Design of the MOLLER Hybrid Torus

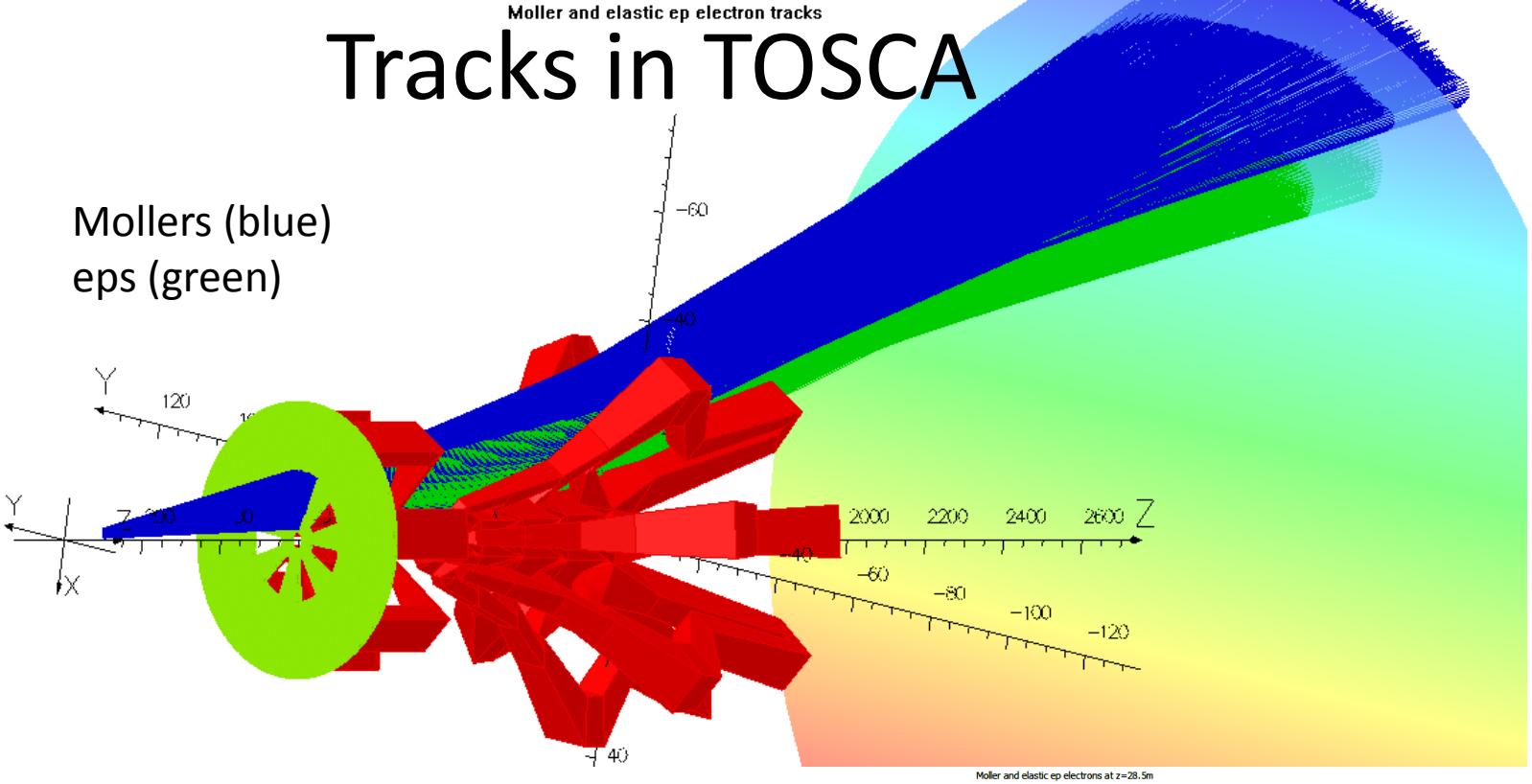
Juliette M. Mammei

Work since the proposal

- "Verified" the proposal model *a la* TOSCA
- Actual conductor layout
  - Execute layout using TOSCA modeller
  - "tweak" the layout (keep out zones)
- Create a blocky model of actual layout
  - Use to test gross modifications to overall design to improve optics (in progress)
  - Scans with different field factors and z locations
- Start thinking about water cooling and mechanical supports (present stage)

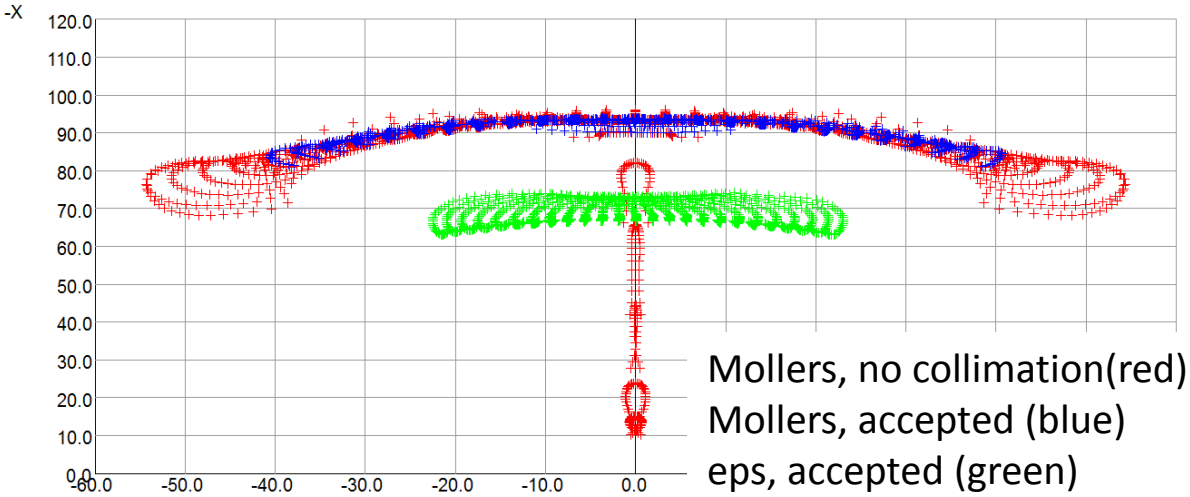
Tracks in TOSCA

Mollers (blue)
eps (green)



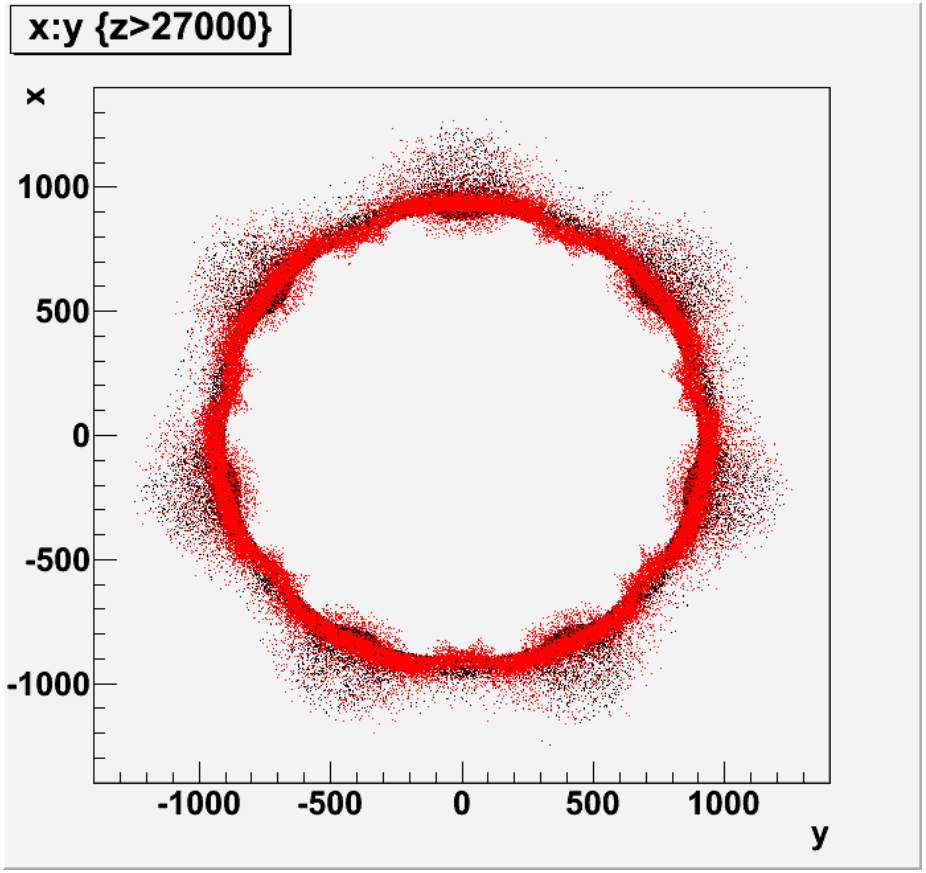
Not using the mesh
- "coils only" calculation fast enough on my machine

- Actual layout much slower – use blocky version or improve mesh



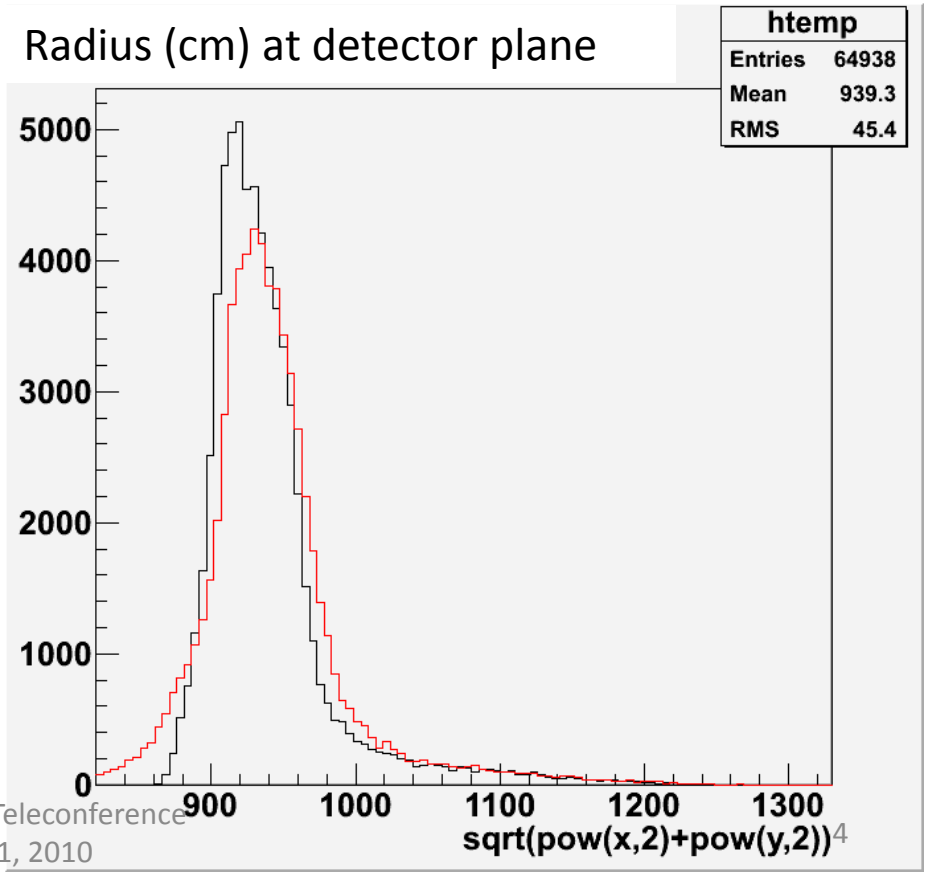
Mollers, no collimation(red)
Mollers, accepted (blue)
eps, accepted (green)

GEANT4 Simulations



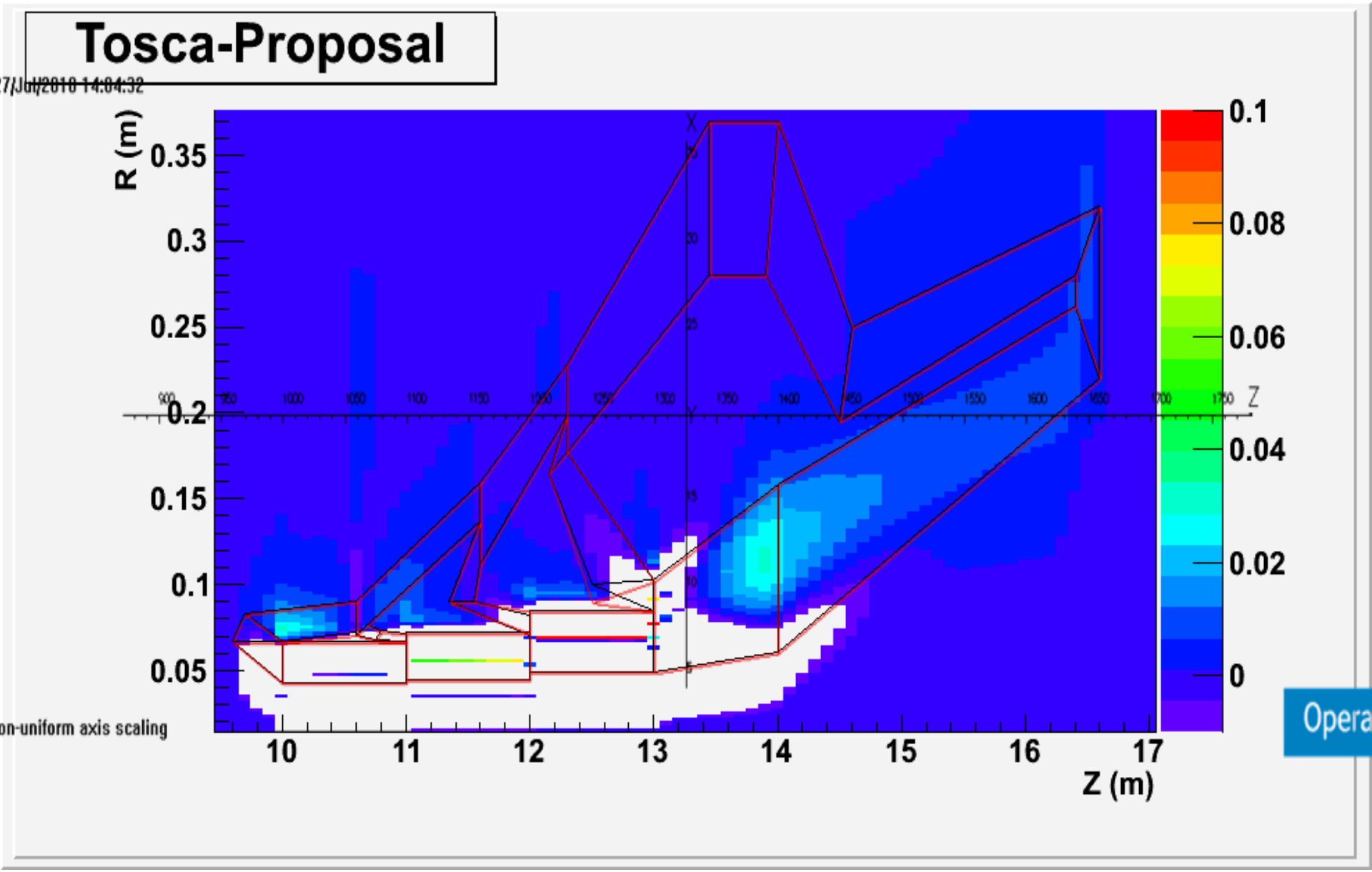
Comparisons of the proposal map (black) and TOSCA version (red) from Mark's simulations using the same collimation, etc. for both maps

