Diffuse Gamma-Rays at 10-300 TeV with the GRAPES-3 Experiment

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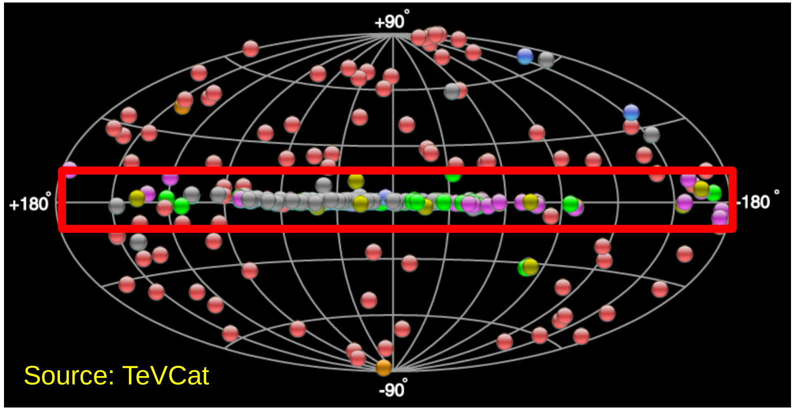
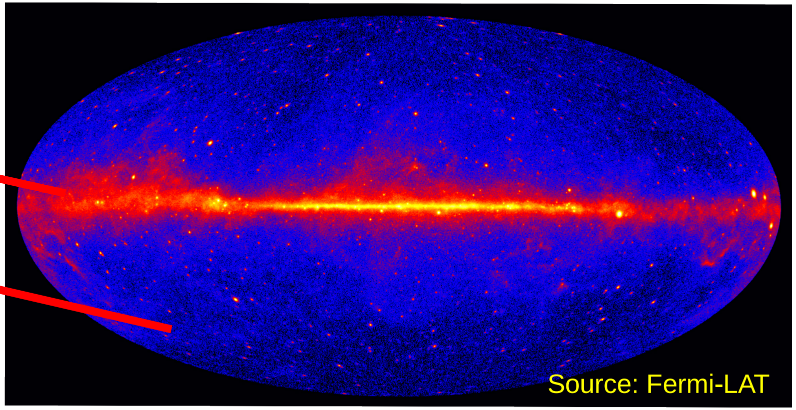
Sources of gamma-rays

- Galactic Sources
  - SNRs, PWNs etc.
- Extragalactic sources
  - AGNs, GRBs etc.
- Diffuse emission
  - Galactic background

    (p-p, p-ɣ interaction)
  - Extragalactic background

    (p-$\gamma_{EBL/CMB}$ interaction)





Searched for diffuse gamma-rays with one year of GRAPES-3 data

Motivation

- **Direct measurements of UHECRs is challenging:**
  - **Being charged in nature gets deflected by interstellar magnetic fields**
  - **Extreme low flux (≤ 1 particle km^{-2} yr^{-1})**
- **Indirect probing through UHE gamma-rays study:**
  - **Provide significant information about sites of origin and acceleration mechanism of UHECRs**

GRAPES-3 experiment in Ooty, India

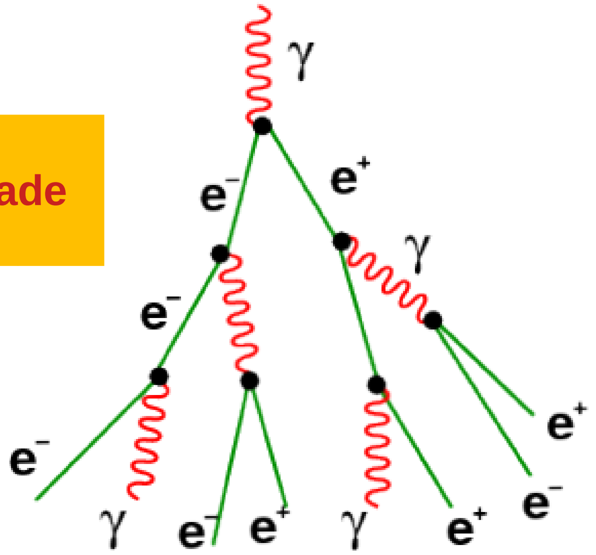
- Indo – Japanese collaboration with 21 institutions
- Located at Ooty, Tamil Nadu, India (~2200 m altitude)
- ~400 plastic scintillator detectors (each 1 m^2 area) with 8 m detectors separation
- Spread over 25000 m^2
- Energy sensitivity is in TeV – PeV range

