

Plastic scintillator detector array for detection of cosmic ray air shower

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Introduction

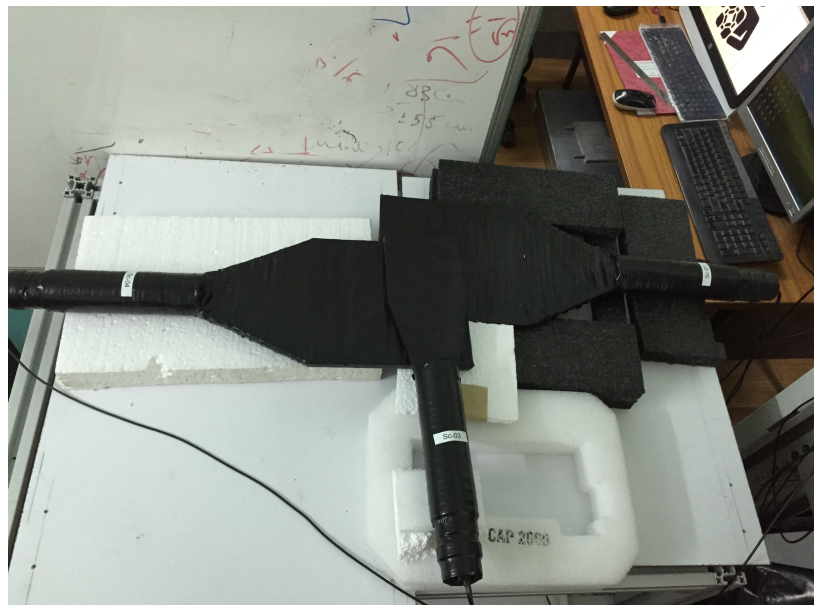
An array of 7 active detectors have been developed to study cosmic ray extended air showers at an altitude of about 2200 meter above sea level in the Eastern Himalayas (Darjeeling). Each detector element consists of four plastic scintillators of dimension 50 cm x 50 cm x 1 cm making the total active area of 1 m x 1m. These scintillators have been fabricated indigenously in Cosmic Ray Laboratory (CRL), TIFR, Ooty, India. All four scintillators of a detector are coupled with a single Photo Multiplier Tube (PMT) using wavelength shifting (WLS) fibers.

We have also measured the cosmic ray muon flux and its variation over time both in Darjeeling and in Kolkata (altitude ~11 m above sea level). In the laboratory at Kolkata, plastic scintillator detector modules have been fabricated using BC400 material. We have also developed a new method to automatically and continuously record the muon flux using NIM electronics and MCA.

The pulse height distribution for the muons has been obtained from a Digital Storage Oscilloscope interfaced with a PC. The pulse height distribution is fitted with the Landau function and the most probable energy deposited by cosmic muons in plastic scintillator is estimated.

Measurement of cosmic ray flux

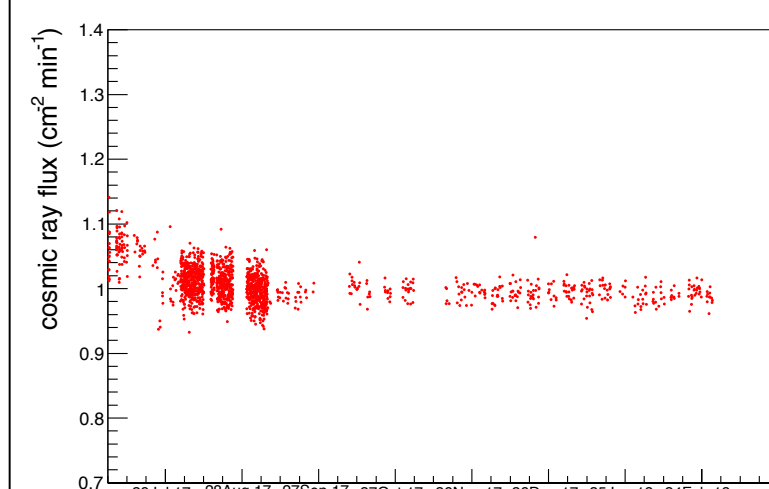
Dimension of the scintillator blocks at Kolkata: 20 cm x 20 cm, 20 cm x 18 cm and 10 cm x 10 cm
Dimension of each scintillator block at Darjeeling: 0.5 m x 0.5 m, One detector consists of 4 such blocks



