LLNL Update

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LLNL-PRES-

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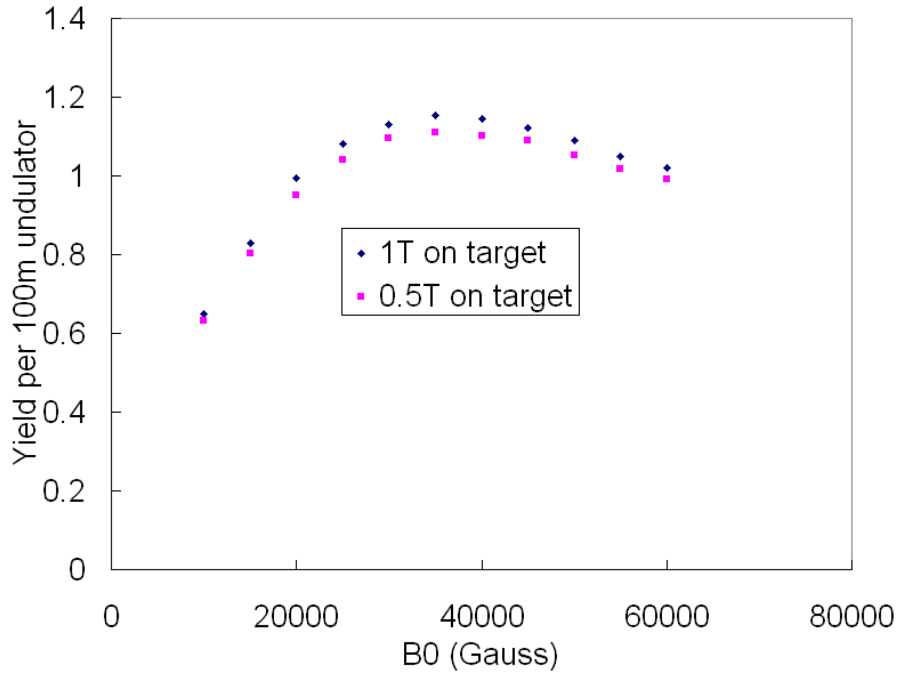
LLNL Work in progress

- EM calculations on Brechna configuration, varying loads in straight bore magnet to achieve a workable design
- Stress calculations based on EM work, narrowing working envelope
- Waiting on funding to continue work on flux concentrator and vacuum seals

Increasing Positron Yield

- Flux concentrator design provides an external magnetic field after the target to increase positron yield

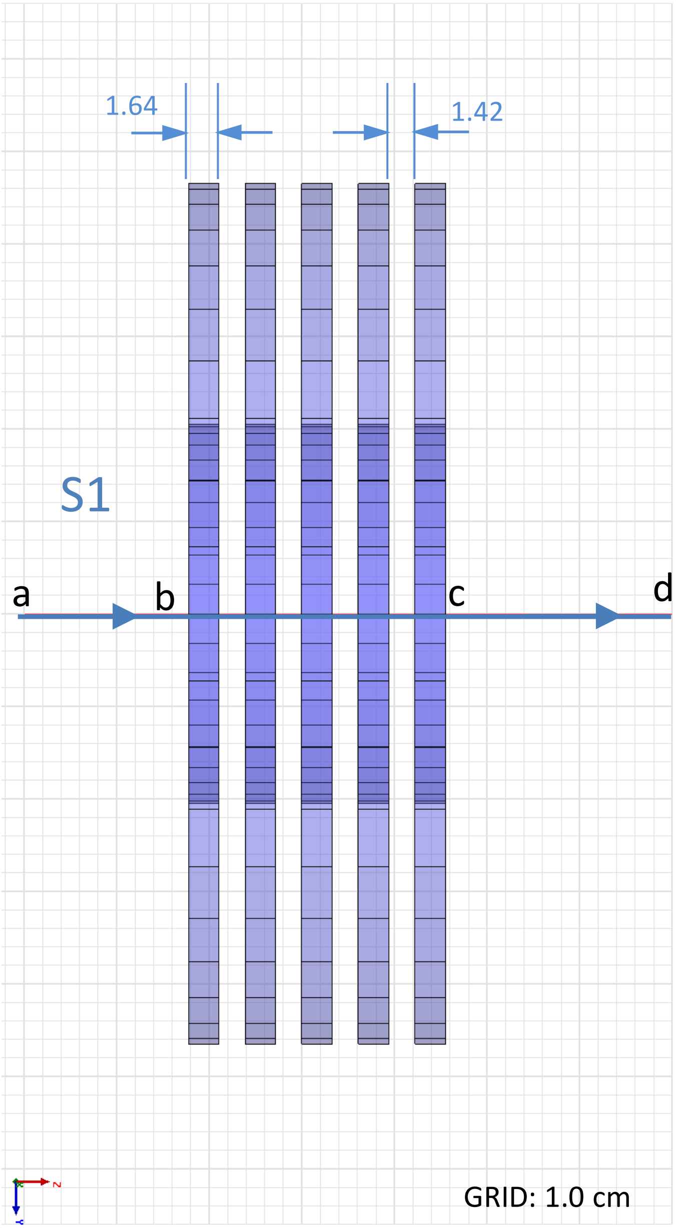


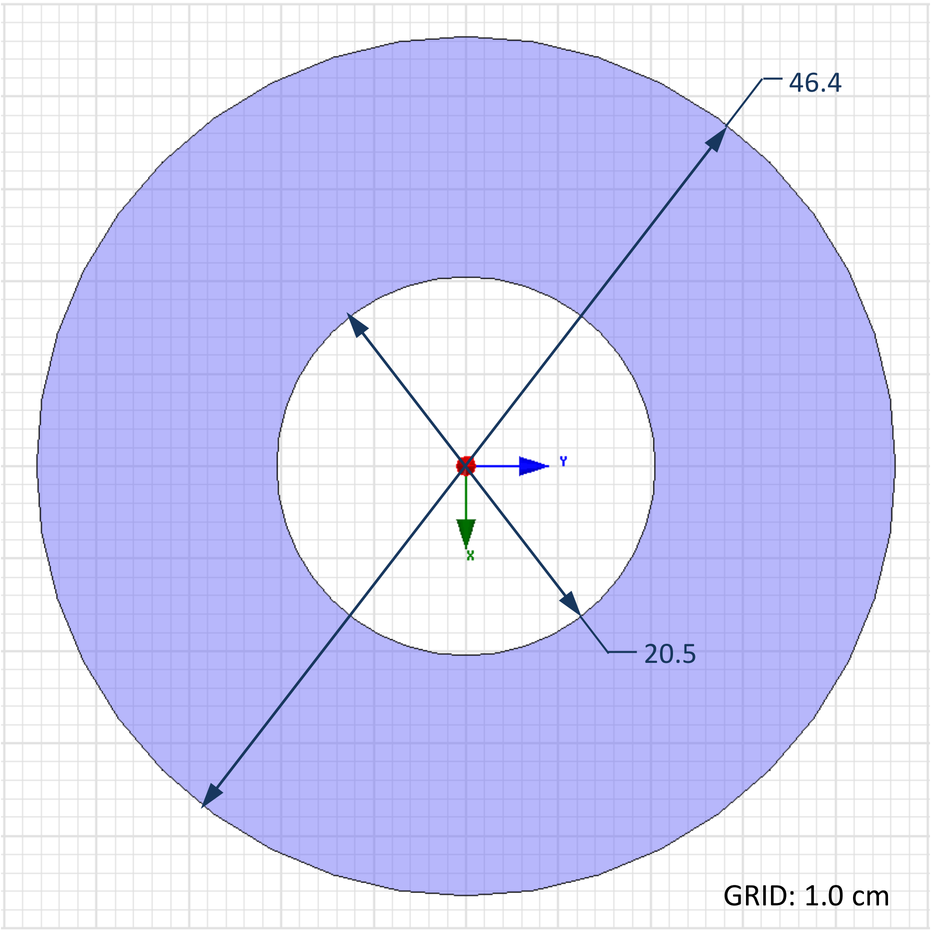
Graphic from W. Liu and W. Gai, Argonne National Laboratory

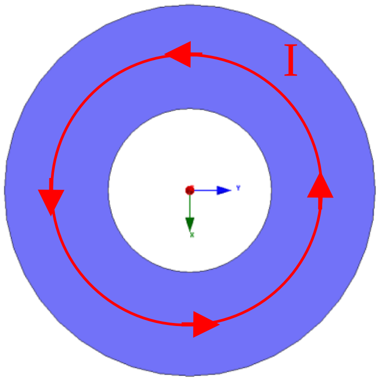
I) Time-transient magnetic analysis of the

Coils-Only Configuration.

