Lawrence Livermore National Laboratory

Flux Concentrator and Vacuum Seal Test Update

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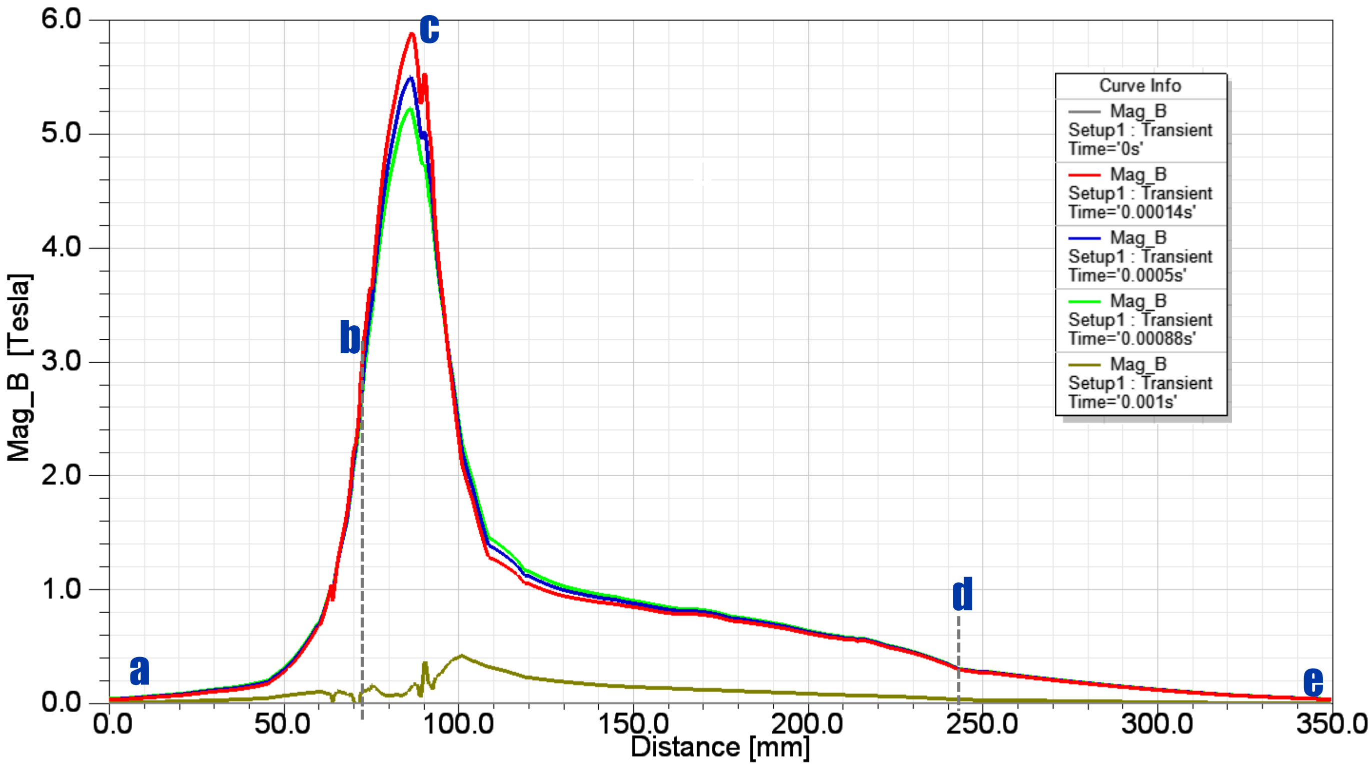
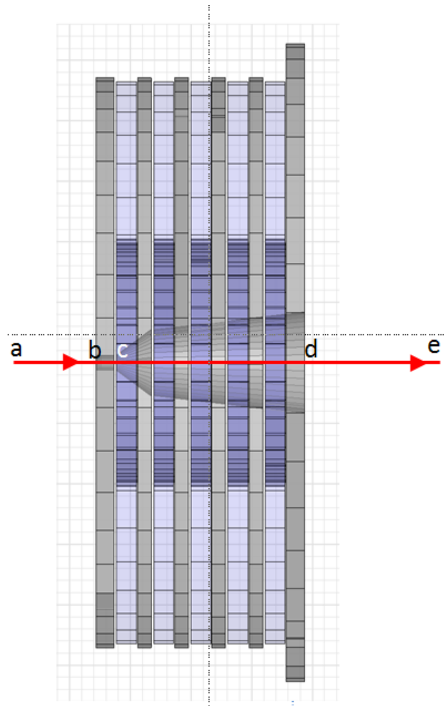
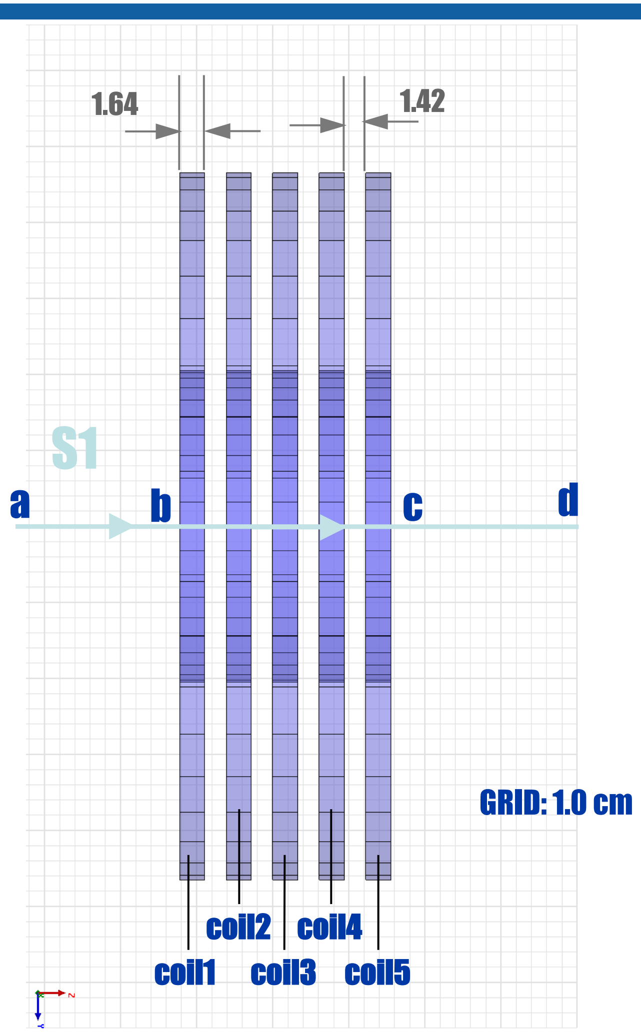
LLNL-PRES-459656

