Computational Challenges in Present and Future Projects

(from a ROXIE developer's perspective)

B. Auchmann, S. Russenschuck, N. Schwerg

Challenges in numerical simulations

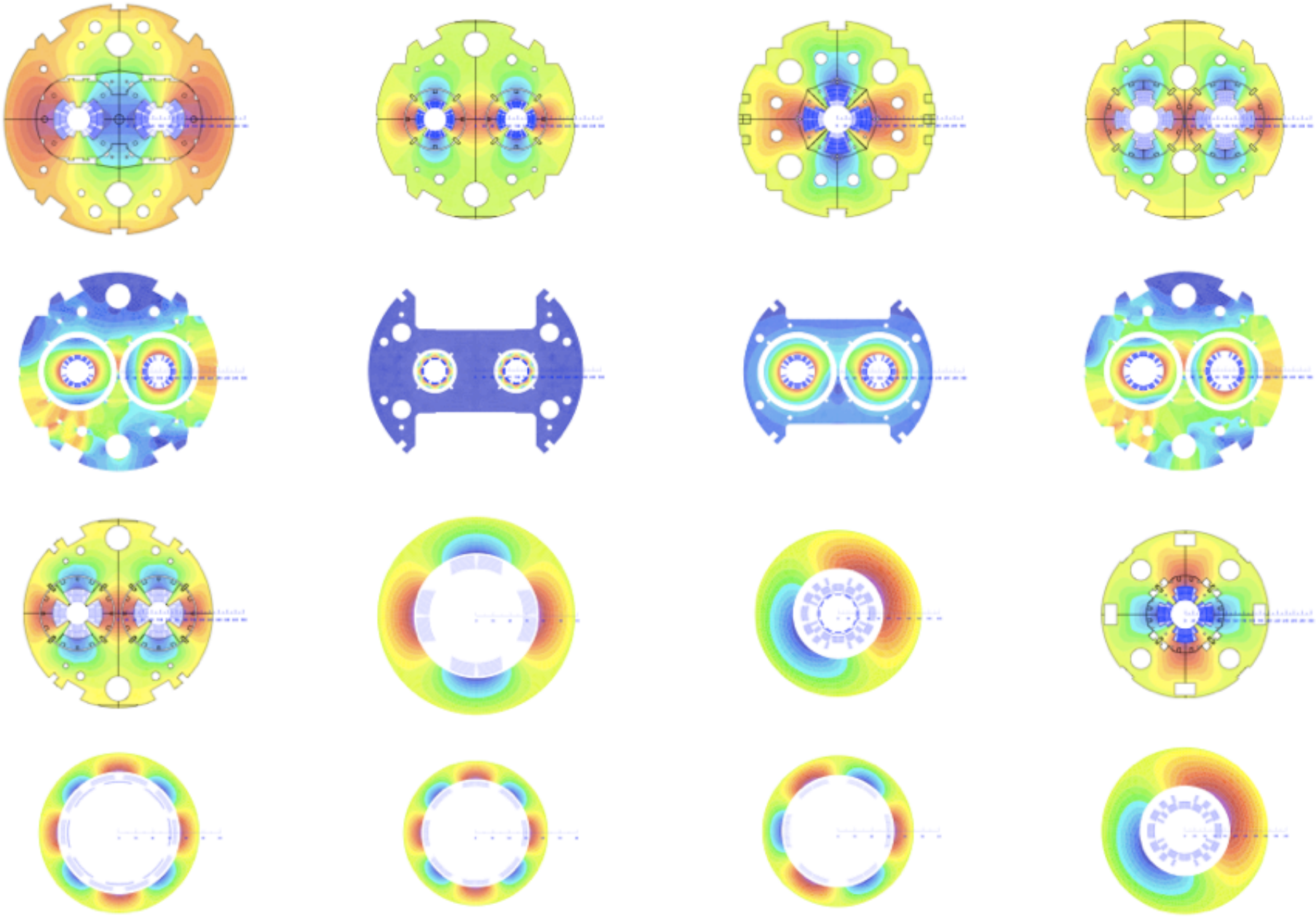
"When the only tool you have is a hammer,
all problems start to look like nails." (American saying)

➔ extending the toolbox:

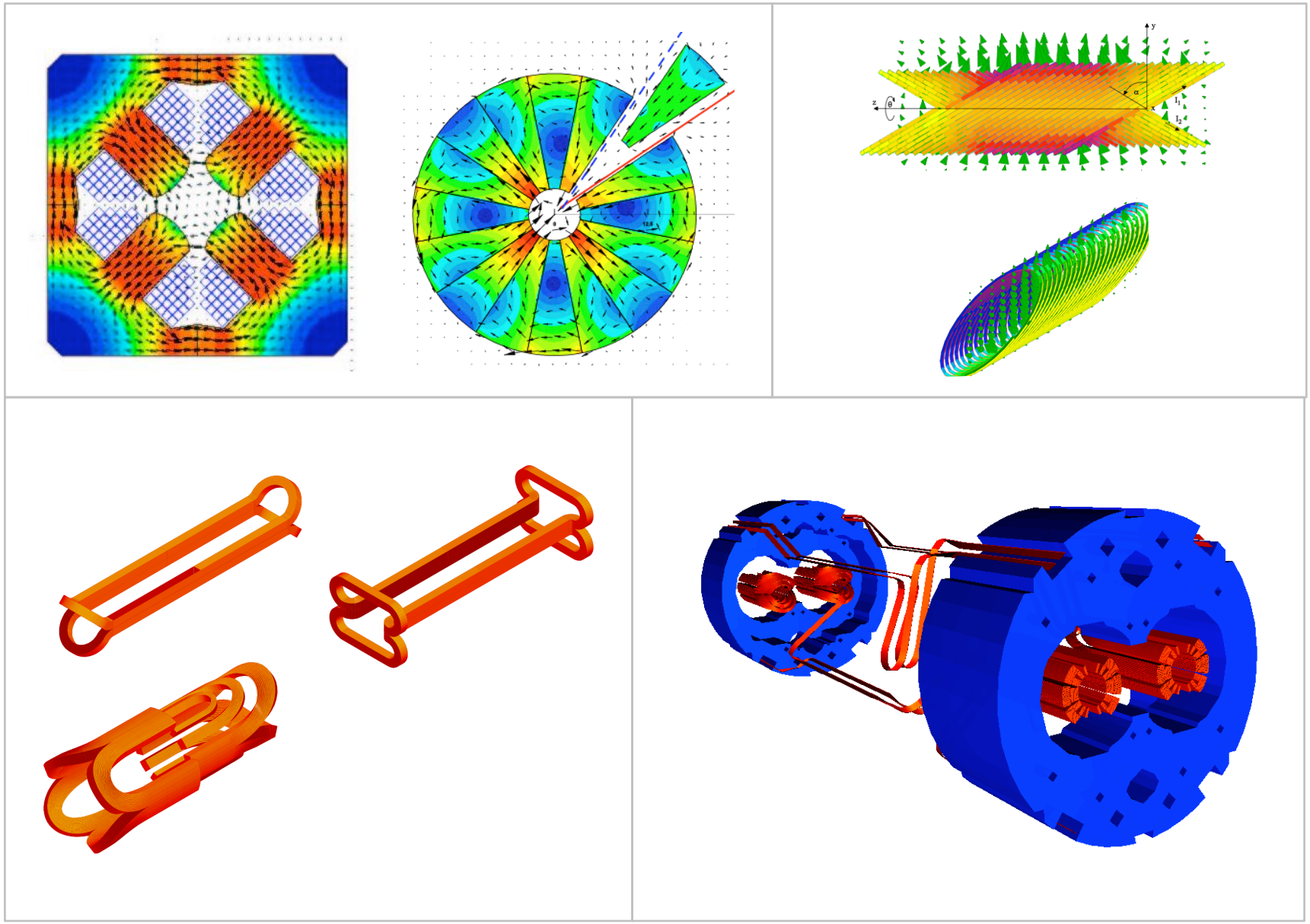
- 2-D, 3-D coil design
- 2-D nonlinear (BEM-FEM)
- 3-D magnetostatics,
- 2-D transient effects and quench

- 3-D transient
- multi-physics (electromagnetic, thermal, mechanical)