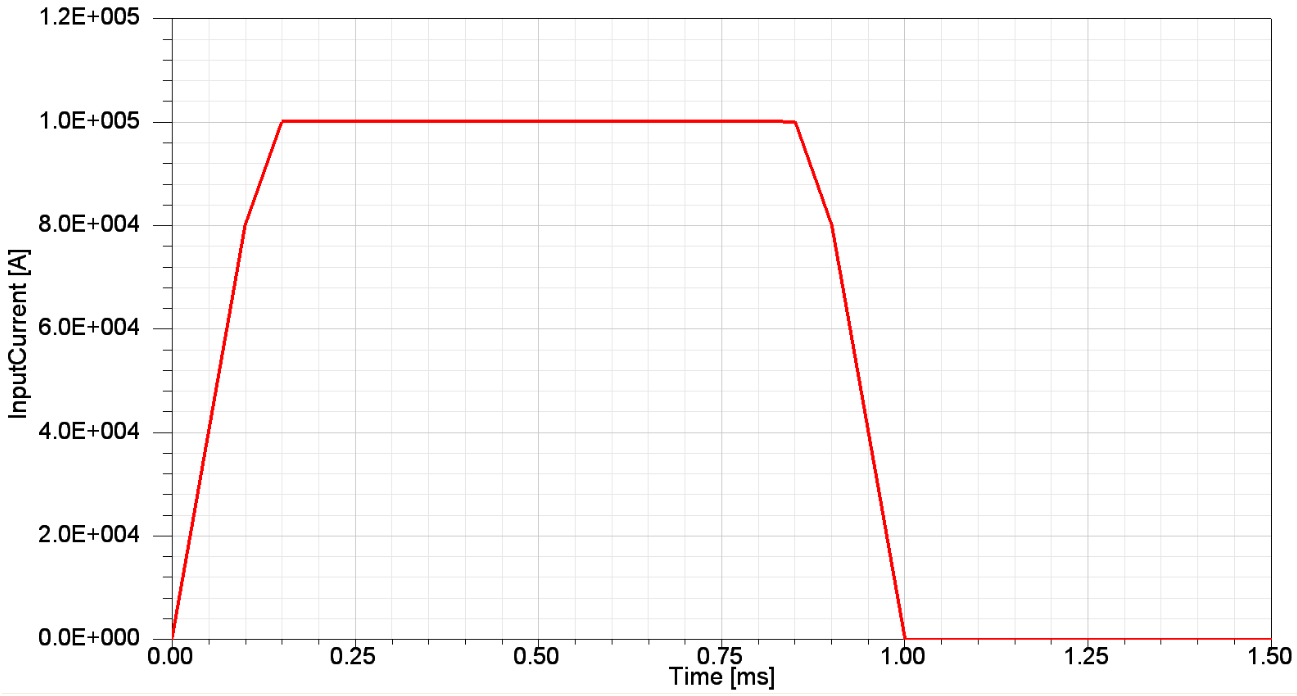
Coils with no magnetic shaping plates



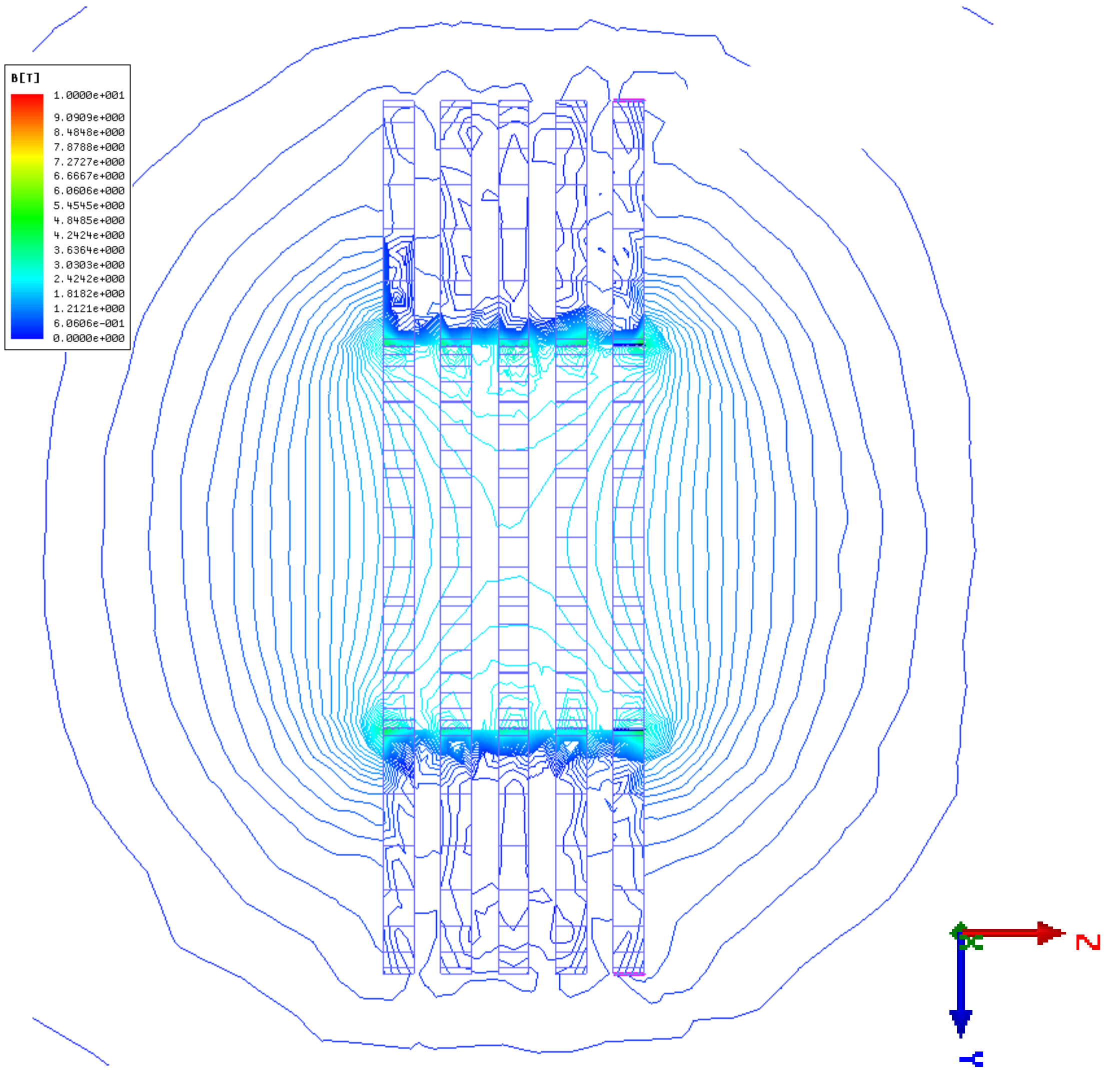




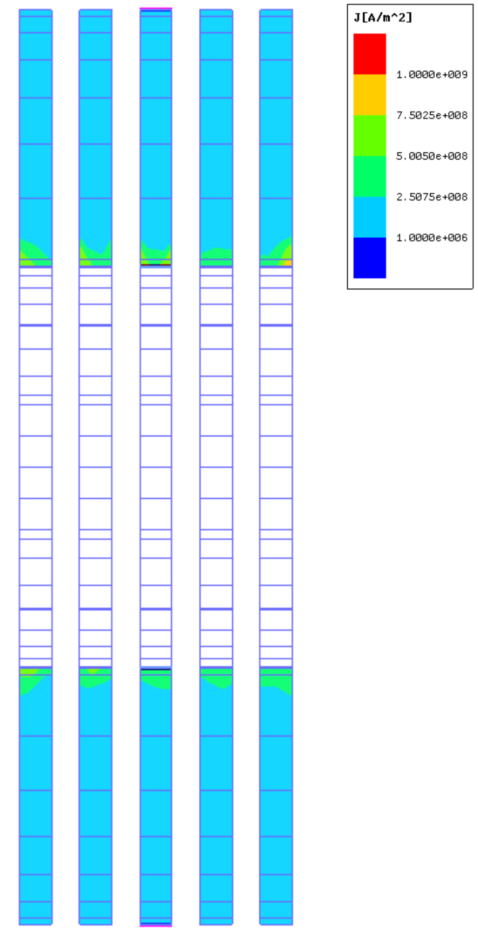
Current injected in each of the 5 coils



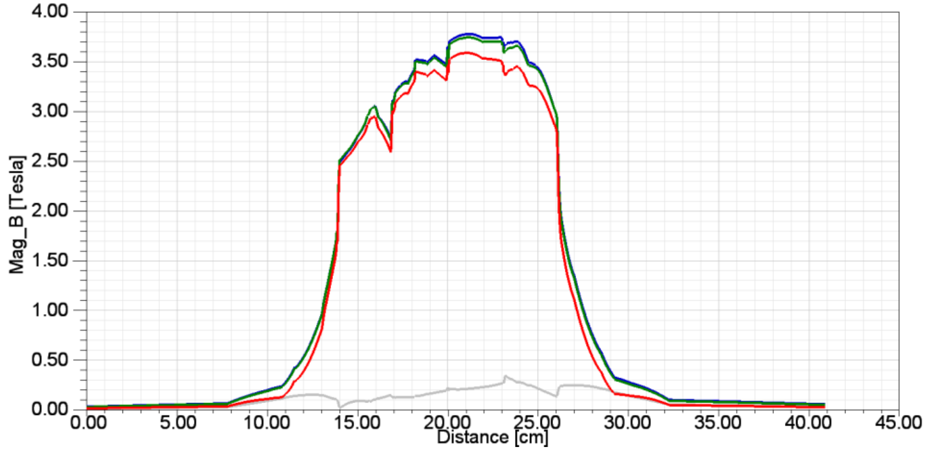
|B| in yz plane at 0.5 ms
(Coils-Only Case)

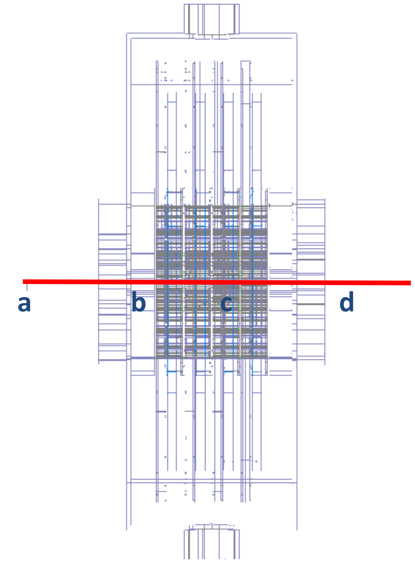


|J| in yz plane at 0.5 ms
(Coils-Only Case)

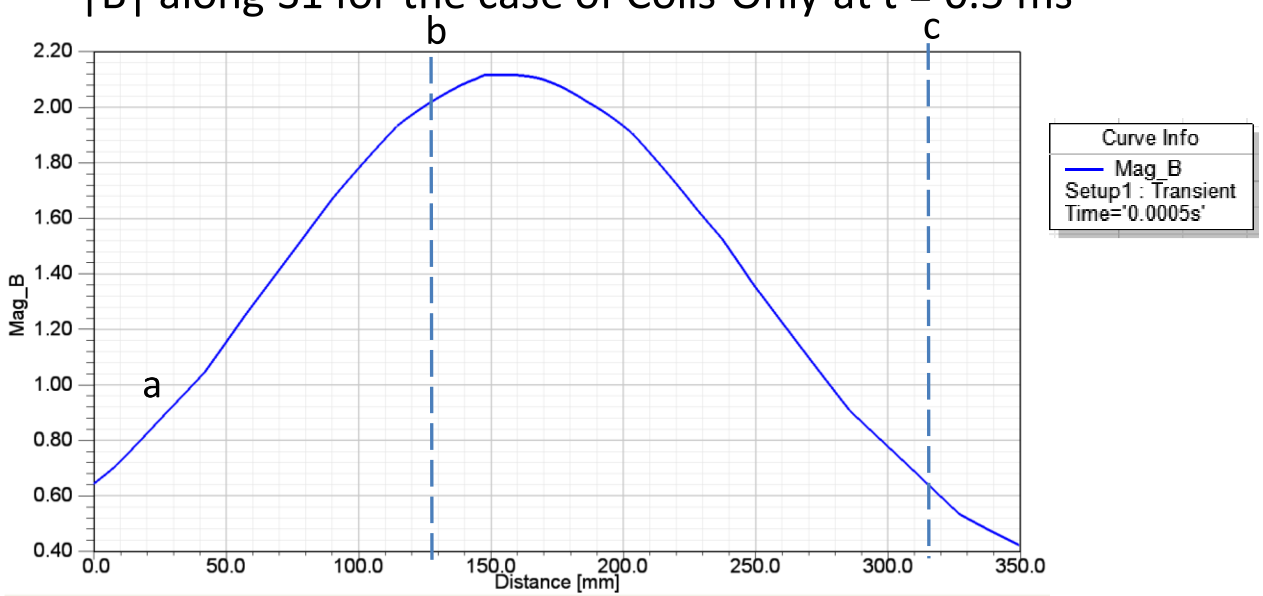


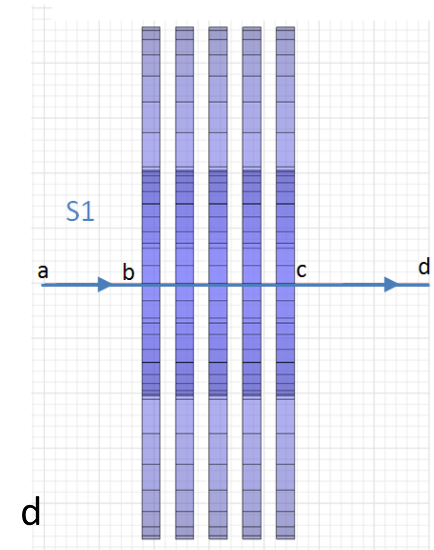
|B| on centerline with plates at t=0.6 ms



