NC 1π0 interactions at the Near Detector of T2K

IOP HEPP meeting 2010

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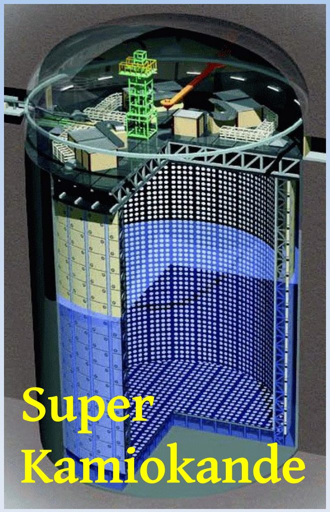
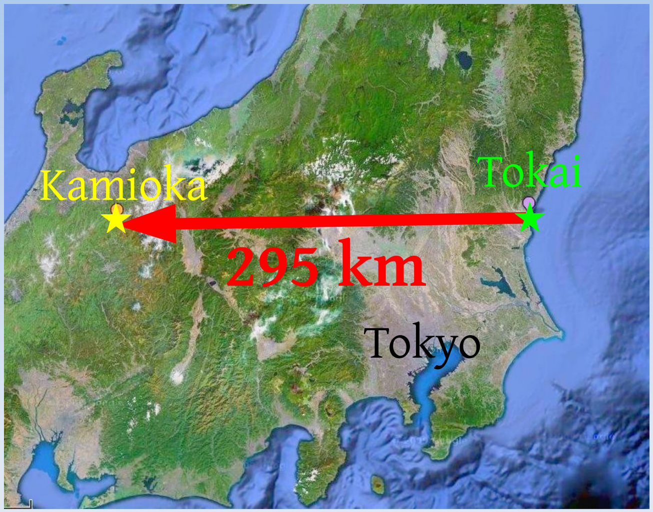
25th March 2010

Outline

- Description of the T2K experiment
- NC π^0 measurement at the Near Detector; importance for the oscillation analysis
- π^0 reconstruction using the ECals

The T2K Experiment





- At J-PARC, the world's most intense neutrino beam is created
- 280m from the production target, beam passes through set of near detectors
  - Beam direction & composition monitoring, cross section measurements
- 295km downstream, the beam passes through Super-Kamiokande
  - 50kt water Cerenkov detector, ν_μ disappearance & ν_e appearance measurement

Motivation

- Neutrino oscillation given by PMNS matrix, mixing mass and flavour eigenstates

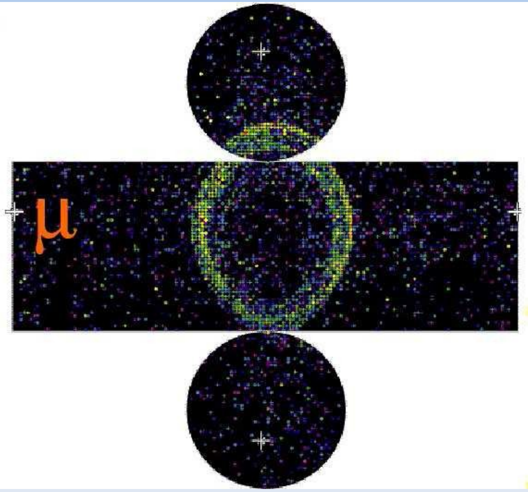
$$\begin{pmatrix}\nu_e\\ \nu_\mu\\ \nu_\tau\end{pmatrix} = \begin{pmatrix}1 & 0 & 0\\ 0 & C_{23} & S_{23}\\ 0 & -S_{23} & C_{23}\end{pmatrix}\begin{pmatrix}C_{13}^{*} & 0 & S_{13}e^{-i\delta}\\ 0 & 1 & 0\\ -S_{13}e^{-i\delta} & 0 & C_{13}\end{pmatrix}\begin{pmatrix}C_{12} & S_{12} & 0\\ -S_{12} & C_{12} & 0\\ 0 & 0 & 1\end{pmatrix}\begin{pmatrix}\nu_1\\ \nu_2\\ \nu_3\end{pmatrix}$$

