Neutrino beamline for JHF-Kamioka long baseline experiment

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Abstract. The JHF-Kamioka neutrino project is a second generation long baseline neutrino oscillation experiment. A high intensity narrow band neutrino beam is produced by secondary pions created by a high intensity proton synchrotron at JHF (JAERI). The neutrino energy is tuned to the oscillation maximum at ∼1 GeV for a baseline length of 295 km at the water Čerenkov detector, Super-Kamiokande. In this paper, the current design of the neutrino beam facility at JHF is described.

1. Introduction

A long baseline neutrino oscillation experiment is being planed in the JAERI-KEK Joint Facility for High Intensity Proton Accelerators (JHF) [1]. A high intensity

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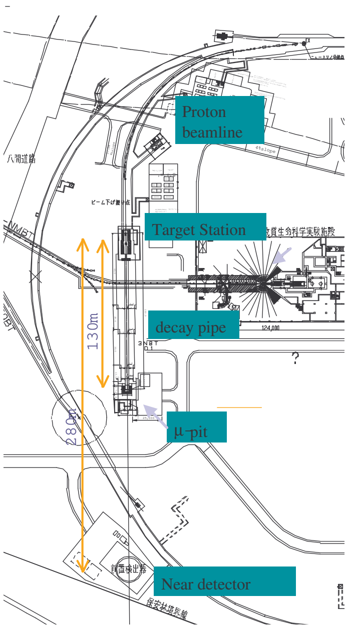

Figure 1. Overview of the neutrino beamline facility at JHF

narrow-band neutrino beam of energy around 1 GeV is produced by using the proton beam from the 50 GeV Proton Synchrotron (PS). The JHF project was officially approved in 2001 by the Japanese government. The construction of the 50 GeV PS will be completed in 2006. The 50 GeV PS is designed to deliver 3.3×10^{14} protons every 3.5 seconds (0.75 MW). The far detector is Super-Kamiokande (Super-K), a 50 kt water Čerenkov detector. The baseline length for the neutrino oscillation experiment is 295 km between JHF at Tokai and Super-Kamiokande at Kamioka.

The main purposes of this experiment are the measurement of ν_μ disappearance and the search for ν_e appearance. One of the main features of the JHF-Kamioka neutrino experiment is its high intensity narrow band neutrino beam produced by the 'off-axis' method[2], which allows one to increase the intensity in a narrow energy window by a factor of two to three over what would be achieved with a conventional on-axis wide-band neutrino beam. This narrow energy window allows one to make cuts which significantly reduce the background in a $\nu_\mu \to \nu_e$ search. The peak of the beam energy will be tuned to the point of maximum oscillation.

In this paper, the current design of the neutrino beam facility is described.

2. Facility

Figure 1 shows an overview of the neutrino beam facility. The proton beam is fast-extracted from the 50 GeV PS in a single turn and transported to the production target. The design intensity of the PS is 3.3×10^{14} protons/pulse at a repetition rate of 0.28 Hz (3.5 second period), resulting in a beam power of 0.75 MW. The spill width is $\sim$5.2 μsec. The protons are extracted toward the inside of the PS ring, and are bent by 90° towards Super-K by the transport line which has a radius of 106 m. The secondary pions (and kaons) from the target are focused by electromagnetic horns, and decay in the decay pipe. The first near detector is located at 280 m from the target.

The proton beamline has a preparation section, an arc section and a final focusing section. The preparation and final focusing section consist of normal-conducting magnets, while the arc sections consist of super-conducting magnets. The arc section has 10 FODO lattices. Each lattice has two 3m-long 4-Tesla dipole magnets and 2 1m-long quadrapole magnets. In order to prevent quenching of the super-conducting magnets, the beam size and halo must be small in the arc section. By tilting the phase-space ellipse at the entrance of the arc section, a smaller beam size in the arc is achieved. To reduce beam halo, beam scrapers will be installed in the preparation section. The assumed beam losses are 0.75 kW in the preparation section and 1 W/m for the arc and final focusing section.

