Muon Collaboration

Modeling of Gas-filled Dipole cooling Rings

Muon Collaboration Meeting

LBL

February 15, 2005

BROOKHAVEN NATIONAL LABORATORY

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Fundamental Strategy

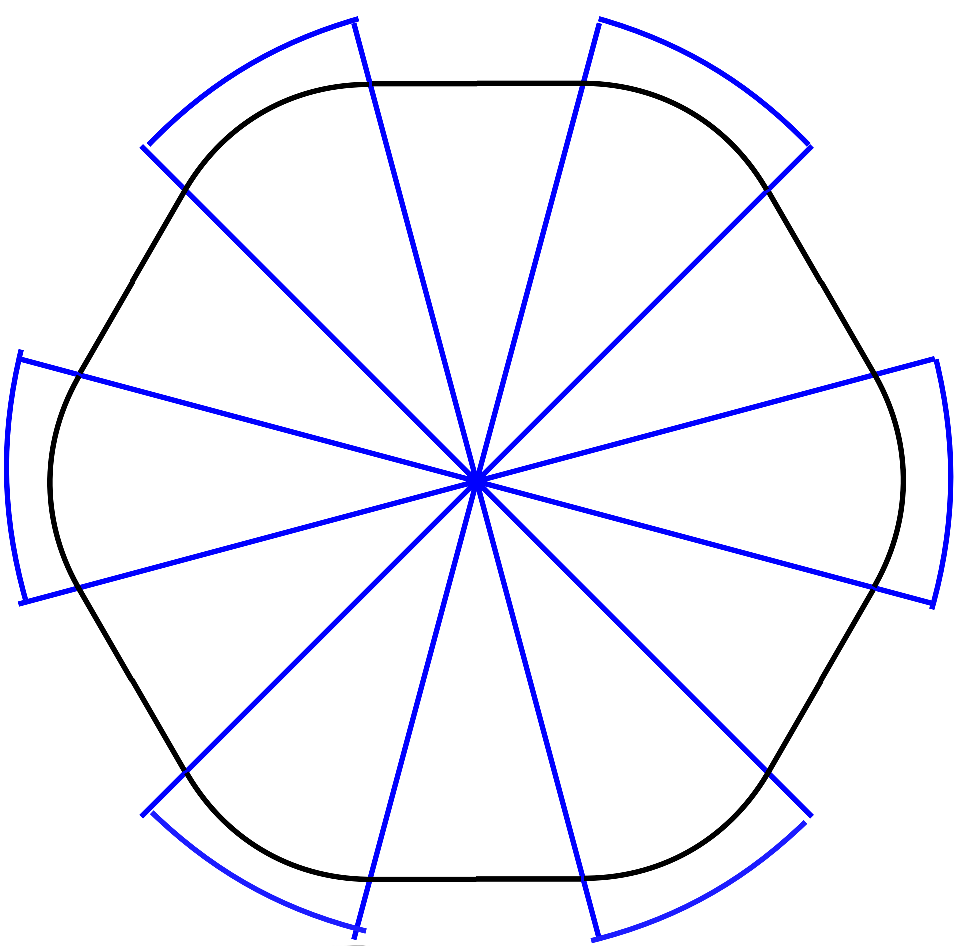
Lattice Design Using SYNCH (Al Garren)
System Optimization using ICOOL (H. Kirk)
Maxwellian Soft-edge Fields (Bob Palmer)
Realistic Fields using TOSCA (Steve Kahn)

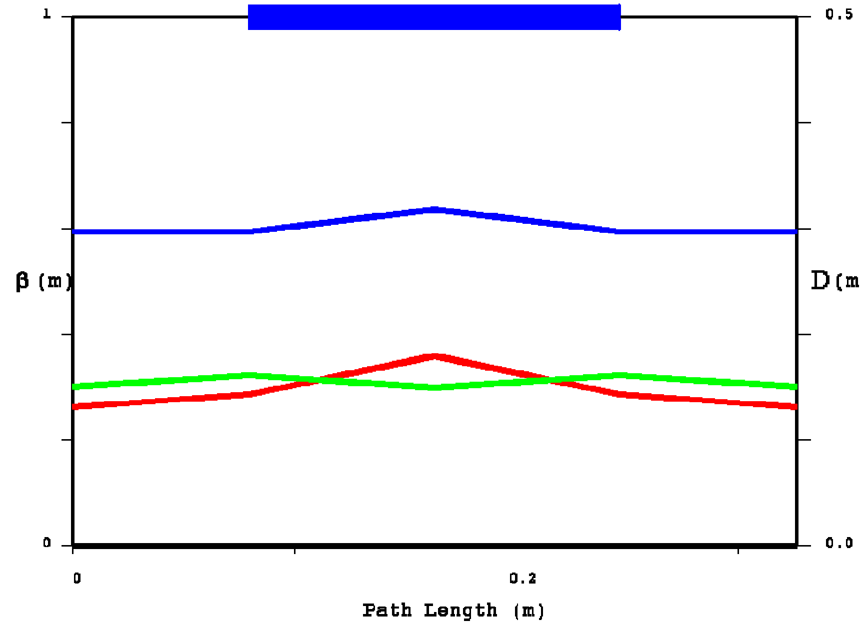
- Explore dipole-only rings utilizing edge focusing
  - Weak Focusing dipoles
  - Strong Focusing (FFAG like)
- Use Gaseous H_2 absorber/moderator

Gas Filled Rings with Hard Edges

	Low Field Ring	High Field Ring	FFAG Ring
Dipole Field	1.8 T	5.2 T	2.6 T
Magnetic Elements	hard edge	hard edge	hard edge
Sectors	4	6	12
Focusing	edge	edge	alternating gradient
β_x Range	38 $\rightarrow$ 92 cm	26 $\rightarrow$ 36 cm	44 $\rightarrow$ 65 cm
β_y Range	54 $\rightarrow$ 66 cm	30 $\rightarrow$ 32 cm	26 $\rightarrow$ 42 cm
p(central orbit)	172 MeV/c	250 MeV/c	250 MeV/c
Hydrogen Pressure	40 Atm. @ 300^0 K	100 Atm. @ 300^0 K	100 Atm. @ 300^0 K
Peak RF Gradient	14 MV/m	45 MV/m	8 MV/m
Total RF Length	1.6 m	0.8 m	3.6 m
Ring Circumference	3.81 m	1.95 m	6.0 m
X Aperture	±20 cm	±25 cm	±25 cm
Y Aperture	±15 cm	±15 cm	±15 cm
p_z Acceptance	±10 MeV/c	±10 MeV/c	±10 MeV/c
Orbits	100	250	40
X, Y, Z Cooling Factors	2.4, 2.3, 7.4	2, 13, 20	16, 15, 2
Muon Decay Included	no	yes	yes
Cooling Merit Factor	20	400	120

