Development of a Low-energy Trigger for VERITAS

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Development of a Low-energy Trigger for VERITAS

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Abstract.
During the 2007/2008 observing season a low-energy trigger configuration was developed and tested for VERITAS. The configuration makes uses of the small ($\sim$35 m) baseline between two of the VERITAS telescopes and employs a much lower discriminator threshold and tighter coincidence window compared to the standard VERITAS trigger. Five hours of Crab Nebula ON/OFF observations were obtained in low-energy mode and were used to test new low-energy analysis algorithms. We present some details of the VERITAS low-energy trigger and the associated data analysis.

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INTRODUCTION

The energy regime between 30 GeV and 100 GeV remains, as yet, a poorly explored domain for astrophysical observations. Recent developments, including the successful launch of GLAST and the ground-based detection of sub-100 GeV pulsed emission from the Crab pulsar by the MAGIC collaboration [1], have highlighted this spectral region as part of the new frontier in gamma-ray astronomy.

During the 2007-2008 observing season the VERITAS collaboration undertook an effort to design and test a trigger system for observations around 100 GeV. We describe here some details of the study.

VERITAS

VERITAS is an array of four imaging Cherenkov telescopes located at the Fred Lawrence Whipple Observatory in southern Arizona. It combines a large effective area ($> 8 \times 10^4$ m^2) over a wide energy range ($\sim$100 GeV to 30 TeV, in standard operating mode) with good energy (15-20%) and angular resolution ($\approx 0.1^{\circ}$). The high sensitivity of VERITAS allows the detection of sources with a flux of 1% of the Crab Nebula in under 50 hours of observations [2].

As shown in Figure 1, the VERITAS array has an asymmetrical layout, being due to the restrictions imposed by the array location. This less-than-ideal positioning of the telescopes, however, has an advantage for low-energy observations in that two of the telescopes, telescope-1 and telescope-4, are situated just 35 m apart. The short separation of telescope-1 and telescope-4 allows the Cherenkov light from low-energy showers, that wouldn't otherwise trigger the 4-telescope array to trigger the telescope-1/telescope-4 sub-array. This short telescope baseline is thus an important consideration in designing a low-energy trigger for VERITAS.

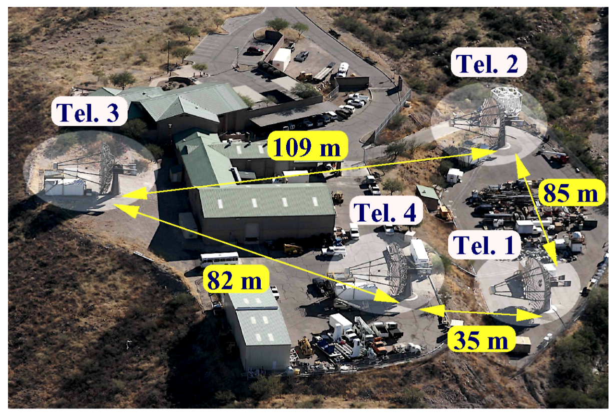

FIGURE 1. Bird's-eye view of the VERITAS telescopes at the basecamp of the Whipple Observatory. The numbering of the telescopes and their separations are shown.

TRIGGER CRITERIA AND ADJUSTABLE PARAMETERS FOR VERITAS

In order to detect the Cherenkov light from gamma-ray air showers at energies below 100 GeV using an imaging atmospheric Cherenkov telescope array, the following

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trigger criteria must be met:

1. **Faint light:** The trigger must be sensitive to faint Cherenkov light, ie must have a low threshold.
2. **NSB:** The trigger must be insensitive to the night-sky background light.
3. **Muons:** The trigger should provide some discrimination against muon events.

In considering the above criteria for VERITAS the following trigger parameters were adjustable:

- Number of telescopes in the array trigger.
  - A tight spatial separation between the telescopes in the trigger is desirable for the detection of small low-energy showers. As such, the short baseline of the telescope-1/telescope-4 sub-array is advantageous.
  - Two or more telescopes are required to guard against triggers produced by cosmic-ray muons passing in the vicinity of the array.
- The time coincidence between telescopes in the array trigger.
  - A tight trigger coincidence is needed to reduce noise triggers due to night-sky-background light.
- Number of pixels in the camera trigger.
  - Reducing the camera size to a small central region helps reduce night-sky-background triggers, while remaining sensitive to the small Cherenkov signature of low-energy air showers.
- The trigger threshold of individual CFDs within a camera.
  - A low CFD threshold is necessary in order to detect the faint Cherenkov light from low-energy showers.
- The Rate Feedback threshold on individual CFDs within a camera.
  - A Rate feedback loop on the VERITAS CFDs allows dynamic adjustment of the CFD parameters to help reduce night-sky-background triggers.

TRIGGER TESTS

To determine the optimum configuration of the above parameters for use in a low-energy trigger on VERITAS, various studies involving Monte Carlo simulations, night-sky trigger tests and test observations were made.