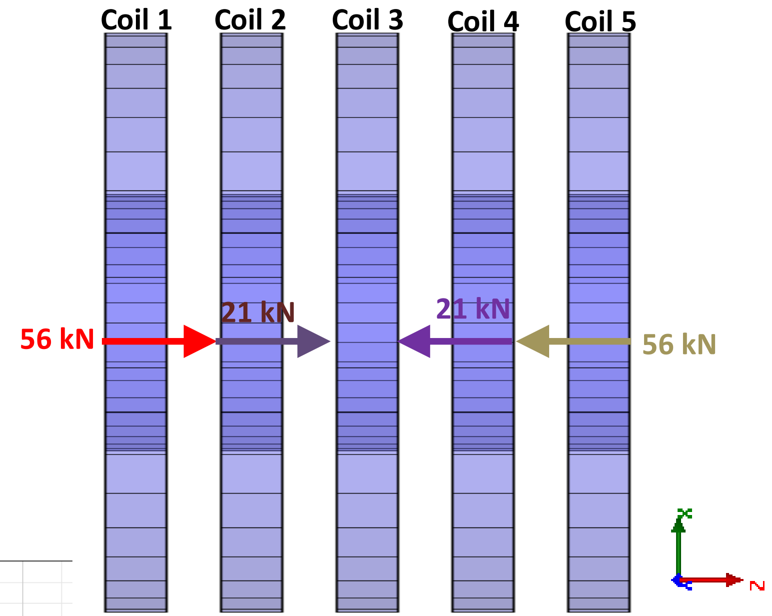


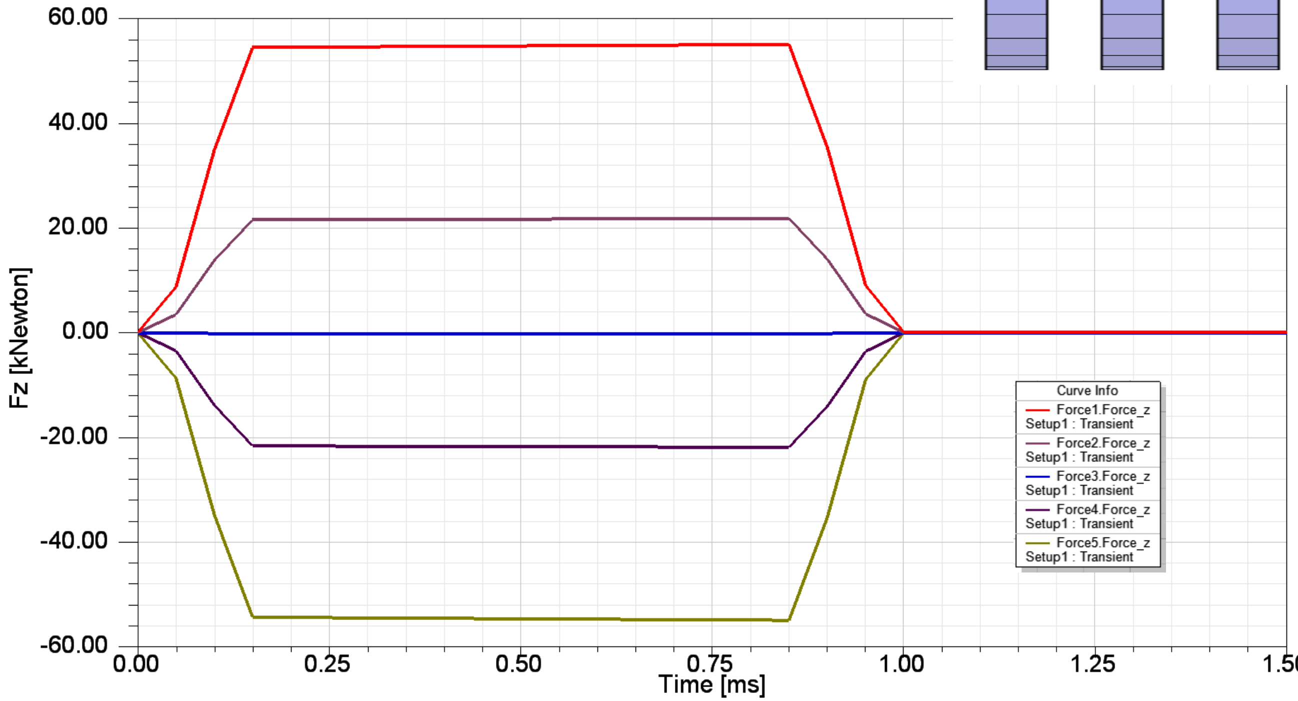
|B| along S1 for the case of Coils-Only at t = 0.5 ms





Forces in z direction on each coil for the case of Coils-Only.



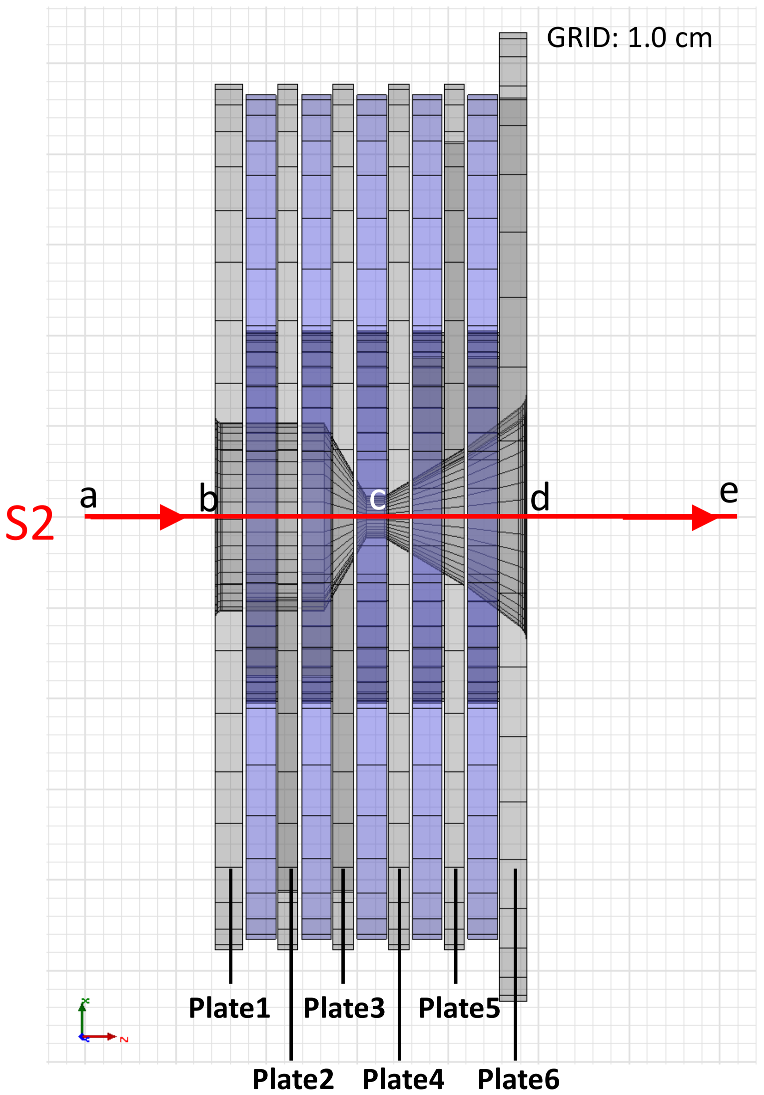


II) Time-transient magnetic analysis of the

Brechna’s Configuration

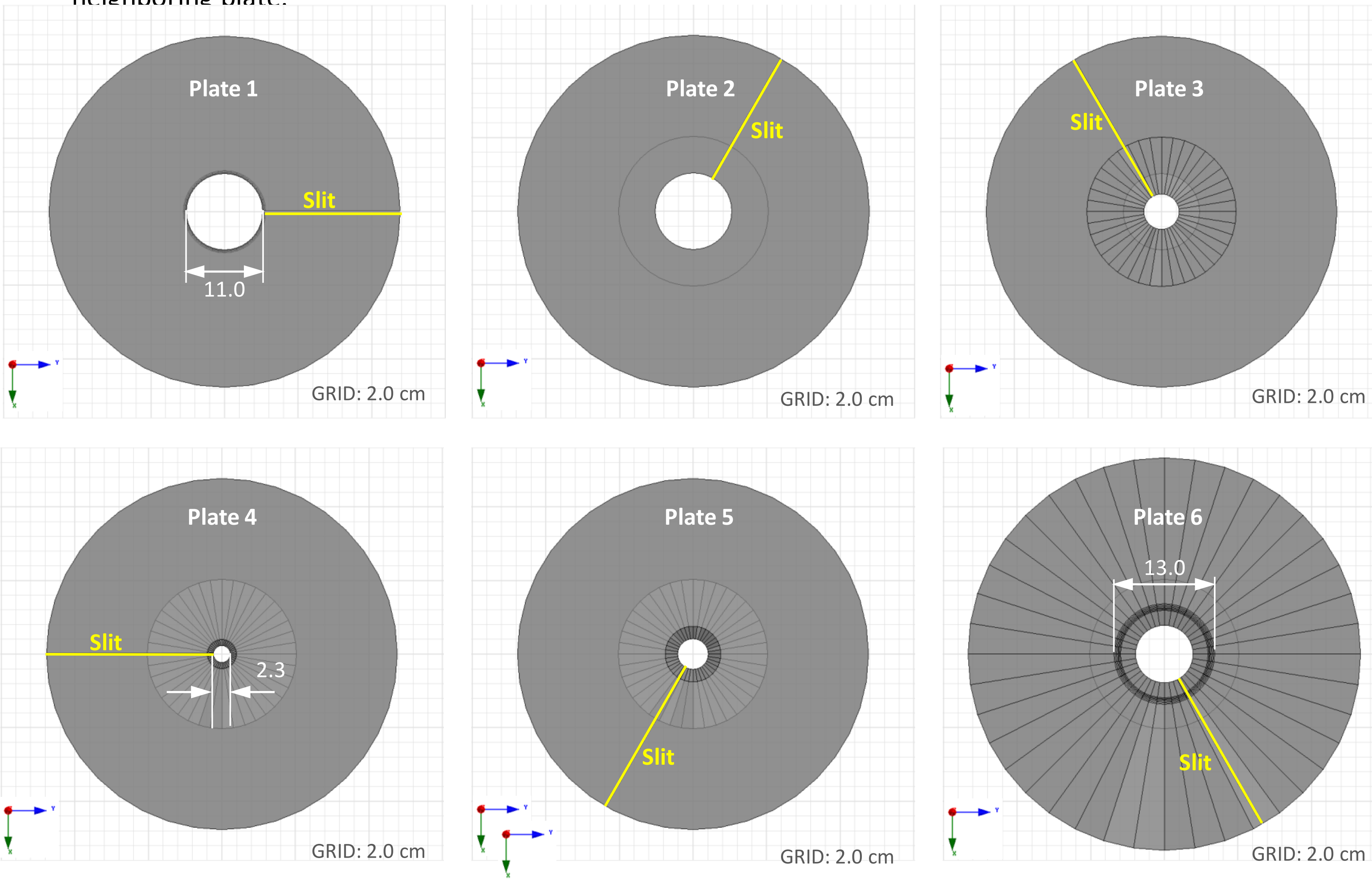
Coils with magnetic shaping plates (Brechna's Configuration)

