Light Output Response of GSO(Ce) Scintillator to Deuterons

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We have measured the preequilibrium reaction process by (p,dx) reaction in intermediate energy region using the cerium-doped gadolinium orthosilicate, Gd_2SiO_5-GSO(Ce) scintillation detector. In order to carry out energy calibration of the measured deuteron spectra at 300- and 392 MeV, the light output response of the GSO(Ce) scintillator to deuterons was investigated by using pp, pd and αd elastic scattering. And the results of calculation by Birks' formula show the overall agreement with experimental data.

1.Introduntion

GSO(Ce) has various advantages compared with other typical crystal scintillators: remarkably high radiation hardness, comparatively large density, higher light output, and no hygroscopic. From these reasons, GSO(Ce) has the characteristic which was excellent to the nuclear reaction experiment.

In order to obtaine the experiment data to double differential cross section (DDX), it is necessary to carry out energy calibration from the relation between a channel obtained by ADC and the energy lost within the scintillator.

Until now, the light output response to protons was studied by Anami et al.[2] up to maximum energy 161MeV and by Avdeichikov et al.[1] up to 30 MeV. And the light output response to deuterons was studied by Avdeichikov et al.[1] up to 40 MeV. It is valuable to extend the investigated energy range up to several hundreds of MeV. Furthermore, in measurements of deuteron energy by stacked spectrometers, one must pay attention to the pulse height difference between the stopping and the penetrating protons and deuterons even if they would deposit the same energies in the crystal.

In this paper, we describe an experimental study of light output response of GSO(Ce) to protons up to 161 MeV and to deuterons up to 215 MeV. Furthermore, the obtained data was compared with the formula which Birks[3] proposed for organic scintillators.

2.Experimental

The beam experiment was performed at the Research Center for Nuclear Physics (RCNP), Osaka University. A sketch of the experimental setup is shown in Fig. 1. The proton beam of 392 MeV and the ^{4}He beam of 400 MeV bombarded polyester target of 17.5 mg/cm^2 and CD_2 target of 50 mg/cm^2. The response of the stacked GSO(Ce) spectrometer was investigated with monoenergetic particles from elastic pp, pd and αd scattering. In a target, nuclei other than a proton and a deuteron are also contained. Those nuclei react with an incidence particle. These reaction events have a continuum energy spectrum and overlaps with a monoenergetic particles from pp, pd and αd scattering. Therefore, they were removed by performing coincidence measurement.

A schematic diagram of the spectrometers was shown in Fig. 2. There were two types of spectrometer. One consisted of three plastic scintillators, two cubic GSO(Ce) crystals of $43 \times 43 \times 43$ mm^3 and a cylinderistical GSO(Ce) crystal of 62 mm diameter by 120 mm length. Another consisted of three plastics, three cubic GSO(Ce) crystals of $43 \times 43 \times 43$ mm^3. One of plastics in each spectrometer had an aperture of 15 mm diameter and acted as an active slit to determined the solid angle of the spectrometer. To optimize the light collection of the plastics and GSO(Ce) crystals, five facets were lapped with aluminum tape. Shading sheet wrapped around the spectrometer.

