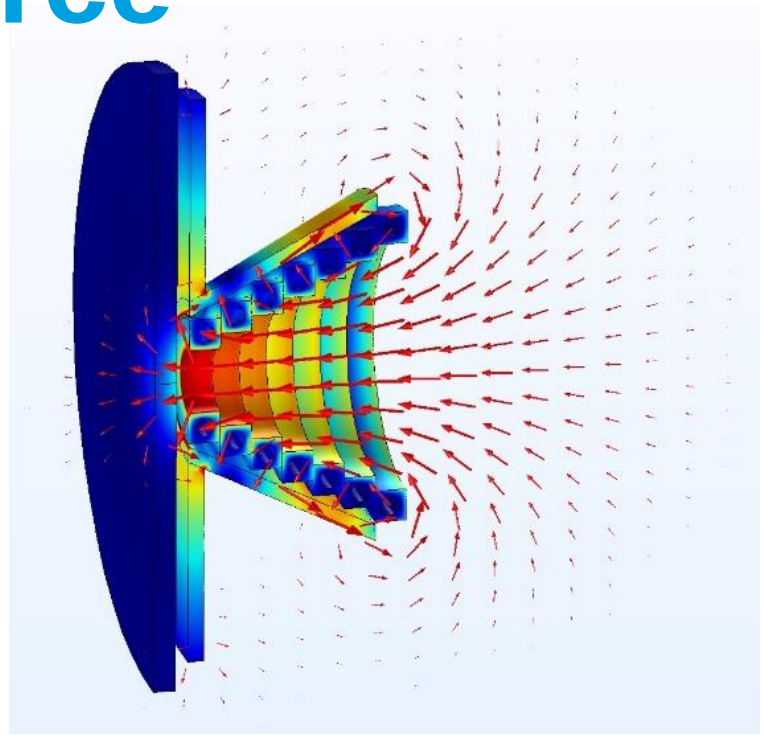
Mechanical and thermal stress on a pulsed solenoid for positron capture at the ILC undulator-based positron source

Status of simulations and mechanical design



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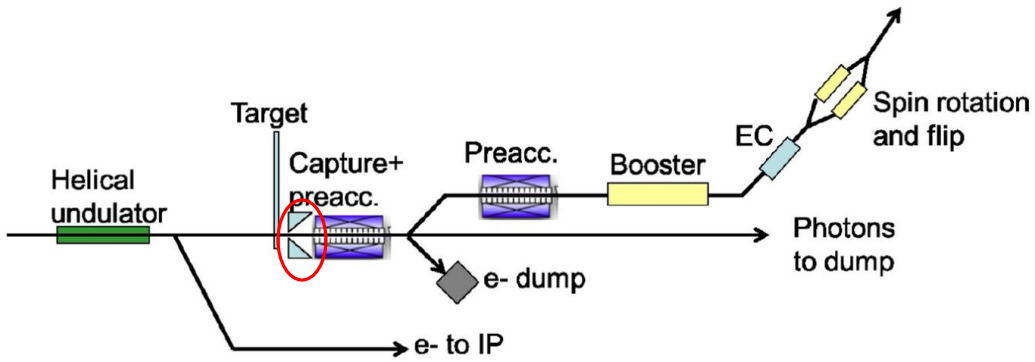
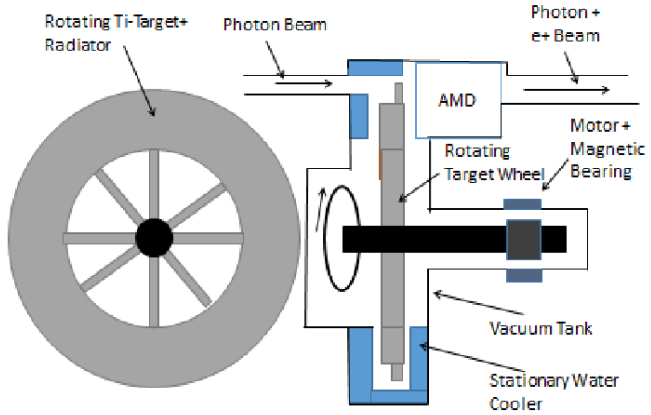
ILC undulator-based positron source