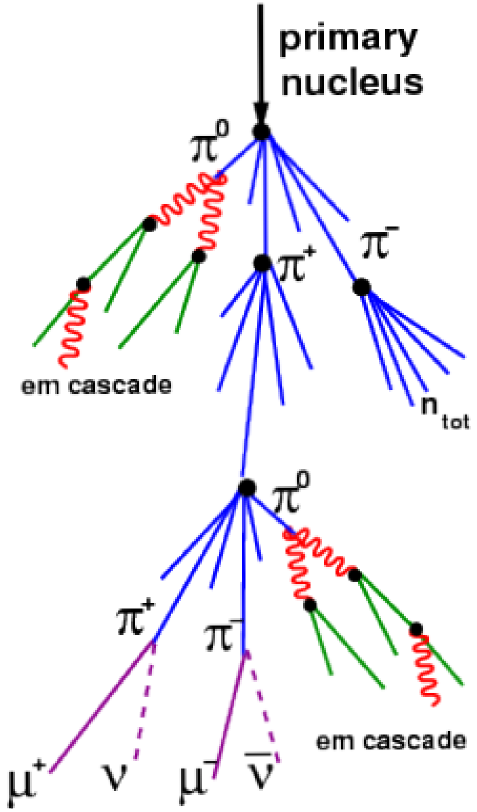
- 560 m^2 area muon telescope (each 35 m^2)
- 4 stations, each with 4 modules
- Each module 4 layers, each layer 58 PRCs
- 3712 PRCs (6m x 0.1m x 0.1m)
- Energy threshold = 1 sec(theta) GeV

Gamma-hadron discrimination

- **Showers with zero muons are considered as gamma-like (muon-poor)**
- **Muon telescope helps in efficiently rejecting charged background**

