The High Resolution Fly's Eye (HiRes) Experiment

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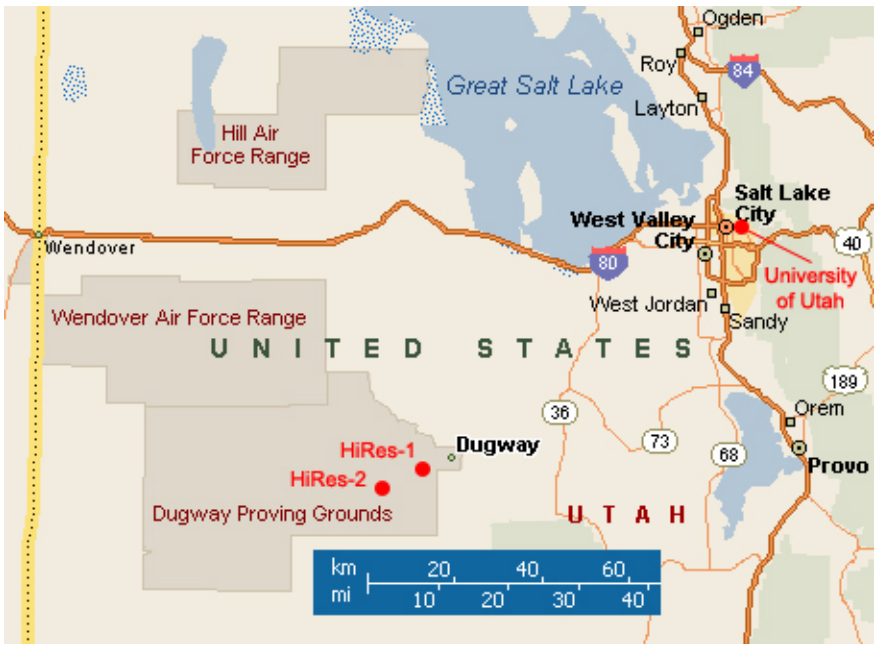
HiRes

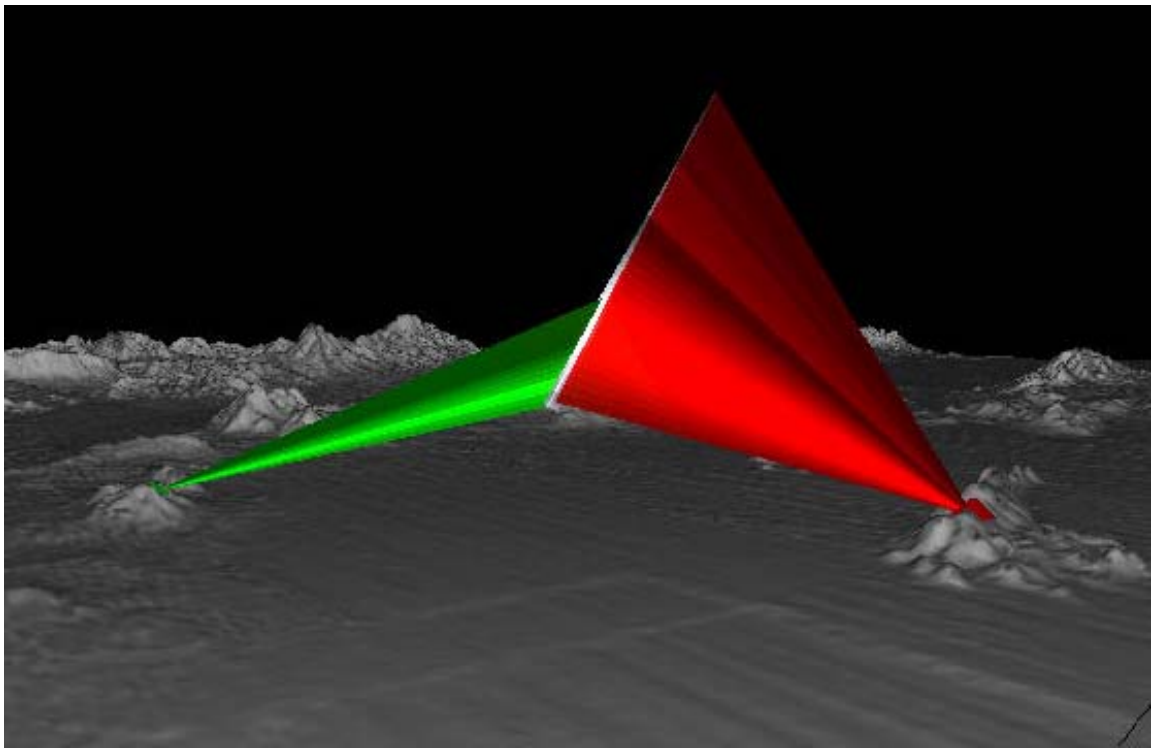
- HiRes is located on the U.S. Army Dugway Proving Ground, ~2 hours from The University of Utah
- The two detector sites are located 12.6 km apart at Little Granite Mountain and Camel's Back Ridge

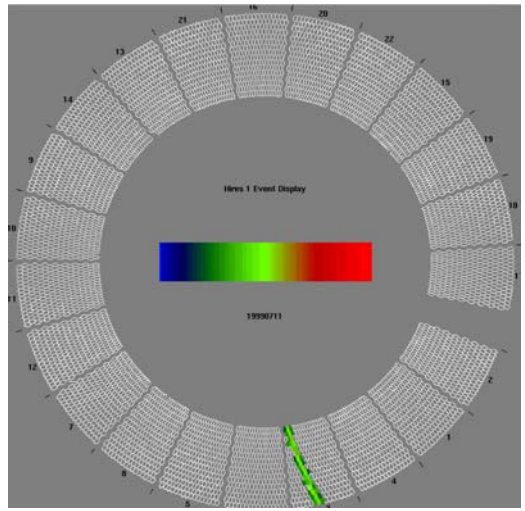


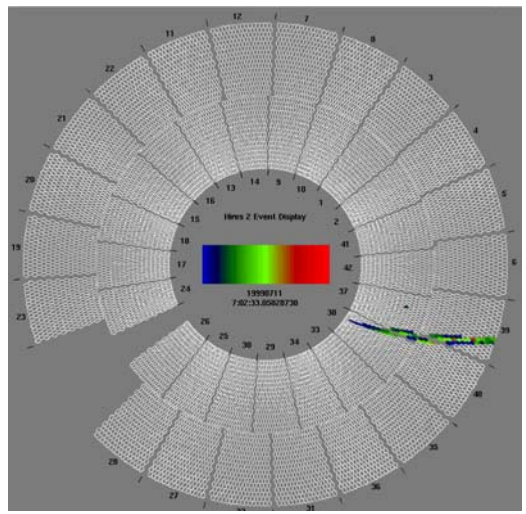
UHECR Subjects:

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

Typical HiRes Event

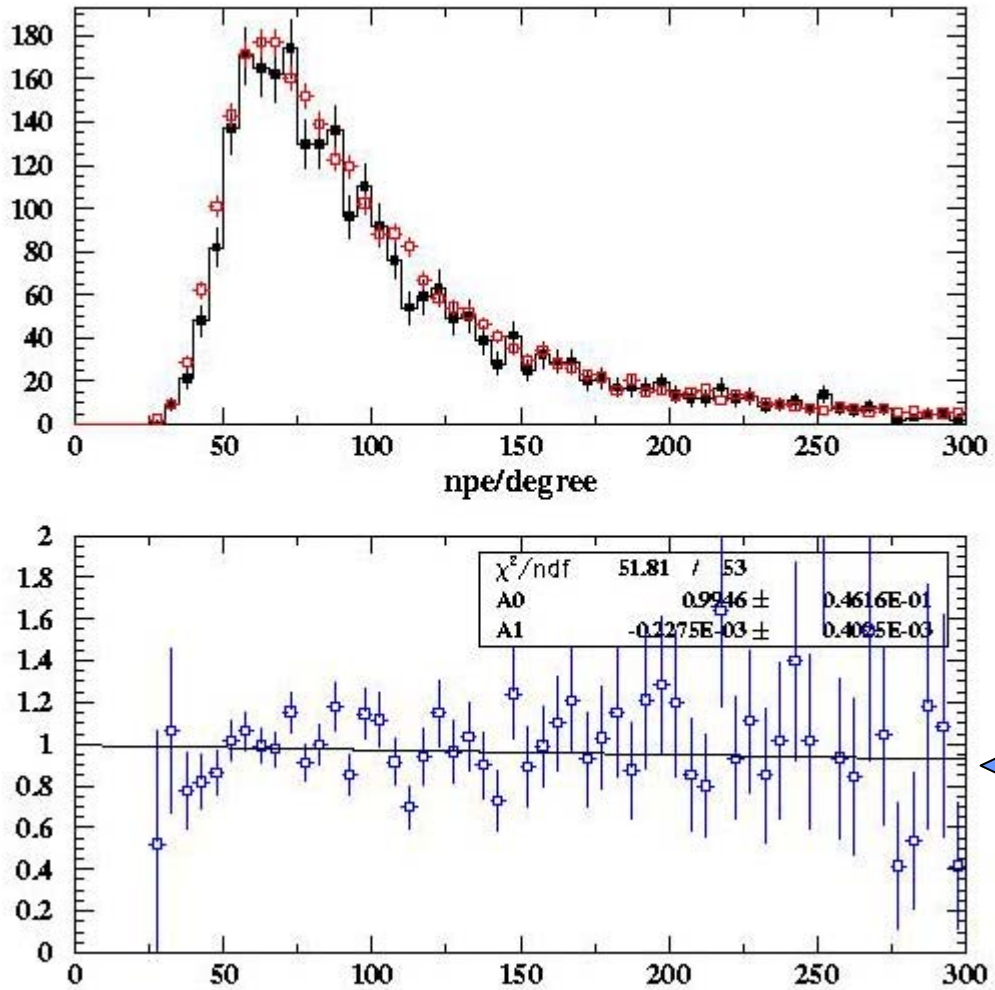






- ~2×10^{19}eV event seen in 1999
- (3× vertical scale)

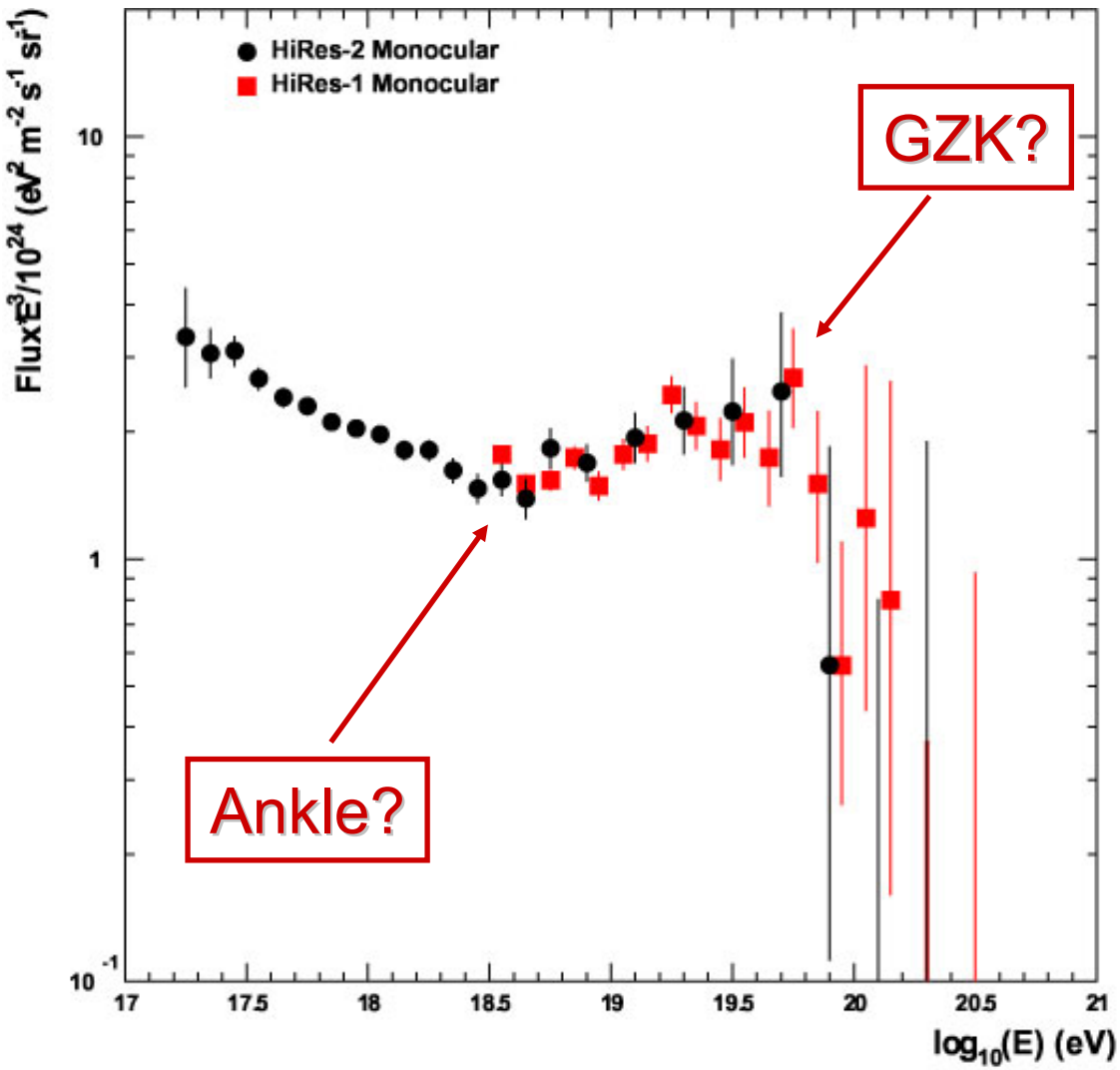
Photoelectrons per degree of track



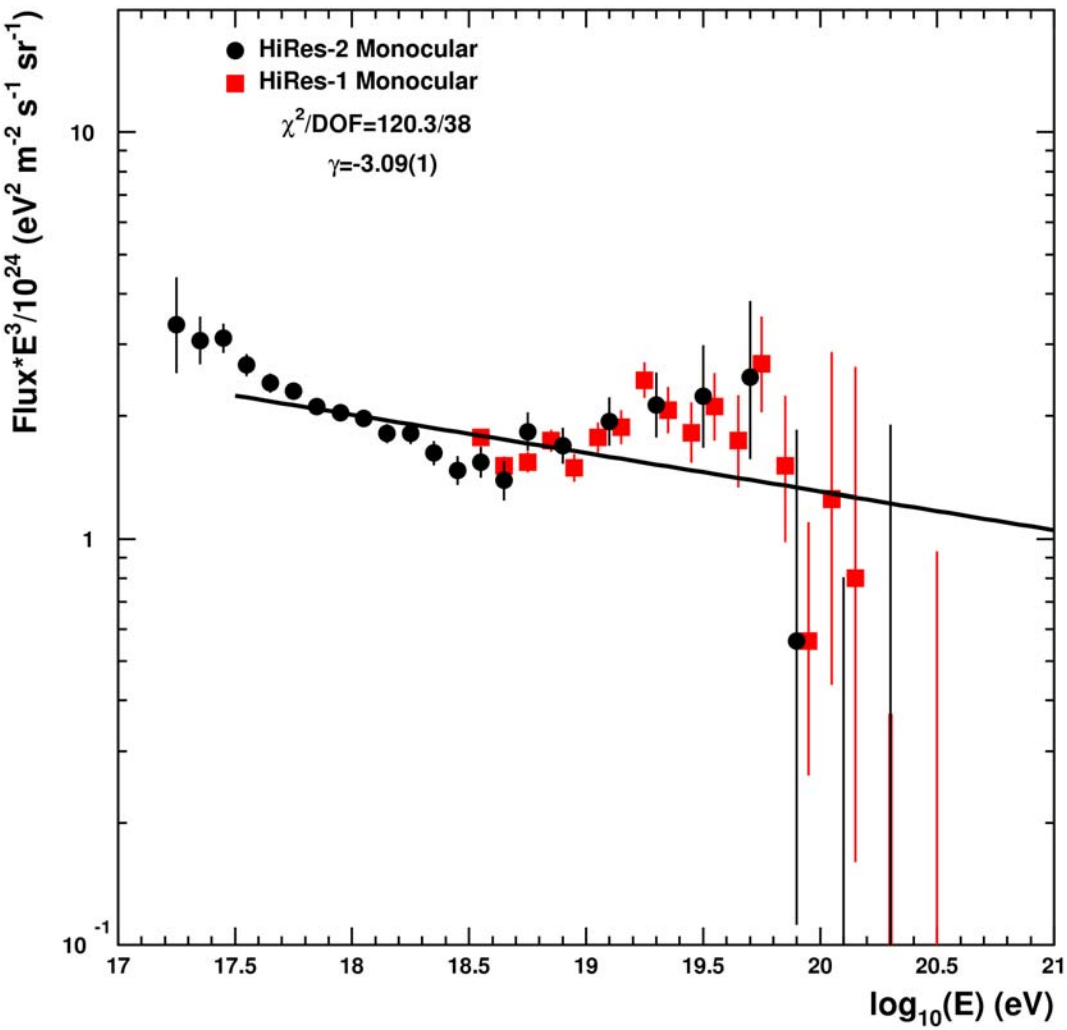
- black: HiRes 2 data
- red: Monte Carlo (5 x data statistics)

