Progress in Dipole 6D cooling Rings

Collaboration Meeting
Riverside, Ca.
January 27, 2004

With significant input from: H. Kirk, A. Garren, and S. Kahn

Harold G. Kirk
Brookhaven National Laboratory

Global Parameters Used

Gas Density 100 atmospheres except where noted

Vertical Aperture +/- 15 cm

Horizontal Aperture +/- 25 cm

Gas filled RF cavities

RF frequency 201.25 MHz

Hard edge magnetic fields

Except where noted ICOOL V2.66

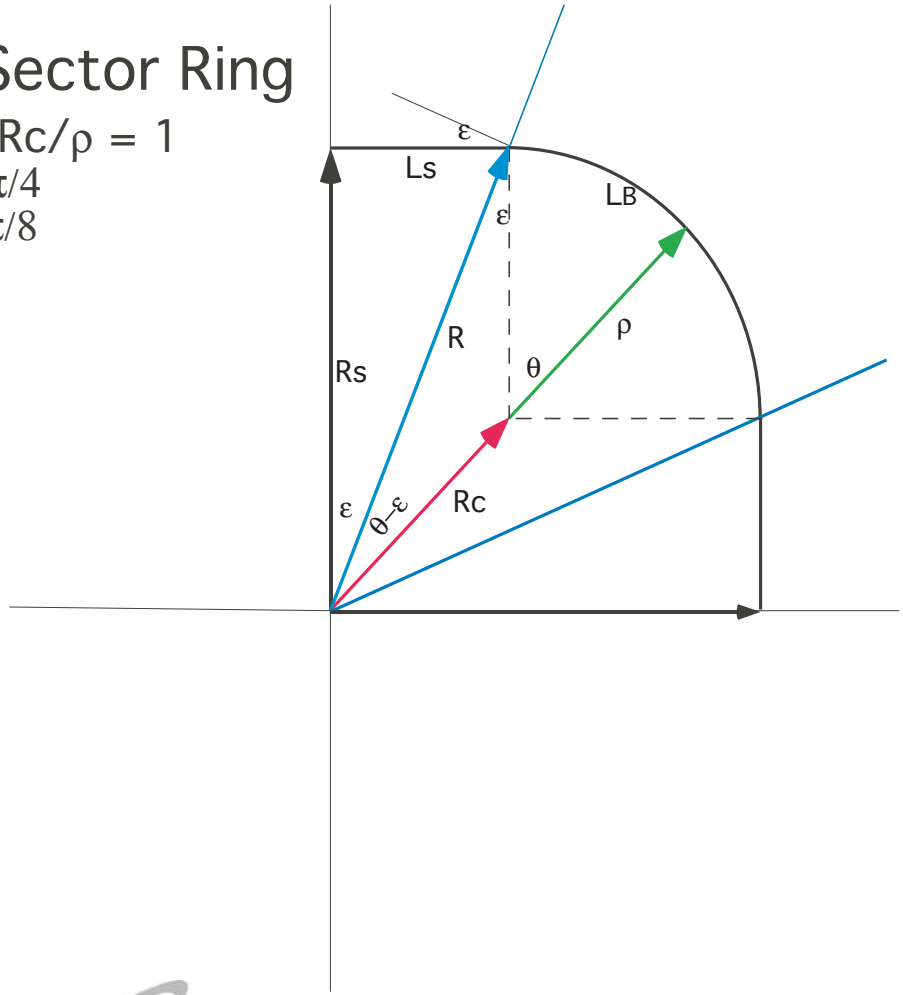
The Weak-focusing Rings

4–Sector Ring

$\lambda = Rc/\rho = 1$

$\theta = \pi/4$

$\varepsilon = \pi/8$



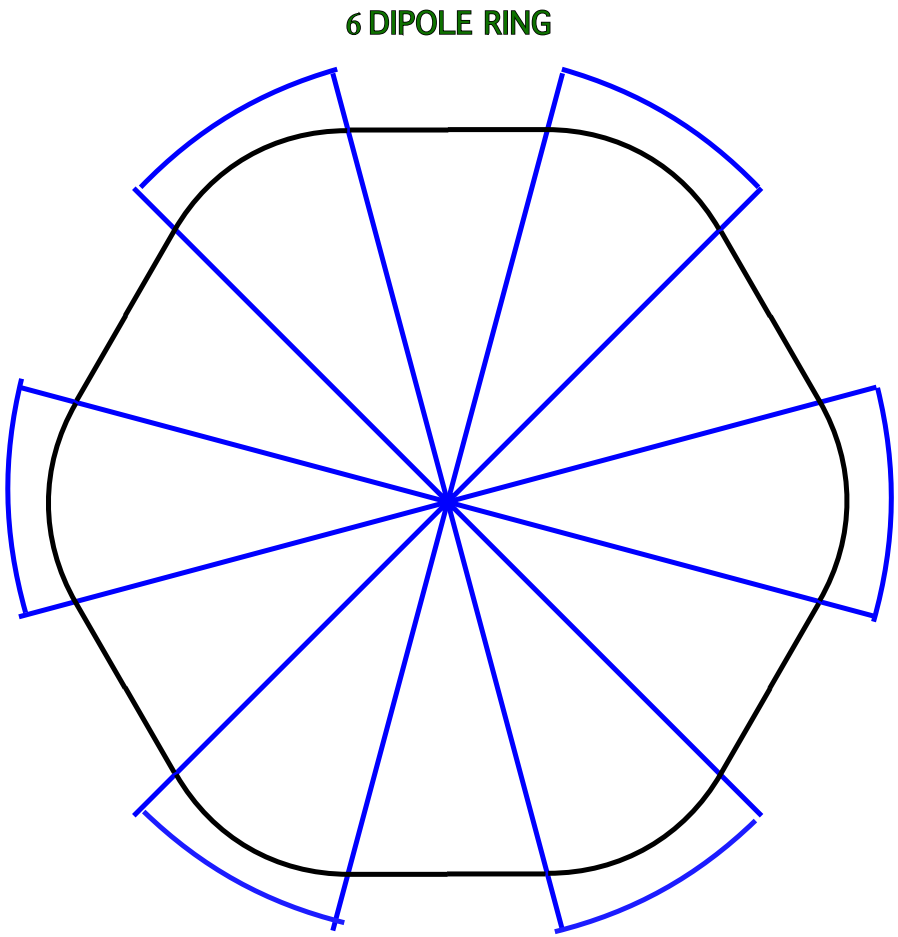
Lattices examined:

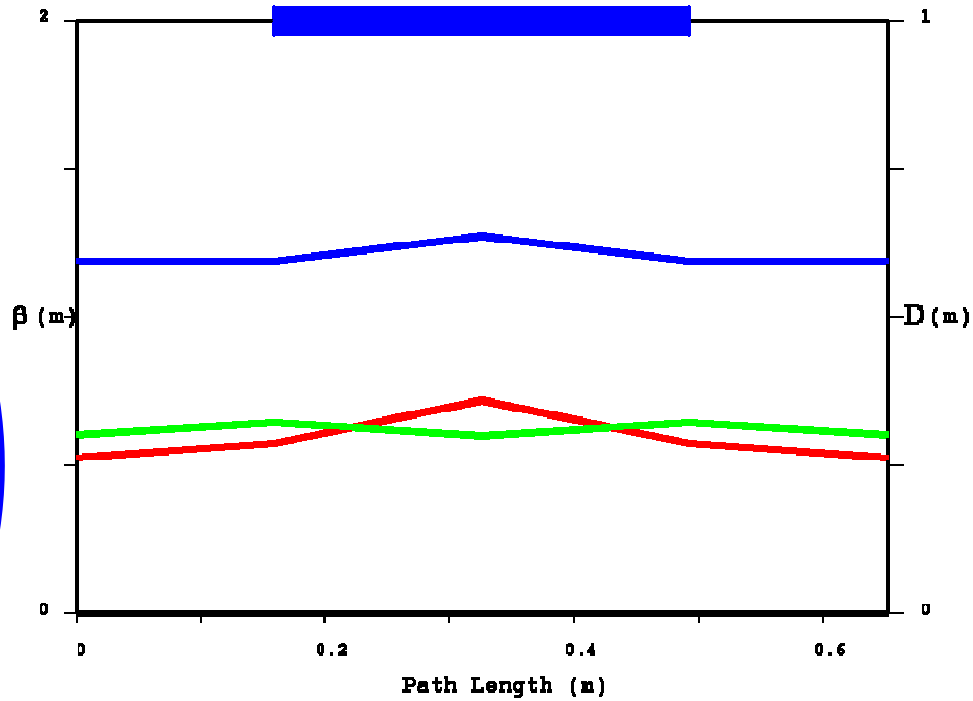
4 sector ring, $\lambda = 1$

4 sector ring, $\lambda = 3/4$

6 sector ring, $\lambda = 1$

Gas Filled Dipole Wedge Rings





Key parameters at r = 60 cm

β_x = 53 to 72 cm ; β_y = 60 to 64 cm

Dispersion = 60 to 64 cm

Circumference = 3.91 m

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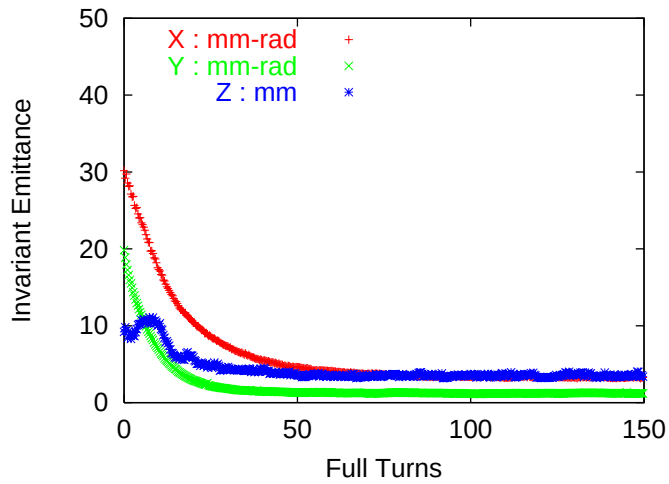
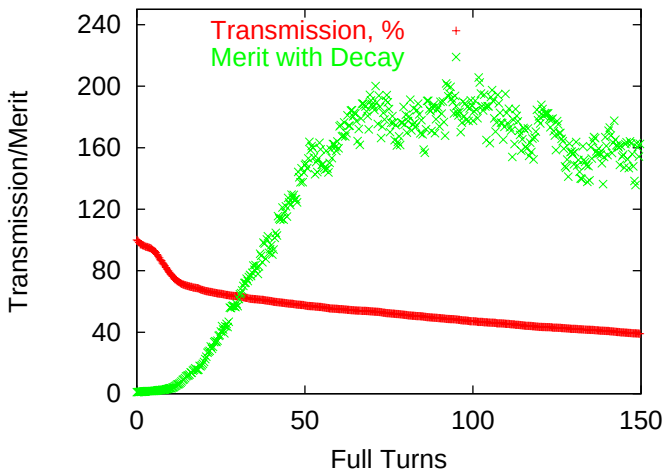
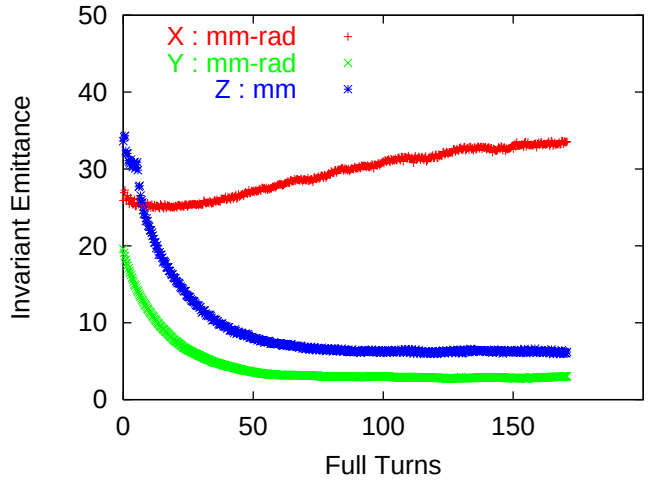
Recalculation with ICOOL V2.66

