Eigenmode Calculations for the PETRA III 7-Cell 500 MHz Cavity

TECHNISCHE UNIVERSITÄT DARMSTADT

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Status Meeting
January 15, 2016
DESY, Hamburg

Outline

TECHNISCHE UNIVERSITÄT DARMSTADT

- Motivation
- Computational Model
  - Drawings and geometry information
  - Numerical problem formulation
- Simulation results
  - Mode pattern and characteristic data for a tuned and untuned structure
- Summary / Outlook

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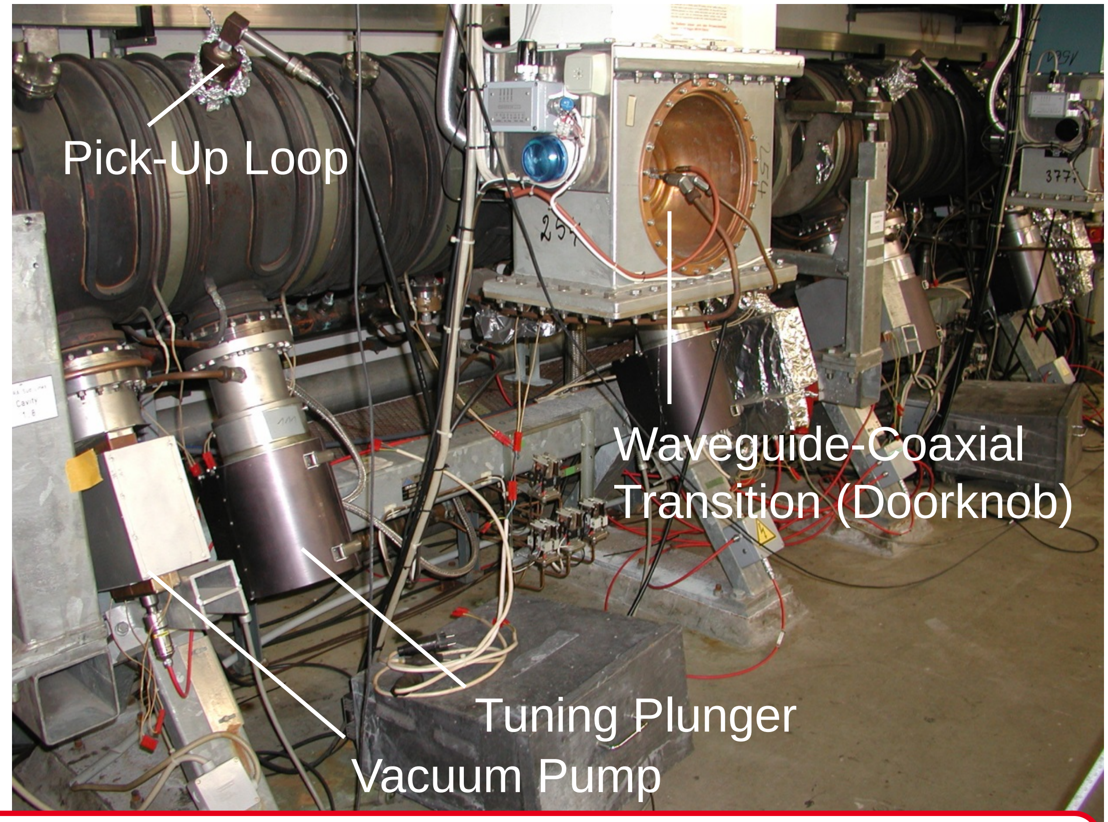
Motivation

- PETRA Cavities
  - Photographs



➡ From time to time automatic switch-off of the power supply due to unexpected high fields in the cavity or waveguide system.

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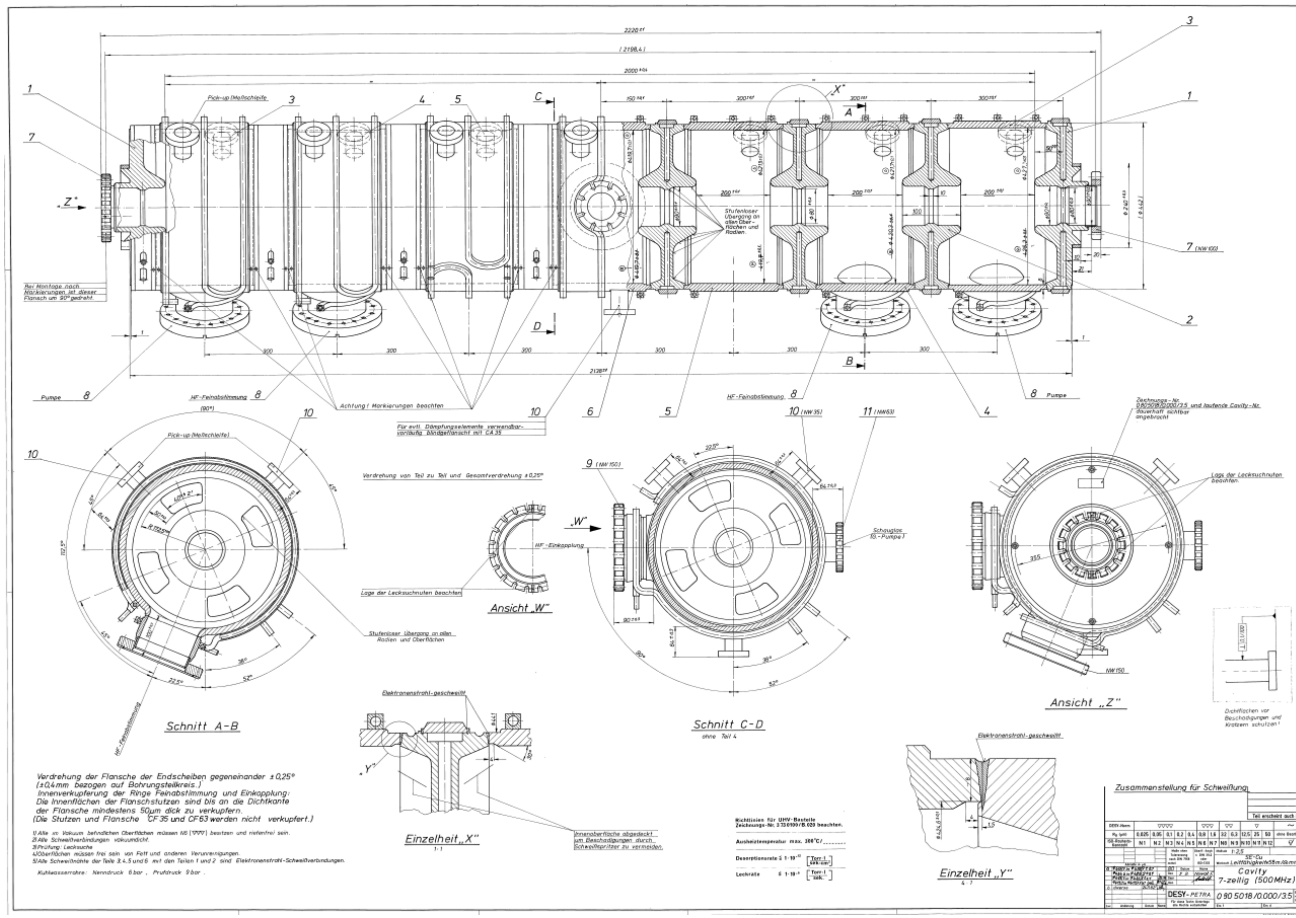
Computational Model

TECHNISCHE UNIVERSITÄT DARMSTADT

- PETRA III, 500 MHz, 7-cell Cavity
  - Drawings

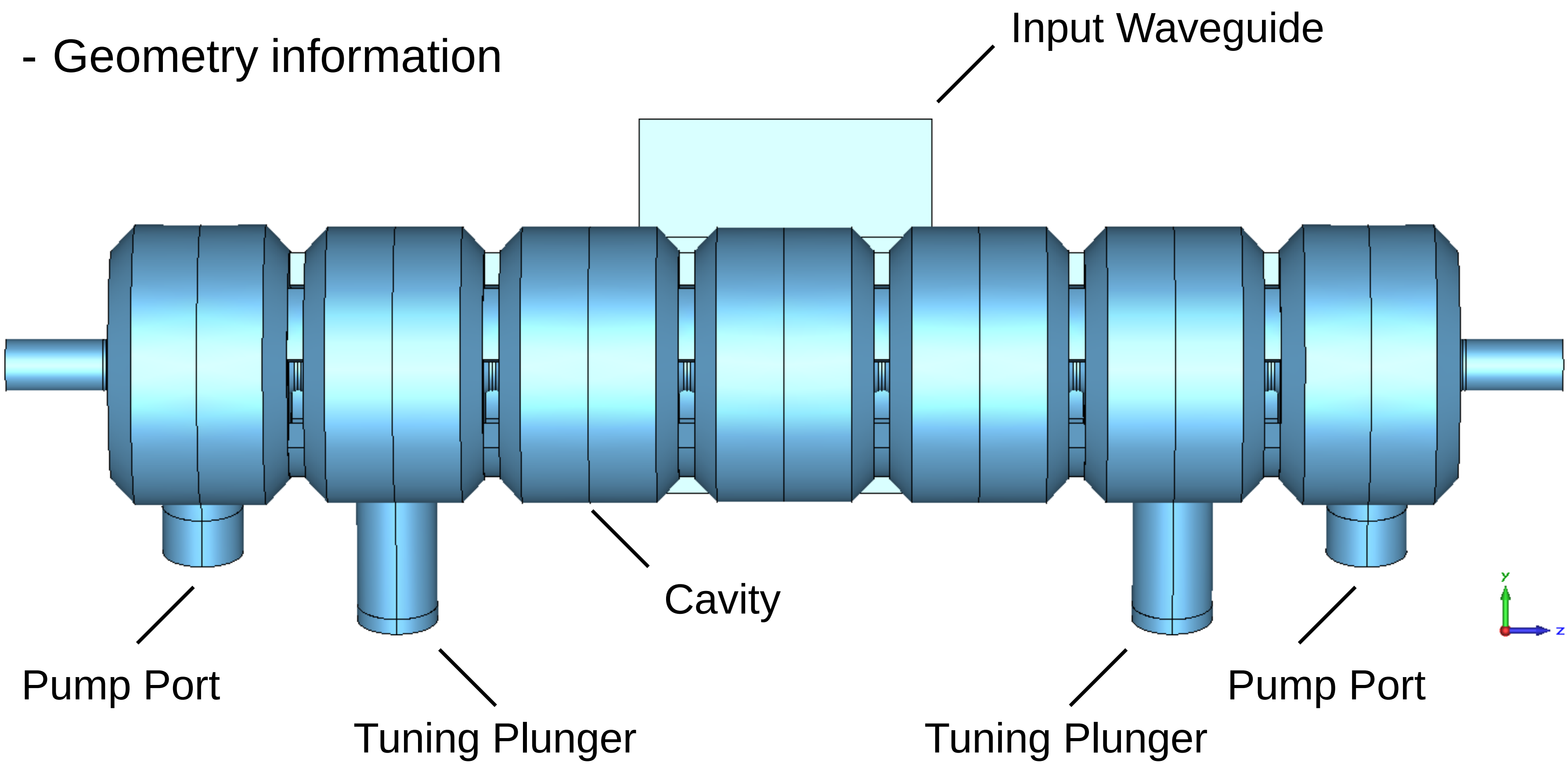


http://mhf-e.desy.de/e5/e63/

Courtesy of
Kathrin Cottel
Michael Ebert
Rainer Wanzenberg

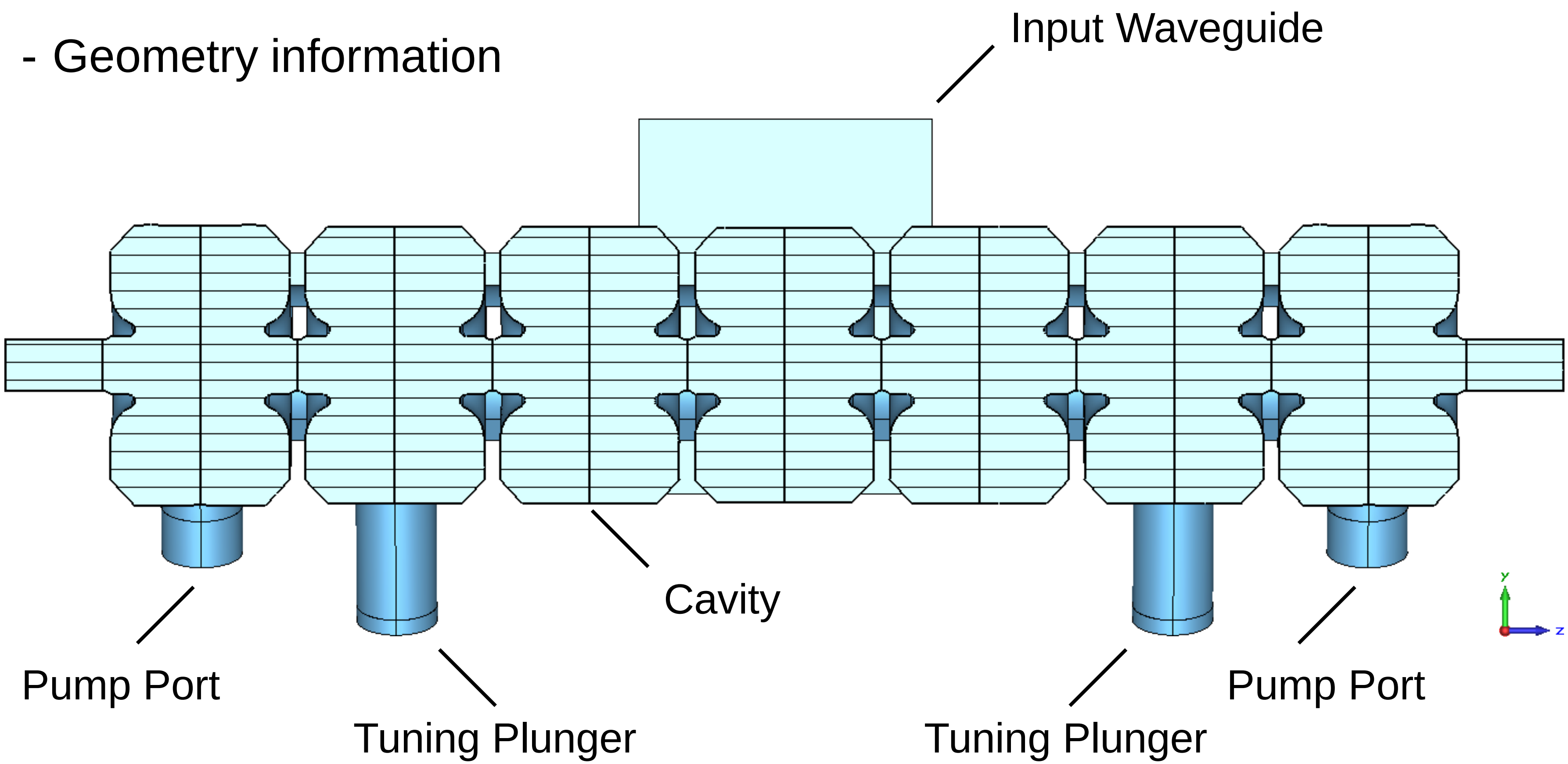
Computational Model

- PETRA III, 500 MHz, 7-cell Cavity
  - Geometry information



Computational Model

- PETRA III, 500 MHz, 7-cell Cavity
  - Geometry information



Computational Model

- PETRA III, 500 MHz, 7-cell Cavity
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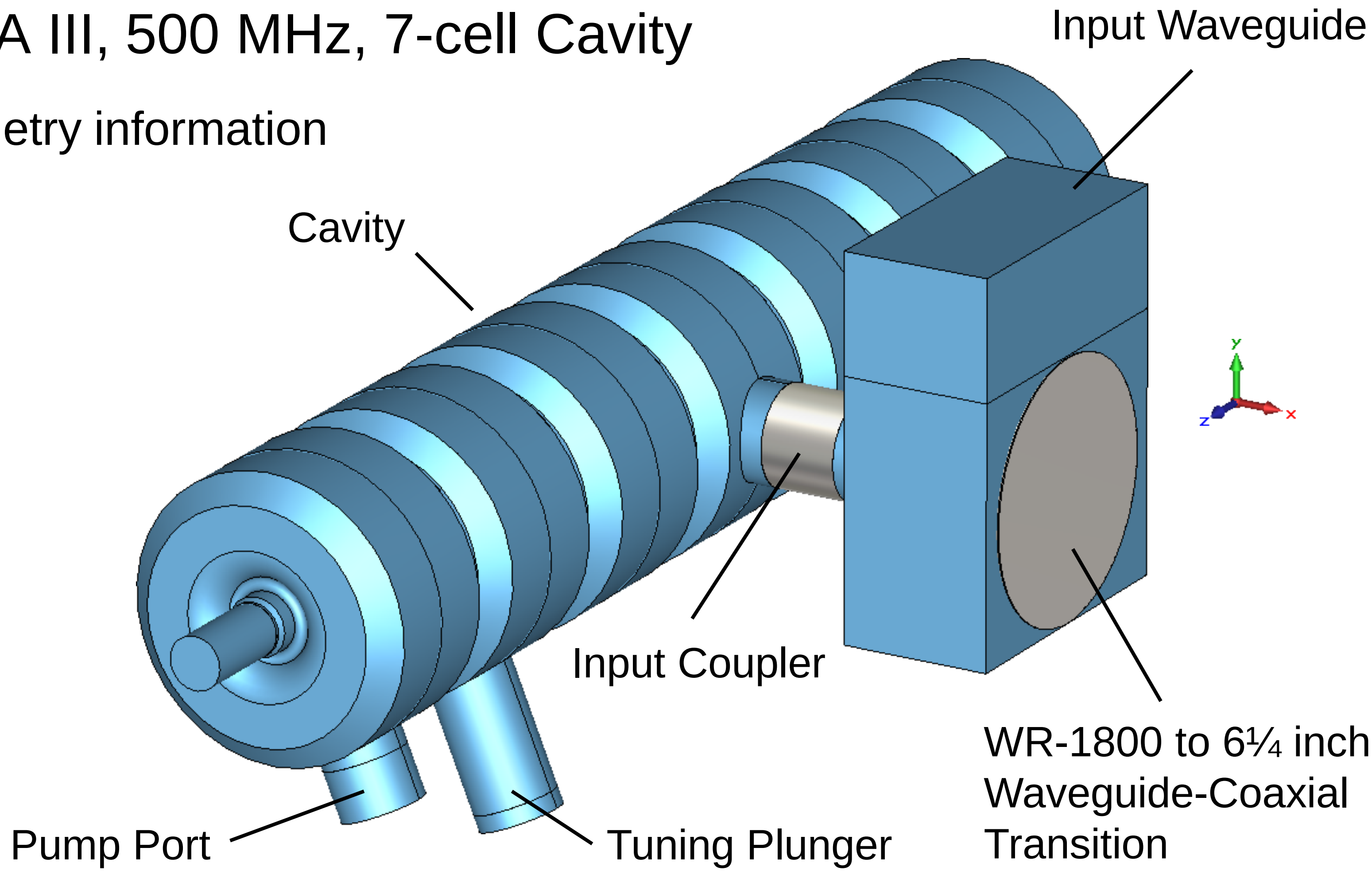
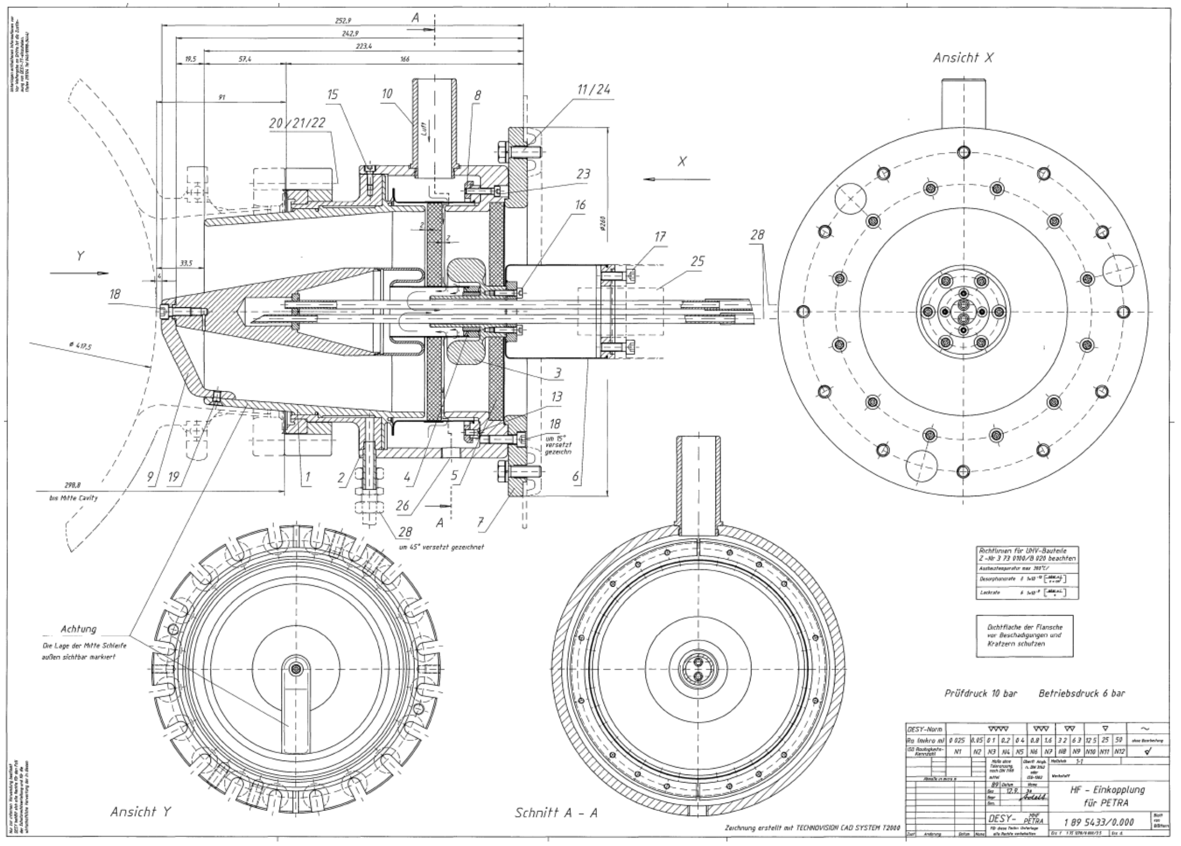


Computational Model

- PETRA, 500 MHz, 7-cell Cavity
  - Drawings

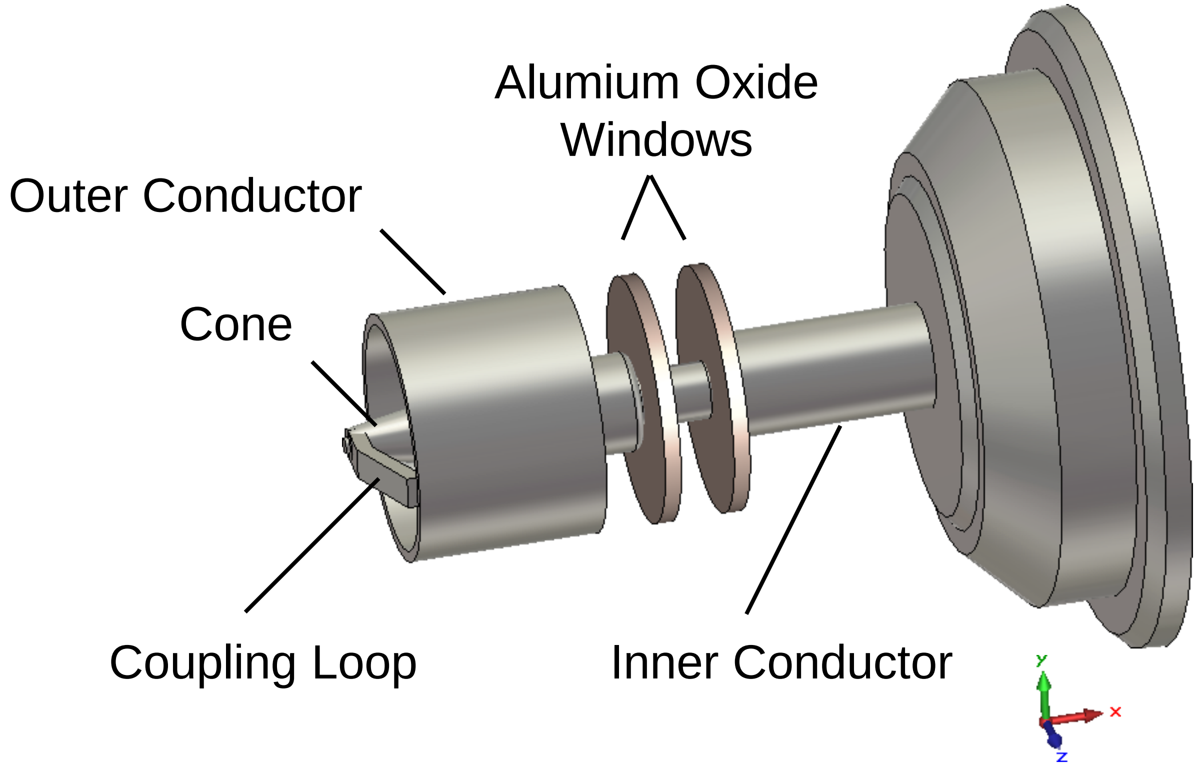


Computational Model

- PETRA III, 500 MHz, 7-cell Cavity
  - Geometry information (Details of the input coupler)

Photograph

http://mhf-e.desy.de/e5/e63/



Courtesy of
Kathrin Cottel

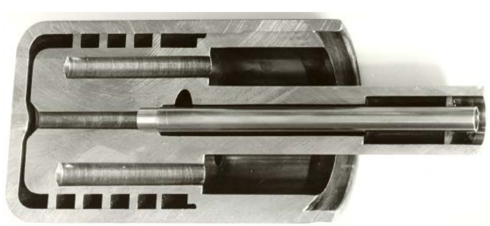
Computational Model

- PETRA III, 500 MHz, 7-cell Cavity
  - Geometry information (Details of the tuning plungers)

