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Aging study for the BESIII-type RPC

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ABSTRACT

Preliminary test results on microscope investigation and BESIII-type RPC aging performance have revealed interesting aging phenomena that had not been seen before in Linseed oil coated Italian-type RPC. We report here on the aging performance of BESIII-type RPC, and on microscopic surface characterization of BESIII-type Bakelite electrodes.

1. Introduction

RPCs built from the new type of Bakelite developed by the BESIII Muon group of IHEP (Beijing) and Gaonengkedi, Inc. (Beijing) for use in the BESIII and Daya Bay Muon Systems [1] have achieved acceptable dark noise rates without Linseed oil coating, but aging effects have not been thoroughly studied—there is no published report available on this topic. A preliminary study of the Daya Bay Muon System RPCs has indicated vulnerability of the BESIII-type Bakelite to HF vapor [2] and its significant aging effect; it might be adequate for underground neutrino experiments, but must be understood and mitigated prior to use of this technology for SiD at ILC and other future accelerator experiments.

2. Aging test of BESIII-type RPC

We have used 5 BESIII-type 50 cm × 50 cm RPCs in the test. These RPCs were made of the same Bakelite as BESIII and Daya Bay muon detectors, working in the streamer mode. The thickness and gas gap of the Bakelite electrode are both 2 mm. The volume resistivity of the electrode is within the range of a few 10^{11} Ω cm. The gas mixture used in the test is Ar/R134A/Isobutane/SF6 (65.5/30/4/0.5) and the flow rate is around 10 cm^3/min. Laboratory temperature and atmospheric pressure are measured by a weather station (La Crosse, model WS-2308) and recorded all the time. Due to its bad initial efficiency RPC#2 has been eliminated in the following discussion and only the other four RPCs are used in the following test.

2.1. Test set-up

Fig. 1 shows a photo of the set-up for RPC aging test and cosmic ray trigger efficiency study.

Fig. 2 shows the scintillation counter array used for cosmic ray trigger. It sandwiches the stack of test RPCs, and divides the test RPCs into 16 regions (#1–#16 from lower-right to upper-left) in a 4 × 4 array.

2.2. Singles rate

A 0.1 mCi ^{60}Co source was placed on top of the RPCs (region #1) through an 18 mm thick stack of copper plates. Singles rates with and without the source are quite different among the 5 RPCs. RPC #1 is the noisiest, ~6 kHz for strip #2. RPC #5 is the quietest, ~0.8 kHz for strip #2. See Fig. 3 for details.

Because of the distance to the source and the intrinsic noise rate difference the aging dose rate is different among these RPCs, with their ratio being (#5):(#3, #4):(#1)~1:2.5:7.5. The equivalent aging dose is based on the following: (1) the background noise rate for a running RPC is 0.4 Hz/cm^2 and (2) a simple Monte Carlo calculation shows 40% of the total rate detected by eight 6 cm-width strips over a 50 cm × 50 cm RPC with a ^{60}Co source that is concentrated in a 10 cm radius circle in region #1. Note: due to the streamer rate limitation the singles rate under source radiation is saturated. It depends mainly on Bakelite resistivity; the rate distribution among 8 strips will not be proportional to their radiation intensity.

2.3. Efficiency test

We measured the initial efficiency for the test RPCs and monitored their dark current in the course of aging test. By comparing efficiency degradation with time the aging effect can

