Anti-neutrino like events from mini-ISMRAN at Dhruva reactor

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Introduction

Indian Scintillator Matrix for Reactor AntiNeutrino - ISMRAN, is a proposed setup for anti-neutrino ($\bar{\nu}_e$) based reactor core monitor and sterile oscillation search at the Dhruva research reactor facility, BARC, Mumbai [1]. It is an above ground, 1 ton by weight plastic scintillator (PS) based detector, with ∼13m standoff from reactor core. A 10 cm thick Pb followed by 10 cm thick borated polythene (BP) shielding is proposed to suppress external γ-ray and neutron background. A 16% by volume prototype of ISMRAN called mini-ISMRAN, with the complete shielding and digitizer DAQ has already been commissioned at the reactor site for quantifying the background and search for possible anti-neutrino candidate events. The results from this analysis are presented here.

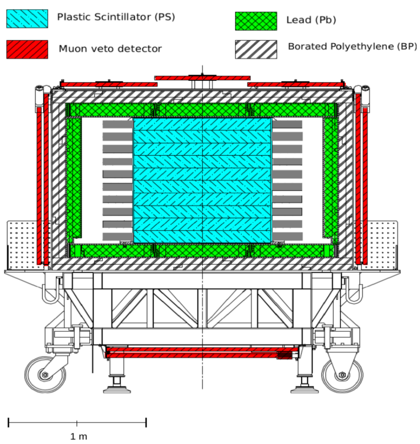

Fig 1: Schematic of ISMRAN setup inside the shielded trolley structure

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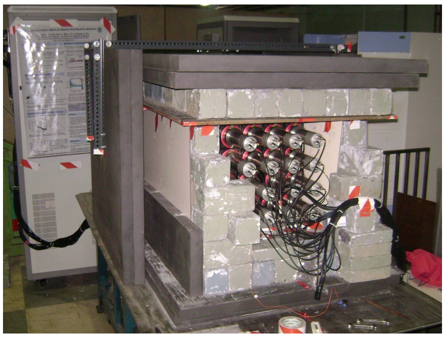

Fig 2: miniISMRAN (16 PS bar) shielded setup in Dhruva reactor hall

ISMRAN and its prototype mini-ISMRAN

The ISMRAN detector will detect the inverse beta decay (IBD) reaction of $\bar{\nu}_e$ from reactor core and use their rate and energy spectrum to monitor the core. Although, the $\bar{\nu}_e$ based monitoring method has already been successfully demonstrated but its feasibility, with a 1 ton scale, above-ground setup using non-hazardous materials is yet to be established. ISMRAN aims to address this challenge with a 10 × 10 plastic scintillator (PS) array of 1 m^3 volume. Each bar has a wrapping coated with gadolinium oxide (4.8 mg·cm^{-2}) for neutron capture and two 3" PMTs at both ends. A digital DAQ based on high sampling rate digitizers will read the total of 200 such signal readouts. The full setup with shielding is planned to be mounted using a stainless steel support structure on a mobile trolley, see figure 1. Taking into consideration, the $\bar{\nu}_e$ flux at 100 MW$_{\rm th}$ power output Dhruva core, the IBD interaction cross section , the expected detection efficiency and the geometrical acceptance of the detector; about 60 $\bar{\nu}_e$ events are expected to be detected in ISMRAN. The prototype - mini-ISMRAN using fully shielded 16 PS bar (4×4) array with

2 digitizers (32 channels) is already commissioned at the proposed site. A quantification of γ-ray and neutron background, as well as, search for possible IBD candidates in reactor ON and OFF is underway. Due to the very limited volume of the mini-ISMRAN, the detection efficiency expected from simulation is a meagre 4% amounting to about 2 IBD candidate detections expected per day.

Selection criteria for IBD candidates and filtered events

An IBD event inside ISMRAN is characterized by the time coincidence of prompt signal from positron annihilation γ-rays and the delayed signal due to cascade γ-rays from neutron capture. The coincidence window: ΔT_{PD} typically ranges from few μs to few 100 μs depending on detector geometry, and, position and concentration of neutron capture agent. The sum total of energy deposits in different bars within a time window of 20 ns: E_{sum} and the number of such bars: N_{bars} are the primary variables for identifying prompt and delayed events. For pure IBD event simulations in ISMRAN and mini-ISMRAN the expected distributions for E_{sum} and N_{bars} are known alongwith the corresponding efficiency for different selection cuts [1]. The ADC response of the PS bars was calibrated using known radioactive sources and then gain matched for uniform application of energy cuts. While analysing the mini-ISMRAN data, the four primary criteria chosen are: 1) threshold requirement: $0.2 < E_{th}(\mathrm{MeV}) < 7.5$ on all bars; 2) prompt selection: $2.6 < E_{sum}(\mathrm{MeV}) < 8.0$ and $1 < N_{bars} < 4$; 3) delayed selection: $3.0 < E_{sum}(\mathrm{MeV}) < 8.0$ and $3 < N_{bars} < 10$; and 4) ΔT_{PD} selection: $8 < \Delta T_{PD}$ μs <500. Additionally, selecting only contagious hits with localized deposits in time and distance along the bar, removing cosmic muon contamination is also implemented in analysis. Prior to applying all the stringent cuts, a fit to the ΔT_{PD} distribution was performed and the mean time delay was found to be in close agreement with the value $\sim$68 μs, expected from simulation (see in figure 3). These selections were imposed on 3 months of RON data with 2-3 days of OFF time and also on 1

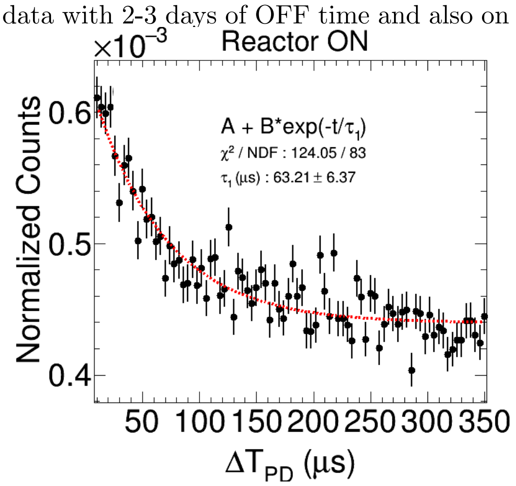

Fig 3: ΔT_{PD} from mini-ISMRAN data for Reactor ON conditions inside full shielding

Table I: IBD candidate events in mini-ISMRAN. All errors quoted are statistical

Datasets(months)	Counts (Data)	Counts (Pred.)
March:ROFF 22 days	7.0±2.8	-
June:RON 28 days and ROFF 2 days	54.2±28.9 and 1.0±0.4	56.8
November: RON 27 days and ROFF 3 days	55.5±30.2 and 2.0±0.8	57.9
December: RON 23 days and ROFF 8 days	43.2±22.3 and 4.5±1.1	45.7

complete month of ROFF data. The analysis results agree reasonably well with the expectations but are limited by statistics as seen in table I.

Conclusion and Outlook

First results from analysis of reactor data from mini-ISMRAN are presented. The measured $\bar{\nu}_e$ count rates are observed to follow the expected value but the statistical uncertainty is dominant. These uncertainties are expected to reduce for the full ISMRAN setup data.

References

[1] D. Mulmule et. al., NIM A 911(2018) 104–114.