Performance for a 6 Dipole Ring





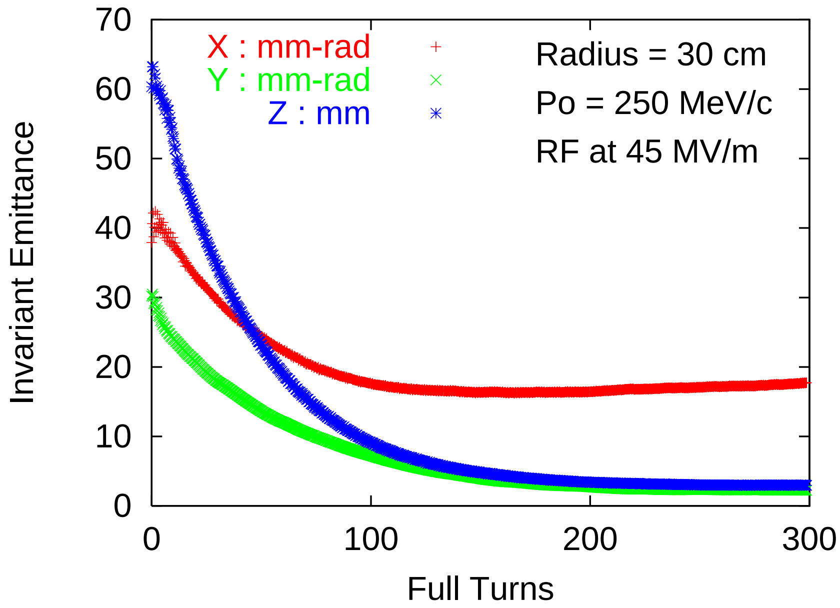
Key parameters at r = 30 cm

β_x = 26 to 36 cm ; β_y = 30 to 32 cm

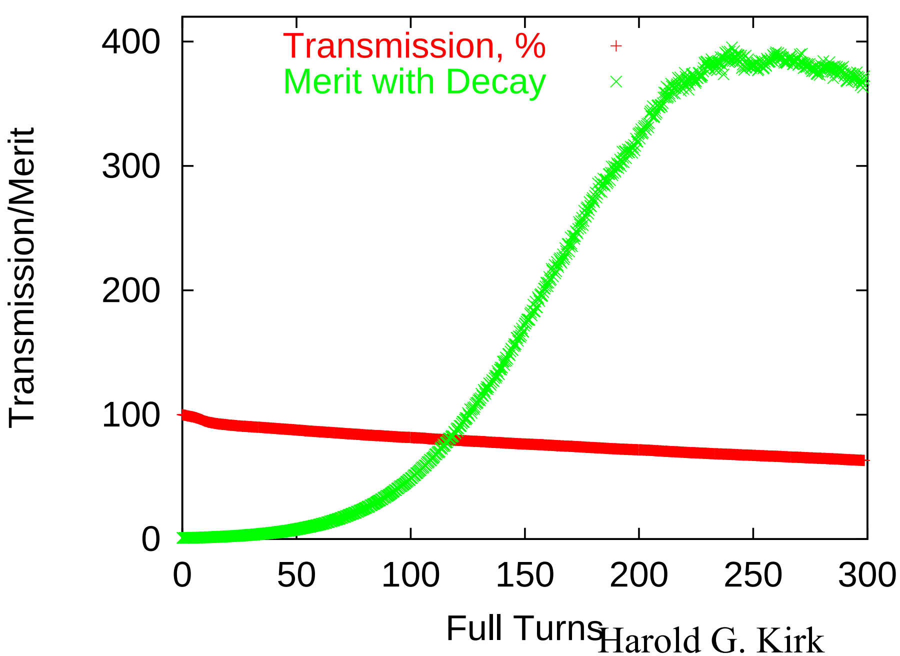
Dispersion = 30 to 32 cm

Circumference = 1.95 m

ICOOL Calculated Performance



- B = 5.2T
- Po = 250 MeV/c
- 100 Atmospheres H_2



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Oxford Mississippi Workshop

Design a demonstration tabletop device

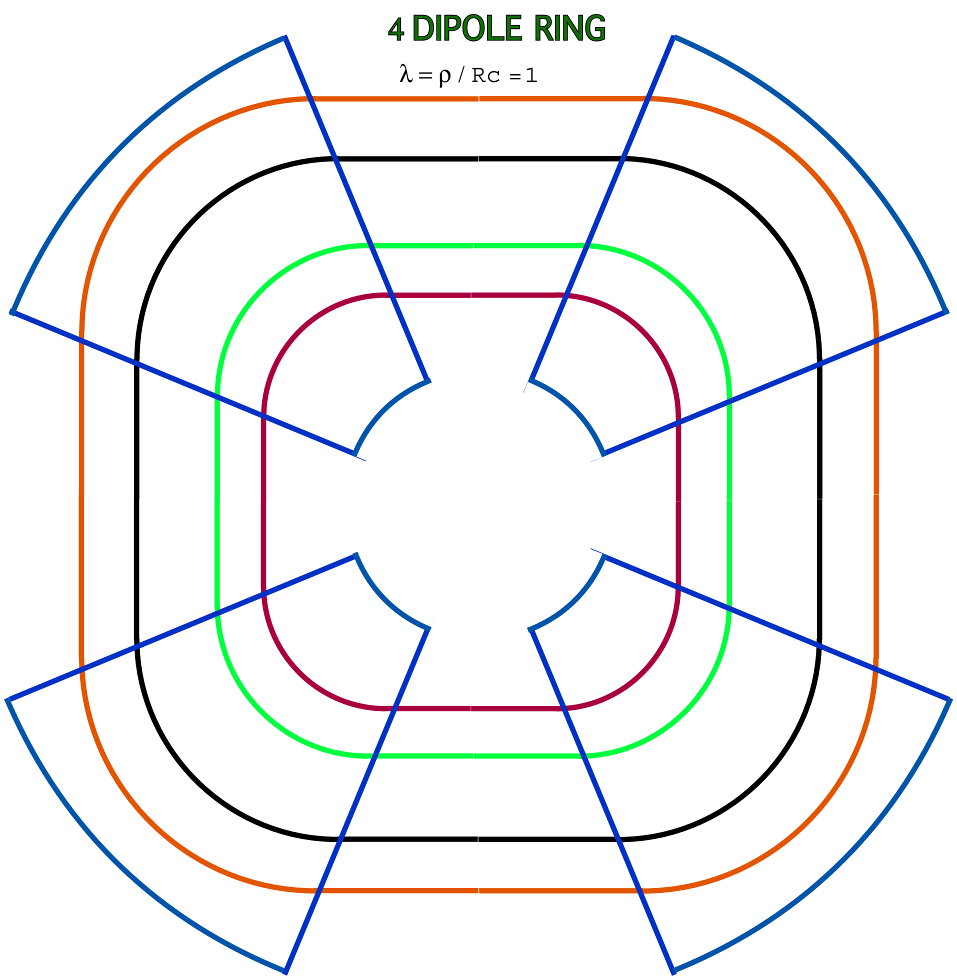
1) Weak Focusing ring with four/six dipoles.

2) Two/Four 201.25 MHz RF Cavities,
   Bore = +-20cm
   Thickness = 43 cm
   Diameter = 120cm

3) 1.8 Tesla DC dipoles with copper coils and iron return yokes
   Vanadium permendur pole faces allow 2.3 Tesla max.
   30 cm magnet gaps
   up to 6m beam circumference

4) 10 atmosphere hydrogen at 77K

1.8T Dipoles and 200 MHz Closed Orbits

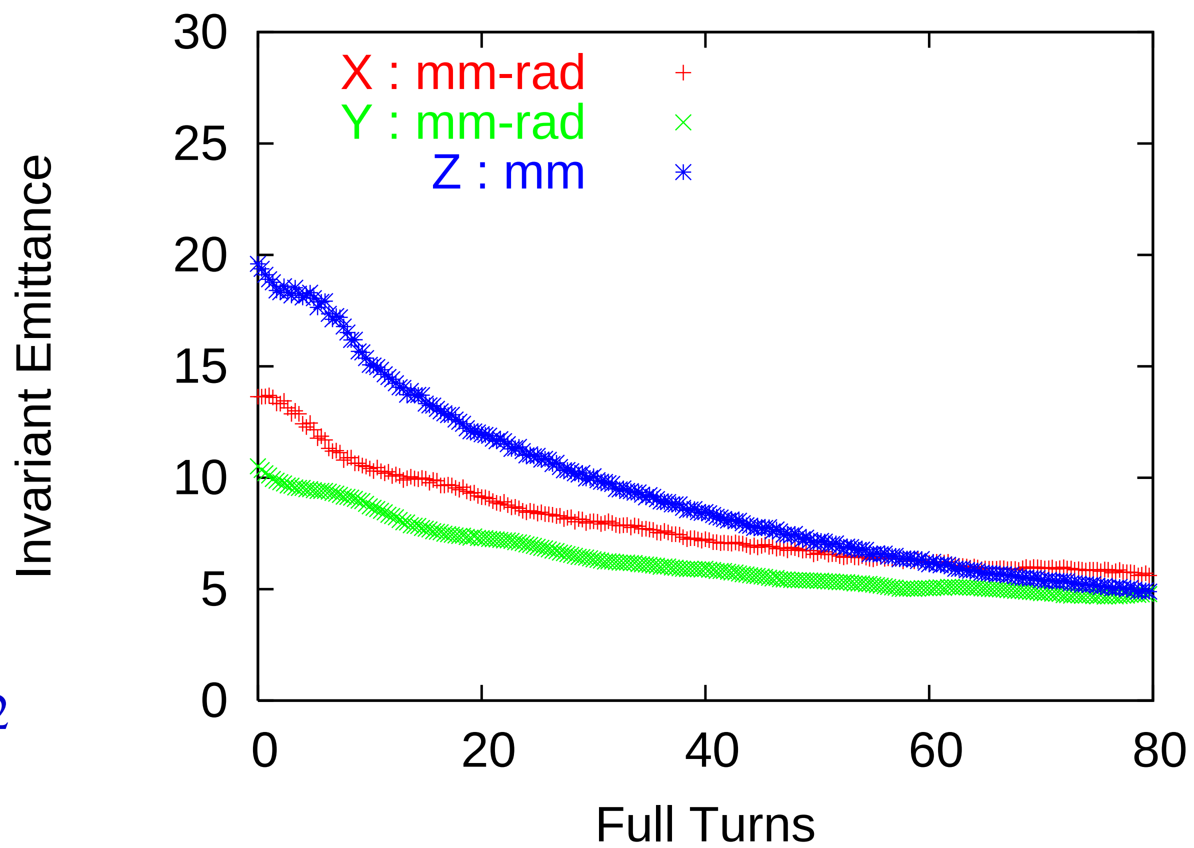


Fix the closed orbits such that the total path length is a harmonic of 200 MHz.

Then:

- Harmonic 2
  - Circumference = 1.76 m
  - P_0 = 77 MeV/c
- Harmonic 3
  - Circumference = 3.76 m
  - P_0 = 165 MeV/c
- Harmonic 4
  - Circumference = 5.45 m
  - P_0 = 240 MeV/c

4 Sector 1.8 T Dipoles



- Harmonic 3
- 40 Atmosphere H_2
- Total Merit

without decay is 20

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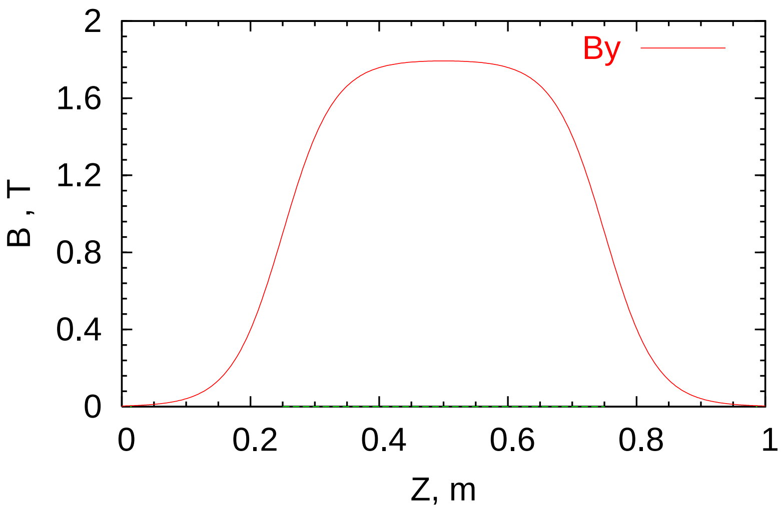
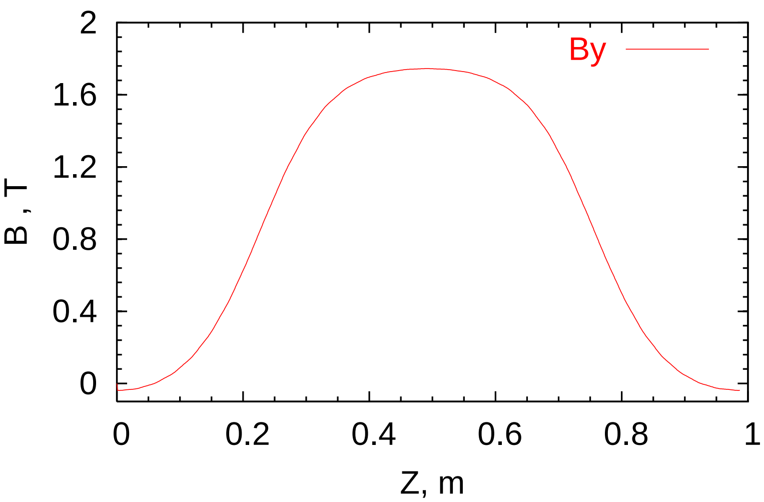
Soft Edge Dipoles

