# Neutral current $\pi^0$events in Super Kamiokande

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# Introduction

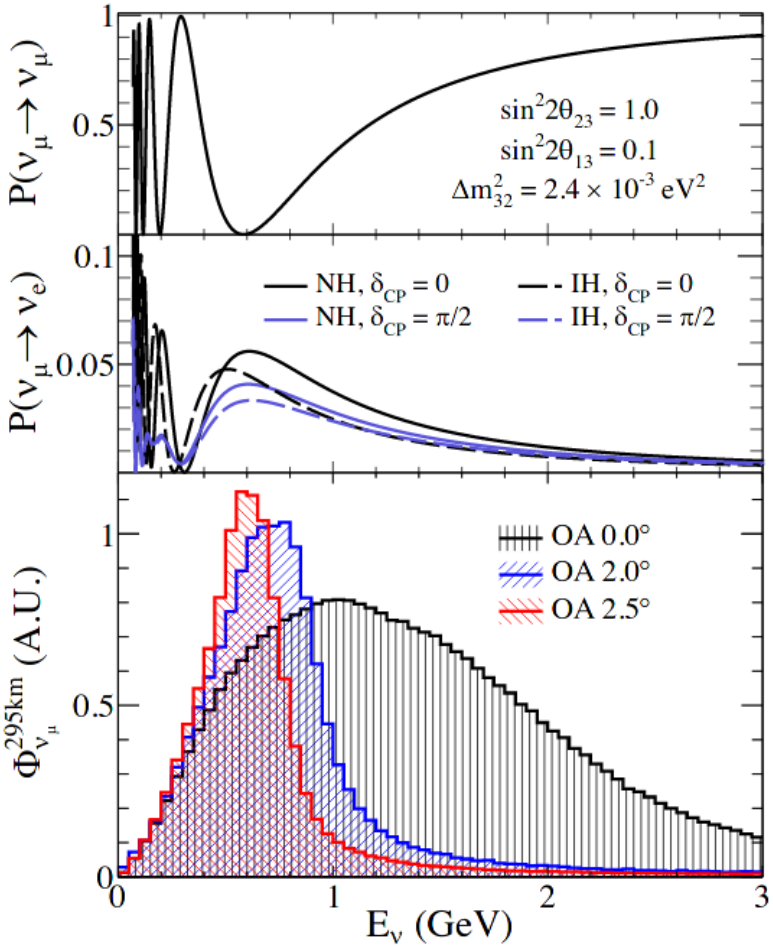
T2K and Super-Kamiokande experiments

Neutral Current $^0$ events

NC $^0$ Sample selection

Further development

# T2K and Super-Kamiokande



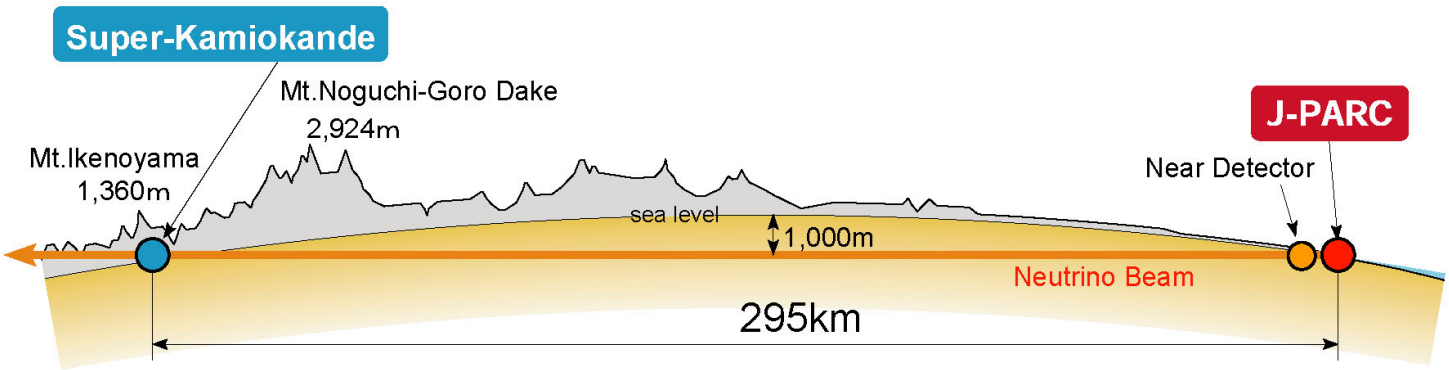

Neutrino flavours oscillate due to the mixing of mass and flavour eigenstates

T2K searches for $\nu_\mu \to \nu_e$ oscillations

2.5deg off axis angle maximises $\nu_e$ 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

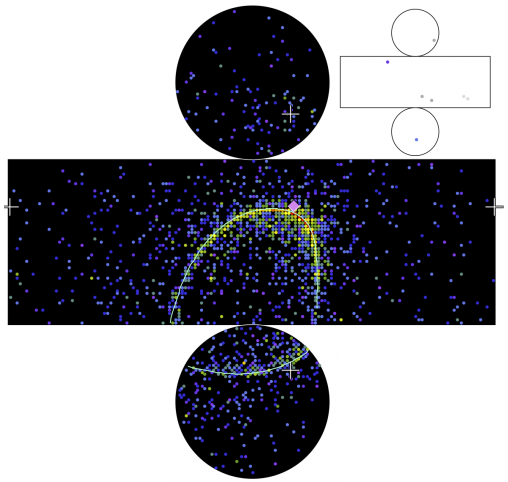
T2K measures muon neutrino disappearance and electron neutrino appearance using a beam

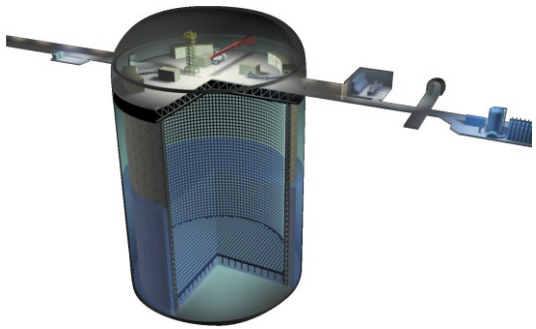
The T2K beam is characterised close to the source (near detector) and far away (far detector)

