

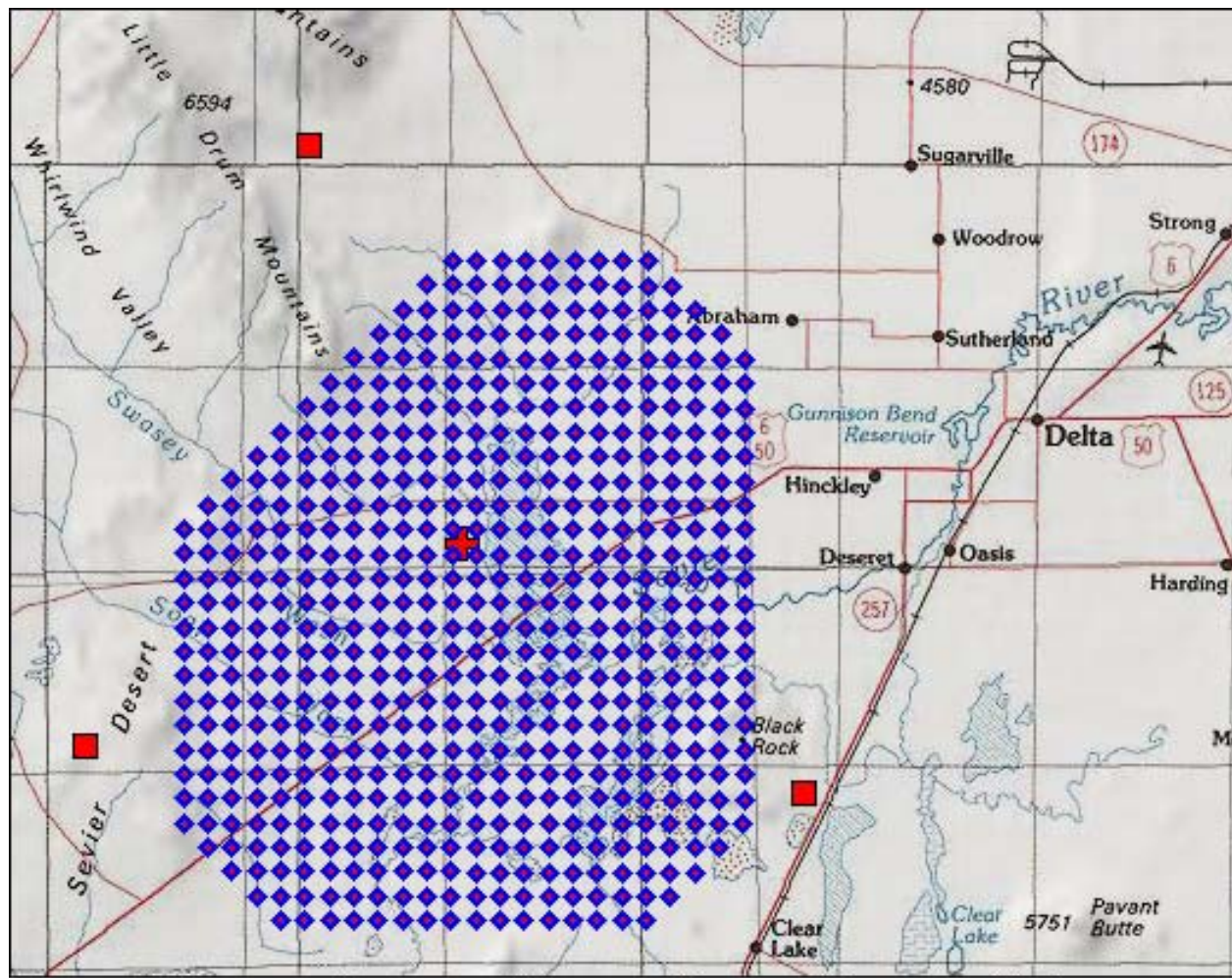
TA/TALE
Telescope Array/TA Low Energy
Extension

P. Sokolsky

For the TA/TALE Collaboration

TA Experiment and Physics Goals

- TA is a funded experiment (12M\$ equivalent from Japan). Japan-ROC-US Collaboration.
- Goal is to resolve the conflict between HiRes and AGASA spectral determination using ground and fluorescence detectors in the same location. Detectors nearly identical to original ones.
- TA is $\sim 10x$ AGASA aperture in ground array + ~ 1 AGASA hybrid coverage.
- Construction begins 2004 and is complete in 2008.



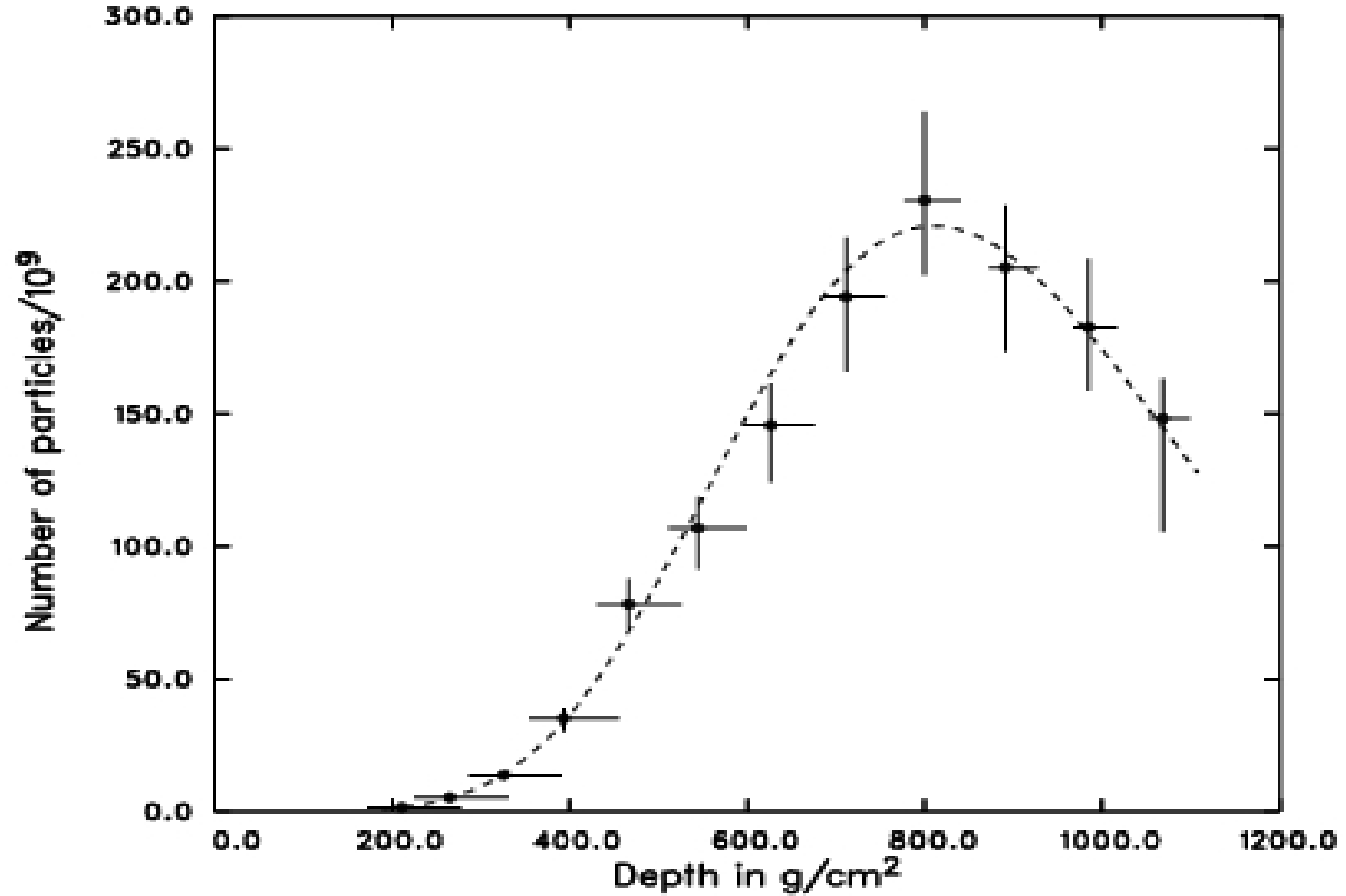
TN \star MN \nearrow
 $13\frac{1}{2}^\circ$
 0 5 10 15 20 25 miles
 0 5 10 15 20 25 30 35 40 km
 Printed from TOPO! ©2001 National Geographic Holdings (www.topo.com)