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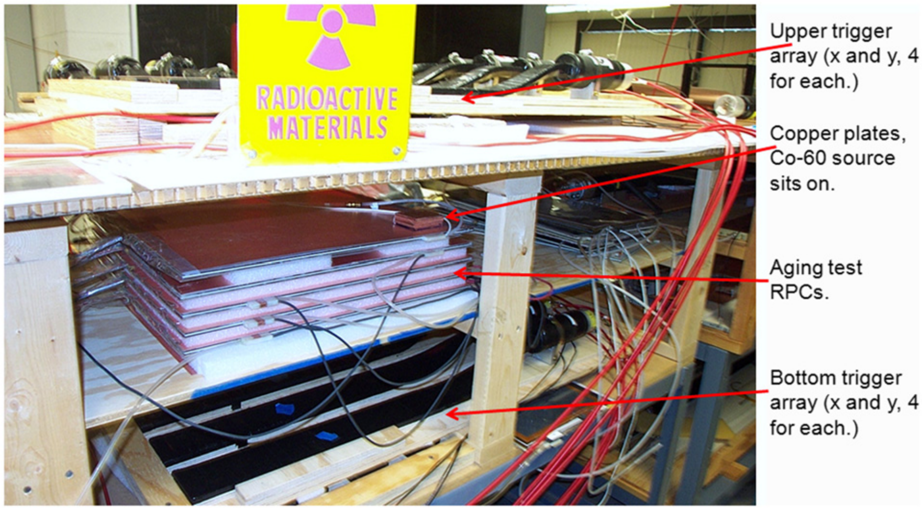

Fig. 1. RPC aging test set-up.

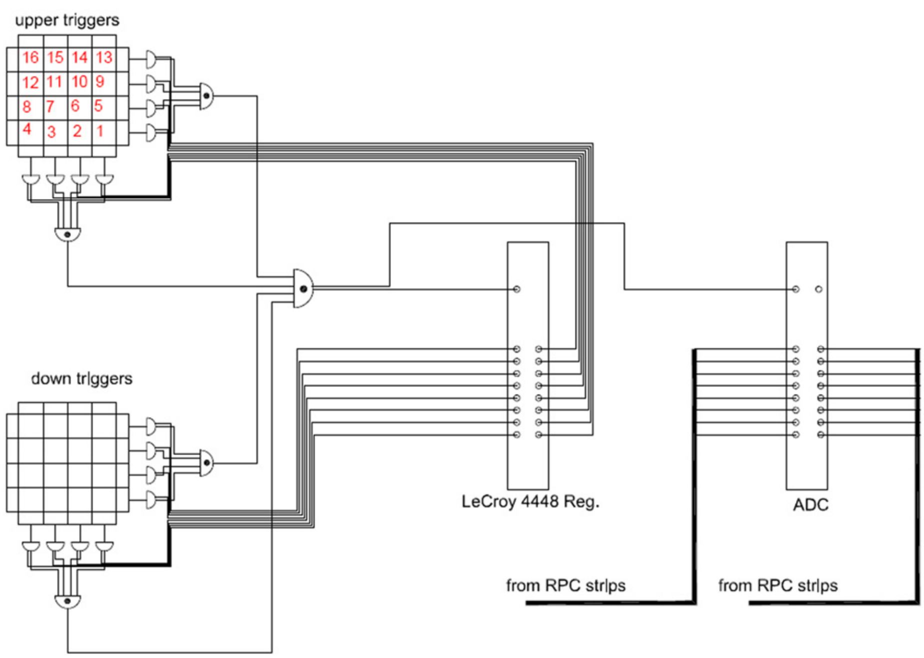

Fig. 2. Scintillation telescope array.

