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Influence of the NSB on the Hillas parameters

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Abstract

The night sky background and starfield in the FOV of a Cherenkov telescope influences the shower images registered on the camera. Here we briefly describe this effect and suggest some methods to correct for it before attempting gamma/hadron discrimination and physical analysis of the data.

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1 NSB and shower images

The level of night sky background on the telescope FOV depends on:

a) **Position in the sky**. In general galactic sources exhibit a higher NSB (e.g. galactic Crab vs extragalactic Mrk-421) due to the higher star density in the galactic plane. In addition isolated bright stars may enhance the noise level for particular pixels (e.g. Zeta Tauri for Crab).

b) **Moon phase and orientation relative to the telescope**. The moon phase and distance to the telescope FOV strongly affect the NSB (the NSB is at its lowest at $40°$ from the moon).

After flat-fielding and conversion into photoelectrons, image cleaning of the background noise is performed by ways of the so-called topological tail cut. The RMS of the pedestal noise in each pixel is determined out of the "pedestal runs" (or the "data runs" themselves in old versions of the CT1 analysis). The level of noise determines which pixels are acceptable and may be integrated into the shower image:

- **CORE PIXELS**. Pixels with a signal larger than 3 pedestal σ's and a neighbouring pixel in the same conditions are called core pixels and accepted.
- **BOUNDARY PIXELS**. Pixels with a signal larger than 2.5 pedestal σ's and a neighbouring *core pixel* are called boundary pixels and accepted.

All other pixels are set to zero and thus never considered to calculate the shower image parameters.

Since the tail cut on the images depends on the pedestal fluctuation level, the images will be determined by the noise level in the telescope FOV. As an example we show in figure 1a the distribution of the image parameter LENGTH for data runs on Crab and Mrk-421. The NSB for Crab is higher than for Mrk-421. Therefore the pedestal RMS is higher and more pixels of the image are rejected. The image dimensions on the camera (reflected in the Hillas parameters LENGTH and WIDTH) are smaller. The effect is similar when we go from moonless observation where the NSB is low to moonlight observations for the same source. Figure 1b shows the Hillas parameter LENGTH for Crab runs with and without moon for the same high voltage level (respectively "HV00" and "Nominal" settings).

2 Methods to correct for the noise in the analysis

In general we use the MC simulation for a given noise NSB (corresponding to moonless Crab conditions) or an optimization on real moonless Crab data to determine the best Hillas cuts for γ/hadron separation. These cuts cannot be optimally applied to data whose Hillas distributions have different shapes, since the efficiency of the cuts would be unknown.

The fact that the Hillas parameter distributions are different for different noise levels means that we are actually dealing with different telescope operation modes that should be analyzed using different MC simulations. The corresponding MC simulation should account for the shapes of the cosmic and gamma ray images and determine the best cuts for γ/hadron separation. Hence in an ideal situation we should make use of a different MC simulation for each different NSB data sample. This is hard to accomplish due to lack of CPU- and man-power, although an attempt to simulate some "reference NSB conditions" should definitely be endeavoured! This should be done using the NSB conditions listed on table 1. Dorota Sobczynska has started with these MC reference simulations.

