



cern.ch/STEAM

Magnet quench 3D simulations
using STEAM-LEDET
EDMS 2454468

2nd STEAM Workshop 11-15 October 2021

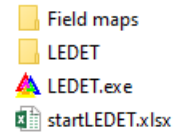
Ola Tranum Arnegaard – Technical student TE-MPE-PE
Norwegian University of Science and Technology

Motivation

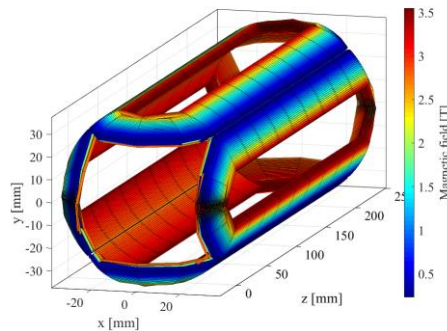
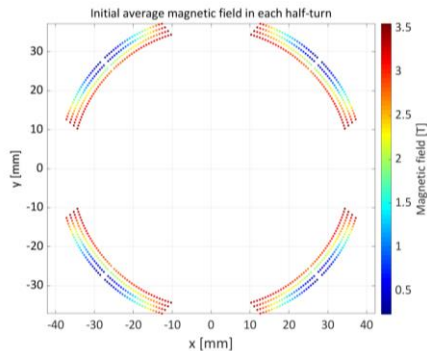
- ❖ Simulate quench in 3D
- ❖ New tool



Run simulation



- STEAM-LEDET input file
 - *Inputs* sheet: 3D parameters
 - *Options* sheet: 3D flag
- Magnetic field map
 - Extended to the entire turn



STEAM-LEDET Input file, 3D parameters:

Inputs

Quench detection voltage threshold [V]	sim3D_uThreshold	100000000
Scaling factor for cooling to thermal sink - Conductor down side	sim3D_f_cooling_down	0
Scaling factor for cooling to thermal sink - Conductor up side	sim3D_f_cooling_up	0
Scaling factor for cooling to thermal sink - Conductor right side	sim3D_f_cooling_left	0
Scaling factor for cooling to thermal sink - Conductor left side	sim3D_f_cooling_right	0
Scaling factor for the heat exchange between bare conductor and insulation	sim3D_fExTIns	1
Scaling factor for the thermal diffusion between conductors along the wider conductor side (UD-->Up/Down)	sim3D_fExUD	1
Scaling factor for the thermal diffusion between conductors along the narrower conductor side (LR-->Left/Right)	sim3D_fExLR	1
Minimum spatial mesh size, in the coarse-mesh part [m]	sim3D_min_ds_coarse	0.100
Minimum spatial mesh size, in the fine-mesh part [m]	sim3D_min_ds_fine	0.010
Minimum number of nodes in each straight-section part [-]	sim3D_min_nodesPerStraightPart	4
Minimum number of nodes in each end-section part [-]	sim3D_min_nodesPerEndsPart	4
Indices of the half-turns with finer mesh [-]	sim3D_idxFinerMeshHalfTurn	526
Center of the temperature gaussian distribution, i.e. position where the quench starts [m]	sim3D_Tpulse_sPosition	2.4896E+03
Peak temperature of the gaussian distribution [K]	sim3D_Tpulse_peakT	20
Width of the temperature gaussian distribution, i.e. 2*sigma [m]	sim3D_Tpulse_width	0.01
Duration of the animated GIF [s]	sim3D_durationGIF	20
	sim3D_flag_saveFigures	1
	sim3D_flag_saveGIF	1
	sim3D_flag_VisualizeGeometry3D	1
	sim3D_flag_SaveGeometry3D	1

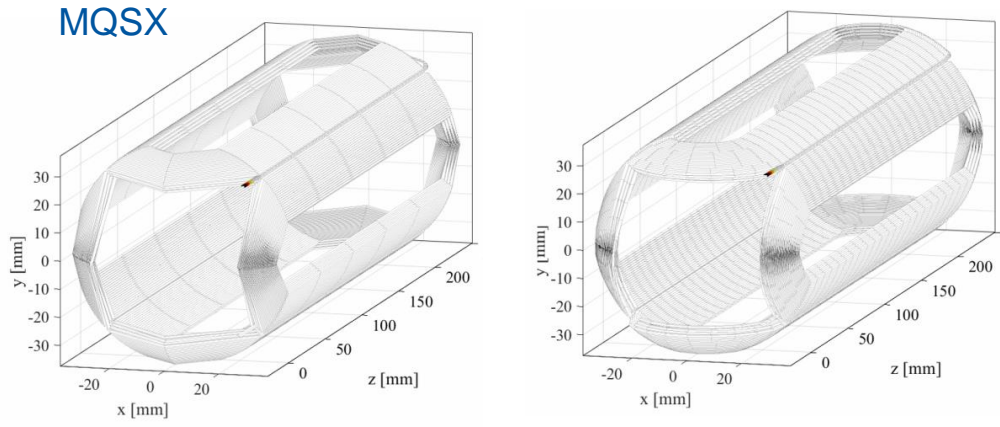
Options

If set to 1, the 3D model will run instead of the default 2D	flag_3D	1
If set to 1, the adaptive time stepping is enabled	flag_adaptiveTimeStepping	0

