The High Resolution Fly’s Eye (HiRes) Experiment

John N. Matthews
University of Utah
HiRes

- HiRes is located on the U.S. Army Dugway Proving Ground, ~2 hours from The University of Utah.
- The two detector sites are located 12.6 km apart at Little Granite Mountain and Camel’s Back Ridge.
UHECR Subjects:

- Spectrum
- Chemical Composition
- Anisotropy
- proton-air Cross-section
- Neutrinos / Exotics
Typical HiRes Event

- $\sim 2 \times 10^{19}$ eV event seen in 1999
- (3× vertical scale)
Photoelectrons per degree of track

- black: HiRes 2 data
- red: Monte Carlo (5 x data statistics)

\[
\chi^2/\text{ndf} = 5.181 / 5.3
\]

- A0: 0.9546 ± 0.4616E-01
- A1: -0.227E-03 ± 0.4005E-03

---

Dec 2005

J.N. Matthews – KICP
Are spectral features seen?

GZK?

Ankle?
1. Single power law fit:
2. Improved fit using two power laws with a single floating break

\[ \chi^2/DOF = 59.3/36 \]

\[ \gamma = 3.24(3) \]

\[ \log_{10} E = 18.43(3) \]

\[ \gamma = 2.93(3) \]
3. Still better fit using three power laws with two floating breaks
Significance of the deficit at high energy end relative to continuation of power law?

Extrapolate middle section:
- Expect 42.8 events
- Observe 15
- Poisson
- $p = \sim 10^{-6}$

4s is $3 \times 10^{-5}$
5s is $3 \times 10^{-7}$
Preliminary Stereo Spectrum

- Fit to power law.
- Single index gives poor $\chi^2$
- Evidence for changing index near $\sim 10^{19.8}$ eV
HiRes
Monocular & Prelim Stereo Spectra

Stereo Aperture-
(Stereo Normalized to Monocular)
Mono versus Stereo Energy Measurements

HiRes-1 mono vs. stereo

The HiRes monocular energy is in excellent agreement with stereoscopic measurements!
ATM and the Aperture

Ratio of Apertures:

numerator:
MC w/ATM database
Reconstruction w/database

denominator:
MC gen w/database
Reconstruction using
Average ATM
Aperture Check

HiRes-2 Data

Artificially cut the data so that you are certain of the aperture.

Cut data with an impact parameter:
- >15 km
- >10 km

Excellent agreement!
Confidence in aperture calculation
HE Aperture Test

Installed a laser to test the reach of our HE aperture 34 km from HiRes2 Detector.

Equivalent light production to a shower of $\sim 6 \times 10^{19}$ to $10^{20}$ eV

Detectors have no trouble seeing this laser under good to worse than acceptable viewing conditions.
All-Energy Xmax Distribution

Data v Proton Models

- **Solid Line:** Data
- **Heavy Dots:** QGSJet
- **Light Dots:** SIBYLL

Data v Iron Nuclei Models

- **Stereo Data:** 
  - ~800 Events
  - 11/1999 – 9/2001

Dec 2005

J.N. Matthews – KICP
Stereo HiRes Elongation Rate

Width is constant from $\sim 10^{18}$ eV on up.

**Width** and **Xmax** imply constant composition in this energy range.

QGSjet (1) prefers 80% “protons”

Sybil prefers 60%

Application of radio-sonde data will move the HiRes Xmax up about 10 gm on average, thus lighter.
Take Home:

- Spectrum clearly shows structure (ankle, GZK suppression) – galactic/extra galactic cosmic rays
- $X_{\text{max}}$ AND Width important to measuring composition
- Point Sources/BL Lacs tantalizing
- $p$ air cross-section connects to accelerator data
- More to come
  - HiRes data taking concludes 30 March 2006
  - Analysis continues for another year or two
  - Telescope Array under construction
- Located west of Delta, UT. ~2.5 hrs S of SLC
- TA Phase-1 is a funded experiment (13M$ equivalent from Japan). Construction underway – complete 2007
  - Main ground array of 576 Scintillators
  - 3 Fluorescence Sites
- US funding sought to add HiRes detectors, infill ground array (fluorescence stereo and hybrid down to $3 \times 10^{16}$ eV)