NEUTRINO BEAM LINE FOR A LONG-BASELINE NEUTRINO OSCILLATION EXPERIMENT AT KEK

M. Ieiri, M. Minakawa, H. Noumi, Y. Yamanoi, Y. Kato, H. Ishii, K. H. Tanaka, Y. Suzuki, M. Takasaki , K. Nishikawa, K. Nakamura, T. Inakagi*, M. Kohama**, T. Maruyama***
KEK, 1-1 Oho, Tsukuba-shi, Ibaraki-ken, 305-0801, Japan
* Physics Department, University of Tokyo, 7-3-1 Hongo, Tokyo 113, JAPAN
** The Graduate school of Science and Technology, Kobe University, Kobe, Hyogo 657, JAPAN
*** Bubble Chamber Physics Laboratory, Tohoku University, Sendai, Miyagi 980-77, JAPAN

Abstract

A neutrino beam line for a long-baseline neutrino oscillation experiment is being constructed at KEK for the commissioning in January, 1999. Muon neutrinos produced by this beam line at KEK will be measured by the SuperKamiokande located 250 km west of KEK.

1 INTRODUCTION

A neutrino beam line, extended from EP1-A primary beam line of the north counter hall[1] towards the direction of the SuperKamiokande[2], is now under construction for a long-baseline neutrino oscillation experiment[3]. Figure 1 shows a plane view of the neutrino beam line at KEK. It consists of the straight section, the arc section, the target station, the decay volume and the μ-monitor pit. A fast-extracted proton beam from 12 GeV PS will be transported about 400 m by DC-electromagnets and focused onto a production target. This production target is a part of the inner conductor of the first horn. Two magnetic horns at the target station will focus produced pions to the forward direction, so as to maximize neutrino flux which will be produced by decay-in-flight of pions in the 200 m decay volume. A primary proton beam will be stopped at the beam dump. A high energy part of muons will be monitored at the μ-monitor pit.

