ν_e measurements in the T2K off-axis near detector (ND280)

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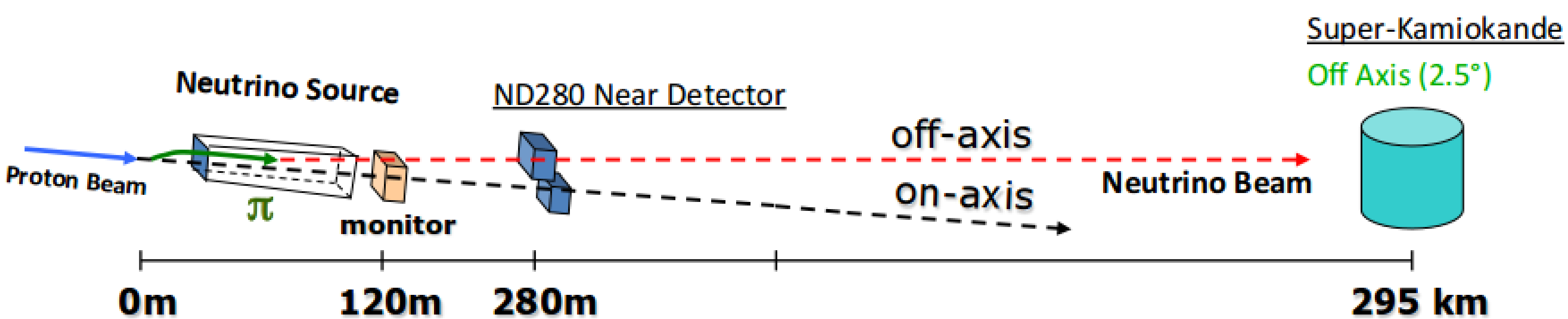
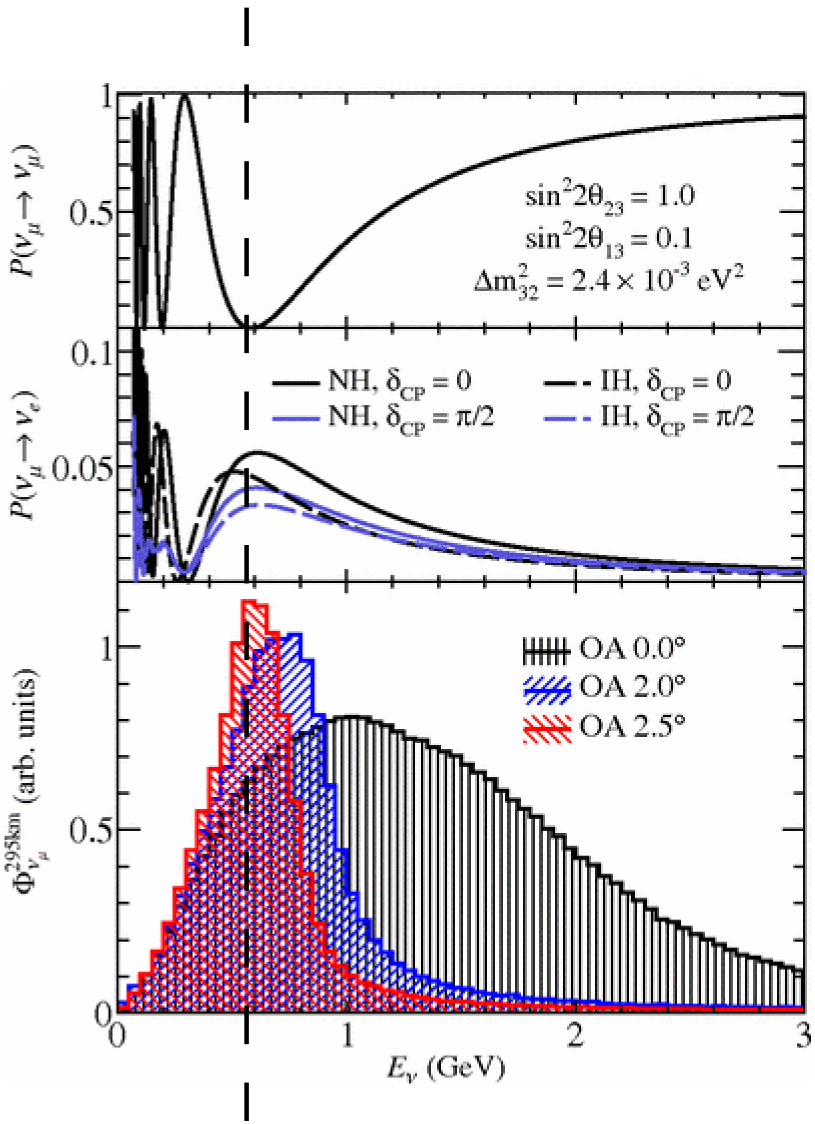
The T2K Experiment



J-PARC → Near Detector (ND280) → Super Kamiokande (SK)

