

Studies and Plans for RPC Muon Detectors

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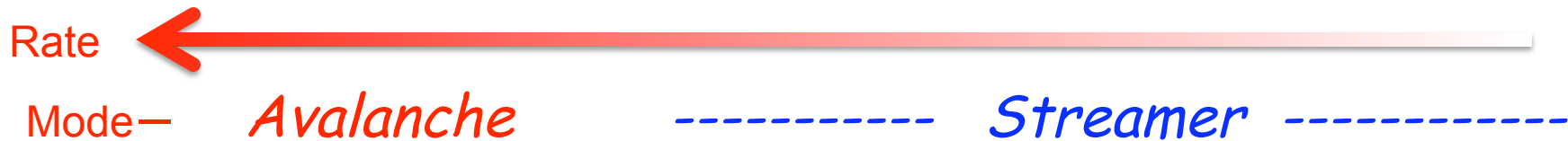
Princeton University

SiD RPCs

- *RPCs are the baseline detector choice for SiD*
 - *Low cost*
 - *Easily made in a variety of shapes*
 - *Adequate performance & reliability*

- *Bakelite RPCs*

– *CMS ATLAS BESIII DAYABAY OPERA*



- *Proposed SiD RPCs*

– *Avalanche mode, KPIX readout, IHEP Bakelite*

SiD Muon

- *Backgrounds*

- *Barrel*

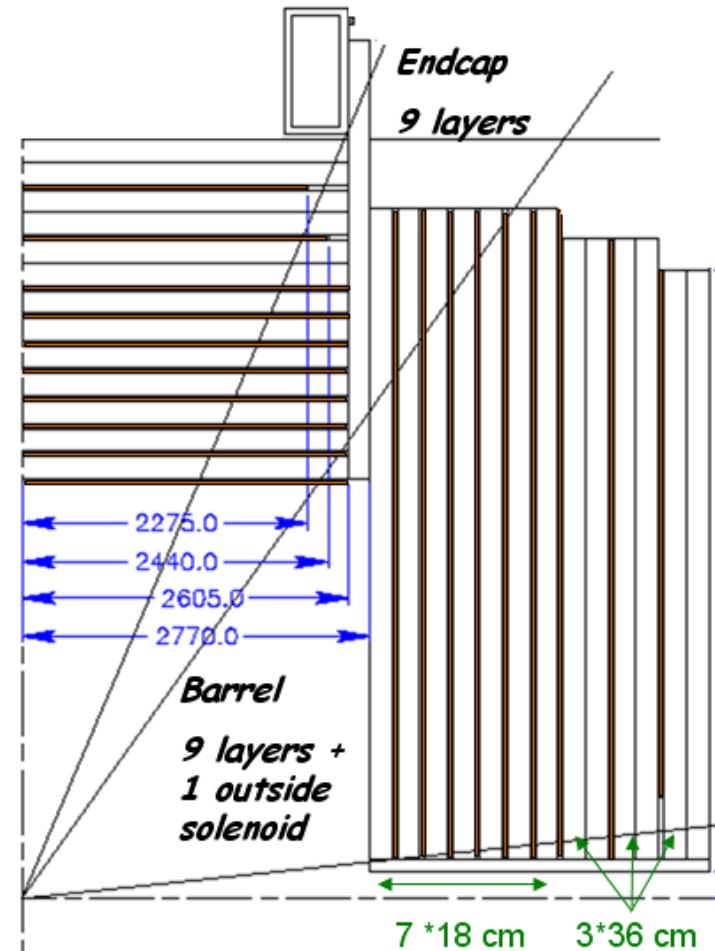
- *Beam halo induced muons*
- $3 \cdot 10^{-3}/\text{cm}^2$ - pulse train

- *Endcap*

- 2γ hadrons & μ
- $4 \cdot 10^{-2} /\text{cm}^2$ - pulse train

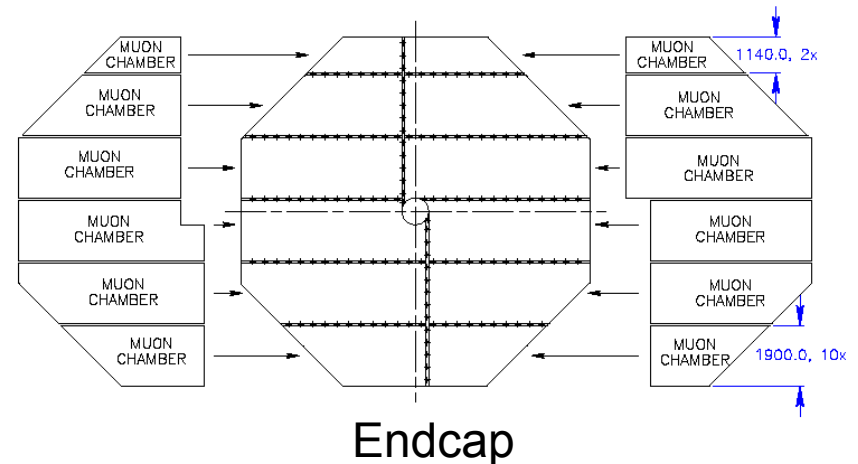
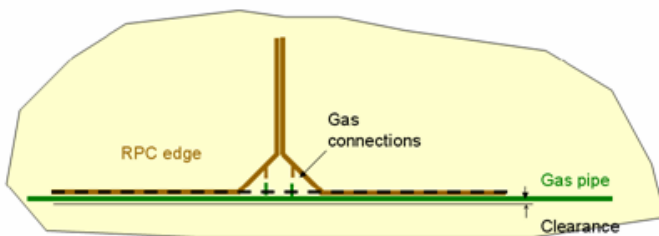
- *Reliability is still a concern*

- *Good results - LHC studies, BaBar low rate RPCs*
- *Continue studies of RPC aging*
- *Keep scintillating strip option*

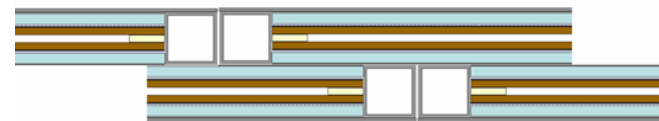
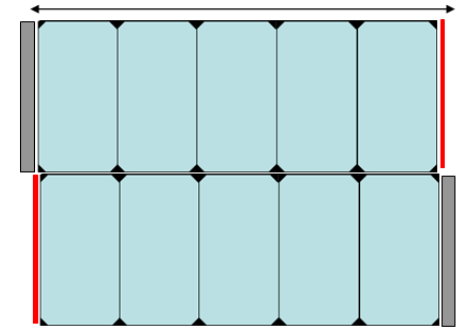


RPC Baseline

- *Double gap RPCs operated in avalanche mode*
- *RPC and steel boundaries staggered to minimize geometric inefficiencies*
- *> 93% eff. per layer*
- *Digitized by KPIX(64or128)*

