R&D on IHEP Bakelite RPC

Changguo Lu

Princeton University

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Outlines

- Bakelite surface VUV photosensitivity study;
- HF acid: production in RPC, attack the RPC;
- Full size (1mX2m) IHEP RPC prototype test report.

I, UV sensitivity of the RPC electrodes

Why we concern the UV sensitivity of the RPC electrodes?
⇒ Cutting down the noise rate.

RPC always has much higher noise rate than the wire chamber. If we compare the single's rate plateau for Iarocci tube and RPC, we'll find:

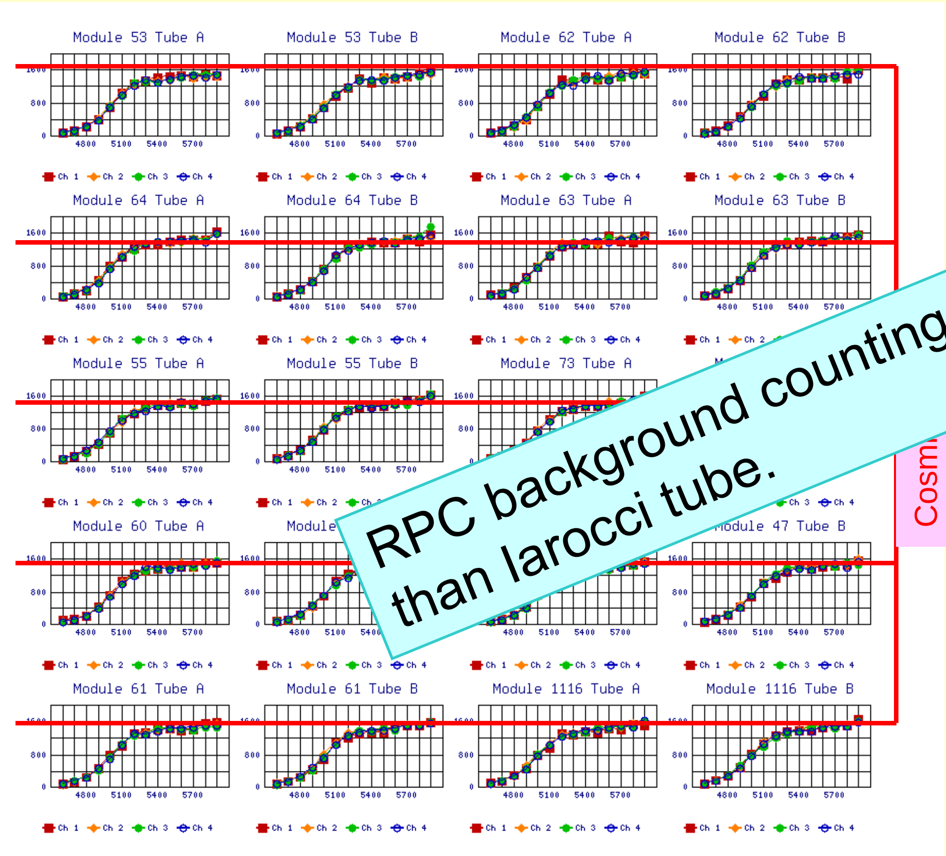
• Iarocci tube can get beautiful single's rate plateau curve, and its plateau counting rate is close to the cosmic ray background;

• RPC never can get real flat single's rate plateau. Its counting rate is much higher than the cosmic ray background. (see next slide)

Much higher electric field strength on the cathode surface.

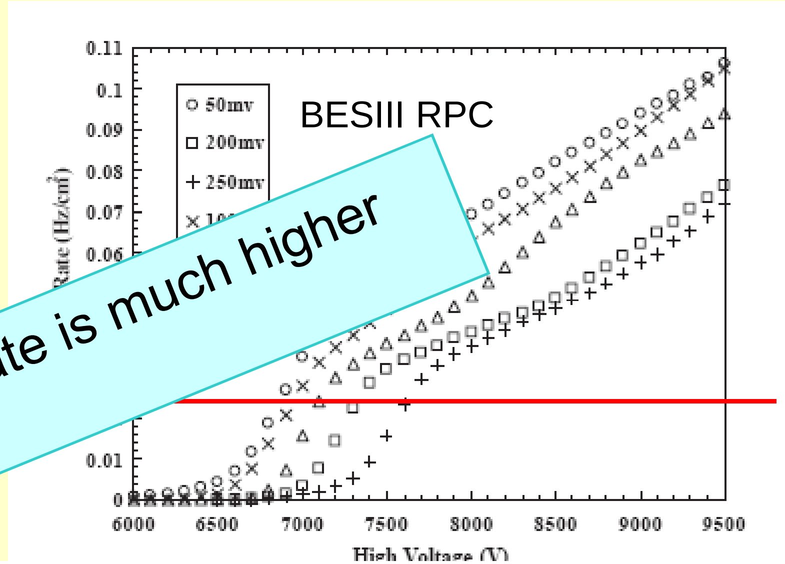
Typical single's rate plateau curves

Iarocci tube



BaBar Barrel LST tubes

RPC



RPC background counting rate is much higher than Iarocci tube.

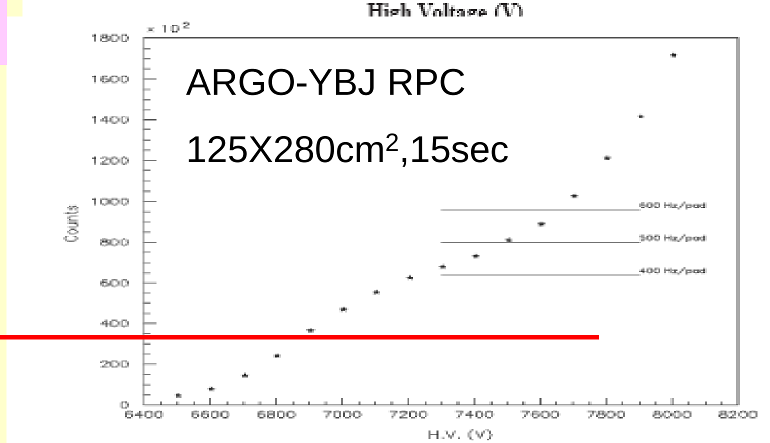
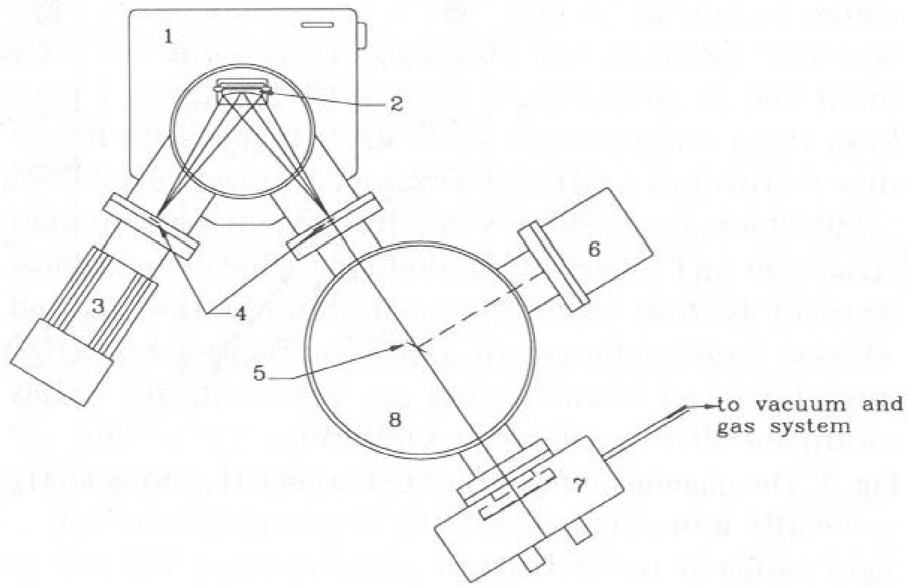


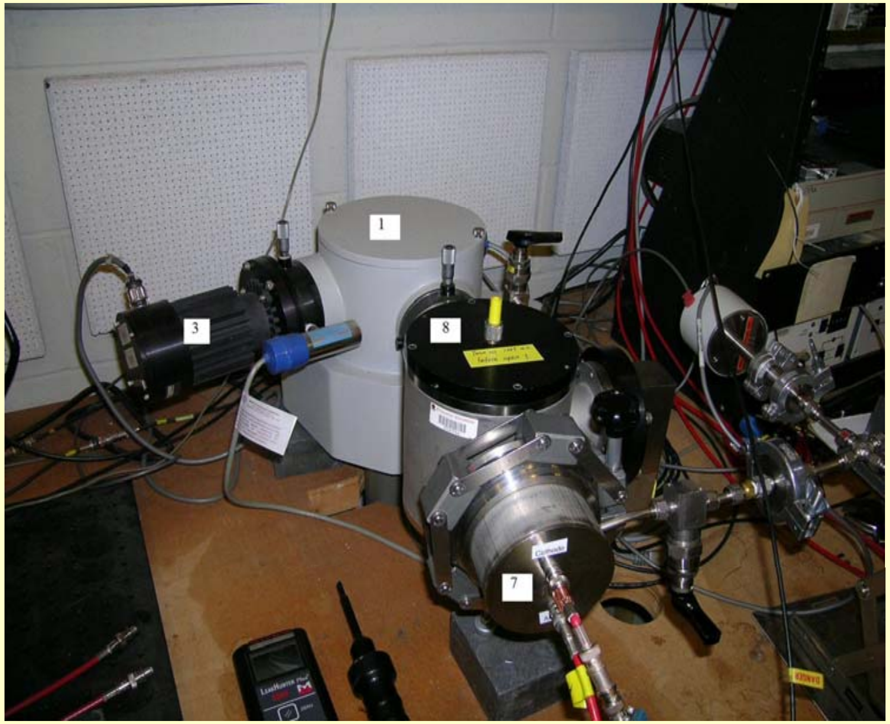
Fig. 5. Counting rate: the counts refer to an entire RPC in a time window of 15 s.

