



bmb+f - Förderschwerpunkt

Astroteilchenphysik

Großgeräte der physikalischen
Grundlagenforschung



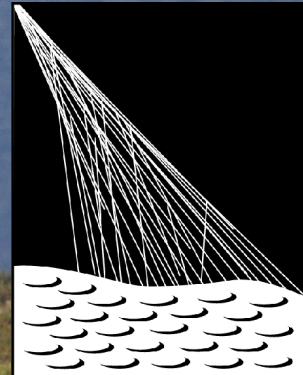
HELMHOLTZ
| ASSOCIATION

Alliance for Astroparticle Physics

RWTH AACHEN
UNIVERSITY

Experimental Status and Recent Results of the Pierre Auger Observatory

Tobias Winchen for the Pierre Auger Collaboration



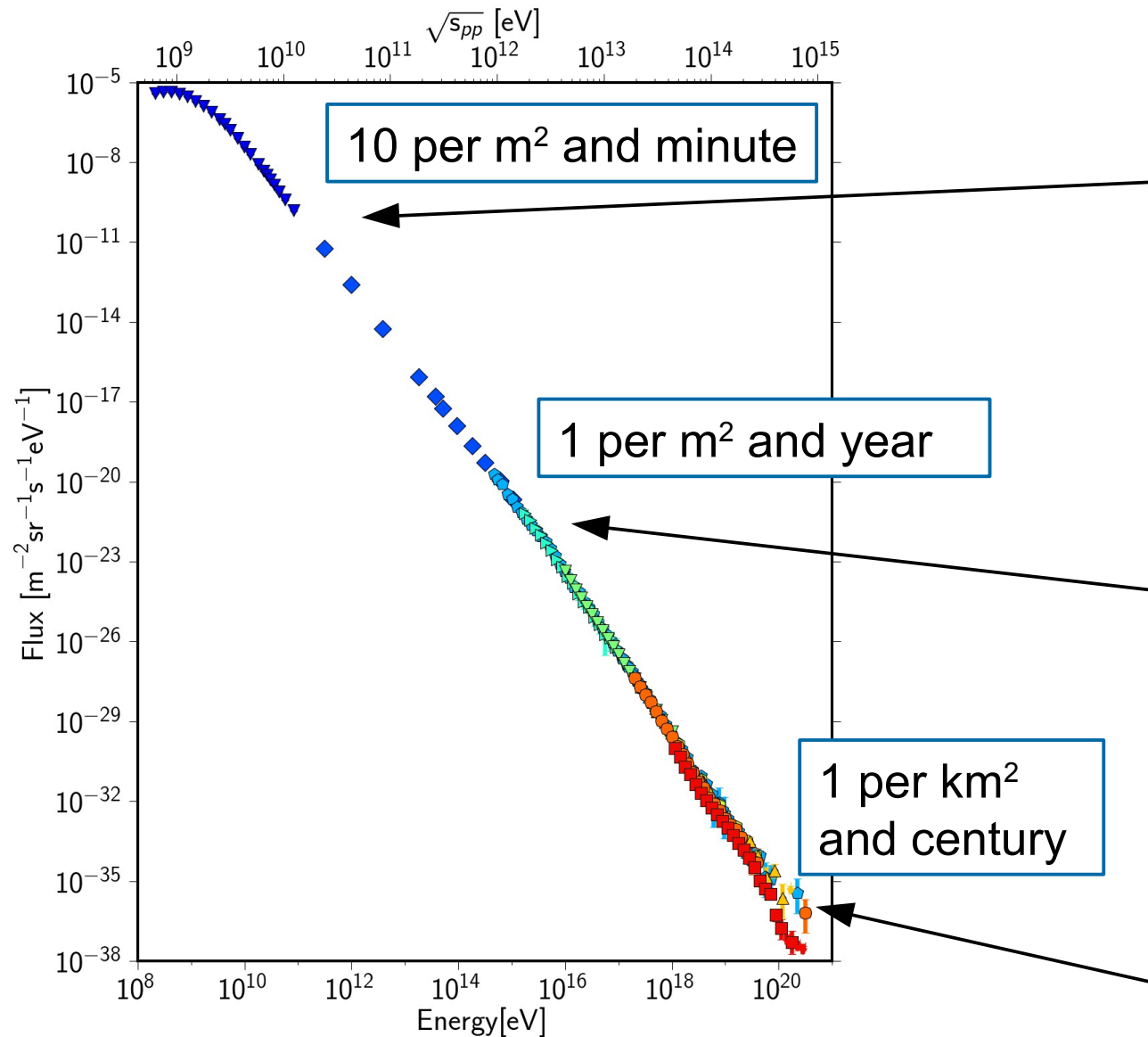
PIERRE
AUGER
OBSERVATORY

DPG Frühjahrstagung 2012, Göttingen

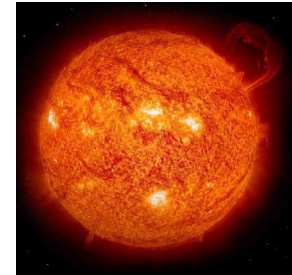
Outline

- Ultra High Energy Cosmic Rays
- The Pierre Auger Observatory
- Selection of Recent Results
 - Composition
 - Proton - Air Cross-section
 - Anisotropy
- Low Energy Enhancements
 - AMIGA
 - HEAT
 - AERA
- Summary

