Muon Collaboration

Gas-filled Ring Coolers

Ring Cooler Workshop
BNL
June 28-29, 2004

Harold G. Kirk
Brookhaven National Laboratory

The Fundamental Strategy

Lattice Design Using SYNCH (Al Garren)

System Optimization using ICOOL (H. Kirk)

Realistic Fields using TOSCA (Steve Kahn)

- Explore dipole-only rings utilizing edge focusing
  - Weak-focusing dipoles
  - Strong-focusing (FFAG like)
- Use gaseous H_2 as absorber

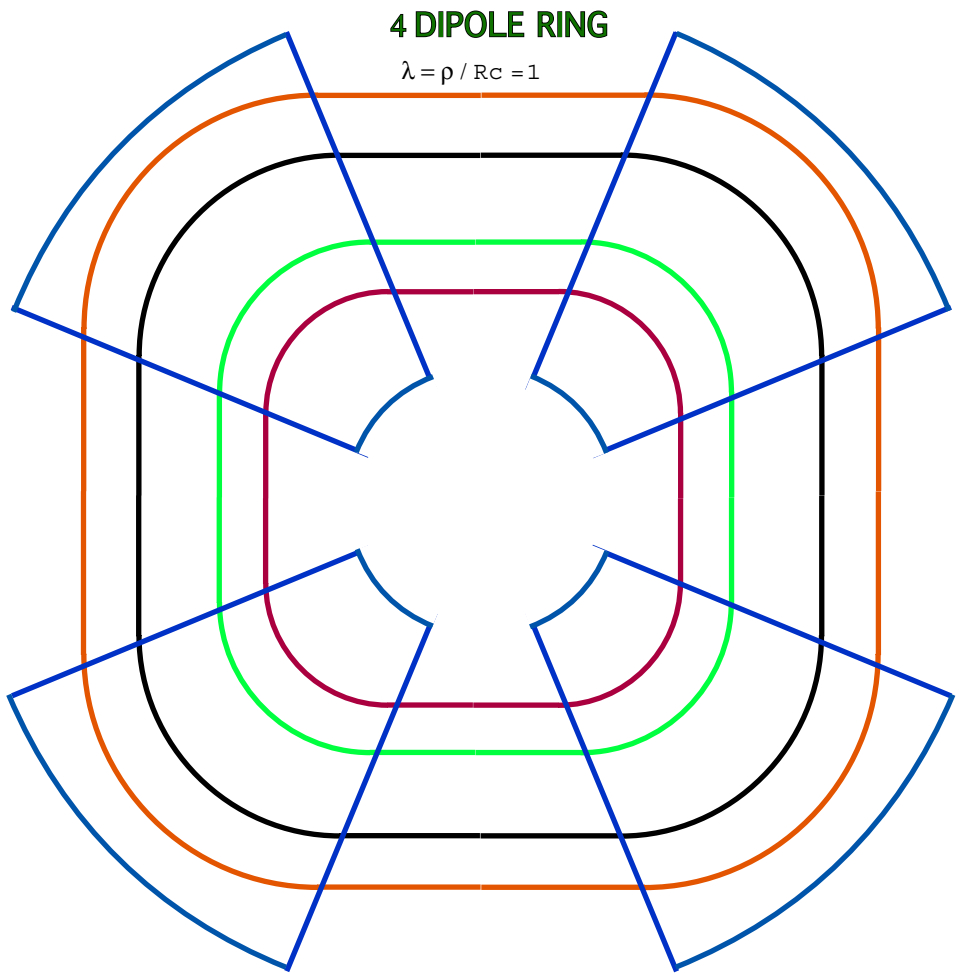
6D Cooling in Gas-filled Rings

Closed orbits scale such that the path length of each orbit is proportional to the particle momentum.

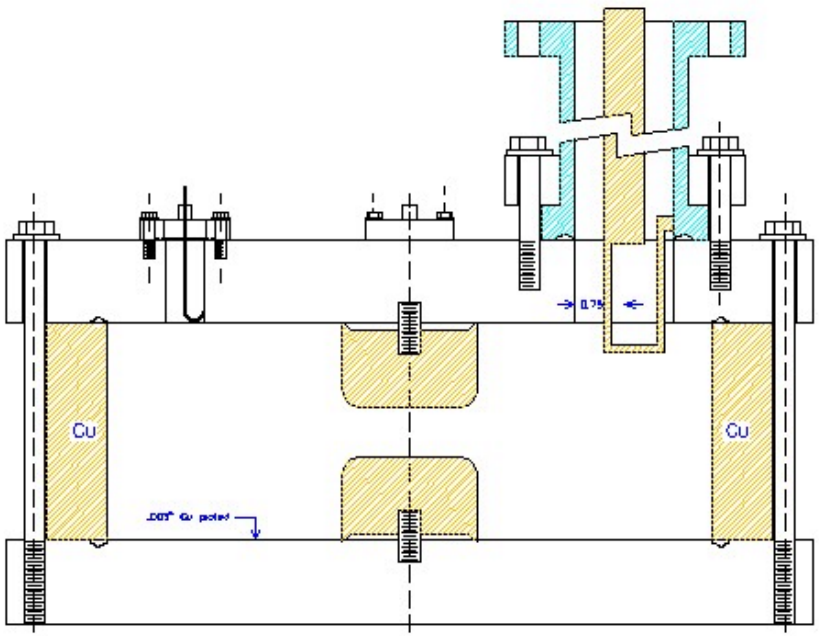
6D Merit = Transmission x

$(\varepsilon_x\, \varepsilon_y\, \varepsilon_z)_{initial} / (\varepsilon_x\, \varepsilon_y\, \varepsilon_z)_{final}$