Radius (cm) at detector plane

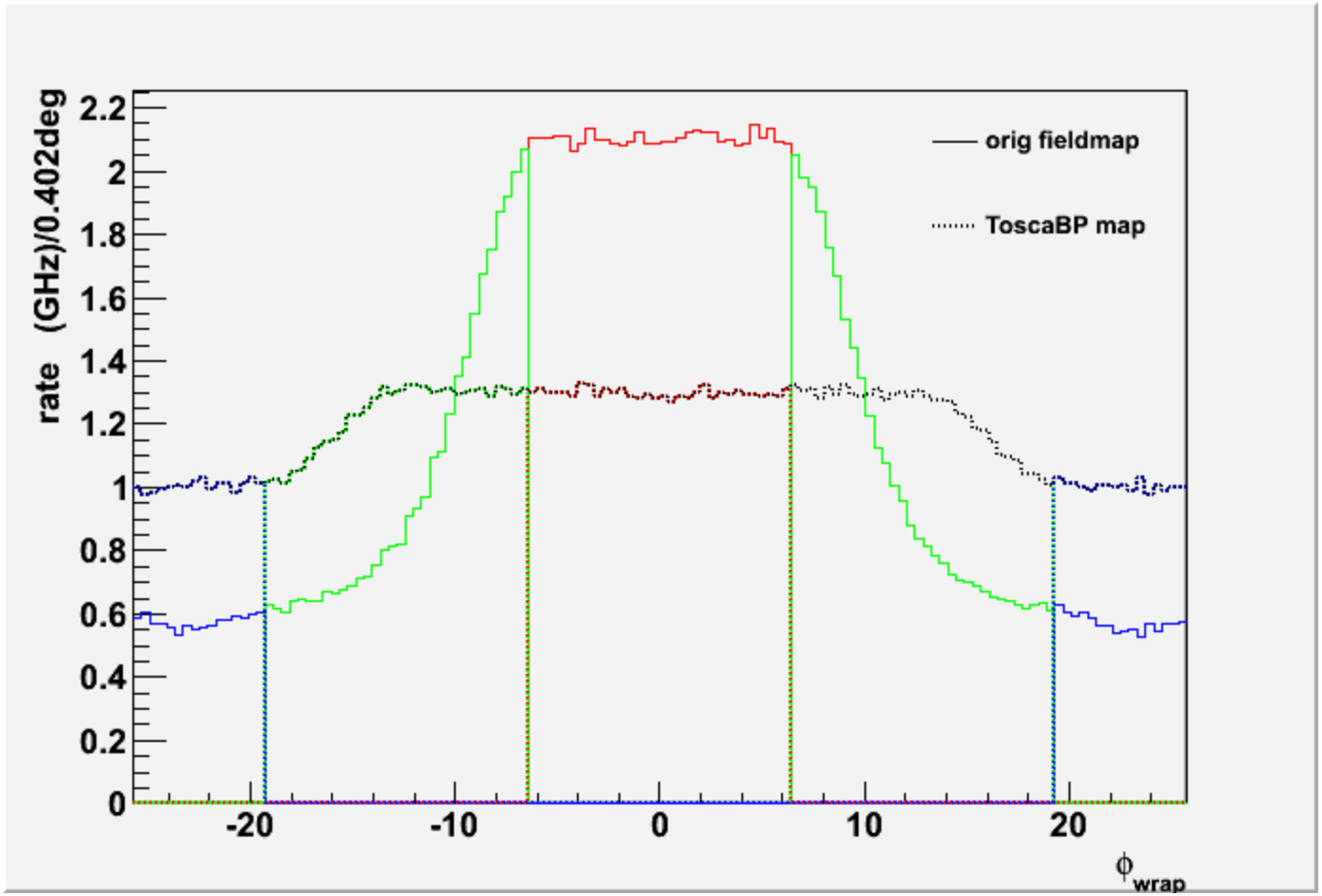


GEANT4 makes it possible to implement energy loss in target, radiative effects, collimation, etc. much more easily

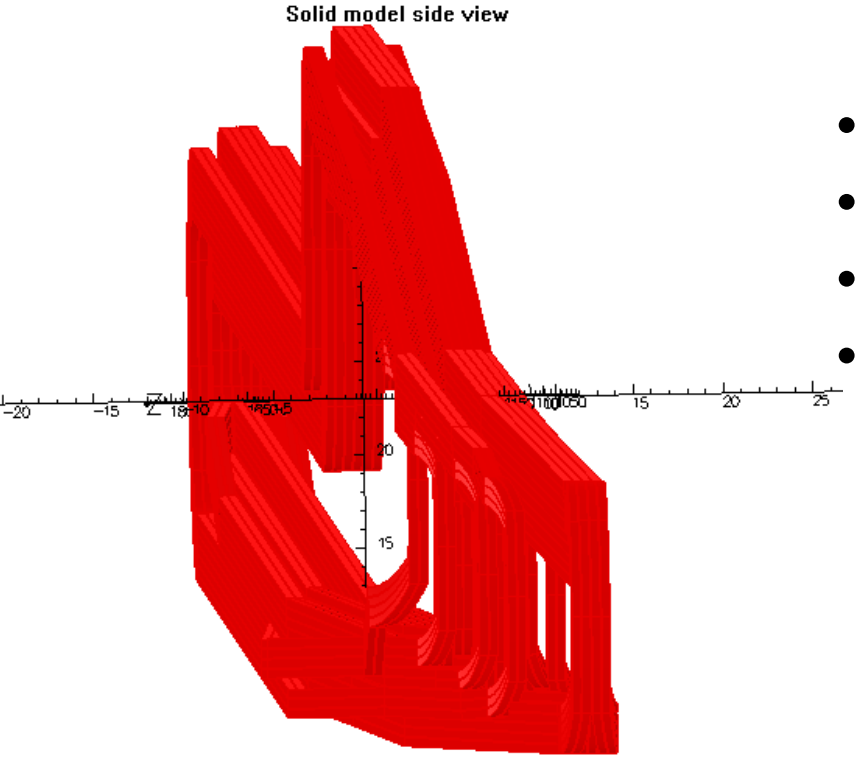
Comparing Map from TOSCA with Proposal



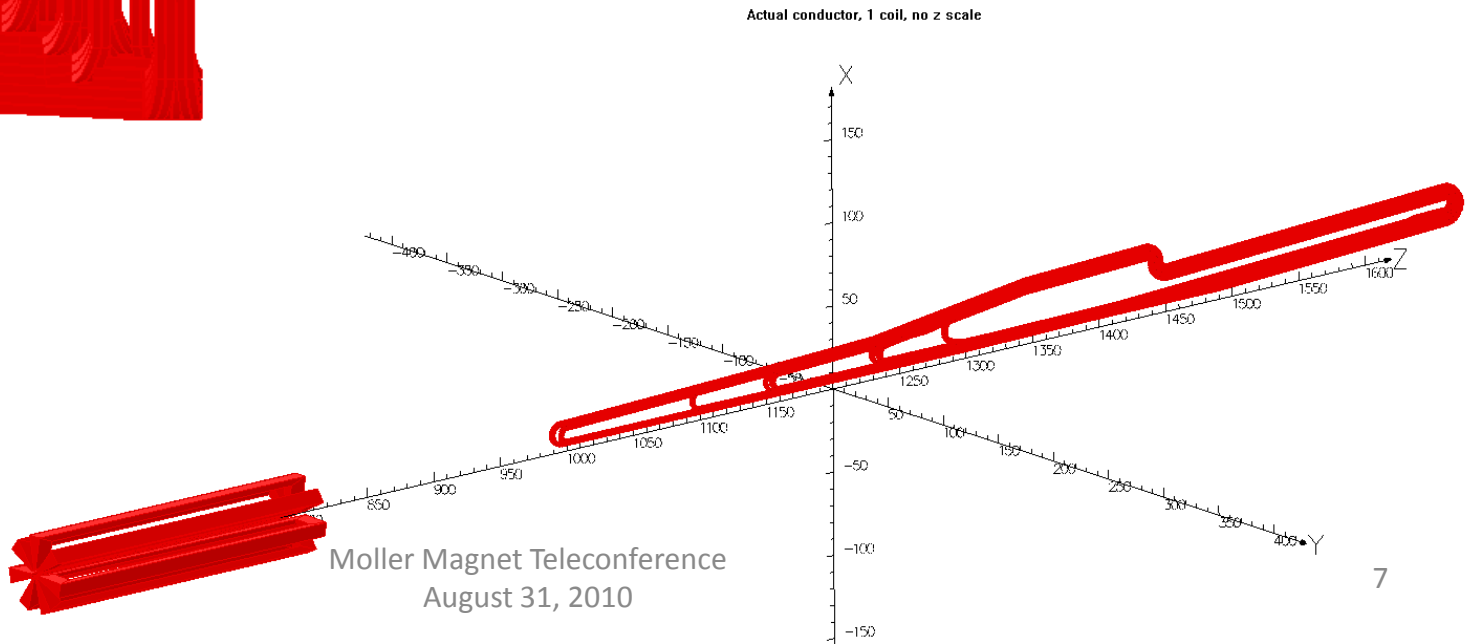
Phi defocusing, TOSCA version of the Proposal



Actual Conductor Layout



- Description of concept
- Pictures of actual conductor layout
- Comparison to proposal model
- GEANT4 simulation results

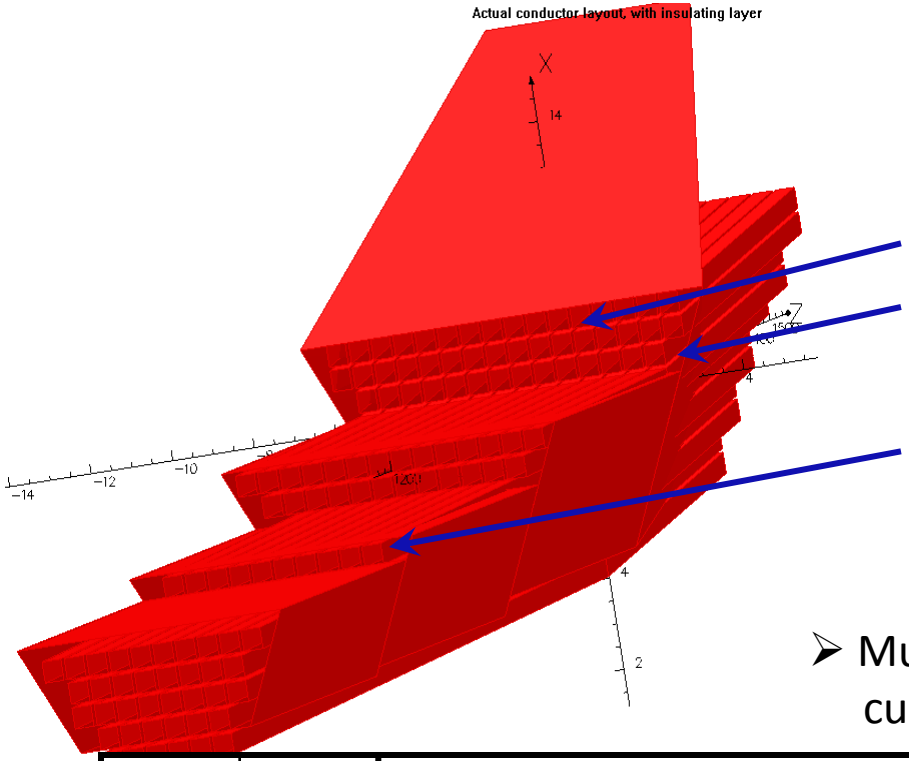


Concept 1 – Choose constraints

- Try to use “double pancakes” structure
- Choose (standard) conductor size/layout minimizes current density
- Keep individual double pancakes as flat as possible
- Fit within radial, angular acceptances (360/7° at low radius and <360/14° at larger radius)
- Total current in each inner “cylinder” same as proposal model
- Take into account water cooling hole, insulation
- Need to consider epoxy backfill and aluminum plates/ other supports?

➢ Radial extent depends on upstream torus and upstream parts of hybrid!!

Conductor Size



Need to “fill” the available space at low radius

Trade-off between more insulation for smaller conductor and losing space at the “edges” with larger conductor

Also need to fit all the conductor in a particular radius at a given z location

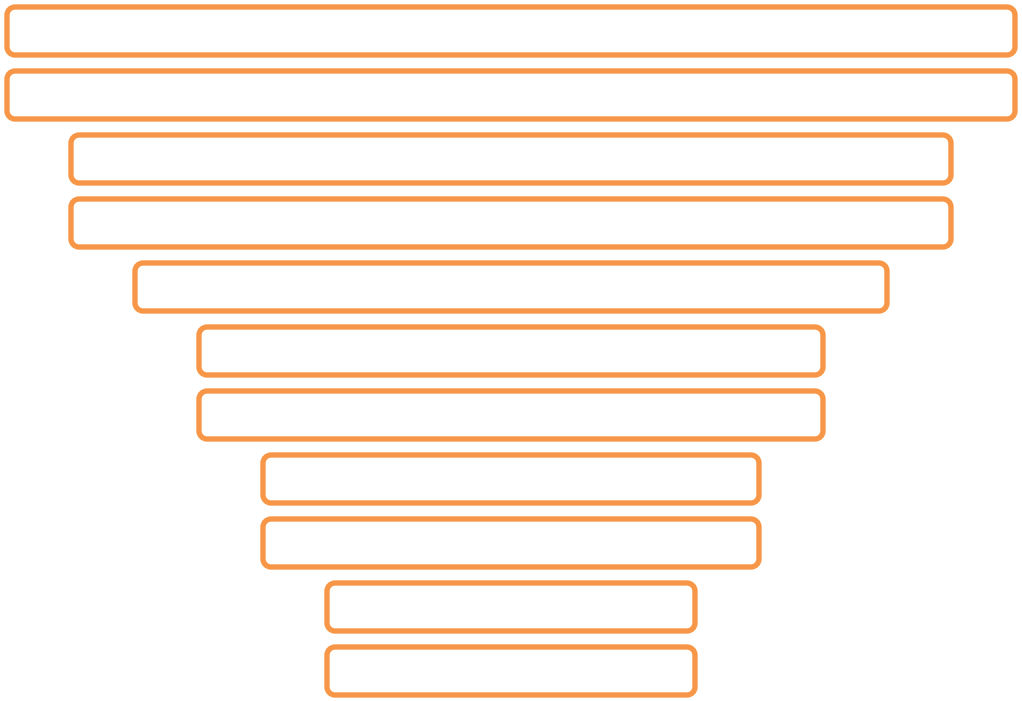
- Much bigger conductors have even higher current densities because of “edge” effects

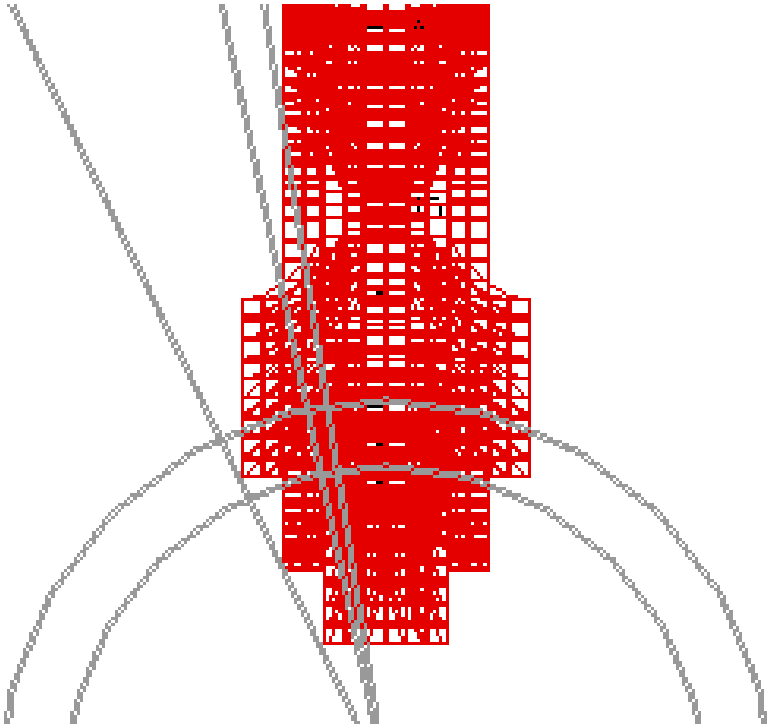
OD (cm)	A_{cond} (cm^2)	Total # Wires				Current (A)				Current per wire	J (A/cm^2)
		X	Y	Z	A	X	Y	Z	A		
Proposal		---	---	---	---	7748	10627	16859	29160	---	~810*
0.4115	0.1248	40	54	86	146	7989	10785	17176	29160	200	1600
0.4620	0.1568	32	44	70	120	7776	10692	17010	29160	243	1550
0.5189	0.1978	26	36	56	94	8066	11168	17372	29160	310	1568
0.5827	0.2476	20	28	44	76	7674	10743	16882	29160	384	1549

Concept 1

Using conductor size and general layout, try to:

- use double-pancake structure
- maintain symmetry
- change the cross section from low to high radius





A - 11	14 16 16
Z - 8	12 14
Y - 6	10
X - 5	6 6 8 8 10

Concept 1

Using conductor size and general layout, try to:

