Study on the Performance of the YBJ-ARGO RPC *

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Abstract YBJ-ARGO experiment is designed to detect small size air showers at an energy threshold of ~ 100GeV using a full coverage RPC array. High detector efficiency, good time resolution (~ 1ns) and low strip multiplicity (~ 1.2) are needed to meet the experiment requirements. Performance of RPC, including the above mentioned detector parameters together with the RPC current, is studied at high altitude (4300m a.s.l.) with a normal RPC gas mixture, under which high strip and hit multiplicity effect is observed due to the float of the CHAMBER mass reference which creates concomitant strip multiplicity when a large streamer develops in the CHAMBER. By adding SF_6 component into the gas mixture to limit the streamer development together with adjusting the pull-down threshold of the signal-receiving system, the mass-reference-float effect is effectively eliminated, thus achieving lower strip multiplicity and lower working current under the same working high voltage.

Key words RPC, efficiency, strip multiplicity, time resolution, float of the mass reference

1 Introduction

YBJ-ARGO (YangBaJing Astrophysics Research at Ground-based Observatory) experiment[1—4] (90°31′50″E, 30°6′38″N, 4300m a.s.l., 606g/cm^2) is designed mainly to study gamma ray astronomy and gamma ray burst covering an energy region of 100GeV—500TeV, by means of detecting small size EAS (Extensive Air Shower) using a full coverage RPC (Resistive Plate Chamber)[5] array (see Fig.1).

The whole array is divided into the central area and the guarding ring with the central area consisting of 10 × 13 detector CLUSTERs. The guarding ring which consists of 24 CLUSTERs is used mainly to discriminate inner against outer events. Each CLUSTER is a combination of 12 CHAMBERs (1.28m × 2.82m) which is made up of 2 × 5 detector units (called PAD, 56cm × 62.5cm). Eight unilateral read-out strips (6.7 cm × 62 cm) on one PAD provide particle number information (referred as strip multiplicity). Totally the whole array consists of 154 CLUSTERs, i.e. 18480PADs.

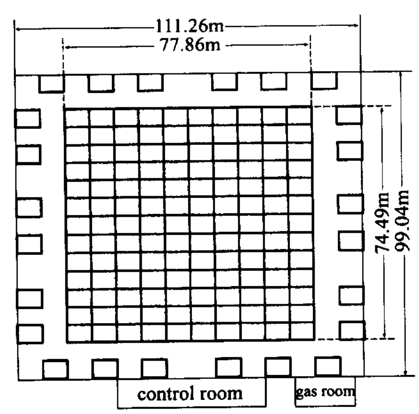

Fig.1. YBJ-ARGO carpet detector
(□ represents one CLUSTER).

The RPCs work under streamer mode[6], while each PAD provides a FAST-OR signal of its 8 strip signals

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representing whether it is fired (called one hit) or not. The trigger signal (called event) is generated according to the hit multiplicity. When an event occurs, the time-position information, which is used to reconstruct the incident direction of the primary particle, and the strip multiplicity, which represents the EAS secondary particle number at the observatory level and is used to reconstruct the primary energy and core position, of each hit are acquired.

YBJ-ARGO experiment requires RPC detector with high detecting efficiency, good time resolution (~ 1ns) and low strip multiplicity (~ 1.2). Here we report the results of a field test to the YBJ-ARGO RPC in the experiment hall in the spring of 2003.

2 Experiment Setup

The test system (Fig.2) is configured with 3 overlapped CHAMBERs working in coincidence mode as a cosmic μ selector, while 2 test CHAMBERs are sandwiched into the selector. The test CHAMBERs are staggered with the selector along the horizontal direction to eliminate the geometric inefficiency. The same gas mixture flows in all the CHAMBERs. The selector CHAMBERs work under normal high voltage (~ 200V above the knee) with the hit multiplicity > 2 as the trigger criteria, while the 2 test CHAMBERs work under the same high voltage which goes from low to high. The same elctronics, trigger and DAQ system as in YBJ-ARGO experiment are used during the test.

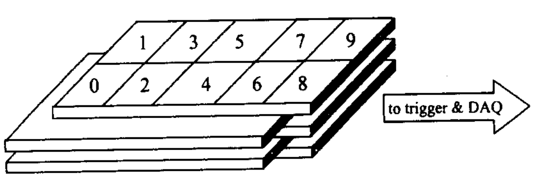

Fig.2. Experiment setup, 0—9 are PAD numbers in one CHAMBER.

