



GEM space point resolution studies for a TPC tracker

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<http://www.physics.carleton.ca/~karlen/gem>

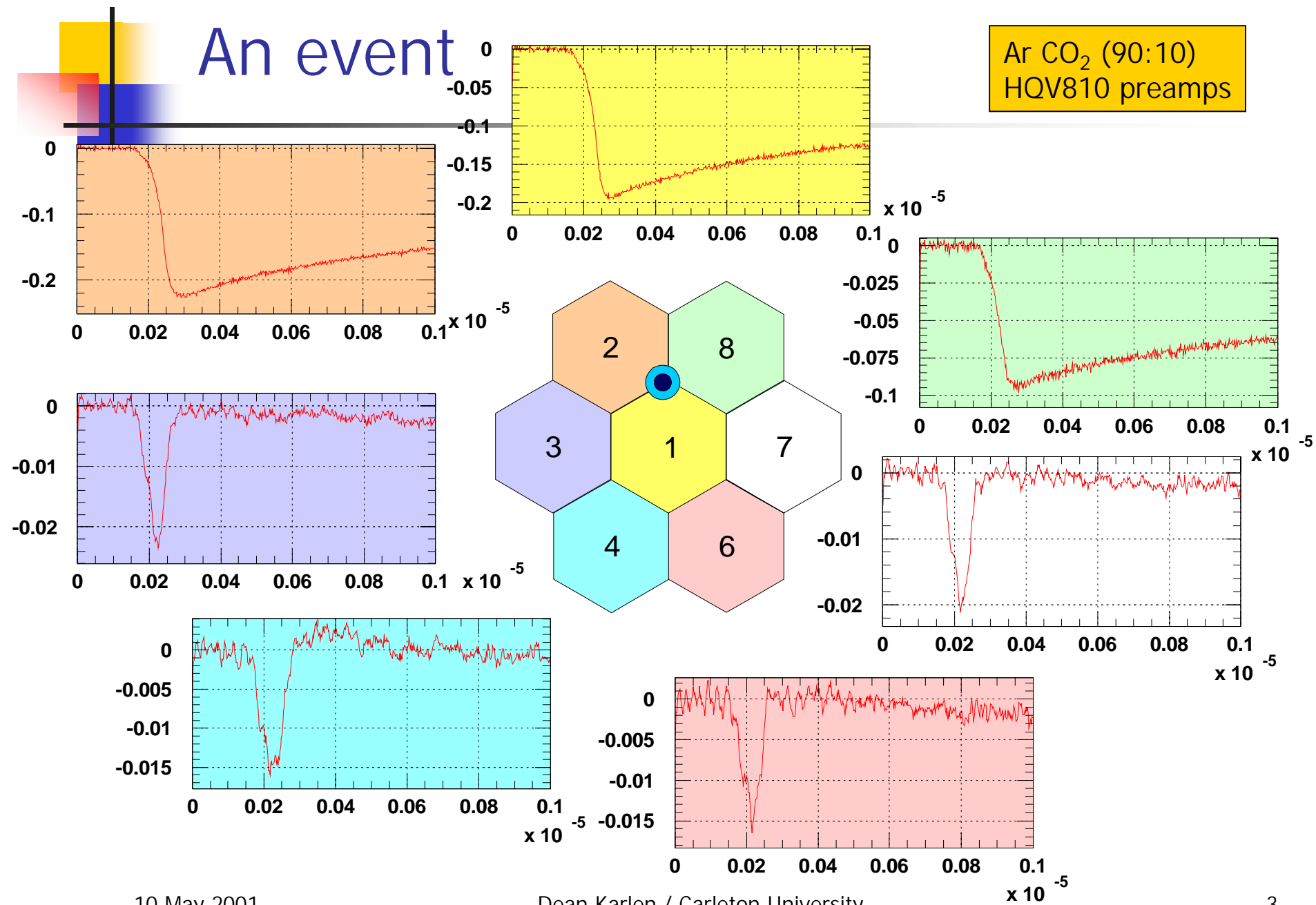


Details

- x-ray mean energy: 4.5 keV
- pinhole diameter: 50 μm
- Gas: Ar CO₂ ($\sim 90:10$) / P10 : Ar CH₄ (90:10)
- pre-amps:
 - fast Lecroy HQV 810 with Ar CO₂
 - slower ALEPH TPC pre-amp with P10
- readout:
 - two 4-channel digital scopes (9 bit ADC)
 - 500 MHz sampling for HQV 810
 - 125 MHz sampling for ALEPH preamps

