The MERIT
High-Power Target Experiment

Muon Collider Design Workshop

BNL

December 3-7, 2007

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The Collaborating Institutions

U.S.

Brookhaven National Laboratory
Fermi National Accelerator Laboratory
Oak Ridge National Laboratory
Princeton

Europe

CERN
Rutherford Appleton Laboratory

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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 $p + W$

$dN/dKE (1/GeV/interacting proton)$

Pion Kinetic Energy, GeV
The MERIT Experiment

MERcury Intense Target

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Site of experiment at CERN

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Profile of the Experiment

- 14 and 24 GeV proton beam
- Up to $30 \times 10^{12}$ protons (TP) per 2.5 μs spill
- Proton beam spot with $r \leq 1.5$ mm rms
- 1 cm diameter Hg Jet
- Hg Jet/proton beam off solenoid axis
  - Hg Jet 33 mrad
  - Proton beam 67 mrad
- Test 50 Hz operations
  - 20 m/s Hg Jet
Proton Beam Characteristics

- PS was run in a harmonic 4, 8, and 16 mode
- We can fill any of the rf buckets with sub-bunches at our discretion.
- Total PS fill can contain up to 30 TP.
- Fast extraction can accommodate entire 2.5 $\mu$s PS fill.
- Single turn extraction at 24 GeV
- Partial/multiple extraction possible at 14 GeV
- First Beam on Target October 17 2007
Run plan for the CERN PS beam

The PS Beam Profile allows for:

- Varying beam charge intensity from 1 TP to 30 TP.
- Studying influence of solenoid field strength on jet dispersal (vary $B_z$ from 0 to 15T).
- Study possible cavitation effects by varying PS spill structure (Pump/Probe)
MERIT Experiment in the TT2a Area

- Material access shaft
- Personnel access
- Racks & electronics
- N2 Exhaust line
- TUNNEL TT2A
- TT2 A TUNNEL
- Beam dump
- Solenoid & Hg loop
- Upstream beam elements (new)
  - Quadrupoles for final focusing
  - Collimator
  - Beam profile measurement
  - Beam intensity measurement

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Installed in the CERN TT2a Line

Before Mating

After Mating and Tilting

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Beam instrumentation

Beam current transformer: 500 MHz sampling!

Particle detector response:
The Pump/Probe Detectors

- ACEM (Aluminum Cathode Electron Multiplier)
- Diamond

In beam line, upstream of target

+/- 10 degrees
+/- 20 degrees

Behind dump in beam line

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Diamond Left $20^0$ Response

Oct. 29, 2007
14 GeV
4TP
10T Field
15m/s Hg Jet

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A 3T Pump Pulse and a 1TP Probe Pulse with 1ms delay

Run 3011, Diam right 10, 1.0 ms Pump/Probe [Pump]

Run 3011, Diam right 10, 1.0 ms Pump/Probe [Probe]
MERIT Beam Shots

- $30 \times 10^{12}$ protons/pulse!!!
- 24 GeV
- 115kJ !!! a PS record

**Graph:**
- X-axis: Beam intensity [protons/pulse]
- Y-axis: Integrated beam intensity to MERIT [$10^{12}$ protons]
- Legend: Hg target OFF, Hg target IN

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The Optical Diagnostic Cameras

FastVision 1

SMD

FastVision 2

Video camera

20 m/s Hg jet, 7 Tesla field

0.1 ms/frame

2 ms/frame

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Influence of Magnetic Field

Jet Velocity is 15m/s

0T   5T

10T  15T

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14 GeV Proton Beam on Hg Jet with Magnetic Field

Viewport 1 at 2ms

Viewport 3 at 26ms

October 26, 2007
Beam Pulse at 8:39pm
Central European Daylight Time

Hg Jet 15m/s
Solenoid Field 5T
Proton Intensity 10TP

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Brookhaven National Laboratory
15TP 14GeV Proton Beam

Oct. 27, 2007
Solenoid Field
at 5T

Viewport 2

Beam 5016, Hg 15m/s, 100μs/frame, Total 1.6ms

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20TP 14GeV Proton Beam

Oct. 27, 2007
Solenoid Field
at 10T
Viewport 2

Beam 5020, Hg 15m/s, 100μs/frame, Total 1.6ms

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Viewport 3: Jet/proton interaction

Shot 16014
- 14 GeV
- $12 \times 10^{12}$ protons/pulse
- B-field 10 T
- 500μs/frame

Disruption Length = 16.5 cm
The 24 GeV 30TP shot

Beam pulse energy = 115kJ
B-field = 15T
Jet Velocity = 20 m/s
Disruption Length = 28 cm

We will replace the 28cm disruption length (2 interaction lengths)

Then the jet transport time is 28cm/20m/s = 14ms
→ Rep rate of 70Hz
→ Proton beam power at that rate is 115kJ *70 = 8MW
4TP + 4TP Delay Study at 14 GeV

Single Turn Extraction ➔ 0 Delay

4TP Probe extracted on subsequent turn ➔ 3.2 μs Delay

4TP Probe extracted after 2nd full turn ➔ 5.8 μs Delay

Target supports 14 GeV 4TP beam at 172kHz rep rate without disruption

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Data Analysis Pipeline

Disruption threshold based on proton beam characteristics
  Intensity variations
  Proton beam harmonic structure
Disruption threshold based on solenoid field strength
Pump/probe studies
  15TP pump + 5TP probe with delays 2 to 700μs
  24 GeV pump/probe studies with delays < 2μs
Magnetodynamic studies
  disruption (filamentation) velocities
  quadruple distortions
Proton beam spot size analysis
The Neutrino Factory/Muon Collider target concept has been validated for 4MW 50Hz operations.