BESIII RPC Aging Study

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Outlines

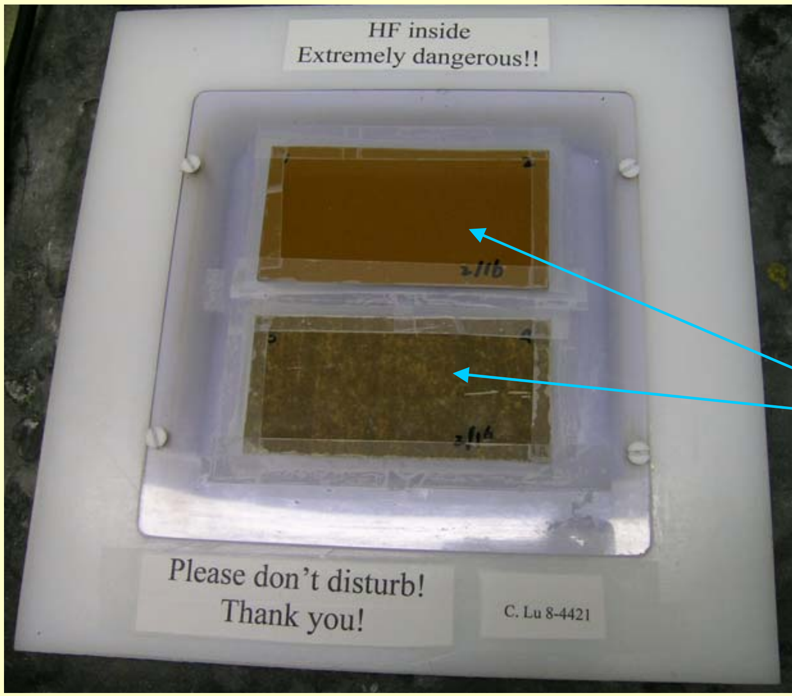
- HF vapor attack to the electrode surface;
- Preliminary source test results;
- Summary

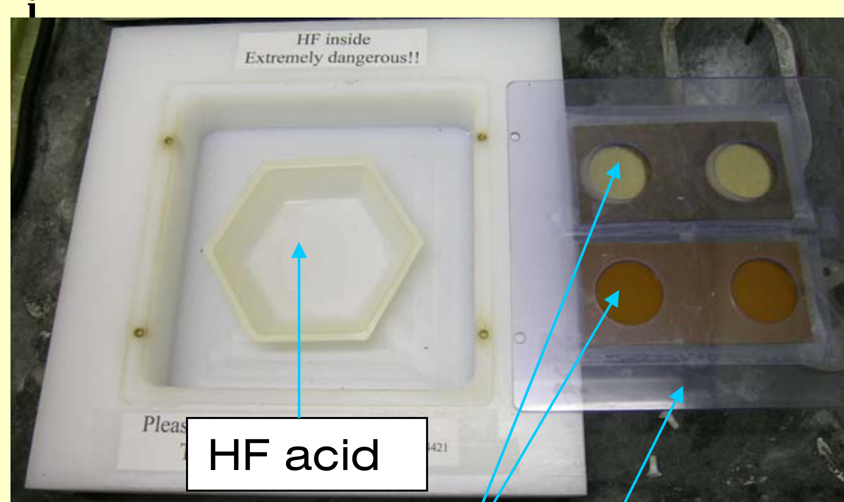
(1) HF corrosive effect on RPC electrode surface

The major component in RPC gas mix is R134A - C2H2F4.
In the electrical discharge it can produce significant fluoride radicals, and further form HF. HF is notoriously chemical reactive, it can attack many materials.

To get the sense of this corrosive action, we exposed various materials in the HF vapor environment. We measured their surface resistivity before and after the exposure. By this we can quickly learn what kind of electrode is more corrosive-resistant.

Test device



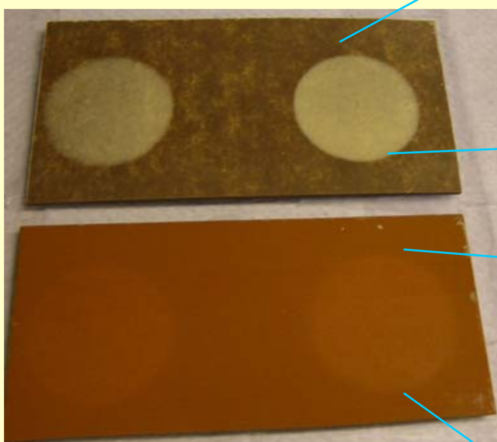


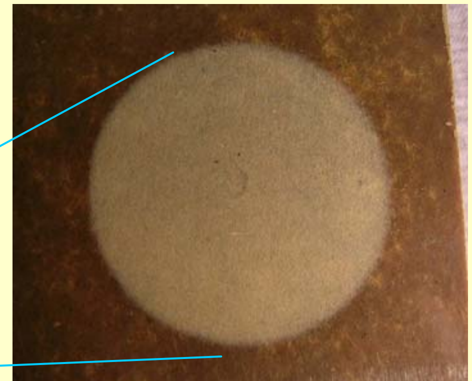
HF acid

Testing samples

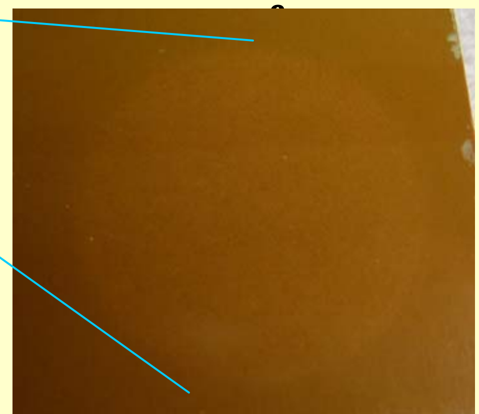
Polycarbonate cover plate has 4 circle windows that let the testing samples exposed to HF vapor.