- Each plate has a 0.2 cm slit that is out of phase by 60^{o} from the neighboring plates

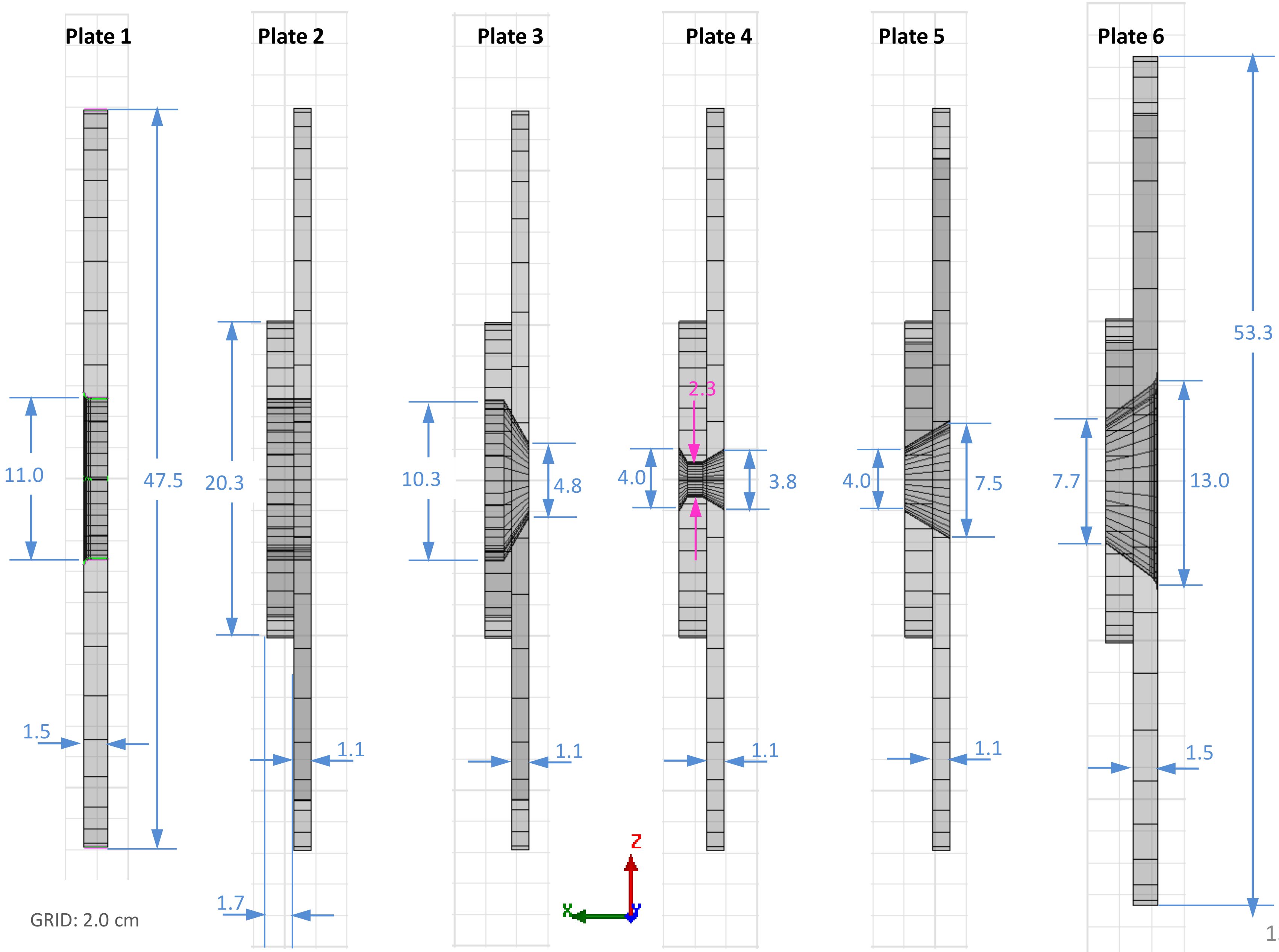


Magnetic Shaping Plates with 0.2 cm Slits in the xy plane

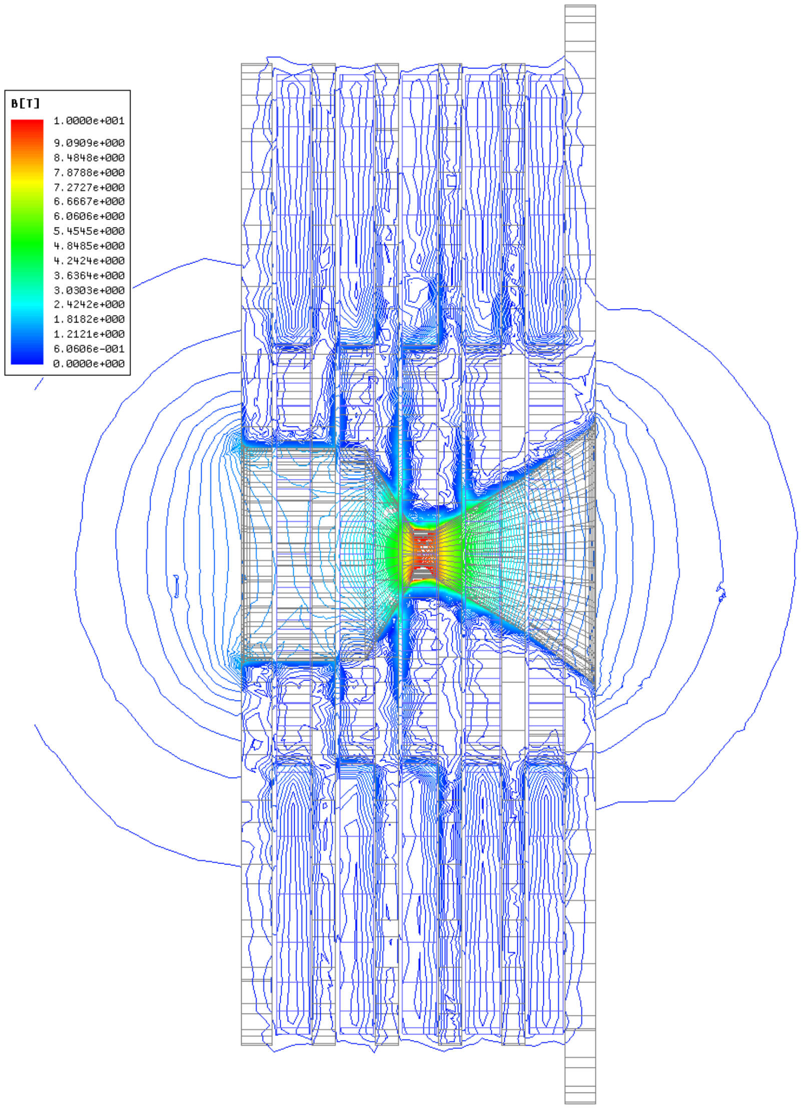
- Note slit orientation in each plate, 1) moves counter-clock-wise and 2) in 60 degrees in each plate neighboring plate.

