3D Simulation of Transient Effects in Accelerator Magnets

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Cooperation DESY - TEMF

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current research topics

- eigenvalue calculations
- resistive wakefield calculations
- photo-emission studies

brainstorm on further cooperation topics

- new cavity structures
- simulation of multipacting
- simulation of wakefield acceleration
- simulation of transient effects in accelerator magnets

Accelerator magnets

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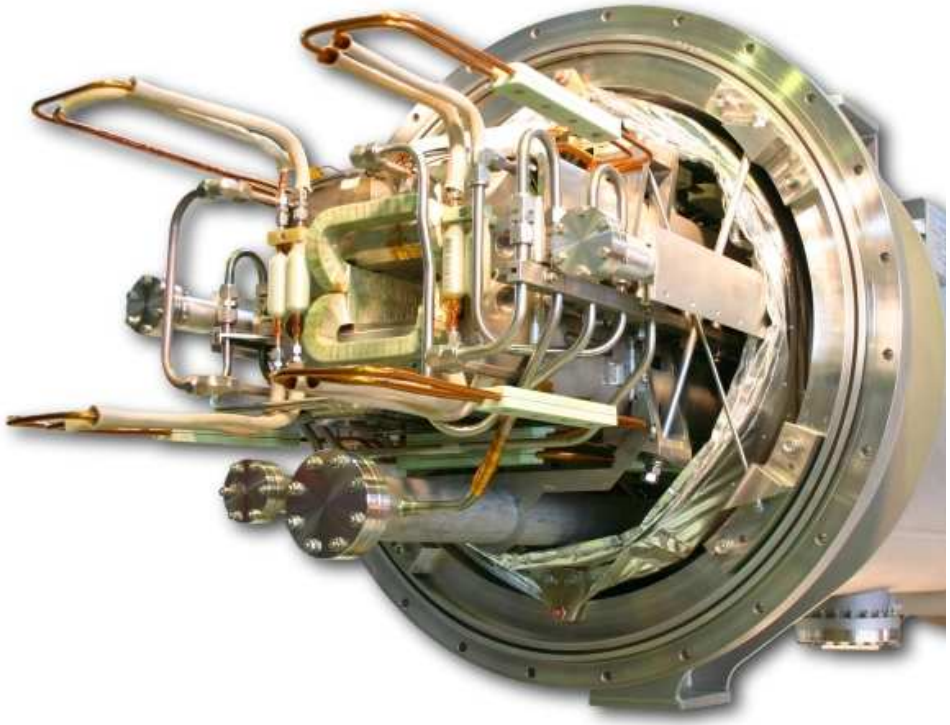
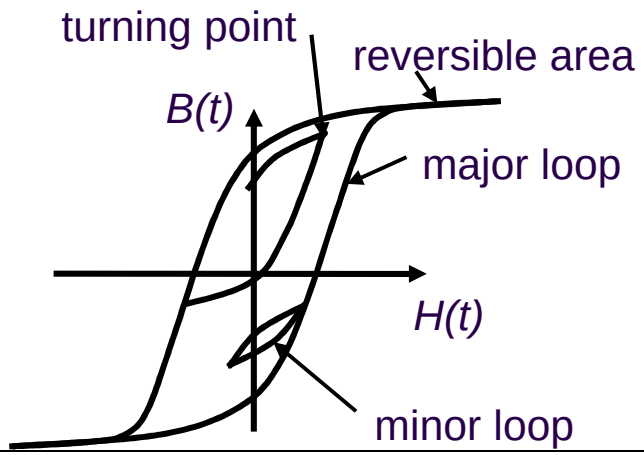
- complicated geometries + production tolerances
- 3D effects (fringing, eddy currents)
- multi-physics (cryogenics, deformation)
- multi-scale models (windings, laminations)
- transients (e.g. remanence)
- materials ...

