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The RPC charge read-out in the ARGO-YBJ experiment

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The ARGO-YBJ experiment at the Yangbajing Laboratory (4300 m a.s.l.) is taking data with about 1900 m^2 of its carpet. The digital read-out of the RPCs, performed by means of pick-up electrodes 7 x 62 cm^2 ('strips'), well suited to detect small size air showers, implies a limitation to the measurable energy of a few hundreds of TeV. In order to extend the energy range up to the knee region an analog read-out of the RPCs has been implemented. Each RPC has been equipped with two large size pads of dimensions 1.40 x 1.25 m^2. The analog read-out system has been put in operation on 180 m^2 of the detector, allowing a cross-check of digital and analog information. In this paper a brief description of the analog read-out system is given, and preliminary results are discussed.

1. Introduction

The energy spectrum of cosmic rays is well described by a power law ($dN/dE=kE^{-\gamma}$) over several decades of energy, before and after the so-called "knee region", 10^{15} - 10^{16} eV, where the slope changes. The origin of this steepening, observed indirectly in the Extensive Air Shower (EAS) data, is still obscure, and it has been the subject of many speculations on the production, acceleration, propagation and composition of cosmic rays. On the experimental side, a comparison between the existing data makes evident that there is a substantial disagreement between the models for the primary cosmic ray composition provided by different experiments [1].
Simulations carried out with the CORSIKA/QGSjet code clearly show [2] that the digital response of the ARGO detector [3] cannot be used to study the primary spectrum at energies above a few hundreds of TeV. In order to reach PeV energies, particles densities up to $10^3/m^2$ have to be measured.
The strip density, $23/m^2$, limits the measurable energy of showers to about 200 TeV for cosmic ray physics (proton showers) and to a few tens of TeV for γ-ray astronomy (γ induced showers).
In terms of particle density, a good correlation between impinging particles and fired strips exists up to 10-15 $/m^2$, while for higher densities the analog signal information is needed to make a good energy estimate.
In order to extend the dynamic range, the signal read-out of the two BigPads (1.40 x 1.25 m^2) of each RPC has been implemented.

2. The Analog Read-out System

The system unit to read out the analog signals is a MINICRATE that has two sections, each one hosting 3 read-out cards (CHargeMeter) + 1 Control-Board; one MINICRATE serves 2 Clusters. The mechanical standard is 6U and the low voltages are provided by a dedicated power supply embedded into the MINICRATE. The CHargeMeter accepts the analog signals and digitizes them, while the Control-Board

manages the digitization of the analog signals and the information transfer to the LocalStation, which finally provides data to the central DAQ. The read-out of the analog information is started by a local “density trigger”, provided by the LocalStation itself, which has to be confirmed by the experiment trigger otherwise it is not performed. The CHargeMeter (CHM) board [4], designed in the laboratories of INFN in Naples, receives the signals from the BigPad; these signals are positive with rise time in the range 20-40 ns and fall time of many microseconds. Each CHM board has 8 inputs, therefore 1 Cluster is served by 3 CHM boards. The single channel is adapted to 50 Ω; a coaxial cable is used to feed the signal to the CHM input, whose length is 12.5 m with an attenuation of about 5%. Each channel measures the peak value of the input signal according to the following scheme: 1) the input signal is verified by a limiter circuit which cuts amplitudes higher than 40 V in order to avoid damages to the board. Then it enters a linear amplifier having a variable gain (VGA); the gain can be set, among eight predefined values, through a three bits register driven by the Control-Board. 2) A constant fraction amplifier is used to cut the long tail of the input signal in order to take into account contribution from further pulses and obtain the sum of the signals at the output. 3) The output from the constant fraction amplifier goes to a Peak&Hold unit which gets the peak value of the signal and keeps it, with a tilt time of 4mV/μs, for 2 μs. The trigger has to arrive in this time window otherwise the Peak&Hold resets automatically. 4) The Peak&Hold output goes to a 12 bits ADC, with input range 0-2.5 V, which converts it and provides an output word.
The words containing the analog information are read out by means of the Control-Board. The Control-Board takes care of: a) Data receiving from 24 ADCs according to a fixed protocol and their transfer to the LocalStation. b) Calibration of each electronic channel in order to keep under control linearity and stability of the system. c) Set of the amplification gain for each electronic channel.

