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Nuclear Instruments and Methods in Physics Research A 568 (2006) 503–519

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

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Secondary beam monitors for the NuMI facility at FNAL

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Received 12 July 2006; accepted 16 July 2006
Available online 5 September 2006

Abstract

The Neutrinos at the Main Injector (NuMI) facility is a conventional neutrino beam which produces muon neutrinos by focusing a beam of mesons into a long evacuated decay volume. We have built four arrays of ionization chambers to monitor the position and intensity of the hadron and muon beams associated with neutrino production at locations downstream of the decay volume. This article describes the chambers' construction, calibration, and commissioning in the beam.

PACS: 13.15.+g; 95.55.Vj; 29.40.Cs; 29.25.−t; 29.27.Fh

Keywords: Neutrino beam; Neutrino, pion, muon detectors; Ionization chambers; Particle sources and targets; Beam characteristics

1. Introduction

The Neutrinos at the Main Injector (NuMI) beam line [1,2] at the Fermi National Accelerator Laboratory (FNAL) delivers an intense muon neutrino beam to the MINOS [3] detectors at FNAL and at the Soudan Laboratory in Minnesota. Additional experiments [4,5] are being planned. A schematic diagram of the NuMI beam line is shown in Fig. 1. The primary proton beam is fast extracted from the 120 GeV Main Injector accelerator onto the NuMI pion production target. The beam line is designed to accept up to 4×10^{13} protons-per-pulse (ppp) with a repetition rate of 0.53 Hz. After the graphite target, two toroidal magnets called "horns" sign-select and focus the secondary mesons from the target (pions and kaons), as shown in Fig. 2. The mesons are directed into a 675 m long volume, evacuated to ~0.5 Torr to reduce pion absorption, where they may decay to muons and neutrinos. At the end of the decay volume, a beam absorber stops the remnant hadrons, followed by approximately 240 m of unexcavated rock which attenuates the tertiary muons, leaving only neutrinos.

The target may be positioned remotely so as to produce a variety of wide band beams with peak energies ranging from 3 to 9 GeV [6]. The target, shown fully inserted into the first focusing horn in Fig. 2, is mounted on a rail drive system and can be driven as much as 2.5 m upstream. Moving the target upstream has the effect of directing smaller-angle, higher-momentum particles into the focusing horns, resulting in a higher-energy neutrino beam, as shown in Fig. 3.[1]

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[1]For maximal efficiency of the ME and HE beams, both the target and the downstream horn are moved with respect to the fixed first horn [1]. Because of the complexity of moving horn 2, the MINOS experiment will make use only of the target positioning system, which can be accomplished

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doi:10.1016/j.nima.2006.07.062