Modeling of
Guide and Spring

Neglect Cooling Channels

Photograph



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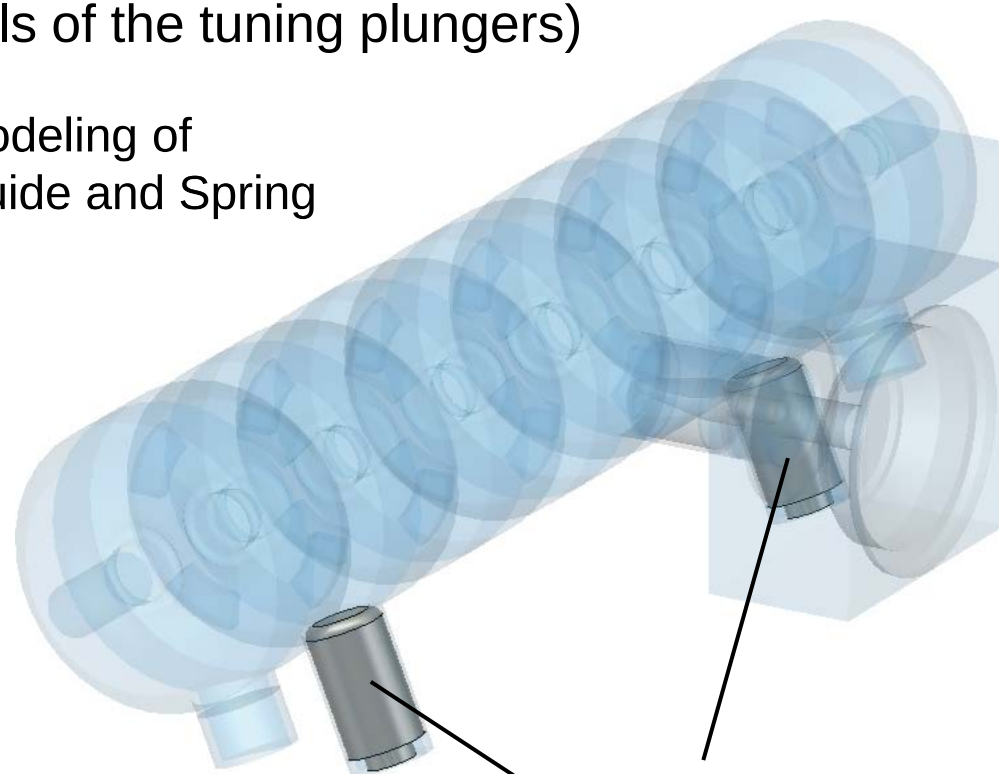
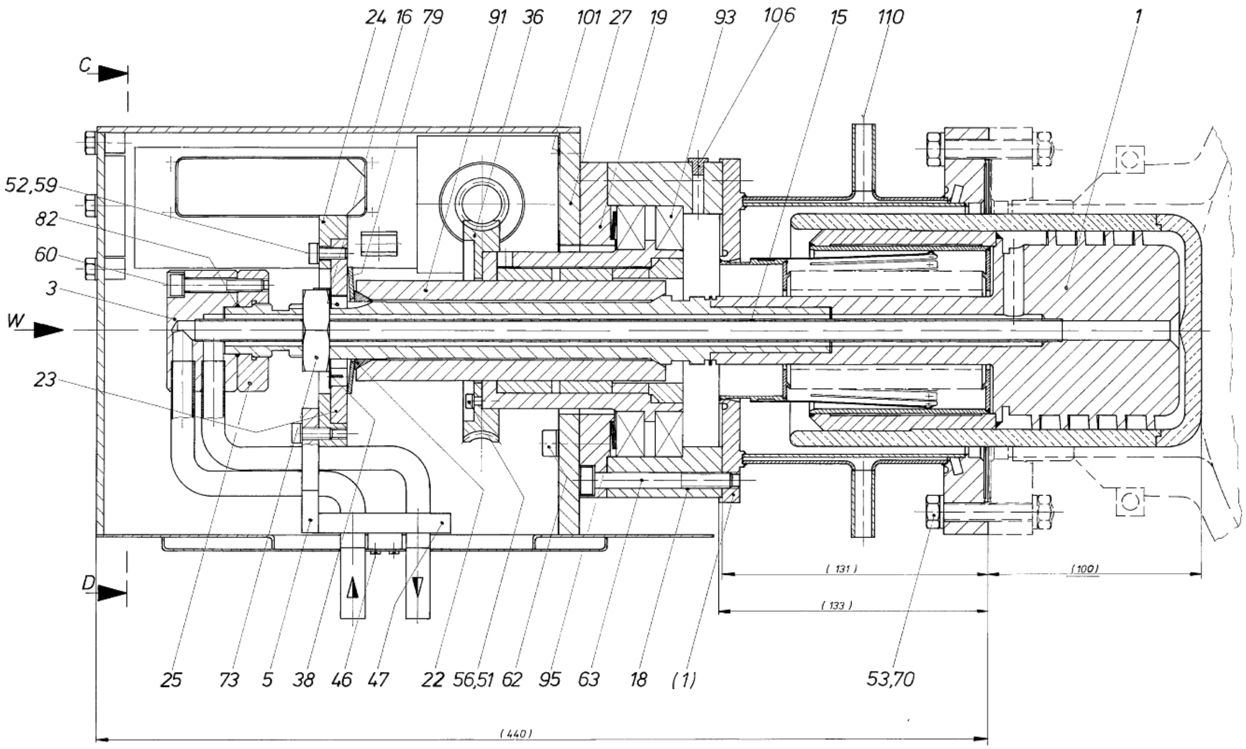


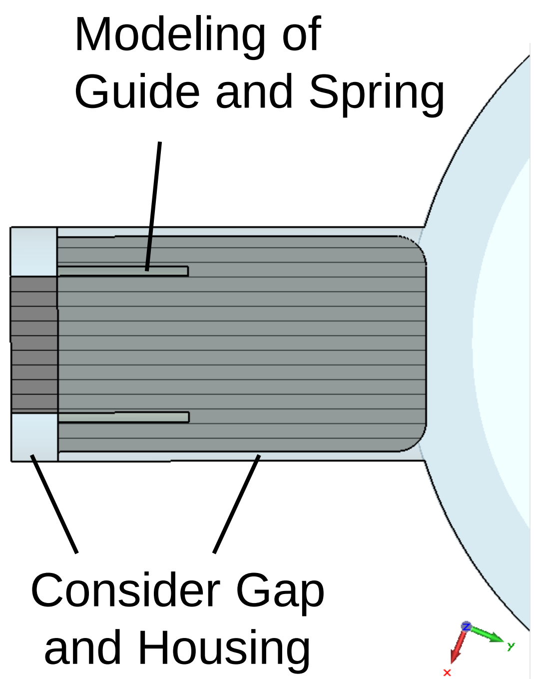
Tuning Plungers

Computational Model

TECHNISCHE UNIVERSITÄT DARMSTADT

- PETRA III, 500 MHz, 7-cell Cavity
  - Geometry information (Details of the tuning plungers)

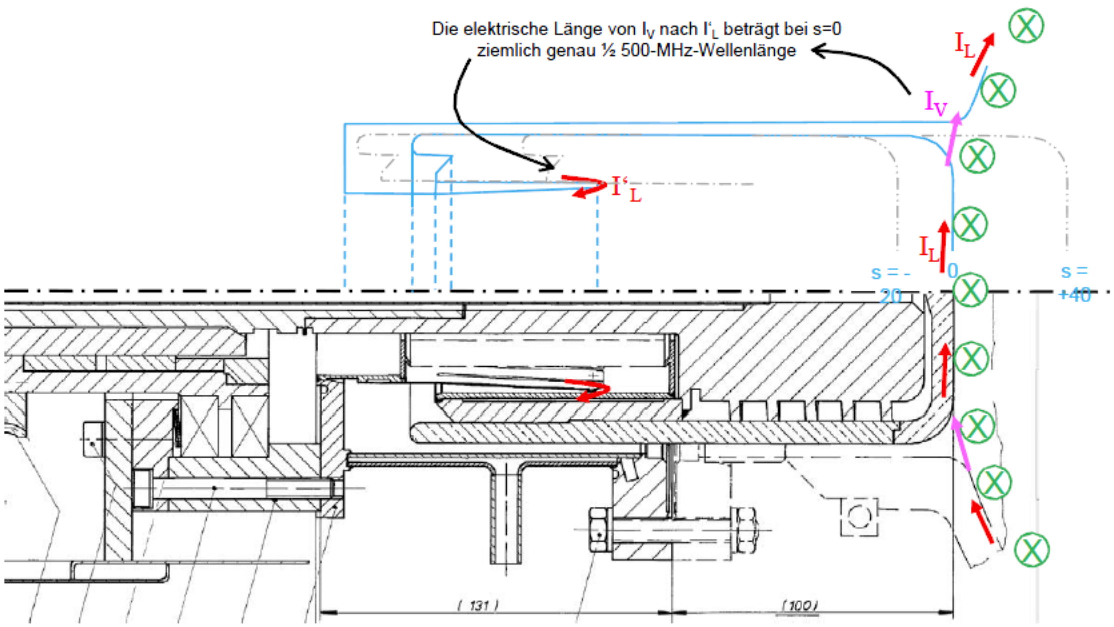




Courtesy of Michael Ebert

Computational Model

- PETRA III, 500 MHz, 7-cell Cavity
  - Estimation of resonances (Beschleuniger-Betriebsseminar 2015)



Michael Ebert | Beschleuniger-Betriebsseminar 2015 | 23. bis 26.3.2015 | Seite 59

Courtesy of Michael Ebert

Computational Model

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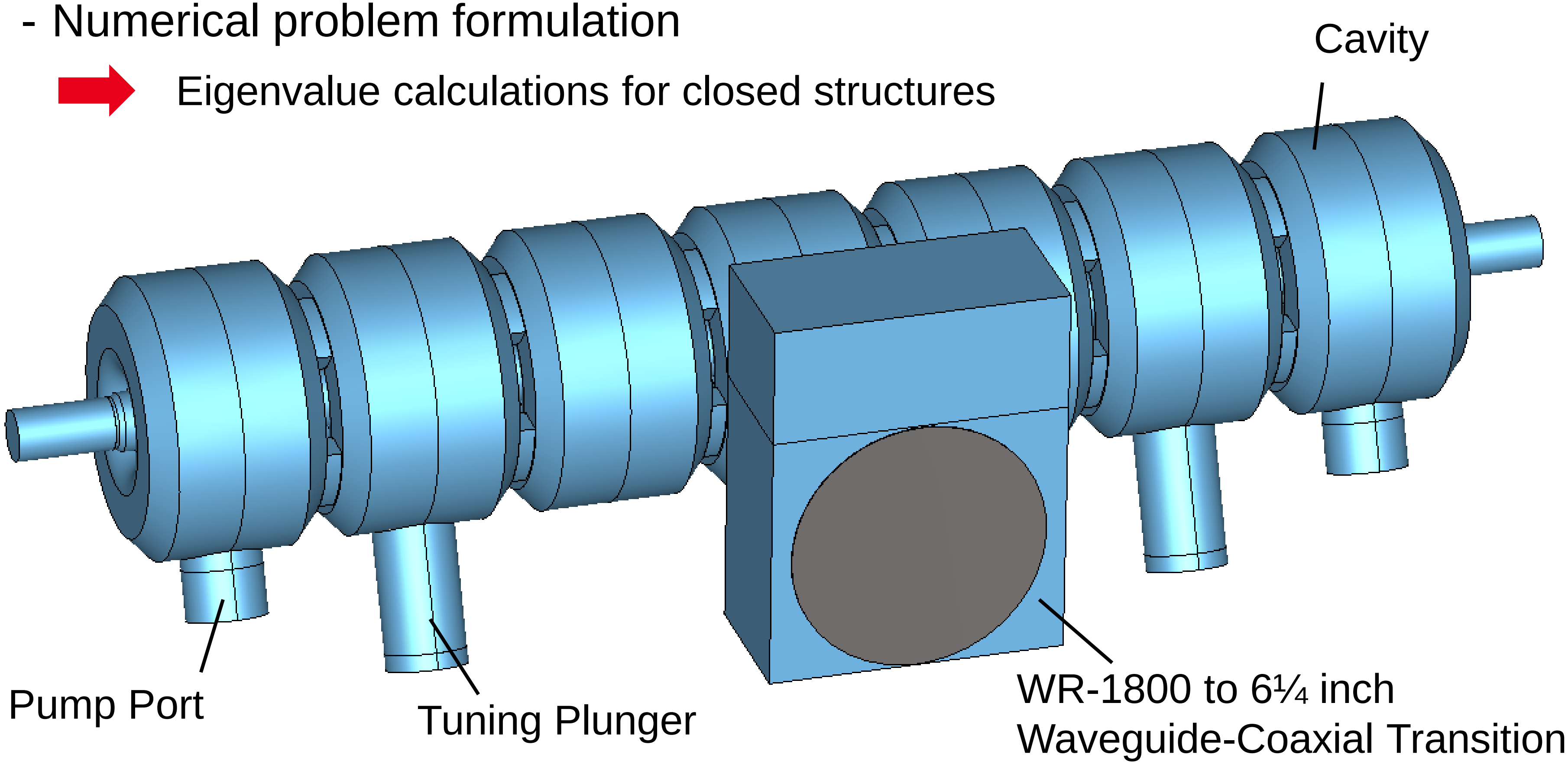
- PETRA III, 500 MHz, 7-cell Cavity
  - Numerical problem formulation

➡ Eigenvalue calculations for closed structures



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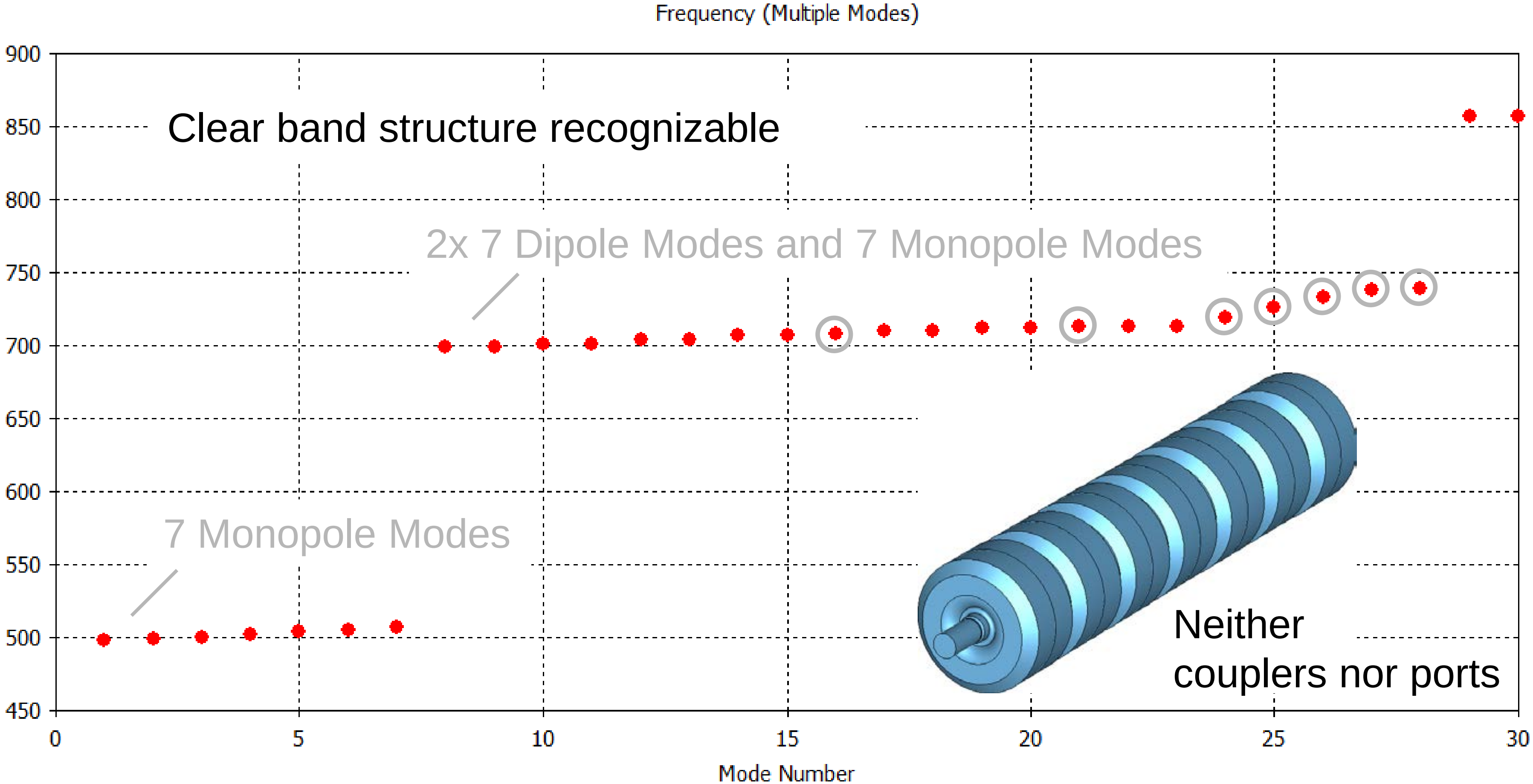
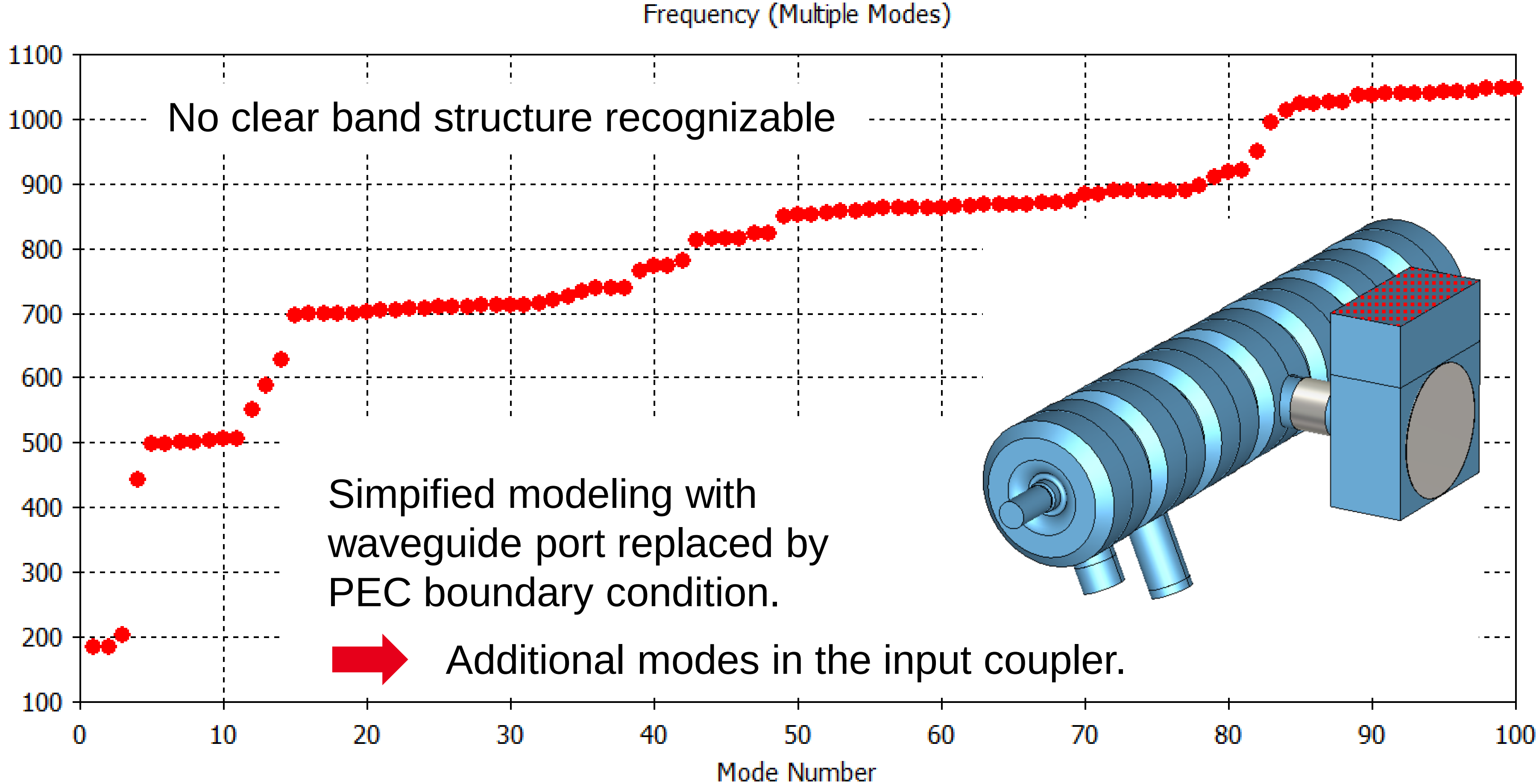
Simulation Results

- Calculated Resonances (first 30 values)



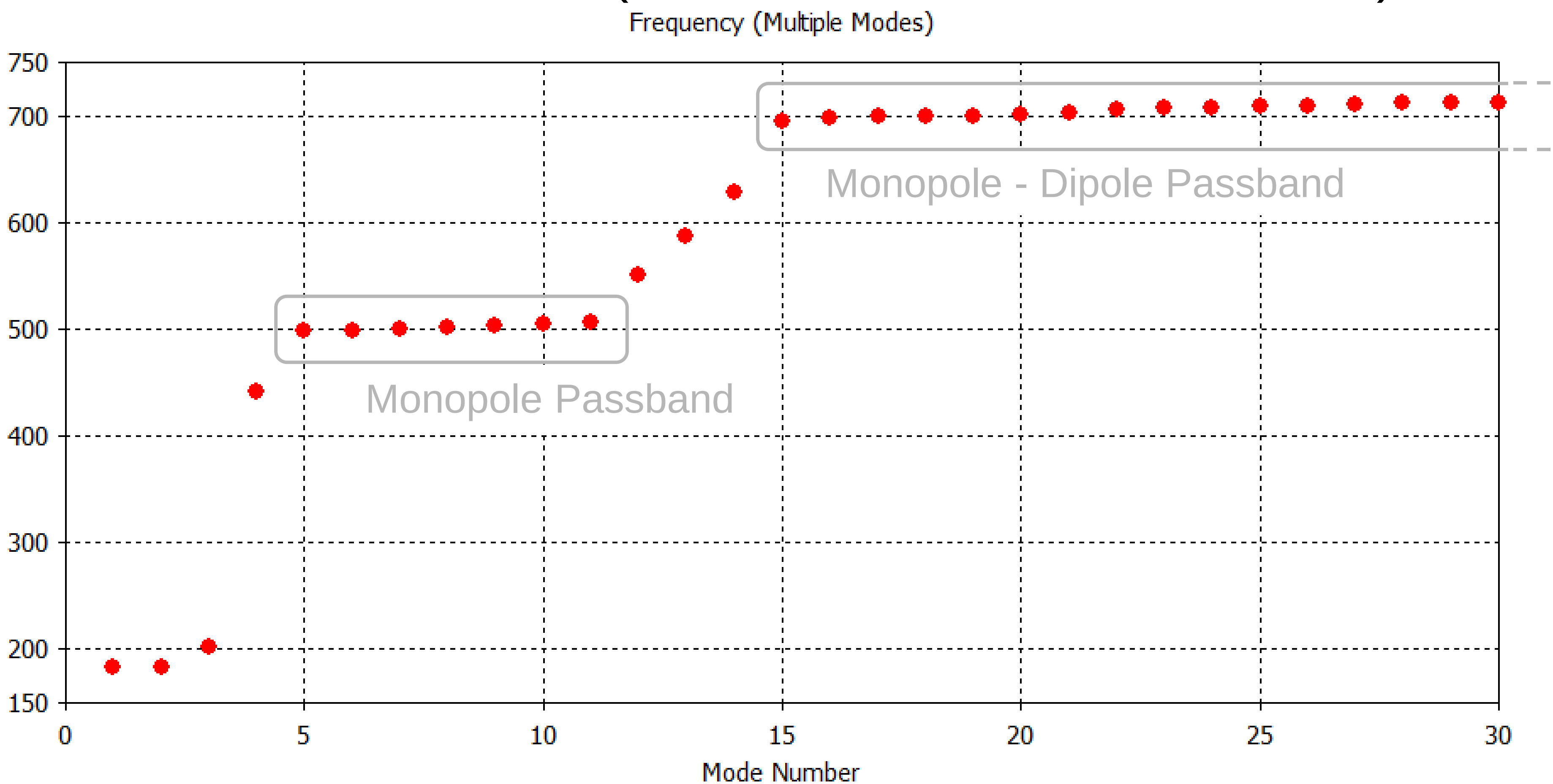
Simulation Results

- Calculated Resonances (first 100 values)



