



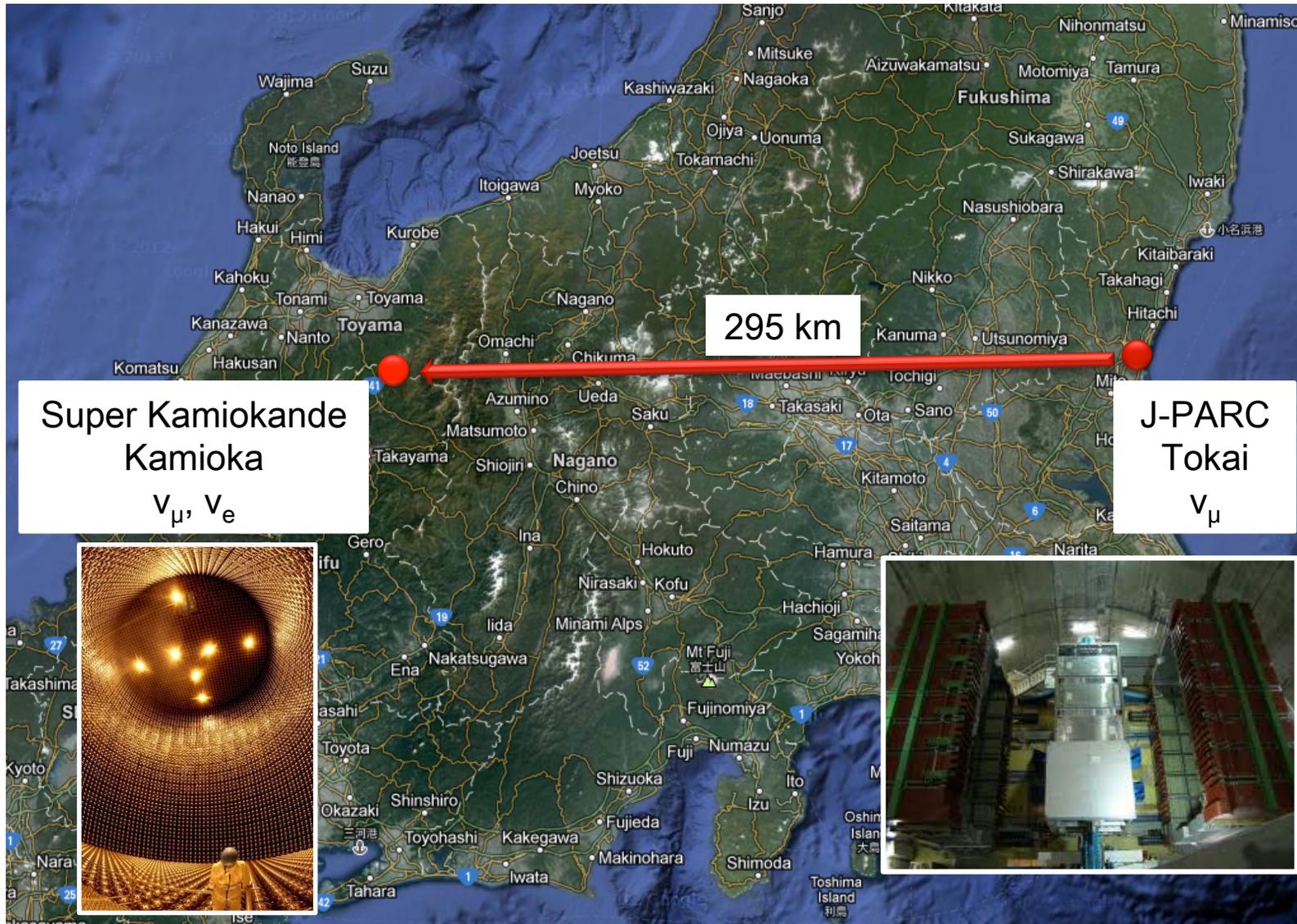
# Measurement of neutrino induced neutral current single $\pi^0$ production in the near detector of the T2K experiment

Dr Helen O'Keeffe  
University of Oxford  
IoP HEPP group meeting  
9<sup>th</sup> April 2013



