The Preparation Status and Plan for the Next Physics Run of the NINJA Experiment

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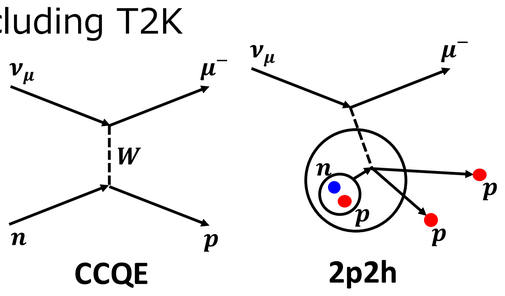
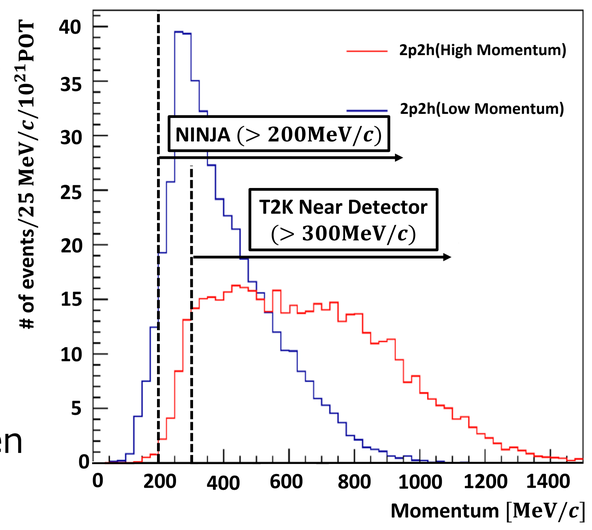
1. NINJA Experiment

- Neutrino Interaction research with Nuclear emulsion and J-PARC Accelerator
- Precisely measure sub~multi GeV neutrino interactions with water target using nuclear emulsion (sub μm resolution)

→Aim to reduce systematic errors in the neutrino oscillation experiments including T2K





Momentum distribution of protons from 2p2h interactions

- Difficult to detect low-momentum protons from 2p2h interactions when using the T2K near detector

→2p2h can mimic CCQE

- Uncertainties of models of 2p2h interactions are very large

→Source of systematic uncertainties in neutrino oscillation experiments

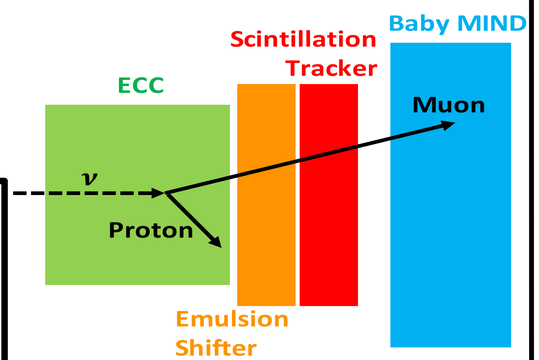
- We can detect low-momentum protons with a threshold of 200 MeV/c

→NINJA is the only experiment in the world capable of measuring neutrino interactions with water at such high precision!

2. Physics Run

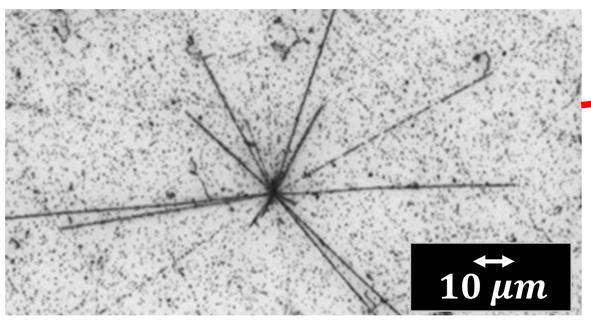
- We acquired data corresponding to 7.7×10^{20} POT (Protons on Target) in two physics runs
- We will start 3rd physics run in the Autumn of 2025
- We will have > 2.3×10^{20} POT
- The water target mass will be larger in the next run: 75 kg → 130 kg

- ECC: Emulsion films + target
- Baby MIND: Muon range detector
- Emulsion Shifter ・Scintillation Tracker: Time stamper

