SENSITIVITY OF SHOWER FOOTPRINT VARIABLES TO HIGH- AND LOW-ENERGY HADRONIC INTERACTION MODELS

Inês Alvito
Supervised by Prof. Pedro Abreu
and Prof. Rúben Conceição

Introduction

- One of the main challenges of gamma-ray detection is the **separation of gamma-rays** from the overwhelming hadronic background [1][2][3].
- Acessing these flux implies the building of instruments at ground level → **inhibits direct detection** of the primary.
- Traditional methods use the **number of muons** arriving at the ground as the standard gamma/hadron discriminative variable → requires **complex** and **expensive systems**.
- Two new variables have been proposed as a **cost-effective solution:** P^{α}_{tail} [2] and LCm [1].
- The goal of this work is to test possible differences of high- and low-energy hadronic models upon both variables.

Simulation Framework

CORSIKA simulations for 100 TeV proton-induced showers.

Detector	→	Water-Cherenkov Detector (WCD) array (1 km^2, 4% fill factor)
Hadronic Models Tested	→	High-Energy: QGSJet-II.04, EPOS-LHC and Sibyll2.3 Low-Energy: FLUKA, Gheisha2002d and UrQMD1.3cr

Variables

P^{α}_{tail}

- Quantifies the presence of **unusually large signals** in detector stations → often indicative of **hadron-induced showers**.
- Sums the tail probabilities of station signals using the alpha power index as a **tunable parameter**, which emphasizes extreme signals when high.

LCm

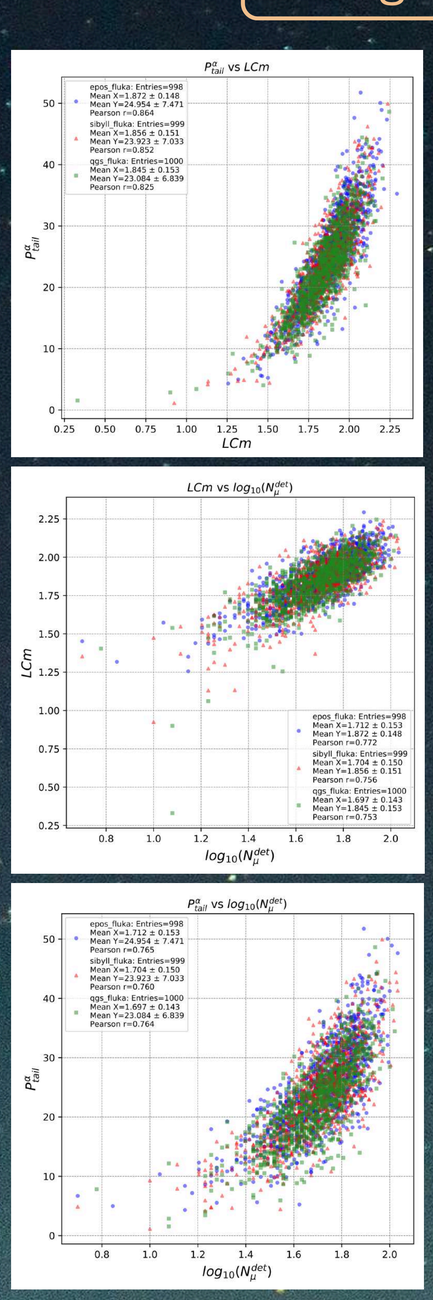
- Derived from the **azimuthal non-uniformity** of the Extensive Air Shower.
- Computed from the **signal variance** in a circular ring of detectors at a fixed radius (360m) from the shower core.

Both capture shower information **without the need of dedicated muon detectors**

Alternative to the number of muons arriving at the ground

Results

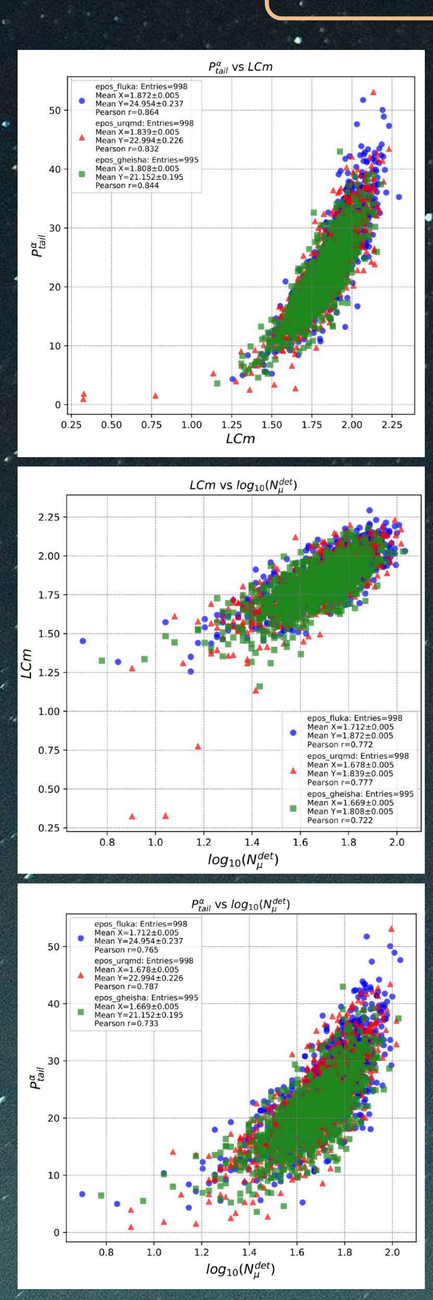
High-Energy



High-energy hadronic interaction models show minimal differences on observables

Model-independency

Low-Energy



Notable differences across different low-energy hadronic interaction models

Possible model-dependency

Conclusions

State of the Art

N^{det}_{μ}, P^{α}_{tail} and LCm are **independent** of the choice of **high-energy** hadronic interaction model.

Low Energy Models

All tested discriminators show some **sensitivity** to the choice of **low-energy hadronic interaction model**, seeming to be **dependent** of these.

Implications

Opportunity to **tune low-energy models** using incoming SWGO data , or select which model better fits the data.

Future Work

Extend this study to other energies, primaries and initial angles and to seek experimental validation.

References

[1] R Conceição, L Gibilisco, M Pimenta, and B Tomé. Gamma/hadron discrimination at high energies through the azimuthal fluctuations of air shower particle distributions at the ground. Journal of Cosmology and Astroparticle Physics, 2022(10):086, 2022.
[2] Ruben Conceição, Aroa Diz Penas, Lucio Gibilisco, Mário Pimenta, and Bernardo Tomé. Dependence of LCm on hadronic models for primary energies around 100 tev. internal note HAP-22-012, 2023.
[3] Ruben Conceição, Pedro J Costa, Lucio Gibilisco, Mário Pimenta, and Bernardo Tomé. High resolution gamma/hadron and composition discriminant variable for water- cherenkov detector cosmic-ray observatories. Physical Review D, 110(2):023033, 2024.

Image: SWGO Chile