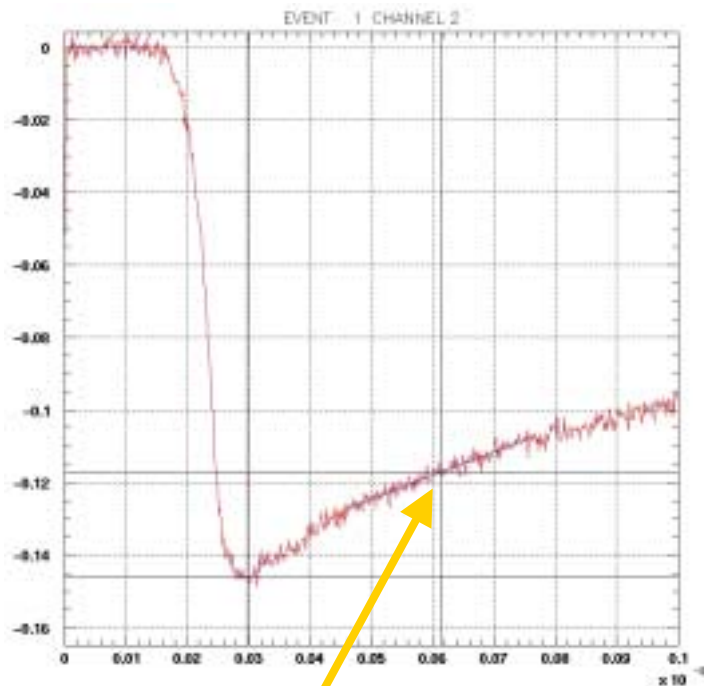
An event

Ar CO₂ (90:10)
HQV810 preamps



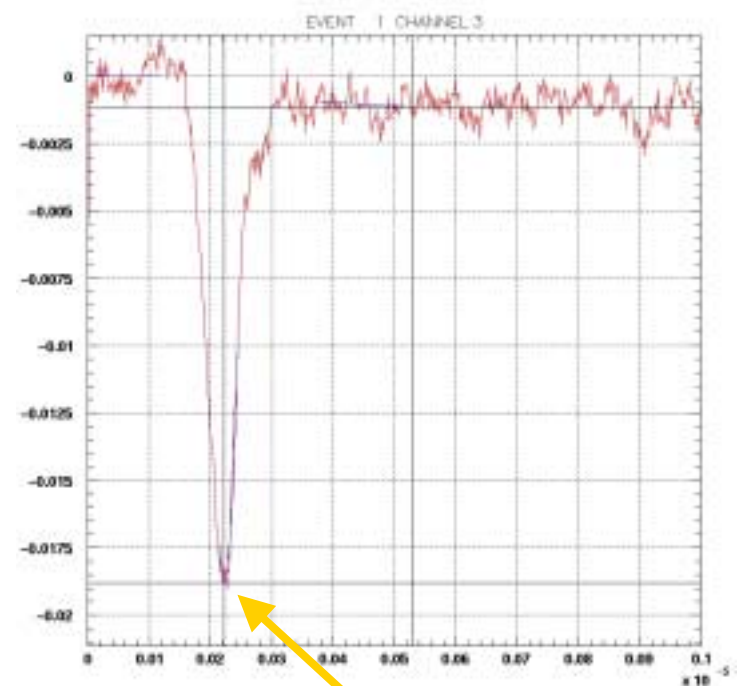
Analysis

Direct pulse



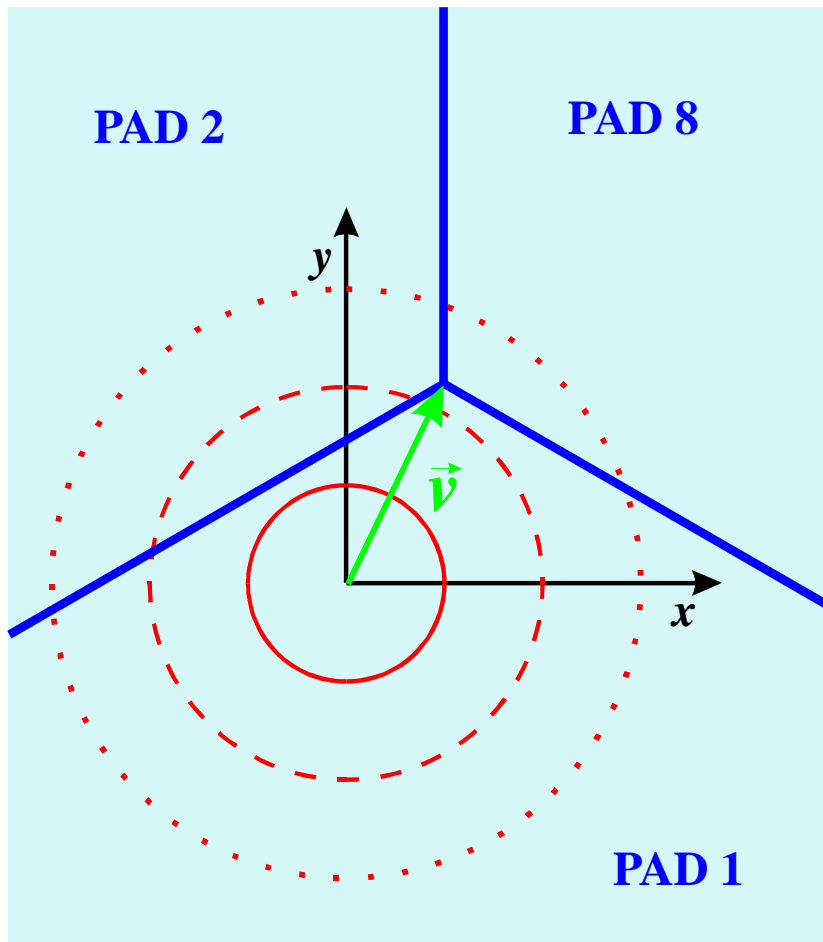
direct charge deduced from tail

Induced pulse



peak value used

Localization using charge sharing

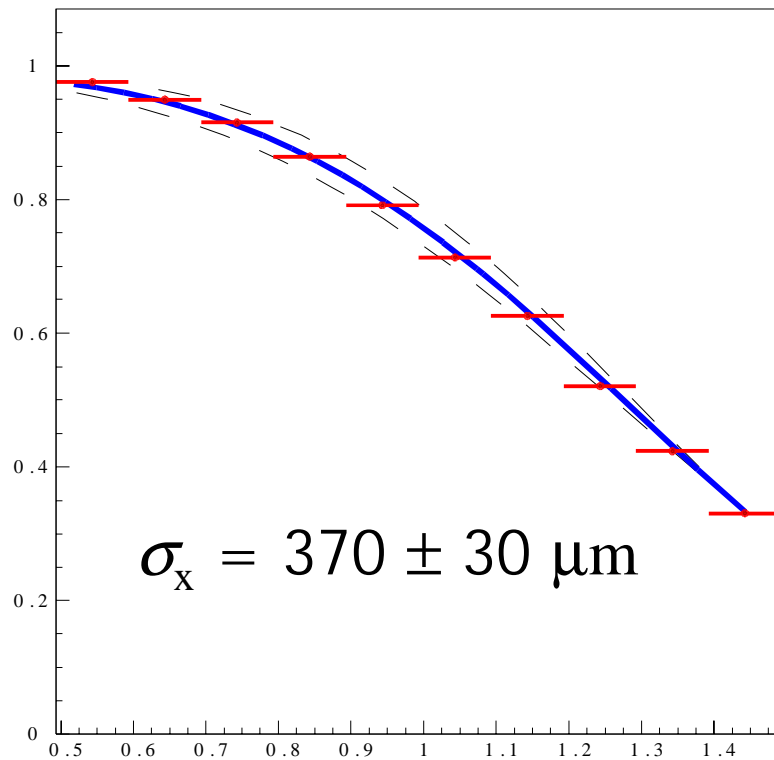


- assume electron cloud is 2D Gaussian
- charge fraction is given by integral over pad area
- 1 to 1 mapping between \vec{v} and (f_1, f_8)
- One free parameter – cloud size

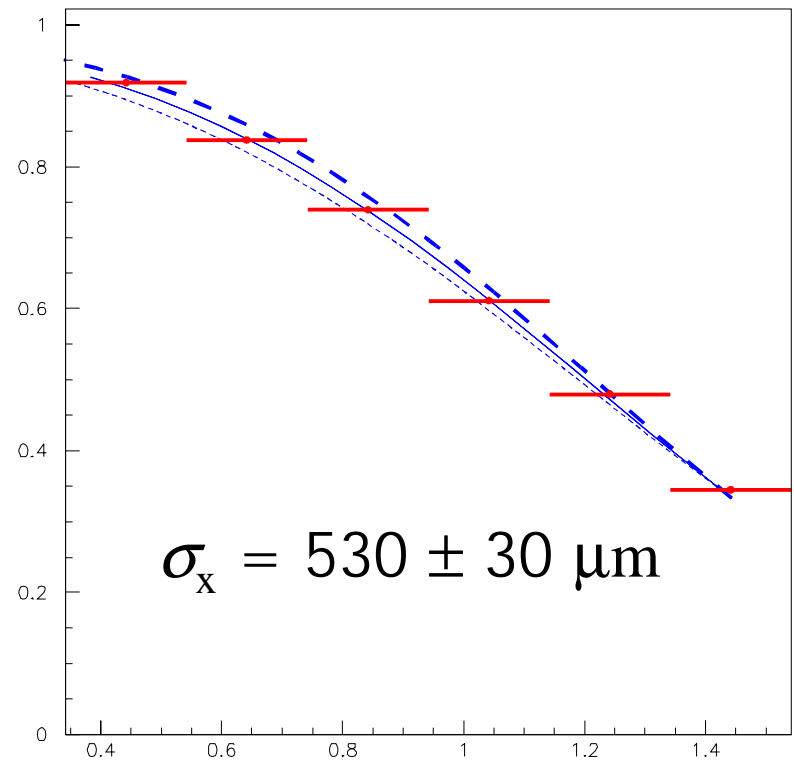
Determining cloud size

Ar CO₂ (~90:10)

charge fraction in central pad



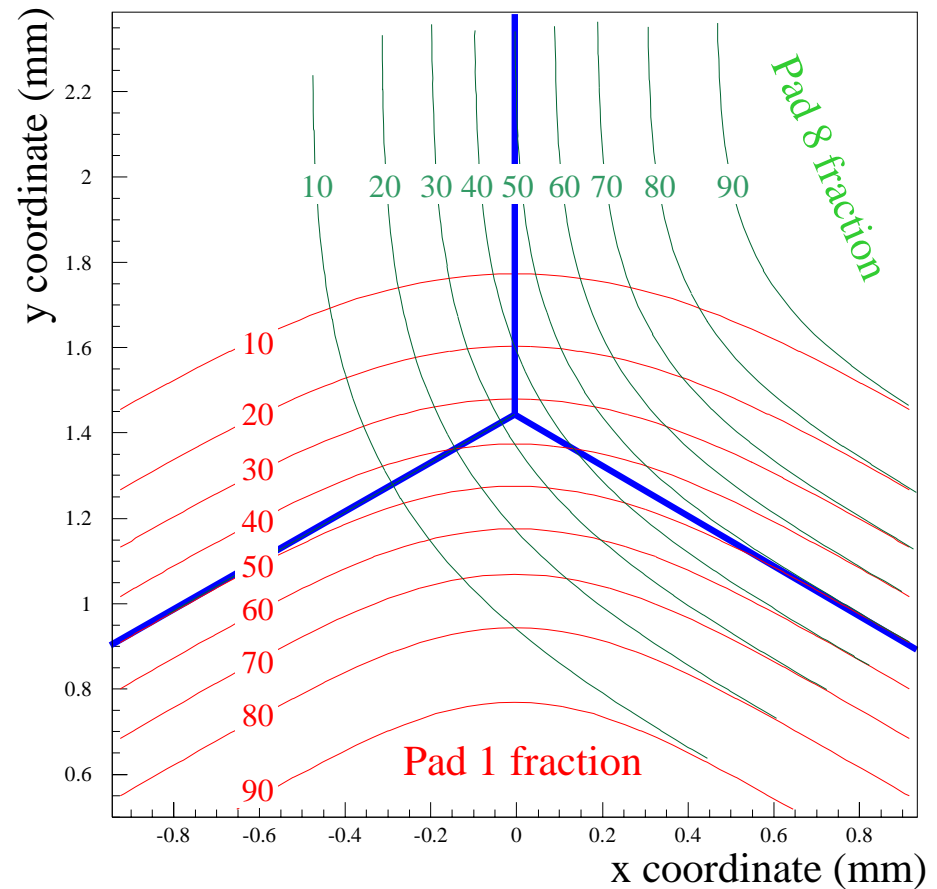
P10: Ar CH₄ (90:10)



y coordinate of collimator (mm)

