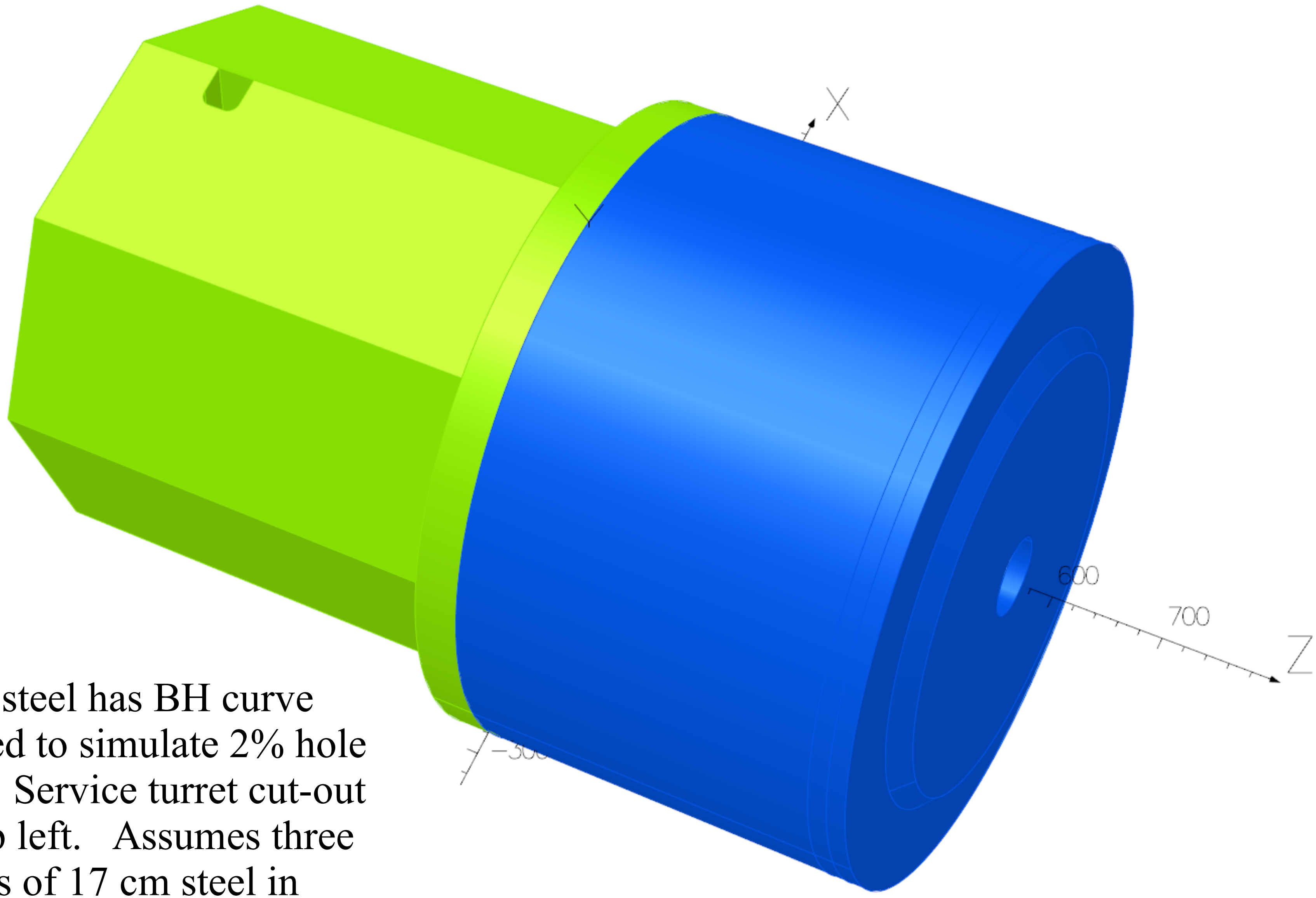
Magnet Modeling

Jay Benesch
13 October 2017
SoLID collaboration meeting

Outline

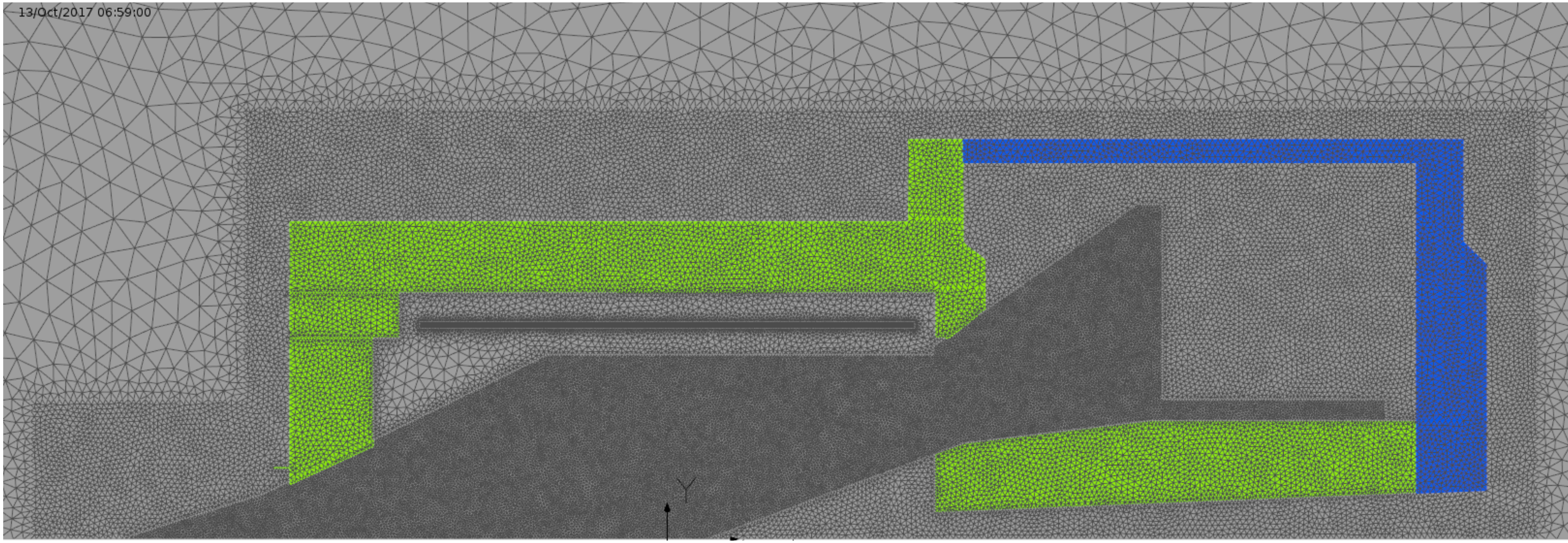
- model with JLab steel
- fields with/without turret cut-out
- conclusions/questions
- He3 target coils
- conclusions

Best model



Blue steel has BH curve altered to simulate 2% hole area. Service turret cut-out at top left. Assumes three layers of 17 cm steel in octagon. Interface ring likely wider than needed.

Model section - symmetric

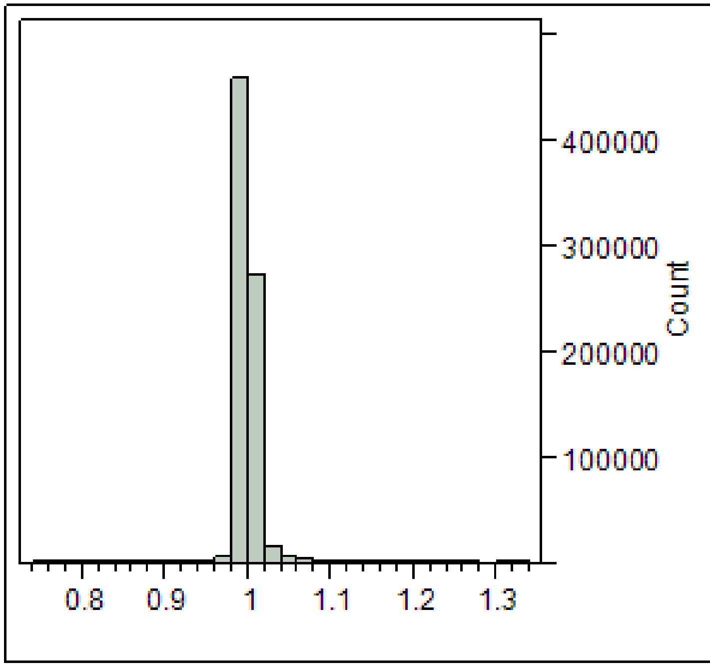


Octagon is 51 cm thick, three 17 cm plates. End cap is rolled from 17 cm plate. End cap plates at right are also 3*17 cm. The items which are not multiples of 17cm are the upstream plug, the interface ring, the coil collars and the nose. I'm not sure why the mesh is coarser in the -Z region outside the acceptance; this may explain the next slide.