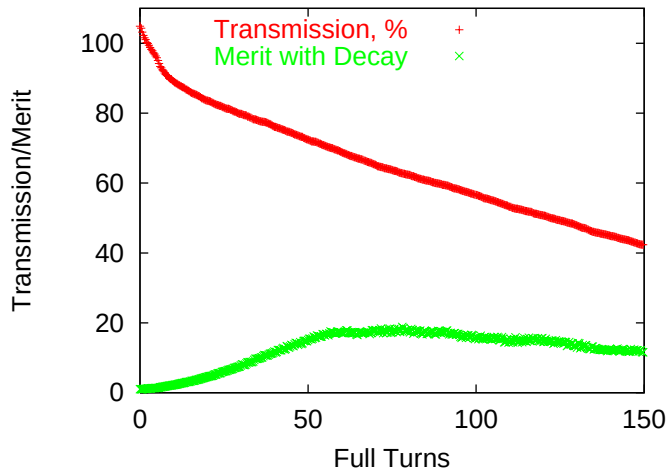
ICOOL V2.59





ICOOL V.266





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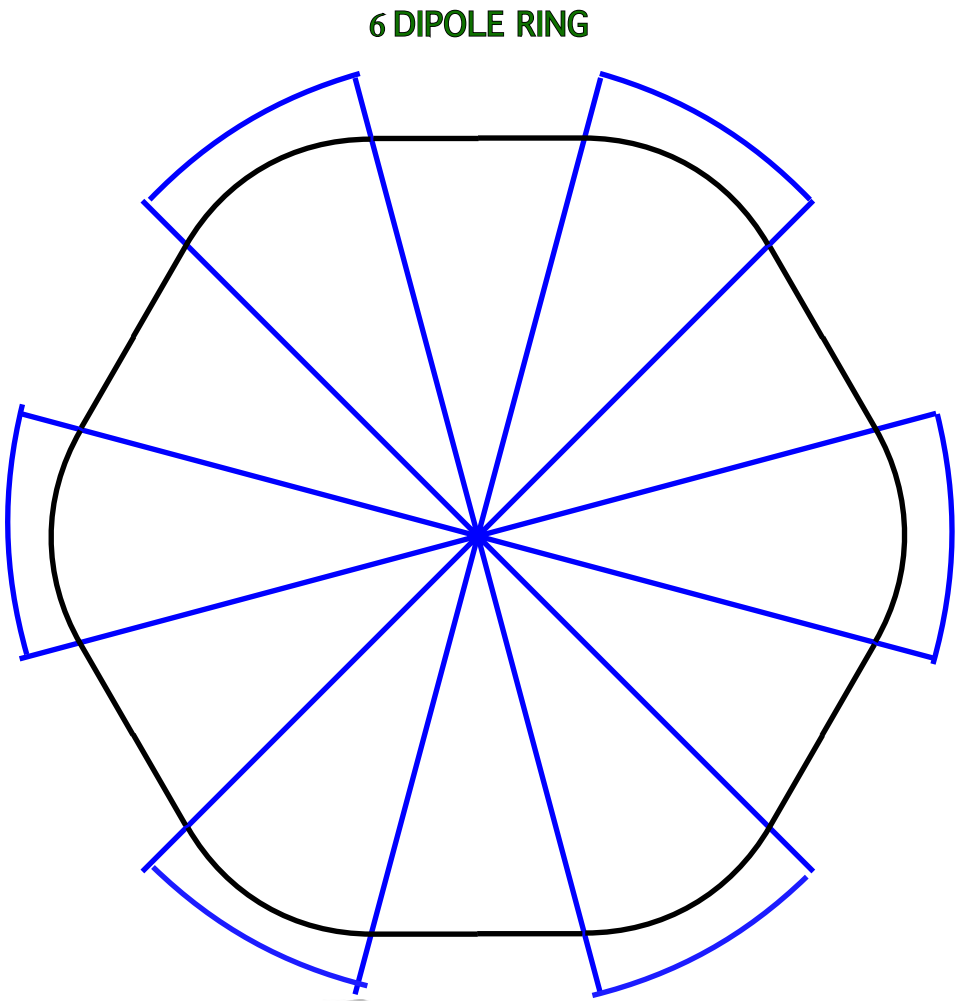
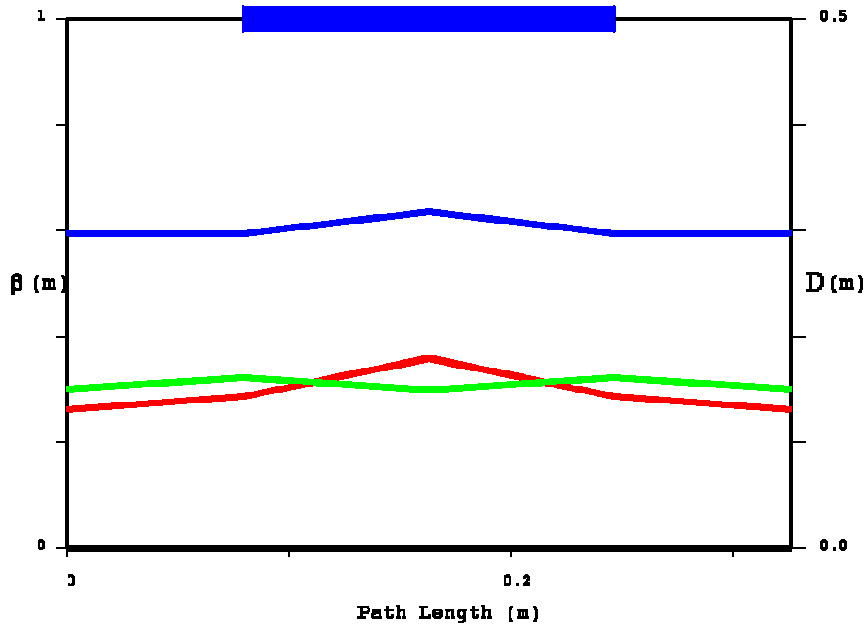
Reduce the Radius





