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Abstract

We give an overview of the current status and scientific goals of VERITAS, a proposed hexagonal array of seven 10 m aperture imaging Cherenkov telescopes. The selected site is Montosa Canyon (1390 m a.s.l.) at the Whipple Observatory, Arizona. Each telescope, of 12 m focal length, will initially be equipped with a 499 element photomultiplier camera covering a 3.5 degree field of view. A central station will initiate the readout of 500 MHz FADCs upon receipt of multiple telescope triggers. The minimum detectable flux sensitivity will be 0.5% of the Crab Nebula flux at 200 GeV. Detailed simulations of the array's performance are presented elsewhere at this meeting. VERITAS will operate primarily as a γ-ray observatory in the 50 GeV to 50 TeV range for the study of active galaxies, supernova remnants, pulsars and gamma ray bursts.

1 Introduction:

The history and present status of the atmospheric Cherenkov imaging technique has been reviewed by Ong (1998). Its great contribution to ground-based VHE astronomy has led to burgeoning designs for "next generation" instruments of increased collection area and complexity, one of which is the Very Energetic Radiation Imaging Telescope Array System (VERITAS), first proposed to the Smithsonian Institution in 1996. Our design study has culminated in a detailed proposal by Weekes et al. (1999) to build an array of 10m aperture Cherenkov telescopes in Montosa Canyon in southern Arizona. This is a topographically flat, dark site, at 1390 m a.s.l., close to the Whipple Observatory which will provide the necessary infrastructure.

VERITAS will consist of six telescopes located at the corners of a hexagon of side 80 m with a seventh at the centre. The telescopes' structure will be similar to the design of the Whipple 10m reflector, which has withstood mountain conditions for over thirty years. By employing largely existing technology in the first instance and stereoscopic imaging, the power of which has recently been demonstrated by HEGRA (Daum et al., 1997), we expect VERITAS to achieve the following:

1) *Effective area*: $\gtrsim$0.1 km^2 at 1 TeV.
2) *Effective energy threshold*: $\lesssim$100 GeV with significant sensitivity at 50 GeV.
3) *Energy resolution*: 10% - 15% for events in the range 0.2 to 10 TeV.
4) *Angular Resolution*: $\lesssim$0.05° for individual photons; source location to better than 0.005°.

The performance of VERITAS is perhaps best summarised by its flux sensitivity versus energy, shown in Figure 1 for an object of spectrum dN/dE $\propto E^{-2.5}$. Here we define a minimum detectable flux for VERITAS as that giving a 5σ excess of γ-rays above background (or 10 photons where the statistics become Poissonian). We expect to detect sources which emit at levels of 0.5% of the Crab Nebula at energies of 200 GeV in 50 hours of observation. VERITAS, together with the southern hemisphere Cherenkov telescope arrays HESS and CANGAROO -III, will obtain high sensitivity in the 100 GeV to 10 TeV range between space-borne instruments and air shower arrays. If sources of UHE cosmic rays are discovered Cherenkov telescopes may further localise and identify them. Also, the MILAGRO wide-field water Cherenkov detector will be sensitive to transient sources, which, once detected can be studied in more detail by VERITAS.

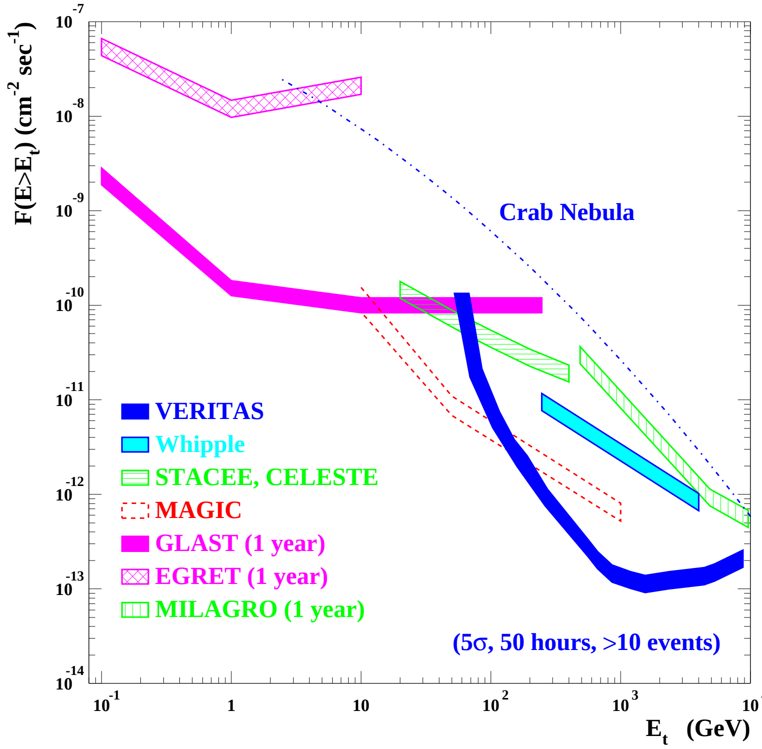

Figure 1: VERITAS' sensitivity to point-like sources as compared to those of Whipple, MAGIC, CELESTE/STACEE, GLAST and MILAGRO (Weekes et al. (1999) and references therein).

