

# Probing electromagnetic state of interplanetary space through measurements of cosmic ray diurnal anisotropy with GRAPES-3 tracking muon telescope

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## • Introduction

The convection of particles outward by solar wind and inward diffusion along interplanetary magnetic field produces a net anisotropic flow of galactic cosmic rays along the orbital direction of motion of Earth which manifests as diurnal variation in the counting rates of ground based detectors. Observations have showed existence higher harmonics in the diurnal anisotropy up to third.



View of the GRAPES-3 experimental site showing scintillator detector array, control room building (center) and muon detector buildings (left)

## • The GRAPES-3 Experiment

The GRAPES-3 experiment is located in Ooty, India (11.4°N, 76.7°E, 2.2 km altitude). It consists of an array of 400 scintillator detectors and a large area (560 m<sup>2</sup>) tracking muon telescope to study cosmic ray energy spectrum, elemental composition,  $\gamma$ -ray astronomy and various solar phenomena.



Inside view of one of the four muon detector halls

## • Tracking Muon Telescope

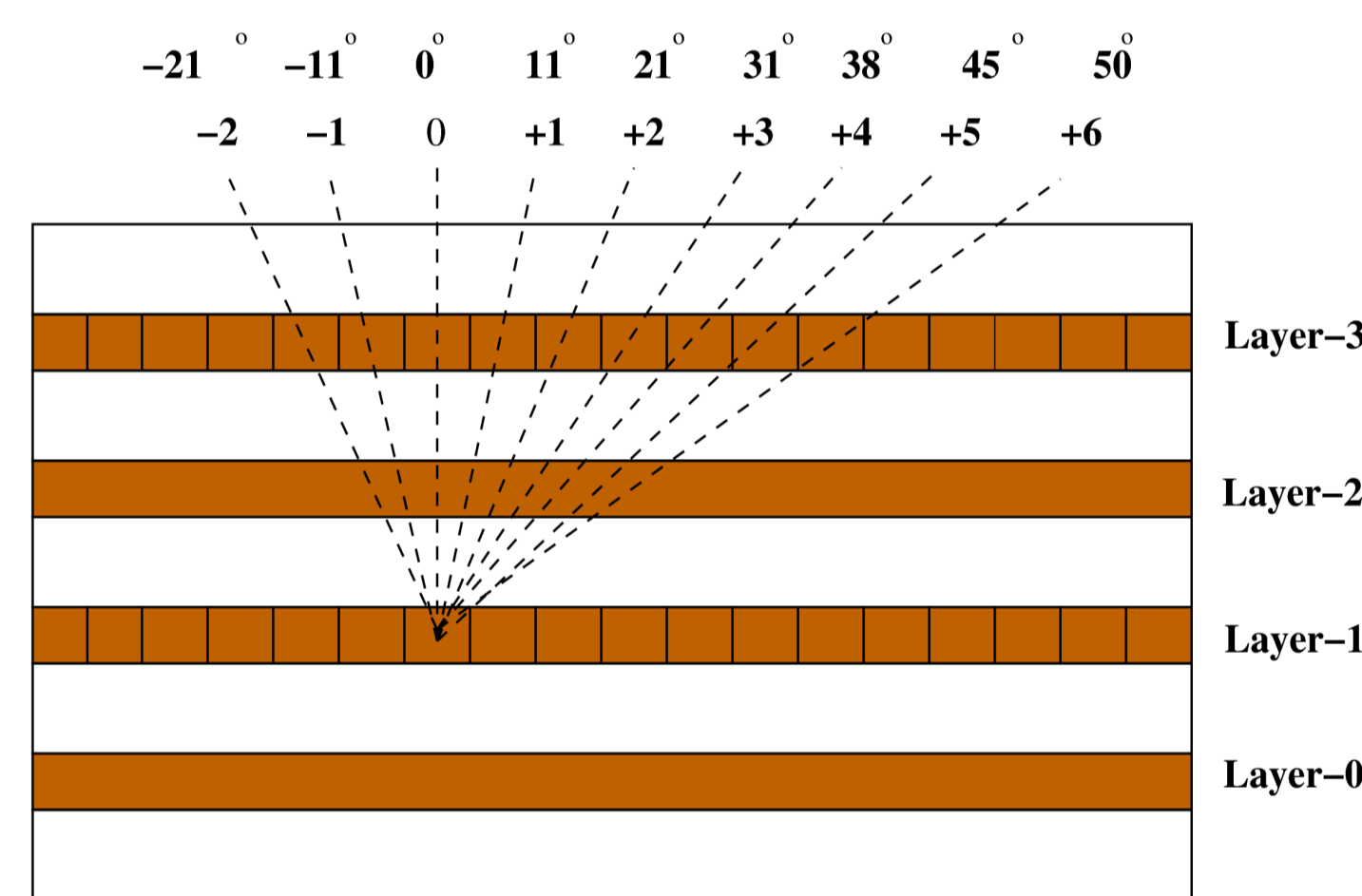
Basic elements: Proportional counters (PRCs)  
 Dimension: 6m x 0.1m x 0.1m  
 Filled gas: P10

Number of modules = 16 of 35 m<sup>2</sup> area each.  
 PRCs per module = 58 x 4 layers = 232

