First Results from the Telescope Array Experiment

J.N. Matthews, University of Utah
For the Telescope Array Collaboration

Quarks-2010 Kolomna, Russia **6 June, 2010**

Telescope Array (TA)

- Telescope Array Collaboration was forged by Members of HiRes and AGASA
  - Study Ultra High Energy Cosmic Rays (spectrum, composition, anisotropy, …)
  - Understand the differences between AGASA and HiRes
  - Study the galactic to extra-galactic transition: measure cosmic rays over the second knee, ankle, and GZK with one cross-calibrated detector
- Telescope Array now has members from the US, Japan, Korea, Russia, and China

Telescope Array Collaboration

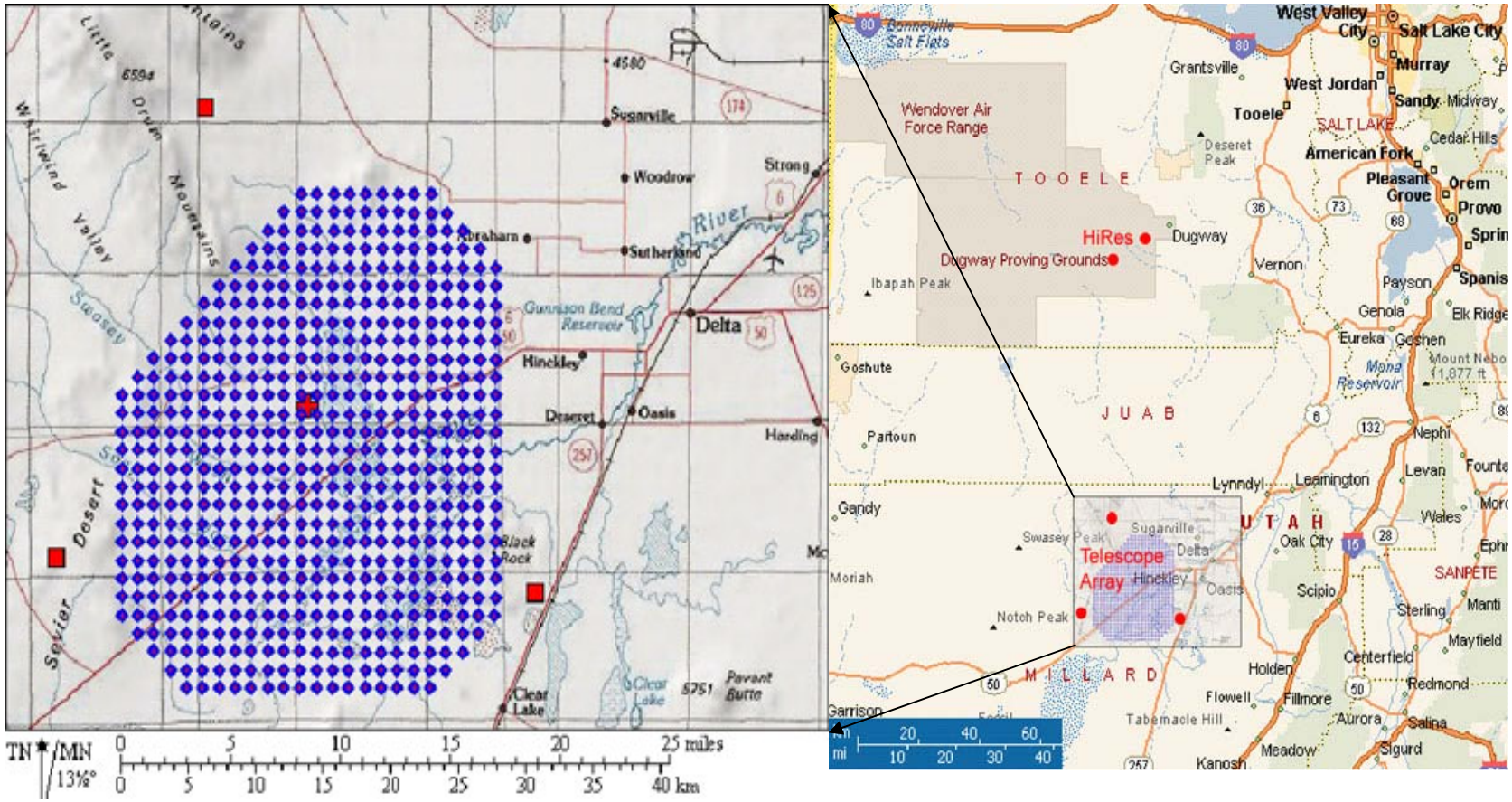
T Abu-Zayyad[1], R Aida[2], M Allen[1], R Azuma[3], E Barcikowski[1], JW Belz[1], T Benno[4], DR Bergman[1], SA Blake[1], O Brusova[1], R Cady[1], BG Cheon[6], J Chiba[7], M Chikawa[4], EJ Cho[6], LS Cho[8], WR Cho[8], F Cohen[9], K Doura[4], C Ebeling[1], H Fujii[10], T Fujii[11], T Fukuda[3], M Fukushima[9,22], D Gorbunov[12], W Hanlon[1], K Hayashi[3], Y Hayashi[11], N Hayashida[9], K Hibino[13], K Hiyama[9], K Honda[2], G Hughes[5], T Iguchi[3], D Ikeda[9], K Ikuta[2], SJJ Innemee[5], N Inoue[14], T Ishii[2], R Ishimori[3], D Ivanov[5], S Iwamoto[2], CCH Jui[1], K Kadota[15], F Kakimoto[3], O Kalashev[12], T Kanbe[2], H Kang[16], K Kasahara[17], H Kawai[18], S Kawakami[11], S Kawana[14], E Kido[9], BG Kim[19], HB Kim[6], JH Kim[6], JH Kim[20], A Kitsugi[9], K Kobayashi[7], H Koers[21], Y Kondo[9], V Kuzmin[12], YJ Kwon[8], JH Lim[16], SI Lim[19], S Machida[3], K Martens[22], J Martineau[1], T Matsuda[10], T Matsuyama[11], JN Matthews[1], M Minamino[11], K Miyata[7], H Miyauchi[11], Y Murano[3], T Nakamura[23], SW Nam[19], T Nonaka[9], S Ogio[11], M Ohnishi[9], H Ohoka[9], T Okuda[11], A Oshima[11], S Ozawa[17], IH Park[19], D Rodriguez[1], SY Roh[20], G Rubtsov[12], D Ryu[20], H Sagawa[9], N Sakurai[9], LM Scott[5], PD Shah[1], T Shibata[9], H Shimodaira[9], BK Shin[6], JD Smith[1], P Sokolsky[1], TJ Sonley[1], RW Springer[1], BT Stokes[5], SR Stratton[5], S Suzuki[10], Y Takahashi[9], M Takeda[9], A Taketa[9], M Takita[9], Y Tameda[3], H Tanaka[11], K Tanaka[24], M Tanaka[10], JR Thomas[1], SB Thomas[1], GB Thomson[1], P Tinyakov[12,21], I Tkachev[12], H Tokuno[9], T Tomida[2], R Torii[9], S Troitsky[12], Y Tsunesada[3], Y Tsuyuguchi[2], Y Uchihori[25], S Udo[13], H Ukai[2], B Van Klaveren[1], Y Wada[14], M Wood[1], T Yamakawa[9], Y Yamakawa[9], H Yamaoka[10], J Yang[19], S Yoshida[18], H Yoshii[26], Z Zundel[1]

[1]University of Utah, [2]University of Yamanashi, [3]Tokyo Institute of Technology, [4]Kinki University, [5]Rutgers University, [6]Hanyang University, [7]Tokyo University of Science, [8]Yonsei University, [9]Institute for Cosmic Ray Research, University of Tokyo, [10]Institute of Particle and Nuclear Studies, KEK, [11]Osaka City University, [12]Institute for Nuclear Research of the Russian Academy of Sciences, [13]Kanagawa University, [14]Saitama University, [15]Tokyo City University, [16]Pusan National University, [17]Waseda University, [18]Chiba University [19]Ewha Womans University, [20]Chungnam National University, [21]University Libre de Bruxelles, [22]University of Tokyo, [23]Kochi University, [24]Hiroshima City University, [25]National Institute of Radiological Science, Japan, [26]Ehime University

Outline

- Introduction
- FD Middle Drum Spectral Analysis
- SD Spectral Analysis
- Hybrid Spectral Analysis
- FD Stereo Composition Analysis
- *(See talk by G. Rubtsov for a search for photon events)*
- Plans
- Conclusions

Telescope Array - HE



The High Energy component of Telescope Array – 38 fluorescence telescopes (9728 PMTs) at 3 FD stations overlooking an array of 507 scintillator surface detectors (SD) - complete and operational as of ~1/2008.

TA Fluorescence Detectors

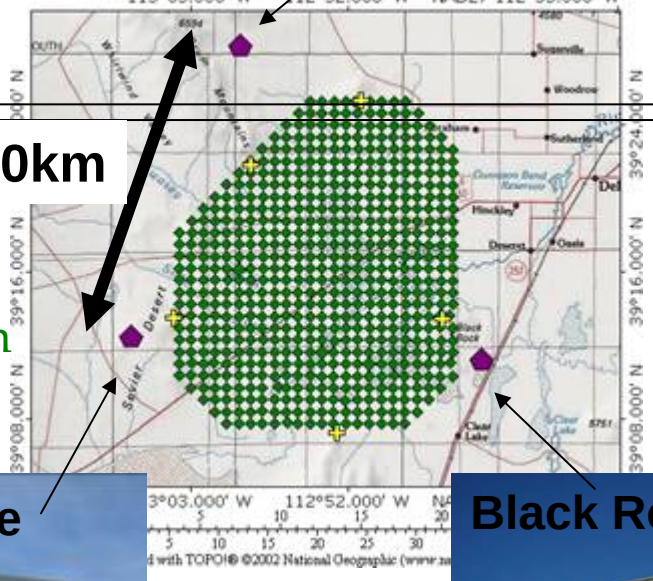
Refurbished from HiRes-I

Observations since ~10/2007

Middle Drum

14 telescopes@station
256 PMTs/camera

5.2 m²



~30km

Observation since ~11/2007

New FDs

12 telescopes/station
256 PMTs/camera
Hamamatsu R9508
FOV~15x18deg

Long Ridge

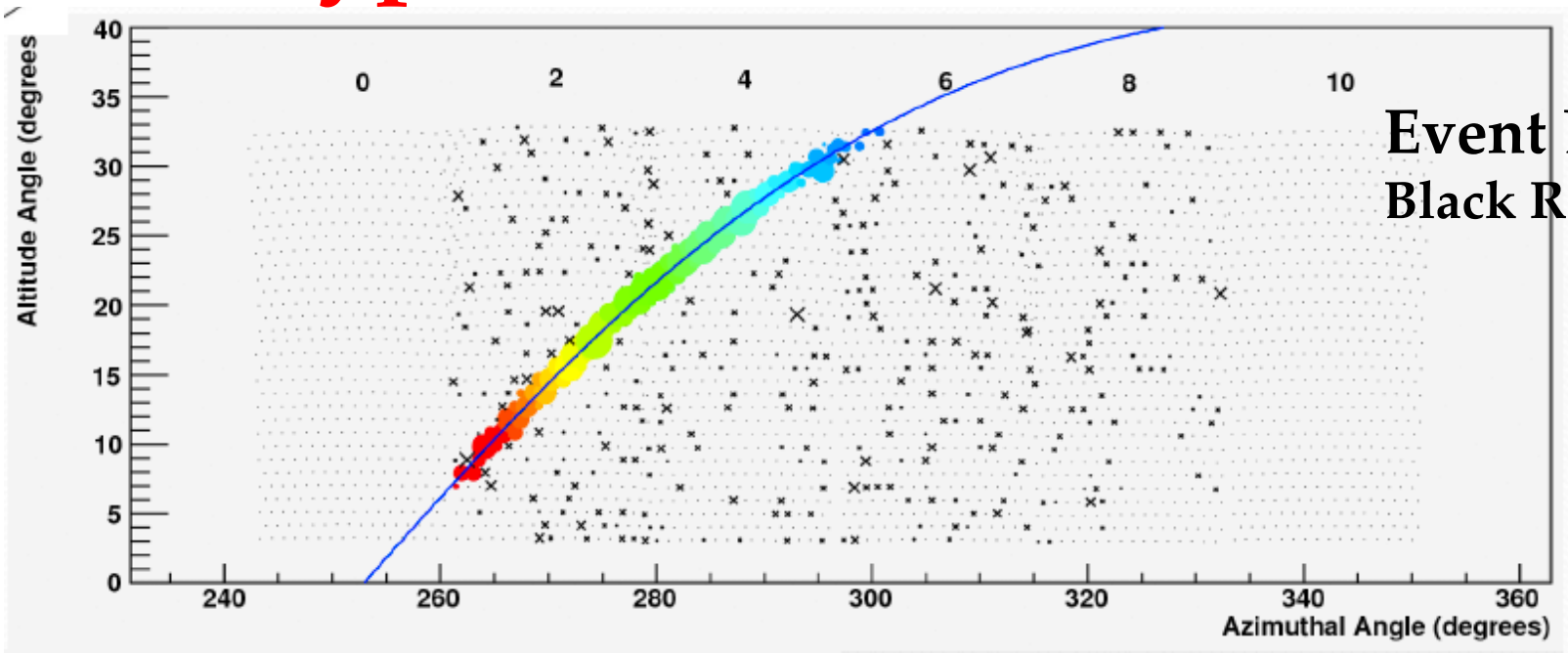
Observation since ~6/2007

Black Rock Mesa

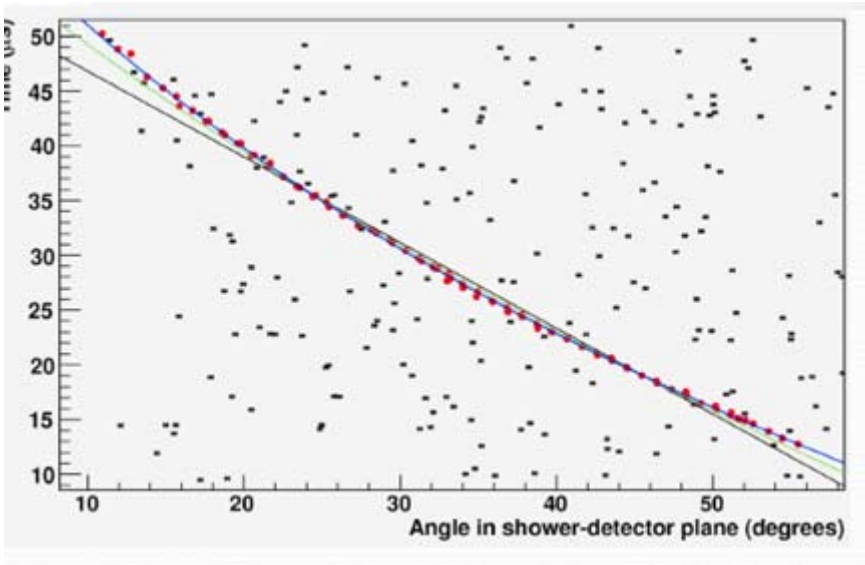
~1 m²

6.8 m²

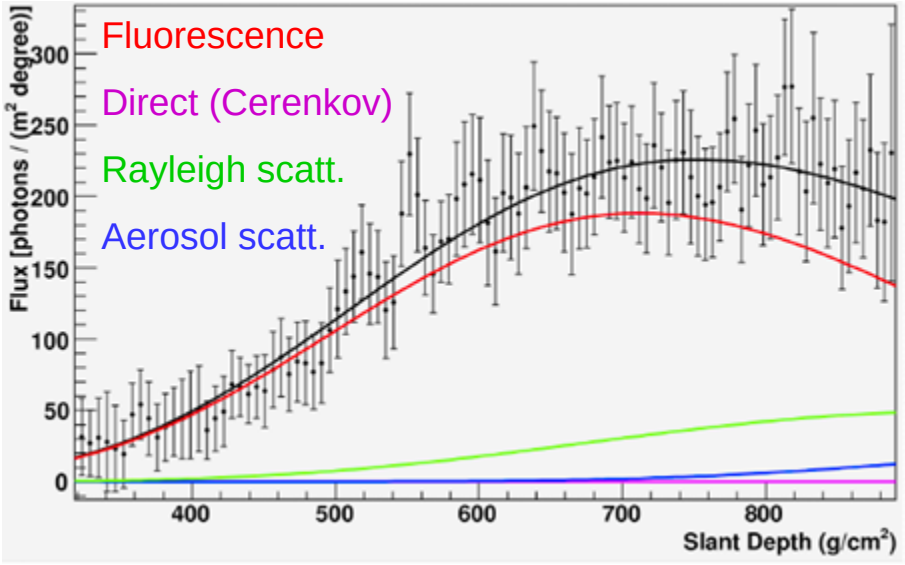
Typical Fluorescence Event



Event Display
Black Rock Mesa

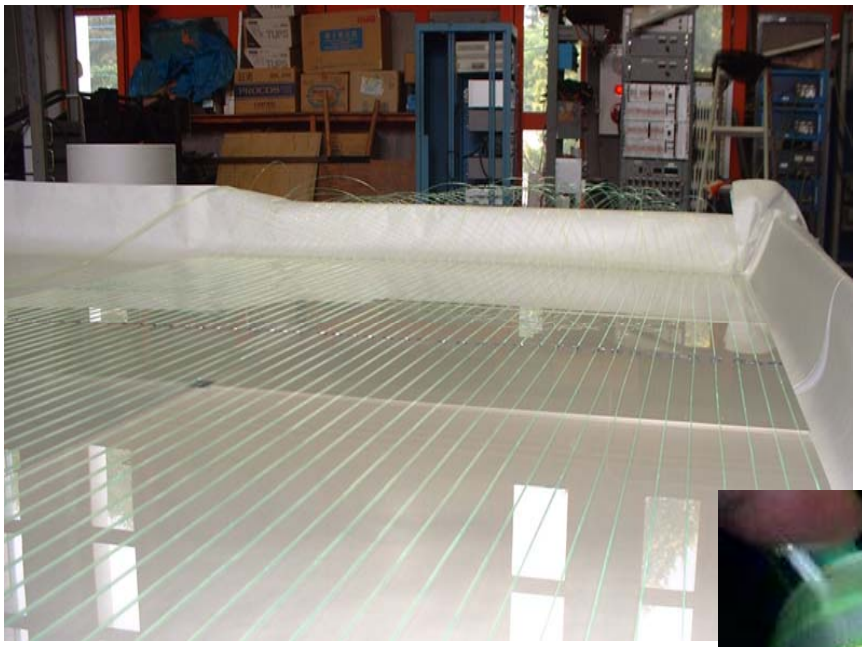


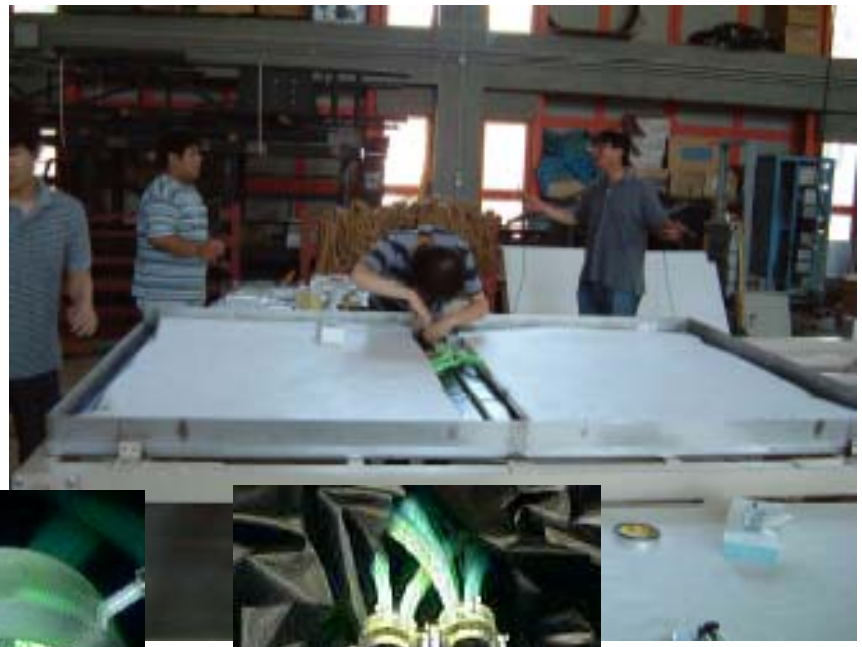
Monocular timing fit



Reconstructed Shower Profile

Surface Detectors





Pre-assembled in Japan, Final Assby/testing in Delta: 2 layers, 1.25 cm scintillator, 3m^2 area

Deployment (up to 50/day)
485 SDs: 10/2006 - 3/2007

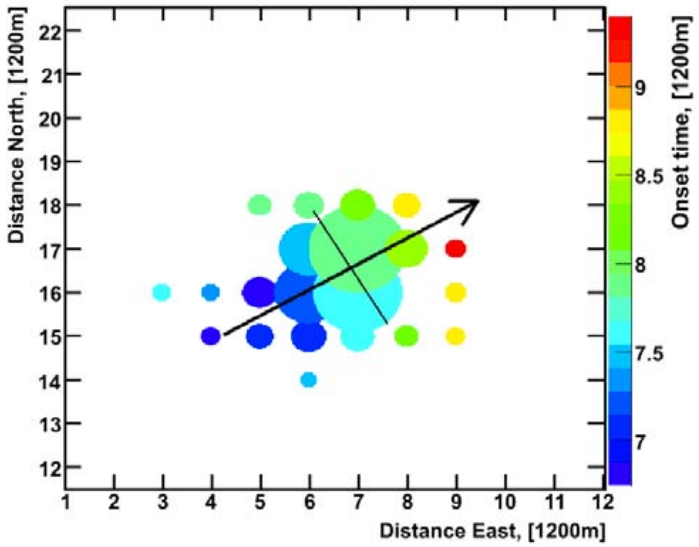

Scintillator Detectors on
a 1.2 km square grid

TA Scintillator Detectors

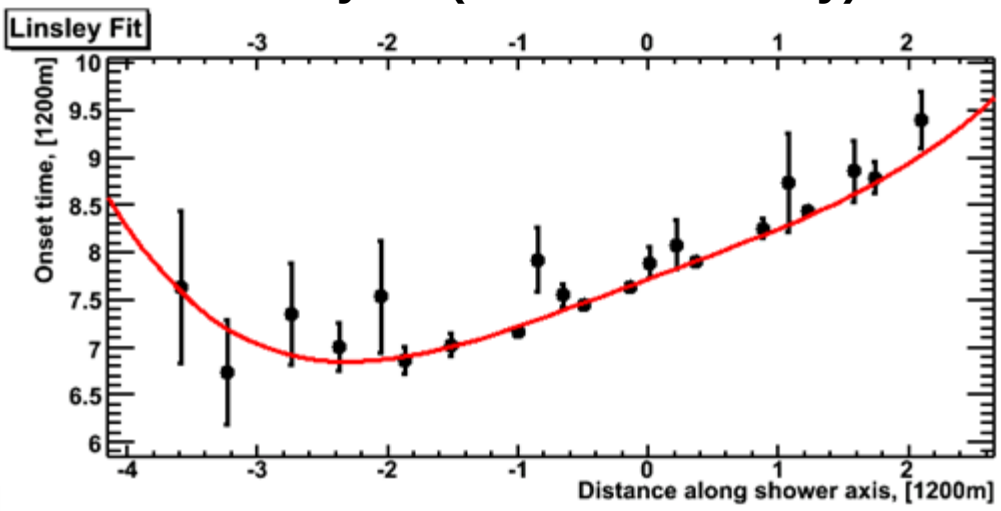
- **Power:**
  Solar/battery
- **Readout:**
  Radio
- **Self-calibrated:**
  μ background
- **Operational:**
  3/2008

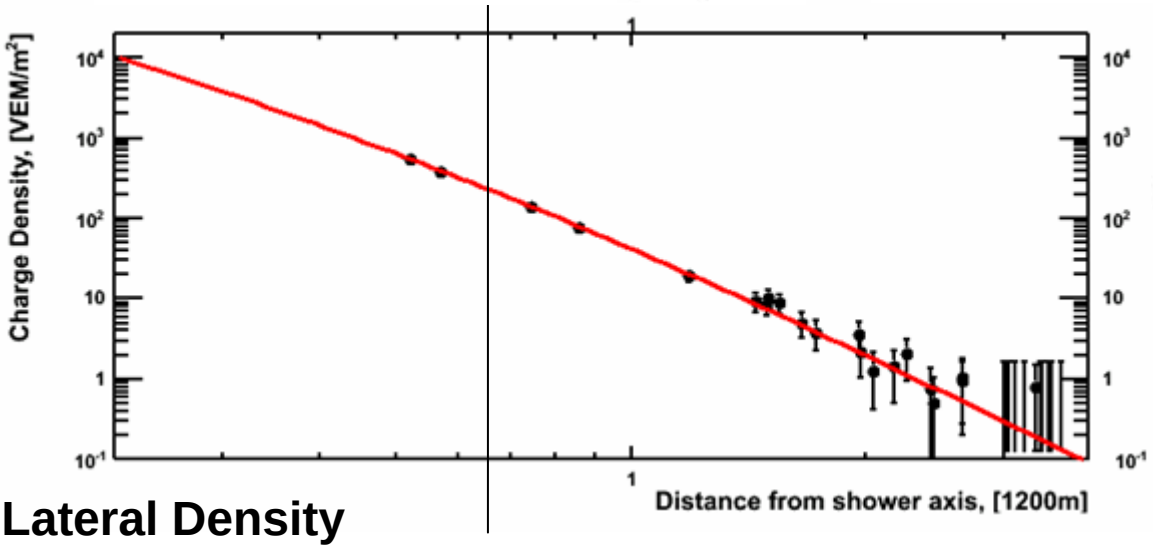
Typical Scintillator Detector Event

2008/Jun/25 - 19:45:52.588670 UTC



Geometry Fit (modified Linsley)





