Puzzling features in reactor antineutrino measurements : role of ISMRAN detector

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Measurements of reactor antineutrino are being widely pursued around the world for investigations into several exciting problems in neutrino physics and their potential use in monitoring the flux evolution of reactor. A discrepancy in the predicted and measured inverse beta decay (IBD) yields referred to as the reactor antineutrino anomaly has been found. A one-ton plastic scintillator matrix detector - Indian Scintillator Matrix for Reactor AntiNeutrino -ISMRAN is being assembled for measurements of antineutrinos from the Dhruva reactor. Initial measurements of the antineutrino candidate events have been performed using the mini-ISMRAN setup which consists of 16 % of full detector. Results of these measurements, simulation studies and future prospects are presented.

1. Introduction

Neutrinos have become one of the most important entities that have been investigated quite intensely for their intriguing features in recent decades. Copious emission of antineutrinos from the nuclear reactors present huge opportunities for investigations into several open problems in neutrino physics. The antineutrinos arise from the beta decay of the fission fragments in the nuclear reactor. The flux and spectral shape measurement of antineutrinos can be utilized to reveal the composition of fissile material in the reactor core and its time evolution. In recent years a couple of additional puzzling features have been observed in reactor antineutrino measurements that have attracted huge attention. A discrepancy has been found in the measured and predicted antineutrino flux at short distances from reactor. This deficit, known as the Reactor Antineutrino Anomaly (RAA), could be explained either by correction in the neutrino flux predictions due to fission fragments or by the existence of a new type of neutrino, a light sterile neutrino. Further a bump like feature at 4-5 MeV is seen in the spectral shape of the measured positron spectrum.

Antineutrinos generated in the reactor are generally measured using the collection of the Inverse Beta Decay (IBD) events in the detector. The interactions of antineutrinos have very low cross sections and therefore large size detectors are required which needs to be placed close to reactor. In case of short baseline measurements, due to proximity of the detector a high radiation environment of a nuclear reactor is encountered. Moreover, if the detector is on the surface it has little overburden to shield against cosmic rays. Therefore, the measurement of antineutrinos is quite challenging. A measurement at shorter distances is necessary whether sterile neutrinos are the cause reactor anomalies.

For the measurements of antineutrinos a short-baseline reactor antineutrino experiment ISMRAN is being setup at Dhruva reactor at BARC, which is designed to address some of these issues. The IBD reaction can be used to detect the antineutrinos from the reactor core and uses their rate and energy spectrum to monitor the core. Taking into account the available flux of antineutrinos at 100 MW thermal power output of Dhruva reactor, the IBD interaction cross section, the expected detection efficiency and the geometrical acceptance of the detector; about 60 antineutrino events are expected to be detected in ISMRAN. Here, we describe the detector design, the experimental setup of ISMRAN and the detection principle. Further, we also

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present the results of measurements of antineutrinos that have been performed using the mini-ISMRAN setup which consists of 16 % of full ISMRAN setup.

2. ISMRAN detector

ISMRAN is a short-baseline reactor antineutrino experiment which employs an array of plastic scintillator (PS) bars in 10 x 10 geometry [1]. It is having a weight of 1 Ton detector material that will be placed above ground at a distance of 13m from reactor core for measurement of antineutrinos. Each PS bar is a 1 metre long with 10cm x 10cm cross sectional area and has a wrapping coated with gadolinium oxide (4.8 mgcm 2) for neutron capture. These bars are individually read by two 3 PMTs at both ends. A 10 cm thick Pb followed by 10 cm thick borated polythene (BP) shielding is being used to suppress the external γ-ray and neutron background. The PS scintillator matrix along with the shielding of 10 cm thick will be mounted using a stainless steel support structure on a mobile trolley that can provide an access to shorter distances.

A digital DAQ based on high sampling rate digitizers has been setup to read the total of 200 PS signal readouts. An IBD event inside the ISMRAN geometry consists of a a prompt event due to positron ionization loss followed by annihilation gamma signals and a delayed event due to cascade gamma signals from neutron capture. The antineutrino candidate events are measured by applying cuts in the time distribution between prompt and the delayed event. The time measurement from both ends helps to localize the IBD event to a certain degree. Neutrons captured in the gadolinium can be separated from positron using the multiplicity and energy deposition.

3. Measurements with mini-ISMRAN

A prototype detector, mini-ISMRAN comprising of 16 PS bars in a 4 x 4 matrix has been setup at the proposed site inside the Dhruva reactor hall. The setup is placed under the full shielding and the data is acquired using 2 digitizer modules with 32 channels. The mini- ISMRAN detector is used to study γ-ray and neutron background during the reactor ON and OFF period as well as to search for anti-neutrino like candidate events [2]. The analysis techniques and results of the analysis will be presented.

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References

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