The Tony Davies High Voltage Laboratory

EPSRC
Engineering and Physical Sciences Research Council

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Filamentary-equivalent domain model for fast simulation of AC transport power losses in first generation high temperature superconducting tapes

Alexander N. Petrov – *A.Petrov@ecs.soton.ac.uk*
James A. Pilgrim
Igor O. Golosnoy

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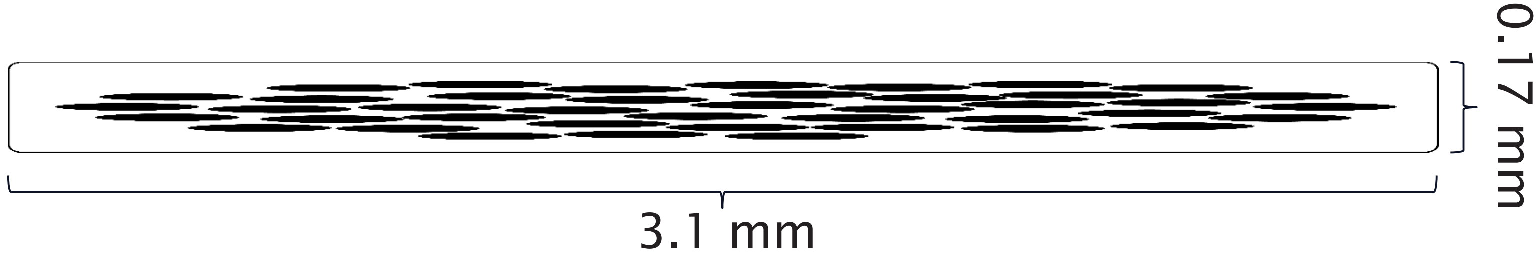
Overview

- Key background
- Motivation
- Proposed methodology
- Numerical technique
- Results
- Conclusions

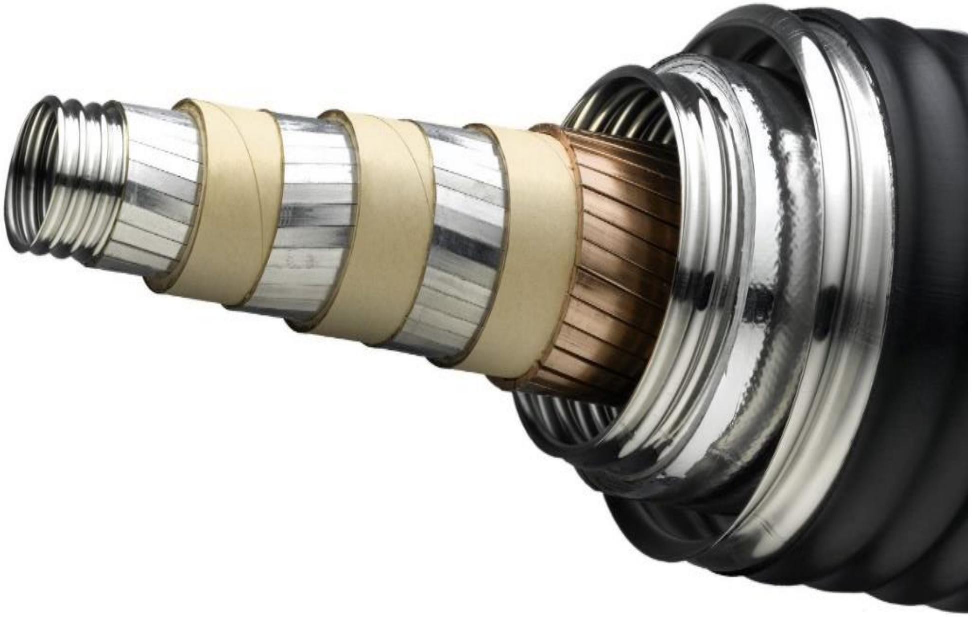
Key background

- Construction of a Bi-2223 tape



Key background

- Construction of a Bi-2223 tape
- Construction of large scale devices



"Superconductors for the Medium Voltage Grid", BINE Information Service. Available: http://www.bine.info/fileadmin/content/Publikationen/Projekt-Infos/2017/Projekt_01-2017/ProjektInfo_0117_internetx_engl.pdf

