

# **Resistive Plate Chambers for Time-of-Flight**

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**Compressed Baryonic Matter**  
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# Plan of the Presentation

- Main physical mechanisms
- Description of several. interesting devices
  - High frequency front-end electronics
  - Small segmented counters
  - Bidimensional position-sensitive single-gap counters
  - Large area
- Practical difficulties to be addressed for future applications
  - Crosstalk
  - Ageing
  - Tails
  - Background
  - Rate capability

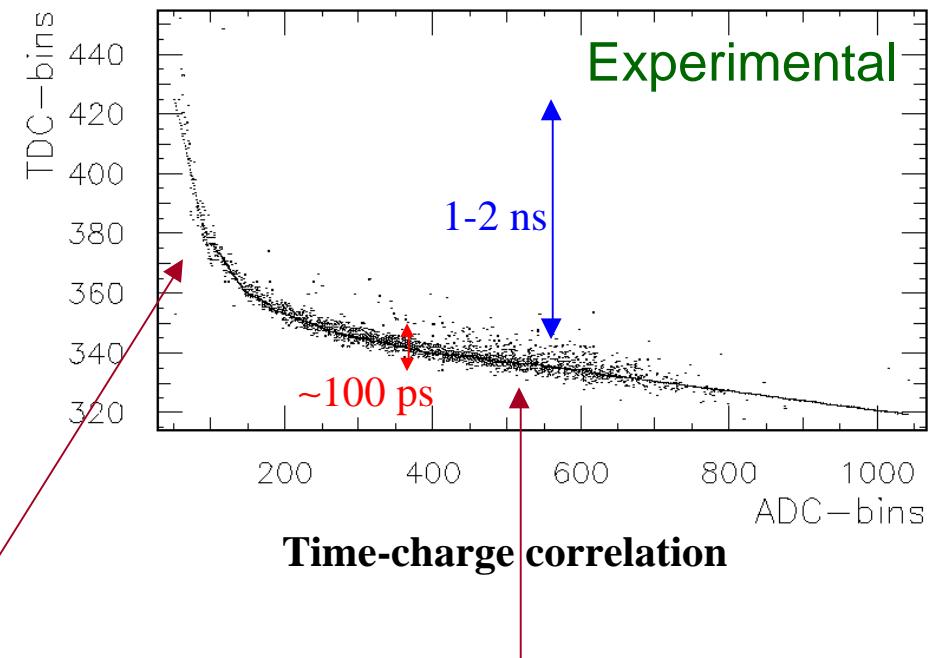
# Timing RPCs – General features



- Several (~4) thin (~ 0.3 mm) gas gaps
- Atmospheric pressure operation
- Both charge and time readout
- Offline correction for time-charge correlation.

Electronics  
rise time

Detector-related  
(not yet fully understood)



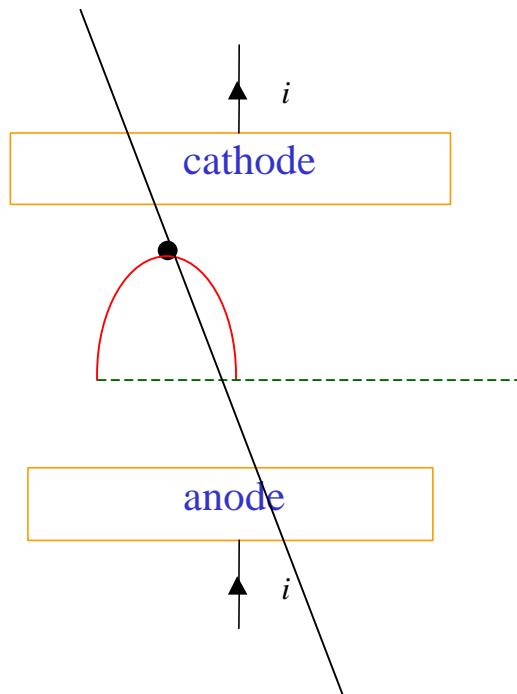
# Basic physical mechanisms



2 main questions:

How can we reach 50 ps  $\sigma$  resolution in a gas counter?

How is it possible to reach efficiencies of 75% in a 0.3 mm gas gap?



Detection level  
independent from  
the cluster position  
 $\Rightarrow$  exact timing

$N$ = average number of  
visible primary clusters

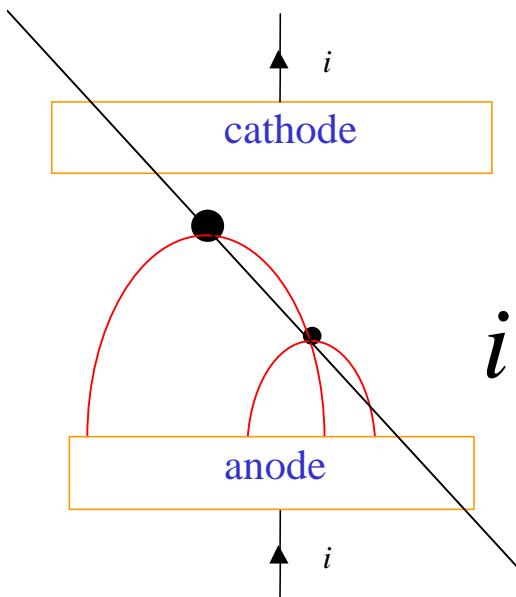
$$\bar{e} = e^{-N}$$

$$N = -\ln(\bar{e}) = 1.4$$

Av. cluster density  
 $\gg 1.4/0.3 = 4.6$

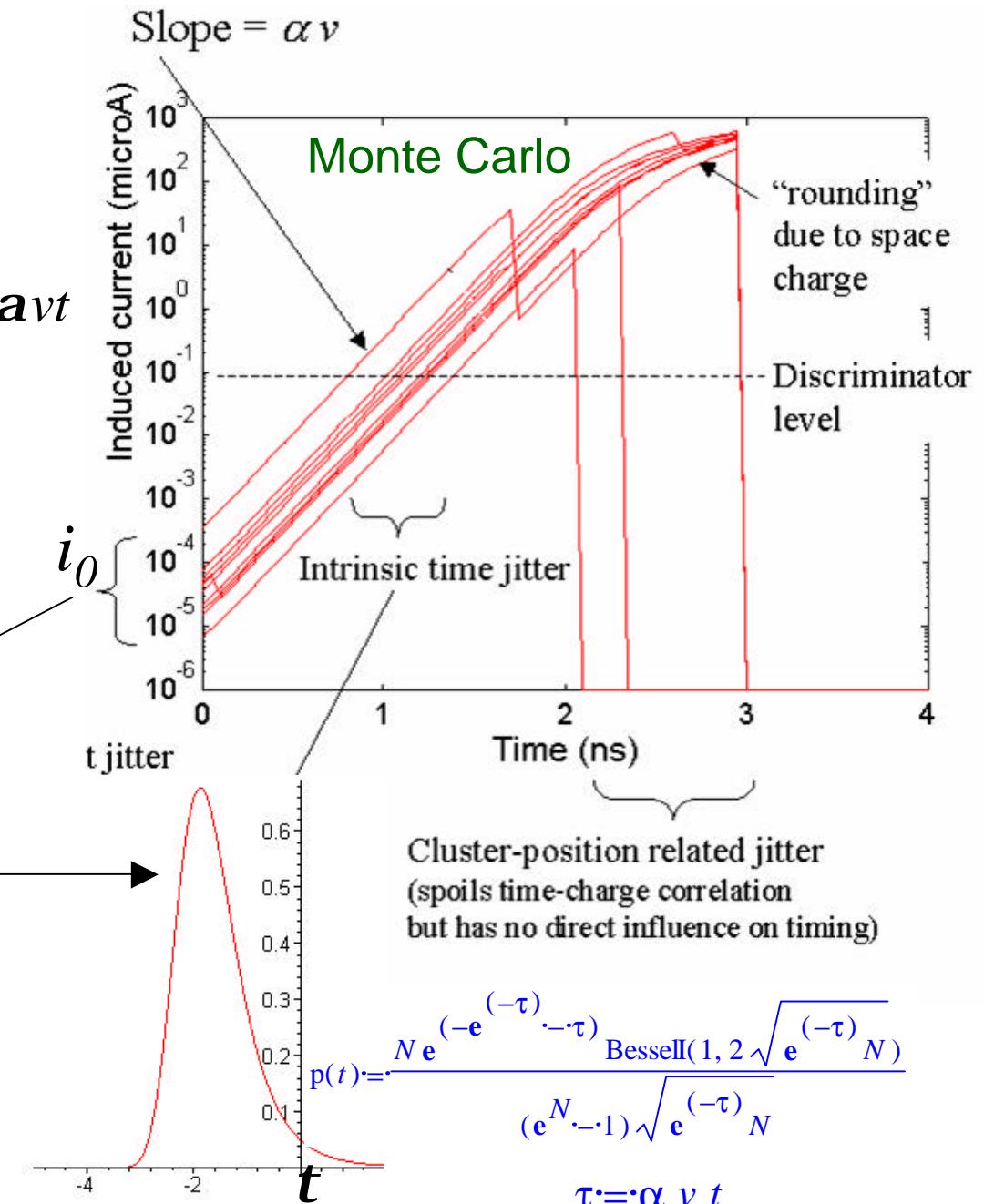
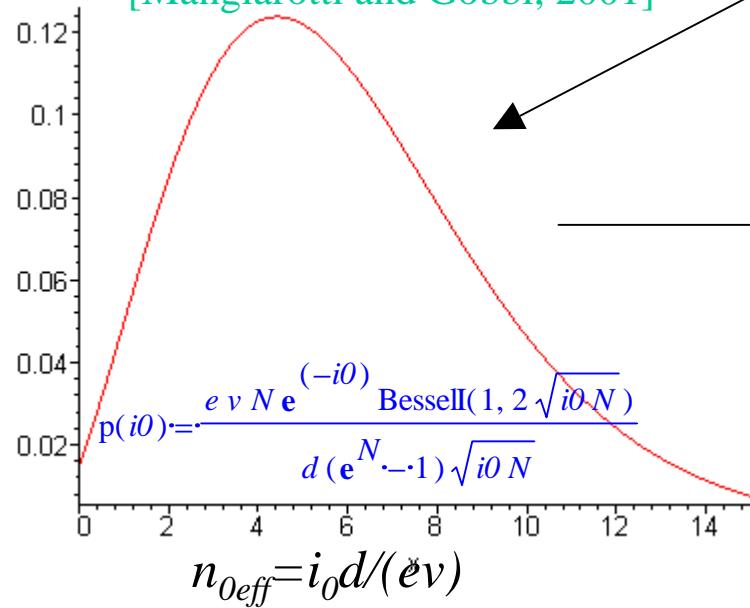


# Time resolution-principles

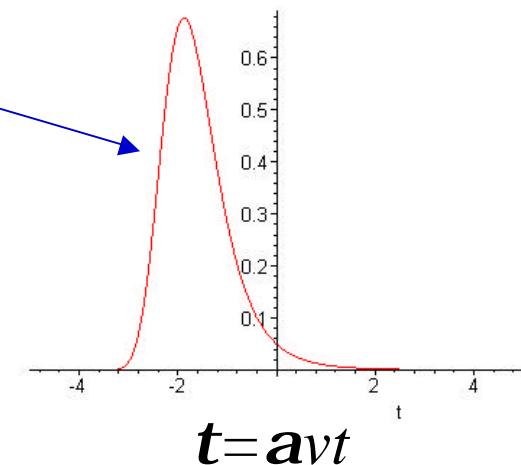
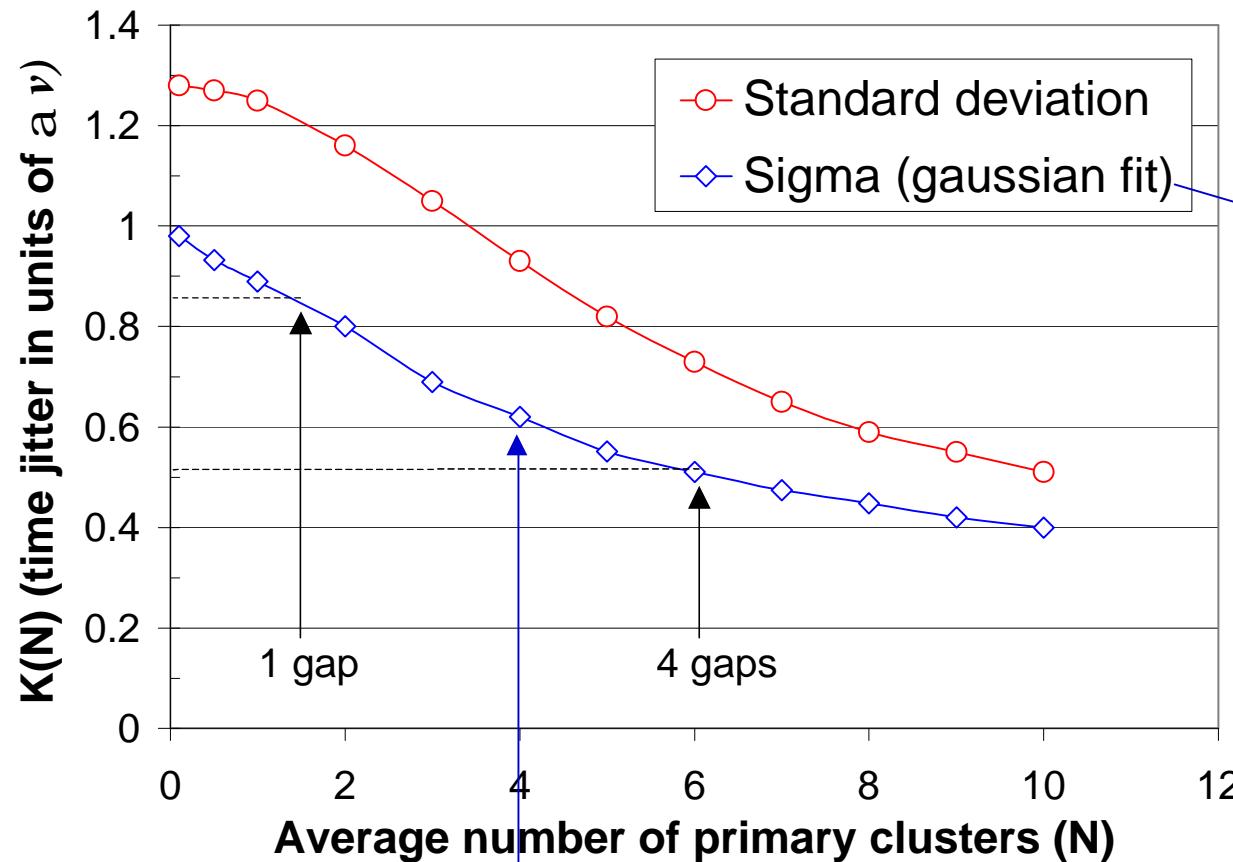


$$i(t) = i_0 e^{\alpha v t}$$

[Mangiarotti and Gobbi, 2001]



# Time resolution-principles



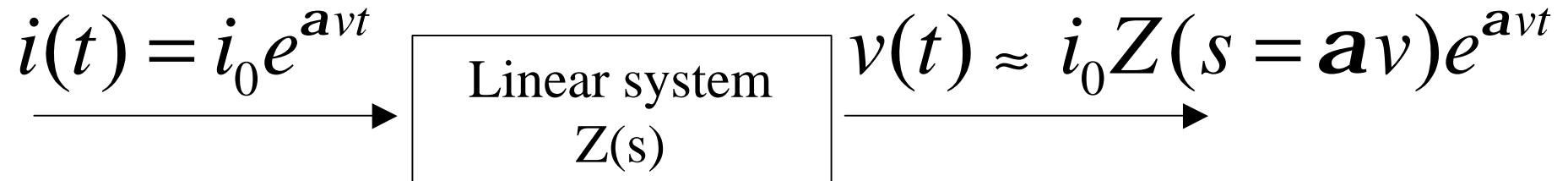
$$\sigma_t = \frac{K(N)}{\alpha v}$$

$\alpha$ =first Townsend coefficient  
 $v$  = electron's drift velocity

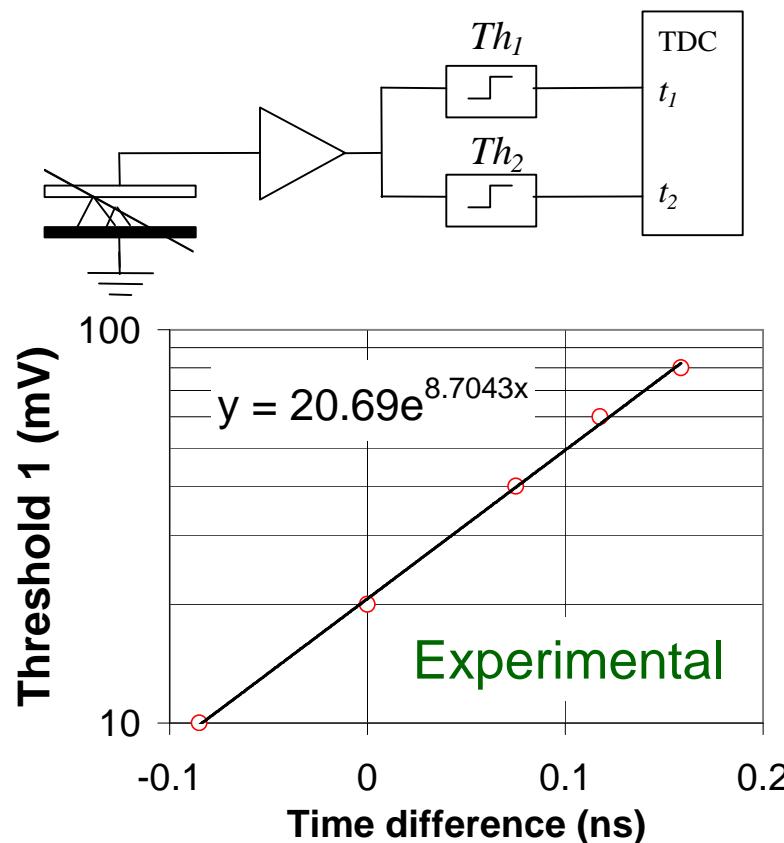
[Mangiarotti and Gobbi, 2001]