The far detector, Super-K is a 22.5 kton ultra-pure water Cherenkov detector

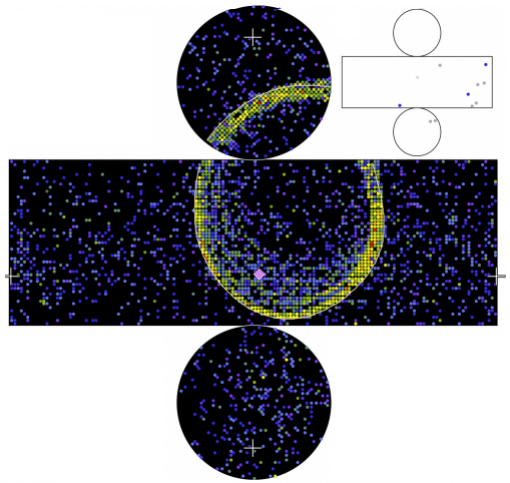
# T2K and Super-Kamiokande

Fuzzy ! e-like





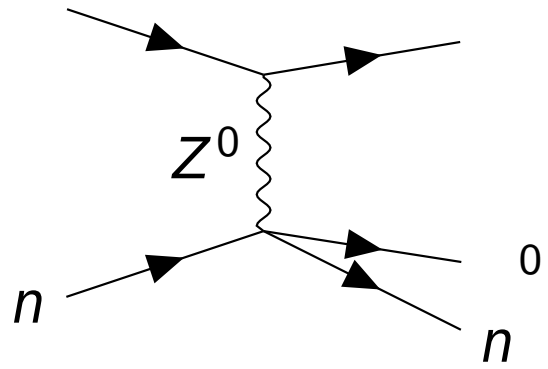
Clean ! -like



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 NC$\pi^0$sample

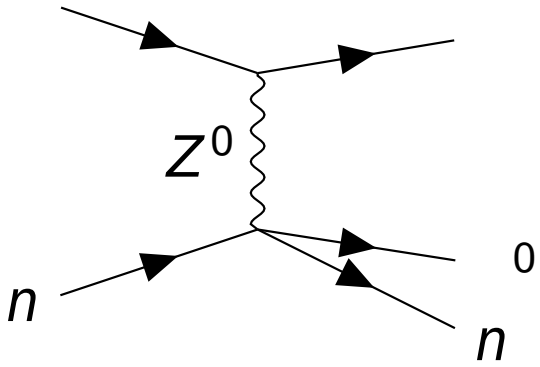



Neutral current interactions are flavour blind so **oscillation of ux at Super-K does not a ect interactions**

The sample helps constrain interaction models as the error on oscillation models is not required

There is a **lower threshold for detection of $^0$decays at Super-K** than the near detector, allowing to check ND280 measurements.

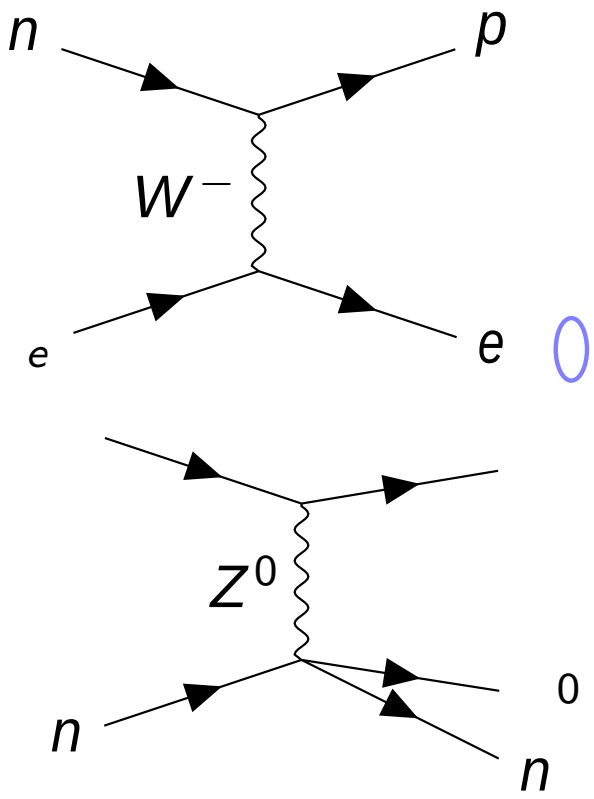
# Purpose of NC$\pi^0$sample



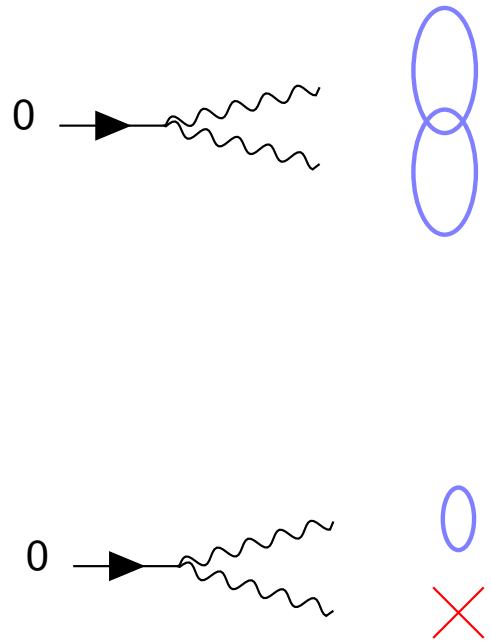

The sample has high purity using both rings and a well known reconstructed $^0$mass, 135 MeV

NC $^0$events are an **irreducible background in $_e$ oscillation samples**.

