Magnetic Modelling
16/04/2013

Consultancy

As has no doubt been discussed already STFC has approved the order for the consultancy work with Vector Fields

We have had an email from Chris Riley stating that they will be in touch as soon as they receive confirmation of this.

It looks like they will be doing most of the work internally with Klaus. Klaus has already had some contact with the project so I believe he is a good choice.

Modelling

This last week I've done two things.

I've extended the model boundary to +/-40m in x and y and +/-60m in z. To try and ensure that the model solve time didn't balloon I did tweak some of the mesh sizes to keep the number of elements approximately the same as the smaller model – tweaks were small as the outer volume is meshed at very poor resolution.

I ran the 240MeV/c solenoid model (Model 71) which solve a couple of days ago. This has been run through the image generator but I've not had chance yet to make comparison plots with model 61. If this looks ok I will (possibly – see later notes) re-run models 62-66 as 72-76 as I can and these will form the new baseline.

It may also be worth running Model 71 with a normal boundary condition for comparison – there should be no difference in output plots in region of interest if the boundary is far enough out.

Before talking about the second thing that I've done I'm going to return to the slides from the other week that I didn't cover… (yellow slides)

ErrB/B plots and mesh convergence.

I mentioned a few weeks ago 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 field size

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.)

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

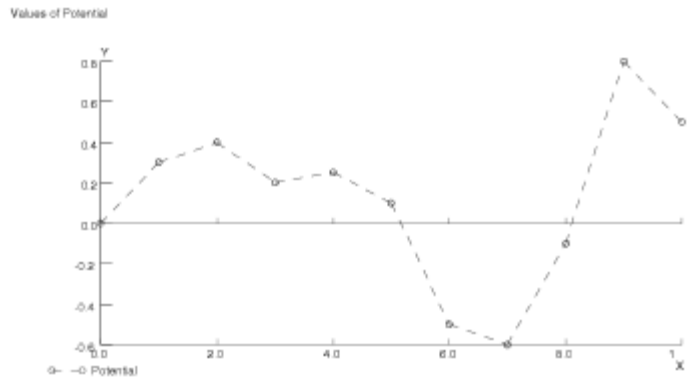


Figure 16 Potential at the nodes of the mesh

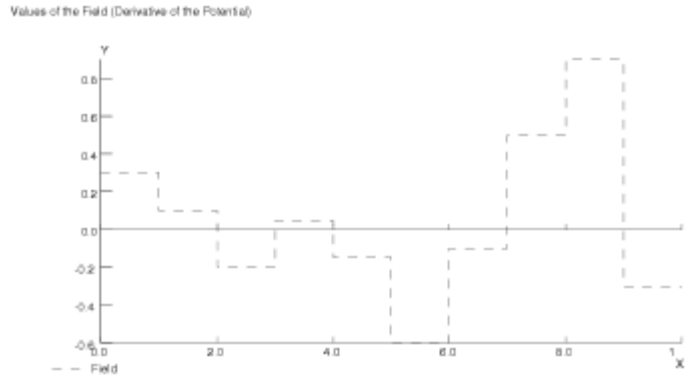


Figure 17 The "field" is the derivative of the potential

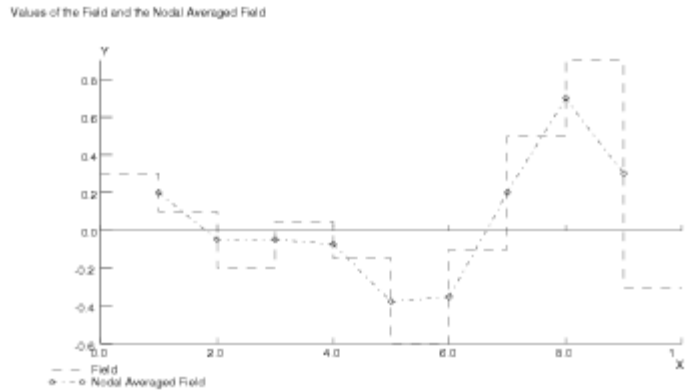


Figure 18 Values of the field and the nodal averaged field

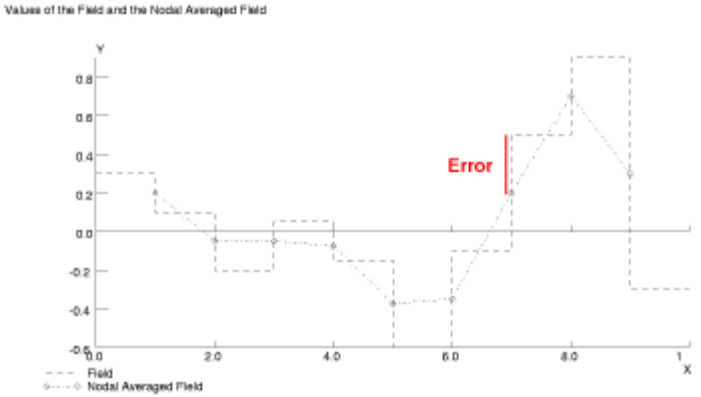
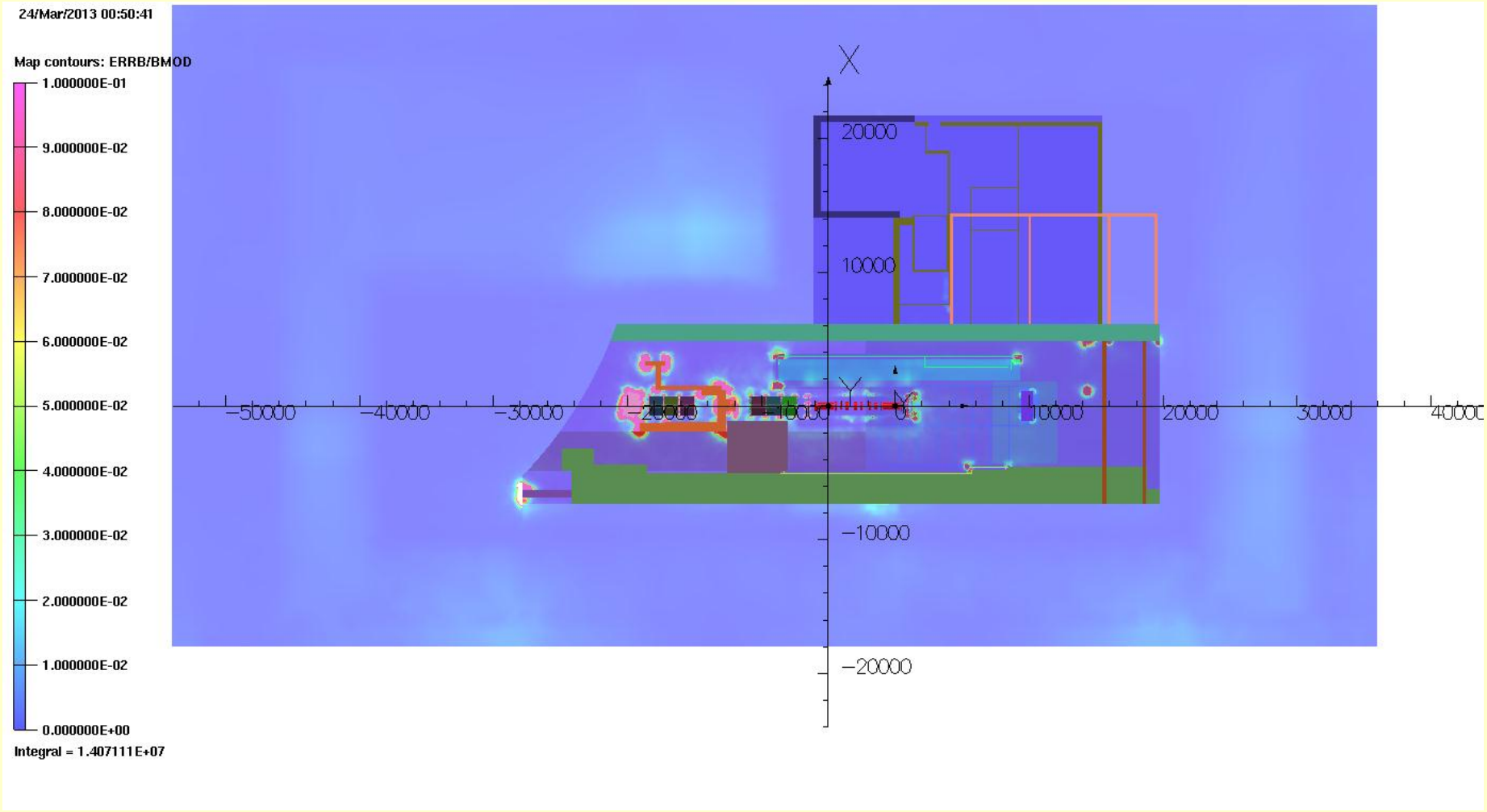


