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NSB rejection with the level 2 trigger

A. Stamerra
<Antonio.Stamerra@pi.infn.it>

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Abstract

Application of selection criteria at trigger level can be effective to reject background events and allow the data acquisition to operate with an accepted dead time. Selection strategies for the Level 2 Trigger (L2T) are discussed. A preliminary study, the pseudo-size method, is described and results are presented. A 90% rejection of the NSB with a 50% acceptance on gamma-ray signal can be detained. An energy threshold of 35 GeV is feasible keeping the trigger rate below 1 kHz and, simultaneously, doubling the effective area at low energies (E<100 GeV) with respect to the standard 4.0mV-4NN L1 trigger condition.

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1 Introduction

The main aim of the MAGIC telescope is the observation of very low energy cosmic gamma radiation ($E_{th} \approx 30$ GeV), keeping the acquisition rate lower than 1kHz. The former is accomplished with a very large area reflective surface, and the latter with a sophisticated trigger system with programmable logic.

The trigger system is expected to reject the accidental coincidences due to various sources – Night Sky Background (NSB), moonlight and bright stars in the field of view of the camera – allowing a reduction of the discriminator thresholds, and a lower energy threshold.

The high trigger rate can be reduced by using tight requests in timing and topology. The L1 trigger applies tight time coincidences and a simple next-neighbor logic. Extensive studies have been already performed ([1], [2], [3],[4]) and will be used as a starting point for the present study. The L2 trigger can be used to perform a rough analysis and apply topological constraints on the event images.

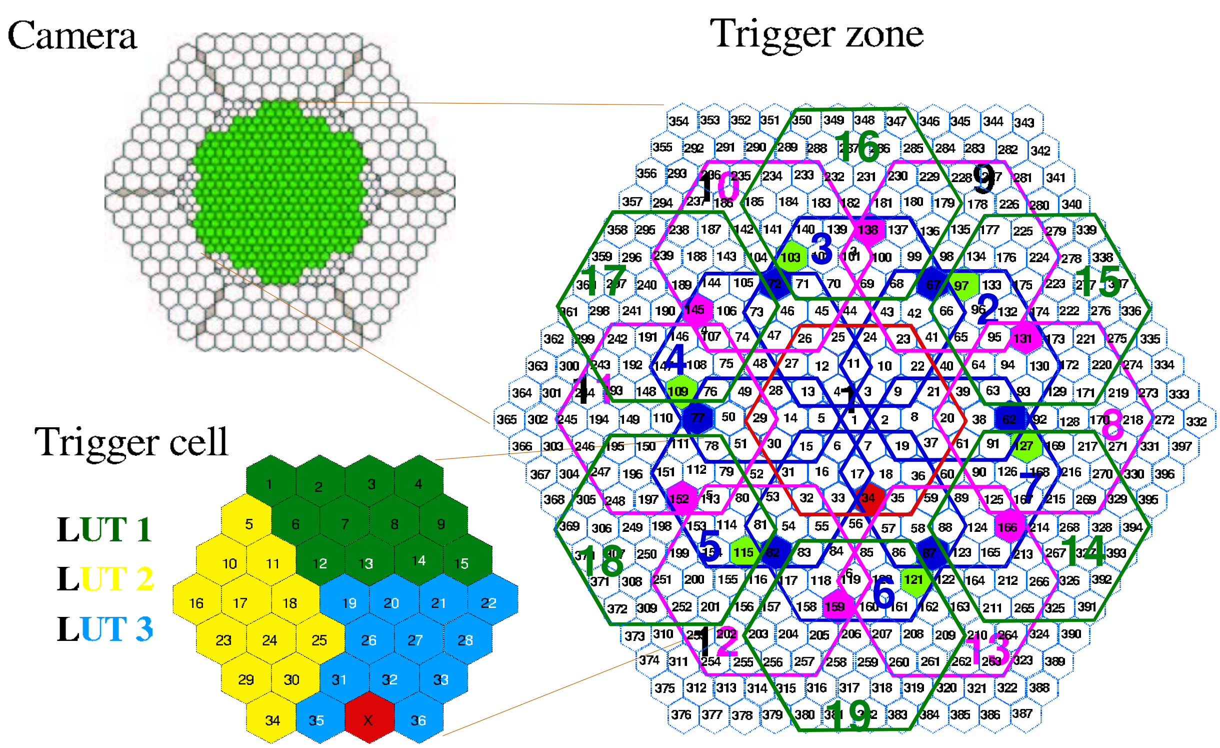


Figure 1: The trigger zone, divided into 19 trigger cells, and a scheme of one cell with its three LUTs.

2 Overview of the MAGIC 2nd level trigger

The hardware details of the L2T are described elsewhere [5]. In this section a short overview of the L2T is given.

In fig.1 the trigger zone of the camera with the 19 trigger cells are shown. Each trigger cell collects 36 pixels (plus 1 dead pixel), that are sent to a SMART module, divided into three 12-pixels regions, called LUT (Look-Up Table). Patterns of fired pixels (≡ pixels that have passed the discriminator threshold) can be selected locally into one SMART and coded in a 6-bit word.

The outputs from several SMART modules are fed into a second and a third stage of SMART modules in a tree-like structure, in order to apply topological cuts (fig.2). The trigger decision is finally coded in a 8-bit word that is sent to the prescaler boards and to the FADC system for event acquisition [6].

