R&D Issues for Targetry and Capture at a Neutrino Factory and Muon Collider Source

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Targetry Workshop, BNL

http://puhep1.princeton.edu/mumu/target/

[This is the 26th edition of targetry reviews that began at the Orange Beach meeting, March 1998.]
Requirements for Targetry and Capture

- Get muons from pion decay: $\pi^\pm \rightarrow \mu^\pm \nu$.
- Pions from proton-nucleus interactions in a target.
- Goal: $1.2 \times 10^{14} \mu^\pm/s$ with a 4-MW $p$ beam (1 MW at $t_0$).
Baseline Scenario

- High-energy proton beam: 16 or 24 GeV.

- High magnetic field (20 T) around target to capture pions with $P_\perp < 220$ MeV/$c$, $50 < P_\parallel < 400$ MeV/$c$.

- Adiabatic reduction of $B$ to $\approx 1$ T in decay channel.

- High-Z target.

- Tilt target by $\approx 0.1$ rad to maximize pion yield.

- No cooling apparatus near target.

- High power of beam could crack stationary target

- $\Rightarrow$ Free liquid metal jet as target: Hg, Pb/Bi, ...

Colin Johnson:

Kirk T. McDonald

December 15, 2000
Baseline Scenario

incident proton beam
injection
Hg pipe
Iron pole
proton beam

SC coil
Cu coil
Magnetic field lines
Hg jet
proton beam
A Carbon Target is Feasible at 1-MW Beam Power

But a few-nsec beam pulse causes severe pressure waves.

A rotating band target is another option:
Two Classes of Issues

1. Viability of targetry and capture for a single pulse (E951).
   - Beam energy deposition may disperse the jet.
   - Eddy currents may distort the jet as it enters the magnet.

2. Long-term viability of the system in a high radiation area (Feasibility Study 2).
The Neutrino Factory and Muon Collider Collaboration

The First Three Stages of E951

1. Tests of targets in an intense beam (without magnetic field).
   - In the BNL A3 beamline: 24 GeV $p$'s, up to $1.5 \times 10^{13}$ $p$/bunch, up to 6 bunches spaced by 20 ms.
   - Targets: carbon, mercury, Wood’s metal, inconel, ....

2. Tests of liquid metal entering a magnet (without beam).
   - At the 20-T hybrid magnet facility of the NHMFL (Florida).

3. Tests of liquid target + beam + 20-T pulsed magnet.
Agenda, E951 Workshop, Dec. 15

Overview

08:30-09:00 K. McDonald (Princeton)

A3 beamline

09:00-09:20 K. Brown (BNL) Beam Optics
09:20-09:40 K. Brown (BNL) Beam Instrumentation
09:40-10:00 R. Prigl (BNL) Beam Shielding Design

10:00-10:20 Coffee Break

10:20-10:40 N. Simos (BNL) Beam Windows
10:40-11:00 J. Scaduto (BNL) Status of Construction

A3 Target Tests

11:00-11:20 K. McDonald (Princeton) Target Test Program
11:20-11:40 C. Finfrock (BNL) Mercury Jets, Horizontal & Vertical
11:40-12:00 H. Wang (BNL) High-Speed Camera System

12:00-13:00 Lunch
A3 Target Tests, cont’d.

13:00-13:20 J. Haines (ORNL) Carbon, Room Temp, Strain Sensors
13:40-14:00 J. Norem (ANL) Schlieren Photography
14:00-14:20 A. Zeller (MSU) Neutron Studies

A3 Safety Committee Issues

14:20-14:50 H. Kirk (BNL) Safety Committee Issues
14:50-15:10 Coffee Break

NHMFL Mercury Test

15:10-15:30 K. McDonald (Princeton) Goals
15:30-15:50 J. Miller (NHMFL) 20-cm Bore, 20-T Hybrid Magnet

20-T Pulsed Magnet Design

15:50-16:10 B. Weggel (BNL) System Requirements
16:10-16:30 P. Hwang (Everson Electric) System Design
16:30-16:50 Steve Van Sciver (NHMFL) System Design