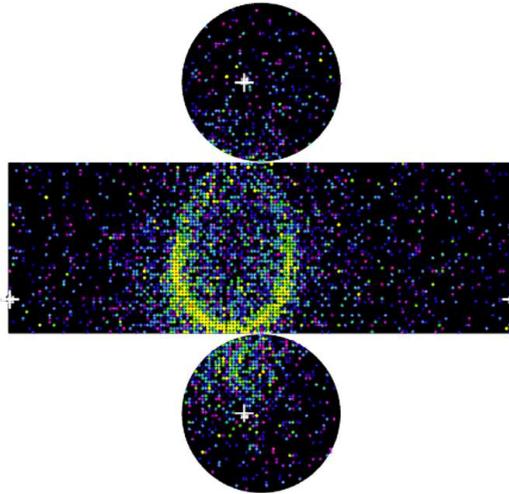


# The T2K experiment

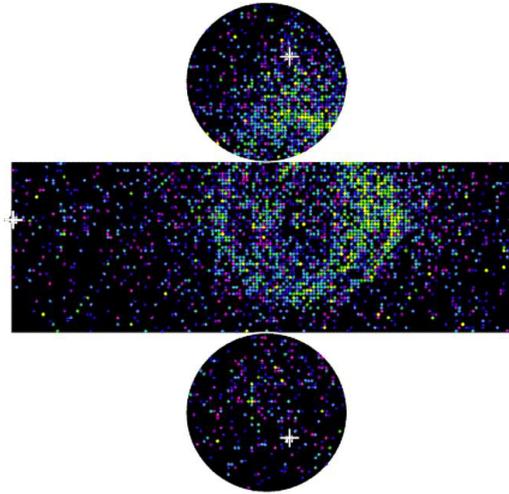




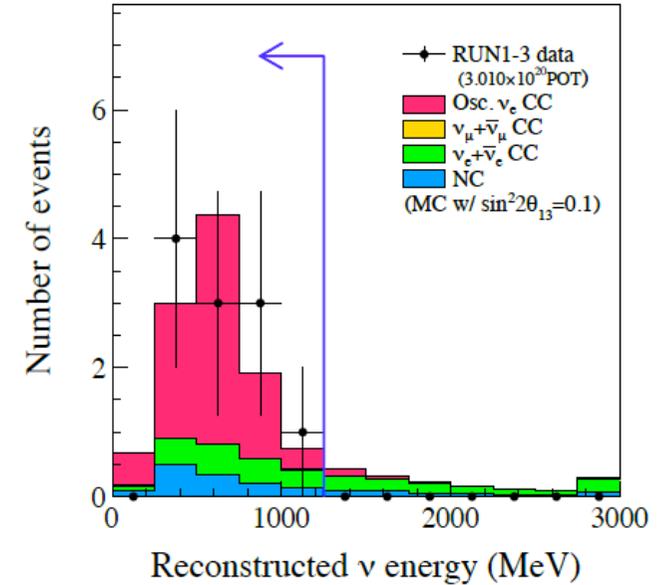
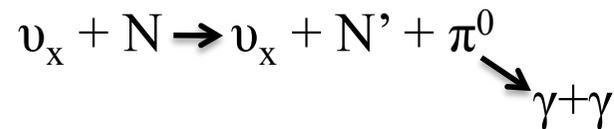
# $\pi^0$ production



SIGNAL



BACKGROUND



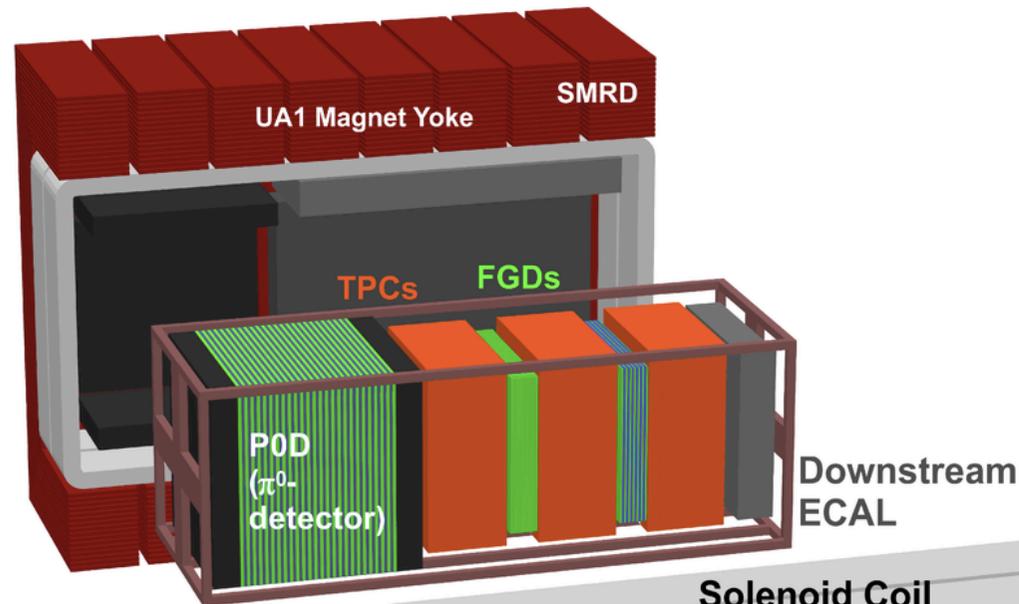
NC background is small, but cross section not well known

→ Significant systematic error

**Measure cross-section at near detector**



# The T2K Near Detector: ND280



## 0.2 T Magnet

### Plastic scintillator detectors:

Fine Grained Detector (FGD)

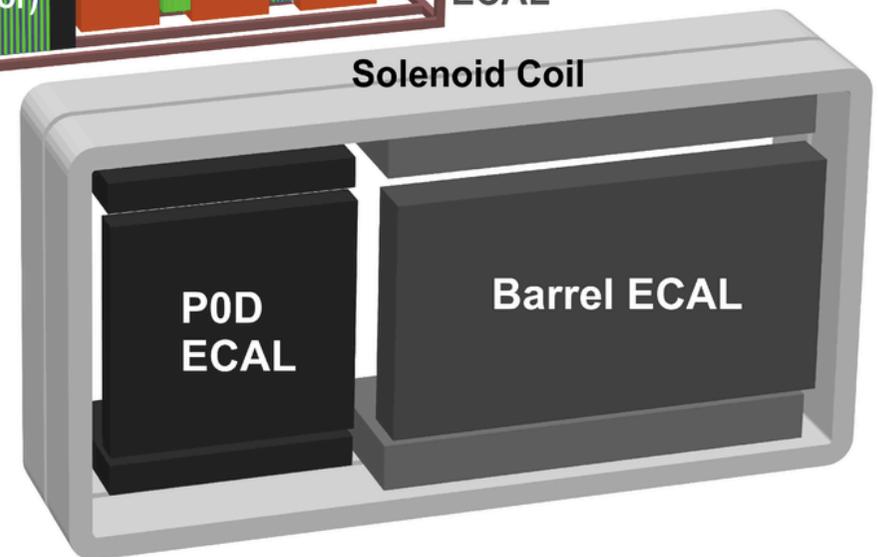
Pi0 Detector (POD)

Electromagnetic Calorimeter (ECAL)

Side Muon Range Detector (SMRD)