EM cascade

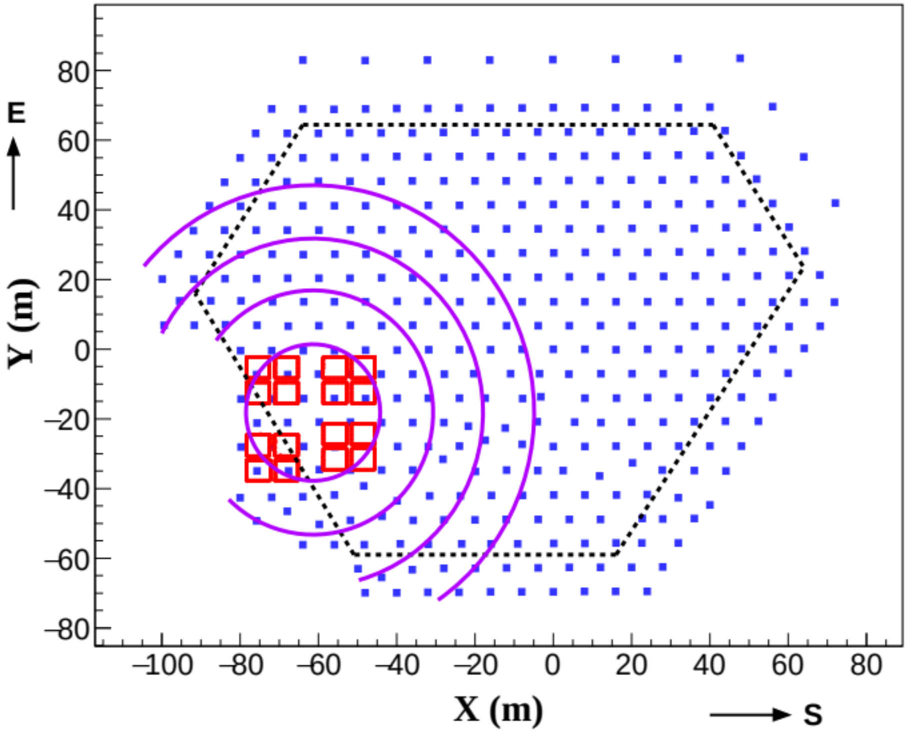




Hadronic cascade

Gamma-ray simulation

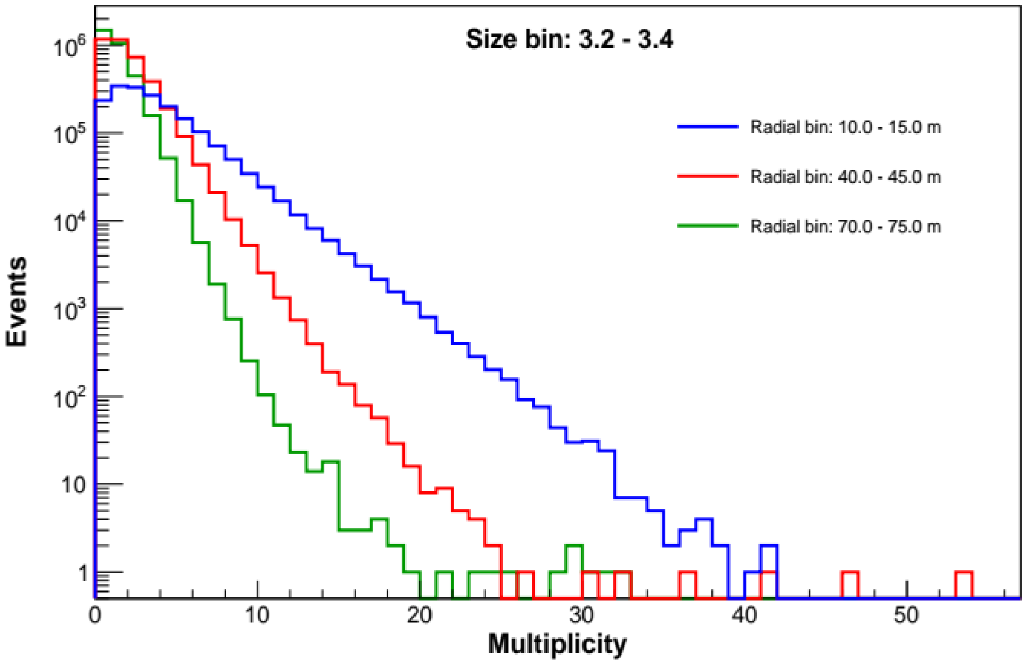
- **CORSIKA v7.4001 is used for the extensive air shower simulation**
  - **High energy hadronic interaction model : SIBYLL 2.1c**
  - **Low energy hadronic interaction model : FLUKA 2011**
- **Reconstruction of shower parameters:**
  - **Each shower is randomly thrown 10 times**
  - **Radial bins of 5 m from the muon telescope center**
- **GEANT4 simulation of the muon telescope**

