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BEAM TRANSPORT AND TARGETRY IN THE 1-TEV FERMILAB MESON AREA

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Abstract

Three ED/S 1 TeV primary beams will be transported to the Meson Area and targeted in above-ground stations designed for intensities up to 5×10^{12} protons/pulse. Muon backgrounds will be reduced to acceptable levels with active shielding. New secondary beams, one providing polarized protons, the other high intensity hadrons, will feed experiments located in new buildings approximately 300 m north of the present Meson Detector Building (MDB).

Introduction

Although the emphasis at this conference is on producing particle beams, their utilization also warrants some discussion. At Fermilab the development of experimental areas for the 1 TeV fixed target program is an important activity. Most experiments at Fermilab have been performed in three areas: Meson, Neutrino, and Proton. This paper describes the conversion of the Meson Area from its 400 GeV capability to 1 TeV and the addition of new secondary beams to increase the diversity of the program.

Primary Beams

The primary beam to the Meson Area is bent horizontally through 153 mr (21 ED/S dipoles),[1] vertically through 8 mr., and then enters the first element (electrostatic septa) in a 3-way split.[2]

Three beams rise to ground level, almost level out, and enter the 3-way Lambertson magnets which provide the major (horizontal) splitting. At the Lambertson exit the beams are 2 cm diameter with divergence 0.02-0.04 mr. due to the long drift space required by the split. The beams, Meson East (ME), Meson Center (MCA, MCB), and Meson West (MW), (see Fig. 1) are transported to MDB target stations.

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Here the transverse distance between target stations is approximately 30 ft. Bend points are built from ED/S dipoles and cooled with ED/S satellite refrigerators. Each string is protected from quenching by upstream collimators. By shutting off vertical or horizontal bends and inserting stops, each beam will be able to be quickly temporarily dumped in the present Meson target box which is shielded for the full Tevatron intensity.

Meson East Primary Beam

ME must be bent about 100 mr to the east. It is the only primary line directly feeding an experiment. Thus the beam must be well controlled to prevent scraping. With continuous tunnel connecting the front end of the line with the MDB there is room to install magnetic elements, aperture control devices and instrumentation along the line. The major elements of the magnetic beam transport system are 3 ED/S bend strings and relatively close spaced conventional FODO lenses. This gives the optimum transport properties at the smallest cost.

Transport coefficients remain small along the beam. Thus, small errors in the incoming beam angle, position, or momentum, or small tuning errors will produce only small displacements at any point. The beam spot at the experimental target is a very thin oval, less than 1 mm high × about 10 mm wide.

In the future[3] a target station will be placed roughly one third of the way along the beamline in the existing Pion Target Hall. The downstream dipoles will be rearranged and additional quadrupoles and sextupoles added to form a secondary beam. In the first third of the beamline, a few quadrupoles will be added to obtain a smaller spot at the new target.

Meson Center Primary Beam

(MC, MP) is a simpler beam than ME except that it is two beamlines which will run alternately as shown in fig. 1. MP must be bent by roughly 25 mr to the east at the end of the Front End Hall (FEH) and