# NC$\pi^0$ Events at Super-K



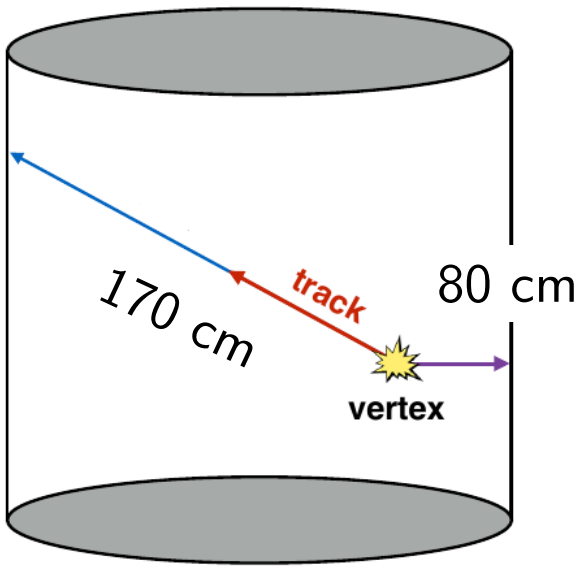

$M_{\pi^0} = 135$ MeV




A $^0$ decays dominantly into two photons, each producing e-like rings

Neutral current events producing a $^0$ in Super-K can produce a detector response similar to electron like events

# Selection for $\pi^0$events




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 $^0$by PID variables when reconstructed

# Final Sample

Reconstructed $^0$mass 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 NC $^0$events

This sample will eventually be included in an oscillation analysis

# Conclusions

An NC $^0$sample of Super-K events is useful for constraining interaction models

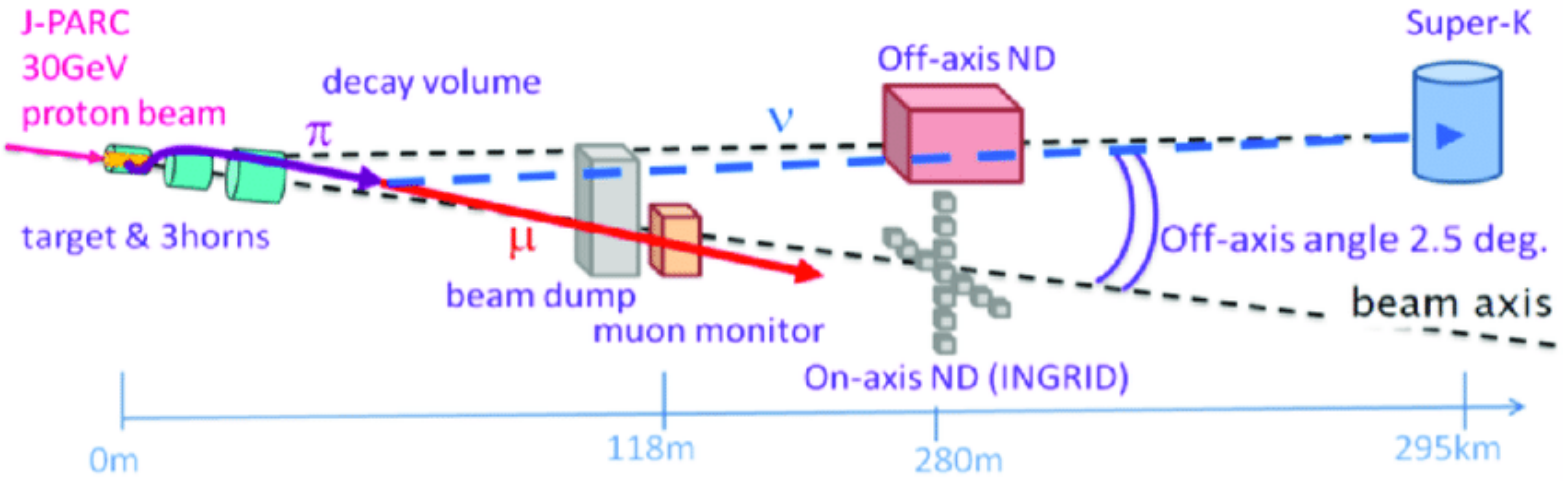
Better understanding of NC $^0$events could help cover discrepancies seen in oscillation samples

