By maths.

To include axisymmetry, define poloidal magnetic flux as:

$$\psi(R, Z) = \int_0^R R' B_z(R', Z)\, dR'$$

And the toroidal current is:

$$-\mu_0 j_\phi = \frac{\partial}{\partial R} \frac{1}{R} \frac{\partial \psi}{\partial R} + \frac{1}{R} \frac{\partial^2 \psi}{\partial Z^2}$$

Going back to terms of Bz:

$$-\mu_0 j_\phi = \frac{\partial B_z}{\partial R} + \frac{1}{R} \frac{\partial^2}{\partial Z^2} \int_0^R R' B_z(R', Z)\, dR'$$

We only see where the MSE emission is, so we can only integrate from some *R = R0:*

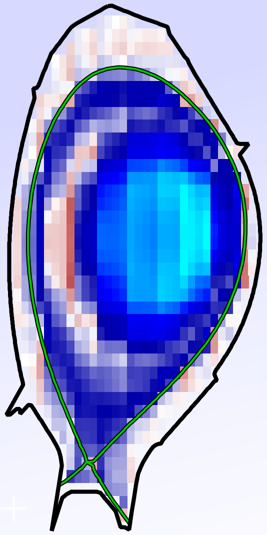
$$-\mu_0 j_\phi = \frac{\partial B_z}{\partial R} + \boxed{\frac{1}{R} \frac{\partial^2 \psi(R_0, Z)}{\partial Z^2}} + \boxed{\frac{1}{R} \frac{\partial^2}{\partial Z^2} \int_{R_0}^R R' B_z(R', Z) dR'}$$

This we have
with 1D MSE.

Function of Z that
we cannot know.

The new term gives
localisation of current
in Z (~via curvature of field).

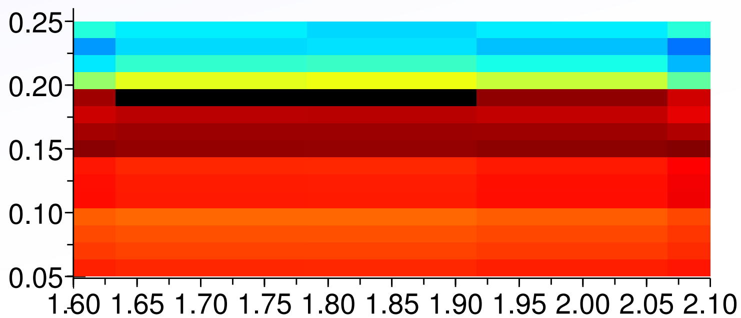
But.... Integral of a second difference of measurement... will be VERY noisy.