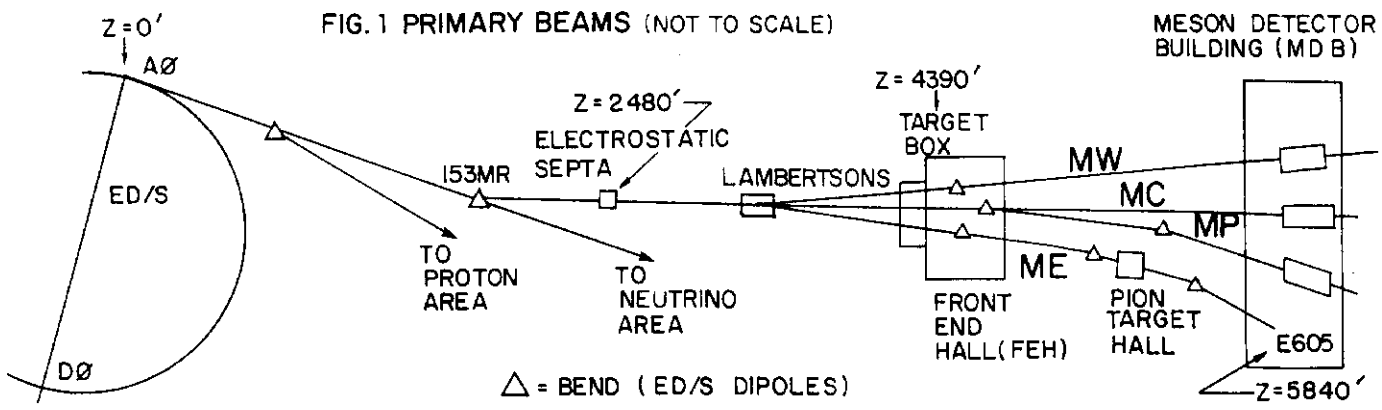

FIG. 1 PRIMARY BEAMS (NOT TO SCALE)

another 25 mr to the east in the 1000 ft. area to pass through the existing berm pipes. Each bend consists of 4 ED/S dipoles. MC requires no bends. The initial bend string switches between the two beamlines.

The optics of the two branches are identical since the momentum variation of the primary beams is so small that dispersion caused by the relatively small bends in MCA can be neglected. A simple quadrupole doublet of 4 magnets is the common front end of the beamlines. In MCA nine conventional 3Q120 quadrupoles run as a doublet to focus the beam onto a production target which is small in both planes. Many quads are needed because of hard focusing. The resulting spot is 1.5×1.0 mm² FWHM. The spot required in MCB is less stringent and fewer quads are needed.

Meson West Primary Beam

MW will not follow existing beamline tunnel systems. It enters FEH west of MC by about 1 ft and is diverging to the west by 3.9 mr and upward by 1.5 mr. Three slightly rotated ED/S dipoles at the upstream end of FEH add a horizontal angle of 20 mr and remove the vertical angle. They are immediately followed by a 4 quadrupole focussing doublet similar in function and location to that in MC. At the end of FEH the beam will pass into a new 16 in. diam. berm pipe which will run unbroken to a new downstream quadrupole enclosure housing nine 3Q120's for MC. The optics of MW is identical to that in MC.

Tevatron Target Stations

A significant part of the upgrade corresponds to a new targeting scheme. Muon backgrounds in the experimental areas and beam losses on components must be kept at manageable levels. Zero degree secondary production is required by proton economics. These needs dictate an active dumping scheme which precludes multiple independent secondary beams from a primary target. Additional secondary beams are best generated from a secondary target in the 0° neutral beam from the primary target.

Target station schemes for the ME, MC and MW branches incorporate, within a shielding pile, an invariant component locating system coupled with a remote guidance and handling system for overhead cranes. This keeps the residual radiation within the system, allows single component servicing, and does not disrupt the beamlines. Typically a station consists of a target followed by dump magnets, collimators, and a beam dump.

The Meson East System

This station will consist of a fixed shielding pile of steel and concrete around the active devices. The outer surface corresponds to a 1-100 mr/hr on contact (position dependent) residual radiation source. The shielding varies from 2.5 ft to 5 ft of steel plus 3 ft of concrete. We refer to this configuration as a "core" pile. Twelve ft. of concrete or berm shielding supplements the beam on shielding. All heavy active components are to be handled and positioned using a remote engaging and disengaging spreader bar. Two crane bridges and trolleys will run at slow speeds to allow critical positioning and alignment. One crane will carry a scanning, zoom TV camera system.

Meson Center and West Branches

These piles located in the MDS will be constructed under the existing 20 ton crane. Dynamic (beam on) shielding requires up to 6.5 ft. of steel and 9 ft. of concrete radially and extended longitudinally along the active devices. From the top, these target stations consist of a "core" with additional local shield covers.

Between the shielding pile walls, there is an open corridor with a thick, rigid base plate underneath it. This provides the required ground water radiation shielding and the upper face contains two alignment rails, one a vee, the other flat, for components. Components with prealigned locating feet are lowered onto the rails. All connections are on the outside of the "core" pile. Rigid water-power leads attached to the component are led up a chimney through the edges of the "core" shielding covers and walls.