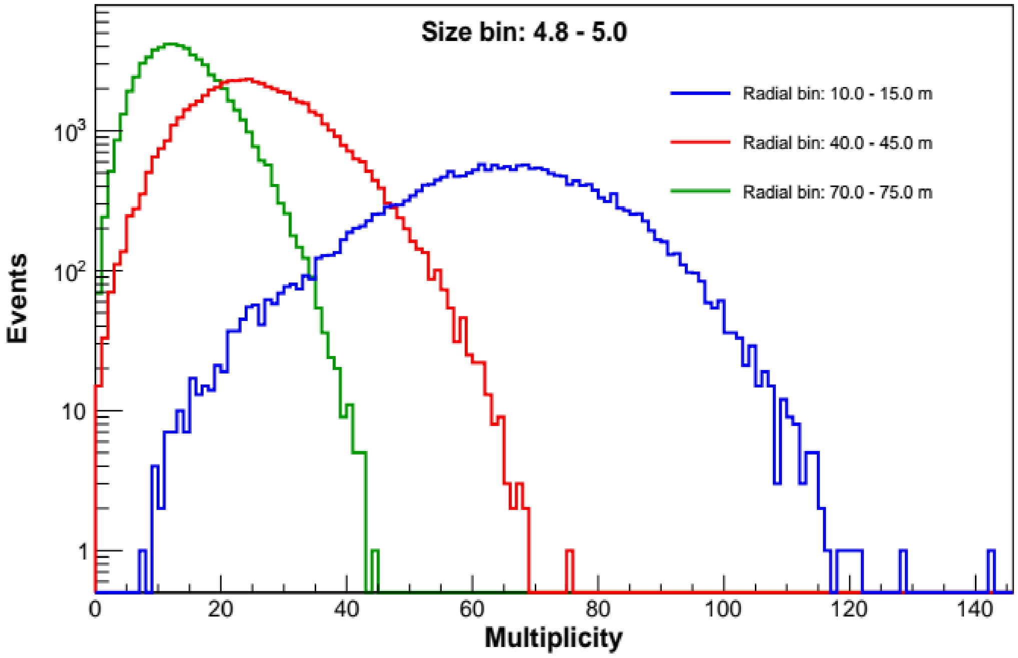


Data Selection

- One year of data is used (2014)
- Quality cuts to select events:
  - Successfully reconstructed showers (NKGFitFlag > 0)
  - NKG cores should lie inside the fiducial area.
  - Shower age between $0.12 \leq s \leq 1.8$
  - Zenith angle < 25 deg.
- For selected showers, muon multiplicity is calculated for logarithmic size bins of interval 0.2 and for radial bins of 5 m

Muon multiplicity (data)



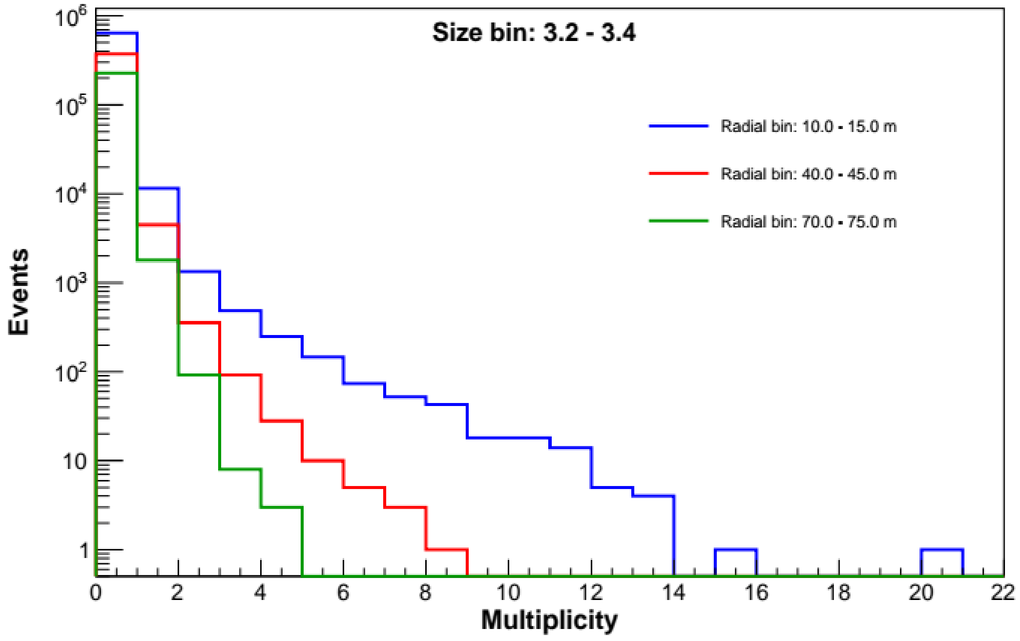


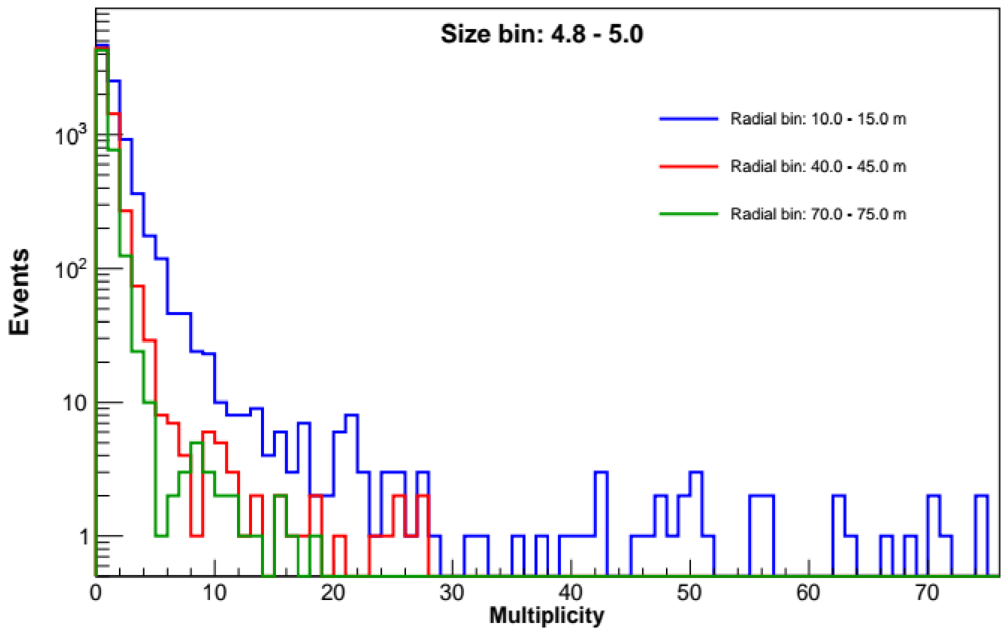
Muon-poor showers:
12.6%, 30.7%, and 46.1%