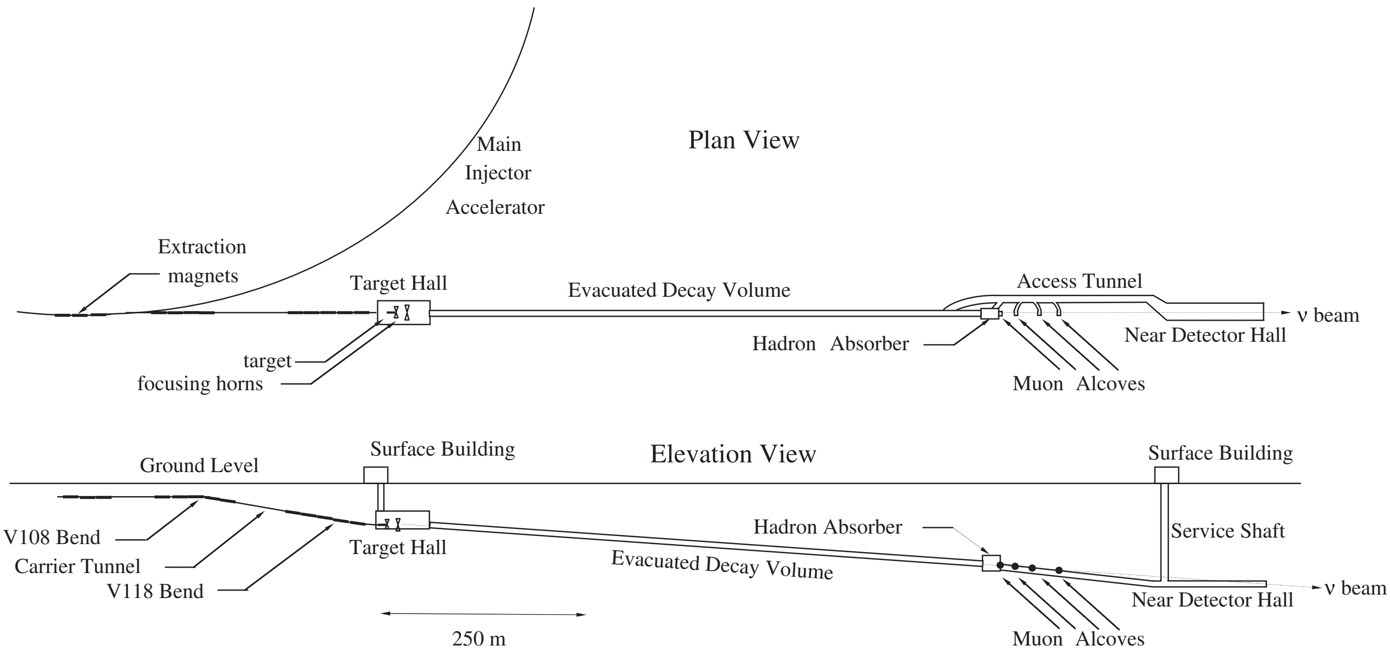

Fig. 1. Plan and elevation views of the NuMI beam facility. A proton beam is directed onto a target, where the secondary pions and kaons are focused into an evacuated decay volume via magnetic horns. Ionization chambers at the end of the beam line measure the secondary hadron beam and tertiary muon beam.

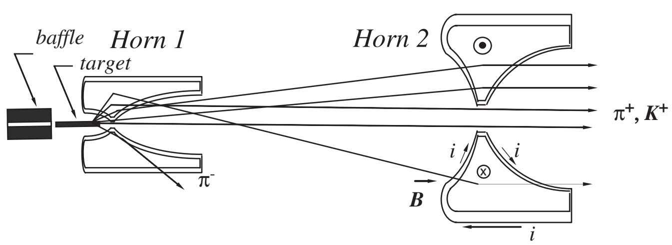

Fig. 2. NuMI two-horn beam: Horns 1 and 2 are separated by 10 m. A collimating baffle upstream of the target protects the horns from direct exposure to errant proton beam pulses. The target and baffle system can be actuated further upstream of the Horns to produce higher-energy neutrino beams [6]. Note that the vertical scale is 4× that of the horizontal (beam axis) scale.

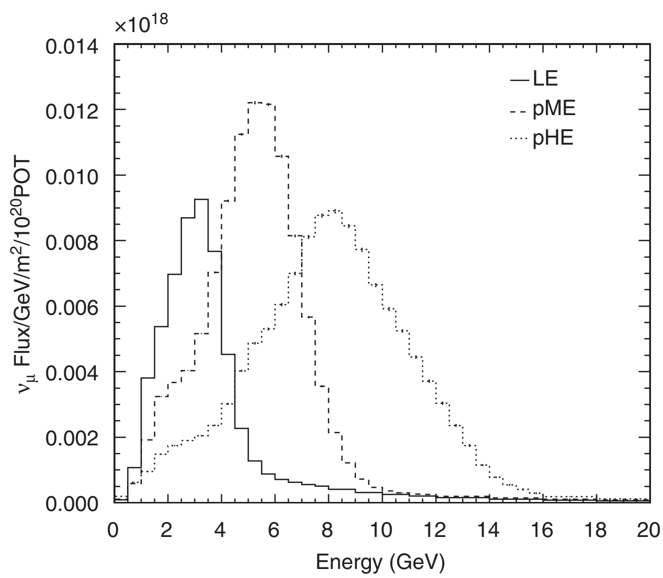

Fig. 3. Calculated flux of muon neutrinos in the detector hall located 1040 m from the NuMI target. Three spectra are shown, corresponding to the low, medium, and high neutrino energy positions of the target [6] (the "LE", "pME, and "pHE" configurations). In these configurations, the target is located 10, 100, and 250 cm upstream of its fully inserted position.

The subject of this paper is the secondary and tertiary beam monitoring system, located at the downstream end of the decay volume, shown in Fig. 4. Its purpose is to monitor the integrity of the NuMI target and of the horns which focus the secondary meson beam. This monitoring is accomplished by measuring the intensity and lateral profile of the remnant hadron beam and of the tertiary muon beam. Because every muon is produced by the same meson decays which produce neutrinos, the muon beam provides a good measure of the focusing quality of the horns. The large fluxes of the hadrons and muons permit the secondary beam monitors to diagnose, in a single spill, problems in the upstream neutrino beam systems.

(*footnote continued*)
in situ [6]. Such are referred to as the pseudo-Medium (pME) and pseudo-High (pHE) beams.

The first accelerator neutrino beam at BNL [7] did not explicitly use muon beam monitors, although in subsequent runs emulsion detectors were placed in slots in the steel shielding in front of the neutrino detector to analyze the muon spectra, and thus provide a check on the muon–neutrino fluxes [8]. The 1965 CERN neutrino beam utilized a spectrometer downstream of its target station to measure