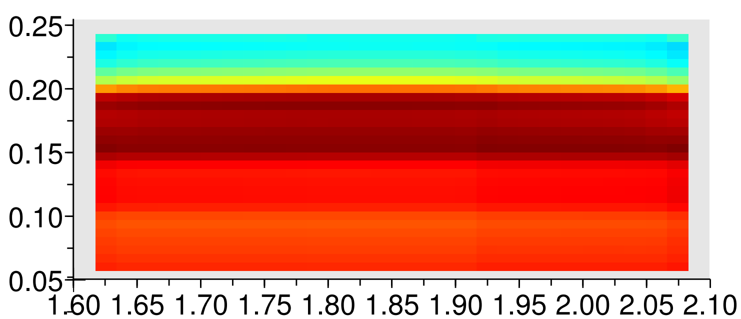


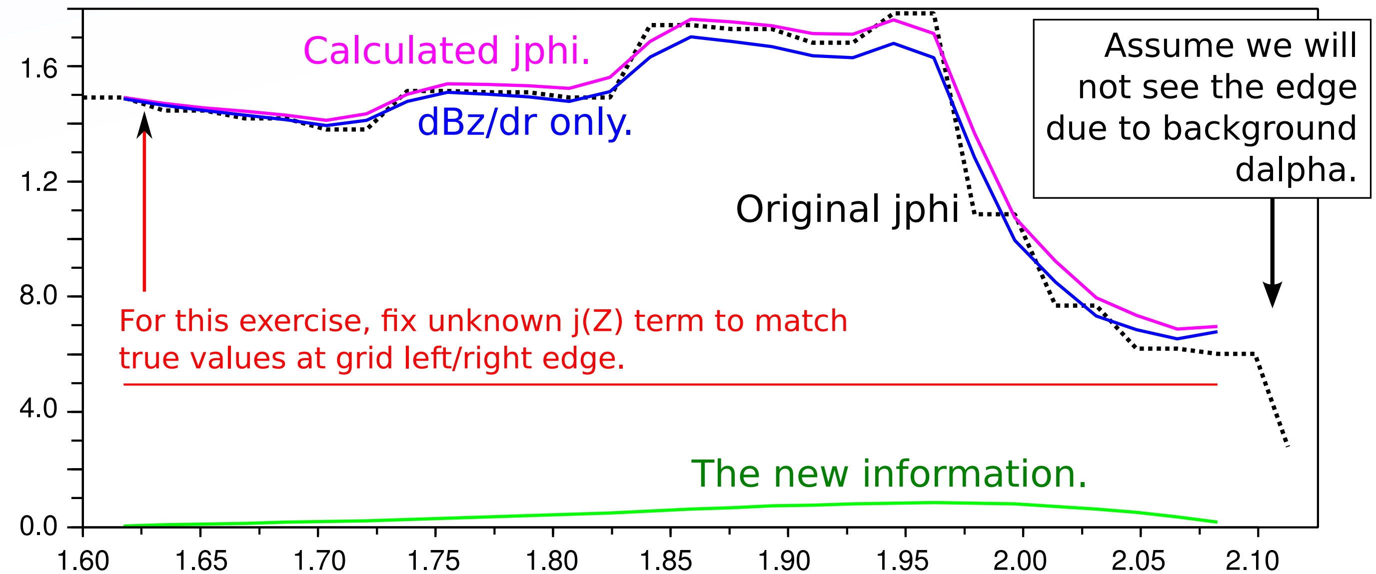
So can we directly calculate *jphi*?

- Take CLISTE current distribution
- Predict 30x30 grid of Bz.
- Try to directly calculate j_phi

$$-\mu_0 j_\phi = \frac{\partial B_z}{\partial R} + \frac{1}{R}\frac{\partial^2 \psi(R_0, Z)}{\partial Z^2} + \frac{1}{R}\frac{\partial^2}{\partial Z^2}\int_{R_0}^{R} R' B_z(R', Z) dR'$$





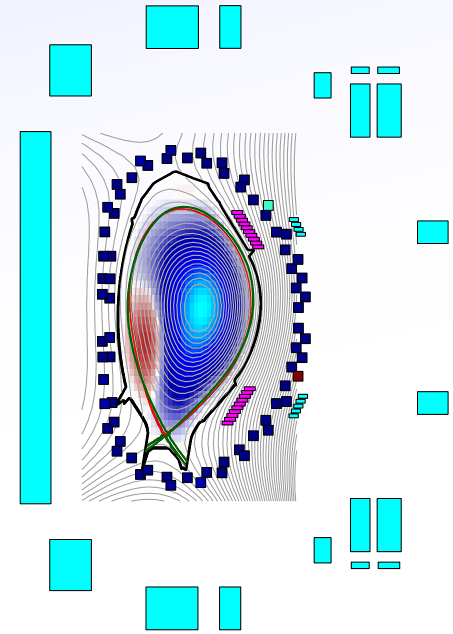


Unknown part above dBz/dR (standard MSE) is < 10% anyway. We do gain it mathmatically but as anticipated, it is entirely lost even with only 1mT noise in Bz (0.02^{o} pitch angle).

