Recent measurement of the Telescope Array energy spectrum and observation of the shoulder feature in the Northern Hemisphere

147 members, 36 institutions, from US, Japan, Belgium, Korea, Russia, and Czech Republic

http://www.telescopearray.org

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Telescope Array

Hybrid detector

Millard County, UT

39.3˚ N , 112.9˚ W,

Alt. 1400m

(~880g/cm^2 of air)

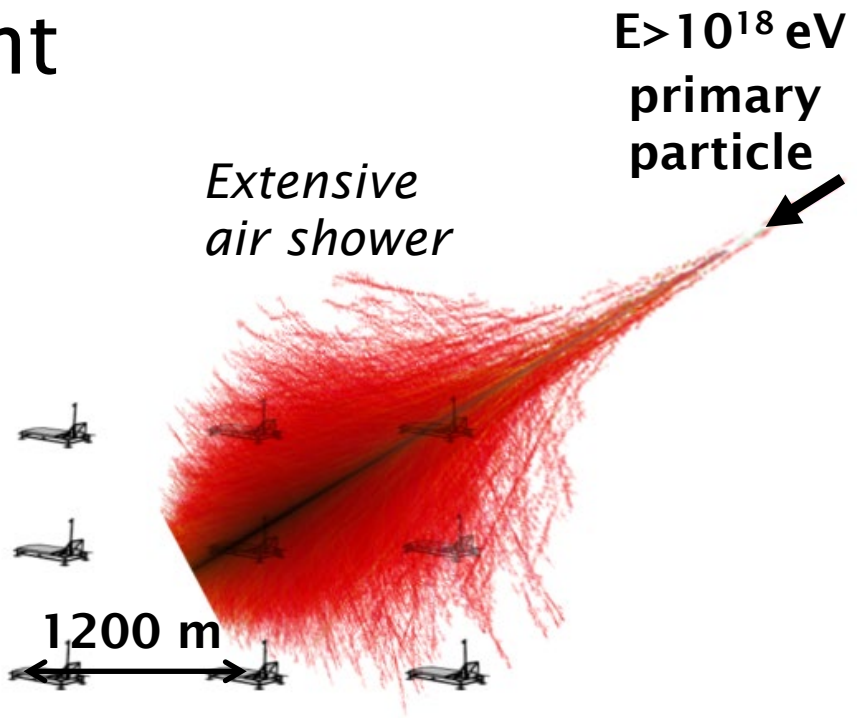
507 Surface Detector (SD) counters 1.2km apart

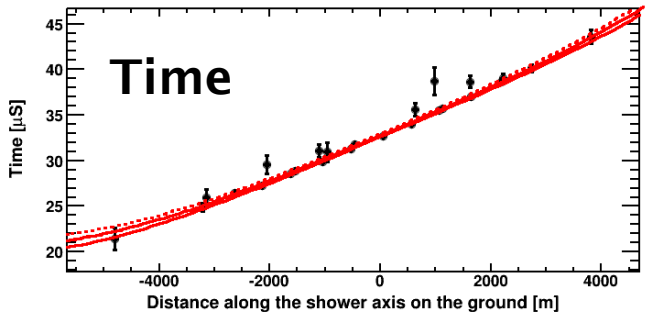
+103 TALE infill array counters of 400m and 600m spacing

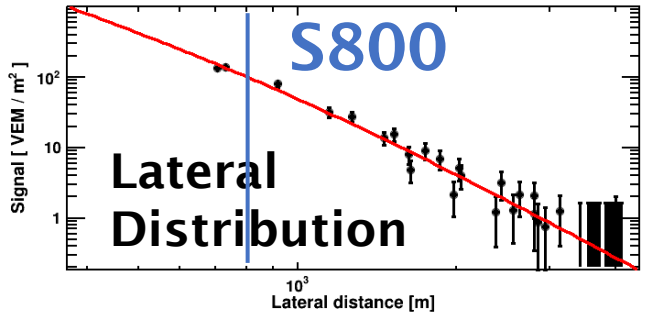
3 Fluorescence Detector sites (FD): BR/TAX4BR, LR, MD/TALE/TAX4MD