Cosmic Ray Spectrum



Solar wind



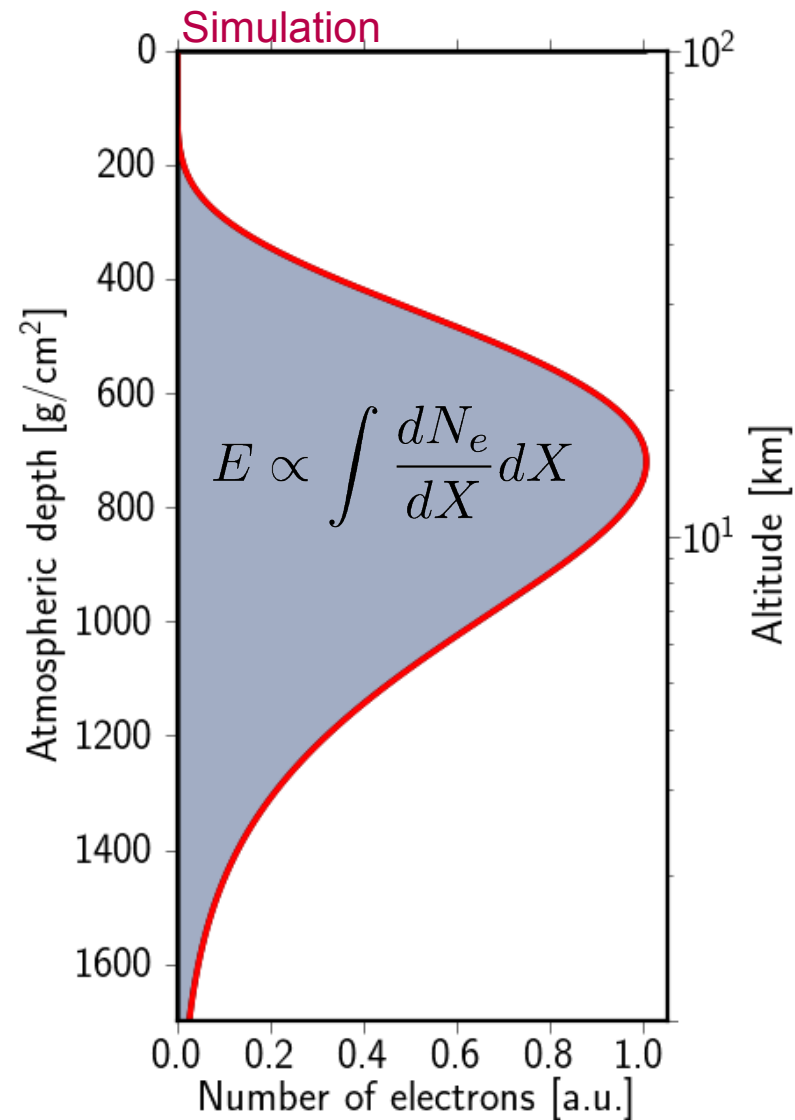
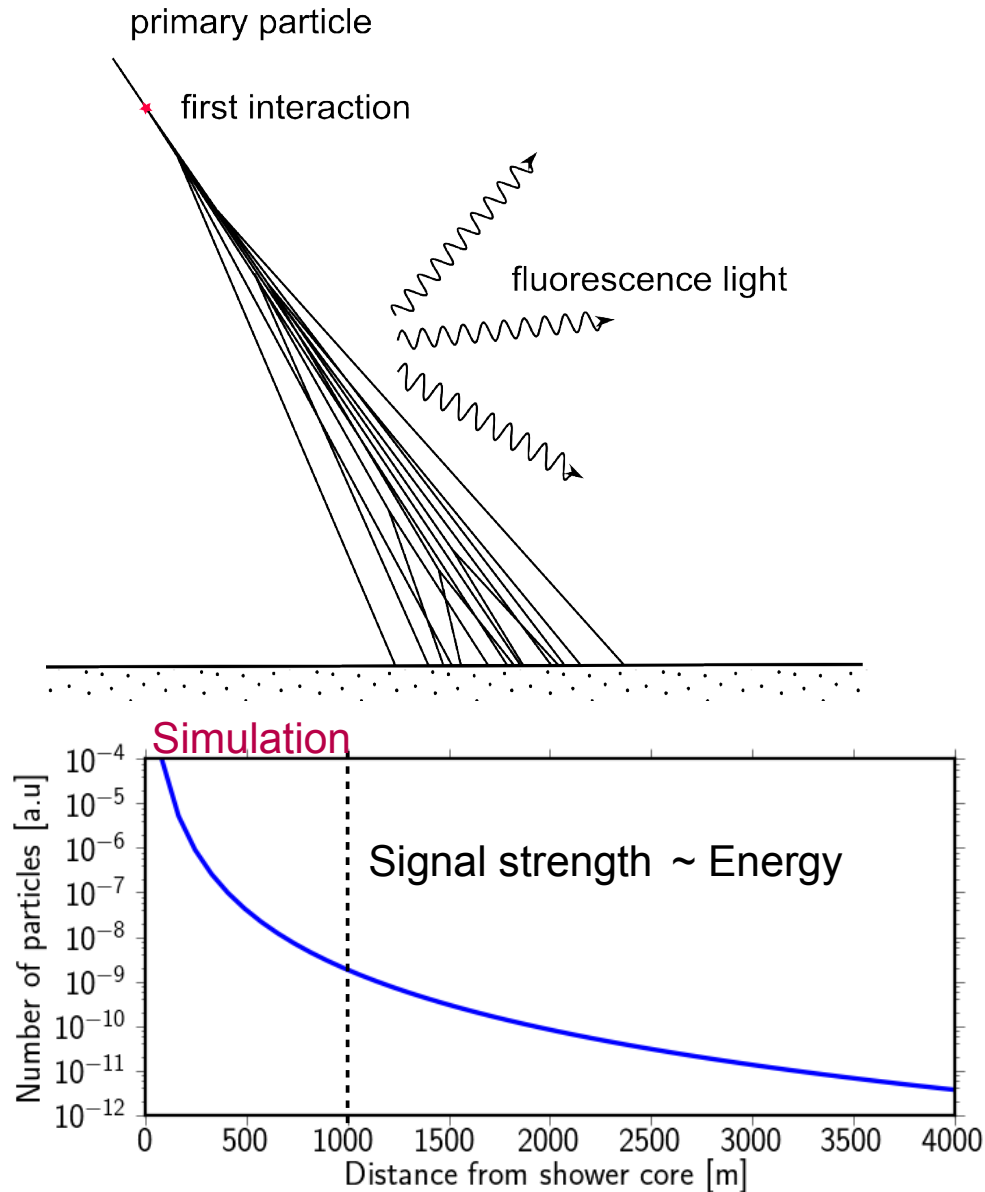
Likely
Supernovae



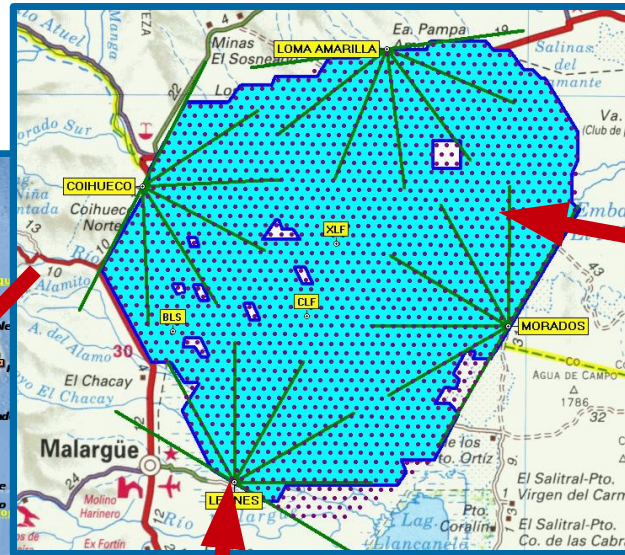
AGN, GRB, ...



Extensive Air Showers



The Pierre Auger Observatory



Surface Detector

1600 Water Cherenkov stations

1.5 km spacing

3000 km² covered area

Fluorescence Detector

4 sites with 180° view

6 telescopes at each site



Main Detector Components

Fluorescence detector

- Energy resolution $\sim 6\%$
- Angular resolution $\sim 0.5^\circ$
- 10% duty cycle: clear and moonless nights