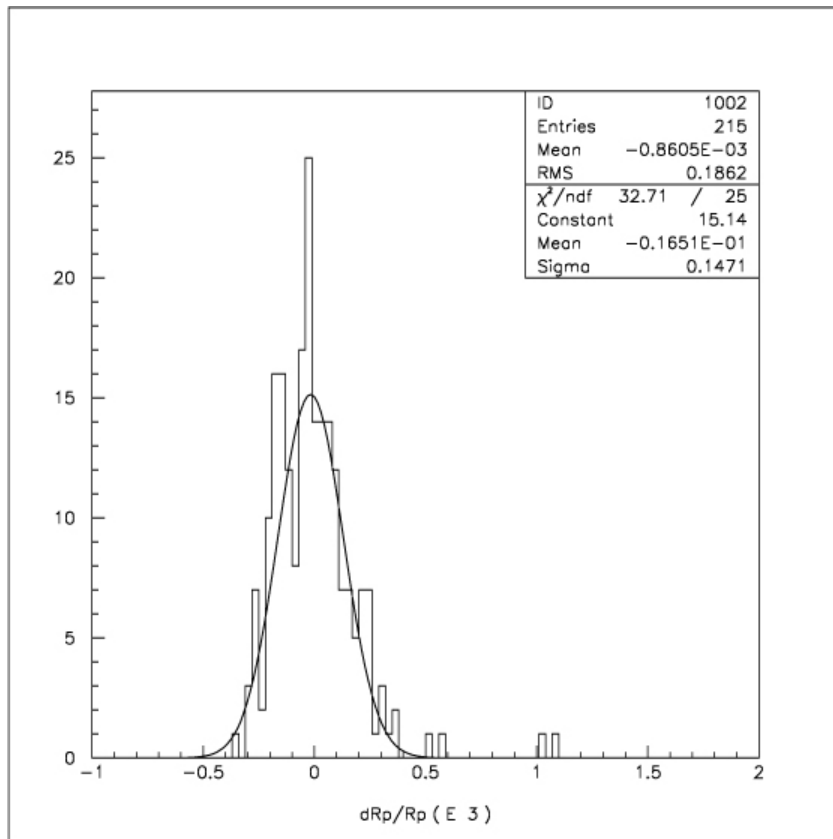
CAMERA

MIRROR

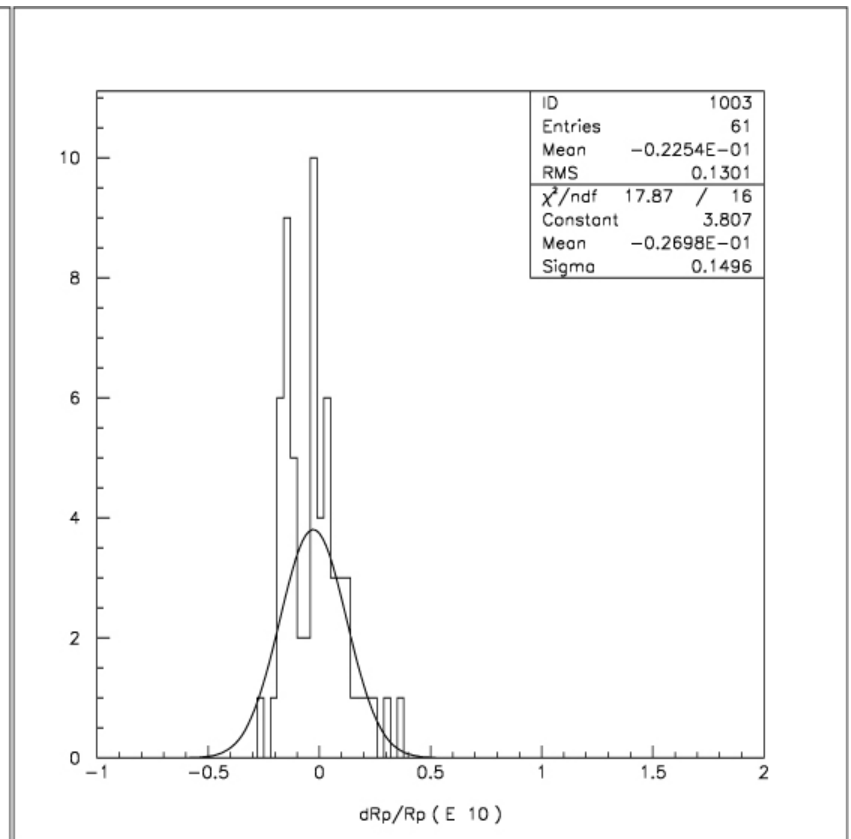
Original **Monocular** Fly's Eye 320 EeV Event



Rp (mono vs stereo)

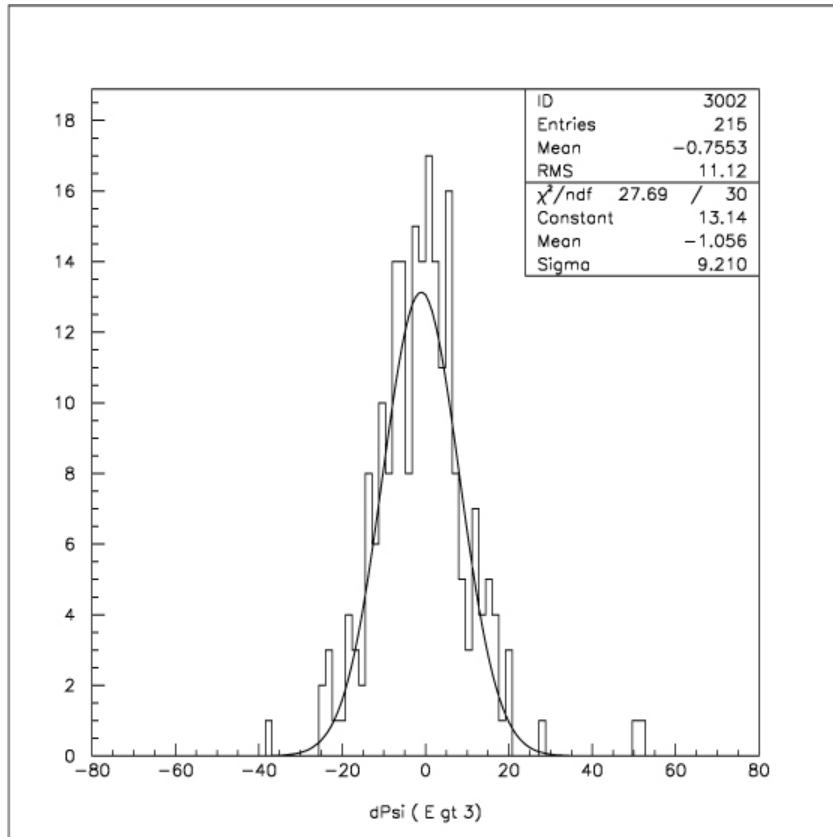


$E > 3$ EeV

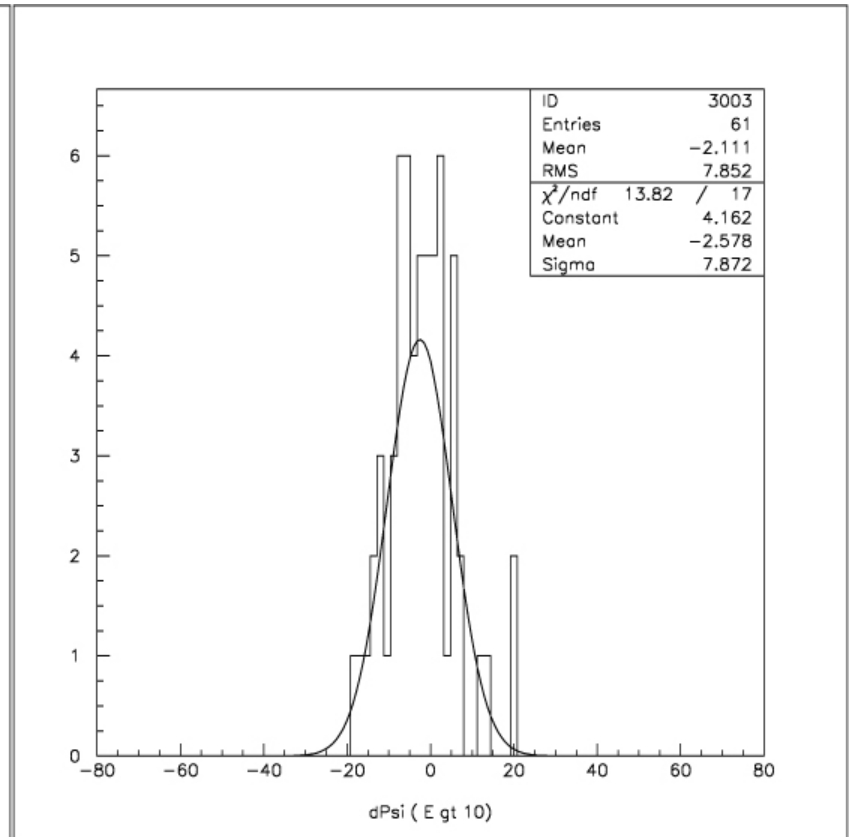


$E > 10$ EeV

Psi (mono vs stereo)

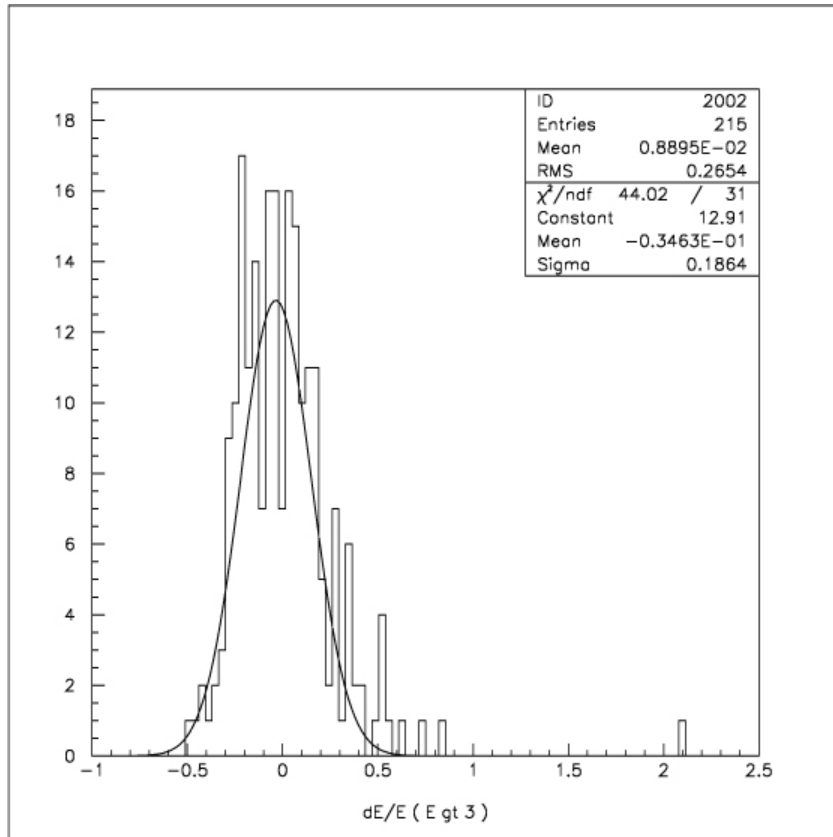


$E > 3$ EeV

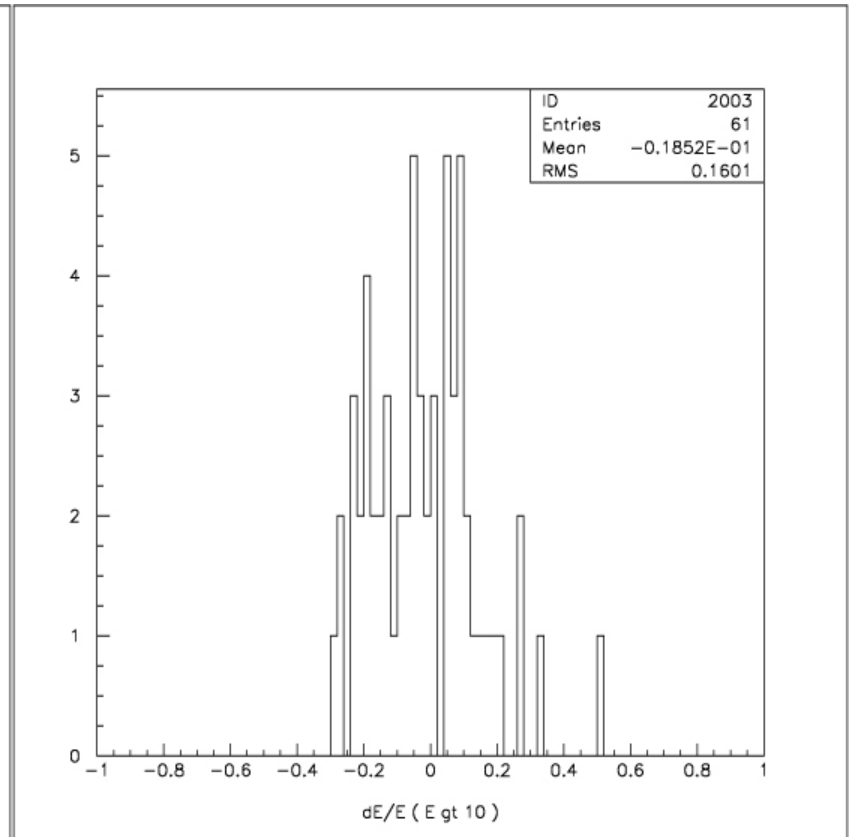


$E > 10$ EeV

Energy (mono vs stereo)

