Analysis of Small RPC DHCAL Prototype Data

(noise and cosmic ray)

- Environmental Dependence
- Gas Flow Dependence
- Secondary signals
- Long-term Stability

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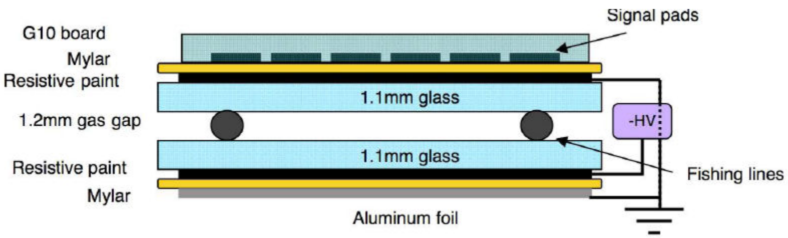
Motivations

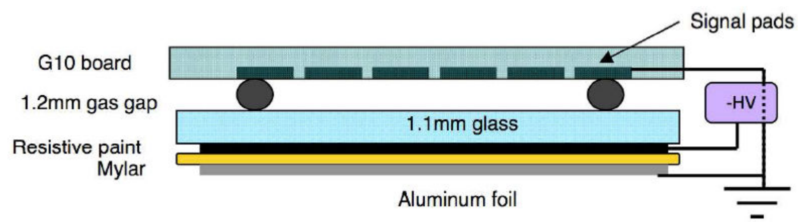
- A competitive candidate for digital hadron calorimeter
  - ✓ Cheap, simple structure, easy to build large-area detectors
- Gaseous Detector with flowing working gas:
  - ✓ It's observed environmental conditions affect RPC's performance.
  - ✓ Previous experimental studies from another groups are limited in efficiency only
- Important for future DHCAL operation
  - ✓ It's needed to measure the effect and understand it, and in the future this information will be important for operating a Digital Hadron Calorimeter
- Helpful to understand the working mechanism of RPCs
  - ✓ This research is meaningful academically

Setup and Configuration

2-glass Design



1-glass Design(RPC#6)



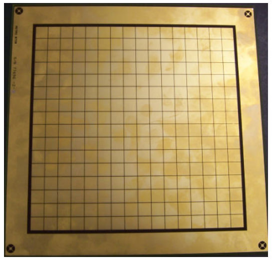
RPC number	0	*1*	*2*	3	4	5	6	7
Glass plates	2	*2*	*2*	2	2	2	1	2
HV [kV]	6.2	*6.2*	*6.2*	6.2	6.2	6.2	6.0	6.2
Condition	good	*damaged*	*damaged*	good	good	good	good	good

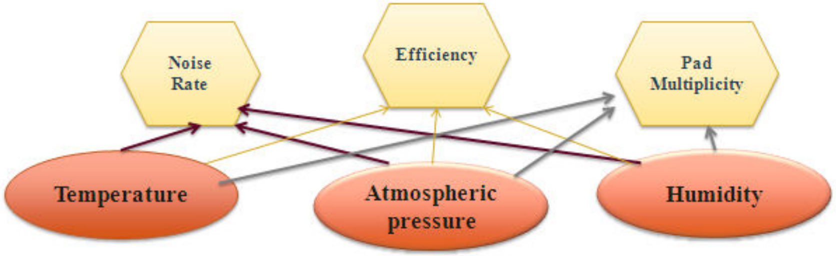
RPC Size:

20cm*20cm(8 layers)

Readout Pad:

1cm*1cm(16*16chs per layer)





Working mode:

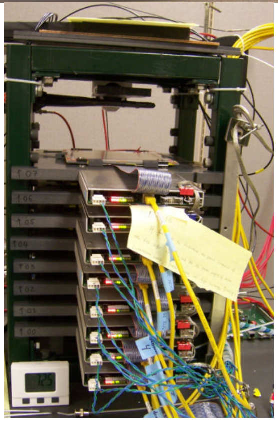
Saturated avalanche @Freon:Iso-butane:SF6=94.5%:5.0%:0.5%

Threshold:

Noise Run:30DAC(~60fC) Cosmic Run:80DAC(~200fC)

Environmental dependence

- Data Collection



Environmental Conditions

$$N = \frac{\sum hit}{TS}, \varepsilon = \frac{\sum_{i=1}^{N} \delta_i}{N}, \mu = \frac{\sum_{i=1}^{n} \mu_i \delta_i}{\sum_{i=1}^{N} \delta_i}$$