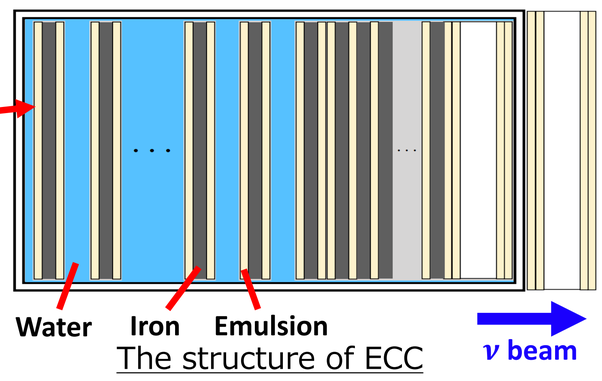


NINJA detectors

3. ECC (Emulsion Cloud Chamber)



The tracks in emulsion



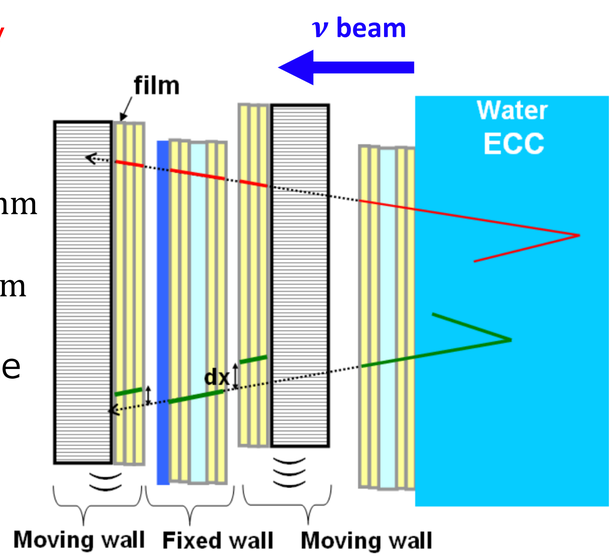
The structure of ECC

- Alternating layers of emulsion films and water targets
- Positional resolution is sub μm
- Does not have timing information and most of tracks are from cosmic rays

→Emulsion Shifter and Scintillation Tracker provide timing information

4. Emulsion Shifter

- Provide timing information roughly using 2 moving walls and 1 fixed wall, on which emulsion films are mounted
- Slow moving wall moves about 1 mm every about 15 hours
- Fast moving wall moves about 1 mm every about 3 minutes
- Time resolution will be better in the next run than previous runs: 4 hours → 3 minutes
- Operation test will be conducted this winter

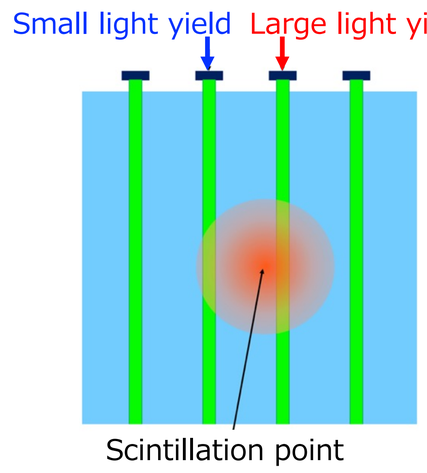


The structure of Emulsion Shifter

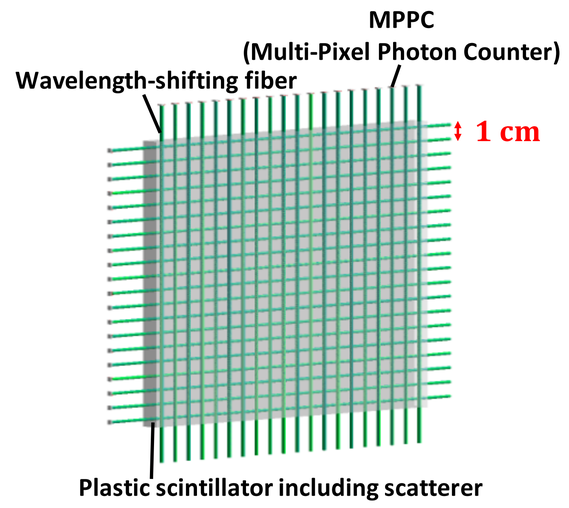
5. Scintillation Tracker

- Provide timing information to the tracks in emulsion
- Since the target mass of ECCs will be larger in the next run, a larger scintillation tracker covering about 1.3 m × 1.3 m is needed (The size of the tracker used in previous runs is 1 m × 1 m)

