Magnetic Modelling
26/03/2013

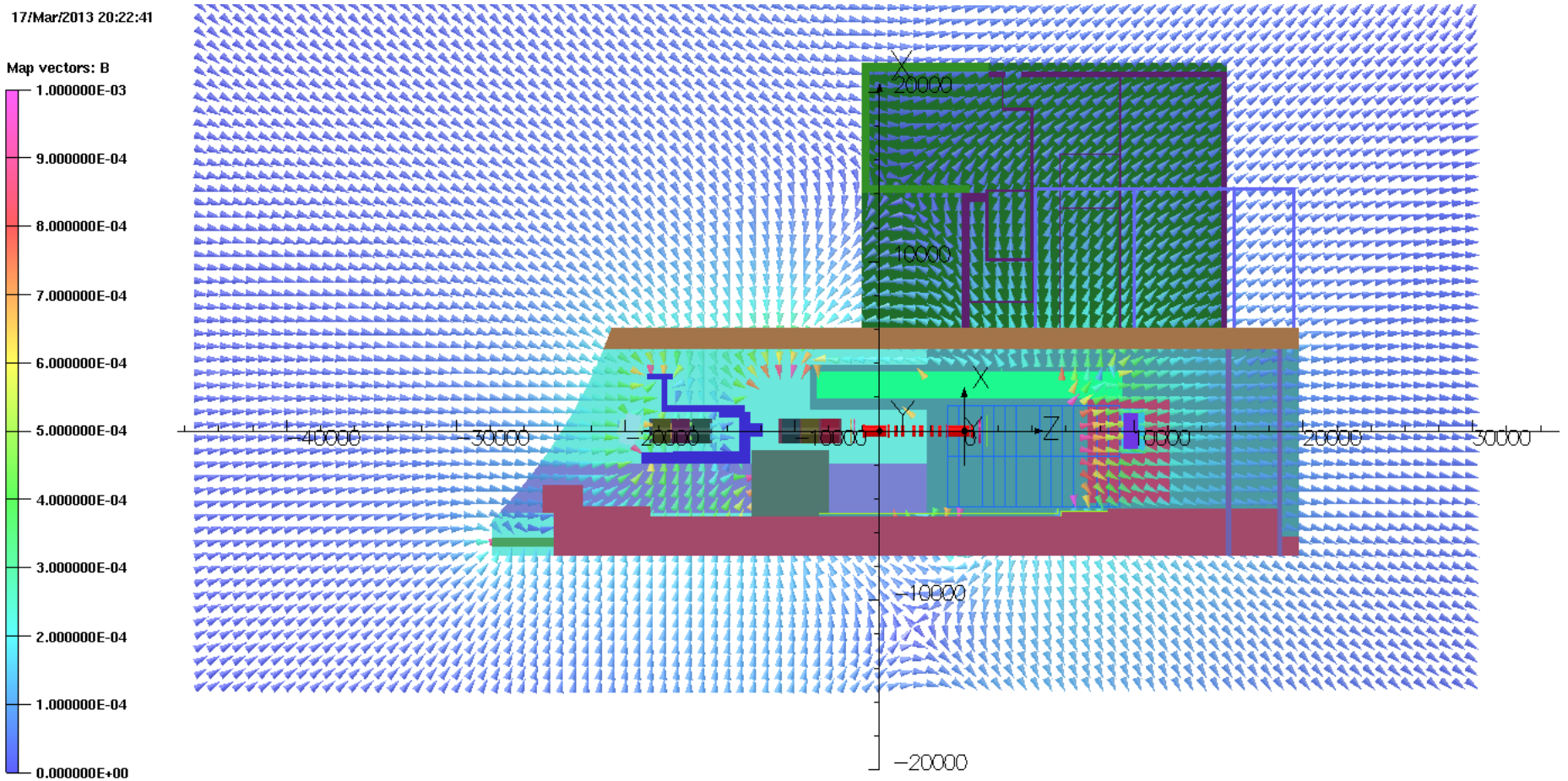
For a good part of the week the post processor and the modeller have been tied up which has limited the amount of analysis that I've been able to do.

1) Modeller – Running Hall Models with corrected boundary conditions. (Basically in the process of rerunning models 51-56 – these have/will be labelled models 61-66 for easy comparison)

2) Post Processor – Running the plot auto-generator on both the quad-sub models that have been previously been run and the updated Hall models. – Thankfully the machine was able to produce a lot of plots over the weekend whilst it would have otherwise been idle.

There have been some interesting plots coming out of the post processor…
Some of this is not very quantitative but I think it is still worth showing.

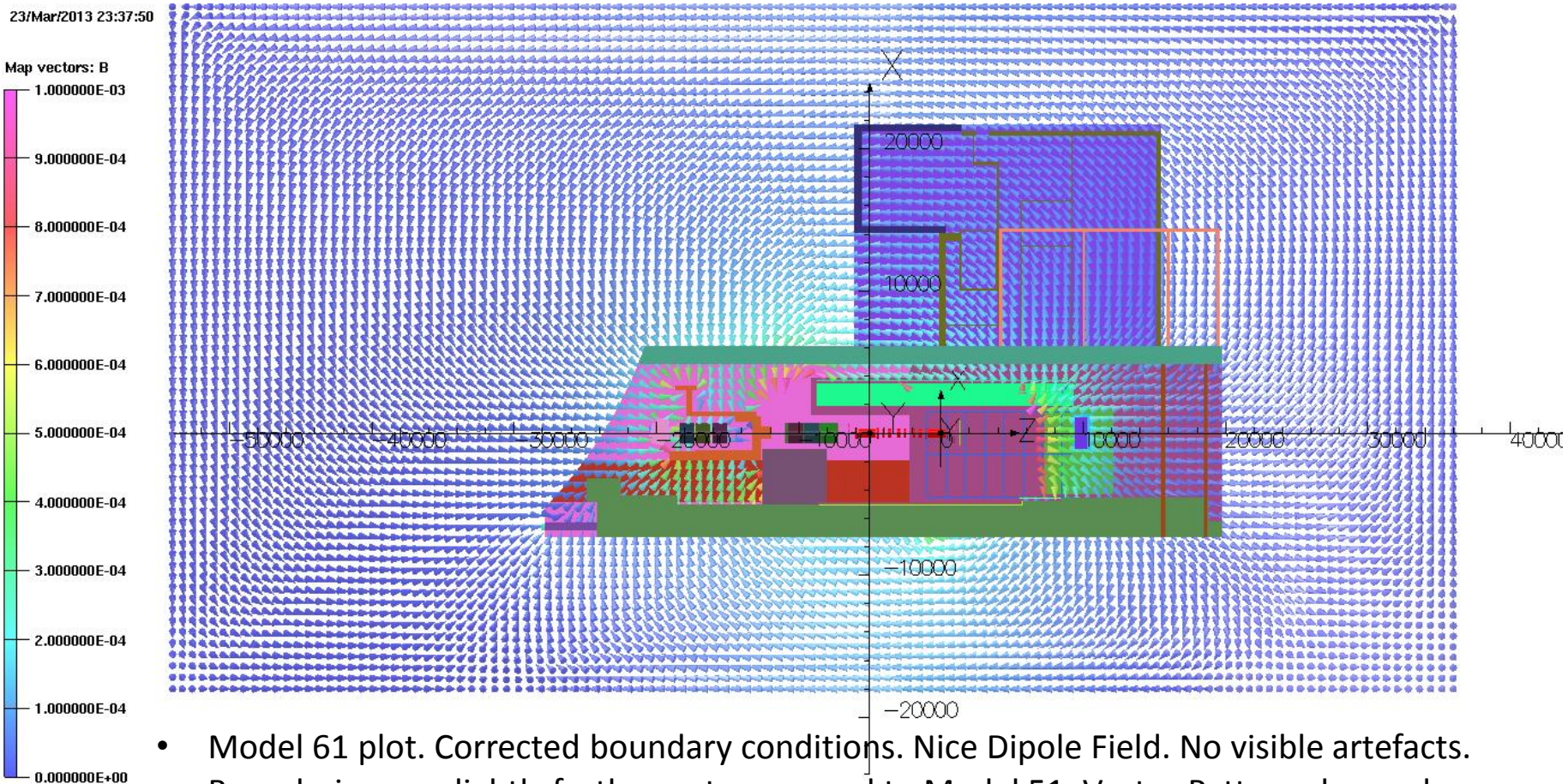
Comparison of Model 51 with Model 61 (Corrected Boundary Conditions)



Model 51 plot. Strange Vector Field at ~1 gauss (10 gauss scale) and note artefacts.