Motivation

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  - Very small filaments require an extremely large mesh detail
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  - That means long simulation times
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Motivation

- FEM modelling of non-linear resistivity, and:
  - Very small filaments require an extremely large mesh detail
  - Hence, lots of degrees of freedom
  - That means long simulation times
  - Effect is amplified when more tapes are added
- Less time <- less degrees of freedom <- less mesh detail
  - Will enable consistently faster simulation of 1G tape models
  - Hence, will enable faster modelling of 1G HTS devices, e.g. cables

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Proposed methodology - SAM

- Using only the superconducting cross-sectional area
  - Superconducting area method (SAM)
  - The local critical current density is not changed
  - The area of the superconducting domain (ellipse) is equal to the total area of all filaments

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  - Have to find optimum aspect ratio

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Proposed methodology - MRM

- Using the region of filaments
  - Multifilamentary region method (MRM)
  - The local critical current density is modified while keeping the overall critical current unchanged (Jc0 = Ic / S)
  - The area of the superconducting domain is the size of the region that contains all filaments

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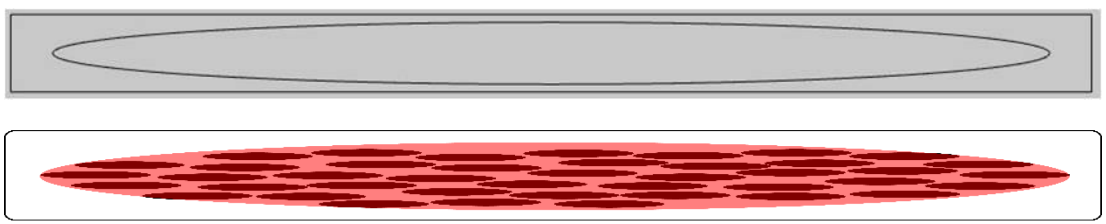

  - Need to use the cross-sectional image to identify size

Tapes

- Tape 1- single tape
  - Transport current only
  - Transport current and applied magnetic field
- Tape 2 - three tapes in parallel, touching horizontally
  - Transport current only
- Tapes 3 & 4: a conductor of 10 tapes in a regular decagon
  - Transport current only
  - One active tape – single mode
  - All active tapes – simultaneous mode

Numerical technique of model verification

- Implemented in COMSOL
- H-formulation:

$$\nabla \times (\rho \nabla \times H) + \mu_0 \mu_r \frac{\partial H}{\partial t} = 0$$

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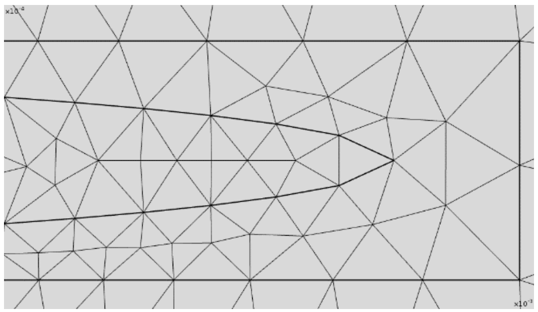
- Loss integration:

$$Q = 2 \int_{1/f}^{1.5/f} \int_S JE dt$$

Numerical technique - meshing

80



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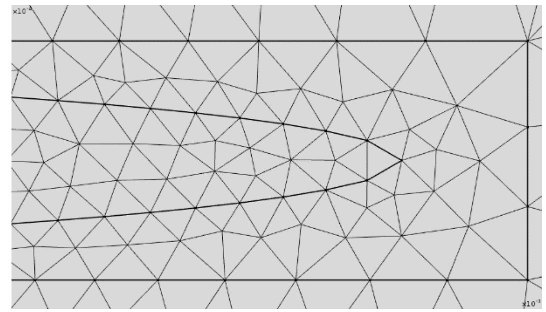