Introduction to layout and technical challenges

- Fast rotating target wheel
- 1ms-positron pulse duration
- OMD for positron capturing
  - Flux concentrator
    - *Focus variation during long pulses*
  - Quarter-wave transformer
    - *Limited yield*



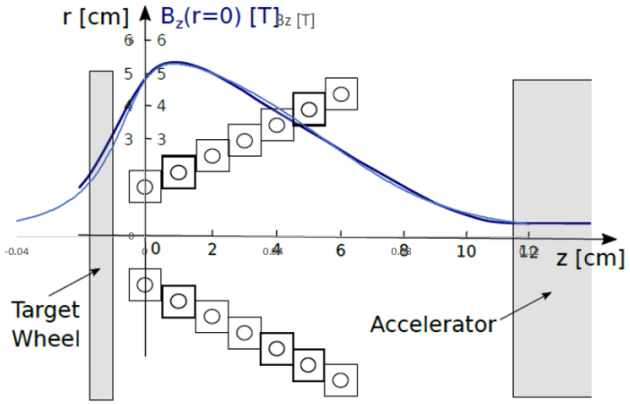
Principal Layout: Ti-Wheel with a Diameter of 1.0 m, rotating at 100 m/s, 2000 rpm.



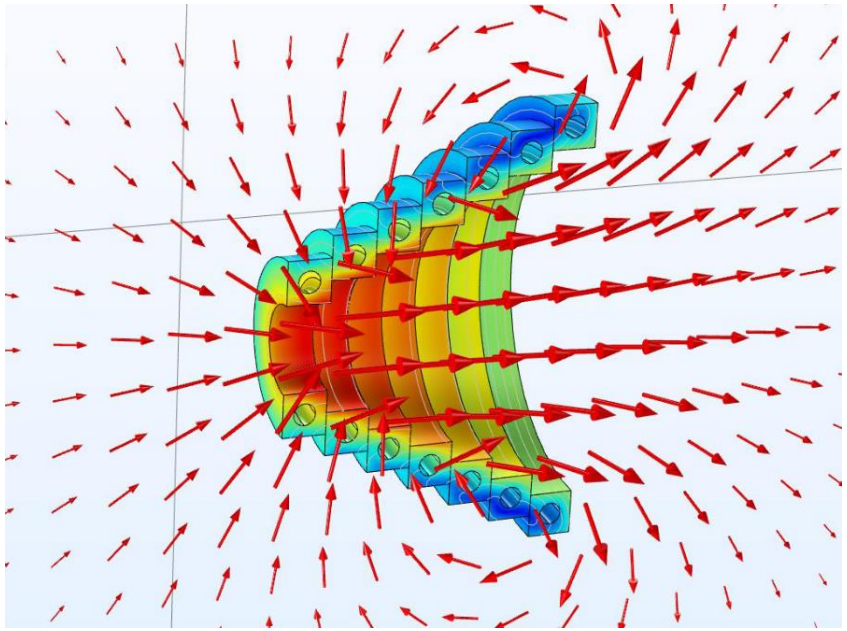
- New approach: Pulsed solenoid
  - Stable and reproducible focus
  - High magnetic flux density
  - Compatible with long pulse duration
  - Manageable heat load in solenoid
  - Manageable heat load on target (!?)