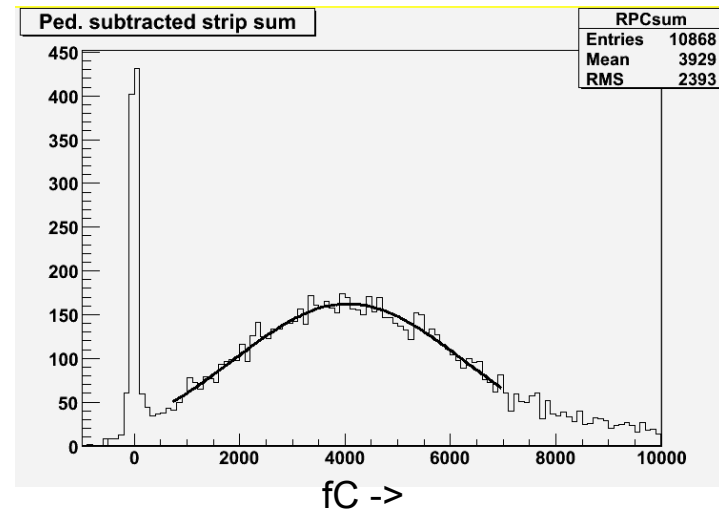


Barrel
5.7 m



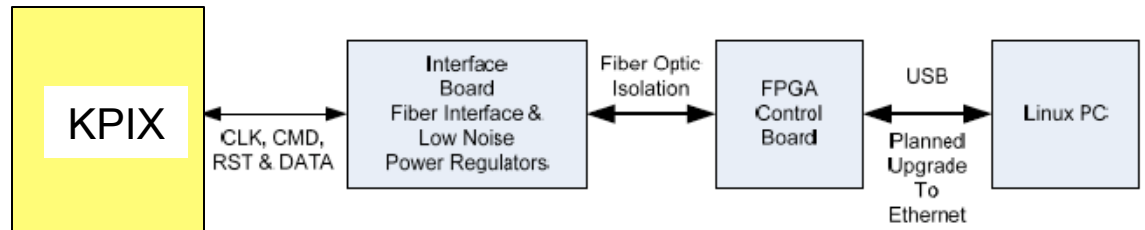
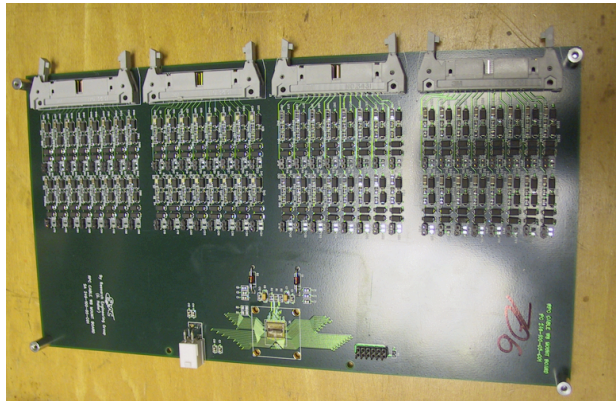
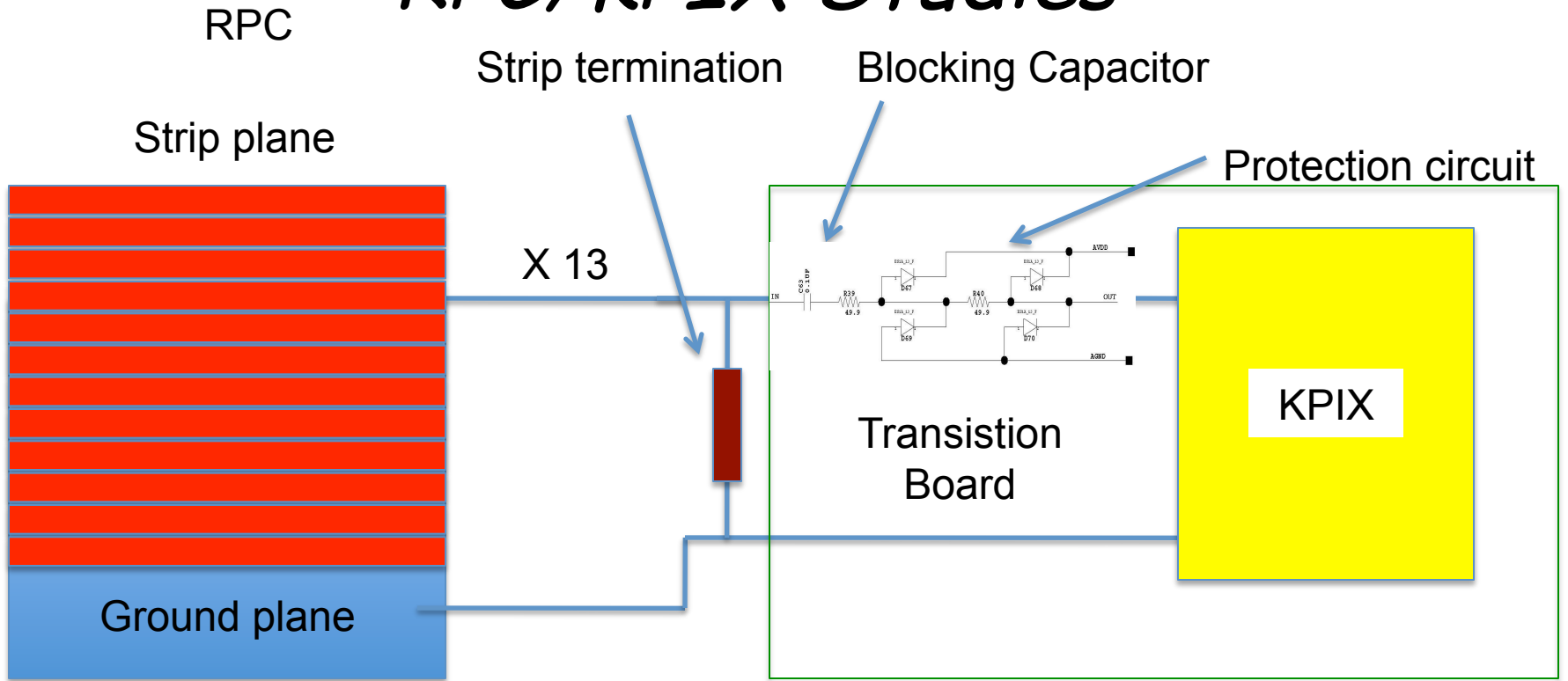
Preliminary RPC/KPIX Data

- "Proof of Concept" last year
- 64 channel RPC interface board with KPiX7
- In collaboration with SLAC KPiX group, R.Herbst, D. Freytag
- First tests -AC coupling
 1. Optimize Ω & capacitor values
 2. Protection circuits
 3. KPIX readout modes



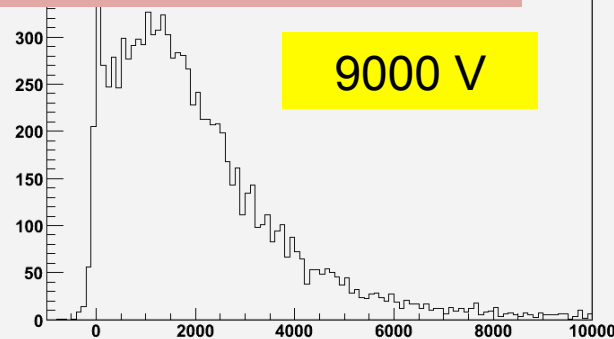
- Italian Bakelite test RPC 0.5m by 0.5 m
- BaBar avalanche gas 75.5% Freon 134a, 19.4% Argon, 4.5% isobutane, 0.6% CF6
- Strips 3.8 cm by 50 cm

RPC/KPIX Studies

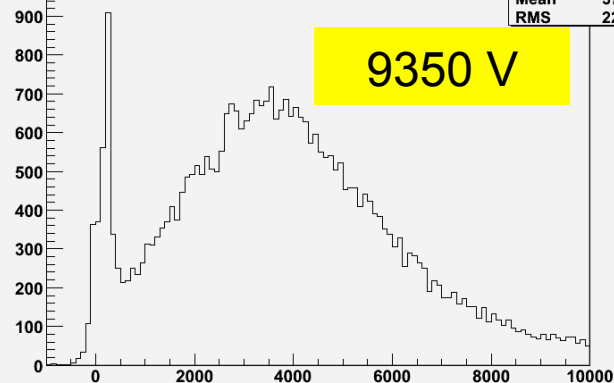


HV Scan

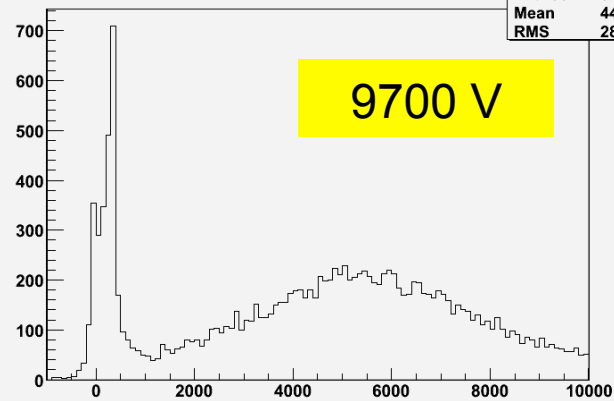
RPCsum	
Entries	10443
Mean	2008
RMS	1714



