Search for gamma rays above 30 TeV from the Crab Nebula with the GRAPES-3 experiment

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On behalf of GRAPES-3 collaboration
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Introduction

- GRAPES-3 experiment is designed to search for cosmic ray sources.
- Detection of γ-rays from the Crab Nebula can help to study the performance of the experiment.
- With improved angular resolution and efficient rejection of background , here is an attempt to detect the γ-rays from the Crab Nebula.

GRAPES-3 experiment

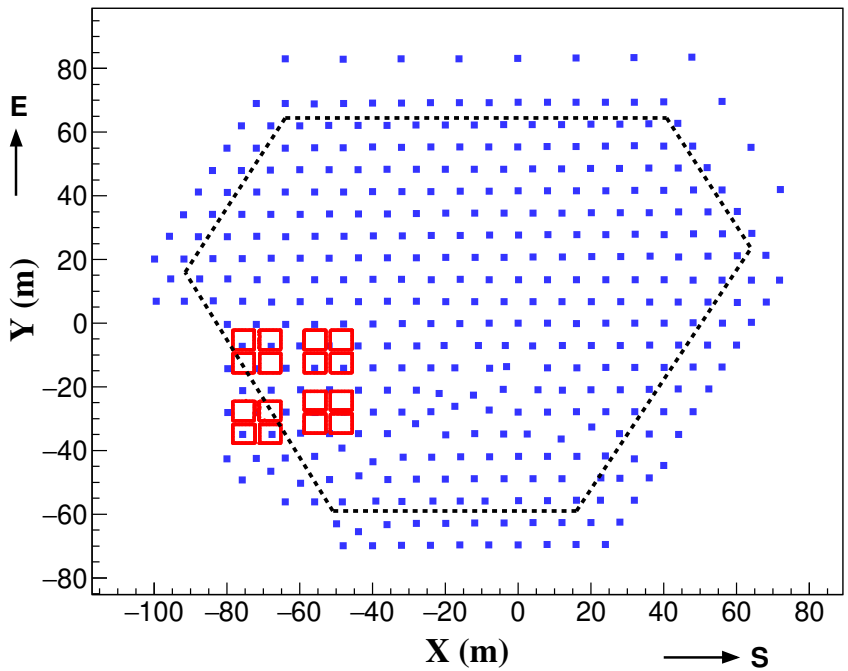


Figure : GRAPES-3 array consisting of the Scintillator detectors (■), Muon telescope (□) and the fiducial area (- - -).

- GRAPES-3 (Gamma Ray Astronomy at PeV EnergieS phase-3) is an extensive air shower array experiment.
- Location : Ooty, India ($11.4°N, 76.7°E$, 2200 m asl).
- 400 (1 m^2 each) scintillator detectors .
- Muon telescope : 560 m^2 area.

Cosmic ray background rejection

- Cosmic rays form an overwhelming background (3-4 orders of magnitude) over the tiny γ-rays.
- An efficient background rejection has been achieved by
  1. Good angular resolution.
  2. Ability to distinguish between cosmic rays and γ-rays.
- Closely packed scintillator array results in a good angular resolution.
- The muon content in the muon telescope helps to achieve an excellent rejection of cosmic rays.

Data selection for the analysis

$\Rightarrow$ Three years (January 01, 2014 - December 31, 2016) of air shower data are used for this analysis.

- Events with successful fit.
- Shower cores within fiducial area.
- Shower age between 0.2 to 1.8.
- Zenith angle $<$ 45°.

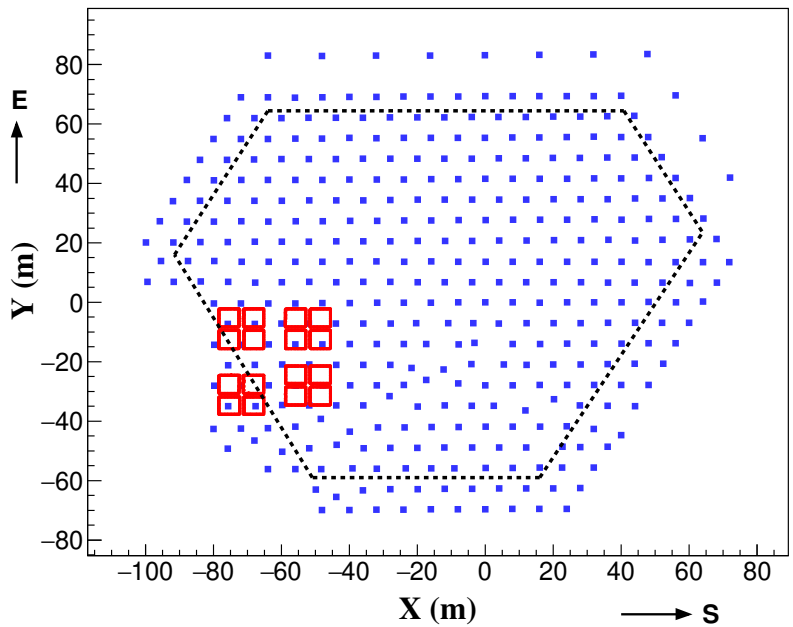
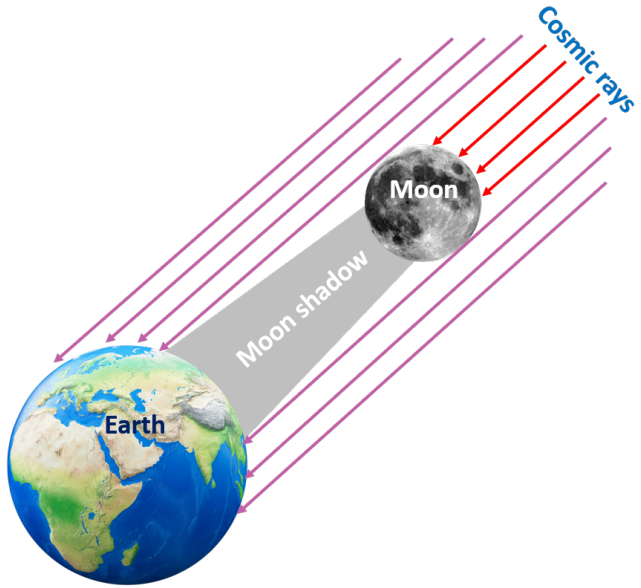