Palmer 4 Sector Dipole Ring



Kahn 4 Sector Dipole Ring

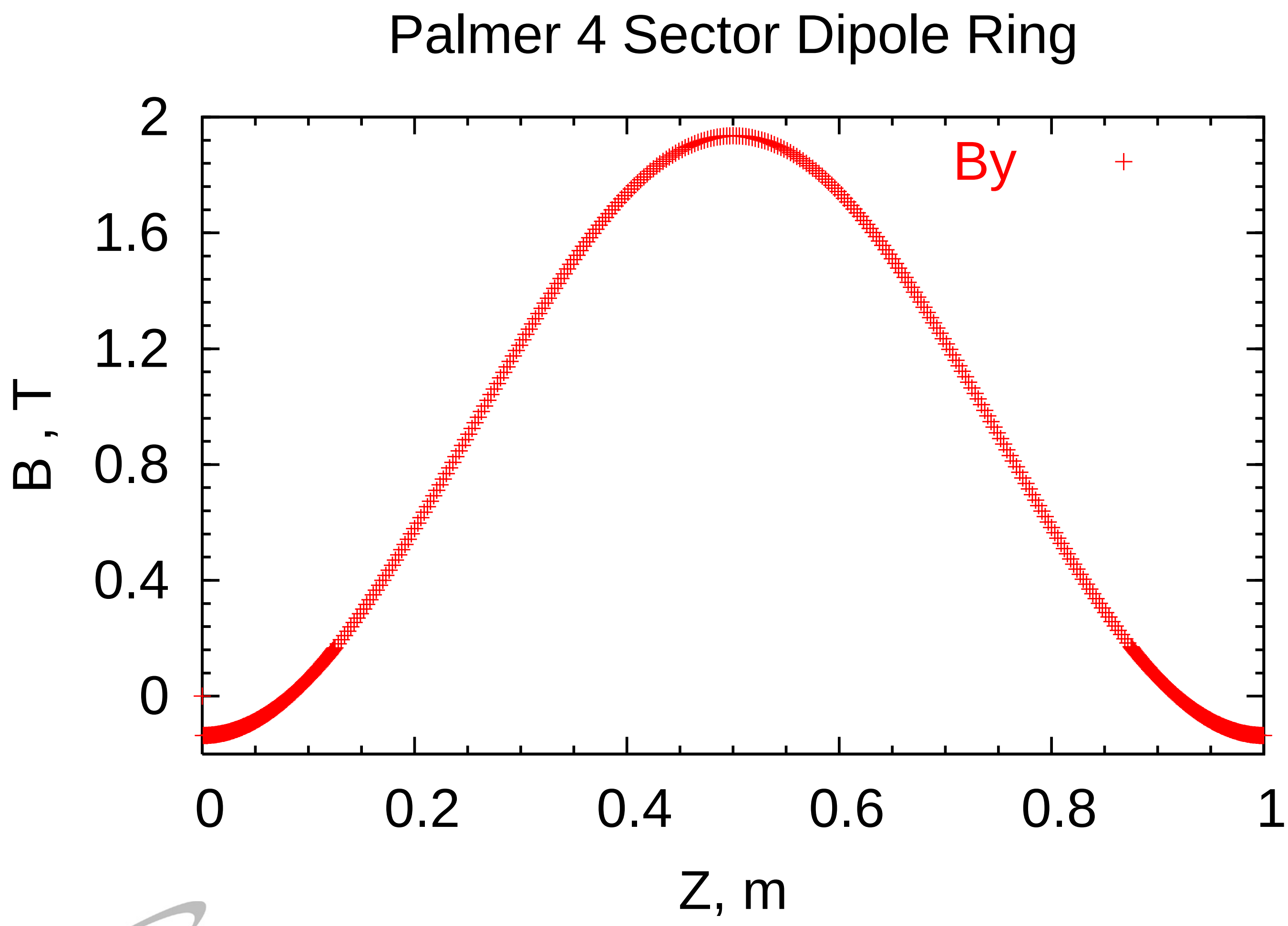


Obtaining the Magnetic field profiles

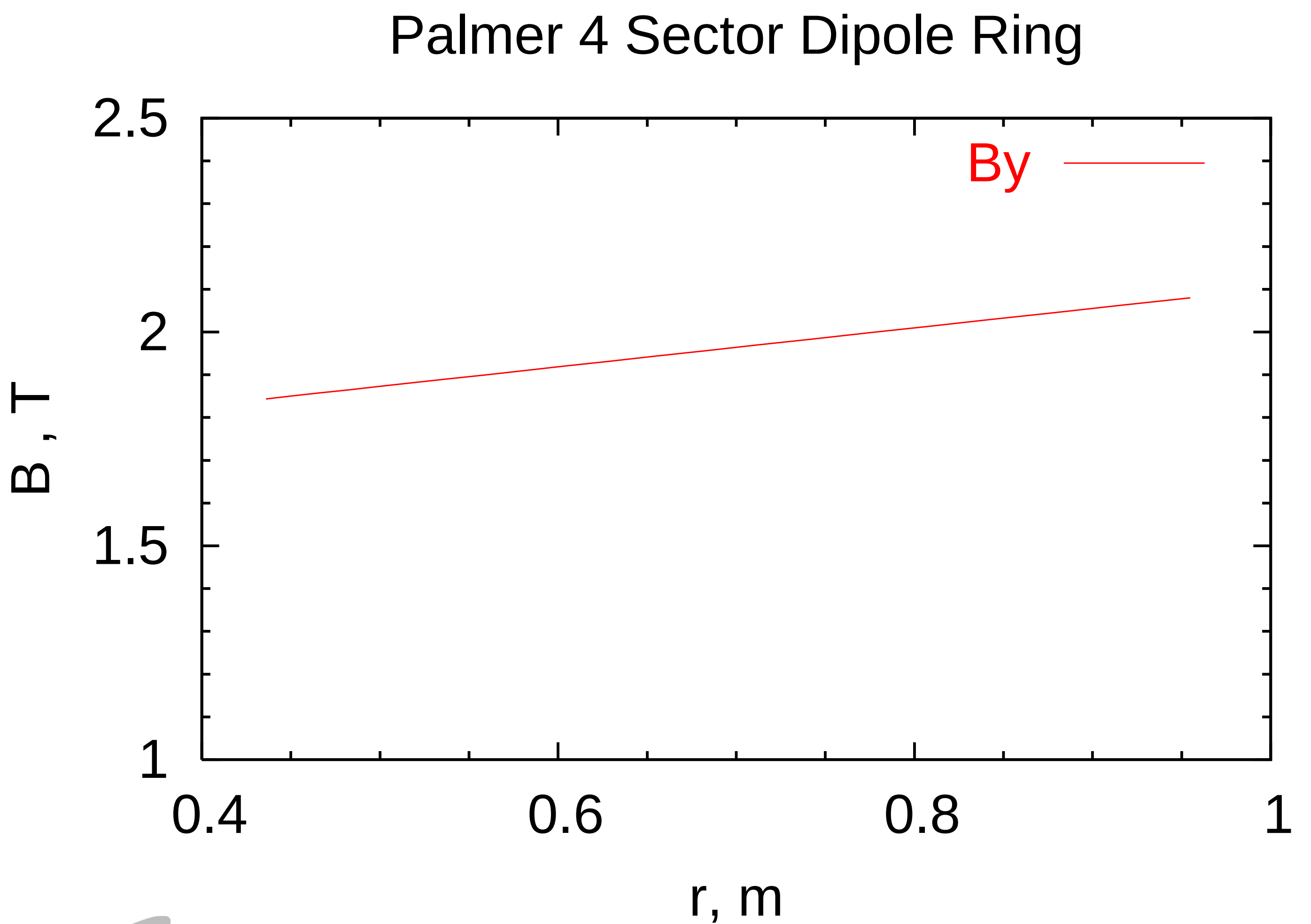
Palmer approach: Construct Maxwellian field with pure dipole and quadrupole components.

Kahn approach: Obtain field maps using TOSCA from current loops and iron. Evaluate harmonic content of field about a closed orbit.

