Identifying shower primaries using individual muons in an EAS (A simulation study)

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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
- Low-cost Large Area Detector Arrays can be employed to detect muon tracks
- We perform an operational research on feasibility of such detectors

Simulation details

EAS:

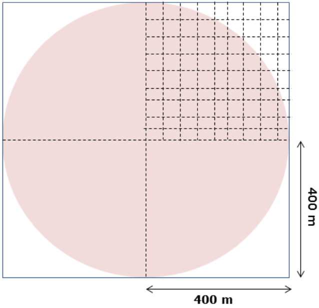
- CORSIKA v7.4002
- Primaries: Proton, Iron
- Energy: 10^{16} eV, 10^{17} eV
- Zenith Angle: 0°
- Hadron Model:QGSJET-II
- 110m above sea level

Detector:

- 2m X 2m stations
- Stations apart by:

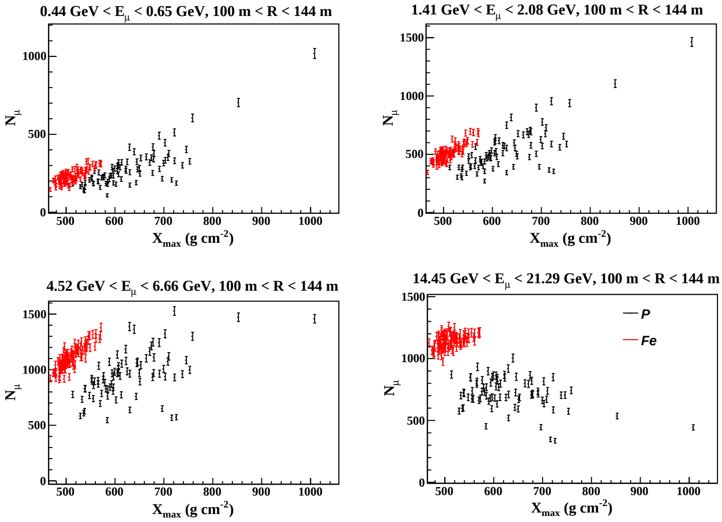
  0m, 20m, 50m, 200m

  (Collection: 100%, 1%, 0.16%, 0.01%)
- $E_\mu = 0.5$ - 50 GeV
- E_μ resolution: 0, 50%



The number of muons and X_{max}

- $E_p = 10^{16} eV$



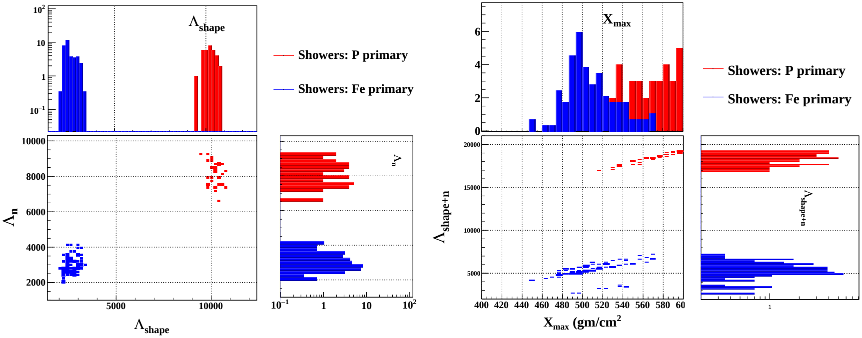
A log-likelihood analysis

- 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)
- $f_s = \frac{dN_\mu}{dE_\mu dR^2}[X_{max}, E_\mu, R] = C_0^2 e^{-RC_3^5 + (R^{-2C_6^7} + C_8^{10})X_{max}}$

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

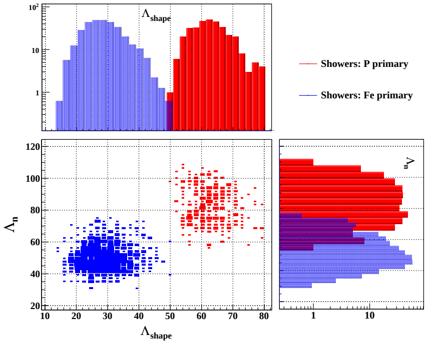
Log Likelihood Analysis

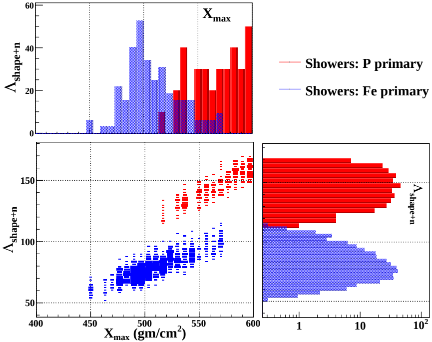
- $E_p = 10^{16} eV$, Continuous detector arrays (100% Collection)



Log Likelihood Analysis

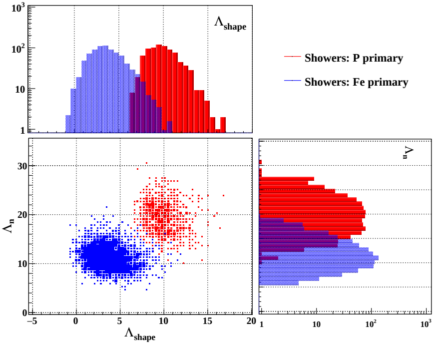
- $E_p = 10^{16} eV$, 2m X 2m Detectors 20m apart (1% Collection)

