The use of adaptive predictor filter as a trigger mechanism in simulated cosmic rays radio signals corrupted with Gaussian noise

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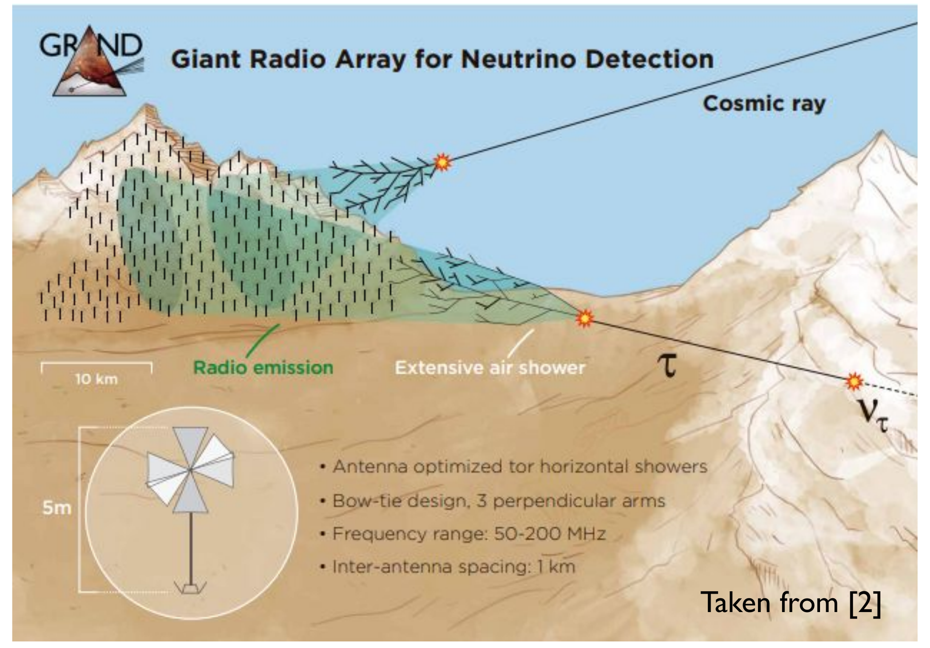
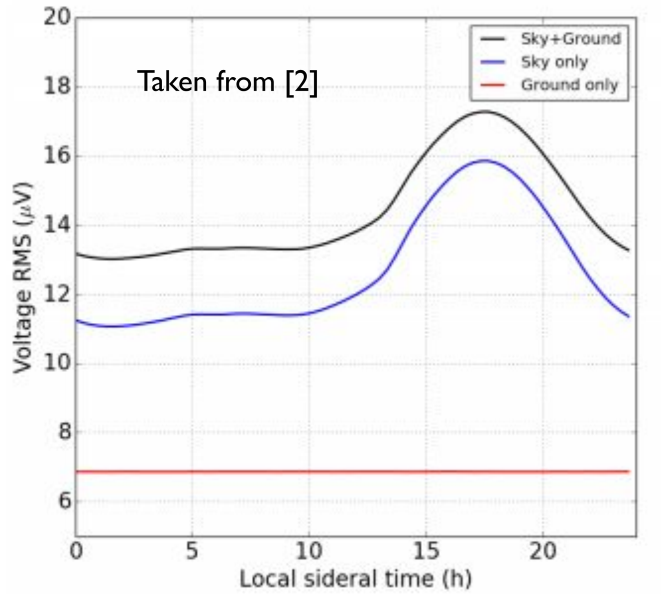
Introduction

Radio-detection of a cosmic ray is a modern, well established, and low-cost technique that uses antennas to detect the electromagnetic component of the air shower.
The community expects improvements on the accuracy of the primary particle energy, composition, and arrival direction [1].