Muon-poor showers:
0.0%, 0.03%, and 0.1%

Muon multiplicity (gamma-ray simulation)

- **Gamma-ray intiated showers can also produce muons**



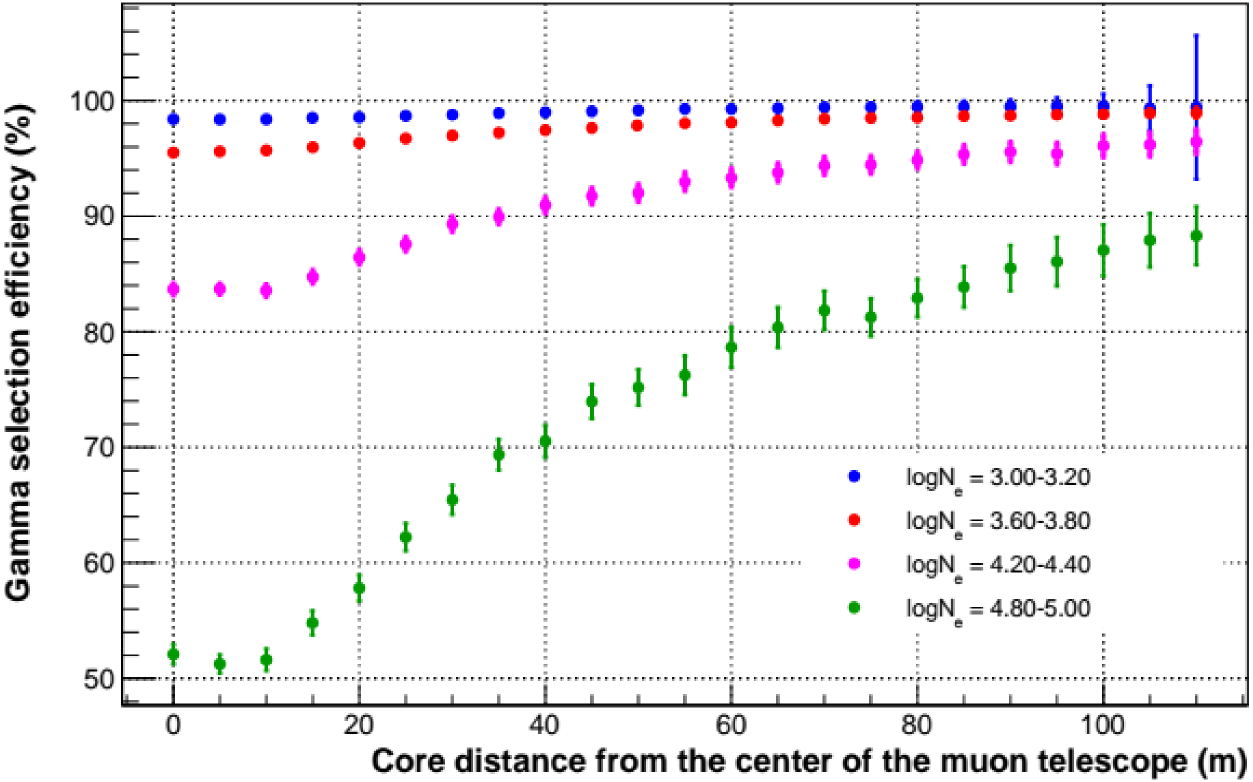


Muon-poor showers:
97.9%, 98.7%, and 99.2%

Muon-poor showers:
51.6%, 70.5%, and 81.8%

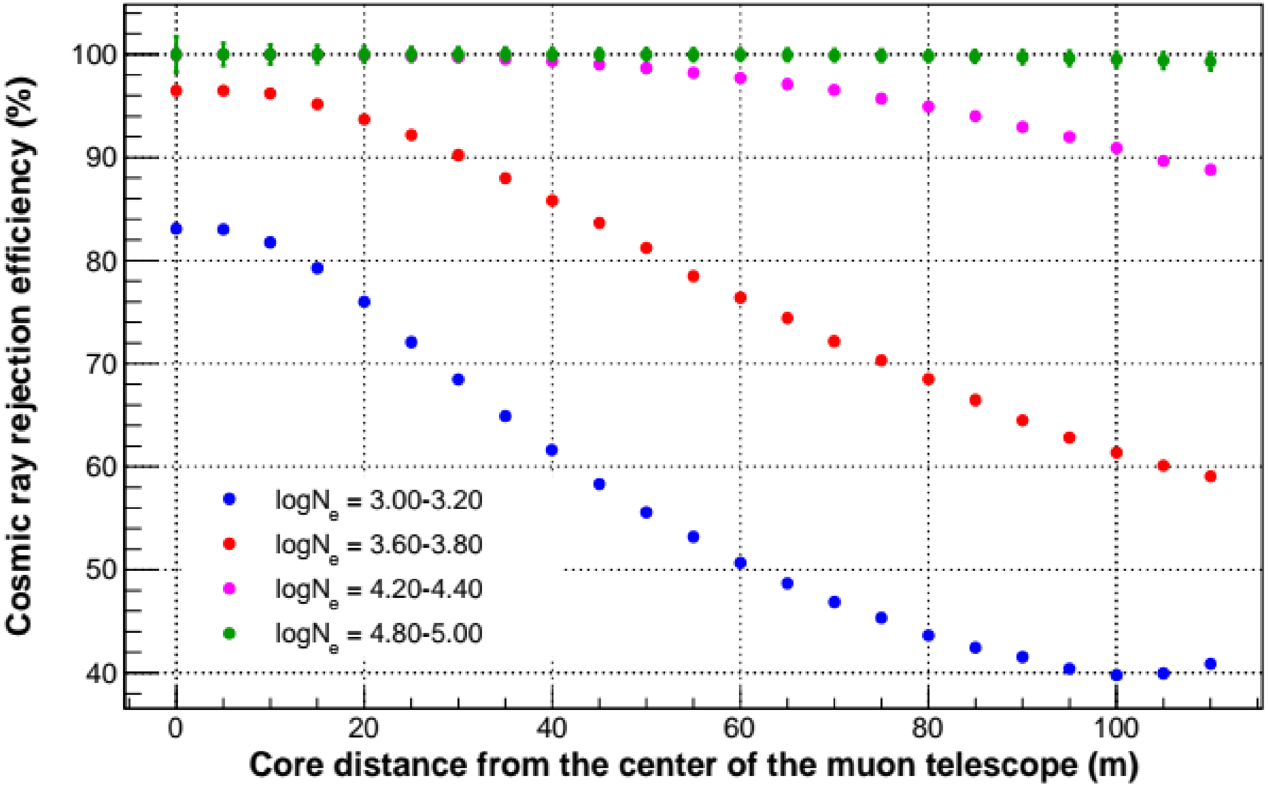
Gamma-ray selection efficiency

- Ratio of muon-poor showers to total incident showers
  - It tells how efficiently we can detect muon-poor showers as gamma-like showers
  - Calculated for each size and radial bin



Cosmic ray rejection efficiency

- Ratio of cosmic ray showers (1 or more muons) to total incident showers
  - It tells how efficiently we can reject charged CRs background
  - Calculated for each size and radial bin