Figure : Scintillator detectors (■), Muon telescope (□) and the fiducial area (- - -).

Observation of cosmic ray shadow of the Moon

- Shadow of the Moon was observed to calibrate the angular resolution[1].
- Six fake-Moon regions selected.
- Each with $+10^{\circ}$ shift in azimuthal angle from the Moon direction successively.

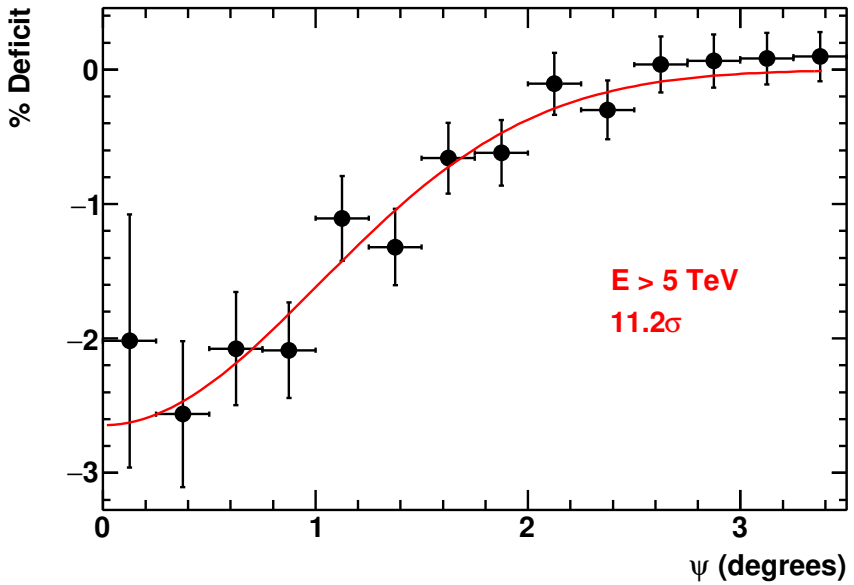


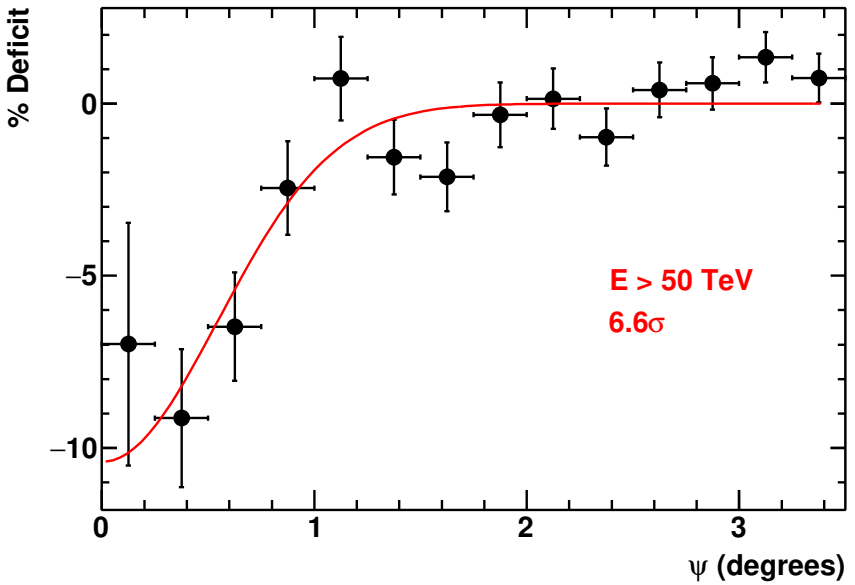
The deficit from the direction of the Moon was then given by,

