Neutral current π^0events in Super Kamiokande

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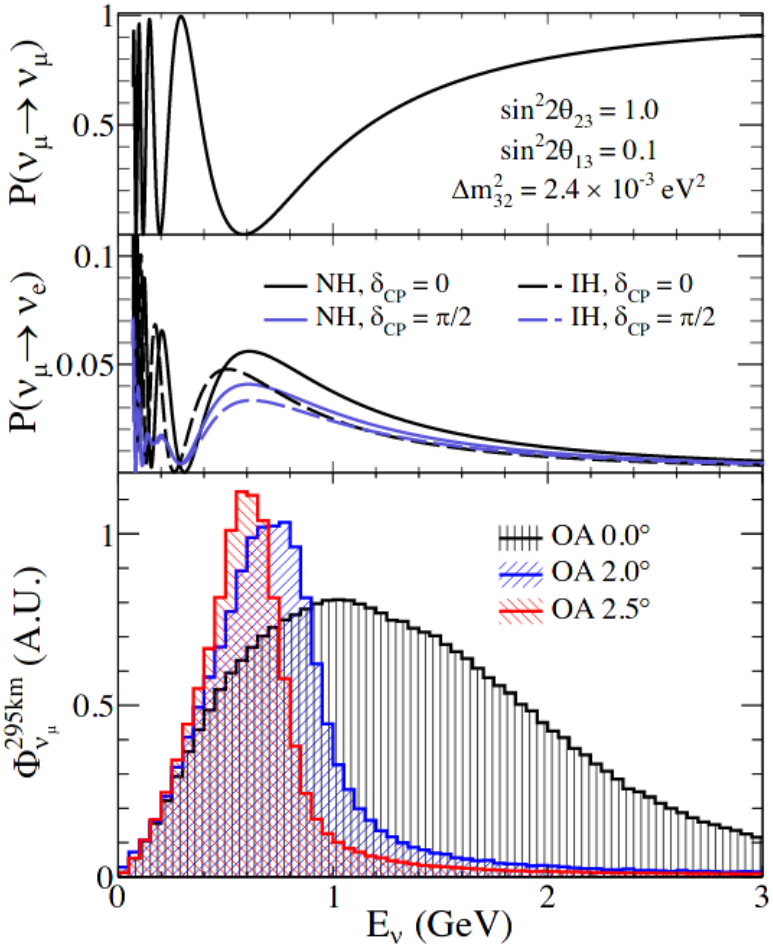
Introduction

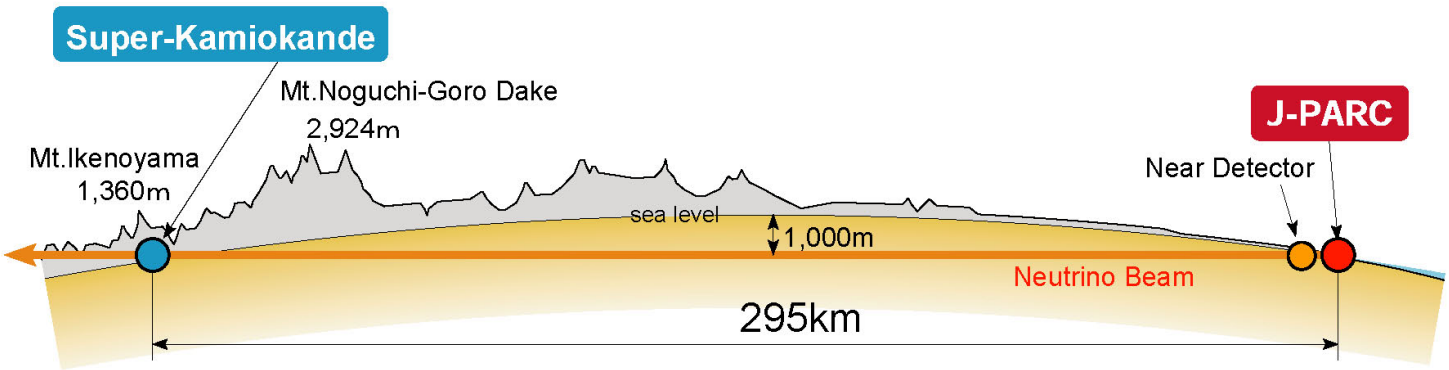
- T2K and Super-Kamiokande experiments
- Neutral Current π^0 events
- NCπ^0 Sample selection
- Further development

T2K and Super-Kamiokande



- Neutrino flavours oscillate due to the mixing of mass and flavour eigenstates
- T2K searches for $\nu_\mu \to \nu_e$ oscillations
- 2.5deg off axis angle maximises ν_e oscillation
- Neutrino oscillation parameters are measured from the flux detected

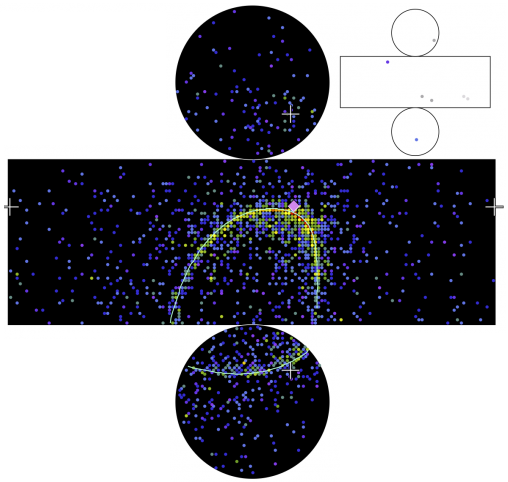
T2K and Super-Kamiokande

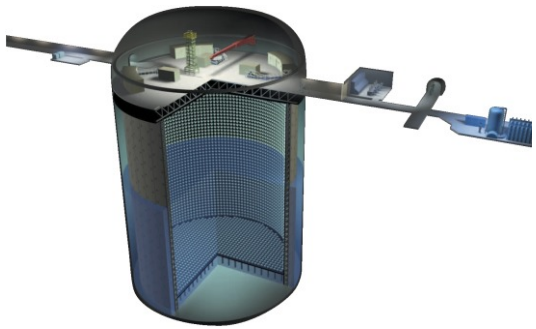


- The T2K experiment in Japan has a baseline of 295 km
- T2K measures muon neutrino disappearance and electron neutrino appearance using a ν_μ beam
- The T2K beam is characterised close to the source (near detector) and far away (far detector)
- The far detector, Super-K is a 22.5 kton ultra-pure water Cherenkov detector