3 Results

An event is considered as a cosmic μ if there exists only one hit in the region totally covered by the test CHAMBERs (i.e. PAD No.0,2,4&6) of each selector CHAMBER. The efficiency of a test CHAMBER is defined as the ratio of the events detected. Events which generate only one hit in a test CHAMBER are used to calculate the strip multiplicity. Supposing the 2 test CHAMBERs have the same time resolution, the flight time divided by $\sqrt{2}$ of events which generate only one hit in each test CHAMBER passing through the 2 test CHAMBERs can be considered as the RPC time resolution.

The YBJ-ARGO normal gas mixture of argon (15 %), isobutane (10 %) and freon (75 %) was tested first, with results shown in Fig.3 which show the efficiency can reach as high as 98 %. Under a high voltage (HV) of 7800V, the time resolution is about 1ns, while the strip multiplicity is near 1.9, much higher than the experiment requirement. At the same time the ratio of events with hit multiplicity > 1 in a test CHAMBER is much larger than random coincidence (see Fig.4(a)), even some single μ fire almost all the PADs of the test CHAMBER. Further analysis shows that is due to the fact that when a strip is fired it causes momentary float of the CHAMBER mass reference, whose discharge time is of the level of ns, comparable to the width of the strip signal (~ 5ns), thus all the strips in that CHAMBER are equivalent to be generating an induction signal. If the streamer is large enough, the amplitude of the above mentioned false signals could excess the front-end discriminator threshold, thus giving concomitant strip and hit multiplicities. When the front-end signals (ECL coupled) pass through a 12 meters long flat cable to the signal receiving system, those concomitant ones, which have more narrow

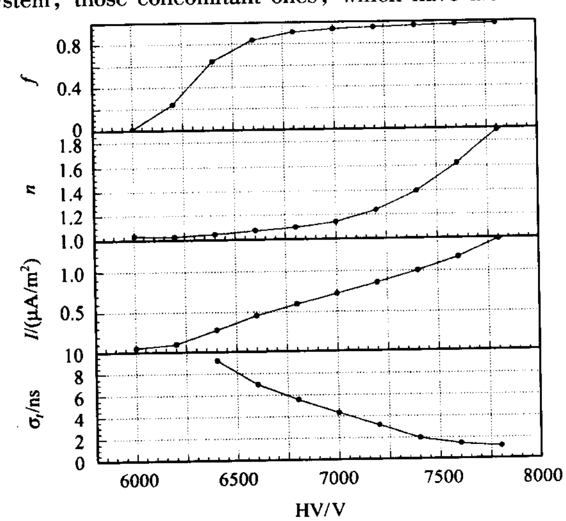

Fig.3. RPC efficiency (f), strip multiplicity (n), current (I) and time resolution (σ_t) varying with high voltage.

width than the true ones, will suffer larger attenuation resulting in lower amplitude, so they can be discriminated by adjusting the pull down threshold V_{pd} at the input side of the signal receiving system. Fig.4(b) shows the hit multiplicity distribution with $V_{pd} = -10V$. The ratio of events with hit multiplicity > 1 and the strip multiplicity varying with V_{pd} are shown in Fig.5, from which one can see adjusting V_{pd} effectively discriminates those concomitant signals caused by the mass reference float.

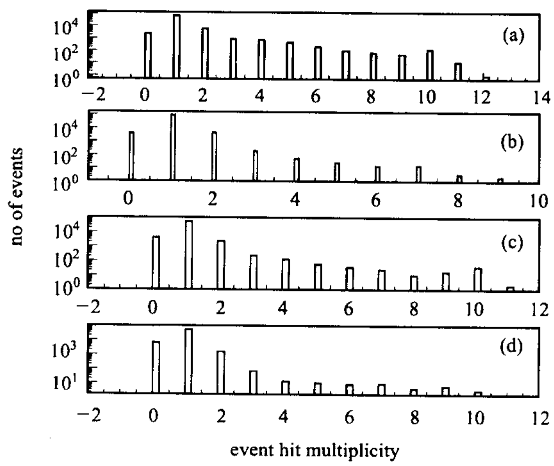

Fig.4. Distribution of event hit multiplicity. (a) without SF_6, $V_{pd} = -5V$; (b) without SF_6, $V_{pd} = -10V$; (c) with SF_6, $V_{pd} = -5V$; (d) with SF_6, $V_{pd} = -9V$.