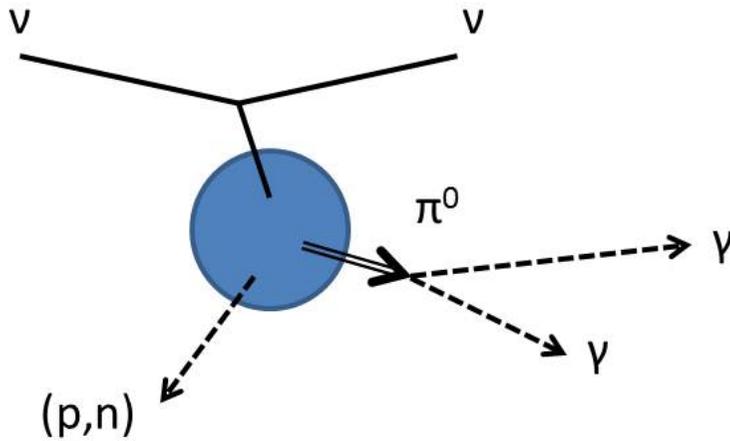
### Gaseous Argon

Time Projection Chambers (TPC)





# Neutral current $1 \pi^0$ events



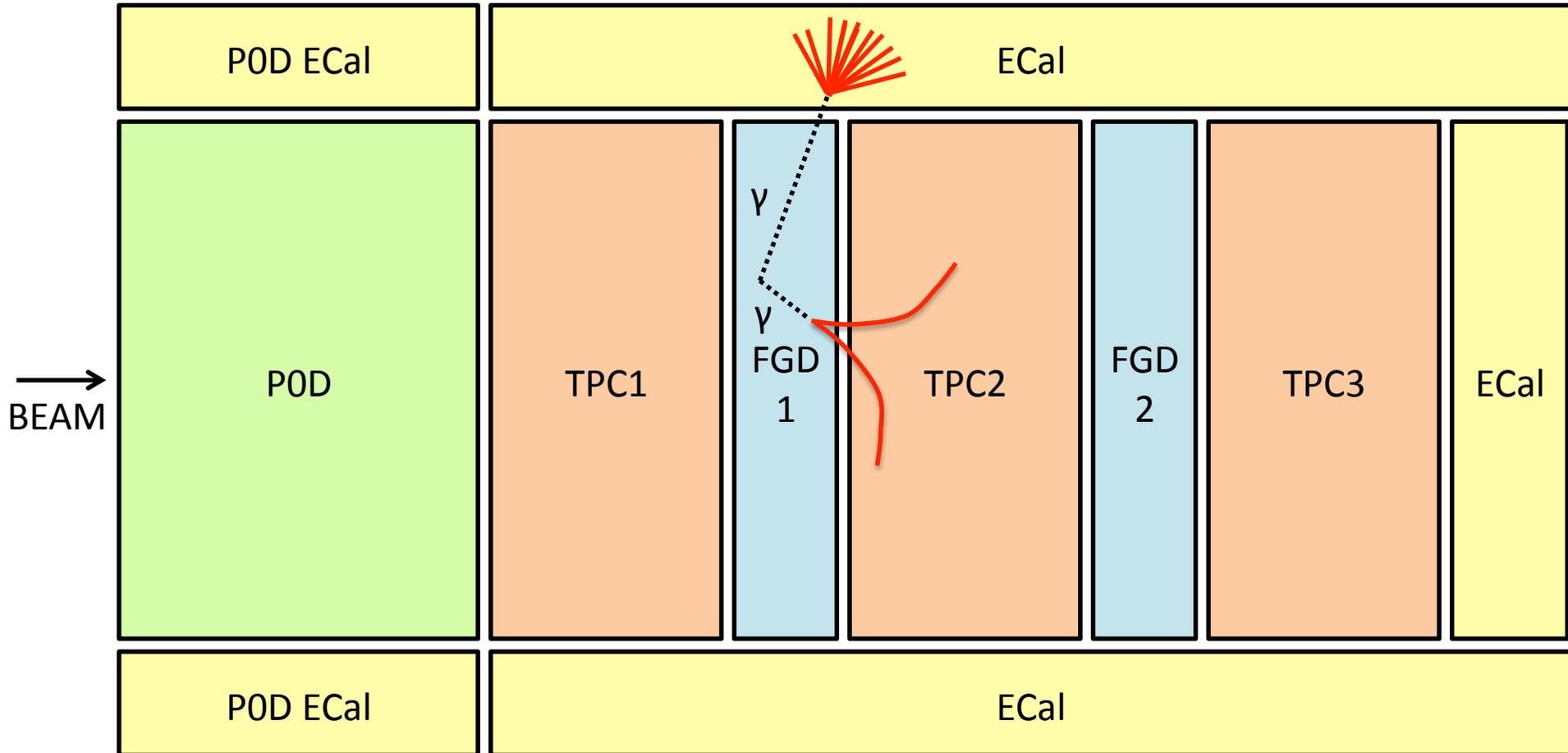
## *Neutral Current $1 \pi^0$ events*

- No charged leptons at vertex
- Any number of neutrons
- Any number of protons
- No charged mesons
- One  $\pi^0$