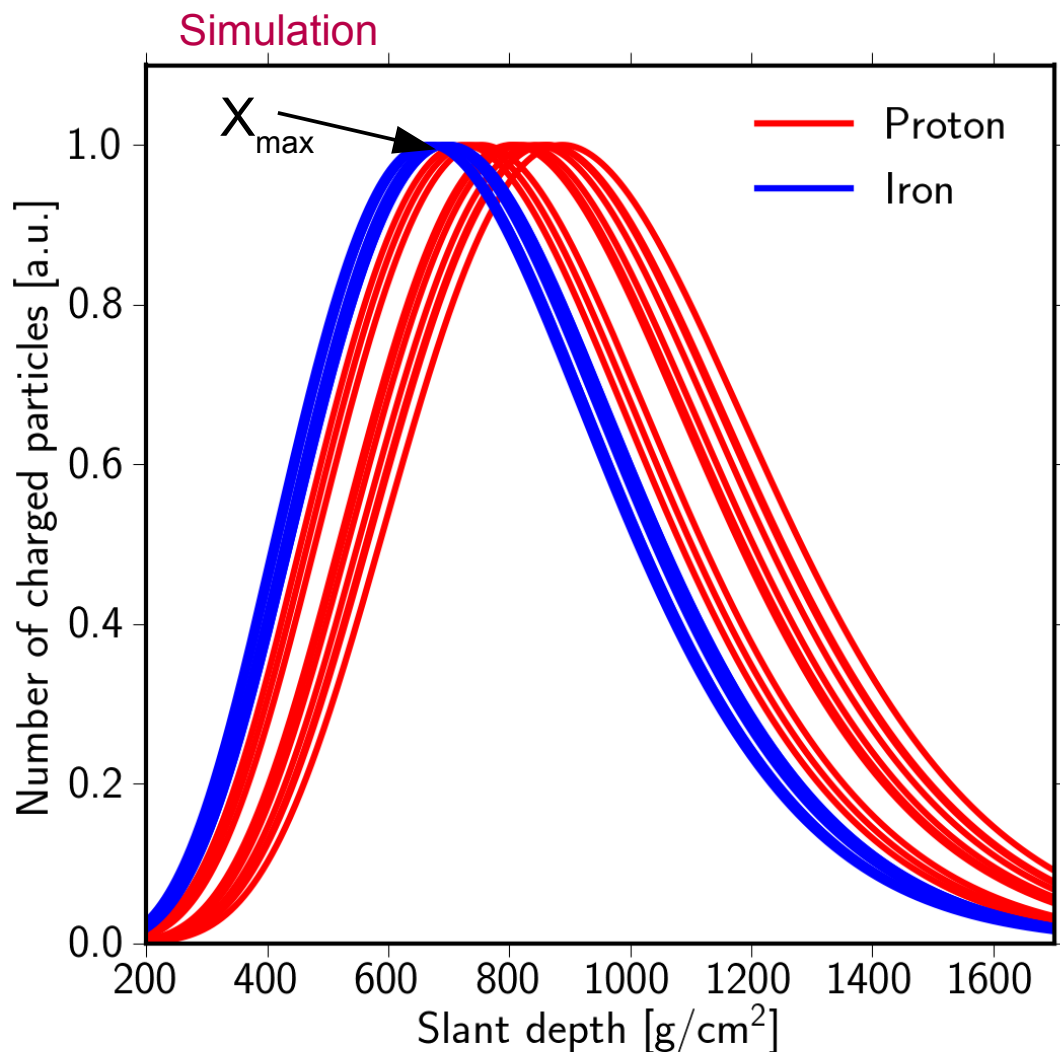


Surface detector

- Energy resolution $\sim 20\%$
- Angular resolution 1°
- $\sim 100\%$ duty cycle



Composition from Longitudinal Shower Profiles



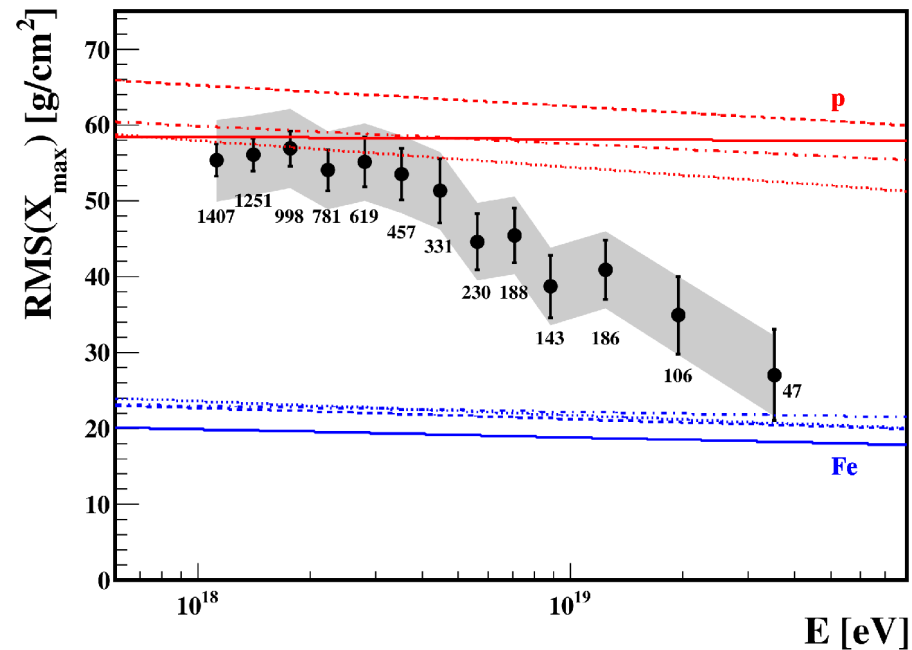
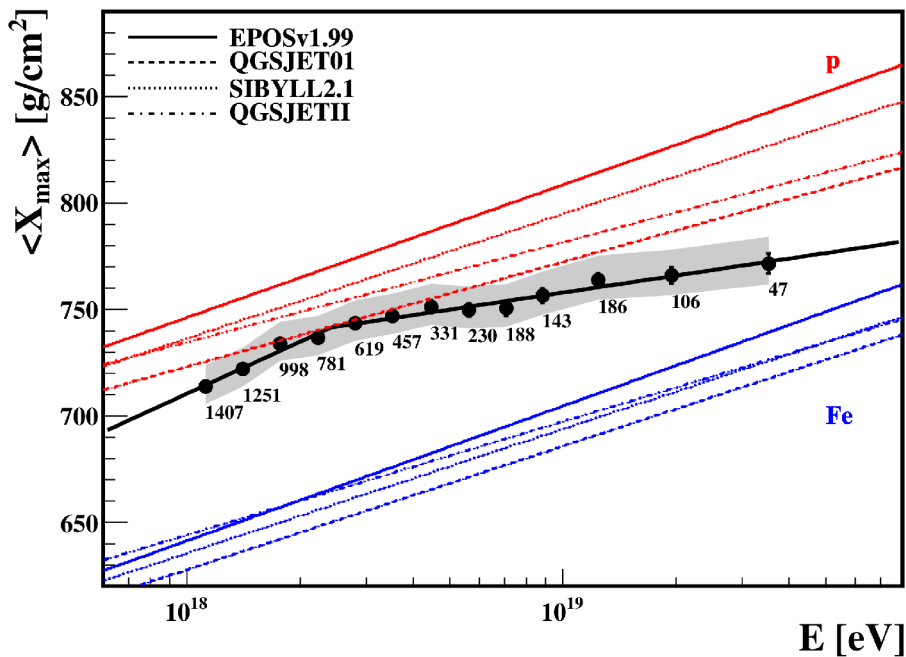
Light Particles

Low cross-section
Deeply penetrating
Late shower development
→ High $\langle X_{\max} \rangle$
Low multiplicity
→ High $\text{RMS}(X_{\max})$

Heavy Particles

High cross-section
Early shower development
→ Small $\langle X_{\max} \rangle$
High multiplicity
→ Low $\text{RMS}(X_{\max})$