Position from pad fractions

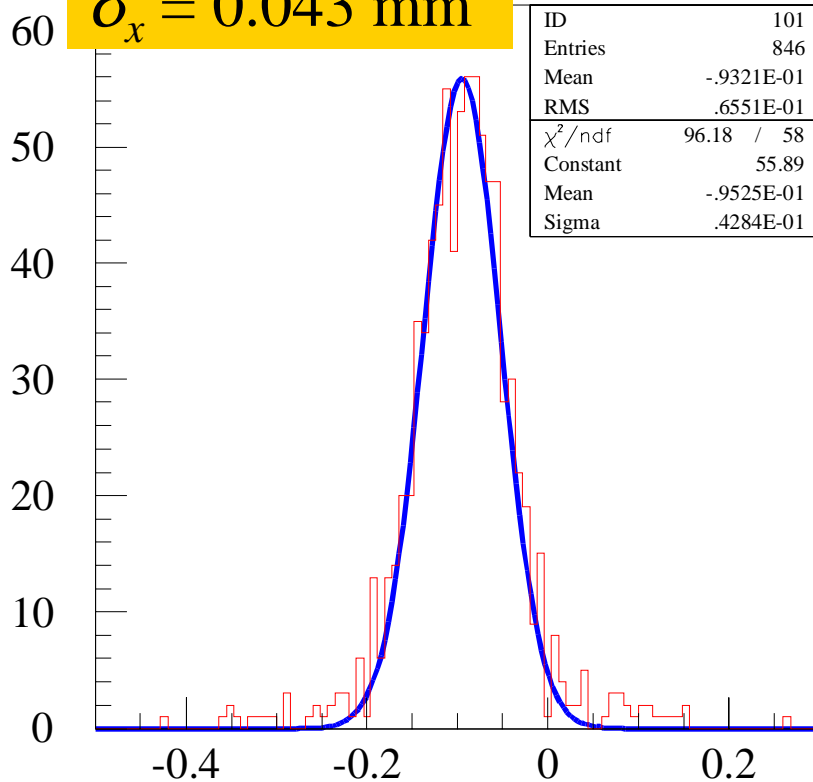
- figure: 1 to 1 mapping from (x,y) to (f_1, f_8)
- invert the mapping to determine (x,y) from (f_1, f_8)



Charge sharing result – Ar CO₂

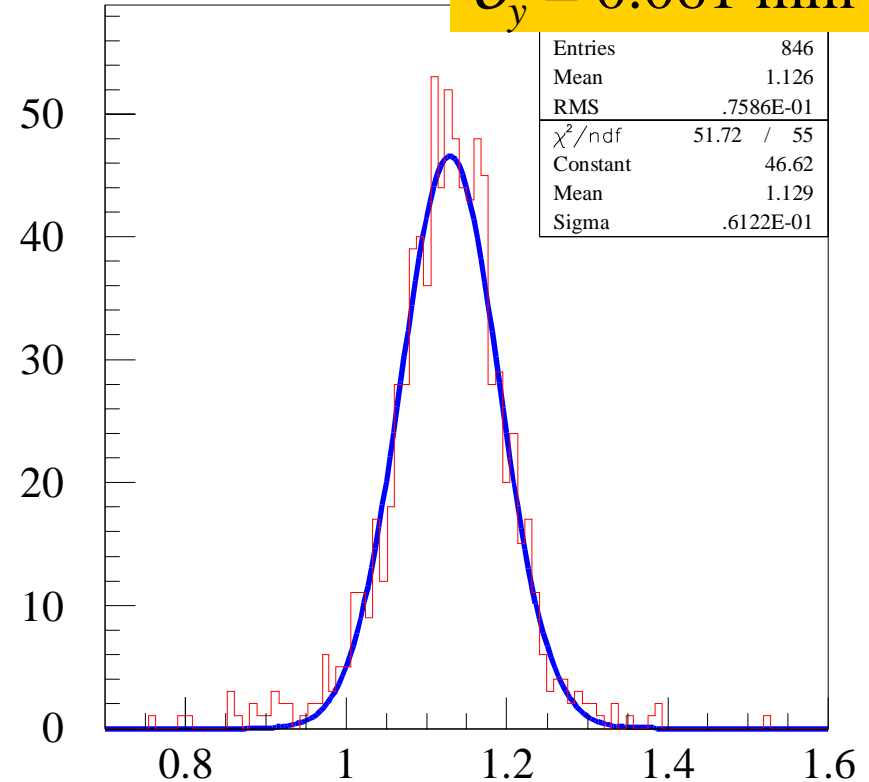
$$(x, y)_{\text{col}} = (-0.1, 1.143) \text{ mm}$$

$$\bar{x} = -0.095 \text{ mm}$$
$$\sigma_x = 0.043 \text{ mm}$$



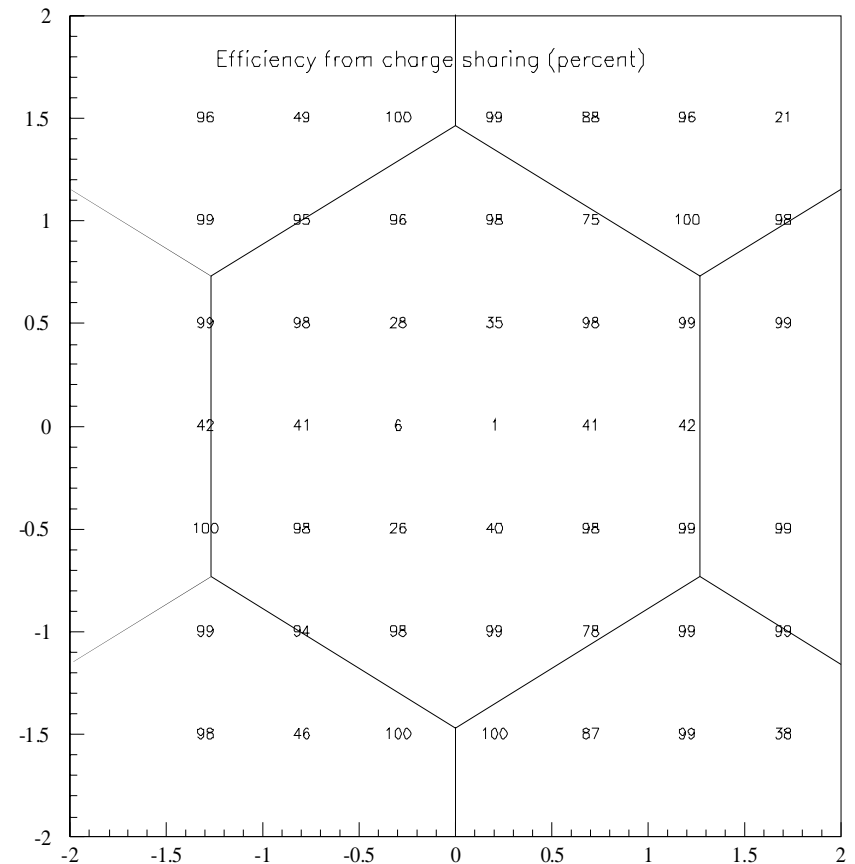
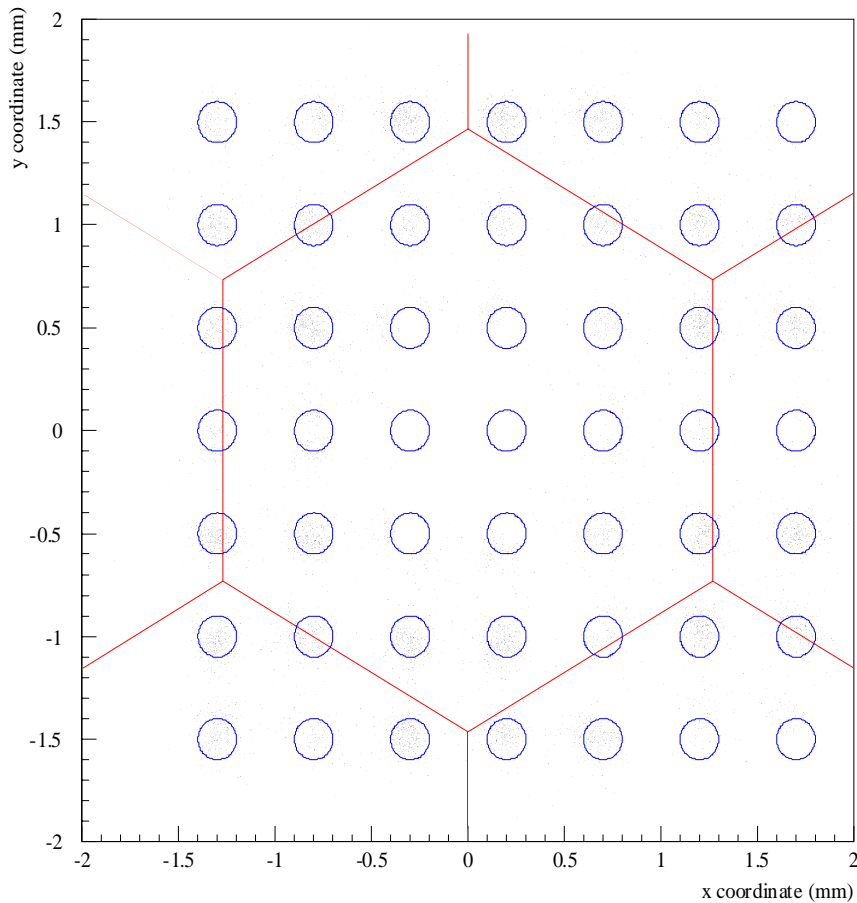
x coordinate

