A two level pattern trigger for the MAGIC telescope

MAGIC-TDAS 00-12
000520/DBastieri

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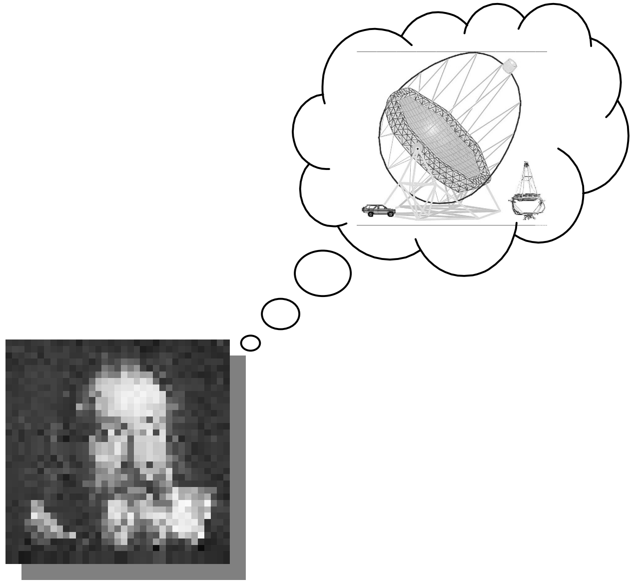
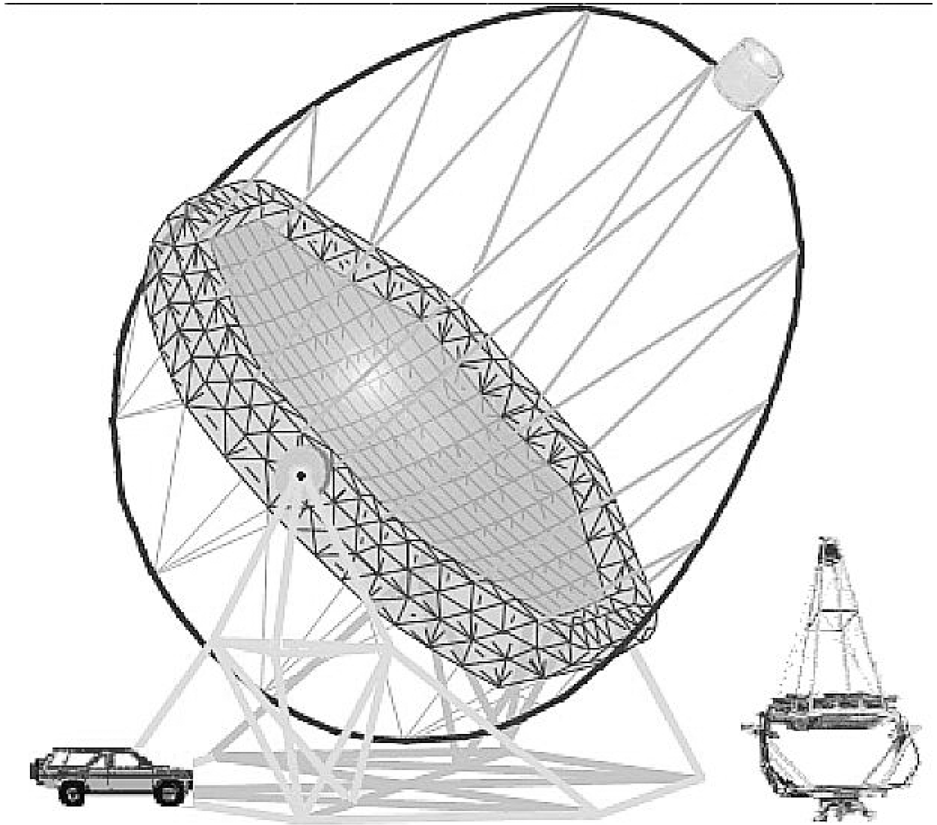
Strong scientific motivation are pushing the second generation of ground base Cherenkov telescopes to lower as much as possible their energy threshold. MAGIC will be the biggest single telescope, in terms of collection area 250m² foreseen for the second half of 2001.
The large collection area, the new photodetectors and the electronic design will allow the telescope to lower the energy threshold below 30 GeV.For this telescope a two-level pattern trigger is designed to work in severe high pixel rate. The MAGIC trigger architecture and its implementation is presented.