Conclusion: No. You still cannot exactly calculate jphi directly.

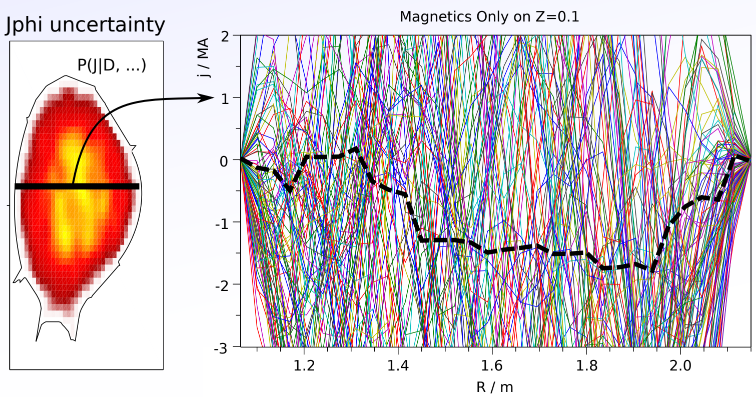
However, we do have measurements of the dBz/dR part at different Zs, and we know that this is most of jphi variation. Together with integral measurements (field pickups and flux loops), it is now part of a complex tomorgraphy problem that we have done before.

By current tomography...



Put description of AUG coils and some pickups into Minerva so we can now do Current Tomorgraphy and Bayesian Equilibrium for AUG.

For magnetics only, we have the usual tomography situation:

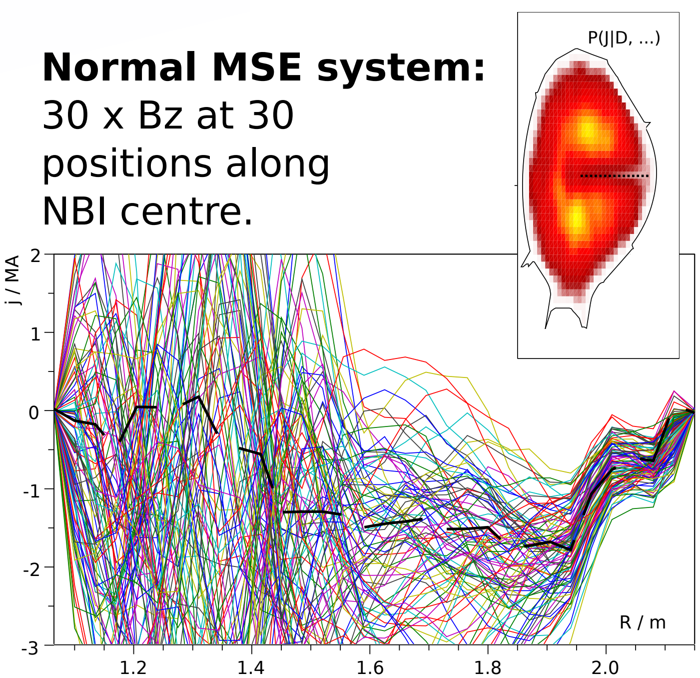


(Almost) no prior/regularisation

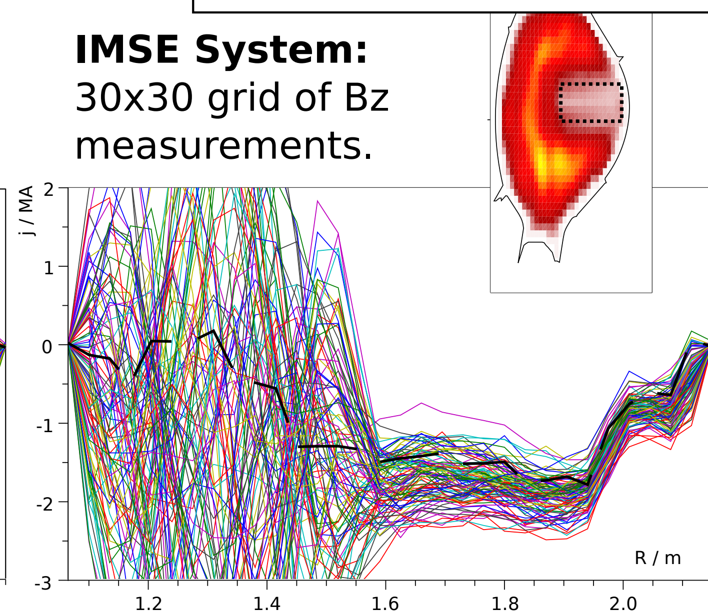
(Almost) infinite uncertainty
(but B/psi still good)