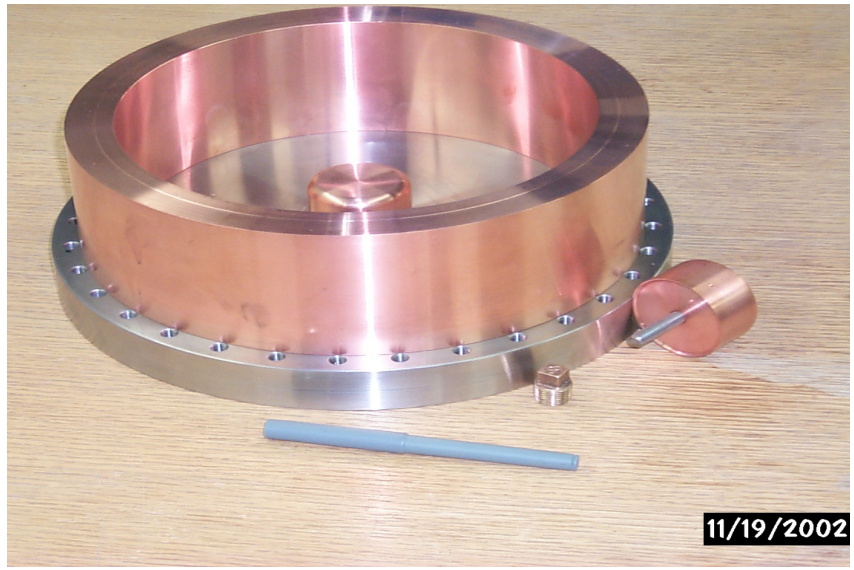
Key Issue: Gas filled RF Cavities



Rolland Johnson's GH_2 R&D

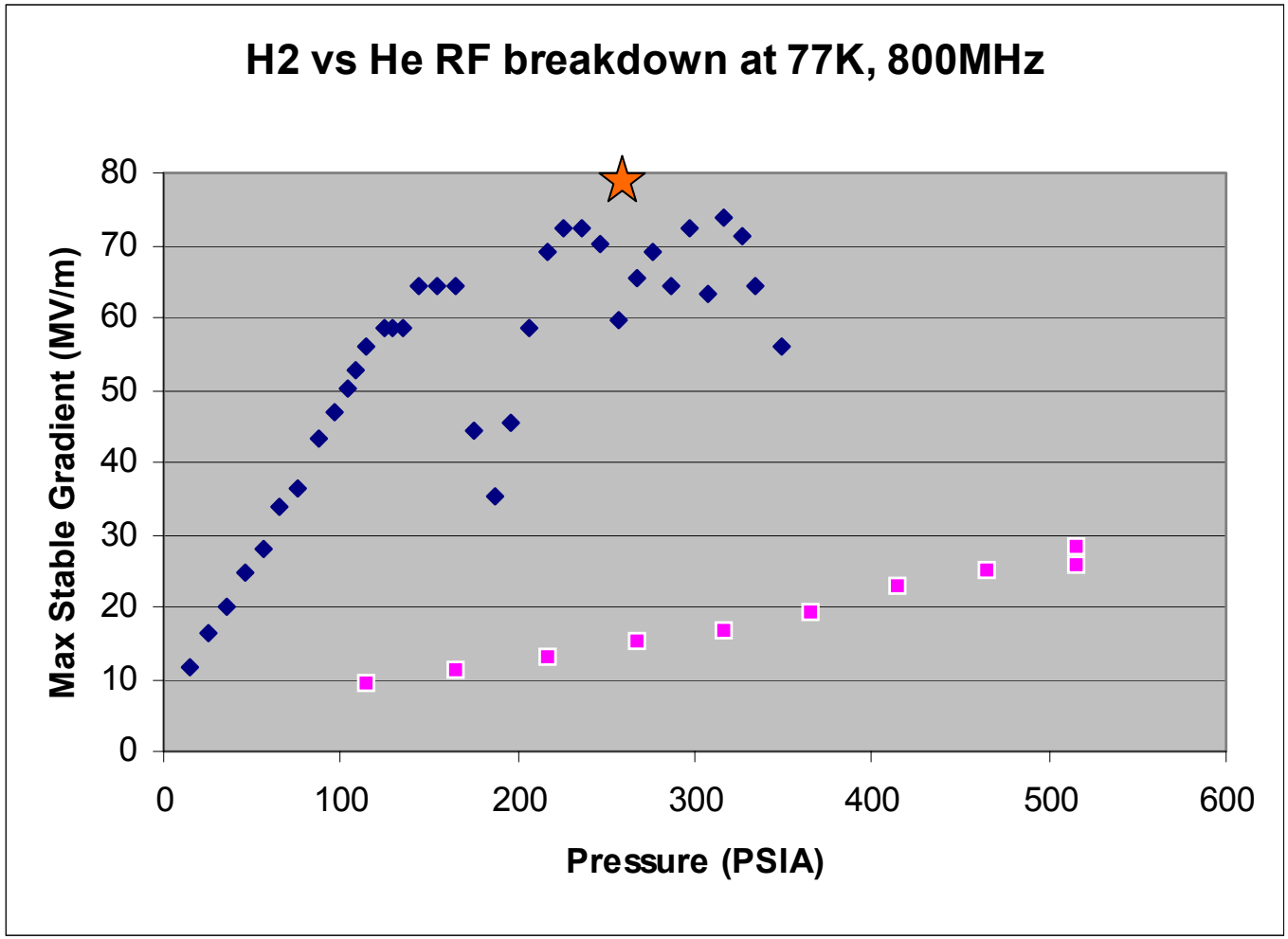


Schematic

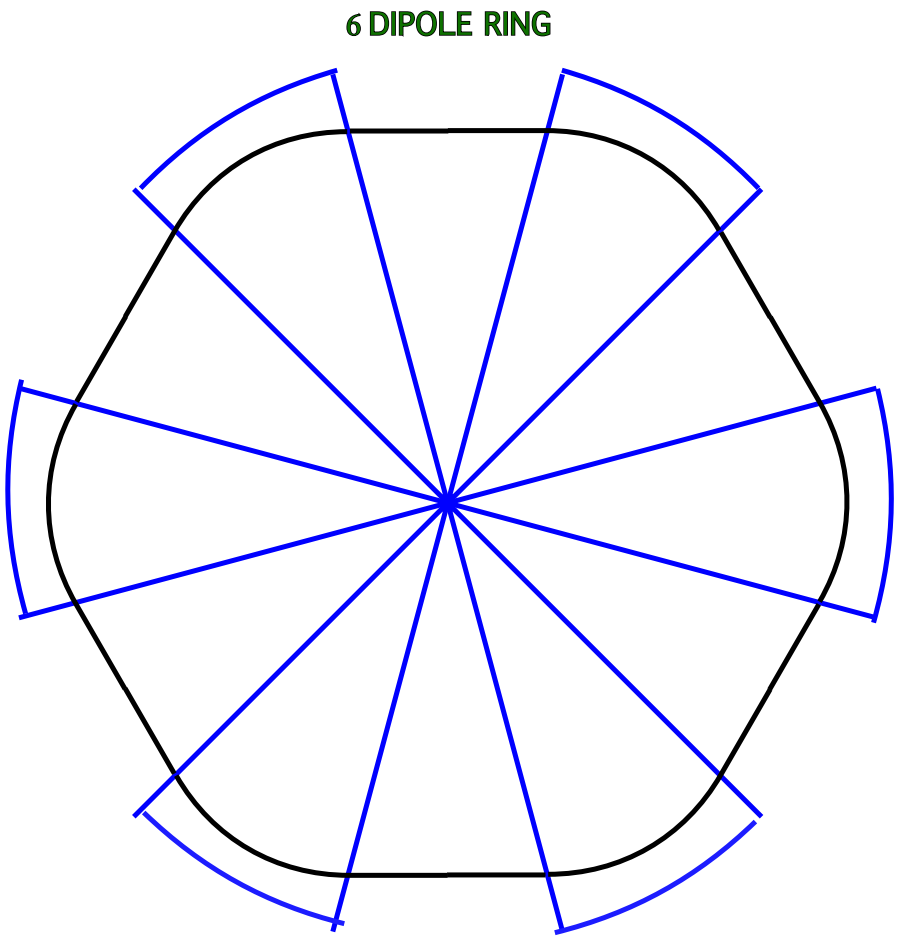


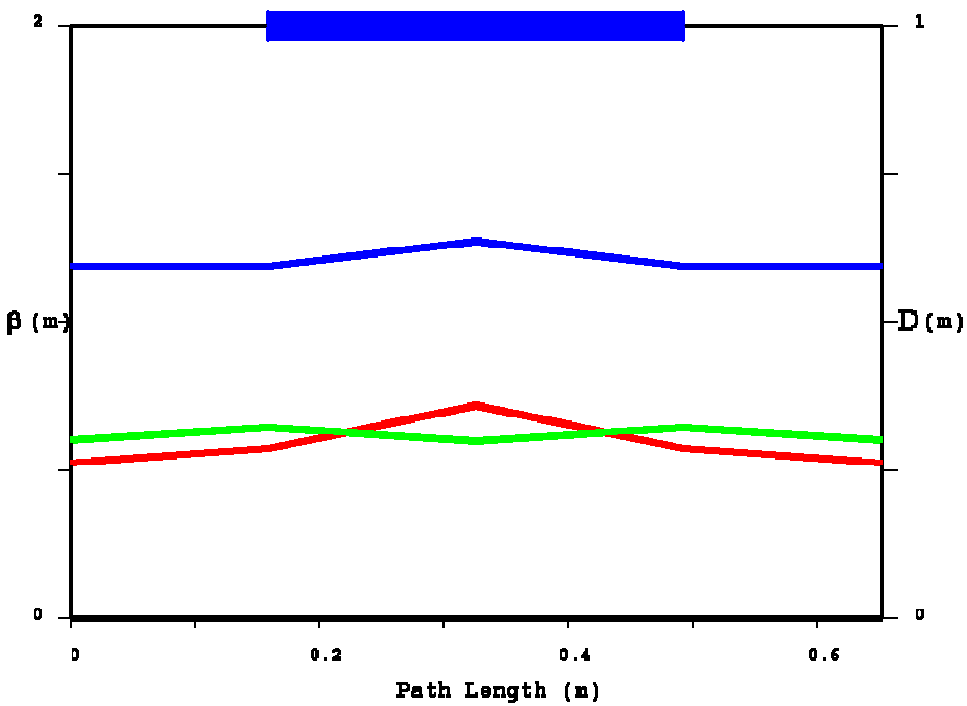
As built

High Pressure GH_2 RF Cell Tests



Gas Filled Weak-focusing Dipole 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