Comparing fields with vs without turret: is an eight-fold symmetric model sufficient?

Distributions

BratioT/S



Quantiles

100.0%	maximum	1.32897
99.5%		1.04721
97.5%		1.02045
90.0%		1.00502
75.0%	quartile	1.00068
50.0%	median	0.99975
25.0%	quartile	0.99908
10.0%		0.99631
2.5%		0.98959
0.5%		0.979
0.0%	minimum	0.7492

Moments

Mean	1.0007444
Std Dev	0.0081258
Std Err Mean	9.3858e-6
Upper 95% Mean	1.0007628
Lower 95% Mean	1.000726
N	749521

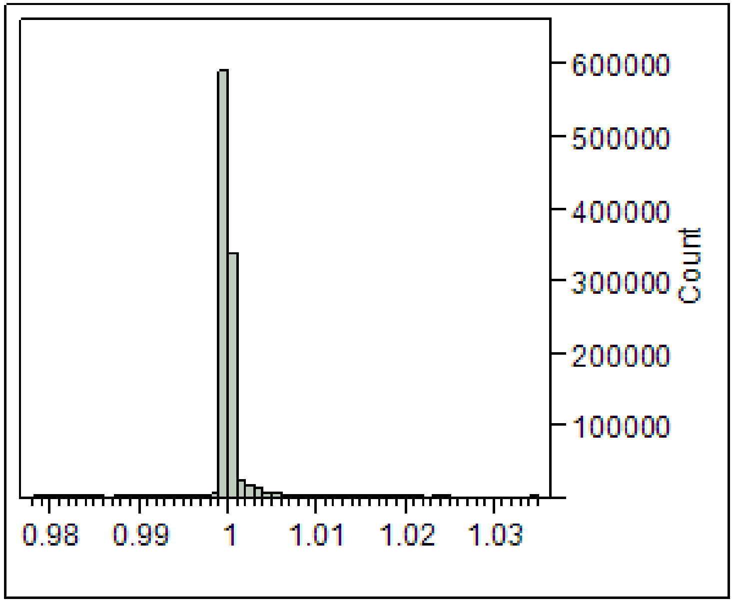
r=[100,140] z=[-205,-105] Ratio of field with turret to symmetric model. Almost all of this volume is outside acceptance.

Most of this volume is outside SoLID acceptance but CLEO would have seen these.

Comparing fields II

Distributions

BratioT/S



Quantiles

100.0%	maximum	1.03422
99.5%		1.00472
97.5%		1.00239
90.0%		1.00045
75.0%	quartile	1.00019
50.0%	median	0.99991
25.0%	quartile	0.99981
10.0%		0.99971
2.5%		0.99956
0.5%		0.99912
0.0%	minimum	0.97855

Moments

Mean	1.0001098
Std Dev	0.0007607
Std Err Mean	7.7071e-7
Upper 95% Mean	1.0001113
Lower 95% Mean	1.0001083
N	974246

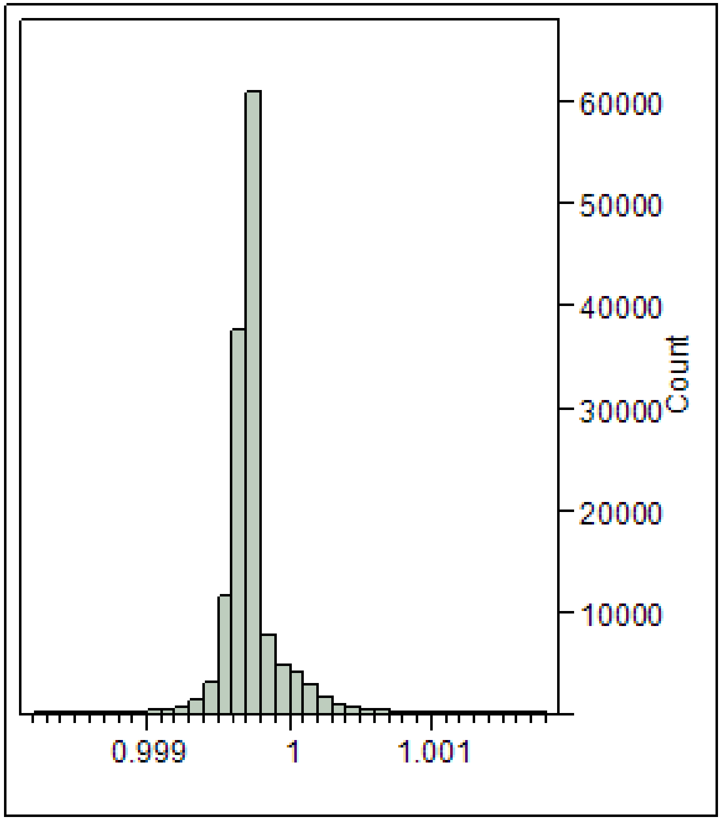
r<100, z=[-205,-105] Some of this is still outside acceptance.

r<100, z=[-205, -105] Some of this is outside acceptance but I don't have the tools to easily separate those points. Tables of field values are in docdb 52 and 53 for examination by those who do.

Comparing fields III

Distributions

BratioT/S



Quantiles

100.0%	maximum	1.00175
99.5%		1.00049
97.5%		1.0002
90.0%		0.99992
75.0%	quartile	0.99978
50.0%	median	0.99972
25.0%	quartile	0.99966
10.0%		0.99958
2.5%		0.99945
0.5%		0.99919
0.0%	minimum	0.9983

Moments

Mean	0.9997367
Std Dev	0.0001743
Std Err Mean	4.711e-7
Upper 95% Mean	0.9997377
Lower 95% Mean	0.9997358
N	136836

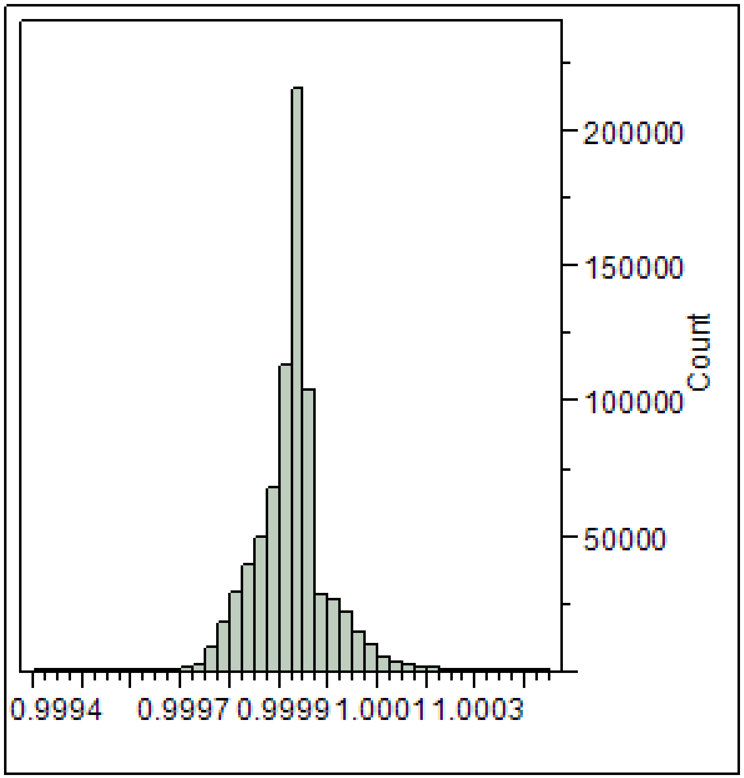
r=[100,140] z=[-135,-105] Most of this volume is within acceptance.

Small volume at larger radii, most of which is in acceptance.
r=[100,140] z=[-135,-105]

Comparing fields IV

Distributions

BratioT/S



Quantiles

100.0%	maximum	1.00045
99.5%		1.00015
97.5%		1.00008
90.0%		1.00001
75.0%	quartile	0.99995
50.0%	median	0.99993
25.0%	quartile	0.99989
10.0%		0.99984
2.5%		0.99979
0.5%		0.99975
0.0%	minimum	0.99942

Moments

Mean	0.9999261
Std Dev	6.7643e-5
Std Err Mean	7.8133e-8
Upper 95% Mean	0.9999262
Lower 95% Mean	0.9999259
N	749521

r=[100,140] z=[-105,0] so most of this is in acceptance.
Ratio of field with turret to field without.

r=[100,140] z=[-105,0] Most of this is within acceptance.

