New progress on BESIII-type RPC aging study

Changguo Lu
Princeton University

SiD Workshop, Oregon, 11/15-17, 2010

ILC R&D program: original motivation of project 6.19

• Address aging issues in RPCs built from the new type of Bakelite developed by the BESIII Muon group of IHEP (Beijing) and a Beijing Bakelite manufacturer for use in the BES III and Daya Bay Muon Systems since RPC using this material 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;

• Our preliminary study of Daya Bay Muon System RPCs has indicated a significant aging effect that must be understood and mitigated prior to use it for SiD;

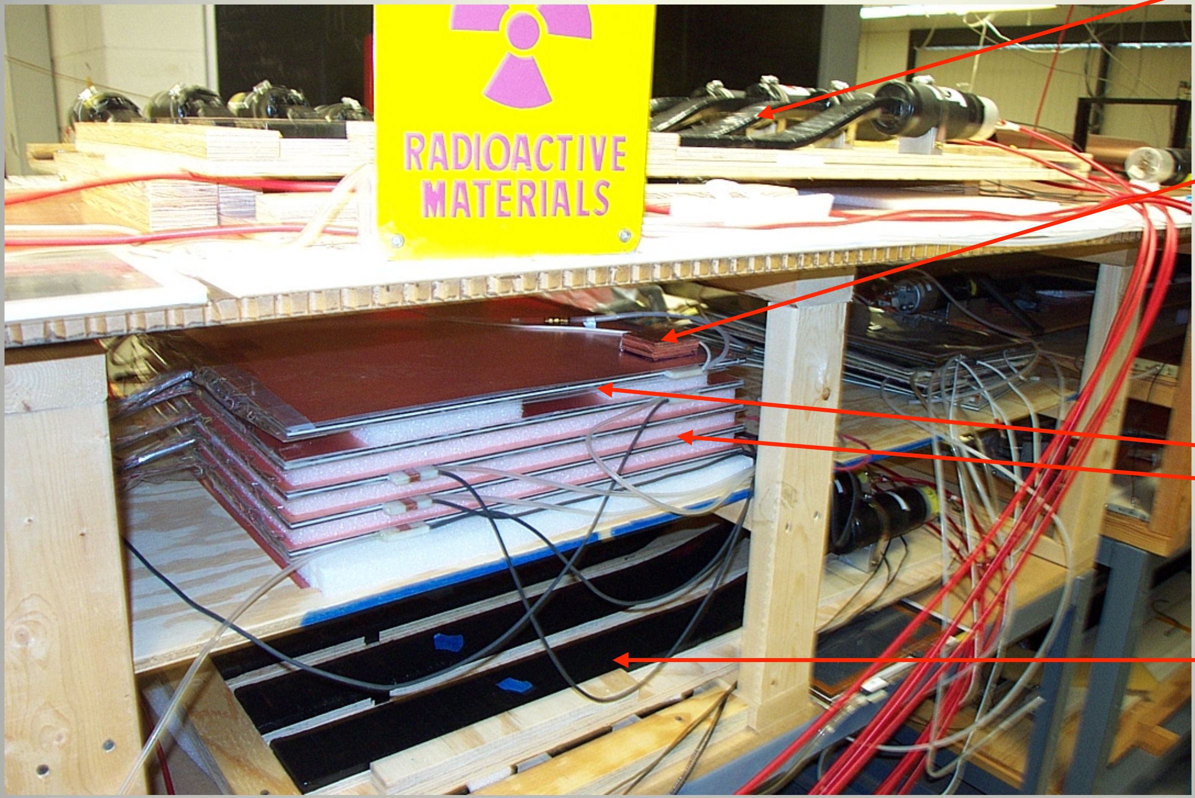
• In the longer-term, a collaboration with IHEP and XianHu, Inc. will lead to develop new variants of Bakelite that are more resistant to aging.

What we have established in the first year

- Set up a 16 strip scintillation counter trigger array for cosmic ray test;
- Assembled 5 BESIII-type aging test RPCs;
- Finished aging test for these chambers;
- Verified the aging test results from the first round of aging test — w/o oil coating BESIII-type RPC is vulnerable to HF attack;
- Set up a Nikon microscope station to study surface morphology before and after the aging;
- Developing new variant Bakelite electrode based on our aging test results;
- Have started a new aging test with new RPCs that are made out of the new Bakelite.

Test set-up

Aging test set-up



Upper trigger array (x and y, 4 for each).

Copper plates, Co-60 source sits on. Co-60 γ ray irradiates the RPCs to speed up the aging.

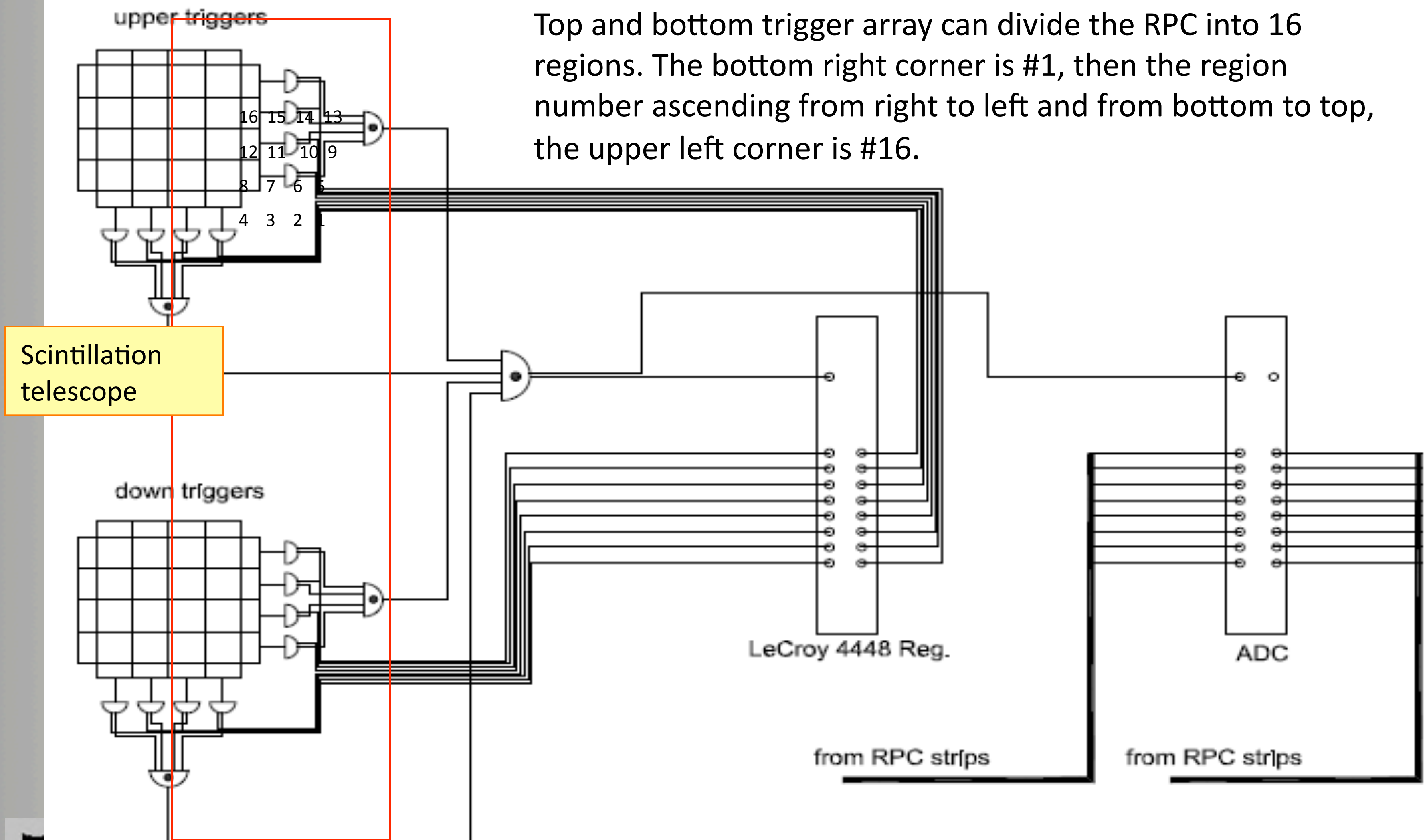
Aging test RPCs, 50x50cm^2.