# Signal properties

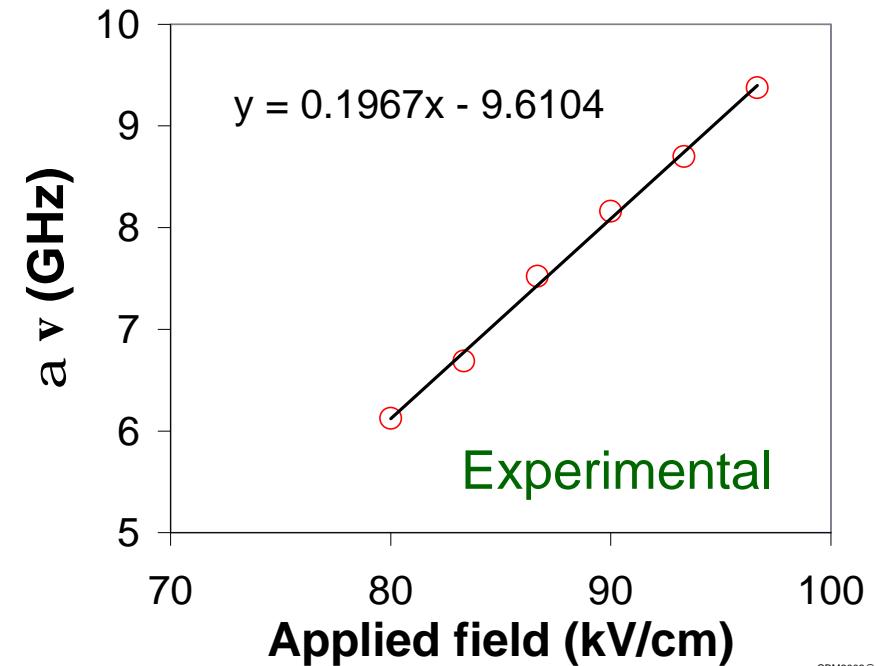
1-Signal shape cannot be changed by any linear system



2-  $\alpha v$  can be easily measured



$$\ln(Th_1 / Th_2) = s (t_1 - t_2)$$

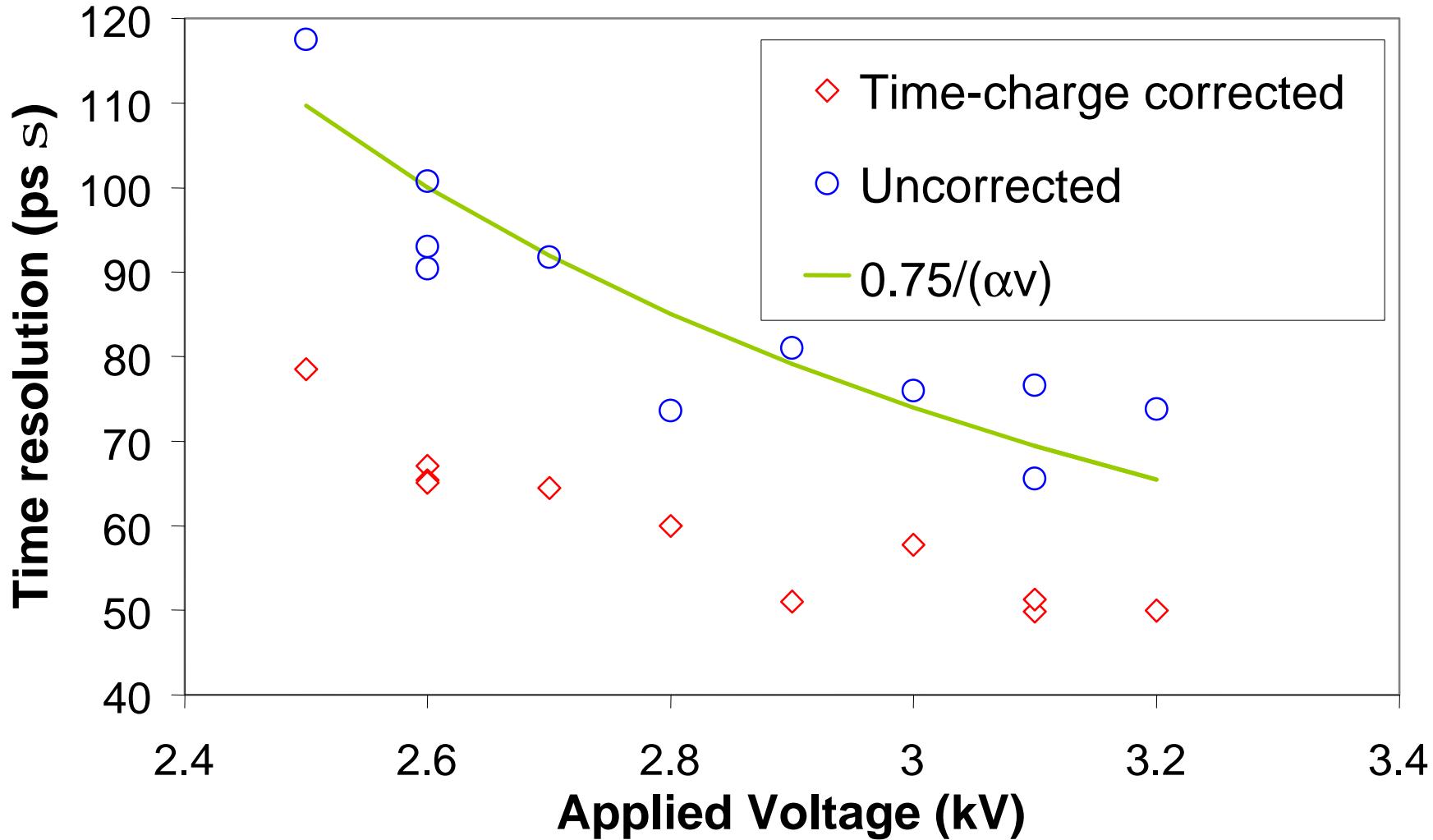




# Time resolution-theory vs. measurements

$$\sigma_t = \frac{K(N)}{\alpha \nu}$$

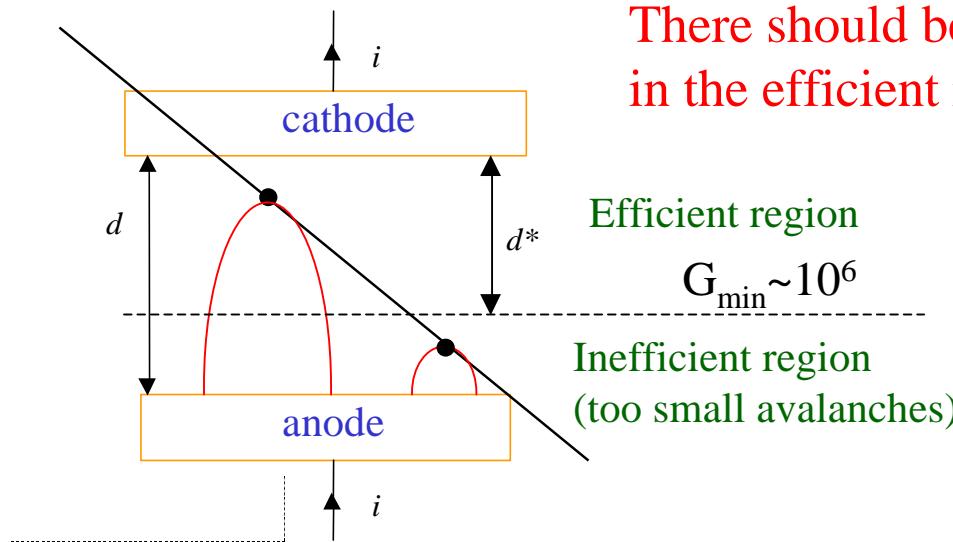
Single 0.3mm gap



Good agreement

## The efficiency problem

There should be at least one cluster  
in the efficient region of the gap

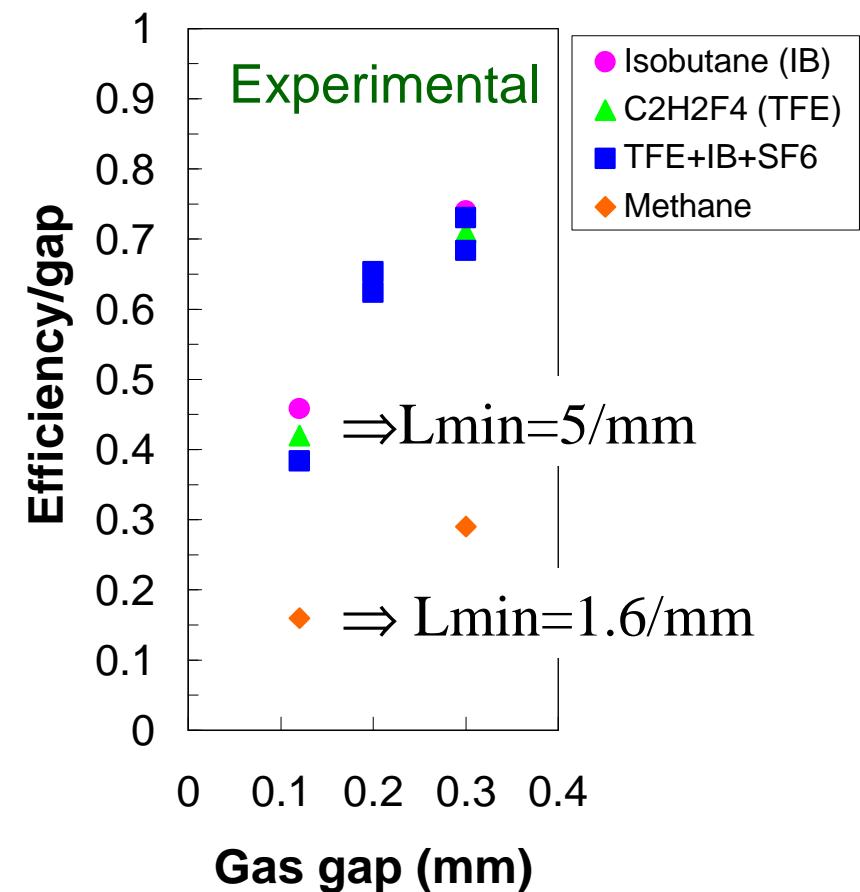


$$d^* = \ln(1 - e)/L$$

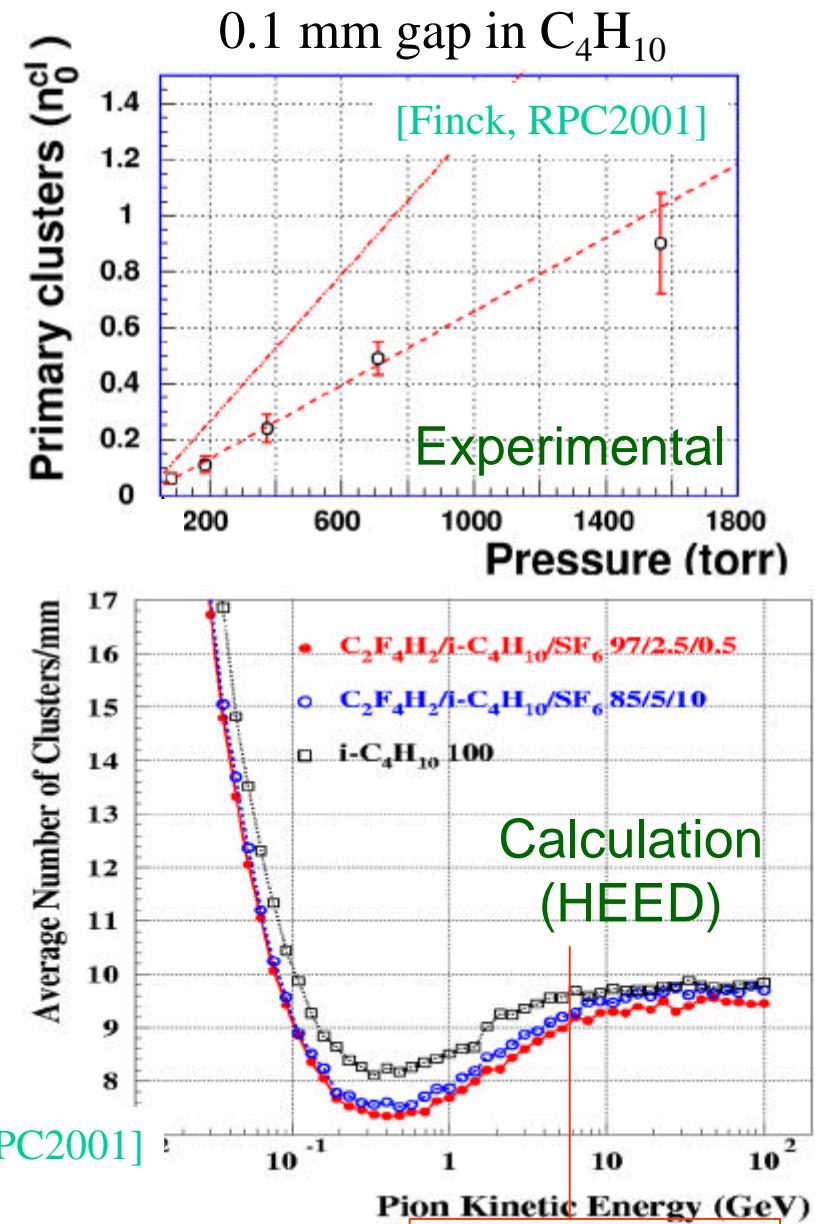
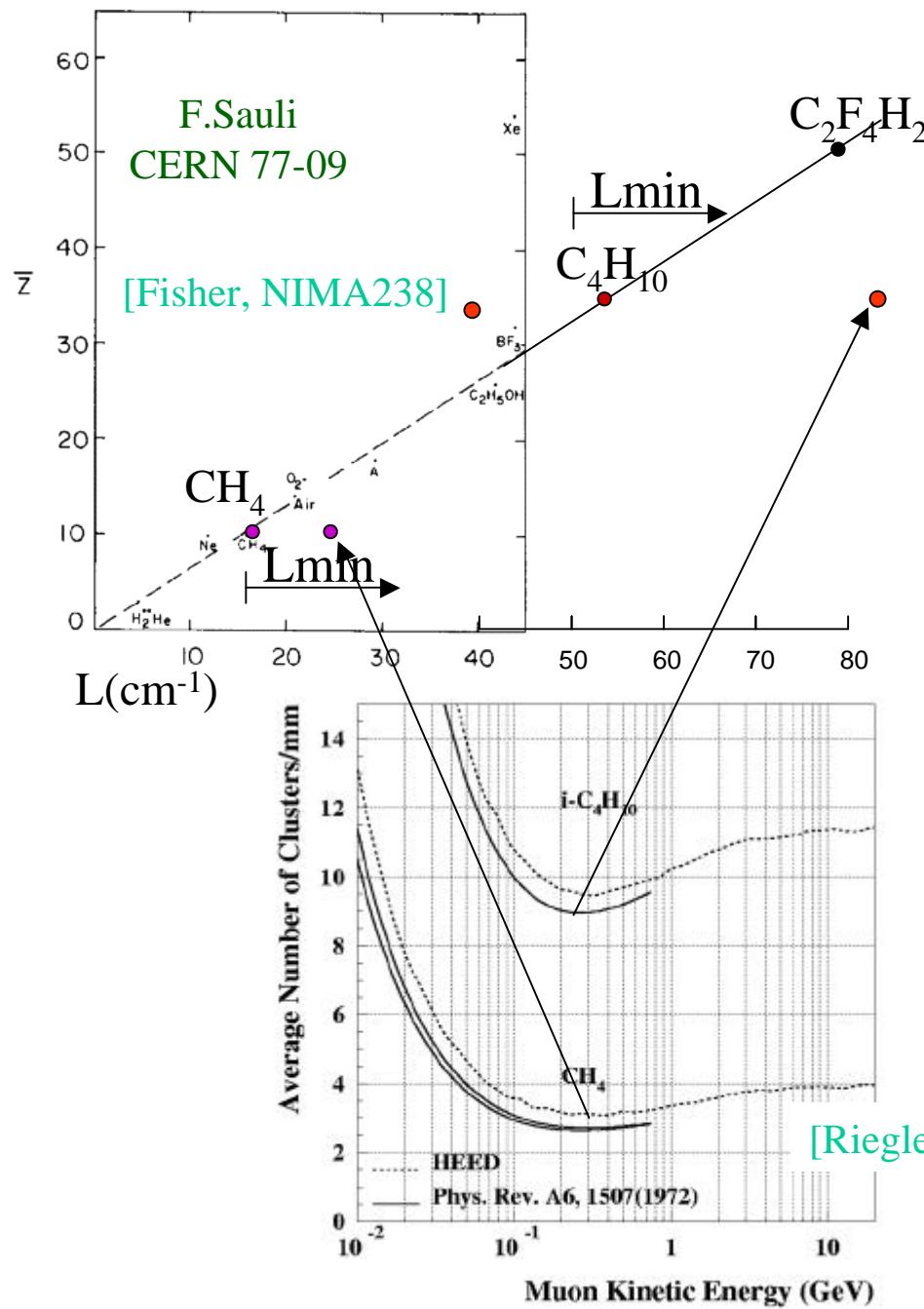
**e** = efficiency