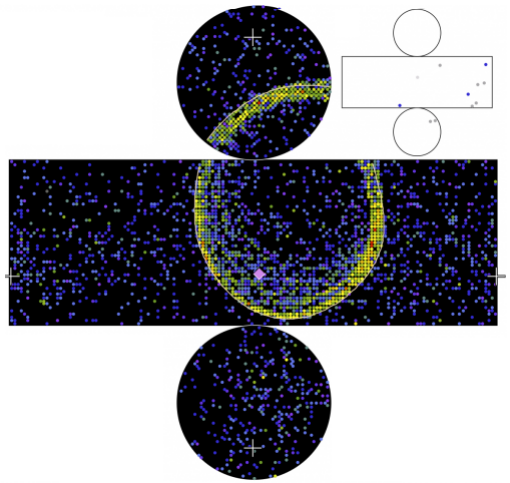
T2K and Super-Kamiokande

Fuzzy $\rightarrow$ e-like



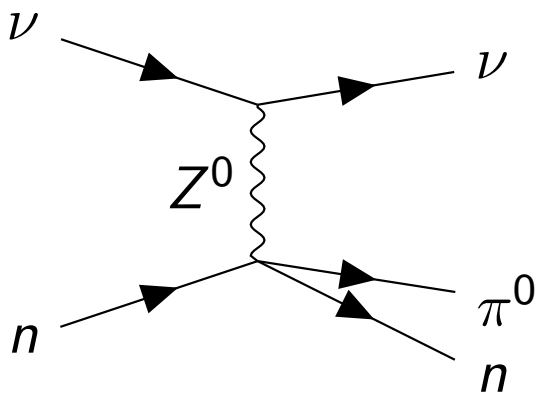


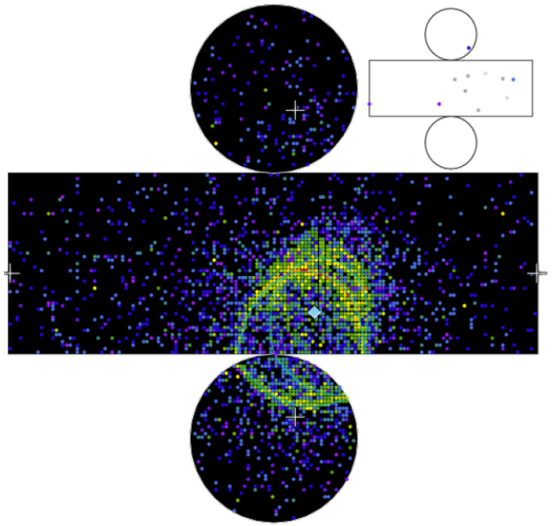
Clean $\rightarrow$ μ-like



- Super-K measures the oscillated flux as neutrinos interact in the detector
- Charged particles from neutrino interactions emit a cone of Cherenkov radiation which is projected onto the detector wall in the shape of a fuzzy electron like (left) or clean muon-like (right) ring

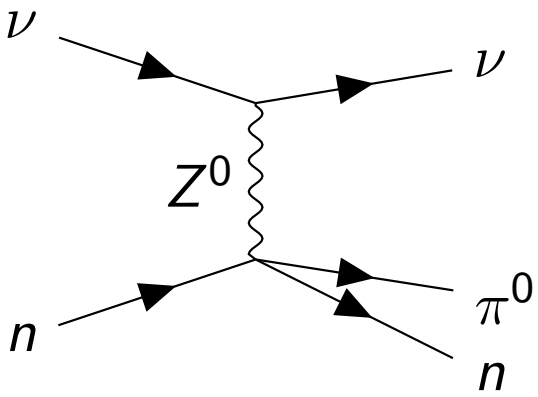
Purpose of NCπ^0sample

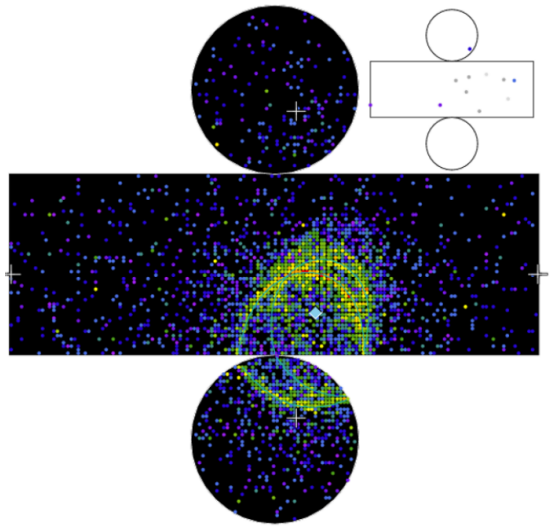




- Neutral current interactions are flavour blind so **oscillation of flux at Super-K does not affect interactions**
- The sample helps constrain interaction models as the error on oscillation models is not required
- There is a **lower threshold for detection of π^0decays at Super-K** than the near detector, allowing to check ND280 measurements.

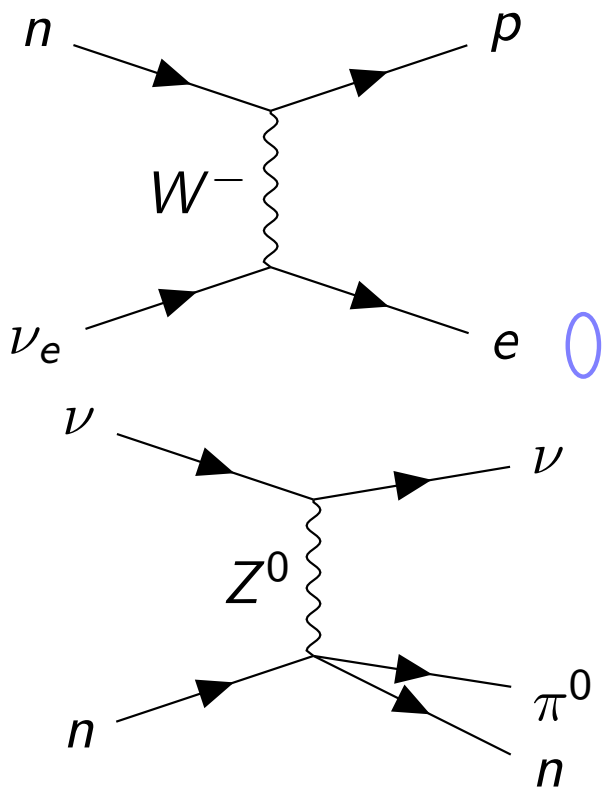
Purpose of NCπ^0sample



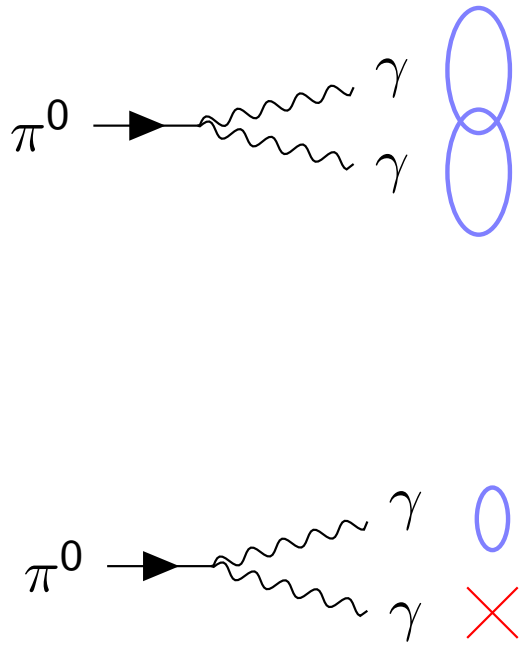


- The sample has high purity using both rings and a well known reconstructed π^0mass, 135 MeV
- NCπ^0events are an **irreducible background in ν_e oscillation samples**.

