Proposal of an emulsion-based test experiment at J-PARC

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Exclusive summary

A test experiment is proposed that equips Emulsion Cloud Chamber as a main detector in order to investigate environmental and beam associated background at the T2K near detector hall in J-PARC, optimal detector structure, and performance of newly developed nuclear emulsion gel. The aim of the experiment is a feasibility study to make a future experimental plan for the study of low energy neutrino-nucleus interactions and the exploration of a sterile neutrino.

1. Introduction

The cross section measurements of neutrino-nucleus interactions in Sub-GeV – Multi GeV region are important for the current neutrino oscillation physics [1][2]. Alternatively, one possible explanation of LSND [3] and MiniBooNE [4] anomaly in this energy region is a result of existence of so-called sterile neutrino. We are planning an experiment to study such low energy neutrino physics by introducing nuclear emulsion detectors. In this proposal, we propose a test experiment for the feasibility study to make a future experimental plan for the study of low energy neutrino-nucleus interactions and the exploration of a sterile neutrino by using nuclear emulsion detector at J-PARC. Nuclear emulsion is a 3-demensional solid tracking detector with sub-micron positional resolution. Thanks to its high spatial resolution, we can investigate the event feature at a primary interaction vertex in detail and also separate an electron-neutrino charged current interaction from a muon-neutrino neutral current interaction with π^0 production very well [5]. In future, we will make a nuclear emulsion detector to have a capability to separate an electron neutrino interaction from an anti-electron neutrino interaction by setting it in a magnetic field [6]. Then there is a lot of flexibility for target selection because

the detector, so-called Emulsion Cloud Chamber (ECC), is constructed as a sandwich structure of thin nuclear emulsion films and the target-material. For example, we can investigate neutrino – water reactions if we put the enveloped emulsion films in a water cistern.

2. This proposal and a future experimental plan

2.1 This proposal

Neutrino experiments with nuclear emulsion have mainly been performed in the energy region of a few tens of 10GeV. So we at first develop basic analysis techniques with nuclear emulsion in the low neutrino energy region of around 1 GeV and we investigate effects from the environmental and beam associated background at the T2K near detector hall in J-PARC as a preliminary measurement in this proposal. Investigation items are shown at Chapter 3.

2.2 Future plan

Then we will propose a test experiment to develop a nuclear emulsion detector which is suitable for low energy neutrino analysis and to check its performance as a detector run. After that, we hope to implement a physics run with ECCs of which targets are Carbon, Iron, Hydrocarbon, and Water, etc. (total weight is about 200 kg) in 2016. We will request 1 x 10^{21} Protons On Target (POT) of the neutrino beam to investigate more than 10,000 muon-neutrino interactions and more than 100 electron-neutrino interactions for each target in this experiment. We will optimize our detector structure and the data taking schedule by feeding back analysis results after each neutrino beam run. Finally, we are willing to propose the real experiment to search for the electron neutrino appearance in a short baseline, to explore the existence of a sterile neutrino, with a several-ton-scale detector in 2018. We will expand the scale of the nuclear emulsion detector gradually, step by step in this plan.

3. Preliminary measurement at T2K near detector hall in November 2014

We request to expose the following 3 kinds of nuclear emulsion detectors (a), (b), and (c) at the T2K near detector hall to the neutrino beam or anti-neutrino beam for 2 months from November 2014 in order to confirm the feasibility of the detector setting there, of the film development process and of analysis in a real situation for the detector run or physics run. The test experiment can run parasitically with T2K, therefore we request no dedicated beam time nor beam condition. The ECC has a sandwich structure of nuclear emulsion films and iron plates in this time. Each

sample is placed in front of INGRID which is one of the T2K near detectors. Our proposal of this test experiment was presented to the T2K collaboration in their collaboration meeting on the beginning of October by the T2K member in our proposal. Then we accepted a positive reply from the T2K collaboration.

Sample-(a) : Small size ECCs (5cm x 6cm x 0.5cm ; ~0.1kg) are set to measure fluxes of cosmic ray muons and side muons from the upstream rock and noise for emulsion analysis caused by gamma rays and neutrons from neutrino interactions at the T2K near detector hall. This sample is constructed with 8 emulsion films and 4 steel plates as shown on the left in Fig. 1. In total, seven samples are used for this measurement. The right in Fig. 1 also shows the positions and the exposure time of each sample. Three samples are in front of INGRID at the on-axis SS floor for 2 weeks, 1 month, and 2 months; two samples are in front of INGRID of the right and left ends in the SS floor for 1 month; and then two samples are in front of each INGRID at the off-axis B2 floor for 1 month.

Sample-(b) : A standard-size ECC（10cm x 13cm x 5cm ; ~3kg）, passive steel plates constituting the target mass interleaved with nuclear emulsion films, is placed in front of INGRID at the SS floor for 2 months as shown in Fig. 2. We will collect about 100 neutrino interactions in this ECC which is expected based on 10^{20} POT in Neutrino mode run at beam center (on-axis) and then we will polish our analysis procedure for low energy neutrino interactions with this sample. The setting place of this sample is shown in Fig. 3.

