UCLA Ring Cooler Simulation

Yasuo Fukui
UCLA, e-mail: fukui@slac.stanford.edu

- March 7-8 2002 UCLA Workshop
  The Use of Ring Cooler for a Neutrino Factory and Higgs Factory/ Muon Collider
  (Ring Cooler Complex and FFAG Front End for a Higgs factory)
- Dec 2001 Tucson Workshop Book is completed. A lot of discussion and things to do. Web page is coming on.
  Y. Fukui, D. Cline, A. Garren, P. He (UCLA)
  A. Bogacz(Jefferson Lab), D. Errede(UIUC),
  H. Kirk(BNL), F. Mills(Fermilab)
- Update on the UCLA Ring Cooler Simulation
  - SYNCH - ICOOL comparison
  - emittance development with/without scattering, straggling
  - muon transmission, lost muons
- Conclusion

MINI WORKSHOP AT

UCLA

THE USE OF A RING COOLER FOR A NEUTRINO FACTORY AND A HIGGS FACTORY / MUON COLLIDER

Organizers:
David Cline, Gail Hanson, Harold Kirk and David Neuffer

March 7, 8, 2002

UCLA

FACULTY CENTER

Muon Collaboration

UCLA

Ring Cooler Workshop

Tucson, AZ
December 3-4, 2001

Organizers:
Yasuo Fukui and Sylvia Vartan

Storage Ring Design is done by Al Garren by using SYNCH code.

- SYNCH is a linear transfer matrix code with all magnet components with hard edge magnetic field.
- SYNCH does not have RF cavities, energy absorbers, higher order transfer matrices, particle tracking.
- SYNCH gives the initial parameters of the magnet location and field strength for the ICOOL, ray tracing code.
- Check consistency of beam functions, β_x, β_y, and η (dispersion) in SYNCH and ICOOL
- Check single particle tracking
- apply RF cavities and wedge absorbers in ICOOL. Modify Dipole and Quadrupole magnet currents accordingly.
- Equilibrium normalized emittances
  ϵ_{nx}, ϵ_{ny}, $\sim$ 1 mm rad (input = 2 mm rad)
  ϵ_{nz} $\sim$ 10 mm (input = 20 mm)
  A factor 8 = 2 x 2 x 2 gain at maximum.
- transmission is a problem due to resonances at Δp/p = $\sim$ +10 %, -5 %. 16 cell ring performs better in the transmission.
- In order to obtain more 6 dimensional cooling, a ring design with the Li lens cooler is a must, with a smaller equilibrium normalized emittances.

Table 1: Comparison of an electron damping ring and the Muon Cooling ring

	e **Damping Ring**		
phase space	x	y	z
Damping	x' synch.rad. +RF	y' synch.rad. +RF	synch.rad. $\Delta E \propto E^4$
Excitation	x-x' orbit change		quantum fluct. $\propto E^{3.5}$
Partition #	$(1 - \mathcal{D})$	1	$2 + \mathcal{D}$

	μ **Cooling Ring with Wedge Absobers**		
phase space	x	y	z
Damping	x' Ion.Cooling	y' Ion.Cooling	$\Delta E \propto$ E in Wedge
Excitation	x-x' orbit change mult.scat.	mult.scat.	$\frac{dE}{dx}$ straggling $\propto E^2$
Partition #	2-d	2	d

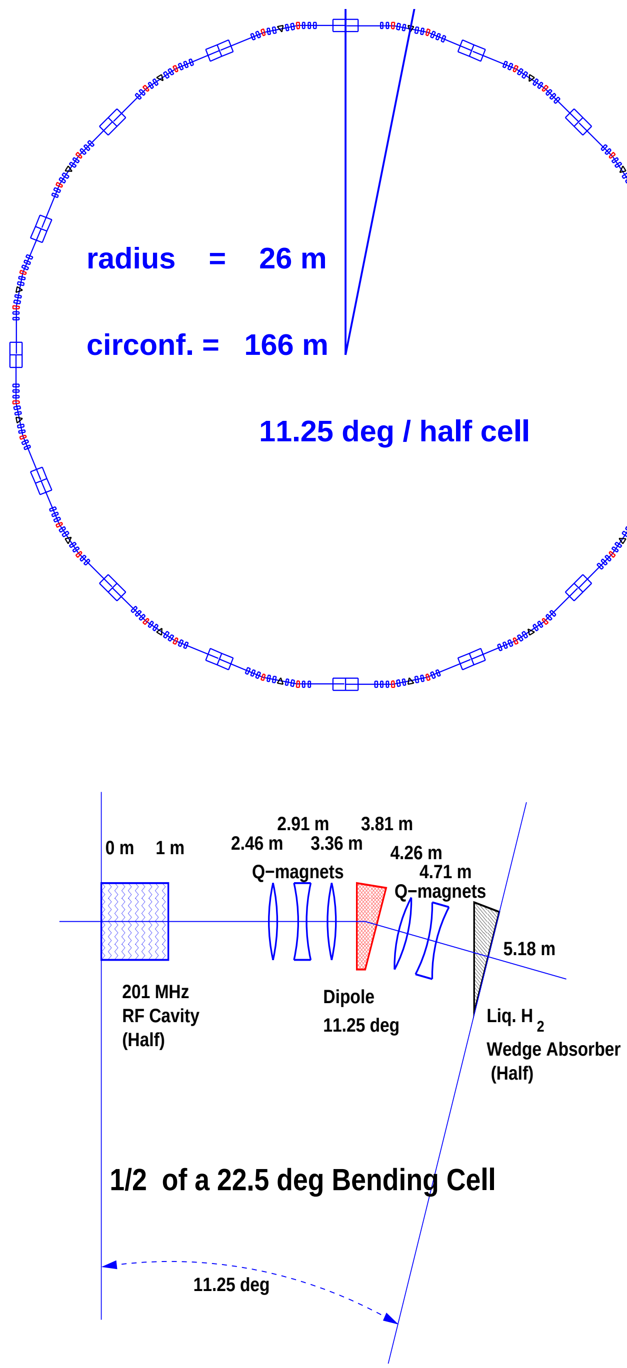


Figure 1: Top view of the 16 cell UCLA Emittance Exchange Ring, and a schematic drawing of a ring components in the 11.25 degree Half Cell section