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

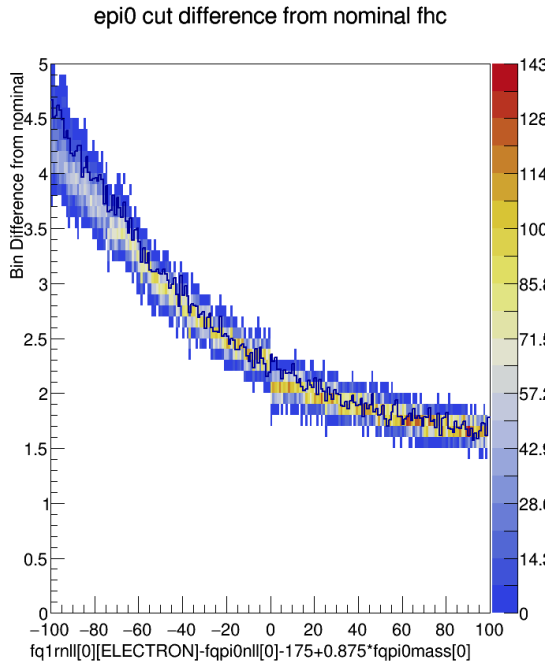
# Backups

# T2K and Super-Kamiokande




More detailed layout of T2K beam

# Systematic Errors



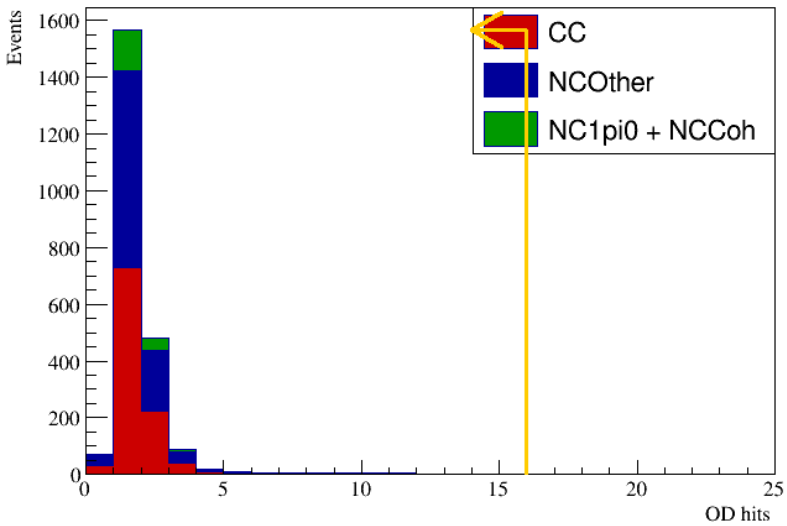

Systematic errors encompass the difference in reconstruction of Super-K data and MC generated data

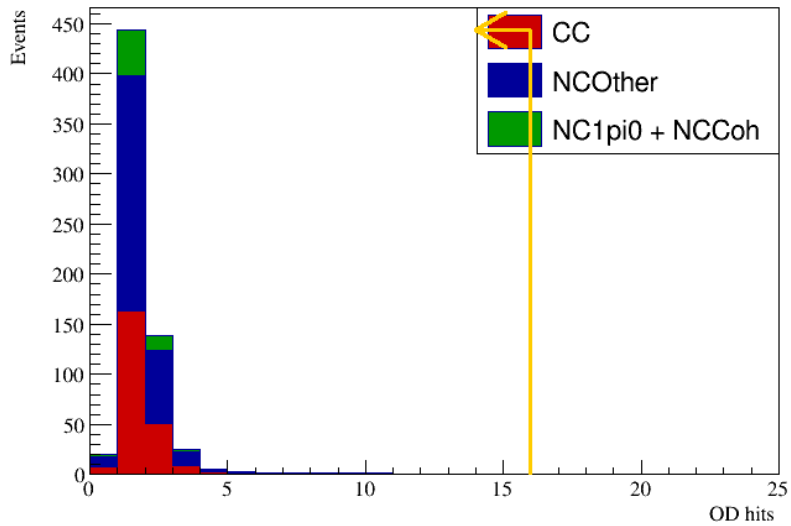
Mismodelling of events is parametised using a bias and smear value

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/ PID variables so the cuts are not included