The T2K Experiment

Optimised to observe electron neutrino appearance in the muon neutrino beam



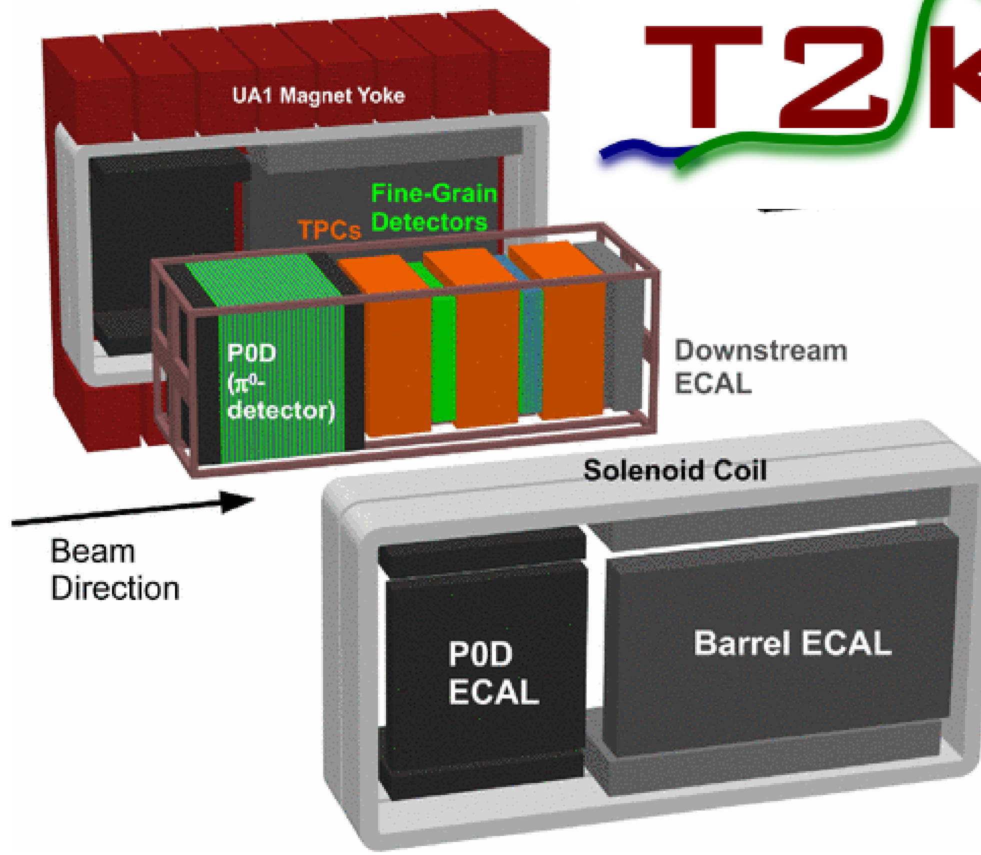
Flux spectrum peaks at:

- first survival min/oscillation max ($\nu_\mu \to \nu_\mu$)
  → θ_{23}
- first oscillation max for ($\nu_\mu \to \nu_e$)
  → θ_{13} and δ_{CP}

Off-axis beam provides:

- greater flux at maximum neutrino energy
- reduced number of high-energy neutrinos
  → less background from high-energy neutrino interactions

ND280
T2K off-axis near detector



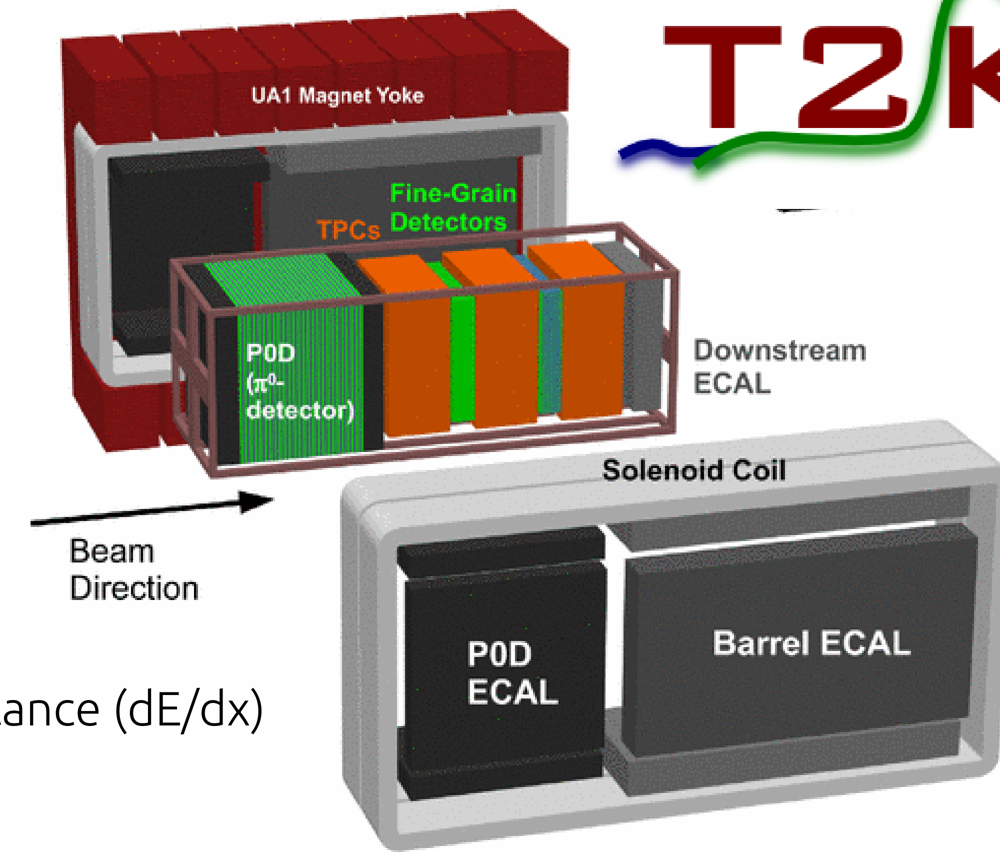
- 280m from source
  (same off-axis angle as SK)

