

Results of the RAuger experiment

Pour la première fois au monde, le réseau prototype RAuger installé à l'Observatoire Pierre Auger (Argentine) a permis la détection complètement indépendante d'événements radio associés à des gerbes atmosphériques générées par des rayons cosmiques. Les résultats correspondant à environ un an d'exploitation de l'instrument sont présentés ici.

The principle of the RAuger experiment has been described in the previous contribution to this report and in ref. [1]. As cosmic ray air shower transients exhibit the same characteristics as most of man-made transient interferences, it is for the moment very difficult to recognize them by the only radio signal. With a large antenna array, this difficulty should be overcome, but RAuger extends only over a few hundred of m² and needs an independent confirmation for cosmic ray identification. This is the reason why radio events are time-tagged by the same GPS system as in Auger, which allows recognizing real cosmic ray events from noise by searching time coincidences between particle events detected by Auger's SD and radio events. Fig. 1 shows an example of such a coincident signal.

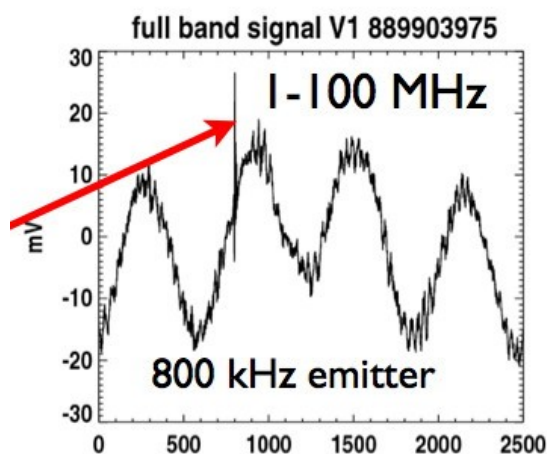


Fig. 1: One of the events observed on RAuger and identified as a cosmic ray signal by time coincidence comparison with Auger's SD event time. The transient (marked with the red arrow) clearly appears in this wide band record, superimposed to the local 800 kHz radio broadcasting frequency.

In about one year of operation, corresponding to some 6 months of effective

time (because of breakdowns and adjustment periods), 25 coincident events have been detected between radio and Auger, above an energy threshold very similar to the one observed on CODALEMA [2]. Those events constitute the first ever detection of cosmic ray events by an independent, self triggered radio system, definitively demonstrating the ability of radio to be a very complementary technique for Ultra High Energy Cosmic Ray (UHECR) studies.

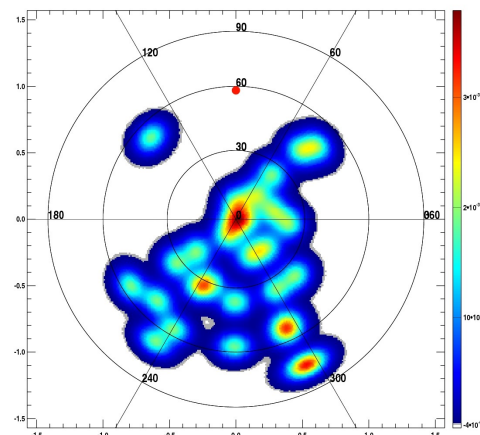


Fig. 2: Contour sky map of the radio detected events (direction of events is given by the Auger's SD). The event density depletion around the direction of the magnetic field (red dot) is clearly visible on the North.

Besides this technical breakthrough, and though low statistics has been reached, a very important result has also been found. In the northern hemisphere, a clear event density depletion has been observed in the distribution of radio detected cosmic ray events in the South direction, where the Earth magnetic field is oriented (see the CODALEMA contribution to this report). In the southern hemisphere, the magnetic field is directed toward North and such depletion would thus be expected in the northern part of the sky. Indeed, such an

asymmetry has clearly been observed by the RAuger system (Fig. 2), undoubtedly confirming a geomagnetic origin for the shower's electric field production process, at least at this energy level.