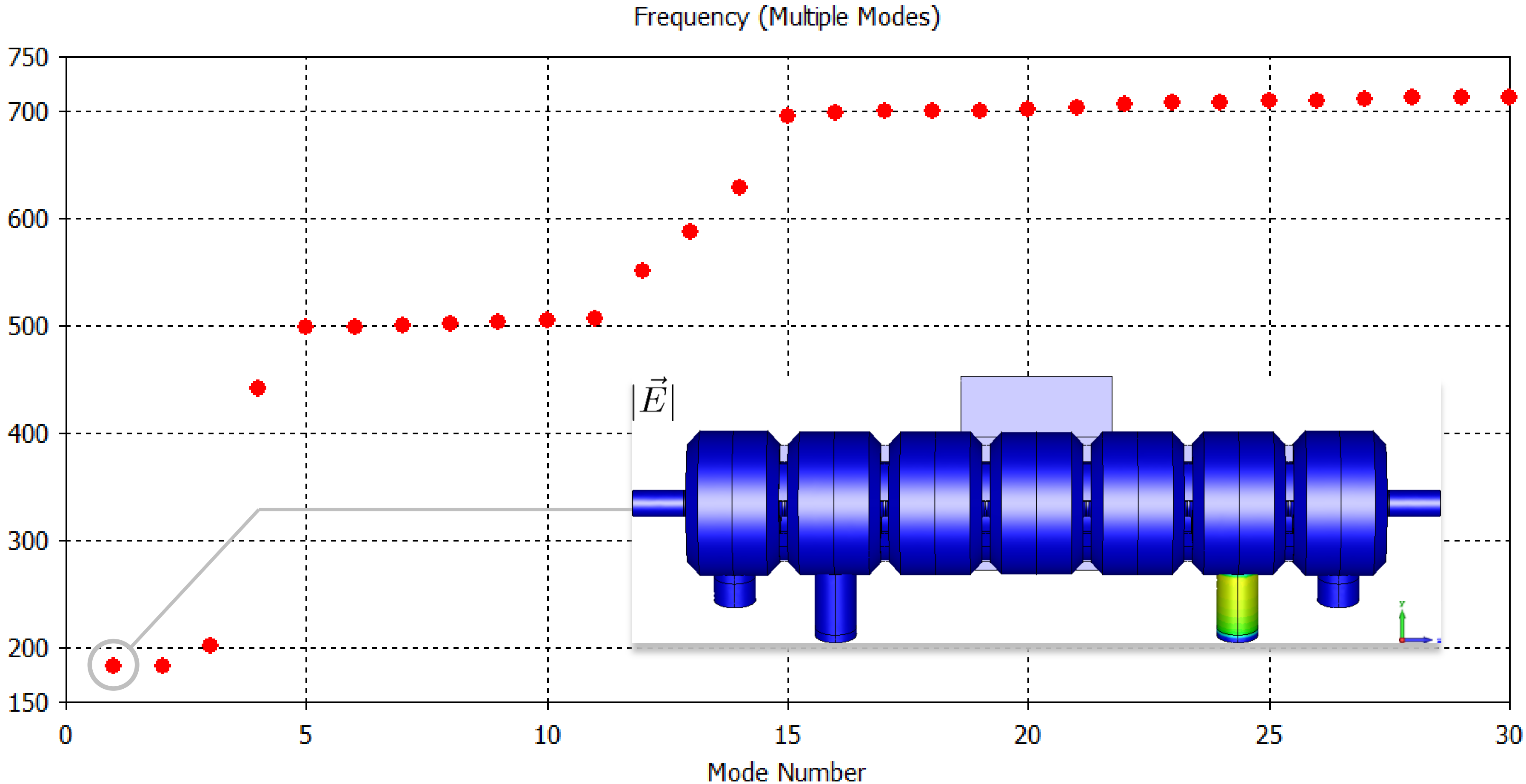
Simulation Results

- Calculated Resonances (concentration on first 30 values)



Simulation Results

- Calculated Resonances



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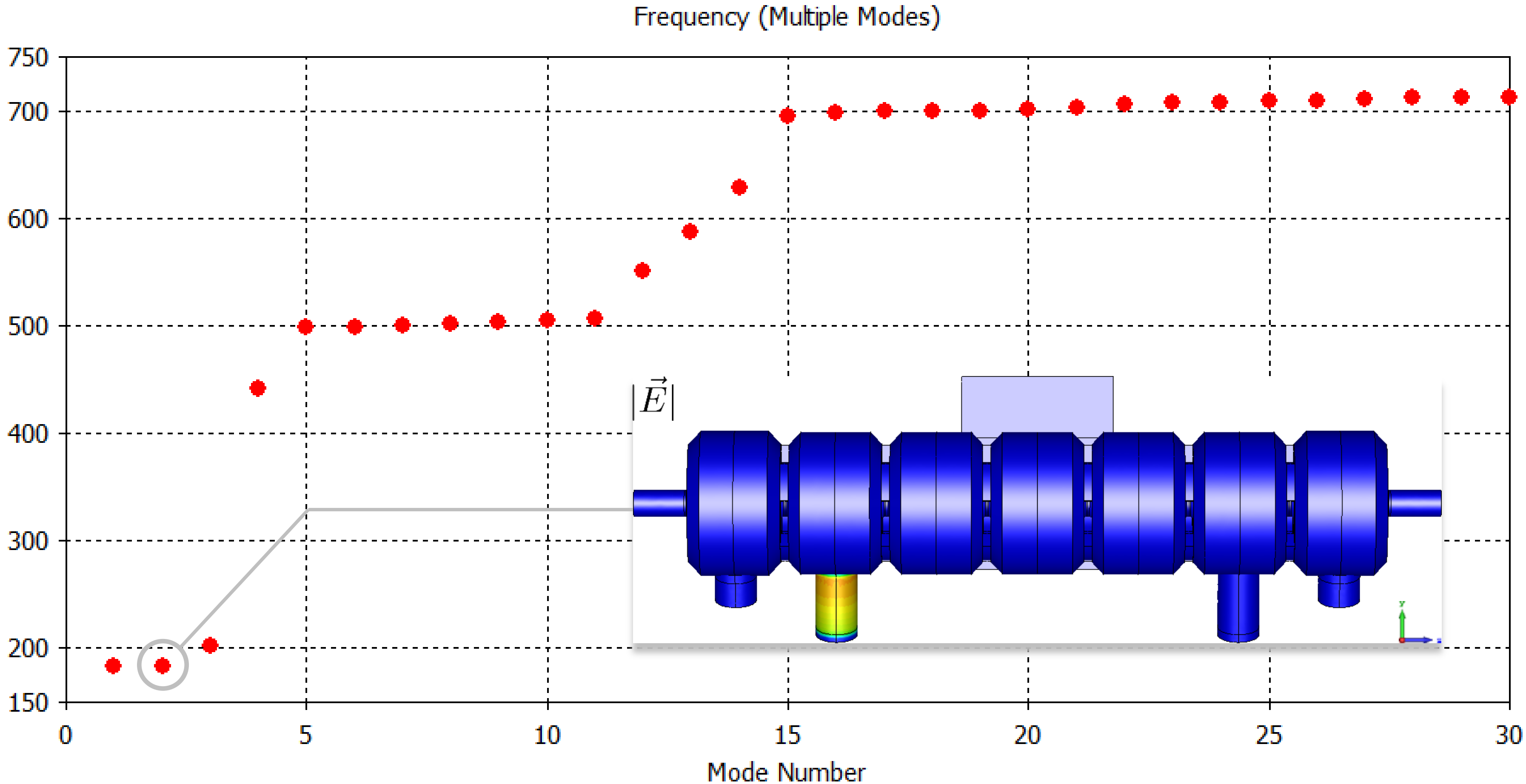
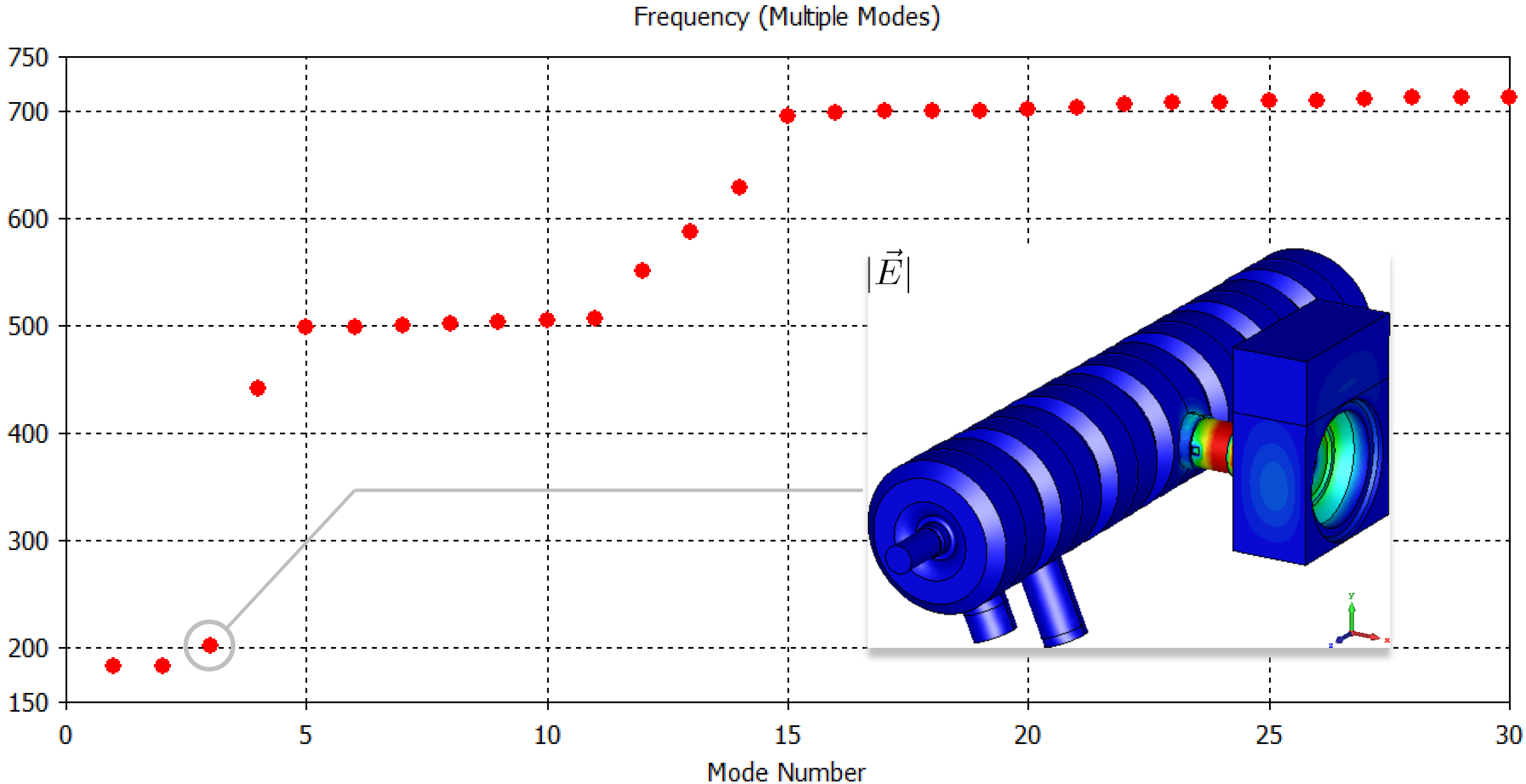


Simulation Results

TECHNISCHE UNIVERSITÄT DARMSTADT

- Calculated Resonances



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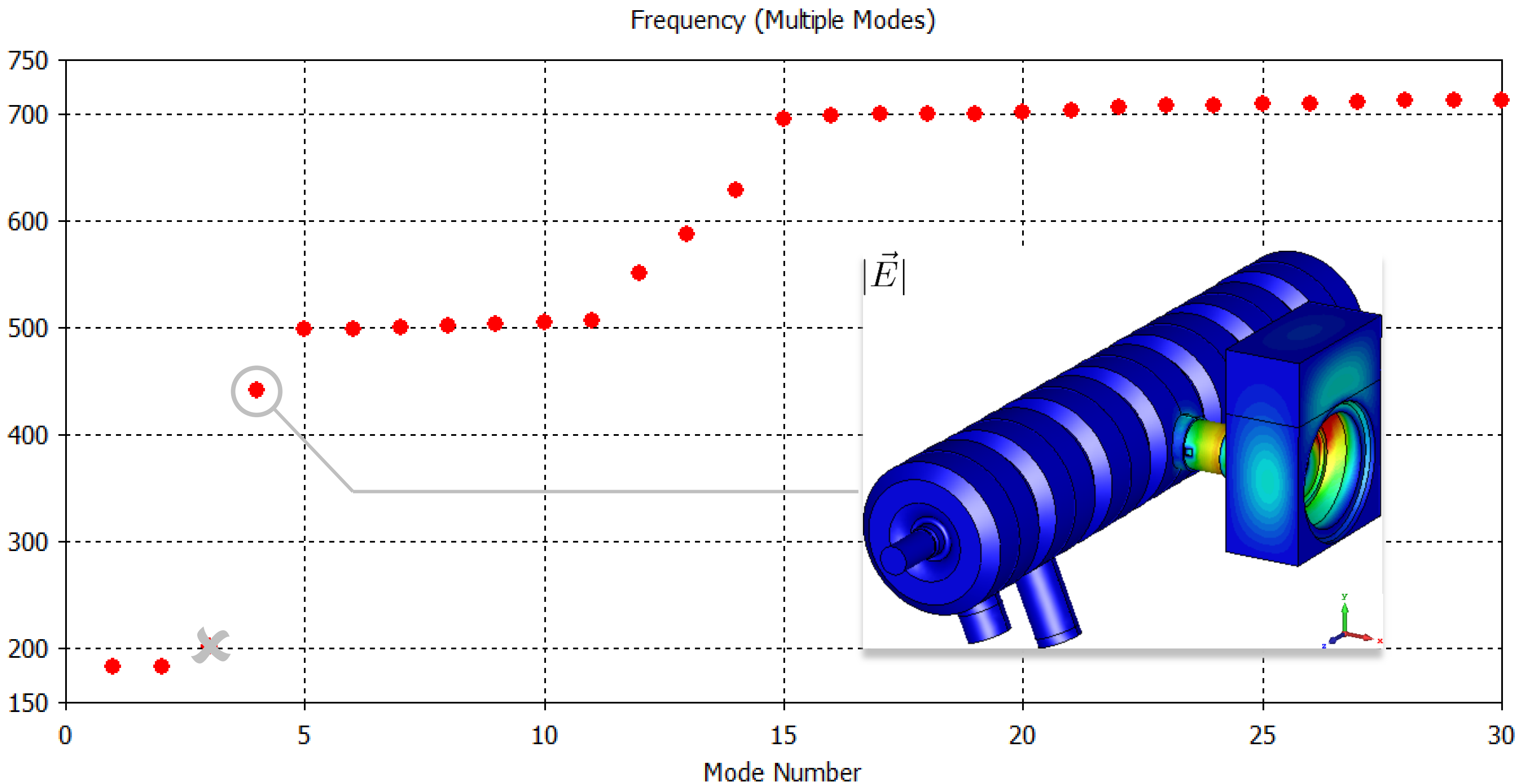

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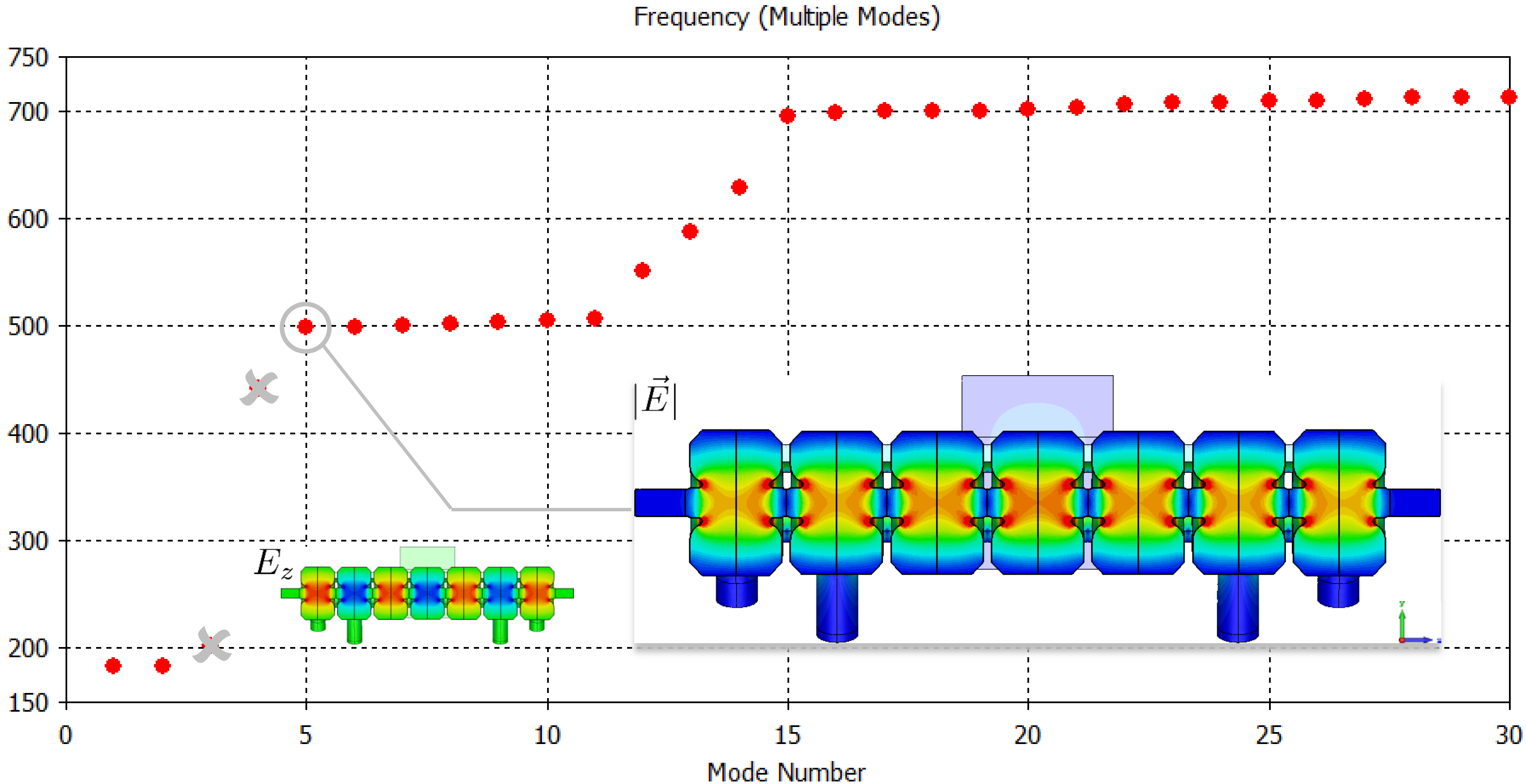

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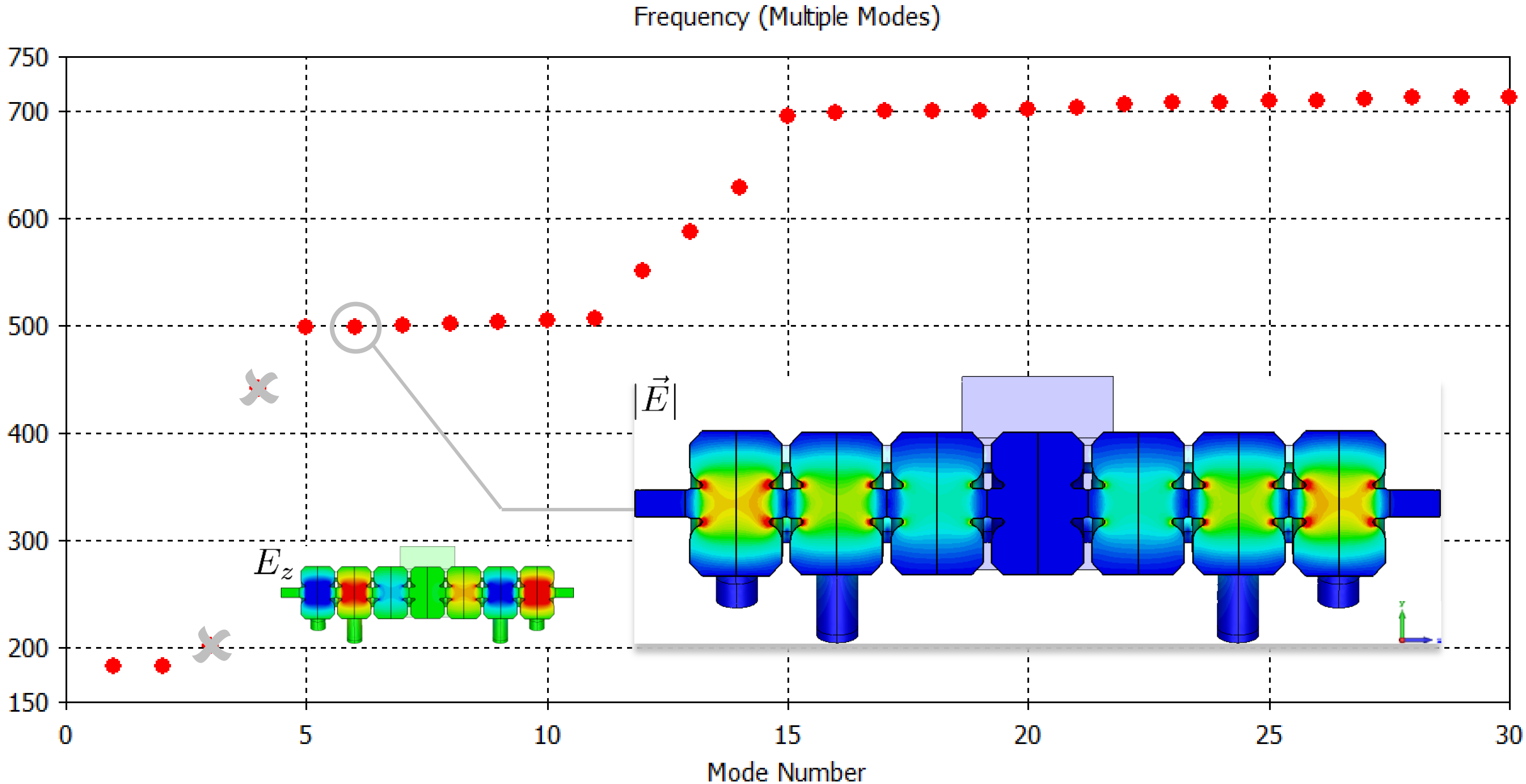

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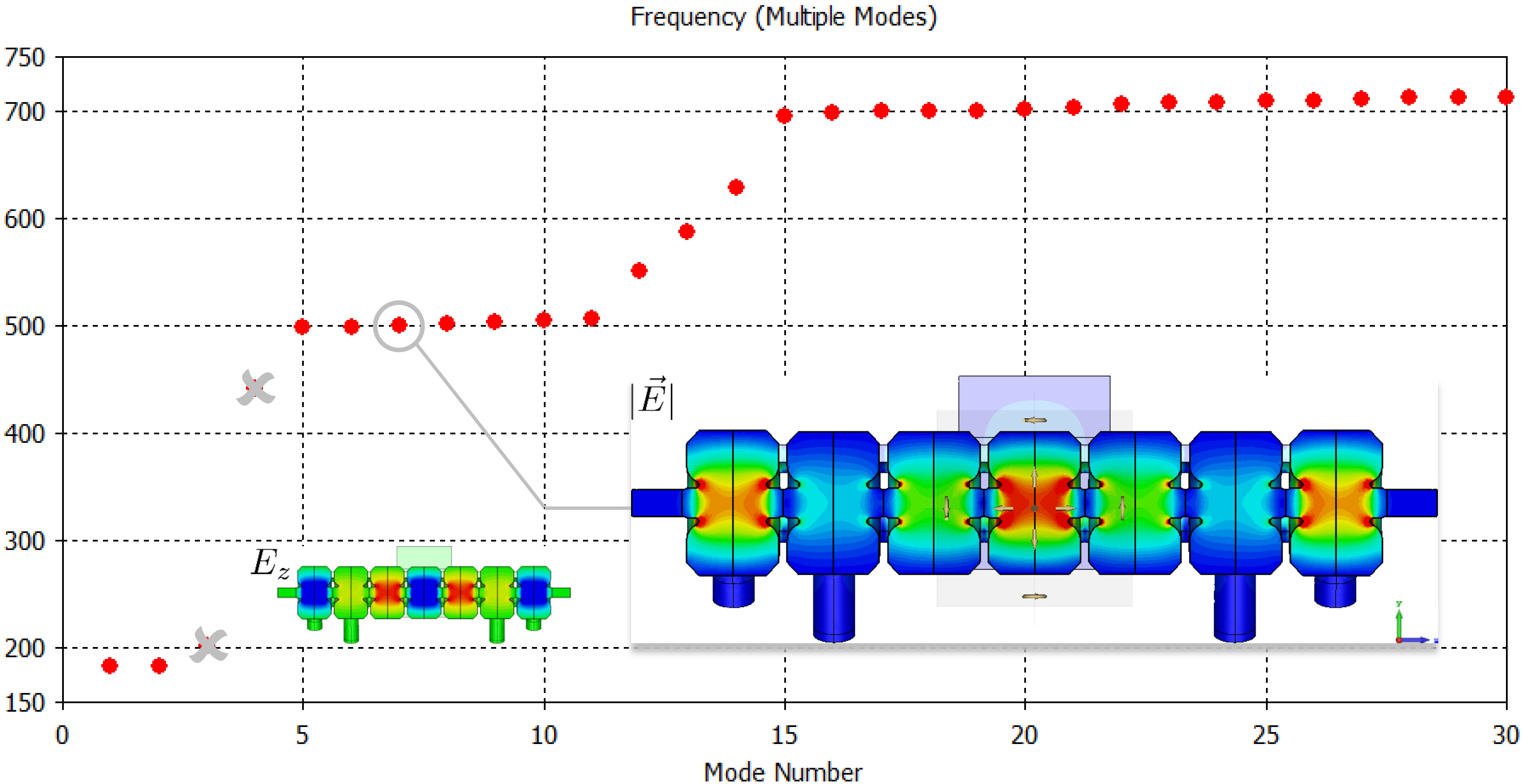

