Flux Sensitivity of VERITAS

V. V. Vassiliev

Whipple Observatory, Harvard-Smithsonian CfA, P.O. Box 97, Amado, AZ 85645, USA
For the VERITAS Collaboration

Abstract

VERITAS is a new major ground-based gamma-ray observatory with an array of seven 10m optical reflectors to be built at the Whipple Observatory in southern Arizona, USA. It will consist of an array of imaging Cherenkov telescopes designed to conduct critical measurements of AGNs and SNRs in the energy range of 50 GeV - 50 TeV. The design of the array has been optimized for the highest sensitivity to point sources in the 100 GeV - 10 TeV band when the stereoscopic imaging technique is employed. Maximum versatility of the array has been another major optimization criterion. We present the flux sensitivity of the baseline VERITAS configuration.

1 Introduction

A new generation of very high energy ground based γ-ray observatories (VERITAS [1], HESS [2], MAGIC [3]) promises to extend their sensitive energy range to below 100 GeV, an energy band which is expected to contain a wealth of new information on high energy physics and astrophysics (for review see [4]). The spectra and variability of AGNs, the origin of high energy cosmic rays, physical processes in strong magnetic fields of pulsars, the puzzle of dark matter, the type of cosmology of the Universe, origin of γ ray bursts, evaporation of black holes, and even a quantum gravity observable effects, are all in the scope of phenomena which will be studied by these projects. In this paper we give the technical characteristics of VERITAS driven by scientific goals. Also, the main motivations for choices of the array parameters are explained. Finally, we discuss factors which limit the flux sensitivity.
2 Simulations

To predict the performance of VERITAS, the response of the array has been simulated with the use of the DePauw-Purdue KASCADE system of air shower Monte Carlo (MC) programs [5]. The study of hadronic showers which may mimic pure electromagnetic cascades has been done with the CORSIKA code [6]. To determine the optimum VERITAS design we have studied the effects of varying the number of telescopes in an array, the spacing between them, reflector aperture, telescope focal length, camera Field of View (FoV) and pixel size. The characteristics of the baseline configuration as well as simulation input parameters are summarized in Table 1.

Table 1
Specifications of the baseline VERITAS design.

| Parameter                          | Value                                  |
|------------------------------------|----------------------------------------|
| Location                           | Montosa Canyon, Arizona, USA            |
| Array elevation                    | 1390 m a.s.l.                           |
| Number of telescopes               | 7 (hexagonal layout)                   |
| Telescope spacing                  | 80 m                                   |
| Mirror                             | Davies-Cotton                          |
| Reflector aperture/area            | 10 m / 78.6 m²                         |
| Focal length                       | 12 m                                   |
| Facets                             | 244, 61 cm hexagon                     |
| Camera                             | Homogeneous                             |
| Field of View                      | 3.5 deg                                |
| Number of pixels                   | 499                                     |
| Pixel Spacing/Photocathode Size    | 0.148 deg / 0.119 deg                  |
| ADC integration gate               | 8 nsec                                 |
| Pixel BS noise                     | 1.1 pe pixel⁻¹                         |
| Weathering reflectivity factor     | 0.9                                     |
| Light-concentrator enhancement     | 1.35                                    |
| Telescope Triggers                 | 2, 3 pixels (adjacent)                 |
| Pixel coincidence gate             | 15 nsec                                |
| Array Trigger                      | 3 telescopes out of 7                  |
| Telescope coincidence gate         | 40 nsec                                |

3 VERITAS design

The VERITAS design has been optimized for maximum sensitivity to point sources in the energy range 100 GeV - 10 TeV, but with significant sensitivity in the range 50 GeV - 100 GeV and from 10 TeV to 50 TeV. Optimization has been performed with fixed total number of channels. The details of the
VERITAS design study are given in [8]. Here we summarize our arguments for the baseline configuration.

- VERITAS should have at least 6 – 7 telescopes for good wide energy range sensitivity and versatility. Seven telescopes provide more flexibility in VERITAS operation modes when the array is split into sub-arrays. The array of three 15m telescopes is rejected because of poor performance at high energies and lack of versatility.
- Camera FoV, 3.5\textdegree, is a compromise between achieving low energy threshold of the array and array performance at high energies, and the ability to conduct an efficient sky survey and study extended sources. Also, the chosen FoV is the minimum necessary for effective image reconstruction with a single telescope.
- The given FoV together with the number of channels per telescope, 500, translates into a pixel spacing of 0.149\textdegree.
- The optical system of the telescope is proposed to be f/1.2. This provides an adequate match to the number of channels in the telescope camera making reflector global aberrations at the edge of the FoV comparable to the pixel size. The f/1.5 system would perform better but it would require a substantial additional investment in an optical support structure and system of mirror alignment.
- The telescope aperture, 10 m, is chosen by previous successful experience of operating the Whipple Observatory telescope and for economy.
- Spacing between telescopes should be in the range 70 – 80 m. Decrease of the spacing reduces efficient event reconstruction, background rejection and array sensitivity in the range 200 GeV - 1 TeV. Increasing the spacing, does not change array sensitivity in this energy range, but it increases the array energy threshold.

4 VERITAS flux sensitivity

The VERITAS flux sensitivity has been estimated for 50 hours of observations on a point source with a spectrum given by $dN_\gamma/dE \propto E^{-2.5}$ as is seen from the Crab Nebula in the sub-TeV energy range [7]. The minimum detectable flux of $\gamma$-rays is constrained by the 5\textsigma confidence level or by the statistics of the detected photons, $N_\gamma > 10$, when the background is almost negligible. The details of the sensitivity calculations can be found in [8].

The VERITAS $\gamma$-ray flux sensitivity as a function of array energy threshold is shown in Figure 1. At high energies, above $\sim 2 - 3$ TeV, VERITAS sensitivity is limited by photon statistics. In this region sensitivity is depressed with energy increase due to a limited FoV of the telescope camera. Large zenith angle observations can improve array performance in this energy band. In the
vicinity of 1 TeV, VERITAS sensitivity will likely be limited by cosmic ray (CR) protons which mimic γ-ray showers. The detection rate of this isotropic background is not well known and it may be of scientific interest by itself because of the large uncertainty in its predicted effect by different proton interaction models available for study within the CORSIKA code. The energy region from 200 GeV to ∼ 1 TeV will most likely be dominated by the diffuse electron background. The steepness of the CR electron spectrum causes this to become a limiting factor of the VERITAS sensitivity. The region below ∼ 200 GeV is strongly affected by the night sky background (NSB) and CR protons. Two curves in this region show the difference in array sensitivity depending on the conditions of the observations. In a favorable situation, dark observation field, the array energy threshold for events which we are able to reconstruct may decrease to as low as 40 – 50 GeV. The single telescope accidental trigger
rate (< 0.1 – 1.0 MHz), however, may limit array operation energy threshold to ∼ 70 GeV. If observations are carried out in a bright region of sky (Milky Way, lower elevation) where the NSB is ∼ 4 times brighter, VERITAS may be limited to a 110 GeV energy threshold. The result of observations in this energy band will be highly sensitive to array trigger condition, and event reconstruction and background rejection methods. The plot is indicative of our current achievement, which will certainly be improved.

References

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