Variation in the thermal neutron flux at the anti-neutrino measurement site in the Dhruva reactor

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Introduction

Reactor based anti-neutrino ($\bar{\nu}_e$) measurements have the potential to detect the fourth generation of neutrinos, called sterile neutrino. The experiment is also capable of remotely monitoring core activities in the reactor. Precise measurement of thermal neutron (n_{th}) yields for background estimation is essential for such experiments. Thermal neutron detector based on single crystal scintillator of $Li_6Y(BO_3)_3$:Ce is an efficient choice for this purpose[1]. It has excellent detection efficiency due to the high atomic density of ^{6}Li and ^{10}B atoms, which have high n_{th} capture cross section.

Nuclear Physics Division, at BARC, has proposed a detector array (1 m × 1 m × 1 m) consisting of 100 plastic bars (1 m × 10 cm × 10 cm), covered with Gd coated mylar, to measure the $\bar{\nu}_e$ spectrum, via $\bar{\nu}_e + p \rightarrow n + e^+$, at short distances (∼ 10 m), from the core of the Dhruva reactor[2]. Various measurements are being performed, both in the reactor ON and OFF conditions, to investigate the response and performance of similar plastic bars(1 m × 6 cm × 6 cm) arranged in a 3 × 4 matrix and placed inside a 10 cm thick lead shielding. It is proposed to measure and quantify the n_{th} induced backgrounds at various positions near the plastic detector set up and estimate the degree of its variation.

Experiment and Results

A series of measurements were performed with the highly efficient (>85%), granular (10 mm diameter × 1 mm thickness), $Li_6Y(BO_3)_3$, single crystal detector(LYBO) for n_{th}, doped with Ce (∼ 0.2 %) and developed at the Crystal Technology Section, TPD, BARC[1]. The polished LYBO crystal was coupled, optically, to a photo multiplier tube (PMT) (Hamamatsu; Model No. R2154, 2″ diameter) and powered through USB. The pulse from the PMT was processed through a pre−amplifier and shaping amplifier and the pulse height spectrum from the LYBO was recorded in a PC based MCA. The detector was characterized with respect to a standard, calibrated Am−Be source of n_{th}, located at the RPAD, BARC.

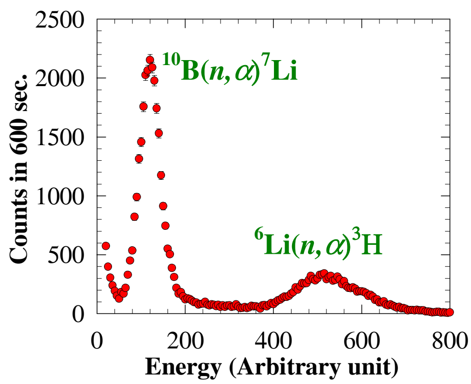

FIG. 1: Response of the LYBO detector for a calibrated, Am−Be, n_{th} source at RPAD, BARC.

FIG. 1 displays the response of the LYBO detector for n_{th} flux ($\phi_{n_{th}}$) ∼ 150 n_{th}/cm^2/sec, from the calibrated Am−Be source. The two peaks result due to the reaction of the n_{th} with the ^{10}B and ^{6}Li present in the LYBO crystal[1].

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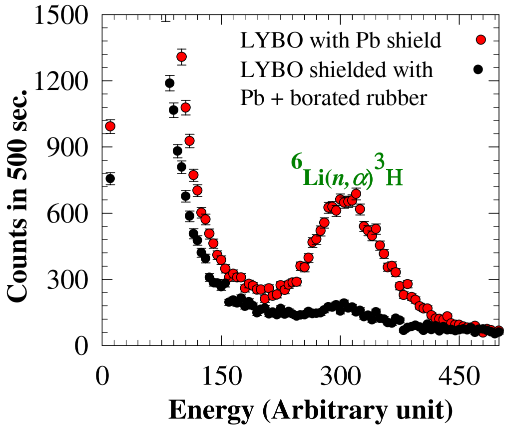

FIG. 2: LYBO detector spectrum near a n_{th} beam port at Dhruva, in the reactor ON condition.

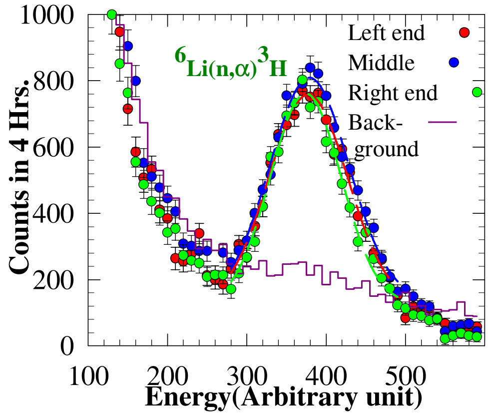

FIG. 3: n_{th} response of LYBO at various positions near the $\bar{\nu}_e$ measurement site in Dhruva.

FIG. 2 shows the spectrum when the LYBO detector was placed near a n_{th} beam port inside Dhruva, supposed to be providing a chopped beam of $\sim 10^6$ n_{th}/cm^2/sec, when the reactor was ON. Although the LYBO crystal was thin enough to ensure less interaction with the gamma background, the detector had to be placed behind a 20 cm thick, lead wall, to reduce the large effect due to the ambient gamma rays. The peak in the spectrum (red circles in FIG. 2)is due to the detection of n_{th} through the reaction ^{6}Li(n,α)^{3}H. The black circles represent the spectrum as registered in LYBO when it was shielded with Borated (40%) rubber, thus resulting in the effective absorption of n_{th} before reaching the detector. The peak, expected at lower energy due to the reaction of n_{th} with ^{10}B, could not be separated from the background, in the reactor hall, in spite of the lead shielding.

The LYBO detector was next placed at various locations near the plastic set up at the $\bar{\nu}_e$ experiment site inside Dhruva. Measurements were performed at fixed thermal powers ($\sim$ 85 Mega Watt) for the reactor. The colored (red, blue and green) circles in FIG. 3 represent the background corrected, normalized spectra due to the ^{6}Li(n,α)^{3}H reaction in LYBO, measured at both extremes and the middle of the plastic detector set up. The detector was shielded throughout, in a lead cage, 20 cm thick, to reduce the gamma background. The best fit Gaussian distributions corresponding to the peaks from the ^{6}Li(n,α)^{3}H reaction are also shown in FIG. 3 as (red, blue and green) dashed curves. The continuous curve(dark pink) represents the typical measured background when the shielded LYBO was covered, additionally, with Borated rubber.

Conclusion

The measured spectra and the fitted Gaussian distributions, due to the ^{6}Li(n,α)^{3}H reaction in LYBO, at various positions along the plastic detector set up, look similar, within experimental errors. The background subtracted, integrated peak counts at different locations are proportional to the measured n_{th} and vary within $\pm$5% among themselves.

The present measurements strongly suggest that the $\phi_{n_{th}}$, at various locations in the $\bar{\nu}_e$ experimental site, does not vary significantly.

References

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