"Proposal of New Test Experiment"

Measurement of the gamma-ray and neutron background from the T2K neutrino/anti-neutrino beam at J-PARC B2 Hall

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Abstract

We propose a new test experiment to measure gamma-rays and neutrons at J-PARC B2 Hall. In this test experiment, we will use some scintillation detectors and test the Pulse Shape Discrimination (PSD) method we developed. This method is necessary for our project to estimate NC-gammas at RCNP. And with this method, we will measure background events at that place. This estimation is important and useful for other experiments done at the same places such as INGRID[1] and WAGASCI[2].

1 Motivation

1.1 NC-Gamma Measurement

The cross section of neutrino's NCQE (Neutral Current Quasi-Elastic) interaction with water is measured by using the T2K beam and the Super-Kamiokande (SK) detector like below[3].

$$< \sigma_{NCQE} >= 1.55 \times 10^{-38} \pm 0.395(\text{stat.}) \pm^{+0.65}_{-0.33} (\text{sys.}) \ [\text{cm}^2]$$

The detailed understanding of this interaction is very important for some physics such as tau-oscillation analysis in T2K, sterile-neutrino search, and supernova relic neutrino search at SK. But now the systematic error of the NCQE cross section is large and will be dominant in the future.

The main reason of this error is thought to be the secondary gamma-rays from the nucleon (mainly neutron) interaction with the oxygen-nucleus (Fig.1).

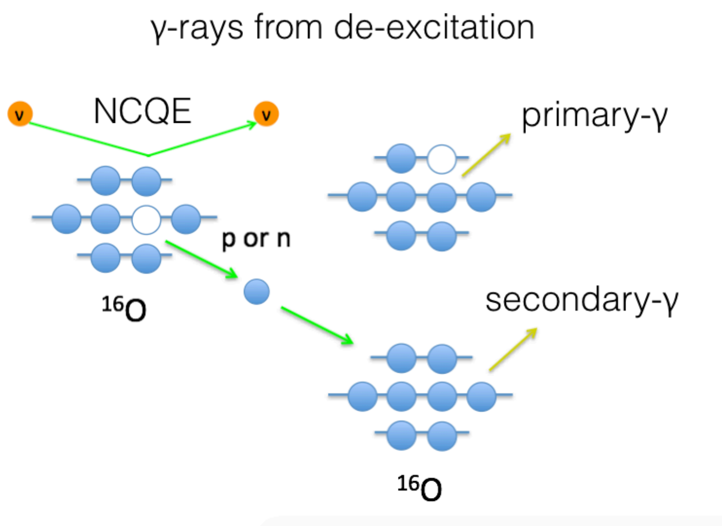

Fig. 1: Primary gamma-rays from the NCQE interaction and secondary gamma-rays from the following nucleon interactions. These gamma-rays cannot be separated in time with the SK detector. The secondary gamma-rays are the reason for the large systematic error of the NCQE cross section.

So now the precise measurement of gamma-rays from neutron oxygen-nucleus interaction at Research Center for Nuclear Physics (RCNP) is planned to reduce the NCQE 's systematic error. In this experiment the RCNP 's neutron beam (mono-energetic: ∼80MeV) will be injected on the water target, and the energy and the multiplicity of the gamma-rays from the interaction of water target with neutrons will be measured precisely. We will have the first beam test time this spring.

1.2 Neutron-Gamma Pulse Shape Discrimination

According to the Monte Carlo (MC) simulation by using PHITS[4], a lot of neutrons scatter from the water target and cover the region of gamma-rays that are the measurement targets (Fig.2). For our purpose to measure just gamma-rays precisely, the discrimination method of gamma-rays from neutrons is necessary.

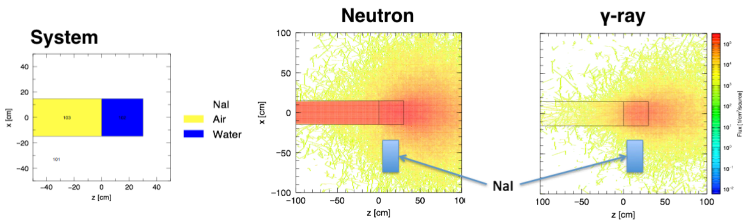

Fig. 2: Monte Carlo simulation of the scattering region of neutrons and gamma-rays from the water target by using PHITS. The region of neutron scattering covers that of gamma-ray scattering.

