The Trigger System of the MAGIC Telescope: On-line Selection Strategies for Cherenkov Telescopes

D. Corti,[1] M. Mariotti,[1] R. Paoletti,[2] R. Pegna,[2] A. Stamerra,[2] and N. Turini[2]
for the MAGIC Collaboration
(1) Università and INFN - Padova, Italy
(2) Università di Siena and INFN Sezione di Pisa, Italy

Abstract

The MAGIC telescope aims at the detection of very low energy gamma rays (E >10 GeV) through the atmospheric emission of Cherenkov light. The high background rate originated by the Night Sky Background (NSB), muons, hadronic showers and bright stars sets a serious challenge to this goal. Application of topological selection cuts at trigger level can have a big impact on the background reduction, allowing the telescope to operate at lower thresholds and reducing the minimum detectable energy. We have developed a series of topological selection methods to be applied at the second level trigger. This technique has been applied to Monte Carlo data and has proven to be effective in rejecting up to 90% of the background events and doubling the collection area for shower energies below 100 GeV.

1. Introduction

The new generation of Cherenkov telescopes is starting to observe above the energy range explored by EGRET ($\approx$ 10 GeV). The lower energy threshold will presumably allow to detect many EGRET gamma sources, as expected by the low number of sources confirmed in the VHE region at $E > 250$ GeV. The reduced energy threshold of the Cherenkov telescopes and their better flux sensitivity, consequence of larger mirrors and more efficient photodetectors, will also allow the detection of new gamma sources.

The aim of the MAGIC telescope is the observation of low energy gamma radiation in the VHE domain ($E_{th} \approx 30$ GeV) [1][2]. This is accomplished with a very large reflective surface. A higher number of background photons, due to various sources – Night Sky Background (NSB), moonlight and bright stars in the field of view of the camera – is also expected, thus increasing the probability of accidental coincidences.

These can be reduced by raising the discriminator thresholds of the camera PMTs, although this results in a higher energy threshold of the collected events. The minimum discriminator threshold which optimizes the signal to noise ratio

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is approximately set to 8 *phe*.

However the high trigger rate can be reduced and the background events rejected by using tight requests in timing and topology, without any need to raise the discriminator threshold.

The trigger in MAGIC is a two-level sophisticated trigger system with programmable logic [3]. The first level trigger (L1T) applies tight time coincidences and a simple next-neighbor logic in the 19 overlapping trigger cells, each collecting 36 pixels out of the 325 pixels of the trigger region.

The second level trigger (L2T) can be used to perform a rough analysis and apply topological constraints on the event images. It consists of a first stage of 19 programmable SMART modules where the L1T information for each trigger cell is divided into three 12-pixels regions, called LUT (Look-Up-Table). The outputs from the 19 modules of the first stage are fed into a second and a third stage in a tree-like structure, in order to apply topological cuts.

As a consequence the trigger of the MAGIC telescope has the capability of performing a true on-line pattern recognition of the event shape.

2. L2T Selection Strategies

The information available at the L2T stage is the digital image filtered by the L1 trigger. The L2T can apply cuts on the event topology based on the number of pixels, the shape and other parameters. The purpose of the L2T is to recognize the class the event belongs to, rejecting the background events and accepting the signal (gamma events). The selection method tries to recognize the trigger image produced by a gamma event, that is the cluster of pixels that have been hit by the Cherenkov photons of the shower.

When a selection strategy is chosen, it must be transformed into logic functions to program the SMART modules. This is not a trivial task, given the overlapping of different trigger cells and the cascade structure of the L2T logic. For this reason the selection should rely as much as possible on the basic trigger structures: LUTs, trigger cells and pixels.

The multiplicity of the cluster has been used as a selection parameter to reject accidental NSB events. This method assumes that the gamma event will produce a cluster whose size will differ from that due to accidental NSB.

We define the *pseudo-size* as the multiplicity of this cluster.

3. Results

The pseudo-size distributions for simulated gamma and pure NSB events are compared in figure 1. for a discriminator threshold of 6 *phe*. The rejection (for NSB) and acceptance (for gammas) percentage for the various pseudo-size cuts is also shown.