Effect on BaBar Bakelite surface



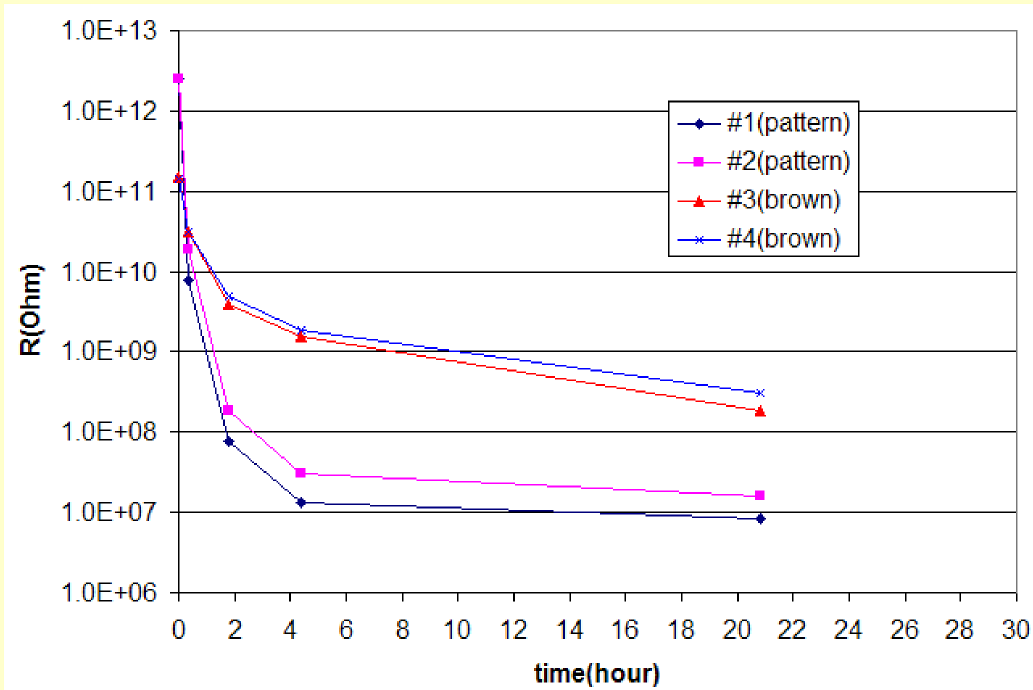


Marble side of BaBar Bakelite plate, the marble-pattern is completely disappeared, also discolored.



Brown side of Bakelite plate shows slightly discolored mark.

Effect on BaBar Bakelite surface (contd.)

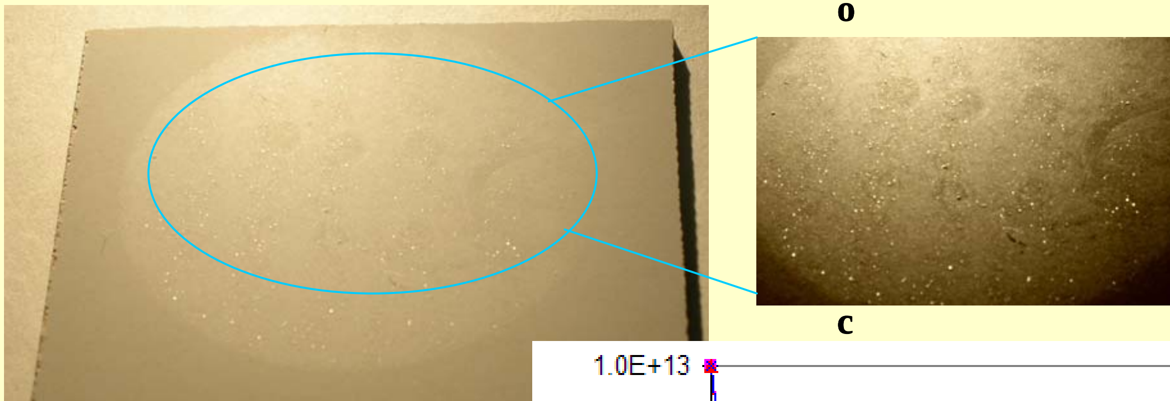


At the very beginning of exposure the surface resistivity drops very fast, then slow down.

Effect on Linseed oil coated Bakelite

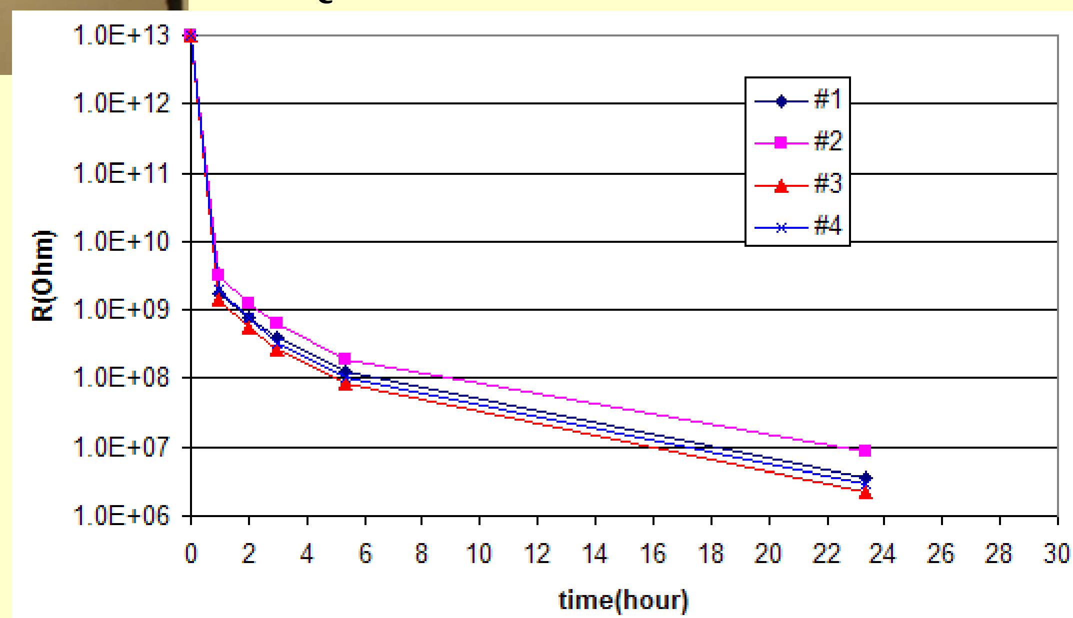
The Linseed oil coated Bakelite surface is much better protected from HF vapor attack. After 24 hours of exposure there is no discolored area can be seen.

