Azimuthal dependance of cosmic muon flux by 2m $\times$ 2m RPC stack at IICHEP-Madurai and comparison with CORSIKA and HONDA flux

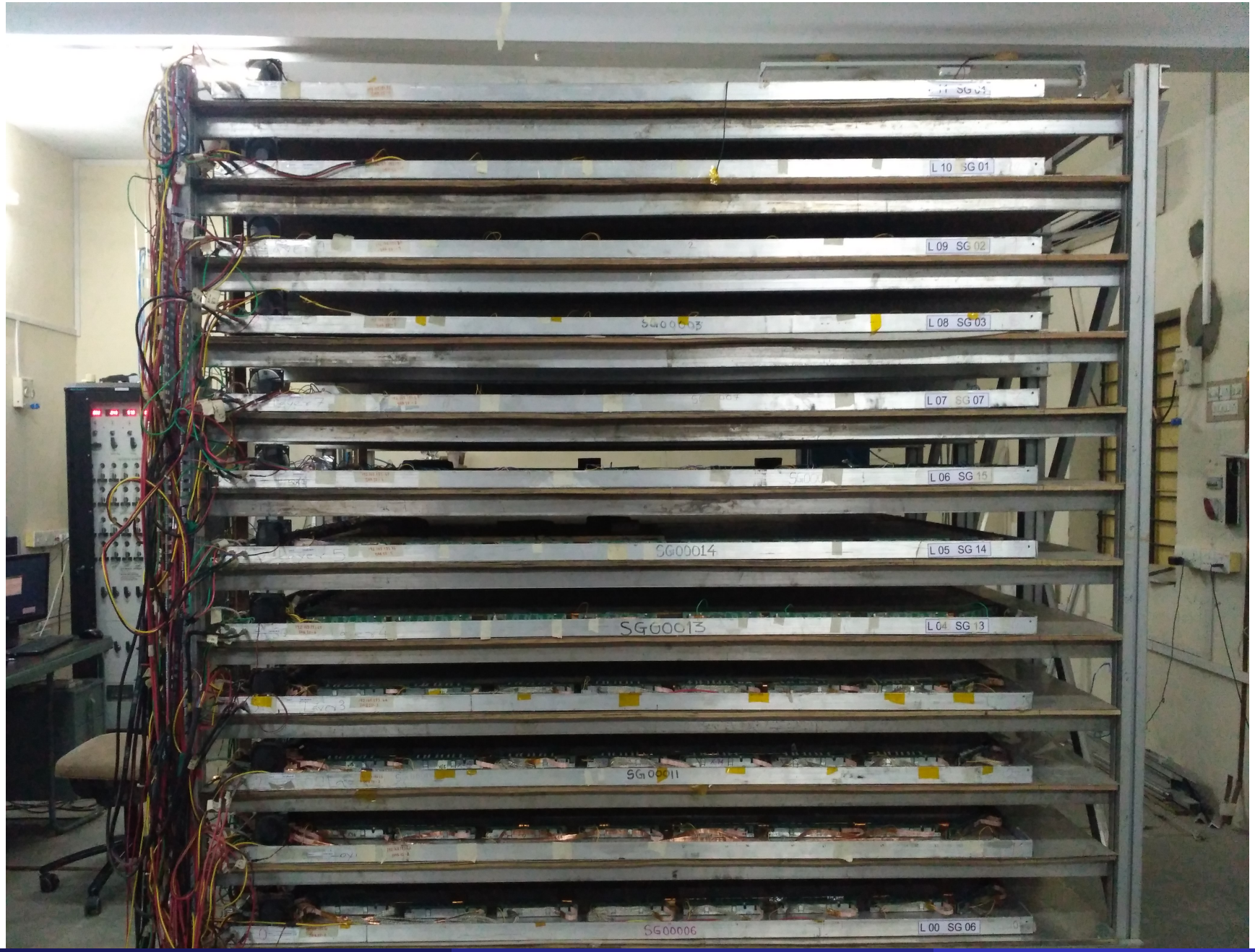
Pethuraj S

India-Based Neutrino Observatory

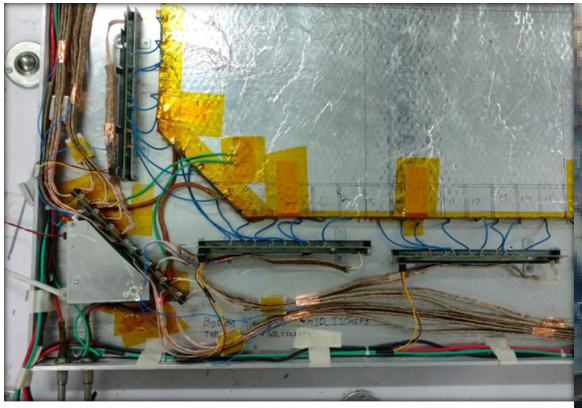
s.pethuraj@tifr.res.in

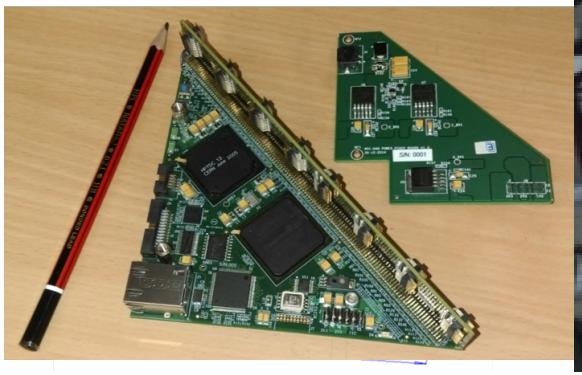
December 13, 2018

Madurai RPC Stack

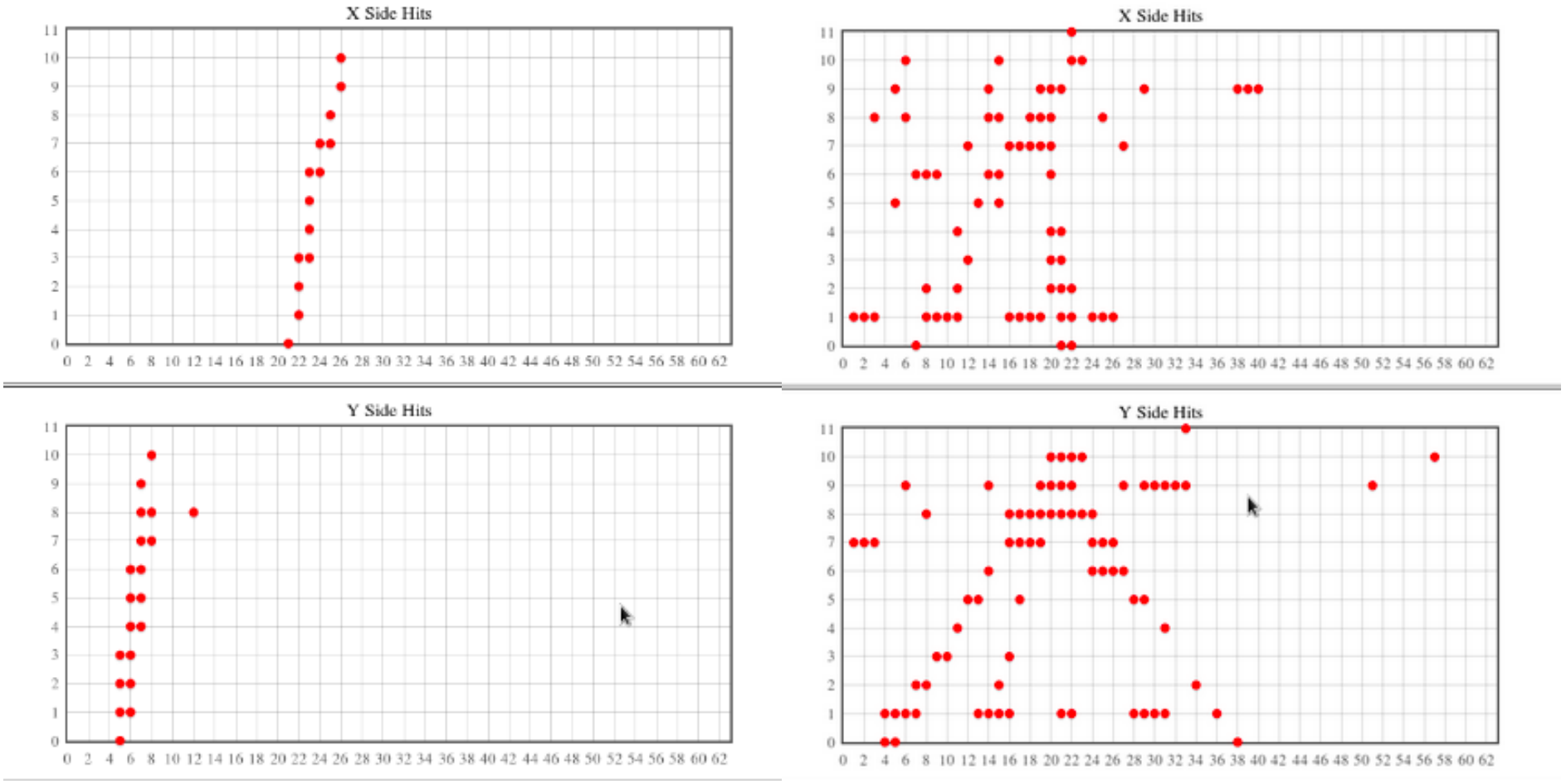


Madurai RPC Stack





Muon and Noisy Tracks

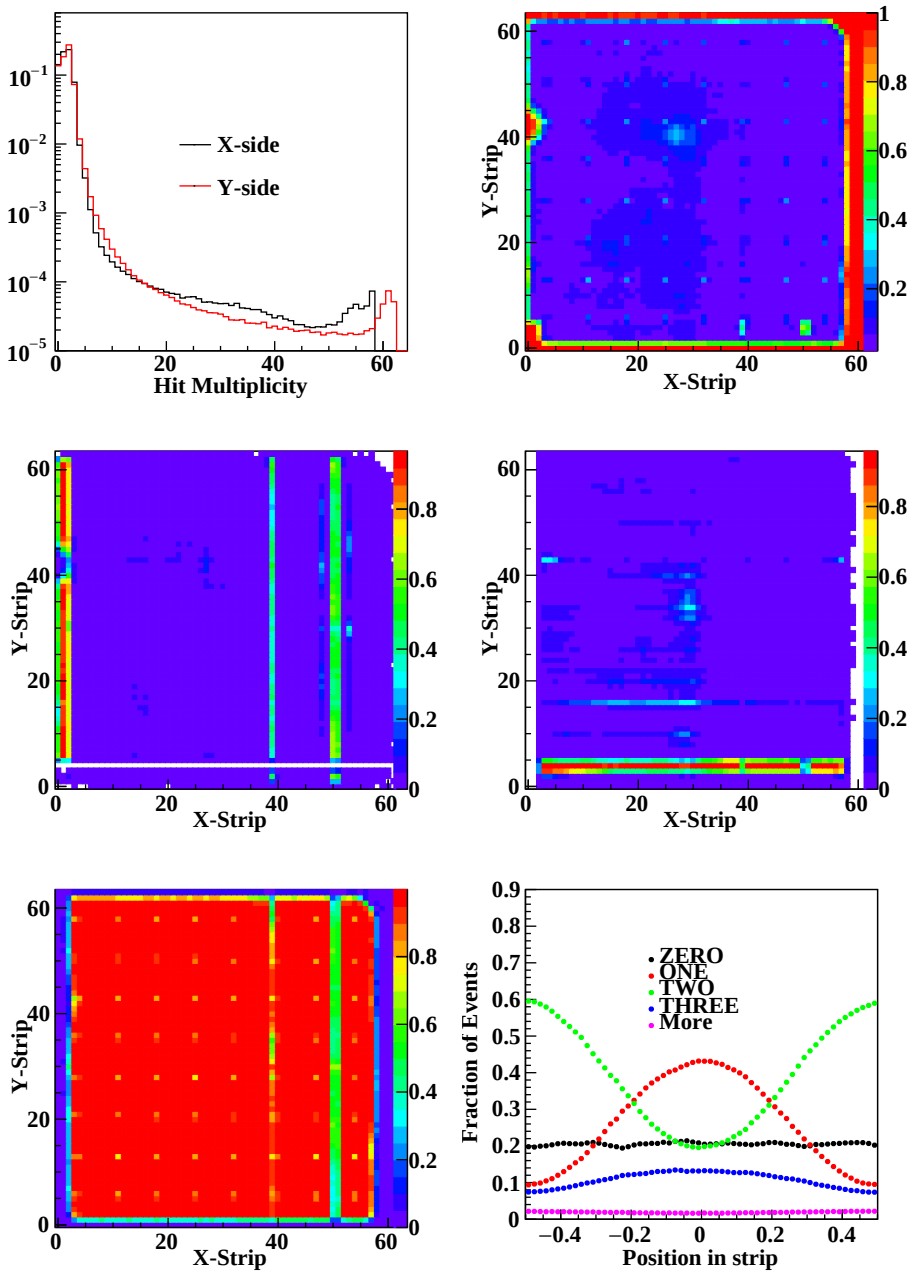


Analysis of Experimental data

- The data is recorded by Hardware Trigger L4.L5.L6.L7 X- or Y- plane.
- Muon hits are selected with multiplicity of 1,2 and 3. So that noisy layers will be removed.
- Accepted Muon hits in all layers are fitted with Straight Line in both X-Z and Y-Z plane.
