International Journal of Modern Physics A

RADIODETECTION OF COSMIC RAY EXTENSIVE AIR SHOWERS : UPGRADE OF THE CODALEMA EXPERIMENT.

[a)] ARDOUIN*D. , [a)] BELLETOILE A., [a)] CHARRIER D., [a)] DALLIER R., [b)] DENIS L., [d)] ESCHSTRUTH P., [a)] GOUSSET T., [a)] HADDAD F., [a)] LAMBLIN J., [a)] LAUTRIDOU P., [c)] LECACHEUX A., [d)] MONNIER-RAGAIGNE D., [a)] RAHMANI A., [a)] RAVEL O.

[a)] *SUBATECH, La Chantrerie, 4 rue Alfred Kastler, BP 20722, 44307 Nantes-cedex 3*
[b)] *Observatoire de Paris - Station de radioastronomie, 18330 Nançay*
[c)] *LESIA, Observatoire de Paris, Section de Meudon, 5 place Jules Janssen, 92190 MEUDON*
[d)] *LAL, Université Paris-Sud, Bâtiment 200, BP 34, F-91898 Orsay cedex*

Received (Day Month Year)
Revised (Day Month Year)

We present the characteristics and performance of a demonstration experiment devoted to the observation of ultra high- energy cosmic ray extensive air showers using a radiodetection technique. In a first step, one antenna narrowed band filtered acting as trigger, with a 4 σ threshold above sky background-level, was used to tag any radio transient in coincidence on the antenna array. Recently, the addition of 4 particle detectors has allowed us to observe cosmic ray events in coincidence with antennas.

Keywords: ultra high energy cosmic rays ; radiodetection.

1. The CODALEMA experiment.

The CODALEMA (COsmic ray Detection Array with Logarithmic Electromagnetic Antennas) experiment has started at the Nançay Radio Observatory in 2003. It uses 6 of the 144 log-periodic antennas (in the 1-100 MHz frequency band for CODALEMA) constituting the DecAMetric array (DAM) [1].

During the first period of observation [2], the setup (see Fig. 1) was self-triggered using one devoted antenna: before entering the ADC, its signal was filtered in an appropriate noise-free frequency band (33-65 MHz) chosen after an exhaustive study in the observed local noise frequency spectrum. The wide band waveform signals (1 - 100 MHz) of the other antennas were registered when a voltage threshold was reached on the trigger antenna. The trigger threshold was set at 4 σ_{sky} (σ_{sky}: the rms sky background noise), leading to an electric field sensitivity of 4 μV/m .

In figure 2 the evolution of the average counting rate at Nancay is presented as a function of the trigger level expressed in units of σ_{sky}. The counting rate evolves greatly with the anthropic activities in the vicinity of the station of Nancay and

*daniel.ardouin@sciences.univ-nantes.fr

with weather conditions.

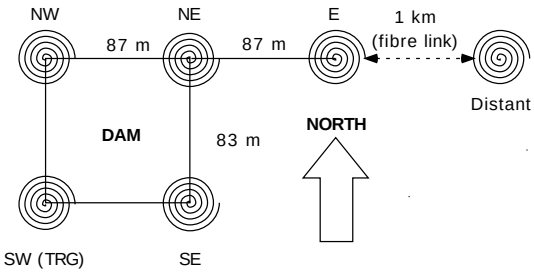

Fig. 1. First CODALEMA setup: the SW antenna acted as a trigger.

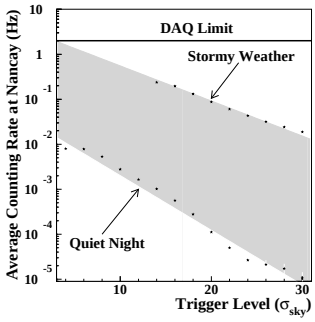

Fig. 2. The shaded area corresponds to the measured counting rate. The lower limit has been measured during quiet night runs whereas the upper limit corresponds to stormy weather.