Effect on BESIII Bakelite surface

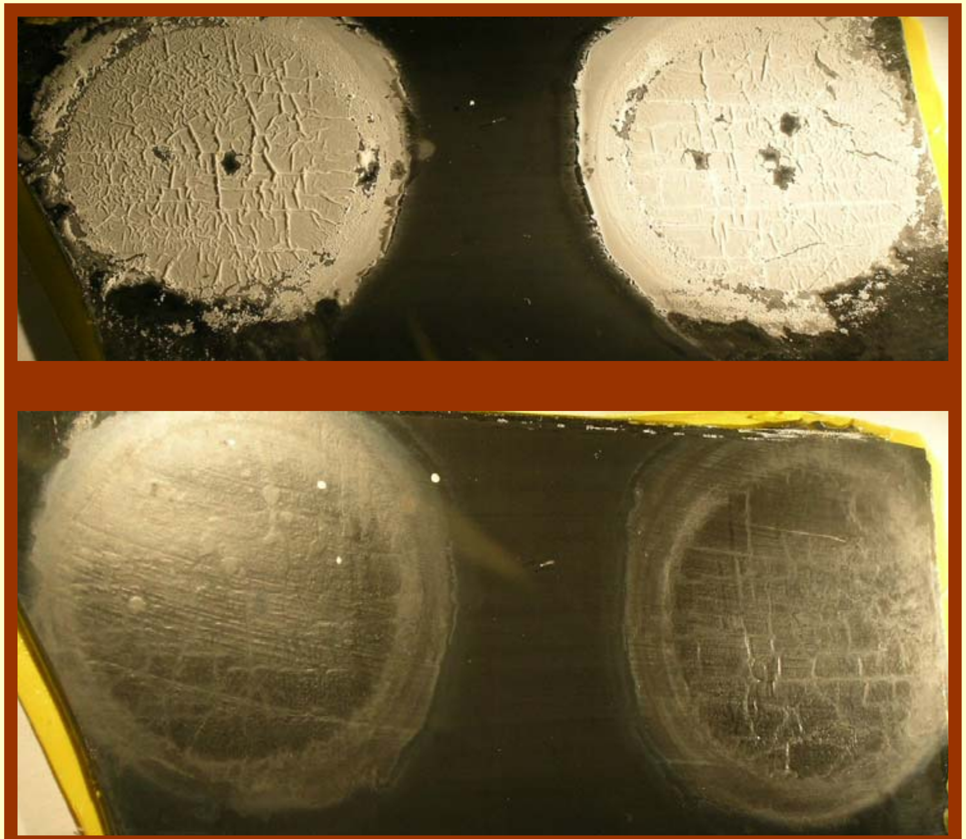


Surface is badly damaged!

Surface resistivity drops very fast in first hour of exposure.