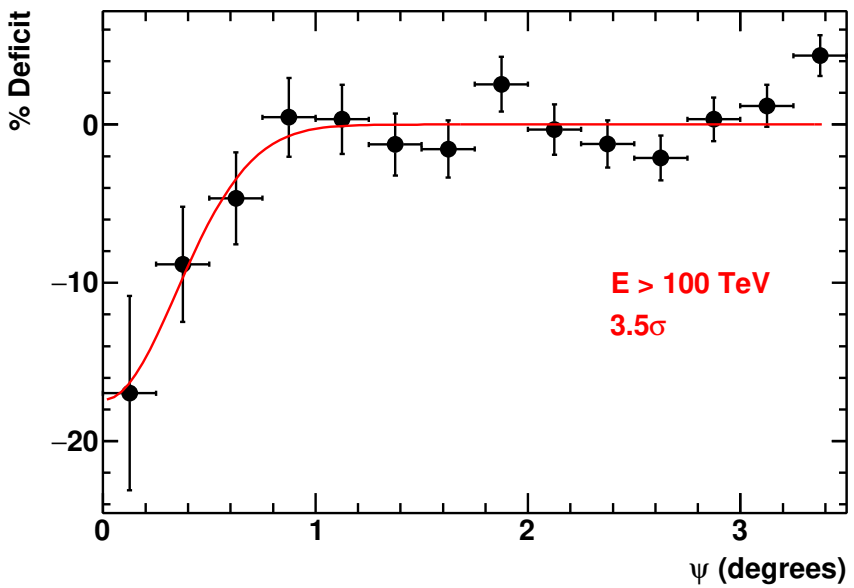
$$\frac{\Delta N_i}{\langle N \rangle} = \frac{N_i^{on} - \langle N_i^{off} \rangle}{\langle N_i^{off} \rangle} \tag{1}$$

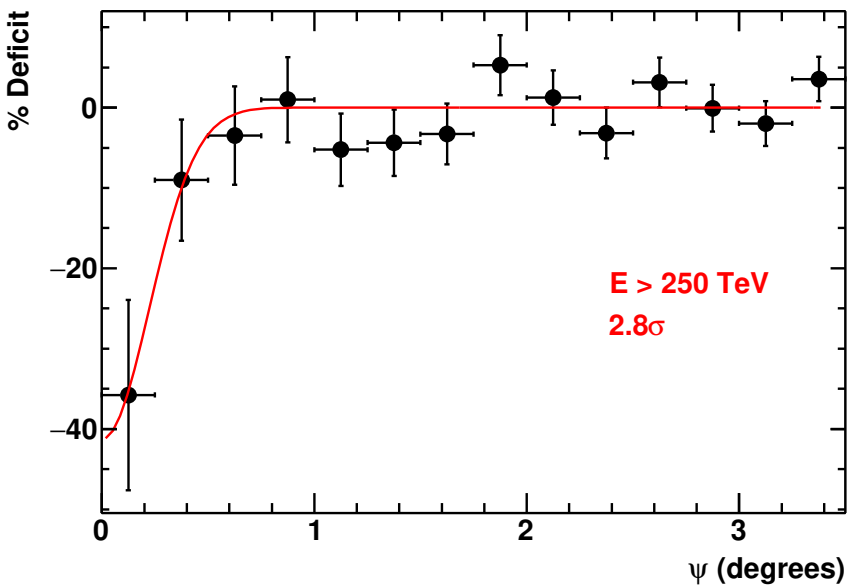
[1] D. Pattanaik et al. PoS(ICRC2021)391.

