UCLA Ring Cooler Simulation

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- 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.
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  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
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, $\beta_x$, $\beta_y$, and $\eta$ (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
  $\epsilon_{nx}, \epsilon_{ny}, \sim 1$ mm rad (input = 2 mm rad)
  $\epsilon_{nz} \sim 10$ mm (input = 20 mm)
  A factor $8 = 2 \times 2 \times 2$ gain at maximum.
- transmission is a problem due to resonances at $\Delta p/p = \sim +10 \%$, -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

<table>
<thead>
<tr>
<th></th>
<th>$e$ Damping Ring</th>
<th>$\mu$ Cooling Ring with Wedge Absobers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>phase space</strong></td>
<td>x, y, z</td>
<td>x, y, z</td>
</tr>
<tr>
<td><strong>Damping</strong></td>
<td>$x'$ synch.rad. +RF</td>
<td>$x'$ Ion.Cooling, y' Ion.Cooling</td>
</tr>
<tr>
<td></td>
<td>$y'$ synch.rad. +RF</td>
<td>$\Delta E \propto E^4$ in Wedge</td>
</tr>
<tr>
<td><strong>Excitation</strong></td>
<td>$x-x'$, orbit change</td>
<td>$dE/dx$ straggling, $\propto E^2$</td>
</tr>
<tr>
<td></td>
<td>quantum fluct.</td>
<td></td>
</tr>
<tr>
<td><strong>Partition #</strong></td>
<td>$(1 - D)$, 1, 2 + D</td>
<td>2 - d, 2, d</td>
</tr>
</tbody>
</table>
radius = 26 m

circonf. = 166 m

11.25 deg / half cell

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
Scattering + Straggling

Only Scattering (No Straggling)

Only Straggling (No Scattering)
\[ \varepsilon_{nx}, \varepsilon_{ny}, \varepsilon_{nz}/10 \text{ (mm*rad)} \]

**Ring with comb.func.dipoles**
- **Block liq.H\(_2\)**
- **Transmission**

**No Straggling**

**Straight lattice channel**
- **Block liq.H\(_2\)**
- **Transmission**

**No. of 10.37 m lattices**

**No. of 8.55 m lattices**
\[ \varepsilon_{nx}, \varepsilon_{ny}, \varepsilon_{nz}/10 \text{ (mm*rad)} \]

- \[ \varepsilon_{nx0} = 2.3 \text{ mm*rad} \]
- 16 cell Ring with qBq dipoles
- 20 deg wedge liq.H\_2 absorber
- Scattering + Struggling

\[ \varepsilon_{ny0} = 2.3 \text{ mm*rad} \]

\[ \varepsilon_{nz0}/10 = 2.1 \text{ mm} \]

\[ \log(\varepsilon_{nx}, \varepsilon_{ny}, \varepsilon_{nz}/10) \text{ (mm*rad)} \]

- \[ \varepsilon_{nx} \text{ transmission} \]
- \[ \varepsilon_{ny} \text{ transmission} \]
- \[ \varepsilon_{nz}/10 \text{ transmission} \]

No. of 10.37 m lattices
\( \varepsilon_{nx} \), \( \varepsilon_{ny} \), \( \varepsilon_{nz}/10 \) (mm*rad)

- \( \varepsilon_{nx0} = 2.3 \text{ mm*rad} \)
- 16 cell Ring with qBq dipoles
- 30 deg wedge liq.H\text{2} absorber
- Scattering + Struggling

\( \varepsilon_{ny0} = 2.3 \text{ mm*rad} \)

\( \varepsilon_{nz0}/10 = 2.1 \text{ mm} \) transmission

\( \log(\varepsilon_{nx}, \varepsilon_{ny}, \varepsilon_{nz}/10) \) (mm*rad)

- transmission

No. of 10.37 m lattices
\( \varepsilon_{nx}, \varepsilon_{ny}, \varepsilon_{nz}/10 \) (mm*rad)

- \( \varepsilon_{nx0} = 2.3 \text{ mm*rad} \)
- \( \varepsilon_{ny0} = 2.3 \text{ mm*rad} \)
- \( \varepsilon_{nz0}/10 = 2.1 \text{ mm} \)

Graph showing the LOG(\( \varepsilon_{nx0}, \varepsilon_{ny0}, \varepsilon_{nz0}/10 \)) (mm*rad) with No. of 10.37 m lattices.

- 16-cell Ring with qBq dipoles
- 40 deg wedge liq.H_2 absorber
- Scattering + Struggling

Graph showing transmission with 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
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 $\beta_x$, $\beta_y$ 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.