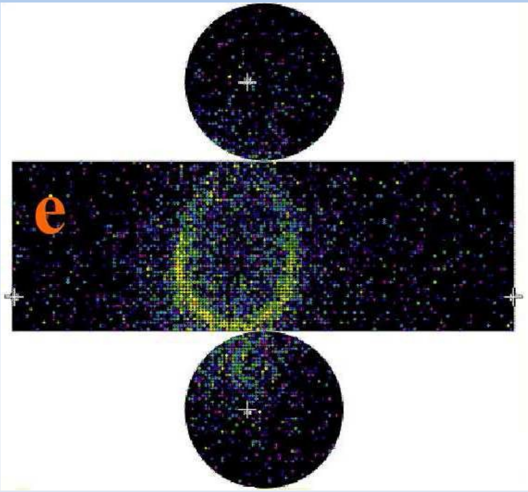
- ν_μ disappearance: $P(\nu_\mu \to \nu_x) \approx \sin^2 2\underset{\sim 45^\circ}{\underline{\theta_{23}}} \sin^2(\underset{\sim 2.4\text{x}10^{-3}\ \text{eV}^2}{\underline{\Delta m^2_{23}}} L/4E)$

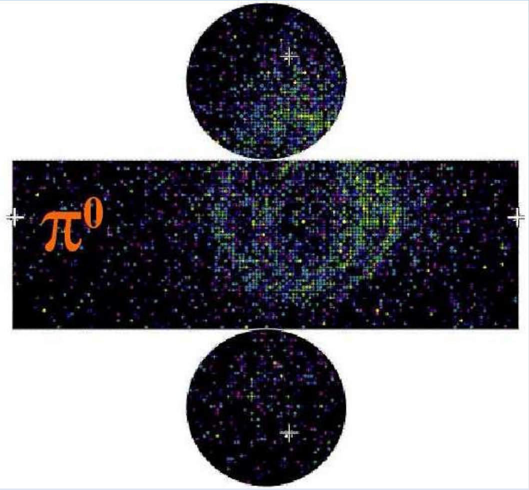
- ν_e appearance: $P(\nu_\mu \to \nu_e) \approx \underset{< 0.1}{\underline{\sin^2 2\theta_{13}}} \sin^2 \theta_{23} \sin^2(\Delta m^2_{23} L/4E)$

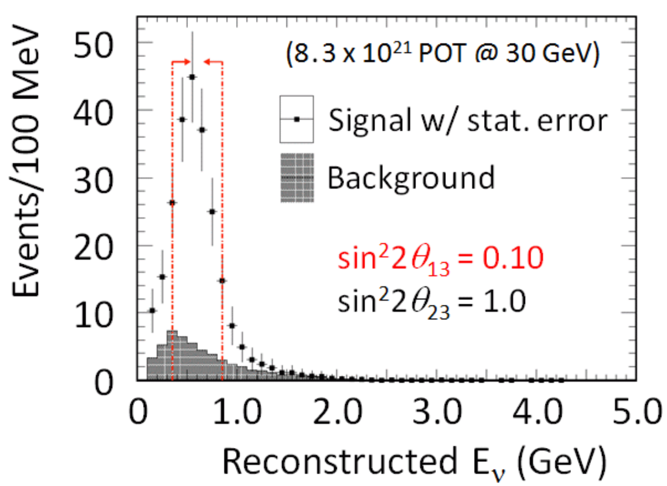
* $C_{13} = \cos\theta_{13}$, etc.

