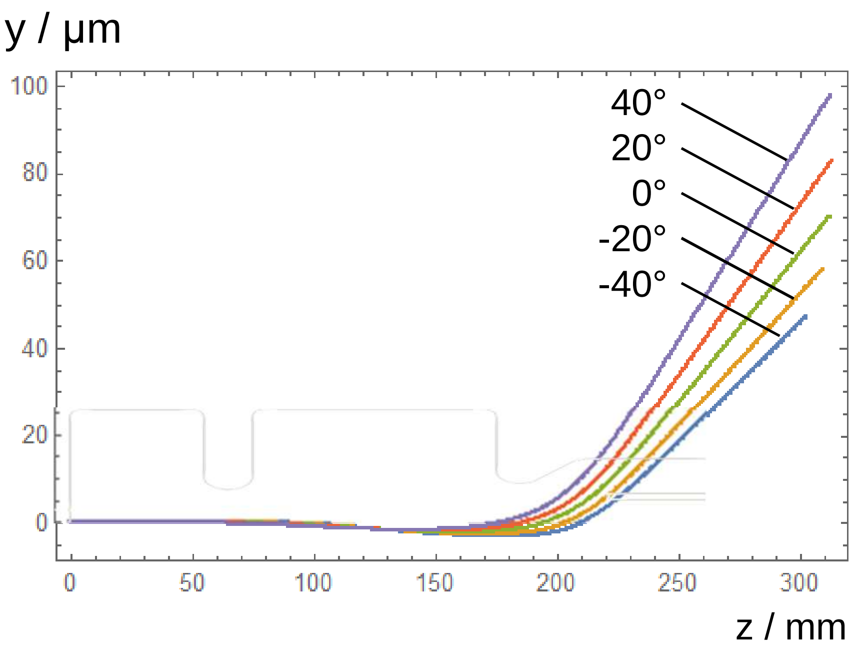
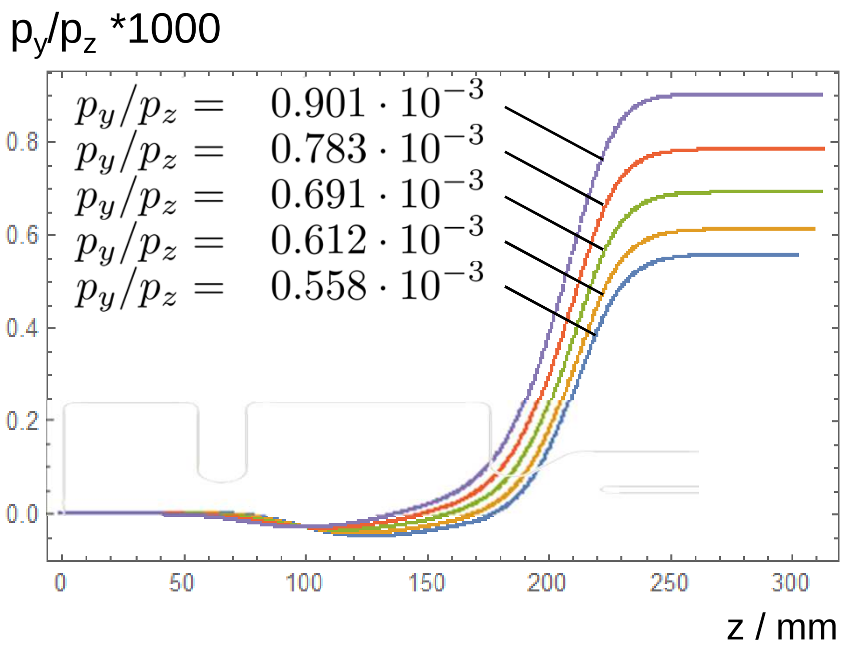
- Single Particle Tracking
  - Trajectory for phase at MMMG



Simulation Results

- Single Particle Tracking
  - Phase scan with respect to MMMG phase (trajectory and kick)





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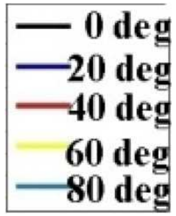

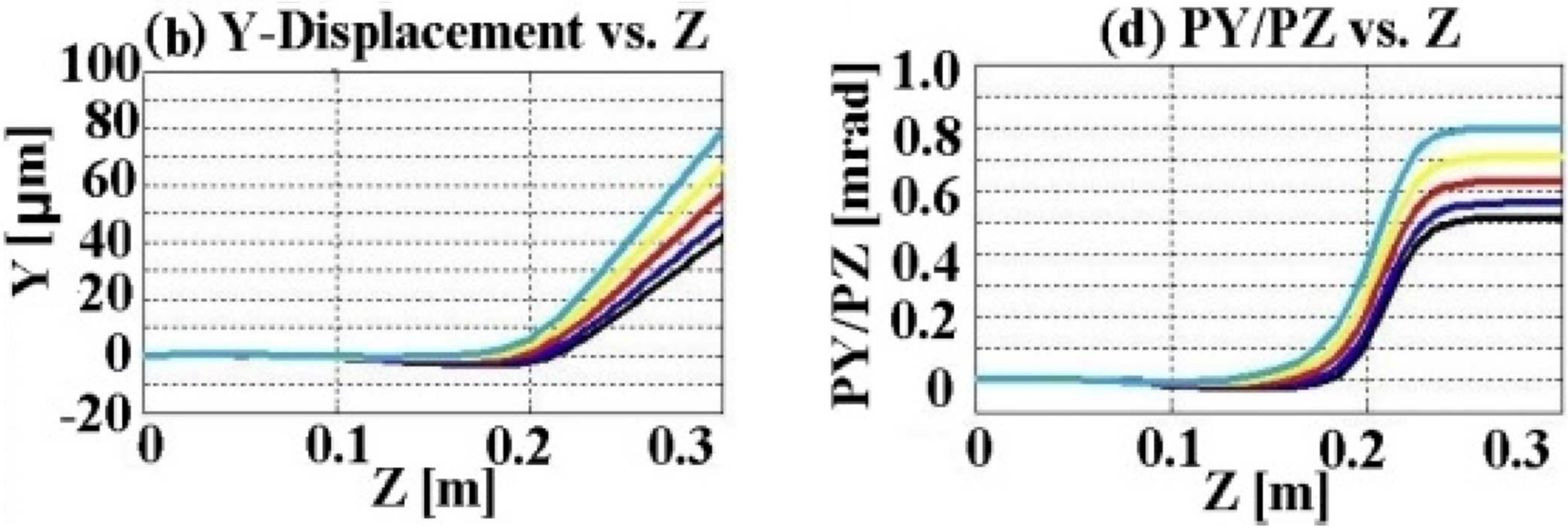

Y. Chen, „Coaxial Coupler RF Kick in the PITZ RF Gun", WEP005, FEL 2017, Santa Fee, NM, USA

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Summary / Outlook

- Summary:
  - Precise modeling of the 1.3 GHz PITZ gun including the rectangular high power input coupler
  - Eigenmode analysis performed for the accelerating mode using port mode excitation and lossy gun material
  - Electromagnetic field extraction based on symmetric tetrahedral meshes for classical FEM solutions and the Kirchhoff integral representation
- Outlook:
  - Field map for accurate beam dynamics studies required?