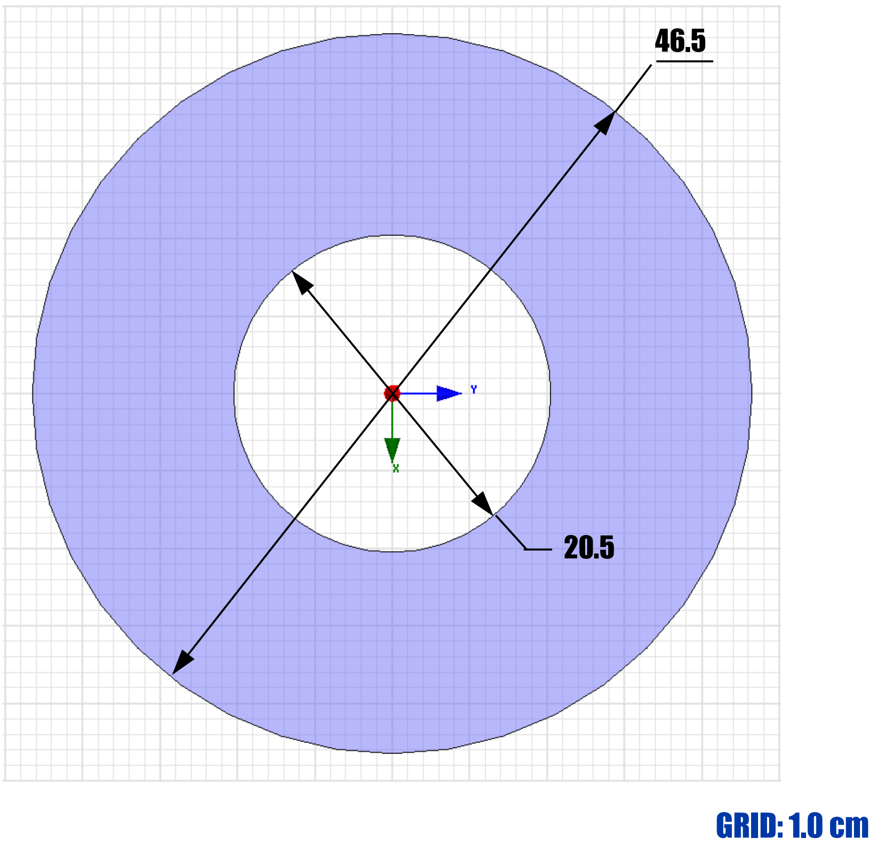
Desired flux concentrator pulse shape



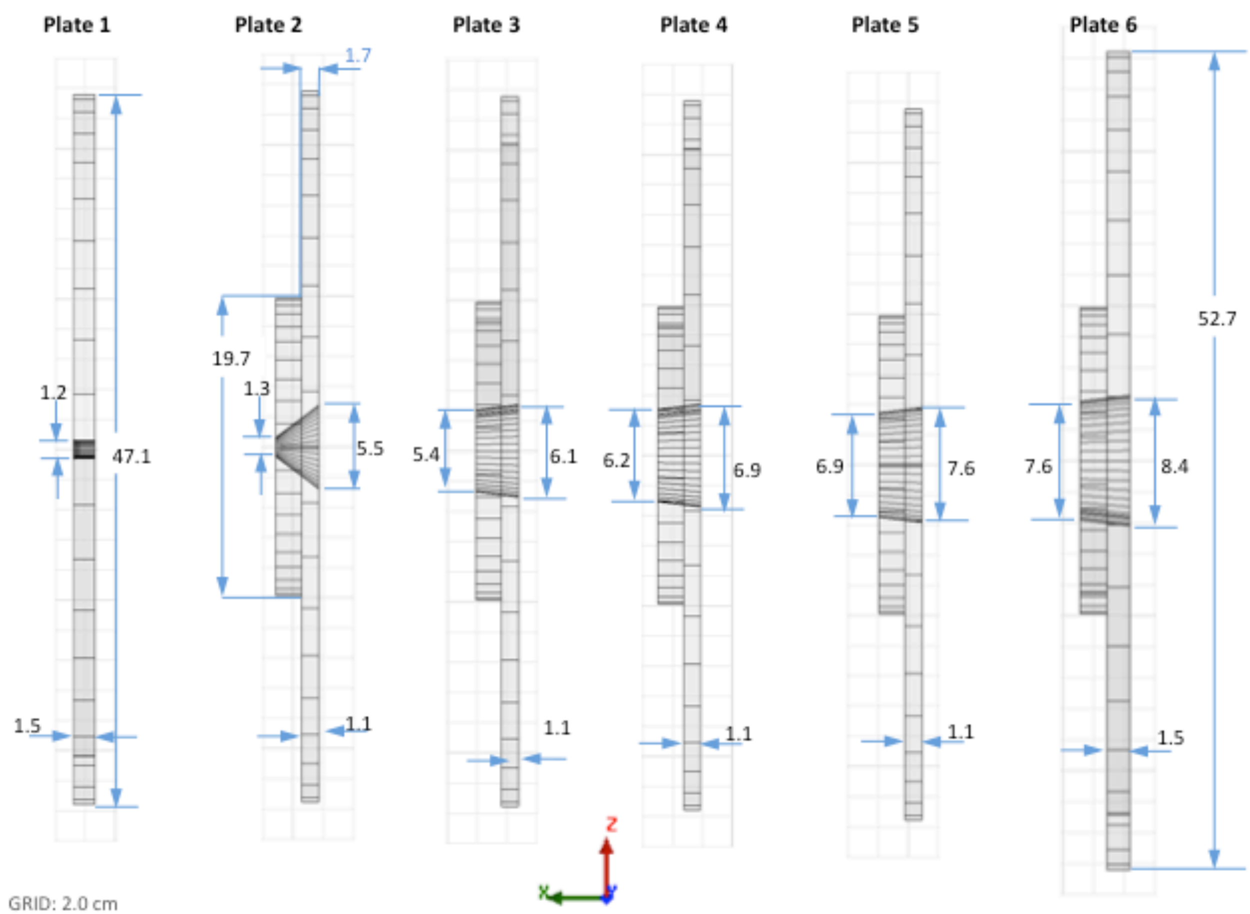


Energizing device with 5 coils



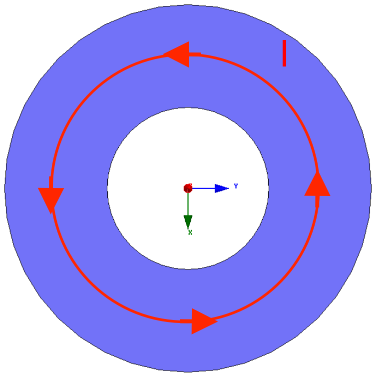


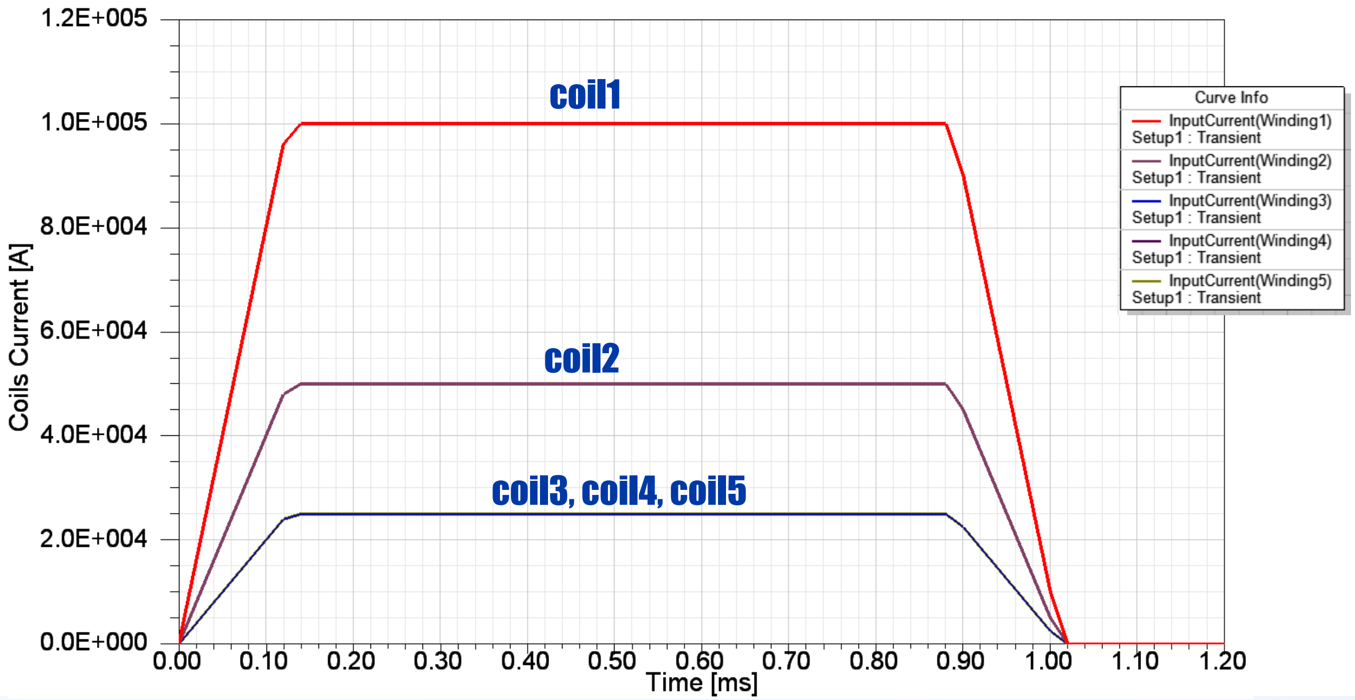
Flux concentrating disks enhance the field