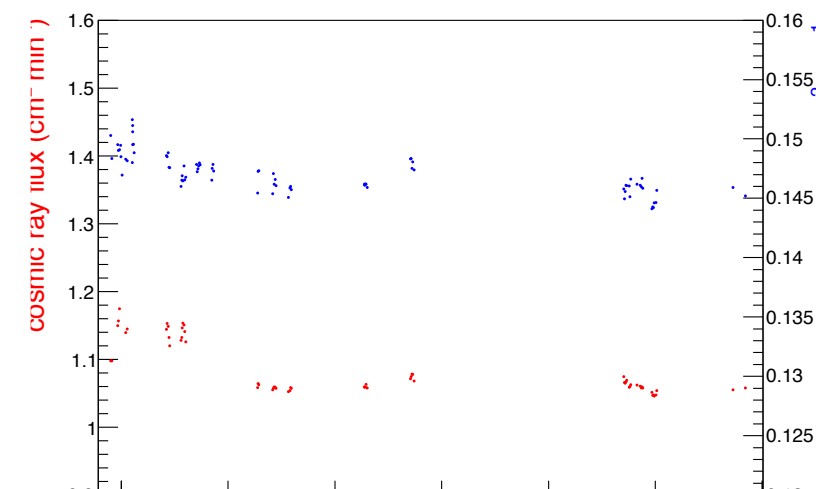
Experimental set-up at Kolkata



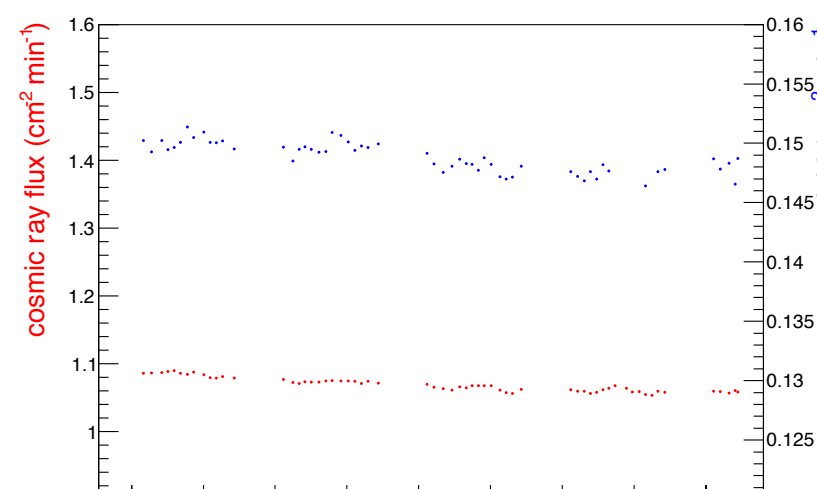
Experimental set-up at Darjeeling



Cosmic ray flux vs. time in 2017-18 at Kolkata