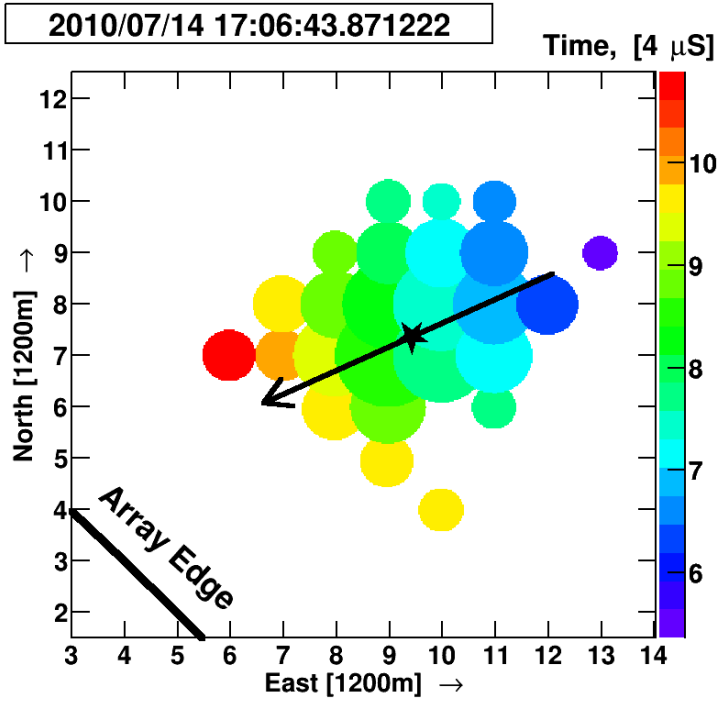
SD Event

- Plastic scintillation counters **sensitive to $e^{\pm}$, γ, $\mu^{\pm}$,** …
- **Time fit -> primary particle trajectory**
- **Lateral distribution fit** -> Signal Size 800 m (**S800**) from shower axis -> **primary particle energy**

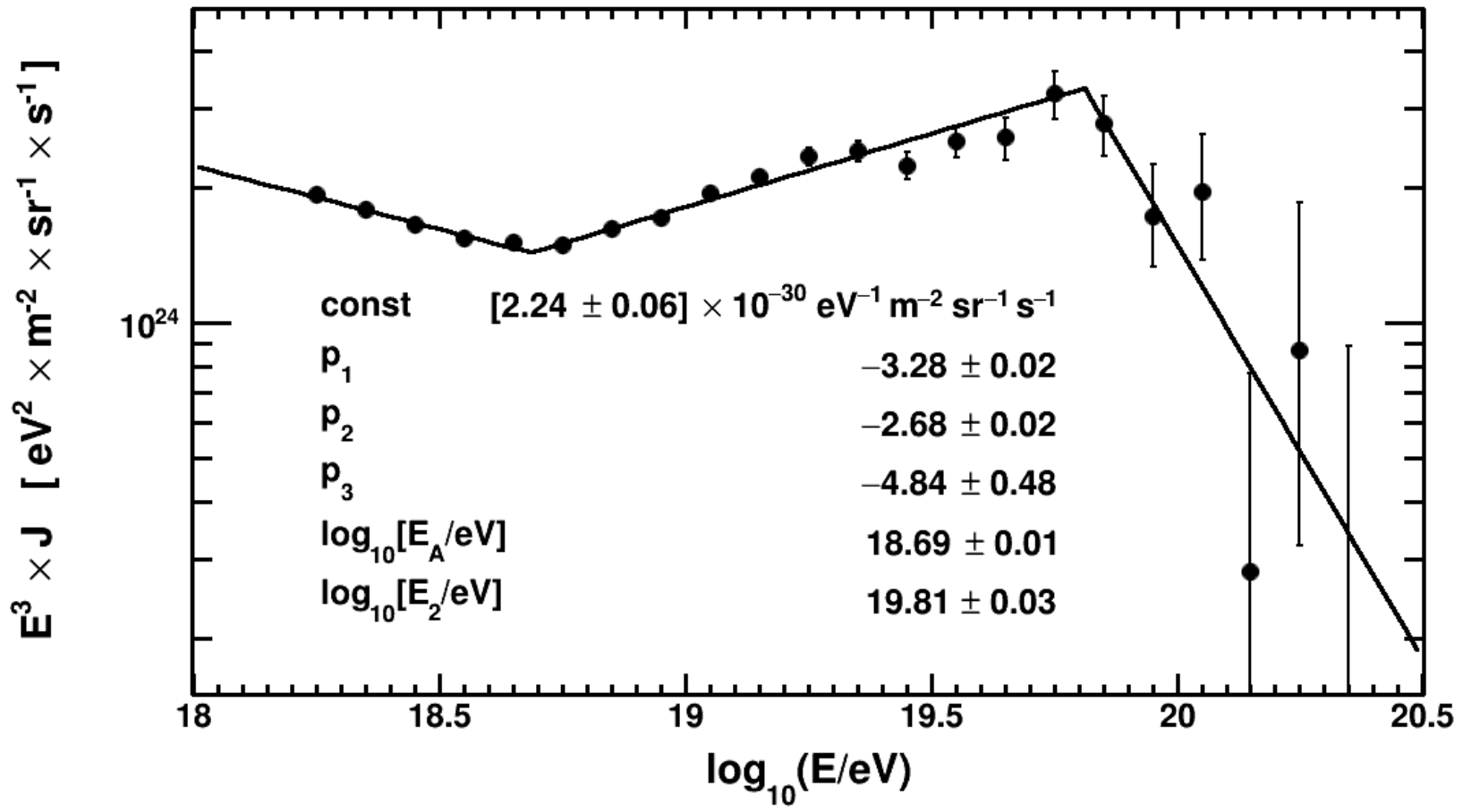








TA SD Spectrum (2008/05/11 – 2019/05/11)