Except for the trigger antenna, transient signals on the antennas were hidden by radio transmitter signals. Consequently, a numerical passband filter (same frequency band as trigger) was applied, offline, in order to observe coincidences involving several antennas [3]. Using the position and the timing differences between antennas, it was also possible to perform trajectory reconstruction of the electromagnetic plane wave using a triangulation technique across the array [4]. This level of analysis enables us to bring to light several cosmic ray air shower candidates.

2. Coincident measurements with particle data : Preliminary results

In the second phase operating since mid 2004, the above setup (see Fig. 3) has been supplemented with four double plastic scintillators [5] placed at the corner of the DAM array ($\simeq 100 \times 100$ m^2). The experiment is triggered with fourfold coincidence from the particle detectors, resulting in an event rate of 0.8 event/mn. All the antennas have now the same role and are passband filtered (24-82 MHz) in order to increase the signal to noise ratio.

The observation of coincident events from antennas and charged particle detectors (Fig. 4) demonstrates the association of transient antenna signals with the occurrence of extensive air showers. This unambiguous evidence of radio signals through the simultaneous detection of shower particles will make possible, for the first time, the characterisation of the shape and amplitude of air shower associated radio pulses. A preliminary event rate of 1/(8 hours) is observed with antenna multiplicity ranging from 3 to 6.

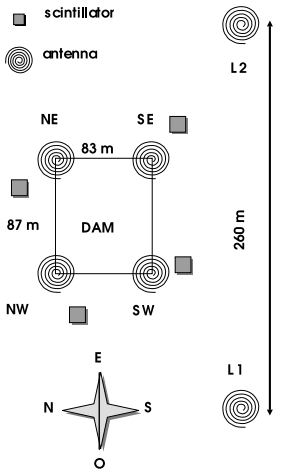

Fig. 3. Actual CODALEMA setup: the particle detectors act as a trigger.

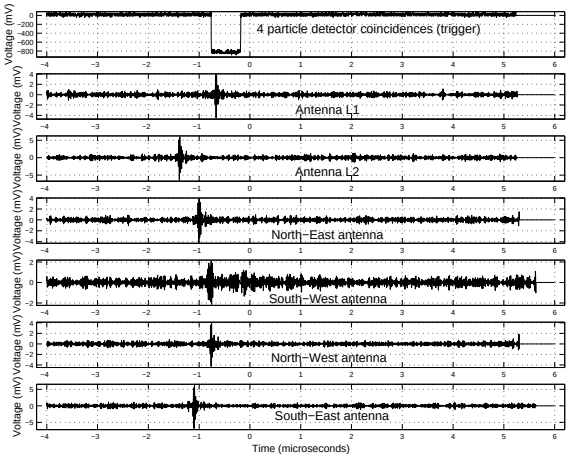

Fig. 4. Filtered antenna signals obtained for a cosmic ray event triggered by the particle detectors.

From the corresponding deposited energy distribution in the scintillators, one may be able to infer the location of the air shower core. The relative time delays between the particle detectors can be used to reconstruct the shower direction. From this information, impact parameter effects can be studied, especially those related to non vertical showers. The latter are expected [6] to generate amplitude and shape field variations which will better show up in the large atmosphere volumes accessible with the radiodetection method. For this reason, 5 antennas will be installed (up to 400 m from the DAM) on a east-west line crossing the existing array. The new antenna line will also be a tool for assesing the interest for designing a larger antenna array dedicated to Ultra High Energy Cosmic Rays.

References

1. http://www.obs-nancay.fr/ and http://www-subatech.in2p3.fr/.
2. Ravel O. *et al.*, *Nucl. Instr. Meth.* **A518**, 213-215 (2004).
3. Dallier R. *et al.*, *SF2A 2003 Scientific Highlights*, ed F. Combes *et al.* (EDP Sciences, 2003).
4. A. Bellétoile *et al.*, astro-ph/0409034 (2004).
5. M. Boratav *et al*, *Proc. of the* 24^{th} *ICRC*, Rome, 954,(1995).
6. T. Gousset, O. Ravel and C. Roy, *Astroparticle Physics*, **22**, 103-107 (2004).