Effect on Belle's glass surface



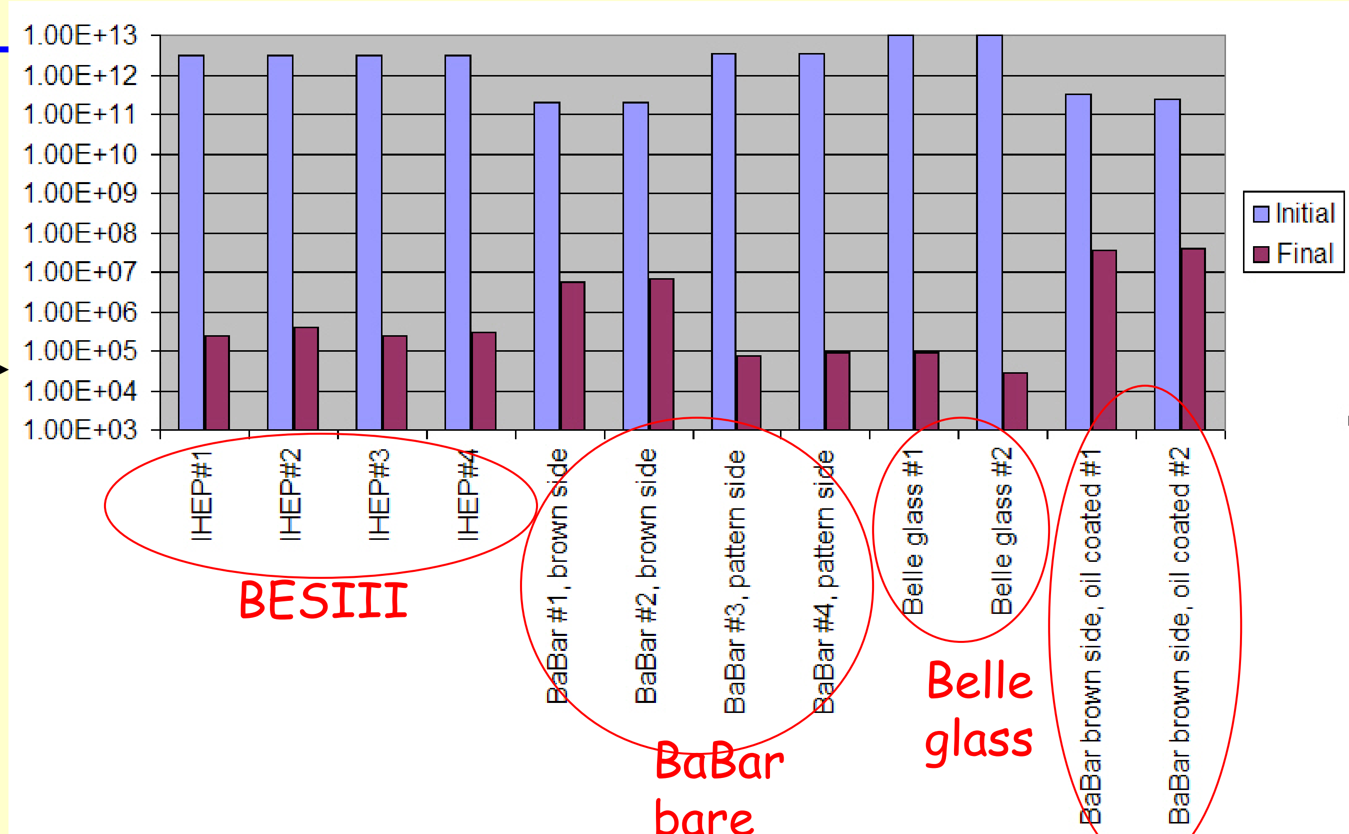
Belle's RPC glass surface

After exposed to HF vapor for ~24 hours, the surface looks fluffy.

After water rings the surface, the fluffy "skin" is removed, the glass surface looks cracky.

Test summary

Surface resistor measured by a special probe (Ω)



Surface resistivity reduction:

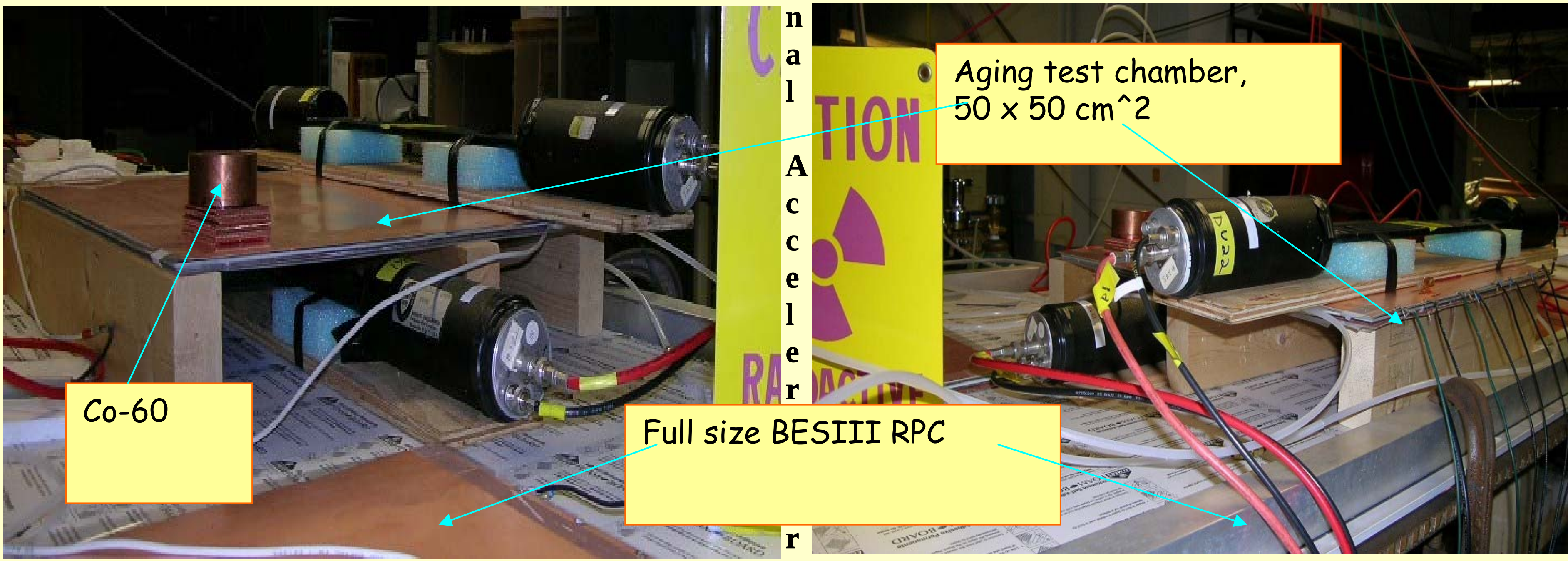
IHEP Bakelite samples ~10^{-7};

Belle glass surface ~10^{-8};

Linseed oil coated BaBar Bakelite ~ 10^{-4}.