P_0 = 250 MeV/c ; B_0 = 2.62T

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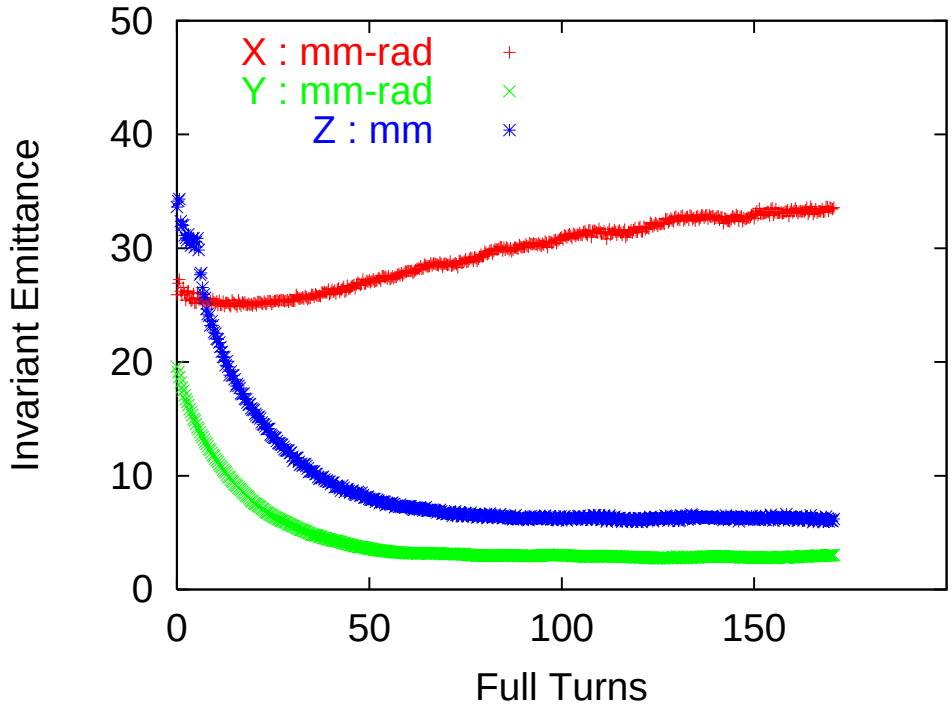
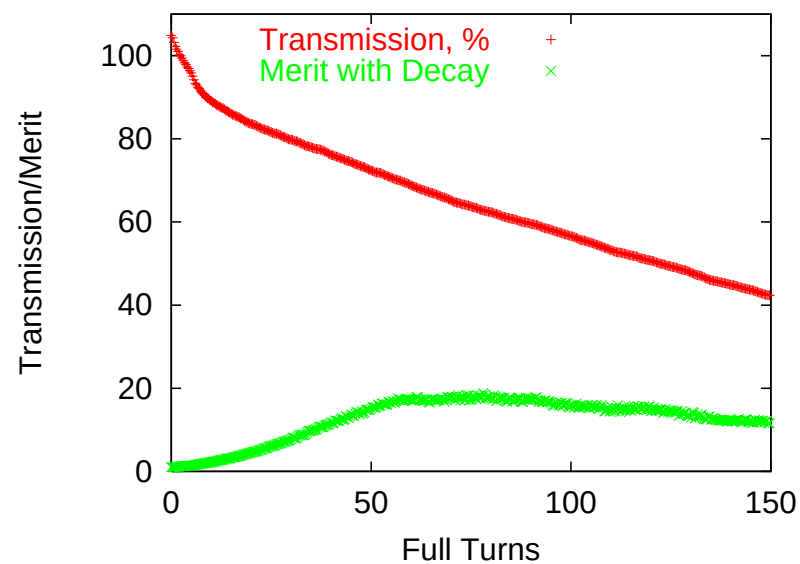
6 Sector Dipole Ring Performance