Key parameters at r = 30 cm

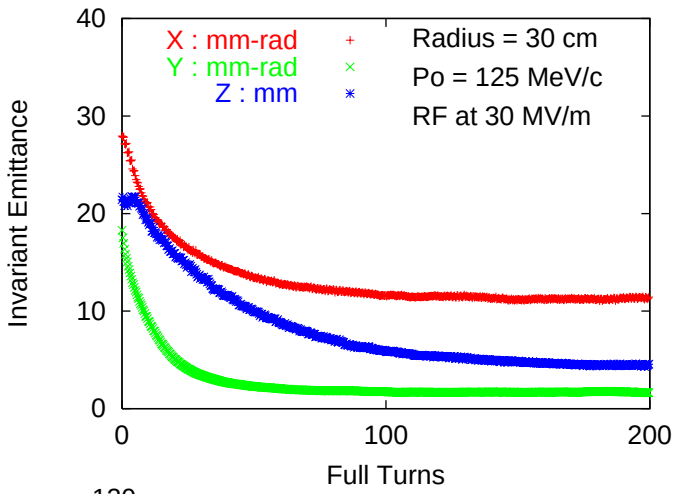
β_x = 26 to 36 cm ; β_y = 30 to 32 cm

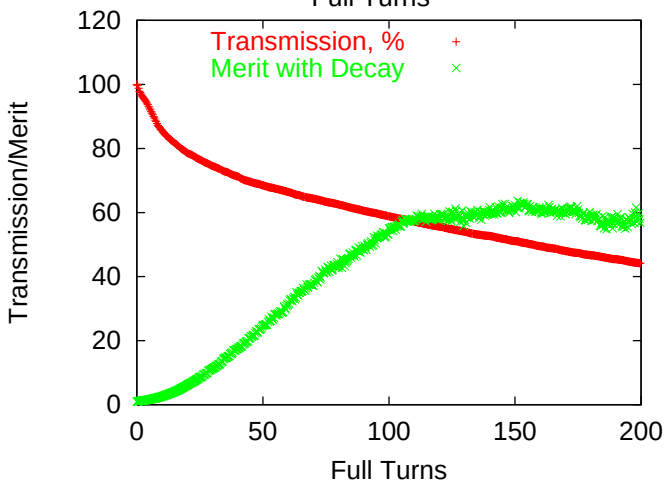
Dispersion = 30 to 32 cm

Circumference = 1.95 m

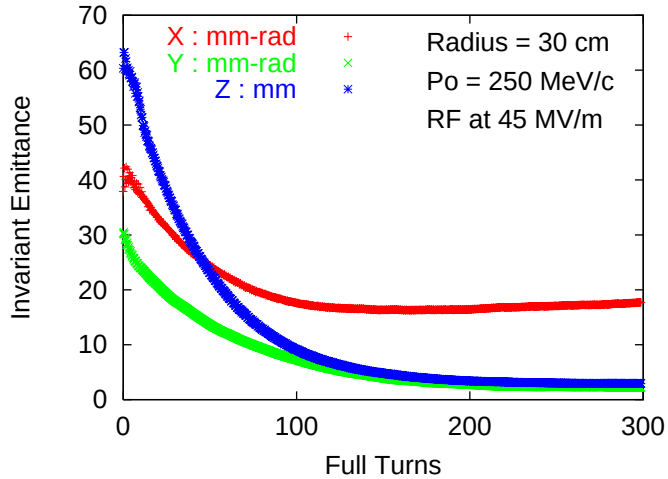
Reduced Radius Performance

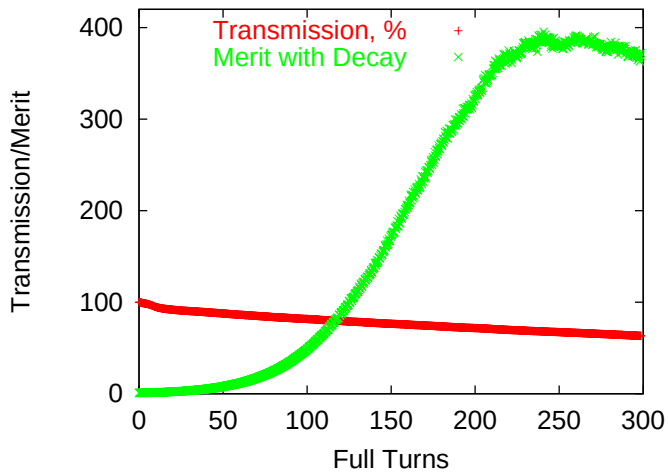
B = 2.6T Po = 125 MeV/c





B = 5.2T Po = 250 MeV/c





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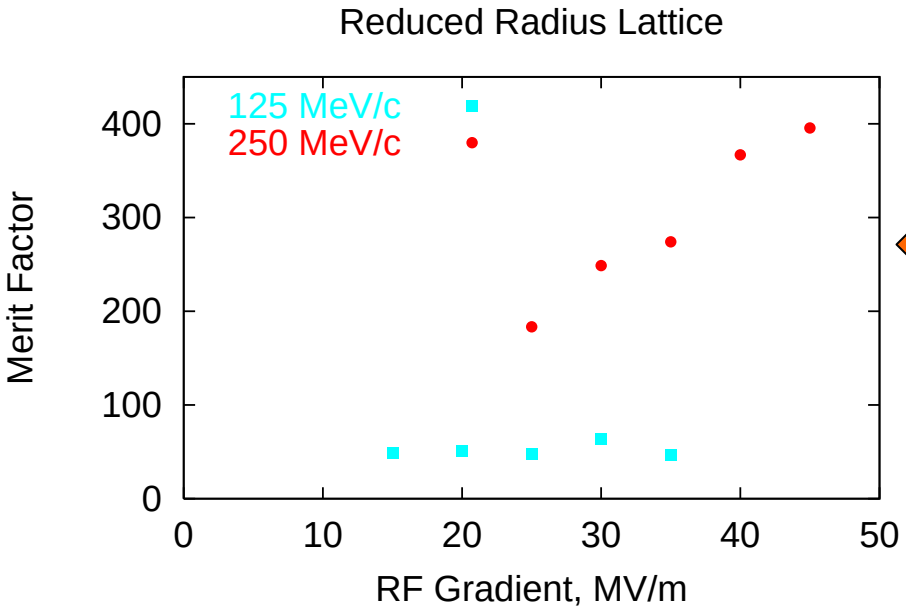
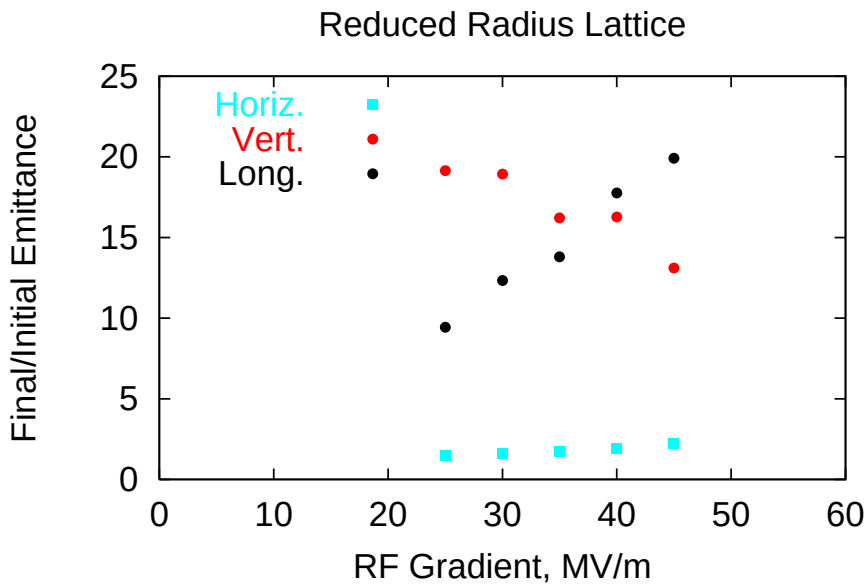
Impact of RF on Performance



Gain in total merit factor results from increasing the rf gradient. Gain is only seen for the high-field, Po=250 MeV/c case.

High-field case. Gain comes from longitudinal cooling.

