Field Calculations for Ring Cooler Magnet System

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Ring Cooler Geometry

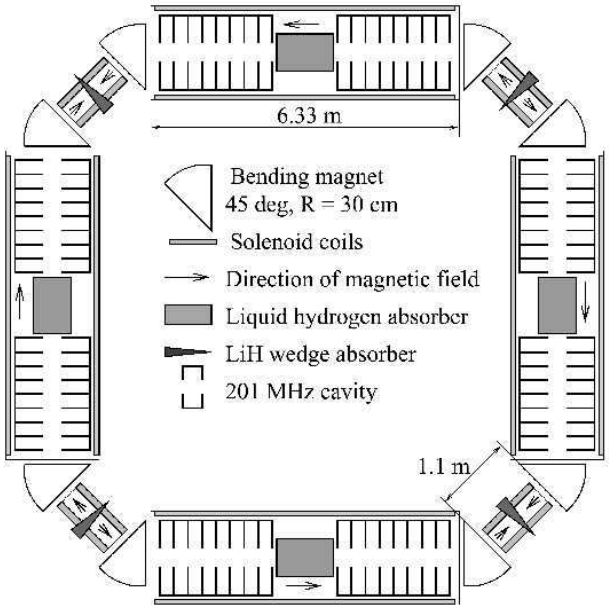


Figure 11: Schematic of ring cooler

2000 Rajendran Raja,IIT Instrumentation workshop

Parameter	Symbol	Original Specification	Current Specification
ole Bend Angle	θ_{bend}	45°	45°
cussing Index	$n=(\rho_o/B_o)\times(dB_y/d\rho)_o$	–½	–½
am Momentum	p_μ	0.226 GeV/c	0.226 GeV/c
Beam Radius	ρ_o	42 cm	52 cm
Dipole Field	B_y	1.8 tesla	1.45 tesla
dial Aperture	R_{aper}	15 cm	17 cm
g Solenoid Field	B_{lsol}	3.5 tesla ?	2.5 tesla
olenoid Half Length	L_{lsol}	3.2 m	3.2 m
ld Flip Solenoid Field	B_{ssol}	3.5 tesla ?	2.5 tesla
olenoid Half Length	L_{ssol}	0.55 m	0.6 m

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!

Dipole Magnet Specifications

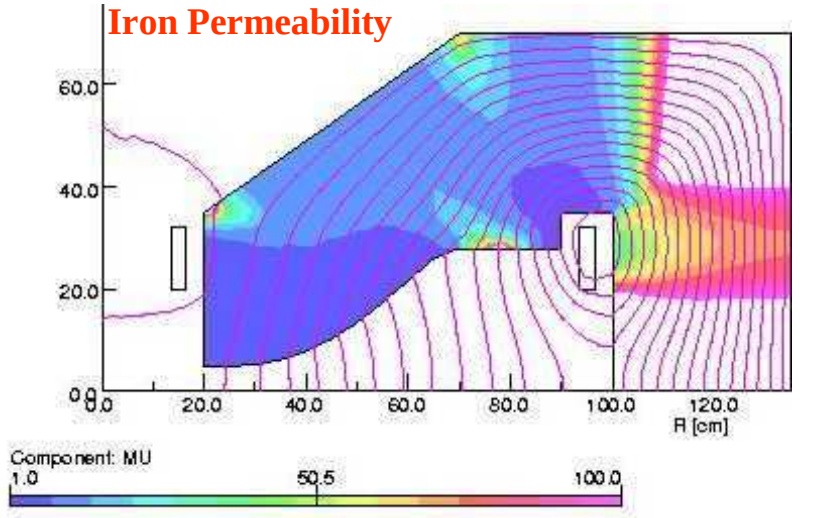
- The condition to obtain focussing in both planes with a wedge shaped dipole magnet is that the field index
  - $n \equiv dB_y/d\rho \times (\rho/B_o) = -0.5$

$$B_y(\rho) = B_o\left[1 + \frac{1}{2}\ln\left(\frac{\rho_o}{\rho}\right)\right]$$

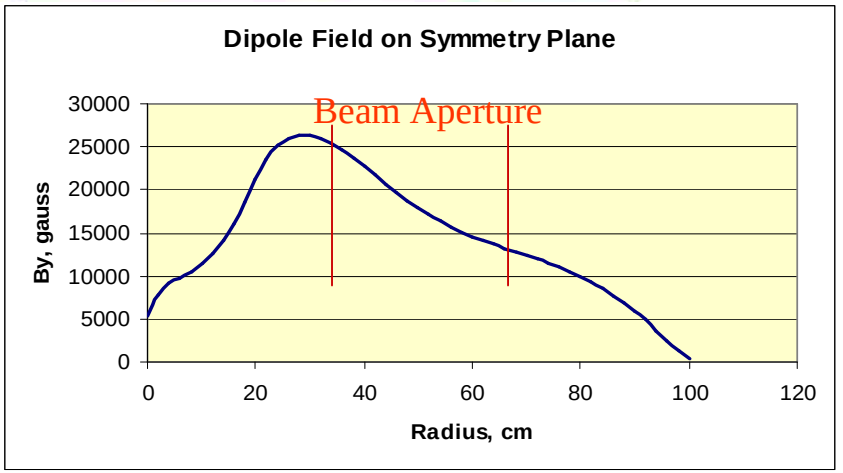
- This above condition also implies that at different ρ will bend the same angle while traversing the dipole magnet.
- We want the *Effective Field Boundary* of the dipole to be located at $\pm\theta\rho$ where $\theta = 22.5^o$.
  - The actual iron boundary will be approximately $\pm 16^o$.
- We can calculate the pole shape assuming the pole iron does not saturate.

