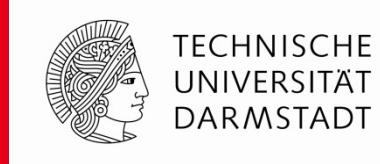


Frequency-domain methods for simulating superconducting components



Herbert De Gersem, Erion Gjonaj, Wolfgang Ackermann
TOSCA meeting, 23th July 2021



Funding Situation



TECHNISCHE
UNIVERSITÄT
DARMSTADT

Institut for Accelerator Science and Electromagnetic Fields (TEMF)
TU Darmstadt

TOSCA (not funded)

- Numerische Simulation und Optimierung von supraleitenden Komponenten unter Verwendung von Frequenzbereichsverfahren
(De Gersem, Gjonaj, Ackermann)

Supraleitende Magnete (50% funded)

- Finite-Elemente-Analysen und Designstudien für Hochtemperatursupraleitenden Magneten
(De Gersem, Loukrezis, Schöps)



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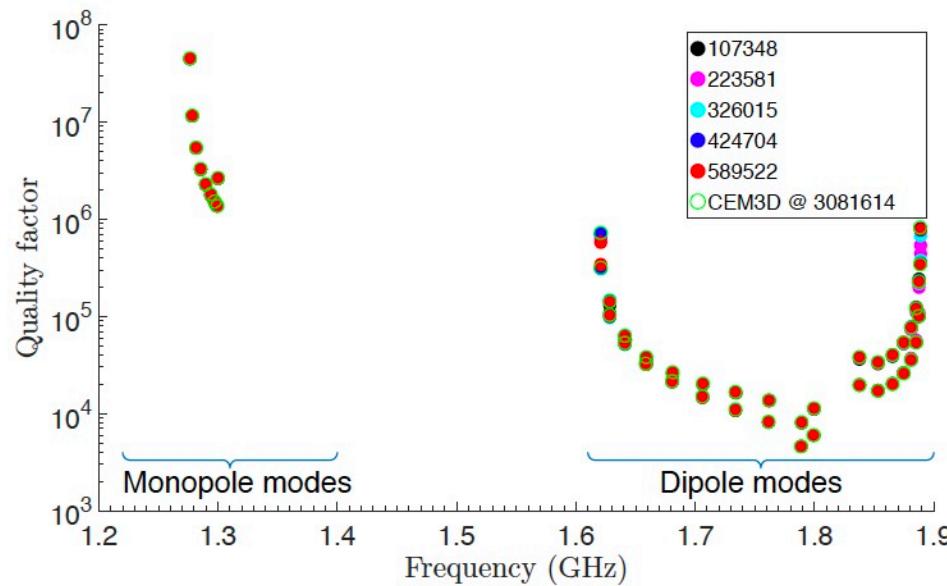
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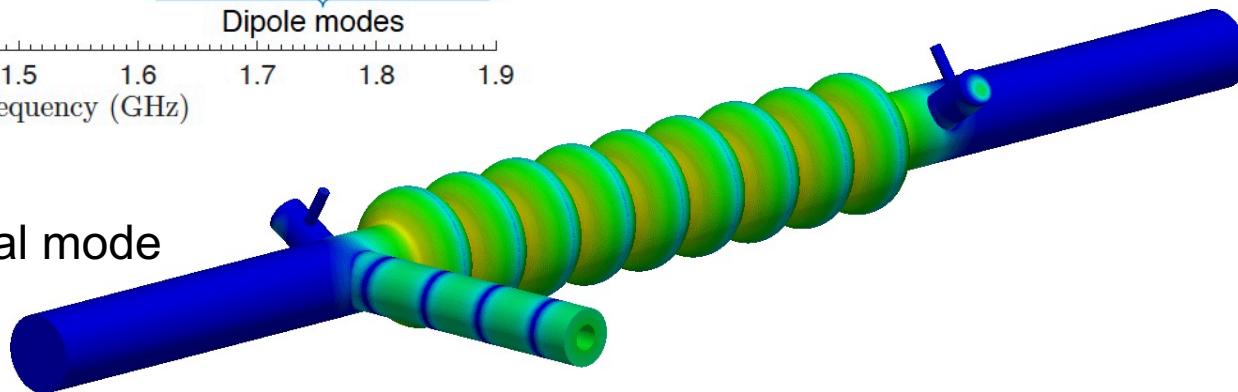
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Tesla Cavities (+DESY)



contour integral method
multi-level preconditioner
parallelisation



Vinh Pham-Xuan,
Wolfgang Ackermann, Herbert De Gersem

Equipment

- Hardware
 - desktop PCs
 - workstations
 - cluster
 - GPU computing
 - access zu HPC
(inside/outside
TU Darmstadt)

200 nodes
400 CPUs
2400 cores
90kW cooling power
80kW power
3200 GB memory
~7t weight
~1M€ investment cost
40 GBIT connection