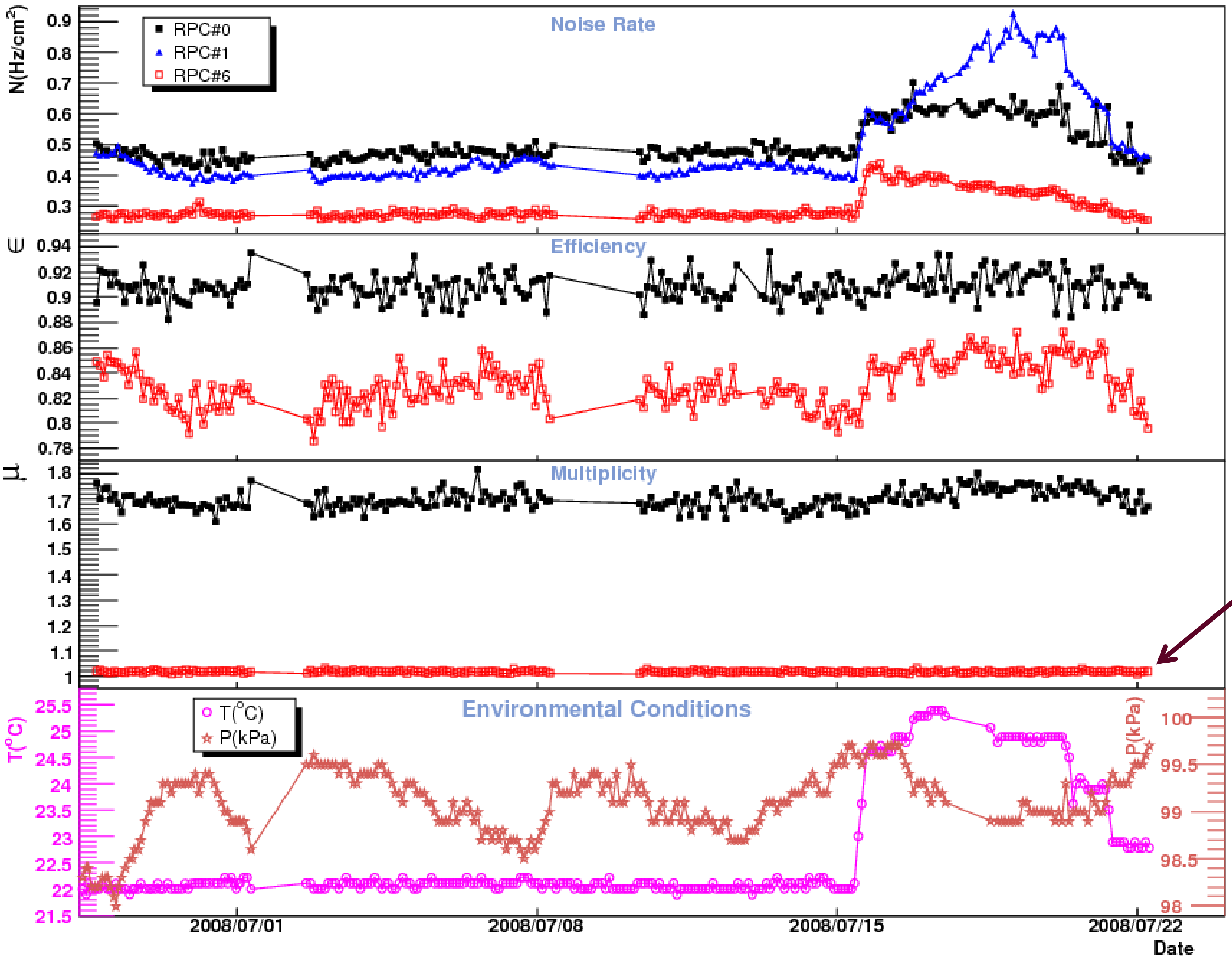
Time Matching

- Since the changes of environmental conditions are relatively small, A linear approach has been implemented.

$$F_i(T,p,H) = F_{i,0} + b_{T,i}\Delta T + b_{P,i}\Delta p + b_{H,i}\Delta H \qquad \text{with } i = N, \varepsilon, \mu$$

Standard Conditions: T=22.5°C, P=100kPa, H=40%

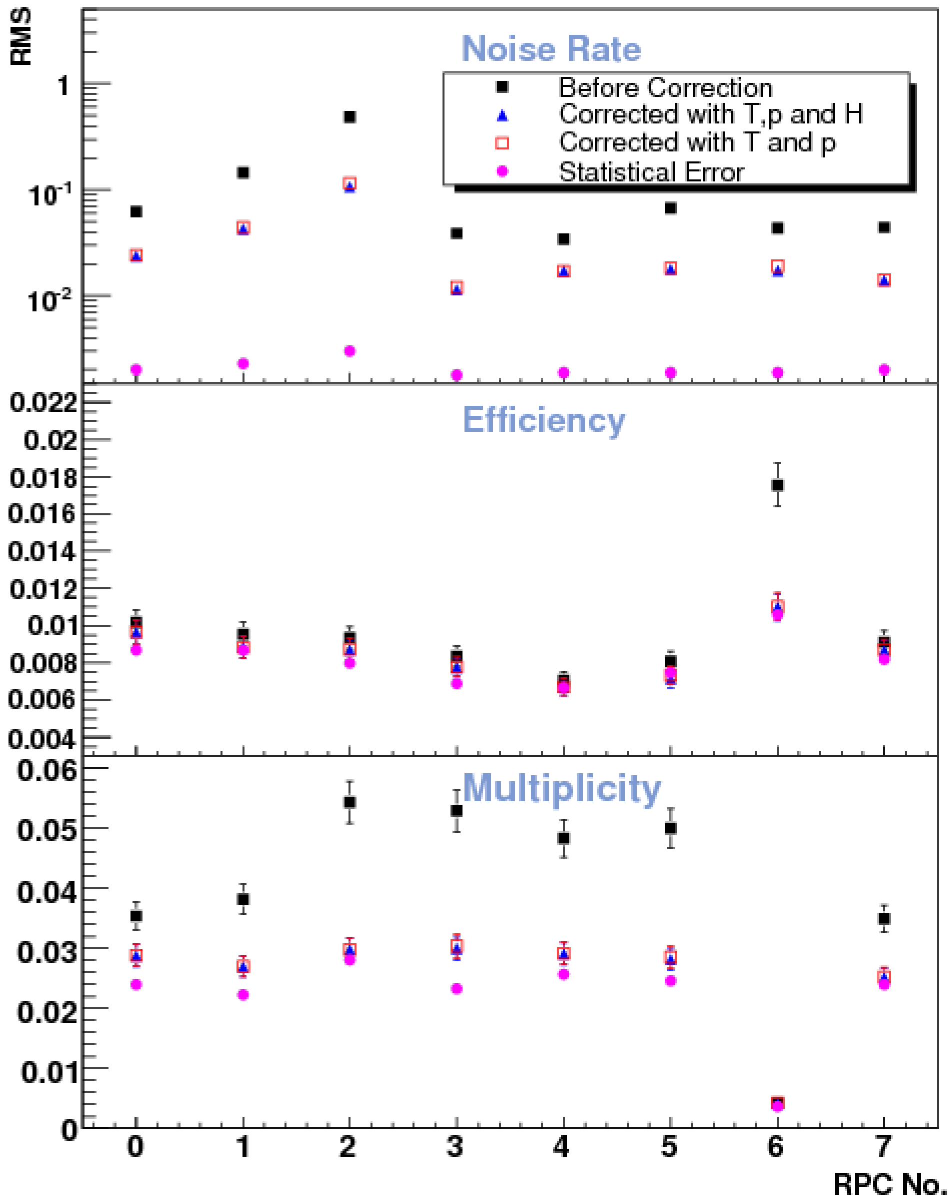
Performance Vs. Environmental Conditions



Performances fluctuate with environmental conditions except …

1-glass RPC (pad multiplicity is stable with weather and close to 1.0)

