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The Primary Target Facility for a Neutrino Factory Based on Muon Beams

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Pres. at the Particle Accelerator Conference (PAC2001), June 18-22, 2001, Chicago, IL.

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THE PRIMARY TARGET FACILITY FOR A NEUTRINO FACTORY BASED ON MUON BEAMS

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Abstract

Neutrino beams from the decay of muons in a storage ring offer the prospect of very high flux, well-understood spectra, and equal numbers of electron and muon neutrinos, as desirable for detailed exploration of neutrino oscillations via long baseline detectors [1]. Such beams require large numbers of muons, and hence a high performance target station at which a 1-4 MW proton beam of 16-24 GeV impinges on a compact target, all inside a high field solenoid channel to capture as much of the phase volume of soft pions as possible. A first concept was based on a carbon target, as reported in 2000 the Neutrino Factory Study-I [2]. A higher performance option based on a free mercury jet has been studied in 2001 as part of the Neutrino Factory Feasibility Study-II [3, 4]. An overview of a mercury jet target facility is presented here, including requirements, design concept and summaries of simulated performance. Further details are presented in related papers at this conference.

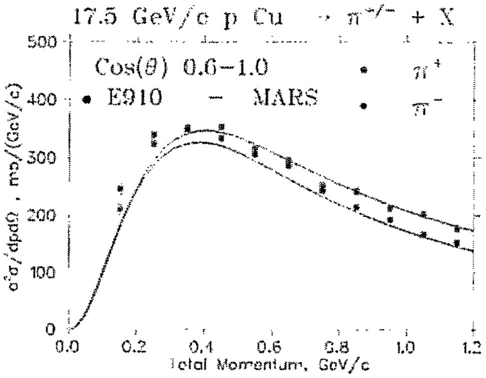

Figure 1: Comparison of pion yield measured in BNL E910 with a MARS calculation.

1 THE TARGET FACILITY

A muon collider [18] or a neutrino factory based on a muon storage ring [1, 2, 3, 4] require intense beams of muons, which are obtained from the decay of pions produced in proton-nucleus collisions. To maximize the yield, pions of momentum near 300 MeV/*c* should be captured, as illustrated in Fig. 1. For proton energies above 10 GeV, the pion yield per unit of proton beam energy is larger for a high-Z target [5]. For proton beam energies in the MW range, beam heating would melt/boil a stationary high-Z target, so a moving target must be used. A mercury jet target is the main option considered here, although several alternatives remain under active study [6, 7]. For greater detail, consult Chap. 3 of [3]. See also [8].

The low-energy pions are produced with relatively large angles to the proton beam, and efficient capture into a decay and phase rotation channel [9] is obtained by surrounding the target with a 20-T solenoid magnet, whose field tapers down to 1.25 T over several meters, as sketched in Fig. 2. Pion yield is maximized with a mercury target in the form a 1-cm-diameter cylinder, tilted by about 100 mrad with respect to the magnetic axis. To permit the proton beam to interact with the target over 2 interaction lengths, the proton beam is tilted by 33 mrad with respect to the mercury jet axis. See also Fig. 3.

A mercury pool inside the capture solenoid intercepts the mercury jet and the unscattered proton beam, as shown in Fig. 4. The mercury pool, surrounding tungsten carbide/water shielding, and the resistive insert of the 20-T capture magnet [10] are isolated from upstream and downstream beamline elements by a pair of double-walled Be windows. This entire unit can be replaced by remote manipulation should failure occur. The absorbed radiation dose on components near the target is quite large [5], as illustrated in Fig. 5, such that in a 4 Mw proton beam, their

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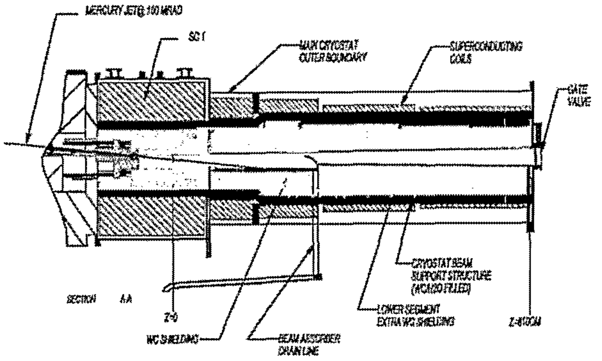

Figure 2: Sketch of the target and capture system based on a mercury jet inside a 20-T solenoid magnet.