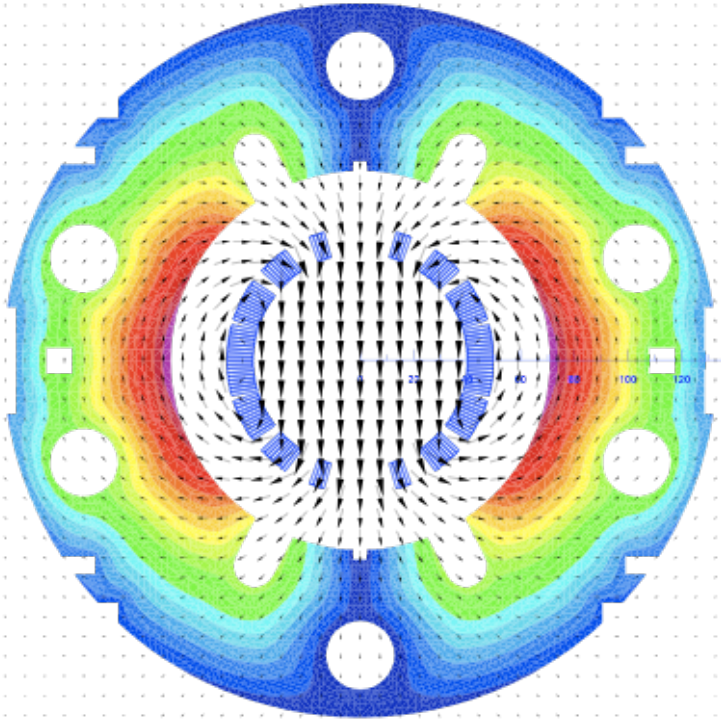
LHC SC magnet zoo designed with ROXIE

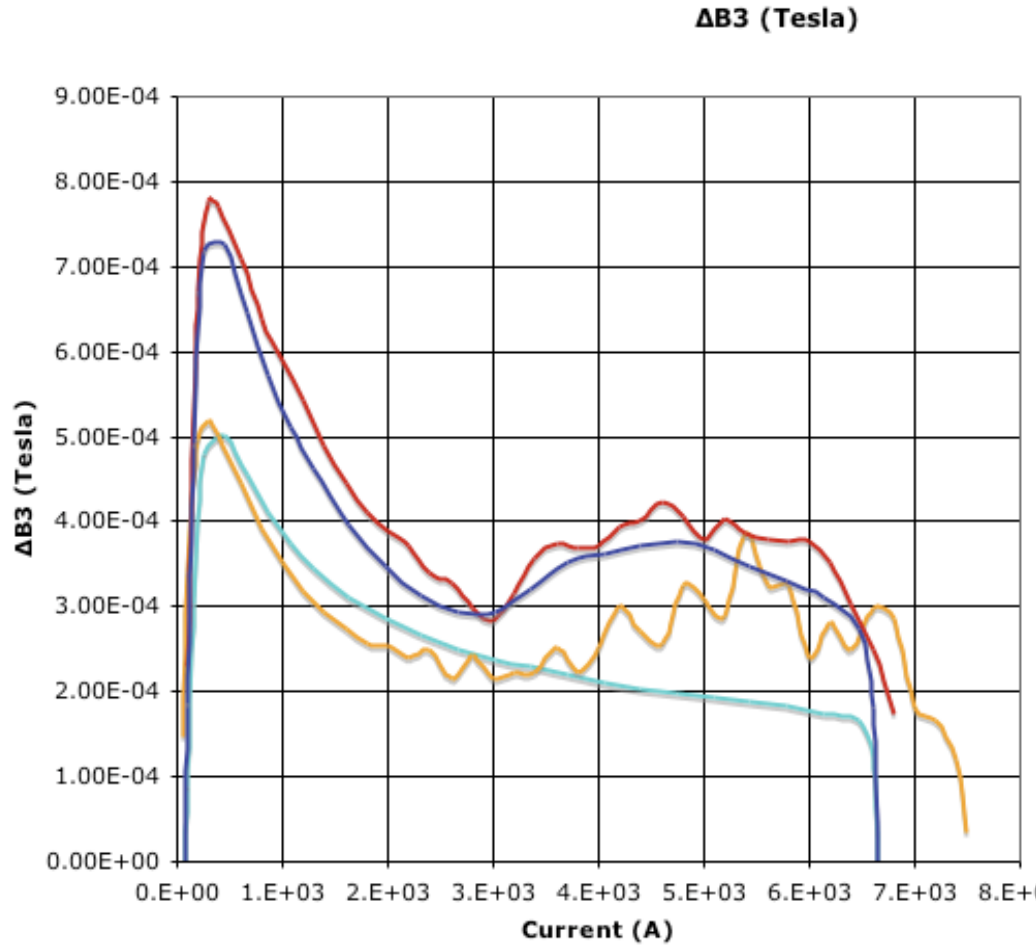


2-D normal conducting, 3-D statics



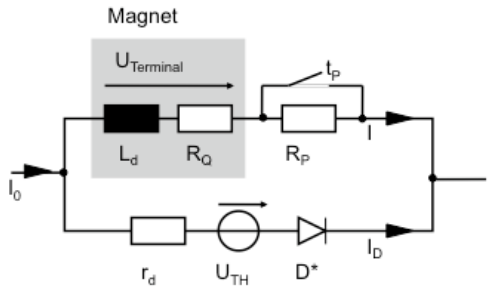
2-D transient

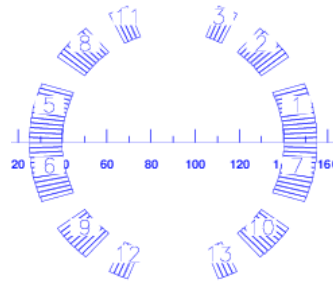


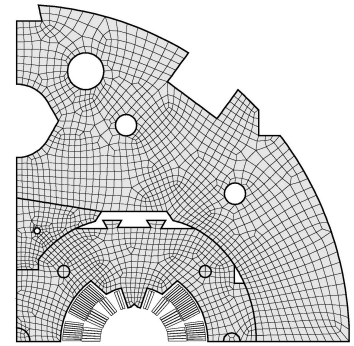


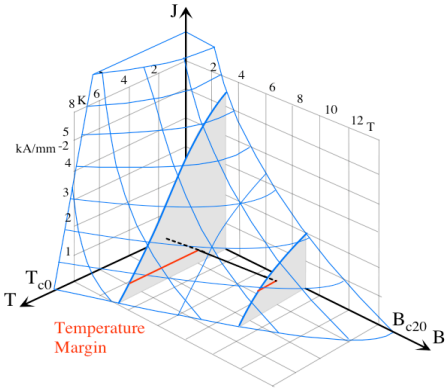
Identification of Ra and Rc from field quality measurement.