TALE FD Monocular Events

Fluorescence event

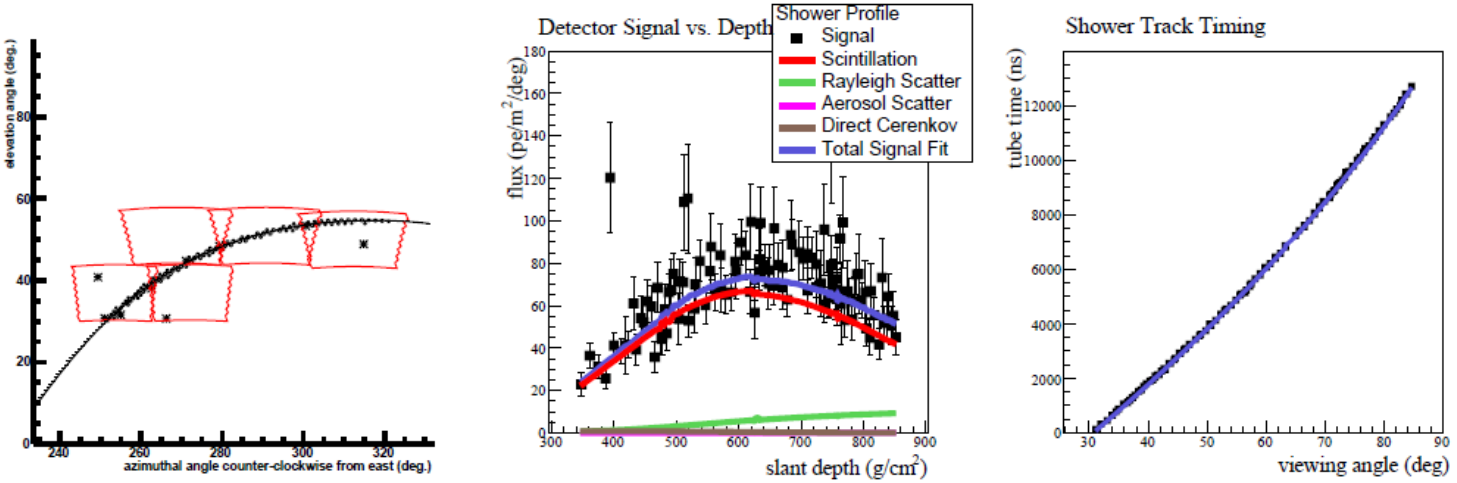


Figure 5: A five-telescope fluorescence event. The display panels show the event image (PMT trigger pattern), the reconstructed shower profile with relative contributions of FL/CL and scattered CL, and the time progression of triggered PMTs.

Cherenkov event, profile-constrained geometry fit.

