Reconstruction of Neutrino Induced NC-1π^0 Using the T2K-ND280 Tracker

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On behalf of the T2K Collaboration

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Abstract. Single π^0 production is the one of the most important backgrounds in the υ_e appearance measurement in T2K. Large uncertainties in this production make it difficult to predict. Measurement at the near detector (ND280) is required both to constrain the background prediction at the far detector (Super-K) and also at the near detector to improve knowledge of beam υ_e contamination. We present an analysis based on Monte Carlo simulation of neutral current (NC) single π^0 in the tracker region. NC-1π^0 events are selected using a specific two-gamma signature in the tracker region. One decay gamma is reconstructed by selecting an e+/e- pair starting in the Fine-Grained target Detector (FGD) and extending into the TPC, where the leptons can be identified and their momentum measured accurately. The second gamma is then selected in-time in the Calorimeter modules surrounding the tracker. Selections cuts, efficiency and purity of the selection are presented and projection of the expected number of single π^0 candidates for 3 x 10^{20} protons on target (PoT) exposure is made.

Keywords: Neutrinos, T2K experiment, J-PARC, ND280
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THE T2K EXPERIMENT

The Tokai-to-Kamioka (T2K) long baseline neutrino experiment is based in Japan [1]. An intense υ_μ beam is produced by colliding 30 GeV protons with a graphite target at the J-PARC facility in Tokai-mura, Ibaraki. Two independent detectors located 280 m and 295 km from the neutrino production point measure the composition of the resultant beam. Both detectors are positioned 2.5° off the beam axis, which results in a narrow band of neutrino energies, which peaks around 600 MeV. At this energy, the position of the far detector coincides with the first maximum of the υ_μ disappearance probability and the dominant interaction mode of neutrinos is charged current quasi-elastic scattering.

Studies of υ_μ disappearance and υ_e appearance at the far detector allow measurements of the neutrino mixing parameters, θ_{13}, θ_{23} and Δm_{32}^2 [2], [3]. Precision measurement of these parameters requires excellent understanding of backgrounds in the far detector. At present NC-1π^0 events are one of the largest backgrounds in the υ_e appearance measurement at the far detector. The majority of NC-1π^0 events are easily rejected by excluding events with multiple Cherenkov rings in Super-K. However, if both gammas are emitted in a very forward direction or if there is a large asymmetry in energy between the gamma-rays and only one has sufficient energy to produce an above threshold signal, only one Cherenkov ring will be detected and the NC-1π^0 event will be very difficult to distinguish from a υ_e interaction. As the production cross-section of NC-1π^0 events is not well known, they contribute one of the largest systematic errors to the υ_e appearance measurement at T2K. Studying π^0 production in the near detector and extrapolating results to the far detector will reduce this systematic error.

The near detector, ND280, consists of five sub-detectors surrounded by a magnet, which produces a 0.2T field. Within ND280, the tracker region comprises of the Fine-Grained Detectors (FGDs) and Time Projection Chambers (TPCs). In this work, signals in the tracker region and the Electromagnetic Calorimeter (ECal) are used to reconstruct NC-1π^0 events produced in an FGD.

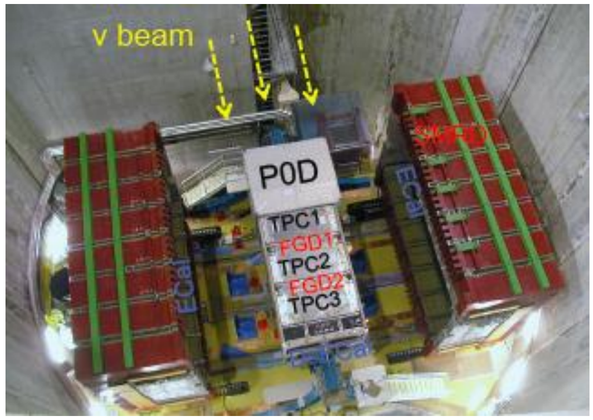

FIGURE 1. Photograph of the T2K near detector, labeled to show the locations of the five sub-detectors. The large red structure is the return yolk of the magnet and is pictured in the open position. During normal running, the magnet is closed.

NC-1π^0 SIGNAL DEFINITION AND TOPOLOGY IN THE TRACKER

A neutral current single π^0 (NC-1π^0) event is defined as a neutrino interaction where there is one π^0, any number of protons and neutrons and no mesons or charged leptons produced in the final state. This is shown in Figure 2.