RMS Comparison

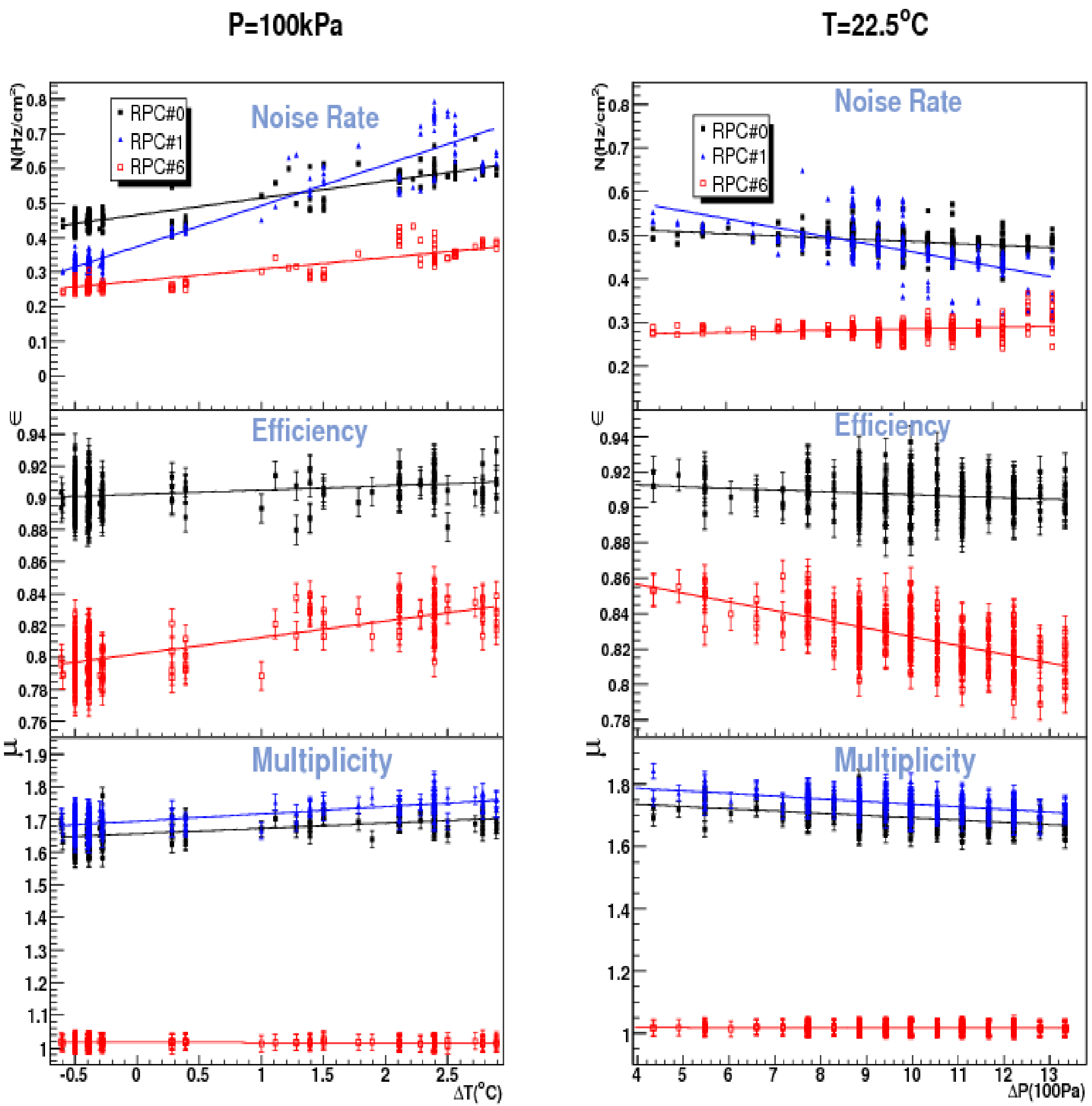


- No effect on improvement of correction performance with Humidity included means that **RPC's performance has no dependence on humidity**
- Δp and ΔT corrections reduce the width of the distributions significantly except….

Efficiency: 2-glass RPCs(minor)

Multiplicity: 1-glass RPC(stable with environmental conditions)

