Field Calculations for Ring Cooler

Steve Kahn

5 February 2002

IIT Mucool Meeting

Ring Cooler Geometry

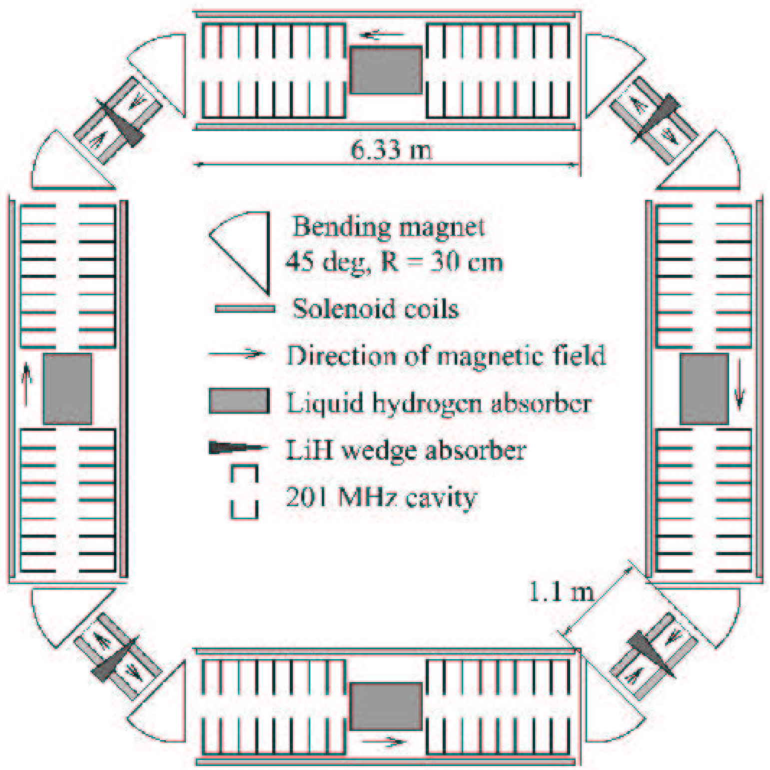
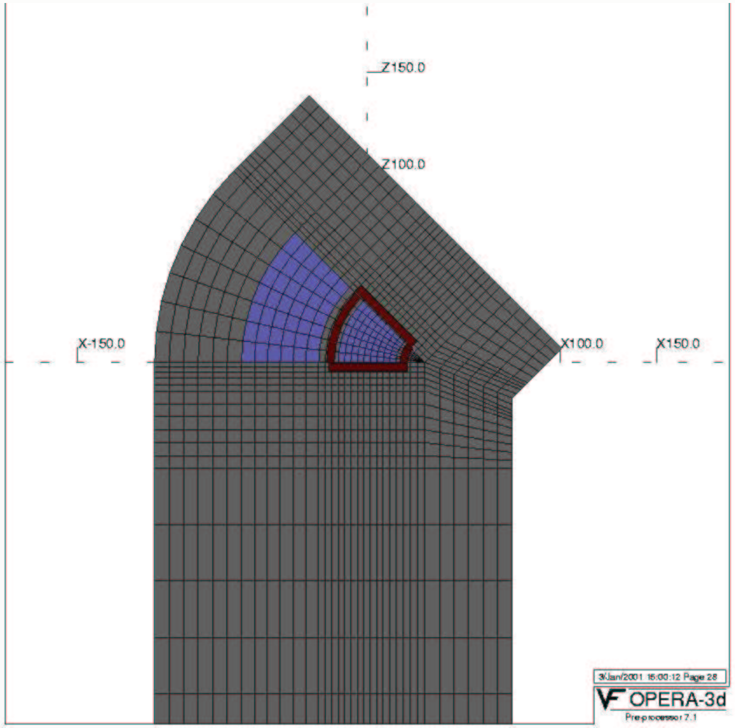


Figure 11: Schematic of ring cooler

2000 Rajendran Raja,IIT Instrumentation workshop



TOSCA finite element program models one octant of ring.

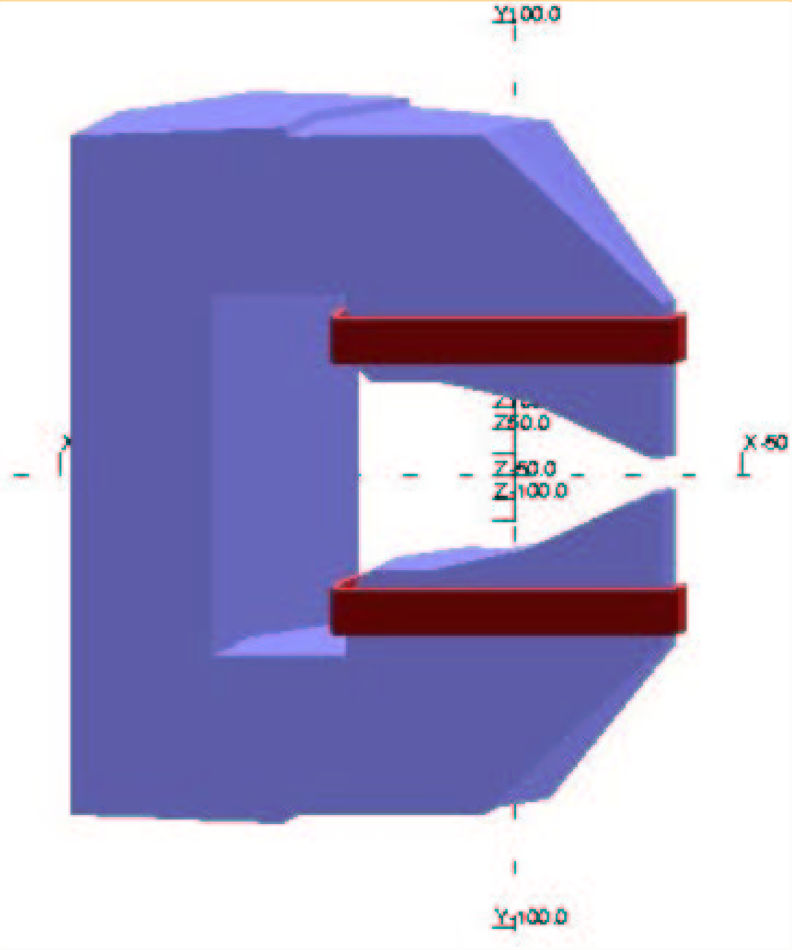
Approach to Field Calculations

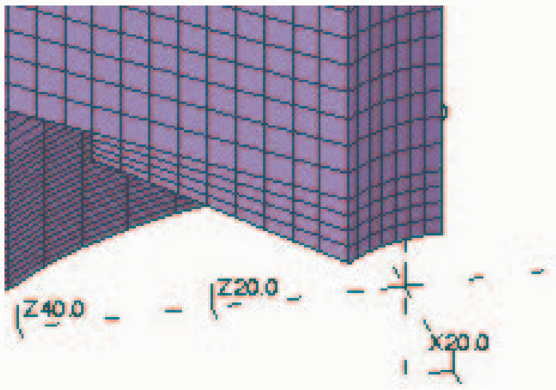
- The smallest *geometric* symmetry unit is the octant. This is not the smallest *magnetic* symmetry unit because of the field flips.
- If we can assume that the magnet iron is linear we can separate the octant into sub-regions:
  - Large Solenoid
  - Wedge Dipole
  - Small Solenoid
- We can calculate the contributions of these magnets and add them.
  - We can evaluate how good an approximation this is.
- The alternative would be to treat the system as a whole.
  - The finite element problem would have ~1000000 nodes and would take a very long time to run!
  - This is not a simple topology for programs like TOSCA.

