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Research and Development of Large Area Resistive Plate Chamber

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Abstract We developed a new kind of material, which is used to construct the prototype of a large area resistive plate chamber (RPC). In this paper, the structure of RPC, the curves of efficiency, counting rate, dark current, multiple hit and signal amplitude versus high voltage measured using cosmic ray are presented. It shows that the RPC efficiency is close to 98 %, counting rate and dark current are superior to currently operating detectors worldwide. Its performances well satisfy the requirements of high energy physics experiments.

Key words resistive plate chamber (RPC), efficiency, counting rate, dark current

1 Introduction

Resistive Plate Chamber (RPC) is a type of parallel plate gas detector. RPC has superior time and spatial properties, which are excellent to measure the track and time of charged particles, and it can be built easily to large area with low cost. The resistive plate chamber is a new type of detector first developed by R. Santonico (Roma) in the early 80's[1]. It has been used in 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 and the YBJ-ARGO at Yangbajing International Cosmic Ray Observatory in Tibet of China, etc. And so a lot of experiences have been accumulated. BESⅢ detector is a large detector to be operated at the upgraded Beijing Electron Positron Collider (BEPCⅡ). We plan to adopt RPC as BESⅢ μ detector. Before mass production is started, we developed a new resistive plate material, and used it to construct a large area RPC prototype. The measured results show that its performances well satisfy the requirements of the experiments.

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2 General picture of RPC

RPC is composed of two parallel high resistive plate electrodes with a gap in between for the working gas to pass through. When a particle passes through this gas room, an avalanche or a streamer signal is produced. The strips are placed outside the gas volume surface, and induced signals on the strips are read out. The multi-layer RPCs allow simultaneous readout. The structure of RPC is shown in Fig. 1.

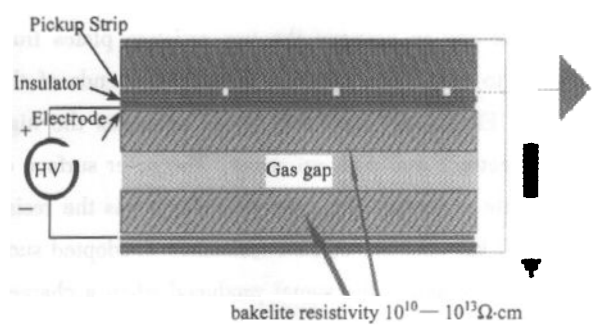

Fig. 1. The sketch map of RPC structure.

Since the material has very high resistance rate ($10^{10}-10^{13}\ \Omega\cdot$cm) and the RPCs are independent from each other, the signals from multi-layer hits increase the track detection efficiency. In case the counting rate is high, only the avalanche mode is used because the streamer signal is larger than the avalanche signal, and so the voltage drop is not recovered on time, leading to a lower efficiency. The advantage of the streamer mode just lies in its large signal, which does not need to be amplified, so it can much reduce the cost of the electronics.

3 Construction of large area RPC

The crucial part of RPC is its gas room, which requires high level of technological process. It demands high degree of uniformities on the resistive plate, including the resistance, thickness, gap and graphite layer sprayed, especially it demands very high degree of smoothness of the surface on resistive plate. Our technical process has been tested repeatedly before suitable resistive plate material is made. The resistive plate with thickness of 2mm is pressed with dense amine film on the surface to guarantee its smoothness. Measured by the instrument of smoothness, its surface well matches the level of smoothness of glass. The bulk resistivity of the Bakelite is $4\times 10^{12}\Omega\cdot cm$ at room temperature. The plates are separated by the circular insulation spacers with thickness 2.0mm, 10mm in diameter and spanning 100mm from each other, and sealed at their surroundings by the strip insulation spacers with thickness 2mm. The mixed working gas, at a certain ratio Ar : F134A : Iso-butane = 30 : 62 : 8, passes through the gap in between the two resistive plates from gas input to output installed on the opposite ends of the chamber. Electrically insulated Mylar separates the high voltage electrode and pick up strips. The outer surface of the Bakelite is coated with graphite, which has the resistivity of 50 kΩ/□. The surface resistance is adopted such that it will not shield the signal produced when a charged particle crosses the RPC, and at the same time the resistance is smaller compared to the resistive plate, which enables the high voltage distributed on the entire resistive plate surface.

