Commissioning of CAGRA + Grand Raiden experiment

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A project called "Clover Array Gamma-ray spectrometer at RCNP/RIBF for Advanced Research (CAGRA)" is in progress. The project is a campaign for experiments at EN-course and WS-course using a clover Ge detector array which consists of 16 clover Ge detectors from Argonne National Laboratory of Yale University and Tohoku University. In the case of experiments at WS-course, we plan to measure ion inelastic scattering with the Grand Raiden spectrometer in coincidence with de-excitation γ-rays from target with the Ge detector array placed around the scattering chamber. The coincidence measurement between the Ge detector array and Grand Raiden provide good signal-to-noise ratio, and it can measure both of excitation and de-excitation at the same time. However, if photon background rate is too high around the scattering chamber, accidental coincidence rate is increased. In addition, the energy resolution of Ge detectors decrease due to radiation damage by neutrons. These reduce the signal-to-noise ratio in the measurements with the Ge detector array. Beam dump and target are assumed as the source points of background. We constructed Grand Raiden Forward beam line (GRAF) to reduce the background from beam dump. The primary beam was transported to the wall beam dump at 20 m downstream side of the scattering chamber by the beam line. On the other hand, background from target is not clear. Therefor we need to confirm the transport efficiency of GRAF beam line and background from a target.

A commissioning was performed at the RCNP WSF beam line. A proton beam with 65 MeV irradiated a natural carbon foil target of 36.3 mg/cm^2 and a aluminum target frame without any foil target. The Grand Raiden is placed at a setting angle of 4.5 degree. We measured photons, neutrons, and charged particles around the scattering chamber by following setup. First, photons were measured by a transistor reset type Ge detector. A pulse signal with 100 Hz frequency was sent to the pre-amplifier of the Ge detector as same pluse height as 1 MeV photons in order to estimate the signal-to-noise ratio. Energy spectra from the targets were obtained by a multi-channel analyzer without coincidence with Grand Raiden. Second, neutrons were measured by a neutron counter using a NE213 organic liquid scintillator. The size of the liquid sintillator is 12.7 $\times$ 12.7 cm^2 in diameter and length and the efficiency was already calibrated by JAEA group using ^{137}Cs, ^{60}Co and ^{241}AmBe γ-ray source [1]. A 3 mm-thick plastic scintillator was placed in front of the liquid scintillator and used as a VETO detector for charged particles. A energy spectrum and flux of neutrons were obtained by a time-of-flight (TOF) measurement. Thied, charged particles were measured by a dE-E plastic scintillator telescope that is a part of a detector named "backward nucleon detector (BAND)" [2]. The positions of these detectors is summarized in Table 1. Materials between the targets and each detector were almost only 0.3 mm-aluminum plate that is the sliding membrane of the scattering chamber.

Figure 1 shows γ-ray spectra with Ge detector. Mainly background radiations came from the foil target irradiated by the beam. As background other than the target, γ-ray of 2.75 MeV from the excited state in ^{24}Mg by β decay from ^{24}Na activated by ^{27}Al(n,α) reaction, annihilation γ-ray and low-energy X ray were found. A symmetric doublet peak was found as γ-ray events from the first 2^+ excited state of 4.44 MeV in ^{12}C. It is due to a Coherent Doppler Effect [3]. Table 2 shows the flux of each background particle, where the flux of neutrons have been integrated from 7.5 MeV to 65 MeV and the flux of charged particles have been integrated from 10 MeV to 65 MeV. Finally, we assume following 5 situations as the realistic case of the experiment with the Grand Raiden and the CAGRA detector. First, the Ge detectors is placed at 16 cm from the target. Second, a proton beam of 65 MeV with the intensity of 5 nA irradiate a natural carbon foil target of 36.3 mg/cm^2. Third, the coincidence width with the Grand Raiden is 100 ns. Fourth, the efficiency of the Ge detectors is 2.1 $\times$ 10^{-4} at 1 MeV. Fifth, the limit of the neutron fluence for the Ge detectors is 10^9 particles/cm^2. In this case, we can estimate following 3 things. (1) The signal-to-noise ratio in a measurement with Ge detectors became 32 for a differential cross section of 12 mb/sr. (2) The time limit to put the Ge detectors is 64 days. (3) The reset rate with the Clover-Ge detector of Tohoku-University by the charged particles from the target became 12.6 kHz. We need to consider some shield against the charged particles between the target and the Ge detector.

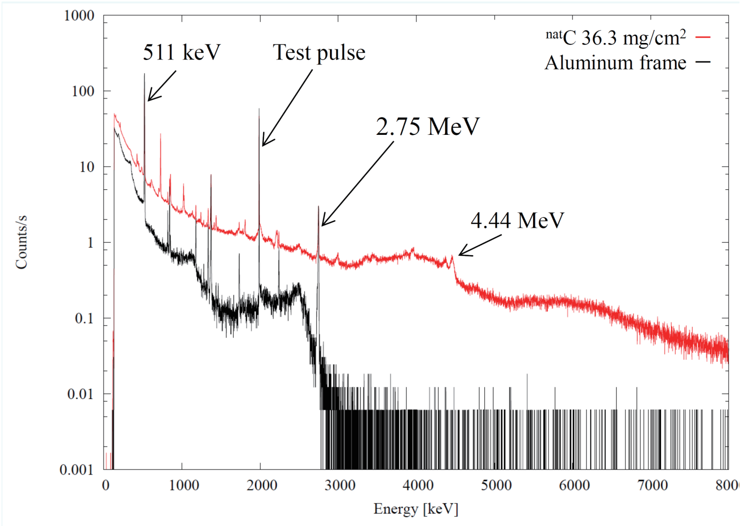

Figure 1: γ-ray spectrum with the Ge detector.

	Ge detector	neutron detector	charged particle detector
a distance from the target [cm]	50	320	40
a direction from the beam axis [degree]	110	77	48

Table 1: Summary of the positions of the detectors.

target	flux [particles/nC/sr] neutrons 77 degree	protons 48 degree	deuterons 48 degree
$^{\mathrm{nat}}$C 36.3 mg/cm^2	$9.3 \pm 0.7 \times 10^3$	$9.08 \pm 0.03 \times 10^4$	$1.04 \pm 0.01 \times 10^4$
Aluminum frame	$3.4 \pm 1.0 \times 10^2$	$7 \pm 3 \times 10^0$	not counted

Table 2: The flux of each background particle around the scattering chamber, where the flux of neutrons have been integrated from 7.5 MeV to 65 MeV and the flux of charged particles have been integrated from 10 MeV to 65 MeV.

References

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