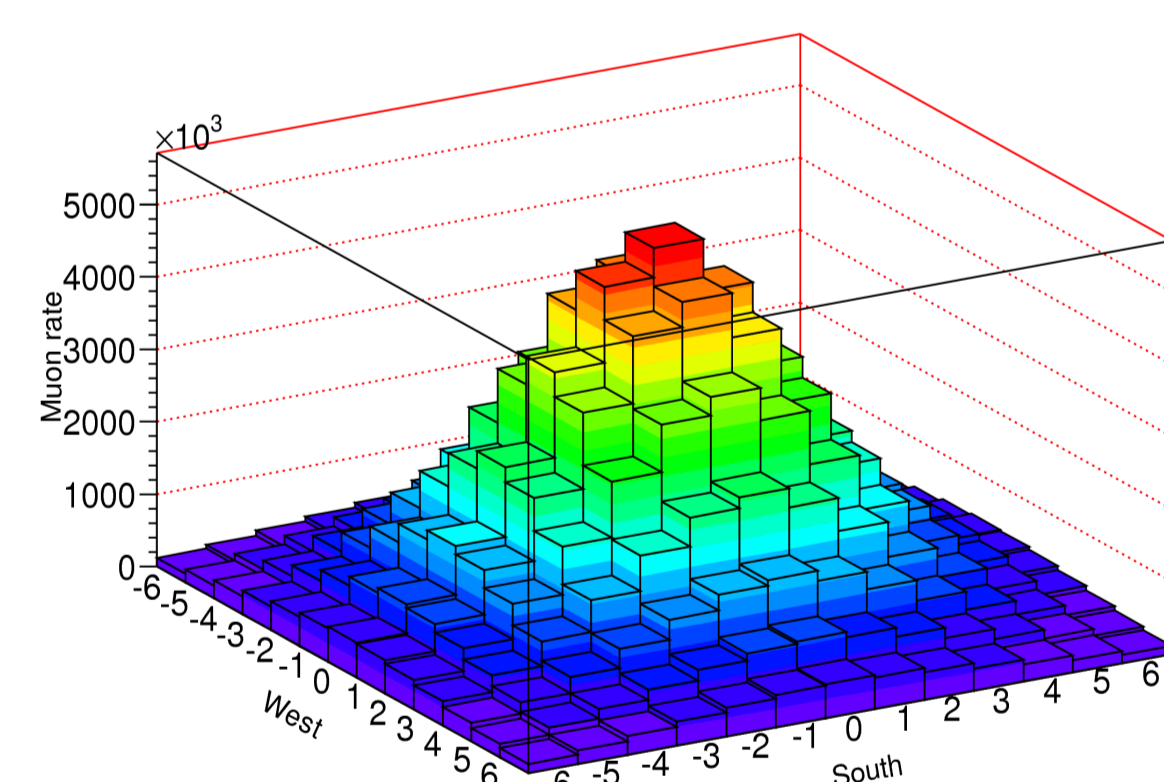
Energy threshold for detected muons = 1 GeV sec $\theta$ .

Number of directional bins = 13 x 13  
 Field of view = 2.3 sr  
 Observation = 24 x 7

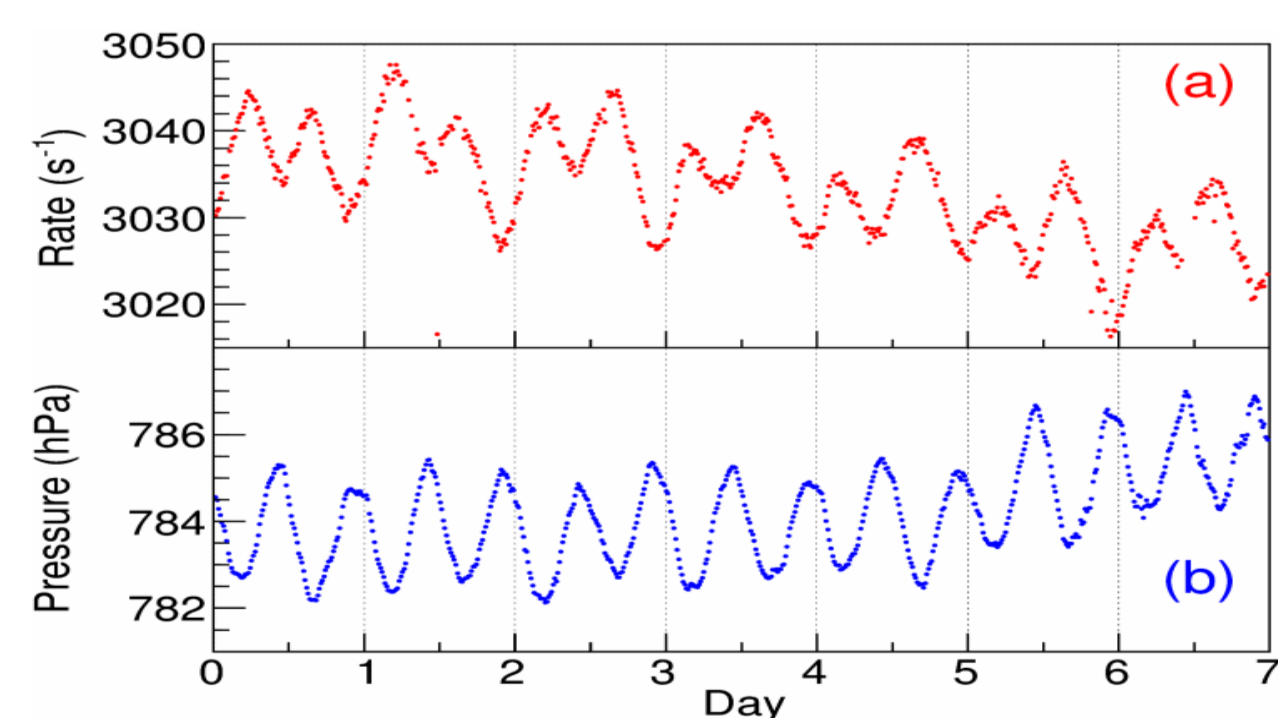
Time bin of recording muon rates: 10 s  
 Statistics:  $\sim 4 \times 10^9$  muons /day