Ped. subtracted strip sum	
RPCsum	
Entries	44380
Mean	3780
RMS	2223

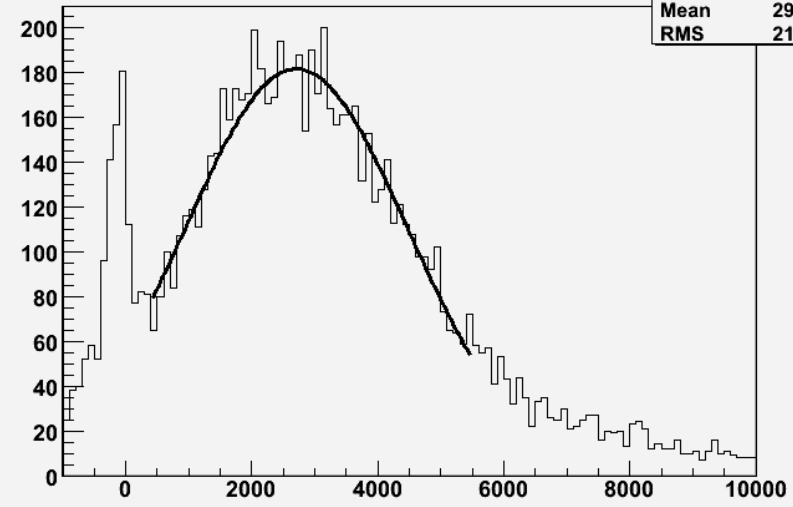


Ped. subtracted strip sum	
RPCsum	
Entries	45295
Mean	4440
RMS	2804



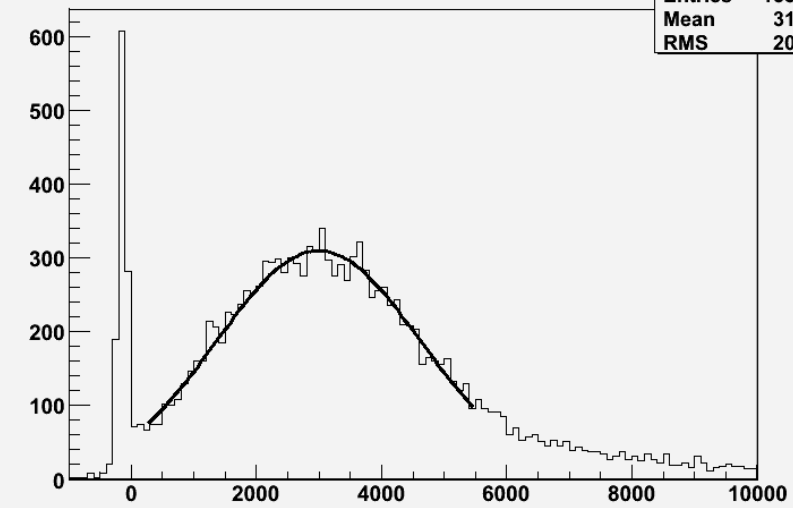
KPiX - DC resets

Ped. subtracted strip sum	
RPCsum	
Entries	10622
Mean	2920
RMS	2154



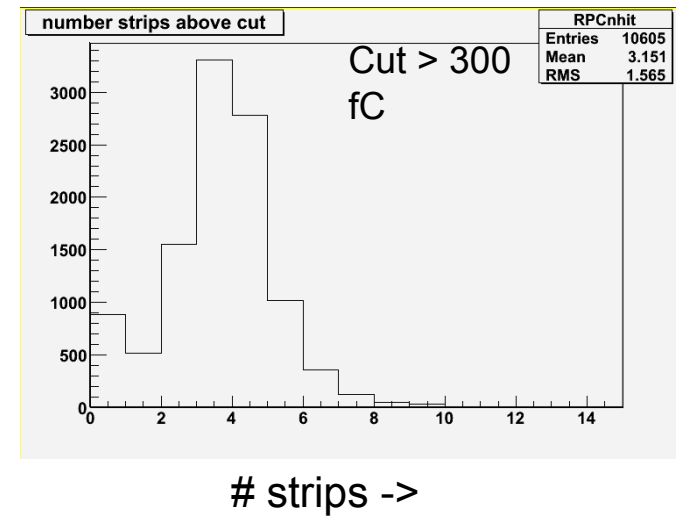
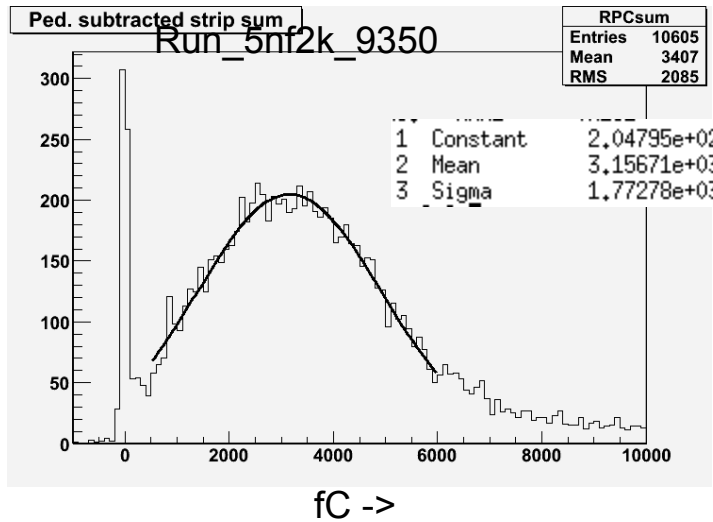
KPiX - periodic resets

Ped. subtracted strip sum	
RPCsum	
Entries	15399
Mean	3184
RMS	2089

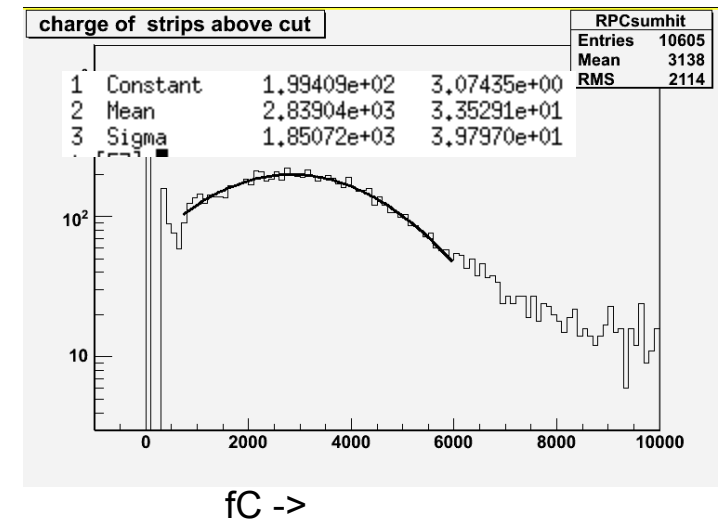
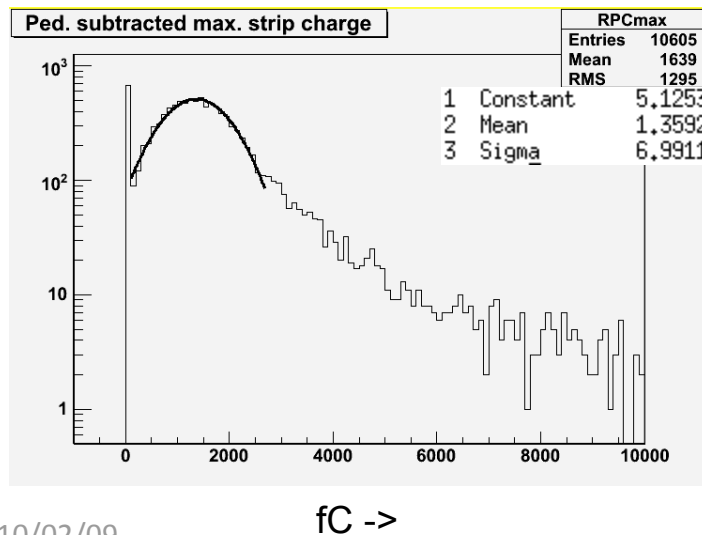


Charge Sum of all strips
 Charge of Max. strip
 Charge Sum of strips above cut

Strips 3.8 cm wide



Less than half
 of the charge is
 in the max.
 strip



RPC/KPiX R&D Plans



- *2009 Milestones*

- *Relocate test-stand*
- *Optimize RPC/KPiX interface board design to maximize efficiency and minimize strip multiplicity.*
- *Make current, rate, and efficiency measurements of IHEP test RPCs operating in avalanche mode.*
- *Test KPiX (v. 7 & v. 8) trigger and reset operating modes.*

- *2010-11 Milestones:*

- *Readout multiple KPiX chips*
- *Use position and charge information from multiple RPC/KPiX devices to make fitted cosmic ray tracks*
- *Study position resolution of RPC/KPiX tracks,*
- *Test HCAL prototypes in teststand*

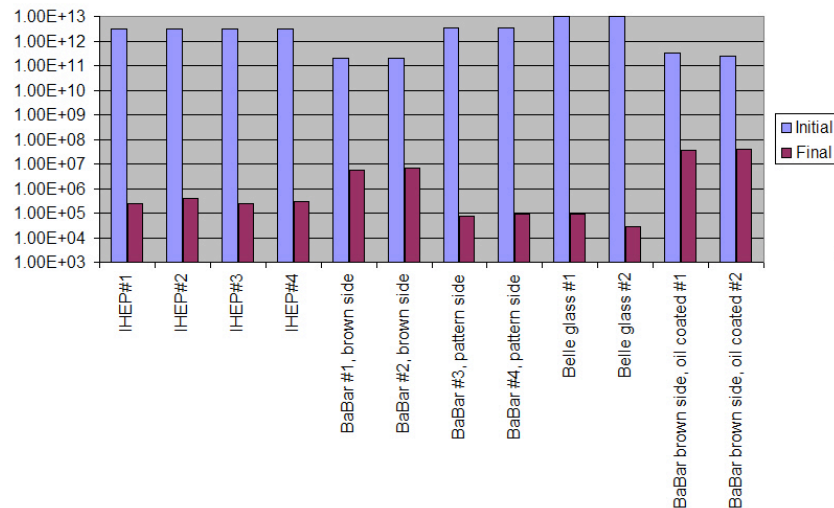
RPC Studies

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*
 - *Source studies*
- *Wisconsin - H. Band*
 - *BaBar forward RPCs*
 - *Construction similar to ATLAS/CMS RPCs*
 - *6 years of data*
 - *Huge range of background & signal rates*
 - *Analysis of trends & correlations*
 - *Autopsy of aged RPCs*