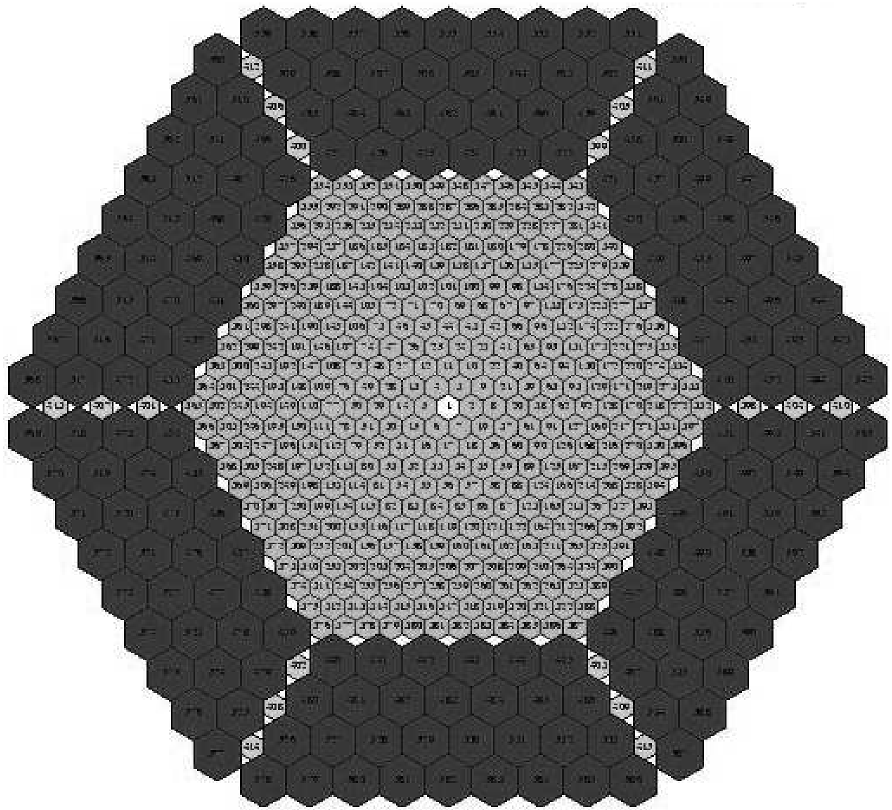


The telescope

•The **MAGIC** (Major Atmospheric Gamma-ray Imaging Cherenkov) Telescope Project aims to detect Cosmic Gamma Rays above an **energy threshold of 10 GeV** by building a large atmospheric imaging Cherenkov telescope with about **240 m2** mirror area and a very sensitive camera using **high quantum efficiency photodetectors.**

The Camera

The first **MAGIC** will be an array of classic PM. The inner part of the camera is equipped by 397 pm 3 cm of diameter, 271 of them will be used for trigger.
An outer ring of large PM is used to enlarge the camera field of view but will be not used for the trigger (at the moment)



TRIGGER ARCHITECTURE

MAGIC is a IACT telescope designed to explore the energy domain below 50GeV. To achieve this very low energy threshold the trigger should take advantage of the fast time evolution of compact images from Cherenkov flashes associated with gamma showers. Low discriminator threshold and consequent high single pixel rate is needed to lower the threshold. The trigger rate is then reduced using tight requests in timing and topology.