→ oscillation effects are negligible

- constrain flux and cross-section systematic uncertainties
- measures neutrino cross-sections
- Magnetised
- Particle tracker
  - Fine Grained (scintillator) Detectors (FGDs)
  - Time Projection Chambers (TPCs)
- Electromagnetic Calorimeters (ECals)
- Pion detectors

ND280

T2K off-axis near detector



Two FGDs

- active target mass
- vertex reconstruction

Three TPCs

- Particle IDentification (PID) using
  Energy deposited as a function of distance (dE/dx)
- momentum reconstruction

Two ECals (around and in front of beam direction)

- energy containment
- improves PID

π^0 Detector (P0D) and Side Range Muon Detector (SMRD)

- designed for neutrino interactions with π^0 in the final state

The importance of ν_e Measurements in ND280

Measure intrinsic ν_e component of the beam

ν_e are the **signal** in the search for $\nu_\mu \rightarrow \nu_e$ (ν_e from **oscillation**)
ν_e are also the largest **background** (**intrinsic ν_e component of beam**)

Measure ν_e cross-section

At the moment only ν_μ data is used to constrain systematic uncertainties at SK
ν_e cross-section appropriated to be the same as ν_μ

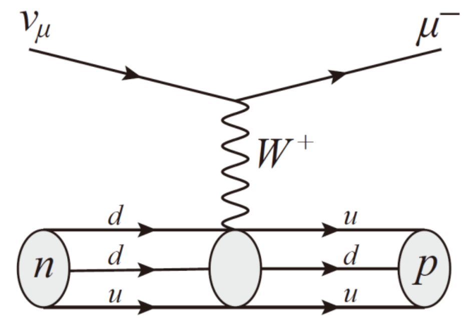
ν_e data can provide a check that the flux and cross-section measurements of ν_μ are reasonable

Measuring differences between ν_μ and ν_e cross-sections will reduce systematics
→ important for other/future experiments

ν_e CC inclusive Interactions in ND280

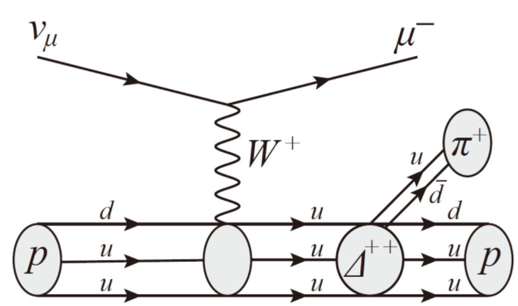
Charged Current Quasi-Elastic (CCQE)

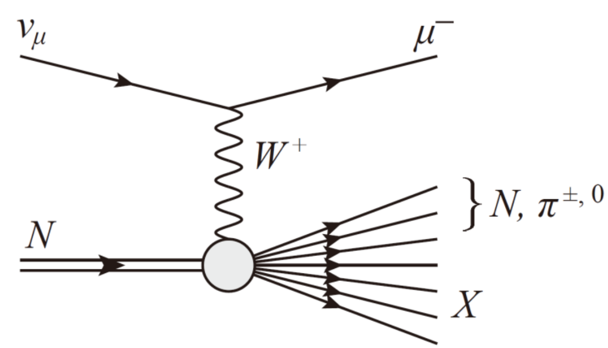
$\nu_e + N \rightarrow e^- + N'$



Charged Current non Quasi-Elastic (CCnonQE)

$\nu_e + N \rightarrow e^- + N' + \text{pions}$





- Detect CC interactions by detecting the electron
- Separate into CCQE and CCnonQE

