Imperial College London

# The T2K Experiment:
## A background introduction

Pawel Guzowski

# Overview

- Description of T2K
- Description of detectors: SuperK and ND280
- Introduction to the backgrounds:
  - The signal for $\nu_e$ appearance
  - A few backgrounds

# Neutrino oscillation

Oscillation is parameterised by:

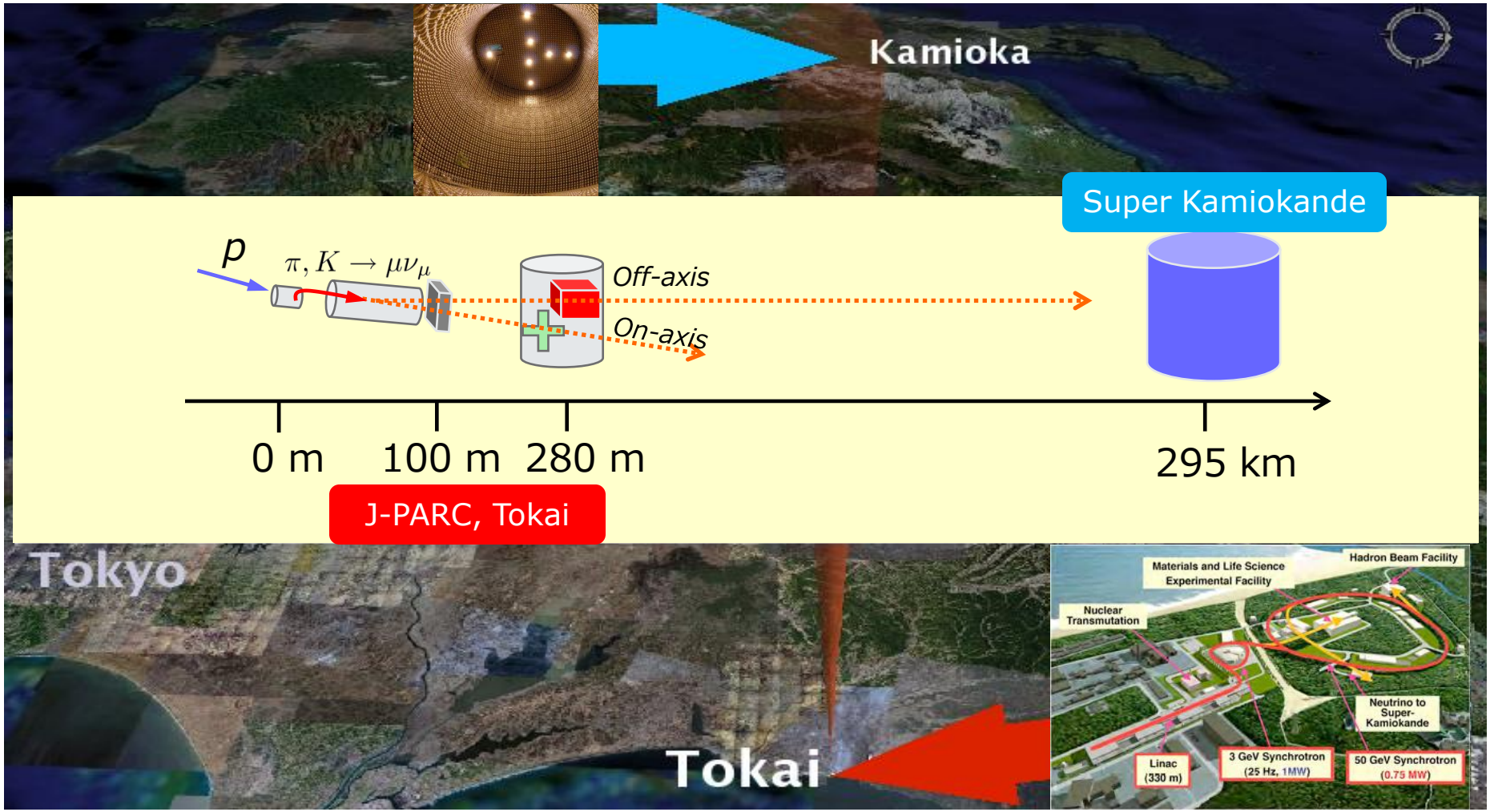
$$\begin{pmatrix}\nu_e\\ \nu_\mu\\ \nu_\tau\end{pmatrix} = \begin{pmatrix}1 & 0 & 0\\ 0 & C_{23} & S_{23}\\ 0 & -S_{23} & C_{23}\end{pmatrix}\begin{pmatrix}C_{13} & 0 & S_{13}e^{-i\delta}\\ 0 & 1 & 0\\ -S_{13}e^{-i\delta} & 0 & C_{13}\end{pmatrix}\begin{pmatrix}C_{12} & S_{12} & 0\\ -S_{12} & C_{12}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