NCπ^0 Events at Super-K

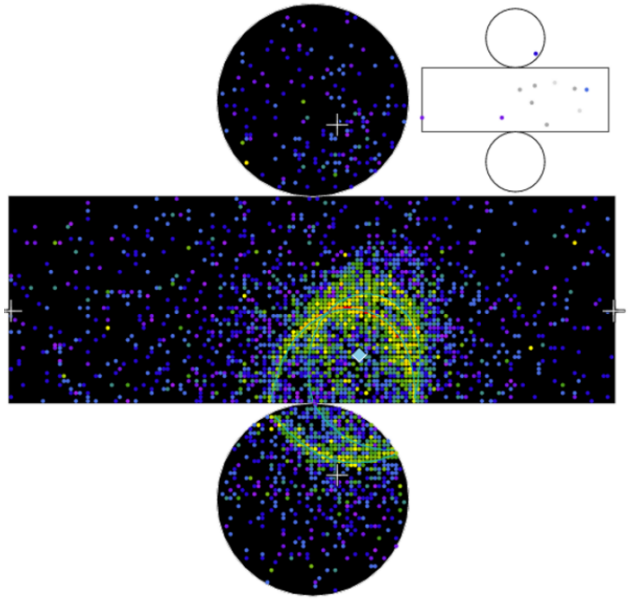


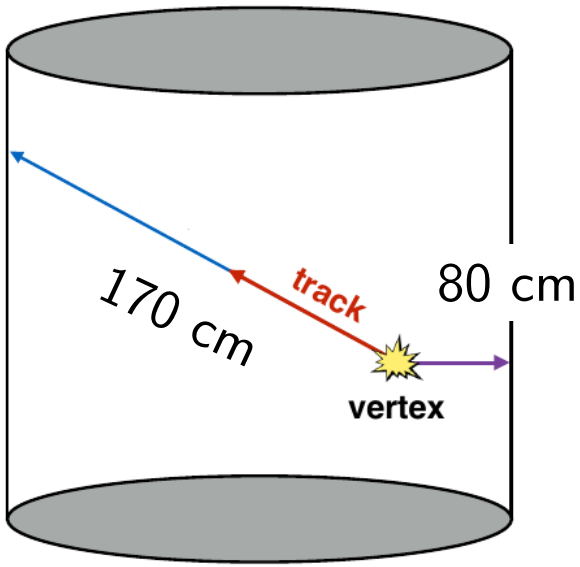
$M_{\pi^0} = 135$ MeV



- A π^0 decays dominantly into two photons, each producing e-like rings
- Neutral current events producing a π^0 in Super-K can produce a detector response similar to electron like events

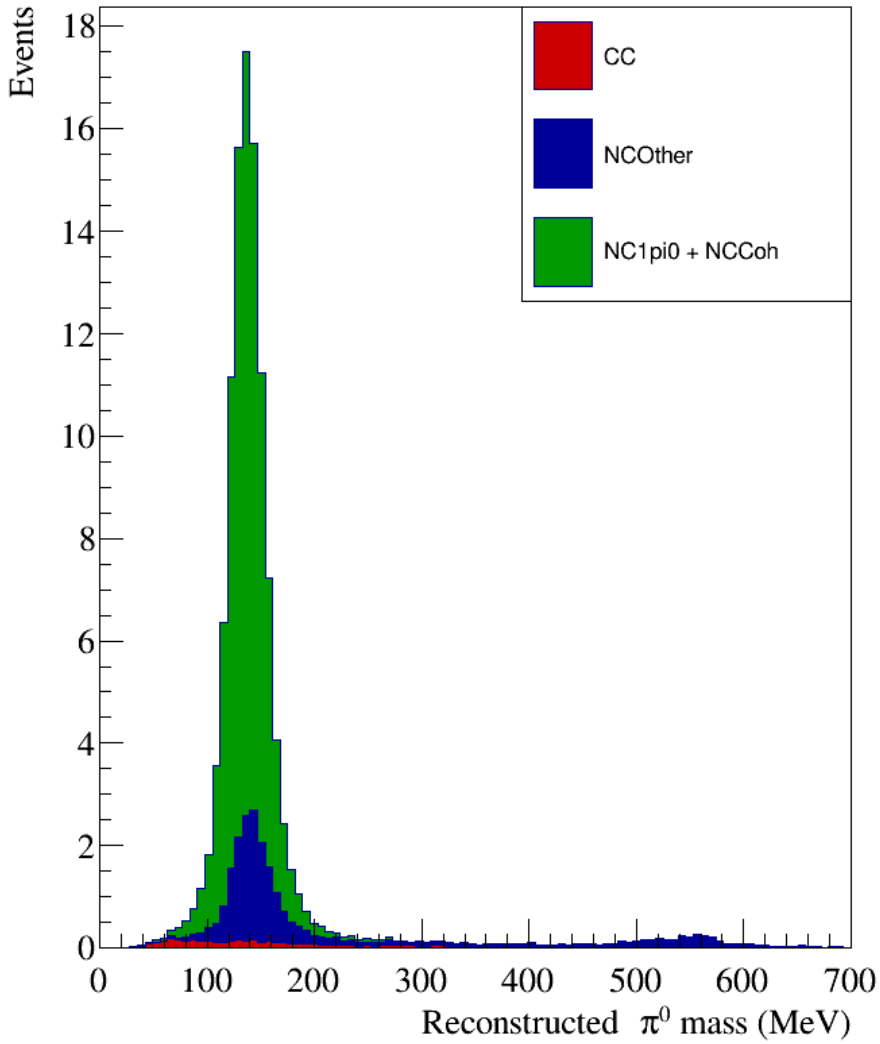
Selection for π^0events





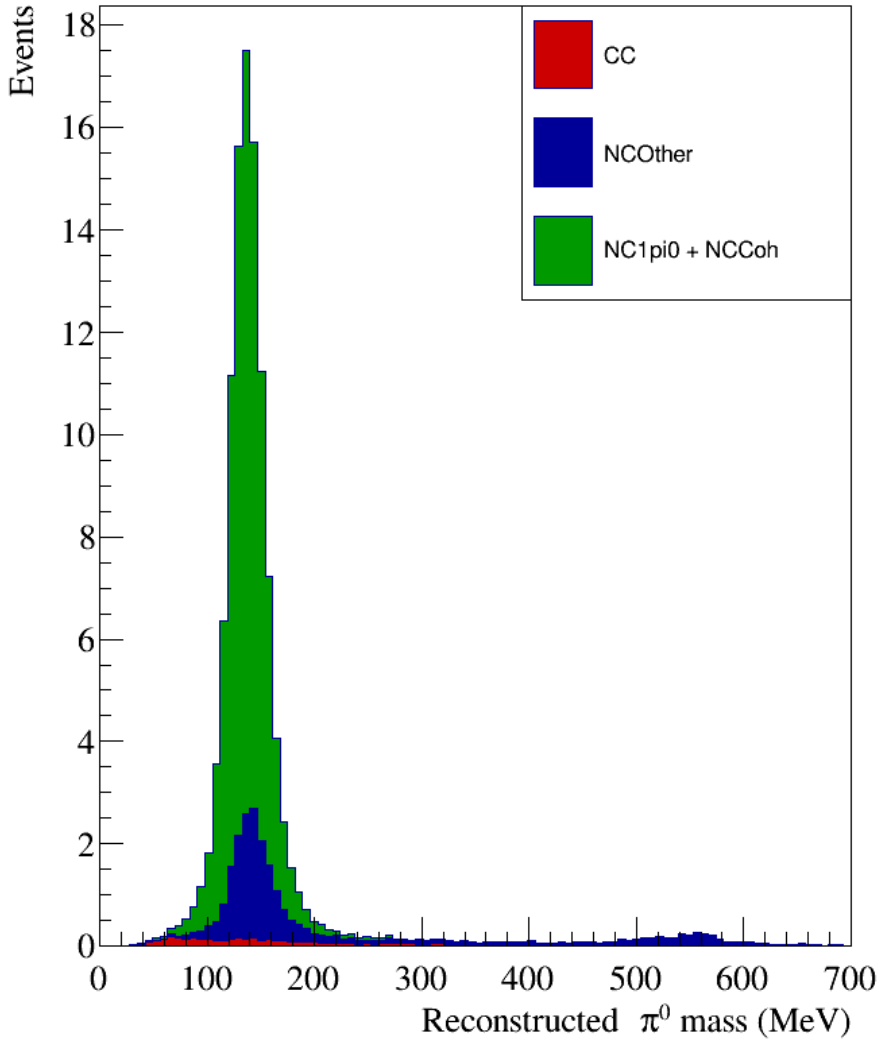
- Data quality cuts:
  - Outer Detector hits < 16
  - Visible energy in inner detector $>$ 100 MeV
  - Vertex distance from ID wall $>$ 80cm
  - Vertex distance from wall in direction of travel $>$ 170cm
- Event topology cuts:
  - No decay electrons
  - 2 reconstructed rings
  - Both rings have electron-like PID
  - Event identified as a $\pi^0$by PID variables when reconstructed

