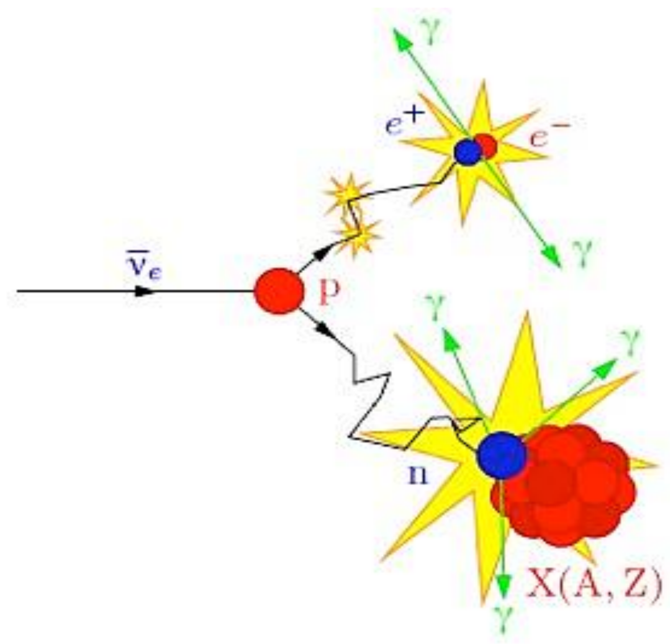
Indian Scintillator Matrix for Reactor Anti-Neutrino detection

D. Mulmule*, P. K. Netrakanti, A. Mitra, V. K. S. Kashyap, V. Jha,
D. K. Mishra, S. P. Behera, L. M. Pant, B. K. Nayak & A. Saxena
Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai, 400 085, India
*** email : dhruv.mulmule@gmail.com***

Introduction :

Reactor anti-neutrino detection:

- Anti-neutrino from reactors provide an excellent non-intrusive probe for monitoring reactor core composition
- The detection of $\overline{\nu}_e$ through the inverse beta decay, with its distinct prompt and delayed event signature, is a useful technique for the above purpose which is being pursued actively across the world by many groups[1]



Inverse Beta Decay

$$\overline{\nu}_e + p \rightarrow n + e^+$$

Prompt e^+ signal: Energy loss+Annihilation

$$e^+ + e^- \rightarrow 2\gamma$$

Delayed neutron signal: Capture on Gd

$$n + {}^{155}Gd \rightarrow {}^{156}Gd^* \rightarrow {}^{156}Gd + \gamma's$$

$$n + {}^{157}Gd \rightarrow {}^{158}Gd^* \rightarrow {}^{158}Gd + \gamma's$$

The Proposed Detector (ISMRAN) :

- Segmented geometry : Plastic Scintillator (PS) bars of 10cm x 10cm x 100cm directly coupled to 3" PMTs at both ends
- Each bar wrapped with a reflective aluminized mylar film coated with 4.8 mg/cm^2 density Gadolinium (Gd) paint to facilitate neutron capture