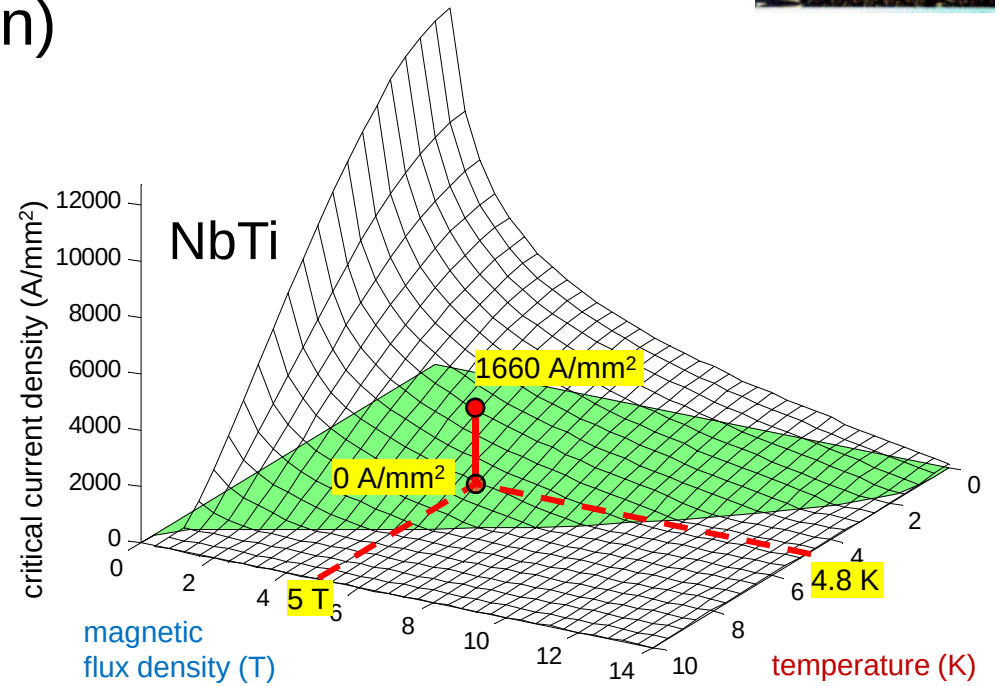


SIS100 magnet, GSI

Materials

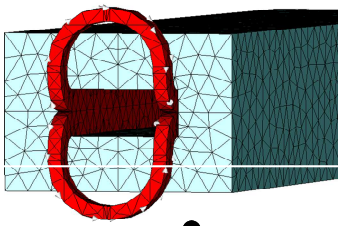
- ferromagnetic materials
  (nonlinear, hysteretic, magnetostriction)
- superconducting materials
  (thermal & magnetic stability, persistent currents)
- composites (homogenisation)
- windings (homogenisation)
- uncertainties





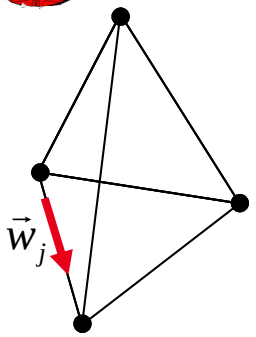
Discretisation in space

differential equation: $$\nabla \times \left(\nu \nabla \times \vec{A} \right) + \sigma \frac{\partial \vec{A}}{\partial t} = \vec{J}_{\mathrm{s}}$$



spatial discretisation
edge finite elements
(curl-conforming)

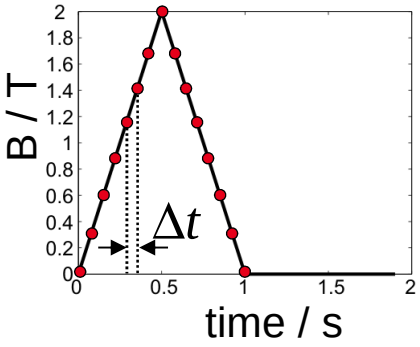
$$\vec{A} \approx \vec{A}_{\mathrm{FE}} \coloneqq \sum_j \hat{a}_j \vec{w}_j$$



semi-discrete system: $$\mathbf{K}_\nu \hat{\mathbf{a}} + \mathbf{M}_\sigma \frac{\mathrm{d}\hat{\mathbf{a}}}{\mathrm{d}t} = \hat{\hat{\mathbf{j}}}_{\mathrm{s}}$$

temporal discretisation
Runge-Kutta

discrete system: $$\left(\mathbf{K}_\nu + \alpha \mathbf{M}_\sigma \right) \hat{\mathbf{a}}_{k+1} = \mathrm{RHS}$$