Dipole Magnet Design

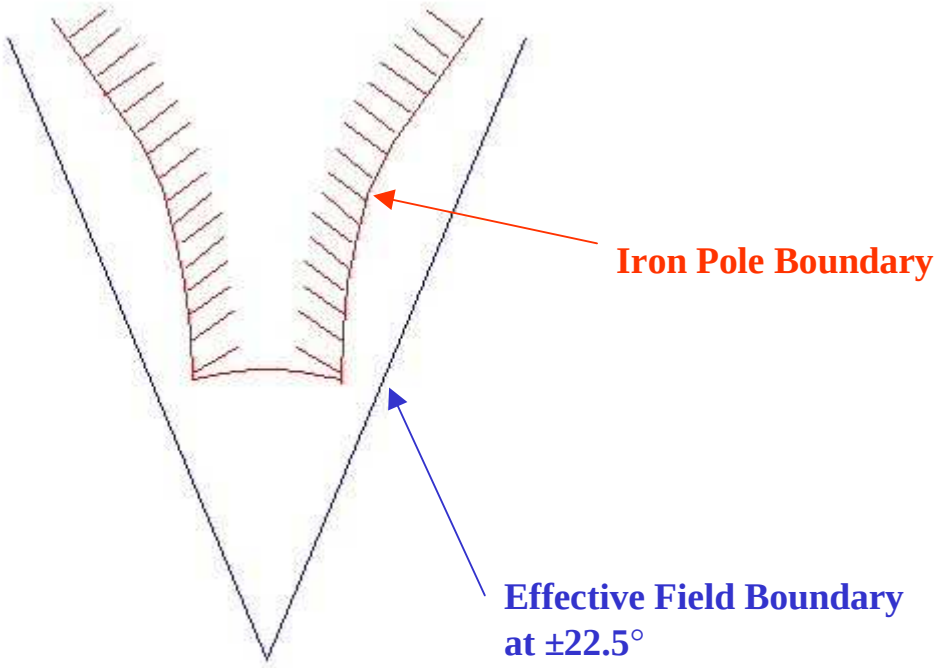
Radius ρ (cm)	Half Gap G/2 (cm)	Half Width W/2 (cm)	Eff Field Boundary $S_{EFB} = \rho\pi/8$ (cm)	$B_v(\rho)$ (kG)
25	5.0	7.8	9.8	19.81
30	5.2	7.8	11.8	18.49
35	6.2	8.0	13.7	17.37
40	7.9	8.5	15.7	16.40
45	10.3	9.5	17.7	15.55
50	13.5	10.8	19.6	14.78
55	17.5	13.0	21.6	14.09
60	21.7	16.2	23.6	13.46
65	26.0	19.4	25.5	12.88
70	28.0	22.6	27.5	12.34
75	28.0	25.8	29.4	11.84
80	28.0	29.0	31.4	11.38



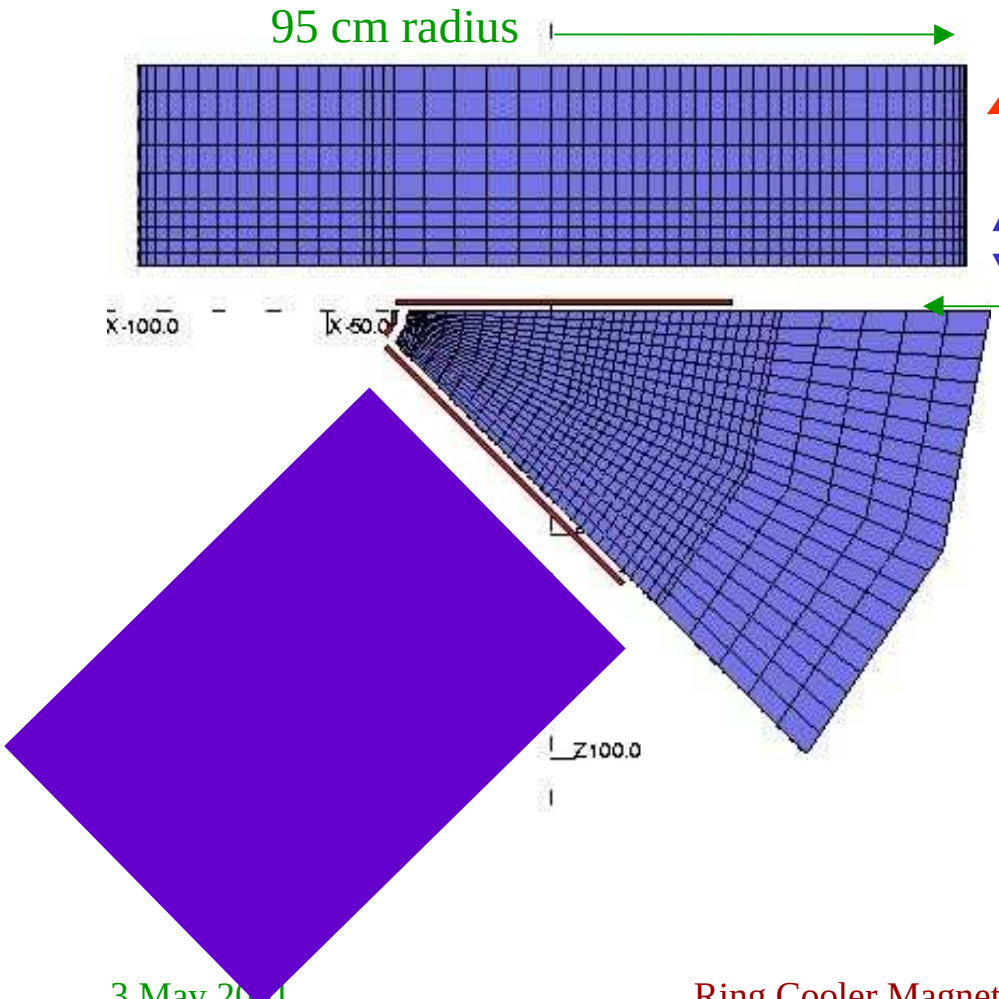
2D Cylindrical Calculation:



Effective Field Boundary



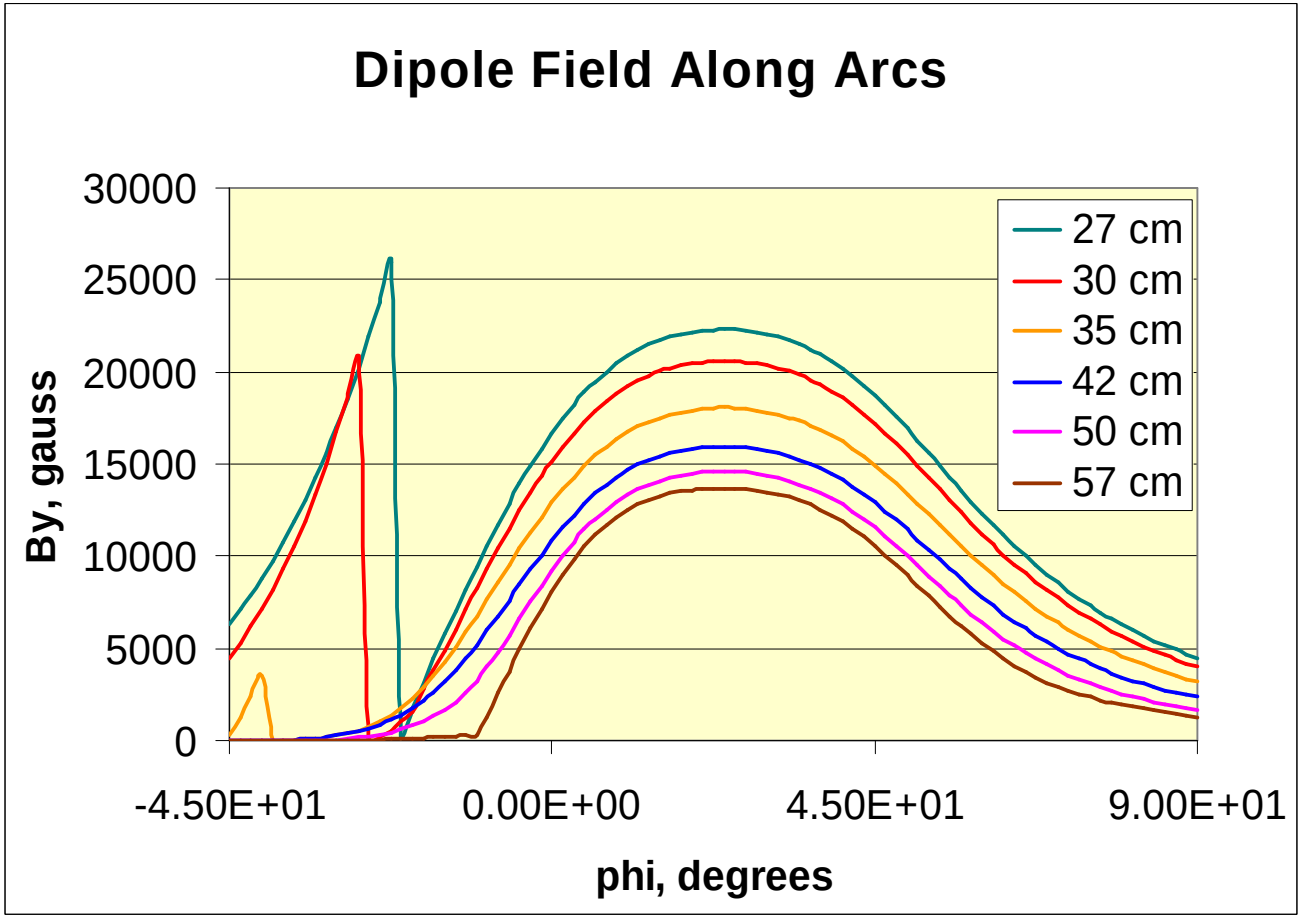
Tosca Model for Wedge Dipole



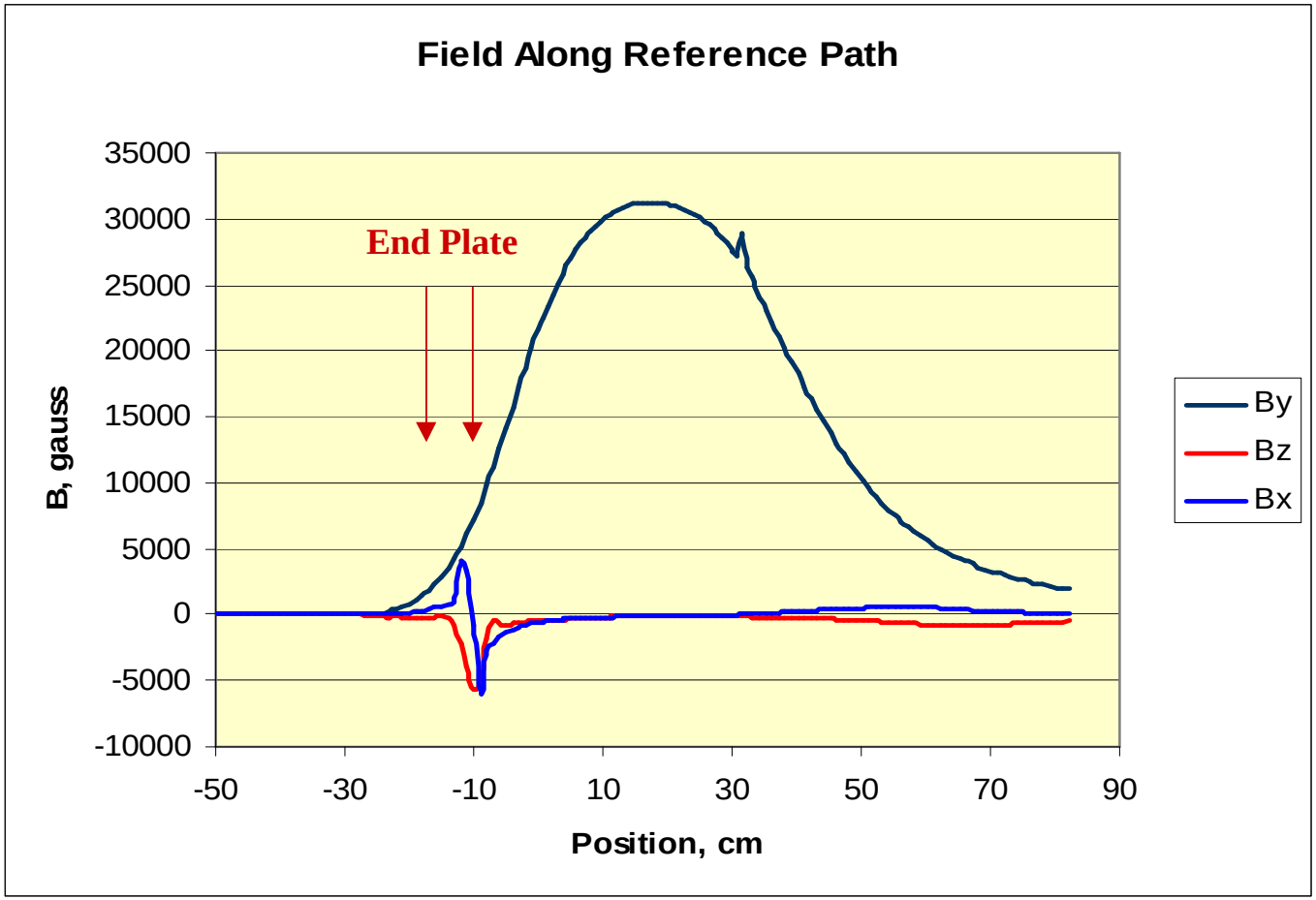
Coils in this Model are assumed to be superconducting