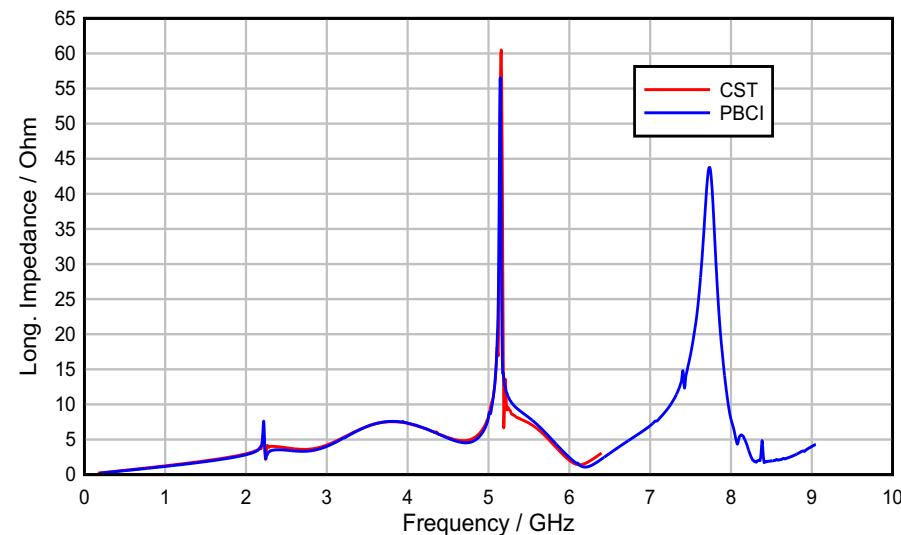
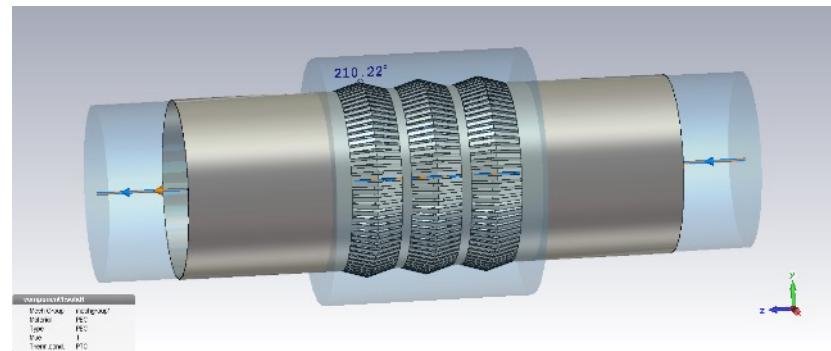
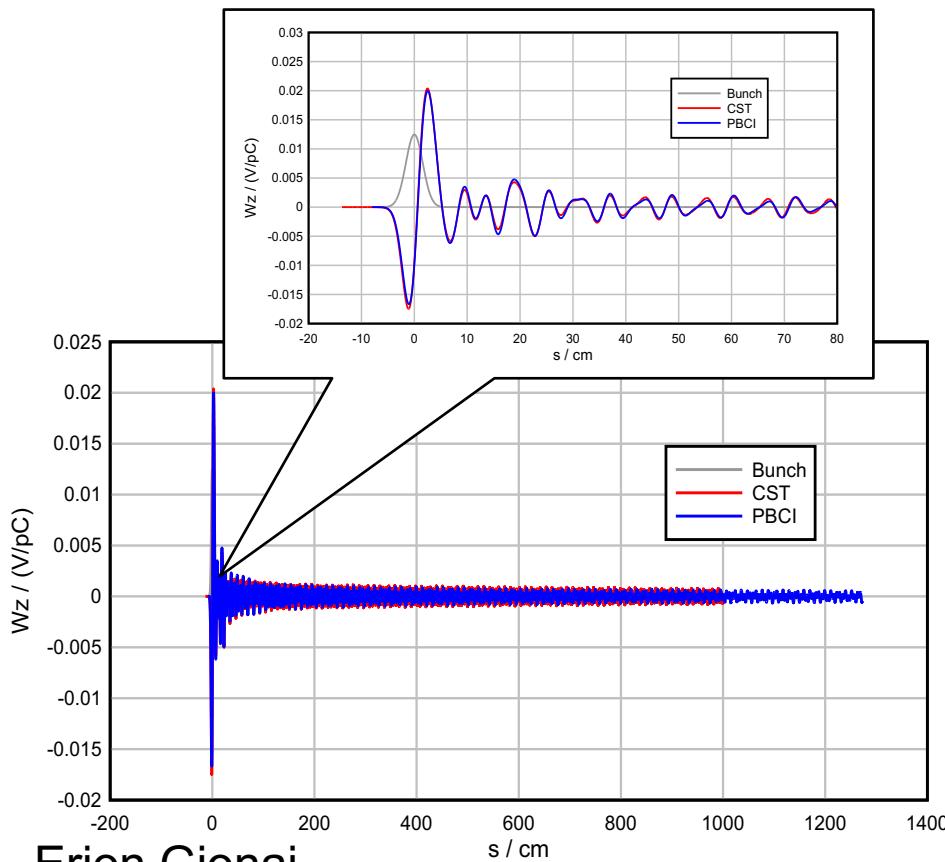


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Wakefield Simulations in the Time Domain