Pulsed solenoid for positron focusing

Background and previous work

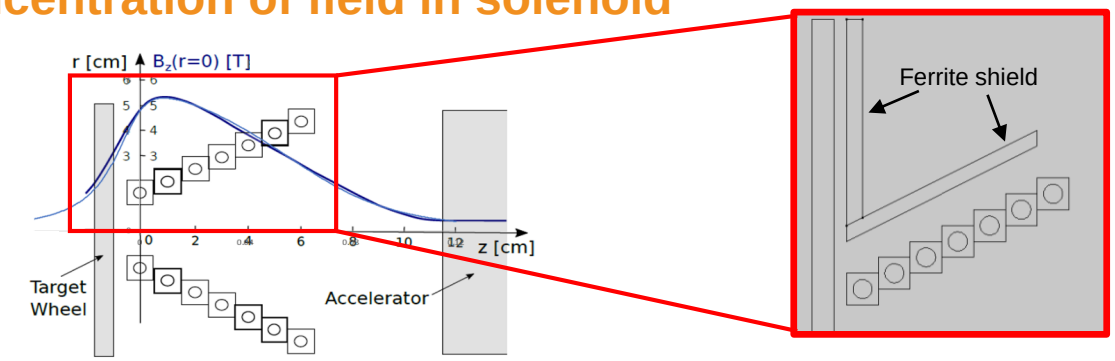


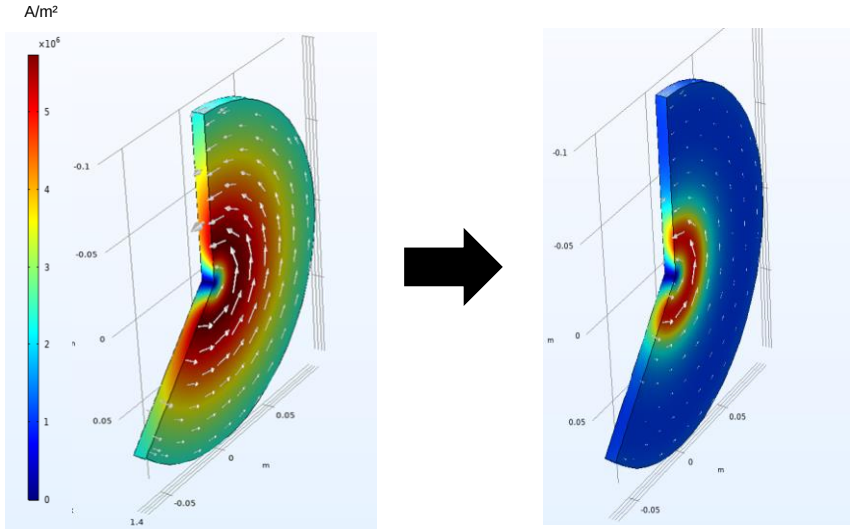
- Pulsed solenoid was e.g. used at LEP
- Constant, small coil winding cross-section for uniform current density
- Pulsed to reduce power/thermal load
- Potentially higher yield (!?)
- Prel. parameters:
  - ~50 kA peak current
  - 4 ms half-sine pulse + 1ms flat-top
  - 7 turns, linear taper (20mm → 80mm)
  - Peak field ~5 T
  - Average heat load on target: 73 W + 711 W
  - Peak force on wheel 612 N