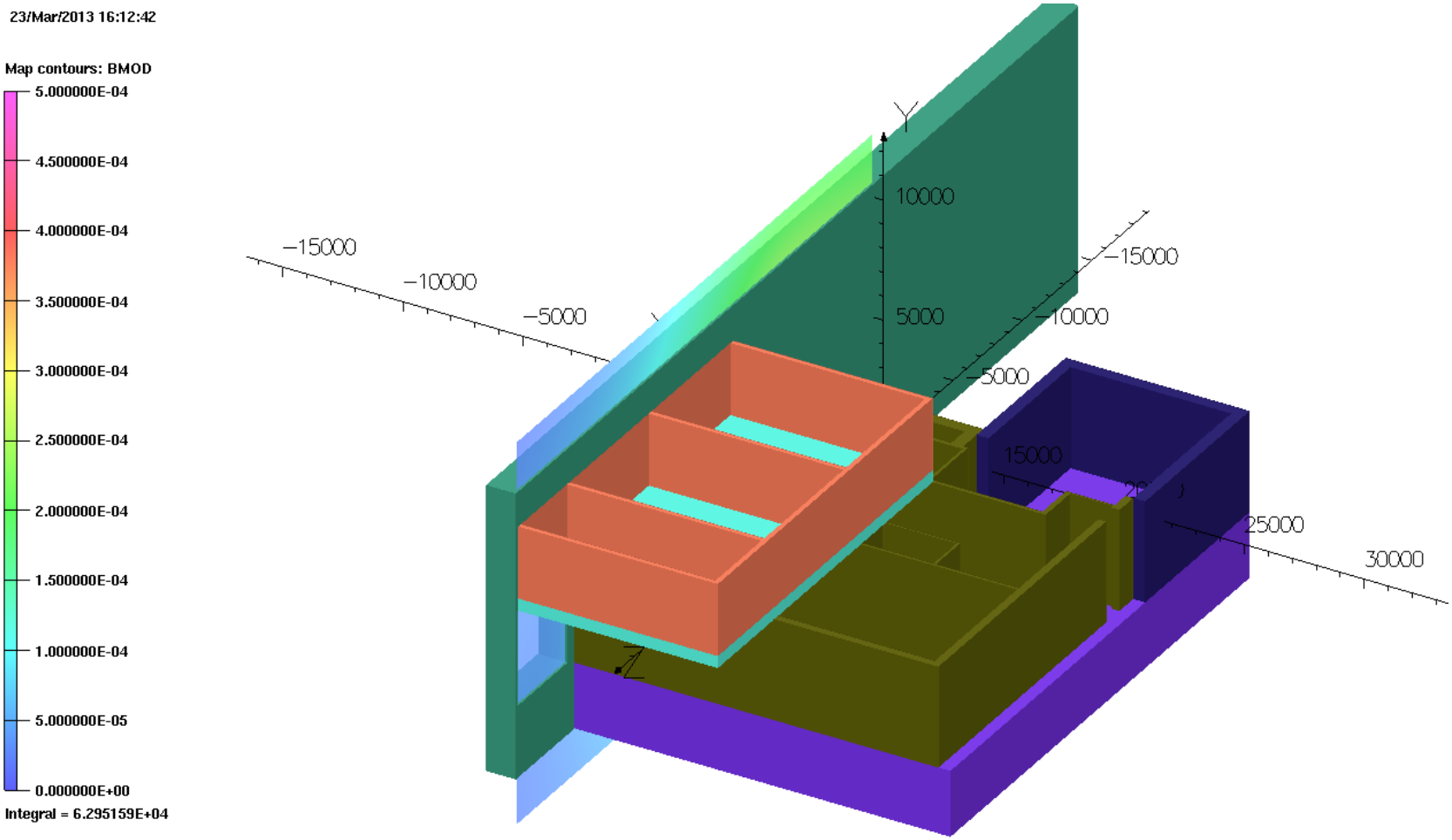
Step IV Solenoid Mode 240 MeV/c

Comparison of Model 51 with Model 61 (Corrected Boundary Conditions)



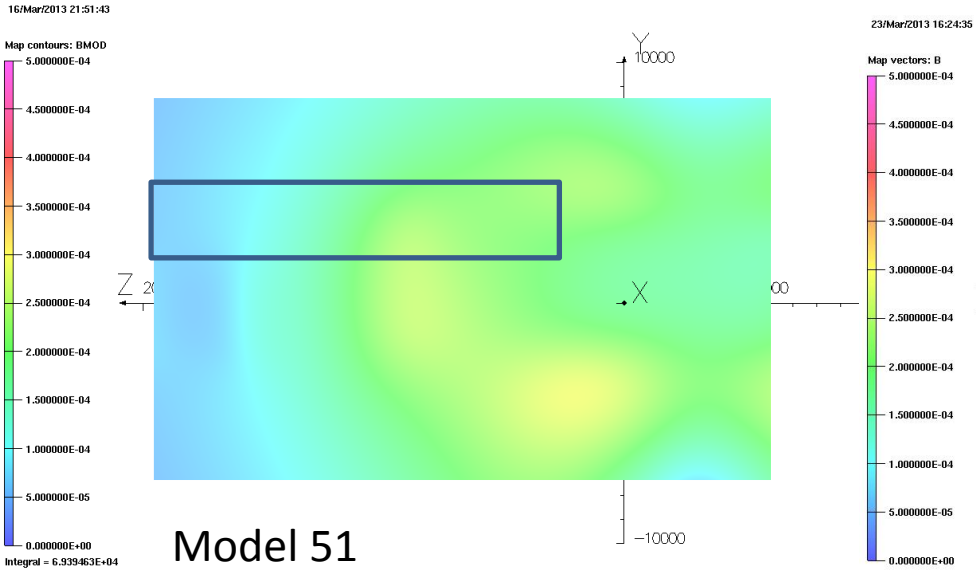
- Model 61 plot. Corrected boundary conditions. Nice Dipole Field. No visible artefacts. Boundaries are slightly further out compared to Model 51. Vector Pattern changed significantly in SSB.
- Some indication that boundaries are too close though (particularly North side). This is clearer on Bmod plots but I'll leave that for you to take a look if you're interested; all results are on-line. (Also see slides 24/25)

Does the change in the boundary conditions materially change anything at the ISIS Control Rooms?

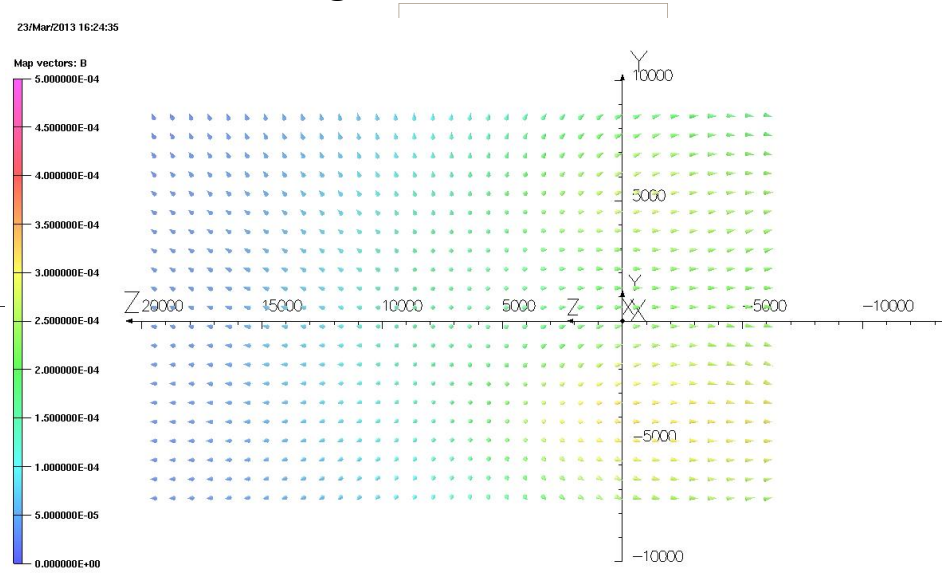


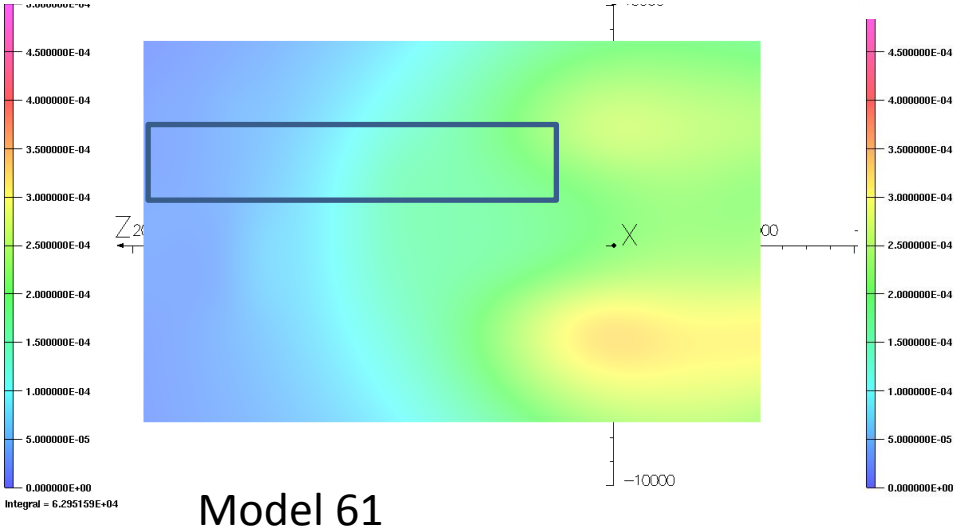
Just a reminder of where we are looking… x=6000 mm

Does the change in boundary materially change anything at the ISIS Control Rooms?
(Apologies a bug means the scale appears behind plot, and turning structures on obliterates the details.) 5 gauss scale; Bmod Left, Vector Right.

