Upgrade of the CODALEMA experimental setup

L'expérience CODALEMA démarrée en 2003 sur le site de l'observatoire de Nançay a sensiblement évolué au cours des années afin d'améliorer ses capacités de mesure des rayons cosmiques de haute énergie. Le dispositif expérimental actuel comprend deux réseaux dédiés respectivement à la mesure des signaux radio et à la mesure au sol des particules chargées produits par les gerbes atmosphériques.

The CODALEMA research program aims to the characterization of the Extensive Air Shower (EAS) radio profile, by measuring simultaneously its particle and radio contents in a hybrid mode. Significant results from the CODALEMA experiment have been already reported [1, 2 – see also contributions to this report]. The present objective of radio detection is to obtain the most achievable characterization of the shower radio emission content with shower location, direction and size. For this purpose two sets of overlapping detection arrays were deployed on the site of the Radio Observatory in Nançay, France, and were gradually improved and extended over the years (Fig. 1).

The ground particle array is dedicated to the characterization of the arrival time, direction, size and core location of the shower by a measurement of the particle density at the ground level. Moreover it provides a logic signal to trigger the antenna digitization and acquisition systems. It consists in 17 scintillator stations located on a grid of approximately 85m of pitch. It covers a $340\times340 m^2$ surface whose center roughly matches the radio array center [2]. Each station includes a thick plastic scintillator seen by two photomultipliers, all inserted in stainless steel box, finally housed in a plastic container for weather protection (Fig. 2). The two photomultipliers have their high voltage supply set to work at different gains (high gain (HG) and low gain (LG)), in such a way to have an overall dynamics from 0.3 VEM to 3000 VEM, switching the signal analysis from HG to LG when the HG is near saturation.

The first attempt to detect radio signals in coincidence with ground detectors was realized successfully by using few of the conic logarithmic antennas taken away from the 144 phased antennas of the Decametric Instrument (DAM) [1]. However their huge size prevented any further utilization as a fast and cheap element to be deployed later on in an open field array.

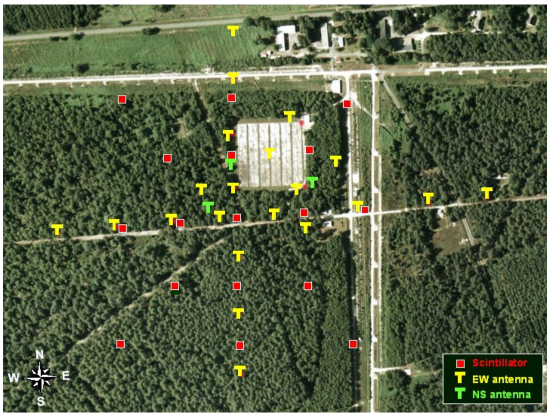

Fig. 1: Schematic view of the CODALEMA experimental setup on January, 1st 2008 superimposed on an aerial view of the Nançay observatory.

Emphasis on simplicity, size, coast and performance was used as guideline to develop a short active dipole. It is made of two 0.6 m long and 0.1 m wide aluminum slats, separated by a 10 mm gap. It is hold horizontally at 1 m above ground by a plastic mast (Fig. 2). This antenna is loaded by a high input impedance dedicated low noise 34 dB amplifier whose 3 dB bandwidth is 100 kHz-220 MHz [3].

The core of the radio array is made of 14 antennas, around 90 m spaced, and forming a cross of two 600 m long arms oriented in the North-South and East-West directions. These antennas are themselves oriented in the East-West direction. 7 antennas were recently added in order to sample the radio signal associated to EAS in a diagonal direction and at smaller distance. 3 dipoles were installed near the array center, close to existing antennas and oriented in the North-South direction to study the polarization of the electric field.

All the detectors and antennas are wired to a central shelter that protects power supplies, racks of electronics and computers for data taking. In the standard acquisition mode, the particle detection system acts as a master EAS trigger while the antennas are configured in a slave mode. Signals from both array detectors are directed to 4 channel 6U VME waveform digitizer boards [4]. The so-called Matacq board performs a fast 12-bits digitalization of the waveforms with a 300 MHz analog bandwidth, at a sampling rate of 1 Gs/s and in a memory depth of 2560 points (2.5 μs of signal). The maximum excursion at 1 V analog input of these ADCs defines a LSB at 250 μV. The noise of the antenna chain (antenna + preamplifier + cable) measured at the input of the digitizer is less than 200 μV rms. All the ADC boards are externally triggered by a dedicated 16-fold multiplicity circuit. This circuit discriminates the HG photomultiplier signals with a threshold corresponding to 0.3 VEM and compares the resulting multiplicity to a remotely controlled level. In standard data taking conditions, we require the 5 central stations to trigger within a 600 ns gate width. These trigger conditions lead to an event rate of about 8 events/hour.

The data acquisition software is running under the LabView environment installed on two conventional commercial PC. Subroutines have been developed to interact with the Matacq boards via GPIB interfaces allowing initializing and programming the boards, to calibrate and readout the data. On line monitoring and data transmission over the network for storage and further processing are also performed from those computers.

The CODALEMA experiment is running and taking data without any major interruption or extended failures since October 2006. These stable running conditions are required in order to cumulate large statistics of events and to allow refined analysis of radio signals associated to EAS. Extending further out the CODALEMA setup at Nançay requires a complete change in the installation strategy. The current strategy (all detection devices connected by underground cables to the central container) clearly reaches its limits in terms of infrastructure workload and cost and in terms of time propagation and attenuation of the signal in the cables. New radio station prototypes are currently built and feature a trigger system, power supply and data transfer autonomous from the wired arrays and able to work in a standalone mode. They will be tested at Nançay and could be integrated in the existing array in order to increase its coverage. This would mark a new milestone towards a large scale radio detection array.

Fig. 2: A dipole near the central container located on the south side of the DAM (left). A dipole antenna and a scintillator station (right).

En amélioration et extension continue depuis ses débuts, l'expérience CODALEMA à Nançay a atteint maintenant une taille permettant des analyses détaillées des signaux radios associés aux gerbes atmosphériques. Deux réseaux de 17 scintillateurs et de 24 antennes dipolaires constituent le dispositif expérimental en place depuis Janvier 2008. Deux bras de 7 antennes forment le cœur du dispositif radio. 10 dipôles supplémentaires permettent de mesurer le signal radio sur de plus courtes distances et d'étudier la polarisation du champ électrique. L'expérience fonctionne sans aucune interruption importante depuis Octobre 2006.
Des prototypes de station autonome seront prochainement testés sur site pour une possible intégration à terme dans le réseau actuel.

[1] D. Ardouin et al, Nuclear Instruments and Methods, A555 (2005) 148–163.
[2] D. Ardouin et al, 2006, Astroparticle Physics 26, p. 341-350, astro-ph/0608550.
[2] D. Lebrun et al, 30th Int. Cosmic Ray Conf. ICRC'07, Mérida, Mexico (2007).
[3] D. Charrier et al, Nucl. Instrum. Meth. A 572 (2007) 481.
[4] D. Breton and E. Delagne, 10th workshop on electronics for LHC and future experiments, Boston, 13-17 sept 2004.