Dipole Magnet Specifications

- The preliminary parameters of the bending magnet as provided:
  - Bending Radius R_{bend} =52 cm
  - Bending Angle $\Theta_{bend} = 45^{o}$
  - Field Strength B = 1.46 T at reference radius
  - Normalized Field Gradient: $$\frac{dB}{dr}\frac{r}{B} = -0.5$$
    - $dB_y/dx \times (R/B_o) = -0.5$
  - Radius of aperture $R_{aperture}$ = 17 cm.

Sketch of Dipole Magnet





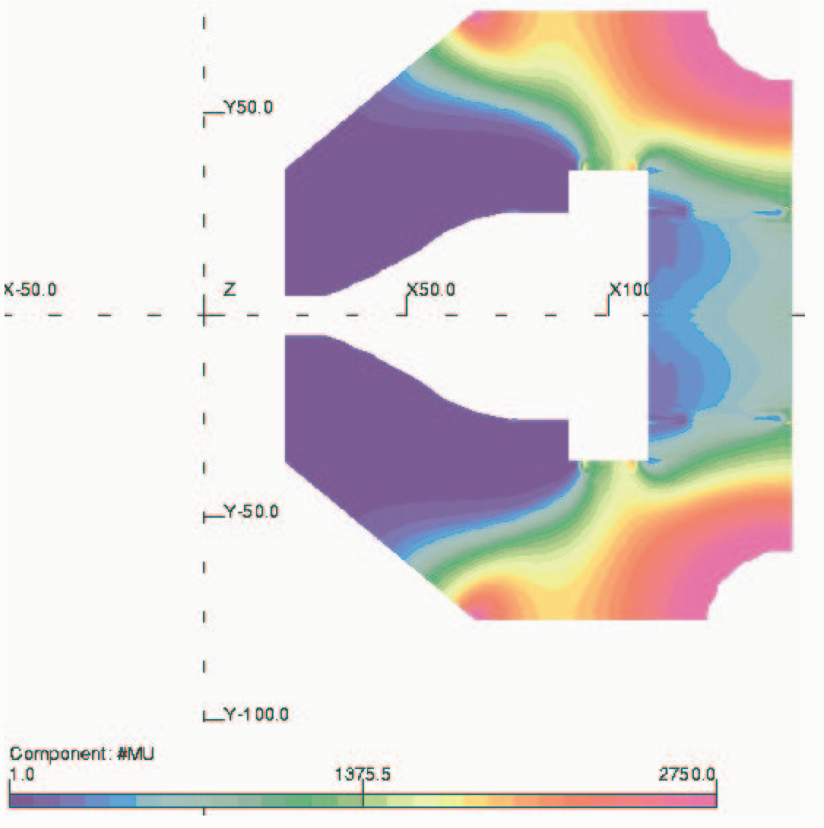
Pole face is shaped to achieve required gradient

The design of the wedge magnet is from P. Schwandt (dated 30 Jan 01).

It has been revised.

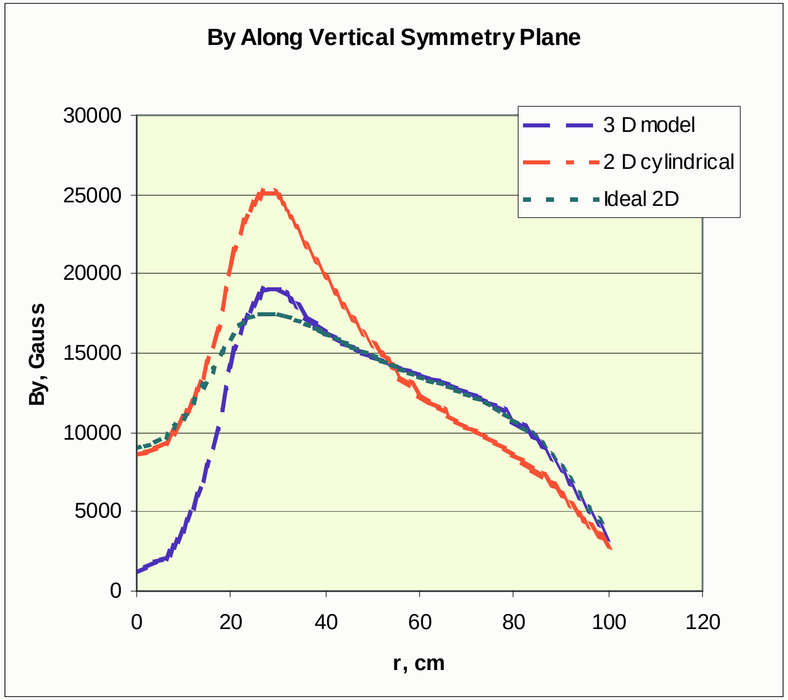
Saturation in Dipole Magnet

- Figure shows the permeability for the vertical midplane of the magnet.
- μ<10 on inner edge of the aperture.



B_y along Vertical Symmetry Plane

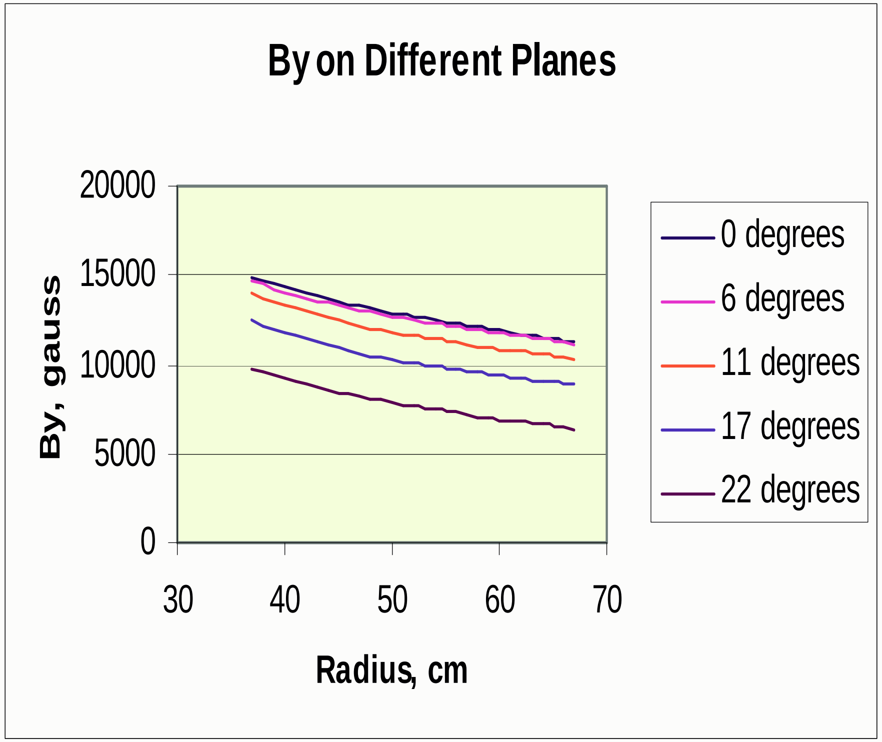
- Figure shows three curves:
  - Ideal Field:
    - 2D field from shaped iron pole and effective yoke width.
    - Calculate index=0.473
  - 3D Field Calculation
    - Calculation using TOSCA
    - Gives index=0.47
  - 2D cylindrical Calculation
    - Uses same pole profile, but has closed cylinder out of plane.