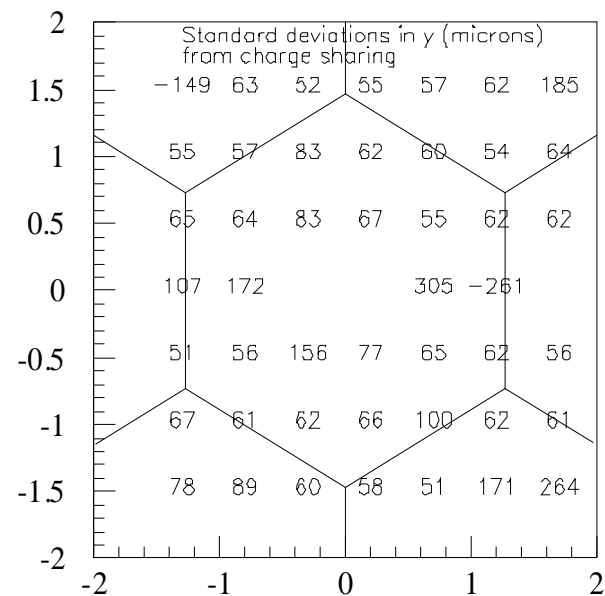
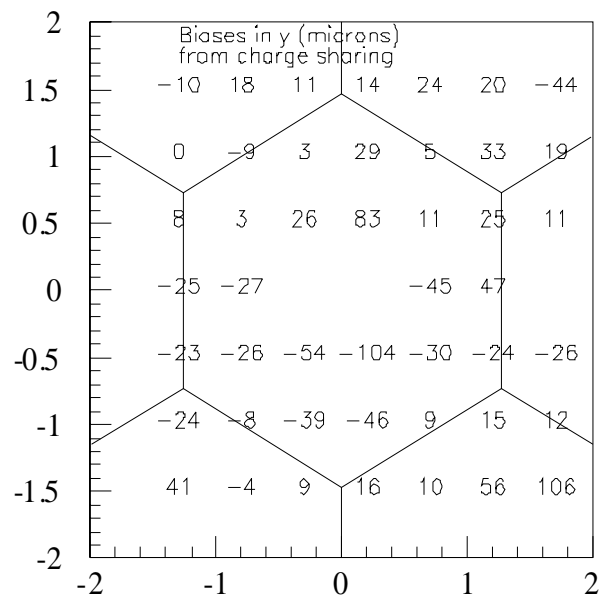
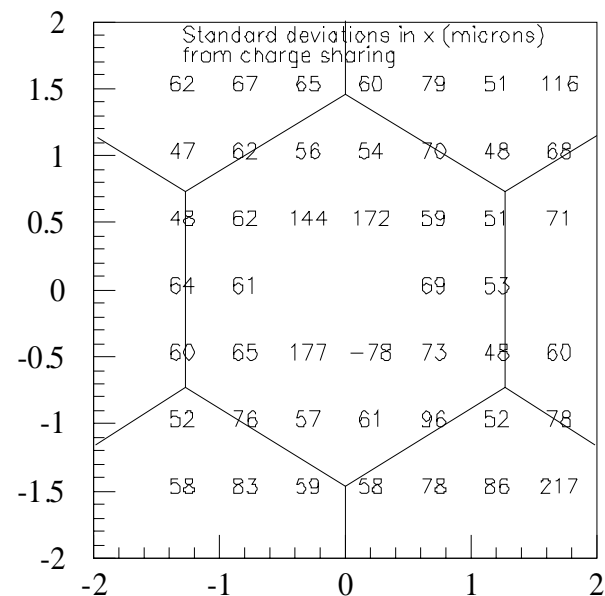
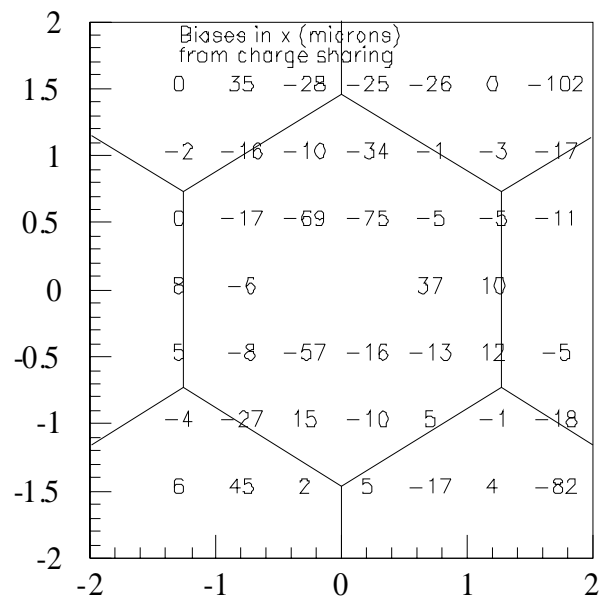
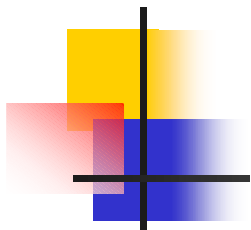
$$\bar{y} = 1.129 \text{ mm}$$
$$\sigma_y = 0.061 \text{ mm}$$



y coordinate

Scan across pad

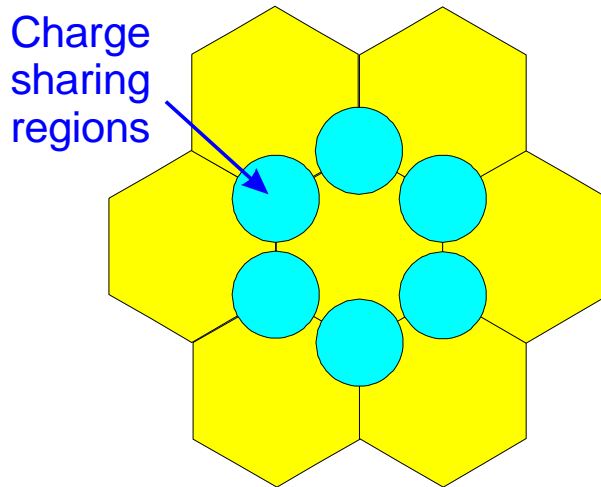




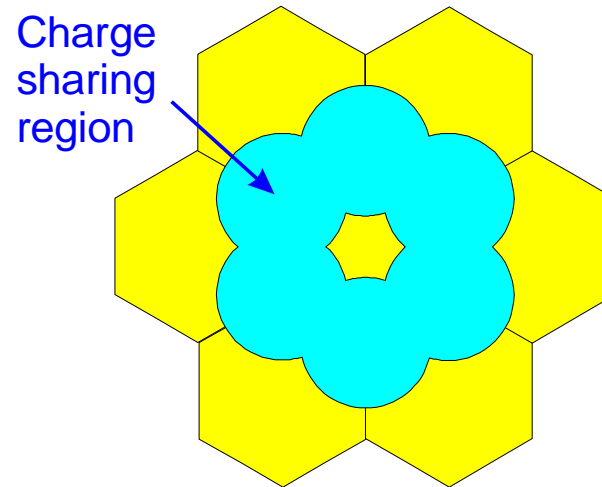
Alternative to charge sharing

- Charge sharing only works in regions where significant charge is deposited on 3 pads

Ar CO₂

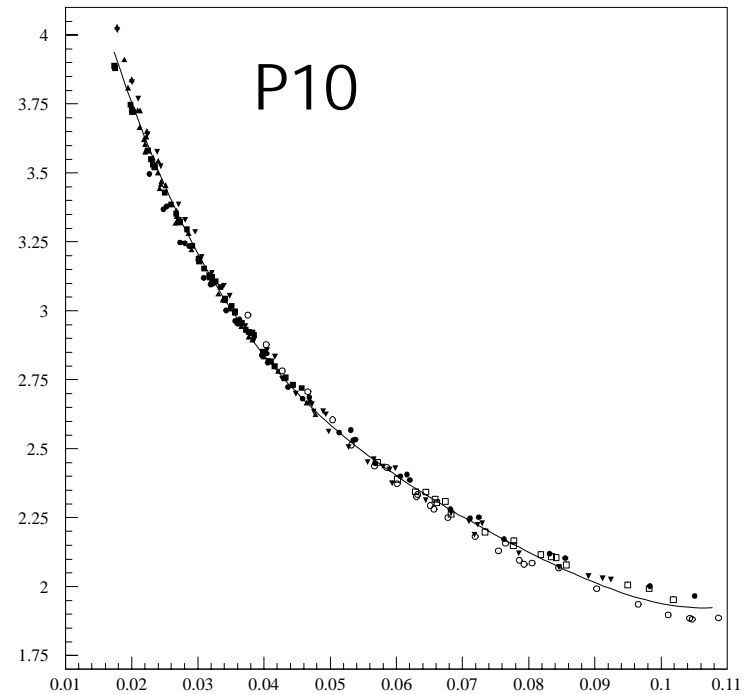
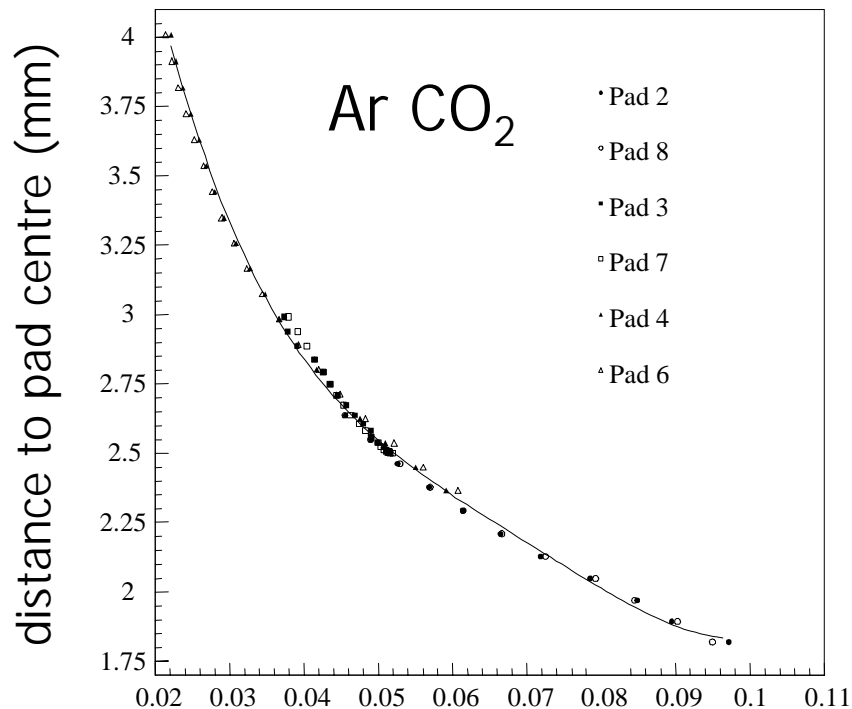


