Measurement of the intrinsic electron neutrino and electron anti-neutrino components in the T2K beam with the ND280 Tracker.

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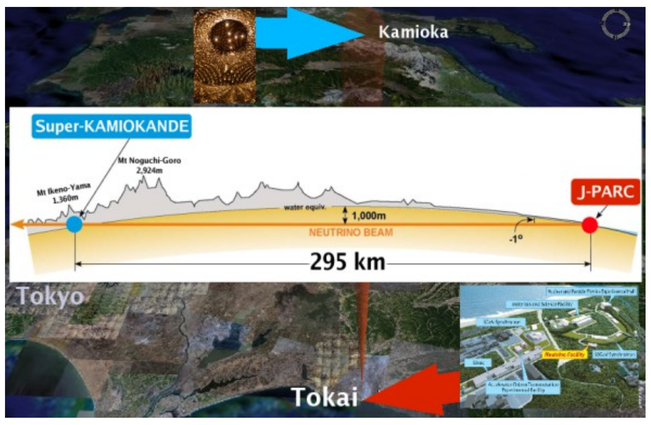
1. T2K Experiment

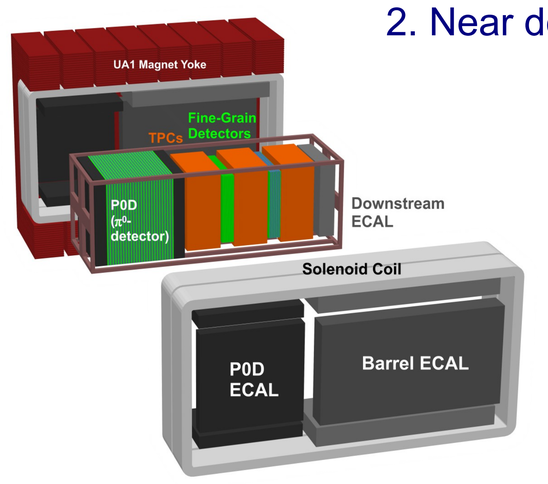


Long-baseline neutrino experiment using a υ_μ beam to investigate neutrino oscillations.
Primary goal is measurement of θ_{13} via υ_e appearance.

Largest background is from intrinsic υ_e in beam from $K^+ \rightarrow e^+ + \upsilon_e + \pi^0$ or from $\mu^+ \rightarrow e^+ + \upsilon_e$

This year, T2K will be changing horn polarity to run with anti-neutrinos.

2. Near detector (ND280)



ND280 can be used to measure the intrinsic υ_e and $\bar{\upsilon}_e$ component of the beam.
Selections for charged-current (CC) υ_e interactions in the near detector (ND280) have been developed.

Fine Grained Detectors (FGDs) are the target mass for neutrino interactions.

Time Projection Chambers (TPCs) and if available Electromagnetic Calorimeters (ECALs) are used to select electron-like tracks.

3. Electron candidates

There are 3 paths available for particle identification (PID): just the TPCs, TPCs and Barrel ECAL or TPCs and the Downstream ECAL. The fraction of electron candidates in each PID branch is shown in the table below. Monte Carlo simulations show that whilst the final sample is 92% pure in electrons, only 27% of these are from υ_e CC interactions, with the main background being from photons showering in the FGDs.

	FGD1 Vertices		FGD2 Vertices	
Category	events (%)	Eff. (%) [Pur. (%)]	events (%)	Eff. (%) [Pur. (%)]
1. TPC only	45.4	56.6 [92.6]	34.1	53.1 [90.9]
2. TPC + DsECAL	32.0	82.6 [97.8]	59.0	89.1 [93.8]
3. TPC + Barrel ECAL	22.6	86.1 [91.4]	6.9	88.6 [86.5]

4. Reducing gamma contamination

Photon conversions in the FGDs are the largest source of background in the selection. They make up 65% of all events at this stage. To reduce photon contamination several cuts are applied:

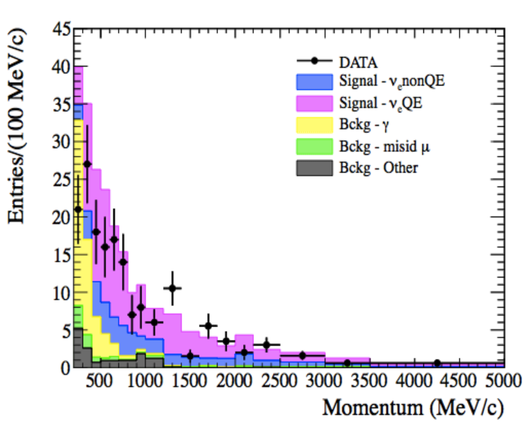
- Veto cuts remove events with reconstructed tracks upstream of the electron candidate.
- An invariant mass cut is also applied if a positive electron-like track is reconstructed near the electron candidate, to reject e^+e^- pairs.

Following these cuts the photon contamination is reduced to 30%.

