Sixty-second summary
The 700-km² Telescope Array Experiment in west-central Utah is the northern hemisphere’s largest cosmic-ray detector.

We measure the chemical composition of ultra-high-energy cosmic rays (E > 10^{19} eV) by:

1. **Observing** air showers, measuring X_{max} and energy for each one
2. **Predicting** air-shower observations resulting from various known compositions, and then

We test the Monte Carlo predictions by comparing distributions of X_{max} (depth of shower maximum) reconstructed for air showers observed stereoscopically.

In this poster, we test the data against two compositions: pure proton, and pure iron. The proton hypothesis more correctly predicts the data (Figures 0 and 1), but the accuracy depends strongly on the choice of hadronic-interaction assumptions.

Results

![Figure 0](image-url) The distribution of reconstructed X_{max} binned by reconstructed primary energy. The proton and iron predictions are based on the QGSJET-II-03 model for high-energy hadronic interactions. The data and proton histograms agree in both mean and overall shape, while disagreeing strongly with iron.

**Key concepts**

**Fluorescence detectors** (FDs) are banks of ultraviolet telescopes, recording both Cherenkov and N_Gaisser fluorescence light from cosmic-ray air showers. Three FDs overlook a central surface-detector array (Figure 2). Each telescope consists of a large spherical mirror and a 256-pixel camera (Figure 3), and this analysis uses data from 38 telescopes.

**Detector simulation** of an air shower begins with light production according to the Gaisser-Hillas profile along the shower trajectory. Light transmission through both molecular and aerosol components of the atmosphere determines the flux at each FD, where the accepted light (calculated by ray tracing) produces a readout via simulated data acquisition electronics.

**Stereoscopic observation** of air showers by multiple FDs precisely constrains the shower trajectory at the intersection of two shower-detector planes (Figure 6), so that the longitudinal-secondary-particle evolution can be reconstructed with high accuracy.

**Simulation details**

**Shower parameters**
Each simulated air shower is generated with a randomly chosen trajectory and impact time, and primary energy sampled from the HiRes spectrum. The shower’s longitudinal profile is selected from a library of 10^6 Gaisser-Hillas fits to individual CORSIKA showers (Figure 8) with appropriate energy and zenith angle. Real detector calibration information is used according to the event time, and the Global Data Assimilation System (GDAS) provides atmospheric density profiles near the TA site with 3-hour time resolution.

**CORSIKA physics models**
The air-shower simulator CORSIKA provides several options for the physics of high-energy hadronic interactions. Each such “model” represents a unique approach to extrapolating from lower-energy laboratory measurements, and as such, the predicted X_{max} distribution for a given particle species depends on the model. The five models we simulate are shown in Figure 9.

![Figure 3](image-url) A map of Telescope Array detectors. The Black Rock Mesa (southern) and Long Ridge (southeast) FDs are used for TA, while the Lakeview Drum (north) is refurbished from the HiRes experiment.

**Aperture fidelity**
A good simulation correctly reproduces the distributions of shower trajectories seen in the data. The comparisons in Figure 10 are a small sample of the many available quantities.

![Figure 4](image-url) Sky map of event showers detected (shaded) for an air-shower trigger. showers are shown by the size (blue) and color (brighter) of each FD.

**Reconstruction accuracy**
By comparing reconstructed properties of simulated air showers to the known values reported by the simulator, we obtain the accuracy and precision of our reconstruction algorithms. Figure 11 presents sample accuracy measurements of quantities important for composition studies. Identical processing of real and simulated shower data ensures that any reconstruction-related bias or uncertainty applies equally to both observation and model- and species-dependent prediction.

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**References**


