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Study on the Analog Read-Out of the YBJ-ARGO RPC *

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Abstract The YBJ-ARGO experiment is presently in the mounting and debugging phase at the Yangbajing High Altitude Cosmic Ray Laboratory, Tibet, China. The YBJ-ARGO EAS array is composed of bakelite RPCs which operate in the streamer mode. The digital read-out, performed by means of read-out strips, allows measuring the secondary particle number of small size air showers. To extend the dynamic range of the secondary particle number density up to $10^4/m^2$, thus to measure the component and spectrum of primary cosmic rays at the knee region, it is necessary to implement the analog read-out of the RPC, which is achieved by encapsulating each RPC with two Big PADs. This paper reports on the primary analysis of the analog read-out signal of the Big PAD under different gas mixtures, including the amplitude distribution and ratio of the single streamer signal.

Key words RPC, detection efficiency, analog read-out, amplitude distribution

1 Introduction

The YBJ-ARGO (Astrophysics Radiation with Ground-based Observatory at YangBaJing) experiment[1—3] is currently in the mounting and debugging phase at the YangBaJing High Altitude Cosmic Ray Laboratory (90°31′50″E, 30°06′38″N, 4300m a.s.l., $606g/cm^2$), Tibet, China. It is aimed for studying the fundamental issues in the cosmic ray physics and the particle astrophysics, including gamma ray astronomy and gamma ray bursts, at an energy threshold of 100GeV, by detecting small size air showers with a ground-based EAS (Extensive Air Shower) array. The whole array is about 100m × 100m, which consists of a full coverage carpet of $5000m^2$ realized with a single layer of Resistive Plate Chambers (RPCs)[4], and a guarding ring partially instrumented with RPCs which improves the whole apparatus performance by enlarging the fiducial area for the detection of showers with the core outside the central carpet.

Fig.1 shows the RPC cross-section. The RPC signals are read out by the digital read-out located on the upper side (strip, 6.7cm × 62cm). Each RPC is subdivided into 10 logic units (PAD, 56cm × 62cm) which consists of 8 strips. The signal receiving system provides each PAD with a FAST-OR signal of its 8 readout strips as its fired status (called hit), together with a strip pattern representing the fired strips. A trigger is generated depending on the hit multiplicity. When a trigger occurs, the hit time is recorded to reconstruct the primary direction, together with the strip pattern which can be used to estimate the injected particle number for reconstructing the shower core and the primary energy.

For cosmic rays at the knee region (10^{14}—10^6eV), the EAS reaches its maximum at Yangbajing height, and its size is less dependent on the primary component, thus the primary energy can be determined more accurately. To study cosmic ray physics at the knee region with the EAS array, it is necessary to measure the secondary particle distribution in the EAS core where the secondary particles take most of the primary energy and its density can be higher than 10^4m^{-2}. While for

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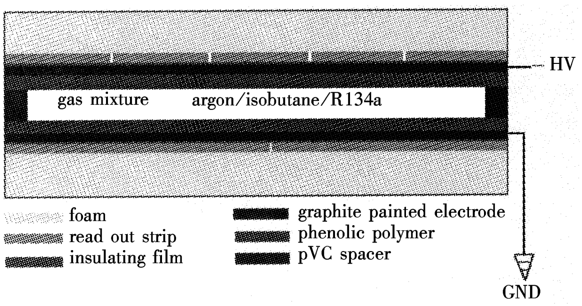

Fig.1. The schematic view of the RPC cross section.

the YBJ-ARGO experiment, using the digital readout, the secondary particle density can be measured with an upper limit of ~ $20m^{-2}$ which is much lower than that in the EAS core at the knee region. In order to extend the detectable particle density to the knee region, the analog readout is implemented by encapsulating at the bottom of each RPC with two big readout strips (Big PAD, 140cm × 125cm), i.e., the amplitude of the induced signal on the Big PAD is used to measure the injecting particle number. It is the first time to use RPC in EAS experiments in the world, and it is also the first time to use the analog readout of RPC as a particle number detector. A preliminary study on the analog read-out signal of the Big Pad at seal level is reported here.

2 Experiment set-up

The experiment was set up with 2 overlapped RPCs working as a cosmic μ selector in the coincidence mode based on the digital readout, with a test RPC sandwiched into it. All the RPCs worked under the streamer mode[5] with the same gas mixture. The vertical distance between the 2 selector RPCs is about 1m, and only one PAD in each selector RPC participates in the trigger, thus only those muons with the zenith angle < 30° were selected. The selector RPCs worked under the normal high voltage (~200V above the plateau knee), while the high voltage of the test RPC went from low to high. The gas mixture was adjusted by a gas controller which at the same time monitored the pressure of the gas mixture. During the experiment the environmental pressure and temperature were somehow stable and their influence on the performance of the RPC was negligible. A NIM scaler was used to measure the counting rates of the test RPC and the selector, and the coincidence rate of the test RPC with the selector. The efficiency of the test RPC was defined as the ratio of the above-mentioned coincidence rate to the counting rate of the selector. The current of the test RPC was monitored by the high voltage supplier. The amplitude of the analog signal of the big PAD was measured with a 50Ω load under the trigger of the selector signal.