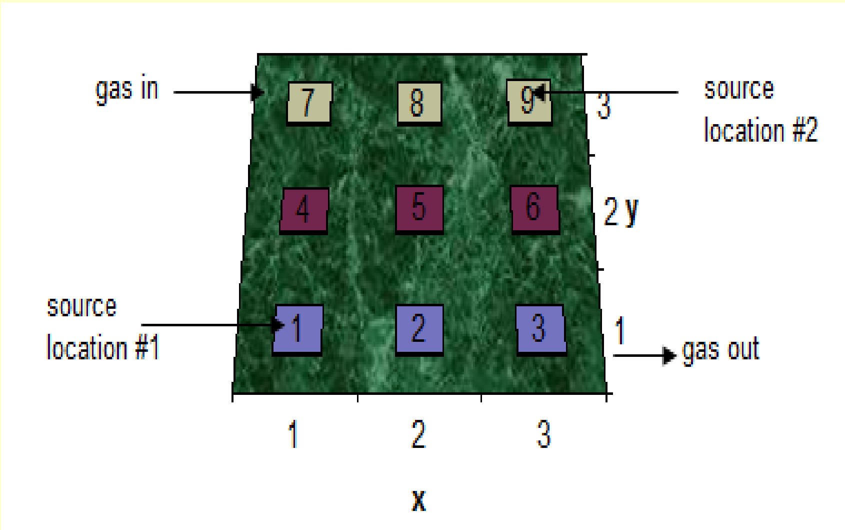
(2) Prototype BESIII RPC aging test

Aging test setup

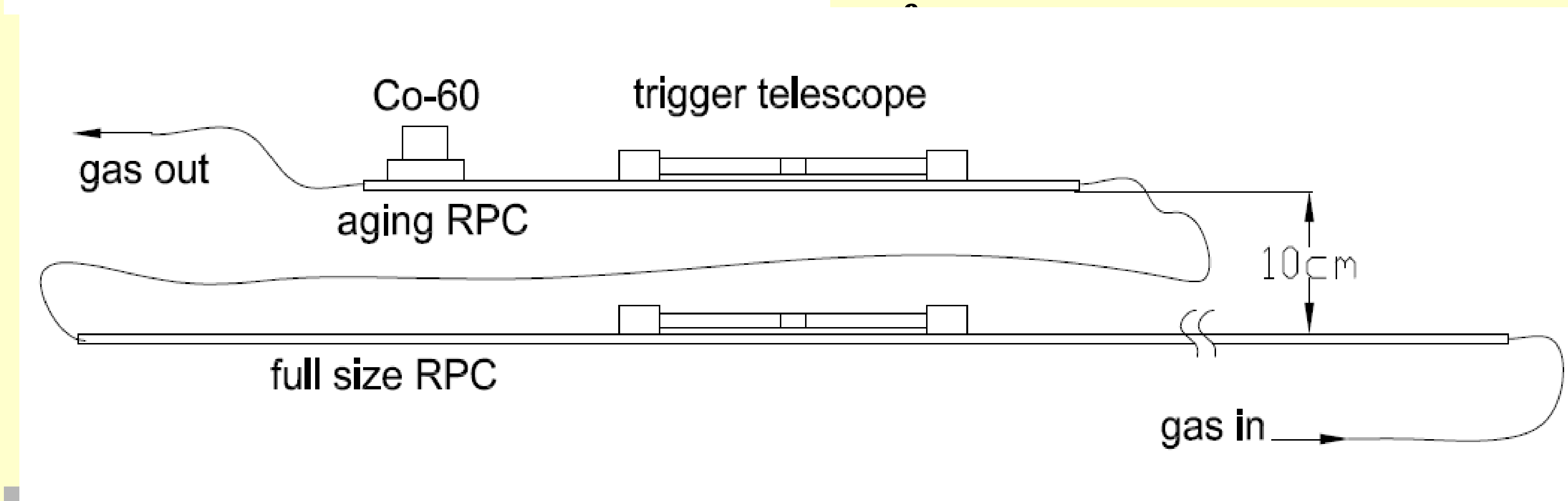


Aging test chamber and a full size BESIII RPC with the Co-60 source and trigger counters (when source is on, the trigger counters are turned off, they are not aligned for cosmic ray trigger.

Aging test chamber

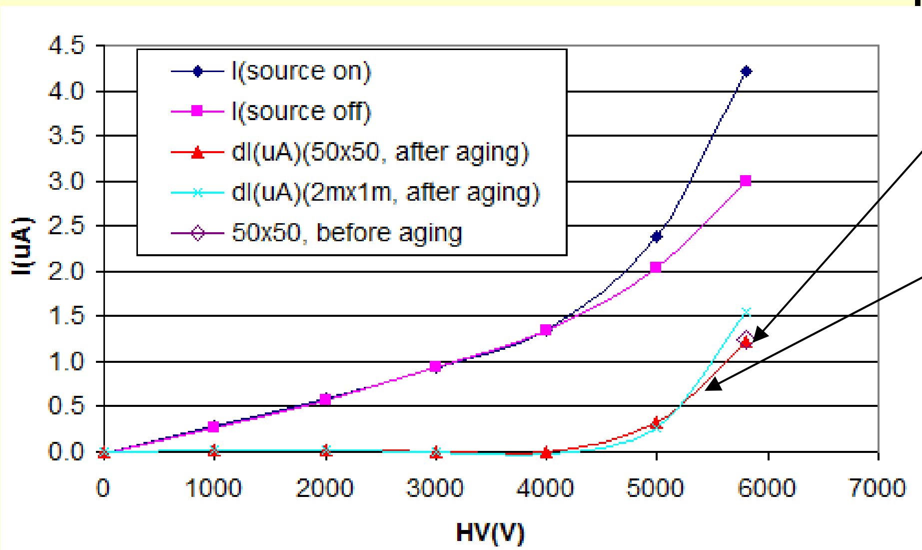


9 regions marked as 1, 2, ...9 for efficiency and dark current test. Two source locations. Notice the gas inlet and outlet locations.



First round aging test results

Aging chamber dark current at 5800V, w/ and w/o source.

