Calibration Systems for the VERITAS Observatory

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Abstract

We describe the calibration systems used in the VERITAS Imaging Atmospheric Čerenkov detector. Calibration systems include a charge injection system for measuring electronic gain and testing pattern trigger functionality, optical injection for flat-fielding PMT gains as well as measuring mirror reflectivity, and atmospheric monitoring for measuring changes in atmospheric attenuation, including ground level aerosol concentrations.

1. Introduction

The VERITAS observatory [1,2] is a next generation facility for Gamma-Ray astronomy in the 50 GeV-50 TeV energy range. Reliable measurements of energy spectra for GeV/TeV Gamma rays requires careful calibration of detector electronic and optical gains as well as reliable measurements of atmospheric clarity. This paper provides a short description of the design of each of these calibration systems to be employed in the VERITAS observatory.

2. Electronics Calibration

The Electronics calibration consists of a charge injection circuit that injects electronic pulses of charge into the preamplifier base in order to ascertain functionality and calibrate the linearity of each data acquisition channel. The charge injection circuit is mounted inside the PhotoMultiplier Tube (PMT) camera, in the focal plane of the telescope, and consists of a Programmable Pulse Generator (PPG) board and 16 Fanout/Mask boards (Figure 1).

The PPG uses an internal crystal oscillator and a programmable countdown clock circuit to generate a programmable clock frequency ranging from 1 Hz to 1 MHz. The clock signal can also be triggered by an external fiber optic signal, allowing precise timing of injected pulses between multiple telescopes from a central location. The clock signal triggers two independent AVTECH programmable pulse generators (AVMM-2 and AVMP-4) which allow programming of the pulse height and pulse width. The pulse height is adjustable over a range of 85dB; the

pp. 2831–2834

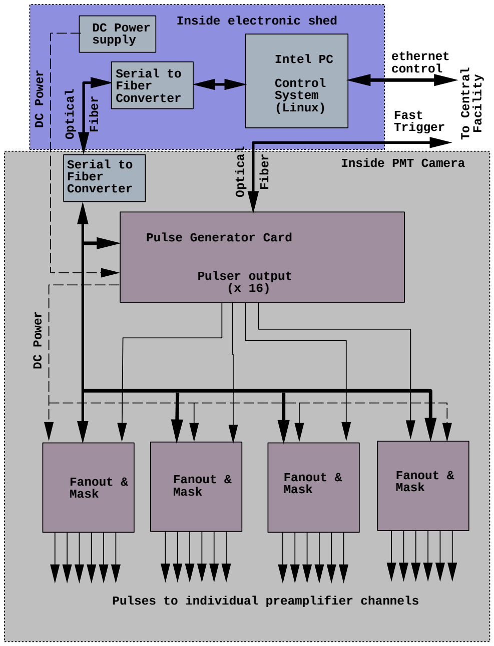

Fig. 1. Schematic Electronic Charge Injection scheme for VERITAS

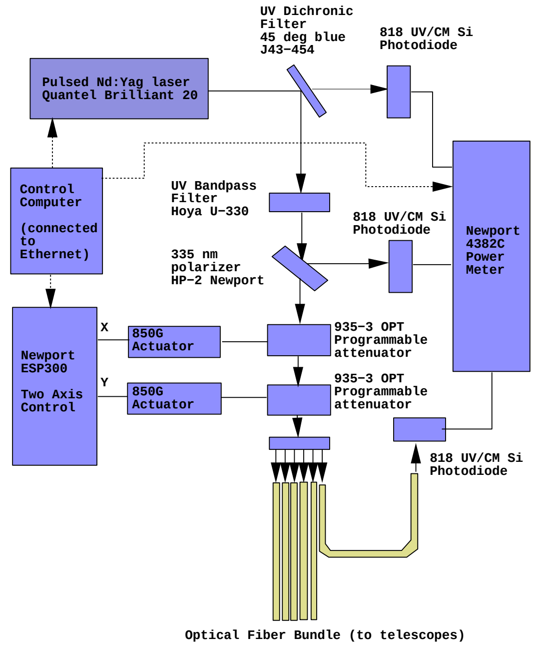

Fig. 2. Schematic Central Optical Injection for VERITAS

output pulse width is adjustable from 1 nsec to 10 msec. The Fanout/Mask board allows individual pixels to be enabled or disabled, thereby allowing detailed study of triggering efficiency using different triggering patterns, crosstalk, diagnostics to find mis-wired/mislabeled channels, and the ability to inject simulated or actual Čerenkov images into the electronics system to examine triggering efficiency.

3. Optical Calibration

The optical injection system consist of a single centrally located Nd-YAG laser (Quantel Brilliant 20) whose light is distributed to each telescope through UV transparent optical fibers. At each telescope, optical fibers terminate at two separate locations: in the center of the reflector, with the emitted optical calibration pulse aimed directly at the focal plane; and at the focal plane, aimed towards the mirror surface, which will reflect the light back to the focal plane. Using the time delay difference in the optical pathlength to these two locations as well as the FADC waveform digitizing electronics , one can simultaneously measure the PMT gain as well as the product of the mirror reflectivity with the PMT gain on a pulse-by-pulse basis.