Palmer New Soft-Edge Profile

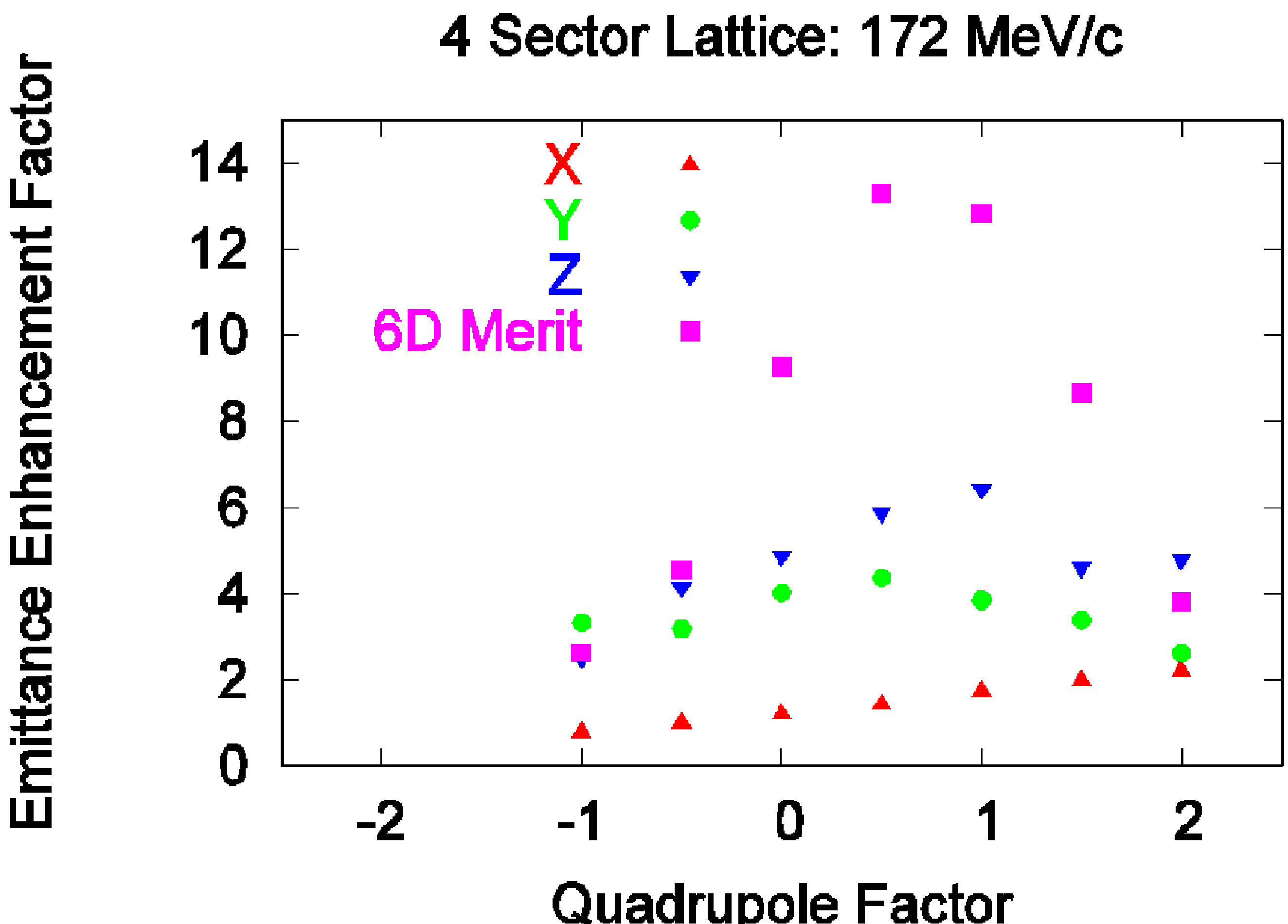


Palmer Model with Quadrupole

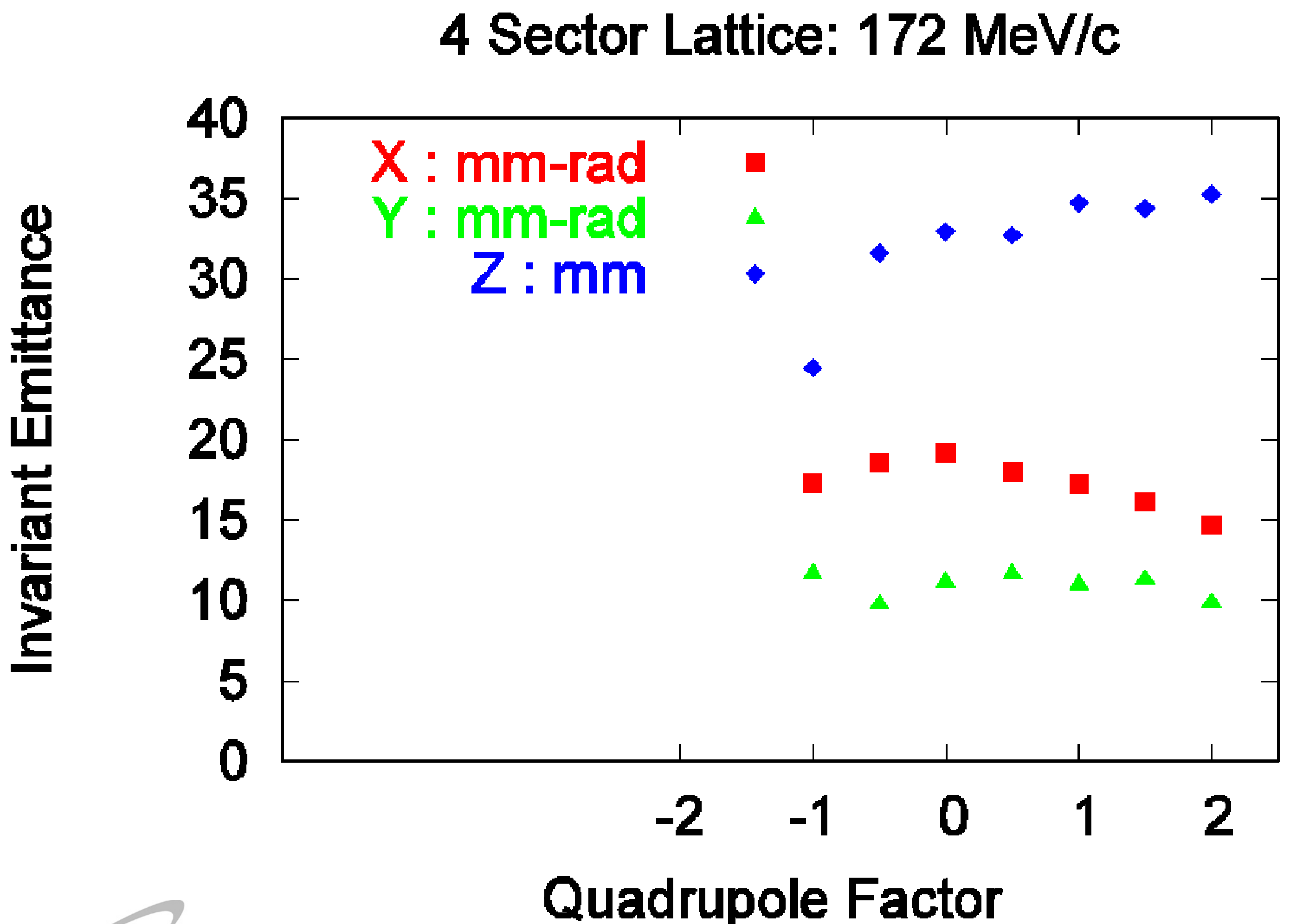


x=y=-1mm

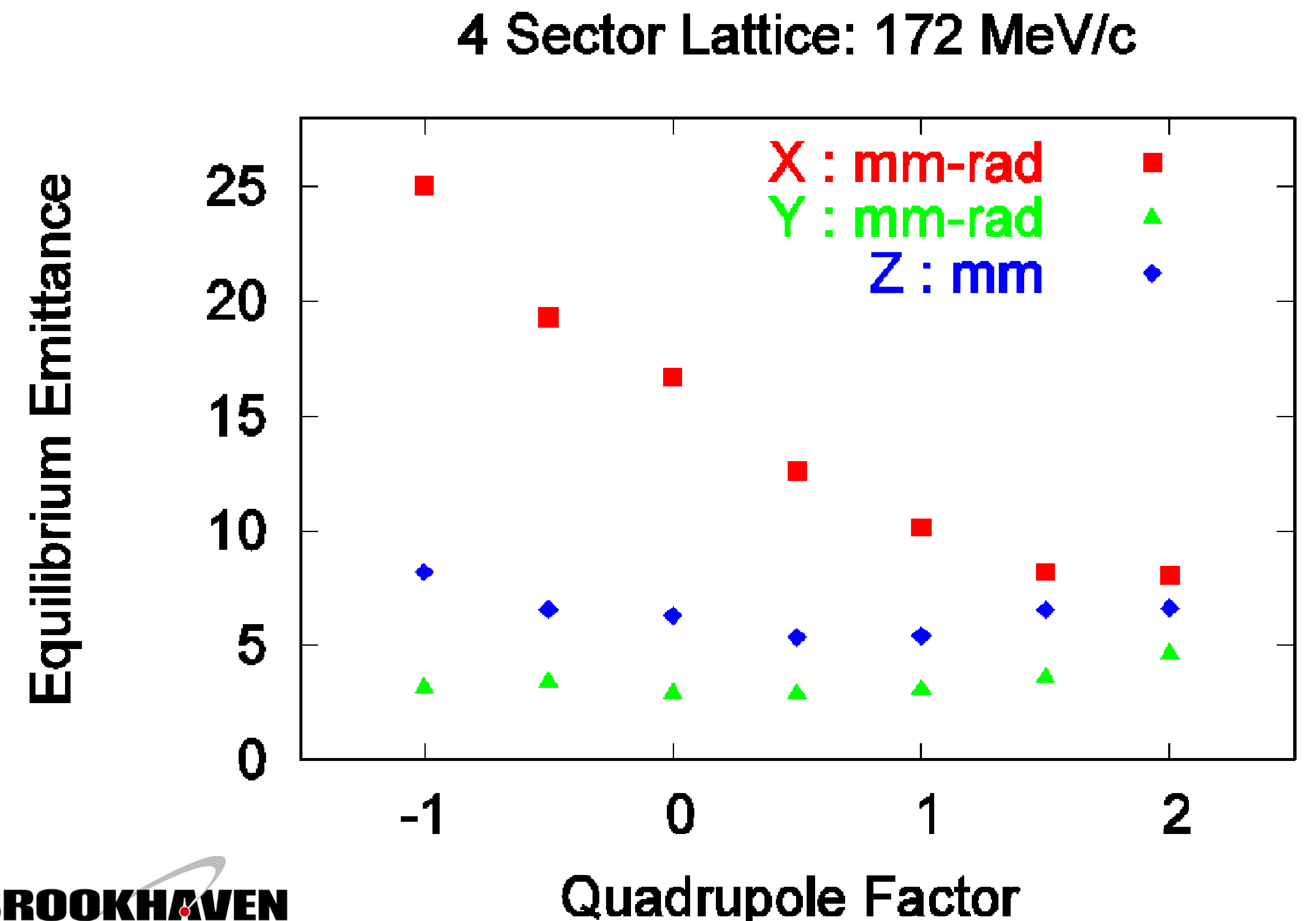
Palmer Soft-edge with Quadrupole



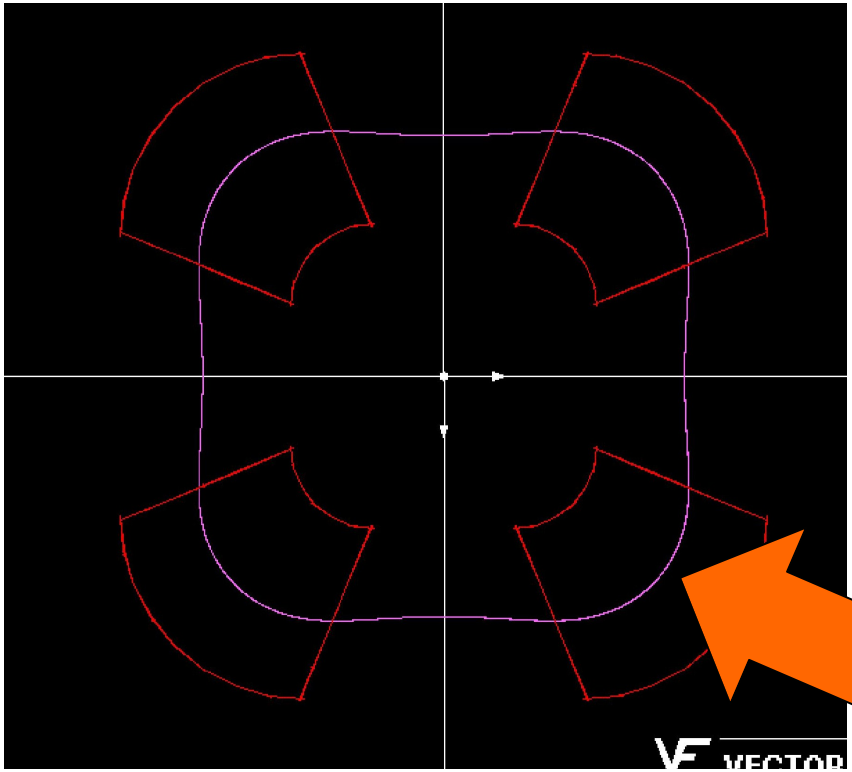
Palmer Admittance

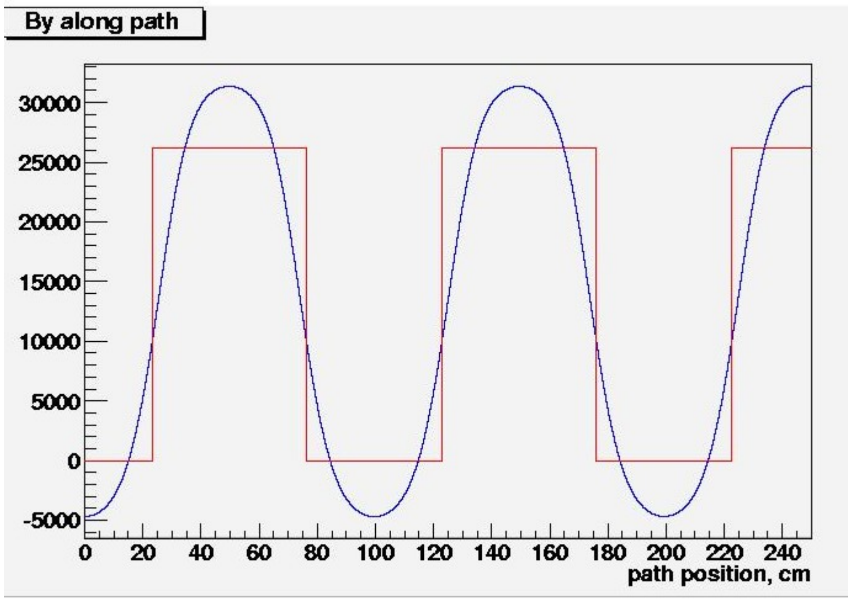


Palmer Equilibrium Emittance



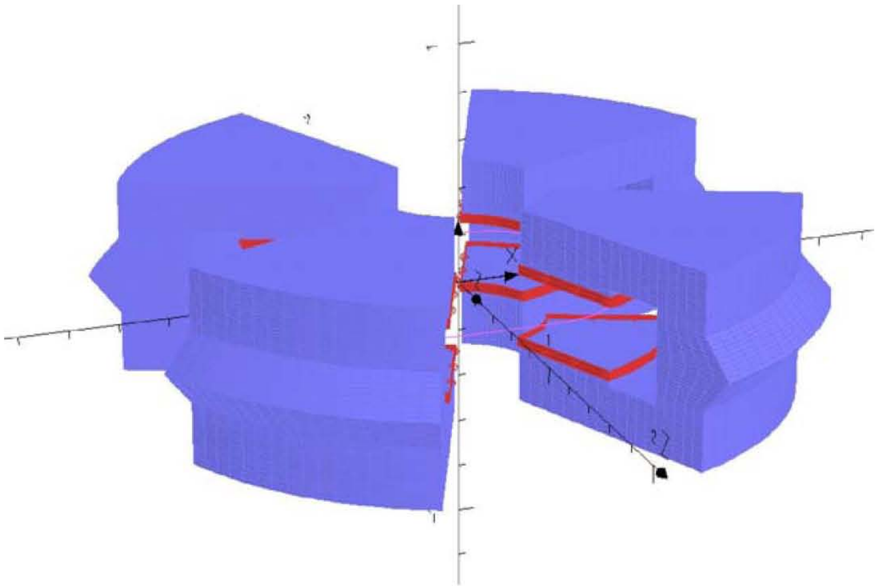
Tosca Results – Steve Kahn