P10



Localization from induced pulses

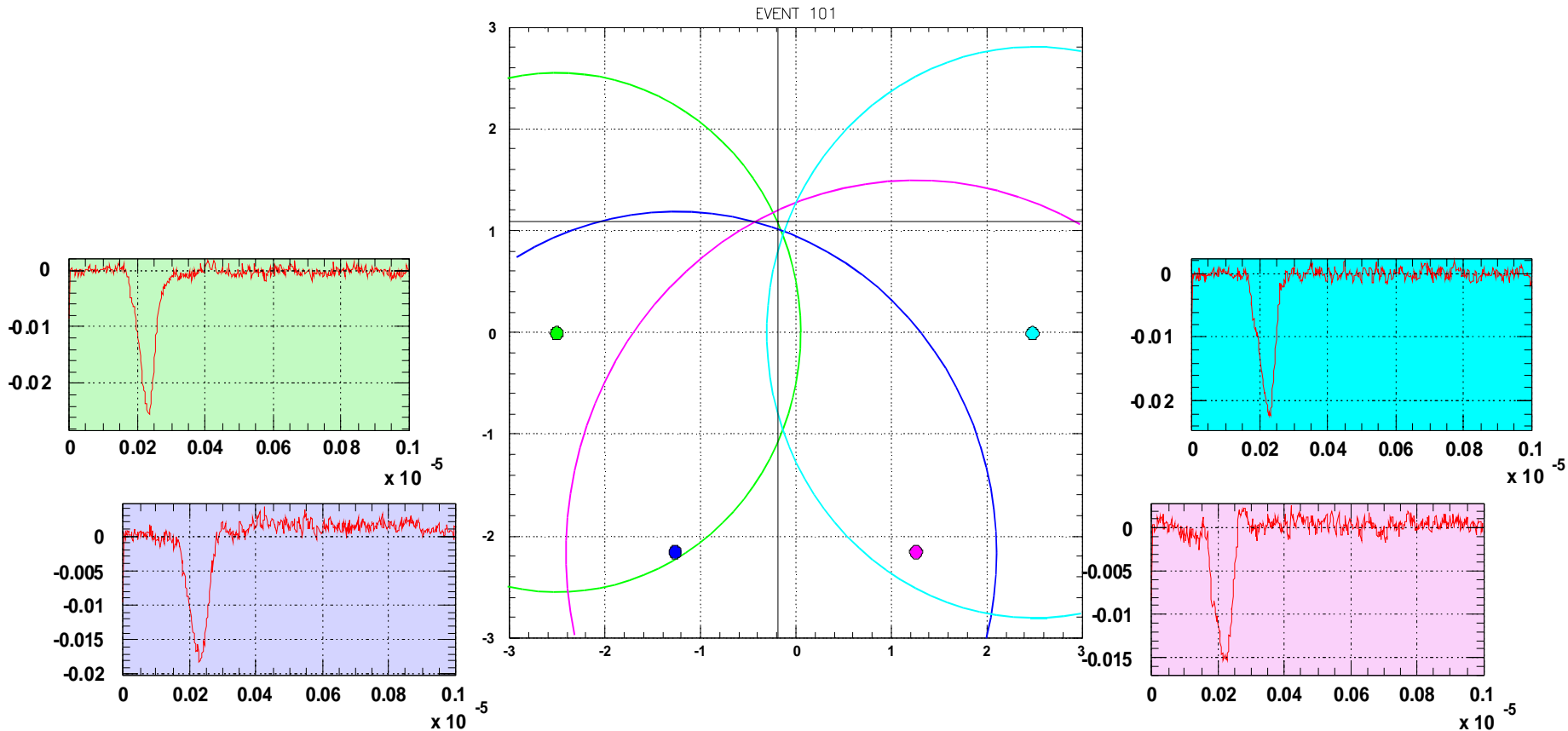
- The amplitude of the induced pulse from a charge cloud that falls on a neighbouring pad depends on the distance between the cloud and pad.



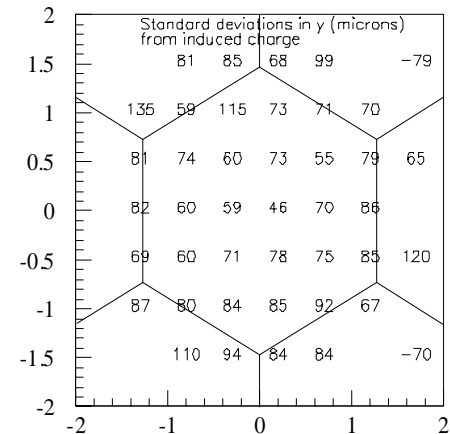
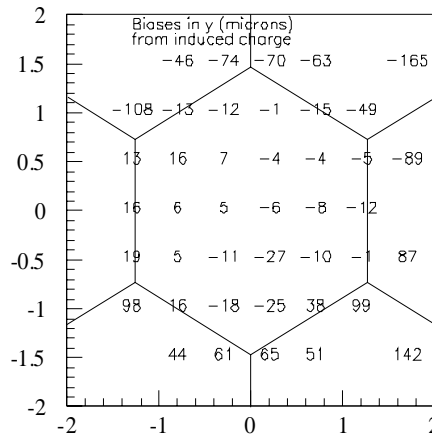
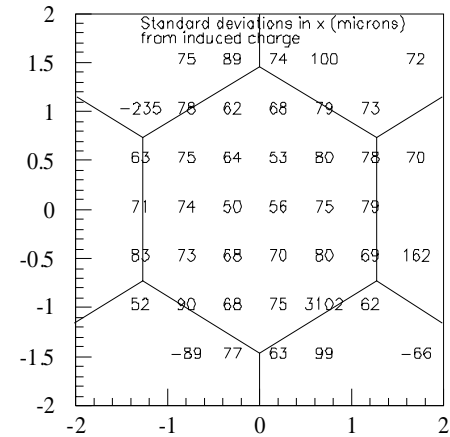
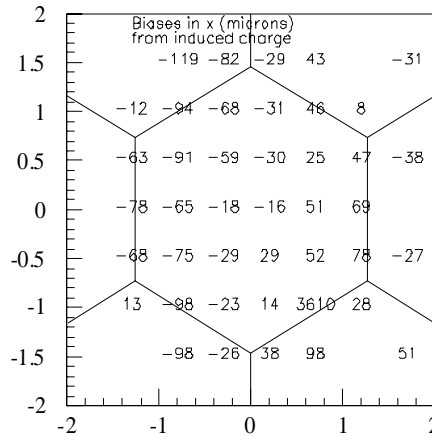
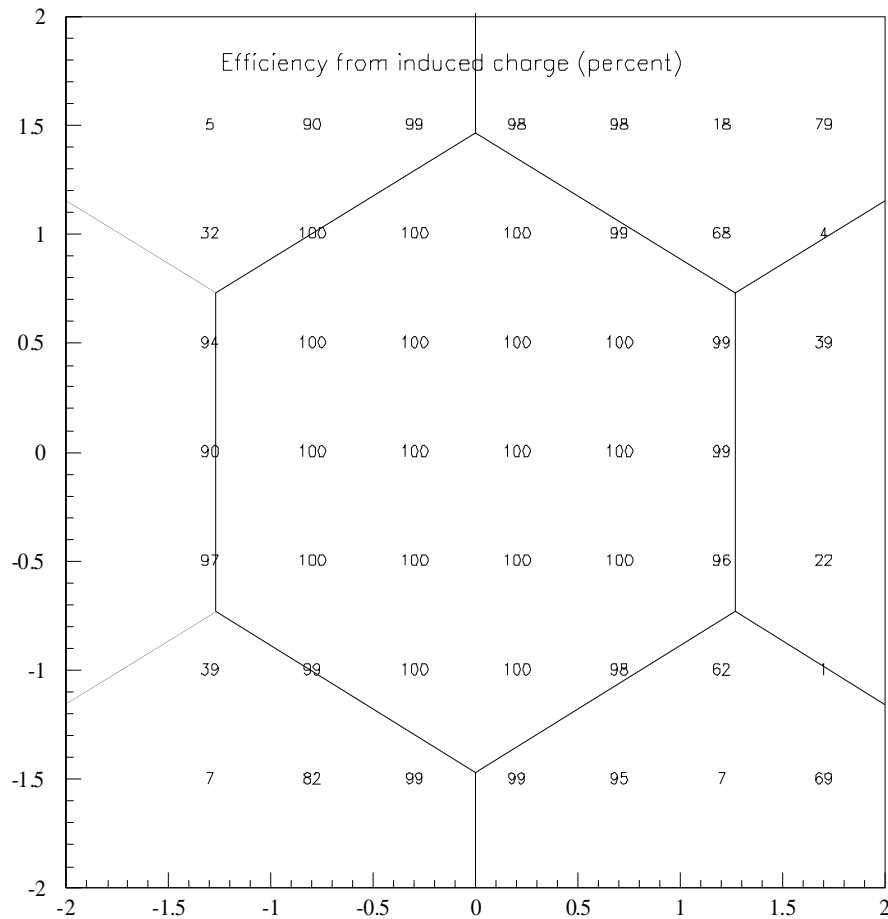
induced pulse / total charge pulse