Cosmic ray shadow of the Moon

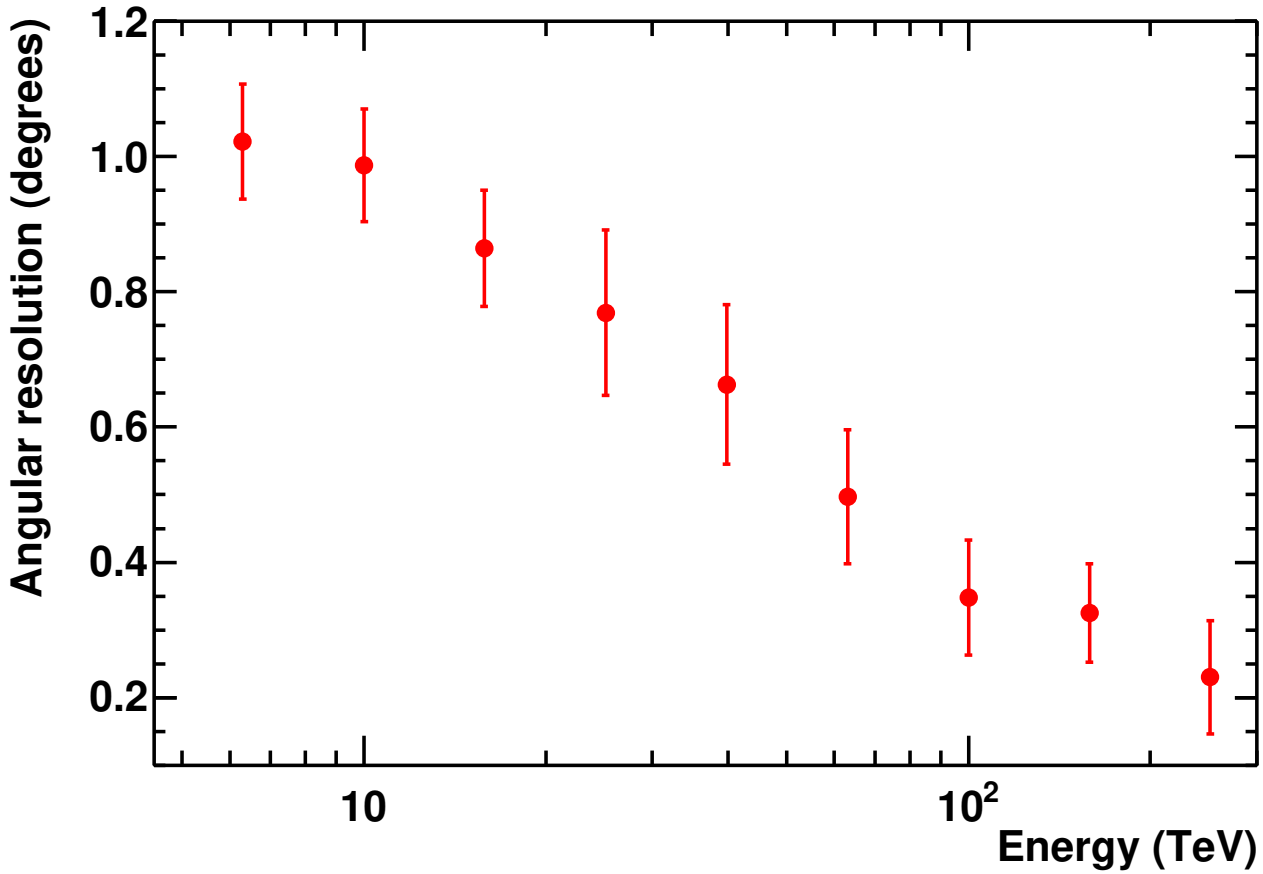








Angular resolution obtained from the Moon shadow



- Since the angular resolution is improving with an increase in energy ($\sim$0.5° for E $>$ 50 TeV), rejection of the background cosmic rays also increases significantly.

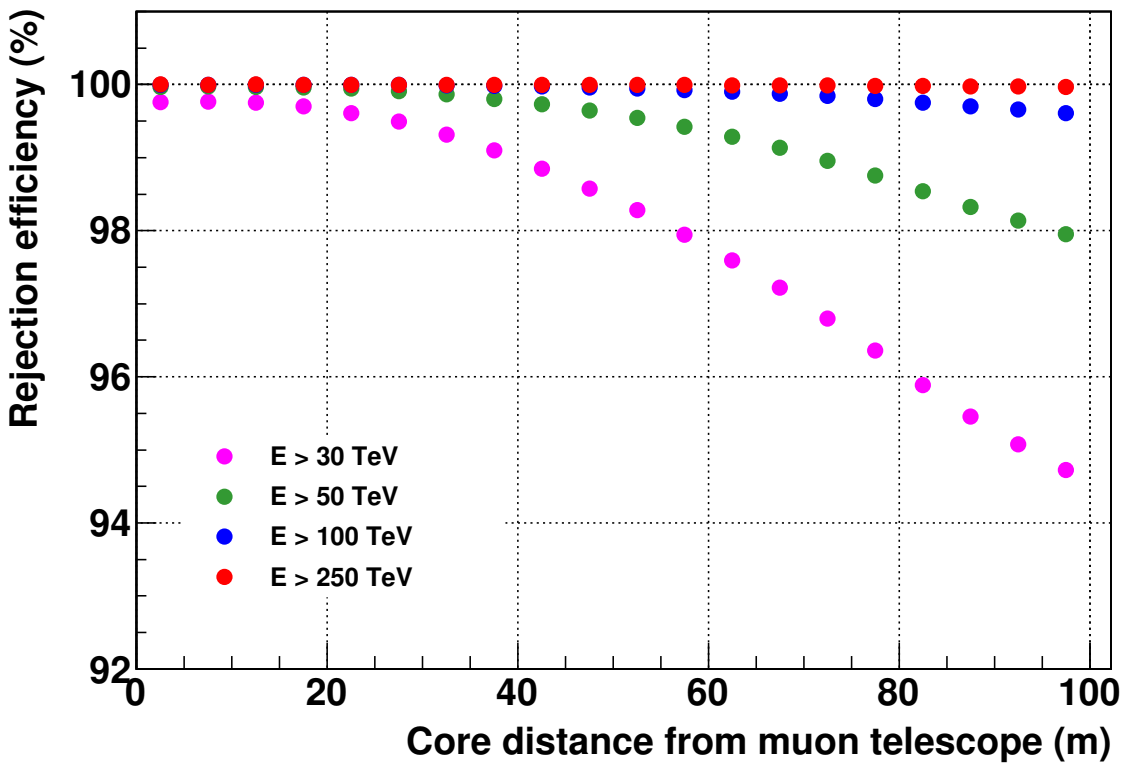
Rejection efficiency achieved by the muon telescope

- γ-rays produces fewer muons.
- Muon-poor showers ($N_{\mu=0}$) are treated as γ-ray like showers.

- Rejection efficiency is given by,

$$Rejection\ efficiency\ (\%) = \frac{N_{\mu \geq 1}}{N_{total}} \times 100$$

where, $N_{\mu \geq 1}$ = Number of events with at least one muon.