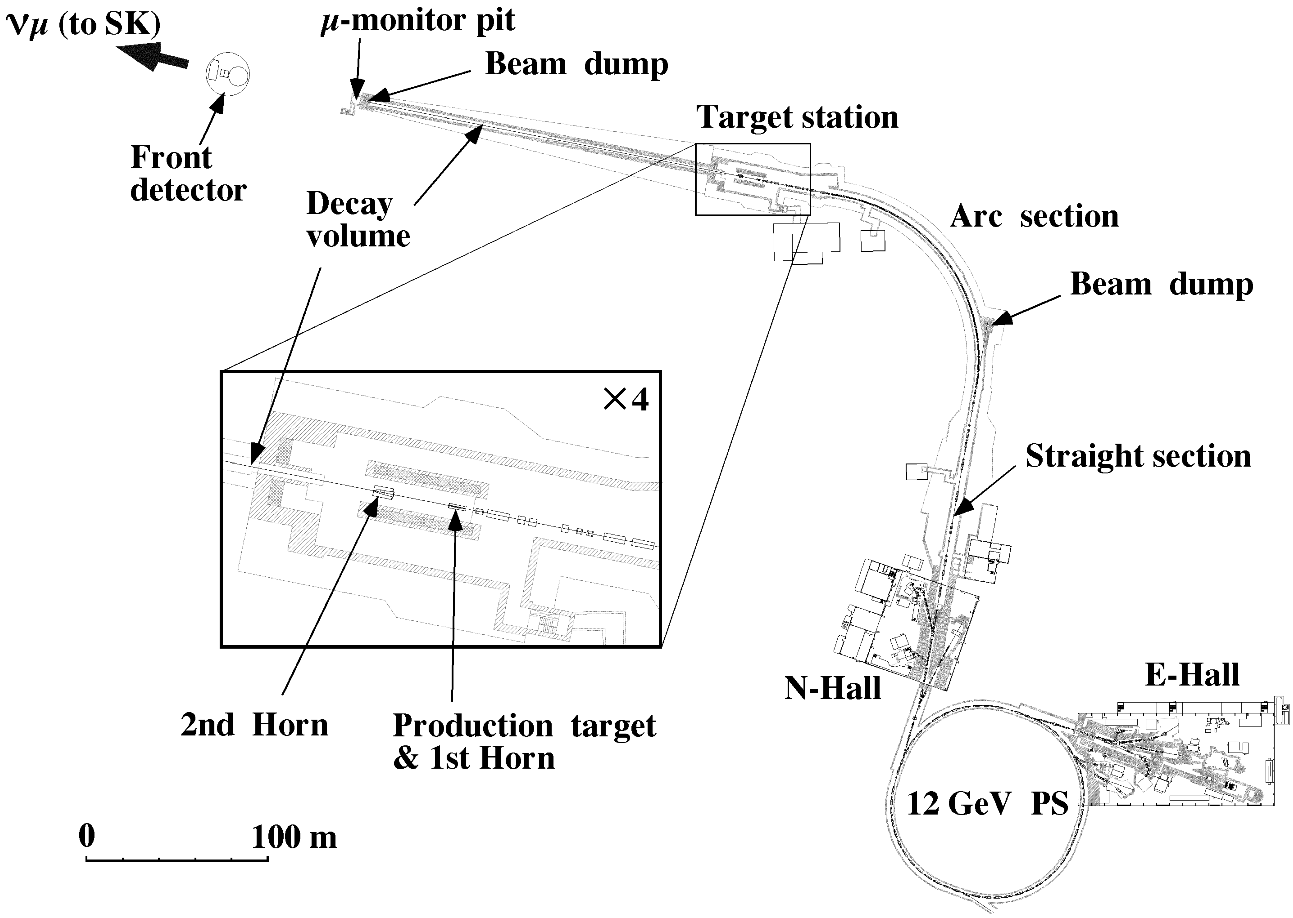

Figure 1 : Plane view of the neutrino beam line

2 CONSTRUCTION OF BEAM LINE

The construction of the housing of the neutrino beam line has been started in October, 1996. The building of the straight- and arc- sections was finished at the end of September, 1997. A downstream part is now being constructed and will be finished in September, 1998. Electromagnets are now being installed from upstream in the straight section.

A positioning of the SuperKamiokande from the KEK site was made by employing the Global Positioning System (GPS). It is found that the EP1-A beam line must turn 88°44'25" to the left (west), and bent 1°04'30" downward with respect to the horizontal plane just before the production target[4].

3 MAGNETIC HORN

The horns are designed considering both beam optics and mechanical strength. The production target must be integrated in the 1st horn as a part of the inner conductor in order to increase the acceptance for the secondary pions, since secondary pions have a wide production angle due to relative low energy (12 GeV) of primary protons. The 1st horn will gather produced pions to the forward direction and the 2nd horn will make them parallel toward the SuperKamiokande for as wide an energy region as possible. Current for horns, shapes of inner and outer conductors and the distance between two horns are determined to maximize the neutrino flux at the SuperKamiokande by a simulation study with GEANT.

Conductors of the horns are expected to be thin as possible, since produced pions pass through them. Mechanical design of horns are optimized under considerations of buckling limit against Lorenz forces, fatigue limit for alternate traction, bending by self-weight, and stress caused from thermal expansion of the 1st horn's inner conductor. In order to avoid breakage due to shocked Lorenz force and the thermal expansion at pulsed 250 kA with a repetition of more than 10^7 for 3 years, the aluminum alloy 6061-T651 is used since it has good electrical conductivity and mechanical properties. The wall thickness, the shape of the rib, the size of bolts and other mechanical parameters are designed to satisfy a safety factor more than 4. The inner conductor is cooled by continuously spraying water onto it. The sprayers are assembled on the outer conductor and cooling water of about 40 l/min. is supplied to each horn.

The power supply system for horns consists of a pulse generator with 12 capacitors of 500 μF and a transformer of ratio 10. Inductance and resistance for 1st horns are 1.03 μH and 187.1 μΩ, respectively and those of total circuit including strip-lines and a transformer are 148 μH and 36 m Ω. The capacitor of 6 mF at 4.7 kV is estimated to supply 250 kA with 1.4 msec rise time for the 1st horn and that of 2 mF at 7.6 kV gives 0.83 msec rise time.