Fast n-fold (n=2-3-4-5) next-neighbor logic is an effective way to select gamma showers and reject most of Night sky background events. A more sophisticated pattern recognition trigger is also useful to mask bright stars and perform a preliminary analysis of the event to reject some hadron background.

The trigger is split into two stages: level 1 (L1) and level 2 (L2). The L1 is a fast coincidence device (2-5 ns) with simple patterns (n-next-neighbor logic) while L2 is slower (20-50 ns) but can do a more sophisticated patter recognition.

Discriminators
L0

Choose the **number of photoelectron** per pixel you want to use in the trigger

Level 1
L1

Make a **tight time coincidence** on simple pattern of packed images and **enable L2**

Level 2
L2

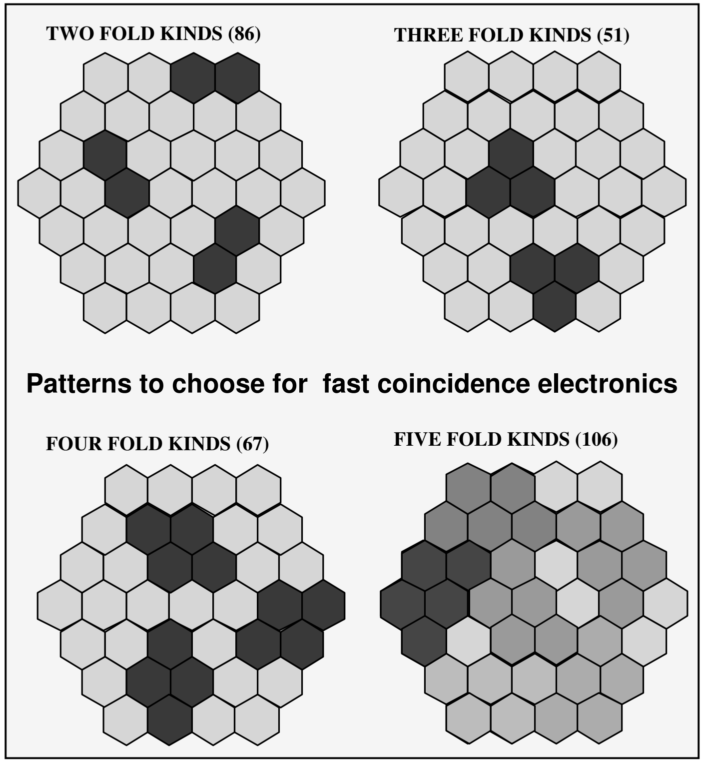
Make an **advanced pattern recognition** to use topological constraint:
- pixel counting in a given region of the detector
- Mask hot spots like bright stars
- Rough center of gravity of the image…etch…..

To FADC

LEVEL 1 TRIGGER

• **<u>fast coincidence</u>** -> 2-5 ns

• **<u>easy topological constraint</u>** -> Search for simple patterns like packed-2-3-4-5 next neighbor logic



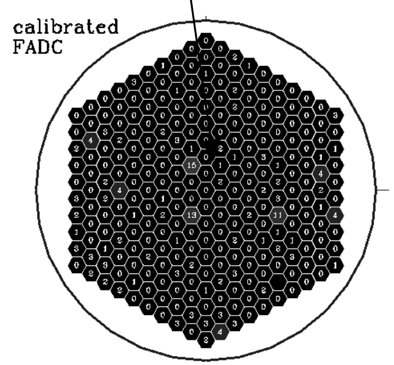
L1 trigger will get 271 central pixels discriminated signals and search for coincidences of small clusters of adjacent channels. The type of clusters is predefined, so that a simple combinatorial preprogrammed logic can handle all the channels.

Overlaps of few nanoseconds should set the L1 accept signal. We provide 4 types of L1 accept signals, one for the n-next-neighbor logic of 2, 3, 4 and 5 pixels. It will be possible to choose remotely between one of the four trigger configurations.