Rejection efficiency achieved by the muon telescope

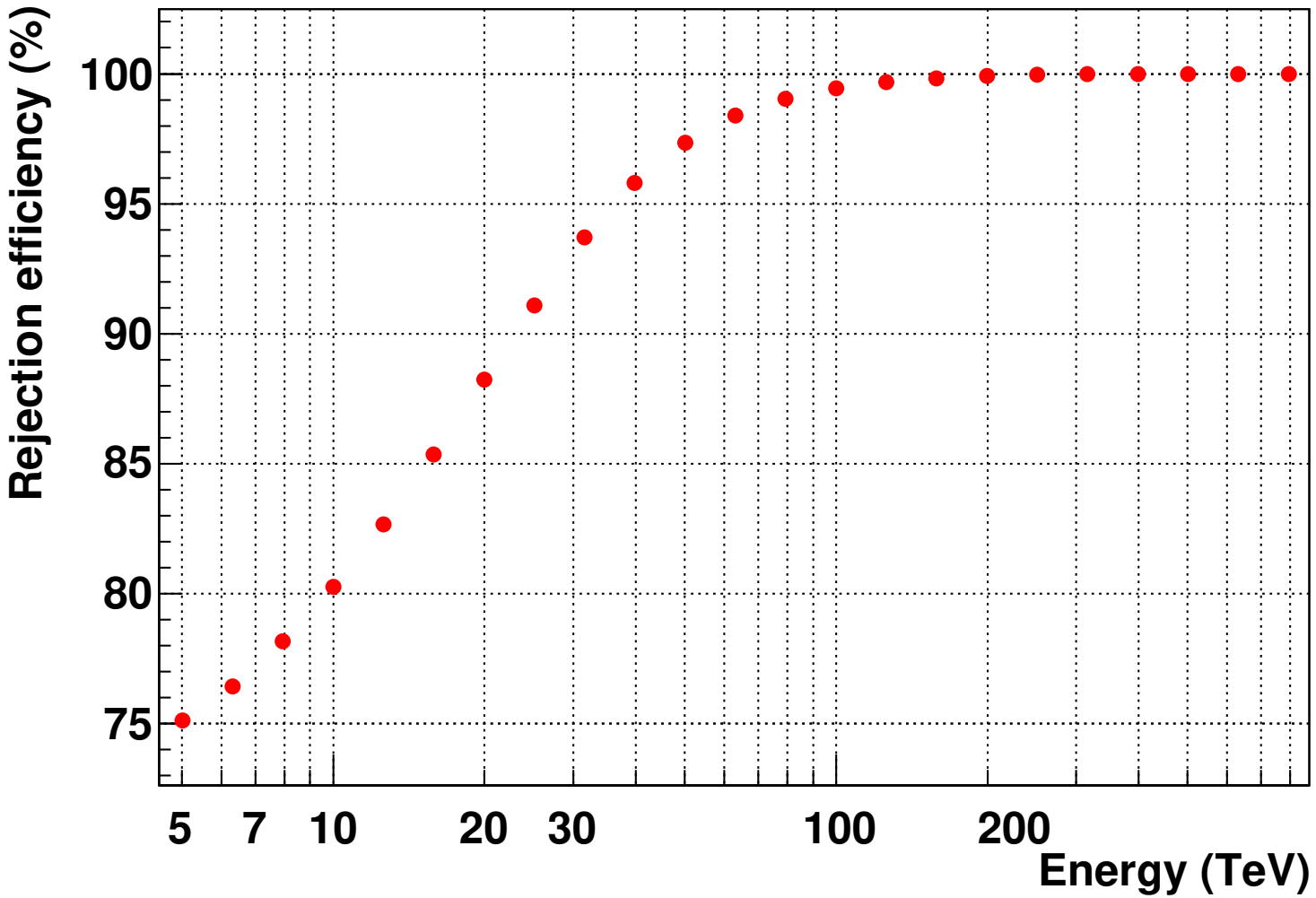


Figure : Cosmic ray rejection efficiency

Background study for the Crab Nebula

- Eight (8) fake-Crab positions were selected.
- Each with $+10^{\circ}$ shift in the azimuthal angle from the Crab Nebula direction.
- Events were distributed over equal incident angle (ψ) bins measured from the direction of the off-source

The background level (N_b) is defined by,

$$N_b = \frac{N_i}{\Omega_i} \times \Omega_0$$

where,
N_i is the Number of events in the i^{th} bin from the fake-Crab direction.
Ω_i = solid angle of the i^{th} bin
$\Omega_0 \approx \pi \Delta\psi^2$ is the solid angle of the first bins.

- Background level was studied before and after rejecting the background based on the muon content.

