Realistic Fields for a Ring Cooler

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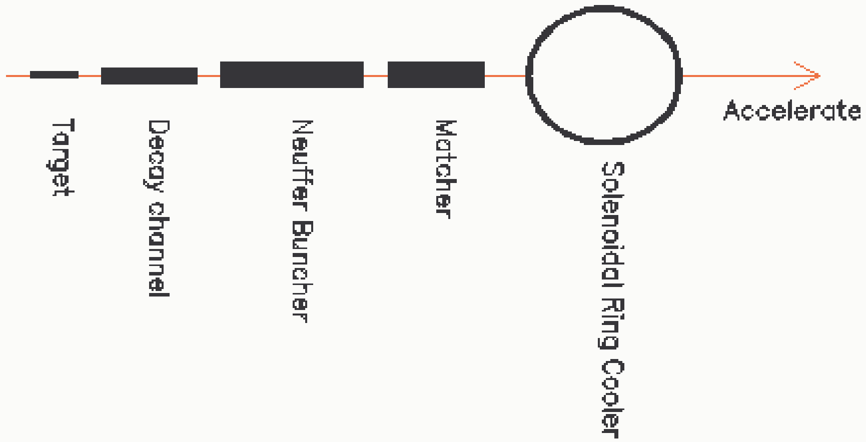
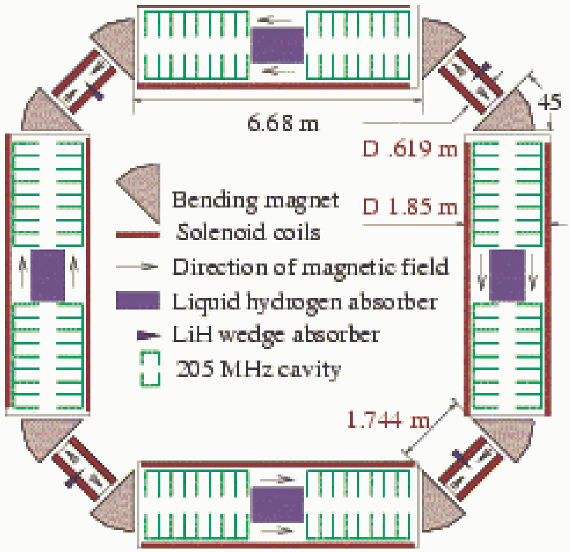
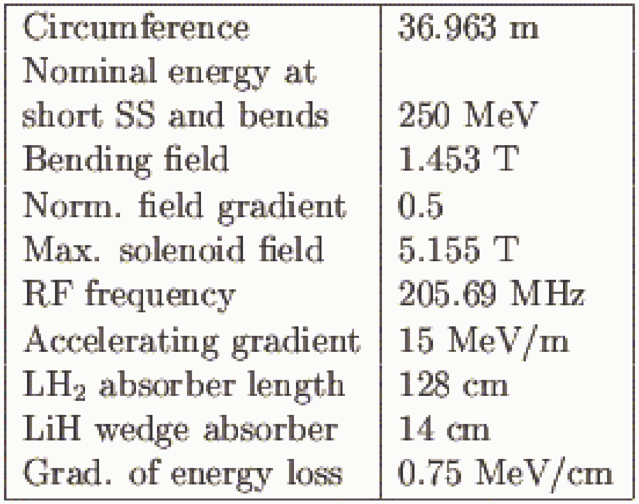
2 July 2002

NuFact'02 Meeting

Ring Cooler Geometry

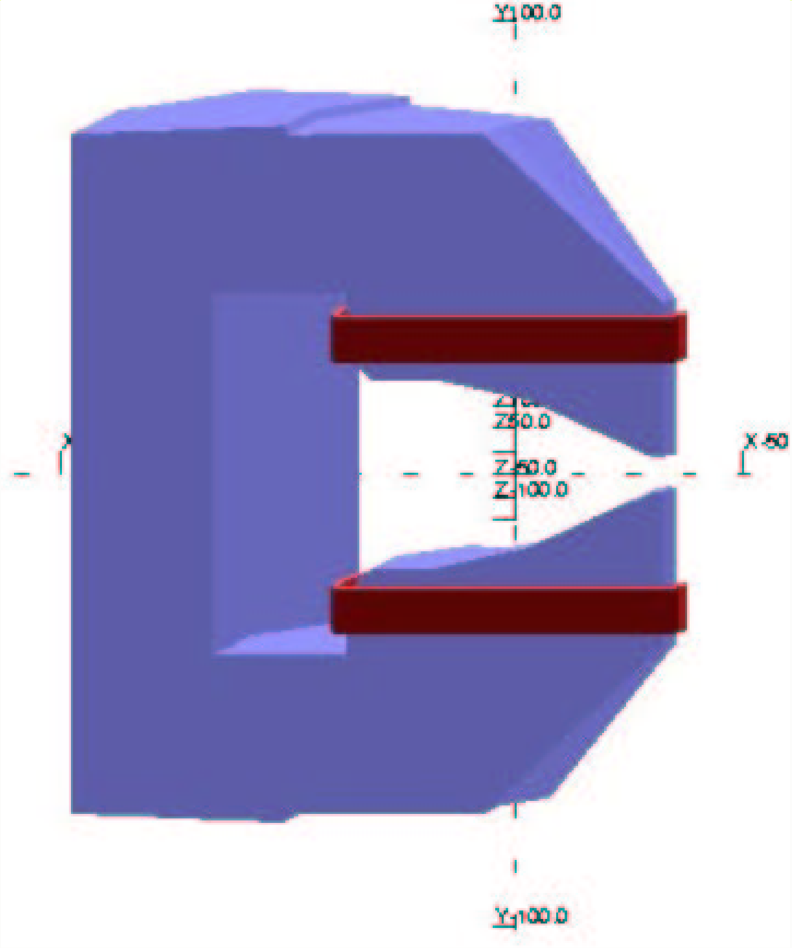


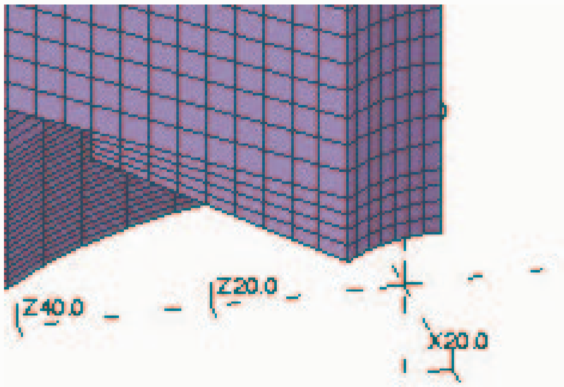




Circumference	36.963 m
Nominal energy at short SS and bends	250 MeV
Bending field	1.453 T
Norm. field gradient	0.5
Max. solenoid field	5.155 T
RF frequency	205.69 MHz
Accelerating gradient	15 MeV/m
LH_2 absorber length	128 cm
LiH wedge absorber	14 cm
Grad. of energy loss	0.75 MeV/cm