At the central Nd-YAG laser optical table (Figure 2), harmonic filters,

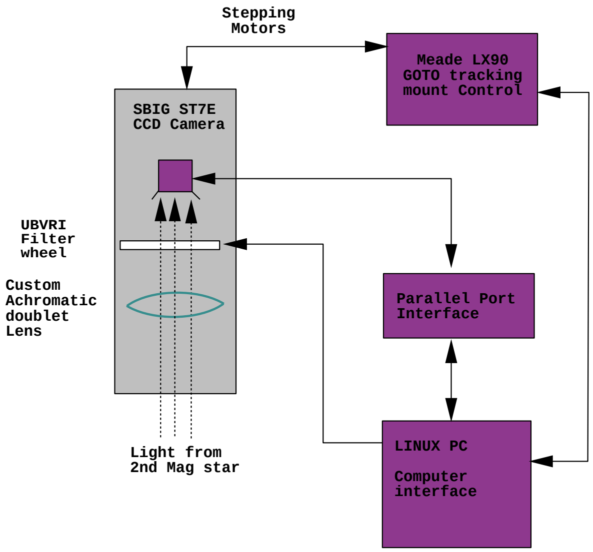

Fig. 3. Schematic drawing of Star Tracking Atmospheric Monitoring system for the VERITAS observatory.

polarizers, and high-power programmable optical attenuators (Newport 935) are used to split off the 355 nm line from the YAG beam and then reliably attenuate the optical intensity. The beam intensity is measured at several locations in the optical train using Newport 818 UV sensitive PIN diodes. The final light is injected into optical fiber cable bundles for distribution to individual telescopes. The optical fiber bundle contains extra fiber optic cables that are monitored to measure the light injection efficiency.

At each telescope, the fiber optic ouputs are terminated into fiber optic heads, each consisting of a solid Teflon diffusor/attenuator, and PVC collimation tube. The Teflon diffusor/attenuator expands the narrow angular emission profile from the fiber optic into an isotropic light emission, with intensity manually adjusted by trimming the thickness of the solid Teflon diffusor to the a desired attenuation length. The collimation tube serves to restrict the light splash from the fiber optic head so that the light only strikes the intended field of view.

4. Atmospheric Calibration

The atmospheric monitor system for VERITAS employs an SBIG 7E CCD camera with UBVRI filter wheel and 25 mm diameter 100-mm focal length achromat doublet lens which is used to focus a 3° field of night sky onto the CCD camera (Figure 3). The doublet lens is fabricated from BK7 and F4 glass, and gives >70% transmission down to 330 nm. A Meade LX90 GOTO mount is used to provide tracking of the CCD camera for both steady, fixed light sources of known intensity to measure ground aerosol attenuation as a function of wavelength, as well as tracking stars from zenith to horizon to measure the total atmospheric extinction from the observation level integrated through the entire atmospheric slant depth (the 'Star Tracking' technique).

Tests of the Star Tracking technique to measure atmospheric attenuation were made at the FL Whipple Observatory at Mt. Hopkins, AZ during 2001 and 2002. Typically, a 2nd magnitude star was continually observed by the CCD camera system as the star traversed from zenith to horizon.

As the camera tracked the star, the CCD camera recorded exposures, and the total light in a 31 pixel x 31 pixel area around the star was summed to give an indication of the amount of light reaching the camera. Sequences of exposures were continually taken in each of UBVRI filter bands and the results for each wavelength were averaged over multiple exposures at similar elevations to reduce statistical fluctuations. By plotting the logarithm of the observed signal versus $1/\cos(\text{zenith angle})$ one can determine the optical attenuation length of the atmosphere from the slope of the line. Figure 4 shows typical measurements and the observed linear dependence.

From these plots we extract UV atmospheric attenuation lengths of 16.5 km and 15.8 for the night of June 14, 2001 at the Whipple Observatory ridge and the FLWO basecamp, respectively. For the night of June 15 the UV attenuation was measured to be 20.4 and 18.6 km, close to the Rayleigh limit (about 20 km at this wavelength).

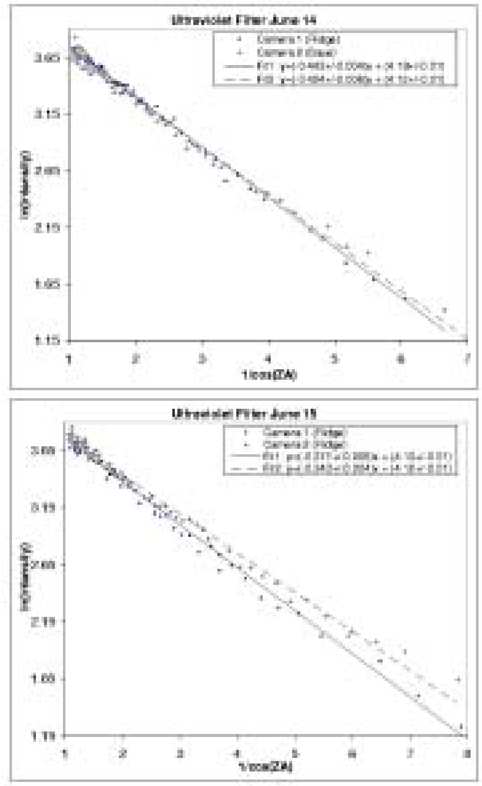

Fig. 4. Plot of data from the 'Star Tracking Technique' : We follow a 2nd magnitude star through different atmospheric slant depths at different altitudes on two successive nights to extract UV extinction from the slope of the best fitting line.

5. Acknowledgment

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6. References

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2. Kieda, D.B. 2002, Proc. of SPIE (Waikoloa) 4834, 276