

# ***SiD RPC Studies***

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*SiD Workshop, Eugene - Nov., 2010*

Lu's full talk will be linked to the agenda page.

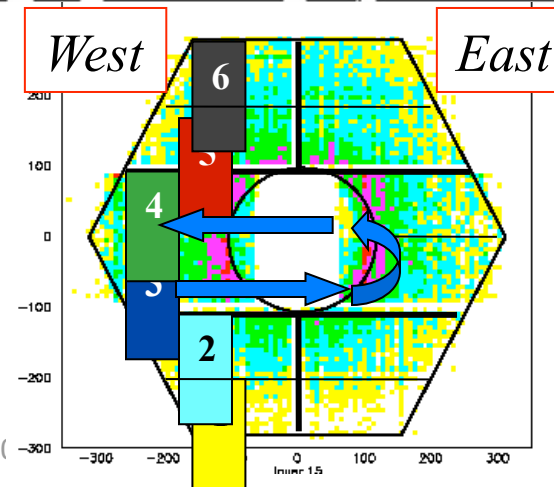
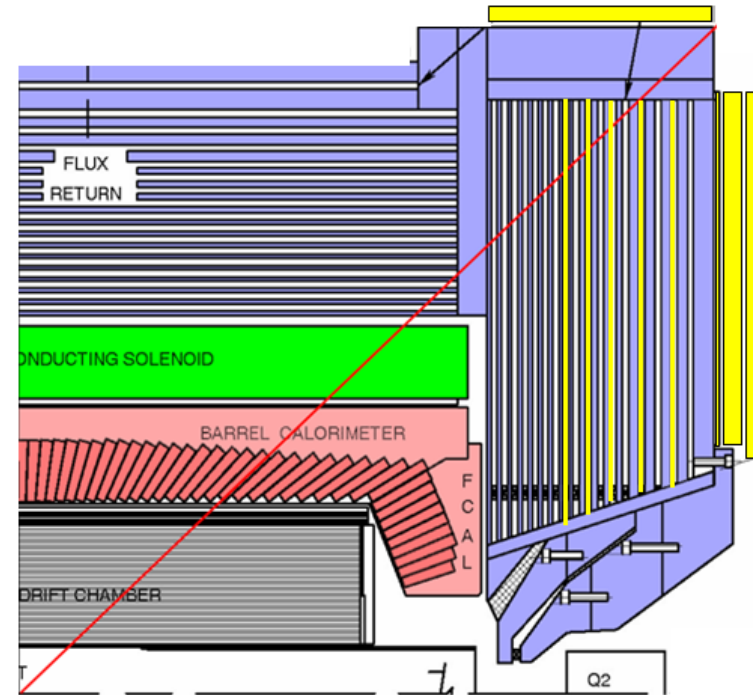
# *RPC Studies*

*Ongoing programs at Princeton and Wisconsin to understand RPC aging (Bakelite/melamine)*

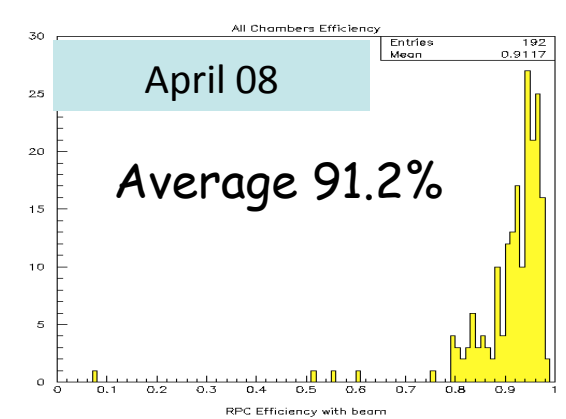
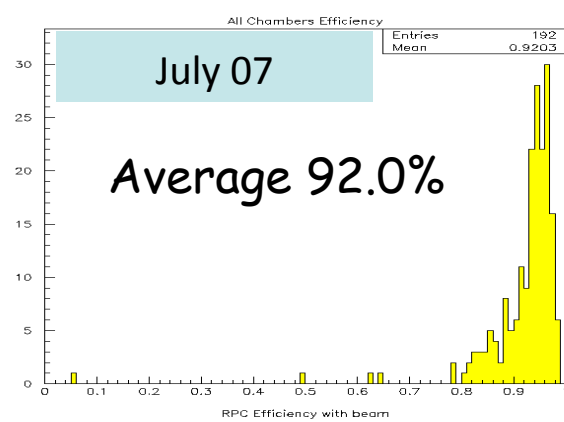
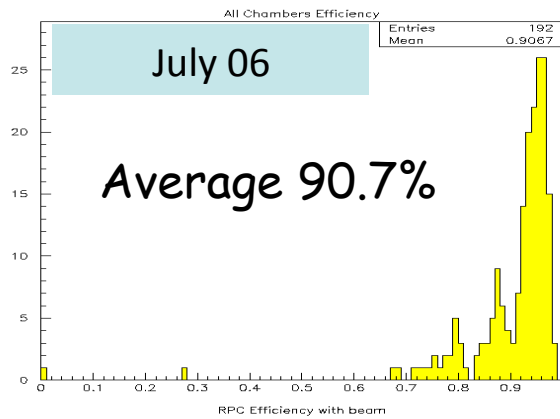
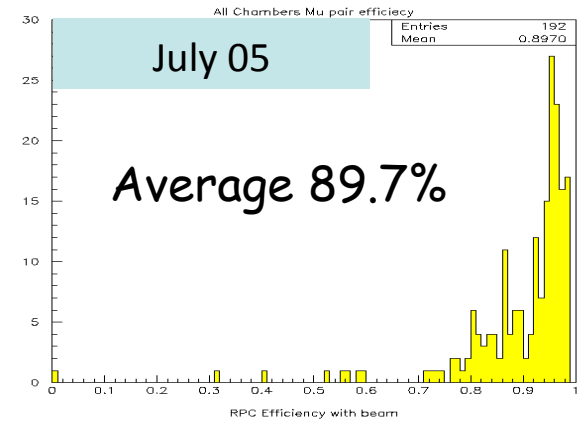
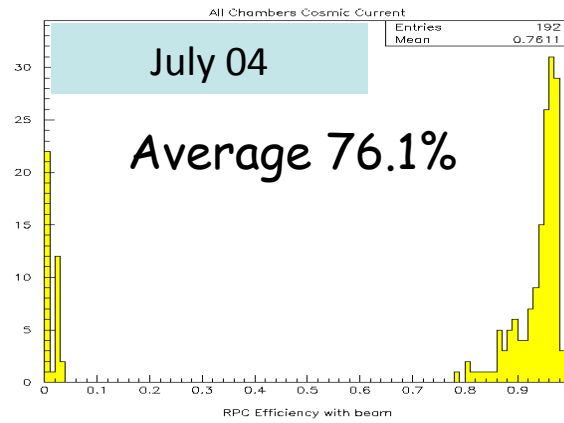
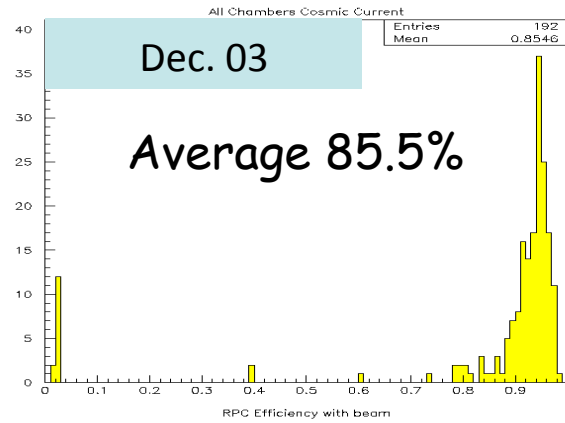
- *Princeton - C. Lu*
  - *IHEP RPCs*
    - *Bakelite/melamine from Chinese industry*
    - *No linseed oil design*
    - *Used in BESIII & DayaBay,*
    - *Proposed for SiD*
  - *Surface quality studies*
  - *Accelerated aging studies*
  - *Development of new materials*
- *Wisconsin - H. Band*
  - *BaBar forward RPCs*
    - *Construction similar to ATLAS/CMS RPCs*
    - *6 years of data*
    - *Large range of background & signal rates*
  - *Analysis of trends & correlations*
  - *Autopsy of aged RPCs*

# Muon - Bakelite RPC R&D

- *Aging Studies*
  - *Babar Forward Endcap RPCs*
    - *H. Band, U. Wisconsin*
      - *Run from Nov.02 - Apr. 08*
      - *Similar construction to Atlas/CMS RPCs*
      - *Wide range of rates/ current accumulated over ~ 6 years*
- *Good overall efficiency but clear signs of aging*
  - *Noise rate 400 Hz → 3 kHz*
  - *Current  $< 1 \mu\text{A} \rightarrow 12 \mu\text{A}$*