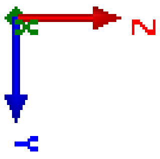


Magnetic Shaping Plates in the xzplane

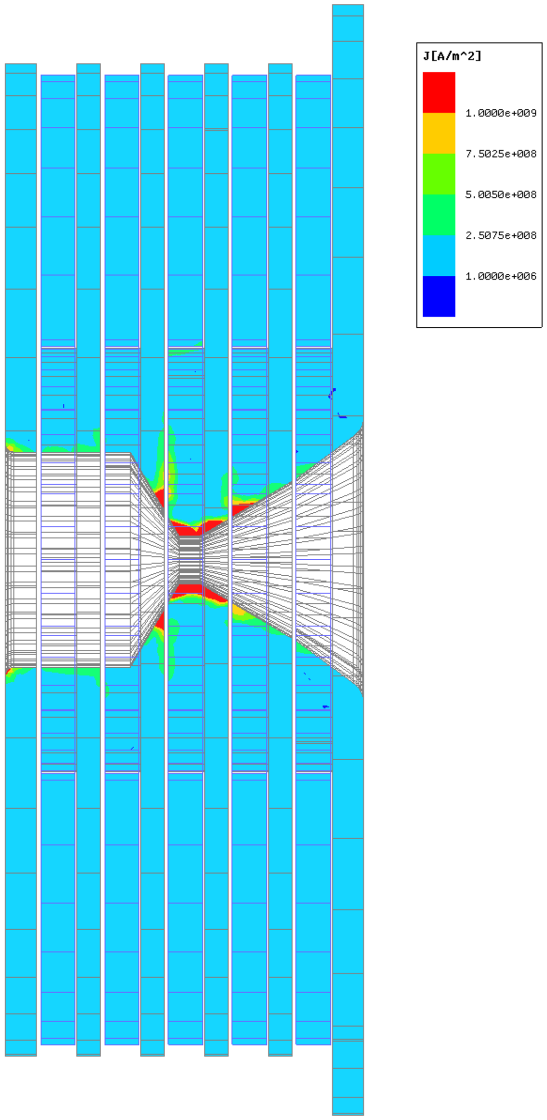


|B| in yz plane at 0.5 ms

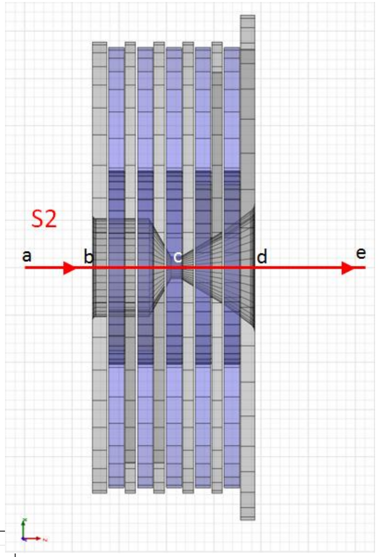


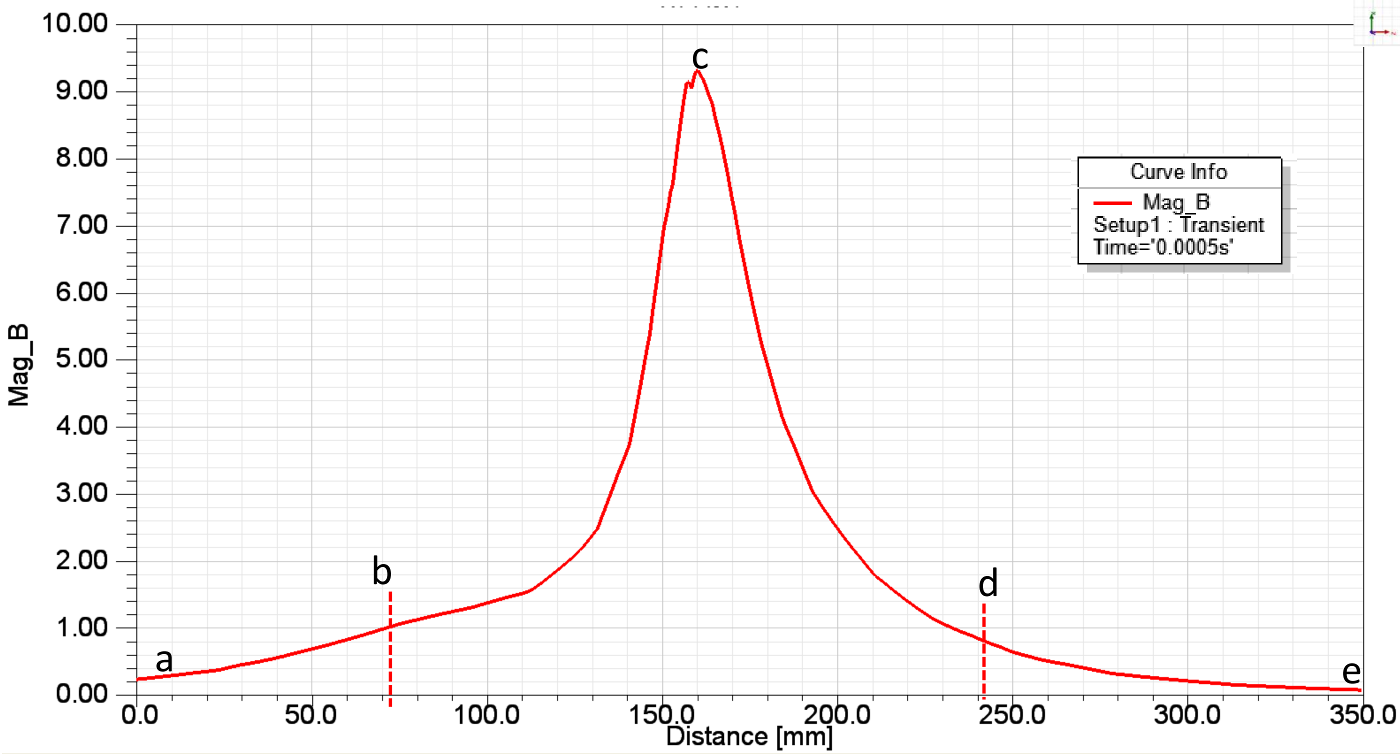


|J| in yz plane at 0.5 ms

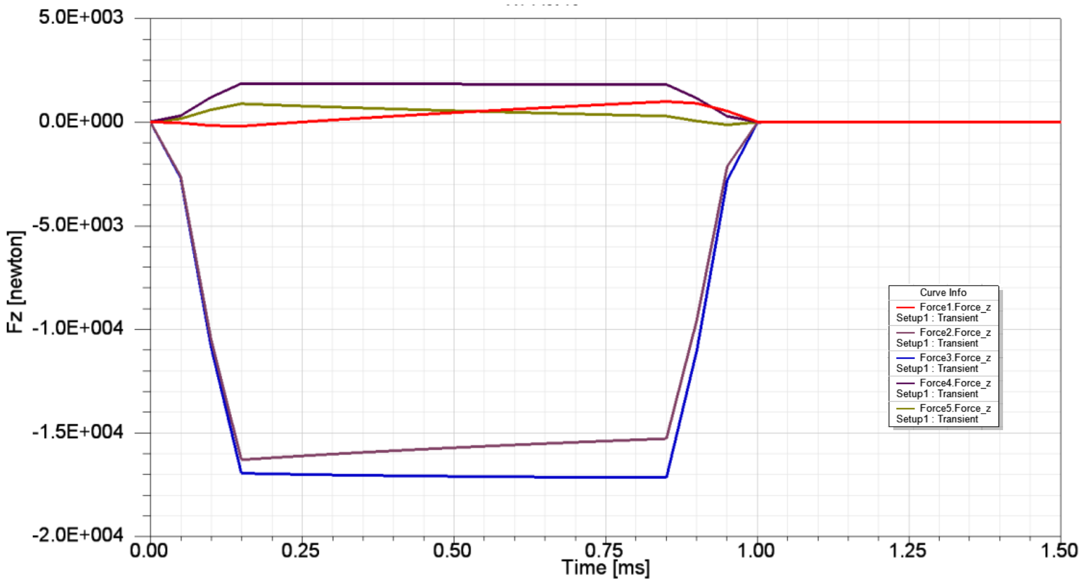


|B| along S2 for the case of with Shaping Plates at t = 0.5 ms

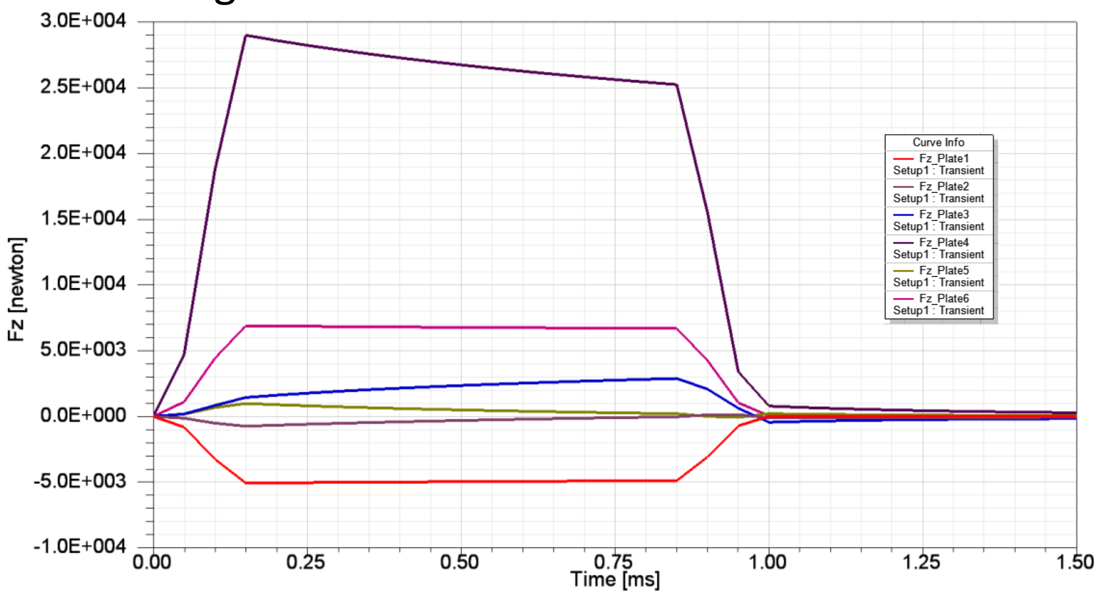


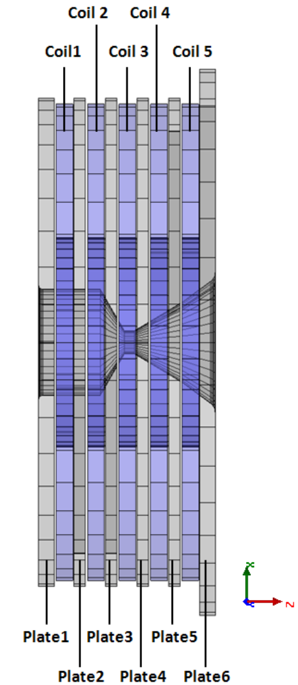


Fz among the Coils as a function of time



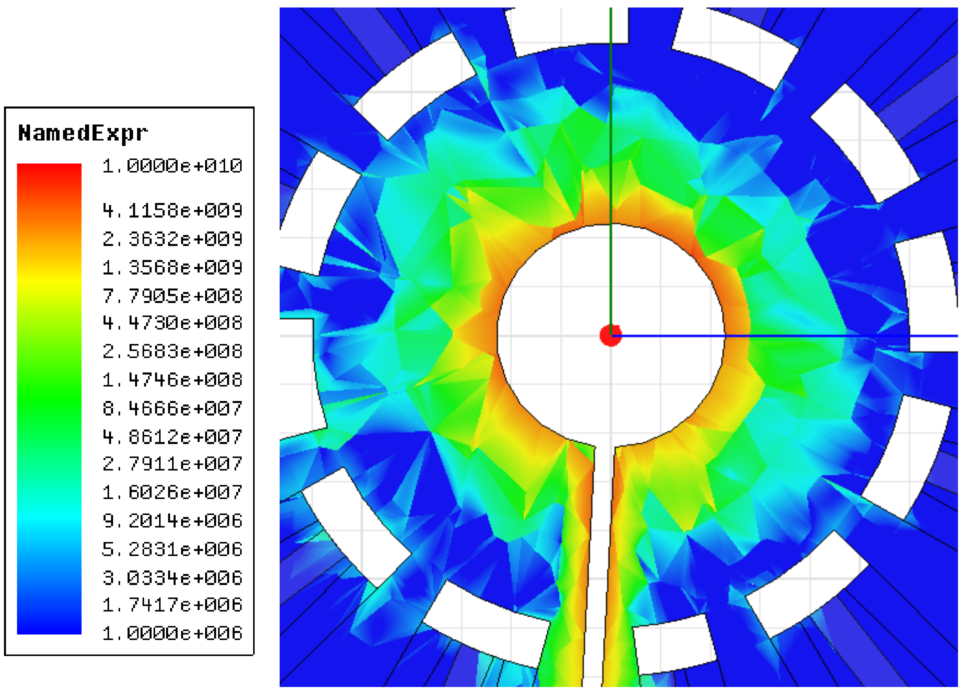
Fz among the Plates as a function of time