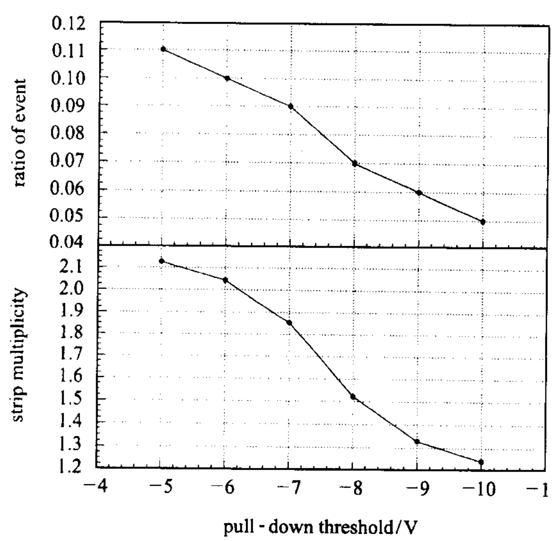

Fig.5. Ratio of events with hit multiplicity > 1 and strip multiplicity varying with V_{pd}.

Adjusting V_{pd} has its electronic limitation, and at the same time higher V_{pd} will lose detector efficiency. A more sufficient way to minimize the mass reference float is to limit the streamer development, which could be achieved by adding a proper percentage of SF_6 as a quenching component into the gas mixture to absorb UV photons induced during the streamer development[7,8]. The new gas mixture was argon (15 %), isobutene (30 %), freon (55 %), together with 0.3 % of SF_6. Figs.4(c) and (d) show the event hit multiplicity, with the strip multiplicity < 1.2 when $V_{pd} = -9V$ and HV = 7800V. The knee voltage shifts right after adding SF_6, but the RPC reaches the time resolution needed by the experiment at the same high voltage with the gas mixture without SF_6, i.e. the working high voltage does not change, and the working current can be reduced by ~ 40 % (see Fig.6).

When cosmic μ hits neighboring PADs of a CHAMBER, strips on two or more PADs could be fired, which also generates events with multiple hits. When RPC works under high voltage of 7800V with SF_6, the expected ratios of this kind of events for $V_{pd} = -5V$ and $-9V$ are 5 % and 2 % respectively, that can well explain why the ratio of events with hit multiplicity > 1 under high V_{pd} is still higher than random concidence (Fig.4(c) and (d)), which is also approved by the analysis to the position of fired strips in multiple hit events.

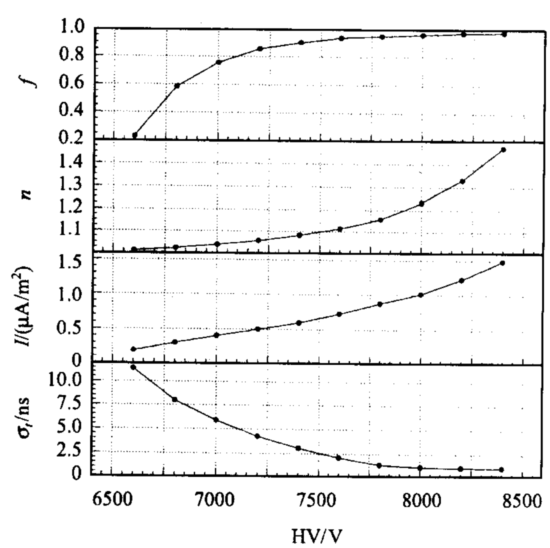

Fig.6. RPC efficiency, strip multiplicity, current and time resolution varying with high voltage after adding SF_6.

4 Conclusions

By adding SF_6 into the working gas mixture, the concomitant hit and strip multiplicities caused by the mass reference float are effectively eliminated, together with the discriminating effect of the pull down threshold of the signal receiving system. RPC as a charged particle detector at high altitude fulfills the requirements of YBJ-ARGO experiment in detector efficiency, time resolution and strip multiplicity. Further study is needed on how the multiple hits generated by a single particle which hits neighboring PADs of one CHAMBER affect the data reconstruction result.

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羊八井 ARGO 实验 RPC 性能*

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摘要　羊八井 ARGO 实验采用全覆盖式 RPC 阵列探测小型空气簇射事例,本文报告了在羊八井高海拔条件下 RPC 的工作性能,包括电流、效率、读出条重数和时间分辨随高压的变化. 通过在气体中添加 SF_6 组分和调节接收系统下拉阈值可以有效遏制由于探测器地浮动引起的伴随多重数.

关键词　RPC　效率　读出条重数　时间分辨　地浮动

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