$$\frac{\text{data}}{\text{Monte Carlo}}$$

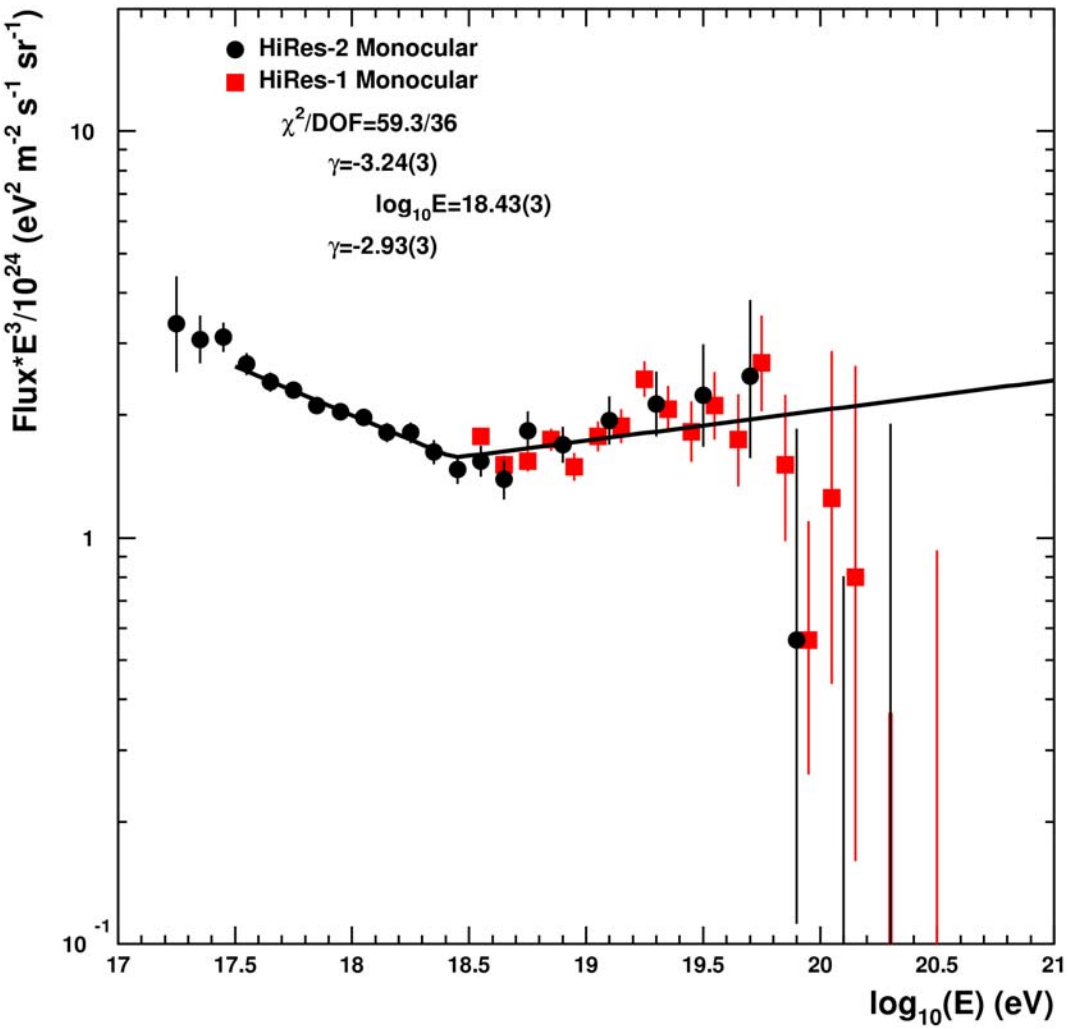
Are spectral features seen?



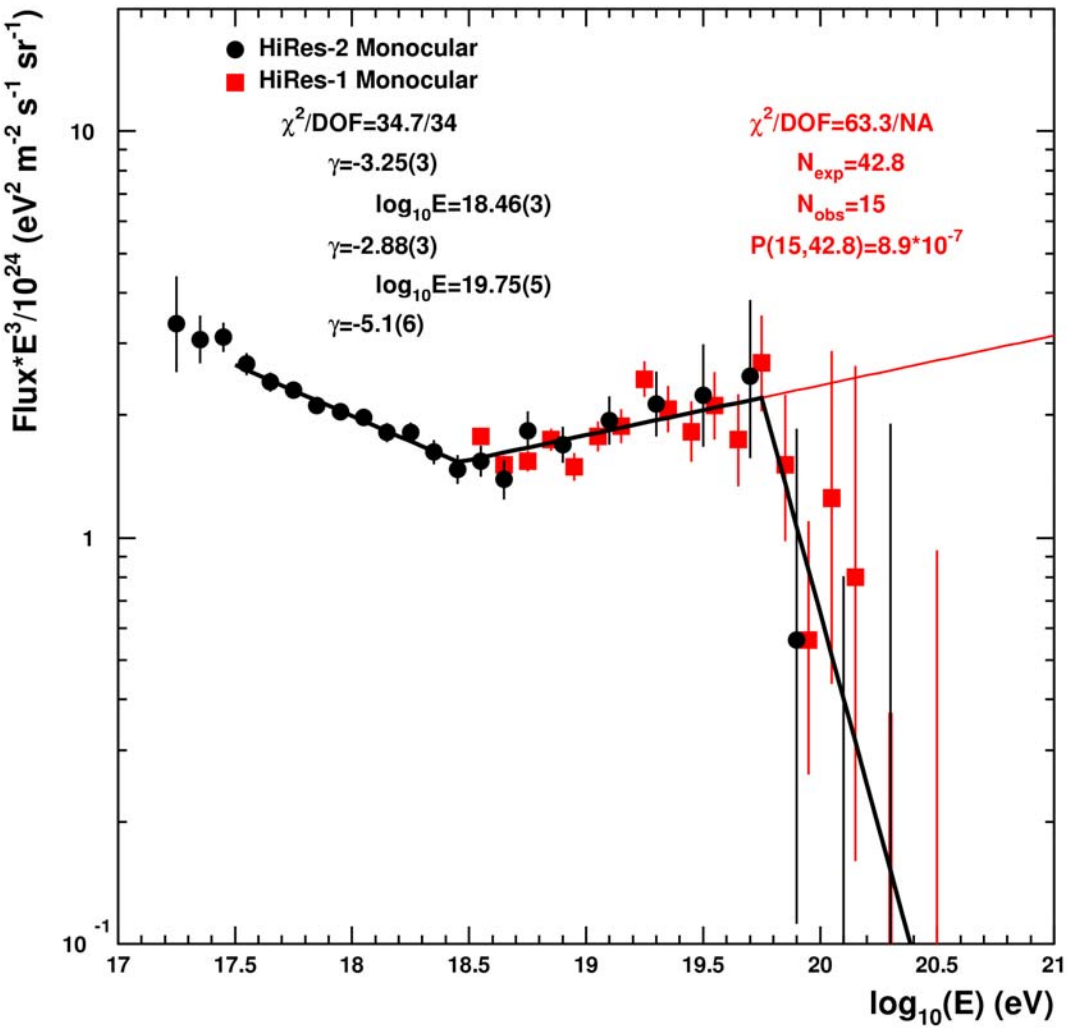
1. Single power law fit:



2. Improved fit using two power laws with a single floating break

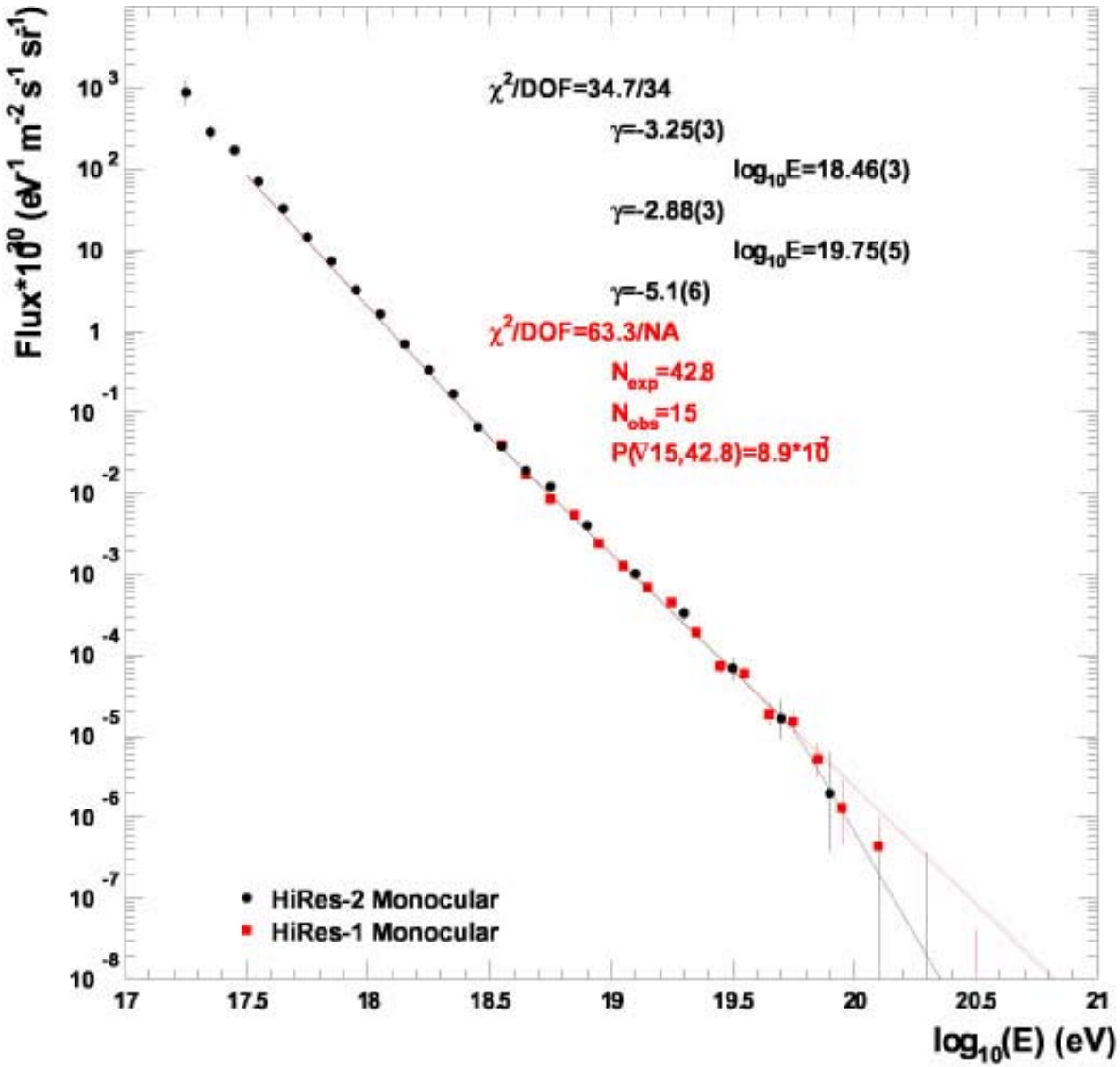


3. Still better fit using three power laws with two floating breaks



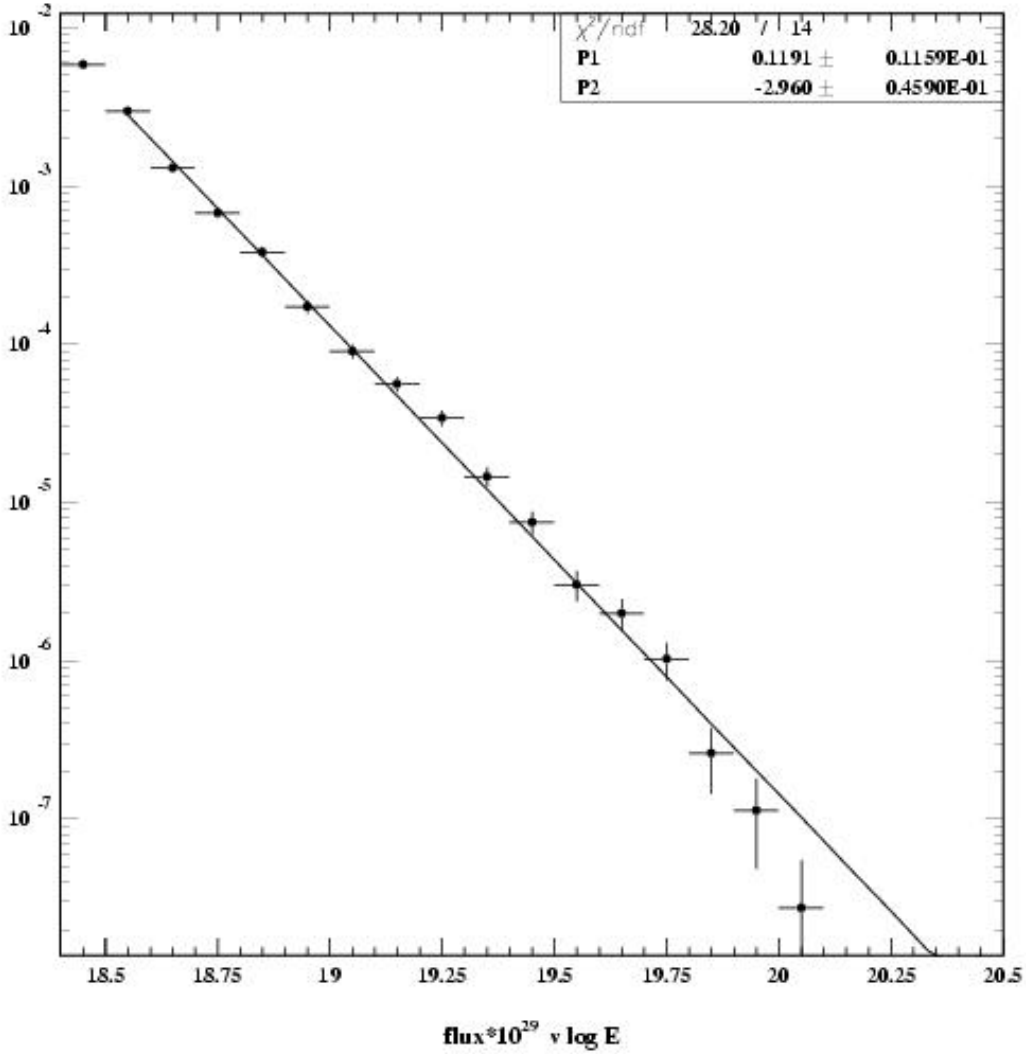
- Significance of the deficit at high energy end relative to continuation of power law ?
- Extrapolate middle section:
  - Expect 42.8 events
  - Observe 15
  - Poisson
  - *p*= ~10-6