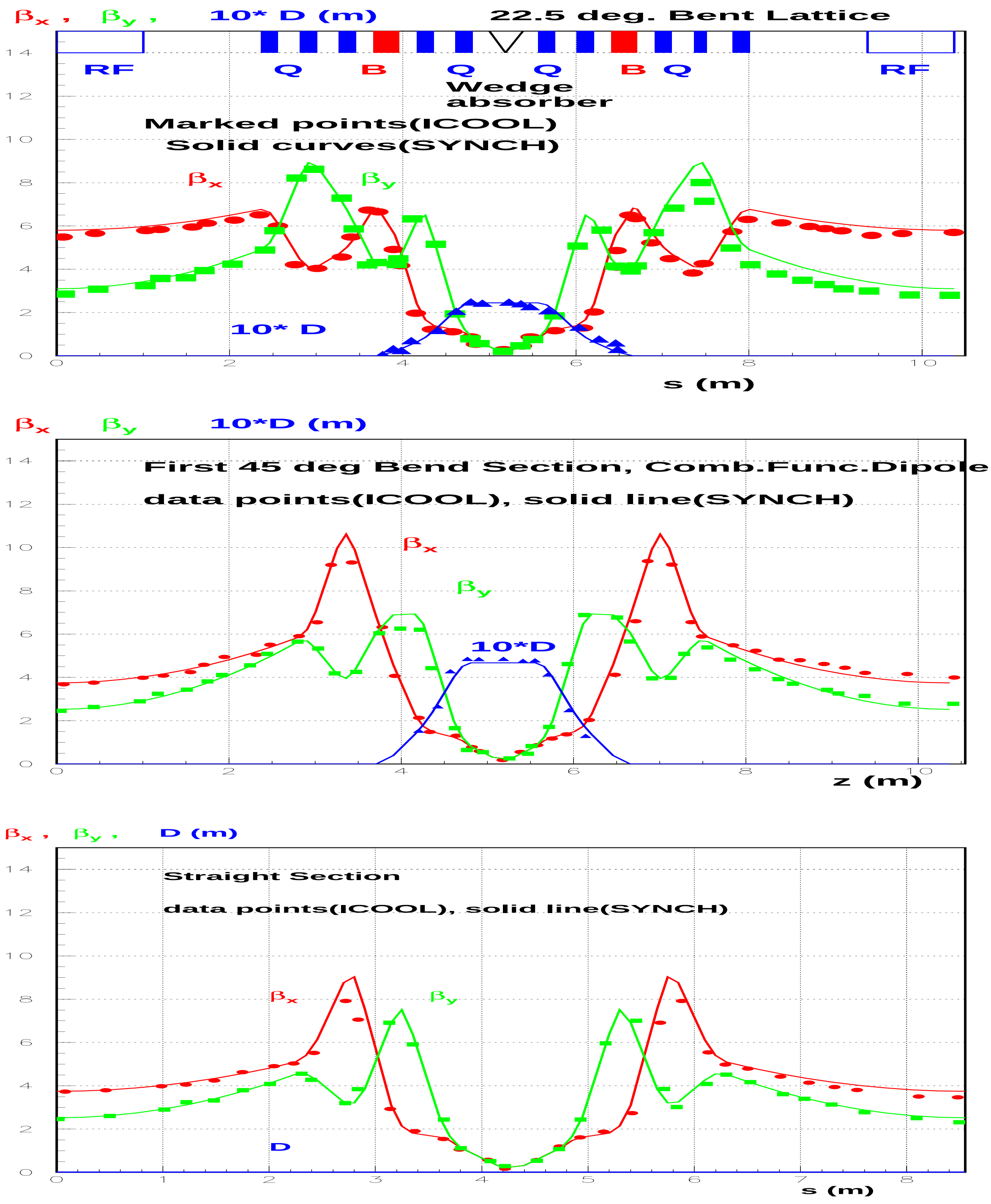