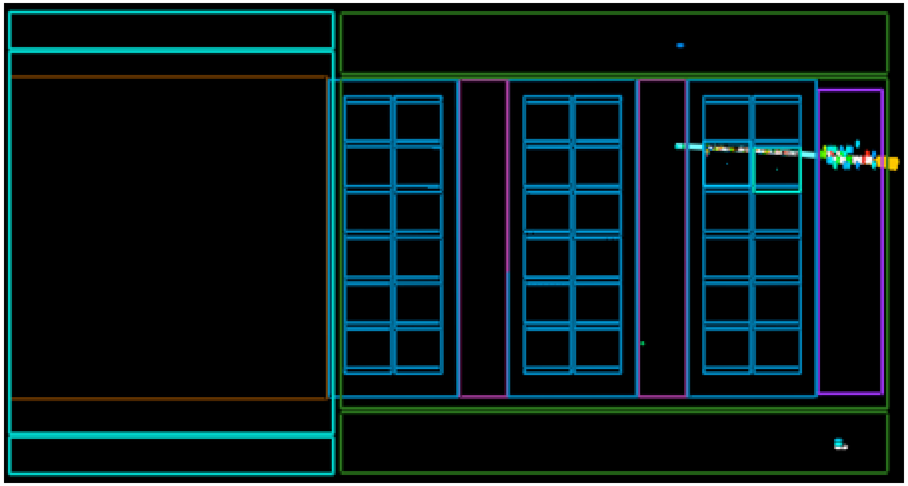
Reconstructing events ND280

For each **sub-detector**
- code that uses the raw data to **reconstruct information** about the event/particles

This is **combined** to give **global reconstruction** information

Fundamental changes to the codes are implemented at the same time
- new 'Production' (e.g. Production1, Production2 etc.)

Using the reconstructed information, variables are defined to make cuts in a selection process



When a new production is released, various tests and checks are done.

For the Production 6 (P6) pre-release (and subsequent releases with bug fixes) I ran the ν_e selection on the newly reconstructed data/MC files and compared to Production 5 (P5)

Selecting ν_e events in ND280

Aims:

1. Measure the intrinsic ν_e component of T2K beam to constrain flux models
2. Measure the ν_e CC inclusive cross-section

→ **These are complete for P5 data up until the last complete run**

Method:

- Select Highest Momentum Negative (HMN) Track starting in FGD FV
- Particle identification using the TPC and ECal to select e-
- Use these detectors, plus P0D, for veto cuts to suppress γ background
  γ selection used to constrain γ background (γ → e+ e- conversions in FGD)
- Separate the sample into CCQE and CCnonQE events (further increasing purity)

→ **Very successful for P5**

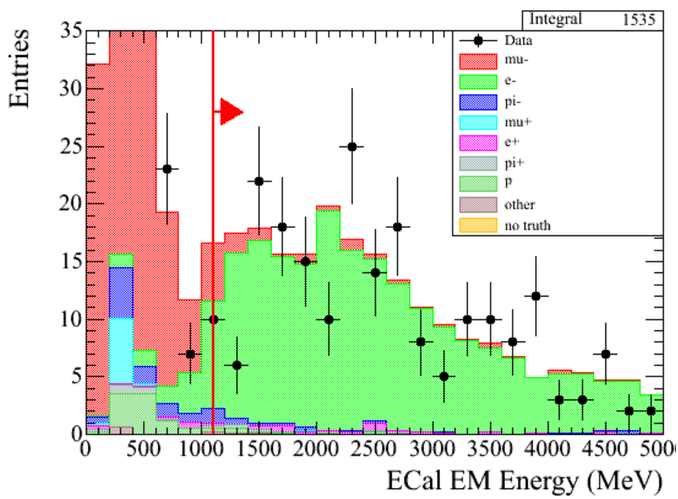
→ **Looking to use P6 capabilities to further improve the selection**

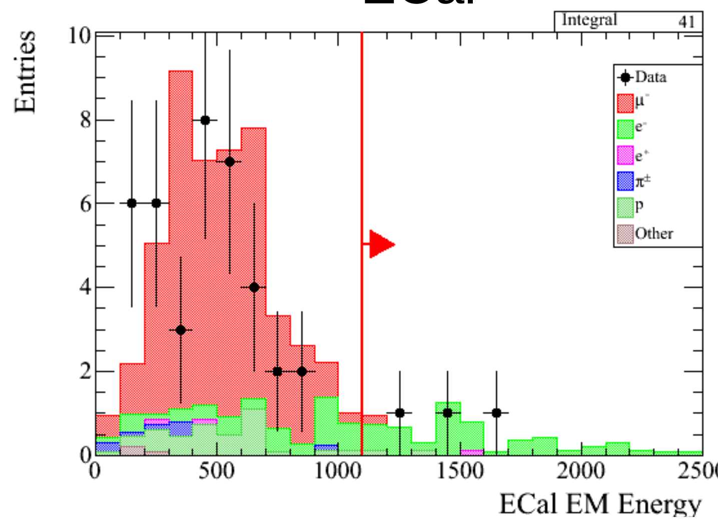
Selection cut example: EM Energy
(ElectroMagnetic Energy deposited in the ECal)

