Recent Results on Ultra-High-Energy Cosmic Rays from the Telescope Array Experiment

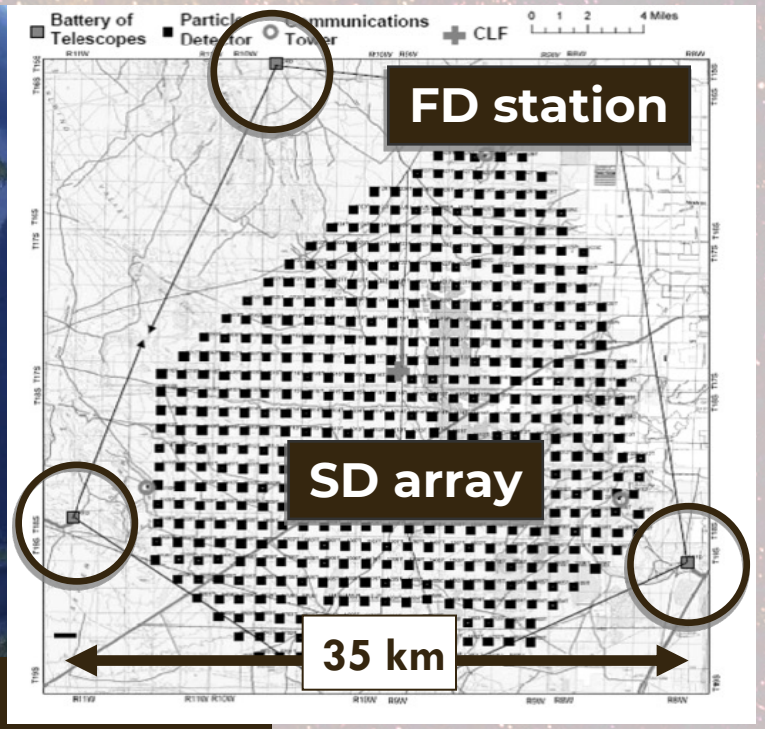
Kudenko Maria (INR RAS)
on behalf of the Telescope Array Collaboration

Photo by O. Kalashev

Telescope Array

The largest CR observatory in the northern hemisphere.





- Delta, Utah, USA. ~1400 m above sea level
- 507 surface detector array covers ~**700 km²**
- 38 telescopes in 3 stations look over the array

Surface Detector: Plastic Scintillator

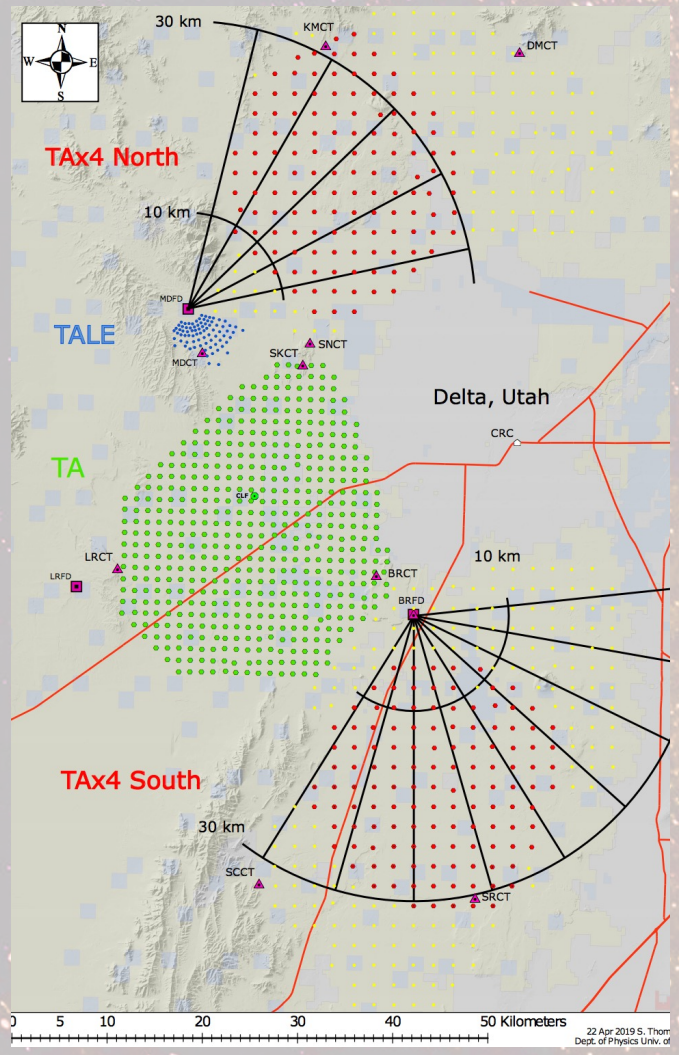


Fluorescence Detector: PMT camera

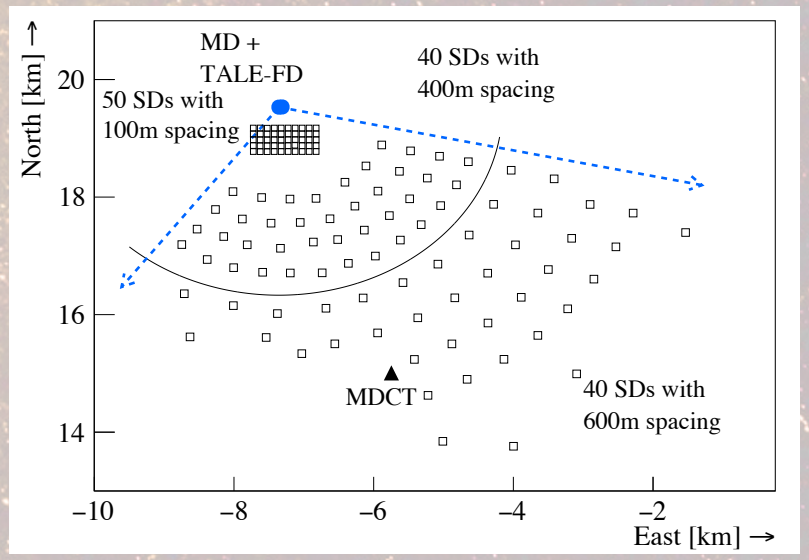


129 members, 30 institutes, 9 countries

Telescope Array







2008 – TA started its operation.

2013 – **T**elescope **A**rray **L**ow-energy **E**xtension (TALE) was deployed.

Goal: get lower energy data.

2019 – TAx4 deployment began.

Goal: increase statistics by extending SD coverage by a factor of 4.

Energy range:

From ~1 PeV to ~100 EeV

Telescope Array



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Scientific goals:

Origin and nature of UHECR:

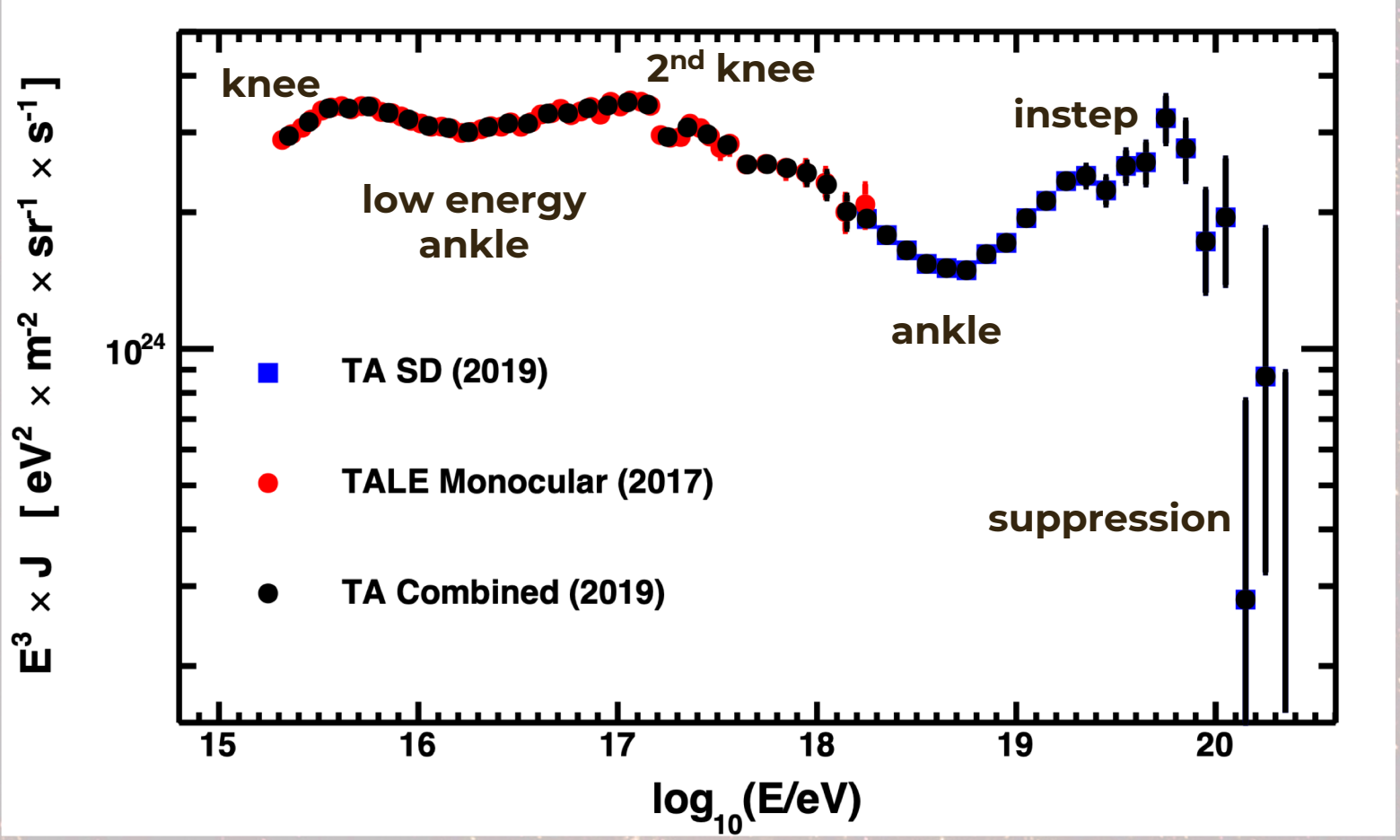
- Spectrum, composition, anisotropy

Physics of high energy hadronic interactions

Multi-messenger and interdisciplinary studies:

- Photons, neutrinos, dark matter
- Thunderstorms, terrestrial gamma-ray flashes

Energy spectrum

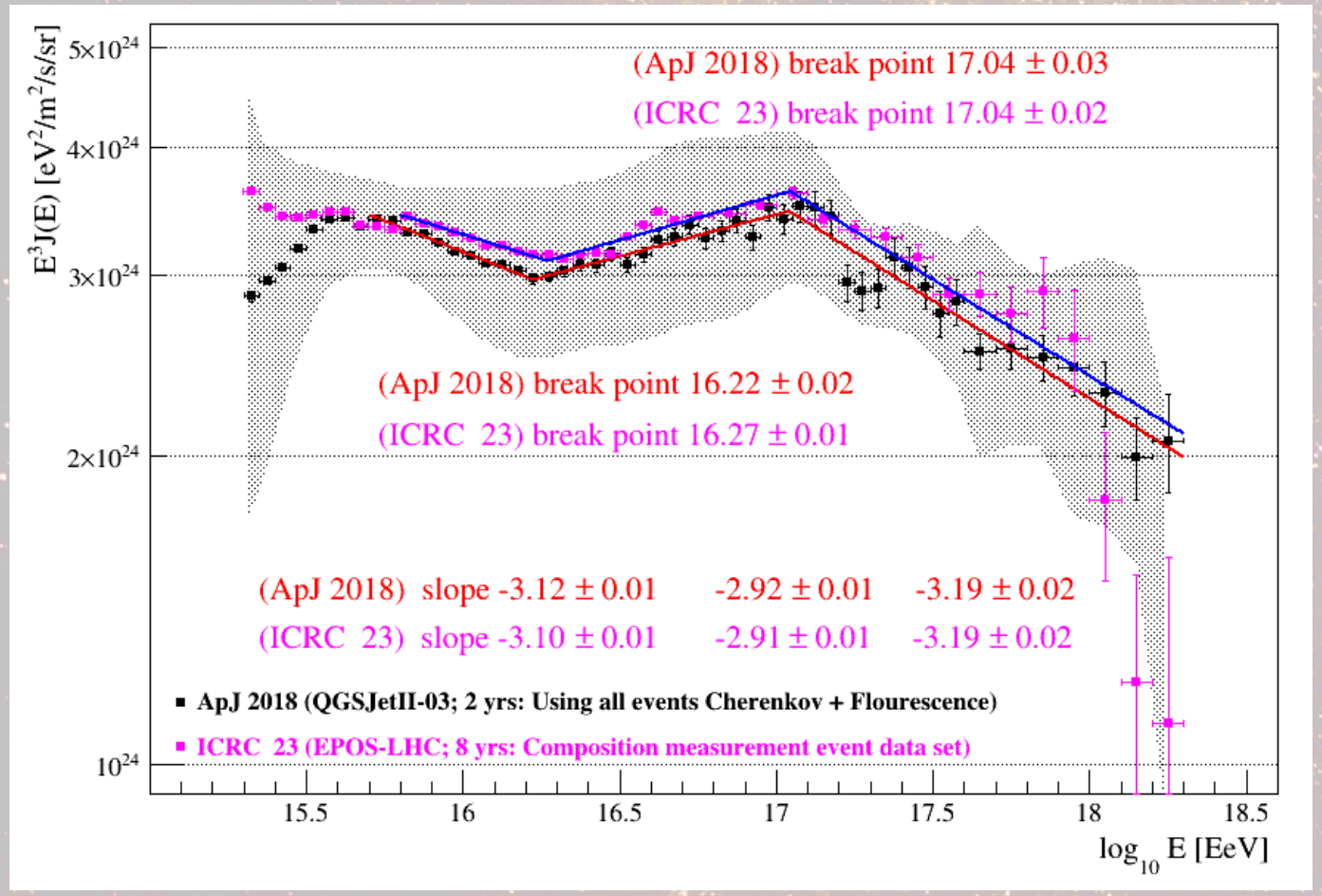


	$\log_{10}(E/\text{eV})$
Knee	~15.5
Low energy ankle	16.22 ± 0.02
2nd knee	17.04 ± 0.04
Ankle	18.73 ± 0.01
Instep	19.25 ± 0.03
Suppression	19.85 ± 0.03