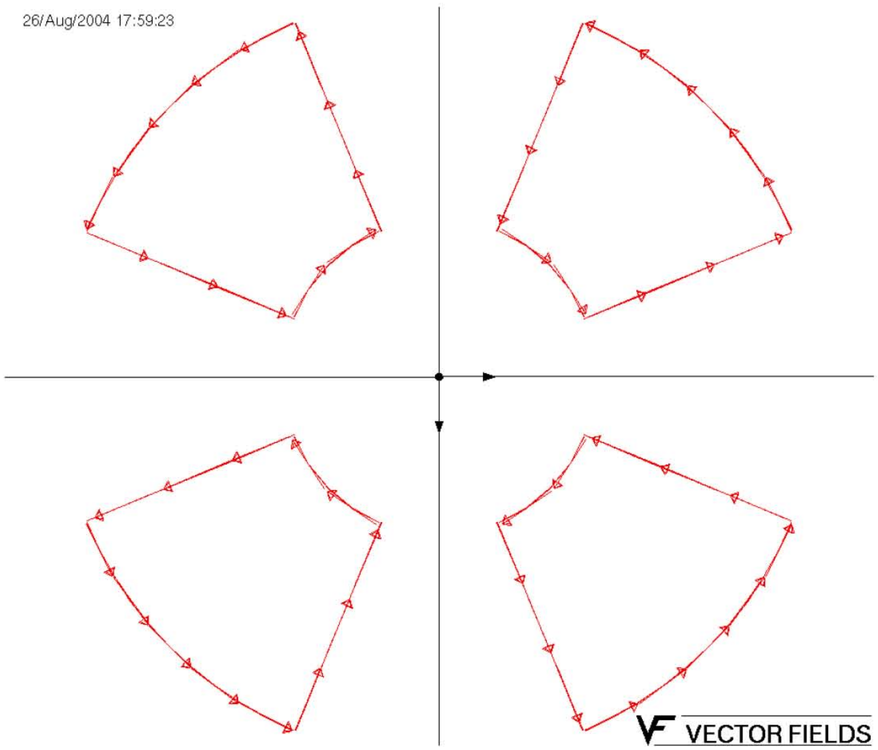




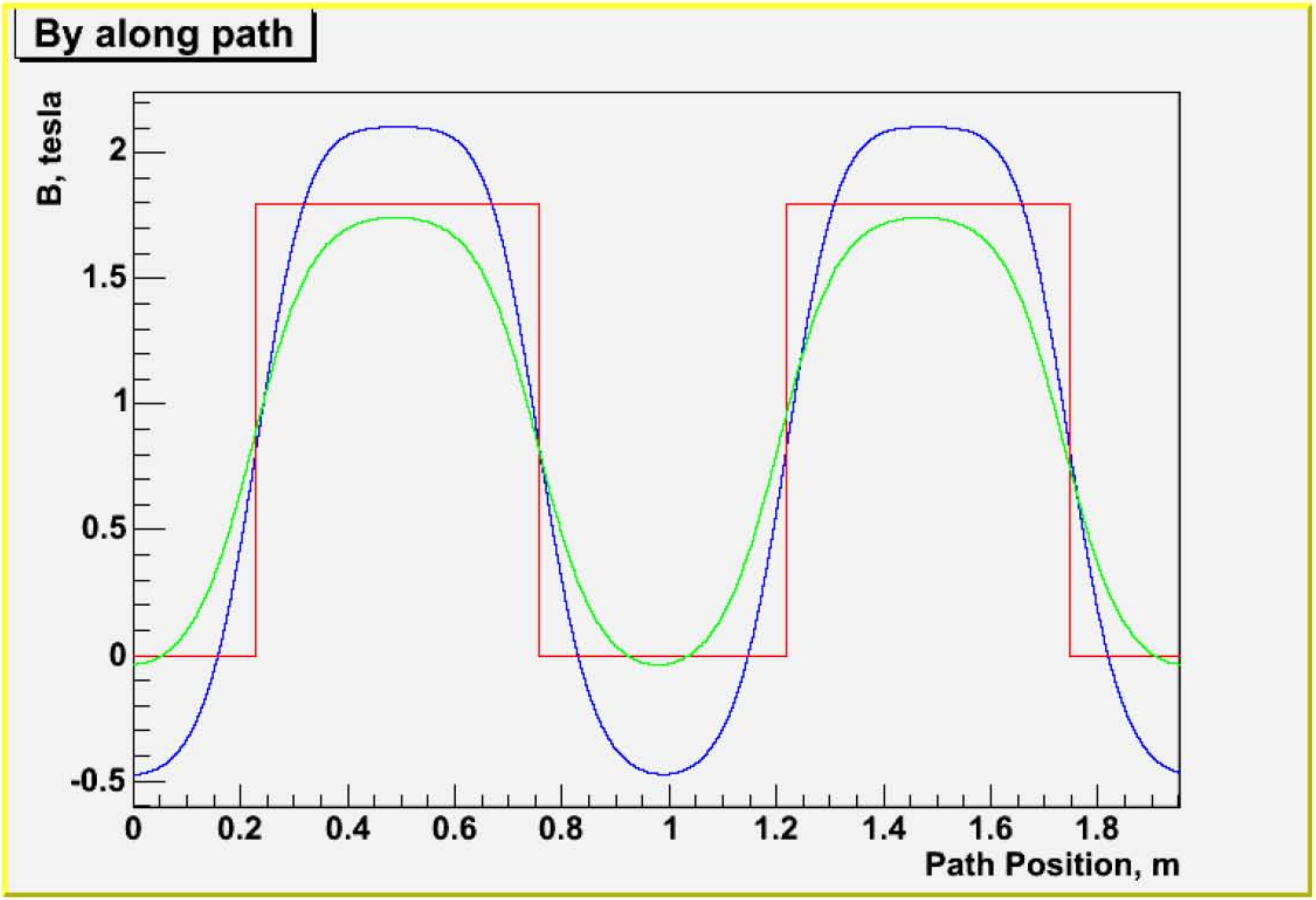
Closed orbit for
250 MeV/c muons
at r = 55.03cm

The Kahn I Ring





B_y for Kahn I – Iron vs No Iron



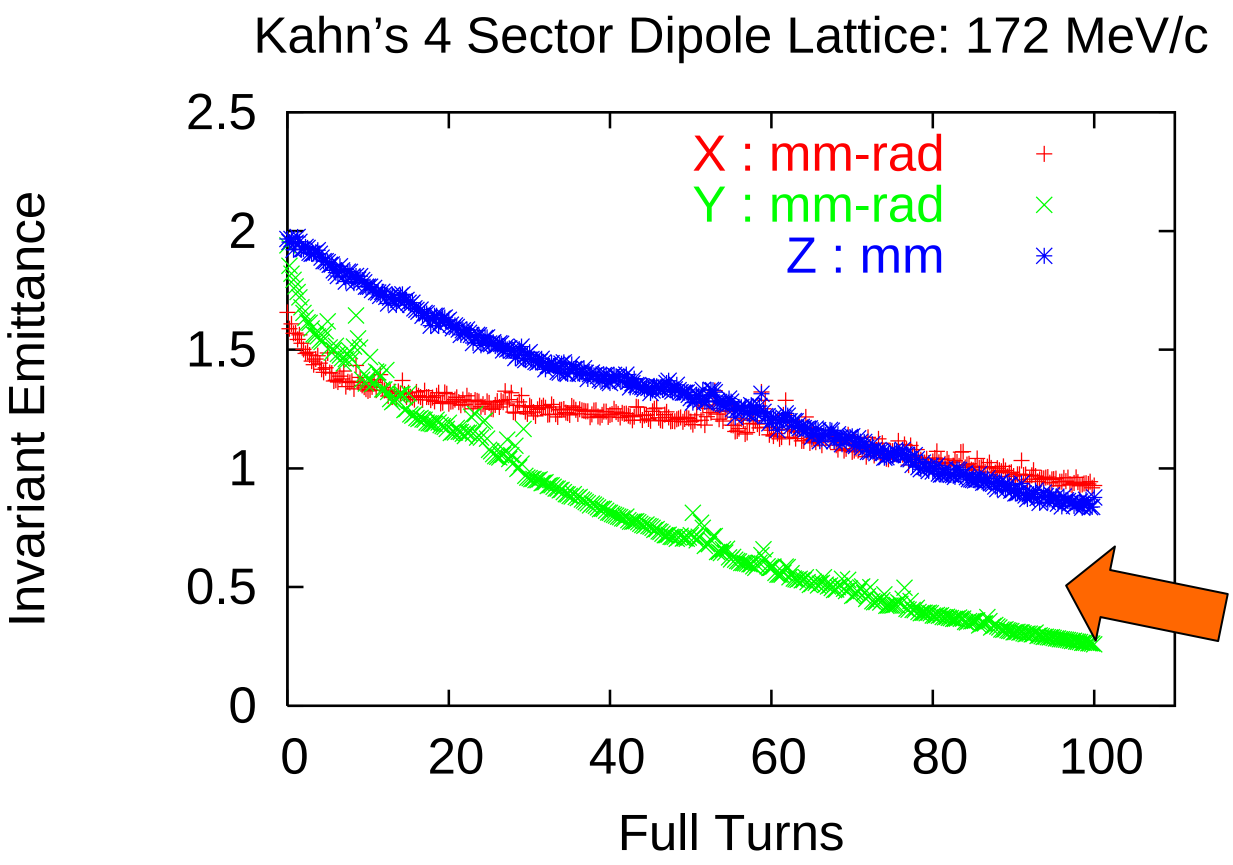
Coils only—No Iron

Coils plus Iron

Constant Hardedge Field

•Since coil only field has large negative field between the magnets, it must have larger field in the magnet to give the same integrated bend.