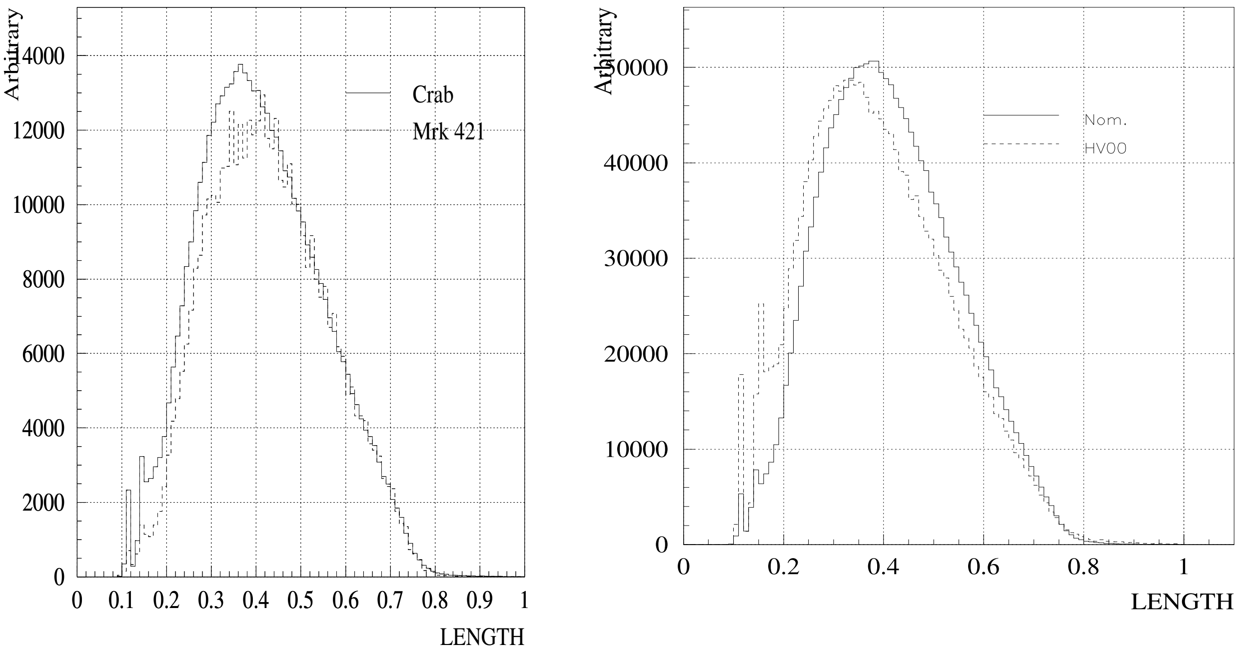

Figure 1: *On the left (a): LENGTH distributions for Mrk 421 january-february 2001 flare and Crab-Nebula january-february. On the right (b): LENGTH distributions for Mrk 421 january-february 2001 flare taken with moon (HV00) and no moon (Nom.).*

HV reduction	trigger (phe)	threshold energy (TeV)	mean pedrms (phe)
Nom.	13	0.7	1.1 $\pm$ 0.3
HV00	13	0.7	1.6 $\pm$ 0.5
HV04	17	0.9	2.1 $\pm$ 0.5
HV08	22	1.2	3.0 $\pm$ 0.4
HV12	30	1.6	3.2 $\pm$ 0.6

Table 1: *Trigger level in photoelectrons, threshold energy and mean RMS for nominal and reduced HV settings in CT1.*

In the absence of exhaustive MC simulation, two methods have been developed to rather bring the real data distributions to "standard conditions" where we can apply the standard fixed γ/hadron separation methods.

2.1 Martin Kestel's method

The shape of the LENGTH and WIDTH distributions (in particular the position of the peak) is directly correlated to the pedestal RMS. Thus Martin Kestel[1] applies a phenomenological rule to shift both distribution to a fixed position matching that of Crab moonless conditions. This procedure is called "data zonking". (In principle data do not even have to be shifted to Crab conditions. Any arbitrary shift can be applied since Crab data can also be shifted and cuts optimized accordingly. The result is always zonked data which can be compared under any NSB conditions.)

Figure 2 illustrates the method. The top and bottom figures show how the method shifts the widths to a common position for all the different voltages. The central figures correspond to different zenith angle bins and illustrate how the widths depend on the pedestal RMS.

This approach has been preliminarily applied to Mrk-421 2001 flare data with significant improvement in the γ signal (47.1σ to 52.9σ).

2.2 Daniel Kranich's method

Since the effect on the Hillas parameters comes from cutting the images at different levels, Daniel Kranich[2] has attempted a basically fixed cut level for all noise conditions. This means that more noise gets into the images and the Hillas parameters are more poorly determined but the distributions look similar for all the noise conditions and the same cuts can be applied. The actual "tailcut pedestal RMS" that is used to perform the tail cut instead of the real pedestal RMS is shown in figure 5.1.1.

3 Conclusions

There is a clear need to correct for the effect of the different noise levels in the different data samples if we are to obtain reliable physical results. This may in principle be accomplished by ways of dedicated MC simulations of all the noise conditions, but this task has proved to be beyond our man and CPU power capacities. Even so two phenomenological methods have been shown to allow data analysis of different samples with the same cutting procedure notwithstanding very different noise conditions. It would be interesting to prove that both methods produce comparable results. As an additional crosscheck a MC sample could be simulated for noisy conditions where both methods could be applied and proved to work out physical results properly.