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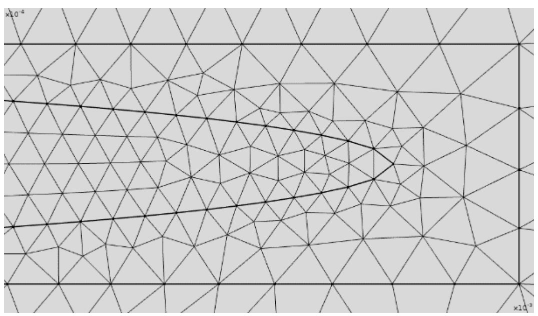

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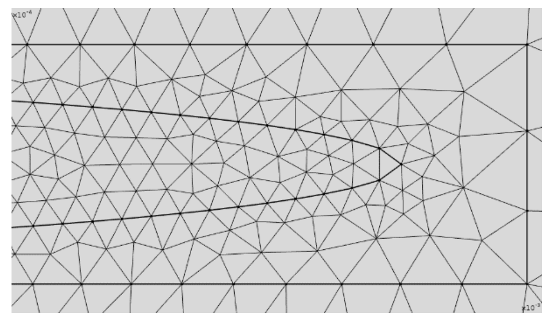
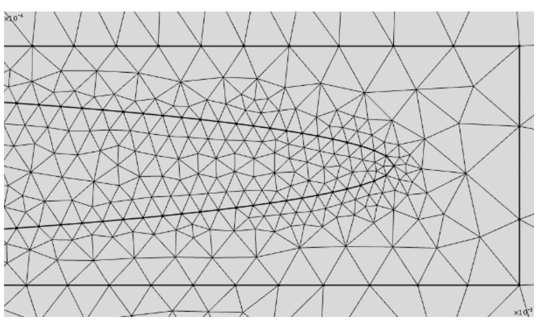
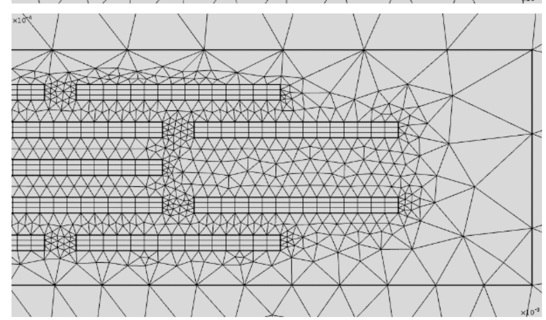