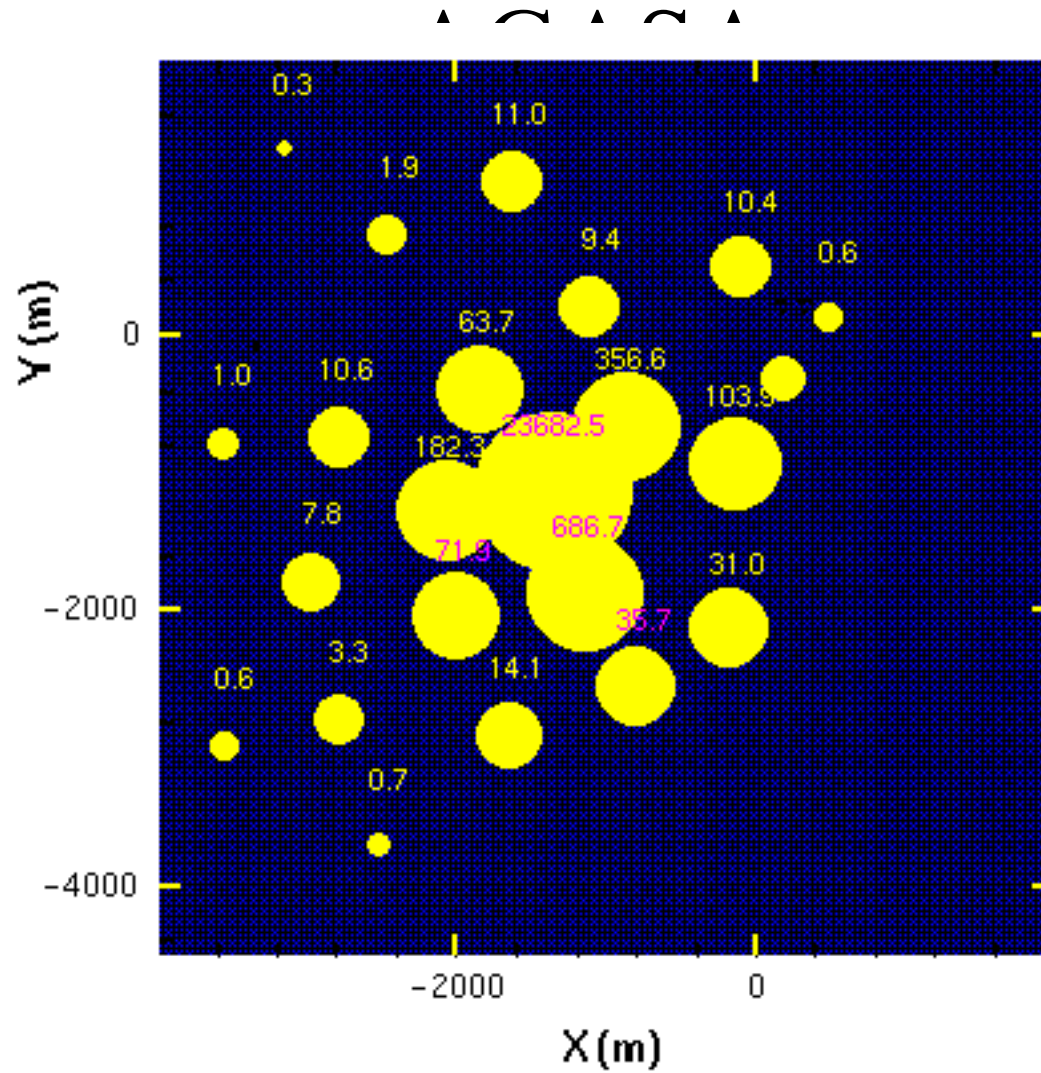


$E > 3$ EeV



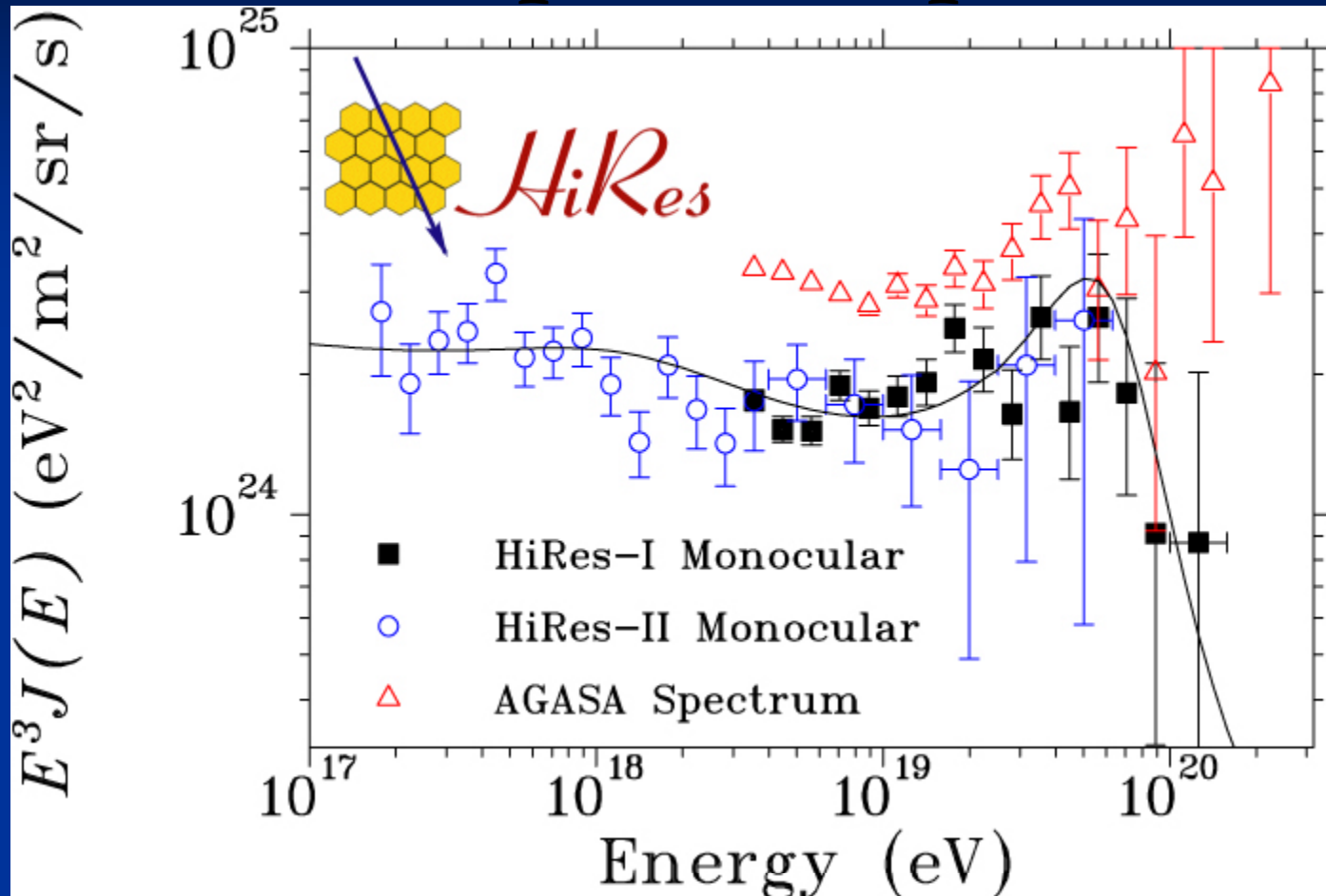
$E > 10$ EeV

Footprint of Highest Energy Event in



Highest Energy AGASA Event

HiRes I Updated Spectrum



TALE – TA low energy extension

- TA/TALE collaboration would like to extend the physics reach of TA down to 10^{17} eV. This will be done by:
- Moving HiRes detectors to TA site after completion of HiRes operations at Dugway.
- Add additional HiRes type mirrors to extend low energy aperture.
- Add infill array using recycled AGASA detectors.

TA/TALE Collaboration

- **US Institutions – Firm**
- University of Utah
- Rutgers University
- University of Montana
- Brigham Young University
- Utah State University

TA/TALE Collaboration

- **US Institutions, Interested, under discussion**
- Stanford Linear Accelerator Center
- Lawrence Livermore National Lab
- **ROC Institutions, Firm**
- COSPA, National Taiwan University