Comparing fields - conclusions

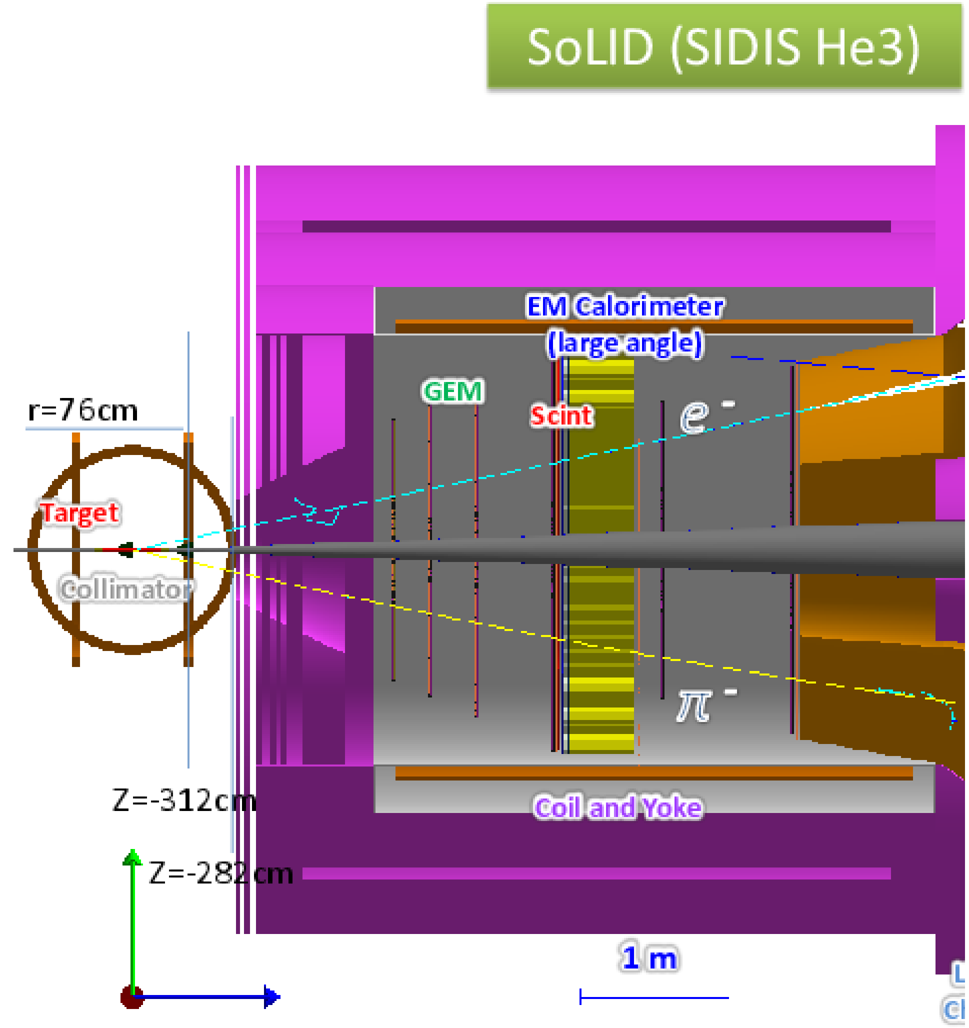
- Models have been solved with and without turret cutout so comparisions may be made. 112M nodes, 1.55B non-zeroes in matrices. Opera limit 2B. Preparation and solution about one week each.
- Sample field maps created as (r,θ,z) but reported as (x,y,z) are in docdb for better comparisons than I can make.
- The model with turret cut-out suggests strongly that load cells will be well within tolerance in this configuration which differs so much from original

He3 target coils

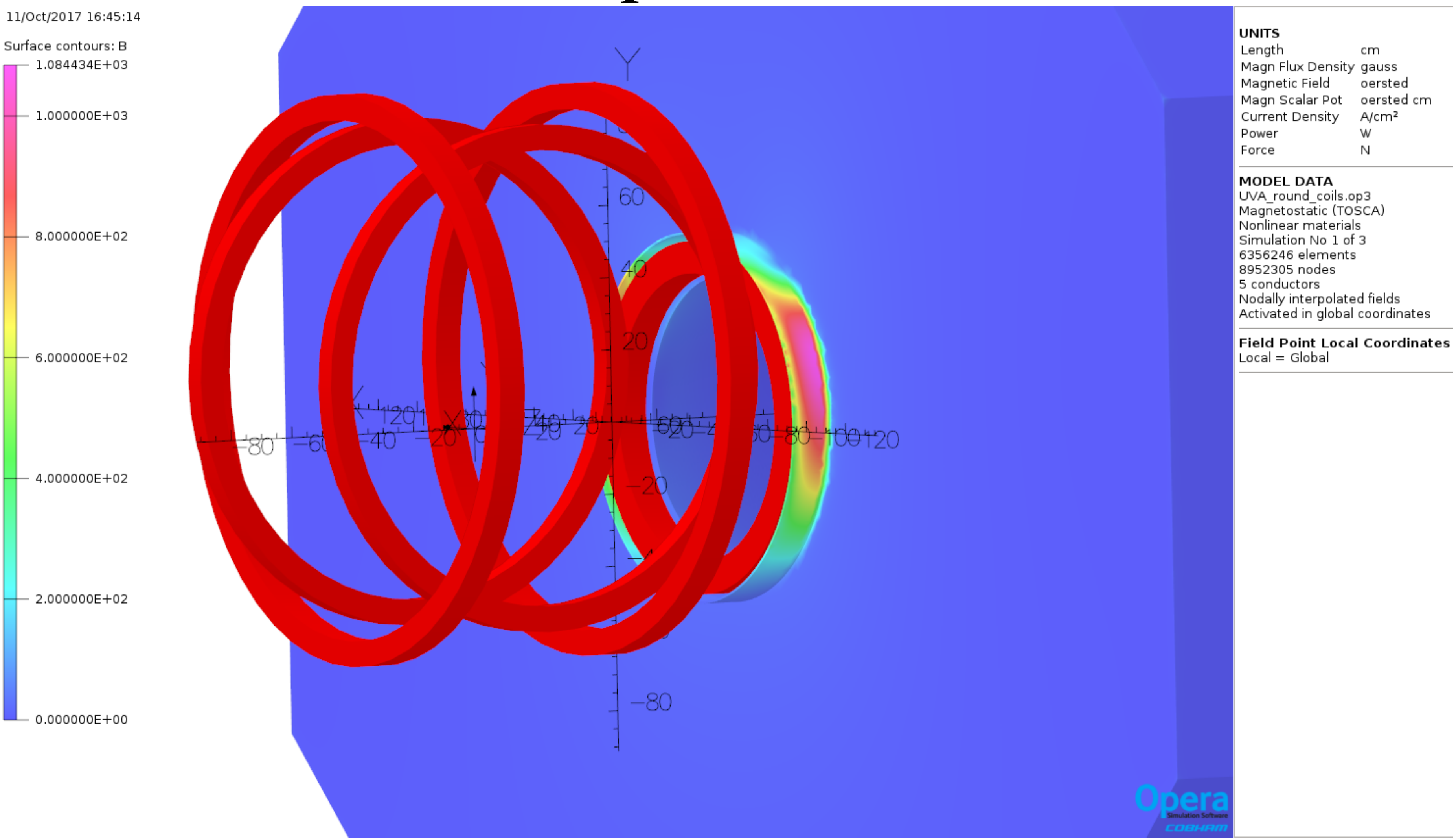
- As dimensioned in wiki, target "Helmholtz" coils will not fit in front of the SoLID system modeled. ***This was a misunderstanding. The coils labeled "small, large and vertical" are NOT used for Bx, By, Bz. Only small (Bx) and large (Bz) are expected to be used and these fit.***
- *Nevertheless, I show recent work in case future He3 experiments require adjusting all three planes.*
- Coils interact significantly with the SoLID steel. It would be better if they were symmetric about solenoid Z axis, not offset 15 cm vertically, to keep coil torque sums zero.
- UVA coils and a three-pair set of my own device were modeled with first 30" of steel
- Coils on edges of a cube were also modeled.

another source of misapprehension

Zhiwen's image shows a transverse coil within ~10 cm of the face of the coil collar. I didn't notice that there was no coil set producing By, nor was it clear that the r=76 cm note referred to the Bz pair.