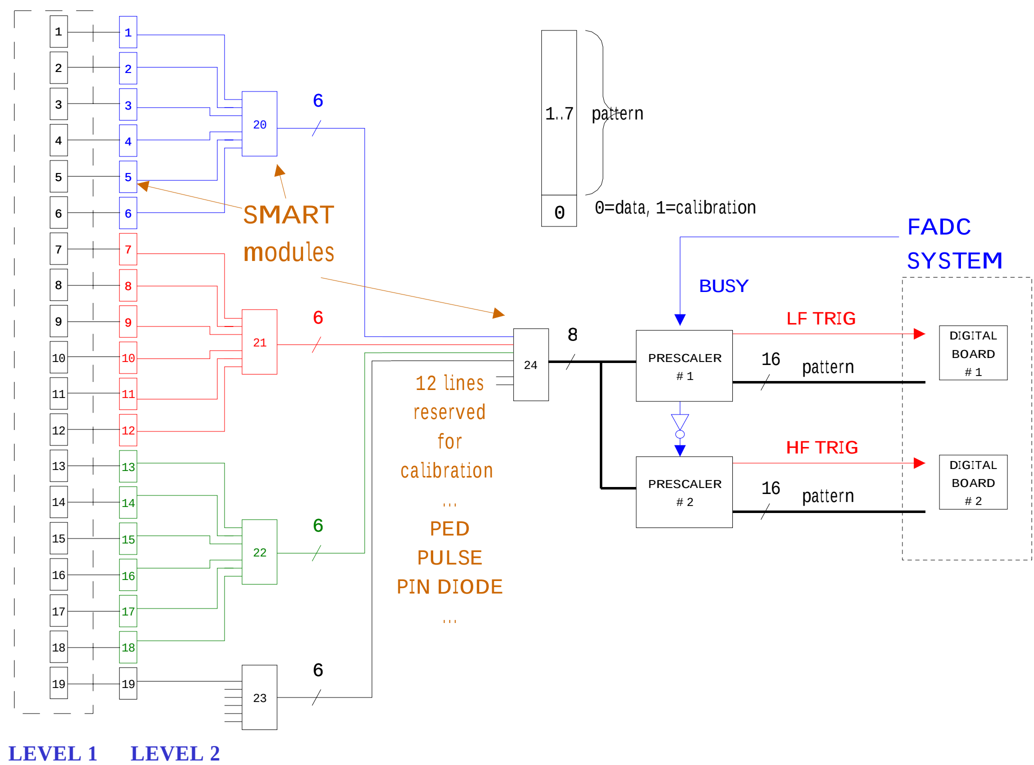


Figure 2: The L2T architecture. The trigger pattern (8 bits) is fed into the prescaler module that generates the trigger signal for the FADC system which starts the acquisition.

3 Bright stars and NSB

The main background source for MAGIC is the light produced by bright stars in the camera field of view, the diffuse light of the sky and the Moon presence. Previous measurements [7] of NSB are used in the camera simulation program.

The bright stars contribution raises the rate of single or small groups of neighbor pixels (*hot spots*). In figure 3 the global rate from all the pixels in the trigger zone is shown, with and without the Crab

