Background reduction studies with shielding for mini-ISMRAN

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Introduction

The Indian Scintillator Matrix for Reactor Anti-Neutrino (ISMRAN), a ∼1 ton above-ground detection setup is proposed at the Dhruva research reactor facility in Bhabha Atomic Research Center (BARC) India, for the detection of reactor anti-neutrinos ($\bar{\nu}_e$). The setup will comprise of 10×10 matrix of 100 cm×10 cm×10 cm Plastic Scintillator (PS) bar wrapped with Gd (Gd_2O_3) foil and is located ∼13 m from reactor core in a mobile trolley structure. Such an experiment requires substantial γ-ray and neutron background suppression [1]. For this purpose, a passive shielding of 10 cm thickness of Pb on the inner side, followed by 10 cm thick, Borated Polyethylene (BP) on the outside is already assembled in the reactor hall for the prototype detector - mini-ISMRAN, which is 16% of the final ISMRAN volume. In this work, we present measurements to test the effectiveness of different shielding assemblies in the laboratory environment and results from the background measurement performed with the chosen 10 cm Pb and 10 cm (BP) shielding in the reactor environment.

Test of different shielding assemblies for ISMRAN

Measurements are performed to evaluate γ-ray and neutron background reduction possible for different shielding assemblies. The experimental setup uses γ-rays and neutrons from Am-Be as the background. The detector is a cylindrical liquid scintillator (LS) of 5 inch diameter and 2 inch height, which has the advantage of pulse shape discrimination (PSD) ability when coupled to a suitably designed acquisition system. The chosen assemblies and the obtained reduction for both γ-rays and neutrons are represented in a combined plot shown in Fig 1. A gradual increase in background reduction for increase in thickness and introduction of layered arrangement is observed. The measurements show that among the combinations, the (ii) + (vii) setup i.e. the current shielding assembly leads to a satisfactory reduction (80 % in neutrons and about 45 % in γ-rays) compared to no-shield arrangement and further combinations don't produce significant improvement. Also, the weight restrictions and the simplicity of assembly support the use of this setup. However, using a 5 cm high density polyethene (HDPE) sheet externally is potentially a useful addition, as it is convenient to assemble and there is a slight increase in neutron reduction ability while obeying the constraints due to the load bearing capacity of the reactor

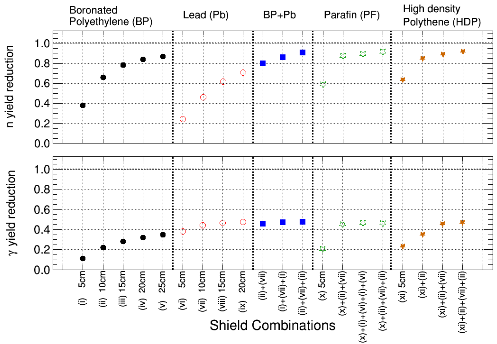

Fig 1: Reduction in accepted neutron background (top) and γ-ray background (bottom) effected by various shields and their combinations

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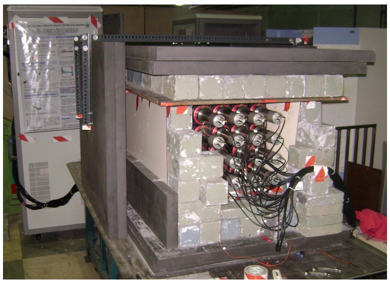

Fig 2: Prototype detector setup mini-ISMRAN with digitizer DAQ in reactor environment

Reactor background measurement with mini-ISMRAN

The primary source of background in the reactor are the γ-rays and neutrons produced due to the fission processess when the reactor is ON and the residual activity from long lived radioactive isotopes when it is OFF. In addition to this, natural background due to γ rays from ^{40}K & ^{208}Tl and cosmic-ray muons is present irrespective of the location of the setup and under both reactor ON and OFF conditions. The background measurement presented here is performed using mini-ISMRAN setup, which comprises of 16 PS bars in a 4×4 array, in the reactor environment. Figure 2 shows the mini-ISMRAN shielding at the time of assembly when the end-cap Pb and BP layers are yet to be assembled. The 16 PS bar matrix is visible with the DAQ system at the back. The plot shown in the Fig 3 compares the reactor ON rates in a single mini-ISMRAN PS bar with and without the 10 cm Pb and 10 cm BP shield for energies upto 8 MeV only, as the anti-neutrino flux from the fissioning isotopes is negligible, for energies beyond this value. It can be observed that the cumulative unshielded rates are of the order $\sim 10^4$ Hz while with shielding they drop down to $\sim 10^2$ Hz which is a significant gain given the simplicity of the two layer shielding. The gradual reduction as the shielding layers are introduced and the further reduction possible with addition of a coincidence criteria, as expected in a multiple γ-ray emission, is shown in table I.

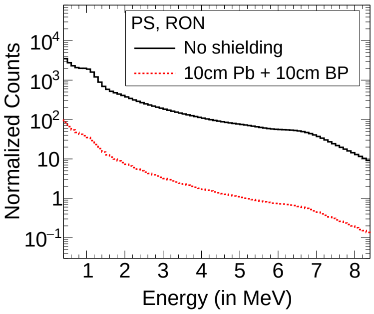

Fig 3: Comparison of reactor ON background spectrum recorded in a central PS bar from mini-ISMRAN setup under no shielding and 10 cm Pb and 10 BP shield.

Table I: Reactor ON background rates in mini-ISMRAN for various shielding.

Detector Configurations	Count rates (Hz)
No Shielding (Single PS bar)	∼24000
10 cm thick lead shield	∼2000
10 cm thick lead + 10 cm thick BP	∼500
10 cm thick lead + 10 cm thick BP (multiplicity = 2 within 40 ns)	∼10

Conclusion and Outlook

The overall reduction in background for mini-ISMRAN in reactor environment is measured using the 10 cm Pb and 10 cm BP shield. Further reduction is possible at least for neutron background with addition of 5 cm HDPE sheet externally and measurements using these are being performed in the reactor environment. Without HDPE, the background is observed to reduce by two orders of magnitude as compared to the no-shielding scenario and can further improve by imposing coincidence conditions. This reduction is significant but needs to futher improve by at least 2 orders for identifying the correlated $\bar{\nu}_e$ like events. Fabrication of mobile trolley structure to house the PS matrix (10×10) and shielding is currently in progress at CDM-BARC and involves machining of the various shielding components before assembly.

References

[1] Y. Kuroda, et. al., Nucl. Inst. and Met. in Physics Research Sec. A 690 (2012) 41–47.