Study of muons from ultrahigh energy cosmic ray air showers measured with the Telescope Array experiment

R. Takeishi for the Telescope Array Collaboration

Sungkyunkwan University, South Korea Email: takeishi@skku.edu

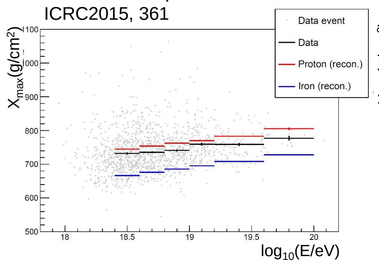
Introduction

- Uncertainty of UHECR composition from hadronic interaction models
- Muon excess of data compared with MC

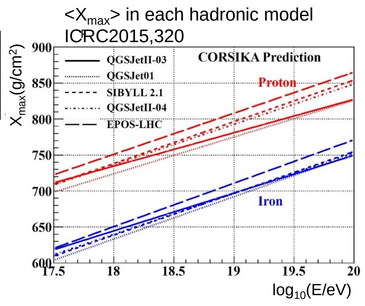
→ present hadronic models do not fully reproduce air showers.

Mass composition uncertainty from hadronic interaction models in air shower MC

TA mass composition
ICRC2015, 361

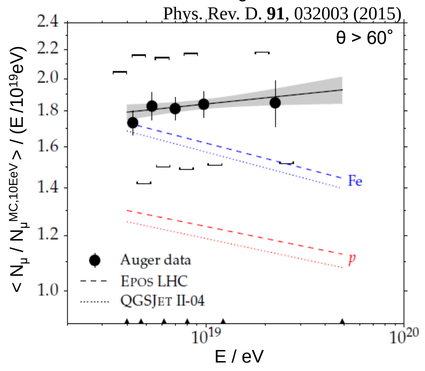


<X_{max}> in each hadronic model
ICRC2015,320



Muon excess from Auger experiment

Pierre Auger Collaboration,
Phys. Rev. D. **91**, 032003 (2015)

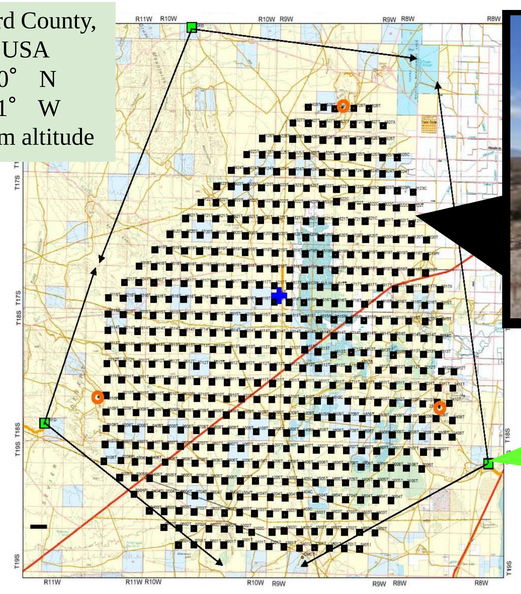


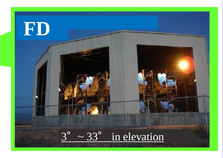
It is useful to compare the measured number of muons with the MC prediction for improving hadronic interaction models.

Detector

Telescope Array experiment

Millard County,
Utah, USA
39.30° N
112.91° W
1400 m altitude





- An array of 507 scintillator surface detectors (SDs) covering 700 km^2
- 3 fluorescence detector stations overlooking the array
- Operational as of 2008

80 – 90% of TA SD signal derives from electromagnetic components.

Analysis method

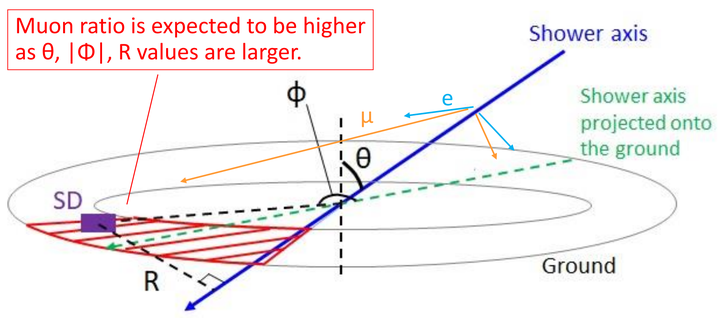
Dataset

- Energy: $10^{18.8}$ eV < E < $10^{19.2}$ eV
- Experimental data: TA 7 years' dataset (20080511 ~ 20150511)
- MC: hadronic models QGSJET II-03, QGSJET II-04, Epos 1.99 and Sibyll 2.1