Slope parameters

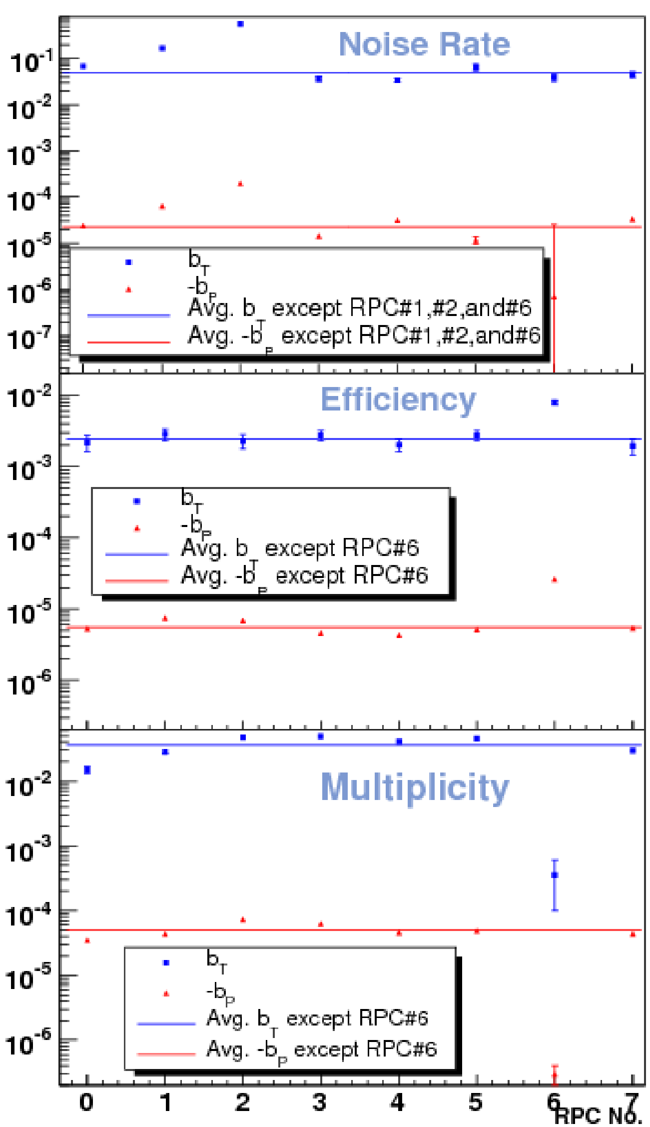


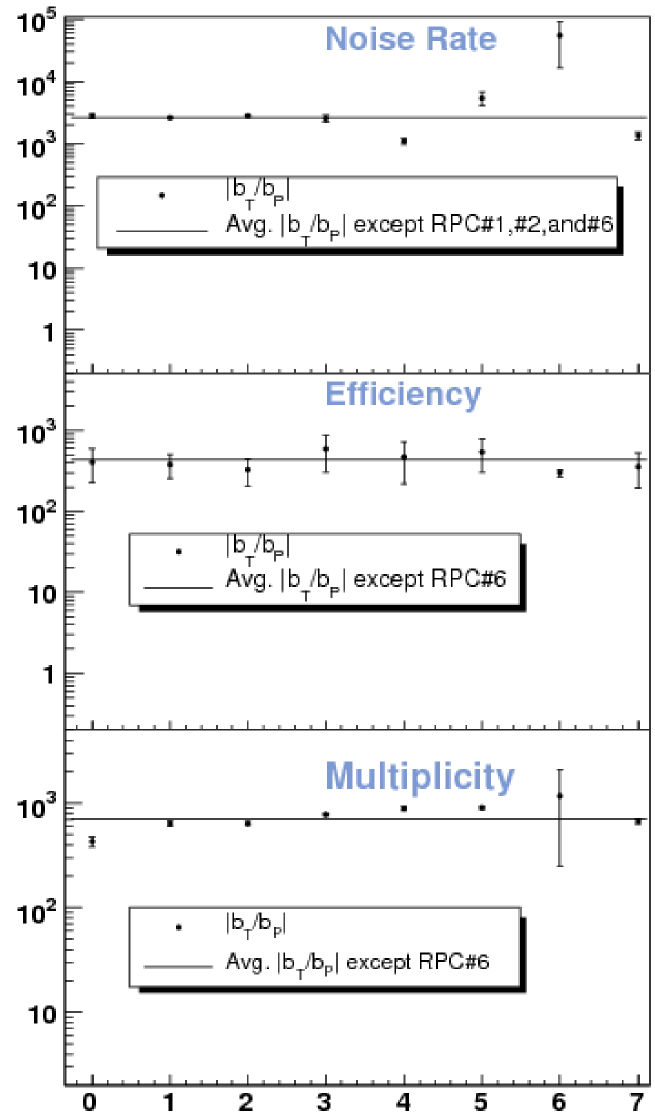
- Except pad multiplicity for exotic RPCs, all the other shows

T↑->N,ε,μ↑

p↑ ->N,ε,μ↓

b_T ,$-b_P$ and $|b_T/b_P|$



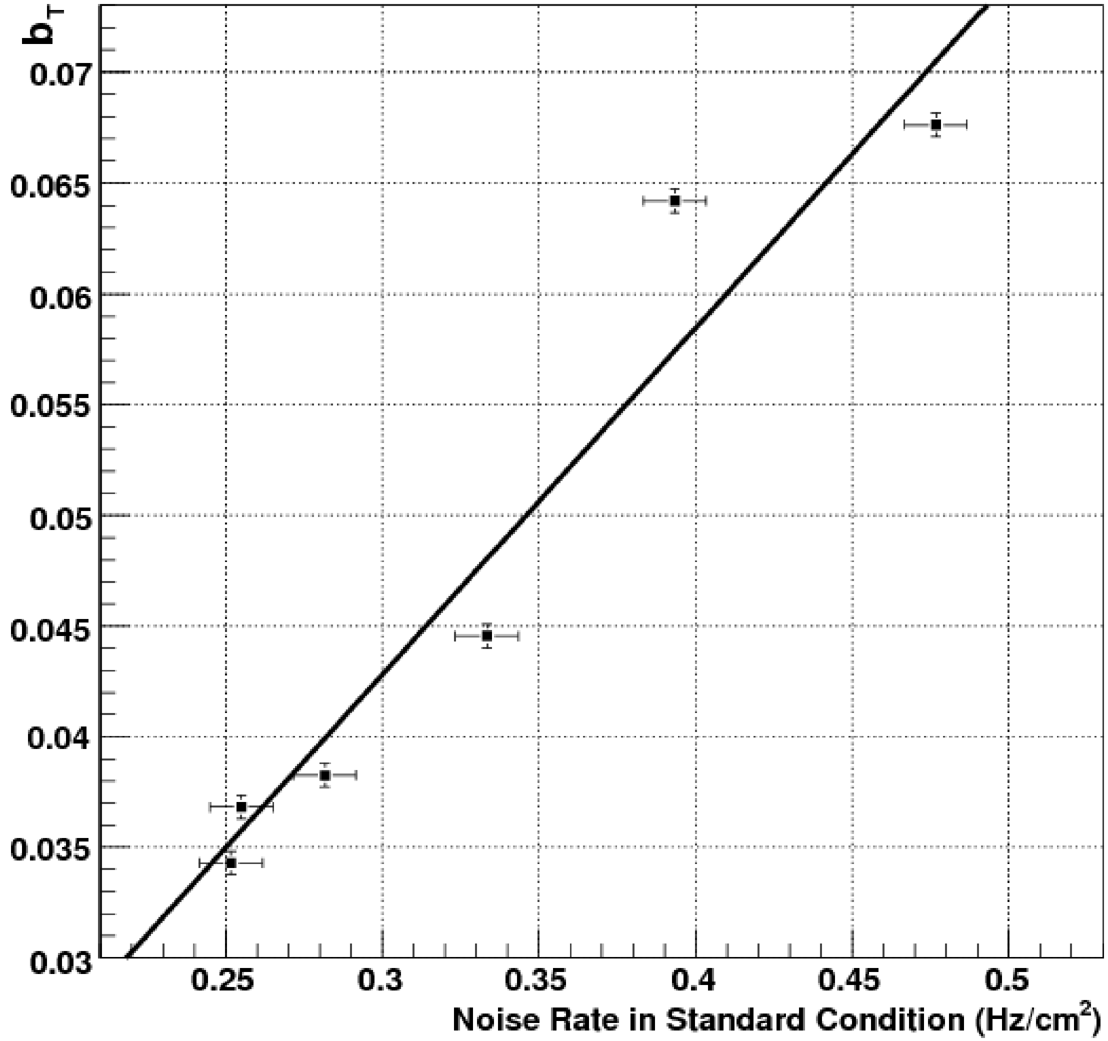


Left: b_T and $-b_P$ from linear fits are consistent for all chambers.