Lateral Density Distribution Fit *r = 800m*

Fit with AGASA LDF

$$\rho(r) \propto \left(\frac{r}{R_M}\right)^{-1.2} \left(1+\frac{r}{R_M}\right)^{-(\eta-1.2)} \left\{1+\left(\frac{r}{1000}\right)^2\right\}^{-0.6}$$

$$\eta = (3.97 \pm 0.13) - (1.79 \pm 0.62)\,(\sec\theta - 1)$$

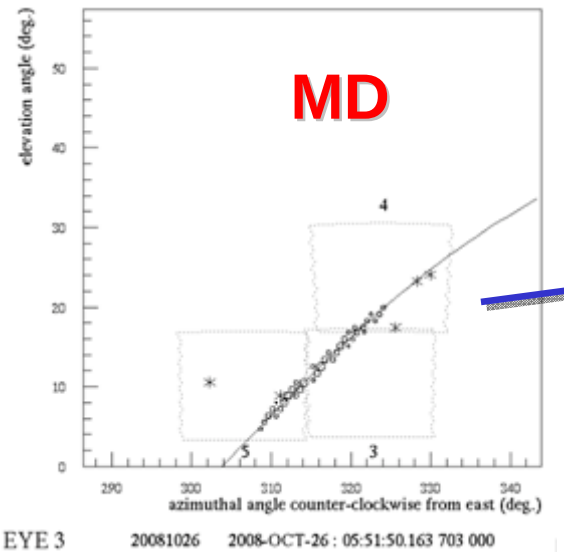
- **S(800): Primary Energy**
- **Zenith attenuation by MC (not by CIC).**

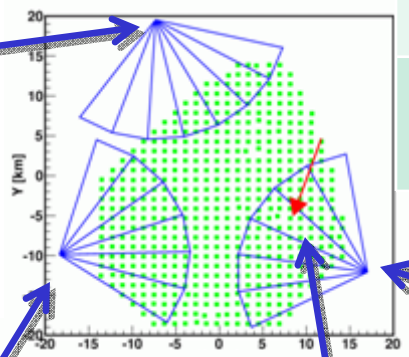
CR Observation:

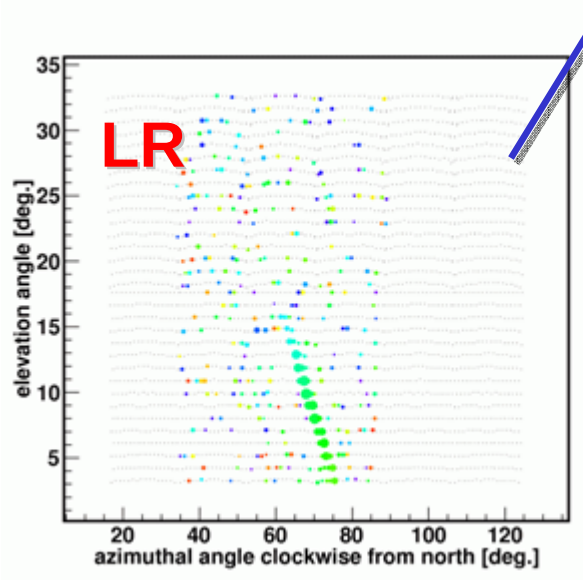
- Detector systems are independently operated thus far, however
- Many events are observed by multiple detector systems
  - FD mono has ~5° resolution in ψ (angle within shower detector plane).
  - Adding SD information (hybrid reconstruction) ➔ ~0.5° resolution.
  - Stereo FD resolution ~0.5°
- Need stereo or hybrid for composition
- Hybrid trigger (FD to SD) currently being installed

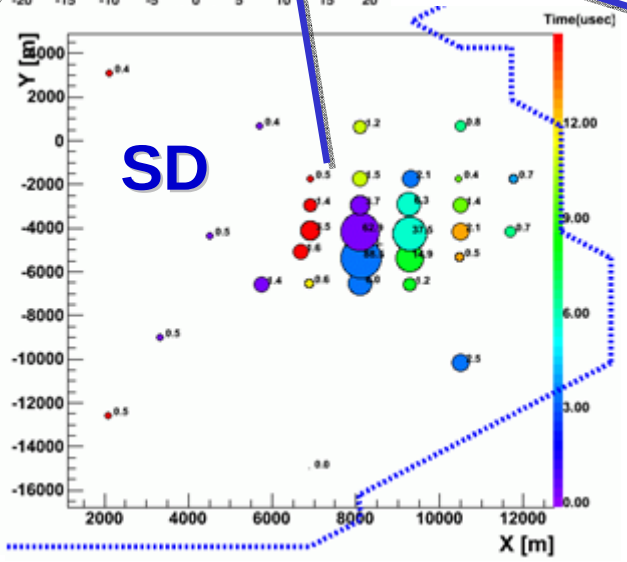
Example Event from 2008-10-26

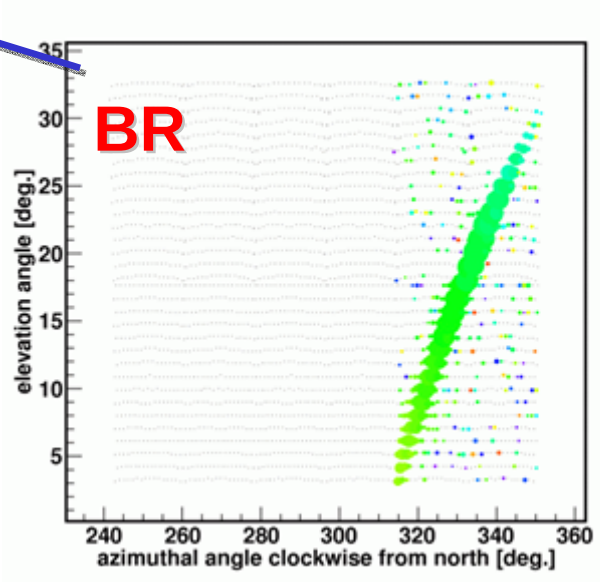
	θ [°]	ϕ [°]	x[km]	y[km]
MD mono	51.43	73.76	7.83	-3.10
BR mono	51.50	77.09	7.67	-4.14
Stereo BR&LR	50.21	71.30	8.55	-4.88











A Careful Analysis Method

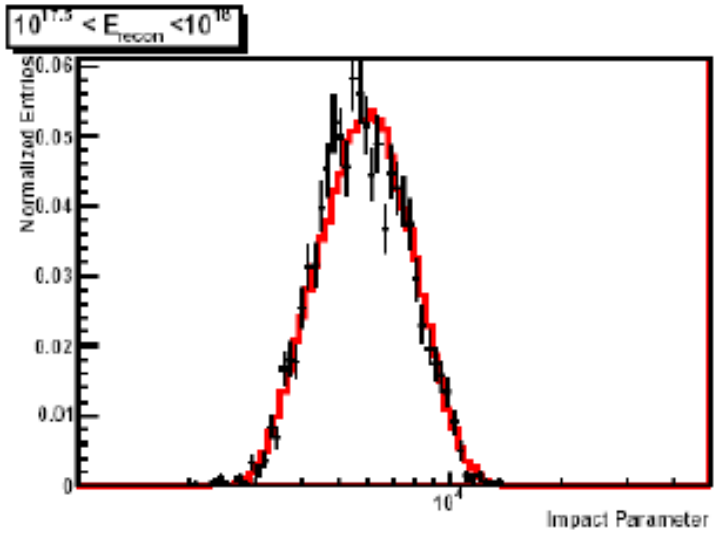
- **Simulate the data the same way it is observed.**
  - **Start with previously measured spectrum and composition**
  - **Select an air shower simulation program (CORSIKA/QGSJET-II/FLUKA)**
  - **Throw an isotropic distribution**
  - **Include atmospheric scattering**
  - **Simulate detector, front-end electronics, trigger, and DAQ**
  - **Write out the MC events in same format as data**
  - **Analyze the MC with the same programs used for data**
- ***Test with data/MC comparison plots***
- **If they agree: "I understand my detector"**
  Otherwise: work harder

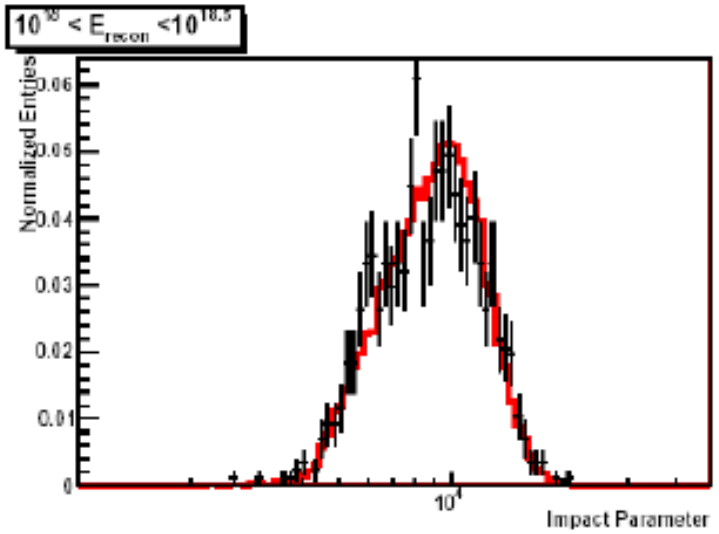
Middle Drum FD Analysis

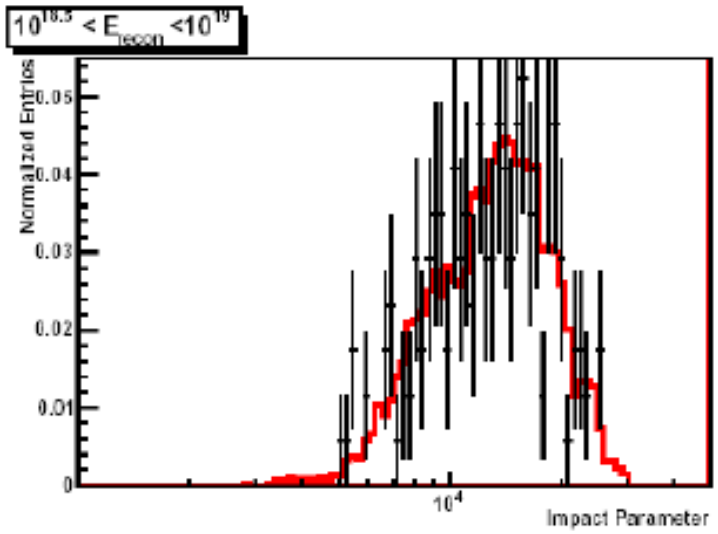
- **Initially use HiRes-I methods:**
  - **Is HiRes spectrum reproduced? (Same telescopes, just moved and reconfigured)**
  - **Test effect of two rings: HiRes-I had one ring of mirrors (3^o-17^o) and short tracks**
  - **Middle Drum like HiRes-II, Black Rock, Long Ridge, & PAO observes 3^o-31^o in elevation**

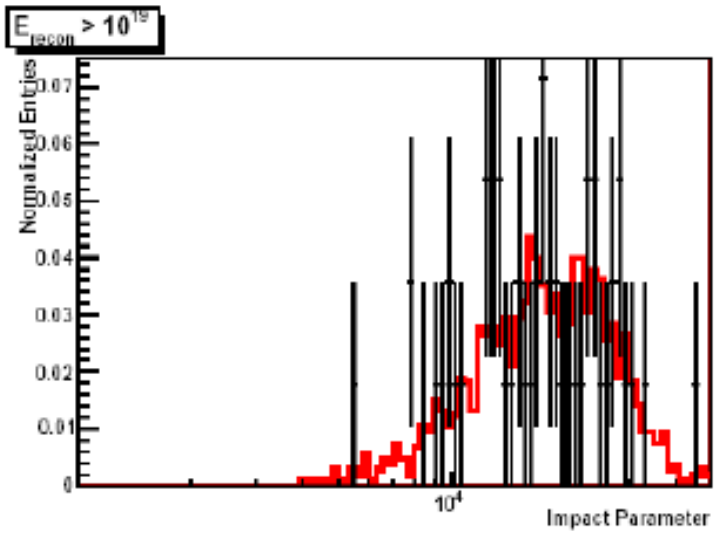
Data – Monte Carlo Comparison

Rp (km)



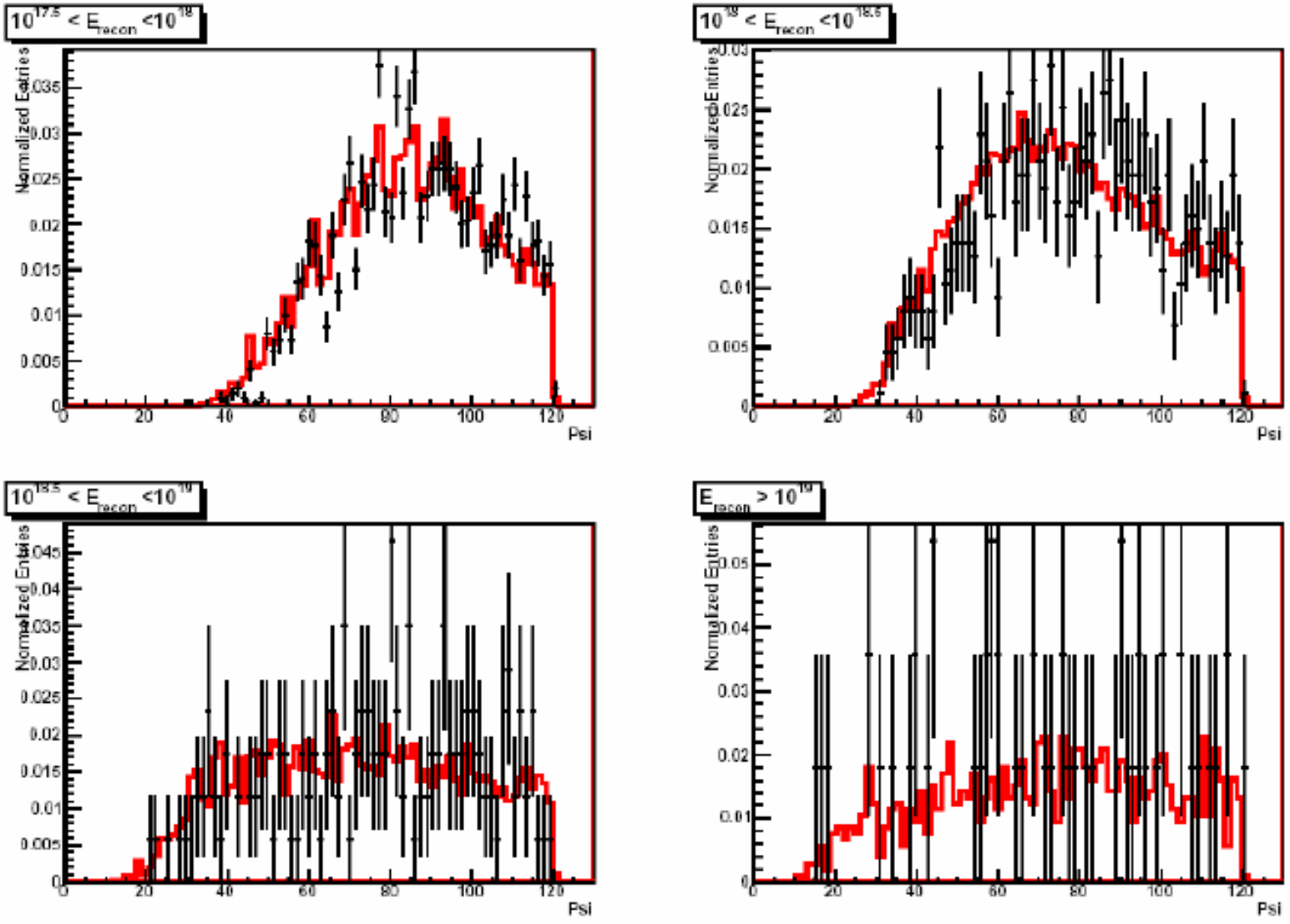






Data – Monte Carlo Comparison

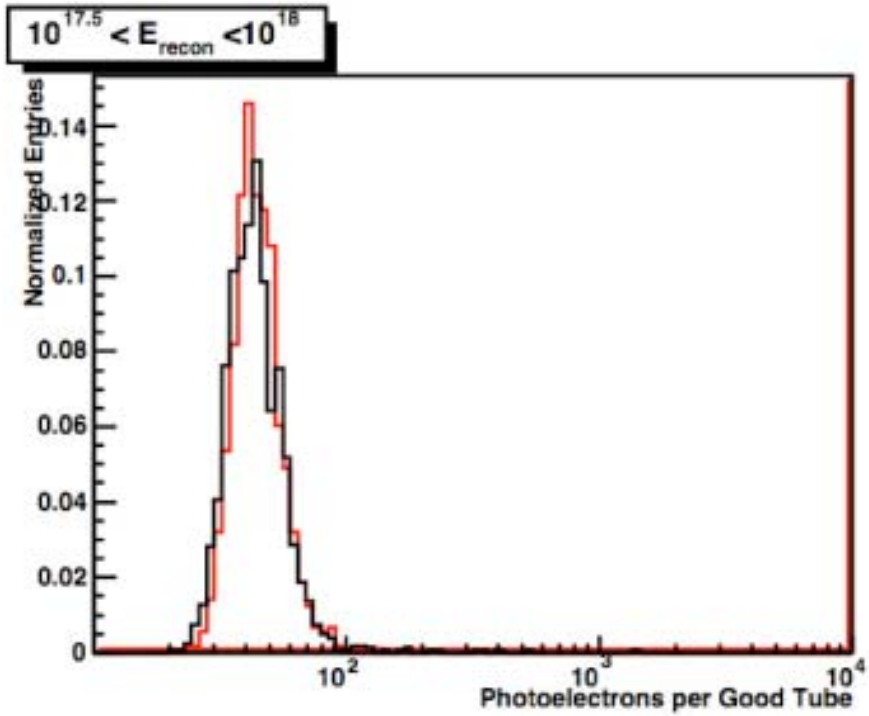
Psi angle (deg)



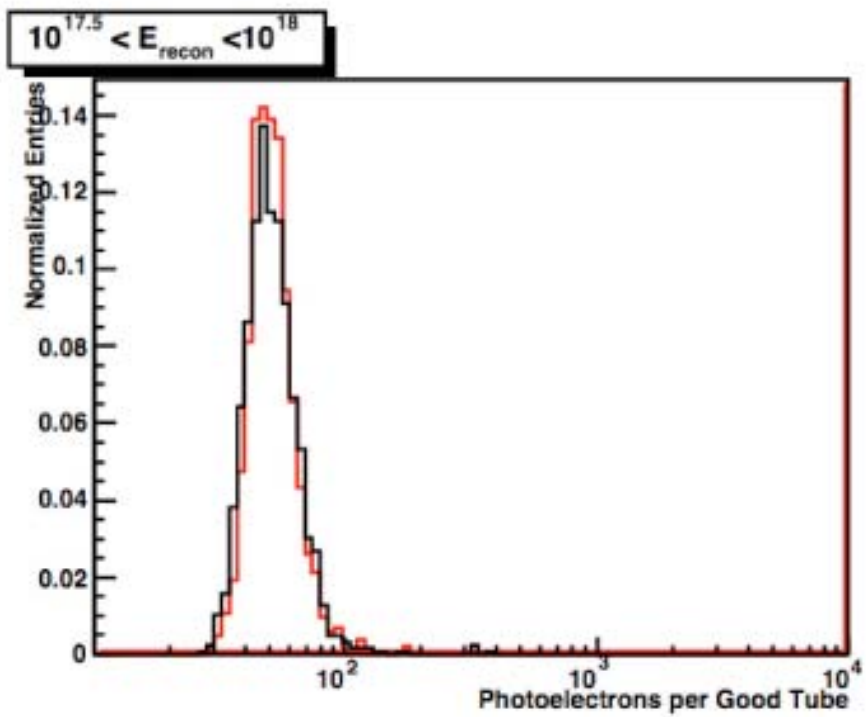
Data – Monte Carlo Comparison

- Photo-electrons per good tube (pepgt)

Group A: Data-black, MC-red

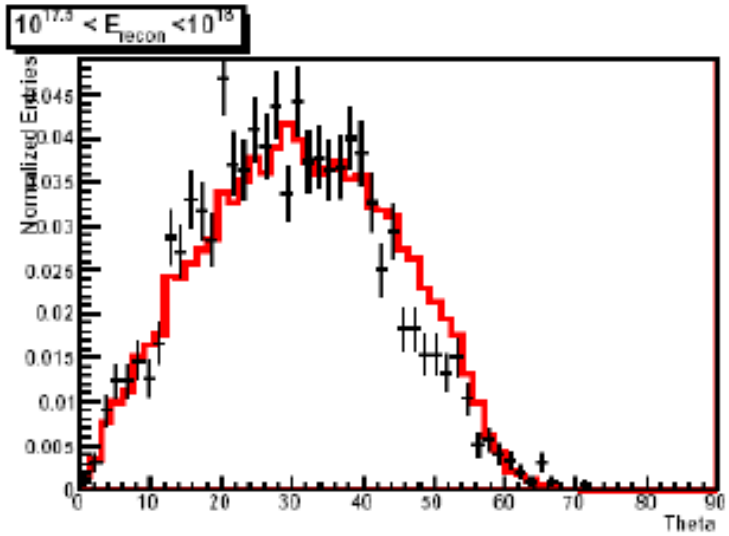


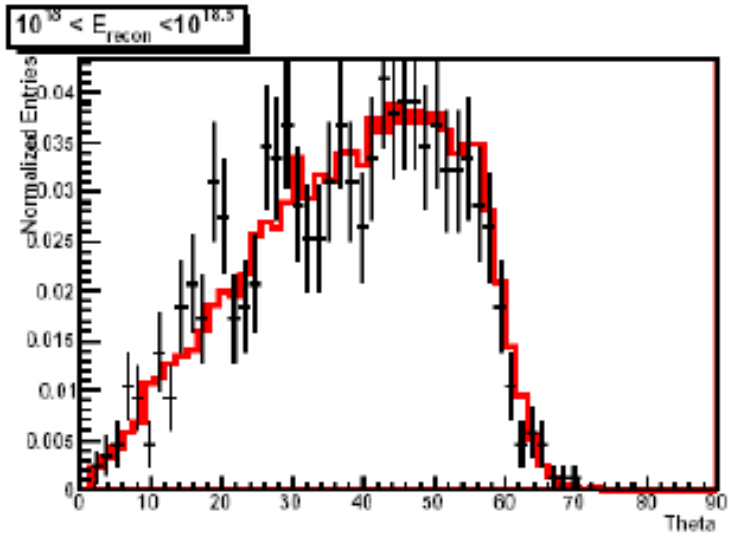
Group B: Data-black, MC-red

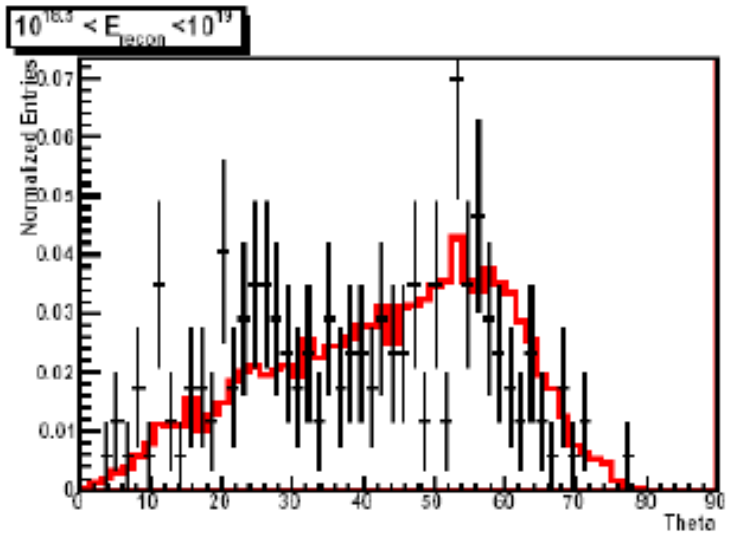


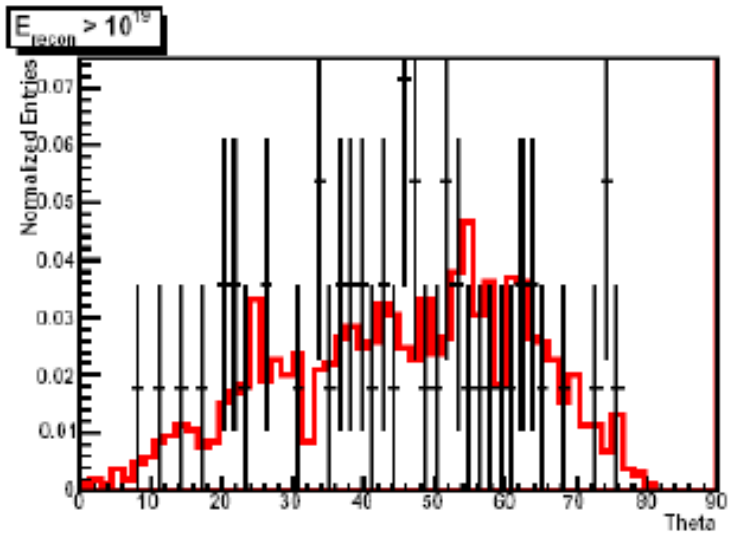
Data – Monte Carlo Comparison

Zenith angle (deg)