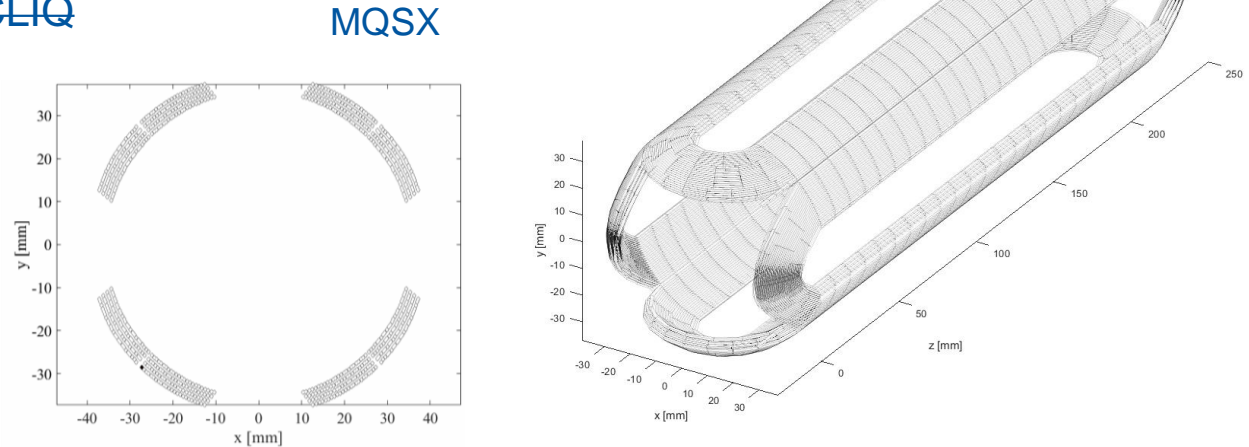


Simulation with 3D enabled

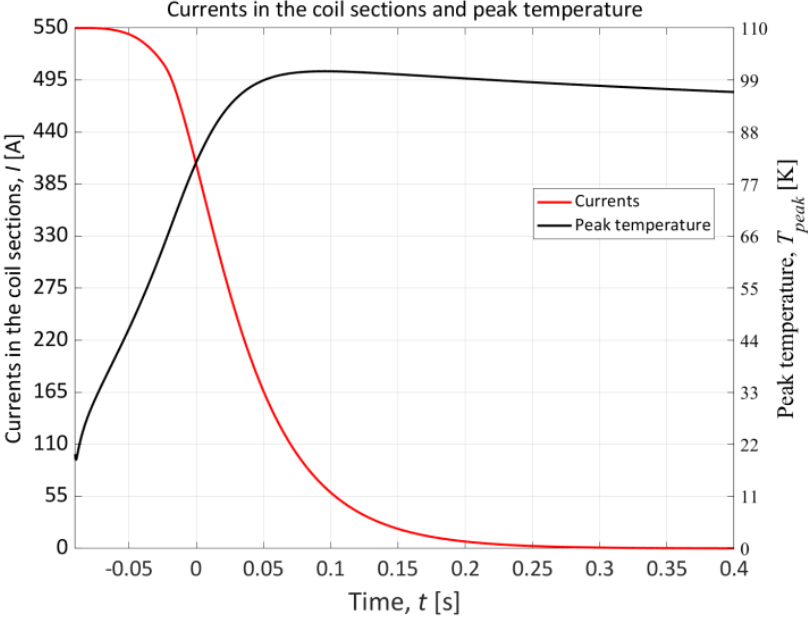
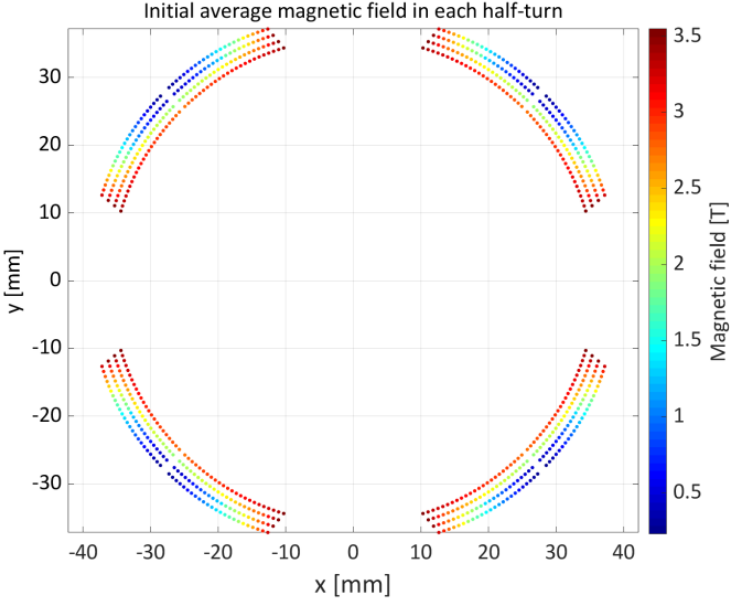
- ❖ 3D model
 - ❖ Quench initialization, heat generation and diffusion in three dimensions
 - ❖ Simplified geometry
 - ❖ Straight section: expanded from 2D
 - ❖ End section: semicircle with radius from cross-section
 - ❖ Inter-filament coupling loss
 - ❖ Adaptive time stepping
 - ❖ Quench heaters and CLIQ

