2 Giant Ground Arrays (30 x AGASA) with Fluorescent detectors (HYBRID detector)

- independent techniques allow control of systematics

Challenge: to reach

$> 10^4 - 10^5 \text{ km}^2 \text{ sr yr}$

Present experiments

$\sim 10^3 \text{ km}^2 \text{ sr yr}$

PIERRE AUGER Observatory (South)

3,000 km² array + 4 Fluorescence Telescopes

Aperture 6,600 km² sr - reach $> 10^4$ in 2 years
The observatory

Pierre Auger Observatory

Northern Auger in Colorado

Southern Auger in Argentina
The plan

Surface Array
1600 detector stations
1.5 Km spacing
3000 Km²

Fluorescence Detectors
4 Telescope enclosures
6 Telescopes per enclosure
24 Telescopes total

AGASA spectrum >> 100 events/yr above $10^{20}$ eV
15 February 2006
There are 1115 tanks deployed, 1043 with water and 919 with electronics
Surface Detectors

- Solar panel and electronic box
- Three 8” PM Tubes
- GPS antenna
- Comm antenna
- White light diffusing liner
- De-ionized water
- Battery box
- Plastic tank
Fluorescent detectors
Zenith angle $\sim 30^\circ$, Energy $\sim 10$ EeV
FD (hybrid events) have both traverse and longitudinal shower information
Energy Losses of protons

Berezinsky et al. 03

modification factor: \( J_{\text{obs}}(E,z) = \eta(E,z) \times J_{\text{injec}}(E) \)
Energy spectrum in Auger

- SD data $\rightarrow$ ground parameter $S(1000) = $ SD signal at 1000m
- Determine the $S(1000)$ $\rightarrow$ Energy & Zenith Angle conversion
  - Zenith Angle dependence: SD and Hybrid data
  - Fluorescence Detector energy scale Normalization via Hybrids (error < 25%)
- $+$ SD exposure
  $\rightarrow$ measured spectrum.
Anisotropies

Astronomy with p is possible at Energies above $\sim 10^{19} - 10^{20}$ eV

- AGASA: excess 4.5σ 20 deg window near the GC with $E=1$-$2.5$EeV.
- SUGAR 2.9σ excess with 5.5 degree window near the GC with $E=0.8$-$3.2$EeV.
- No evidence from other experiments
Auger sees nothing (ICRC2005)!

Coverage

Significance (1.5°)

Significance (3.7°)

Significance (13.3°)
Suggested readings

P. Sokolsky Introduction to Ultrahigh Energy Cosmic Ray Physics
Addison-Wesley 1989
Stanev High Energy Cosmic rays Springer 2004
T.K. Gaisser Cosmic Rays and Particle Physics
M. Lemoine & G. Sigl, Physics and Astrophysics of Ultra-High-Energy Cosmic Rays