Performance of the Kahn I Model



Admittance

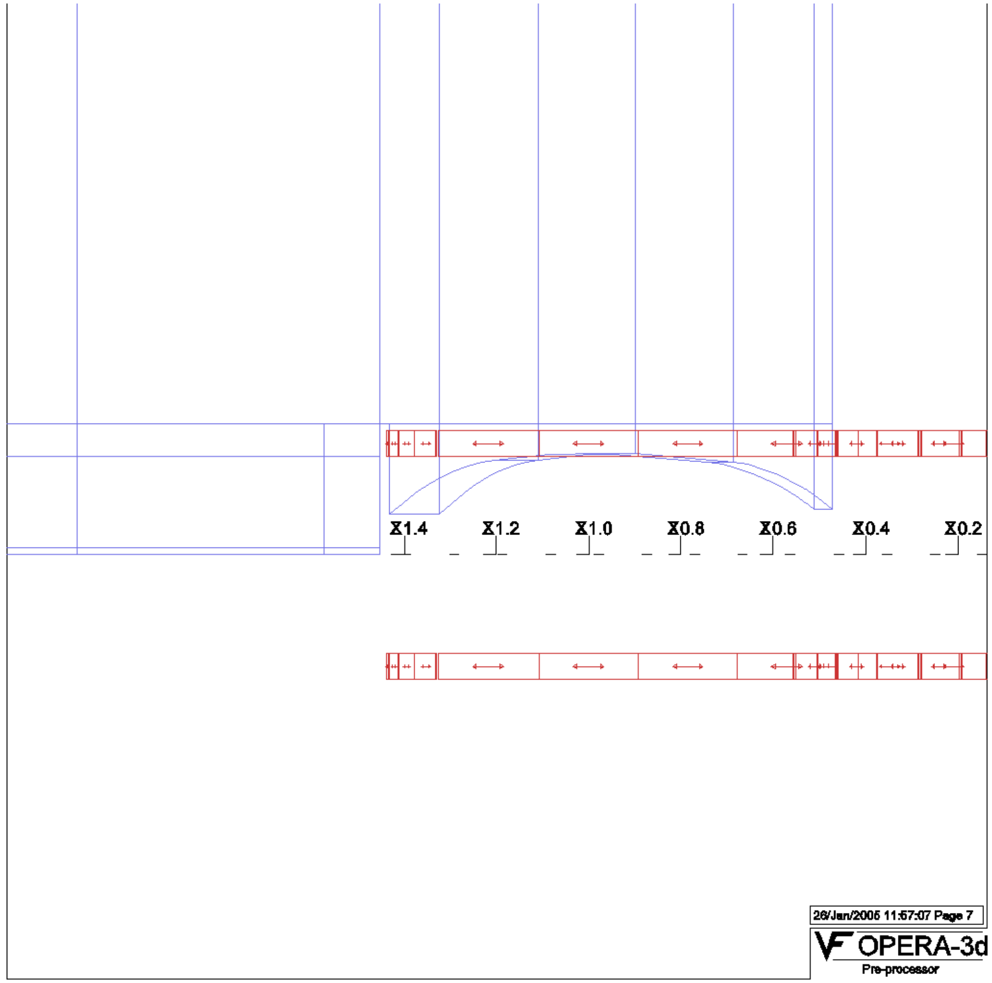
ε_x = 1.7 mm

ε_y = 1.9 mm

ε_z = 2.0 mm

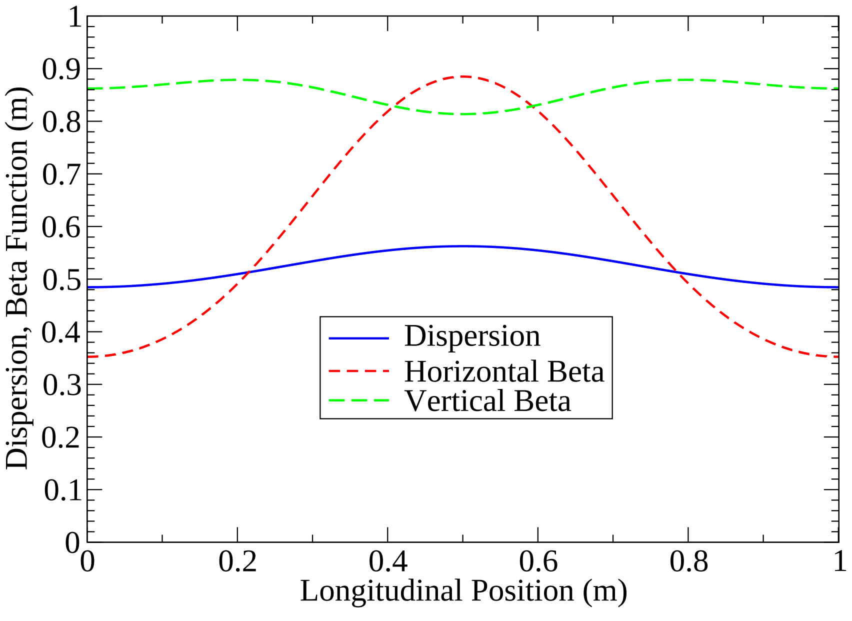
Note: No MC or Straggling

Kahn II Dipole Iron Profile

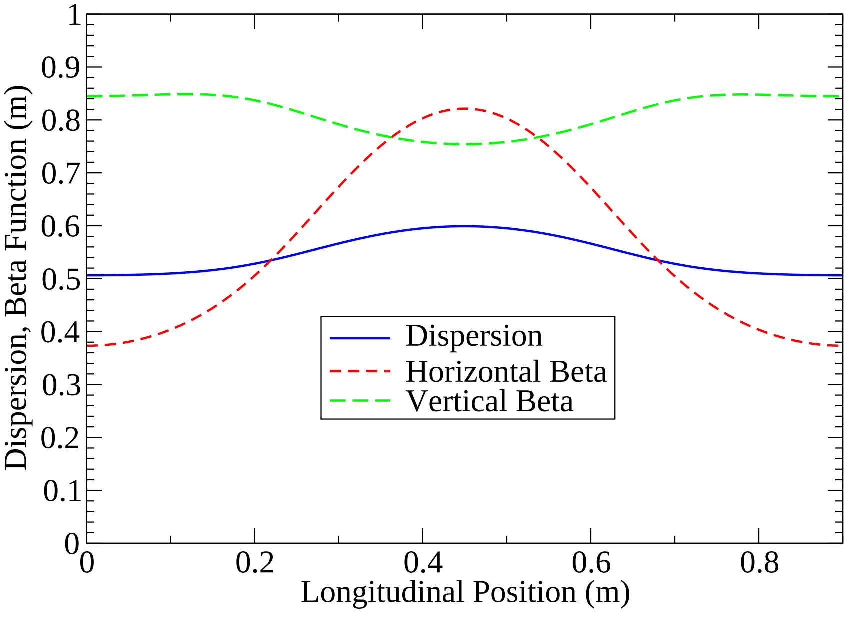


Lattice Parameters

Calculations by Scott Berg



Palmer Lattice with Quadrupole



Kahn II lattice with Iron

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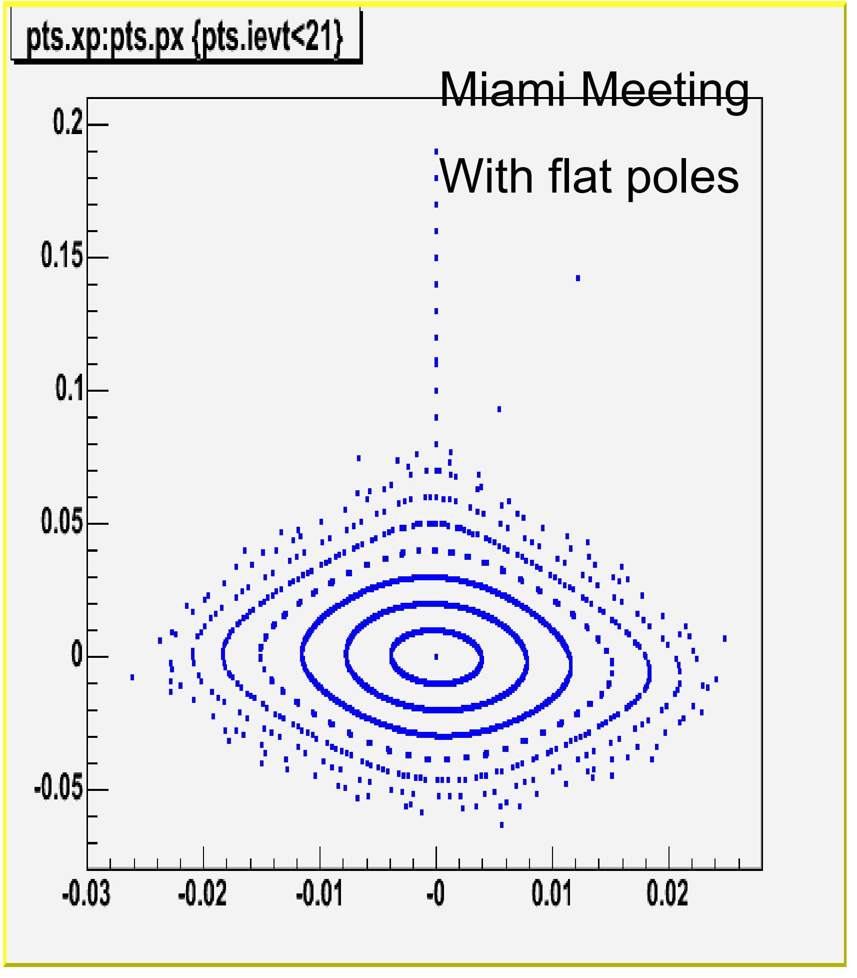
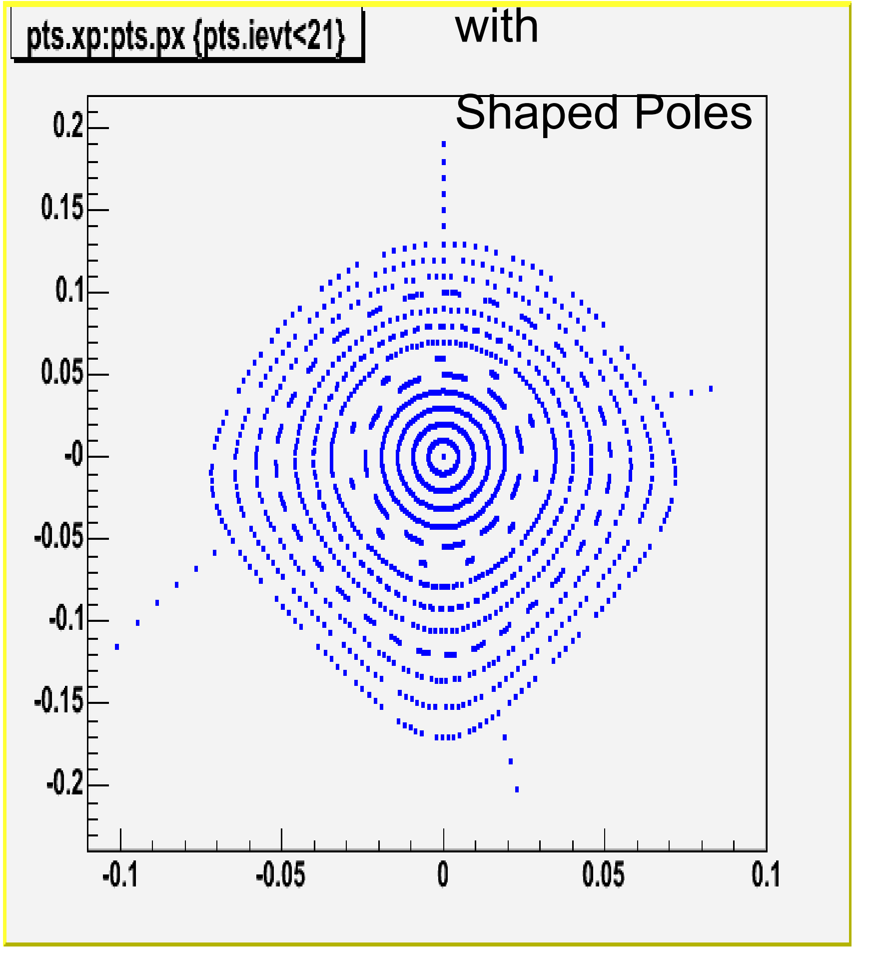
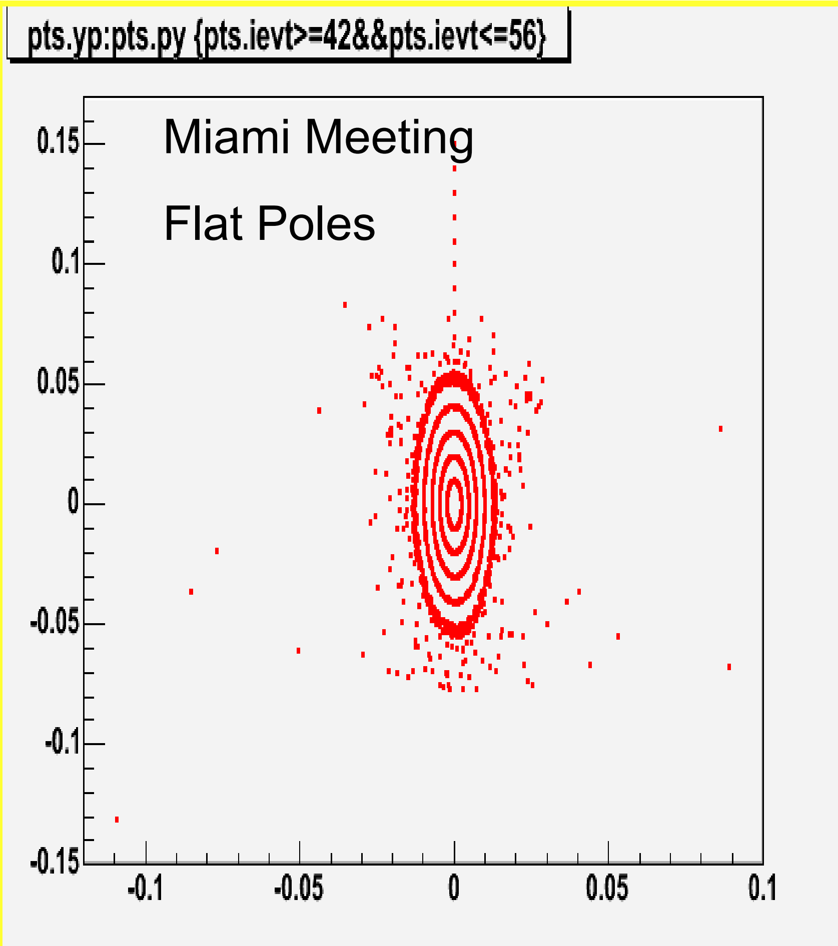