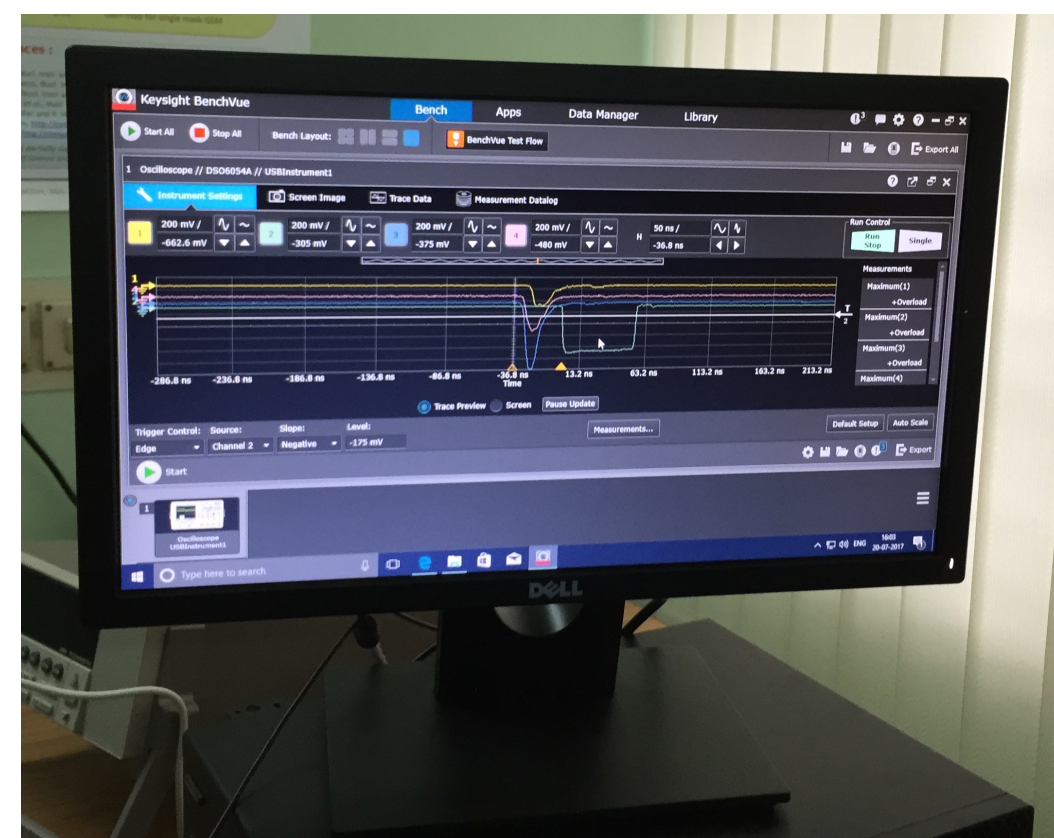
Cosmic ray flux vs. time in 2017 at Darjeeling



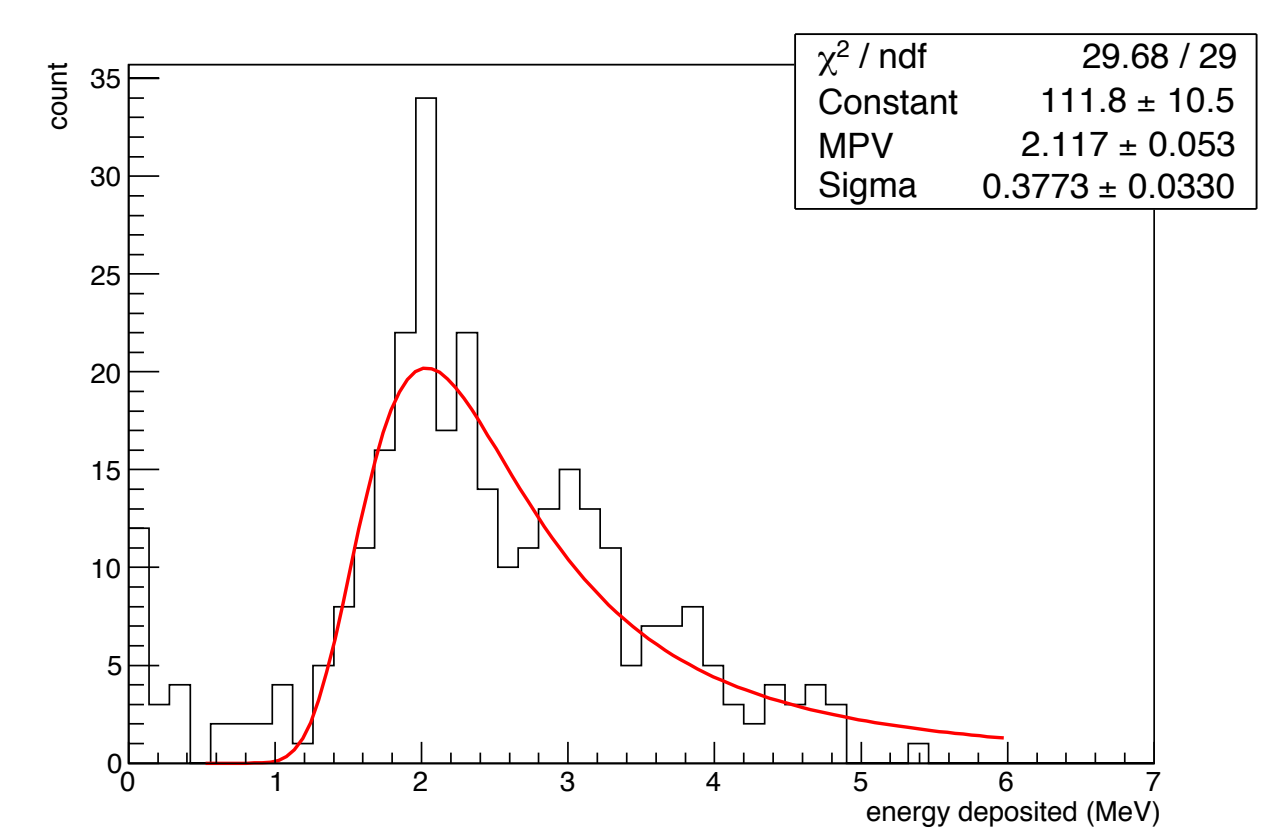
Cosmic ray flux vs. time in 2018 at Darjeeling