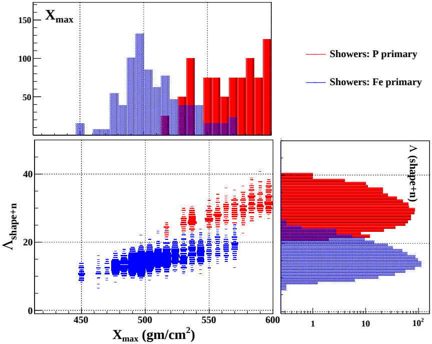




Log Likelihood Analysis

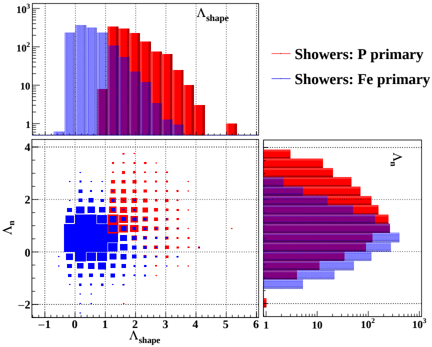
- $E_p = 10^{16} eV$, 2m X 2m Detectors 50m apart (0.16% Collection)

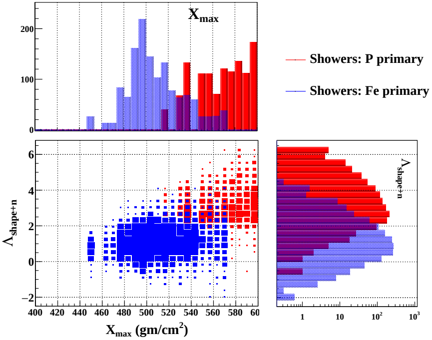




Log Likelihood Analysis

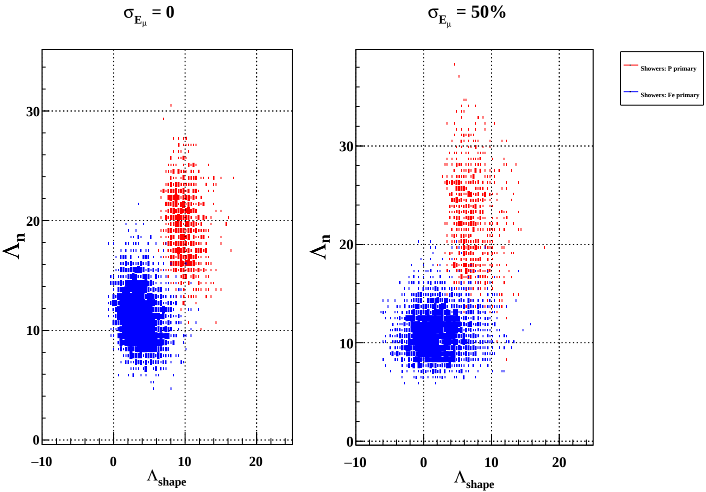
- $E_p = 10^{16} eV$, 2m X 2m Detectors 200m apart (0.01% Collection)





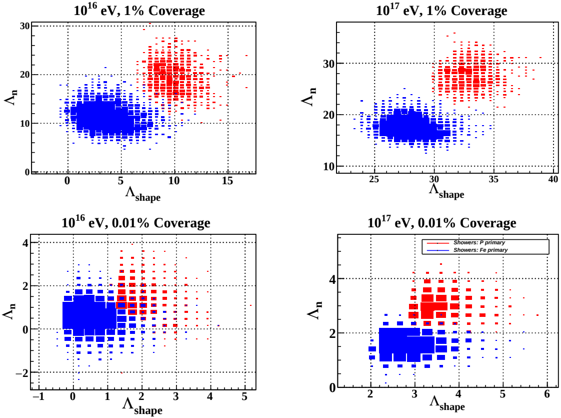
Likelihood Test Results:

- $E_p = 10^{16} eV$, 2m X 2m Detectors 50m apart (0.1% Collection), E_μ resolution 0% and 50%



Likelihood Test Results:

- $E_p = 10^{16} eV$ and $E_p = 10^{17} eV$, 1% and 0.01% coverage

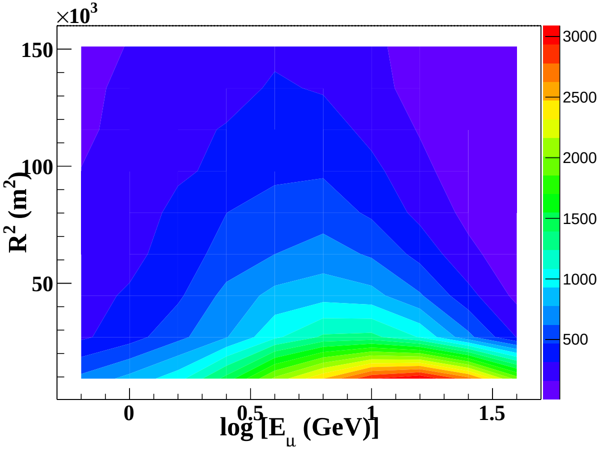


Prospects of upgrading existing surface arrays

- Introduction of muon tracker arrays would 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, e.g, THGEM

Concluding Remarks

- The shape of the muon shower component in an EAS has been parametrized.
- Information on the shape and flux are used to identify primaries.
- Identification of primaries with muons collected is possible with 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.
- Low cost large area detectors can be employed.
- Future scope: This study will now be extended to different type, energy and direction of the shower primary. The various models of hadron interaction would also be probed. Realistic values of X_{max} resolution, E_p resolution; the detector parameters, like energy resolution, position resolution etc. will also be included.


×10^3
150
100
50
R^2 (m^2)
0
0.5
1
1.5
log [E_μ (GeV)]
3000
2500
2000
1500
1000
500

Thank you!