Right: $|b_T/b_P|$ is calculated to understand the mechanism of this phenomenon, which will be discussed later.

Observation:

noise/temp. dependence related to the noise rate at standard conditions (good RPCs)

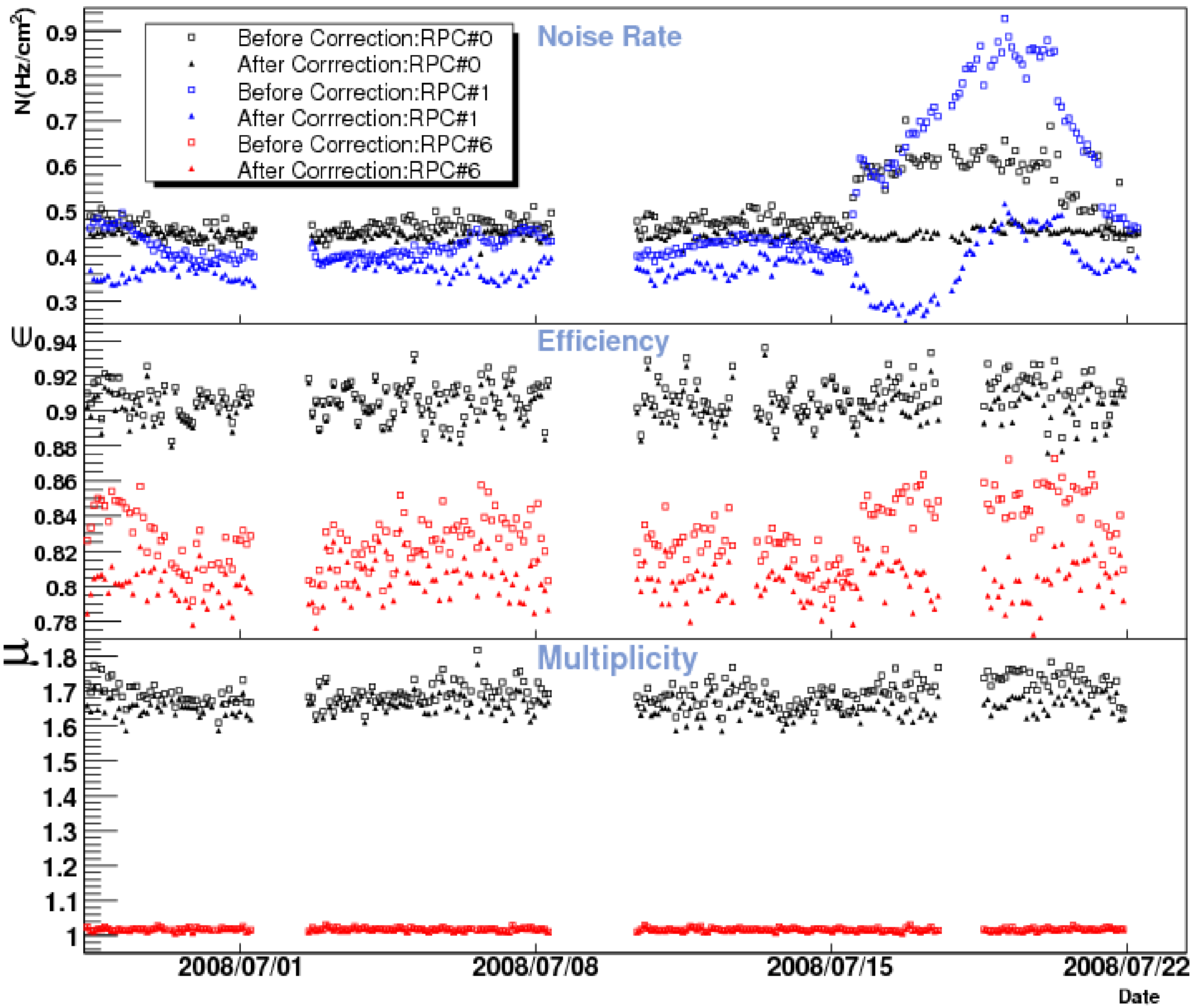


Percentage Change of the Performance Vs Unit Change of Temp./Pressure

Performance variable	Changes for $\Delta T = 1\ ^0C$			Changes for Δp= 100 Pa		
RPC design	2-glass		1-glass (Good)(%)	2-glass		1-glass (Good) (%)
	Good(%)	Damaged(%)		Good(%)	Damaged(%)	
Noise rate	14±1.6	42±1.2	13±1.8	0.70±0.037	1.73±0.028	0.02±0.694
Efficiency	0.26±0.051	0.28±0.056	0.98±0.078	0.06±0.001	0.08±0.001	0.32±0.001
Pad multiplicity	2.0±0.09	2.0±0.09	0.035±0.0250	0.30±0.002	0.26±0.002	0.003±0.0010

Corrected data points

The correction smoothed out the bumps and dips in the measurements.



- For the damaged RPCs, the noise rate is overcorrected, which needs further study to understand.

- correction has a minor effect for the 2-glass RPCs being operated on the efficiency plateau

Due to its stability in multiplicity, correction has no effect on the 1-glassRPC.

Discussions on environmental dependence

- Gas gain and Primary ionizations depend on Mean free path (or the density of working gas)

$$\lambda = \frac{RT}{\sqrt{2}\pi d^2 N_A P}$$

$$f(\frac{T}{p}) \approx f(\frac{T_0}{p_0}) + f'(\frac{T_0}{p_0}) \times (\frac{T_0}{p_0} \times \frac{\Delta T}{T_0} - \frac{T_0}{p_0} \times \frac{\Delta p}{p_0}) = f(\frac{T_0}{p_0}) + b_T \Delta T + b_P \Delta p$$