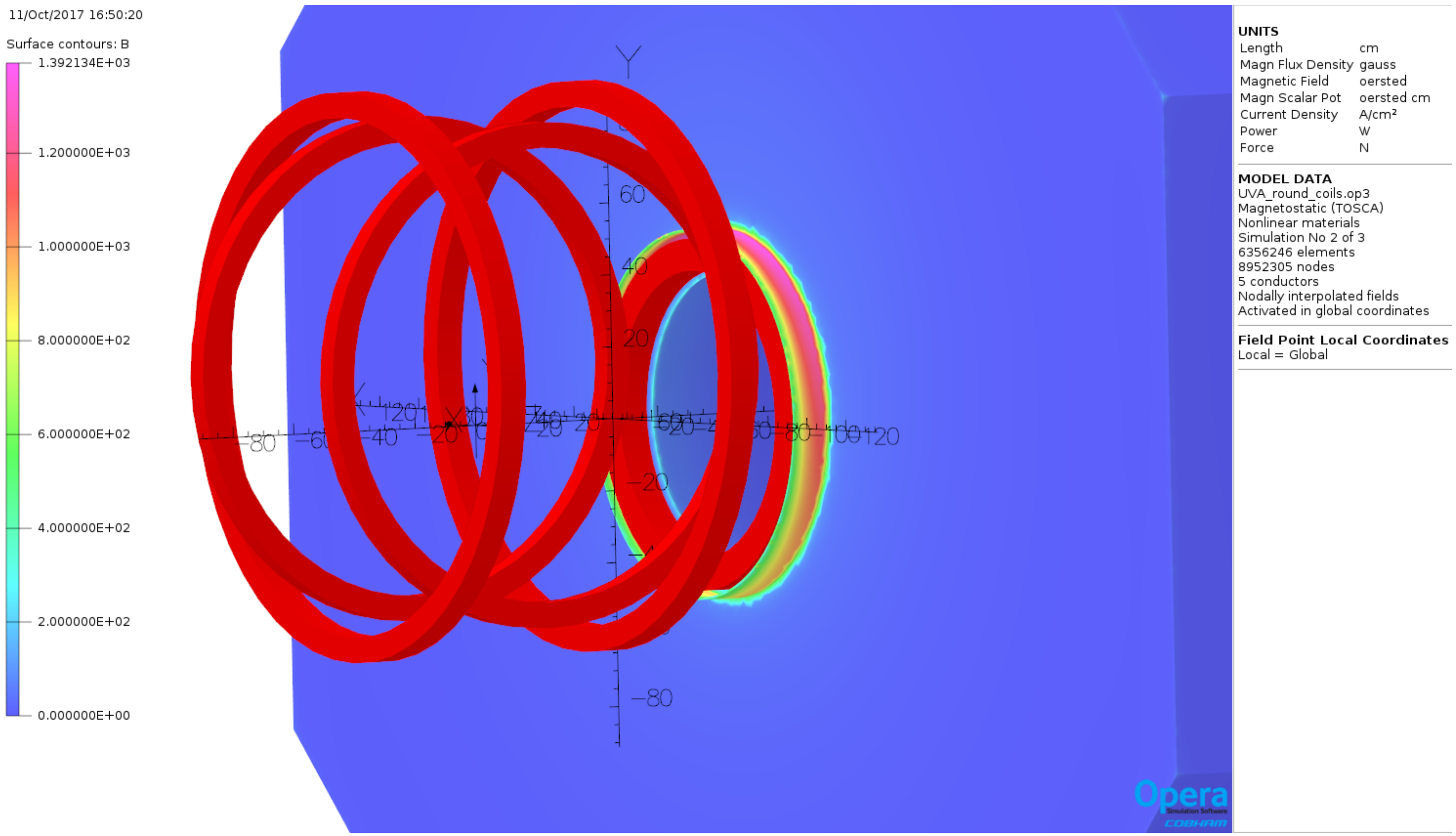


Temple coil set I



Bx coil set with 2316.8 AT. Bz set 0.

Temple coil set II



Bz coils with 2889.7 AT. Magnetization of ring around compensation coil still asymmetric due to vertical offset. Bx R 66.8 Bz R 75.8 cm

Forces and torques on Bz coils (x,y,z)

Torques calculated with respect to (0,0,0).

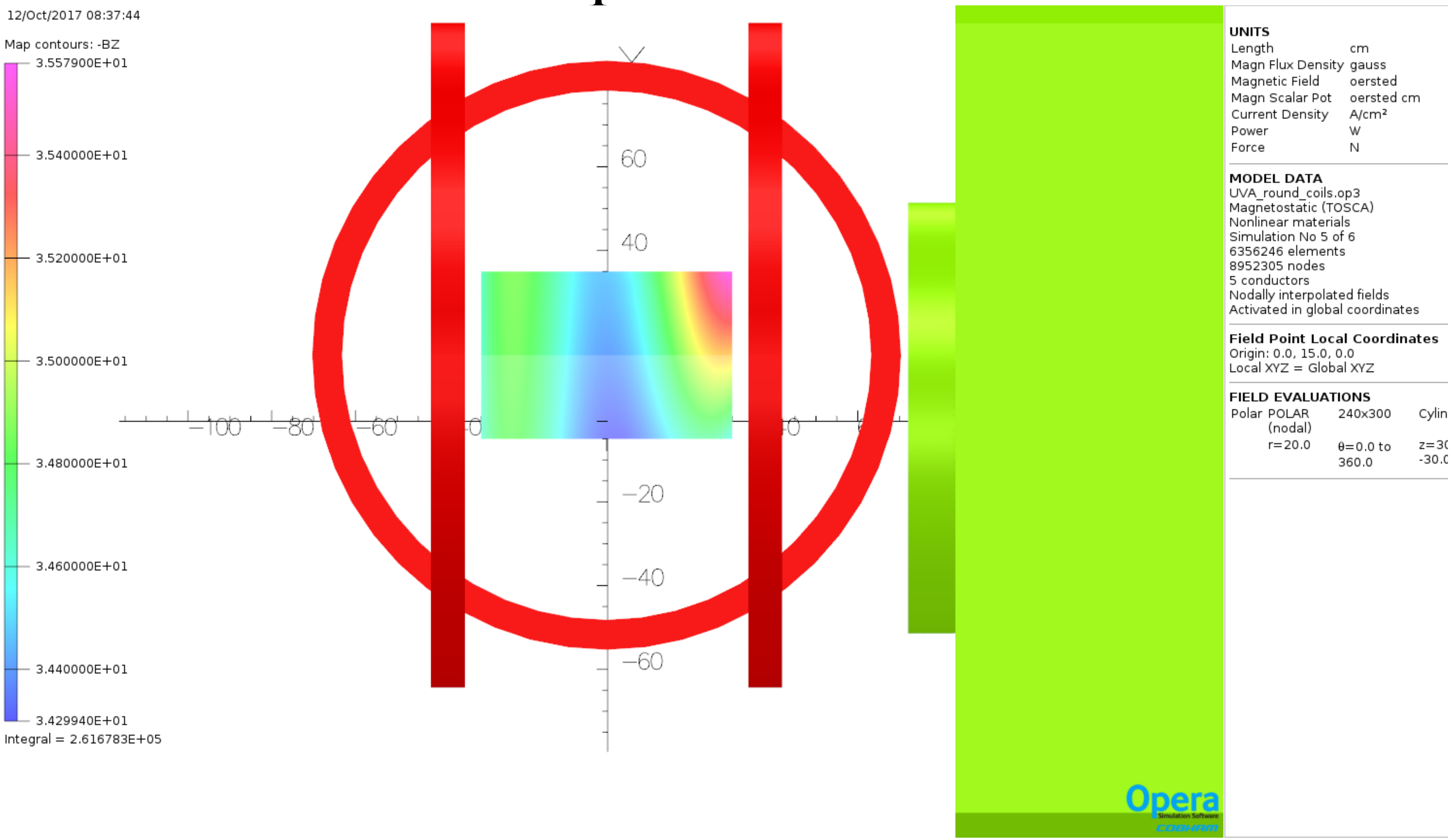
Total force on downstream Bz coil = 0.7, 1.5, 7.7 N