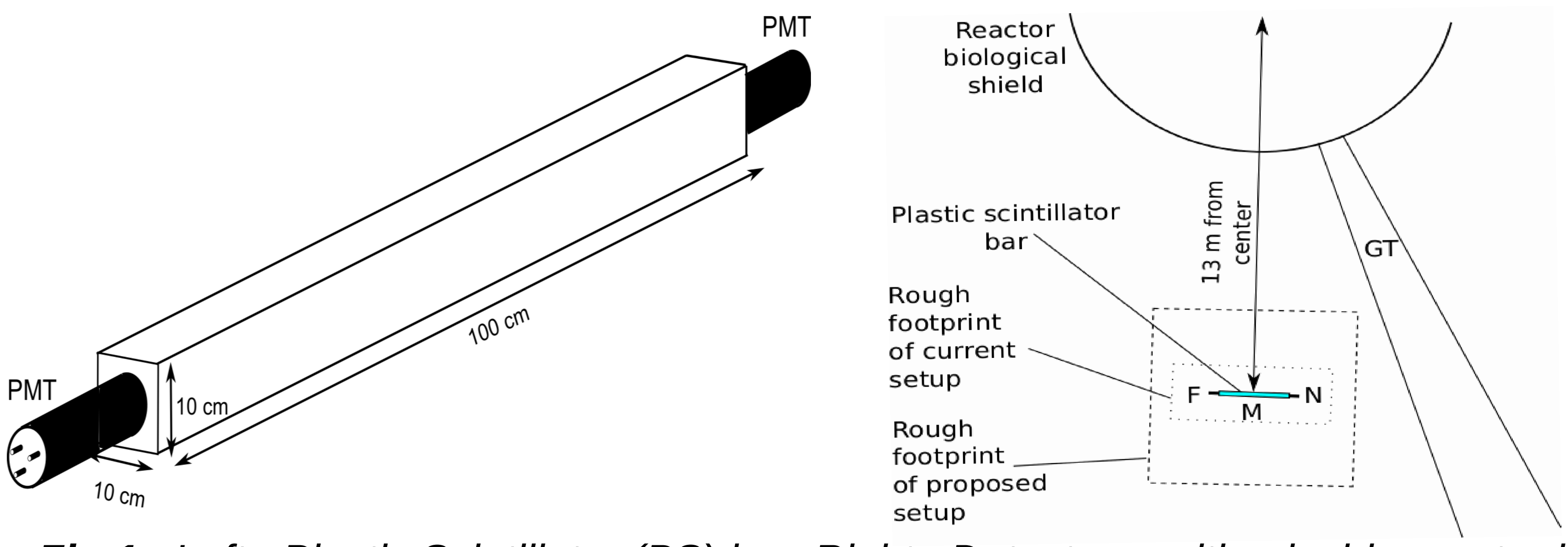


Fig 1. *Left : Plastic Scintillator (PS) bar. Right : Detector position inside reactor hall*

- Total 100 such bars forming a 1m^3 volume of 1 ton weight of detector.
- About 115 neutrino interactions per day are expected a 13m distance from the reactor core operating at 100 MW_{th}
- High sampling rate (500 MS/s) digitizers to read the 200 PMT channels.

Characterization of 10x10x100cm^3 PS bars :

Energy calibration and position dependent response measurements:

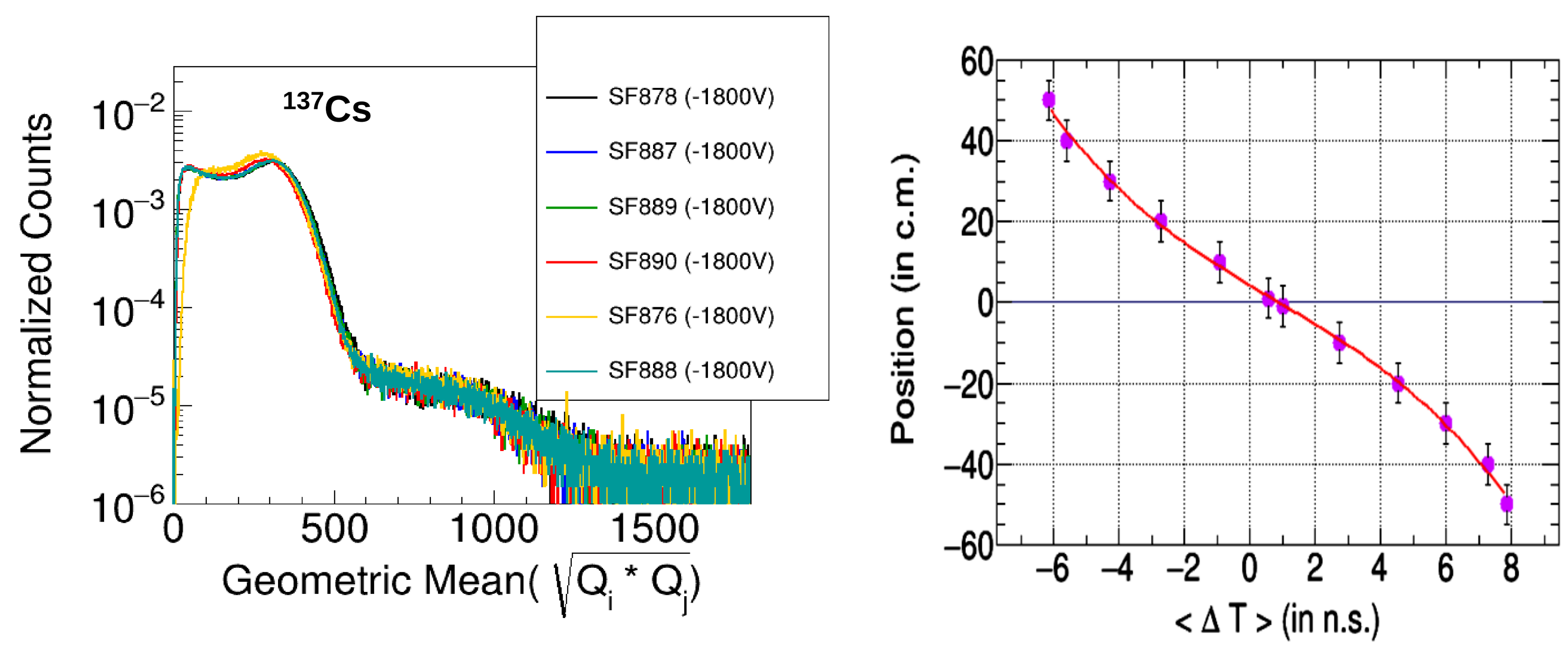


Fig2 *: Left : Response of PS bars for ^{137}Cs source. Right : Parametrization of hit position as a function of time difference from both the ends of a PS bar*

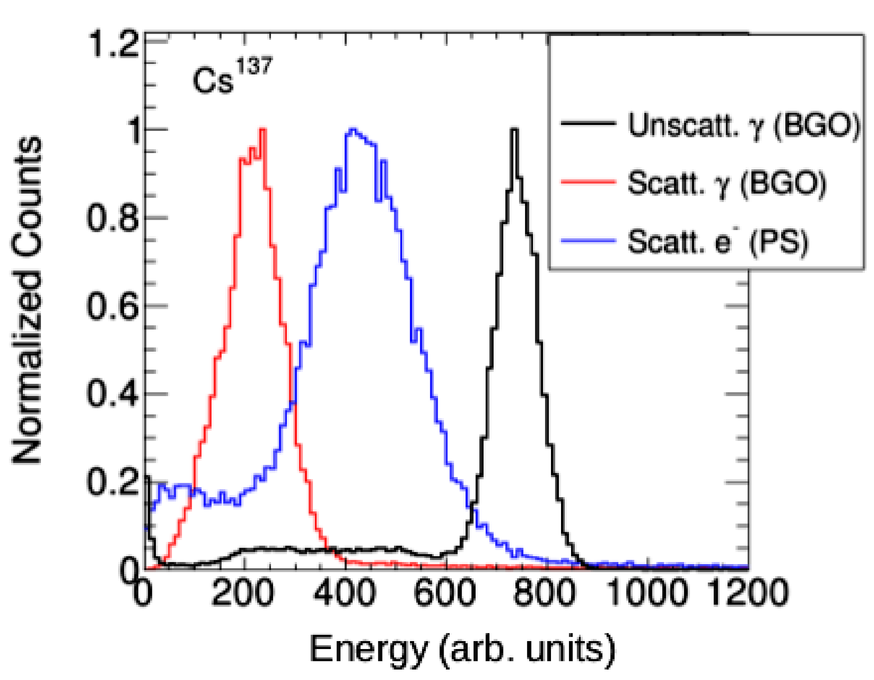


Fig 3. *Energy distribution for Compton scattered gamma from BGO detector (red) in co-incidence with electron detected in the PS bar (blue)*
Also shown is the unscattered ^{137}Cs gamma photo-peak in BGO detector (in black)