Bottom trigger array (x and y, 4 for each).

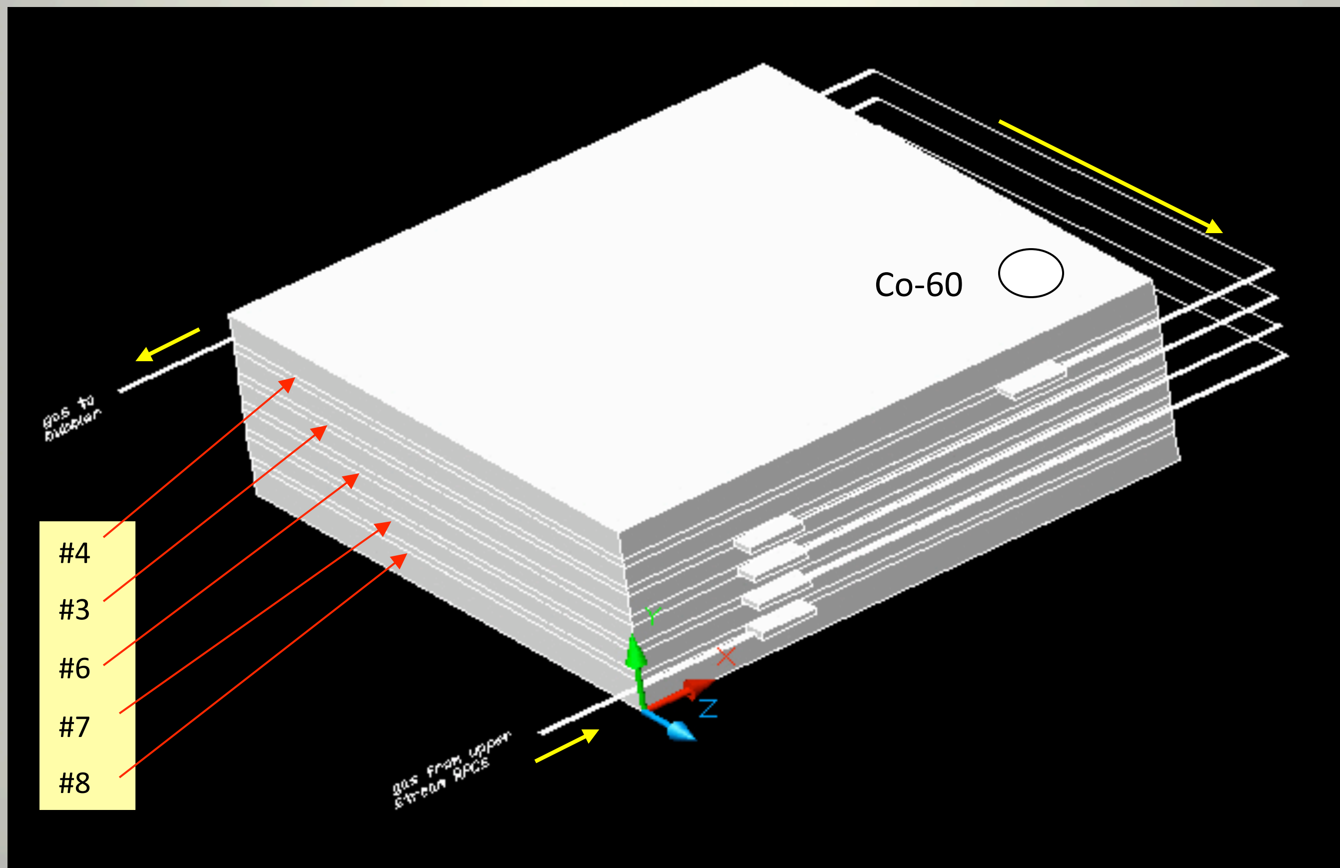
Gas mixture used: Ar/R134A/Isobutane/SF6(65.5/30/4/0.5)

Test set-up: Scintillation telescope & trig logic

Top and bottom trigger array can divide the RPC into 16 regions. The bottom right corner is #1, then the region number ascending from right to left and from bottom to top, the upper left corner is #16.

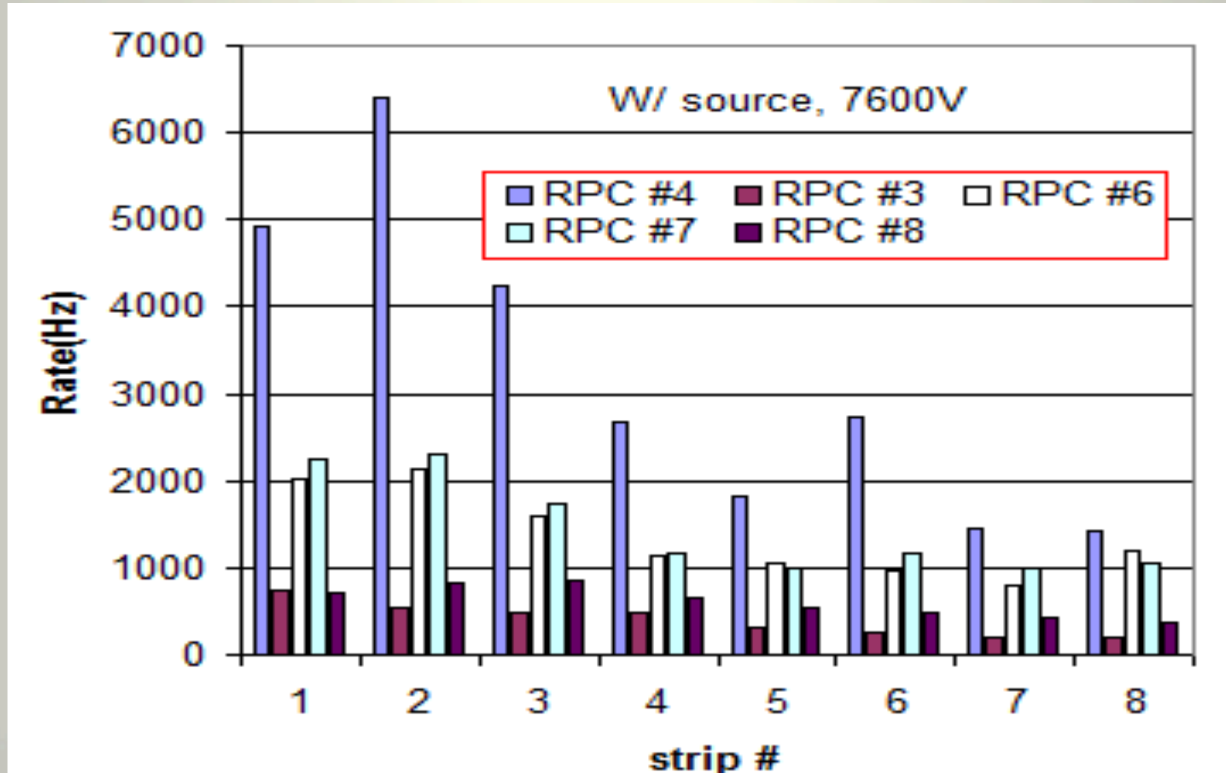


Test set-up: five RPC chamber stack



All RPCs are connected in a series.