L = clusters/mm

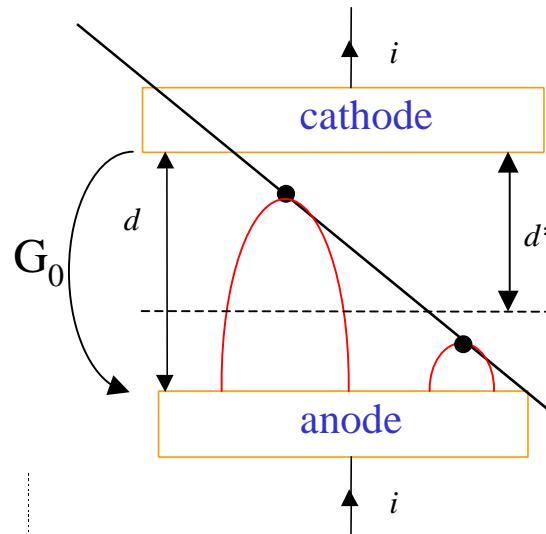
$$L > L_{\min} = \ln(1 - e)/d$$



# The efficiency problem-cluster density data



# The efficiency problem (maybe solved)

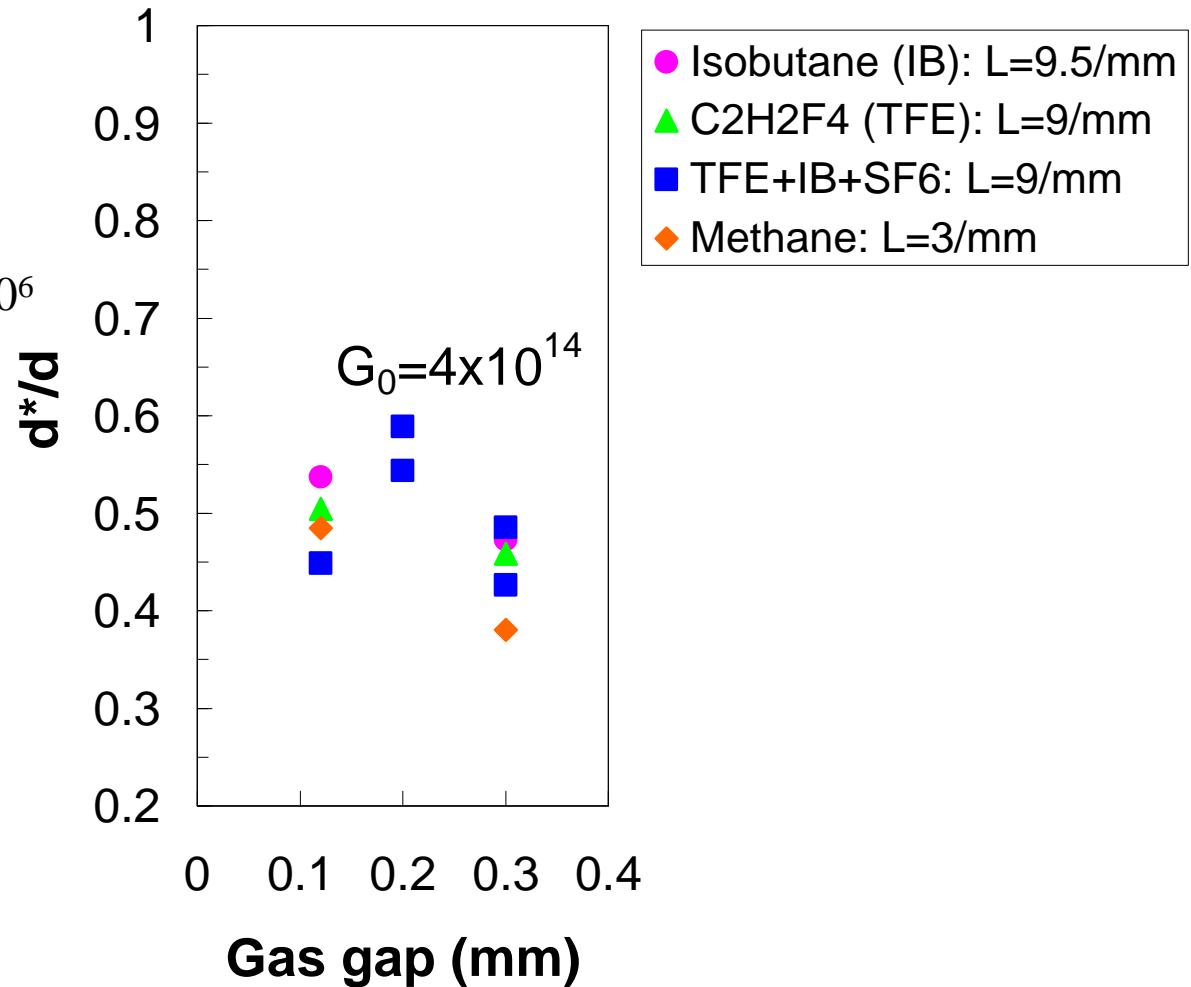


$$d^* = \ln(1 - e) / L$$

$e$  = efficiency

$L$  = clusters/mm

$$G_0 = (G_{\min})^{\frac{1}{1-d^*/d}}$$



Large values of  $G_0$  must be assumed (much above the Raether limit of  $10^8$ ).  
Possible by an extremely strong avalanche saturation effect (space charge effect).

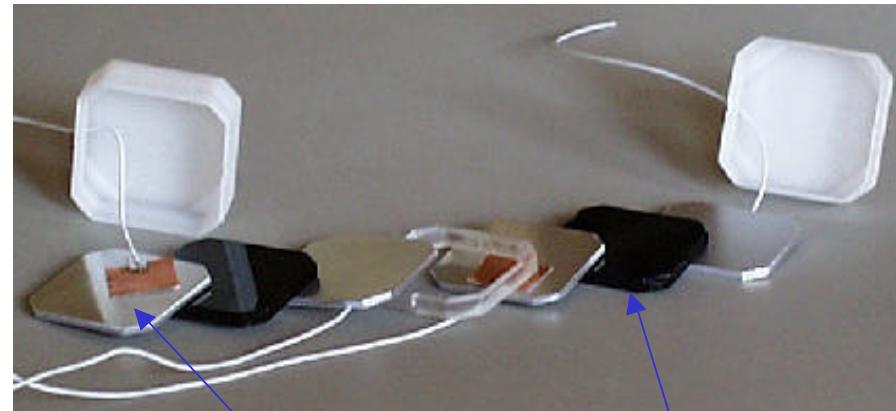
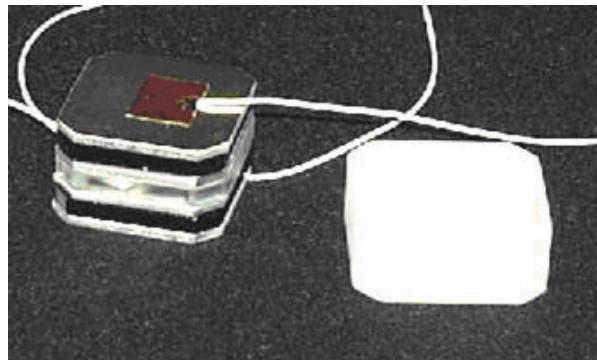


# Some hardware

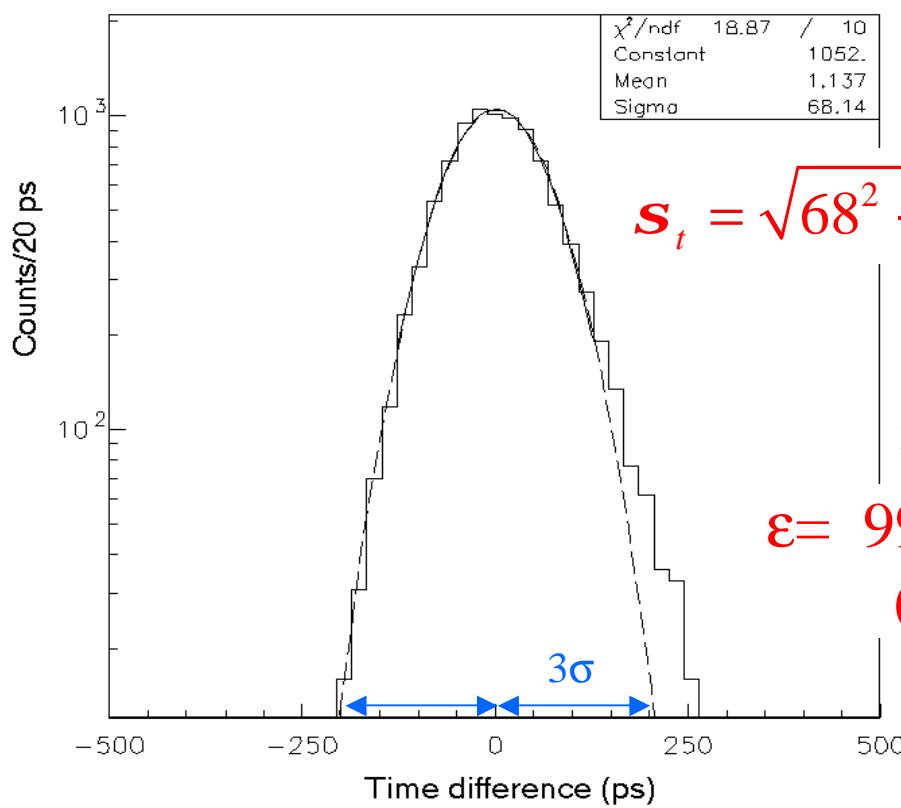
# Timing RPCs – Small single counters ( $9\text{ cm}^2$ )



4x0.3 mm gaps



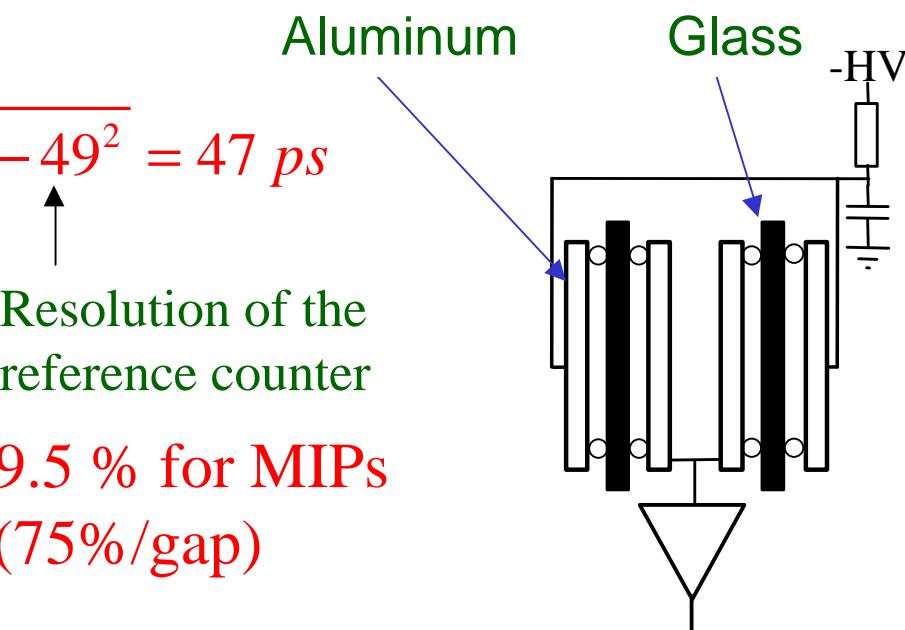
[ Fonte 2000 ]



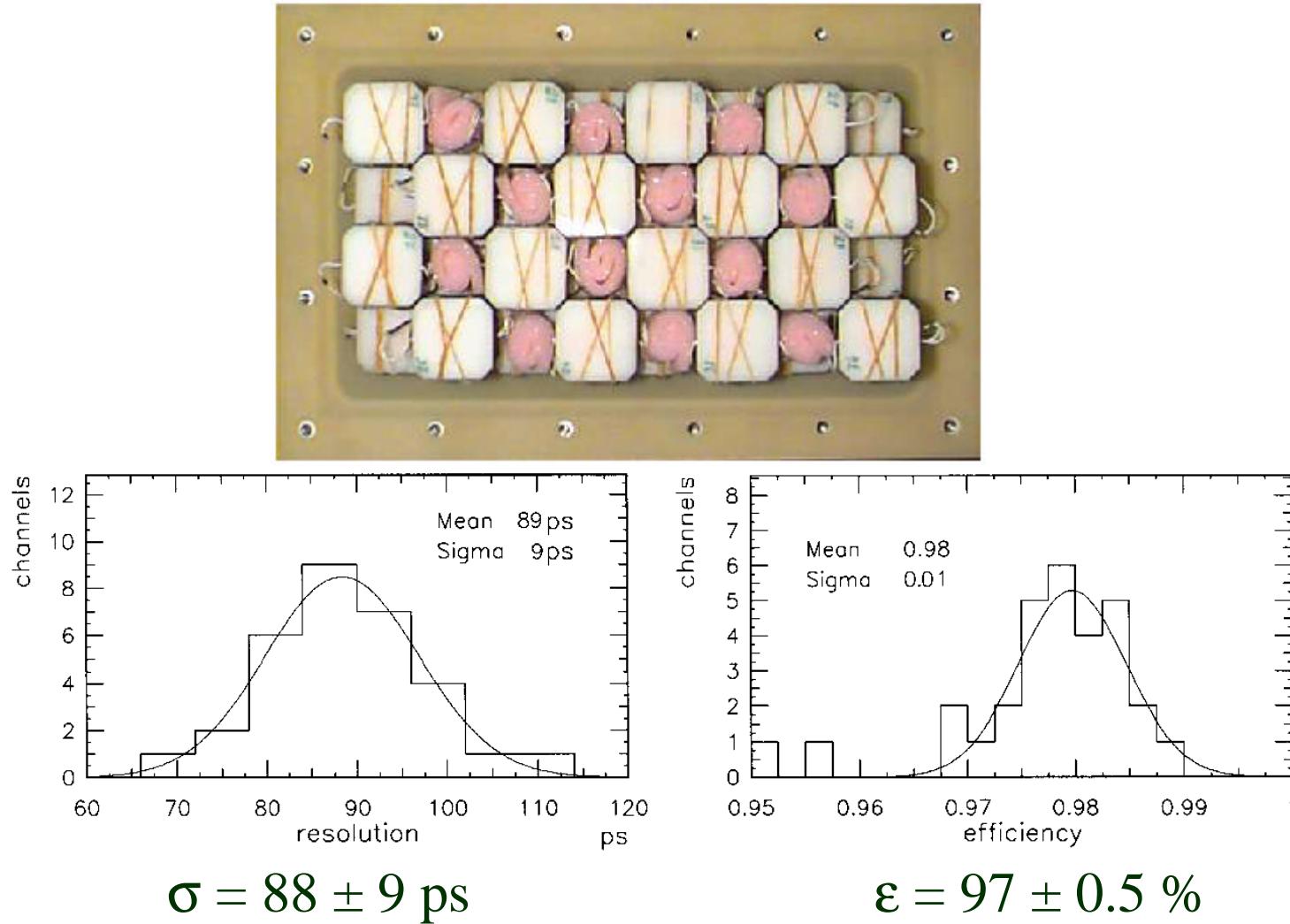
Resolution of the  
reference counter

$\epsilon = 99.5\% \text{ for MIPs}$   
(75%/gap)