RPC R&D - Princeton

- *Focus on IHEP RPCs*
- *DAYABAY streamer mode operation*
- *Accelerated aging studies with source*



Previous HF studies

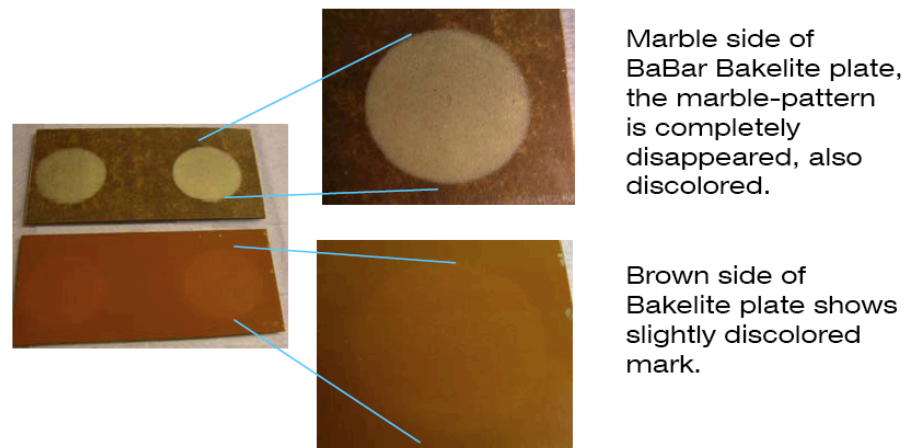


Figure4. HF vapor corrosive action on BaBar Bakelite surface.

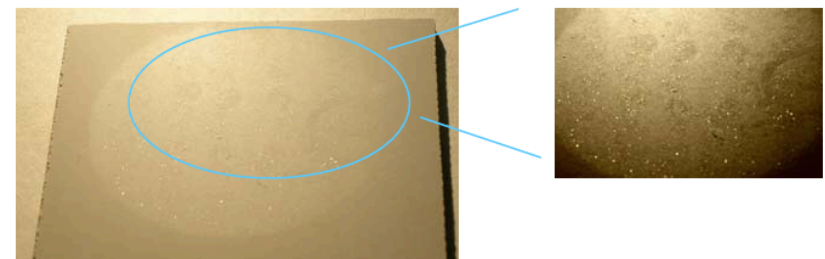


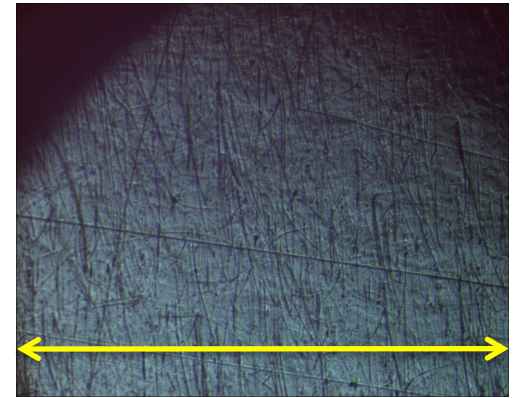
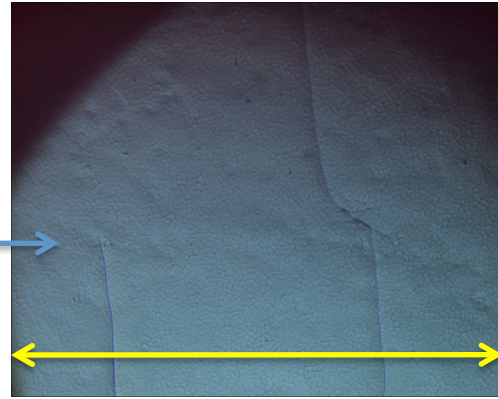
Figure 5. HF corrosive action on BES III bakelite surface.

Surface finish

- *Optical photos of inner surfaces before after aging*

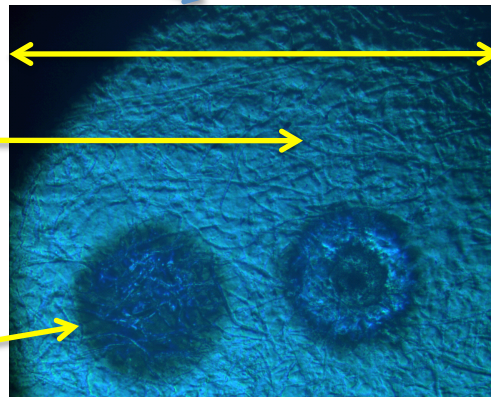
IHEP

CMS

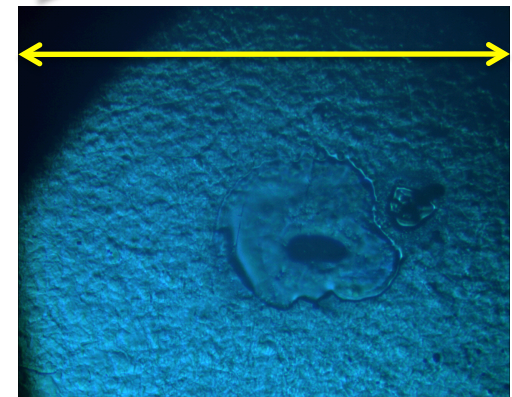


Surface roughened

Aged RPCs
Discharge points



Anode

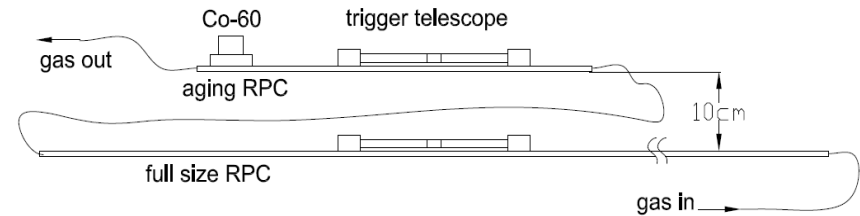


Cathode

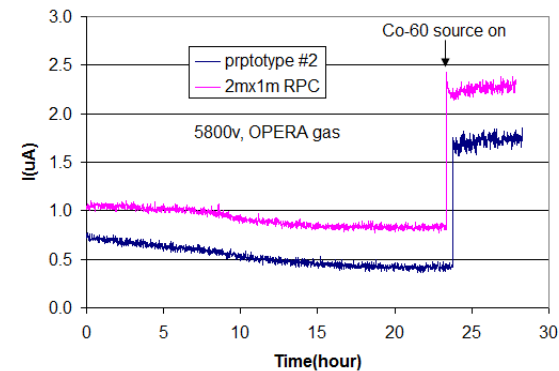
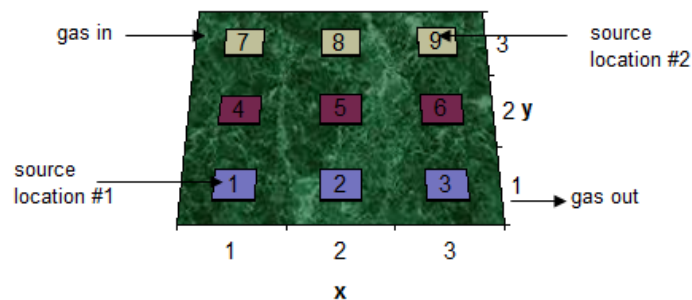
2.25mm

Accelerated Aging studies

- *Co-60 source*
- *Aging ~ 30 times faster than cosmic + chamber noise*
- *2 rounds*
 - *1 month at position 1*
 - *1 month at position 9*

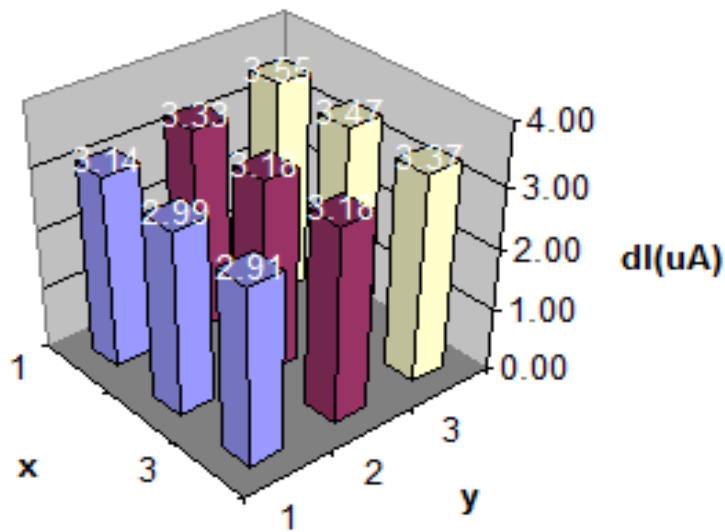


This jump of $1.3 \mu\text{A}$ is due to the source, $1.3 \mu\text{A} \times 40\% = 0.5 \mu\text{A}$ concentrated on 10cm radius circle area.