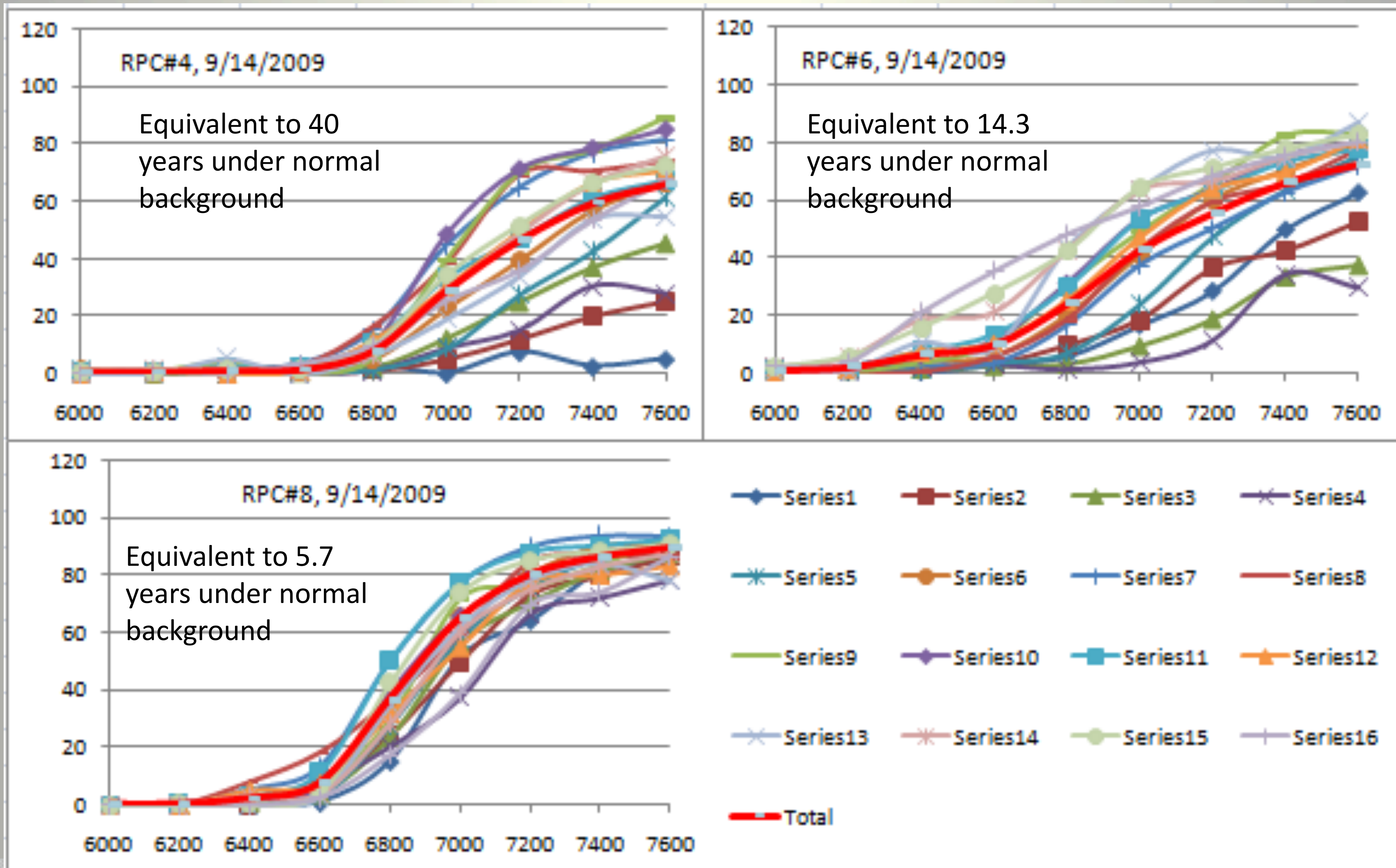
Aging test: Single's rate



Singles' rates w/ source are quite different for RPCs. RPC #4 is the noisiest, ~6kHz for strip #2. RPC #8 is the quietest, ~0.8kHz for strip #2.

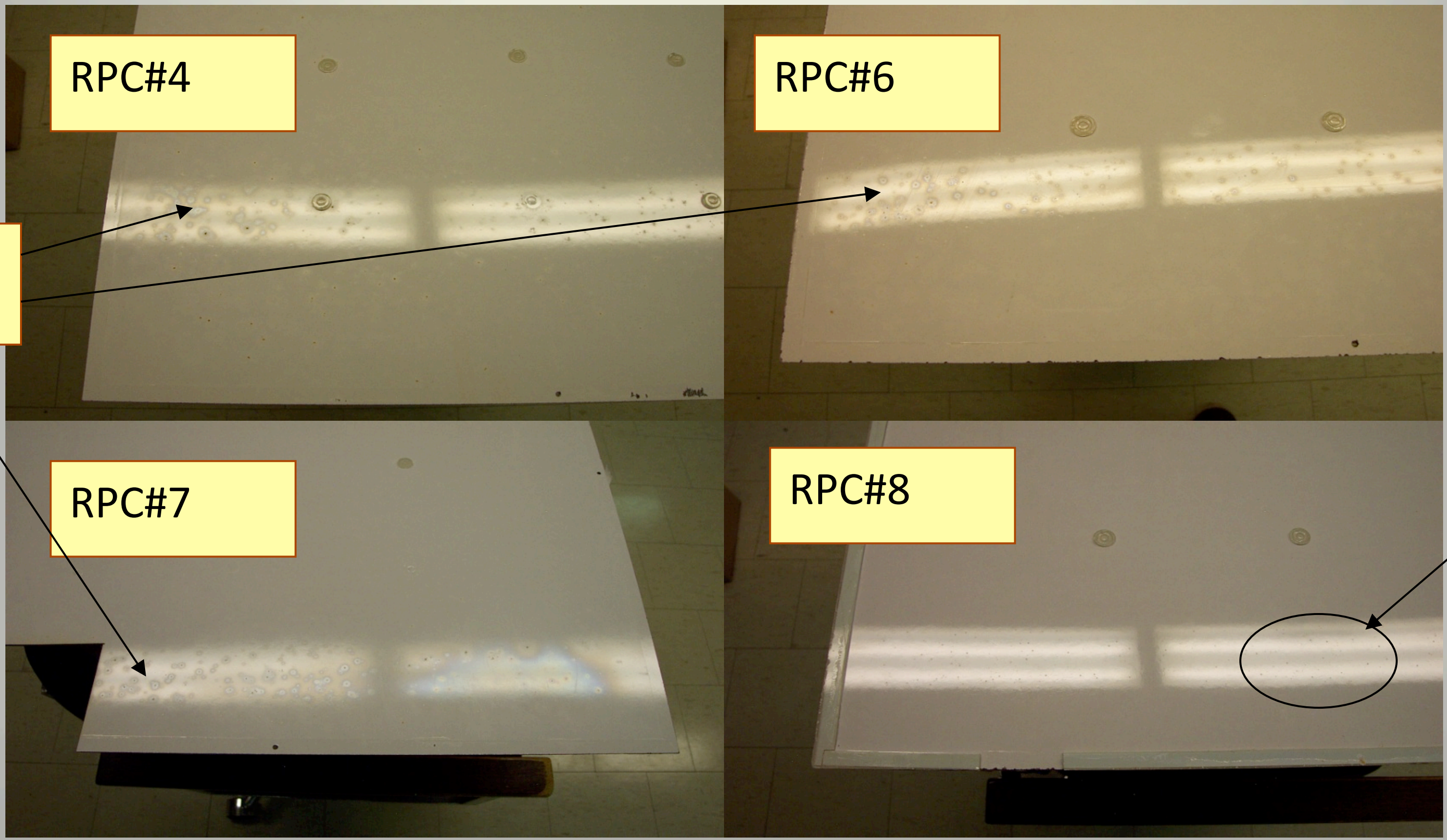
Aging dose per day is different among these RPCs, their ratio is (#8): (#6, #7): (#4) ~ 1: 2.5: 7.5.