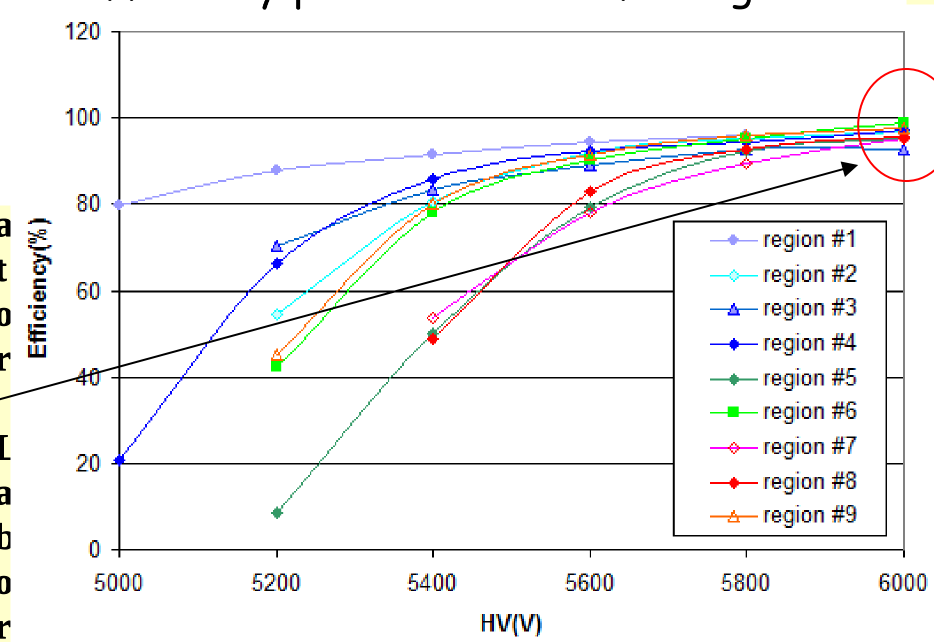


Before aging

After aging

There is no noticeable change after the first round aging test.

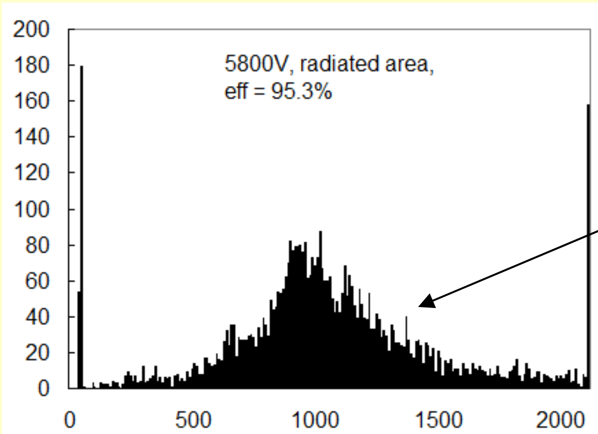
Efficiency plateau curves of 9 regions.

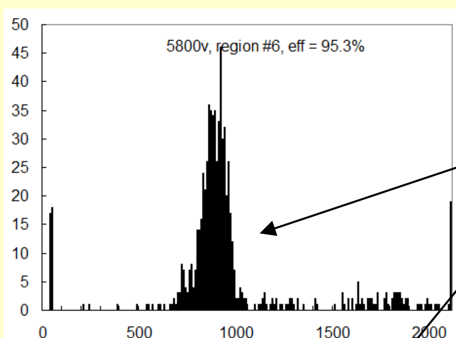


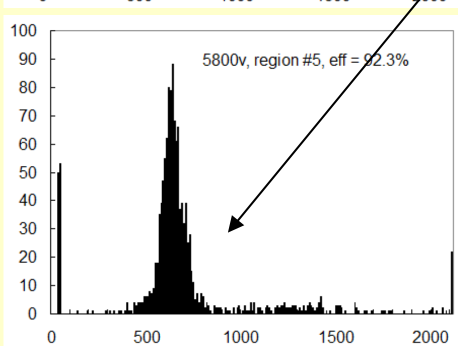
Efficiency plateau starting points are quite different for different regions, but at 6000V all of them are above 90%.

First round aging test equivalent to ~ 5 years of cosmic ray run.

First round aging test (cont'd)







We also measured the peak spectrum for 9 regions.

A noticeable spectrum distortion can be seen for the aged region #1. The spectrum on radiated region shows a very broad distribution, although the efficiency is still high, but the distorted spectrum may reflect the aging damage to the internal electrode.

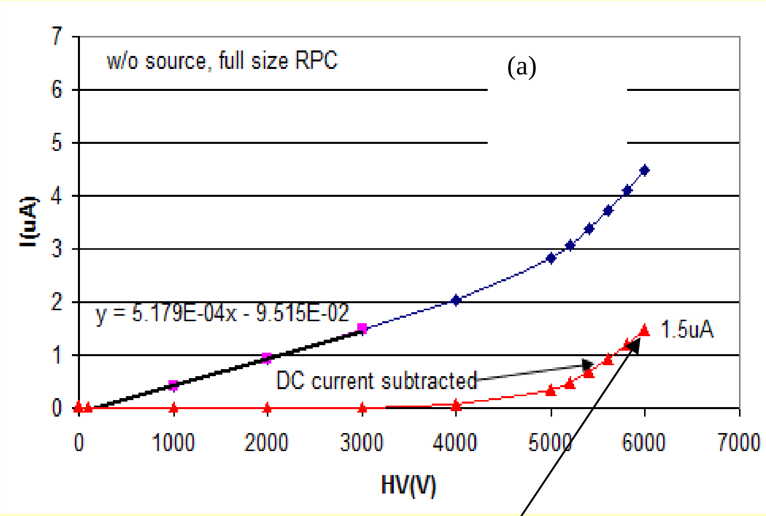
The other two spectra, triggered on the unradiated regions, show a narrow distribution, which is a typical streamer distribution.