Unfortunately, no 3-fold antenna coincidences could have been detected for various reasons (breakdown of individual station, high dead time...), and cosmic ray direction reconstruction by triangulation of radio data is thus not possible on those events. However, numerous storm events have also been detected by the antennas, among them a large amount being "triangulable". Fig. 3 shows the map over a 6 months period of stormy episodes, whose location and path in the sky have been reconstructed by using the radio data of the 3 antennas.

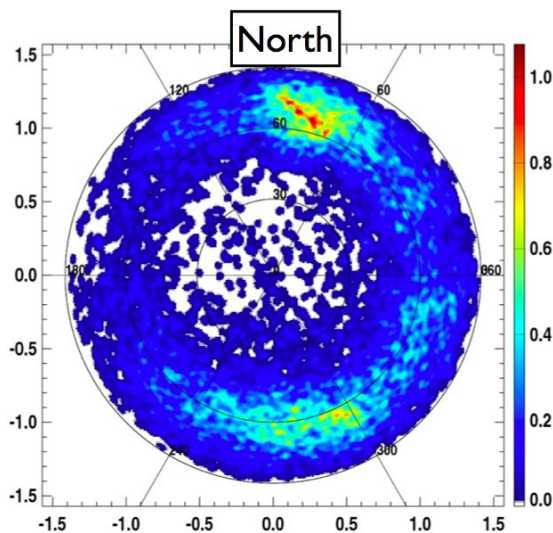


Fig. 5: Sky map of the radio 3-fold events triangulated over a 6 months period. All of them are identified as storm transient events, and two storms with an especially important accumulation of events appear on North and South. The weak occurrence probability of a storm just above the array explains the few number of events detected at low zenith angles: most of the storms develop far from the array, and appear closer to the horizon.

Such a map confirms, if needed, the ability of this method of radio detection of fast transients to give important information on the arrival direction of any transient event, and especially of cosmic ray air shower events. Moreover, the remarkable homogeneity in azimuth of this map (where two specially strong stormy episodes clearly appear on North and South) demonstrates that the system is able to detect in any sky direction: the observed depletion in the North direction for cosmic ray events has thus a physical

origin, intrinsic to the shower electric field generation processes, called "geomagnetic effect".

Though RAuger was a prototype system, it really gave some fundamental features of what could and will be an autonomous radio detection station and its use in a larger array. The results obtained are closely related to the ones of CODALEMA and are very encouraging for the subsequent activities of our group.

En un peu plus de 6 mois de fonctionnement, effectif, l'expérience prototype RAuger de radio détection autonome à l'Observatoire Pierre Auger a pu observer 25 événements radio clairement identifiés comme ayant pour origine une gerbe atmosphérique initiée par un rayon cosmique. Malgré la faible statistique, la répartition des directions d'arrivée de ces événements dans le ciel confirme l'origine géomagnétique du processus de création du champ électrique dans la gerbe de particules. Comme attendu, la densité d'événements observée autour de la direction du champ magnétique terrestre (au Nord pour l'hémisphère sud, au Sud pour l'hémisphère nord) est clairement plus faible. Ce résultat, dont la carte de détection d'événements transitoires liés à des orages vient confirmer l'origine physique et non instrumentale, vient en appui des découvertes réalisées par l'expérience CODALEMA en France. L'activité future du groupe Astroparticules de SUBATECH autour de la radiodétection s'appuiera fortement sur ces expériences pour le développement de futurs grands réseaux d'antennes de radio détection des rayons cosmiques.

[1] B. Revenu and the CODALEMA collaboration, 2007, *Proceedings of the XXXth ICRC, Merida, Mexico*

[2] S. Acounis et al., 2007: "First detection of radio signals from cosmic ray air showers with a self triggered, fully autonomous system", Auger internal note GAP-2007-130