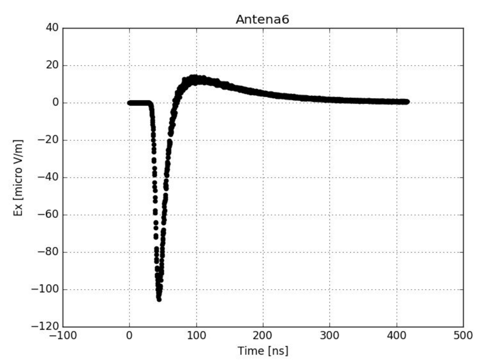


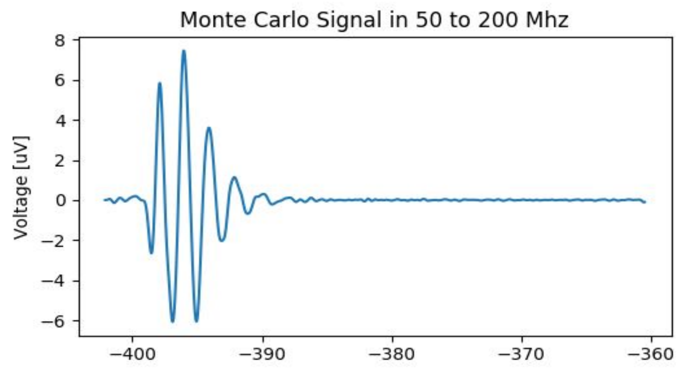
Using thresholding methods on the signal read by the antennas, a self-triggered mechanism leads to a high number of false-positive or false-negative events. This scenario pushed radio experiments to develop a hybrid trigger mechanism. Ideally, the trigger would have to work independently of another detector, especially in large-scale experiments. The main challenge for this type of detection is the background present at the experimental site due to human-made radio noise, and the Galactic Gaussian noise [3]. The former can be drastically reduced if site is chosen in deserted and remote areas, while the second one is irreducible. **This work is motivated by the task of self-trigger in cosmic rays induced radio signals experiments,** especially in the case of **the GRAND experiment** a large-scale experiment planned to be designed at a remote and deserted site in China [2].

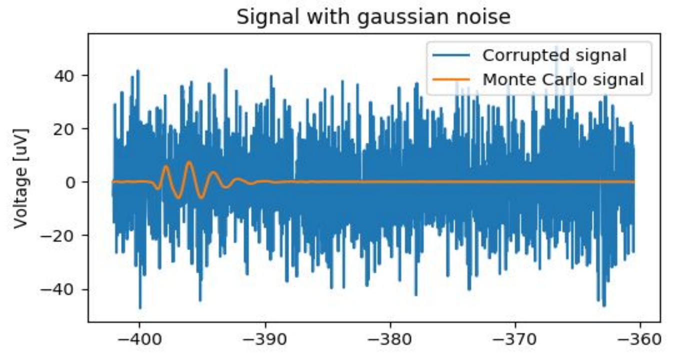


Simulation

The simulated data used in this analysis were generated using the COREAS [5] radio emission simulation tool from CORSIKA [4] software. We also simulated the GRAND collaboration' antenna response and added the noise to the signal in order to mimic the realistic scenario, i.e., the voltage trace plus the Gaussian distribution [2].