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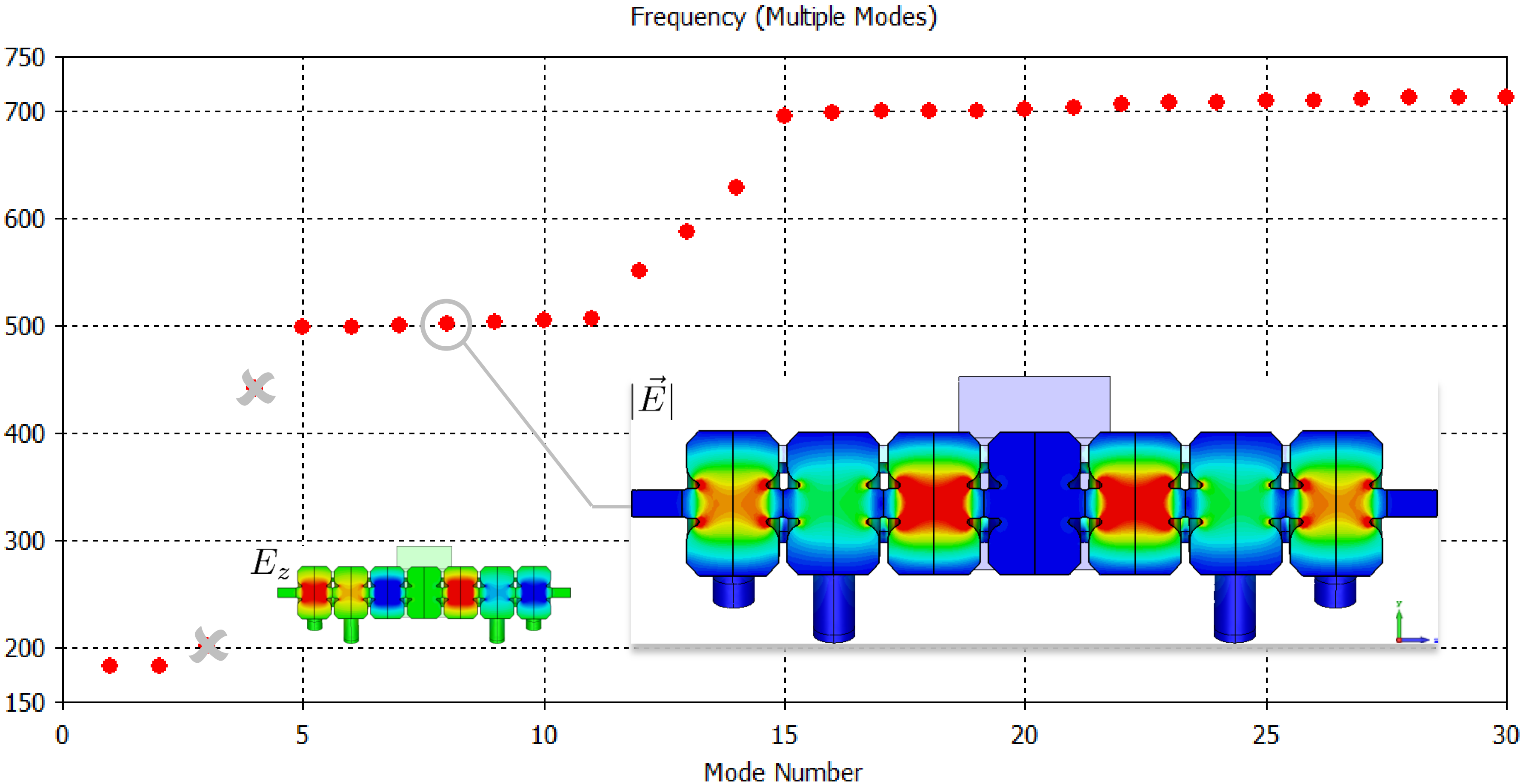

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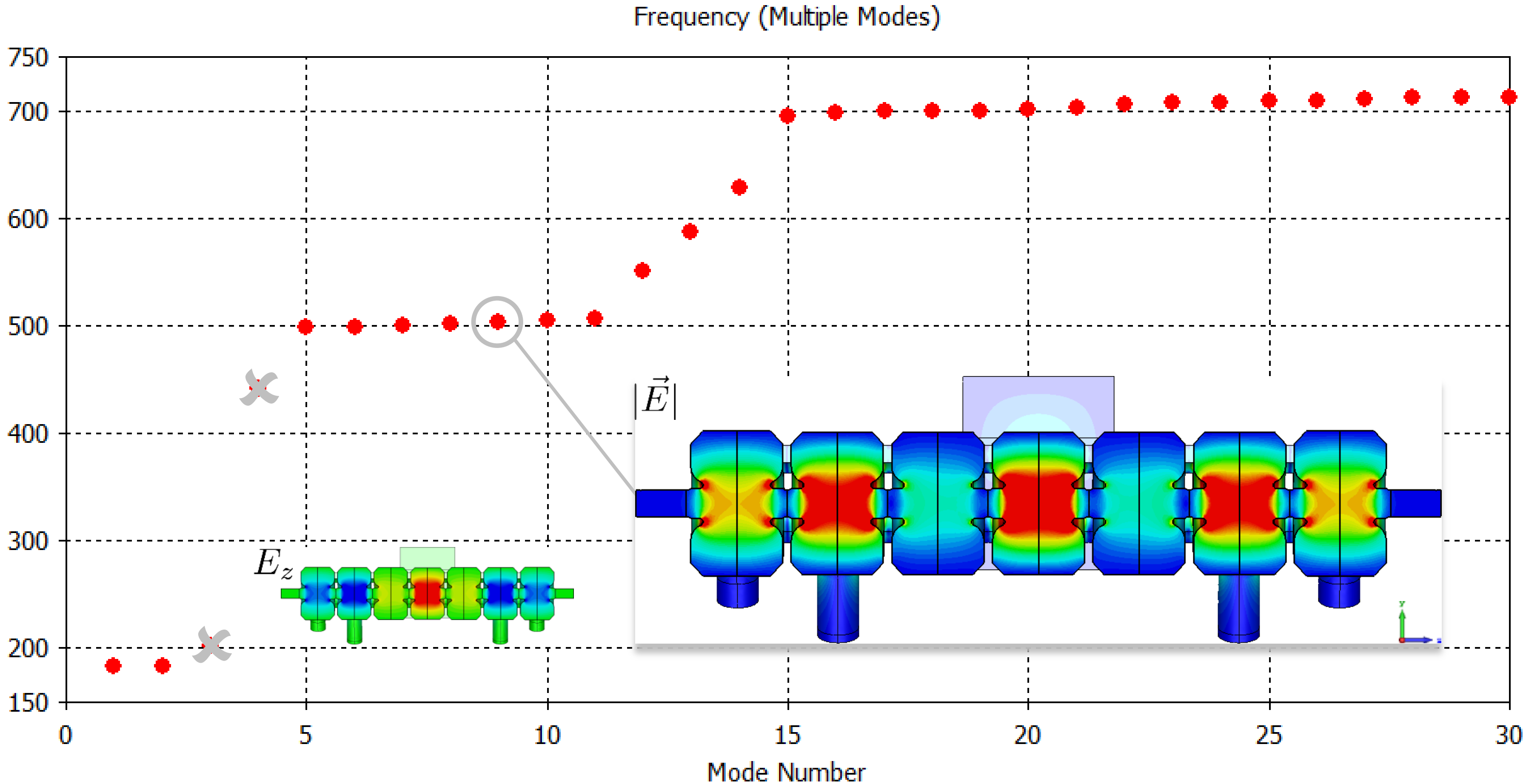

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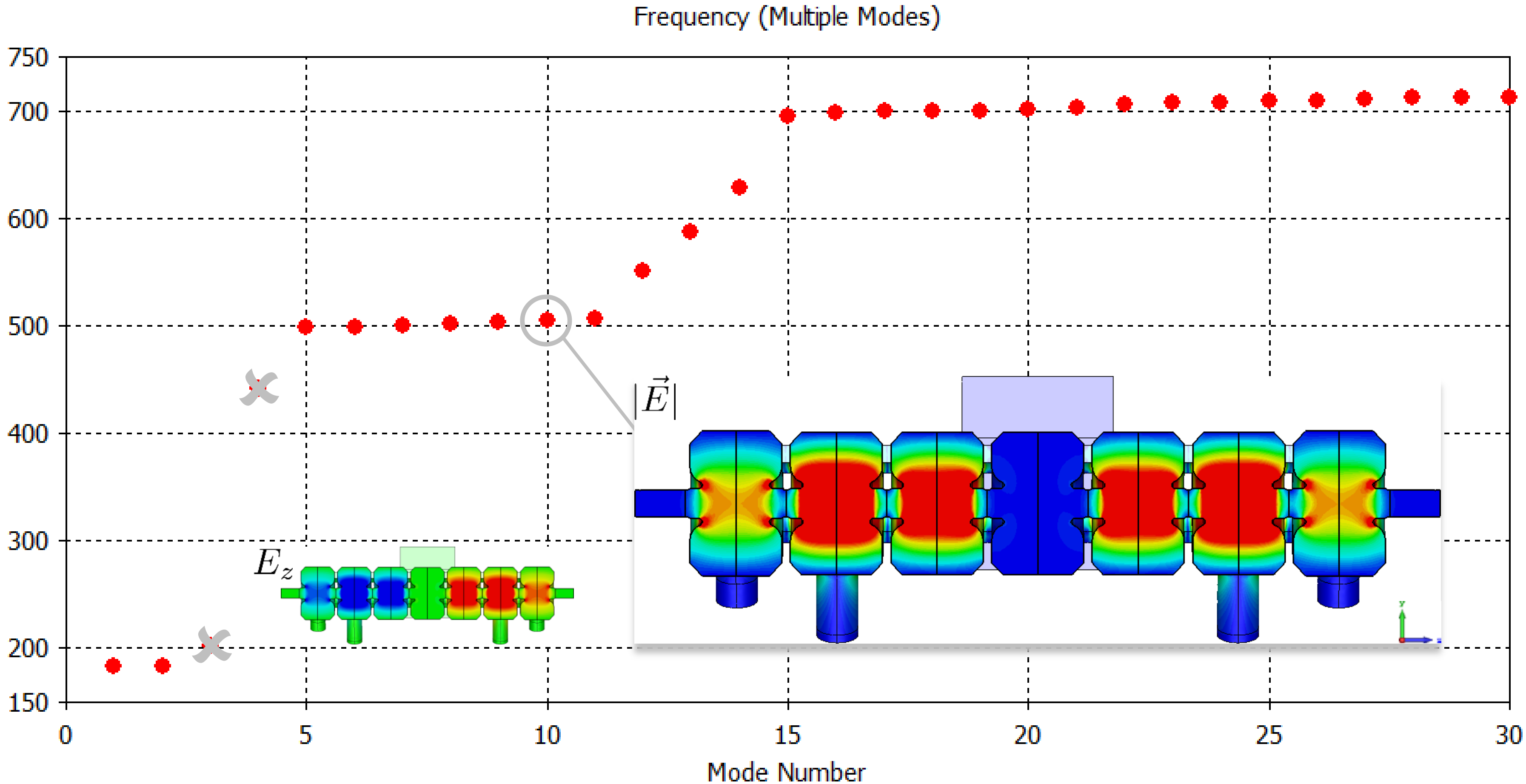

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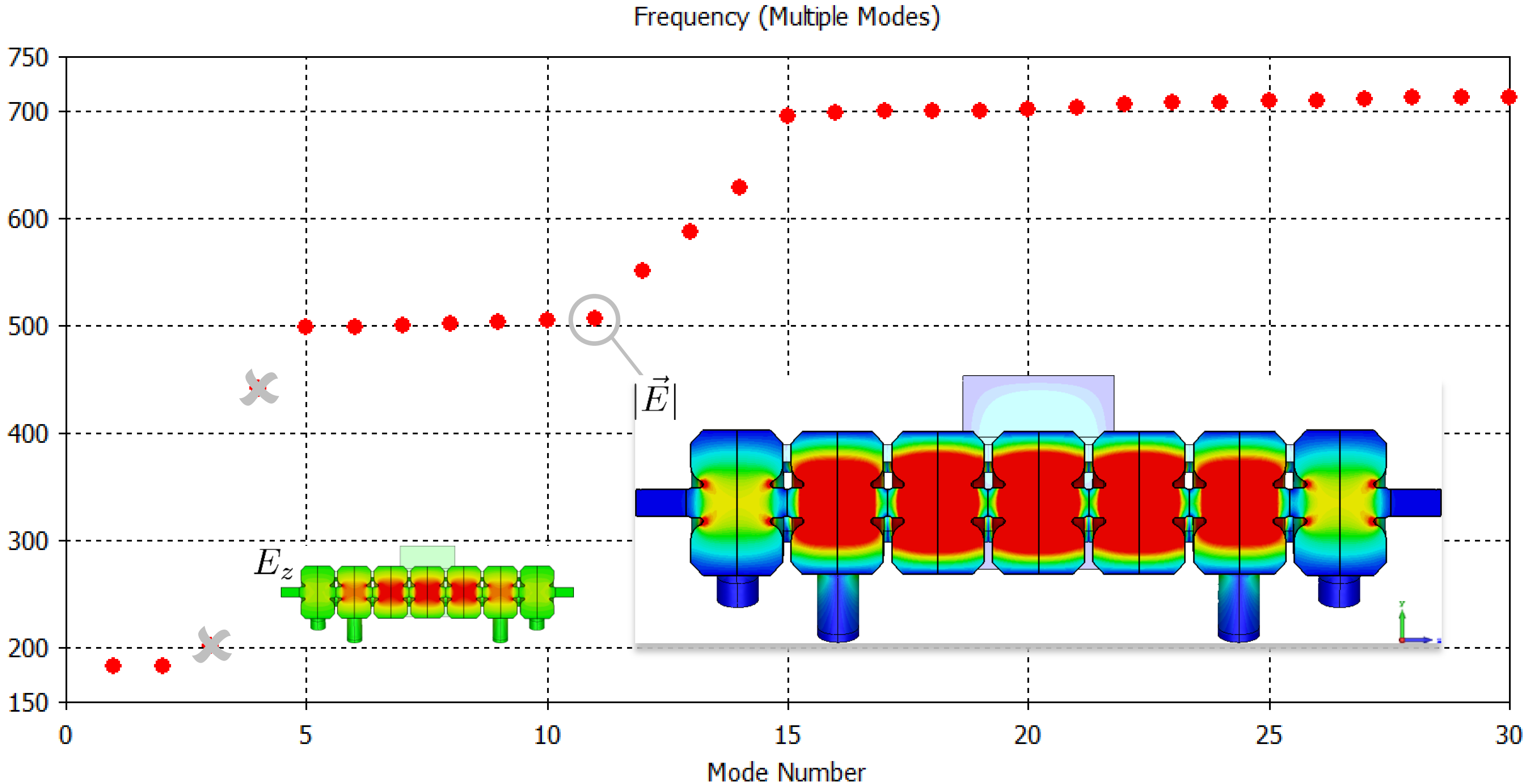

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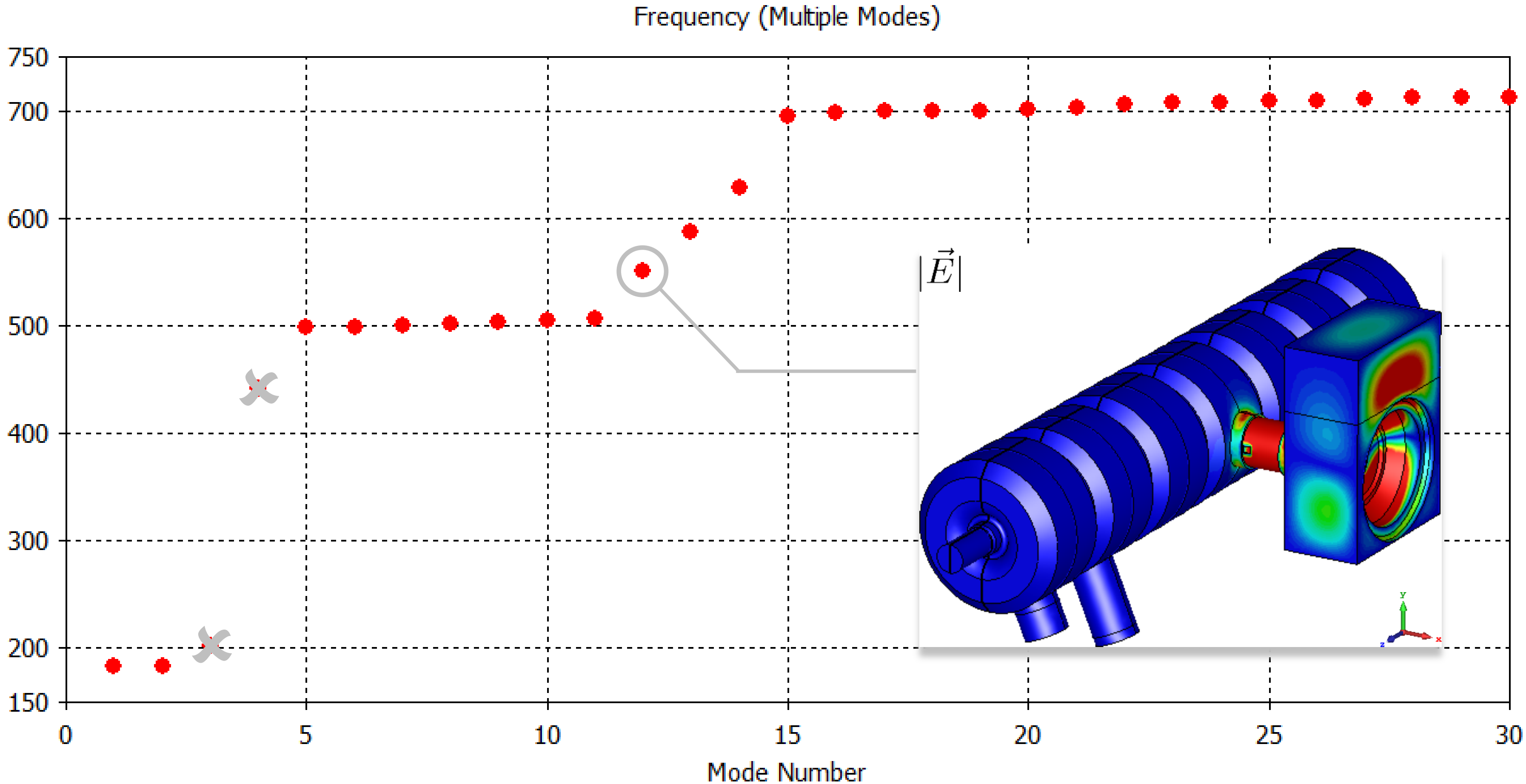

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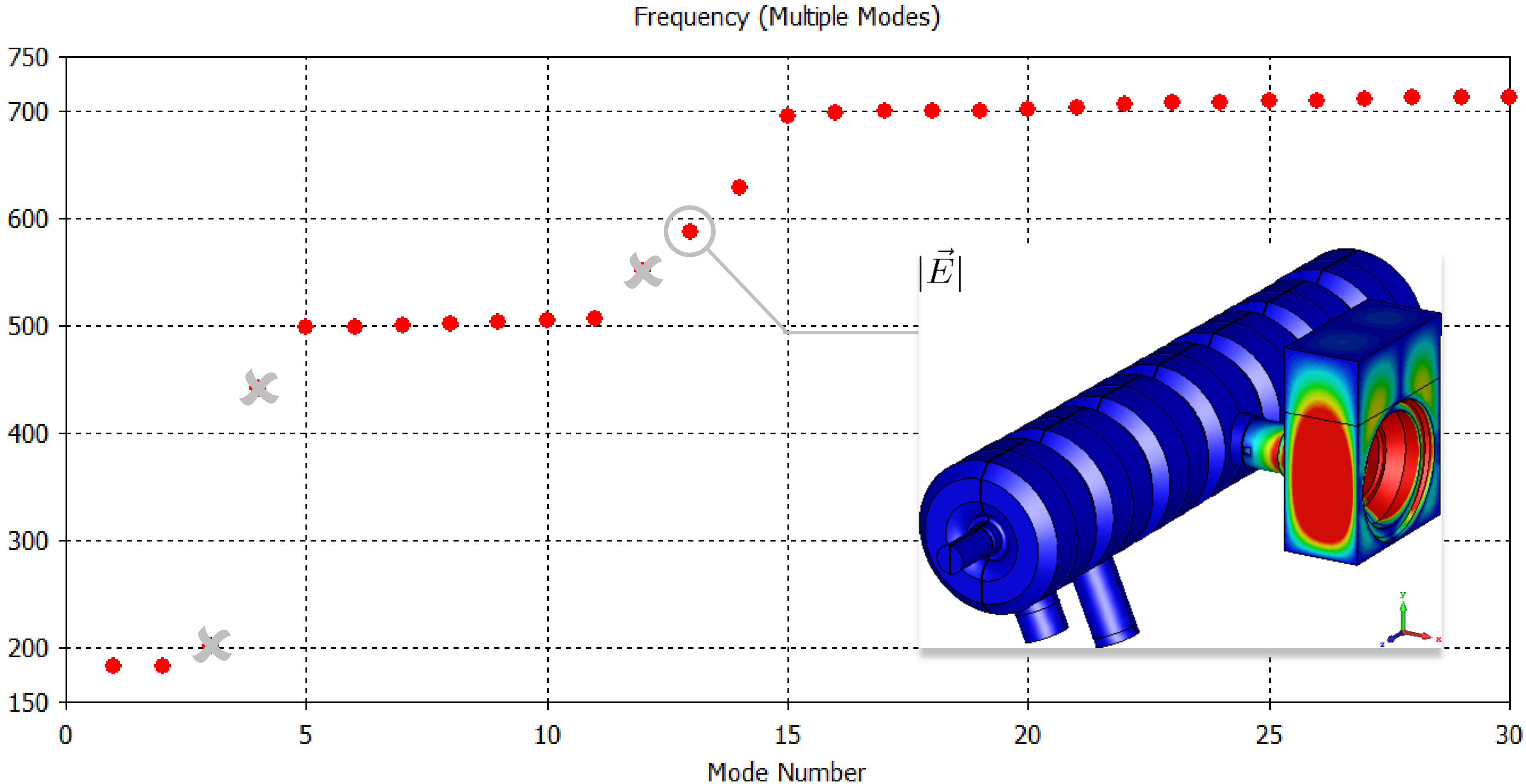

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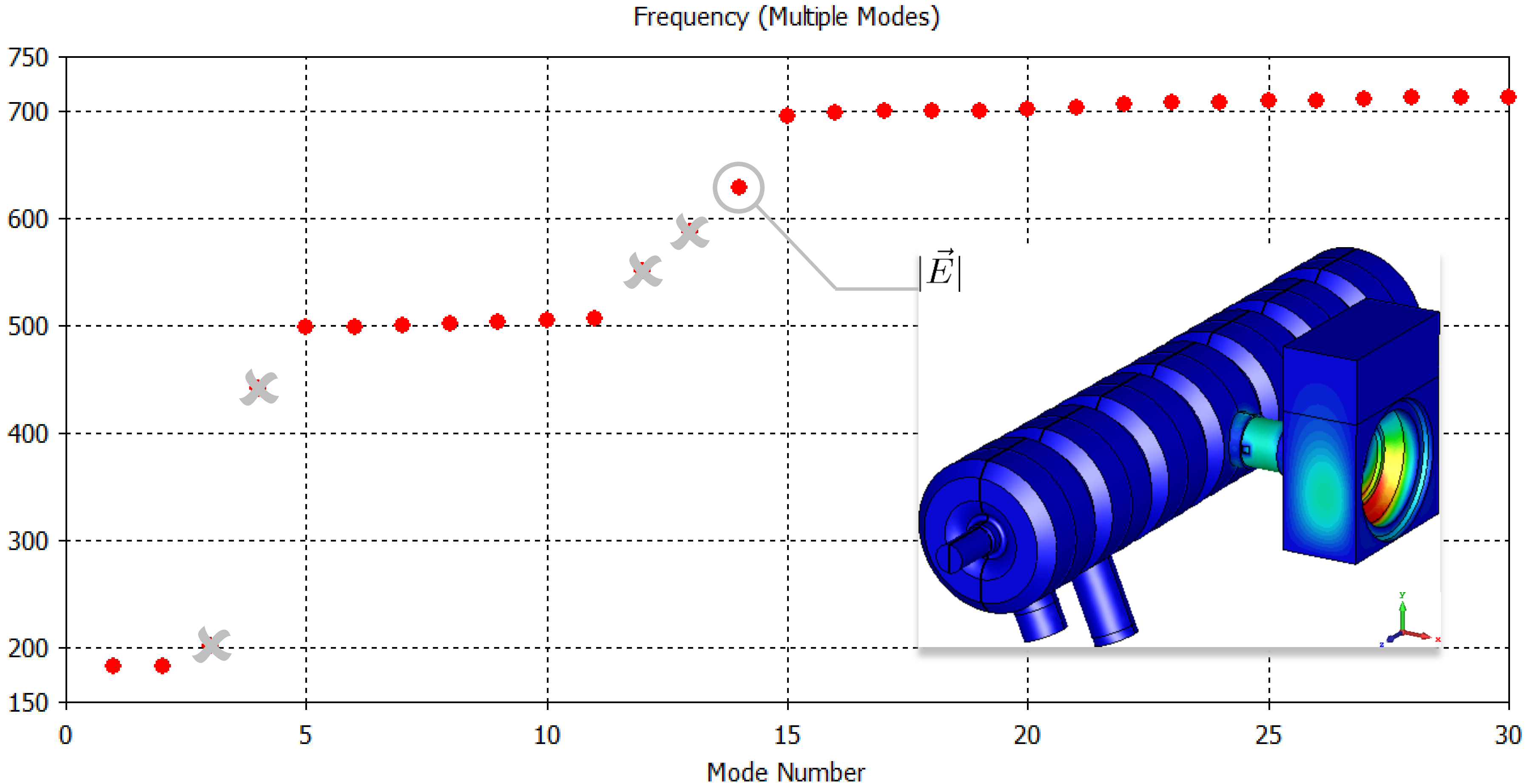