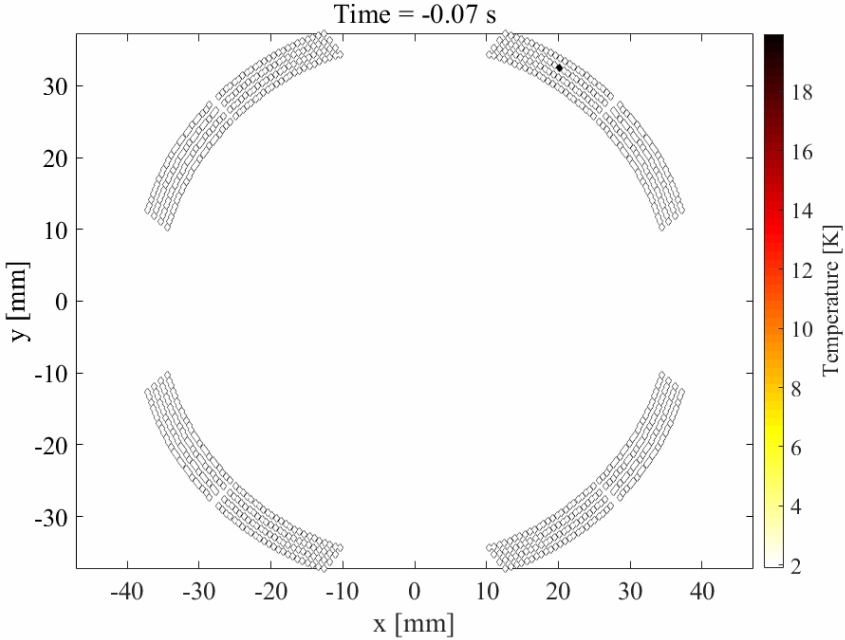
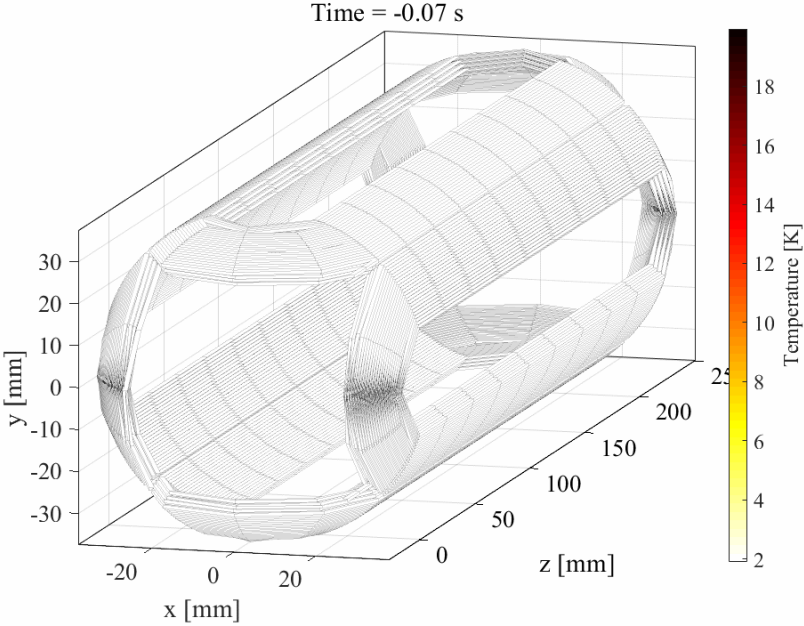