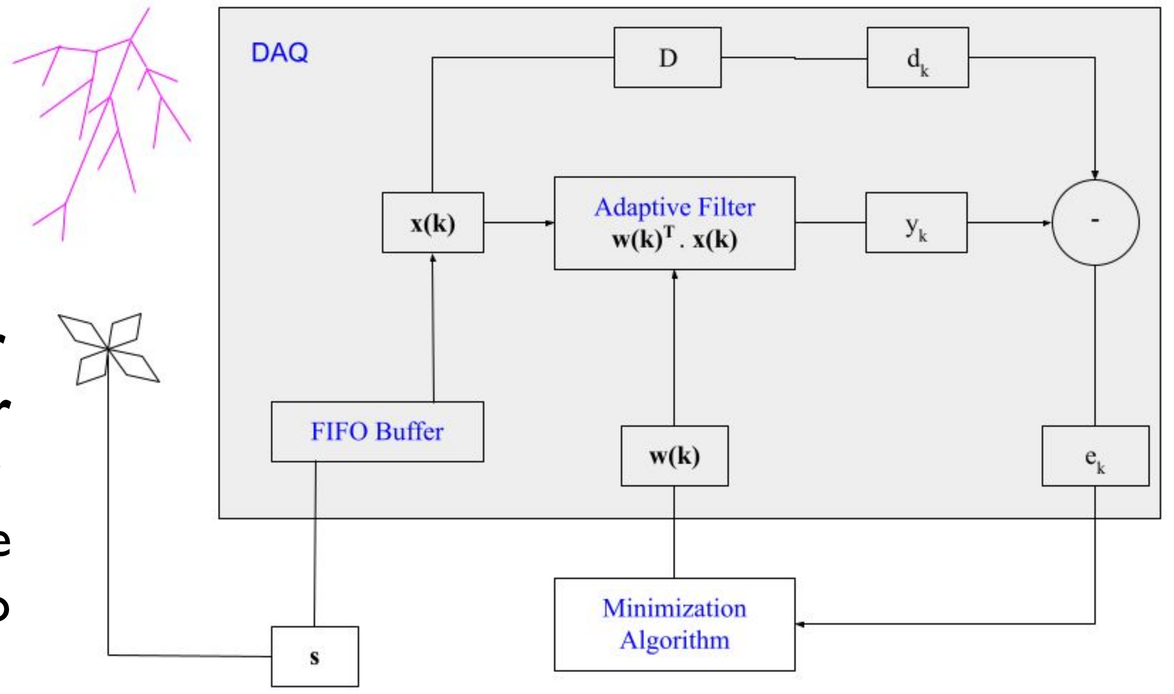




Adaptive Predictor Filter

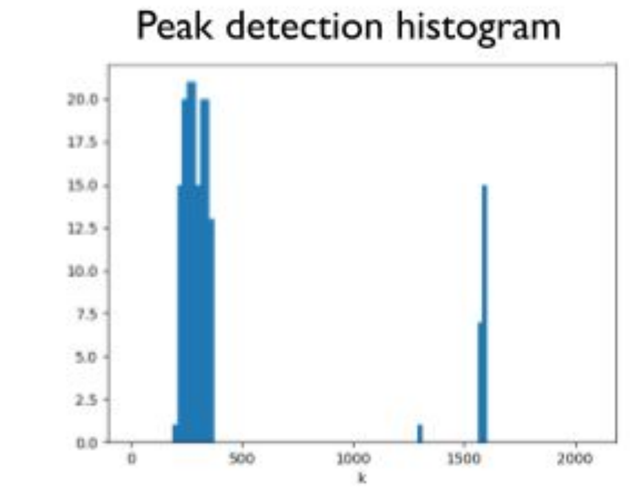
An adaptive filter is an online learning algorithm, that among several applications, can be used for denoising, system recognition, and time series prediction. The latter one we use to test its efficiency as a self-trigger mechanism [6].
Given an input signal **x(k)**, the output signal **y(k)** is defined as the inner product of a coefficients weight vector **w(k)** with the input-data vector.
The goal is to minimize a function of the error between an ideal desired signal **d(k)** and its output signal **y(k)**, i.e., the error **e(k)** squared, with a constant adjustment of the coefficients weight vector, based on the cost function minimization algorithm.

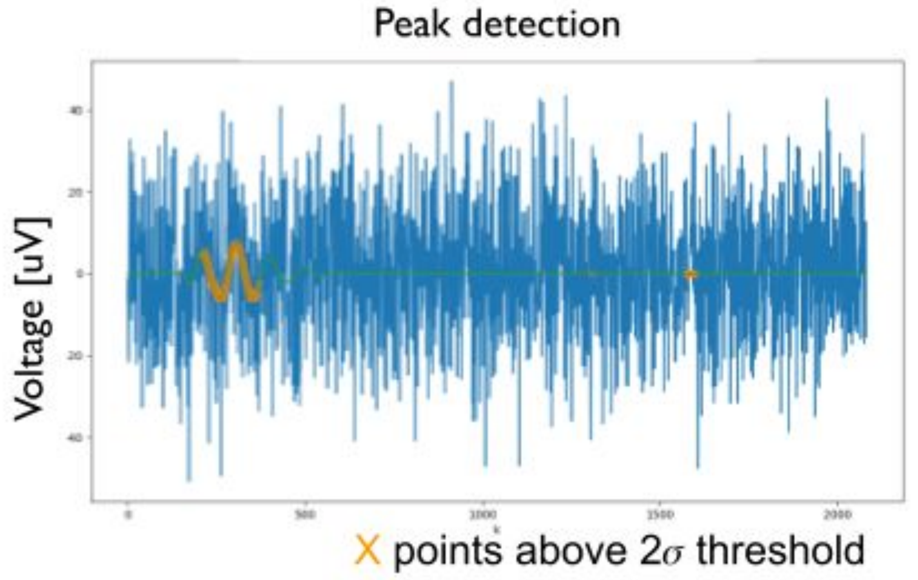
$$y(k) = \mathbf{w}(k)^T \cdot \mathbf{x}(k)$$
$$e(k) = d(k) - y(k)$$
$$\mathbf{w}(k+1) = \mathbf{w}(k) + \mu\mathbf{x}(k)\mathbf{e}(k)$$