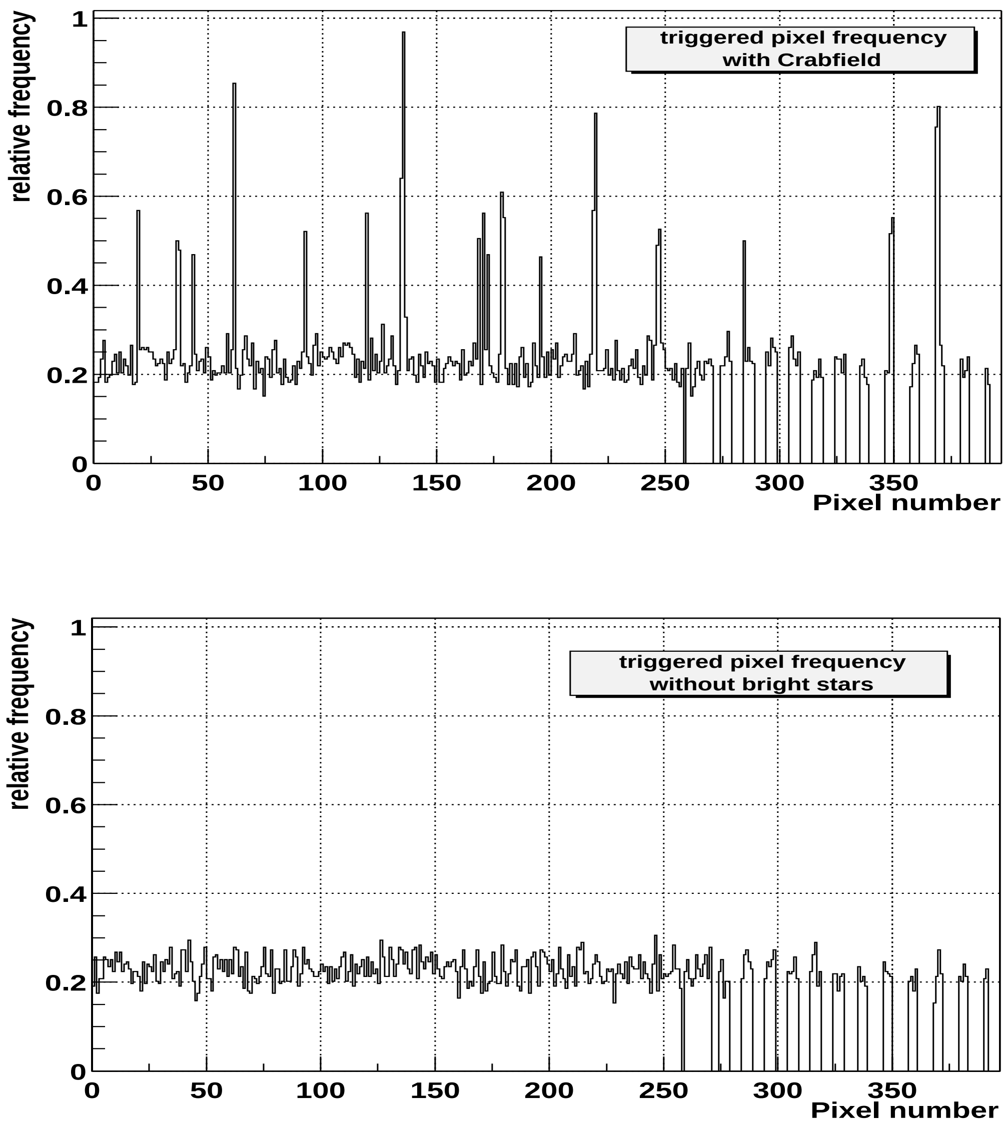


Figure 3: Trigger rate for single pixels in the trigger area with (top) and without (bottom) the bright stars in the Crab Nebula starfield (L1: 3.00mV-4NN; 192 triggered events). 25 hot pixels can be identified; 6 of them are isolated while the others are grouped in clusters of 2-4 pixels. The present plot is affected by a bug in the reflector program which smears the photons in the camera, possibly producing an higher number of hot-pixels [8].

Nebula starfield contribution (the NSB is included in both cases). The pixels lighted by bright stars are clearly detectable and can be easily rejected at a trigger level, removing these pixels from the trigger table logic.

In the following, the effect of diffuse NSB only is taken into consideration.

4 Simulation

In this work 10^6 simulated (reflector) gamma events at 0^o zenithal angle, in the energy range 10 GeV-10 TeV (slope $\alpha = -2.6$), have been used. They are processed by the camera program (ver.05, may 2002) that simulates the camera response and the NSB signal for each different trigger condition (discriminator threshold and next-neighbor multiplicity). Empty reflector files are used to simulate the NSB only events. The number of simulated events and the L1 trigger rates for some trigger conditions are reported in table 1.

L1 Trigger	γ-events			NSB-events		
	# sim $\cdot 10^3$	# trig	% trig	# sim $\cdot 10^3$	# trig	Rate (Hz)
4.00 mV-4NN	800	9280	1.16	-	-	-
3.50 mV-4NN	100	1745	1.75	1500	4	16^{+24}_{-11}
3.50 mV-3NN	800	20949	2.62	600	428	4450
3.00 mV-4NN	800	18886	2.36	1500	740	3100
3.00 mV-3NN	800	50060	6.25	500	15759	200×10^3
2.75 mV-4NN	800	26524	3.30	100	546	34×10^3

Table 1: Sample of simulated (*sim*) and triggered (*trig*) γ and NSB events. Percentage for γs and rate for NSB events is stated.

5 The pseudo-size method

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.

In fig.4 typical events for some classes of events are shown. The purpose of the L2T is to recognize the class the event belongs to, rejecting the background events NSB, proton, muon, and accepting the signal (gamma events).

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 smallest trigger structure, the fired pixel, is defined as *n-compact* if at least n of its neighbor pixels (n=1...6) have been fired. From now on a *n-compact* pixel will be simply called compact pixel.

5.1 Cluster recognition

The pseudo-size 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. This method assumes that the gamma event will produce a cluster whose size will differ from that due to accidental NSB or proton events.

