Tracking Stars with the Fluorescence Detector of the Pierre Auger Observatory

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Abstract

Recording tracks of stars traversing the field of view of the Auger's fluorescence detector (FD) is a powerful tool to monitor various FD parameters. For instance, the telescope absolute pointing and its stability during the life of the experiment, the sky quality and the uniformity of the photocathodes response, are good examples. Regular control of those tracks would allow checking the telescopes stability during the whole life of the experiment, estimated to be about 20 years. The Engineering Array phase of Auger comprised 32 Cherenkov tanks plus a few auxiliary ones and 2 fluorescence telescopes each one covering 30^o in azimuth by 30^o in elevation. All 880 PMTs of both telescopes have been equipped with a novel optoelectronic system developed to perform a highly sensitive measurement of the DC component of the anode current, despite the PMT is biased with cathode grounded. This method demonstrated to be extremely sensitive even to 5.4 visual magnitude stars that could be clearly recorded although an UV filter was present at the telescopes aperture. We report records of stars of various magnitudes, a reconstruction of the pointing of one of the telescopes, and comparisons of a PMTs response to shower and star signals.

1. Introduction

The Auger fluorescence detector comprises 24 telescopes each one consisting on a large, 3.5 m x 3.5 m mirror of 3.4 m focal distance and a 2.2 m diameter aperture. A camera of spherical surface consisting of an array of 20 columns by 22 rows of Photonis XP 3062 PMT's is positioned at about 1.7 m of the mirror's centre of curvature. This system, which constitutes a Schmidt optics, largerly reduces the coma aberration. The aperture is covered by an UV filter to increase the signal-to-noise ratio. For a point object like a star, the spot size is $0.5°$ in diameter, i.e. one third the pixel size.

The telescopes look to the sky and are subject to the background light, which comprises various sources like stars and planets, atmospheric glow, human pollution and other objects. Although those sources increase the background noise, the possibility to make the FD sensitive to the sky-background light is

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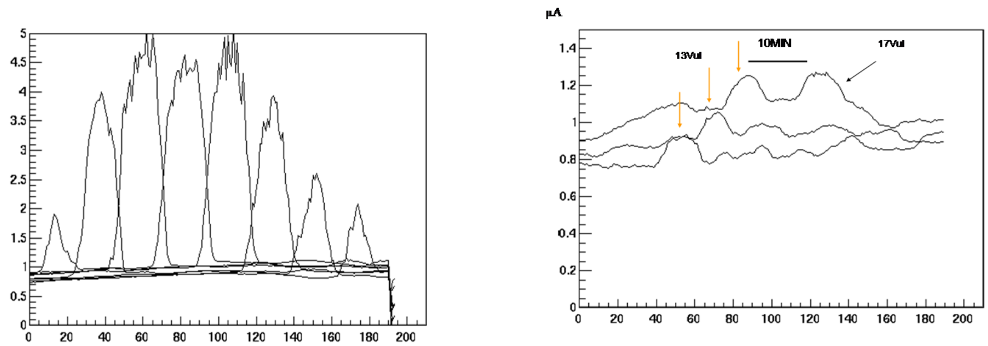

Fig. 1. The first stars signals seen by the FD Optical Current Monitor on June 25, 2001. The horizontal scale is the number of 20 sec interval. A star takes about 6 min to traverse a PMT along its diameter. The fluctuations at the top do not seem compatible with Poisson statistics. The vertical scale is mean anode current in μA.

very attractive. In fact, many telescopes parameters could be determined as, for instance, its absolute pointing and stability during the life of the experiment, the sky quality (f.i. presence of clouds) and also the uniformity of the photocathode response. Regular control of star tracks would allow checking the telescopes stability during the whole life of the experiment. Superposition of star tracks taken over several days in a given pixel, reduces the baseline noise and returns the profile of the PMT response along the track. The XP 3062 has been investigated in the past [1].

The PMTs are biased with positive supply, i.e. cathode grounded. This ensures simplicity of operation and better stability of response but, in principle, it seems that direct measurement of the DC or very slow component of the background light will be impossible to perform. We could solve for the first time this very old problem by implementing an optically coupled feedback loop of novel design [2,3] included in the 880 Head Electronics, that serve the PMTs of the two telescopes. The results were excellent as this innovative optical current monitor system proved that the DC component of the background light was readable with very high resolution. In fact, stars of visual magnitude 5.4 or even dimmer were clearly visible trough the UV filter. Brighter stars like αLyræ clearly showed a structure when the light spot was traversing the PMTs photocathode (Fig.1.). To reduce the cost of the electronics to be used with the full production, we also incorporated an indirect method for the measurement of the background light by evaluating the variance of the baseline fluctuations. In the following sections we will report on the use of star tracks to determine the pointing of one of the telescopes, as well as photocathode anisotropy. Finally, we will show results of an XY scan on a PMT's photocathode, and will draw our conclusions.