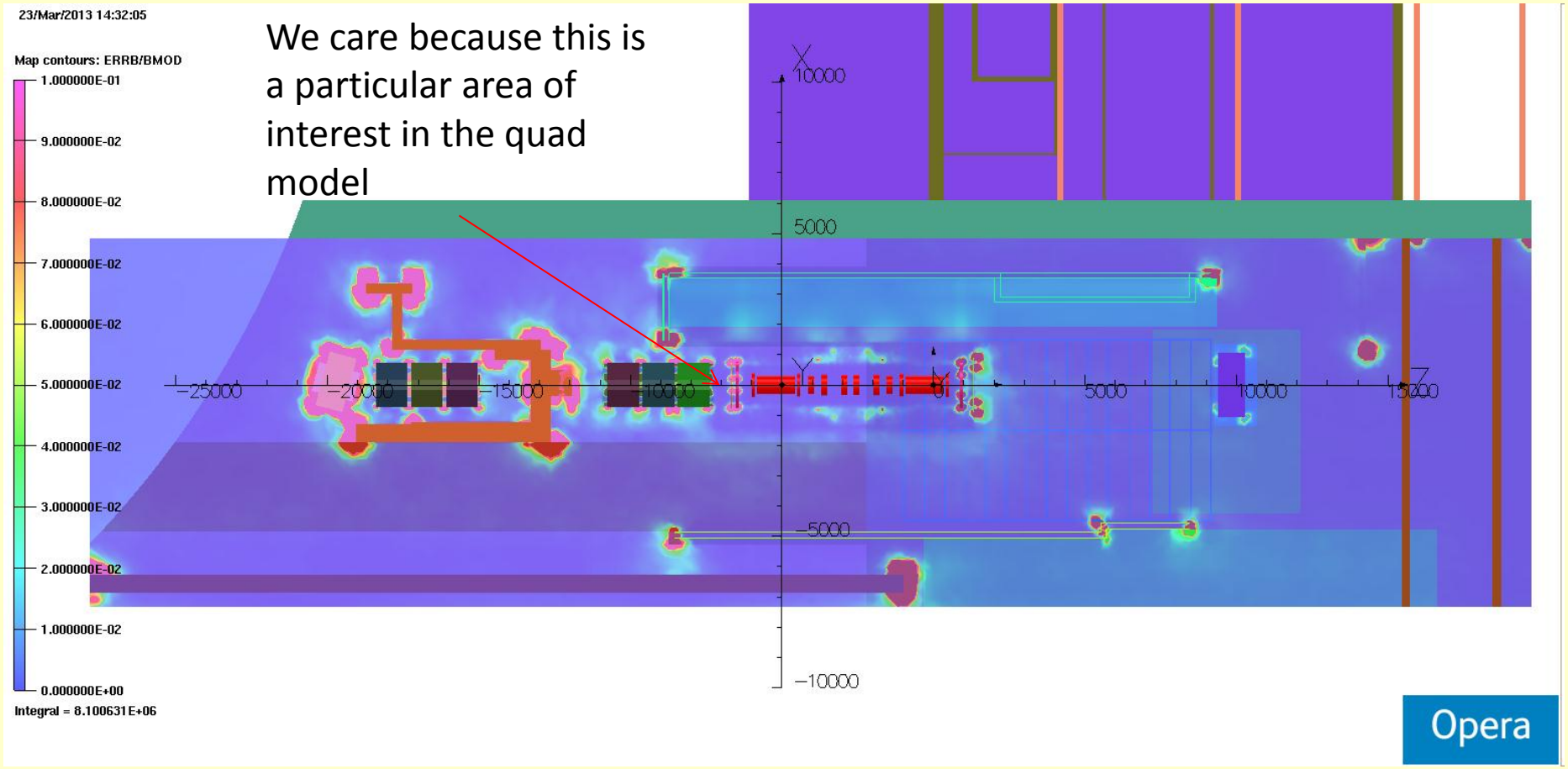
Figure 19 The error is the difference between the nodal averaged field and the field (derivative of the potential)