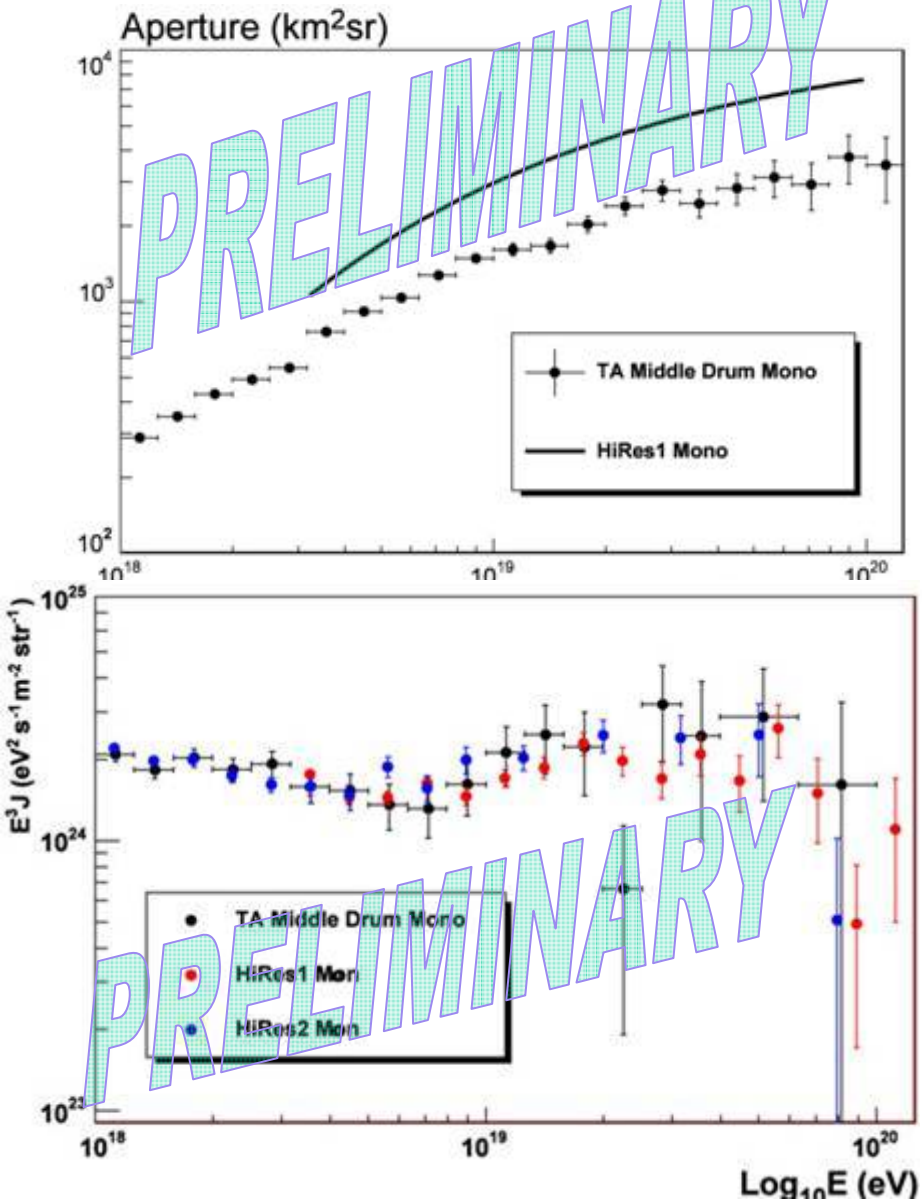




Energy Spectra

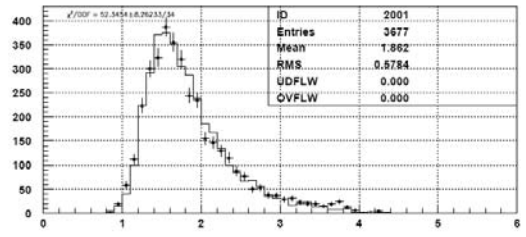
Monocular Energy Spectrum from Middle Drum (MD) Detector

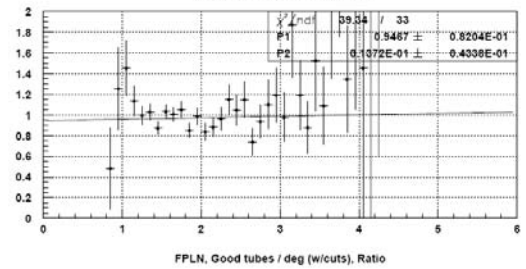
- 14 refurbished HiRes-I telescopes
- TAMD mono processing is identical to HiRes-I monocular data analysis
  - Same program set, event selection, cuts
  - Using the same "average" atmospheric model (aerosol VAOD=0.04)
- Differences
  - telescope location and pointing directions
  - Thresholds (~20% lower than HiRes-I – Delta is darker!)
- Preliminary MD spectrum in good agreement with HiRes

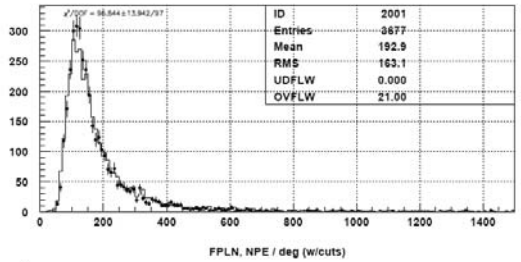


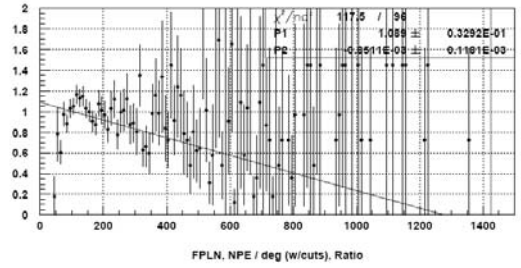
Black Rock, Long Ridge FD Analysis

- Carrying out the same type of analysis for the Black Rock and Long Ridge FD's.
- Analysis ongoing (no spectrum yet).









FD Conclusions

- **Middle Drum spectrum:**
  - **Used identical analysis programs to HiRes-I**
  - **The spectrum is identical to HiRes mono**
- **Black Rock and Long Ridge FD analysis is proceeding well.**

SD Analysis

- **Rigid quality cut strategy**
  - **Must calculate aperture by Monte Carlo technique**
- **Consistency**
  - **Use the same techniques for the SD as we've used for FD analysis (HiRes & TA)**

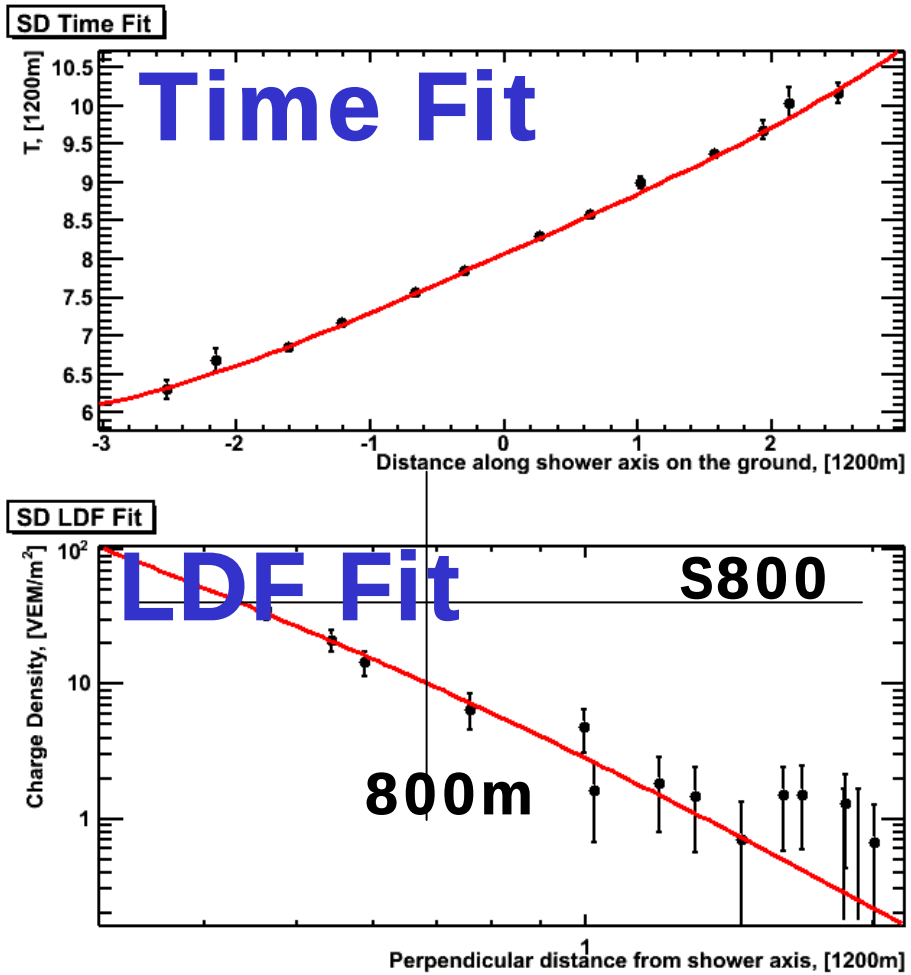
SD Monte Carlo

- **Simulate the data in detail – just like for the FDs**
  - **Start with previously measured spectrum and composition**
  - **Use CORSIKA/QGSJET-II/FLUKA events**
  - **Throw an isotropic distribution**
  - **Simulate front-end electronics, trigger, DAQ**
  - **Write out the MC events in same format as data**
  - **Analyze the MC with the same routines used for data**
- ***Test with data/MC comparison plots***

SD Analysis

- Basic TA SD event reconstruction is done in a model independent way:
  - Fitting functions of previous ground array experiments are used as a starting point
  - Reconstruction procedures and formulas are adjusted to fit TA SD data by applying self-consistency tests to the results of fitting
  - This is then used to reconstruct event geometry, as well as lateral distribution profile
- A carefully tested MC set, which shares all the characteristics of the real data, is then introduced to estimate the event energy and calculate the aperture

SD Event Reconstruction

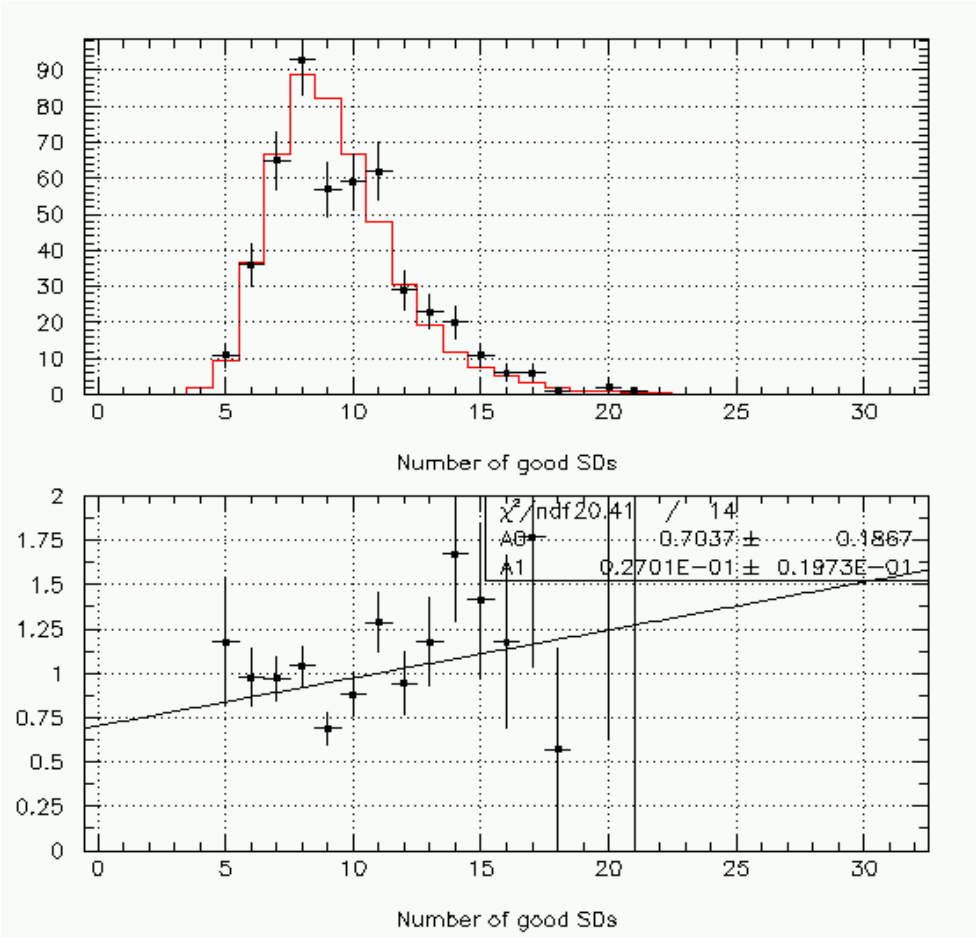


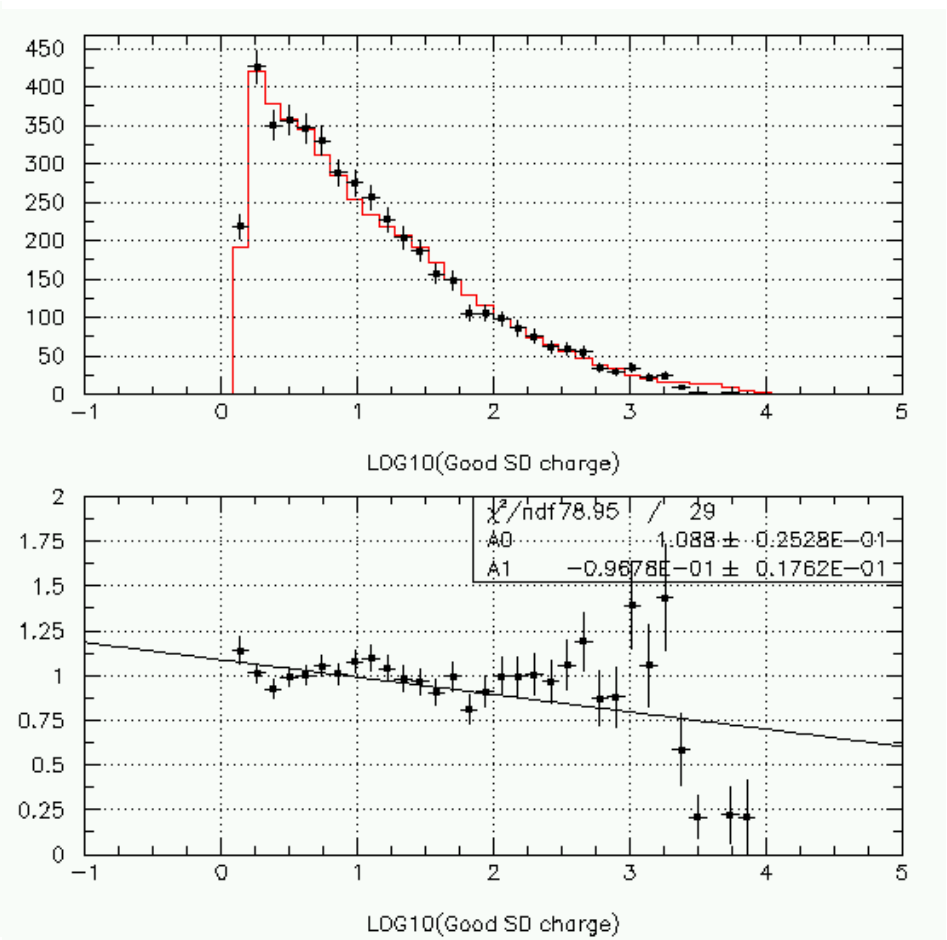
- **Two fits:**
  - **Time fit to determine event geometry (modified Linsley function)**
  - **Lateral Distribution Fit (LDF) to determine signal size 800m from the shower axis, S800 (AGASA fitting function)**
- ***Fitting procedure and formulas are adjusted using only the data***

SD Monte-Carlo: Methodology

- **Simulate an event set which has as many of the characteristics of the real data as possible:**
  - **Energy distribution is continuous and follows previously measured power laws:**
    - $E^{-3.25}$, $E < 10^{18.65}$ eV
    - $E^{-2.81}$, $E > 10^{18.65}$ eV
  - **Angular distribution is continuous and isotropic in the local sky.**
  - **Use previously measured composition**
  - ***Use actual CORSIKA events***
- **Record the MC in the same format as the data**
- **Analyze the MC with the same routines as the data**
- **Validate the SD MC by comparing the distributions of its reconstructed variables with the real data.**