(optimum operating point  $\Rightarrow 1\%$  of discharges)



# Timing RPCs – Array of 32 small counters



Crosstalk < 1%  
(not tested for multiple hits)

[ Spegel et al, 2000 ]

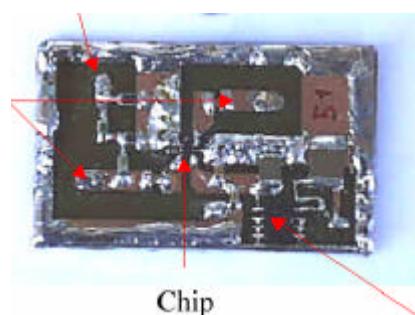


# Very high frequency front-end electronics based on commercial chips

Input signal  
(experimental)

$$i = i_0 e^{st}$$

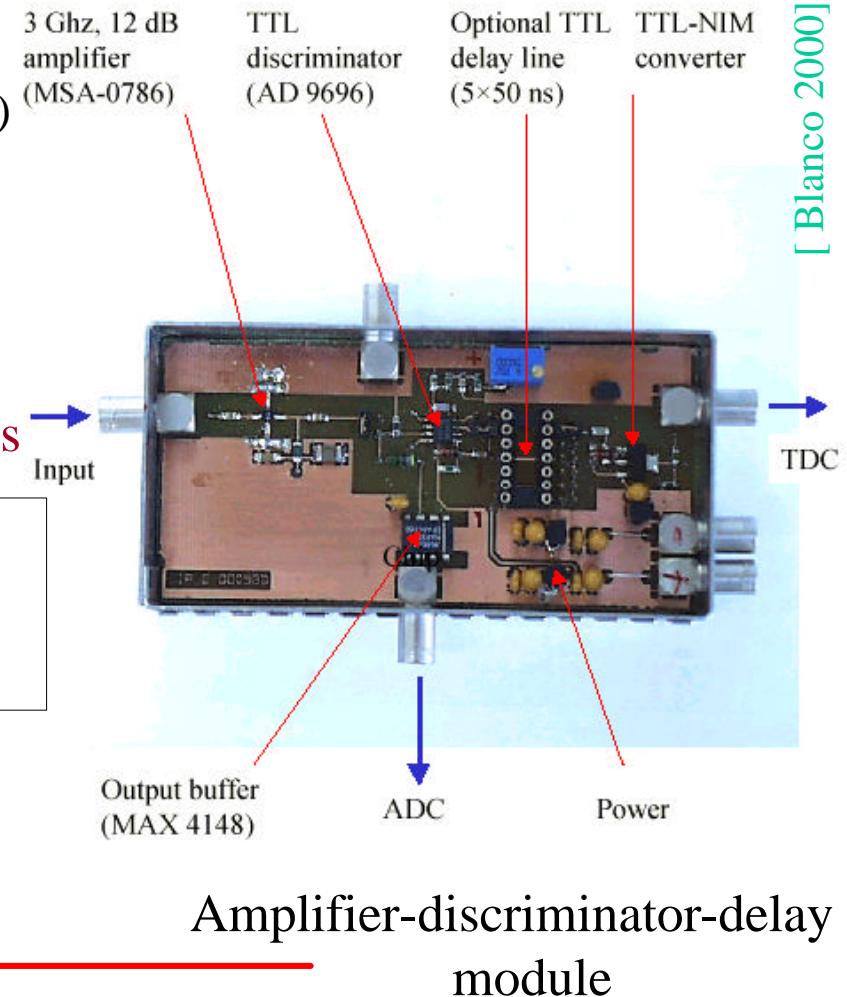
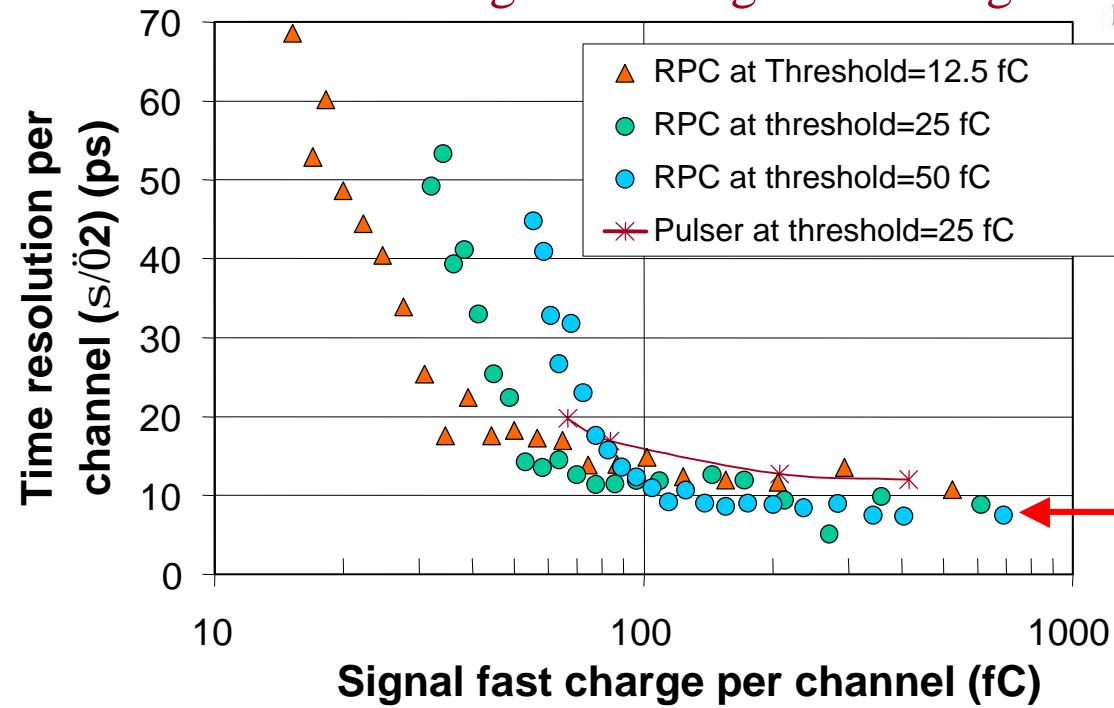
$s=8.7 \text{ GHz}$



Pre-amplifier based on the  
INA-51063 chip (HP/Agilent)

- 2.5 GHz bandwidth
- 20 db power gain
- 3 dB noise figure

Realistic tests using chamber-generated signals



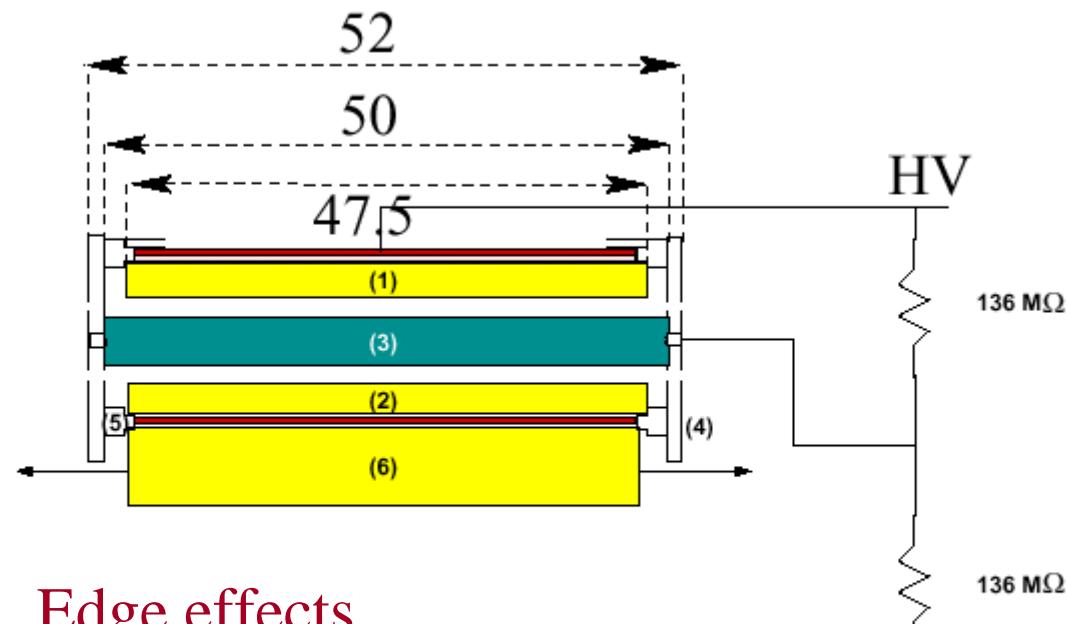
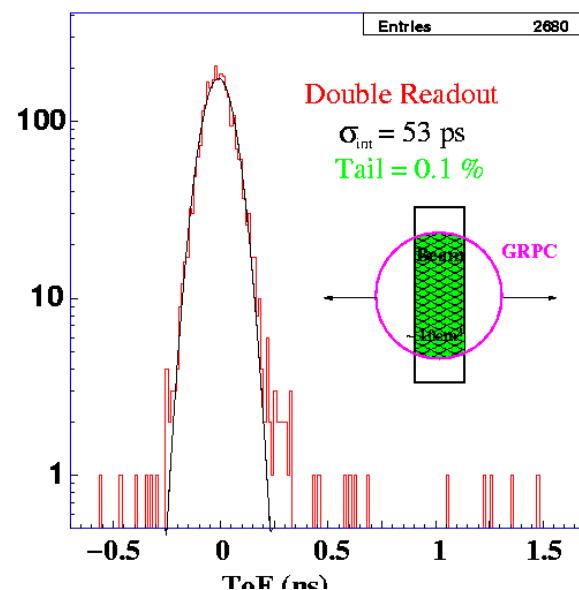
[ Blanco 2000]

TDC

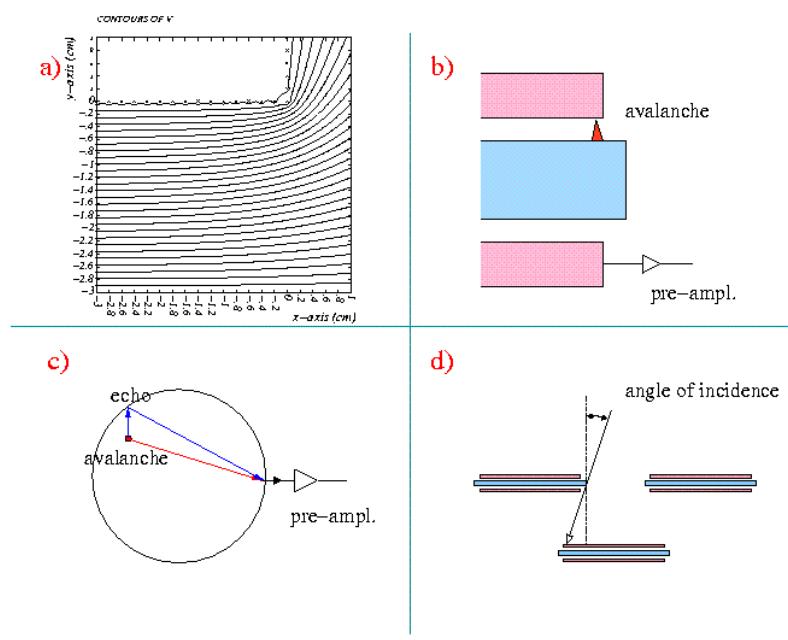
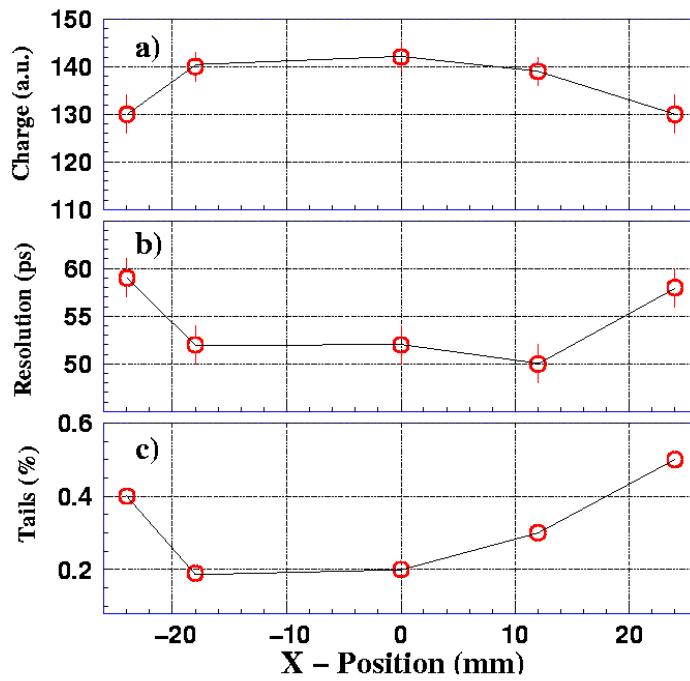
Amplifier-discriminator-delay  
module

CBM2002@GSI 15

# Double readout 4-gaps glass-metal counter



## Edge effects

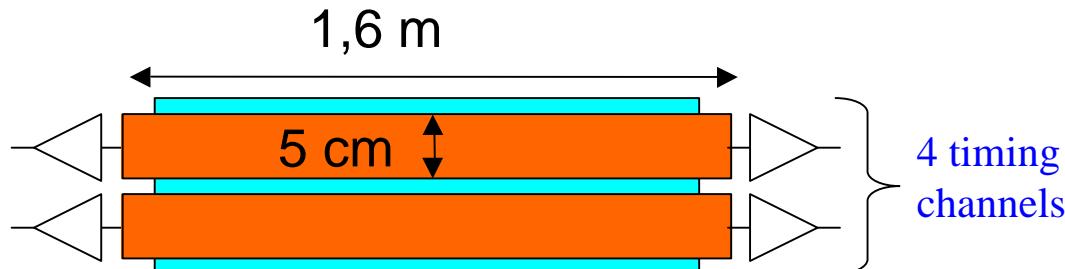


[Finck, Gobbi et al, RPC2001]

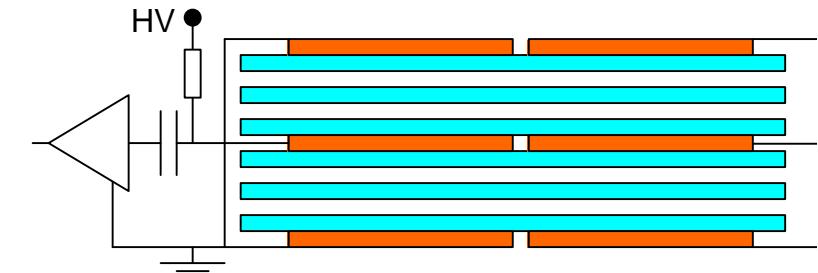


## Timing RPCs – Large counter

Active area =  $10 \text{ cm} \times 160 \text{ cm} = 0.16 \text{ m}^2$   
( $400 \text{ cm}^2/\text{electronic channel}$ )