Figure 2 shows a neutrino momentum distribution expected at the SuperKamiokande after 10^{20} protons on target. The neutrino flux will be enhanced by a factor of 14 when the horns are operated properly.

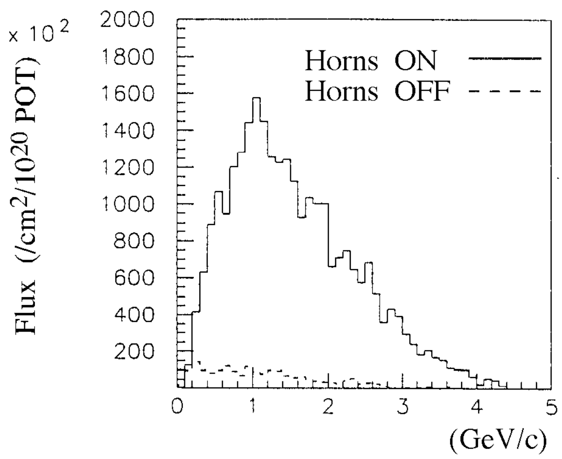

Figure 2 : Neutrino momentum distribution at the SuperKamiokande for 10^{20} protons on target

4 DECAY SECTION & μ MONITOR PIT

Produced pions will decay in flight to μ and ν_μ in the 200 m long decay pipe in this section. Size of a decay pipe is 1.5 m in diameter for the upstream 10 m, 2 m for the next 90 m, and 3 m for the last 100 m. Helium gas will be filled in this pipe during the experiment. The pipe was set in the ground with a tilted angle of 1°04'30", and is now being covered with concrete of about 2 m thick to avoid soil activation.

3 m thick iron will be installed just downstream of the decay pipe as a beam dump. Almost charged particles including primary protons will be stopped here except for high energy muons. This muon's profile will be measured by an ion chamber at the μ monitor pit.

Schematic drawings of the decay section and the μ monitor pit are shown in figure 3 and 4, respectively.

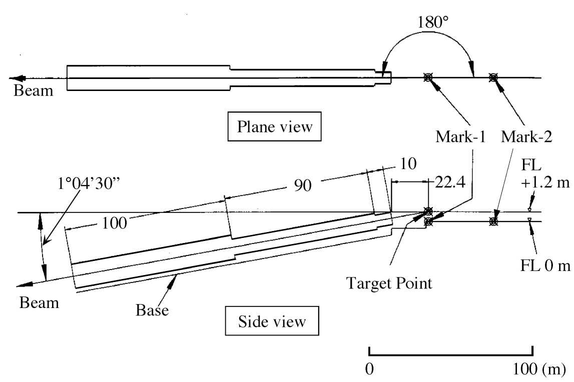

Figure 3 : Schematic drawing of the decay section.

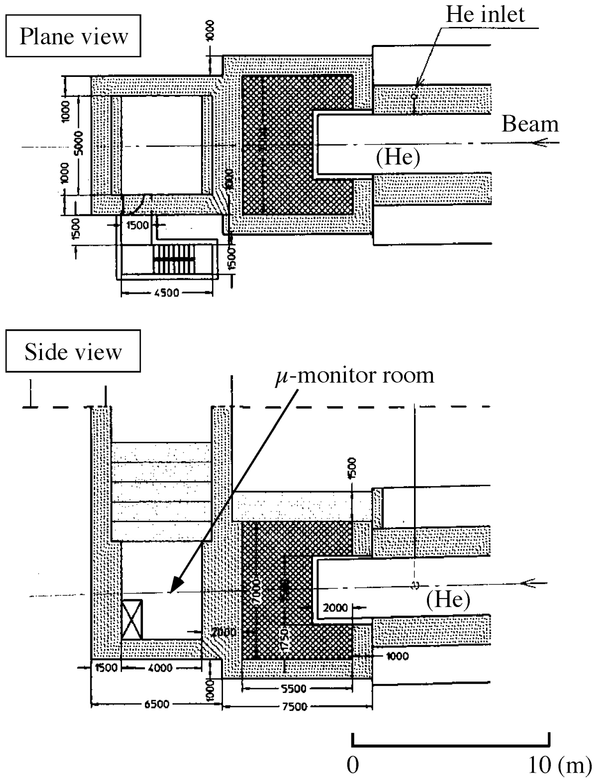

Figure 4 : Schematic drawing of the μ monitor pit.