UV sensitivity test device

McPherson Monochromator

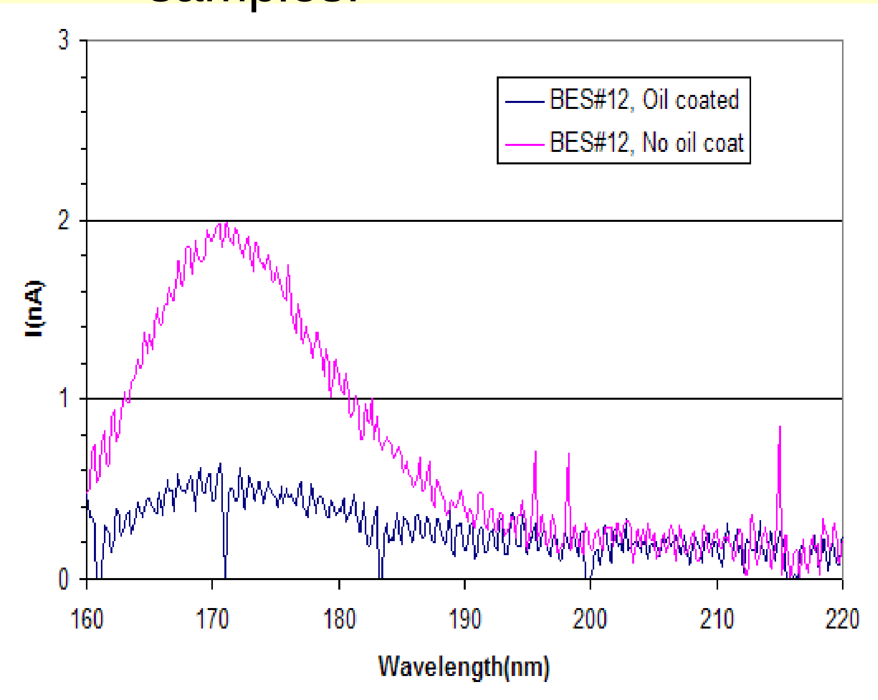


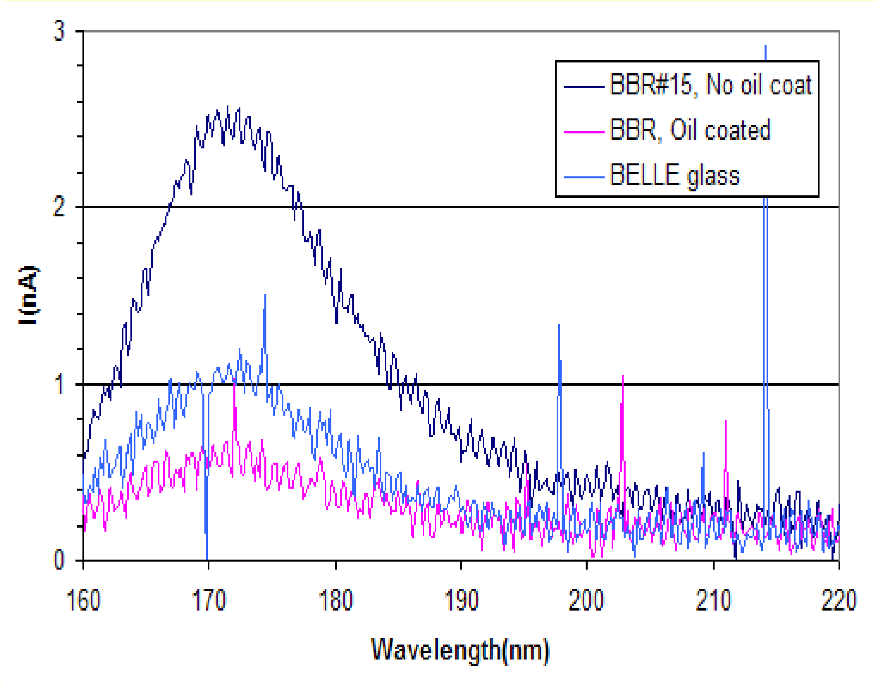
Sketch of the VUV monochromator. 1: Model 234/302 0.2 m vacuum monochromator; 2: Halographic grating; 3: model 632 deuterium source unit; 4: entrance and exit slits; 5: UV mirror; 6: model 654 side-on PMT detector with sodium salicylate screen; 7: test chamber (semitransparent or reflective photocathode); 8: vacuum compatible sample chamber.



VUV sensitivity test results

Comparison of w/, w/o Linseed oil coating Bakelite and glass samples:





Linseed oil coating — very essential for dramatically cutting down the UV sensitivity of the cathode surface.

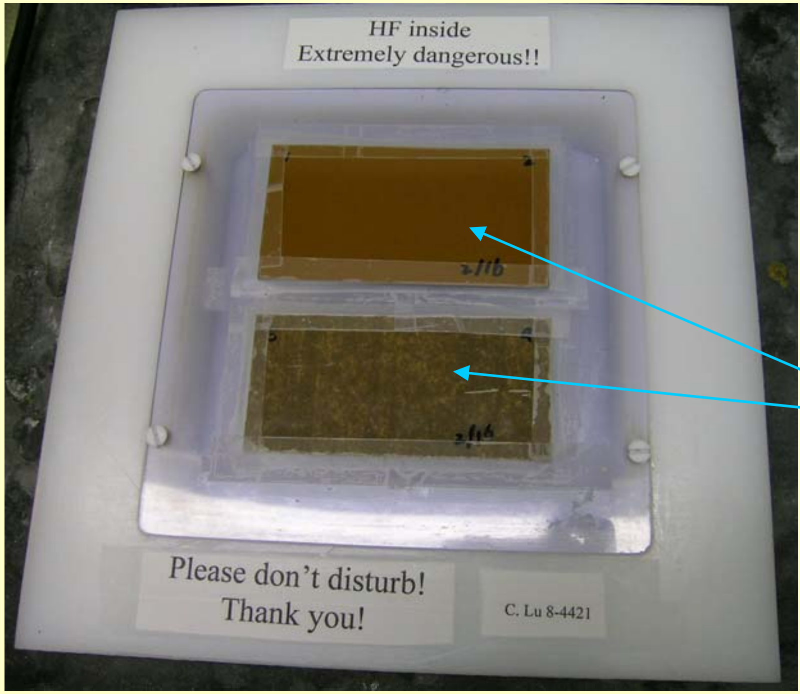
II, HF corrosive effect on RPC electrode surface

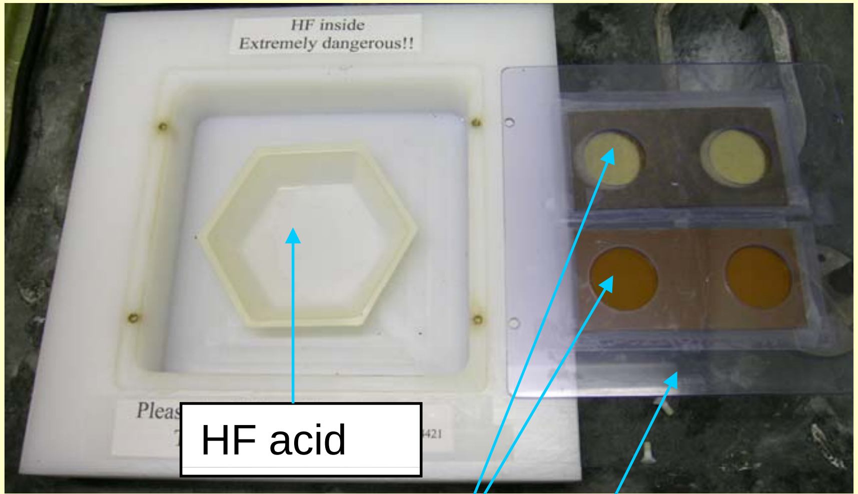
The major component in RPC gas mix is R134A - $C_2H_2F_4$.
In the electrical discharge it can produce significant fluoride radicals, and further form HF. HF is notoriously chemical reactive, it can attack many different materials.

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 robust to the HF attack.