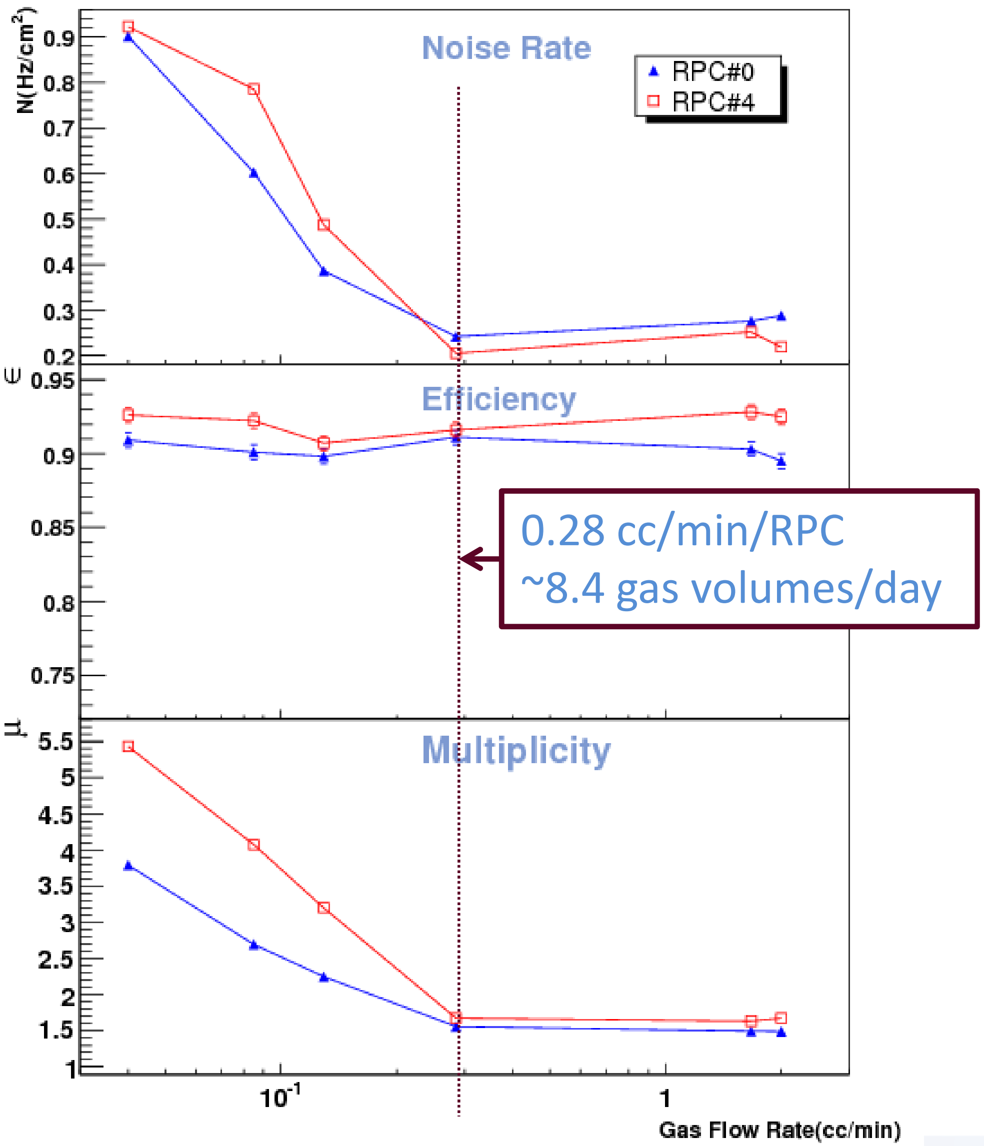
$$b_T = f'(\frac{T_0}{p_0}) \times \frac{T_0}{p_0} \times \frac{1}{T_0}, b_P = -f'(\frac{T_0}{p_0}) \times \frac{T_0}{p_0} \times \frac{1}{p_0} \qquad f = N, \varepsilon, \mu.$$

$$|\frac{b_T}{b_P}| = \frac{p_0}{T_0} = \frac{100kPa}{295.65\text{K}} = 338\, pa / K$$

338 Pa pressure change equals 1^{O}C temperature change in affecting the performance

Noise: ~2000, migration of electrons out of the cathode (only related to temperature)
✓Efficiency: ~340, consistent with this calculation
Multiplicity: ~700, need further study.

Performance Vs. Gas Flow Rate



- Studies of the performance as a function of gas flow rate shows **no effect** on **the efficiency,** but **a dramatic increase** in **noise rate** and **pad multiplicity** for flow rates below 0.28 cc/min/RPC corresponding to about 8.4 gas volumes/day.

- This effect is most likely related to the contamination from avalanches.

Secondary signals

2-glass RPCs

	$\Delta d=0$	$\Delta d>0$(can cross fishing line)
$\Delta T=1$	0%	18.8%->3.4% with threshold
$\Delta T>1$	14.9%->0% with threshold	18.2%->0.1% with threshold

1-glass RPCs

	$\Delta d=0$	$\Delta d>0$(can cross fishing line)
$\Delta T=1$	0%	1.1%->0.3% with threshold
$\Delta T>1$	14.2%->0% with threshold	0.6%->0.4% with threshold

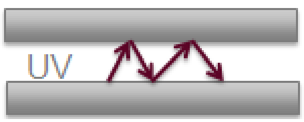
Cathode (positive ions?)

Slow drift velocity of positive ions +space charge effect
→ only appear certain time after the initial avalanches and the amplitude is very small
(the ratio is very sensitive to threshold)

(Anode difference, UV photons?)

