THE CENTRAL PIXEL OF THE MAGIC TELESCOPE FOR OPTICAL OBSERVATIONS *

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The MAGIC telescope has been designed for observation of the Cerenkov light generated in Extensive Air Showers. However, its 17 m. diameter and optical design makes it suitable for optical observations of varying astronomical objects. We report here on the installation of a dedicated photo-multiplier (PMT) for optical observations placed at the center of the MAGIC camera (the so-called central pixel). An electro-optical system has been developed in order to transmit through optical fiber the output signal to the counting room, where it is digitalized and stored for off-line analysis. The system was tested by observing the optical pulsation from the Crab pulsar. The results of the tests and the possibilities of the system will be presented here.

1. Introduction

The MAGIC telescope [1] (Fig. 1) is an innovative detector aimed to detect very high-energy γ-rays from astrophysical sources using the Imaging Atmospheric Čerenkov technique. The telescope collects the very short flashes of atmospheric Čerenkov radiation (5-20 nsec in duration) emitted during the development of the Extended Atmospheric Showers (EAS) produced in the interaction of the cosmic γ-rays with the atmospheric nuclei.

*This work was supported by the Spanish CICYT (project FPA2003-9543-c02-01)

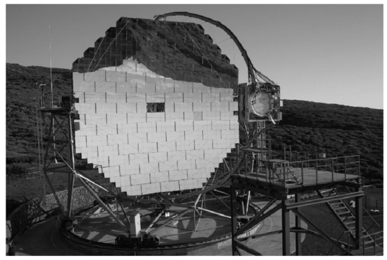

Figure 1. The MAGIC telescope.

The main characteristics of the telescope are its 17m. tessellated mirror, a system of analog signal transmission based on optical fiber and signal digital sampling with 300 MHz Flash ADCs. The main detector, or camera, located at the focus of the telescope, is composed by a matrix of 576 fast-response PMTs.

Besides the main γ-ray observations, the large collection area of the MAGIC telescope can also be used to perform optical observations of slow varying astronomical objects. That can be done by measuring the variations in the DC-current output of a PMT installed at the telescope focus. This technique was already applied by other Čerenkov telescopes (HEGRA CT1 [2], Whipple [3], Celeste [4], HESS [5]) which detected the optical pulsed emission from the Crab pulsar and estimated the photon content of the nebula surrounding the pulsar itself [2].

At commissioning time, the center of the MAGIC camera was deliberately left empty in order to host a dedicated PMT for optical observations. Such modified PMT, the so-called *central pixel*, was installed at the end of March '05 and tested successfully with the detection of the optical pulsed emission from the Crab pulsar.

2. The central pixel

The PMT installed at the center of the MAGIC camera is a standard 1" MAGIC PMT, ET9116 [6], especially designed for fast pulsed-light detection. The DC branch of the pre-amplifier placed at the PMT base has been modified in order to have an integration constant $\tau = 0.5$msec. The overall tension was set to 1.08kV, corresponding to a gain of around 20k and an average current of 0.1-0.5μA under normal Night Sky Background (NSB) illumination.

The transmission of the DC output signal from the PMT base to the counting room for its digitalization and storing is made through optical fiber. The electro-optical transceiver (transmitter+receiver) was designed in order to transmit Crab-like signals, that is, analog pulsed signals with 10-100 Hz periods and widths of the order of milliseconds [8]. For the optical transmitter, installed inside the camera, a wide dynamic range LED was used (Honeywell HFE 4050-014 [9]) to perform the electro-optical conversion while at the receiver (placed after 170m of optical fiber, inside the counting room), a pin diode (Honeywell HFD3038-002 [10]) with an analog pre-amplifier implements the re-conversion. The LED was set to an operation point of 40mA, thus providing linear operation over a wide dynamic range (up to 200 mV). The bandwidth of the transceiver goes from 1Hz to 4kHz, thus allowing transmission of Crab-like signals and rejecting high and low frequency noise (mainly due to the night sky background). The transceiver allows to measure DC variations at the level of 0.2%.

Both the central PMT and the optical transmitter are powered through independent and isolated power supplies installed on the side of the MAGIC camera. The ON-OFF switching of the central pixel is software-controlled through a Programmable Logic Controller (PLC).