Efficiency


RPC#4, 9/14/2009
Equivalent to 40 years under normal background
RPC#6, 9/14/2009
Equivalent to 14.3 years under normal background
RPC#8, 9/14/2009
Equivalent to 5.7 years under normal background
0
20
40
60
80
100
120
6000
6200
6400
6600
6800
7000
7200
7400
7600
Series1
Series2
Series3
Series4
Series5
Series6
Series7
Series8
Series9
Series10
Series11
Series12
Series13
Series14
Series15
Series16
Total

Aged RPC inner surface

Opened the aged RPCs we can see very dense sparking marks distributed all over the inner surface. RPC#8 has much smaller size sparking marks. The microscope images of the inner surface are shown in the following slides.



Sparking marks

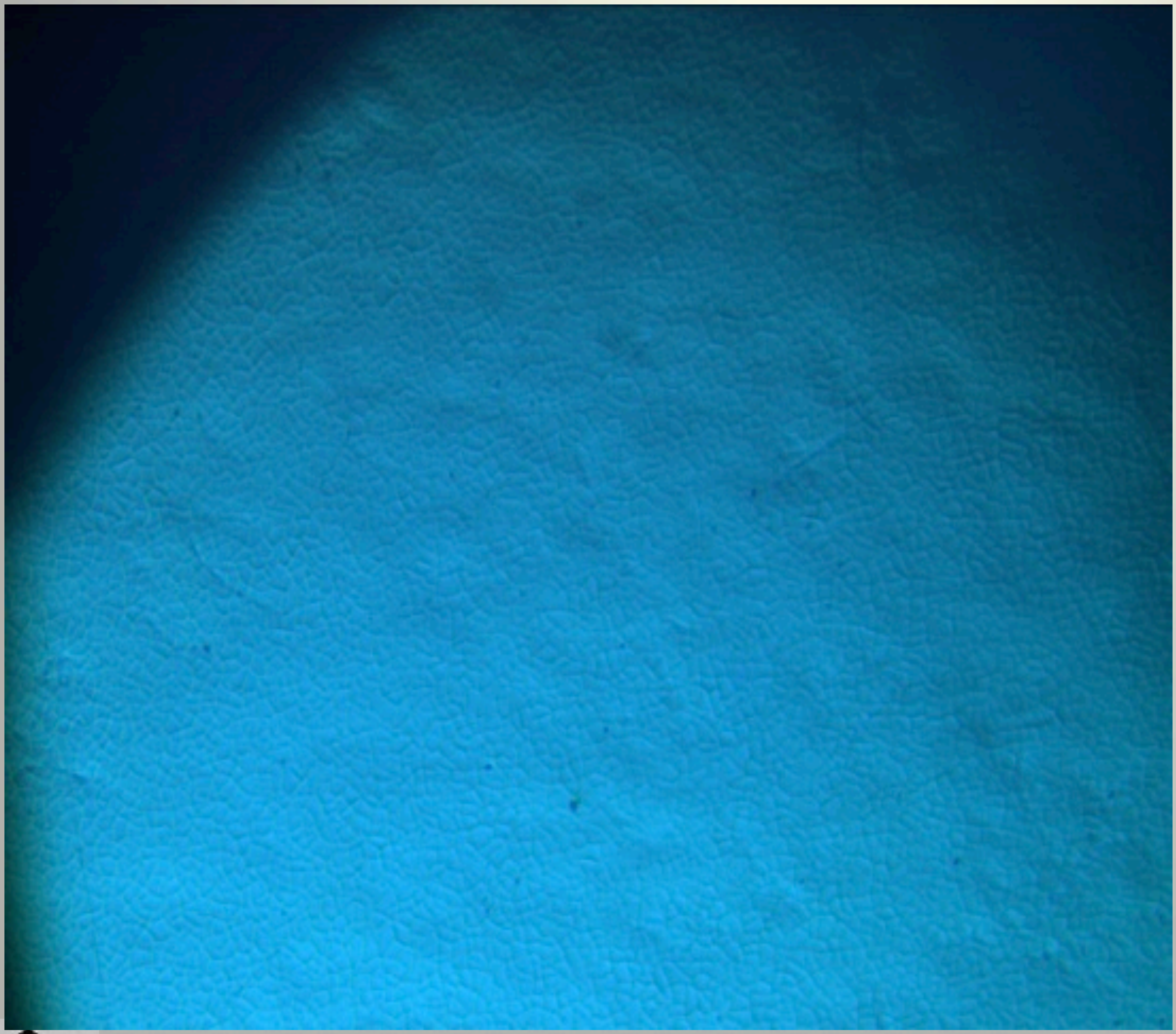
Small sparking marks, display slide in larger scale will see them.

Surface comparison at various stages of aging

We investigate the surface image under the microscope for various aging chamber samples and try to give a plausible working hypothesis of the BESIII-type RPC aging.

- Virgin Bakelite surface;
- Exposed to HF vapor surface;
- Less aged RPC inner surface;
- Serious aged RPC inner surface;
- BaBar aged RPC inner surface.