D. Ivanov, PoS(ICRC2019)298

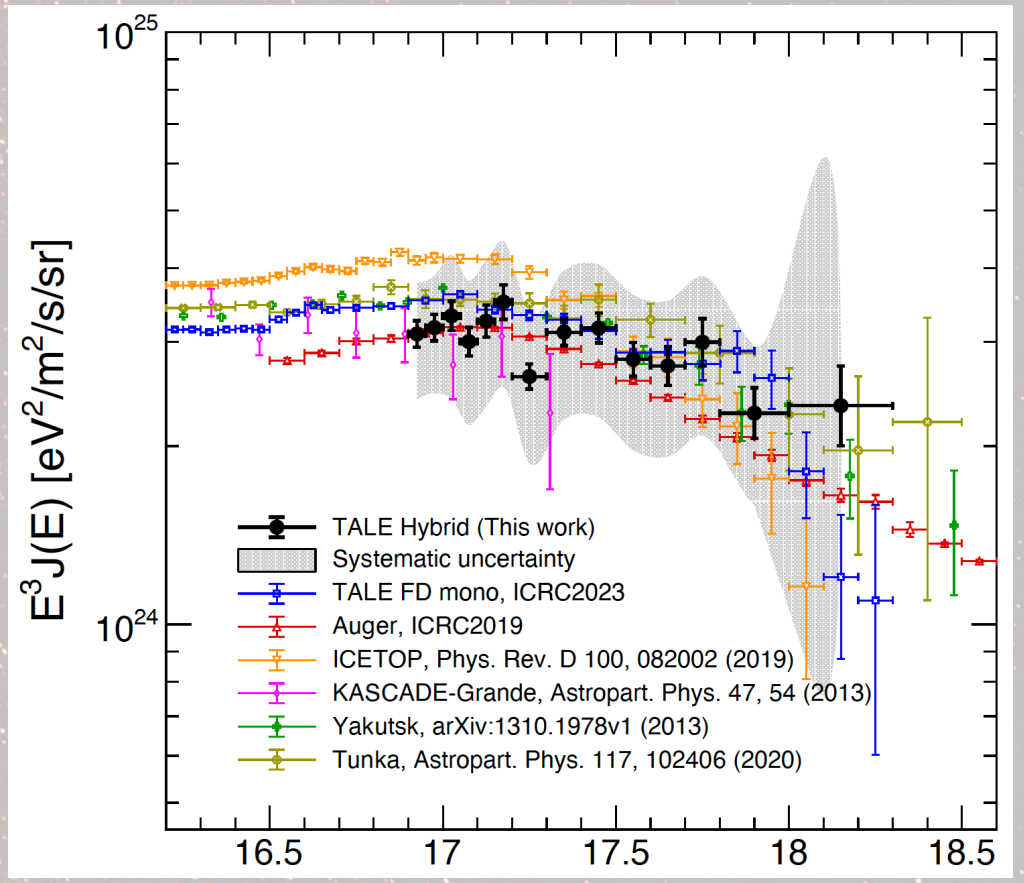
Energy spectrum. Updates

TALE FD Monocular Data



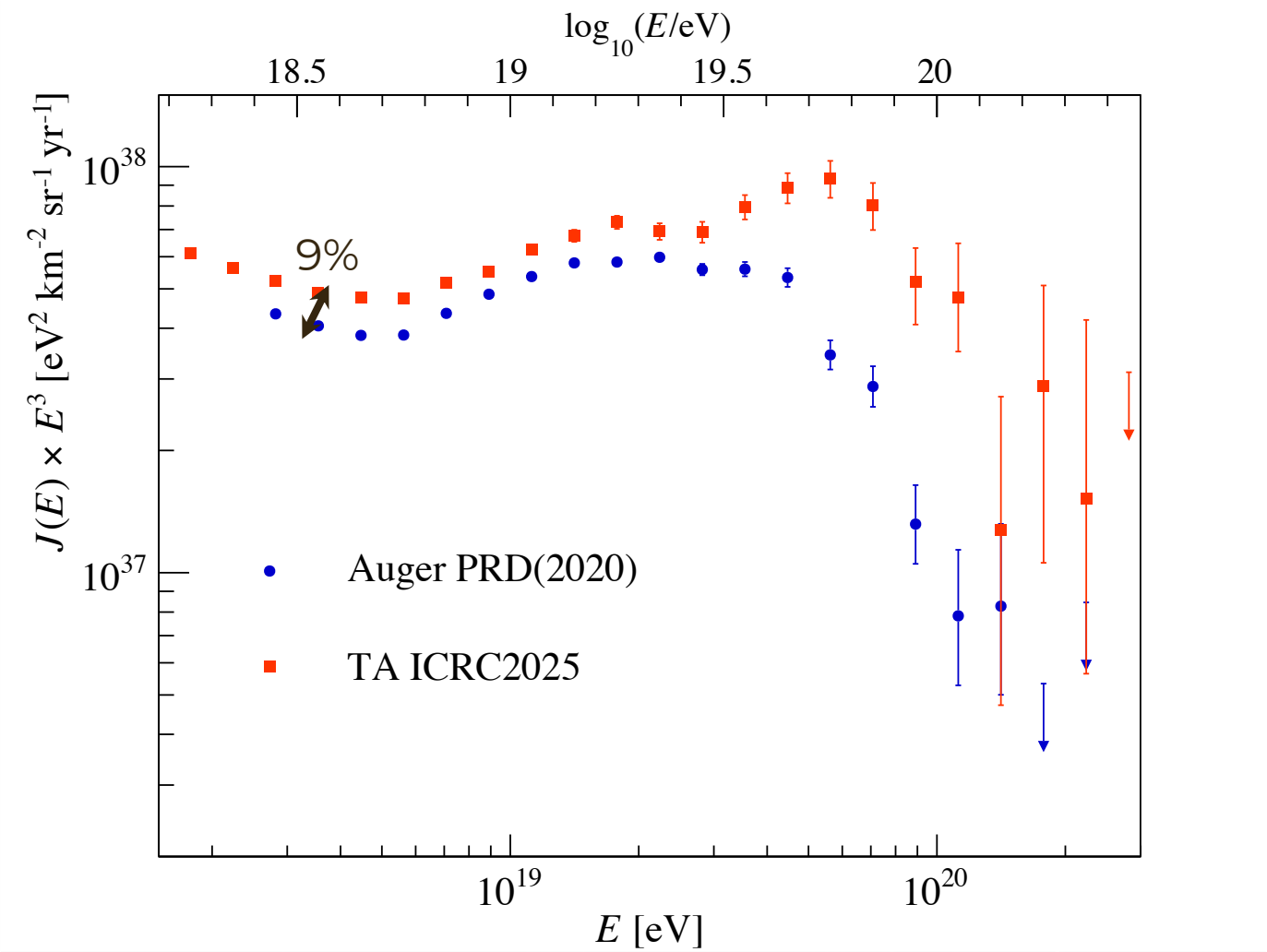
T. AbuZayyad, PoS(ICRC2023)379

TALE Hybrid Data



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Energy spectrum. Comparison



Differences in energy reconstruction between PAO & TA:

- fluorescence yield

  TA/Auger ~ 1.14

- invisible energy correction

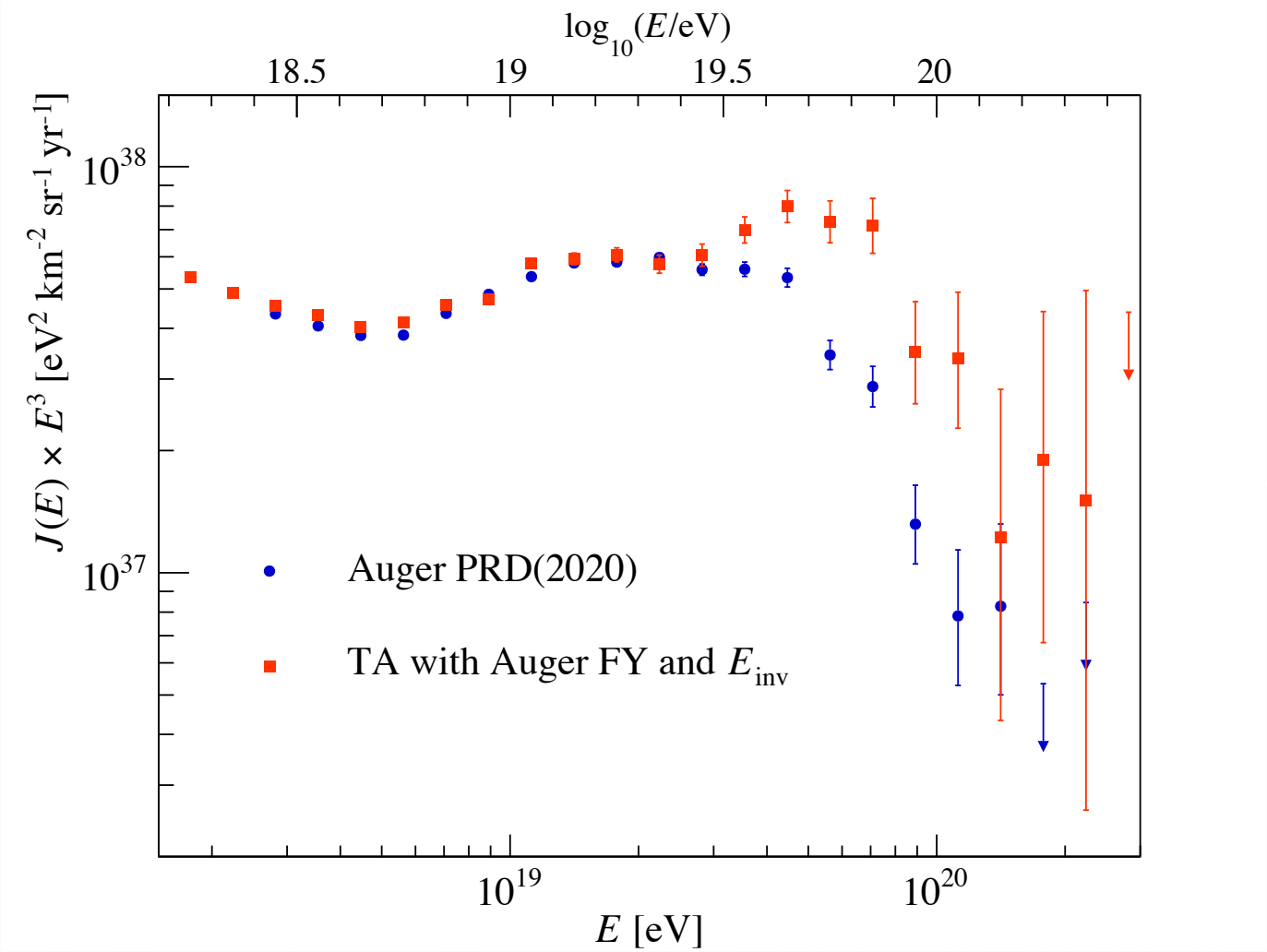
  Auger: data-driven empirical formula

  TA: estimated from proton MC

  TA/Auger ~ 0.93

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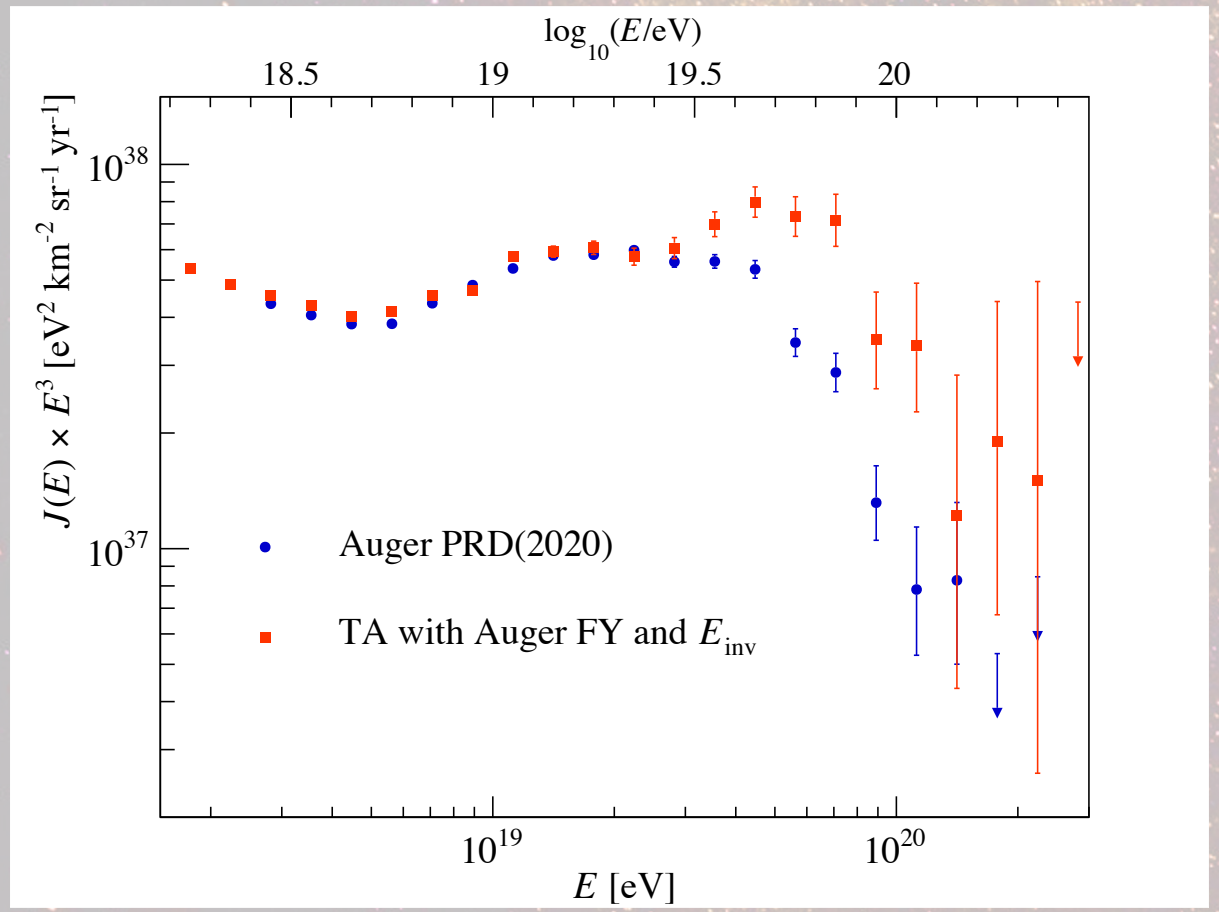
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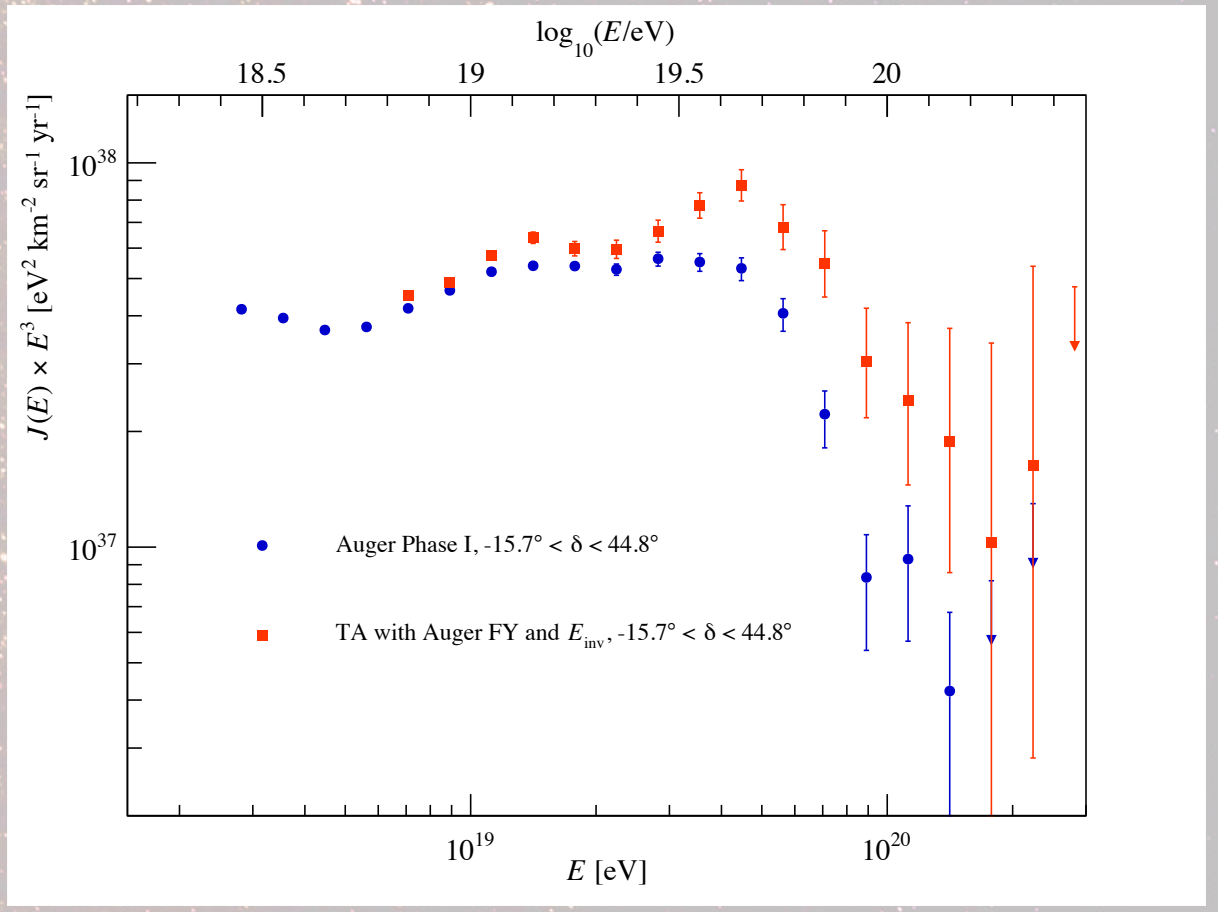
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Energy spectrum. Comparison