- use double-pancake structure
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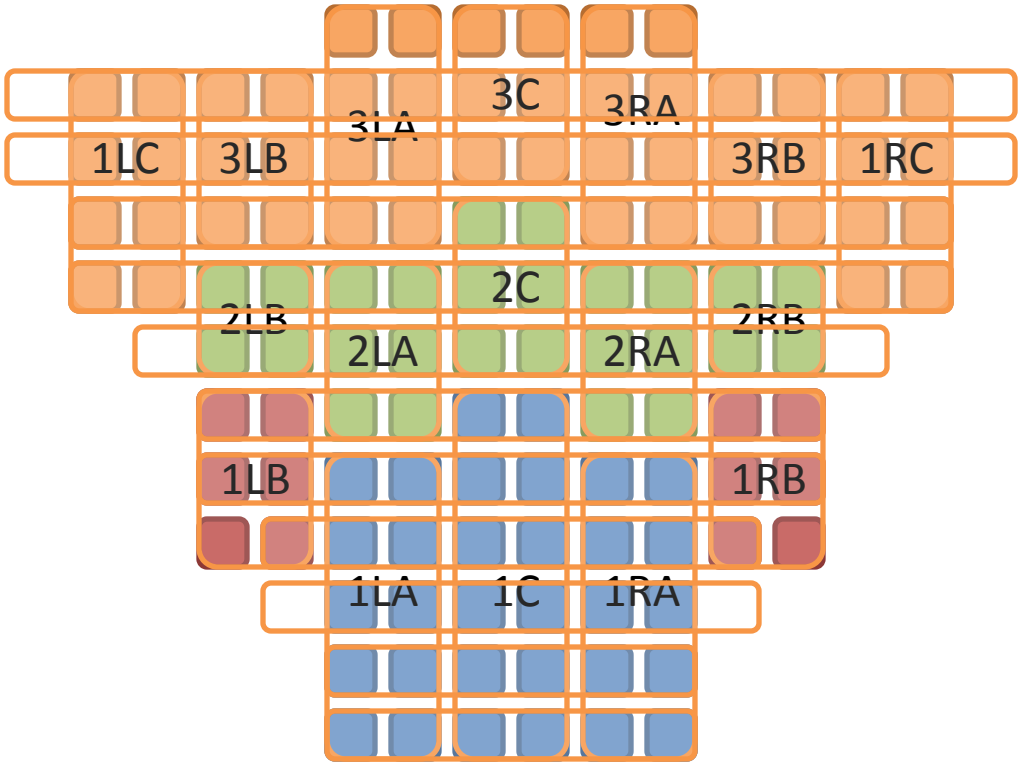
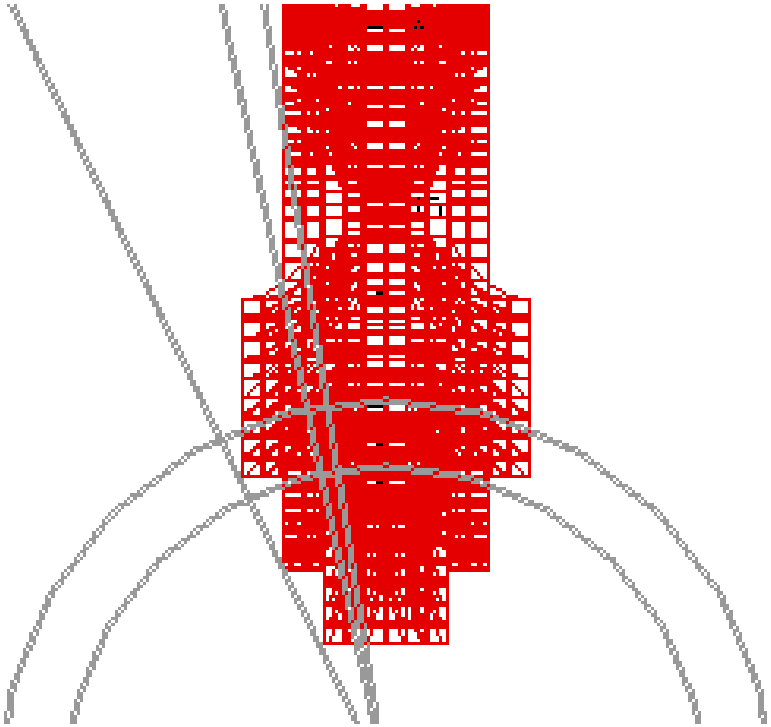
- change the cross section from low to high radius





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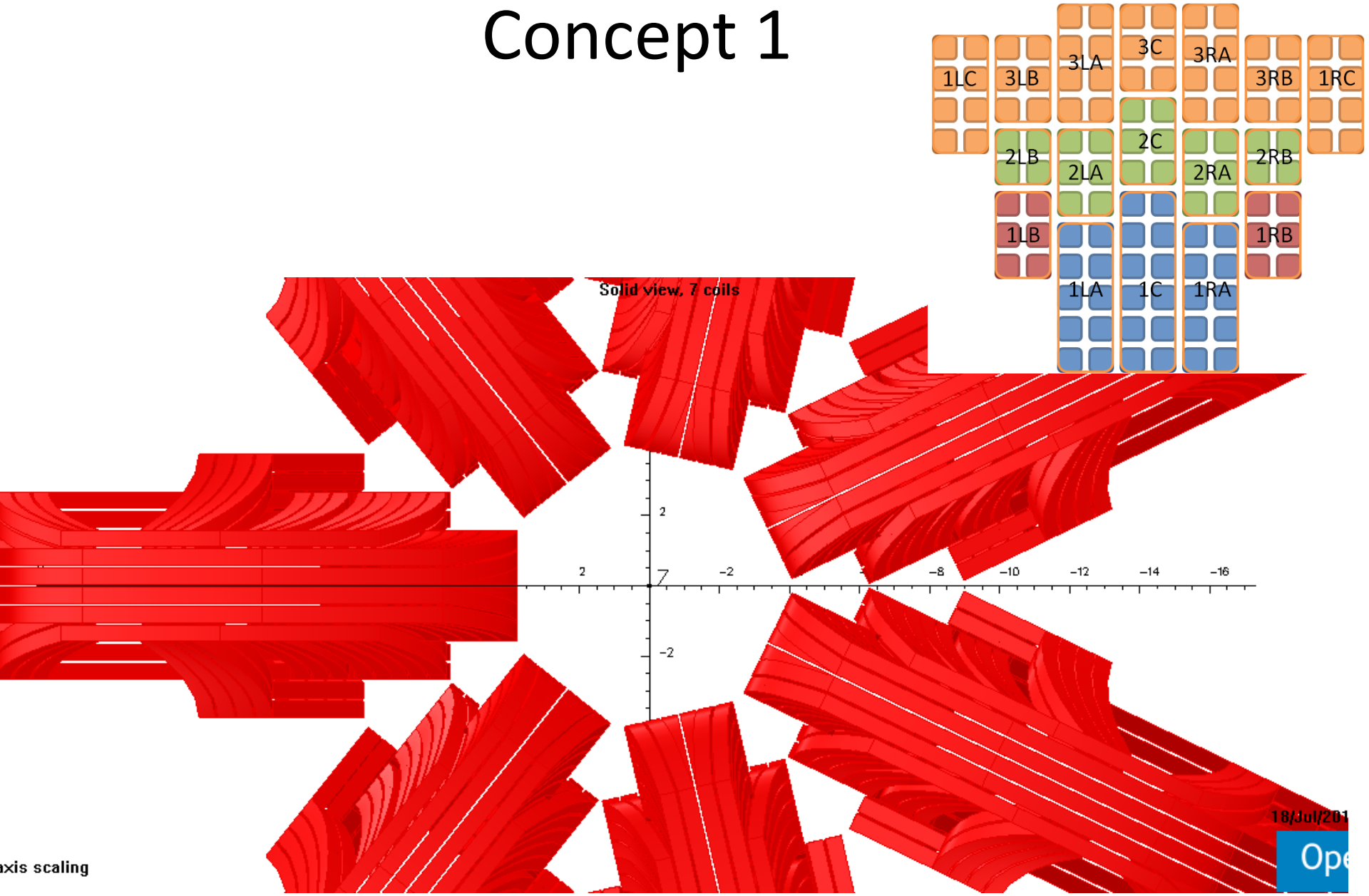
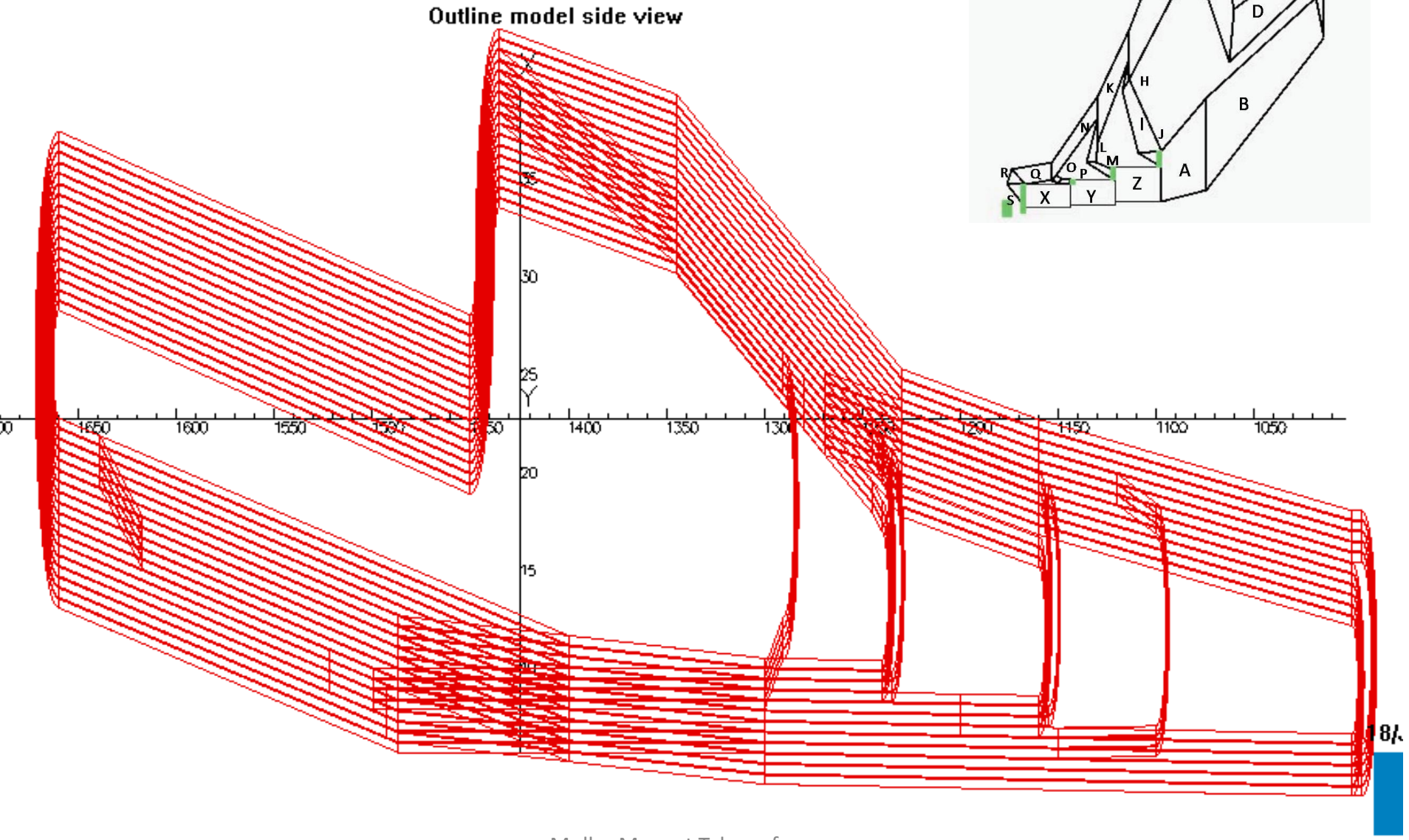
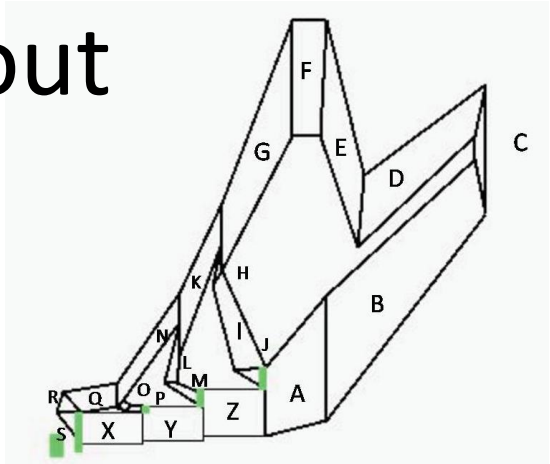
Concept 1

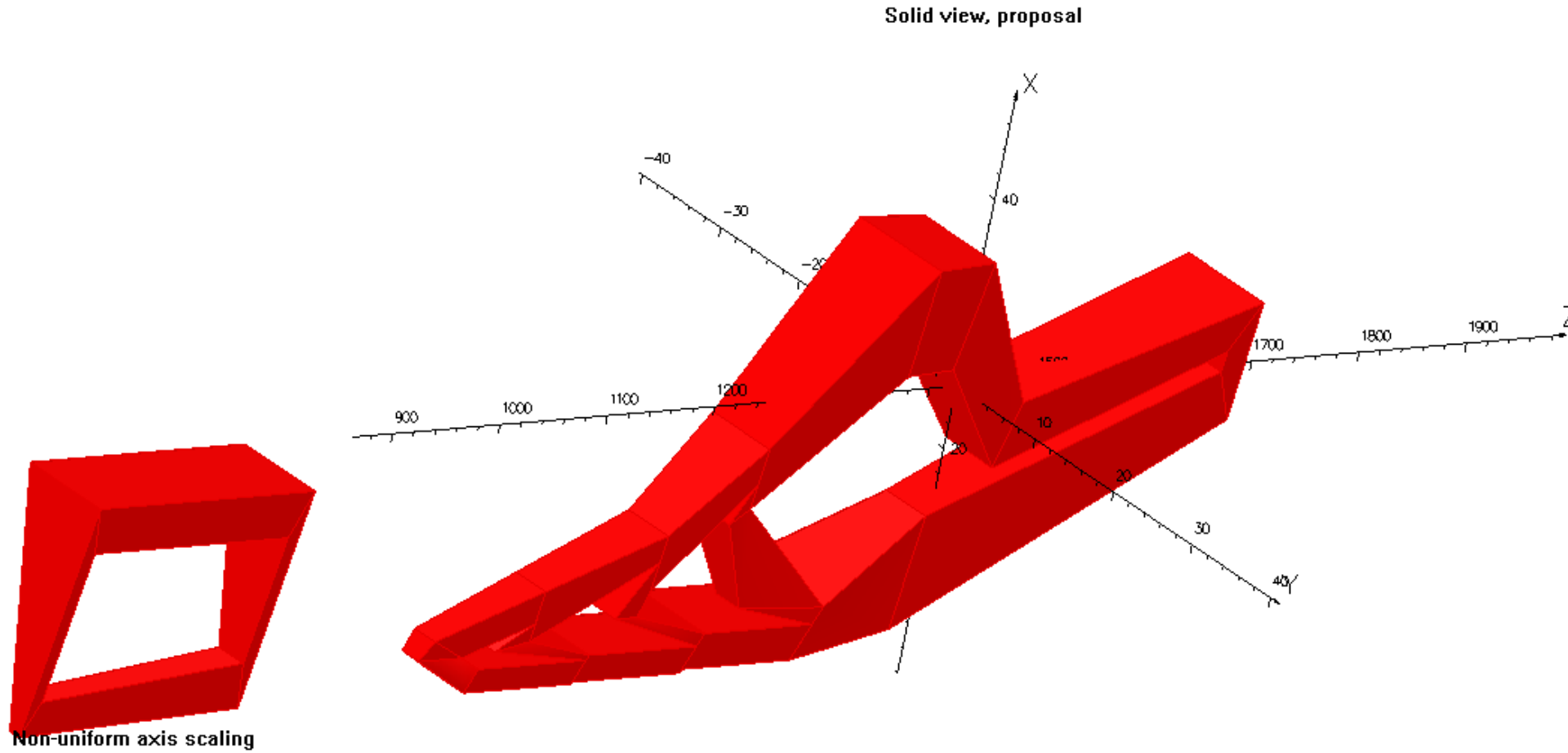

1LC
3LB
3LA
3C
3RA
3RB
1RC
2LB
2LA
2C
2RA
2RB
1LB
1LA
1C
1RA
1RB
Solid view, 7 coils
2
-2
-8
-10
-12
-14
-16
-2
18/Jul/201
axis scaling

