Initial Look At $\nu_e$ Appearance Search

James Imber
Stony Brook
23rd Feb 2010
Outline

• Brief revision of Super-K
• $\nu_e$ Event selection cuts
  – Development work
  – Example analysis
# Detector Input

<table>
<thead>
<tr>
<th>Beam</th>
<th>ND280</th>
<th>Super-K</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Energy spectrum</td>
<td>• Beam $\nu_\mu$</td>
<td>• ‘Oscillated’ $\nu_\mu$</td>
</tr>
<tr>
<td>• Beam dimensions</td>
<td>• Intrinsic $\nu_e$</td>
<td>• ‘Oscillated’ $\nu_e$</td>
</tr>
<tr>
<td></td>
<td>• $\pi^0$ background</td>
<td></td>
</tr>
</tbody>
</table>
Super-K

- 22.5 kton (F.V.) water Cerenkov detector
- 11,146 PMTs in ID
- 1885 PMTs in OD
- 2700m of water equivalent overburden
CCQE $\nu_e/\nu_\mu$ Selection

Geometry cuts

Signal selection cuts

$\pi^0$ reduction cuts

Fiducial volume

Visible Energy cut

Fully Contained

Single Ring

e-like

No decay electrons

Cos(\theta)

Reconstructed

pi0 mass cut

pi0 likeness cut

Reconstructed energy cut

$\mu$-like

One or fewer decay electrons
5 year MC analysis

• 07a MC flux files
• Analysis code from T2K.org uploaded by Josh Albert
  – MCproxyprocess.C
  – MCcheck.cc
• Oscillation – $\sin(2\theta_{13}) = 0.01$
Fiducial volume

Visible Energy cut

Fully Contained

Single Ring

e-like

No decay electrons

Cos(\theta)

Reconstructed

\pi0 mass cut

\pi0 likeness cut

Reconstructed energy cut

wall > 200cm

Distance to closest wall in any direction
Fiducial volume

Visible Energy cut

Fully Contained

Single Ring

e-like

No decay electrons

Cos(\theta)

Reconstructed pi0 mass cut

pi0 likeness cut

Reconstructed energy cut

wall > 100cm and towall > 200cm

Distance to closest wall in any direction
Fiducial volume

Visible Energy cut

Fully Contained

Single Ring

e-like

No decay electrons

Cos(\theta)

Reconstructed pi0 mass cut

pi0 likeness cut

Reconstructed energy cut

Sarah Dipper & Gil Kogan
Total visible energy in the ID > 100 MeV
Rejects low momentum pions and electrons decayed from muons below the Cerenkov threshold.

Fiducial volume

Visible Energy cut

Fully Contained

Single Ring
e-like

No decay electrons

Cos(theta)

Reconstructed pi0 mass cut

pi0 likeness cut

Reconstructed energy cut
No. of hit PMTs in the OD PMT cluster with the highest charge < 16
Selects fully contained events

Fiducial volume
Visible Energy cut
Fully Contained
Single Ring
e-like
No decay electrons
Cos(theta)
Reconstructed pi0 mass cut
pi0 likeness cut
Reconstructed energy cut
Only one ring is detected by the ring finding algorithms
Boosts CCQE over background

Fiducial volume

Visible Energy cut

Fully Contained

Single Ring

e-like

No decay electrons

Cos(theta)

Reconstructed

pi0 mass cut

pi0 likeness cut

Reconstructed energy cut
Single ring is “e-like”
Selects electron events

Fiducial volume

Visible Energy cut

Fully Contained

Single Ring

e-like

No decay electrons

Cos(theta)

Reconstructed pi0 mass cut

pi0 likeness cut

Reconstructed energy cut
Fiducial volume
Visible Energy cut
Fully Contained
Single Ring
e-like
No decay electrons
Cos(theta)
Reconstructed pi0 mass cut
pi0 likeness cut
Reconstructed energy cut

Good events’ that fail this cut tend to have a mis-reconstructed vertex
Fiducial volume
Visible Energy cut
Fully Contained
Single Ring
e-like
No decay electrons
Cos(theta)
Reconstructed
pi0 mass cut
pi0 likeness cut
Reconstructed energy cut

Vertex shifted back
e misidentified as μ

 Vertex shifted forward
μ misidentified as e
No $\mu \rightarrow e$ decay detected in a 30 $\mu$s time window after the event

Removes muons and pions that have been wrongly identified as electrons

Fiducial volume

Visible Energy cut

Fully Contained

Single Ring

e-like

No decay electrons

Cos($\theta$)

Reconstructed pi0 mass cut

pi0 likeness cut

Reconstructed energy cut
Cos(\(\theta\)) < 0.9
Removes forward scattered \(\pi^0\) coherent events

Fiducial volume
Visible Energy cut
Fully Contained
Single Ring
e-like
No decay electrons
Cos(theta)
Reconstructed pi0 mass cut
pi0 likeness cut
Reconstructed energy cut
Fiducial volume

Visible Energy cut

Fully Contained

Single Ring

e-like

No decay electrons

Cos(theta)

Reconstructed

pi0 mass cut

pi0 likeness cut

Reconstructed energy cut
Fiducial volume
Visible Energy cut
Fully Contained
Single Ring
e-like
No decay electron: Cos(\theta) 
Reconstructed 
\pi^0 mass cut 
\pi^0 likeness cut 
Reconstructed energy cut
Fiducial volume

Visible Energy cut

Fully Contained

Single Ring

e-like

No decay electrons

Cos(theta)

Reconstructed

π⁰ mass cut

π⁰ likeness cut

Reconstructed energy cut

π⁰ mass < 100MeV

POLfit tries to fit a second ring and calculates π⁰ invariant mass
Fiducial volume

Visible Energy cut

Fully Contained

Single Ring

e-like

No decay electrons

Cos(\theta)

Reconstructed

\pi^0 mass cut

\pi^0 likeness cut

Reconstructed energy cut

**\pi^0like[0]-\pi^0like[1] < 80**

Removes events that are significantly more \(\pi^0\)-like than e-like
350<\text{recnuE}<850\text{MeV}
Selects events in region with maximum probability of oscillation

Fiducial volume
Visible Energy cut
Fully Contained
Single Ring
e-like
No decay electrons
Cos(\theta)
Reconstructed
\pi^0\text{ mass cut}
\pi^0\text{ likeness cut}
Reconstructed energy cut

\[ E_{\text{rec}} = \frac{m_n E_\mu - m_\mu^2 / 2}{m_n - E_\mu + (P_\mu \cos \theta_{\nu\mu})} \]

Fanny Dufour
Fiducial volume

Visible Energy cut

Fully Contained

Single Ring

e-like

No decay electrons

Cos(theta)

Reconstructed pi0 mass cut

pi0 likeness cut

Reconstructed energy cut
Main items towards the first run

- **Finalize selection criteria for first data set**
  - Determine expectations, sensitivity and efficiencies
  - Find straightforward technique relatively insensitive to systematics *(Request by ASG).*
  - Optimize cuts
- **Determine Normalization (tied to numu)**
- **e/π0 algorithms**
  - Will we use them in the first run? If yes how/which ones?
  - Testing of algorithms against control samples. How?
  - Further development
- **Systematic constraints on Bkg from SK alone (sidebands).**
- **Determine systematic errors from reconstruction, interaction etc.** Depends on choice of cuts *(Some in common with numu. Also need to compare with ATMPD).*
- **Other possible extensions to analysis (FV etc)**