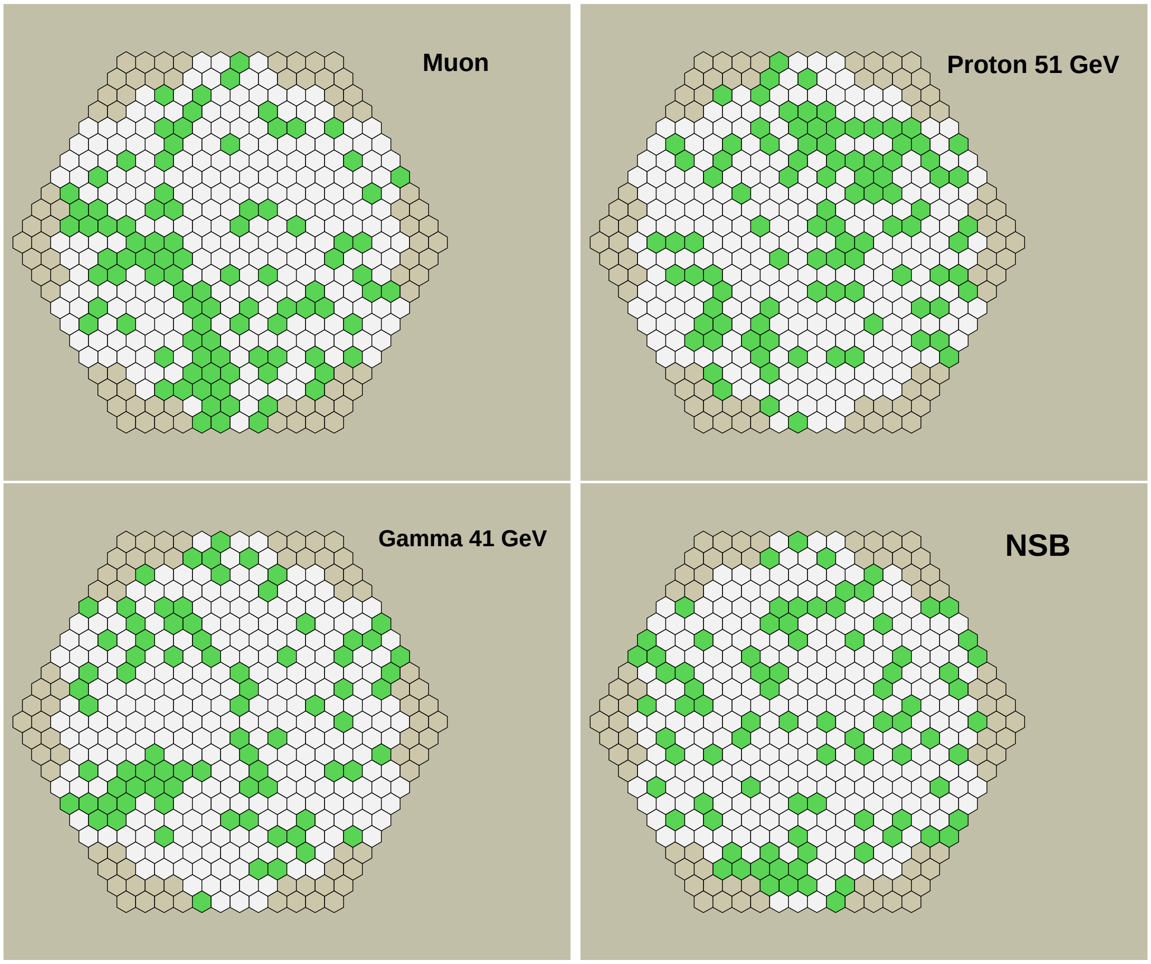


Figure 4: Examples of trigger events produced by a muon (top-left), proton (51 GeV, top-right), gamma (41 GeV, bottom-left) and pure NSB (bottom-right). A night sky background signal produced by 3.00 mV-4NN L1 trigger conditions is added in all events.

The recognition of a cluster starts by looking for the LUT with the highest multiplicity of compact pixels, and then iteratively looking for neighbor pixels.

When a cluster is recognized, its multiplicity is defined as its *pseudo-size*.

It should be pointed out that this method does not take into account other topological features of the cluster, which can further improve the selection.

6 NSB rejection

Once a cluster has been identified, its pseudo-size is used to discriminate between gamma and the other classes of events.

Gamma events produce clusters (fig.4) with a large pseudo-size. Low energy gamma showers give small clusters, possibly misidentified as spurious NSB triggered pixels. Lower discriminator thresholds will trigger a higher number of pixels, raising the probability of spurious cluster formation.

