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Quality studies of the data taking conditions for the Auger Fluorescence Detector

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As more than half of the Fluorescence Detector (FD) of the Auger Observatory is completed, data taking is becoming a routine job. It is then necessary to follow strict procedures to assure the quality of the data. An overview of the data taking methods is given. The nature of the FD background signal is due to the night sky brightness (stars and planet faint light, moonlight, twilight, airglow, zodiacal and artificial light) and to the electronic background (photomultiplier and electronic noise). The analysis of the fluctuations in the FADC signal (variance analysis), directly proportional to the background mean light level, performed for each night of data taking is used to monitor the FD background signal. The data quality is analysed using different techniques, described in detail. Examples of trigger rates, number of stereo events, dead time due to moonlight, weather or hardware problems are given. The analysis comprises several months of data taking, giving an overview of the FD capabilities, performance and allowing a systematic study of data and their correlation with the environment.

1. Introduction

The Pierre Auger Observatory studies high energy cosmic rays in the region of the Greisen-Zatsepin-Kuz'min (GZK) cutoff [1]. One of the detection methods used is the collection of air fluorescence light generated in the Earth atmosphere by extensive airshowers. Currently there are 18 fluorescence telescopes in operation, distributed in 3 "eyes", which overlook the entire surface array. The last eye is foreseen to be completed in early 2006.

Every eye building houses 6 telescopes, each detecting fluorescence light by means of a camera formed by 440 photomultipliers (PMTs), covering a field of view of roughly 30 x 30 degrees. Each PMT works as one pixel to form the complete image of the shower.

To assure the quality of the FD data, it is necessary to follow well defined procedures on data taking and on reporting the problems that might arise. The study of the background associated with each measurement is important for the sensitivity that the telescopes can achieve. Statistics on different parameters associated with the measurements help identify hardware and software problems or simply calculate the effective measurement time. This work gives an overview of the efforts made to achieve these goals.

2. Data taking procedures

Every month, during the period around the new moon, a group of physicists takes care of the FD data taking shift. They are instructed on how to operate the data aquisition system and then supervised until they get aquainted with the procedure. All the information that the operators might need during the shift is contained in an internal web page. There are links to hardware and software manuals, information about the moon fraction, twilight times and weather.

Every occurrence during the shift is reported in the FD electronic e-log, accessible from the FD web page. A template is provided to unify the way of reporting different events.

3. Variances analysis of FD background signal

The contribution to the background signal comes from stars and planet faint light, moon light (in the field of view or diffuse), twilight at the start or the end of the data taking run, lightning, air glow, zodiacal light and man-made light pollution. The electronic noise comes from the PMTs and the electronics chain. Thus, the total background signal is the sum of the sky and electronic background

$$S_{ADC}^{bckg} = S_{ADC}^{sky} + S_{ADC}^{ele}$$

and the ADC signal variance is the sum of the sky background variance and the electronic noise variance

$$[\sigma^2_{ADC}]^{bckg} = [\sigma^2_{ADC}]^{sky} + [\sigma^2_{ADC}]^{ele} \qquad .$$

The environment background signal can be studied on an event-by-event basis, looking at pixels not passing the First Level Trigger (FLT) [1] or with special background measurements, by registering the background value every 30 seconds during the data taking. To estimate the electronic noise value, we used the background files acquired with closed shutters every night before data acquisition. This background measurements last for a few minutes sampling the pixels every 5 seconds.

The direct current induced by the background is eliminated by the AC coupling of the PMT base. The noise will be generated by the fluctuations of the mean value, which is proportional to the mean number of photons reaching the PMT. This motivates the present systematic analysis of the variances.

A stand-alone code has been developed to monitor the FD background signal and the detector status for any data acquisition night for all mirrors and telescope sites. The program can process the background signal in the FD data runs event by event and/or the special background files with closed or open shutters. The output consists in ROOT [2] files that can be then analyzed off-line. It can also plot variances, pedestals, thresholds and pixel hit rates on a nightly basis using an on-line display.

For each event in the FD data runs, the algorithm extracts the pixel information, including their ADC traces. For each trace, the mean value (pedestal) and the variance are obtained. Only pixels not triggered by FLT logic *(noise pixels)* are used while for the special background measurements all pixels in the camera are considered.

A typical result is shown in Figure 1 (left) where data from three telescopes in Los Leones eye are shown.

The results in Figure 1 can help in classifying the nights according to the data taking conditions, just looking at the variances. Typical results are shown in Figure 1 (right) for telescope 4 in Los Leones. Note that the variance is very sensitive to the data taking conditions . The nights can be easily classified, as shown in the figure. The electronic noise for a typical night is reported in Table I, for all telescopes in Los Leones and Coihueco sites. A systematic investigation for all data taking nights in 2004 has been performed.

4. Analysis of the data taking period

After each data taking period, a report is generated with information about the performance of the FD telescopes. It is divided in a short report that shows the measurement and down times for every night, in every FD site, and a long report that adds information about every run, start and end times and telescope fraction (see section 4.1), shows links to PostScript and ROOT [2] files containing information about the total number of triggers and trigger rate as a function of time. Finally there is a link to the e-log written during the shift period. The source of information for this analysis are the log files written by the data aquisition (DAQ) program and the data files, which are automatically analysed using a stand-alone program.