References

[1] M. Kestel, contribution to MAGIC Physics and Analysis meeting, Hinterriss, March 2001.

[2] D. Kranich, Ph.D. thesis, LMU Muenchen, in preparation.

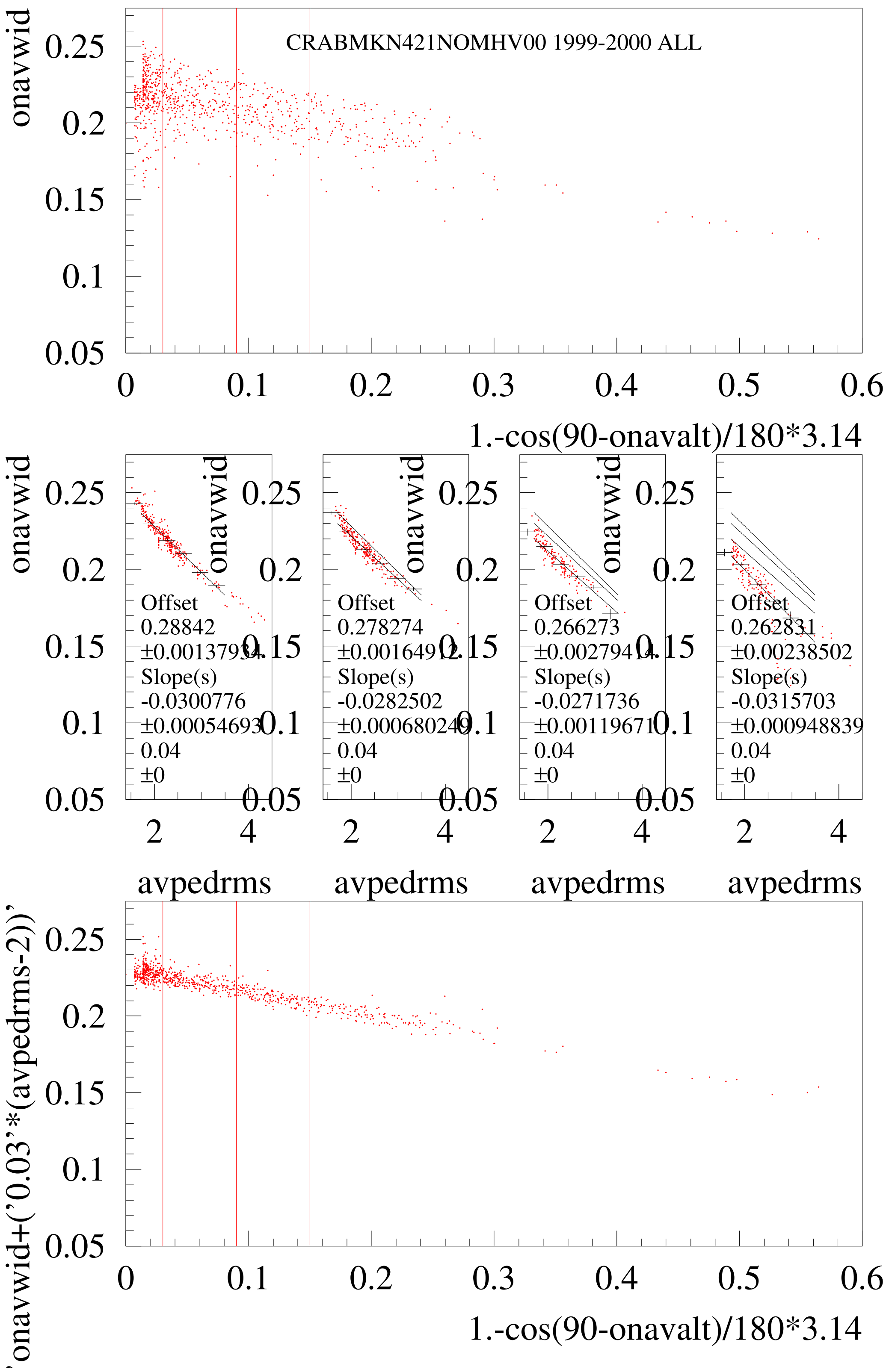

Figure 2: *Top: Original average widths as a function of zenith angle for a combination of Nom. and HV Crab and Mrk 421 data. Center: Average widths as a function of pedestal RMS for the four zenith angle bins in the top figure. Bottom: Average widths of the same data sample after zonking.*