4s is 3 x 10-5
5s is 3 x 10-7

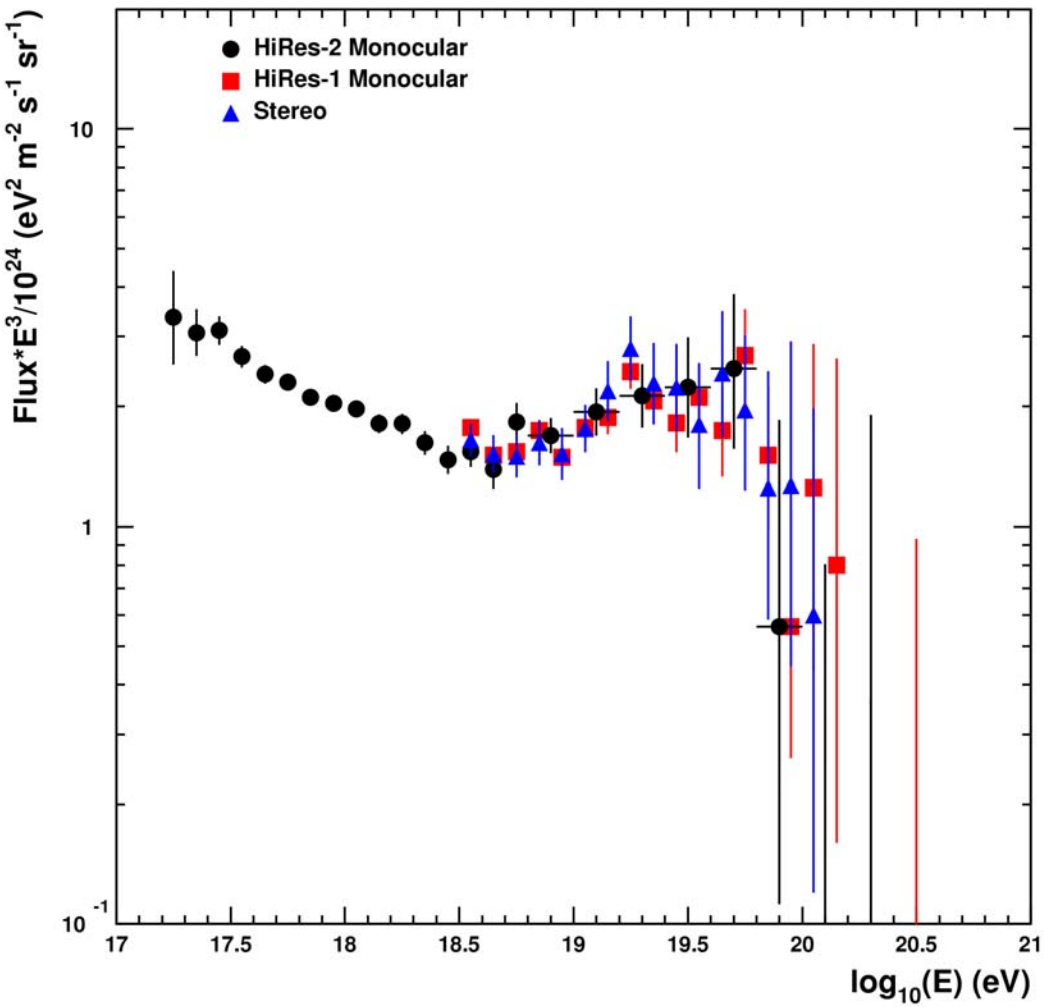


Preliminary Stereo Spectrum

- Fit to power law.
- Single index gives poor χ^2
- Evidence for changing index near ~$10^{19.8}$ eV

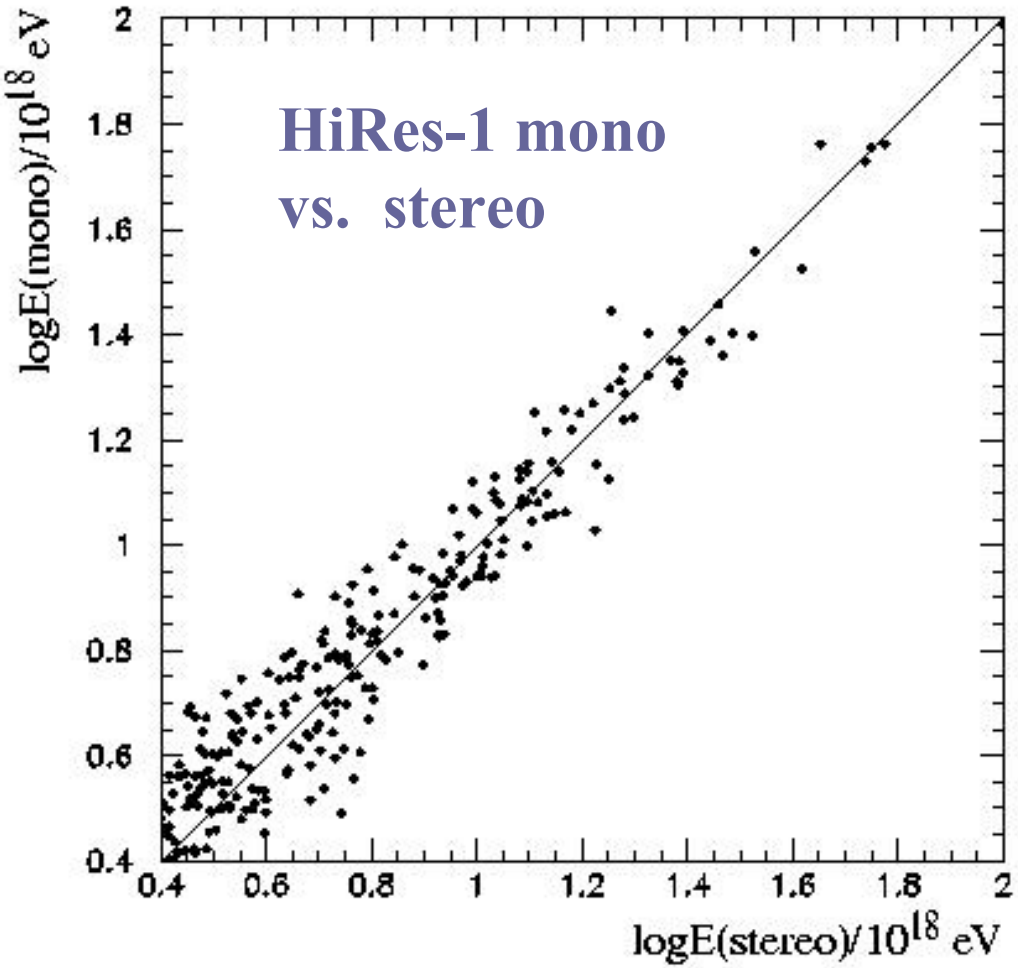


HiRes Monocular & Prelim Stereo Spectra



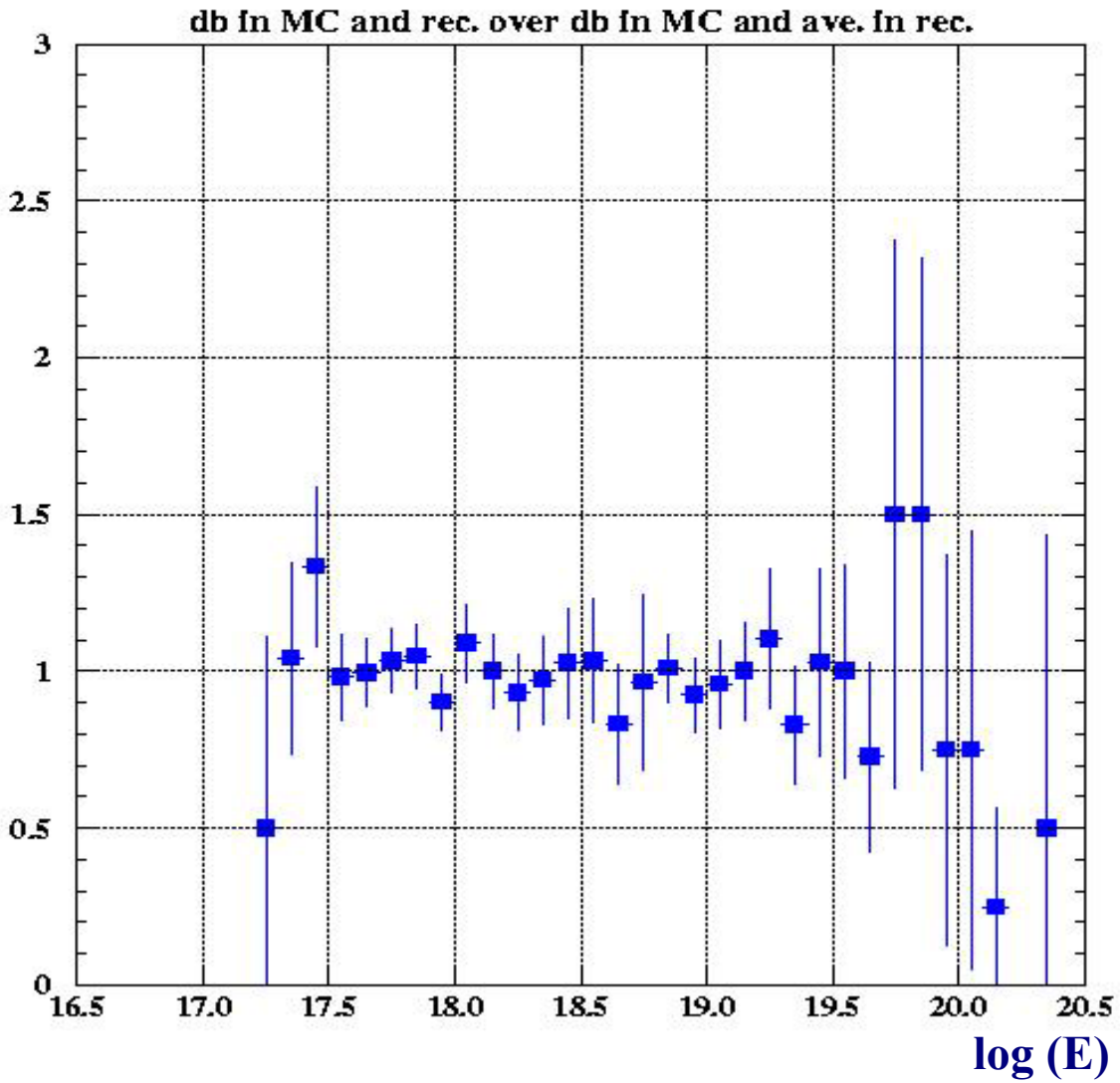
Stereo Aperture- (Stereo Normalized to Monocular)

Mono versus Stereo Energy Measurements



The HiRes monocular energy is in excellent agreement with stereoscopic measurements !