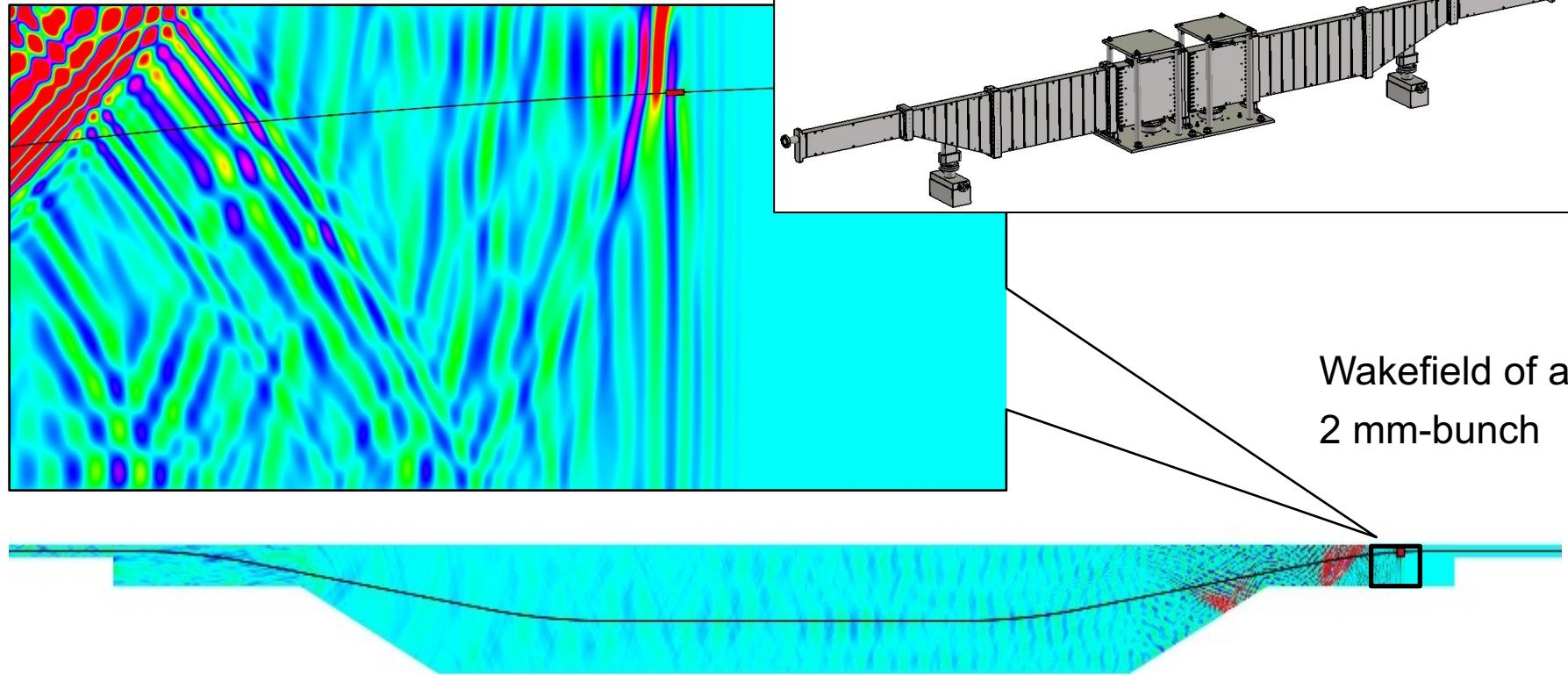


- LHC RF-Fingers – massive parallelization for complex geometry



Wakefield Simulations in the Time Domain

- CSR Wakefields (DESY bunch compressor)

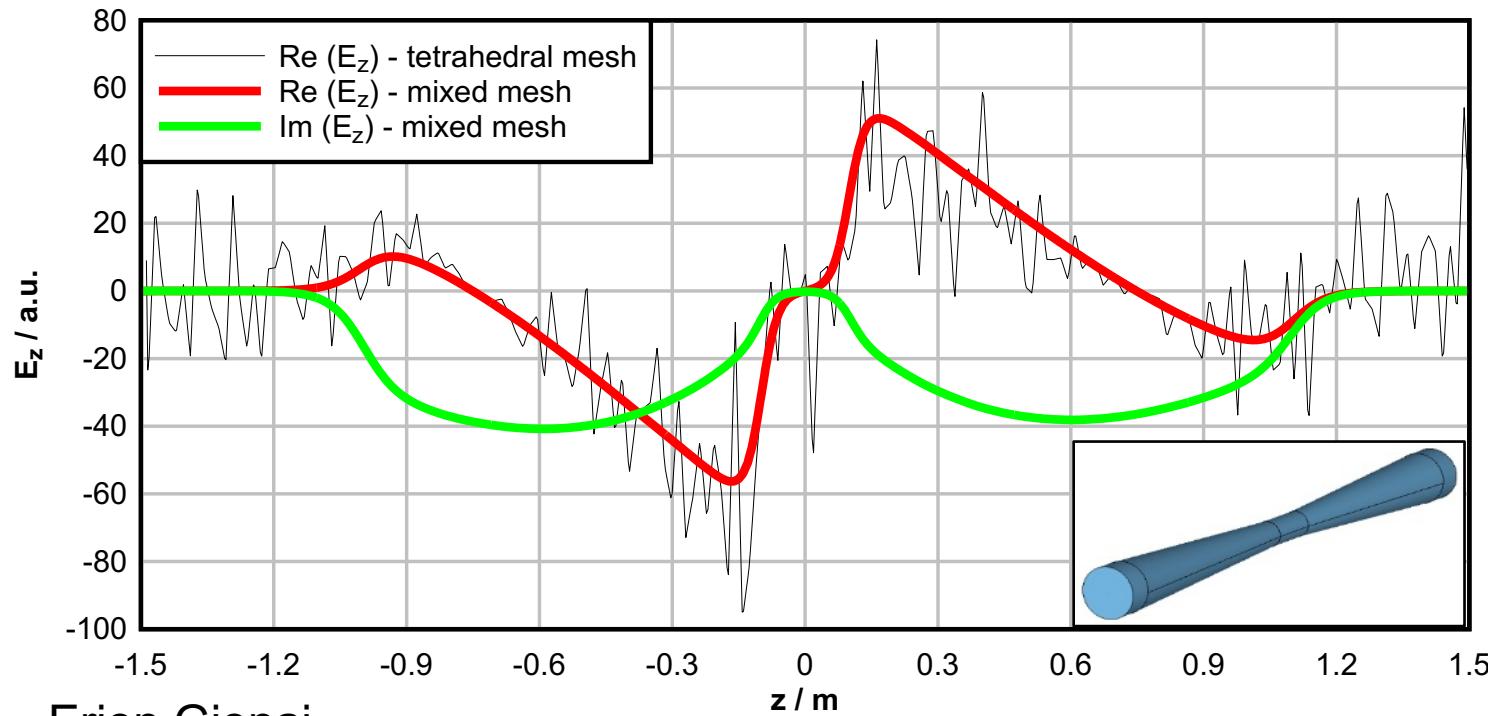
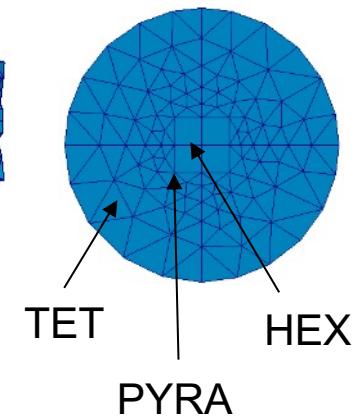
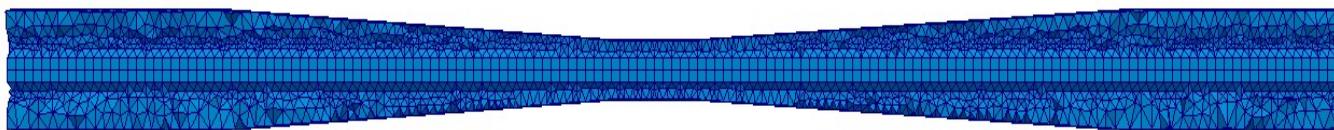