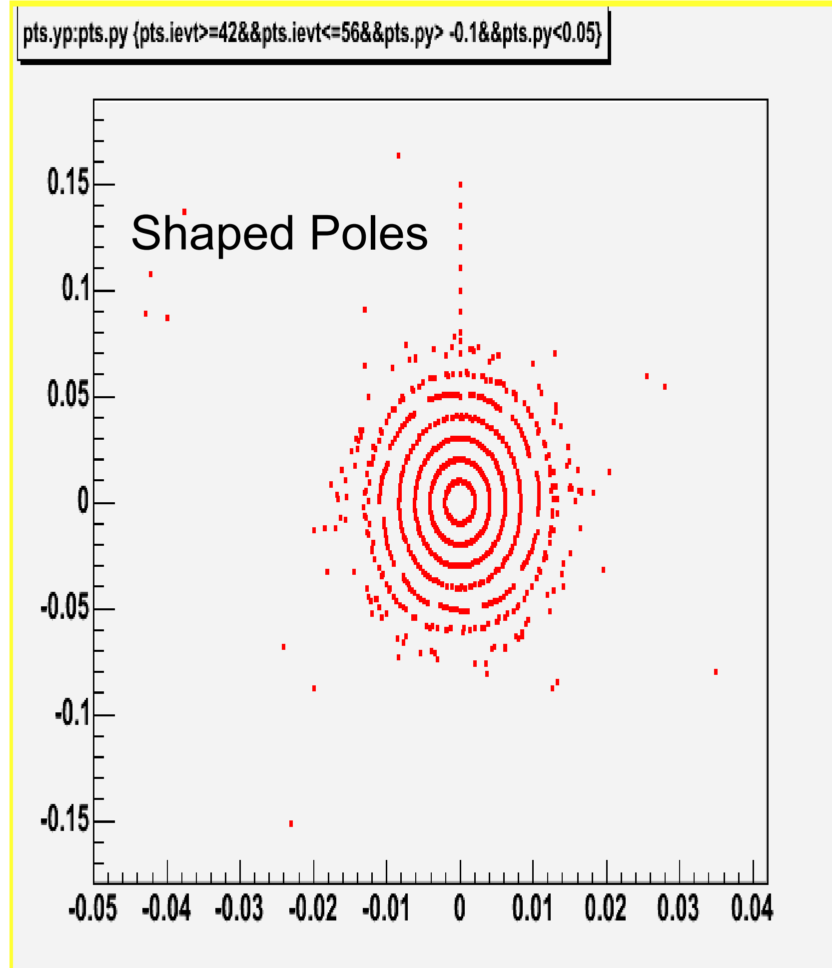
X Px Phase Space Aperture





Y Py Plase Space Aperture





Kahn II Magnet Profile Results

	Admittance	Equilibrium
εx =	17.2 mm	5.8 mm
εy =	3.5 mm	2.1 mm
εz =	18.0 mm	5.0 mm

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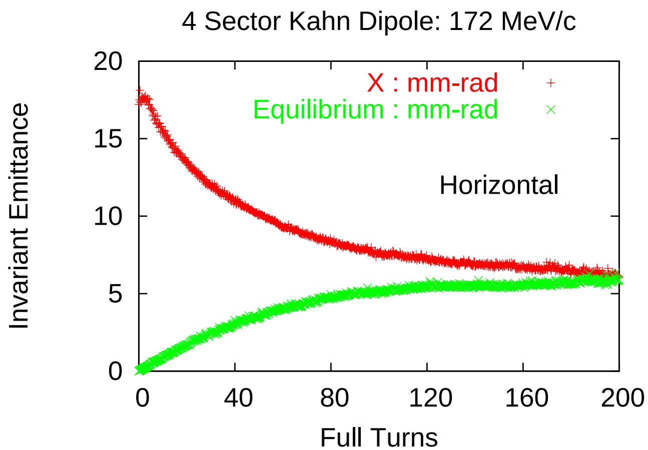
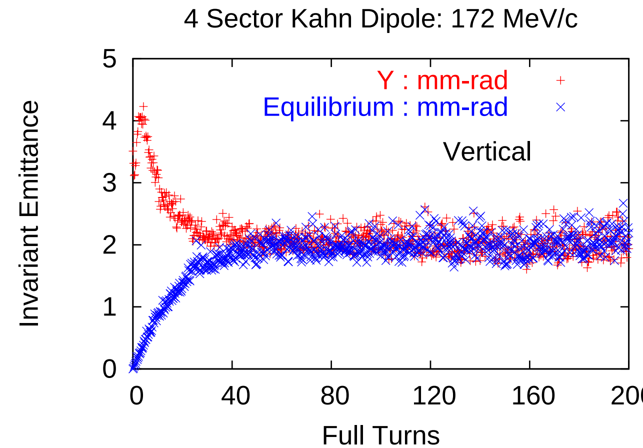
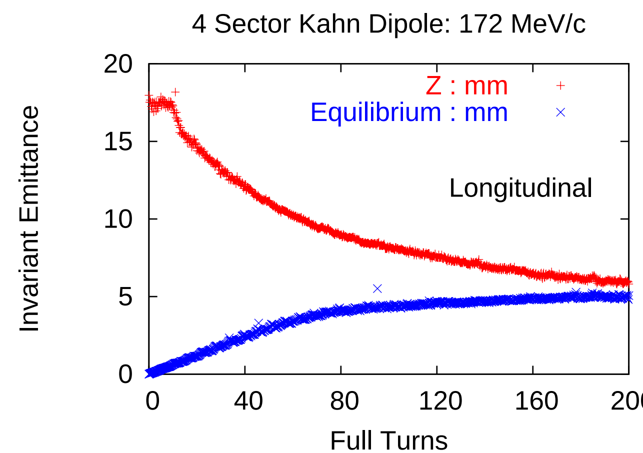
Cooling in each dimension







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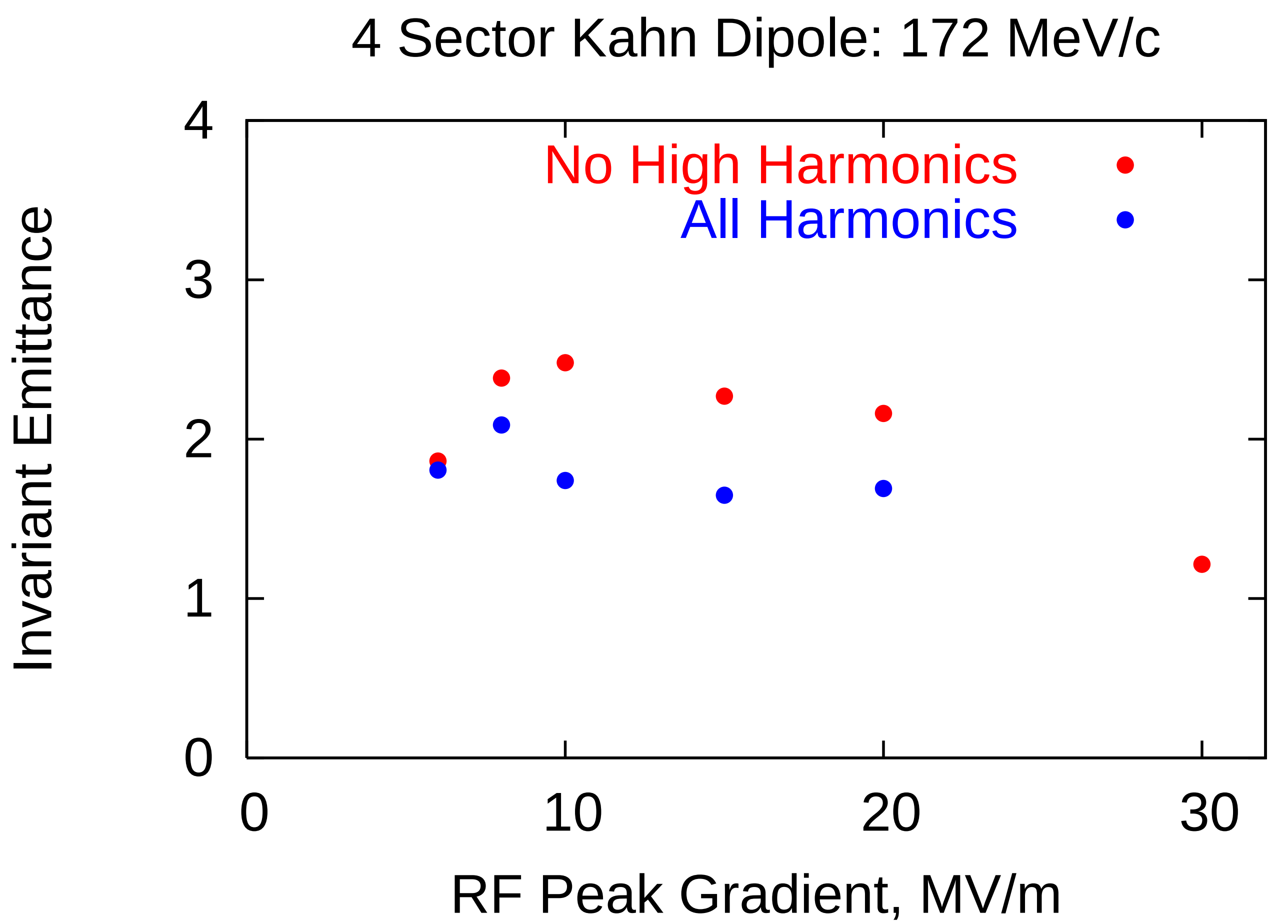
Kahn II Performance