- ❖ Simulation time
 - ❖ 20 min to 1 h
 - ❖ Mesh size
 - ❖ Time step

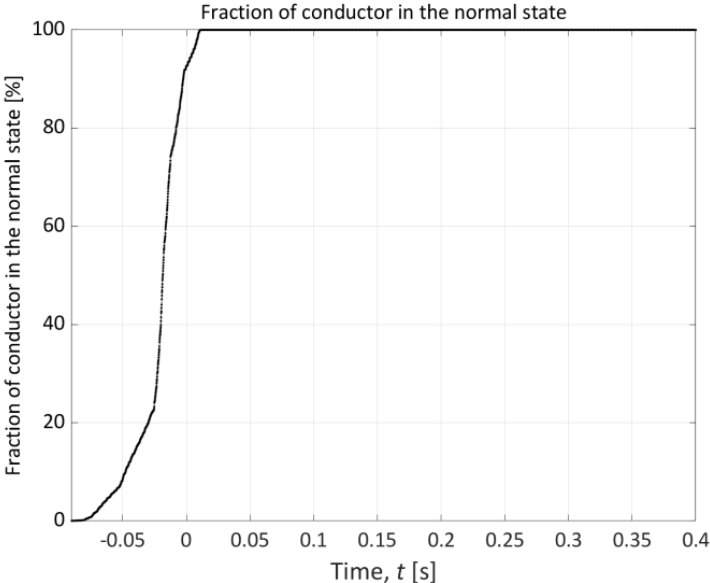
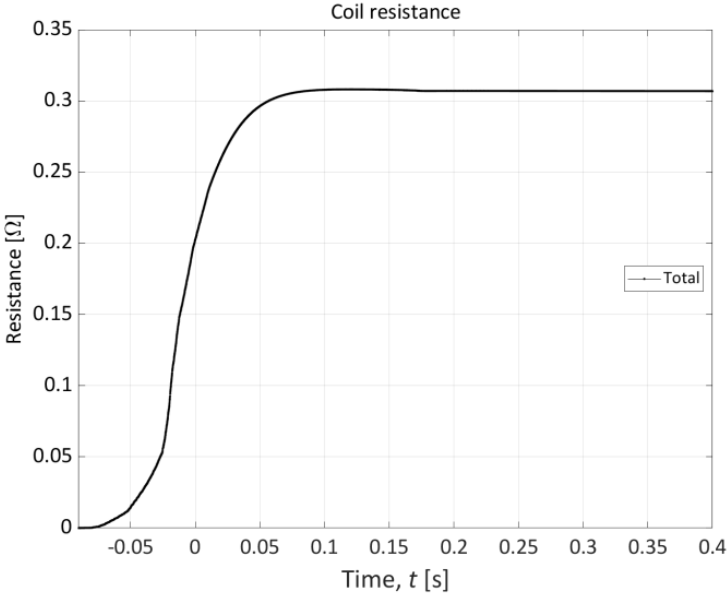


MQSX

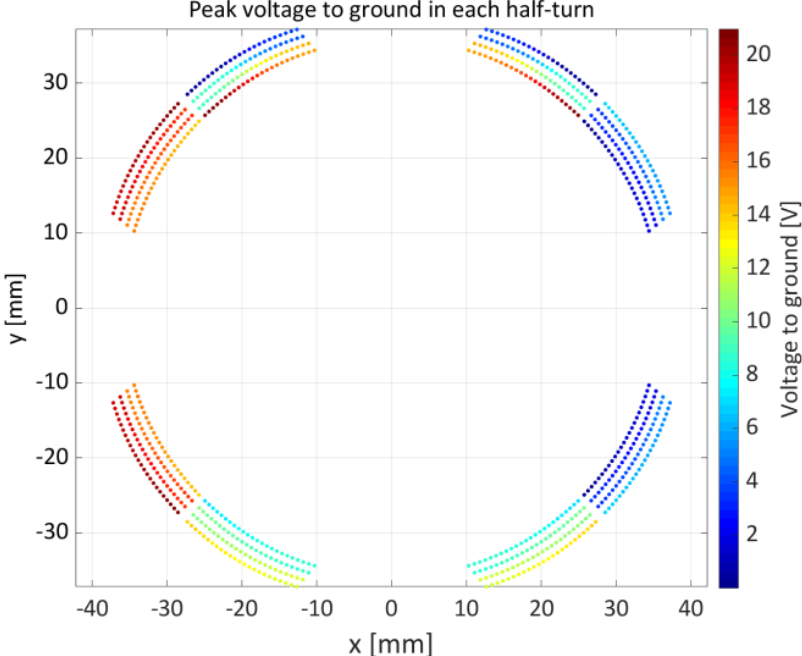
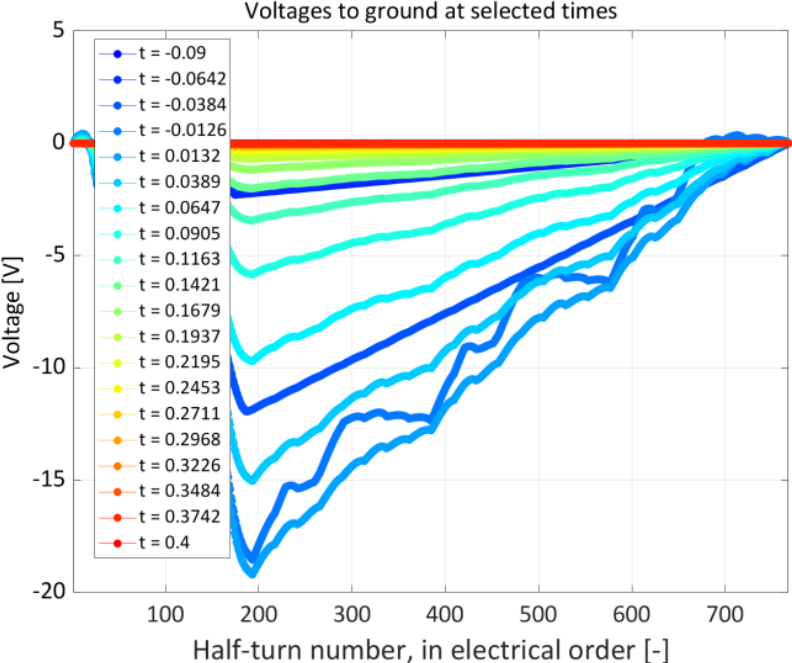