*How can we identify these events in ND280?*



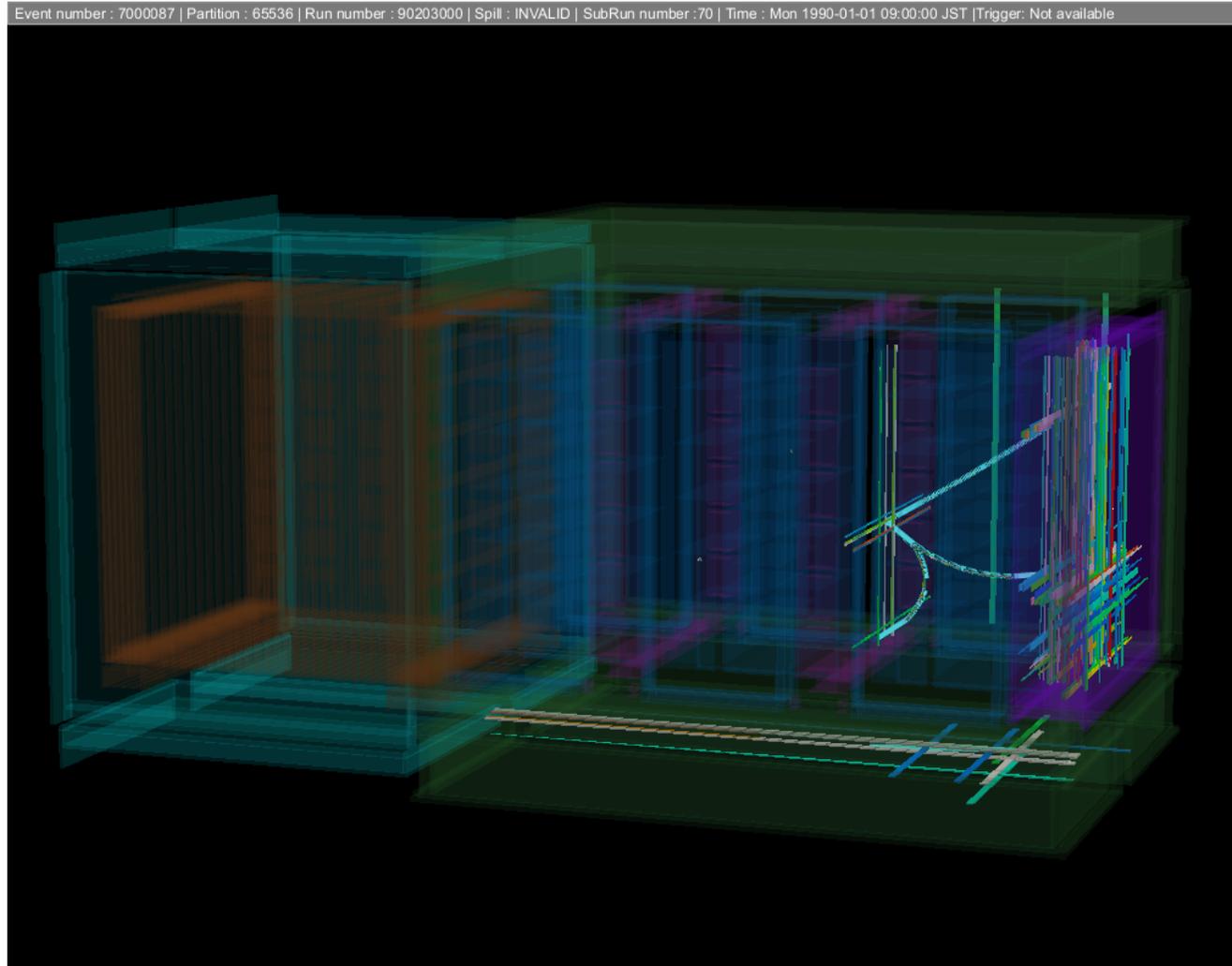
# Topology of interest



Single  $\pi^0$  produced by NC interaction in FGD



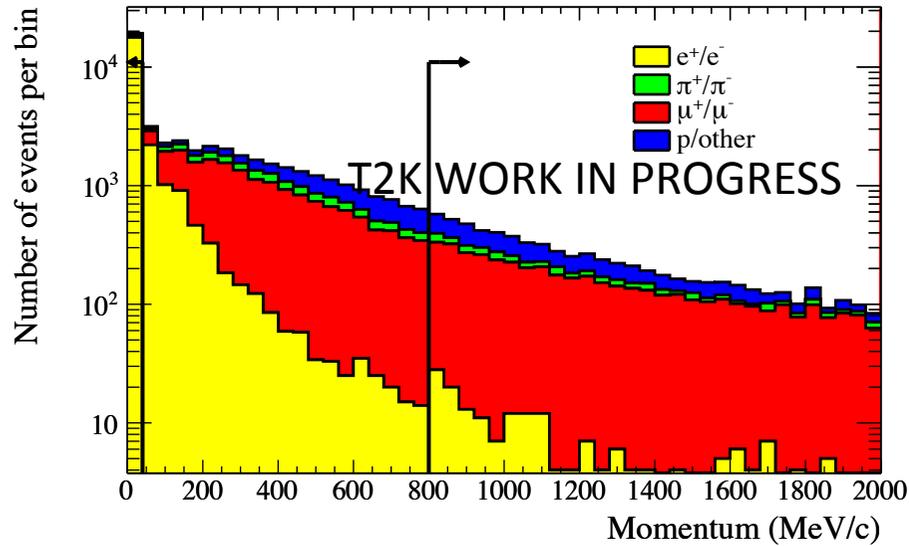
# Topology of interest



Monte Carlo simulation of a Single  $\pi^0$  produced by NC interaction in FGD

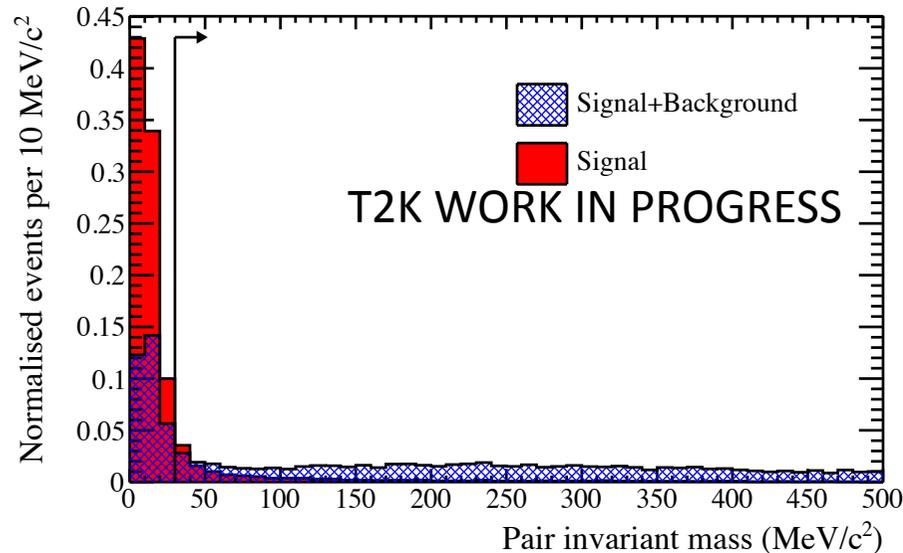


# Selecting a pair



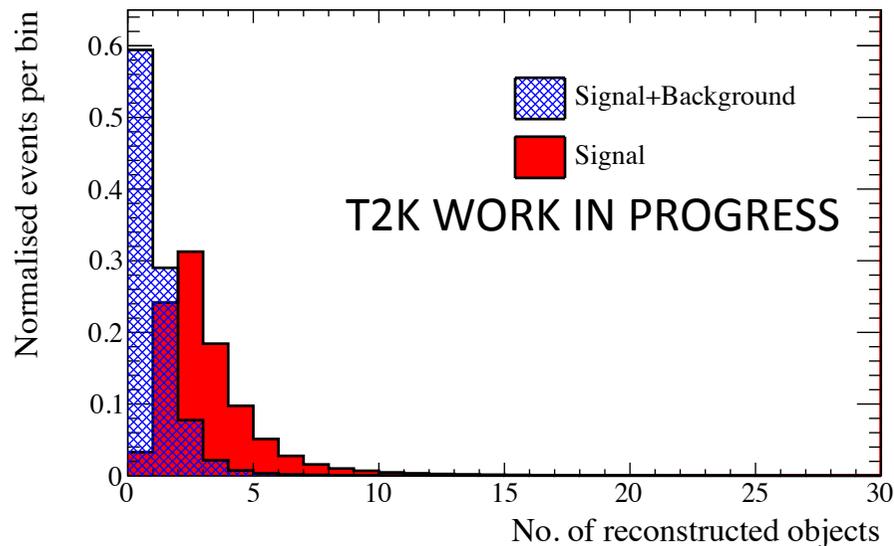
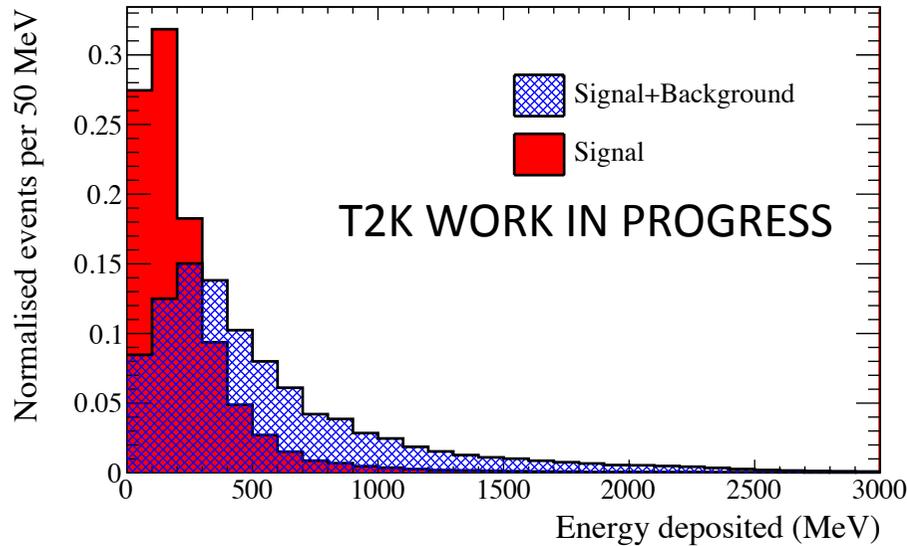