Upper limit of gamma-ray flux over cosmic ray

- **The upper limit of the ratio is given by:**

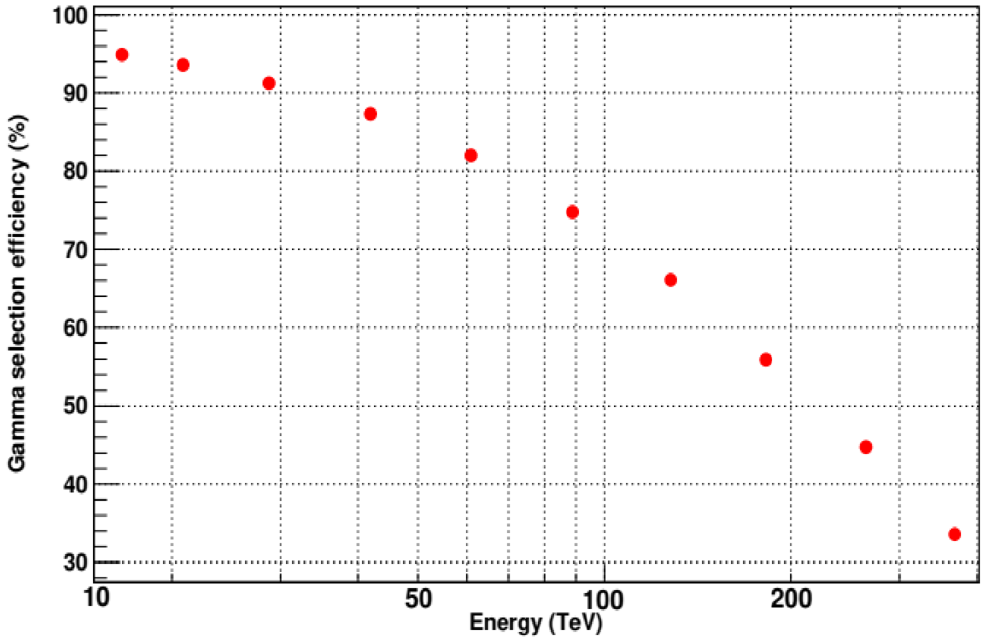
$$\frac{I_\gamma}{I_{\rm CR}} \leq \frac{N^{\mu=0}_{90\%{\rm C.L.}}}{N_{\rm all}} \frac{1}{\epsilon_\gamma} \frac{1}{1 - n_{\rm chance}}$$

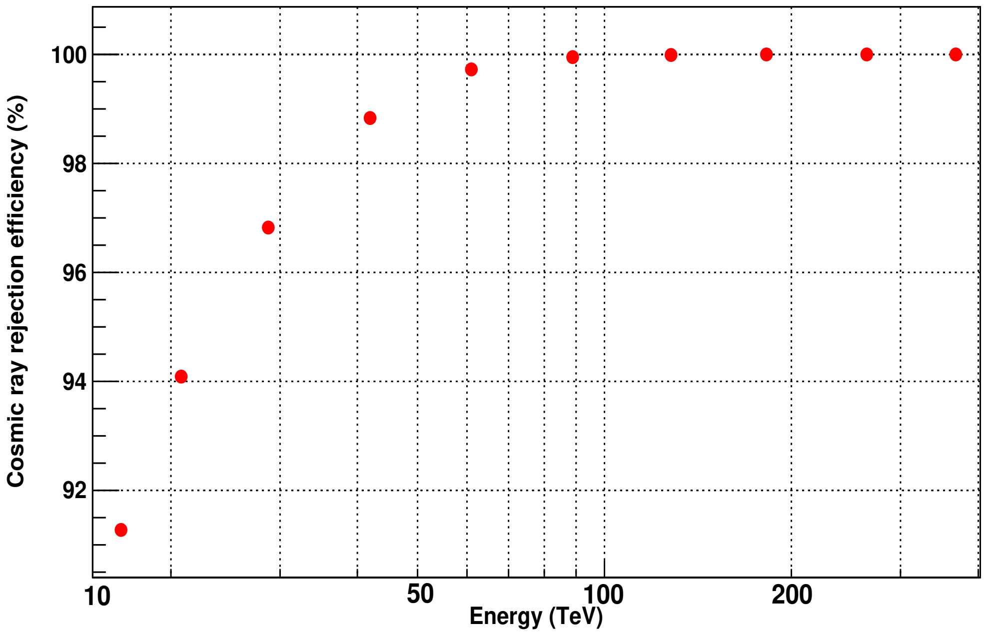
where,

$N^{\mu=0}_{90\%{\rm C.L.}}$	**90% C.L. upper limit on the number of muon-poor air showers**
$N_{\rm all}$	**total number of air showers.**
ϵ_γ	**selection efficiency.**
$n_{\rm chance}$	**avg. number of chance muons**