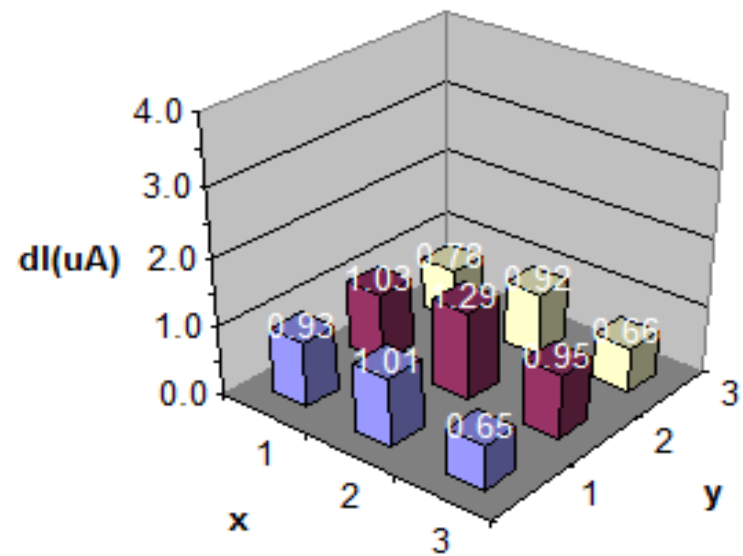
Dark current change with source

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 dl .



(a)

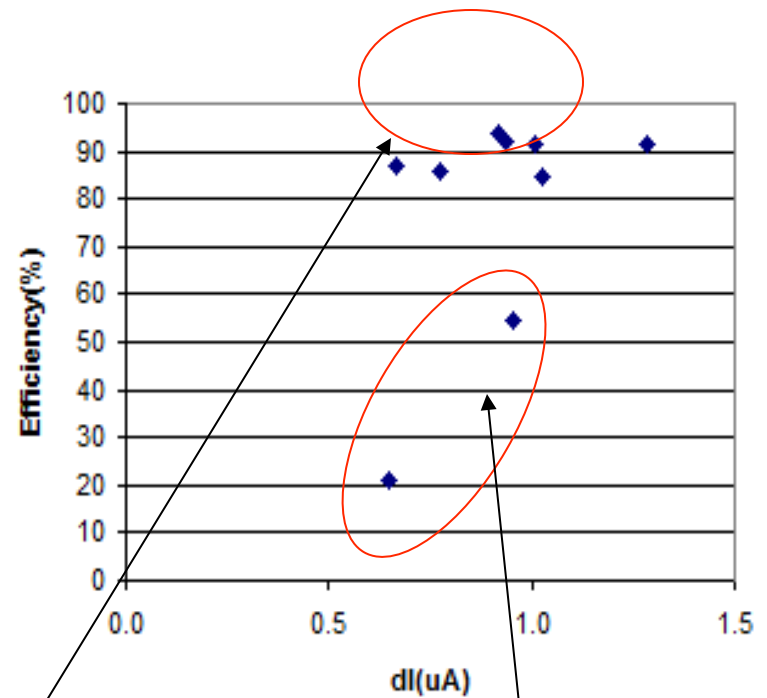
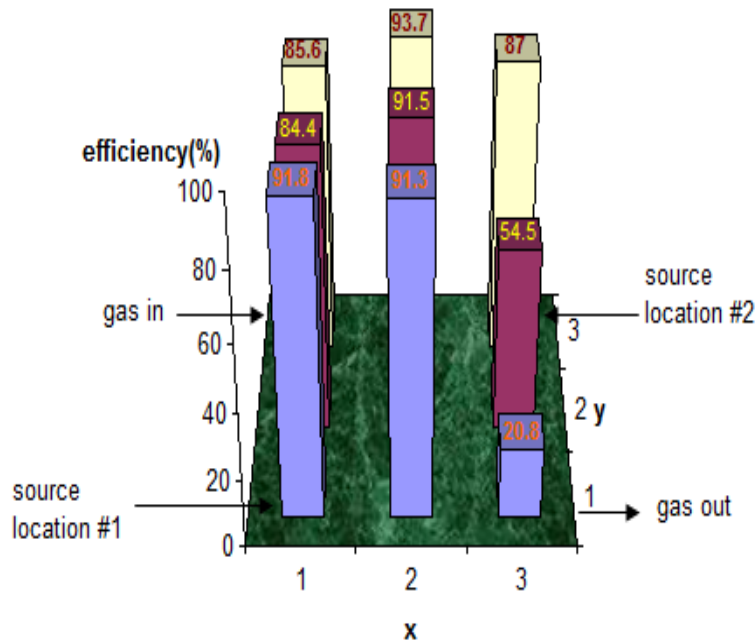
Full size RPC, dl larger, small relative variation.



(b)

Aging RPC, dl much smaller, larger relative variation.

Efficiency map after 2 rounds of aging



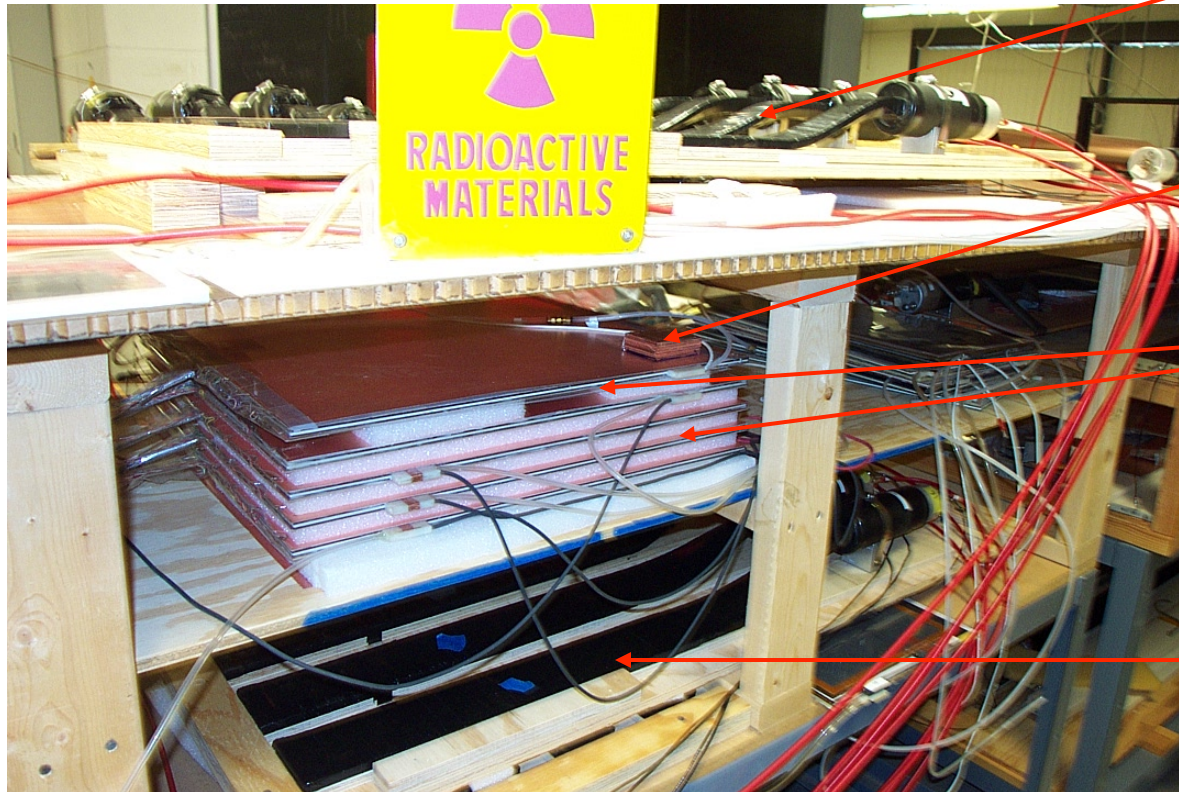
Efficiency survey results at the end of second round of aging tests.