Data/MC: Event Size

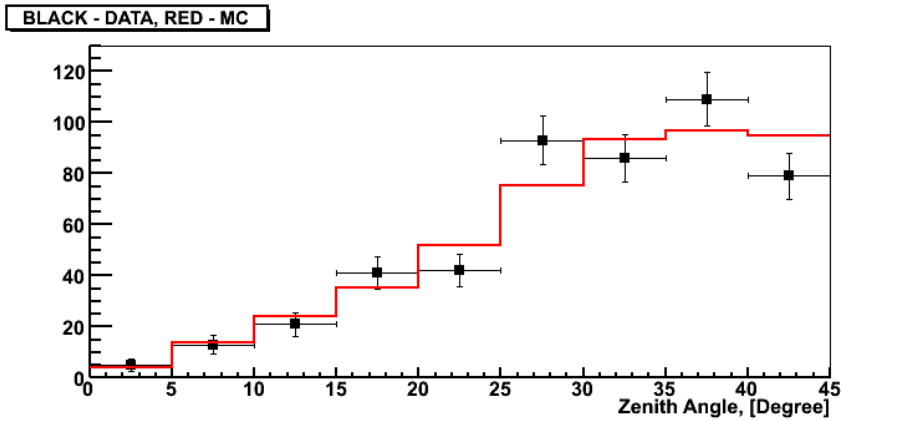


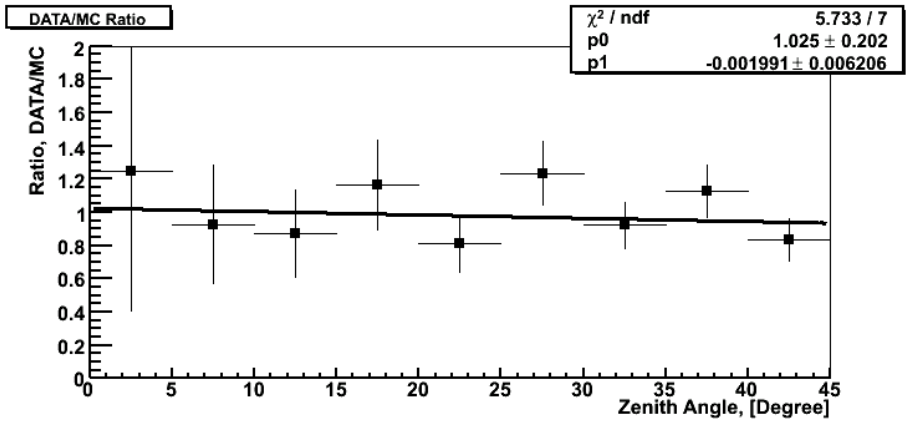


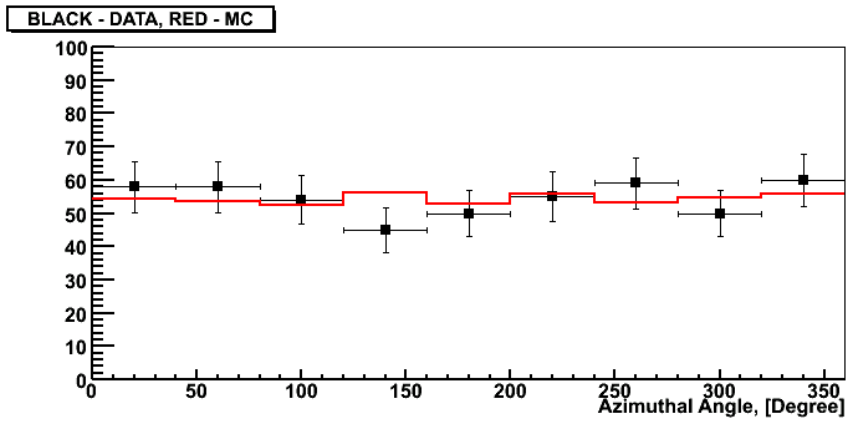
Number of good SDs / event

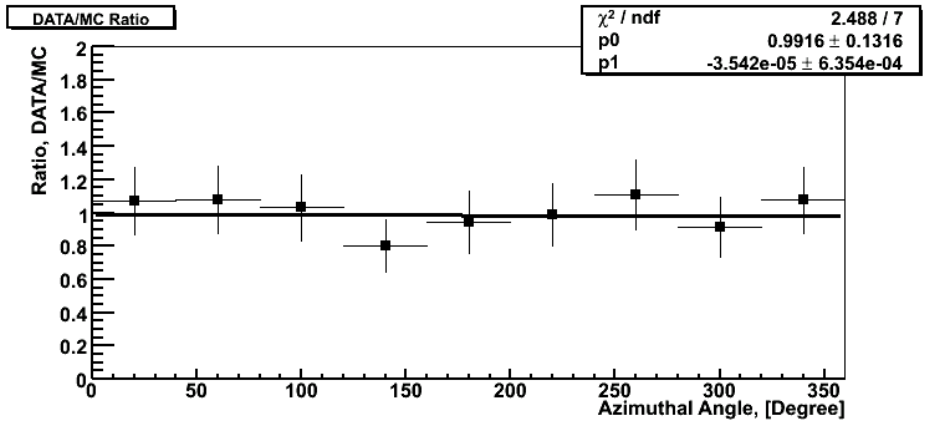
VEM / SD

Data/MC: Geometry





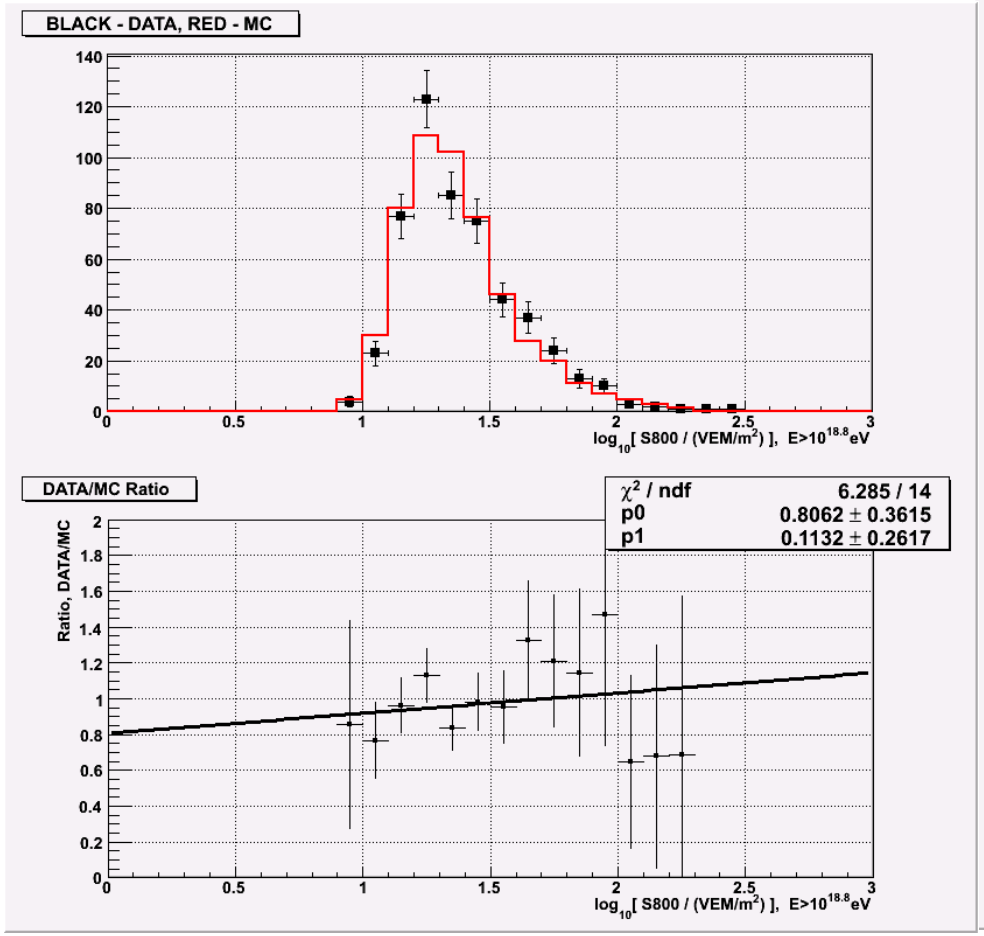


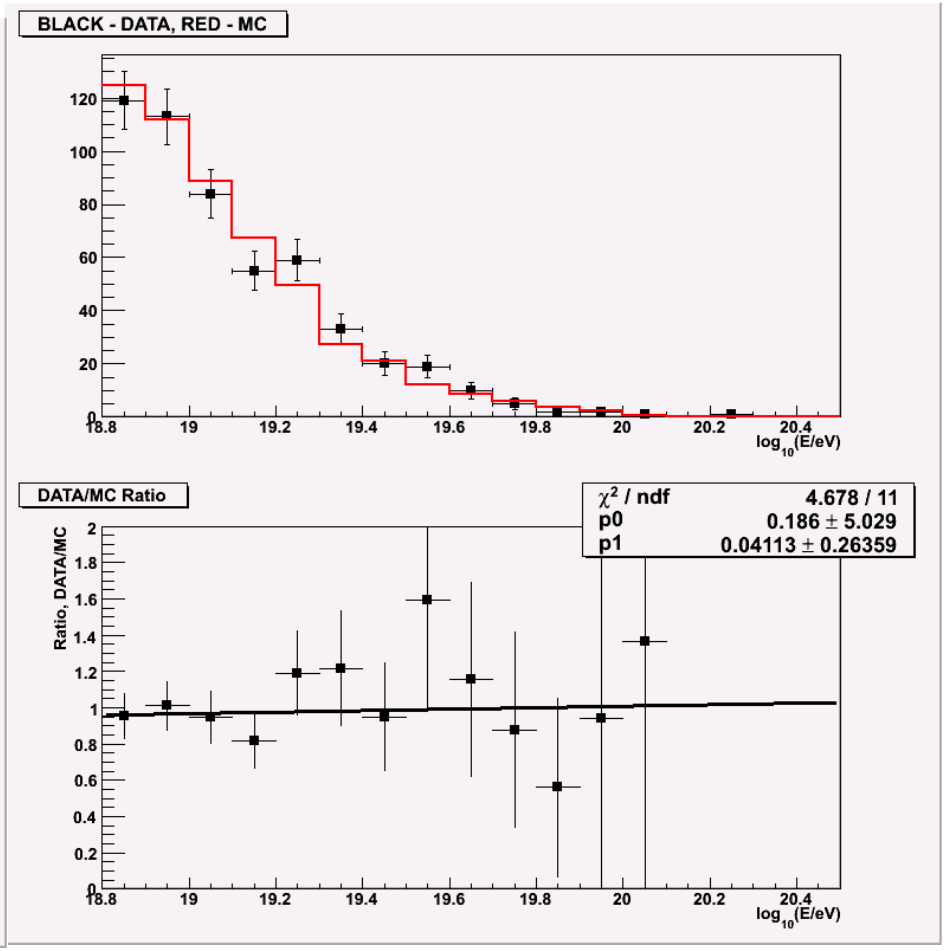


Zenith angle

Azimuthal angle

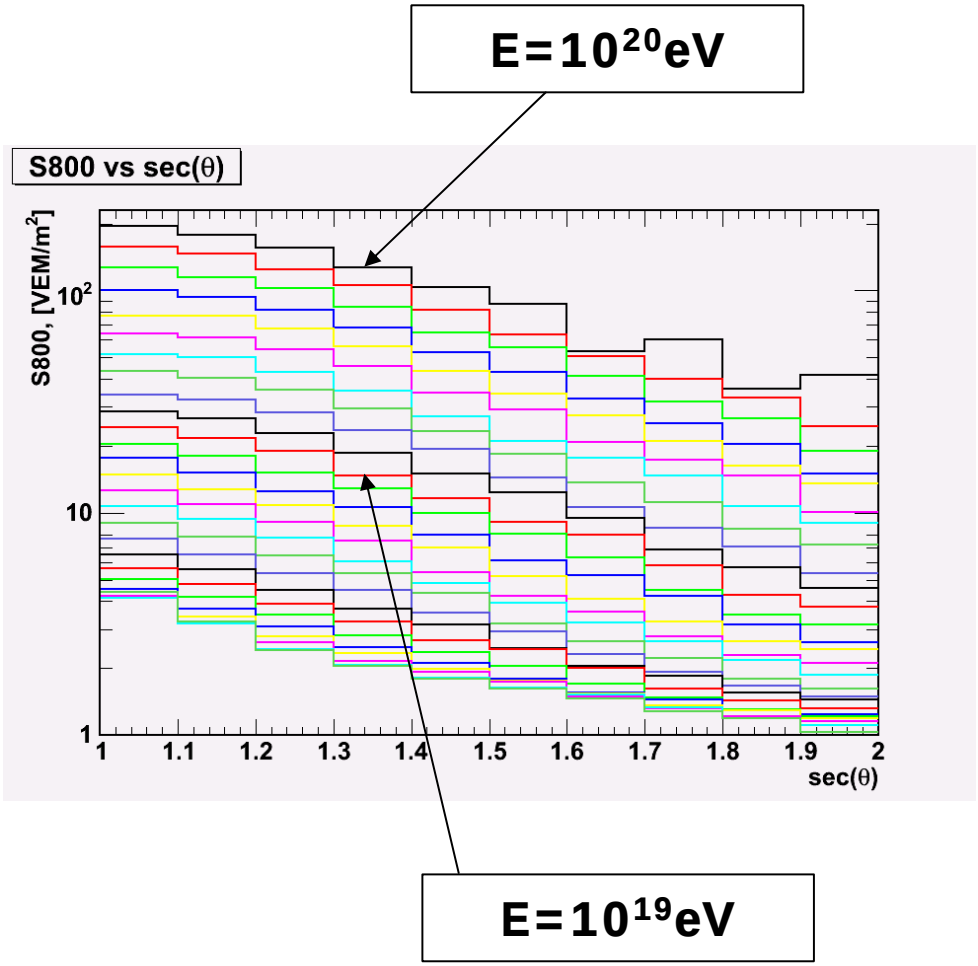
Data/MC: S800, Energy





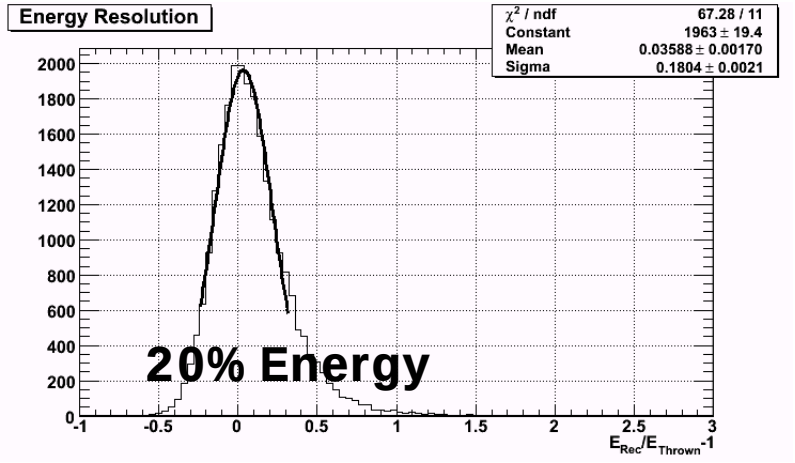
S800 **Energy**

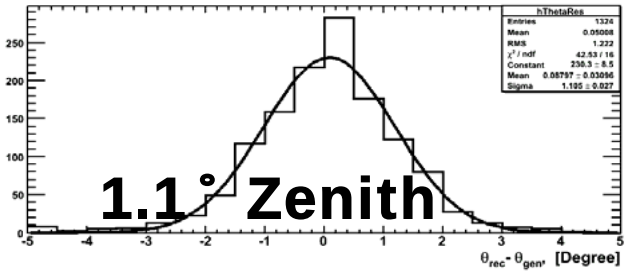
First Energy Estimation

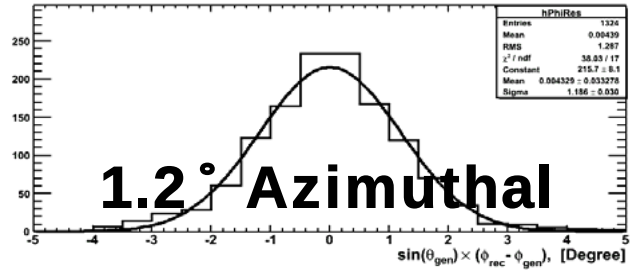


- Energy table is constructed from the MC
- First estimation of the event energy is done by interpolating between S800 vs secθ lines

TA SD Resolution

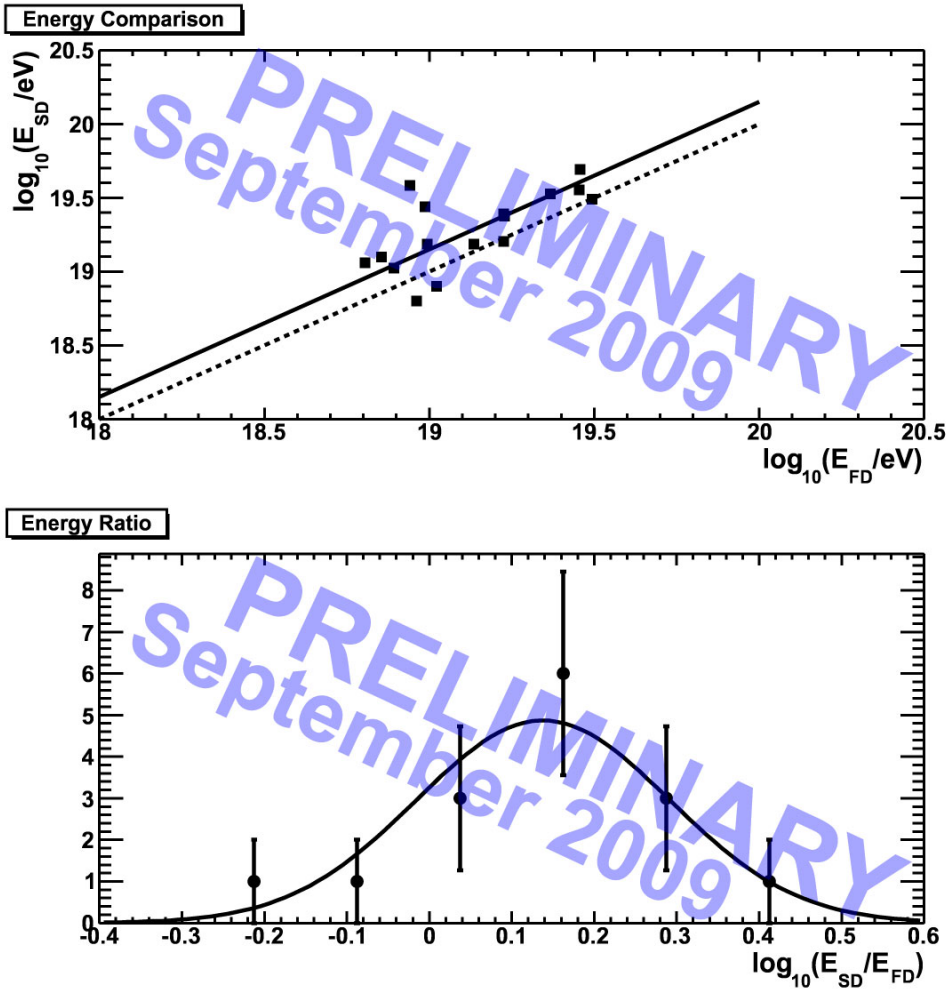






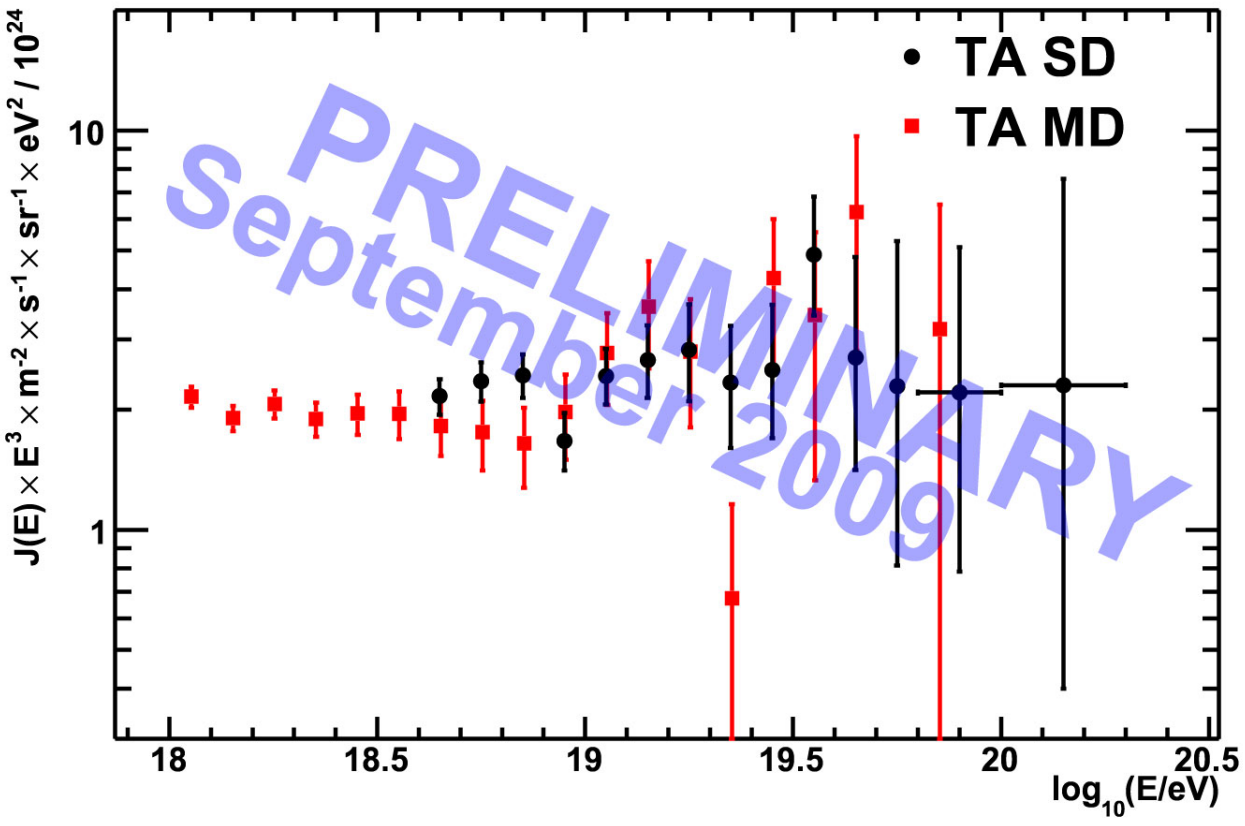
- To achieve good resolution one applies quality cuts
- Correct aperture is calculated from MC which:
  - Agrees with the data
  - Analyzed in the same way as the data, *including the quality cuts*

Energy Scale



- Energy scale is determined more accurately by FD than by CORSIKA QGSJET-II
- Set SD energy scale to FD-Mono using well reconstructed events observed by both detectors

Energy Spectrum



TA SD and FD results agree

SD Conclusions

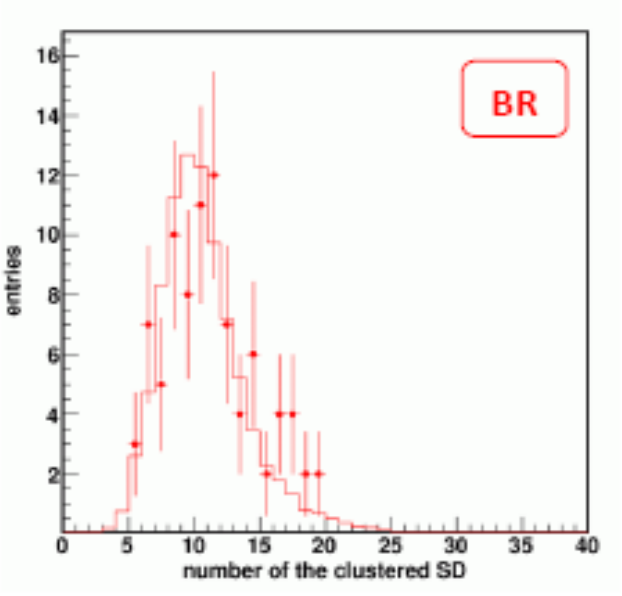
- Calculated SD energy spectrum :
- Geometry and LDF reconstruction are based solely on characteristics of the data
- Generated MC set with all characteristics of the real data
- Tested the accuracy of our MC by comparing with the data
- Tied SD energy scale to FD
- TA SD and FD energy spectra are in agreement

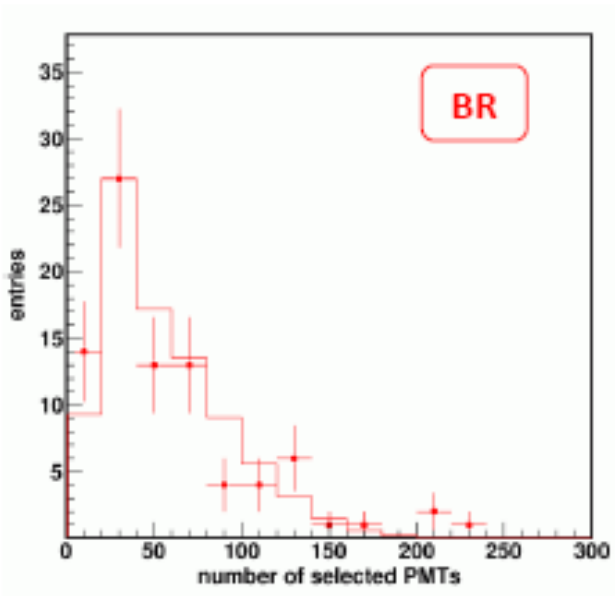
SD/FD Hybrid Results

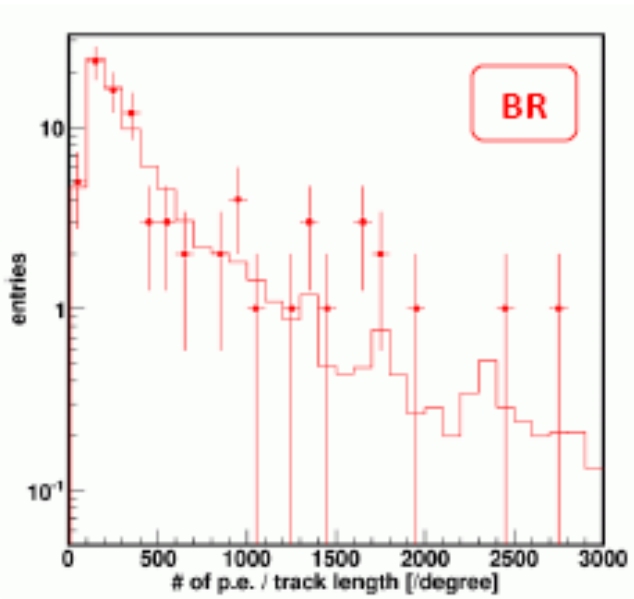
- Combine SD with Black Rock and Long Ridge FD observations
- Improved resolution over FD
- Efficiency at energy threshold can be modeled more reliably than with SD alone
- Analysis done as with SD and MD

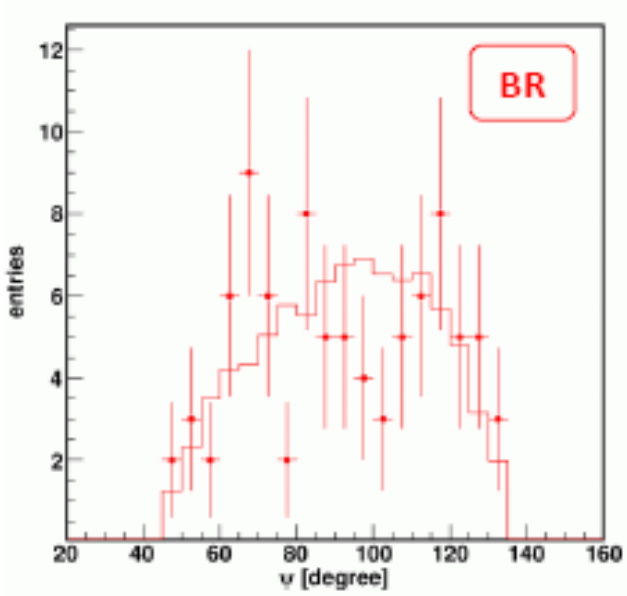
Data/MC comparison1

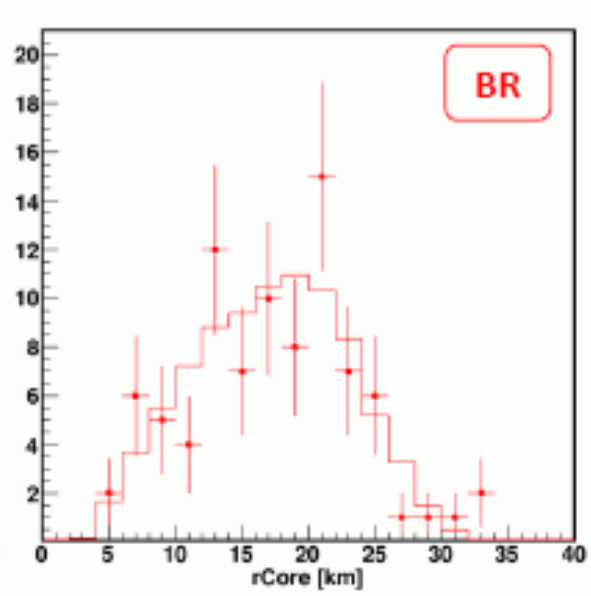
- BR station
- Filled circles : data
- Histograms : MC

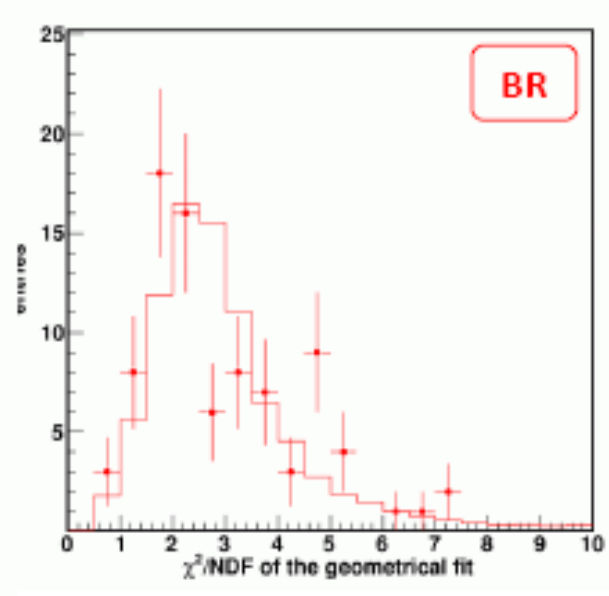




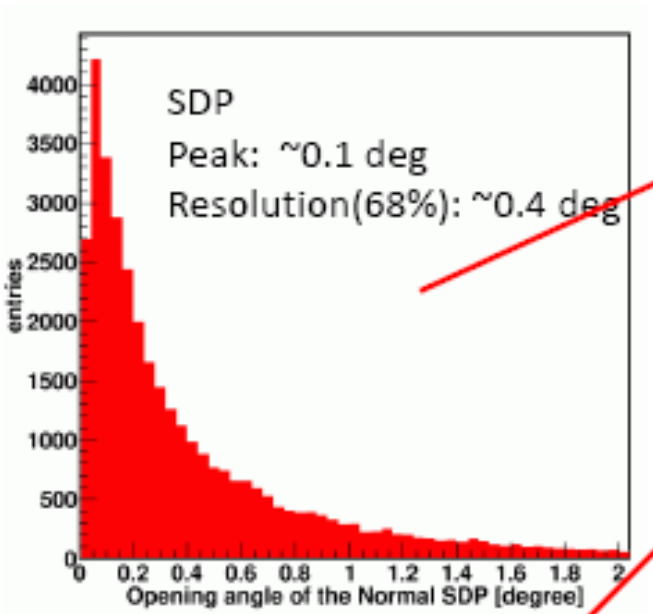


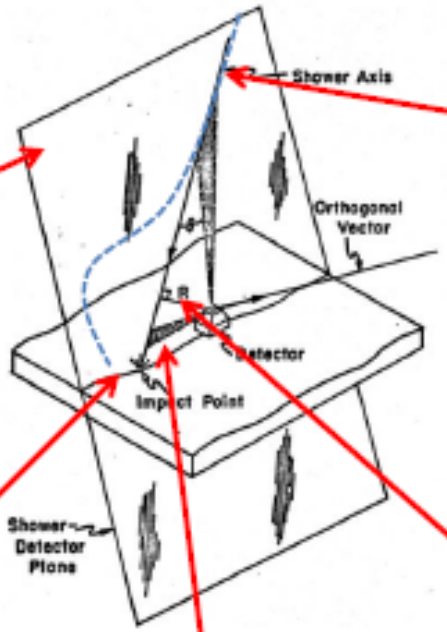


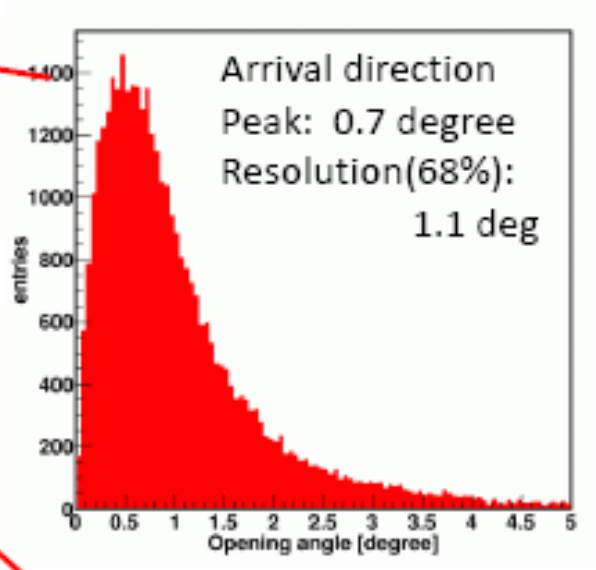


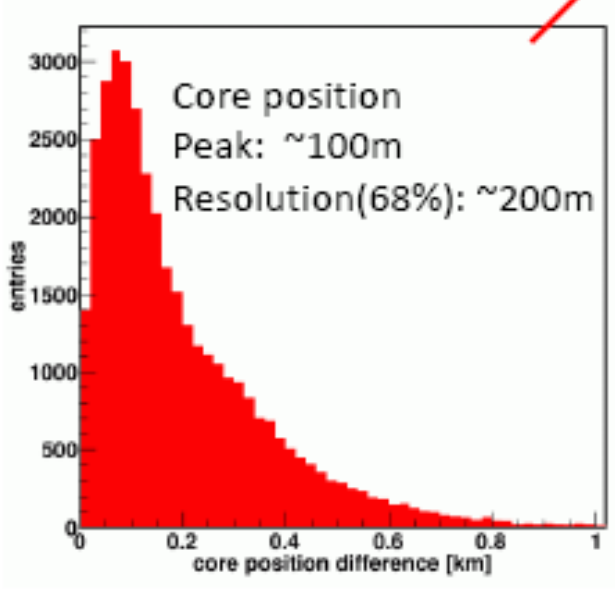


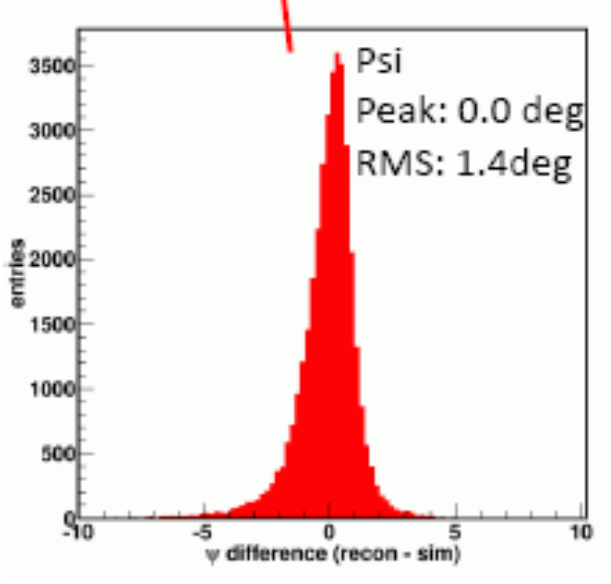
Resolution (Geometry)