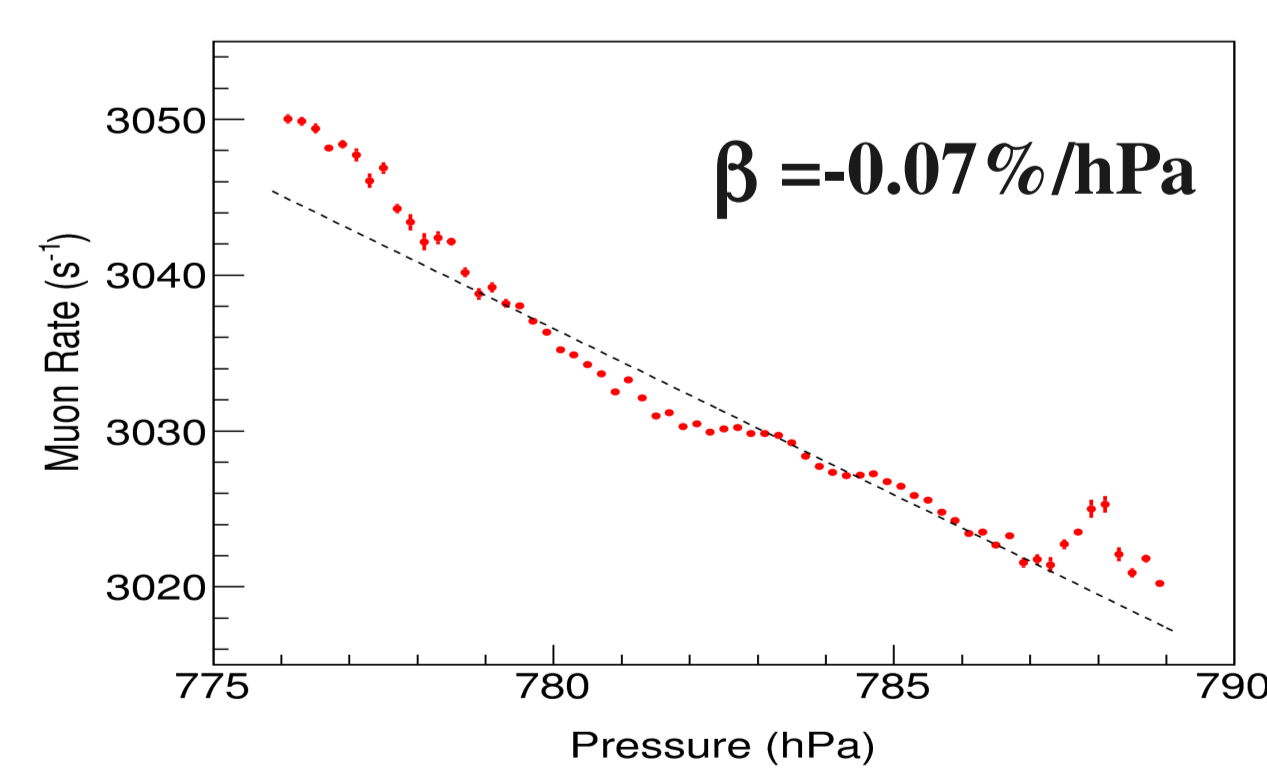
Direction reconstruction method for muons