To install or remove a component long posts are dropped in by crane on fixed pins on the system baseplate which rise above the pile walls. They are aligned and magnetically clamped in place. The remote spreader bar with guides is led onto the posts, and lowered down to engage or release the component and set the crane position. For removal, once the engagement is confirmed the component is lifted out. When manipulation is complete, the guideposts are removed and the shielding covers are replaced.

Target Manipulators

These are cross slide x,y manipulators with mechanical absolute position encoding. Drive stepping motors and encoders are well upstream of the targets to allow radiation backshielding and change/repair without disruption of the target and manipulator. The target assemblies are electrically isolated allowing for charge depletion monitoring of targeting efficiency.

Beam Dumps and Collimators

The beam energy is absorbed in a $10 \times 30 \times 450\text{-}600$ cm³ efficiently water cooled copper slab. To insure its survival under the thermal stress cycle of a fast Tevatron spill (1 msec), the energy deposition, $\delta E/\delta V$, is normally limited to one GeV/cm³/proton. Assuming beam emittances from 0.08 to 0.4 mm-mr, one can so limit $\delta E/\delta V$ in the copper, providing the beam strikes an aluminum bar 1.25 cm high × 1.8 m long imbedded in the copper dump. Because of the slow longitudinal variation of $\delta E/\delta V$ the heat flow is radial. The cooling paths are as close as possible to the core. However, one is limited in approach by water activation problems (H^3 and Be^7), irradiation damage of the heat transfer film, and the required opacity of the dump over the transverse development of the hadron showers. This limits the minimum cooling time constants to 4-6 sec. for heat transfer. Thus initially the adiabatically deposited energy diffuses out of the core. Even so, 50% of the energy remains in the core. In a long spill the core becomes nearly uniform in temperature. If stresses exceed the elastic limit, the ductile Al and Cu will locally yield without fractures. Tapered beam collimator apertures are built into the dump core by fabricating the core from split pieces.

The special dipoles for active dumping have a high magnetic field (19-22 kg) to provide the necessary resolution between the proton beam profile and the secondary beam acceptances to allow x_{max} beam = +0.6 within the target pile. The magnets have a very large, clear aperture with no coils in the mid-plane to minimize radiation activiation. In order to achieve the best sign selection for dilution of muon backgrounds at the experimental area, the pole tips are as wide as possible (6 in.) with nearly uniform field. The magnets run D.C. or slow pulsed to avoid cyclic stressing and are solid iron to shield ripple. The magnets are low power devices to allow operation on a limited heat capacity closed loop water system.

The Meson North Area (Fig. 2)

It is proposed to build two large experimental halls roughly 300 m north of the existing MDB. Experiments in each will be fed by new secondary beams. A third beam and experimental hall is possible if justified.

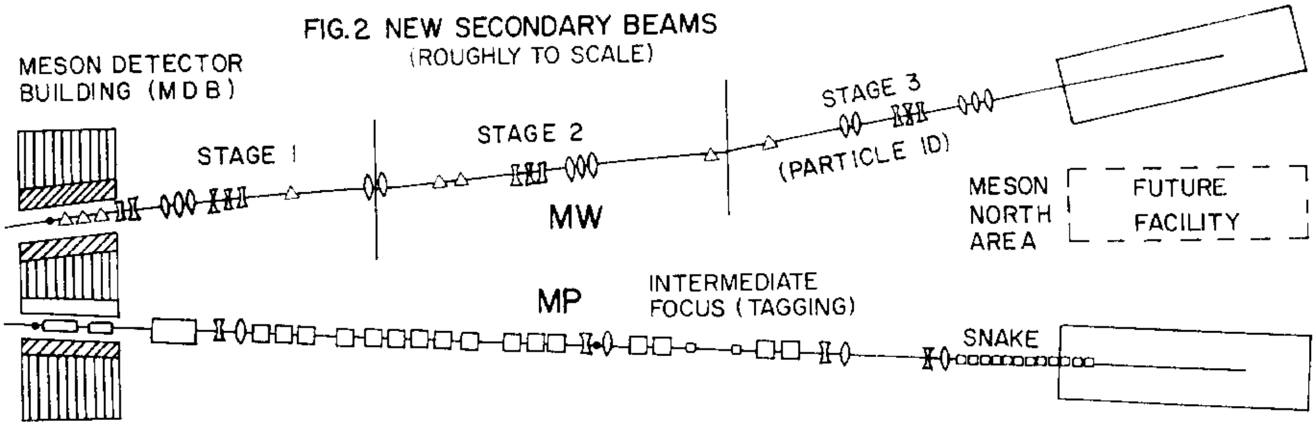

FIG.2 NEW SECONDARY BEAMS
(ROUGHLY TO SCALE)