10 deg. Wedges



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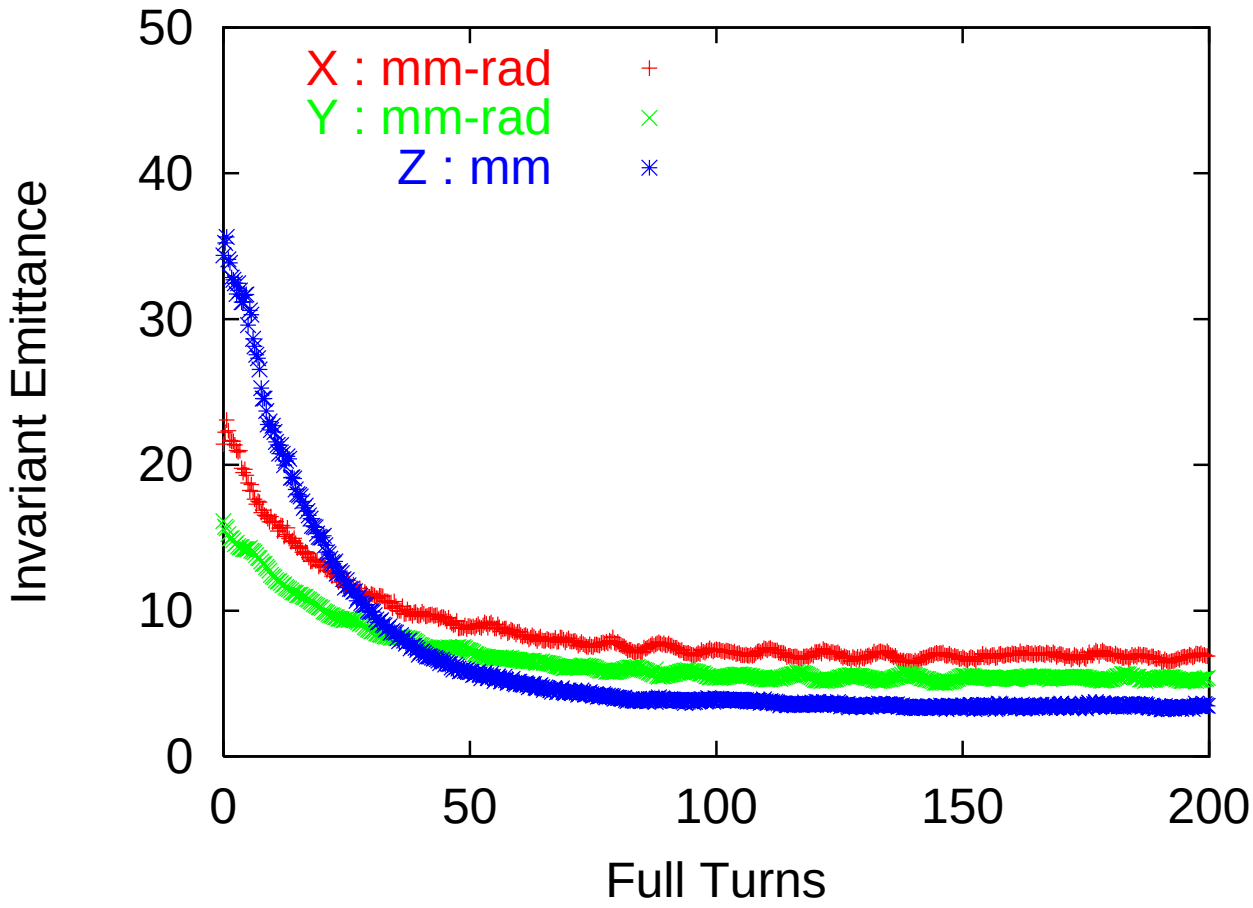
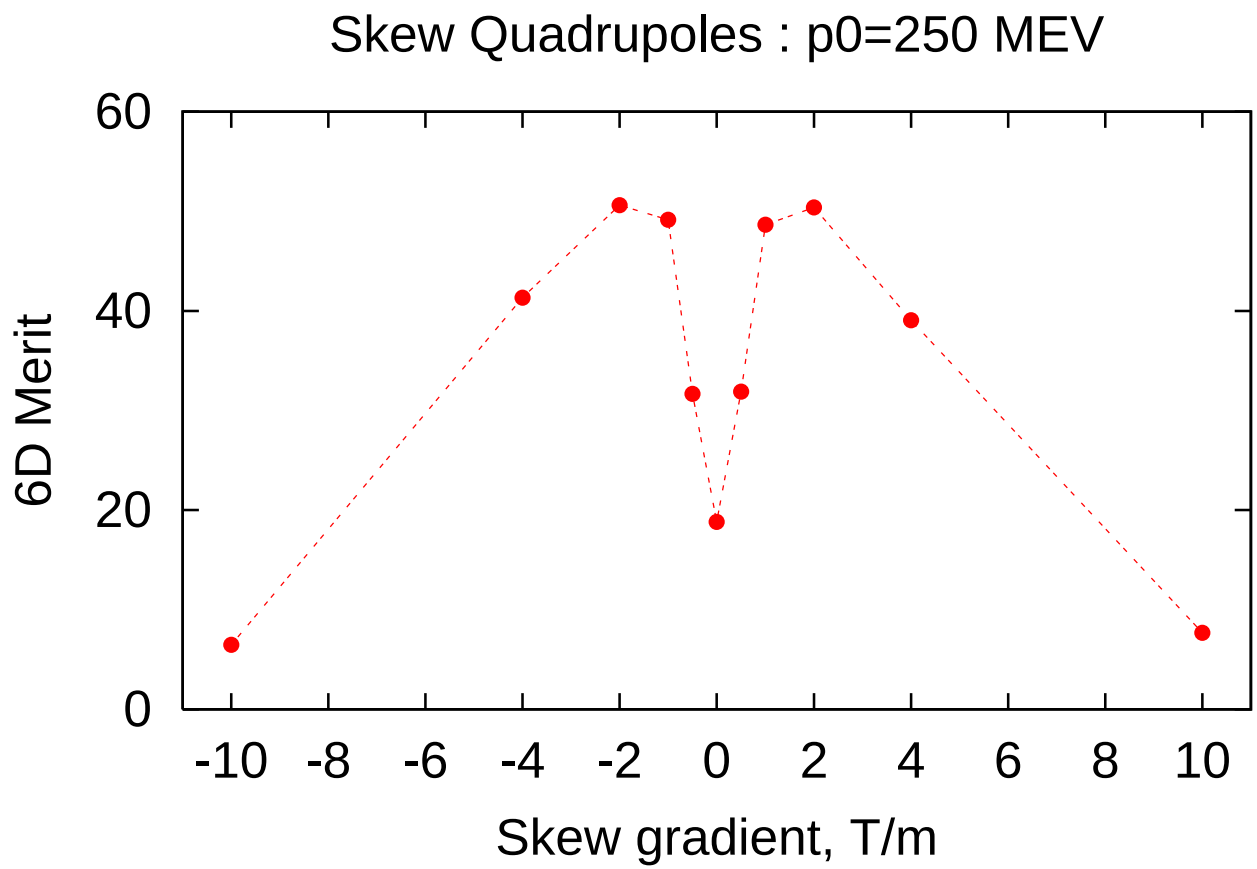
Introduce Skew Quadrupoles

- Bracket dipoles with thin (3cm) skew quadroles
- Skew quadrupoles real estate at 9% circumference
- Test various gradients.
- X/Y Coupling achieved