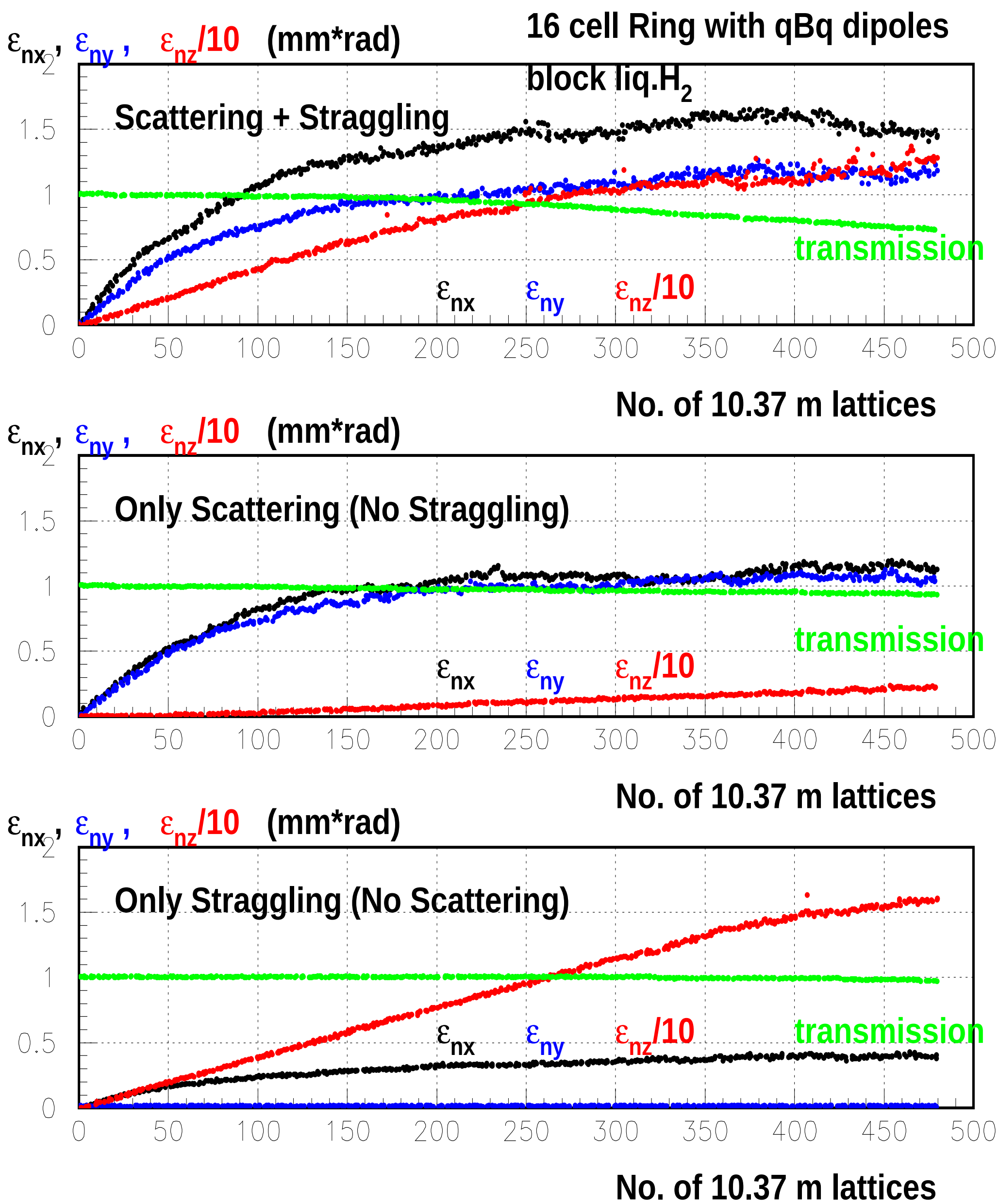
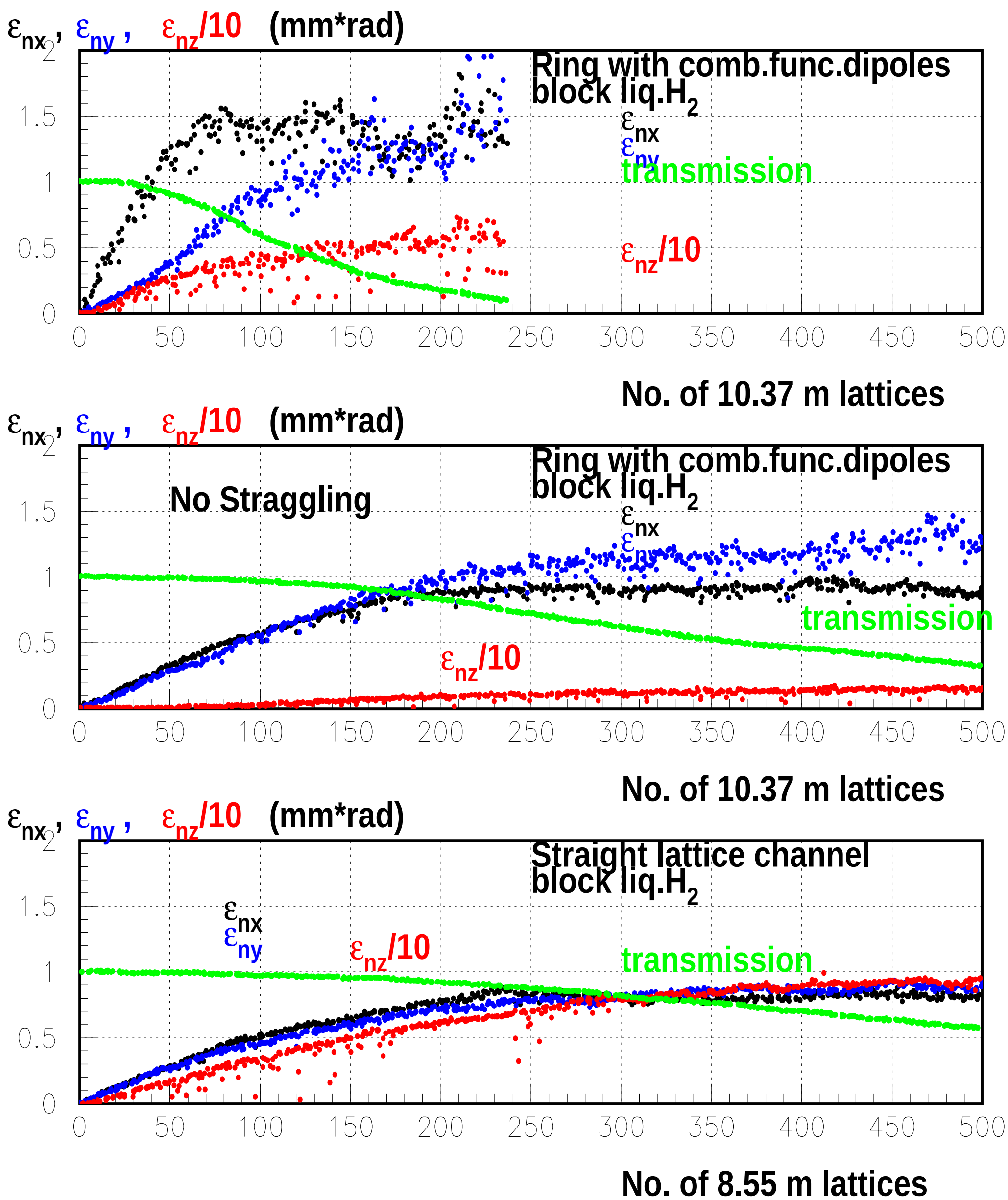