Test device



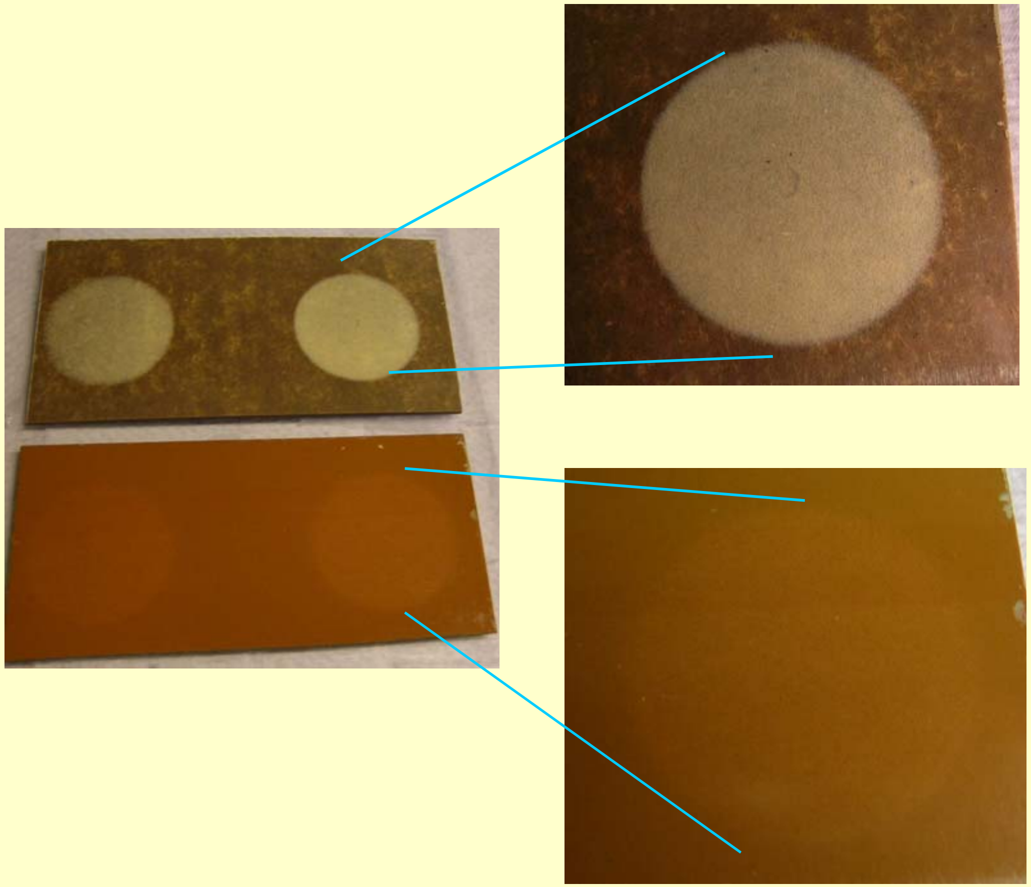


HF acid

Testing samples

Cover plate with 4 round windows that let the testing samples exposed to HF vapor.

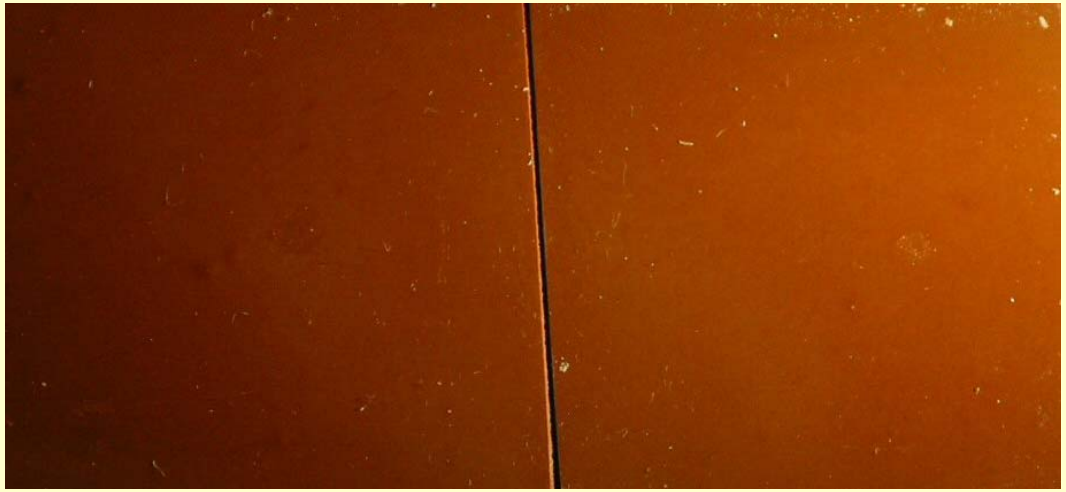
Effect on BaBar Bakelite surface



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

Brown side of Bakelite plate shows slightly discolored mark.

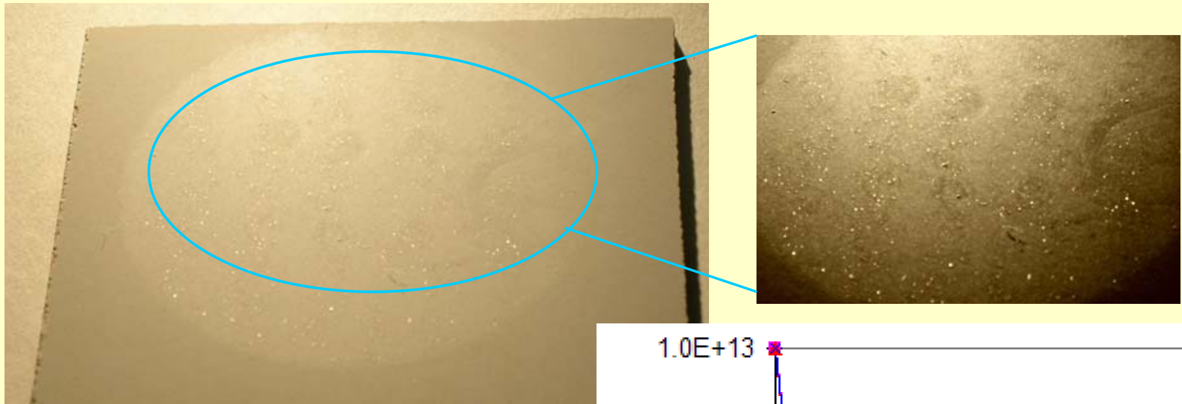
Effect on Linseed oil coated Bakelite



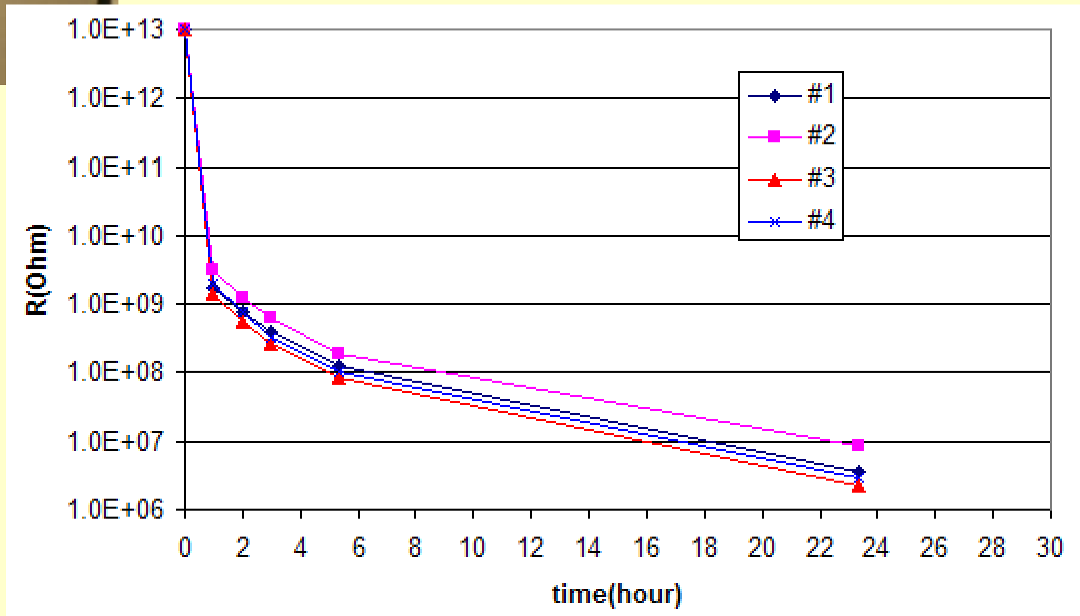
The Linseed oil coated Bakelite surface is much better protected from HF vapor attack. After 24 hours of exposure there is no discolored area can be seen.

Effect on IHEP Bakelite surface

Surface has been badly attacked by HF vapor.



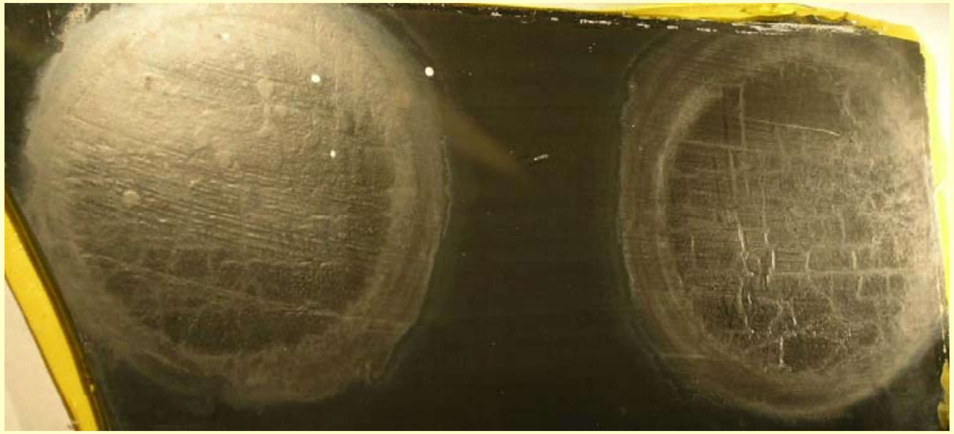
Surface resistivity drops very fast in first hour of exposure.