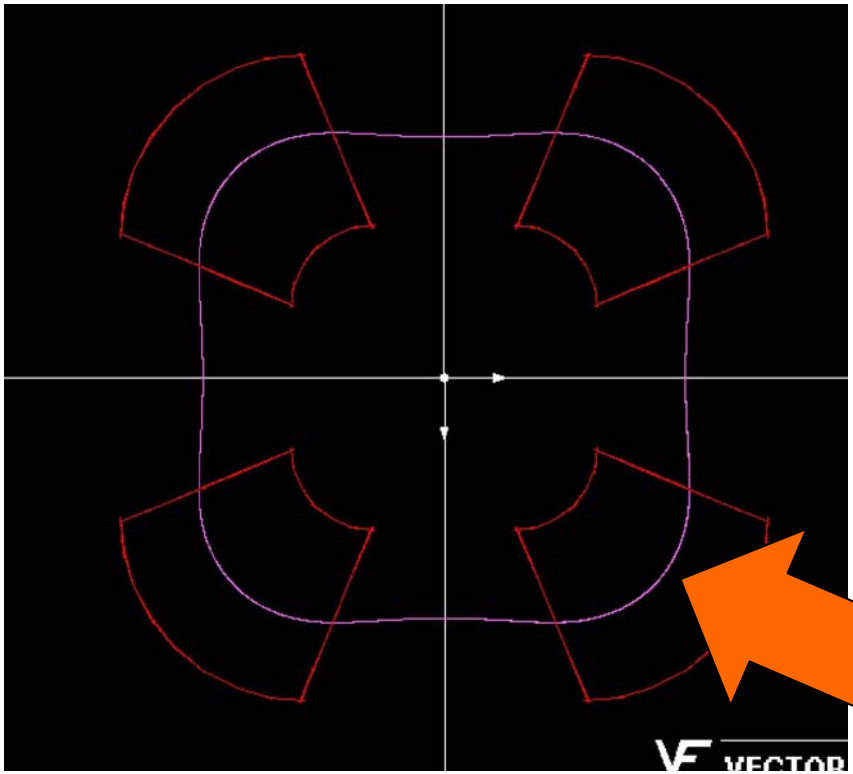


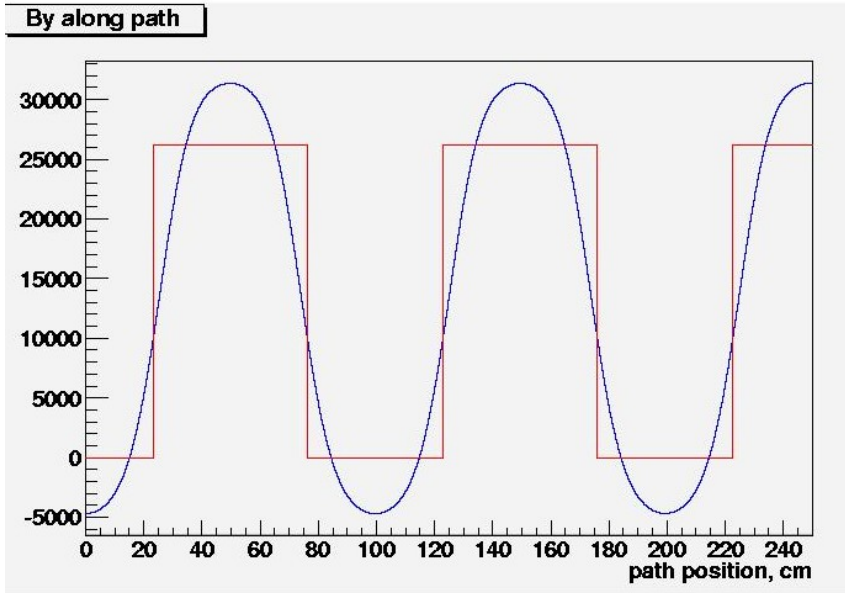
Skew Quadrupoles Performance



Horizontal Focusing 

Tosca Results – Steve Kahn

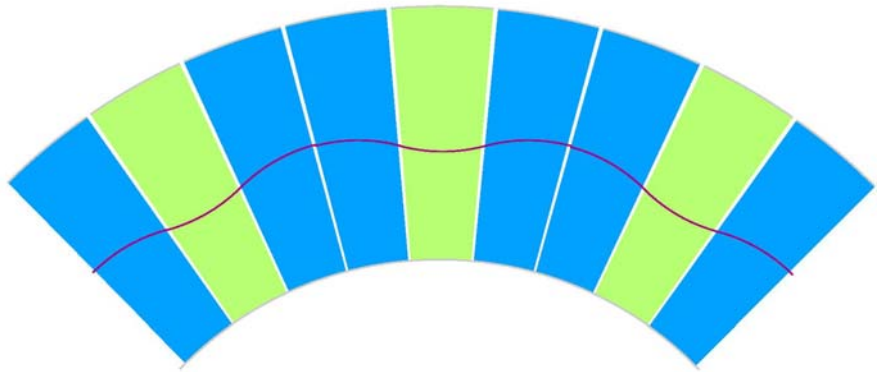




Closed orbit for
250 MeV/c muons
at r = 55.03cm

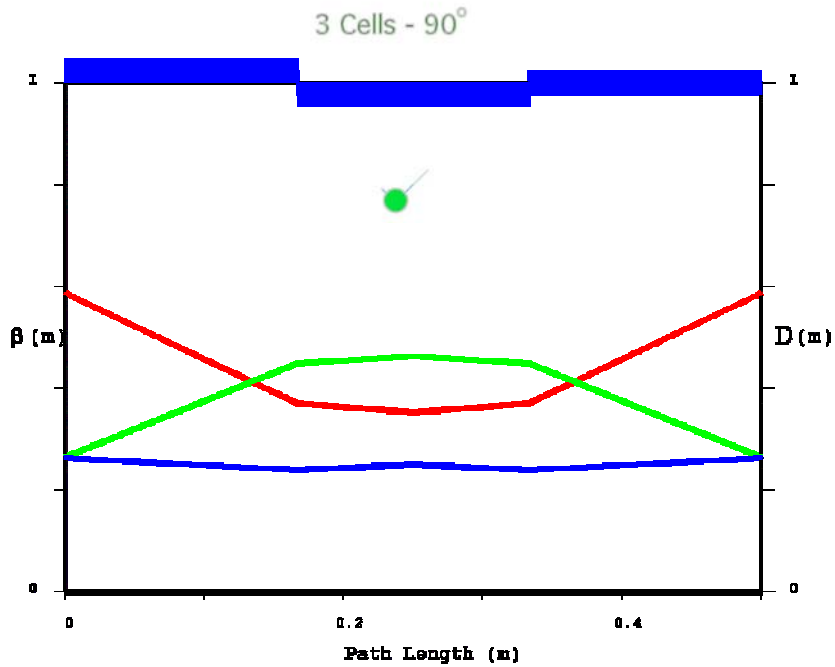
An FFAG-like Lattice

Lattice consists of alternating Horz. Defocusing and Horz. Focusing with $L_{HD} = ½ L_{HF}$.
No drift cells between dipole elements.



Parameters

12 cells
Bend angles 30° and –15°
Circumference = 6m
B_o = 2.6T and P_o = 250 MeV/c
Dispersion = 25 cm