π^0 background to ν_e appearance





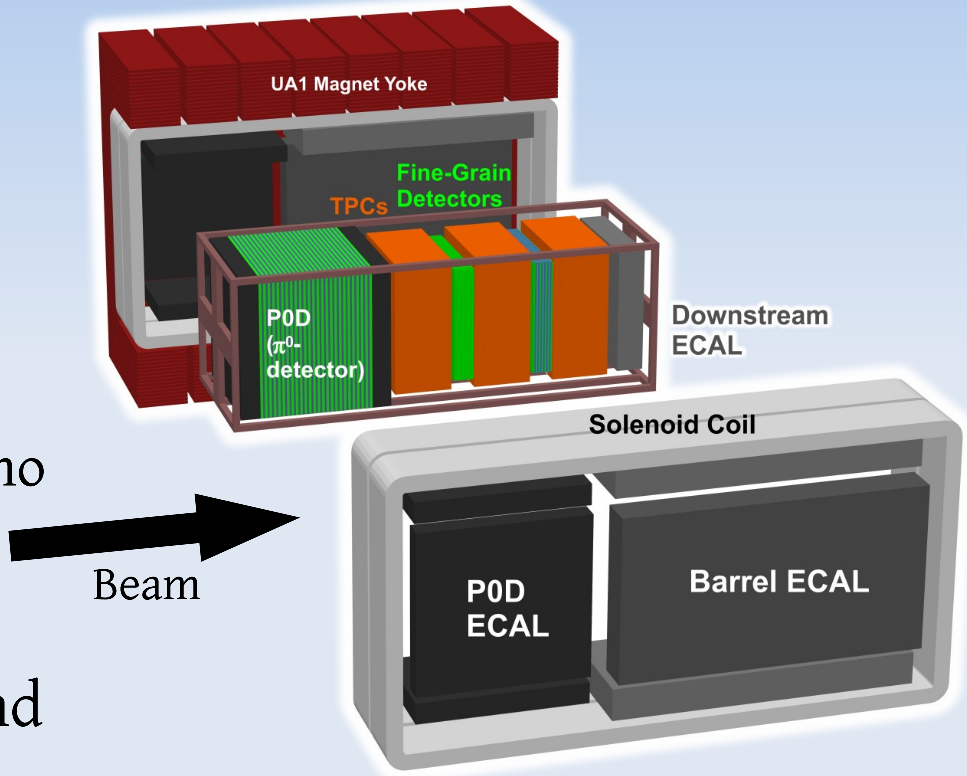




- ν_e signal: 1 e-like ring
- Main backgrounds:
  - ν_e contamination in the beam (~60%)
  - NC π^0 where photon rings misreconstruct as single e-like ring (~40%)

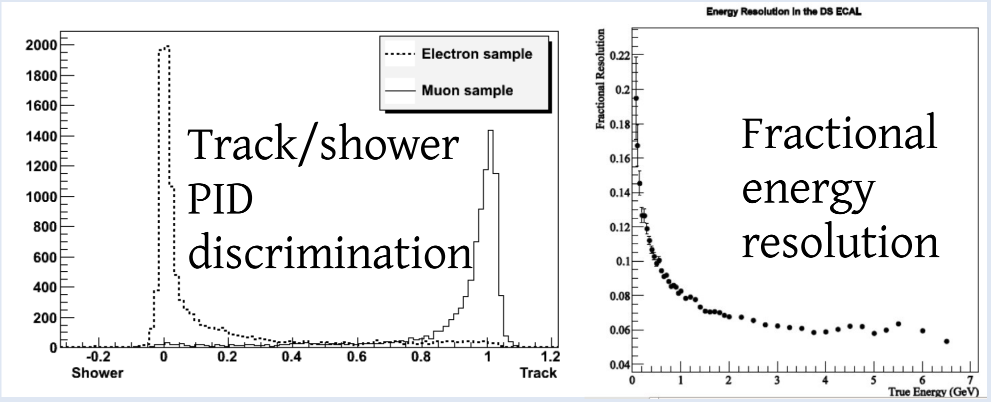
The Off-Axis Near Detector

- P0D makes high-statistics measurement of inclusive π^0 production
- Tracker region (TPCs + FGDs) allows for charge, PID determination of tracks
    - FGDs act as targets for neutrino interactions in the region
- ECals perform additional PID, make energy measurement, and convert photons
    - This allows for another π^0 analysis using the tracker, to perform a complementary measurement to the P0D