Background measurements @ Dhruva reactor :

- Due to very small neutrino interaction cross-section (~10^{-43} cm^2) reactor background dominates over the neutrino signal
- Measurements were performed using liquid and plastic[2,3] and scintillators inside the reactor hall using different configurations of shielding

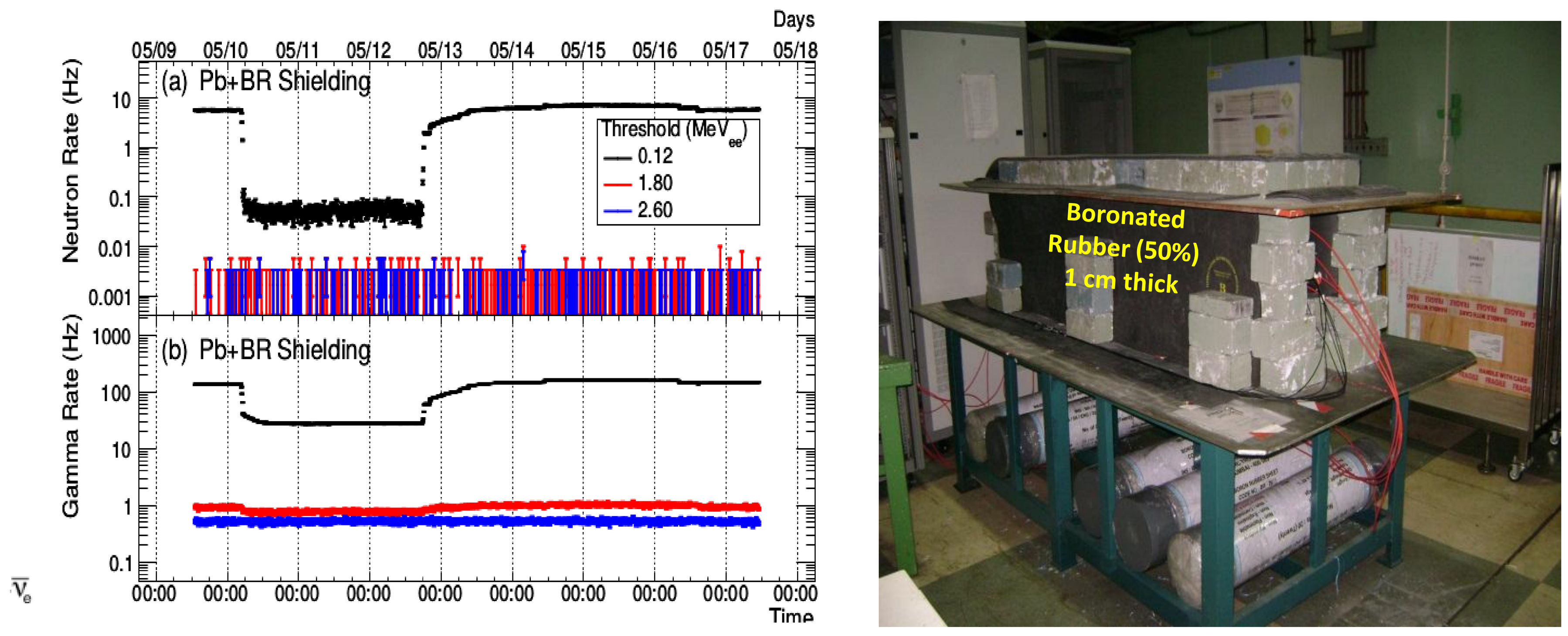


Fig 4. *Left : Gamma and neutron background rates measured using 5" diameter, NE-213 liquid scintillator with 10cm thick Pb + 1cm thick boronated rubber sheets during both reactor ON and OFF periods.[3] Right : Snapshot of the prototype detector setup (PS : 6cm x 6cm x 100cm) in the Dhruva reactor hall*

