Using EAS muons to identify Cosmic Primaries: Impact of the hadronic models

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ICRC Talk

Outline

- Introduction: Study of the muon component
- Methodology: using the horizontal spread of secondary muons to determine primaries
- Results
- Effect due to different hadronic models
- Concluding Remarks

A study of the muon component of EAS

- The reconstruction of the primary particle: utilizing the shower characteristics of the components of the secondary radiation.
- Open problem: The identification of the primary particle in a UHE EAS.

Goal

- Identifying primary particle shower–by–shower using muons
- The information on the muons in a simulated EAS, combined with X_{max} and energy of the primary E_p, are used for a log likelihood analysis to distinguish primaries

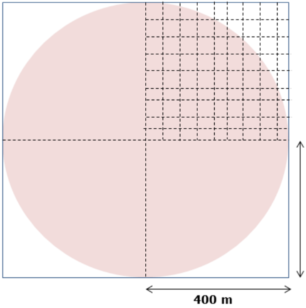
Simulation details

EAS:

- CORSIKA v7.6900
- Primaries: Proton, Iron
- Energy: 10^{16} eV - 10^{19} eV
- Zenith Angle: 0°
- Hadron Model:QGSJET-II
- 110m above sea level

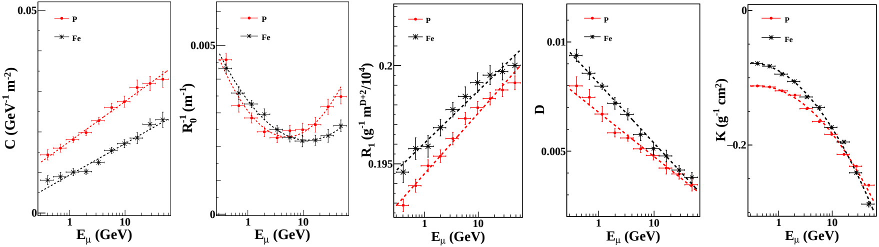
Detector:

- 2m X 2m stations
- Stations apart by:
  0m, 20m, 50m, 200m
  (Collection: 100%, 1%, 0.16%, 0.01%)
- $E_\mu = 0.5$ - 50 GeV
- E_μ resolution: 0, 50%



The Mapping

- $f_s = \frac{dN_\mu}{dE_\mu dR^2}[X_{max}, E_\mu, R] = Ce^{-RR_0^{-1}+(R_1 R^{-2D}+K)X_{max}}$



- The formulation gives stable fit results
- Makes calculations efficient compared to e.g. binned data

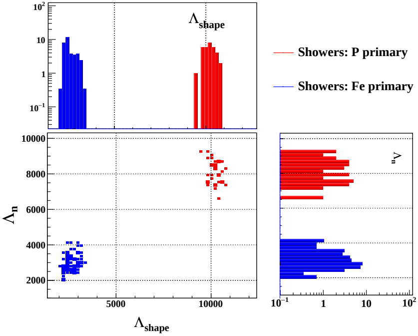
A log-likelihood test

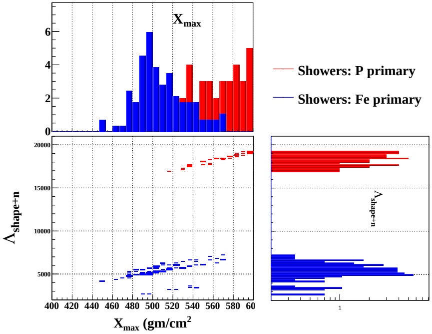
- We have modeled the shower shape analytically
- Construction of a likelihood function: $\ln L = \ln L_{shape} + \ln L_n$
- $L_{shape} = \prod_{i=1}^{N_\mu^{obs}} f_s^i(E_\mu^i, R^i)$ (f_s^i is normalized)
- $f_s = \frac{dN_\mu}{dE_\mu dR^2}[X_{max}, E_\mu, R] = C_0^2 e^{-RC_3^5+(C_6^7 R^{-2C_7^8}+C_9^{11})X_{max}}$

  $(C_i^j = \sum_{n=i}^{j} C_n \bar{E}_\mu{}^n,\ \bar{E}_\mu = \ln\,[E_\mu\ (\mathrm{GeV})])$
- $L_n = Poisson(N_\mu^{obs} | N_\mu^{exp})$
- $\boxed{\Lambda = \ln L(\text{Proton model}) \text{ - } \ln L(\text{Iron model})}$

Results

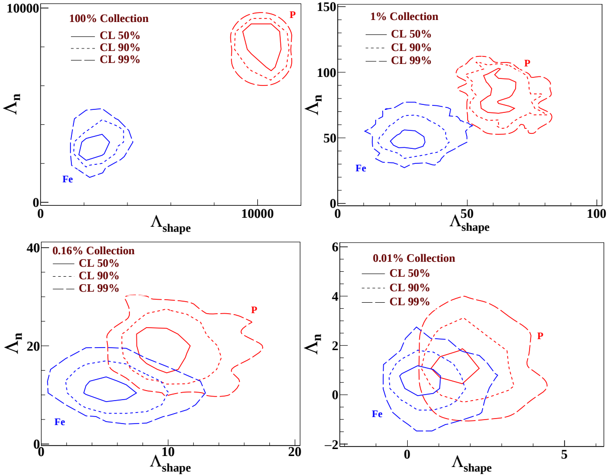
- $E_p = 10^{16} eV$, Continuous detector arrays (100% Collection)