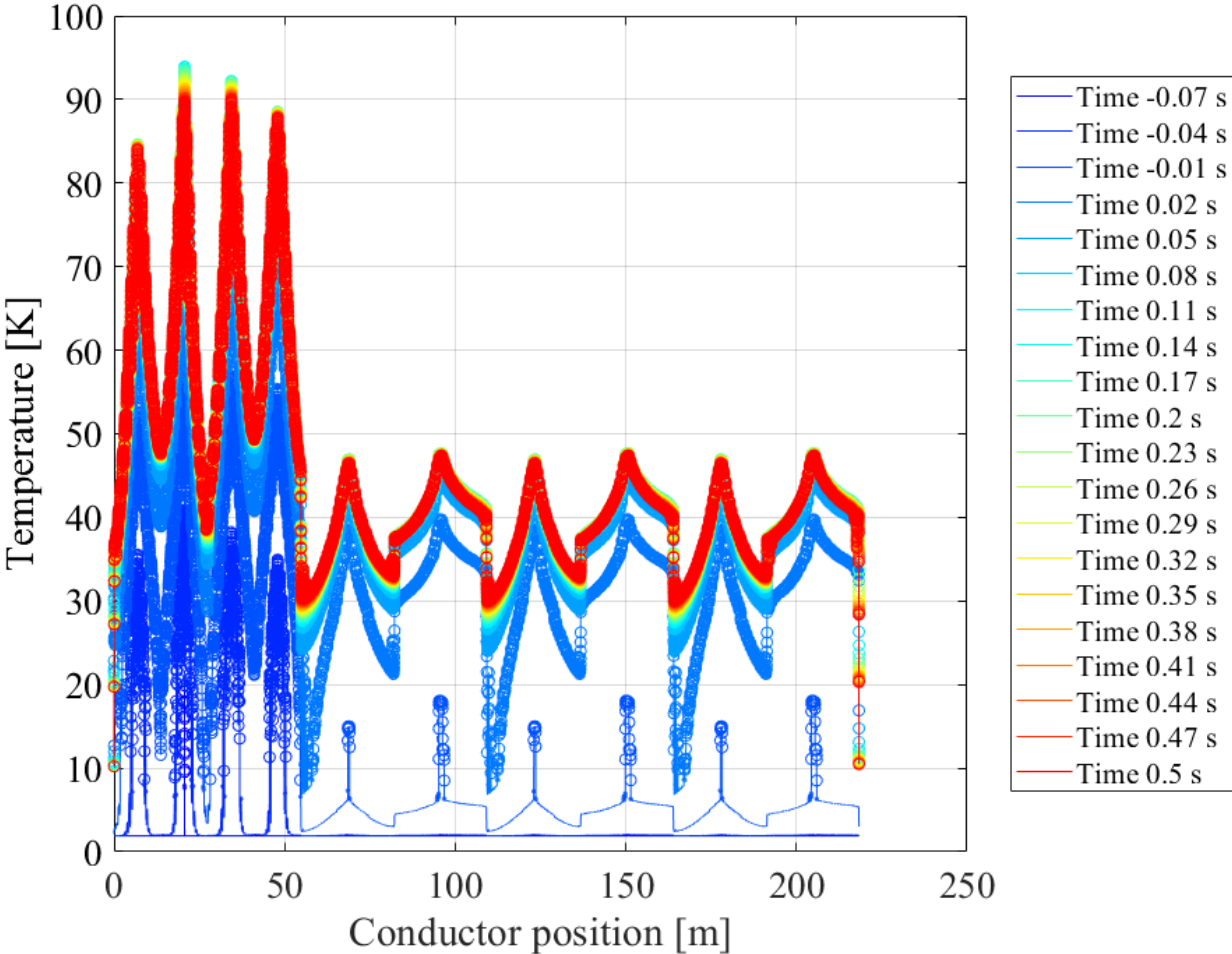
MQSX



MQSX

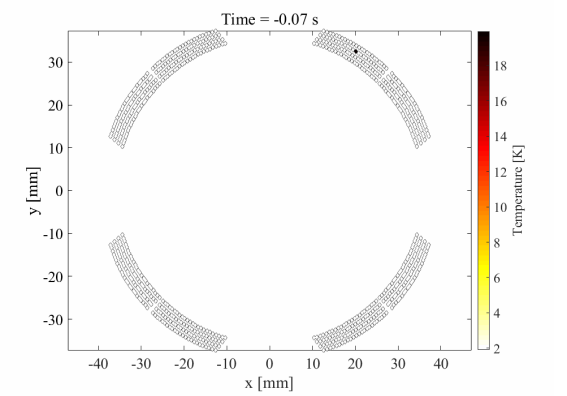


MQSX

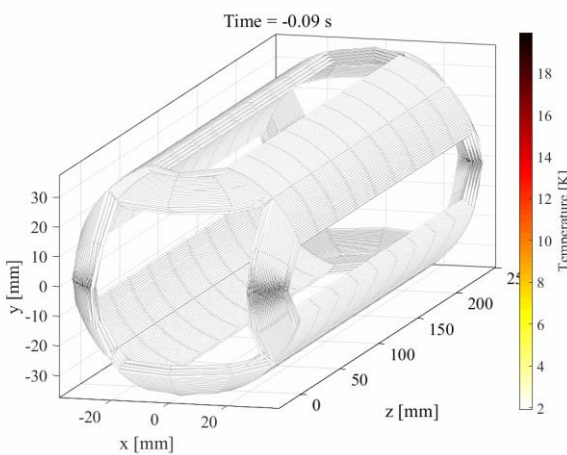
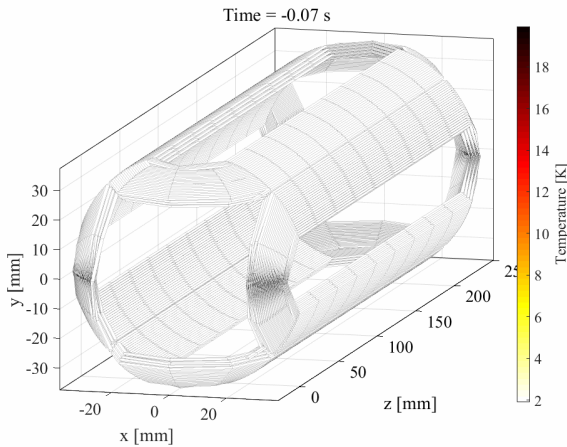
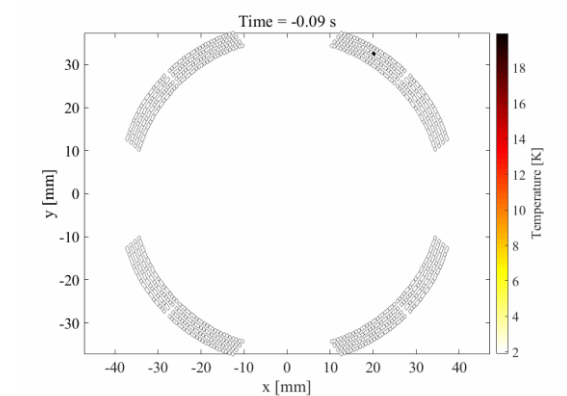