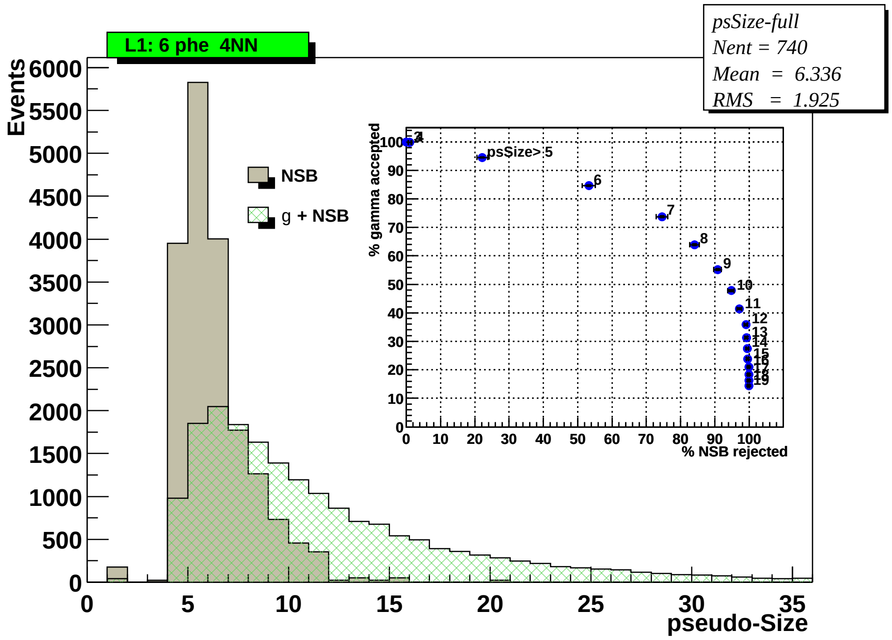

Fig. 1. The pseudo-Size distribution, for gamma (green, dashed) and pure NSB (gray, solid) events, for the 4 Next Neighbour (NN) L1 trigger topology and discriminator threshold of 6 *phe*. The inset shows the gamma-acceptance vs. NSB-rejection for different pseudo-size cuts. The value of the cut is reported next to each point.

In figure 2. the ratio of L2T accepted events with a discriminator threshold of 6 *phe*, to the L1T accepted events with an higher discriminator threshold (8 *phe*) as a function of energy is shown. Two different pseudo-size cuts have been applied, both resulting in a reduction of the trigger rate of γ and NSB events to $\approx 300 - 500$ Hz, well below the maximum sustainable acquisition rate (1 kHz). A proton rate of few hundreds of Hz is expected, but has not been considered in this work.

The collected events in the energy region below 100 GeV can be increased up to a factor 2-3 respect to the standard L1 trigger (8 *phe* and 4 Next Neighbour topology).

4. Conclusion

The application of selection criteria at trigger level for the MAGIC telescope has been discussed. The pseudo-size selection method can reduce the rate of NSB events below the maximum sustainable acquisition rate (1 kHz). More than 90% of the NSB events can be rejected, retaining half of the gamma events and the trigger collection efficiency can be 2-3 times higher than the standard L1

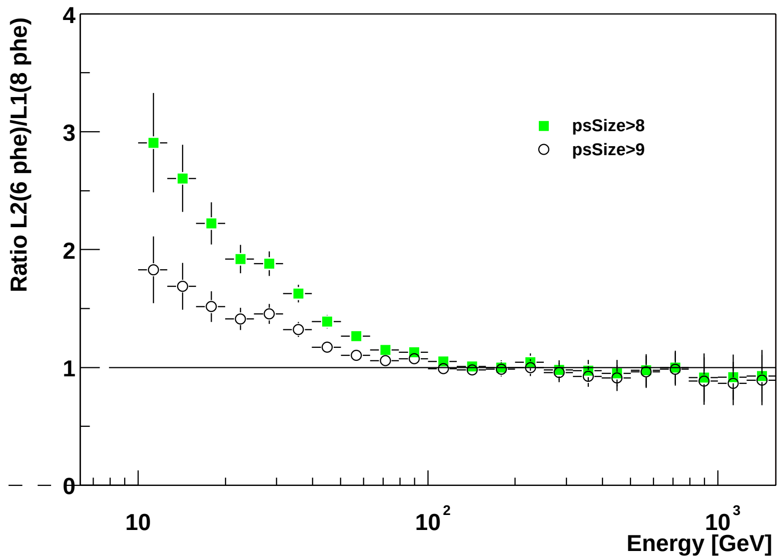

Fig. 2. Ratio of L2T accepted events with a discriminator threshold of 6 *phe*, to the L1T accepted events with an higher discriminator threshold (8 *phe*) as a function of energy, for two different selection cuts on pseudo-size.

trigger.

Having a bigger collection area results in being more sensitive at lower energies. This fact is important to detect the signal from sources with a sharp cutoff at low energies, such as pulsars [4] and distant AGNs [5].

5. Acknowledgments

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References

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