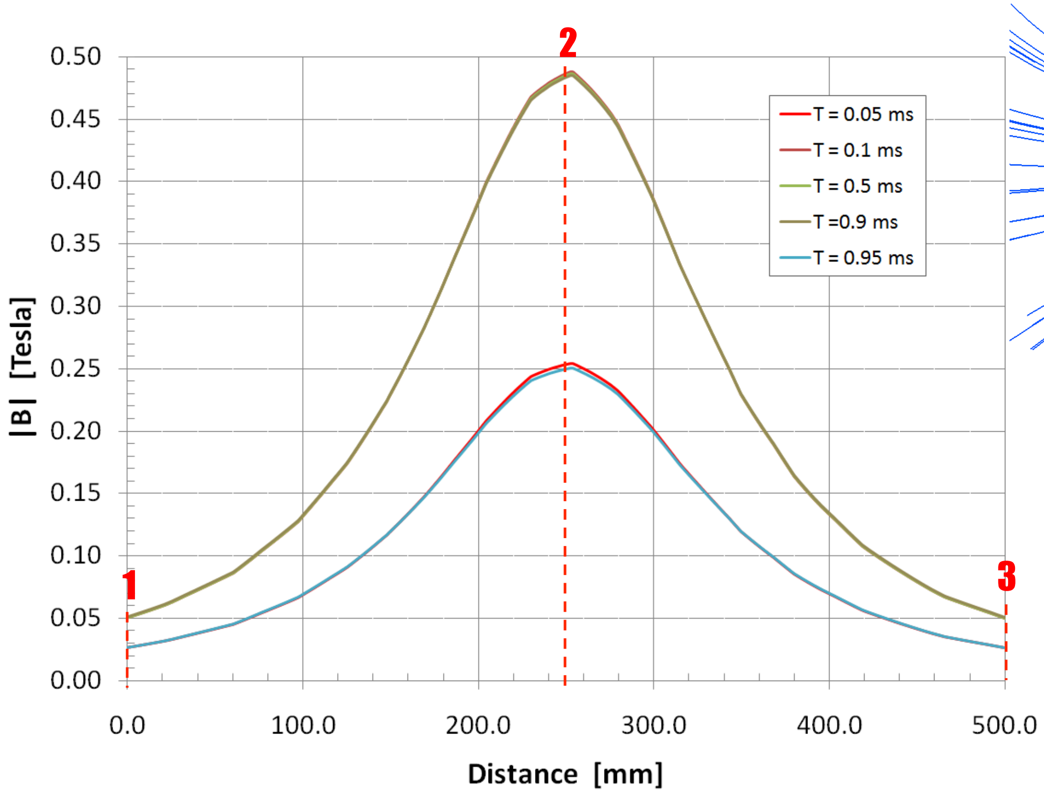
Coil currents vary with field location

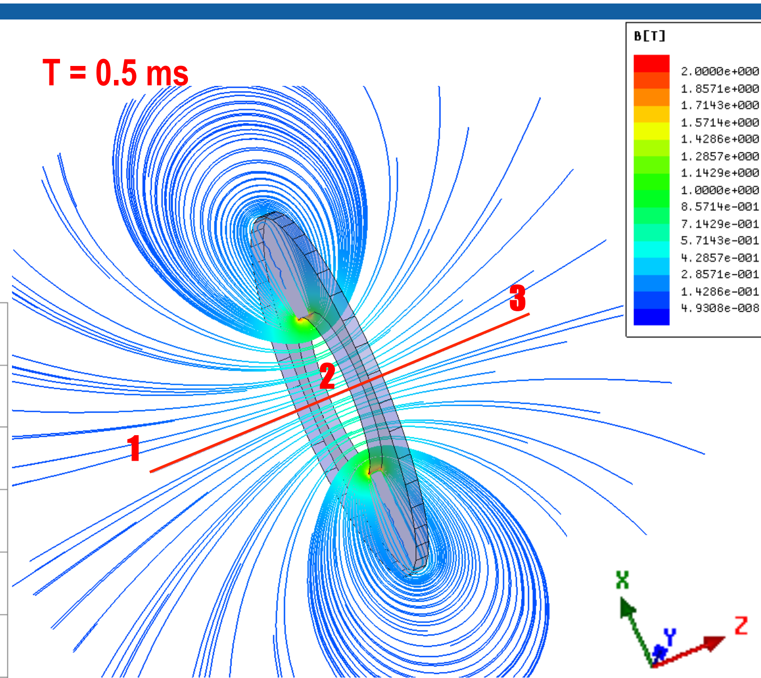
Coil material: OFHC Copper σ = 3.5714E+08 s/m