Calculation approach

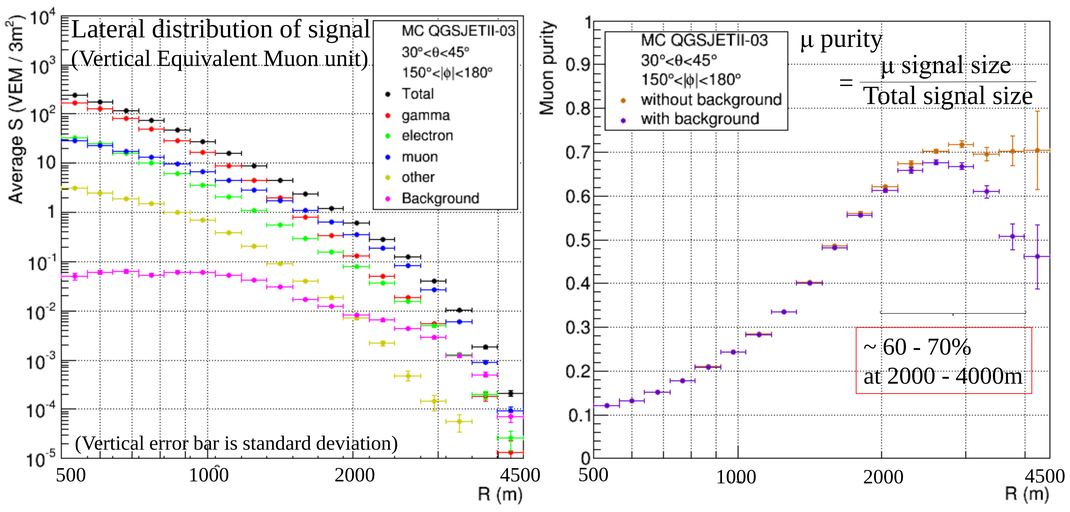
• EM components (e, γ) generated on the shower axis are attenuated faster than muons in the atmosphere.

• To increase the muon purity in the signal, we divide the detector hit in the air shower events using zenith angle θ, azimuth angle Φ, lateral distance R.



Muon purity expected from the MC

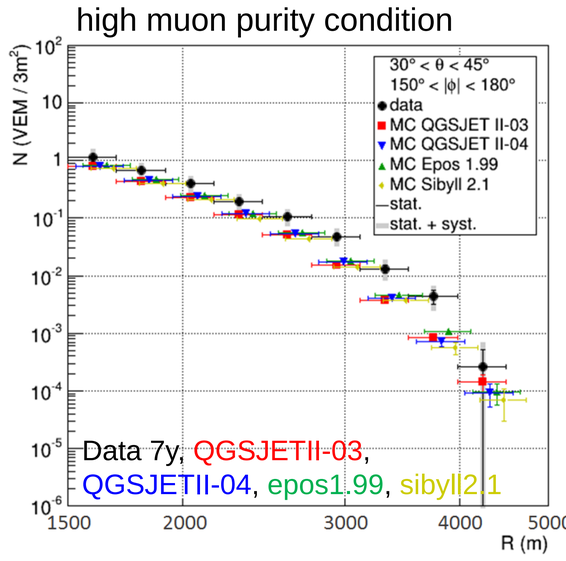
- Mainly 60 – 70% for 30° < θ < 45°, 150° < |Φ| < 180°, 2000m < R < 4000m
- We use this condition for comparison between data and MC.



Results

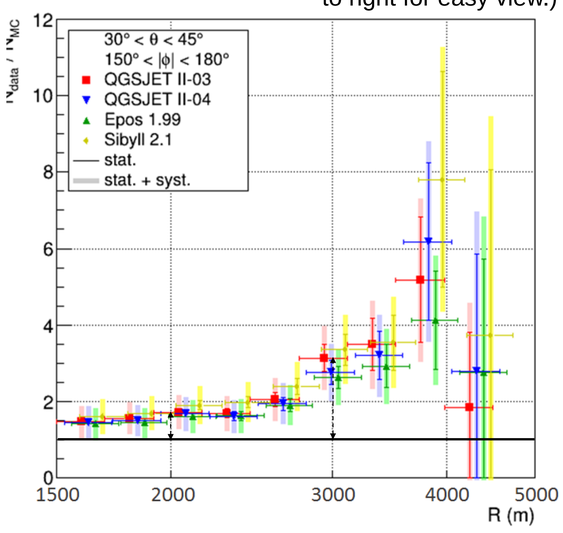
- Lateral distribution on condition μ purity 60 - 70%
- Data is larger than MC by more than 1.5 times.
  For QGSJETII-03,
  1.72±0.10(stat.)±0.40(syst.) (1910 m < R < 2160m) (1.8σ)
  3.14±0.36(stat.)±0.72(syst.) (2760 m < R < 3120m) (2.7σ)
- Larger data/MC ratio at larger lateral distance