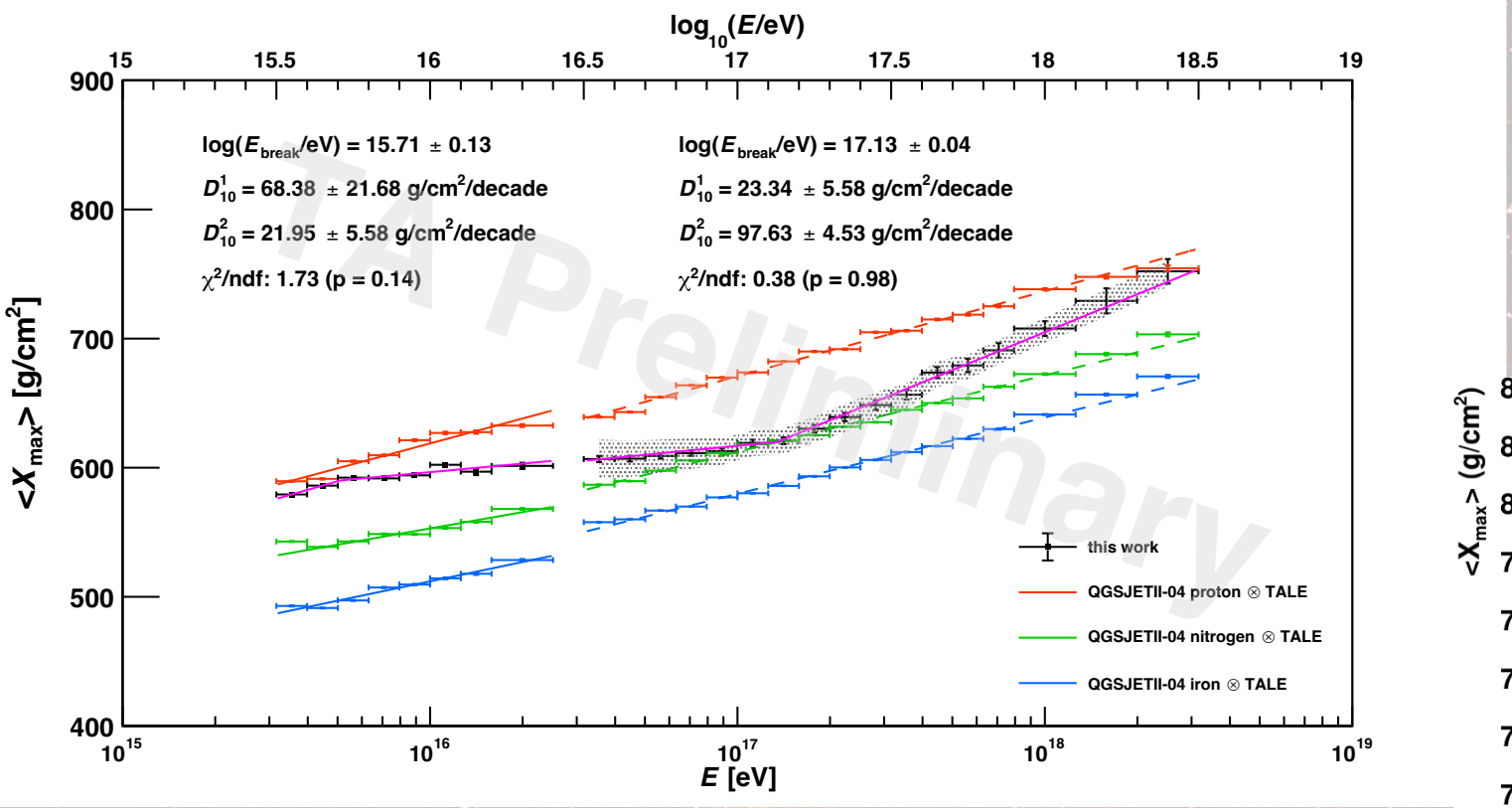
Common sky : $-15.7° < \delta < +44.8°$





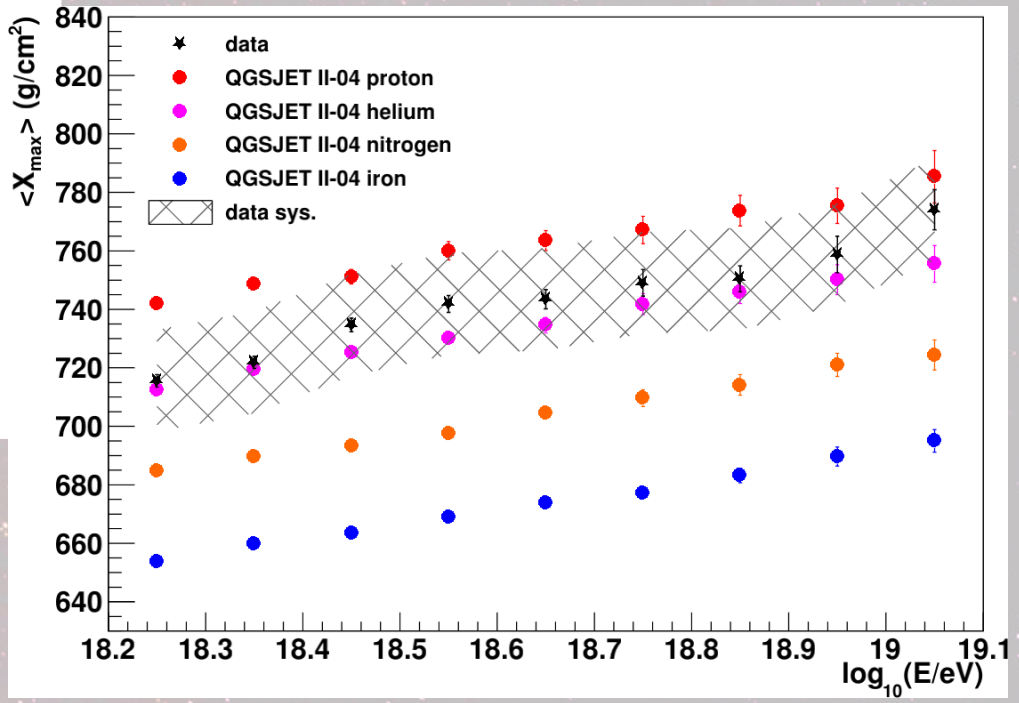
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Mass composition

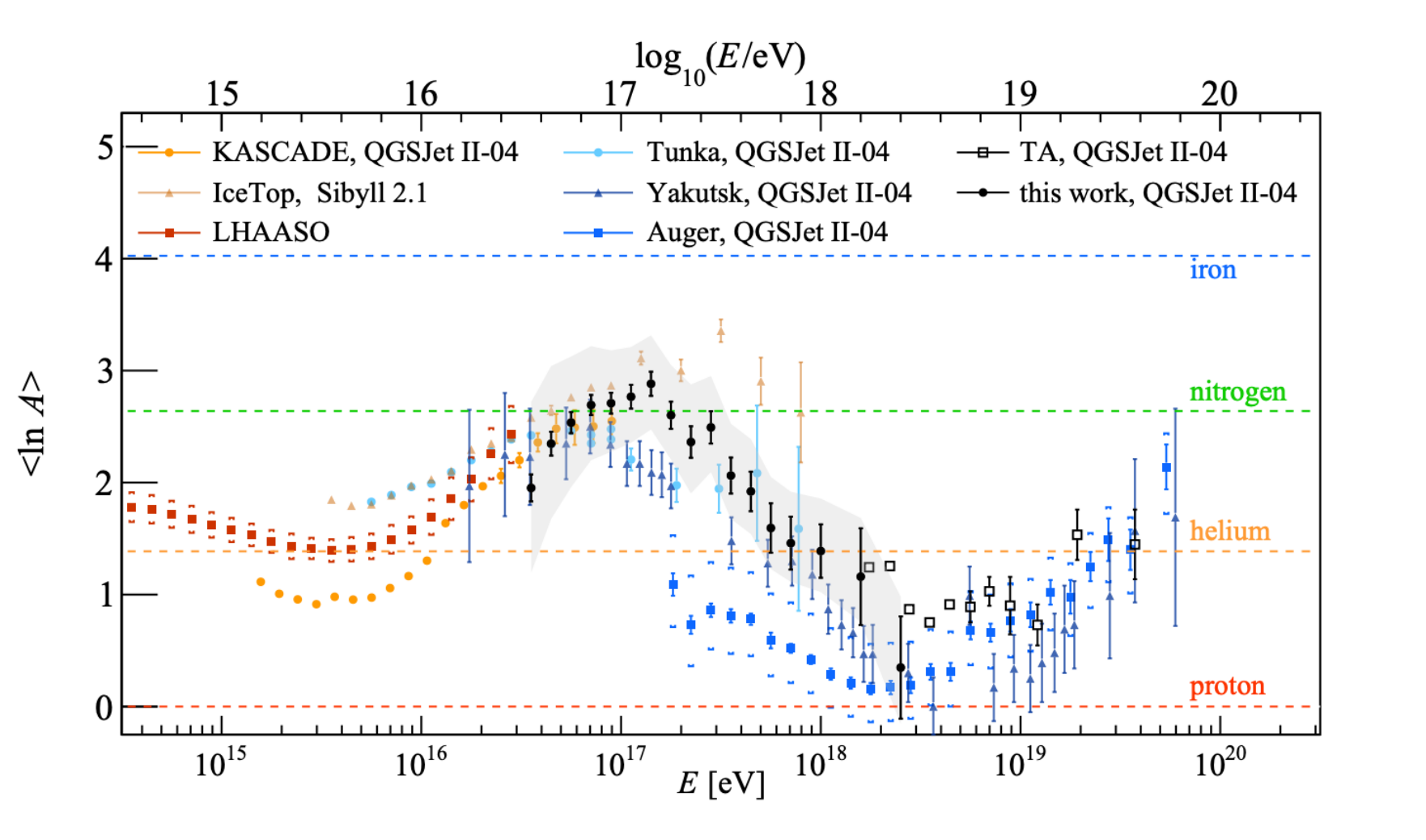


Abbasi et al. 2018 *ApJ* 858 76
K. Fujita, PoS(ICRC2025)261
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- Breaks in the $\langle X_{max} \rangle$ coincide with the knee and second knee.
- X_{max} distribution fits show a transition from light to heavy composition, peaking near $10^{17.13}$ eV.