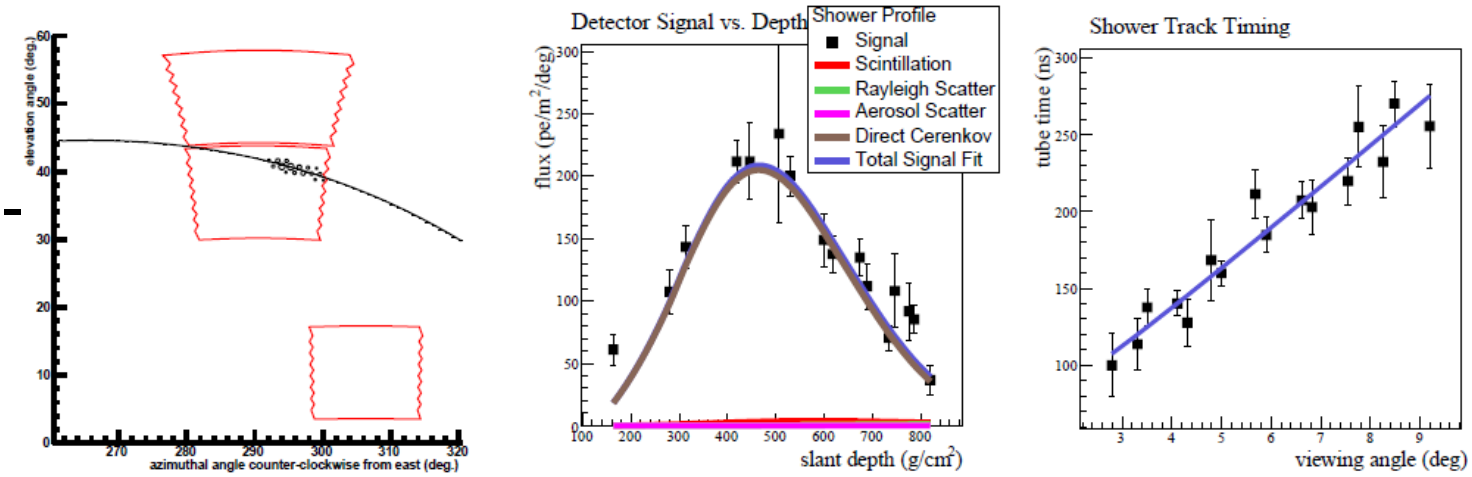
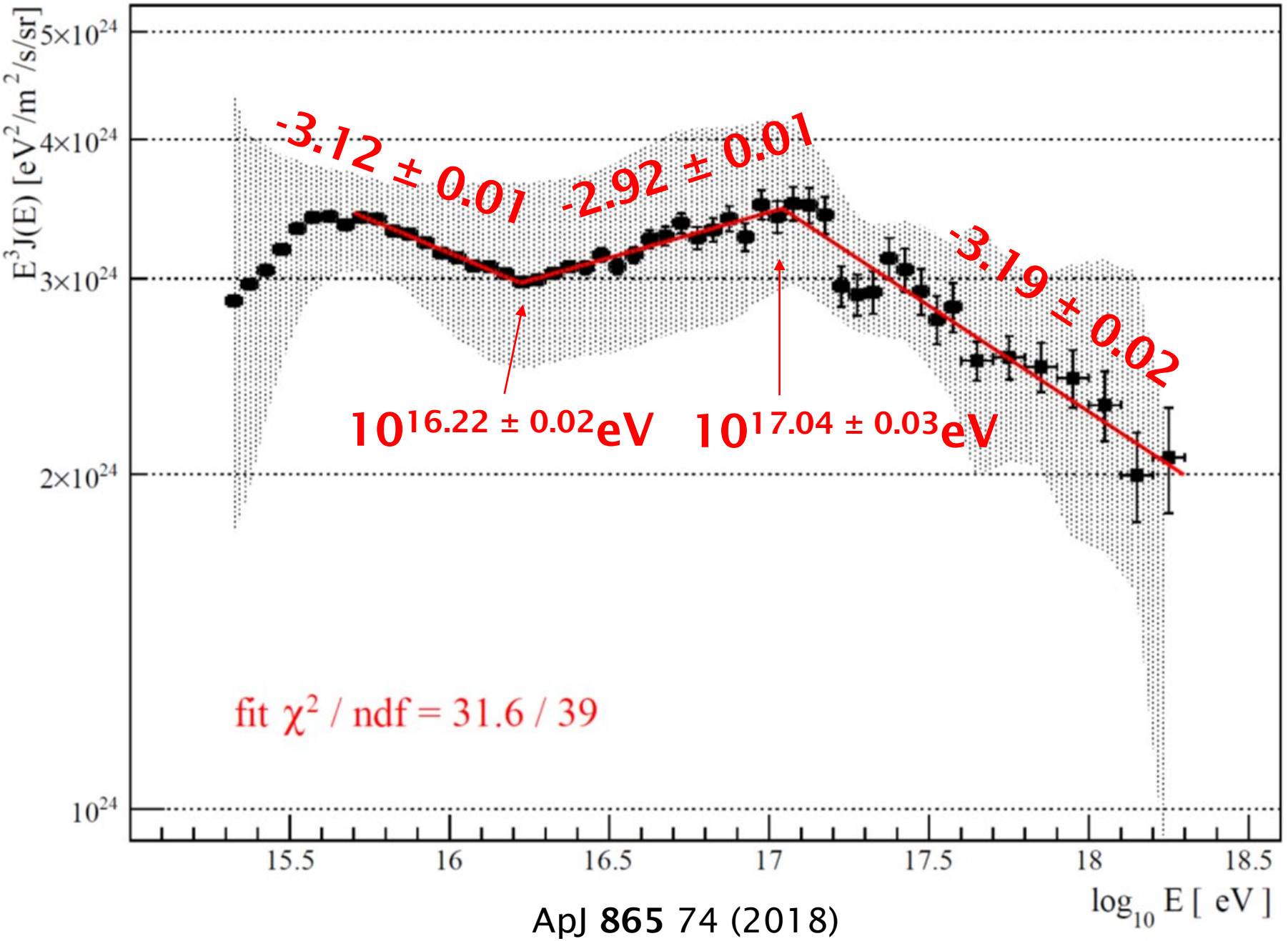


Figure 6: A one-telescope Cherenkov event. The display panels show the event image (PMT trigger pattern), the reconstructed shower profile with relative contributions of FL/CL and scattered CL, and the time progression of triggered PMTs.