The ECal

- The tracker region is surrounded by 7 ECal modules
- Each is formed of layers of lead and scintillator bars; lead to provide dense material for showering, and scintillator as the active material
- The scintillators are read out in two views (e.g. XZ and YZ, where the Z axis is perpendicular to the module)
  - Reconstruction has to match both views together
- Modules can also be used for Track/EM/Hadronic shower PID
- Energy resolution of EM showers: $7\%/\sqrt{E}$(GeV)



Track/shower PID discrimination

Fractional energy resolution

Photon shower pointing

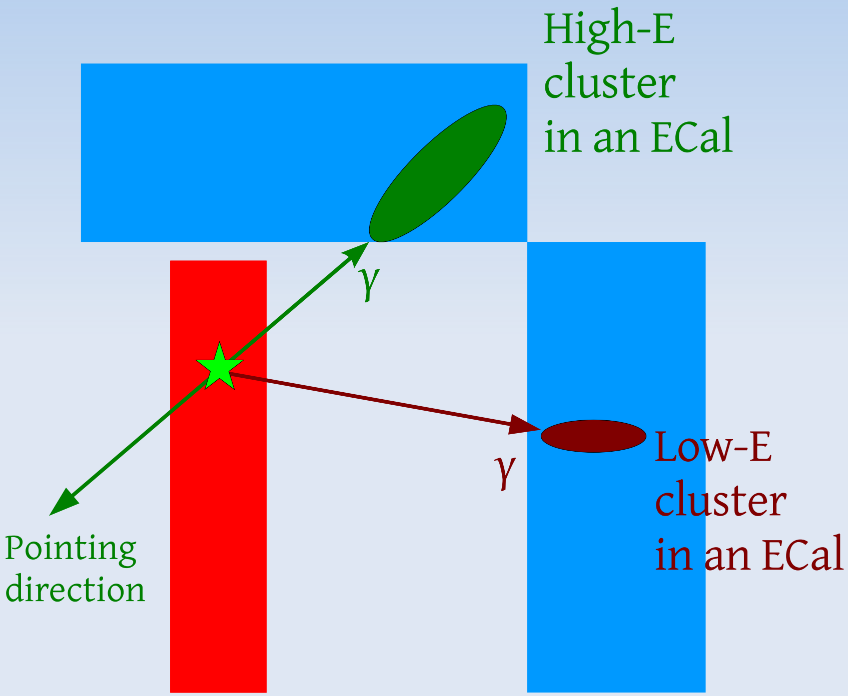
- An important of the ECal modules is to provide directional information for photon showers
  - This isn't a collider experiment – the vertex position is not localised
- Take the shower origin as mean hit position in the innermost layer
- Adapting a “thrust” algorithm (used in other PP experiments, e.g. BaBar), the direction is taken as the axis a which maximises the quantity t (thrust) given by:

$$t = \frac{\sum |a \cdot P|}{\sum \sqrt{P \cdot P}}$$

- Here, P is the position vector of each hit relative to the shower origin

π^0 vertex reconstruction

- Given an event with two clusters in the ECals, take the pointing direction of the higher energy cluster, and extrapolate until it intersects an FGD
- Place vertex at the midpoint of this intersection
- Use this vertex as a candidate for a π^0 decay, and assume photons come from this position
- Reconstruct the π^0 mass and momentum, using the energies and directions of the photons