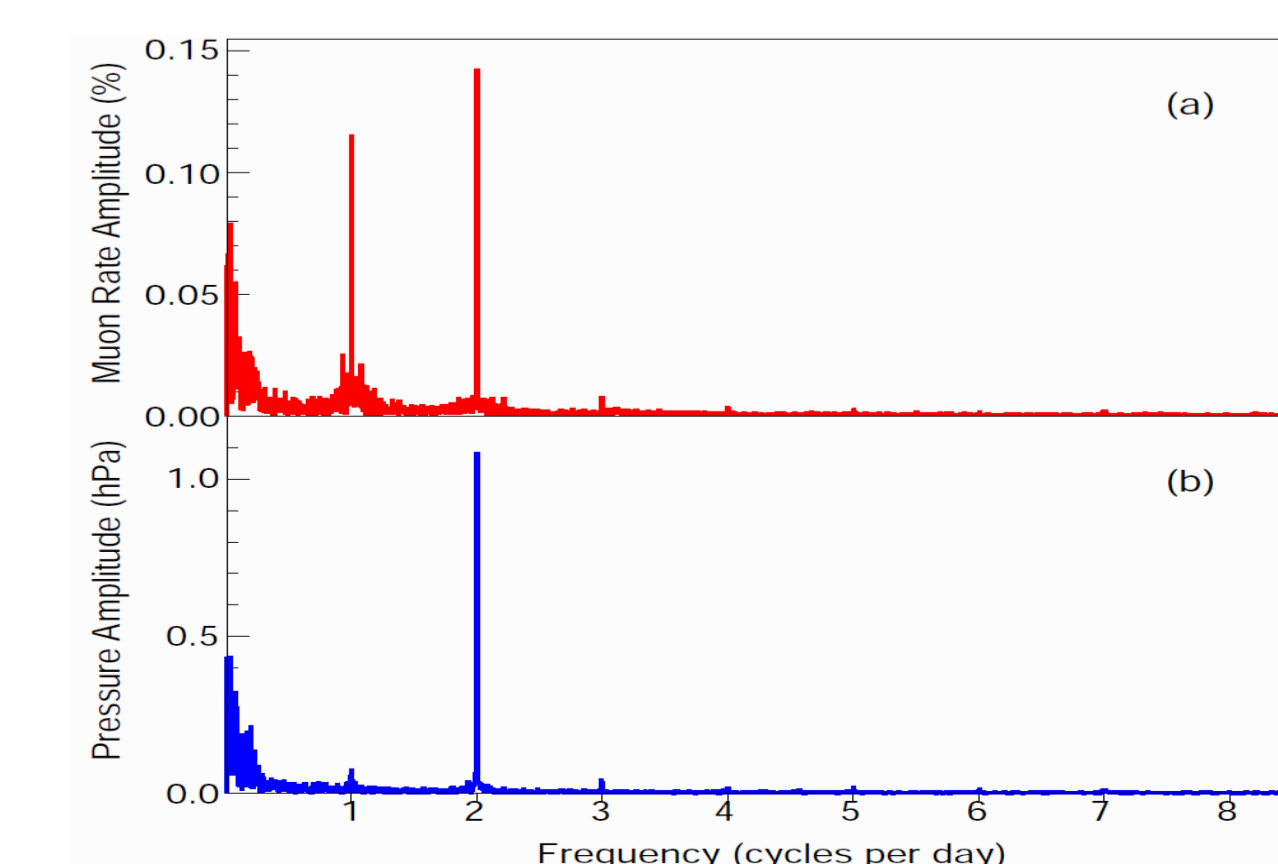
## • Atmospheric Pressure Coefficient ( $\beta$ ) Angular distribution of muons for one day data



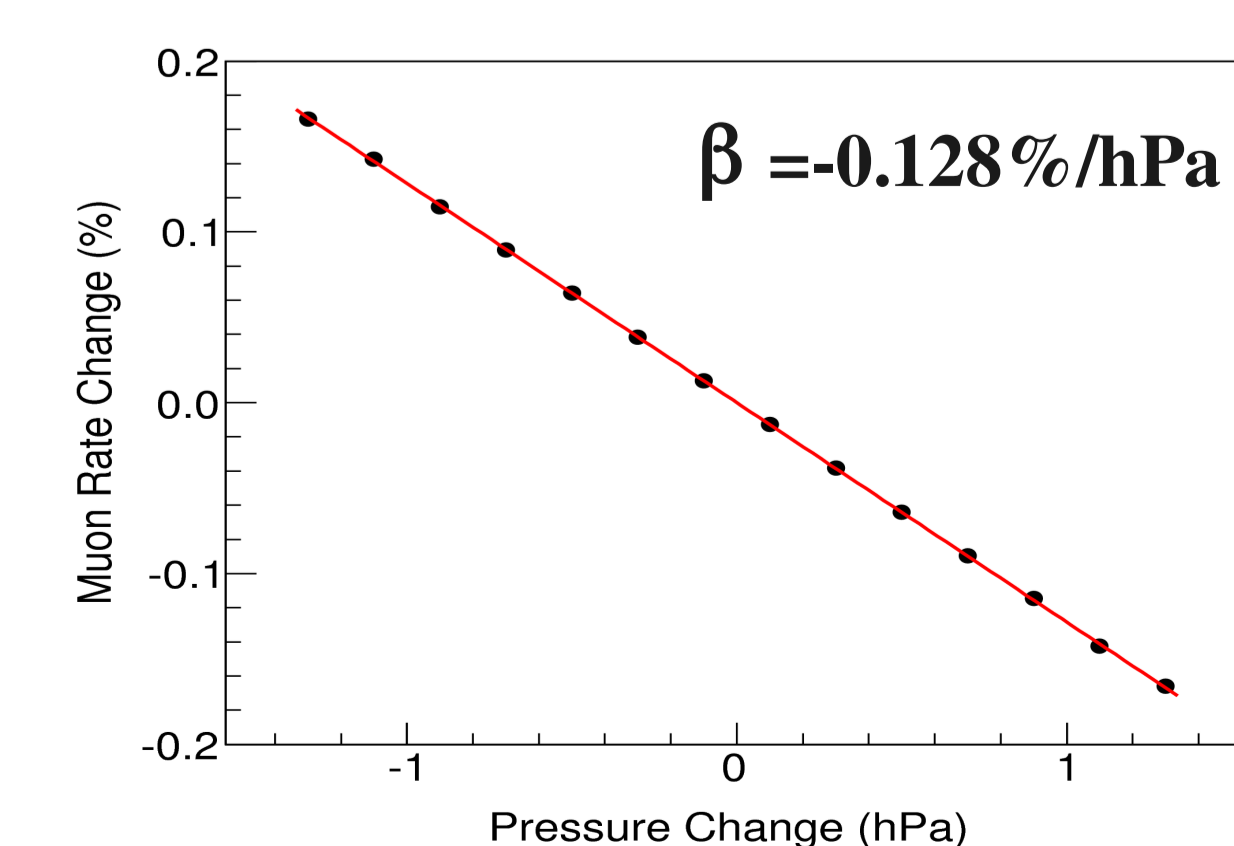
Variation of (a) muon rate (b) pressure for a period of one week (1- 7 March 2006)