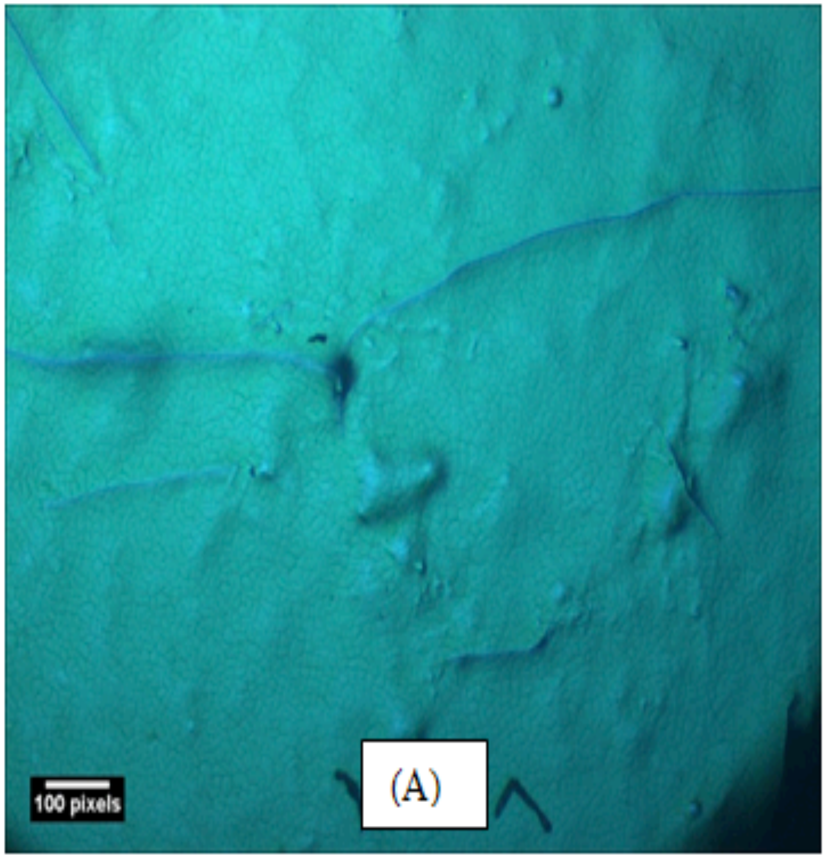
Virgin BESIII Bakelite surface

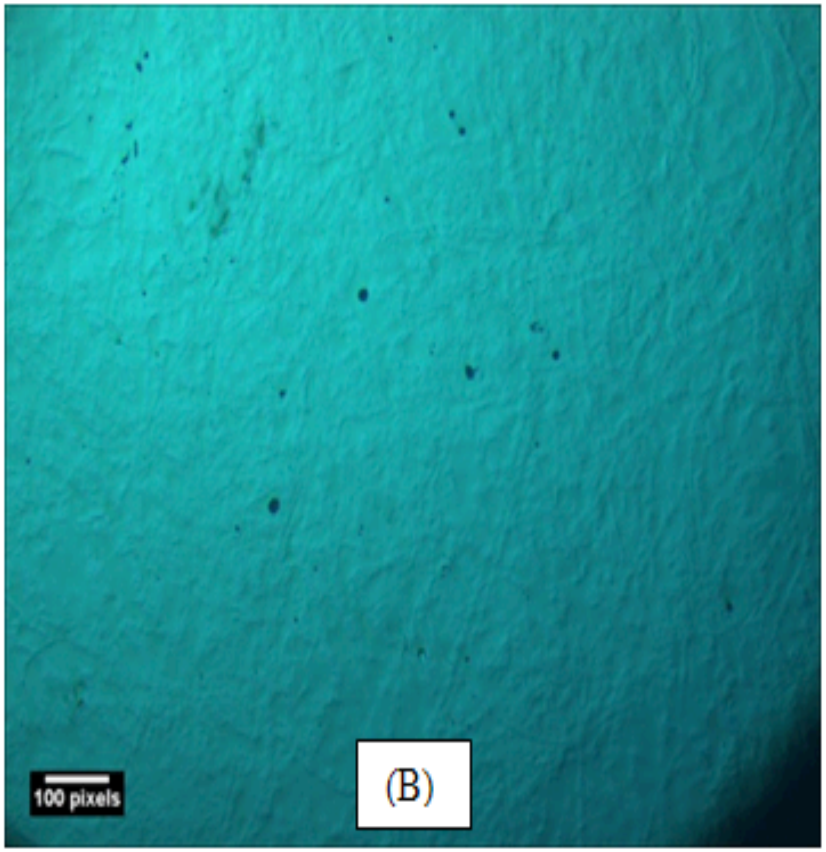


Characteristic:

• Smooth;
• Dense and uniformly distributed "skin-like" texture;
• No broken surface.

HF vapor exposed surface

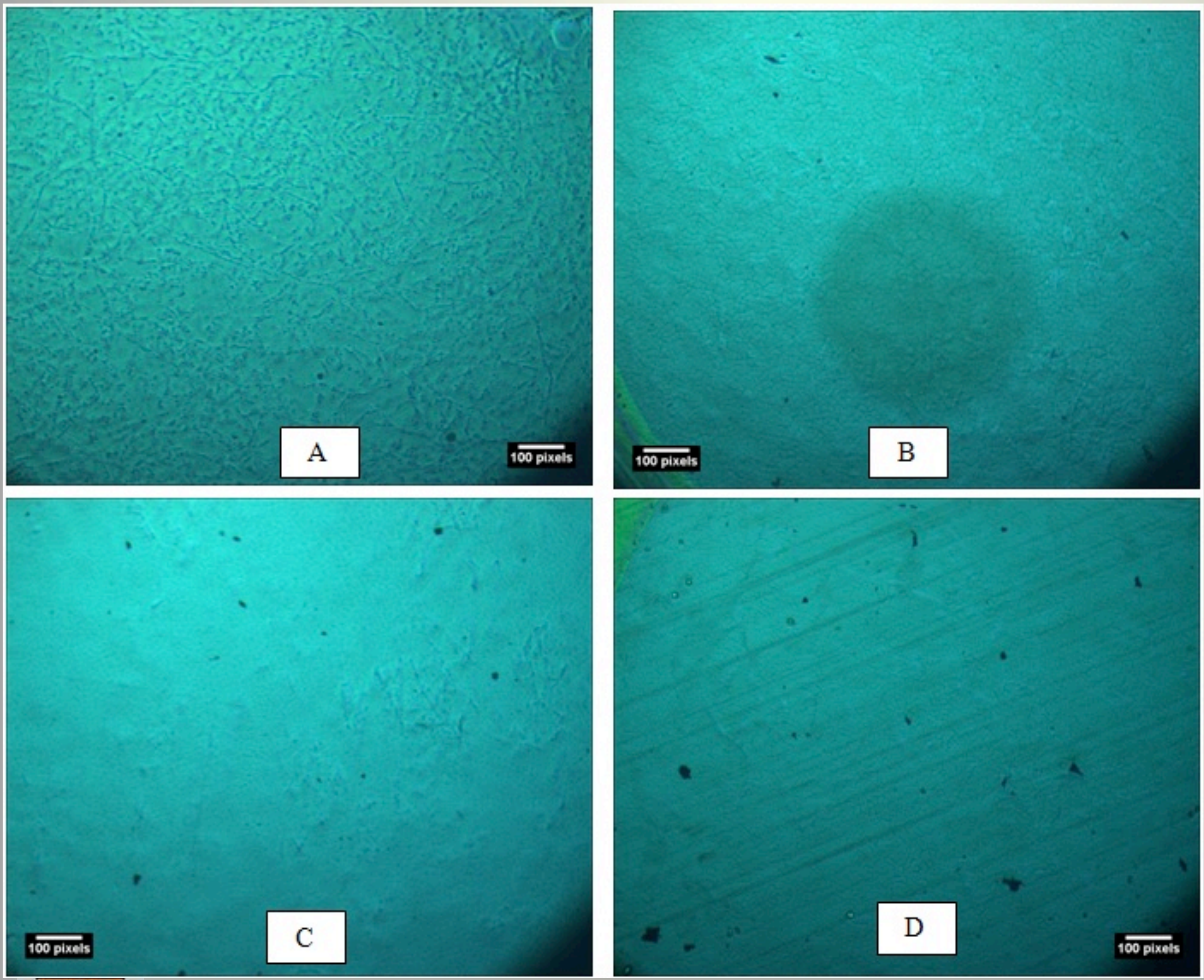




Bumps, cracks, but still can see "skin-like" texture.

No more "skin-like" texture can be seen.