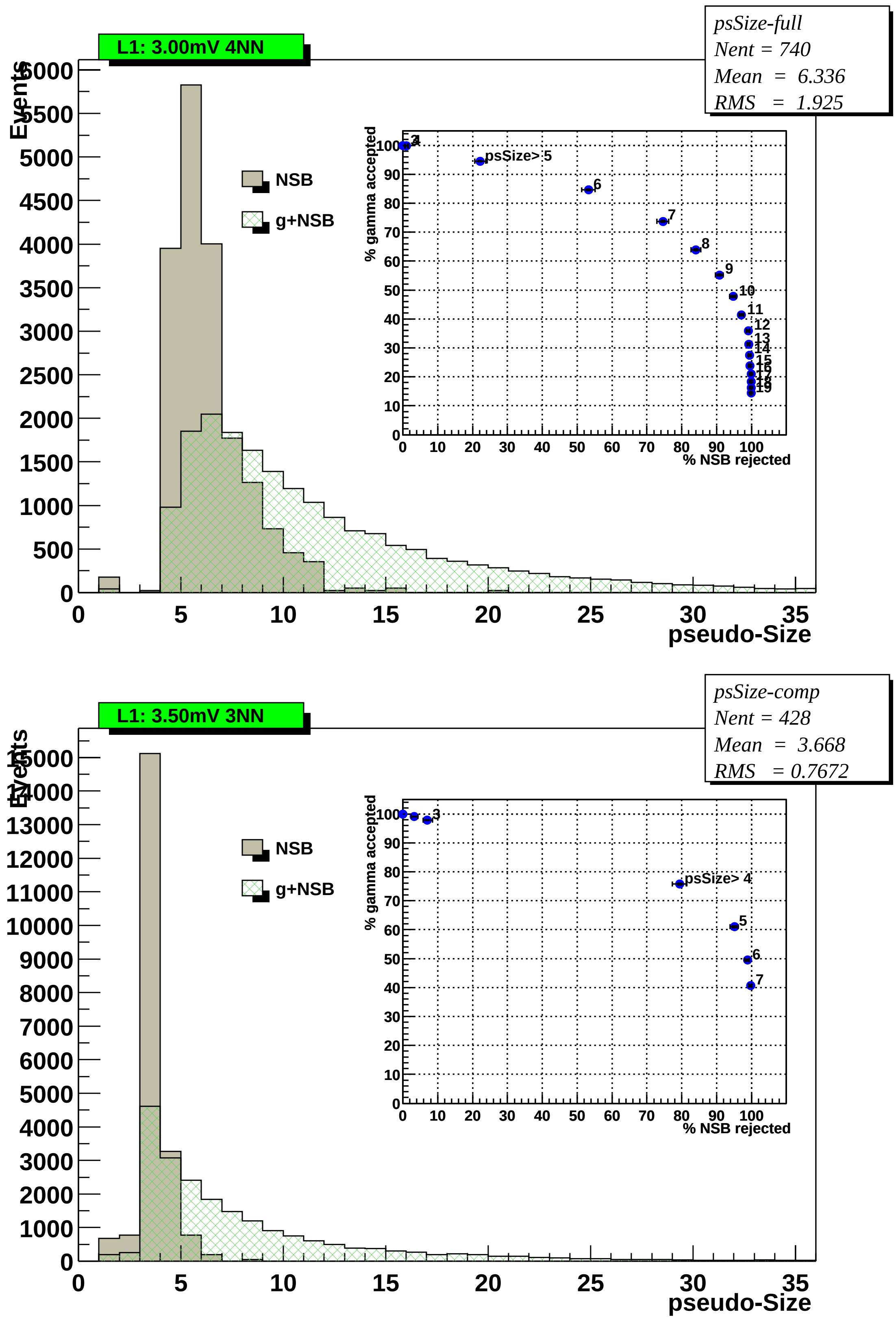


Figure 5: The pseudo-Size distribution, for gamma (green, dashed) and pure NSB (grey, solid) events, for some L1 trigger topologies and discriminator thresholds (from top to bottom: 3.00mV-4NN, 3.50mV-4NN). The inset shows the gamma-acceptance vs. NSB-rejection for different pseudo-size cuts. The value of the cut is reported next to each point.