5 BEAM MONITORS

Since it is not practical to control primary proton beam by the information of ν detected at the SuperKamiokande, profiles and intensities of primary protons, secondary pions and decay μ must be monitored in order to control magnets of the primary beam line. We will use detectors such as a current transformer (CT), a secondary emission monitor (SEM), a segmented parallel-plate ion chamber (SPIC) and a Cerenkov counter (CC) as shown in Table 1.

Table 1. Detectors used in the neutrino beam line

measured particle	monitoring item	detector
Primary protons	intensity	CT
	profile	SEM
Secondary particles	profile	SPIC
Secondary pions	flight direction	CC
Decay μ	profile	SPIC

By using the information obtained from the above detectors, the direction of proton beam and its focusing on a target will be tuned on-line and monitored for the long-term stable operation. A positioning of a production target, these detectors and the SuperKamiokande will be performed by the GPS several times during 3 year operation.

A schematic drawing of a segmented parallel-plate ion chamber is shown in figure 5, which will be used at the primary proton beam line as a profile monitor.

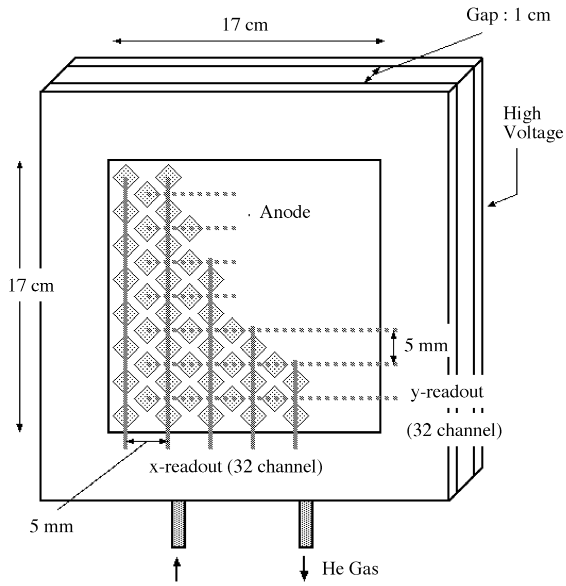

Figure 5 : Schematic drawing of a segmented parallel-plate ion chamber.

6 ACKNOWLEDGMENTS

The authors would like to thank Professors H. Sugawara, S. Yamada, and S. Iwata for their continuous support. The authors would like to express our thanks to members of the E362 group for their collaborative works. The authors are very grateful to Dr. J. M. Maugain, Mr. G. Acquistapace, Mr. S. Rangod, and Dr. V. Falaleev of CERN for their important remarks. The present work was supported in part by Grant-in Aids for Scientific Research (B) (No. 08454071) and for Over seas Scientific Researches (No. 07041103 and No. 09041113) of Ministry of Education, Science, Sports, and Culture (Monbusho).

7 REFERENCES

[1] K. H. Tanaka et al. : 'Primary and secondary beam lines at the KEK 12 GeV proton synchrotron', 5D072 of this conference

[2] Y. Fukuda et al. : 'Measurement of a small atmospheric ν_μ/ν_e ratio', ICRR-Report-411-98-7 (submitted to Phys. Lett. B)

[3] K. Nishikawa et al. : 'Proposal for a long baseline neutrino oscillation experiment, using KEK-PS and Super-Kamiokande', KEK-PS E362 Proposal, unpublished.

[4] H. Noumi et al. : 'Precision positioning of SuperKamiokande with GPS for a long-baseline neutrino oscillation experiment', Nucl. Instrm. & Meth. A398 (1997) 399.