Various aged RPCs' inner surface

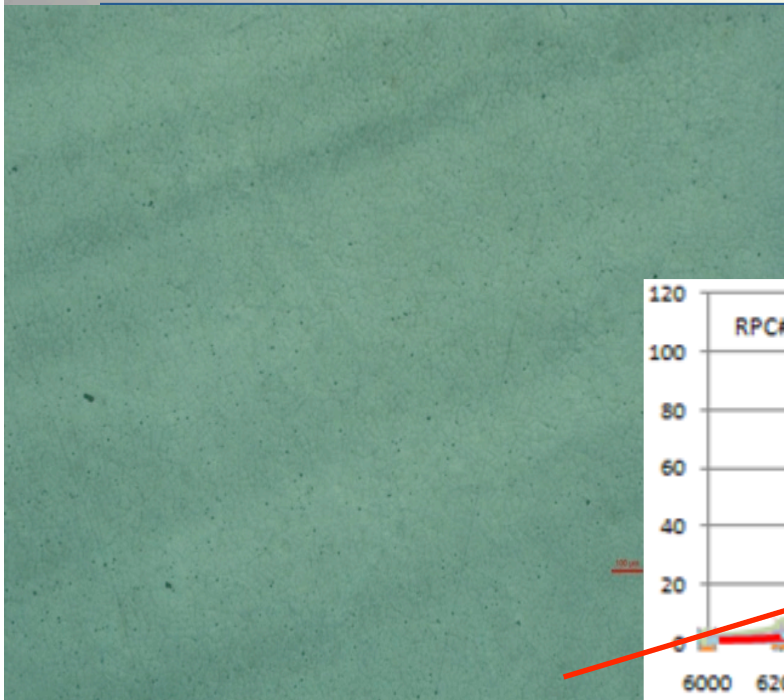


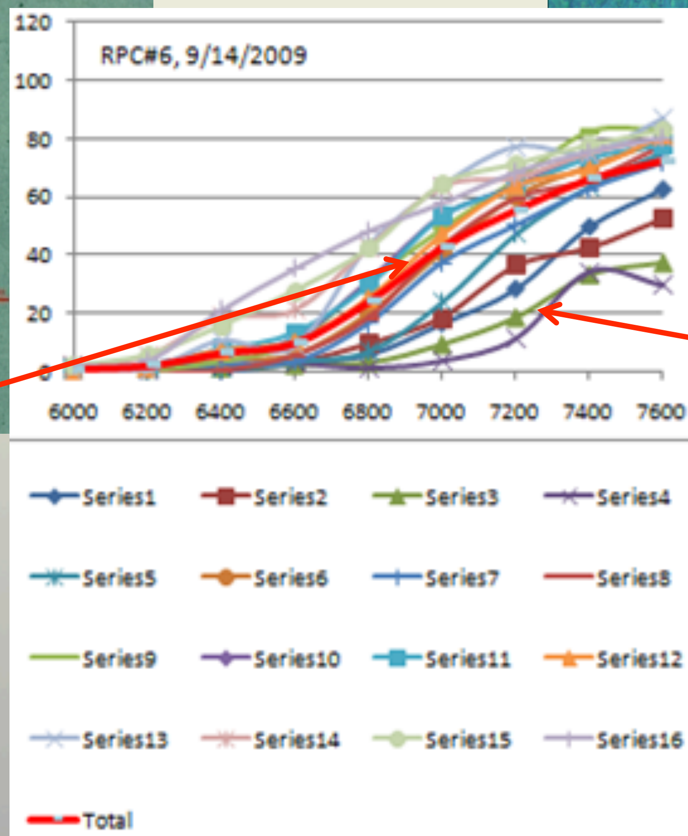
(A)RPC#4.
entire surface corroded, no more "skin-like" texture;

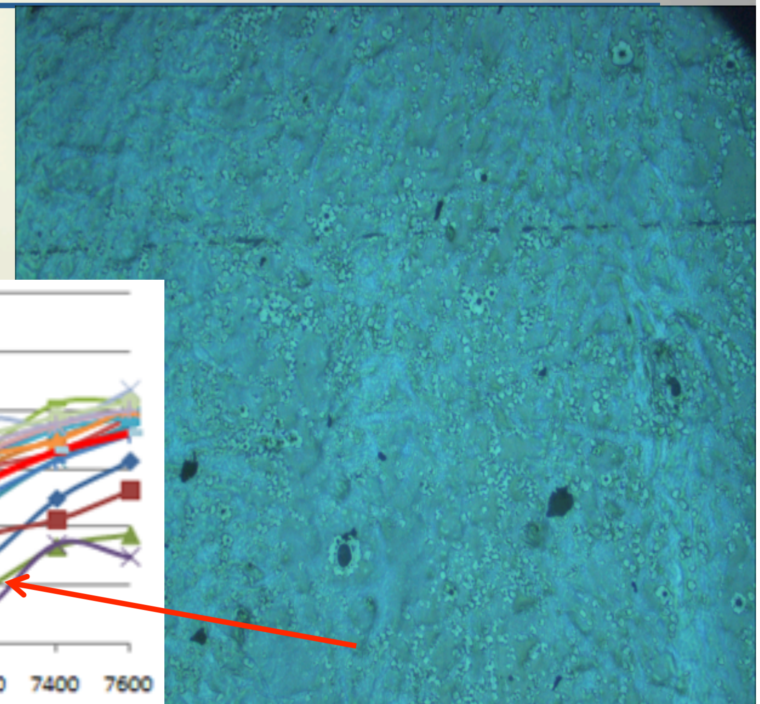
(B) (C) RPC#6/#7.
"skin-like" texture is atill can be seen, but start to show "veins";

(D) RPC#8.
Very faint "veins" on top of the "skin-like" texture.

Two different areas in same aged RPC



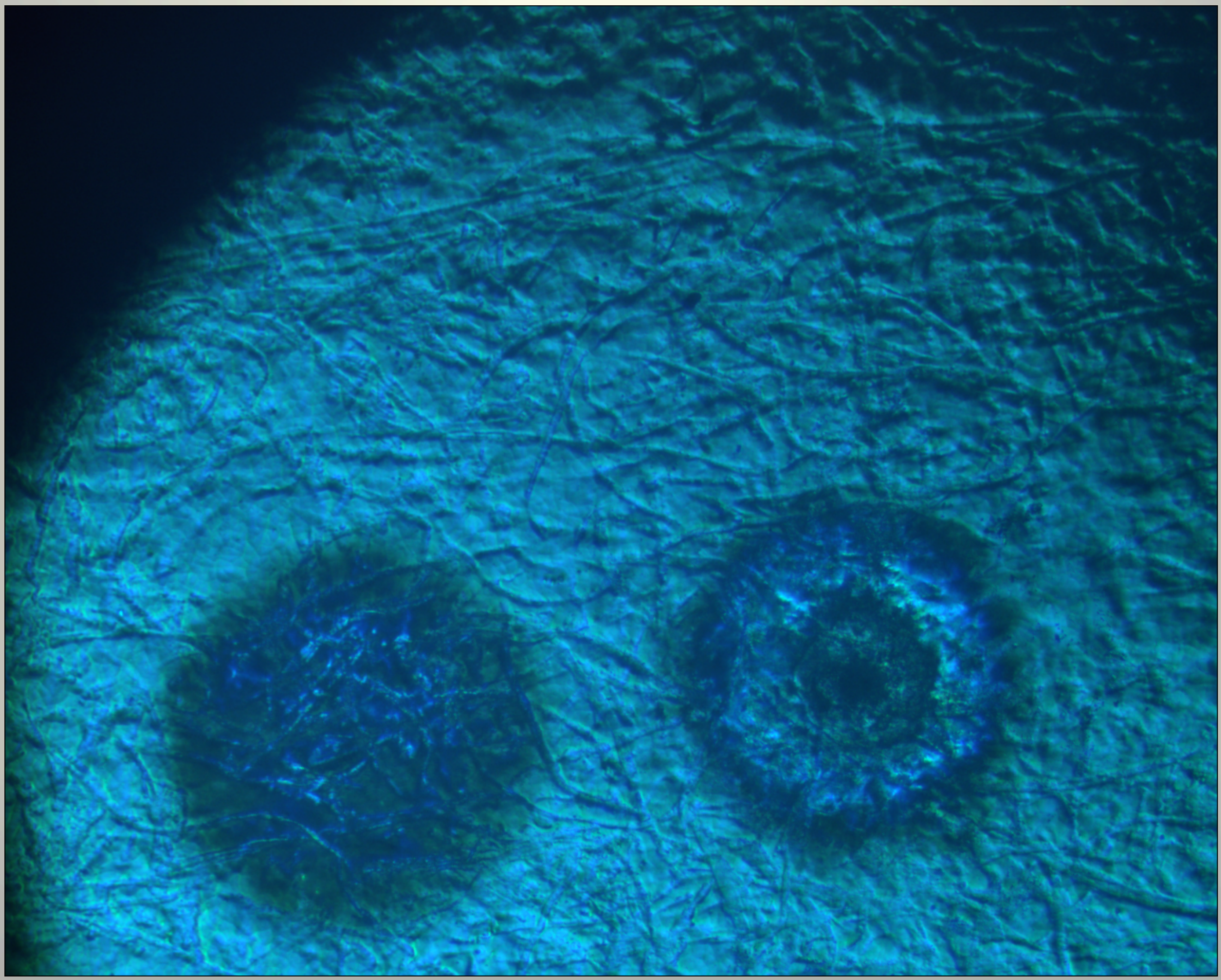




RPC #6, area #8, less aged area.

RPC #6, area #4, severely aged area.

Sparking marks



Working hypothesis of BESIII-type RPC aging

- With the gas mixture of Freon and others, the gas avalanches will produce HF molecules.

- These HF molecules are adsorbed on the inner surface, form HF acid with the water molecules released from the Bakelite electrodes.

- The corrosive action will take place on the inner surface. As the results the bumps may help to initiate the sparks.

- With the progress of the HF corrosion the inner surface is getting worse and worse, it would destroy the virgin Bakelite surface completely, the characteristic "skin-like" texture is then completely disappeared.

