Status of neutrino event reconstruction in the NINJA experiment

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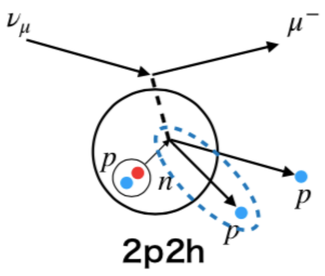
NINJA Experiment

Neutrino Interaction research with Nuclear emulsion and J-PARC Accelerator

- Measurement of neutrino-nucleus interactions on H2O target in 1 GeV energy region
  -> Systematic uncertainty in the T2K(/HK) experiment(s)
- Very good position/angle resolution of nuclear emulsion films



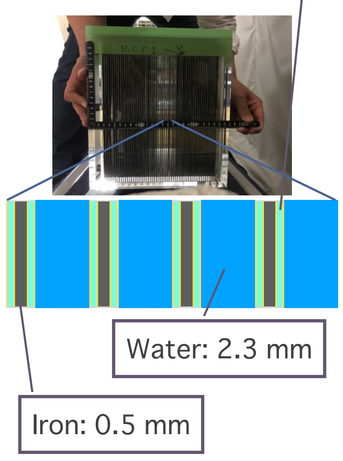
- 2p2h (2-particle 2-hole) is not well understood int. mode.
- Detection of low-p protons which are hard to detect with any other experiment is necessary.

Detectors

- We placed 3 kinds of detectors in B2 floor of the J-PARC Neutrino Monitor building
- 75 kg H2O target exposed to 4.7 x 10^{20} POT (protons on target) neutrino beam.

ECC (Emulsion Cloud Chamber)

- Alternate structure of water layers and emulsion tracking layers
- Fine segmentation
  -> short range track detection



Baby MIND (MRD)

- Scintillator & magnetized iron detector
- Provide muon track information with beam triggered timing

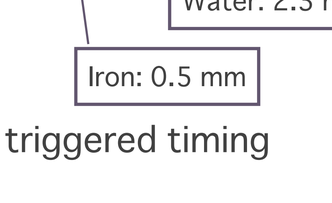
Timestamper

- To connect muon tracks in ECCs and Baby MIND, we used two kinds of timestamp detectors
  A. Emulsion Shifter (left)
  B. Scintillation Tracker (right)
- Provide good position/angle information of (muon) tracks

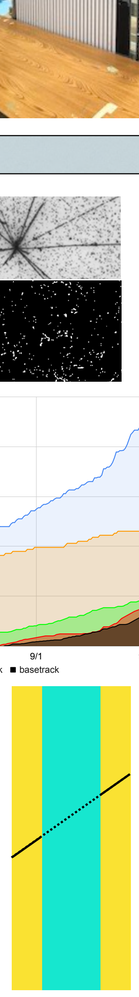
Reconstruction

Emulsion Film

- After the beam exposure, films are developed and scanned by Hyper Track Selector in Nagoya University.

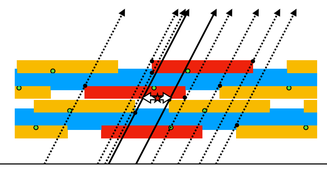


- One film consists of two gels on a plastic sheet
- We reconstruct "virtual" track in plastic using "visual" tracks in gel <- Gel is not as rigid as a plastic sheet.
- Plastic tracks are connected to neighbor film tracks and one particle's track is reconstructed.

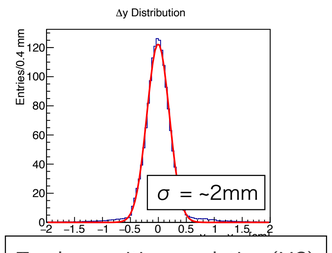


Shifter, Tracker & Baby MIND

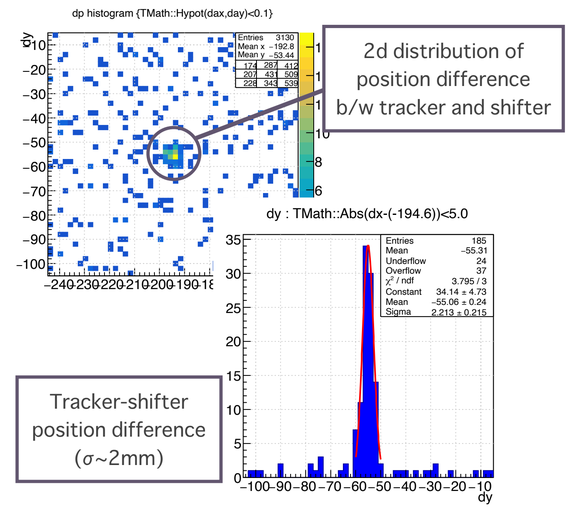
1. Track matching b/w tracker and Baby MIND is done using beam timing information
2. Then, reconstruct Tracker-Baby MIND track position/angle
3. Track matching b/w those tracks and Shifter tracks using all position/angle and timing information
4. Extrapolate shifter tracks into the ECC and find matching ones



Tracker structure and reconstruction image



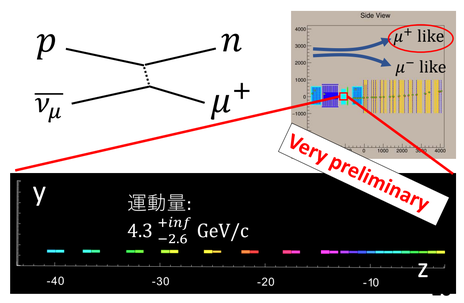
Tracker position resolution (MC)

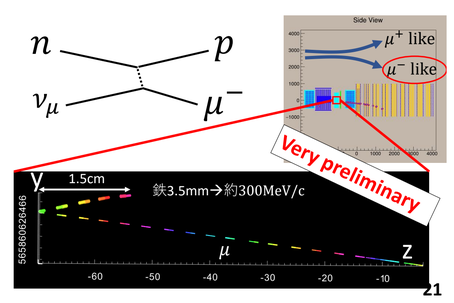


Tracker-shifter position difference (σ~2mm)

Neutrino Interaction Candidates

- Tracks starting from inside of the ECC are searched for.
- Then, tracks attaching to the starting point are searched for (secondary hadrons from interactions).
- Two candidates were found in the pilot analysis.
  $\bar{\nu}_\mu$ (left) w/o any tracks and ν_μ (right) w/ one proton?





Future Prospects

- One out of nine ECCs scanning are now finished.
  -> Our first goal is to complete analysis flow with its data.
- We can provide
  - Charged particle multiplicity w/ low momentum threshold and fine track separation
  - Momentum & angle w/ ultimate resolution (O(um), O(mrad))
  - Particle identification using track blackness (= dE/dx) and multiple Coulomb scattering (= $p\beta$)
- More than 1000 neutrino-water interaction events are expected
  -> New constraint on neutrino interaction model

Machine Learning Possibility

- Track seeding & reconstruction from emulsion images (Apply CNN to 2d binary pixel image?)
- Particle identification from track blackness and other parameters (Multivariate analysis of the track information?)
- Track matching b/w NINJA detectors (Pattern recognition and select best matching tracks?)
- (Baby MIND curving track reconstruction)

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