

# Technical Status of VERITAS

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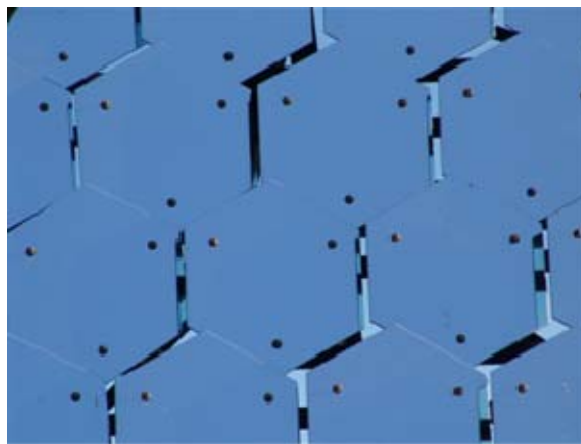
**Abstract.** VERITAS, the Very Energetic Radiation Imaging Telescope Array System, is a major new ground-based observatory for studying nonthermal astrophysics in the gamma-ray band above 100 GeV. VERITAS has operated a stereo pair of telescopes using a true array trigger at the Mt. Hopkins base camp site in southern Arizona since March, 2006. We report here on the status of certain key technical aspects of the project, including the optomechanical system and the trigger electronics.

## 1. Introduction

VERITAS, the Very Energetic Radiation Imaging Telescope Array System, is a new ground-based observatory for studying nonthermal astrophysics in the gamma-ray band above 100 GeV. VERITAS is located at the Mt. Hopkins base camp in southern Arizona (longitude 111° W, latitude 32° N) and consists of four telescopes, each with a 12-m diameter reflector (figure 1). The first two telescopes have been operational since February, 2006, and the full array is expected to be operational in January, 2007. A detailed description of the design of VERITAS can be found in [1] and the performance of the first telescope is discussed in [2]. The status of the array is described in [3] in these proceedings; this paper focuses on the performance of some of the critical hardware components of the system, including the optomechanical system and the trigger electronics.



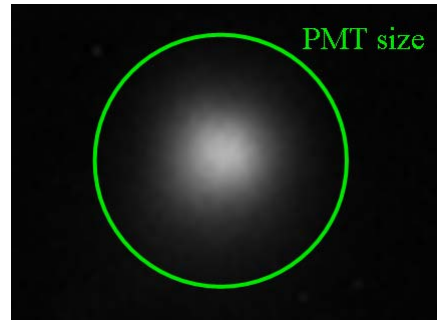
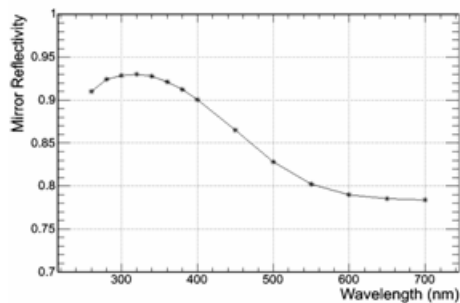
**Figure 1.** The VERITAS telescopes.



**Figure 2.** The mirrors of Telescope 1.

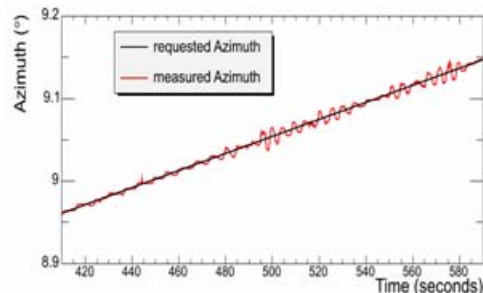
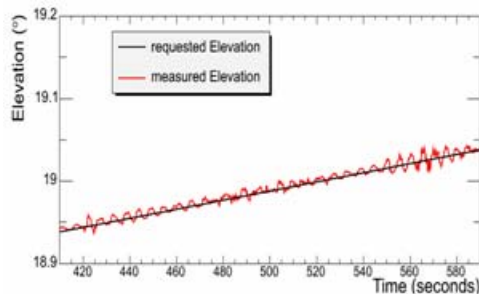
## 2. Optical and Mechanical Performance

The optics for the VERITAS telescopes follows the Davies-Cotton design [4], with a 12-m diameter reflector and a 12-m focal length. The segmented reflector is made of 340 hexagonal mirror facets, each with an area of  $0.31 \text{ m}^2$ , providing a total mirror area of  $106 \text{ m}^2$ . The mirror facets (figure 2) are glass with an anodized aluminum coating applied on-site in a dedicated facility. They provide a reflectivity  $> 90\%$  at 320 nm (figure 3). The mirrors are aligned using a laser system located at twice the focal length from the reflector. The point-spread function (figure 4) is  $\sim 0.06^\circ$  full-width at half-maximum, significantly less than the angular diameter of one PMT ( $0.15^\circ$ ), at an elevation of  $31^\circ$ .