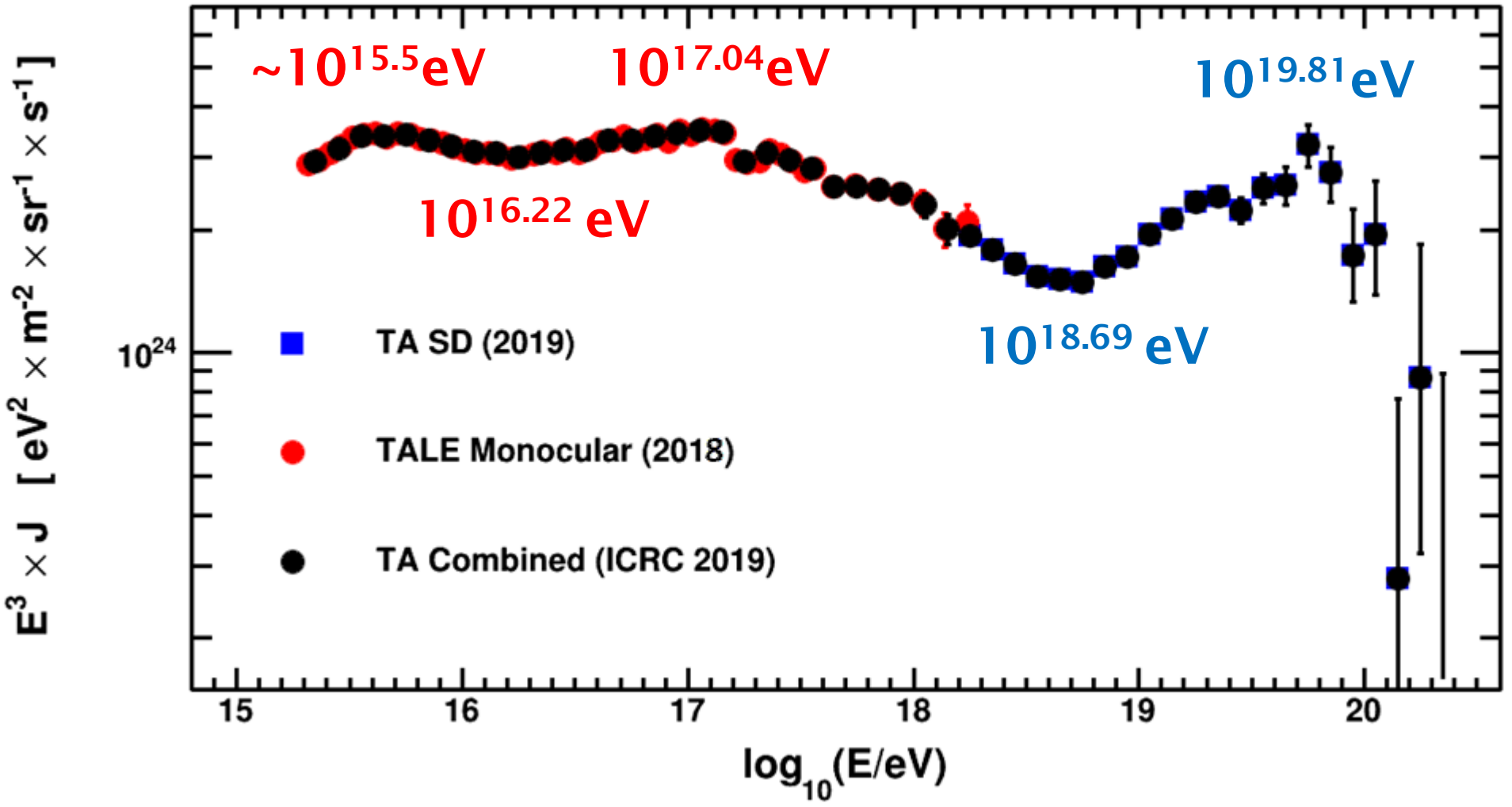
ApJ **865** 74 (2018)

