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The Telescope Array Low Energy Extension (TALE)

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Abstract: The Telescope Array Low Energy Extension (TALE) will consist of an array of scintillation counters and fluorescence telescopes designed to lower the minimum energy of the Telescope Array (TA) experiment by about an order of magnitude. The fluorescence detector will have 11 telescopes which cover elevation angles between 31 and 59 degrees, and 108 degrees in azimuth. There will be 45 scintillation counters with 400m spacing, 31 with 600m spacing, and 37 counters with the same 1200m spacing as the existing TA surface array. The physics aims of TALE are to study the second knee of the cosmic ray spectrum and the galactic-extragalactic transition, and to characterize cosmic ray showers at 10^{17} eV to compare with LHC measurements at the equivalent center of mass energy.

Keywords:

1 Introduction

The Telescope Array (TA) experiment is designed to study ultrahigh energy cosmic rays of energies above about $3x10^{17}$ eV, and is the largest such experiment in the northern hemisphere. TA consists of a surface detector (SD) array of 507 scintillation counters deployed on a grid of 1.2 km spacing, and three fluorescence detectors (FD) overlooking the SD.

The TA Low Energy Extension (TALE) project consists of a set of detectors to be added to TA which will lower the minimum energy of the experiment by an order of magnitude. The TALE fluorescence detector will consist of 11 telescopes which cover elevation angles between 31° and 59°. The TALE surface detectors will include an infill array of 76 counters and an addition to the TA SD of an additional 37 counters. The TALE detectors will operate as one experiment with those of TA. This experiment will have the widest energy range in the ultrahigh energy field. They will operate with a single energy scale from below 10^{17} eV to just above the GZK cutoff.

TALE will be sensitive to a rich set of physics topics. The second knee of the spectrum is almost totally unexplored. In this energy region the composition has been measured previously by the HiRes prototype + MIA hybrid experiment, and needs confirmation. The galactic-extragalactic transition should be in this region. There could be anisotropy at the end of the galactic portion of the spectrum as well.

In addition, the Large Hadron Collider (LHC) will soon run at a center-of-mass energy of 14 TeV, which is equivalent to $1x10^{17}$ eV in fixed target mode. LHC experiments will measure cross sections that can be used in Monte Carlo programs that simulate cosmic ray air showers. TALE will be able to study showers at the LHC energy to test these simulations.

2 TALE Physics

Several features of the cosmic ray spectrum are now agreed upon. The GZK cutoff [1,2] was first observed by the High Resolution Fly's Eye (HiRes) experiment [3], and later confirmed by the Pierre Auger Observatory [4]. The TA spectrum [5] (see papers 1264 and 1297 of this conference) also includes this feature. The ankle of the cosmic ray spectrum has been observed convincingly, at $4x10^{18}$ eV. The second knee, in the middle of the 10^{17} eV decade, is poorly known, and is one of the main topics of study in this energy range. Whether this is a galactic or extragalactic feature is unknown. Important information can be learned about the second knee by performing a correlated spectrum + composition study:

if the feature appears in the heavy component of the composition it would be a strong argument for a galactic origin.

The composition of ultrahigh energy cosmic rays is a subject of considerable debate. The HiRes collaboration saw a consistently light (protonic) composition [6] above 10^{18} eV, whereas the Auger collaboration sees a trend toward heavy nuclei [7]. An independent result from the TA collaboration should adjudicate between the two, and that will be presented in paper 1268 in this conference.

The TALE measurement of the composition will be very interesting. To take the HiRes-MIA measurement [8] as a guide, TALE should see a trend in the mean depth of shower maximum, <Xmax>, from heavy to light. This trend merges with a protonic result at about $1x10^{18}$ eV. The state of the art in measuring and interpreting Xmax has improved since HiRes-MIA. For example, the importance of the width of the Xmax distribution at a constant energy has been recognized. In the region of the galactic-extragalactic transition if the composition is galactic iron plus extragalactic protons the distribution of Xmax values will be very wide. This will be an unmistakable signature.

Anisotropy in the 10^{17} and 10^{18} eV decades is likely to be galactic in origin. The critical energy of the galactic magnetic field is thought to be in the middle of the 10^{17} eV decade. If there were any protons of galactic origin at this energy anisotropy in the form of a galactic dipole moment or an excess near the galactic plane could result.

Experiments at the LHC plan to measure cross sections that are important for modeling the air showers produced by ultrahigh energy cosmic rays. After the new information is included in such models, experiments like TALE will provide very useful measurements to test the models. In particular, since the proton-proton total cross section will be known at $1x10^{17}$ eV, a more accurate simulation of Xmax can be made. This will be very important for ultrahigh energy cosmic ray experiments.