B_y Off Vertical Symmetry Plane

Index Calculated on Difference Planes:

Angle Position	index
0	0.473
5.625	0.469
11.5	0.516
17.125	0.584
22.5	0.746



Dipole Field along Reference Path

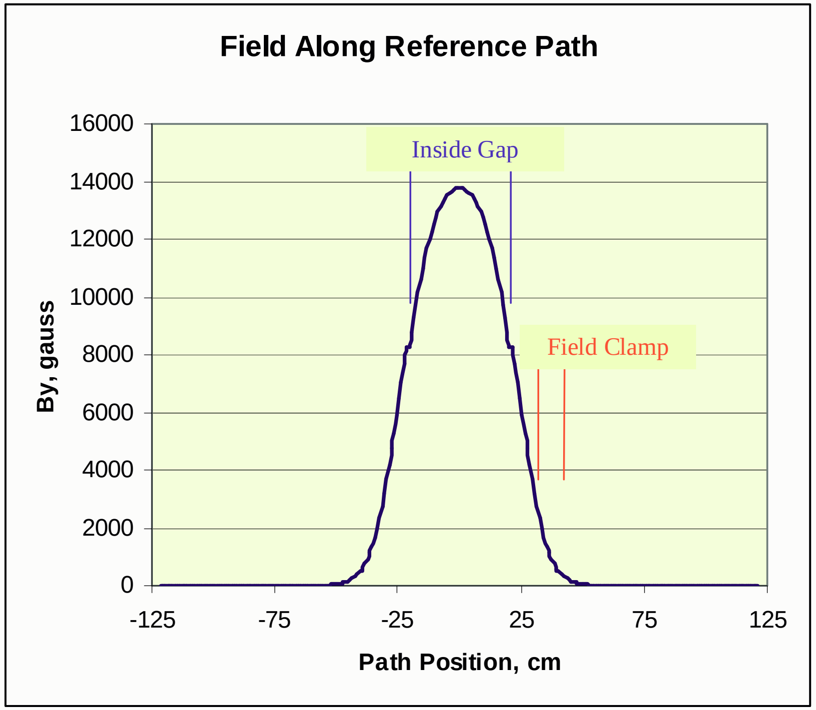


Figure 3: B_y along central reference path.

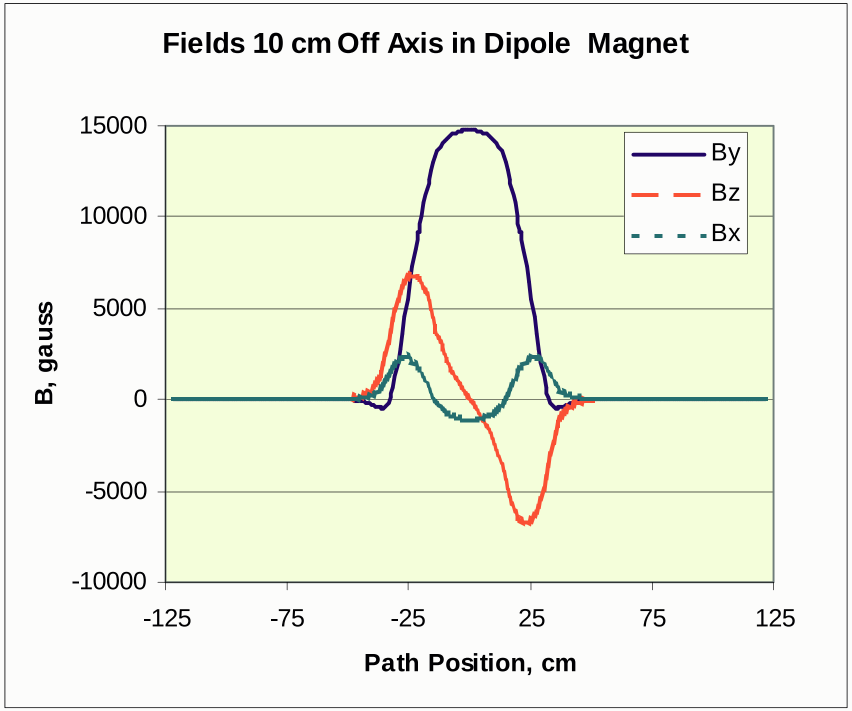


Figure 4: Field components for a path displaced 10 cm vertically from the reference path

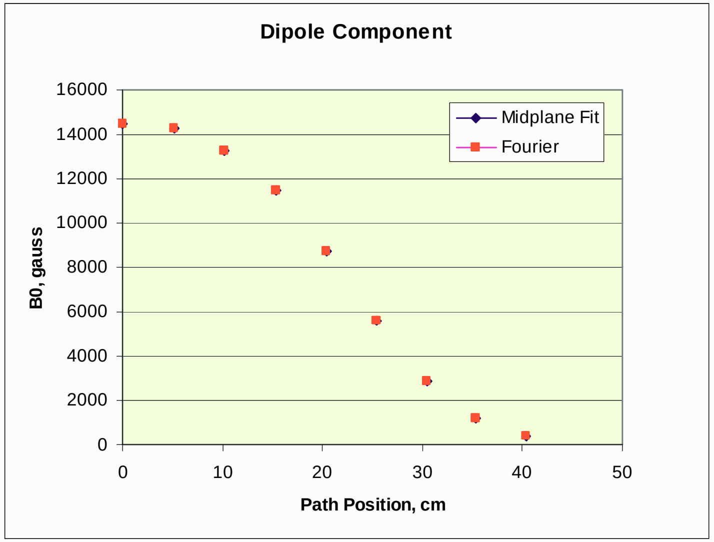
Avoiding a 3D Map

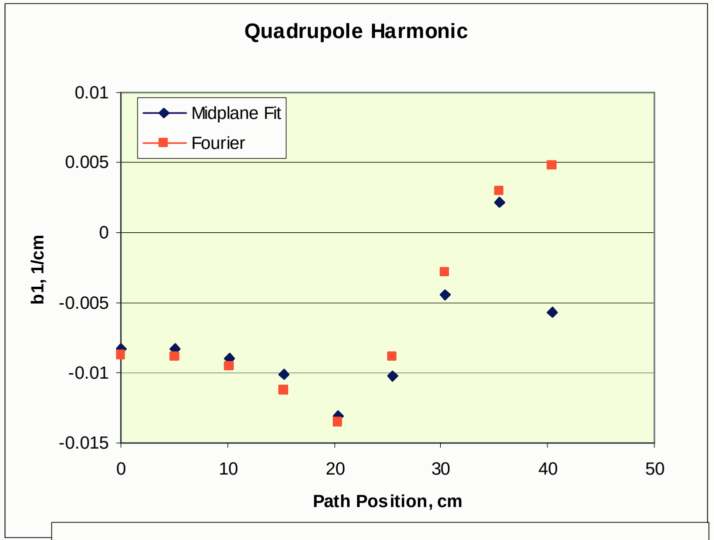
- The 2D part of a long accelerator magnet is traditionally parameterized by Fourier harmonics.
- A generalization of the traverse field that takes into account the s dependence of the field has the form:

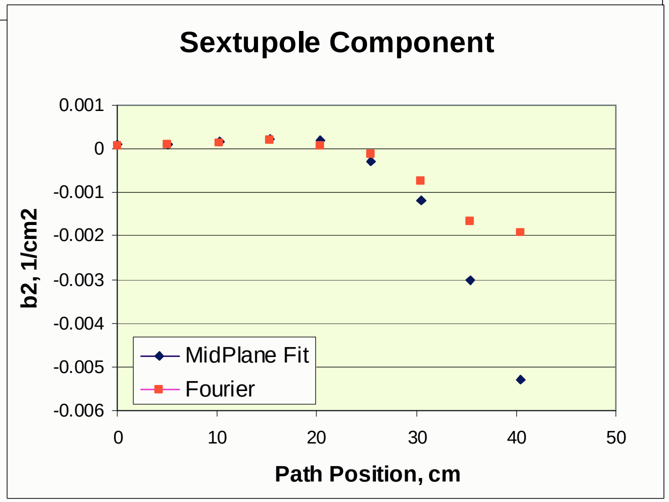
$$B(r,\varphi,s)=\left[K_1(z)-\frac{3}{8}\frac{d^2K_1}{ds^2}r^2+\frac{5}{192}\frac{d^4K_1}{ds^4}r^4+\cdots\right]\sin(\varphi)+$$

$$\left[K_2r-\frac{1}{6}\frac{d^2K_2}{ds^2}r^3+\frac{1}{128}\frac{d^4K_2}{ds^4}r^5+\cdots\right]\sin(2\varphi)+\cdots$$

Transverse Harmonics as a Function of s



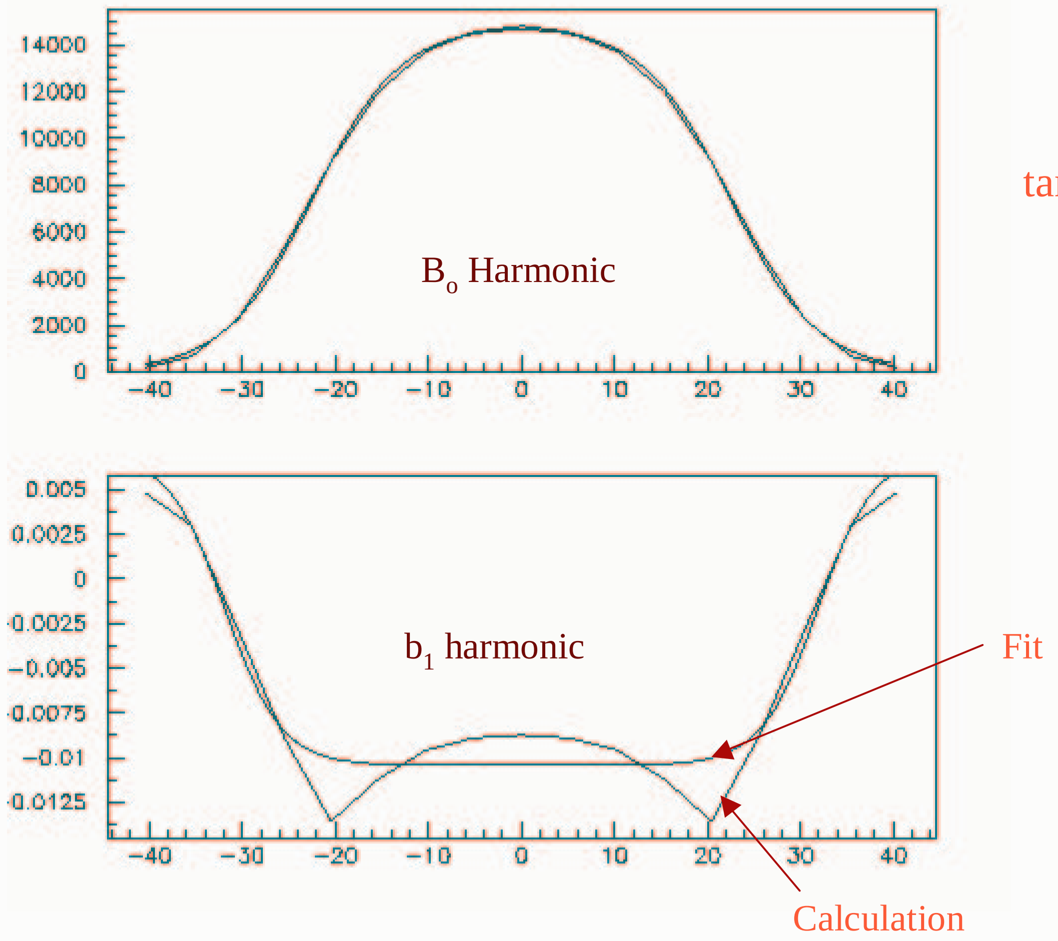




$$\frac{1}{B_o \pi} \oint B(\varphi)\cos(2\varphi)d\varphi$$

Calculated along the reference path

Dipole Profile Fits



Fit to

tanh[k(x-χ)]-tanh[k(x+χ)]

