Vetoing the high energy showers in the GRAPES-3 experiment whose cores lie outside the array

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ABSTRACT

High energy showers landing hundreds of meters away from the array also generate trigger in the array. Some of such showers have their reconstructed cores within the array due to misreconstruction. This hampers the cosmic ray(CR) energy spectrum measurements. This poster demonstrates methods to remove such contaminated showers and the resulting improvements in energy spectrum.

Keywords: cosmic ray indirect, NKG reconstruction, energy spectrum, BDT

INTRODUCTION

- High energy showers landing far away from the array and generating trigger sometimes have their cores mis-reconstructed cores landing inside
- This number increases with energy due to lateral spread of shower
- This hampers the study of precise measurements of the cosmic ray (CR) energy spectrum

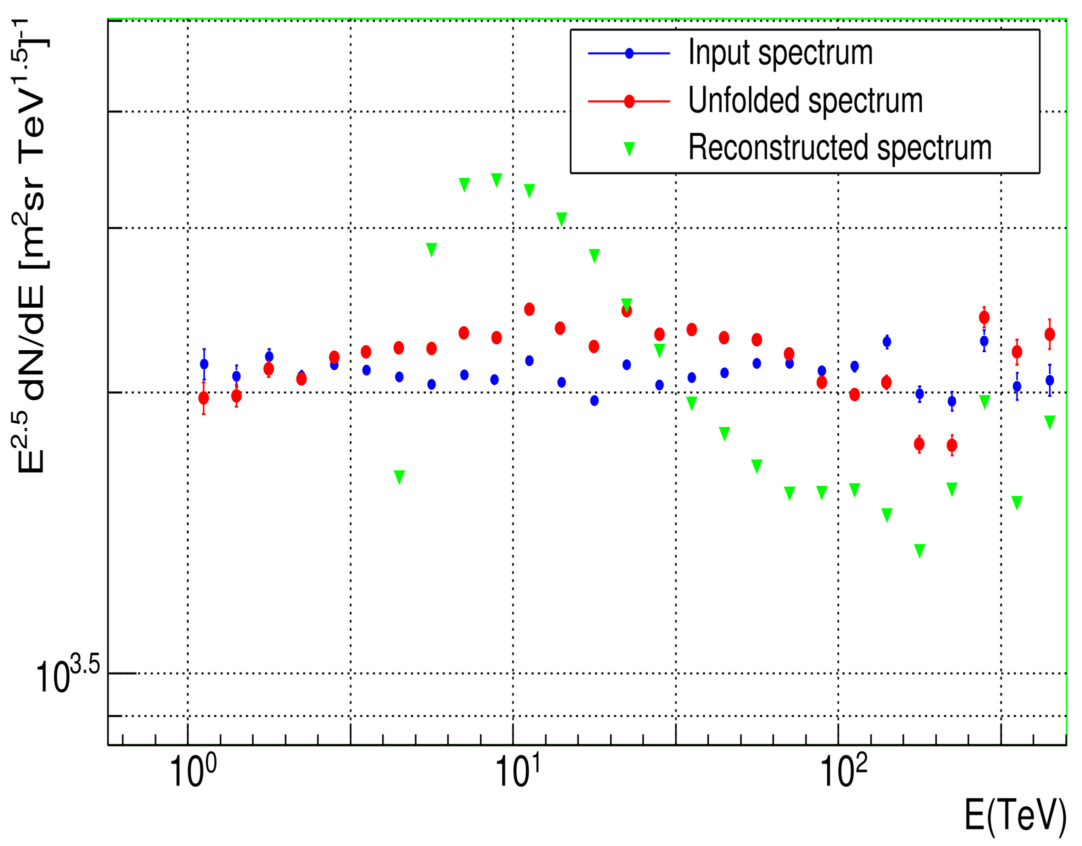

Figure 1: The true energy spectrum and the unfolded spectrum (generated with ROOUNFOLD[2]) of spectral index -2.5, the unfolded spectrum shows some deviation from true spectrum

REFERENCES

[1]Tanaka et,al,Nucl.Phys.B(Proc.Suppl.)175–176(2008)
[2]https://hepunx.rl.ac.uk/ adye/software/unfold/RooU

GRAPES-3 EXPERIMENT

- Location: Ooty, India (11.4°N, 76.7°E, 2200 m asl)
- ~ 400 plastic scintillators spread in $25000m^2$, 8 m inter detector separation
- Trigger: L0- 3 line coincidence, L1: atleast 10 detectors hit.
- Observables: particle densities and relative arrival times
- Statistics: ~ 3 million showers per day
- Muon telescope covering 560 m^2
- Energy range: 1 TeV - 10 PeV