Erion Gjonaj

Wakefield Simulations in Frequency Domain



- Collimator – hybrid meshes

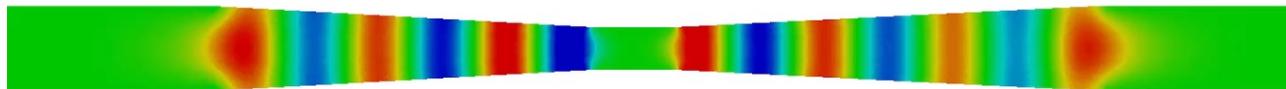


Longitudinal
wakefield on axis
at 100MHz

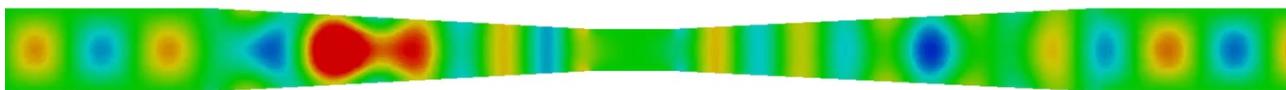
Frequency Domain Formulation



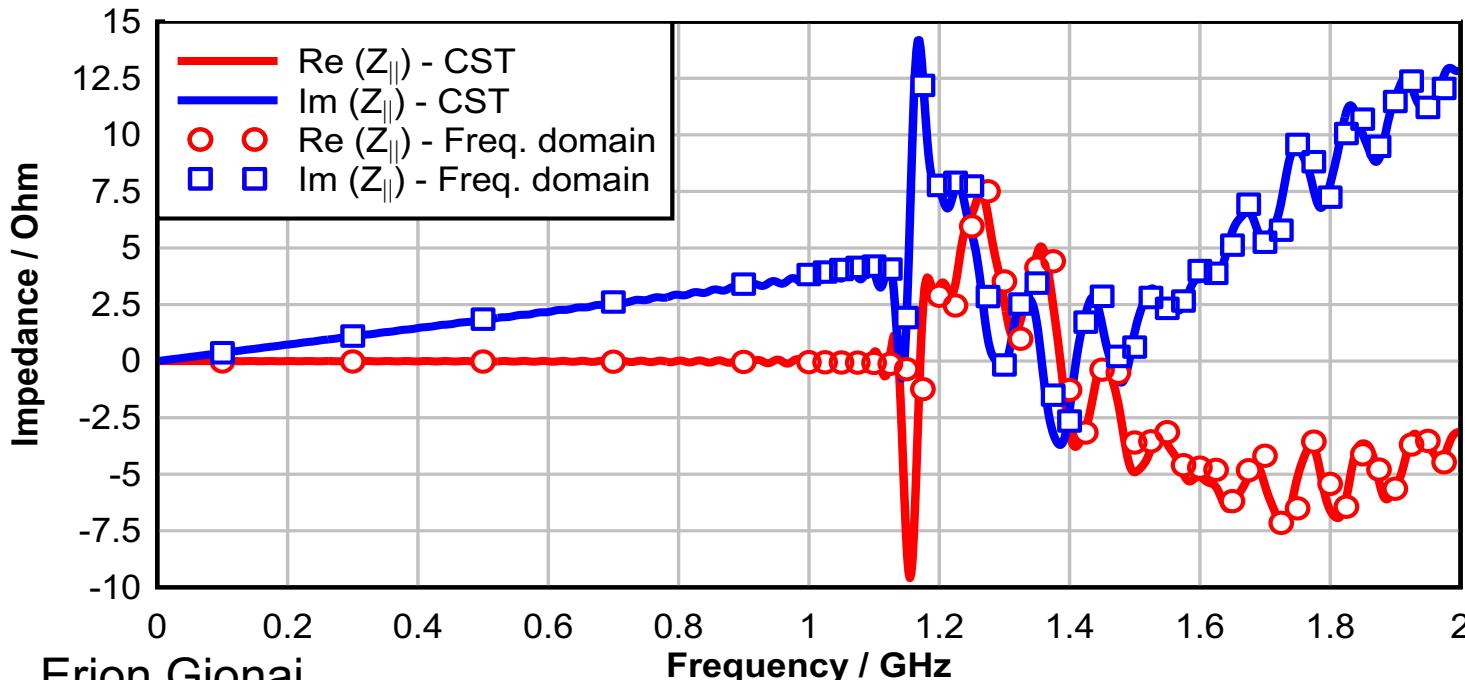
- Collimator – impedance



$E_z - 1\text{GHz}$



$E_z - 1.5\text{GHz}$



Comparison with
CST PS

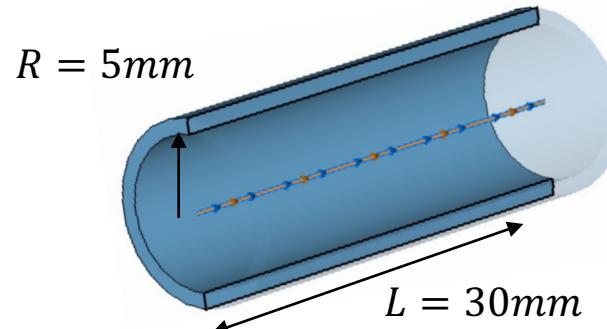
Wakefield Simulations in Frequency Domain