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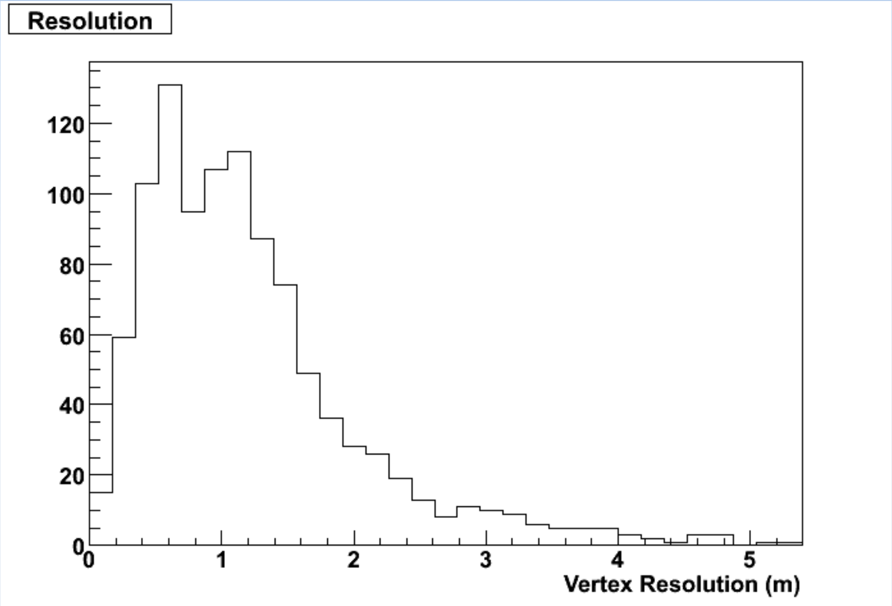
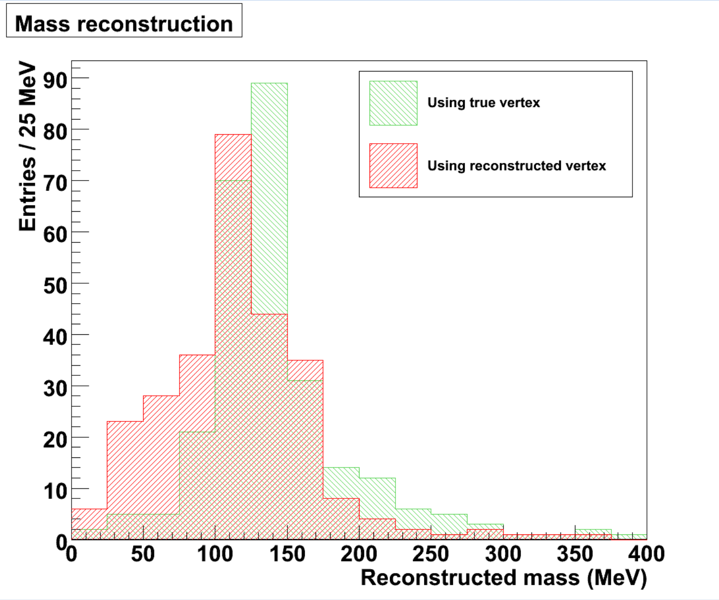
Analysis cuts

- Firstly, make an activity cut in the FGDs
  - NC interactions should produce less hits in the FGDs
- Use truth information to remove any charged clusters in the Ecal
  - Should leave only photon, neutron showers
- Time difference cut when matching two views of a single cluster
- Maximum energy cut on a single cluster
  - Should remove clusters produced by neutrino interactions in the ECal modules themselves
- Time difference cut when matching two clusters to a single π^0 candidate

Reconstruction performance





- Vertex resolution (recon – true position difference)

- Reconstructed mass. Shown is the mass if the true vertex is used (i.e. only energy resolution effects), and when the reconstructed vertex is used