Dependence of muon rate on pressure



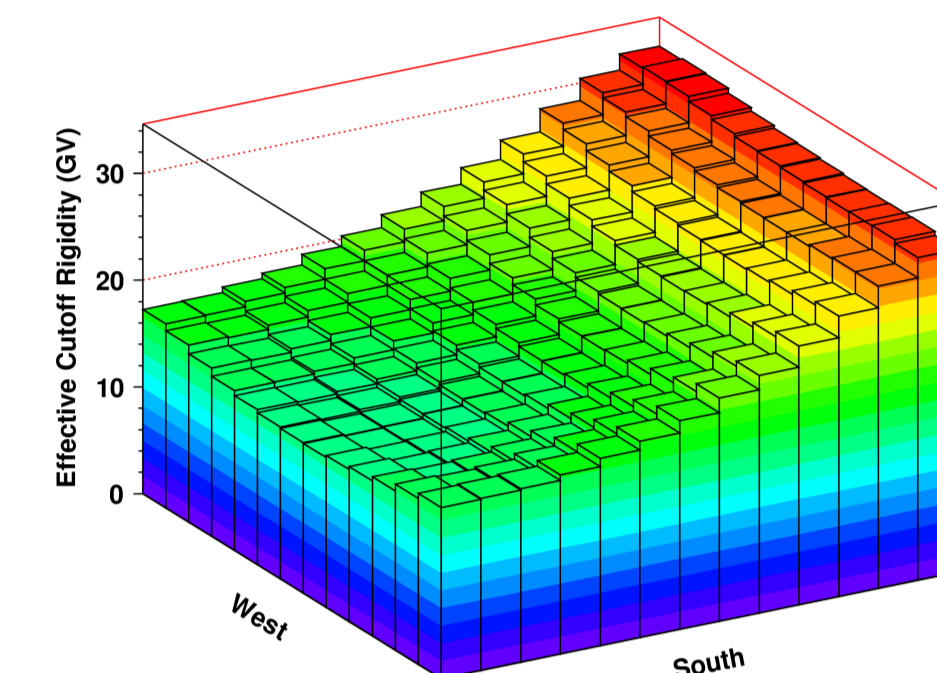
FFT spectrum of, (a) muon rate and (b) atmospheric pressure



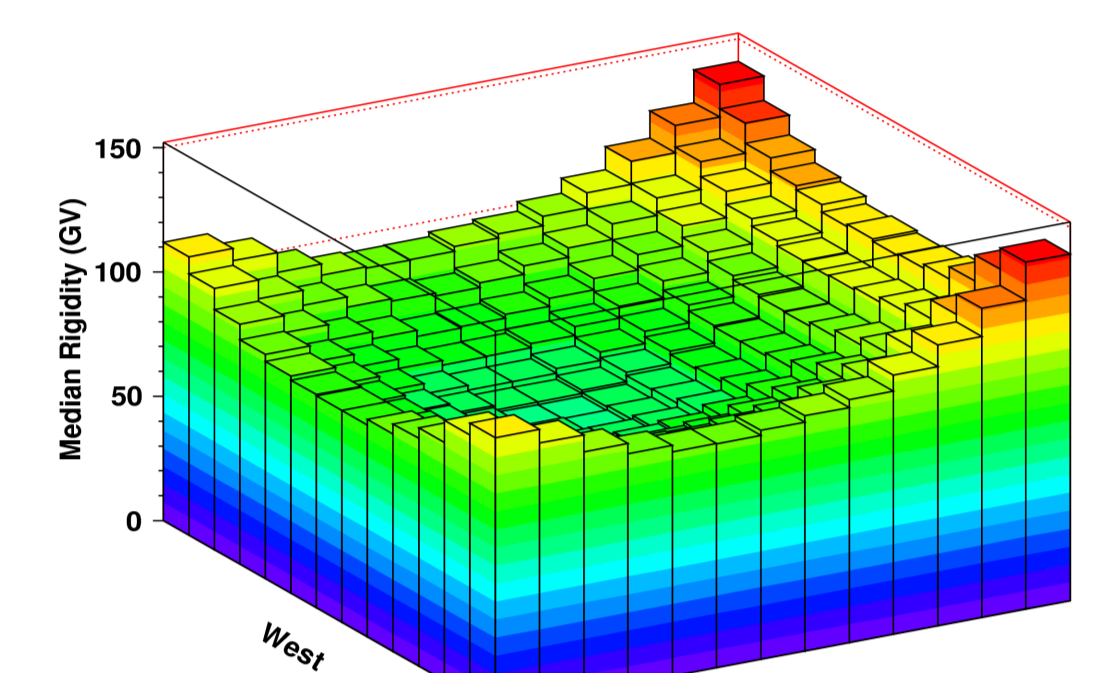
Dependence of muon rate on pressure obtained by selecting second harmonic components from FFT spectrum