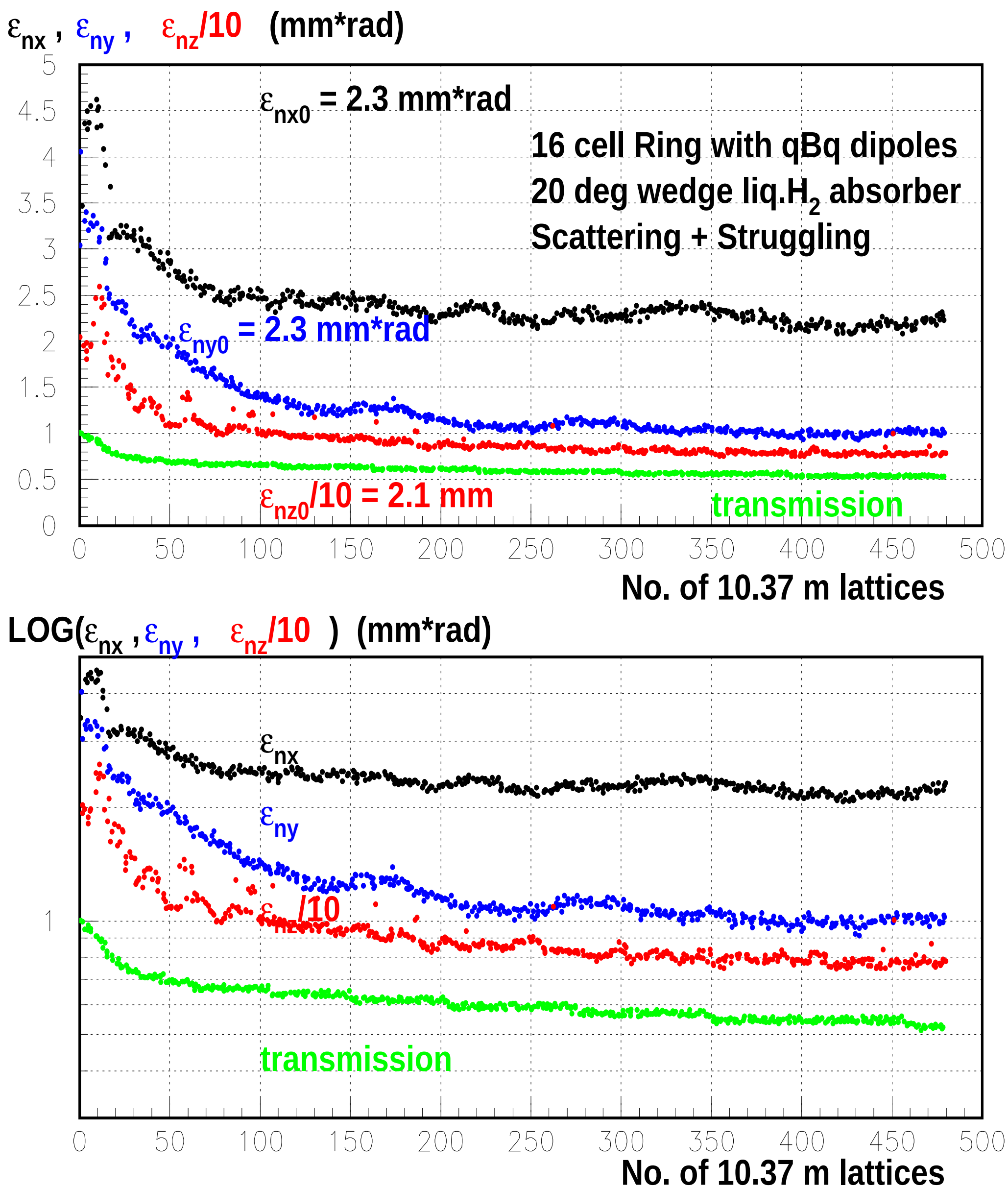