3 TALE Fluorescence Detectors

The TALE fluorescence detector is designed to operate intimately with the TA Middle Drum FD. They will trigger together and data will be reconstructed using both FD's together. Events will have long tracks, since the joint detector system will cover from 3° to 59° in elevation. Fluorescence detectors that cover up to 31° in elevation, such as existing detectors of HiRes, Auger, and TA, cannot make a bias-free measurement of <Xmax> below about $1x10^{18}$ eV. The TA+TALE FD system will be able to operate without biases more than an order of magnitude lower in energy.

The region of coverage for the TA+TALE FD, in azimuth and elevation, is shown in Figure 1. Both FD's consist of reconditioned telescopes from the HiRes experiment. The TA telescopes came from the HiRes-I detector. The

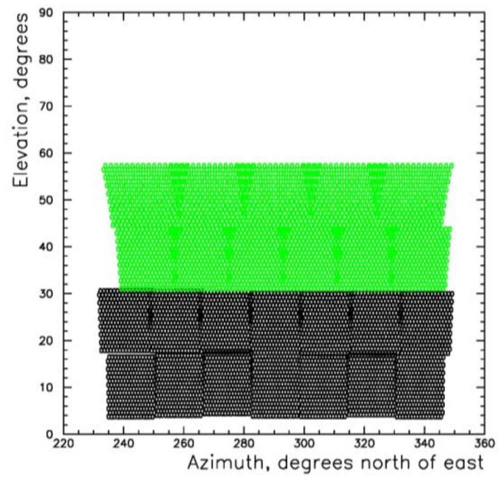

Figure 1. Coverage of the TA and TALE fluorescence detectors in elevation and azimuth. The darker areas represent the TA Middle Drum FD, and the lighter areas show the coverage of the TALE FD.

TALE FD telescopes are coming from the HiRes-II detector. As of this writing improvements are being made to the DAQ system, and telescopes will be ready to deploy this calendar year.

The building to house the TALE FD is now being designed, and will generally resemble the Middle Drum FD building. Its plan will be in the form of an arc, and telescope bays will hold two telescopes each and have roll-up doors.

4 The TALE Infill Array

In front of the TA+TALE FD detectors will be an infill array. This detector is designed to operate from $3x10^{16}$ eV, up to the highest energies. All of the scintillation counters of the infill array will be similar to those of the TA SD. The infill array consists of three parts. One has 45 counters with a spacing of 400 m. This part is closest to the TALE FD (1.5 km at its closest point), and is designed to have 10% efficiency at $3x10^{16}$ eV. Since most events in the 10^{16} eV decade that are seen by the FD fall within 3 km of the FD, for distances between 3 and 5 km we change the spacing to 600 m to cover more area. At this spacing the infill array is 10% efficient at $1x10^{17}$ eV. The excellent TA analysis and simulation techniques have been used to predict these efficiencies. We have shown that these techniques are bias-free at this efficiency level. For larger distances we use the spacing of the main TA SD array, 1200 m. Figure 2 shows the outline of the TALE infill array, plus how it connects with the main TA SD array. The light colored circles are the new SD's, and the dark colored circles are the northwest corner of the existing TA SD.

The TA infill array is designed to work as a stand-alone detector, or in hybrid mode (as is the TA SD). It should

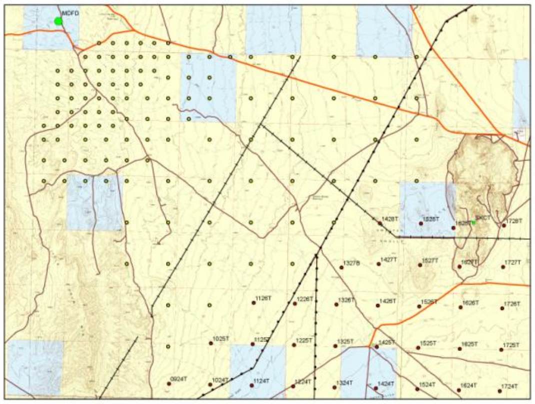

Figure 2. Layout of the TALE infill array. The light colored circles represent the TALE counters to be added, and the darker circles show the locations of existing counters in the northwest part of the TA SD.

make a measurement of the spectrum of cosmic rays for energies above $3x10^{16}$ eV. The hybrid operation will be in conjunction with both the Middle Drum TA FD detector and with the TALE FD detector. Both stand-alone and hybrid data will be of good quality for anisotropy searches as well.

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