- Remaining question: Why the corroded surface affects the efficiency so severely? Macroscopically we didn't find dramatic change for their surface and volume resistivity.

BaBar RPC samples

Henry Band has opened some BaBar endcap RPCs. Some sample discs have been cut from the opened RPCs.

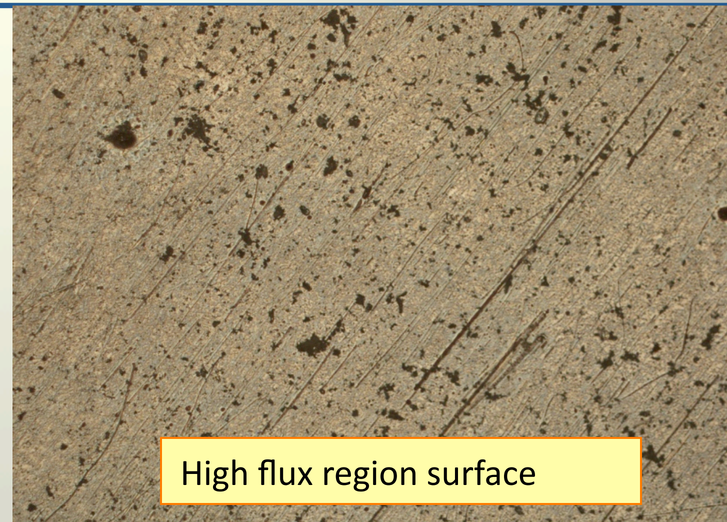
Some sample discs are cut from the high particle flux region, which is surrounding the beam pipe. Apparently the Bakelite is discolored in this region, which is consistent with what we have found in our HF vapor test. The sample from low particle flux region is less discolored.

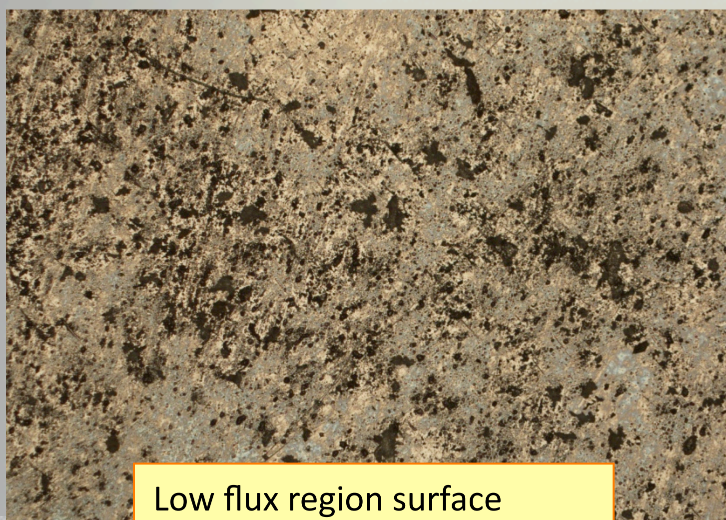
New Italian Bakelite

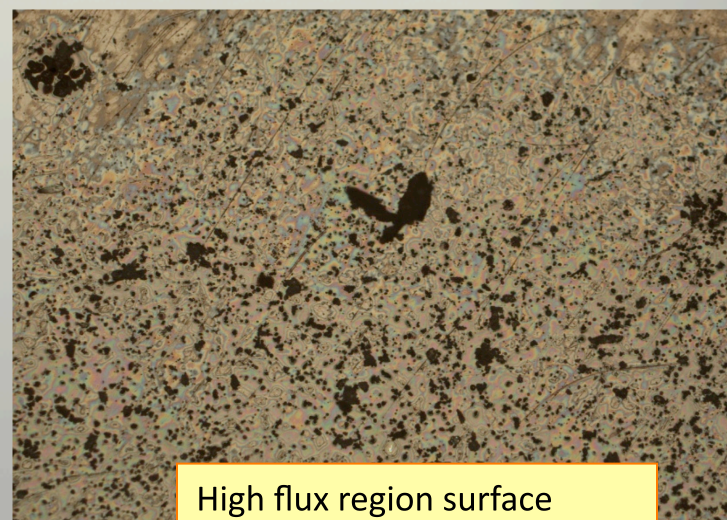
Discolored Bakelite (from high particle flux region)

Less discolored Bakelite (from low particle flux region)