Actual conductor layout

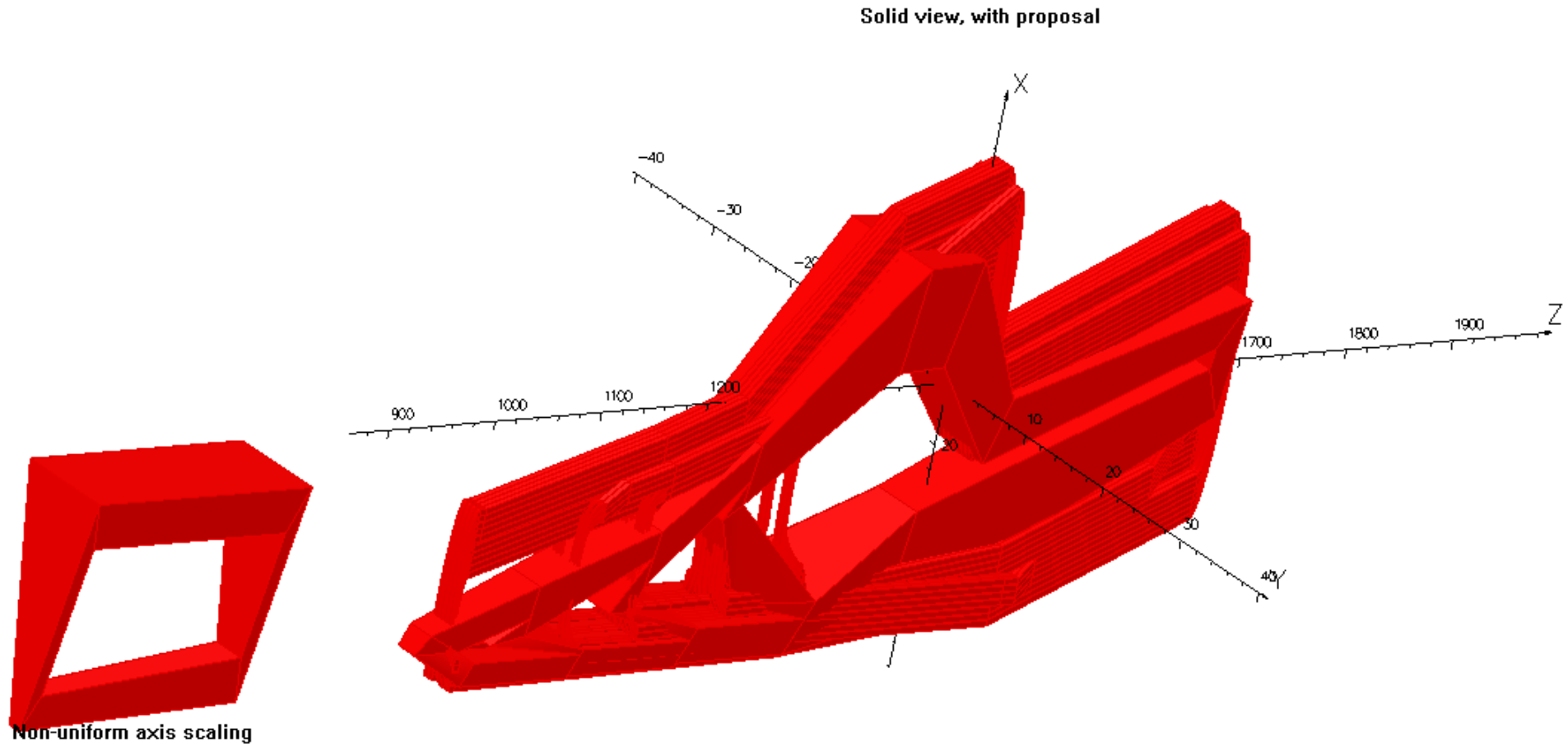




Proposal Model in TOSCA



Actual conductor layout



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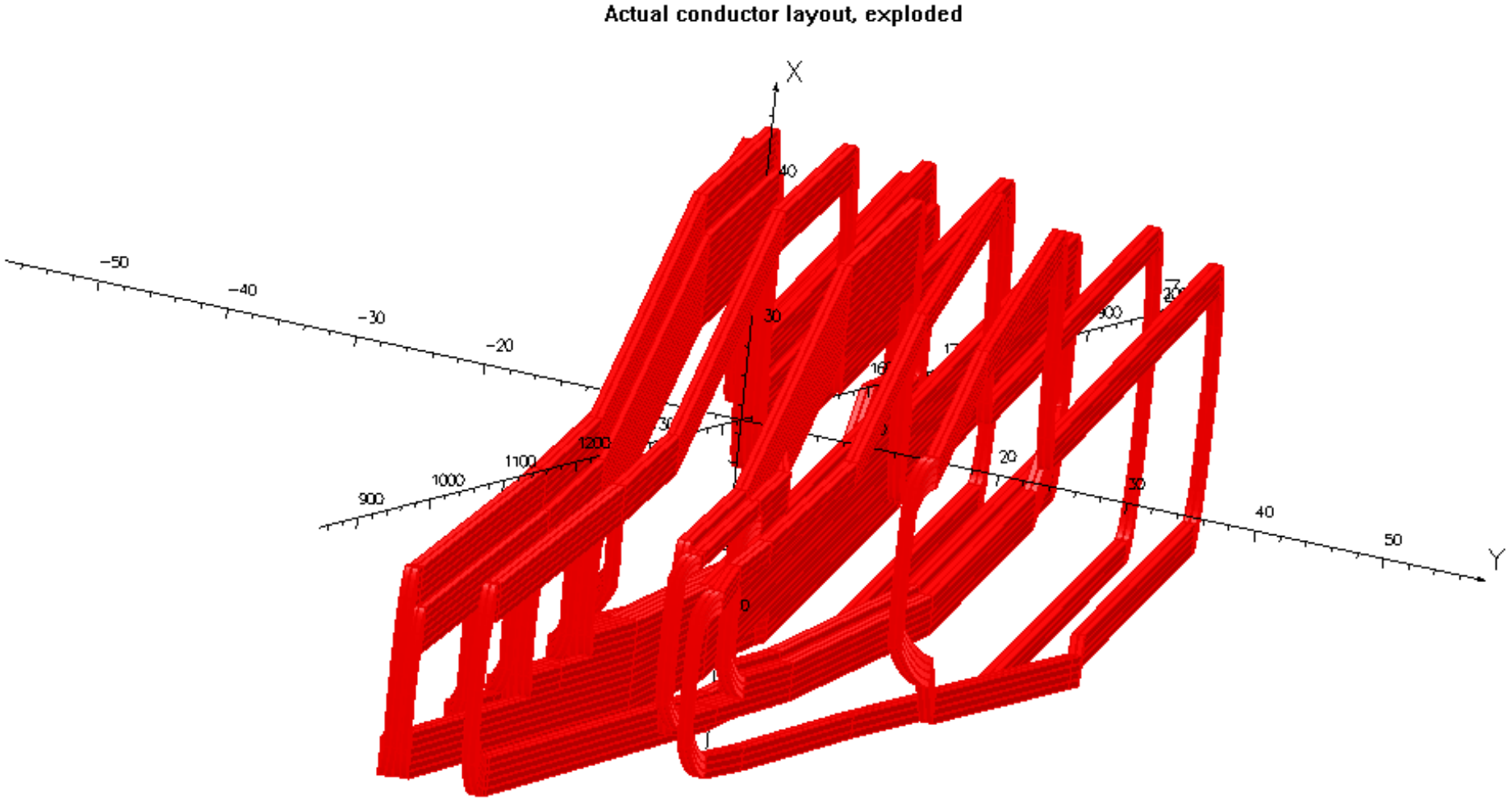
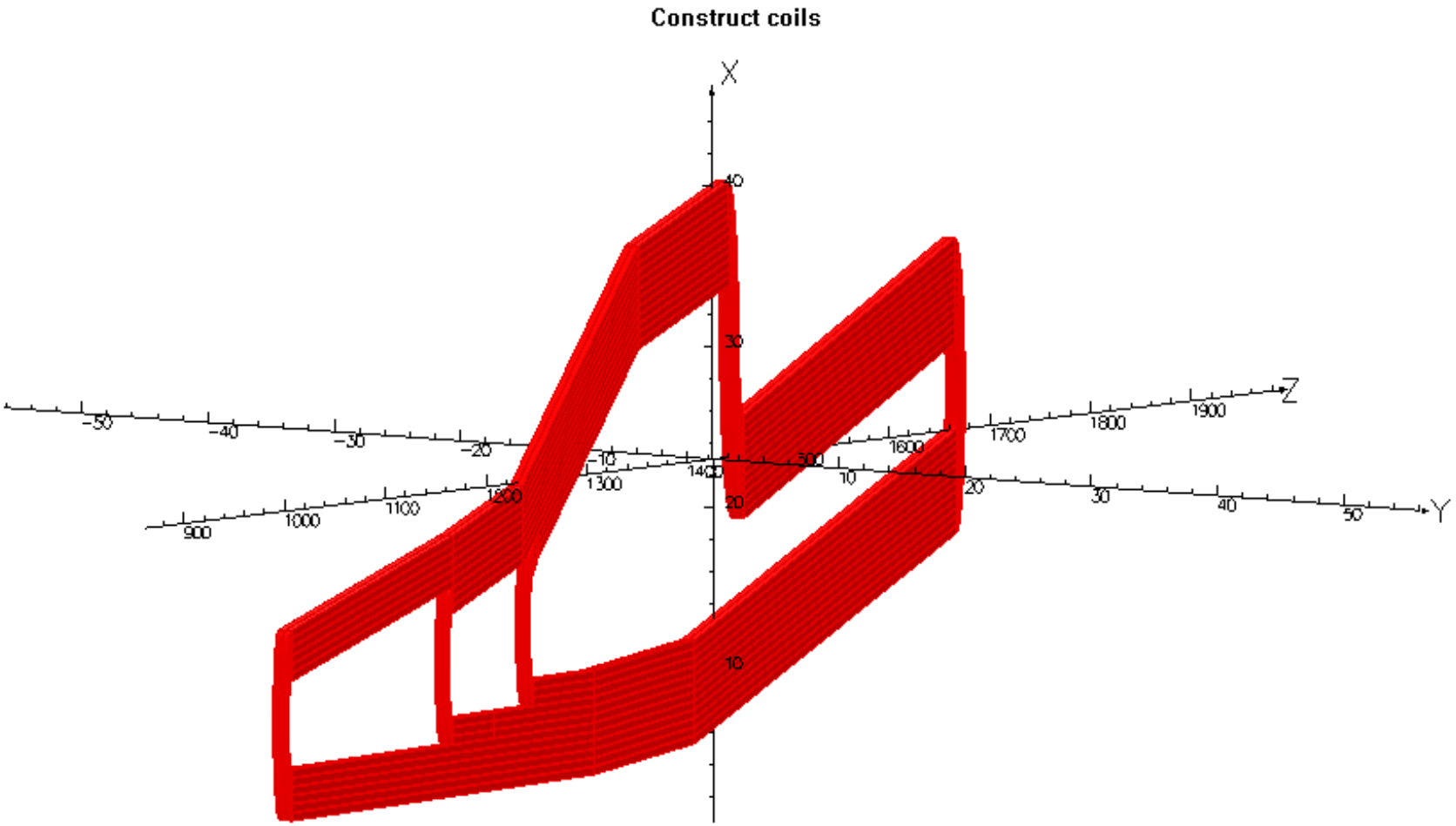


Actual conductor layout



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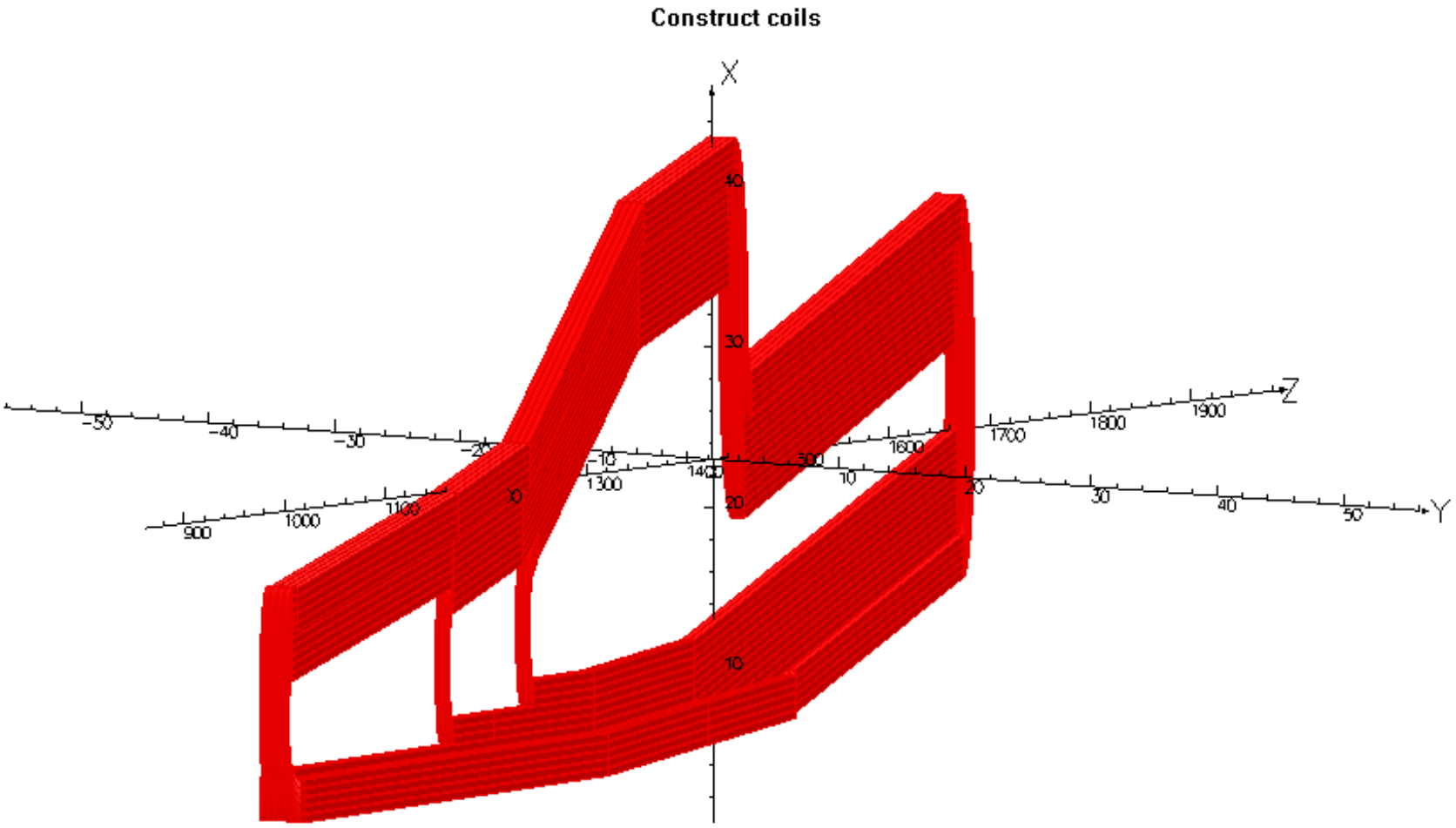

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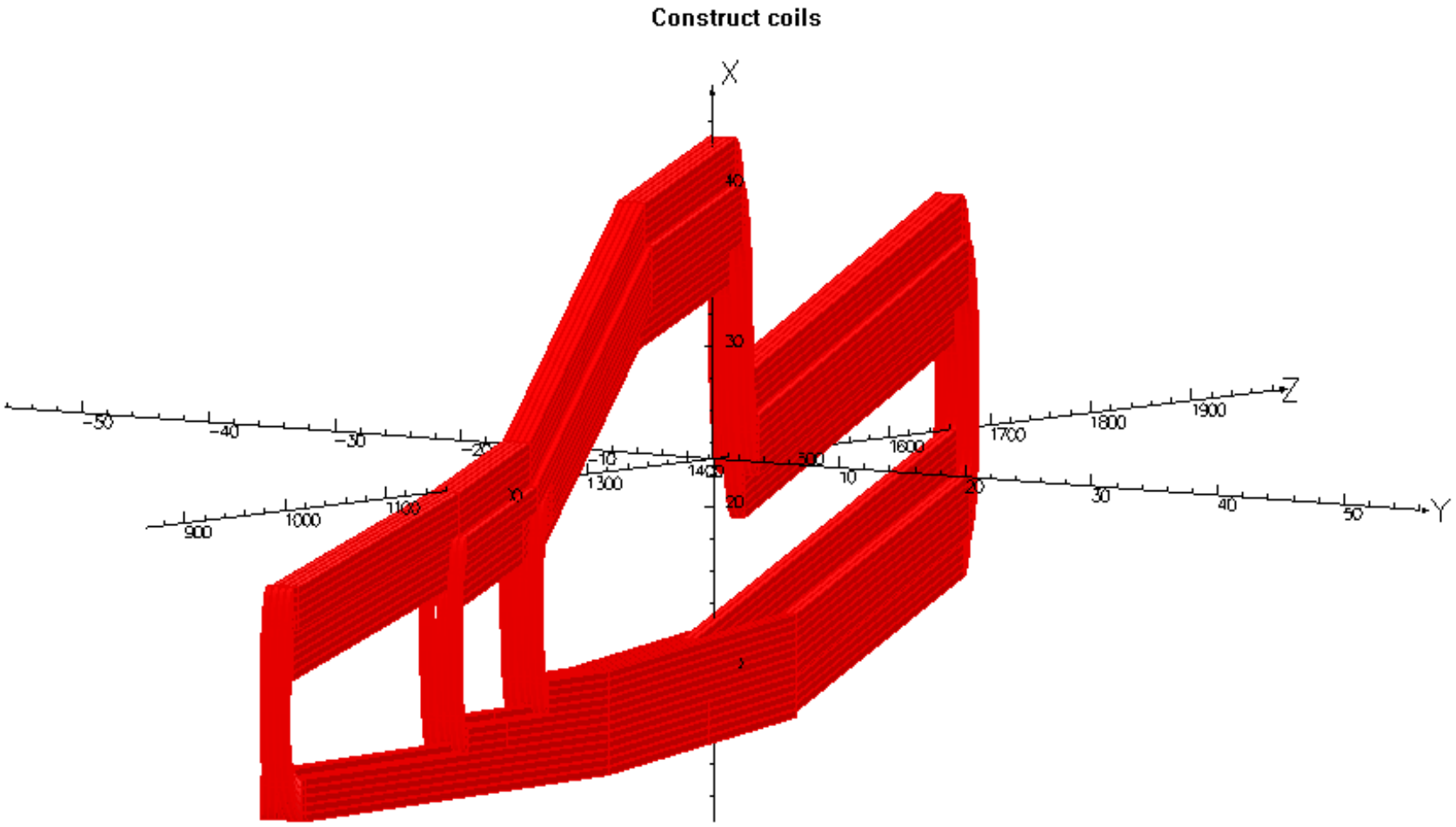