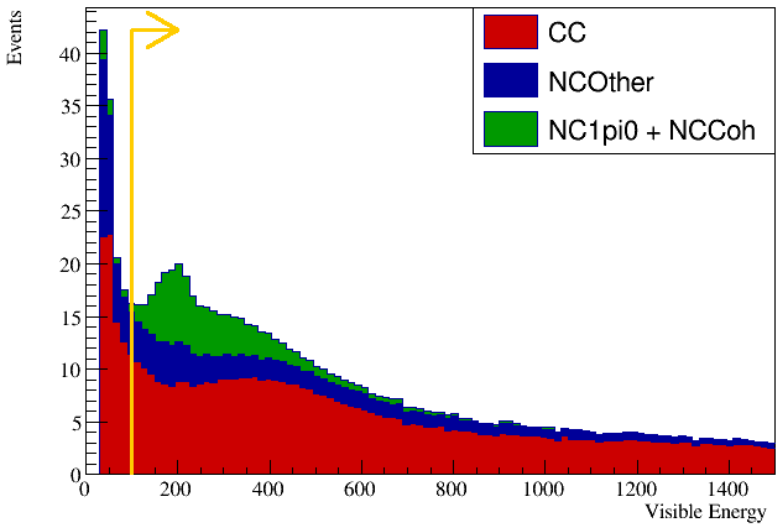
# Cut by cut selection

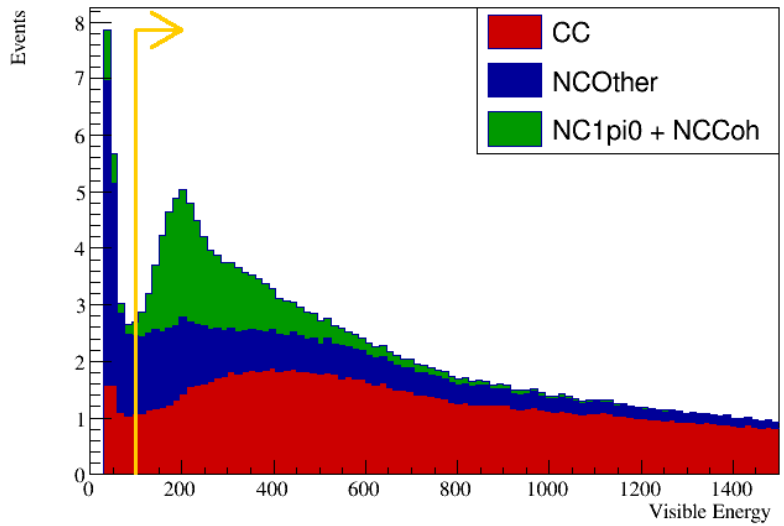



FHC (left) and RHC (right) Outer detector hits

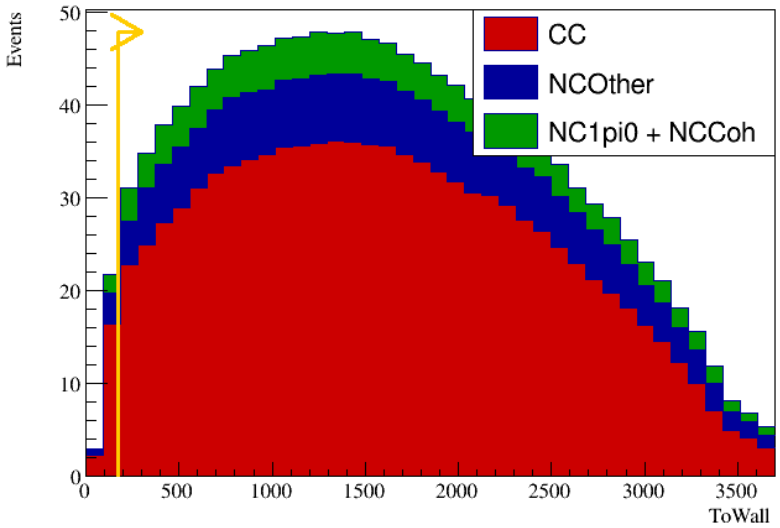
# Cut by cut selection

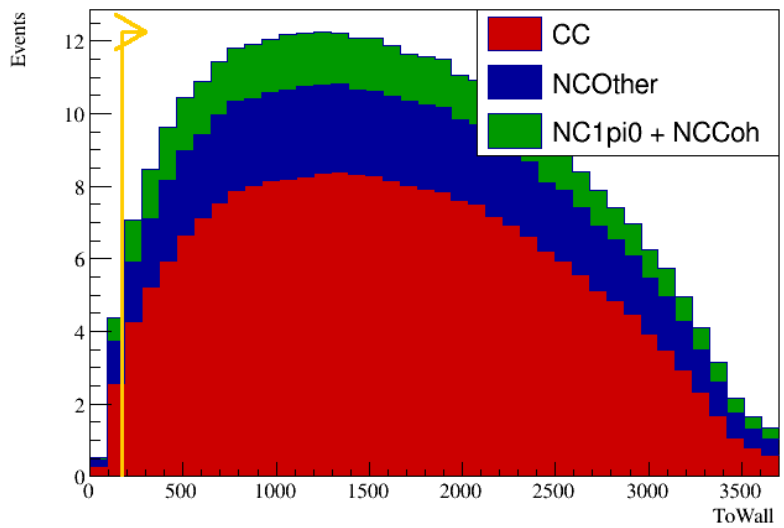



FHC (left) and RHC (right) Visible energy

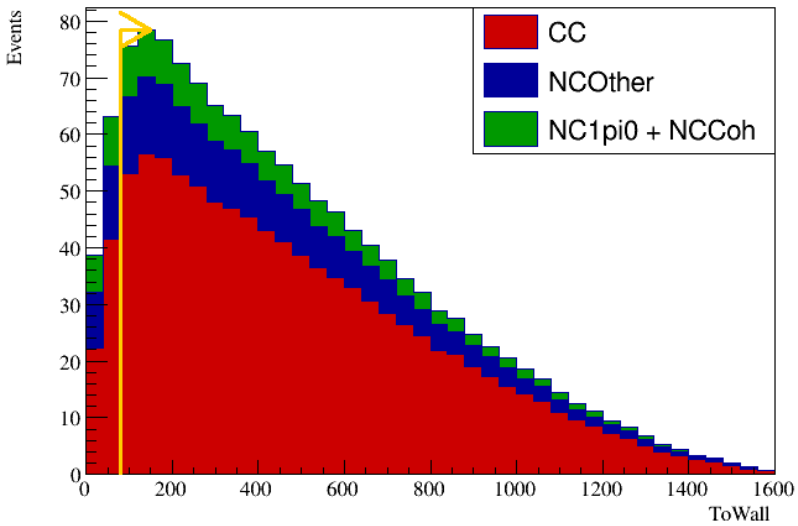