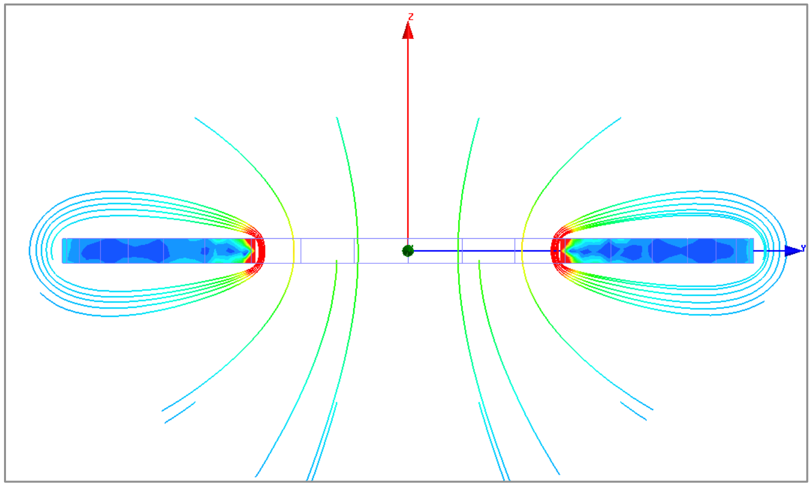


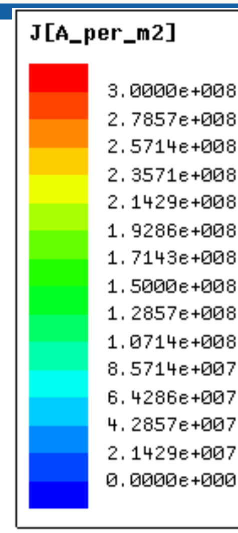
Initial analysis using simplified coil

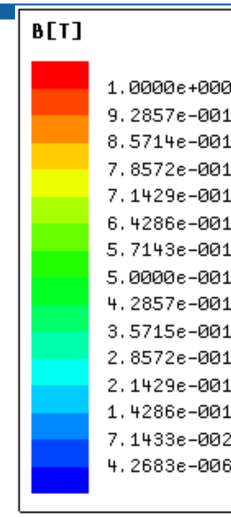


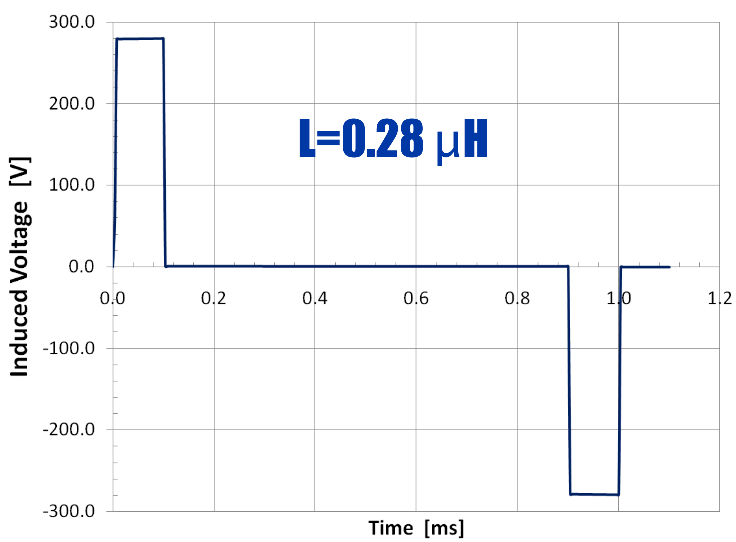


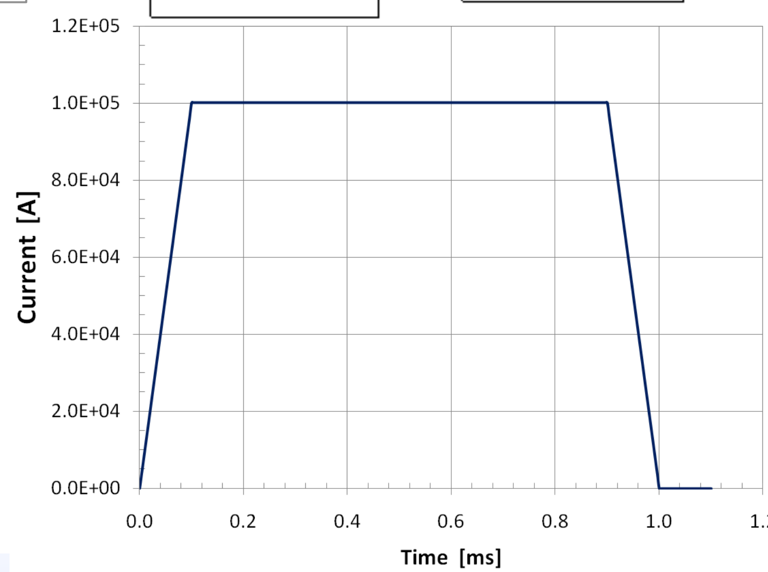
Compute inductance and induced field







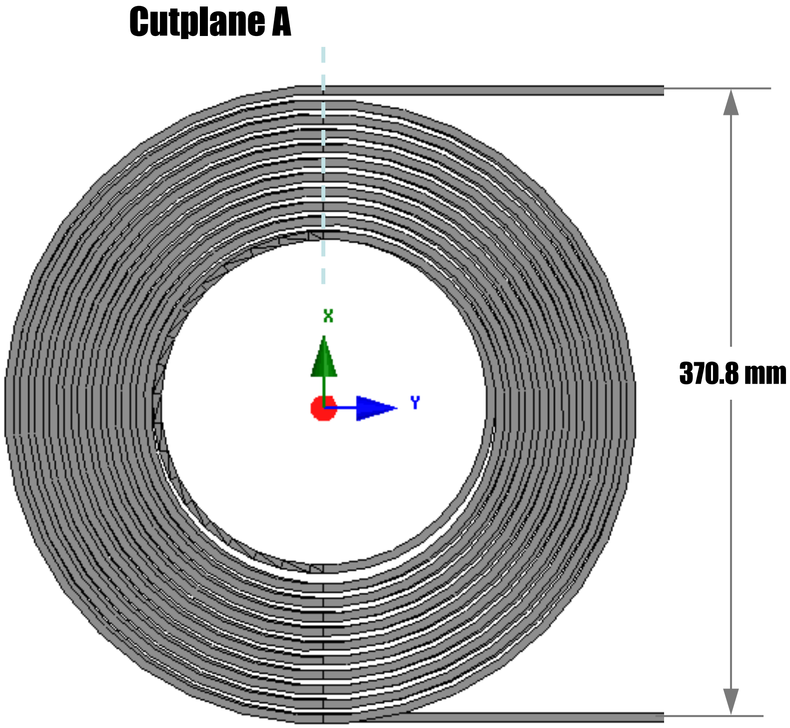


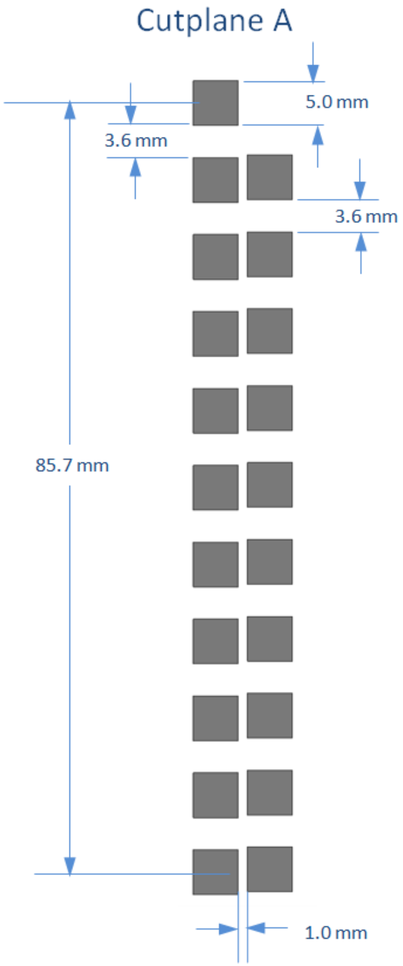


Coil design choices and tradeoffs

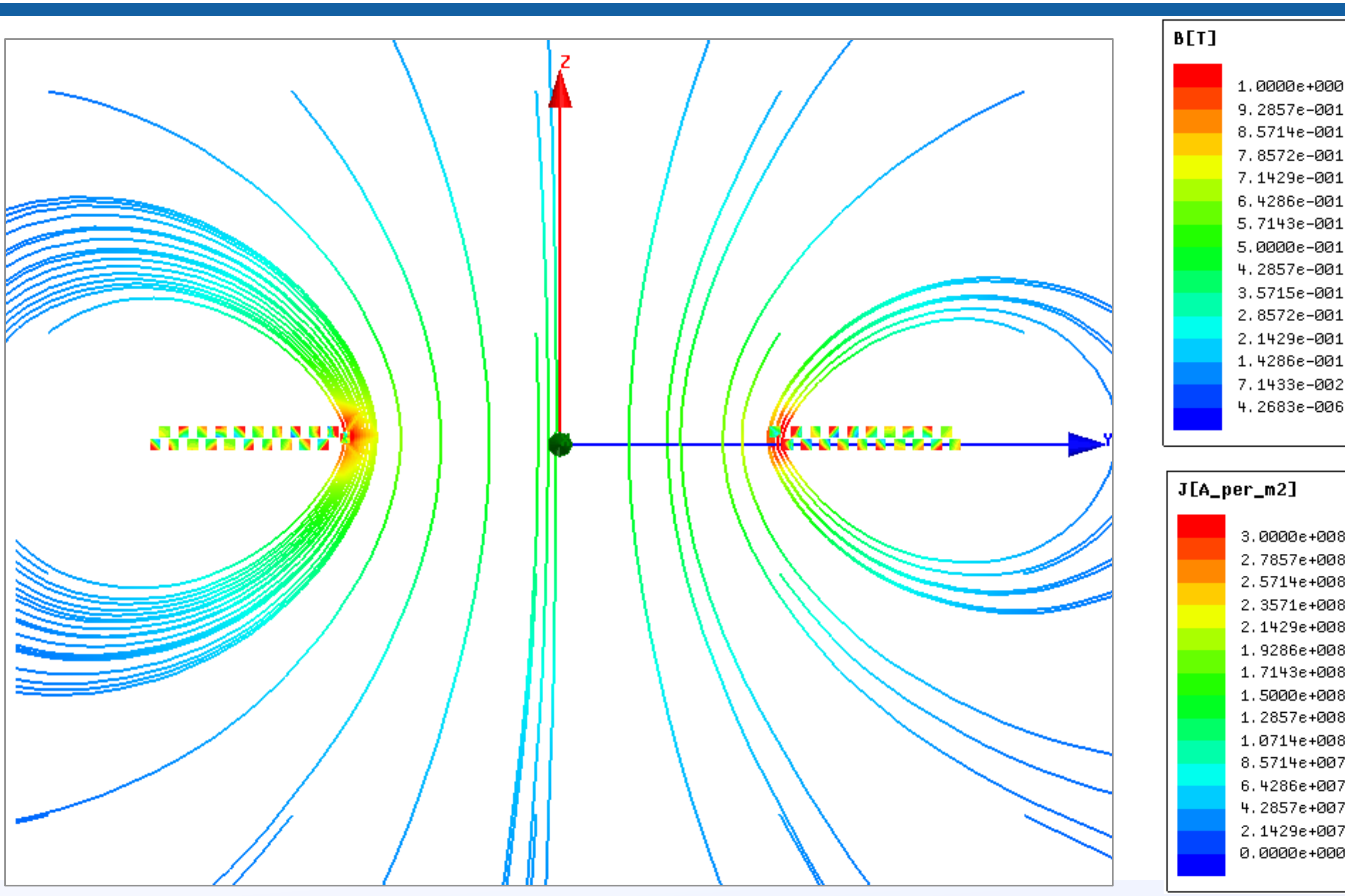
- Number of turns per coil
- Parallel or series connections between coil
  - I_act=I_desired/N_turns
  - More turns, more voltage drop, more insulation
  - $V=L(dI/dt)$
    - L scales with N^2
    - dI/dt scales with 1/N
    - V scales with N
- Design of pulse-forming network depends on inductances and resistances of coils and connectors