$$P\left(\nu_\mu \rightarrow \nu_e\right) = \sin^2 2\theta_{13}\sin^2\theta_{23}\sin^2\left(1.27\Delta m^2_{23}L/E\right)$$

($\nu_e$ appearance)

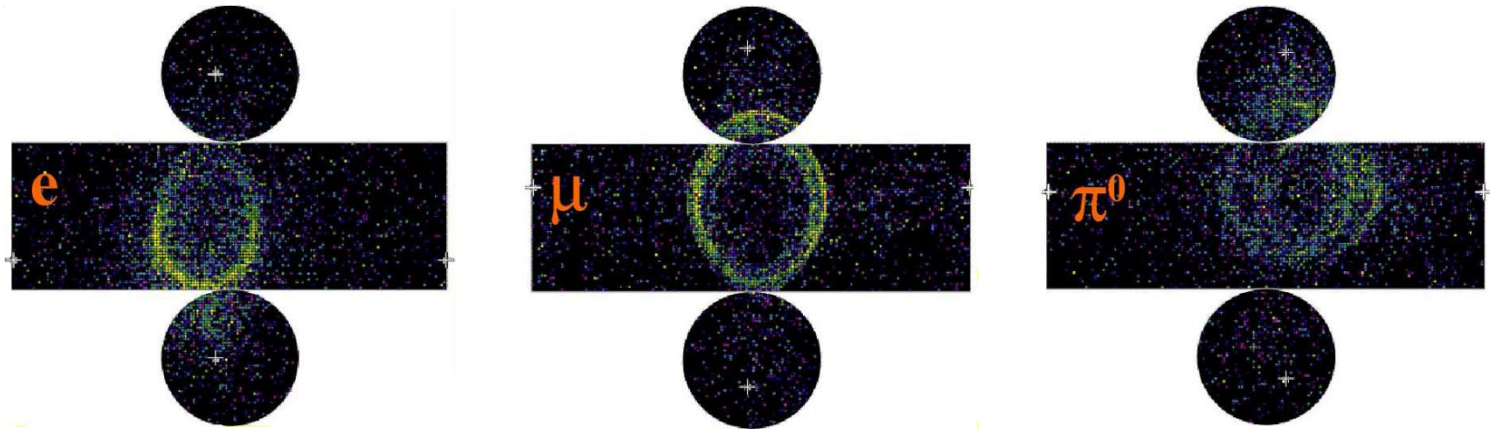
To make measurement you need two detectors, separated by length L. Measure flux (convoluted with cross section) spectrum at each detector, then extrapolate and compare to obtain parameters

# Tokai 2 Kamioka



# Super-Kamiokande

- Cherenkov light emitted from electrons and muons
  - (in ND280 can distinguish particles below C. threshold)
- Can distinguish electrons from muons by nature of the rings:
  - Electrons give fuzzy rings (from EM showers)
  - Muons give clean rings
- In some cases can also distinguish neutral pion production
  - Two electron-like rings



