A Novel Alternative to UV-Lasers Used in Flat-fielding VHE γ-ray Telescopes

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Abstract

Preliminary tests of an alternative calibration system for the H.E.S.S. telescope array show that it is possible to replace the currently operating UV-Laser device with an optical LED apparatus. Together with complementary optics, it is able to simulate the Cherenkov flashes, while at the same time illuminating the whole of the telescope's camera uniformly. The device in question is capable of driving a fixed number of specifically chosen LEDs to produce frequent flashes of very short duration similar to the Cherenkov emission generated by electromagnetic cascades. The design of the system continues to be refined. We describe the components and the operation of the device as developed so far.

1. Introduction

Calibration and monitoring of H.E.S.S. cameras is crucial for the post-processing of the recorded events. Exact knowledge of the individual gain for each photomultiplier tube (PMT) is required to translate the number of photoelectrons (p.e.) produced by the PMTs into the air shower's energy. This information can be acquired by using a well defined light source situated on the telescope, simulating Cherenkov flashes, and by recording the output from the camera's PMTs. One can summarise what specifications this light source should have to optimally match Cherenkov flashes. Chiefly, the light source's flashes should be as short as a few ns and have a spectrum that, ideally, matches that of the Cherenkov flash (see Fig. 1). Furthermore, it will have to be wide enough so as to cover the camera completely. Last but not least, its light beam should be uniform so that each PMT receives the same amount of reference light during a flash.

The flat-fielding device used with the first H.E.S.S. telescope was based on a UV-LASER which would, in conjunction with a scintillator, produce short

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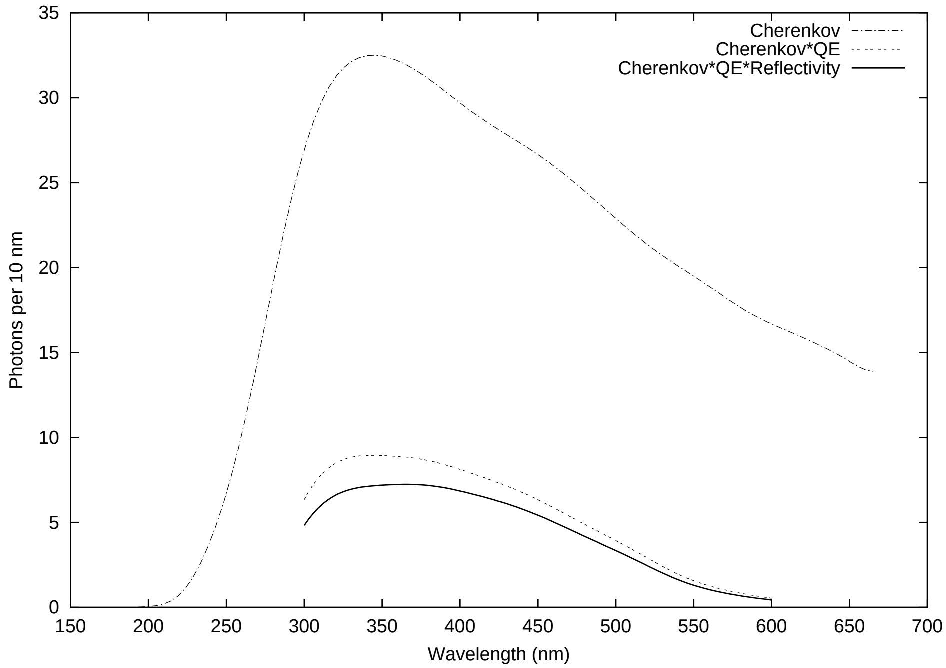

Fig. 1. The Cherenkov Spectrum for 1 TeV γ-rays at the Gamsberg plateau in Namibia (H.E.S.S. site). The dash-dotted line is derived from MOCCA simulations. The dotted line represents the same spectrum with the PMT's quantum efficiency (QE) included. The solid line is the simulated spectrum with both the PMT's QE and the mirror's reflectivity taken into account.

(<7 ns), frequent pulses [1]. Whilst this system performs well, there are several disadvantages, notably cost, a relatively low repetition rate, the problems inherent in the use of optical fibres and poor long-term stability. We therefore wanted to improve the device for later H.E.S.S. telescopes.

While keeping our initial requirements for such a device within acceptable standards, we have constructed a much cheaper (6 times less), much higher repetition rate (40 times more) and much easier to maintain flat-fielding system.

2. The System

2.1. General Description - Circuitry

The flat-fielding device is composed of two independent circuits; the main circuit, which produces the actual flashes, and a monitoring sub-circuit, which monitors the light output coming from the LEDs. A complete schematic of the device is shown in Fig. 2.