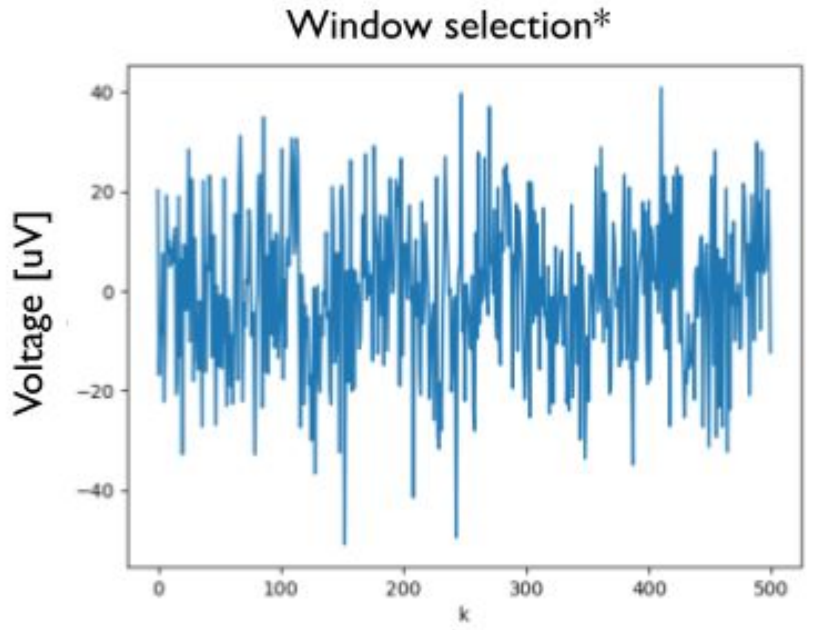


The behavior of **the weight vector can be used as a trigger mechanism** because it will vary during a possible transient since the weight vector will vary as it tries to minimize the error.

The main advantage of this method is that the behavior of the weight vector spectrum can be more sensitive than the signal power spectrum itself [7].