Summary

16:50-17:10 H. Kirk (BNL) Action Items
**Proton Driver:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>24 GeV</td>
</tr>
<tr>
<td>$p$ per bunch</td>
<td>$\approx 1.7 \times 10^{13}$</td>
</tr>
<tr>
<td>Bunches per cycle</td>
<td>6</td>
</tr>
<tr>
<td>Time between extracted bunches</td>
<td>20 ms</td>
</tr>
<tr>
<td>Average repetition rate</td>
<td>2.5 Hz</td>
</tr>
<tr>
<td>Peak repetition rate</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Beam power</td>
<td>$\geq 1$ MW</td>
</tr>
<tr>
<td>rms bunch length</td>
<td>$\leq 3$ ns</td>
</tr>
</tbody>
</table>

![Diagram showing 6 extracted bunches with 1.7e13 protons each, spaced 200 ms apart, with a 400 ms period.](image-url)
# Feasibility Study 2, Target-related Parameters

## Target:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>mercury</td>
</tr>
<tr>
<td>Velocity</td>
<td>$\approx 30 \text{ m/sec}$</td>
</tr>
<tr>
<td>Diameter</td>
<td>$1 \text{ cm}$</td>
</tr>
<tr>
<td>Angle: target axis to magnet axis</td>
<td>$100 \text{ mrad}$</td>
</tr>
<tr>
<td>Angle: beam axis to target axis</td>
<td>$33 \text{ mrad}$</td>
</tr>
<tr>
<td>Interaction region</td>
<td>$60 \text{ cm}$</td>
</tr>
<tr>
<td>Displacement of front from axis</td>
<td>$\approx 1 \text{ cm}$</td>
</tr>
</tbody>
</table>

## Issues:

- How to get the jet into the magnet?
- Will the first of 6 beam pulses disrupt the whole jet?
Capture and Matching Solenoids

The 20 T capture solenoid would be a hybrid, with copper (insert) and superconducting (outsert), magnet similar to that discussed in Feasibility Study 1. However, it is proposed here to use hollow copper conductor for the insert, rather than a Bitter style magnet in Study 1. The choice is aimed at achieving longer magnet life and avoiding any problems with highly irradiated water insulation. It is understood that the initial cost will be higher.

After the 20 T magnet, coils are designed to taper the axial field down slowly to 1.25 T over a distance of approximately 18 m. The form of the tapered field is approximately $B(z) \approx \frac{20}{1 + k z}$. The final design will have to include space for the beam dump and shielding.
Beam Dump

The proton beam is dumped, and the mercury jet collected, several meters downstream of the interaction region:
Phase Rotation

08:30-08:55 L. Reginato (LBNL) Induction Linac: Baseline Design
08:55-09:20 Y. Fukui (UCLA) Option C Modifications

Target Station and Decay Channel

09:20-09:45 P. Spampinato (ORNL) Decay Channel Systems Issues
09:45-10:10 N. Mokhov (FNAL) Prompt & Residual Radiation Environment
10:10-10:30 Coffee Break
10:30-10:55 H. Ravn (CERN) Targetry R&D at CERN
10:55-11:20 J. Haines (ORNL) Mercury Target Issues
11:20-11:45 J. Cline (ANL) Radiation Chemistry of Cooling Water
11:45-13:00 Lunch
Agenda, Feasibility Study 2 Workshop, Dec. 16, Cont’d.

Liquid Metal Jet – Magnet Interaction

13:00-13:25  K. McDonald (Princeton)  Review of Analytic Studies
13:50-14:15  R. Samulyak (BNL)  Numerical Studies with the Frontier Code

20-T Solenoid – Hollow Conductor Option

14:15-14:45  J. Miller (FSU)  Issues and Criteria
14:45-15:10  B. Weggel (BNL)  Design Concept
15:10-15:30  Coffee Break

Beam Simulation Issues

15:30-15:55  I. Stumer (BNL)  GEANT Studies
15:55-16:20  Y. Torun (BNL)  Comparison with E910

Discussion

16:20-17:00  All  Discussion