Field Profile Along Arcs

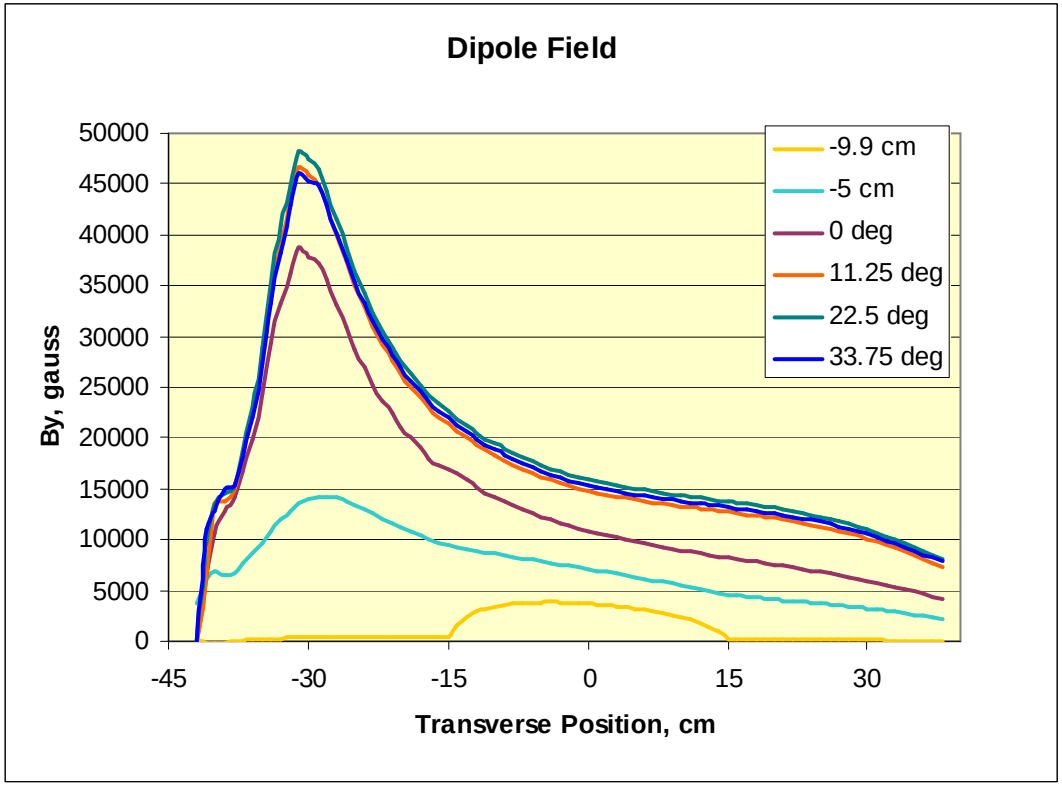
ρ (cm)	$\int B_y dl$ (T m)
27	0.935
30	0.876
35	0.780
42	0.787
50	0.803
57	0.806



