Performance of RPCs operated at the Yangbajing Laboratory

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Abstract

The ARGO-YBJ experiment will be installed at YangBaJing Cosmic Ray Laboratory (Tibet, China), 4300 m a.s.l . It consists of a full coverage of $\sim 10^4\ m^2$ realized with RPC chambers. A small carpet of $\sim 50\ m^2$ has been operated at YangBaJing in order to check the RPC performance in these high altitude conditions. Results concerning efficiency and time resolution are reported.

1 Introduction

The aim of the ARGO-YBJ experiment (Abbrescia et al. (1996)) is the study of cosmic rays, mainly γ-radiation, in an energy range down to $\sim 100\ GeV$, by detecting small size air showers with a ground detector. This very low energy threshold, which is below the upper limit of the next generation satellite experiments, is achieved in two ways:

1) By operating the experiment at very high altitude to better approach the level where low energy air showers reach their maximum development. The choice of the YangBaJing (YBJ) Cosmic Ray Laboratory (Tibet, China), 4300 m a.s.l, was found to be very appropriate.
2) By utilizing a full coverage detector to maximize the number of detected particles for a small size shower.

The ARGO-YBJ detector consists of a single RPC layer of $\sim 5000\ m^2$ and $\sim 92\%$ coverage, surrounded by a ring of sampling stations which recover edge effects and increase the sampling area for showers initiated by $> 5\ TeV$ primaries.

The trigger and the DAQ systems are built following a two level architecture. The signals of a set of 12 contiguous RPCs, referred to as a Cluster in the following, are managed by a Local Station. The information from each Local Station is collected and elaborated in the Central Station. According to this logic a Cluster represents the basic detection unit.

A Cluster prototype of 15 RPCs has been put in operation in the YBJ Laboratory in order to check both the performance of RPCs operated in a high altitude site and their capability of imaging a small portion of the shower front.

In this paper the results concerning the performance of $2\ mm$ gap, bakelite RPC detectors operated in streamer mode at an atmospheric depth of $606\ g/cm^2$ are described. Data collected by the carpet and results from their analysis are presented elsewhere (D'Ettorre Piazzoli et al. (1999)).

2 The experimental set-up

The detector, consisting of a single gap RPC layer, is installed inside a dedicated building at the YBJ Laboratory. The set-up is an array of 3x5 chambers of area $280 \times 112\ cm^2$ each, laying on the building floor and covering a total area of $8.7 \times 6.1\ m^2$. The active area of $46.2\ m^2$, accounting for a dead area due to a 7 mm frame closing the chamber edge, corresponds to a 90.6% coverage. The RPCs, with a $2\ mm$ gas gap, are built with bakelite electrode plates of volume resistivity in the range $(0.5 \div 1)\ 10^{12}\Omega \cdot cm$, according to the standard scheme reported in (ATLAS (1997)).

The RPC signals are picked up by means of aluminum strips $3.3\ cm$ wide and $56\ cm$ long which are glued on a $0.2\ mm$ thick film of Poly-Ethylen-Tereftalate (PET). The strips are embodied in a panel, consisting of a $4\ mm$ thick polystyrene foam sheet sandwiched between the PET film and an aluminum foil used as a ground reference electrode. At the edge of the detector the strips are connected to the front end electronics and terminated with 50 Ω resistors. A grounded aluminum foil is used to shield the bottom face of the RPC and an extra PET foil, on top of the aluminum, is used as a further high voltage insulator. The front end circuit contains 16 discriminators, with about $50\ mV$ voltage threshold, and provides a FAST-OR signal with the same input-to-output delay ($10\ ns$) for all the channels. This signal is used for time measurements and trigger purposes in the present test. The 16 strips connected to the same front end board are logically organized in a pad of $56 \times 56\ cm^2$ area. Each RPC is therefore subdivided in 10 pads which work like independent functional units. The pads are the basic elements which define the space-time pattern of the shower; they give indeed the position and the time of each detected hit. The FAST-OR signals of all 150 pads are sent through coaxial cables of the same length to the carpet central trigger and read out electronics. The trigger logics allows to select events with a pad multiplicity in excess of a given threshold. At any trigger occurrence the times of all the pads are read out by means of multihit TDCs of $1\ ns$ time bin, operated in common STOP mode. The set-up was completed with a small telescope consisting of 3 RPCs of $50 \times 50\ cm^2$ area with 16 pick-up strips $3\ cm$ wide connected to front end electronics board similar to the ones used in the carpet. The 3 RPCs were overlapped one on the other and the triple coincidence of their FAST-OR signals was used to define a cosmic ray crossing the telescope.

3 Experimental results

The measurements described in this paper were performed in the second half of February 1998 with an external temperature in the range $-20 \div -5\ C$ and in the first half of May when the temperature was in the range $-5 \div +15\ C$. The internal temperature was kept, by using some heaters, between $\sim +4 \div +8\ C$ in the first run and $\sim 16 \div 18\ C$ in the second. The laboratory temperature and pressure were monitored during all data taking. The RPCs of the test carpet were operated in streamer mode as foreseen for the final experiment. This mode delivers large amplitude saturated signals, and is less sensitive than the avalanche or proportional mode to electromagnetic noise, to changes in the environment conditions and to mechanical deformations of the detector. On the other hand the larger rate capability achievable in avalanche mode is not needed in a cosmic ray experiment.