$P_0 = 250$ MeV/c

$B_0 = 2.62$ T



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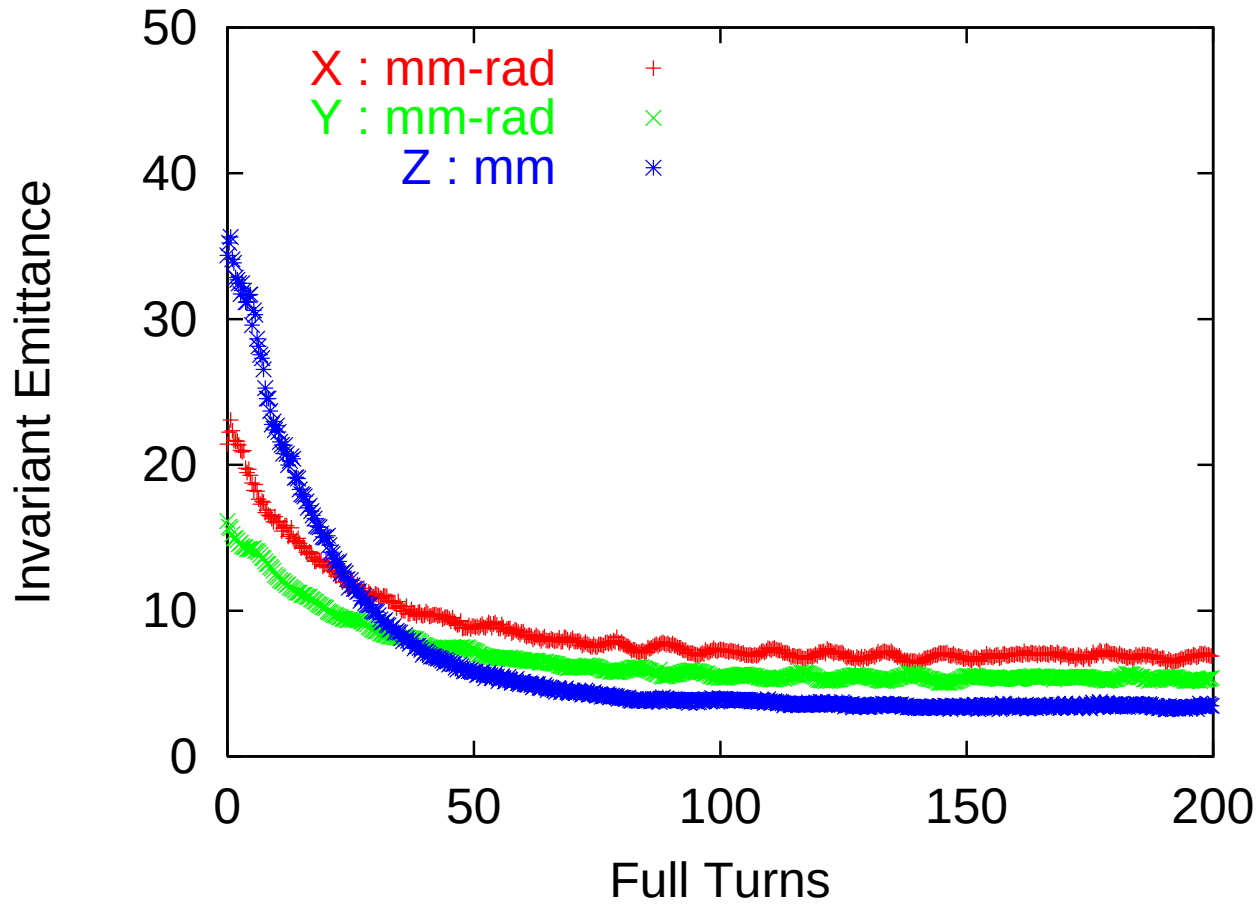
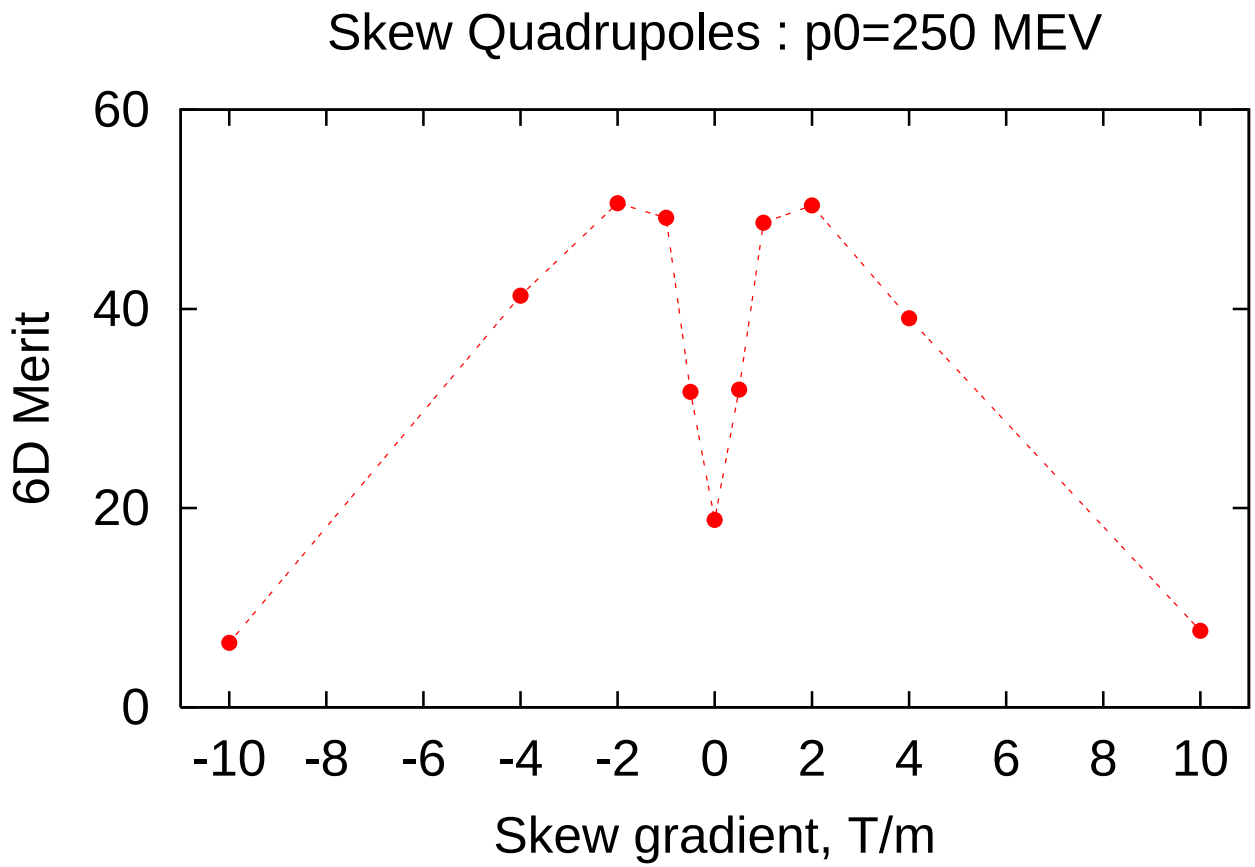
Introduce Skew Quadrupoles