Inter-filament coupling loss - MQSX

With IFCL

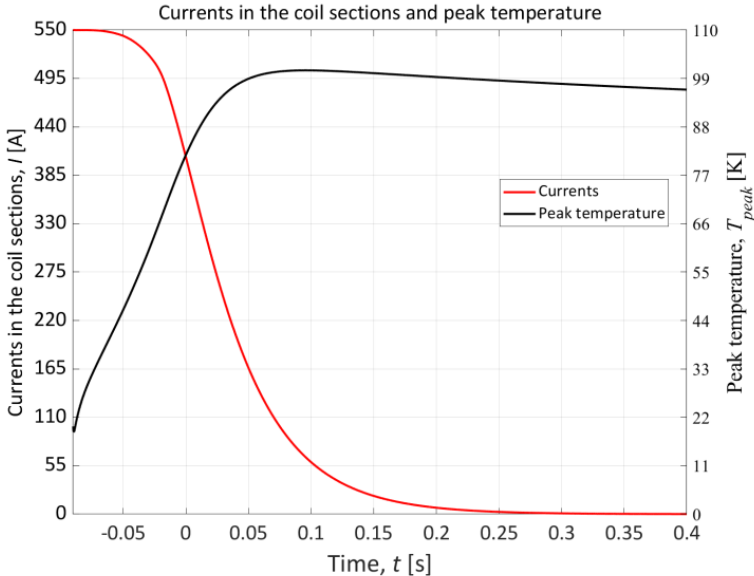


Without IFCL

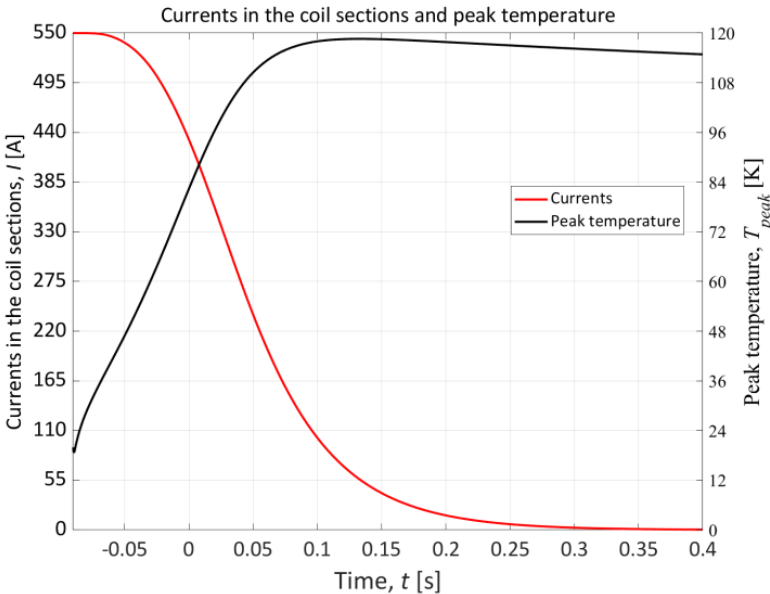


Inter-filament coupling loss - MQSX

With IFCL