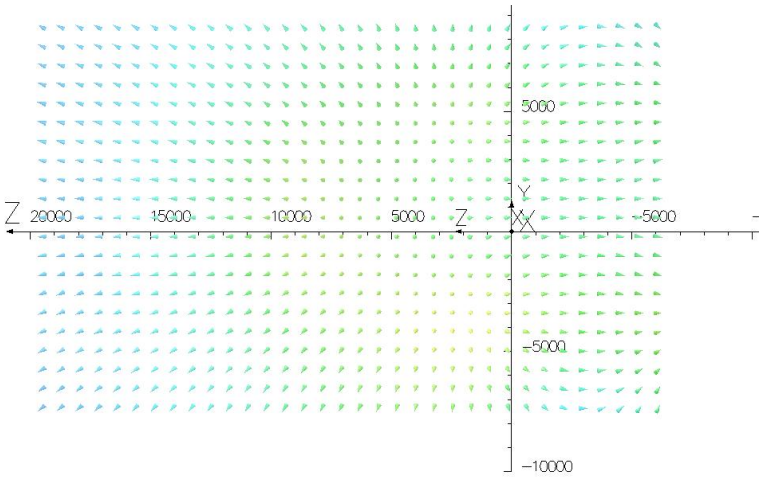


Model 51



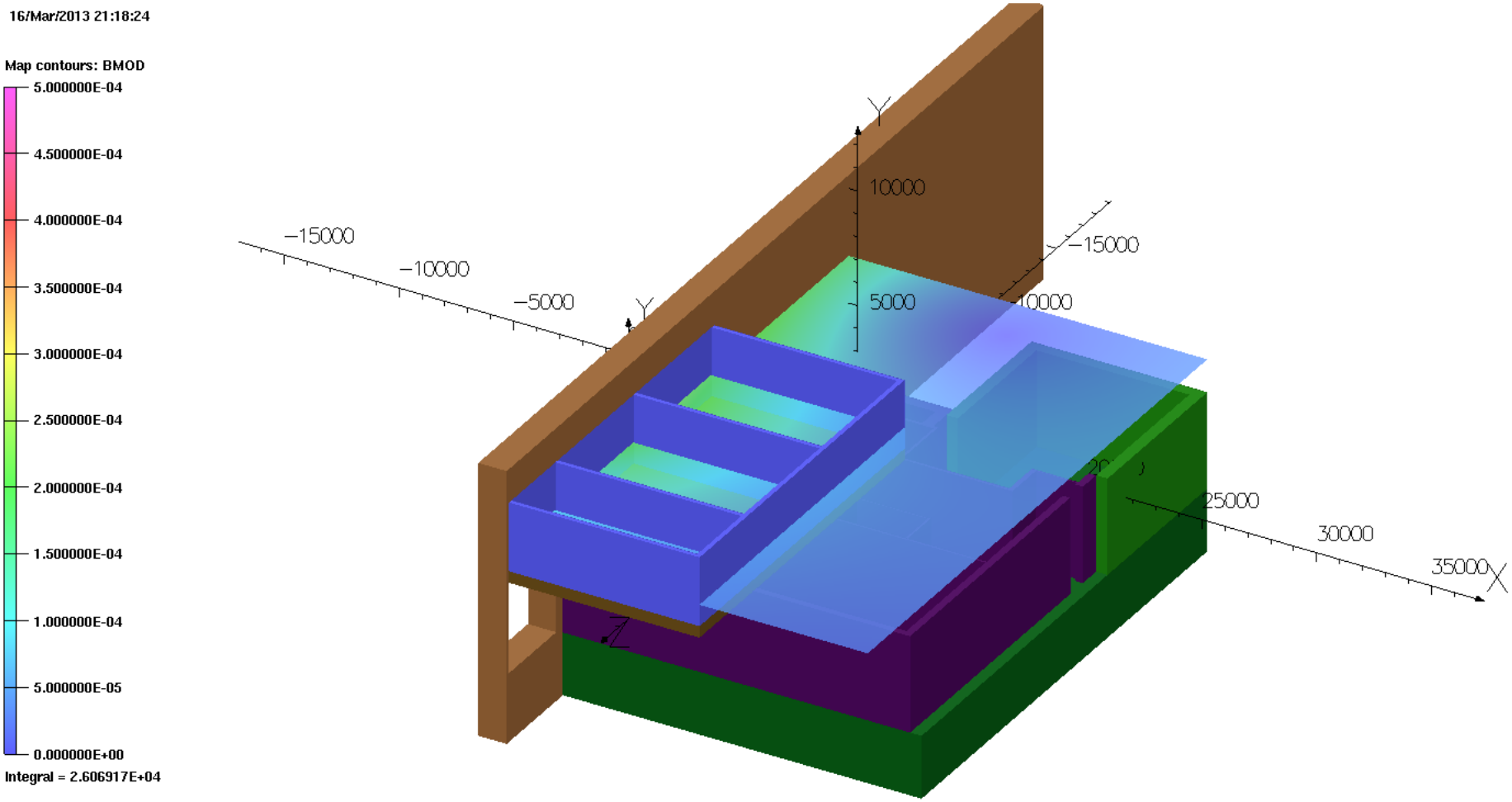


Model 61



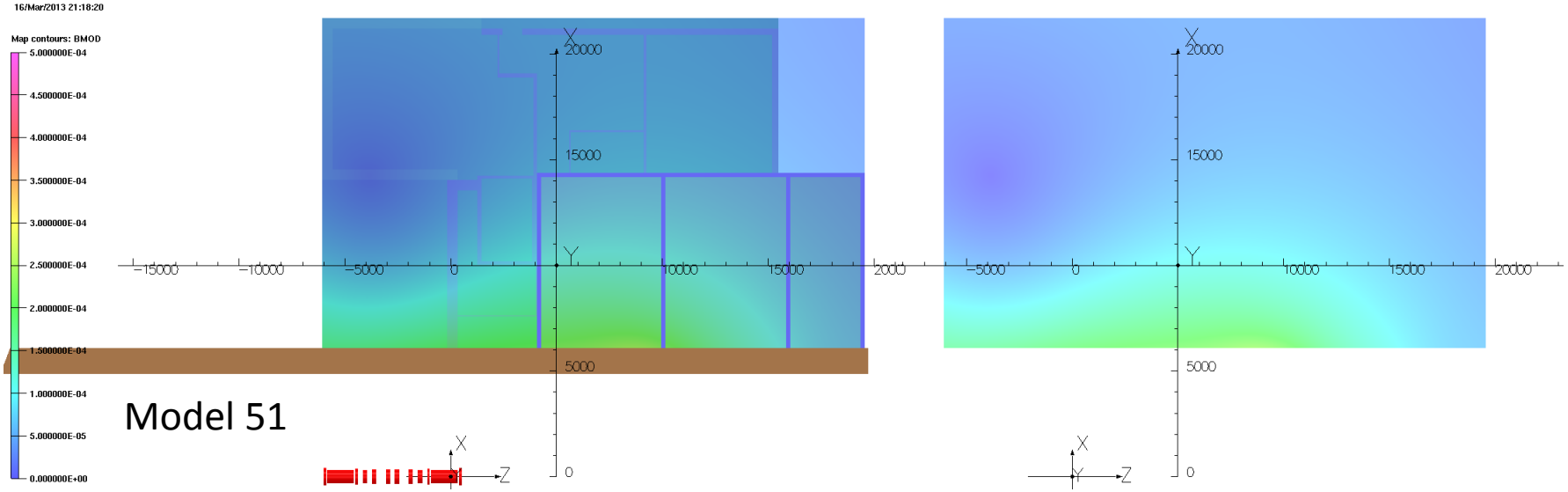
Minor change in field direction on this particular plane

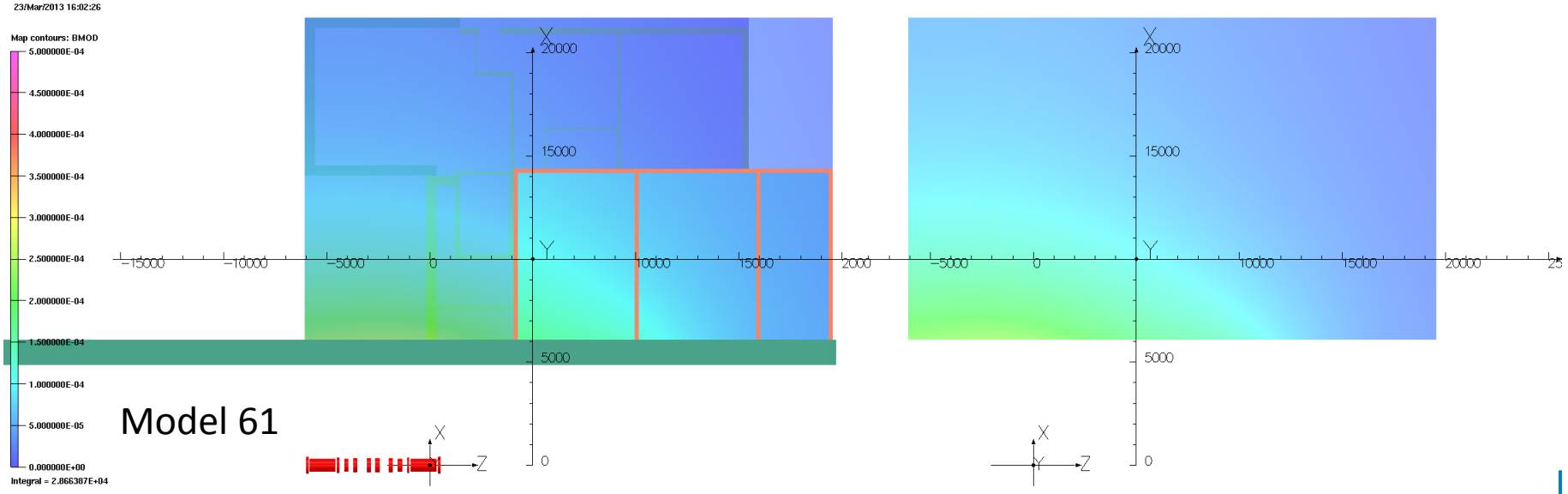
Does the change in boundary materially change anything at the ISIS Control Rooms?



Just a reminder of where we are looking… y=3000

I’m showing structures both ‘on’ and ‘off’ because when structures are turned ‘on’ the transparency affects the apparent colouration of the plots. 5 gauss scale Bmod.