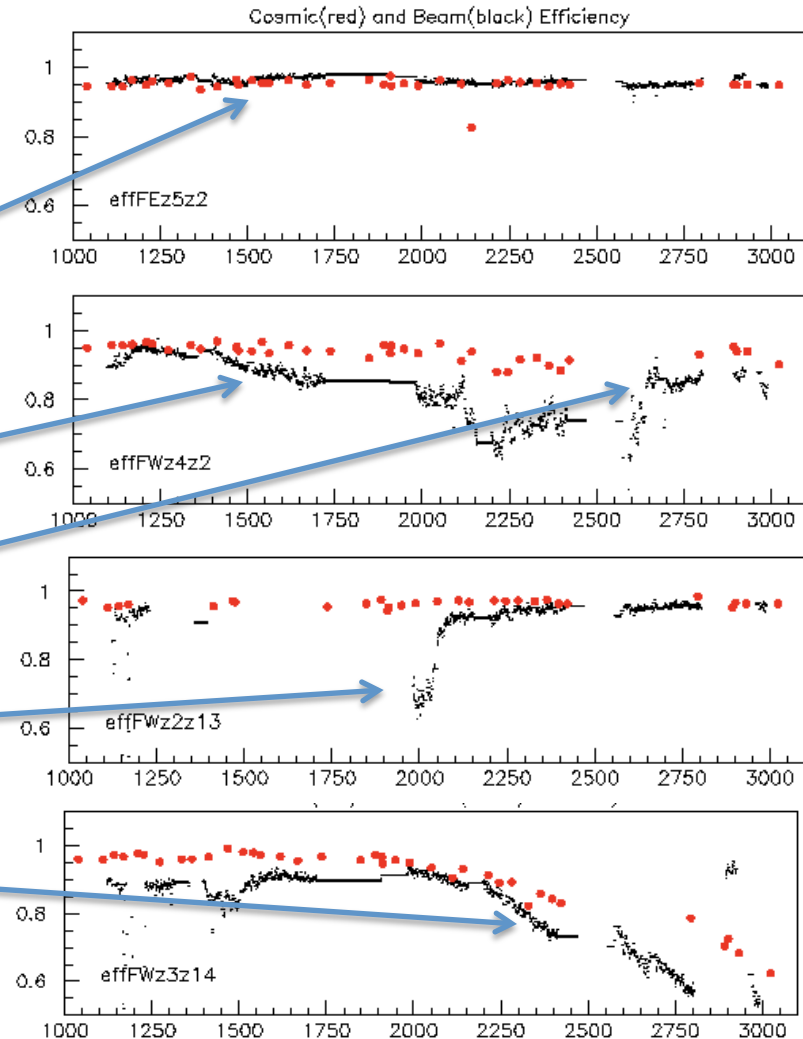
# Endcap efficiency





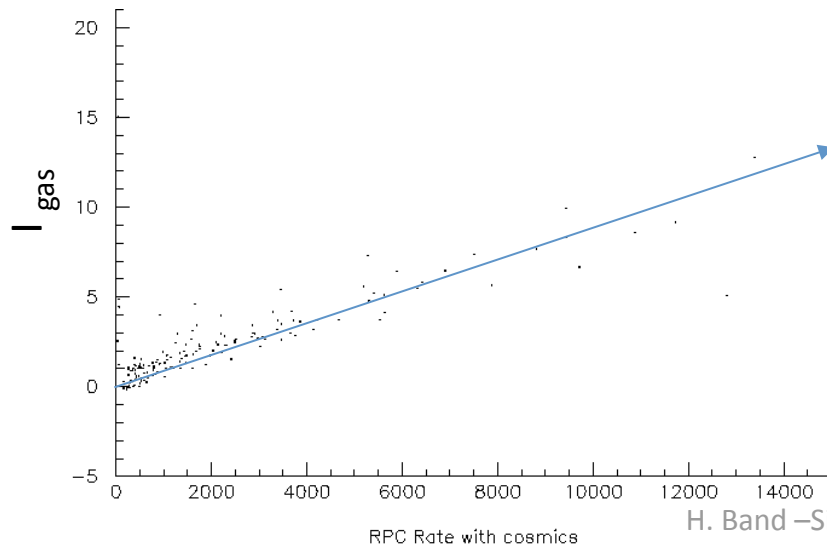
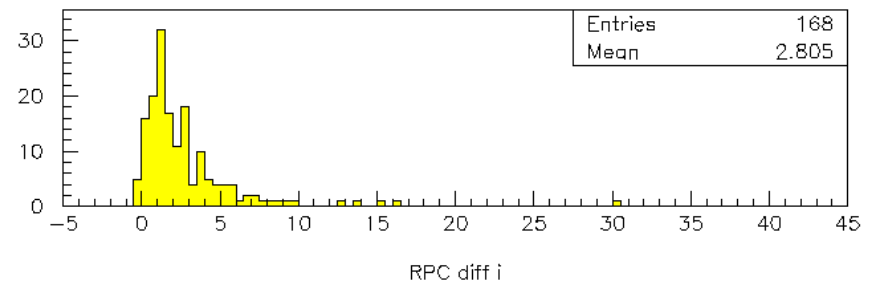
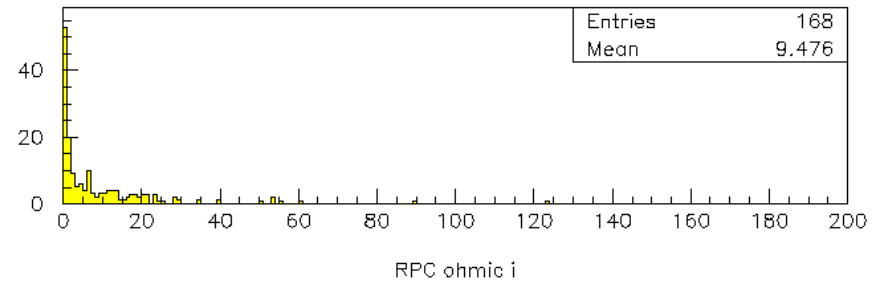
# Beam/Cosmic Histories

- *Difference between beam and cosmic ray determined efficiencies highlight rate induced inefficiencies*
- *Many RPCs have stable efficiency*
- *Near the beamline a rate dependent inefficiency*
- *Conversion to avalanche mode restored efficiency*
- *Rate dependent inefficiency due to dry Bakelite restored by humidifying input gas*
- *Inefficiency due to poor gas flow similar in both*



# Noise Rate and Currents with Cosmic Rays

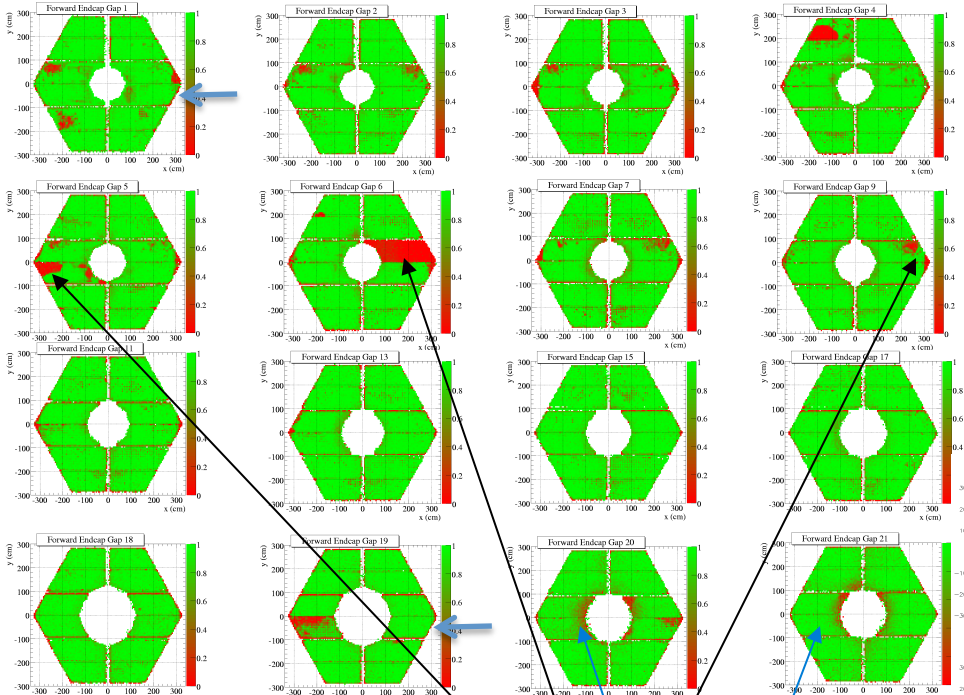
- About  $\frac{3}{4}$  of current increase due to rise in ohmic current (Estimated by extrapolating the  $I$  vs  $V$  curve below the gas gain turnon)
- Remaining  $\frac{1}{4}$  strongly correlated with increased noise rate



- Trying to understand causes of:
  - Ohmic current
    - No correlation with integrated current seen
  - Increased noise