This report highlights the physics goals and some technical aspects of VERITAS emerging from the core proposal/design study. Monte Carlo simulations of the array's performance are presented by Vassiliev et al. (1999).

2 Physics Highlights:

At a capital cost of ∼\$16 M, less than 10% of that of the Gamma-ray Large Area Space Telescope, VERITAS will be an excellent investment in terms of scientific return.

The large effective area of VERITAS ($\gtrsim 2.5 \times 10^4$ m^2 at 200 GeV) will allow accurate measurements of extremely short variations in γ-ray flux. We illustrate this in Figure 2. For dense temporal coverage, VERITAS can be divided into dedicated sub-arrays, with one sub-array observing a single object, e.g. throughout a multi-wavelength campaign. Thus, we minimise the impact on other scientific programmes.

2.1 Extragalactic Astrophysics: We estimate that VERITAS will detect ∼11 of the active galactic nuclei identified at EGRET energies, or more if they are observed in high emission states. VERITAS should also detect ≥ 30 X-ray selected BL Lac objects (based on the spectra of Mrk 421 and Mrk 501) and possibly the "Extreme BL Lacs" hypothesised by Ghisellini (1999). We hope to distinguish intrinsic spectral features from those due to pair-production on the IR background. A large sample of energy spectra for a single class of blazar will dramatically improve our estimate of the background IR density.

Gamma ray bursts should be visible out to z≈1 or more at energies ≤100 GeV. VERITAS' rapid slew speed, good angular resolution and field of view (up to 10° with offset pointing of individual telescopes to cover the position error box) make it excellent for counterpart searches. Attenuation at high energies from interaction with background IR fields could provide distance bounds, if source energetics are known.

2.2 Galactic Astrophysics: For a typical supernova remnant (SNR) luminosity and angular extent, VERITAS should be able to detect such objects within 4 kpc of Earth according to the Drury, Aharonian & Völk (1994) model of γ-ray production by hadronic interactions ($\sim$ 20 shell-type SNRs are known to lie

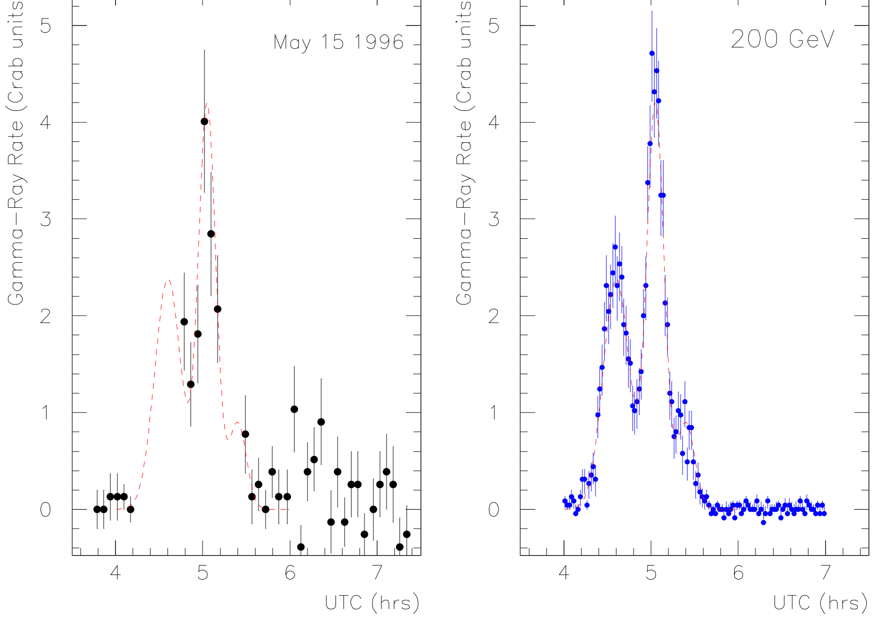

Figure 2: *Left:* Observation of a VHE flare from Mrk 421 (Gaidos et al. 1996). The dashed curve is a possible intrinsic flux variation consistent with this data. *Right:* Simulated response of VERITAS to such a flare above 200 GeV (GLAST would detect ∼3 photons above 1 GeV from a flare of this duration and power).

within that range). As regards plerions and pulsars, VERITAS should be sufficiently sensitive to detect Crab-like objects anywhere within the Galaxy if their declination is $> -28°$. The detection of pulsed γ-rays above 50 GeV might be decisive in favor of the outer gap pulsar model over the polar cap model, as the latter predicts a sharp spectral cut-off at low energies.

