# Aging Test of Multi-gap Resistive Plate Chambers*

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**Abstract** We present the results of an aging test on two six-gap multi-gap resistive plate chambers (MRPC) designed for the RHIC-STAR TOF system. The test was carried out with a 100mCi $^{60}$Co $\gamma$ ray source. MRPCs were irradiated by different dose rates of the source. One module has been irradiated by high dose rate ($2.87\times10^{-2}$Gy/h) for 24h. Great degradation of noise rate, dark current and other main specifications can be seen. Another module has been irradiated for 530h by relative lower dose rate of $5.31\times10^{-4}$Gy/h and no any significant performance degradation is observed. The goal of the test is to study the performance varaition of the detector by the large irradiation dose expected in the experiment in several years of operation.

**Key words** MRPC, aging effect, current, count rate

## 1 Introduction

In this paper we report the result of an aging test of multi-gap resistive plate chamber (MRPC), designed for the RHIC-STAR TOF system and built in Tsinghua University[1, 2]. The goal of the test is to know if the performance of the detector is deteriorated by the large irradiation dose expected in the experiment in several years of operation. The luminosity of Au-Au collision and proton-proton collision of RHIC are $10^{27}$cm$^{-2}\cdot$s$^{-1}$[3] and $10^{31}$cm$^{-2}\cdot$s$^{-1}$, respectively. When STAR is upgraded, their luminosity will achieve $8.3\times10^{27}$cm$^{-2}\cdot$s$^{-1}$ and $4\times10^{32}$cm$^{-2}\cdot$s$^{-1}$, respectively. The corresponding count rate of MRPC is about 100Hz/pad. The irradiation at the STAR-TOF is harmful for MRPC modules. In order to accelerate aging test, relatively higher dose rate irradiation flux is used.

The test was carried out with $^{60}$Co $\gamma$ ray source. The structure of the MRPC module was described in detail in Ref. [1]. We designed a system to monitor the current and signal count rate of the tested module. In order to understand the withstander to irradiation, two MRPC modules were tested with different $\gamma$ ray dose rates.

## 2 Description of $\gamma$ ray source

$3.7\times10^{9}$Bq (100mCi) $^{60}$Co $\gamma$ ray source was used to do the irradiation experiment[4]. A specific lead collimator was designed to get different dose rates at test position. Fig.1 shows the structure of the $\gamma$ ray source. The lead collimator is designed to assure that the leakage rate is less than 1μGy/h at 1m distance. The $^{60}$Co source is attached on a pole. When the pole is drawn out, the source is closed. MRPC modules are irradiated at two position sites ($A$ and $B$). The output of the collimator is designed as in Fig. 1 so irradiation area at site $A$ is about 200mm×70mm. When the $^{60}$Co source locates at point $C$ ($\gamma$ ray is on), the dosage rate at point $A$ and $B$ are about $2.7\times10^{-2}$Gy/h and $5\times10^{-4}$Gy/h respectively. We

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can get the irradiation performance of MRPC in different $\gamma$ ray flux.

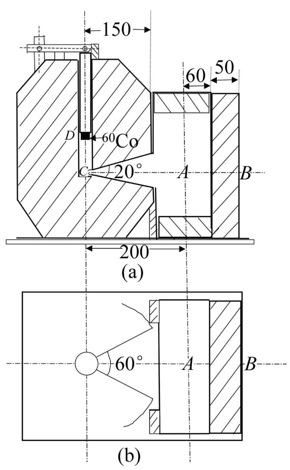


Fig. 1. The structure of the $\gamma$ ray source. (a) side view; (b) top view.

## 3 Setup for the aging test

In order to get the irradiation performance of MRPC in real time, an automatic monitoring system is designed. Current and count rate of the module can be monitored in the interval of 1 minute. Fig. 2 shows the block diagram of the irradiation test experiment.

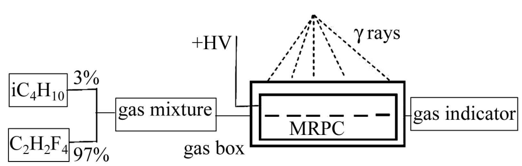


Fig. 2. The block diagram of the radiation test experiment.

The working gas consists of 97% of $C_2H_2F_4$ and 3% of $iC_4H_{10}$. The flux is 19.4cm$^3$/min. MRPC works at high voltage of 14kV. When the MRPC module is irradiated, its current and signal count rate are all recorded simultaneously. The circuit shown in Fig. 3 is designed to monitor current and count rate of MRPC. N471A high voltage source provides ±7kV voltage for MRPC, the current of MRPC Imon can be obtained from N471A. The time signal from FEE is NIM electric and needs to be transformed to TTL electric. Imon and time signals are recorded by PCI-1712 data card.