# Cosmic vs Collisions

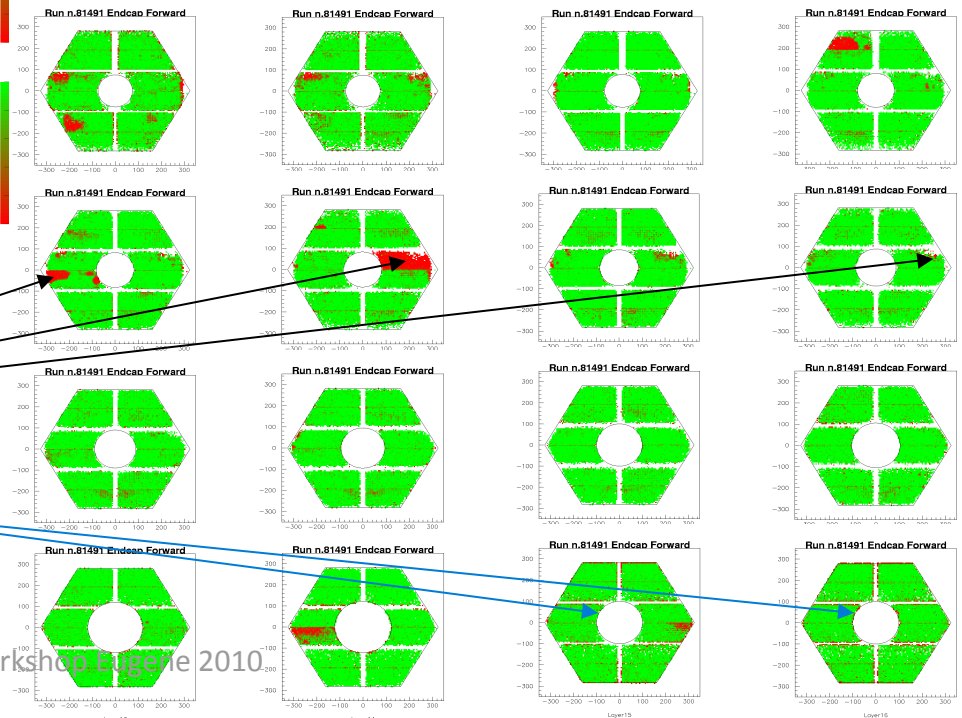
$\mu$  pairs with beam



## 2-D Efficiency map

*Overall - efficiency at the end of running remains high*

Cosmic rays



*Need to decouple the aging effects from other failures ~ 8%:*

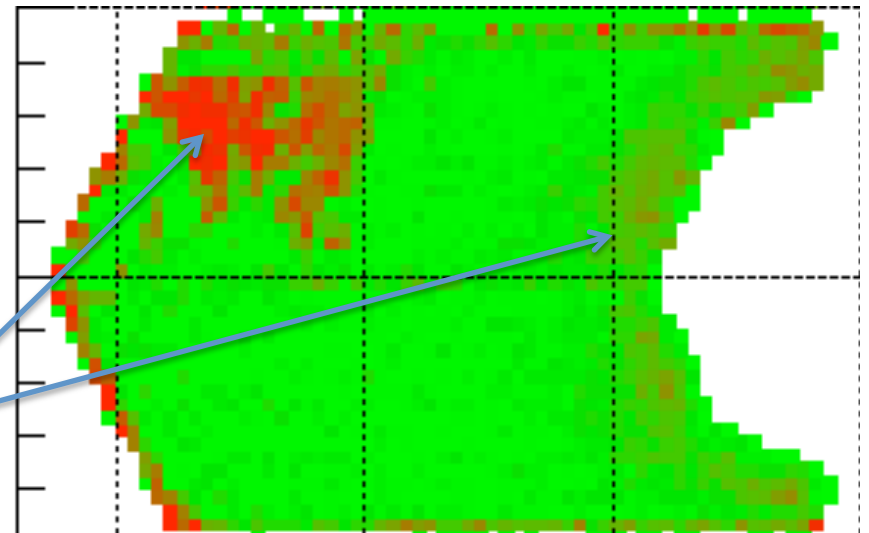
- *gas problems*
- *HV problems*

Low efficiency ring around beam-line only seen at high rates with beam

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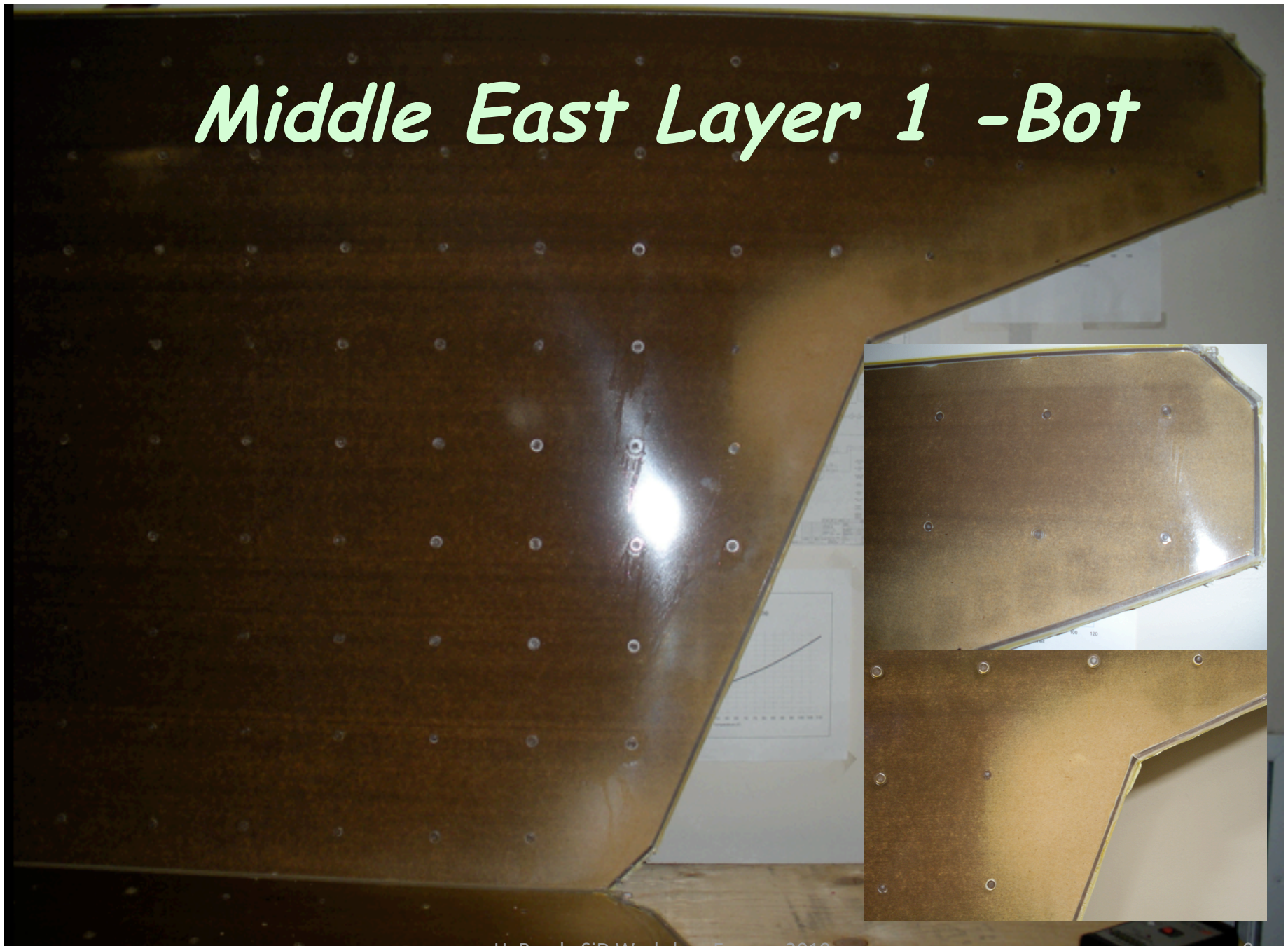
# Final Tests

- *10 RPCs were selected for further tests*
  - *No HV or gas problems over 6 years*
  - *Finally removed from BaBar steel Mar. 2010*
- *2 failure modes of most interest*
  - *Rate inefficiency around beamline*
  - *Noisy, inefficient regions near gas inlets*
  - *Correlate problem areas with changes in Bakelite or graphite resistivity or HV surface finish*