Quench simulation

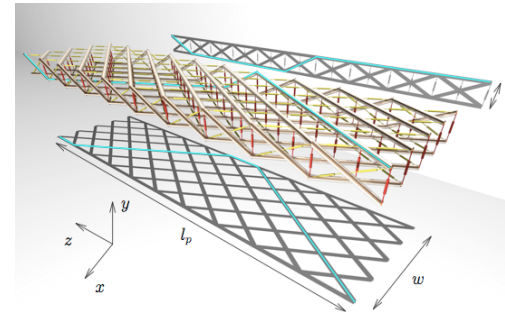


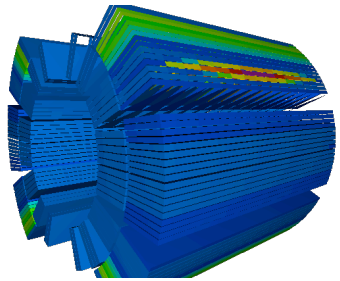


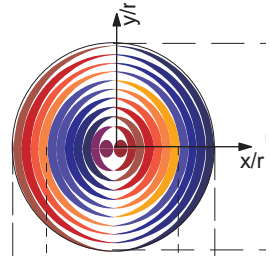


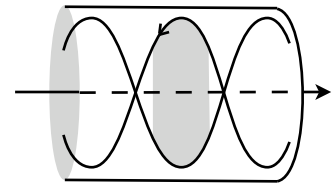


Quench Simulation in ROXIE