Three gas mixtures were tested which used the same components, Argon, Isobutane and Tetrafluoroethane, in different proportions: TFE/Ar/i-But = 45/45/10; 60/17/13 and 75/15/10. In the three cases the ratio Ar/TFE was changed to a large extent, living the i-But concentration relatively stable. TFE is an heavy gas with good quenching properties (Cardarelli et al. (1996)). An increase of TFE concentration in place of the Ar concentration should therefore increase the primary ionization thus compensating for the 40% reduction caused by the lower gas target pressure (600 $mbar$) and reduce the afterpulse probability. For each of the three gases a voltage scan was made for RPC2 (the RPC in the central position of the telescope), leaving the other two RPCs at a fixed operating voltage, and the following measurements were made: RPC2 counting rate, current and efficiency. The detection efficiency vs the operating voltage for the three gases is shown in Fig. 1. The reduction of the Argon concentration in favor of TFE results in a clear increase of the operating voltage as expected from the large quenching action of TFE.

In spite of the different operating voltages all three gases approach the same efficiency of $\sim 90\%$ which include the inefficiency due to geometrical effects. The ratio of the operating current to the counting rate gives the charge per count delivered in the RPC gas, which is shown in Fig. 2 as a function of the operating voltage for the three gases. Here a small term corresponding to the current leaks is subtracted to the total current. The data shows that the higher the TFE fraction, the lower is the charge delivered in the gas by a single streamer. Since a lower delivered charge extends the dynamic range achievable for the analogical read-out, we decided to operate the test carpet with the gas mixture corresponding to the highest TFE fraction.

Fig. 3 shows the operating efficiency for the ORed pads 2-3-7-8 of one RPC of the carpet. The efficiency was measured using cosmic ray signals defined by the triple coincidence of the RPCs of the auxiliary telescope which was placed on top of the carpet and centered on the corner among the pads 2-3-7-8. The same curve for a 2 mm gap RPC operated at sea level is also shown for comparison. The detection efficiency vs

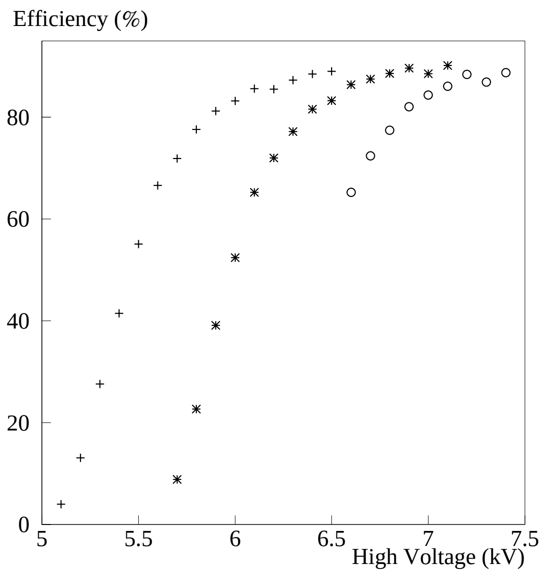


Figure 1: *Detection efficiency of one RPC of the auxiliary telescope vs operating voltage for 3 gases: TFE/Ar/i-But=45/45/10 (+); 60/17/13 (*) and 75/15/10 (○)*

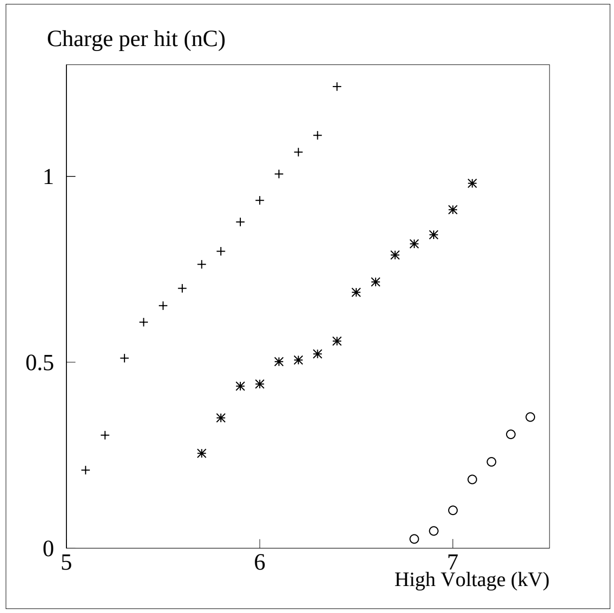


Figure 2: *Charge delivered per count for the 3 gases vs operating voltage: TFE/Ar/i-But=45/45/10 (+); 60/17/13 (*) and 75/15/10 (○)*

operating voltage, compared to the operation at $606\ mbar$ pressure in YBJ, shows an increase of $\sim 2.5\ kV$ in operating voltage. The effect of small changes in temperature T and pressure P on the operating voltage can be accounted for by rescaling the applied voltage V_a according to the relationship:

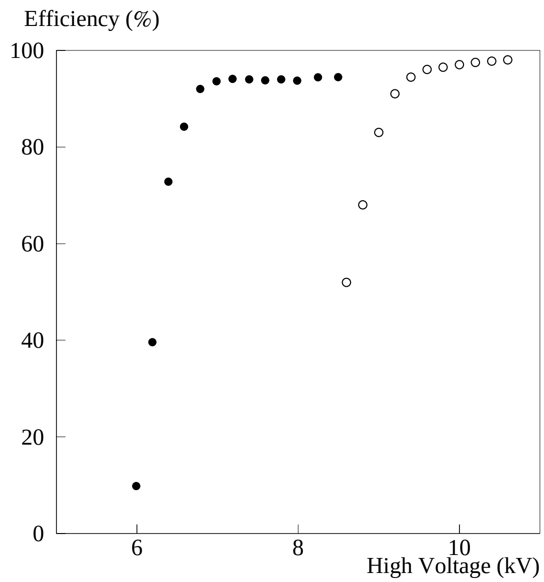
$$V = V_a \frac{P_0}{P} \cdot \frac{T}{T_0} \tag{1}$$

where P_0 and T_0 are arbitrary standard values, e.g. $1010\ mbar$ and $293\ K$ respectively for a sea level laboratory. This formula predicts, starting from the YBJ data, an operating voltage at sea level which is considerably smaller than the experimental one. However, a good consistency is recovered by assuming that, in the ideal gas approximation, the parameter which fixes the operating voltage is given by *gap* $\cdot$ *pressure / temperature*. Measurements on RPCs with different gas gap size justify this assumption (Bacci et al. (1999)).

Fig. 3 also shows that the plateau efficiency measured at YBJ is $3-4\%$ lower than at the sea level. Although a lower efficiency is expected from the smaller number of primary clusters at the YBJ pressure, we attribute most of the difference to the underestimation of the YBJ efficiency. At the YBJ level indeed the ratio of the cosmic radiation electromagnetic to muon component is ~ 4 times larger than at sea level. A spatial tracking with redefinition of the track downstream of the carpet would eliminate the contamination from soft particles, giving a more accurate and higher efficiency. On the other hand the lower efficiency could hardly be explained with the gas lower density. The number of primary clusters in the YBJ test, estimated around 9, is the same as in the case of some gas, e.g. Ar/i-But/CF3Br = 60/37/3, that was frequently used at sea level with efficiency of $\sim 97-98\%$.

A rather flat singles counting rate plateau is observed at a level of $\sim 400\ Hz$ for a single pad of area 56×56 cm^2.

The time jitter distribution of the pad signals was obtained by measuring the delay of the FAST-OR signal with respect to RPC2 in the trigger telescope by means of a TDC with $1\ ns$ clock. This distribution is shown



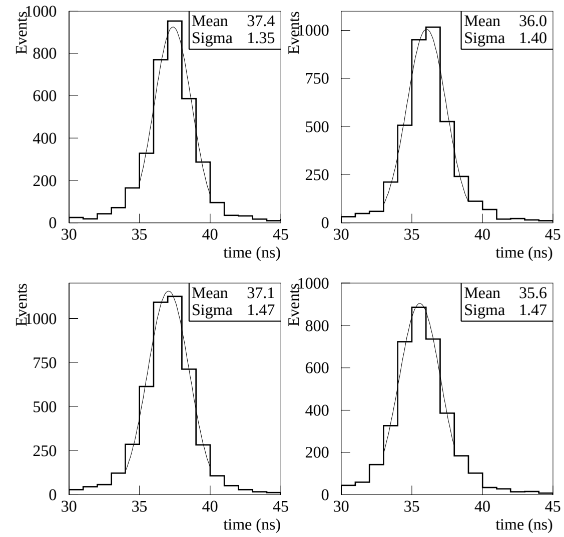


Figure 3: *Detection efficiency vs operating voltage for one of the carpet RPCs (•). The same curve for a 2 mm gap RPC operating at sea level is also reported (○) for comparison.*

Figure 4: *Time jitter distribution of 4 pads of the carpet. The telescope RPC2 signal is used as Common Stop.*

in Fig. 4 for the four pads. The average of the standard deviations is $1.42\ ns$ corresponding to a resolution of $\sim 1\ ns$ for the single RPC if we account for the fact that the distributions show the combined jitter of two detectors.

4 Summary

The use of RPCs in high altitude laboratories poses some basic questions concerning how the operating voltage, the plateau efficiency and the time resolution do scale with the pressure for the streamer mode operation.

Data collected at the Yangbajing Laboratory with a RPC carpet of $\sim 50\ m^2$ and with a small RPC telescope of area $50 \times 50\ cm^2$ confirm that this detector can be operated efficiently ($\geq\ 95\%$) at high altitude with excellent time resolution ($\sim\ 1\ ns$). The shift of the operating point is well understood. Other noticeable advantages as low cost, large active area, pixel size defined by external electrodes and the possibility of an easy integration in large systems, make this detector well suitable for using in EAS physics.

References

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