Each case has 900 measurements at sigma = 10mT.
So difference is only in the ***type*** of information.

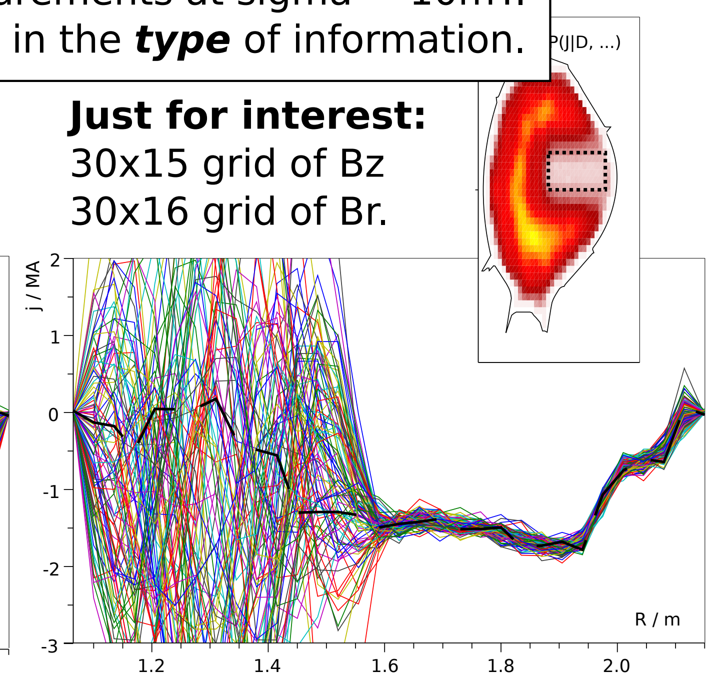
Normal MSE system:
30 x Bz at 30 positions along NBI centre.



IMSE System:
30x30 grid of Bz measurements.