Calculation of integral flux

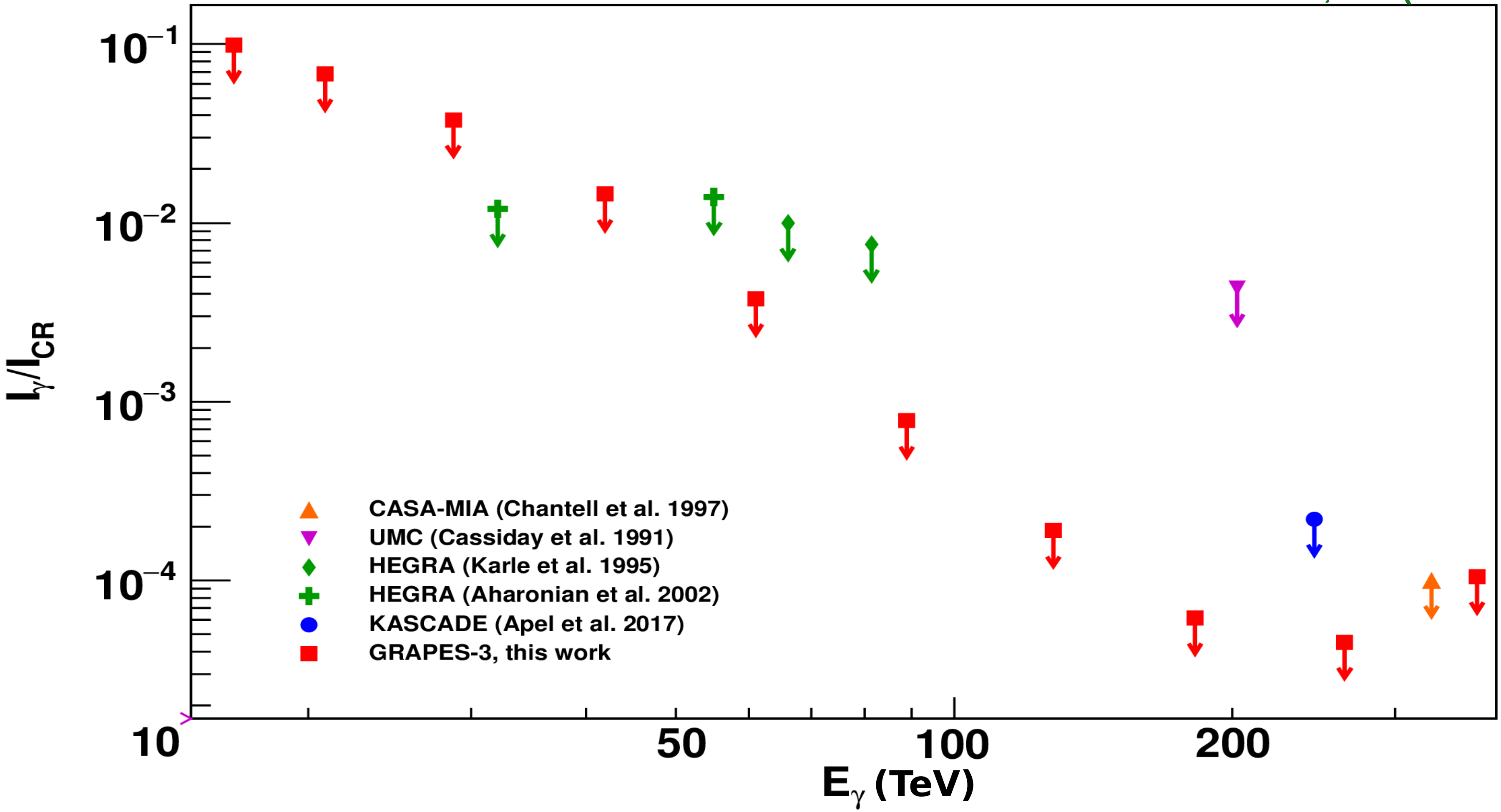
- Events chosen above different threshold shower sizes (>3.2, >3.4, >3.6…)
- Radial distance up to 30 m from the muon telescope
- Selection & rejection efficiency is calculated at various median gamma-ray energies





Upper limit of gamma-ray flux over cosmic ray

B. P. Pant et al., PoS(ICRC2019)691



Summary

- **90% C.L. upper limit on diffuse gamma-ray flux is placed using one year of GRAPES-3 data**
- **Upper limits: $\sim 10^{-5}$ (182 - 265 TeV)**


Thank You