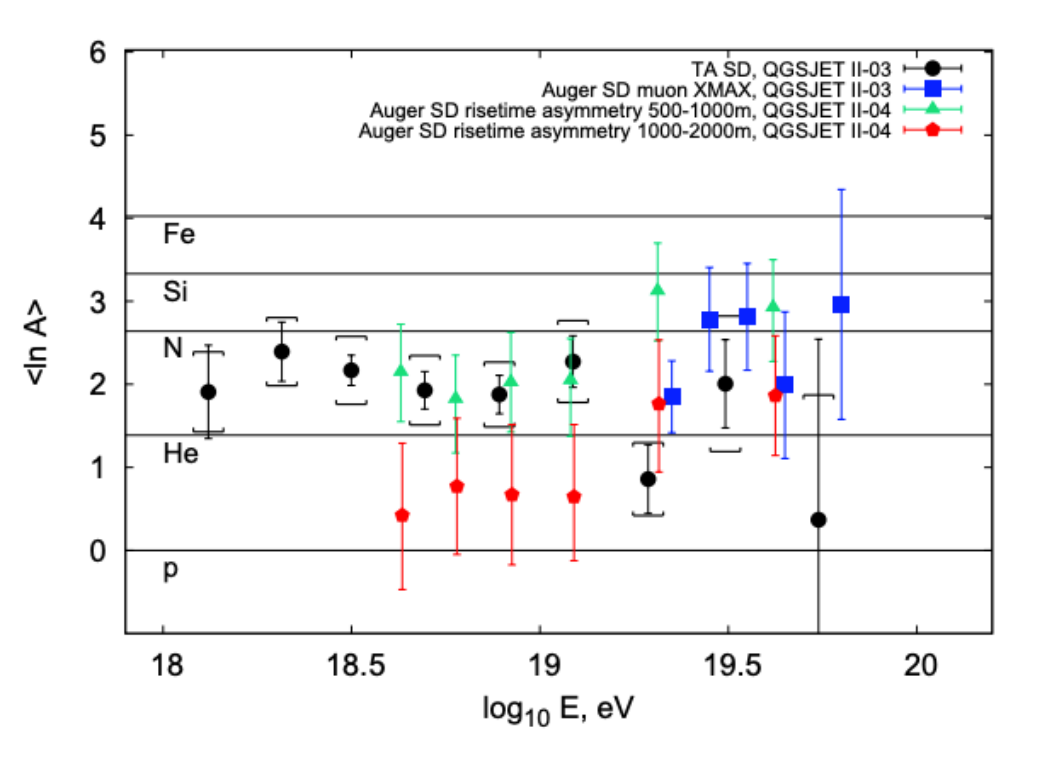
Mass composition. Context



Above ~100 PeV discrepancy with IceTop and PAO becomes evident.

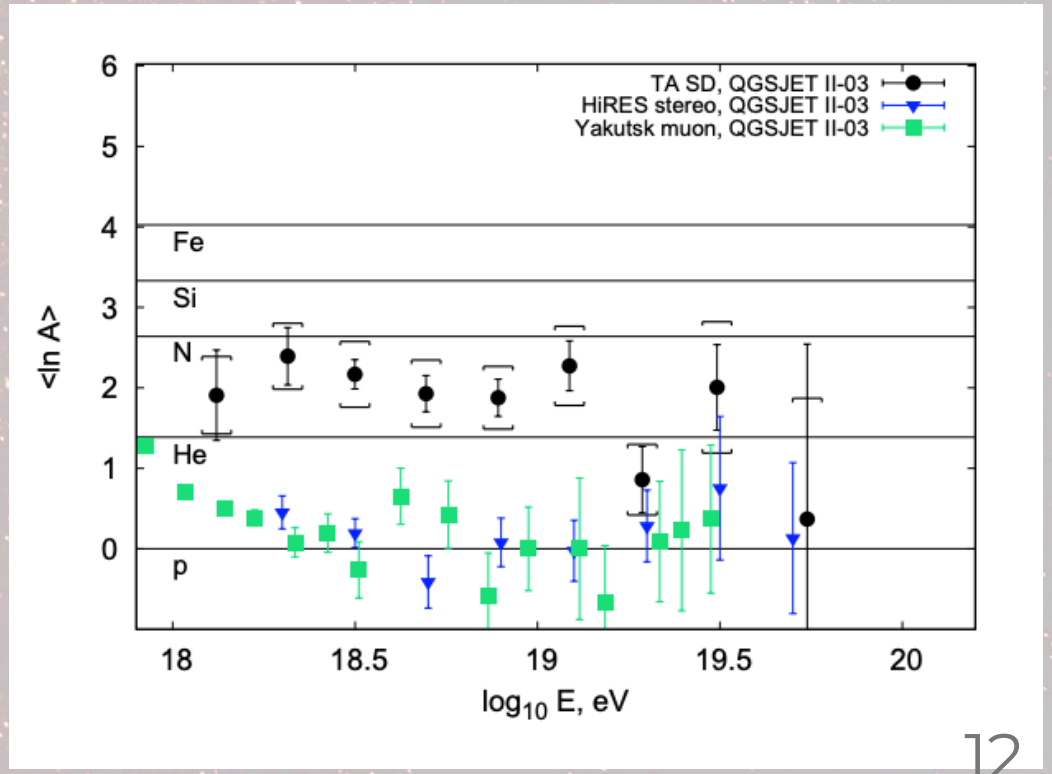
Phys.Rev.D 113 (2026) 6, 062003

Mass composition with ML

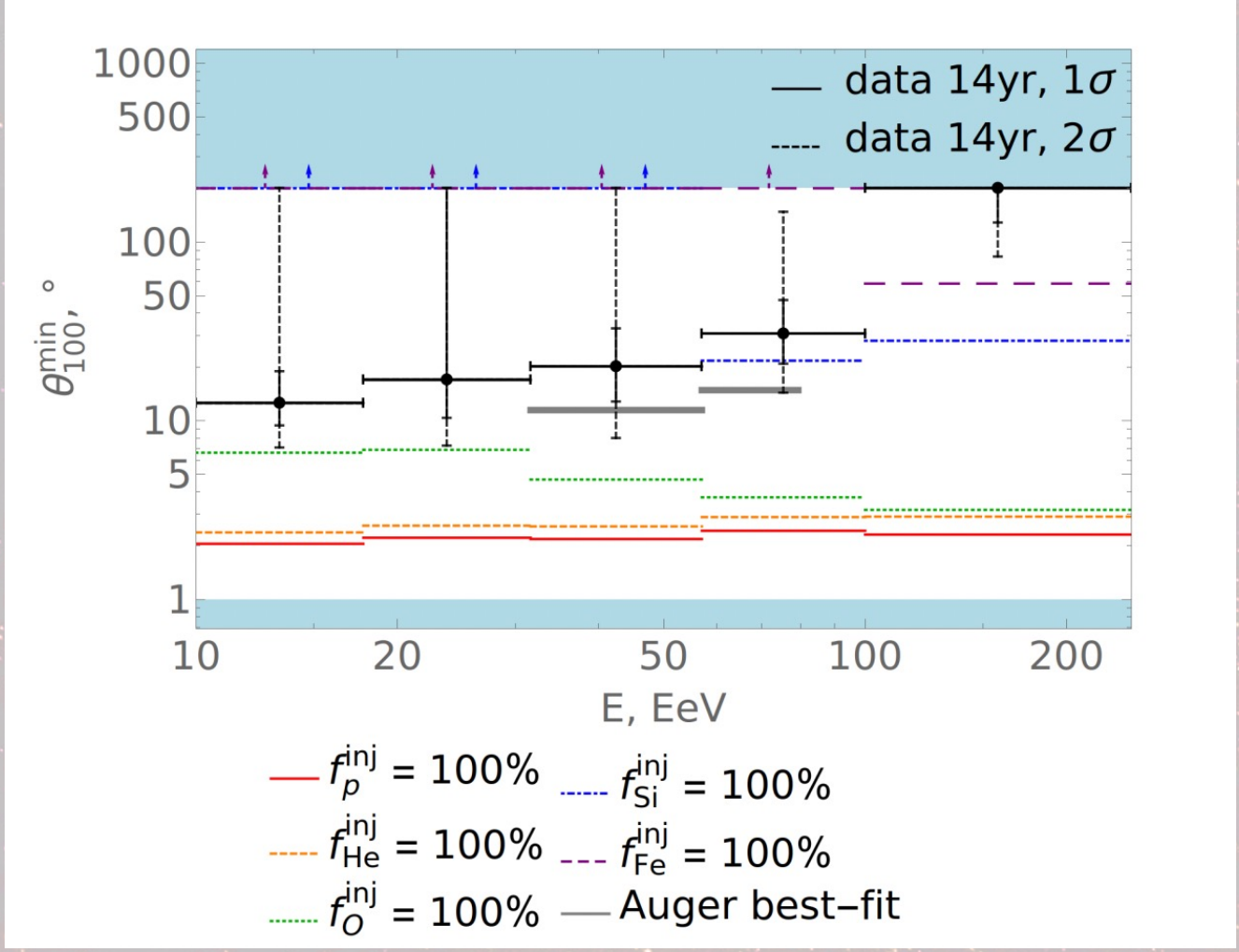


Phys.Rev.D 99 (2019) 2, 022002

In this approach multivariate boosted decision tree is used.