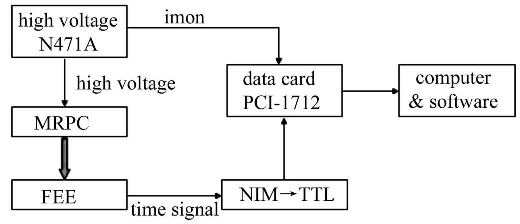


Fig. 3. Diagram of count rate and current monitoring system.

## 4 Test result and discussion

### 4.1 Module in site *A*

The module (numbered 2004-31) in position *A* was exposed at a high dose rate $2.7\times10^{-2}$Gy/h. During the experiment, the module worked at voltage 14kV. Its current and signal count rate were monitored in the interval of 1 minute. Fig. 4 shows the current changes with irradiation time. Before irradiation, its performance such as dark current, noise rate, efficiency and time resolution were tested extensively.

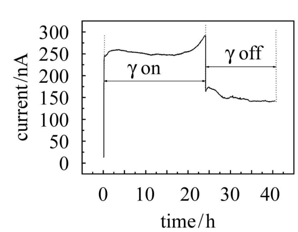


Fig. 4. Current changes with irradiation time.

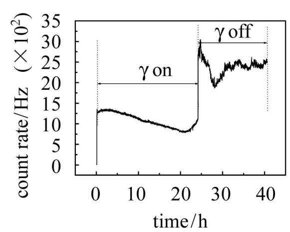


Fig. 5. Count rate changes with irradiation time.

It can be seen the current was about 1nA before irradiation, when the irradiation started in zero time, the current increased to about 250nA. $\gamma$ rays generated electrons in the glass, only the electrons near the surface of the glass could form signals in the gas gaps. 2004-31 module has been irradiated for 24h, the integrated charge is about 22mC. It can be seen the current increases slightly with irradiation time. When the $\gamma$ rays source was closed 24h later, it could be seen that the current decreased sharply, but it was still too large for a good module. This shows that the performances of the module degrade. Fig. 5 shows count rate per pad changes with irradiation time. It could be seen signal count rate decreased slightly with irradiation time. But when $\gamma$ rays source was closed, the count rate increased sharply. This is because during the irradiation time the dose rate is very high, the $\gamma$ ray flux at the module is about $7\times10^5 cm^{-2}\cdot s^{-1}$. The FEE can't respond to each single signal, this causes the count rate recorded during the irradiation is much lower than its actual value.

Table 1 shows the performance of the module before irradiation and after 24 hours' irradiation. Signal amplitude increases sharply (from 364.6 to 893 ADC channels), and accordingly the percentage of avalanche signals decreases (from 98.7% to 35.7%). Noise rate and dark current are also increase sharply. All of these specifications show the deterioration of the performance of the MRPC module. Most likely this effect in glass MRPCs is due to a material deposit on the electrodes glass, precipitated from the chemical action of the avalanche on the gas[5]. There is a significant enrichment in fluorine content on the glass surface after irradiation. The material deposit on the glass surface causes the deterioration of the performance of the MRPC module.

Table 1. Performance of 2004-31 chamber (HV=14kV).

| | efficiency (%) | average amplitude | percentage of avalanche signals (%) | noise rate/Hz | time resolution /ps | dark current/nA |
|---|---|---|---|---|---|---|
| before irradiation | 85 | 364.6 | 98.7 | 8 | 112 | 0 |
| irradiated 24h | 85 | 893 | 35.7 | 2450 | 144 | 140 |

### 4.2 Module in site *B*

The module (numbered YJ02) in position *B* was exposed at a relative lower dose rate $5.31\times10^{-4}$Gy/h. The current and signal count rates are shown in Figs. 6 and 7. In order to monitor its performance, we closed the $\gamma$ ray source at time *A*, *B* and *C* for about 30 minutes. It could be seen that the current and count rates resumed rapidly. This shows that the module is in good performance. In the meantime, it could be seen the current and count rates were relatively larger when the irradiation began. The current and count rates decreased sharply to stable state in a very short time (less than one hour). The module has been irradiated continuously about 530h. Figs. 6 and 7 show that there are undulations in current and signal count, this is because of temperature effect. In our experiment, the gas mixture is located on the second floor of our laboratory, and the $^{60}$Co $\gamma$ ray source is located in the first floor. The working gas goes through a 30m long nylon tube to the gas box. An about 25m long tube is outside the room. So the fluctuation of outside temperature directly influences the temperature of working gas. As we know, the performance of MRPC is related with temperature. We measured the temperature in the course of irradiation. Figs. 8 and 9 show the current and count rates of the module in different temperature. In the meantime, we can see an overall decreasing trend from Figs. 5 and 7. There may be two reasons. First, with the increase of radiation dose, the charge collected by the electrodes increases, and the number of ions integrated on the electrodes also increases. So the amplitude and width of signals (streamers) increase, this cause the FEE can't discriminate each single streamer signal, so the count rates decrease. Second, the space charge in the module may cause the reduction of electric field and signal count rate reduced.