'Downstream' ECal

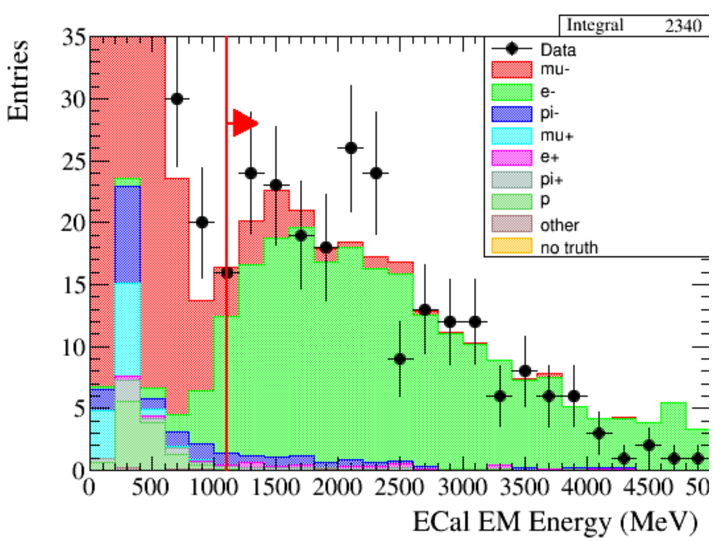
'Barrel' ECal

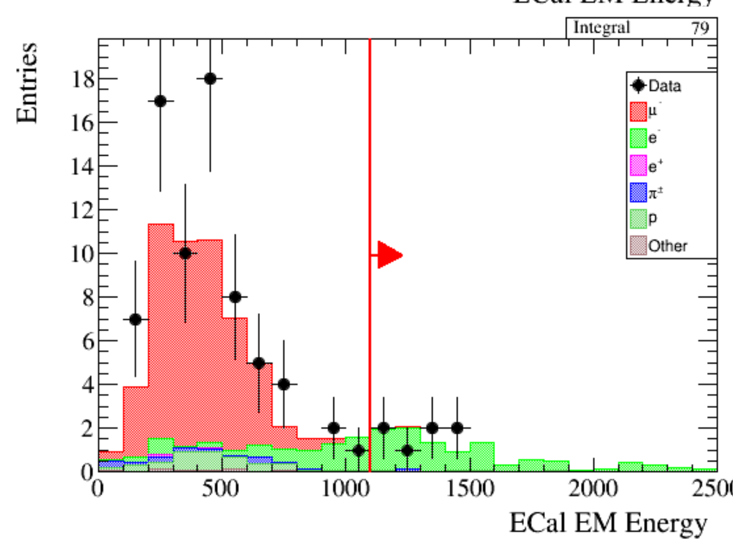
P5F





P6B

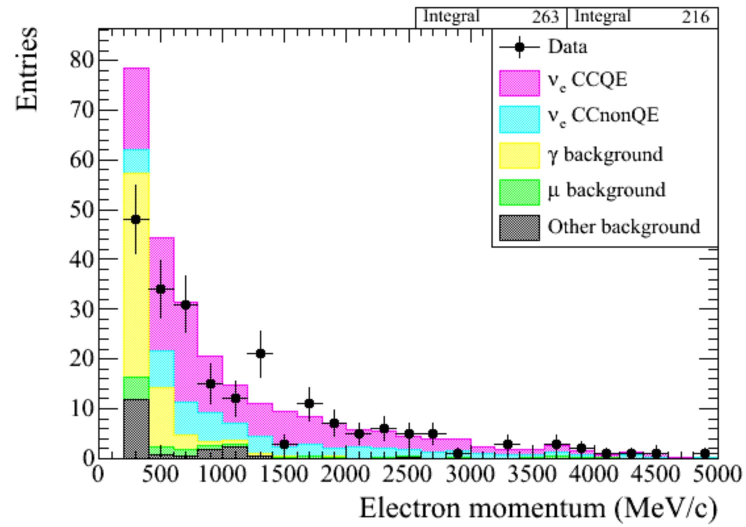


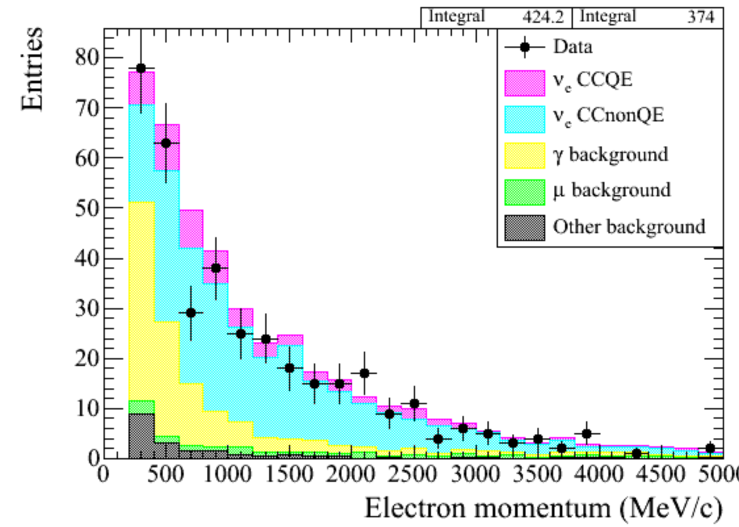


Final Selections

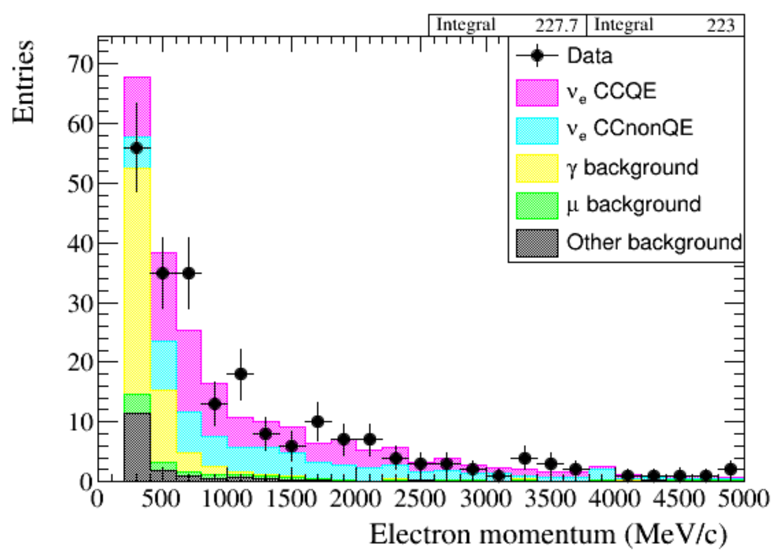
CCQE | CCnonQE