Total torque on downstream Bz coil = -247.4, 67.7, -11.1 N cm

Total force on upstream Bz coil = 3.0, 0.1, 6.2 N

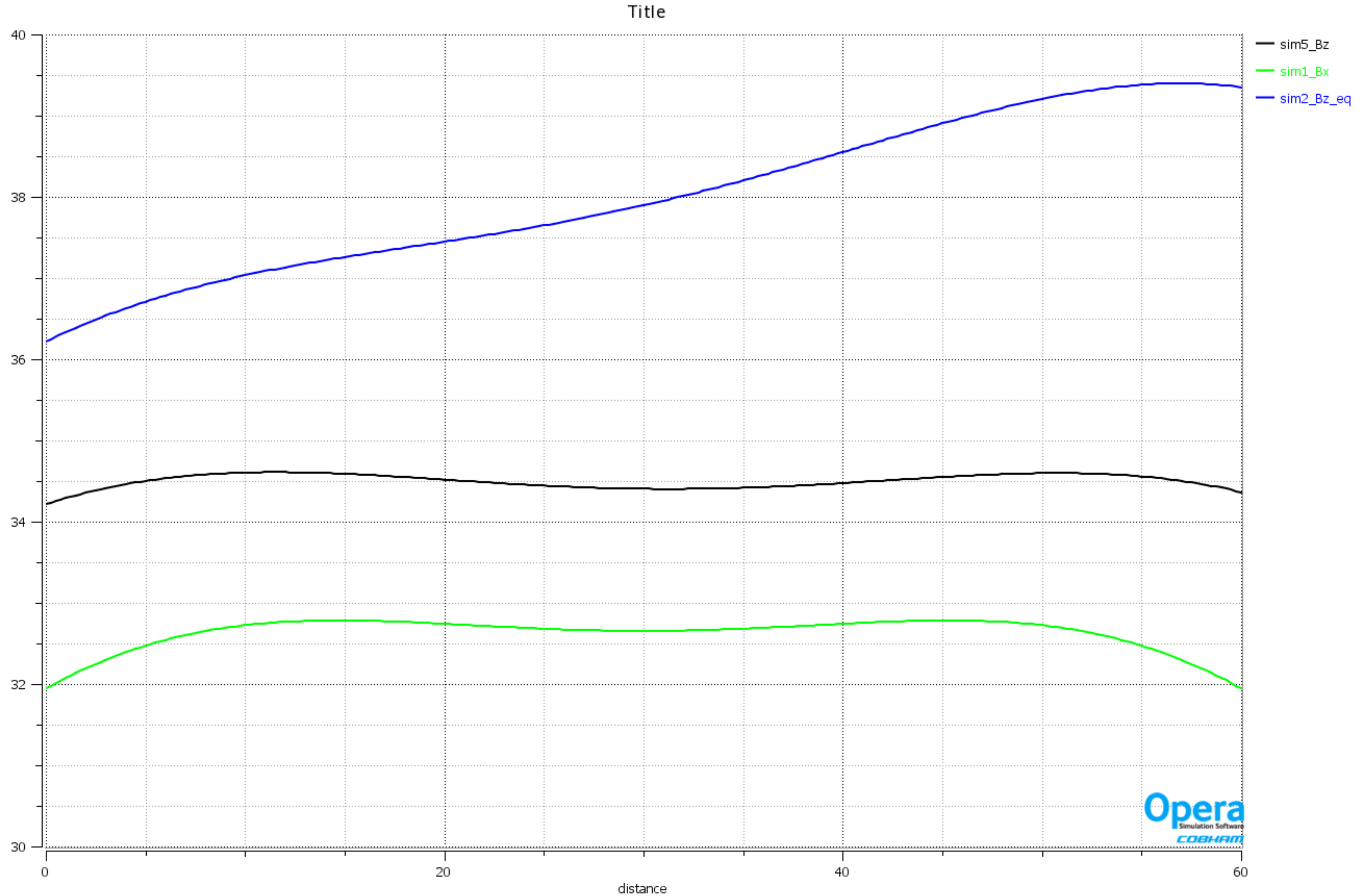
Total torque on upstream Bz coil = 75.5, -718.4, -45.6 N cm

Temple coil set III



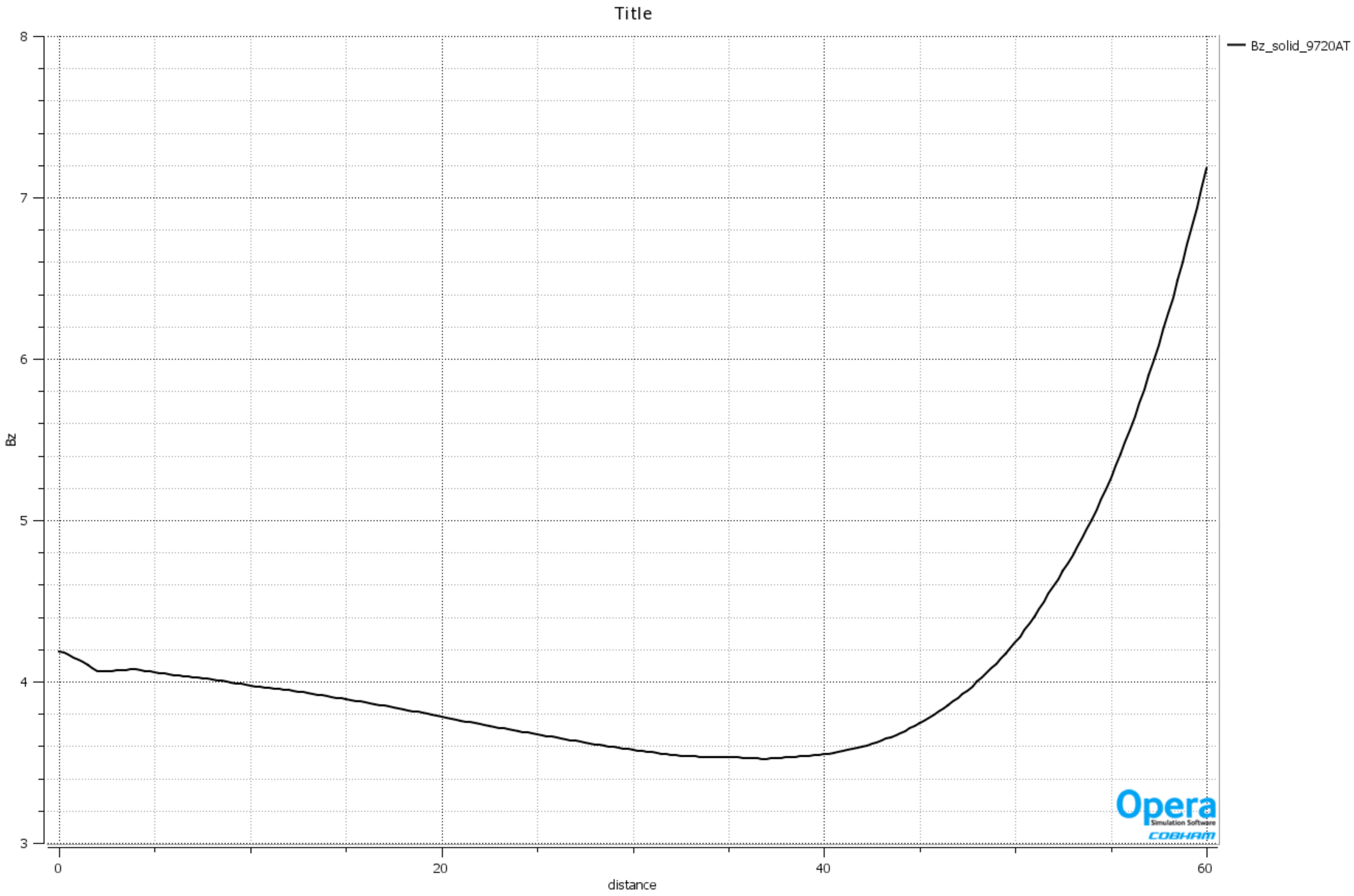
Bz on 40 cm radius cylinder offset 15 cm vertically.
Upstream 2890 AT, downstream 82.5%