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



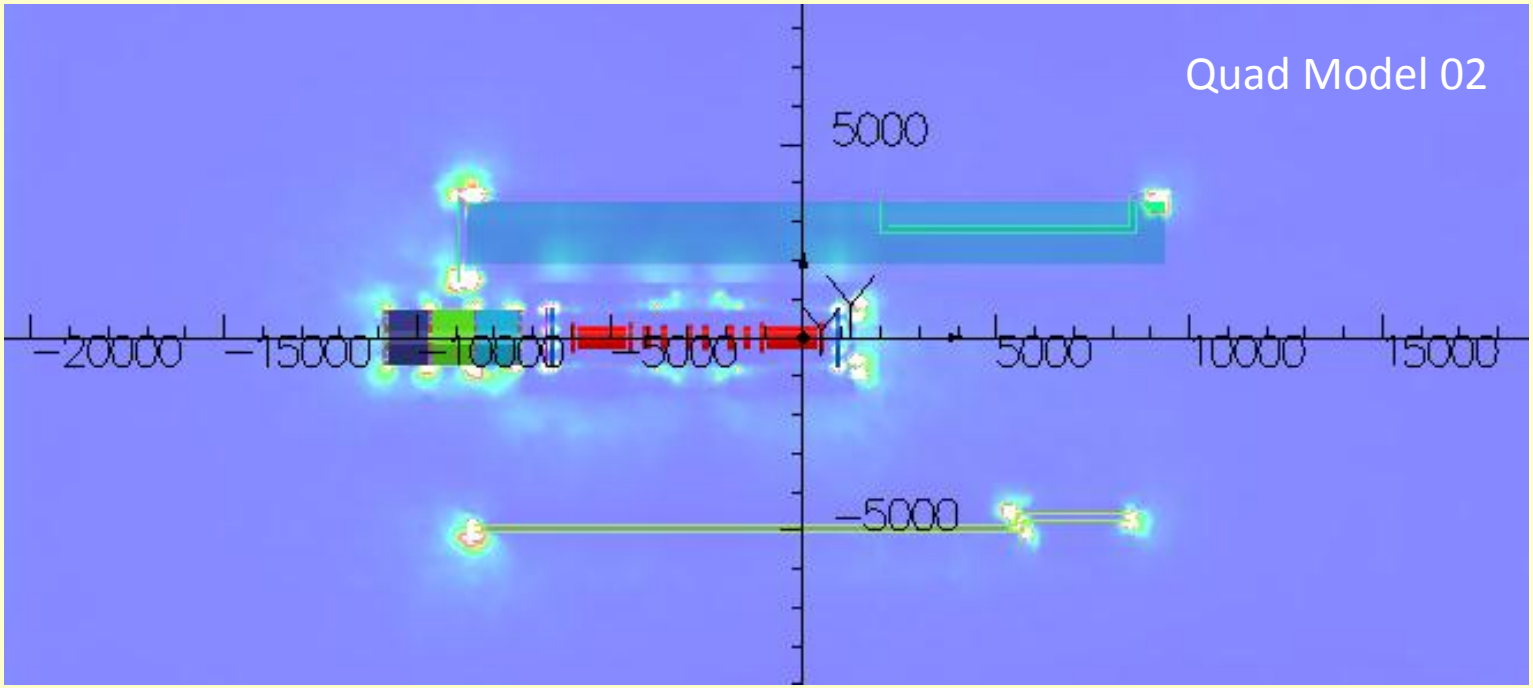
Scale is 0.1. Area on RHS is deliberately meshed at lower resolution (D2 DSA etc) so no surprises at indication of poor meshing here. Of slightly more concern are the hot spots on the Virostek Plates, SSW, Quads Q9-Q7, etc.