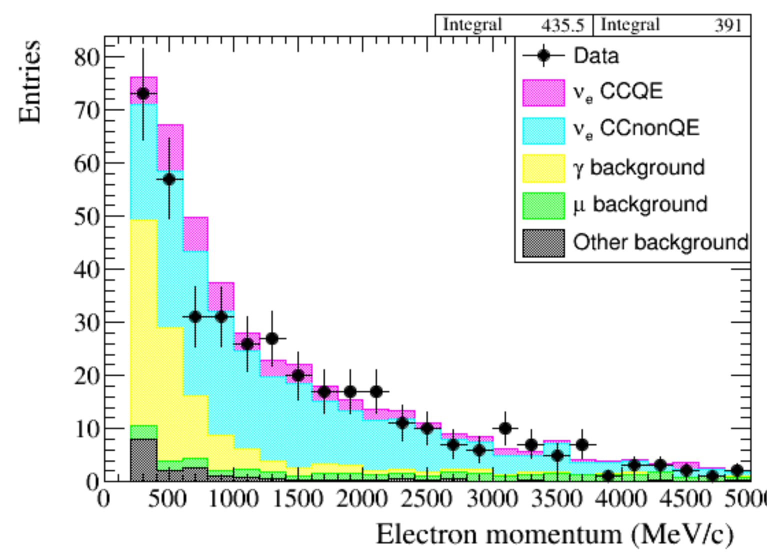
P5F





P6B





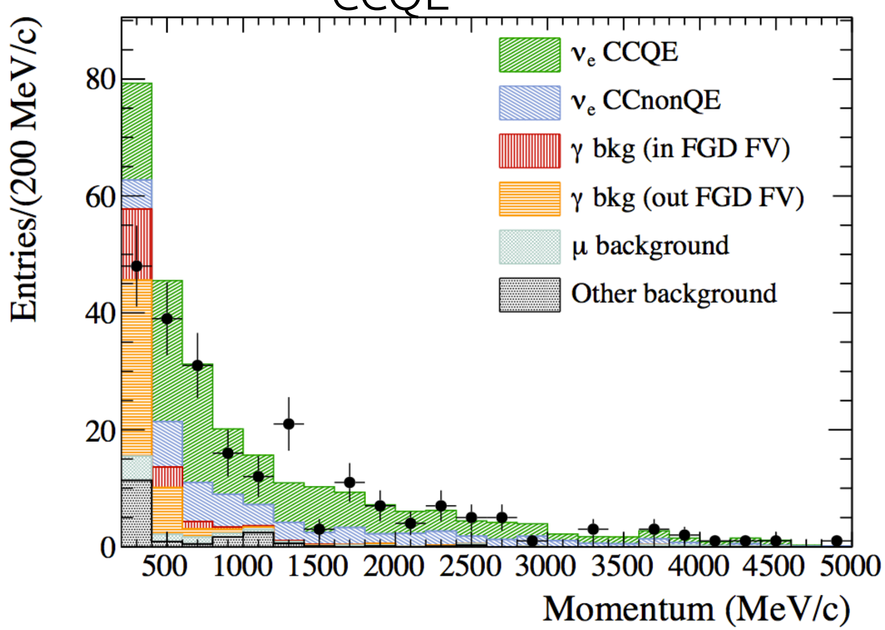
Measuring the intrinsic ν_e component with P5

Paper accepted for publication:
Measurement of the intrinsic electron neutrino component in the T2K neutrino beam with the ND280 detector