Effect on various other materials

Belle's RPC glass surface

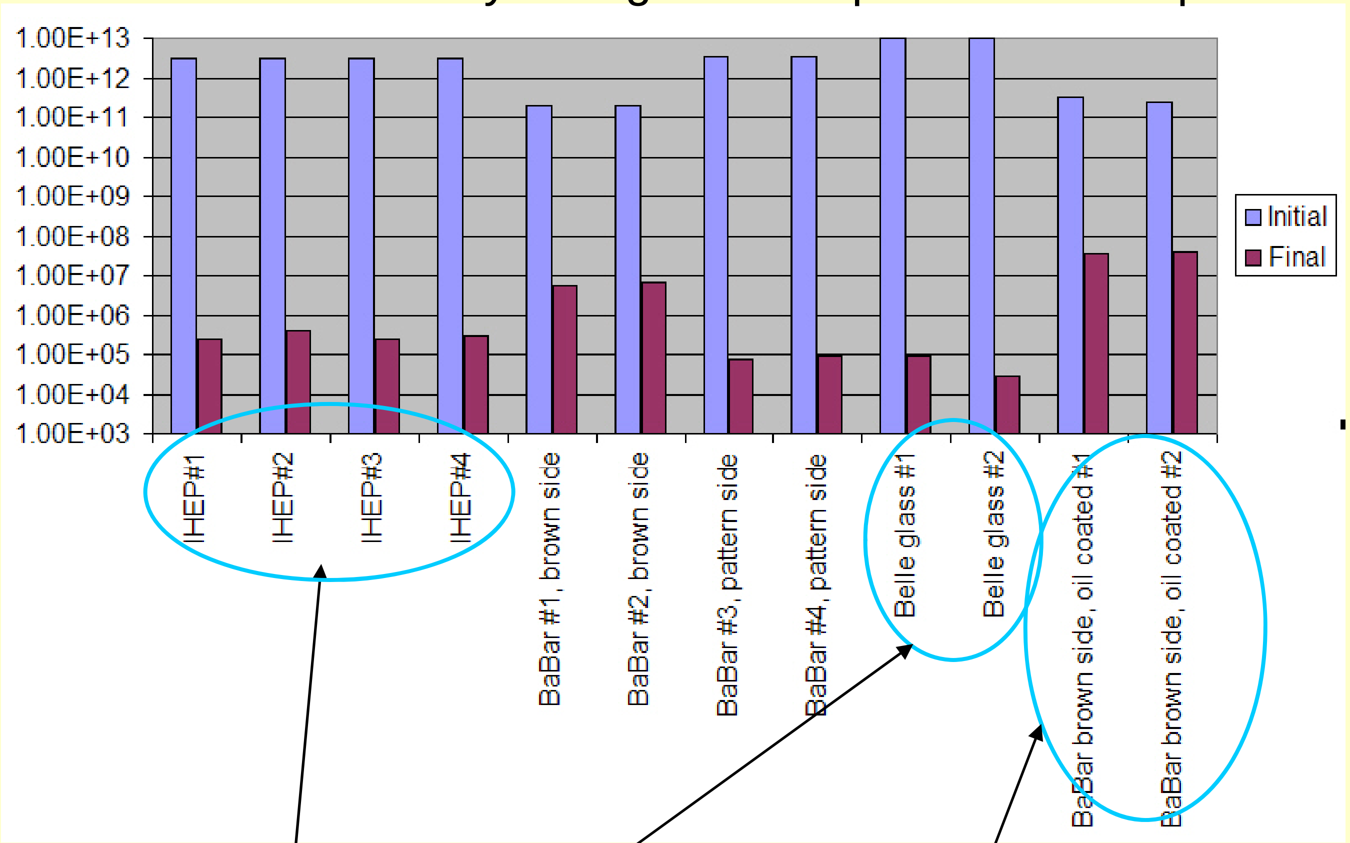
After exposed to HF vapor for ~24 hours, the surface looks powdery fluffy.



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

Summary of the HF tests

Surface resistivity change after exposed to HF vapor



We can see that the surface resistivity reduction for IHEP Bakelite samples is ~10^{-7}, for Linseed oil coated BaBar Bakelite samples is ~ 10^{-4}, the glass surface is worse than IHEP Bakelite.

What we observed in BaBar RPCs?

On the inner surface of an opened BaBar RPC **many white spots** on the anode were found, and on the opposite cathode surface corresponding Linseed oil droplets can be seen*.

It is not a fiction, HF corrosive effect is a real threat to the aging of RPC!!

Po… hese white …

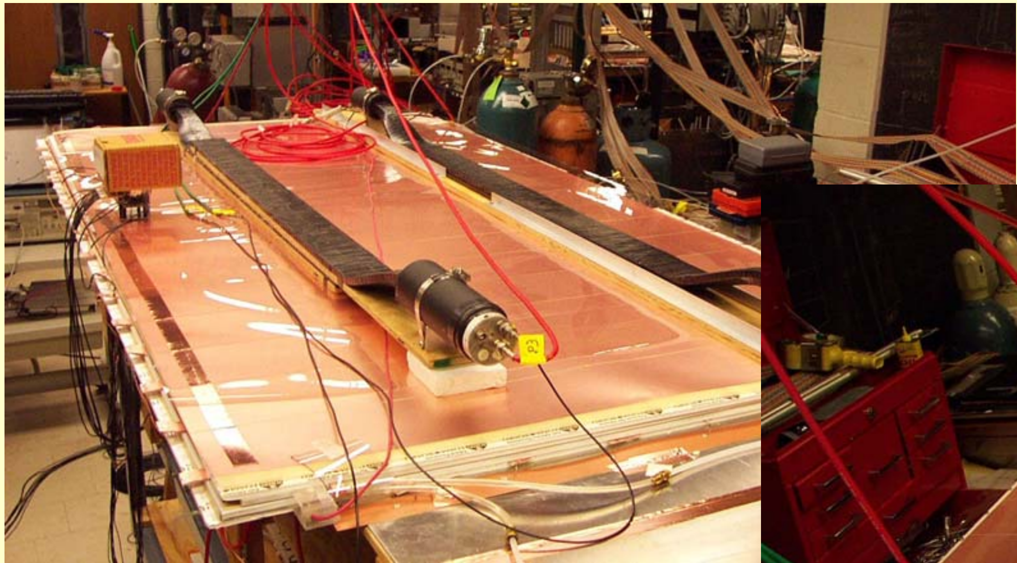
…ght be due to HF corrosion effect. In a self-sustaining sparking mode, tremendous HF can be formed on the anode surface (F^- drifts towards anode), as we found in our HF corrosive test, the "marble" surface would be "bleached" and the surface becomes very rough, it would further worsen the sparking area. This action is irreversible.

*J. Va'vra, http://www-nova.fnal.gov/workshops/stanford03/transparencies/vavra_RPC_summary_2003_talk.pdf

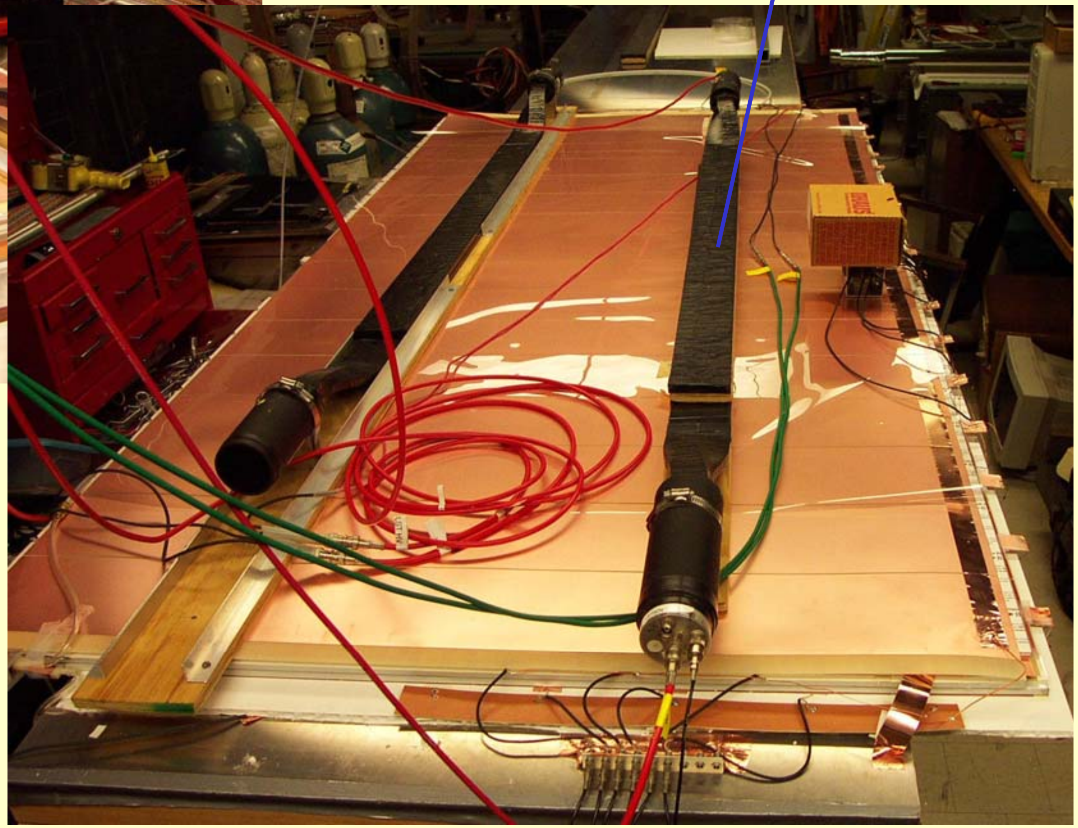
III, Test IHEP full size RPC prototypes

- Test setup;
- Double gap RPC;
- Dark current;
- Cross talk on neighboring strips;
- The effect of strip termination on the pulse shape;
- Charge spectrum, Q vs HV;
- Efficiency plateau.

