Performance Test of a BaF2 Detector System for High Energy γ-rays

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journal or publication title	CYRIC annual report
volume	1990
page range	56-59
year	1990
URL	http://hdl.handle.net/10097/49578

I.13. Performance Test of a BaF_2 Detector System for High Energy γ-rays

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Due to its good timing specification and higher intrinsic efficiency, BaF_2 detector has recently attracted much attention as a high energy (10 ~ 100 MeV) γ-ray detector. In the last Annual Report [1)], we have described a system for high energy γ-ray experiments at CYRIC. In this report, we discuss about the results of performance test carried out by counting γ-rays from (p,γ) reactions on ^{11}B and ^{12}C at bombarding energies ranging 18 through 40 MeV.

In order to resolve a high-energy γ-ray emitted from the rare event of radiative capture by nuclei for a medium-energy proton, it is of crucial importance to reject a numerous number of neutron events by means of the technique of "particle identification". Figure 1 shows a pulse shape spectrum taken for proton bombardment on ^{11}B at $E_p = 40$ MeV. The horizontal axis stands for the ratio of the integrated light amount of the "tail", the dominant component of which comes from the slow light-frash (600 nsec) by neutrons, to that of "total" of the light-frash, where the fast component (30 psec) by γ-ray contributes as well. As such, the light event for a neutron has much longer tail in the BaF_2 detector than that for a γ-ray, when assumed these two events have the similar total light amount, thus enabling us to separate γ-ray events as shown in the figure. These signals corresponding to the total-light and partial-light at the tail are fed into the two charge-sensitive analog-to-digital converter with different gates, i.e. 1.5 μsec for the total-light and 30 nsec for the partial-light.

Another powerful technique for particle identification with the BaF_2 detector is the time of flight (TOF) method since this type of detector has excellent time resolution as described previously report. A time of flight spectrum is illustrated in fig. 2, showing γ-ray events are clearly separated from velocity dependent neutron events. The time resolution measured for the γ-ray peak in the figure is 700 psec (FWHM), the dominant part of which (~ 600 psec) is due to beam time spread.

As a performance test, we have counted γ-rays emitted from the proton bombardment on ^{12}C at several proton energies. Roughly speaking, two groups of isolated γ-rays are emitted from ^{12}C; i. e. those for enhanced inelastic-scattering leading to the 1^+, T = 0 and T = 1 states at E_x = 12.71 and 15.11 MeV in ^{12}C, respectively, and those due to weakly-populated but higher-energy direct-capture of proton by ^{12}C, forming the residual nucleus of ^{13}N. The γ-ray energies for the latter group are, therefor, incident-energy dependent. Figure 3 shows a γ-ray spectrum emitted for proton inelastic scattering at E_p = 20 MeV, while fig. 4 illustrate that for the γ-rays from proton direct capture at E_p = 30 MeV. Lines in these figures are peak fitting results calculated by the code EGS4[2)] where the response functions of the BaF_2 detector for γ-ray are computed along with its energy by taken into accounts the electron-photon shower. The optimized energy resolution, thus obtained for a 15-MeV γ-ray, is 6.7 % (FWHM). Resultant γ-ray yields for these peaks are compared in table 1 with those reported by Berghofer and his collaborators.[3)] As seen in listed results, comparison is quite satisfactory as listed in the table.

We have carried out the performance test of the BaF_2 detector by analyzing high energy γ-rays from the ^{12}C + p reaction. γ-ray events were successfully separated from those of neutrons by means of pulse shape discrimination technique together with TOF method. The energy resolution achieved for a 15-MeV γ-ray was 6.7 %, being rather poorer compared to those so far reported for BaF_2 detectors. As a summary, this system is readily used for the nuclear physics by, for example, the (p, γ) or (n, γ) reaction.

References

1) Ohura M. et al., CYRIC Annual Report 1989.
2) Berdholfer D. et al., Nucl. Phys. **A263** (1976).
3) Nelson W. R. et al., The EGS4 CODE SYSTEM SLAC Report 265 (1986).

Table 1. Comparison of cross sections for (p,p'γ) and (p,γ) reaction on ^{12}C with those reported in ref. 3.