Example

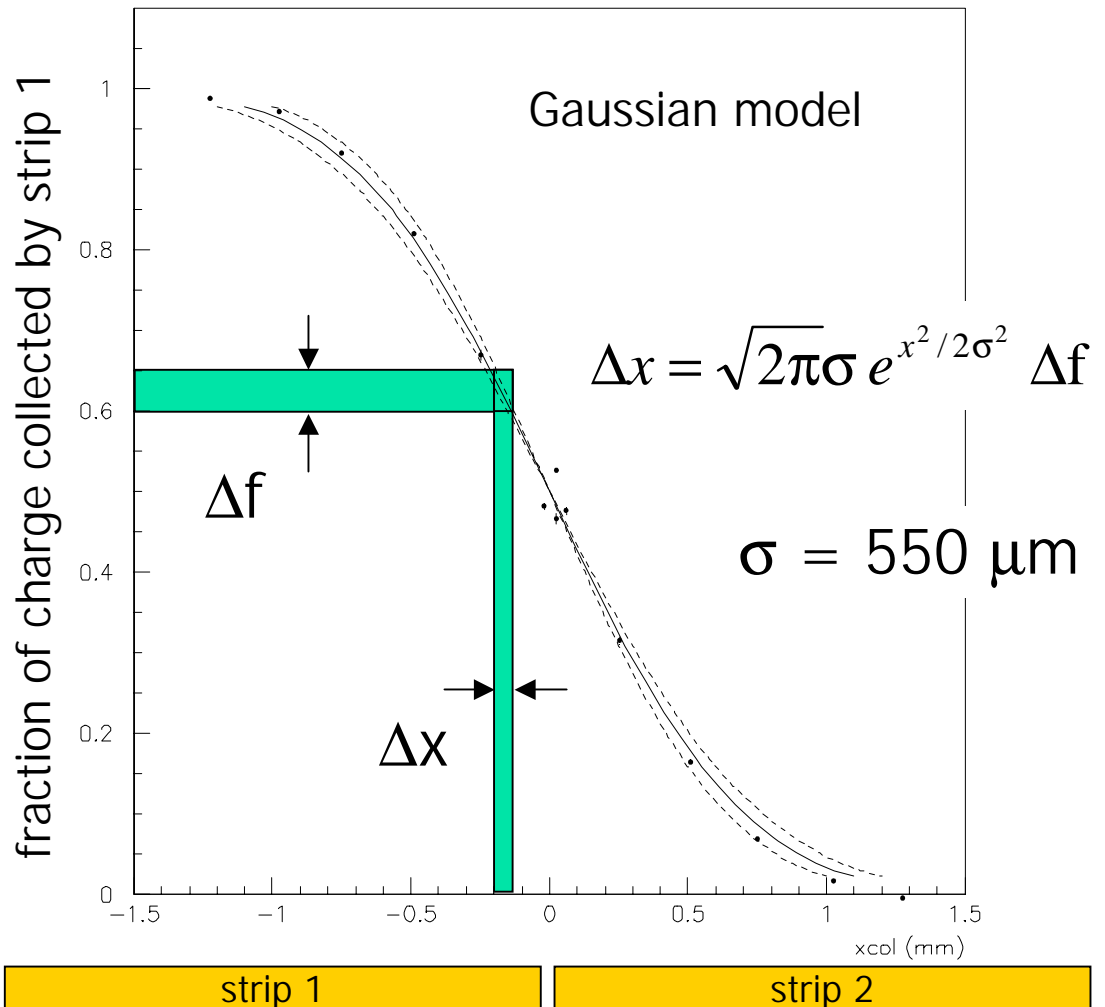
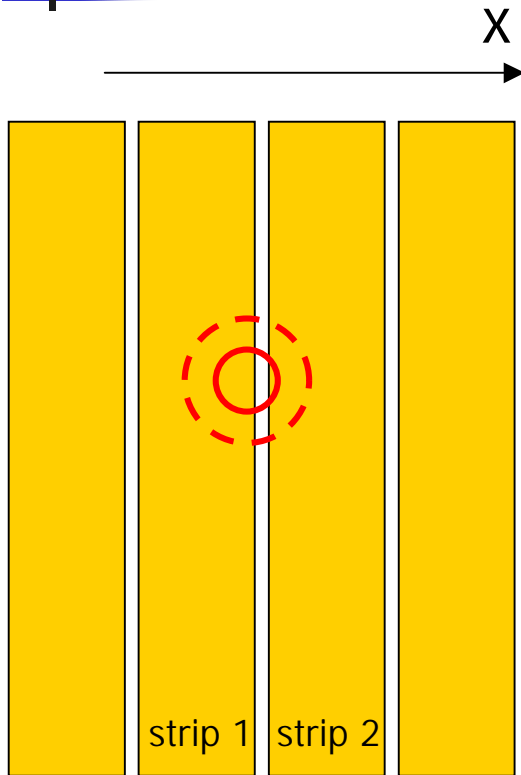
- collimator location: $(-0.1, 1.143)$