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



Skew Quadrupoles Performance



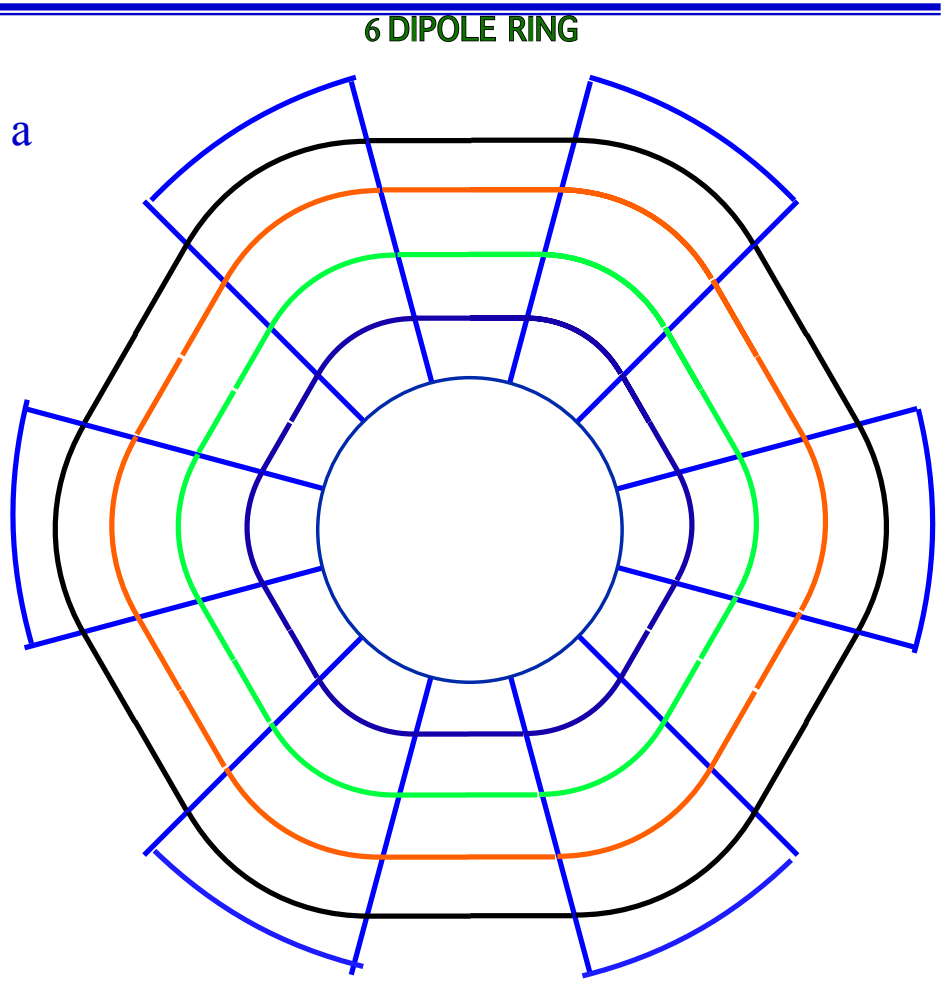
Horizontal Focusing

250 MeV/c and 200 MHz Closed Orbits

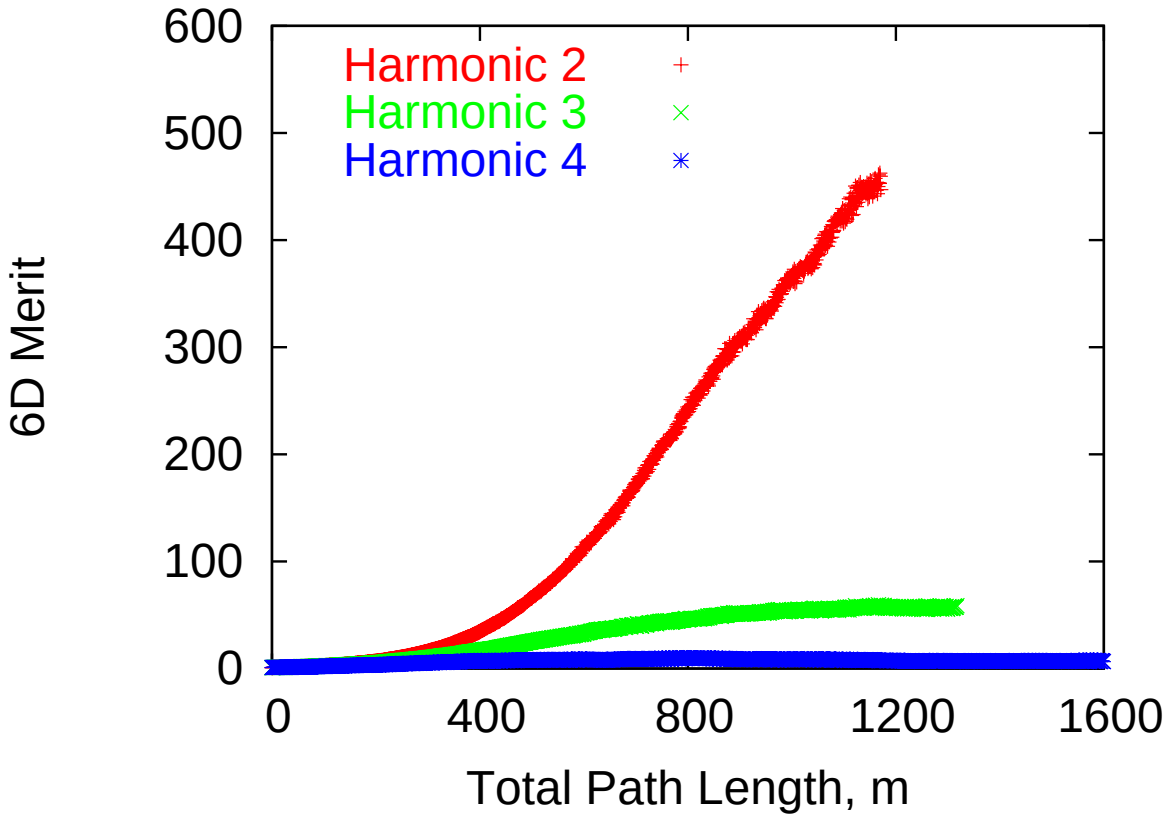
Fix the closed orbits for 250 MeV/c muons such that the total path length is a harmonic of 200 MHz.

Then:

- Harmonic 2
  - Circumference = 2.74 m
  - B_0 = 3.73T
- Harmonic 3
  - Circumference = 4.11 m
  - B_0 = 2.49T
- Harmonic 4
  - Circumference = 5.49 m
  - B_0 = 1.87T



Merit Factors vs 200 MHz Harmonics



Results: 250 MeV/c

Harmonic 4

Merit Factor 10

Harmonic 3

Merit Factor 60

Harmonic 2

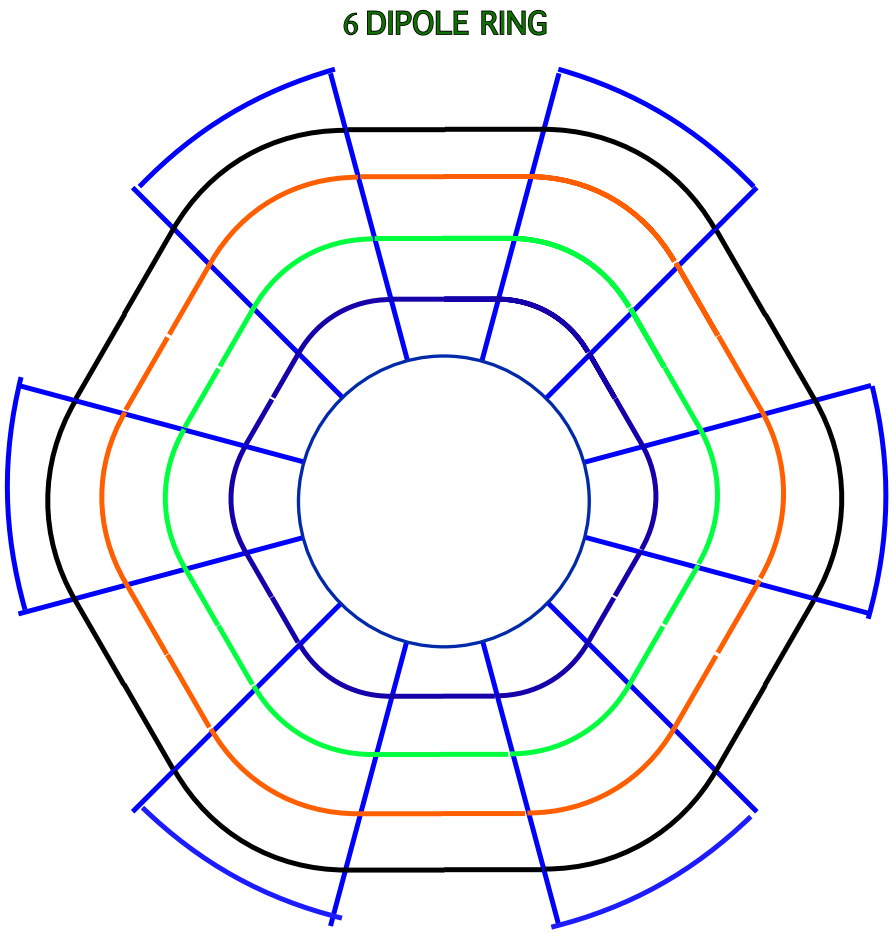
Merit Factor 460

Toward A Demonstration Scenario

- DC dipole field at 1.8T
- Pulsed dipole field ~ 3T (or SC)
- Merit factor of ~ 10 is sufficient
- Muon decay ignored
- Gas density at 10 atmos at 77° K
- Vertical aperture at ±15 cm
- Horizontal aperture at ±20 cm

Oxford Miss. Workshop: Cost estimate is ~$5M

1.8T Dipoles and 200 MHz Closed Orbits

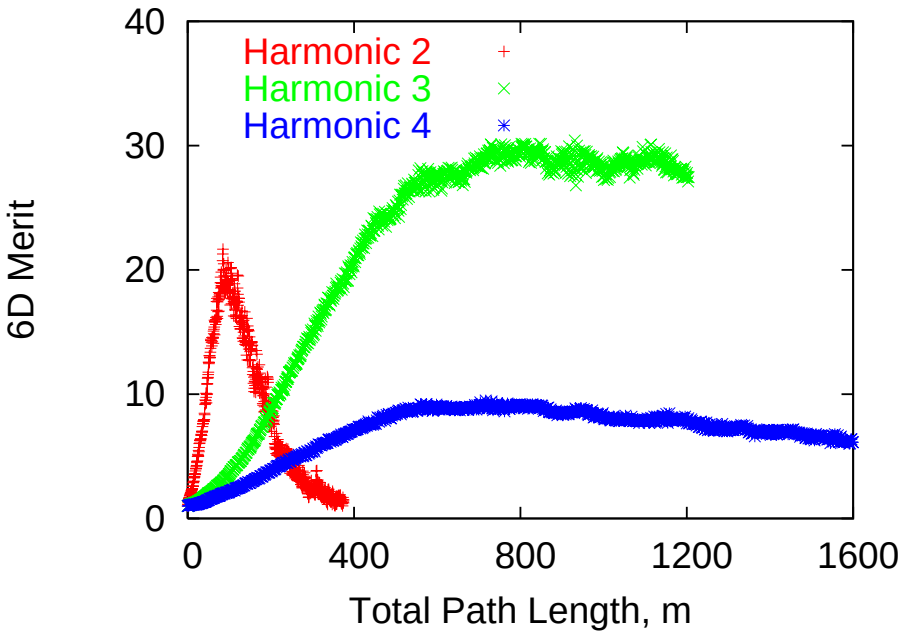


Fix the closed orbits for a 1.8T dipole such that the total path length of the muons is a harmonic of 200 MHz.