Sketch of Dipole Magnet





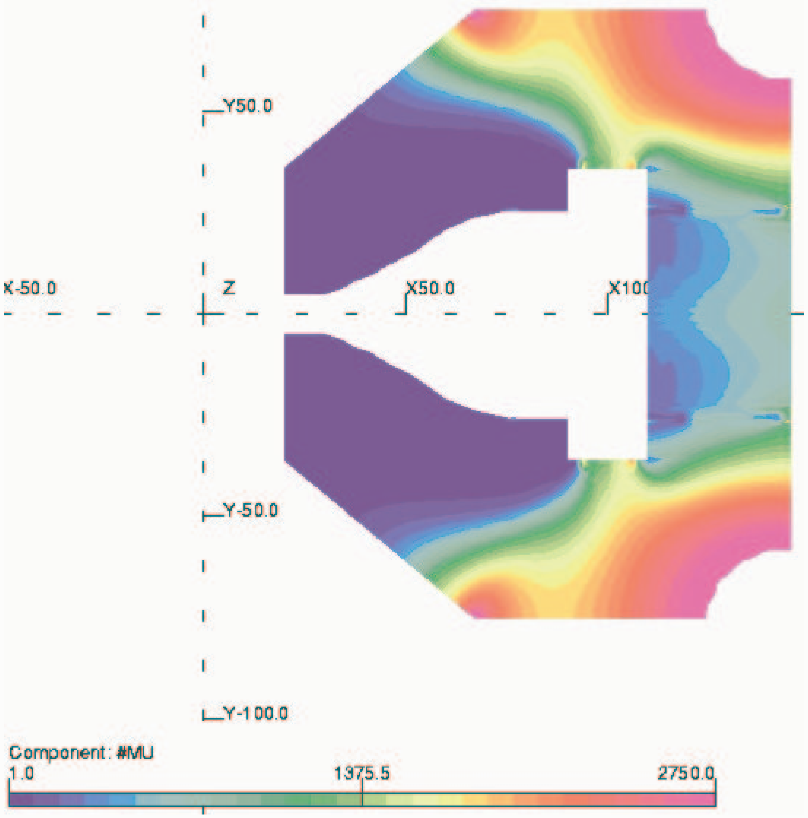
Pole face is shaped to achieve required gradient

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

It has been revised.

Saturation in Dipole Magnet

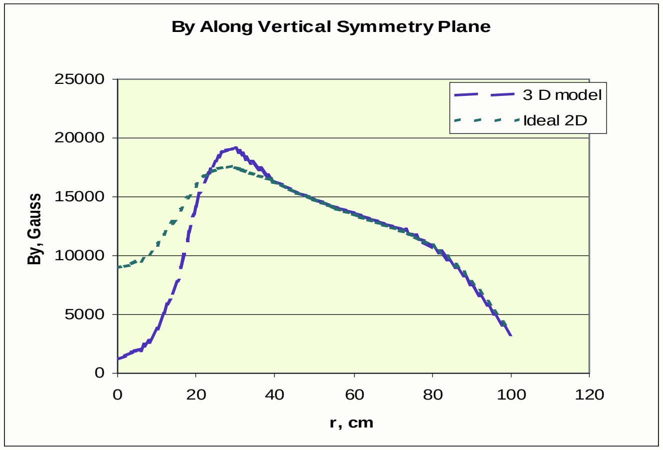
- Figure shows the permeability for the vertical midplane of the magnet.
- μ<10 on inner edge of the aperture.

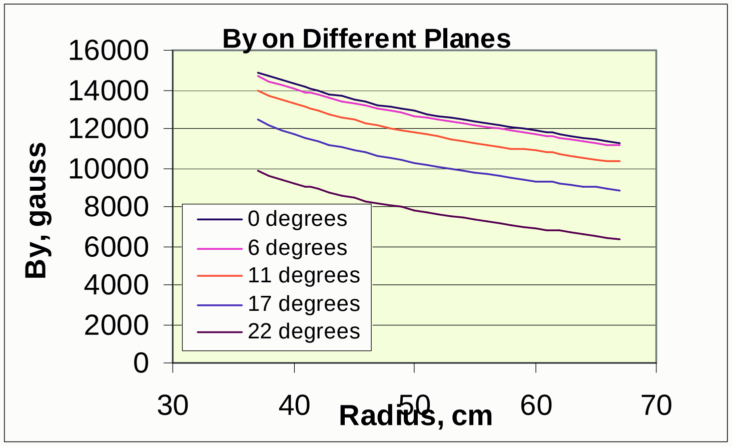


B_y on and off the Vertical Symmetry Plane

- Figure shows two 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

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

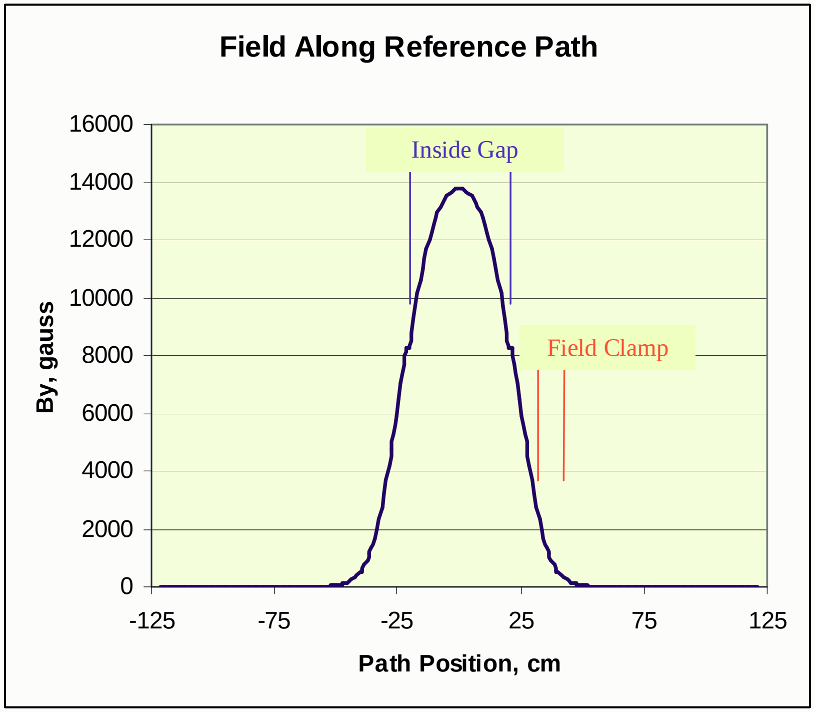


Figure 3: B_y along central reference path.