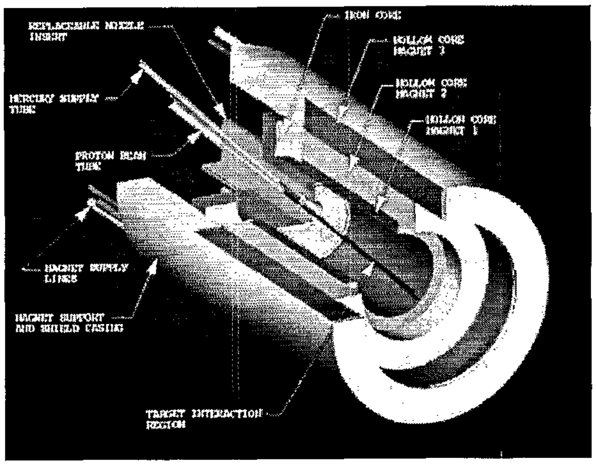

Figure 3: The inner region of the 20-T capture magnet along with the tilted mercury jet target and proton beam.

lifetime against radiation damage may only be 5 years.

The capture solenoid is encased in thick concrete shielding as part of the target facility that includes an overhead crane, hot cells with remote manipulation capability, and a mercury pumping and purification loop [11], as sketched in Fig. 6.

The use of a mercury jet target raises several novel issues. The rapid energy deposition in the mercury target by the proton beam leads to intense pressure waves that can disperse the mercury [12, 13, 14]. Further, as the mercury enters the strong magnetic field eddy currents are induced in the mercury, and the Lorentz force on these currents could lead to distortion of the jet [15, 16]. On the other hand, the magnetic pressure on the mercury once inside the solenoid will damp mechanical perturbation of the jet.

An R&D program is underway to assess these critical issues [17].

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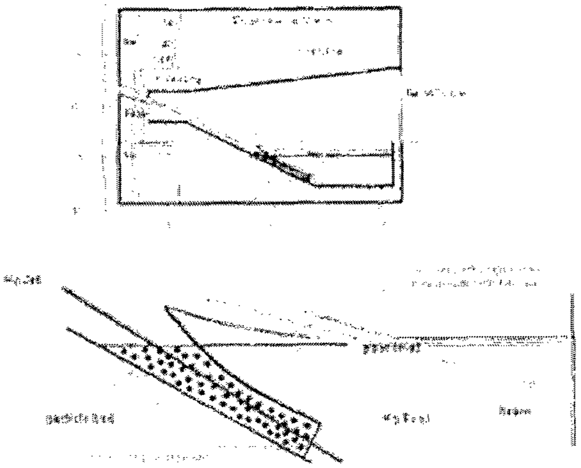

Figure 4: A mercury pool inside the capture solenoid intercepts the mercury jet and the unscattered proton beam.

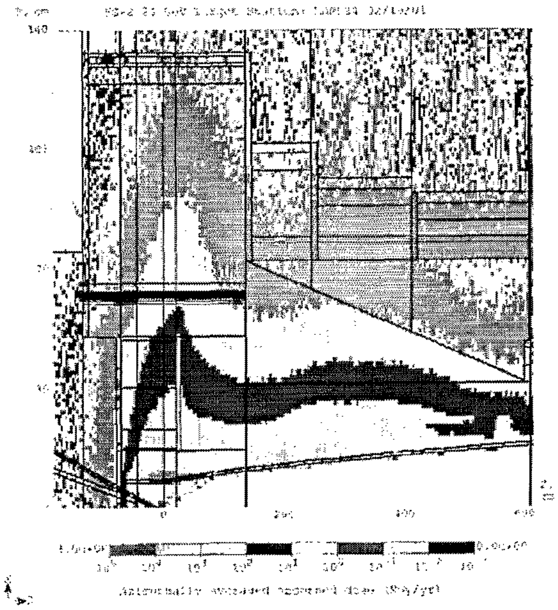

Figure 5: Absorber radiation dose in the pion capture system per 2×10^7 s of a 1-MW, 24-GeV proton beam on a mercury target.

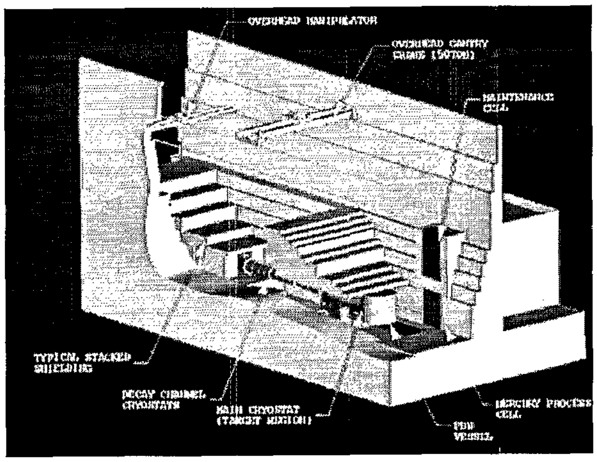

Figure 6: Sketch of the target facility.

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