B_y along Beam Path in Wedge Magnet



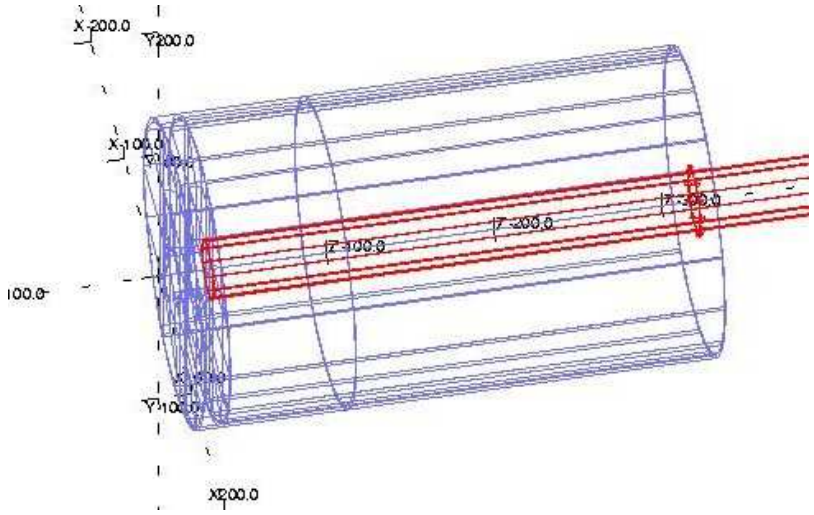
Field along the Vertical Transverse Plane of the Wedge Dipole



- These calculations were made with previous TOSCA model with 42 cm radius reference path.
- Field inside gap retains profile as a function of arc position.
- Fringe field has different profile
- Field is not separable as Z(s)X(ρ)
- A real map should be used to correctly represent the field.

Large Solenoid Magnet

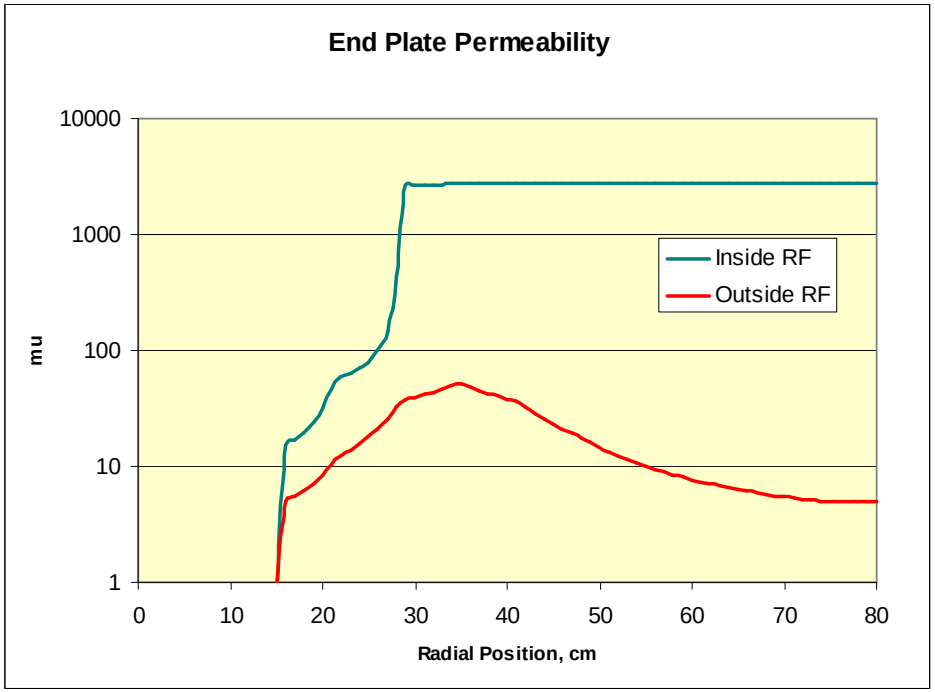
- Figure shows coils with 15 cm radius *inside* RF cavities.
  - Such coils would consist of short coils that would sit in the *nose* of the cavities.
- Coils could be placed outside the cavity instead. It is simple to calculate the field for that also.
  - The large coils are likely to be quite expensive.
- There is a 15 cm endplate with a 2.5 cm thick cylinder to return the flux.



•Solenoid calculation uses BH table for Low Carbon 1010 steel.

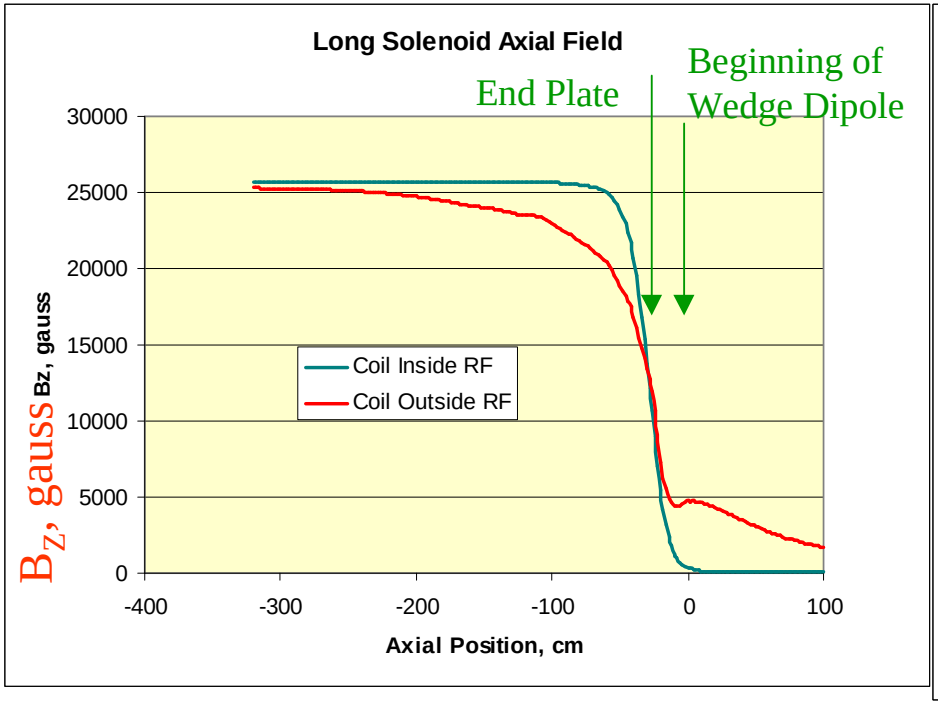
Should the coils be inside or outside RF Cavities?