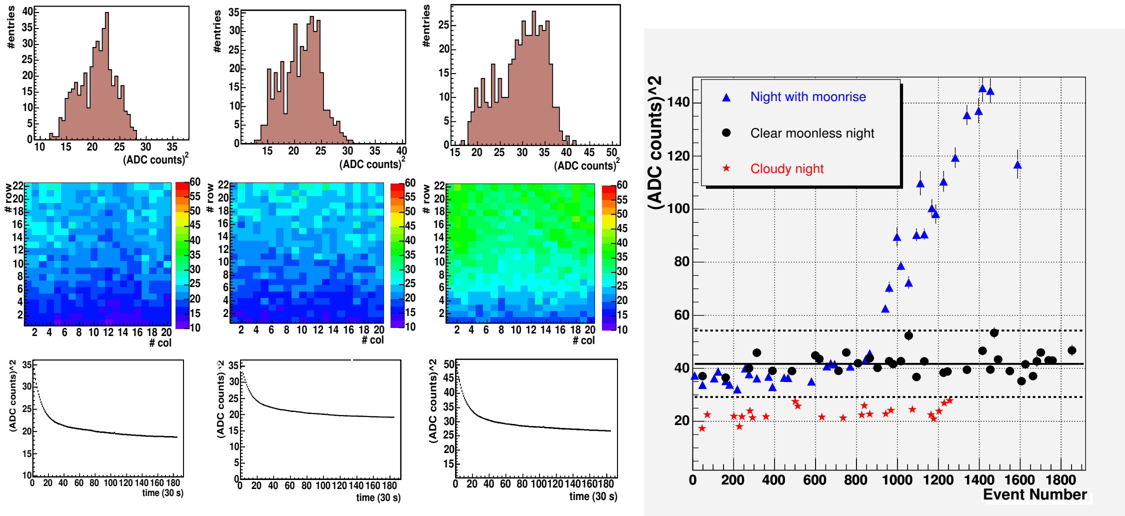

Figure 1. (Left) Total variance (sky background + electronic noise) for telescopes 1, 2 and 3 in Los Leones eye for a typical clear moonless night, in terms of distributions (top) and color maps (middle), averaged over the whole night. Each point in the time profiles (bottom) is the total variance averaged over all pixels vs. time in 30 s units. (Right) Variances vs. event number for three typical data taking nights: i) (triangles) night with moonrise; ii) (circles) clear moonless night; iii) (stars) cloudy night. Each point is the average value of the variance taken over all noise pixels in telescope 4 at Los Leones. The continuous line is the mean value over the whole night for clear moonless conditions, the dashed lines indicate $\pm 1\sigma$.

ELECTRONIC NOISE

Coihueco Tel Id	Variance $(ADC\ counts)^2$	Pedestal $(ADC\ counts)$	Threshold $(ADC\ counts)$	Pixel Hit Rate (Hz)
1	3.9 ± 0.3	140 ± 20	1400 ± 200	85 ± 9
2	3.8 ± 0.3	130 ± 30	1300 ± 300	100 ± 4
3	4.2 ± 0.5	120 ± 20	1200 ± 200	100 ± 3
4	3.9 ± 0.6	130 ± 20	1400 ± 200	93 ± 5
5	3.8 ± 0.3	140 ± 20	1400 ± 200	86 ± 8
6	3.8 ± 0.3	130 ± 10	1400 ± 100	100 ± 10

Table 1. Values for variances, pedestals, thresholds and pixel hit rates, averaged over all PMTs in Coihueco. Results obtained from the electronic noise monitoring with closed shutters.

4.1 Dead time

The total available dark time is defined as the time between the end of the astronomical twilight at the beginning of the night and the start of the twilight the following day. Everything that prevents the measurement to be as long as this period is considered dead time. The main source of this dead time is the presence of the moon close to or inside the field of view (FOV) of a telescope. But also bad weather, hardware or software problems can decrease the measurement time.

The different types of down (or dead) times are defined as follows:

* **Moon**: this is calculated using a program written by M. Prouza. The time when the moon is closer than

Los Leones - Night from 2004-12-13 to 2004-12-14
Run number: 627
Start time (UTC): 2004-12-14 02:41:54
End time (UTC): 2004-12-14 07:30:17
Total time in this run: 17303 s (04:48:23)
Total dark time: 21300 s (05:55:00)
Total measurement time: 20505 s (05:41:45) 96 %
Down time due to moon: 0 s (00:00:00) 0.00 %
Down time due to DAQ: 769 s (00:12:49) 3.61 %
Down time due to weather/other: 43 s (00:00:43) 0.20 %
Number of stereo events LL-CO: 6

Table 2. Measurement and dead times for one night in Los Leones. The number of stereo events registered is also indicated.

5 deg to the FOV of each telescope is used to calculate the period when that telescope is not able to take data. The operators are requested to close the corresponding shutter at the reported time.

* **DAQ/Hardware**: it is defined as the time between runs in the same night. Takes care of the fact that some runs are stopped due to a problem with the hardware or software and a new run is started as soon as the problem is solved. The assigned time could be modified later if the information in the e-log shows evidence against the assumption.

* **Weather/other**: the down time that cannot be classified as any of the previous cases is attributed to the weather or unknown causes. The real cause is later deduced from the e-log entries.

There is another source of dead time, related to the normal operation of the DAQ software and hardware. As any other system, it has internal delays that can lead to loss of measurement time. This dead time is calculated by the system itself. It is not yet taken into account in the reports, but will be in a near future.

For each run, the measurement time is calculated as the time difference between the start and end times, multiplied by the telescope fraction. The telescope fraction is calculated as the number of mirrors used in the run times 1/6. This is useful when some mirrors are not present in the DAQ (for example, they are taken out because the moon is in their field of view). Run measurement times are added to obtain the total measurement time of the night. Runs shorter than one minute are discarded. A summary of the obtained results for one run and the whole night are shown in table 2. The number of stereo events is calculated by comparing the GPS times and visually discarding those that could be chance coincidences between two eyes.

References

[1] J. Abraham, et al. (P. Auger Collaboration), Nucl. Instr. Meth. **523** (2004) 50
[2] http://root.cern.ch