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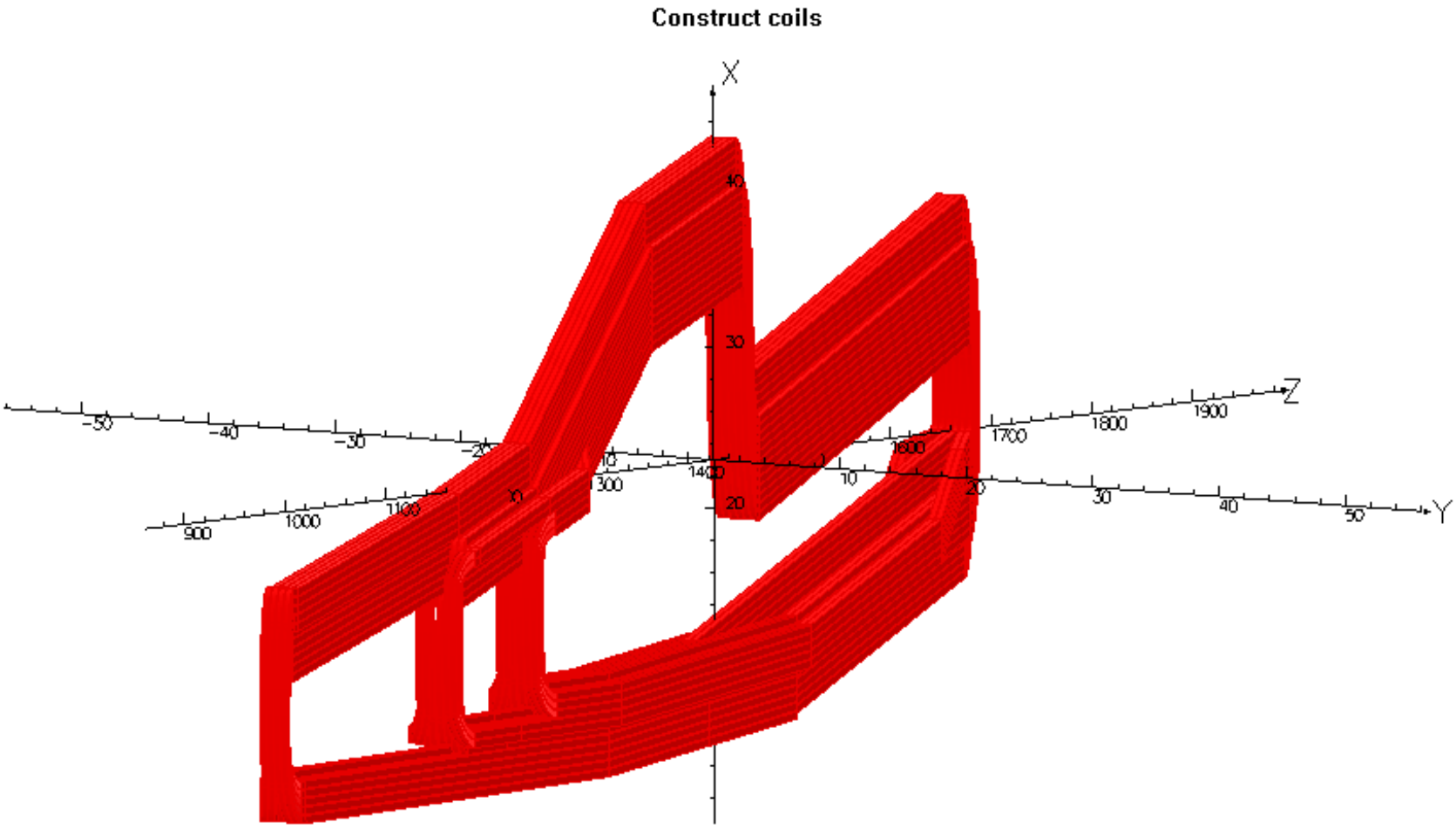
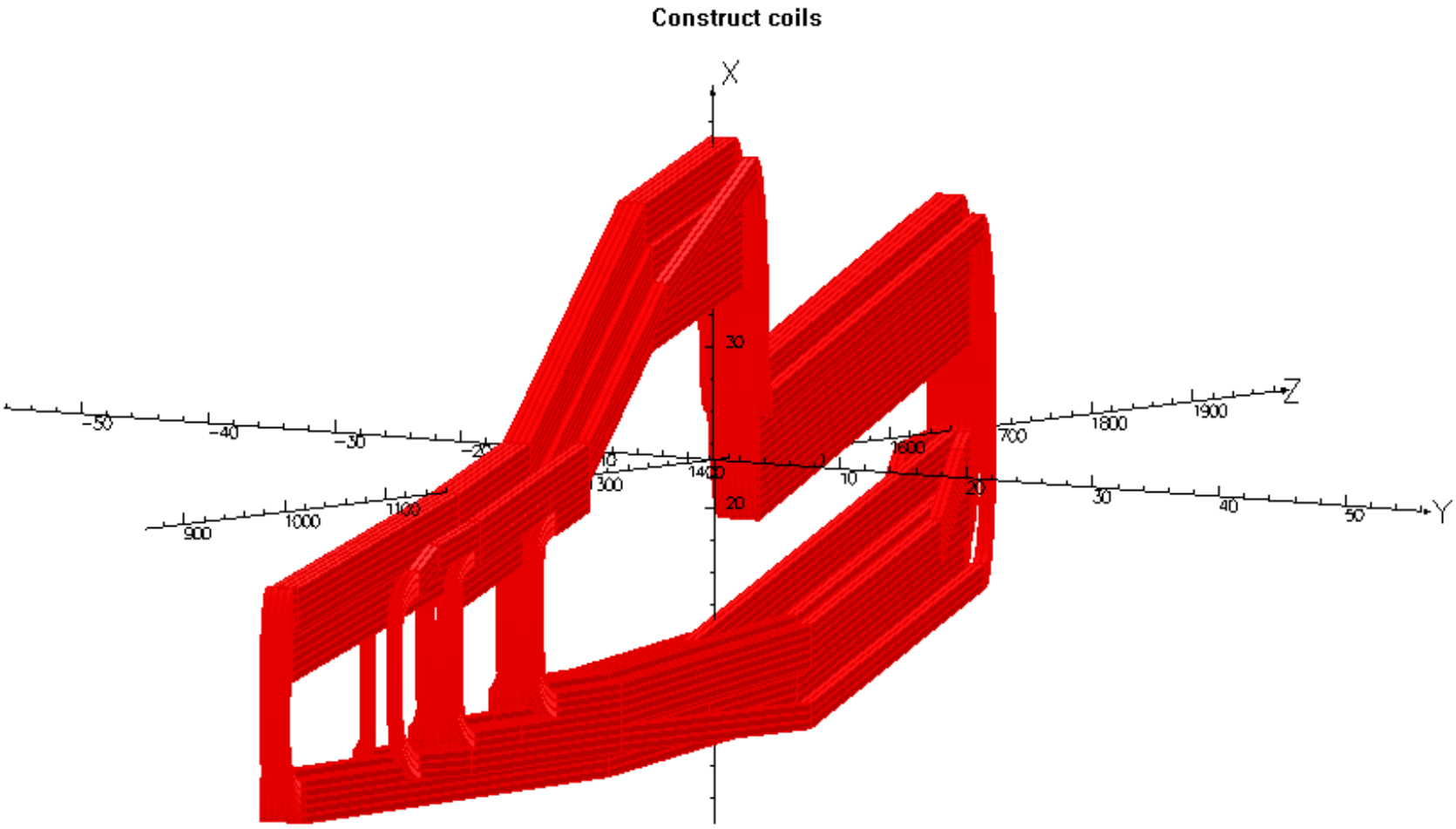
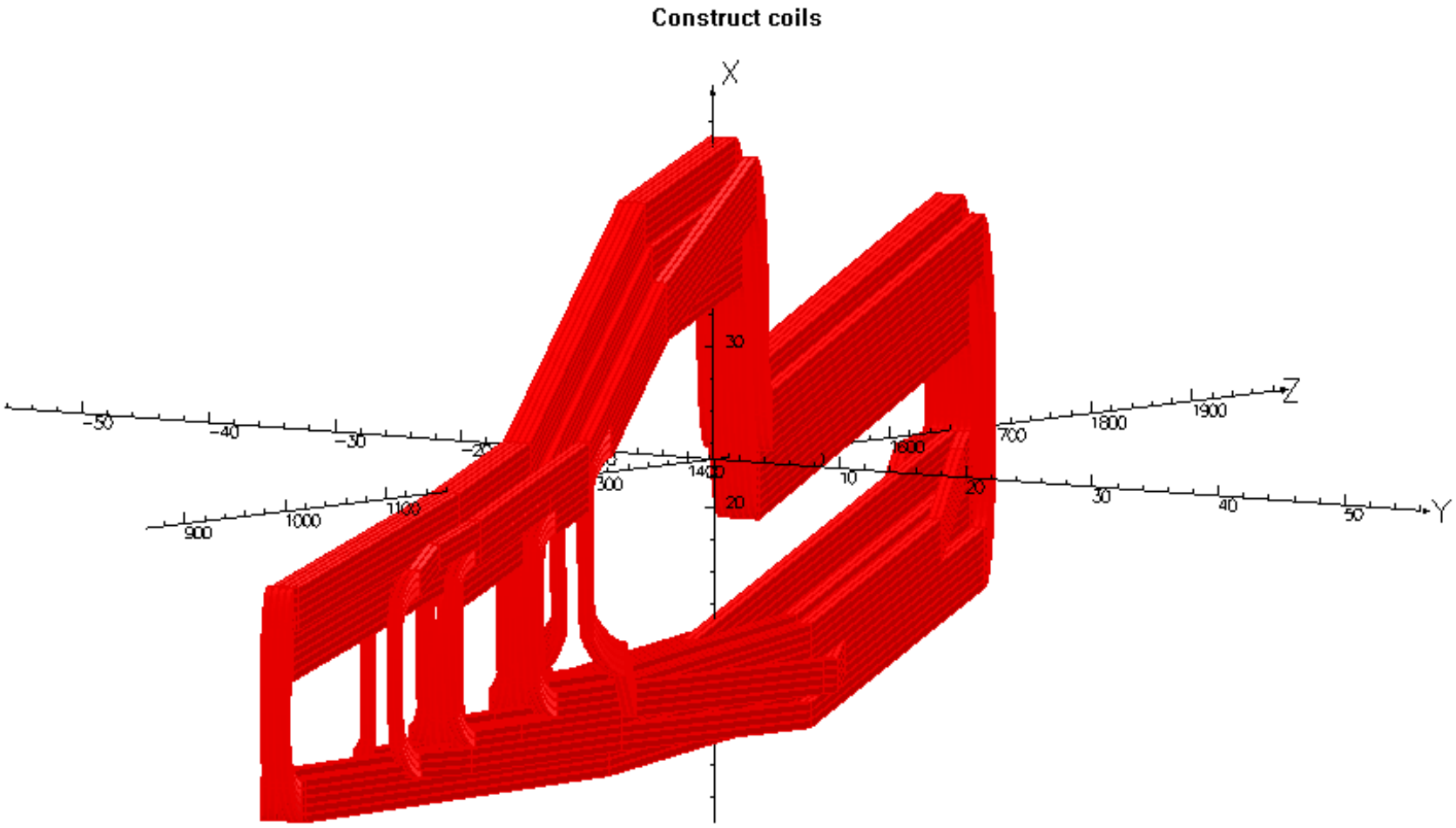