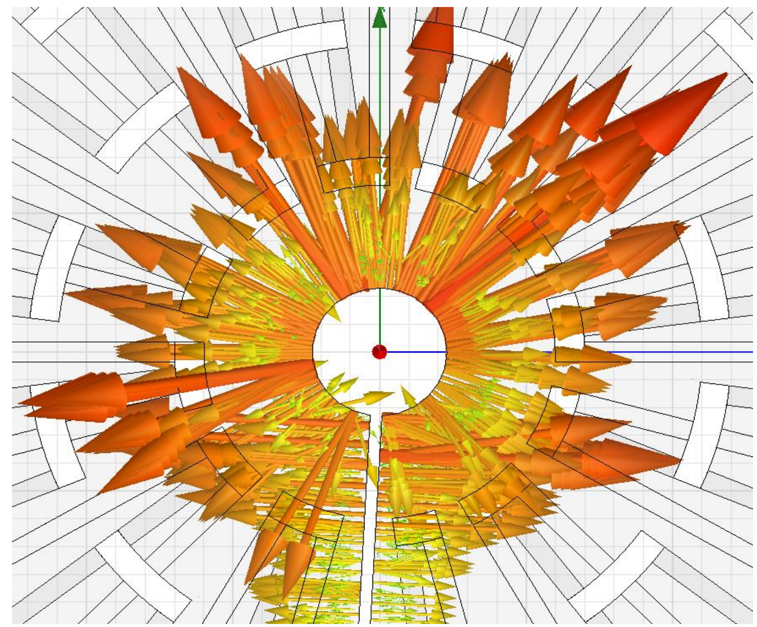




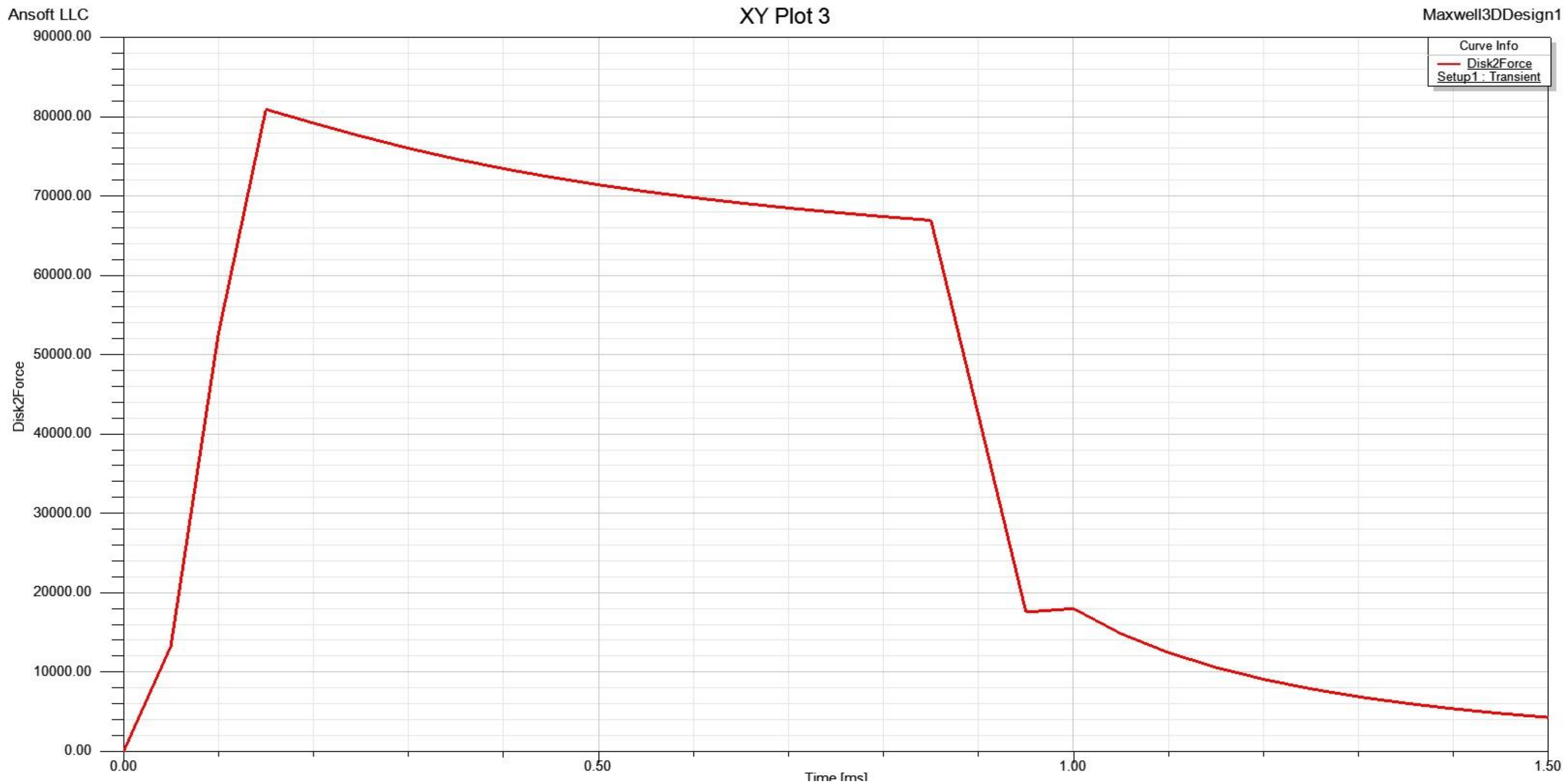
	Fz (t=0.50 ms) newton
Plate1	-5000.0
Coil1	+500.0
Plate2	-200.0
Coil2	-15,700.0
Plate3	+2,400.0
Coil3	-17,000.0
Plate4	+27,000.0
Coil4	+1,900.00
Plate5	+300.00
Coil5	+500.00
Plate6	+6,900.00

The J×B force density near the bore of the flux concentrating discs is directed radially outward for the straight bore magnet



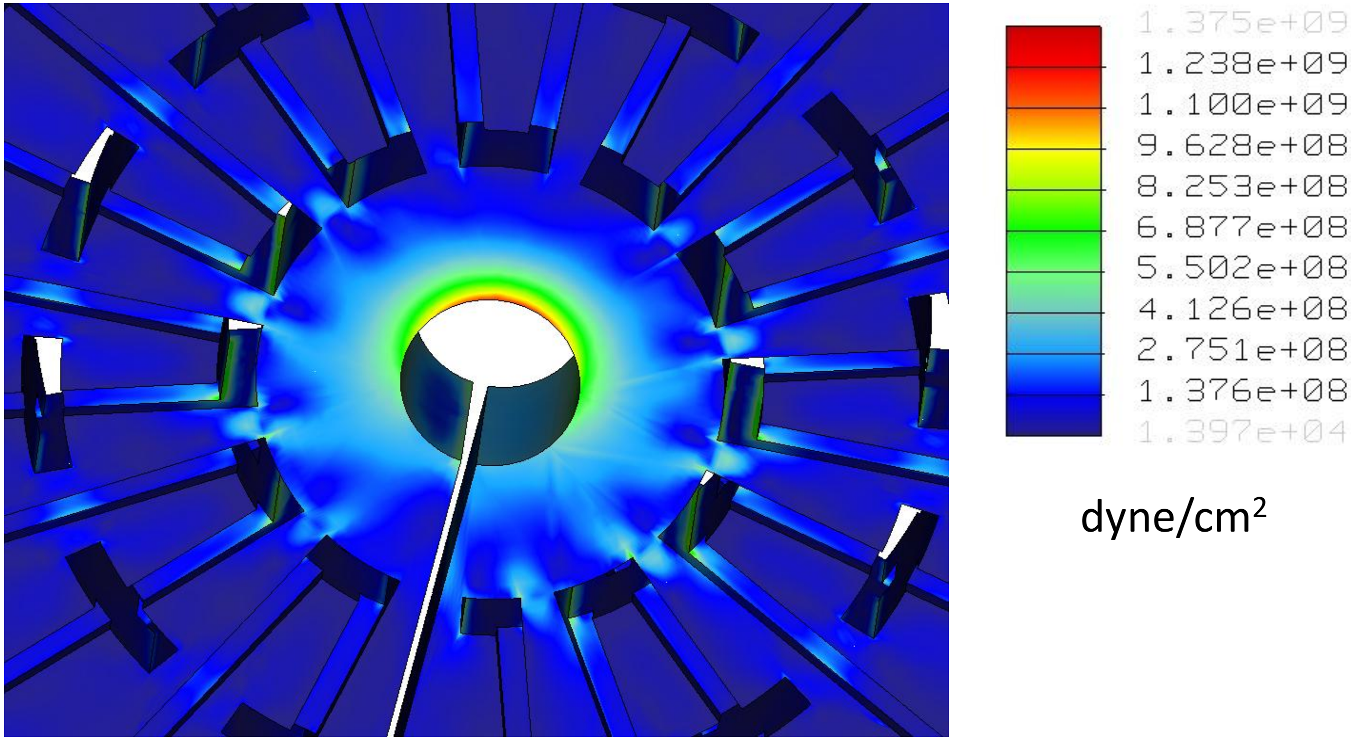


The magnetic force is fairly constant over the pulse time of 1 ms



The peak volume integrated force over the disc is ~ 80 kN. Speed of sound in copper is ~ 400 cm/ms, so transient force effects should translate into stresses provided bulk displacement is small.