Sample-(c) : A subsidiary emulsion detector (55cm x 22cm x 6cm ; ~5kg) gives a time-stamp to emulsion tracks by using a clock-based multi-stage emulsion shifter technique [7]. Sample-(c) is located on behind of Sample-(b) as shown on the left in Fig. 3 and placed between INGRID and Proton Module which is also one of the T2K near detectors at the SS floor. The hybrid analysis between ECC and INGRID becomes available by using timing information from this emulsion shifter device in the physics run. Then tracks found in ECC are fed muon identification information from INGRID. In the case that this shifter works well and can supply timing information to emulsion tracks, the track-connection test between emulsion and INGRID will be carried out. Some T2K INGRID experts joined in our proposal and take care of providing INGRID track information under the supervision of the T2K analysis group.

The nuclear emulsion films will be made at Nagoya University. After the neutrino beam exposure, they will be developed at either Toho University or Nagoya University. The analysis of all samples will be shared in the collaboration.

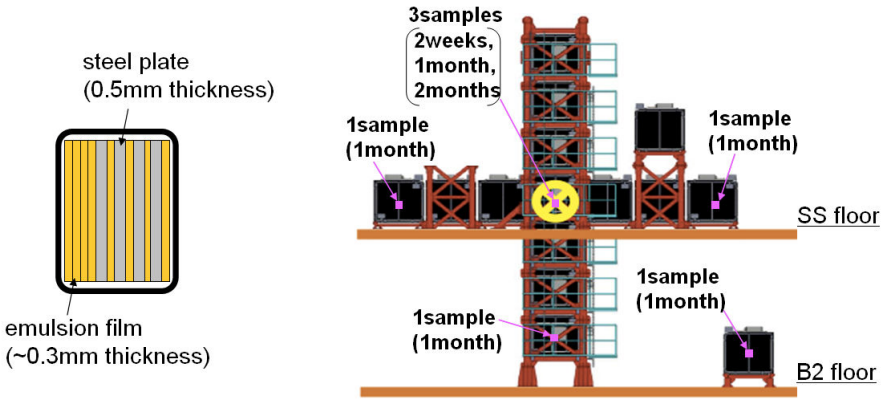
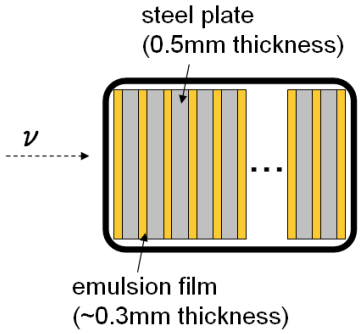


Figure 1. The structure and positions of Sample-(a).



61 emulsion films + 60 steel plates

Figure 2. The structure of Sample-(b).

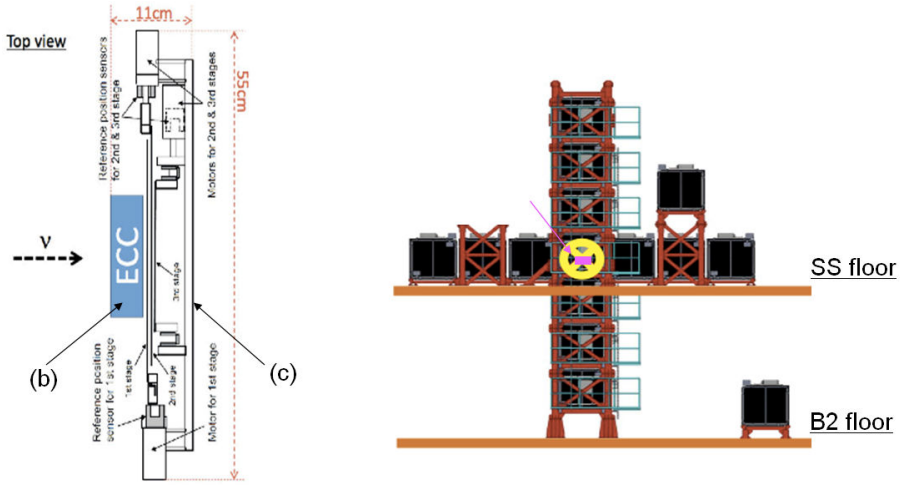


Figure 3. Top view of Sample-(b) and (c) and its setting place.

4. Schedule

In 2014,

- End of October : detector installation.
- Beginning of November : data taking start.
- November – December : beam exposure and small sample analysis.
- End of December : an ECC extraction and emulsion film development.

In 2015,

- Beginning of January : ECC analysis start.
- March : First result will be reported.

5. Requests

We requests the following to operate the test experiment and to check the detector performance from this November 2014 until the end of this year.

- Site for detectors in the SS hall and B2 hall as shown in Fig. 1 and 3.
- Electricity (~100W) for the working of the multi-state emulsion shifter and the monitor laptop.
- Network connection to monitor the multi-stage emulsion shifter.

References

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