3 Results

Three gas mixtures were tested with Argon (Ar), Tetrafluoroethane (TFE) and Isobutane (i-But) in different ratios: Ar:TFE:i-But = 60:30:10, 30:60:10 and 15:75:10 (the one being used in YBJ-ARGO experiment) respectively with the ratio of i-But unchanged. The detection efficiency, the single rate and the current of the test RPC vs. the operating voltage for the three gas mixtures are shown in Fig.2, from which one can see that the plateau knee goes higher with the reduction of Argon at a ratio of ~ 50V for every 1% of the Argon ratio, but the detection efficiency, the single rate and the current are about the same for all kinds of gas mixtures at the plateau knee. All the three gas mixtures show good performance.

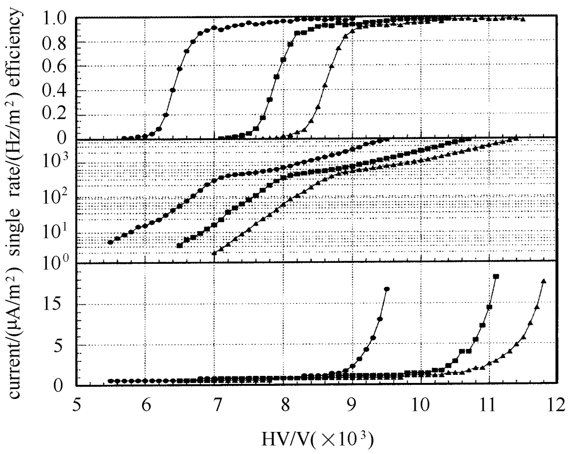

Fig.2. The detection efficiency, the single rate and the current vs. the operating voltage for the three gas mixtures: Ar:TFE:i-But = 60:30:10(●), 30:60:10(■), 15:75:10(▲).

Fig.3 shows some typical signals of the Big Pad for the gas mixture Ar:TFE:i-But = 30:60:10 seen by a digital oscilloscope. The amplitude goes from ~ 5mV to a few volts with the rise time in a range of 10—100ns. The fall time which depends on the signal amplitude varies from μs to 10μs. The analog signals of different gas mixtures show the same charac-

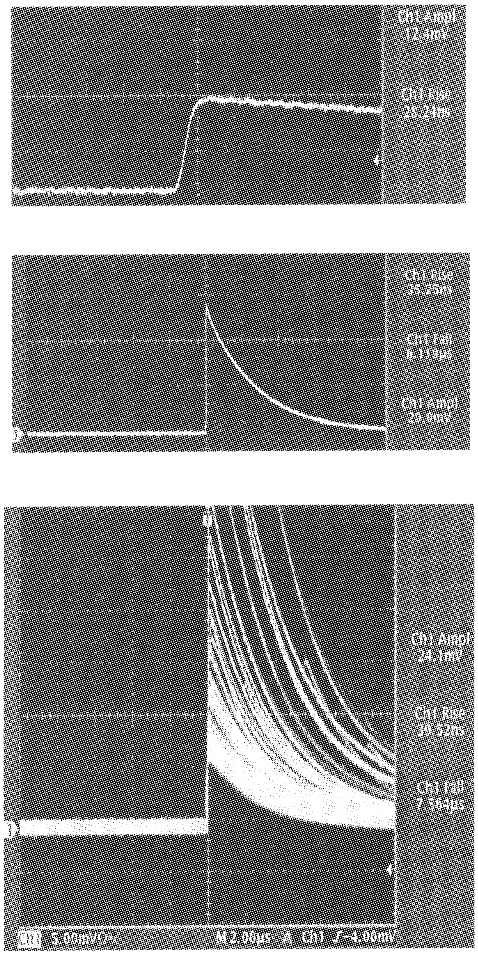

Fig.3. The analog read-out signal of the Big Pad.