Final Sample



- Reconstructed π^0mass for FHC (RHC and other plots in backups)
- 1114 events in FHC and 37 in RHC
- Sample purity: 75% in FHC, 74% RHC
- Sample Efficiency: 39% in FHC and RHC

Further developments



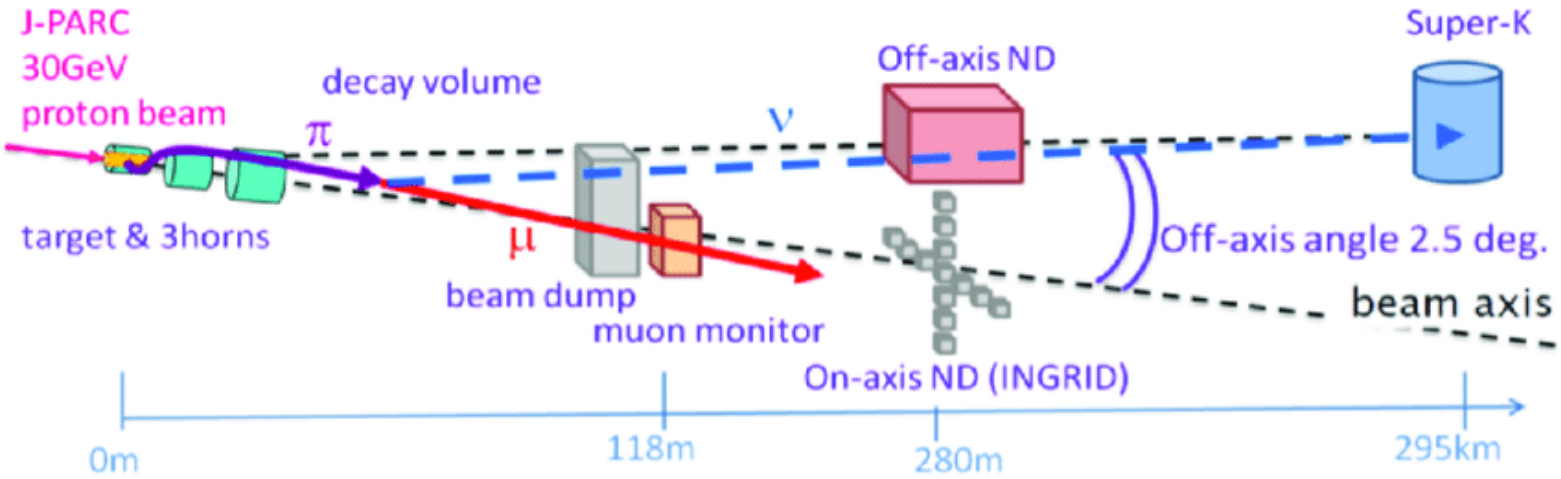
- Current work is to calculate systematic errors on sample
- The cuts need to be tuned to better select NCπ^0events
- This sample will eventually be included in an oscillation analysis

Conclusions

- An NCπ^0sample of Super-K events is useful for constraining interaction models
- Better understanding of NCπ^0events could help cover discrepancies seen in oscillation samples
- An initial sample has been made with systematics based on the 1 ring e-like sample already in place
- Further work will refine the selection with tuned cuts and electron-like PID on both rings

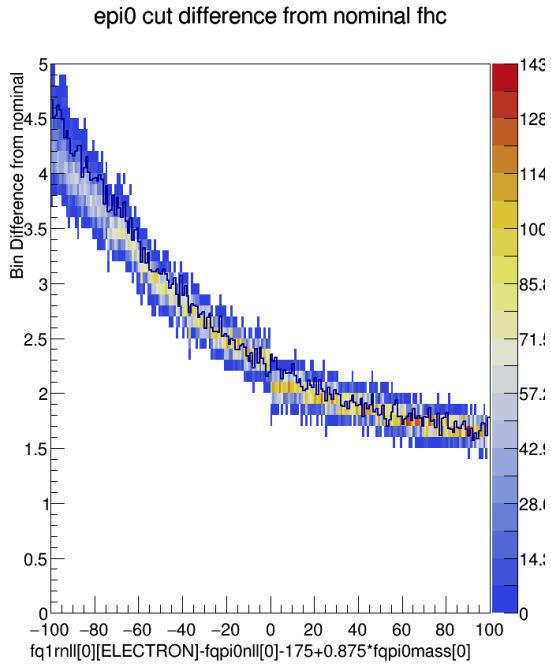
Backups

T2K and Super-Kamiokande



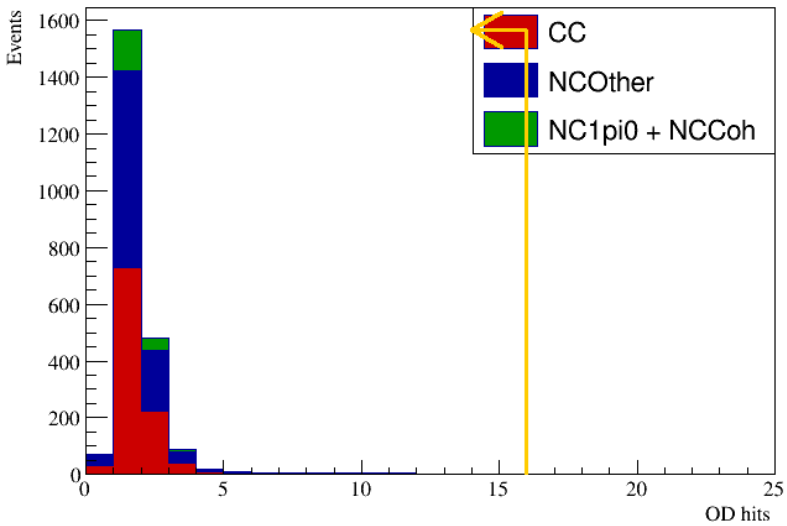
- More detailed layout of T2K beam

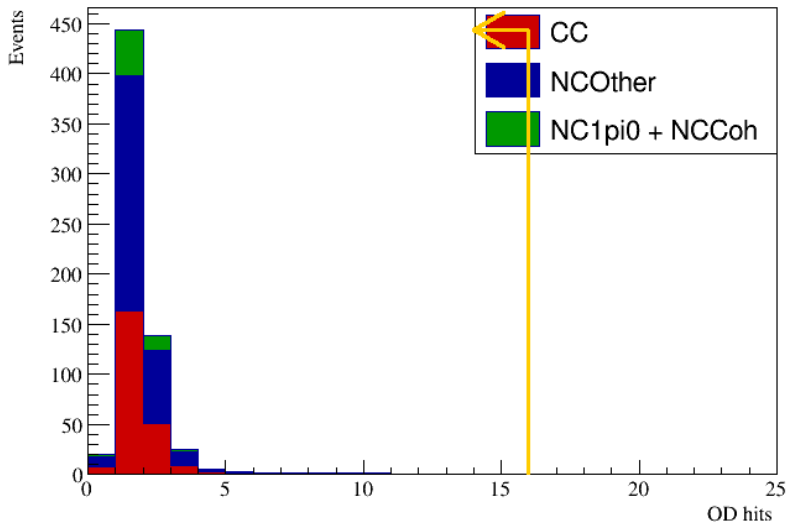
Systematic Errors



- Systematic errors encompass the difference in reconstruction of Super-K data and MC generated data
- Mismodelling of events is parametised using a bias and smear value
- The cut variables used need to be incorporated into the MCMC chains to shift and smear their values to get an accurate systematic error
- The chains used so far do not include multi ring e/μ PID variables so the cuts are not included

