We present an update on the status of the Very Energetic Radiation Imaging Telescope Array System (VERITAS) currently under construction in southern Arizona. As a new generation array of four Imaging Cherenkov telescopes VERITAS will represent a significant improvement over previous instruments in terms of energy threshold, energy resolution, angular resolution and flux sensitivity. We provide details on the performance of the VERITAS prototype telescope and on the construction of the VERITAS array.

1 Introduction

1.1 VERITAS

VERITAS is a new-generation array of Imaging Atmospheric Cherenkov (IAC) telescopes for the study of cosmic gamma-rays in the energy range 50 GeV to 50 TeV [1].

As a first step in the construction of VERITAS, the VERITAS collaboration has successfully constructed and operated a prototype instrument at the Whipple observatory basecamp in Arizona, to evaluate and confirm the performance and reliability of all major telescope subsystems.

1.2 The Imaging Atmospheric Cherenkov Technique

Using an IAC telescope the Cherenkov light, emitted by the secondary charged particles in gamma-ray and cosmic-ray initiated air showers, may be imaged using a PMT-camera to obtain spatial, temporal, and calorimetric information regarding the initiating photon or particle.

Employing multiple IAC telescopes allows for improved background rejection (mainly muons and cosmic ray air showers), provides for a lowering and extension of the detectable energy range, and yields superior energy and angular resolution in off-line analyses.

2 Telescope Structure and Optical Design

2.1 VERITAS

The VERITAS telescope design specifies segmented optical reflectors, with f-number f/10, based on the Davis-Cotton model. Each telescope will comprise a spherical tubular steel Optical Support Structure (OSS), mated to a commercial all-sizemuth positioner, with a focal length and aperture of 12 m.

Total mirror area for an individual telescope will be ~13 m², provided by 350 identical mirror facets made of front-aluminized and anodized, slumped and polished float glass. Aluminization and anodizing of the mirror facets is accomplished at a dedicated on-site facility.

2.2 The VERITAS Prototype Telescope

The prototype telescope comprises 86 mirrors mounted on a complete OSS-positioner unit. The positioner and OSS were assembled and installed at the Whipple observatory basecamp in June 2003, and all 86 mirrors were mounted a short time later. Optical quality measurements of the mirrors indicated that their performance exceeds that of the original specification.

2.2.1 Prototype Mirror Surface

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2.2.2 Point Spread Function

Initial Point Spread Function (PSF) measurements of the aligned mirrors suggested the necessity of a focal plane adjustment and a tightening of the OSS. The final PSF was obtained after adjustments, and following a bias alignment to accommodate for OSS elevation-dependent deflection, is less than 0.04% across most of the telescope’s operating range, figure 4. Note: individual pixels have an angular spacing of 0.15°.

3 Camera and Data Acquisition

3.1 VERITAS

Each VERITAS telescope will contain a focal plane camera comprising an array of 499 4×4 inch photomultiplier tubes (Photons). High voltage for the PMT will be provided by commercial multichannel power supplies (CAEN SY1927/A192D) allowing individual channel control. High bandwidth preamplifiers and anode current monitoring circuits (US patent 6,717,541) are fully and partially integrated into the PMT bases.

3.1.2 Data Acquisition System

The VERITAS DACQ system is designed around a custom-built 500 Msamples/second Flash-ADC system. The signal from each PMT pixel is digitized by its own FADC with a dynamic range of 11 bits and a memory depth of ~16 µs. FADC traces of Cherenkov flashes provide intensity and temporal information regarding the interrogating gamma-ray or background air-shower for use in off-line analysis.

3.1.3 Trigger

The VERITAS trigger will comprise a 3-level system to provide optimum rejection of night-sky-noise and background hadronic air shower signals at the hardware level, figure 5. Individual pixel triggering (L1) is performed by constant fraction discriminators co-located on the FADC modules. Second level triggering (L2) is performed using a topological hardware trigger which uses the pattern of level-1 triggered pixels to discriminate against background events. The top level trigger (L3) takes level-2 trigger signals from each telescope, dynamically provides appropriate delays to account for shower geometry, and initiates array triggers using a multiplicity criterion.

3.2 The VERITAS Prototype Telescope

All the camera, trigger and DACQ electronics and associated software for the half-camera VERITAS prototype telescope were integrated and tested at the University of Chicago in late 2002 and installed in Arizona during the summer and fall of 2003. Rate versus Threshold curves for the prototype’s L1 and L2 trigger systems are presented in figure 7.

4 Observations and Data Analysis

4.1 First Cosmic-ray Observations

The VERITAS prototype’s first cosmic-ray observations were obtained on September 24, 2003, figure 8.

4.2 Tune-up Observations

During the fall and winter of 2003, observations of cosmic-ray events together with calibration measurements were used to tune the prototype detector. PMT gain and FADC timing adjustments were undertaken and the telescope’s tracking interface was developed. An example cosmic-ray event after timing and gain adjustments is presented in figure 9.

4.3 Gamma-ray Source Observations

Regular gamma-ray source observations were undertaken between January and April 2004, with both the Crab Nebula and Markarian 421 detected at high significance, figure 10.

5 Future Work

With all major subsystems of the VERITAS prototype telescope now integrated and tested, and following the successful detections of the Crab Nebula and Markarian 421 the VERITAS collaboration is advancing with plans to upgrade the prototype instrument to a full VERITAS telescope during the summer and fall of 2004. Valuable lessons learned from the prototype telescope will be applied during its upgrade and during construction of the remainder of the VERITAS array. Preparations for the construction of VERITAS (which will ultimately incorporate the upgraded prototype) on Kitt Peak, Arizona are already at an advanced stage with completion expected in 2006.