Mass composition from anisotropy of arrival directions

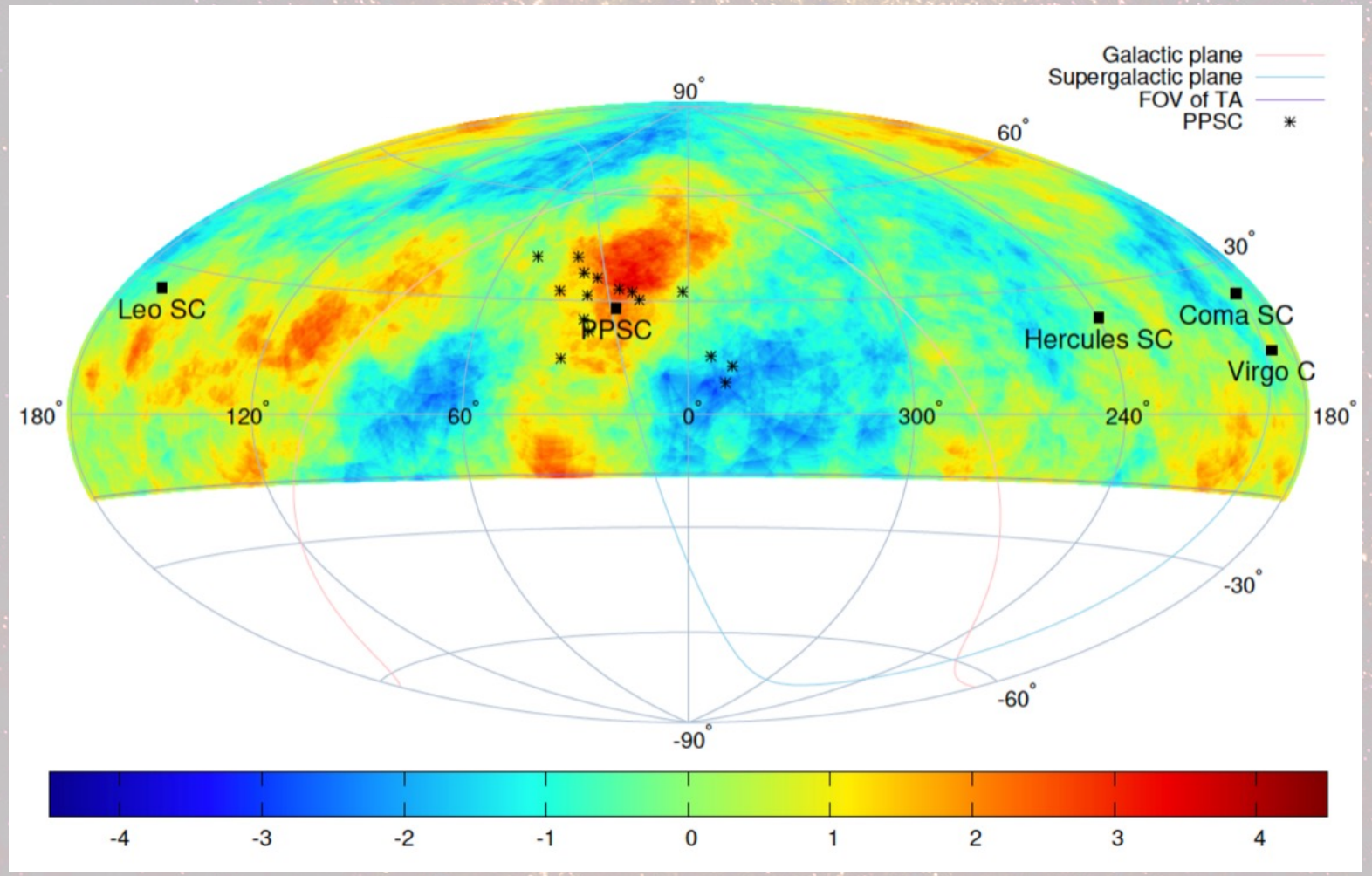


Events with E>100EeV imply heavy mass composition.

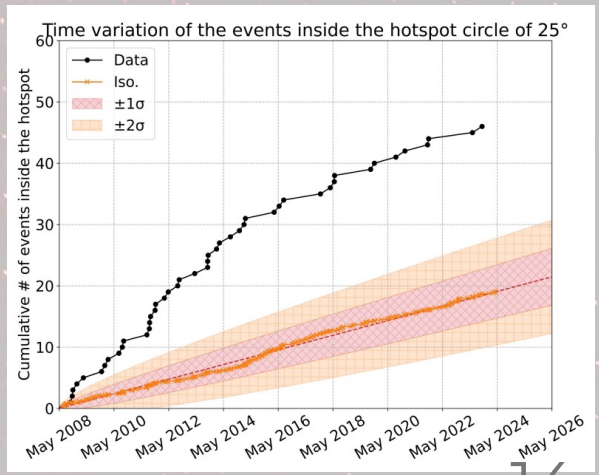
See the next talk by M. Kuznetsov.

PRL 133(2024) 041001
PRD 110(2024) 022006

Telescope Array hot spot

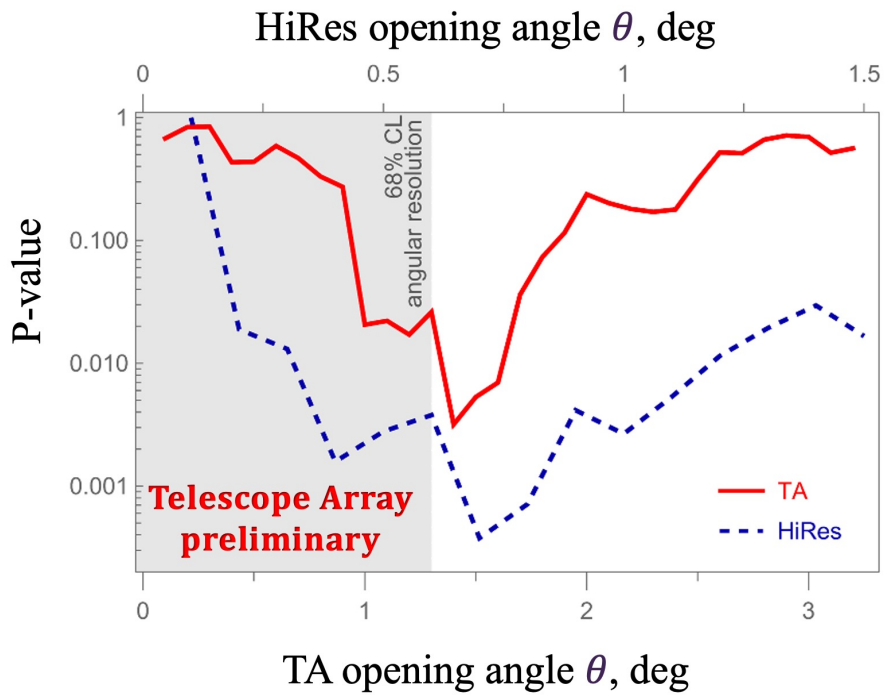


- 16 years of TA SD
- E>57EeV
- Max. local significance: **4.9σ**
- Post-trial probability: **2.9σ**



J. Kim, PoS(ICRC2025) 302
Korockin, Tinyakov, Semikoz 2511.09406

BL Lac correlations



The results are consistent, but signal for TA is weaker.