GSI SIS100 magnet

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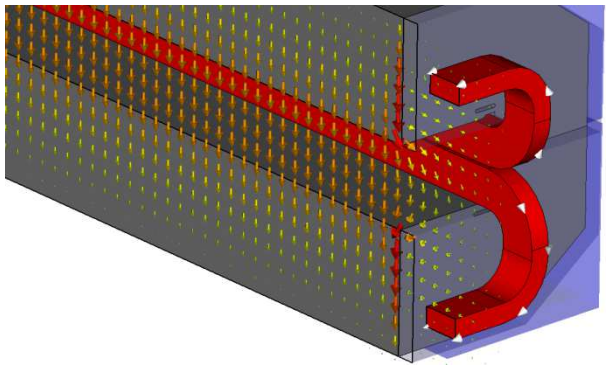
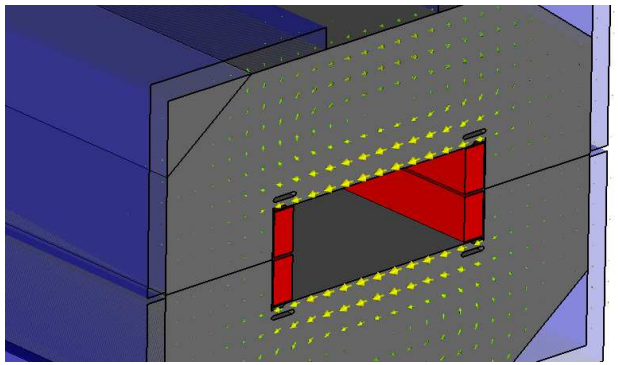