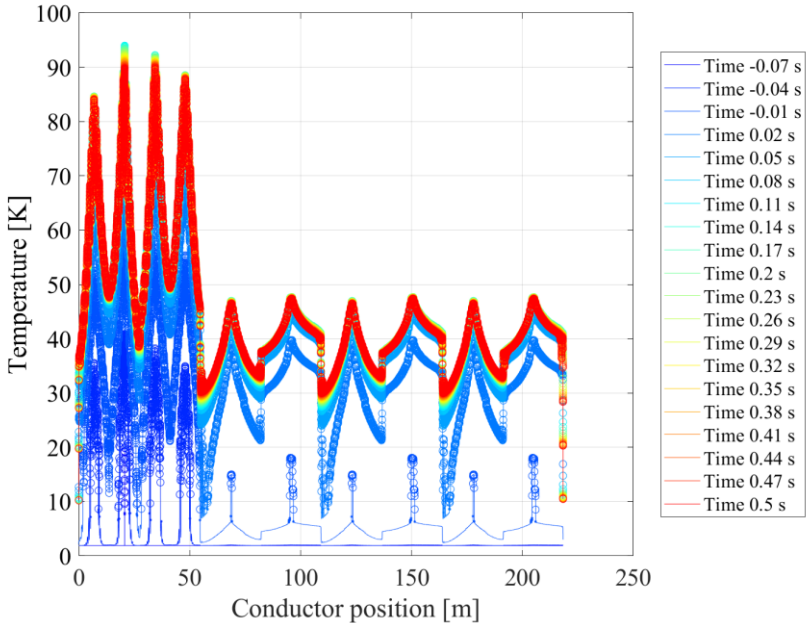


Without IFCL

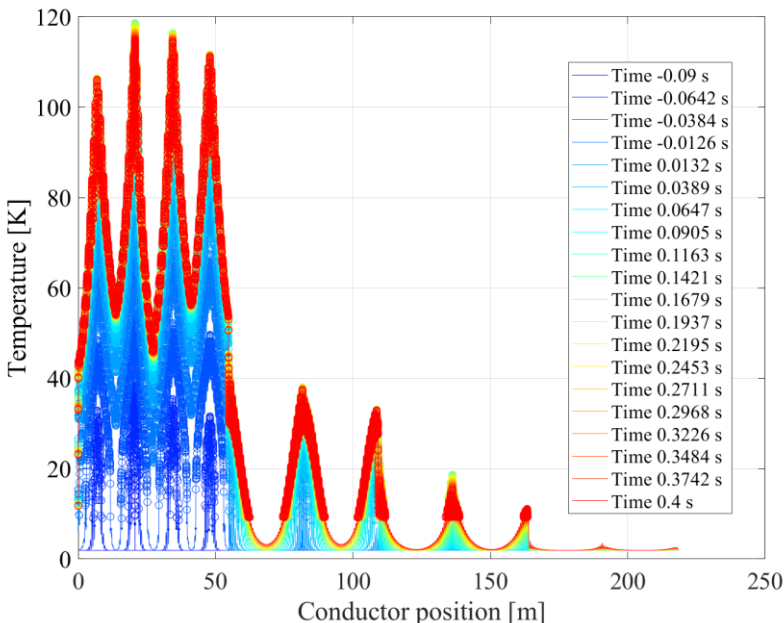


Inter-filament coupling loss - MQSX

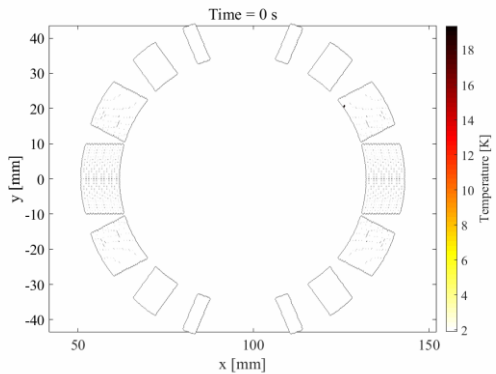
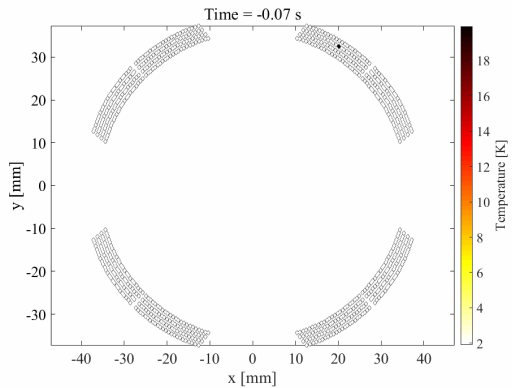
With IFCL



