Efficiency estimation of self-triggered antenna clusters for air-shower detection

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Challenge

- Low signal-to-noise ratio
- Air-shower pulse distortion
- Need for additional detector to give the trigger for radio

Purpose

- Develop processing pipeline for radio self-trigger
- Implement the possibility of processing various data from different hardware
- Define the requirements for FPGA-based hardware trigger

Approach

- Classification of station-specific background
- Rejection of noise-contaminated data
- Station (L0) and cluster (L1) layer trigger includes different algorithms
- Modular framework for testing the algorithms
- Using compact antenna clusters

Structure of the framework for trigger tests

Data

- Set of signal traces
- Coordinates of stations
- Timestamps
- Sampling rate
- Additional information about station (hardware type, response pattern etc.)

Calibration run →

Measurements run ↓

Trigger

Software imagination of hardware trigger.
Contains a chain of modules for trigger generation. Supports user-defined structure and interface for writing new modules.

Modules parameters ←

Trigger function ↑ ↑

Modules

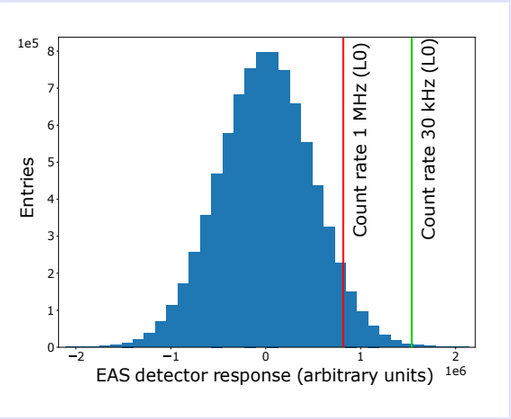
L0 Low-level optimized algorithms organized to multi-layer structure. Process data and mark it as candidates to noise- or signal-related.

L1 Contains separated parts for configuration and for triggering.

Config function →

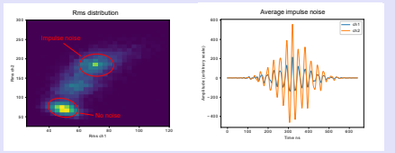
Trigger configurator

Generates station-specified parameters for trigger (thresholds and others) based on the current dataset and trigger structure. Generation is performed in offline mode (calibration run)

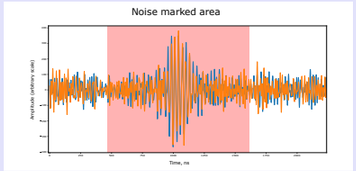


Example L0 modules:

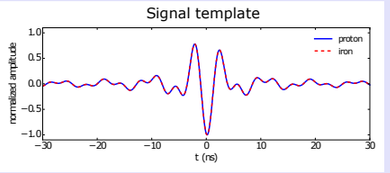
RMS analyser



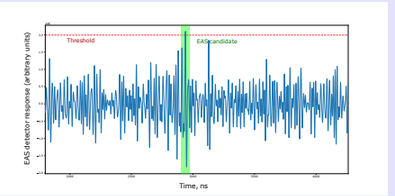
Test run: Looking for stationary noise sources with analysis of channel-to-channel RMS distribution. By estimation of concentration of entries in this distribution (2D Gauss fit) module distinguishes the cores and make averaged template of noise pulse corresponds to each core.
Measurements run: convolution of input data with corresponded template. Areas with convolution above the given thresholds are marked as noised and excluded from further analysis.



EAS template module



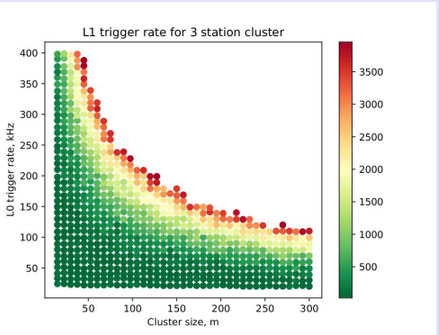
Test run: definition of thresholds based on requested count rate. At current stage templates are fixed and same for proton and iron.
Measurements run: convolution of input data with signal template and generation of trigger.
Timestamp with peak of convolution exceeds the threshold is marked as EAS candidate.



3 station cluster estimates:

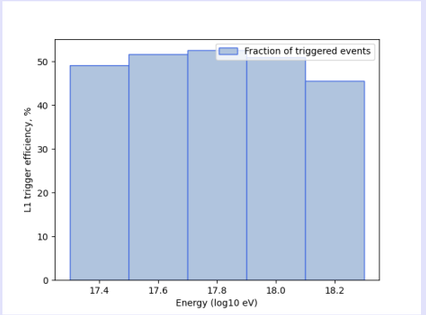
Count rate

Count rate of station-level L1 trigger (color, Hz) in dependence on cluster-level L0 trigger and size of cluster (distance between farthnest antennas, related to time window)



Efficiency

Fraction of triggered events for 3-station cluster with size ≈ 200 m in dependence of air-shower energy by Tunka-Rex data



References:

Towards the Tunka-Rex Virtual Observatory
P.A. Bezyazeekov et al. - Tunka-Rex Collaboration, Proceedings of the 3rd International Workshop on Data Life Cycle in Physics, Irkutsk, Russia, 2019, CEUR-WS 2406 (2019) 3, arXiv:1906.10425

Development of Self-Trigger Algorithms for Radio Detection of Air-Showers
O. Fedorov et al., Proceedings of the IV International Workshop on Data Life Cycle in Physics, Irkutsk, Russia, 2020, CEUR-WS 2679 (2020)