An extensive study for correcting the nonlinear particle density measured by GRAPES-3 scintillator detectors

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Introduction

- Located at Ooty, India at 11.4° N latitude, 76.7° E longitude and an altitude of 2.2 km amsl.
- 400 (1 m^2) plastic scintillation detectors with 8 m inter–detector separation.
- 105 dual-PMT scintillator detectors.
- Tracking muon telescope (560 m^2).
- Total area covered 25,000 m^2.
- ∼3 million air shower events/day.

Figure 1. GRAPES-3 Air Shower Array

GRAPES-3 Plastic Scintillator Detectors

- Cone Type Detectors

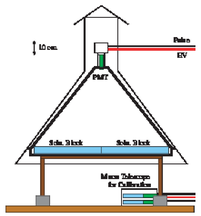

Figure 2. A Cone Type Detector, which is the first design @ GRAPES-3

- Fiber Type Detectors

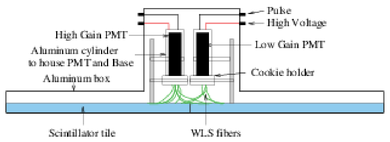

Figure 3. A Fiber Type Detector, which has two more types of configuration; one in which a single-PMT is attached and another 2-PMTs are attached

Observed Density Spectrum

- Particle Density Spectrum (HG-PMT): Follows a single slope ∼ 50 particles.
- After 50 particles, spectrum starts following non-linearity.
- Then, after 200 - 300 particles, saturation region.

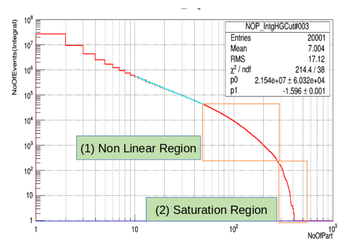

Figure 4. Observed Particle Density Spectrum

Correction Method

- Density Extrapolation and Correction Models

$$Y = A_{50} \times \left(\frac{x}{50}\right)^{-\gamma} \quad (1)$$

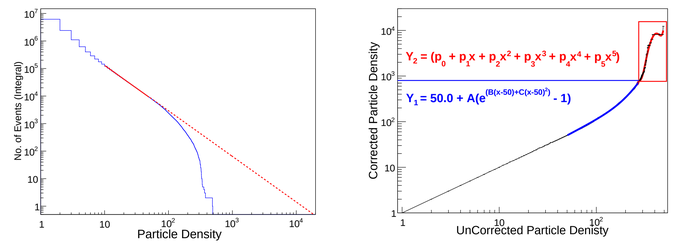

Figure 5. Left: Extraolation of particles, Right: Variation of Corrected Vs UnCorrected Density

- For NonLinearity Region (Model1): $Y_1 = 50 + A \times (e^{(B(x-50)+C(x-50)^2)} - 1)$
- For Saturation Region (Model2): $Y_2 = p_0 + p_1 x + p_2 x^2 + p_3 x^3 + p_4 x^4 + p_5 x^5$

References

1. S.K. Gupta et al., Nuclear Instruments and Methods in Physics Research A 540 (2005) 311–323.
2. P.K. Mohanty et al., Astroparticle Physics 31 (2009) 24 – 36.
3. A. Chandra et al., PoS (ICRC2017) 479.
4. A. Chandra et al., PoS (ICRC2019) 212.

Results and Discussion

- Correction methods are applied in two cases as shown as below:
- Left side panel, corrected with only NonLinearity model1, i.e. slowly varrying function.
- Left side panel, corrected with only Saturation region with model2, i,e. polynomial of 5^{th} order. In this case, the corrected density is extended to higher vales as compared to model1.

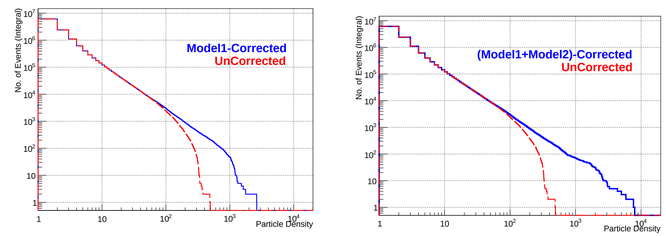

Figure 6. Left: Correction when only Model1 is used; Right: Correction when combined Model1+Model2 is used.

- A Density spectrum corrected with Model1+Model2 is compared with the observed density spectrum from the LG-PMT fo the same detector. Where corrected density spectrum is in good agreement with the observed density spectrum upto the particle density ∼ 5000 m^{-2}.

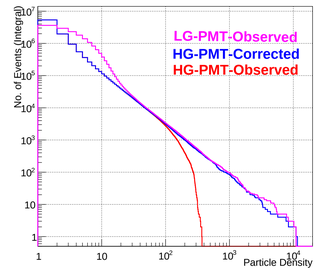

Figure 7. Corrected desnity spectrum of a HG-PMT is compared with density observed from LG-PMT

Conclusions

- Correction when using only Model1 is limited upto particle densities ∼ (500 – 800) m^{-2}.
- Correction when using combined Model1+Model2 is extended upto particle densities ∼ 3000 m^{-2}.
- This later is compared with the observed densities and hence, correction shows a good agreement with observations.