- 15 cm iron end plate would be saturated if coils are outside cavities. (left figure)
- Significant B_Z leakage out end plate aperture if coils outside cavities. (Next transparency)
- $\Delta B/B$ ~25% in RF cavity region if coils outside.
  - Can this complicate multipacting?
- If Magnet cost scale as stored energy, there is a significant advantage to putting coils inside cavities.

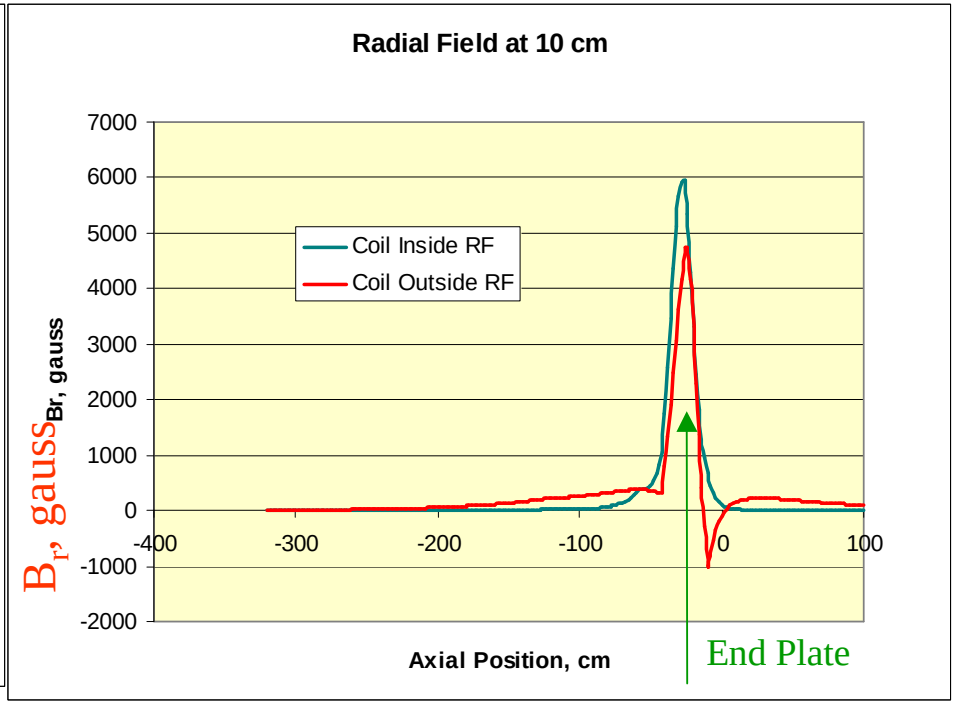


Permeability of 15 cm iron end plate for cases when coils are inside and outside RF cavities