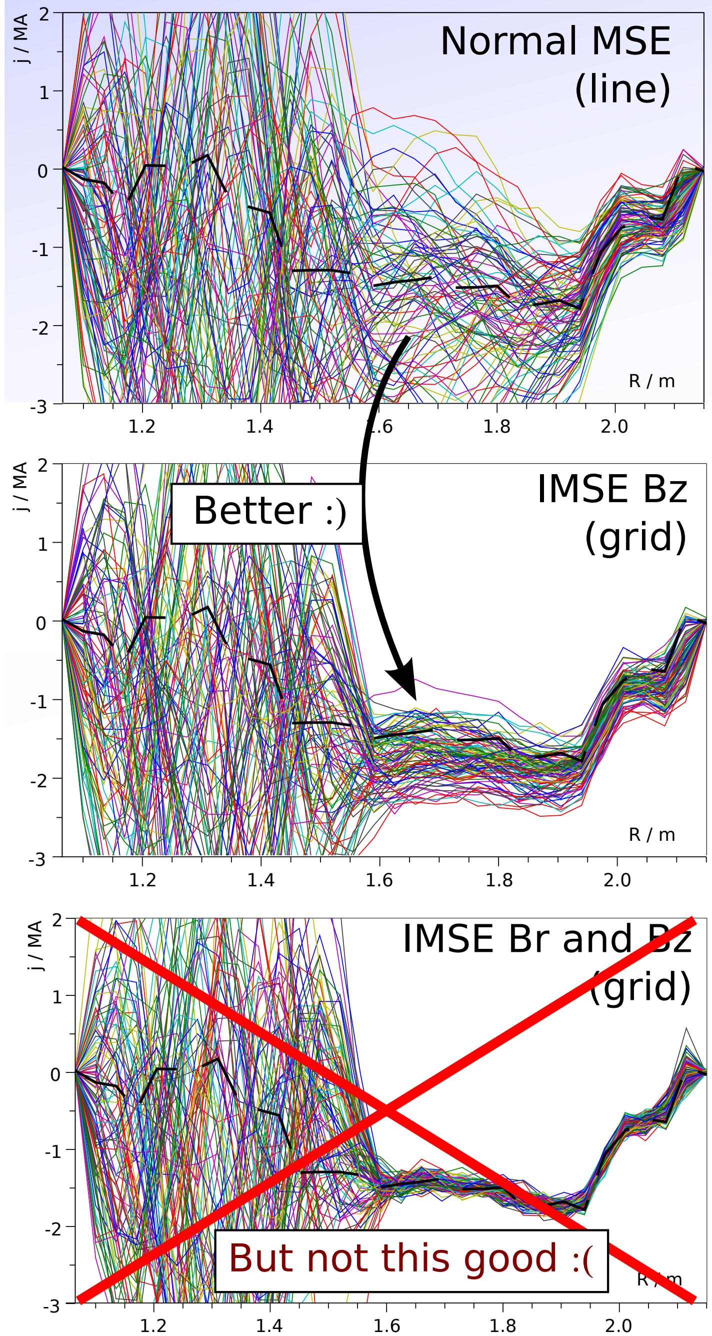


Just for interest:
30x15 grid of Bz
30x16 grid of Br.



All sigmaBr = sigmaBz =10mT

By current tomography II

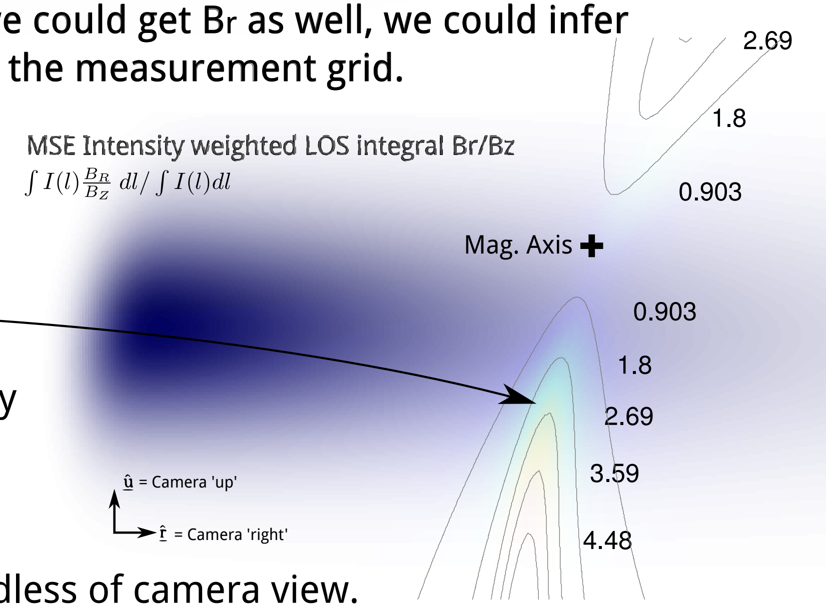


The IMSE still has some a large uncertainty in jphi offset. The unknown term it is not entirely pinned down by the magnetics.

However, the 2D IMSE inference is much better than the equivalent MSE system, for some reason.

Result with Br is much better: If we could get Br as well, we could infer the current almost exactly, within the measurement grid.