## Require:

- Two oppositely charged tracks
- $50 < \text{Momentum} < 800 \text{ MeV/c}$
- Start within 10 cm of each other
- Invariant mass  $< 30 \text{ MeV}/c^2$
- Pair starts in FGD fiducial volume





# Selecting an ECal object



## Require:

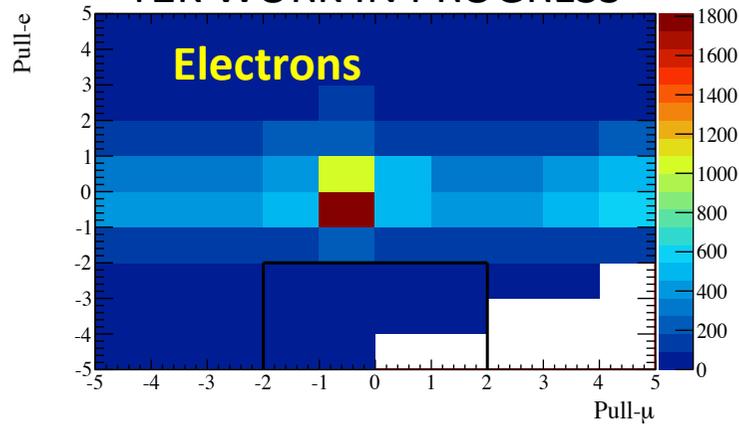
- Not connected to a track
- Maximum of 2 possible objects
- $30.0 < \text{Energy} < 1000.0$  MeV
- $5 < N_{\text{hits}} < 70$
- No delayed electrons
- If two possible objects, take higher energy one