Fields in Large Solenoid

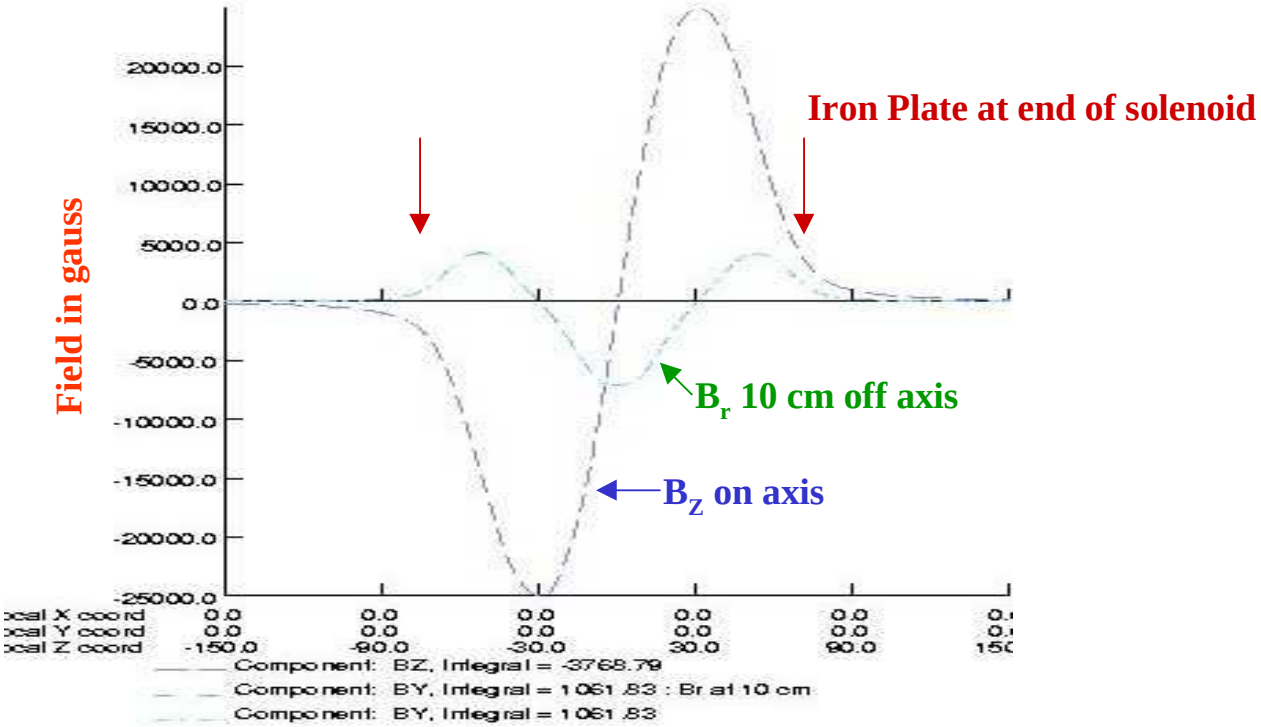


Axial Field



Radial Field 10 cm off axis

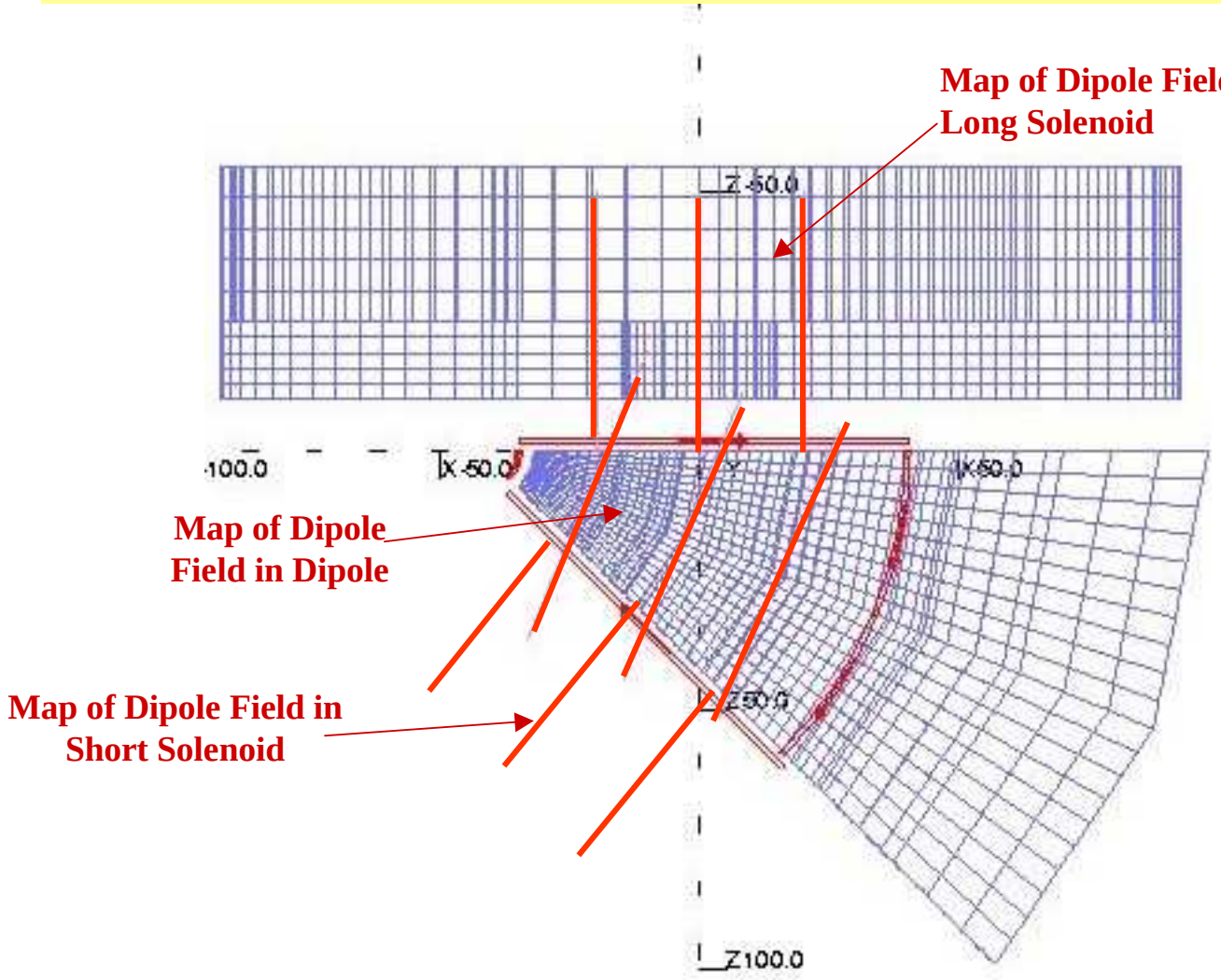
Field in Short Field Flip Solenoid



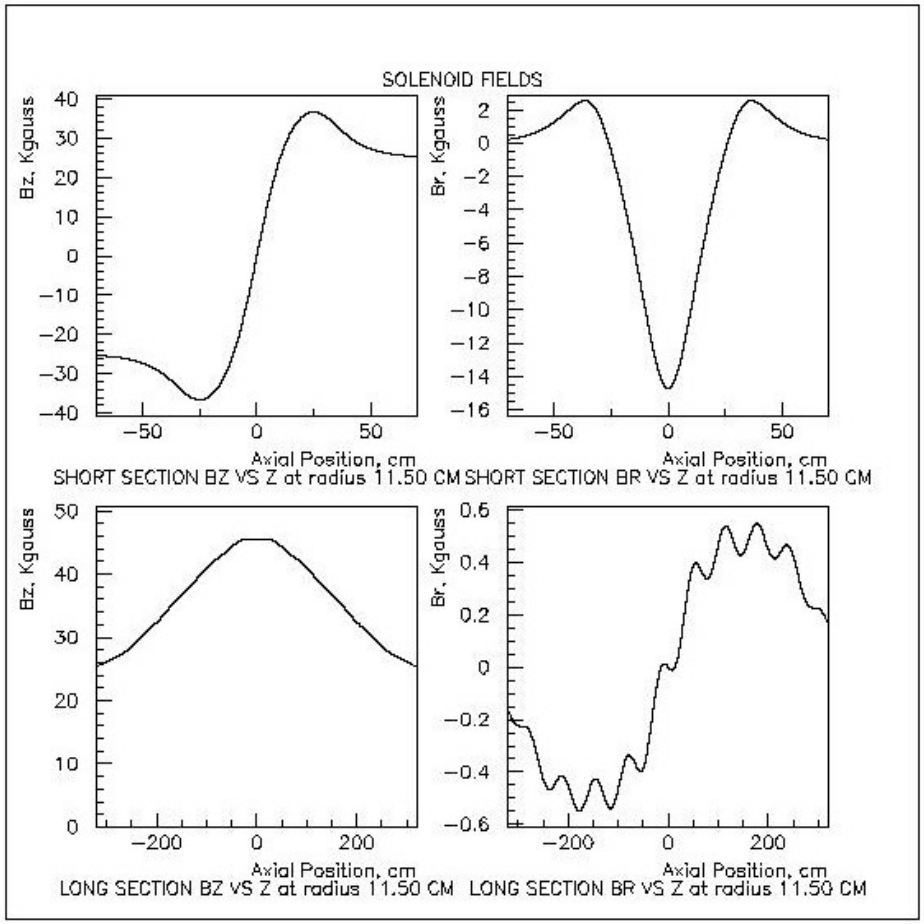
Field Maps

- The **TOSCA** program can generate 3D field grids.
- I have generated a 3D grid in the vicinity of the Dipole Magnet with 2 cm×2 cm×2cm segmentation:
  - Center of Wedge Dipole
    - Local coordinate system tilted 45º
  - Tail of Dipole in Large Solenoid
