Developments for the camera trigger system of the Cherenkov Telescope Array

III Congreso IPARCOS

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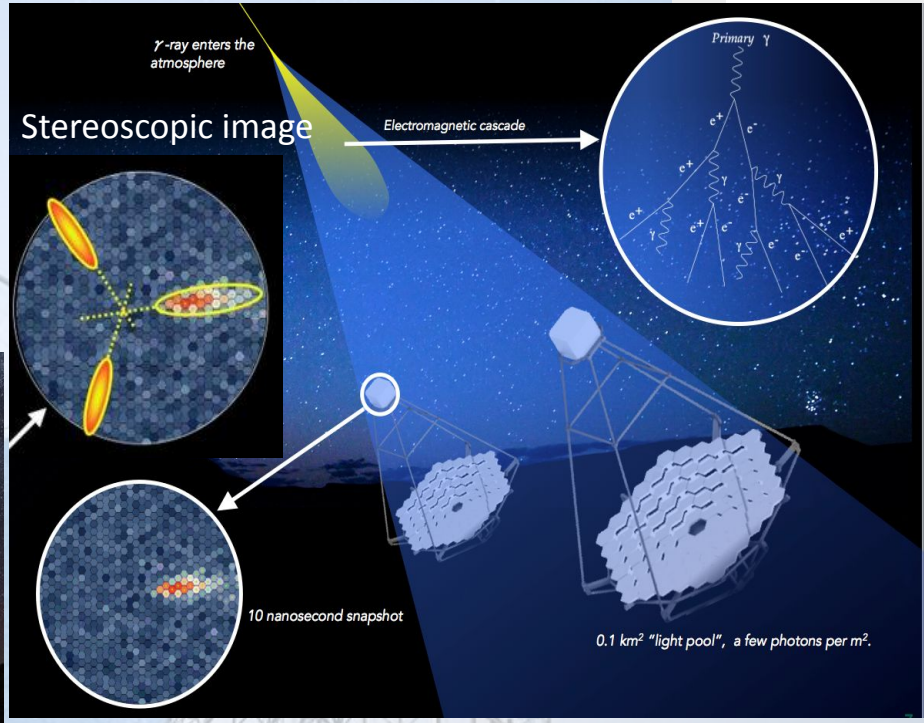
IACTs introduction

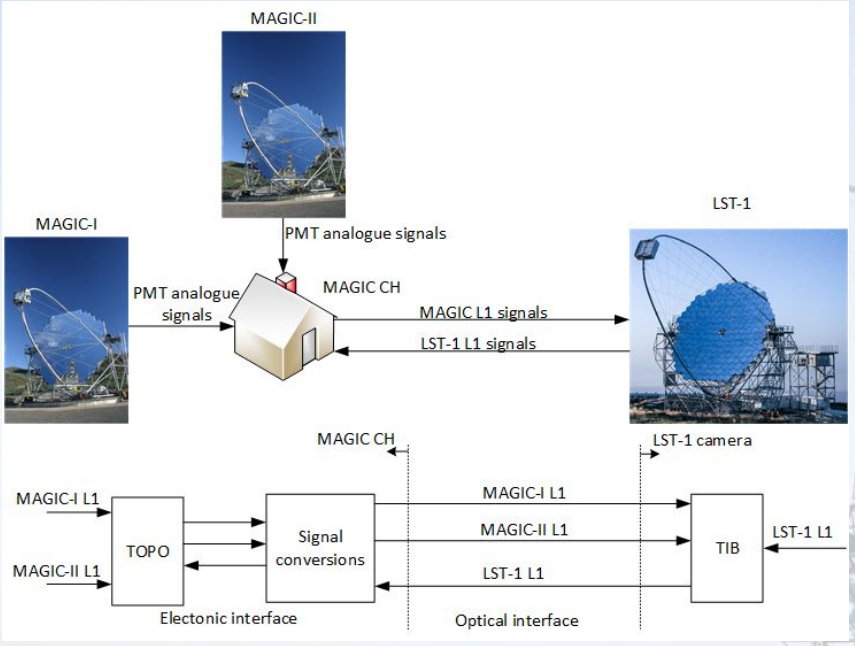
(Main) Challenges:

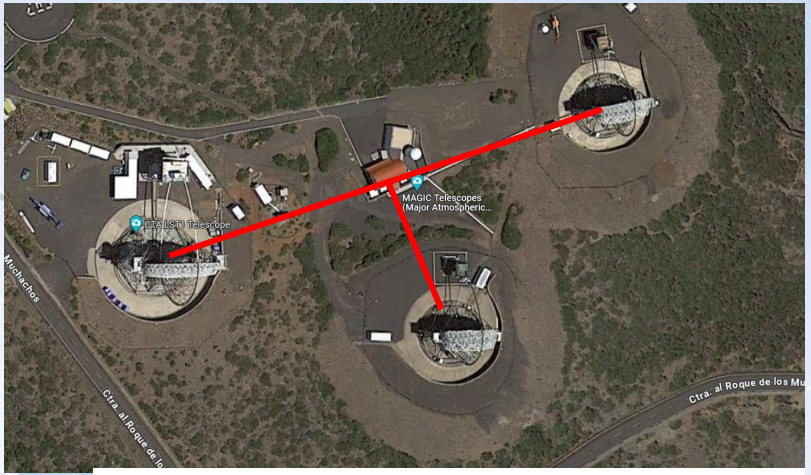
- Capture few ns duration light pulses.
- Higher energy range: low particle flux (over 150 GeV).
- Lower energy range: high night sky background (NSB) presence (less than 150 GeV).

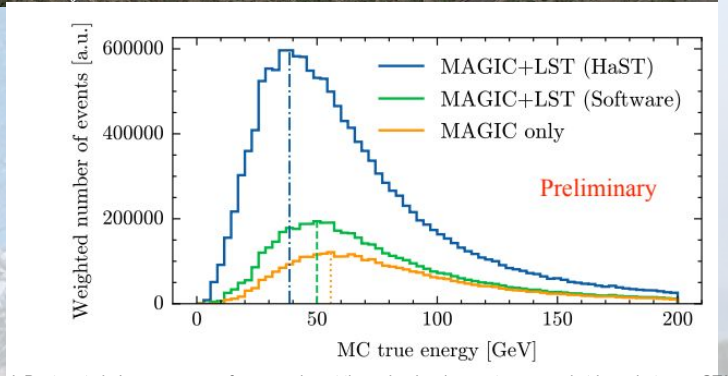
Observatorio Roque de los Muchachos (La Palma, Canary Islands): MAGIC and CTA-N observatories