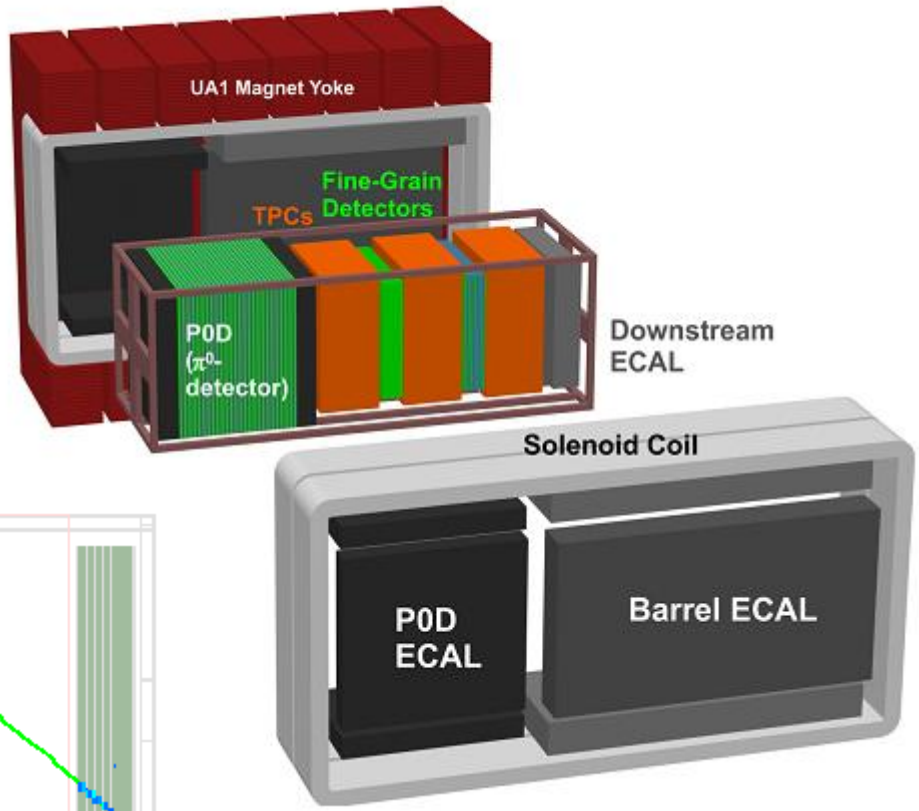
# The ND280 detector

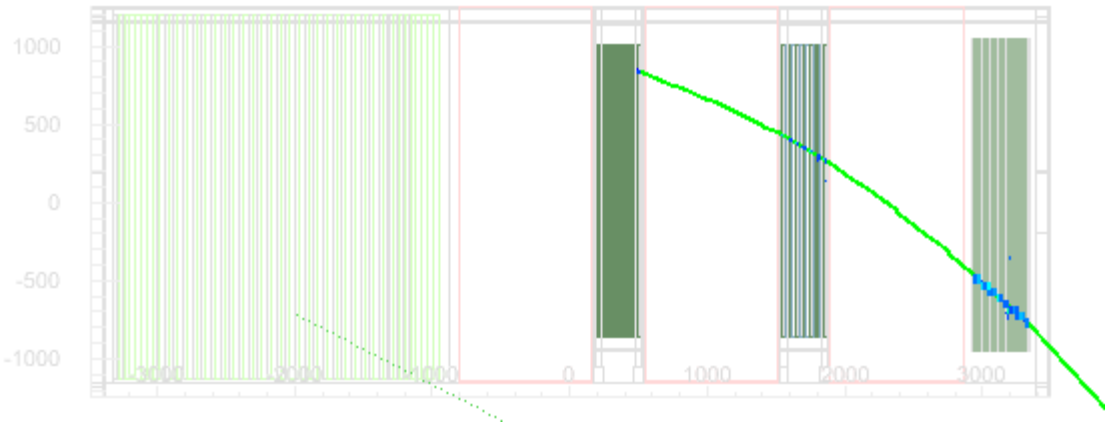
P0D designed to measure the rate of $\pi^0$ production.

TPCs and FGDs track the charged particles produced.

ECAL measures energy deposits from photons and electrons.