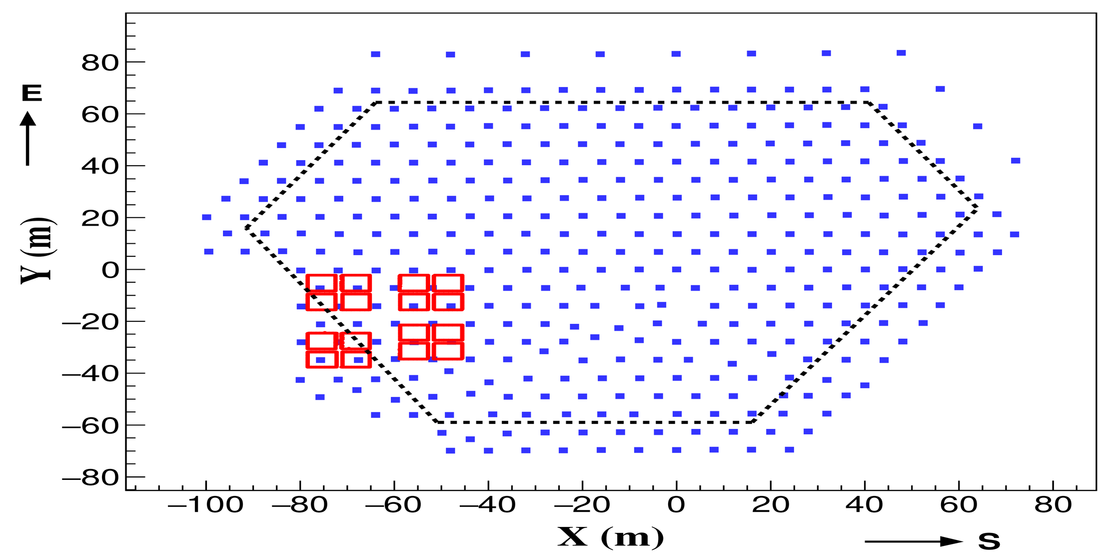

Figure 5: GRAPES-3 experiment, fiducial area marked by black dashed line

CORSIKA SIMULATION AND RECONSTRUCTION

- Hadronic interaction generator SIBYLL-FLUKA
- Proton : 1 TeV - 10 PeV with spectral index -2.5
- Detector response using GEANT4
- Reconstructed by fitting with NKG function using negative log-likehood minimisation, described in [1].
- Showers thrown upto distance beyond which trigger fraction is less than 1depending on energy.
- Zenith, $\theta \leq 25°$
- Showers with successful NKG fits, reconstructed cores within the array

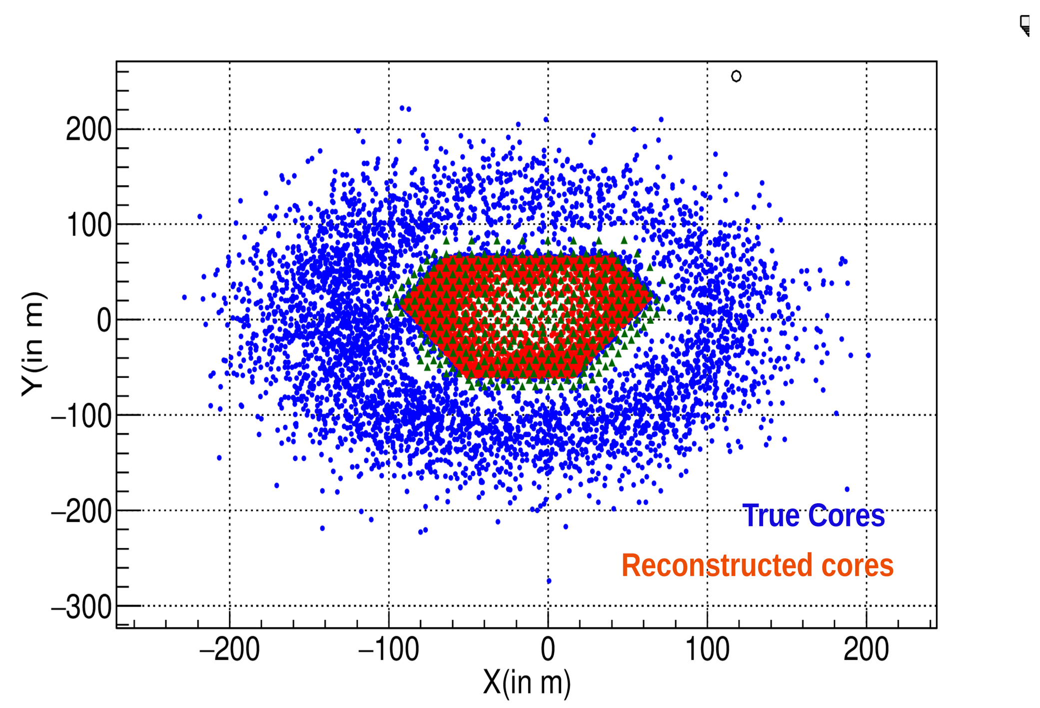

Figure 6: $100 < E < 158$ TeV showers, showing True cores and corresponding Reconstructed cores

