



**"OBSERVATION OF THE GZK
SUPPRESSION WITH THE
TELESCOPE ARRAY
FLUORESCENCE TELESCOPES
AND DEPLOYMENT OF THE
TELESCOPE ARRAY
EXPANSION"**

presented by

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A presentation to the faculty of
The University of Utah
Department of Physics
in partial fulfillment of the requirements
for the degree of

Doctor of Philosophy

Open to anyone interested

COMMITTEE MEMBERS

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ABSTRACT

The Telescope Array (TA) Cosmic Ray Observatory, located in Millard County, Utah, is the largest cosmic ray detector in the northern hemisphere. TA was built to study the highest energy particles in the universe, Ultra-High Energy Cosmic Rays (UHECRs) with energies above 10^{18} eV. TA is a hybrid detector that consists of three fluorescence detector (FD) stations overlooking a ground array of 507 scintillating surface detectors (SDs).

TA is currently undergoing an expansion known as TAx4, to quadruple the detection aperture with the addition of 500 SDs with a northern and a southern extension to the main array. The SD array expansion is accompanied by 4 new fluorescence telescopes at the Middle Drum (MD) FD station and 8 new fluorescence telescopes at the Black Rock (BR) FD station. The new fluorescence telescopes are comprised of refurbished and upgraded detectors from the HiRes-II experiment. The TAx4 FD expansion looks out over the TAx4 SDs to allow for hybrid energy calibration of the new surface array. TAx4 MD FD began operation in 2018. In this dissertation, we calculate a preliminary energy spectrum using the first year of data from the new TAx4 MD FD. This preliminary spectrum is in agreement with previous TA measurements.

In the main effort for this dissertation, we calculate a combined cosmic ray energy spectrum using reconstructed monocular events with energy above $10^{17.5}$ eV from the Black Rock (BR) and Long Ridge (LR) FD sites using 10 years of data, from 2008 to 2018. We implement a novel weather classification method using machine learning to increase the quality of the BR and LR FD data. We observe excellent agreement comparing the combined fluorescence spectrum to the TA SD measurement, as well as the HiRes experiment fluorescence measurement. We fit the monocular combined spectrum with a series of broken power law fits and found the spectrum fit well with three breaks in the spectrum. We claim the fourth observation of the GZK suppression with the combined fluorescence energy spectrum with a significance above 4σ .

PUBLICATIONS

- [1] Telescope Array FD Weather Classification using Machine Learning, **Greg Furlich**, Proceedings of Science (ICRC2019) 261, 36th International Cosmic Ray Conference, Madison, WI, July 2019
- [2] Towards a Telescope Array 10 Year FD Monocular Energy Spectrum, **Greg Furlich**, Douglas Bergman, Proceedings of Science (ICRC2019) 260, 36th International Cosmic Ray Conference, Madison, WI, July 2019
- [3] Constraints on the diffuse photon flux with energies above 10^{18} eV using the surface detector of the Telescope Array experiment, R.U. Abbasi et al. (Telescope Array Collaboration), *Astropart. Phys.* **110** (2019)
- [4] Testing a Reported Correlation between Arrival Directions of Ultra-high-energy Cosmic Rays and a Flux Pattern from nearby Starburst Galaxies using Telescope Array Data, R.U. Abbasi et al. (Telescope Array Collaboration), *ApJ.* **867** 2 (2018)
- [5] The Cosmic-Ray Energy Spectrum between 2 PeV and 2 EeV Observed with the TALE detector in monocular mode, R.U. Abbasi et al. (Telescope Array Collaboration), *ApJ.* **865** 74 (2018)
- [6] Evidence of Intermediate-scale Energy Spectrum Anisotropy of Cosmic Rays $E \geq 10^{19.2}$ eV with the Telescope Array Surface Detector, R.U. Abbasi et al. (Telescope Array Collaboration), *ApJ.* **862** 91 (2018)
- [7] Depth of Ultra High Energy Cosmic Ray Induced Air Shower Maxima Measured by the Telescope Array Black Rock and Long Ridge FADC Fluorescence Detectors and Surface Array in Hybrid Mode, R.U. Abbasi et al. (Telescope Array Collaboration), *ApJ.* **858** 76 (2018)
- [8] Gamma-ray Showers Observed at Ground Level in Coincidence With Downward Lightning Leaders, R.U. Abbasi et al. (Telescope Array Collaboration), *Journal of Geophysical Research: Atmospheres* **123** (2018)