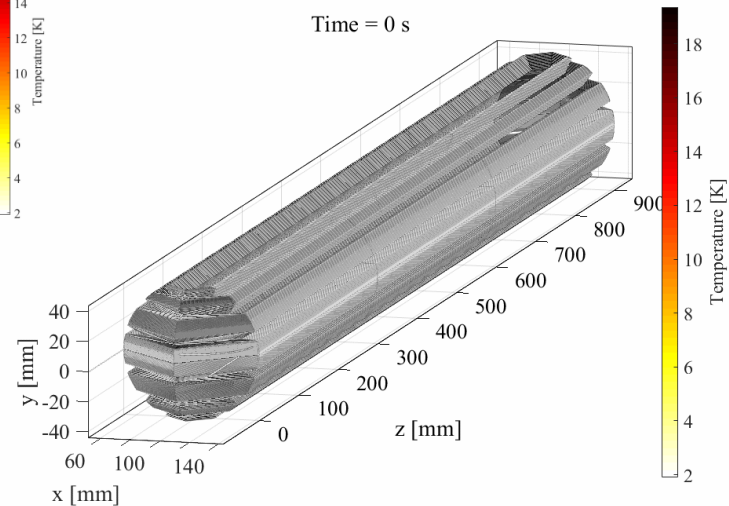
Without IFCL



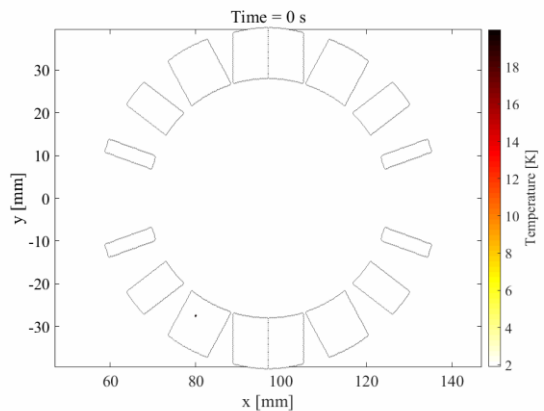
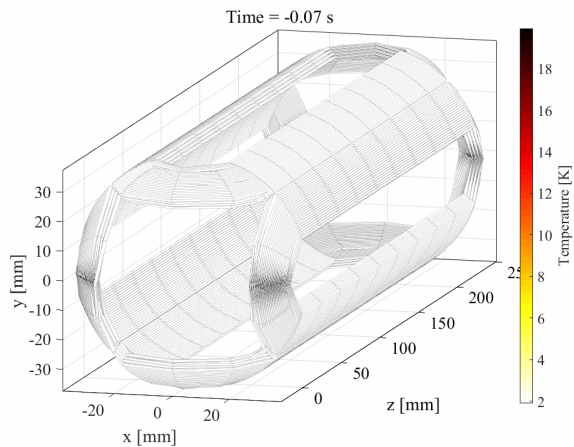
More magnets



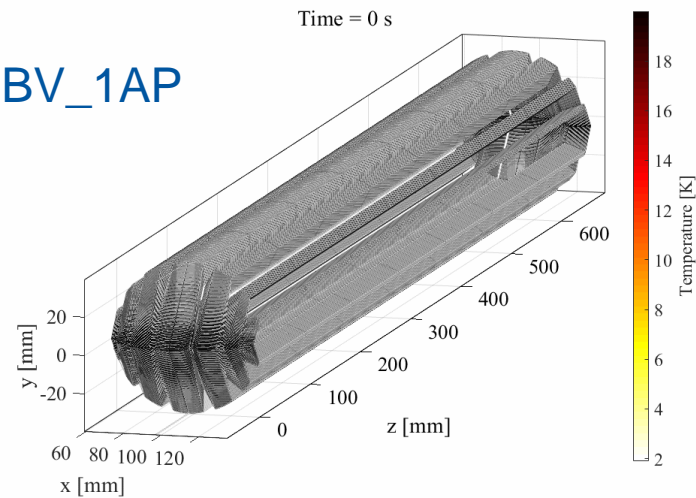
MCBYH_1AP



MQSX



MCBV_1AP



Conclusion

- ❖ New tool
- ❖ Heat diffusion in three dimensions
- ❖ Frequent updates