ANALYSIS

Cuts are developed based on shower size manually as well as using machine learning.

- PSumRatio : Total particle density collected in outer two rings of detectors/Total particle densities collected leaving the outer two rings
- LnNKGP : The best value of log-likelihood function obtained, describes quality of NKG fit
- Age : Fit parameter
- Age error : error in age parameter
- ChiSq1 : ChiSq1 of planar fit performed on arrival times of secondaries to obtain shower direction

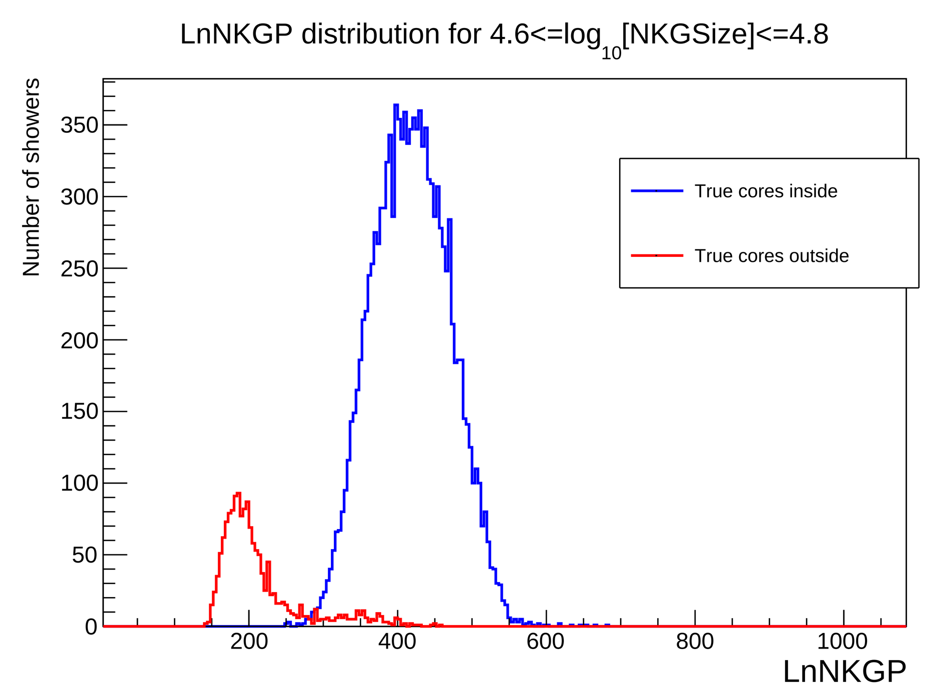

Figure 7: LnNKGP has been shown for $4.6 \leq log_{10}[NKGSize] < 4.8$

ANALYSIS METHODS

Manual cuts S: True and reconstructed cores inside, B: Only reconstructed cores inside (mis-reconstructed). We plots signal significance $S/\sqrt{S+B}$, and apply where is reaches maximum.

ML cuts Method used: Boosted decision tree with gradient boost Data is divided into train and test parts. Good agreement between train and test is ensured by KS test result> 0.05.

Finally contamination and signal losses are calculted with true energy.