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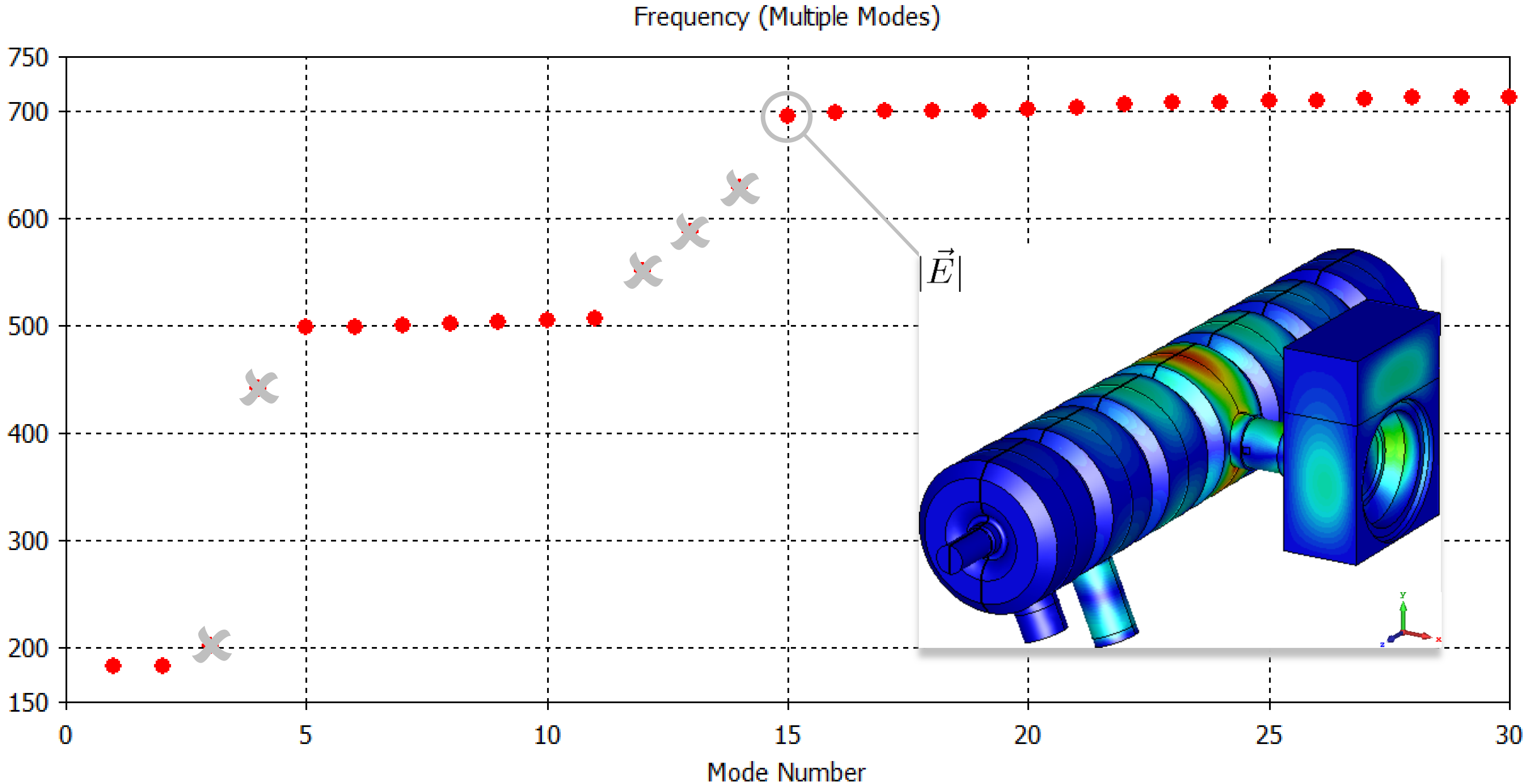

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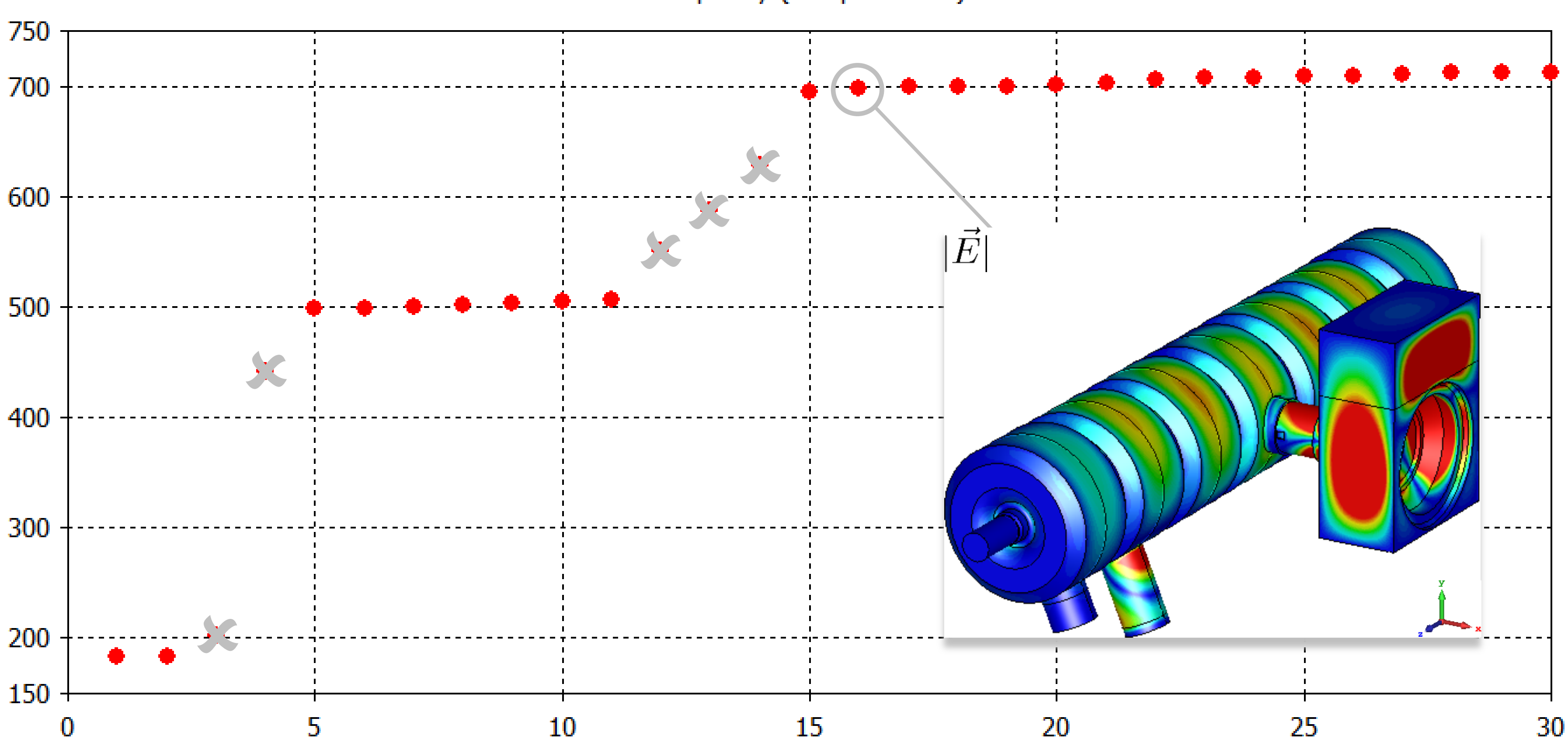
- Calculated Resonances



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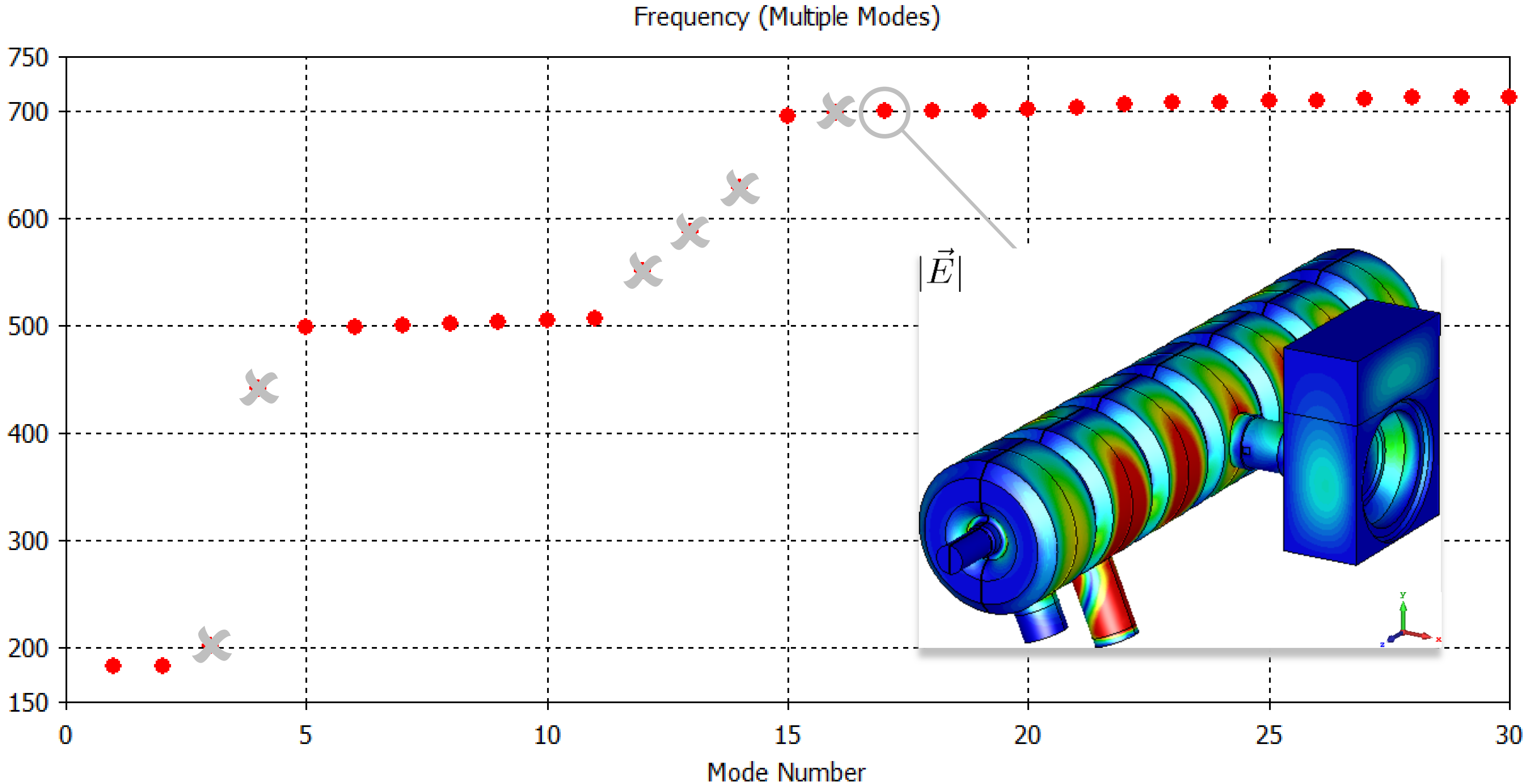

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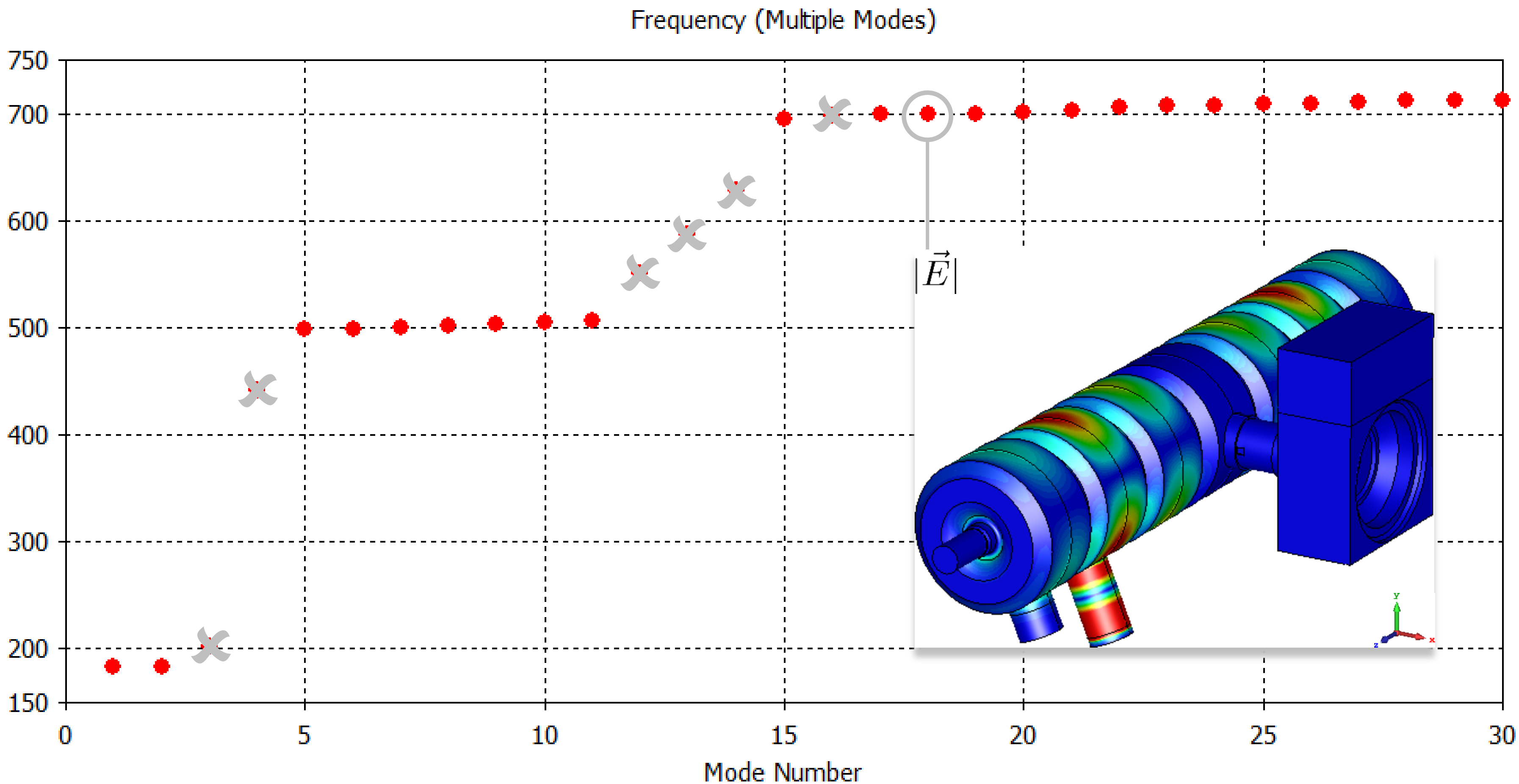

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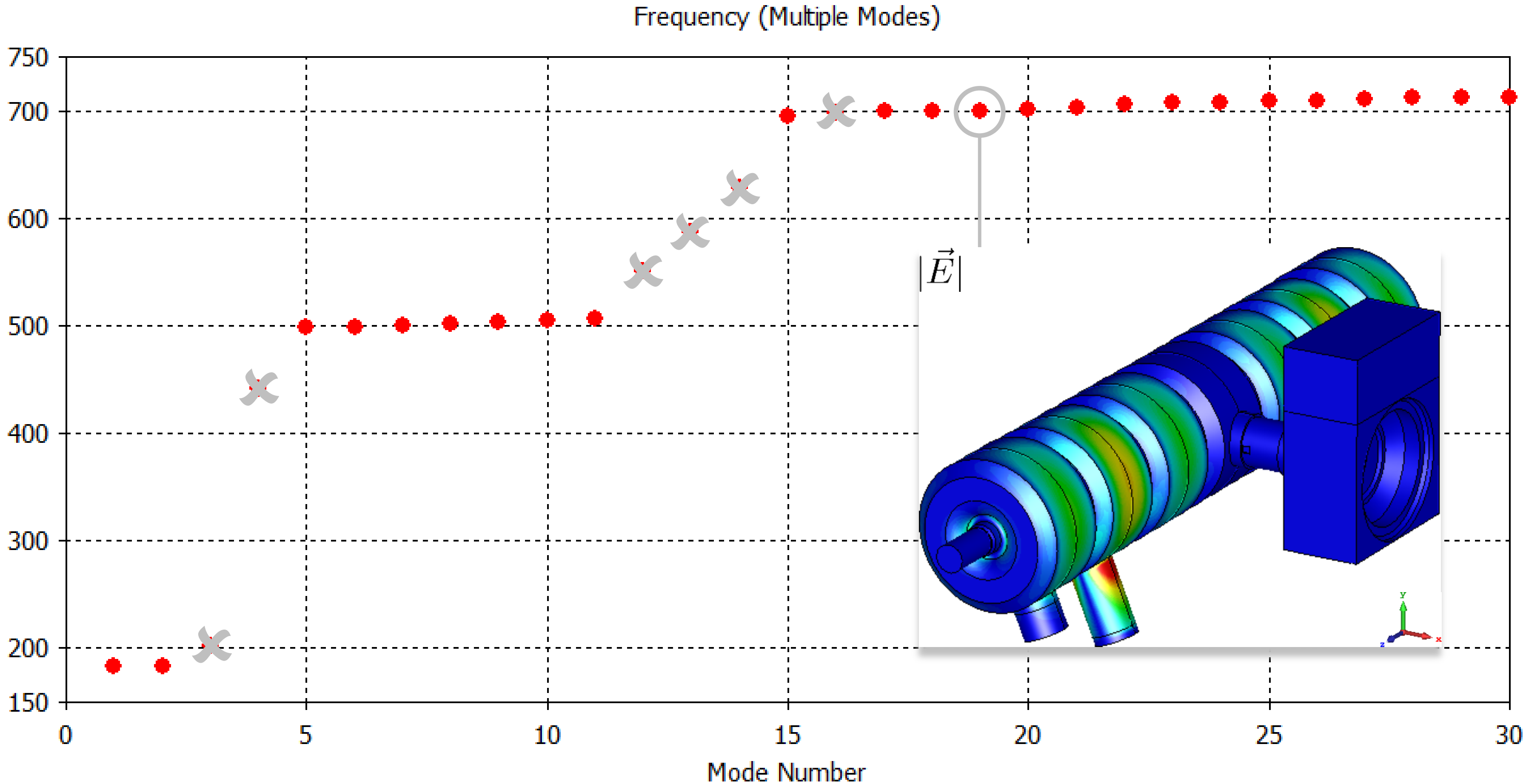

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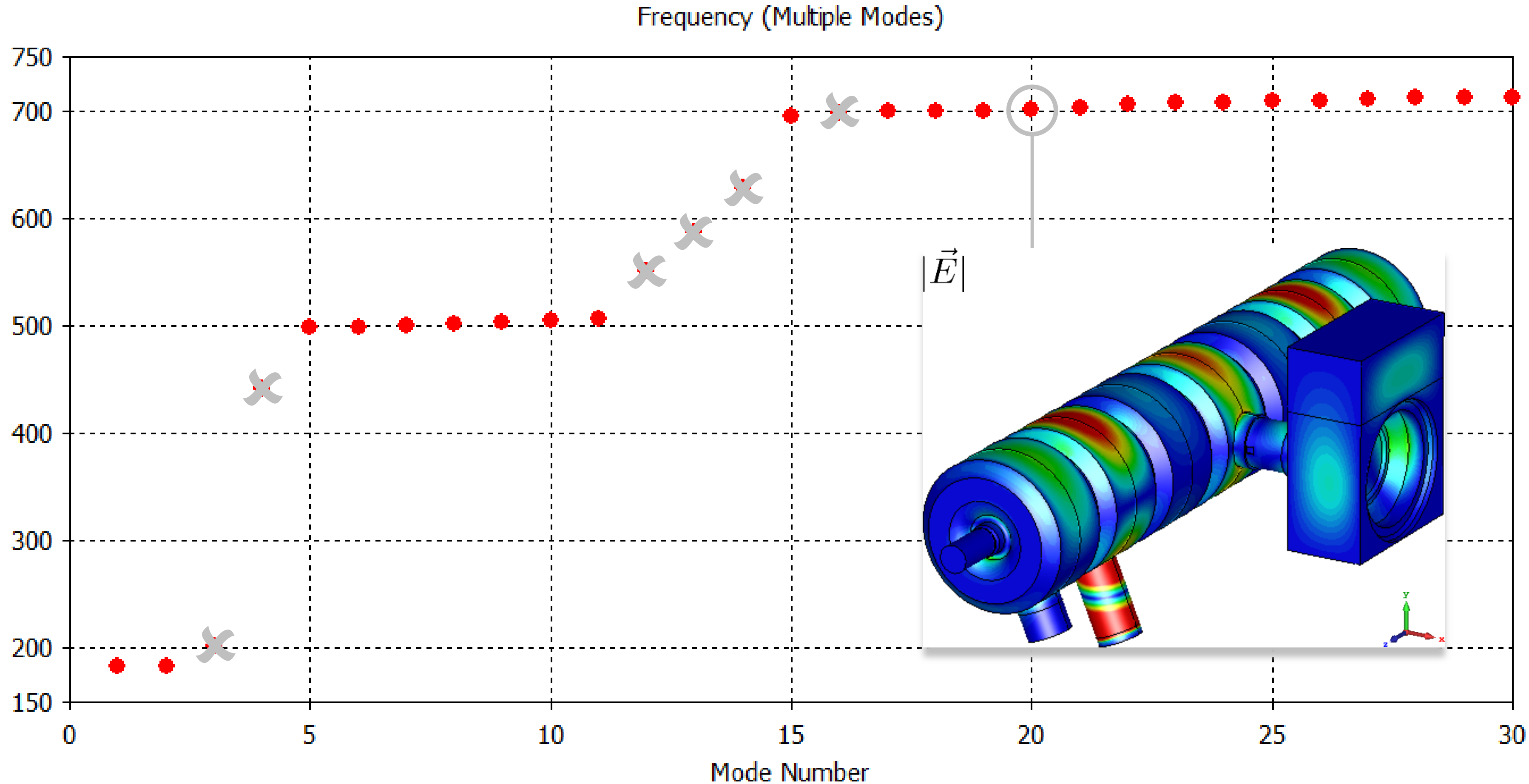

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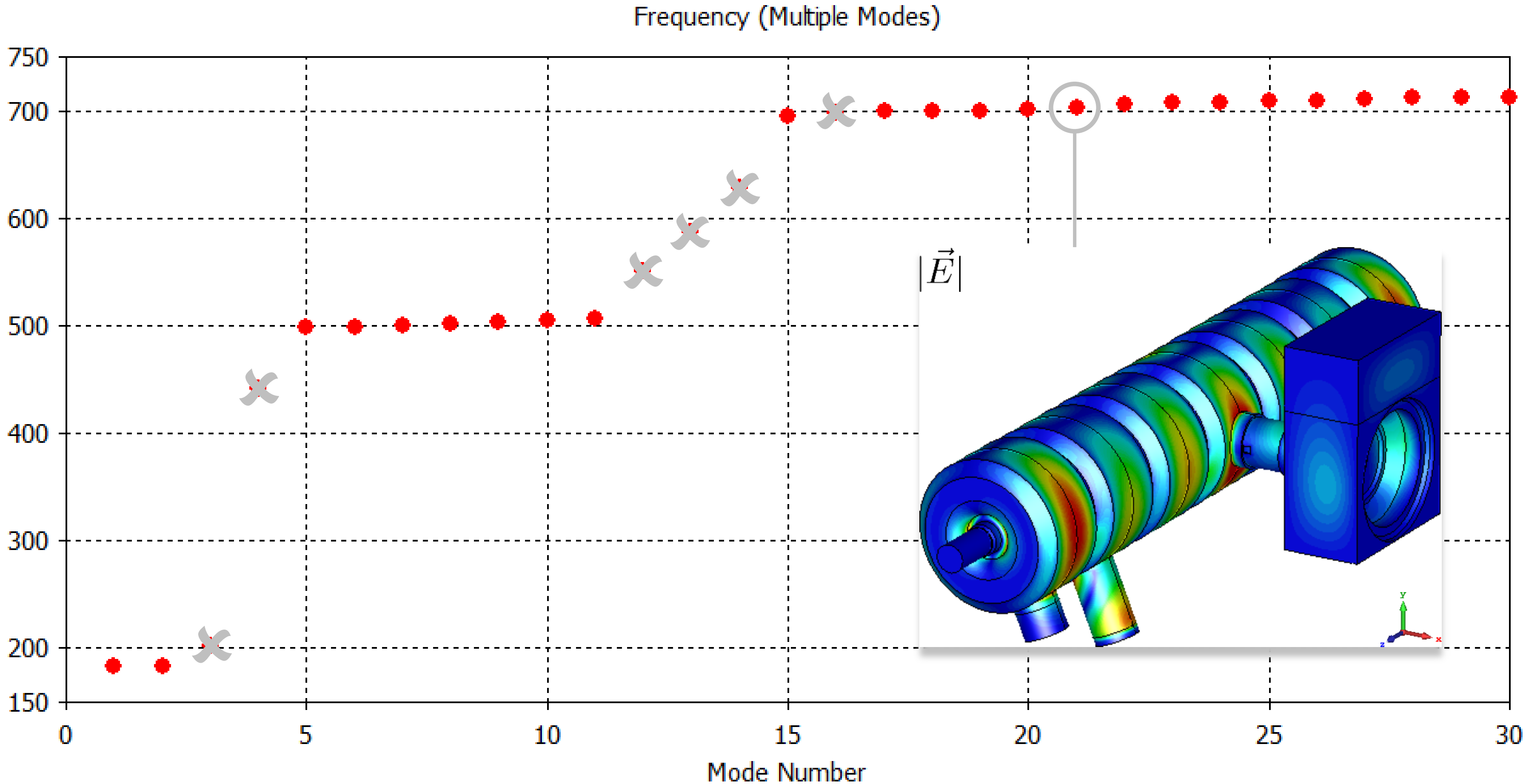