Preliminary Results from Fit

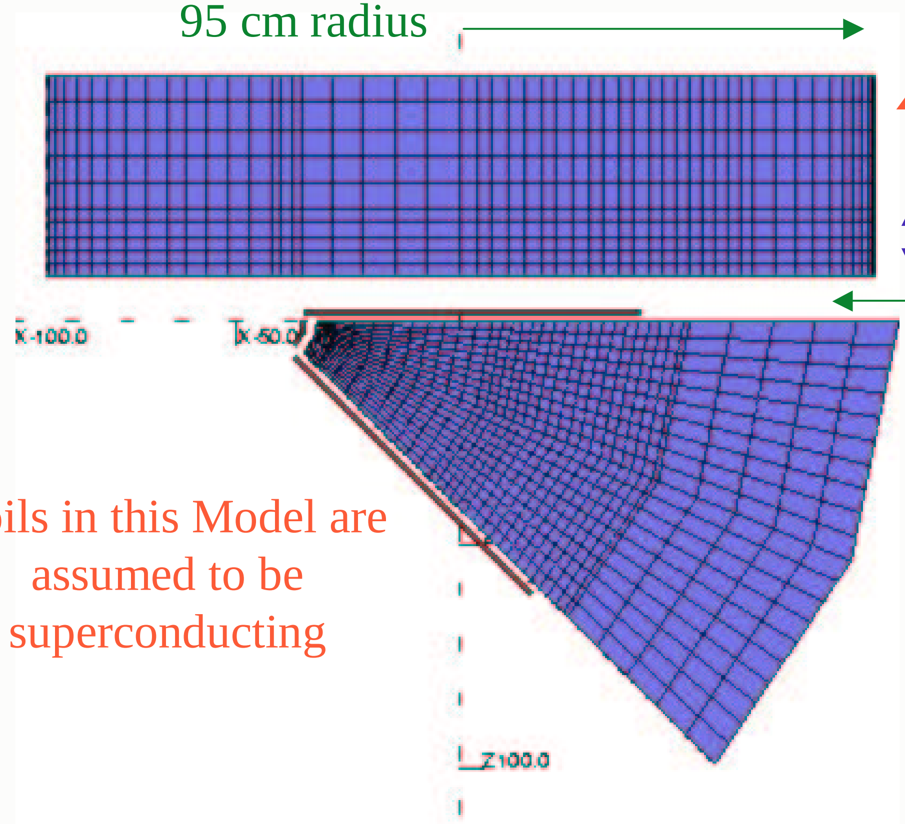
		From Bphi			From Br		
Fit results							
	a	lambda	z0		a	lambda	z0
Dipole	-7358.6	11.392	22.244		-7643.2	23.329	21.395
	0.12909	4.64E-04	3.33E-04		0.1199	3.34E-04	2.81E-04
Quadrupol	56.529	7.0725	23.769		48.213	6.45E+00	18.622
	8.05E-03	1.97E-03	2.16E-03		8.22E-03	7.06E-04	1.00E-03
Sextupole	1.0784	6.895	21.415		1.1072	7.7163	24.129
	6.10E-04	3.85E-03	5.06E-03		5.48E-04	3.35E-03	4.00E-03

Dipole Field Description

- The harmonic description is currently in Muc_Geant.
  - I have calculated harmonics of $B_\phi(s)$ and $B_r(s)$ at positions along a reference path through the dipole magnet at 7 different radii using the TOSCA program.
  - I have fit the previous formula (2 transparencies ago) parameterizing K(s) as:
    - $K_n(s) = a[\tanh((z-z_o)/\lambda) - \tanh((z+z_o)/\lambda)]$ for each n
    - The parameters for K(s) come from a combined fit of B_r and B_ϕ
  - The fits for the *Dipole* and *Sextupole* components look reasonably good. The fit to the *Quadrupole* component is not that stable.
    - Note the difference in the B_r and B_ϕ for z_o for the quadrupole fit.
  - Since the harmonics are power series r the field at large radius will be less reliable. This can be seen in the field for r>14 cm.