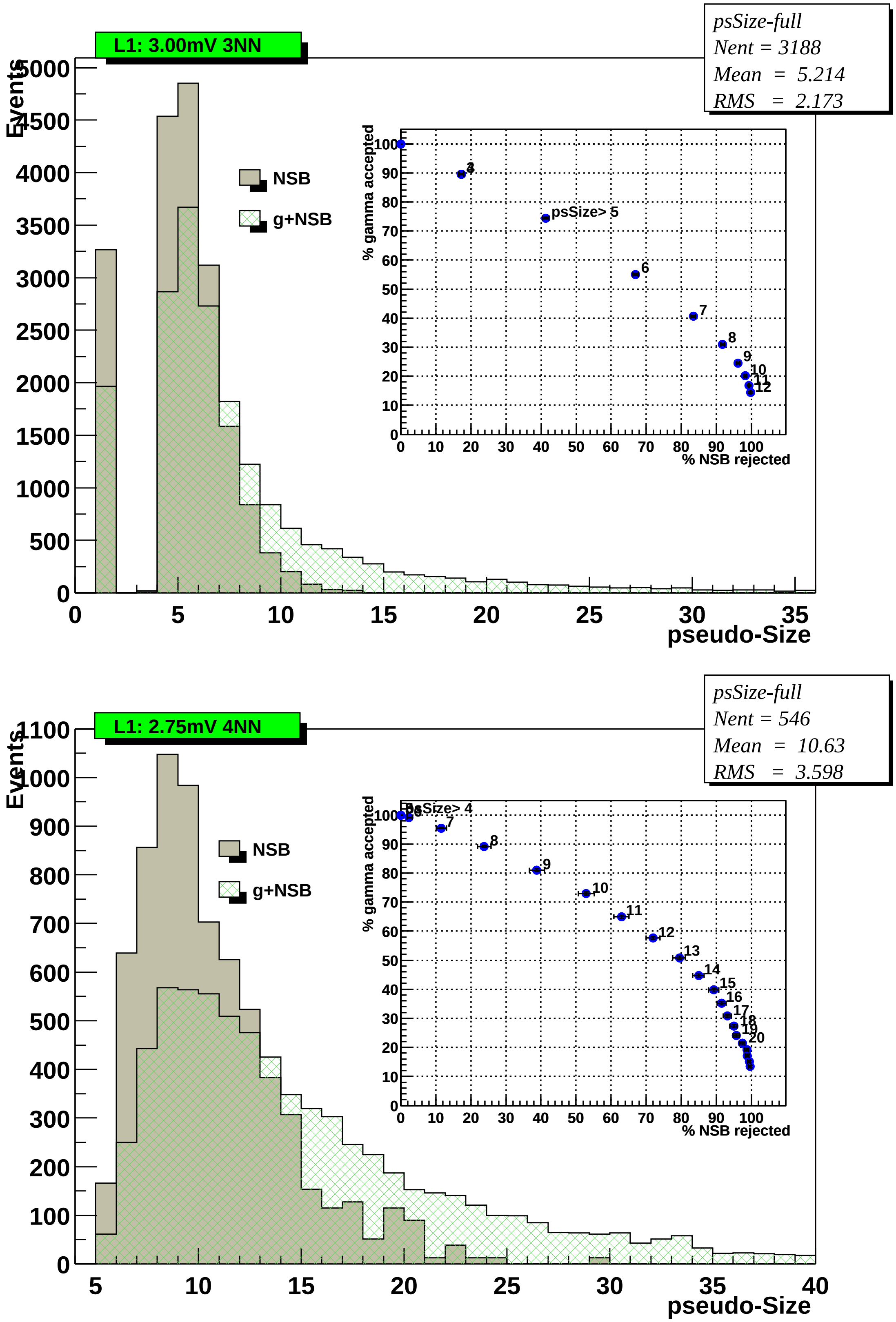


Figure 6: The pseudo-size distribution, for gamma (green, dashed) and pure NSB (grey, solid) events, for some L1 trigger topologies and discriminator thresholds (from top to bottom: 3.00mV-3NN, 2.75mV-4NN). The inset shows the gamma-acceptance vs. NSB rejection for different pseudo-size cuts. The value of the cut is reported next to each point.

The pseudo-size distributions for gamma and pure NSB events are compared in figure 5, for the trigger conditions of table 1. The rejection (for NSB) and acceptance (for gammas) percentage for the various pseudo-size cuts is also shown.

In table 2 it is reported the reduction of the trigger rate for different pseudo-size cuts. These rates are compatible with the maximum rate sustainable by the data acquisition (1kHz).

L1 Trigger	L1 trig. Rate (Hz)	L2 trig. Rate (Hz) psSize>cut1	psSize>cut2	psSize>cut3
3.5 mV-3NN	4450	756 (4)	222 (5)	32 (6)
3.0 mV-4NN	3100	500 (8)	279 (9)	155 (10)
3.0 mV-3NN	200×10^3	8000 (9)	3600 (10)	1600 (11)
2.75 mV-4NN	34×10^3	4760 (14)	3400 (15)	

Table 2: Trigger rates before (L1) and after the pseudo-size cuts applied at L2T. In parentheses is shown the value of the cut.

6.1 Trigger collection areas

Once a pseudo-size cut has been chosen the efficiency on the collection of gamma events must be computed. This can be done by looking at the effective collection area for the events that have survived the cuts, as reported in figure 7 and 8.

The collection area after the pseudo-size cut is sensibly reduced respect to the L1 area. In the low energy region ($E < 100$ GeV) it is higher than the area of the standard L1 trigger 4.00mV-4NN.

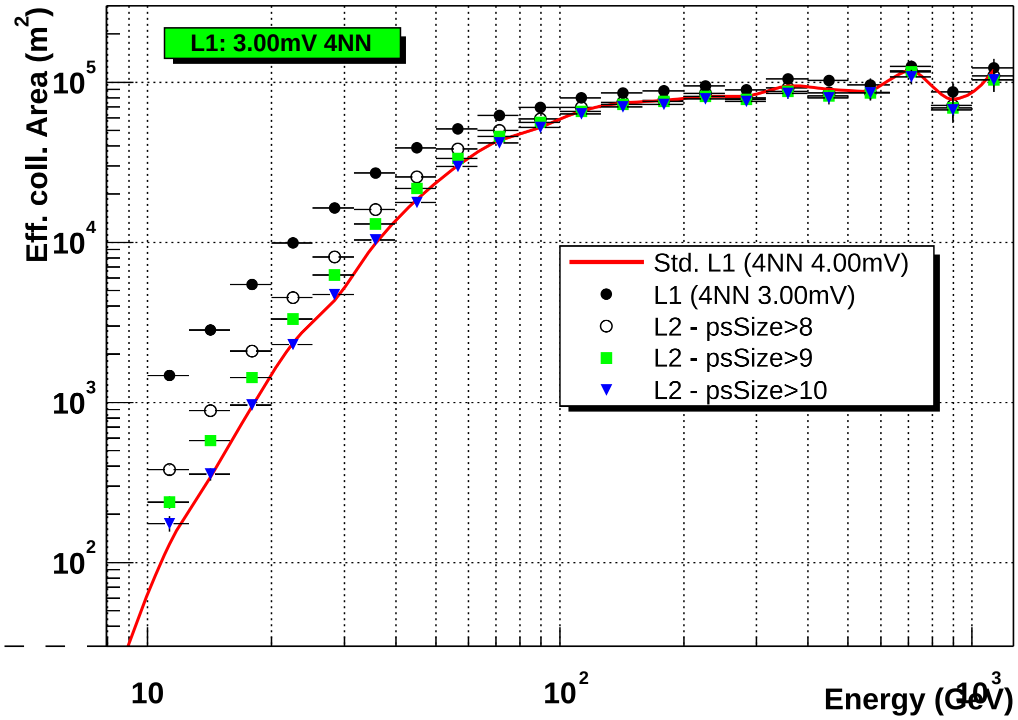
It is important to stress the fact that the efficiency of these cuts should be checked on the complete analysis chain. The pseudo-size method is a selection criterion corresponding to a primitive image analysis. If the rejected events are proven not to be recontructable in the offline analysis this would enhance the efficiency of the selection criteria itself. This check is currently under way.