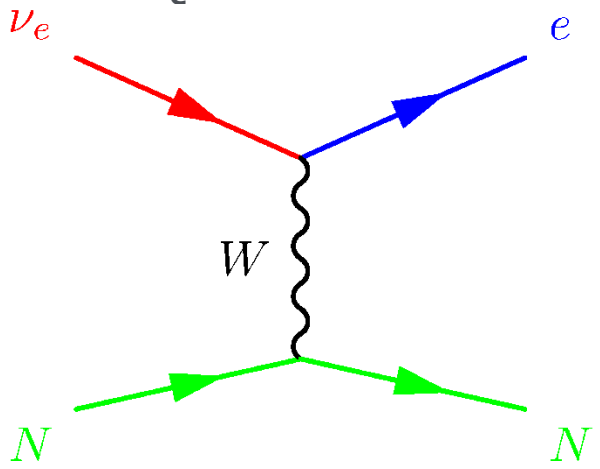
Typical event:



# The signal

Look for Charged Current Quasi-Elastic scattering:




40% of all $\nu$-nucleon interactions are of this type

Signal is the single electron produced in the detector

→ showing up in the trackers or ECAL (ND280)

→ producing e-like ring (SK)

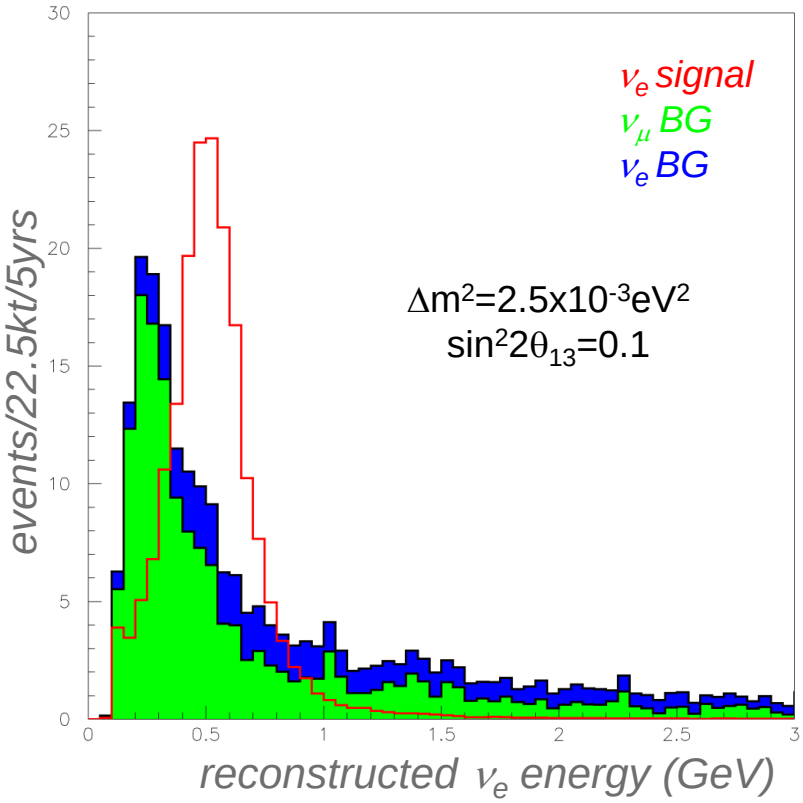
# Backgrounds

To make accurate flux & energy spectrum measurements, need to know about the backgrounds

Involve faking an electron-like signal

Some backgrounds:-

- $\nu_e$ contamination in the beam, from original pion/kaon decay, and from muon decay
- $\pi^0$ production from resonances
- A single photon production process