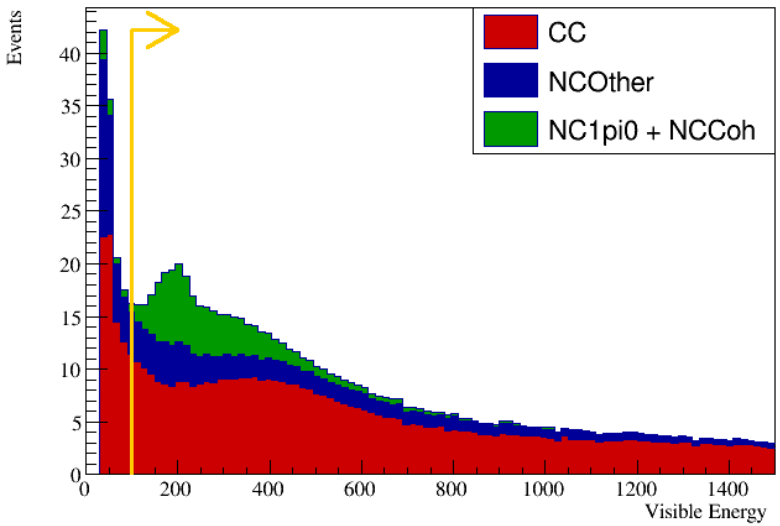
Cut by cut selection

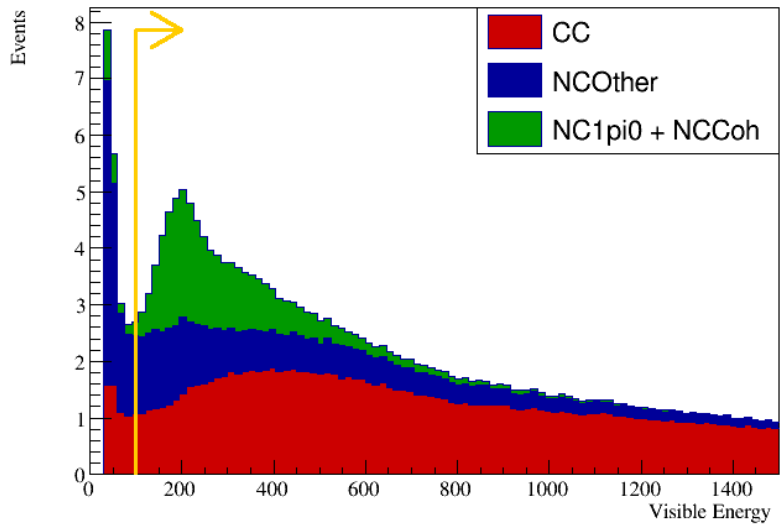




- FHC (left) and RHC (right) Outer detector hits

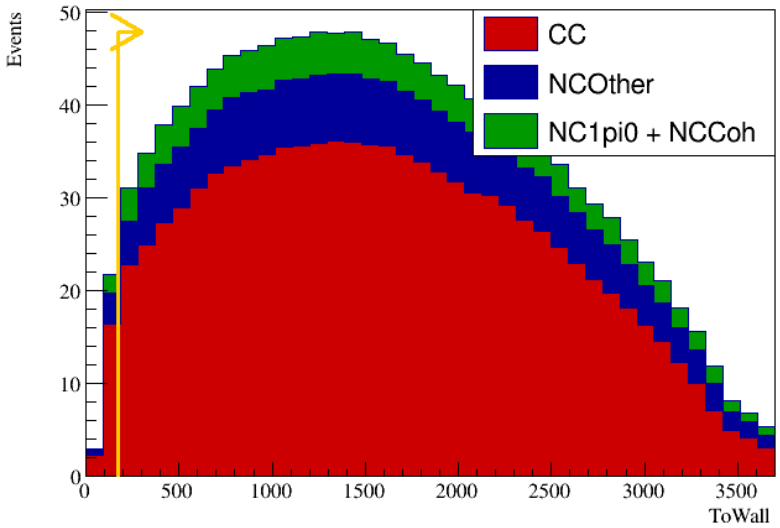
Cut by cut selection

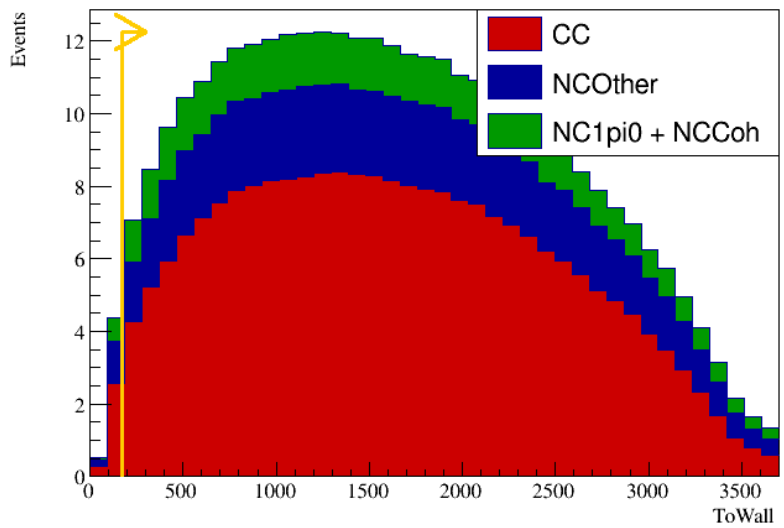




- FHC (left) and RHC (right) Visible energy

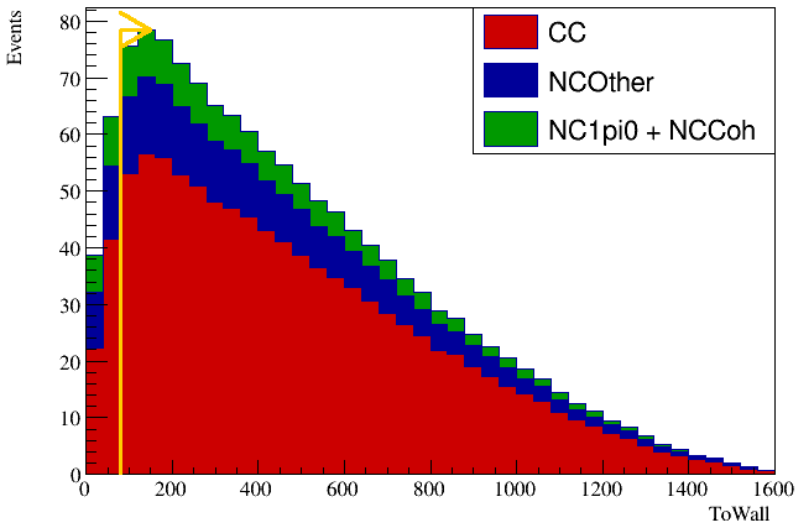
Cut by cut selection