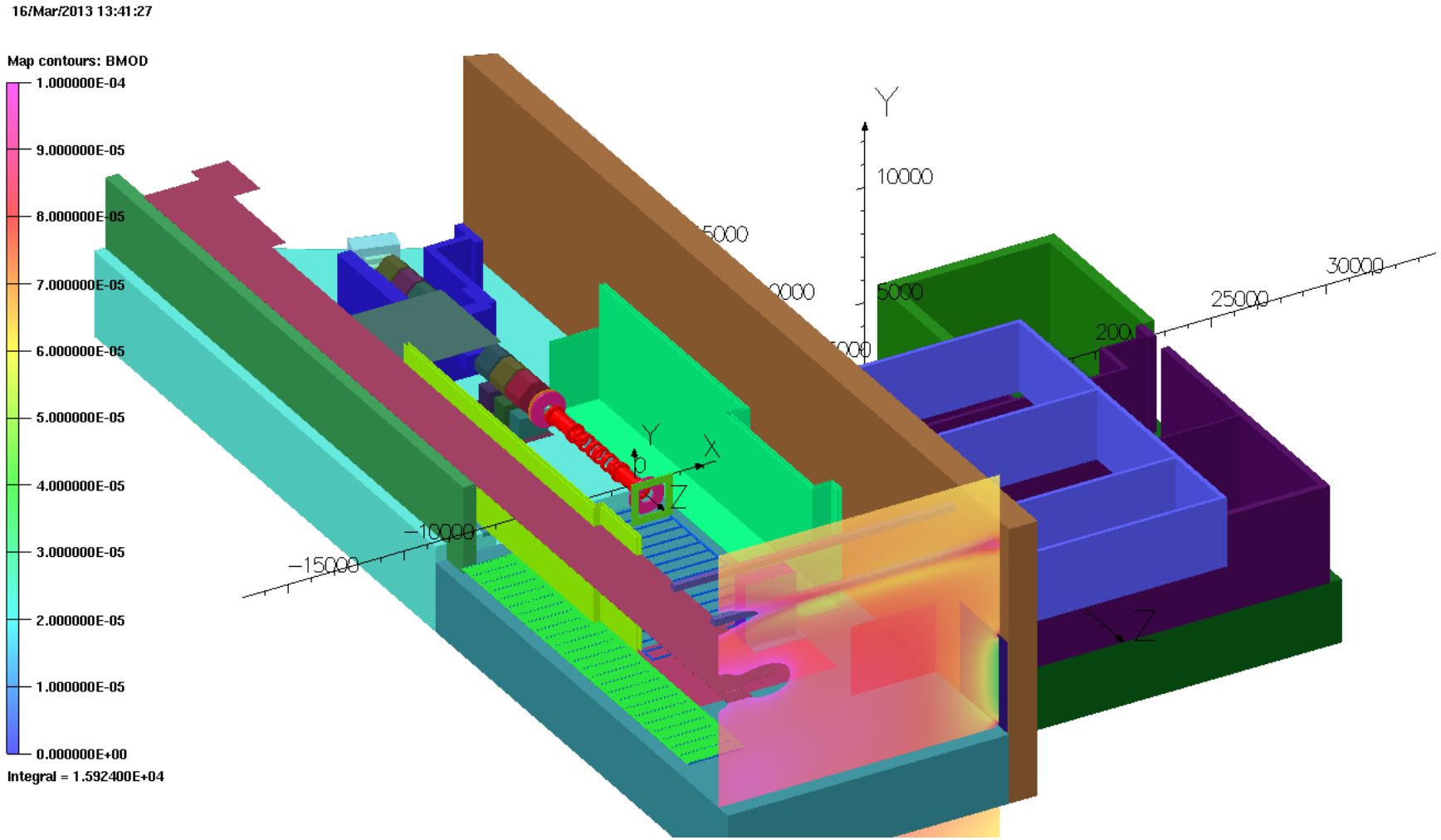


If the model is to be believed and on the basis of these few plots it appears that the change in the boundary condition appears to have marginally improved the situation at step IV for the ISIS control rooms . However the difference maybe irrelevant in context of the uncertainties in other aspects of the model.

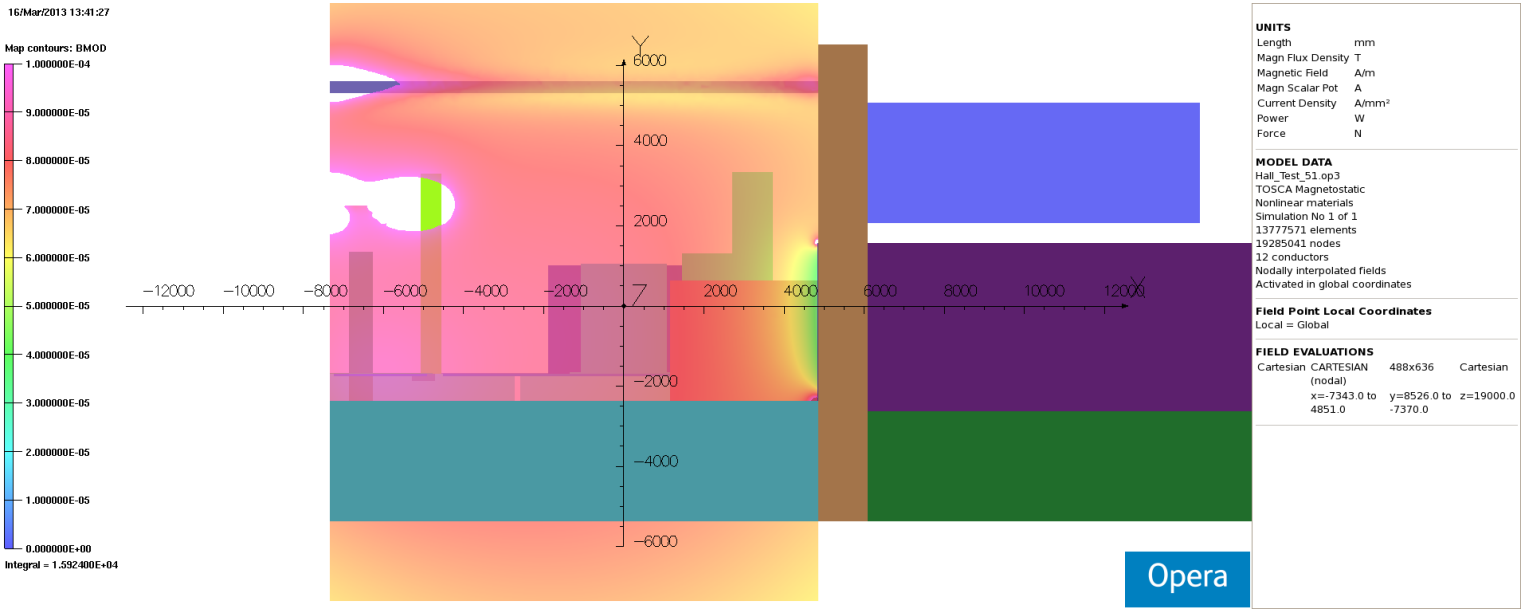
Clearly I'm trying to repeat this for all the other models (52 – 56 and their updated counterparts: models 62-66) but I will not have all of these solutions ready for Thursday. I have Step VI solenoid solved (model 63) but not post processed and I'm currently solving Step IV Flip (model 64).

I definitely want to push the model boundaries further out and re-solve them– I will try to do this on some models over the Easter hols – Models 71-76.

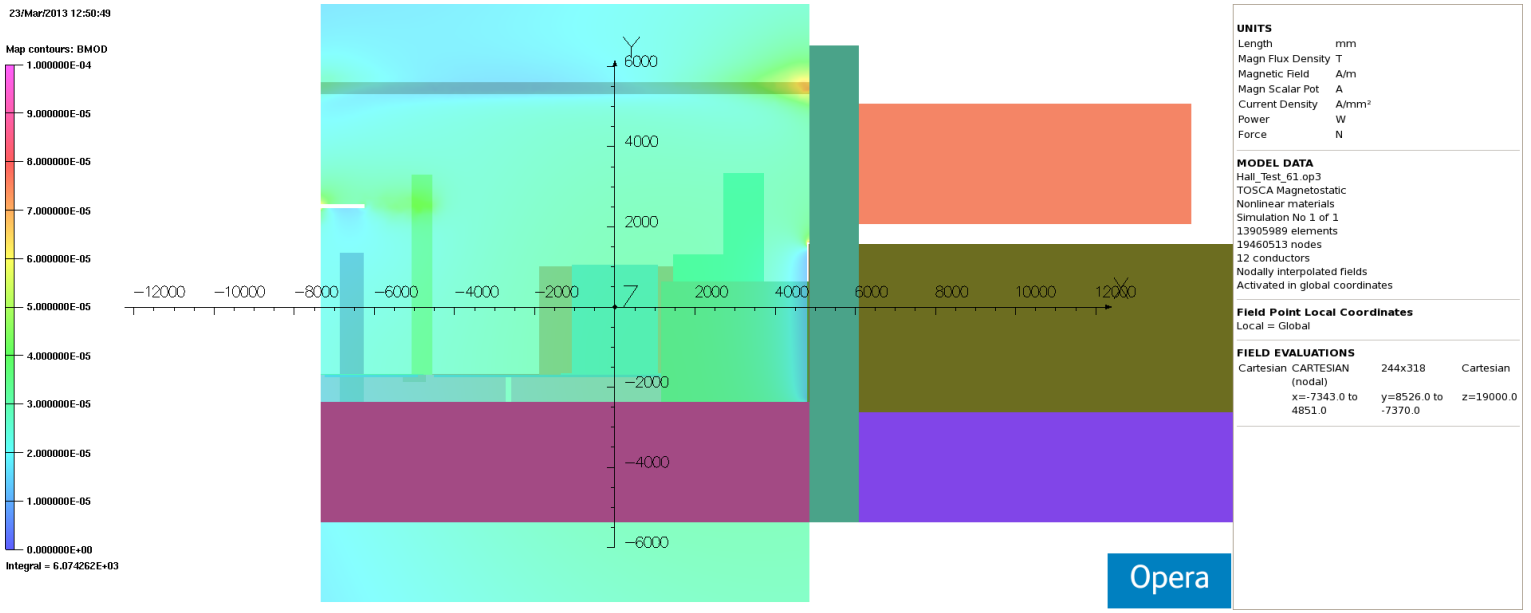
Does the change in the boundary conditions materially alter our perspective at the West Wall?