Tosca Model for Wedge Dipole

95 cm radius



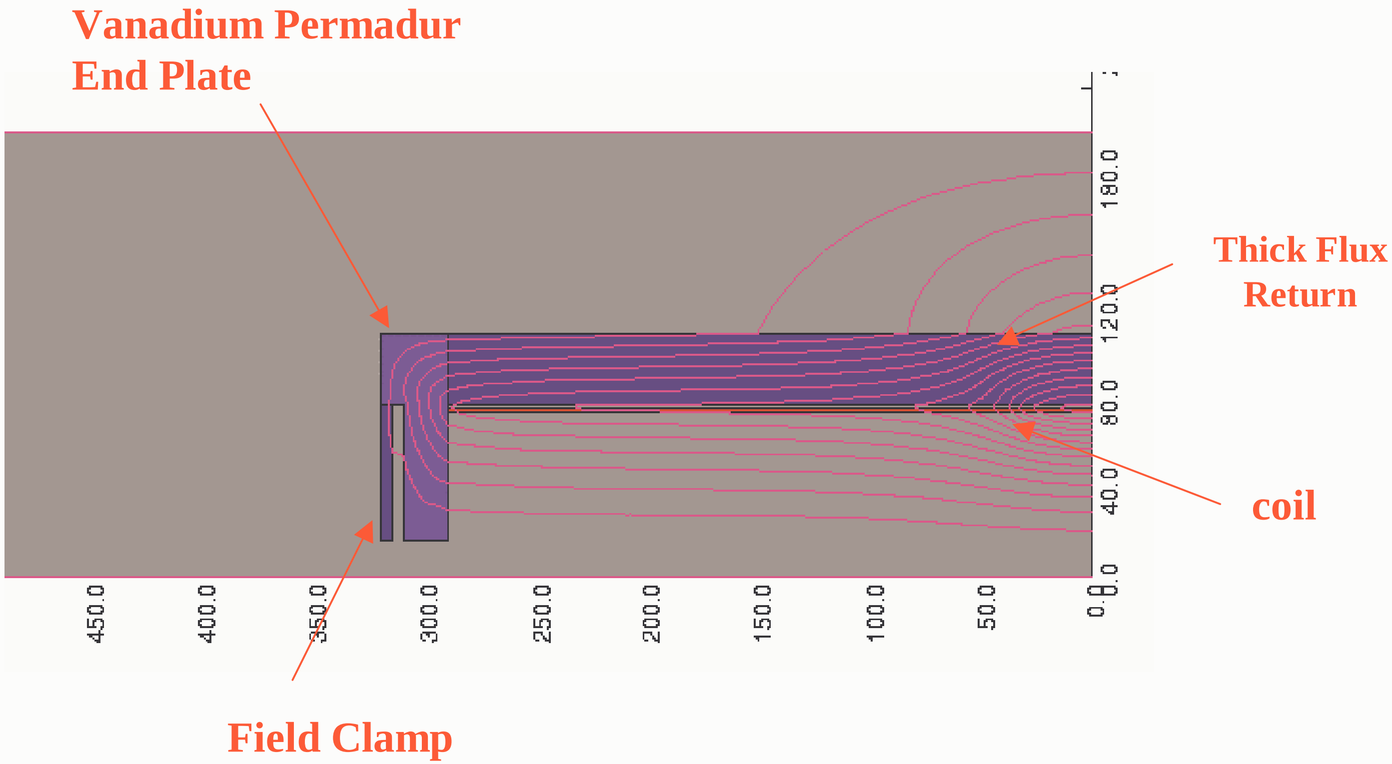
End of Return Iron for Large Solenoid

15 cm endplate

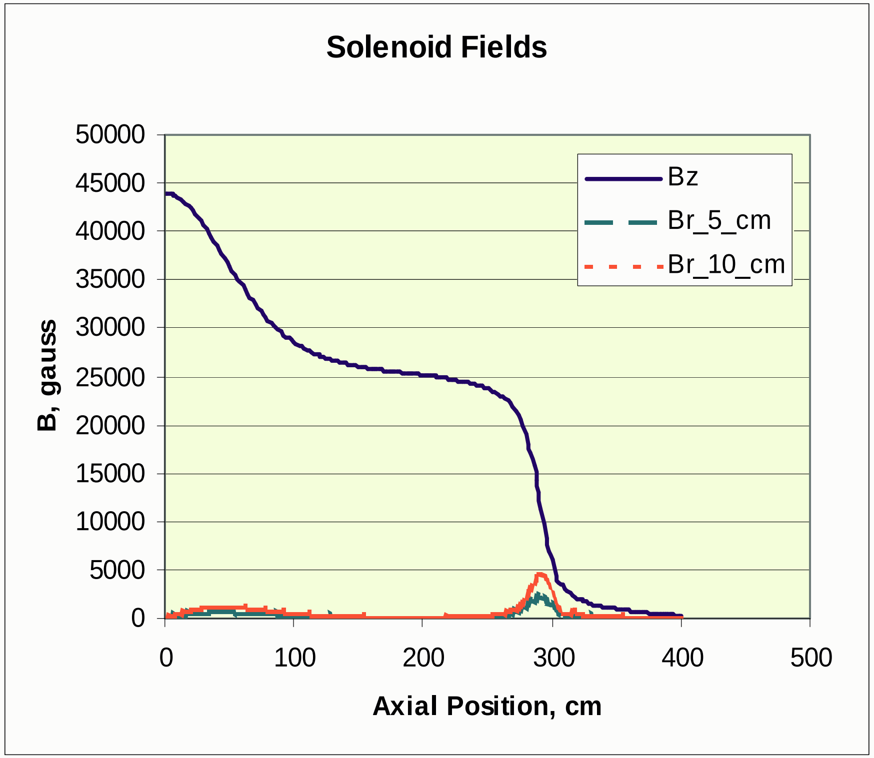
10 cm gap between dipole and shield

Coils in this Model are assumed to be superconducting

Long Solenoid Magnet



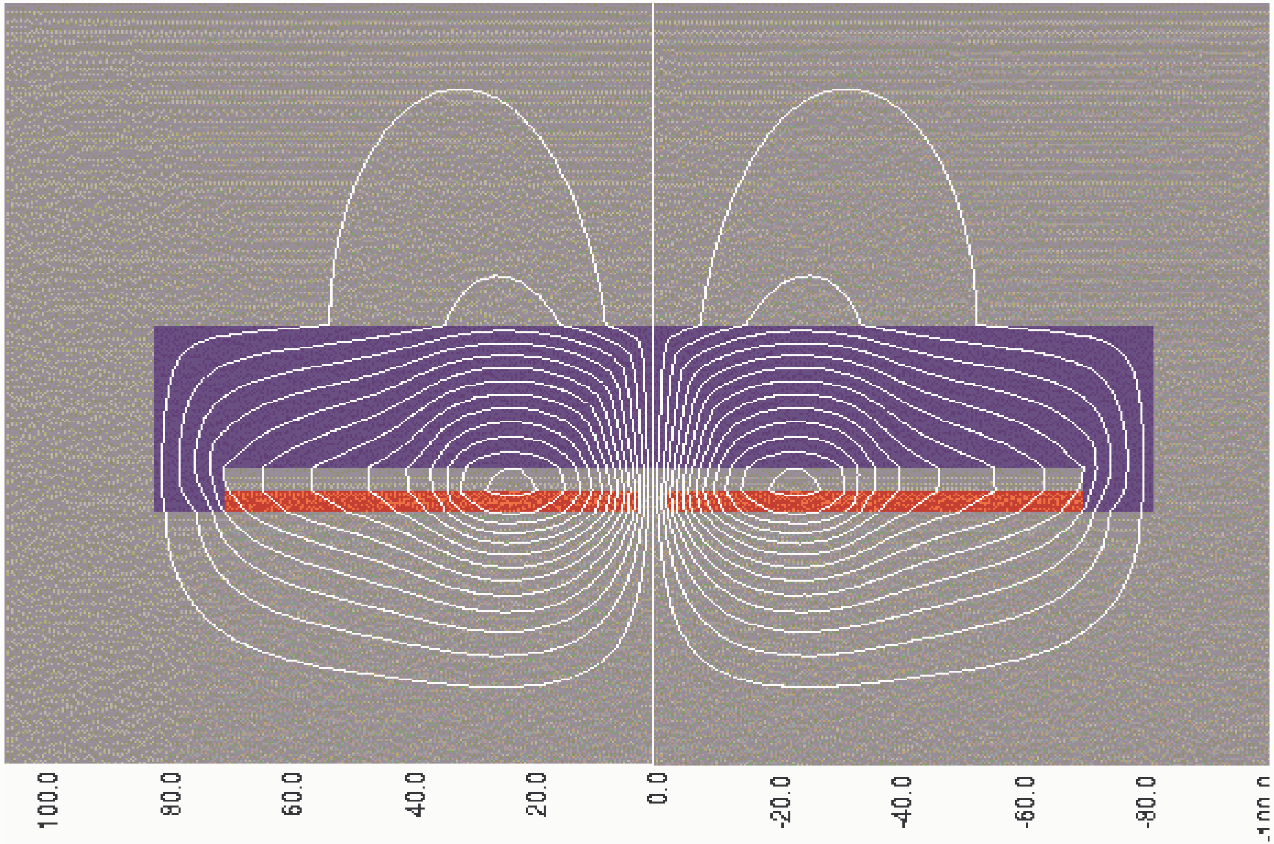
Fields in Long Solenoid



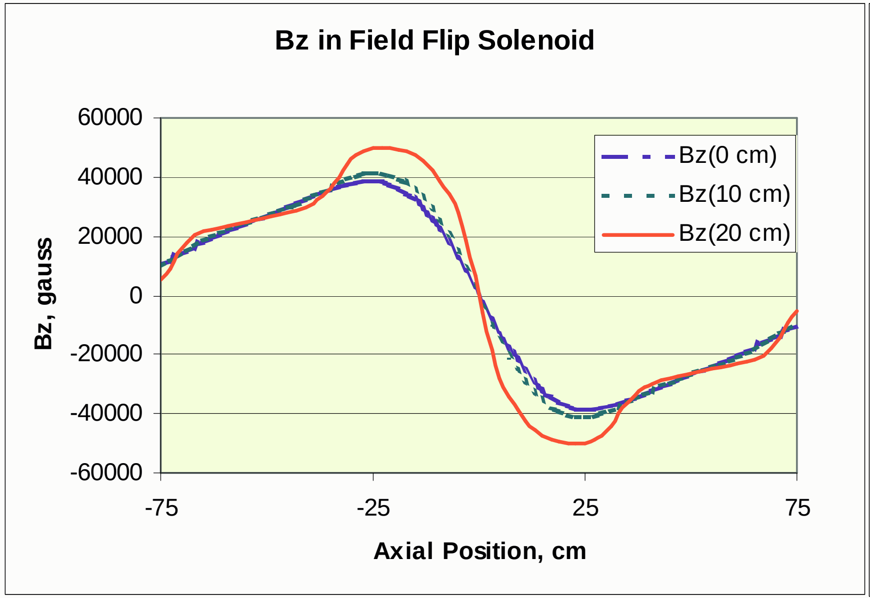
Comments on Solenoid Field

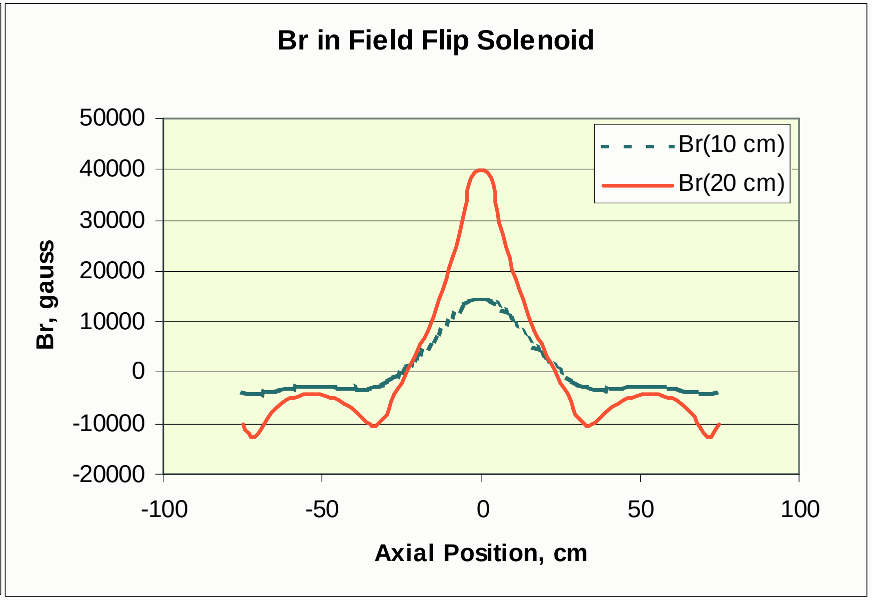
- The end plate effectively separates the solenoid field from the dipole for the case with small aperture coils.
  - This still has to be shown for the large coil case.
- Radial field are present only in vicinity of end plate.
  - Extend approximately one coil diameter (as expected).

Short Solenoid Magnet