Off axis and near the core, the AUG IMSE system will see Br/Bz > 2 with reasonable signal strength:



Unfortunately, the beam geometry means information about Br is always swamped by Bphi. With NBI **v** in the midplane; **v** x **r** and **v** x **phi** are always together, regardless of camera view. There is a slight angle though. Full geomtry:

$$\tan\beta \approx \frac{(\hat{v}\times\hat{\phi})\cdot\hat{r}}{(\hat{v}\times\hat{\phi})\cdot\hat{u}} + \left[\frac{(\hat{v}\times\hat{R})\cdot\hat{r}}{(\hat{v}\times\hat{\phi})\cdot\hat{u}} - \frac{(\hat{v}\times\hat{\phi})\cdot\hat{r}}{(\hat{v}\times\hat{\phi})\cdot\hat{u}}\frac{(\hat{v}\times\hat{R})\cdot\hat{u}}{(\hat{v}\times\hat{\phi})\cdot\hat{u}}\right]\frac{B_R}{B_\phi} + \left[\frac{(\hat{v}\times\hat{Z})\cdot\hat{r}}{(\hat{v}\times\hat{\phi})\cdot\hat{u}} - \frac{(\hat{v}\times\hat{\phi})\cdot\hat{r}}{(\hat{v}\times\hat{\phi})\cdot\hat{u}}\frac{(\hat{v}\times\hat{Z})\cdot\hat{u}}{(\hat{v}\times\hat{\phi})\cdot\hat{u}}\right]\frac{B_Z}{B_\phi}$$

LOS Intensity averages of coefficients gives:

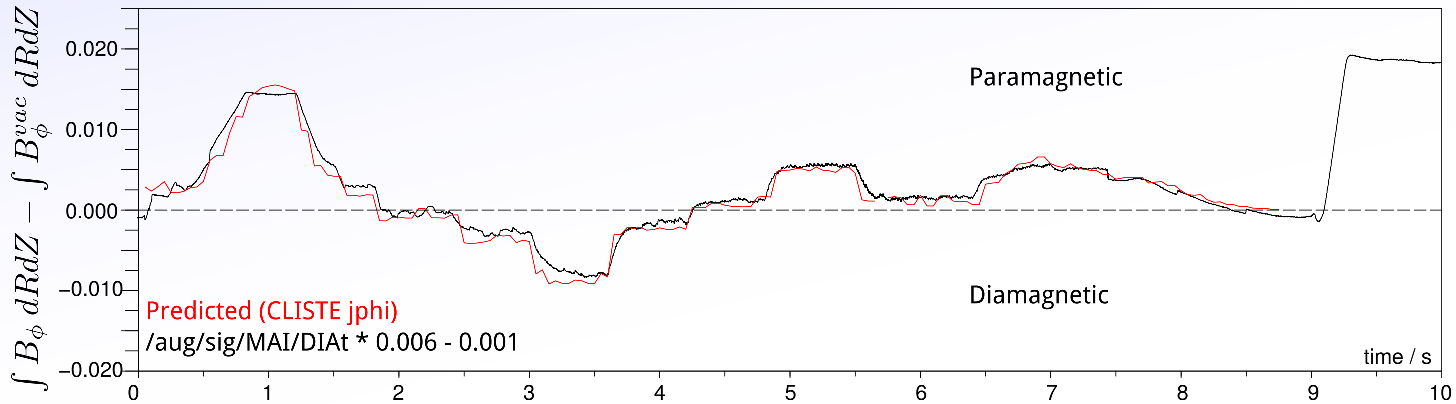
$$\tan\beta \approx 0.17 + 0.54\frac{B_Z}{B_\phi} + 0.05\frac{B_R}{B_\phi}$$

At 5 - 10%, it will have an effect, but we do not expect to see the full current recovery from 2D tomography.