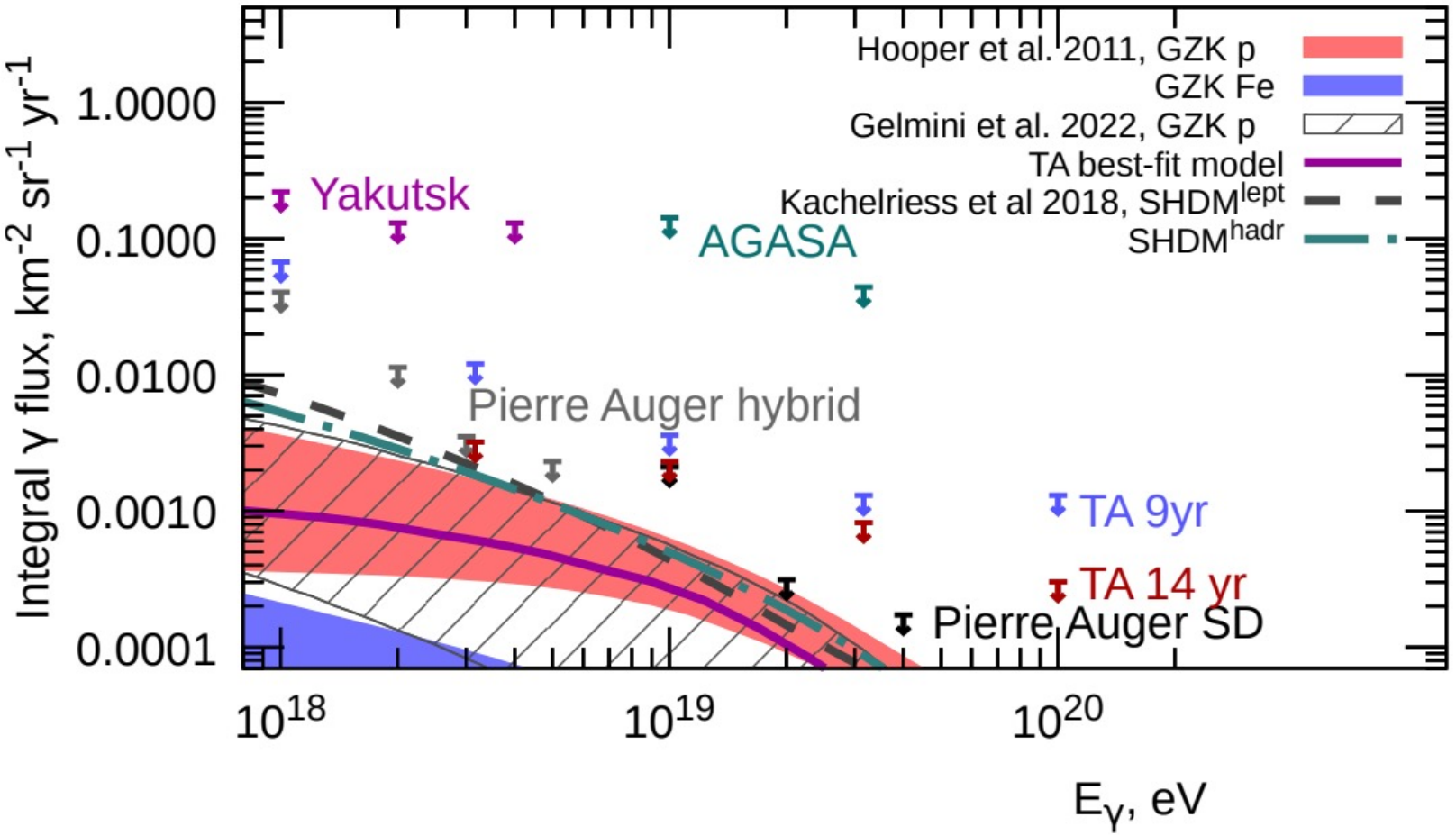
Fraction of excess events from BLLs in the data set:

Data set	fraction, %	68% CL	95% CL
HiRes stereo	3.0	± 1.2	$^{+2.7}_{-2.0}$
TA SD	0.66	± 0.25	$^{+0.50}_{-0.47}$

M. Kudenko, PoS(ICRC2025) 311

- HiRes reported correlations of CRs above 10 EeV with BL Lacs
- 15 years of TA SD
- Post-trial probability: **2.1σ**

Search for primary photons



- 14 years of TA SD data
- Neural Networks and domain adaptation
- Approached upper edge of GZK predictions
- Increased TA exposure time needed

I. Kharuk, JCAP 06 (2026) 052

Conclusion

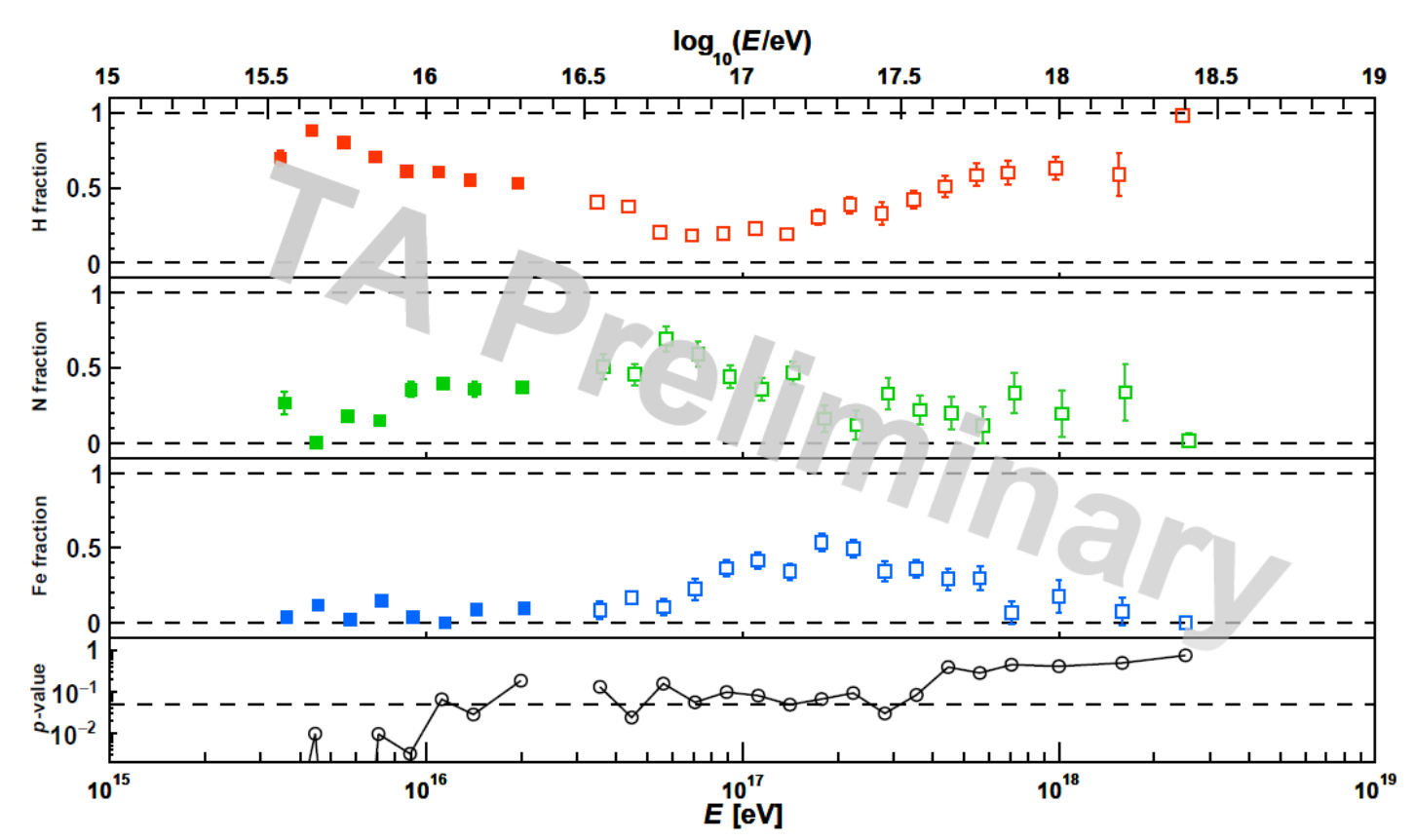
- Telescope Array provides valuable insights into the origin and nature of UHECRs.
- With the use of 15 years of data TA provided spectrum measurements over 5-orders of magnitude in energy.
- Nice agreement with other experiments, but still under discussion in higher energies.
- Mass composition observe light-heavy-light pattern, but for energies above 100 EeV heavy mass composition is implied.
- The TA hot spot may indicate the nearby source
- The enhanced exposure of TAx4 is crucial for future research.

Thank you for your attention!

This work is supported in the framework of the State project ”Science” by the Ministry of Science and Higher Education of The Russian Federation under the contract 075-15-2024-541.

Back up

Mass composition



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Key idea: fitting observed $X_{\max}$ distribution using MC $X_{\max}$ distributions.