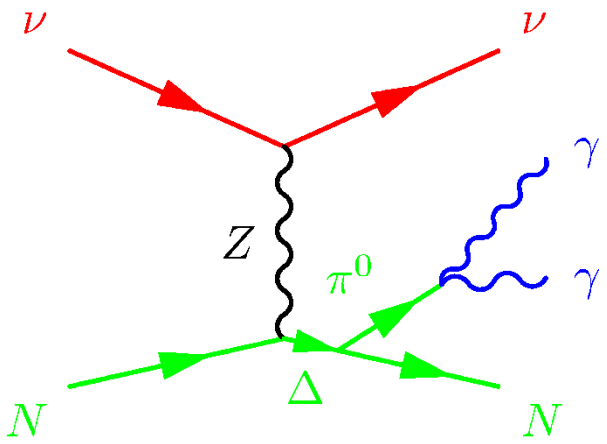


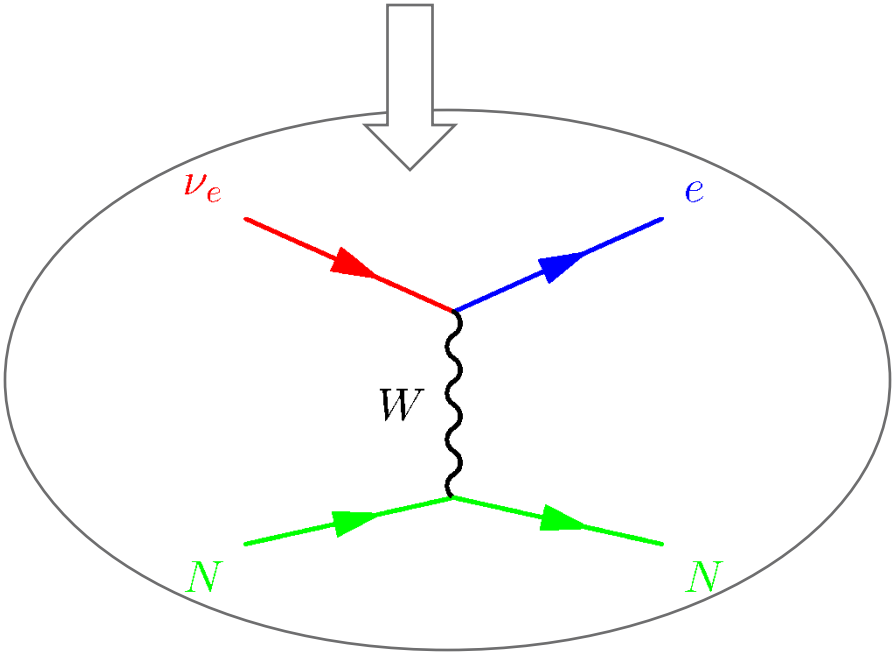
# Neutral pion production

NC interaction (with any neutrino) excites a Δ resonance of the nucleon

Δ emits a $\pi^0$ as it relaxes to ground state.

$\pi^0$ decays to 2 photons, which fake an electron signal, especially in SK if the photons have low angular separation



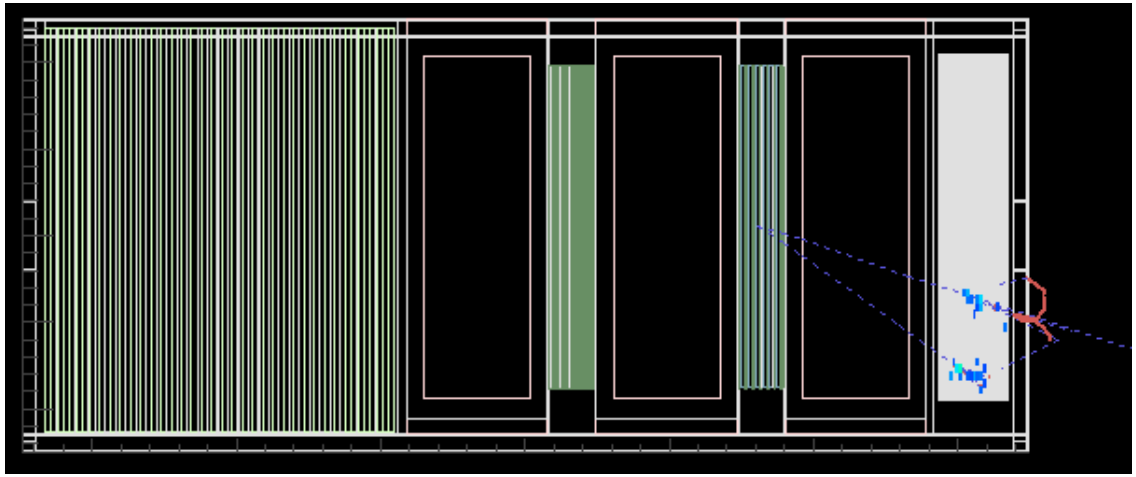



# $\pi^0$ production...

The P0D and ECAL components of the ND280 detector are designed to examine this sort of background