- From the fitting slope in both X-Z and and Y-Z , intercept, deviation, chisquare and NDF will be extracted.
- Further analysis is done, only when there are at least 5 layers with selected hit position (both X- and Y-side) for this fit and fitted $\chi^2/ndf < 8$
- The zenith angle and azimuthal angle of the selected muon is calculated.
- Pixel wise(3cm $\times$ 3cm) correlated inefficiency, uncorrelated inefficiency and trigger efficiency maps are calculated

Analysis of Experimental data

- Correlated inefficiency: when a fitted muon has passed through a pixel, but there is no hit in that position in both the X- and Y-plane of the detector within 3 cm of the extrapolated point.
- The uncorrelated inefficiency X: when the X-plane does not have any hit, but the Y-plane has a hit within 3 cm of extrapolated point.
- Trigger efficiency: If any hit in the layer when muon pass through.
- Position dependent strip multiplicity for each strip in 16 x 16 pixel is calculated based on hit position in a strip and its multiplicity.



Monte-Carlo Generated Data

- To incorporate the interaction of Muon with detector medium, GEANT4 toolkit is used to simulate the 12 layer detector stack along with the detector hall.
- The CORSIKA software was used to generate the secondary cosmicray on the experimental site. The primary energy of corsika input is 10 to 10^6 GeV , the primary zenith angle is from 0 to 80 degree and azimuthal angle from 0 to 360 degree.
- The secondary particles information (x-position, y-position, Px, Py, Pz) at the experimental site is stored in the output root file. The position of the secondary particles are digitized in the dimension of 2m x 2m squares.
- The secondary particles are generated above ceiling of the building at a momentum threshold of 0.11 GeV/c.
- Pixel wise correlated inefficiency map is used to accept any hit point.
- The position (hit position with respect to strip center) dependent strip multiplicity is also used to simulate position dependent multiplicity.
- The trigger efficiencies are incorporated only for the trigger layers.
- In the experimental data, random noise hits due to electronics and multi-particle shower within the detector volume are also observed. These noise hits are also extracted from data and incorporated duing the digitization process.