Top view



Cross section

- Ordinary 3 mm  
“window glass”
- Copper strips

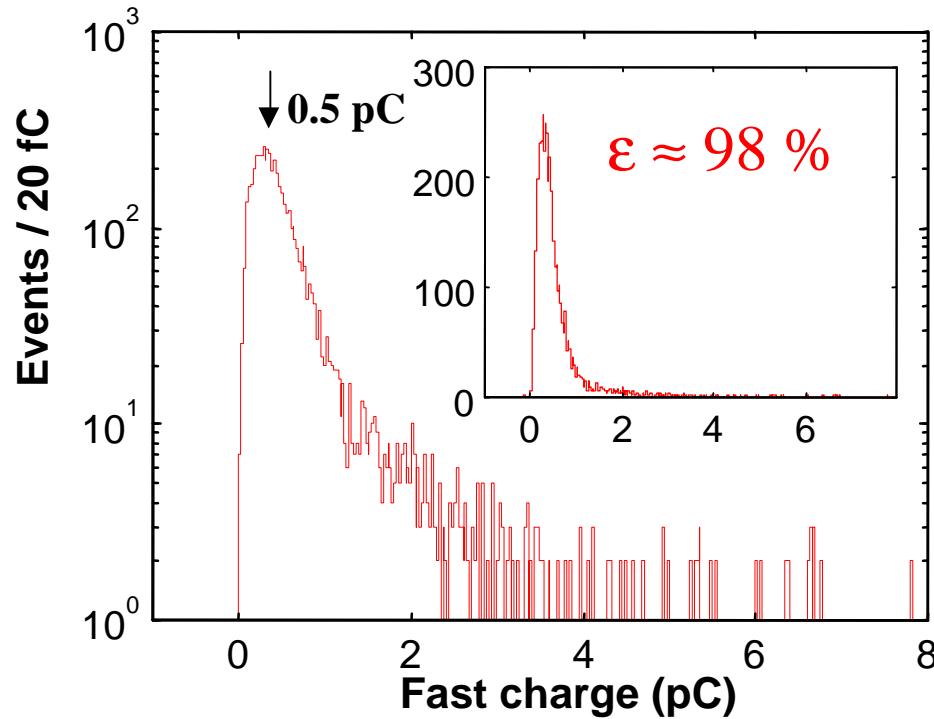
[Blanco 2001]



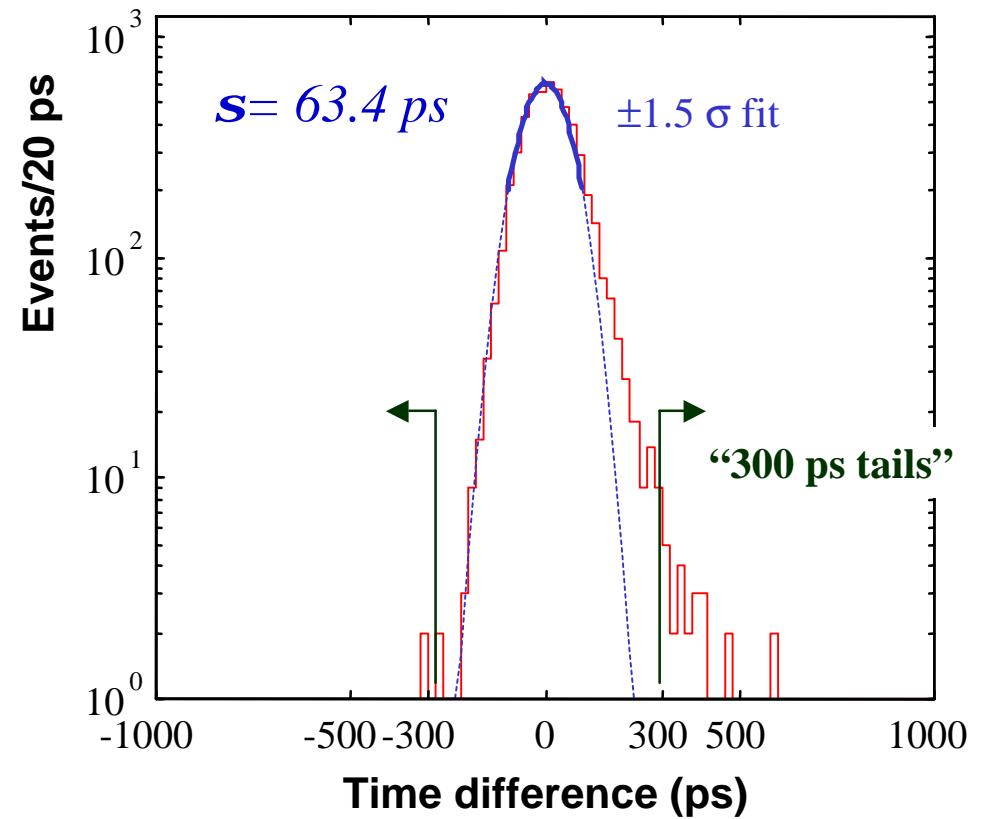
# Timing RPCs – Large counter



Charge distribution



Time distribution

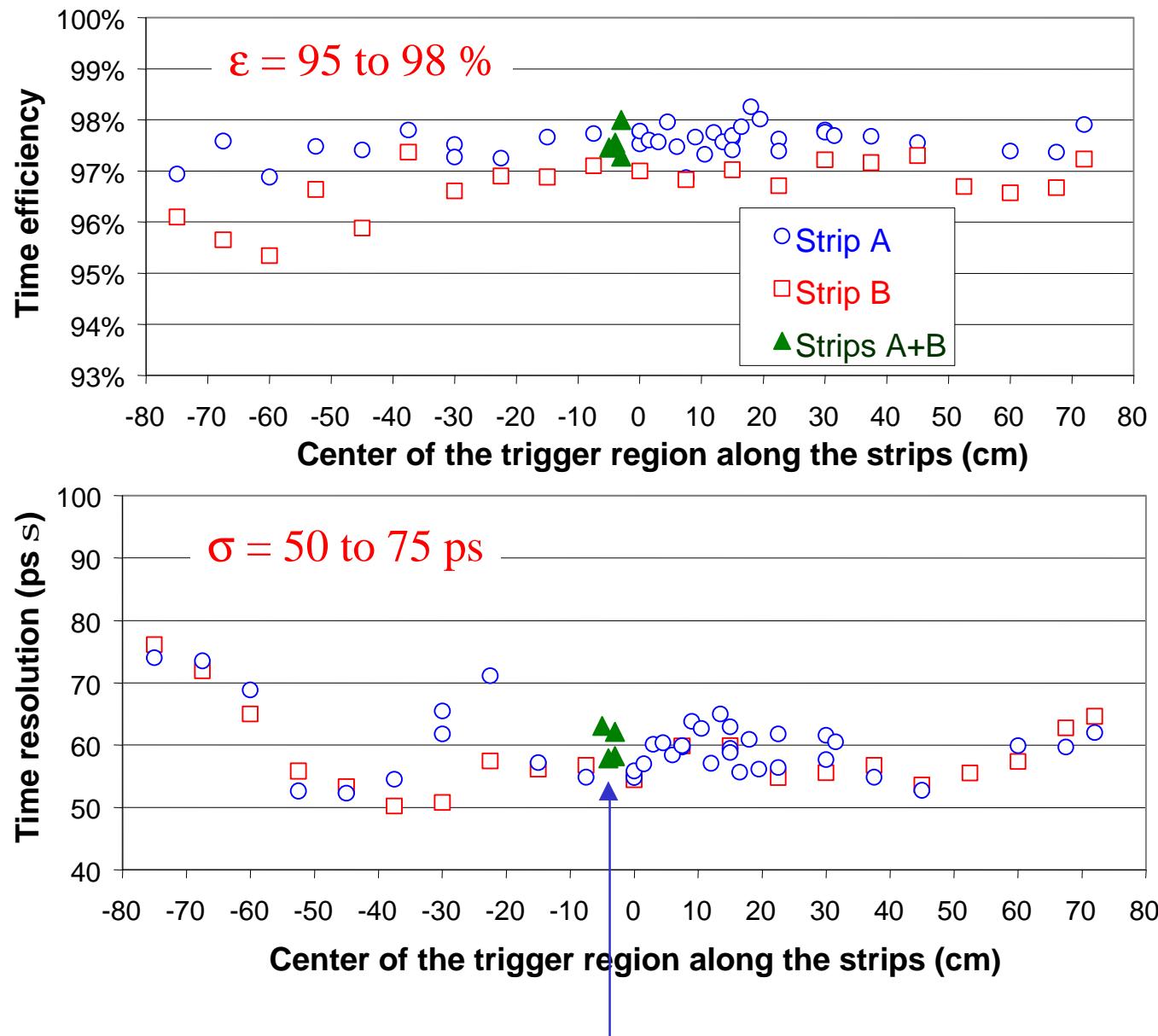


$$s = \sqrt{64^2 - 35^2} = 54 \text{ ps}$$

Time resolution essentially  
independent from electrode size



# Timing RPCs – Large counter



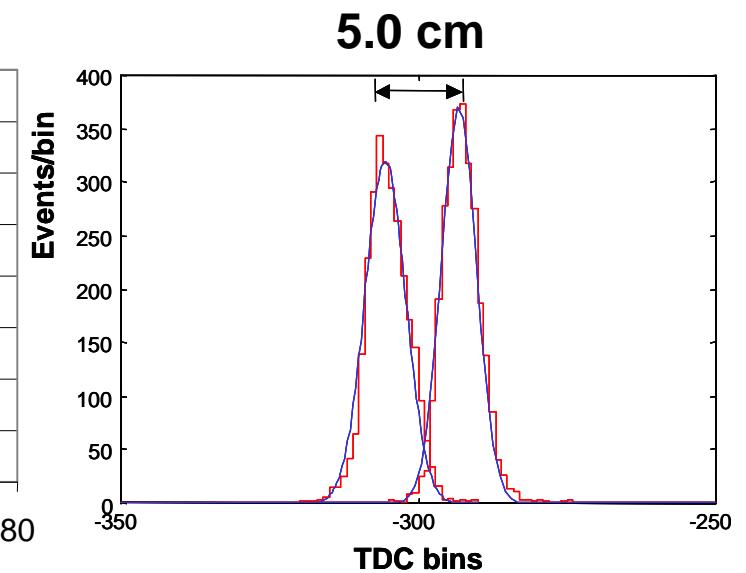
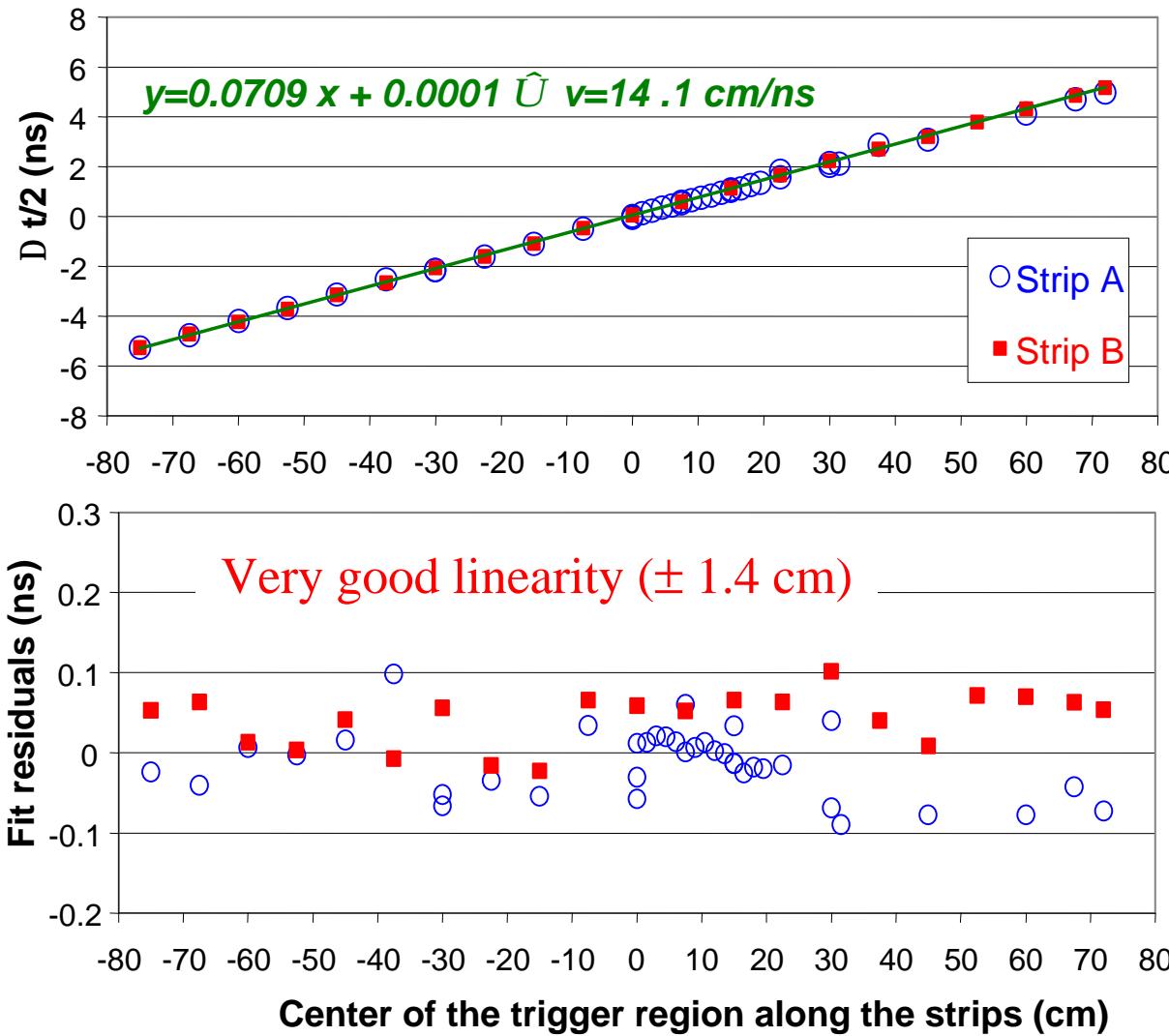
No degradation when the area/channel was doubled to  $800 \text{ cm}^2/\text{channel}$

[Bianco 2001]

# Timing RPCs – Large counter



## Position resolution along the strips

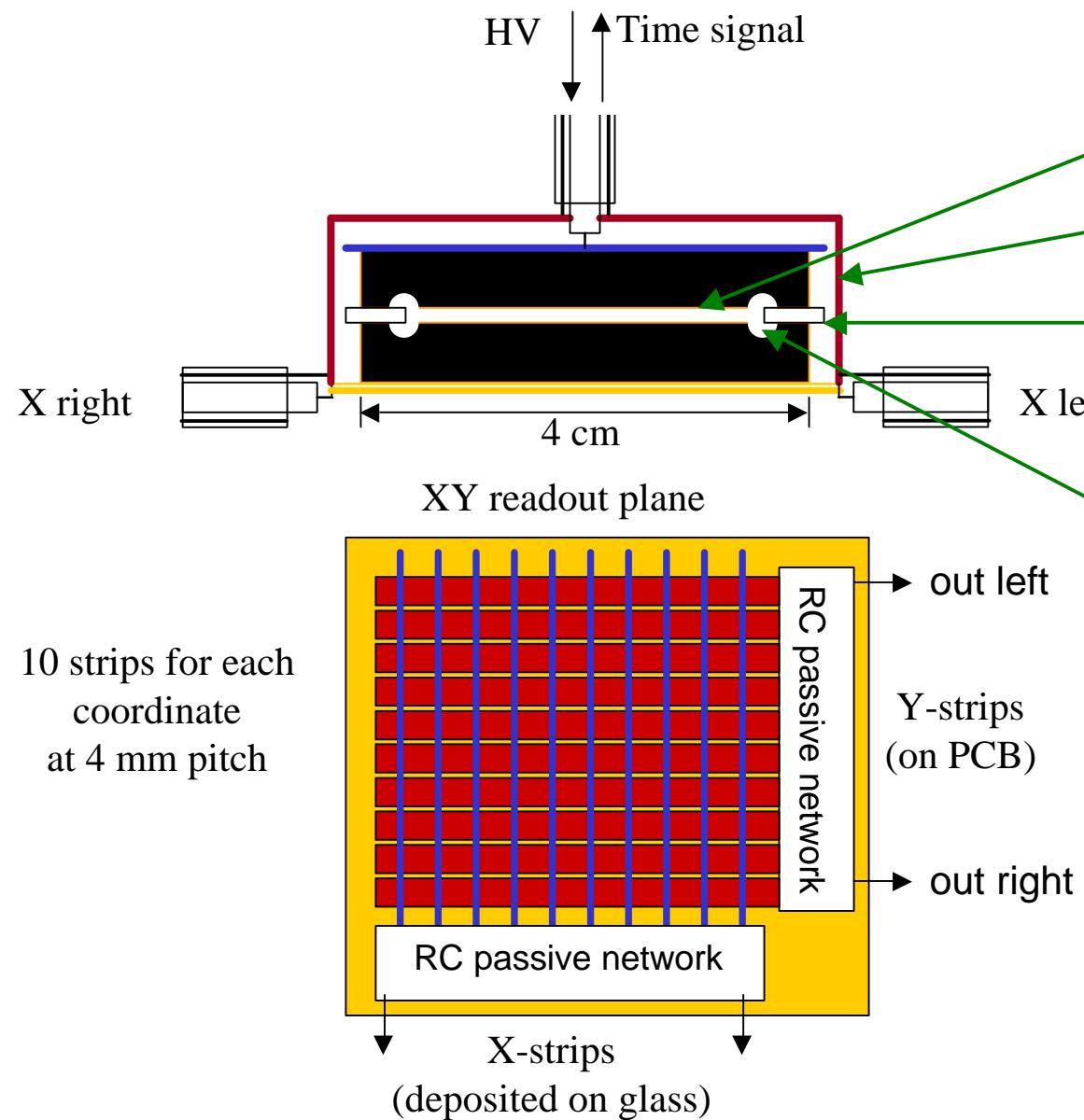


$\sigma_x = 1.2 \text{ cm}$   
(0.75% of detector length)