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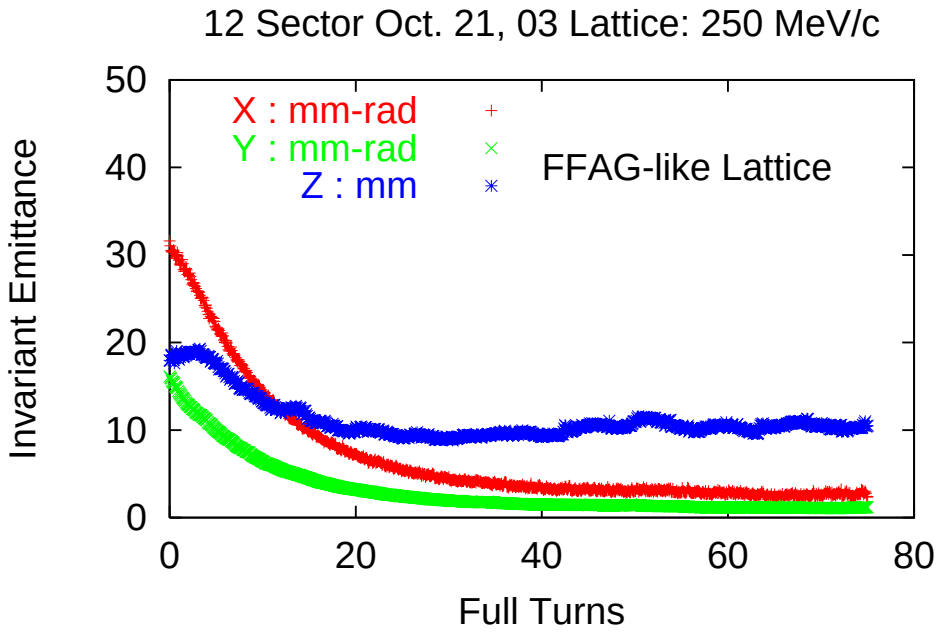
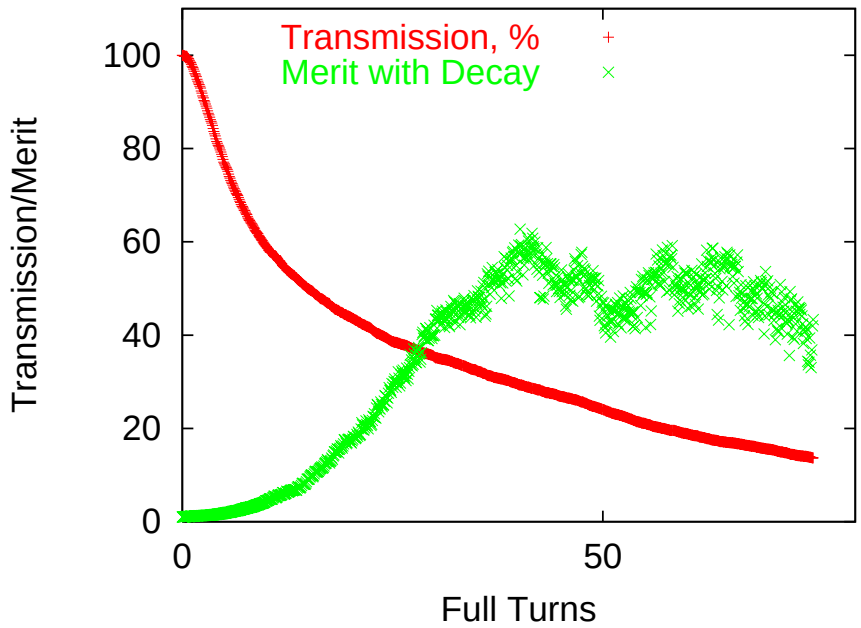
FFAG Lattice Performance



RF at 25 MV/m over
60% of circumference



Horizontal Emittance Reduction Factor 10
Vertical Emittance Reduction Factor 11
Longitudinal Emittance Reduction Factor 2

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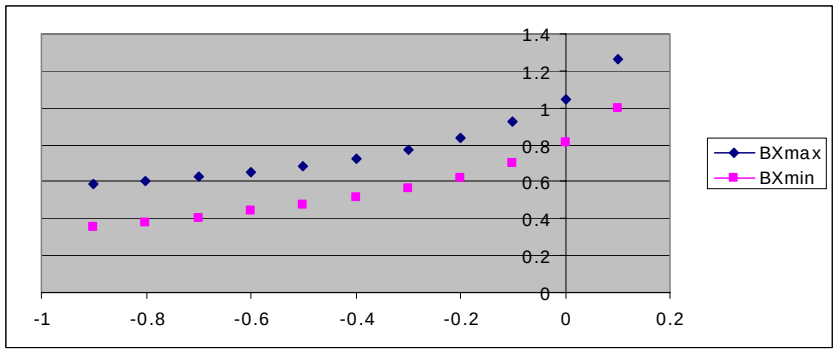
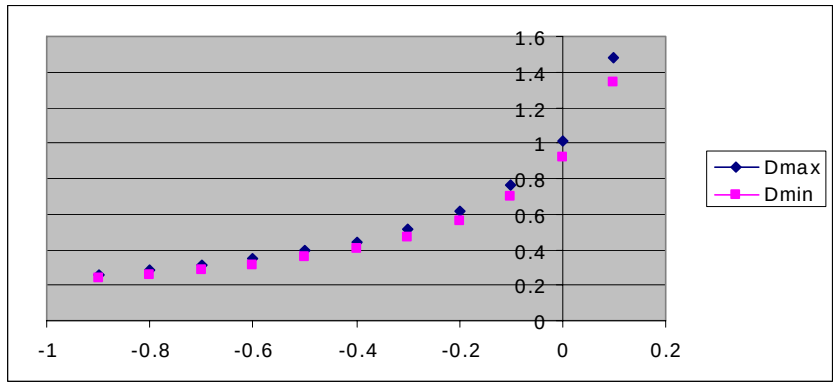
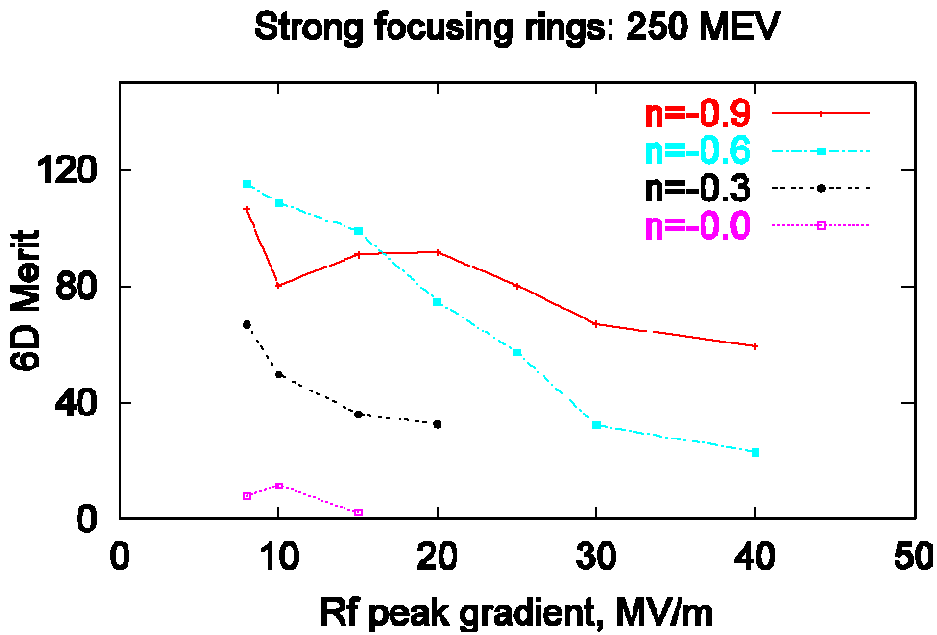
Vary the Focusing Parameter n