# Cut by cut selection

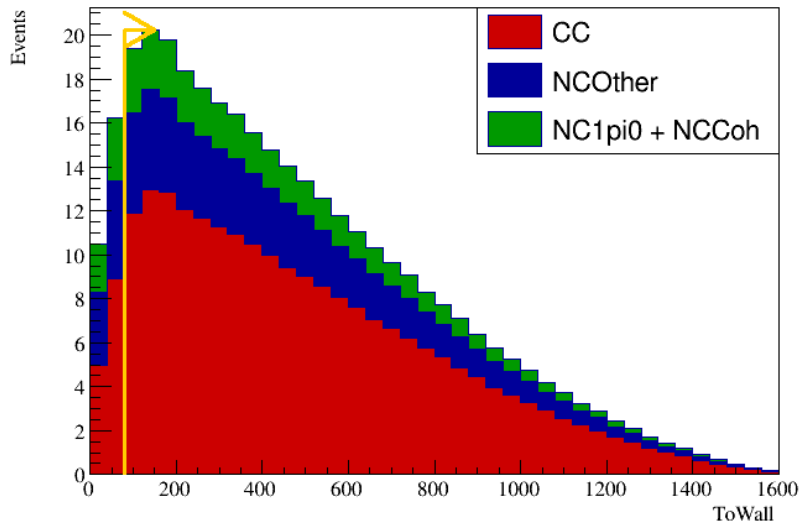



FHC (left) and RHC (right) ToWall

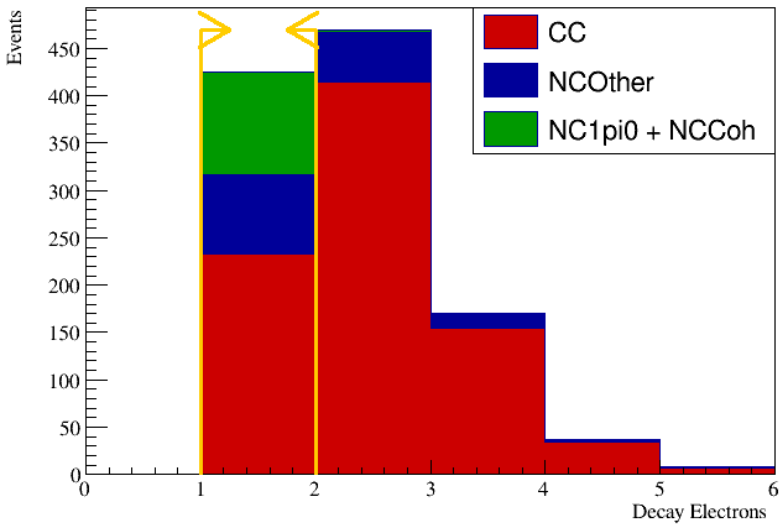
# Cut by cut selection

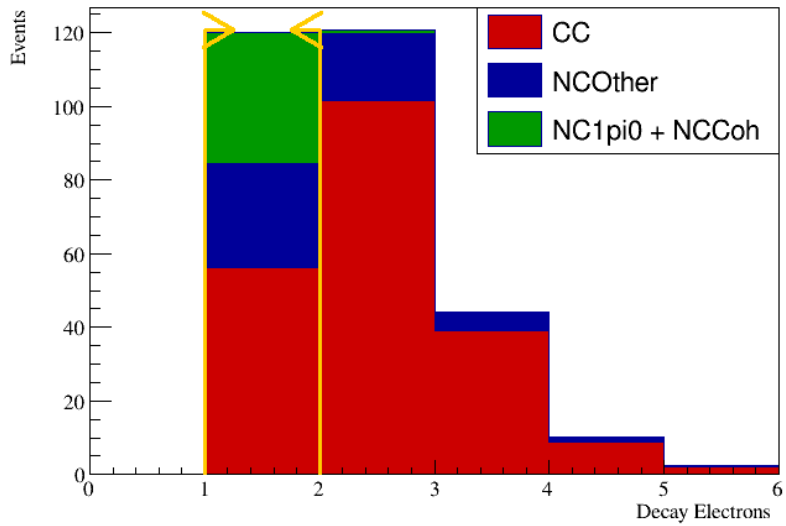



FHC (left) and RHC (right) DWall

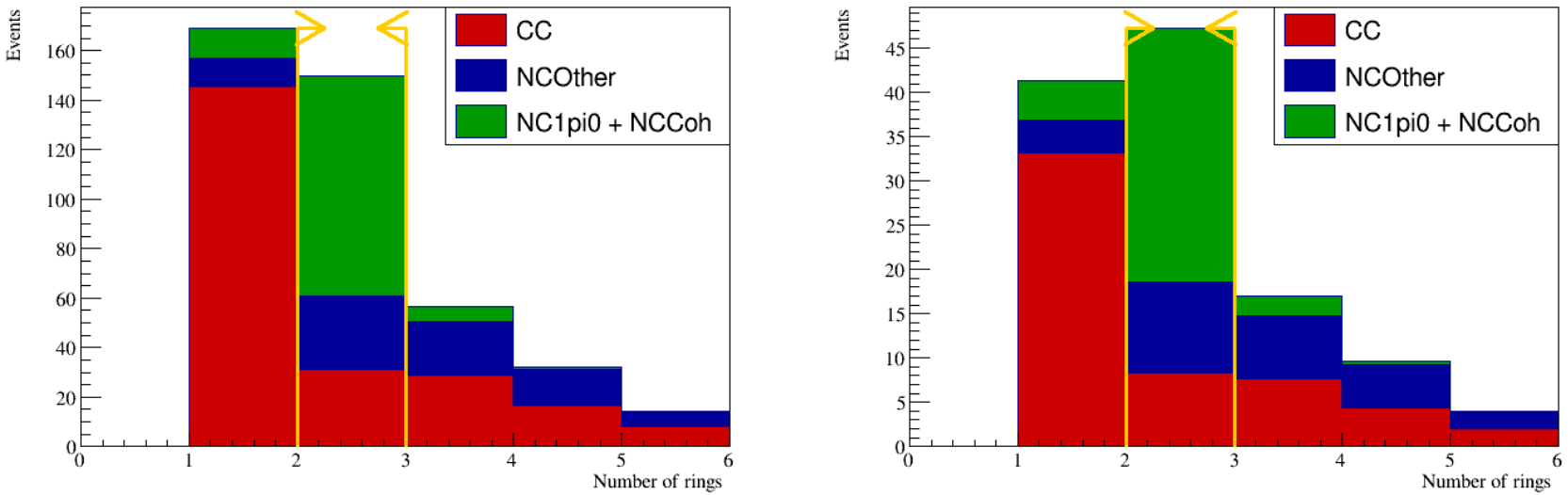
# Cut by cut selection



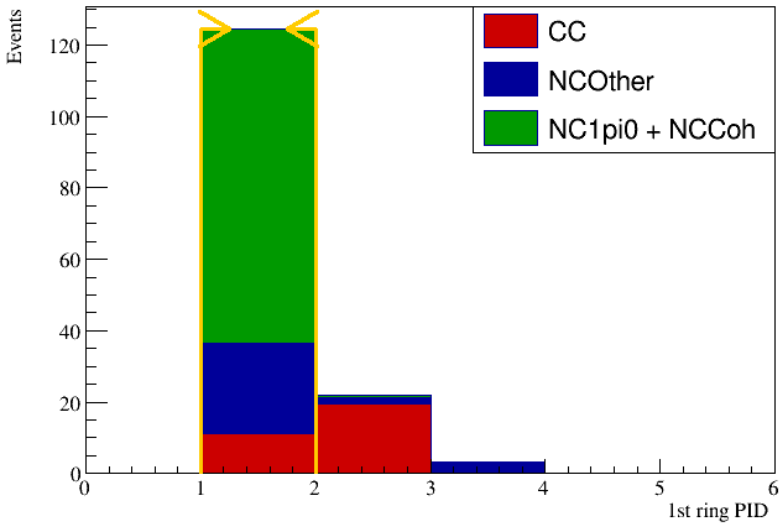