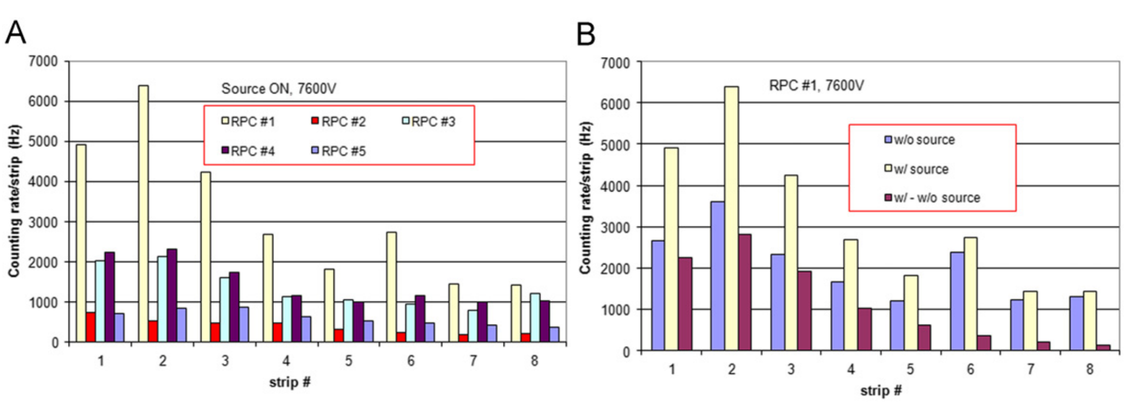

Fig. 3. Singles rate of the test RPCs. (A) Rate for all five RPCs with source and (B) rate for RPC #1 with and without source.

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be clearly revealed. Fig. 4 shows the efficiency before and after 23 days aging. The equivalent aging dose for RPC#1 equals 7.6 years of background run. By this time serious aging has already shown up. The other three RPCs have much less degradation because their equivalent aging dose is smaller.

2.4. Linseed oil coated BESIII-type RPC

From our previous tests we have observed that the Linseed oil coating can protect the Bakelite surface from HF attack [2]. Experience with Italian-type RPC shows better aging performance that confirms our observation. To obtain direct confirmation we coated the inner surface of a BESIII-type RPC with diluted Linseed oil (35% Linseed oil + 65% of n-pentane); the coating thickness is ~7 μm.

The initial performance of this chamber is extremely good. The noise rate without source is very close to cosmic ray background. Under the source radiation the equivalent aging dose ratio to the background rate (0.4 Hz/cm^2) is estimated as 40:1.

In Fig. 5 we compare the aging performance for Linseed oil coated RPCs and other two RPCs: RPC #1 and #5. The number of years shown in the plot is the equivalent aging dose. Up to 11 years of the equivalent aging dose the oil coated RPC still has good efficiency curve, although the efficiency plateau's shoulder has shifted higher by ~400 V. For other two regular RPCs without oil

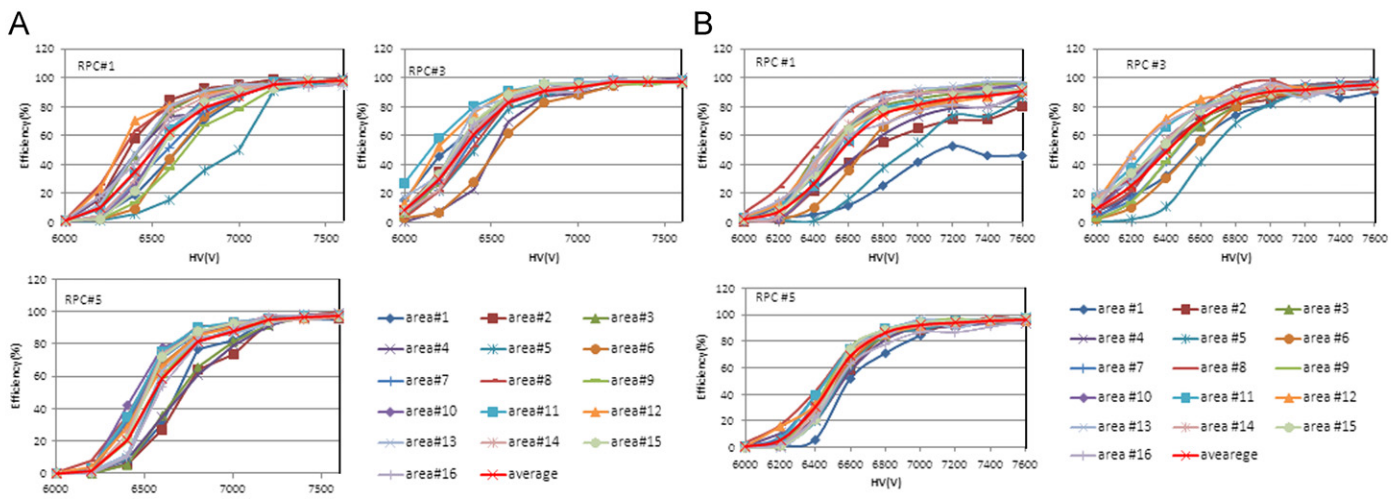

Fig. 4. (A) Initial efficiency and (B) after 23 days, RPC #1 area #1 efficiency dropped.