Figure 2: ICOOL - SYNCH comparison in a 22.5/45 deg Bending Cell and in a straight cell

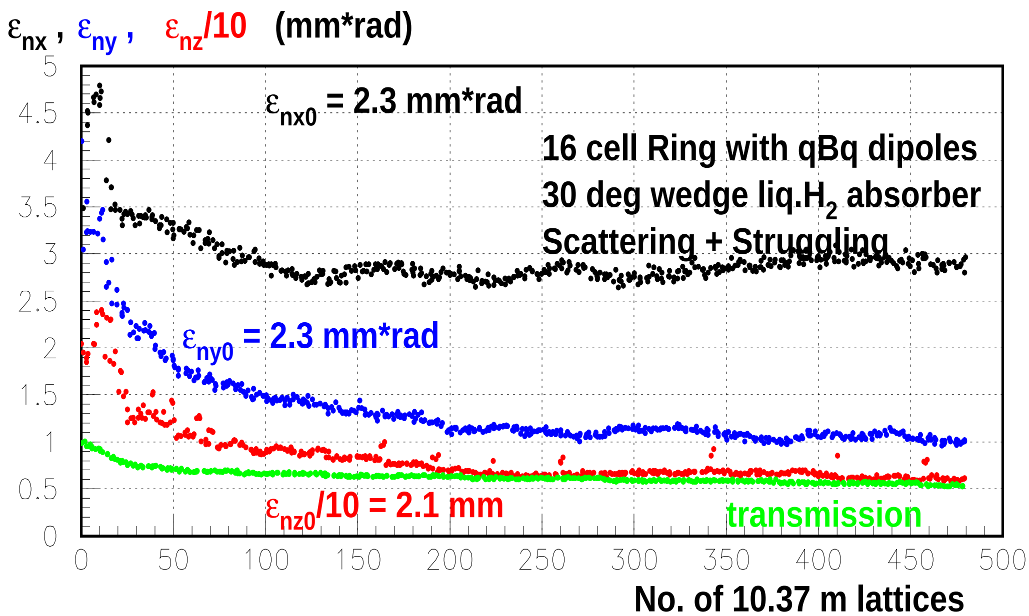

16 cell Ring with qBq dipoles
block liq.H_2
ε_{nx}, ε_{ny}, ε_{nz}/10 (mm*rad)
Scattering + Straggling
transmission
ε_{nx} ε_{ny} ε_{nz}/10
No. of 10.37 m lattices
ε_{nx}, ε_{ny}, ε_{nz}/10 (mm*rad)
Only Scattering (No Straggling)
transmission
ε_{nx} ε_{ny} ε_{nz}/10
No. of 10.37 m lattices
ε_{nx}, ε_{ny}, ε_{nz}/10 (mm*rad)
Only Straggling (No Scattering)
transmission
ε_{nx} ε_{ny} ε_{nz}/10
No. of 10.37 m lattices



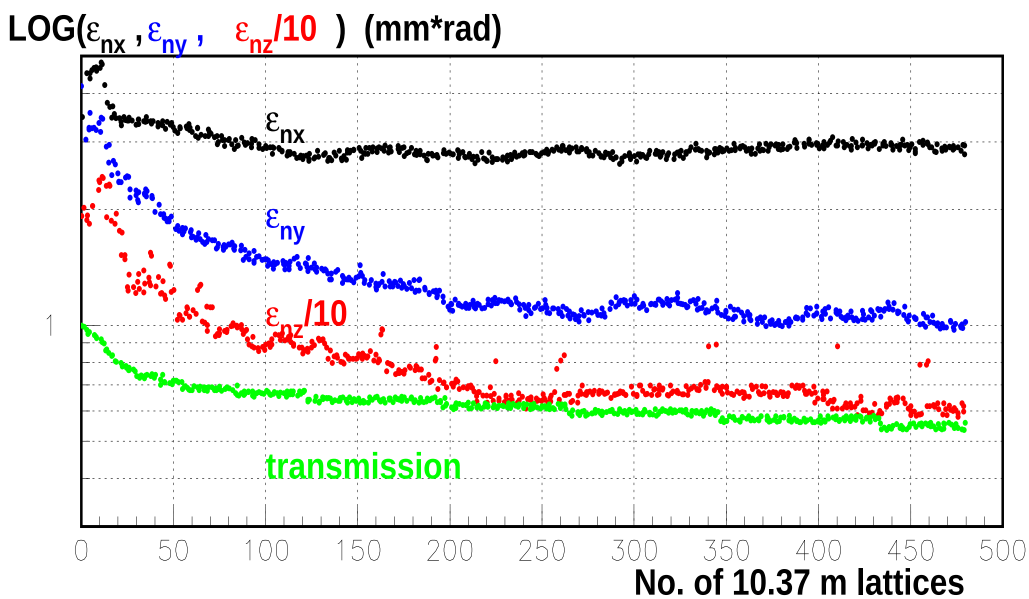
εnx, εny, εnz/10 (mm*rad)
Ring with comb.func.dipoles
block liq.H2
εnx
εny
transmission
εnz/10
0 50 100 150 200 250 300 350 400 450 500
0 0.5 1 1.5 2
No. of 10.37 m lattices
εnx, εny, εnz/10 (mm*rad)
Ring with comb.func.dipoles
block liq.H2
No Straggling
εnx
εny
transmission
εnz/10
0 50 100 150 200 250 300 350 400 450 500
0 0.5 1 1.5 2
No. of 10.37 m lattices
εnx, εny, εnz/10 (mm*rad)
Straight lattice channel
block liq.H2
εnx
εny
εnz/10
transmission
0 50 100 150 200 250 300 350 400 450 500
0 0.5 1 1.5 2
No. of 8.55 m lattices