ATM and the Aperture



Ratio of Apertures:

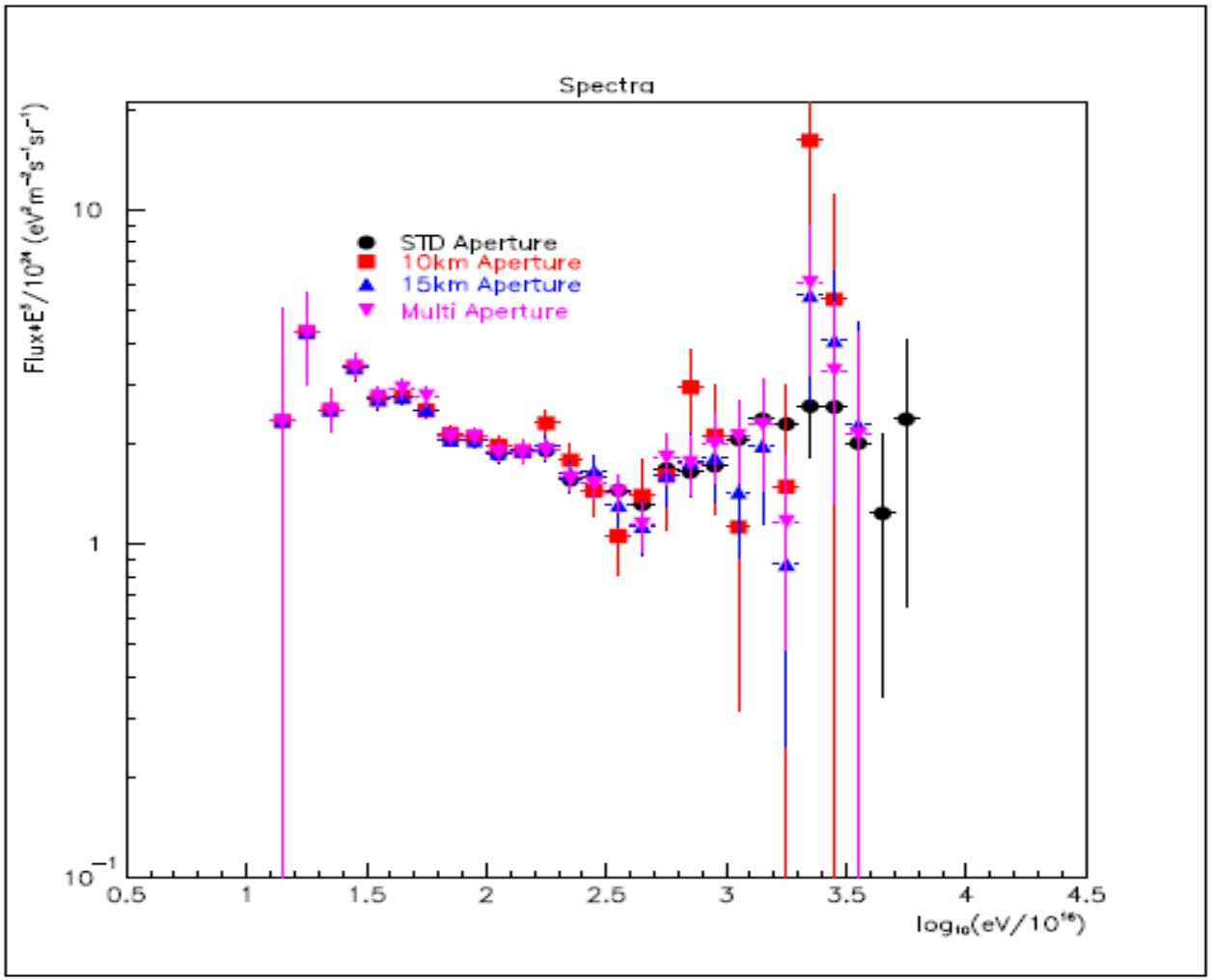
<u>numerator:</u>

MC w/ATM database Reconstruction w/ database

<u>denominator:</u>

MC gen w/database Reconstruction using Average ATM

Aperture Check



HiRes-2 Data

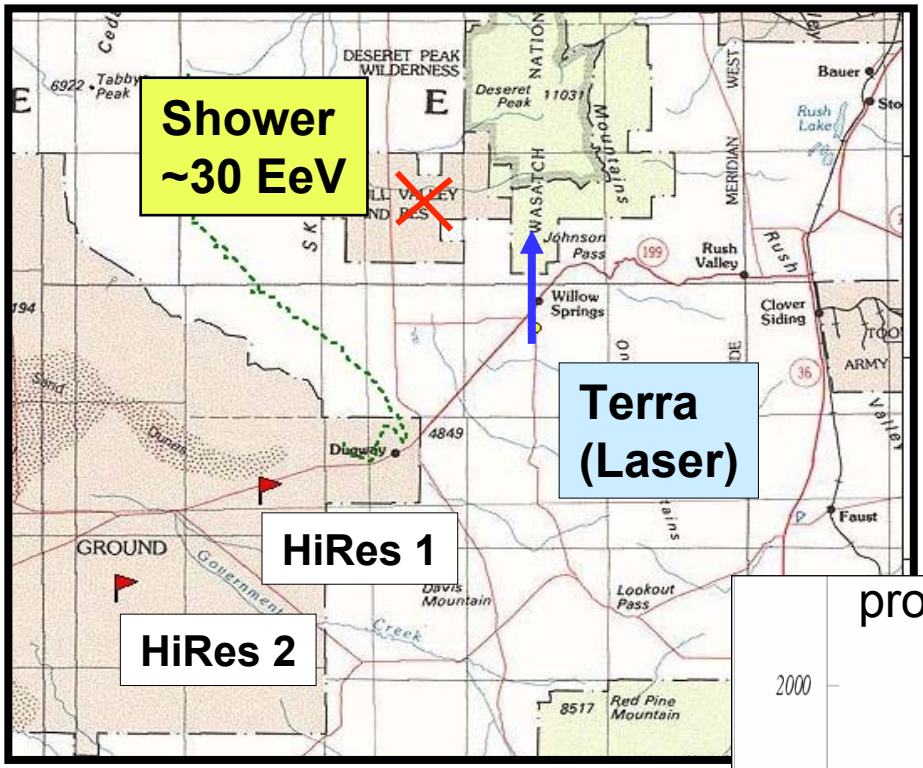
Artificially cut the data so that you are certain of the aperture.