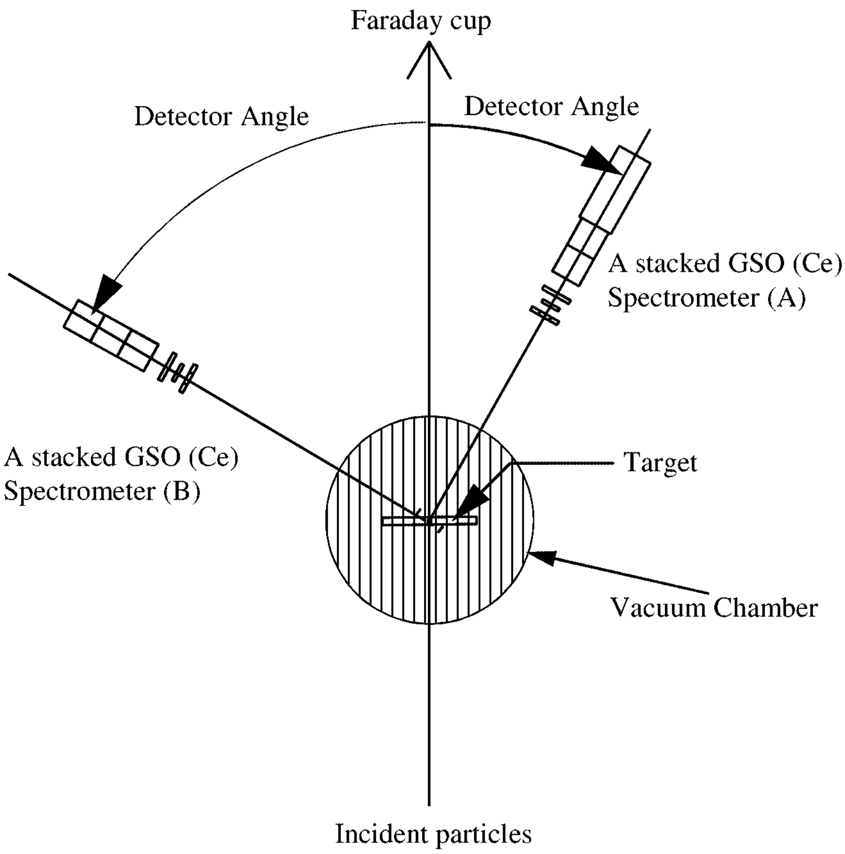

Figure 1: Experimental set up for the monoenergetic proton and deuteron measurement.

3.Results and Discussion

The energy dependence of the GSO(Ce) light output for protons and deuterons has been measured by using pp, pd and αd scattering. Fig. 3 shows the measured light output, in arbitrary units, as a function of the energy for protons and deuterons. The error bars of the present data correspond to FWHM of the peaks in measured energy spectra. The curves are results of calculations proposed by Birks for inorganic scintillators. The light output per unit length, dL/dx, is defined as

$$\frac{dL}{dx} = \frac{S(dE/dx)}{1 + kB(dE/dx)} \tag{1}$$

where S is the absolute scintillation factor, BdE/dx represents the density of quenching centers per unit distance and k is a quenching parameter (kB is Birks parameter). The parameters, S and kB, are

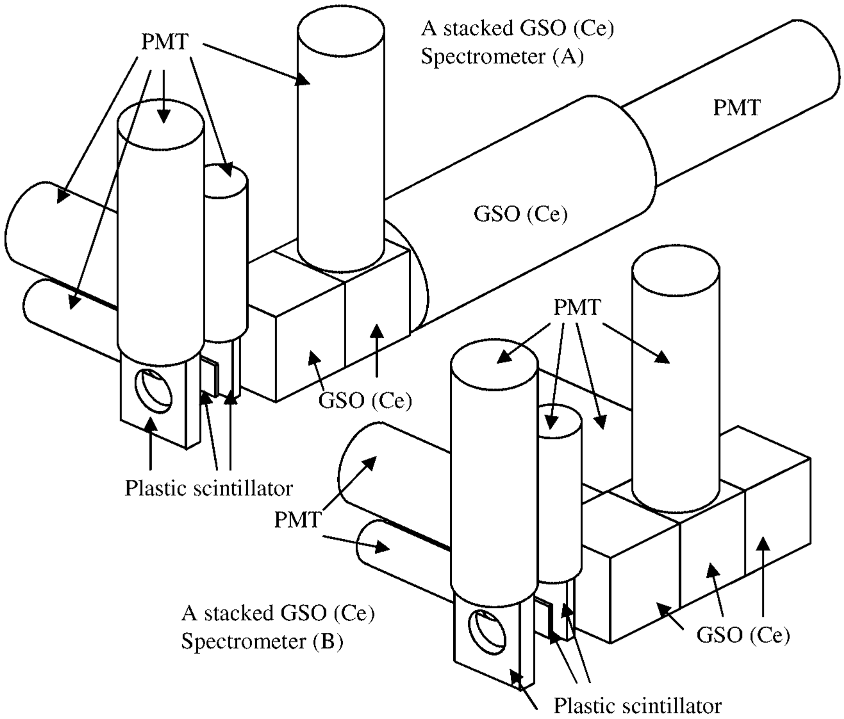

Figure 2: A schematic diagram of the stacked GSO(Ce) spectrometer.