2 This Proposal

The neutron-gamma (n-γ) discrimination method is necessary as explained above. Some scintillators have the different decay time of the scintillation pulse for different incident particles that give energy to the scintillators. The scintillation pulse originated from the fast neutron has longer decay time than that from the gamma-ray, because the fast neutron knocks-out protons that have larger dE/dx (The slow neutron doesn't knock-out protons in the detector, so the pulse shape is not different). By using this property, the PSD of fast neutrons from gamma-rays is possible.

Of a lot of scintillation detectors, we consider that the CsI(Tl) scintillator is suitable for our purpose (In the previous research[5], protons could be well separated from gamma-rays). Although the liquid scintillator has a good PSD ability, its energy resolution is thought not to be so good. For our purpose of the measurement the energy resolution is important, so this is unfavorable. So we would like to use the CsI(Tl) detector and test its PSD ability at the place where there are some fast neutrons and gamma-rays. We think that B2 Hall satisfies this requirement as explained below.

The event estimation is done by using JNUBEAM[6], NEUT[7] and Geant4[8] for one of the INGRID modules at B2 Hall. In the JNUBEAM simulation, the anti-neutrino beam is selected as T2K beam. In the NEUT, 2m $\times$ 2m size of the concrete wall in front of the INGRID is used for the neutrino interaction target. And in Geant4, the module7 at the bottom of the Vertical INGRID is used. The size of the module7 is set to be 1.2m $\times$ 1.2m. The beam statistic is set to be 1×10^{21}POT (the amount of one month beam statistic is about 1×10^{20}POT). Fig.3 shows the momentum distribution of neutrons generated from the wall, and Fig.4 the momentum distribution of neutral pions (π^0) when at least one hit of γ is detected by the module7 (π^0 decays into two γs ($\pi^0 \rightarrow 2\gamma$)).

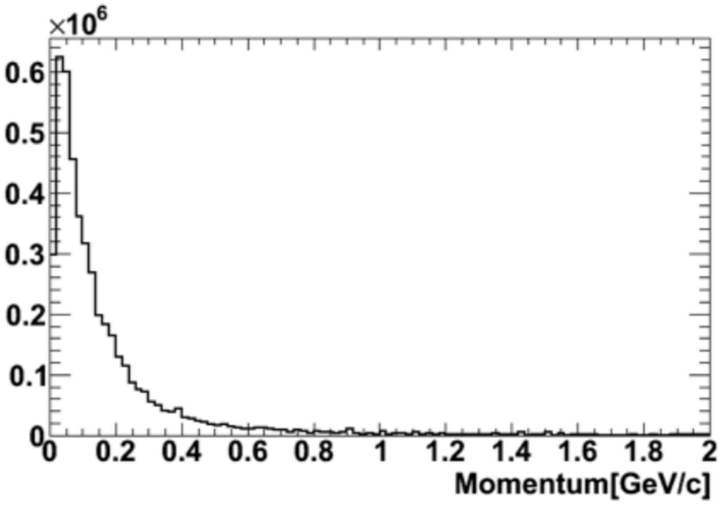

Fig. 3: Simulated momentum distribution of neutrons originated from the 2m $\times$ 2m wall. The beam statistic is set to be 1×10^{21}POT.

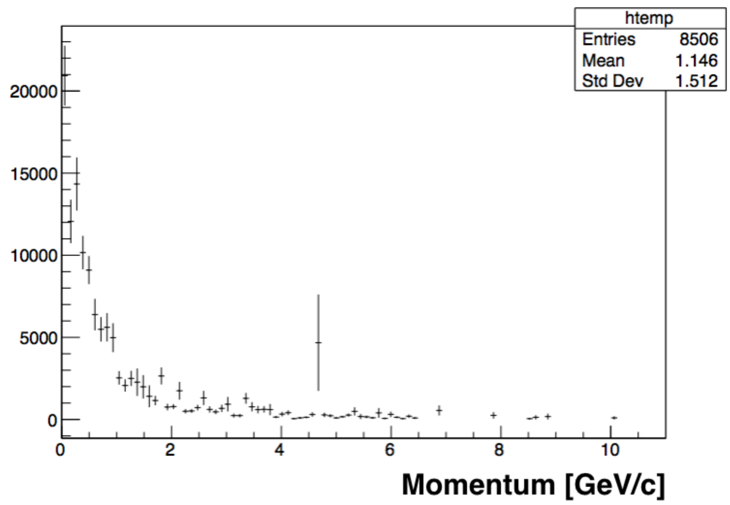

Fig. 4: Simulated momentum distribution of neutral pions originated from the 2m $\times$ 2m wall. This distribution is selected only when at least one hit of γ is detected by the module7. The beam statistic is 1×10^{21}POT.