# Background rejection



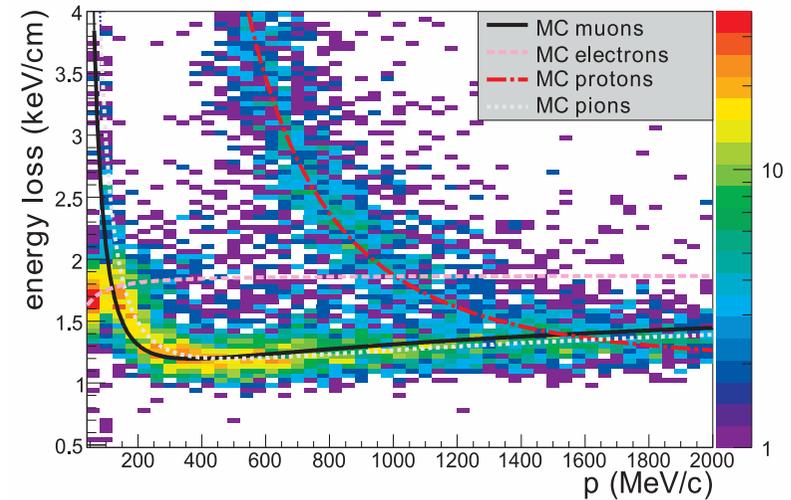
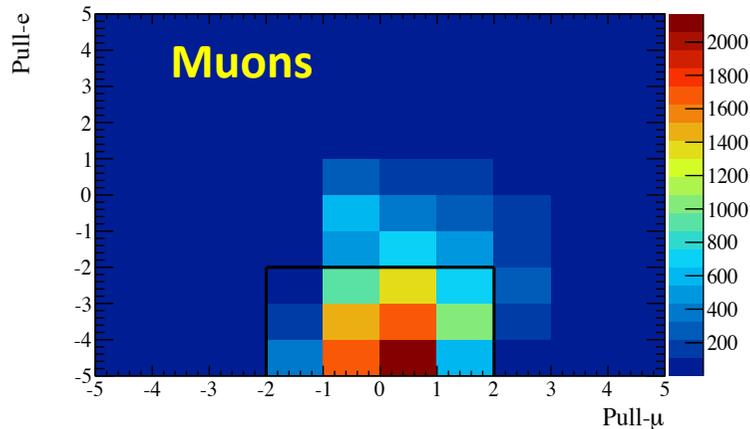
T2K WORK IN PROGRESS



**Reject any event with:**

- Activity upstream of FGD1
- A track with momentum  $> 1$  GeV
- Reconstructed muon