determined by a best fit to the experimental data. The fitting result gives best fitted value S is 6.6 and kB is 1.70×10^{-5} $(\mathrm{MeV/m})^{-1}$. The calculations provide an excellent description of the shape of relative light output. The maximum energy deposited in the cubic GSO(Ce) crystal of $43 \times 43 \times 43$ mm^3 are 161 MeV and 215 MeV at a proton and a deuteron, respectively. The response to protons and deuterons which penetrate 43 mm cubic GSO(Ce) is calculated by the use of Birks' formula. The calculated light outputs are shown in Fig. 4, and compared with the results of the present measurements. The measured data are well described by using the relation dL/dE versus E determined presently. Fig. 5 shows the energy spectra for 247 MeV monoenergetic protons and 256 MeV monoenergetic deuterons. A horizontal axis is the energy which changed the channel obtained by ADC by the relation between light output and energy in Fig. 4. The full energy peaks agree quite well with the energy calculated by two calculation codes (elastic scattering calculation and energy loss calculation).

4.Conclusion

The light output response of GSO(Ce) to protons and deuterons was investigated by using pp, pd and αd scattering. The energy dependence of the light output response of GSO(Ce) was interpret by Birks' formula. The light output difference between the stopping and the penetrating particles has been reasonably described by Birks' formula. The parameters were obtained $S = 6.6$ (arbitrary unit) and $kB = 1.70 \times 10^{-5}$ $(\mathrm{MeV/m})^{-1}$ for both protons and deuterons. The parameters, S and kB, were not dependent on a particle.

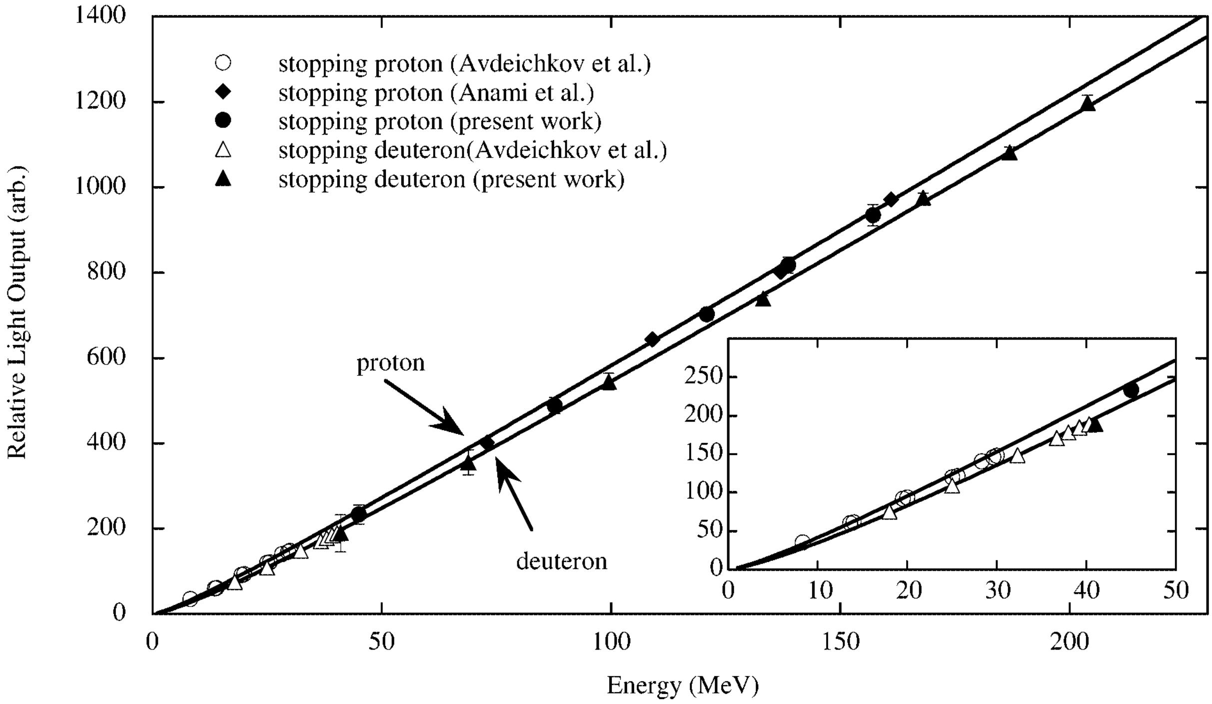

Figure 3: Light output of the GSO(Ce) as a function of energy for protons and deuterons.