$^{12}C(p,p'\gamma)$ Ep = 20 MeV		
	Present Results	Berghofer et al. (ref.3)
E_γ = 12.7 MeV	53 μb/sr	45 μb/sr
E_γ = 15.1 MeV	600 μb/sr	560 μb/sr
$^{12}C(p, \gamma_0)$		
E_p = 18 MeV	1.8 μb/sr	1.4 μb/sr
E_p = 20 MeV	3.2 μb/sr	2.8 μb/sr
E_p = 30 MeV	0.93 μb/sr	1.0 μb/sr

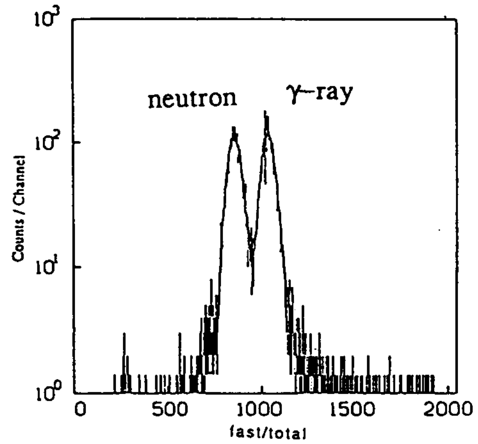

Fig. 1. Display of n-γ discrimination. The threshold for the light out put is 11 MeVee.

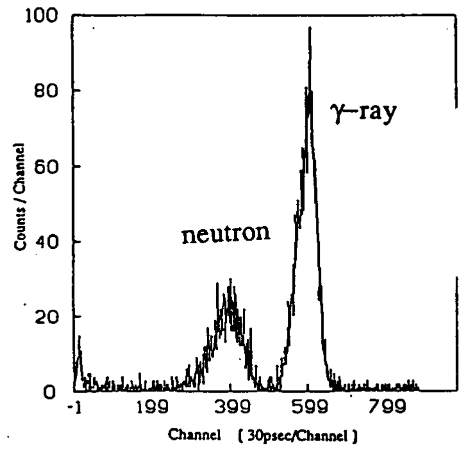

Fig. 2. Time of flight spectrum for neutrons and γ-rays over a flight path of 1.5 m.

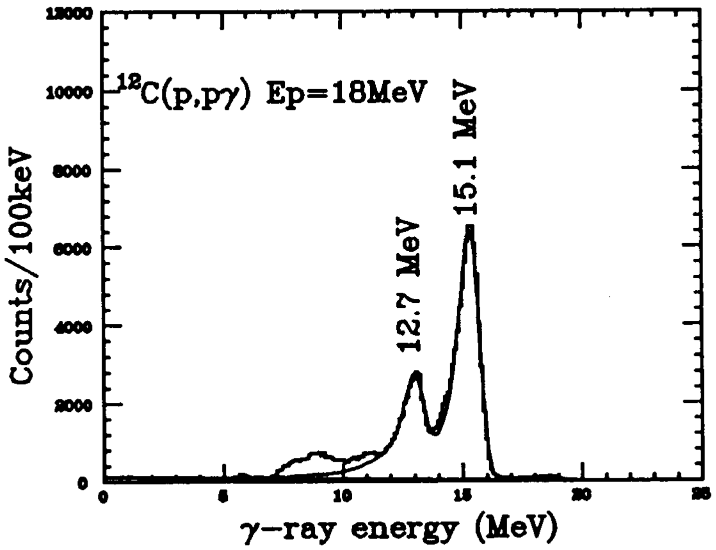

Fig. 3. Spectrum of γ-rays emitted from the $^{12}C(p,p'\gamma)$ reaction at E_p = 20 MeV leading to the T = 0 and T = 1, 1^+ states in ^{12}C at 12.7 and 15.11 MeV, respectively.

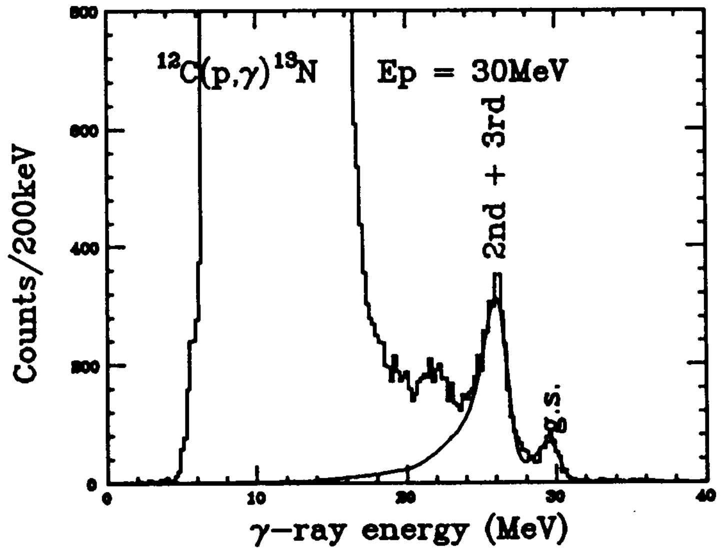

Fig. 4. Spectrum of γ-rays emitted from direct capture of protons by ^{12}C at E_p = 30 MeV leading to the ground and 3.51-MeV states