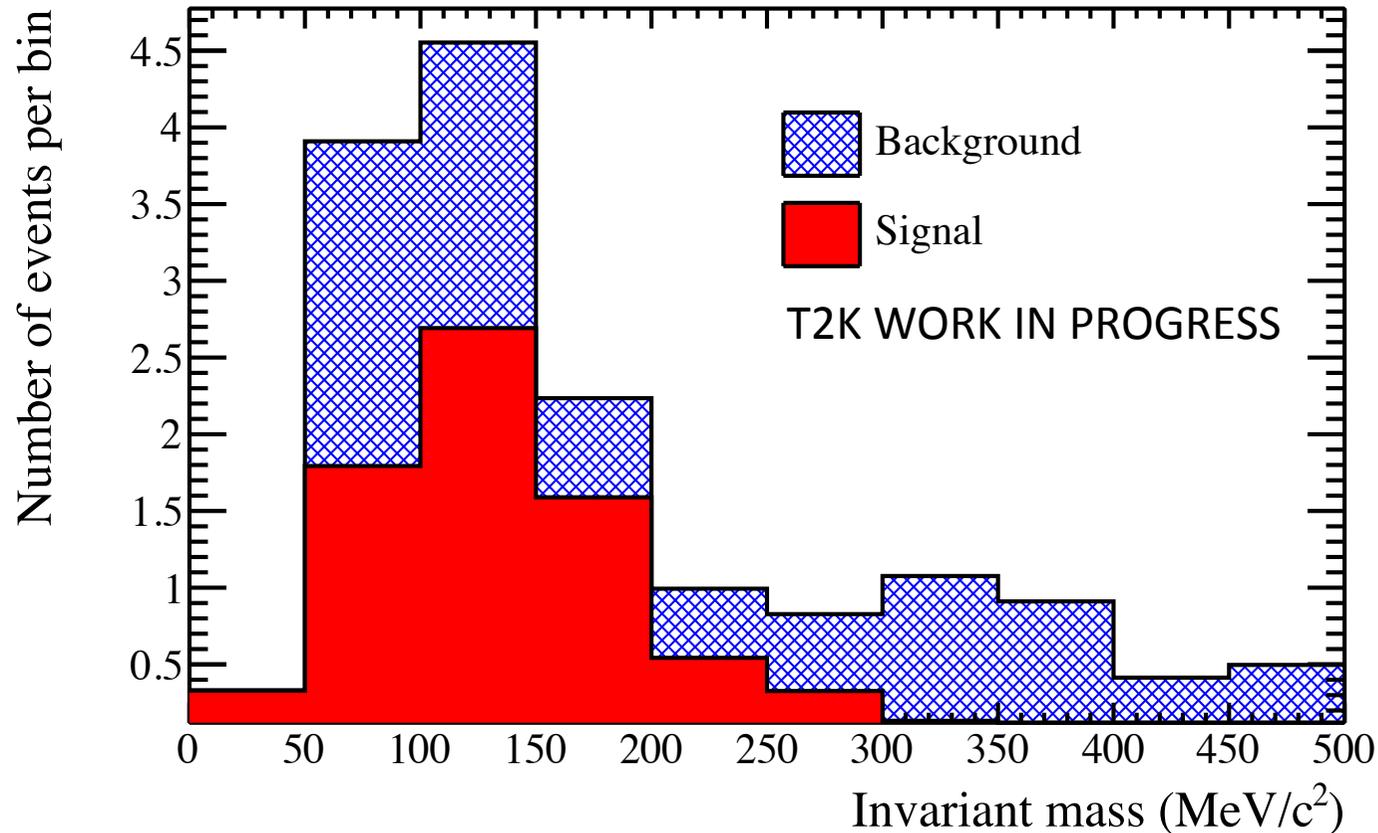
T2K WORK IN PROGRESS



J. Phys.: Conf. Ser. 309 012019



# Putting it all together...



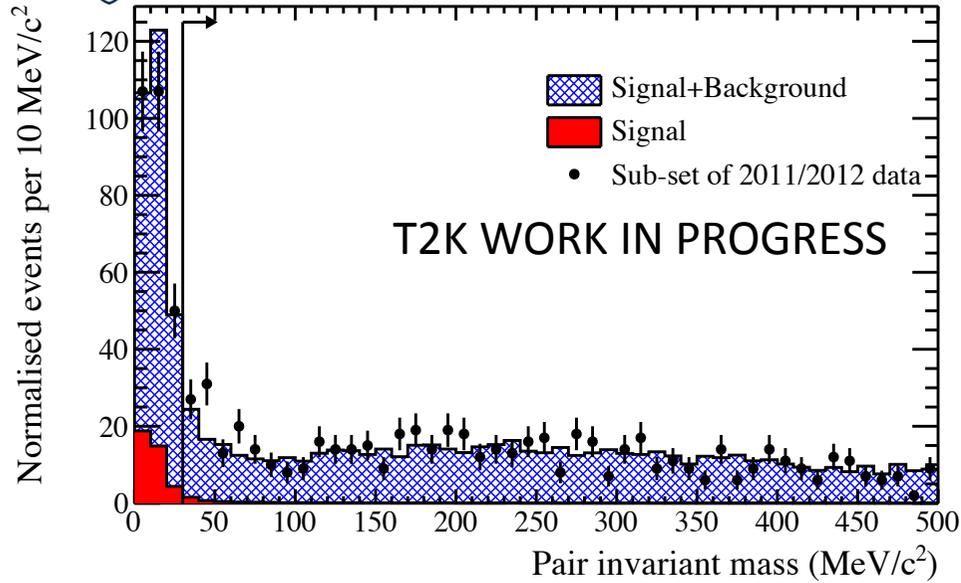
**Predictions for the 2011/2012 data set:**

Signal = 32 events

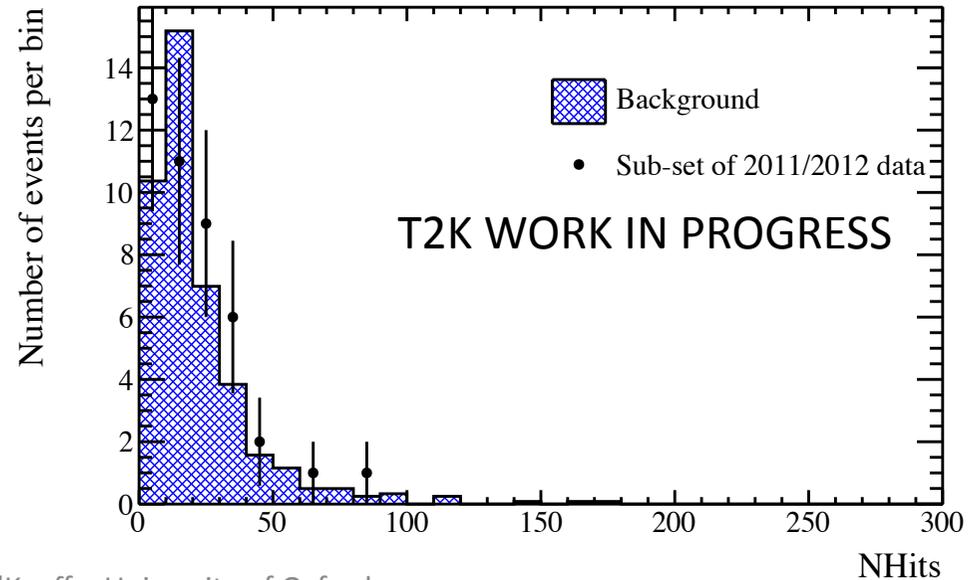
Purity for  $50 < \text{Invariant Mass} < 200 \text{ MeV}/c^2 = 48\%$



# Comparison of data and Monte Carlo **T2K**

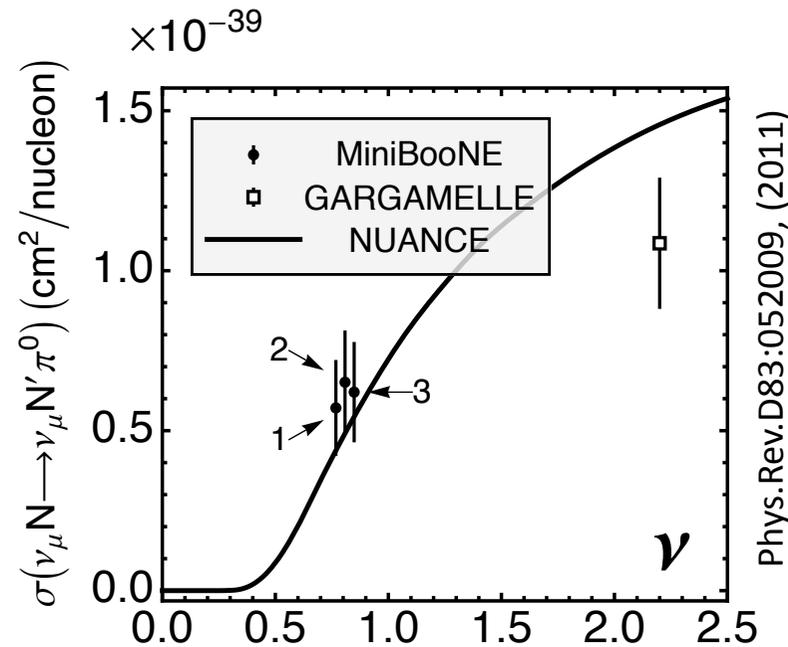


*Good agreement between data and Monte Carlo*





# Towards a cross-section



## Combine different topologies -> better results:

TPC/FGD+ECal	32 events, purity 48%
FGD+FGD	32 events, purity 30% (Z. Williamson, Oxford)
ECal+ECal	40 events, purity 15% (S. Short, Imperial)