Scan across pad

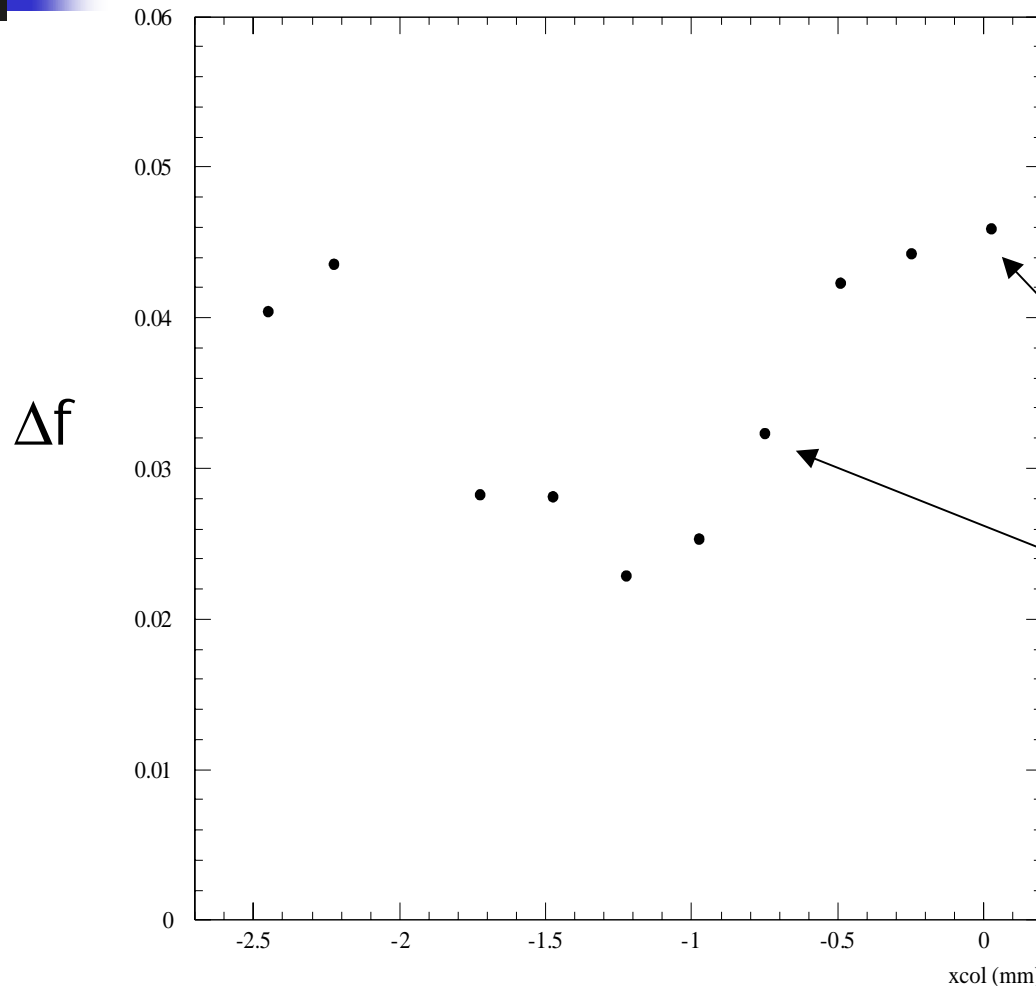


Strip geometry – charge sharing



- With P10 gas:
 - x standard deviation: $\sim 70 \mu\text{m}$

Variation in charge fractions



Δf depends on x
because cloud
centroids not fixed

$\Delta x = 60 \mu m$

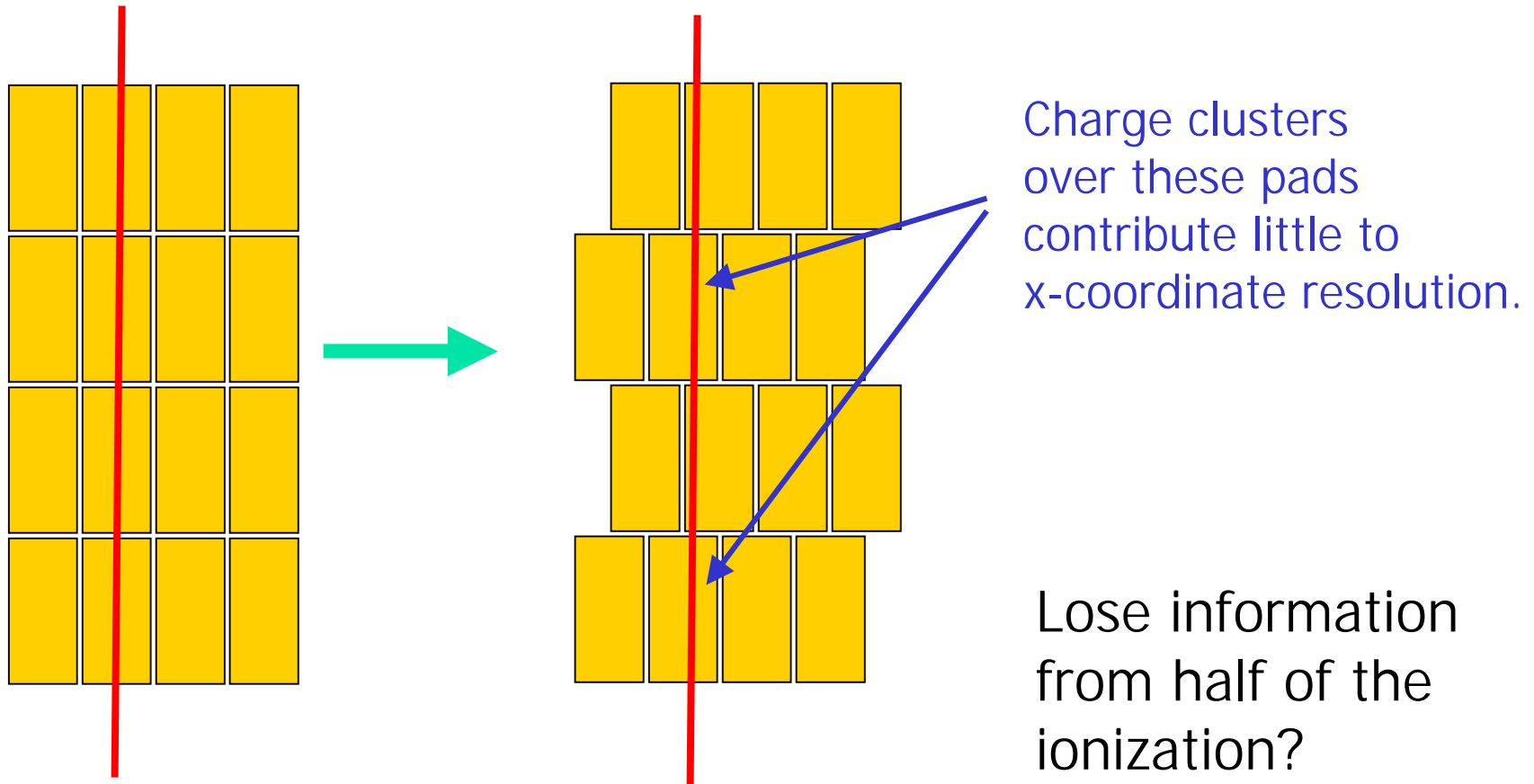
$\Delta x = 100 \mu m$

For $\frac{1}{2}$ the area, Δx
is $100 \mu m$ or less



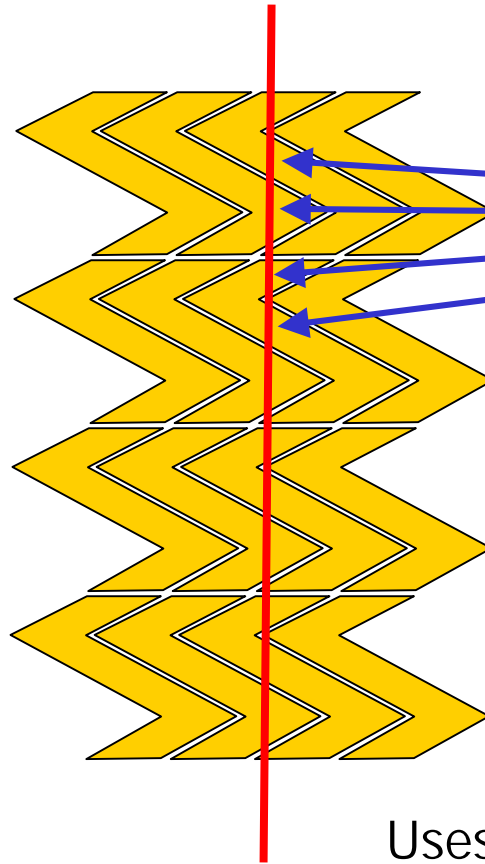
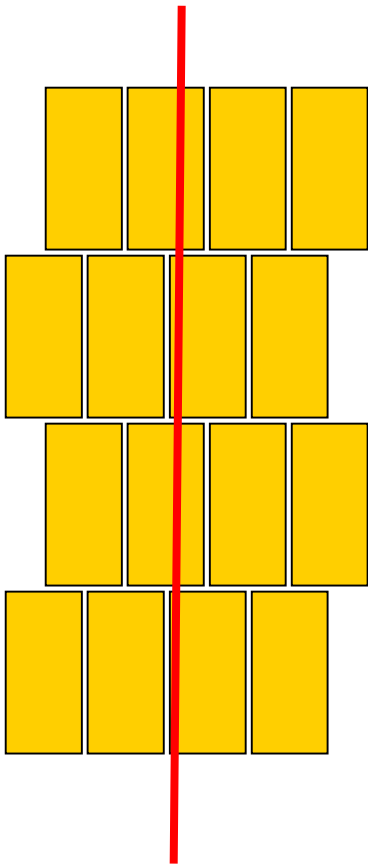
Pad geometries – optimizing resolution

- To avoid poorly measured tracks: stagger?



Pad geometries – optimizing resolution

- Is this improved in Chevron design?



An individual cluster over these regions contributes little to x-coordinate resolution

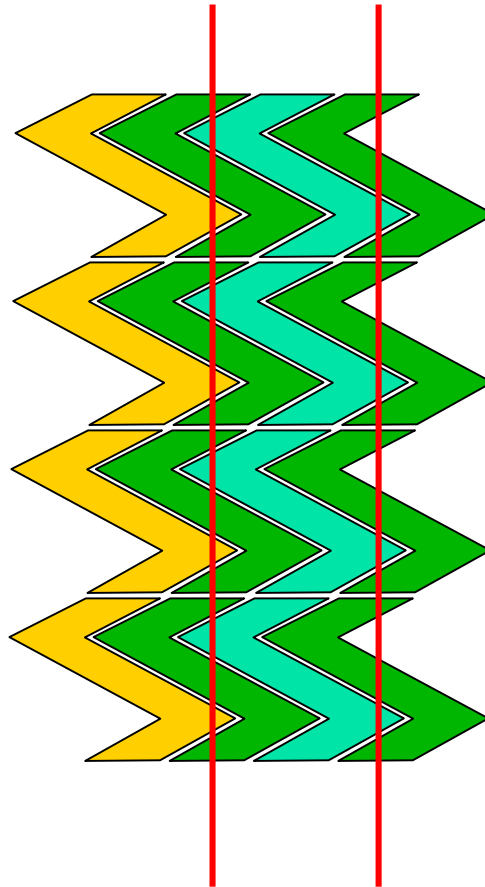
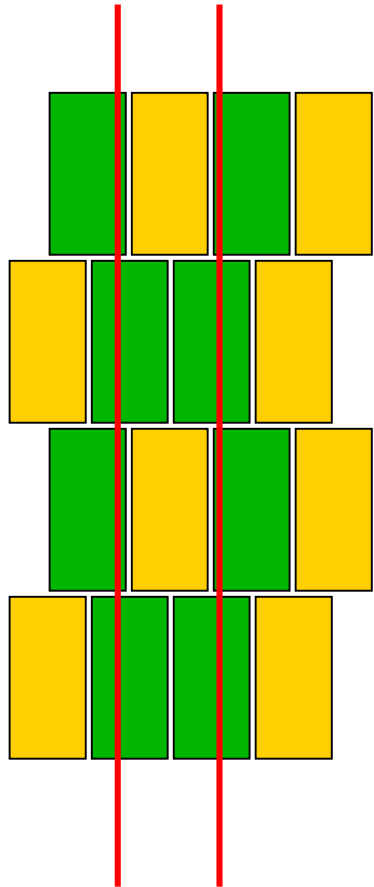
All clusters provide x-coordinate information collectively if you assume uniform ionization along the track.