[Blanco 2001]

# Timing RPCs – single gap 2D-position sensitive readout

(for small and accurate TOF systems)



## Precise construction

2 mm thick black glass  
lapped to  $\sim 1\mu\text{m}$  flatness

metal box (no crosstalk)

300  $\mu\text{m}$  thick high  $\rho$   
glass disk (corners)

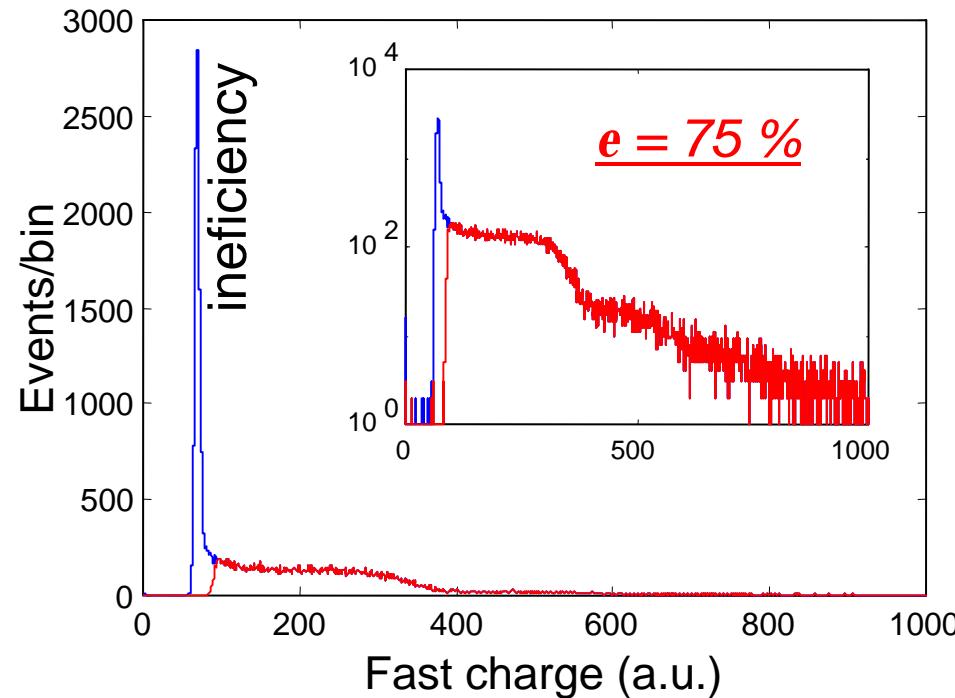
Well carved into  
the glass  
(avoid dark currents  
from the spacer)

[Bianco 2002]

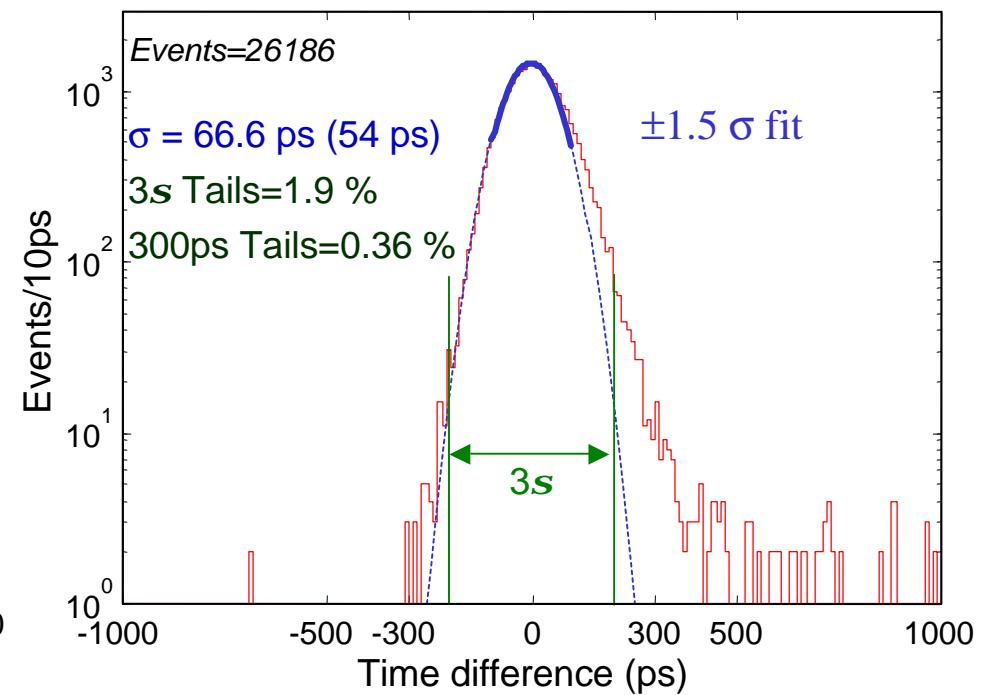
# Timing RPCs – single gap



Charge distribution



Time distribution



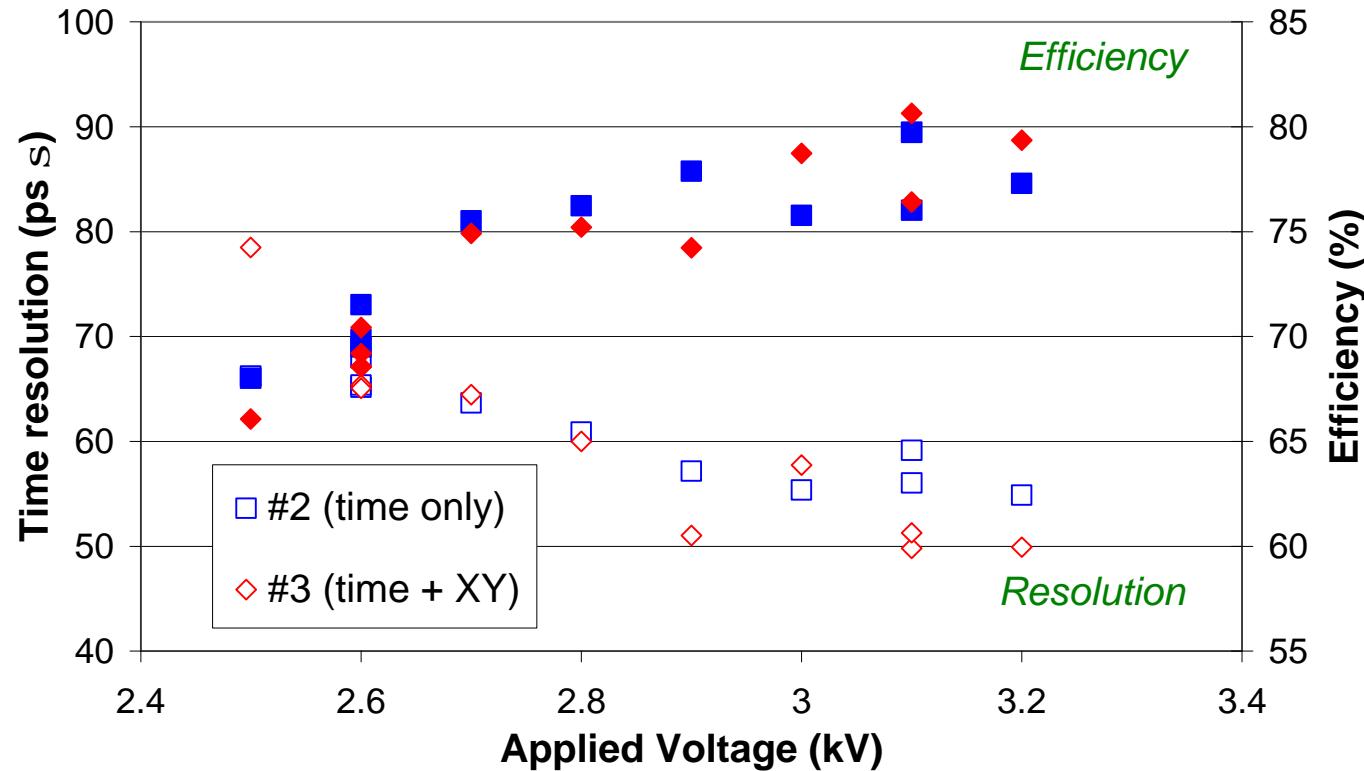
$$s = \sqrt{67^2 - 40^2} = 54 \text{ ps}$$

Time resolution of single-gap and 4-gap counters may be similar!



# Timing RPCs – Single gap

## Efficiency and time resolution



$$\sigma = 50 \text{ to } 60 \text{ ps}$$

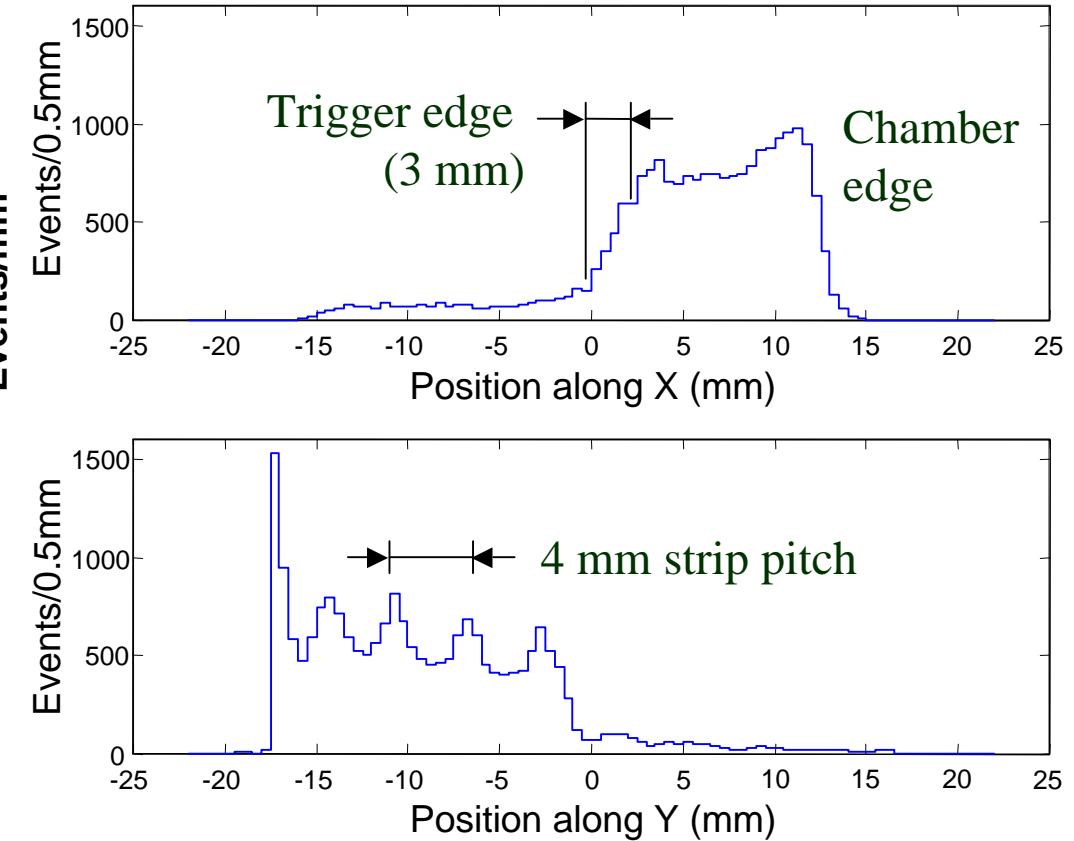
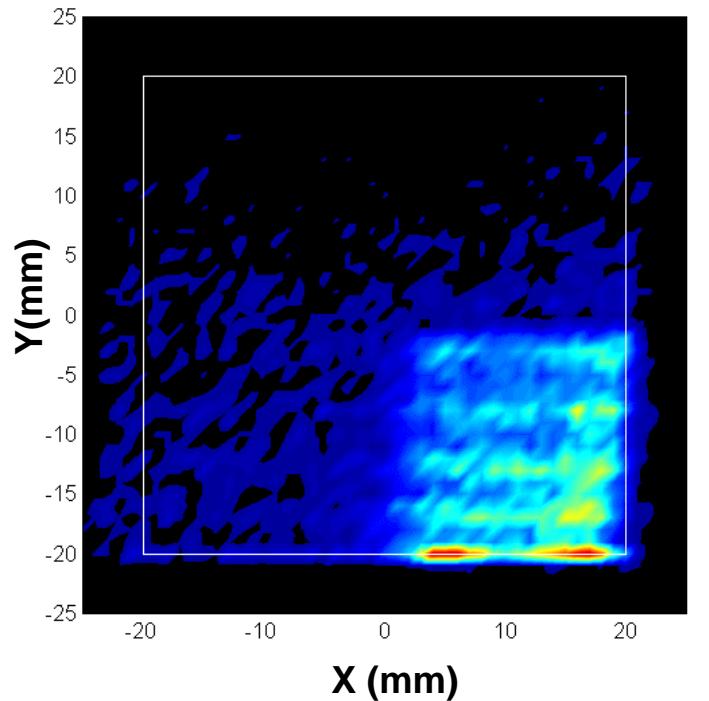
$$\varepsilon = 75 \text{ to } 80 \%$$

No influence from XY readout

# Timing RPCs – single gap



## Bidimensional position resolution

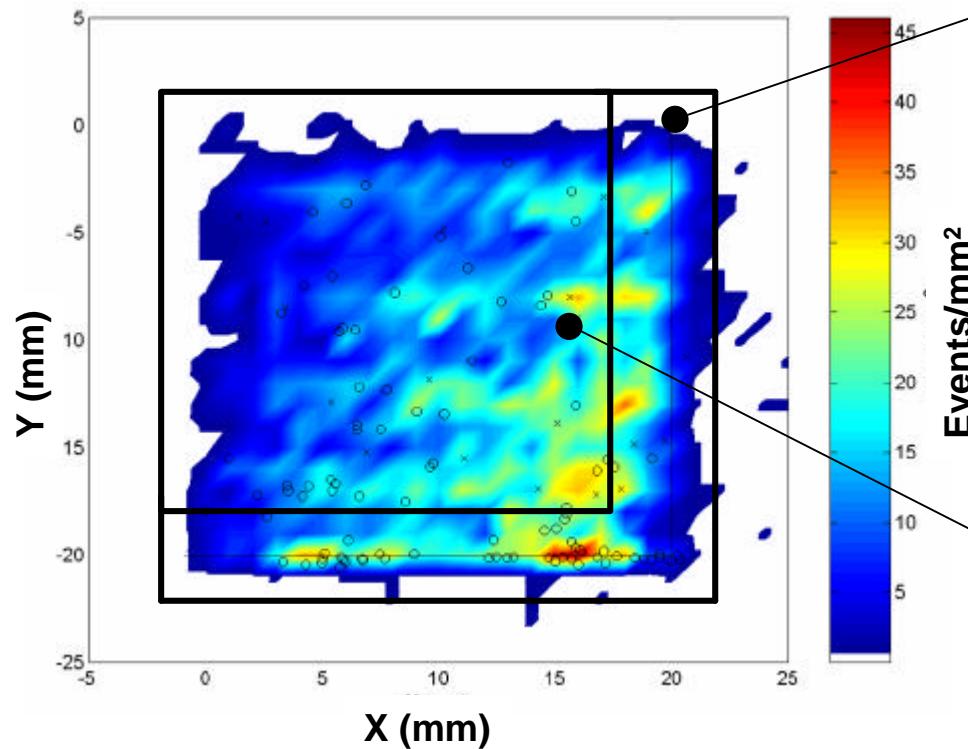


edges  $\leq 3$  mm  
↓  
resolution  $\leq 3$  mm FWHM  
(strips=4mm)

# Timing RPCs – single gap



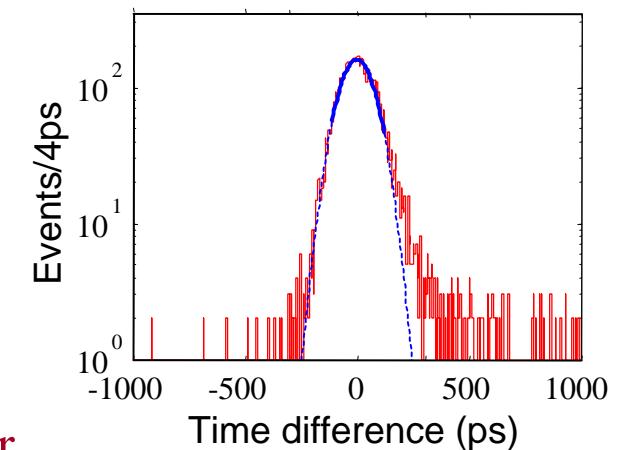
Edge effects?