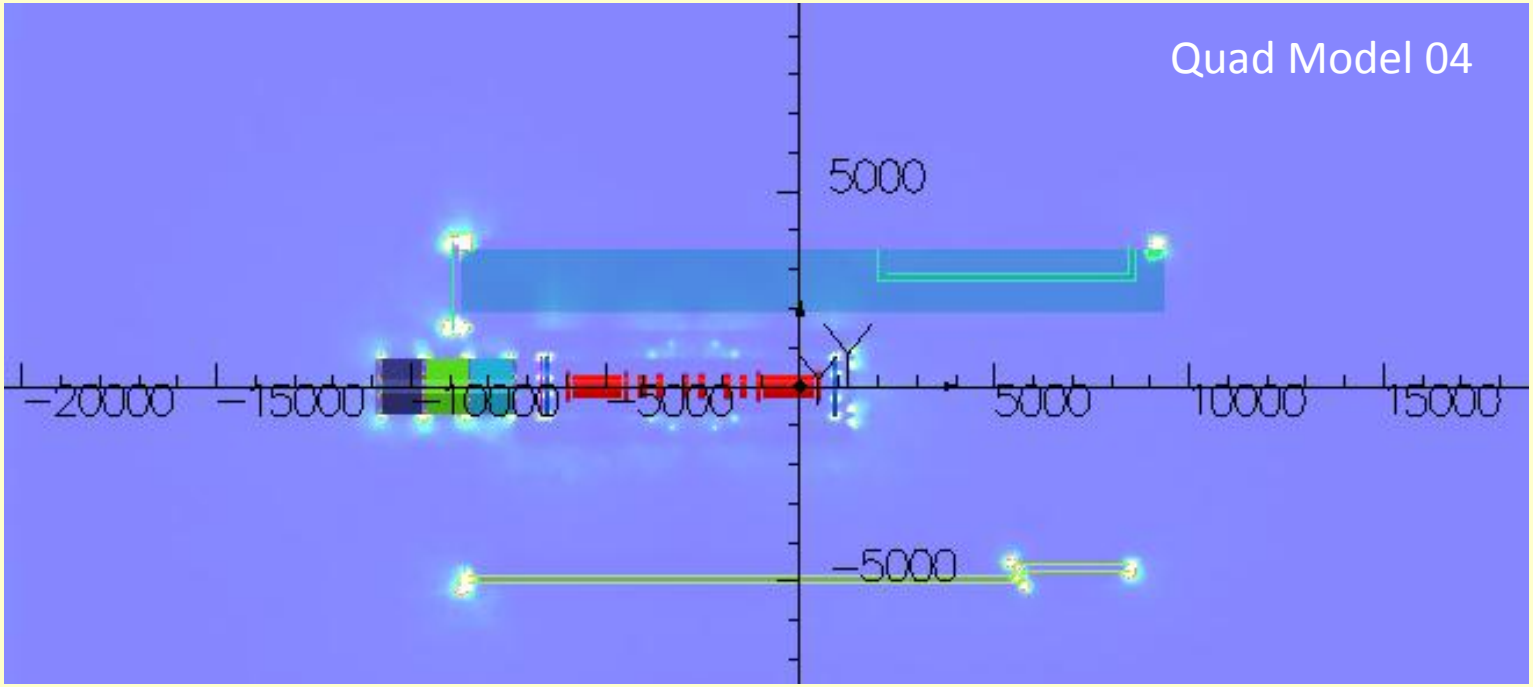
A couple of weeks ago (update 16/04/2013: well before easter now) I ran some Quad models at increasing meshing resolutions – did this improve the ErrB/B?

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.