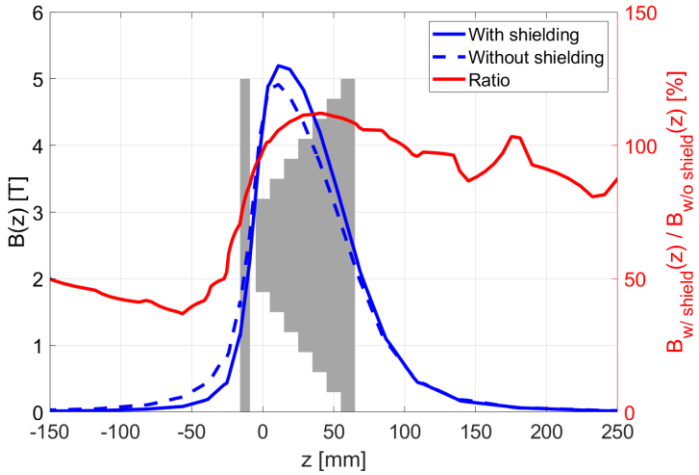
Ferrite shielding

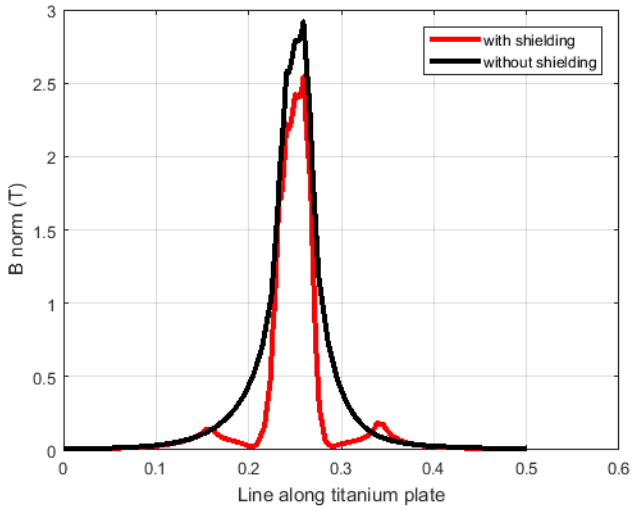
Concentration of field in solenoid





- 2D & 3D simulation in Comsol w/ moving titanium plate (100m/s) & 47kA peak current
- Ferrite shield plates around solenoid
- Increase of peak magnetic flux in solenoid <10%
- Reduction of area & amplitude of mag. field on wheel
- Induced heat reduced 73W + 711W → 31W + 298W
- Reduction of peak force on target 612N → 263N
- Increase of peak B(z) ~10%