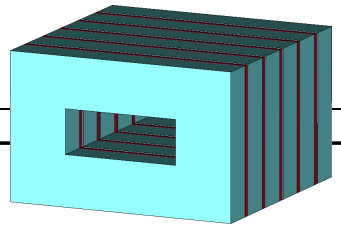
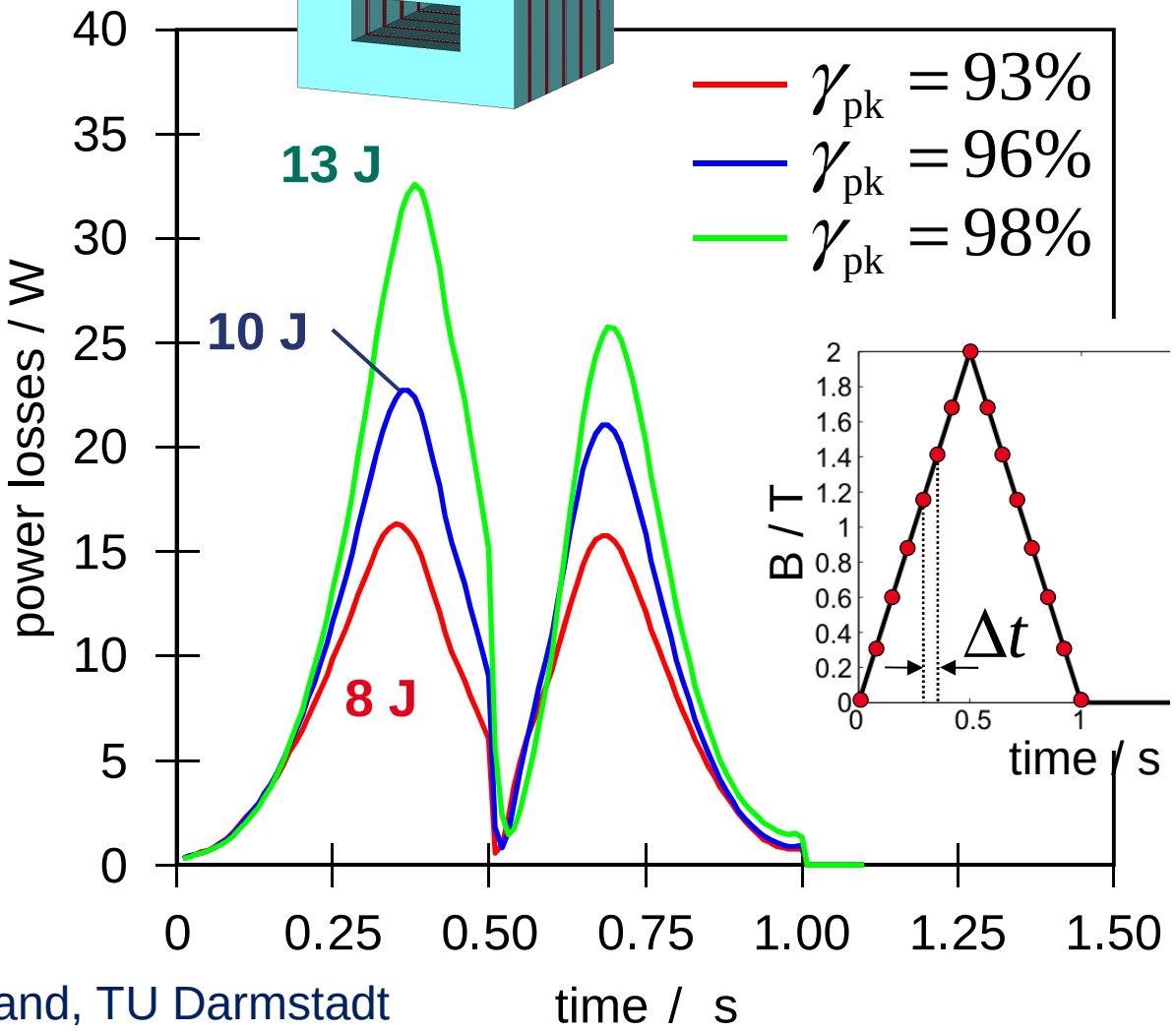
eddy-current losses over one cycle for different stacking factors γ_{pk}



