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DCT trigger in a high-resolution test platform for a detection of very inclined showers in the Pierre Auger surface detectors

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The paper is presenting the first results from the trigger based on the Discrete Cosine Transform (DCT) operating in the new Front-End Boards with Cyclone V E FPGA deployed in 7 test surface detectors in the Pierre Auger Engineering Array.

The patterns of the ADC traces generated by very inclined showers were obtained from the Auger database and from the CORSIKA simulation package supported next by OffLine reconstruction Auger platform which gives a predicted digitized signal profiles. Simulations for many variants of the initial angle of shower, initialization depth in the atmosphere, type of particle and its initial energy gave a boundary of the DCT coefficients used next for the on-line pattern recognition in the FPGA.

Preliminary results have proven a right approach. We registered several showers triggered by the DCT for 120 MSps and 160 MSps.

Very inclined showers generated by hadrons and starting their development early in the atmosphere produce a relatively thin muon pancake (˜1m thickness) on a detection level. Ultra-relativistic charged particles trespassing the water in a surface detector generate the Cherenkov light detected next in photo-multipliers (PMT). A direct light gives a peak with a very short rise time and fast exponential attenuation. The DCT trigger allows recognition of ADC traces with specific shapes The standard trigger requires 3-fold coincidences in a single time bin. The present sampling frequency in the surface detectors is 40 MHz. The new Front-End Board developed for the Auger-Beyond-2015 surface detector upgrade allows a sampling up to 250 MSps (120 MSps and 160 MSps were used in tests).

Neutrinos can generate showers starting their development deeply in the atmosphere, known as “young”. They contain a significant amount of an electromagnetic component, usually preceded by a muon bump. Simulations show that it is often fully separated from the EM fraction and the 16-point DCT algorithm can also be used.

A probability of 3-fold coincidences of direct light corresponding to a standard Auger trigger is relatively low. Much more probable are 2-fold coincidences of a direct light. The 3rd PMT is next hit by reflected light, but with some delay. By fast sampling (120-160 MSps) this delay gives signal in the next time bins. The standard T1 trigger ceases giving a sufficient rate for horizontal and very inclined showers. The rate drops down below an acceptable level. We had to modify the T1 trigger to get approximately standard trigger rate.

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