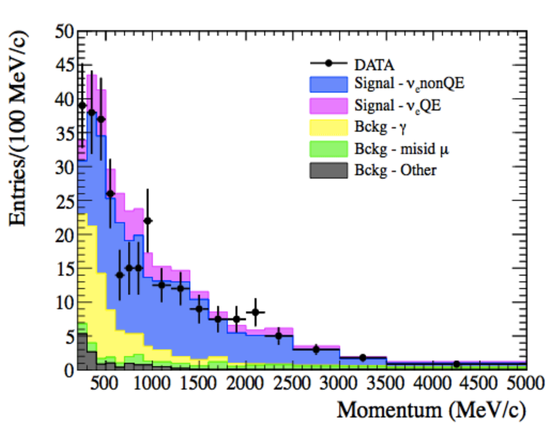
Further cuts are then applied to separate the sample into CC quasi-elastic (CCQE) and CC non-quasi-elastic (CCnonQE) categories.

5. υ_e results

It was found that the ratio between observed and predicted beam υ_e content is 1.01 ± 0.10. The υ_e produced by muon and kaon decays were also separately measured resulting in ratios of 0.68 ± 0.30 and 1.10 ± 0.14 respectively [1].



Reconstructed electron momentum of events in the CCQE-like sample.



Reconstructed electron momentum of events in the CCnonQE-like sample.

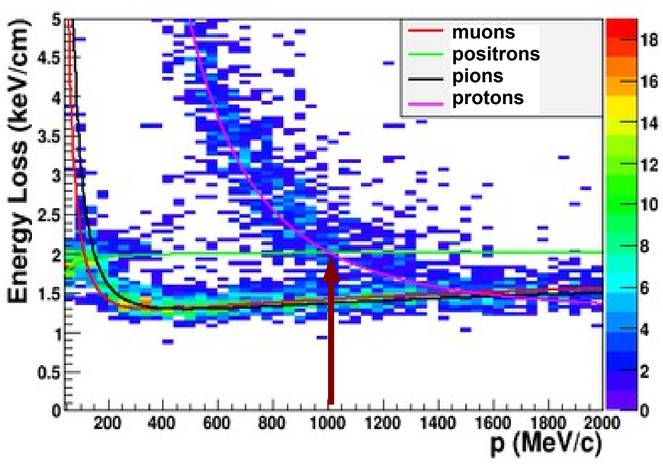
6. $\bar{\upsilon}_e$ challenges

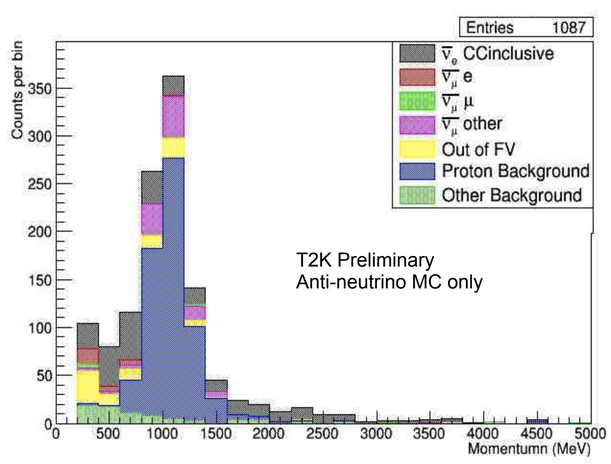
Selecting $\bar{\upsilon}_e$ events causes additional complications. The dE/dx curves for protons and positrons at 1000 MeV/c are similar and therefore the TPC PID has difficulties distinguishing between them.

This is not an issue in the υ_e selection, as the protons are removed by a negative charge requirement.

This causes a large background in the $\bar{\upsilon}_e$ selection which cannot be removed with the TPC's, shown in the figure bottom right.

In the plot to the right the proton background can be seen in blue, with the $\bar{\upsilon}_e$ signal in black. The highest momentum particle coming from background $\bar{\upsilon}_\mu$ interactions is also identified.



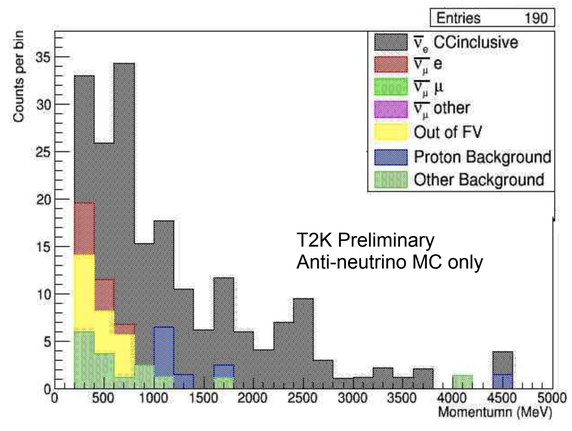


7. Updated $\bar{\upsilon}_e$ selection

The ECAL PID was used in combination with TPC information in order to remove the proton background which could not be removed solely by TPC PID. By combining the momentum measured by the TPC with electromagnetic energy deposited in the ECALs the majority of the proton background can be removed.

Requiring an ECAL track means that PID category 1 from the table in section 3 cannot be used. For events from categories 2 and 3, an additional 15% of events are then removed by the proton cut requirements. The result is a selection with a purity only 5% lower than the official T2K υ_e selection. A Monte Carlo simulation of the selected candidates after these requirements can be seen right.

We plan to run this selection on future anti-neutrino data taken by the T2K experiment.



References
[1] K. Abe et al, Measurement of the intrinsic electron neutrino component in the T2K neutrino beam with the ND280 detector, Phys. Rev. D 89, 092003, 2014.