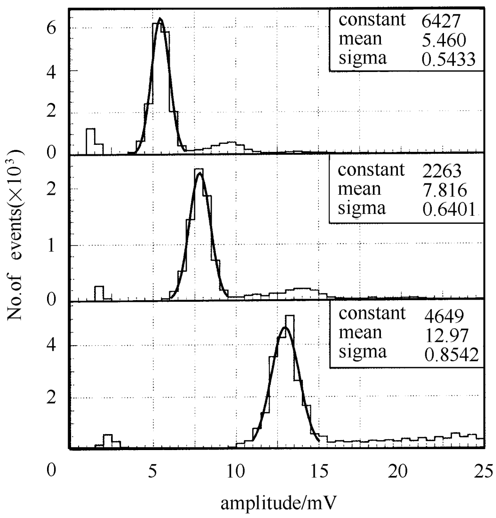

Fig.4. The amplitude distribution at the plateau knee for the three gas mixtures: Ar∶TFE∶i-But = 15∶75∶10(top), 30∶60∶10 (middle), 60∶30∶10(bottom), together with the Gaussian fitted curves.

teristics. Fig.4 shows the amplitude distribution for the three tested gas mixtures working at the plateau knee. The first peak of the distribution curve corresponds to the Big PAD inefficiency which is consistent with the efficiency measured through the digital readout, and the second peak is considered as the single streamer signal, while the rest corresponds to the signals with 2 or more streamers generated. The single streamer peak follows Gaussian distribution with the mean value 5.4mV, 7.8mV and 13.0mV respectively. The ratio of the single streamer peak decreases as the ratio of Argon increases (92%, 72%, and 64% respectively), which will lead to bad particle number resolution.

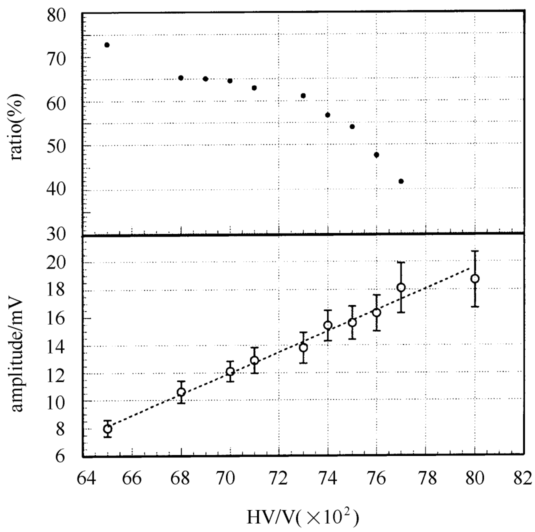

Fig.5. The ratio (top) and the amplitude (bottom) of the single streamer signal vs. the operating voltage for the gas mixture: Ar∶TFE∶i-But = 60∶30∶10, the dashed line is the linearly fitted curve.

With the operating voltage going higher, the amplitude of the single streamer signal increases slowly and approximately linearly(~ 7.6mV/kV for the gas mixture of Ar∶TFE∶i-But = 60∶30∶10, see Fig.5, here the distribution width is drawn as the error bar, so the change of the single streamer amplitude caused by a < 100V change of the working high voltage, for any reason including the high voltage un-stability, is less than 10%), while the ratio of the single streamer peak decreases resulting in worse particle number resolution. For the YBJ-ARGO experiment the time resolution of 1ns is critical which can be achieved at a high voltage of ~ 600V higher than the plateau knee with the normal gas mixture Ar∶TFE∶i-But = 15∶75∶10, while at such a working high voltage the particle number resolution of the Big PAD is worse than that working at a high voltage near the plateau knee. By adding a proper ratio of SF_6 to the normal gas mixture, the needed time resolution can be achieved right after the plateau knee[6], where the ratio of the single streamer peak could be higher that 90%, thus a good particle number resolution could also be expected.

4 Conclusions

The YBJ-ARGO RPC together with its analog readout show good performance under different gas mixtures. The amplitude of the single streamer signal follows a Gaussian distribution, whose mean value increases slowly and approximately linearly with the working voltage (about several mV/kV), while the ratio of the single streamer signal decreases when either the Argon ratio or the working voltage is increased. A good particle number resolution could be expected with the YBJ-ARGO gas mixture added with SF_6.

The YBJ-ARGO experiment is expected to start data taking in the middle of 2005, and the study on the knee physics with the analog readout is one of the main goals of its Phase Ⅱ array. Further studies on the analog readout will be continued.

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羊八井ARGO实验RPC模拟读出*

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摘要 羊八井ARGO实验正处于探测器安装及试运行阶段,整个阵列由1848个工作于流光模式的单层RPC探测器构成.依靠RPC读出条的数字读出只能测量小簇射事例的次级粒子数目,为了实现逐事例区分“膝区”原初宇宙线的成分及其能谱研究,对探测器增加了模拟读出,以实现对EAS芯区高达$10^4/m^2$的次级粒子数密度的精确测量.本文对RPC探测器性能及大动态范围模拟读出板的信号和性能做了初步的分析和研究.

关键词 RPC探测效率 模拟读出 幅度分布

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