6.2 Energy thresholds

The higher collection area at low energies contributes to lower the energy threshold on gamma sources. Infact the energy threshold, defined as the peak in the dN/dE distribution for triggered showers [1], depends on the primary spectrum of the source. Table 3 shows the energy thresholds for a Crab-like spectrum when the L2T cuts are applied. The pseudo-size cuts result in a energy threshold between 25 and 40 GeV, sensibly reduced respect to the standard L1 trigger energy threshold.

L1 Trigger	L1 (GeV)	L2 (GeV) psSize>(cut1)	psSize>(cut2)	psSize>(cut3)
4.0 mV-4NN	40 ± 3	-	-	-
3.5 mV-4NN	31 ± 3	-	-	-
3.5 mV-3NN	18 ± 3	26 ± 4 (4)	33 ± 4 (5)	40 ± 4 (6)
3.0 mV-4NN	22 ± 3	30 ± 4 (8)	34 ± 4 (9)	38 ± 4 (10)
3.0 mV-3NN	≈ 13	19 ± 3 (9)	33 ± 3 (10)	41 ± 4 (11)
2.75 mV-4NN	≈ 17	24 ± 4 (14)	27 ± 4 (15)	-

Table 3: Energy thresholds before (L1) and after the pseudo-size cuts applied at L2T. The value of the cut is shown in parentheses.



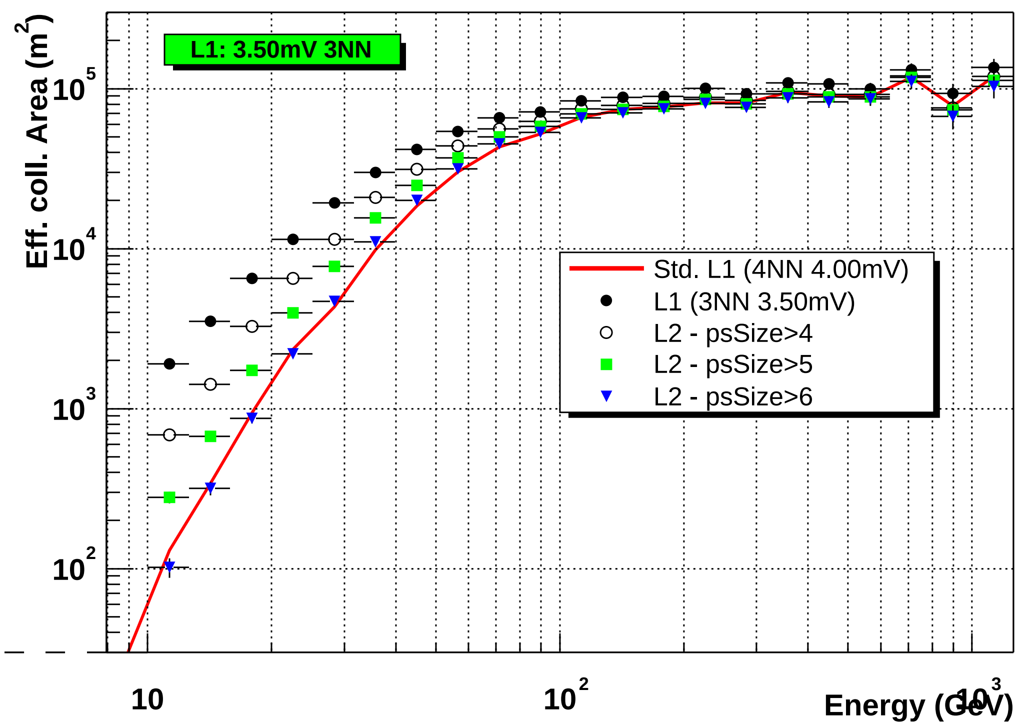


Figure 7: The effective collection area for gamma events, for some L1 trigger topologies and discriminator thresholds (from top to bottom: 3.00mV-4NN, 3.50mV-3NN), and for some pseudo-size cuts. As a reference the collection area of the "standard" trigger condition (L1: 4.0mV-4NN; no L2T cuts) is shown as a solid line.