Cut data with an impact parameter > 15 km

>10 km

Excellent agreement! Confidence in aperture calculation

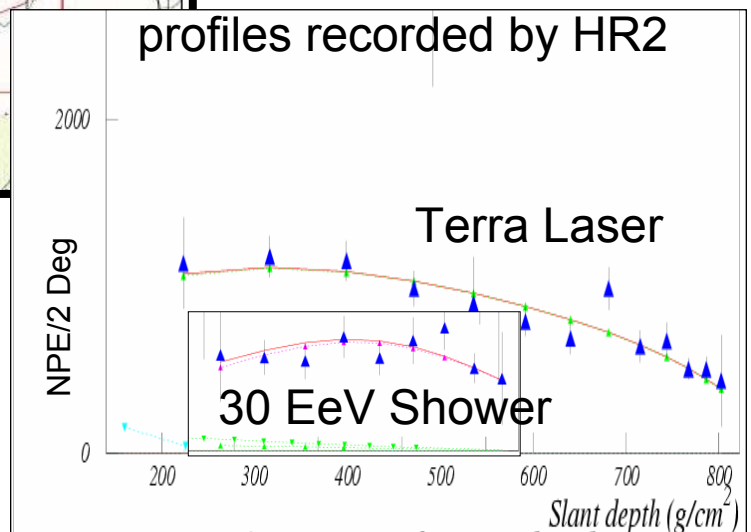
HE Aperture Test



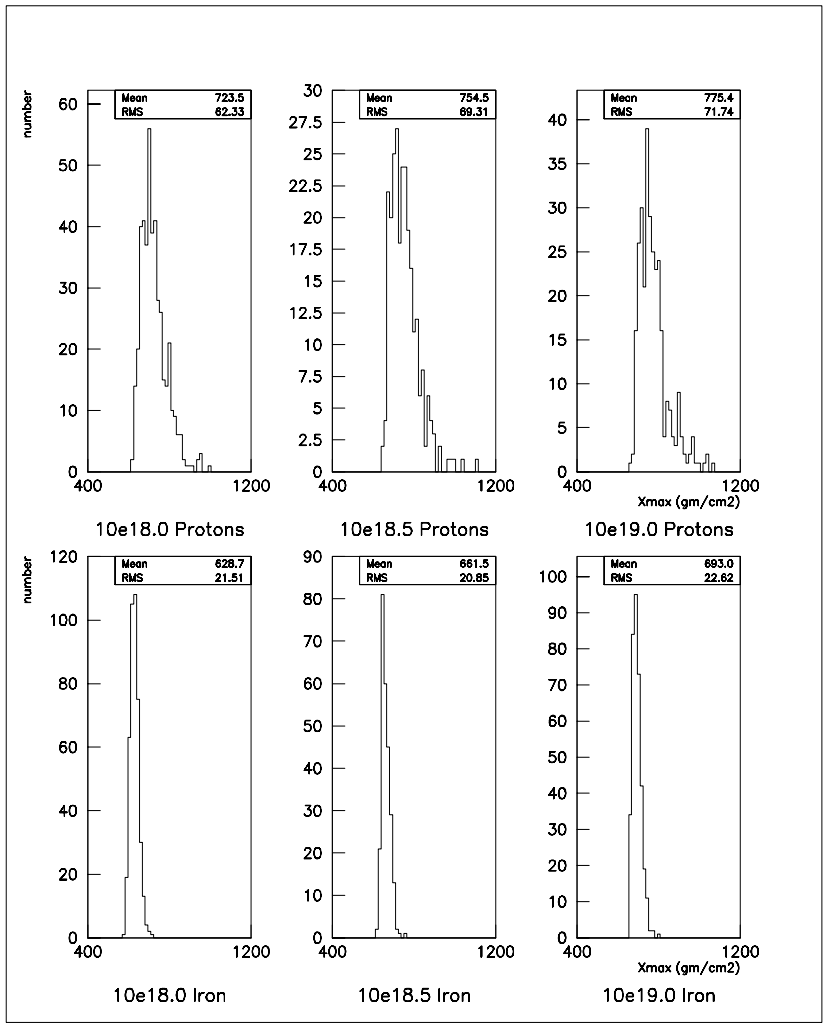
Installed a laser to test the reach of our HE aperture
34 km from HiRes2 Detector.

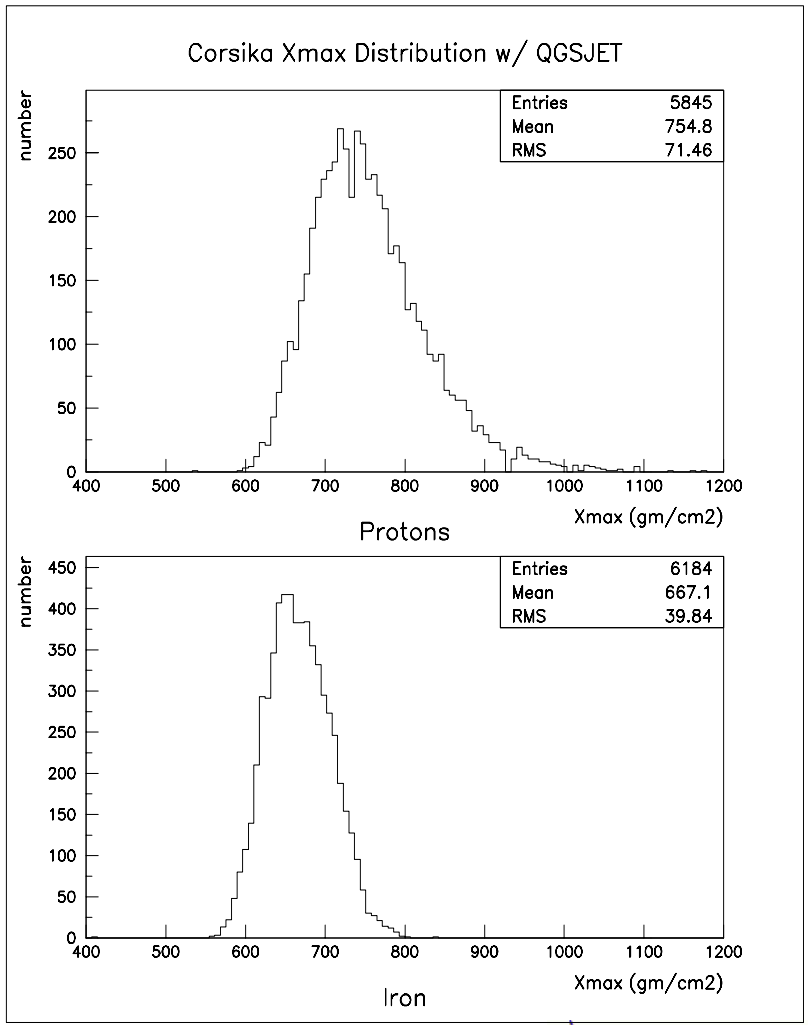
Equivalent light production to a shower of ~6×10^{19} to 10^{20} eV

Detectors have no trouble seeing this laser under good to worse than acceptable viewing conditions.