Comparison of Data and MC

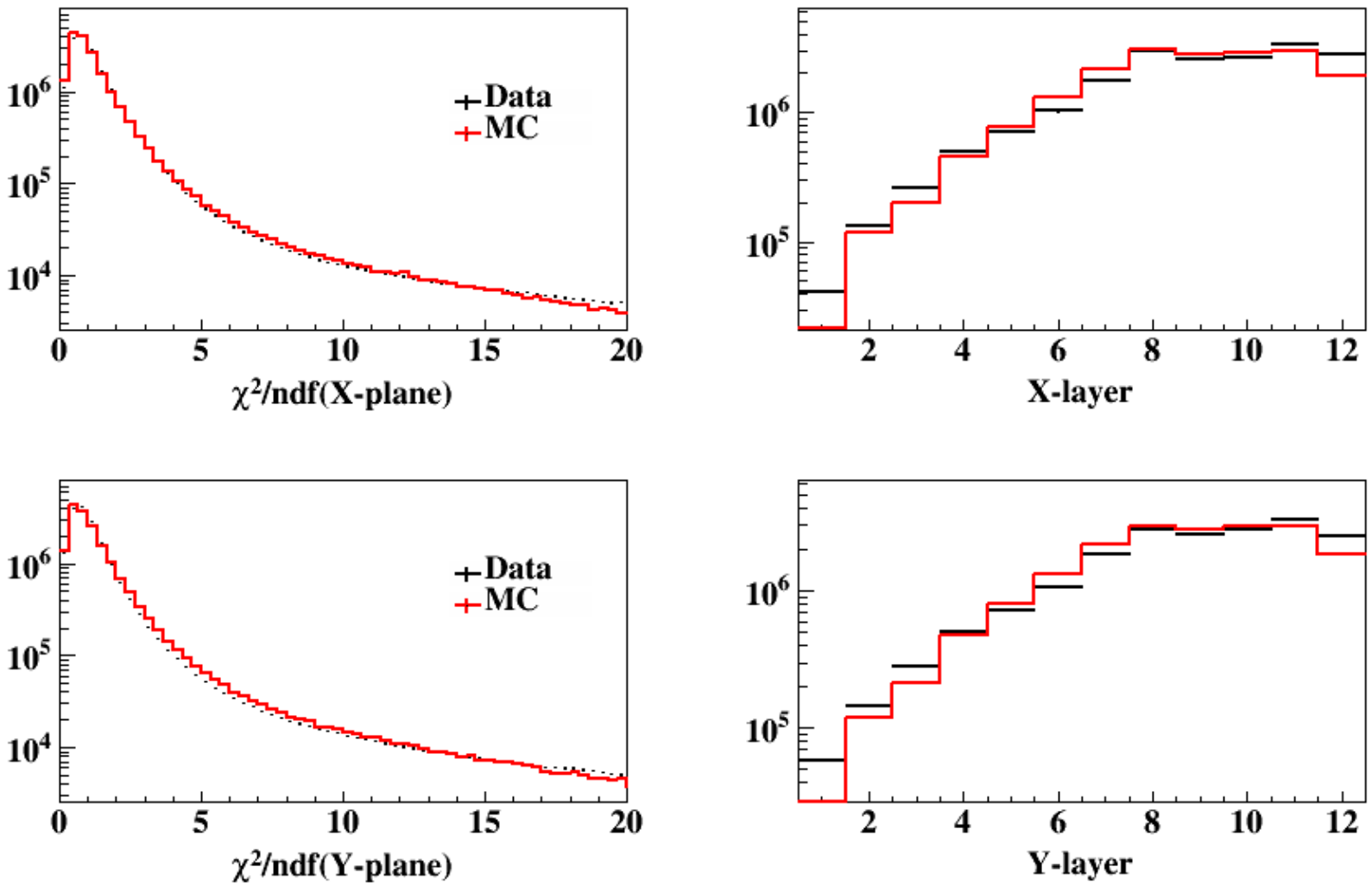


Figure: comparison χ^2/NDF and number of used layer in Data and MC.

Azimuthal dependent muon flux

$$I_{\theta,\phi} = \frac{I_{\mathrm{data}}}{\epsilon_{\mathrm{trig}} \times \epsilon_{\mathrm{selec}} \times \epsilon_{\mathrm{daq}} \times T_{\mathrm{tot}} \times \omega} \tag{1}$$

where, I_{data} is the integral of the observed θ distribution at θ–ϕ bin , ϵ_{trig} is the trigger efficiency at θ–ϕ bin, $\epsilon_{\mathrm{selec}}$ is the event selection efficiency in mc at θ–ϕ bin, ϵ_{daq} is the efficiency due to dead time in the data acquisition system, T_{tot} is the total time taken to record the data(in seconds) including DAQ's dead time (0.5 ms/event) and ω is the accepted solid angle times the surface area, which is further defined as,

$$\omega = \frac{AN}{N'} \int_{\theta_1}^{\theta_2} \cos^n\theta \sin\theta d\theta \times \int_{\phi_1}^{\phi_2} d\phi \tag{2}$$

where, A is the surface area of the RPC on top triggered layer, N is the number of events accepted at θ–ϕ bin, when the generated position on the top and bottom trigger layer are inside the detector, N' is the number of events generated on top trigger layer at θ–ϕ bin.