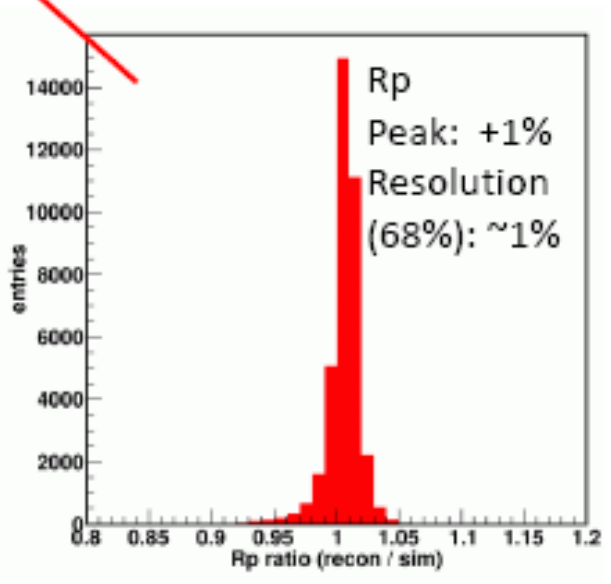










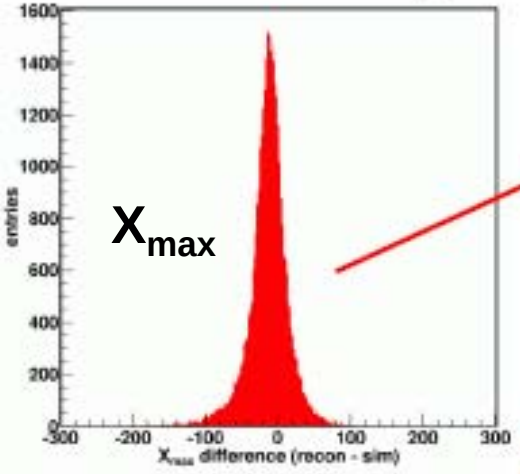


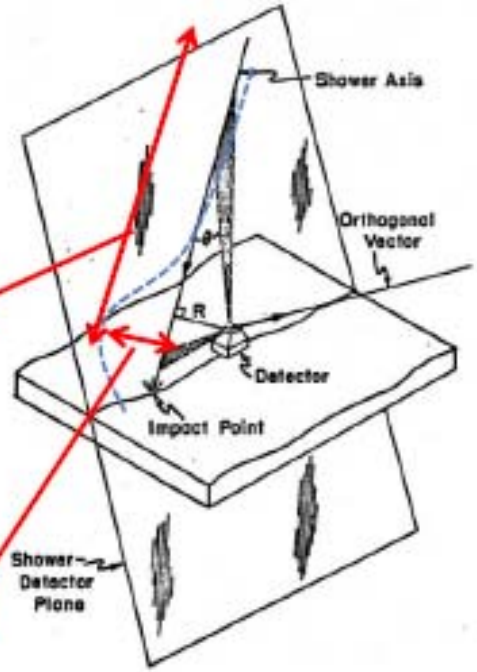
Resolution (Shower profile)

Xmax

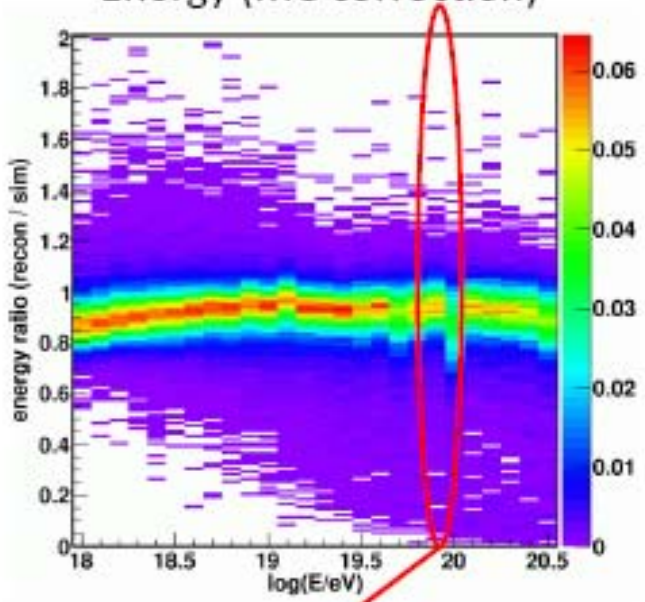
Peak: -11g/cm²

Standard deviation: ~30g/cm²





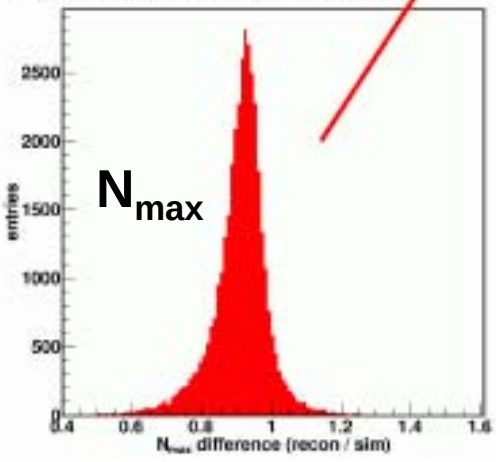
Energy (MC correction)

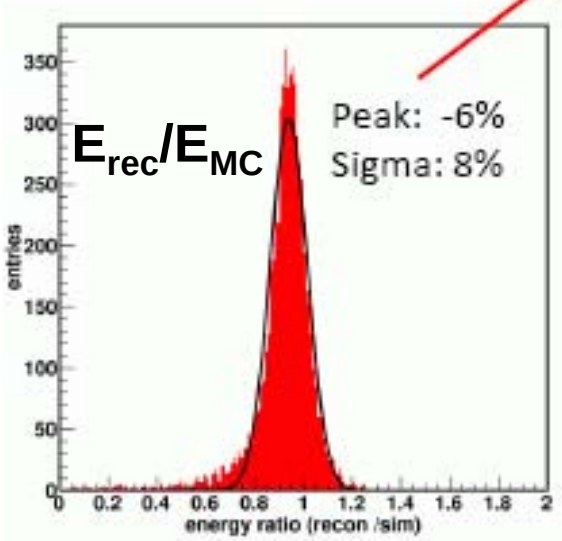


Nmax

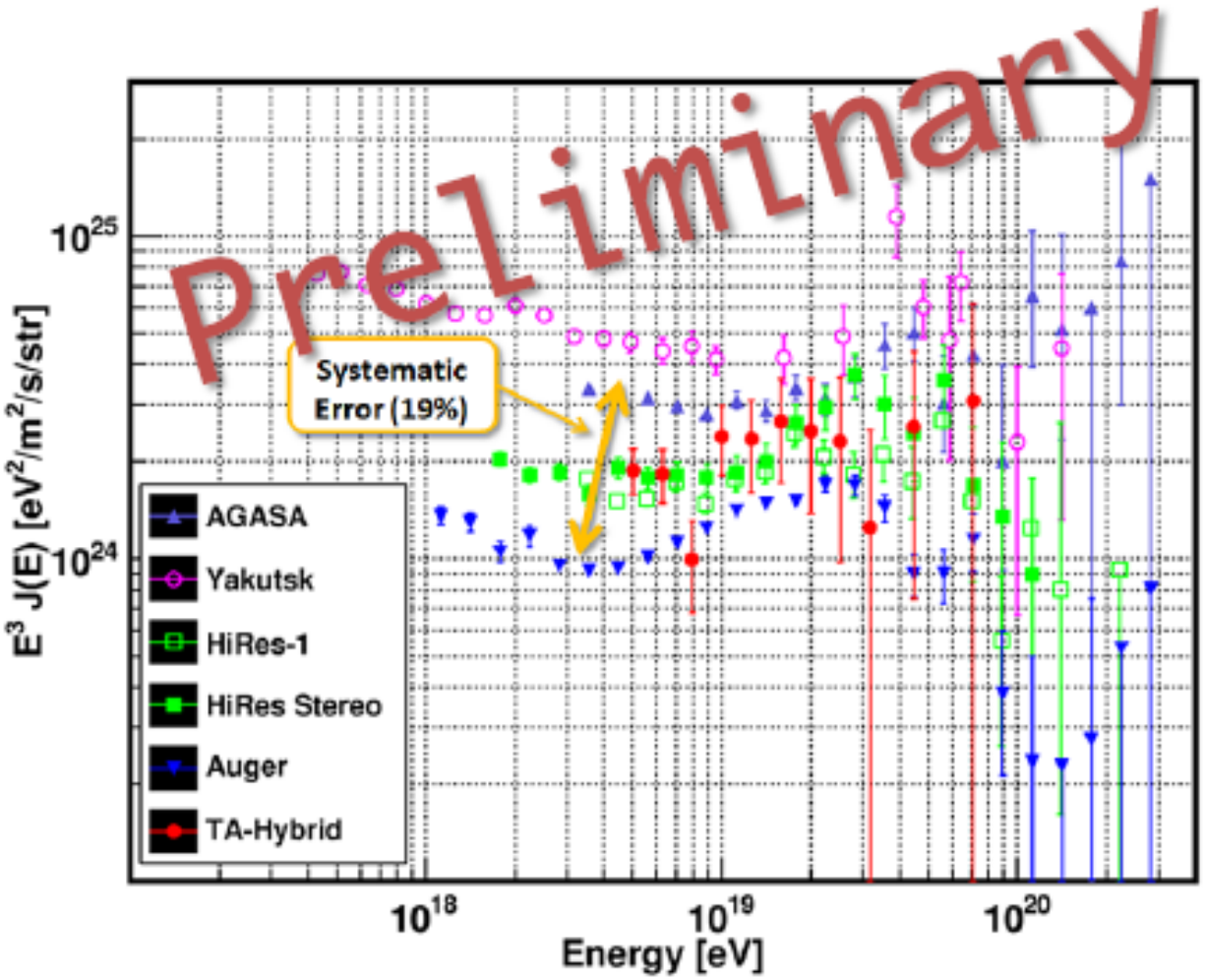
Peak: -9%

Standard deviation : 8%





Energy spectrum



Systematic errors

Item	Systematic error
Fluorescence yield	12%
Detector	10%
Atmosphere	11%
Primary particle mass	5%
MC correction	3%
Total	19%

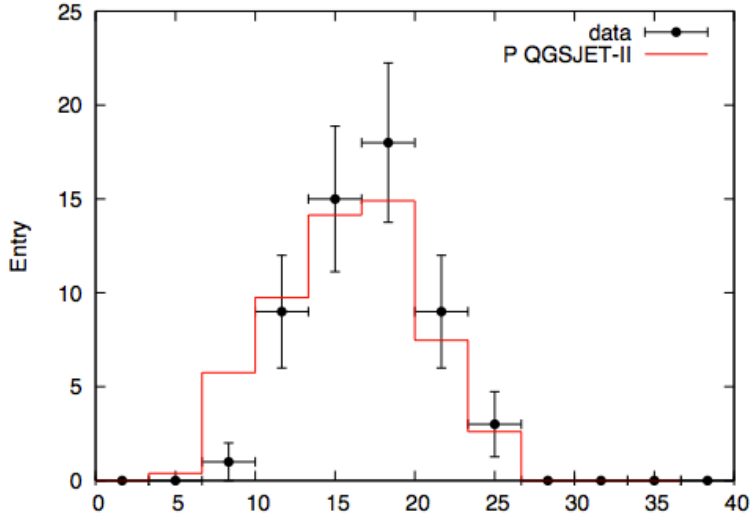
FD Stereo: Composition

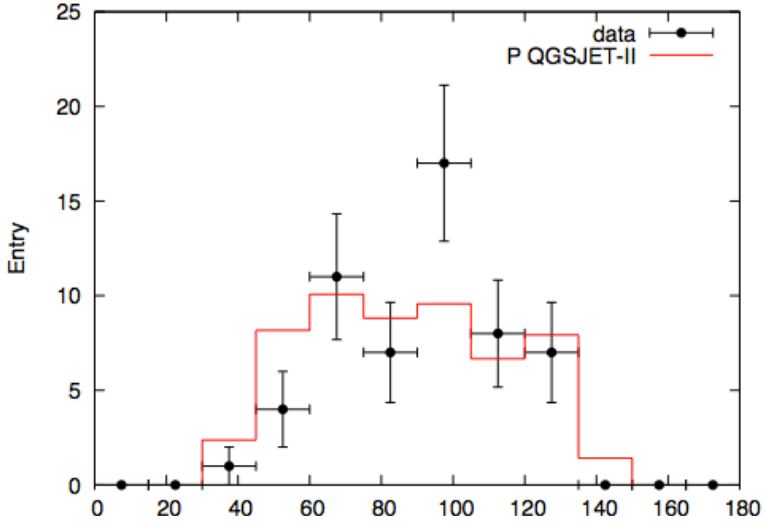
- Measure x_{max} for Black Rock/Long Ridge FD stereo events
- Apply strict quality cuts in order to improve x_{max} resolution
- Create simulated event set
- Apply exactly the same procedure as with the data

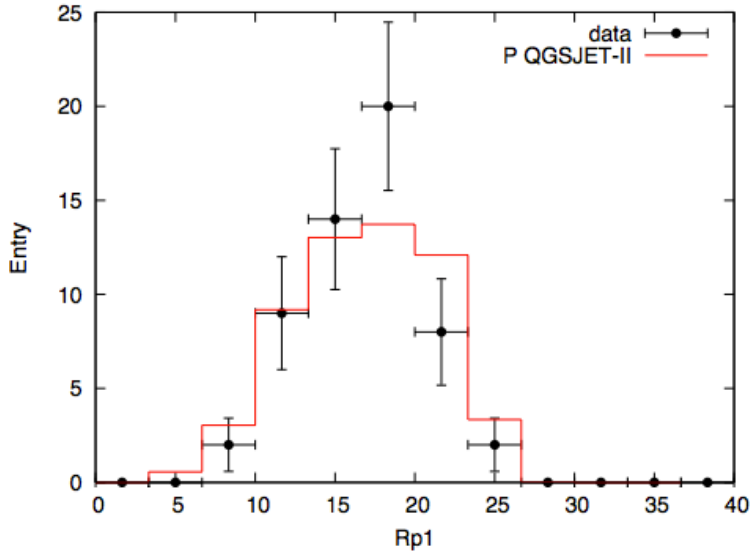
Data/MC Comparisons

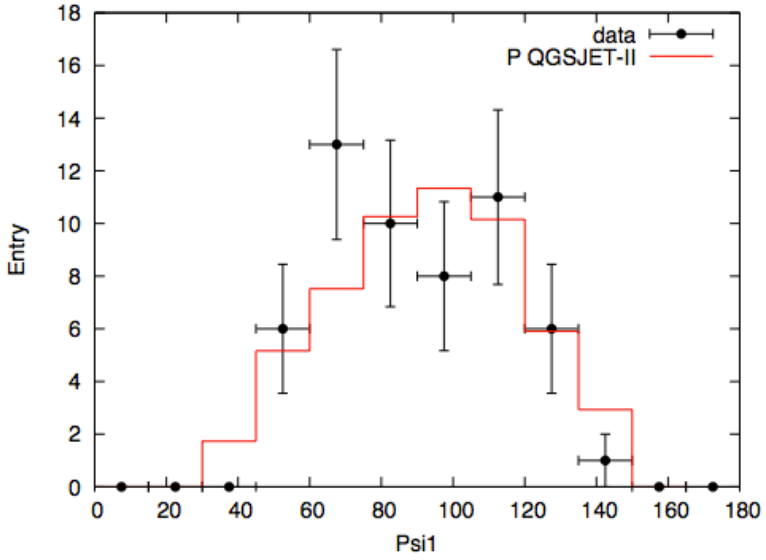
Black Rock

Long Ridge





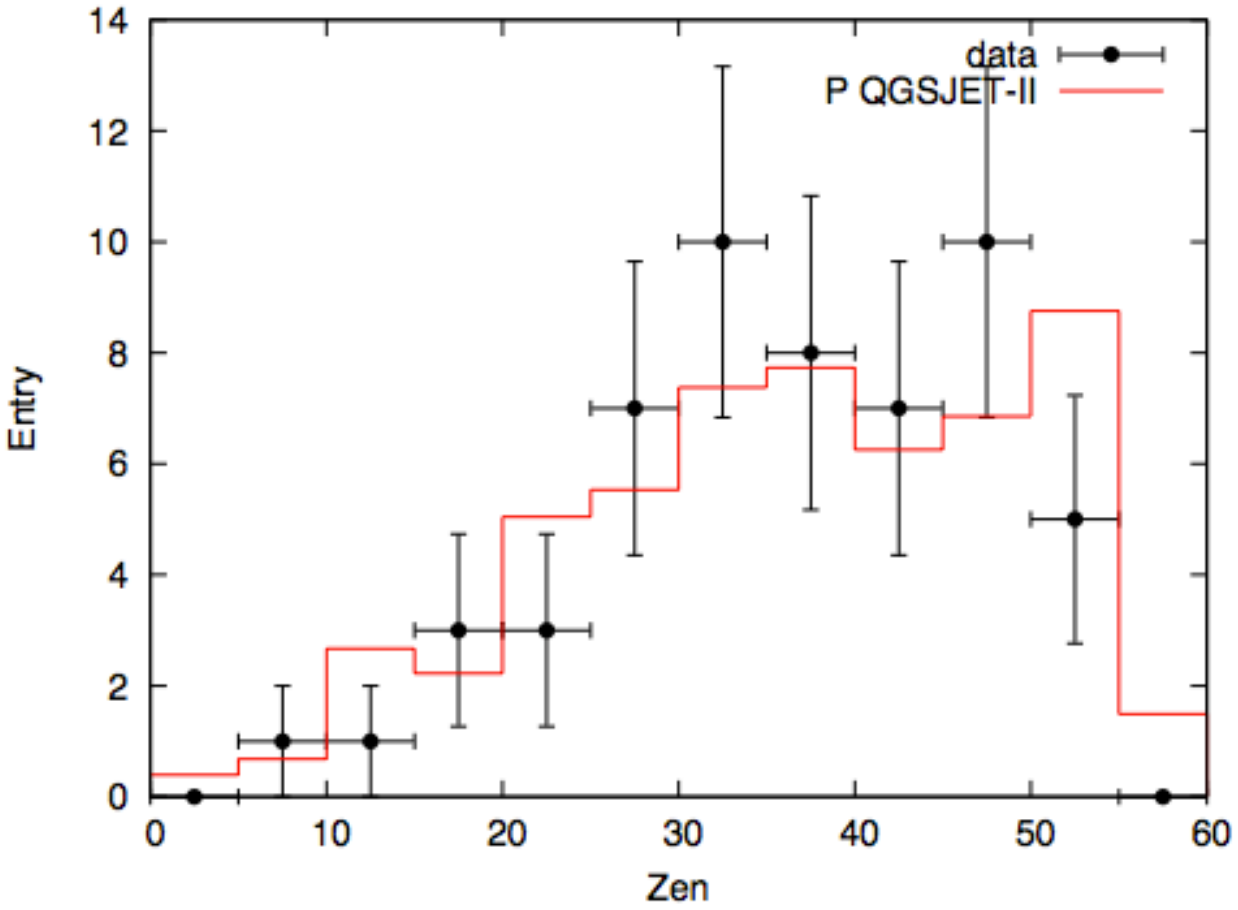




R_p

ψ

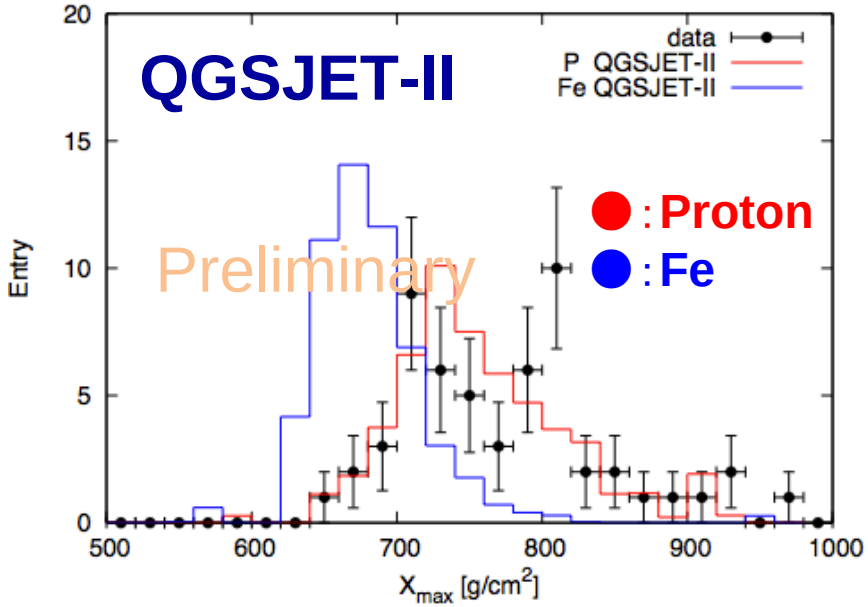
Data/MC Comparisons (cont.)