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

Merit Factors for 1.8T Dipole Case



Results:

Harmonic 4

Merit Factor 9

Harmonic 3

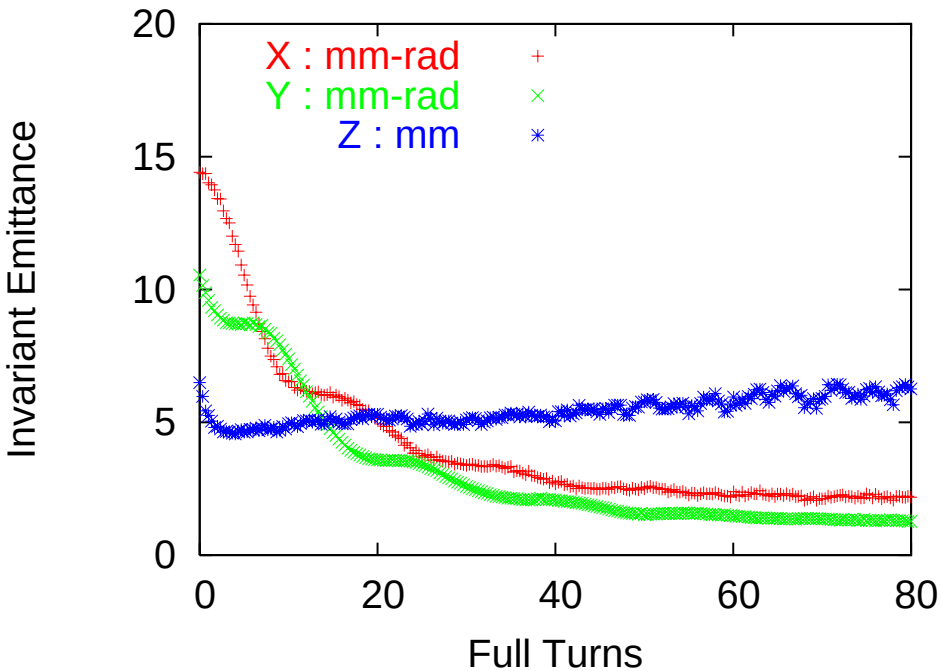
Merit Factor 30

Harmonic 2

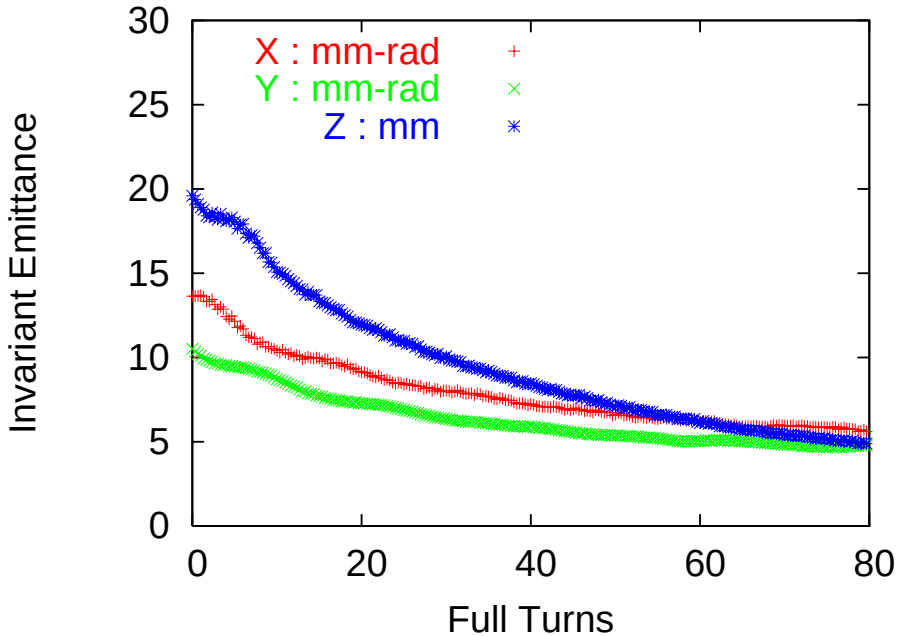
Merit Factor 21

1.8 T Dipoles

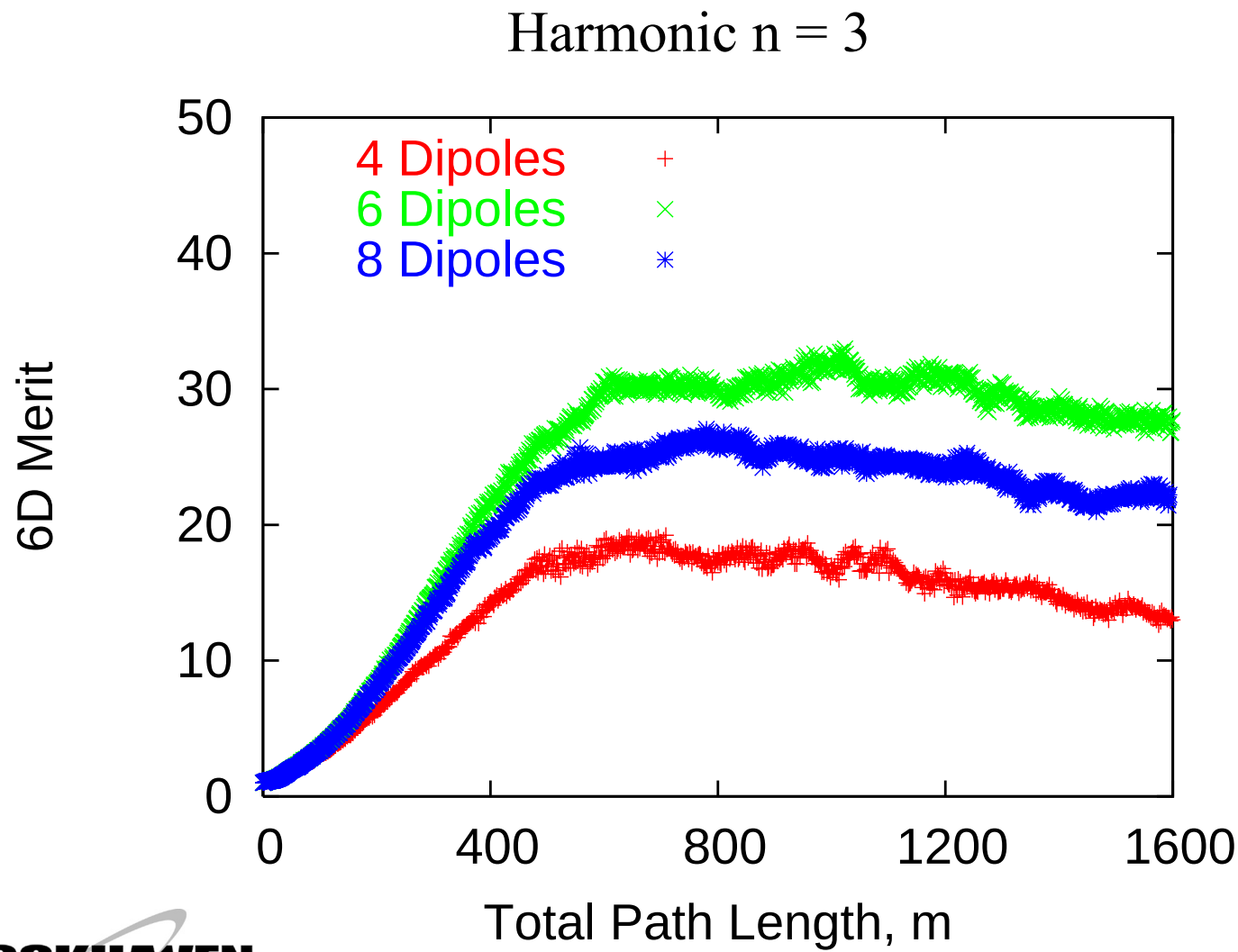