Simulation Results

TECHNISCHE UNIVERSITÄT DARMSTADT

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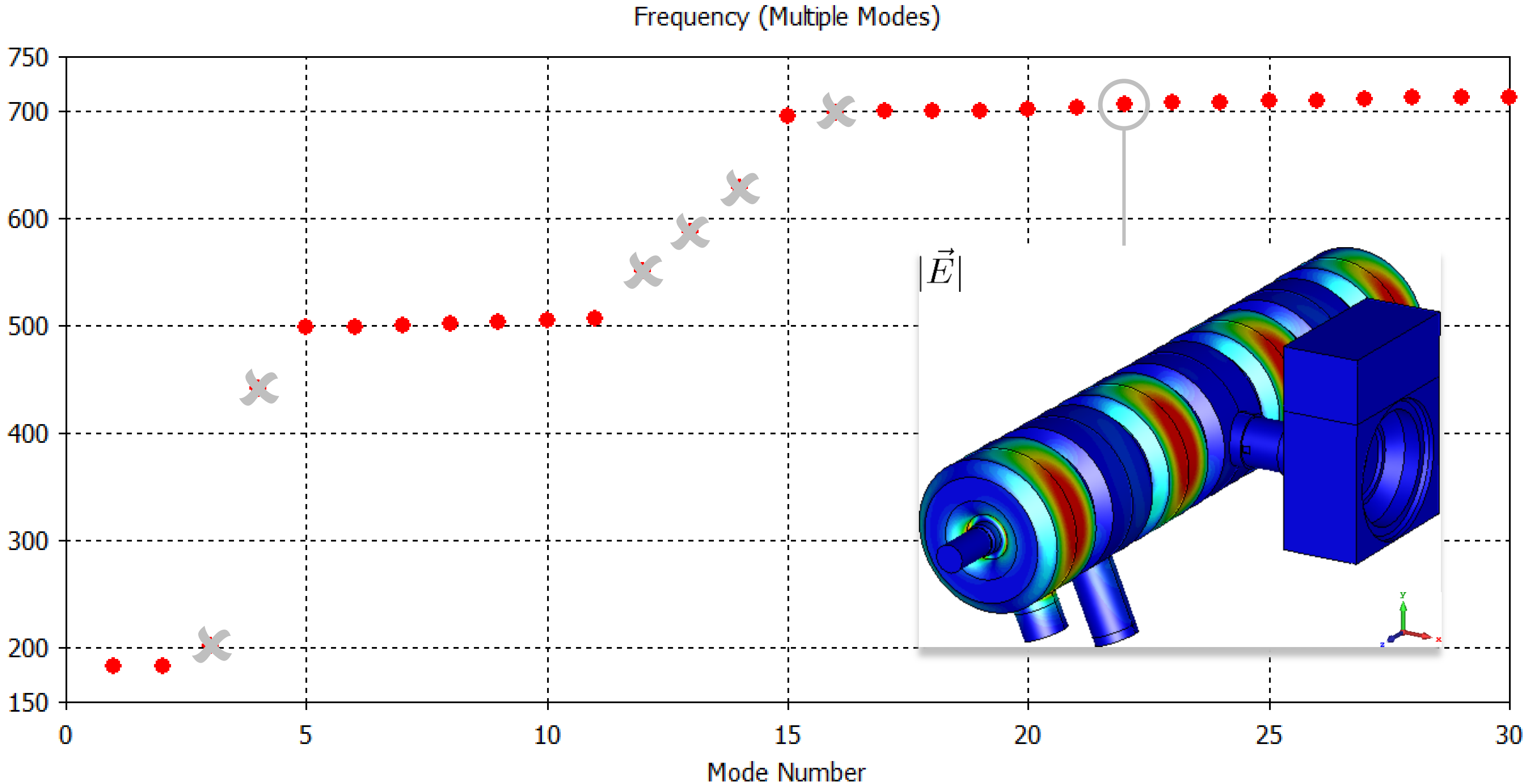

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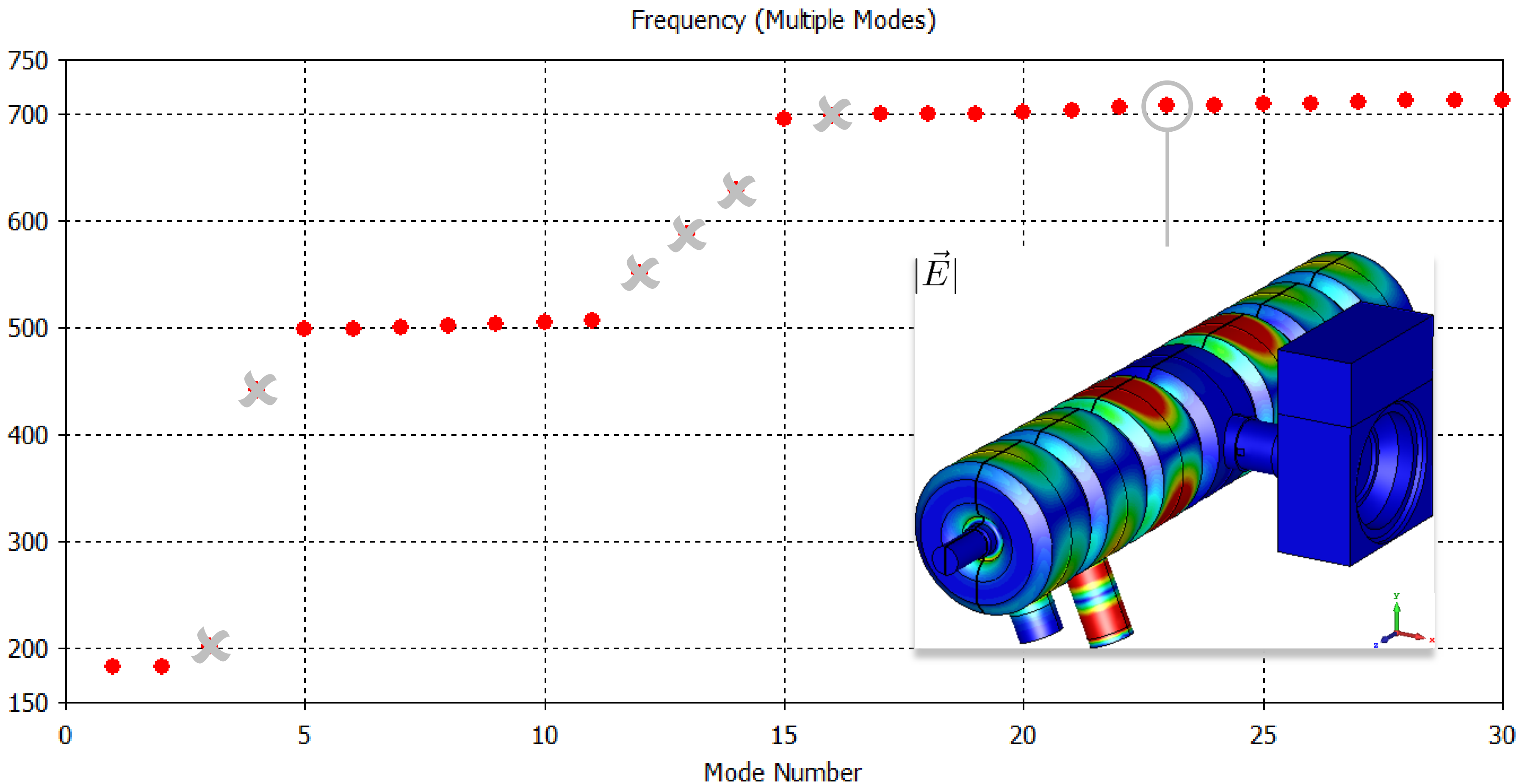

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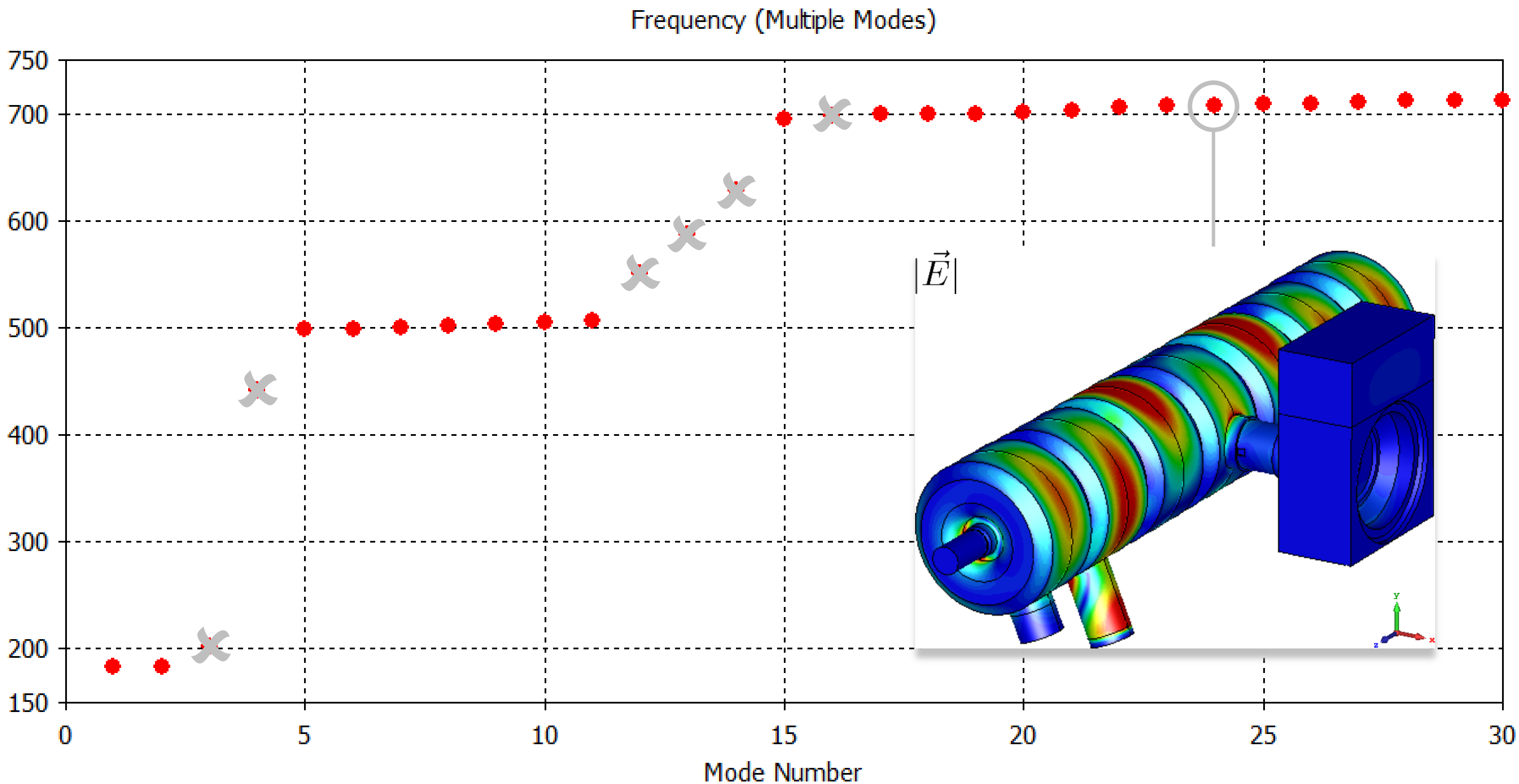

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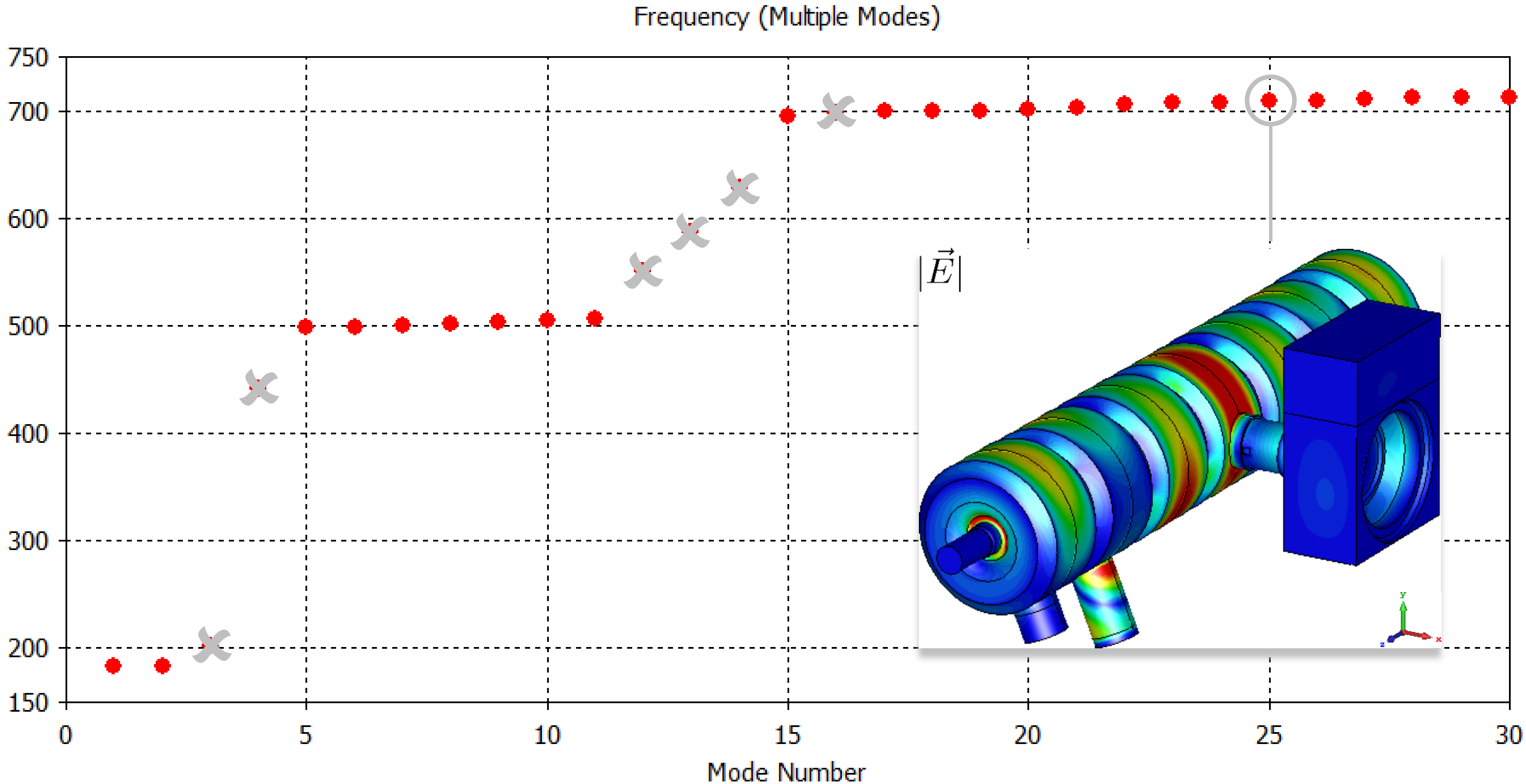

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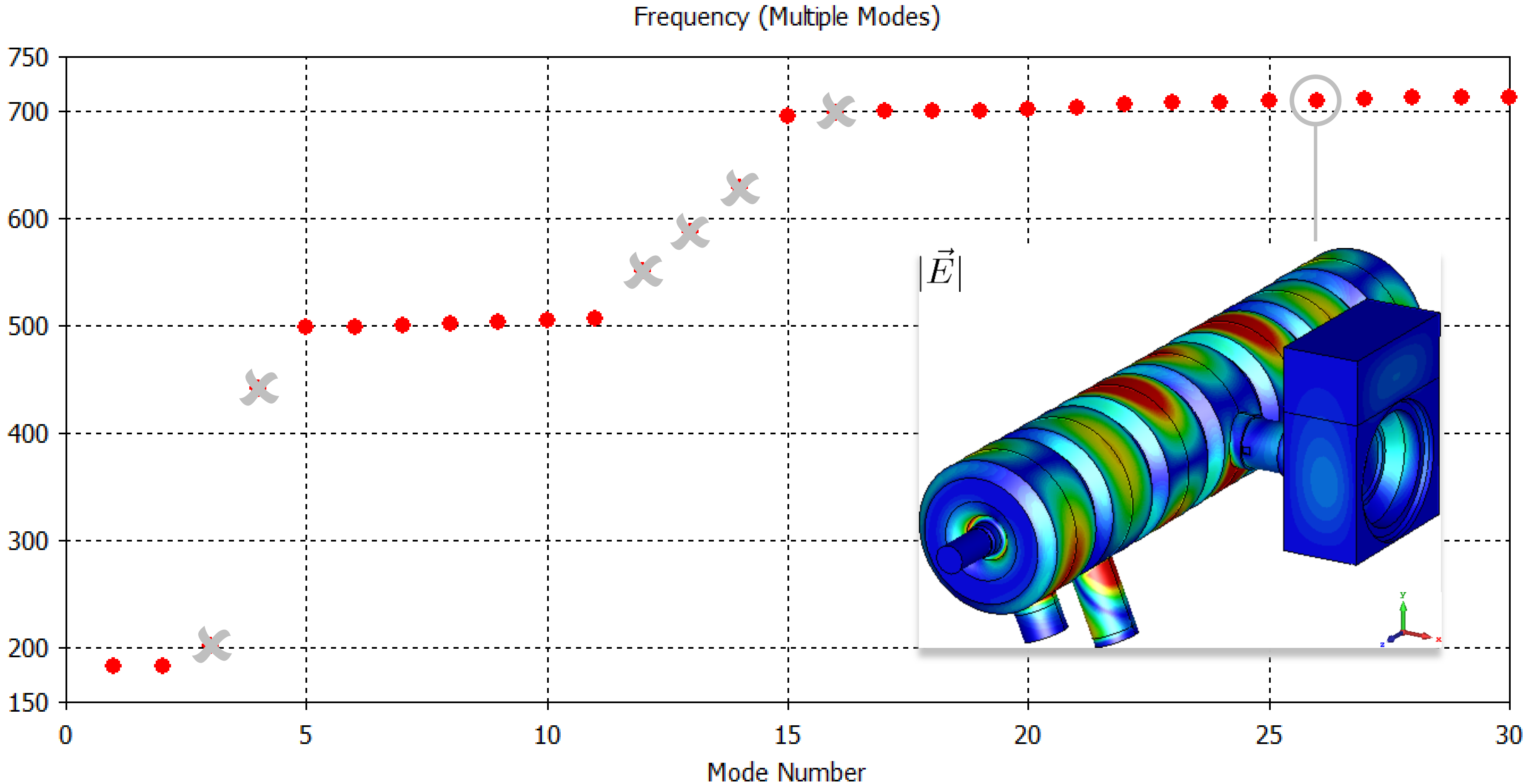

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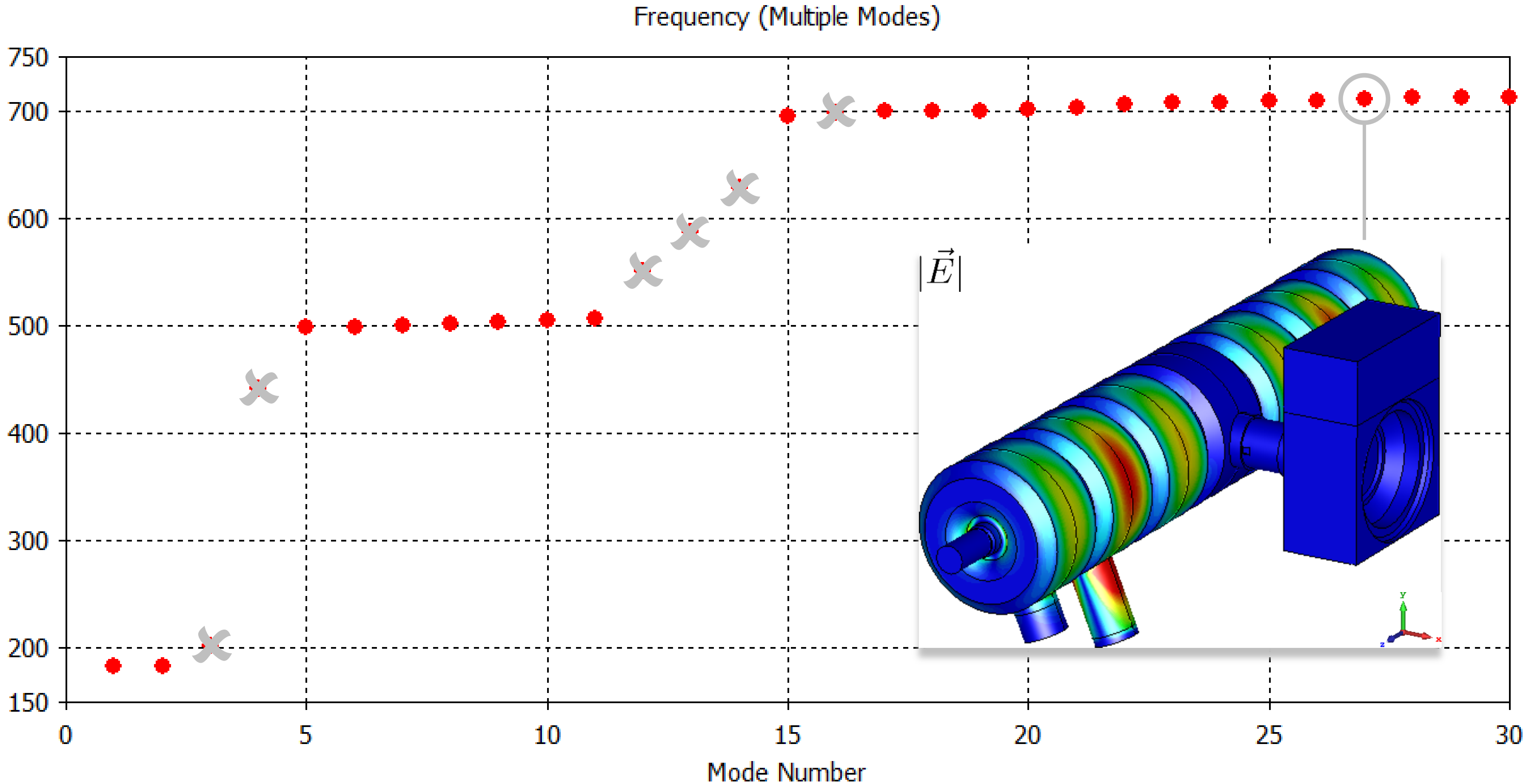

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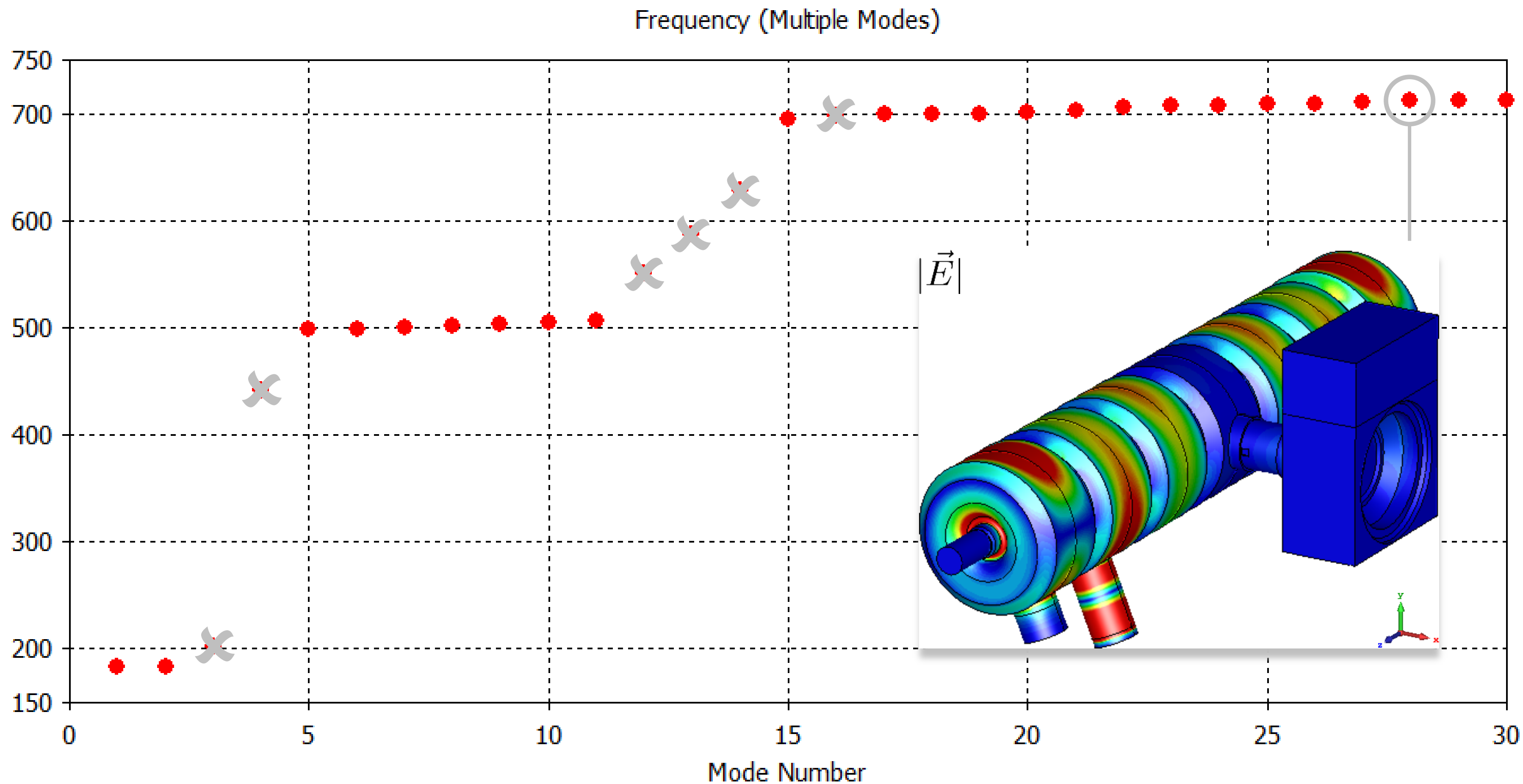