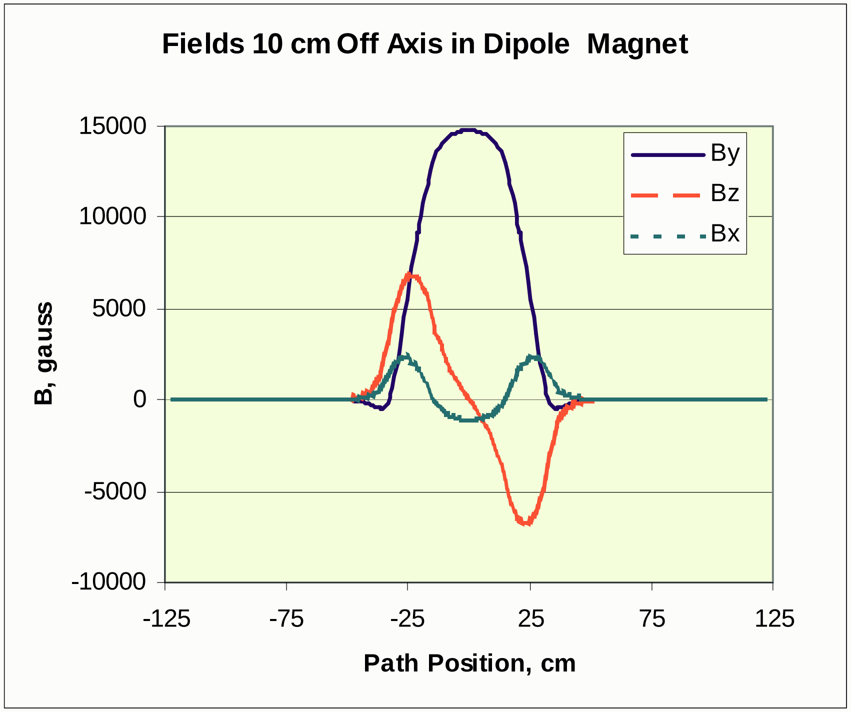


Figure 4: Field components for a path displaced 10 cm vertically from the reference path

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:

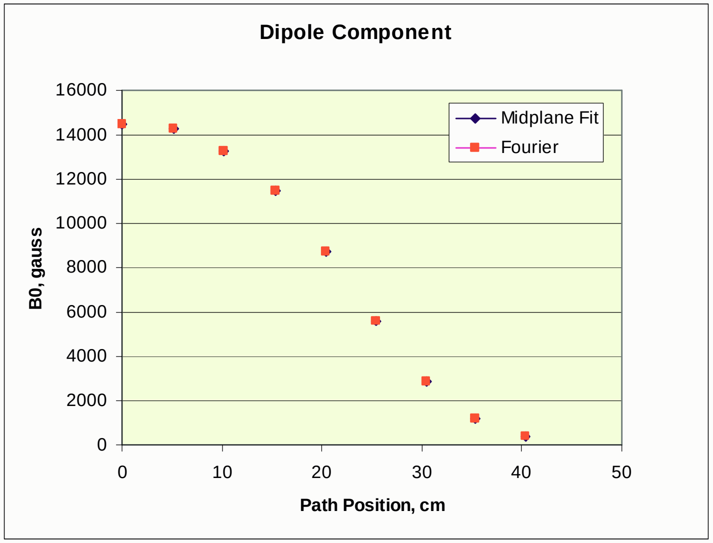
$$B_r(r,\phi,s)=\left[K_1(s)-\tfrac{3}{8}\frac{d^2K_1}{ds^2}r^2+\tfrac{5}{192}\frac{d^4K_1}{ds^4}r^4+\cdots\right]\sin\phi+\left[K_2(s)r-\tfrac{1}{6}\frac{d^2K_2}{ds^2}r^3+\tfrac{1}{128}\frac{d^4K_2}{ds^4}r^5+\cdots\right]\sin 2\phi+$$

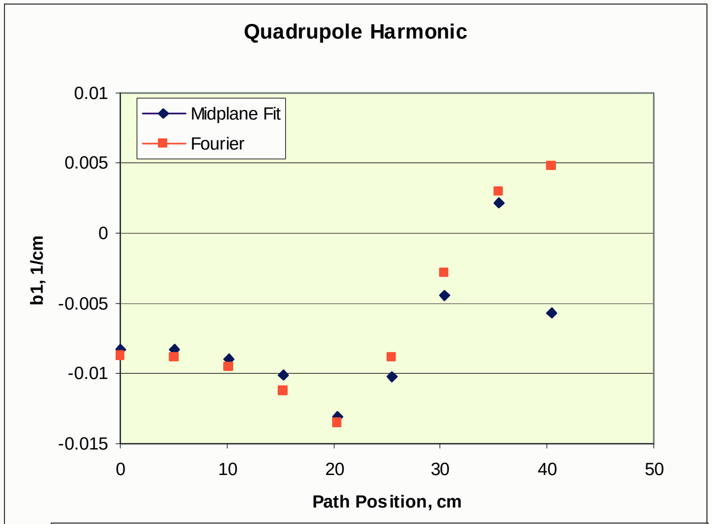
$$\left[K_3(s)r^2-\tfrac{5}{8}\frac{d^2K_3}{ds^2}r^4+\tfrac{7}{1920}\frac{d^4K_3}{ds^4}r^6+\cdots\right]\sin 3\phi+\cdots$$

$$B_\phi(r,\phi,s)=\left[K_1(s)-\tfrac{1}{8}\frac{d^2K_1}{ds^2}r^2+\tfrac{1}{768}\frac{d^4K_1}{ds^4}r^4+\cdots\right]\sin\phi+\left[K_2(s)r-\tfrac{1}{12}\frac{d^2K_2}{ds^2}r^3+\tfrac{1}{384}\frac{d^4K_2}{ds^4}r^5+\cdots\right]\sin 2\phi+$$

$$\left[K_3r^2-\tfrac{3}{8}\frac{d^2K_3}{ds^2}r^4+\tfrac{1}{640}\frac{d^4K_3}{ds^4}r^6+\cdots\right]\sin 3\phi+\cdots$$