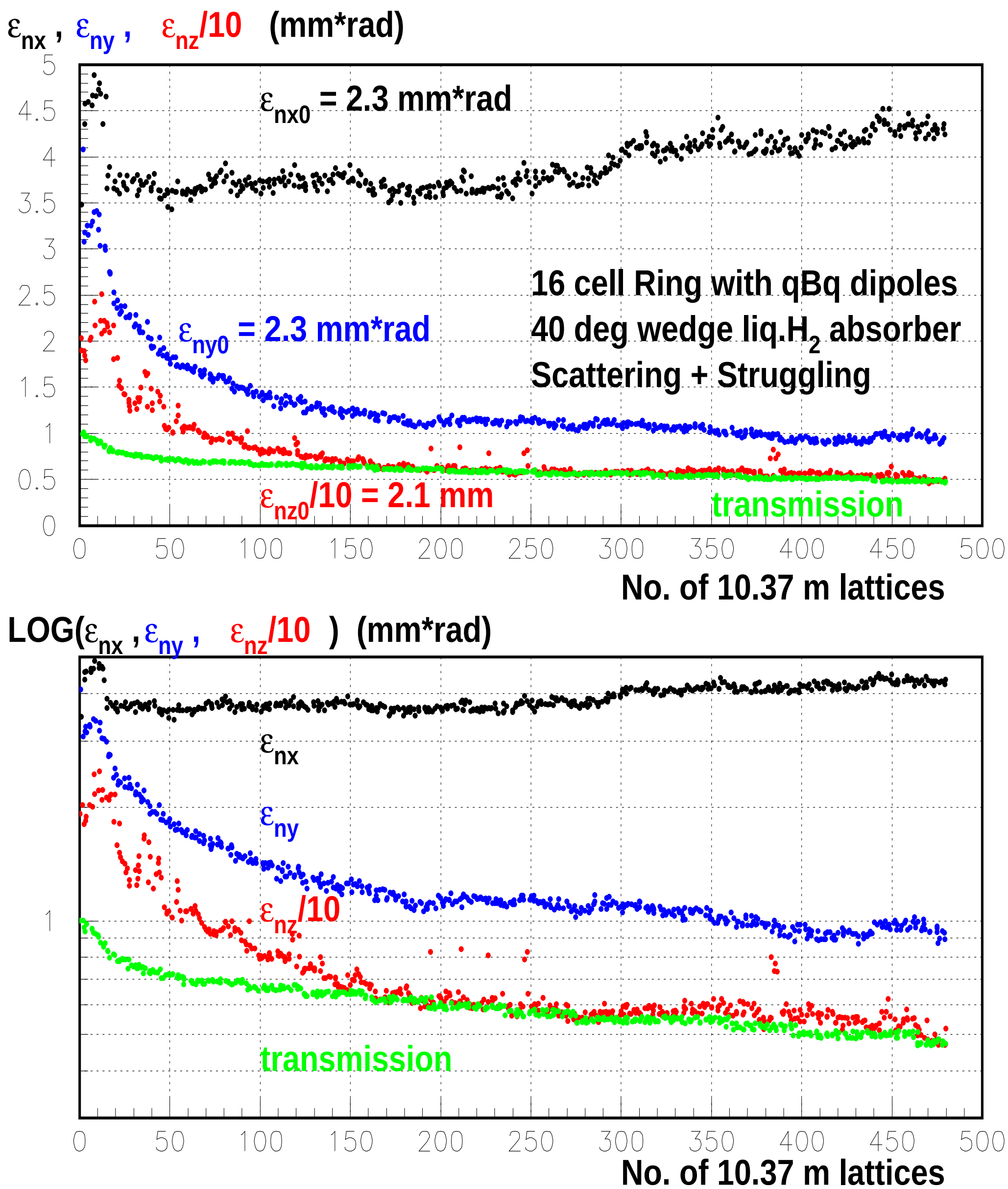
εnx , εny , εnz/10 (mm*rad)
εnx0 = 2.3 mm*rad
16 cell Ring with qBq dipoles
20 deg wedge liq.H2 absorber
Scattering + Struggling
εny0 = 2.3 mm*rad
εnz0/10 = 2.1 mm
transmission
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5
0 50 100 150 200 250 300 350 400 450 500
No. of 10.37 m lattices
LOG(εnx , εny , εnz/10) (mm*rad)
εnx
εny
εnz/10
transmission
1
0 50 100 150 200 250 300 350 400 450 500
No. of 10.37 m lattices



εnx , εny , εnz/10 (mm*rad)
εnx0 = 2.3 mm*rad
16 cell Ring with qBq dipoles
30 deg wedge liq.H2 absorber
Scattering + Struggling
εny0 = 2.3 mm*rad
εnz0/10 = 2.1 mm
transmission
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5
0 50 100 150 200 250 300 350 400 450 500
No. of 10.37 m lattices



LOG(εnx , εny , εnz/10) (mm*rad)
εnx
εny
εnz/10
1
transmission
0 50 100 150 200 250 300 350 400 450 500
No. of 10.37 m lattices


εnx , εny , εnz/10 (mm*rad)
εnx0 = 2.3 mm*rad
εny0 = 2.3 mm*rad
16 cell Ring with qBq dipoles
40 deg wedge liq.H2 absorber
Scattering + Struggling
εnz0/10 = 2.1 mm
transmission
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
50
100
150
200
250
300
350
400
450
500
No. of 10.37 m lattices
LOG(εnx , εny , εnz/10) (mm*rad)
εnx
εny
εnz/10
transmission
1
0
50
100
150
200
250
300
350
400
450
500
No. of 10.37 m lattices