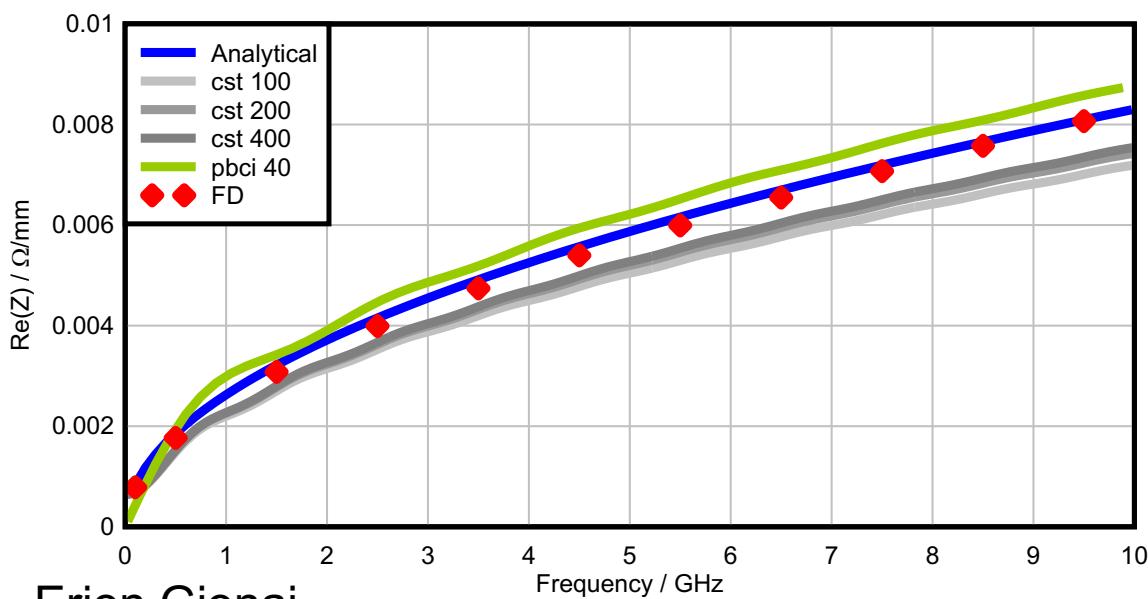
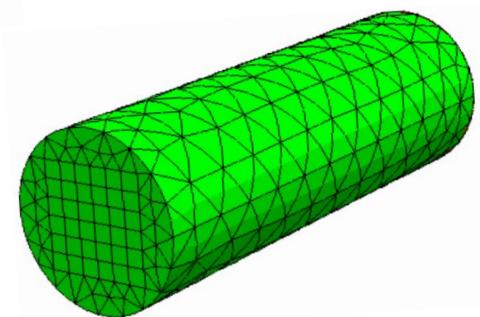
- Lossy structures

analytical:

$$Z(\omega) = L \frac{1 + j}{2\pi R} \sqrt{\frac{\omega Z_0}{2c\sigma(\omega)}}$$



TiAl – $\sigma = 0.58 \text{ MS/m}$

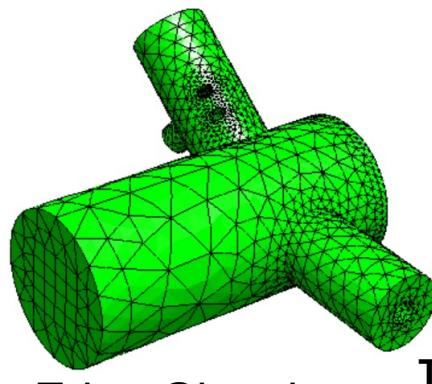
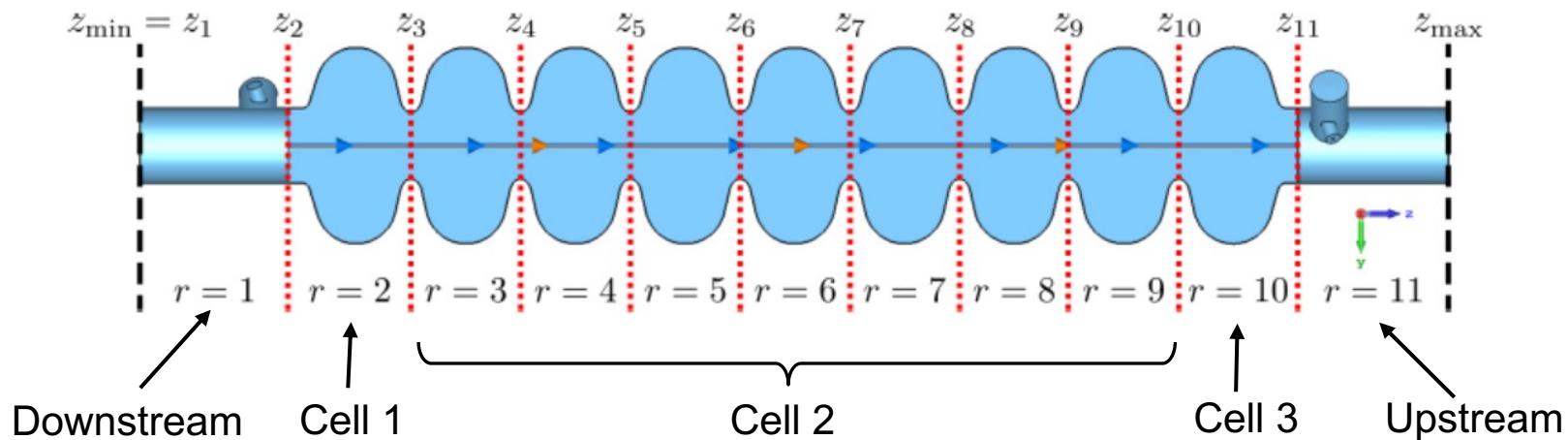


- Large mesh errors in time domain codes
- Sparse unstructured mesh
- Few evaluation points in the frequency domain

Wakefield Simulations in Frequency Domain

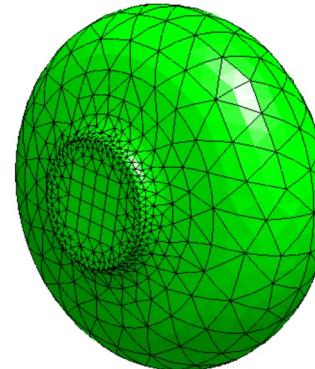


- Tesla 1.3GHz cavity – Impedance concatenation

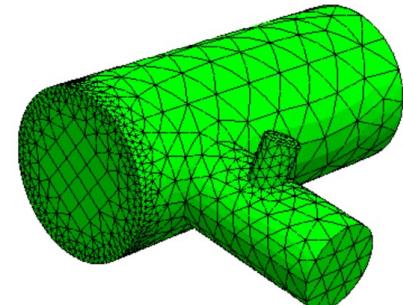


15 TE-Modes
 $(\omega_{max} = 8.2\text{Ghz})$
15 TM-Modes
 $(\omega_{max} = 10.6\text{Ghz})$

TEM, ...