→Developing a newly designed scintillation tracker

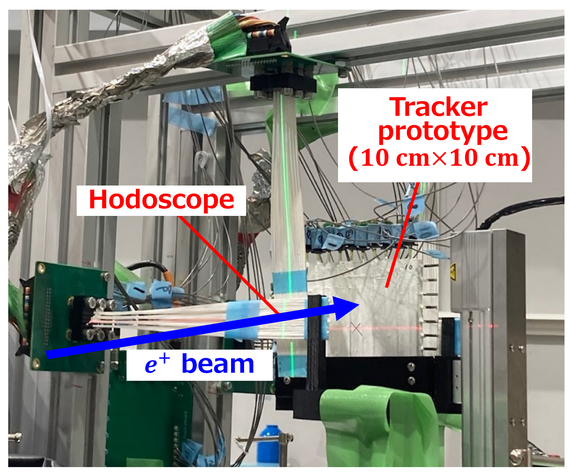


The mechanism of position reconstruction

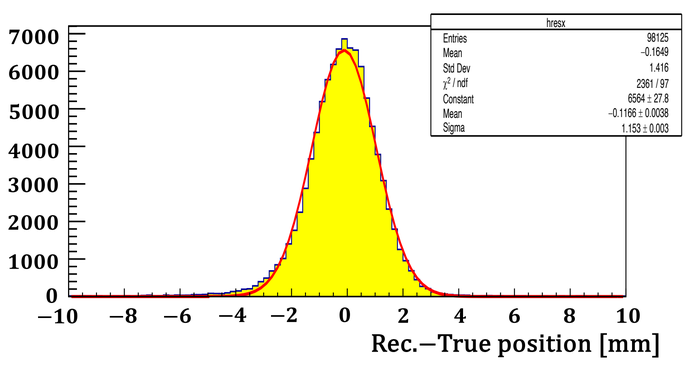


The design of a new scintillation tracker

- Monolithic wide plastic scintillator plane
- Read out scintillation light by wavelength-shifting fibers and MPPCs (Multi-Pixel Photon Counters)
- Use light yield balance to predict the position:
  - The channel near a scintillation point: Large light yield
  - The channel far from a scintillation point: Small light yield
- The plastic scintillator includes scatterer to localize scintillation light
- Required positional resolution is about 8 mm



The setup of the beam test



The histogram of Rec.−true position

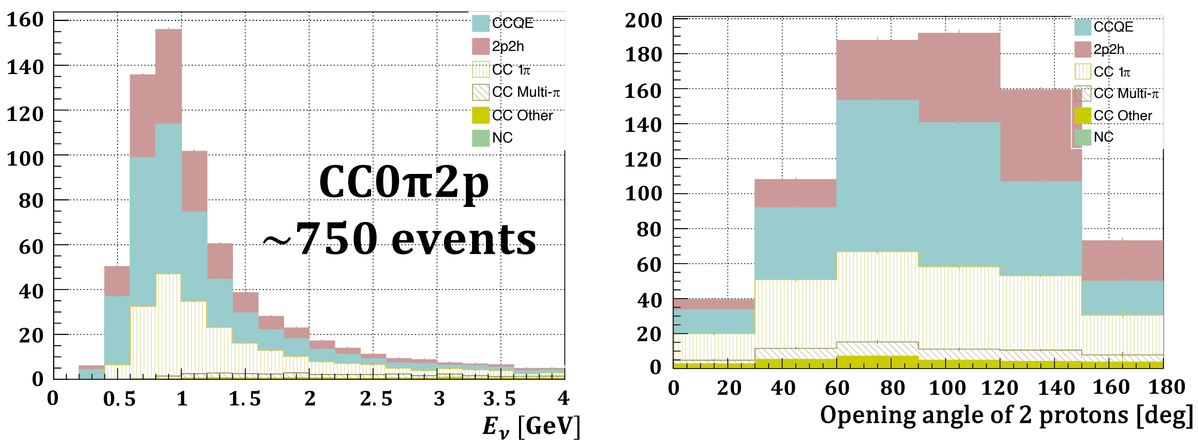
- Evaluated the performance of the new tracker using prototypes and e^+ beam at RARiS, Tohoku Univ.

Incident angle	Positional resolution
$\theta = 0°$	1.44 mm
$\theta = 45°$	1.84 mm

→The tracker can reconstruct positions with better resolution than required

We thank Research Center for Accelerator and Radioisotope Science (RARiS), Tohoku University for the allocation of beamtime

6. Prospects of the Physics Results



The expected # of CC0π2p events (left) and distribution of the opening angle of 2 protons in CC0π2p (right) in all physics runs (1.0×10^{21} POT)

- We will observe ~750 CC0π2p events out of ~5480 CC events in all physics runs (1.0×10^{21} POT)
- 2p2h interaction tends to have a large opening angle of 2 protons

→The key to constraining 2p2h interaction model

7. Summary

- The NINJA experiment will start 3rd physics run in the Autumn of 2025
- Use a newly designed scintillation tracker
- It was found from the beam test that the tracker can reconstruct positions with better resolution than required
- We aim to measure neutrino interactions and constrain interaction models