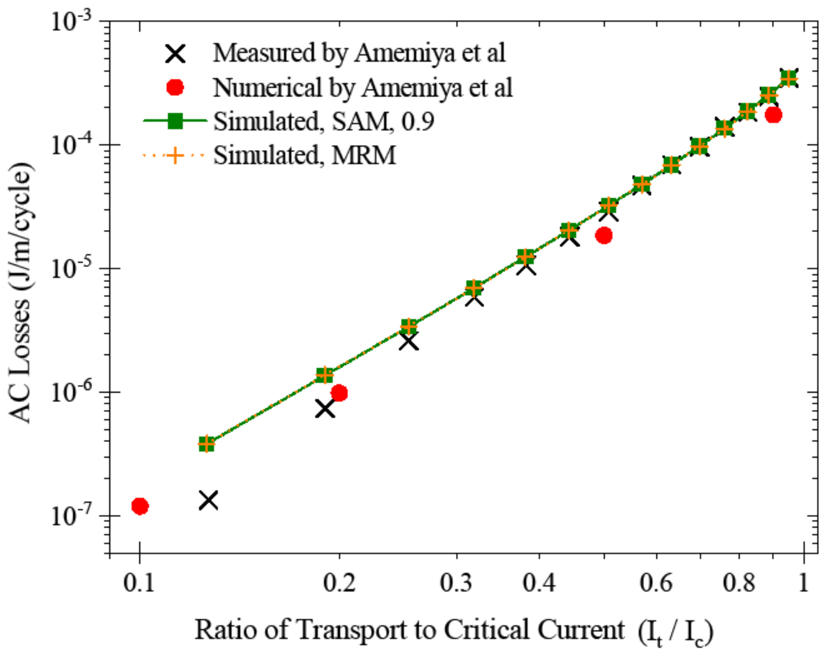


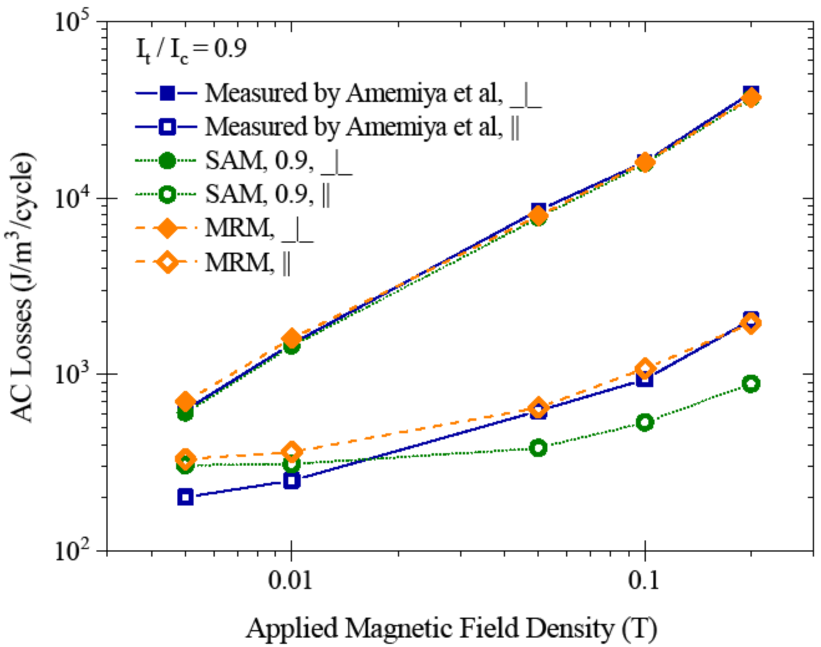
240 elements on edge



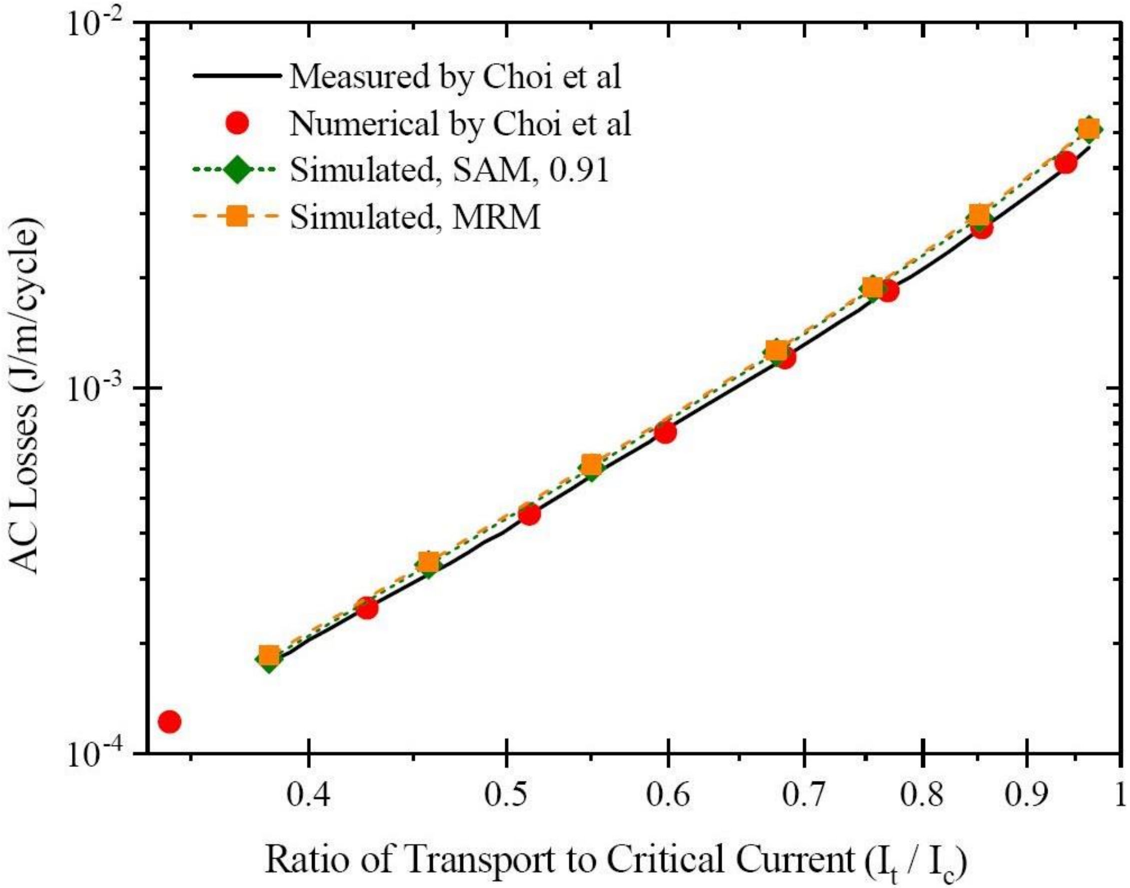
Multifilamentary (example)