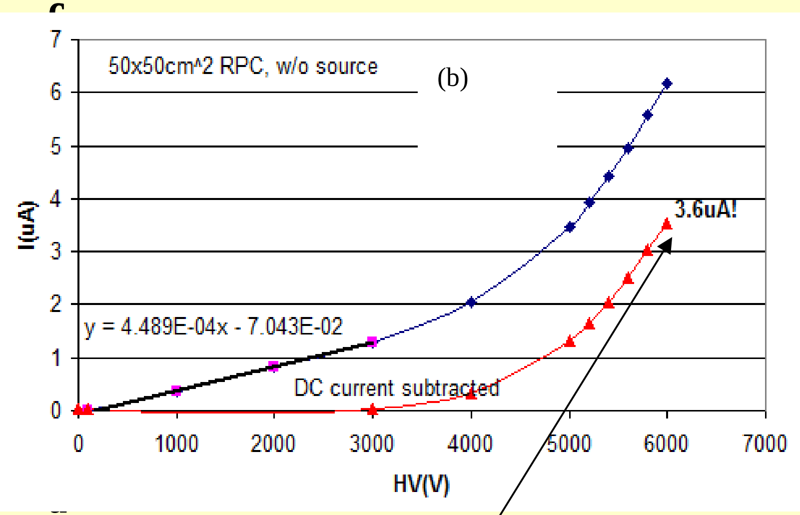
We didn't record the peak spectrum before the aging, not sure if this is solely due to the aging, or may be just due to the bad region originally.

Second round of aging

To make sure if the aging effect is real, we started a second round of aging test on 8/18/2008, this time placing the Co-60 source on region #9. The second round of aging lasted for ~ 30 days. The HV was set at 6000V.

After only 16 days another aging effect appeared: the dark currents on two RPCs became different.



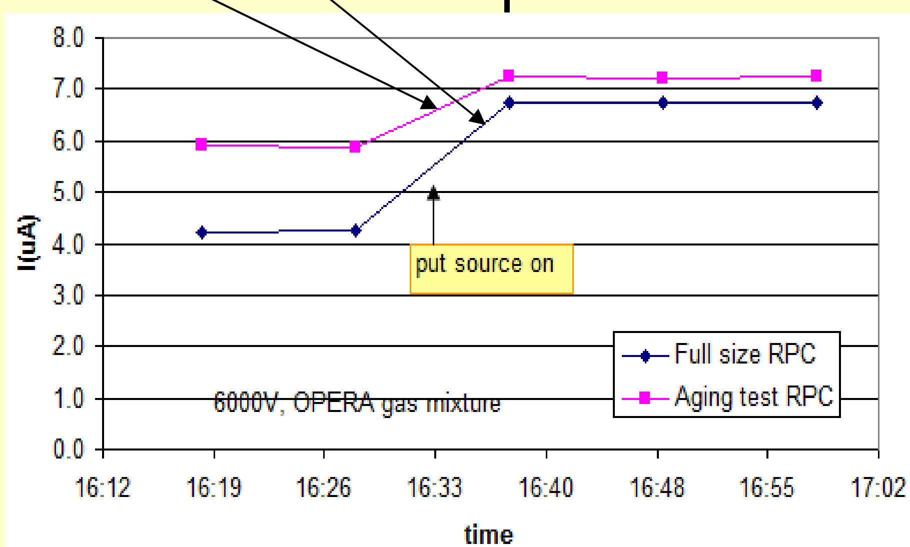


Full size RPC, 1.5μA @6000V, w/o source.

Aging RPC, 3.6μA @6000V, w/o source.

Second round of aging (cont'd)

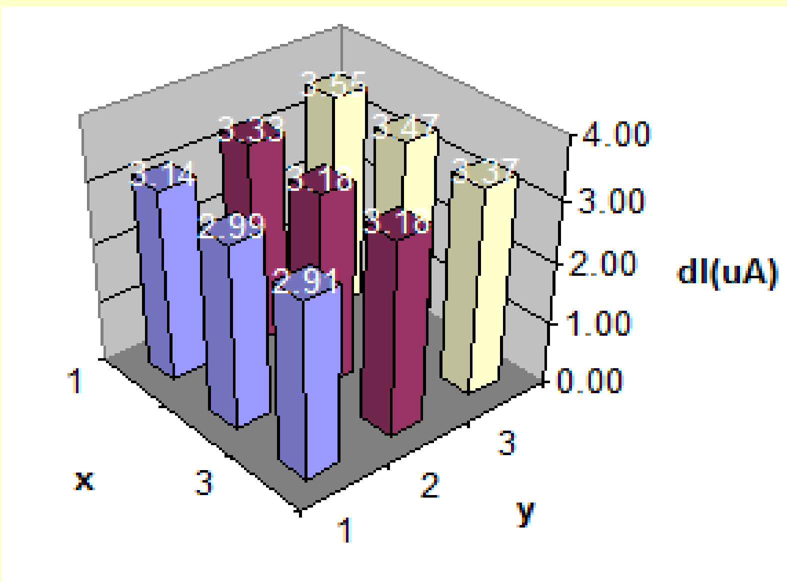
In addition, the current jump due to the source was now smaller for the small RPC. On 9/3/2008, the 16th day in the second round of aging, the current in the small chamber jumped from 5.89μA to 7.25μA, so *dI* ~ 1.36μA, but the current in full-size RPC jumped from 4.26μA to 6.74μA, for *dI* ~ 2.48μA.



