Calibration results for the first two H.E.S.S. array telescopes

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Abstract

The first two telescopes of the H·E·S·S· stereoscopic system have been installed in Namibia and have been operating since June 2002 and February 2003 respectively. Each camera [2] is equipped with 960 PMs with two amplification channels per pixel, yielding both a large dynamic range up to 1600 photo-electrons and low electronic noise to get high resolution on single photo-electron signals. Several parallel methods have been developed to determine and monitor the various calibration parameters using LED systems, laser and Cherenkov events. Results including pedestals, gains, flat-fielding and night sky background estimations will be presented, emphasizing the use of muon images for absolute calibration of the camera and mirror global efficiency, including lower atmosphere effects. These methods allow a precise monitoring of the telescopes and have shown consistent results and a very good stability of the system since the start of operation.

1. Introduction

The H·E·S·S· detector performance can be monitored with calibration data obtained each night of Cherenkov observation. Methods of calibration and monitoring using LED and laser systems, and also Cherenkov events from muon rings and arcs are presented here.

2. "Classical" calibration

At the initial calibration step, the ADC to photo-electron(γe) coefficient (ADCγe) is determined using an LED system providing a $\sim 1\gamma$e pulsed signal; the γe distribution follows a Poisson distribution with an average value of 1γe. The single γe spectrum is described by a sum of Gaussian functions normalized

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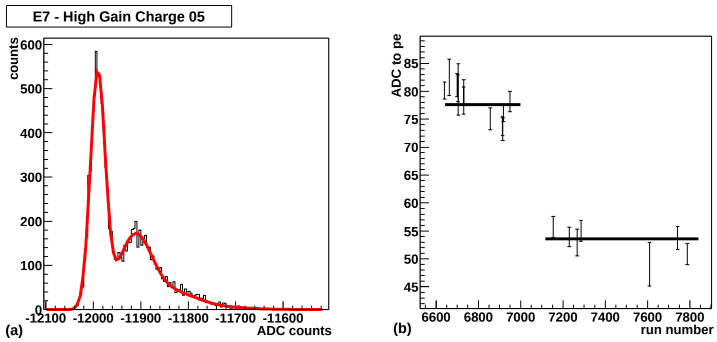


Fig. 1. (a) Example of gain determination in high gain channel. (b) Gain of one damaged pixel with run number; the gain decrease is due to a too bright illumination.

by the Poisson probability to have from 1 to n γe; the pedestal being represented by a Gaussian function weighted by the probability of having zero γe (fig. 1(a)). The gain of every pixel is monitered showing good stability apart from those PMs whose base has been damaged by a bright illumination (see figure 1(b)).

The relative pixel efficiencies are measured using a laser located at the centre of the mirror which provides a uniform illumination in the focal plane. The ADCγe are then flat-fielded with these relative efficiencies. To acquire information on electronic noise (typically 0.18γe) some data are also taken with the lid closed and the high voltages on. Such runs provide baseline parameters to take into account temperature dependencies in the electronics response, for example the pedestal position is shifted by 10 ADC counts/°C.

Finally, some calibration parameters are determined for each Cherenkov run. First the pedestal position is determined every minute of acquisition to take account the above-mentionned temperature dependance. Then the Night Sky Background (NSB) value for each pixel is determined by using the HVI (High Voltage Intensity) shift or the pedestal charge distribution. HVI represents the sum of the anode and divider currents; a baseline value is determined in the runs with closed lid.

In addition, the pixels to be excluded from the analysis are identified, for example those with a star in the field of view, with high voltage switched off or unstable. Also ARS readout chips [2] (each serving 4 channels) with incorrect read-out settings are searched for. After the detector commissioning, the mean number of pixels excluded from the analysis is ~ 40 (4%).

3. Calibration with muon rings

Another useful tool for the calibration of Cherenkov telescopes is provided by muons produced in hadronic showers which cross the mirror, whose Cherenkov light is emitted at low altitude (up to 600m above each H·E·S·S· telescope). The intensity of the muon images can be used to measure the absolute global light collection efficiency of the telescope.

The two principal advantages of using muons are : 1) an easily modelled

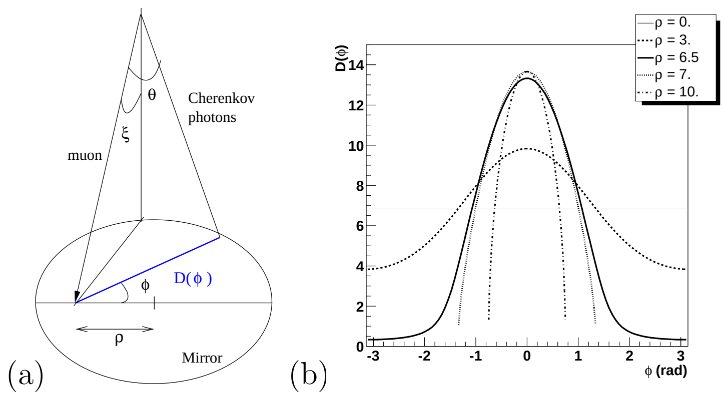


Fig. 2. (a) Geometry of the Cherenkov emission from a muon near the mirror: ξ is the inclination of the muon to the vertical, ρ the impact parameter, and θ the Cherenkov angle. (b) $D(\phi)$ for different impact parameters.