Analyzing real coil geometry



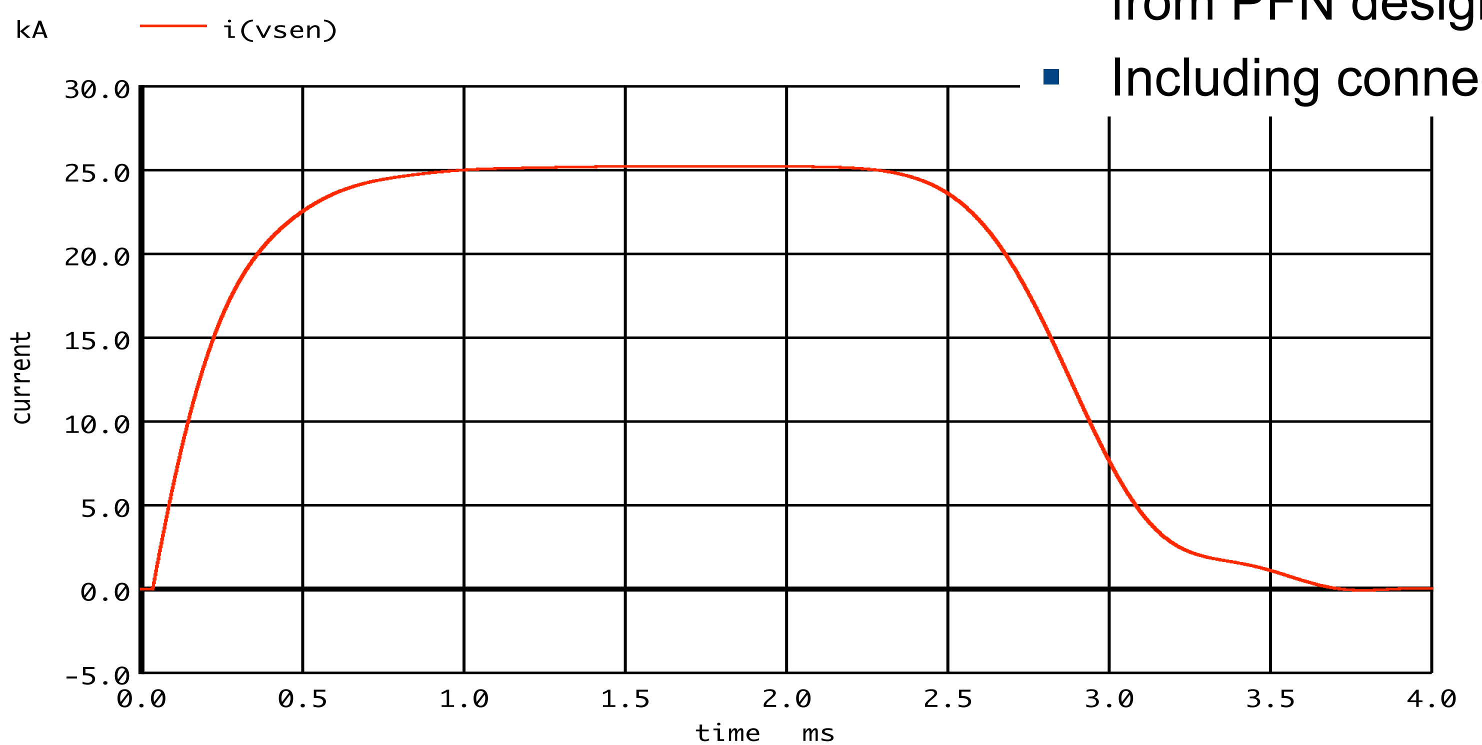


Current and field in multiple turn coil



Initial PFN design

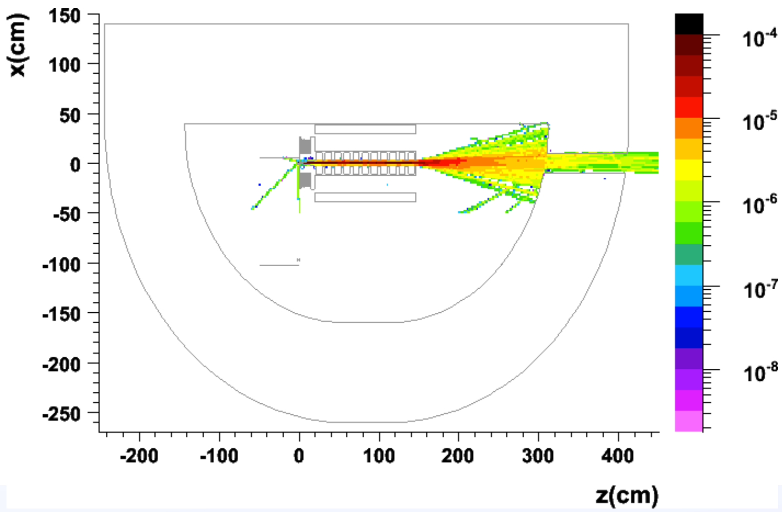
- Coils connected in series
- 25 kA current
- 4 turns in coil 1, 2 in coil 2, 1 in coils 3-5

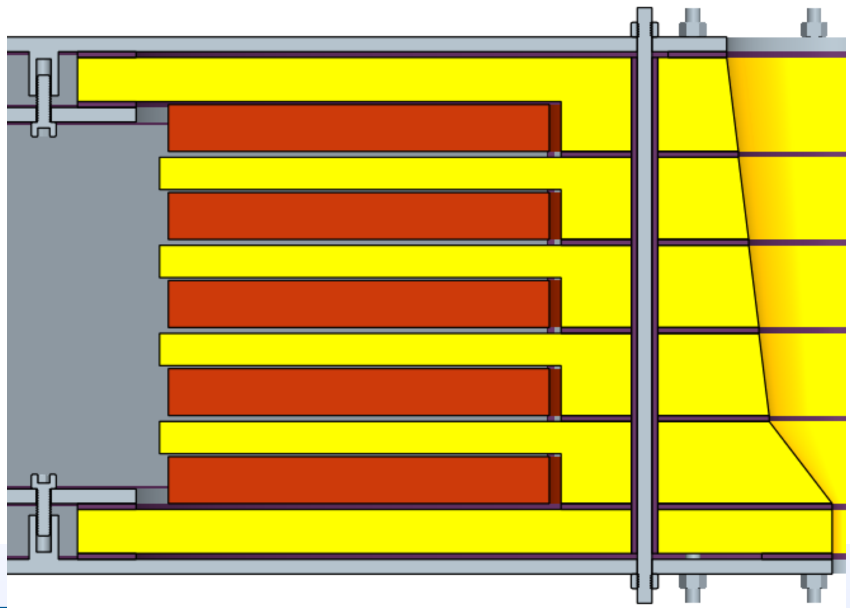


- Designing PFN to power device
- Using SPICE to evaluate current output and rise time from PFN design
- Including connector effects

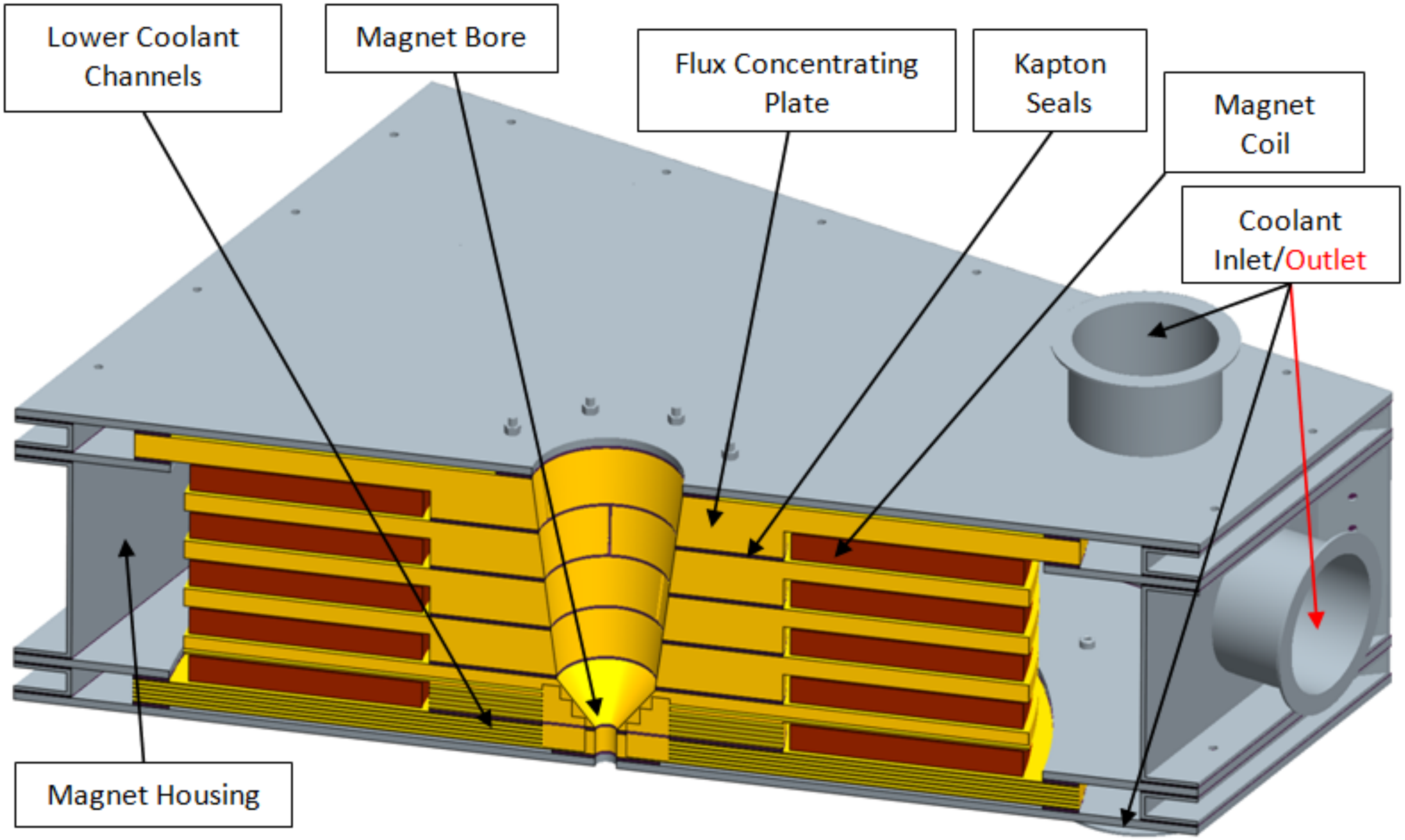
Insulator evaluation

- Kapton recommendation of magnet manufacturer (Wang NMR)
- Collaborating with DESY to evaluate radiation suitability of insulator material
- Kapton manufacturer radiation damage threshold is 100 MGy