Essentially  
no  
edge effects

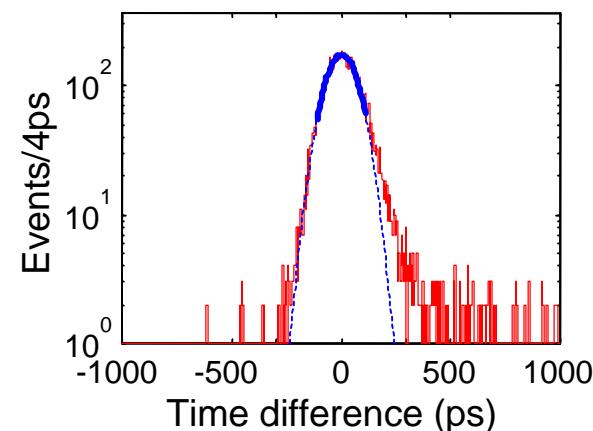
Edge & Corner

$\Sigma = 76.9 \text{ ps}$  ( $66 \text{ ps}$ )  
 $3\text{-}\Sigma \text{ Tails} = 2.9 \%$   
 $300\text{ps Tails} = 1.8 \%$



Center

$\Sigma = 74.0 \text{ ps}$  ( $62 \text{ ps}$ )  
 $3\text{-}\Sigma \text{ Tails} = 3.0 \%$   
 $300\text{ps Tails} = 1.5 \%$

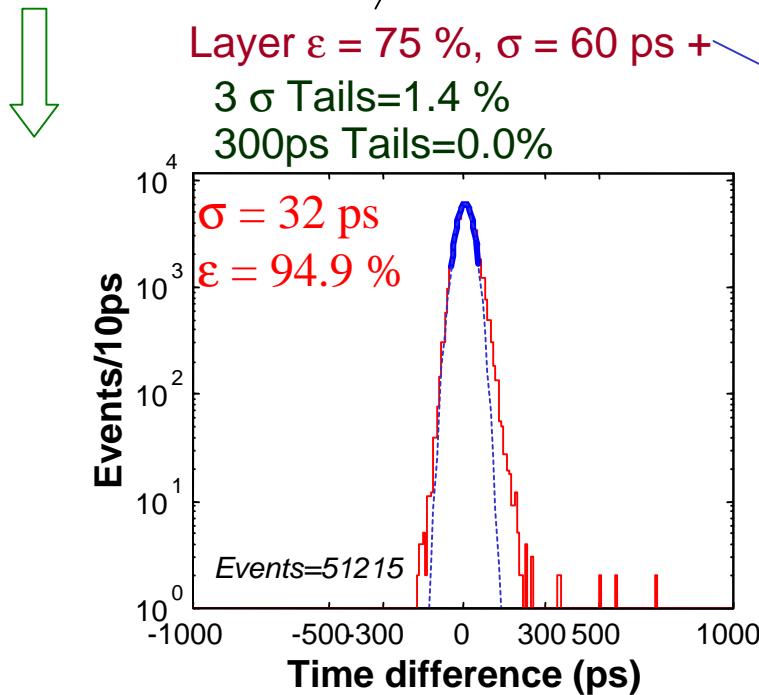




# Timing RPCs – multilayer

4 layers of single-gap chambers

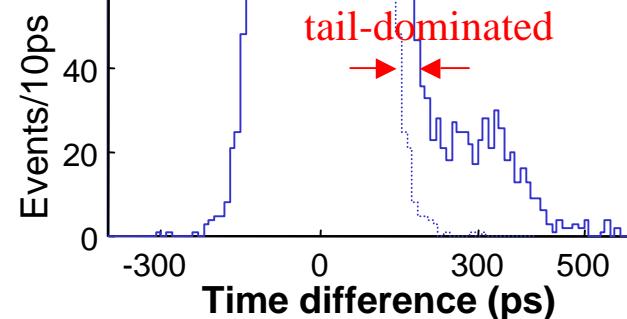
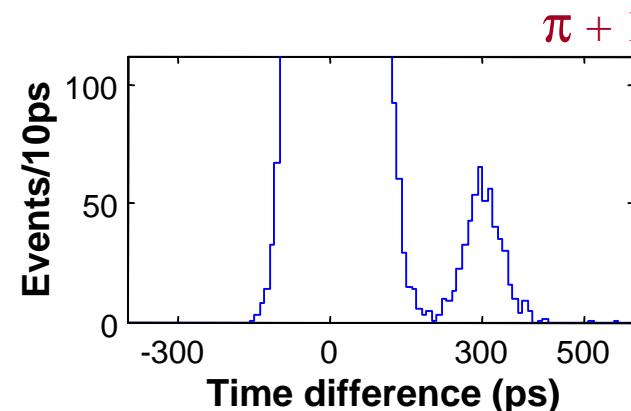
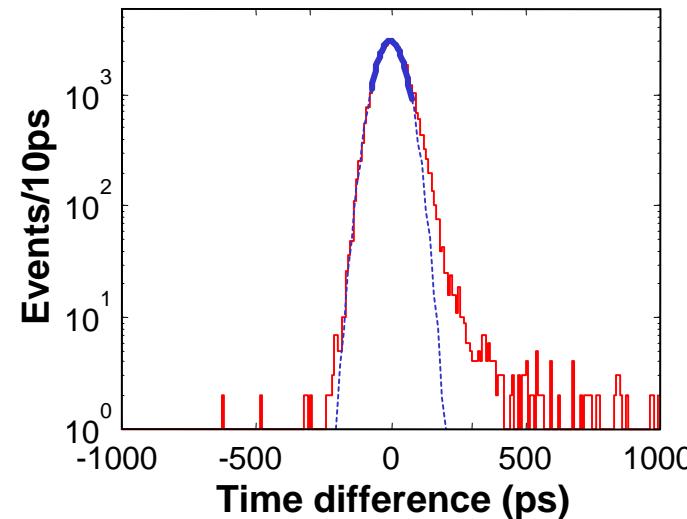
M.C.



Single layer of 4-gap chambers

$\sigma = 50\text{ ps}$  @  $\varepsilon = 99\%$   
3  $\sigma$  Tails=1.5 %  
300ps Tails=0.20%

Experimental

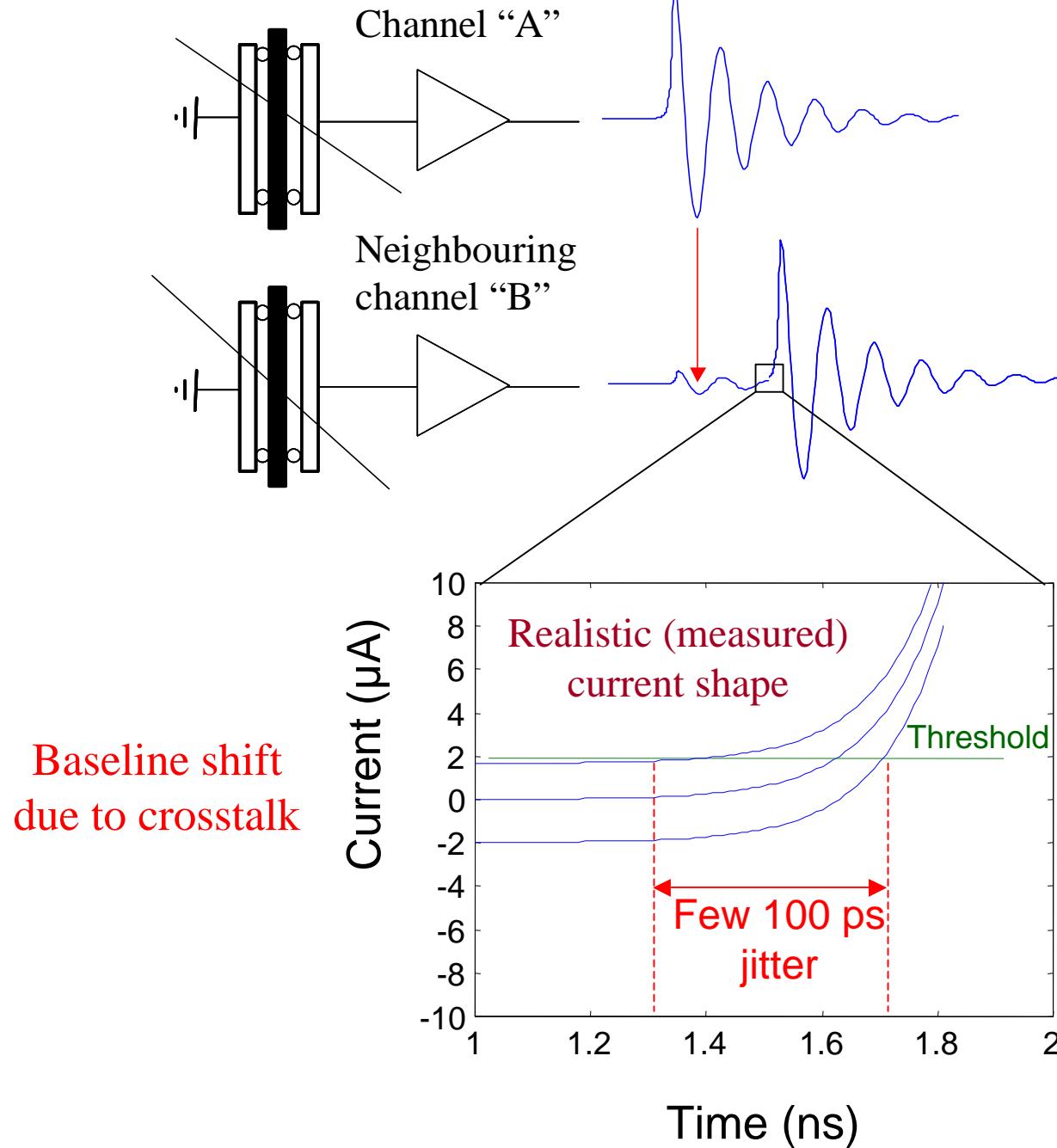




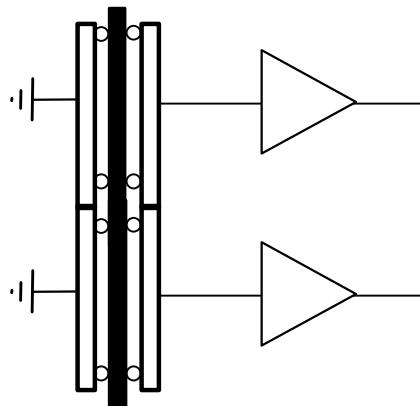
# Open problems



# The subtle crosstalk problem

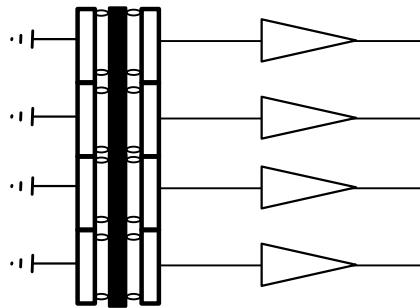


# The crosstalk problem – main approaches



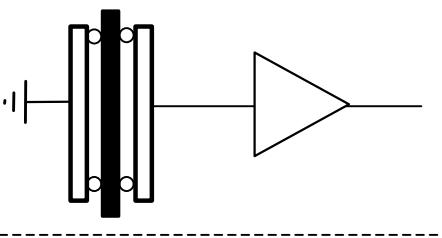
1 – Do nothing and hope  
the problem is small or  
correctable offline

- + Simple and economic
- + Being massively implemented  
(ALICE, STAR)
- Possible fragile performance



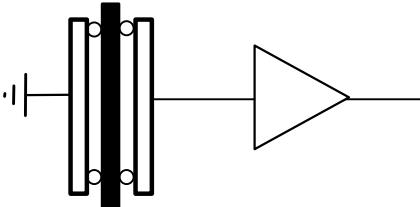
2 – Accept crosstalk and use  
many more channels than  
strictly needed.

- + Good 2D position resolution
- Expensive
- Effective granularity must be  
defined by testing
- Possible fragile performance.



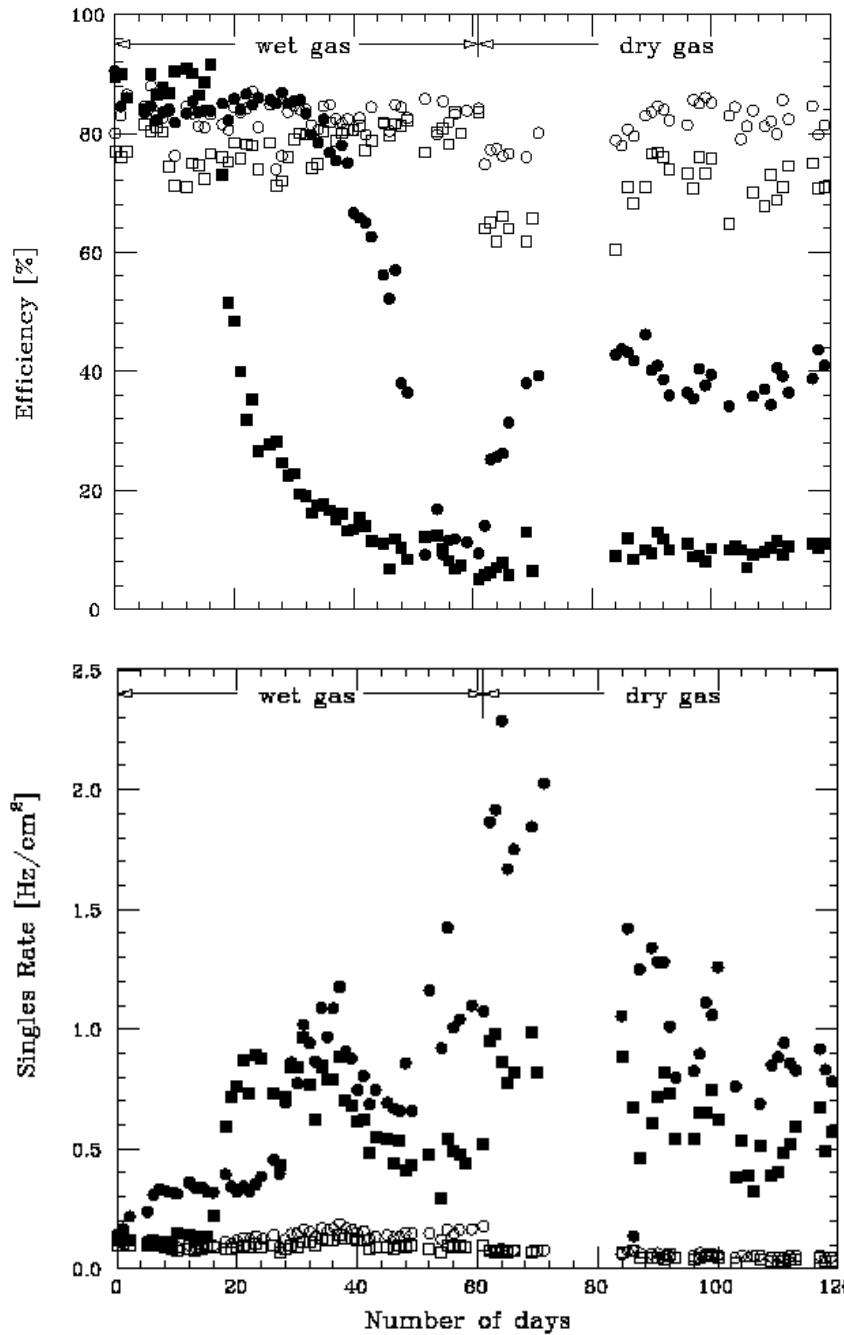
3 – Shield channels and try to  
totally avoid crosstalk

- + Robust performance.
- + Testable in the lab.
- Segmented mechanics.