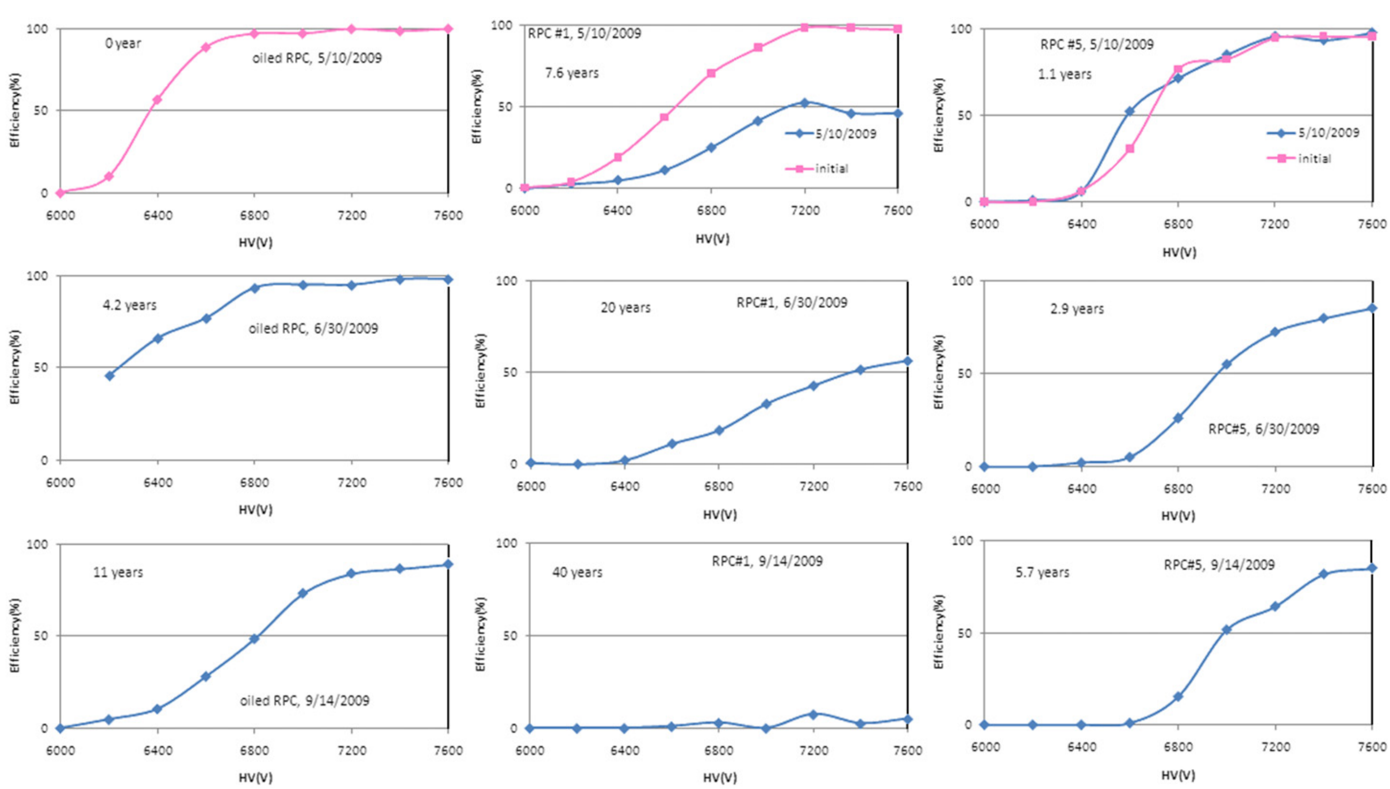

Fig. 5. Comparison between oiled BESIII-type RPC and regular BESIII-type RPC.