Background level for Energy > 50 TeV

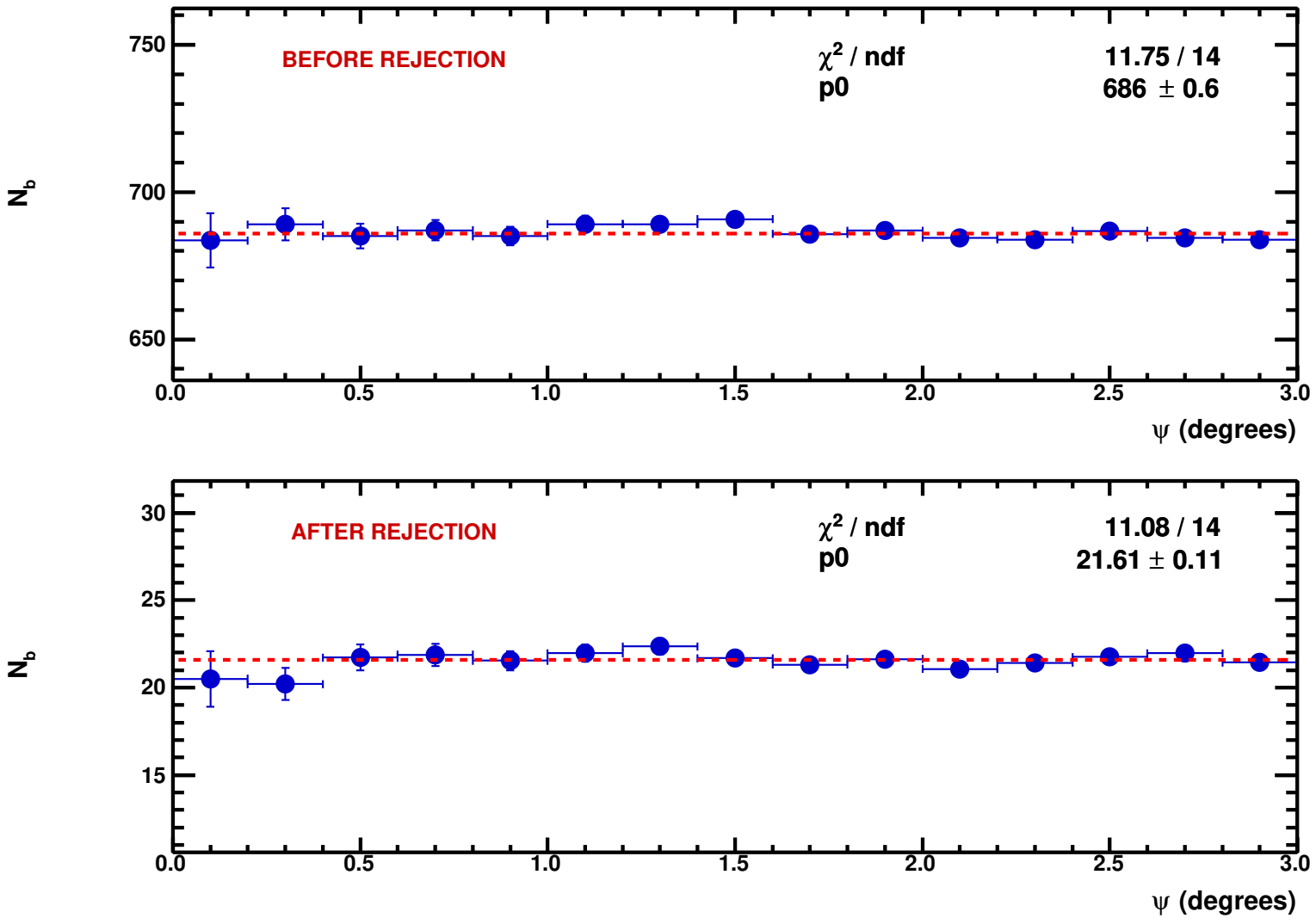


Figure : Distribution of the events as function of incident angle (ψ) measured from the direction of off-source regions.

