The Muon Collider/Neutrino Factory
Solenoid Capture System

Solenoid Capture Workshop

Brookhaven National Lab

November 29-30, 2010
The Muon Collider Concept

Key technical issues:

- Requires a multi-MW proton driver
- A production target system to produce copious pions
- A cooling system to reduce the phase space of the collected muons
- High gradient rf for rapid acceleration
The Neutrino Factory

The muons in a storage ring decay such that:

\[
\mu^+ \rightarrow e^+ \bar{\nu}_e \nu_\mu \quad \text{and} \quad \mu^- \rightarrow e^- \nu_e \bar{\nu}_\mu
\]

Further, the \( \nu \)'s are projected forward with an opening angle \( \sim 1/\gamma \).

This gives rise to a very powerful \( \nu \) beam capable of being projected over long baseline distances.
Layout of a Neutrino Factory

- Proton Driver
- FFAG/synchrotron option
- Linac option
- Neutrino Beam
- Hg Target
- Buncher
- Bunch Rotation
- Cooling
- 0.9-3.6 GeV RLA
- 3.6-12.6 GeV RLA
- Linac to 0.9 GeV
- 12.6-25 GeV FFAG
- 755 m

Muon Storage Ring

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The Neutrino Factory Target Concept

Maximize Pion/Muon Production

- Soft-pion Production
- High-Z materials
- High-Magnetic Field

Meson Production - 16 GeV $p + W$

Feasibility Study-2: 24 GeV $p$ on Hg-jet  MAS914(2001)

Palmer, PAC97

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# The Proton Beam Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proton Beam Energy</td>
<td>8 GeV</td>
</tr>
<tr>
<td>Rep Rate</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Bunch Structure</td>
<td>3 bunches, 320 μsec total</td>
</tr>
<tr>
<td>Bunch Width</td>
<td>2 ± 1 ns</td>
</tr>
<tr>
<td>Beam Radius</td>
<td>1.2 mm (rms)</td>
</tr>
<tr>
<td>Beam $\beta^*$</td>
<td>$\geq 30$ cm</td>
</tr>
<tr>
<td>Beam Power</td>
<td>4 MW ($3.125 \times 10^{15}$ protons/sec)</td>
</tr>
</tbody>
</table>
# The Target System

<table>
<thead>
<tr>
<th>Target type</th>
<th>Free mercury jet</th>
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<tbody>
<tr>
<td>Jet diameter</td>
<td>8 mm</td>
</tr>
<tr>
<td>Jet velocity</td>
<td>20 m/s</td>
</tr>
<tr>
<td>Jet/Solenoid Axis Angle</td>
<td>96 mrad</td>
</tr>
<tr>
<td>Proton Beam/Solenoid Axis Angle</td>
<td>96 mrad</td>
</tr>
<tr>
<td>Proton Beam/Jet Angle</td>
<td>27 mrad</td>
</tr>
<tr>
<td>Capture Solenoid Field Strength</td>
<td>20 T</td>
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</tbody>
</table>
The NF Study 2 Target System

Neutrino Factory Study 2 Target Concept

Harold G. Kirk
Target System Exploded View

All insertion/extraction from upstream end
Locating & supporting features not shown – will require additional space
MARS15 Study of the Hg Jet Target Geometry

Previous results: Radius 5mm, $\theta_{\text{beam}} = 67\text{mrad}$
$\Theta_{\text{crossing}} = 33\text{mrad}$
Multiple Proton Beam Entry Points

Entry points are asymmetric due to the beam tilt in a strong magnetic field.

Proton Beam Entry points upstream of jet/beam crossing

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Production of soft pions is most efficient for a Hg target at $E_p \sim 6-8$ GeV, Confirmation of low-energy drop-off by experiment (HARP, MIPP) highly desirable.
Meson Production vs $\beta^*$

Meson Production loss $\leq 1\%$ for $\beta^* \geq 30\text{cm}$
MARS15 study of Study 2 configuration yields 38KW energy deposition in SC1 alone
Reconfigure SC magnets

Increase the SC ID’s. Fill released volume with shielding. Total energy deposition in all SC’s reduced to ~4kW. But SC magnets around target are now extremely difficult.

Details to be provided by N. Souchlas
Key Target Challenges

General Target Issues
- Thermal management (~3MW power deposited)
- Shielding (SC Solenoids required)
- Target integrity (Thermal Shock)
- Target regeneration (50Hz rep-rate)
- 20T environment

Liquid Hg specific issues
- Stable fluid flow (Nozzle performance)
- Hg handling system