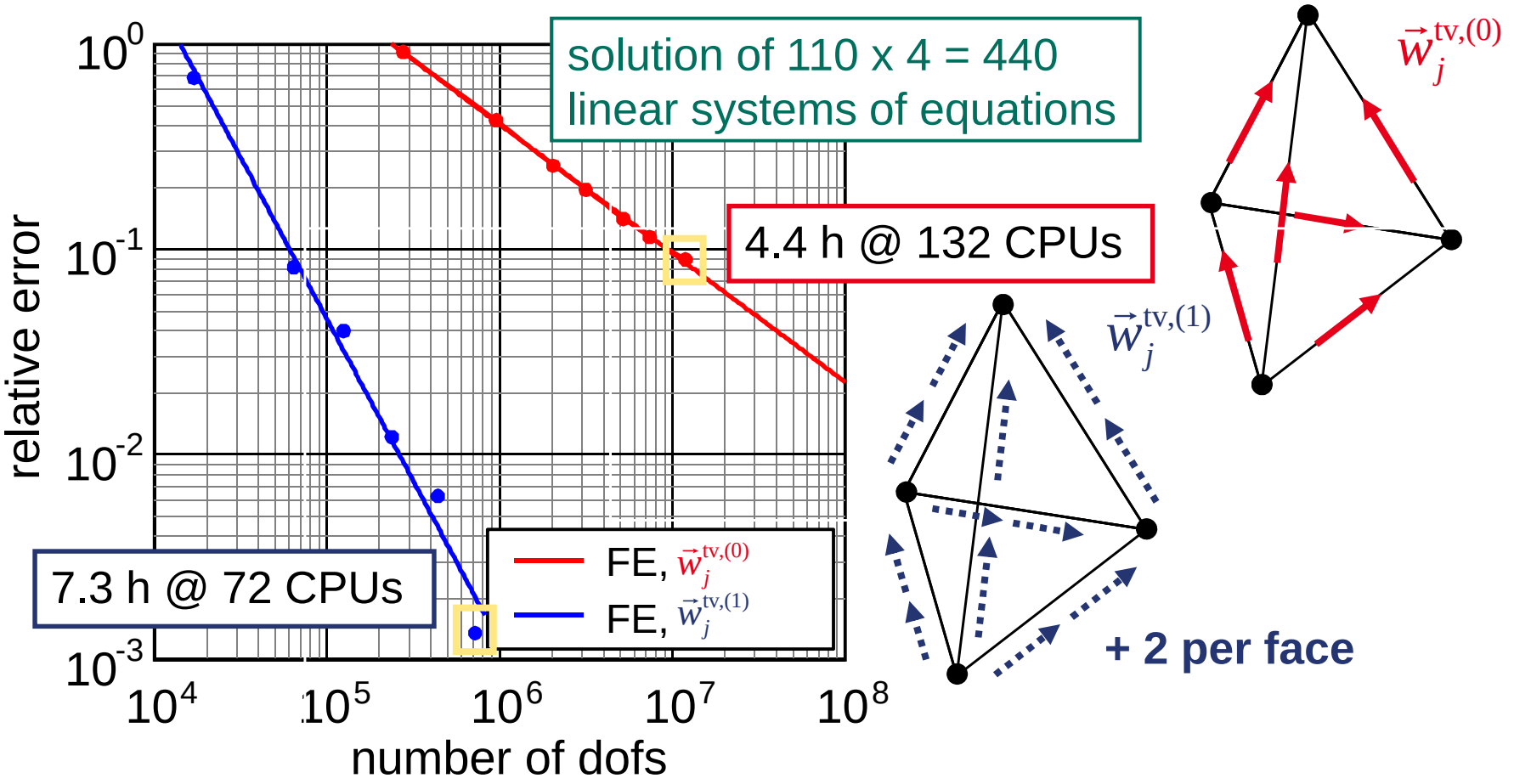






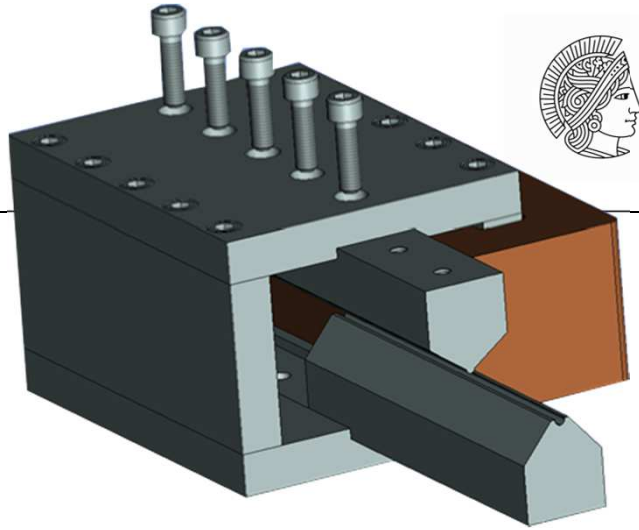
S. Koch, J. Trommler, T. Weiland, TU Darmstadt