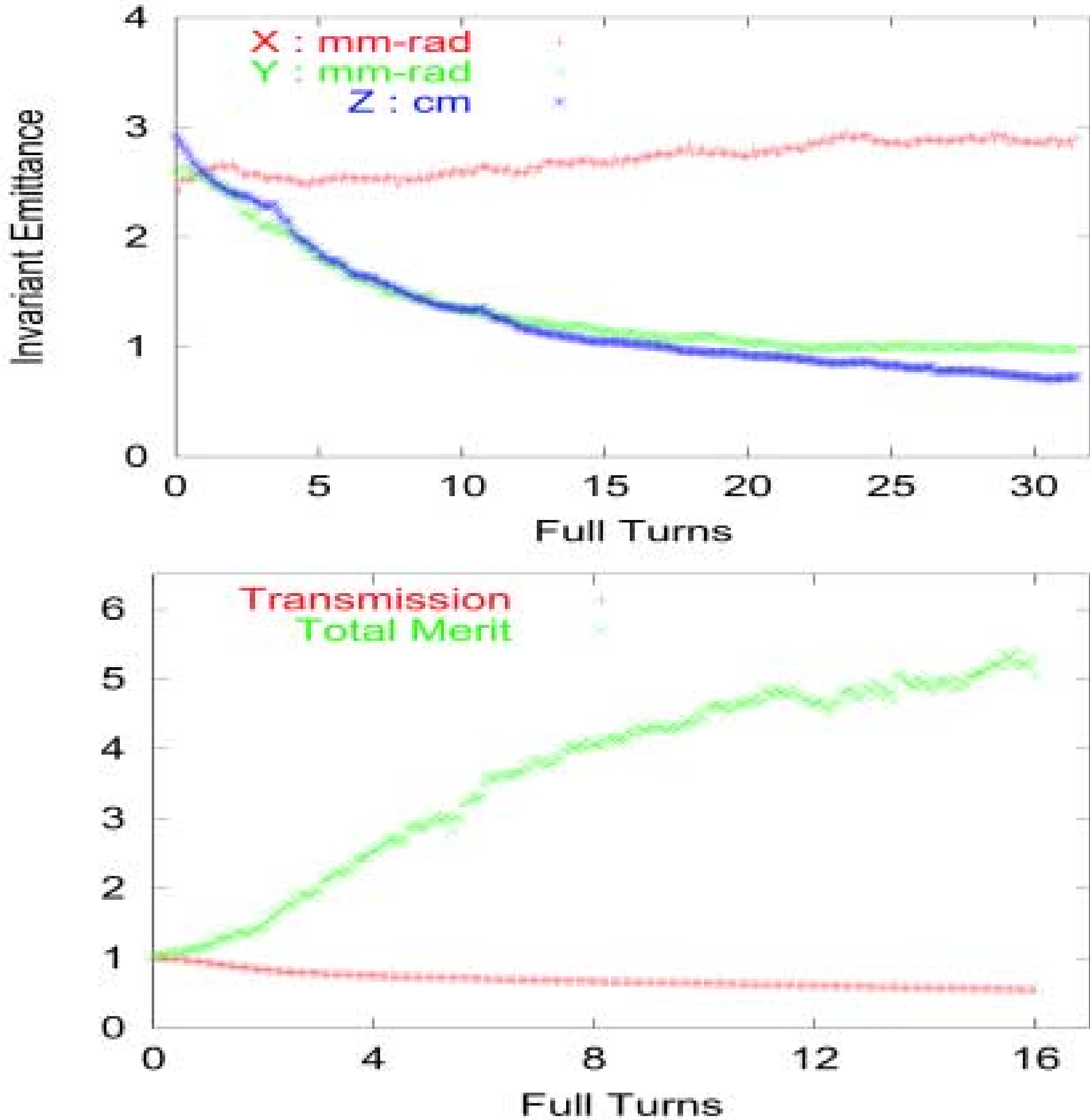


Figure 3: Normalized Emittance evolution in a 16 cell ring(Top) and evolution of a merit factor and muon transmission(Bottom). (H. Kirk, Tucson UCLA Ring Cooler Workshop)