For an 80-night survey of the galactic plane region $0° < l < 85°$, VERITAS would be sensitive to fluxes down to ∼0.02 Crab above 300 GeV. This part of the sky includes 19 young, energetic pulsars and 12 hitherto unidentified EGRET sources. In addition, estimates of the annihilation line flux for neutralinos at the galactic center by Bergström, Ullio & Buckley (1998) predict a signal potentially detectable by VERITAS.

3 Design:

3.1 Telescope Structure: The telescopes will be constructed following the Davies-Cotton reflector design with spherical and identical facet mirrors of pyrex glass (slumped and polished, aluminised and anodised) to provide the optimum combination of optical quality and cost effectiveness. A study is underway to design a stress-free mounting scheme for the hexagonal (60 cm flat to flat) mirrors incorporating remotely controlled motorized alignment. The time spread in light across the proposed $f/1.2$ reflector is only 3-4 ns and 100% of the light from a point source is captured by a 0.125° pixel out to 1° from the optical axis, decreasing to 72% at 2°. It is then possible to match the inherent angular fluctuations in the shower images with a camera that has a reasonable number of pixels (499) and a field of view (3.5°) which is large enough to conduct surveys and observe extended ($\leq 1°$) sources efficiently. For the optical support structure of trussed steel on a commercially available pedestal, effects due to gravitational slumping during slewing will be less than 2.2 mm on the camera face. Slew speed can be as high as 1° per second on both axes.

3.2 Electronics: At present, the need for a low noise, high gain ($> 10^6$), photon counting detector, with risetimes of less than a few ns is satisfied only by photomultipliers (PMTs). The Hamamatsu R7056, with a bialkali photocathode, UV glass window and 25 mm active diameter meets our requirements. The collection efficiency will be increased by Winston cones. The spacing between the PMTs will correspond to a focal plane angular distance of $0.15°$. We plan to use a modular high voltage supply (e.g. LeCroy 1458) where each PMT has a separately programmable high voltage, supplied from a system crate located at the base of the telescope.

Each PMT signal will be taken via a linear amplifier in the focus box to a custom CFD/scaler module. The targeted gain of the PMT plus amplifier (based on a standard 1GHz bandwidth integrated circuit chip, AD8009) provides a signal level of $\sim$2 mV/photoelectron. Optical fibre signal lines may be an attractive alternative to RG58 coaxial cabling allowing the CFD and downstream electronics to be located in the central control building. A prototype multi-channel analog optical fiber system is now being installed on the Whipple 10 m telescope.

The CFD/scaler board, incorporating an adjustable channel by channel delay, will provide an analog fanout of the PMT signal to an FADC system. A prototype 500 MHz FADC system, each channel using a commercially available 8-bit FADC integrated circuit, has been developed and tested successfully on the Whipple telescope (Buckley et al. 1999).

VERITAS will operate at a minimal threshold by requiring a time coincidence of adjacent pixel signals to form a single telescope trigger and $>$ n coincident telescope triggers to initiate data recording. For example, at a threshold of 5 photoelectrons the CFD trigger rate of a single pixel will be $\sim$300 kHz. A telescope trigger will then require a coincidence of ≥ 3 *neighbouring* pixel signals. This topological trigger will be similar to that used on the Whipple telescope (e.g. Bradbury et al. 1999). Telescope triggers will be received at a central station where they can be used to immediately initiate a telescope readout, or delayed to account for orientation of the shower front (e.g. by a CAEN V486 digital delay) and combined in a more complex trigger requirement. For example, if an array trigger requires that 3 of 7 telescopes trigger within a 40 ns coincidence window then the *accidental* array trigger rate is $<$ 1Hz at the 5 photoelectron trigger threshold.

The acquisition system architecture will be based largely on a fast VME backplane and distributed computation by local CPUs running a real-time operating system. For an array trigger rate of $\sim$1 kHz each telescope is expected to have an average data flow rate of $\sim$800 kbyte/s, resulting in a 200 kbyte/s rate on any VME backplane. Each crate controller will be connected to a local workstation which in turn will communicate with a central CPU. The central CPU will perform control and quicklook functions, data integration and compression. Telescope guidance and high voltage control will be performed by inexpensive Pentium PCs.

4 Conclusion:

Our aim is to commission the first VERITAS telescope in 2001. The 10m Whipple telescope nearby will operate throughout the construction phase and serve as a test-bed for innovative technologies. By staged construction of the array over a four year period, we expect to maintain an astronomical facility at all times. VERITAS is expected to be in routine operation prior to the launch of GLAST in 2005.

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