Temple coil set fields along axes IV



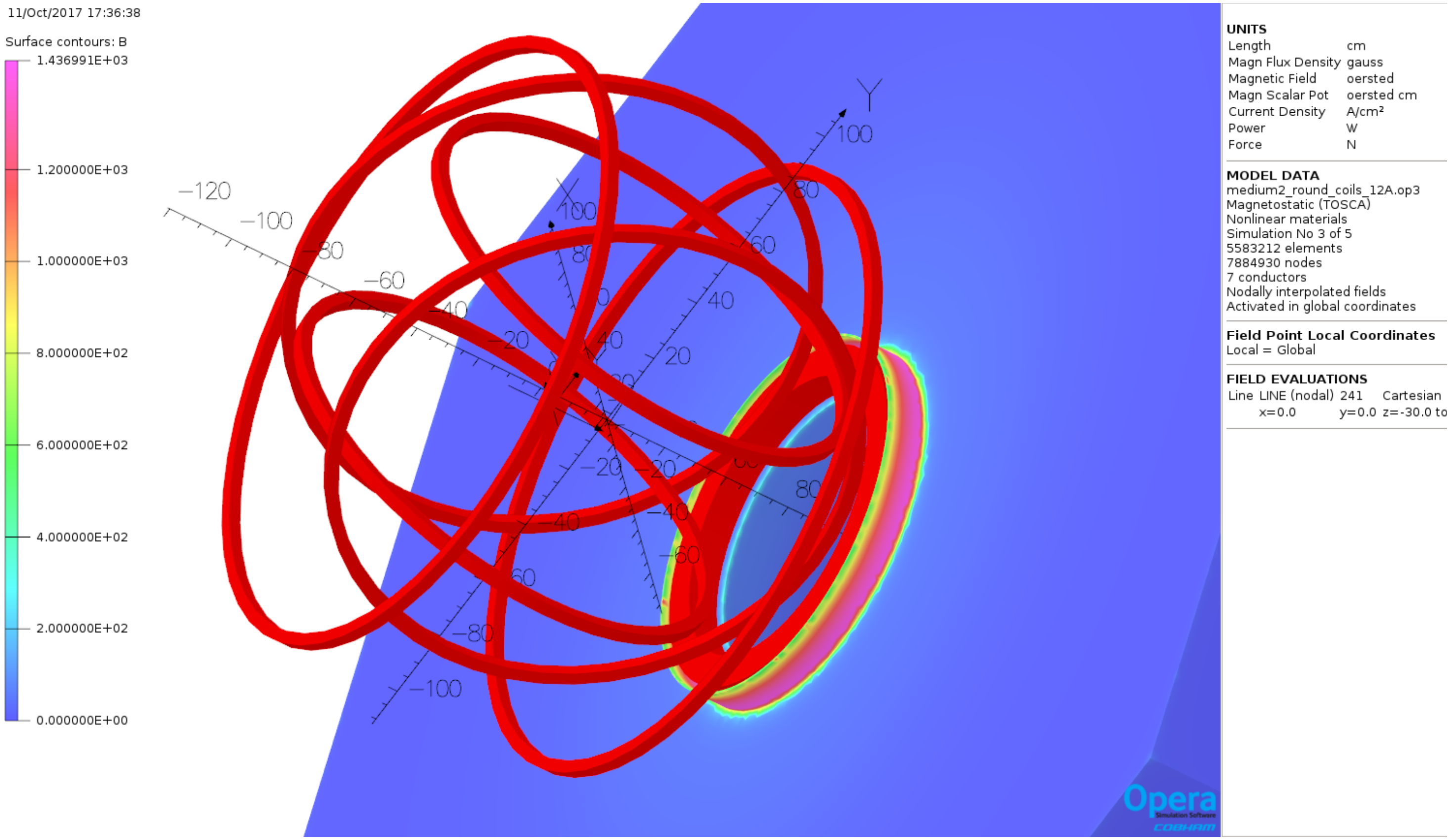
Blue line is Bz coils with 2890 AT in each
Black line has upstream Bz 2890 AT, downstream at 82.5% of 2890 AT
Green line is Bx coil set with 2317 AT

Field exiting SoLID



Bz field from SoLID with 9720 AT in compensation coil, Z=[-380,-320]

Proposed round coil set I



Bz coils with 2880 AT. Magnetization of ring around compensation coil symmetric: no vertical offset. X and Y coils offset 10 cm vertically. Inner pair By R 62.46, middle Bx R 70.26, outer Bz R 85.26. Forces and torques on Bz coils (x,y,z). Z torques zero as coils NOT offset.

Torques calculated with respect to (0,0,0).

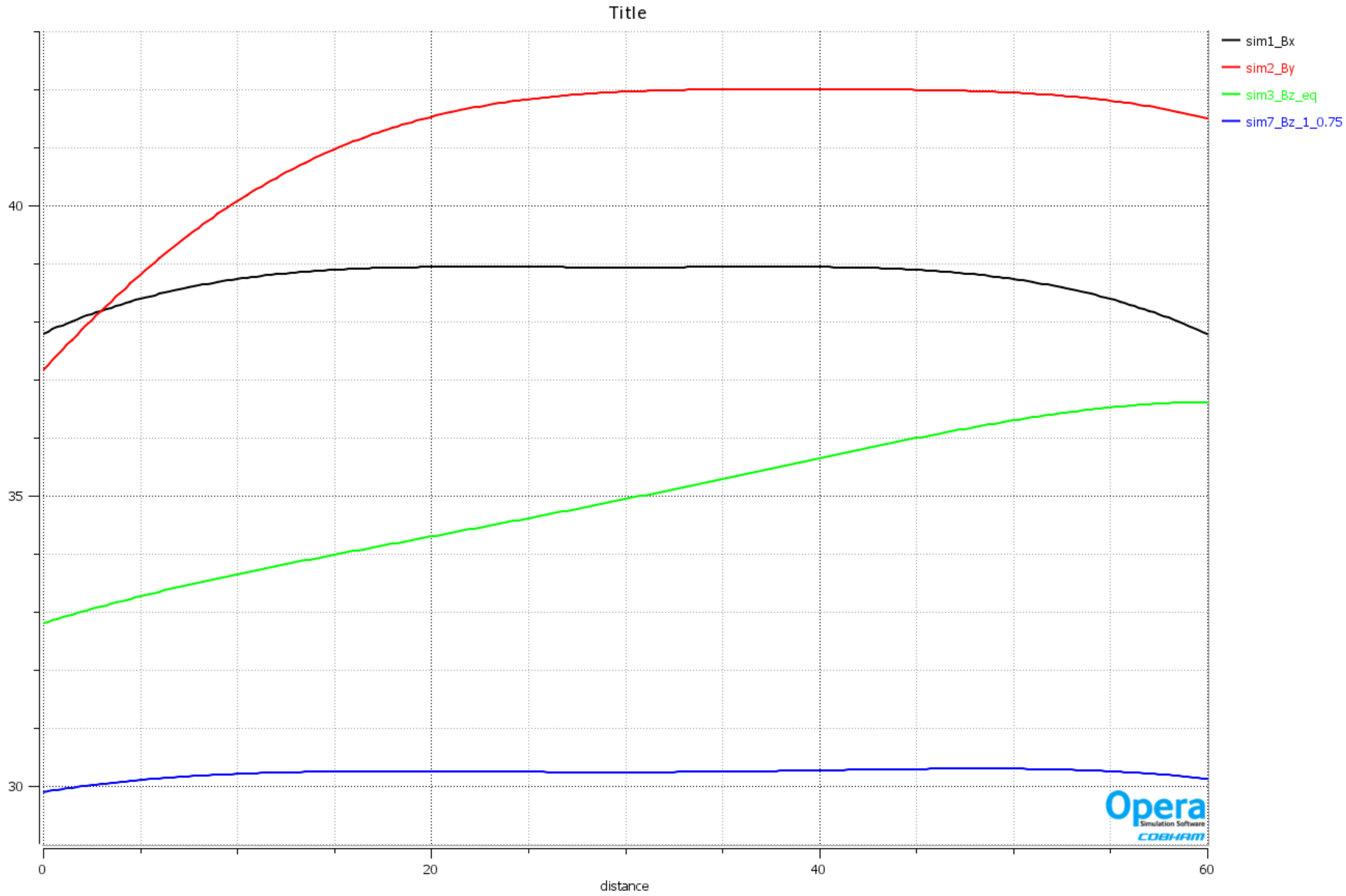
Total force on downstream Bz coil = 5.1, -18.6, -9.2 N