## Beginning to develop combined analysis



# Summary



- FGD/TPC pair + ECal selection is advanced
- First comparisons of data and MC are promising
- Analysis of full dataset is in progress
- Systematic error assessment has started
- Combination with other NC  $1-\pi^0$  topologies is beginning



# Backup slides





# Neutrino oscillation



$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu1} & U_{\mu2} & U_{\mu3} \\ U_{\tau1} & U_{\tau2} & U_{\tau3} \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

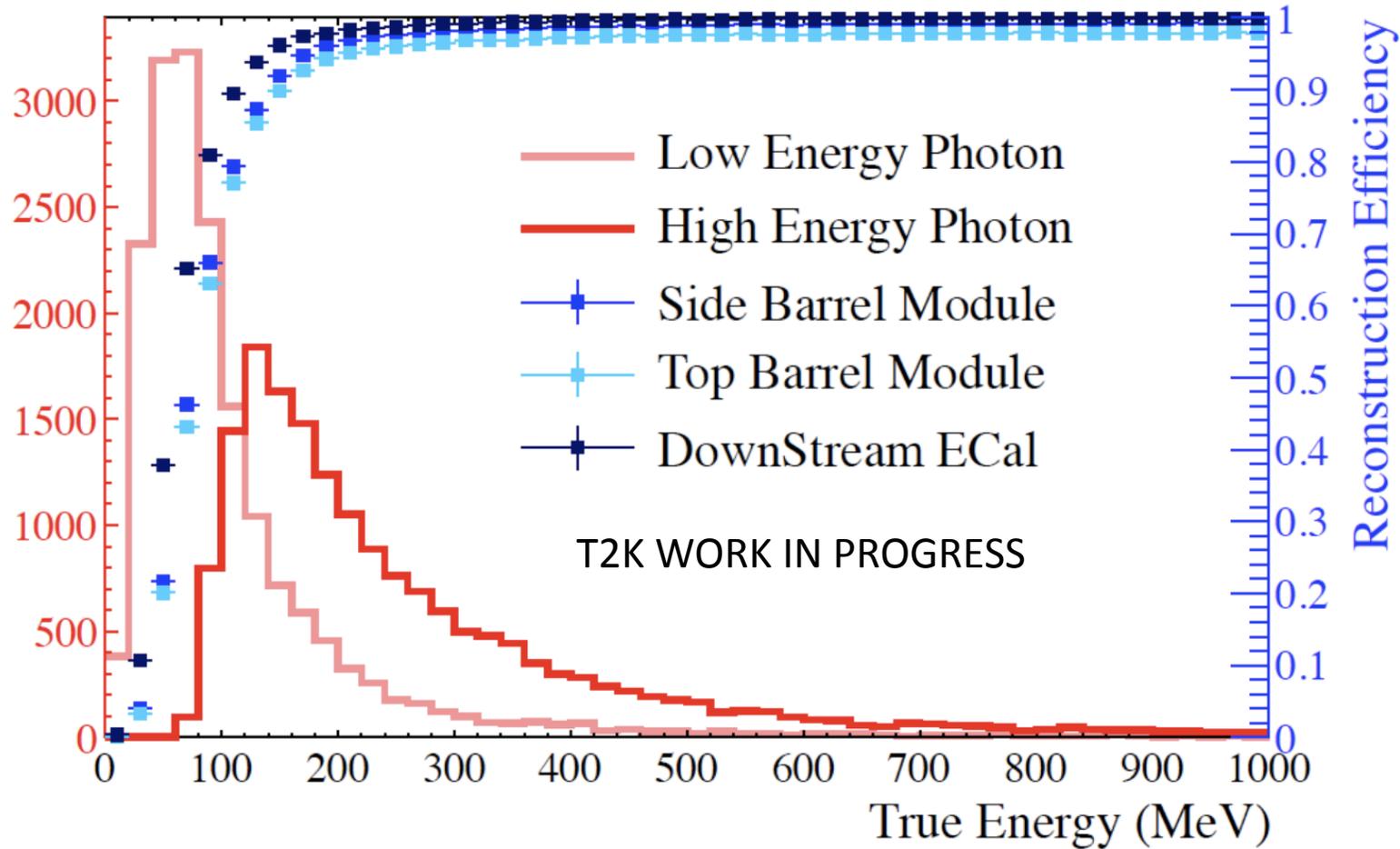
$$\begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu1} & U_{\mu2} & U_{\mu3} \\ U_{\tau1} & U_{\tau2} & U_{\tau3} \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \times \begin{pmatrix} c_{13} & 0 & s_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -s_{13}e^{-i\delta} & 0 & c_{13} \end{pmatrix} \times \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

***Oscillation parameters obtained by measuring the probability  
of flavour change***

***$P(\nu_x \rightarrow \nu_{x'})$  or  $P(\bar{\nu}_x \rightarrow \bar{\nu}_{x'})$***



# Ecal reconstruction efficiency



Plot courtesy of Abraham Jacob, University of Oxford



# Track reconstruction efficiency