Test setup and gas mixture



Double-gap RPC



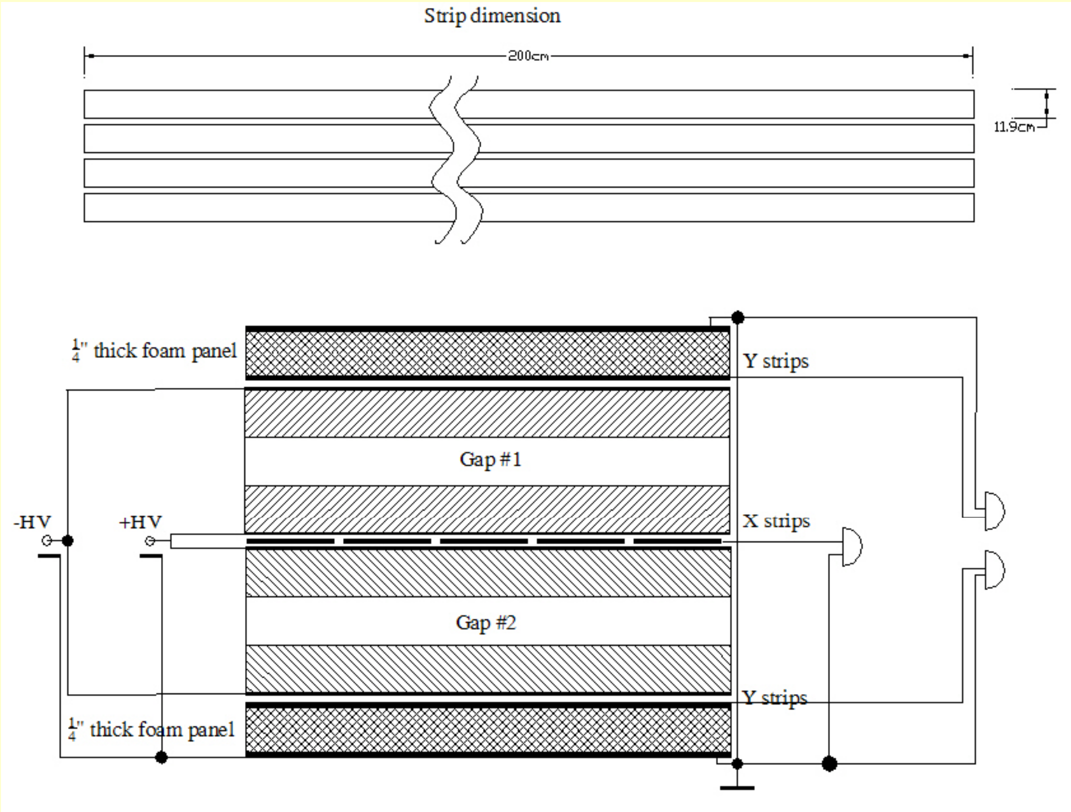
Trigger counters

(7.2cm wide, 100cm long, 1cm thick)

The gas mix and flow rate used in this test: R134A/Isobutane/Ar (10/1.9/12 sccm), e.g. the mixing ratio is (41.8/8/50.2%)

Double-gap RPC

Strip dimension and double gap RPC structure:



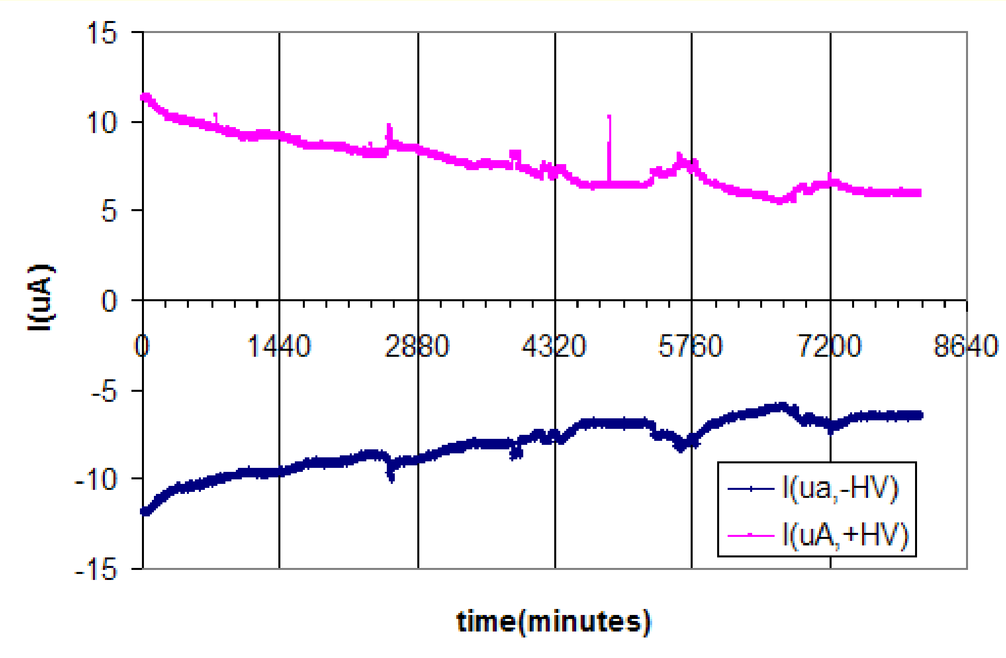
The X-strips have induced charge from both top and bottom gaps, so the signal size would be doubled!

We were doubt about the signal return path for the X-strips and didn't find report on this readout scheme, so just test with the real chambers.

X-strips: vertical; Y-strips: horizontal.

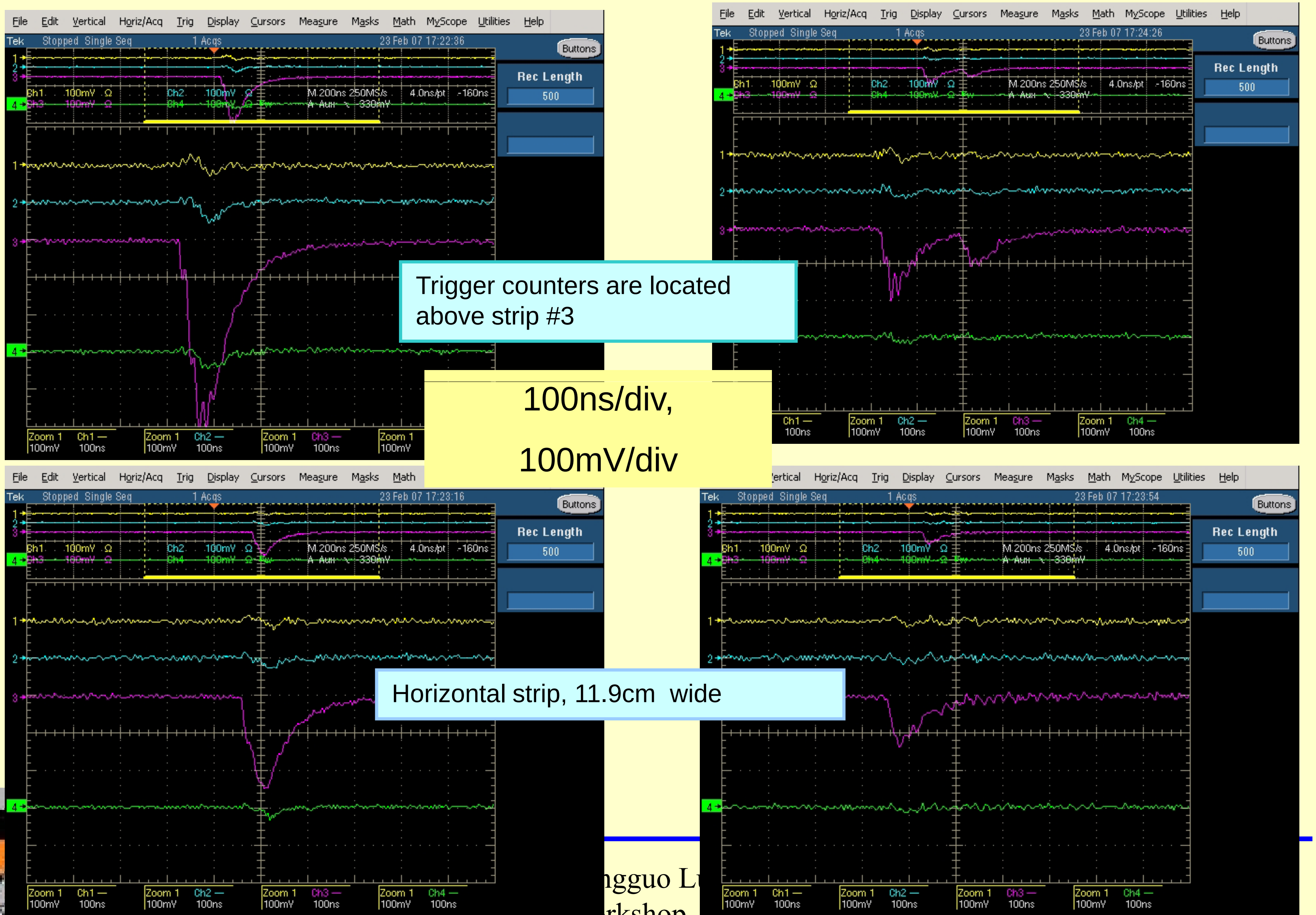
Drawing currents from +/- HV supplies

The drawing currents from +/-HV supplies (Bertan) are almost identical, it indicates that there is no leakage current through outside surface of the RPCs. Otherwise it would show the unbalance +/-HV currents. After 5 days continuous HV training the dark current drops to half of initial value: 6μA/4m^2 at 7400V, the efficiency at this HV already reaches plateau.