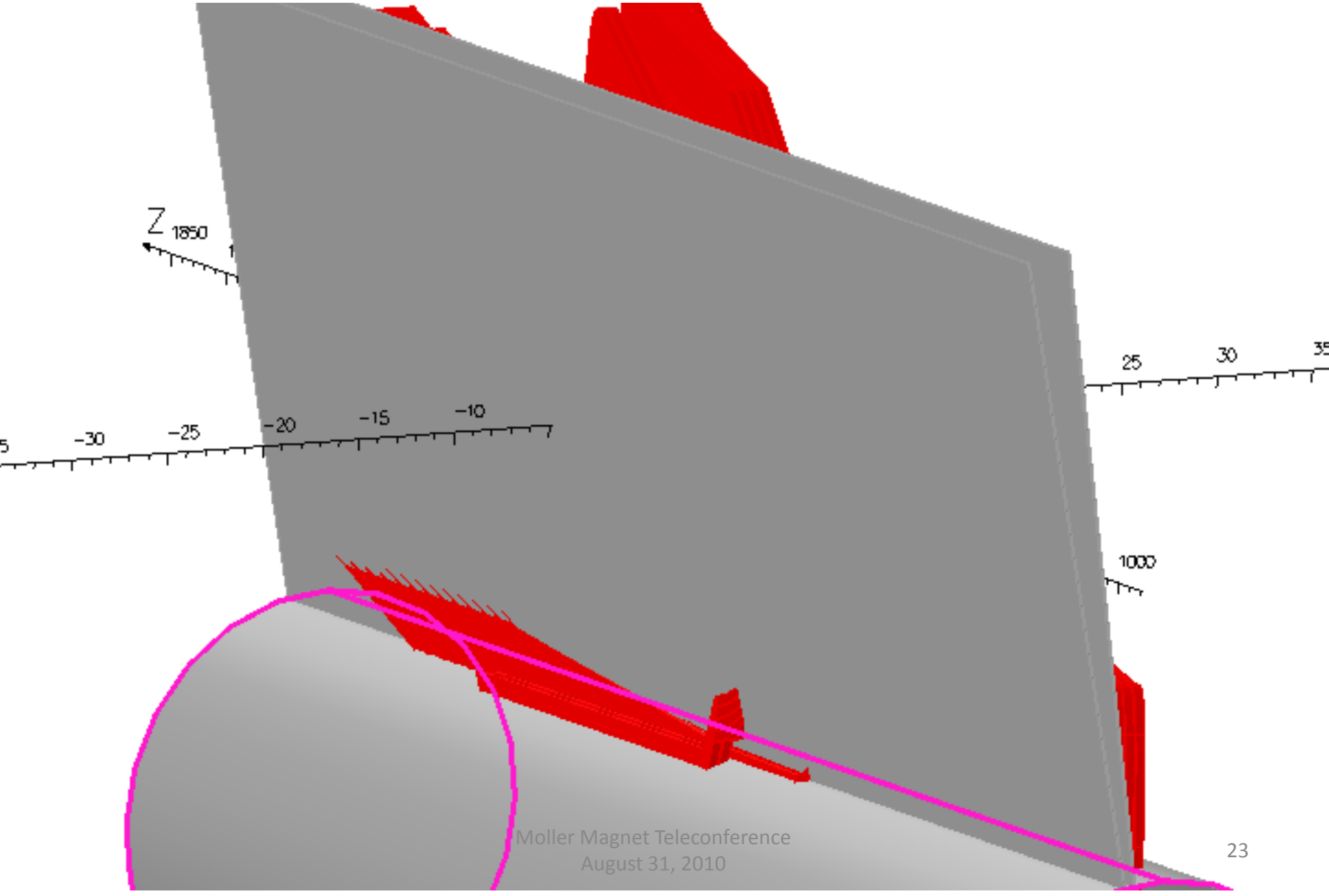
Actual conductor layout



Actual conductor layout



Intrude into keep-out zones



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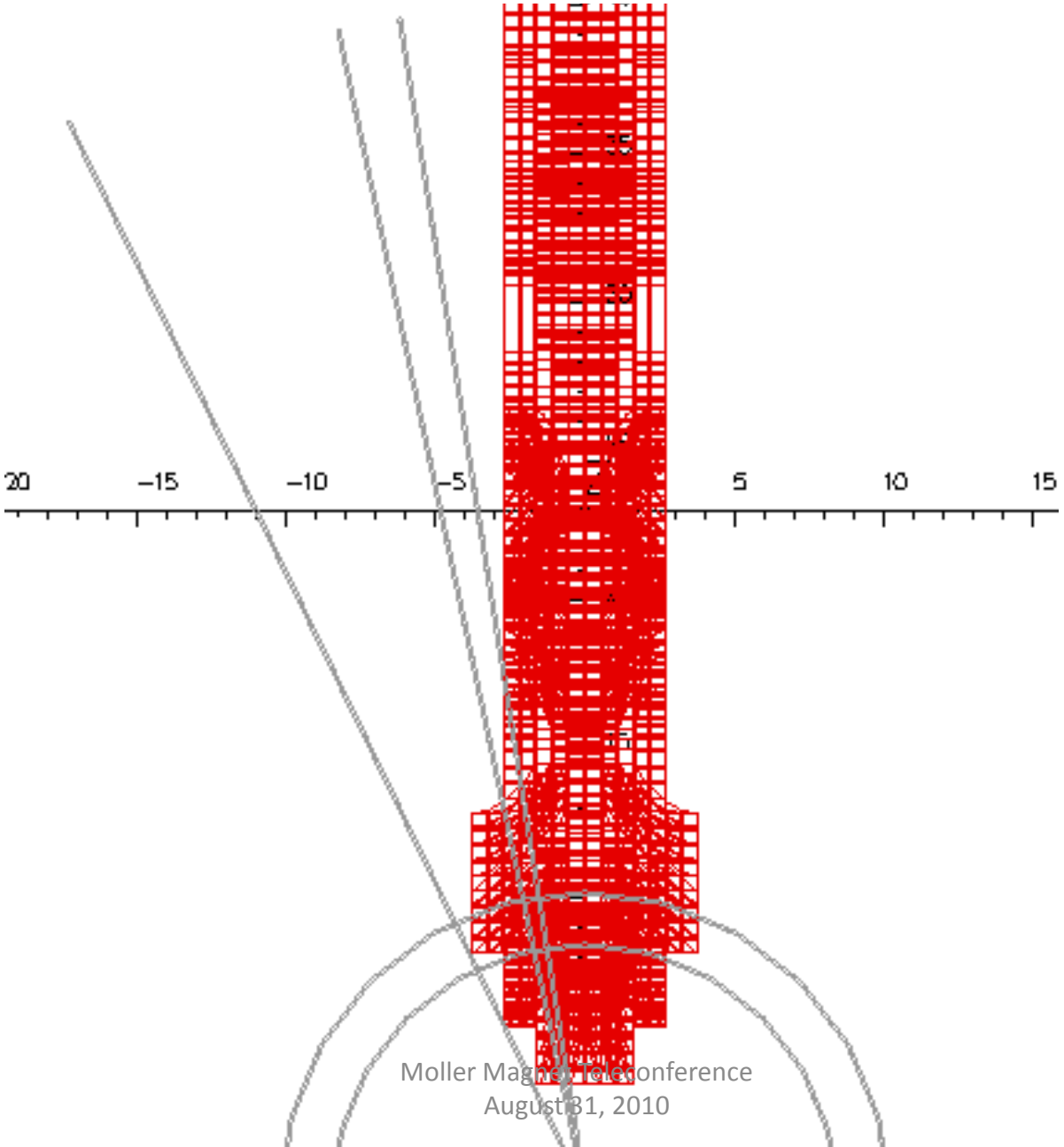
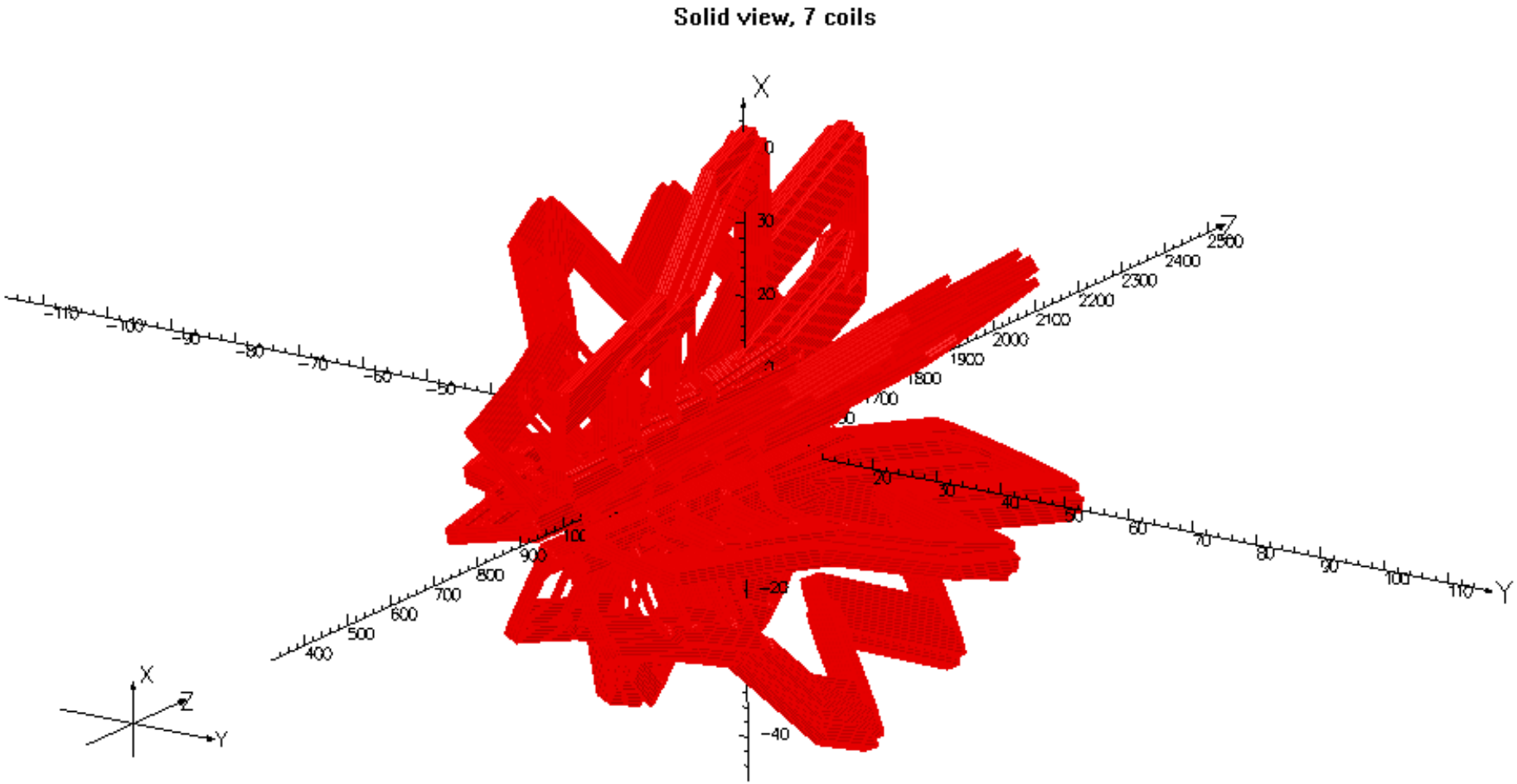


Actual conductor layout – all coils



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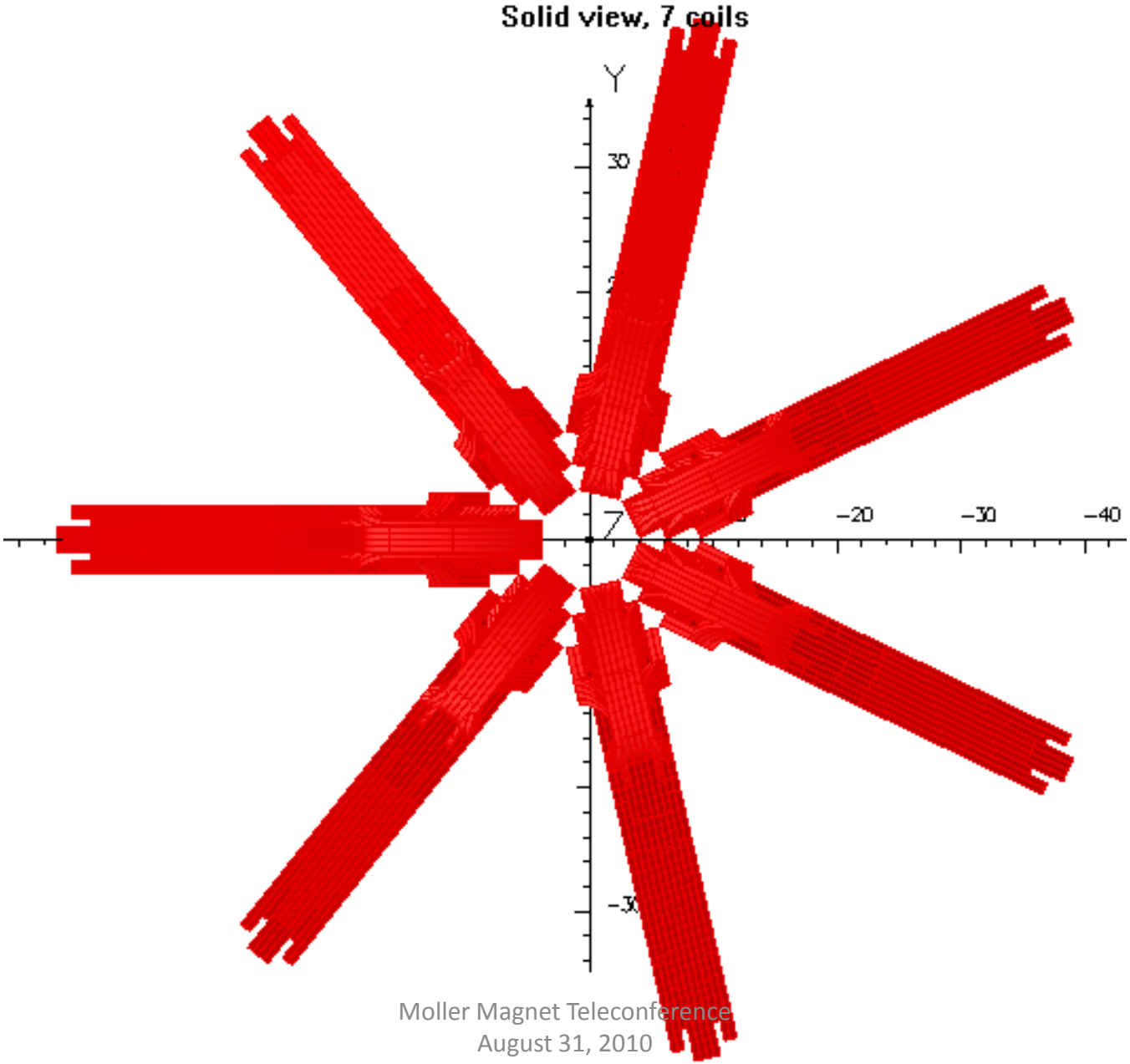
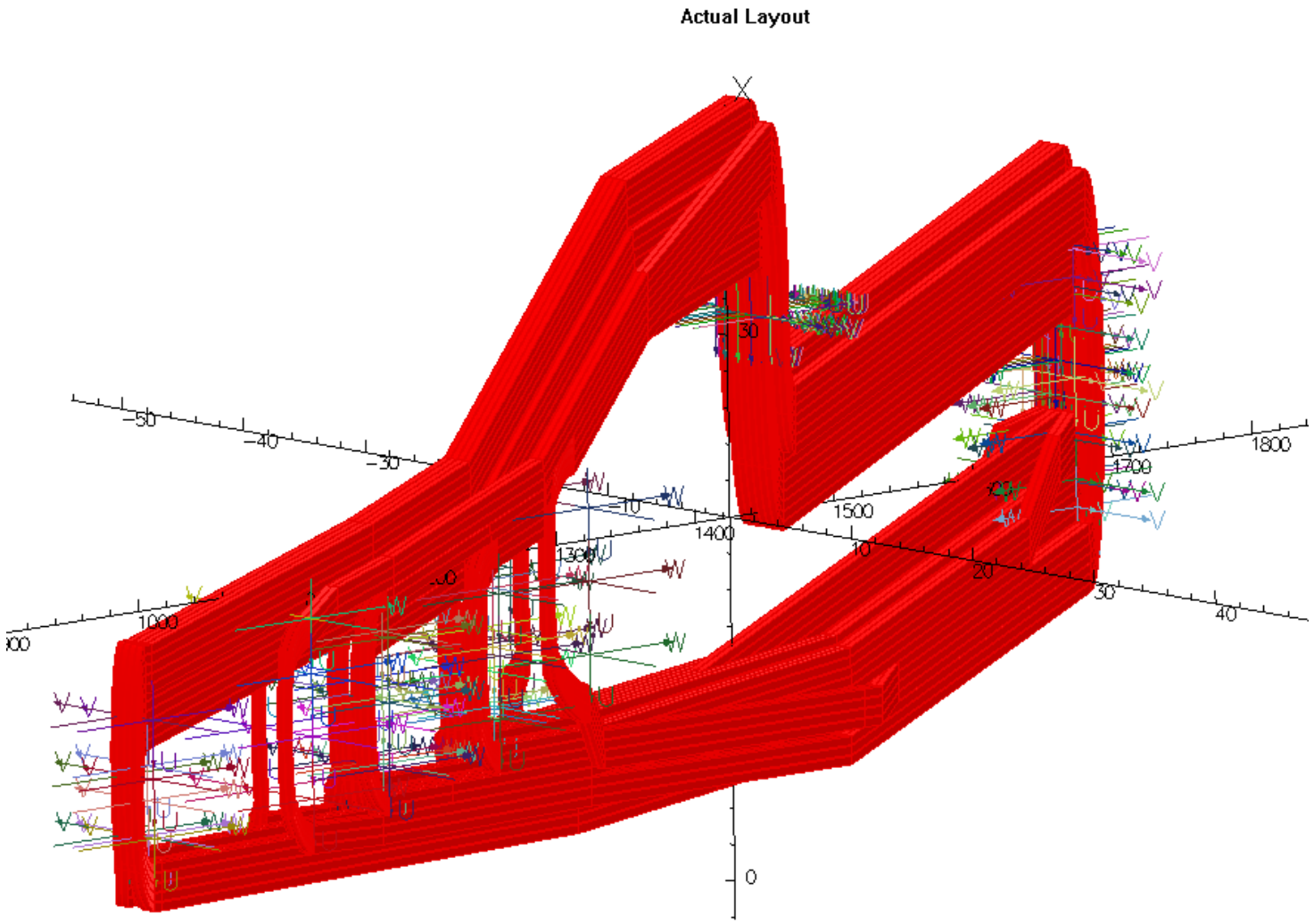
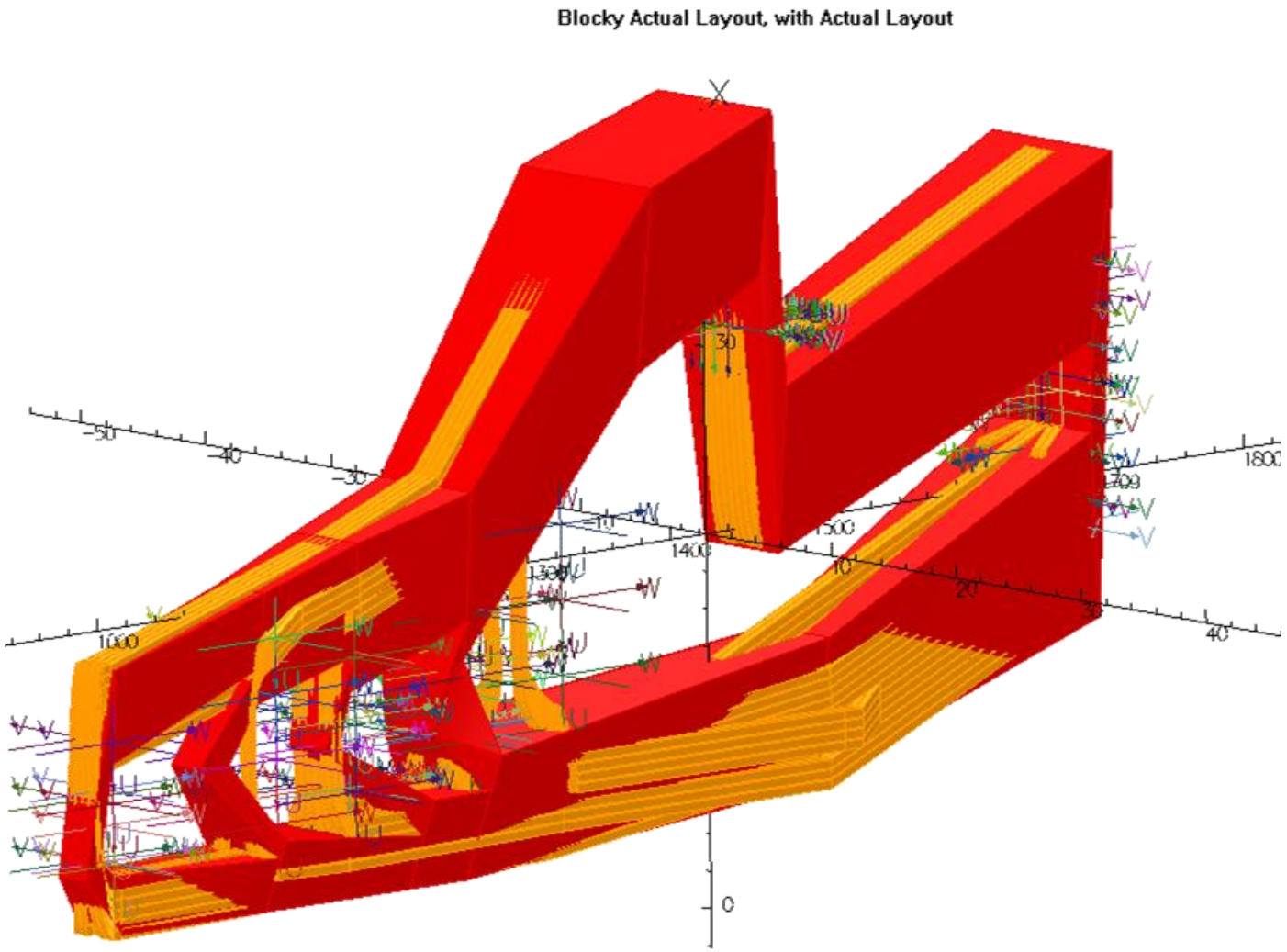


