Mass Composition Studies with the Pierre Auger Observatory

M. Unger (KIT) for the Pierre Auger Collaboration

Mass Composition Studies

(a) Longitudinal Development of Air Showers with FD



Measurement of Longitudinal Profiles with FD



Event Selection



Event Selection



Performance

Statistics:

42662 event $> 10^{17.2}$ eV, 842 $> 10^{19}$ eV, 62 $> 10^{19.5}$ eV

Resolution:

Systematics:





Cross Checks: Sub-Samples, Cuts, Method



Average Shower Maximum vs. Energy

Pierre Auger Coll., PRL 2011, PRD 2014; update at ICRC17



 $\langle X_{
m max}
angle \propto D_{
m 10} \log{(E/A)}$ (mass A, energy E, elongation rate $D_{
m 10} \sim$ 60 g/cm²/decade)

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Standard Deviation of X_{max} vs. Energy

Pierre Auger Coll., PRL 2011, PRD 2014; update at ICRC17



Standard Deviation of X_{max}

mixed composition:
$$\sigma(X_{\max})^2 = \langle \sigma_i^2 \rangle + \left(\left\langle \langle X_{\max} \rangle_i^2 \right\rangle - \langle X_{\max} \rangle^2 \right)$$



Comparison to Air Shower Simulations



hadronic interaction models tuned to LHC data

Fit of X_{max} Distributions (p, He, N, Fe)



Pierre Auger Coll., PRD 90 (2014) 12, 122006; update at ICRC17

Fit of X_{max} Distributions



Pierre Auger Coll., PRD 90 (2014) 12, 122006; update at ICRC17

Mass Composition Studies

(b) Correlation of X_{max} and Ground Signal



Measurement of Longitudinal Profiles with FD



Correlation of Xmax and Ground Signal

 $18.5 < \lg(E/eV) < 19.0, X_{max}^*/S^*(1000)$: scaled to $10^{19} eV$



Correlation of X_{max} and Ground Signal

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Correlation of X_{max} and Ground Signal

 $18.5 < \lg(E/eV) < 19.0, X_{max}^*/S^*(1000)$: scaled to $10^{19} eV$



Mass Composition Studies (c) time profiles of SD signals



X_{max} from Risetime of SD Signals



X_{max} from Risetime of SD Signals



X_{max} from Risetime of SD Signals



Measurement of X_{max} with SD

FD-SD cross-calibration:

Full SD data set (517 events > $10^{19.5}$ eV):



Summary:

- measurement of X_{max} distributions, $\langle X_{\text{max}} \rangle$, $\sigma(X_{\text{max}})$, r_{G} , $t_{1/2}$.
- complex evolution of mass composition between 10^{17.2} and 10²⁰ eV
 - light composition just below the ankle
 - increasing mass towards UHE
 - mixed composition at low energies

Outlook:

• mass composition with AugerPrime (emag.- μ separation, see Friday)

