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Study of Different Gas Mixtures for RPC Detector

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Abstract Plenty of experimental studies on the effects of performances of RPC operated with different gas mixtures have been carried out. The curves of signal amplitude, multi-counting, efficiency, single counting rate and dark current versus the high voltage were measured using cosmic rays, based on the gas mixtures of Argon, Iso-butane and F134A with different fractions. The measured results show the plateau length could be prolonged, the detection efficiency increased and the dark current decreased in the plateau region of RPC, if the Argon ratio was reduced and the ratios of Iso-butane and F134A increased correspondingly, at the cost of increasing the working high voltage.

Key words RPC, gas mixture ratio, plateau length, detection efficiency, dark current

1 Introduction

During the last few years Resistive Plate Chambers (RPC) have been widely used in high energy experiments. Several large scale detectors, such as the BELLE detector at KEK-B, the Babar at SLAC, the L3 at CERN, the CMS and ATLAS at LHC currently being built at CERN, the YBJ-ARGO at Yangbajing International Cosmic Ray Observatory in Tabit of China, have used plenty of Resistive Plate Chambers. At present most of the RPC in these systems are working in streamer mode with a gas mixture of Argon, Iso-butane and CBrF3, F134A or SF6 as a substitute of CBrF3, and with the different gas mixture ratios for different experiments. The use of Iso-butane and CBrF3 is to prevent a secondary streamer and the streamer size from spreading transversely, respectively (Iso-butane can absorb photons and CBrF3 can absorb electrons). These gas mixtures have the unpleasant features being highly flammable and containing the CBrF3, a gas forbidden to use for its ozone destroying property. Therefore careful research of different gas mixtures for RPC detector should be made to meet with the requirements of the BESⅢ μ detector, which is very important for the detector's long time reliability and stability.

2 Resistive plate chamber and test equipment

The RPC used in the experiment is composed of two parallel sheets of 2.0mm thick Bakelite[2].

When the high voltage is put on the Bakelite, there is an electric field inside the gap, and when a charged particle passes through the detector, a streamer discharge is produced, the outside readout strip picks up the signal. For the gas mixture, because the Bakelite has high resistivity and the discharge is limited at small region, a secondary streamer can be prevented.

For testing, we use the test system that we established to measure the RPCs[2].

3 Tests performed on RPCs

First, we fix the ratio of Argon at 20 %, 30 %, 40 %, then change the ratio of Iso-butane to 4 %, 8 %, 12 % and change the ratio of F134A correspondingly, therefore we get 9 different gas mixtures for test. With each gas mixture we tested the signal amplitude, the multiple counting, the single counting rate, the efficiency and the dark current curve versus the high voltage. In the testing, the threshold value of discriminator is set at 150mV.

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3.1 Signal amplitude

The signal amplitude is measured by using the CAEN C420 ADC. The signals of three scintillators are coincided and expanded as the ADC's trigger signal. The signal from strips is delayed and then sent to ADC input. The amplitude distribution chart is measured from 5.0 to 10.0kV, with a step of 100V. Fig.1 shows the averaged value of the signal amplitude versus the high voltage with different gas mixtures. From it, we can see that when the voltage is lower, the signal amplitude is a linear function to the high voltage, and it is in the streamer mode range. When the voltage goes high, the signal amplitude increases rapidly, this means the transition region from streamer mode to spark mode. When the high voltage goes much higher, the signal amplitude no longer changes, this means it is in spark mode. Furthermore, if the quenching gas's ratio goes lower, the streamer range goes shorter and the signal amplitude goes bigger, vice versa, if the quenching gas's ratio goes higher, the streamer range goes longer and the signal amplitude goes smaller.

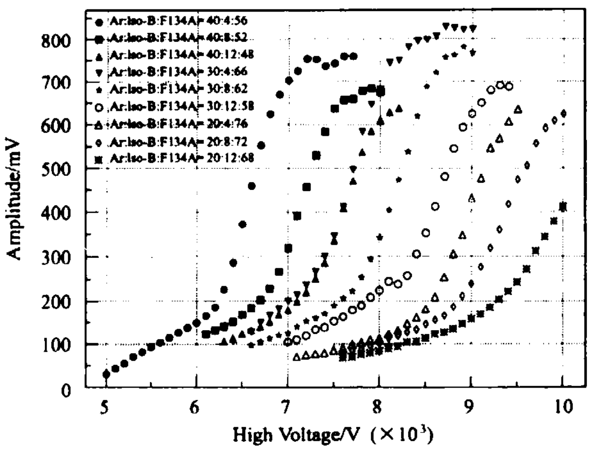

Fig.1. The signal amplitude versus high voltage.