TALE FD Monocular Spectrum

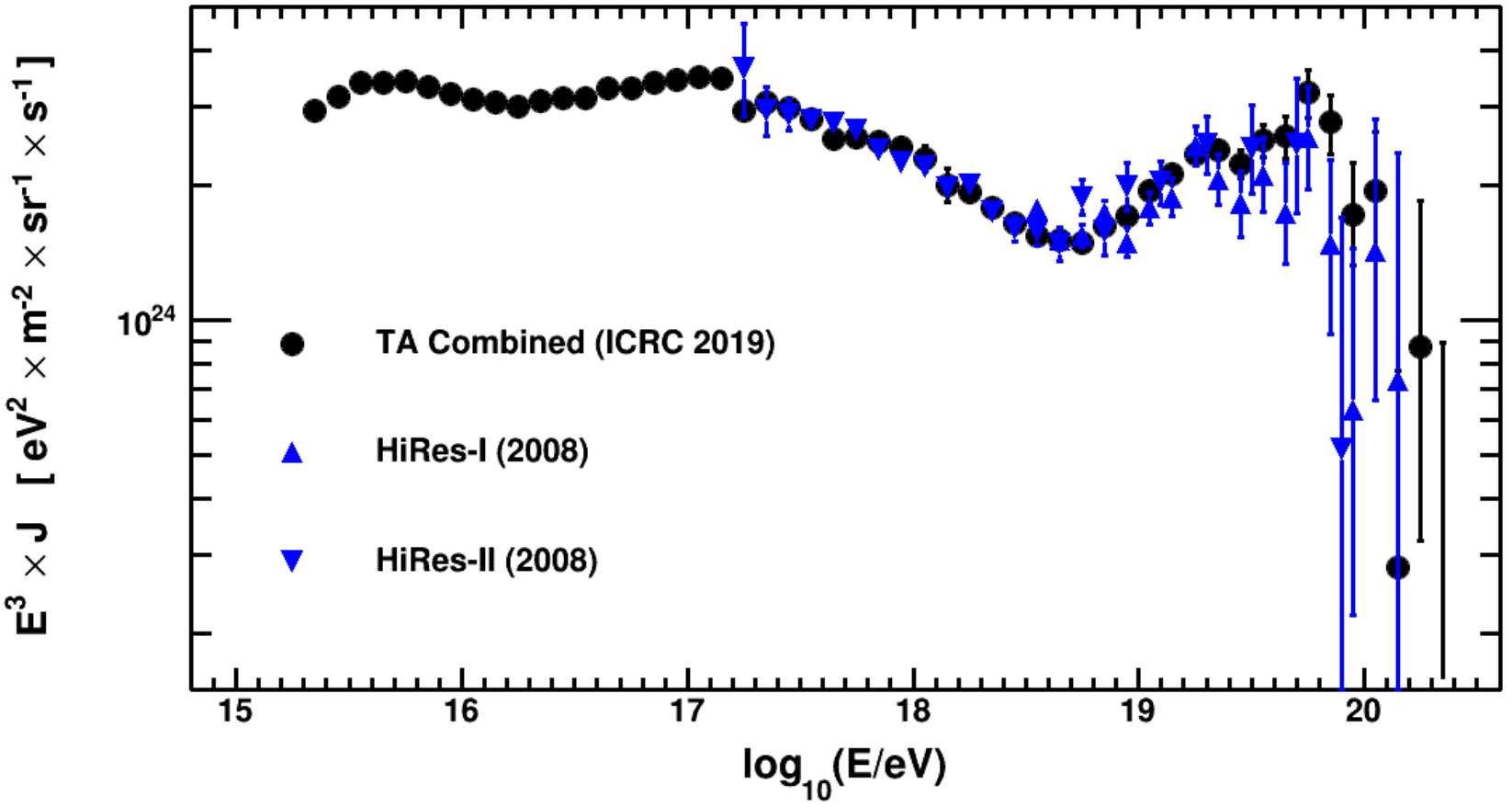


ApJ **865** 74 (2018)