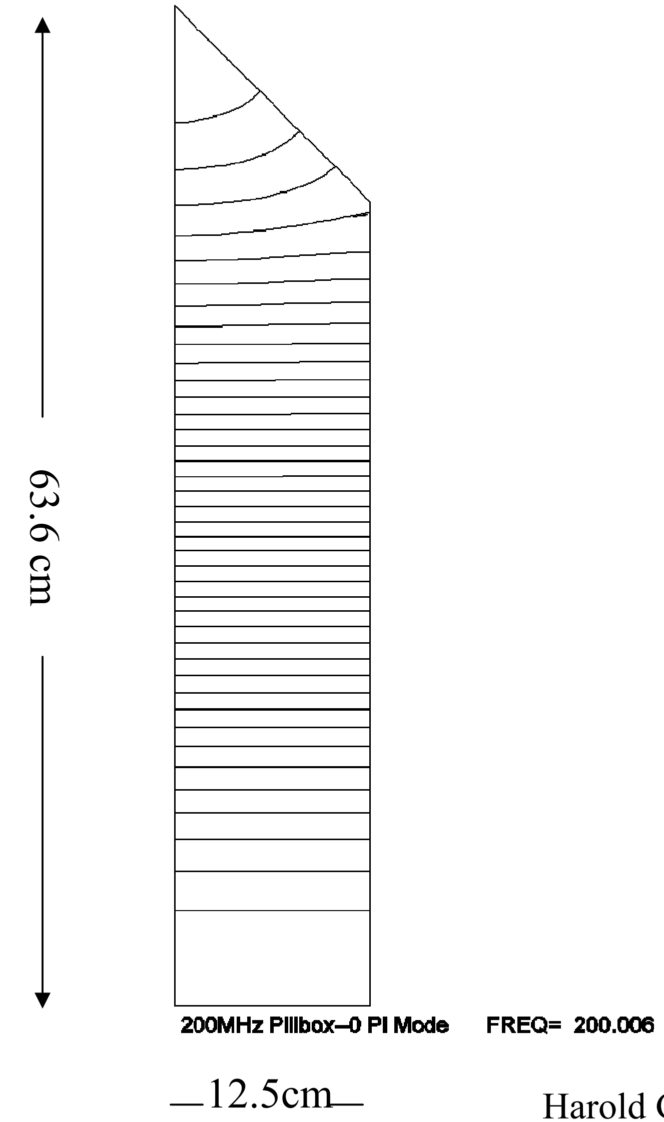
200 MHz RF Cavities

Power Requirements
(For 10 MV solution)

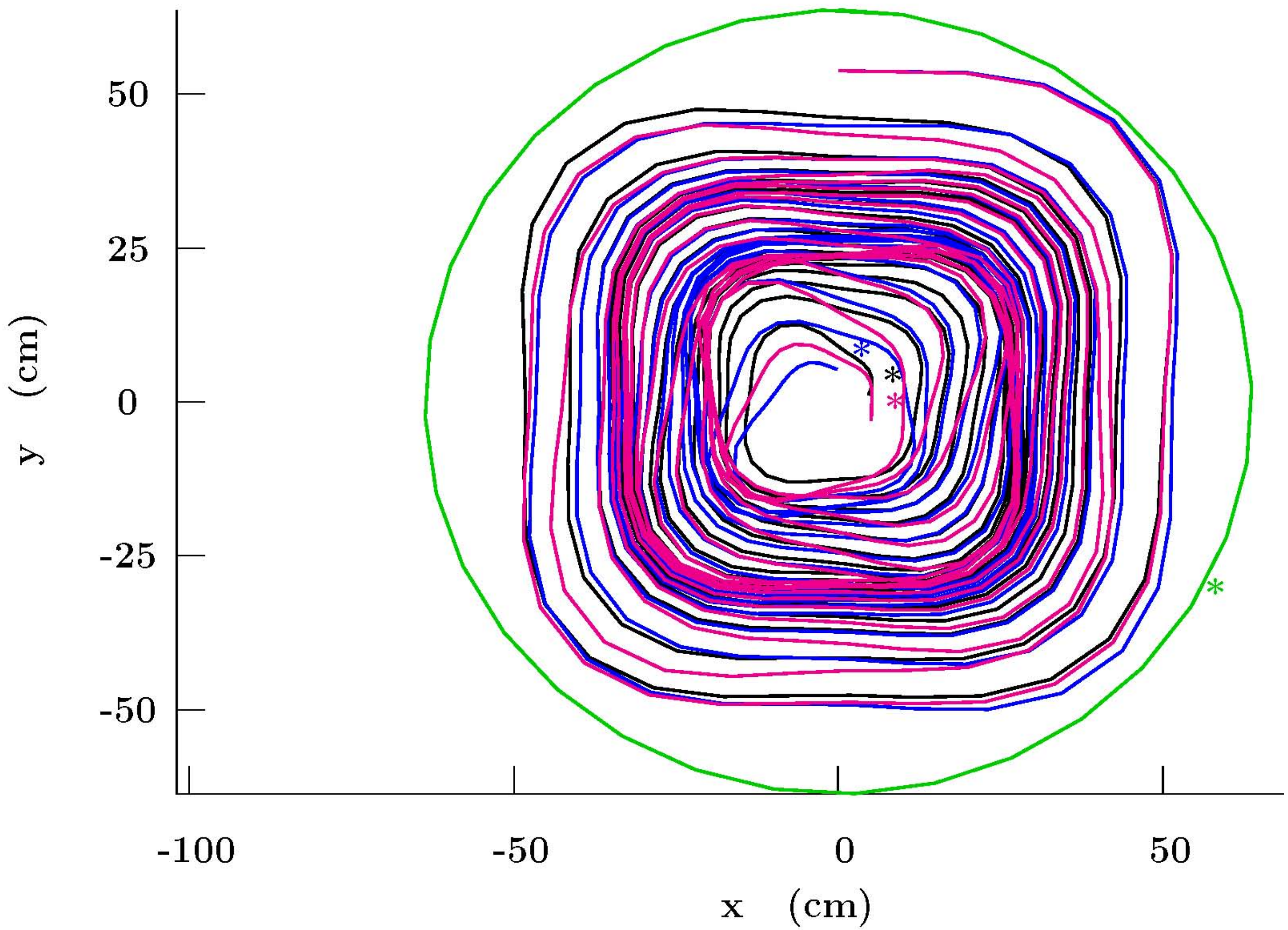
For room temperature single cavity
→ 2.4 MW

For four cavities → 9.8 MW

Expect a factor of ~ 2 enhancement for operations at LN_2 operations



Don Summer Proposal-No RF



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Scheme for dE/dx Injection

Single Turn Energy Loss Injection

Four Magnet (1.8T) Sector Cyclotron

Soft edged fields, ICOOL simulation.

Multiple scattering and straggling on

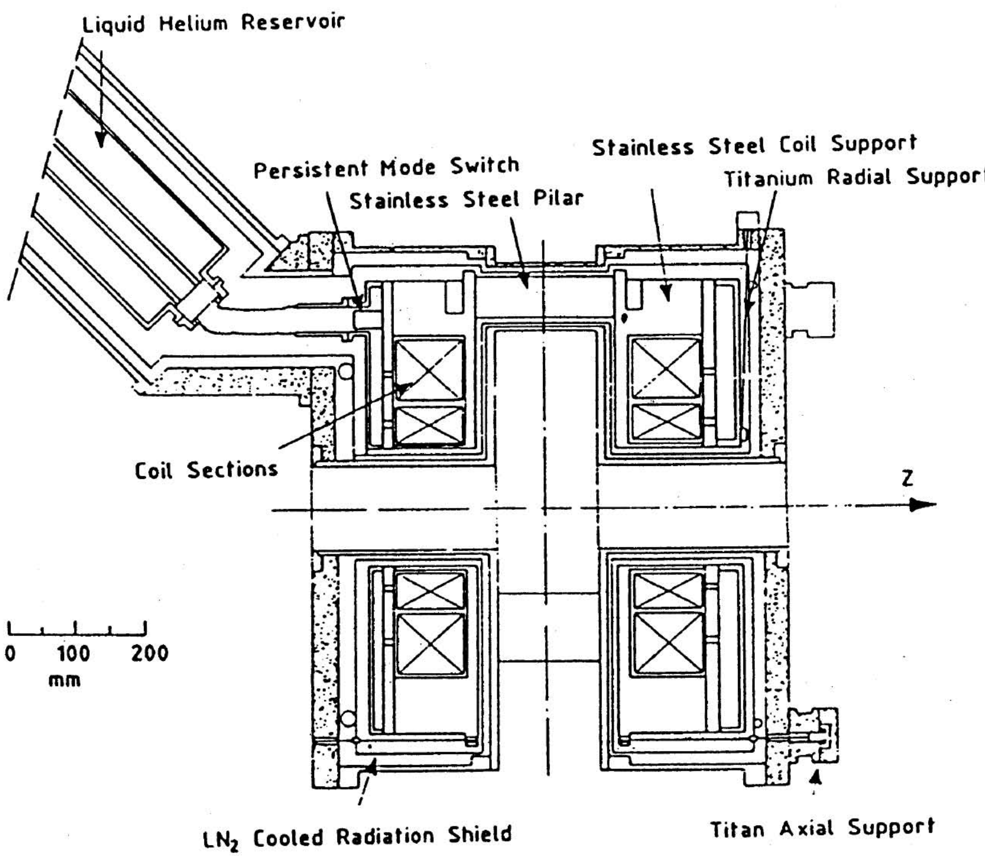
Radial LiH wedges surrouded by hydrogen

Matter decreases adiabatically with radius

3 identical 172 MeV/c muons are injected

The Lear Anti-Proton Collector

Anti–cyclotron, NIM A278 (1989) 368



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Project Status

- Work supported by a $100K SBIR phase I grant
- SBIR phase II proposal in preparation
  - Detailed engineering of ring
  - Construct and measure one magnet
- Explore possibility of creating source of stopped muons
- Explore possibility of forming bunched muons from a long train
- Non-engineered total cost estimate ~$5M