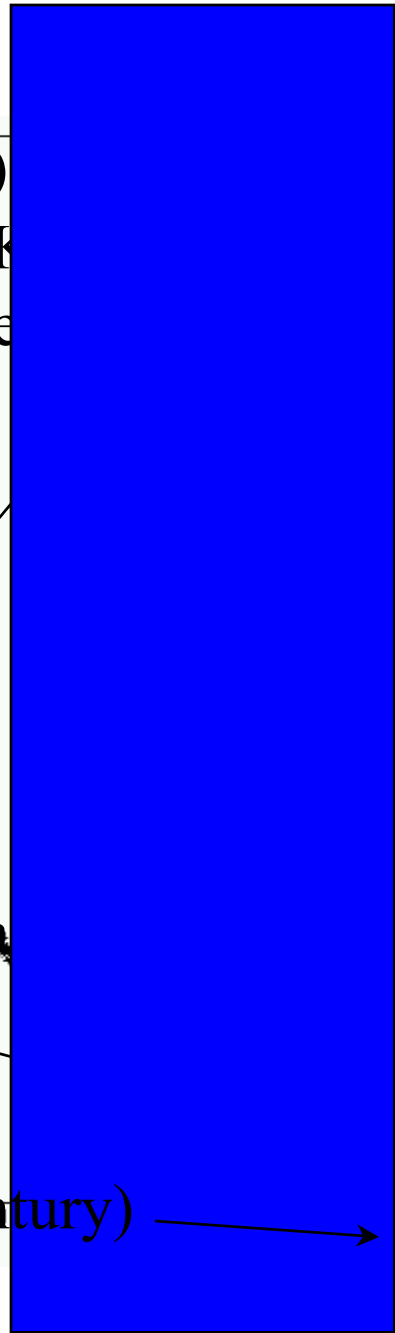
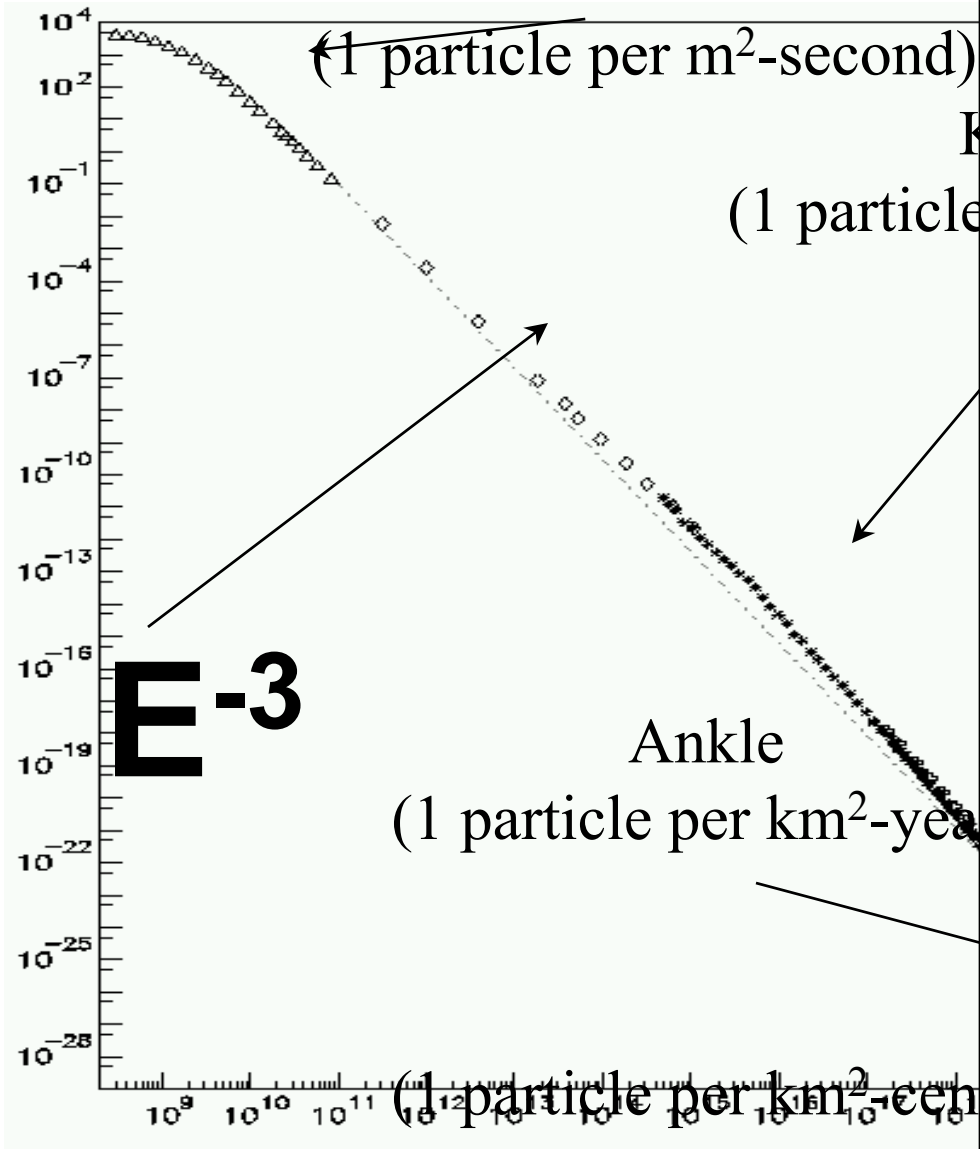
Japan TA/TALE Institutions

- ICRR, Tokyo University- M. Fukushima
- KEK
- Chiba University
- Ehime University
- Osaka City University
- Kanagawa University
- Kinki University
- Kochi University
- Saitama University
- Shibaura Institute of Technology
- Communications Research Laboratory
- Tokyo Institute of Technology
- Hiroshima City University
- National Institute of Radiological Sciences
- Musashi Institute of Technology
- Yamanashi University

Physics of the End of the Galactic Spectrum

- Origin of cosmic rays beyond the first knee (10^{15} eV) not understood
- Downward-turning shape at knee implies a connection with lower energy cosmic rays or an unusual coincidence in normalization.
- Jokipi, Axford and others proposed several such “re-acceleration mechanisms” but theories failed in numerical detail
- Paraphrasing Jokipi, **there are presently no good ideas for understanding the post-knee spectrum.** All that is known with some certainty is that the origin of this flux, up to the ankle region, is galactic and that it obeys a power law.

Flux ($\text{m}^2 \text{sr s GeV}^{-1}$)

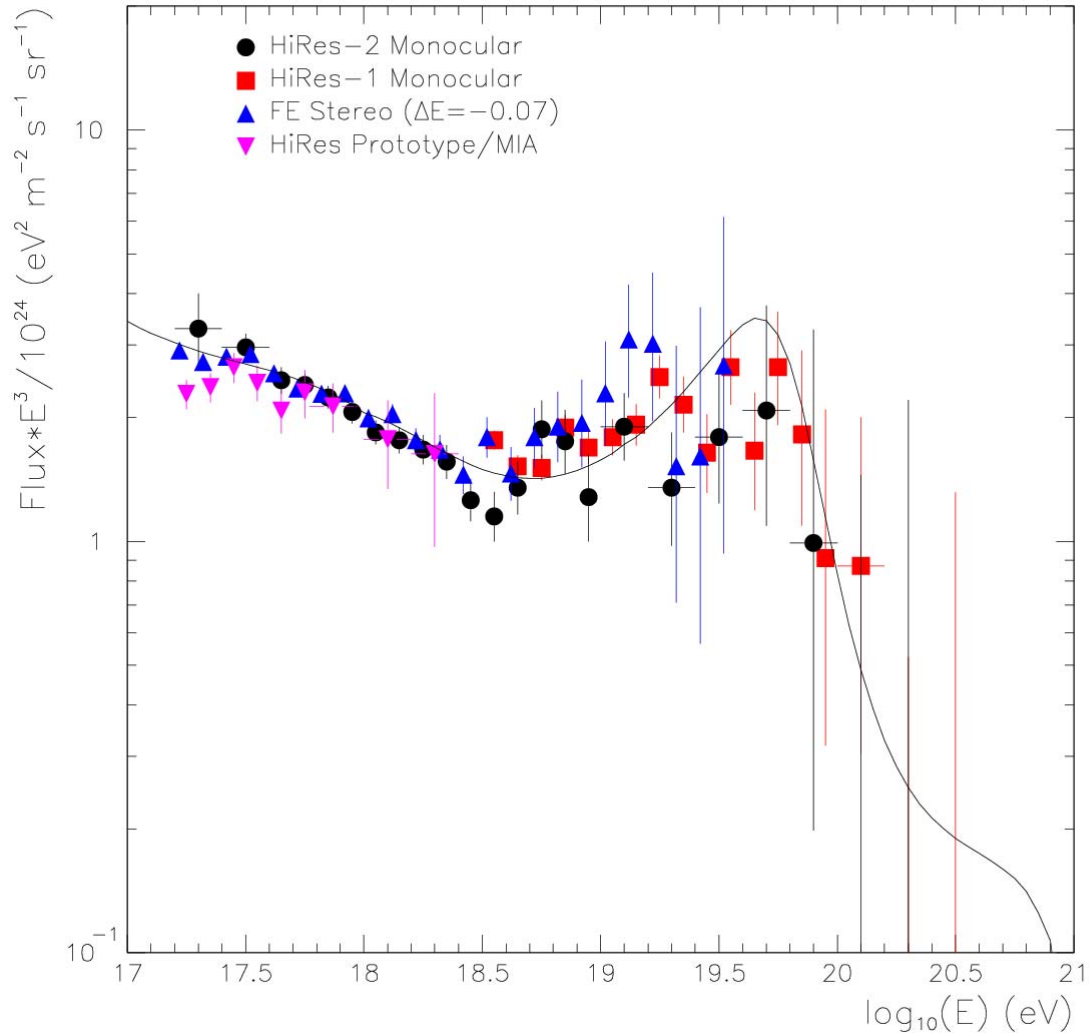


Physics of the End of the Galactic Spectrum – cont.

- Second knee observed near $3\text{-}5 \times 10^{17}$ eV.
- Some evidence for galactic plane clustering observed near 10^{18} eV.
- Ankle structure observed with minimum near 3×10^{18} eV.
- Change of composition (as measured by X_{max}) observed from 10^{17} to 10^{18} eV.
- One explanation: galactic spectrum ends and a harder, extragalactic spectrum continues.

Evidence for Second Knee from four experiments

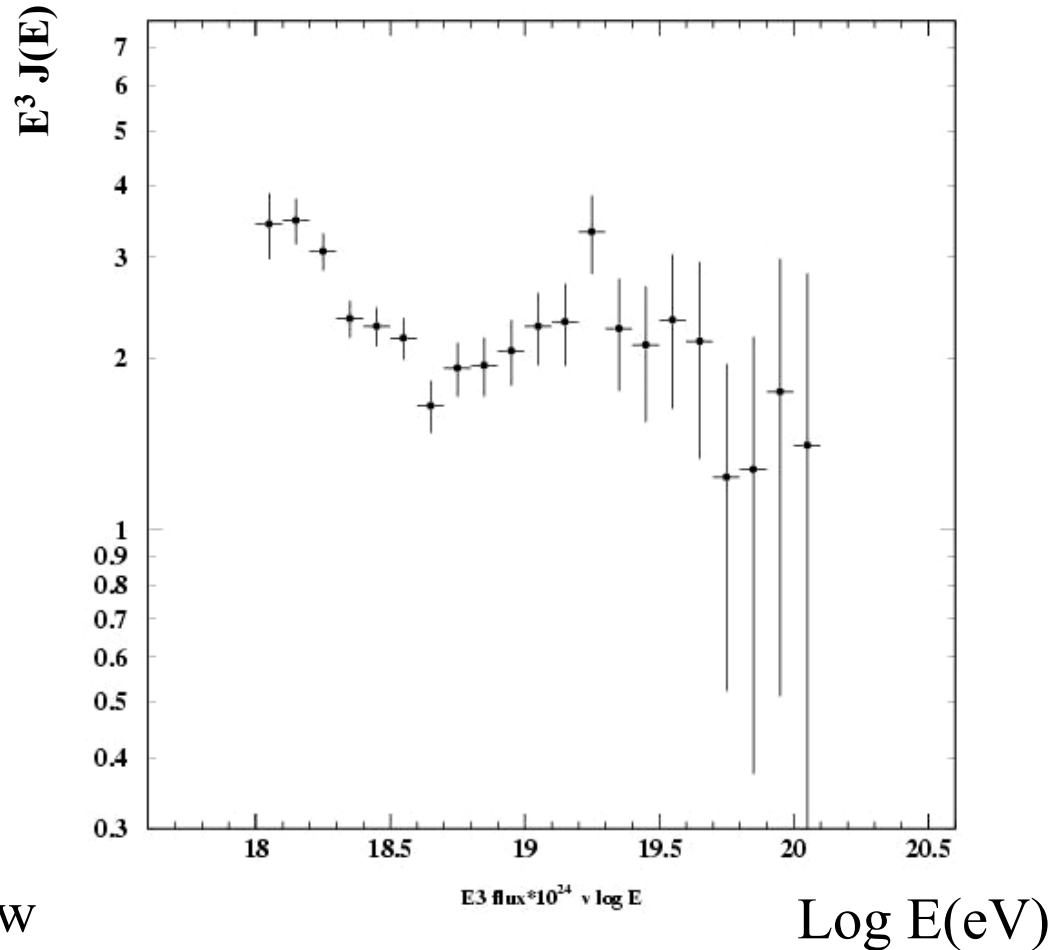
Evidence for ankle from four experiments