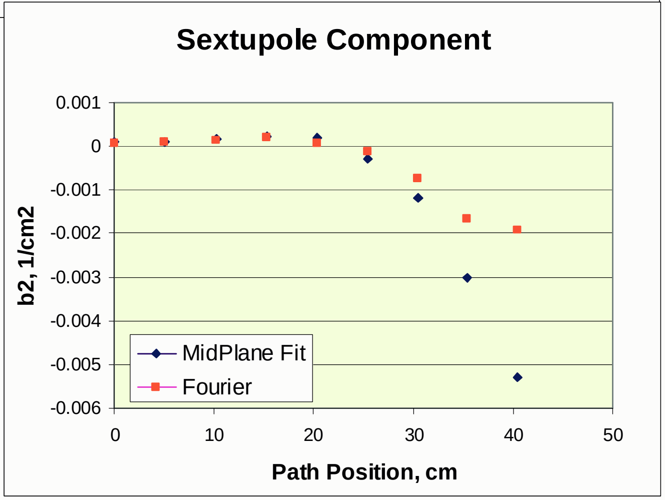
Transverse Harmonics as a Function of s





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

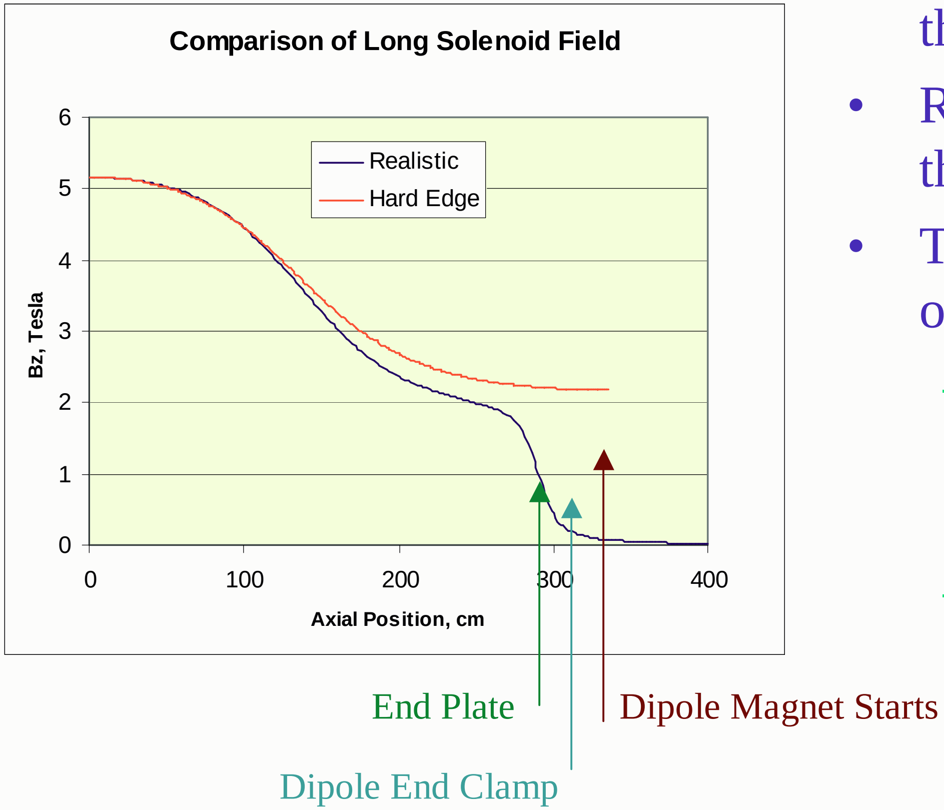
Calculated along the reference path



Dipole 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) to parameterize 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.
    - This may be a serious problem since tracks at large radius may be lost by *incorrect* fields.
- I am investigating if there is a better parameterization than the harmonic series.

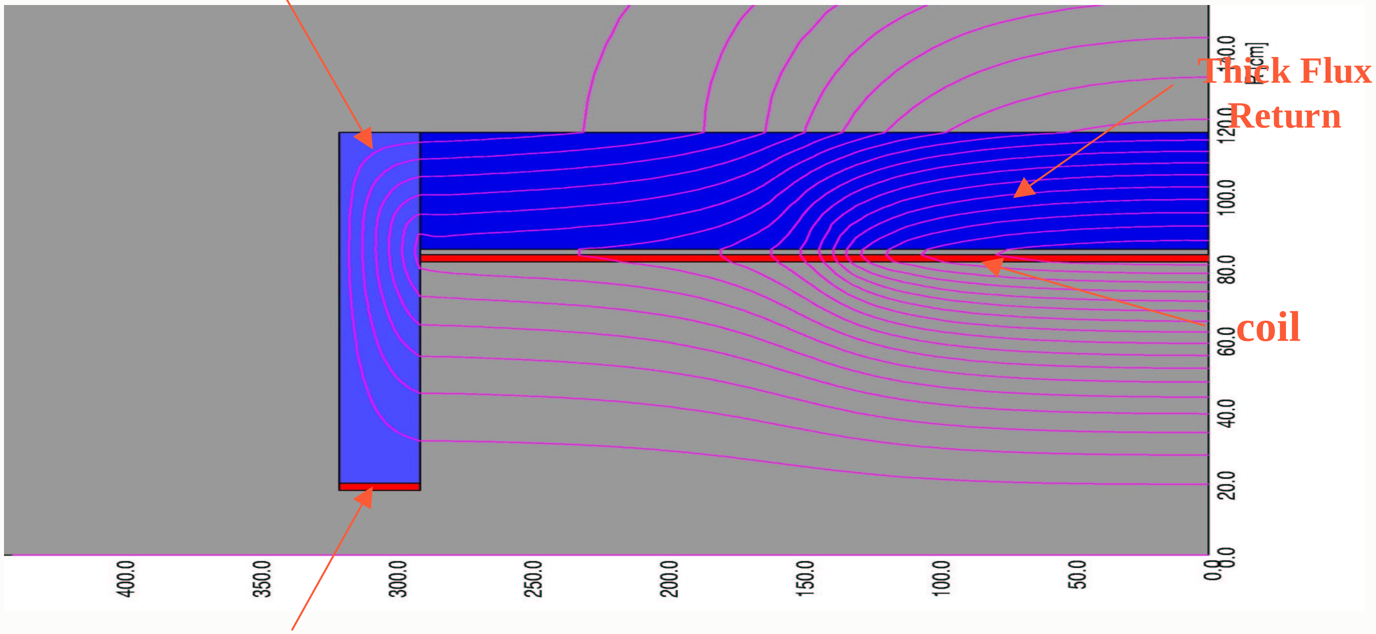
Previous Comments on Long Solenoid Magnet made at Shelter Island



- The end plate effectively separates the solenoid field from the dipole.
- Radial fields are present only in the vicinity of the end plate.
- The end plate takes about 40 cm of longitudinal space.
  - Actually I have the solenoid end plate and the dipole field clamp overlapping in space!
  - We need to determine reasonable amounts of allowable space

