Extending the Particle Densities Observed by GRAPES-3

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GRAPES-3 (Gamma Ray Astronomy at PeV EnergieS-3)

Scintillation Detectors Array
(11.4° N latitude, 76.7° E longitude and 2.2 km a.s.l)

- 400 Plastic scintillation detectors (1 $m^2$ each).
- 8-m inter detector separation.
- Hexagonal layout.
- Total area covered 25,000 $m^2$.
- Measures density, relative arrival time of particles to estimate energy and direction.
- Nuclear composition of EAS by using Muon Multiplicity Distribution (MMD).

Anuj Chandra (35th ICRC, Busan, S. Korea)
Proportional Counters Array

Detects clean muon.

- 3712 proportional counters (600 $\times$ 10 $\times$ 10 $cm^3$ each).
- 4 muon stations each contains 4 modules, spanning a total area $(4 \times 4 \times 35 \ m^2) = 560 \ m^2$.
- Concrete absorber of ($\sim$550 gm-cm$^{-2}$)
- Records muon flux ($> 1$GeV), detect and measure the muon components in EAS.
Motivation

A better understanding of cosmic ray spectrum around the knee ($\sim 10^{15}$ eV).

By using data of higher particle density in the estimation of energy for compositions of cosmic rays.

Therefore, particle density is a key parameter.
For a very large EAS, PMT gets saturated.
Limits the measuring particle densities at high energy cosmic rays.

To increase the dynamic range of particle density: The modified configuration of 2-PMT scintillation detector with Wave Length Shifting (WLS) fibers (blue to green).
Detector Components

<table>
<thead>
<tr>
<th>High Gain PMT</th>
<th>Low Gain PMT</th>
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<tbody>
<tr>
<td>No. of Fiber: 72</td>
<td>No. of Fibers: 24</td>
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<tr>
<td>Direct Single Particle Calibration</td>
<td>Indirect Single Particle Calibration</td>
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- All 105 double PMT detectors are in operation.
Gaussian fit to the single particle distribution after pedestal subtraction in the appropriate range gives the gain value of the detectors.
Normal ADC Distributions of Low Gain PMT merges with pedestal, therefore it does not allow to calibrate low gain PMTs directly.
Indirect Method of Calibrating Low Gain PMTs

- Ratio of High Gain PMT to Low Gain PMT output (HLR) is calculated.
- Operating voltage of Low Gain PMT is adjusted to keep $<\text{HLR}>$ of $50 \pm 10\%$. 

![Graph showing the relationship between ADC counts and Ratio(HLR).]
Pulse cable was cut into pieces by some wild animal.
Estimation of Particle Density

- Particle density is calculated by subtracting the concurrent pedestal value of observed ADC counts.
- Divided by single particle gain for the detector.
- Present study is based upon the 5 months of uninterrupted data.
HG & LG PMT Particle Density

Figure: Red distribution is High Gain PMT and Blue distribution is Low Gain PMT particle density

- Since there is a good overlap of particle density from both PMTs in the range of around 30 - 60.
Particle density has been extended $\gtrsim 5000$ particles (m$^{-2}$) for each detector.
Combined Particle Density Spectrum from HG & LG

- $\leq 50$ particles for HG PMT
- $> 50$ particles for LG PMT
Fit with power law in the range of 5 - 500 particles.

$\gamma \sim 1.61$. 
Summary

- Study of particle densities from 2-PMT detectors show the extended dynamic range upto ($\gtrsim 5000$ particles).

- Power law fit gives the spectral slope of 1.61.

- The extended particle densities from 2-PMT detectors will be used for extending the energy range of GRAPES-3 measurements beyond the knee.
Thank You