Scatter plot of efficiency vs. current jump, dl , 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.

Expanded Aging Test

4 new RPCs - Additional 23 days



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

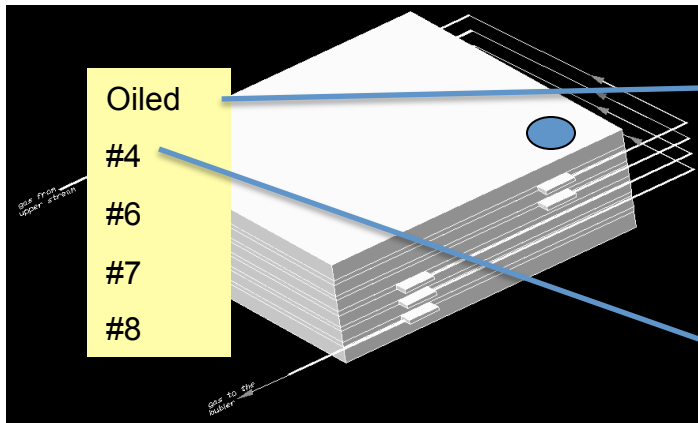
Copper plates, Co-60 source sits on.

Aging test RPCs.

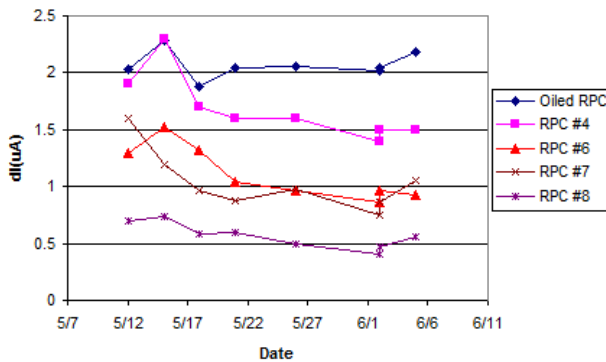
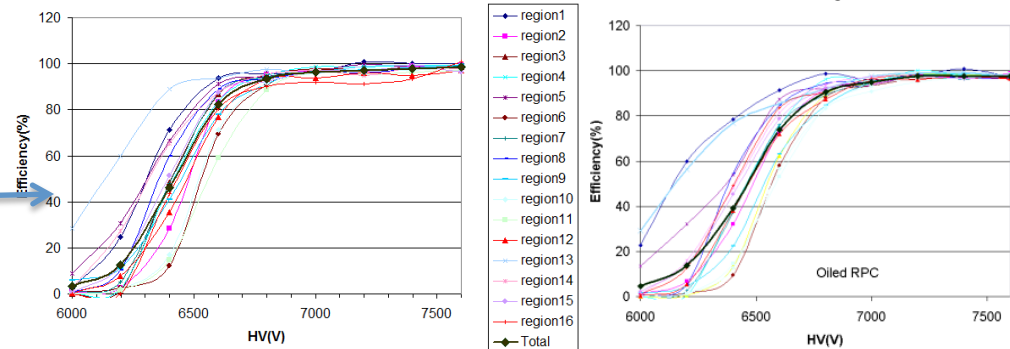
Bottom trigger array (x and y, 4 for each).

Plus oiled IHEP RPC

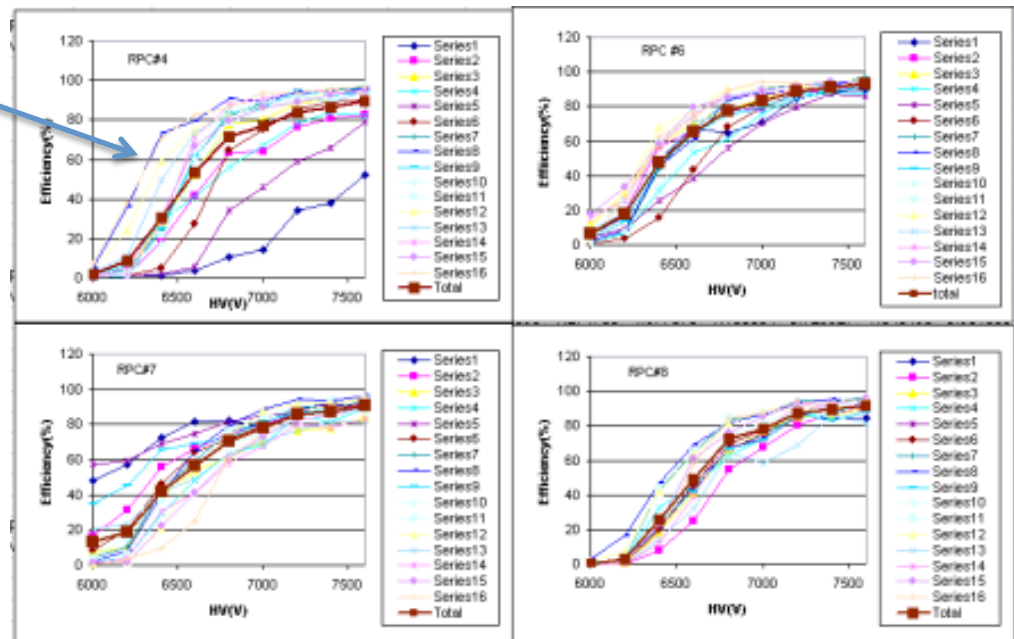
Efficiency & currents after Source Exposure



23 days



Degradation of current jump due to source



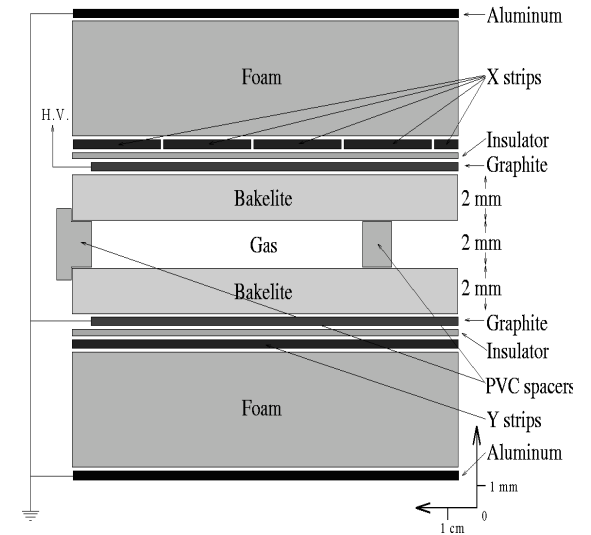
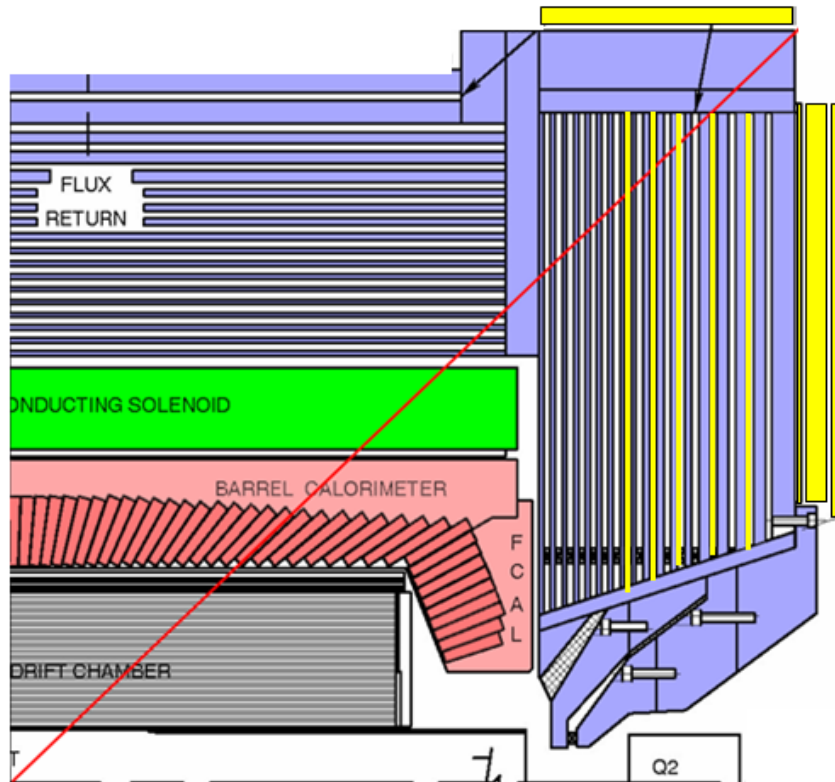
53 days