Z=19000 mm



Model 51



Model 61

1 Gauss Scale – Model 61 looks slightly better but the field level is so low that the difference is irrelevant in context of the model.

Part II

This following section could wait until after Easter if we are running short on time…

ErrB/B plots and mesh convergence.

I mentioned last week that I had been introduced to a new tool in Opera called ErrB; this plots what Opera estimates to be the error in the meshing resolution. By plotting ErrB/B you can get a relative error on the mesh wrt predicted field.

The autogen was updated to output these plots alongside the Bmod plots and vector plots.

It's not a magic bullet but it could be a useful tool in indicating where further mesh refinement could be undertaken without having to increase the meshing resolution everywhere in the model (and the significant associated increase in computation time.)

I haven't really used this tool in anger yet as I have been waiting to get more time on the post-processor but this is an introduction as to what it is and what I'm currently seeing in the autogen plots.

Copied from VF Ask Manual

"The Finite Element algorithms used in the Opera analysis modules solve for a potential. However most of the time a user is interested in the magnetic or electric fields and not in the potential."

"The field is the derivative of the potential. Presenting the true derivative value would result in sharp discontinuities in the values of the B-field at element boundaries. Therefore the values are averaged at the nodes. A reflection of the difference between the derivative values and the nodally averaged values is given in ERRB."

…

"It can be seen that the error is not related to the amplitude of the field, but to the derivative. This indicates that a fine mesh or quadratic elements is needed where the field is changing rapidly."

Copied from VF Ask Manual

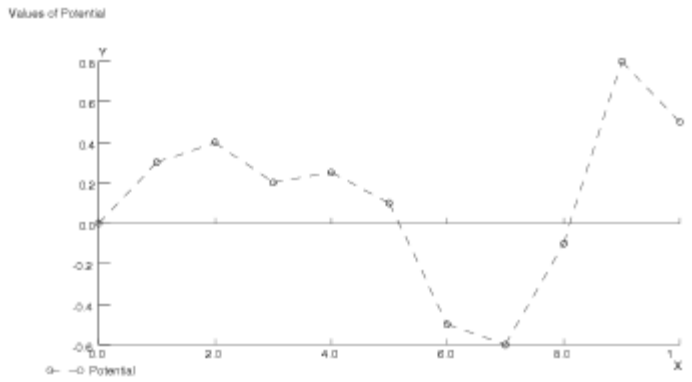


Figure 16 Potential at the nodes of the mesh

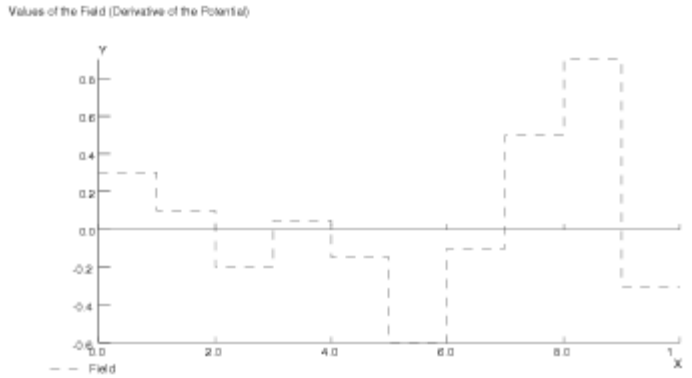


Figure 17 The "field" is the derivative of the potential

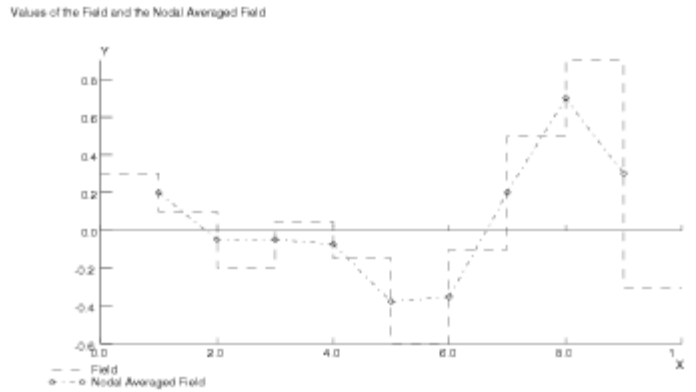


Figure 18 Values of the field and the nodal averaged field

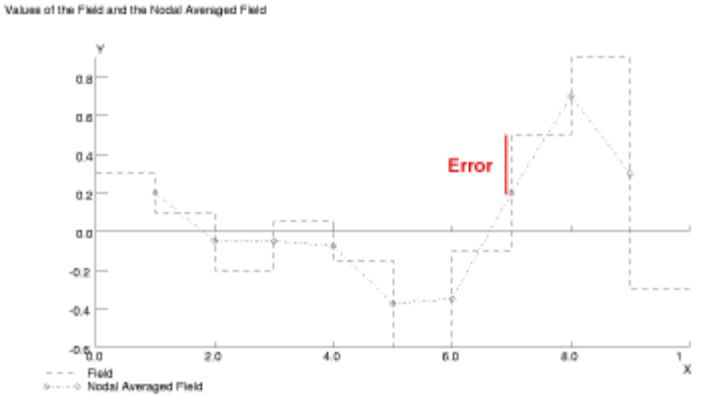
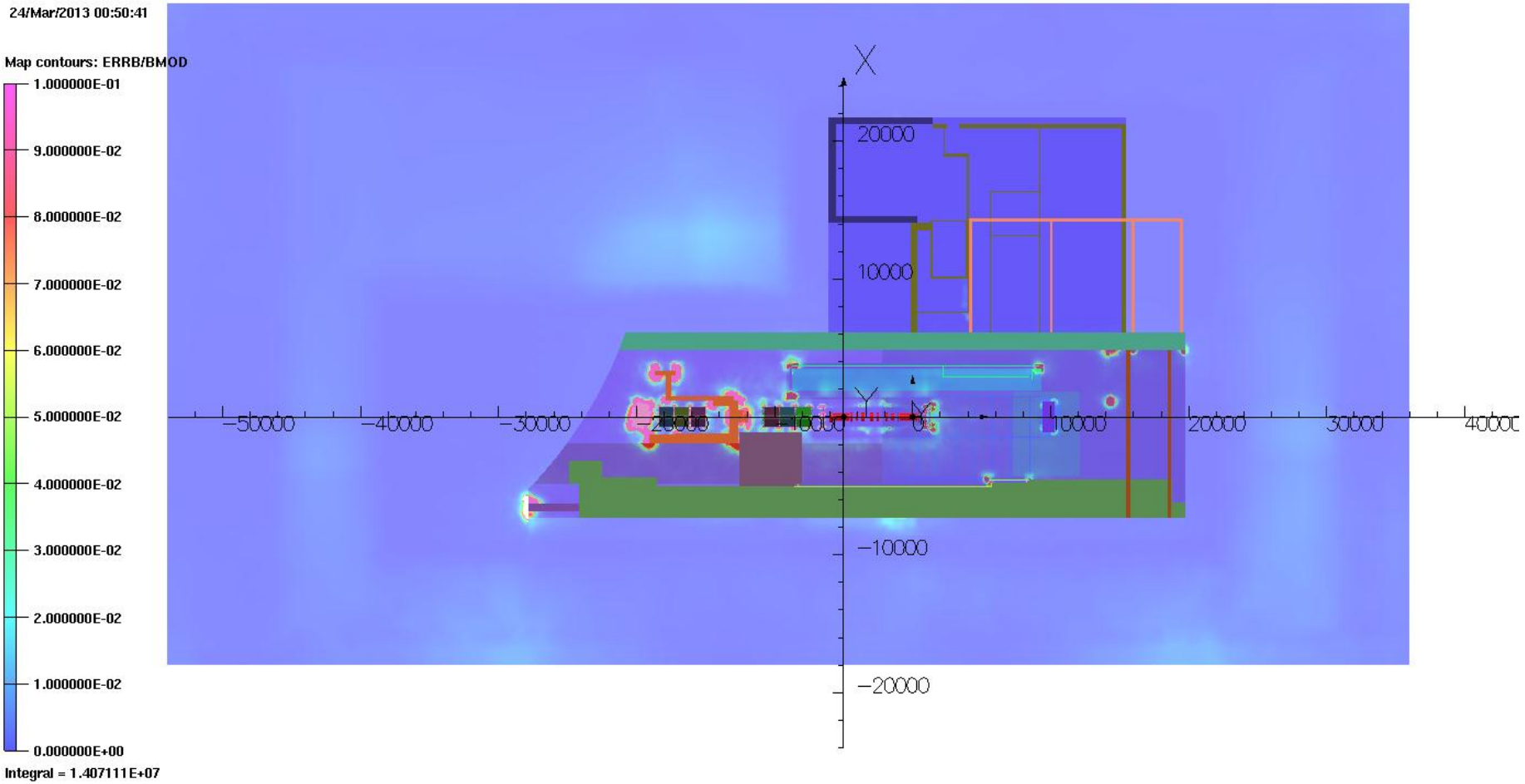