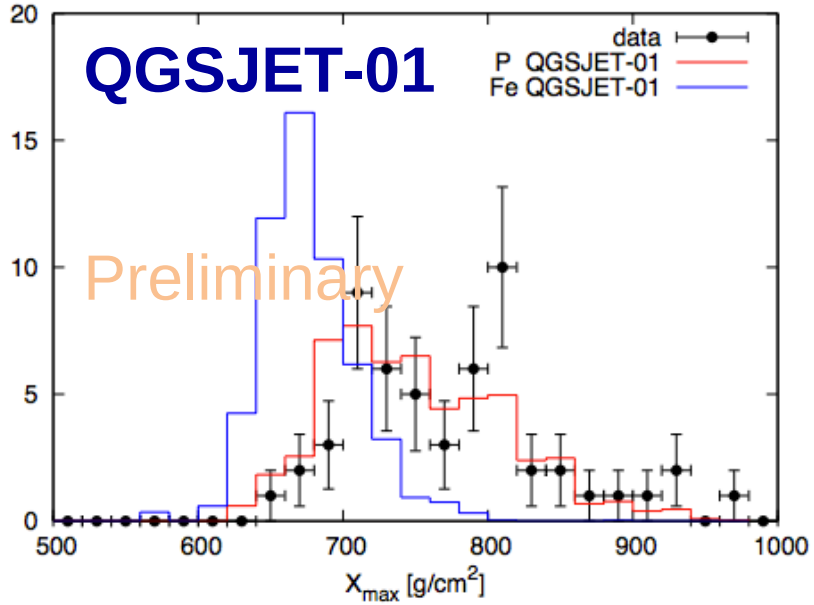


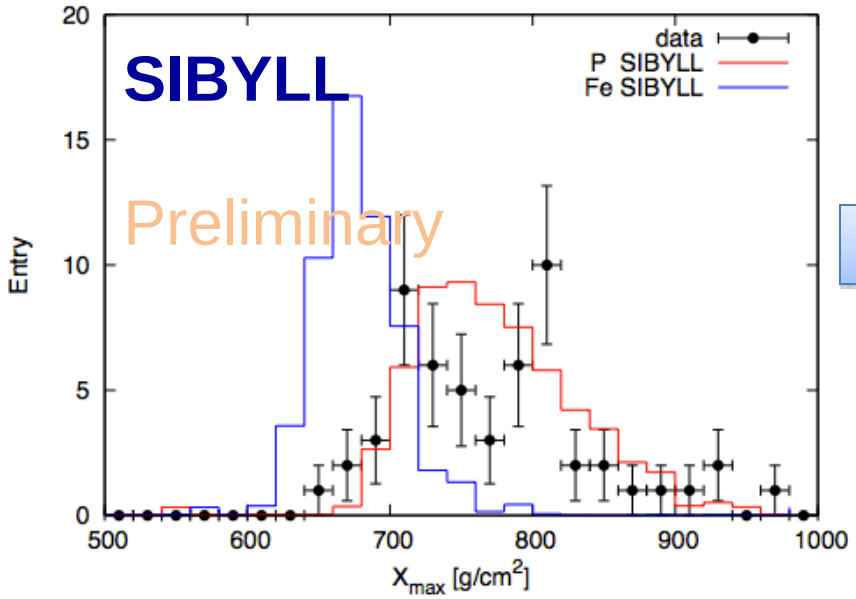
Zenith Angle

- Data and MC show excellent agreement geometric agreement
- What about x_{max}?

x_{max} Data/MC comparison



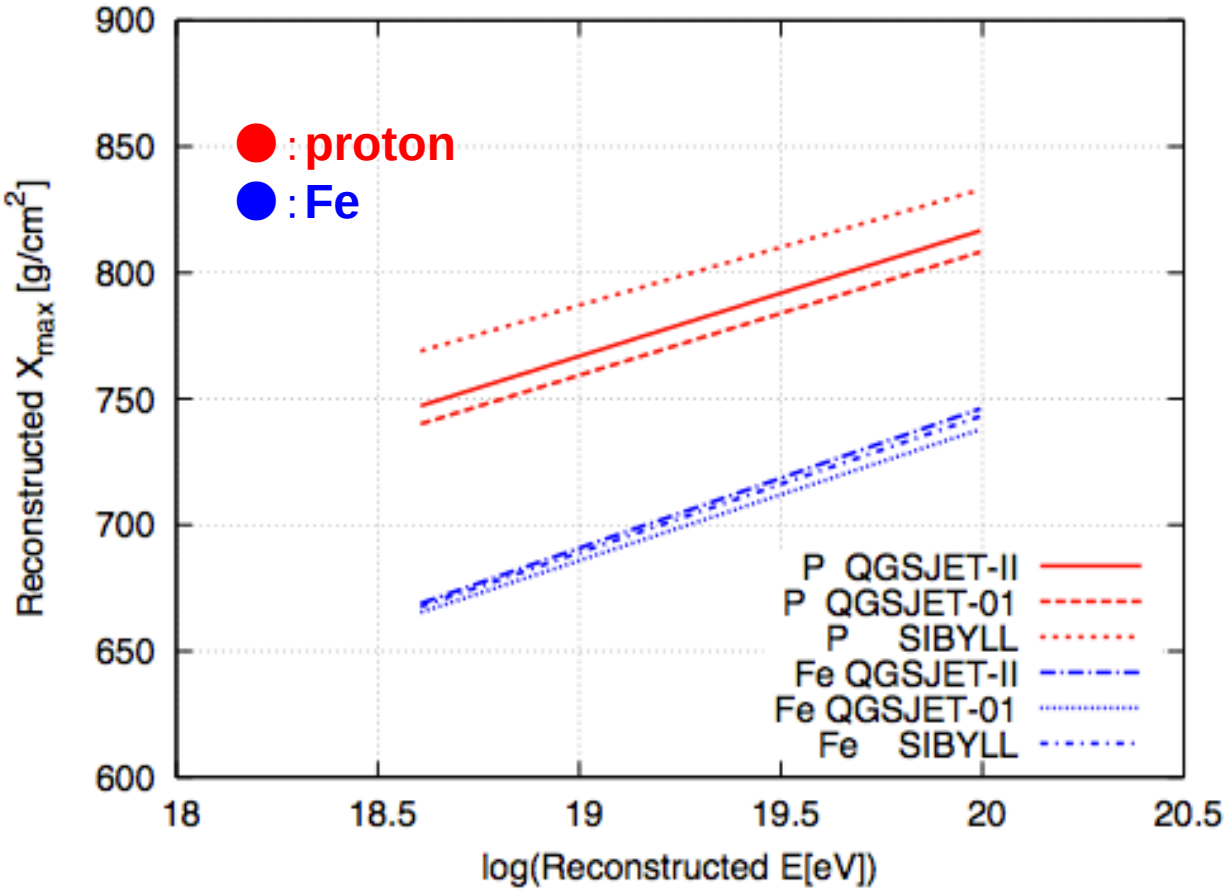


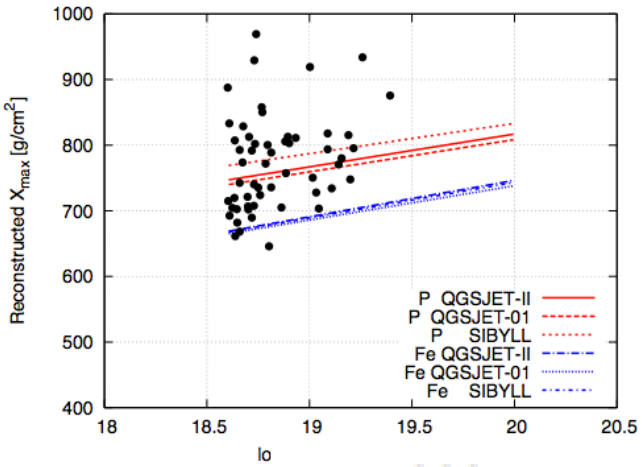


χ^2 /dof	QGSJET-II	QGSJET-01	SIBYLL
P	1.44	1.046	1.63
Fe	55.54	56.67	85.71

x_{max} vs. Energy

- **Use MC treated identically to the data to establish energy dependence**





x_{max} vs. Energy + Data

Stereo Composition Conclusion

- **Data consistent with continuing light composition above 10^{19} eV**
- **However…statistics are very limited at this time**
- ***(HiRes talk by J.Belz)***
- ***Stay Tuned! – More to come…***

Ongoing…

TA
Electron
Light
Source
@ BRM

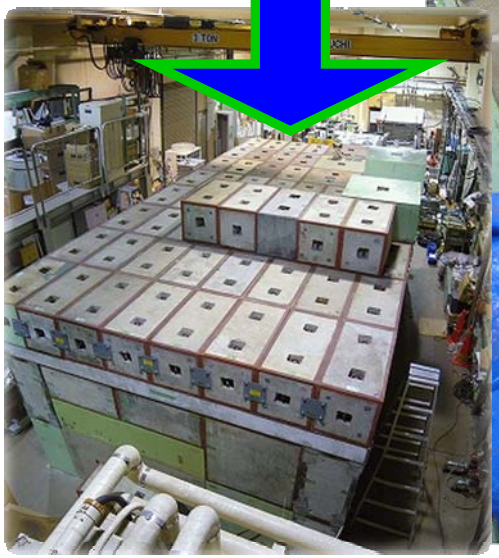
ELS Facility in Delta, UT 2/2010

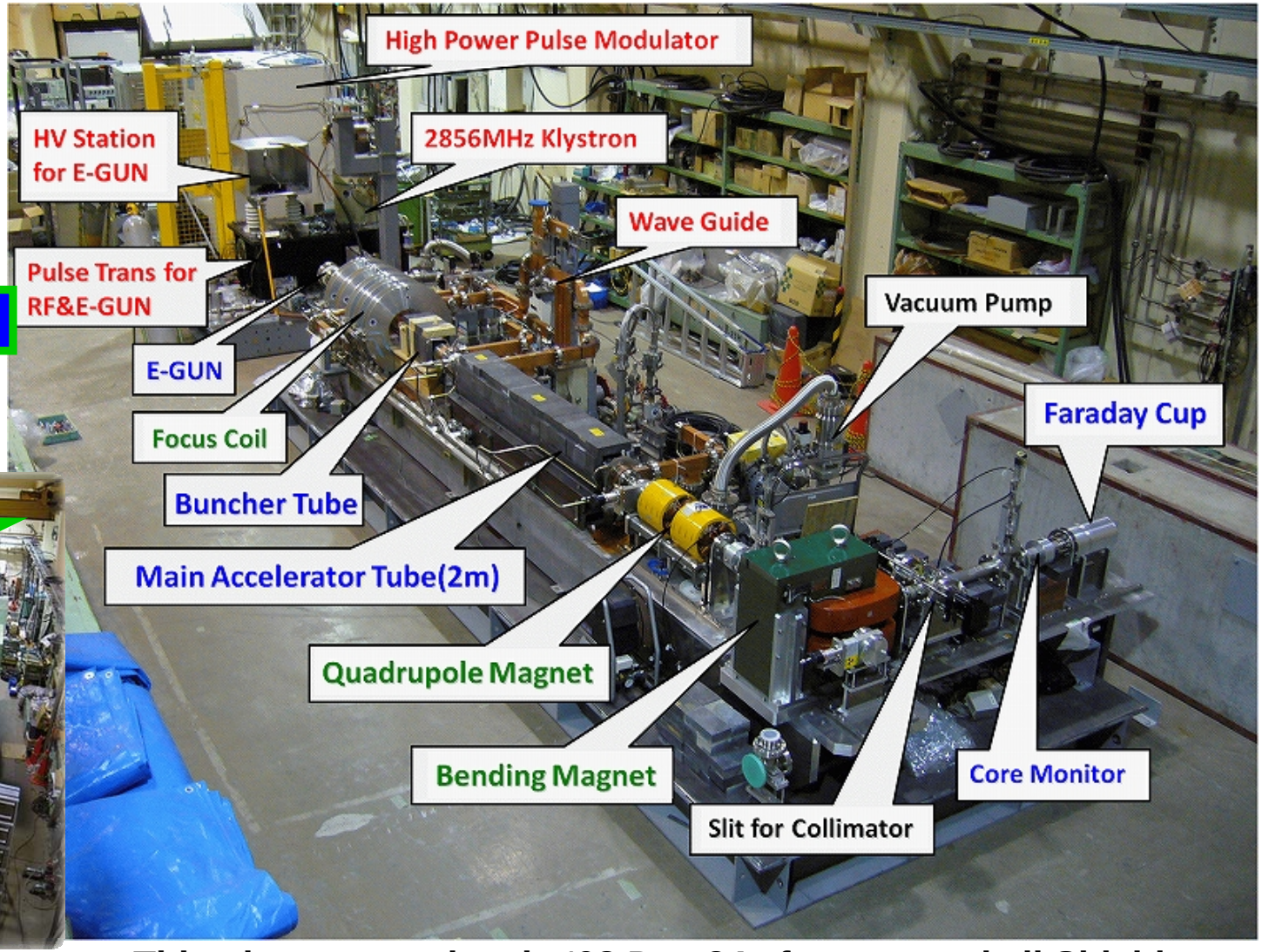
The Electron Light Source @ KEK

- Beam Operation '08.Feb.22th - Dec.10th (89days = 716hours)

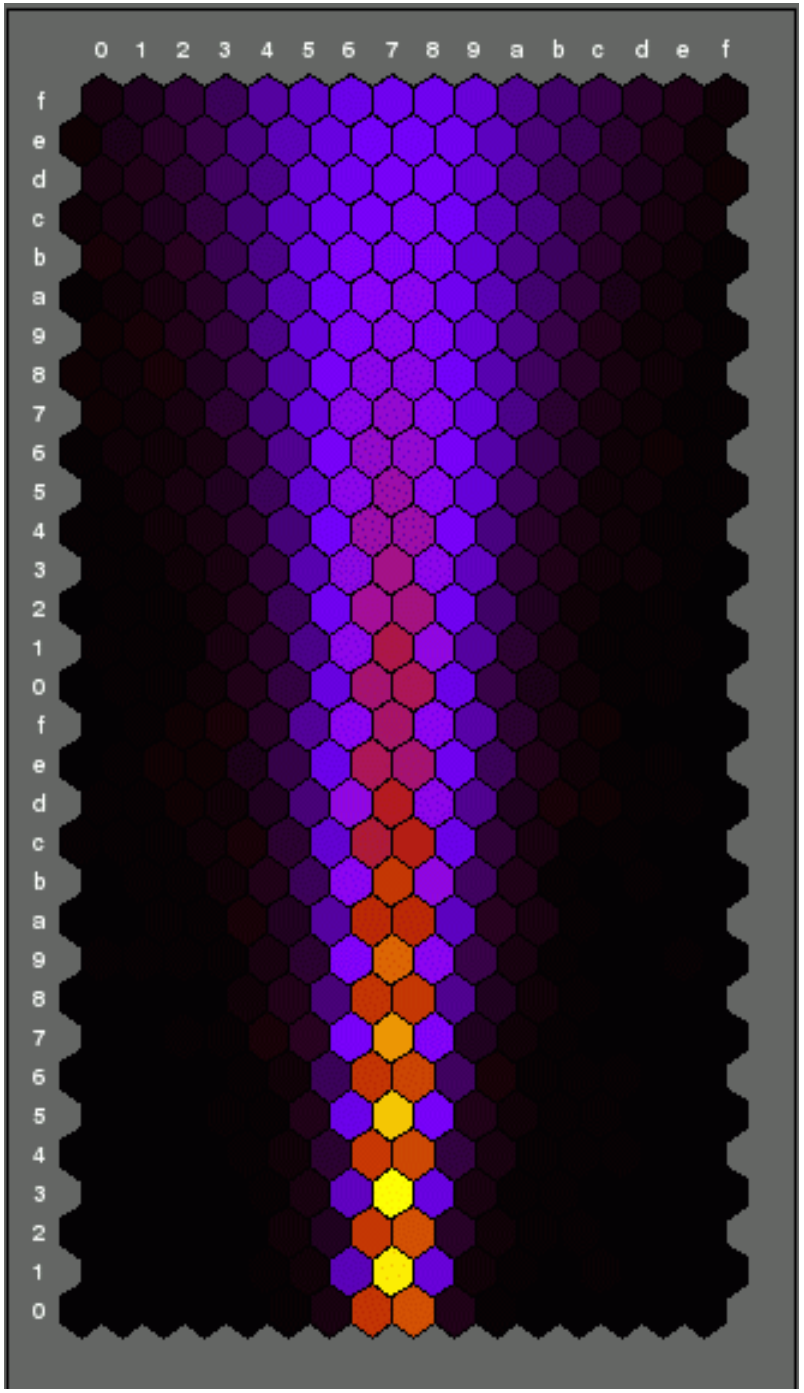
Beam Condition
- Repetition ~ 0.5Hz
- Energy ~ 40MeV
- Current
  10~250pC/pulse

Built in Shield room





This photo was taken in '08.Dec.24 after removal all Shields.



Absolute Energy Calibration *in situ* by 40 MeV electron beam fired vertically into the sky

Automatically takes into account fluorescence yield (λ) and detector inefficiencies

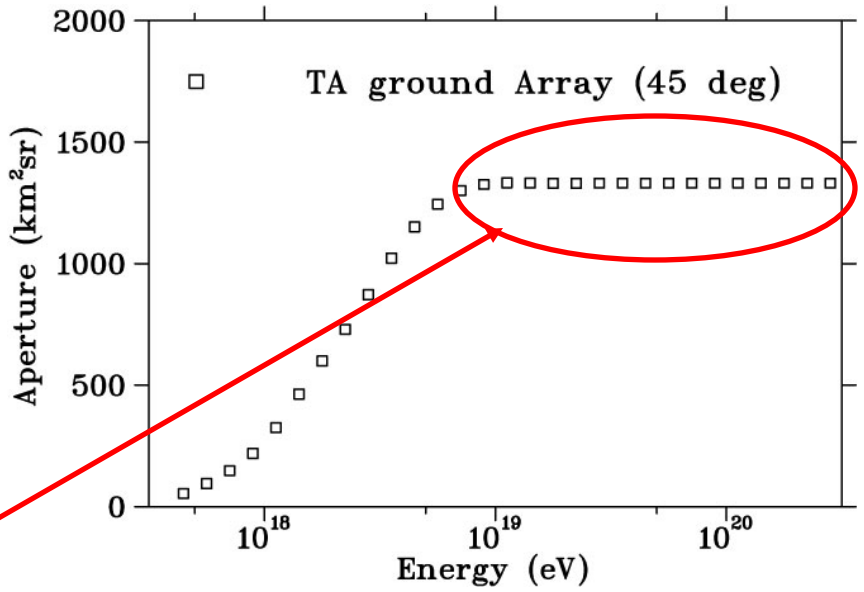
ELS Status

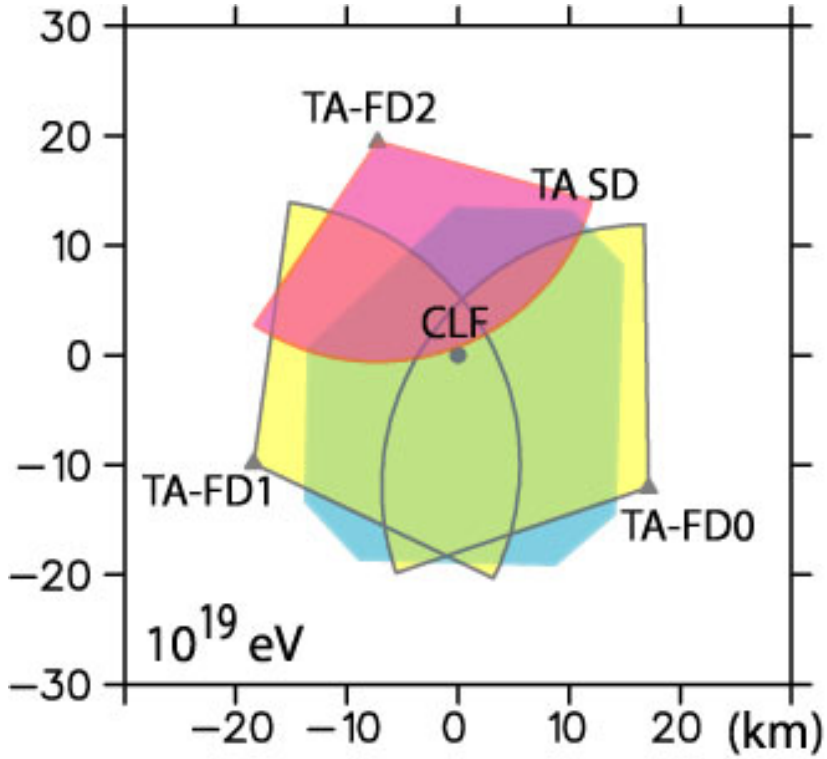
- Background measurements ongoing for a couple years
- Suffered some minor damage in transit to Utah – finishing repairs
- Beginning to re-commission the accelerator (testing the klystron, electron gun, etc)
- Hope to have first beam shots soon! (end of the month??)

TA Stage-1

- The energy region > 10^{19} eV is well-covered by the existing TA detectors
- Ground Array becomes fully efficient at ~5x10^{18} eV
- The three FD stations
  - TA-FD0 at Black Rock Mesa
  - TA-FD1 at Long Ridge
  - TA-FD2 at Middle Drum

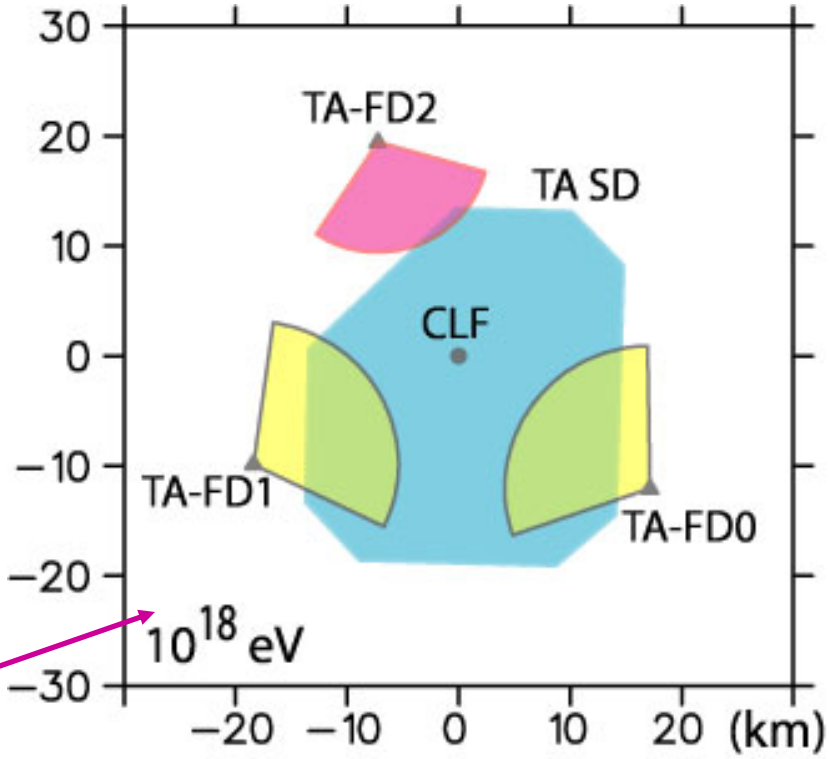
  provide ~100% coverage of the ground array above 10^{19} eV

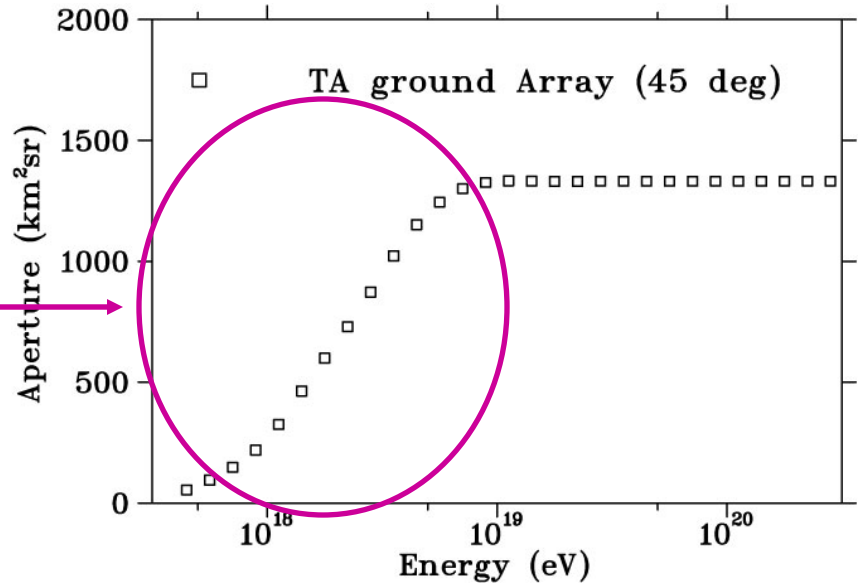




Below 10^{19} eV

- However, Stage-1 of TA was not designed for physics below 10^{19} eV
- There is no overlap at all in the aperture of the three fluorescence detectors at 10^{18} eV
- The ground array efficiency drops quickly in the 10^{18}-10^{19} eV decade

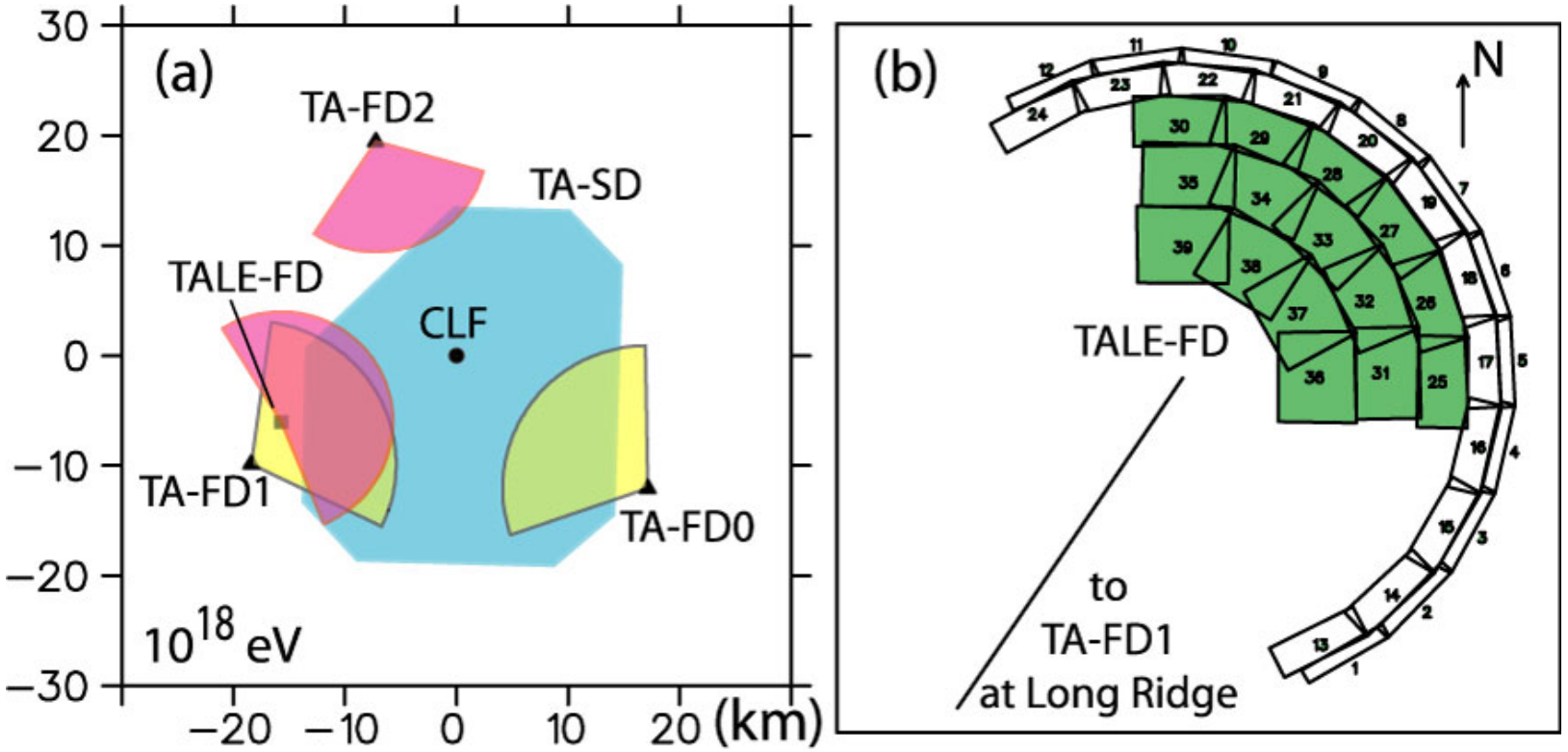




Plan: TA Low Energy Extension (TALE)