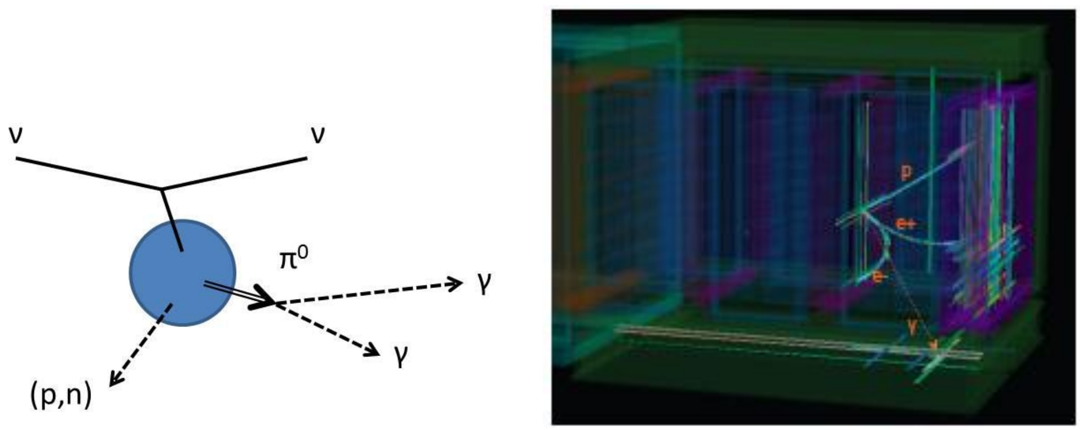

FIGURE 2. Left, definition of a NC-1π^0 event. Right, an event display of a Monte Carlo generated NC-1 π^0 event with the topology of interest.

Gamma-rays produced from π^0 decay can convert in different sub-detectors. This work focused on developing a selection for cases where one gamma converts, producing an e^+e^- pair in the FGD/TPC, and the other gamma converts in the ECal. Approximately 14% of all NC-1π^0 produced in an FGD have this topology.

SELECTION CUTS AND BACKGROUND REJECTION

The selection begins by identifying e^+e^- pairs in the tracker region. For a well-reconstructed pair, the tracks have opposite charge, the momentum of each is between 40 and 1000 MeV/c, the start positions are within 15 cm of each other and the reconstructed pair invariant mass is less than 50 MeV/c. If more than one combination is possible, the two tracks that create the smallest invariant mass are used. The efficiency and purity of this selection are 20% and 80% respectively.

Once a pair has been identified, the selection of the ECal object takes place. The ECal object is not connected to a track, its energy is greater than 50 MeV, there are no Michel electrons associated with it and it occurs within 100 ns of the pair production. If more than one candidate satisfies this ECal selection, the object with the highest energy is used. The efficiency and purity of this selection are 45% and 60% respectively.

Before reconstructing the π^0 mass, the direction of the decay gammas should be known. The direction of the gamma that converted into the e^+e^- pair is well known, but that of the gamma detected in the ECal is not, due in part to its low energy. An improved estimate of the ECal gamma direction can be obtained, if the vertex position and the point of conversion in the ECal are known. As the pair is typically created a few centimeters from the vertex, the mean free path of the gamma can be used to estimate the most probable vertex position. The direction of the gamma is calculated by taking the difference between this vertex and the point of conversion in the ECal. As both directions are known, a reconstruction of the invariant mass is possible and any combination with a mass greater than 500 MeV/c^2 is rejected.

Finally, to minimize contributions from out of fiducial volume backgrounds, beam bunches which contain any activity upstream of the first FGD, muons, more than 4 ECal objects or greater than 9 tracks in the tracker are rejected. Figure 3 shows the reconstructed π^0 mass for Monte Carlo generated signal events selected using the cuts and methods described in this section.

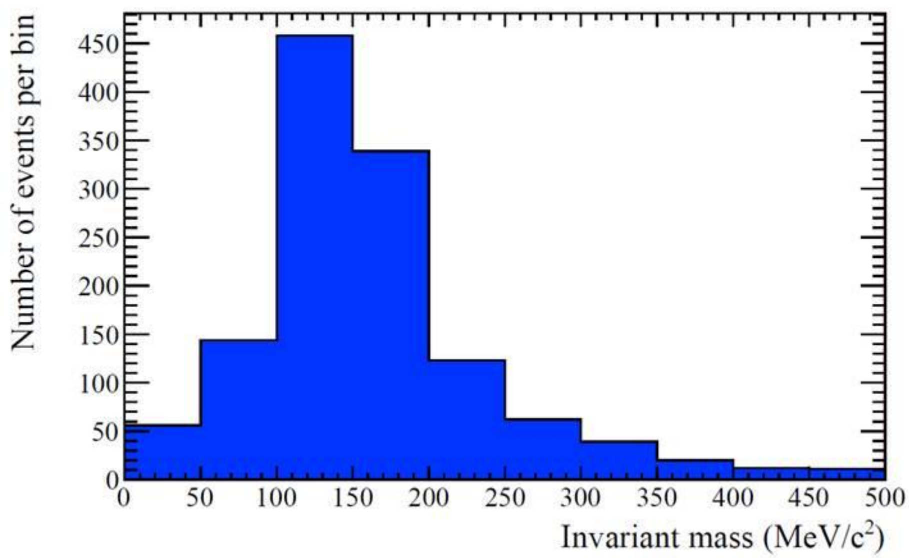

FIGURE 3. Reconstructed invariant mass for Monte Carlo signal events.

FINAL SELECTION AND SUMMARY

A topology with one gamma converting close to the vertex to produce a pair and the second converting the ECal provides a good acceptance of NC-1 π^0 events and an accurate reconstruction of their mass. At present, the selection efficiency for the specified topology is ~5%, with a purity of ~22%. Based on this work, approximately 25 signal events are expected for 3 x 10^{20} protons on target. Work is in progress to optimize the selection and minimize CC and external backgrounds.

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