Cross talk on neighboring strips (single strip)

S1
S2
S3
S4



Trigger counters are located above strip #3

100ns/div,

100mV/div

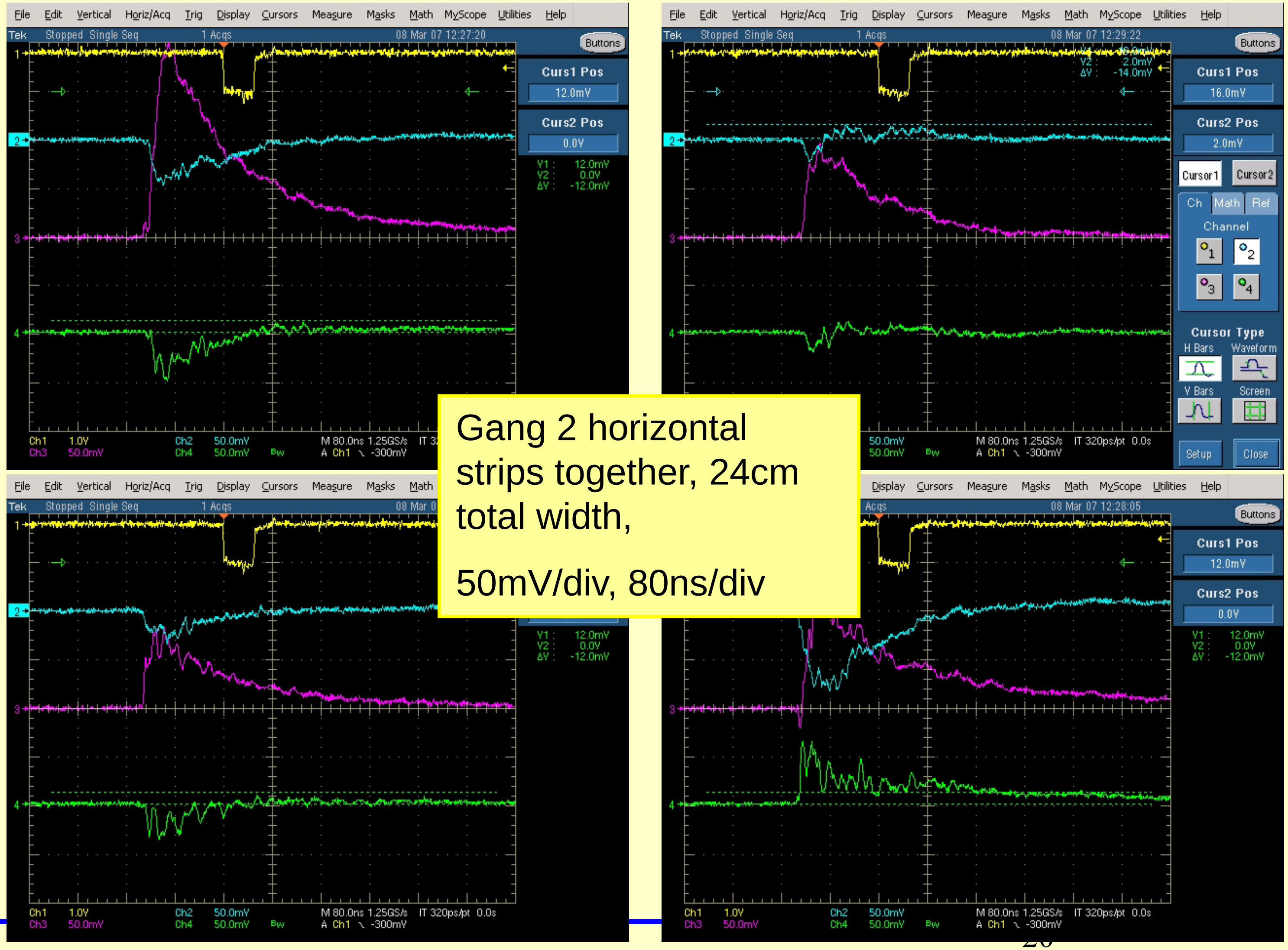
Horizontal strip, 11.9cm wide

Cross talk on neighboring strips (double strip width)

Neighboring strip

Strip aligned with trig.

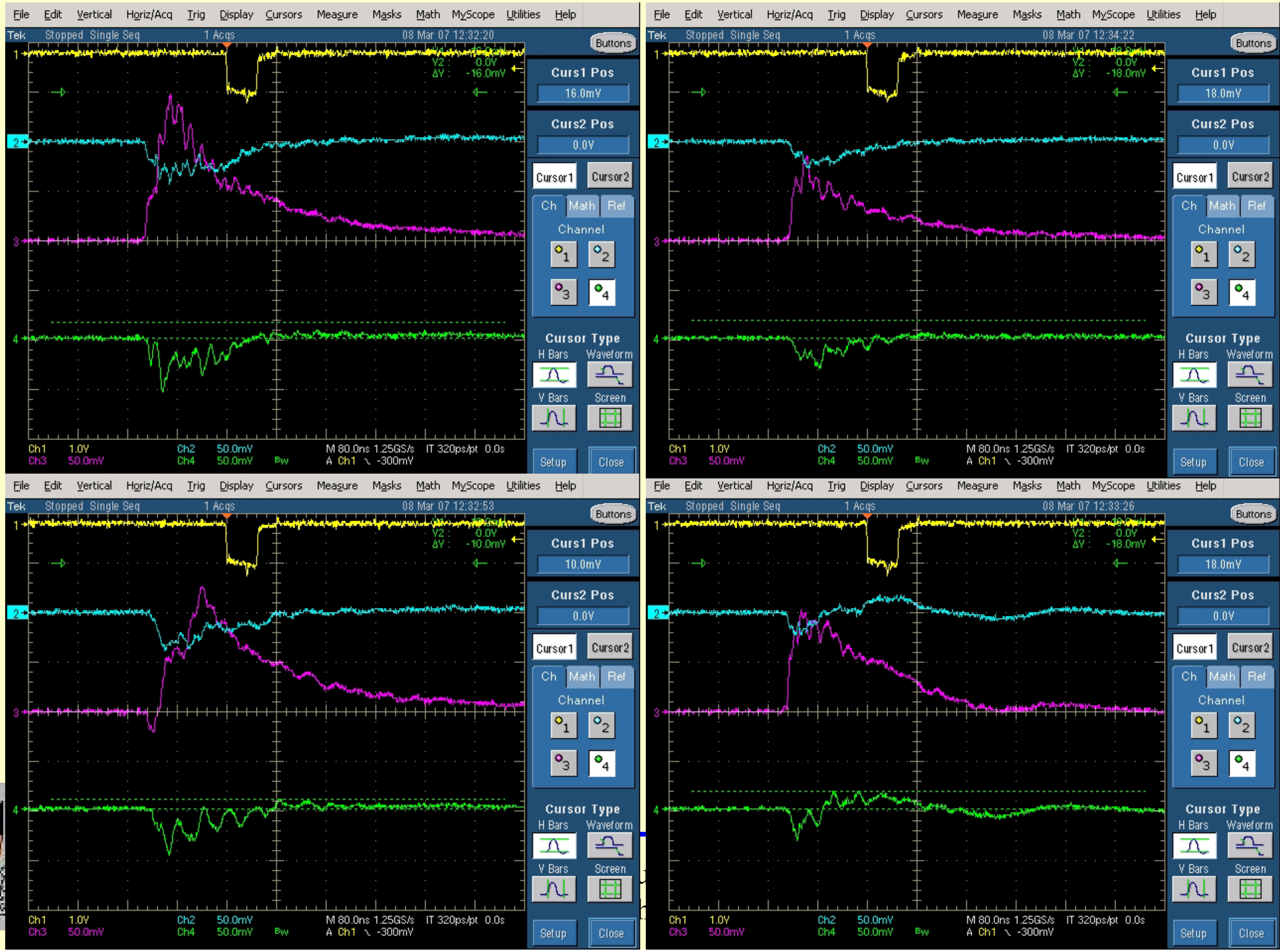
Neighboring strip



Gang 2 horizontal strips together, 24cm total width,

50mV/div, 80ns/div

More screen captures of the cross talk signals
(double strip width)