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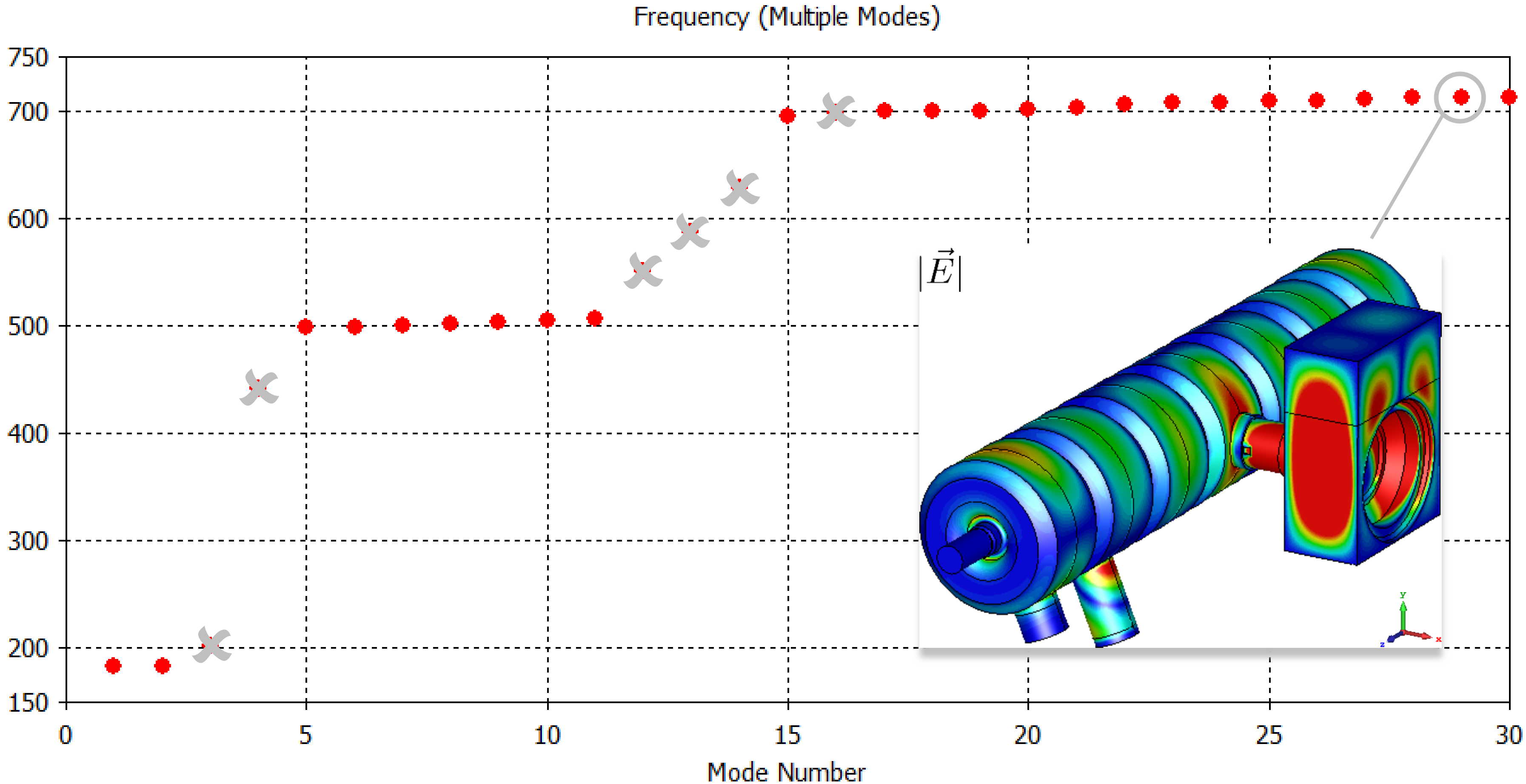
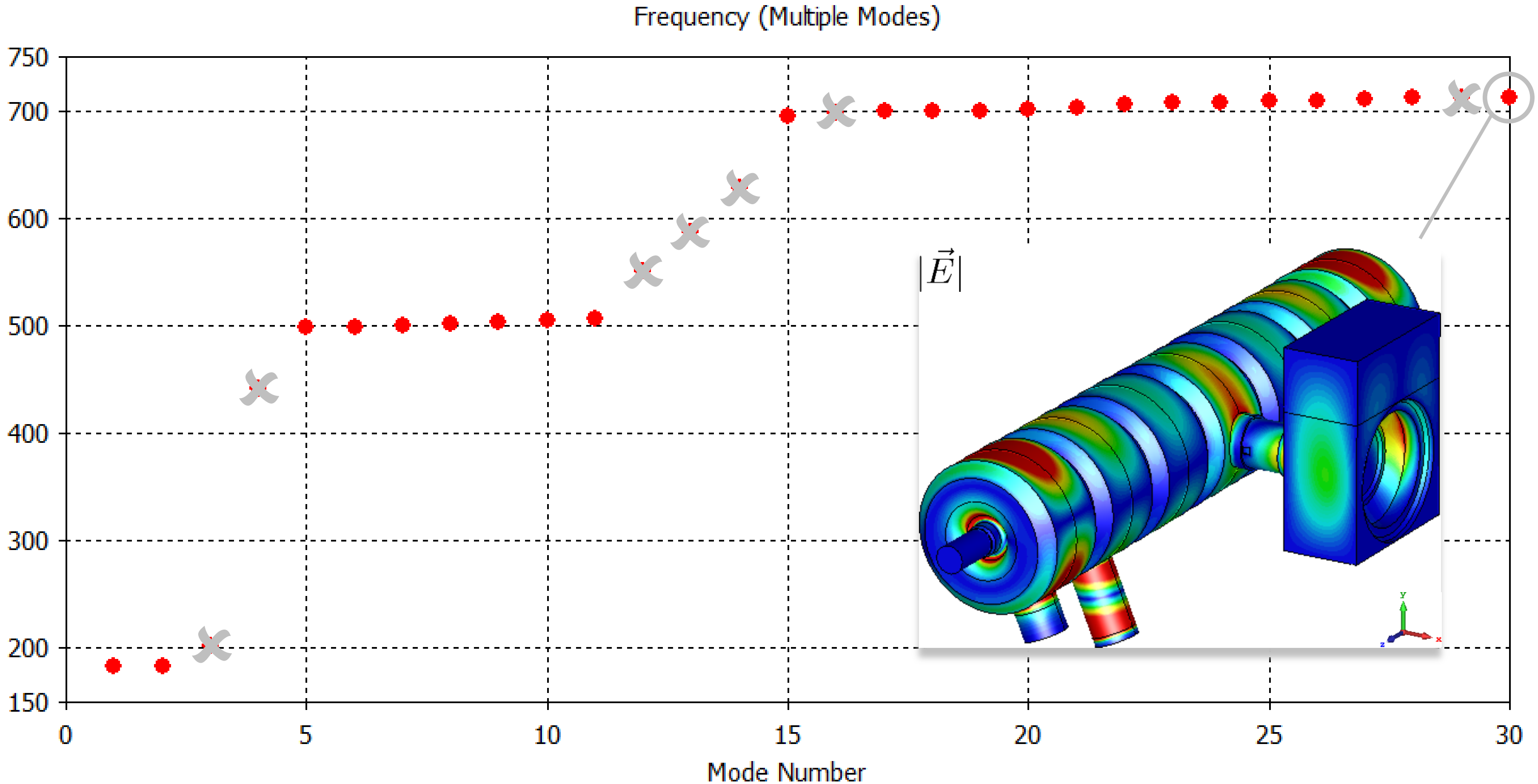


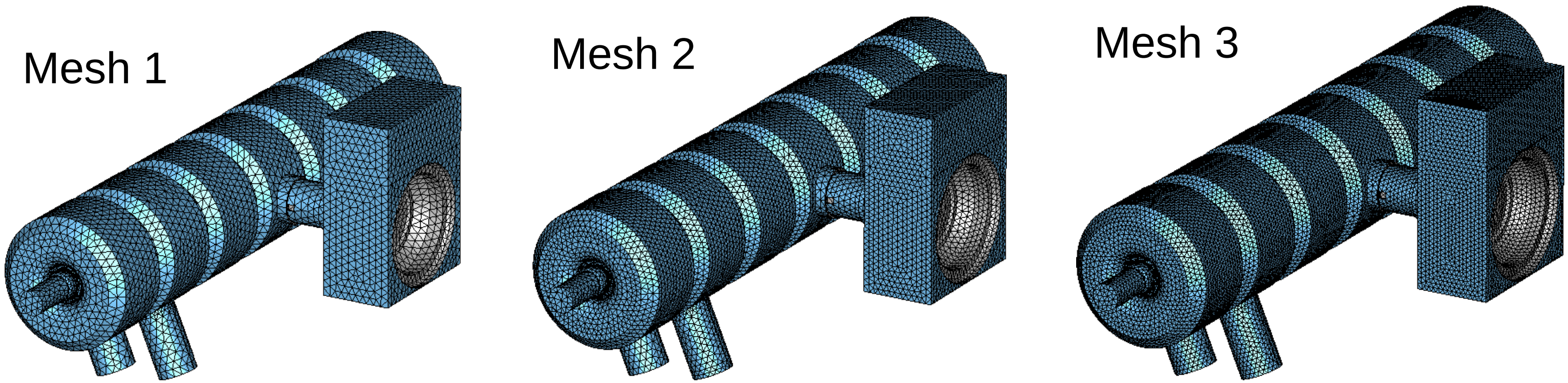
Simulation Results

- Calculated Resonances



Accuracy Considerations

- Computational Method
  - Finite Element Method
    - ➡ Second-order Nedelec-Elements on curved tetrahedrons
  - Closed structure with PEC boundary conditions
  - Evaluation on different meshes

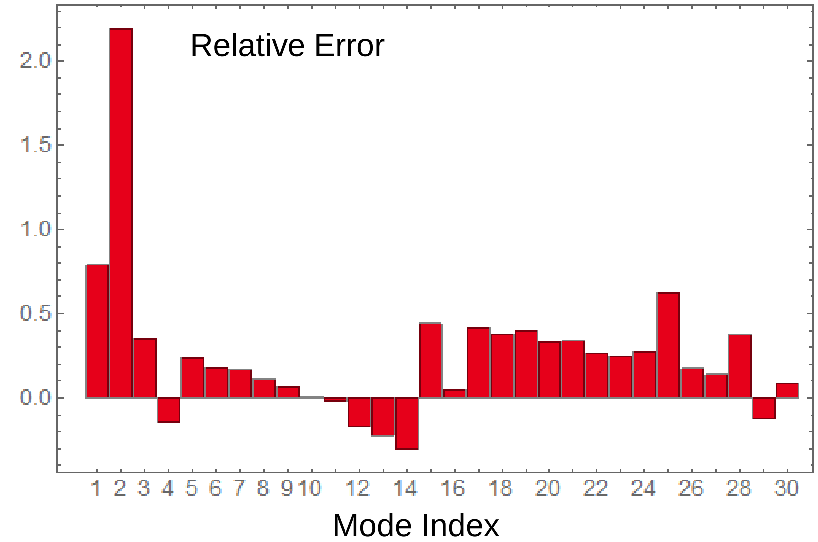


267.262 Tets | 562.339 Tets | 1.070.017 Tets

Accuracy Considerations

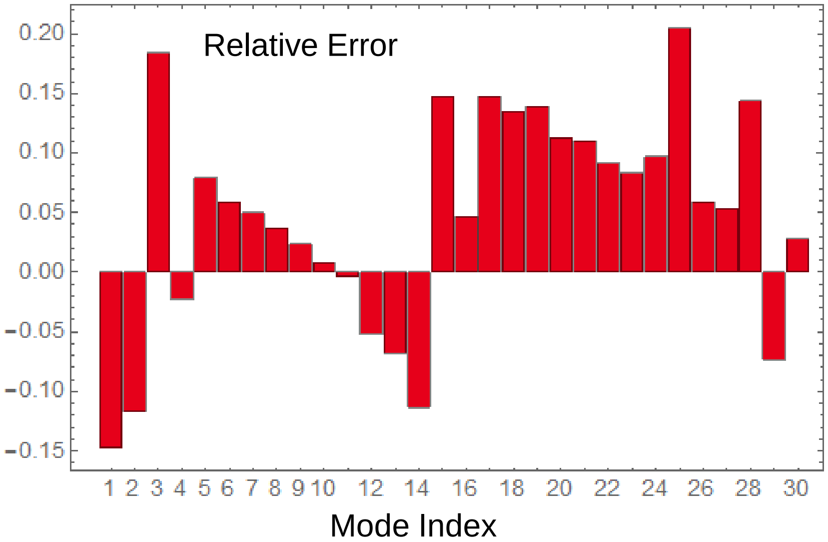
- Calculated Resonances
  - Estimation of the relative error with respect to the resonance frequency

Comparison: Mesh1 – Mesh3



$$\mathrm{err} = \frac{f|_{\mathrm{Mesh1}} - f|_{\mathrm{Mesh3}}}{f|_{\mathrm{Mesh3}}} \cdot 1000$$

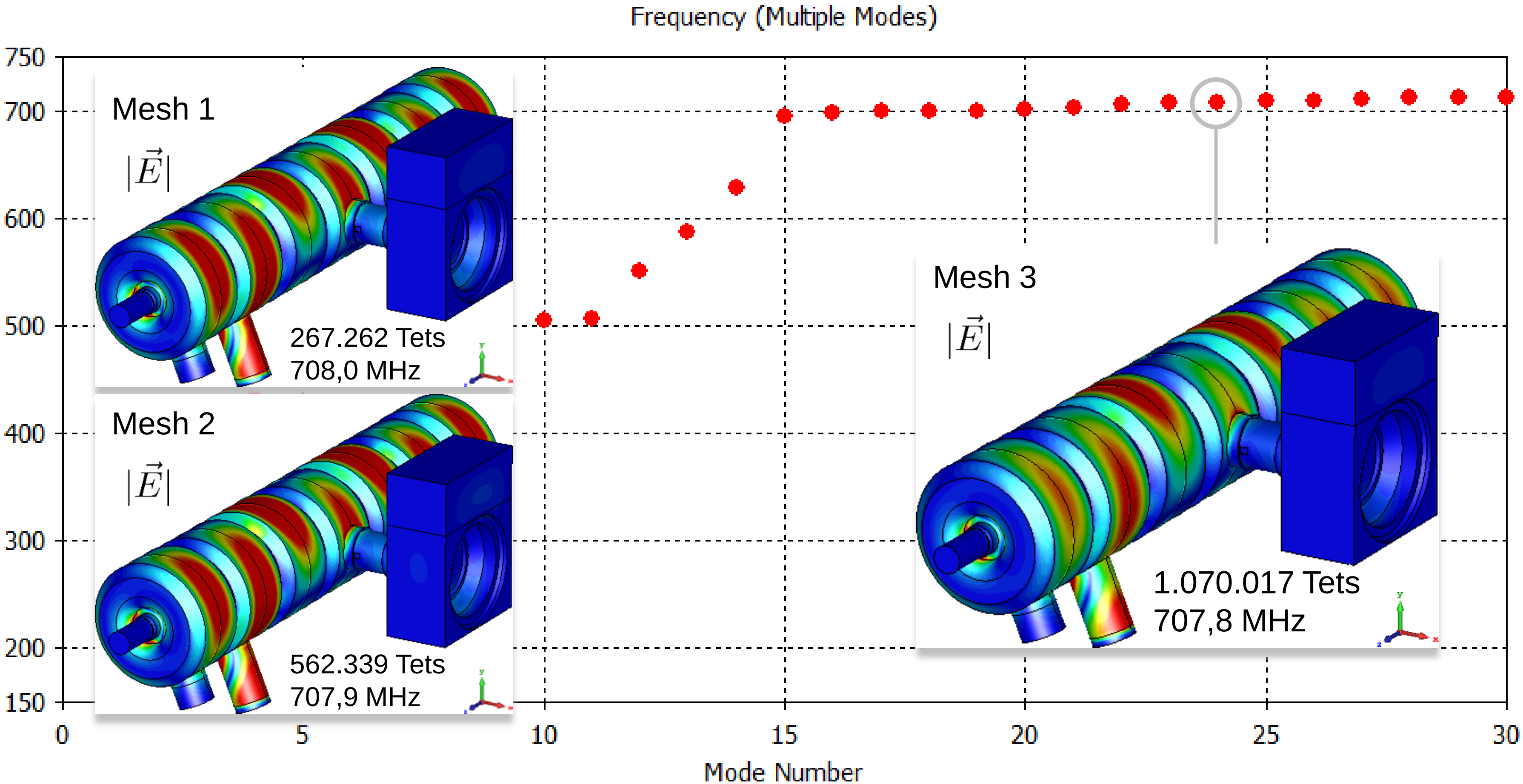
Comparison: Mesh2 – Mesh3



$$\mathrm{err} = \frac{f|_{\mathrm{Mesh2}} - f|_{\mathrm{Mesh3}}}{f|_{\mathrm{Mesh3}}} \cdot 1000$$

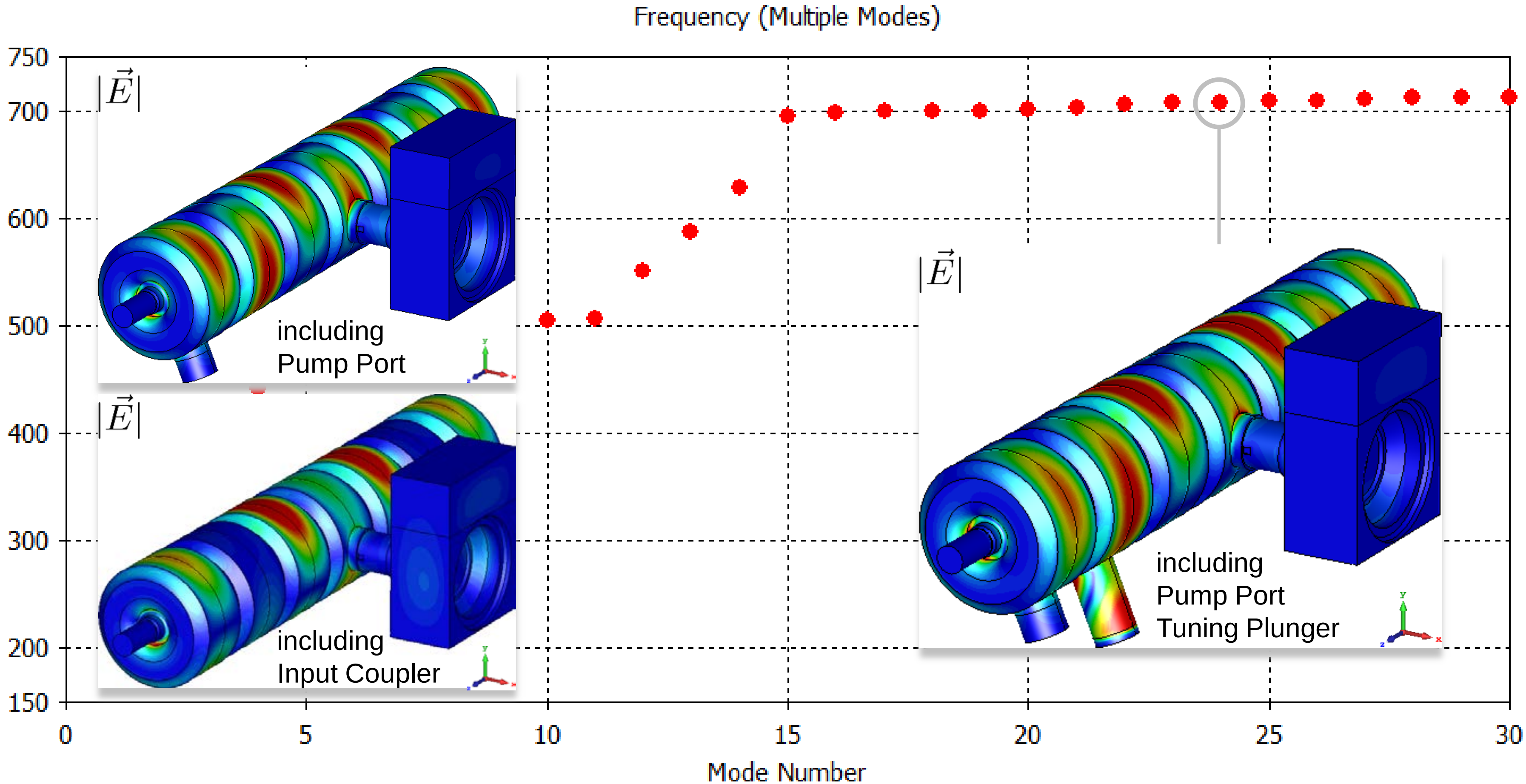
Accuracy Considerations

- Capability to separate modes (mixed polarization observed)



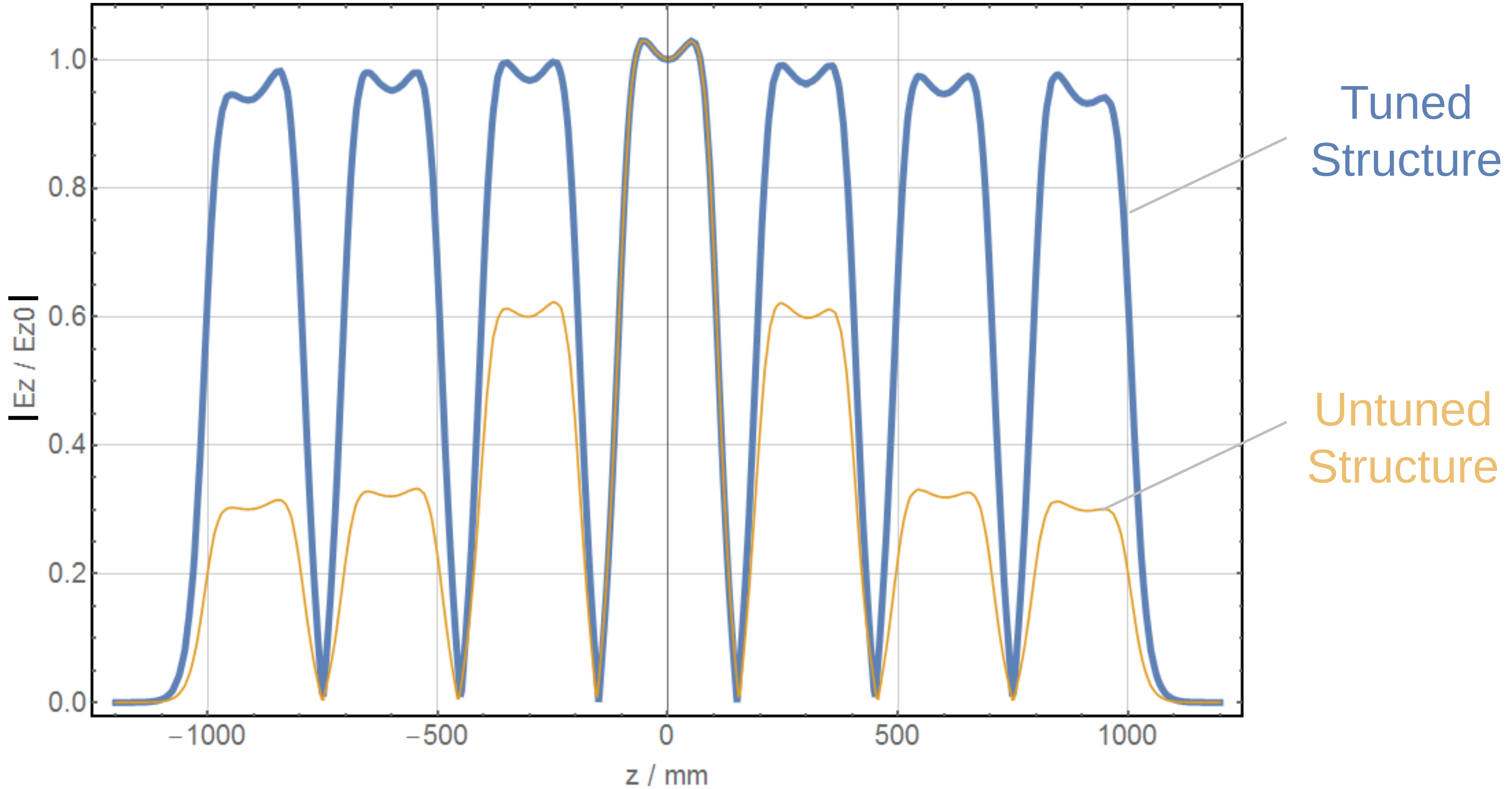
Accuracy Considerations

- Rotation of the Polarization



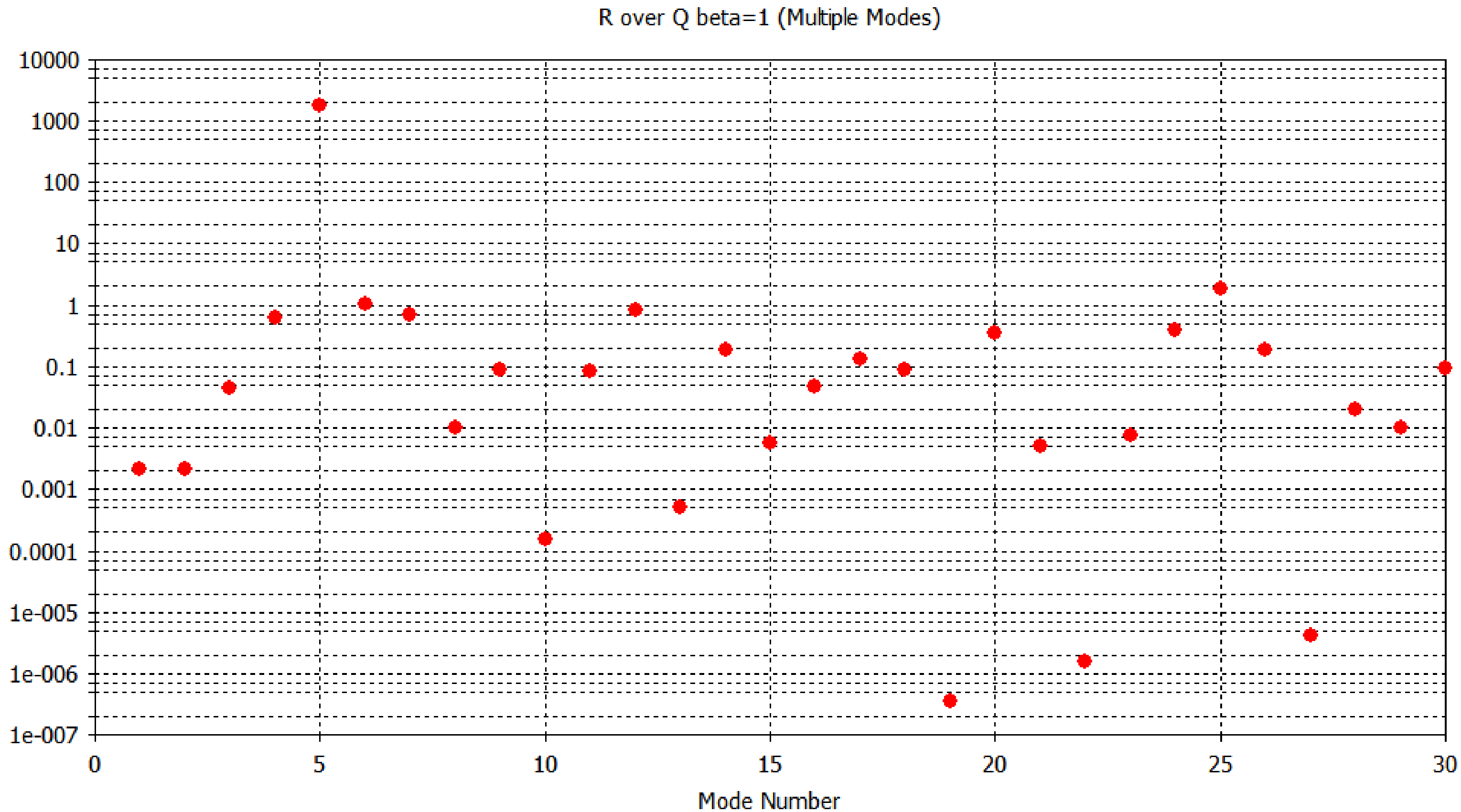
Simulation Results

- Comparison: Tuned and Untuned Structure
  - Evaluation of the longitudinal electric field component along the axis