Background level for Energy > 100 TeV

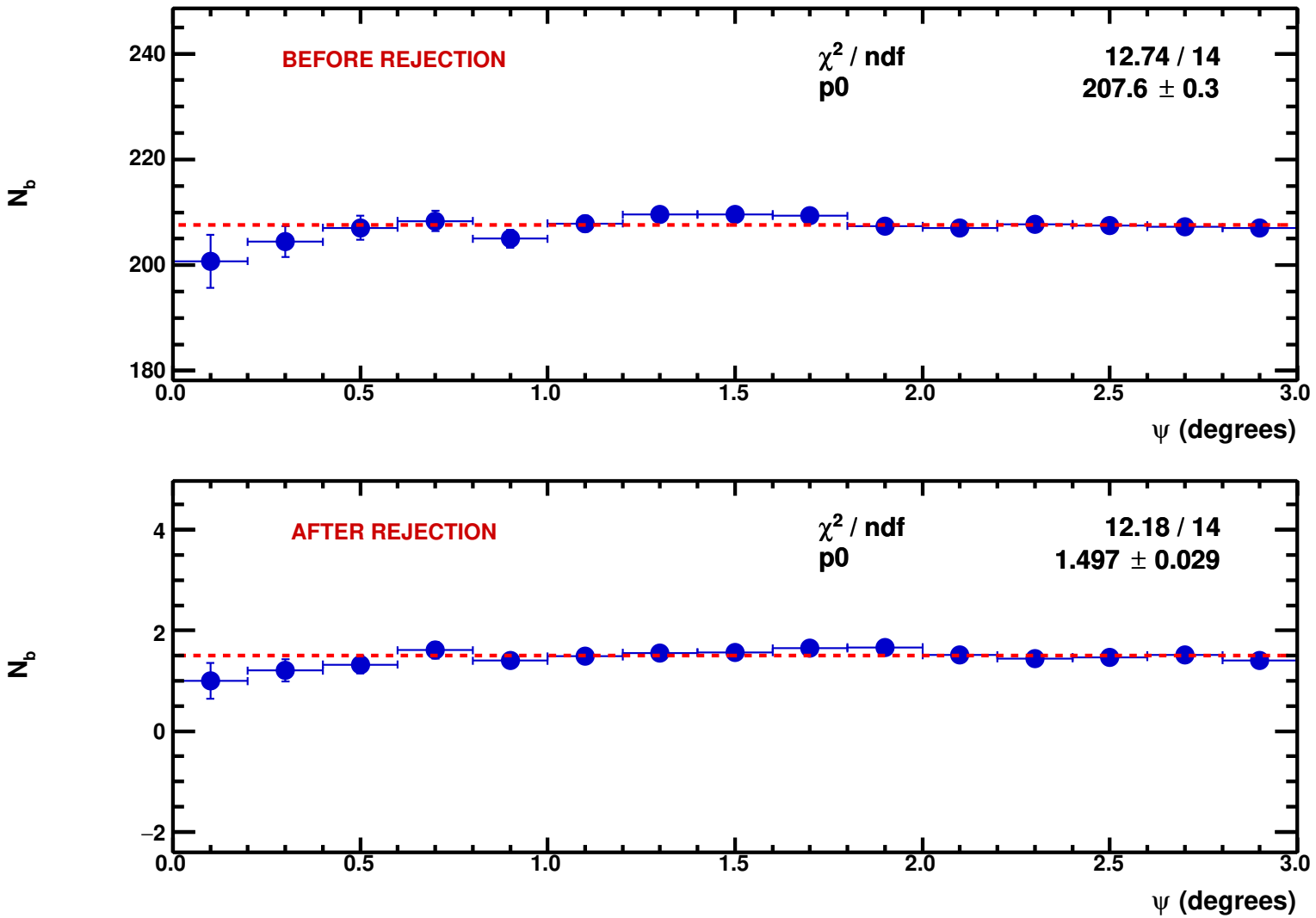


Figure : Distribution of the events as function of incident angle (ψ) measured from the direction of off-source regions.

Search for γ-rays from the direction of Crab Nebula

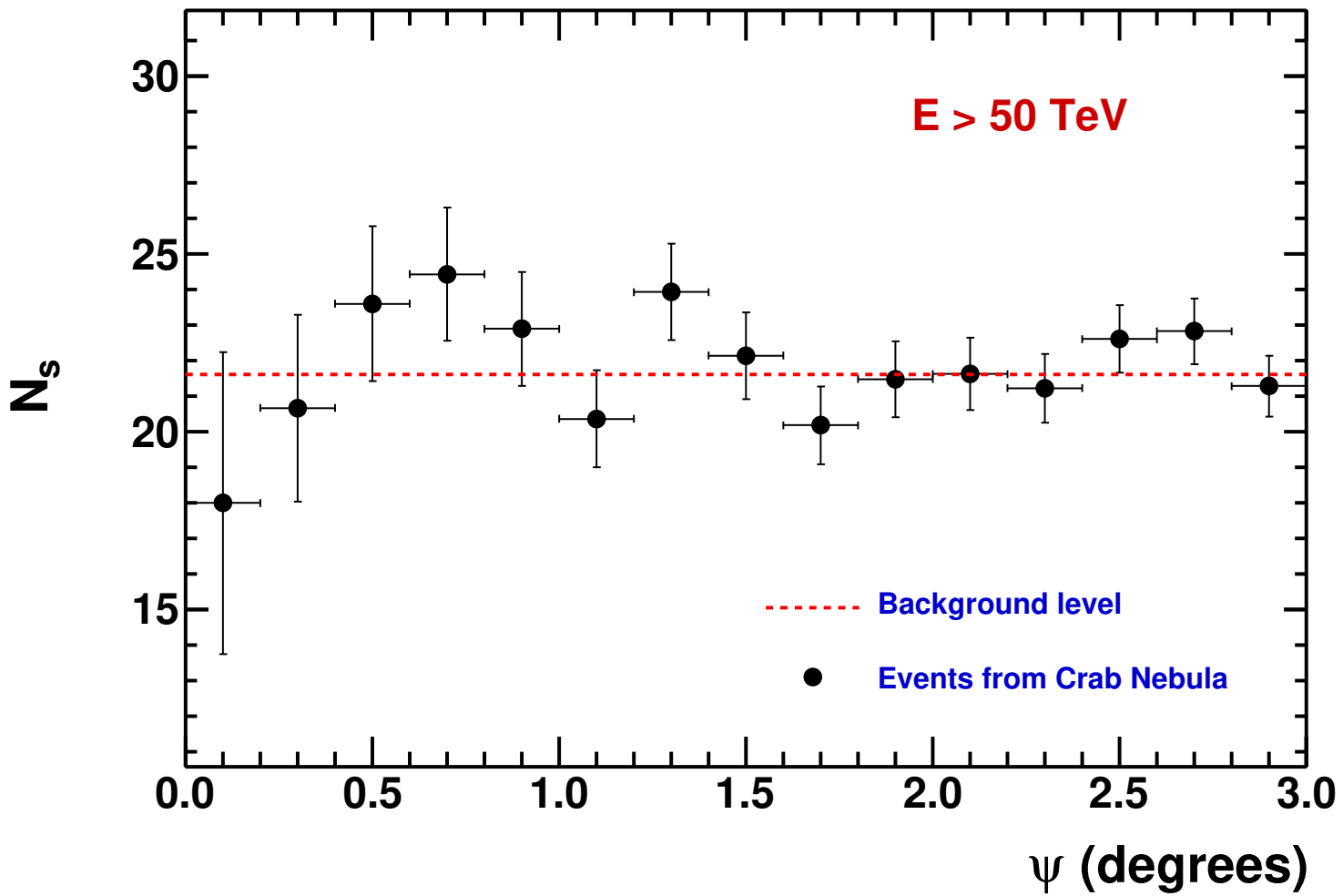


Figure : Distribution of the events observed as a function of incident angle (ψ) measured from the direction of Crab Nebula .