According to the simulations, the amount of neutrons detected by the INGRID module7 is about 8,000 and that of gamma-rays is about 25,000 in the statistic of 1×10^{20}POT anti-neutrino beam (one-month statistics). These estimations show that B2 Hall is suitable for the PSD test of neutrons and gamma-rays, because the amount of neutrons is in the similar order to that of gamma-rays.

And at B2 Hall, there are a lot of beam muons and cosmic-ray muons. The amount of beam muons (originated from the T2K anti-neutrino beam) is simulated like Fig.5. The situation of the simulation is the same as that of Fig.3 and 4.

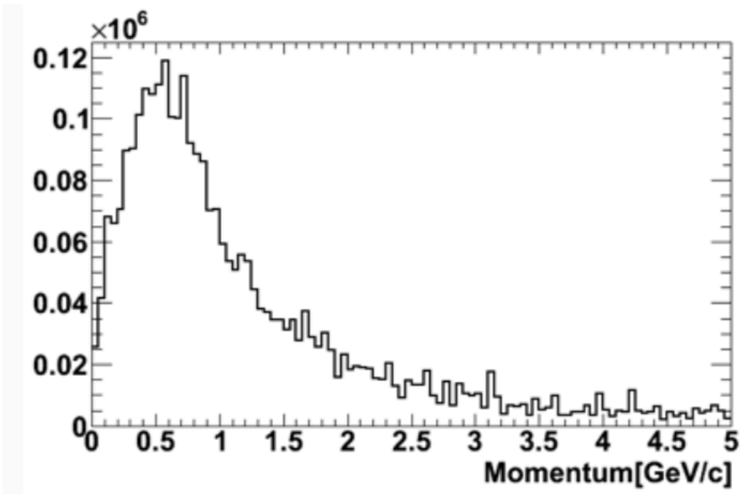

Fig. 5: Simulated momentum distribution of muons originated from the 2m × 2m wall. The beam statistic is set to be 1×10^{21}POT.

According to this result, the amount of beam muons is also in the similar order to that of neutrons and gamma-rays. And there are thought to be more cosmic-ray muons. So we need the muon cut system. For this purpose, we will use plastic scintillators. We will put detectors between these plastic scintillators and cut muon events by timing.

For the measurement, we will use three CsI(Tl) scintillators (6.5cm×6.5cm×60cm, 7.5kg). In addition to these, we will use two NaI(Tl) scintillators (6cm×6cm×30cm, 2kg), a liquid scintillator (ϕ22cm×45cm, 7kg) and a $LaBr_3$(Ce) scintillator (ϕ8.5cm×23cm, 1kg) for comparison. All of these dimensions and weights are measured containing PMTs installed with scintillators. We will take pulse shape data of each event with the Flash-ADC and do PSD analysis by using these data later. Considering our detectors' size and statistic, we would like the beam statistic of 1×10^{20}POT. This is corresponding to about one month. So we would like to do our test for at least one month. In this period, we will get about 1,000 neutron events and more gamma-ray events. These are the estimations from the rough simulations by using the anti-neutrino beam. We don't care which beam (neutrino or anti-neutrino) is coming, because the neutrino beam is more intense than the anti- one so is better for our measurement.

And also with this PSD method we will estimate the background events at B2 Hall. This estimation would be helpful for other groups that are doing measurements at the same place, because there has been no measurements on background events at B2 Hall so far.

3 Schedule

Now we plan to start the measurement on 10th of February in 2016. This is the earliest possible date for us. The schedule below is one in the case that we start the test on 10th of February. If there is any delay, we would like to continue the test after 10th of March.

- 10th, February, 2016 ~ 14th, February, 2016: Preparation (set-up, module check, and calibration)
- 15th, February, 2016 ~ 10th, March, 2016: Data Taking
- 11th & 12th, March, 2016: Withdrawal

4 Requests

We request the following during the measurement described above. And we don't care whether the T2K beam is neutrino or anti-neutrino for our purpose.

- Site for the experiment in the B2 floor of the near detector hall (B2 Hall)
- Electricity to provide our devices for the measurement
- Beam timing signal and spill information
- Network connection
- Checking source for the calibration of detectors
- Tables and chairs

References

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