PhD by Nikolai Schwerg

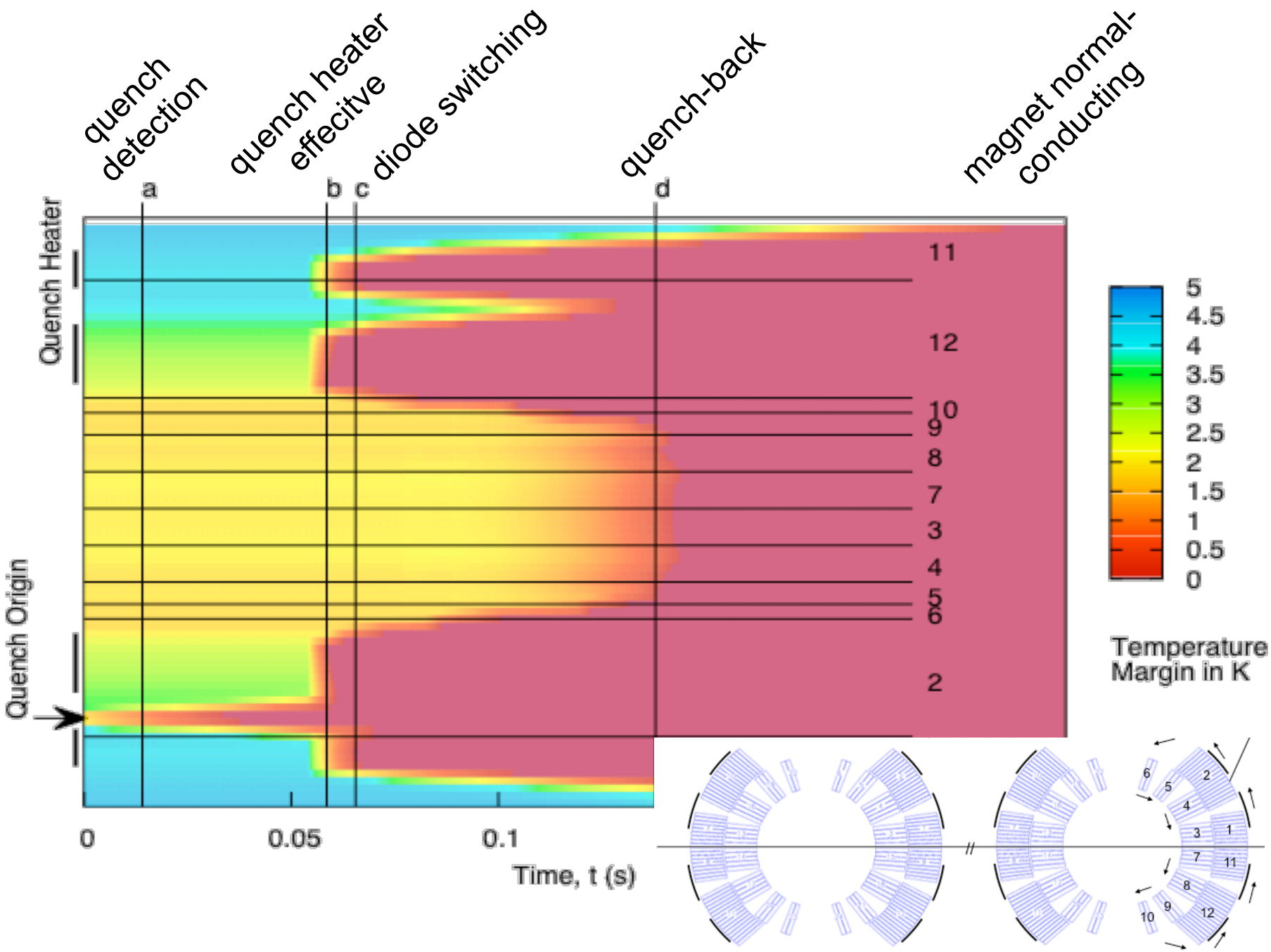




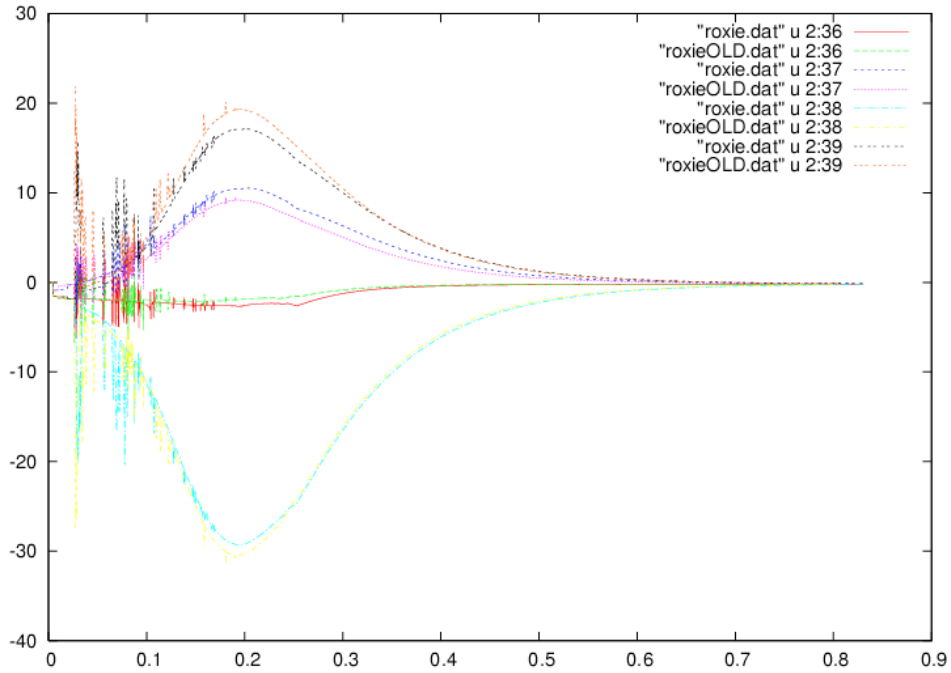


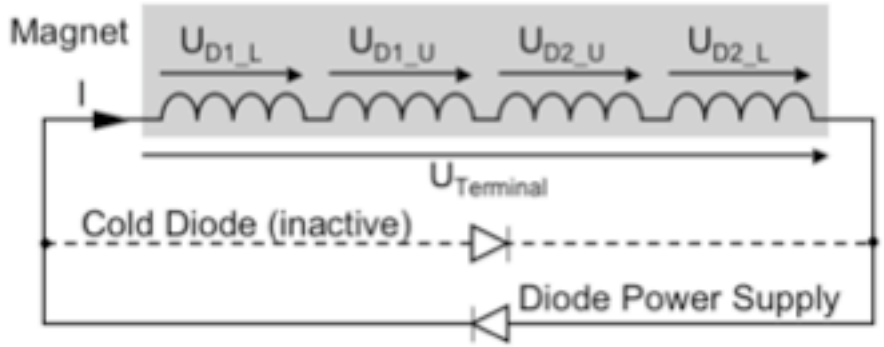


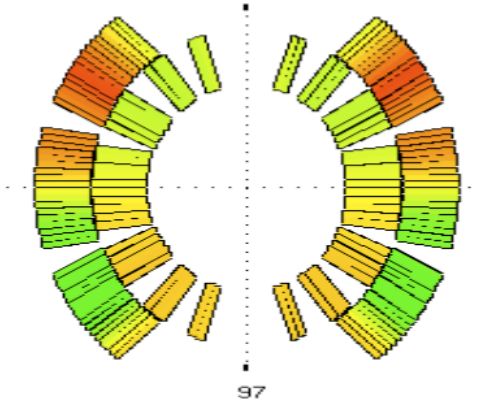
Margin to quench