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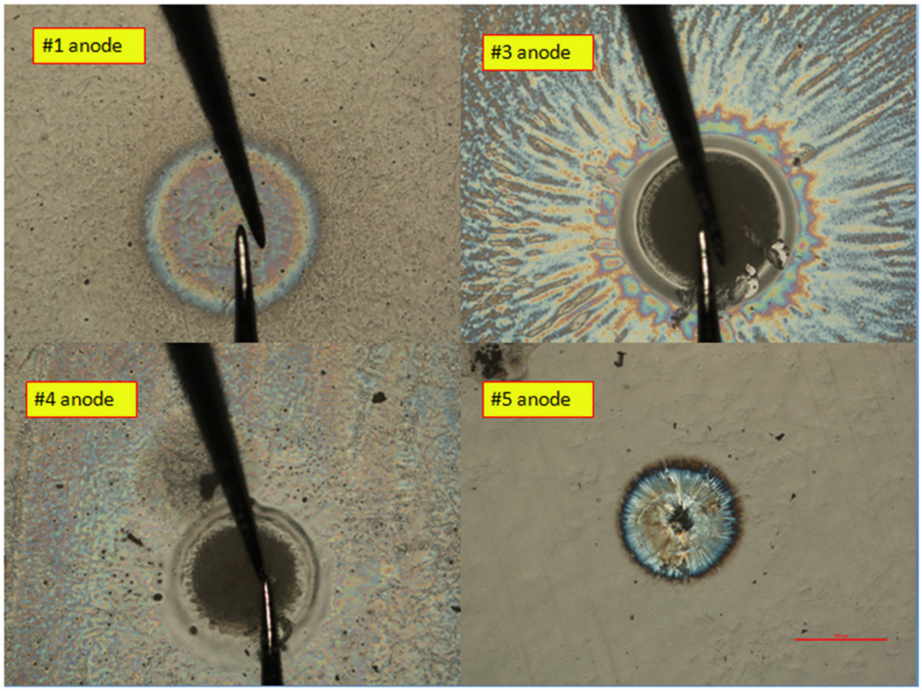

Fig. 6. Sparking mark images from four RPCs: #1, #3, #4 and #5. The 0.5 mm microscope scale is shown in #5 image.

coating (7.6 and 5.7 years, respectively) the efficiency plateaus already degraded profoundly in spite of significantly less aging dose.

Ninety seven days after the efficiency test the RPCs were still under the normal aging test condition, however a month later when we tested the efficiency again we found drastic efficiency drop for the radiated region of the oil coated RPC. An "autopsy" revealed that the Linseed oil coating had not been cured completely, causing several big oil stalagmites to form in the gap of the radiated region, similar to the serious failure of the first generation of BaBar RPCs [3]. We believe if we improve the curing process this problem can be avoided as demonstrated by the second generation of BaBar RPC [4,5]. The advantage of the Linseed oil coating is clear: lower noise rates and better aging performance.

3. Microscope study of various aged Bakelite electrodes

After opening the aged RPCs we found a lot of sparking marks all over the surface for both anode and cathode. Distribution density of the marks varies and shows a correlation between the degree of efficiency drop and density of the sparking marks. RPC #1 has suffered the highest aging dose, and presented the highest sparking density. RPC #5 has the least aging dose and the lowest aging mark density.

In Fig. 6 we show images of typical sparking marks for different RPCs. The sharp pins shown in the picture are the pin probes. Scratching the sparking marks with the probe can produce clear scratching traces. By contrast there is very little sparking evidence found on the Linseed oil coated RPC electrodes. More detailed microscope studies of the aged electrodes will be in our future report.

Acknowledgment

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