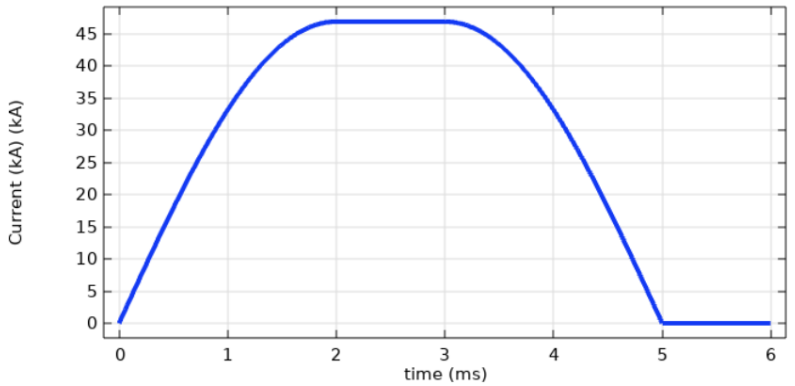


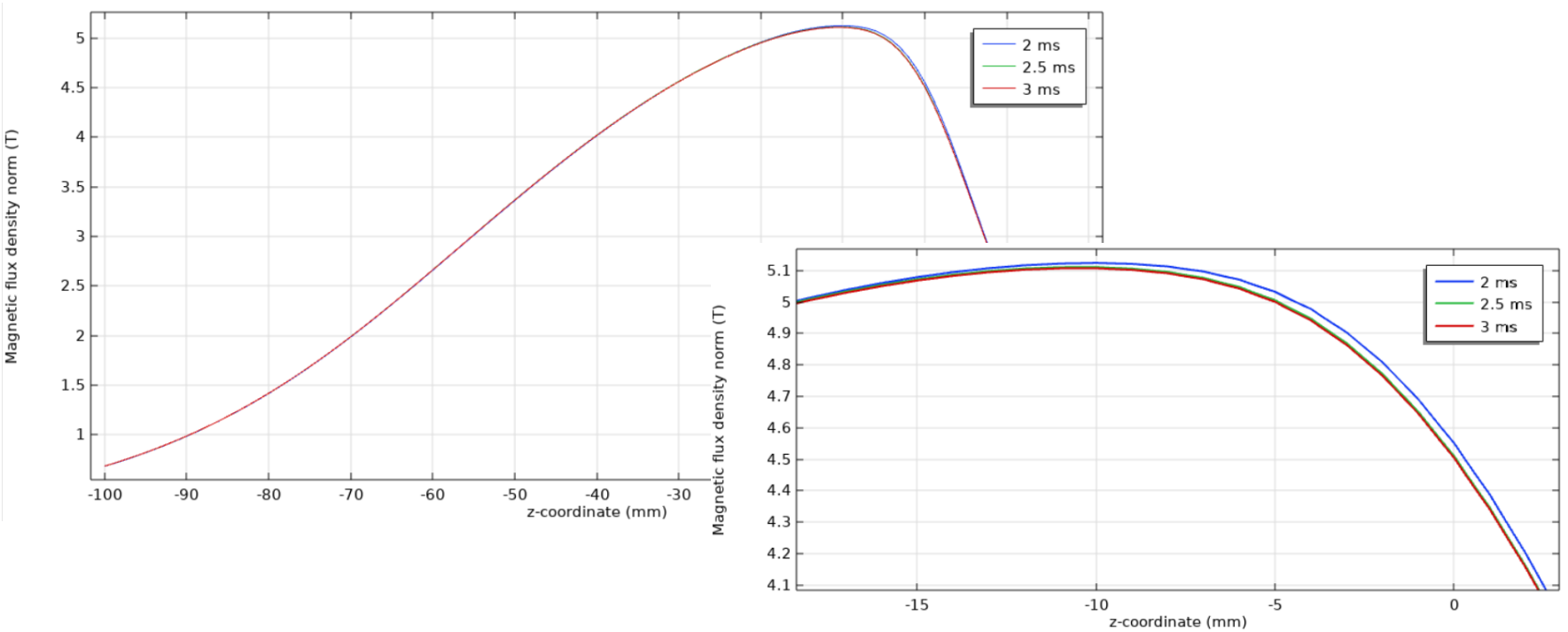


Magnetic field stability

Variation of magnetic field during flat-top current

- Transient current distribution subject to skin-effect
- Skin depth @125 Hz ~6 mm → current distribution should be stable
- < 1% deviation of field simulated

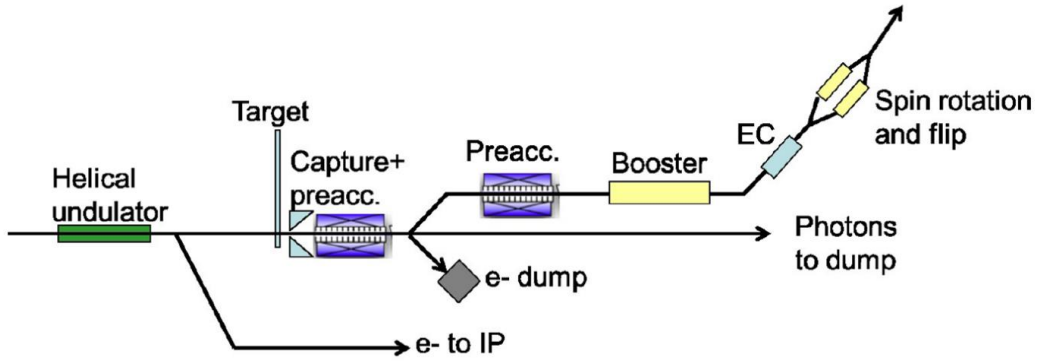




Yield simulations

Brief overview of simulations target → damping ring

- Yield of undulator-based positron source w/ solenoid matching device simulated
- Significant yield improvement to QWT
- Possible trade-off: target heatload ↔ yield
- Further optimisation maybe possible