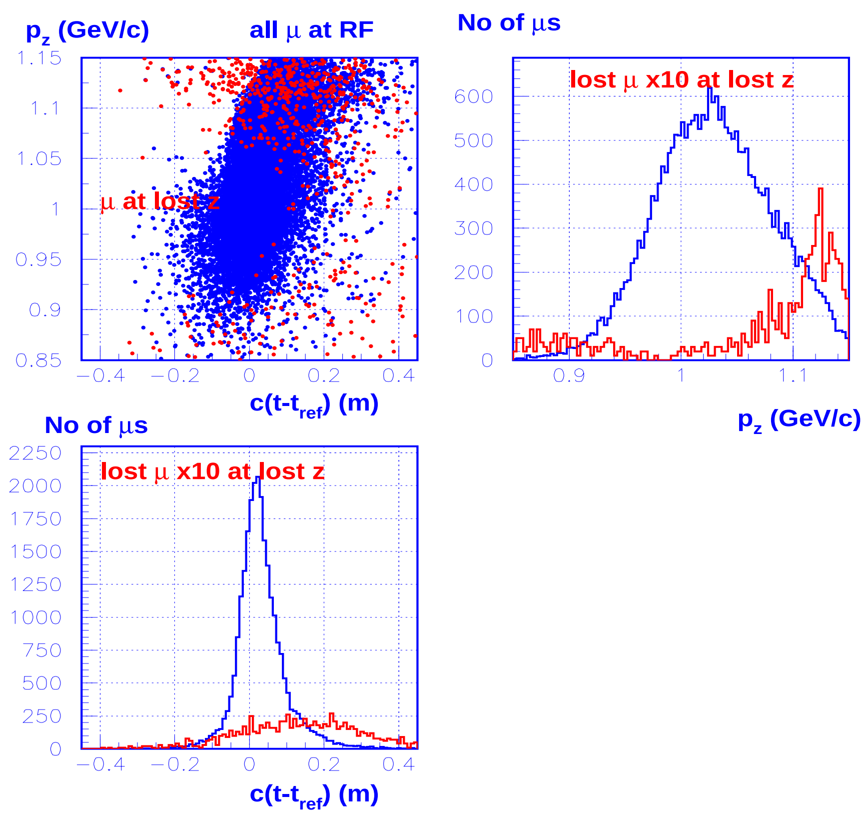
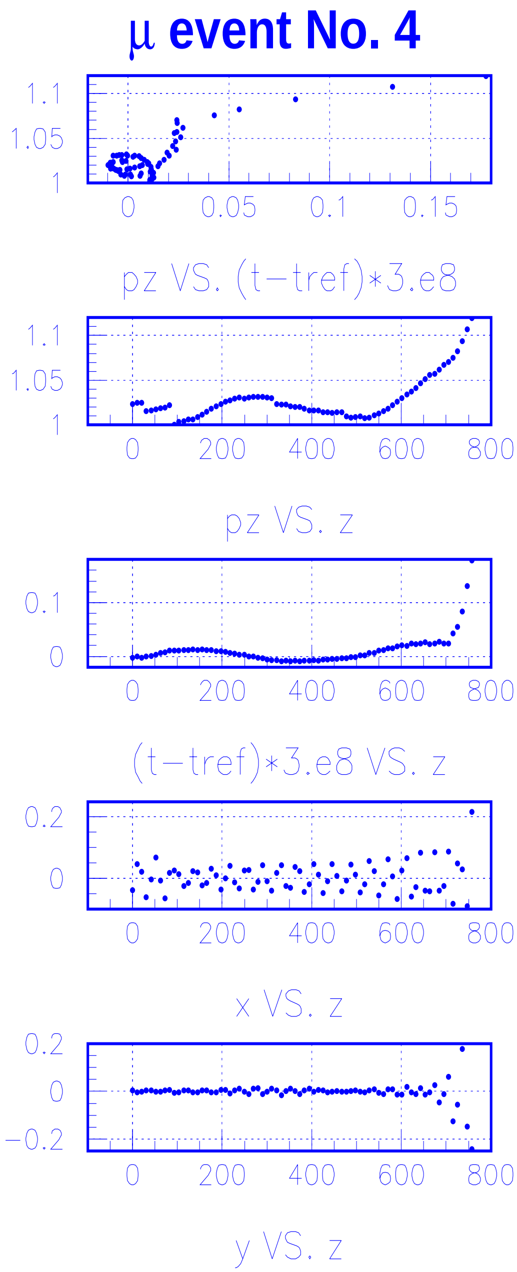
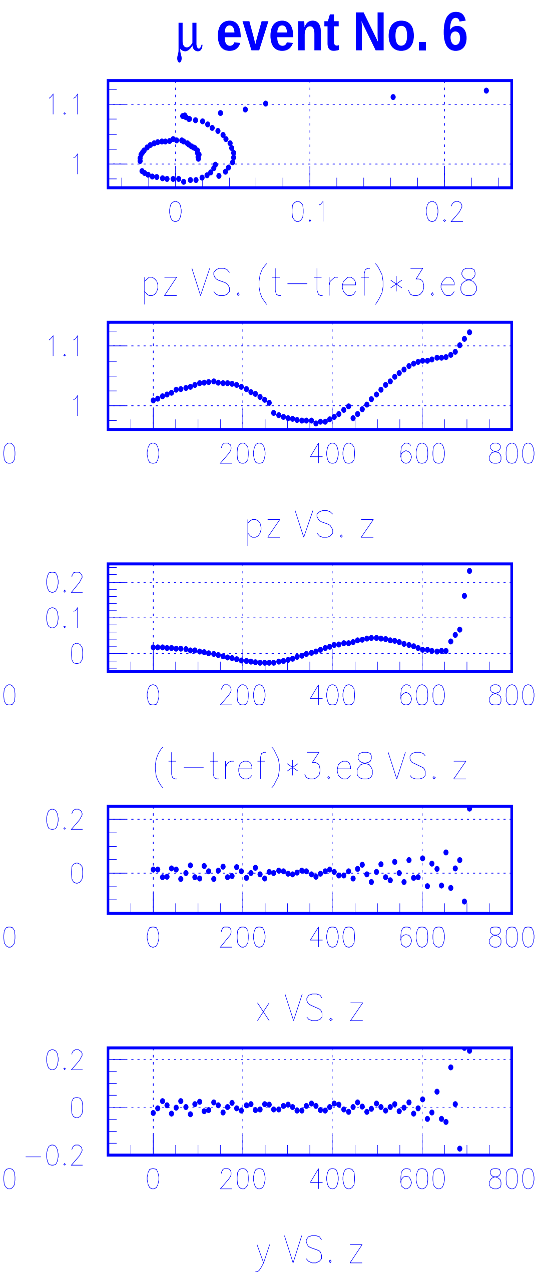


Figure 4: Longitudinal phase space of the lost muons and surviving muons


μ event No. 4
1.1
1.05
1
0
0.05
0.1
0.15
pz VS. (t−tref)∗3.e8
1.1
1.05
1
0
200
400
600
800
pz VS. z
0.1
0
0
200
400
600
800
(t−tref)∗3.e8 VS. z
0.2
0
0
200
400
600
800
x VS. z
0.2
0
−0.2
0
200
400
600
800
y VS. z


μ event No. 6
1.1
1
0
0.1
0.2
pz VS. (t−tref)∗3.e8
1.1
1
0
200
400
600
800
pz VS. z
0.2
0.1
0
0
200
400
600
800
(t−tref)∗3.e8 VS. z
0.2
0
0
200
400
600
800
x VS. z
0.2
0
−0.2
0
200
400
600
800
y VS. z

things-to-do list

1. Make the 16 cell ring design with combined function bending magnets as a baseline model.
2. Apply skew quadrupole magnets in the baseline model to couple the x and y emittances.
3. Implement sextupoles in a ring to improve muon transmission.
4. Design magnets and generate realistic magnetic fields with a design aperture radius of 21 cm.
5. Use COSY to get the initial parameters of a ring with fringe fields (soft edges) of dipoles and quadrupoles.
6. Study on storage rings with various number of lattices, where the sizes of dispersion at the absorber with low β_x, β_y are different.
7. Check the performance of a muon cooling ring with vertical bending lattices and horizontal bending lattices.
8. Use Li lenses in the muon cooling ring or in an FFAG cooling ring for stronger 6 dimensional cooling power.

Summary

- Emittance Exchange and 6D cooling was demonstrated with the conventional magnet ring by using ICOOL simulation.
- 6D Cooling in a Cooling Ring with conventional magnets is similar to the phase space cooling in the electron damping rings.
- Need simulating the soft edged magnetic field, sextupole magnets, windows in liq. H2 wedges.
- Need a model of the emittance exchange/6D cooling ring with Li lens for much more 6D Cooling.