3. Crab observations

The whole system has been installed at the end of March '05 and tested by observing the Crab pulsar. The DC current from the central pixel, converted to voltage, was digitized at a sampling frequency rate of 2 kHz by means of a 16-bits National Instruments PCI-6034E ADC card [11] and stored for off-line analysis. The ADC card was set to a resolution of 0.16μ-volts.

As the Crab pulses are completely embedded in noise (generated by the night sky background and the electronics), in order to observe its optical pulsation at the expected frequency, a time-correlated analisys of the data has to performed. A time stamp reflecting the sampling frequency was associated at each event and transformed to an inertial reference frame, which is assumed as the solar barycentric system. For this transformation, the TEMPO software [13] has been used.

The corrected times then are folded with the radio ephemerides corresponding to the epoch of observation provided by the Jodrell Bank observatory [14]. A phaseogram was produced around the expected Crab rotational frequency for each independent test frequency defined by the Independent Fourier Spacing IFS=1/T$_{obs}$. The folded intensities were then tested

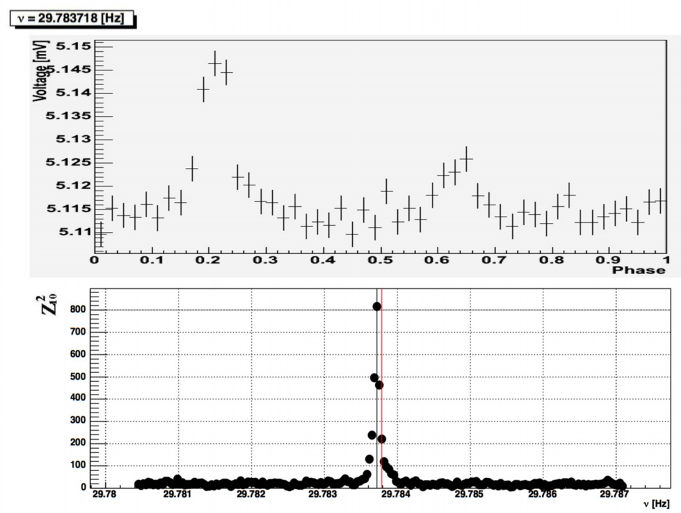

Figure 2. *Upper plot*: Optical light-curve of the Crab pulsar obtained with the central pixel of the MAGIC telescope. *Lower plot*: Z^2_m statistical test. A clear peak appeared at the frequency expected for the observation epoch.

against a uniform distribution by performing a Z^2_m statistical test [15]. Figure 2 (lower plot) shows the Z^2_{10} test scanning different frequencies around the expected Crab frequency. A clear peak appeared at the frequency expected for the observation epoch. Figure 2 (upper plot) shows the well-known double-peaked lightcurve calculated at the maximum Z^2_{10} value and after 20 min. of observation.

4. Conclusions

In this work, we have reported about the installation in the center of the MAGIC camera of a photo-multiplier, the central pixel, dedicated to optical observations. The central pixel has been tested successfully by the detection of the Crab optical pulsations. The minimum time requested for a 5σ detection was lower than 1 minute. The expected detection time was 30 sec [2]. However, due to extreme weather conditions preceding the weeks immediately before the observations, the optical conditions of the telescope were not the optimal ones. The pointing error of the telescope was estimated offline in about $0.1°$, while the Point Spread Function (PSF) was around 0.1° (FWHM). This limited the amount of collected light over the Central Pixel to about 7-9% of the total light emitted by the pulsar. Recent alignments of the mirrors have reduced the PSF to less than 0.05°. Thus, we expect to improve the detection time by at least a factor 2.

The applications of the central pixel will be mainly focused in the simultaneous observations of the Crab pulsar both in the optical and in the γ regimes, in order to have real-time ephemerides for periodicity search in γ-rays. Before that, the central pixel will be also used to test the whole timing system of the MAGIC telescope [12]. Optical observations of quasi-periodic flaring AGNs (Mrk 421, 501, ..) and X-ray binary systems (AE Aquarii) are also contemplated.

Acknowledgements

The authors wish to thank the financial support given by the CICYT (project FPA2003-9543-C02-01) to make this work and the IAC for providing excellent working conditions in La Palma. The MAGIC telescope is mainly supported by BMBF (Germany), CICYT (Spain), INFN and MURST (Italy).

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