Water-target neutrino event measurement with nuclear emulsion in the **NINJA** experiment

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Introduction

NINJA experiment

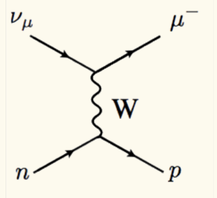
Neutrino **I**nteraction research with
Nuclear emulsion and **J**-PARC **A**ccelerator

NINJA

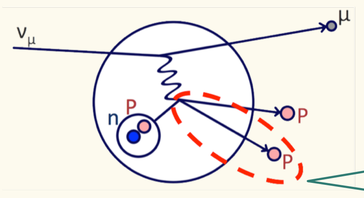
Physics Motivation

❖ Measure low momentum proton/pion and understand multi-nucleon interactions (such as 2p2h interactions) at sub-multi GeV region.

CCQE



2p2h (multi-nucleon)



→ Could be a dominant systematic error for T2K by changing reconstructed E_ν at Super-K.

short track protons
= hard to detect…

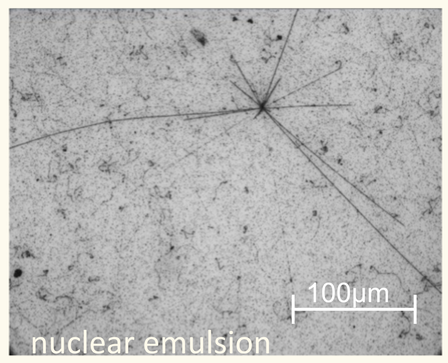
Nuclear Emulsion

3D solid tracking detector

- Sub-micron position resolution
- Flexibility for target materials: **H_2O**, Fe…

→ Low threshold for short-track protons even for water target

→ High capability to distinguish ν_e electrons from gamma



The emulsion detector is expected to provide far more precise information on short-track particles that are hard to reconstruct in the current T2K detectors.

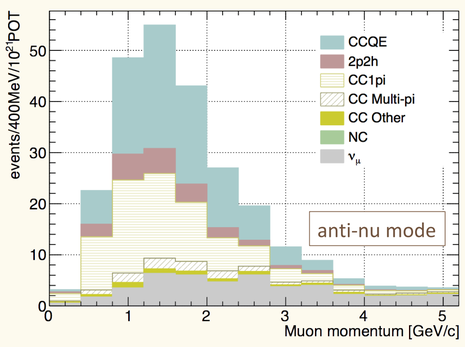
What we can measure

❖ PID: We can distinguish proton-like particles from MIP particles by using energy deposit information.

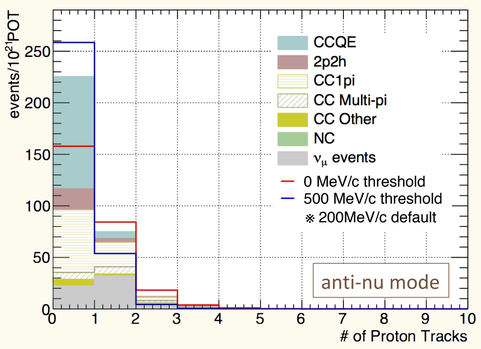
❖ Short track detection: Low momentum protons (and pions), typically down to ~200MeV/c are available.

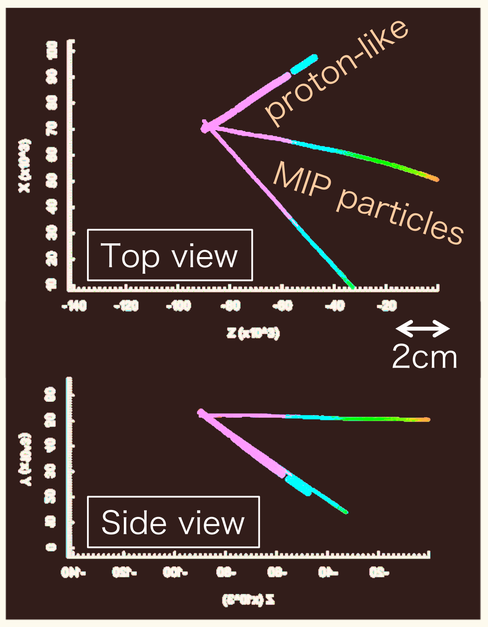
❖ Momentum measurement:
We can measure momentum of particles by using multiple scattering information among steel plates between emulsion films.
: ~25% accuracy @ 1GeV
-> P_μ differential measurement is achievable!
(and of course good angle resolution)