3. Discussion of the Data

Last November two MINICRATES have been put in operation at YBJ on 4 Clusters, corresponding to an area of about 180 m^2. A first data taking has been carried out. The gain of the electronics was set in order to operate in the amplitude range 0-330 mV of the input signals. The reference amplitude of a m.i.p. signal was 2 mV. The condition to start the analog read-out was: more than 32 particles on at least one Cluster. Fig 1 shows different typologies of events that have been recorded. In the upper left corner there is an almost contained event with a maximum signal of about 50 particles/BigPad while, in the upper right corner, a saturation event is shown where almost all 4 Clusters have BigPads with a saturated signal corresponding to 166 particles. The other two events shown in Figure 1 refer to very localized releases of energy, in particular the one in the lower left corner involves about 15 BigPads (about 25 m^2) with high particle density, namely whose maximum is 100 particles. The lower right event is also intriguing, since it has only 1 BigPad with signal corresponding to 25 particles. Figure 2 shows the correlation between mean strip number and mean amplitude of a BigPad; the BigPad area corresponds to 40 strips (half RPC). The digital saturation happens above 30 fired strips, while below a strip multiplicity of 10 there is no sensitivity; a good linear correlation exists in the multiplicity range 14-26 (see Figure 2 insert) where we find a correlation coefficient of 250 ADCcounts/12 strips, or 21 ADCcounts/strip, that is consistent with 24 ADCcounts/particle once a strip multiplicity of 1.2 is taken into account. Figure 3 shows the scatter plot of the signals coming from two adjacent BigPads belonging to different RPCs. The correlation is evident and it lasts all over the amplitude range, say up to 166 particles/BigPad. No saturation effects are visible; saturation may can come from electronics and detector. We expect saturation of the detector behavior to happen at densities much higher than 10^3 particles/m^2.

3. Conclusions

We have implemented the RPC analog read-out on 180 m^2 of the ARGO detector at YBJ. The system performs correctly. This instrument opens a window of opportunity both for shower parameter reconstruction and for the study of those "spot events" whose origin has to be understood. We plan to implement the analog read-out on 30 Clusters by the end of 2005 and on 60 Clusters at the beginning of 2006.