Results – Tape 1





Results – Tape 2



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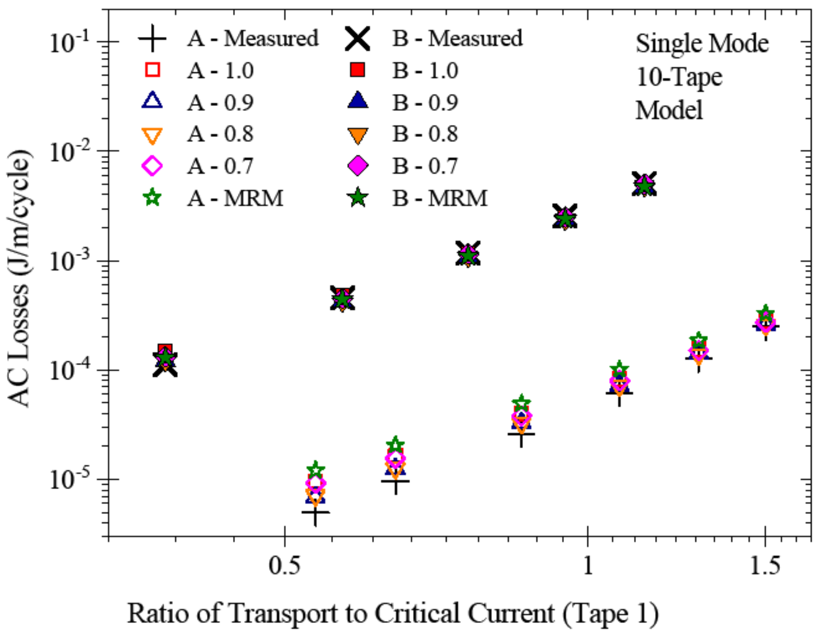
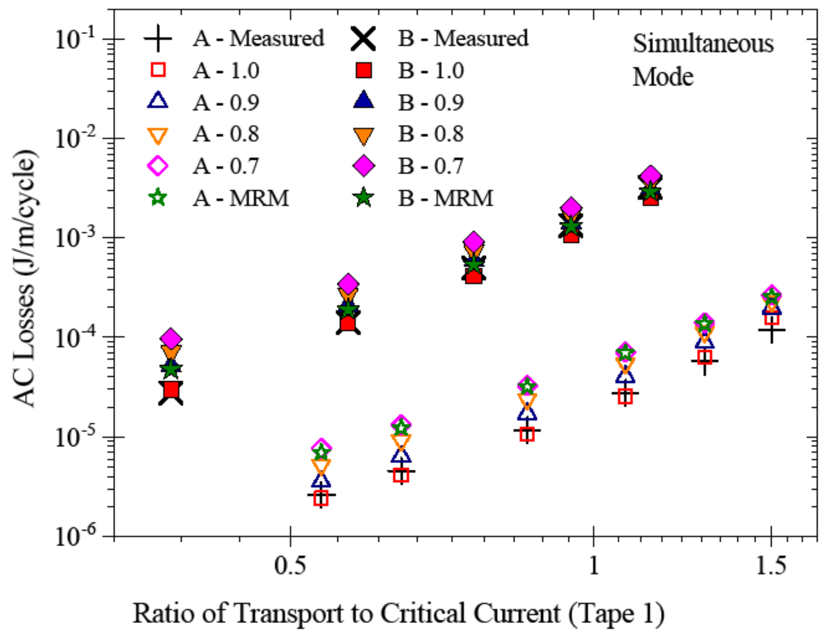
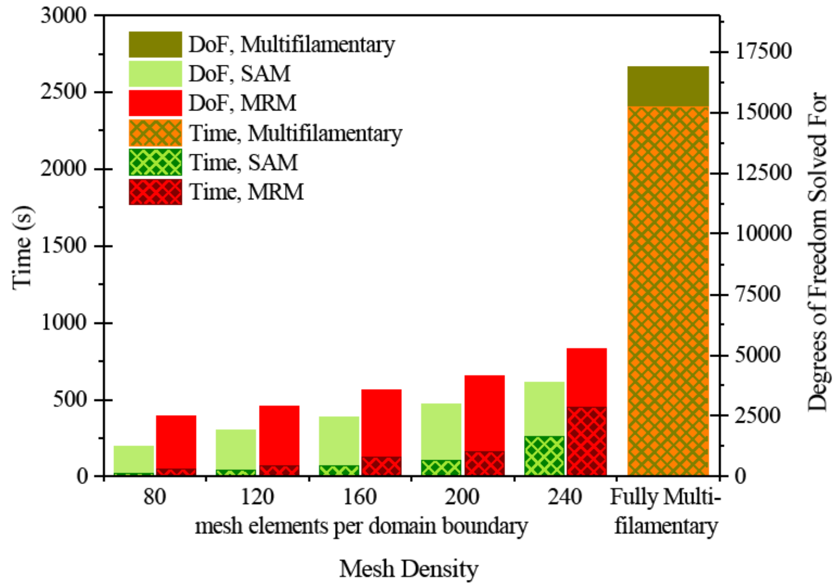
Results – Tapes 3 & 4