HiRes Stereo Flux Measurement

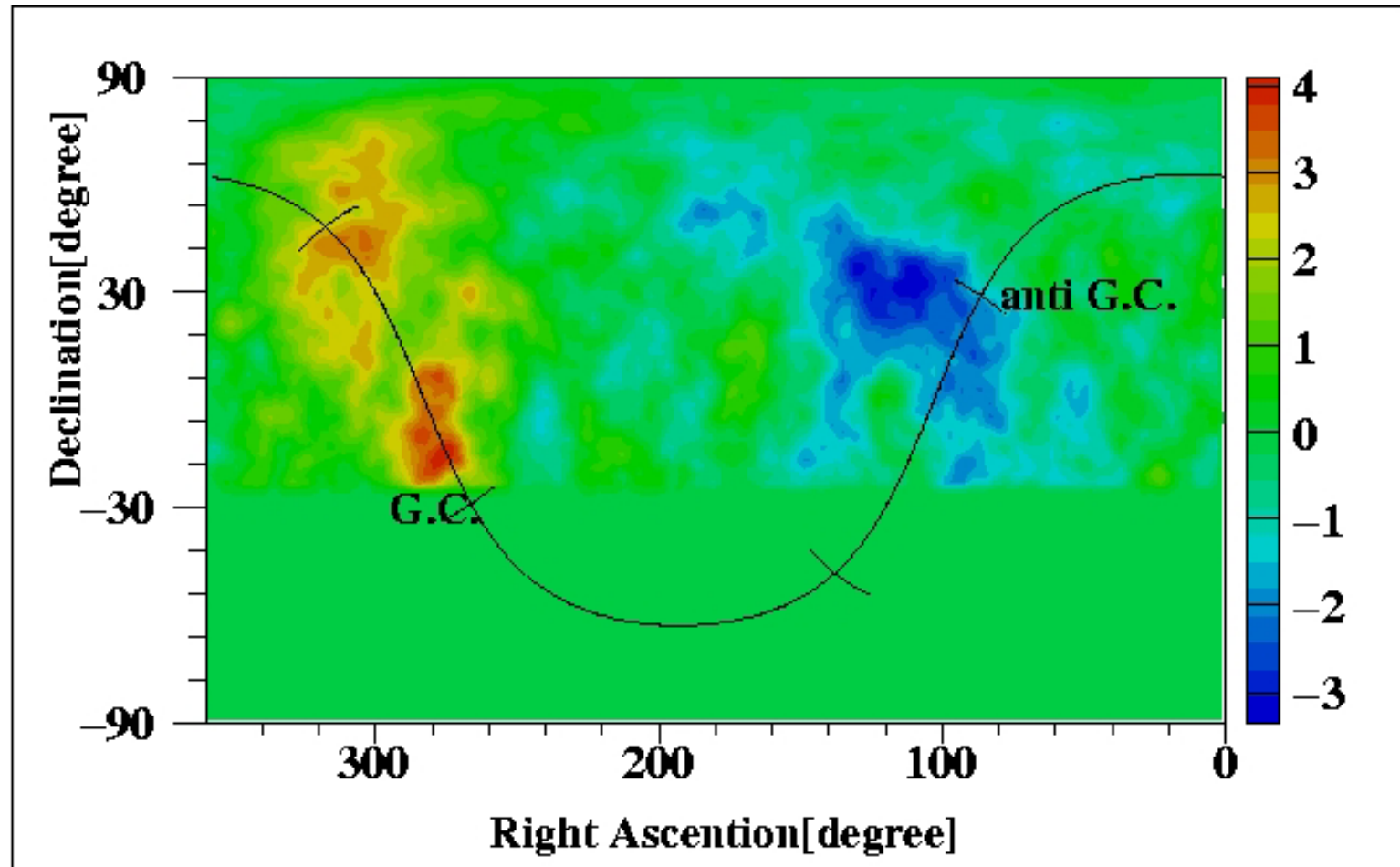
Energy**3 * Flux

- HiRes Stereo Spectrum is consistent With HR1 Monocular Spectrum above $10^{18.5}$ eV.
- Change in spectral index observed at an energy of approximately $10^{18.6}$ eV.
- ONLY STATISTICAL ERRORS Shown here
- Aperture rapidly varying and sensitive to details below 3×10^{18}



Evidence for change of composition from HiRes prototype and Stereo HiRes

Evidence for galactic anisotropy from AGASA



TALE – precision, high statistics study
of composition-tagged spectrum in 10^{17} -
 10^{19} eV region

- Use X_{\max} to tag galactic and extragalactic components and map out the shape of the end of the galactic spectrum.
- Physics goals: Maximum energy of galactic accelerator, anisotropy near maximum energy, location of e^+e^- energy loss dip in extragalactic spectrum.

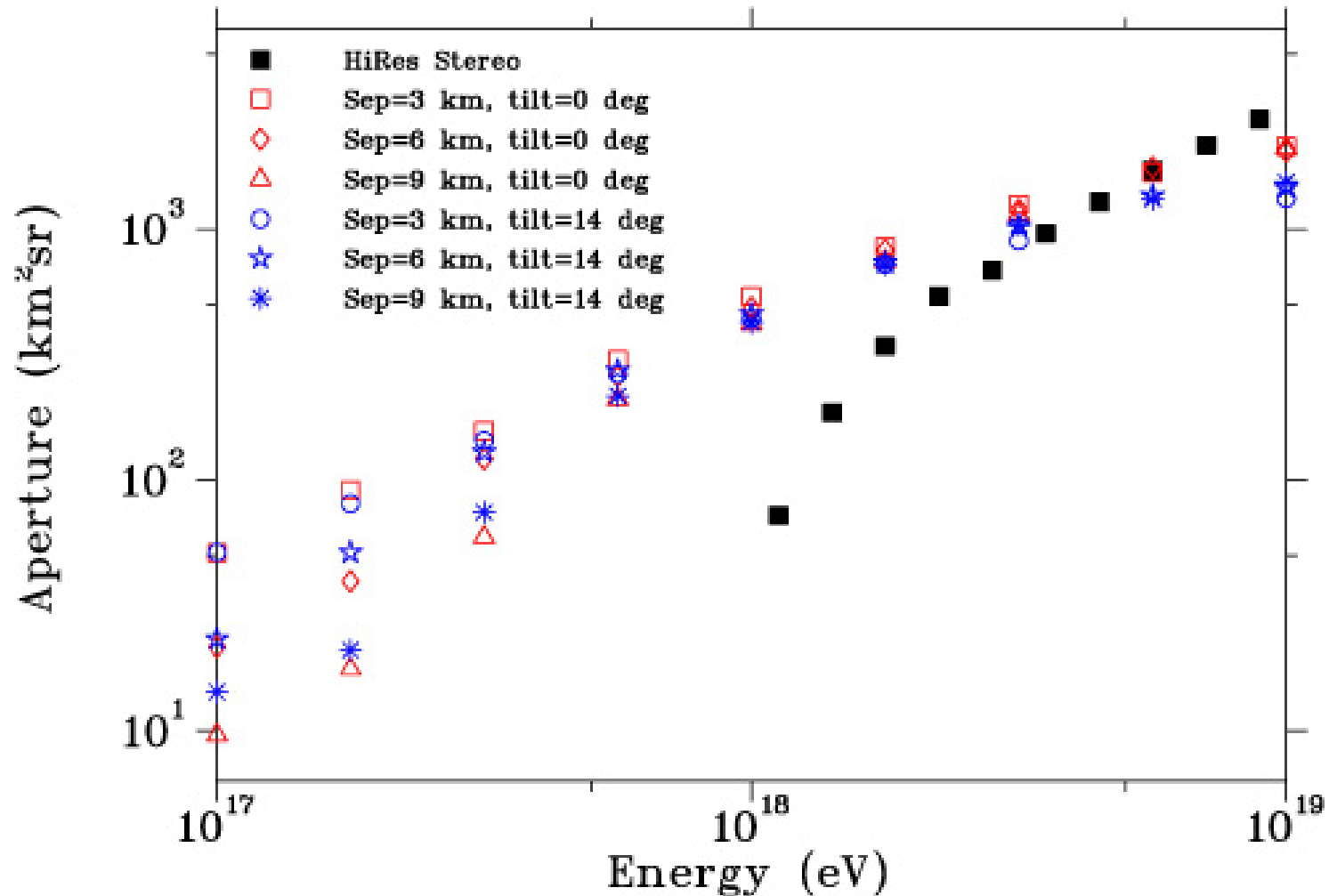
Experimental Requirements

- Precise determination of X_{\max} and Energy from 10^{17} to 10^{19} eV,
- Significant improvement in statistics over Stereo HiRes in this energy range
- Smooth, slowly changing aperture that is robustly determined over this energy range.