None of these approaches has been proven so far  
(as of Nov 2001)

# Ageing in streamer mode glass RPCs (BELLE)



Freonless gas

Freon gas

Problem  
water+freon+streamers



Fluoridric acid



Glass corrosion



Dark current



Ineficiency

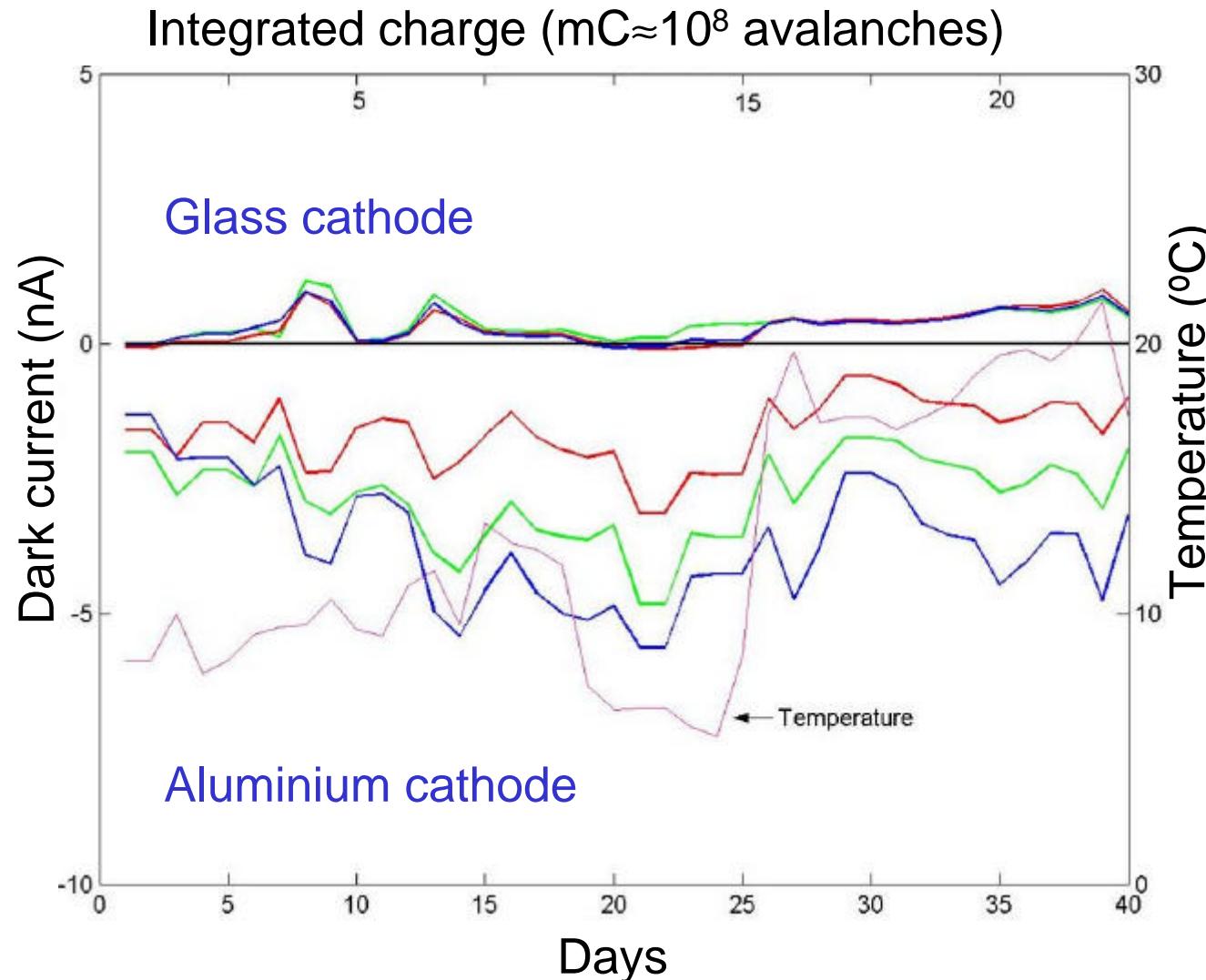
[Kubo et al, RPC2001]

# Ageing in avalanche mode glass RPCs?



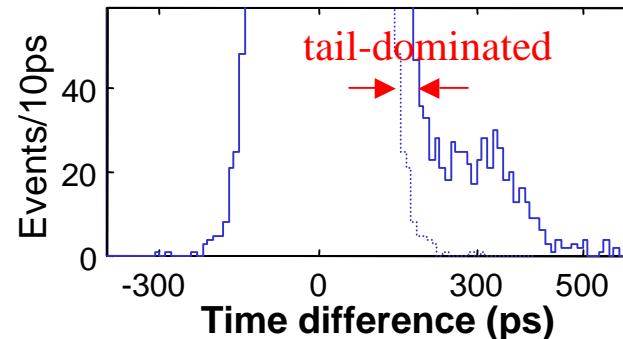
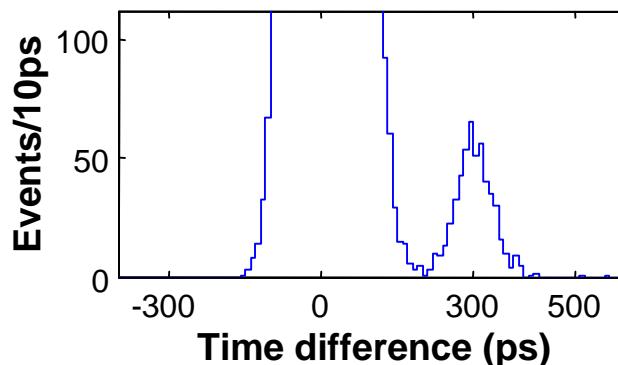
Test in progress

- 3 glass cathode and 3 aluminium cathode counters
- Gas:  $(85\% \text{ C}_2\text{H}_2\text{F}_4 + 10\% \text{ SF}_6 + 5\% \text{ C}_4\text{H}_{10}) + 10\%$  rel. humidity

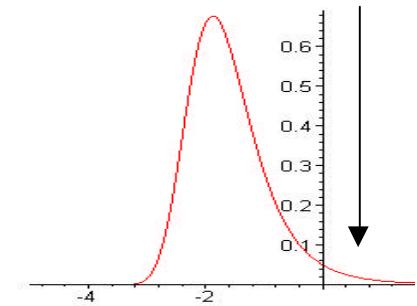




## Tails



Theoretical time distribution has a tail



Almost completely compensated by t-q correction

## Background

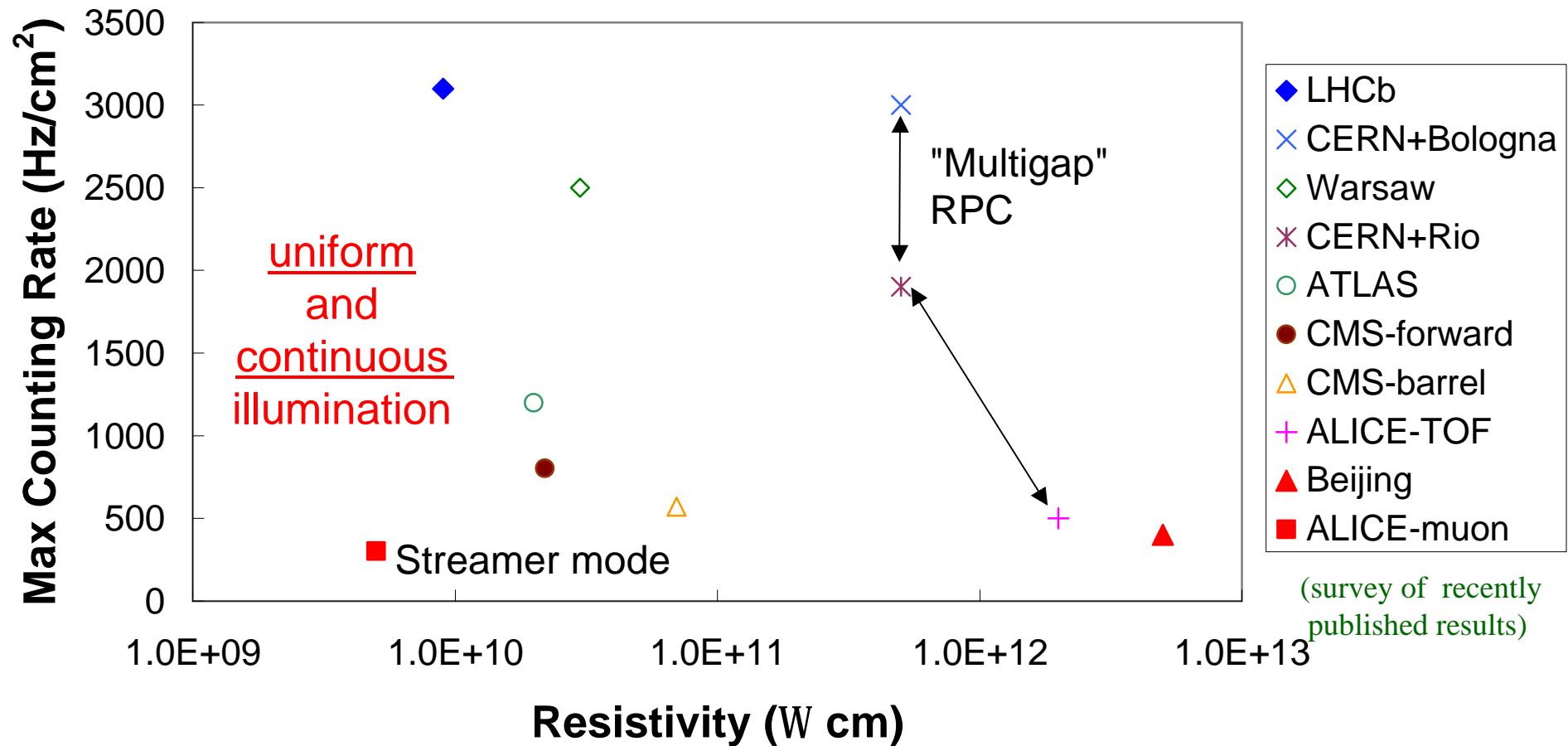
Highly ionising background  $\Rightarrow$  more streamers  $\Rightarrow$  lower rate capability  
 $\Rightarrow$  lower resolution

Problem was not studied so far. Severity unknown.

# Rate capability – Standard RPCs



Typically max. rate corresponds to an efficiency drop of a few percent

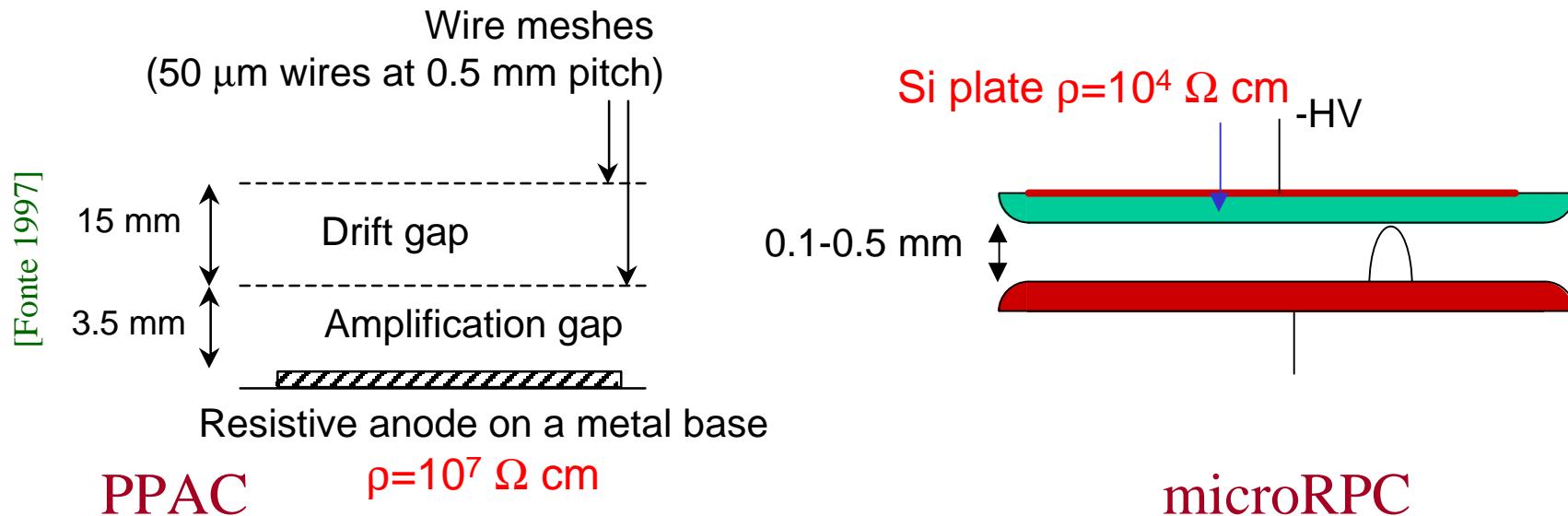


Streamer mode  $< 300 \text{ Hz/cm}^2$

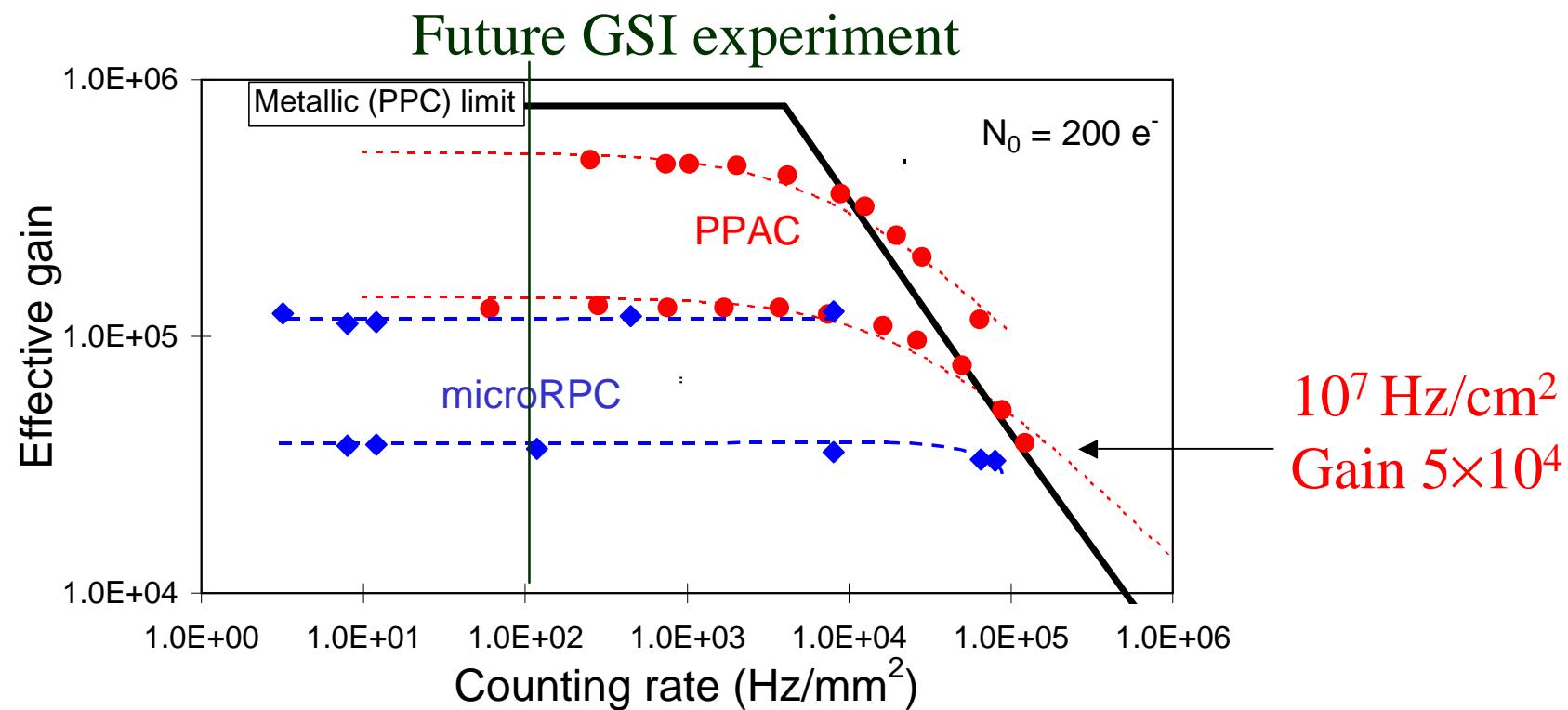
Avalanche mode  $< 3000 \text{ Hz/cm}^2$



## Rate capability – Special RPCs



[Carlson et al, NSS2001]





# Conclusions

- Main physical mechanisms – mostly understood except t-q correlation.
- Several interesting devices have been successfully tested with  $\sigma < 100$  ps and very small tails or edge effects
  - Small segmented counters.
  - 2D position-sensitive single-gap counters.
  - Large area counters.
- Practical difficulties to be addressed for future applications
  - Crosstalk – several approaches proposed, none proven.
  - Ageing – tests in progress, no problem so far.  
If problem: avoid water, freon or glass cathodes. Use chemistry to avoid formation of fluoridric acid.
  - Tails – redundancy should solve any problem if really needed.
  - Background – severity unknown.
  - Rate capability – solutions should exist up to  $\sim 10^5/\text{cm}^2$ .