4 Test system

For testing, we use 3 scintillator detectors as RPC trigger signal. The area of all the 3 scintillator detectors are 150 mm × 900mm. The two scintillator detectors below the RPC are separated by lead brick, which removes the soft cosmic ray. The cosmic ray that crosses the 3 scintillator detectors at the same time must also crosses the RPC. The area of PRC is 600mm × 1000mm. The gas mixing is completed by MKS mass flow control system, with the three gases flowing into MKS 1259B mass flow controllers by the appropriate ratios. The RPC works in streamer mode. The high voltage is provided by the CAEN SY127 high voltage systems. The positive voltage is applied on the anodes and the negative voltage on the cathodes. This approach minimizes the potential to the ground on connecters, cables, and surfaces and it serves as a precaution against external discharges through and around insulators. A computer controls the system, therefore the tests are completely automatic. Electronic system is partially NIM plug-in unit, while CAMAC and personal computer control system are used for the data collection and the high voltage control. The personal computer operates on Linux operating system and the control interface and graphic display are based on Root software development platform and C + + language environment. The system set-up is shown in Fig.2.

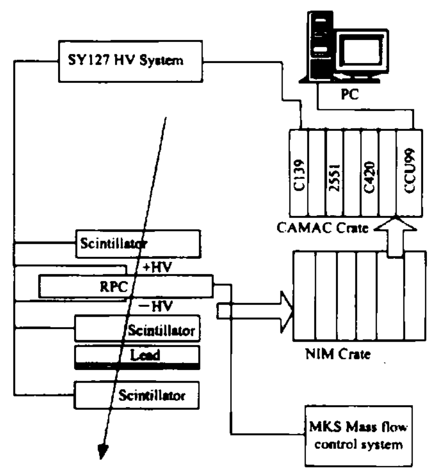

Fig.2. RPC test system.

5 Test result

5.1 Detection efficiency

In the testing, the threshold value of discriminator is set at 50, 100, 150, 200, 250mV. Fig.3 shows the efficiency plateau curve versus the high voltage with different threshold values. This efficiency does not include the dead band of detector edge, but includes the loss of efficiency due to dead band of spacers, which takes 1.25 % . From Fig.3, we find that the RPC reaches the efficiency plateau as the high voltage reaches 6.8kV, and the efficiency is close to 98 % for the high voltage at 7.2kV. The length of the efficiency plateau comes up to 1.0 kV. If two gaps of RPCs are used, the efficiency is virtually 100 % , which completely satisfies the requirement of BES Ⅲ. Threshold values below 200mV do not make visible differences at efficiency plateau. As threshold value goes above 250mV, the efficiency plateau obviously moves backward.

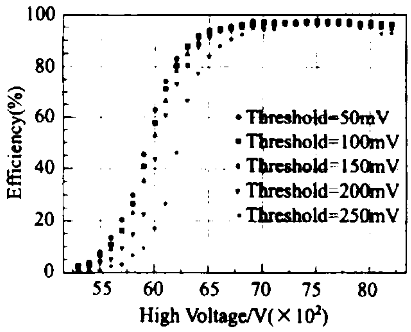

Fig.3. The efficiency curve versus high voltage.

5.2 Counting rate and dark current

Fig.4 is the counting rate curve versus the high voltage under different threshold values. Fig.5 is the dark current curve versus the high voltage. The counting rate is the sum of read out from 4 pick strips of 50mm widths. On a RPC, the counting rate on efficiency plateau between individual strips deviates up to 15 % . Here only the average results of 4 strips are given.

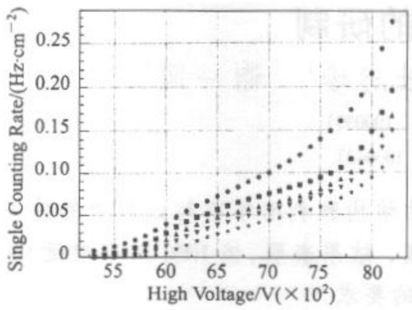

Fig.4. The single counting rate versus high voltage. The illustration is the same as Fig.3.