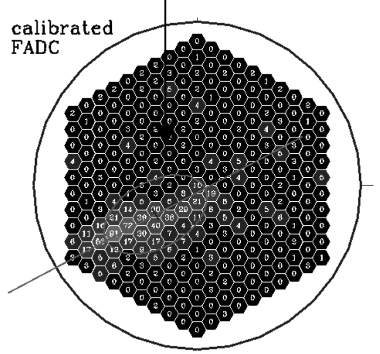
L1 writes in the output buffer the complete pixel configuration when a chosen L1 accept has been set. The overall time delay of L1 is expected to be less than 50 ns.

The input rate per pixel is expected to be of the order of 1 MHz or more depending on the level of the discriminators thresholds. We expect a L1 rate of the order of 1 kHz or less with a rejection factor between 10^2 -10^3 . During a Gamma ray burst we may expect an increase of the rate of one order of magnitude.

Typical **night sky background event** of a IACT: scattered pixels above threshold



Gamma shower event: compact image pointing towards the source position



L1 implementation

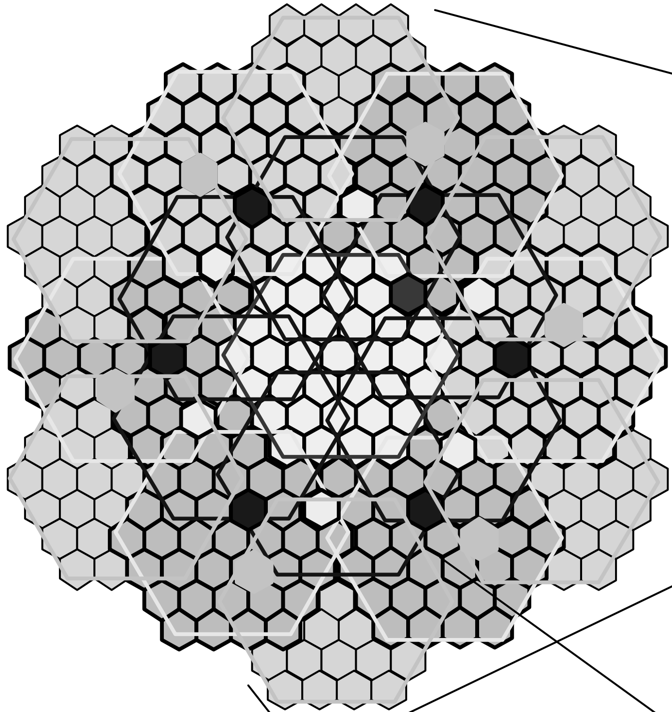
The heart of the L1 board will be made with PLD devices. The L1 accept should be a boolean sum of coincidences, and this is the natural way the PLD are working.Internal delay in the combinatorial array of the devices is better than 1 ns as required by the L1 specs and independent from the route of the signals if the all sets of equation can be written in a single macro-cell of the PLD. A complete simulation of such device was done using EPLD128ATC100-7.

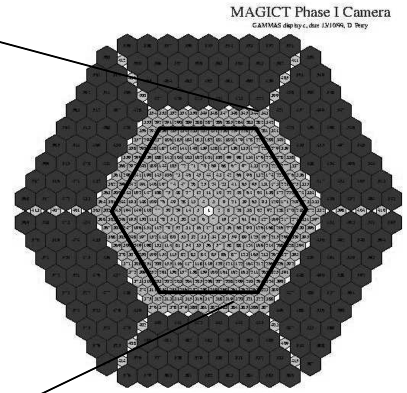
All the equations have been implemented for each n-fold (n=2,3,4,5) next neighbor logic and no routing delay happens if the number of pixels does not exceed 36, the size of one PLD macro-cell.