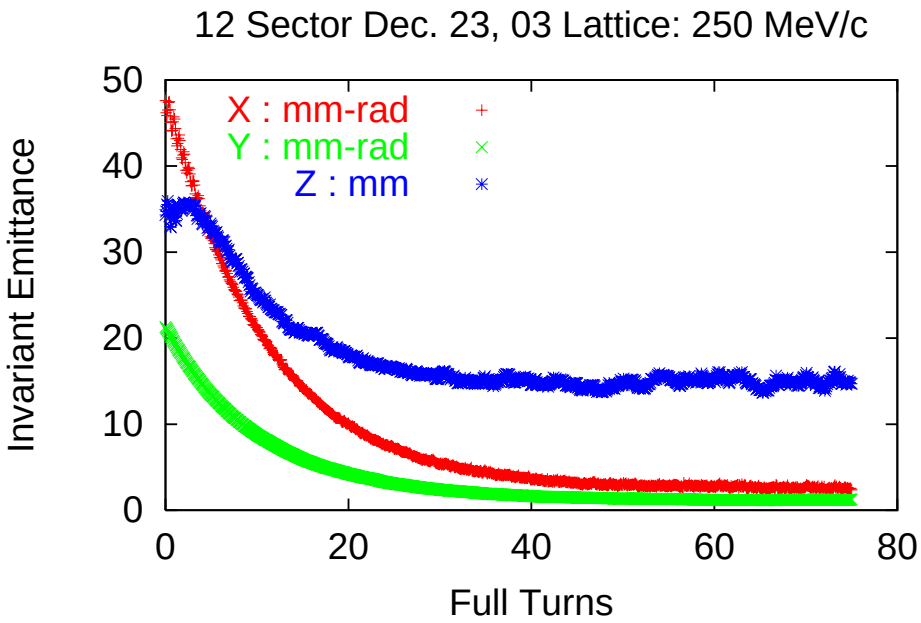


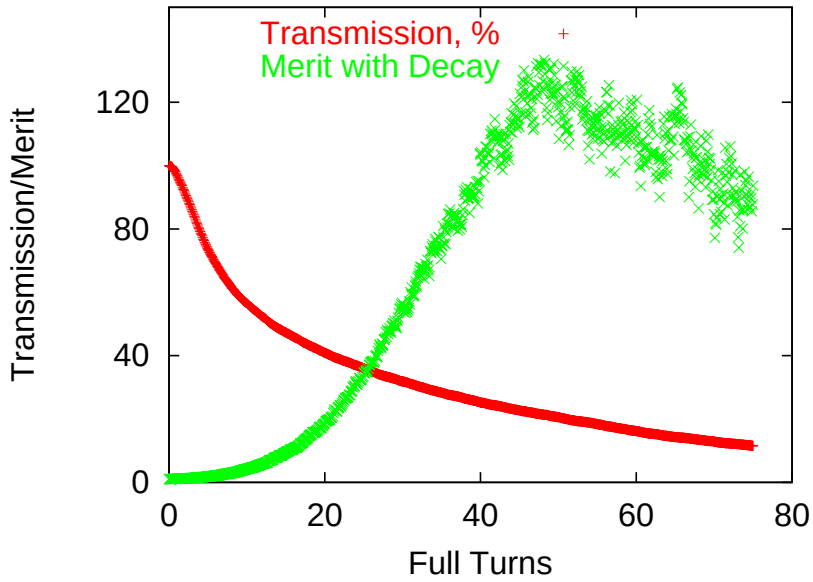




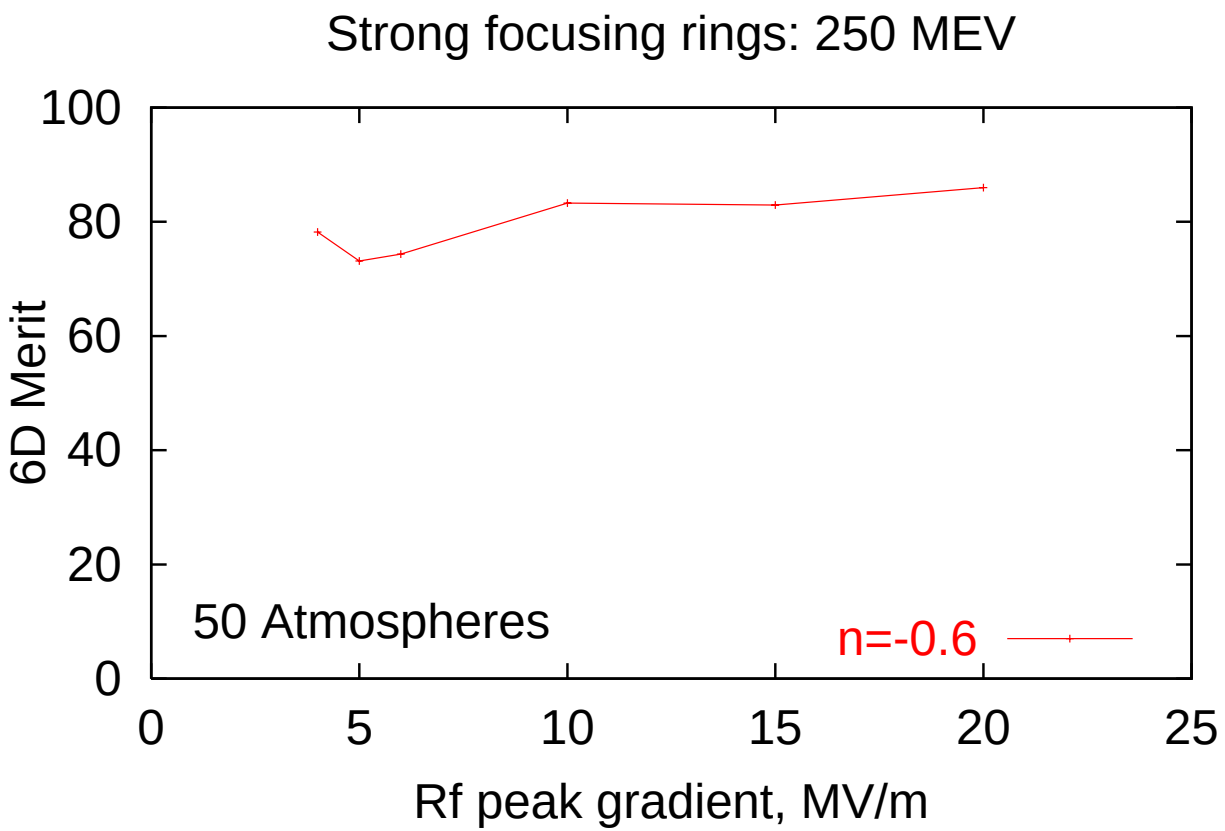
Strong Focusing Ring Performance

n = -0.6 rf at 8 MV/m





50 Atmospheres Performance



A Demonstration Scenario

- Merit factor of ~ 10 is sufficient
- Muon decay ignored
- Rf frequency at 800 MHz
- Beam aperature at ±7 cm
- Gas density at 10 atmos at 77^{o} K
- DC dipole field at 1.5T
- Pulsed dipole field ~ 3T

Future Directions

- Pursue weak-focusing rings with skew quadrupole insertion.
- Explore strong-focusing rings with FFAG like dipoles (radial gradient B_O)
- Search for a viable demonstration scenario

Summary

- The ICOOL fix (> V2.66) significantly affected the performance of rings with gas loaded rf cavities
- The wedge dipole-only rings are still viable but with a reduction in scale or with the introduction of X/Y coupling.
- For weak-focusing lattices, high magnetic field , high rf gradients are favored.
- For strong-focusing lattices, low rf gradients are favored.