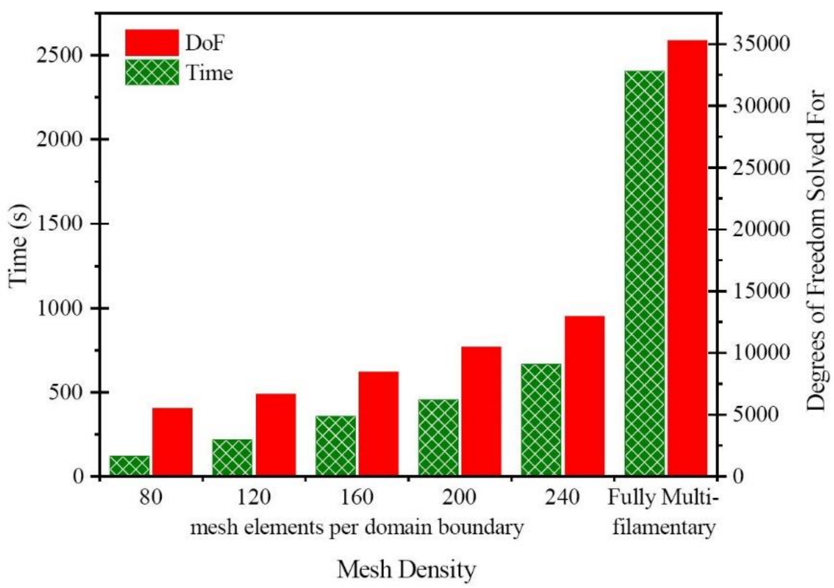


Results – simulation time

(Tape 1)



(Tape 2 - MRM)



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Conclusions

- MRM > SAM
- Accuracy
  - Tape 1: 1%-20% deviation, but with overestimation at low current
  - Tape 2: 1%-15% deviation from losses presented in literature
  - Tape 3 (conductor): Large overestimations
  - Depends on the precision of measurement of power loss and tape parameters
- Computational requirements
  - 3-5 times decrease in simulation time
- Homogenization techniques successfully model non-twisted sections of tape in 3D

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Thank you for your attention!

Alexander Petrov – *A.Petrov@ecs.soton.ac.uk*