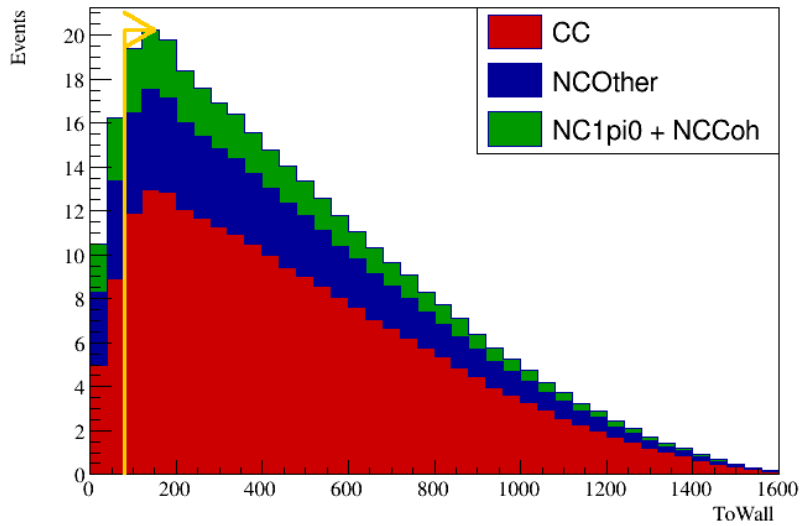




- FHC (left) and RHC (right) ToWall

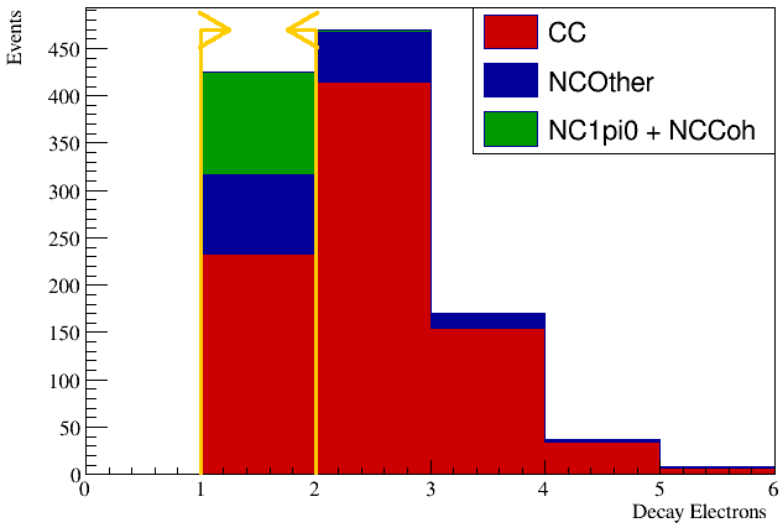
Cut by cut selection

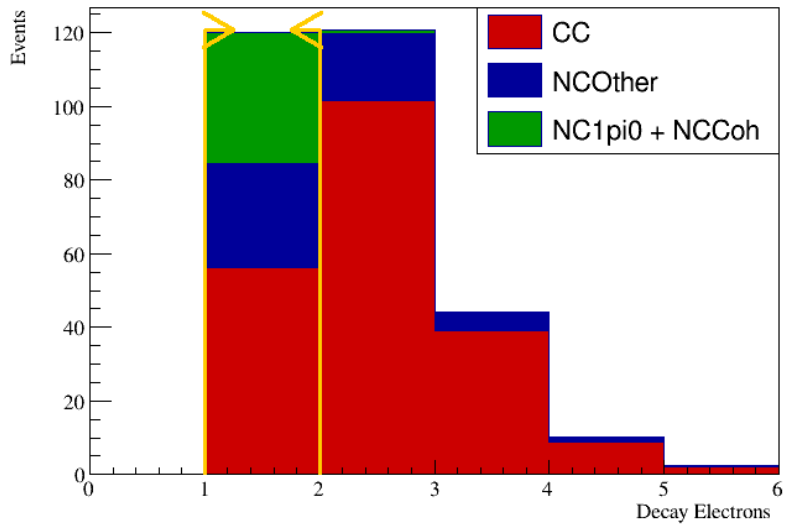




- FHC (left) and RHC (right) DWall

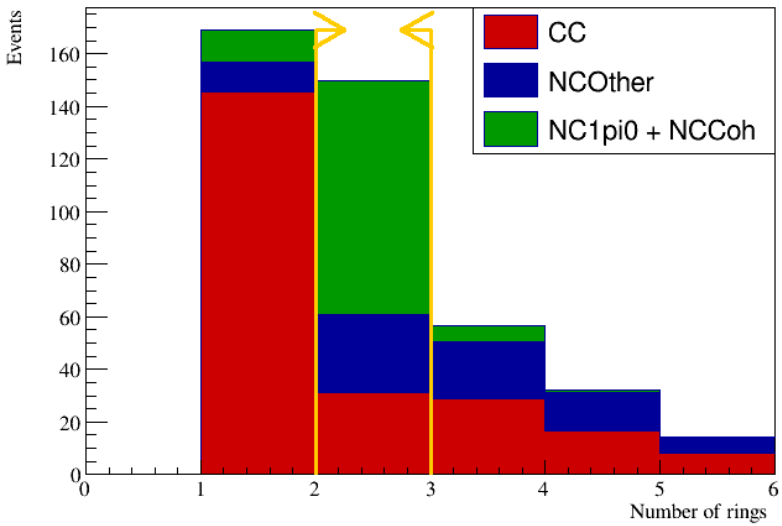
Cut by cut selection

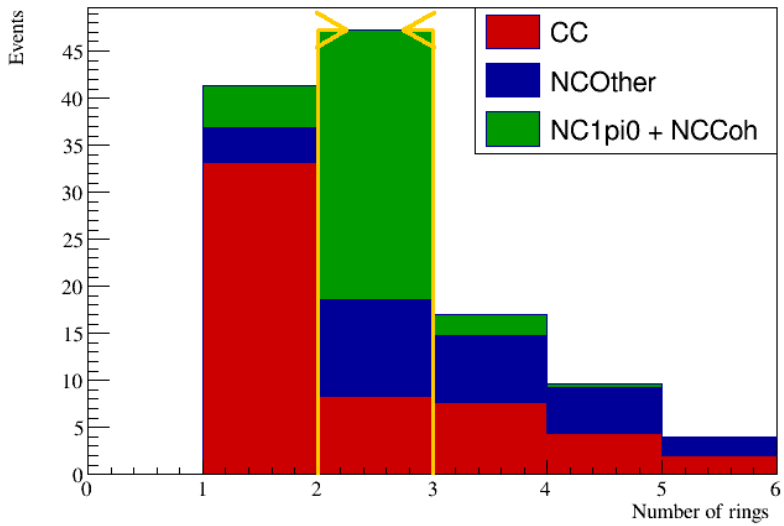