# *Middle East Layer 1 -Bot*



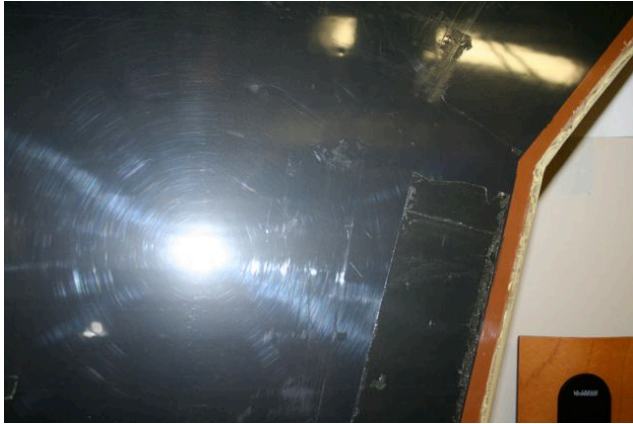
# *Bakelite Samples*

## *Middle East Layer 1 -Bot*

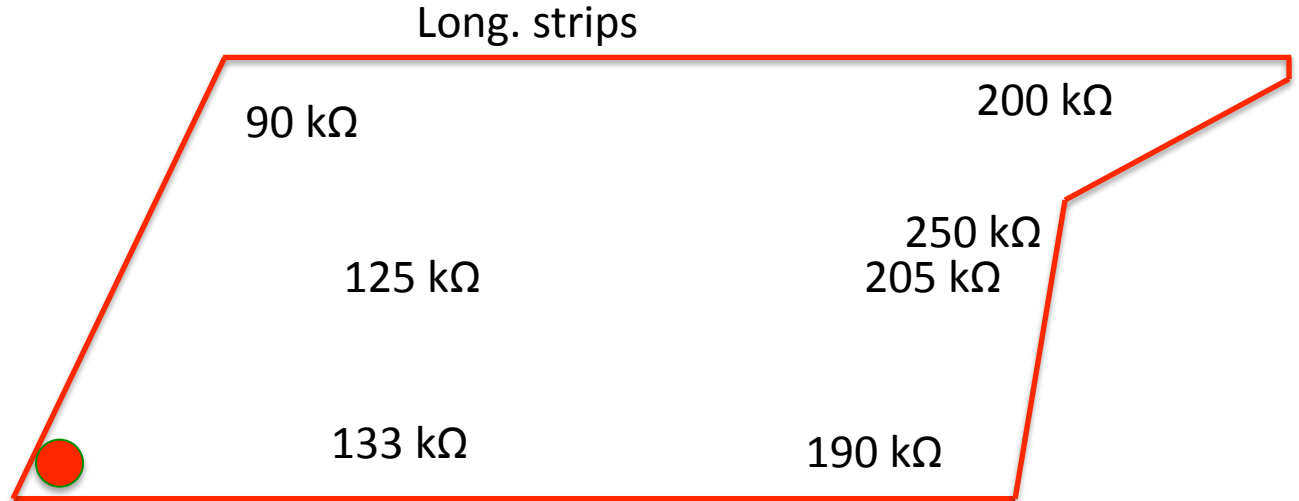




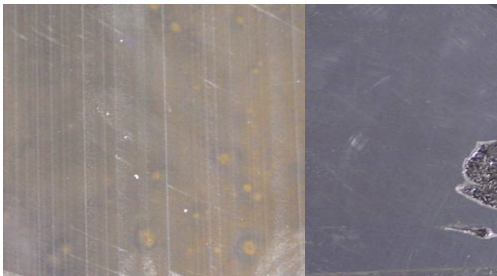
# East Layer 14 - Graphite



HV contact

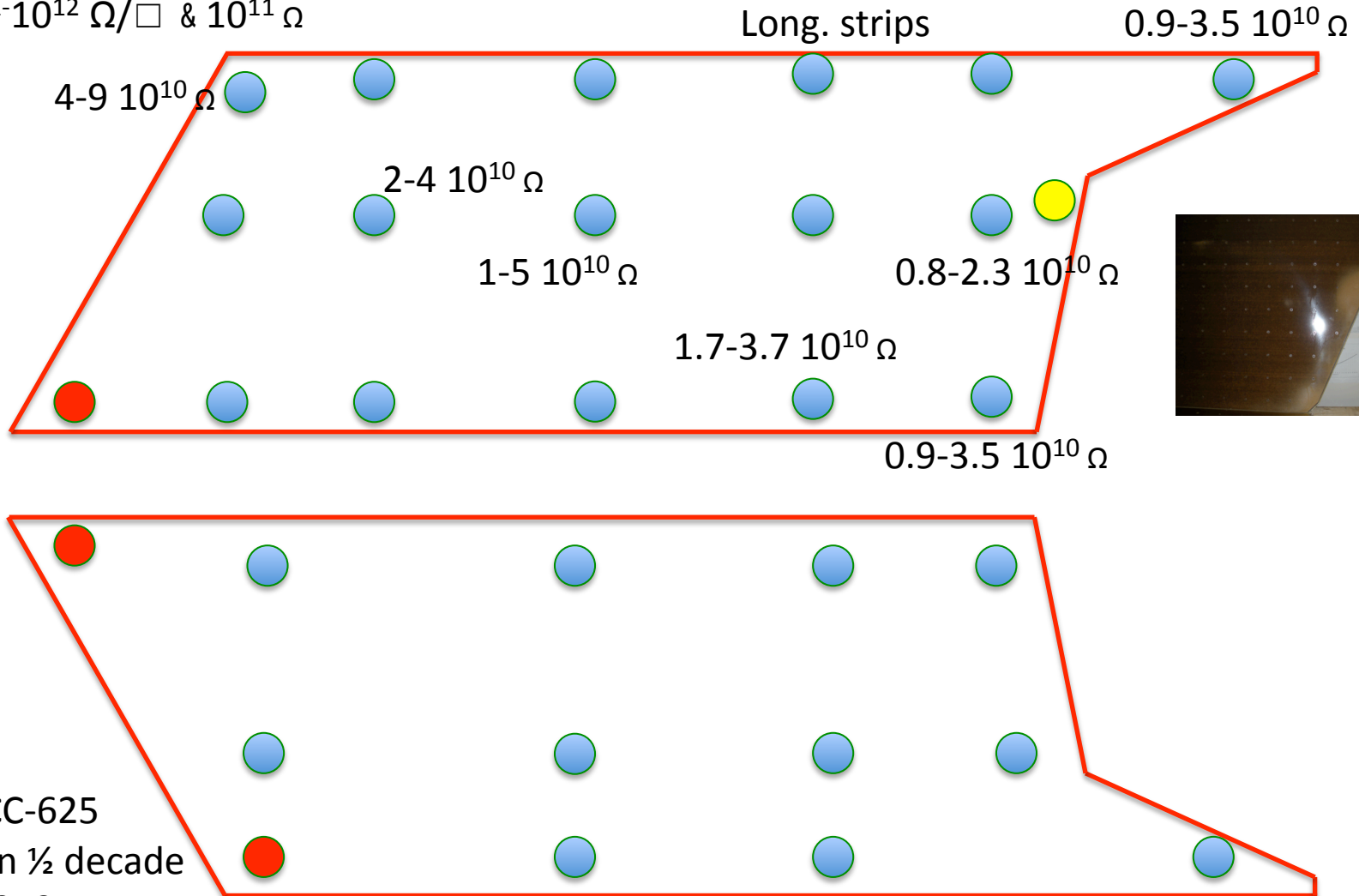


Original RPC Many suffered a complete efficiency (graphite loss on anode



- $10^{11} \Omega/\square$  &  $10^{10} \Omega$
- $10^{10} \Omega/\square$  &  $10^9 \Omega$
- $10^{11}-10^{12} \Omega/\square$  &  $10^{11} \Omega$

# East Layer 1 - Bakelite



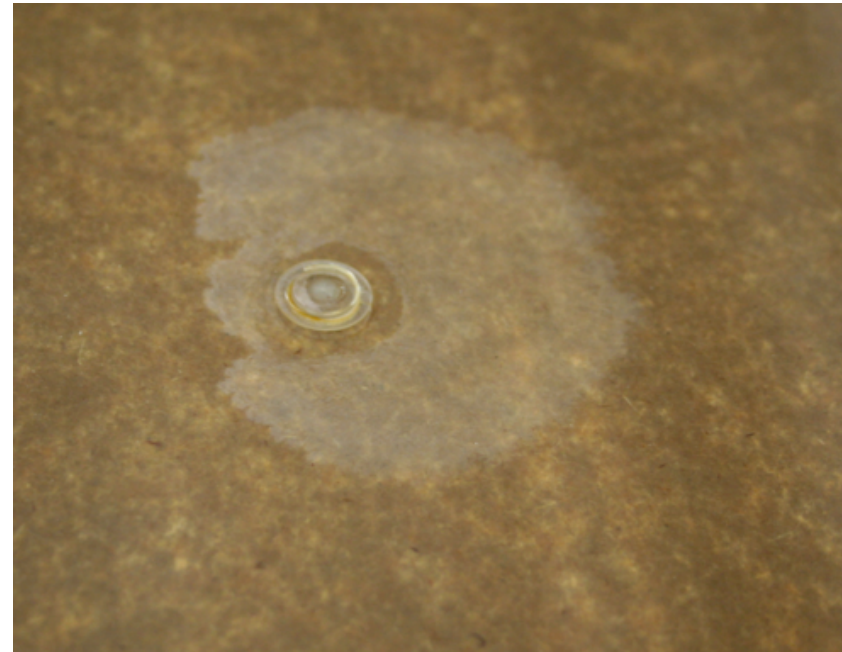
Meter SCC-625  
 resolution ½ decade  
 Monroe 272  
 resolution 0.1  
 decade



# *RPC Surface*

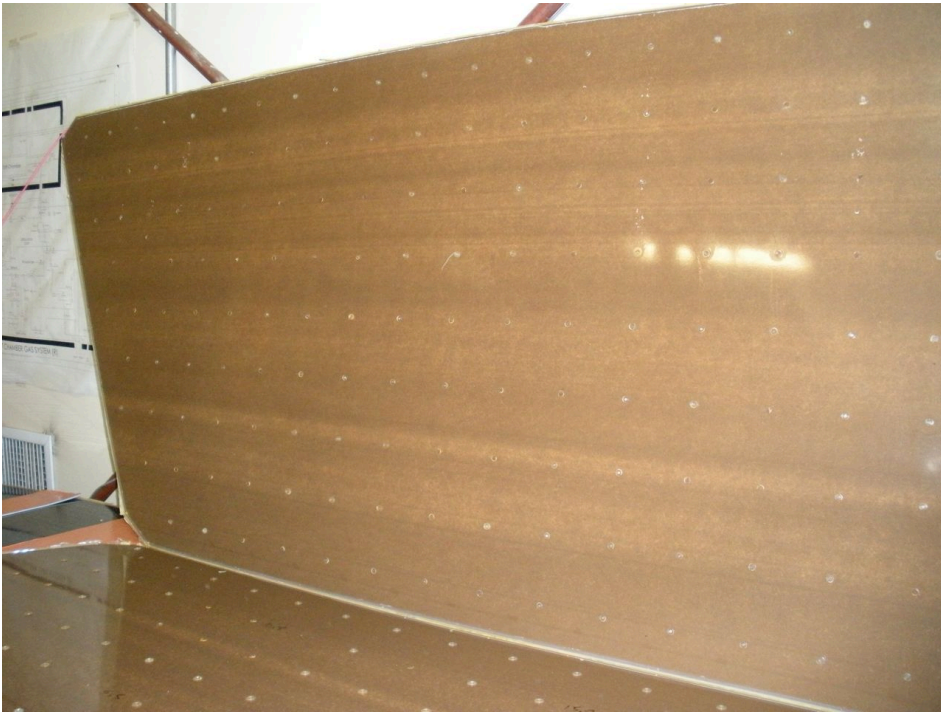


Drain Marks Around Buttons



Rough Area around button

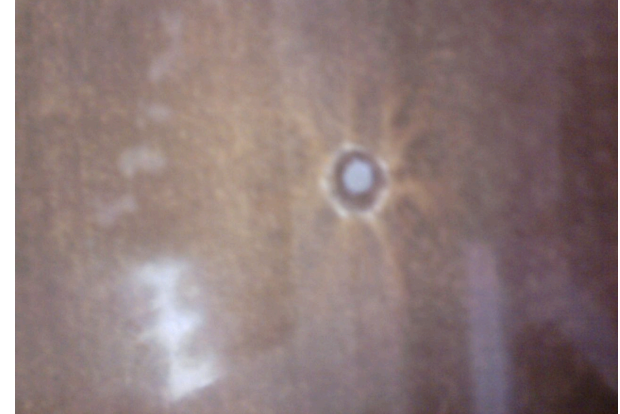
# *More Surface Photos*



Middle – High rate RPC

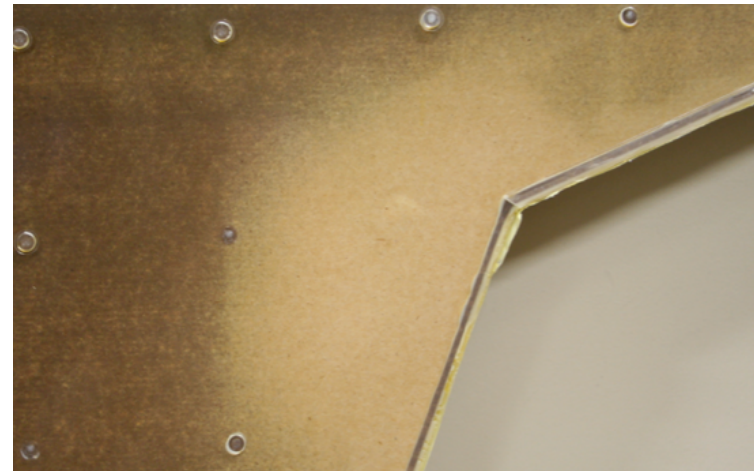


Belt –  
very low  
rate RPC

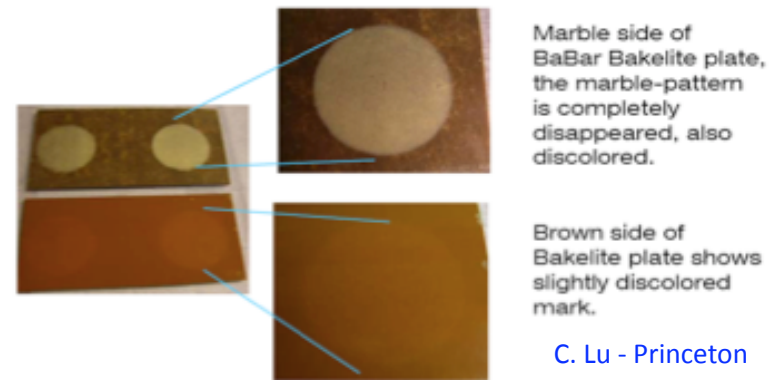


# Autopsy Summary

- *No evidence of graphite problems*
- *Linseed oil dry & smooth*
- *Bakelite resistance is fairly uniform*
  - *Lower in "bleached area"*
  - *Need more measurements*
- *"Bleached" surface in areas of high rate inefficiency*
- *Not yet clear if inefficiency simply due to higher rate*



## Previous HF studies



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

Brown side of Bakelite plate shows slightly discolored mark.