Long Solenoid Magnet

We have added an inner coil on end plates to reduce *no field* region



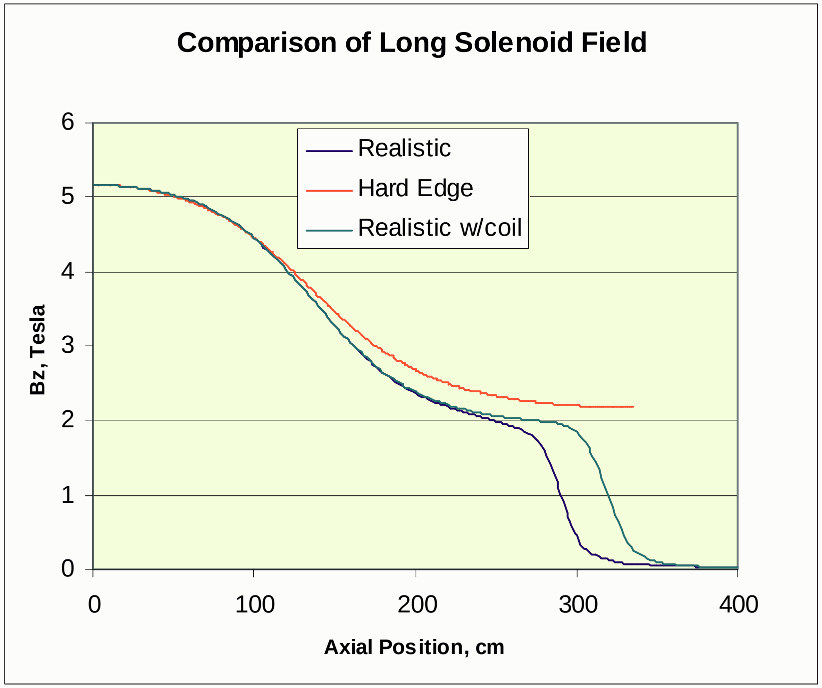
Vanadium Permadur End Plate

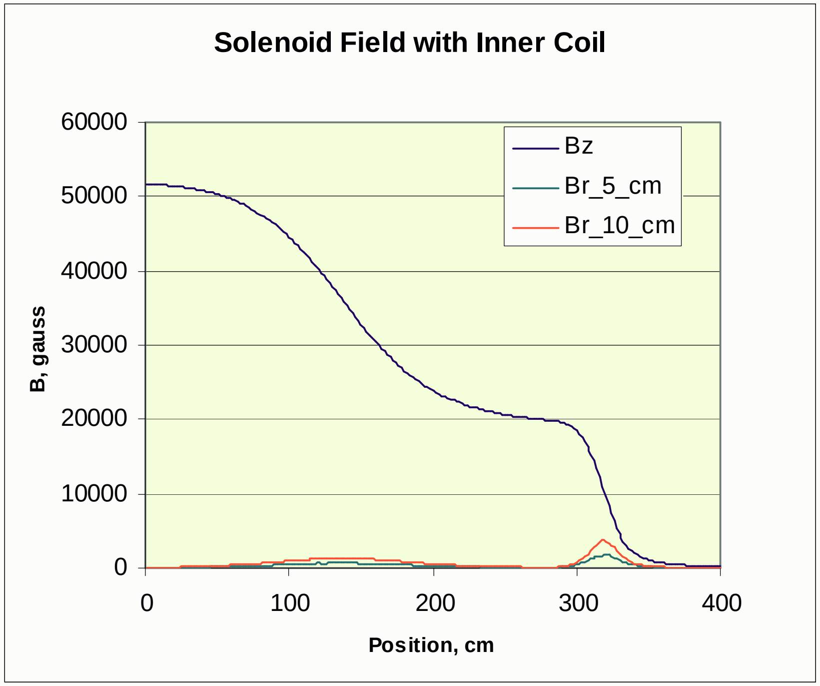
Thick Flux Return

coil

Supplemental Inner Coil

Fields in Long Solenoid

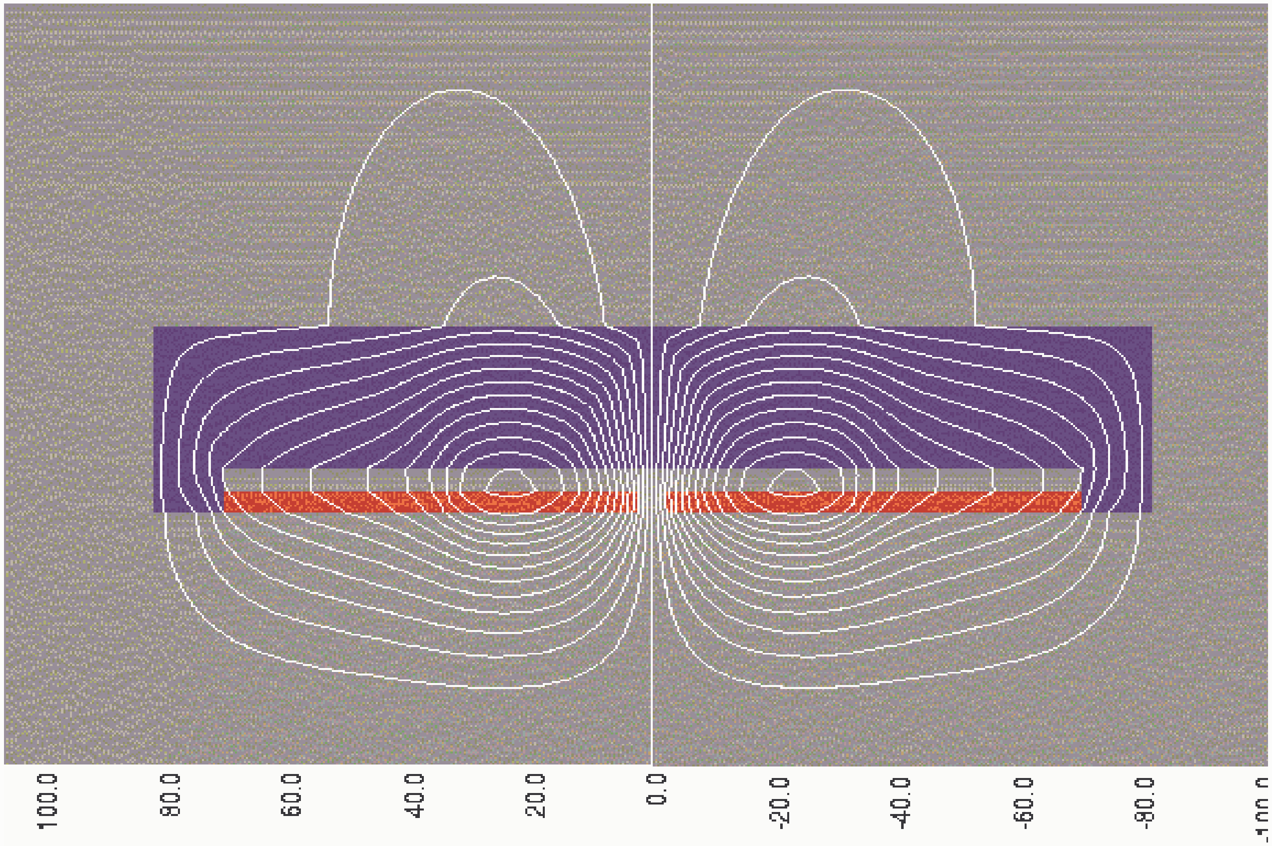




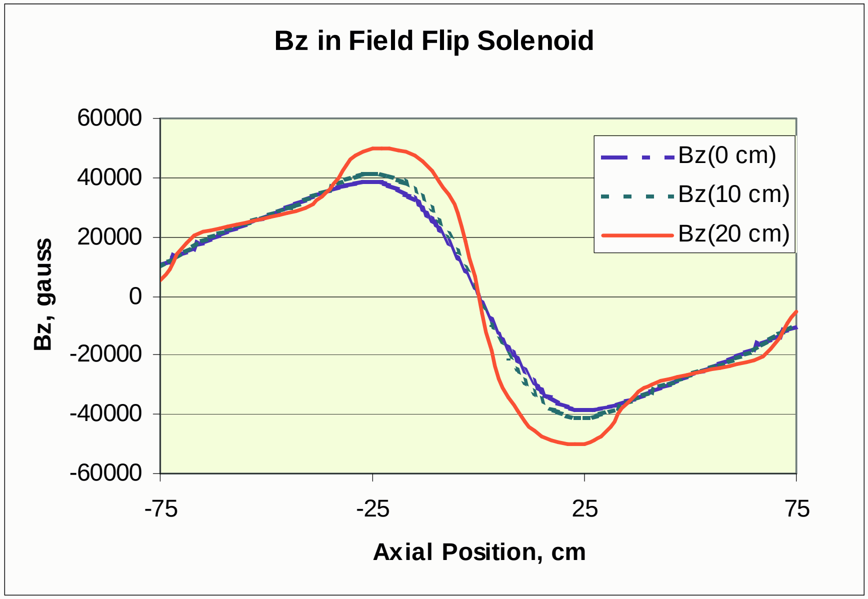
Comparison of B_z with and without supplemental inner coil