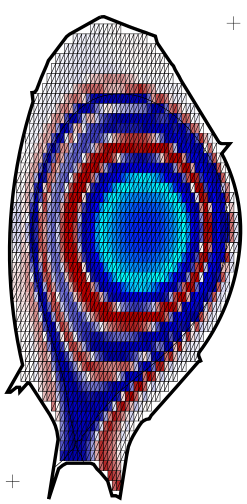
Para/Diamagnetics

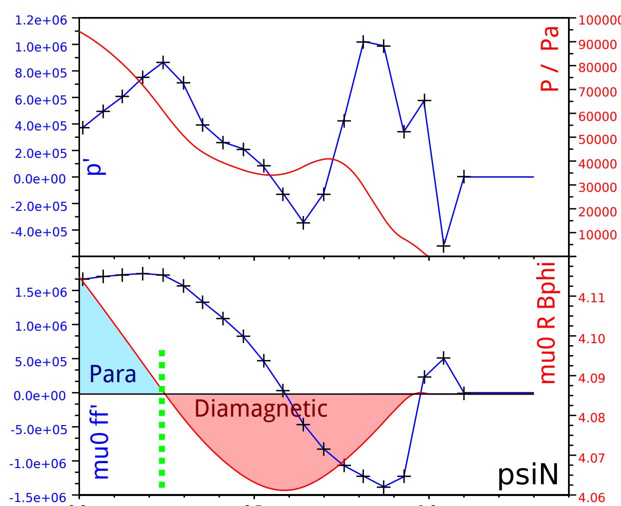
Some notes about Renee's results from the equilibrium point of view:

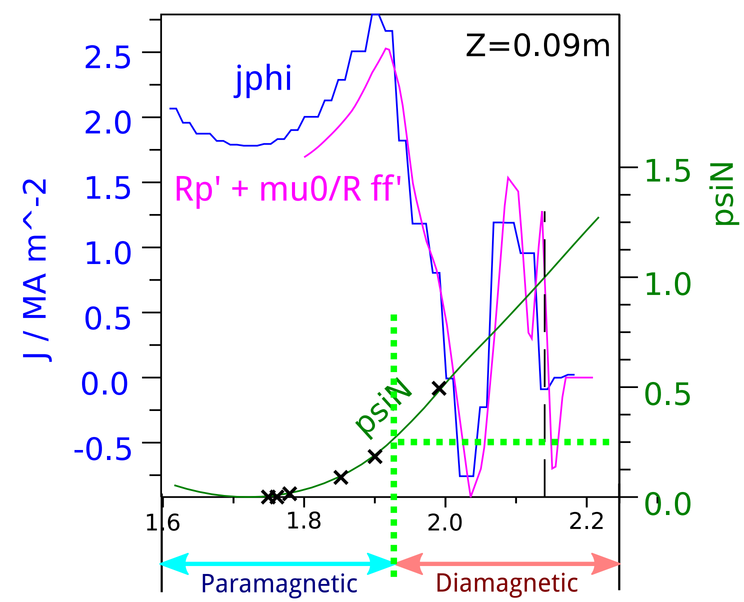
Just to see, we can load CLISTE's jphi into Minerva and integrate the toroidal flux over the whole vessel (calc. grid). There is a diagmagnetic signal outside the vessel which appears to be uncalibrated. With an offset and scale it mostly agrees with what CLISTE says:



Also, I can now run the code from my PhD work on JET which tries to extract the pedestal pressure from magnetics, wuth the AUG magnetic model. (P. McCarthy has already shown this works at AUG, as I did at JET). With sufficient relaxation of the ff' and p' smoothing priors, it actually finds an equilibrium which is paramagnetic in the very core and diamagnetic at the edge (albeit with a slightly silly pressure profile):