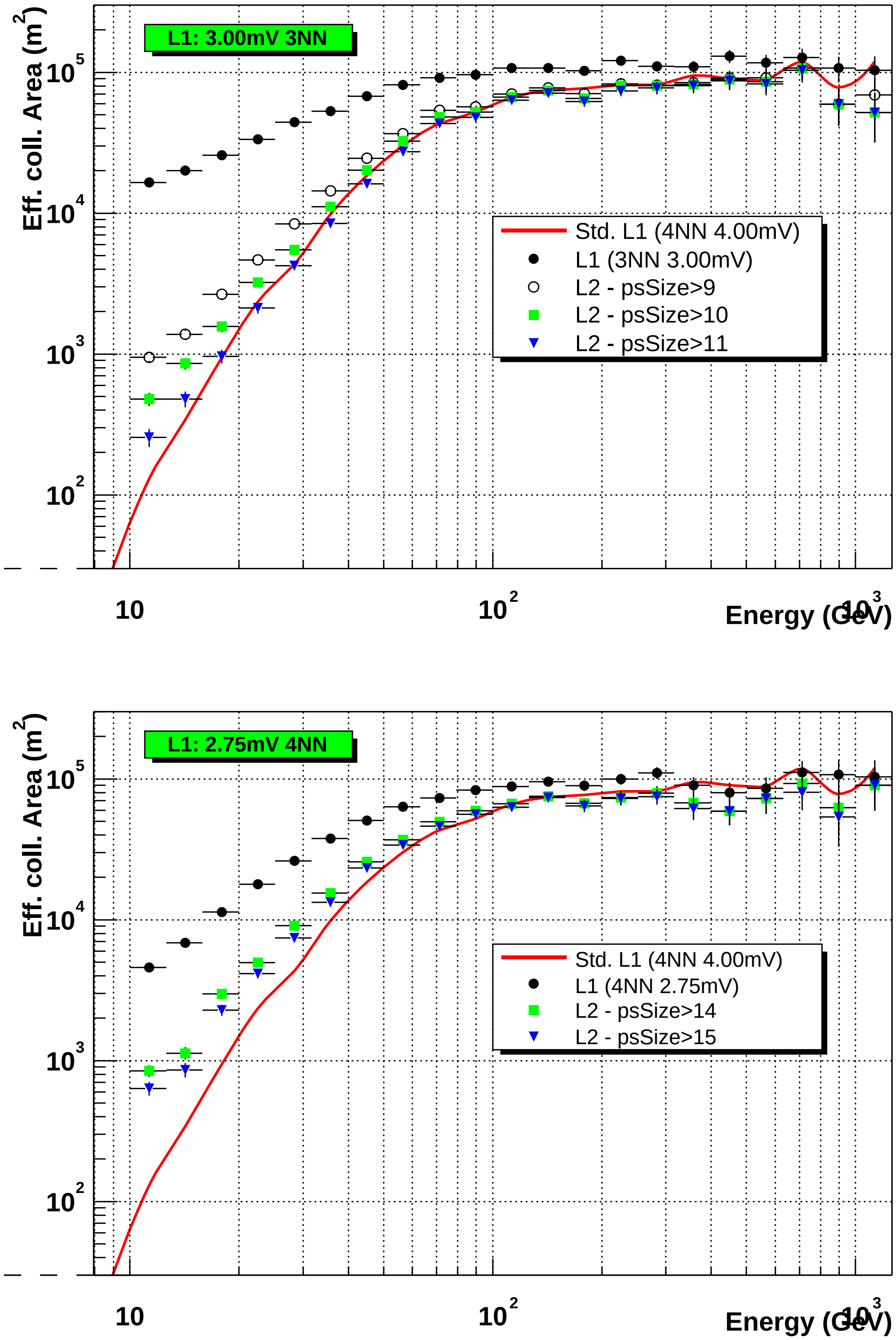


Figure 8: The effective collection area for gamma events, for some L1 trigger topologies and discriminator thresholds (from top to bottom: 3.00mV-3NN, 2.75mV-4NN), and for some pseudo-size cuts. As a reference the collection area of the "standard" trigger condition (L1: 4NN; Disc. thr.: 4.0mV; no L2T cuts) is shown as a solid line.

7 Conclusions

The application of first selection criteria at trigger level has been discussed. The pseudo-size selection method can reduce the rate of NSB events below the maximum sustainable acquisition rate (1 kHz).

About half of the gamma events are accepted and the trigger collection area can be 2-3 times higher than the standard L1 trigger (4.00mV-4NN). 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 pulsar and distant AGNs.

Improvements and new applications of the L2T selection criteria are under study. The selection can be improved by applying topological cuts on the cluster (pseudo-length, pseudo-distance and so on) and can be used to reduce the accidental events caused by the moonlight, resulting in a higher duty cycle of the experiment.

References

[1] O. Blanch, J.C. Gonzales, H. Kornmayer,"Detailed Monte Carlo studies for the MAGIC telescope", Proc. ICRC 2001 Hamburg, 2931, (2001).

[2] O. Blanch, "Trigger threshold and rates from Monte Carlo studies", MAGIC-TDAS 01-08, 010906/OBlanch, (2001).

[3] A. Moralejo, "Level 1 Trigger Studies", MAGIC-TDAS 25-june-2002, (2002).

[4] N. Tonello,"Misure ottiche e strategie di trigger per il telescopio MAGIC" , Tesi di Laurea, Padua, (2002).

[5] D. Bastieri et al.,"A two-level pattern-trigger for the MAGIC telescope", Nucl. Instrum. Meth. A 461 (2001), 521-523.

[6] "Specifications of the digital DAQ modules and their digital inputs", J.A.Coarasa, J.Cortina, F.Goebel, R.Paoletti, R.Stiehler, N.Turini, MAGIC-TDAS 02-07, (2002).

[7] R. Mirzoyan, E. Lorenz, *Measurement of the Night Sky Light Background at La Palma*, Max-Planck-Institut für Physik, Föhringer Ring, 6, 80805 München, MPI-PhE/94-35, 1994.

[8] A. Moralejo, MAGIC Software Meeting, Muenchen, october 2002.