Lateral distribution on the high muon purity condition

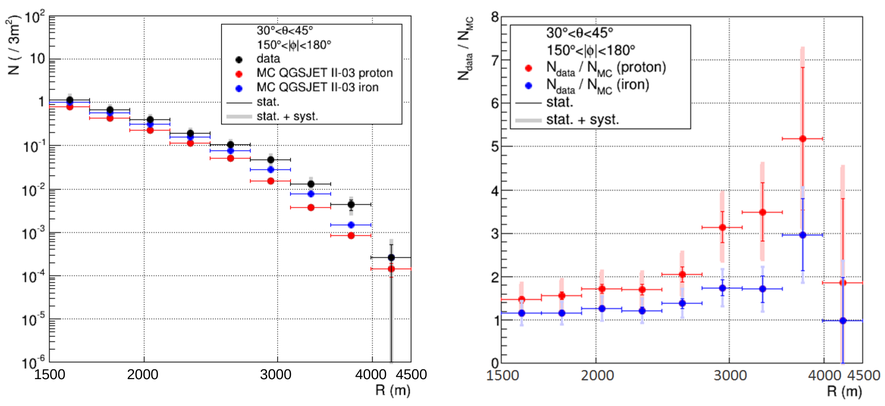


Data / MC ratio

(QGSJETII-04, Epos 1.99, Sibyll 2.1 plots are shifted to right for easy view.)

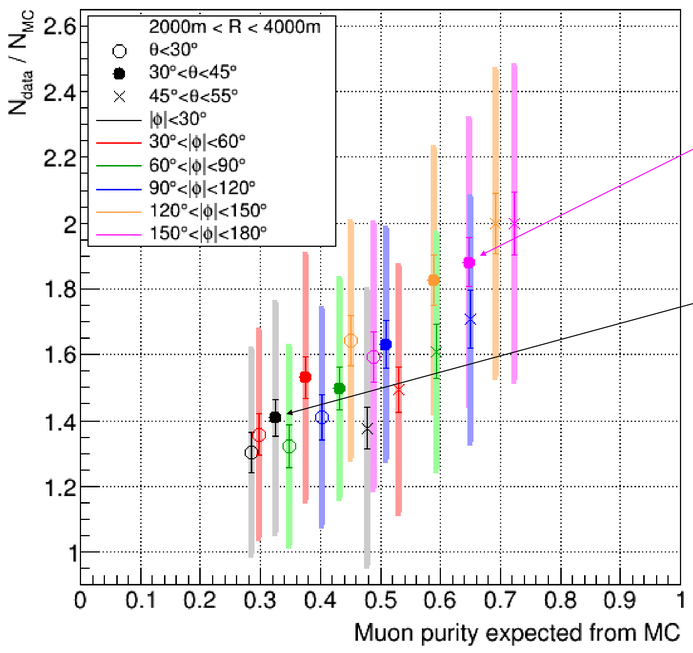


Lateral distribution and data / MC ratio for iron composition



Correlation plots between muon purity and data/MC ratio

One plot corresponds to one (θ, Φ) condition (R range is fixed).



• For 30° < θ < 45° 150° < |Φ| < 180°, μ purity = ~ 65 % and Data/MC = 1.88 ± 0.08(stat.)± 0.40(syst.)

• For θ < 30° |Φ| < 30°, μ purity = ~ 28 % and Data/MC = 1.30 ± 0.06(stat.)± 0.27(syst.)

Larger difference in signal size at higher muon purity

These results imply that part of the discrepancy between data and MC is due to muon excess.

Conclusion

• We developed an analysis for muons from UHECR with TA scintillator SD by using high muon purity (θ, Φ, R) condition.

• Difference between observed number of particles from UHECR air showers measured with TA SD and expected value from MC is:

R (m)	Data/MC proton	Data/MC iron
[1910, 2160]	1.72±0.10(stat.)±0.40(syst.)	1.26±0.07(stat.)±0.29(syst.)
[2760, 3120]	3.14±0.36(stat.)±0.72(syst.)	1.74±0.19(stat.)±0.40(syst.)

for QGSJETII-03 at $10^{18.8}$ eV < E < $10^{19.2}$ eV, 30° < θ < 45°, 150° < |Φ| < 180° (muon purity expected from MC : 60 ~ 70 %)

• Results show same feature with muon excess reported by Auger experiment.

• In addition, we found larger difference between data and MC at larger lateral distances, which provided information to improve reliability of hadronic interaction models.