Search for γ-rays from the direction of Crab Nebula

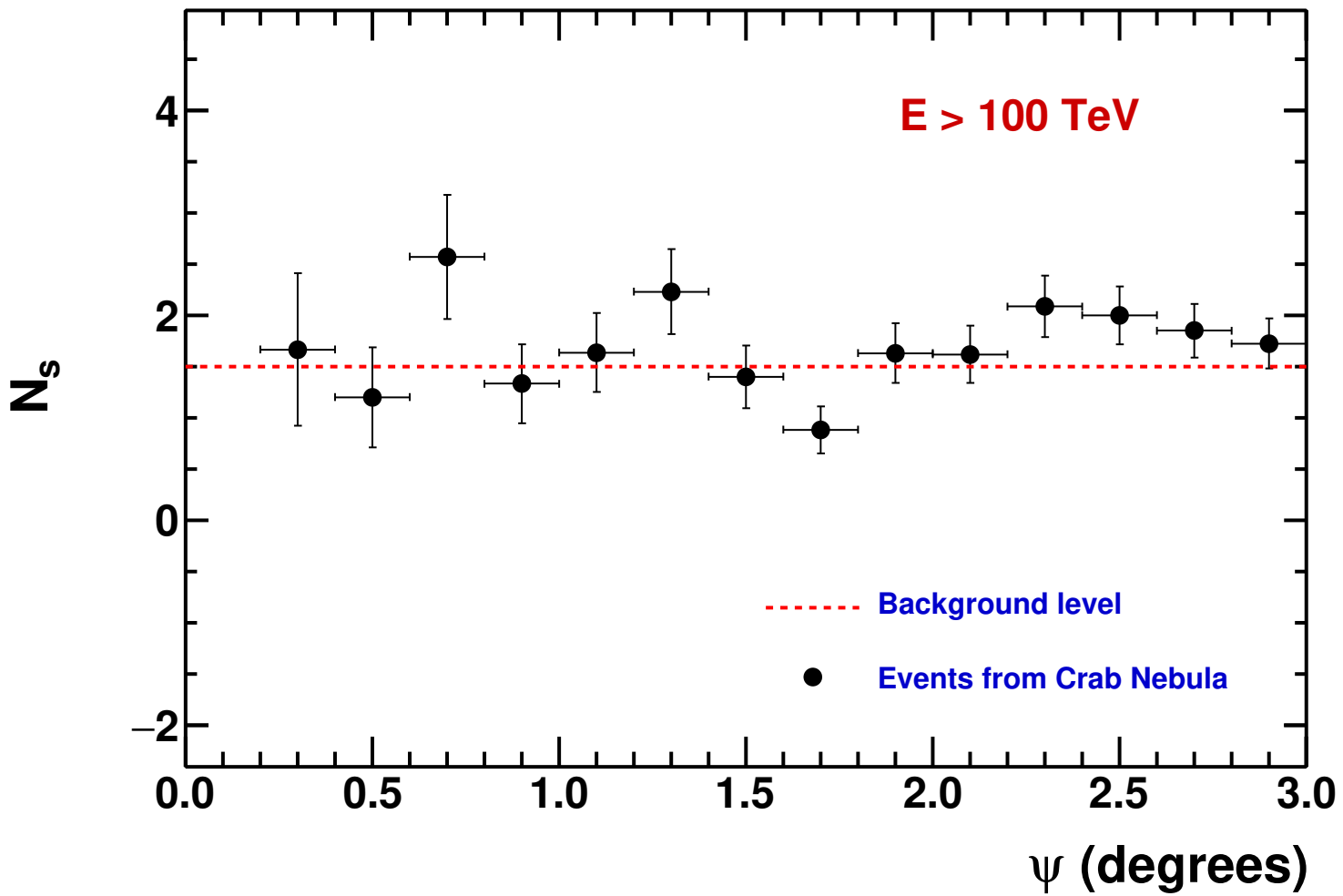


Figure : Distribution of the events observed as a function of incident angle (ψ) measured from the direction of Crab Nebula .

Summary and future work

- The current study helped us to understand the background rejection mechanism of the GRAPES-3 experiment in detail.
- Background cosmic rays were rejected by > 97 % above 50 TeV and $> 99\%$ above 100 TeV.
- From this preliminary studies, we have not observed any excess of γ-rays from the Crab Nebula.
- We are doing a more systematic study to understand the background.

ICRC2021 session details

- Date and time (Berlin) of ZOOM-Meeting : **16. July 2021 - 18:00.**
- Presenter-Forum Number: **220**

Thank You