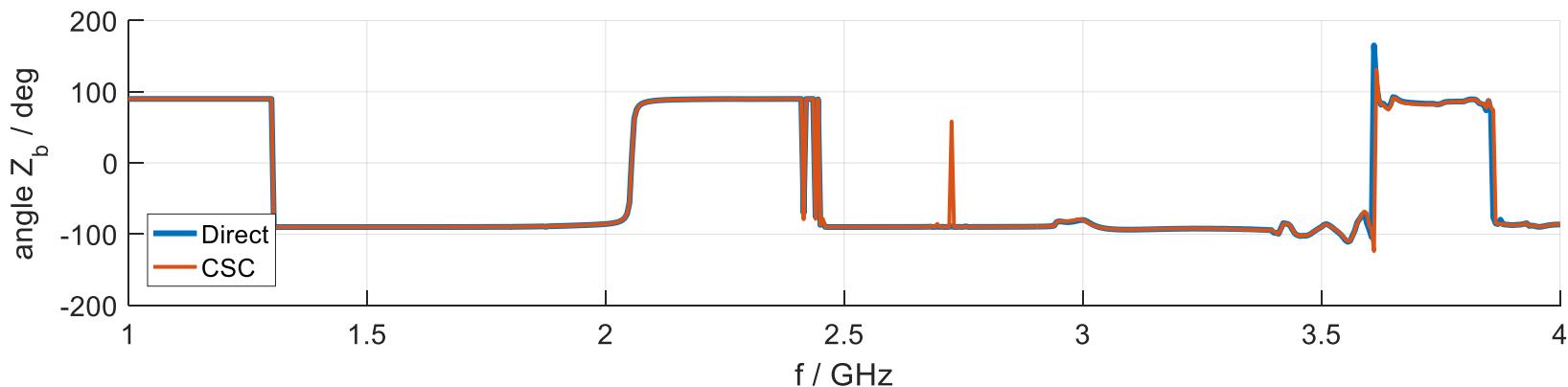
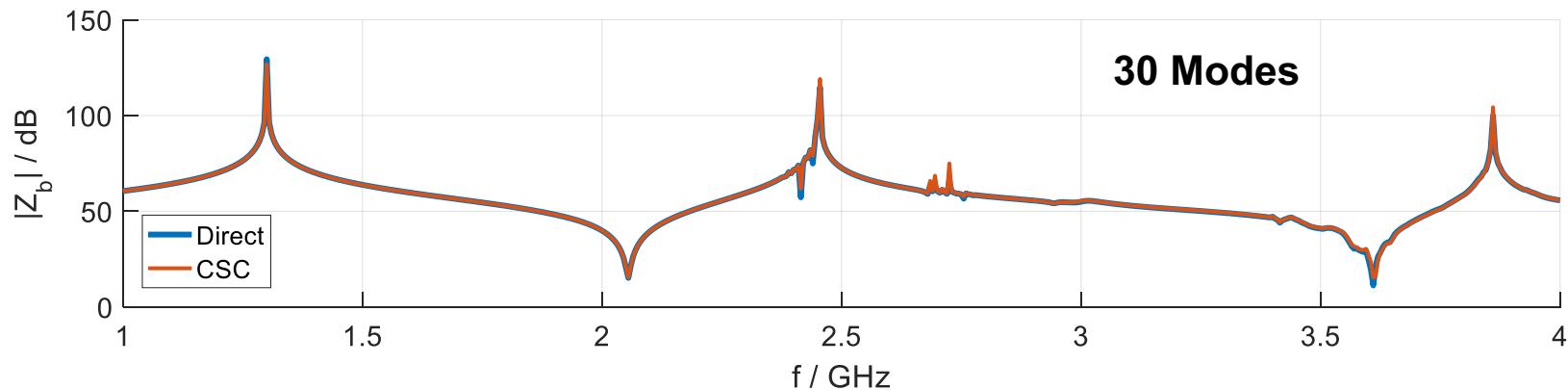
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Wakefield Simulations in Frequency Domain



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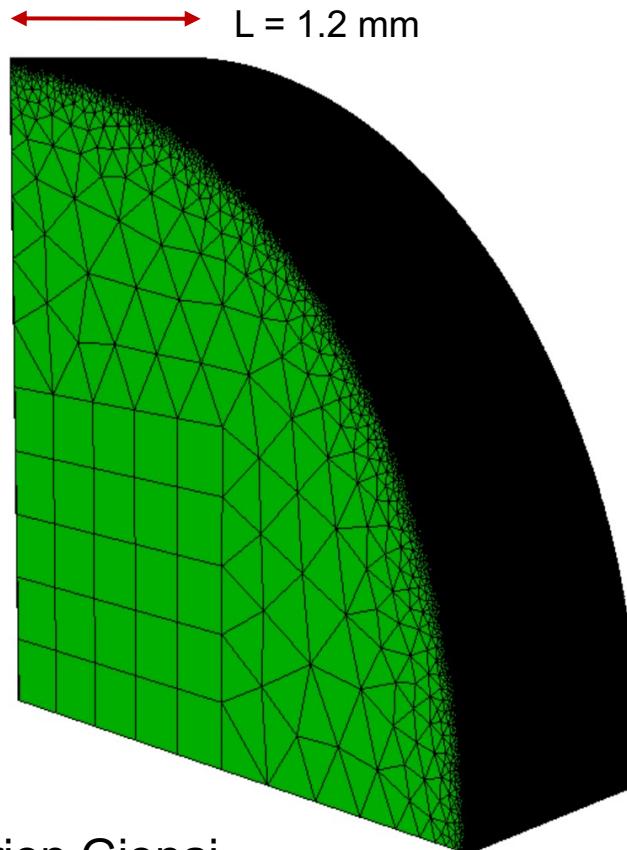
Erion Gjonaj