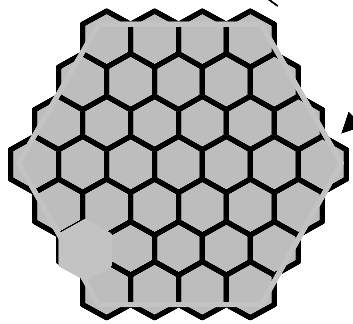
We have decided to map the entire trigger region of the chamber in 36 channels sub-regions, partially overlapping, to ensure a complete n-fold logic in the borders. The chamber is so subdivided in trigger sub-regions.

Trigger map for the MAGIC camera

19 macro-cells of 36 pixels
271 pixels of inner hexagon covered







Trigger macro-cell of 36 pixels for L1 and L2

LEVEL 2 TRIGGER, L2

• **<u>pattern recognition capability</u>** ->

Topological constraint for the event

• **<u>Programmable</u>** ->

The trigger table may change in different observational and environmental condition like bright stars, moon light, GRB alert etc..

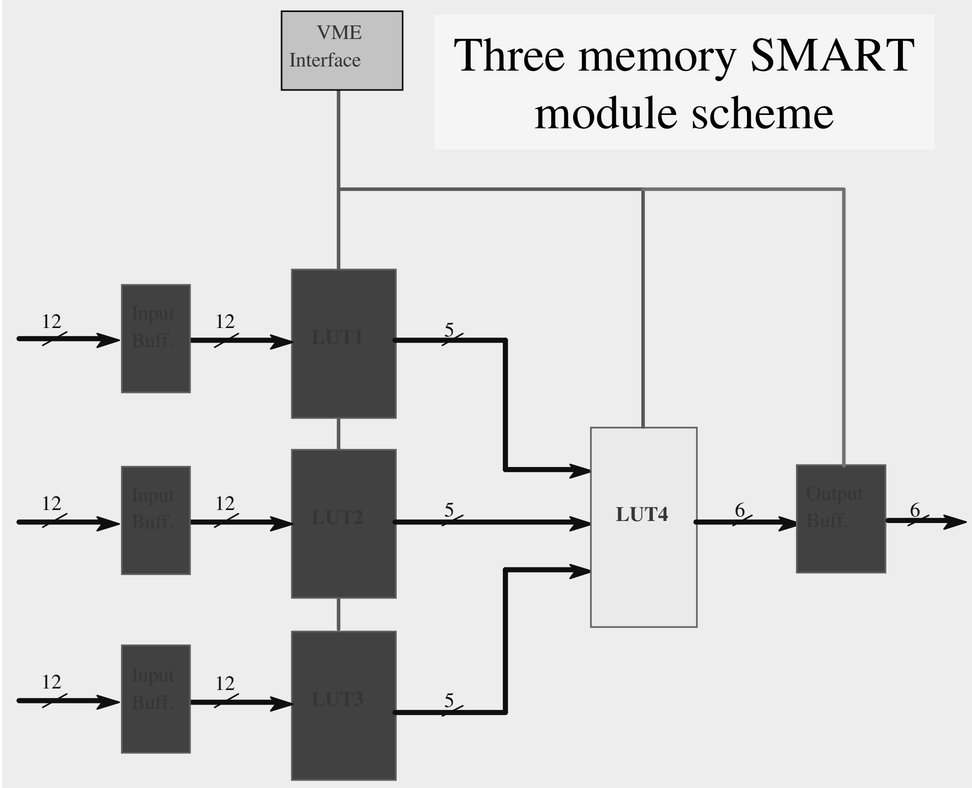
The second level trigger will be able to analyze the digital images in each trigger sub-region of the chamber using look-up tables that contains the information of likely patterns, and thereafter merge the pictures for a global analysis of the image.

The trigger will be based upon a 36 channel programmable VME board. This board, named SMART, exists already and is used at the moment as first level trigger for the CLUE experiment. The 271 pixels will be mapped into 19 SMART modules one for each L1 sub-region.