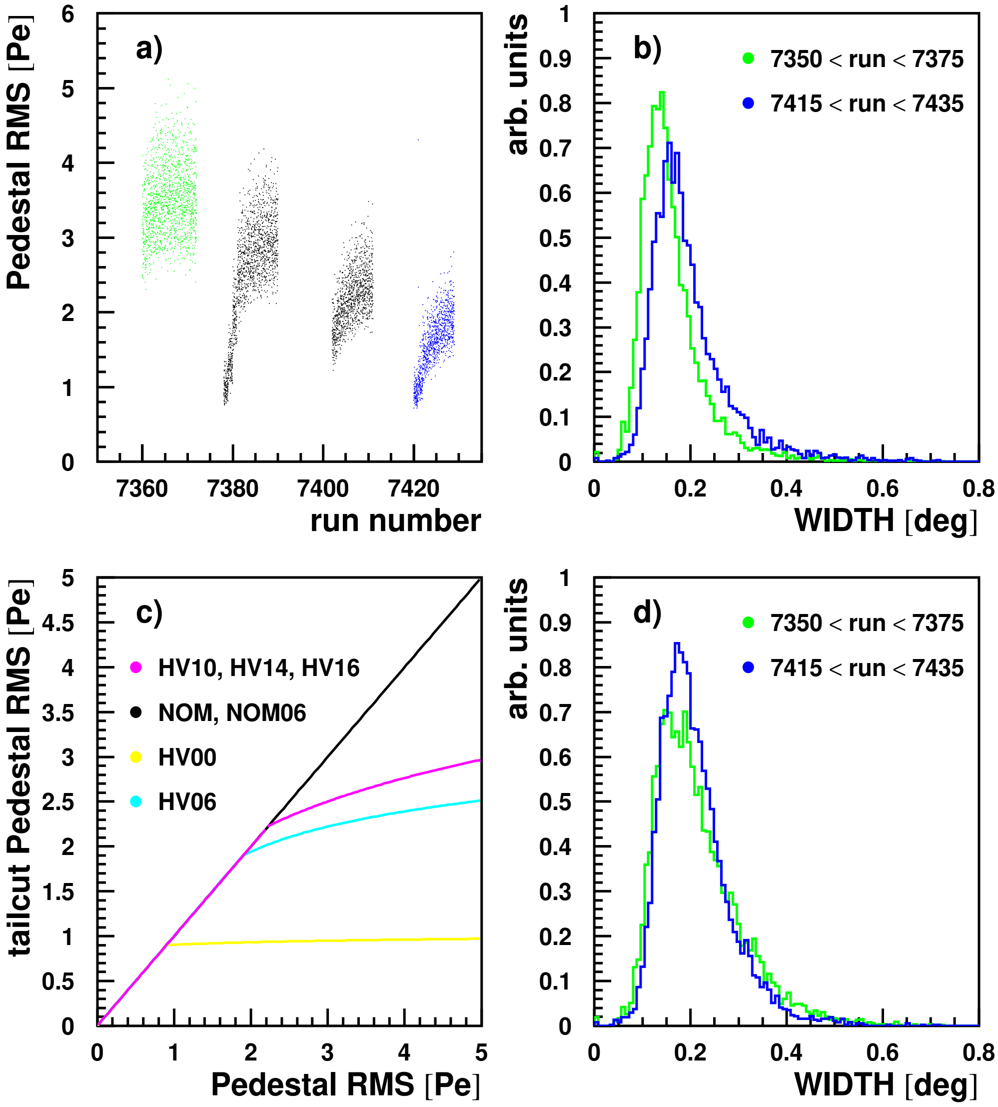

Fig. 5.1.1: a) Pedestal RMS values as a function of the run number for a Mkn 501 HV06 data sample. b) Distribution of the image parameter $WIDTH$ for the two marked data sets of fig. a) using the standard tailcut procedure. c) Shape of the modified tailcut pedestal RMS as a function of the measured pedestal RMS for the different HV settings in use. d) Distributions of the $WIDTH$ image parameter using the modified tailcut procedure.