- FHC (left) and RHC (right) Decay electrons

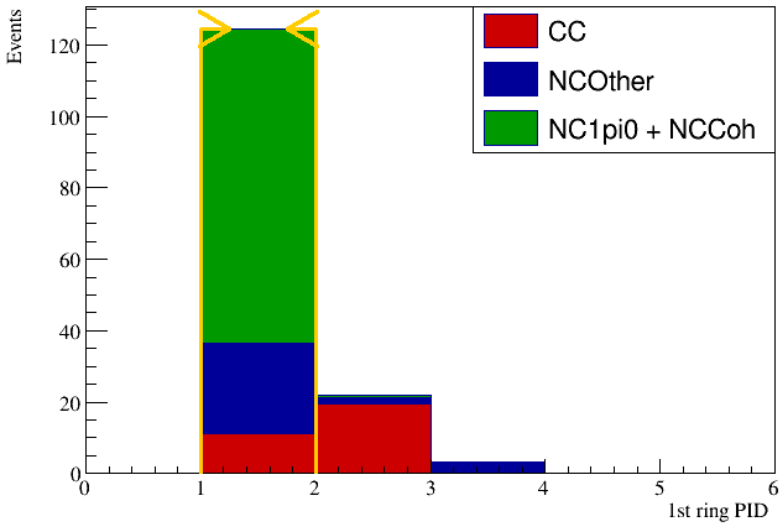
Cut by cut selection

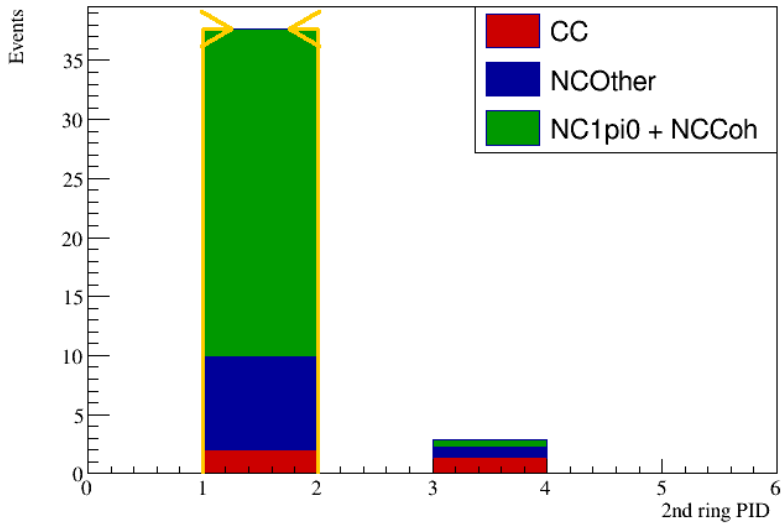




- FHC (left) and RHC (right) Number of rings

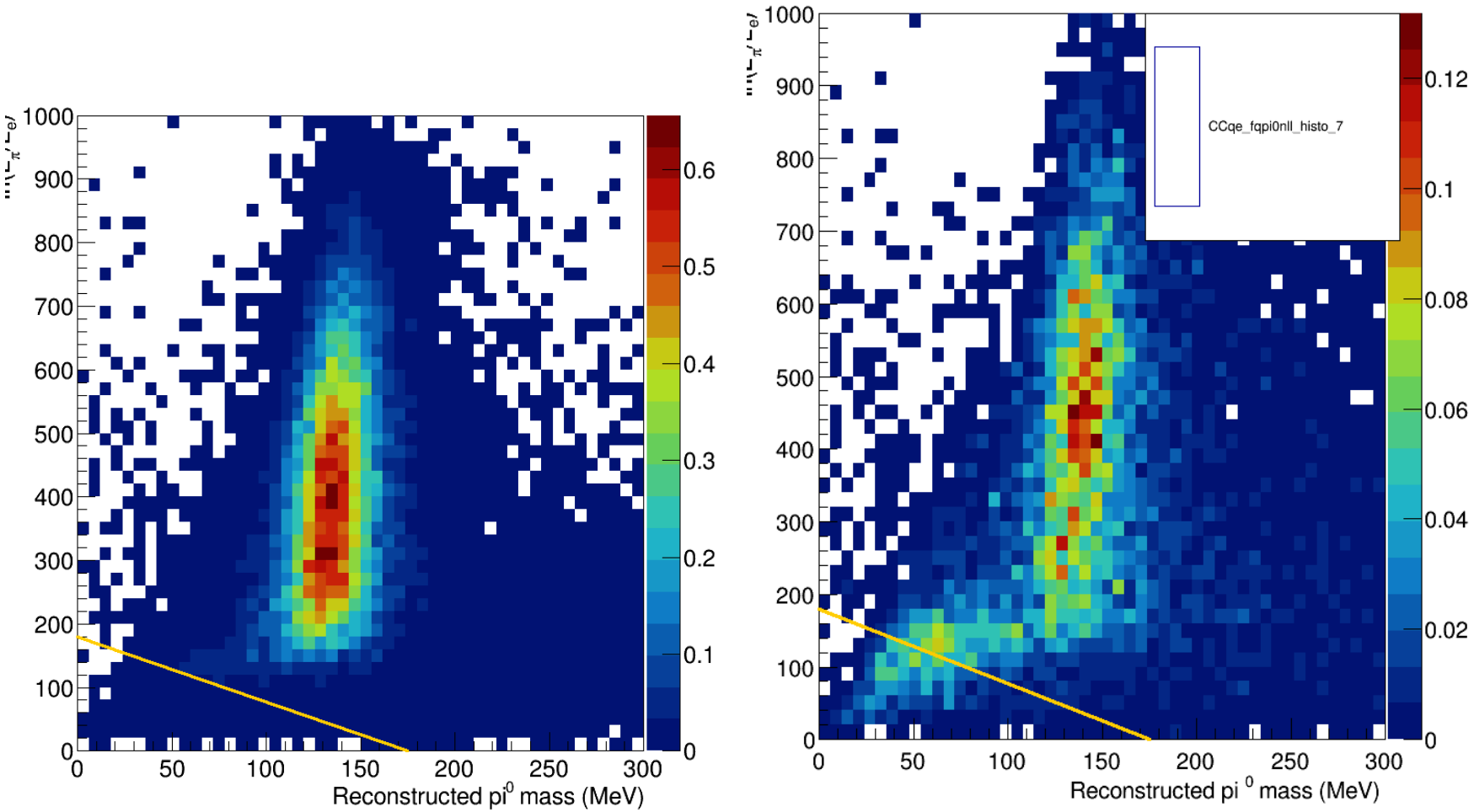
Cut by cut selection





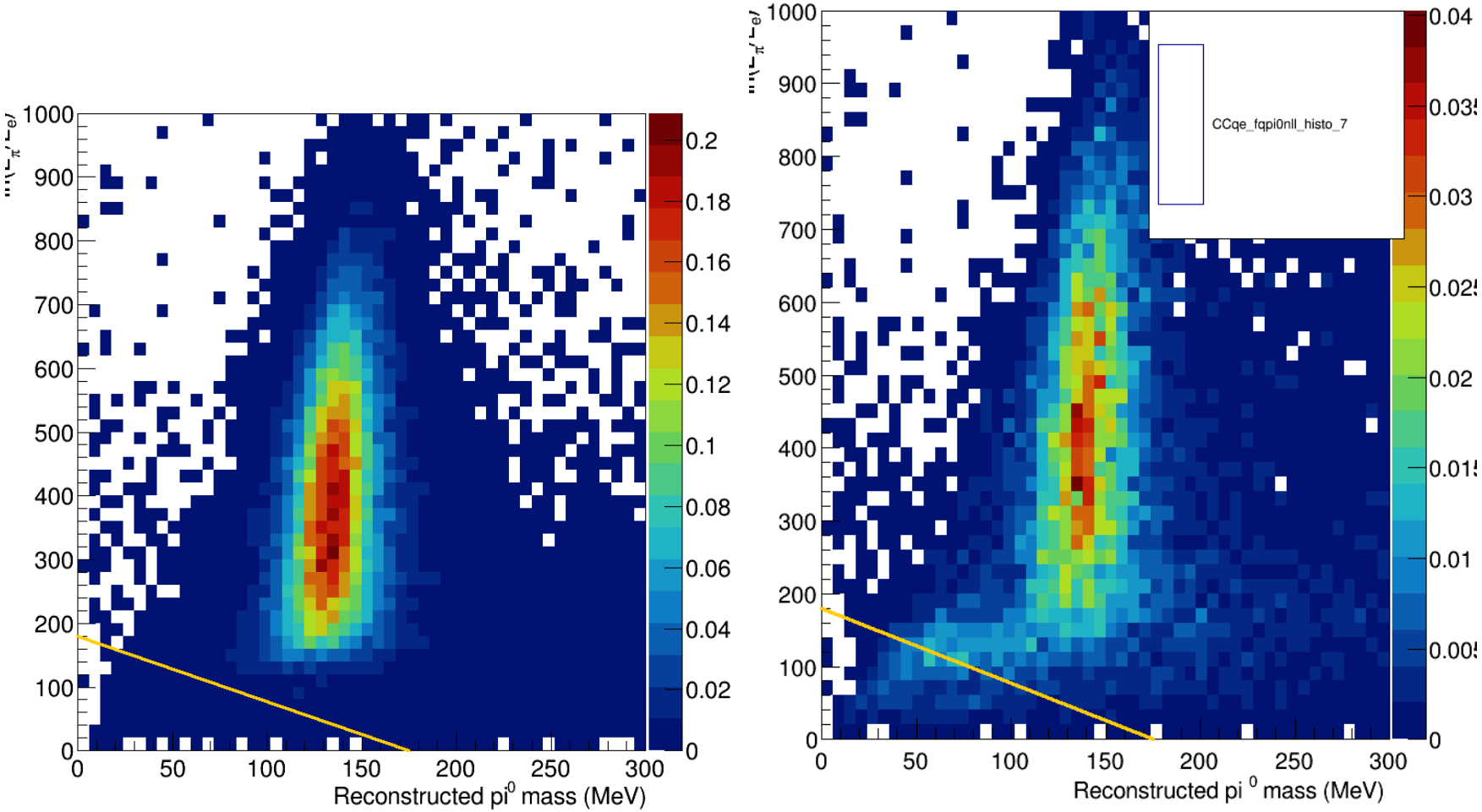
- FHC (left) and RHC (right) 1st ring PID
- 1 = Electron, 2 = Muon, 3 = Pion

