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Results from the Telescope Array Experiment

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Abstract

The Telescope Array (TA) is the largest ultrahigh energy cosmic ray detector in the northern hemisphere. The experiment consists of three fluorescence stations viewing the air space over a surface array of 507 scintillation counters deployed over 700 square kilometers. TA has been in operation since 2008. The most recent results from TA, including that of composition studies and search for arrival direction anisotropy, will be presented. We will also report on the progress of the new TA low energy extension (TALE).

Keywords: particle astrophysics, cosmic rays, energy spectrum, anisotropy, composition, Telescope Array

1. Introduction

The Telescope Array is the largest experiment studying ultrahigh energy cosmic rays in the northern hemisphere. The project is located near the city of Delta, Utah, U.S.A. The apparatus consists of a surface detector (SD) of 507 scintillation counters arranged in a square grid [1]. The nearest neighbour distance is 1.2km, and the array covers an area of about 730 km^2. Three fluorescence detectors (FD) look inward from the periphery of the SD array [2]. The arrangement of the detector is shown in Figure 1.

The TA collaboration consists of about 120 members from 30 institutions in Japan, the U.S, Russia, Republic of Korea, and Belgium. The Telescope Array experiment began construction in 2006, and has been in routine operations since 2008. Data from the FD and SD detectors can be analysed separately in SD-only or FD monocular modes. Data can also be combined in stereo mode between FD stations, or in hybrid co incidence mode between FD and SD.

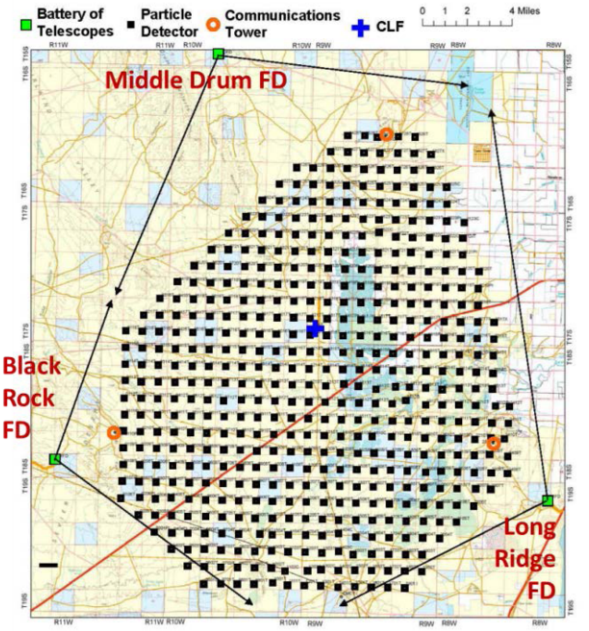

Figure 1: Layout of the Telescope Array experiment. The surface detectors are shown by the black squares and the fluorescence detector stations by the green squares.

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2. TA detectors

2.1. Surface Detector

Each SD counter consists of two layers of plastic scintillators of 1.25cm each in thickness, and 3.0m^2 in total area. Wavelength-shifting optical fibers are embedded in extruded grooves of the plastic to achieve uniform collection of light. The fibers are each bundled into separate photomultiplier tubes (PMTs), one for each layer for readout. The power for the SD stations is provided by solar panels with deep-cycle batteries. Each counter communicates over a 2.4GHz wireless network with one of three communication towers located near the FD stations.

Once every ten minutes, each SD unit runs through a calibration cycle using distribution of pulse heights from minimum-ionizing cosmic muons. The signal from each PMT is digitized at 50Msps. Data is stored for pulses that exceed 0.3 vertical equivalent muons (VEM) in area over background. An array trigger is formed when three adjacent counters report ≥3 VEM pulses in time coincidence, after which the counters are polled and all stored pulses in the trigger window are transferred to the central data acquisition.

2.2. Fluorescence Detector

Each FD station views between 3° and 31° in elevation, and ~110° in azimuth. A total of 38 telescopes are distributed over the three FD stations. The two southern sites at Black Rock Mesa (BRM) and Long Ridge (LR) are equipped with 12 new telescopes constructed in Japan. Each has a segmented spherical mirror of 6.8m^2 in area. The focal plane camera consists of 256 PMT pixels in a 16×16 hexagonal honeycomb structure. Each pixel views approximately a 1.1° cone in the sky. The northern site at Middle Drum (MD) houses 14 telescopes refurbished from HiRes-1 detector site of the High Resolution Fly's Eye (HiRes) Experiment. The FD telescopes operate on clear, moonless nights and accumulate an average of about 10% live time.

2.3. Low Energy Extension

In addition to the primary SD array and FD telescopes, the TA collaboration has added a TA low-energy extension (TALE) consisting of ten high elevation telescopes at the MD site, and an infill surface detector array [3]. The new telescopes view between 31 and 59° in elevation, and 80° of azimuth. The TALE FD was completed in the fall of 2013. The infill SD consists of 75 counters identical to those in the main array. They are arranged in a graded spatial distribution shown in Figure 2. As of summer 2014, 32 SD counters are in place, of which 16 have been instrumented with readout electronics.

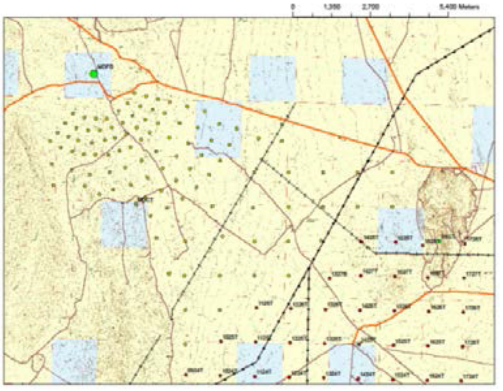

Figure 2: layout of the TALE surface detectors. The Middle Drum (MD) FD site is shown by the square circle in the upper left, and the TALE SD units fan out in a graded pattern to the south of MD. The array shown in the lower right hand of the map are those of the main TA SD array with 1.2km spacing between nearest neighbors.

3. Data Analysis

3.1. SD Data Analysis

Figure 3 shows a typical high energy event seen by the SD array. The axes show the grid position (1200m spacing) of the hit counters. The size of the circle gives the pulse height, and the color indicates the arrival time. The arrival times are fit to a curved shower front model in order to determine both the arrival direction and the shower core—the location where the shower axis intersects ground.

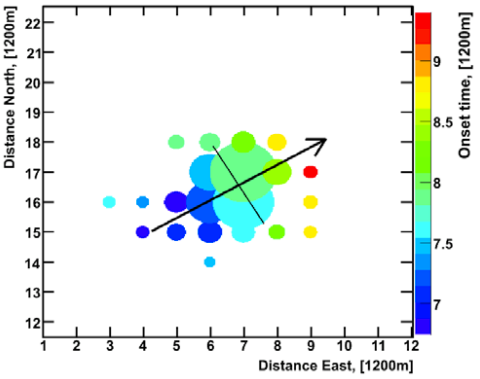

Figure 3: Display of a surface detector event from June 25, 2008. The size of the circles indicates relative particle density seen by each counter in the event. The colors indicate the time of the signal.