Radiative proton capture to low-lying states in ^{10}B

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Radiative proton capture has been studied for many years extracting valuable information on the giant dipole resonance (GDR) in light nuclei employing the direct-semidirect (DSD) capture model [1]. Although the GDRs built on discrete and continuum states have been extensively studied, those built on the isobaric analog states in self-conjugate nuclei have been reported only for two cases so far. These are on isospin T=1, 2.31 MeV state in ^{14}N [2] and on T=1, 15.1 MeV state in ^{12}C [3].

The GDR built on a state of isospin T can have T_{GDR} = T-1, T and T+1. In self-conjugate nuclei, the GDR built on T=1 state can have T_{GDR}=0 or 2 only due to the isospin selection rule for E1 transition. In the proton radiative capture, forming a self-conjugate nucleus, the excitation of the T_{GDR}=2 state is isospin forbidden. The excited GDR is, thus, of almost pure T_{GDR}=0 character. The T=1 state is the isobaric analogue of neighbouring unstable nuclei with ground state T=1. Photo-absorption experiments on these nuclei can excite T_{GDR}=1 and 2 components only. From a comparison of the results from these experiments, one can address the isospin splitting into all three components. Moreover, in light nuclei, structure effects play an important role and such studies can provide stringent information on nuclear structure.

We have initiated a program to study this phenomenon in ^{10}B using the $^{9}Be(p,\gamma)$ reaction over a wide range of proton energies. The present paper reports on the first experiment done at E_p=8 MeV. This reaction was reported in an unpublished thesis [4]. The present study utilises the coincidence method unlike the earlier singles measurements. This, in principle, is a cleaner method considering the close-by low-lying states in ^{10}B. In ^{10}B, the first T=1 state is at 1.74 MeV in the vicinity of two states at 0.72 and 2.15 MeV. It is difficult to discriminate clearly between the transitions to these states with a practical high energy γ-ray detector beacause of the spread in the line shape due to shower leakage. A coincidence measurement between the primary high energy γ-ray and successive secondary low-energy γ-rays (in a detector with good energy resolution) is required in this case. In ^{10}B, the second T=1 state is at 5.16 MeV having >80% γ-decay branch. Thus, the GDR built on both the T=1 states can be studied along with those on other T=0 states.

The experiment was performed at PLF, Mumbai, with the proton beam bombarding a self-supporting beryllium foil of thickness 1.1 mg/cm^2. The primary high energy γ-rays were detected in an array of 19 hexagonal BGO detectors, each with a face to face distance of ~5.8 cm and length 7.6 cm. Secondary low-energy γ-rays were detected in two cylindrical $LaBr_3$(Ce) detectors of diameter 7.6 cm and length 15 cm. The BGO-array was kept at 90^0 to the beam direction at a distance of 7.3 cm and the $LaBr_3$(Ce) detectors were kept at 90^0 and 135^0 at a distance of ~7.0 cm. The energy calibration was done with radioactve sources with γ rays of 0.511 to 6.13 MeV. For the BGO array, the high energy points were obtained from the gamma spectra measured in (p,γ) reaction on ^{11}B and ^{27}Al targets. These spectra were also used to get the response function of the detector array and compared with those simulated by the EGS4 code.

Fig.1 shows the projection of the two-dimensional coincidence spectra on the energy axis of the $LaBr_3$(Ce) detectors gated

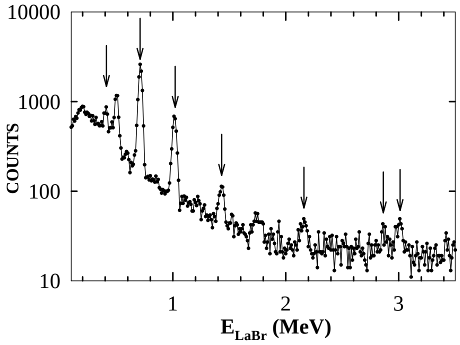

FIG. 1: Gated $LaBr_3$ γ-spectrum. Arrows indicate transitions in ^{10}B.

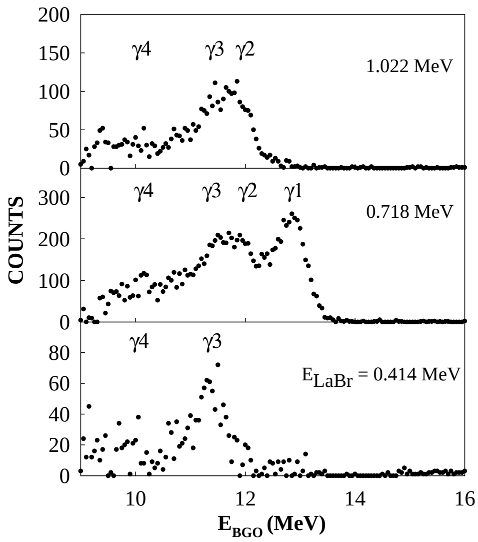

FIG. 2: Gated BGO γ-spectra. Labels indicate primary transtions to the low-lying states numbered 1 to 4.

by high energy deposited in the BGO-array. The discrete lines originating from the transitions in ^{10}B are shown by the arrows. Fig.2 shows three E_{BGO} spectra gated by E_γ=0.414, 0.718 and 1.022 MeV detected in $LaBr_3$ detectors. There is no one-to-one correspondence between the primary and the secondary γ-rays because of the inter-state transitions among the low-lying states. This is exemplified in Fig.2 showing different primary transitions in coincidence with each secondary γ-ray. However, from a knowledge of the branching ratios, the line shapes and efficiencies of the detectors, one can extract the cross sections of individual primary transitions to the final states.

TABLE I: Experimental and calculated cross sections to final states of energy E_{Xf}. $\sigma_{cal}^{(1)}$ is with only direct and $\sigma_{cal}^{(2)}$ is with DSD capture.

E_{Xf} (MeV)	$\sigma_{exp}(\mu b)$	$\sigma_{cal}^{(1)}(\mu b)$	$\sigma_{cal}^{(2)}(\mu b)$
0.718	7.16±0.43	5.35	7.07
1.740	3.24±0.22	2.52	3.43
2.154	2.27±0.25	2.09	2.67
3.587	0.33±0.14	1.89	1.69
5.164	1.44±0.33	1.00	0.89

Table I shows the experimental and the calculated cross sections from a DSD model calculation without and with GDR excitation (assuming GDR energy and width as 14 and 10 MeV, respectively). The spectroscopic factors for the final states were taken from the calculation of Cohen and Kurath [5]. The agreement is generally good except for the 3.587 MeVstate. The reason for this is not clear at this stage. The full information on the GDR will be revealed only after the future measurement covering a wide range of proton energies.

Acknowledgments

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