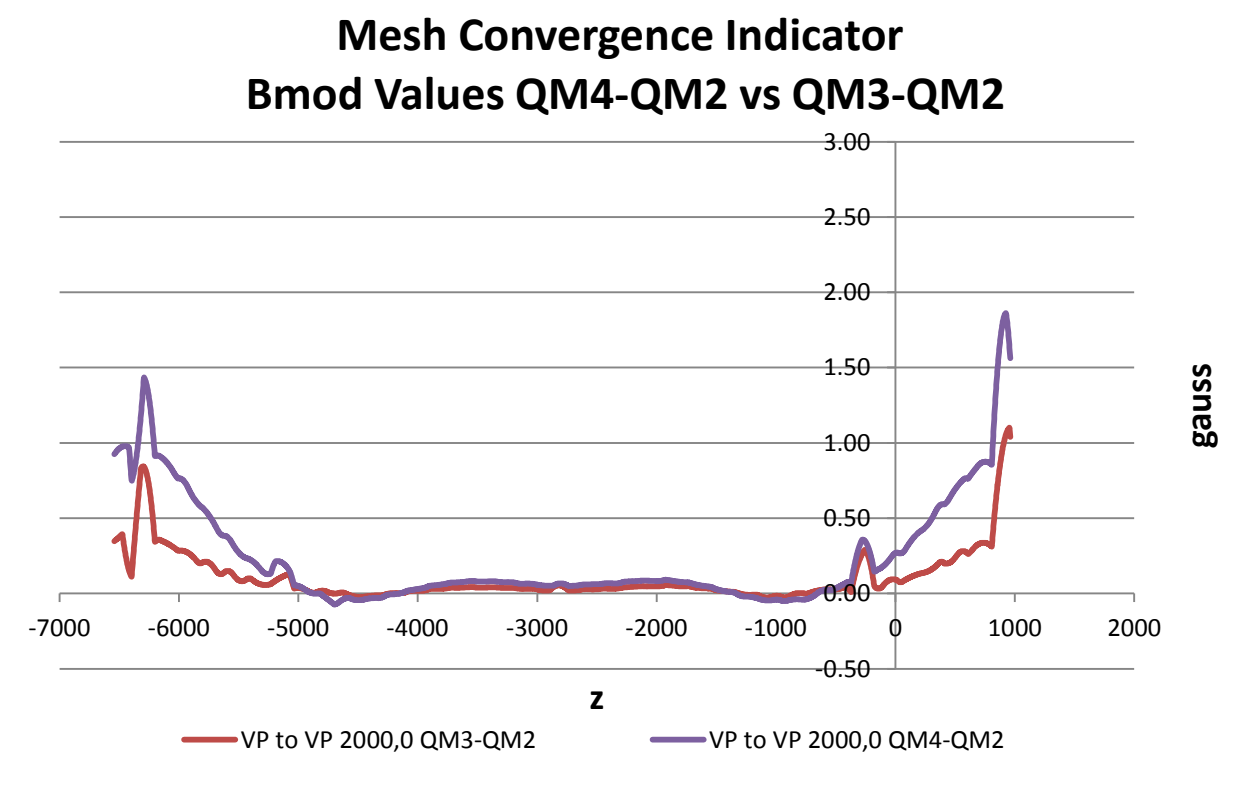
There is a difference in Quad Model 04 but at a huge cost in computational time.

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?