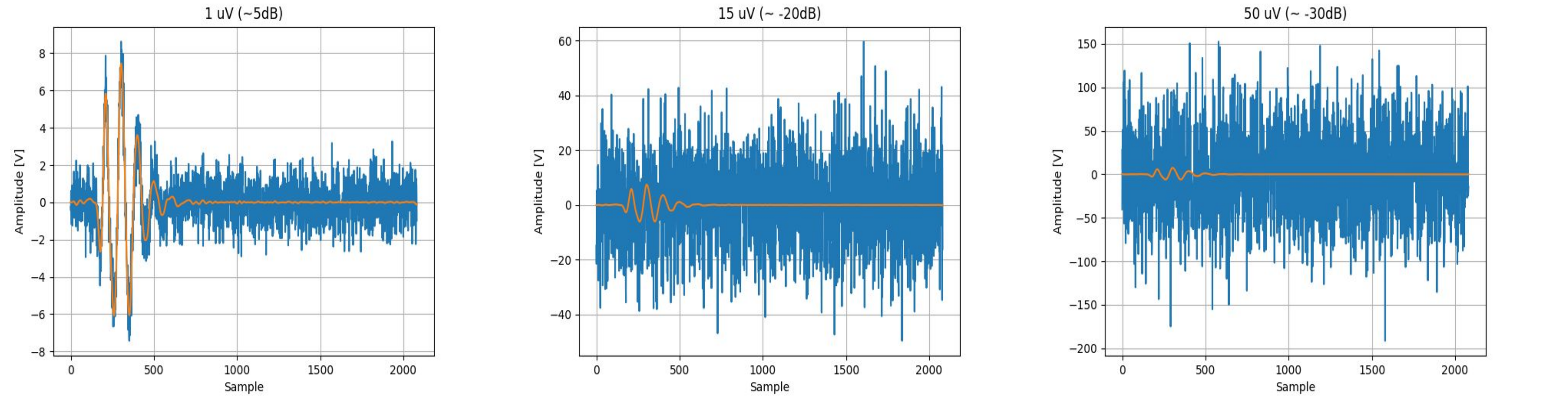




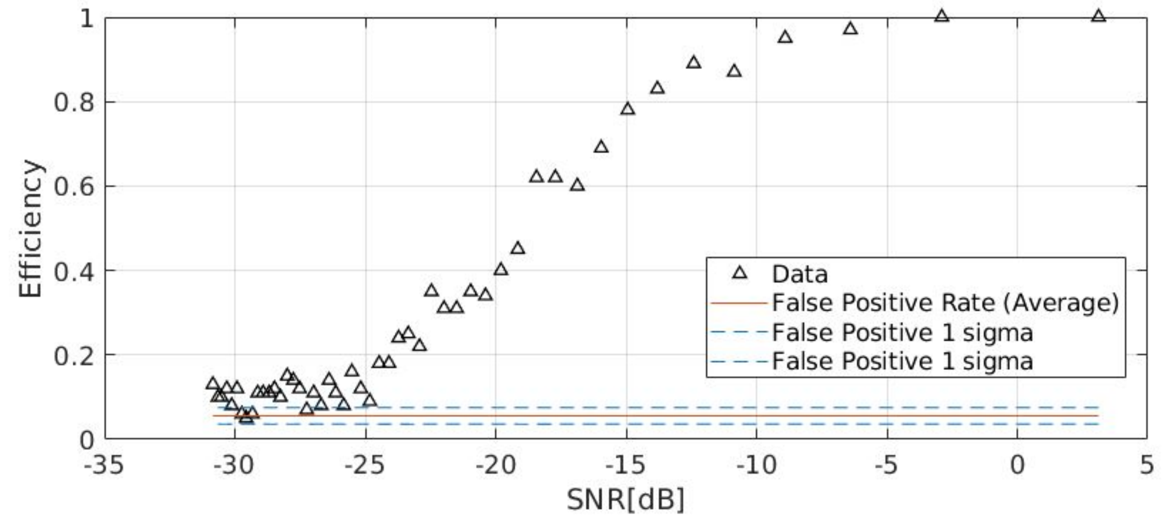


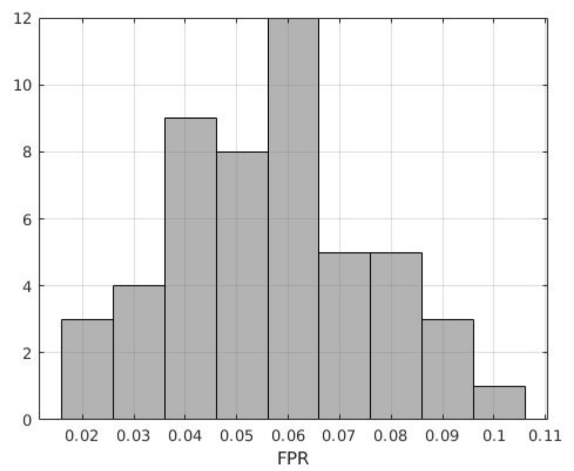
Results

The dataset consists of a single voltage trace template with 5000 Gaussian background samples of different widths. These ranged from 1μV to 50μV in 1μV steps, and for each width, 100 distributions were generated.



The efficiency was estimated using the three antenna polarizations (**x,y,z**) and to estimate the False Positive Rate were used 5000 traces of pure random Gaussian noise.





We can assume that above -15 dB, the efficiency is almost 90%, with a very low and constant **FPR** ~ 6% per 2082 samples, or ~15 kHz (for a 500 MHz sampling rate [2] of the GRAND experiment).

Acknowledgments

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