**Figure 3.** Mirror reflectivity vs. wavelength. **Figure 4.** Telescope PSF.

The tracking system uses an altitude-over-azimuth positioner. The maximum slew rate is  $1^\circ/\text{s}$ , with a relative tracking error of typically  $< 0.01^\circ$  (figures 5-6). An absolute pointing monitor is under development, with a goal of continuously monitoring the absolute pointing of the camera and reducing the pointing error below  $10''$ .



**Figure 5.** Tracking error in elevation.

**Figure 6.** Tracking error in azimuth.

## 3. Trigger Performance

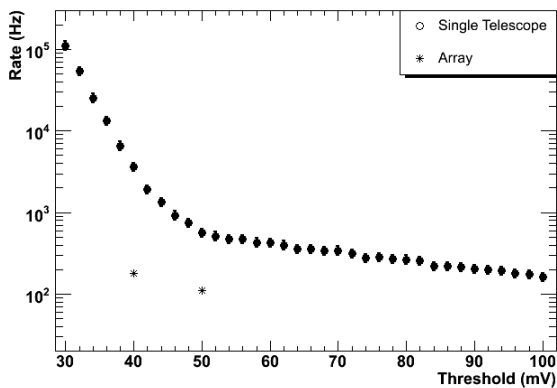
The VERITAS trigger electronics work in three stages:

1. Each PMT pulse is evaluated by a constant-fraction discriminator (CFD) [5], which is typically set to fire at a level of 4-5 photoelectrons. The CFD produces a digital pulse approximately 10 ns in length.
2. At the telescope level, a Pattern Selection Trigger (PST) [6] requires that a specified multiplicity of adjacent pixels fire within  $\sim 5 \text{ ns}$ . The PST can be programmed to require 1-4 adjacent pixels; it is typically run with a requirement of three adjacent pixels.

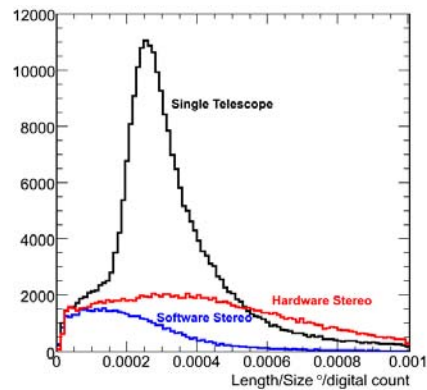
3. A hardware array trigger evaluates coincidences between telescope triggers. The preliminary system installed in March, 2006 is typically configured to require that two telescopes trigger within 100 ns of each other, after delays have been applied to correct for shower geometry and cable travel times. This coincidence window is short enough for accidental triggers to occur at a negligible rate, while safely longer than the limit of  $\sim 30$  ns imposed by both the hardware and the timing fluctuations intrinsic to the air showers. The full array trigger, being installed at the time of this writing, will be able to handle arbitrary subarrays of telescopes and will provide additional trigger lines for high-multiplicity events in a single telescope and the capability to handle as-of-yet undefined exotic physics triggers.

Figure 7 shows the trigger rate of an individual telescope as a function of CFD threshold, as well as the array trigger rate measured at two typical operating thresholds, 40 mV and 50 mV, corresponding to 3.6 and 4.5 photoelectrons, respectively. The key feature of the rate curve for an individual telescope is that above the break point at  $\sim 50$  mV the rate is dominated by cosmic-ray triggers, while below the break point the rate is dominated by triggers from the night-sky background. The hardware array trigger suppresses night-sky triggers by requiring coincidences between two or more telescopes and allows individual telescopes to run well into the night-sky noise regime while triggering the array at an acceptable rate. At a threshold of 40 mV, the rate is  $\sim 180$  Hz and the deadtime is  $< 10\%$ .

Figure 8 shows a histogram of the length over size (LoS) parameter, which is sensitive to local-muon events. For a single telescope, LoS has a large peak at  $\sim 0.0003$ /digital count, corresponding to local muons and limiting the energy threshold of a single telescope. Running two telescopes independently and matching up events using GPS timestamps offline (“software stereo”) removes the muon peak but does not lower the energy threshold. However, introducing the hardware array trigger (“hardware stereo”) allows reduction of the trigger threshold and hence a lower energy threshold for the stereo pair.



**Figure 7.** Trigger rate vs. CFD threshold for a single telescope (filled points) and the array (stars), using the hardware stereo trigger.



**Figure 8.** Length over size histograms for a single telescope (black), software stereo (blue), and hardware stereo (red).

## References

- [1] T. C. Weekes *et al.* *Astropart. Phys.* **17** (2002) 221.
- [2] J. Holder *et al.* *Astropart. Phys.* **25** (2006) 391.
- [3] F. Krennrich, “Status Report from VERITAS,” this proceedings.
- [4] J. M. Davies and E. S. Cotton, *Journal of Solar Energy* **1** (1957) 16.
- [5] J. Hall *et al.* *Proc. 28<sup>th</sup> ICRC, Tsukuba* (2003) 2851.
- [6] S. M. Bradbury and J. H. Rose, *Nucl. Instr. & Meth. A* **481** (2002) 521.