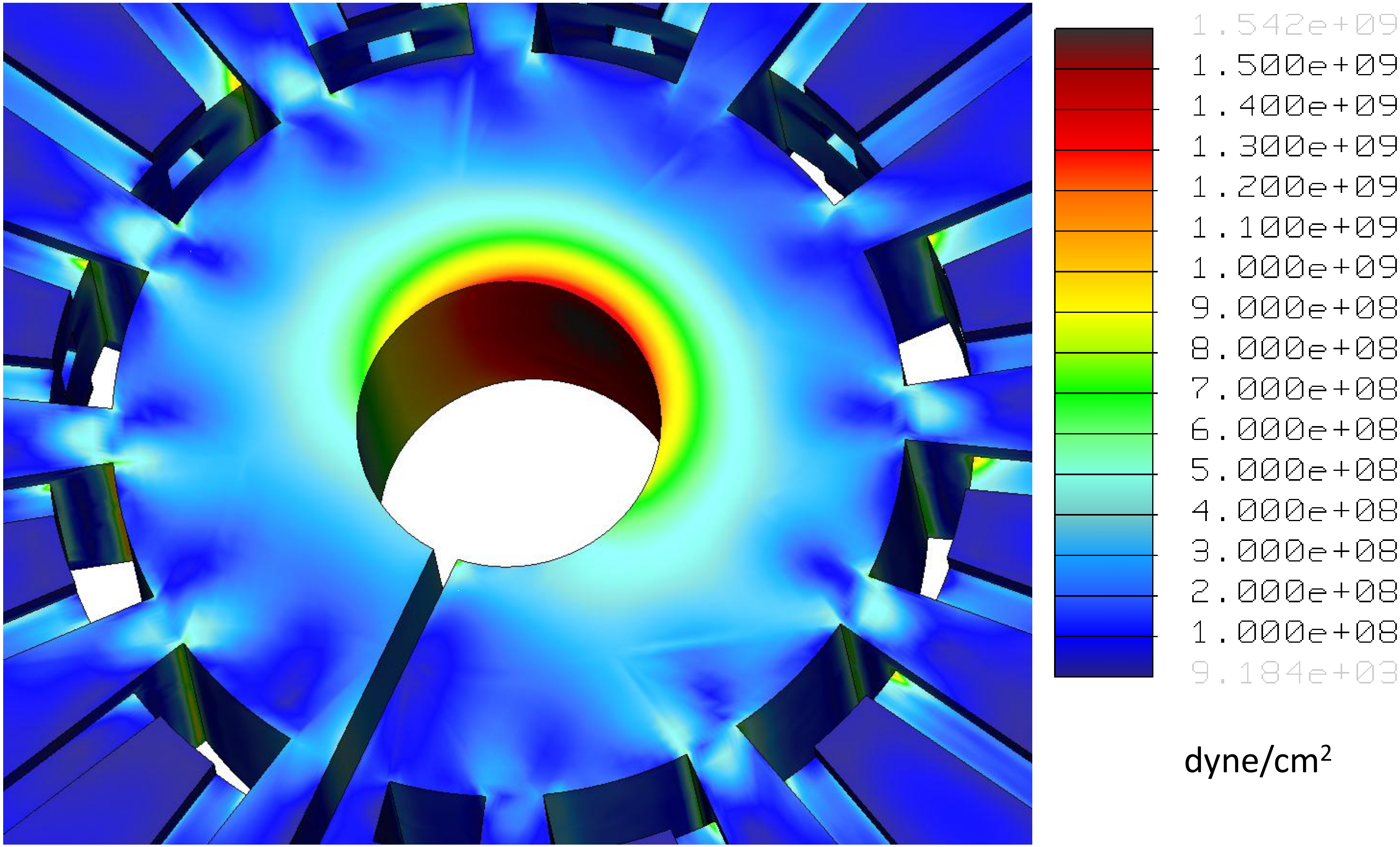
To estimate the stress field, this force is applied as a pressure to the inside surface of the bore



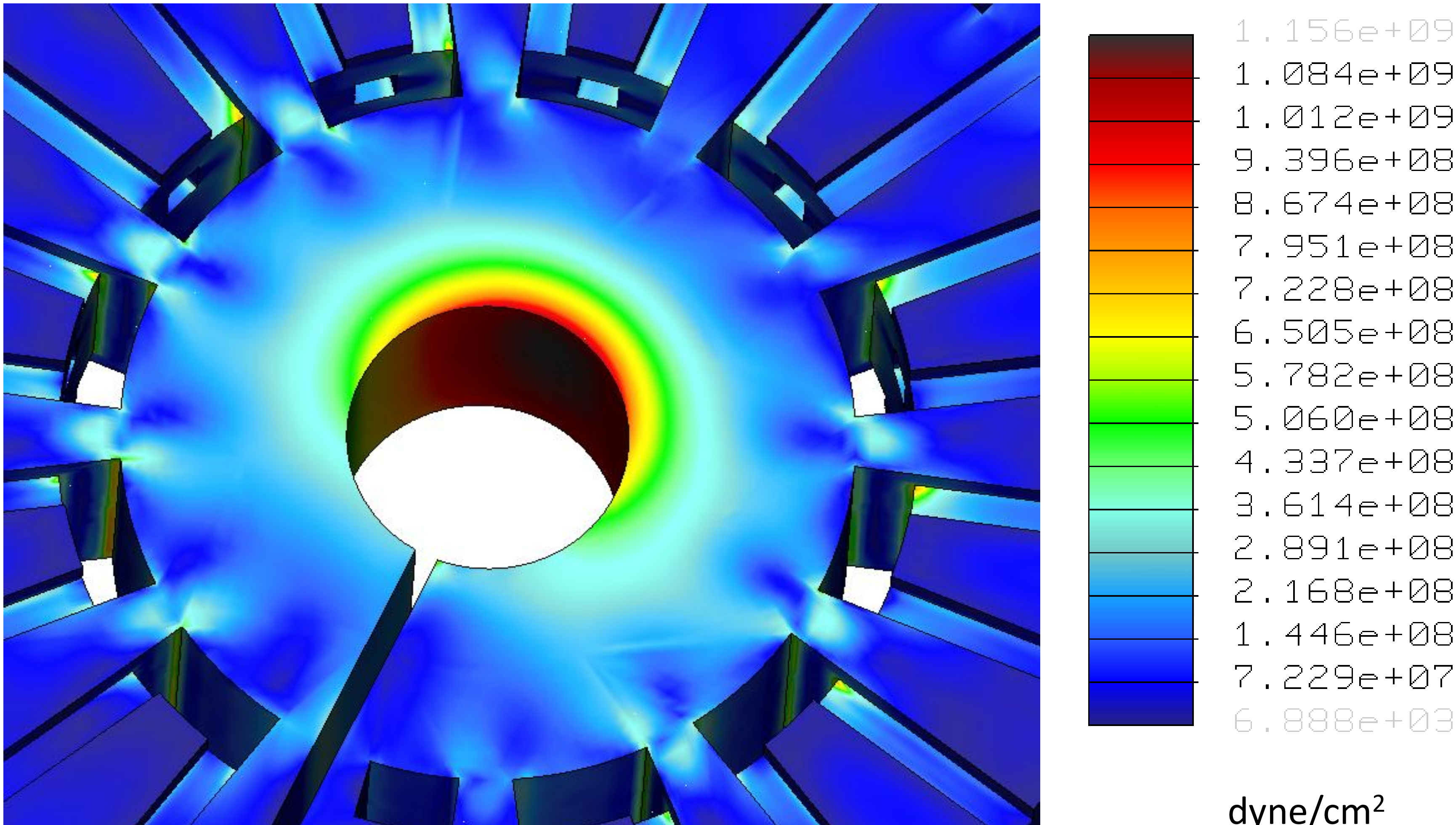
The required pressure on the inner bore was 39 MPa

Peak von Mises stress is on the order of 150 MPa. Yield stress of best OFC copper at 77 K is ~ 350 MPa. Still looking for cryogenic fatigue data. Best indication right now is ~ 160 MPa or less. This is too small a safety margin, so we are evaluating lower fields.