Short Solenoid Fields





Ideal Short Solenoid Field Flip Magnet

- Top figure shows Valerie's design for the short field flip solenoid.
- The lower figure shows the field and dispersion for that magnet.
- This form of the field assumes that there is a Neumann condition at the end of the magnet.
  - The field will continue ~2 T forever.

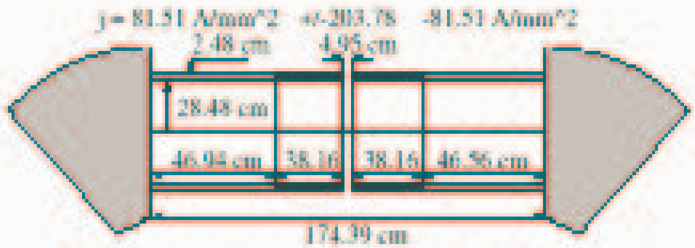


Figure 2: Layout of the short straight section.

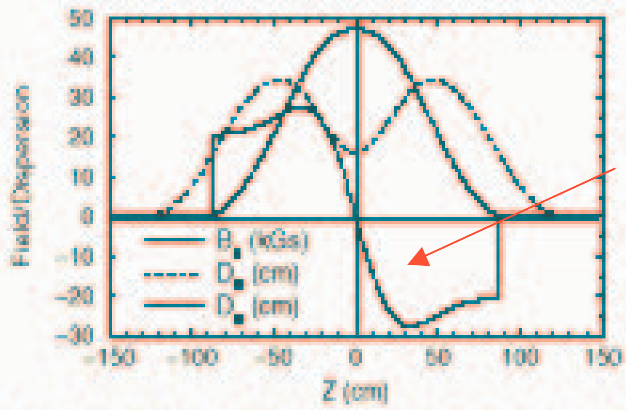
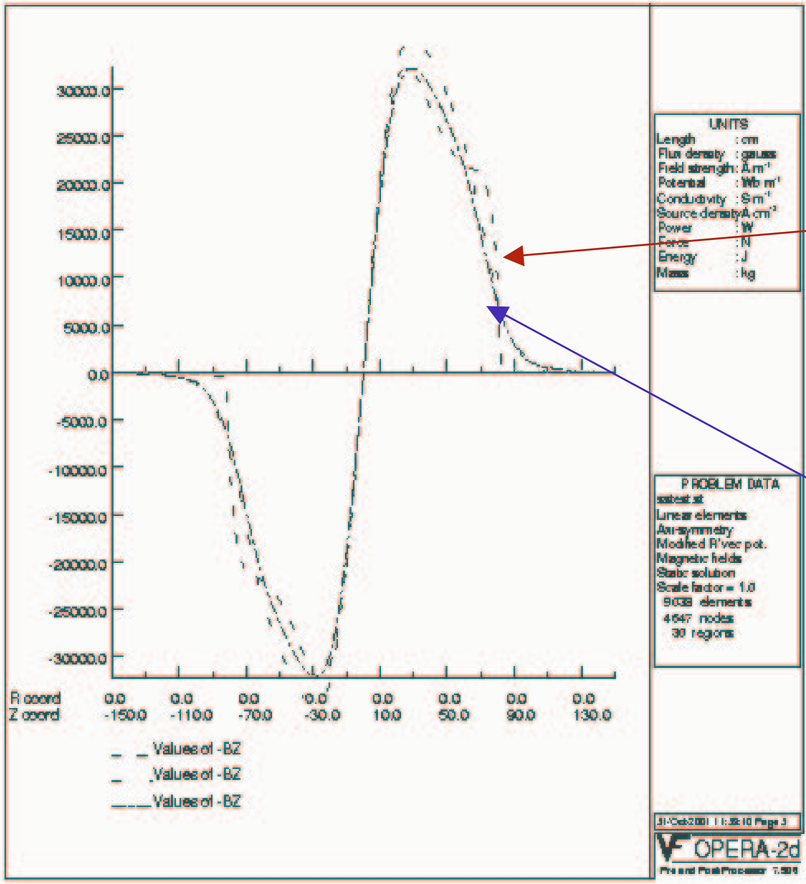


Figure 3: Axial field and dispersion functions in short SS.

B_z on axis

Short Solenoid Fields From Opera2D

How critical is it to have this field plateau?



Field with iron covering ends

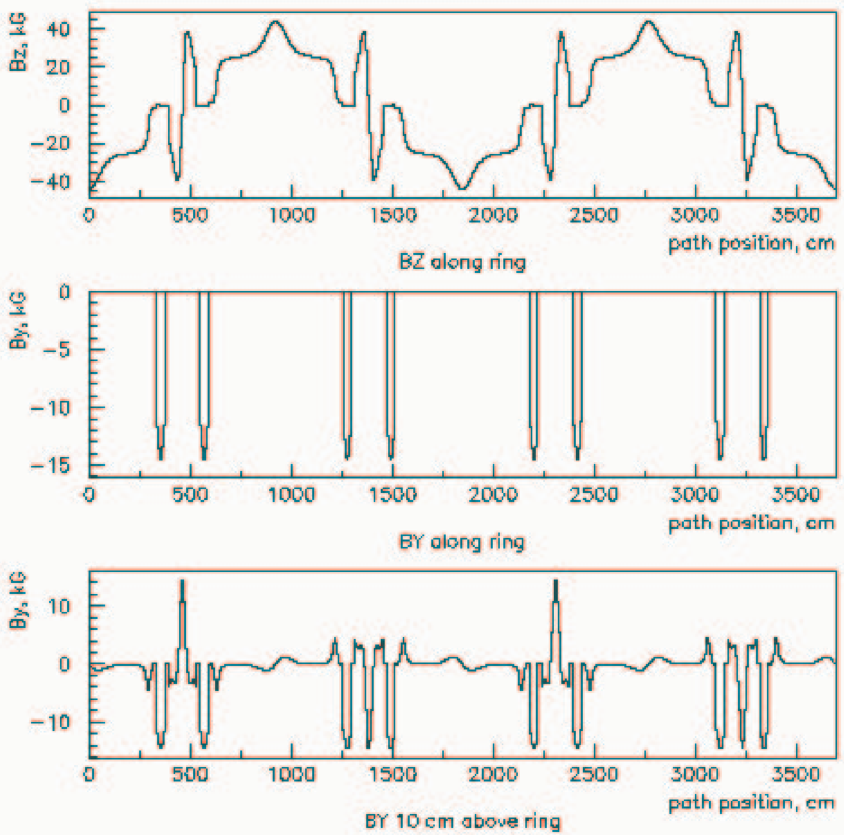
This forces field to be sort of parallel to axis