RPC R&D - Princeton

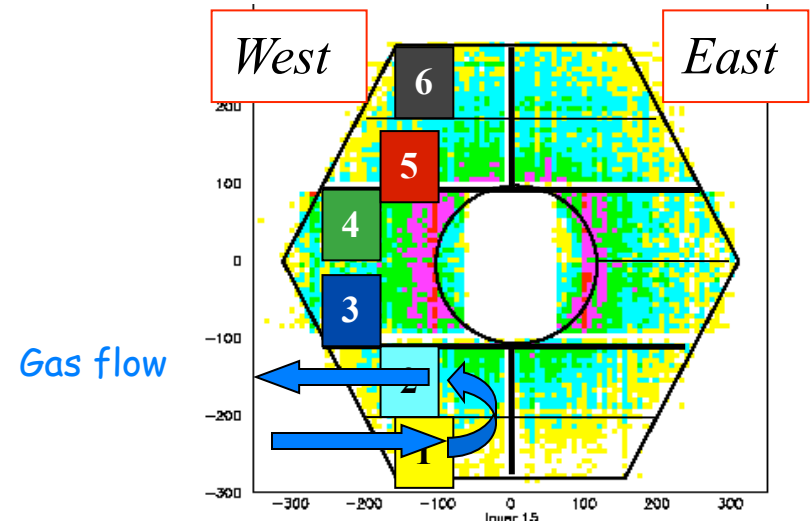
- *Summary*
 - *Changes in both efficiency and current observed*
 - *Region near gas outlet & under source most sensitive*
- *Reinforces previous findings that streamer mode operation at $> 10 \text{ Hz/cm}^2$ is a problem*
- *Beyond FY2009*
 - *Collaborate with IHEP and Gaonengke to try out various new Bakelite electrodes*
 - *Bench top test robustness to HF*
 - *General performance test for new Bakelite electrode*
 - *Aging test for the new RPCs.*

BaBar Forward RPCs

BaBar 2nd generation RPCs were installed in the forward endcap muon detector
 All initially streamer mode, some converted to avalanche mode



12 RPC HV modules per layer, grouped into 6 gas volumes



RPC Studies

- Over 200 2nd generation RPCs were installed in fall 2002
- Run from Nov.02 - Apr. 08

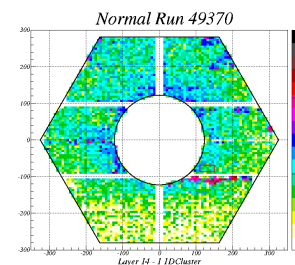
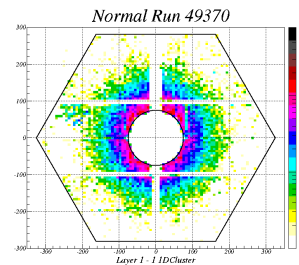
Accumulated a lot of data for an aging study:

- from chambers: current, rate, efficiency
- environment: temperature, humidity, gas flow

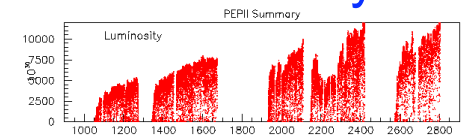
Need to decouple the aging effect from other kind of failures ~ 8%:

- gas problems
- HV problems

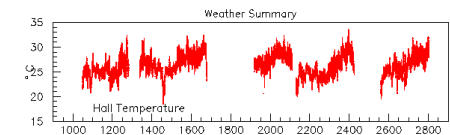
Take into account the different operating conditions



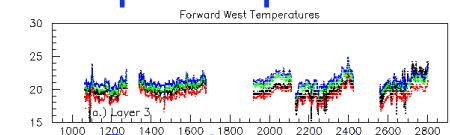
Luminosity



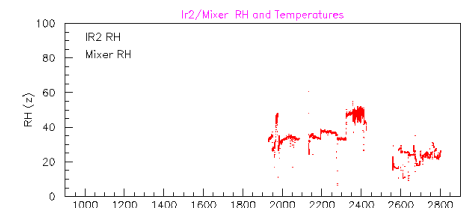
Hall Temperature



Gap Temperature

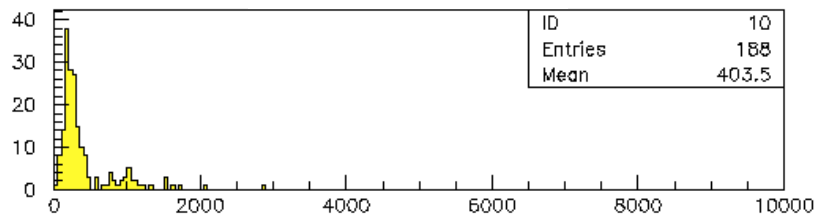


Gas humidity

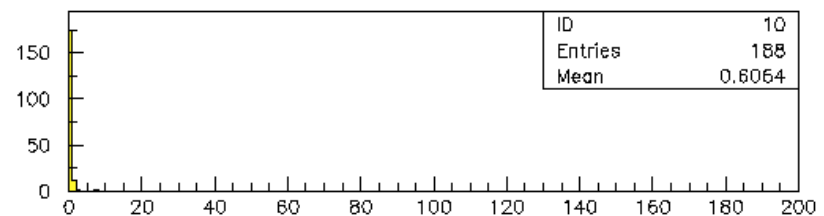


Noise Rate and Currents with Cosmic Rays

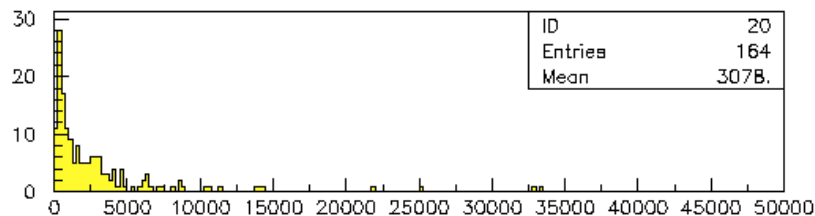
- Both noise and currents have increased over 5 years
- Average noise rate 400 Hz \rightarrow 3 kHz (area 1.5 - 2 m²)
- Average current $< 1 \mu\text{A} \rightarrow 12 \mu\text{A}$