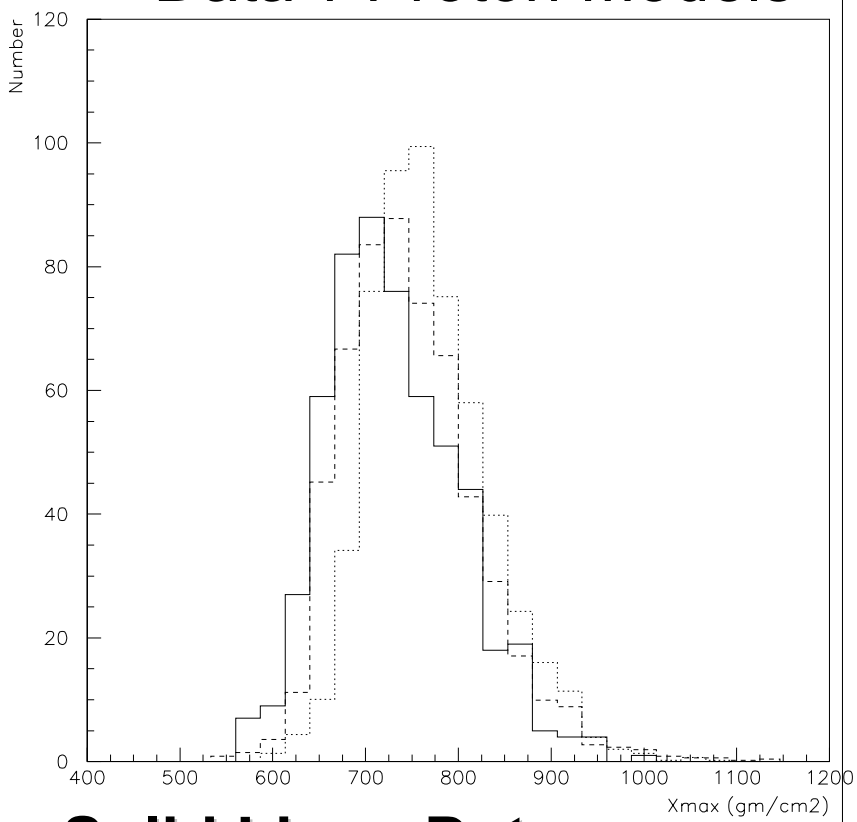
Xmax DistributionWidth Predictions



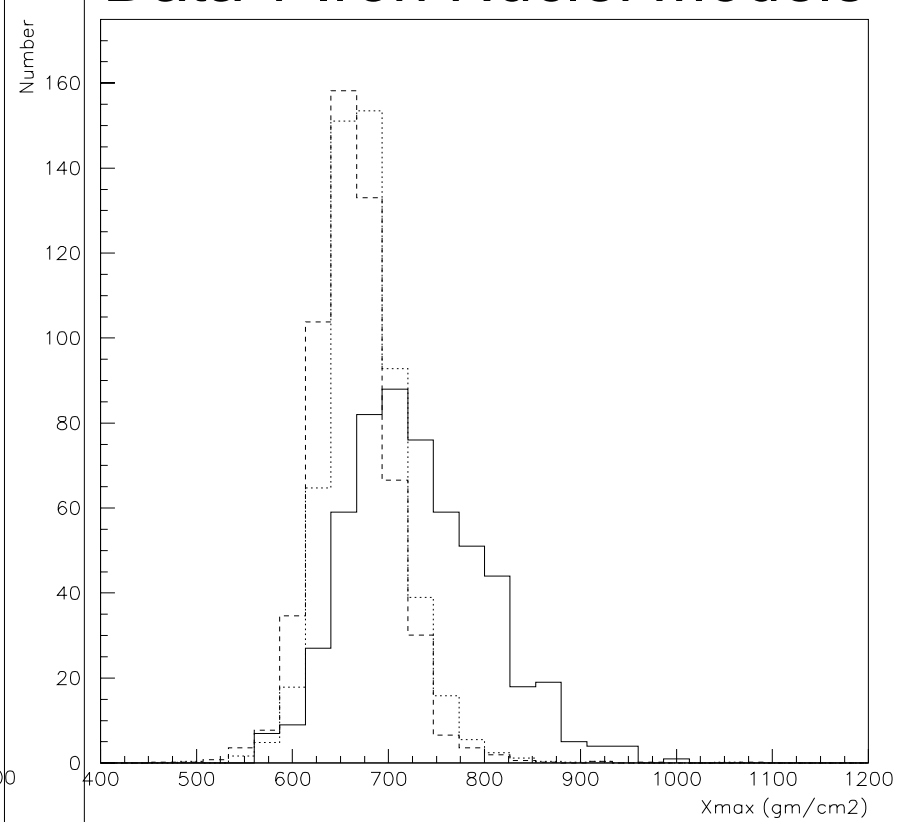


All-Energy Xmax Distribution

Data v Proton Models



Data v Iron Nuclei Models



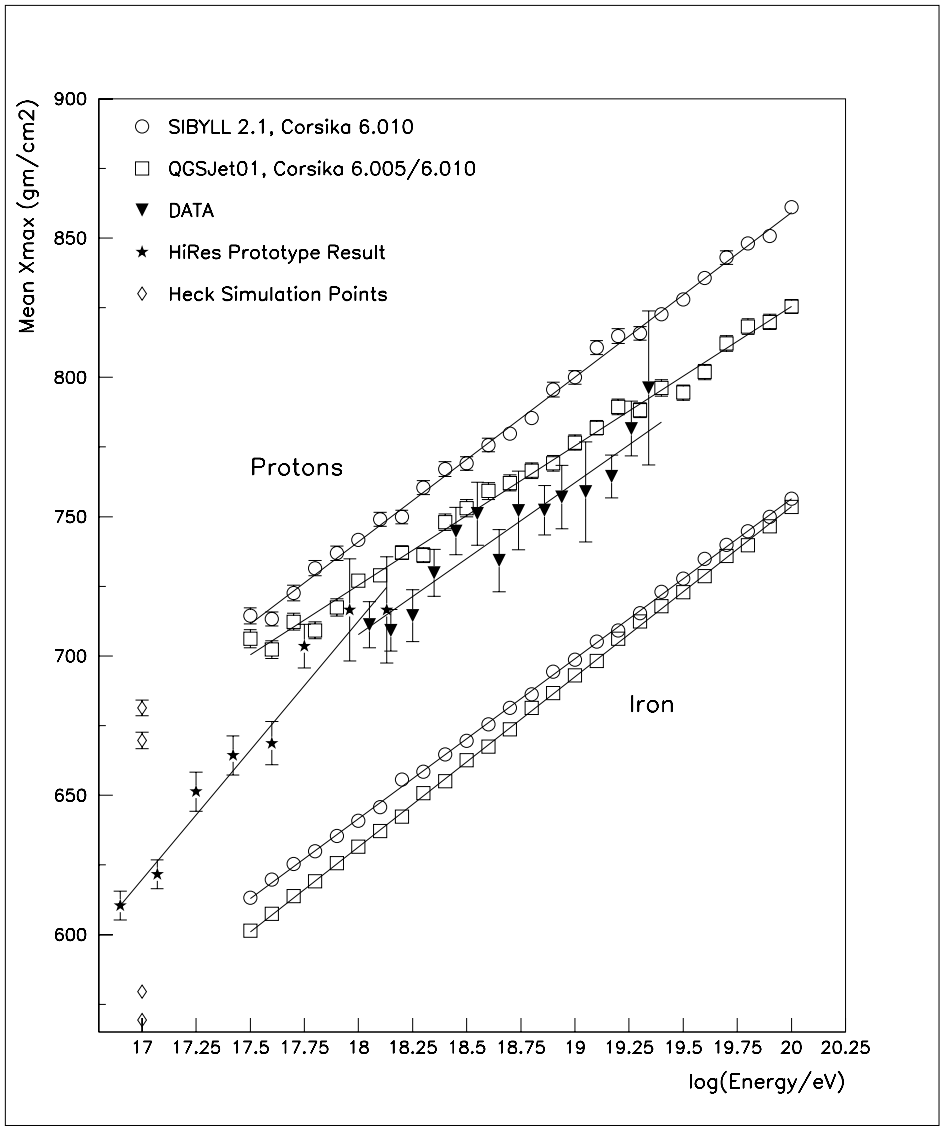
Solid Line: Data

Heavy Dots: QGSJet

Light Dots: SIBYLL

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

Stereo HiRes Elongation Rate



Width is constant from ~10^{18} eV on up.

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

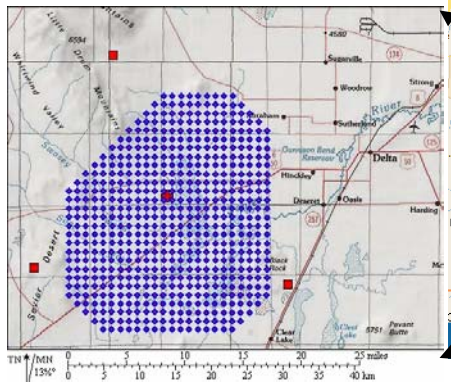
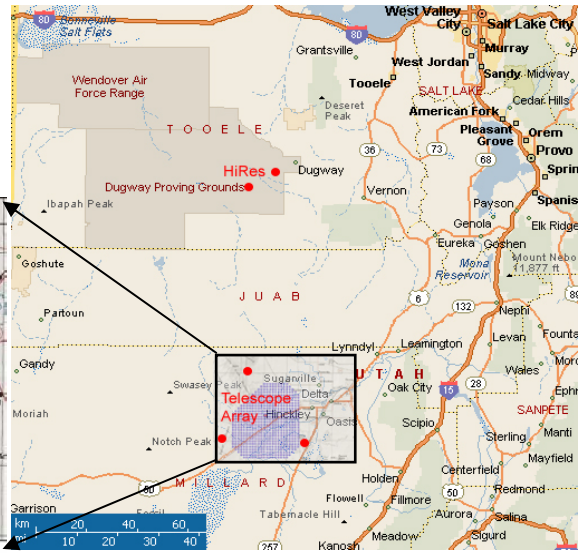
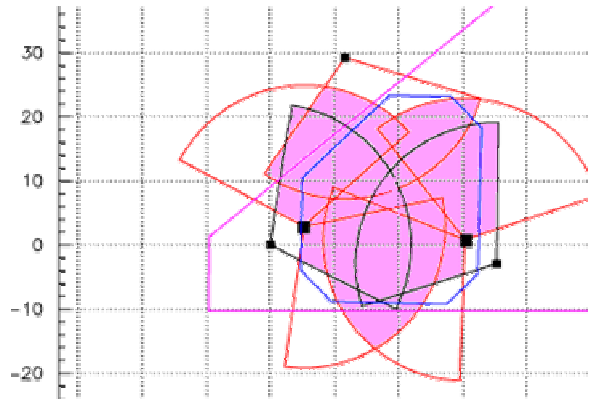
QGSjet (1) prefers 80% "protons"

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
- Xmax 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

Telescope Array Experiment

- 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
- Japan-ROC-US Collaboration.
- US funding sought to add HiRes detectors, infill ground array (fluorescence stereo and hybrid down to 3×10^{16} eV)