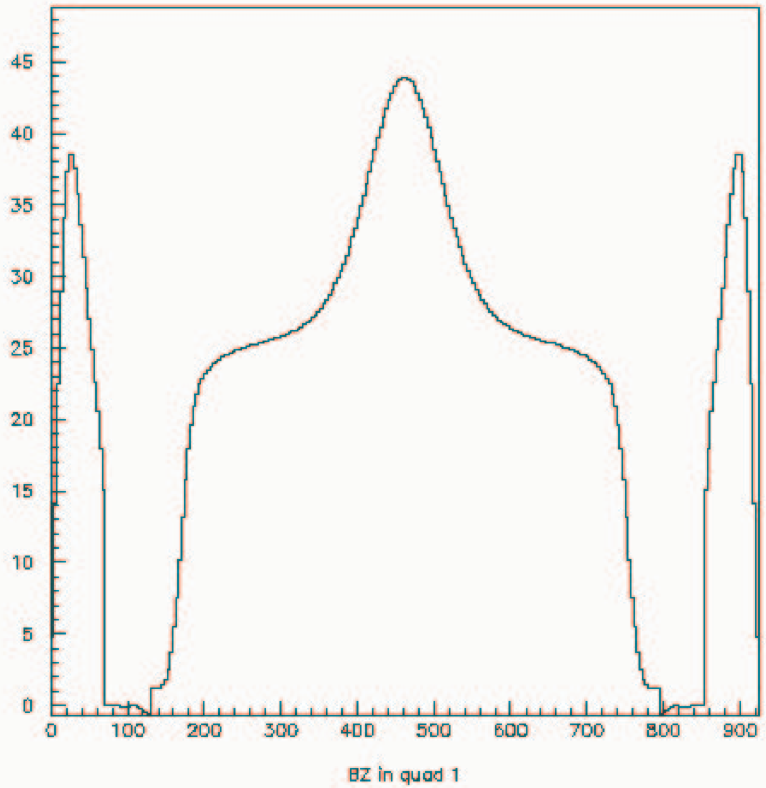
Field with aperture for muons

Field Maps

- The **TOSCA** program can generate 3D field grids.
  - Wedge Dipole
- Opera2D is used to generated the following grids with 1 cm×1 cm segmentation:
  - Large Solenoid
  - Tail of Dipole in Large Solenoid
  - Tail of Dipole in Small Solenoid
  - Small Solenoid
- The **gufld** (or **guefld**) subroutine in GEANT will have to keep track of which octant it is in, which grid it should use and what signs to apply to the field for each point in space.

Field in Geant



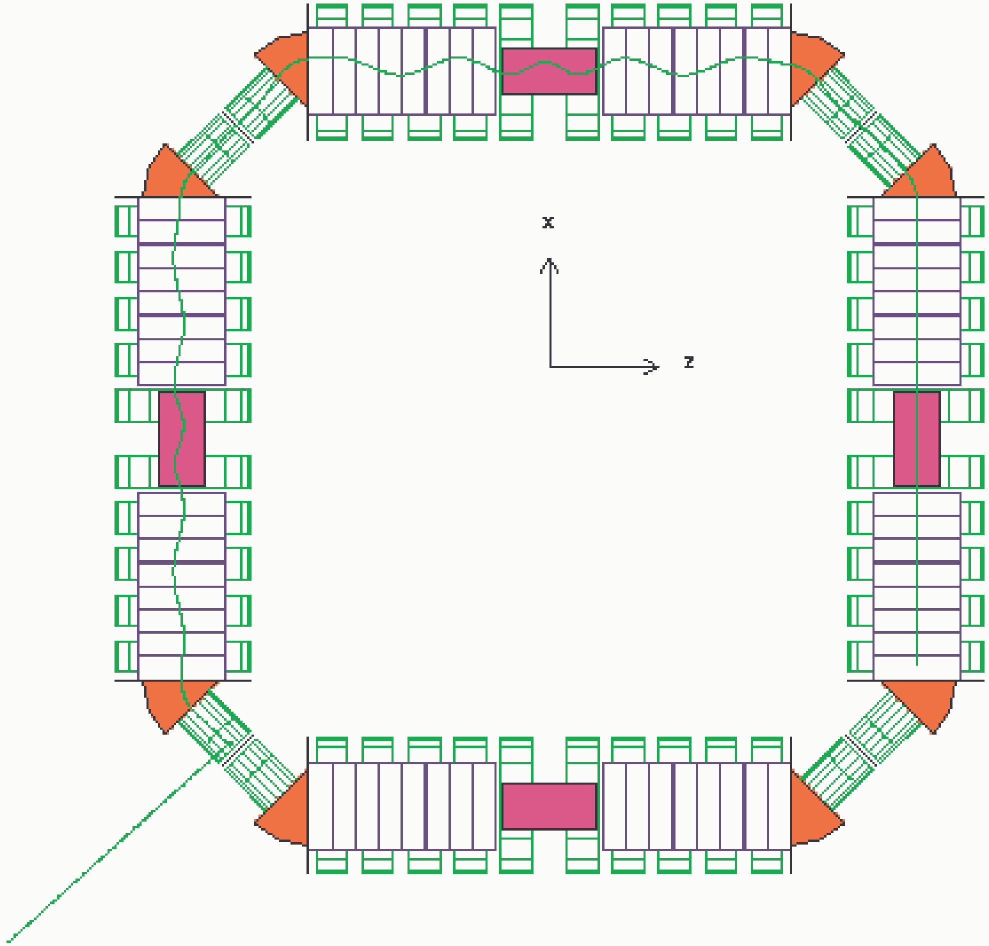


Tracking Muons Around the Ring

- Tracking to test the field.
  - Set all absorber material to vacuum.
  - Remove all RF.
  - Cooling ring now is just a storage ring.
- Current State:
  - A *so-called* on momentum muon can get 2 revolutions around the ring.
  - This just requires tuning the overall dipole field with a small scale factor.
  - There is a very small transverse displacement necessary since the reference path is not exactly circular because of the fringe field.

ARTE RING COOLER-NEW SCHEME FROM BALBEKOV 12/11/01

This is the only graph I could find. The on momentum track shows very little Larmor motion.



Current Status

- I am beginning to look at tracking muons through the ring with the RF. I have large losses at this point.
  - This is merely debugging a new system. I need to put more work here.
- I have placed all of the code and field maps for this realistic field representation into the MUC_GEANT CVS.
  - They are available for others to use.
  - There are still some details that need to be fixed.