Summary of Results from the Telescope Array Experiment
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Telescope Array (TA)

- Utah, USA. ~200 km from Salt Lake City
- Hybrid: 507 SD @ 1.2 km separation, ~700 km²
- 3 FD: Black Rock/Long Ridge/Middle Drum(+TALE)
- Operating since 2008
TA Low Energy Extension (TALE)

- 10 new telescopes with larger elevation angles (31-59°) allow to observe showers at lower energies
- Lower threshold because of a smaller spacing
TA SD detector

- **wLAN (2.4GHz)**
- **solarpanel (120w)**
- **GPS**
- **scintillator box**
- **electronics box + battery (100Ah)**

- WLSF: 1.0mmφ (2cm separation)
- PMTs: ET 9123SA × 2
- 3m² (12mm × 2 layers)
TA Fluorescent Detectors

Middle Drum
14 telescopes @ station
256 PMTs/camera
5.2 m²
Reutilized from HiRes-I

Long Ridge

Black Rock Mesa
12 telescopes/station
256 PMTs/camera
~1 m²
6.8 m²
Hybrid event
TA results

• Spectrum
**TA SD spectrum (9 years of data)**

**fit to broken power law**

Power index $=-3.27 \pm 0.03$

Power index $=-2.69 \pm 0.02$

Power index $=-4.63 \pm 0.49$

Log($E$/eV) Ankle $=18.69 \pm 0.02$

Log($E$/eV) GZK $=19.81 \pm 0.04$

Normalized Log Likelihood / NDOF = 21.96/22

N_EXPECT (> GZK, no cut-off) = 79.8

N_OBSERVE (data > GZK) = 22

GZK CHANCE PROBABILITY $= 2 \times 10^{-12} \sim 7\sigma$

BEREZINSKY E_1/2, log10(E/eV) $= 19.80 \pm 0.05$

ICRC2017
TALE mono spectrum (3.5 years of data)

**Knee**

- **Break Point:** 17.04 +/- 0.032
- **Slope before:** 2.86 +/- 0.012
- **Slope after:** 3.19 +/- 0.018

- **Break Point:** 16.25 +/- 0.015
- **Slope before:** 3.21 +/- 0.012
- **Slope after:** 2.87 +/- 0.010
Combined spectrum (1/2)

\[ E^3 \frac{d^2N}{dE d\Omega} \text{[eV}^2\text{m}^2\text{sr/s]} \]

TA SD 9 years
- TA FD mono 9 years
- TALE Cherenkov

\[ \log_{10}(E/\text{eV}) \]

15 16 17 18 19 20
• Composition
$<X_{\text{max}}>$ from BRM/LR hybrid analysis


arXiv: 1801.09784
Composition from $X_{\text{max}} + \sigma_{X_{\text{max}}}^{(1/2)}$

- **Data vs MC**
- **Compare both $X_{\text{max}}$ and $\sigma_{X_{\text{max}}}$**
- **Data – rectangles, MC – contours**
- **Single primary, 5000 MCs**
- **At low energies data with a 10-20 g/cm$^2$ shifts looks like protons**

arXiv:1801.09784
Composition from $X_{\text{max}} + \sigma_{X_{\text{max}}}$ (2/2)

- At higher energies primaries seem to be heavier than protons
- Small statistics
- Future: TA SD, see poster #27 Y. Zhezher “Composition studies with the Telescope Array surface detector data”
Telescope Array

• Anisotropy
• KS p-value 0.01 data/iso for E>57 EeV in SG lat
• All other distros (E, longitude) are compatible
• In the SGP region break is higher @ 3.2σ
C: Centaurus SCI (60 Mpc); Co: Coma Cl (90 Mpc); E: Eridanus Cl (30 Mpc); F: Fornax Cl (20 Mpc); Hy: Hydra SCI (50 Mpc); N: Norma SCI (65 Mpc); PI: Pavo-Indus SCI (70 Mpc); PP: Perseus-Pisces SCI (70 Mpc); UM: Ursa Major Cl (20 Mpc); and V: Virgo Cl (20 Mpc).

- Sky map of expected flux at $E > 57$ EeV (Galactic coordinates);
- smearing angle is 6°.
E > 1.0 \times 10^{19} \text{ eV}

E > 4.0 \times 10^{19} \text{ eV}

E > 5.7 \times 10^{19} \text{ eV}

Consistent with LSS Inconsistent with isotropy

E>5.7\times10^{19} \text{ eV}
Hotspot 2014, 5 years

Total events: 72
Observed: 19
Expected: 4.5

Best circle center: RA=146.7°, Dec=+43.2°
Best circle radius: 20°
Local significance: 5 σ
Global significance: 3 σ
Total events: 143
Observed: 34
Expected: 13.5

Best circle center: RA=144.3°, Dec=+40.3°
Best circle radius: 25°
Local significance: 5 σ
Global significance: 3 σ
Coldspot 2017, 9 years

- 'Coldspot' at $10^{19.2} - 10^{19.7}$ eV
- Very close to hotspot
- 3.7σ global significance
• Future
- TAx4 now under construction:
- Will double TA data sample by mid-2021
• Extended results
TA 9 yrs exposure

\[ \text{[Area } \times \text{ FoV } \times \text{ Time}] \]

\[ \theta < 45^\circ \]

8100 km\(^2\) sr yr

TA 7 years (ICRC2015)

SD 9 years
2008/May/11 - 2017/May/11

BRLR FD mono 9 years
2008/May/11 - 2017/May/11

TALE Cherenkov
2014/Jun - 22 months
TALE 4 yrs exposure

TALE Aperture (Any: Ckov/Scin/Mixed)

- Black: combined
- Red: Cerenkov
- Blue: Fluorescence
- Green: Mixed
Energy spectra of TA and Auger in the common declination band. The locations of the high energy breaks agree to within $1\sigma$.

Energy spectra of TA above and below $\delta=24.8^\circ$. The locations of the breaks disagree at $\sim4\sigma$ level.
$\tau X_{\text{max}}$ distributions

arXiv: 1801.09784
Comparison of PAO and TA compositions

average difference: \( \langle \Delta \rangle = (2.9 \pm 2.7 \text{ (stat.)} \pm 18 \text{ (syst.)}) \text{ g/cm}^2 \)