A possible explanation: UV light

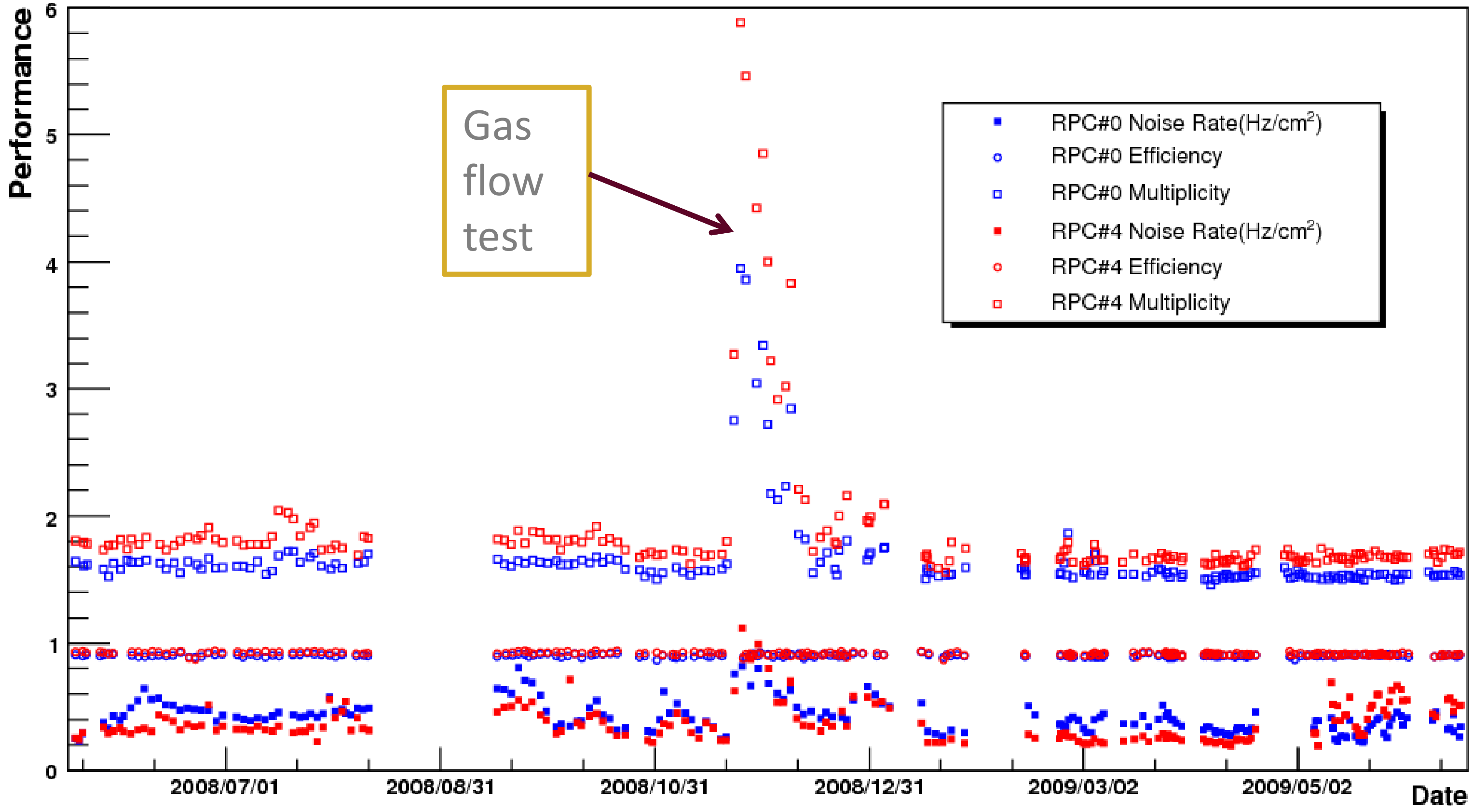
(suppressed by the material of readout pads for 1-glass RPCs)



Fishing line, Insulating tubing : transparent to UV?

Readout pads , glass: absorption to UV light?

Long-term Stability



- **In twelve months of almost continuous operation, no aging has been observed.**

Summary

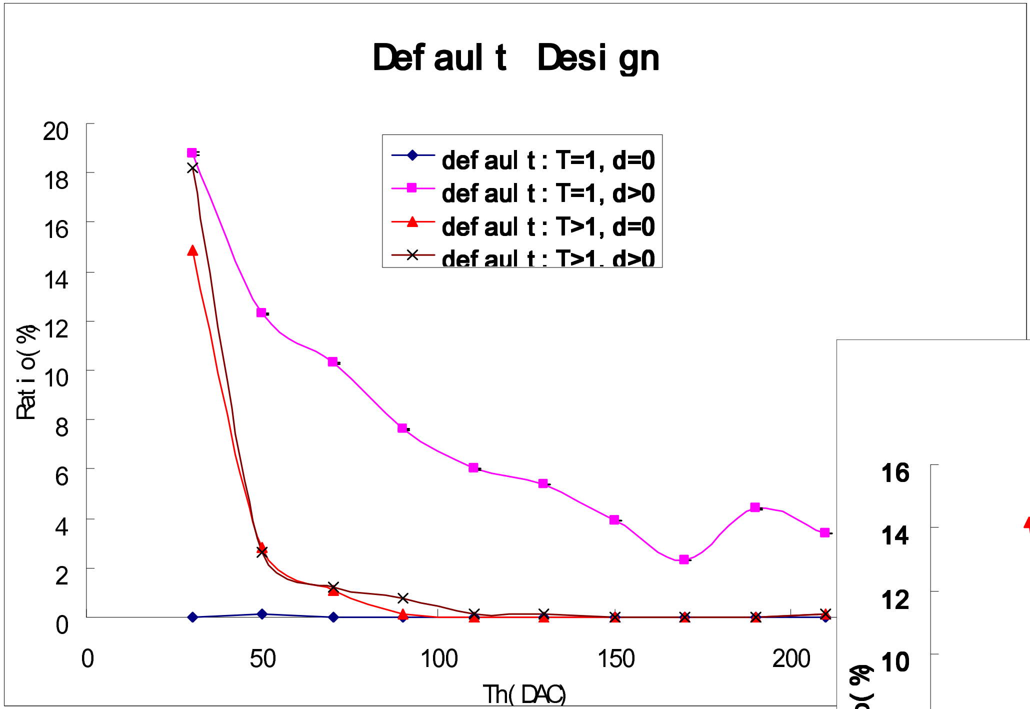
- No evidence suggests the RPC's performance depends on humidity.
- Corrections on environmental conditions have worked very well except some exceptions, most of which we have understood.
- 1-glass RPC shows its constant and ideal (~1.0) pad multiplicity.
- Lower gas flow rates increase the noise rate and pad multiplicity due to the contaminants from avalanches
- Secondary signals have been partially understood and need further check to confirm the explanation.
- **The RPCs have been monitoring continuously for 12 months, and we haven't found any aging effect!**