- Underlines importance of good vertex resolution

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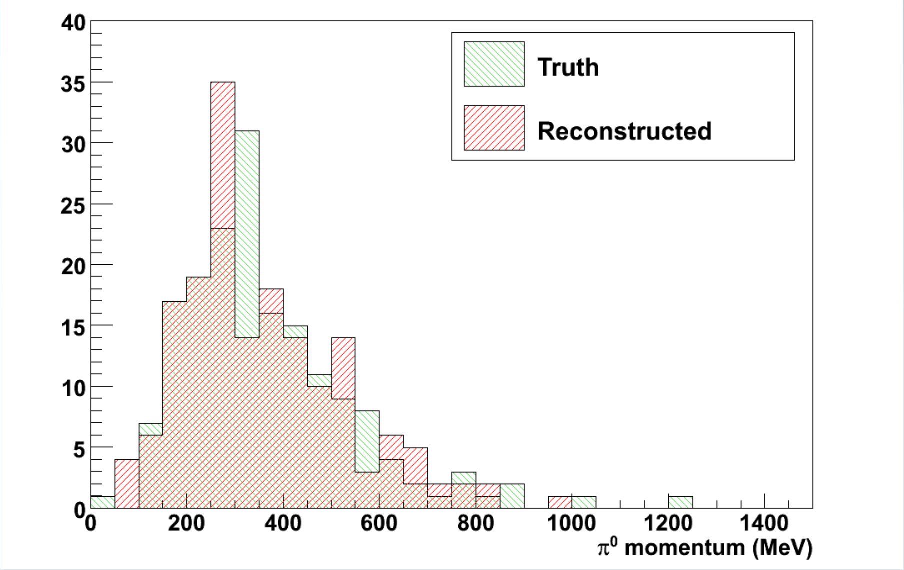
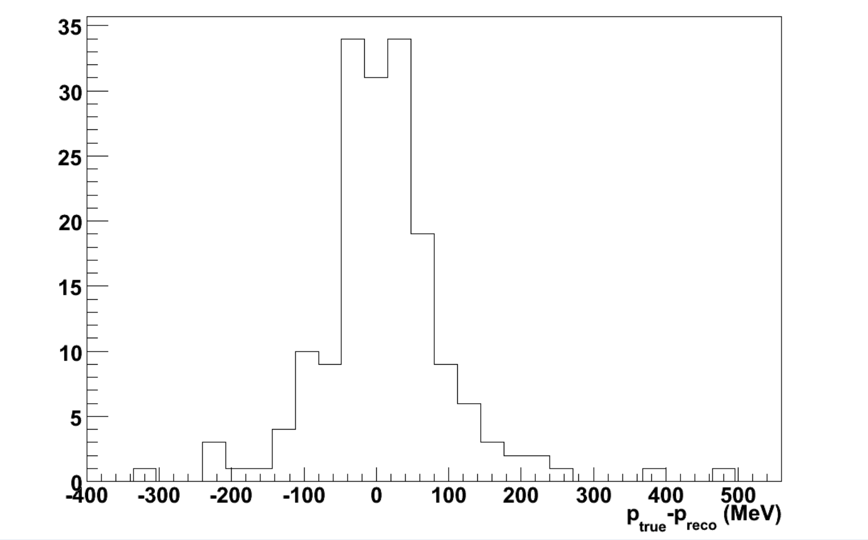
T2K UK

Momentum resolution





- True & reconstructed momentum

- Momentum resolution
- σ ~ 60 MeV

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Improvements in progress

- Have already begun upgrading the reconstruction
  - Will integrate it with global tracker reconstruction. This will allow the removal of the FGD activity cut and the truth based cluster charge cut, by matching with tracks in the TPCs
  - Removal of constraint that the vertex has to be in an FGD; now use the intersection of both photon directions
  - Including photon directional resolutions into the vertex resolution
  - Incorporate directional information, i.e. discriminating between particles coming in to the ECal modules from the tracker region, or from the magnet

Summary

- Measuring NC π^0 interactions at the Near Detector important: provides a constraint on a systematic for the ν_e appearance measurement at SK
- Using the ECals to reconstruct π^0 events in the tracker is proceeding
- Work is being done to improve the reconstruction