Microscopic images of the BaBar samples

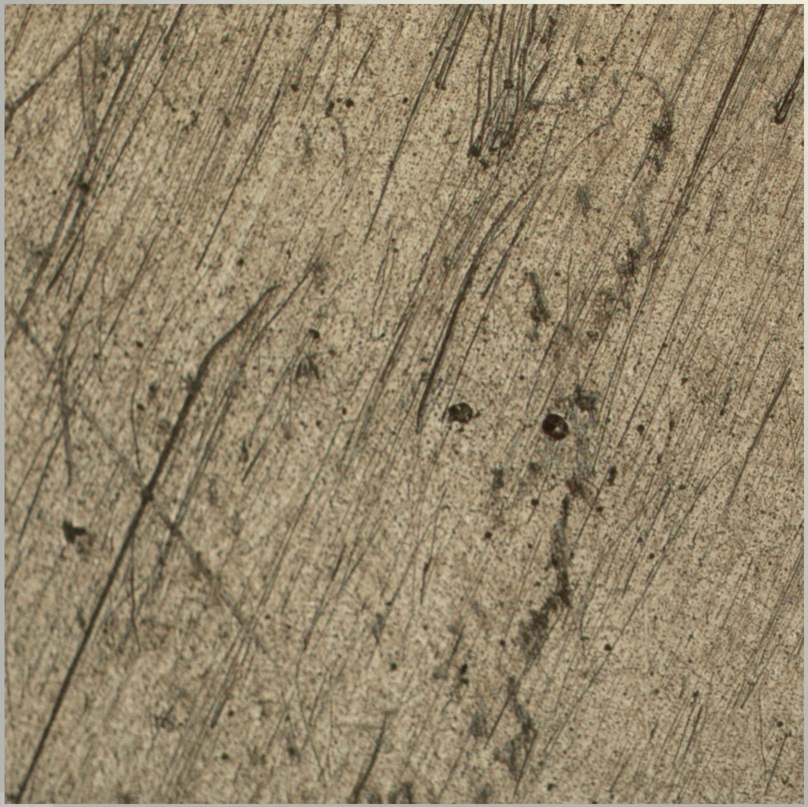




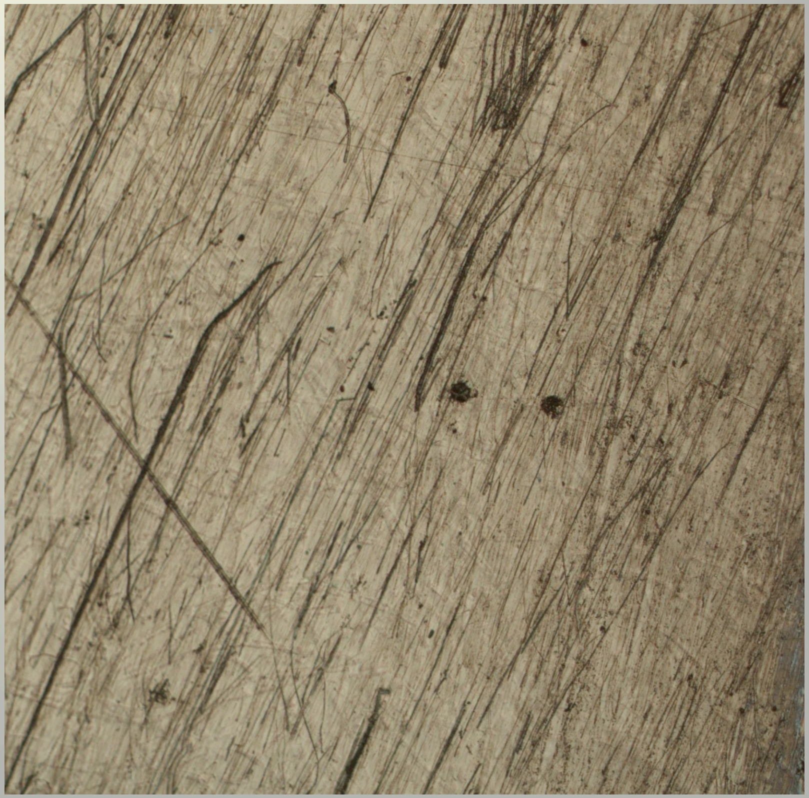


Highly discolored area sample

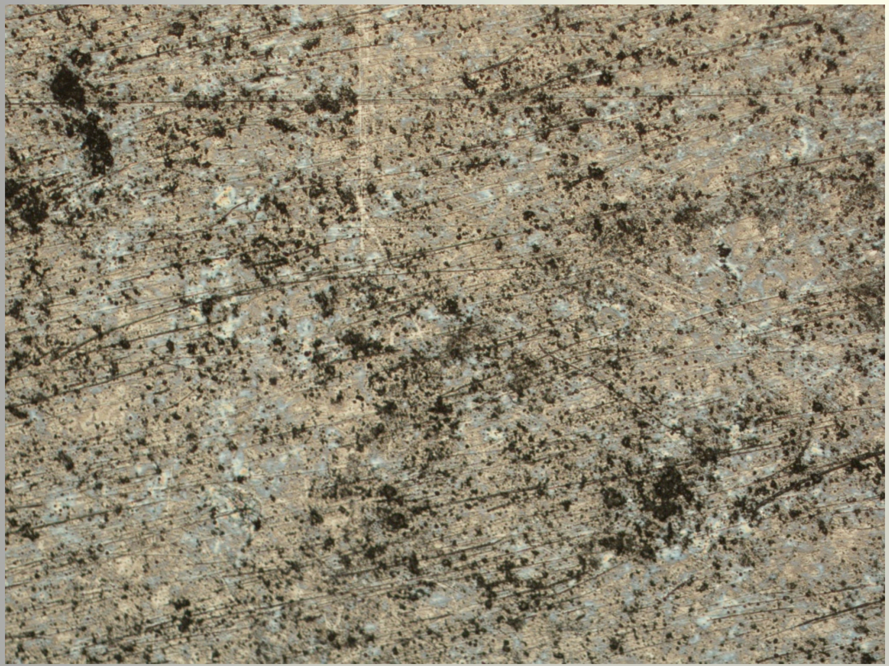
Surface with the Linseed oil coating, the sample is from high intensity area, the Bakelite is highly discolored.



Same area, use ethanol wipe out the surface oil coating. The Bakelite substrate looks no damage.



Less discolored area sample



Surface with Linseed oil coating.

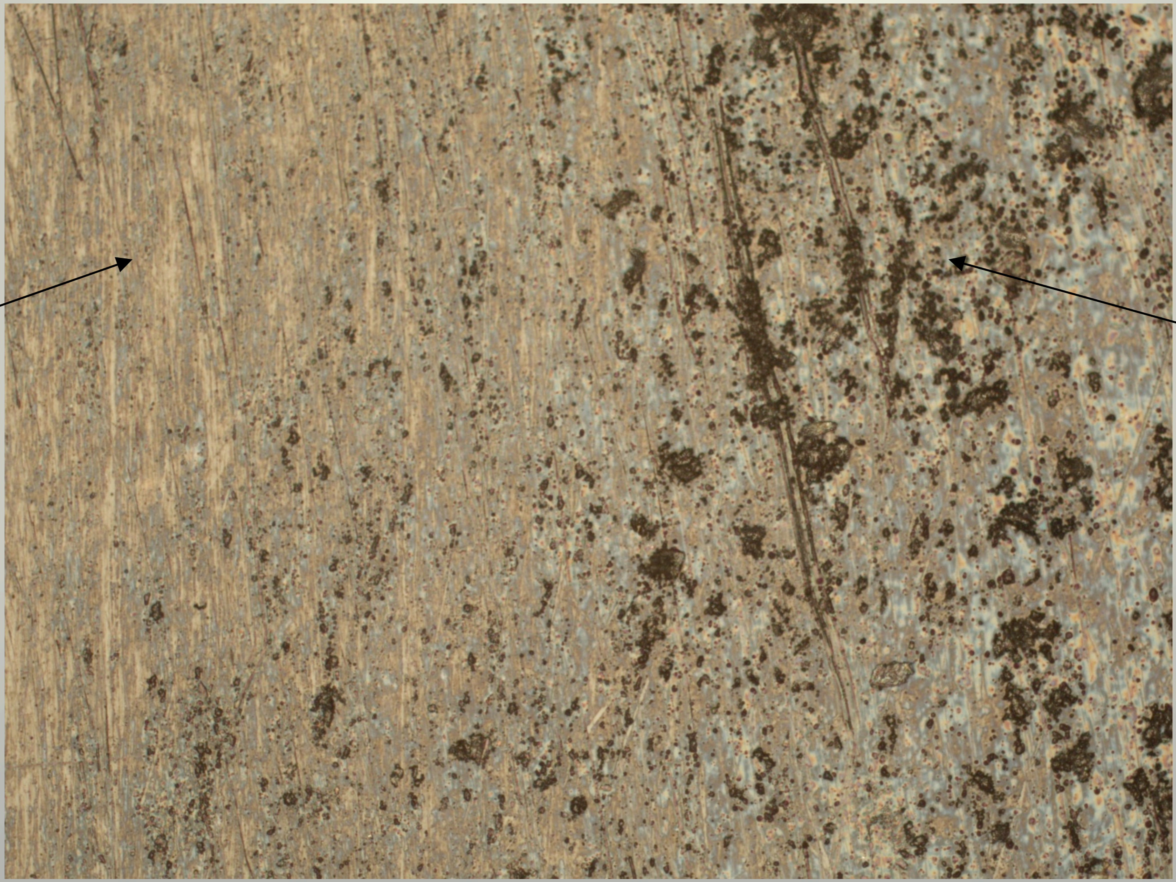
Same area Linseed oil coating has been removed by ethanol.

Compare two images we can clearly see the damage on Linseed oil coating. Actually the Bakelite substrate has not been etched by HF.

Less discolored area sample (cont'd)

Sample from low particle flux region:

Oil coating removed area



Oil coating remained area, the dark spots might be the damaged oil coating film.

BaBar samples surface resistivity test

The BaBar RPC electrode samples are coming from one RPC, therefore we can assume their initial surface resistivity more or less should be same. We measured 5 samples with a high resistivity meter: two of them are highly discolored samples, their resistances are $6.6\times10^{10}\ \Omega$ and $5.3\times10^{10}\ \Omega$; the other three samples are coming from low particle flux region, their resistances are $2.5\times10^{11}\ \Omega$, $3\times10^{11}\ \Omega$ and $2.5\times10^{12}\ \Omega$. The average resistance for high flux and low flux regions are: $6\times10^{10}\ \Omega$ and $1\times10^{12}\ \Omega$, respectively. Surface resistance is reduced by one order of magnitude.

What causes the surface resistivity lower?

What are the dark marks on the aged electrode surface?

How these changes can cause the efficiency degraded?

What to do next?

The surface of BESIII-type Bakelite is vulnerable to the HF attack, which is the major culprit of aging.
We have found that Linseed oil coating film has good resistance to the HF, that is a backup solution for prolong the aging of the BESIII-type RPC.
We are also developing new variant of Bakelite sheet, which has embedded Linseed oil during the Bakelite production, therefore no longer need to coat the inner surface after the RPC has been made.
There is some encouraging sign of this technique, we decided to pursue this solution.
Our Chinese collaborator has made some new Bakelite with embedded Linseed oil coating on the surface, also made some RPC chambers with this new Bakelite. We'll test the new RPCs soon. This will be the starting point of our second year's R&D project.