- At Kolkata the overlapping area of three scintillators is 100 cm².
- Efficiency of the detector system is found to be 68%.
- Cosmic ray flux over time is measured keeping +1650 V to all three scintillators and counting the 3 fold coincidence using a scalar counter.
- At Kolkata the average value of the cosmic ray flux is found to be 1.007 per cm² per minute with a fluctuation of 0.026 (RMS).
- At Darjeeling seven 1m x 1m plastic scintillator detectors are used in a vertical stack.
- The cosmic ray flux is measured using three topmost detectors of the stack. The count rate for the 7-fold coincidence is also measured to get the idea of number of exactly vertical muons.
- The average cosmic ray flux at Darjeeling is found to be ~ 1.077 per cm² per minute with RMS 0.029. The average 7-fold coincidence rate is 0.148 per cm² per minute with RMS 0.001.

Pulse height distribution for cosmic ray



Screenshot of the oscilloscope in computer monitor



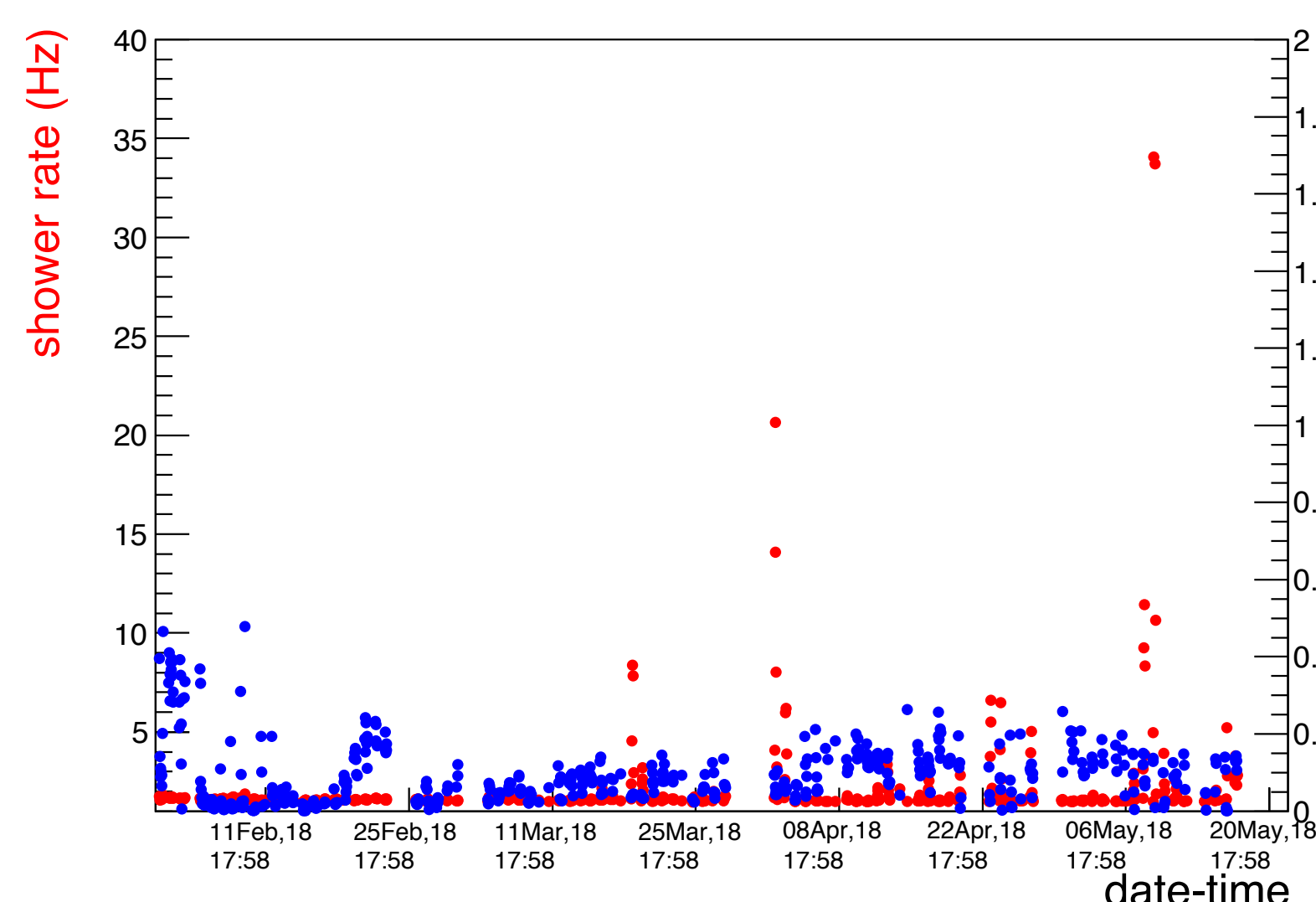
Pulse height spectrum from a plastic scintillation detector