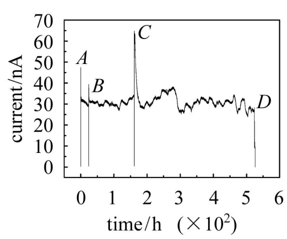

Fig. 6. Current in YJ02 module.

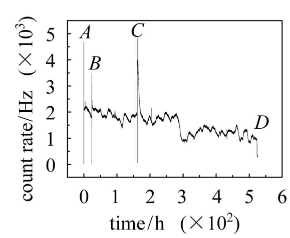

Fig. 7. Signal count rate in YJ02.

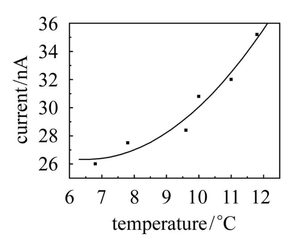

Fig. 8. Current in different temperature.

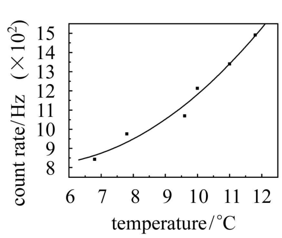

Fig. 9. Count rate in different temperature.

In order to know how its performance changes as a function of irradiation dosage, the performance is measured using our cosmic ray test system after the module has been irradiated for a definite dose. The results are shown in Table 2.

It can be seen that with the increase of irradiation dose, only the noise rate increases slightly, other specifications such as efficiency, time resolution, dark current and signal amplitude have no significant deterioration after long time irradiation. Fig. 10 shows that the efficiency changes with high voltage. The module has been irradiated for 530h, and the corresponding dose is 0.28Gy. The integrated charge is about 57mC. It can be seen that the efficiency has not any deterioration after 530h irradiation.

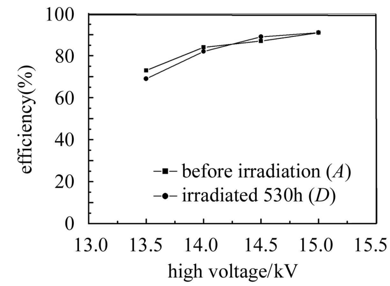

Fig. 10. Efficiency of YJ02 module.

Table 2. Performance of YJ02 chamber.

| | efficiency (%) | average amplitude | percentage of avalanche signals (%) | noise rate/Hz | time resolution/ps | dark current/nA |
|---|---|---|---|---|---|---|
| before irradiation($A$) | 84 | 368.3 | 98.7 | 12.8 | 110 | 0 |
| irradiated 24h($B$) | 84 | 370.8 | 97.6 | 14 | 112 | 0 |
| irradiated 230h($C$) | 82 | 377 | 91.8 | 23 | 120 | 0 |
| irradiated 530h($D$) | 82 | 379.5 | 96.8 | 33 | 114 | 0 |

## 5 Conclusions

In this paper, we study the aging effect of the MRPC irradiated by different dosage of $^{60}$Co $\gamma$ ray source. 2004-31 module has been irradiated by high dosage ($2.87\times10^{-2}$Gy/h) for 24h. Great degradation of noise rate, dark current and other main specifications can be seen. YJ02 module has been irradiated for 530h by relative lower dosage of $5.31\times10^{-4}$Gy/h. Its performance is carefully measured before and after irradiation. We do not observe any significant performance degradation.


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# 多气隙电阻板室抗辐照性能研究*

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**摘要**　给出了为RHIC-STAR飞行时间探测器设计的多气隙电阻板室(MRPC)的辐照实验结果. 实验采用100mCi $^{60}$Co $\gamma$源, 采用不同的剂量率对MRPC进行辐照. 一个室在大剂量率$2.87\times10^{-2}$Gy/h下辐照了24h后, 其性能如噪声计数率, 暗电流等均大大退化. 另一个室在相对低剂量率$5.31\times10^{-4}$Gy/h下辐照了530h, 其性能没有见到任何变坏. 实验的目的是为了了解这种探测器在几年的运行中经过大剂量的辐照后的性能变化情况.

**关键词**　多气隙电阻板室　辐照效应　电流　计数率

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