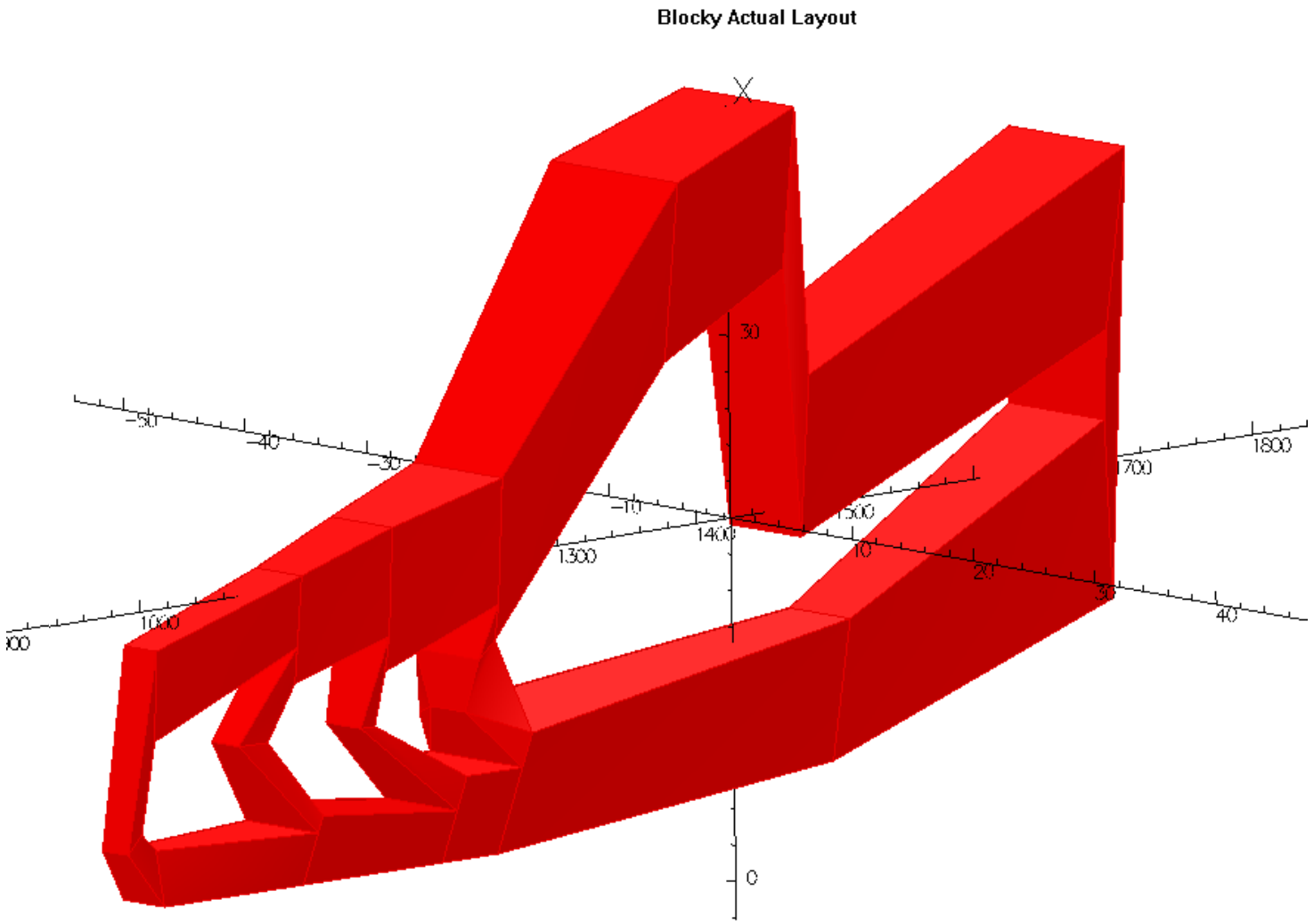
Actual Conductor Layout



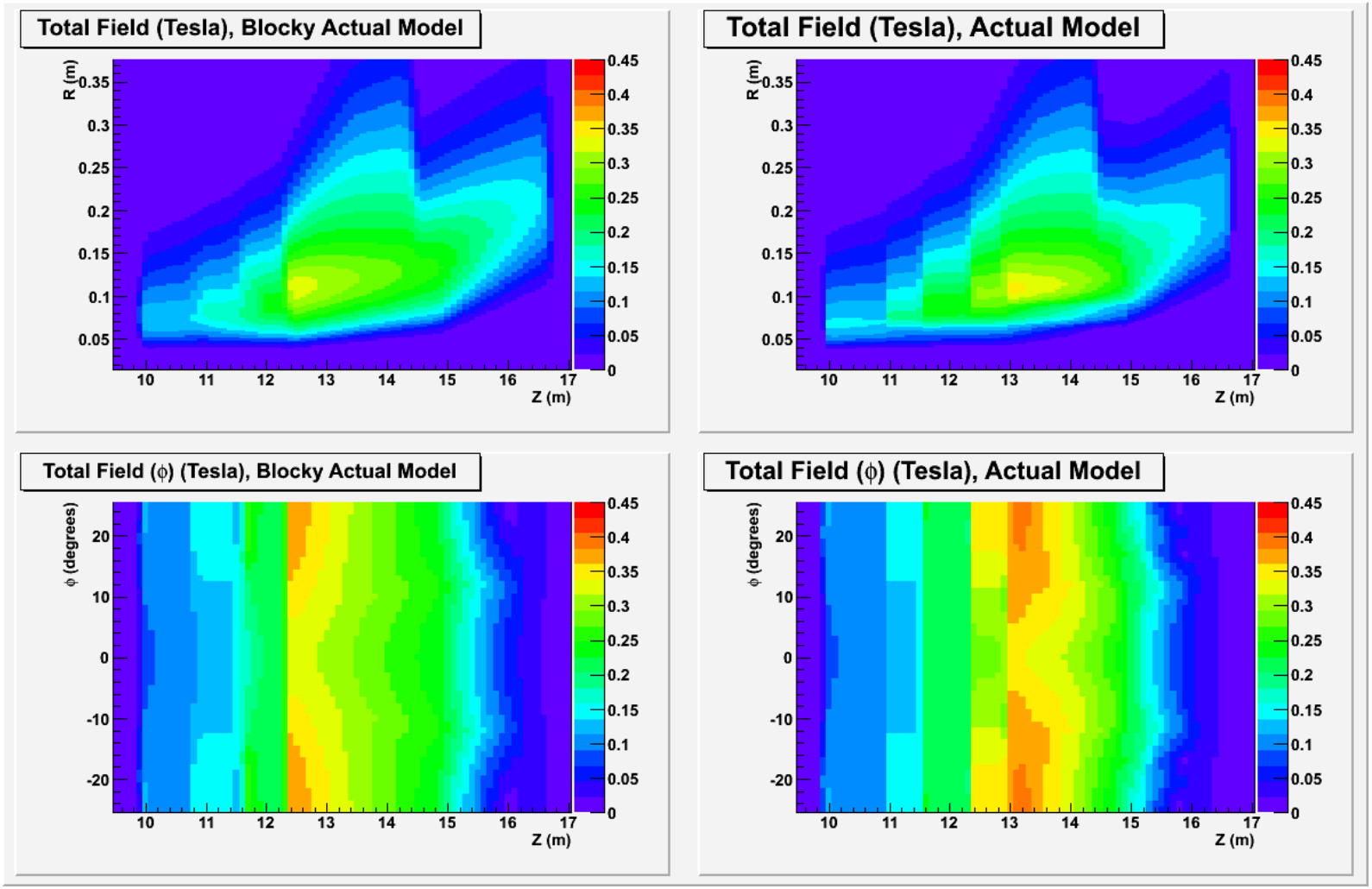
Blocky Model superimposed



Blocky Model

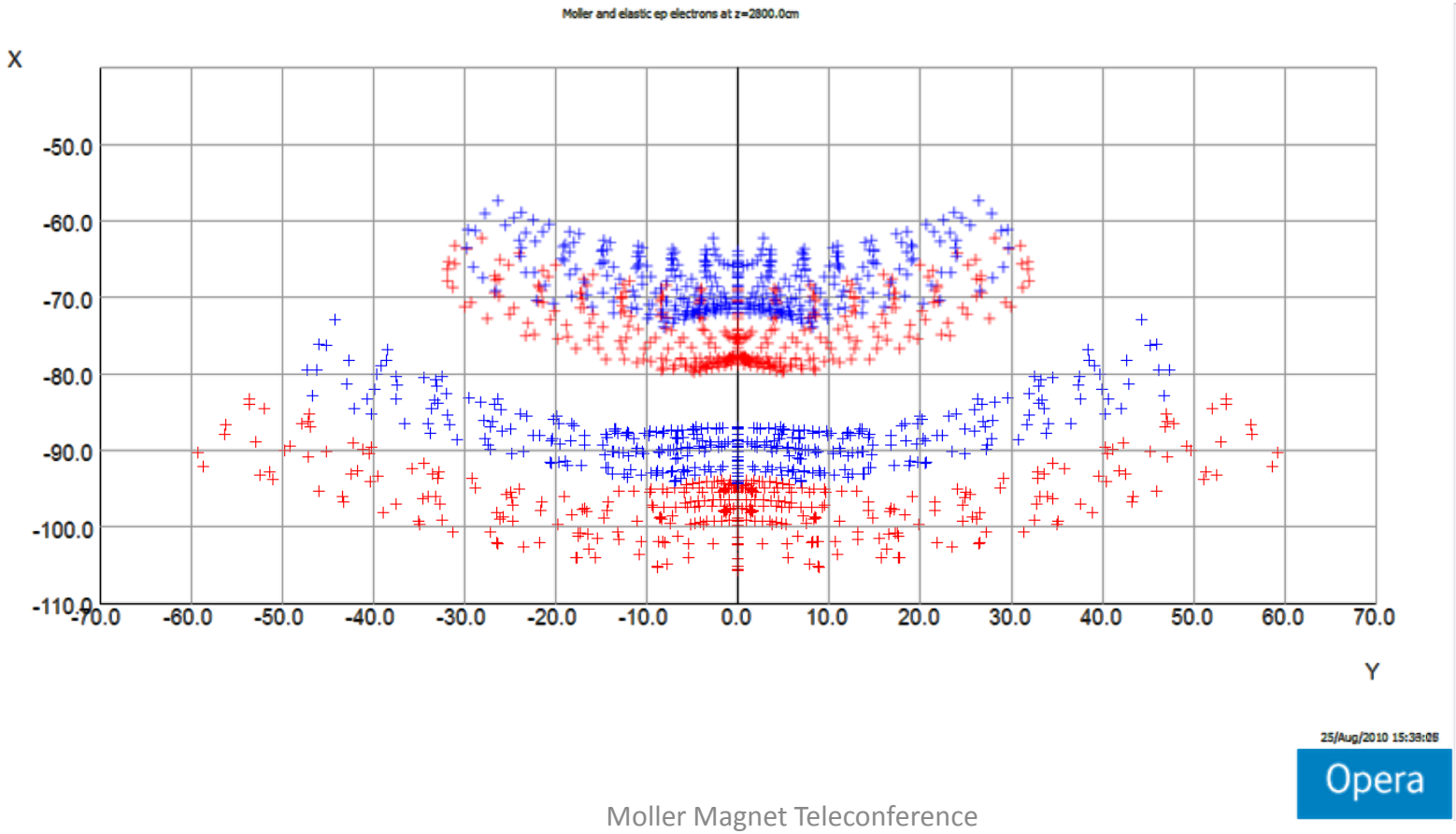


Comparison of Actual/Blocky Actual

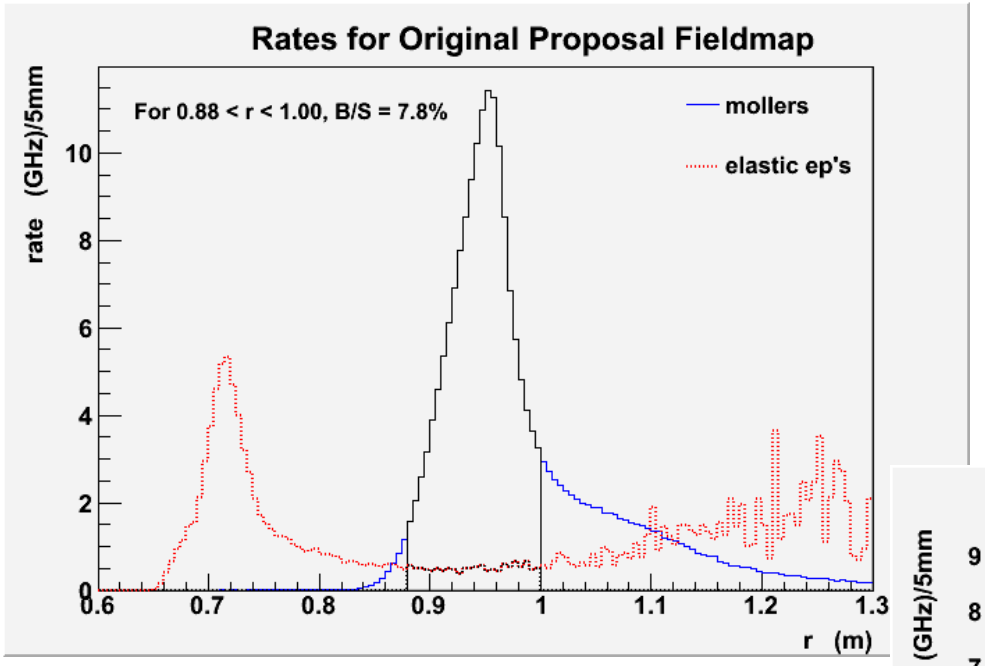


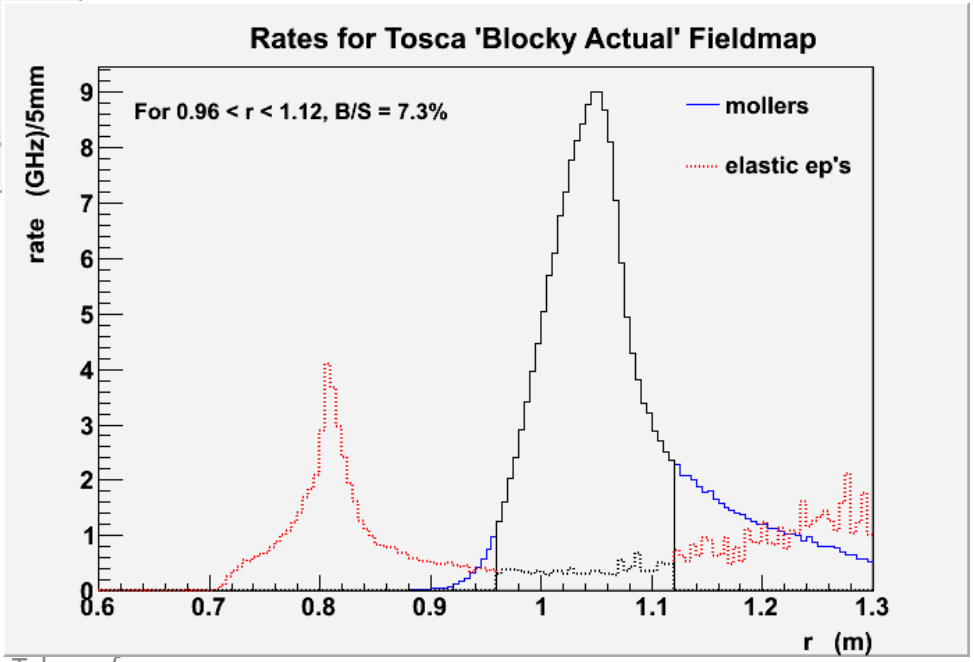
Comparison to Proposal Model

Blue – proposal
Red – blocky actual



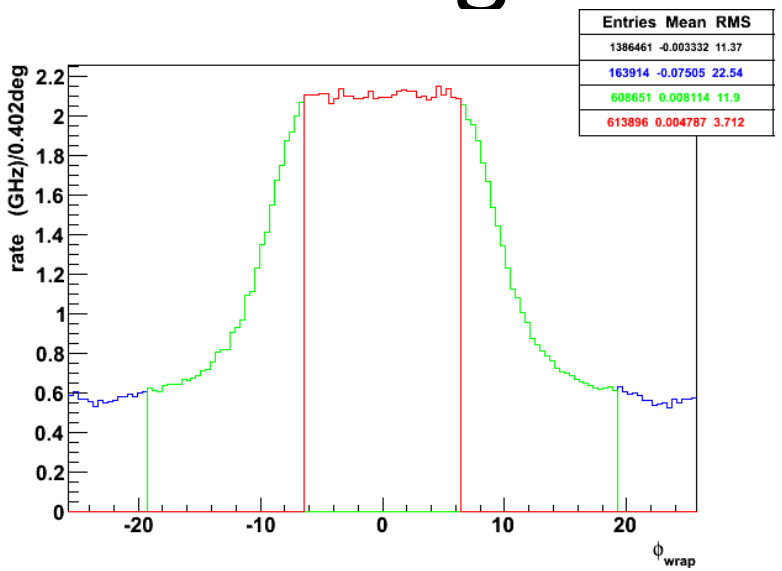
GEANT4 Simulation Results

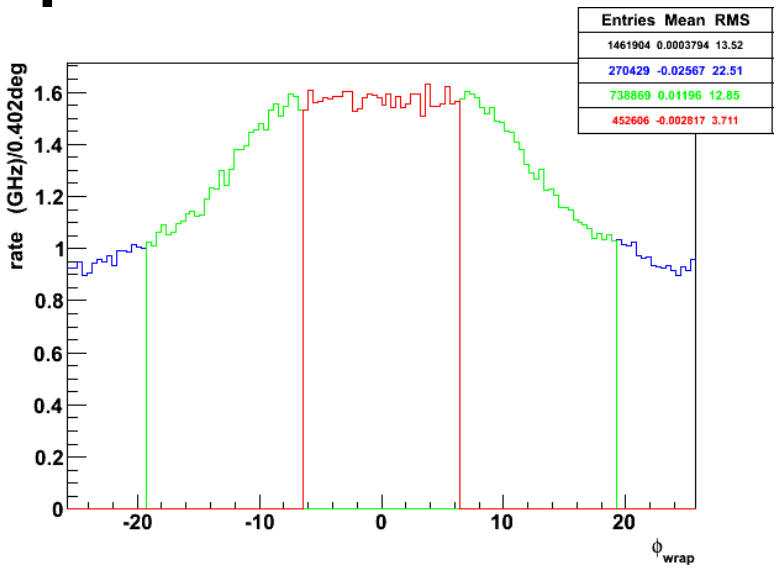


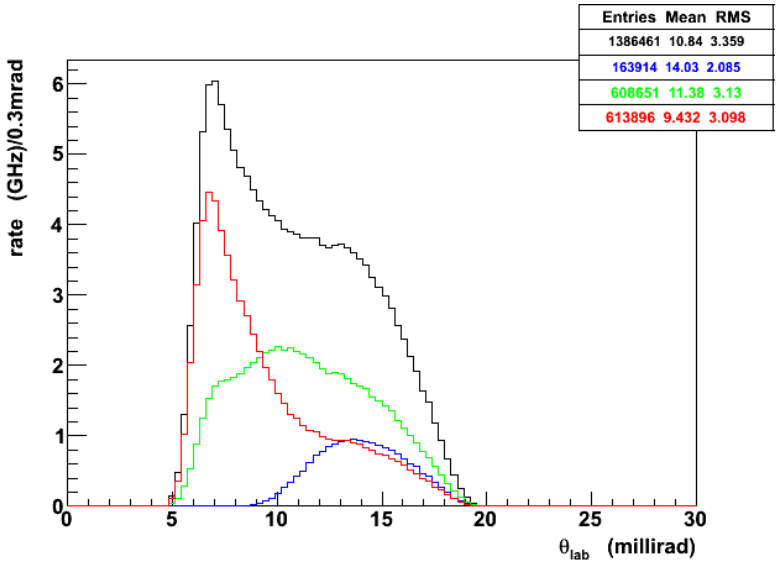


Some of the apparent broadening is due to the “drooping” of the distribution – it doesn’t exactly follow a circular arc

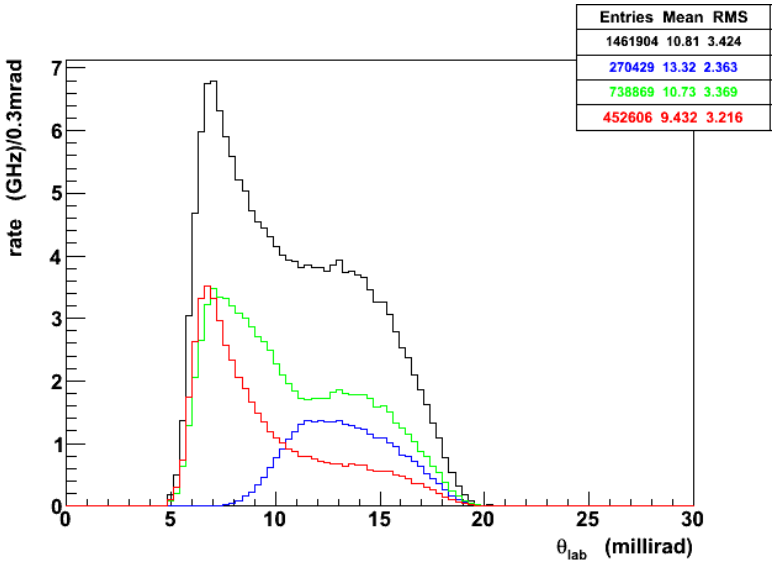
Angular Acceptances





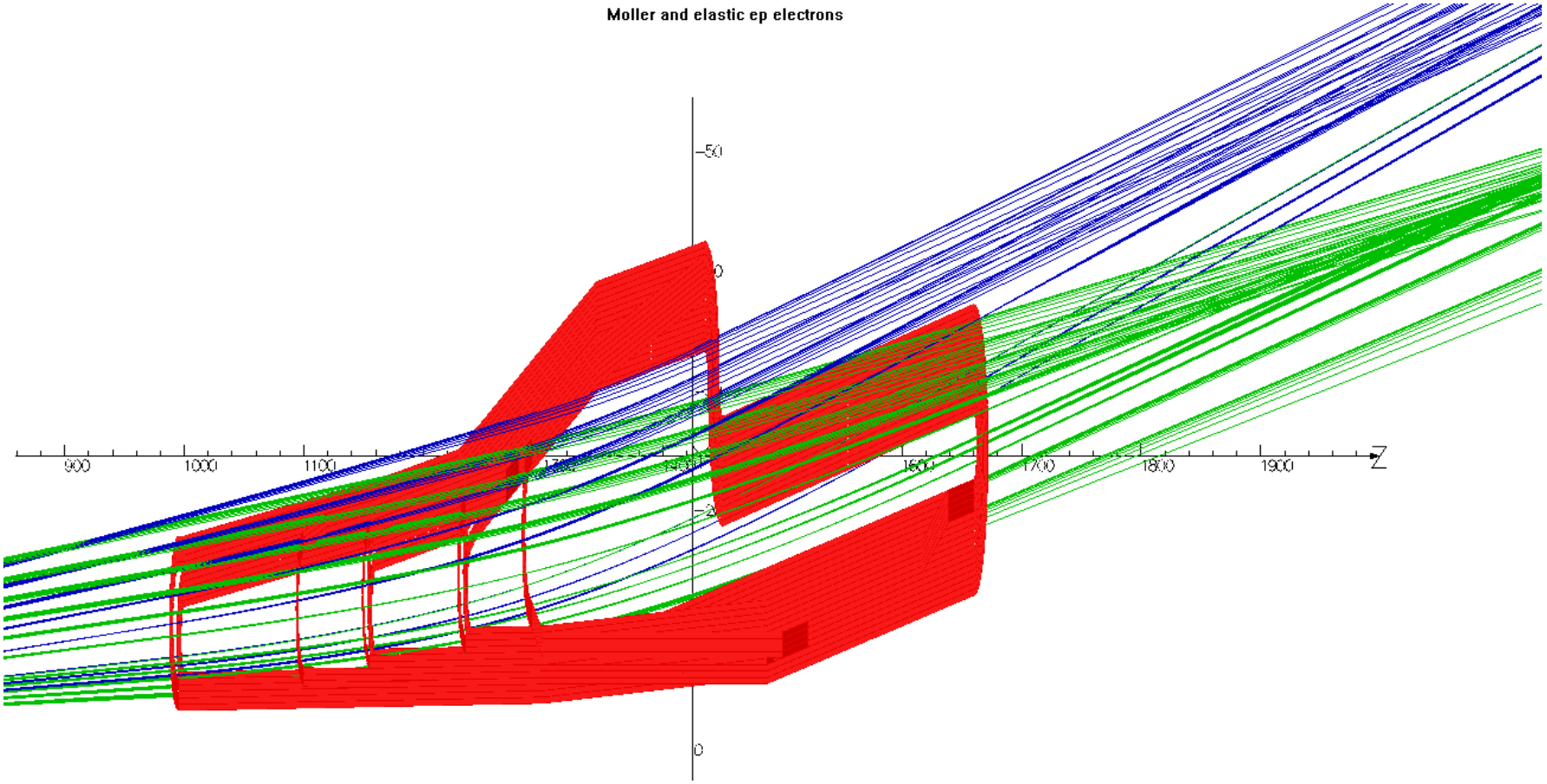


Proposal Model

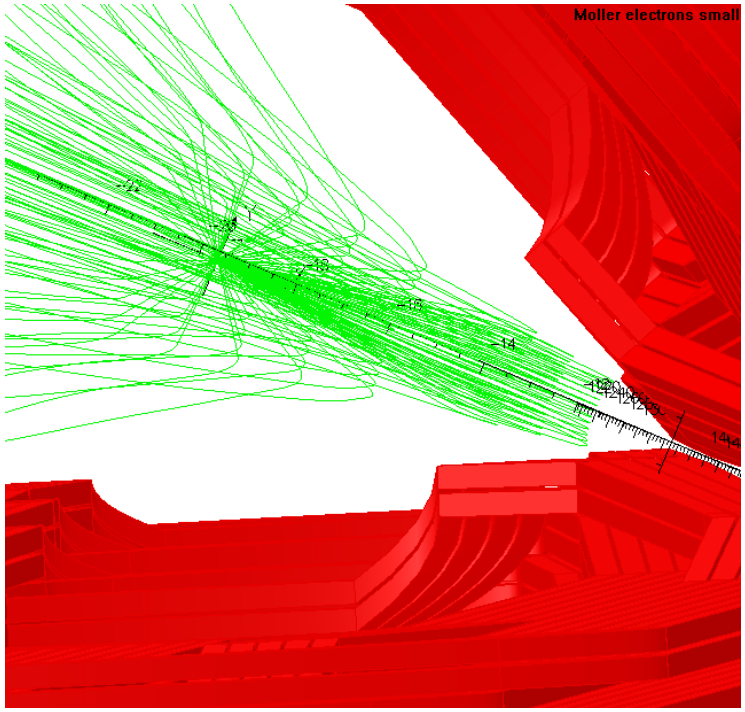


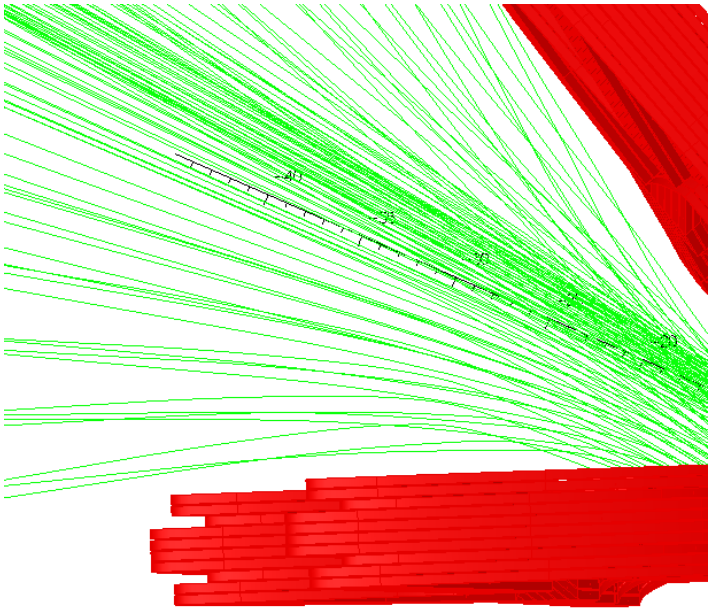
Blocky Actual Model

Tweaking the Optics



Interferences

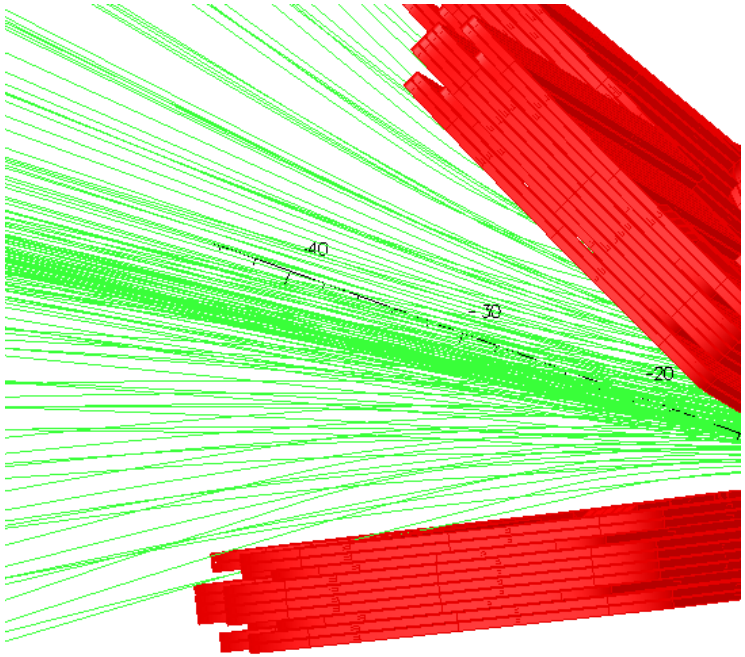


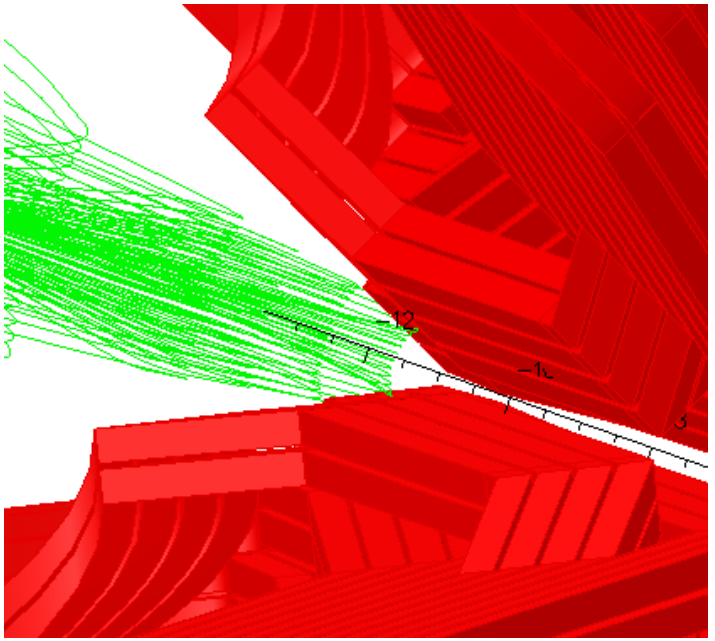


Angular range:

$-12° < \phi < 12°$
$6.0 < \theta < 17$ mrads

Interferences





Angular range:

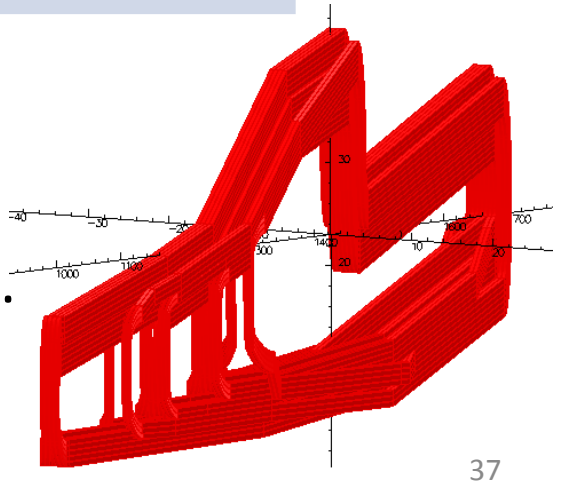
$-14° < \phi < 14°$
$5.5 < \theta < 19$ mrads

Magnet Stats

Property	Moller	Qweak
Field Integral (Tm)	1.4	0.89
Total Power (kW)	820	1340
Current per wire (A)	243	9500
Voltage per coil (V)	480	18
Current Density (A/cm^2)	1600	500
Wire cross section (ID: water hole) (in)	0.182x0.182 (0.101)	2.3x1.5 (0.8)
Weight of a coil (lbs)	556	7600

Latest from Robin:

– cooling each conductor individually will work… but may be too cumbersome to be practical



Possible Solutions to Cooling Issue

- Cool each conductor individually
- Use bigger conductors (2x2 and 2x3)
  - Each with current density ~1300A/cm^2
  - Have to use two different currents
  - Bend radius could alter the physics results
- Cast the shapes we want and machine water cooling holes?

Questions

- Can it be built…
- Can it be cooled…

- We need to know “what we need to know” to continue tweaking the design and not move away from something buildable…

Extra Slides

Custom Extruded Copper or Custom Cast?

THE ELECTRIC MATERIALS CO.

Right The First Time – On Time – Every Time

ETM

A United States Co.

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Copper Extrusions

Chemical composition of our copper extrusions is tested in our laboratory to ensure precise alloy control, with Certificate of Compliance available.

Copper Extrusions

Sector Orientation