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Figure4. HF vapor corrosive action on BaBar Bakelite surface.



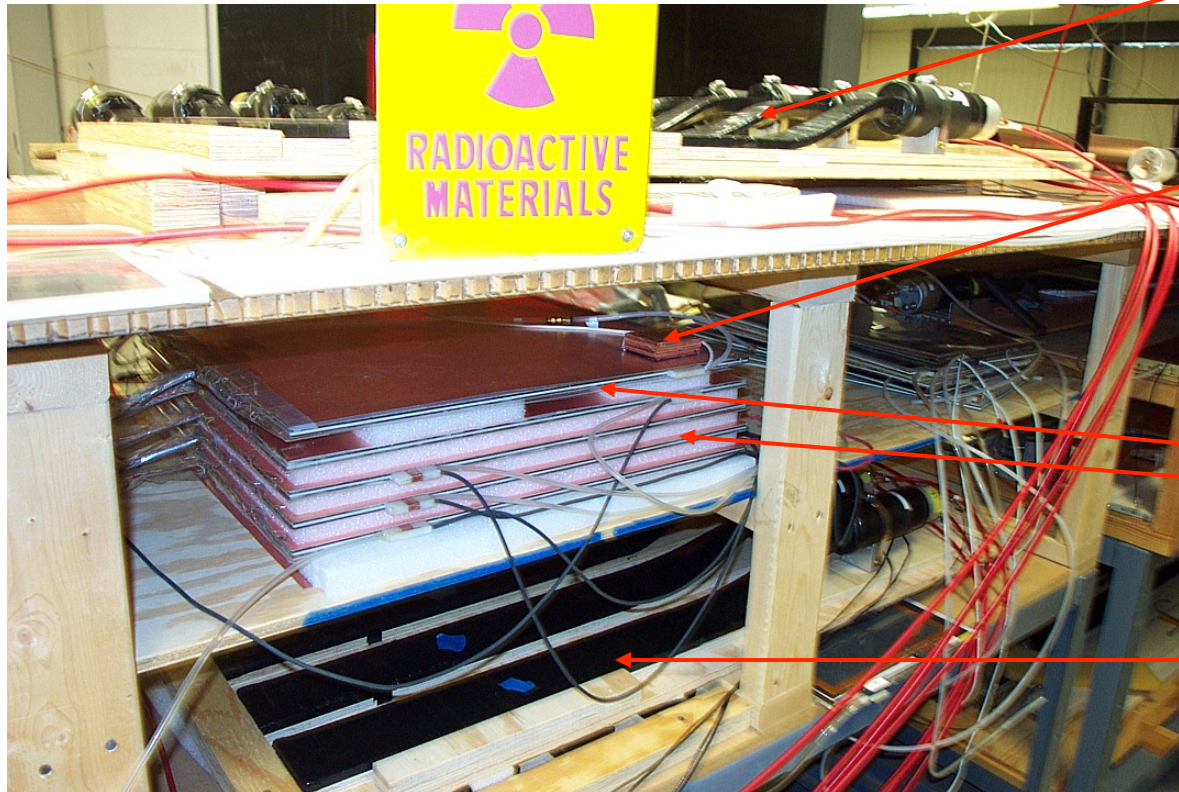
# *What we have established in the first year*

C. Lu -  
Princeton

- 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  $\gamma$  ray irradiates the RPCs to speed up the aging.

Aging test RPCs, 50x50cm<sup>2</sup>.

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

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

# *Surface comparison at various stages of aging*

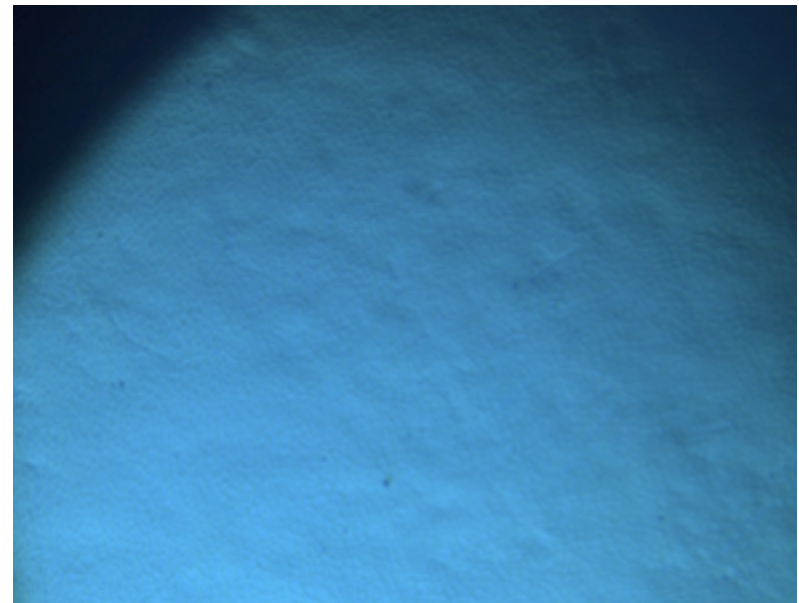
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We investigate the surface image under the microscope for various aging chamber samples and try to give a plausible working hypothesis of the BESIII-type RPC aging.

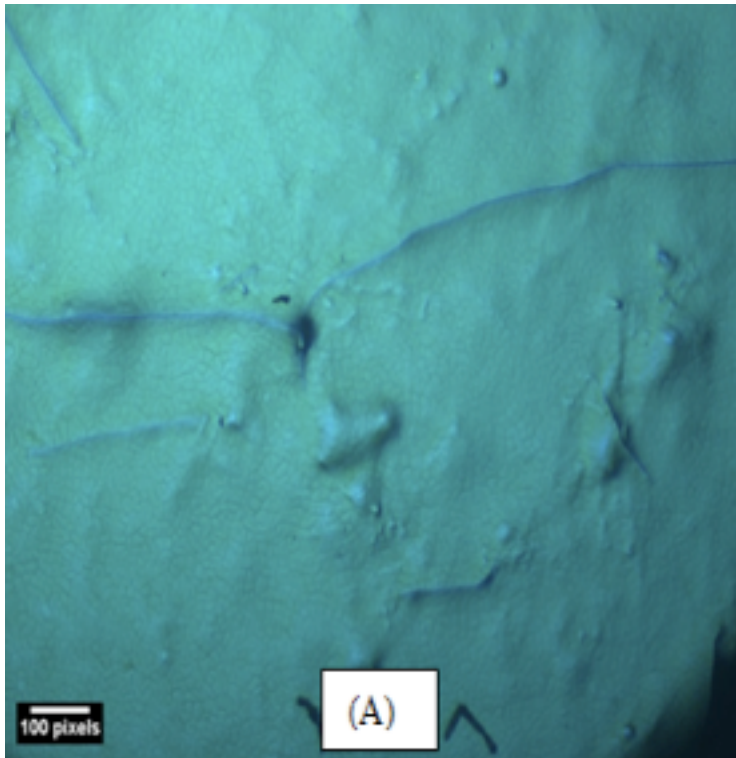
- Virgin Bakelite surface;
- Exposed to HF vapor surface;
- Less aged RPC inner surface;
- Serious aged RPC inner surface;
- BaBar aged RPC inner surface.

## Virgin BESIII Bakelite surface

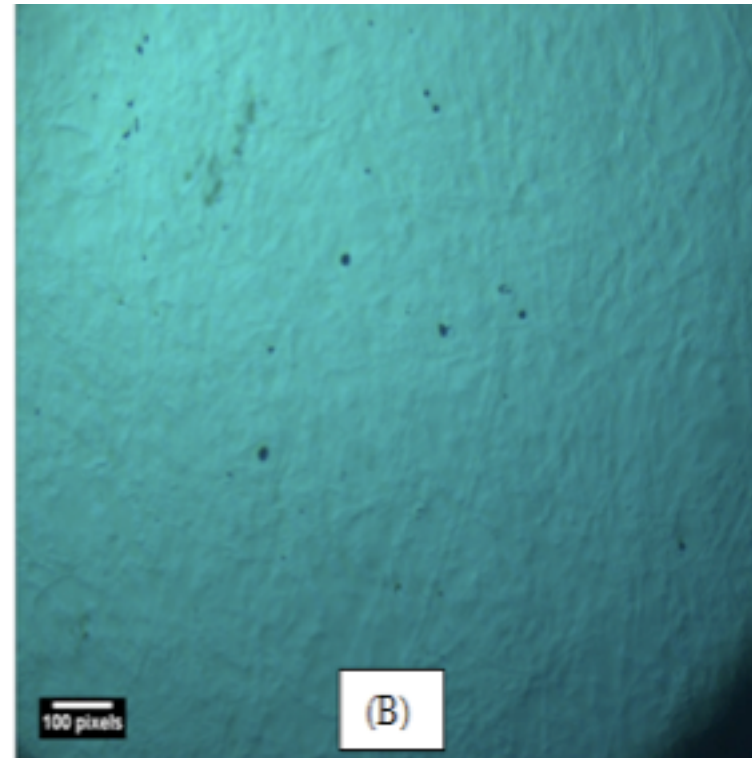
- Smooth;
- Dense and uniformly distributed "skin-like" texture;
- No broken surface.