Wakefield Simulations in Frequency Domain

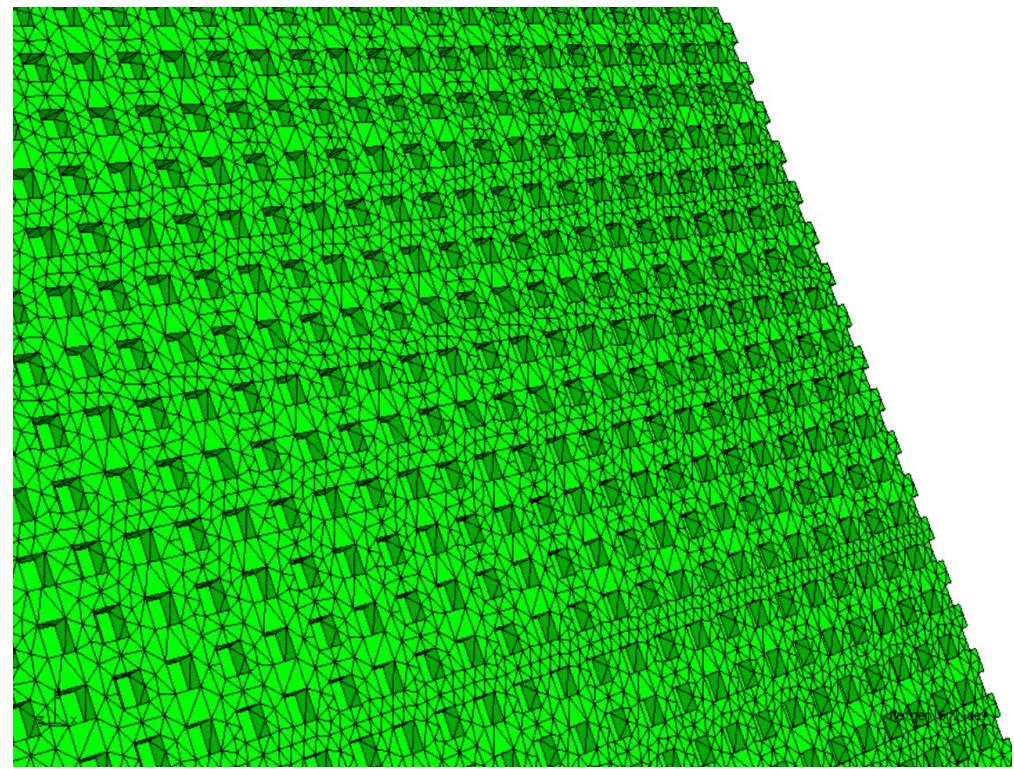


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- Surface roughness modeling



$\sim 6.5 \times 10^6$ elements (hex, tet, prism)



Erion Gjonaj

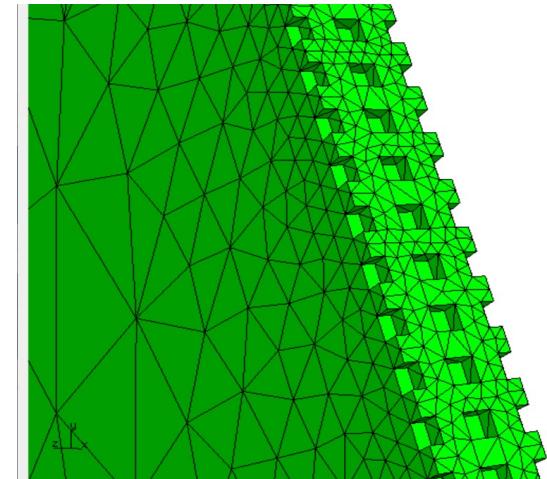
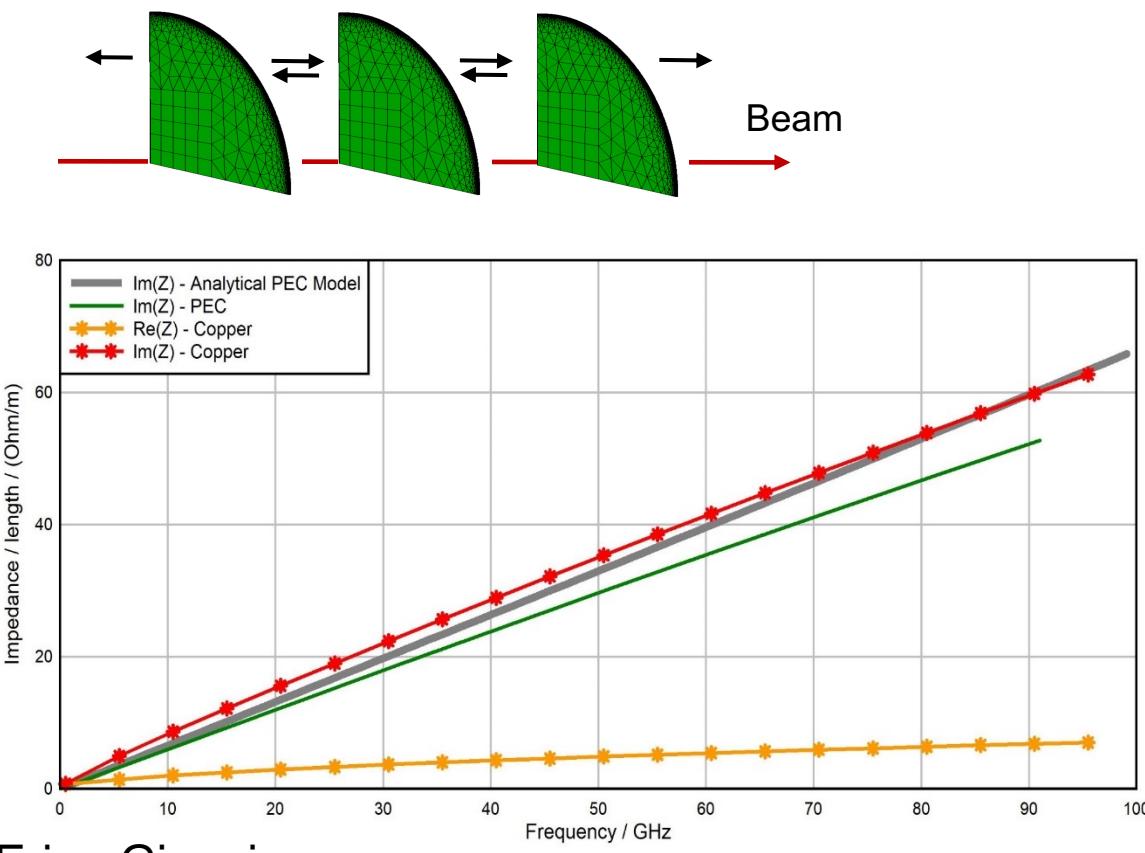
23.07.2021 | TU Darmstadt | Institut für Teilchenbeschleunigung und Elektromagnetische Felder | Prof. Dr.-Ing. Herbert De Gersem | 13