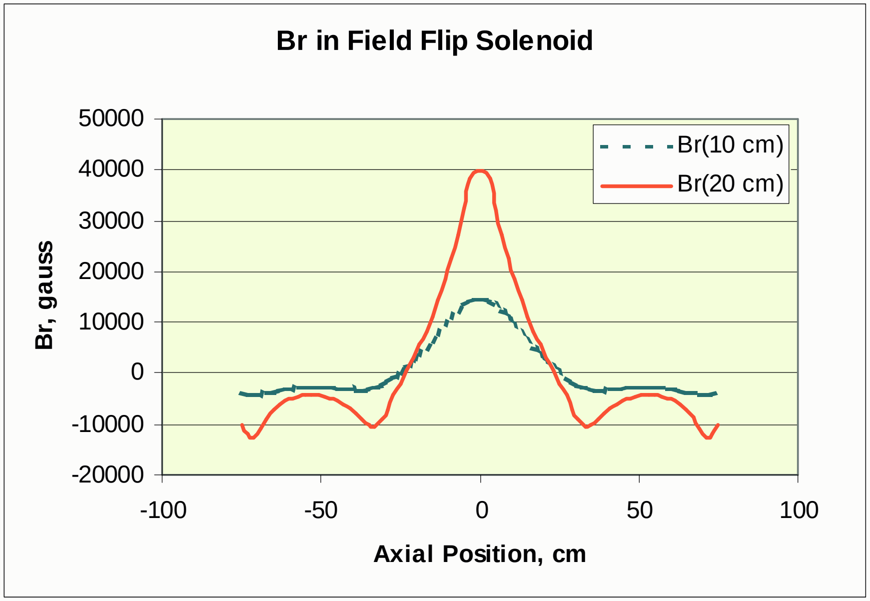
Axial and radial field components along long solenoid

Short Solenoid Magnet



Short Solenoid Fields

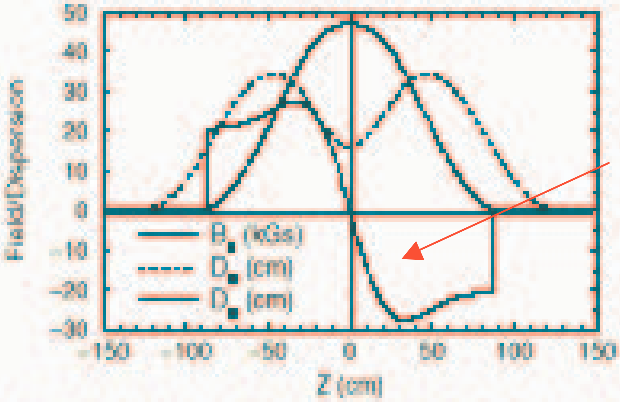




Ideal Short Solenoid Field Flip Magnet

- Top figure shows Valeri’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.

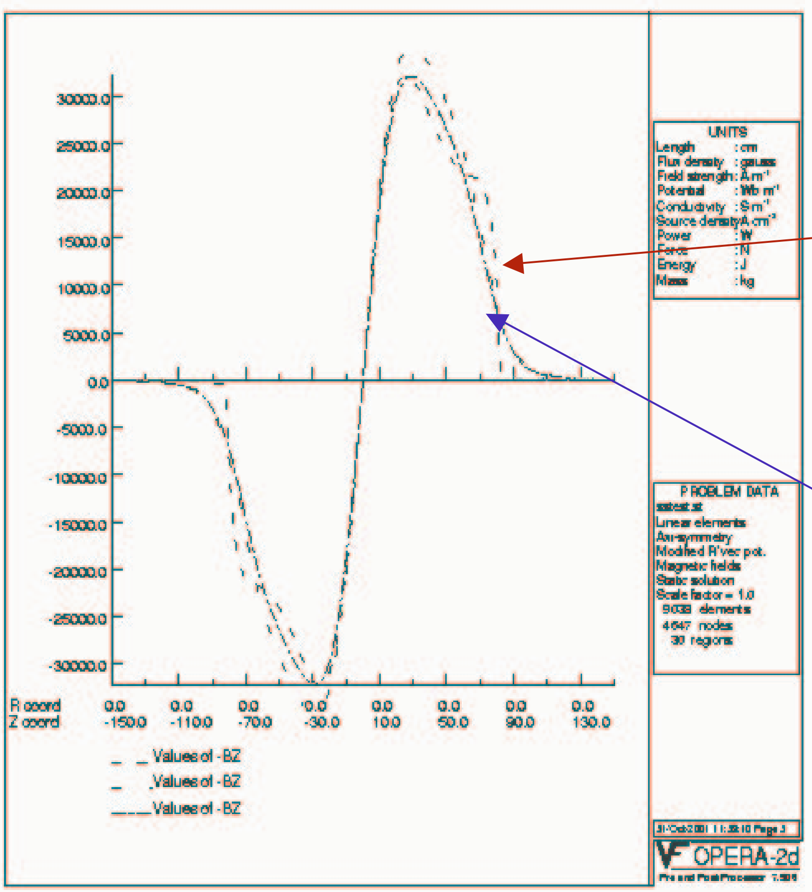


B_z on axis

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

Short Solenoid Fields From Opera2D

How critical is it to have this field plateau?