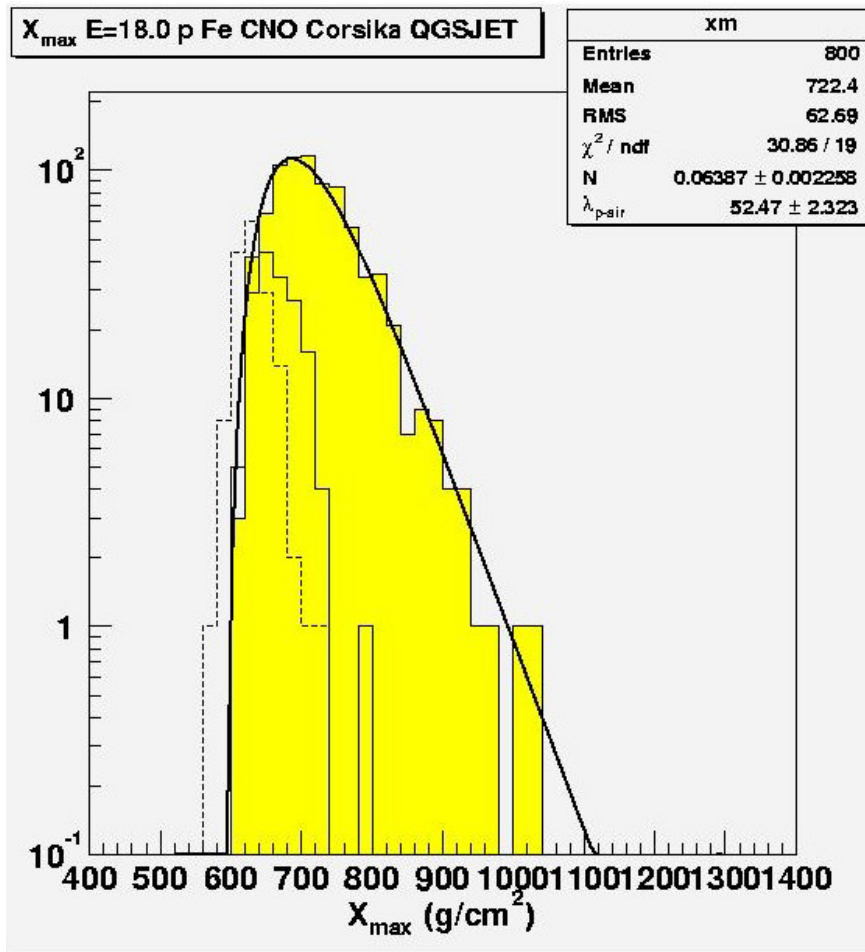
Realization

- TA FD provides opportunity for asymmetric stereo pairs. – smooth aperture and large increase in statistics over HiRes
- TA SD and infill array provides opportunity for significant statistics with hybrid stereo events. Very precise determination of X_{\max} .

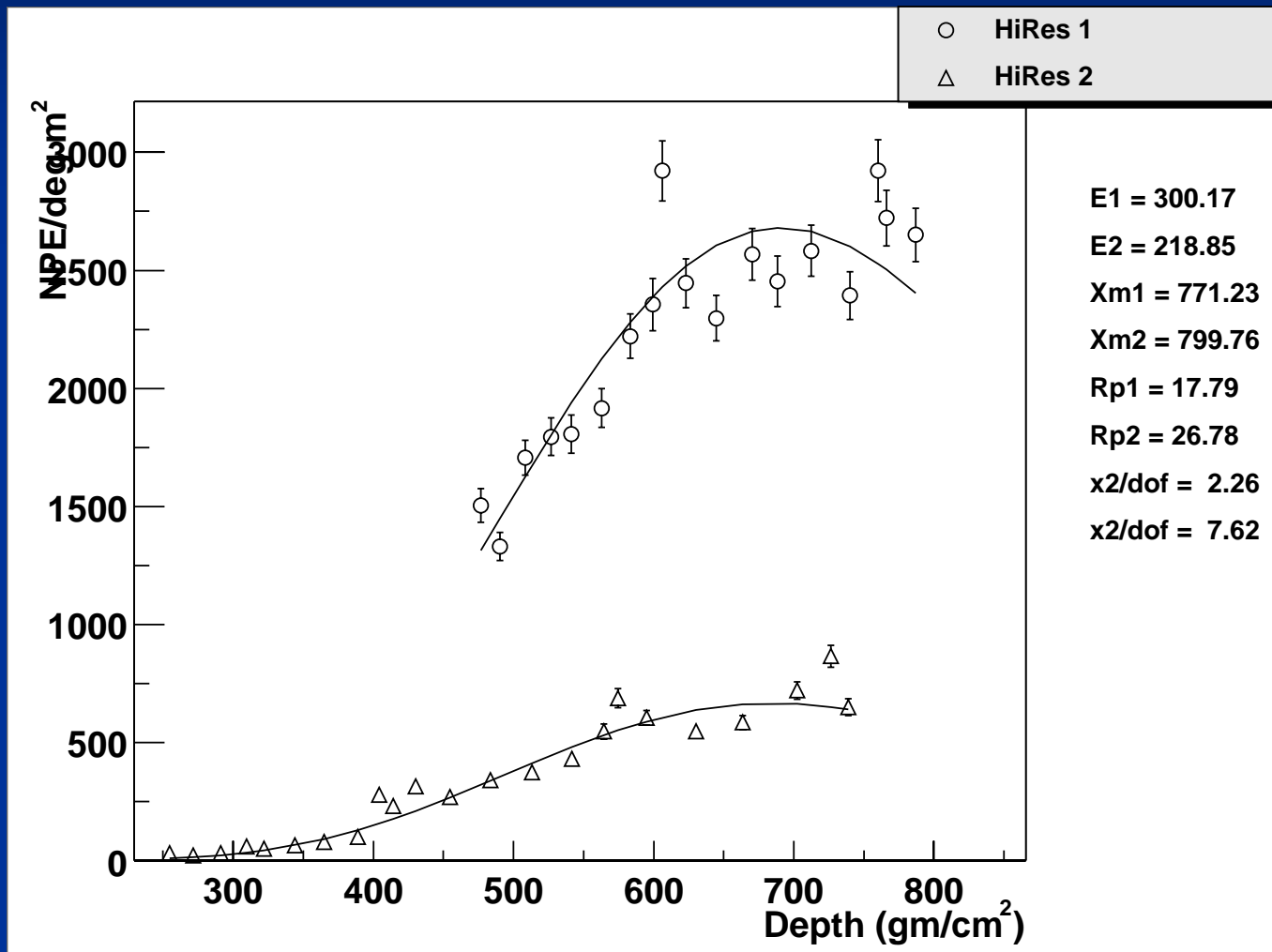
Asymmetric Stereo Aperture

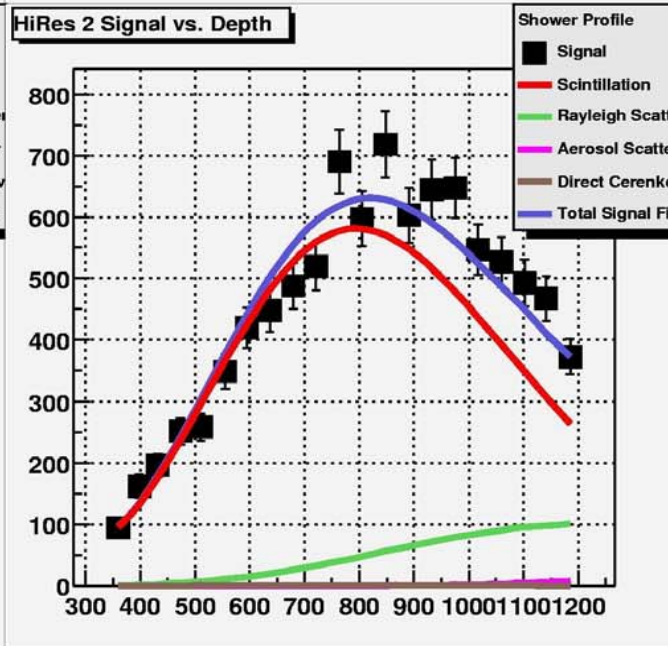
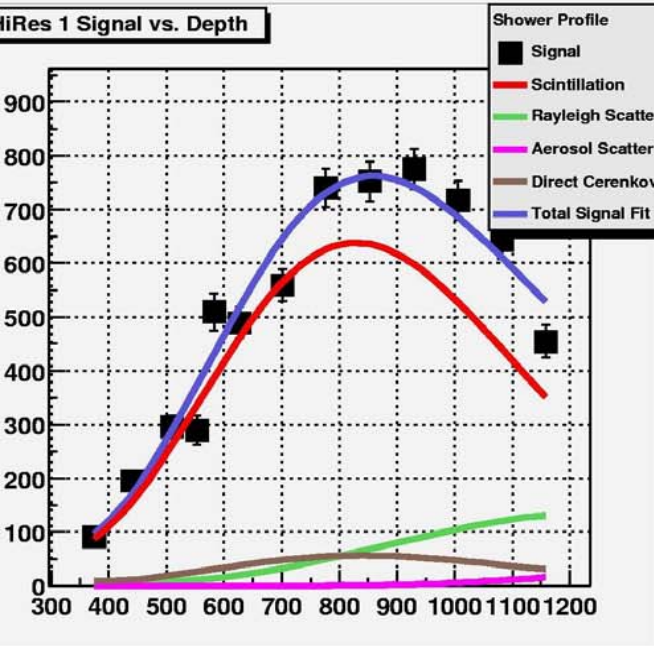
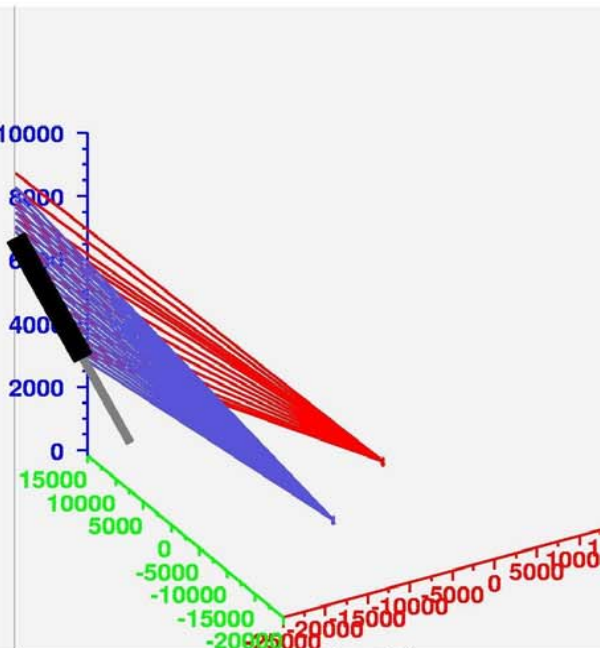
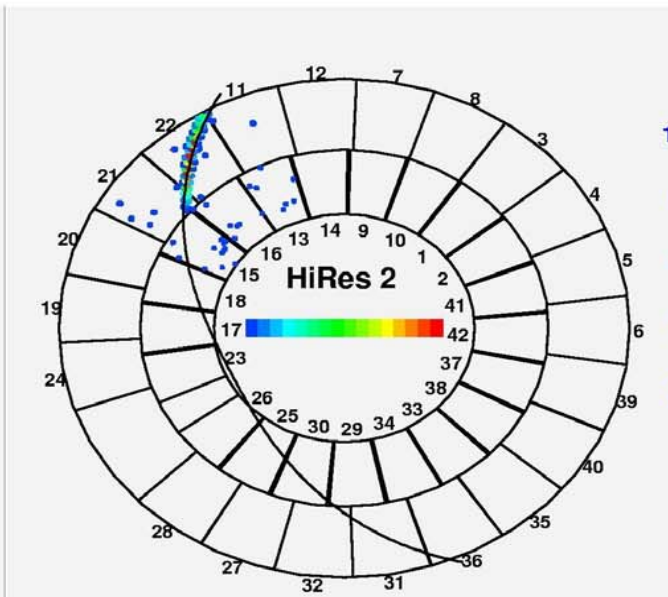
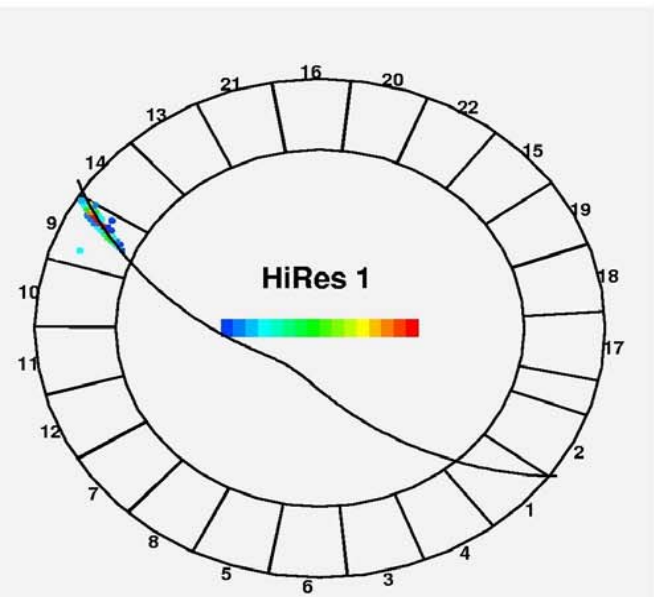


