Advanced Gamma-ray Imaging System (AGIS)
- Topological Array Trigger -

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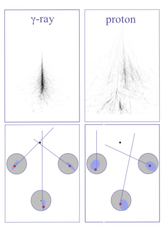
Abstract

The Advanced Gamma-ray imaging System (AGIS) is at the conceptual planning stage and is intended to become the next generation ground-based gamma-ray telescope with an order of magnitude better sensitivity over the existing instruments VERITAS, HESS and MAGIC. The AGIS concept is based on an array of 50 - 100 imaging atmospheric Cherenkov telescopes covering a square kilometer in area. The large array concept is a major step forward since it allows the detection of air showers while the shower core is well contained within the array, substantially increasing the event reconstruction capabilities. AGIS furthermore allows to form a trigger decision based on multiple viewpoints which can be processed to further reduce background from the night sky fluctuations and cosmic rays. A topological array trigger based on real time image analysis is poised to lower the energy threshold of a large array.

Parallax & Background Rejection

Fast Cherenkov flashes from air showers are used to detect gamma rays at Very High Energies (0.05 - 50 TeV). A fast topological trigger with the capability of carrying out a basic image analysis in real time would be extremely useful for three purposes:

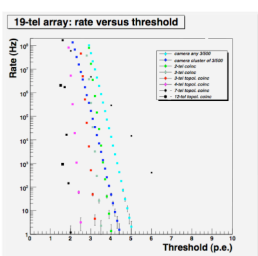
- a reduction of cosmic-ray background events
- a reduction of night sky background accidentals
- a lower the energy threshold



The geometry of a typical gamma-ray (left) and hadron initiated shower differs substantially in the lateral and longitudinal charged particle distributions. The resulting Cherenkov light images in the focal plane of IACTs are distinct with hadronic showers exhibiting a larger lateral and longitudinal spread compared to gamma-ray induced showers. This translates into substantial parallactic displacements [1] of individual images with respect to a reconstruction point of origin.

Fig. 1

Rates



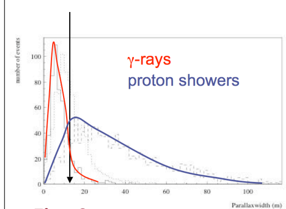
- Pixel size ~ 0.15 deg.
- Pixel coincidence time ~ 2 ns
- array coincidence ~ 100 ns
- Night sky background ~ 2 x 10^{12} photons/m^2/s/sr

Fig. 2

Simulations

The effectiveness of using a parallactic displacement analysis to reduce the background from cosmic-ray induced showers can be evaluated with Monte Carlo simulations. A system of 19 ten meter class telescopes with a spacing of 60 m was used to study the ability of a simple algorithm that is based on the first moments of Cherenkov light images. The first moment analysis is applicable to the lowest energy events where the Cherenkov light images are limited by photon statistics. Fig. 3 indicates the ability to reject 90% of proton showers while keeping 90 % gamma rays.

- figure of merit: Q ~ 3



$$Parallaxwidth \approx \sqrt{\frac{\sum_{i=1}^{n}(\vec{r}_i - <\vec{r}>)^2}{n}}$$

Fig. 3

$\vec{r}_i$ = location of intersection point i
$<\vec{r}>$ = averaged core location

Trigger Scheme

- camera: 3 adjacent pixels within 2.5 - 10 ns (400 MHz clock)
- calculate radial distance r and azimuth Φ
- time stamp at each telescope
- array trigger adjustable delay
- return array trigger to T_i and use time stamp
- synchronized GPS clocks at each T_i

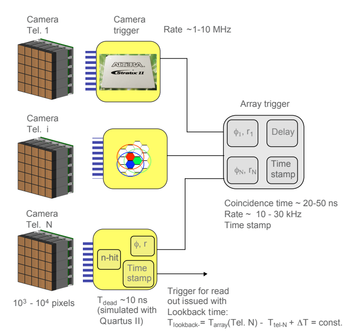


Fig. 3

Hardware & Prototype

- L1.5, L2, L3 prototypes under construction (ISU/ANL)
- to be tested at VERITAS
- alternative L2 tests (by WashU)
- scalable L1.5/L2 design (500 to 10^4 channels)
- L1.5 processes 200 pixel sub-regions (overlap) for coincidences
- L2 processes the L1.5 patterns and calculates image parameters
- L2 sends out 15 bytes of data including time stamp

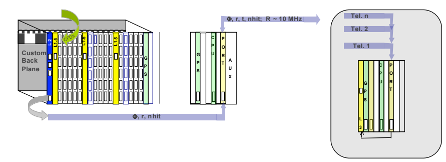


Fig. 5

Summary

The recent availability of 400 MHz FPGAs provides the technology to perform a real time stereoscopic image analysis for future large arrays of IACTs such as AGIS. A substantial reduction of night sky background accidentals combined with additional cosmic-ray rejection at the hardware level provides a cost effective means to lower the energy threshold of large arrays. First tests of different trigger schemes will be tested in VERITAS over the next year.

References

[1] Krennrich, F. & Lamb, R.C., Experimental Astronomy, 6, 285 (1995)

Acknowledgements

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