RESULTS

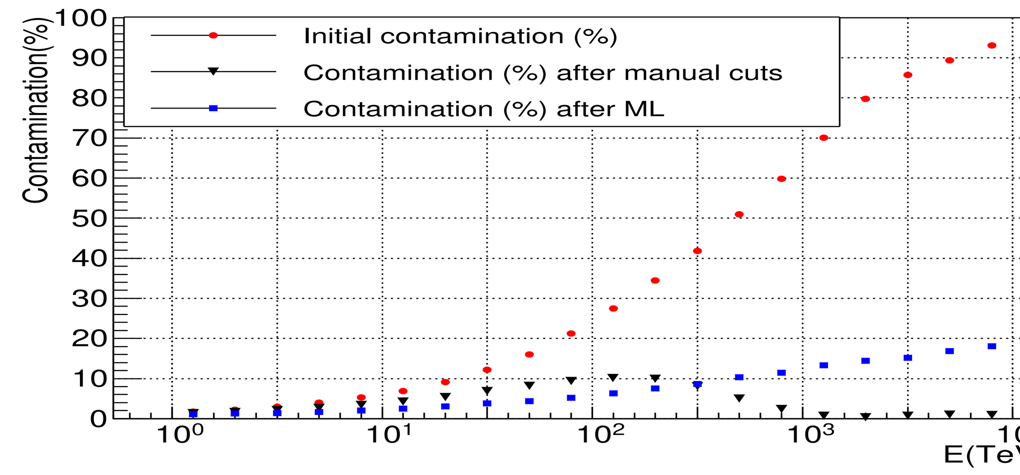

Figure 2: Contamination initially, and after applying cuts manually and by ML (preliminary)

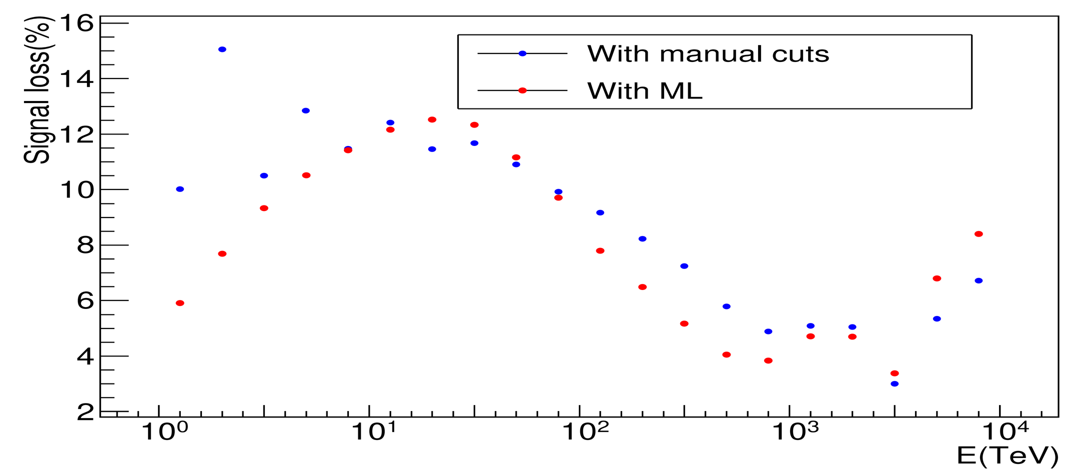

Figure 3: Loss of well reconstructed events after applying cuts using both methods (Preliminary)

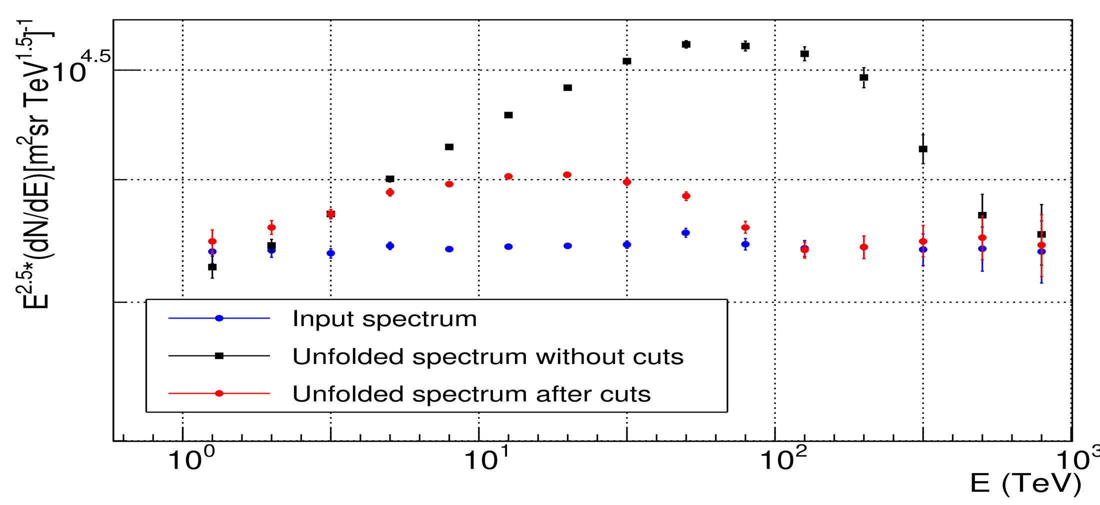

Figure 4: Improvements in energy spectrum measurement after applying manual cuts (Preliminary)

Future work: Furthur improvement of the results