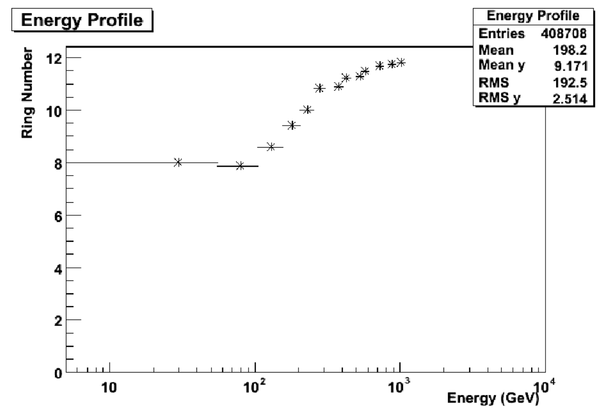

FIGURE 2. Maximum extent of triggering images in a VERITAS camera for a source at the center of the field of view, as a function of energy. Ring number refers to the rings of pixels in a VERITAS camera, as shown in Figure 3.

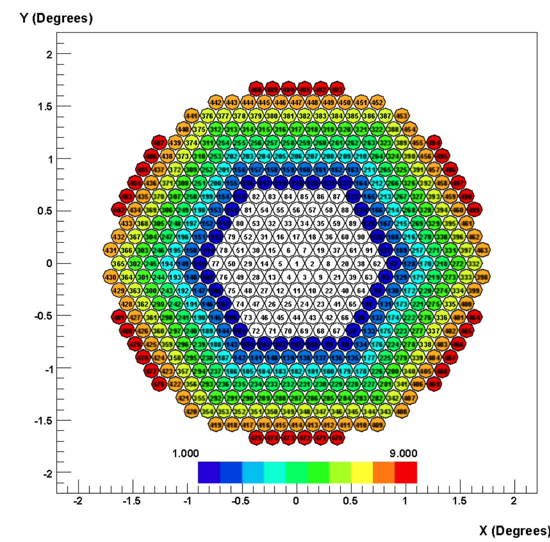

FIGURE 3. Triggering regions of telescopes T1 and T4 as tested for use in the VERITAS low-energy trigger. In the final configuration, the triggering regions of telescopes T1 and T4 were reduced to just the 126 inner pixels (region 3), for a field of view of ~0.9 degrees. The colors shown refer to the numbering of the regions tested.

Monte Carlo Simulations

Monte Carlo Simulations of air showers, produced by the KASCADE simulation package, were used to examine the maximum extent of triggering images for gamma rays from a source at the center of the camera, as a function of gamma-ray energy. It was found that showers at or below 100 GeV extend, at maximum, to ~1.18 degrees from the camera center, Figure 2.

Night-Sky Trigger Tests

Night-sky trigger rate versus threshold curves were measured for an array trigger consisting of just telescopes 1 and 4 for a range of triggering areas and array coincidence windows. It was found that the lowest trigger threshold that would suppress night-sky background triggers was 27 mV with a triggering region of just 126 pixels and an array coincidence window of 25 ns.

Test Observations

A set of several 5-minute test observations using the low-energy trigger were used to confirm the stability of the trigger and the VERITAS data acquisition system for data taking in low-energy mode.

FINAL TRIGGER CONFIGURATION

The following low-energy trigger configuration was decided upon based on the results of the trigger tests:

- **Array trigger mode:** T1+T4 Required, 25 ns coincidence window
  - only events that trigger telescopes T1 and T4 read out
  - standard coincidence window is 100 ns
- **Telescope trigger (T1 and T4):** CFDs set at 27 mV for inner pixels, 50 Hz/mV RFB
  - first 126 pixels enabled, outer pixels disabled
  - field of view restricted to 0.9 degrees
  - standard CFD threshold is 50 mV
- **Telescope trigger (T2 and T3):** CFDs set at 30 mV, RFB at 200 Hz/mV
  - standard RFB is 50 Hz/mV

COMPARISON WITH THE STANDARD VERITAS TRIGGER

Using Monte Carlo simulations, produced using the KASCADE and CORSIKA simulation codes, it is clear that the low-energy trigger greatly increases the collection area of VERITAS at low energies, Figure 4. The trigger threshold for the low-energy trigger is $\sim$70 GeV.

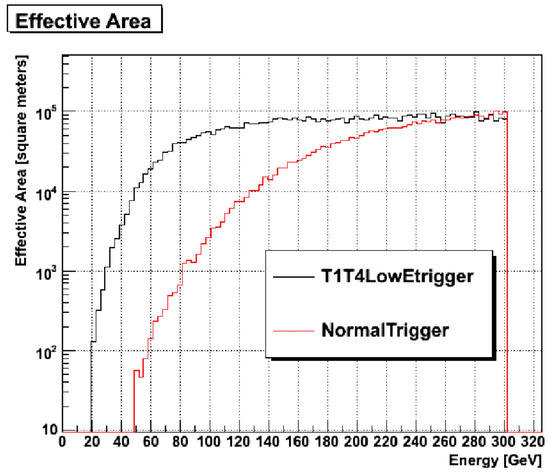

FIGURE 4. Comparison of the collection areas for the low-energy and standard VERITAS triggers.

DATASET AND ANALYSIS

A total of 5 hours of ON/OFF Crab Pulsar data were recorded using the low-energy trigger during the 2007/2008 observing season. The observations were made at an average source elevation of 73 degrees. Initial quality checks have confirmed the validity of the data and the stability of the low-energy trigger. Final analysis of these data is ongoing. Development of a new low-energy image cleaning procedure that uses the timing information provided by VERITAS' FADCs and the pixel trigger information provided by the CFDs is in progress.

FUTURE WORK

Further observations of the Crab pulsar using the VERITAS low-energy trigger are planned for the 2008/2009 observing season.

ACKNOWLEDGMENTS

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