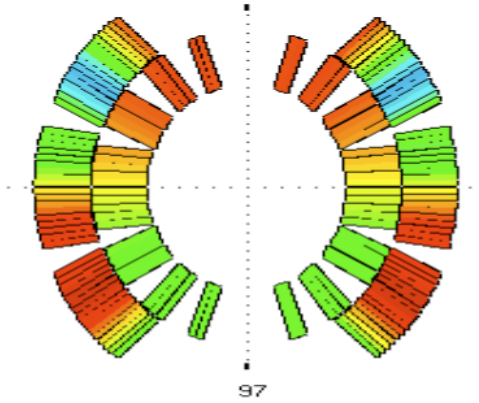


➔ Measured and simulated voltages on the 4 coils of an MB magnet during a quench on the test bench.

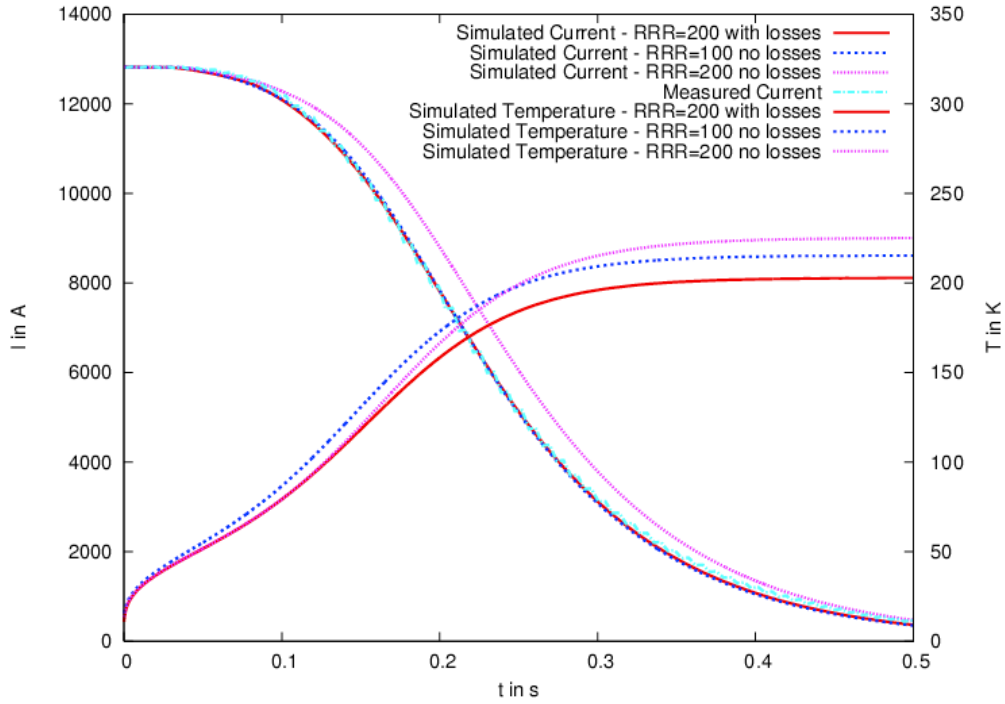








Validation 2



Empirical parameters:

