Measurement of fast neutron background in ISMRAN experimental site at Dhruva reactor

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1.Introduction

In this report we present measurements of the fast neutron rate at the ISMRAN experimental site[1] . These measurement are useful in context of ISMRAN detector which propose to measure antineutrino through inverse beta decay (IBD) process at DHRUVA reactor at 13 meter distance and the fast neutron can mimic IBD signal . High intensity fast neutron flux is encountered inside the nuclear reactor hall.But the neutron identification against dominant γ background is challenging,to which the detectors are sensitive . This has been studied by measuring the pulse shape (pulse shape discrimination (PSD) technique) of gamma and neutron signals from a NE213 liquid scintillator , because in liquid scintillator the shape of gamma and neutron pulses are different .

2.Experimental Details

To measure the fast neutron rate,we use an experimental setup which consist of NE213 liquid scintillator shielded by 10 cm thick of lead (Pb) followed by 5 cm thick of boronated polythene(BP)over a movable trolly . The schematic diagram of the experimental setup is shown in Fig.1(a) . CAEN V1730 16 channel 500MS/s frequency VME based waveform digitizers are used for pulse processing and data acquisition system . In this system,the discrimination,gate generation , charge integration are processed by FPGAs . The digitizers are programmed with the latest CAEN DPP PSD firmware version 4.11.139.6. This firmware allows for discrimination of different radiations such as γ-rays , neutrons if their pulse profiles in the given scintillator volume are different . The data are recorded for 4-5 days by keeping the setup in each position .

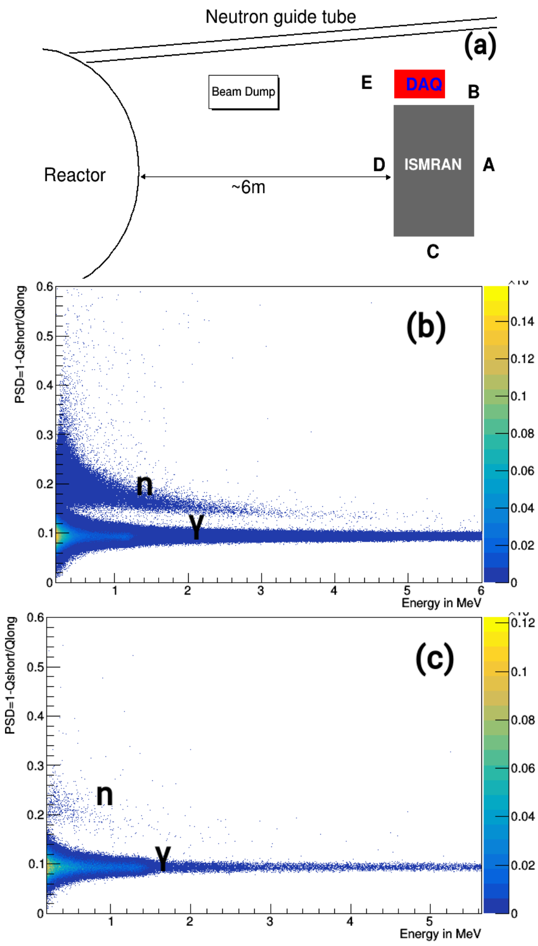

FIG. 1: a)The schematic drawing of the experimental setup at five different positions indicating by A,B,C,D and E,b)Reactor ON PSD vs Energy,c)Reactor OFF PSD vs Energy.

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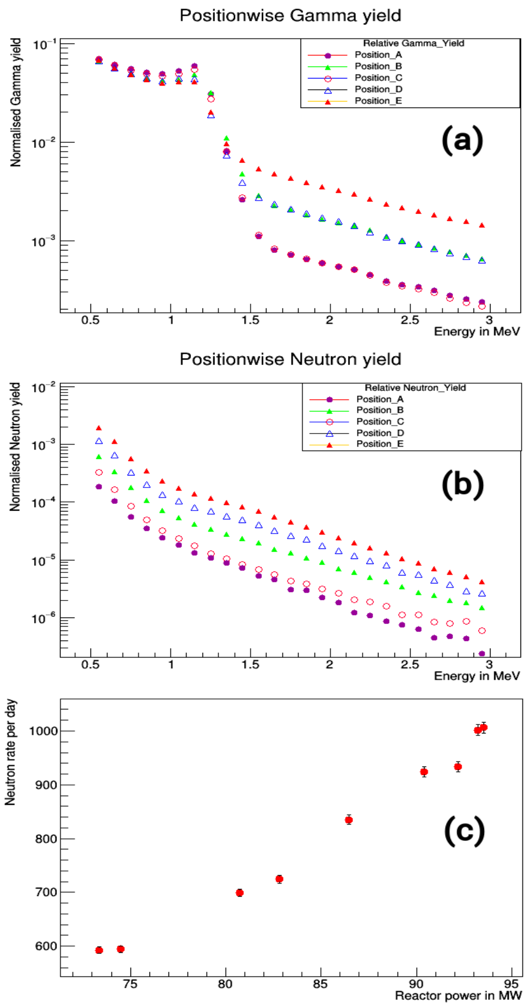

FIG. 2: a)Normalised Gamma yield Vs Energy at different positions.b)Normalised Neutron yield Vs Energy at different positions.c)Integrated Neutron rate (/day) Vs Reactor power.

3.Data analysis and Results

In order to know the specific relationship between light output distribution and the energy deposited in scintillator , the gamma energy calibration for the NE213 liquid scintillation detector was done with standard gamma sources such as Na^{22}, Cs^{137} and Co^{60} (assuming that below 5 MeV to get the same light output for gamma and neutron in liquid scintillator neutron energy has to have 2-3 times higher than gamma energy) . To seperate fast neutron from γ we use PSD technique , which is introduced :

PSD = 1 - Q_{short}/Q_{long} , where Q_{short} = Charge integrated in short gate ; Q_{long} = Charge integrated in long gate .

Using this PSD parameters we measure the variation of gamma yield and neutron yield . with energy,which is shown in fig 2(a) and fig2(b) respectively , both yield has been normalised with reactor power .

Some kind of measure for the quality of separation is necessary for studying the efficiency of the separation and how the results vary when the gates are displaced . In order to check the quality of n-γ separation , a figure-of-merit(FOM) is introduced :

FOM = μ_n - μ_γ /2.35(σ_γ + σ_n).

FOMs over different time intervals were extracted for the purpose of evaluating the optimum integration intervals for Q_{short} and Q_{total} . The fast neutron yield increases with the increasing Reactor power in the measured region of power from 73 MW$_{th}$ to 93 MW$_{th}$, which is shown in fig 2(c) .

4.Conclusion

We got a peak around 1.2 MeV in normalised gamma yield spectrum at both reactor ON and reactor OFF condition , due to compton edge of K^{40}. Measured normalised neutron yield at position 'E' is higher than any other position . The optimum value for Q_{short} gate is 28 ns with FOM = 1.72 , at which we can separate the fast neutron against gamma background by $> 3\sigma$ at 99% C.L . At 95 MW_{th} reactor power measured integrated neutron rate per day is around $\sim$ 1000 and at reactor OFF condition measured integrated neutron rate per day is around $\sim$ 35

5.Acknowledgments

I am thankful to Dr.P.C.Rout for giving NE-213 liquid scintillator .

References

[1] A plastic scintillator array for reactor based anti-neutrino studies, DOI: 10.1016/j.nima.2018.10.026.

[2] Sensitivity to sterile neutrino mixing using reactor antineutrinos.Eur. Phys. J. C (2019) 79:86.