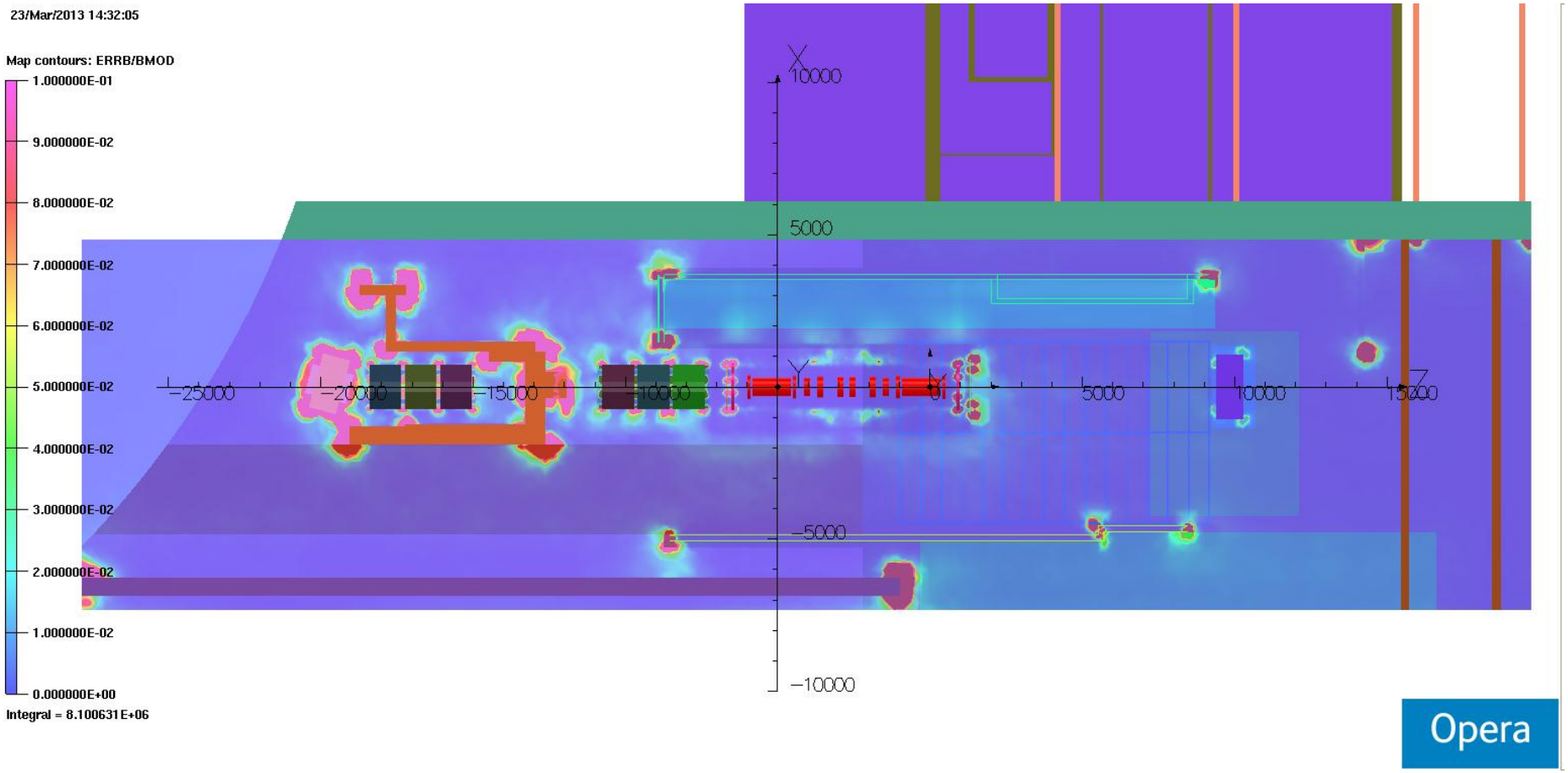
Figure 19 The error is the difference between the nodal averaged field and the field (derivative of the potential)

Model 61 – Step IV Solenoid



Scale is 0.1. There is nothing of concern in SSB so I'll zoom straight into the hall on the next slide. (Note some slight ghosting in blue region where the meshing resolution changes but this is not of any concern.)

Model 61 – Step IV Solenoid



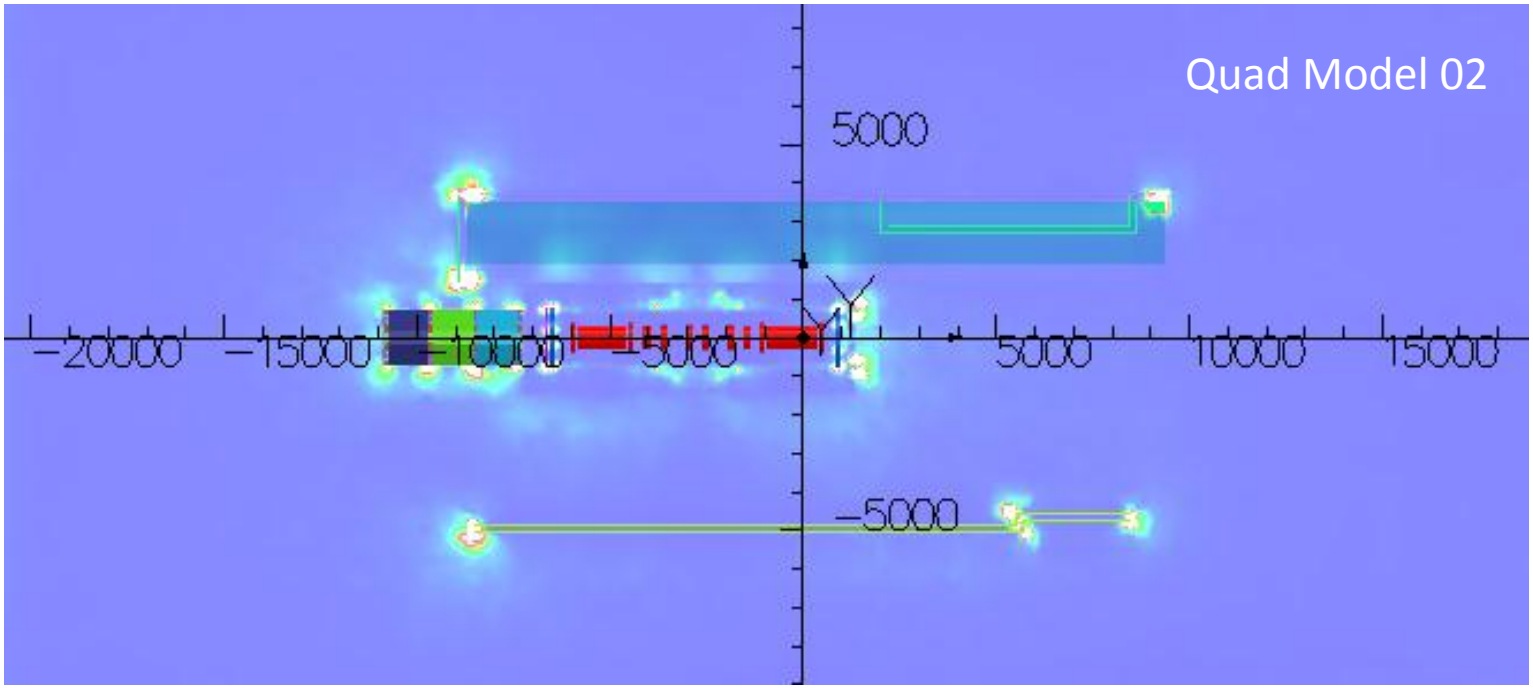
Scale is 0.1. Area on RHS is deliberately meshed at lower resolution (D2 DSA etc) so no surprises at indication of poor meshing here. Of slightly more concern are the hot spots on the Virostek Plates, SSW, Quads Q9-Q7, etc.

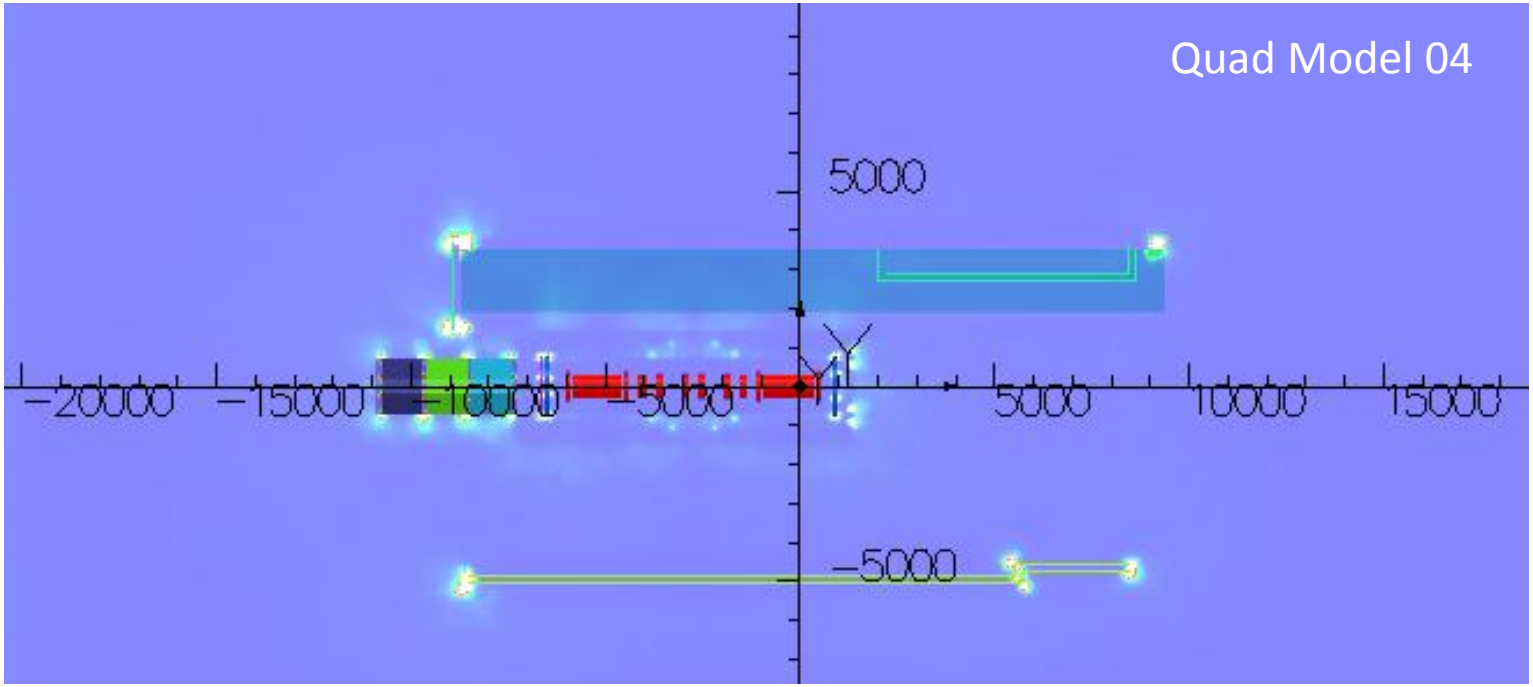
A couple of weeks ago I ran some Quad models at increasing meshing resolutions – did this improve the ErrB/B?