2. Fluorescence events and star tracks

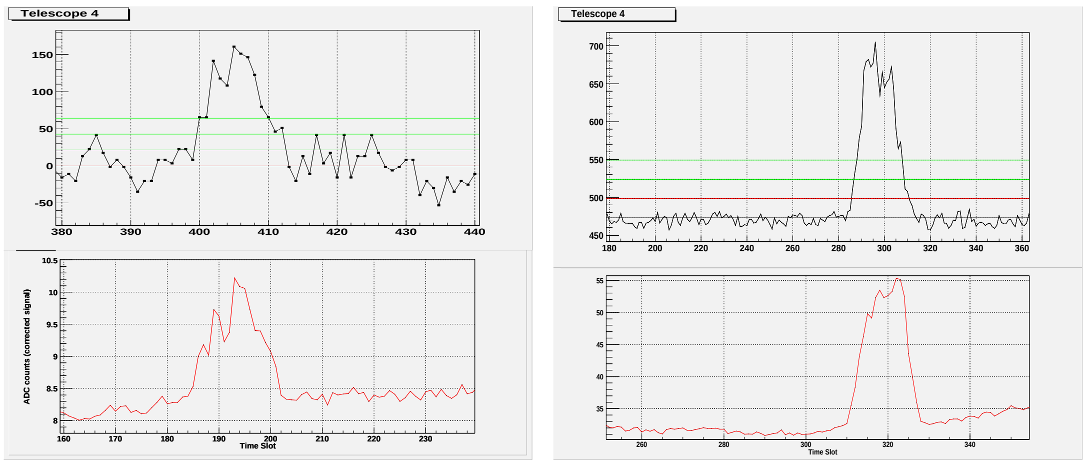

Fig. 2. Signal from a flourescence event (top) and from a star (bottom). Although the time resolution is quite different, we observe similar shapes. The right panel shows a mirror symmetry due to the fact that the shower axis of the fluorescence event and the star are crossing the camera in opposite directions

During the analysis of the star signals, it was noted that despite the fluorescence signal and a star signal are in a completely different time scale, both left in the same PMT a very similar pattern (Fig.2. left panel). In some cases a signal of a star and of a fluorescence event had mirror-like fluctuations at the top (Fig.2. right panel). In the first case the star and the fluorescence signals corresponded to star tracks and fluorescence events traversing the camera in the same direction. In the second case the star and the shower move in almost the same direction but in opposite senses. This fact led us to think that the fluctuations seen were most probably to be assigned to photocathode anisotropy. To verify that, the mean value of star signals over 10 nights were performed. Results are shown in Fig.3. (left), where the outcome of this operation can be observed. The pattern seen at Fig.3. (right) corresponds to a slice cut of the photocathodes response obtained at our Lab using an xy table and an UV LED.

3. Camera Positioning

One important task for a long life experiment like Auger is to keep a regular monitoring of the detector pointing. The stars tracks recorded by FD can be used for this scope. The pointing direction of the camera's center for each telescope of the flourescence detector can be tested minimizing $\chi^2 = \sum_{pixels}(\Delta\theta_{theor.} - \Delta\theta_{meas.})^2$ where $\Delta\theta_{theor.} = \delta_{star} - \delta_{pixel}$ (δ is the declination) and $\Delta\theta_{meas.}$ is calculated by $\Delta\theta_{meas.} = \sqrt{(0.75^\circ)^2 + (\frac{360^\circ}{24h.}\frac{\Delta T}{2}cos\delta_{star})^2}$

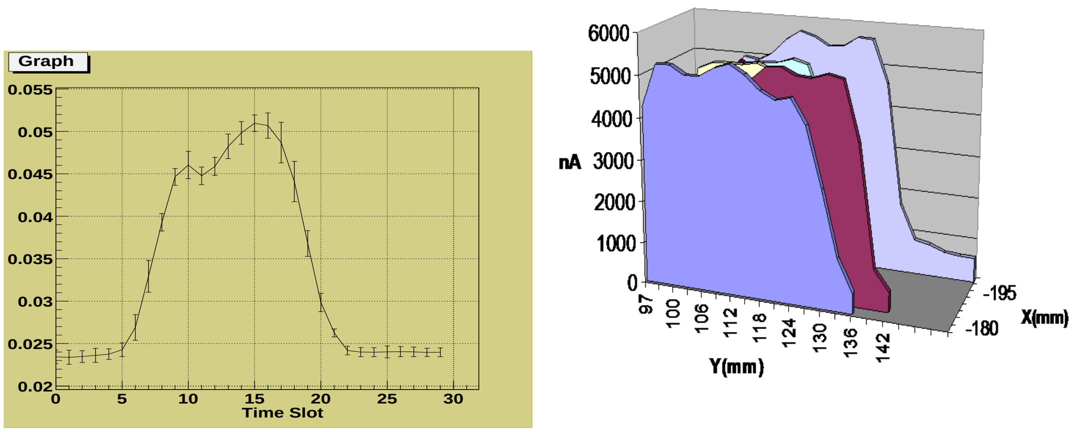

Fig. 3. The average shape of star signals on the same PMT of 10 different nights (left) shows the photocathode anisotropy in one of the FD PMTs. The right panel shows the photocathode response obtained at the Lab making an xy scan.

We performed the above analysis for 7 of the brighter stars (α Aur, α Lyræ, α_2 Can Ven, α Gem, β Gem, β Tauri and α Cor Bor) and obtained the latitude of one telescope $\theta = 125°42' \pm 11'$ (0^o means the North Pole) while the actual latitude is $\theta_{True} = 125°29'47''$

4. Conclusions

We have demonstrated a high-resolution star-tracking capability of the Auger FD. Dim stars were clearly identified with a novel optoelectronic system incorporated in the 880 PMTs of the two FD prototype telescopes. Later on, the calculation of the variance of the baseline fluctuation, have shown to be a low-cost alternative and therefore more convenient for the full production. We have used these data to verify the pointing of telescope $n°4$.

Finally, we averaged star signals in various pixels over a few days and found the expected reduction of the baseline fluctuations and an enhacement of a non-constant response (of aprox $\pm 10\%$) along the photocathode. This was confirmed by xy scanning of a PMT illuminated by an UV LED.

5. References

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3. S. Argiró et al., Nucl. Instr. and Meth. **A 461** (2001)440-448