Wakefield Simulations in Frequency Domain



- Surface roughness modeling



Analytical PEC-model

$$Z_s = \frac{jg}{g + w} Z_0 \tan(k_o h)$$

$$Z_b = \frac{Z_s}{2\pi R} \frac{1}{1 + \frac{j\omega R}{2c} \frac{Z_s}{Z_0}}$$

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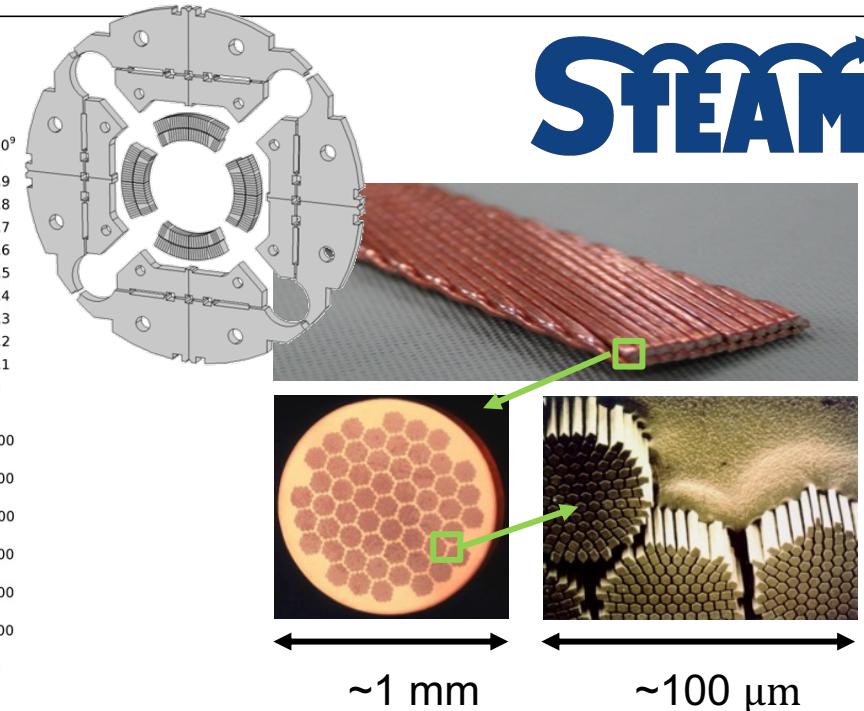
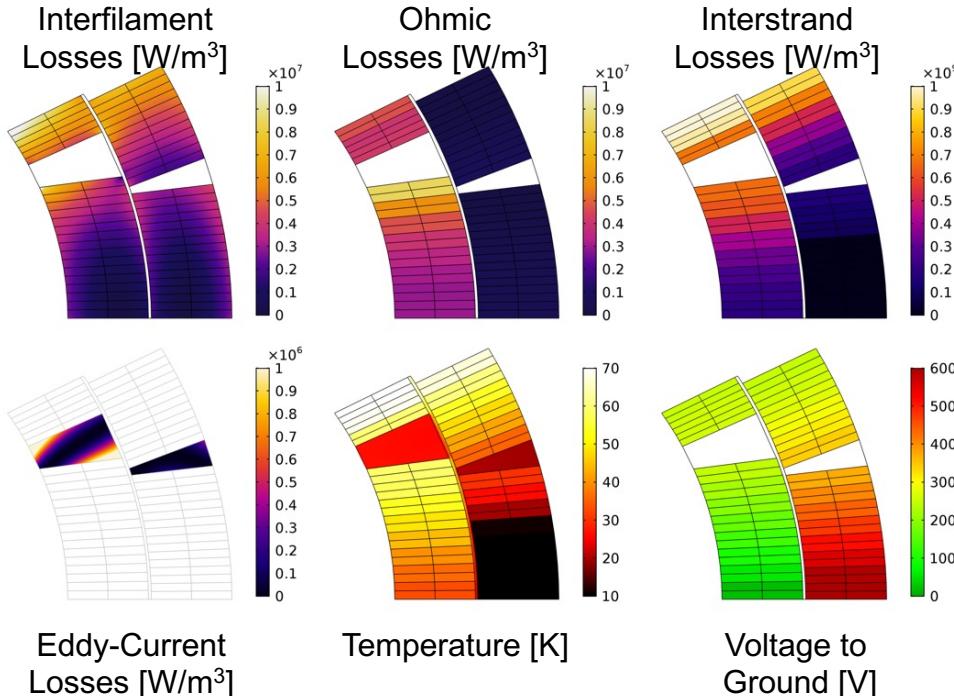
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(De Gersem, Loukrezis, Schöps)

BMBF-STEAM: Simulation of transient effects in accelerator magnets (+ CERN)



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L. Bortot et al., „A 2-D finite-element model for electrothermal transients in accelerator magnets, IEEE Trans. Magn. 54(3) 2018.

Idoia Cortes Garcia, Laura A.M. D'Angelo,
Herbert De Gersem, Sebastian Schöps