FHC (left) and RHC (right) Decay electrons

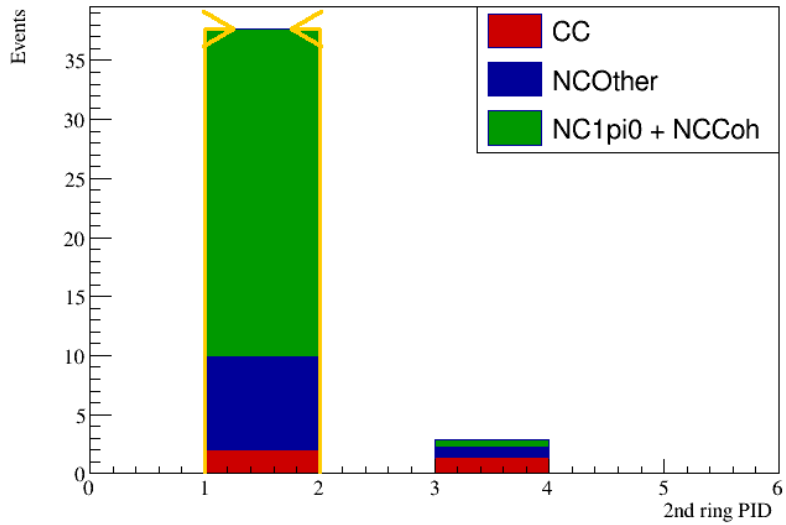
# Cut by cut selection




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

# Cut by cut selection

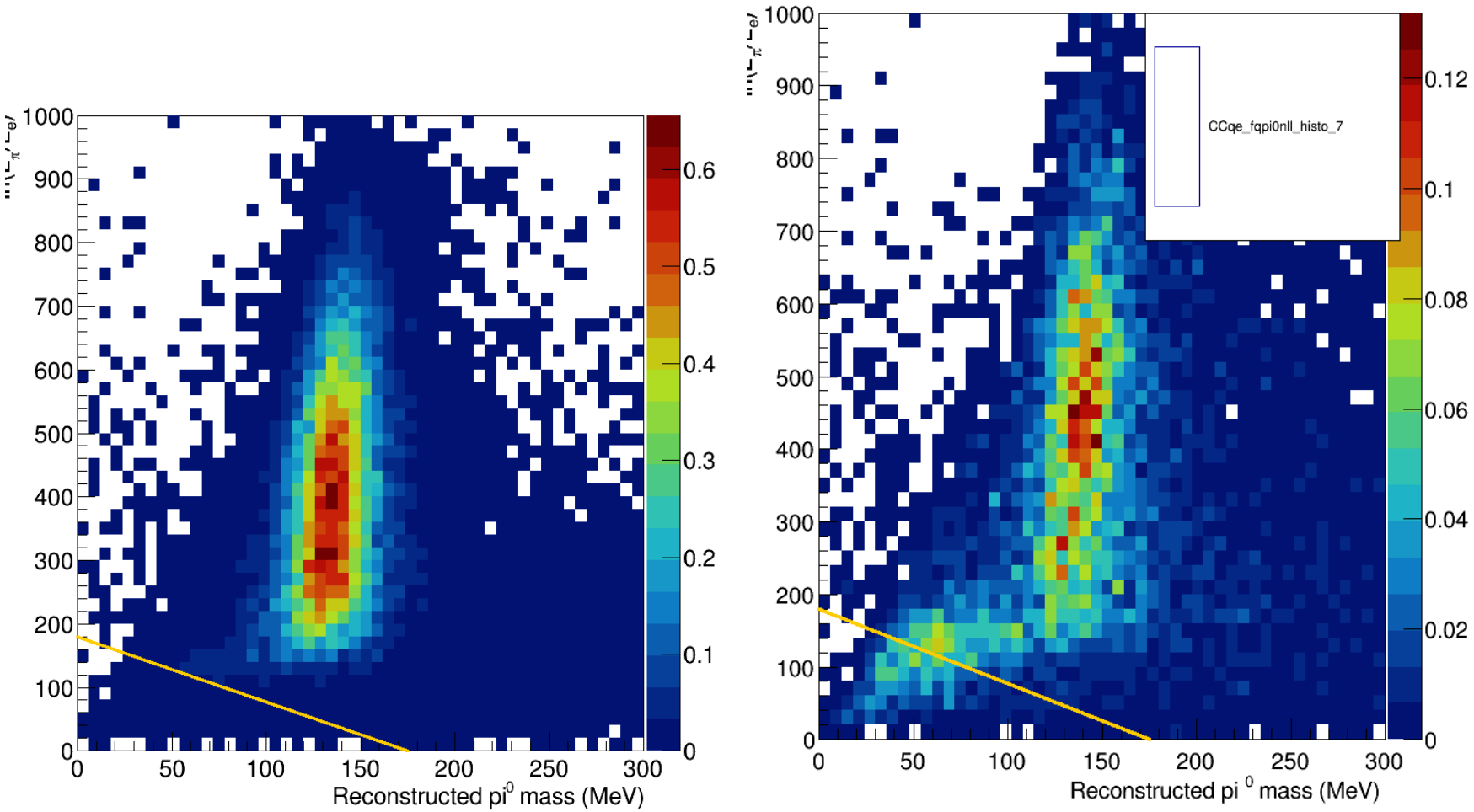



FHC (left) and RHC (right) 1st ring PID

1 = Electron, 2 = Muon, 3 = Pion