Composition from X_{\max} Studies



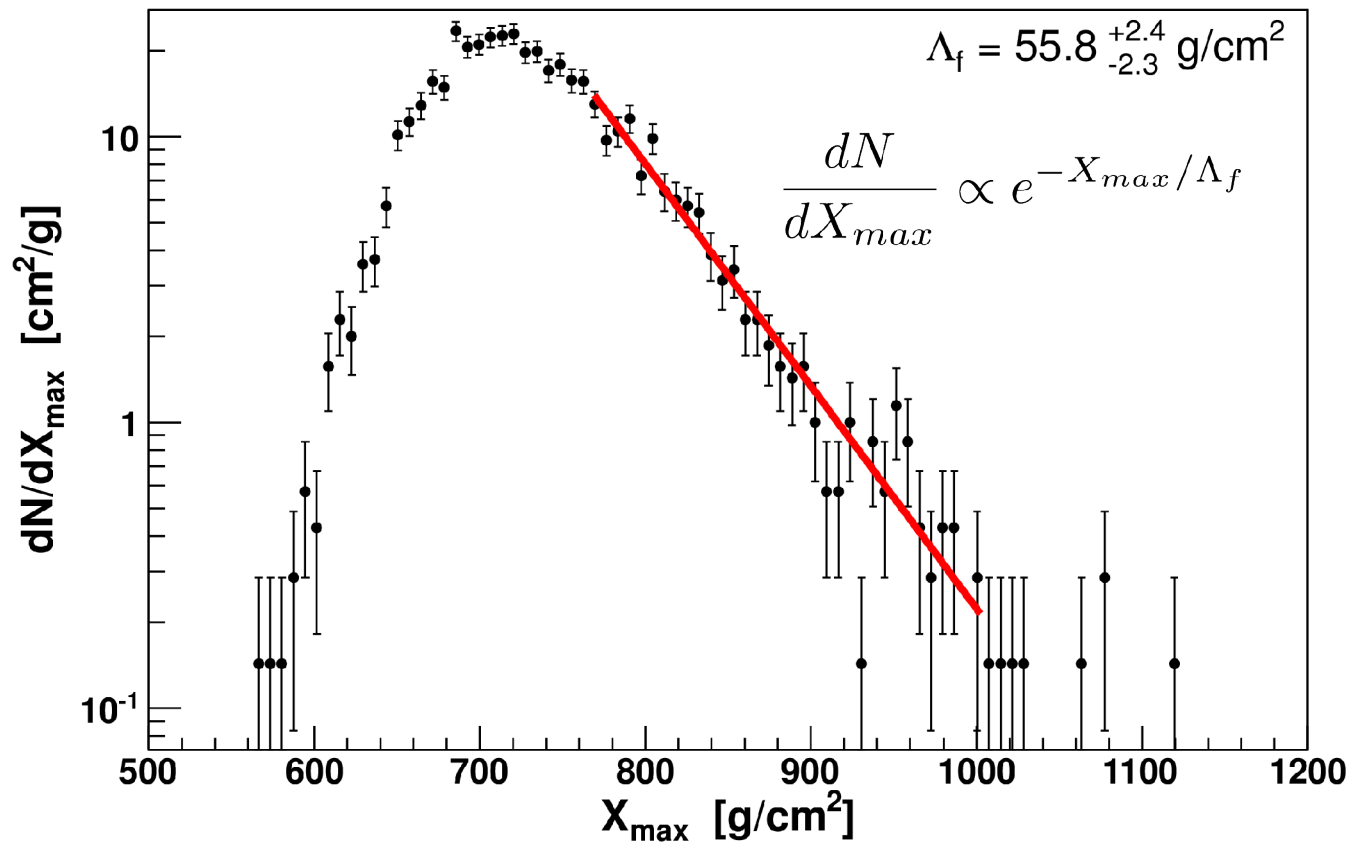
Transition from light to heavy composition
or extrapolation of interaction models insufficient

More on nature of UHECRs:

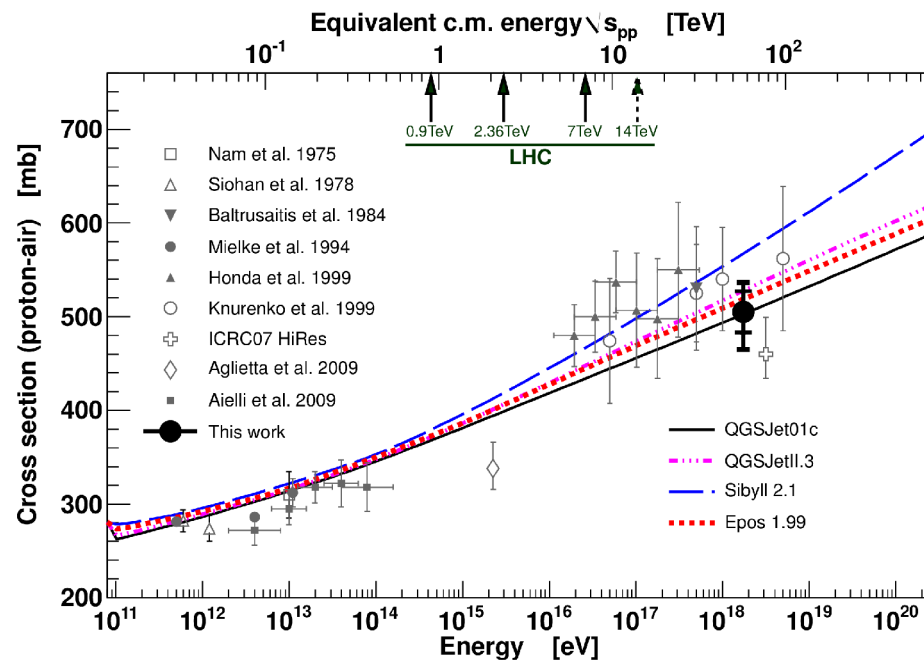
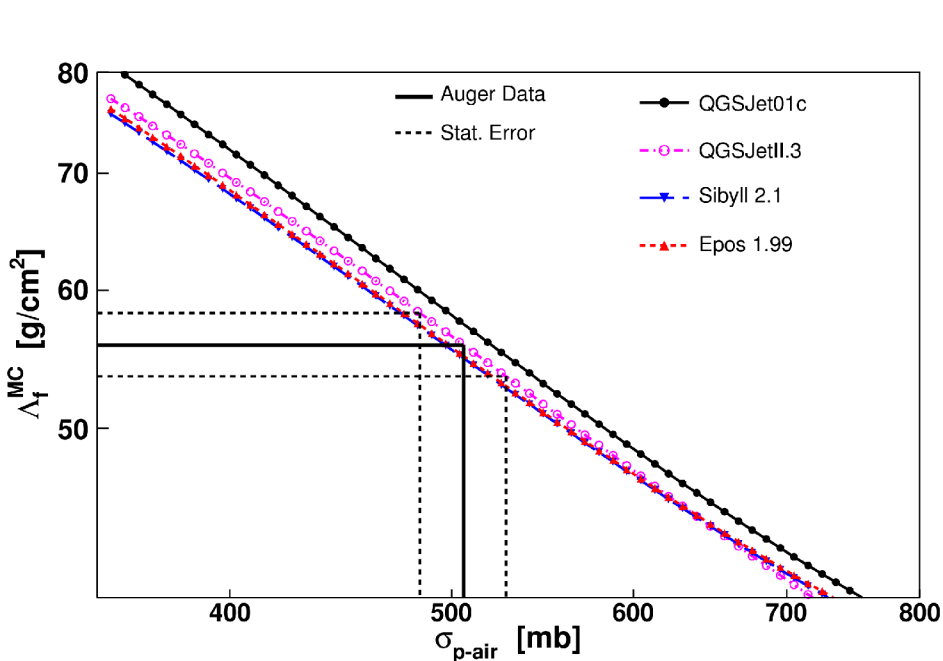
T99.2 E. Mawuko et al.,
T99.4 N. Krohm et al.,
T99.7 L. Middendorf et al.,
T99.9 M. Niechciol et al.,
T100.8 D. Maurel