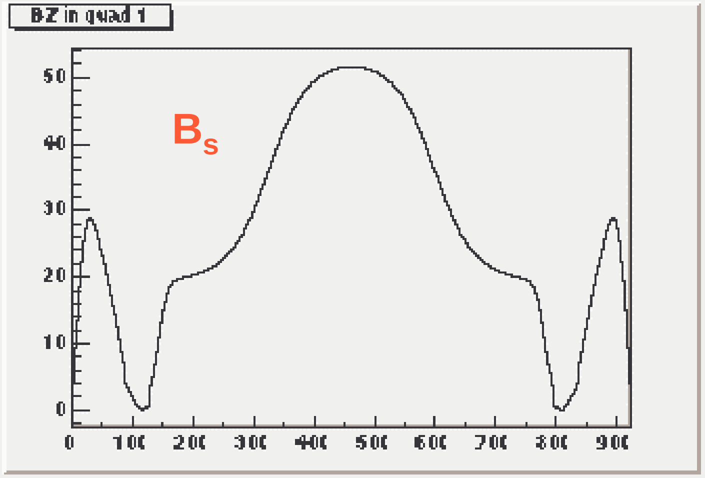


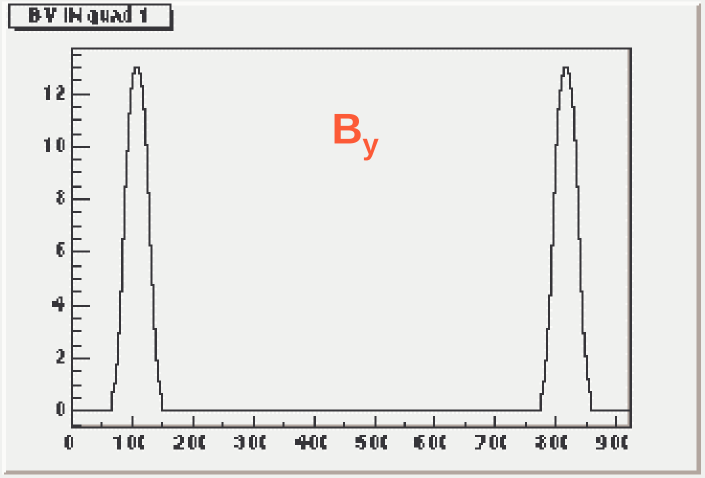
Field with iron covering ends

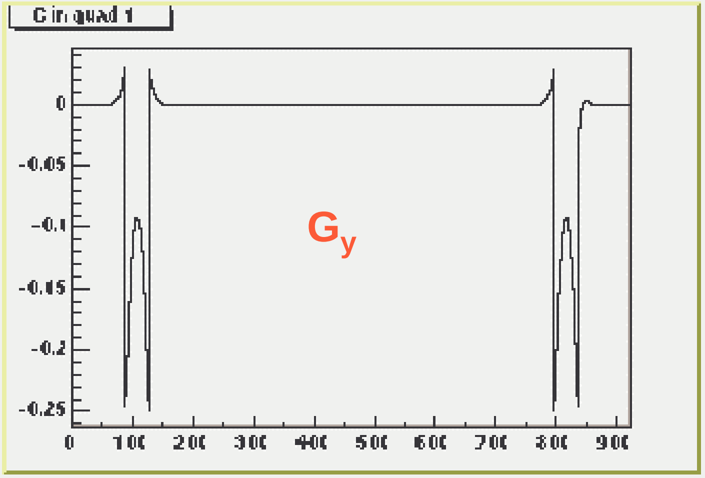
This forces field to be sort of parallel to axis

Field with aperture for muons

Fields in Geant







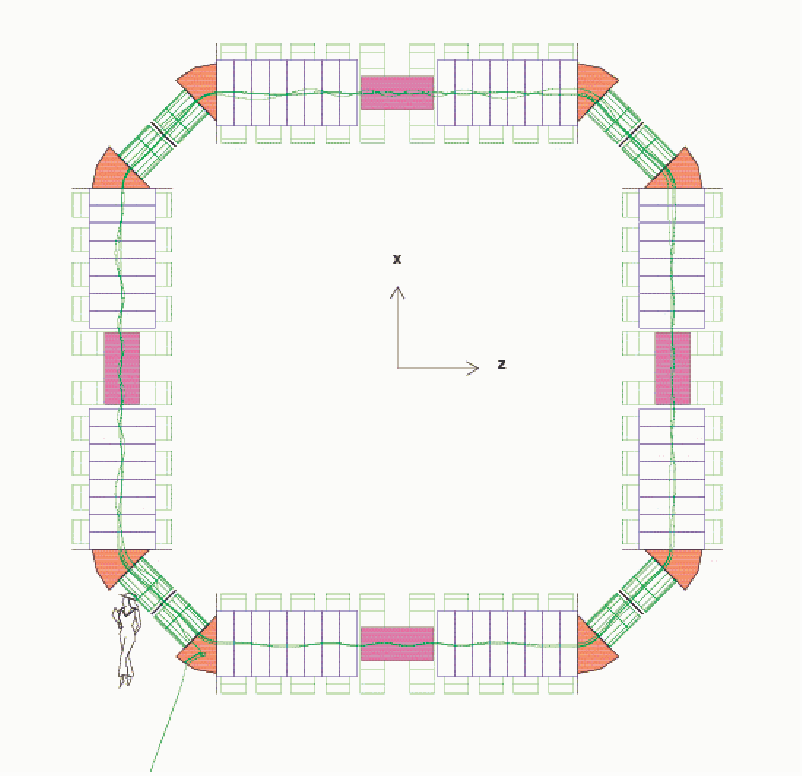
The figures shows the field components along the reference path in one quadrant of the ring.

B_s and B_y are in kgauss and G_y is in kgauss/cm

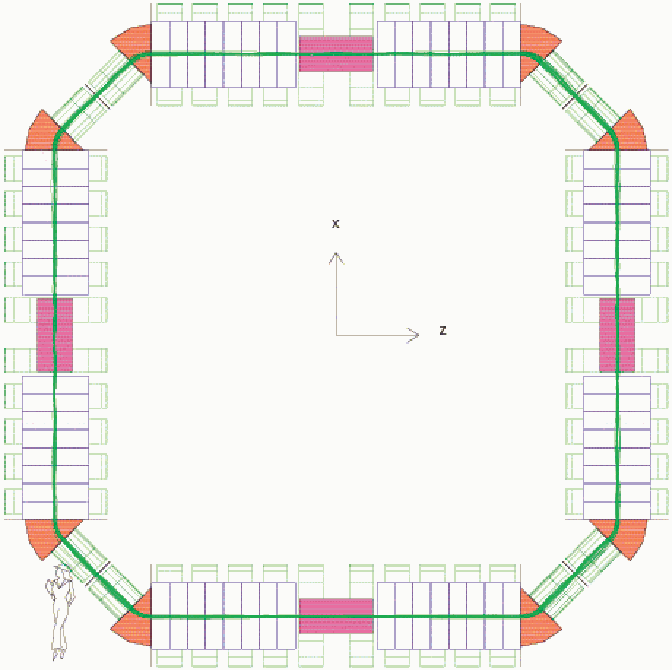
This field description is from the muc_geant and there is a provision to write this out for ICOOL