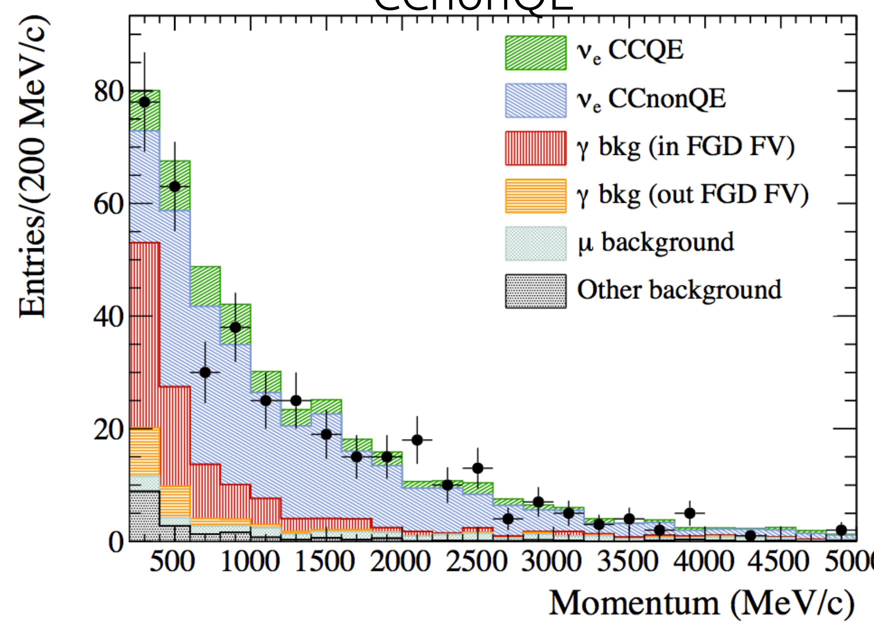
ν_e component predicted to constitute 1.2% of the T2K neutrino beam

→ Tracker analysis found the ratio between the observed ν_e component and this prediction to be 1.01±0.10

CCQE



CCnonQE



ν_e CCinclusive Cross-section (P5)

Ben Smith

Measuring ν_e CC inclusive cross section on carbon

Only other measurement at GeV-scale is from Gargamelle in 1978

Differential cross-section as a function of
- Electron momentum
- Electron angle
- Q^2 of interaction

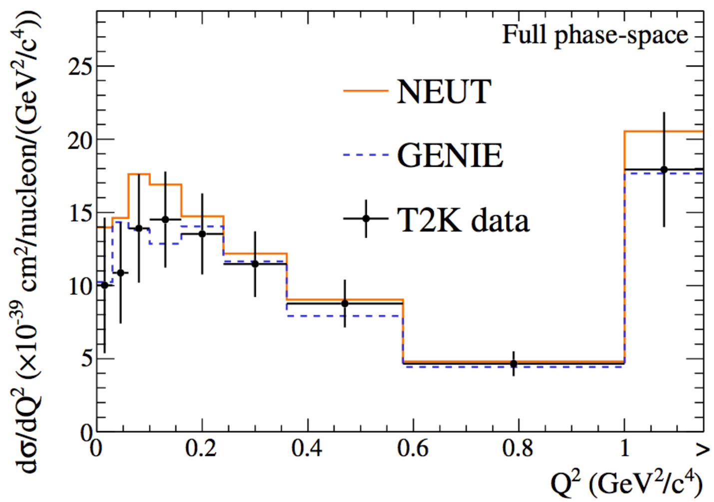
Flux averaged cross-section

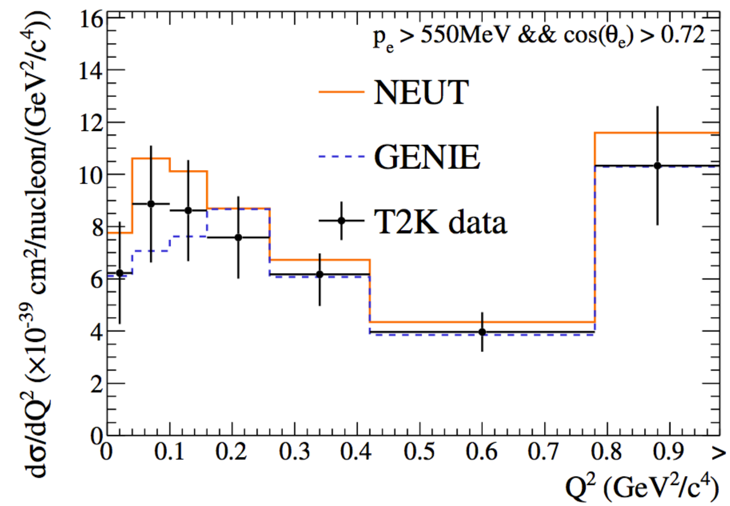
Also Includes reduced phase-space anlysis: (P>550MeV and cosθ>0.72 only)