From the figures, we find that the curve of counting

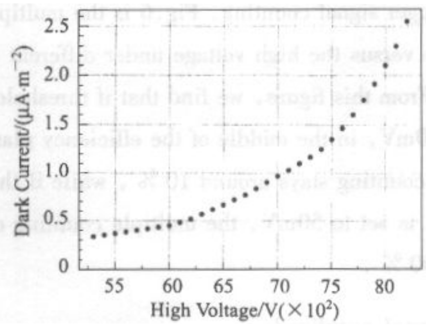

Fig.5. The dark current versus high voltage.

rate apparently has a plateau. For the threshold value of 150mV, the counting rate stays around 0.08Hz/cm^2 on the efficiency plateau. As the high voltage goes up to 8kV, the dark current and the single rate increase rapidly. Compared with the experimental results worldwide, we find this result has come up to the level of glass RPC and the RPC with the resistive plate surface covered by linseed oil. From this we can see the smoothness of the resistive plate surface developed by us. The technological process is simple to master, which makes it easy to guarantee the smoothness of the resistive plate surface.

5.3 Multiple counting

The multiple counting is defined as the ratio 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

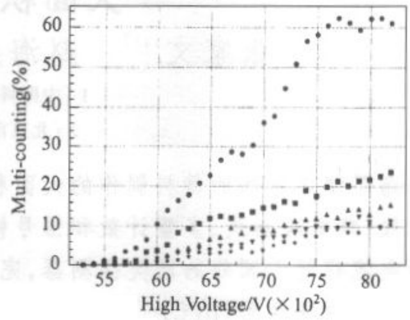

Fig.6. The multiple count versus high voltage. The illustration is the same as Fig.3.

to the trigger signal counting. Fig.6 is the multiple counting curve versus the high voltage under different threshold values. From this figure, we find that if threshold value is set to 150mV, in the middle of the efficiency plateau, the multiple counting stays around 10 %, while if the threshold value is set to 50mV, the multiple counting can be as high as 60 %.

5.4 Signal amplitude

The signal amplitude is measured using the CAEN C420 ADC. The signals of three scintillators are coincided and expanded as the ADCs trigger signal. The signal from strips is delayed by 50ns and then sent into ADC input. The amplitude distribution chart is measured from 6.6 to 9.0kV, with a step of 100V. Fig.7 shows the averaged value of the signal amplitude versus the high voltage. From it, we find that for the high voltage lower than 8kV, the signal amplitude is a linear function of the high voltage. This is the streamer mode range, and the signal amplitude is approximately 150—300mV. At 8—8.6kV, the signal amplitude increases rapidly. This is the transition point from streamer mode to spark mode. As the high voltage goes above 8.6kV, the signal amplitude no longer changes. In this range, it is seen from the efficiency plateau that the detection efficiency drops substantially.

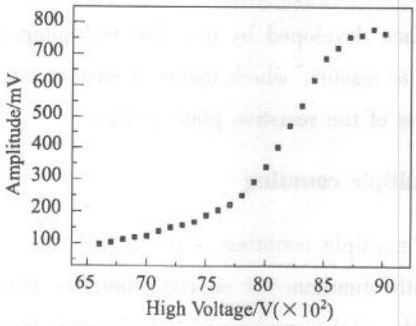

Fig.7. The signal amplitude versus high voltage.

6 Conclusion

We have successfully constructed a large area RPC using the material developed by ourselves. The length of the efficiency plateau exceeds 1.0kV and the efficiency is close to 98 %. So if the high voltage is fixed in the central efficiency plateau, the efficiency of the detector is at ideal status.

With the new technology developed by us to make the material, its surface smoothness is comparable to the glass. This reduces the noise signal. The RPC produced with this technology has the good property of glass RPC, without the shortcomings such as the heavy weight of the glass, fragility and erosion. It is also without the shortcomings of linseed oil RPC that is unstable. At the same time, this technology makes it easy to guarantee the quality and speed in mass production.

Reference

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大面积阻性板探测器的研制

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摘要 介绍了使用自制的材料制作的大面积阻性板探测器模型的结构和利用宇宙射线测量的效率曲线、单计数率曲线、暗电流曲线、多重计数和信号幅度随高压的变化曲线.结果表明,该RPC效率接近98%,单计数率和暗电流都好于国外的同类探测器,完全可以满足通常实验的要求.

关键词 阻性板探测器(RPC) 效率 计数率 暗电流

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