3.2 Multiple counting

The multiple counting is defined as the ratio of the numbers of the events with simultaneous signals from two adjacent pick strips to the total event number. It depends mainly on the value of the high voltage, the front-end electronic threshold and the gas mixture ratio.

To measure the multiple counting, the signal from pick strips is discriminated through the discriminator and is AND-ed with the signal from adjacent strip. Then all the AND-ed signals are OR-ed and afterwards AND-ed with the trigger signal before sending it to the scaler to count. The multiple counting is the ratio of this counting to the trigger signal counting. Fig.2 shows the multiple counting curves versus the high voltage with different gas mixtures. From it we can see, when the Iso-butane and F134A's ratios go lower, the multiple counting rate goes higher, but the multiple counting rate with different gas mixtures does not change very much in streamer mode.

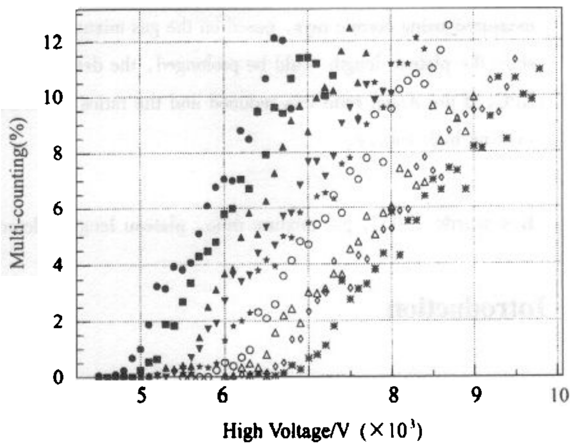

Fig.2. The multiple count versus high voltage. The illustration is the same as Fig.1.

3.3 Detection efficiency and single counting rate

Fig.3 is the detection efficiency curves versus high voltage with different gas mixtures. The efficiency does not include the dead band on the edge of the detector, but includes the loss of the efficiency due to dead band of the insulating spacers, which takes about 1.25 %. The detecting time interval is set to 1500s to reduce the statistics error. From it we can find that, when Iso-butane and F134A's ratios go lower, the efficiency plateau is shorter, the detection efficiency is a little lower. This is because the signal is big, and it takes long time for the electric field to recover. Compared with the amplitude curves before, we can see the efficiency plateau is fallen into the detection's streamer mode range. When the voltage goes higher, the detection efficiency fall down rapidly, it is because the noise caused by the non-signal discharge goes higher, the detection goes into the spark range.

Fig.4 shows the single counting rate versus high voltage with different gas mixtures . The counting is the

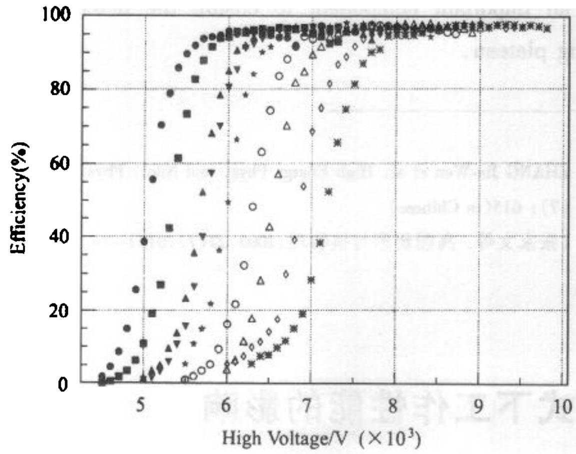

Fig.3. The efficiency curve versus high voltage. The illustration is the same as Fig.1.