- 4^{th} Fluorescence Station - 6 km separation
  - 24 telescopes (3-31^{o} elevation) – "ring 1 & 2"
  - 15 large area Tower telescopes (31-73^{o} elevation)
- Infill scintillator array 111 (3m^2/ea) detectors at 400 m spacing
- Graded muon array – 25 (12m^2 /ea) detectors, buried 3 m

6 km Stereo and Tower



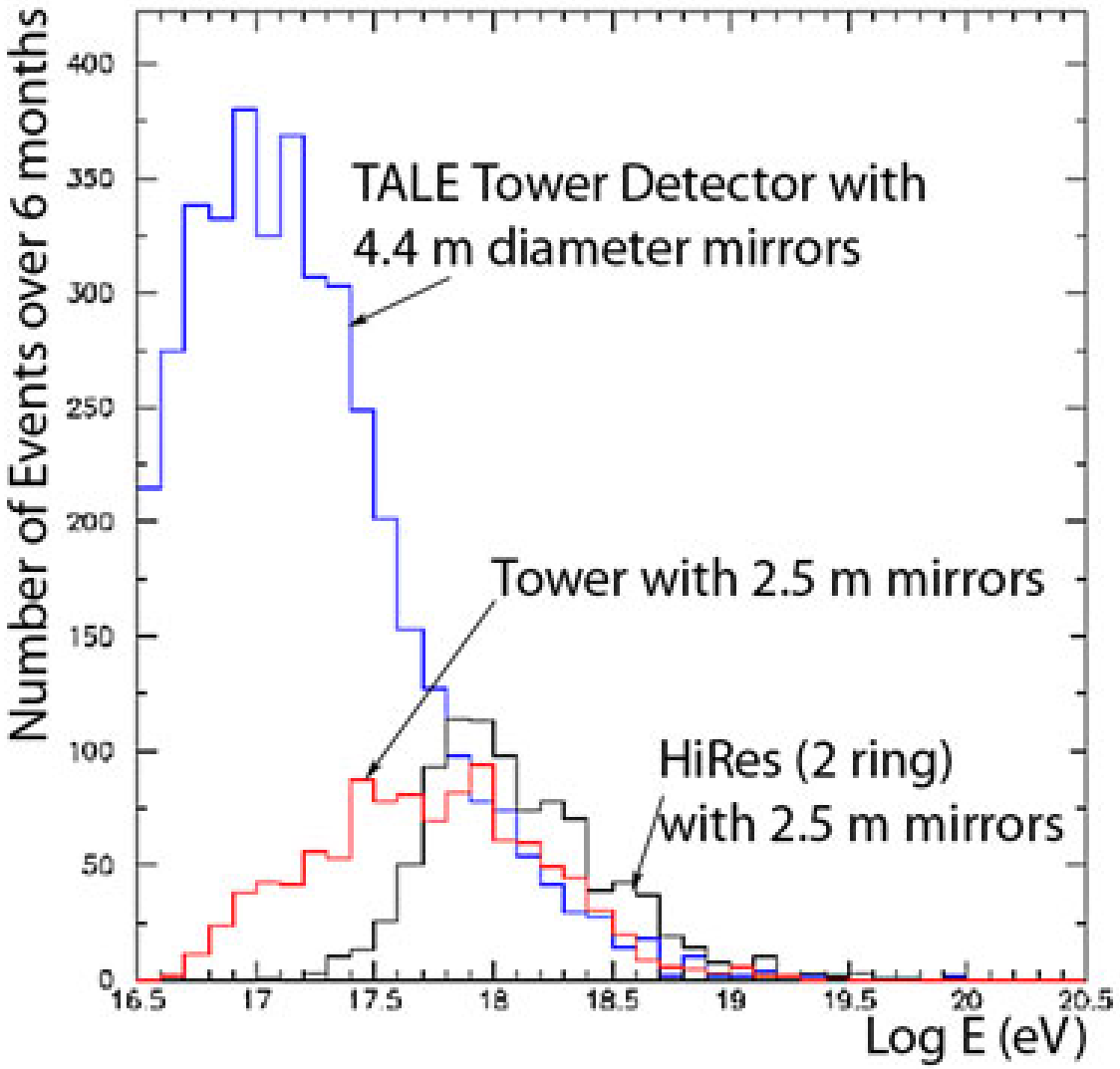
- 24 low elevation (ring 1 & 2) telescopes; mirrors the same effective area as HiRes and Auger
- 15 higher elevation (rings 3-5) telescopes; mirrors 3x larger area

Zero in on the Ankle

- **The energy, angular, and Xmax resolutions of the** 6km stereo pair **is expected to be similar to that of the HiRes stereo pair, except that the aperture is flattened in the decade of energy containing the ankle.**
- **Will provide** stereo composition measurement **down to ~10^{18} eV, where we expect the elongation rate to begin to change…overlapping with the "Tower" hybrid detector.**

Improved Sensitivity

- The increased mirror size will improve substantially the sensitivity of TALE in the $10^{16.5}$-$10^{17.5}$ eV energy decade
- Note the gain in sensitivity comes from the improvement in signal.
- The HiRes trigger scheme is not S/N limited, but limited by having enough signal to reconstruct a reliable shower profile.



Conclusions

- The Telescope Array (TA) Experiment has picked up where HiRes left off and is collecting UHE cosmic ray data in the northern hemisphere
- TA is a large experiment is attempting to carefully control systematic uncertainties
- Multiple analyses are all ongoing:
  - FD mono, Stereo, SD mono, hybrid, hybrid-stereo
- More TA spectrum, composition, and anisotropy results will be presented in the coming year
- TALE – the Low Energy Extension to TA will soon be extending the reach of TA down to ~3×10^{16}eV to sort out the measurements between galactic and extra-galactic regions.

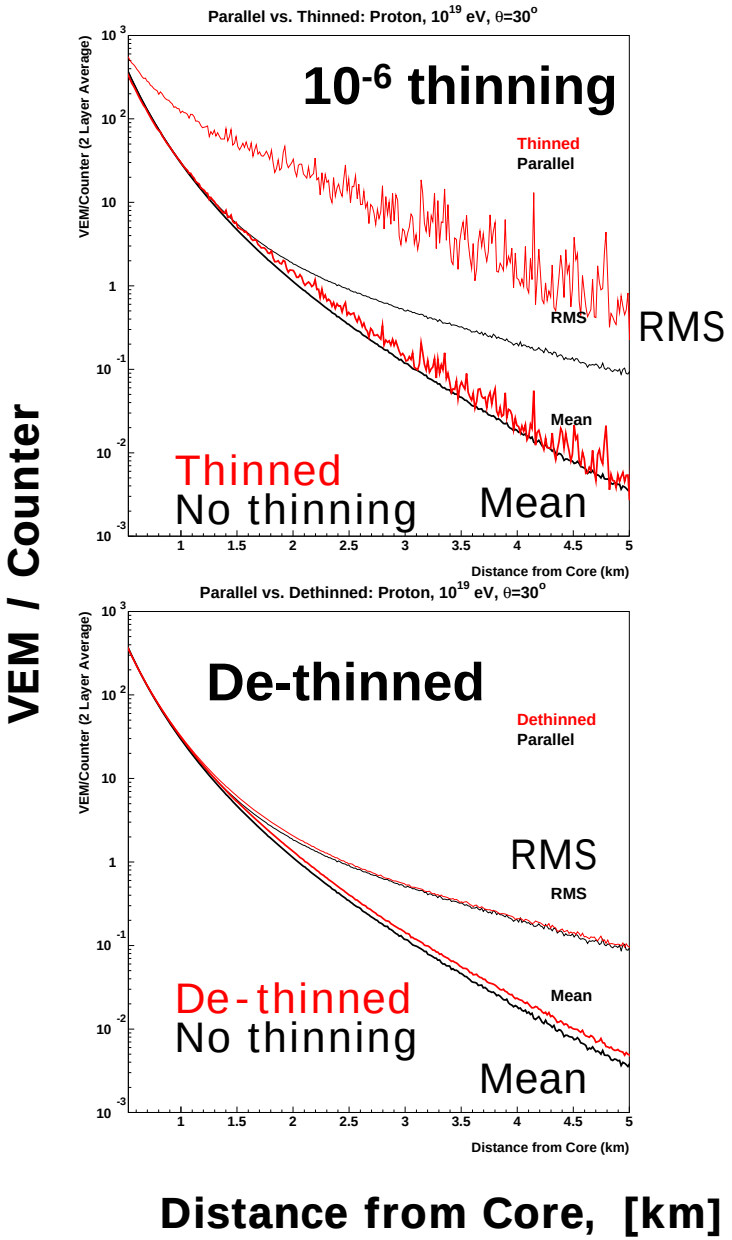
Acknowledgments

The Telescope Array experiment is supported by the

- Ministry of Education, Culture, Sports, Science and Technology-Japan
- U.S. National Science Foundation
- Korea Research Foundation
- Korean Science and Engineering Foundation
- Russian Academy of Sciences,
- Belgian Science Policy
- Dr. Ezekiel R. and Edna Wattis Dumke Foundation
- Willard L. Eccles Foundation
- George S. and Dolores Dore Eccles Foundation
- State of Utah Economic Development Board
- University of Utah, Office of the Vice President for Research
- Utah School and Institutional Trust Lands Administration (SITLA)
- U.S. Bureau of Land Management
- U.S. Air Force

We also wish to thank the people and the officials of Millard County, Utah, for their steadfast and warm supports. We gratefully acknowledge the contributions from the technical staffs of our home institutions and the University of Utah Center for High Performance Computing

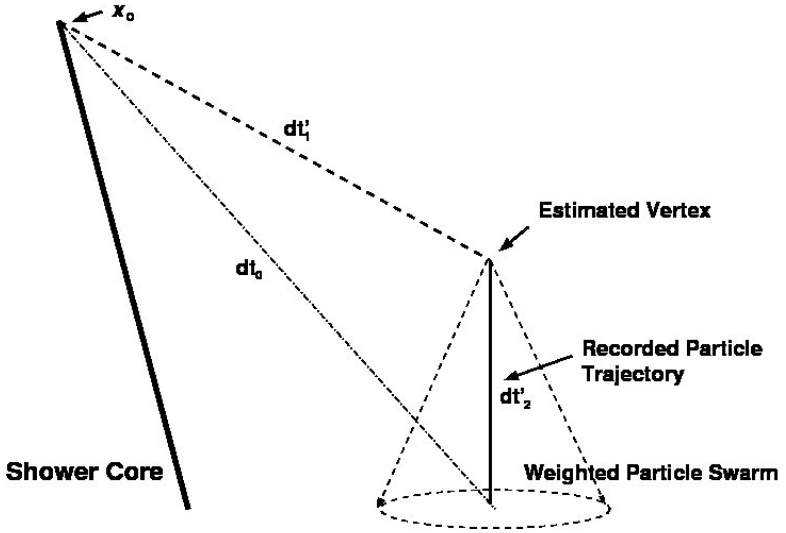
Using CORSIKA Events

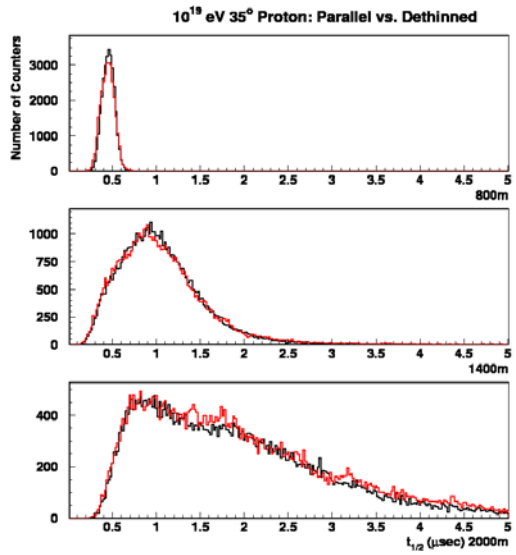


- Use 10^{-6} – thinned CORSIKA QGSJET-II proton showers that are de-thinned in order to restore information in the tail of the shower.
- De-thinning procedure is validated by comparing results with non-thinned CORSIKA showers, obtained by running CORSIKA in parallel
- We fully simulate the SD response, *including actual FADC traces*

Dethinning Technique

- Change each CORSIKA output particle of weight w to w particles; distributed in space and time.
- Time distribution agrees with un-thinned CORSIKA showers.





Lateral Distance:

800m

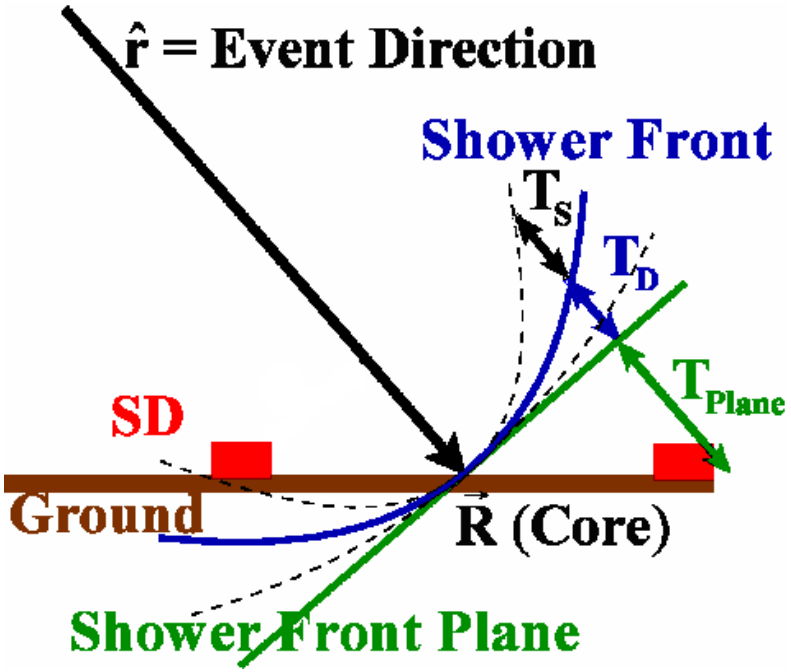
1400m

2000m

SD Time Fit

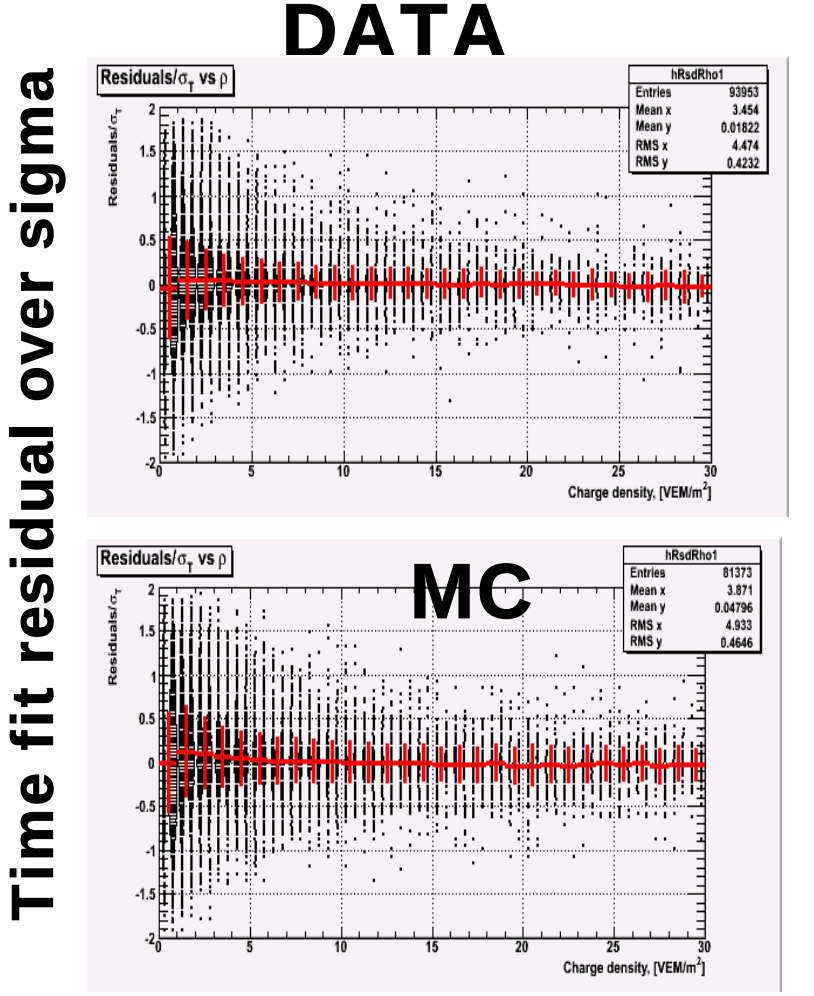
- **Event direction is found by minimizing:**

$$\chi^2 = \sum_{i=1}^{\text{nSDs}} \frac{\left(t_i - T_0 - T_{\text{Plane}} - T_{\text{D}}\right)^2}{T_{\text{S}}^{\,2}} + \frac{\left(\vec{\mathbf{R}} - \vec{\mathbf{R}}_{\text{COG}}\right)^2}{(180\text{m})^2}$$



T_0	**Time of the core hitting ground**
T_{Plane}	**Time of the shower front plane**
T_{D}	**Time delay (Modified Linsley)**
T_{S}	**Fluctuation of time delay (Modified Linsley)**
$\vec{\mathbf{R}}$	**(Fitted) core position**
$\vec{\mathbf{R}}_{\text{COG}}$	**Core position found from the center of gravity of charge**

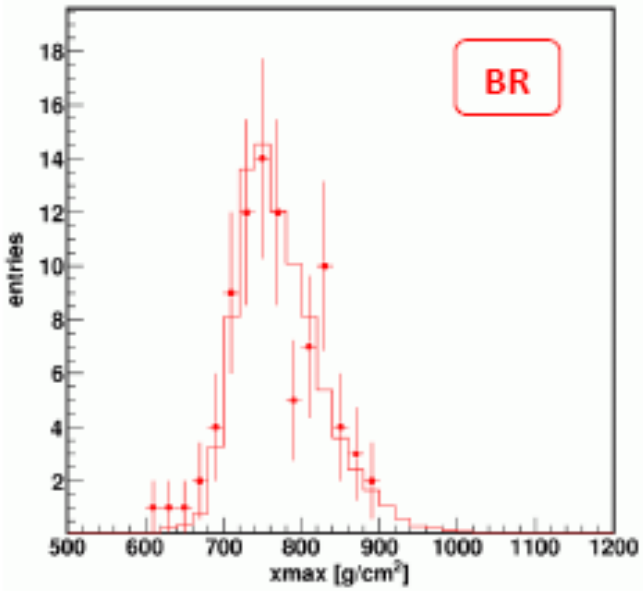
Fitting results

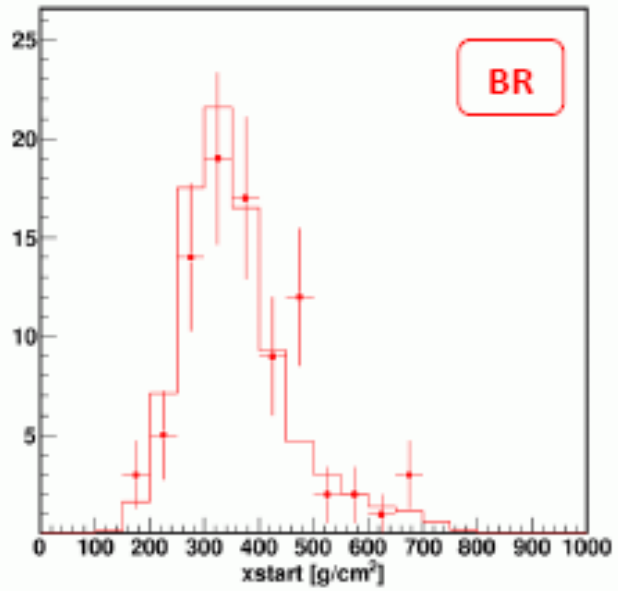


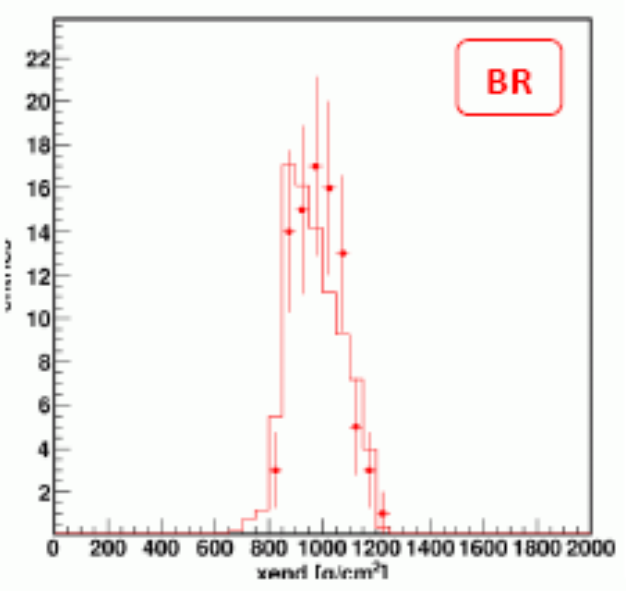
- Fitting procedures are derived solely from the data
- Same analysis is applied to MC
- Fit results are compared between data and MC
- *MC fits the same way as the data.*
- Consistency for both time fits and LDF fits.

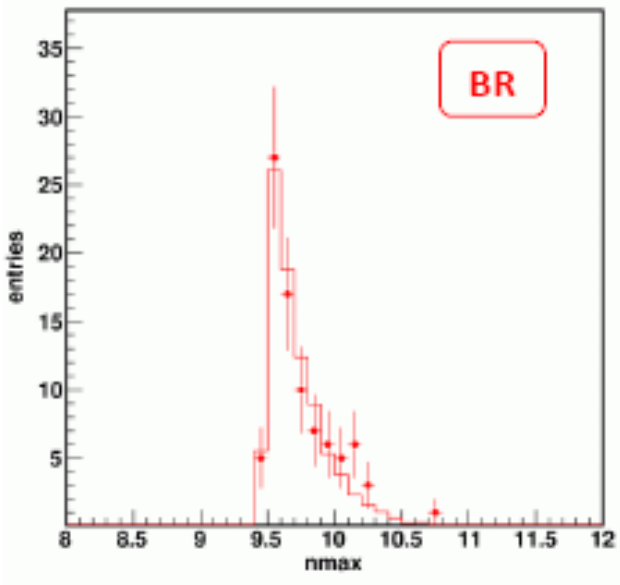
Data/MC comparison2

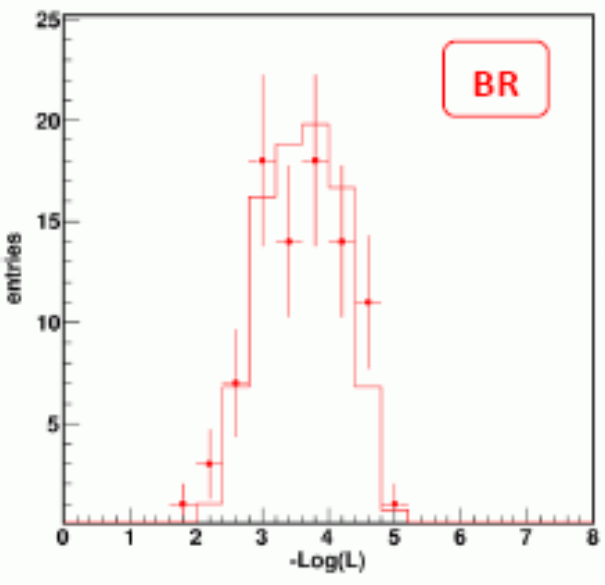
- BR station
- Filled circles : data
- Histograms : MC