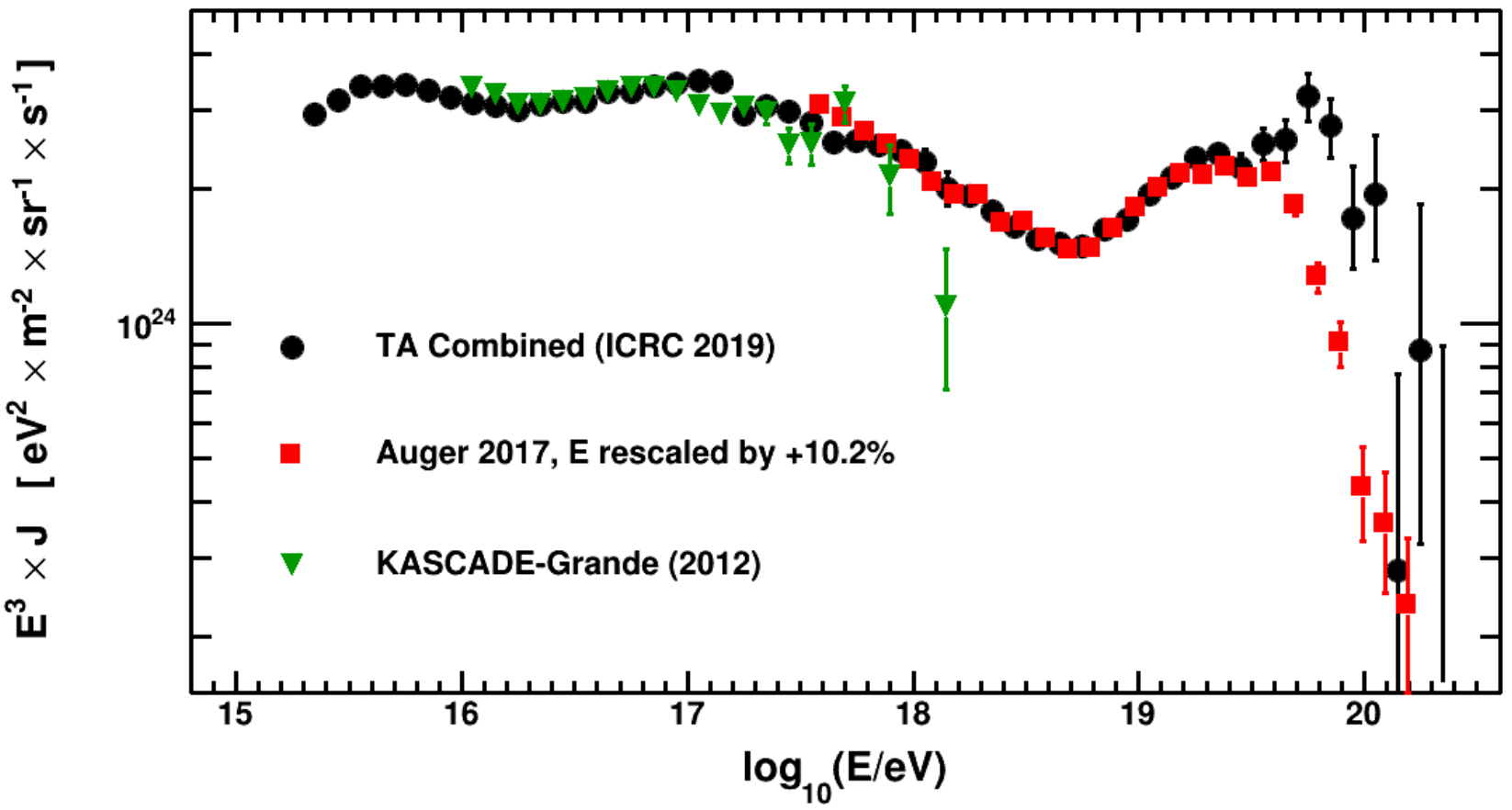
Combined TA Spectrum



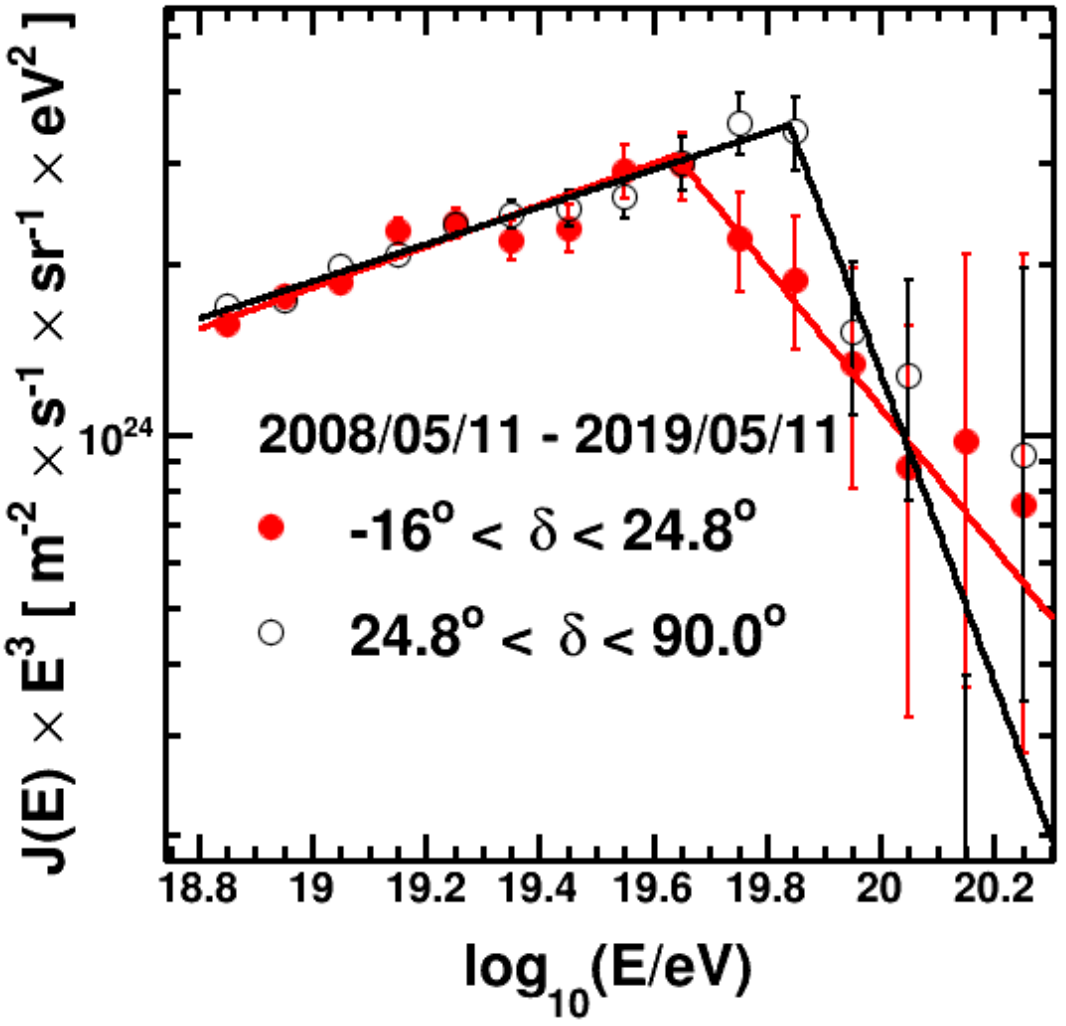
Compare with HiRes



Compare with KASCADE-Grande and Auger

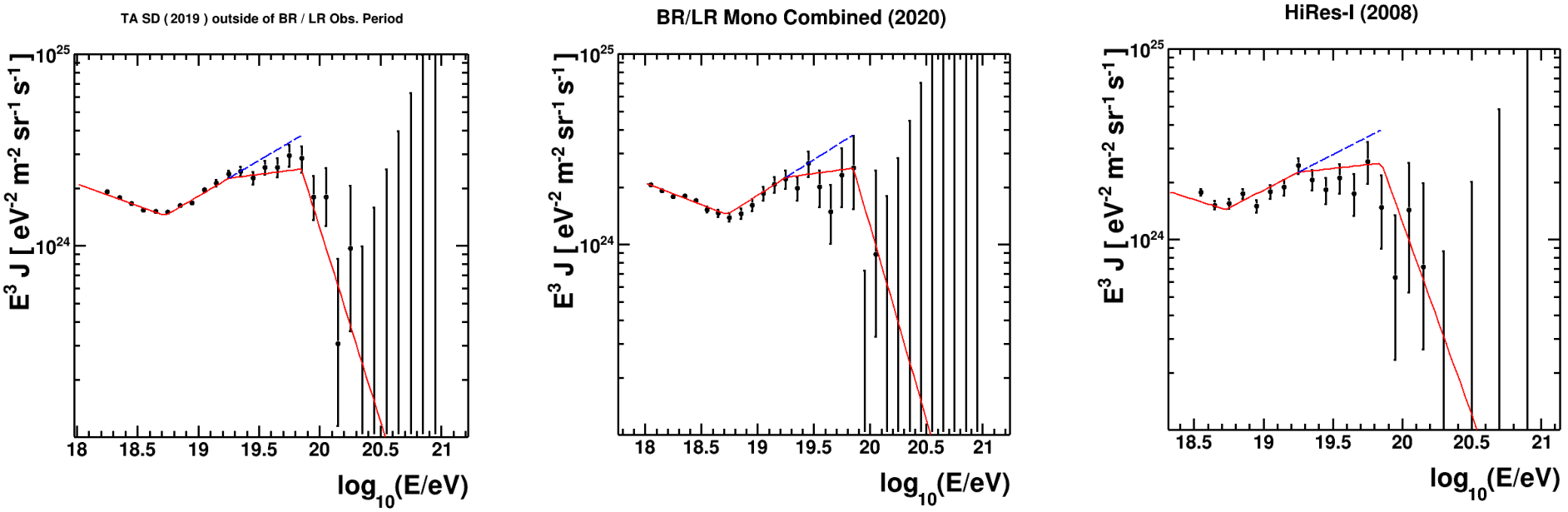


Declination dependence of the energy spectrum



- Cutoff energies in lower and higher declination bands now 4.7 σ different.
  - **4.3 σ global chance probability of the effect**
- **Strong evidence of cosmic ray spectrum declination dependence in the Northern Hemisphere**

Confirming the new spectral feature first reported by the Pierre Auger Observatory



- Pierre Auger found a spectrum hardening in 10^{19} – $10^{19.5}$ eV range
- Combining TA SD, FD and HiRes data, we observe the same *Shoulder* feature in the Northern Hemisphere at $10^{19.25\pm0.03}$ eV with a 5.3 σ significance:
  - In the absence of the Shoulder feature, one expects 1269.3 events in HiRes - TA data
  - HiRes and TA observe 1086 events
  - The chance probability of this being a random fluctuation is 7.4×10^{-8}

Summary

- Cosmic ray spectrum measured over 5 orders of magnitude in energy by TA and TALE
- Detected 5 spectral features
- Strong evidence of the spectrum anisotropy in the Northern Hemisphere at the highest energies
- HiRes and TA confirm the spectrum shoulder feature first reported by the Pierre Auger Observatory above 10^{19} eV