- RRR
- Ra/Rc
- IFCC effective res.
- heat conductivity
- heat capacity

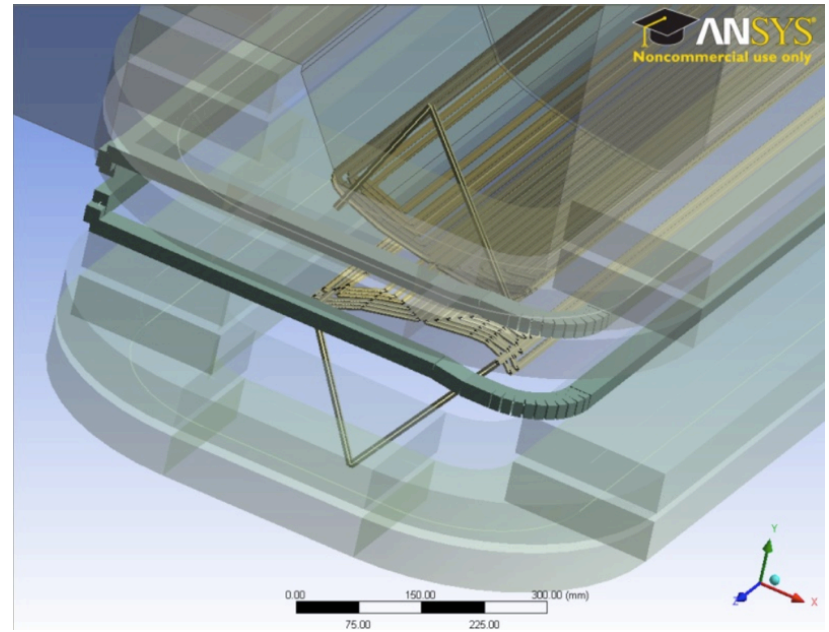
➔ Different families of parameters yield exactly the same observable I(t).

➔ More than one solution exists.

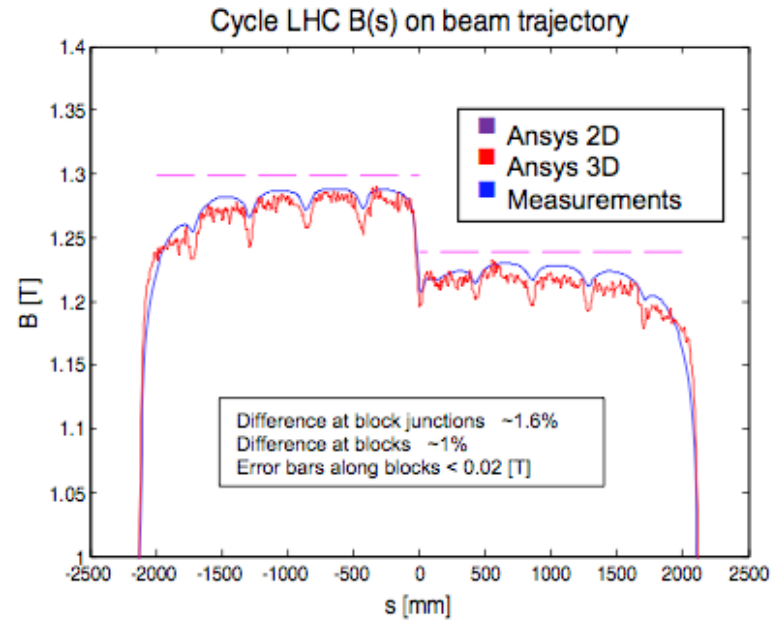
➔ Great care must be taken to model

- all relevant phenomena,
- using realistic material parameters.