- Analog signals from 3 scintillator detectors and the three-fold coincidence signal are fed to a DSO
- The DSO is interfaced with computer using BenchVue software
- For each coincidence signal three individual analog signals are stored with amplitude, rise time and fall time information
- For each pulse the integrated charge (q₀) collected at the anode of the PMT is measured
- The initial charge q_i = q₀/10⁶; 10⁶ = gain of the PMT
- Knowing q_i and from the definition of quantum efficiency (η_q) of the photocathode of the PMT, the number of photons that reach the cathode is calculated
- It is known that only 1/3 of the total photons reached on the PMT
- Total Number of Photons = Number of Photons × 3
- Light output of BC400 is 10,000 photons/MeV.
- Amount of Energy Deposition in MeV = Total Number of Photons/10000
- The typical energy distribution for a scintillator detector is shown
- The experimental data is fitted with Landau distribution and the most probable value is found to be 2.1 MeV for a 1 cm thick plastic scintillator

Detection of cosmic ray air shower



Cosmic shower detection array at Darjeeling



Cosmic shower rate Vs. time

- To measure the cosmic ray shower at Darjeeling six detectors are kept at the vertices of a hexagon and one at the center of it in the horizontal plane. The distance between any two detectors is kept to be 8 meter. The negative high voltage (HV) to the PMTs of the scintillators is applied using MHV cable and the signal is collected by BNC cable.
- A custom-built module with seven inputs is used to generate multi-fold trigger. The trigger is generated when the central detector and any two detectors give signal simultaneously. Continuous measurement of cosmic ray air shower is going on since end of January 2018. At the altitude of about 2200 meter the average air shower rate has been found to be ~1.6 Hz with a RMS 0.2. An oscillating nature of shower rate is also observed with time. The rate of air shower hitting all 7 detectors are also measured and it is found to be ~ 0.04 Hz with a RMS 0.02.

Summary and outlooks

The cosmic ray flux is measured at Kolkata (altitude ~11 m above sea level) and at Darjeeling (altitude of about 2200 meter above sea level). The cosmic ray flux at Darjeeling and Kolkata are found to be ~ 1.077 and 1.007 per cm² per minute respectively. In the first experiment at Darjeeling at the altitude of about 2200 meter the average air shower rate has been found to be ~1.6 Hz. An oscillating nature of shower rate is also observed with time.

Acknowledgements

We would like to thank the scientists of Cosmic Ray Laboratory (CRL), Tata Institute of Fundamental Research (TIFR), Ooty, India for fabrication of these scintillators indigenously. We are thankful to Bose Institute workshop for all the mechanical work. We would also like to thank Mr. Deb Kumar Rai, Mrs. Yashodhara Yadav, Mr. Sabyasachi Majee, Mr. Vivek Gurung for their help in this work. Special thanks to Mrs. Sharmili Rudra for helping in some measurements at Darjeeling. Finally we acknowledge the IRHPA Phase-II project of Department of Science and Technology, Government of India.



PM2018 - 14th Pisa Meeting on Advanced Detectors, 27 May- 02 June 2018, La Biodola, Isola d'Elba, Italy