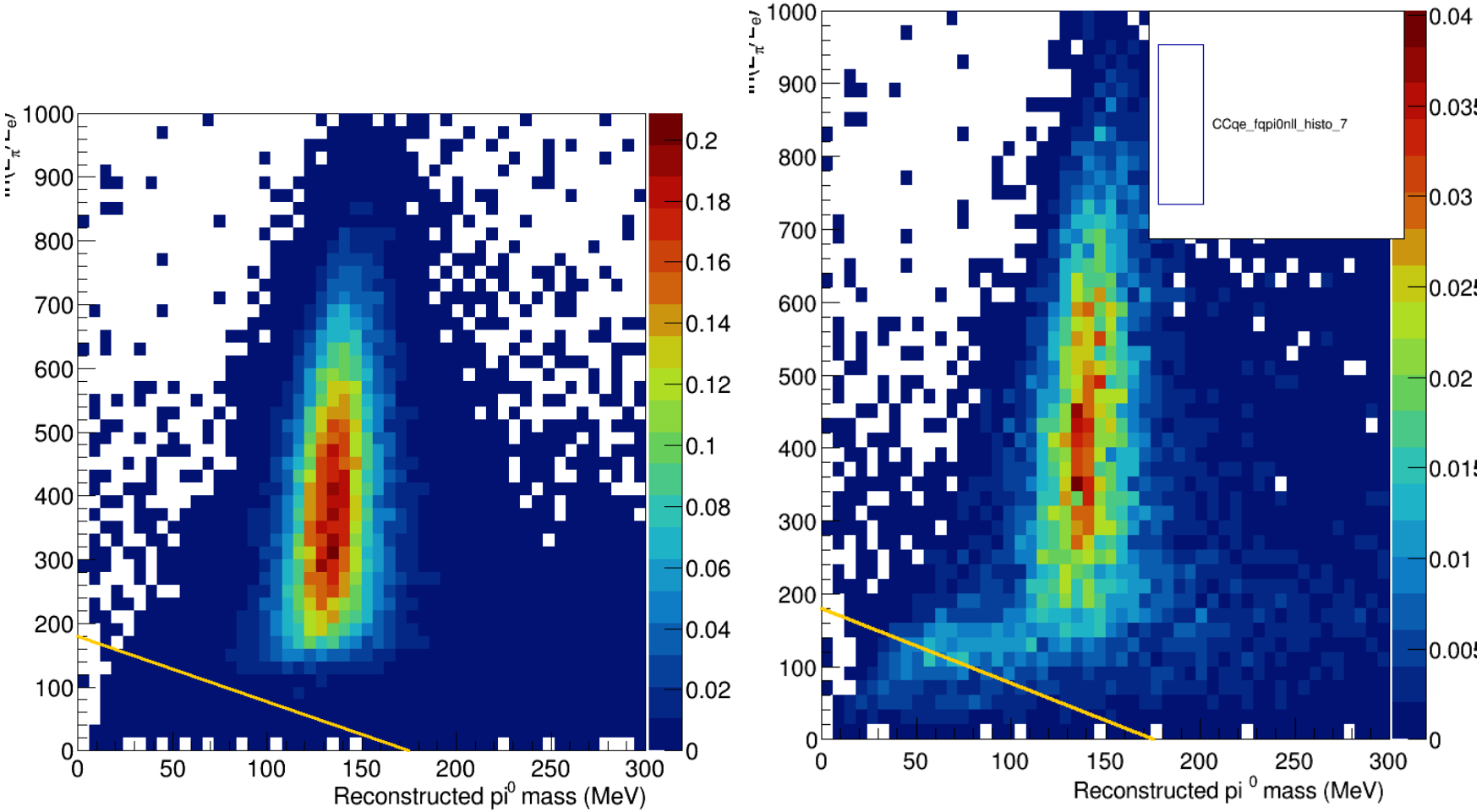
# Cut by cut selection




FHC signal (left) and background (right) electron/ $^0$PID cut

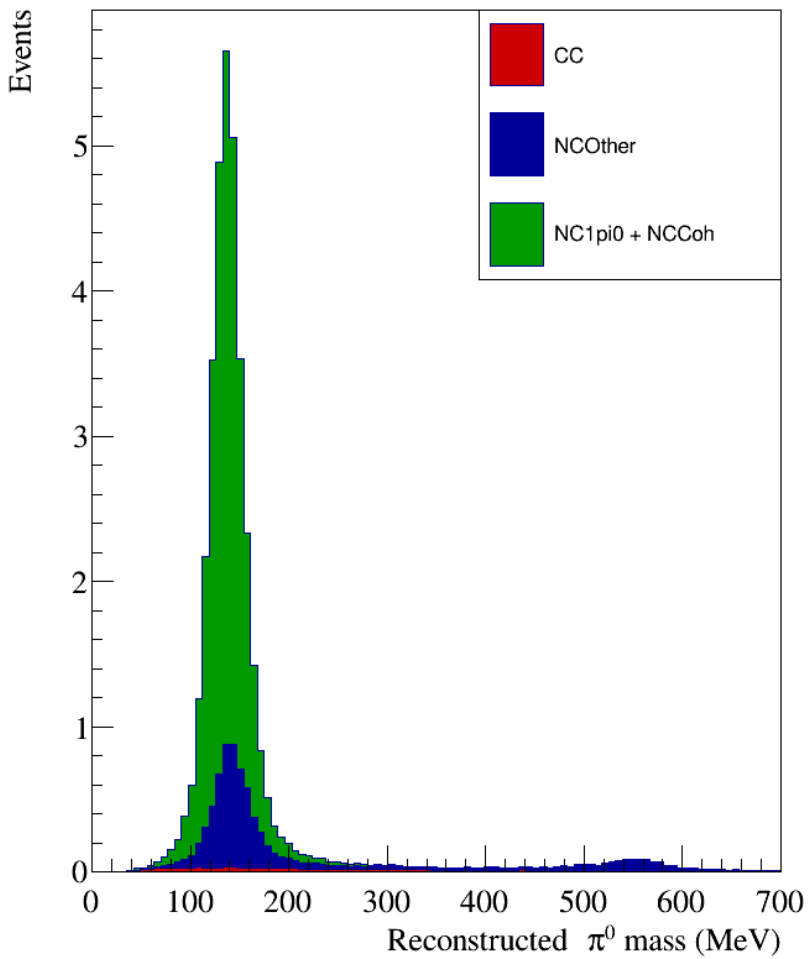
1 = Electron, 2 = Muon, 3 = Pion

# Cut by cut selection




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

# Cut by cut selection




Reconstructed $^0$mass after all selections