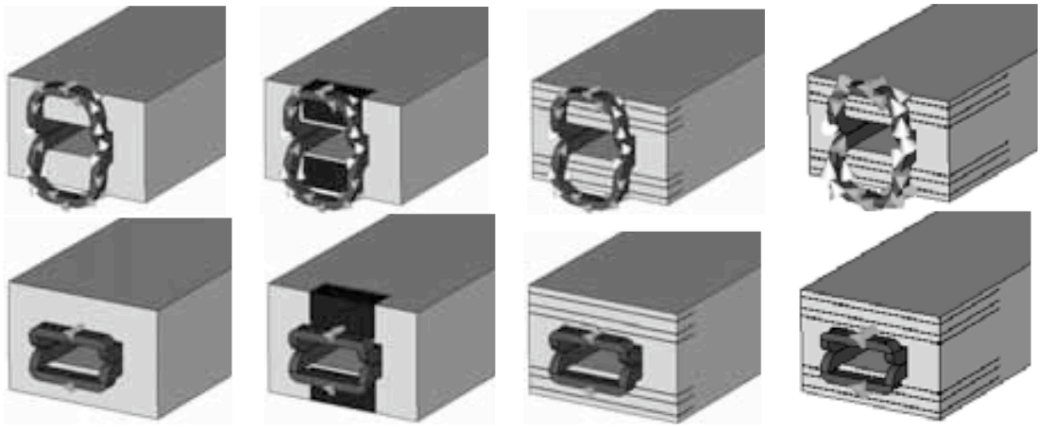
3-D statics

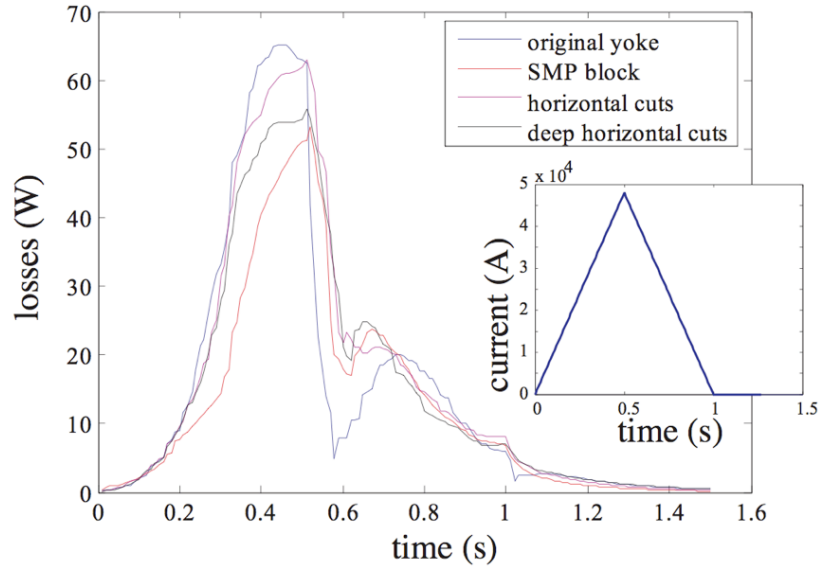


- Full-scale model of PS main magnet.
- Predict integrated multipoles at different excitation of
  - main coils,
  - pole-face windings,
  - figure-of-8 loops.



3-D transient





INTEGRATED EDDY-CURRENT LOSSES OVER ONE CYCLE TOGETHER WITH SIMULATION TIMES ON A 4-PROCESSOR SHARED MEMORY COMPUTER

# degrees of freedom	model	time / h	losses / J
22,000	3D-FE	0.09	54.96
82,000	3D-FE	0.75	45.84
526,000	3D-FE	6.00	30.16
1,537,000	3D-FE	18.75	25.51
3,100,000	3D-FE	40.00	23.98
4,600,000	3D-FE	54.00	23.37

S. Koch, H. D. Gersem, T. Weiland, E. Fischer, and G. Moritz. Transient 3D finite element simulations of the SIS100 magnet considering anisotropic, nonlinear material models for the ferromagnetic yoke. IEEE Transactions on Applied Superconductivity, accepted for publication, 2008.

H. D. Gersem, S. Koch, and T. Weiland. Magnetodynamic formulation resolving eddy-current effects in the yoke and the superconductive cable of the FAIR dipole magnets. *Proceedings of ICAP 2006, Chamonix, France*.

Challenges - Conclusion

implemented	in the pipeline	true challenges
2-D, 3-D coil design	ANSYS interface	large 3-D static simulations
2-D, 3-D nonlinear magneto-statics	FLUKA interface	3-D eddy-current problems
transient cable effects	materials beyond NbTi (persistent currents, ...)	heat transfer and cooling
quench simulation		stress dependence of materials
optimization, tolerances, parameter studies		

- limited resources
- incremental development with students (required knowledge in physics, numerics, and informatics)
- user-friendly interface
- licensing, user support, documentation