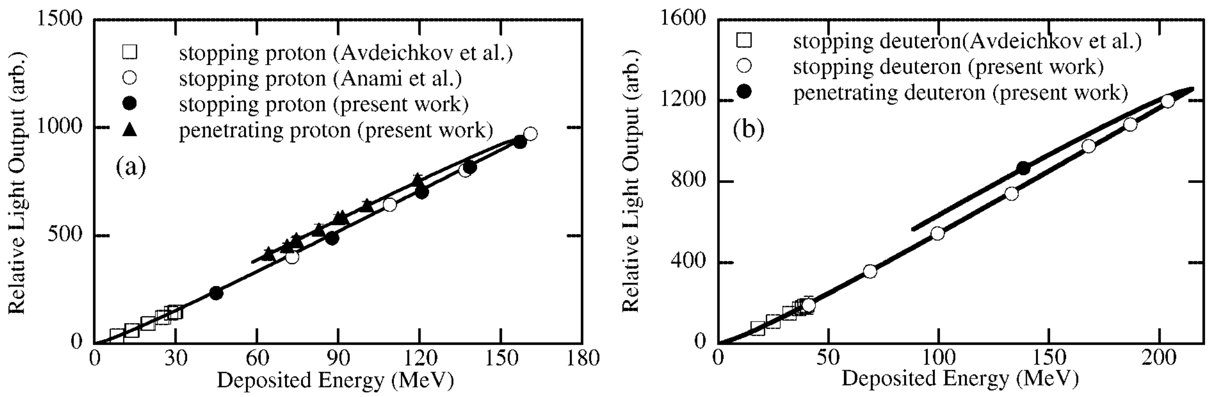

Figure 4: Light output of the GSO(Ce) to (a) penetrating prptons as well as stopping protons and (b) penetrating deuterons as well as stopping deuterons.

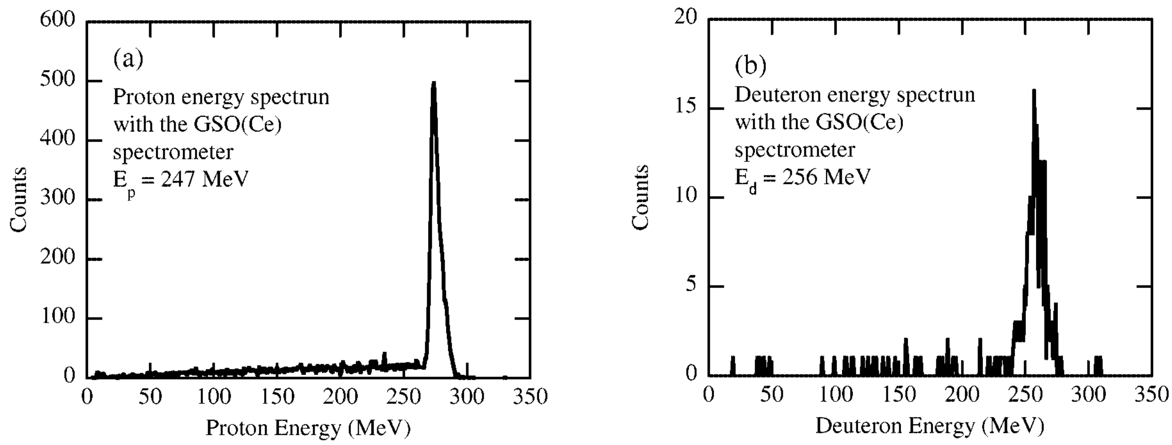

Figure 5: Energy spectrums for (a) 274 MeV monoenergetic protons and (b) 256 MeV monoenergetic deuterons

References

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[3] J. B. Birks, The Theory and Practice of Scintillation Counting, Pergamon Press, Oxford, 187 (1964).