LST-1 + MAGIC stereo trigger



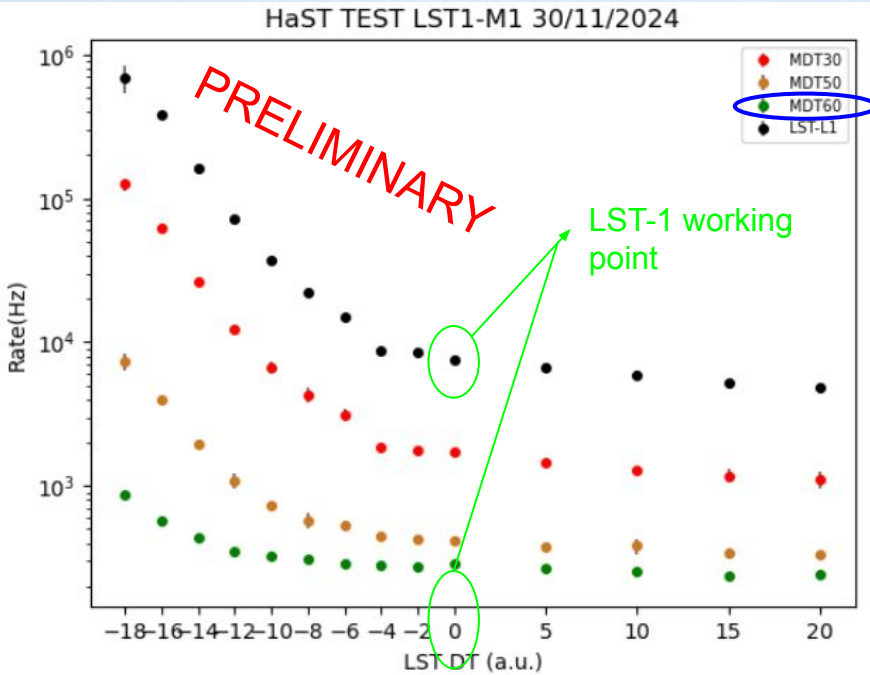


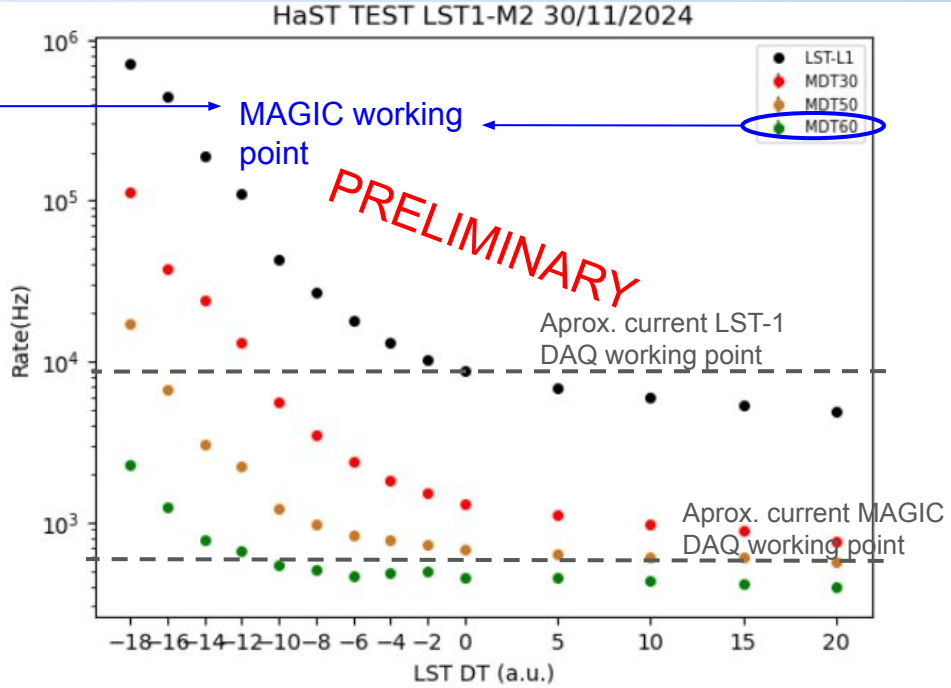


Until the LST2-4 are ready, we have combined LST-1 + MAGIC to test LSTs stereo system and potentially enhance astronomical observations.

J. Baxter et al., Low energy performance boost through a hardware stereo-scopic trigger between CTA LST-1 and MAGIC, PoS, ICRC2023,700,2023

LST-1 + MAGIC stereo trigger

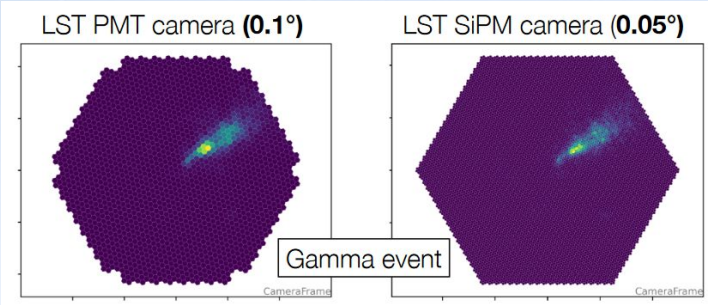




Tests conducted during dark time tracking 1ES0229; ZA steps [15, 10, 8, 11, 17, 23] (30 min steps)

Stereo allows to observe lower energies at the same DAQ rates and reject NSB.

The trigger for a future SiPM camera for LSTs



This camera will generate around 1.2 Tb/s of data, thus a trigger system with real time data reduction algorithms is needed. Therefore, FPGAs will run advanced trigger algorithms in real time to discard NSB only events (most of them).

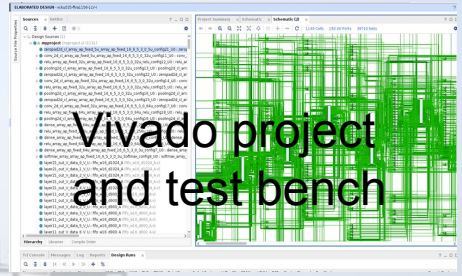
Evaluating CNNs for the trigger system:

CTLearn

```
Model: "CTLearn_model"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
waveforms (InputLayer)       [(None, 30, 30, 5)]       0
_________________________________________________________________
SingleCNN_block (Functiona   (None, 16)                1536
l)
_________________________________________________________________
fc_particletype_1 (Dense)    (None, 32)                544
_________________________________________________________________
particletype (Dense)         (None, 3)                 99
_________________________________________________________________
type (Softmax)               (None, 3)                 0
=================================================================
Total params: 2179 (8.51 KB)
Trainable params: 2179 (8.51 KB)
_________________________________________________________________
```

Reduced CNN TensorFlow model used for IACT offline event analysis.

hls 4 ml



Preliminary results when simulating with RoIs composed of 5 samples of 30x30 pixels

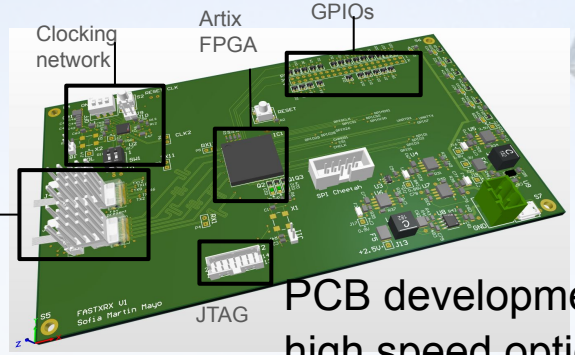
Latency is our main constraint!!