Cherenkov signal is used, and 2) the calibration includes all detector elements in the propagation. For a muon impacting the telescope, the number of γe detected in the camera can be expressed [1] as

$$\frac{\mathrm{d}N}{\mathrm{d}\phi} = \epsilon \frac{\alpha I}{2} \sin(2\theta) D(\phi) \tag{1}$$

where I is the integrated photon wavelength, ϵ the average collection efficiency, θ the Cherenkov angle of the muon, α the fine structure constant, ϕ the azimuthal angle of the pixel in the camera and $D(\phi)$ is a geometrical factor representing the length of the chord defined by the intersection between the mirror surface (assumed circular and ignoring gaps between mirror tiles) and the plane defined by the muon track and the Cherenkov photon (see figure 2 (a) and (b)).

The Cherenkov emission modelling includes the geometry of the ring (centre position, radius, width), impact parameter, and light collection efficiency. These parameters are determined by a χ^2 minimization.

This method has been tested by simulating muons falling near the telescope. Figure 3(a) shows that the number of photons generated from the MC simulation is well reconstructed by the muon analysis. Thus, muon data can be very useful to test the simulation of the H·E·S·S· instrument. The model is also

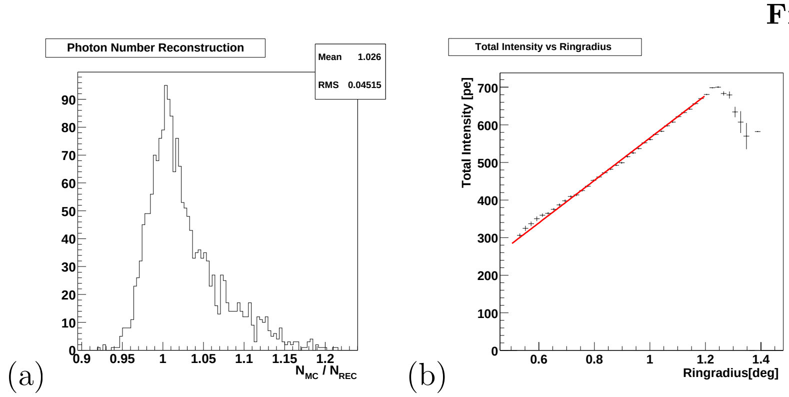
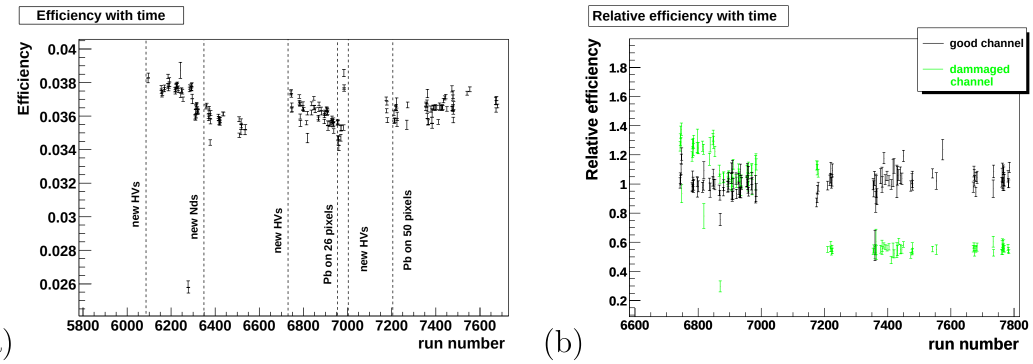


Fig. 3. (a) Distribution of the ratio between MC photons and reconstructed photons with the muon analysis. (b) Total intensity vs. Cherenkov angle on Crab data. The solid line is the dependance in radius from eqn. 1.



(a) (b)

Fig. 4. (a) Collection efficiency of Cherenkov light from muon analysis with time. Some hardware changes are indicated. The run numbers are from October to December 2002. (b) Monitoring of the relative efficiencies of two channels.

able to provide a good reconstruction of real data. In figure 3(b) the solid line shows the expected dependance with θ (muon ring radius) from eqn. 1. The data points beyond radius 1.2 are due to a small number of misreconstructed rings (4% of the muon events).

Figure 4(a) shows the evolution of the collection efficiency for Cherenkov photons between 200 and 700 nm for observation runs from complete rings (~1 Hz). The variations are less than 10% and it is possible to see the effects of hardware changes. No significant correlations with zenith and azimuth angles are observed.

The presence of a large number of muon arcs ($\sim$ 10 Hz) in every data run allows us to determine the light collection efficiency of each individual pixel relatively to the rest of the camera on a run-by-run basis. The relative efficiencies are determined from the mean of the residuals between data and the model fit in each pixel. The residuals follow a Gaussian distribution with small tails due to bad or incorrectly calibrated pixels. The RMS of these efficiencies is $\sim$ 7%, consistent with laser measurements. This method, which also includes incomplete rings in order to increase the available statistics, provides a very sensitive monitoring tool. The figure 4(b) shows the monitoring of two PMs, the damaged channel was overexposed to light.

4. Conclusion

The calibration methods used by the H·E·S·S· experiment utilize LED and laser systems dedicated to this purpose and also Cherenkov images from local muons selected from the collected data. These independent methods allow us to monitor detector response on the few percent level, and additionally provide information for the selection of runs of good quality.

5. References

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