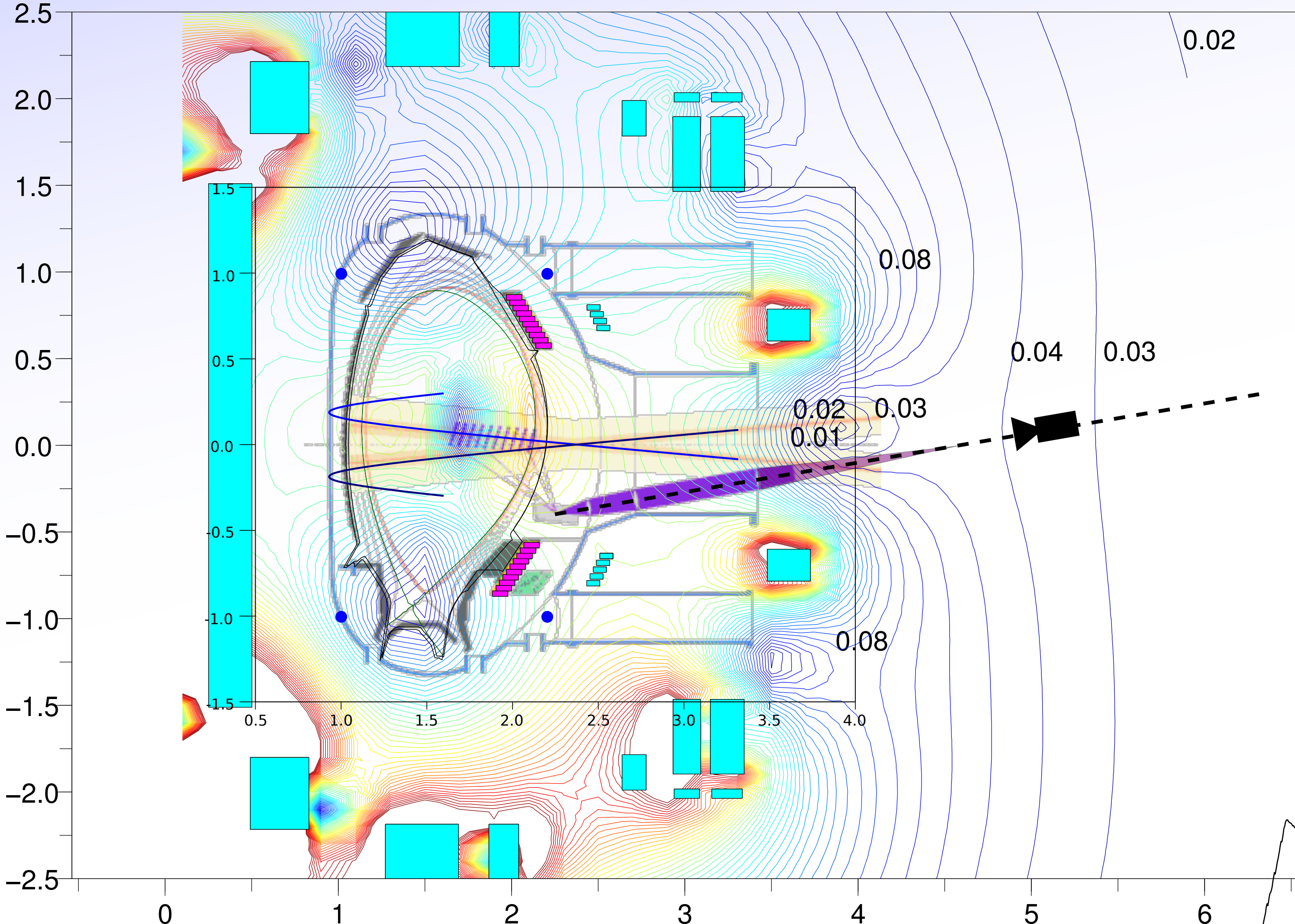




I'm not saying that this is happening, just that with a strong pedestal pressure gradient, it could be.

Poloidal Field at camera

The Minerva AUG magnetostatics model also lets us predict the field from the PF coils:



|B| < 50mT