R. Factor	Latency (us)	DSP
1	5.2	122
8	12.9	66
16	15.3	52
32	15	29
64	20.4	17
128	33	9
256	41	6

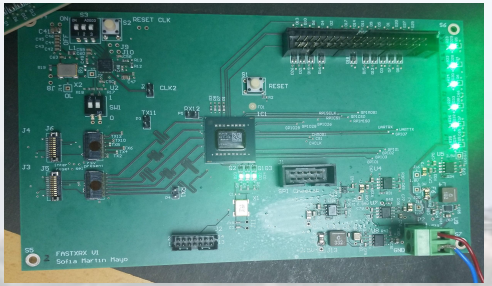
Optimization features:
-Reuse factor
-Quantization
-Prunning…
-others…

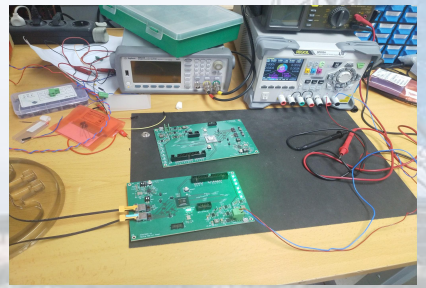
The trigger for a future SiPM camera for LSTs

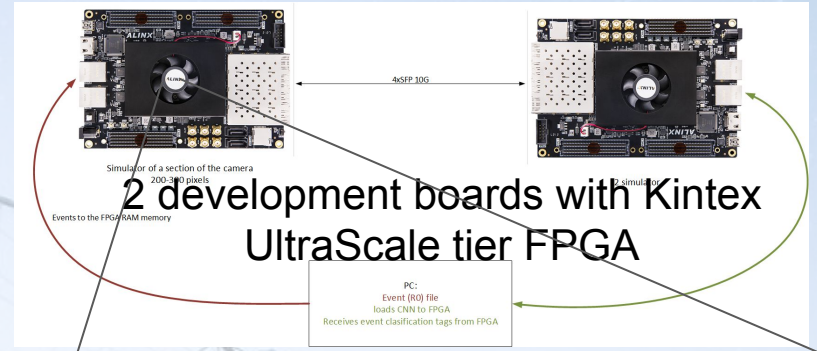
We are developing hardware testbenches to deploy the tentative algorithms.



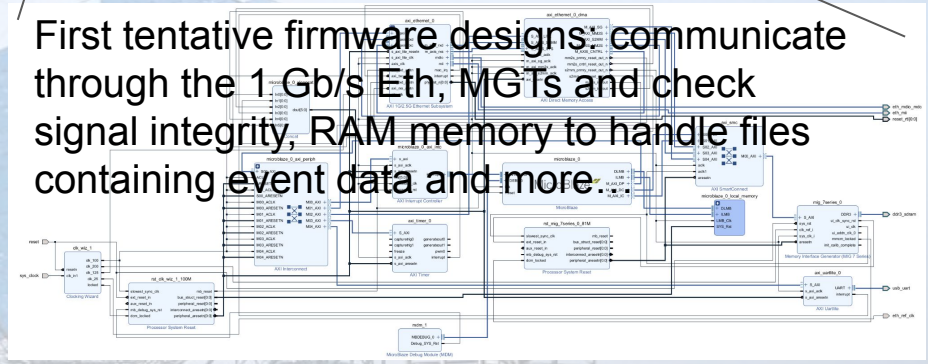
PCB development to test high speed optical links







2 development boards with Kintex UltraScale tier FPGA



First tentative firmware designs: communicate through the 1 Gb/s Eth, MGTs and check signal integrity, RAM memory to handle files containing event data and more...

Summary

- IACTs are instruments that detect atmospheric Cherenkov light produced by gamma rays coming from cosmic accelerators.
- Arrays of IACTs doing stereoscopic observations prove to be efficient enough to overcome some challenges derived from this technique.
- The PhD candidate has worked on the development of the stereo trigger system for CTA and on the joint LST-1 + MAGIC stereo system.
- The PhD candidate is working in deploying advanced image recognition algorithims in FPGAs to perform real time image processing for a future SiPM camera for LSTs.