Total torque on downstream Bz coil = 1888.2, 318.8, 0 N cm

Total force on upstream Bz coil = -10.4, -4.8, 33.9 N

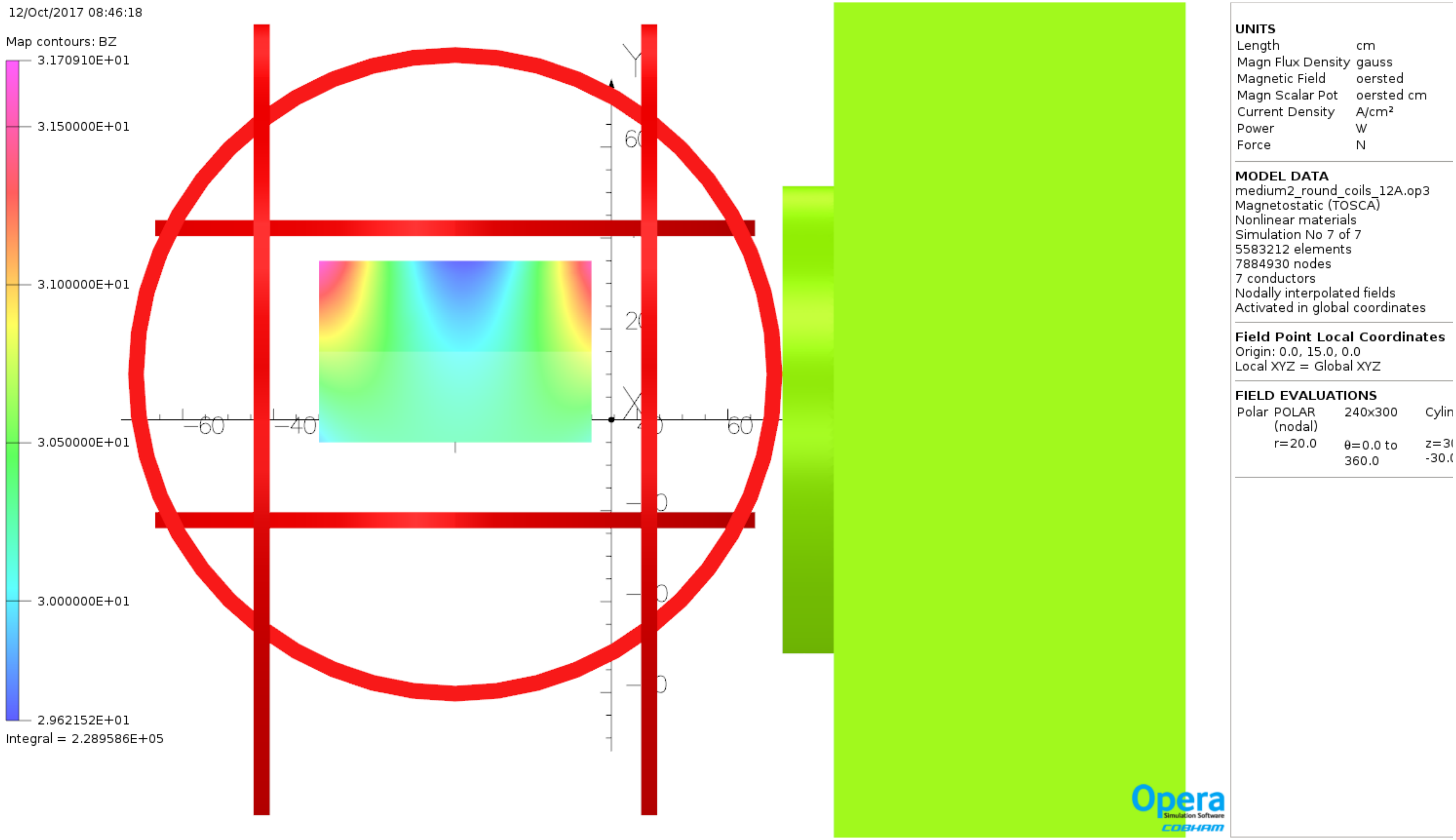
Total torque on upstream Bz coil = 137.8, 138.1, 0 N cm

Proposed round target coils II



B along axes (Bx along x axis, etc) with 2880 AT in each coil except blue Bz, with 2880 AT upstream and (75%) 2160 AT downstream
By (red) not symmetric as x,y coils offset 10 cm vertically.
Black Bx set, green symmetric Bz set.

Proposed round target coils III

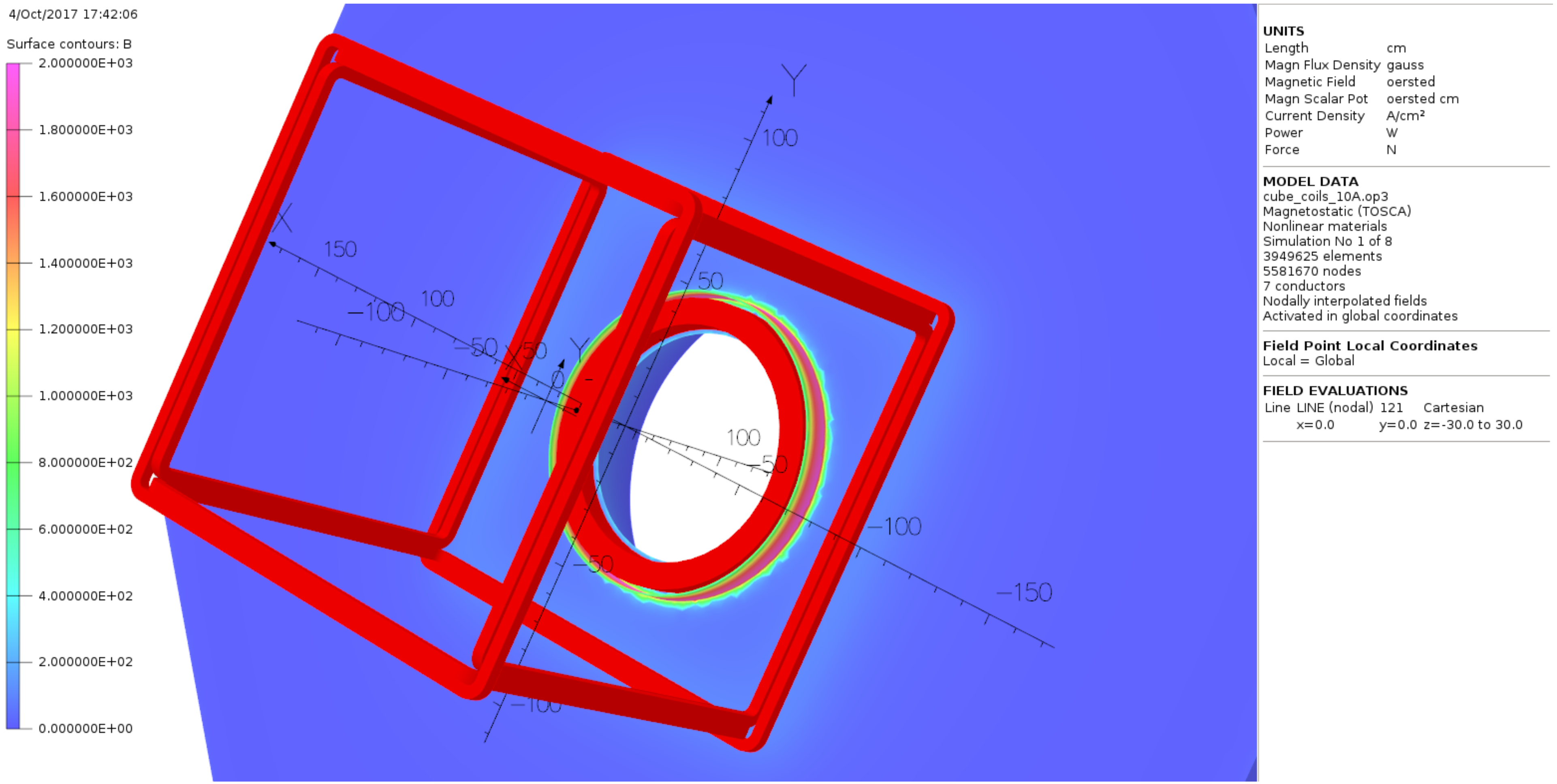


Side view. Bz on 40 cm diameter, 60 cm long cylinder, offset 15 cm vertically, sim7.
Bz with 2880 AT upstream and (75%) 2160 AT downstream
Minimal clearance between Bx coils and steel at right but OK in 3D.
Bx and By coils offset +10 cm.