## • Rigidity Calculation

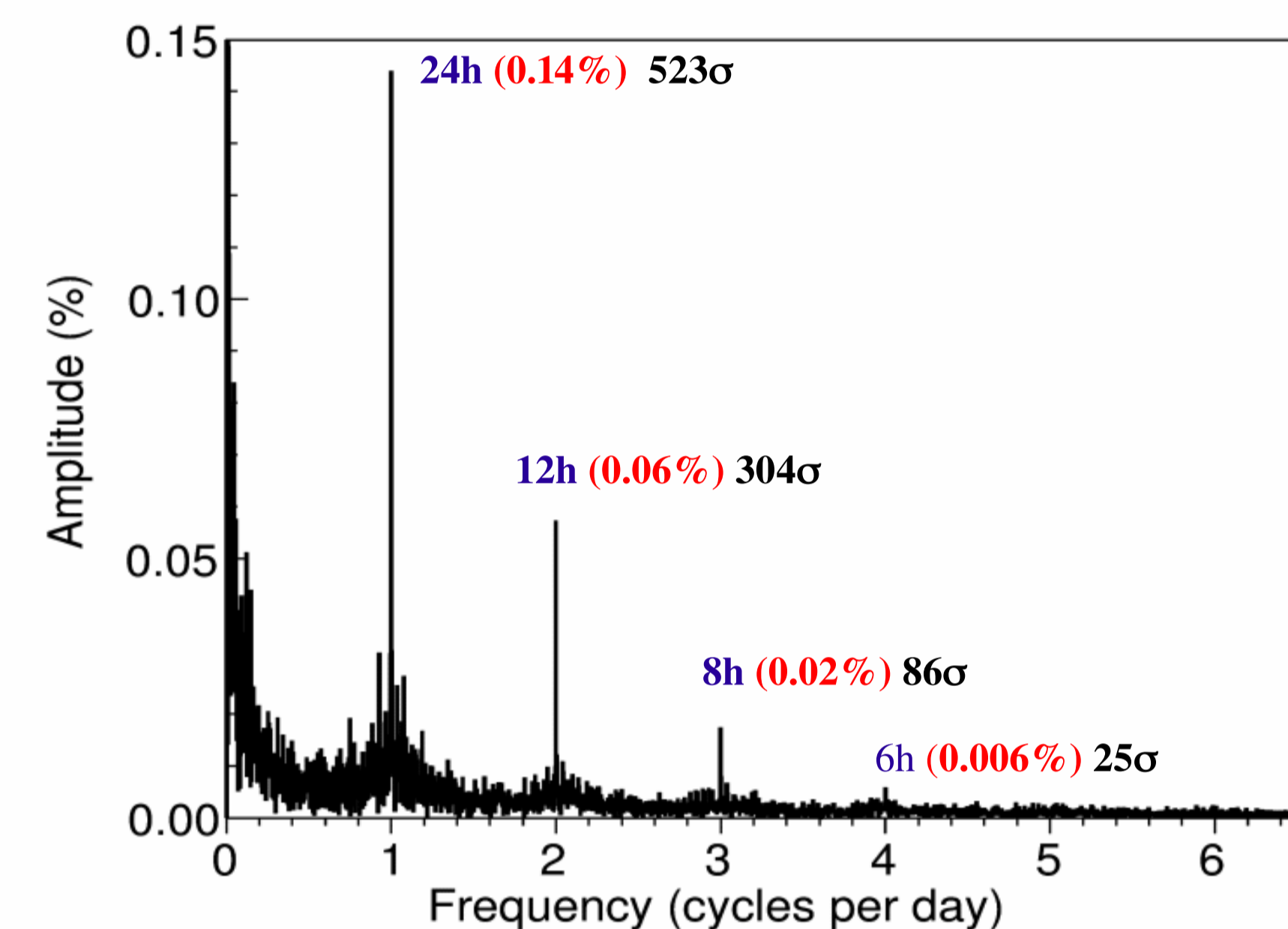
Rigidity of cosmic ray proton primaries were calculated for the 169 directional bins of the GRAPES-3 muon telescope using (1) back tracing method with IGRF-11 model (2) atmospheric shower simulation with CORSIKA and (3) detector simulation.



Cutoff rigidity map (14 - 32 GV)