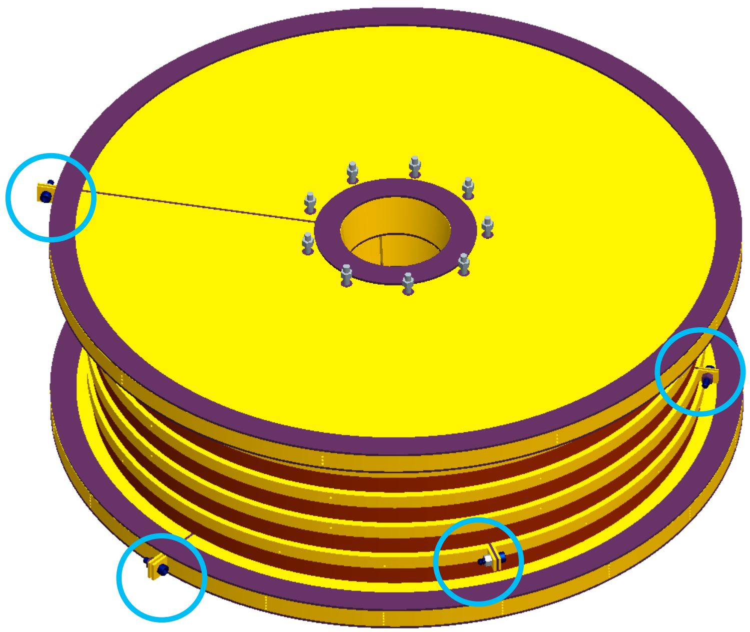
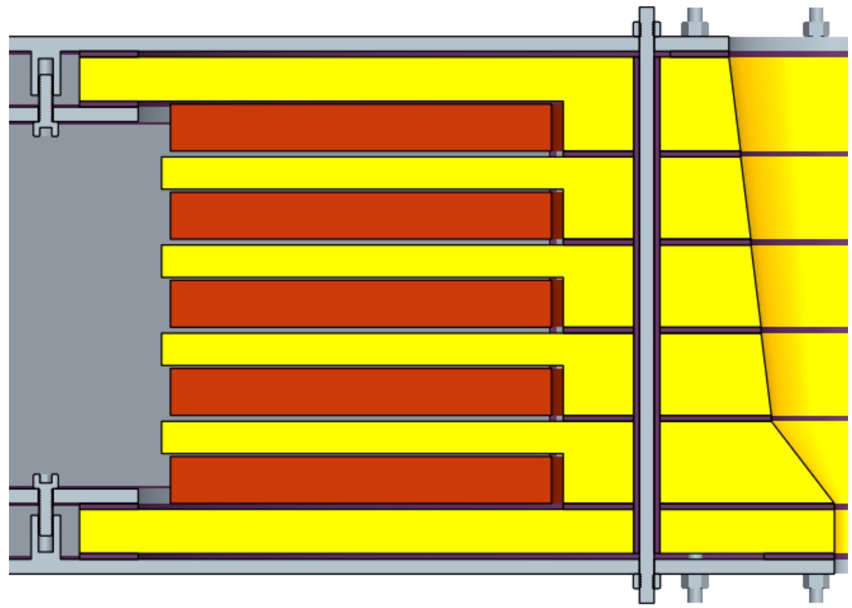