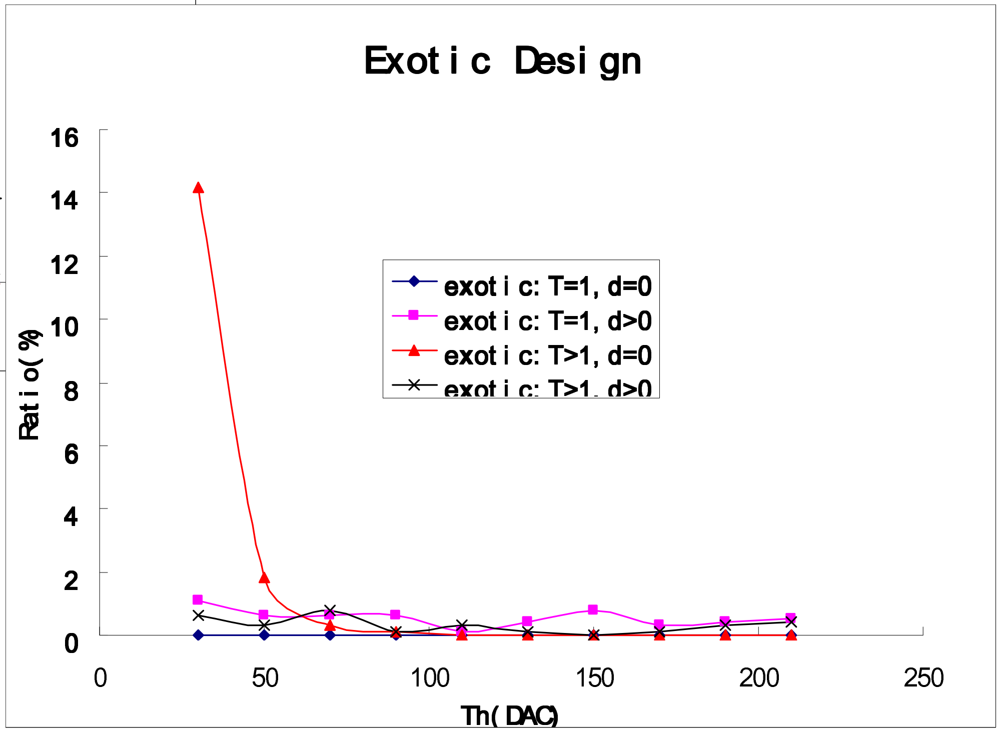
The End

Thanks!

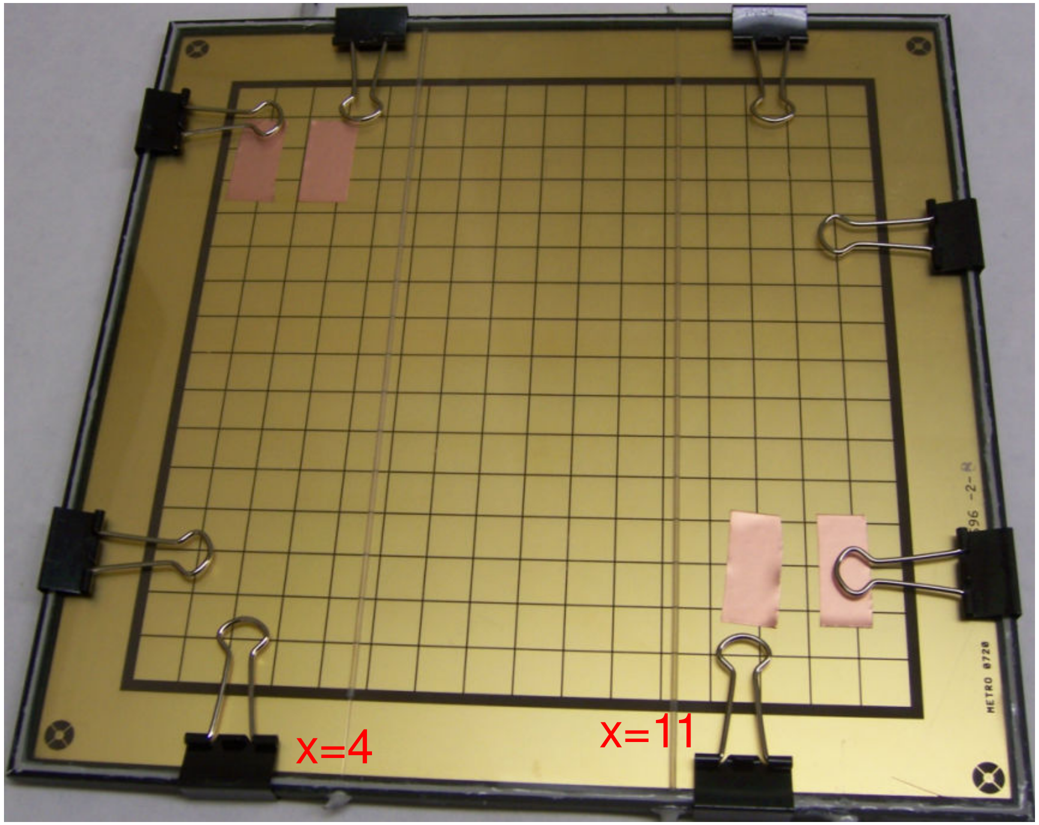
BACKUP

Ratio for two designs(secondary avalanches)





Check the secondary signals crossing fishing line Run203597



The values used for estimation of accidental coincidence :

1.Average Noise Rate:
10.4Hz/cm^2(including#1and#2)

1.4H/cm^2 (w/o #1and#2)

2.Distance: no common fired pad

3.Time window: 100ns or 1000ns after the initial signal.

4.Position requirements for original signals:

1)x>=12||x<=3 2)y>=12||y<=3

5.Position requirements for secondary signals

1)4<x<11 2)4<y<11

Comparison

Orig.	Sec.	RPC#	TW	#orig.	Est. Acc.	Result from data
X 4(1)	X5(1)	8	100	514	10^{-4}	4.1%
X 4(1)	X5(1)	8	1000	514	10^{-3}	16.7%
X 4(1)	X5(1)	6	100	361	1.4×10^{-5}	3.9%
X 4(1)	X5(1)	6	1000	361	1.4×10^{-4}	15.2%
Y4(2)	Y5(2)	8	100	547	10^{-4}	1.5%
Y4(2)	Y5(2)	8	1000	547	10^{-3}	16.6%
Y4(2)	Y5(2)	6	100	377 943(202921)	1.4×10^{-5}	1.1% 0.0%(run202921)
Y4(2)	Y5(2)	6	1000	377 943(202921)	1.4×10^{-4}	14.9% 0.1%(run202921))

X 4(1) means the position requirement for the original avalanches is x>=12||x<=3, see the previous slides.
X 5(1) means the position requirement for the secondary avalanches is 4<x<11, see the previous slides.

Run 202921 is run at normal gas flow.