Muon Momentum



Proton Multiplicity

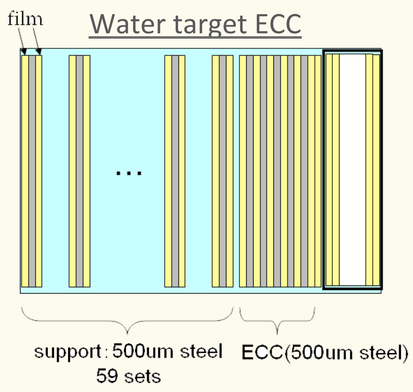




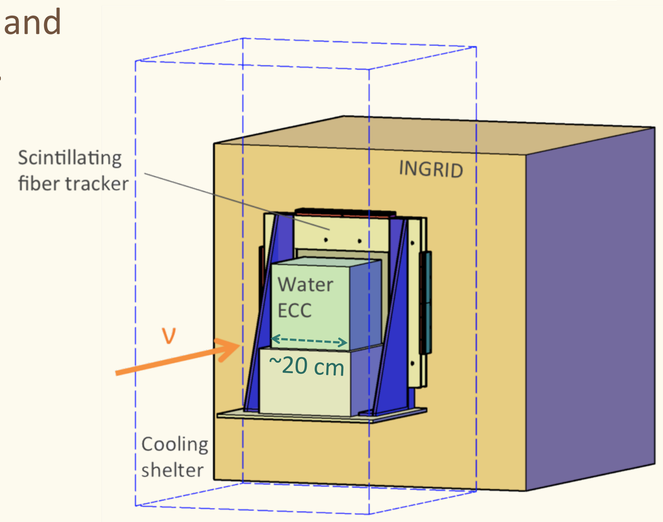
Detectors

ECC (Emulsion Cloud Chamber)

❖ Emulsion based detector having a sandwich structure of target layers (e.g. 2mm thickness water) and thin nuclear emulsion films.



NINJA Run8 detectors at J-PARC

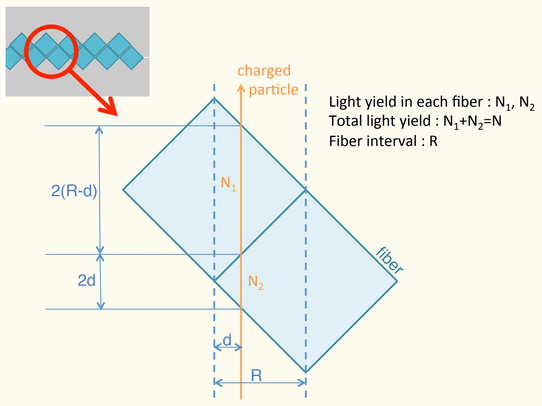


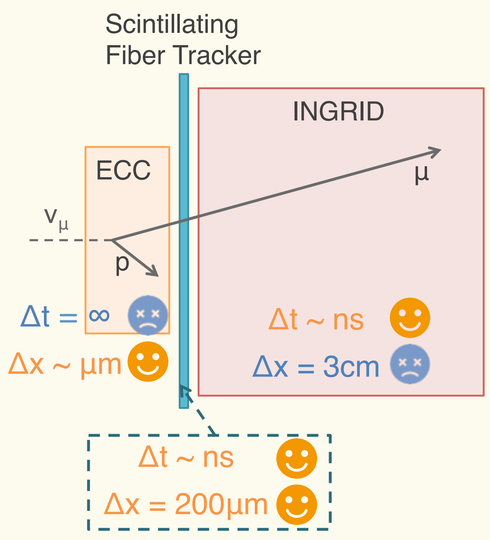
INGRID

❖ T2K on-axis near detector which consists of 14 identical modules.
❖ Each INGRID module consists of a sandwich structure of 9 iron plates and 11 scintillator planes.
❖ NINJA uses an INGRID module as a Muon Range Detector (MRD)

SFT (Scintillating Fiber Tracker) New!