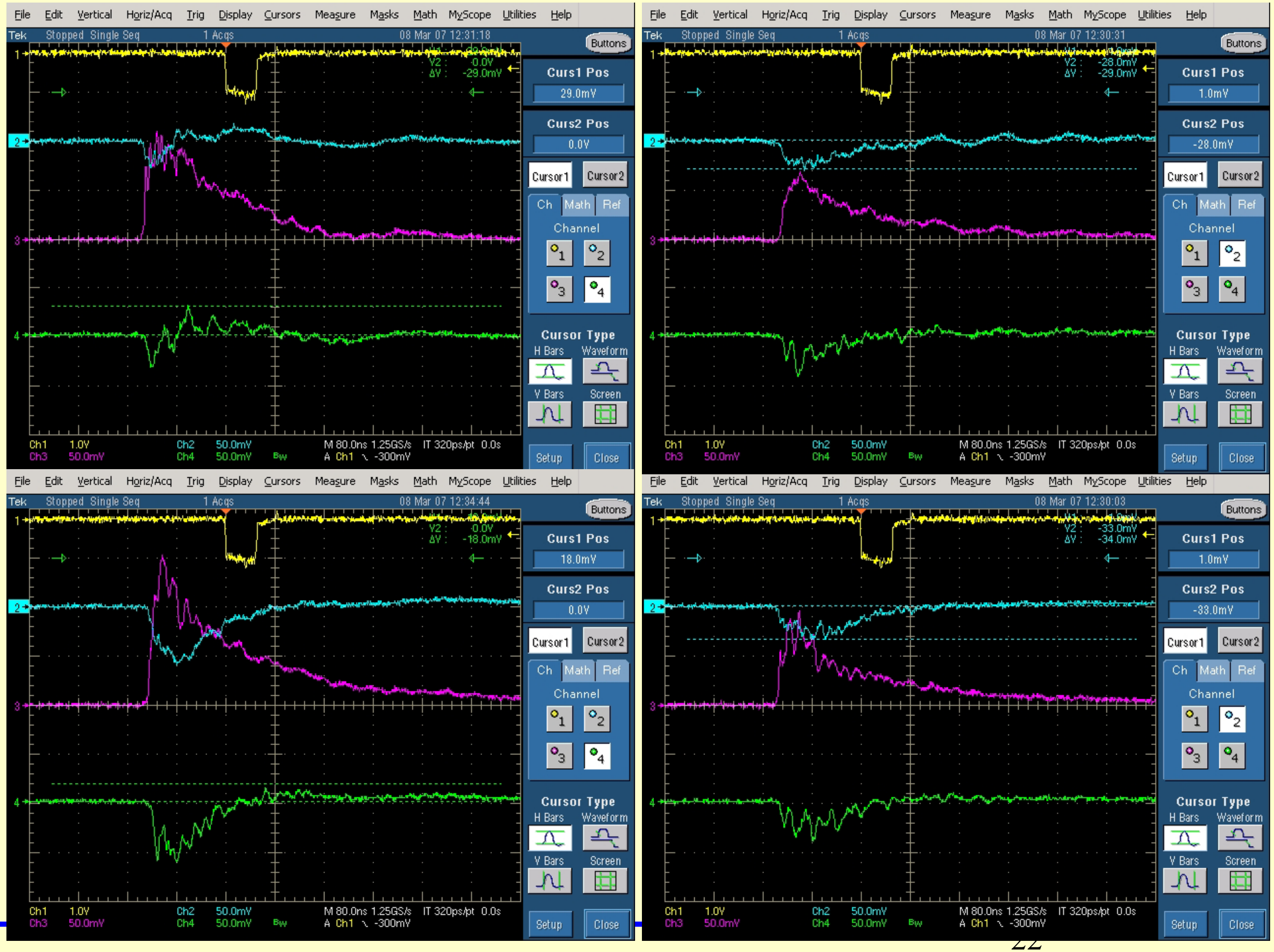


… More cross talk …

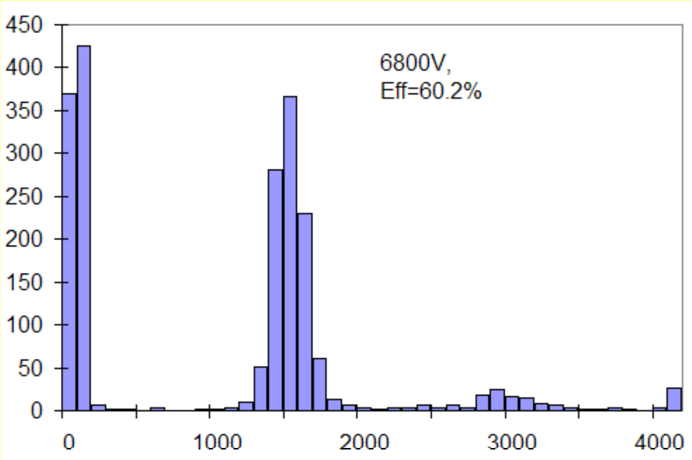
(double strip width)

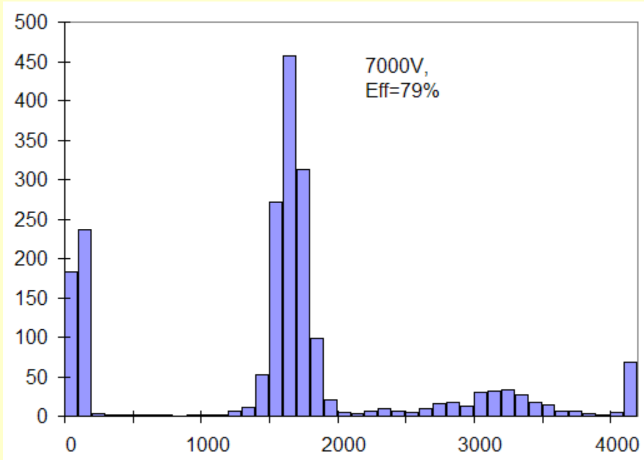
When doubled the strip width, the cross talk signal changes polarity. They won't trigger the polarity defined discriminator. This is a very nice feather!

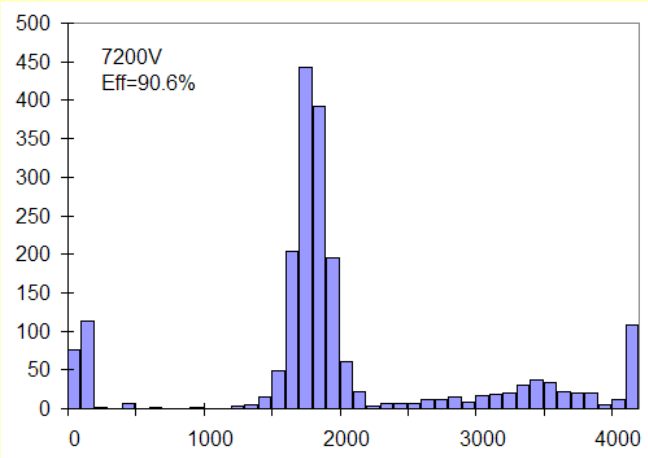
The main signal width becomes broader, amplitude smaller, but looks still large enough! Need to use discriminators to check efficiency.