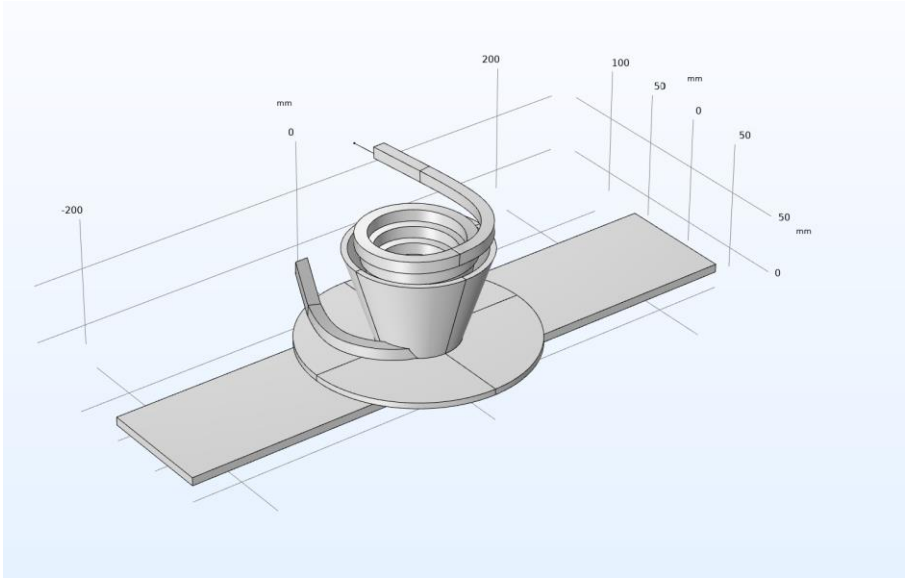


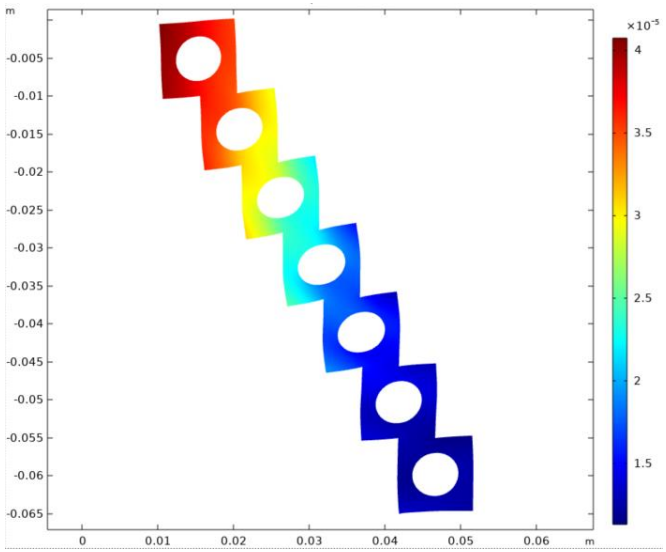
	Beamloss Power				Positron Yield	
	@dogleg	@booster	@EC	@DR	@capture (|Z|<7mm)	@DR
QWT	0.677 kW	0.014 kW	4.01 kW - 5.56 kW	13.15 kW - 14.3 kW	1.07	**~1.1**
Pulse solenoid w/o shield	0.927 kW	0.055 kW	5.86 kW - 7.93 kW	17.39 kW - 16.01 kW	1.81	**1.91**
Pulse solenoid with shield	0.871 kW	0.064 kW	5.58 kW - 7.90 kW	17.73 kW - 16.24 kW	1.64	**1.74**

Coil stress

Dynamic deformation w/o support & heat load

- Average power in coil ~10 kW
- Peak mag. flux 4.6 T
- von-Mises stress ~570 MPa
  - Soft Cu tensile strength ~200MPa
  - → very sensitive to exact shape
  - → very localized
  - Has to be iterated w/ mechanical design (solenoid + support structure + connectors)
  - Global optimisation pending (current amplitude & waveform, coil shape, etc.)
- If stresses too high: multiple layers + reduced peak current