Estimation of Proton – Air Cross-section

$E = 10^{18} \text{ eV} - 10^{18.5} \text{ eV}$,
center of mass energy: 57 TeV

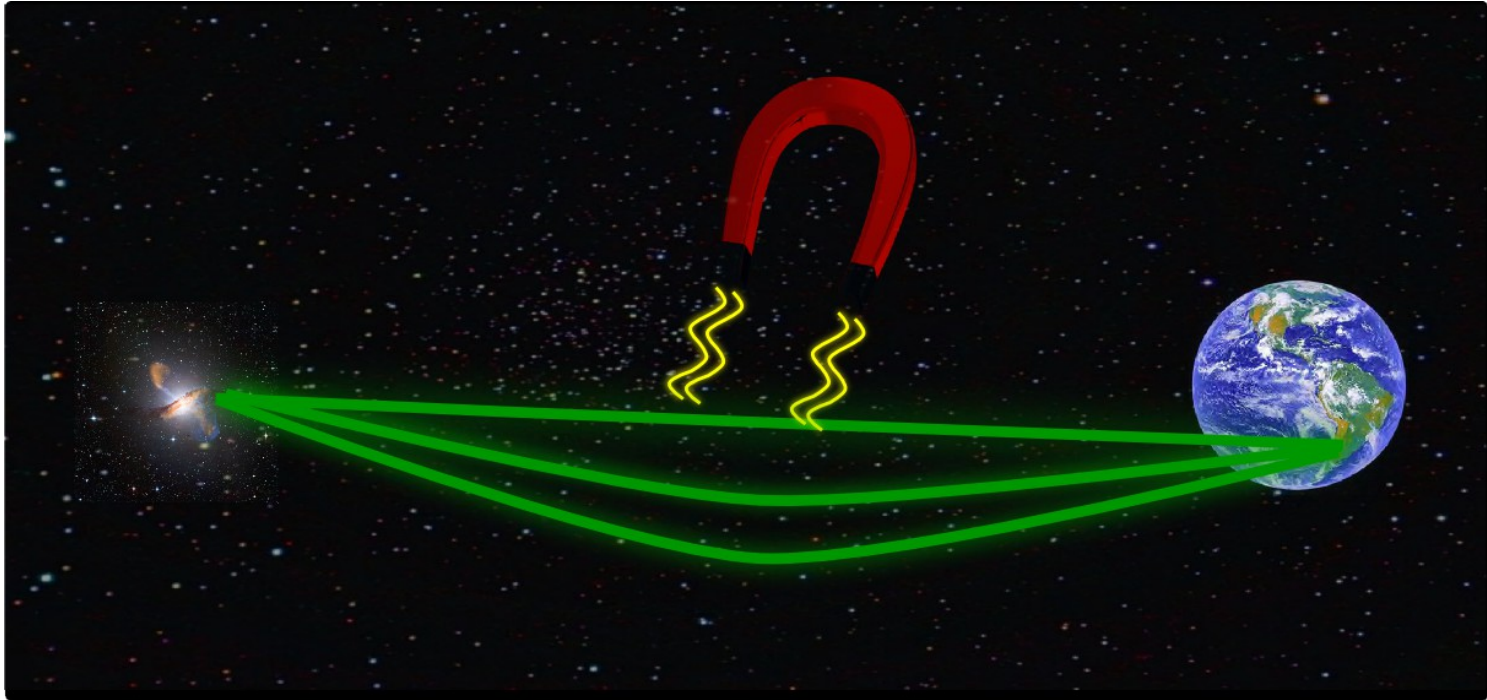


Estimation of Proton – Air Cross-section



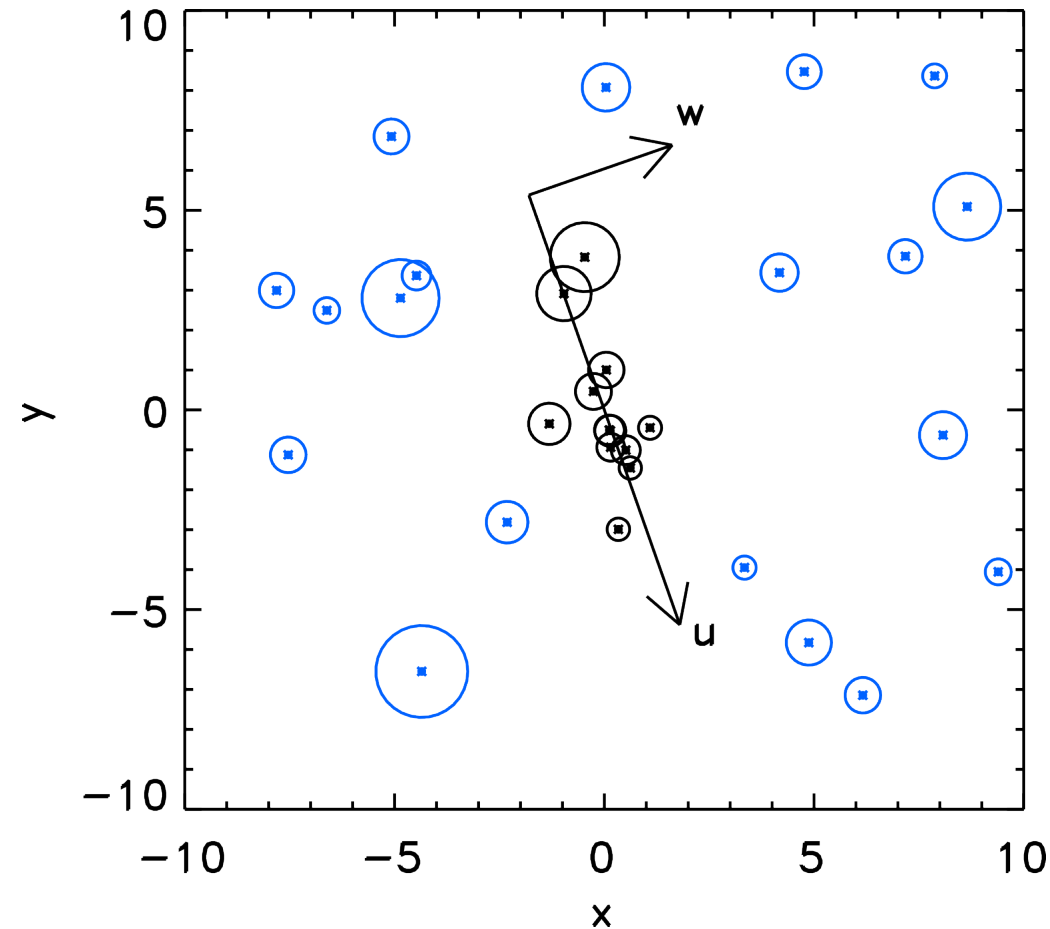
$$\sigma_{p-air} = (505 \pm 22_{stat.} ({}^{+20}_{-15})_{syst.}) \text{ mb}$$

Anisotropy and Magnetic Fields



Analysis of deflection patterns yields information on sources and intervening magnetic fields

Search for Multiplets



Assume linear deflection:

$$\vec{\theta} \simeq \vec{\theta}_S + \frac{\vec{D}(\vec{\theta}_S)}{E}$$

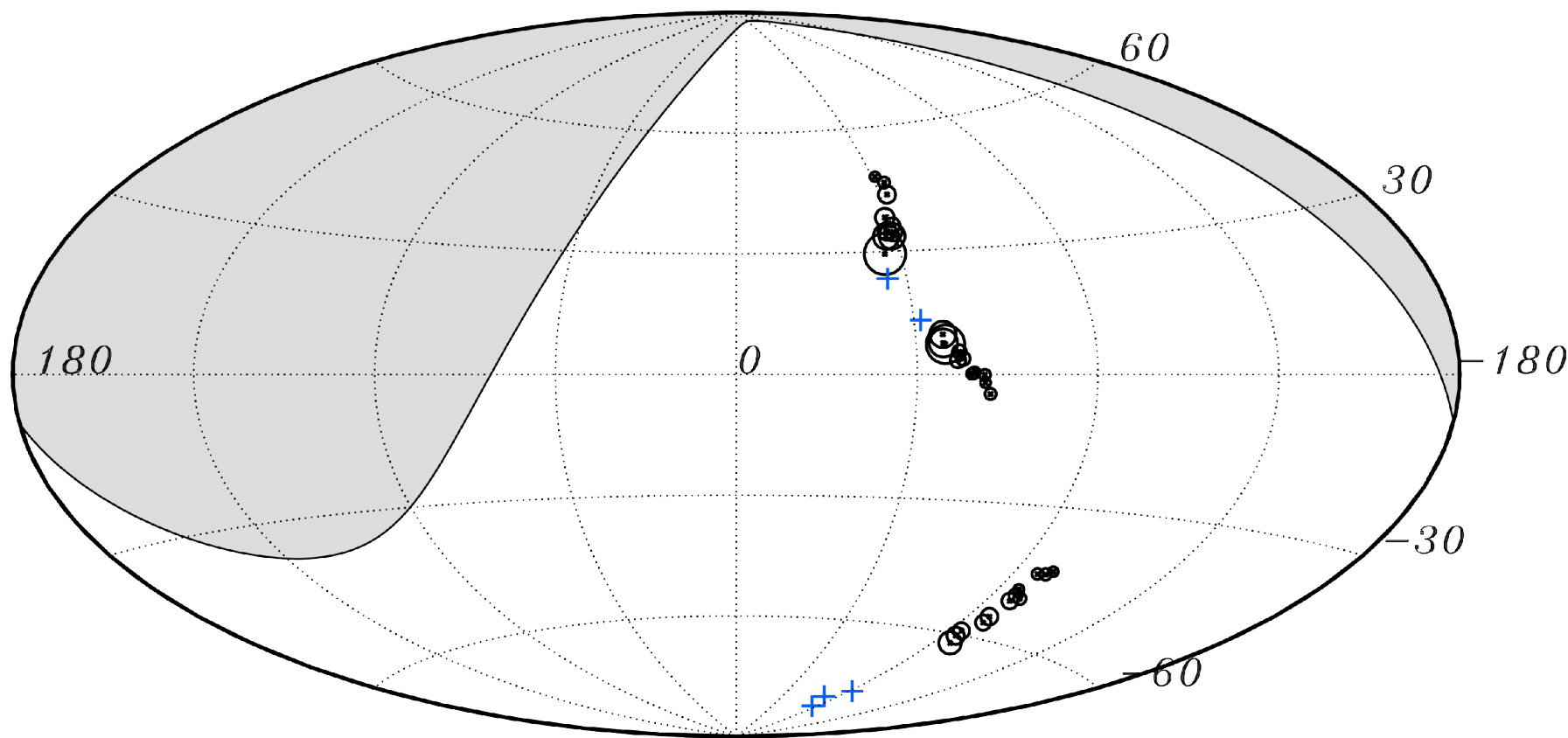
Valid above 20 EeV in typical models for the Galactic field

Maximize local correlation coeff.
 $C(u, 1/E)$ for any set of UHECRs

Identify multiplet if
 $C(u, 1/E) > C_{\min}$ and $W < W_{\max}$

Optimal parameters from
Monte Carlo simulations:
 $W_{\max} = 1.5^\circ$, $C_{\min} = 0.9$

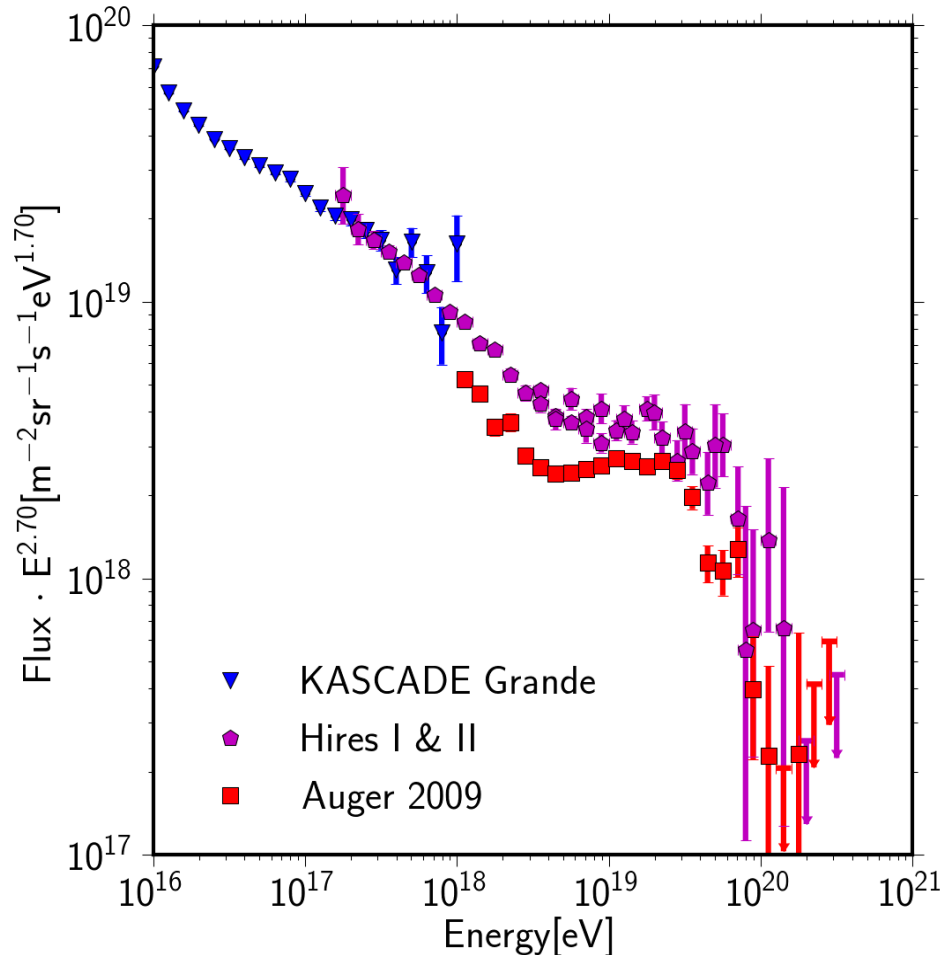
Observed Multiplets



2 x 10-plets and 1 x 12-plet found in data up to Dec. 2010
Chance probability from isotropy 6%

**More on Anisotropy
and Magnetic Fields:**
T99.3 H. - P. Bretz
T99.8 M. Plum

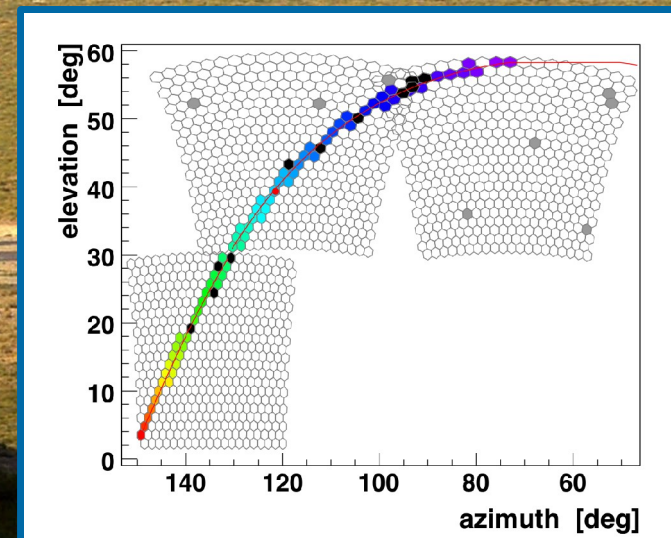
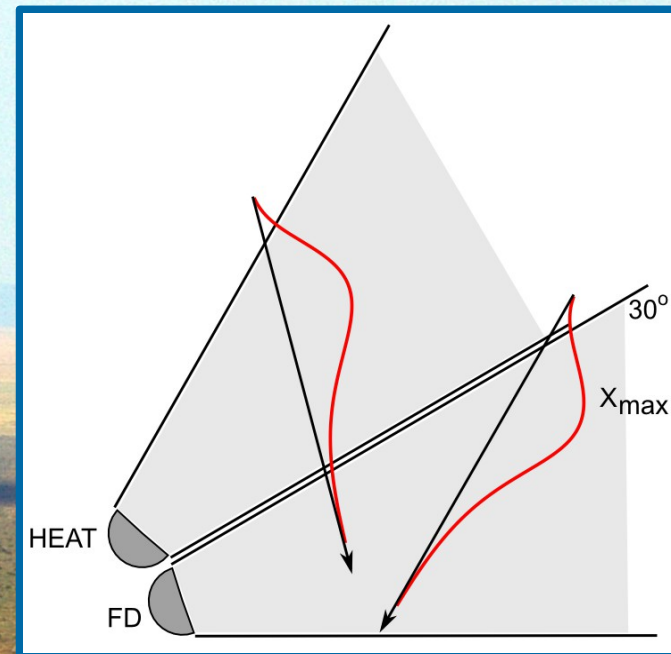
Low Energy Enhancements