Stresses scale linearly with field reduction- 100% field

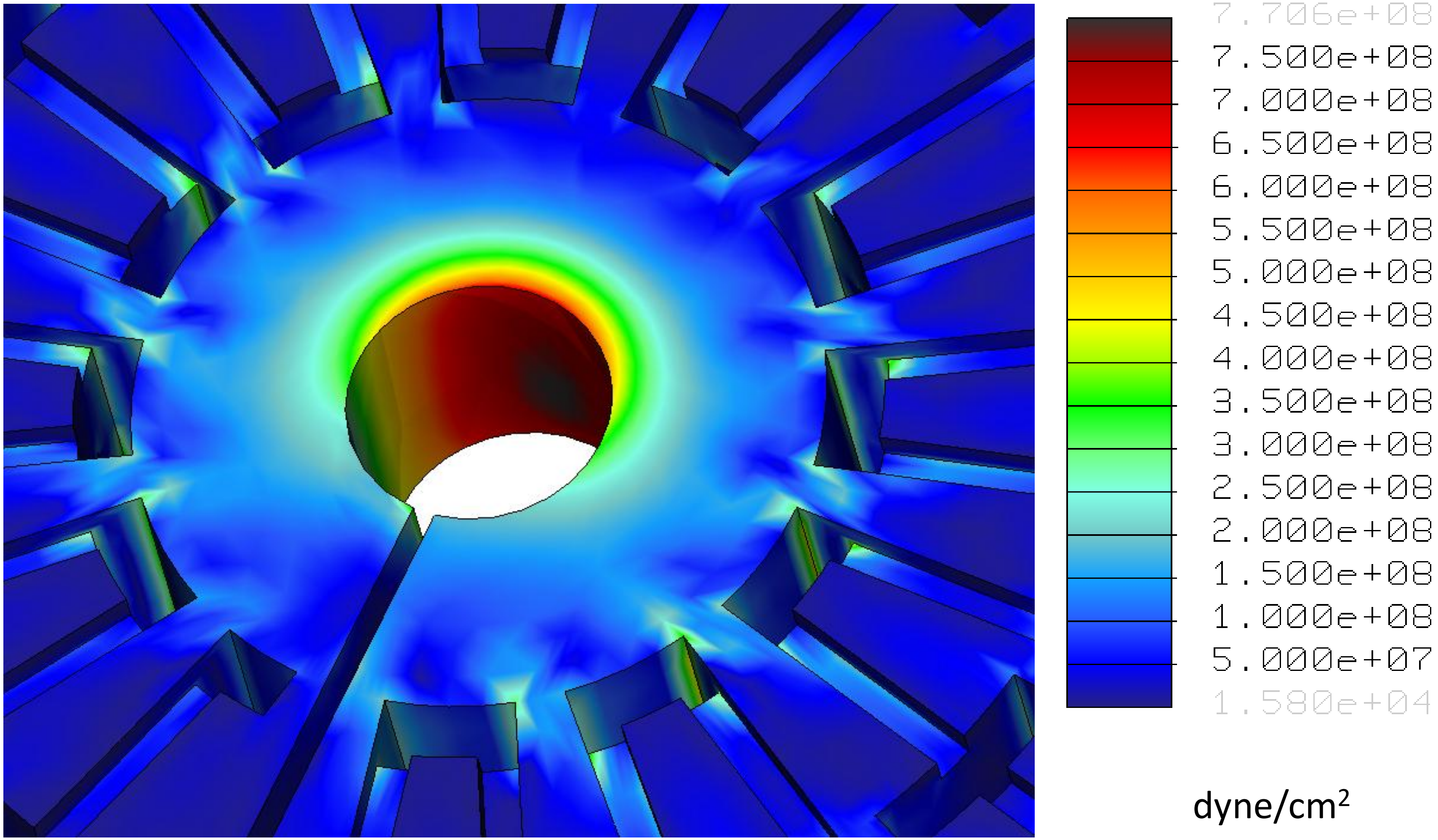


75% field

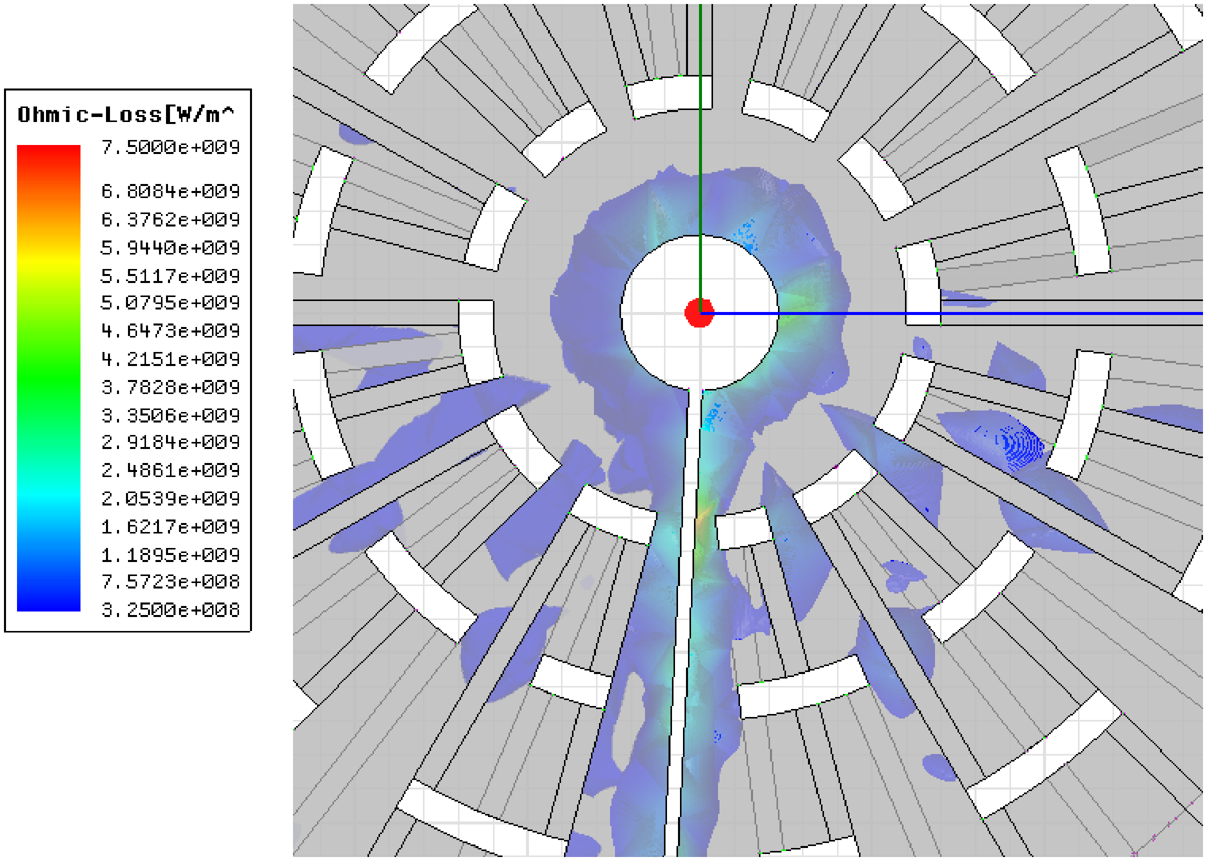


1.156e+09
1.084e+09
1.012e+09
9.396e+08
8.674e+08
7.951e+08
7.228e+08
6.505e+08
5.782e+08
5.060e+08
4.337e+08
3.614e+08
2.891e+08
2.168e+08
1.446e+08
7.229e+07
6.888e+03
dyne/cm^2

50% field

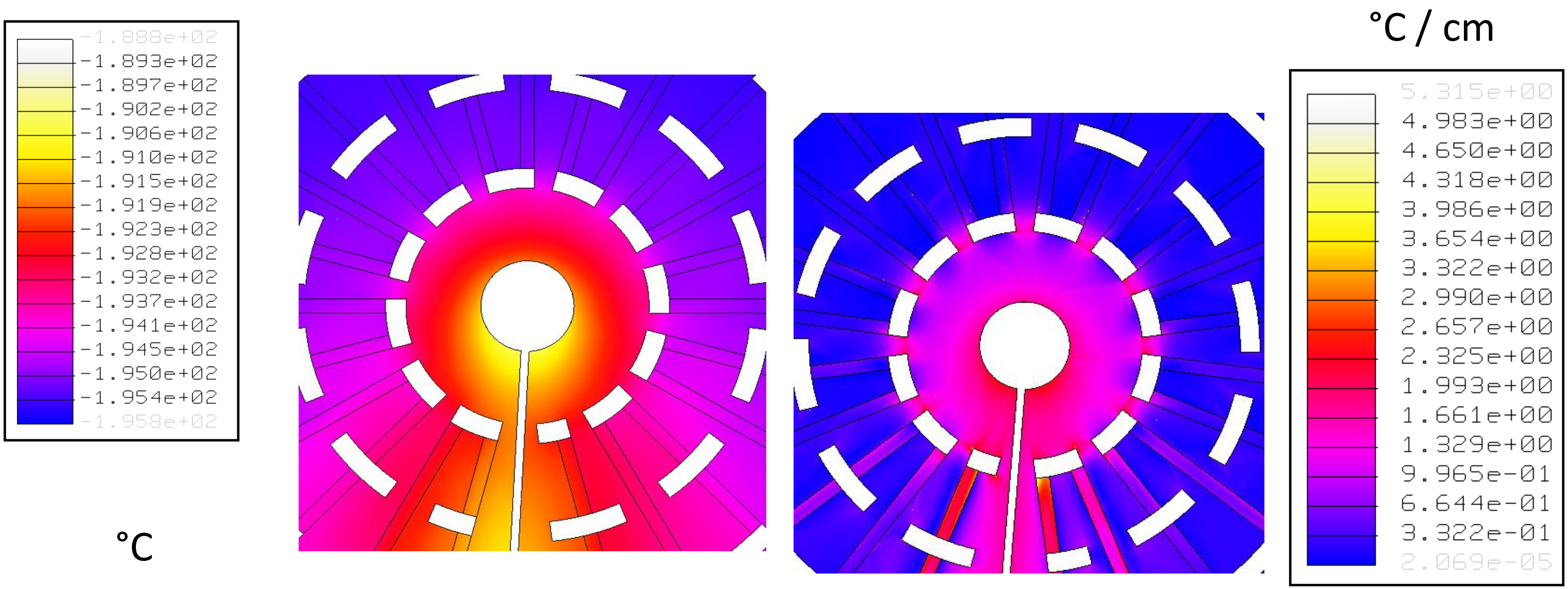

7.706e+08
7.500e+08
7.000e+08
6.500e+08
6.000e+08
5.500e+08
5.000e+08
4.500e+08
4.000e+08
3.500e+08
3.000e+08
2.500e+08
2.000e+08
1.500e+08
1.000e+08
5.000e+07
1.580e+04
dyne/cm2

Ohmic heating is also concentrated in the 'bore' and 'slit' region of the flux concentrator



Total <u>averaged</u> Ohmic heating in the disk is 494 W. Applying this power at the bore and slit surfaces, we can get an estimate of the steady magnet temperature profile.

The averaged temperature gradient is also greatest in the ‘bore’ and ‘slit’, as expected



Heating was also applied as a heat flux in the ‘bore’ and ‘slit’ region.
An estimate puts the thermal stress at ~ 10 MPa for this temp profile.

Cryocooler Cost Estimate

- Real FC will dissipate ≈ 10 kW in ohmic losses
- Largest commercial cryocoolers able to remove 0.5 – 1 kW at ≈70 K with 4% efficiency and cost ≈ 100 $/W
- FC cryocoolers will cost ≈ 1 M$ for equipment and 330,000 $/yr in electricity assuming rates of 15 ¢/kW-hr

Summary

- Continued analysis of flux concentrator- extending to different geometries
- Used simplified models to evaluate stress for survival simulations
- Evaluating options for refining stress and thermal calculations

Summary

✓ A Flux Concentrator was modeled in Maxwell3D based on Brechna’s [+] configuration. (A “Coils-Only” case was modeled in advance and magnetostatic results reported to serve as a reference to gauge the effect of shape plates). The concentrator based on Brechna’s configuration is about 17 cm in length and 26 cm in radius. The bore is 11.0 cm in dia. at the input end and 3.0 cm in dia. at the output end. The bore minimum dimension is 2.3 cm, at 8.3 cm from input end and extends for 1.0 cm. The coils’ and disks’ material were assumed to be OFHC Copper (σ = 3.5714E+08 S/m).

✓ The concentrator is comprised of 5 current carrying coils and 6 flux shaping plates. Each coil is sandwiched between plates. For example, Coil1 is sandwiched between Plate1 and Plate2 and Coil2 is sandwiched between Plate2 and Plate3 and so on. Each plate has a radial 2.0 mm slit. The slit is rotated by 60 degrees in each successive plate.

✓ The current in each turn was assumed to be a square-like pulse of 100 kA with 0.001s duration.

✓ $|B|$ mapping in the yz plane at t = 0.5 ms was reported.

✓ $|J|$ mapping in the yz plane at t = 0.5 ms was reported.

✓Maximum 9.3 Tesla at 0.05 ms was estimated at the bore of the concentrator. This field is 4.4 times more in magnitude when compared to the Coils-Only case, although it is focused over a narrower space.

✓Forces on the coils and plates in the z direction as a function of time were also reported. – A higher resolution model will give solutions with better time profile of the forces (total number of tetrahedral mesh elements for the model was 1.44E+05).

+ H. Burchna, et.al., “*150 kOe Liquid Nitrogen Cooled Pulesd Flux Concentrator Magnet*,” Review of Scientific Instruments, V.36, No. 11, Nov 1965, pp. 1529-1535