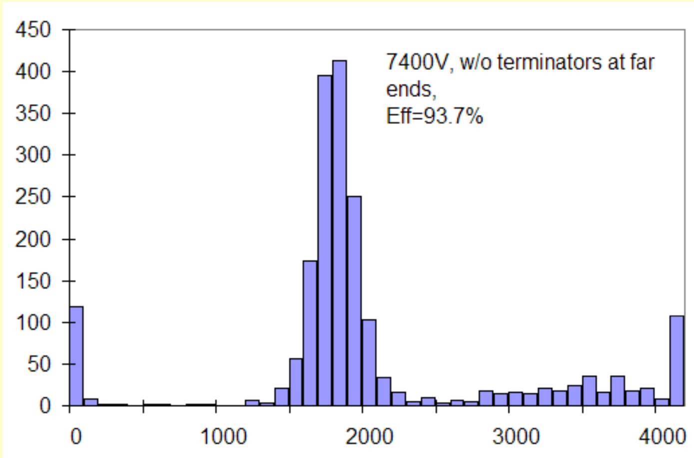


Charge spectrum of single gap RPC



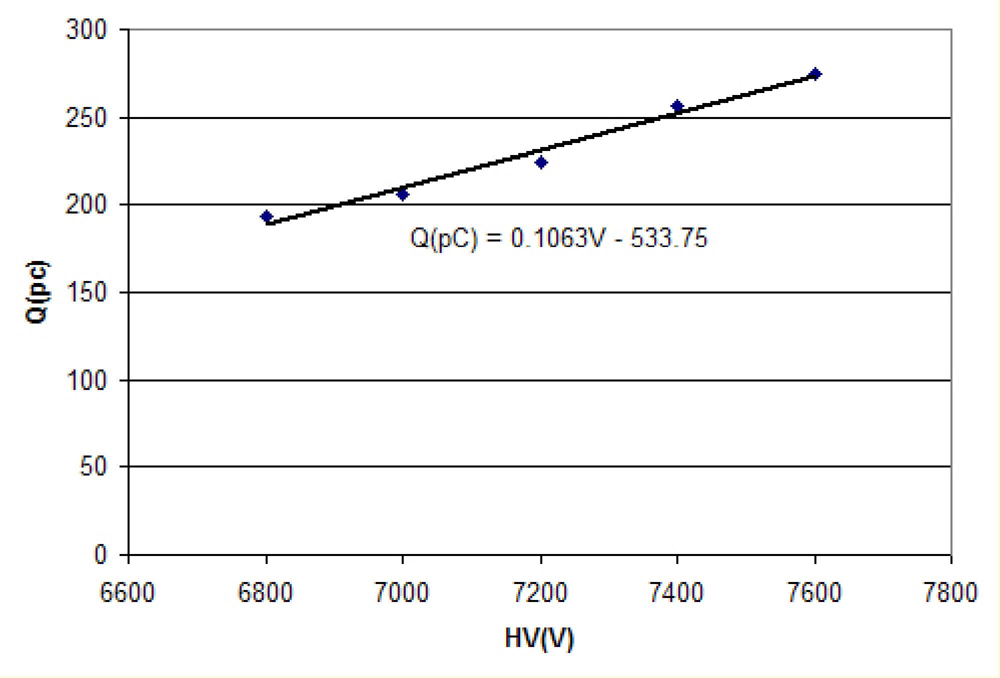






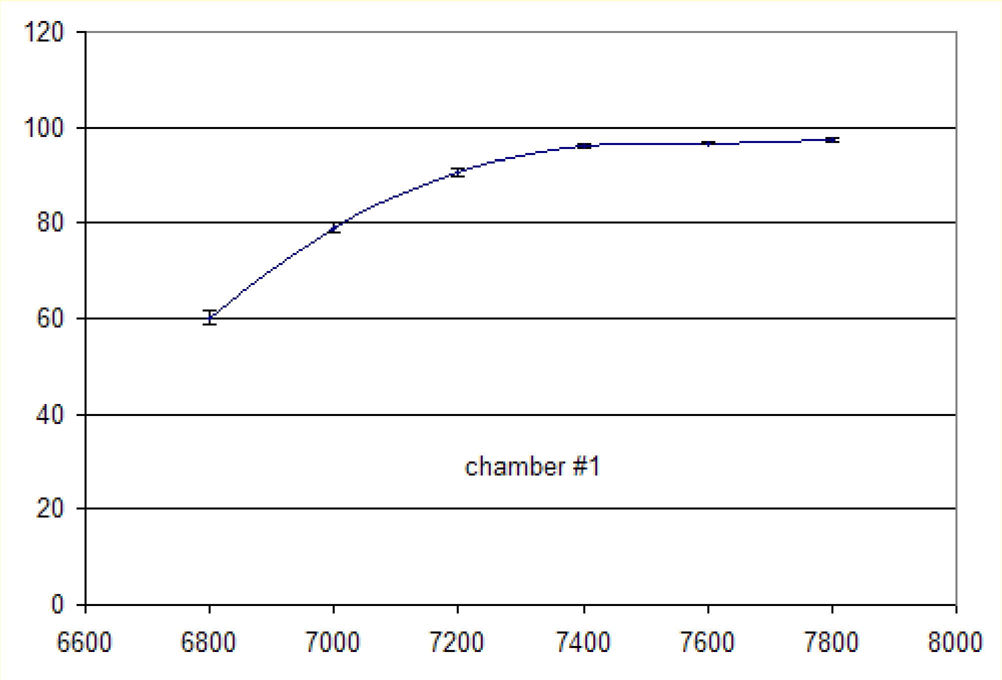
Charge vs. HV in single gap RPC

Plot the charge at the largest peak of the spectrum vs. HV:



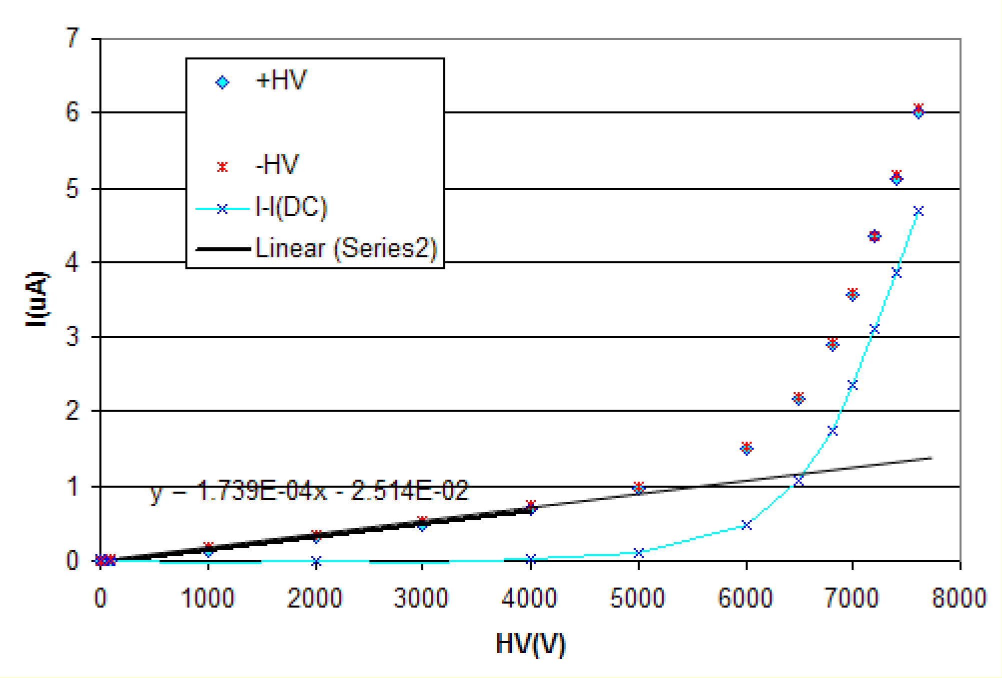
Efficiency plateau for single gap RPC

For single gap RPC at HV = 7400V it reaches efficiency plateau ~94%.



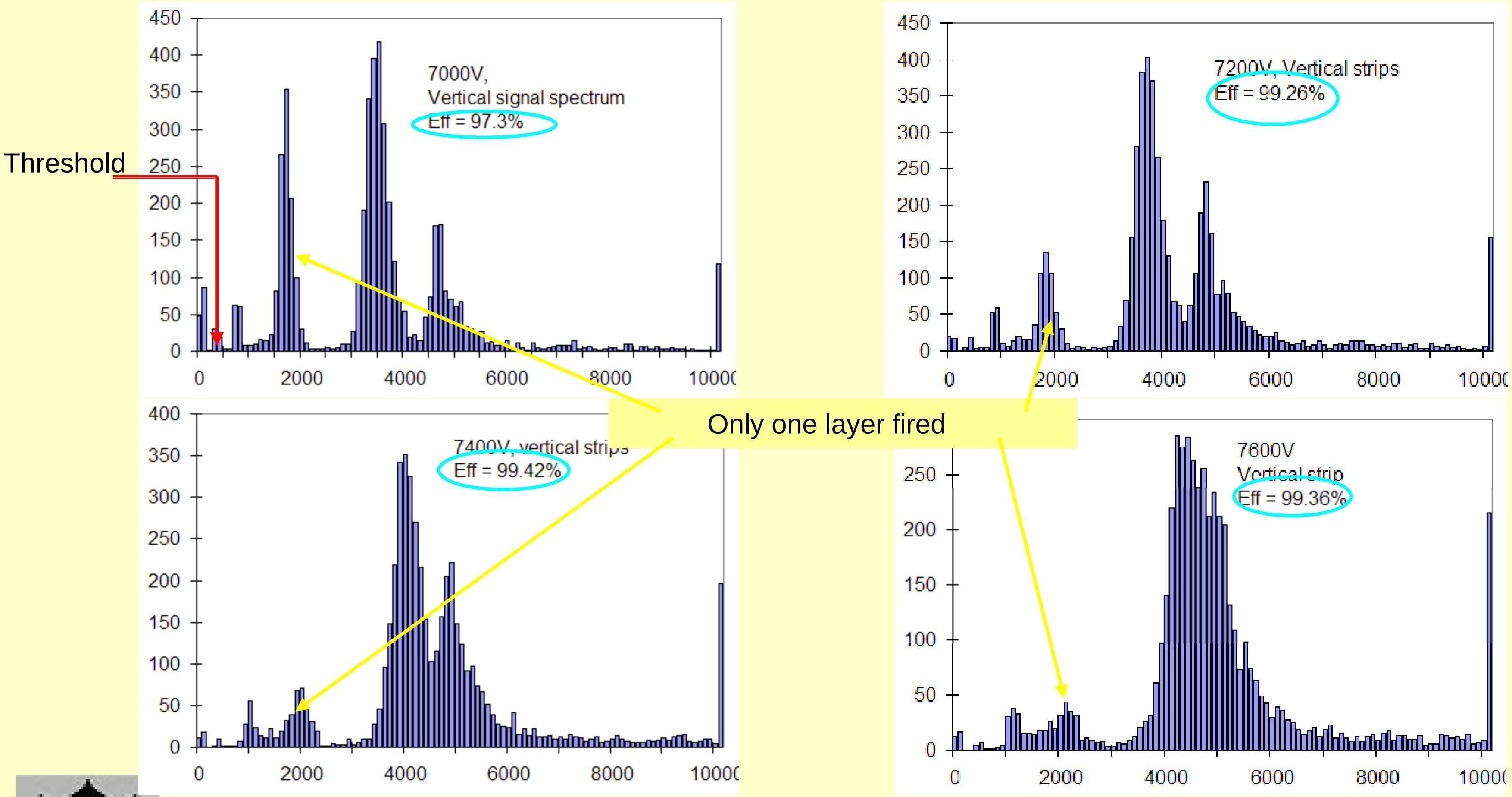
Dark current due to streamers

The linear part of the curve between 0V and 4000V shows the DC Ohmic leakage current, subtract this linear current from the total current the green curve represents current due to streamers. +/-HV draw almost identical current.



Charge spectrum on middle strip plane

Use QDC system to test the charge spectrum at various HV.



More R&D plan for IHEP Bakelite RPC

IHEP Bakelite RPC does not require Linseed oil coating, but we haven't made fair comparison between IHEP Bakelite and Italian Bakelite RPC performance.

IHEP Bakelite resistivity is very high, in-situ measurement of Bakelite resistivity for IHEP RPC prototype shows $\rho = 2.5 \cdot 10^{12}\ \Omega\text{cm}$, it just like glass RPC, there is no special advantage to glass RPC. If we can lower the resistivity by fact of ~10, still maintain low dark current and single's rate, then it will be able to raise the rate capability. We are still working with IHEP and Gaonenkedi to develop this new material.

Conclusions

• Because of the simplicity of the RPC technology and the knowledge accumulated in the past 25 years, the Bakelite RPC becomes a commercially available “standard” product.

• G. T. (Italy) and Gaonenkedi (Beijing) have manufactured Bakelite RPCs for several large muon systems.

• After L3, BaBar and Belle, the next big step to validate this technology will be the experiments at LHC. IHEP shall be eagerly waiting for BESIII muon system’s running experience.

• Belle’s RPC is a successful story of glass RPC.

• For Daya Bay application both Bakelite and glass RPC will do the job. BESIII Bakelite RPC is a “glass-like” Bakelite RPC (BESIII - 2.5×10^{12} $\Omega\cdot$cm vs. Belle - 6.6×10^{12} $\Omega\cdot$cm).