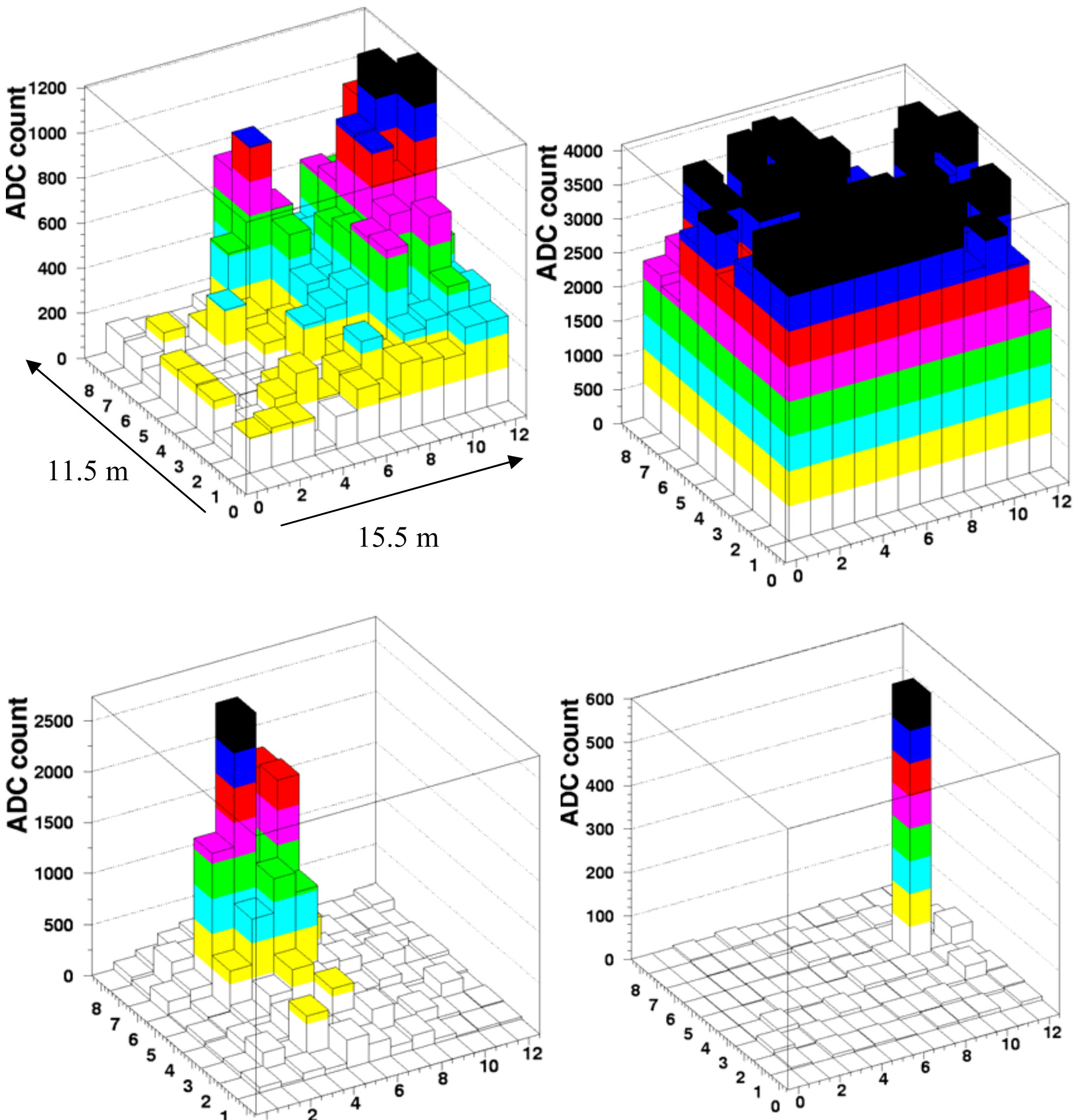

Figure 1 Events on 4 Clusters at YBJ, as seen by the analog read-out system: upper left) contained event; upper right) saturation event; lower left) "spot event"; lower right) "single pad event". (See text for details).

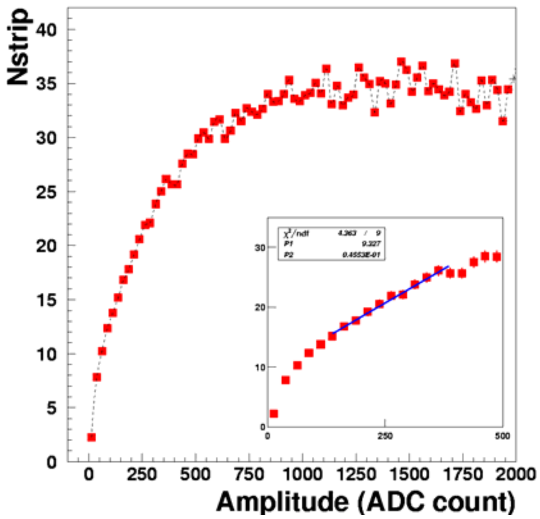

Figure. 2 Mean strip number vs. mean BigPad amplitude. (See text for details).

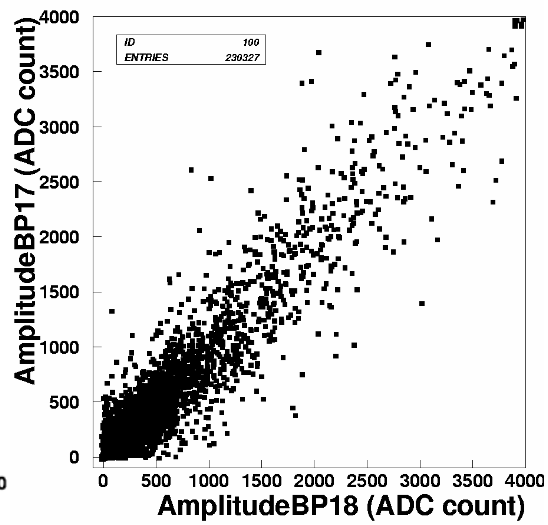

Figure. 3 Correlation between the amplitudes of two adjacent BigPads. (See text for details).

4. Acknowledgements

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