# *HF vapor exposed surface*



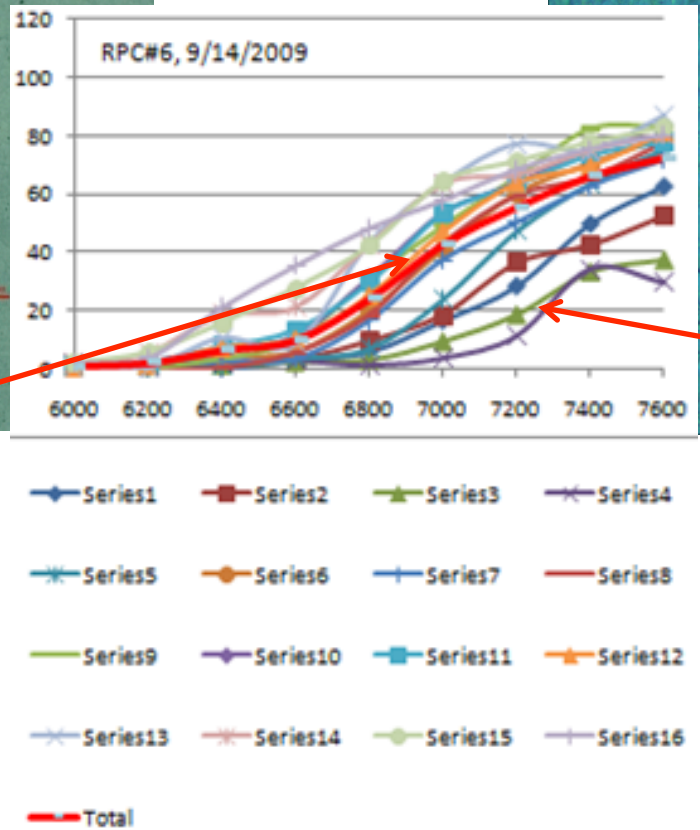
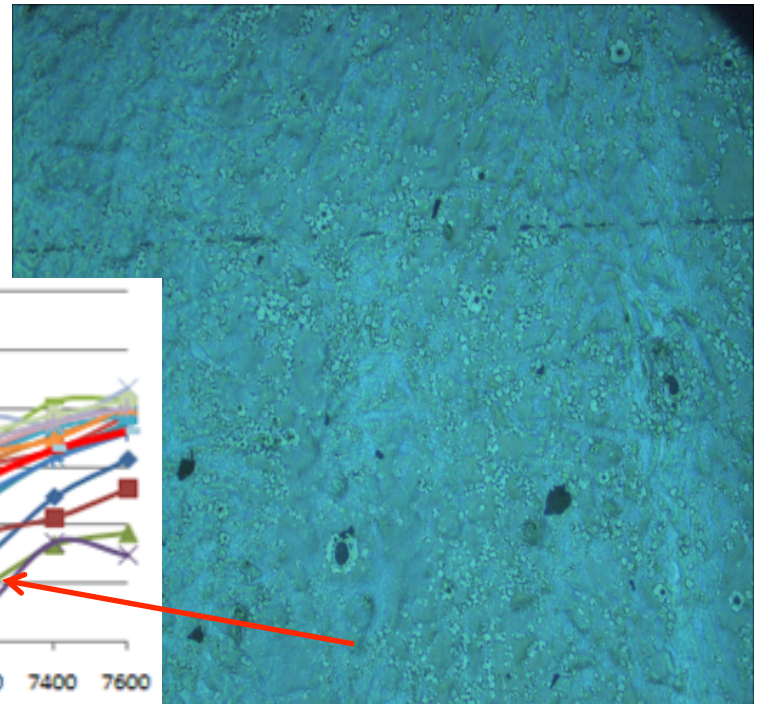
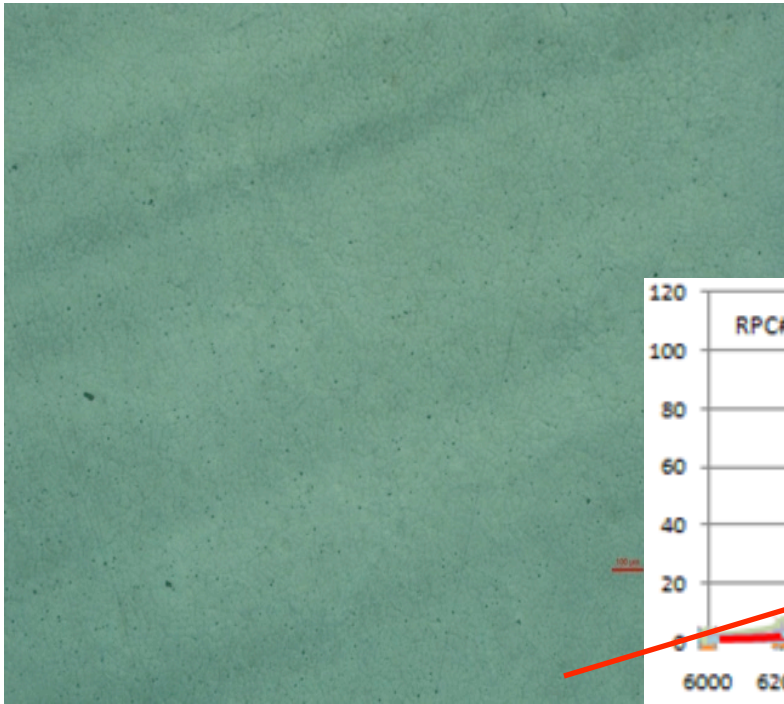
Bumps, cracks, but still can see "skin-like" texture.



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



# Two different areas in same aged RPC



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

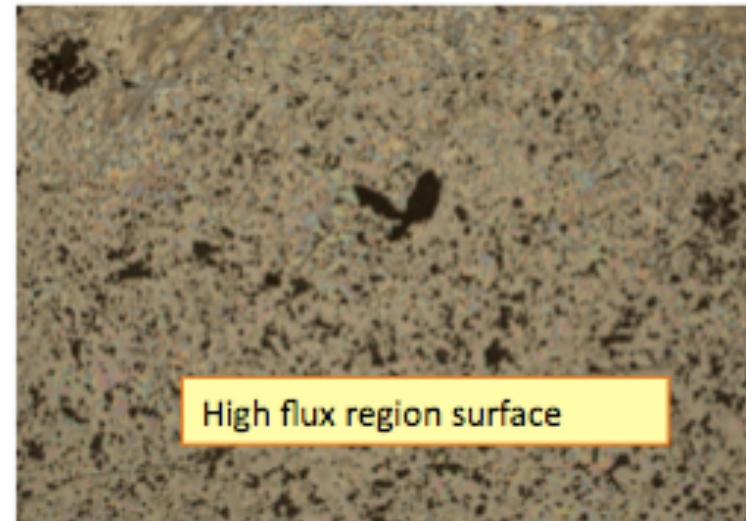
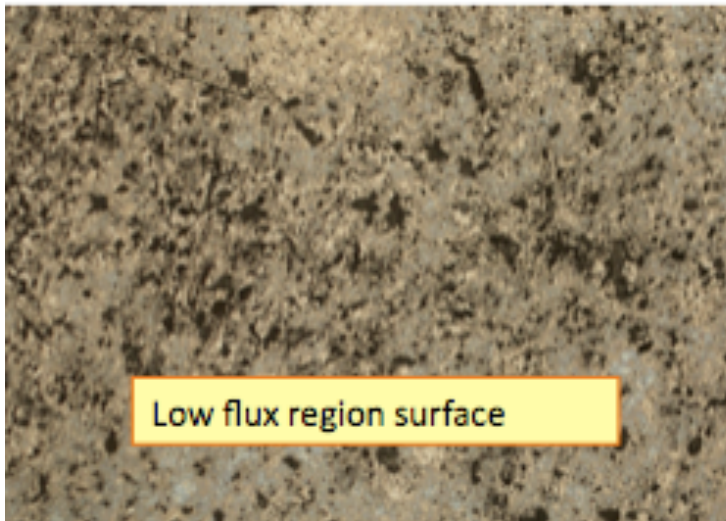
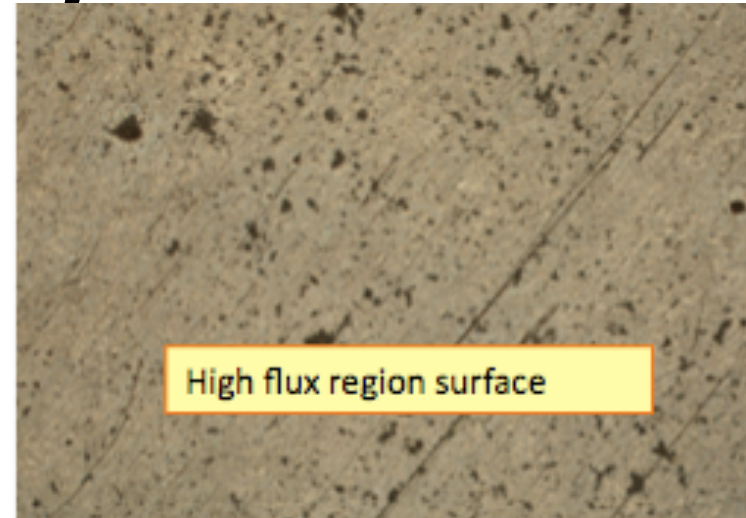
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Princeton