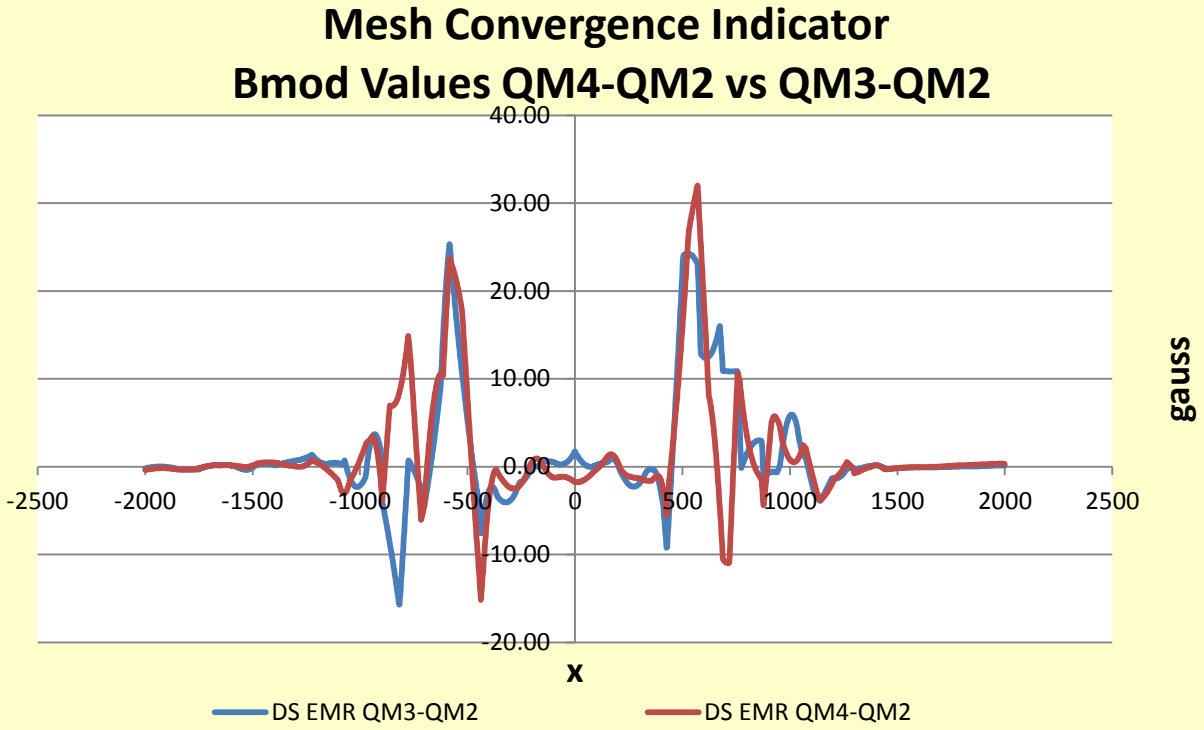
A couple of weeks ago a showed a series of plots illustrating the difference between QM3 and QM2 in a number of places.

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



There's a change but do we care about this level of change or do we treat as an error?

