Muon Induced Neutron measurement setup at TIFR (MINT)

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Introduction

Background minimization is extremely important for experiments involving rare decays like neutrinoless double beta decay (NDBD), dark matter (DM) search etc. Neutron background is one of the major sources which arises from natural radioactivity in surrounding materials (spontaneous fission and (α, n) reactions. High Z materials such as Pb, used for shielding γ-ray background, enhances the production of neutrons from cosmic muons. Given the discrepancy between the existing measurements and simulations[1, 2], independent measurements employing different techniques are very much important. With this motivation, we have developed the Muon Induced Neutron measurement setup at TIFR (MINT).

Experimental details

The MINT setup consists of a couple of Cs_2LiYCl_6 (CLYC) detectors (1" dia × 1" height) [3] for the detection of muon induced neutrons after thermalization. Thermal neutrons produce a unique signal in CLYC with 3.2 MeVee light ouput by $^6\mathrm{Li}(\mathrm{n}, \alpha)^3\mathrm{H}$ reaction (see FIG.1). The CLYC detector has high intrinsic efficiency for thermal neutrons($\sim$ 35%) and excellent pulse shape discrimination (PSD) capability for n-γ separation. The CLYC is also capable of detecting fast neutrons via $^{35}\mathrm{Cl}(\mathrm{n,p})^{35}\mathrm{S}$ channel. High density polyethylene (HDPE) of 10 cm surrounds the detectors, for thermalizing fast neutrons. Pb blocks of 30 cm thickness and 40cm × 40cm footprint are placed above the detector, outside the HDPE. Plastic scintillators of 50 cm × 50 cm dimensions, were placed surrounding the set up for detecting muons. The data is acquired with CAEN V1730B digitizer (500 MHz, 14 bit) in singles mode. ROOT [4] based analysis codes were developed for extracting the coincidence between n/γ in CLYC and muons in the plastic detectors.

Data analysis and results

The major contribution to the muon induced neutrons at sea level comes from the stopping muons in Pb (E_μ ~200 MeV). Coincidence time window was optimized to ±10 ms taking into account neutron transport time in Pb and thermalization time in HDPE. The

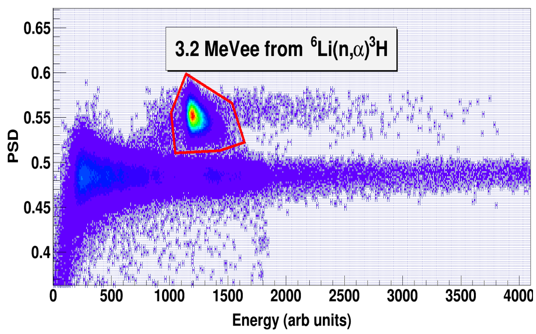

FIG. 1: Q_L vs PSD($\frac{Q_L - Q_S}{Q_L}$), Q_L and Q_S are charges integrated in long (700 ns) and short gates (150 ns) for CLYC detector

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coincidence time spectrum between the CLYC and the top plastic scintillator is shown in FIG.2.

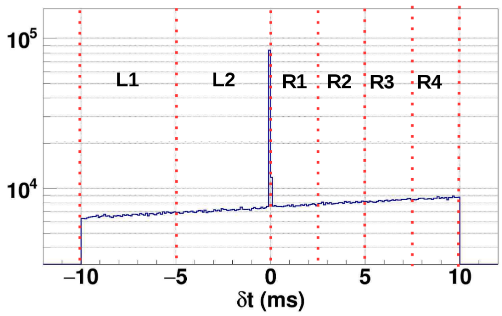

FIG. 2: Coincidence time spectrum between top plastic scintillator and CLYC detector (50 days)

TABLE I: Integrated counts under the thermal neutron peak for different TAC windows. Counts scaled to 2.5 ms TAC width

Gate	Integral counts (Pb) (day^{-1})	Integral counts (bkg) (day^{-1})
L1 (-7.5 ms)	3.1 (0.2)	2.4 (0.3)
L2 (-2.5 ms)	3.5 (0.2)	1.9 (0.3)
R1 (2.5 ms)	9.2 (0.5)	3.0 (0.4)
R2 (5.0 ms)	4.5 (0.3)	2.3 (0.4)
R3 (7.5 ms)	3.7 (0.3)	3.4 (0.5)
R4 (10 ms)	4.7(0.3)	2.6 (0.4)

The prompt in the time spectrum corresponds to muons and γ-rays in CLYC. The transport and thermalization time for a 20 MeV neutron in MINT geometry is estimated to be ≤ 600 μs from GEANT4[5] simulations. Hence to estimate a suitable prompt window for muon induced neutrons, the following procedure was adopted : the total range in the time spectrum is divided in to 6 windows : L1 and L2 of 5 ms to the left of the prompt and R1,R2,R3 and R4 of 2.5 ms width each to the right of the prompt(see FIG.2). The width of the R1 window was varied and the number of counts in neutron PSD gated energy spectrum in CLYC were observed. It was found that the counts increase initially upto a width of ~2.5 ms and then saturates, making it the appropriate choice for prompt window for muon induced neutrons. The Table.1 lists the integral counts in the thermal neutron peak in each window for runs with and without Pb. The same is plotted in FIG.3. It can be seen from the table that the background level in R2,R3 and R4 is slightly higher than L1 and L2. The background data is extracted from the average of chance gated (i.e. L1,L2,R2,R3,R4) data appropriately scaled to the prompt width and is also shown in the figure for comparison. The mean neutron counts above the background in R1 comes out to be 5.3 ±0.9 day^{-1} for 544 kg of Pb.

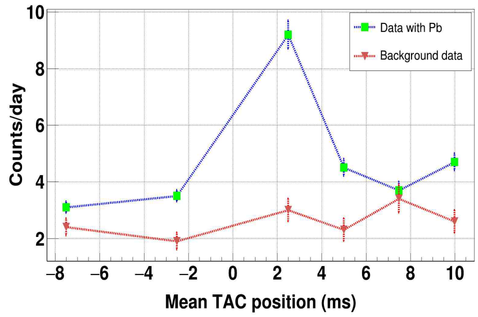

FIG. 3: Integrated counts under the thermal neutron peak for different TAC windows.

The simulations for neutron production in Pb for MINT setup are in progress. Detailed results from the MINT experiment and comparisons with the simulations will be presented.

Acknowledgments

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