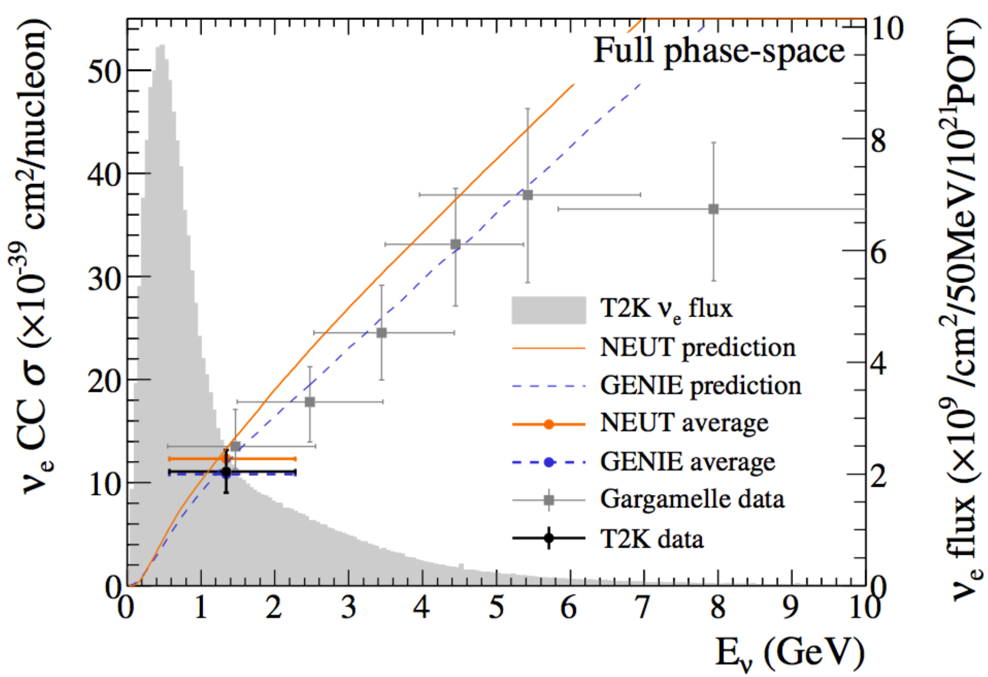
The analysis is performed using the nueCCAnalysis selection, selecting only FGD1 events, with CCQE and CCnonQE combined into a CCinclusive selection

ν_e CCinclusive Cross-section (P5)

Ben Smith







Agreement with NEUT and GENIE (the two leading neutrino interaction simulators)

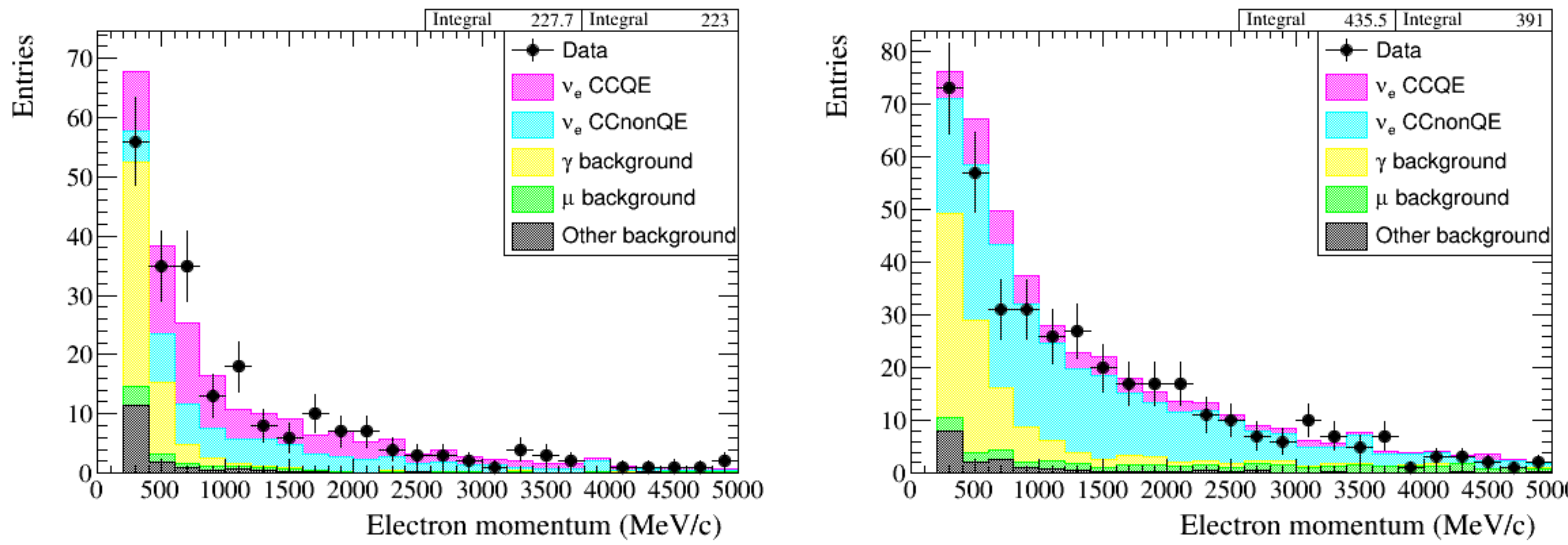
Agreement with Gargamelle

Results to be published

Improvements

CCQE CCnonQE

P6B



The final selection still has a significant background of gamma-rays that interact In the FGD to produce a e+e- pair.

At the moment, the e+ is required to reach the TPC for PID

Looking into using FGD hit information (Charge, time, position) to identify e+e- pairs where the e+ does not make it into the TPC (or has too few hits in TPC)

Thanks for listening

The Beam

Major neutrino-producing decay modes in the decay volume:

$\pi^+ \rightarrow \mu^+ + \nu_\mu$

$K^+ \rightarrow \mu^+ + \nu_\mu$

$K^+ \rightarrow \pi^0 + \mu^+ + \nu_\mu$

$K^+ \rightarrow \pi^0 + e^+ + \nu_e$

$\mu^+ \rightarrow e^+ + \nu_e + \nu_\mu + \bar{\nu}_e$