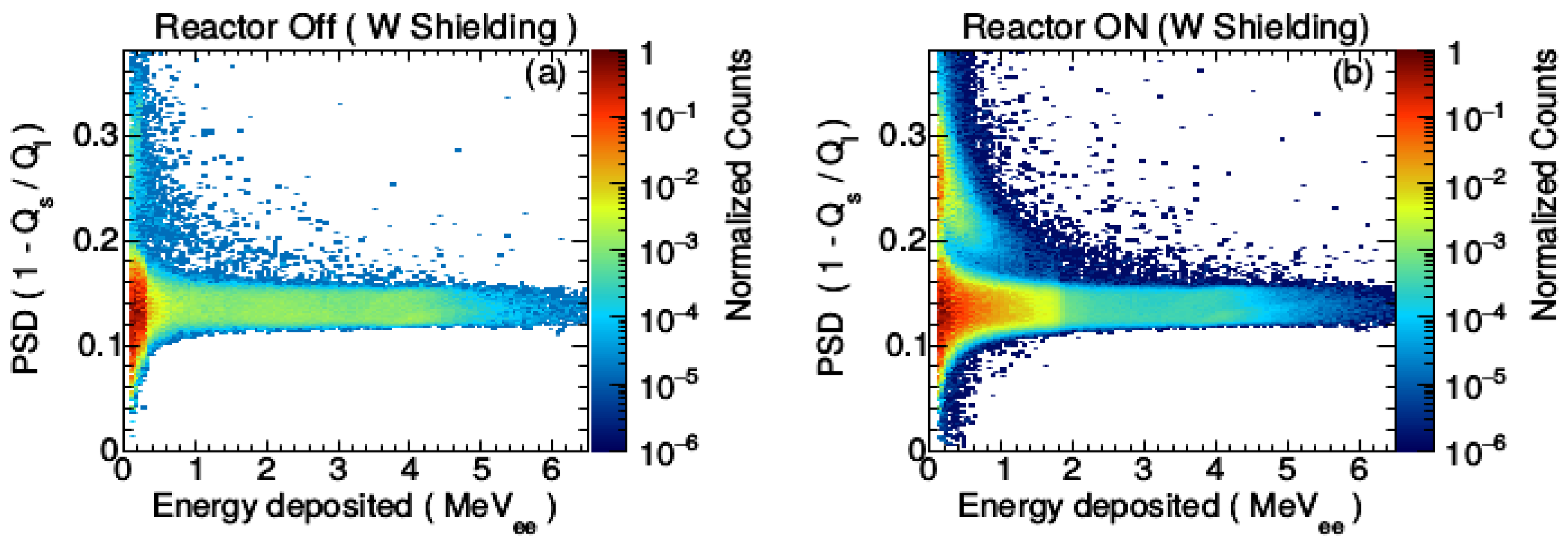


Fig 5 *: Pulse shape discrimination parameter as a function of energy deposited using NE-213 Liquid scintillator detector in reactor ON and OFF conditions.*

Table 1. Background statistics obtained in a 4x2 matrix of 6cm x 6cm x 100cm PS bars. Reduction can be seen in PS bars, when in addition to shielding, certain specific co-incidence conditions are applied (here 2 bars firing in a certain time window of the order of 100 μs). Reactor was operating between 80-85 MW.