High Flux Tagged Hadron Beam, MW

One motivation for tranporting the MW primary beam to the MDB is to provide a source for a tagged secondary beam which will be totally unconstrained by the tunnels and berms of the old 200-GeV Meson Area. The design goal of a 600 GeV π/K line with large acceptance can be met in a 700 ft lattice consisting of 16 3Q120's and 4 B2 dipoles. The first 100 ft are tightly filled with active components for muon spoiling and cleanup. The momentum dispersed envelope of the two-stage beam is not totally recombined until the second focus at 700 ft. To allow for particle velocity tagging a third stage is necessary.

The maximum energy in the proton mode is 1 TeV, and 0.6 TeV in the π mode. The 0.6 TeV π^- flux per 1 TeV interacting proton will be 3×10^{-4}, $\Delta p/p = 10\%$. There will be hadron indentification using a combined TRD/Cerenkov system over the momentum range 200-600 GeV/c. All stages can be either a distributed lattice or lumped components. The choice of configuration will depend ultimately on the design of the tagging apparatus and on power supply and utility considerations. Described here is a three-stage lumped component beam with a tagging capability. This 1000 ft beam has H,V acceptances of ±0.8 mr, ±0.7 mr, and a spot size 1 cm diameter containing 90% of the hadrons.

Polarized Proton Beam, MP

The beam line, built jointly with Argonne National Laboratory will provide[4] a clean source of polarized protons or antiprotons over a momentum range from 100 to at least 200 GeV/c utilizing a primary beam of up to 1 TeV. When this beam strikes a target, Λ^0's are produced. When the Λ^0's decay, the resultant protons are polarized; the direction of polarization is along the proton direction in the Λ^0 rest frame. This polarized beam is then guided by a series of magnets, conserving the polarization, to a polarized target.

The beam is two-stage four-doublet with fixed dipole strength independent of momentum. Maintaining dipole strength independent of momentum while transversely displacing the momentum selection collimator is a way to produce maximum flux while keeping the effect of chromatic aberration smaller than the image of the virtual source. An electronic tagging system determines virtual transverse target position and momentum on a particle-to-particle basis. Thus it is possible to run beams of both signs of polarization simultaneously. The insertion of the tagging region requires that the longitudinal range of focal positions from different momenta be limited giving another reason to maintain constant dipole field strength. The polarization in the horizontal plane can be reversed or the plane of polarization can be rotated from horizontal to vertical or longitudinal using a 12 dipole magnetic "snake"[5] preceding the polarized target.

Typically 3×10^{12} protons per spill will be targeted. The intensities of polarized protons (antiprotons) at 200 GeV/c expected under these conditions from 1 TeV primary protons are 2×10^7 (2×10^6). Alternately the beam can feed other secondary particles to the polarized target or to an experiment at the intermediate focus, at maximum momentum of 400 GeV/c with an acceptance up to as much as 20 μsr%.

Muon Background

The original 200 GeV Meson Area provided up to 1400 feet of earth shielding between the target station and the MDB, corresponding to the range of a 210 GeV muon. With 1 TeV targeting the earth perforated with tunnels is of limited value and active dumping is required in any configuration.

In MW downstream spoilers have a rectangular transverse area of 4×7 ft^2 and total length 85 ft. Power consumption in the spoiler system is low since B^{iron}_{max} = 14 kg. The beam passes through a 2×2 in.^{2} hole place in the lower half of the magnet in the horizontal field region (≈10 Kg.). Halo muons are deflected vertically. The halo (in a 3×3 m^2 area) is ≈7% of the beam for energies of 50-200 GeV and decreases linearly to ≈3% at 600 GeV.

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