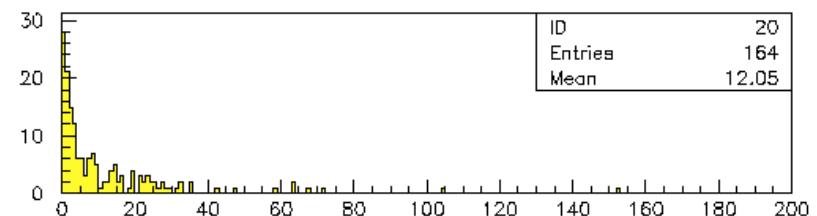
Cosmic Noise Rate Begin Run 3



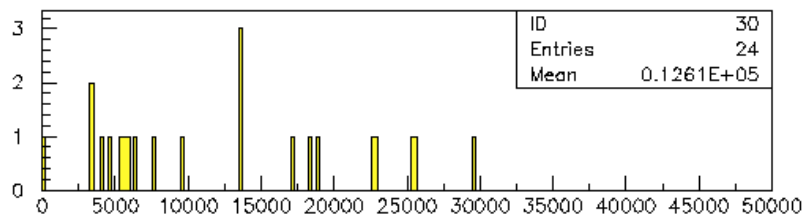
Cosmic Current Begin Run 3



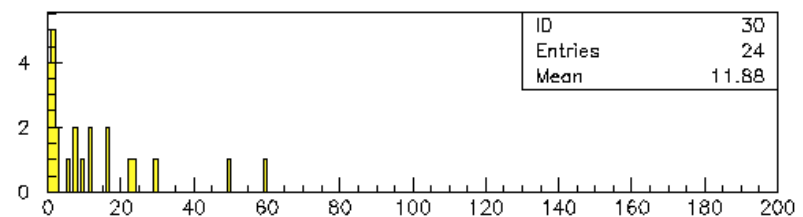
Cosmic Noise Rate End Run 7 Streamer



Cosmic Current End Run 7 Streamer



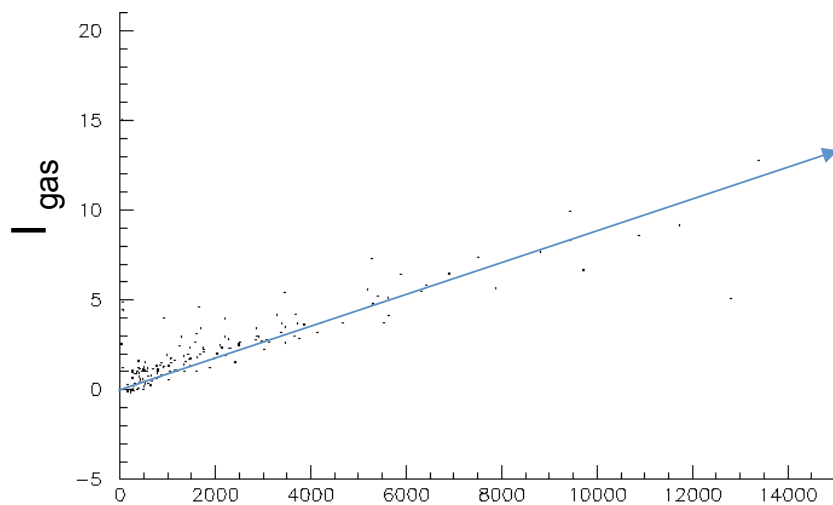
Cosmic Noise Rate End Run 7 Avalanche



Cosmic Current End Run 7 Avalanche

Noise Rate and Currents with Cosmic Rays

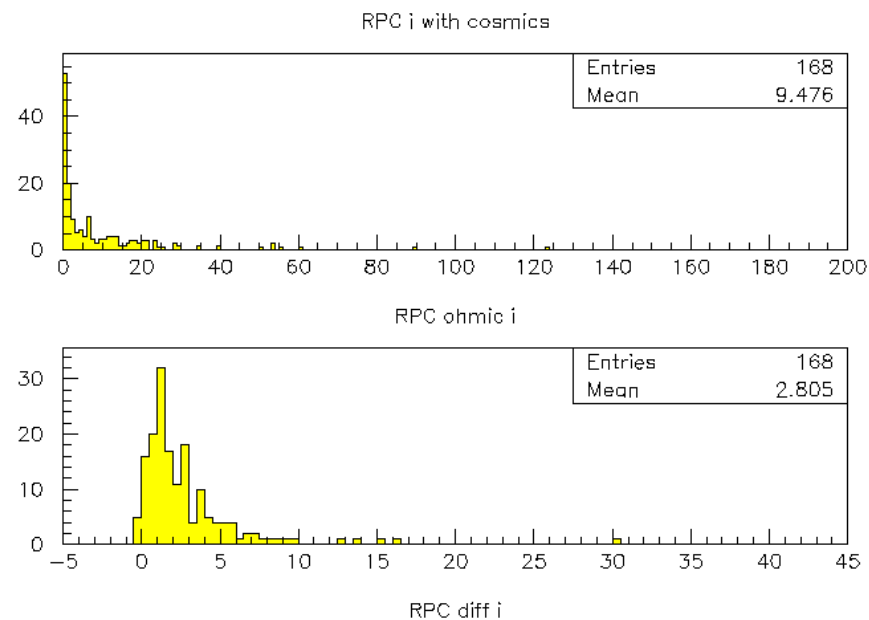
- About $\frac{3}{4}$ of current increase due to rise in ohmic current (Estimated by extrapolating the I vs V curve below the gas gain turnon)
- Remaining $\frac{1}{4}$ strongly correlated with increased noise rate



10/02/09

RPC Rate with cosmic rays

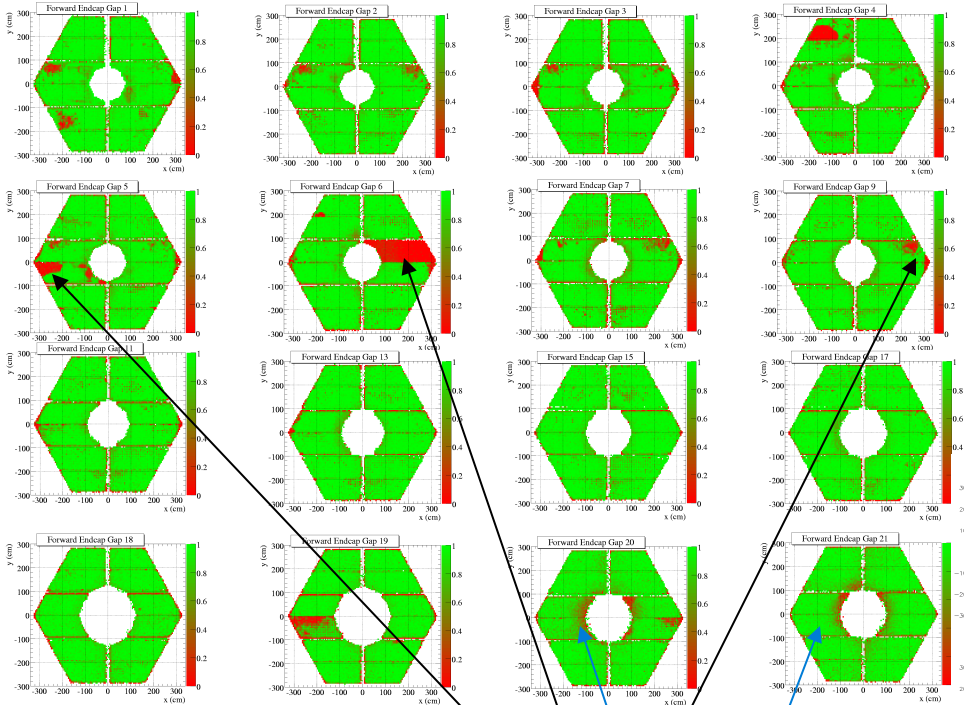
H. Band -LCWA 09



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

Cosmic vs Collisions

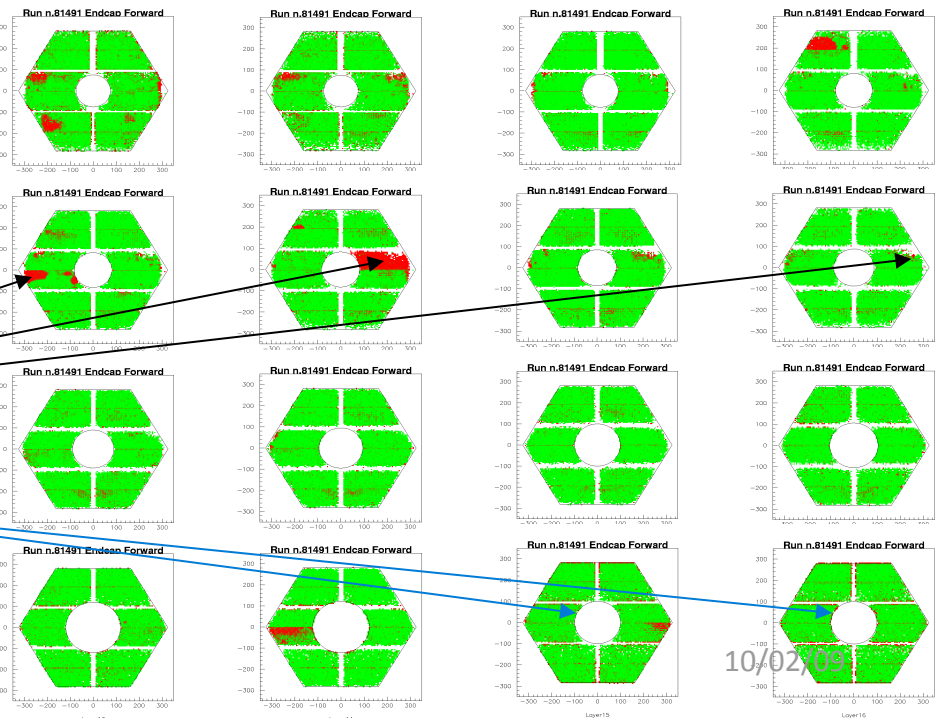
μ pairs with beam



2-D Efficiency map

Overall - efficiency at the end of running remains high

Cosmic rays



Certain features due to gas, HV, high noise are common

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

BaBar RPC Plans

- *RPCs finally being removed from BaBar steel (this week)*
- *Two aging symptoms not understood in detail*
 - *Rate dependent inefficiency around beam line*
 - *Rate independent inefficiency near gas outlets*
- *Sample of 10 chambers chosen for further study/autopsy*
- *Will try to correlate measured bulk properties of the Bakelite and graphite and surface condition of the cathode/anode with these failure modes*

Summary

- *KPiX readout of RPCs looks very promising*
- *Still much to be do to optimize interface, KPIX operation*
- *RPC aging studies have mostly done in streamer mode.*
 - *Exception - LHC avalanche mode at high rates OK*
 - *Most, if not all aging observed in streamer mode, associated with high rates $\gg 1 \text{ Hz/cm}^2$*
 - *Unclear if IHEP RPCs are more resistant to aging*