Current Status: μ Travels 3.5 Revolutions when RF is turned on

Track is lost with REALISTIC field after 3.6 turns

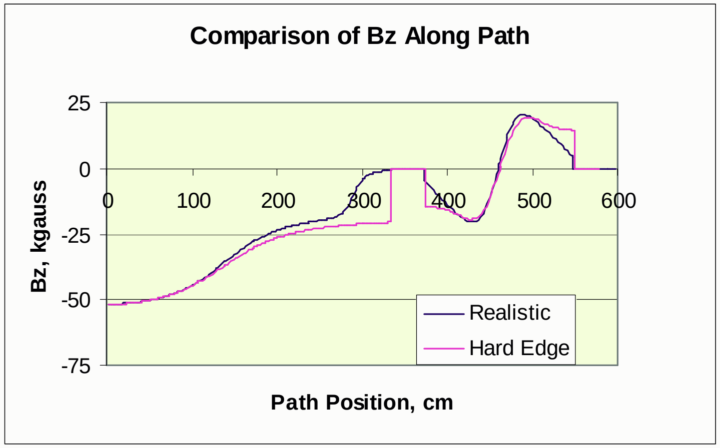


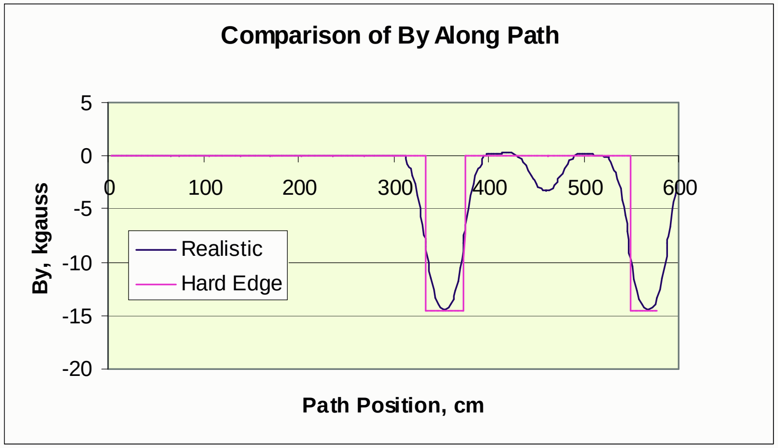
Track goes > 19 turns in HARD EDGE field



Tracking on axis μ with the RF and Absorbers

Comparison of Field Along Tracks



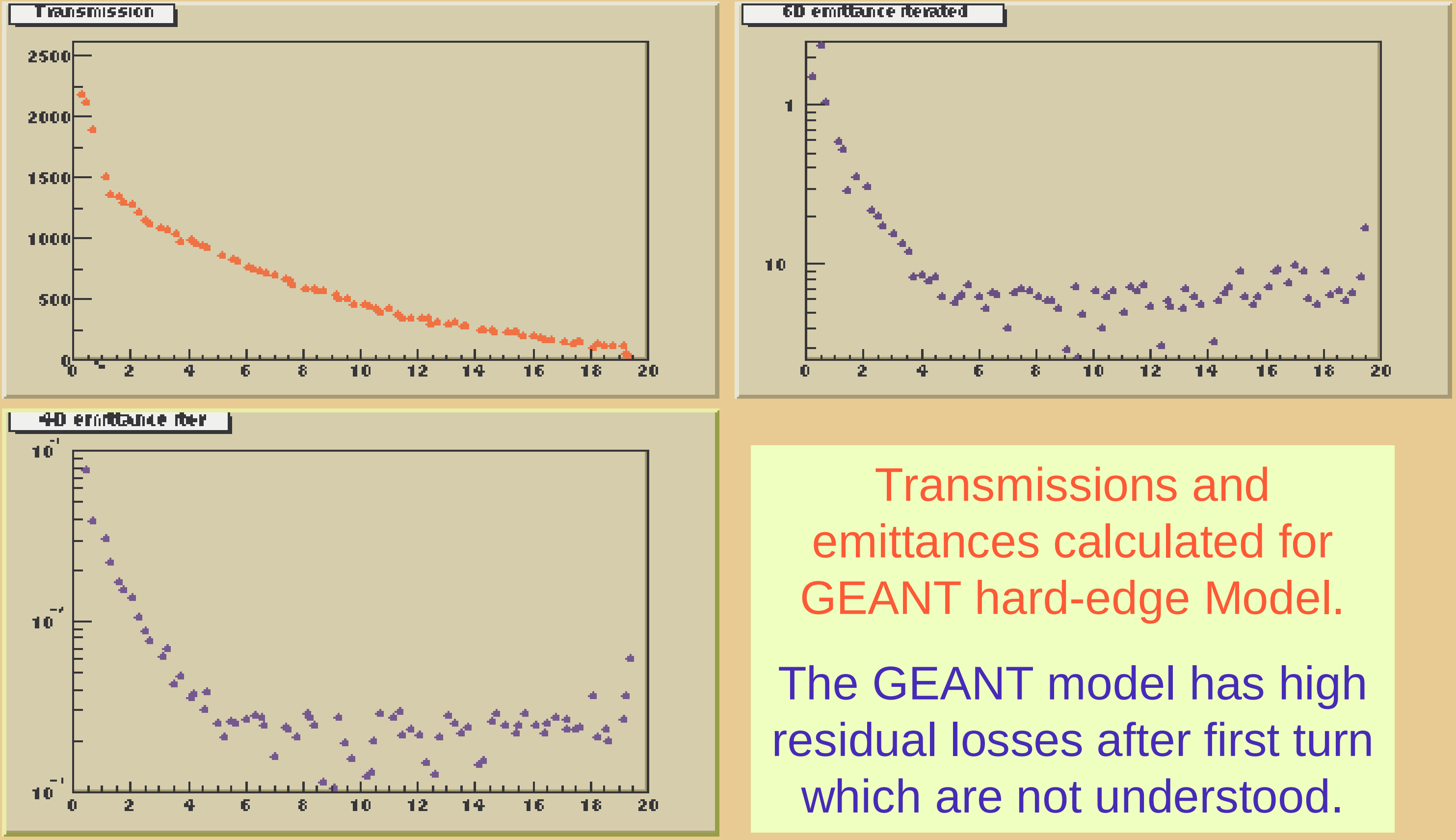


- The figures at the left show the field seen by *on axis* μ traversing first octant of ring.
  - There are differences at the ends of the short and long solenoids as expected.
- There is B_y in the center of the Short Field Flip solenoid for the *realistic muon* since its does not have zero displacement at that point.
  - This is an indication that the ring would have to be *tuned* for the realistic fields.

Tracking With a Realistic Beam

- I have shown how the reference particle looks with the *Realistic Fields* and with the *Hardedge Field*. As an exercise, I would like to look at the *Hardedge Field* case with realistic muon bunch with the following parameters:
  - $\sigma_x = \sigma_y = 4\ cm$.
  - $\sigma_{Px} = \sigma_{Py} = 32\ MeV/c$.
  - $\sigma_E = 18\ MeV$.
  - $\sigma_{ct} = 9\ cm$.
  - *There is also an energy-momentum correlation.*
- Use newer RF cavity times, phases, and frequency. These still are not perfectly optimized, but they are better than previously available.

Properly Phased (?) with RF and Absorbers



Transmissions and emittances calculated for GEANT hard-edge Model.

The GEANT model has high residual losses after first turn which are not understood.

ICOOL Models for Comparison

- On the right are the results of the Rick Fernow's ICOOL model of the Balbekov Ring.
  - It uses the *hard-edge field* model.
  - It shows ~50% transmission
  - It shows a significant 6D emittance cooling.
- I have made my own ICOOL model using the *on-axis* realistic fields that I have shown.
  - The initial attempt shows significant losses.
    - This was done the day before I left for England and needs still to be worked on.