Cut by cut selection



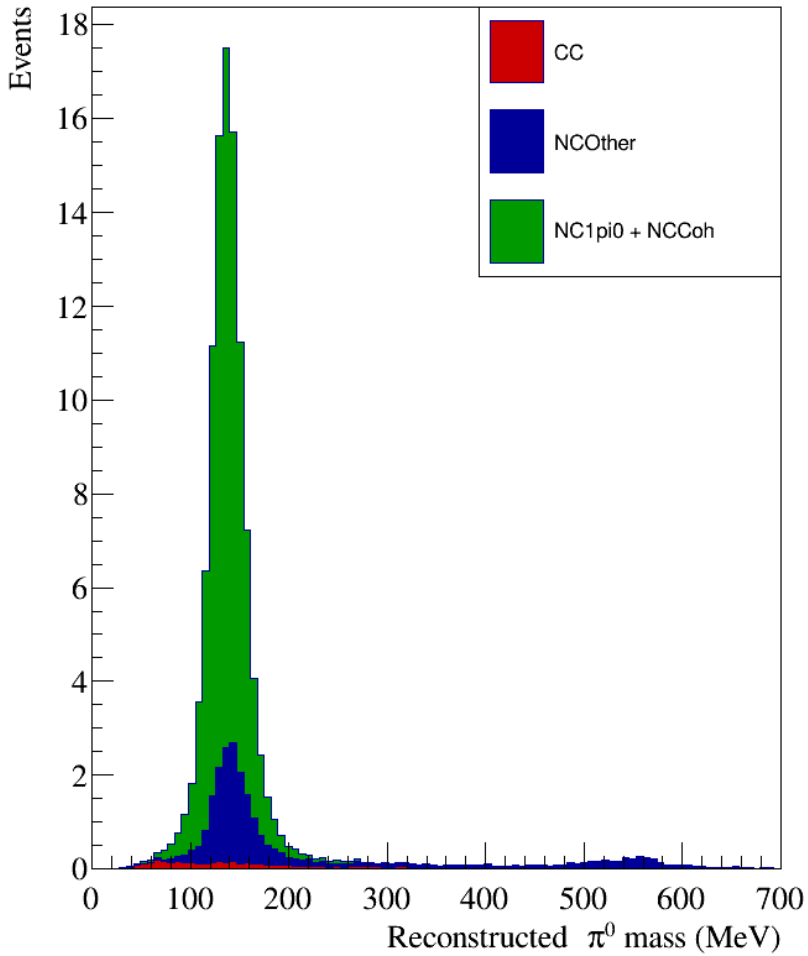
- FHC signal (left) and background (right) electron/π^0PID cut
- 1 = Electron, 2 = Muon, 3 = Pion

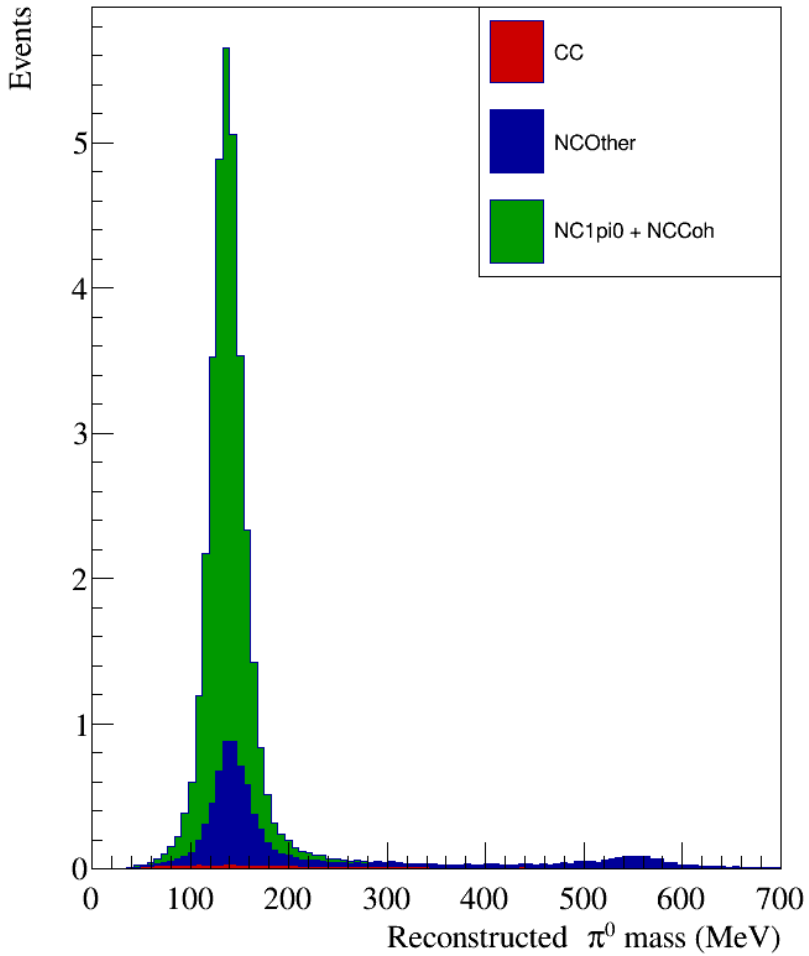
Cut by cut selection



- RHC signal (left) and background (right) electron/π^0PID cut

Cut by cut selection





- Reconstructed π^0mass after all selections