- Auger standard detectors optimized for $E > 10^{18}$ eV
- Low energy enhancements to extend to $E > 10^{17}$ eV
- Connect energy range to KASCADE and others
- Investigate possible transition from galactic to extragalactic cosmic rays

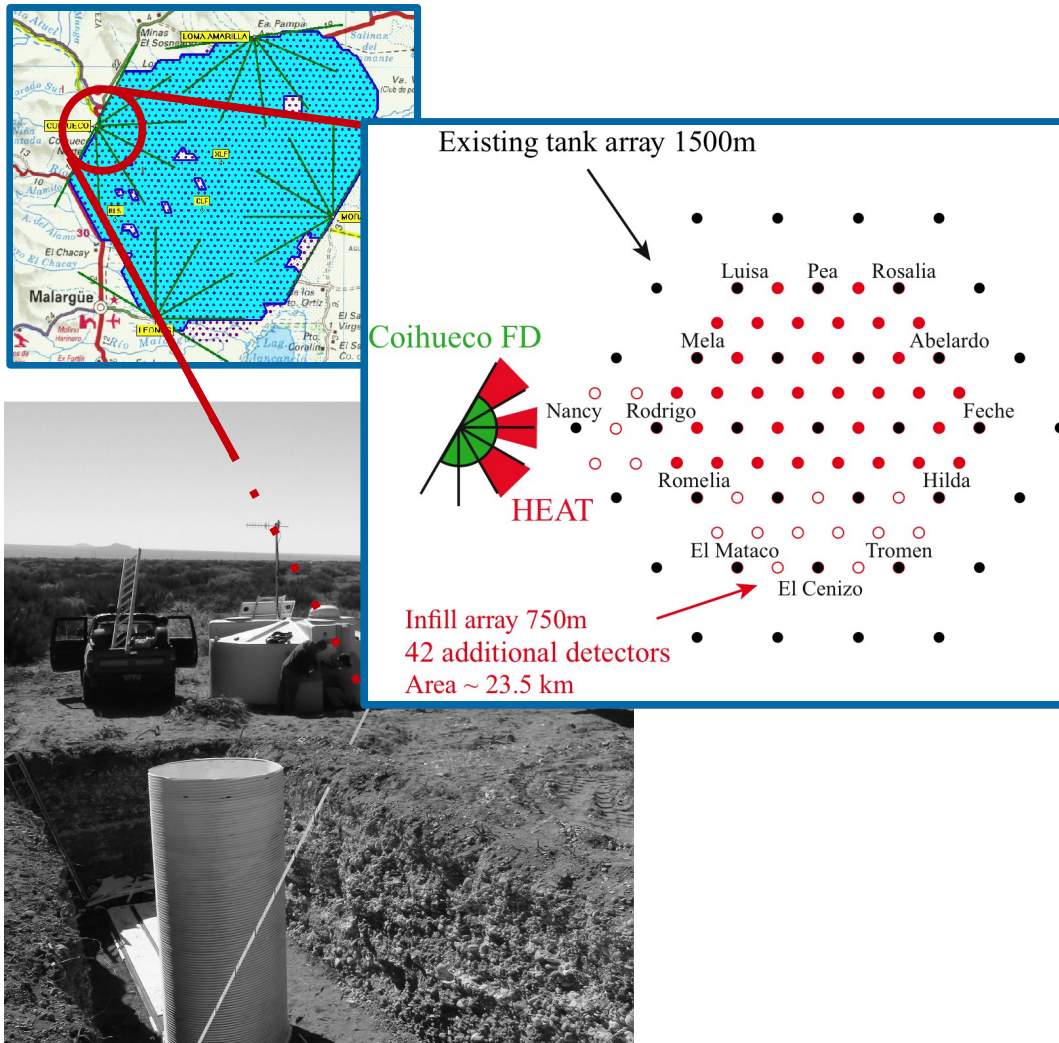
High Elevation Telescopes (HEAT)

- Taking data since 2009
- Results on composition presented on this conference
- Spectrum in preparation



More on HEAT:
T103.4 M. Straub, T103.5 I. Bekman, T103.6 T. Münzig,
T103.7 D. Kruppke-Hansen

Auger Muon and Infill for the Ground Array (AMIGA)



Infill

49 additional SD Stations in
750 m grid
Completed in Sept. 2011
→ Lower energy threshold

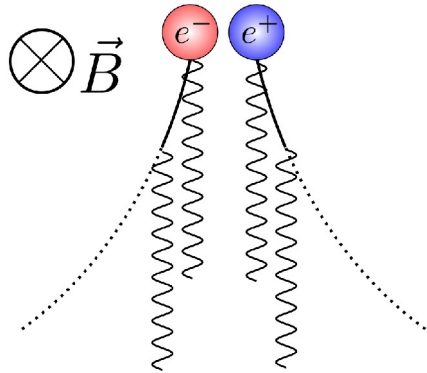
Muon Detectors

84 additional underground
muon counters
Under construction
→ Distinguish electromagnetic
and muonic component

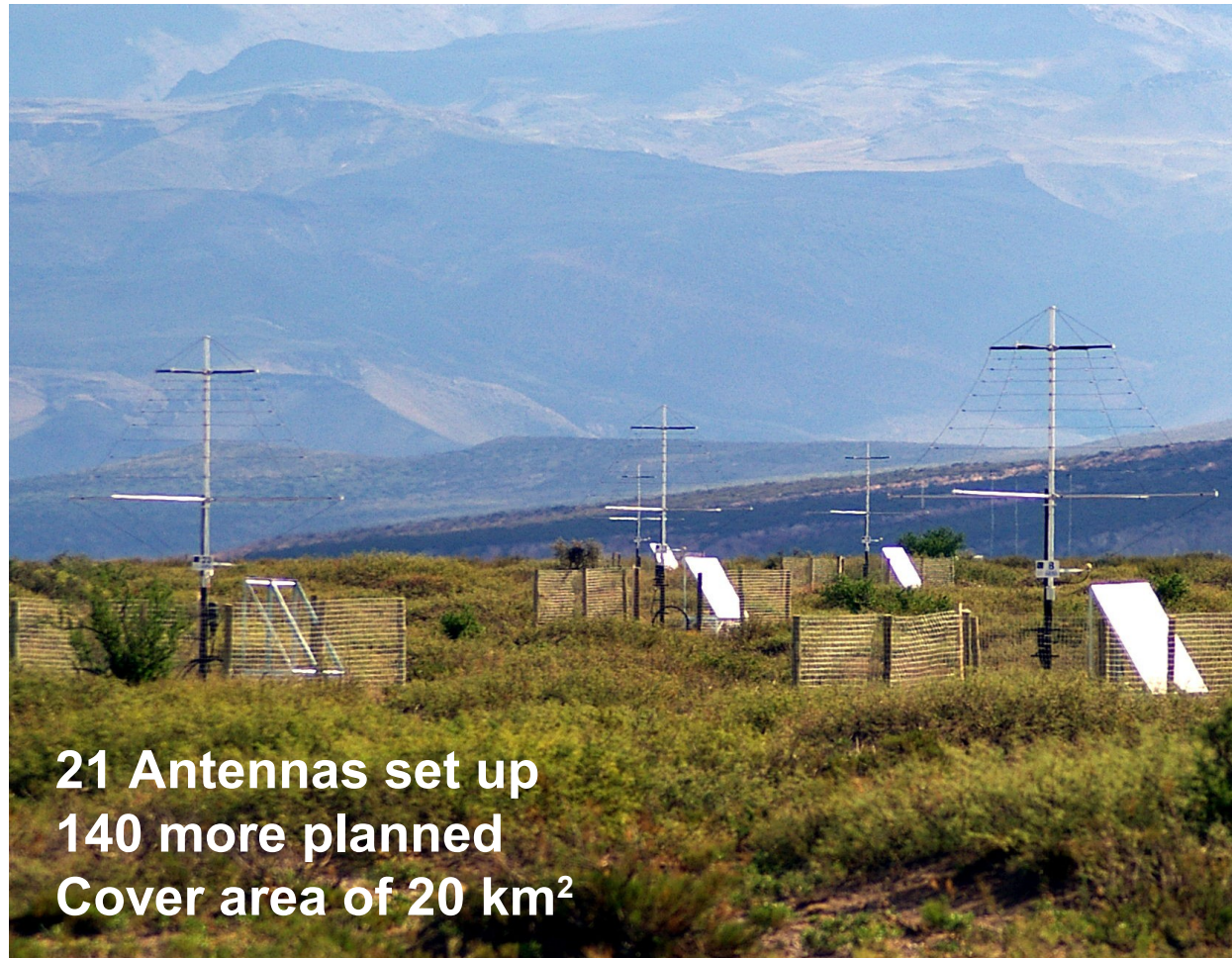
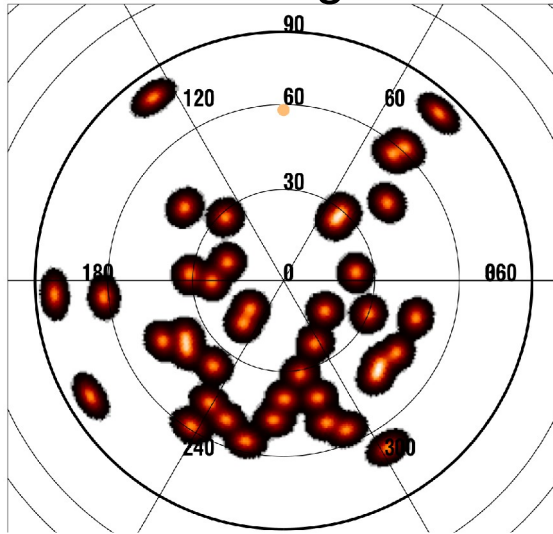
See also:

T99.5 R. Hiller et al.,
T99.6 A. Schulz et al.,
T114.2 U. Froehlich et al.,
T114.8 M. Pontz et al.

Auger Engineering Radio Array (AERA)



Coherent Radio Pulse
MHz regime



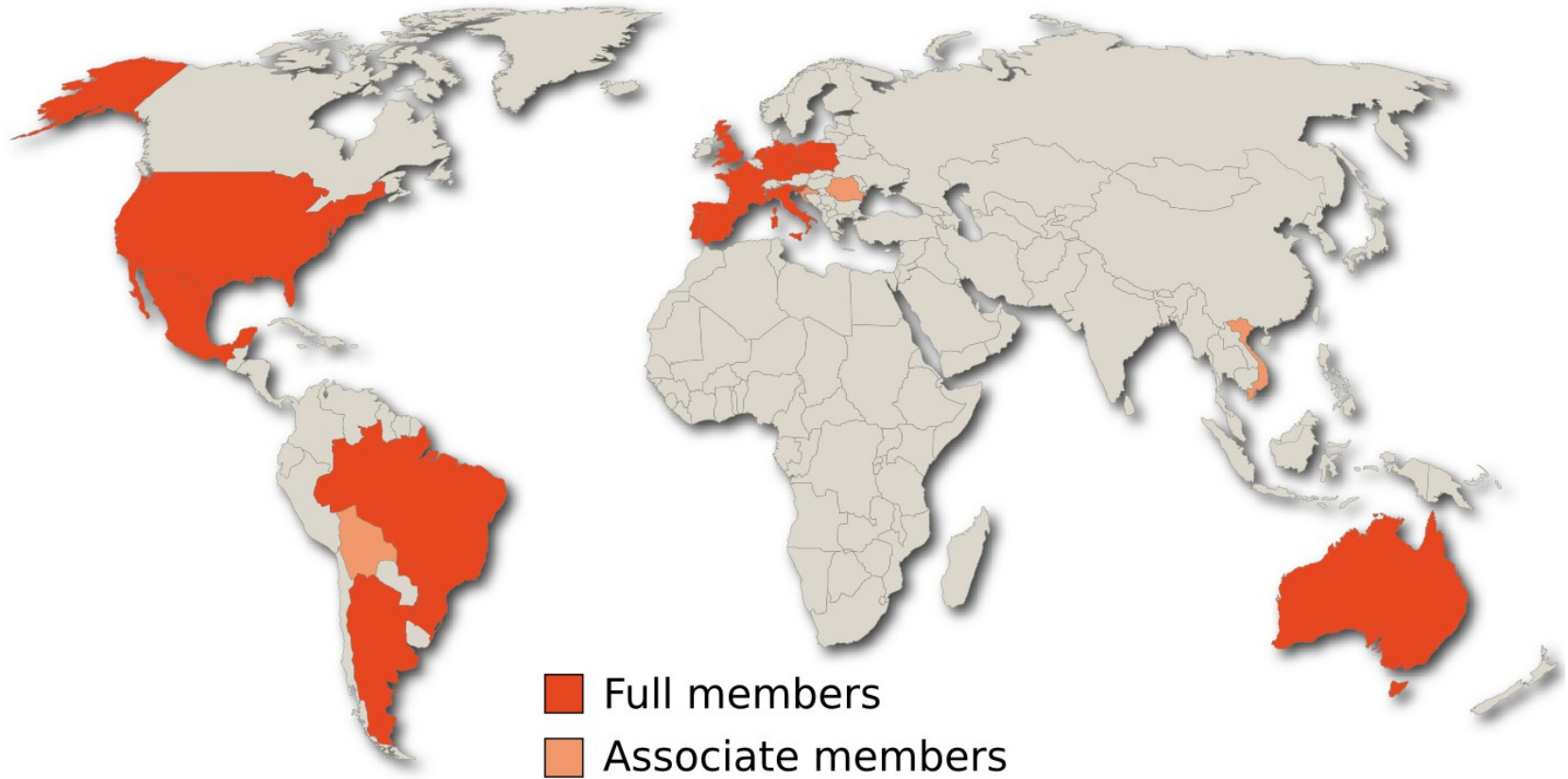
21 Antennas set up
140 more planned
Cover area of 20 km²

More on Radio:

T100.1 T. Huege et al., T100.2 M. Melissas et al.,
T100.3 K. Weidenhaupt et al.,
T100.4 J. Neuser et al., T100.5 I. Jandt et al.,
T100.6 G. Toma et al., T100.7 B. Fuchs et al.

>70 recorded UHECR Events

International Collaboration



- More than 490 scientists from institutions in 19 countries
- German contributions from Aachen, Bonn, Hamburg, Karlsruhe, Siegen and Wuppertal
- More than 30 contributions to this conference

Summary

- The Pierre Auger Observatory is the largest facility to study Cosmic Rays with $E > 10^{18}$ eV
 - Low energy enhancements connect to other experiments and study possible transition from Galactic to extragalactic UHECR
 - Selection of recent results
 - Composition studies
 - Proton-Air cross-section
 - Multiplets
 - Additional topics on this conference
 - Limits on Photon and Neutrino fractions
 - Atmosphere Physics
 - New detector technologies
 - ...
- T100.9 M. Will et al.,
T103.1 M. Lauscher et al.,
T103.2 T. Niggemann et al.,
T103.3 M. Stephan et al.,
T115.5 D. Kuempel et al.,
T115.6 S. Querschfeld et al.