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



# *Microscopic images of the BaBar samples*

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Princeton



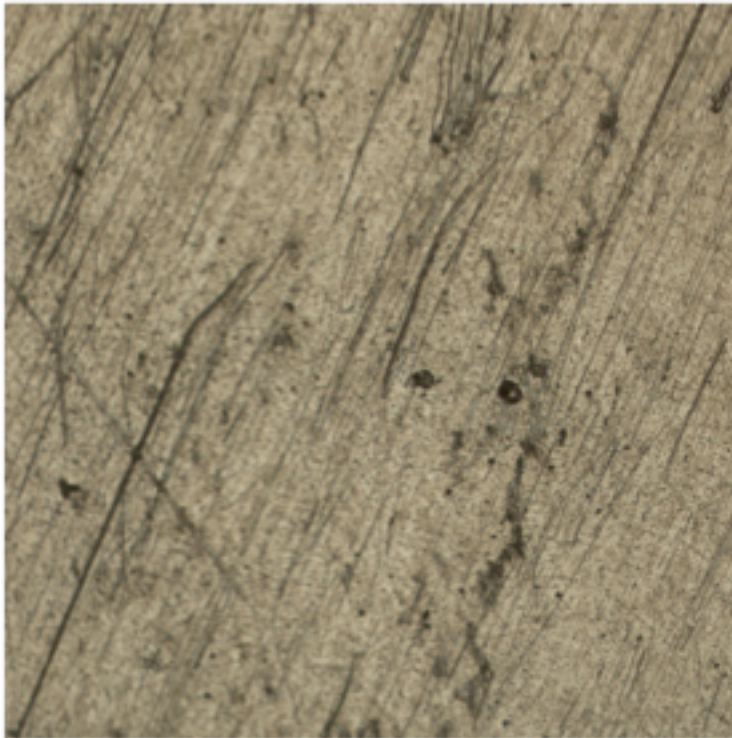
C. Lu -

Princeton

# ***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*

Sample from low particle flux region: *(cont'd)*

Oil coating  
removed  
area



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

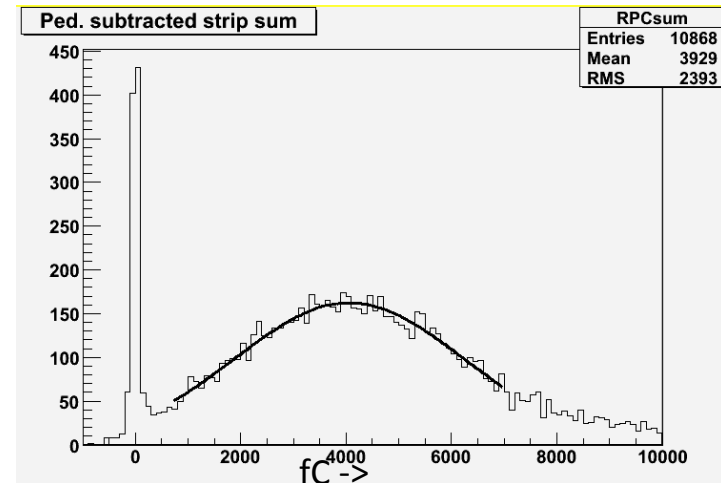
# *RPC Studies - Next Steps*

- *BESIII type*
  - *2<sup>nd</sup> generation linseed oil impregnated RPCs delivered to Princeton*
  - *Initial rates better than 1<sup>st</sup>*
  - *Aging studies started*
  - *Next year - build and study thinner ~1 mm bakelite designs*
- *BaBar type*
  - *Finish physical properties study*
  - *Verify rate and eff. unchanged since end of data taking*
  - *Develop model to explain time & rate dependence of eff.*
  - *Study inefficient areas near gas inlets*

# *Backups*

# RPC/ KPiX Studies

- *RPC readout with KPiX chip previously reported at LCWS08 and ALCPG09*
- *64 channel interface board with KPiX7*
- *First tests*
  - *Optimize  $\Omega$  & capacitor values*
  - *Protection circuits*
  - *KPIX readout modes*

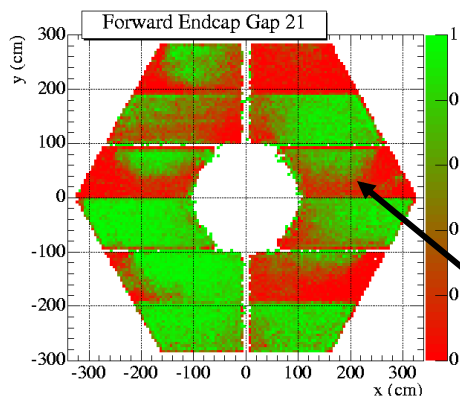


- *Good efficiency but 3.1 strips/track*
- *Next steps*
  - *Reduce noise*
  - *Reduce multiplicity*

# Gas Humidity

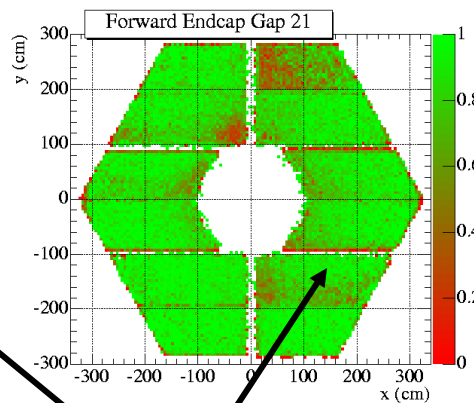
Run 53918

April, 05



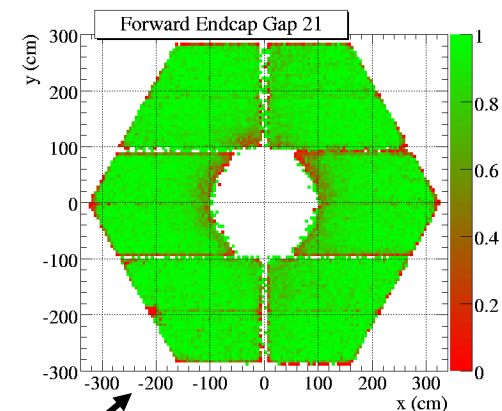
Run 57387

Aug. 23, 05

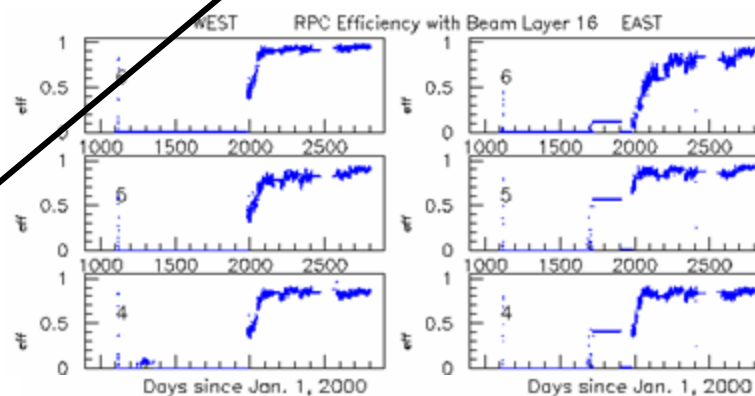


Run 74506

July 07

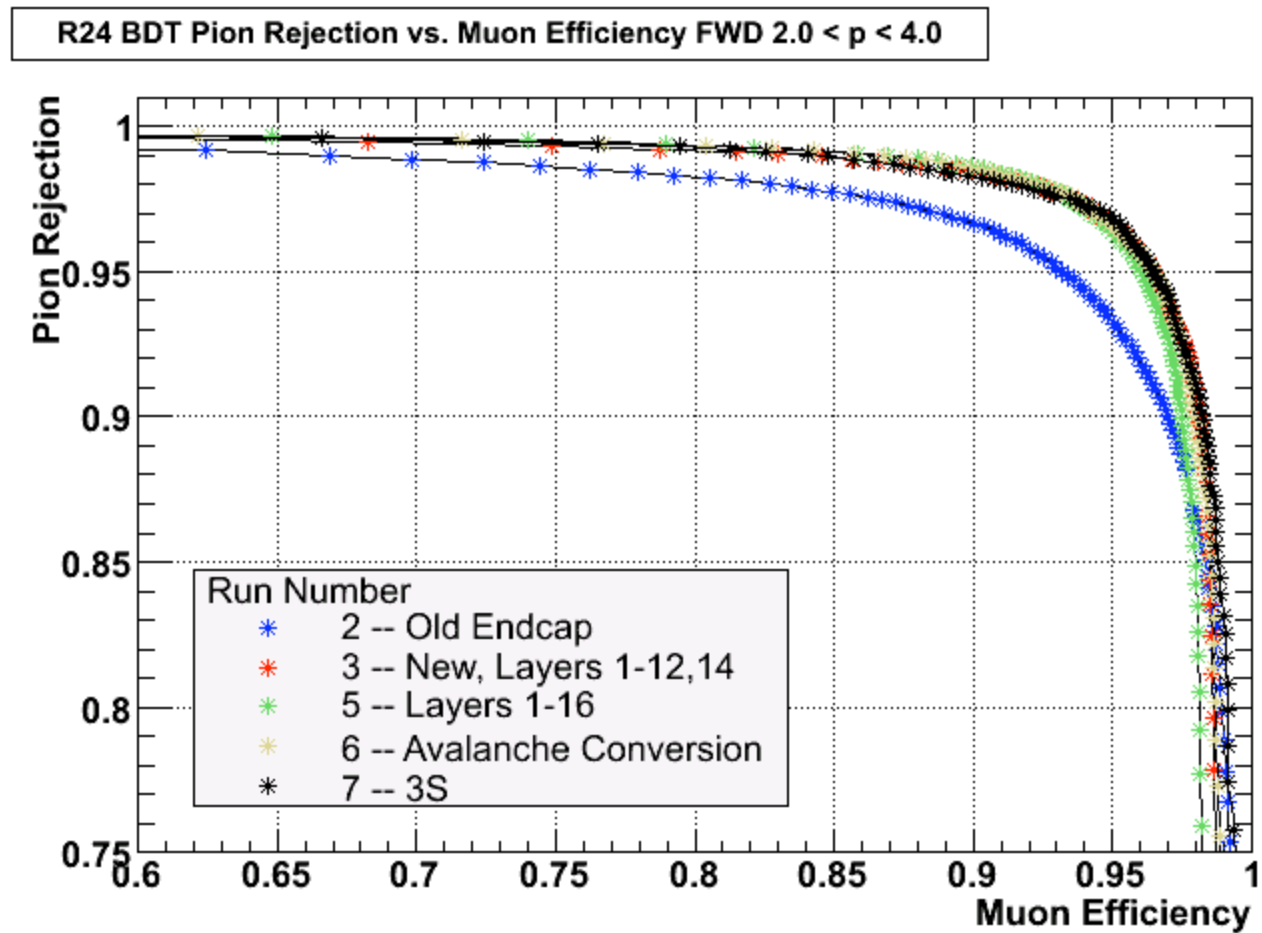


- *Outer layers inefficient in Run 5 even some which had been off*
  - *But OK with cosmics*
  - *Input IFR gas ~0% RH*
  - *RPC exhaust ~30% RH*
- *Humidify input gas to 35% for some and later all in Run 5b*
- *Clear improvements seen*
- *Stable efficiency in Run 6*



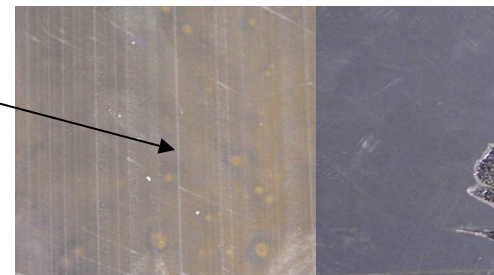
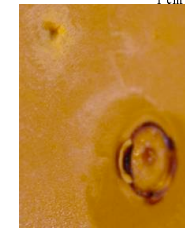
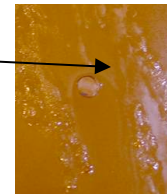
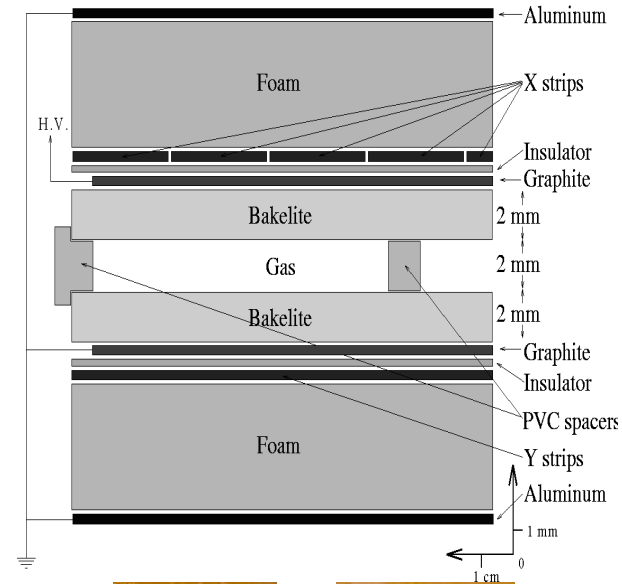