Simulation Results

- Postprocessing: R / Q (tuned cavity)



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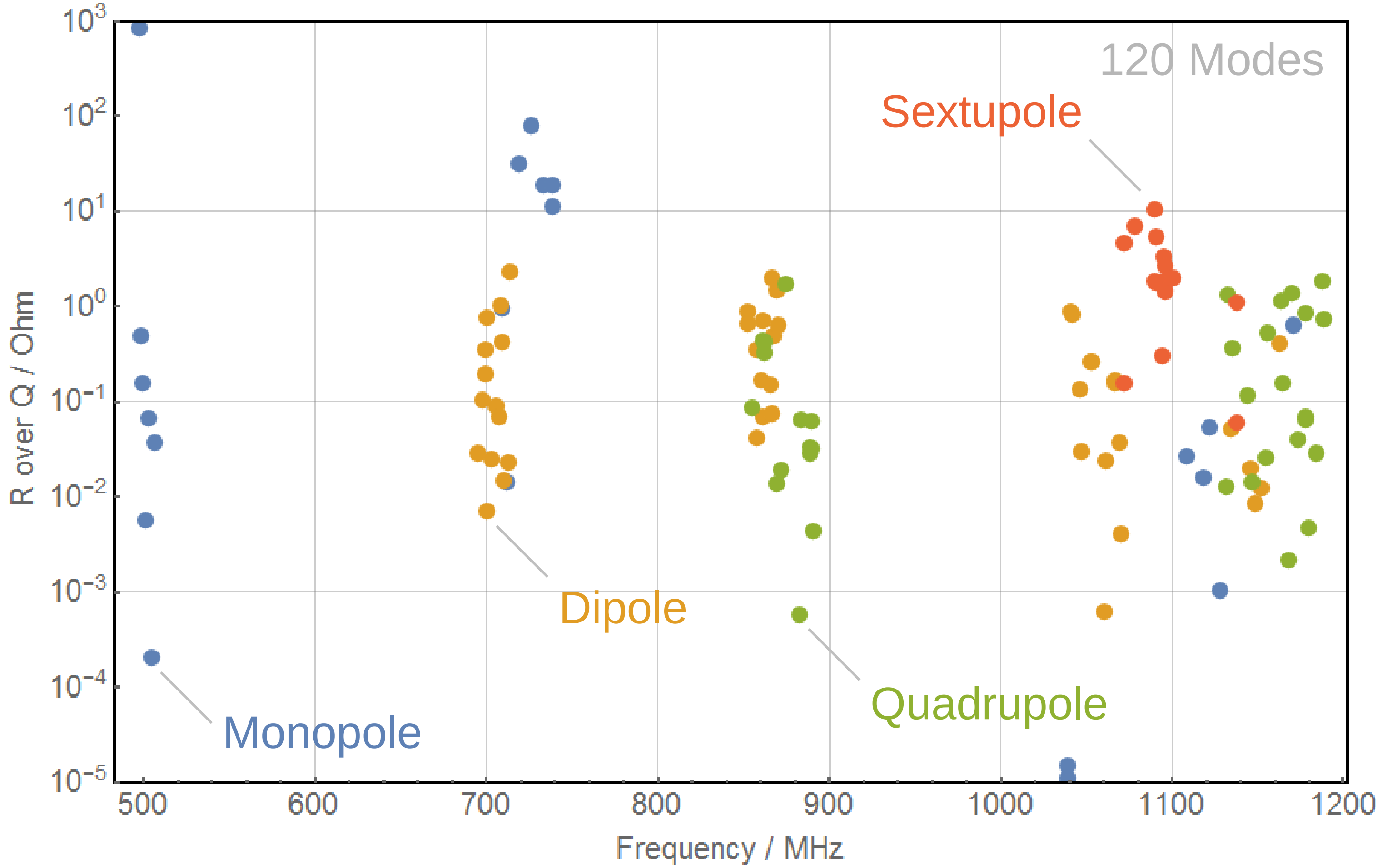

Simulation Results

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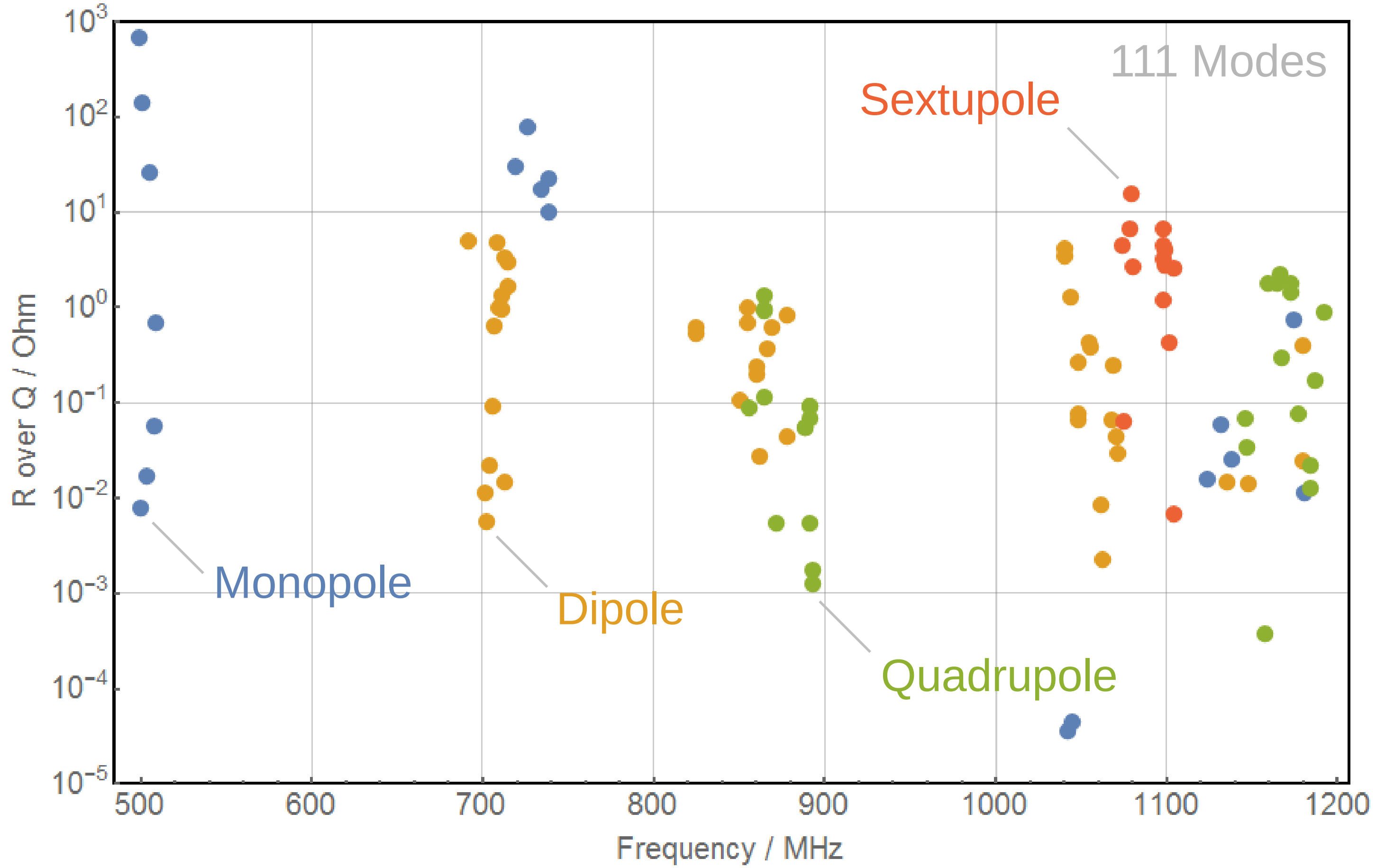
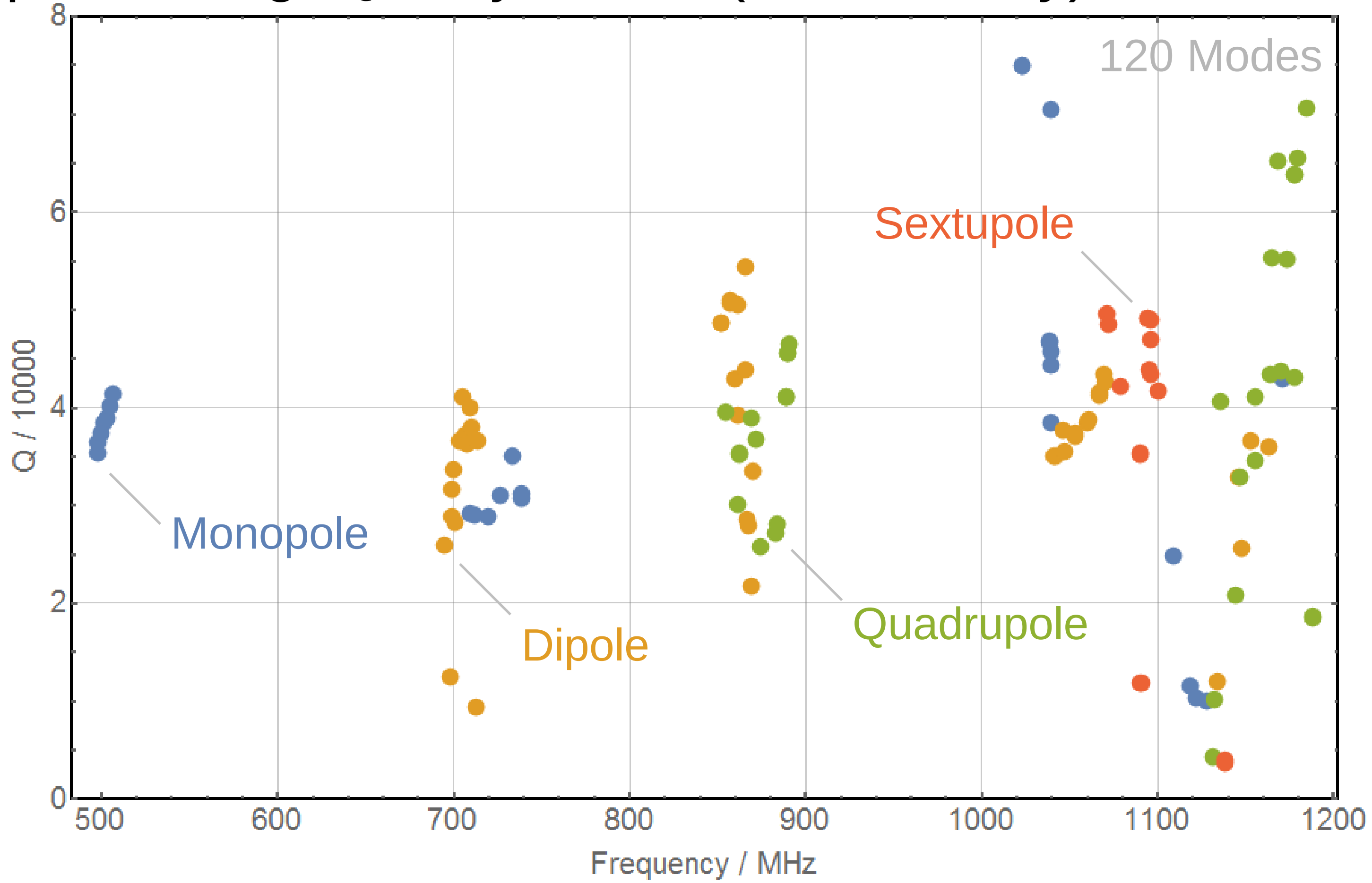
- Postprocessing: R / Q (untuned cavity)



Simulation Results

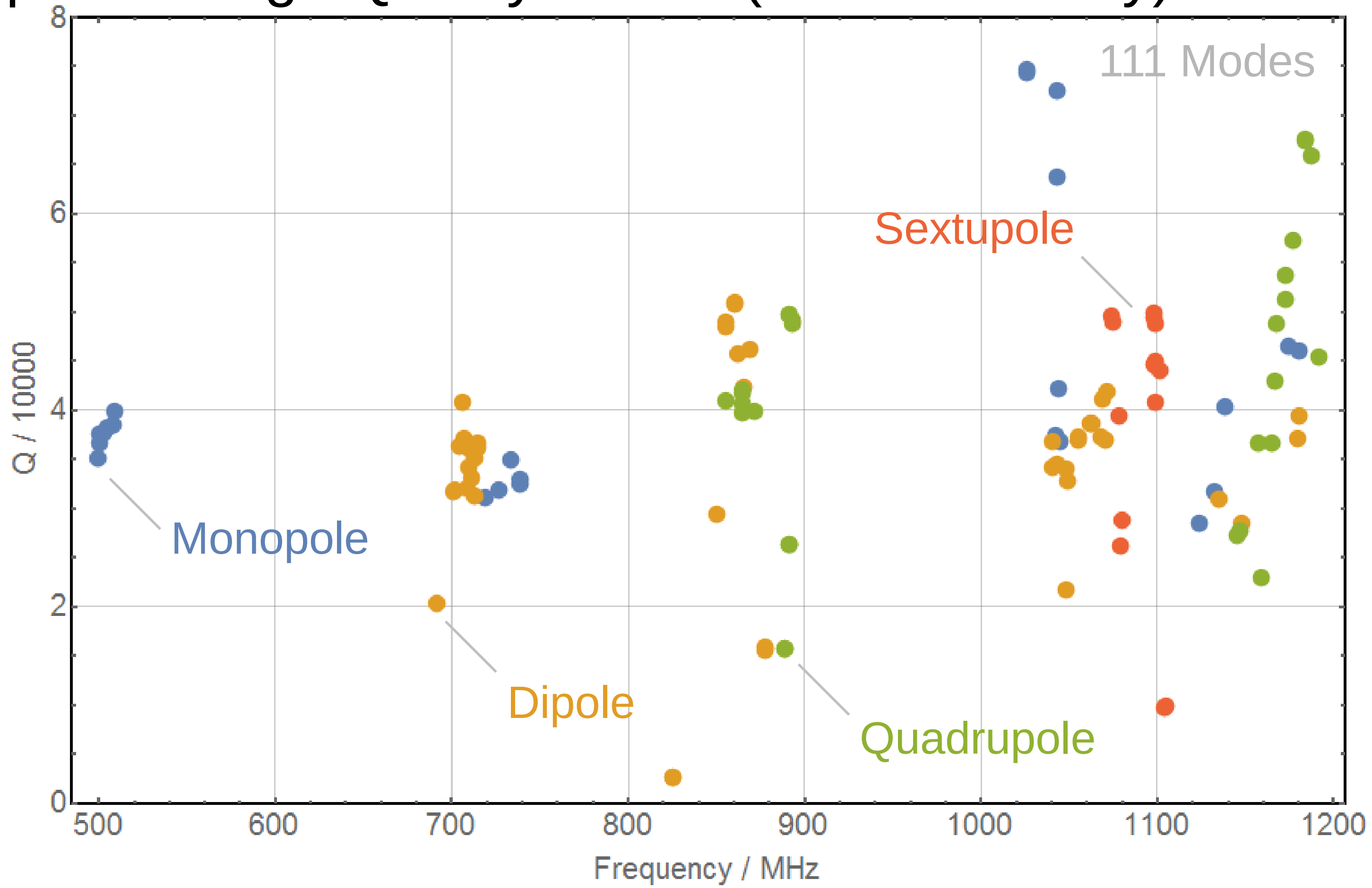
- Postprocessing: Quality Factor (tuned cavity)



Simulation Results

TECHNISCHE UNIVERSITÄT DARMSTADT

- Postprocessing : Quality Factor (untuned cavity)



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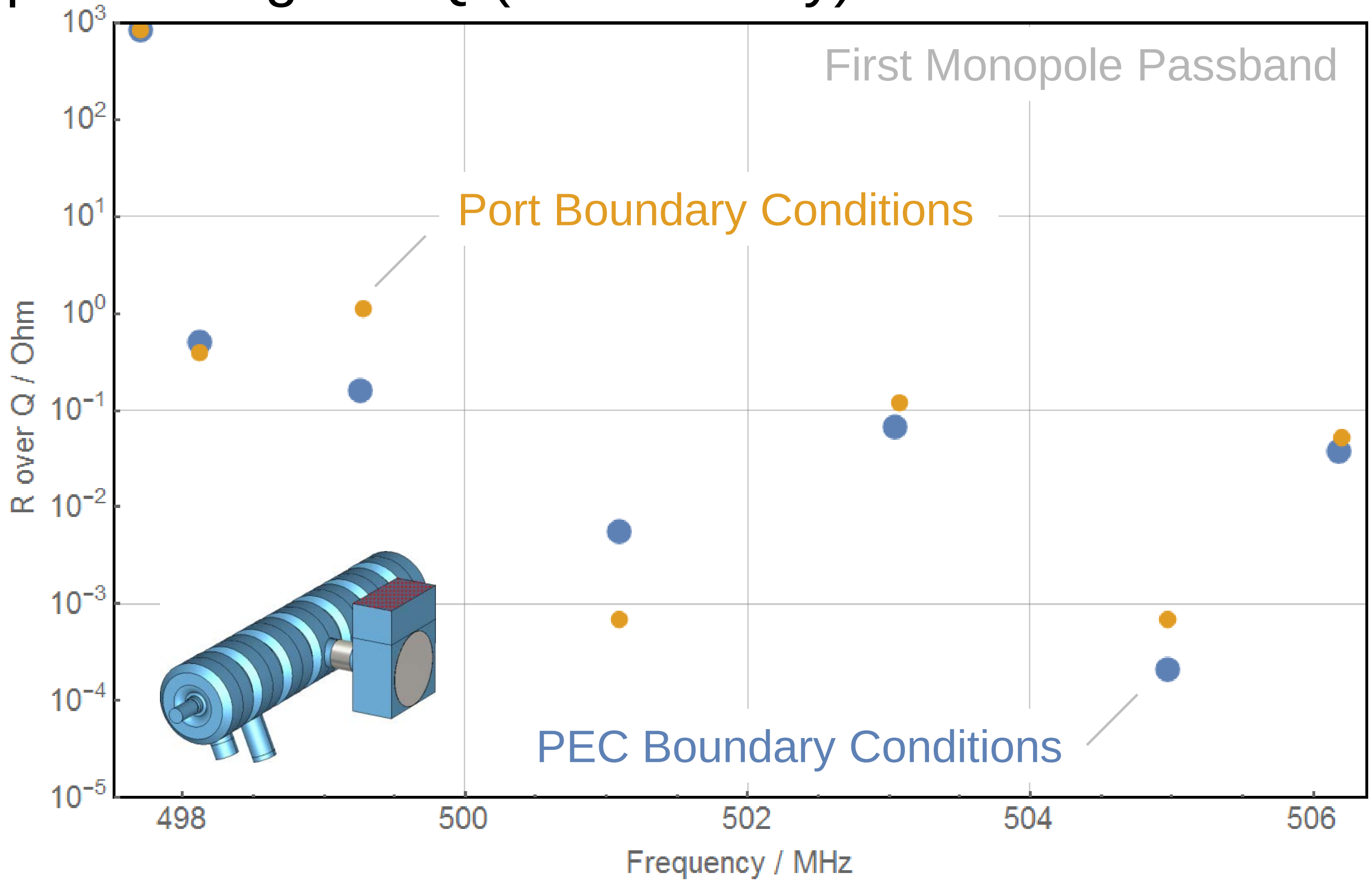
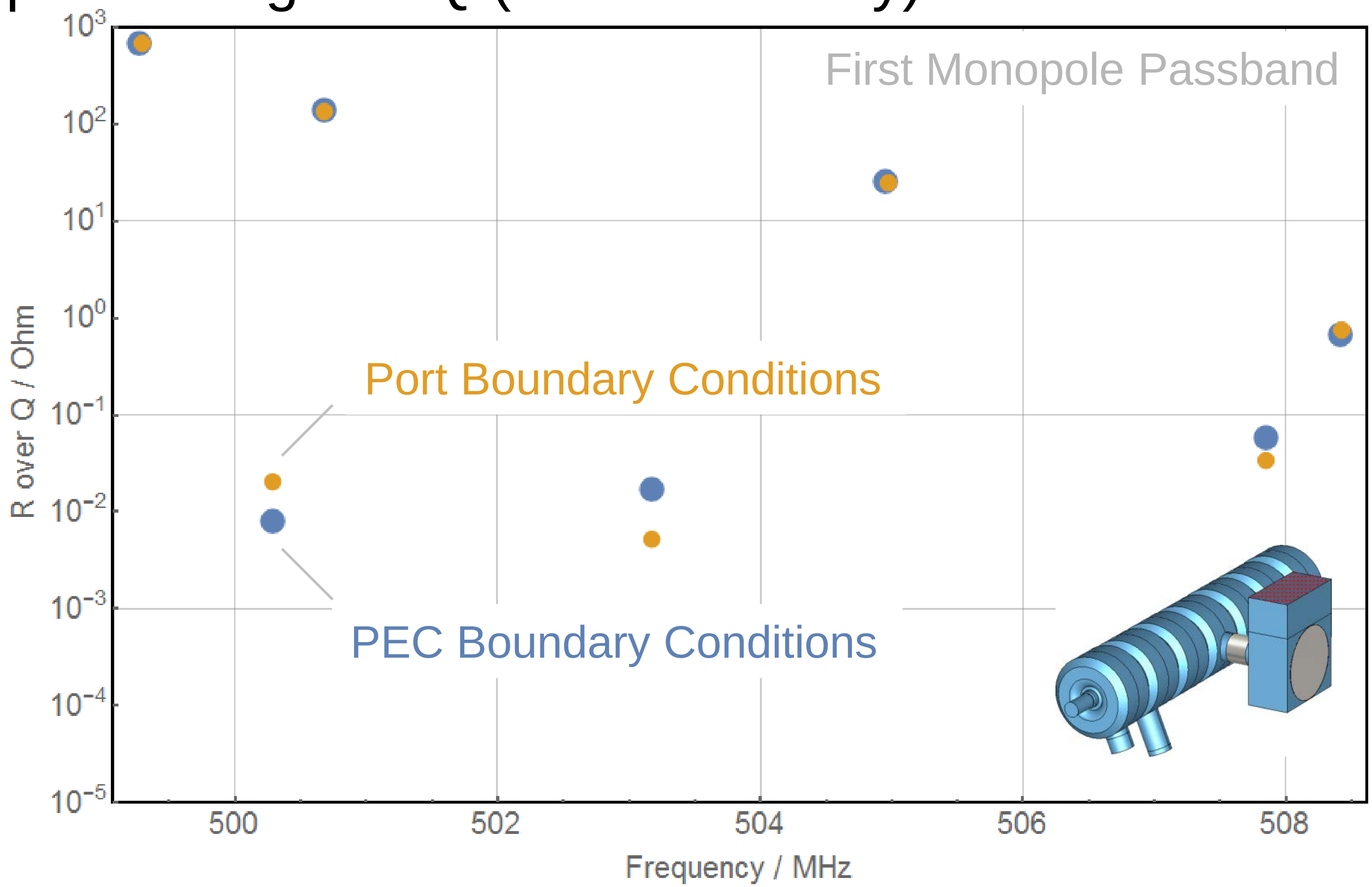
- Postprocessing: R / Q (tuned cavity)



Simulation Results

- Postprocessing: R / Q (untuned cavity)



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- **Summary / Outlook**

Summary / Outlook

- Summary:
  - Precise modeling of the PETRA III cavity including pump ports, tuning plunger and input coupler
  - Eigenmode analysis performed up to the first sextupole passband (mode pattern, frequency, R/Q, Q via power loss)
  - Modes in the second dipole passband possess unexpected high valued for R/Q

- Outlook:
  - Application of the complex eigenvalue solver