Flux concentrator layout



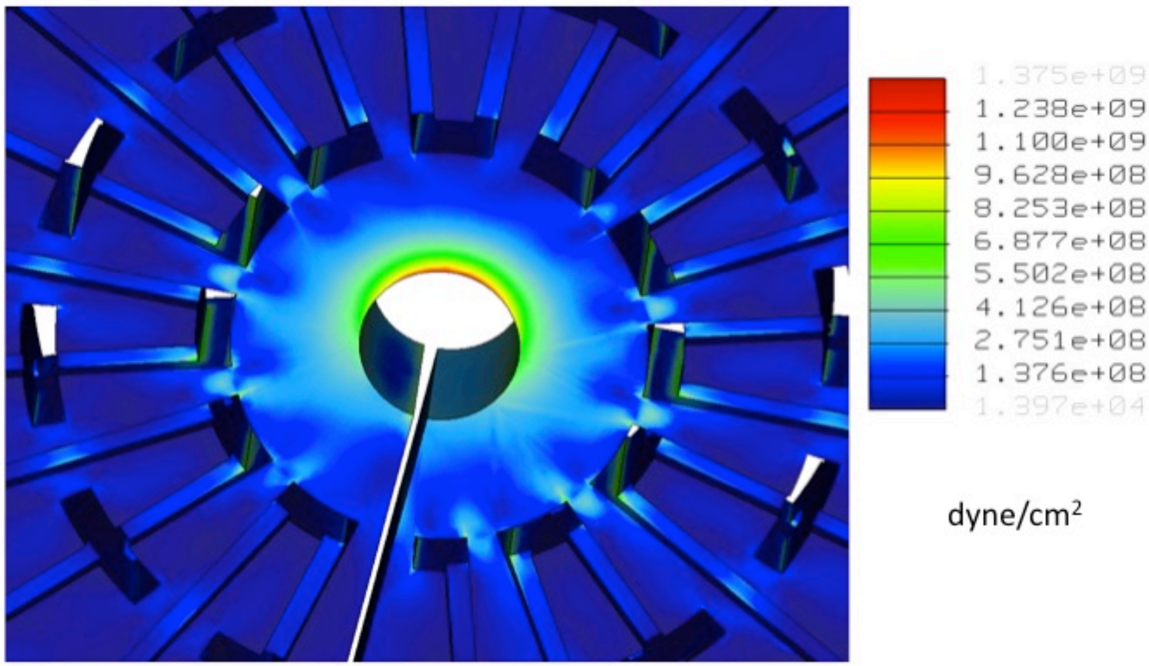
Current support bolt layout

Non-conductive support bolts

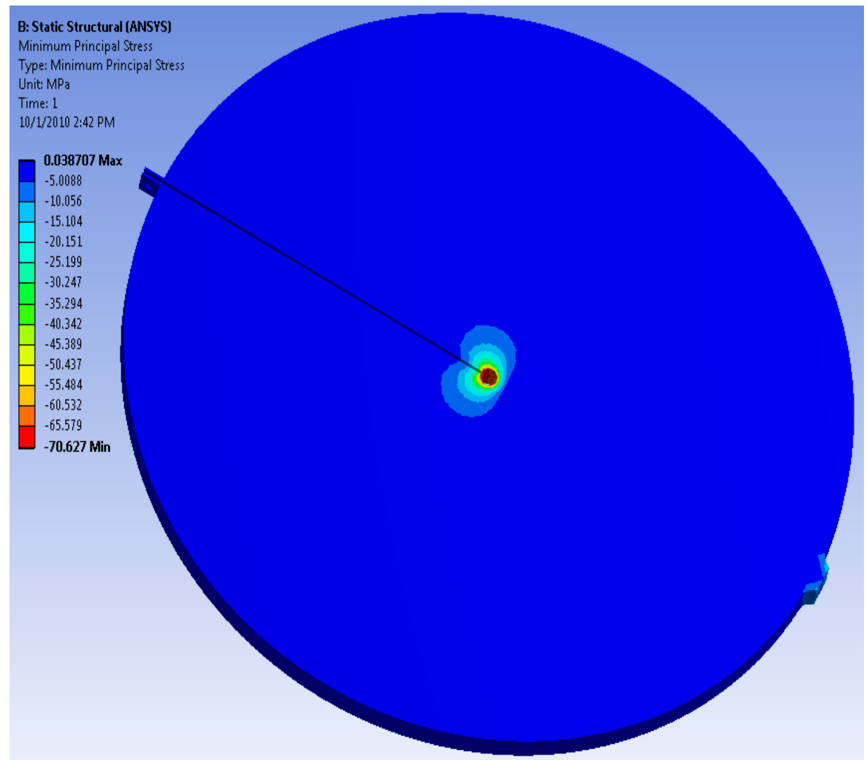
Stress calculation in disks

- Stress input as a pressure on the bore interior



Structural Behavior

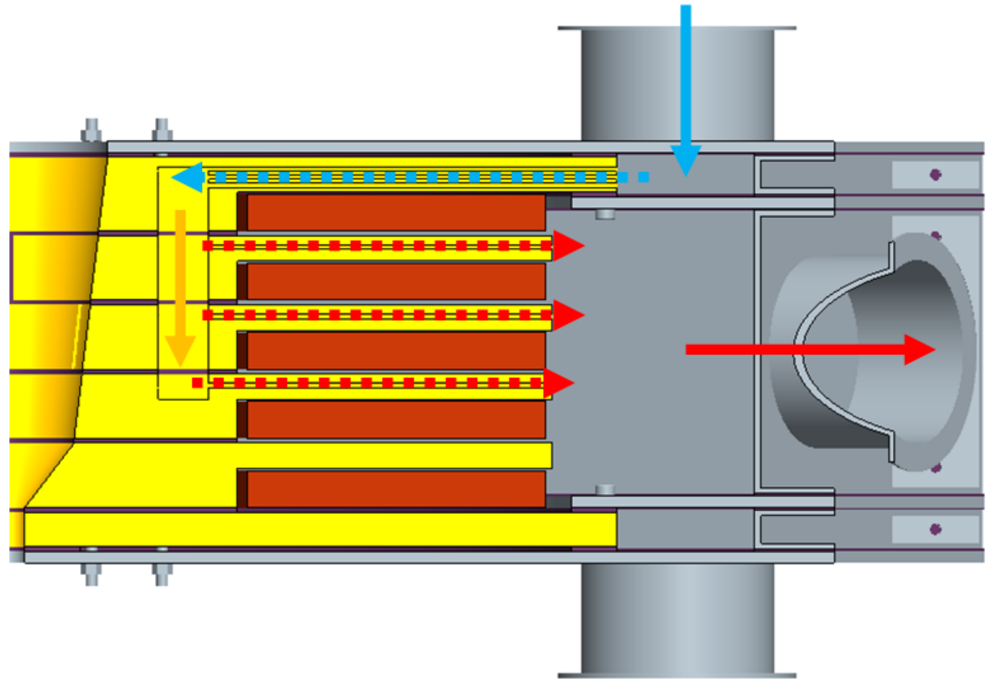
- Evaluating stress relief for fatigue life
- Bolt sizes and arrangement
- Additional strain relief from confinement/ case possible solution