Various Configurations	Count Rates (Hz)
No Shielding (Single PS bar)	30000
10 cm Pb (Single PS bar)	2000
10 cm Pb (Co-incidence of two PS bars)	300
10 cm Pb + 1 cm of Boronated Rubber (Co-incidence of two PS bars)	70

Outlook :

- Detection of anti-neutrinos in current set-up will need a S/B ratio of at least 1:10 and also a thorough understanding of background sources, both originating from reactor and the cosmogenic sources. These studies are currently being pursued.
- Trigger logic implementation at hardware level for candidate anti-neutrino events
- We plan to setup mini-ISMRAN with a matrix of 4x4 (PS : 10cm x 10cm x 100cm) in a non-reactor environment, before shifting to Dhruva reactor hall

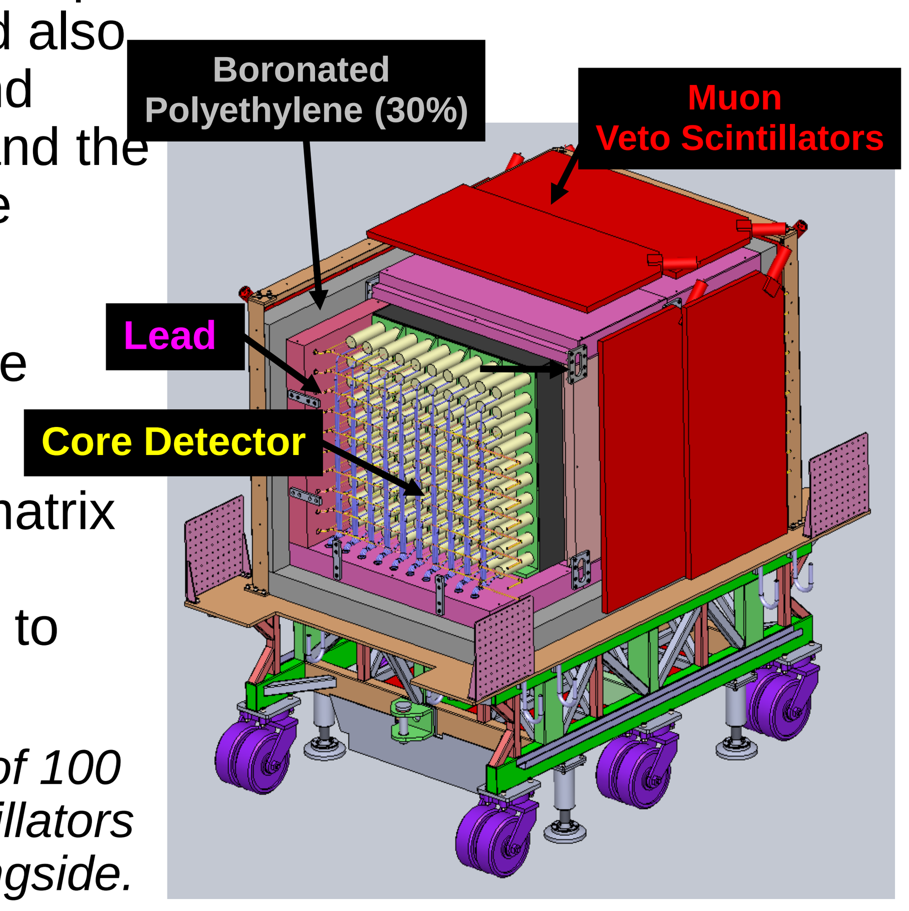


Fig 6*. The final setup (tentative) consisting of 100 PS bars with shielding and muon veto scintillators Is shown in figure alongside.*

References :

[1] Y. Kuroda et. Al, Nuclear Instruments and methods A, 690 (2012), 41-47.

[2] V.K.S. Kashyap et. Al, Proceedings of the DAE-BRNS Symp. on Nucl. Phys. 60 (2015)

[3] Neutron and Gamma rate measurements at Dhruva reactor for ISMRAN experiment, DAE-BRNS Symposium 2016, SINP, Kolkata(submitted)