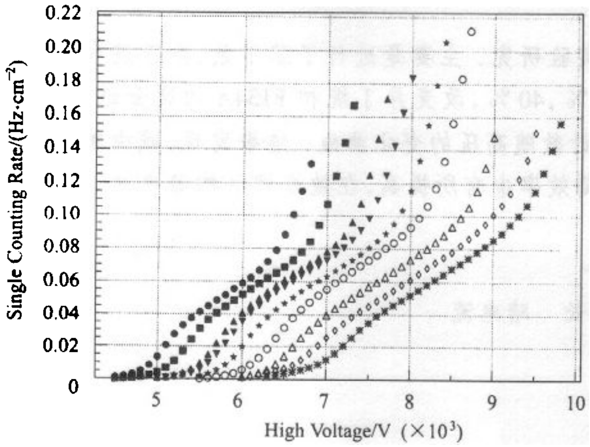

Fig.4. The single counting rate versus high voltage. The illustration is the same as Fig.1.

sum of the 4 read out strips. In one RPC, the counting rate of different strips differs from each other, and the difference can come to 15 %, here we just give the average of the 4 strips. Compared with all the 4 figures, we find that the plateau of the single counting rate, the plateau of the detection efficiency and the range of streamer mode are all the same. For all the gas mixtures we tested, the single counting rate is below 0.1Hz/cm^2 in efficiency plateau.

3.4 Dark current

Fig.5 shows the dark current versus high voltage with different gas mixtures. Compared with the figures before, we find that when the signals go bigger, the single counting rate goes higher, the dark current goes higher. From it we can come to the conclusion that the dark current is caused mainly by the discharge of the signals. So the size of the dark current is determined by the size of the signal and the counting rate.

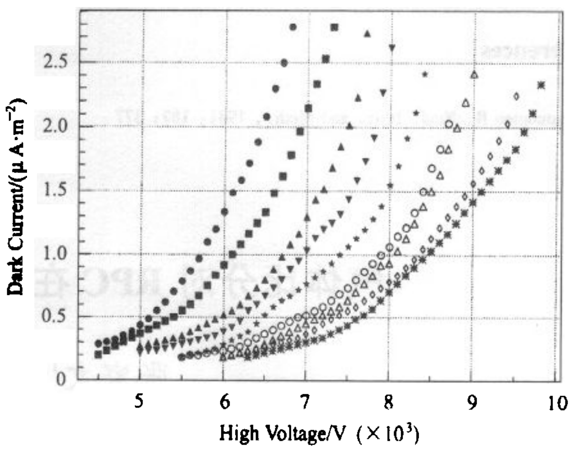

Fig.5. The dark current versus high voltage. The illustration is the same as Fig.1.

4 Conclusion

The plateau of the detection efficiency is the range that RPC works. To ensure RPC's stable operation, the working voltage should be set in the middle of the plateau. If the voltage is lower, the efficiency is also lower. If the voltage is too high, the detector goes into the spark mode, and the electric field recovers slowly for the big signals, which caused the detection efficiency goes down.

For all the gas mixtures we tested, the single counting rate is below 0.1Hz/cm^2, and the dark current is about 1—2μA/m^2.

For different gas mixtures the high voltage at which the plateau starts is different. When Argon's ratio goes higher, and the ratios of the Iso-butane and F134A go lower correspondingly, the signal amplitude goes higher, and it comes to plateau earlier, but the plateau becomes shorter, the detection efficiency in the plateau goes a little lower, the multiple counting goes higher, the dark current goes up more quick. When the ratios of Iso-butane and F134A go higher, the signal amplitude goes lower, and it comes to plateau later, but the plateau goes longer, the detection efficiency in the plateau goes higher, the multiple counting goes lower, the dark current goes up slowly when it is in the plateau region. From the test, the detection is more sensitive to Iso-butane than to F134A. But since Iso-butane is flammable, and the price is higher, so its ratio should be as low as possible. Therefore, F134A is an important component to ensure the detector have long plateau.

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气体比分对RPC在流光模式下工作性能的影响

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摘要 对不同比分气体对RPC性能的影响进行了大量的实验研究. 主要是进行了基于氩、异丁烷和绿色氟利昂F134A($C_2H_2F_4$)的实验. 保持氩气的比分为20%,30%,40%,改变异丁烷和F134A的比分进行实验,分别测量了探测效率、单计数率、暗电流、信号幅度和多重计数随高压的变化曲线. 结果发现,减少氩气的比分,增加异丁烷和F134A的比分可以增加RPC的坪长,探测效率也有所提高,在效率坪区的暗电流也有所减小,但工作高压也需要相应地增加.

关键词 阻性板探测器(RPC) 气体比分 探测效率 坪长 暗电流

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