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

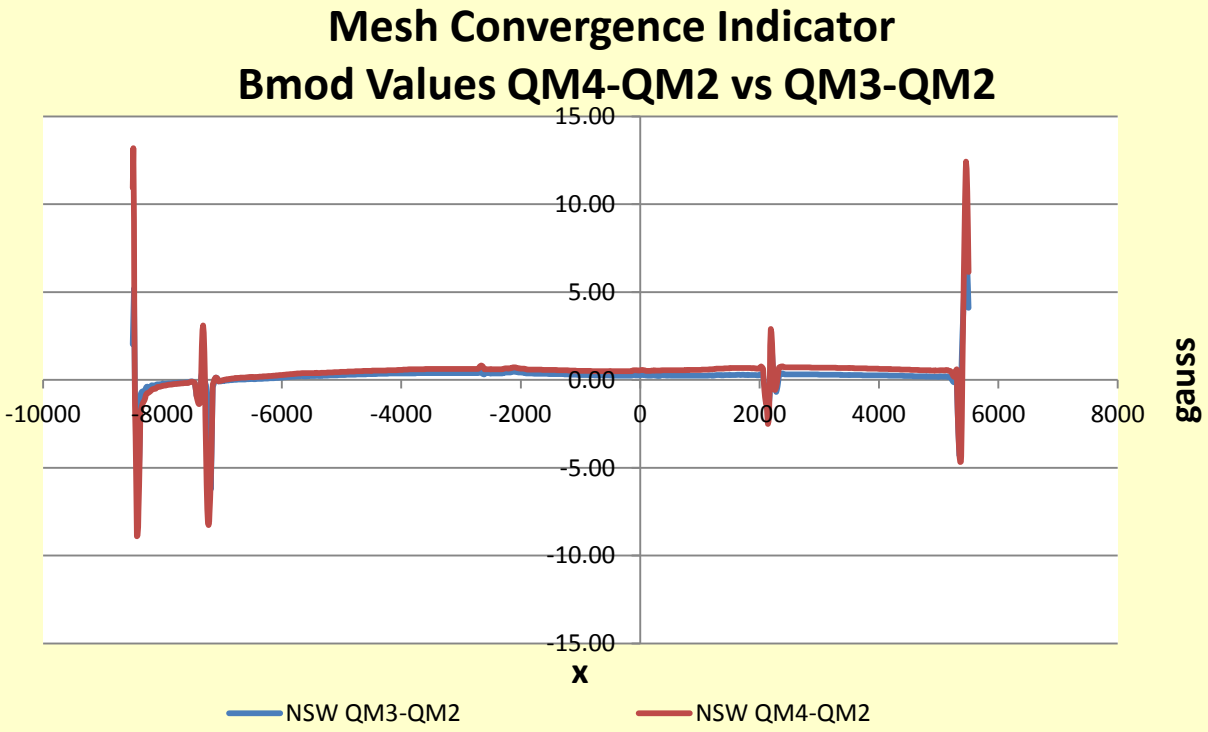


Perhaps plotting differences in Bmod in the regions where ErrB/B is large is not a good idea as the ErrB/B is telling me that there is a bigger error on Bmod in the first place! (obvious with hindsight…)

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.



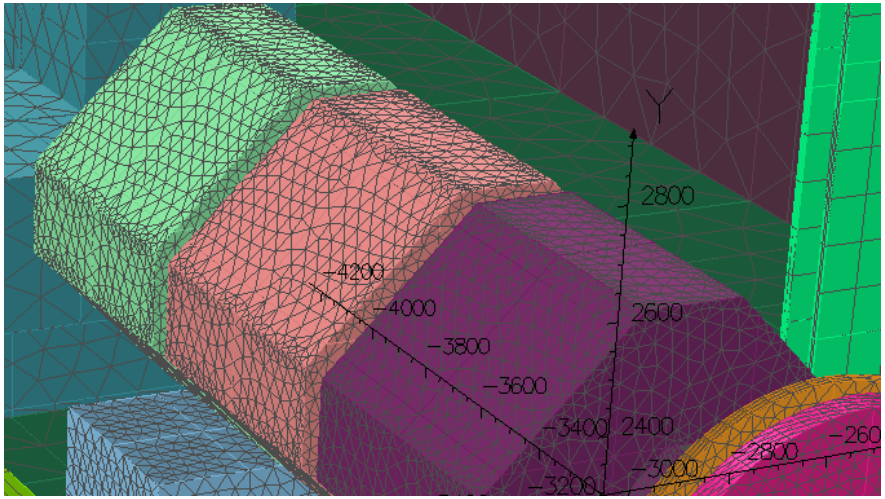
- Doesn't appear to be much gained in the NSW…
- Changes in the magnetisation of the NSW were much more noticeable when the model boundary was moved – recall plots from a few weeks back.
- I don't know what is causing the spikes – End spikes could be ErrB/B
- Spikes at 2000/-7000 unknown– maybe some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

Modelling

What I've done is I've gone around various components and improved the meshing along edges/faces where I have been able to infer that the meshing geometry is poor from the ErrB/B plot on the y=0 plane (Yes, I know this means I may need another iteration later on different planes but I want a test run….)

What components have I worked upon?

Beam Dump
EMR
Virostek/TOF Plates
Quads
Linac Wall



This was then run as model 77. This completed last night. Note solve time was only 12 hours longer than model 71 (66 hours vs 54 hours). Now I'm waiting for the autogen to produce ErrB/B plots for comparison.

I've also since then updated the NSW and I'm currently working on the SSW.

Modelling

If this works then this is clearly a much more efficient way of getting mesh convergence in areas where the meshing is obviously poor but I need to spend a bit of time taking a look at the output.

How far to take this – at the moment unsure but the code has been configured so that it is easy to alter the meshing in these areas so there is plenty of play if necessary.

The point of this is that I would like to understand these results before I go back to looking at the field across the quads in the quad sub-model; the meshing around the quads are shown to have a high error.

I suspect we will get some feedback on this from the consultation with VF, the question of mesh convergence was in the consulting scope.