Harmonic 2



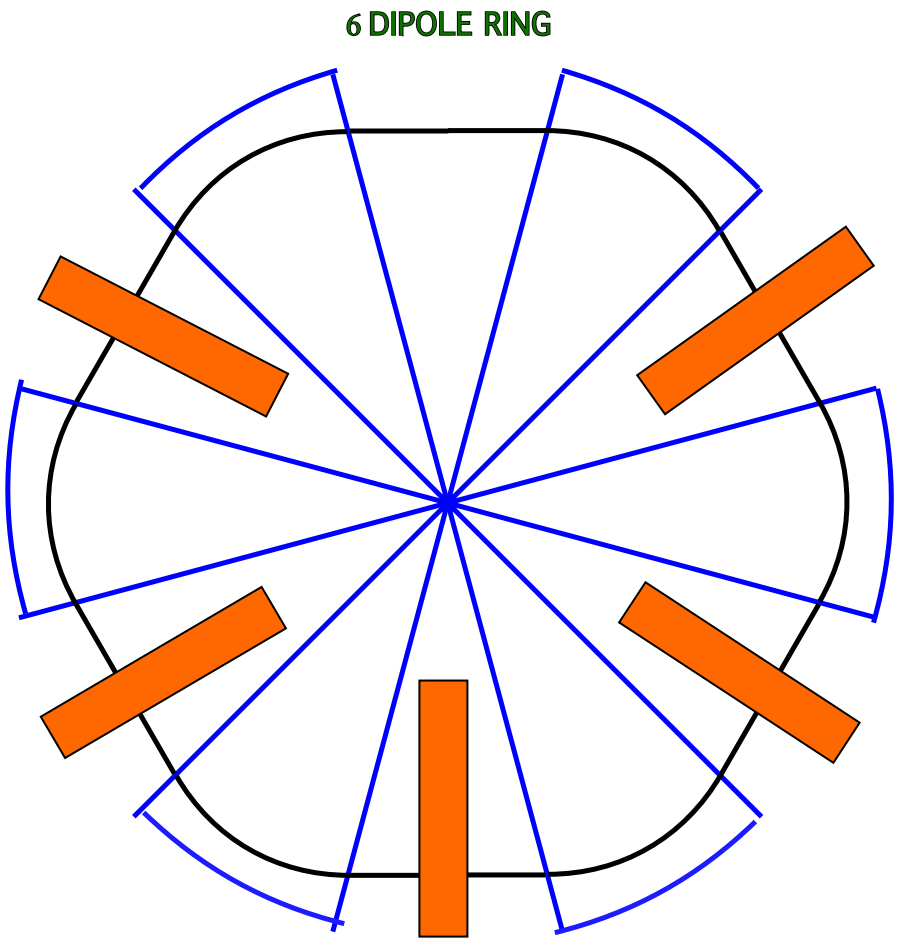
Harmonic 3



Merit Factor for n-sector Dipoles



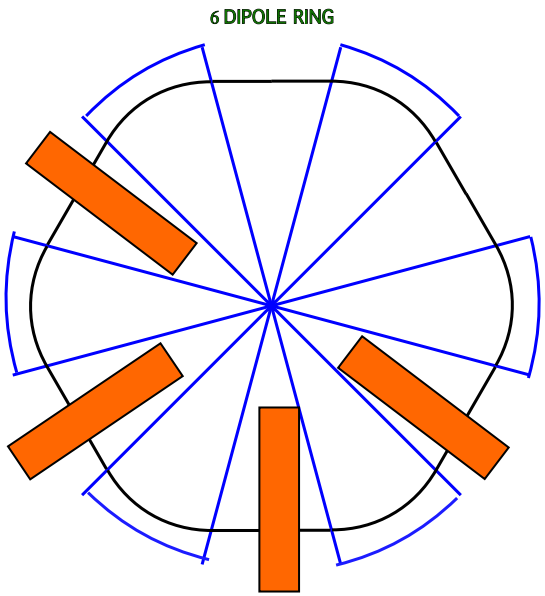
Empty Cells – One vacant cell

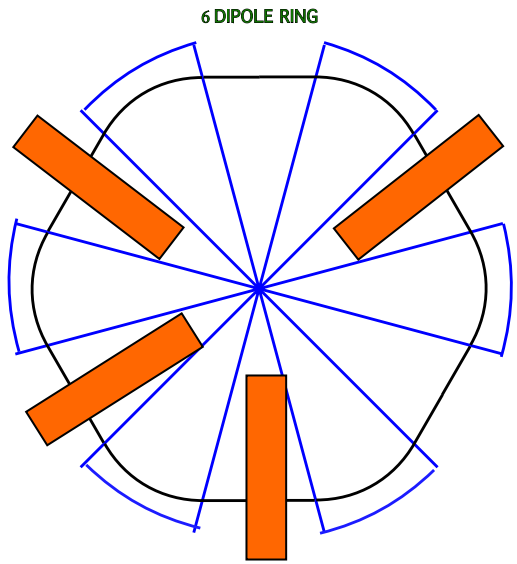


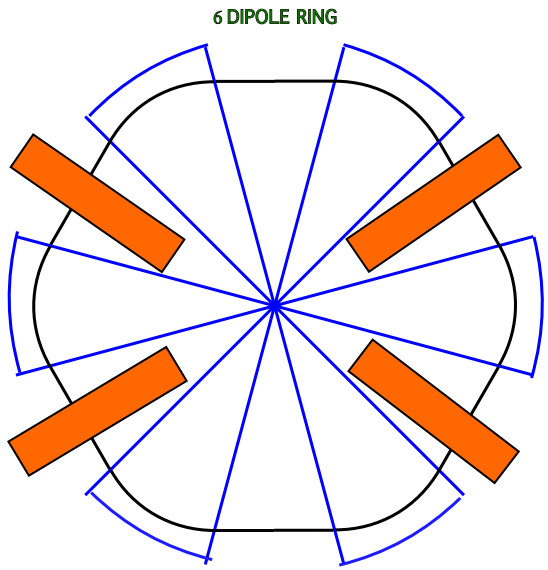
Excluded:

No throughput

Empty Cells – Two vacant cells







Excluded:

No throughput

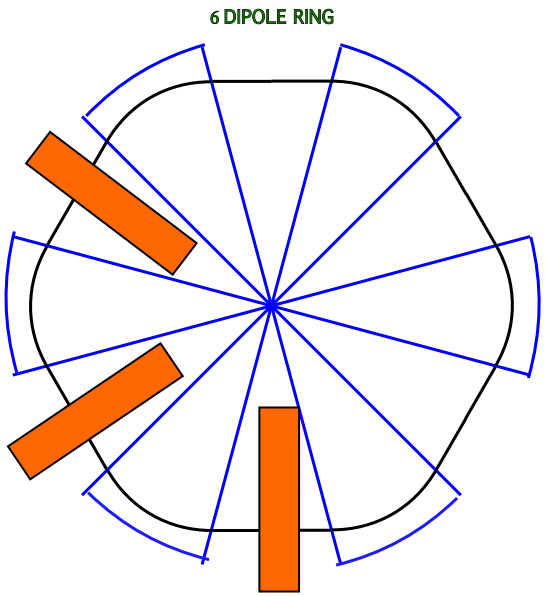
Excluded:

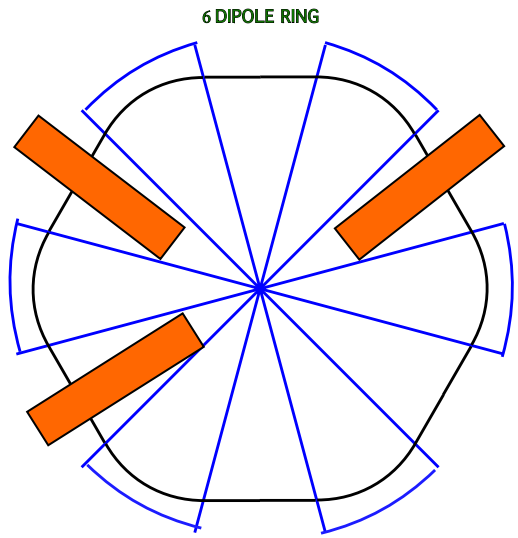
No throughput

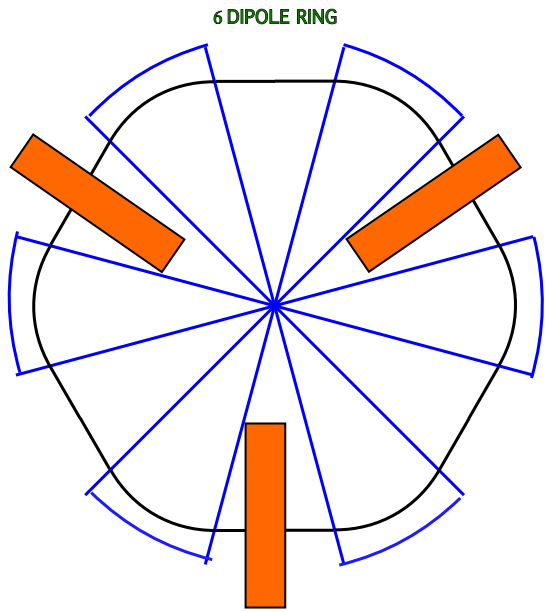
Merit Factor:

12

Empty Cells – Three vacant cells







Excluded:

No throughput

Excluded:

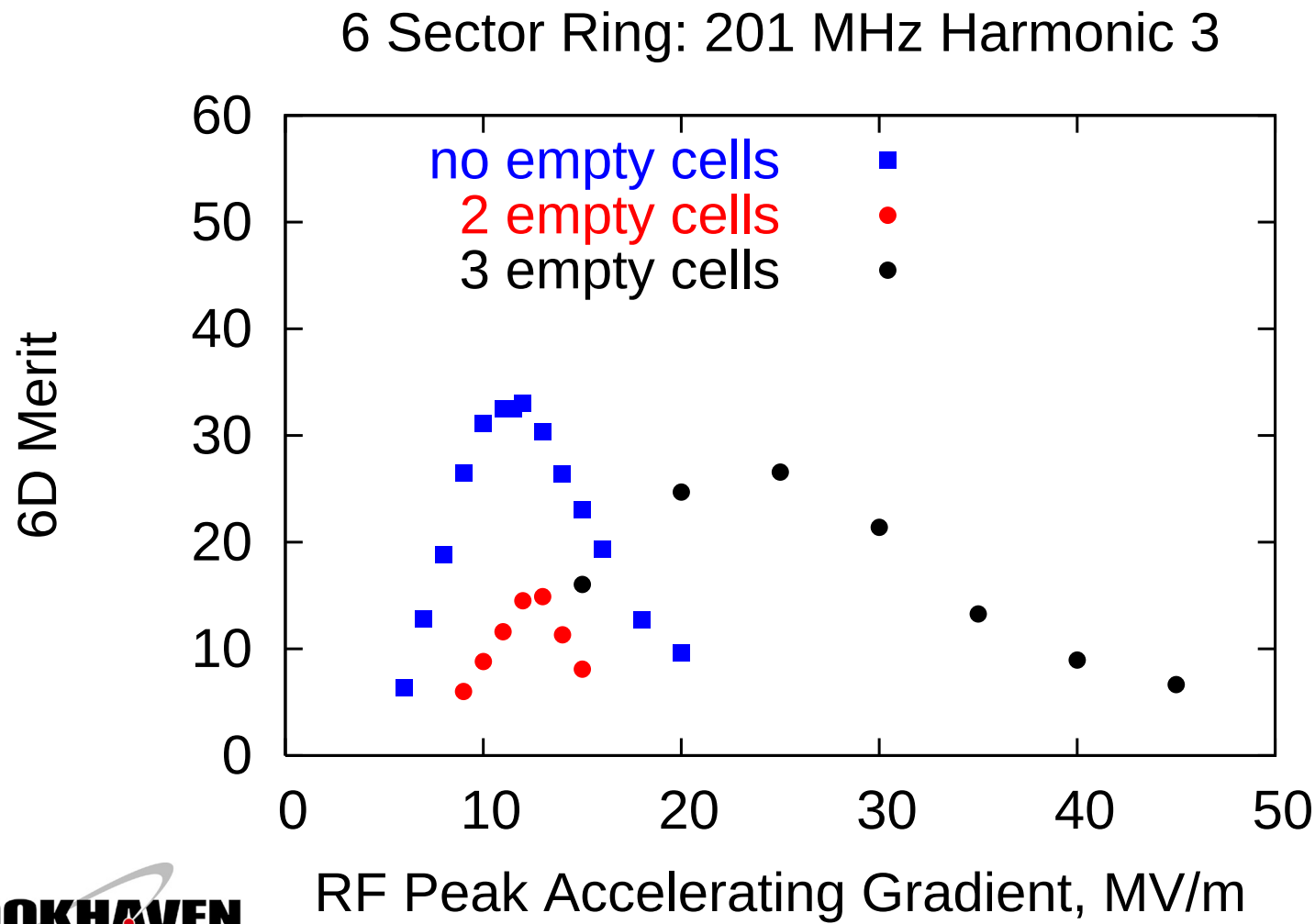
No throughput

Merit Factor:

26

Empty cells for 6-sector Dipoles

Leave empty cells for injection/ejection



Empty Cell Results Summary

# Dipoles	Atmospheres	Missing Cells	Vertical Aperture (cm)	Merit
6	40	0	±15	33
6	40	3	±15	26
6	40	0	±10	9
6	40	3	±10	9
4	40	0	±15	20
4	40	2	±15	6
4	20	2	±15	7

4 Sector Dipoles—3rd Harmonic

Freq. MHZ	X ε_I mm	Y ε_I mm	Z ε_I mm	X Merit	Y Merit	Z Merit	Total Merit
100	12	8.7	41	2.2	2.4	12.2	34
200	13	8.9	24	2.4	2.3	7.4	20.3
400	11	7.8	8.5	1.8	1.8	1.8	2.0

Summary

- Gas filled rings have potential as muon cooling/storage rings.
- The weak-focusing, 6-sector dipole lattices configured for harmonic n=3 at 200 MHz is a promising model for a prototype system.

Still to do

- Injection/ejection system.
- Full (GEANT) 3D simulation.