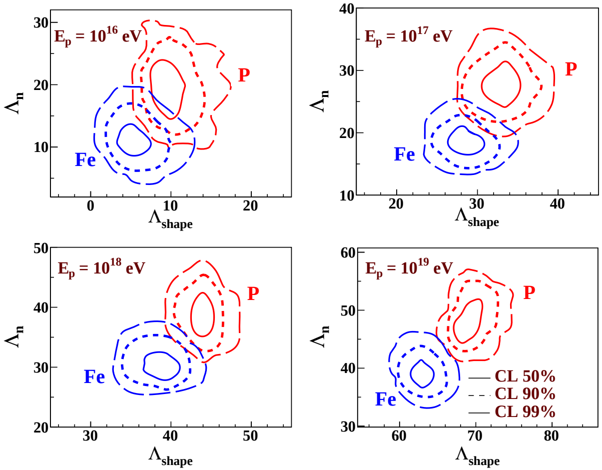
Results: At Different Collection Efficiencies

- $E_p = 10^{16}$ eV, ideal muon detectors



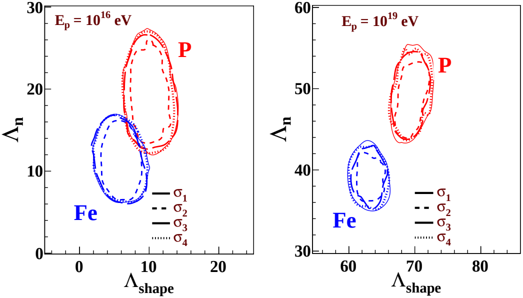
Results: At Different E_p

- Ideal muon detectors, 0.16% Collection



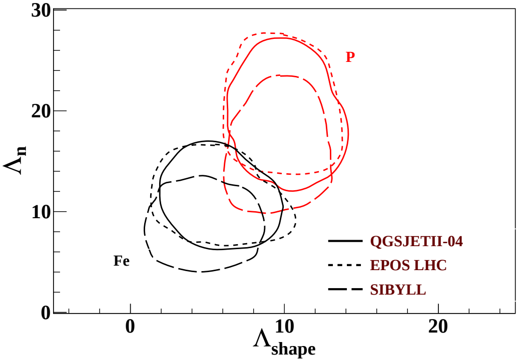
Results: With Detector Resolution

- σ_1 50%
- σ_2: 20% ($E_\mu \leq 10$ GeV) & 50% (rest)
- σ_3: 20% (10 Gev$\leq E_\mu \leq 20$ GeV) & 50% (rest)
- σ_4: 20% ($E_\mu \geq$20 GeV) & 50% (rest)



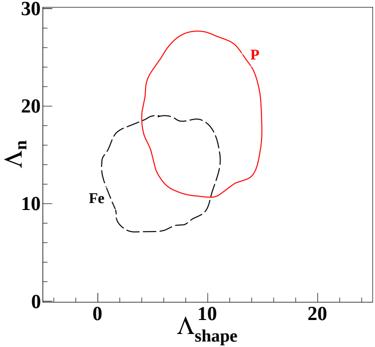
Different Hadron Models

- L_n and L_{shape} are governed by the lateral number as well as the number density of the muons
- Both of the parameters are observed to be varying in a slight different way in different hadron models



Results: With Hadron Models

- A model averaged f_s for shape analysis, and corresponding L_{shape}
- A model averaged L_n
- 50 showers each of P and Fe: Compared with the proton average shape.



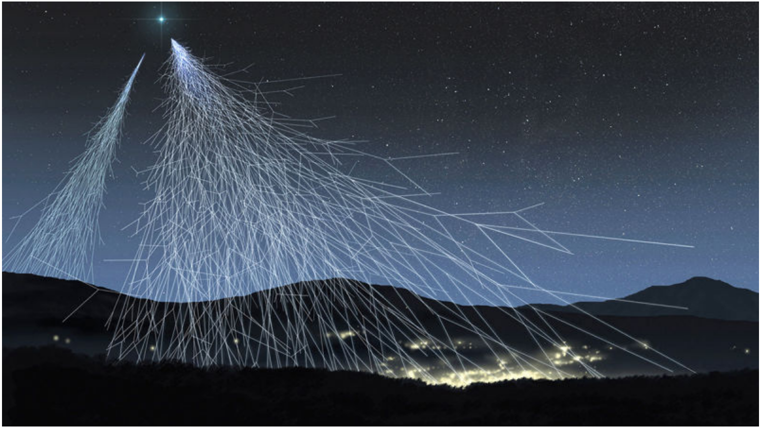
$10^{16} eV$

Prospects of upgrading existing surface arrays

- Introduction of muon tracker arrays can provide us the necessary information on muons
- 2m X 2m detectors 50 m apart provides good separation between P and Fe primaries
- Arrays of large area low cost detectors are suitable for the primary identification
- Reasonable options: Gaseous large area detectors with suitable pickup strip pixels
- Ongoing Work: A GEANT4 simulation with RPC/GEM tracker arrays.

Concluding Remarks

- The muon component of an EAS contain important information on the primary CR
- The shape of the muon shower component can be parametrized
- The hadronic models give rise to a higher uncertainty in the primary separation mechanism. A model averaged shower shape may be utilized.
- Information on the shape and flux can be used to identify primaries using a realistic surface array
- Separation of primaries improves with increase in primary energy. At higher energies the flux is much lower, but more precise information on the primaries are obtainable
- The composition of the primary can be useful to probe the source of UHECR.



Thank you for the kind attention!