Effect of stray field of the SAMURAI spectrometer on the neutron detector array WINDS

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The (p, n) reaction has been used as a powerful probe to study nuclear isovector responses such as Gamow–Teller transitions, as extensively done in the region of stable nuclei[1)]. The extension of such studies to unstable nuclei can realized by combining the neutron detector array WINDS[2)] with the SAMURAI spectrometer[3)] for measuring high-intensity radioactive ion beams at the RIKEN RIBF.

From an experimental point of view, however, there is concern that the stray field of the SAMURAI magnet may deteriorate the gain of photomultiplier tubes (PMTs) of the WINDS bars. It is well known that the effect of the stray field is maximized when the direction of the magnetic field is parallel to that of the PMT. In this experiment, we examined this effect with several magnetic settings and also tested the restoration of gain with additional magnetic shielding on PMTs.

One of the WINDS bars was vertically placed near the entrance of the SAMURAI spectrometer. Thus, the PMTs (Hamamatsu H7195) attached at both ends of the bar are also aligned vertically. The direction of the stray field can also be considered more or less vertical, and the strength is large around the PMTs. Therefore, this setup provides the most severe gain-deterioration conditions. In the present work, three settings — (i) without any additional shielding, (ii) with one-fold shielding, and (iii) with two-fold shielding — were tested, as shown in Fig. 1. The magnetic field settings were 1.6, 2.2, 2.9, and 3.0 T. For these settings, the stray field at the location of the PMT was measured to be 0.5, 0.7, 4.5, and 6.0 mT, respectively.

The left panel of Fig. 2 shows the light output spectra of ^{137}Cs for 2.2 T. The relative gain was calibrated with the Compton edge of the 661.7-keV γ-ray emitted from ^{137}Cs. For each spectrum, we assumed the position corresponding to 70% of the maximum height as the Compton edge. The relative gain of the PMT decreased to 28% at 2.2 T when no additional shielding was used. With the addition of one-fold shielding, the relative gain was restored up to 97%. It was also confirmed that a relative gain of 92% or more can be achieved up to 2.9 T by using two-fold shielding, if necessary. However, at 3.0 T, a relative gain of 59% was obtained even with two-fold shielding. This is because of the drastic increase of the stray field due to the saturation effect of the iron yoke of the SAMURAI magnet around 3 T[4)].

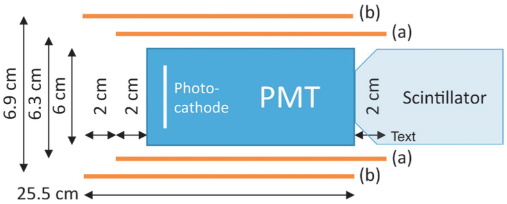

Fig. 1. Schematic view of the additional shielding consisting of 2-mm-thick iron (SUY-1). We use only inner (a) as a one-fold, and both (a) and (b) as a two-fold shielding.

The right panel of Fig. 2 shows the light output spectra of ^{241}Am. Gamma rays of 60 keV from ^{241}Am produce almost same light output as 100-keV neutrons. The spectrum was strongly distorted when the magnetic field was changed from 2.9 to 3.0 T because of the same reason as stated above. Below 2.2 T, the effect of the distortion can be made negligibly small with at least one-fold shielding.

In summary, the additional one-fold or, at most, two-fold magnetic shielding is sufficient to restore the gain for the SAMURAI magnet settings up to 2.9 T, but at 3.0 T, shielding of more than three-fold or thicker will be necessary. Thus, the setting of 2.9 T is practically much better than that of 3.0 T for the similar setup with PMTs, if there is no significant difference between 2.9 and 3.0 T in the performance of the SAMURAI spectrometer.

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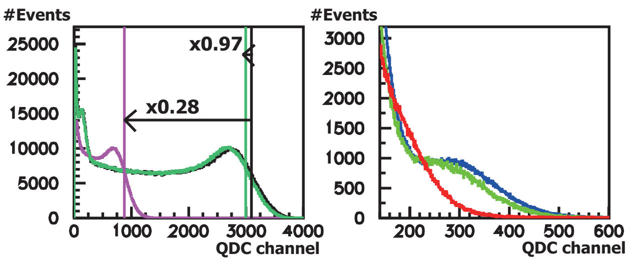

Fig. 2. Left panel shows light output spectra of ^{137}Cs without additional shielding (purple) and with one-fold shielding (green) at 2.2 T. Black line shows that at 0.0 T. Each vertical line shows the position of each Compton edge. Right panel shows light output spectra of ^{241}Am with two-fold shielding at 0.0 T (blue), 2.9 T (green), and 3.0 T (red).

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References

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