  - Tail of Dipole in Small Solenoid
- I have generated 2D grids for the solenoid fields with 1 cm × 1 cm in Δz, Δr. These maps are in the same format used by the current **gufld.**
  - Large 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.
  - This has not yet been done.

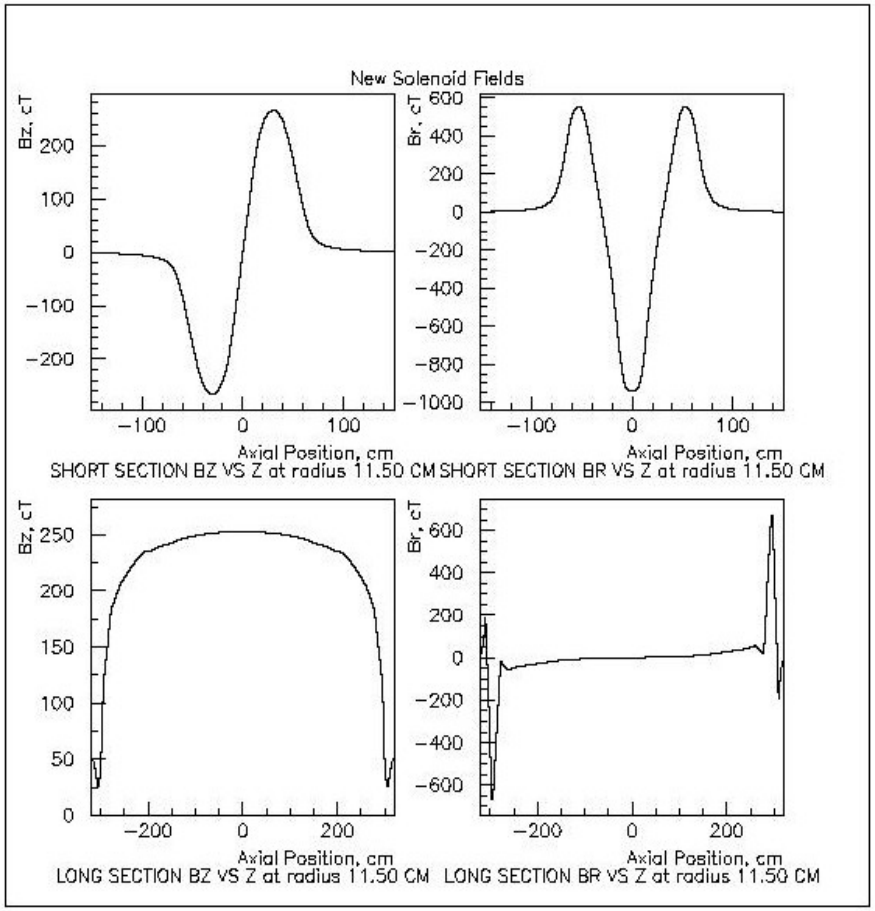
Dipole Magnet Maps



Solenoid Field Maps



Raja's Fields in Muc_Geant



My Fields in Muc_Geant (Ignore normalization. The map is correct. It is not read by Raja's program correctly.)