Systematic studies

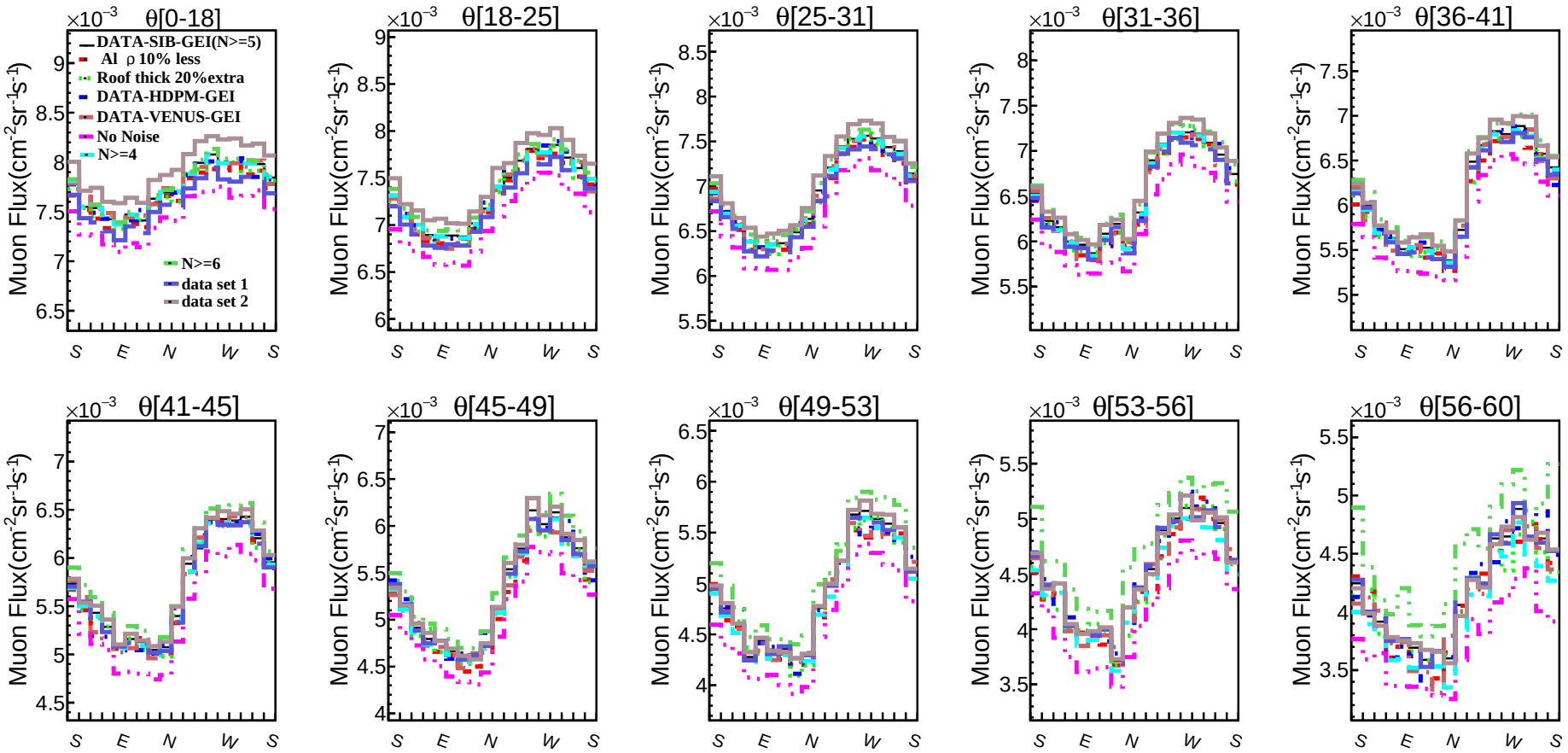
The change in the central value of $I_{\theta-\phi}$due to uncertainties of different parameters listed below along with the plot contains the muon flux calculated by normalising the data below listed MC samples,

- To see the effect of multiple scattering, the density of the aluminium tray which holds the RPC is decreased by 10%
- A complete description of different detector materials is included in the GEANT4 geometry description. The effect of any mismatch of material description in the GEANT4 geometry, the thickness of concrete above the detector is increased by 20%.
- To check the effect of input muon spectrum to GEANT4, the interaction model at higher energies in CORSIKA event generation is changed to HDPM.
- Similarly VENUS High energy interaction model was used to generate CORSIKA events.
- Random noise is also simulated to reproduce MC hit pattern with data. The effect due to possible incorrect modelling of noise was tested without including random noise hits in MC.