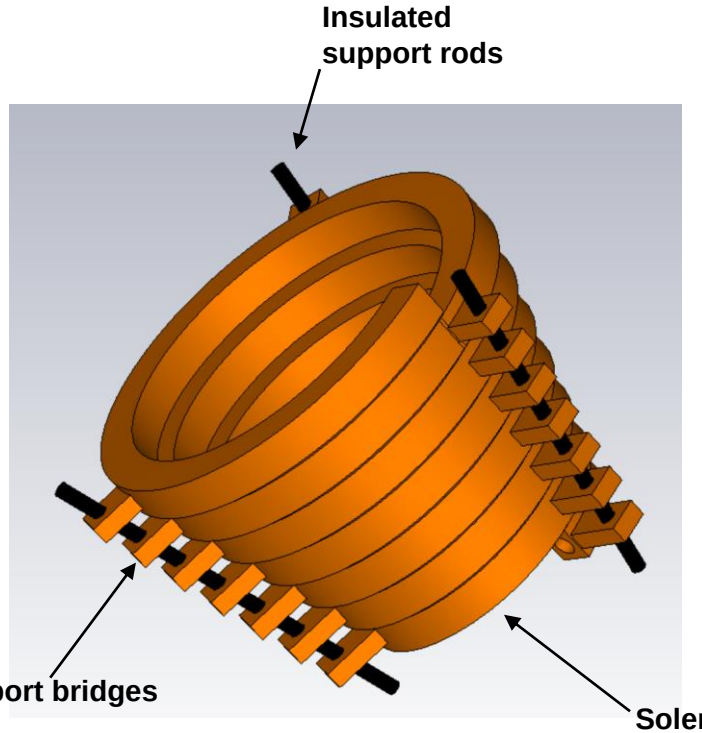


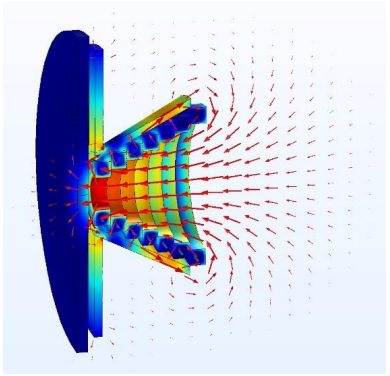


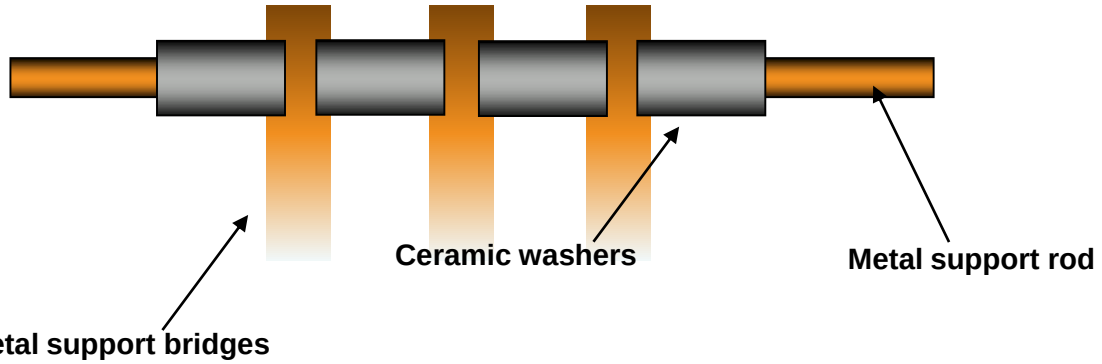
Solenoid construction

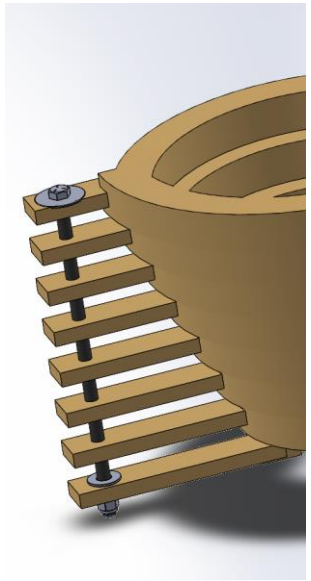
Possible mechanical design

- Solenoid coil
  - Tapered winding
  - 7 planar windings with interconnections
  - Conductor cooled from inside
- Metal supports to hold coil
- Support rods insulated from support bridges
  - Washers e.g. of SiN ceramics
- Magnetic shielding cut at support locations
  - Influence on field to be determined
  - Main shielding to target unaffected









Summary & Outlook

Recent progress and next steps

- Solenoid provides superior yield compared to QWT
- Heat load on coil & target wheel no show stoppers
- Mechanical stress significant, exact mech. design required
- Simulations now moving to answering mech. design questions
- Collaboration being set up formally to build prototype
- Global optimisation of solenoid parameters could further reduce stresses & heat load

Thank you for your attention!

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