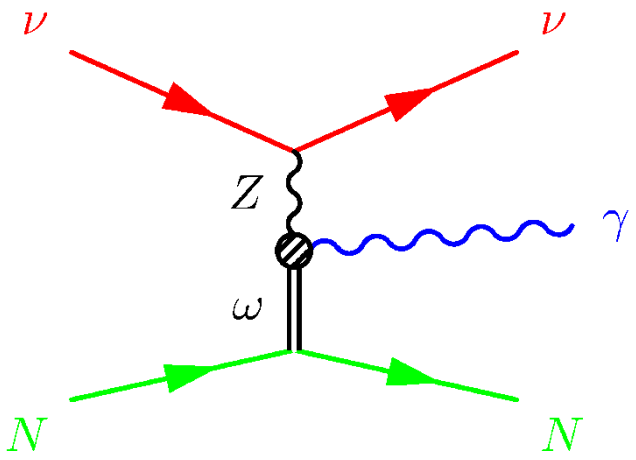
The P0D will contain a water target in between scintillators, so that this process can be examined on a similar material as SK, leading to some cancellation of systematics

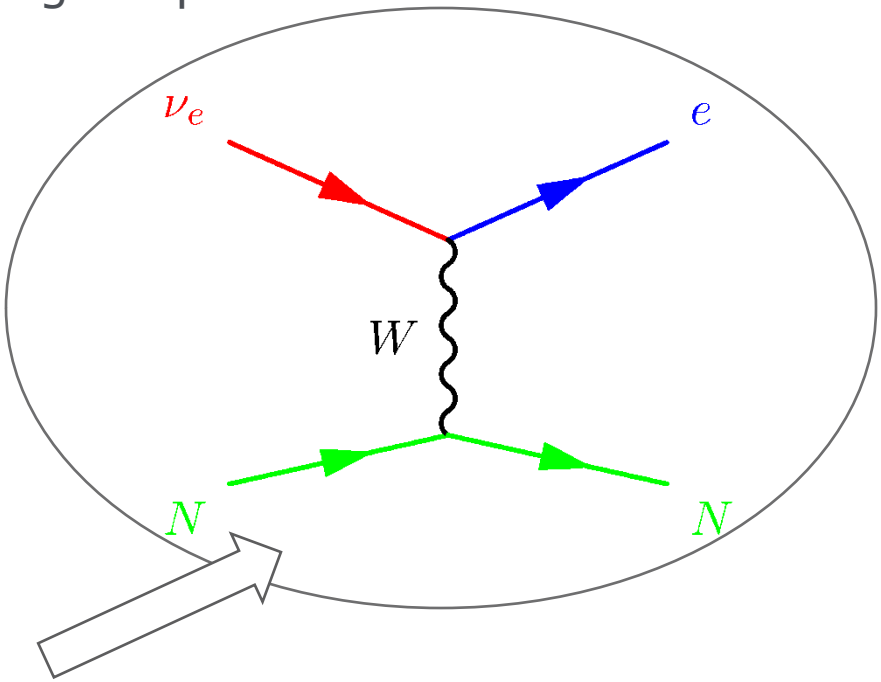
The ECAL provides a handle on photon ($\rightarrow\pi^0$) production in the tracker region:



# Single photon production

- This is mediated by the following SM process:




- Not considered until recently
- Background to $\nu_e$ appearance
- arXiv:0708.1281v2 [hep-ph]

# Single photon production...

Postulated to explain the MiniBooNE excess events at low energy

In SuperK, events look identical to CCQE (only a single ring is produced)

Has not really been looked at within the wider community

I will be studying this further...

# Summary

Have given a very brief introduction to the backgrounds in the experiment

Next step is to start to understand them, to be able to cope with them and to separate these backgrounds from the signal