Highest Energy Stereo Event



Highest Energy Stereo Event





Event 1
19 Nov 2003

HiRes 1
Event Starting: 6:35:31.263281
Energy: 121.956 Eev
Distance to Core: 24949.022 m
Profile Fit χ^2 : 6.1178
Shower max: $6.133e+10$ particles
Depth at shower max: 865.069 g/cm²

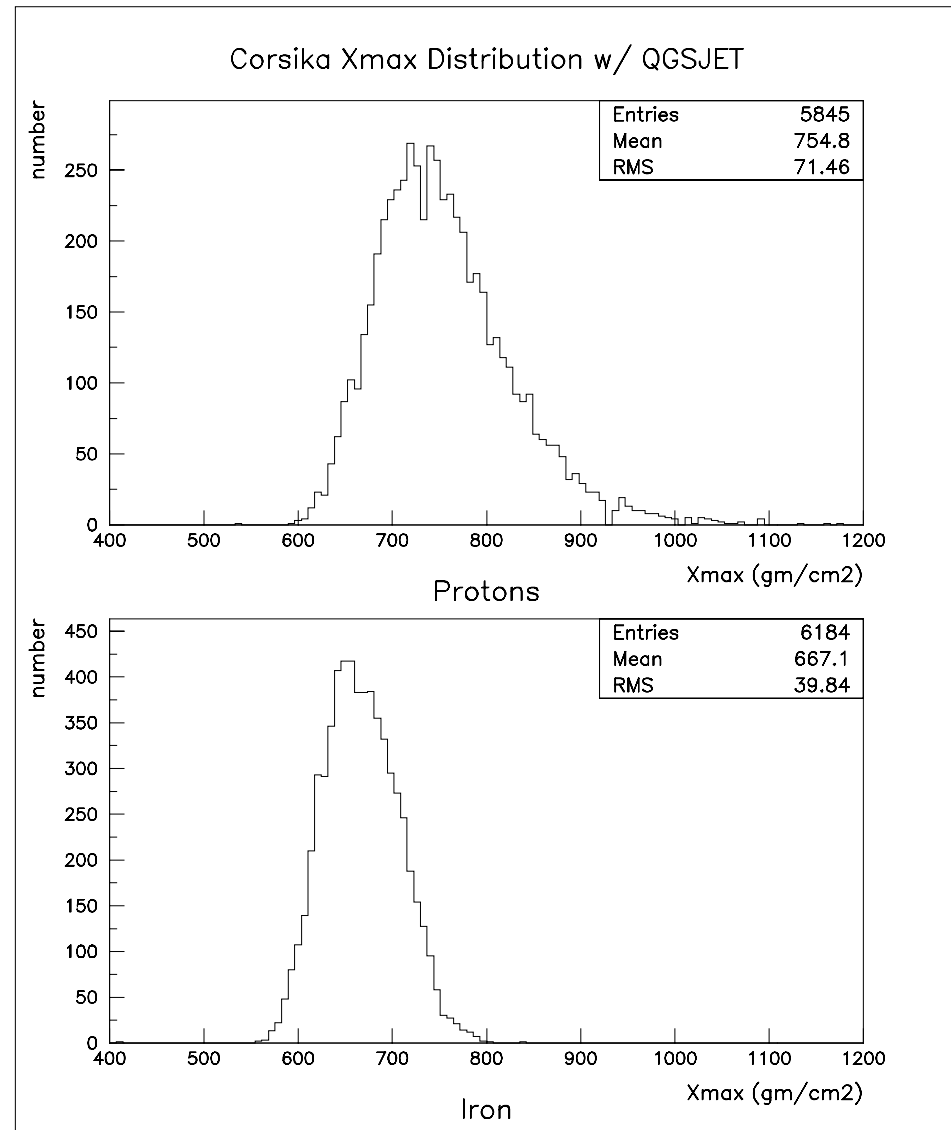
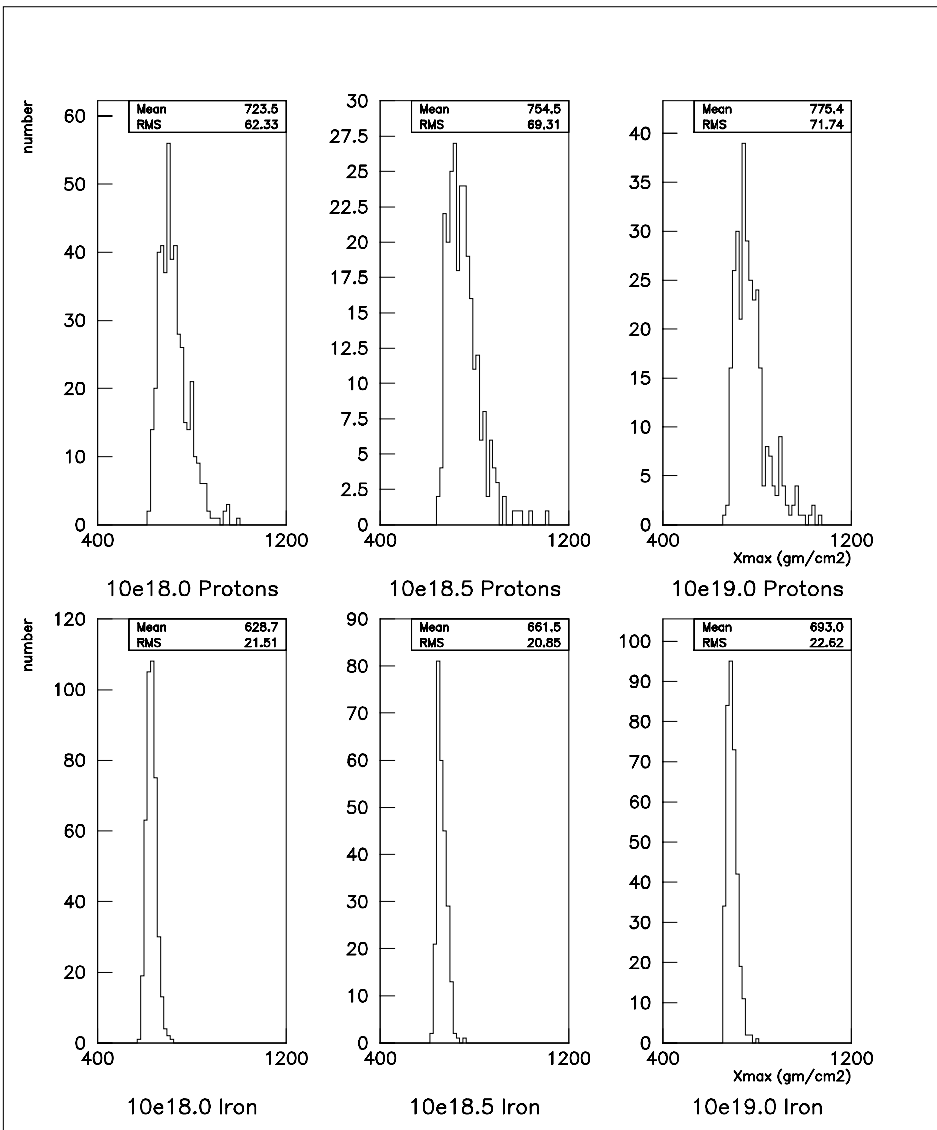
Shower azimuthal angle: 169.2 degrees
Shower zenith angle: 60.1 degrees

HiRes 2
Event Starting: 6:35:31.263180
Energy: 122.491 Eev
Distance to Core: 23533.923 m
Profile Fit χ^2 : 1.8318
Shower max: $6.050e+10$ particles
Depth at shower max: 830.569 g/cm²

Pull Distribution – Data and MC

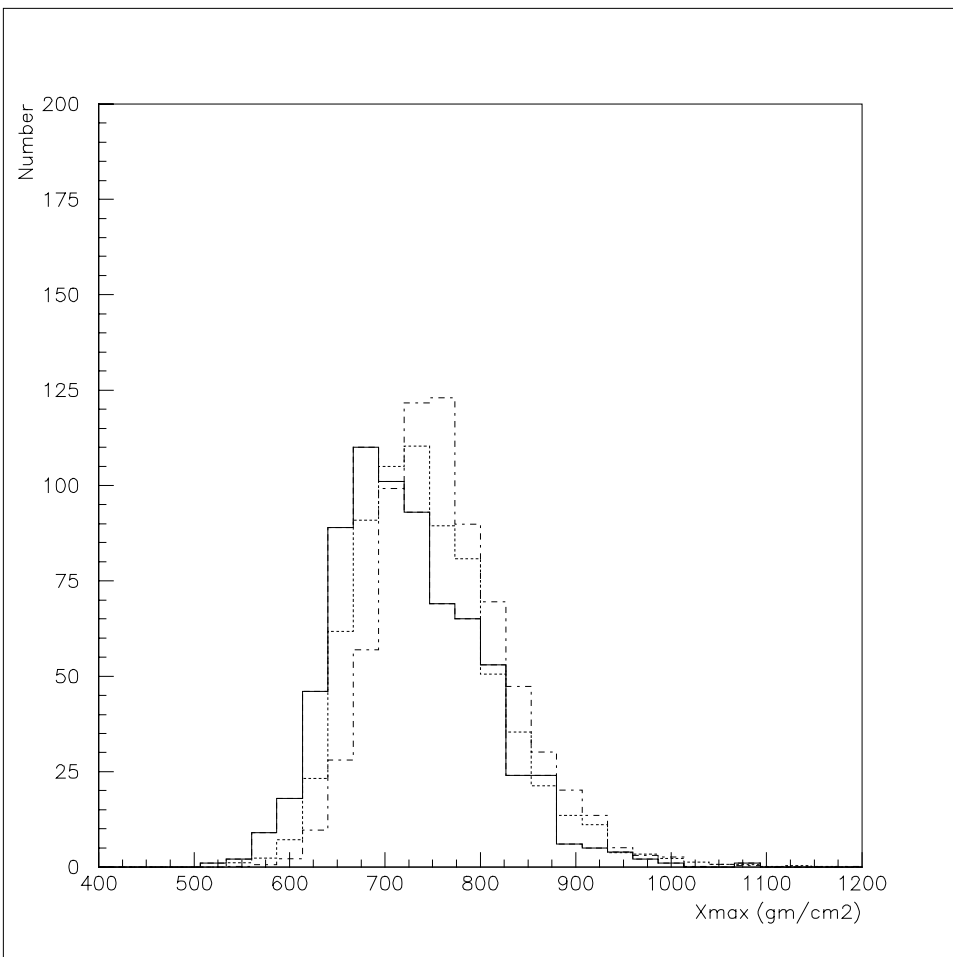
$$\frac{(X_{\max}^{\text{I}} - X_{\max}^{\text{II}})}{((X_{\max}^{\text{I}} + X_{\max}^{\text{II}}) / 2)}$$