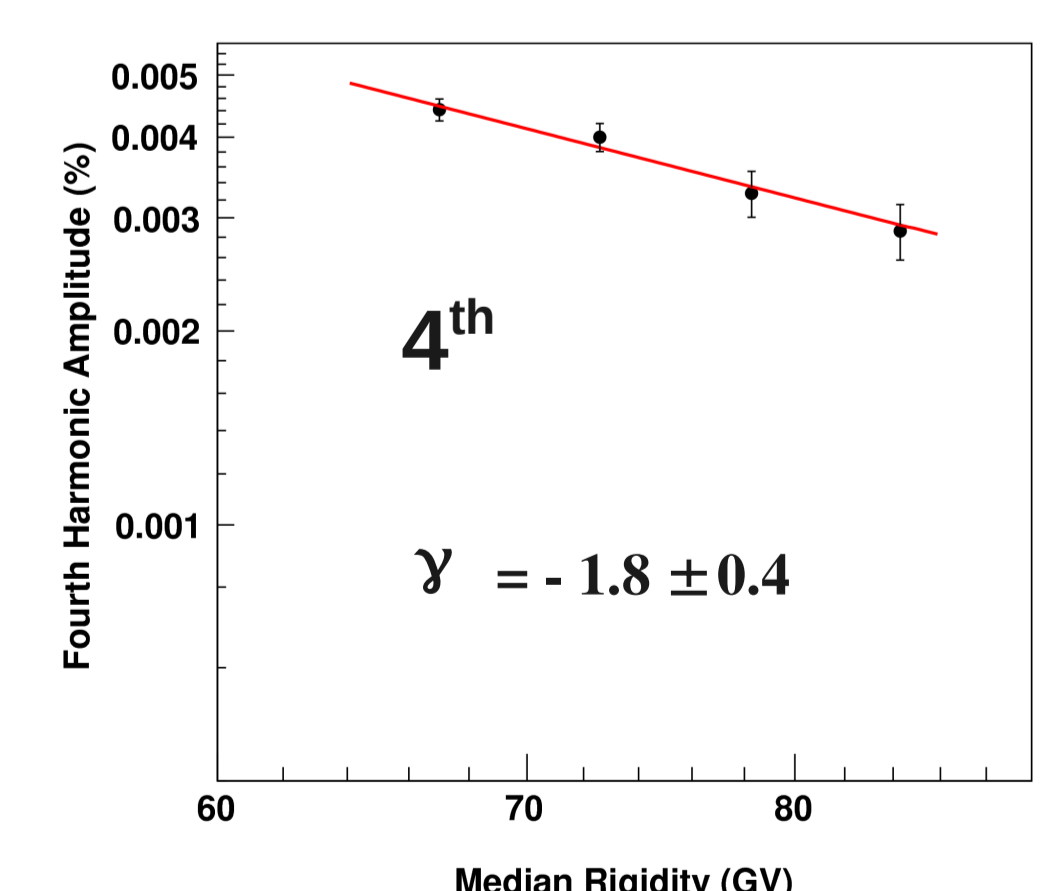
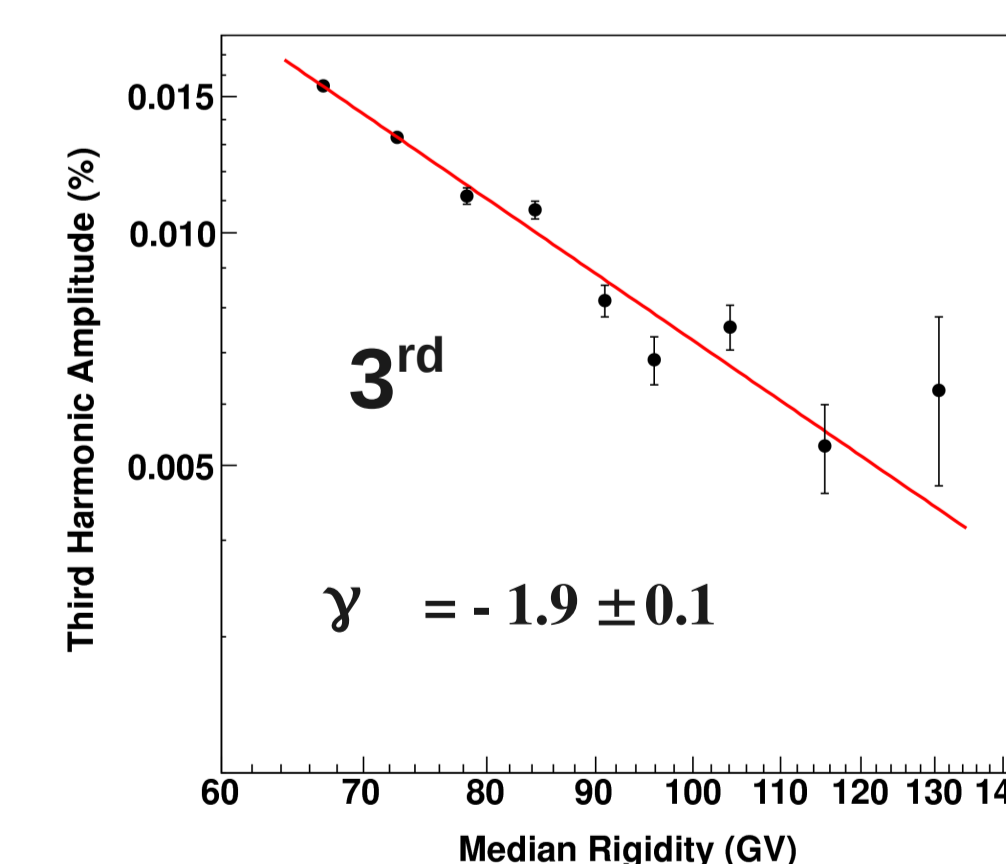
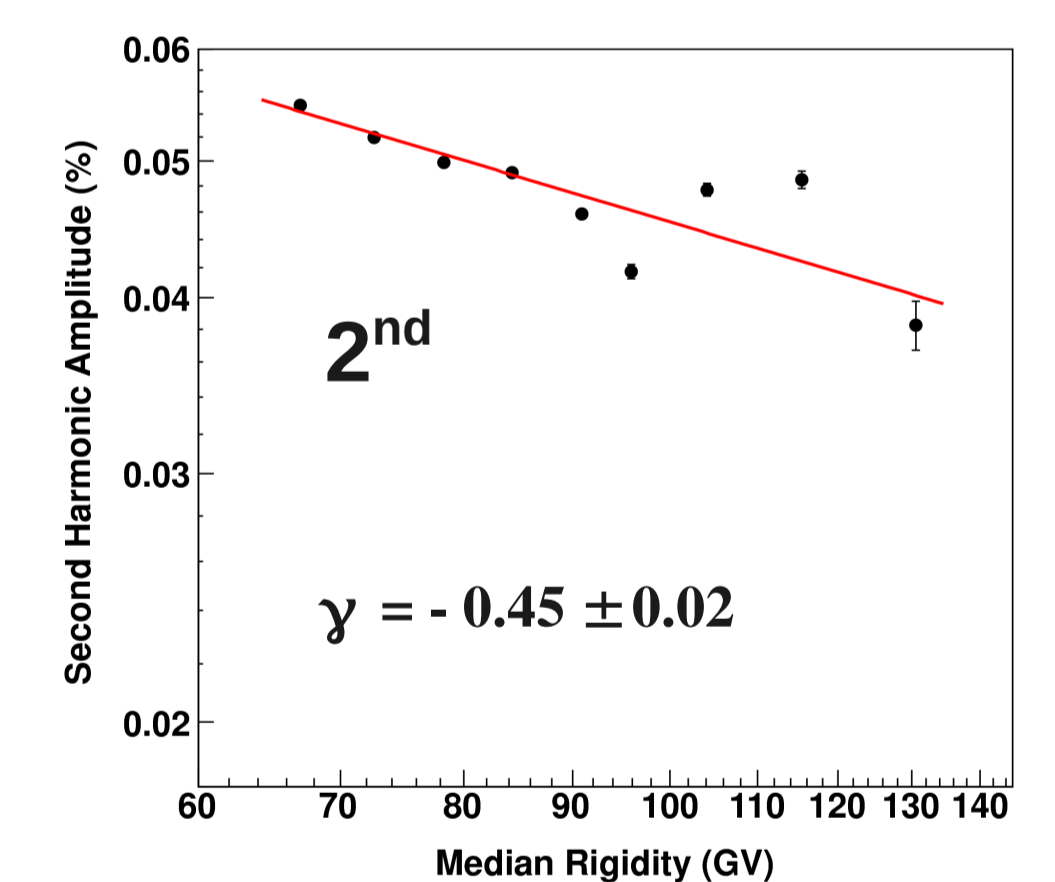
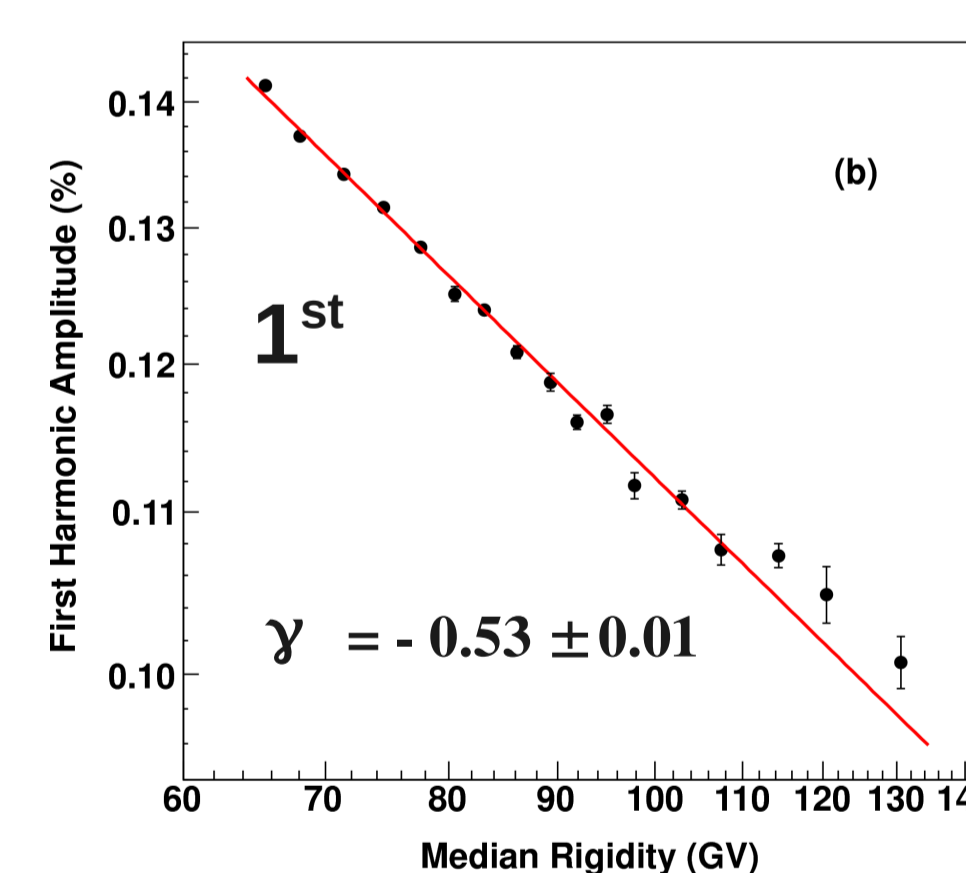


Median rigidity map (64 - 141 GV)



FFT spectrum of muon data for rigidity bin 64 - 70 GV.

## • Rigidity spectra of harmonics of diurnal anisotropy



Power law fit of form  $K \times R^\gamma$  for different harmonics. R is median rigidity

## • Summary

The GRAPES-3 high statistics data have clearly revealed first three harmonics as well as a fourth harmonic for the first time. A clear rigidity dependence of each of the four harmonics was also obtained.