# Muon ID Performance



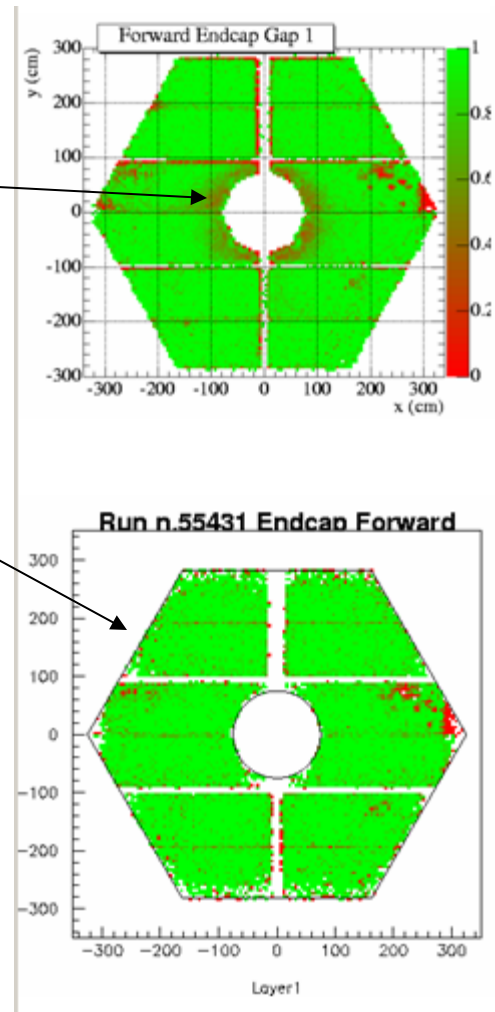
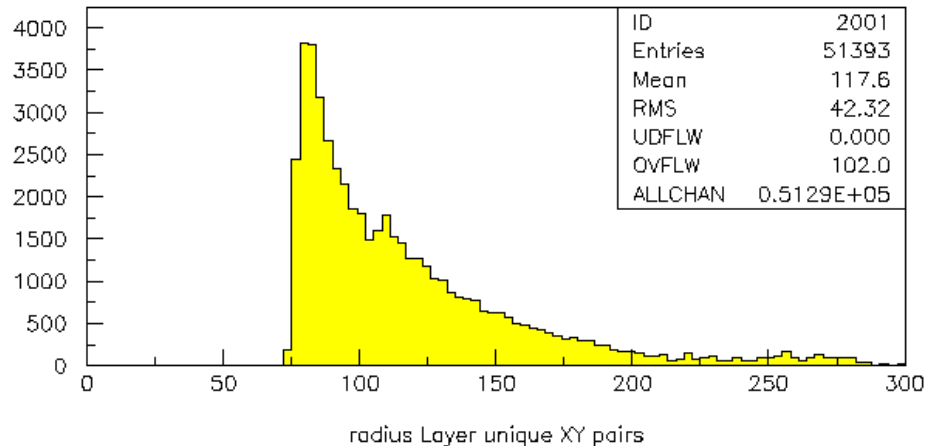
# Original Production RPCs

- **Original RPCs**
  - Constructed at General Technica Factory 1996-7
    - 2 mm gas gap with polycarbonate spacers
    - Bakelite electrode
      - $\rho_V = 3-12 \cdot 10^{11} \Omega \text{ cm}$
    - Graphite paint
      - $\rho_S = 100 \text{ K}\Omega/\text{cm}^2$
- Exhibit many failure modes
  - Nearly all RPCs show a slow decline in efficiency (*linseed oil, debris*), & increased current and noise rate
  - Many also suffer a complete efficiency loss in 1-2 months (*graphite loss on anode*)
  - Correlated with position in gas chain -barrel 1(52%), 2(39%), 3(26%)
  - Barrel  $\langle \text{eff} \rangle$  35% when replaced

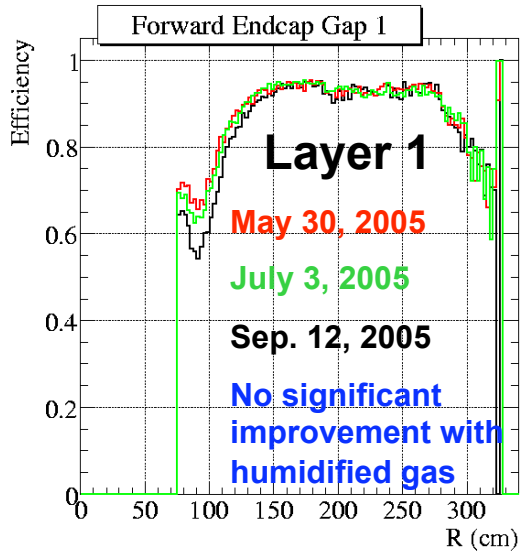
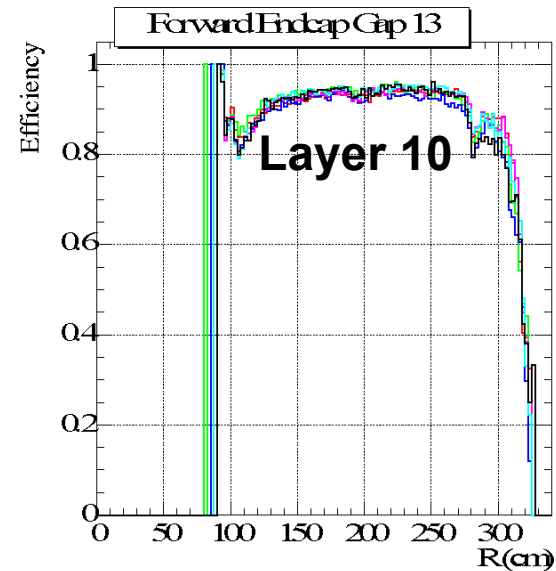
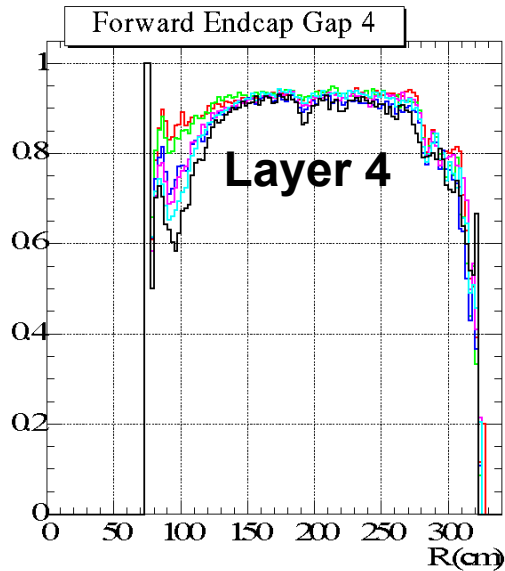
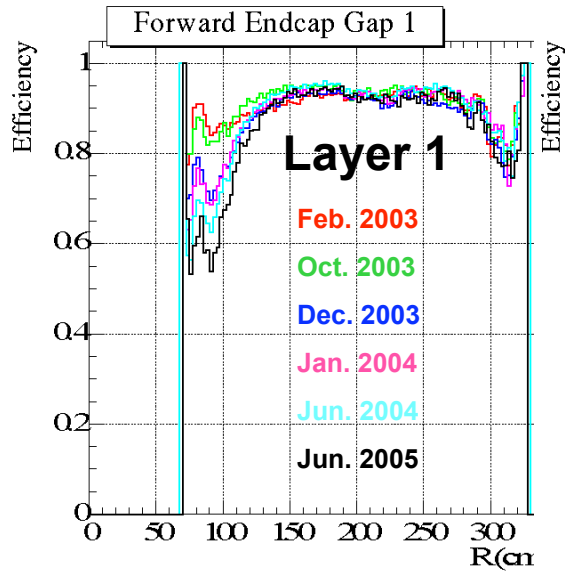


# Small Radii

- *Many of the middle RPCs in layers 1-6 have lost efficiency near the beamline*
- *Eff. OK with cosmics only*
- *Not improved by humid gas*



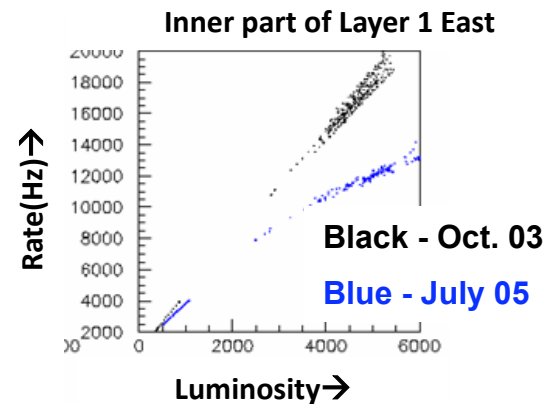
# Efficiency loss at small radii



NOV. 2, 2000

- *Efficiency loss in highest rate regions growing worse with time*
- *Loss of rate capability*

Measured rate vs. luminosity



# Avalanche Mode studies

- Accumulated charge in the high rate ring ( $>600 \text{ mC/cm}^2$ ) would likely damage the RPC graphite
- Other aging processes proportional to integrated charge
- Test avalanche mode (used by LHC RPCs)
- 3 middle RPCs converted for Run5b
  - 22% Ar, 72.9%  $\text{C}_2\text{H}_2\text{F}_4$ , 4.5%  $\text{C}_4\text{H}_{10}$ , 0.6%  $\text{SF}_6$
  - @9500 V
- Convert middle RPCs Layers (1-8) in this