The main circuit is triggered via an RS232 interface controlled by the H.E.S.S. central data acquisition system via a W&T Com-Server. The RS232 pulses are fed at the speed of 19600 bauds into an RS232-to-TTL converter that

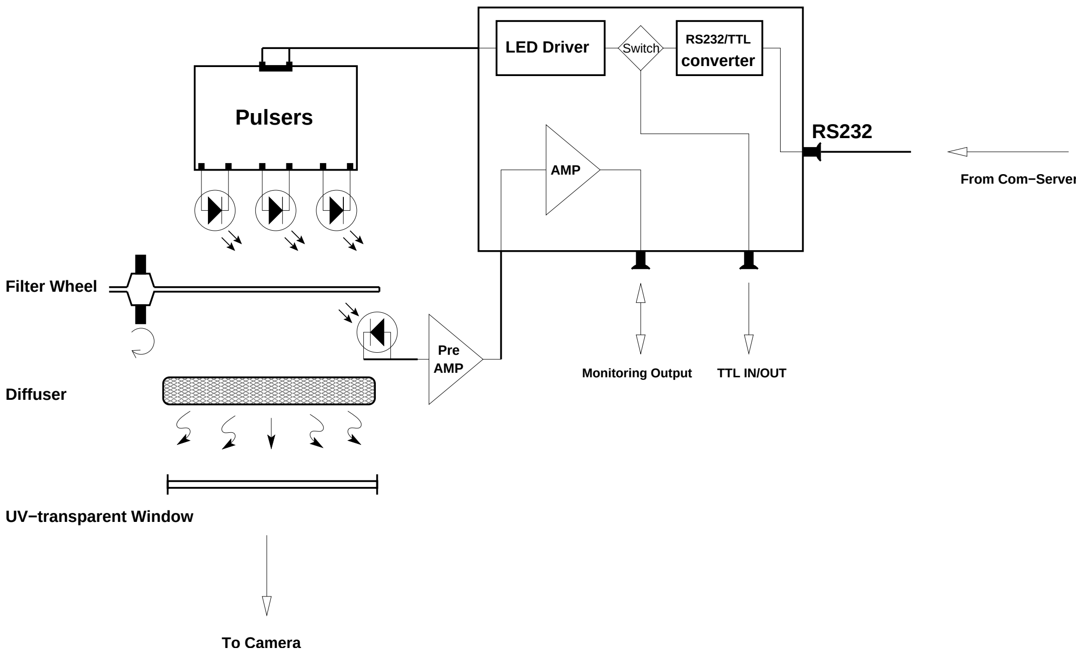

Fig. 2. The layout of the flat-fielding device.

converts them to TTL gates. The UV-LASER system could only be triggered as fast as 25 Hz due to limitations of the laser itself. Our new system uses a trigger rate of 1 kHz, making it a useful tool for testing the response of the DAQ system under high incident event rates.

Apart from the remote operation of the device, a built-in switch allows us to feed in TTL pulses from a local pulse generator (TTL-in mode). When set to the opposite position, the switch sends the TTL signature to an external display, thus allowing the monitoring of the remote operation (TTL-out mode).

The TTL signal, either coming from a remote or a local source, is directed into a driver, which is responsible for transforming the former into a signal compatible with the pulser circuits. These pulser circuits have been built by Sheffield University for the Antares collaboration, for timing calibration purposes [3]. There are 3 of these pulsers connected in parallel in the current configuration, all conveniently embedded on one board and each carrying a single LED. In front of the LED/pulser array there are a filterwheel, a monitoring photodiode, a diffuser and a UV-transparent window (Fig. 2).

2.2. System components

The ‘heart’ of the flat-fielding system is the LED pulser developed by Sheffield University. A complete description of the device can be found in [2]. It exhibits low jitter (<0.5 ns) and a pulse drift rate <0.25 ns/y [3]. Our tests confirmed that this pulser produces pulses with a FWHM of $\simeq$5 ns and a rise time of about 2.5 ns, a significant improvement from the UV-LASER system, whose pulse rise time is 3.3 ns [1]. We also found that the pulse intensities deviate by less than 5% RMS.

Most of the LEDs we tested were found to be compatible with the Sheffield pulser. The current configuration at the H.E.S.S. site uses the HUVL400-520 LEDs by HERO Electronics. Their spectrum ranges from 390 to 410 nm and their half-intensity angle is 20°.

The response of a PMT varies with intensity and the calibration process should take into account these gain variations to result in more accurate flat-fielding. Hence, an automated filter wheel is installed in front of the LEDs to control the intensity of the light output. It is supplied by Elliot Scientific and is capable of holding 6 filters. Currently, it holds 5 neutral density filters —supplied by Coherent-Ealing—, graded as follows: 0.5, 1.0, 1.3, 1.5 and 2.0; while one position is left empty to transmit the full intensity. By analysing the data recorded during the calibration runs, we can estimate the number of p.e. that the H.E.S.S. PMTs detected from the flat-fielding apparatus. Using the filter wheel settings we can get a photon flux per pulse ranging from 2.5 to 250 ph cm^{-2} at a distance of 15 m.

A complementary accessory that allows the monitoring of the LED intensity without having to access the dish is also part of the flat-fielding system. It is based on a photodiode and allows us to monitor the light pulses with, e.g. an oscilloscope.

Since it is crucial to have the same photon intensity on all of the PMTs when calibrating them, it was decided to place a diffuser before the UV-window in the flat-fielding apparatus. We used a 25 mm diameter holographic diffuser by Coherent-Ealing that produces a circular diffusing output 20° wide, for collimated incident light beams.

In order to protect the flat-fielding apparatus from the weather, we shielded it with a UV-transparent window made of borosilicate glass supplied by Edmund Optics. The window's transmissivity, in the frequency range between 350 and 800 nm, is $\approx$90%.

3. References

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3. McMillan, J.E. on behalf of the ANTARES Collaboration 2001, Calibration Systems for the ANTARES Neutrino Telescope, Proc. 27th Int. Cosmic Ray Conf., 2919