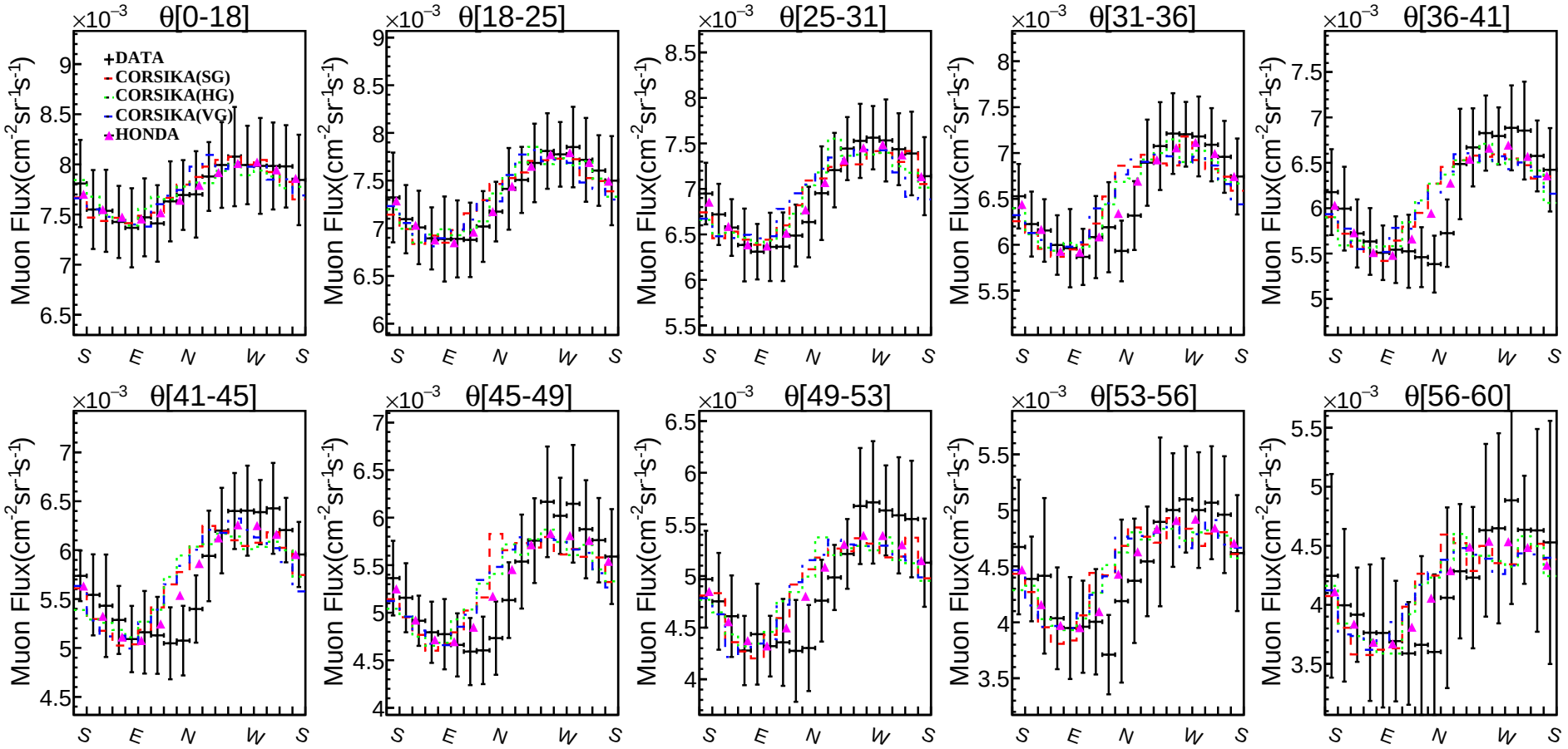
Systematic studies

- In the calculations, a minimum of 5 layers in both X- and Y-plane fit are used as a trade off between the fitting quality and the total statistics. Thus, $I_{\theta-\phi}$ are calculated from the fitted events, which are having hits in a minimum of 4 layers.
- Similary $I_{\theta-\phi}$ calculated for events having minimum of 6 layer hits.
- It was assumed that the efficiency and performance of the detector remains the same during whole data taking period. But, that may not be the case. To see the time dependent performance of detector, experimental data are divided according to time into two sets. The values of $I_{\theta-\phi}$ are calculated separately for the first and the second data sets.

Systematic studies



Comparison of Data with CORSIKA and Honda flux



Conclusions

- The azimuthal flux dependence shows East-West anisotropy in secondary muons from Data.
- The azimuthal flux from CORSIKA and HONDA is comparable with data except North direction.

Thank You