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Observations under Moonlight and Twilight with the MAGIC telescope

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MAGIC
Major Atmospheric Gamma Imaging Cerenkov Telescope

Abstract:

We study the capability of the MAGIC telescope to observe under moderate moonlight. TeV gamma-ray signals from the Crab nebula were detected with the MAGIC telescope during periods when the Moon was above the horizon and during twilight. This was accomplished by increasing the trigger discriminator thresholds. No change is necessary in the high voltage settings since the camera PMTs were especially designed to avoid high currents. We characterize the telescope performance by studying the effect of the moonlight on the gamma-ray detection efficiency and sensitivity, as well as on the energy threshold [1].

- IACTs normally observe under fully dark conditions
- By observing under Moonlight duty cycle can be increased from ~12% to ~15%
- MAGIC [2,3] uses low-gain (3×10^4) PMTs yielding anode currents from 0.8 (Dark) to 8μA (strong moonlight) [4]
- Observations until (since) 3 days before (after) full Moon for distance source-Moon > 50° by increasing PMT discriminator thresholds (DT). See Fig. 1

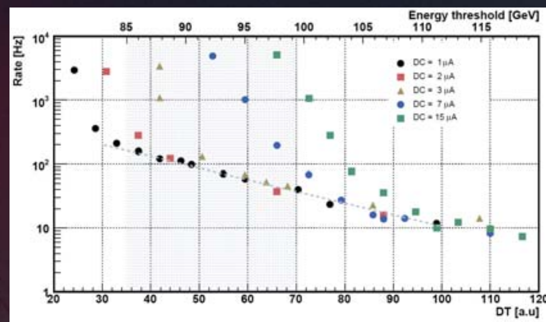


Fig 1. Trigger rate vs DT for four neighboring pixels configuration and different camera illuminations. The shaded area shows the range used for MAGIC regular observations (dark and under moonlight). The dashed line shows the linear regime. The upper axis shows the corresponding energy threshold (after image cleaning) for observations at zenith angles [20°-30°]

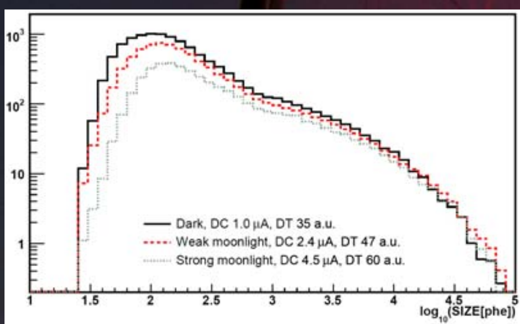


Fig 2. Distributions of SIZE before analysis cuts for three Crab nebula samples acquired under different light conditions and zenith angle between 20° and 30°. The histograms have been normalized to a common observation time. Note that the distributions are completely dominated by hadronic events (~99%)

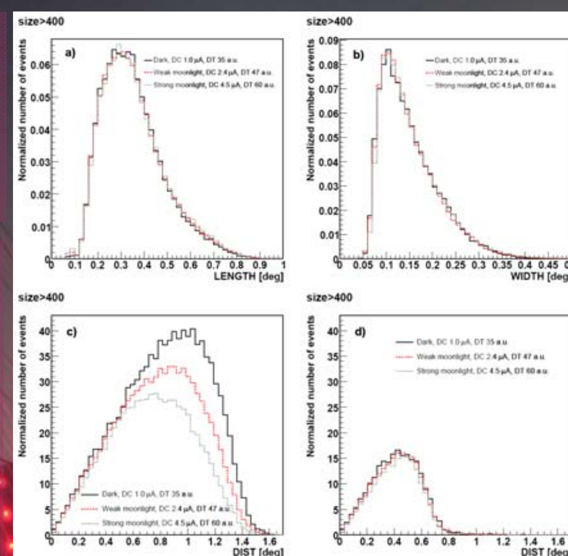
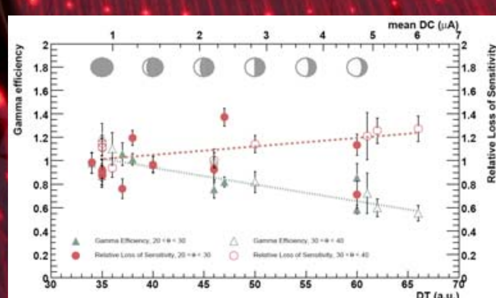


Fig 3. Distributions of LENGTH (a), WIDTH (b) and DIST for all recorded events (c) and for images fully contained in the inner camera (d) for SIZE>400 phe. Three Crab nebula samples acquired under different moonlight conditions and zenith angle between 20 ° and 30 ° are shown. The histograms are normalized to a unit area in (a) and (b) and to a common observation time in (c) and (d). Note that the distributions are completely dominated by hadronic events (~99%)

- SIZE distribution (Fig. 2) shows a loss of events up to 10^4 phe due to DT increase
- WIDTH & LENGTH not much distorted → no loss in gamma-hadron separation power
- Events lost at high DIST due to trigger area not spanning whole camera (Fig. 3)

Fig 4. Relative γ-ray detection efficiency (green triangles, left axis) and sensitivity (red circles, right axis) as a function of DT (SIZE> 400 phe), for zenith angle bins [20°, 30°] (filled markers) and [30°, 40°] (empty markers) measured from Crab nebula observations. The sketches showing the Moon phase are meant to guide the reader, since the camera illumination does not only depend on the phase, but also on the angular distance between source and Moon, etc.

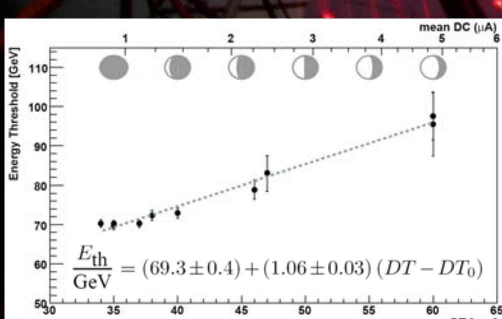


- The loss of gamma-ray detection efficiency and sensitivity are evaluated using Crab nebula observations at different camera illuminations for different SIZE/energy ranges (Fig. 4 for SIZE>400phe)
- Linear behaviour:

$$R/R_0, s/s_0 = (1 - S_{R,s}(DT - DT_0))$$

with:

$$R/R_0 = 1 - (1.41 \pm 0.32) \times 10^{-2}(DT - DT_0)$$
$$s/s_0 = 1 + (6.3 \pm 1.6) \times 10^{-3}(DT - DT_0)$$



- The trigger energy threshold increases from 70 GeV (dark) to 100 GeV (strong illumination) due to the increase of the DT

Fig 5. Energy threshold after image cleaning as a function of DT obtained from MC simulated γ-ray events (for zenith angle between 20° and 30°). The top axis shows the typical mean DC for a chosen DT value.

References

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[3] Cortina, J. et al., (MAGIC Collaboration), AIP Conf. Proc. (2005) 745, 730
[4] Armada, A. Master thesis, 2005. Available at:: http://wwwmagic.mppmu.mpg.de/publications/theses/