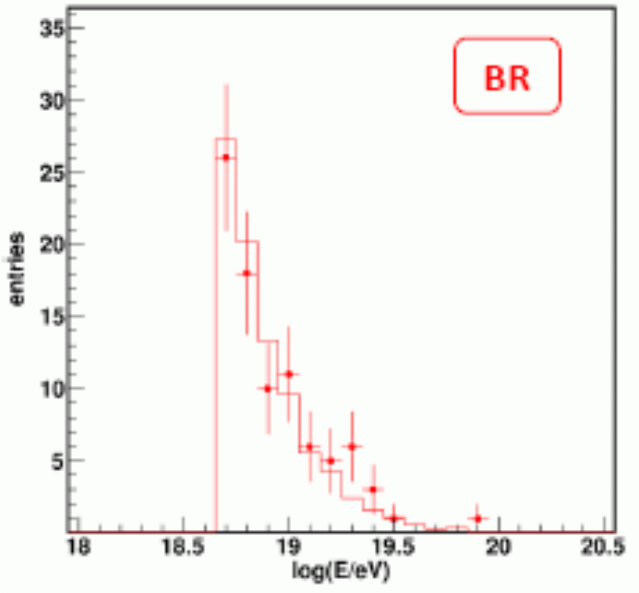






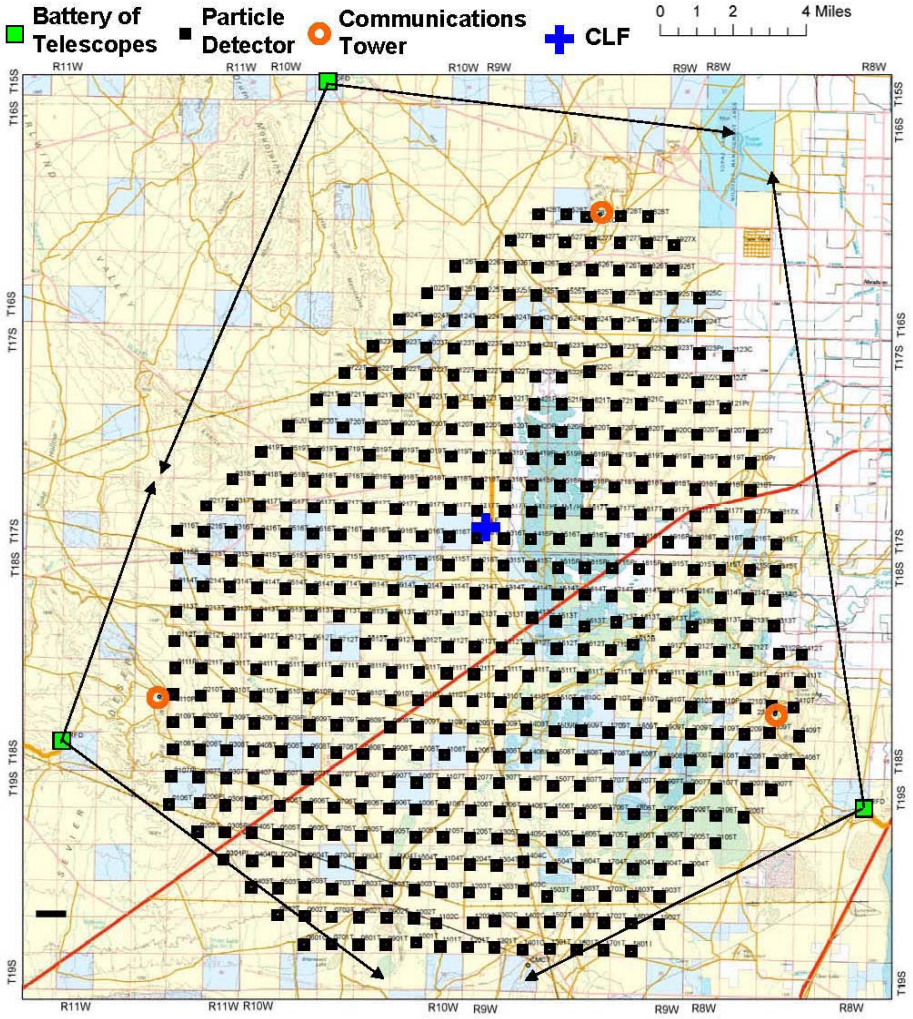




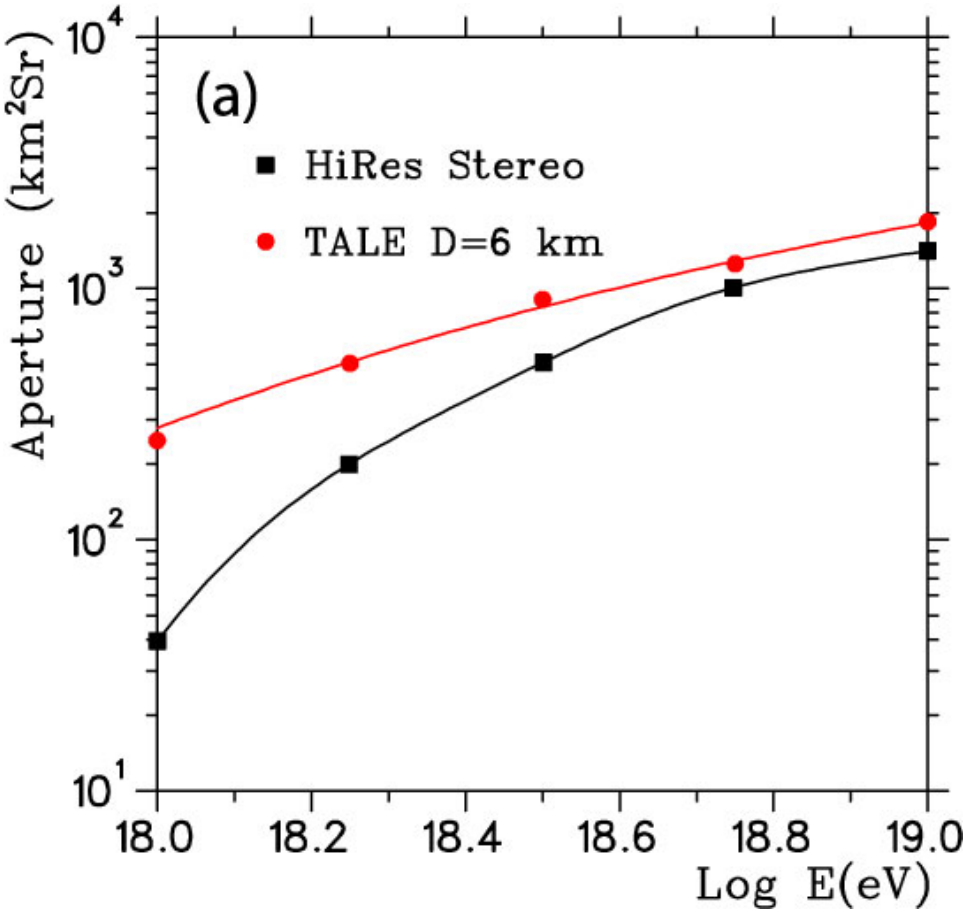


Introduction:
The Telescope Array

- TA is in Millard County, Utah, ~200 km southwest of Salt Lake City
- SD: 507 scintillation counters, 1.2 km spacing, scintillator area= 3 sq. m., two layers.
- FD: 3 sites, each covers 120° az., 3°-31° elev.
- 2.5 yr (FD) and 2 yr (SD) of data have been collected.



Tale Aperture

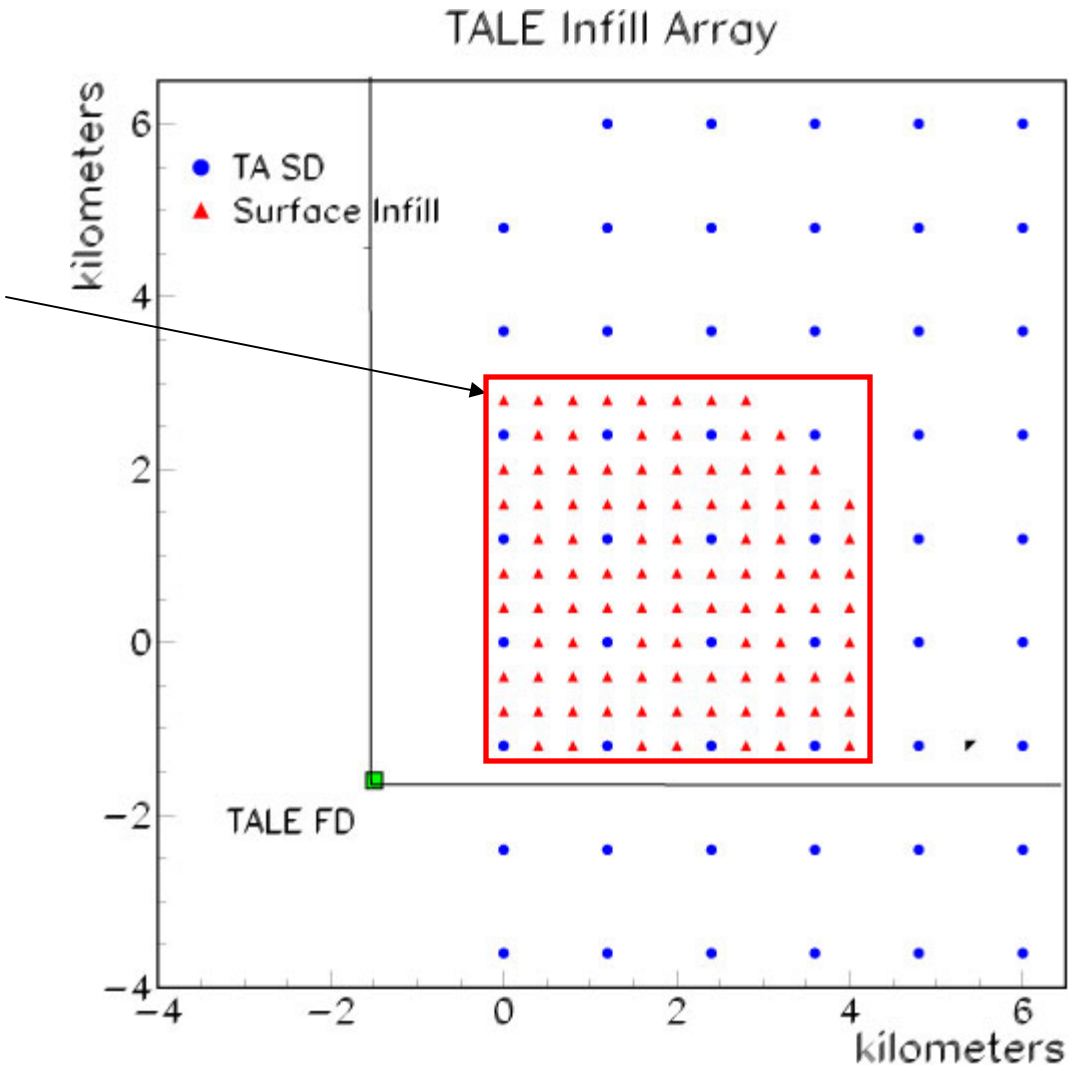


The 6 km stereo provides

- a much flatter stereo aperture than HiRes
- a 10x increase in aperture at 10^{18} eV

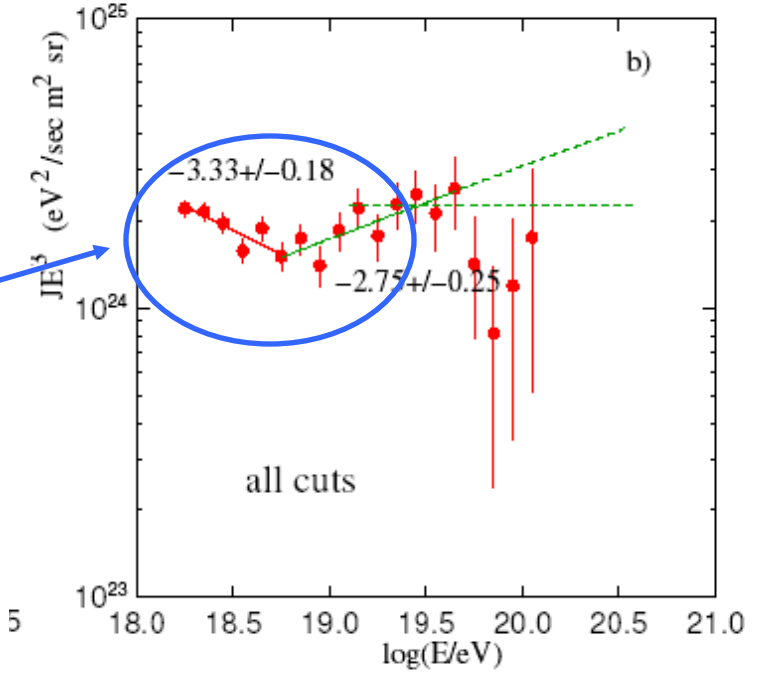
Infill Array

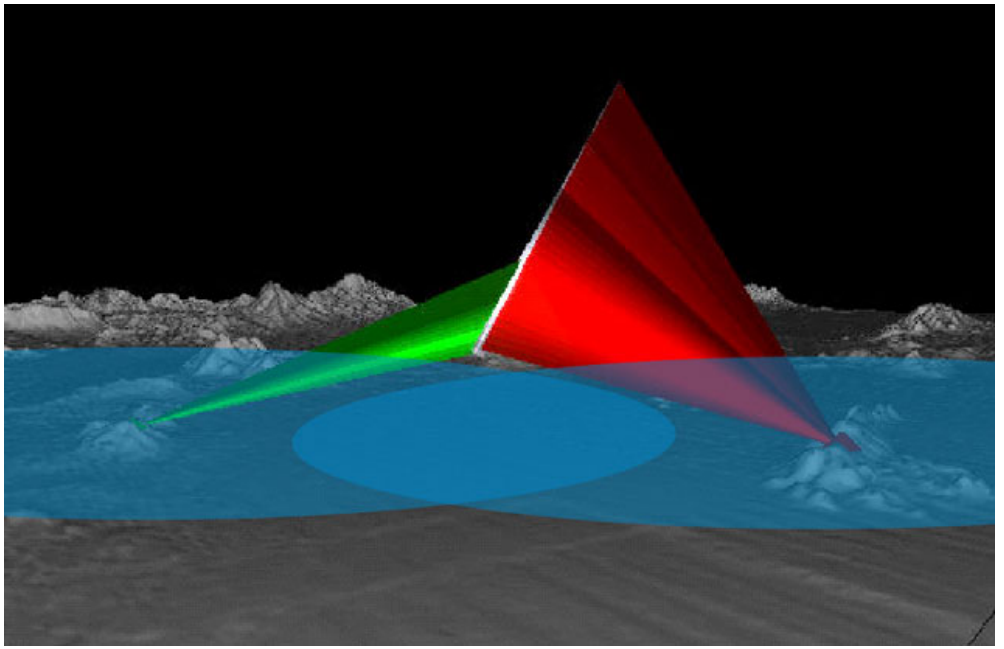
- Will place 111 additional surface array counters overlapping with main ground array: 4km x 4km
- 16 of the counters in the main ground array will form part of the infill
- Potentially re-use the AGASA scintillators and PMTs for the infill array



HiRes Stereo

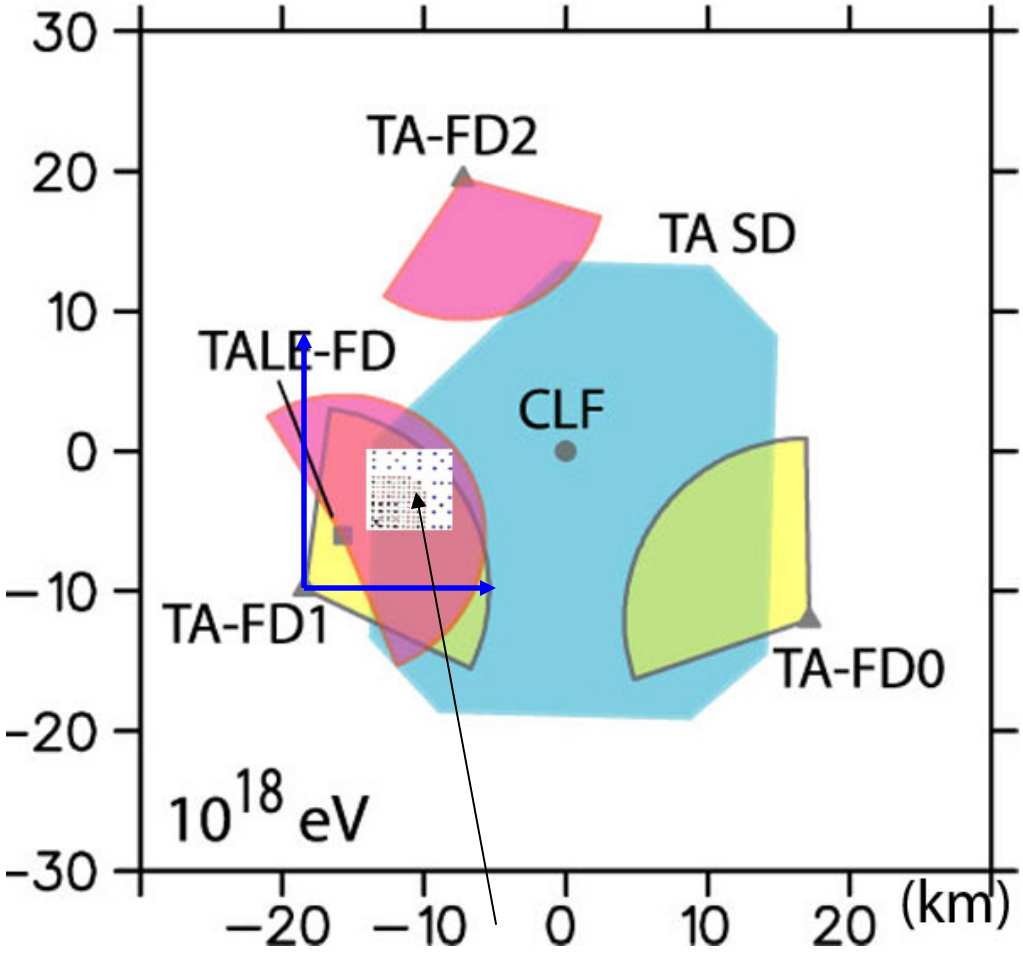
- HiRes Stereo aperture falls too rapidly through the ankle region to extend flux measurements much below ~3×10^{18}eV.
- There are two primary reasons for this:
  1. The 12.6 km separation of the two stations is too large: the overlap between the two shrinks very quickly below 3×10^{18}eV
  2. HiRes-1 only covers elevation angles up to 17°, which further limits the aperture near and below the ankle itself





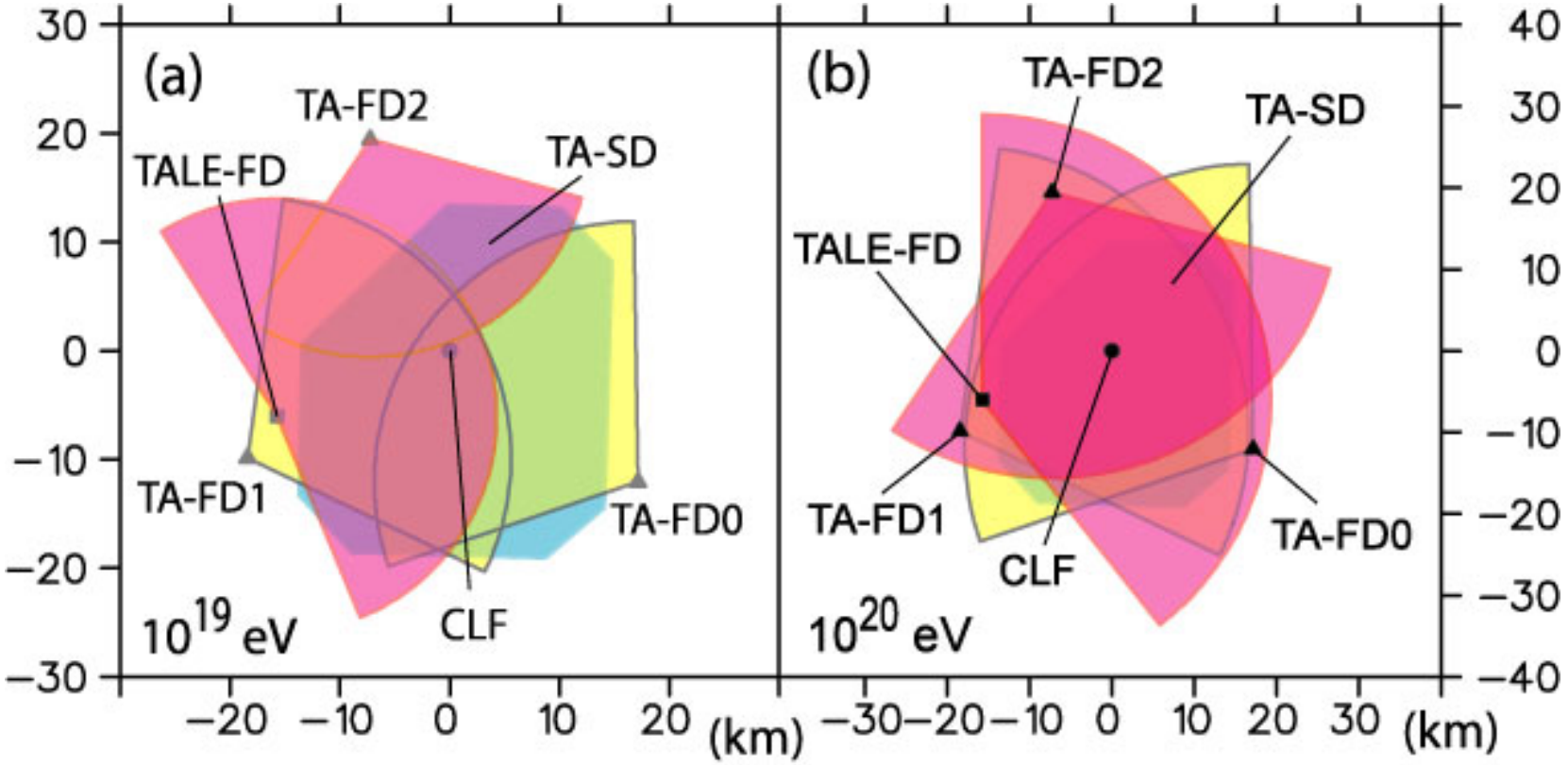
Hybrid Operation

- **The tower can operate in monocular mode, but limited to Xmax resolution of ~50 g/cm^2.**
- **Stereo overlap with Long Ridge FD site is too small to have large enough stereo aperture (but enough for direct MC validation of resolutions**
- Need infill array for hybrid operation
- **Simulations show 400 m spacing and ~4km x 4km array to be the optimal solution for hybrid operation the $10^{16.5}$-10^{19} eV energy range**



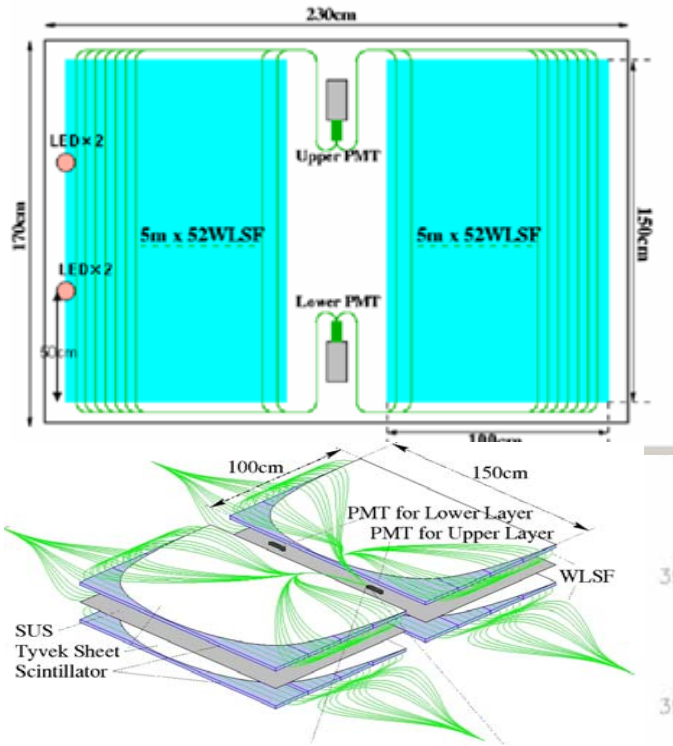
Part of the main ground array northeast of TALE-FD site is suitable for infill AND muon array

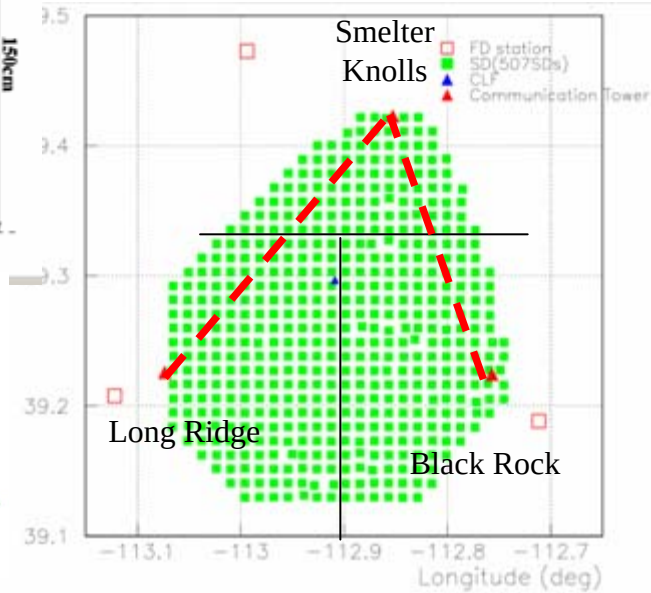
Telescope Array - HE

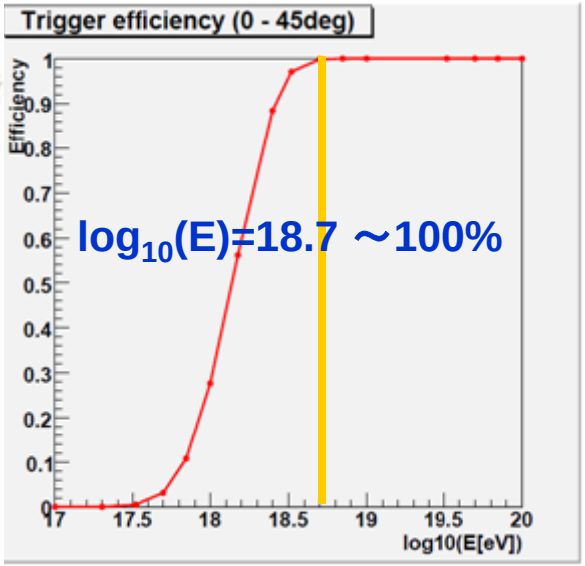


Complete FD Coverage of the scintillator array at 10^{19} eV and complete stereo hybrid coverage at 10^{20} eV

TA Surface Array







Counter Trigger

0. Wave form recording
   - >1/3 mip signal (160ns)
   - 740 counts/sec
1. List of large signal
   - >3mip signal (2560 ns)
   - ~20 counts/sec

Array Trigger:

>3 mip & 3 adjacent detectors (within 8 μ sec)

(+cross boundary trigger)

Save wave forms >0.3mip

$\pm 32\ \mu$ sec

Event Rate: ~20 trig/hr

Milestones

- 485 counters deployed 10/2006 - 3/2007
- Test with 3 small arrays: 6/2007
- Observations with 507 counters divided into 3 sub-arrays: 3/2008
- Observations with full array trigger: 11/2008