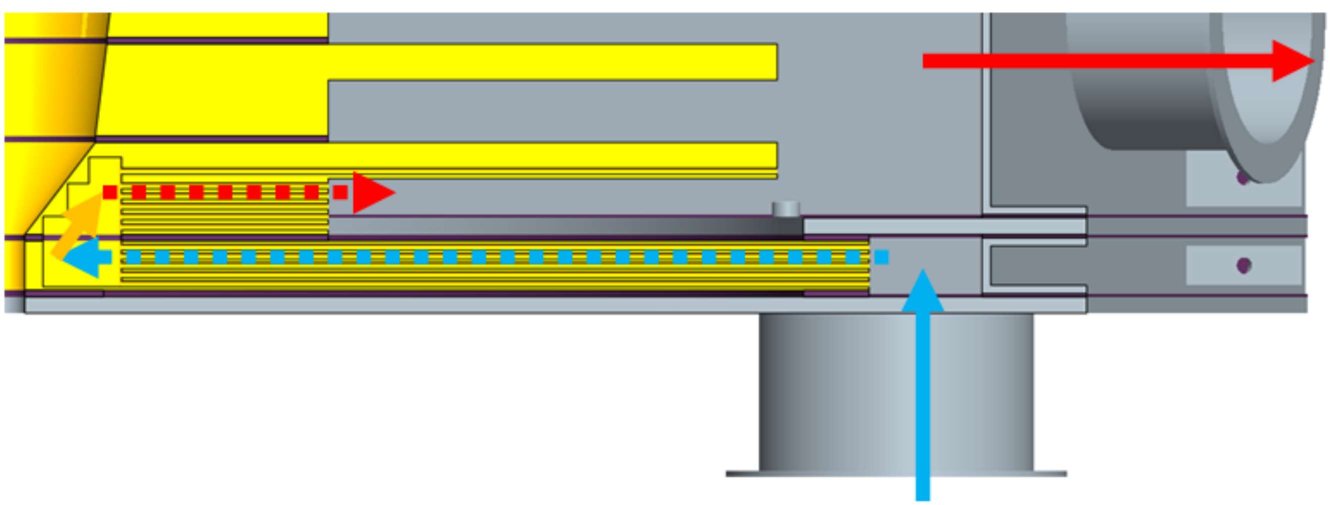


Tensile Stress

Cooling flow pattern

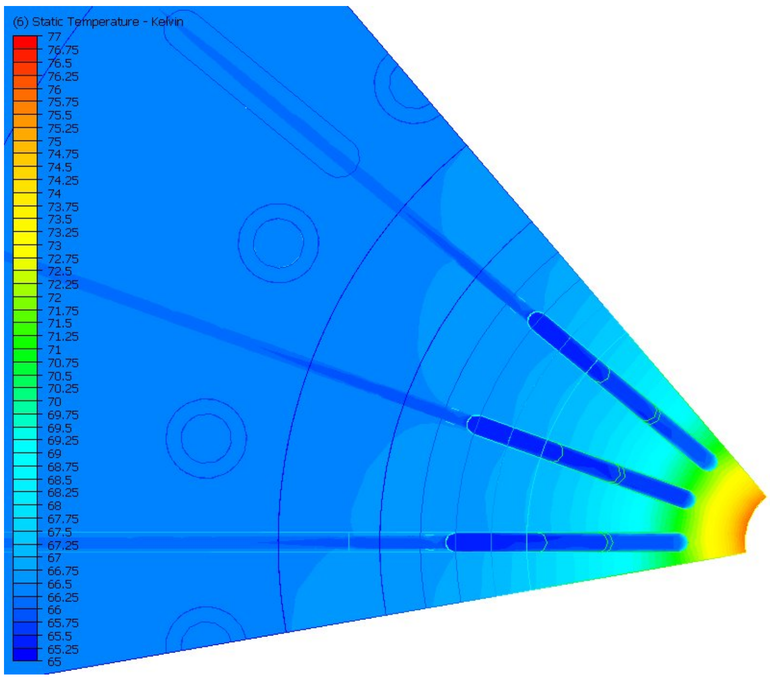
Upper Four Disks

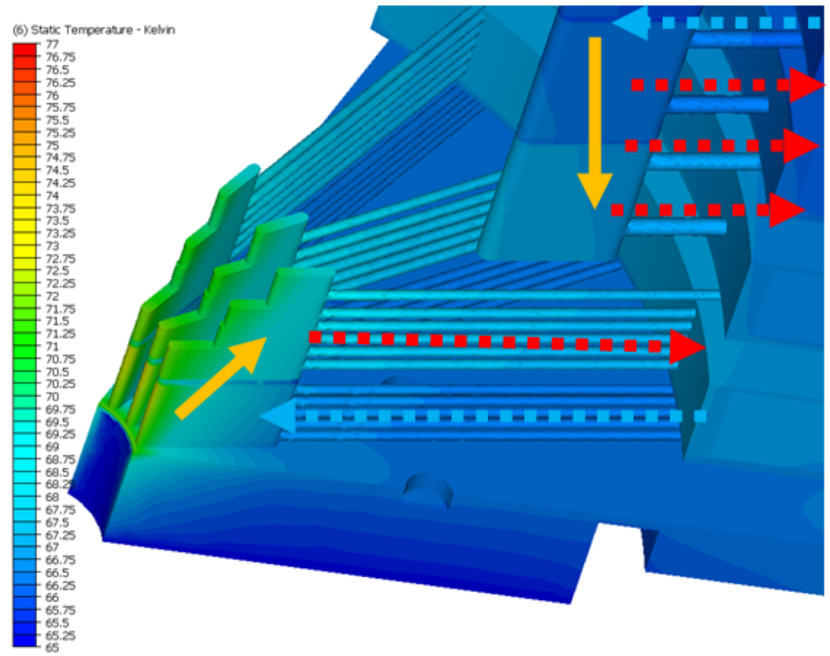




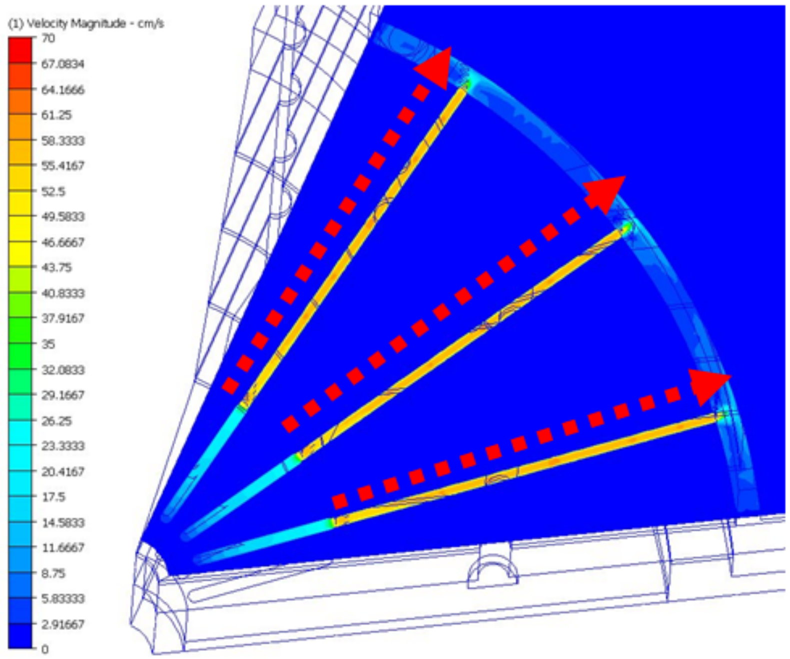
Lower Two Disks

Temperatures

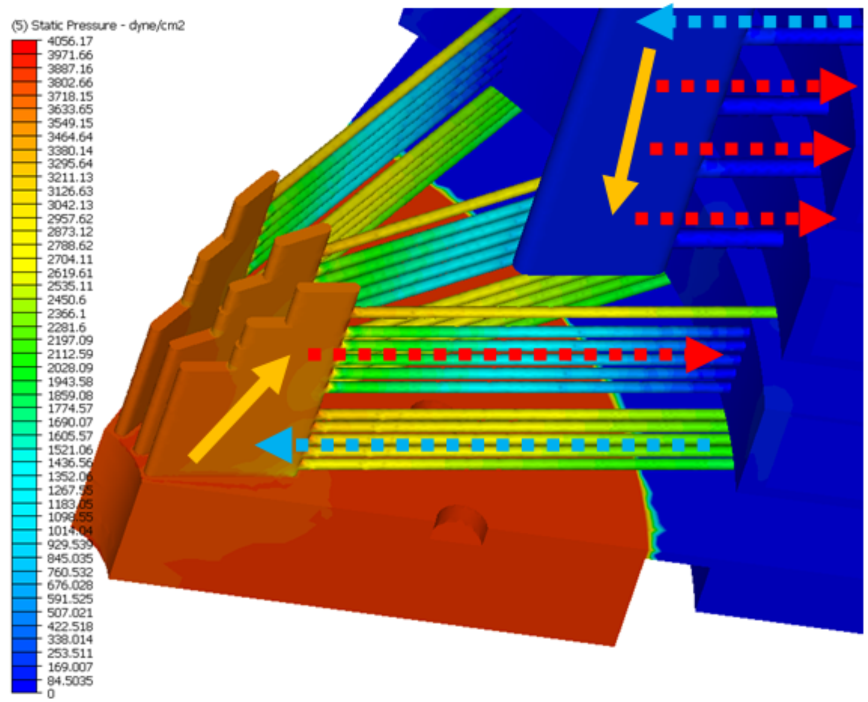




Fluid velocity and pressure



Flow Velocity



Pressure

Continuing flux concentrator analysis

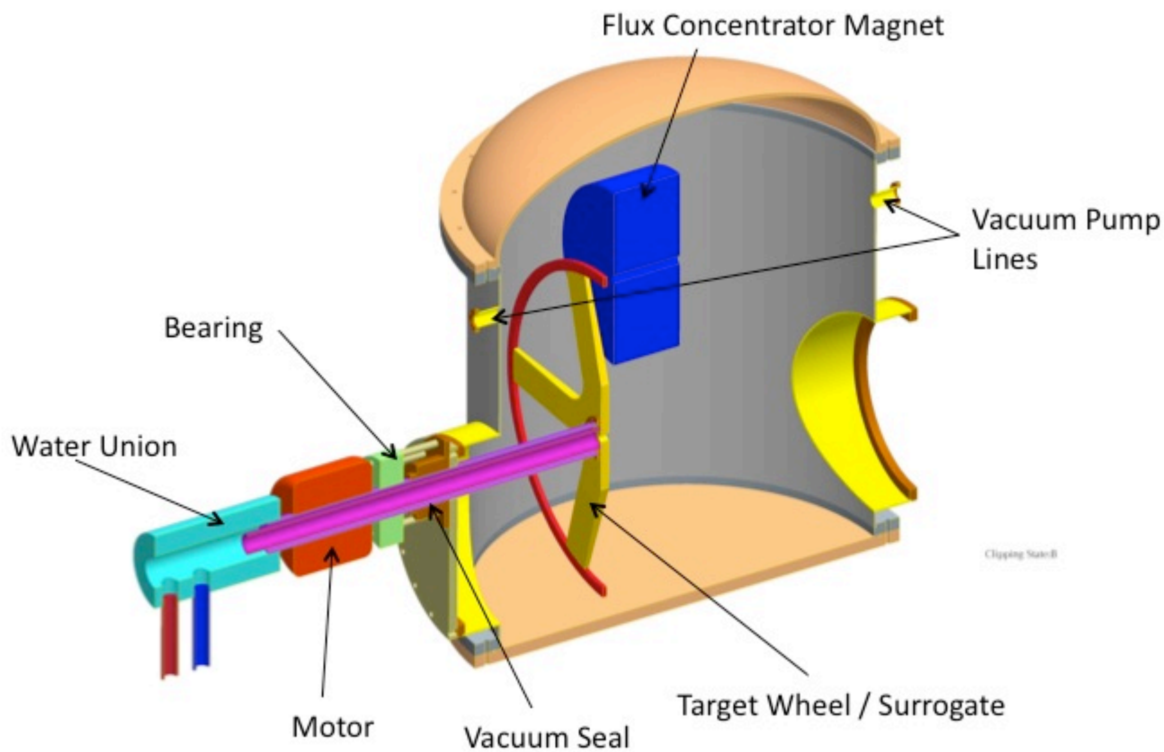
- Final design phase tasks
  - Structural support changes
  - Evaluation of coil voltages, tradeoffs relating this with connector and power supply hardware
  - Connector evaluation and selection
  - Insulator radiation survival analysis
- Preparation for prototyping
  - Developing detailed assembly drawings
  - Test plan, particularly evaluating possibilities for testing without full cooling plant
  - Obtain LLNL ES & H approved safety plan

Flux concentrator test plan

- Initial tests at low pulse rate, room temperature (uncooled)
  - Characterize magnetic field
  - Validate predictions of decay time constant for field
- Tests at low pulse rate, cryogenic temperature
  - See pulse flat-top over pulse duration
- Full system test (5 Hz operation, cryogenic temperature)

Rotating vacuum seal test

- Evaluating commercial ferrofluidic seals
  - Leakage (vacuum/fluid)
  - Magnetic field effects
  - Vibration

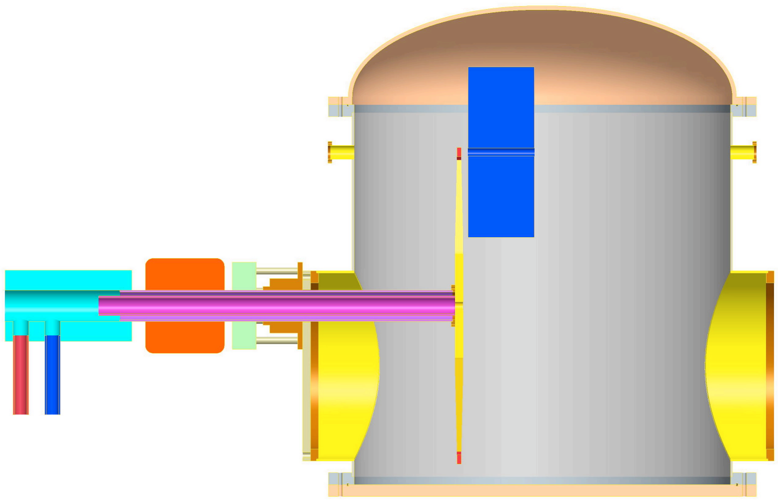


Vacuum seal test

- Using existing tank ($100K) at LLNL
  - large enough to hold Daresbury prototype target wheel and flux concentrator for future tests
  - Initial test with equivalent weight only

Vacuum seal layout

- Altered layout after discussions with Rigaku
- Single-shaft design, larger bore
- Hollow shaft motor Rigaku has used previously
  - Alternative connections (non-belt drive) being considered
- Water union may not be in this test configuration



Vacuum seal test

- Rotordynamics analysis and design for cantilevered layout
  - Changed layout from Daresbury test
  - Requires re-evaluation of vibration modes due to new components and configuration
- Diagnostics setup (pressure sensors, filter and witness plate chemical analysis, mechanical behavior)
- Developing drawings
- Acquire LLNL ES & H approval for operating plan