The internal tree structure of the SMART module will be replicated to higher level SMARTS to give the final answer of the trigger. The 6 bits output of each SMART boards are merged into 3 SMARTs modules and a last module will take the final decision.

L2 implementation

The SMART board look up tables are made by 12 bit asynchronous memories merged in a tree structure to give 6 programmable outputs.
Each output can be programmed to perform a boolean function of the 36 input channel. The logic unit is obtained with two cascaded Look Up Tables (LUT). Each firs level LUT is made with a 4096 bytes static memory in which the 12 address bits are connected with the inputs.
Three 12 inputs LUTs make the first stage of selection.
The 5 less significant bits (LSB) of each memory are grouped in a 15 bits word to be connected at the input of a fourth memory.
Every input configuration is seen at the input of the three LUTs as three independent sets of configurations, this mean that instead of 2^{36} of possible combinations of the whole set of inputs it is possible to recognize a subset of $3*2^{12}$.
The selection criteria is coded in the output five bits of each first step LUT; LUT4 should recognize the selection criteria of the previous three LUTs and merge them in order to get at the end a trigger pattern to be coded in a six bits output word.

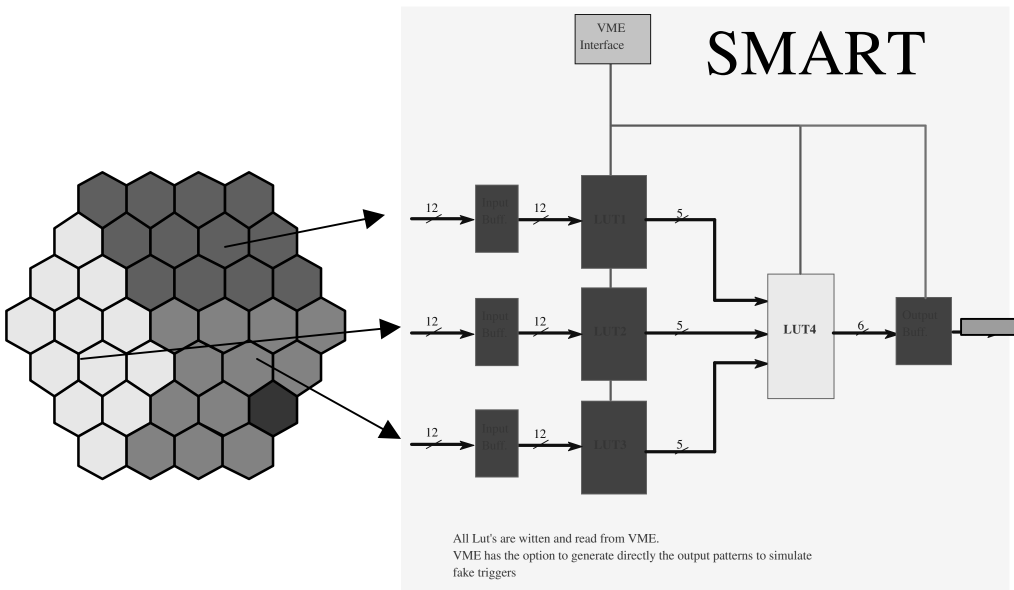


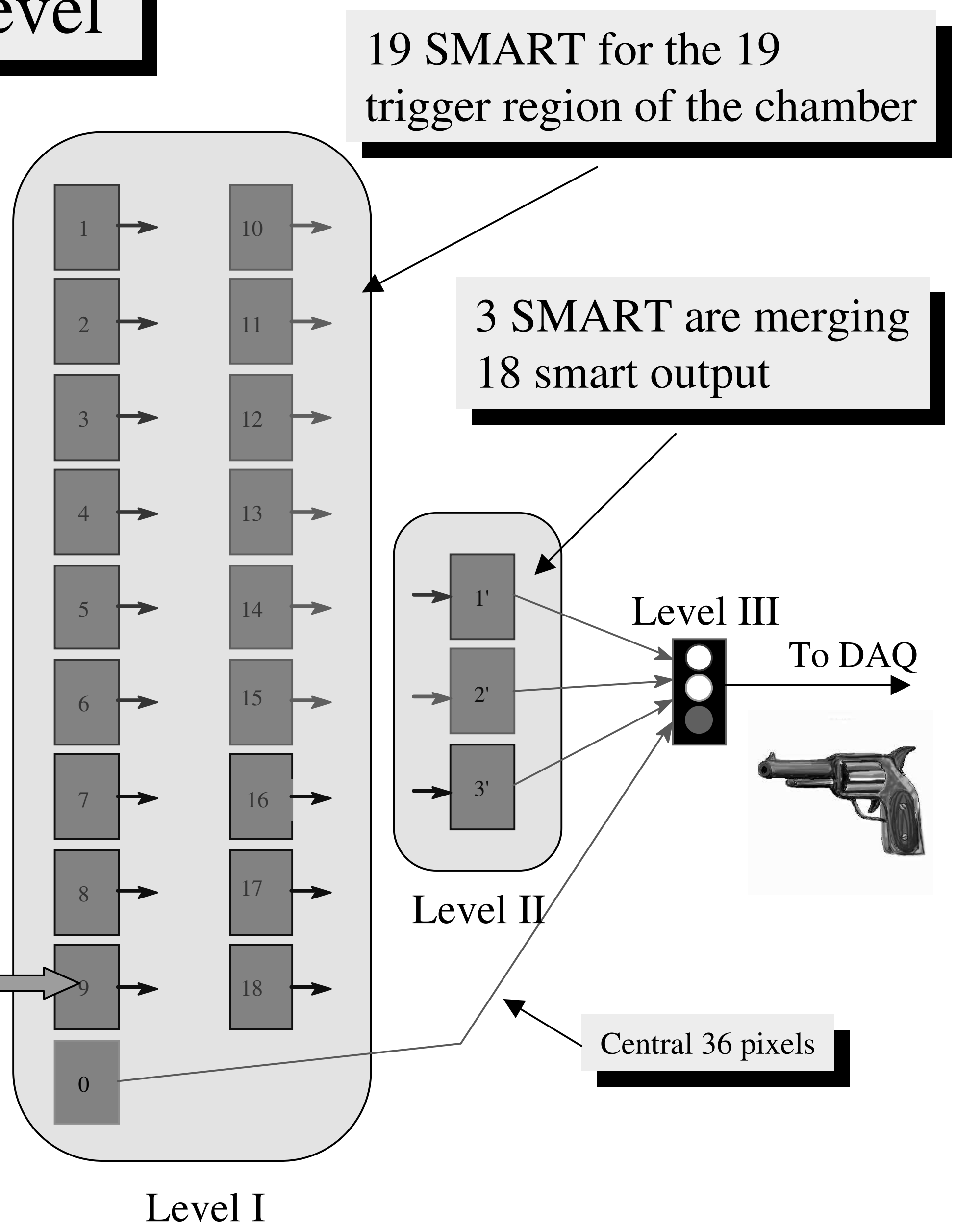
Three memory SMART module scheme

All Lut's are witten and read from VME.
VME has the option to generate directly the output patterns to simulate fake triggers

The merging structure of L2 in 3 level

The SMART outputs can feed another SMART module, replicating a tree structure or at the end provide the trigger signals.
L2 will be made with three levels, 16 smarts of the first level will feed 3 smarts of the second level and a final smart will merge all the information to give the final answer of the trigger. All the memories that form the internal LUT of the SMART module can be written and read via VME, allowing a big flexibility of this trigger to fit the different observational requirements of the telescope.
The transition time of a SMART module is 60 ns.





An example of pixel counting and centroid evaluation with L2