The transported proton beam is injected into the hadron production target. The heat load in the target is a severe problem. Graphite, which has rather low-Z, high-density($\rho = 1.8g/\mathrm{cm}^3$) and high melting point(> 3000°C) is a candidate. In a 3 cm diameter, 1 m long graphite target, about 60 kJ energy will be deposited with one spill. According to a finite element analysis, although the temperature is as high as 230 °C in the center, it is well below 100 °C when the target is cooled with surrounding water.

The length of the decay volume is 130m. A shorter decay volume is adopted to lower the ν_e flux from muon decays, which is an intrinsic background in the $\nu_\mu \to \nu_e$ search. The shape of the volume is optimized to accept off-axis beams from 2 degrees to 3 degrees. The volume is contained in the iron tunnel, which is surrounded by a concrete shield. The iron tunnel is water-cooled to prevent temperature rise due to radiation. Energy deposition in the concrete shield is greatly suppressed by a collimator just after the 2nd horn.

The peak energy of the neutrino beam can be changed by changing the off-axis angle. However, precise alignment of the target and two horns in a high radiation environment is a difficult task. Therefore, as another strategy to change the peak energy, we have a plan to install a bending magnet after the 2nd horn. The direction of the primary proton beam, target and horns is fixed. The dipole field bends the tracks of pions and Kaons and effectively changes the direction of the particles with respect to the Super-K direction. Just by chainging the magnetic field, the peak energy can be changed. The neutrino beam fluxes expected at Super-K for both off-axis method and off-axis with bending magnet are shown in Fig.2. The two methods produce almost the same flux. These two methods will be evaluated both technically and in physics point of view.

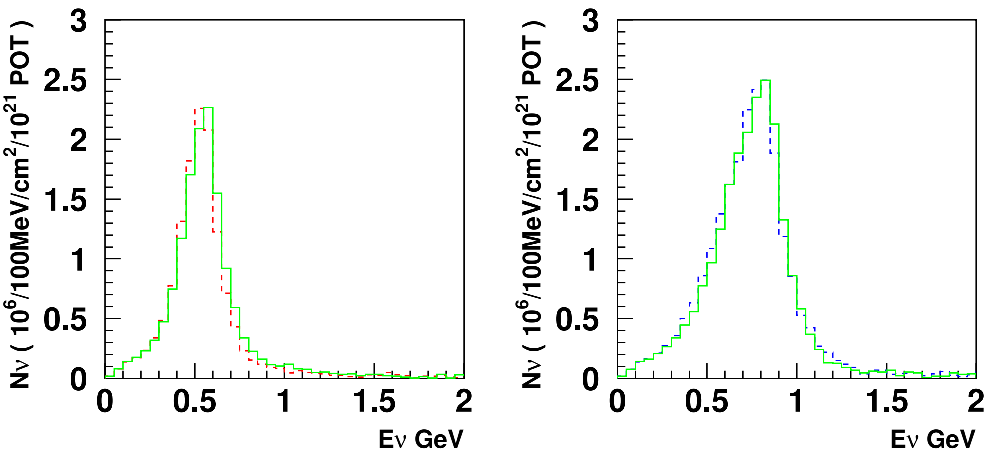

Figure 2. Neutrino beam fluxes expected at Super-K for the off-axis method(solid line) and off-axis with bending magnet(dashed line). Right(Left) figure shows comparison between the fluxes for the off-axis 3 (2) degrees and off-axis 2.6 degrees with a 0.06 (-0.134) Tm magnet.

3. Summary

The design of the neutrino beamline for the JHF-Kamioka neutrino oscillation experiment is in progress. The facility will utilize a 0.75 MW proton source and produce the most intense neutrino beam, clearing the way for a second generation of long baseline oscillation experiments.

References

[1] Y. Itow *et al.*, hep-ex/0106019
[2] D. Beavis, A. Carroll, I. Chiang, *et al.*, Proposal of BNL AGS E889 (1995)