All solved in 8 iterations:

Quad Model 02 –Same Mesh resoution as Hall Model	– 22 hours solve
Quad Model 03 – (mesh size/2^(1/3))	– 45 hours solve
Quad Model 04 – (mesh size/4^(1/3))	– 116 hours solve

This is curious as I would have expected ~90 hours solve time for Model 04 but the post processor was running a lot so this may have caused the solver core to throttle back slightly?





ErrB/B. Scales are both 0.1.

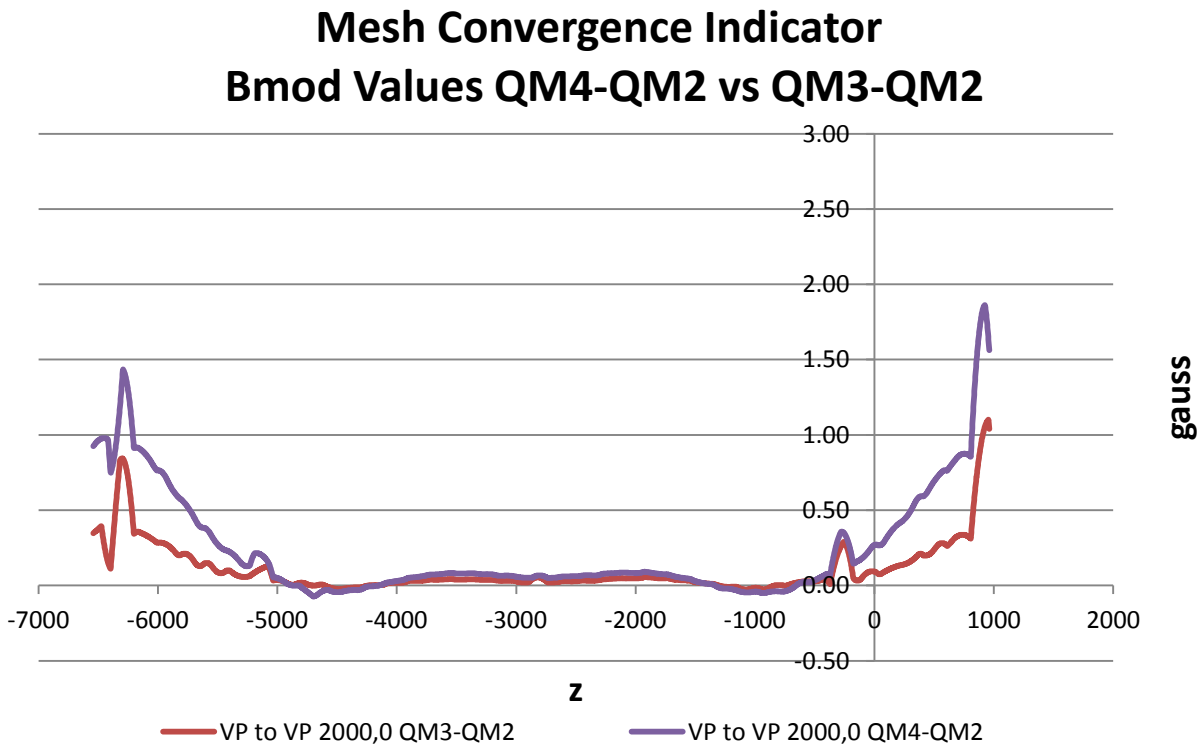
There is a difference in Quad Model 04 but at a huge cost in computational time.

Indicative that smart use of the ErrB/B plots to improve the meshing could be a much better way of improving the models.

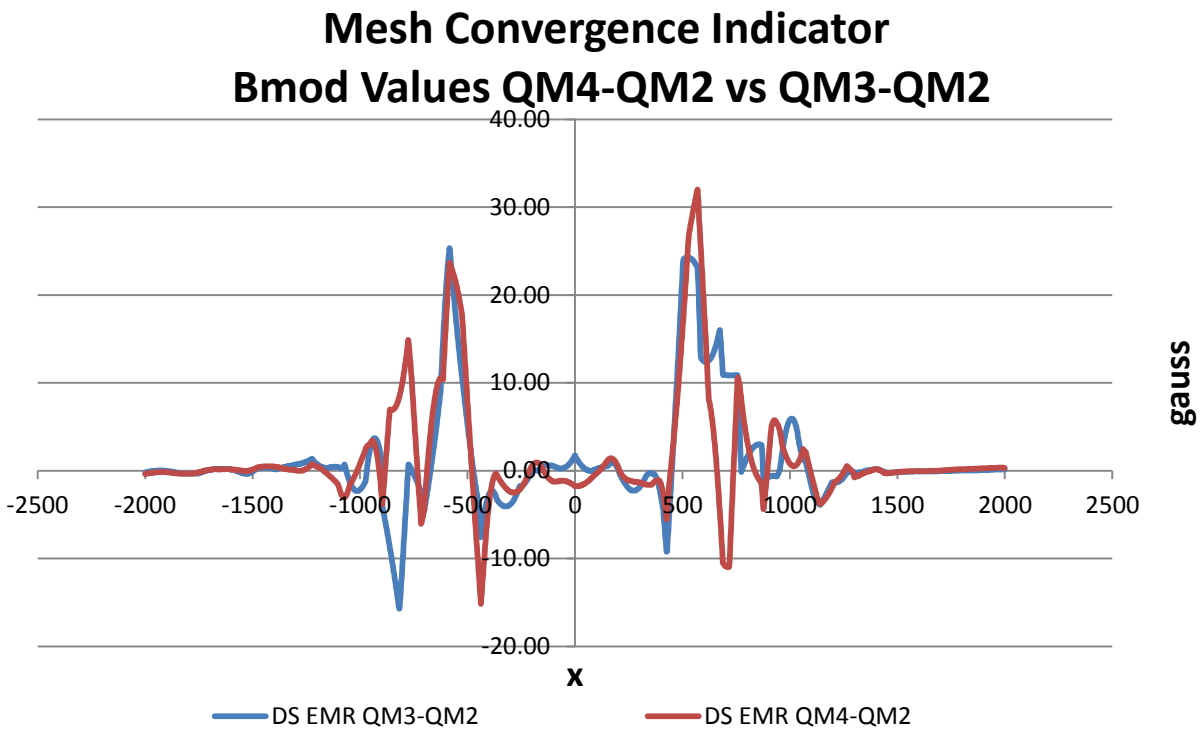
Does this correlate with the Quad Model Plots?

A couple of weeks ago a showed a series of plots illustrating the difference between QM3 and QM2 in a number of places.

One of those places was a line that I had chosen quite randomly that ran along z parallel to Virostek Plate (US_Z0) to Virostek Plate (DS_Z1) at y=0 x= 2000.



I also tried plotting at the West side of the EMR but this plot is inconclusive.

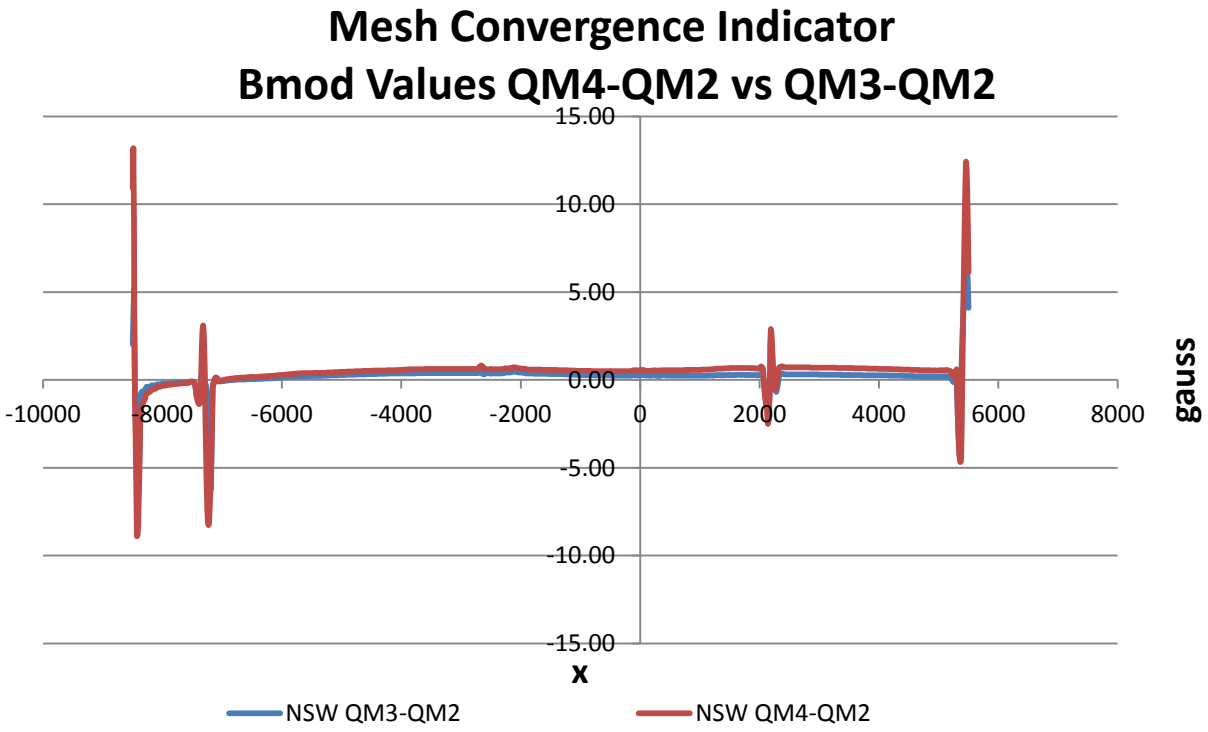


Perhaps plotting differences in Bmod in the regions where ErrB/B is large is not a good idea as the ErrB/B is telling me that there is a bigger error on Bmod in the first place! (obvious with hindsight…)

It is difficult to draw any general conclusions without making an industry of producing many plots in different regions.