Comparing round coil sets

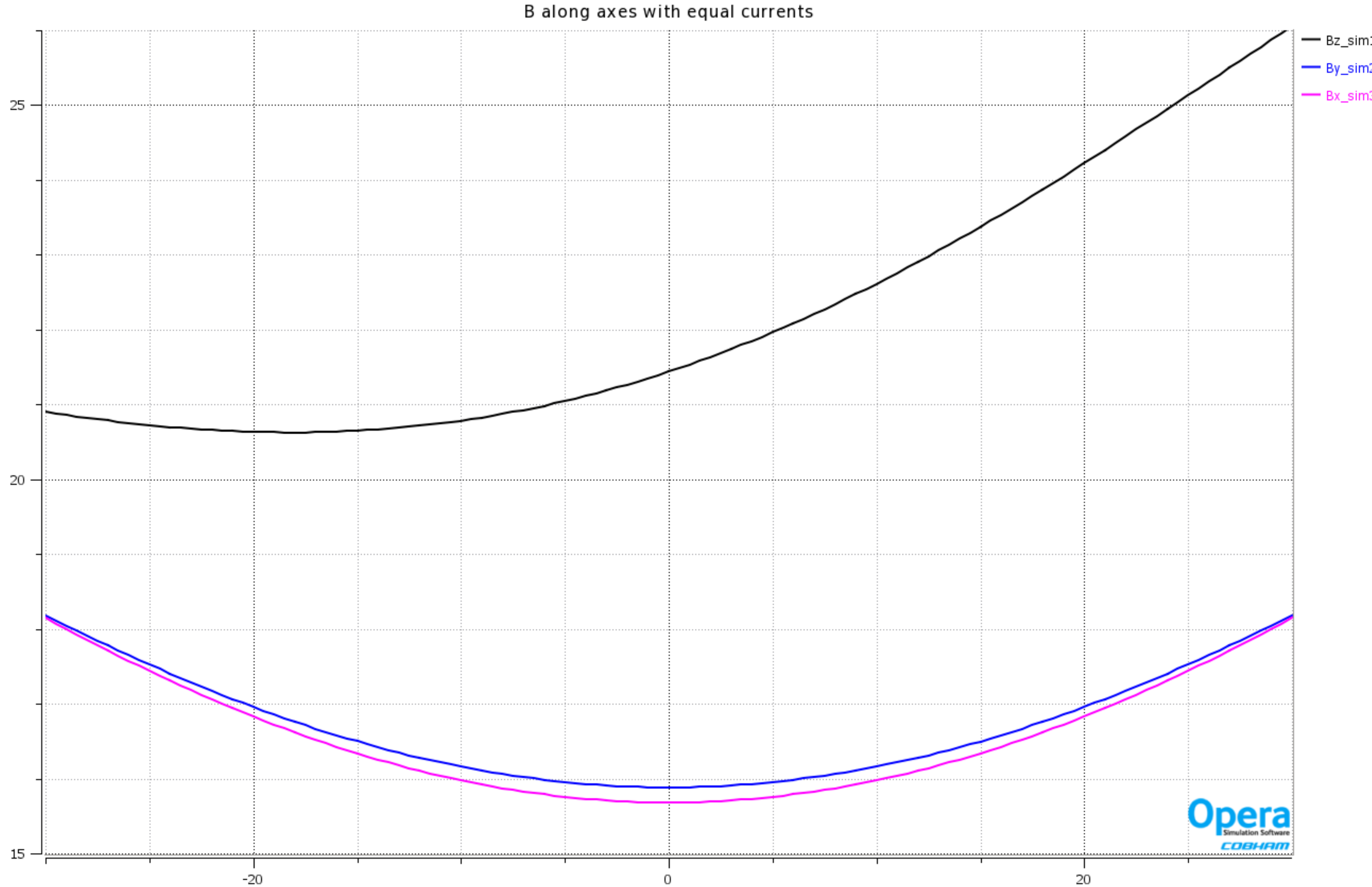
- Existing coil set fits.
- Mean radii: Temple Bx 66.8 cm, Bz 75.8 cm
- Mean radii new: Bx 70.3 cm Bz 85.3 cm By 62.6 cm
- Temple offset vertically 15 cm, proposed new 10 cm given larger radii in x, z.

He3 cube coils I



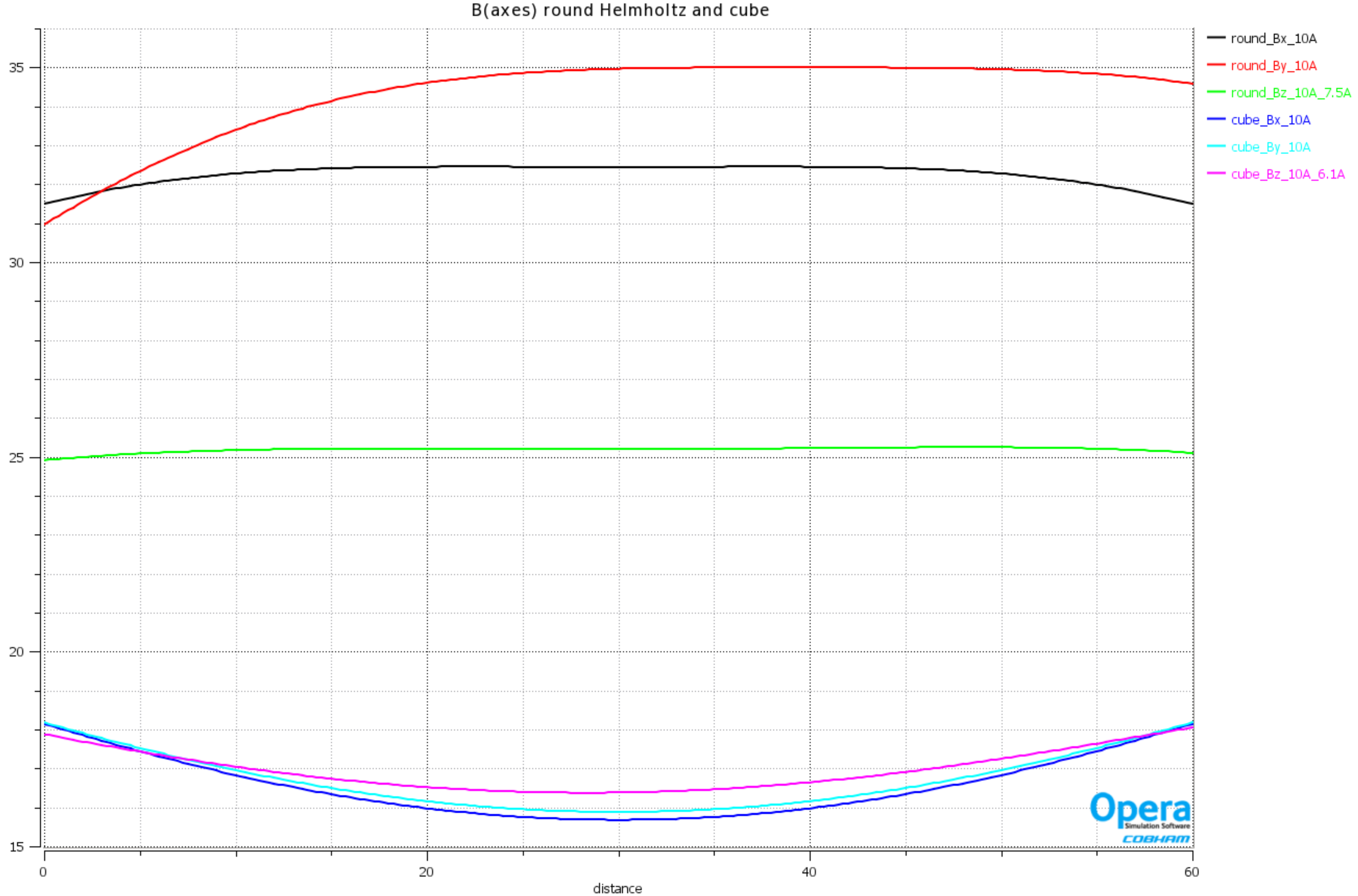
4.4 decades ago I learned from George J Schulz (Yale, dec.) that coils on the surface of a cube work almost as well as a Helmholtz set. They provide much better access.

He3 cube coils II



B along axes (Bx along x axis, etc) with 2400 AT in each coil. Z (black) higher close to steel. Lower B amplitude due to larger volume with fixed AT.

Comparing round vs cube



Comparing round (top) with cube (bottom). Transverse coils all have 2400 AT.
Z coils have 2400 AT upstream. Z downstream 1800 AT round, 1472 AT square.

He3 target coils conclusions

- If three existing target coils are used to set (Bx, By, Bz) they interfere with the compensation coil needed to flatten the Bz field from the hole in coil plug.
- Three options have been shown which do fit including existing (Bx, Bz) pair.
- All coils interact strongly with the SoLID steel.
- Something between round and cube may be a useful compromise between field flatness and access.
- I did not (and don't intend to) look at the interaction of He3 coils with HB (A1N) or BigBite. Since these are at an angle to hall axis, things will get interesting.

Engineering notes

- All coils designed to interface with 20A/75V trim supplies.
- Cooling: simple air convection.
- Single large compensation solenoid 9720AT in #8 square aluminum (lower activation) or copper. 650 turns, 25 turns in 26 layers.
- Proposed round Bx, By coils #12 square Cu, 240 turns, 15 turns in 16 layers. Weight ~50 kg. Bz #10 square Cu, 75 kg
- Cube coils #10 square Cu, 240 turns, 15 turns in 16 layers to allow 31 G at 20A in large volume. Shrink the cube slightly to get higher fields. Coils ~90 kg each.