X_{\max} Distribution Width Predictions

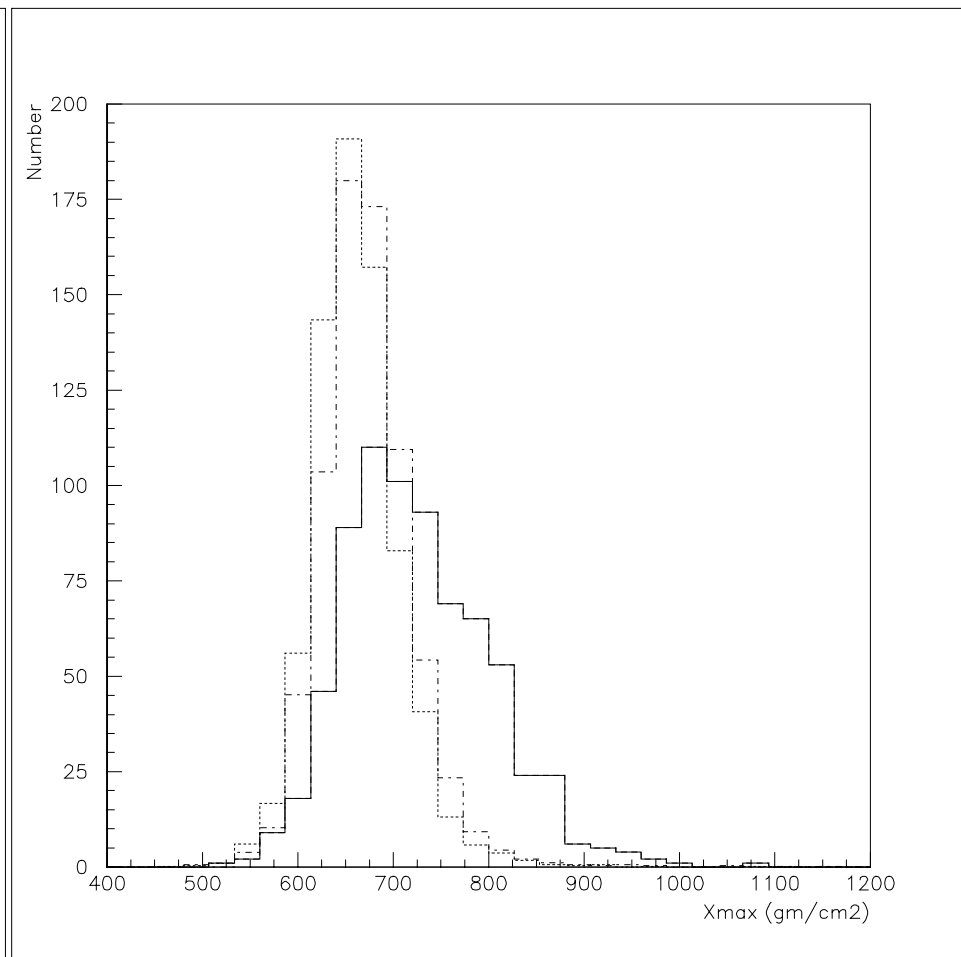


All-Energy X_{\max} Distribution

Protons



Iron Nuclei

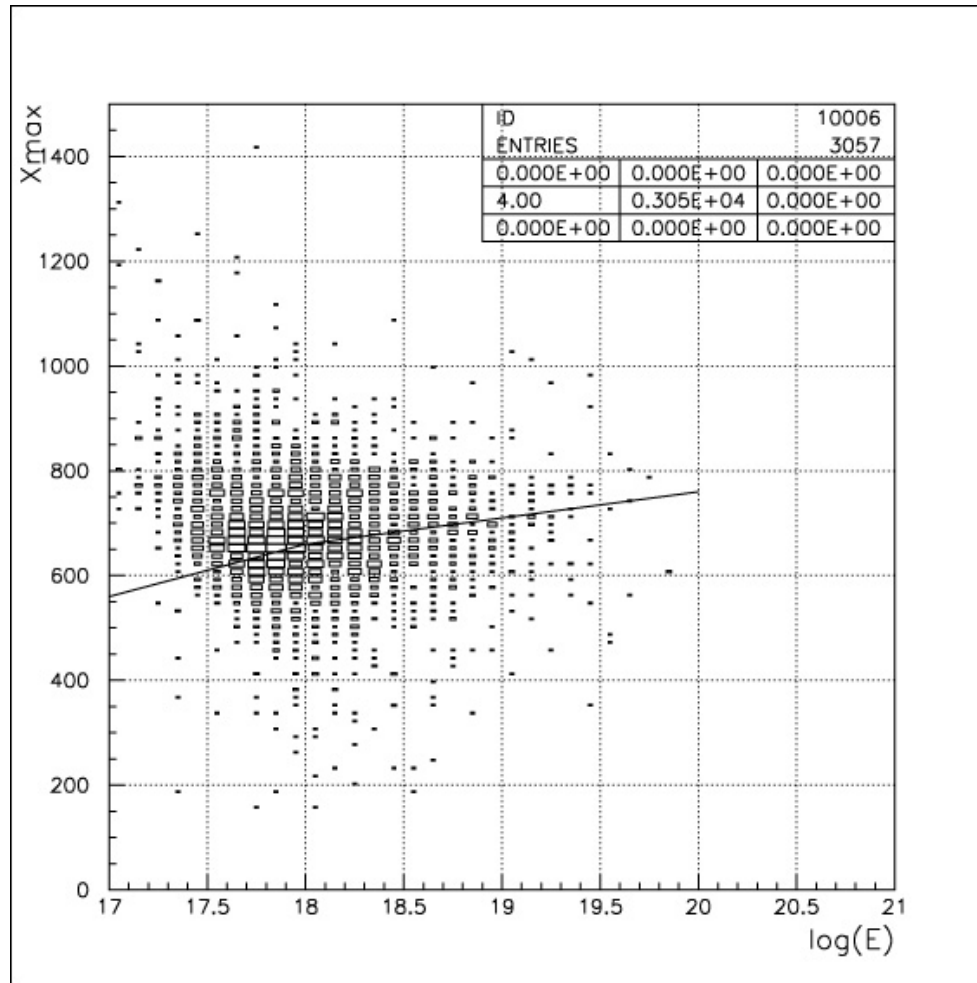


Solid Line: Data. Dotted: QGSJet. Dot-dash: SIBYLL

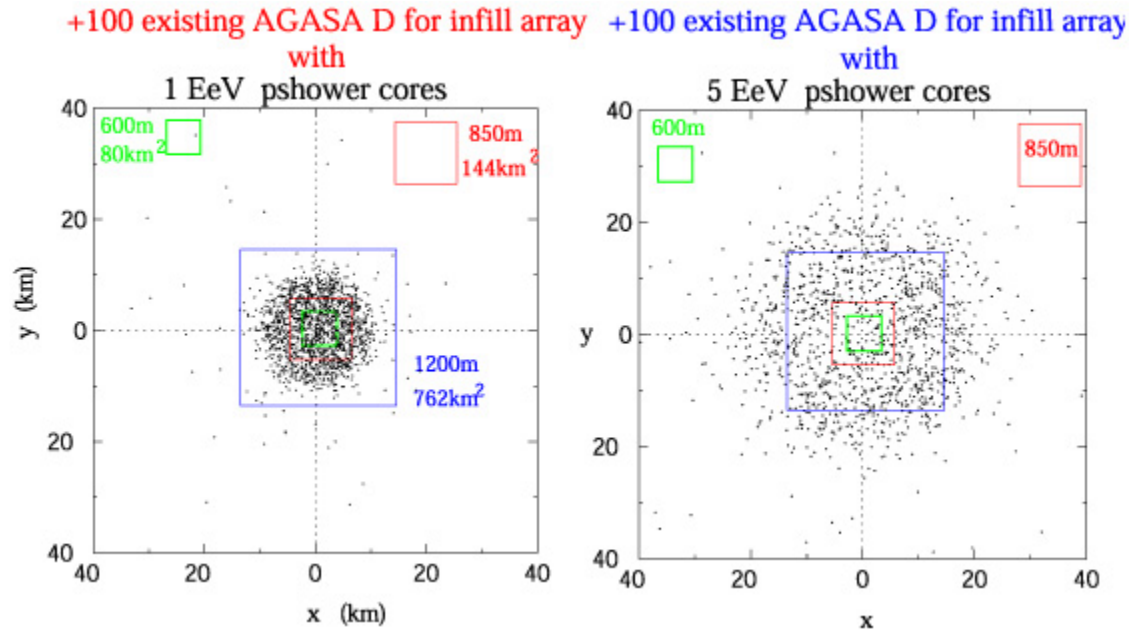
Estimated Event Rates based on HiRes Stereo data

- HiRes Stereo – 1400 events/year between 3×10^{18} and 10^{19} eV.
- TALE – expect ~ 5600 events/year above 3×10^{18}
- 5 year run – 28000 events.
- >800 gm/cm² Xmax cut $\sim 15\%$ events survive – 4200 events in “proton enhanced sample”
- <650 gm/cm² Xmax cut $\sim 14\%$ events in “Fe enhanced” sample – 3900 events.

Xmax bias for two ring detector



Match with TA and infill arrays



Conclusion

- Existence of funded TA detector and HiRes detectors gives opportunity for unique Stereo-hybrid experiment
- TA/TALE collaboration being formed
- TALE can be built after completion of HiRes operation for $\sim 7\text{M}\$$
- Most of the funding can be accommodated as an extension of HiRes funding



In case northern Auger is built in Millard County, TA is willing to provide its FD triggers and associated data in exchange for the trigger related Auger SD information. In stated case TA is also willing to work in good faith with the Auger collaboration towards more comprehensively integrating data taking and analysis.

Approved by TA collaboration, March 2004.