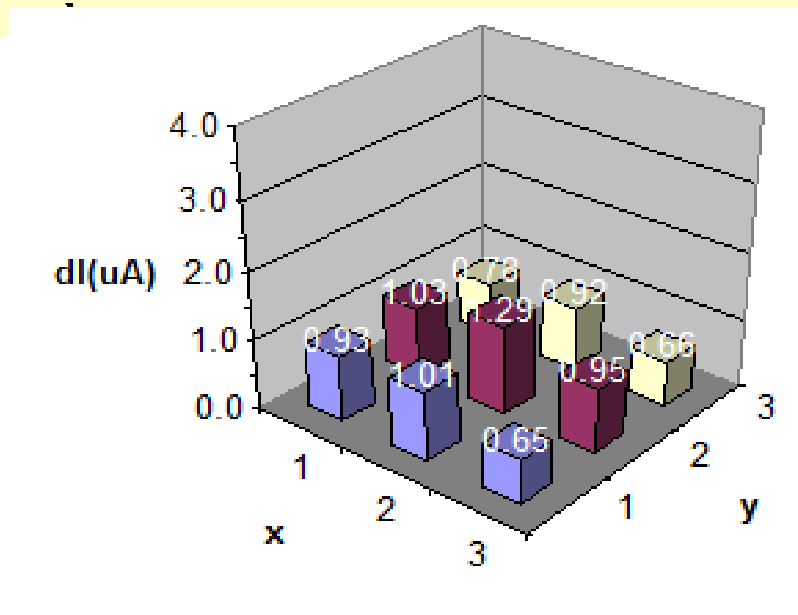
Apparently the aging RPC had higher background current, which very much likely was due to the damaged Bakelite inner surface.

Dark current jump map after 2-nd round aging

At the end of the second round of aging we surveyed the dark current response in 9 regions. By placing the source on each region and measuring the dark-current jump *dI*.



(a)

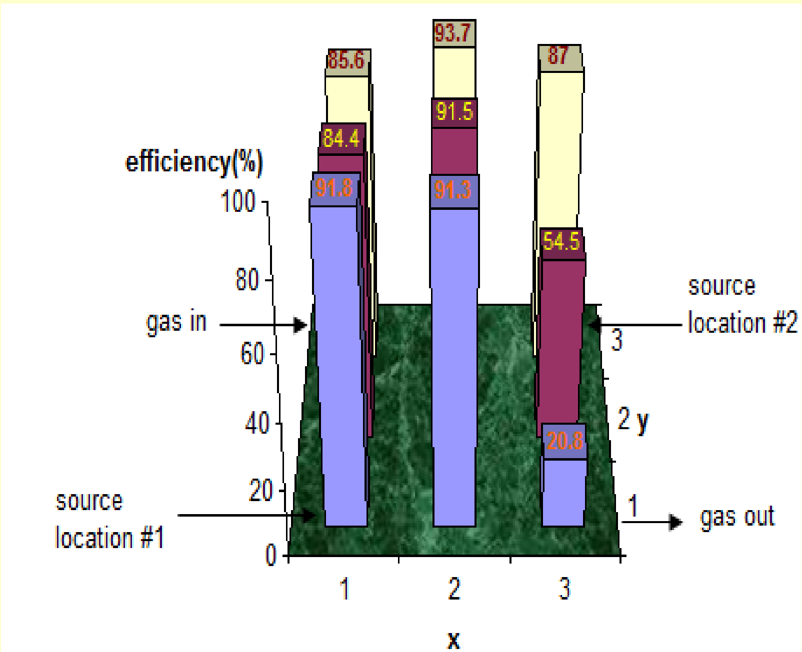


(b)

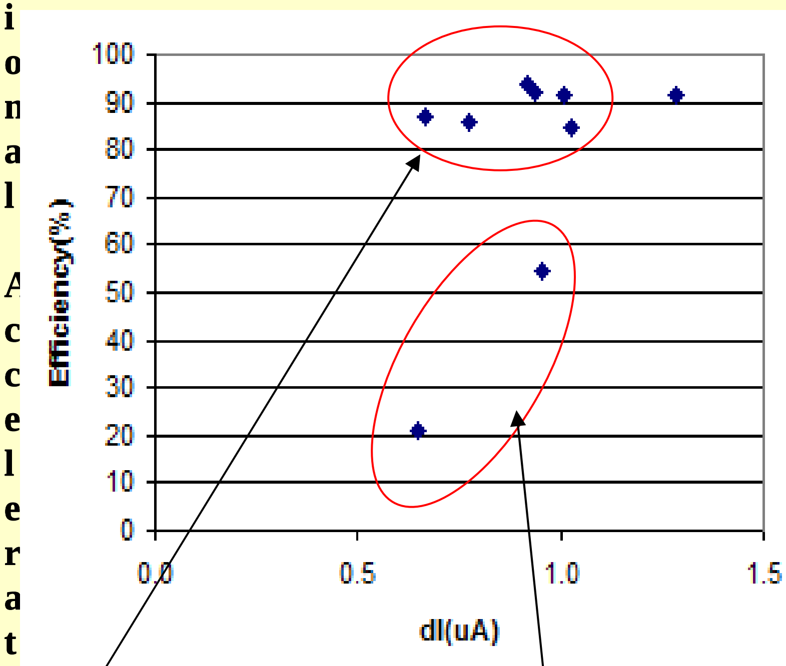
Full size RPC, dI larger, small relative variation.

Aging RPC, dI much smaller, larger relative variation.

Efficiency map after 2-nd round aging



Efficiency survey results at the end of second round of aging tests.



Scatter plot of efficiency *vs.* current jump, *dI*, for 9 regions.

Two lowest-efficiency points show a correlation: lower efficiency related to lower current jump, but the other regions did not follow this trend.

Summary of the aging test so far

One month of aging test is equivalent to 30 months of cosmic-ray background operation. After two months of aging, some aging effect had already appeared. An additional one month aging at a different RPC location caused serious aging; in some regions the efficiency dropped dramatically.

If we propose this BESIII-type of RPC for SiD muon system, more careful aging test is absolutely needed. More likely we have to develop better Bakelite electrode. Collaborated with IHEP and Gaonenkedi, Inc. we'll seek new treatment to the Bakelite surface, which may can lead to a new solution.