❖ Tracker placed behind the ECC which gives time stamps to ECC tracks.
❖ To achieve higher position resolution, fibers are arranged in a slanting lattice pattern and the ratio of light yields in neighboring fibers is used for position measurements

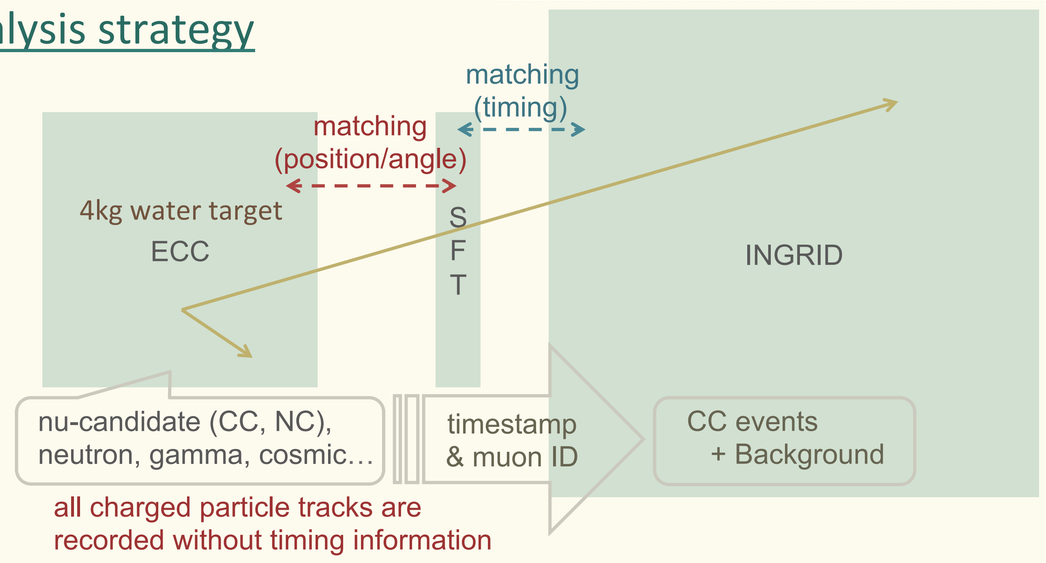




NINJA Run8 Status

~0.7*10²¹POT anti-neutrino mode data
-> only ~0.2*10²¹POT data are used below

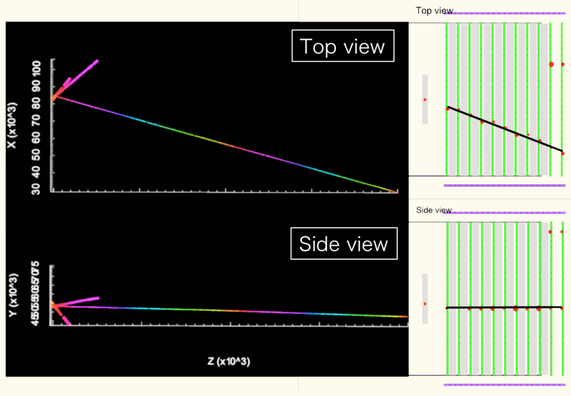
Analysis strategy

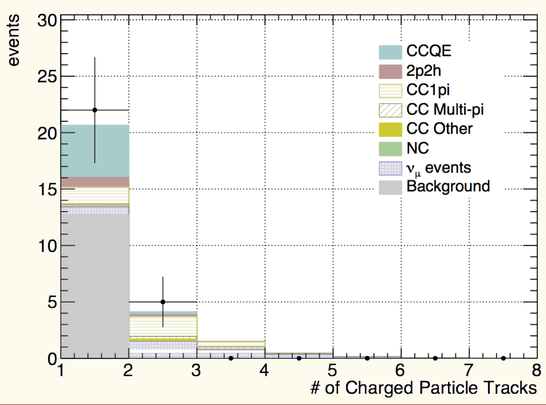


Outcomes

❖ CC-inclusive analysis is now ongoing. 27 candidates are observed so far.
❖ For example, charged particle multiplicity is shown below.
- Shape comparison only.
- At least one μ-like track (|tanθ|<0.5) reaching to INGRID is required.

❖ Current dominant background comes from connection inefficiency of track reconstruction among emulsion films.





Summary & Future

- NINJA experiment is ongoing for precise measurement of neutrino-nucleus interactions by using nuclear emulsion detector (ECC).
- CC-inclusive analysis using ~30% of Run8 all data is now ongoing.
- Physics run: ~50kg water target measurement will start 2019.