Computation effort

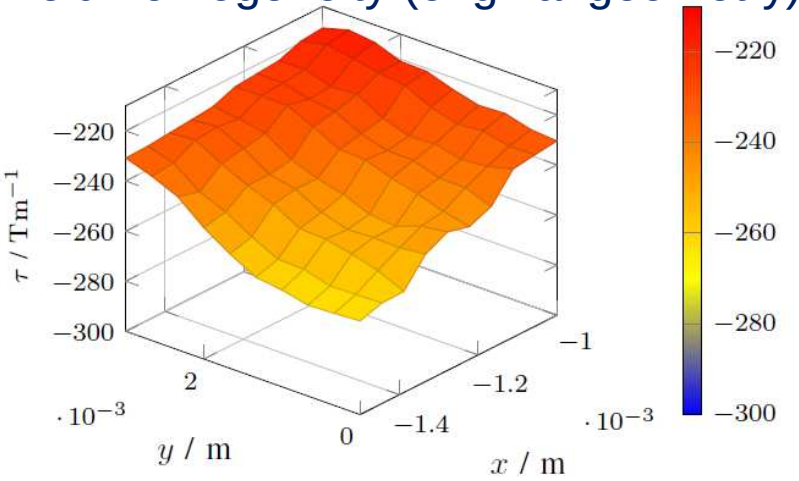


S. Koch, J. Trommler, T. Weiland, TU Darmstadt, 2009

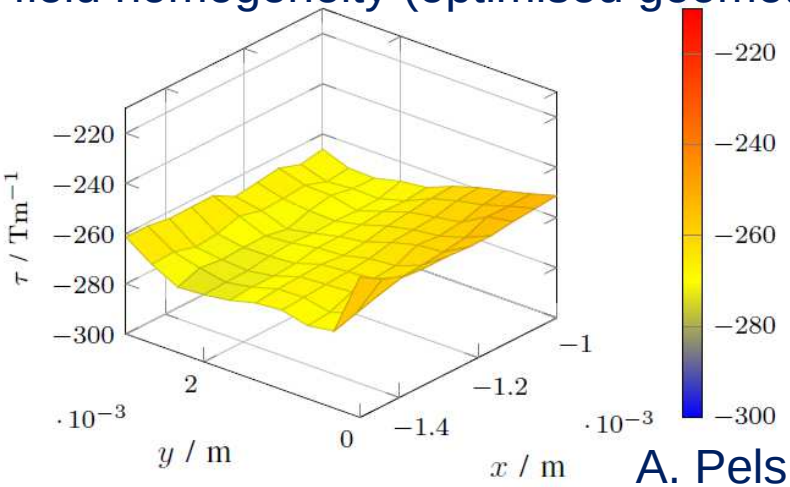
Stern-Gerlach magnet

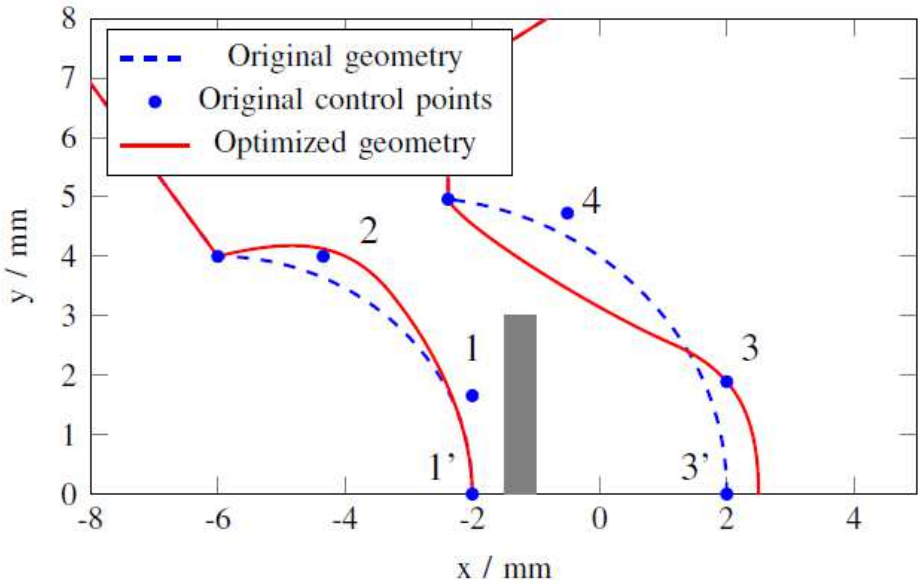


field homogeneity (original geometry)



field homogeneity (optimised geometry)





B. Masschaele, H. De Gersem (KU Leuven)
A. Pels, J. Corno, Z. Bontinck, S. Schöps, (TU Darmstadt)

Magnet simulation @ TEMF

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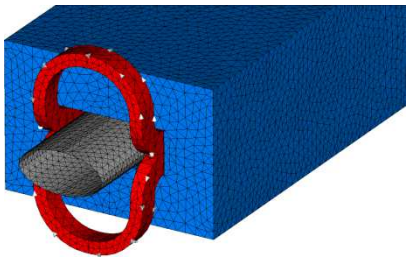
Competence

- 3D transient FE solvers
- material models
- accurate post-processing (multipoles)
- uncertainty quantification and sensitivity analysis



Cooperation

- S-DALINAC magnets
- GSI magnets
- cooperation with CERN on the modelling of quench propagation