However it is clear that the mesh is not optimised but it is not yet clear what benefit there is in the optimisation process. But we do now have a tool that can help to determine where to start improving it.

And in the North Shield Wall. This is a line that passes through the inner layer of steel in the NSW. X=-4869, y=0, z=-8500 to 5500.



- Doesn't appear to be much gained in the NSW…
- Changes in the magnetisation of the NSW were much more noticeable when the model boundary was moved – recall plots from a few weeks back.
- I don't know what is causing the spikes – End spikes could be ErrB/B-Spikes at 2000/-7000 unknown– maybe some cut plane feature in the model?

Part III

This following section could also wait until after Easter if we are running short on time…

Quick Comparison of Normal vs Tangential

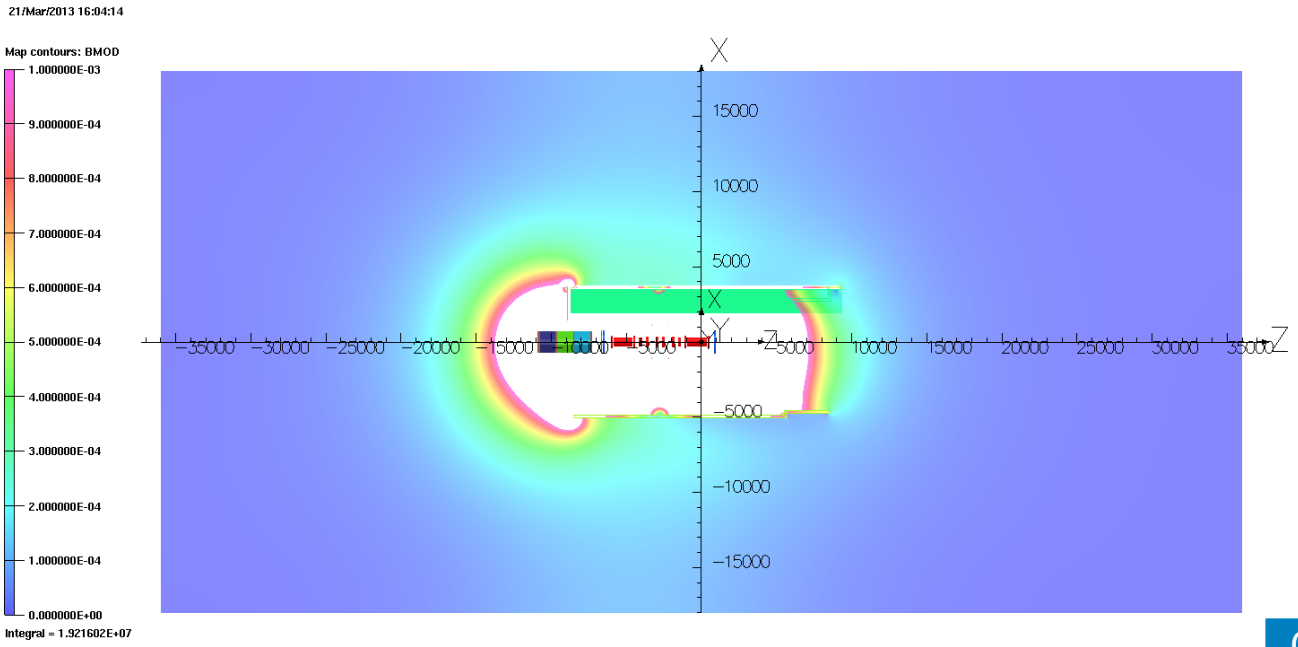
Quad Model 05 was run with Normal Boundary conditions as opposed to Tangential.

Comparing two models run with identical meshes but different boundary conditions and looking for differences is one way of ascertaining whether the boundaries are too close.

I haven't done any quantitative analysis on this but comparison of the Bmod/Vector Plots should give a clear indication whether the boundaries are still too close.

Comparison of the two Bmod plots (10 gauss range) show subtle but noticeable differences in the field strength even quite close to the shield wall. Vector plots show similar differences close to the shield wall with marked differences at boundary as expected! These can be viewed online. The result from the Quad models can be extrapolated to the Hall models as they have similar boundary limits.

Conclusion: The boundaries in all of my models are still too close and this is the next issue to rectify. Needs to be done in a way that doesn't result in poor meshing resolution in areas of interest or large increase in solve time, although I expect some increase in the solve time to be inevitable.



UNITS

Length	mm
Magn Flux Density	T
Magnetic Field	A/m
Magn Scalar Pot	A
Current Density	A/mm²
Power	W
Force	N

MODEL DATA

Quad_Sub_Model_02.op3
TOSCA Magnetostatic
Nonlinear materials
Simulation No 1 of 1
9327364 elements
13052338 nodes
12 conductors
Nodally interpolated fields
Activated in global coordinates

Field Point Local Coordinates

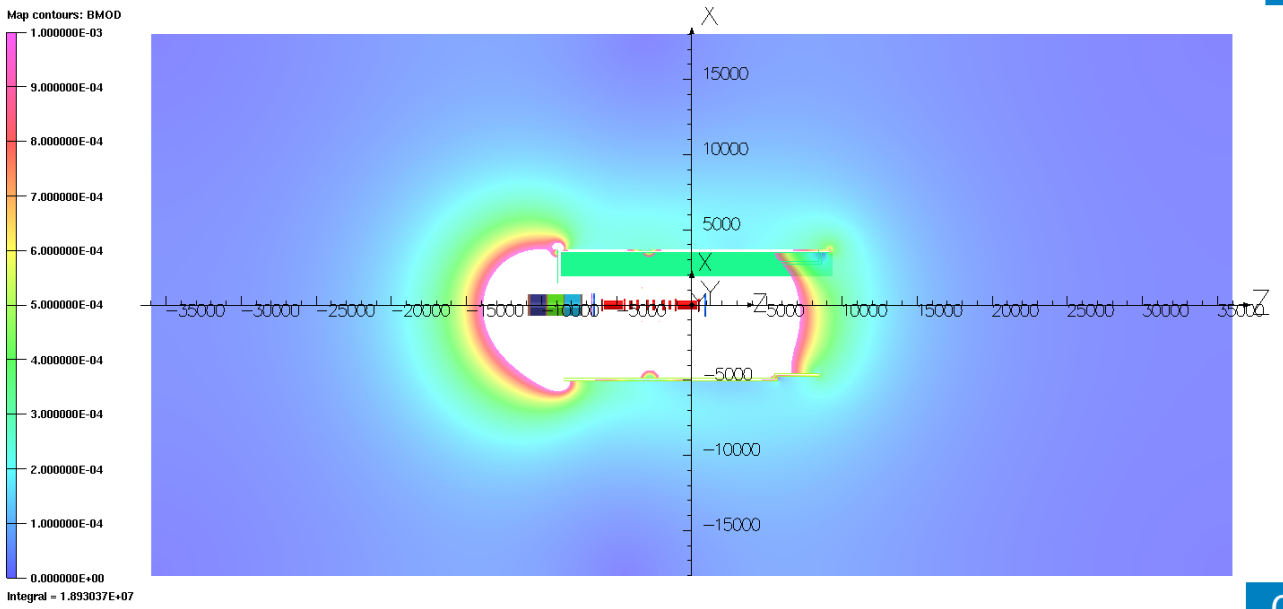
Local = Global

FIELD EVALUATIONS

Cartesian	CARTESIAN (nodal)	2880x1440	Cartesian
	x=-18000.0 to 18000.0	y=0.0	z=-36000.0 to 36000.0

Quad Model 02 – Tangential Border

Opera



UNITS

Length	mm
Magn Flux Density	T
Magnetic Field	A/m
Magn Scalar Pot	A
Current Density	A/mm²
Power	W
Force	N

MODEL DATA

Quad_Sub_Model_05.op3
TOSCA Magnetostatic
Nonlinear materials
Simulation No 1 of 1
9327364 elements
13052338 nodes
12 conductors
Nodally interpolated fields
Activated in global coordinates

Field Point Local Coordinates

Local = Global

FIELD EVALUATIONS

Cartesian	CARTESIAN (nodal)	1440x720	Cartesian
	x=-18000.0 to 18000.0	y=0.0	z=-36000.0 to 36000.0

Quad Model 05 – Normal Border

Opera

Conclusions

At the moment I think there are two obvious outstanding issues with the Hall model before it is handed over to VF (or to be done in parallel with their work).

1) The model boundaries need moving further out. (Trivial)

2) The meshing needs to be looked at. (Time Consuming)
   - Improve meshing in areas where it is suggested by ErrB/B plots.
   - Reduce meshing resolution in other areas to compensate for the larger solve volume and improved meshing in other areas. This needs to be done to try and keep the solve time of the model reasonable.

As my opinion stands at the moment I think these changes, particularly 1), would put the hall model in reasonable shape, or at least in good shape for review by VF.

I couldn't predict whether these changes will have any significant effect on the field in areas of interest. (I have to confess that if I was building a hall model from scratch again I would do it very differently….)