Uses information from all clusters, but sensitive to ionization fluctuations

Pad geometries – 2 track resolution

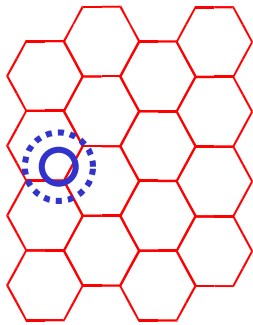
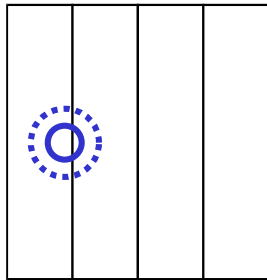
- Naively, this appears to be worse in Chevron design

Minimum
separation in
limit of no
diffusion:

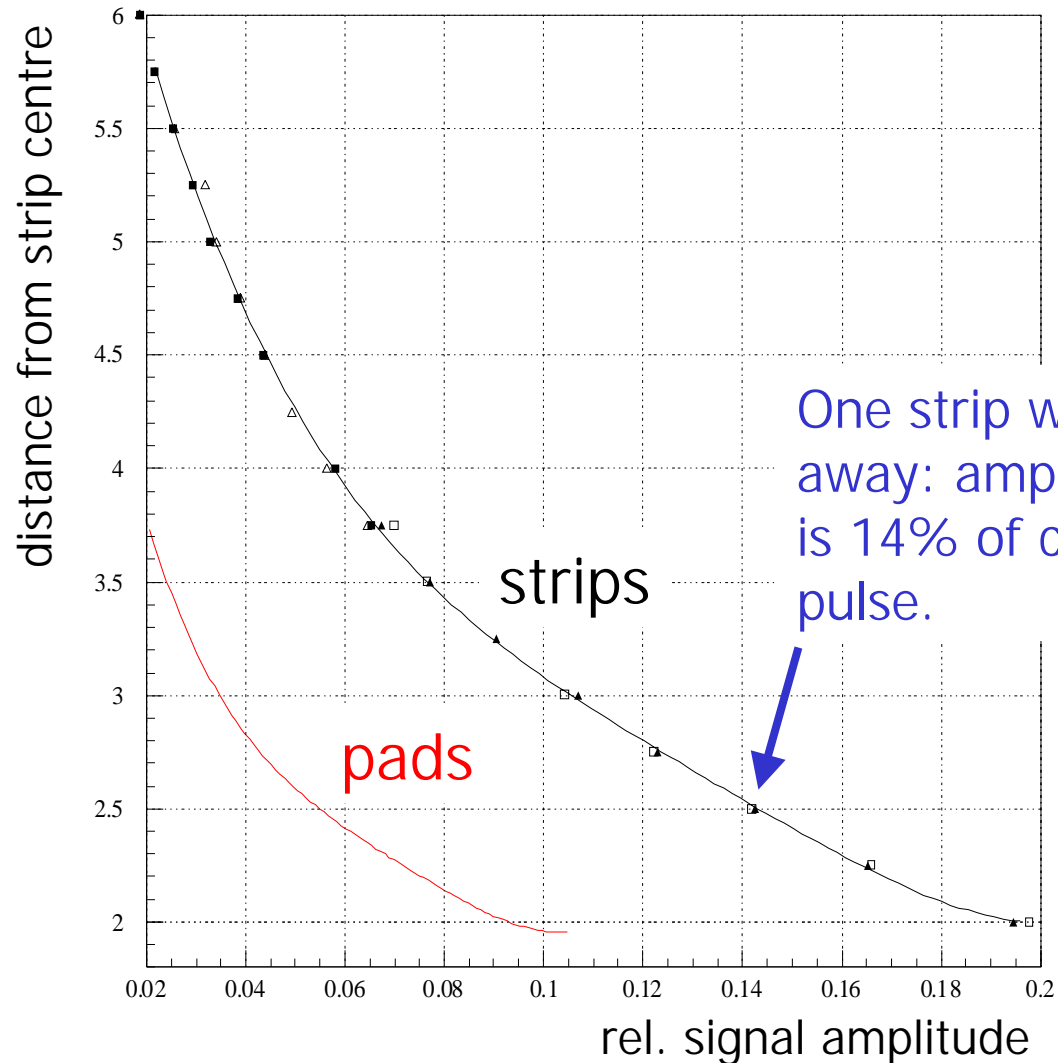


Factor of 2?

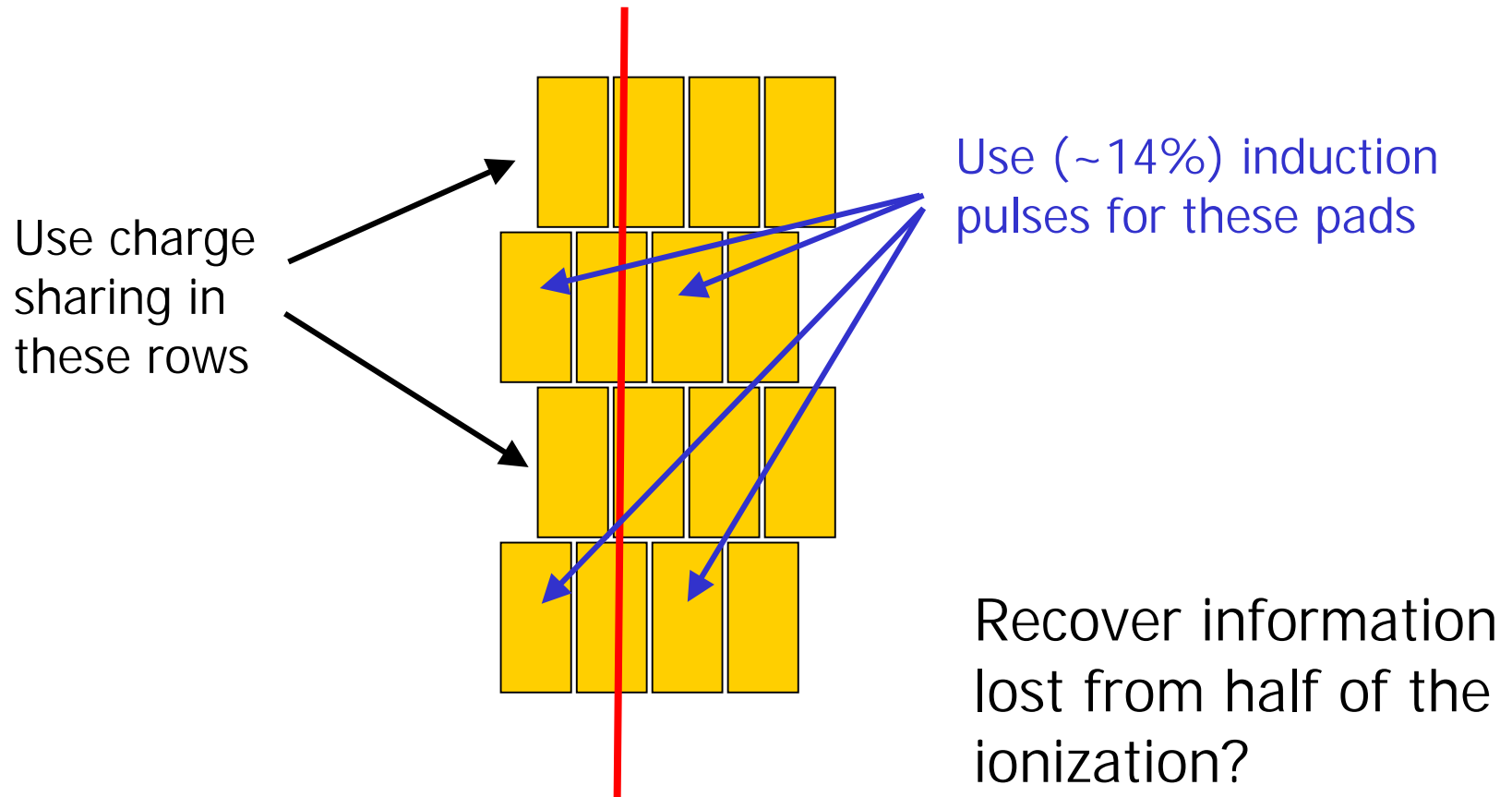
Strip geometry – induced signals



- Strip geometry has larger induced signals by factor of 2 – 3
 - x standard deviation: $\sim 70 \mu\text{m}$

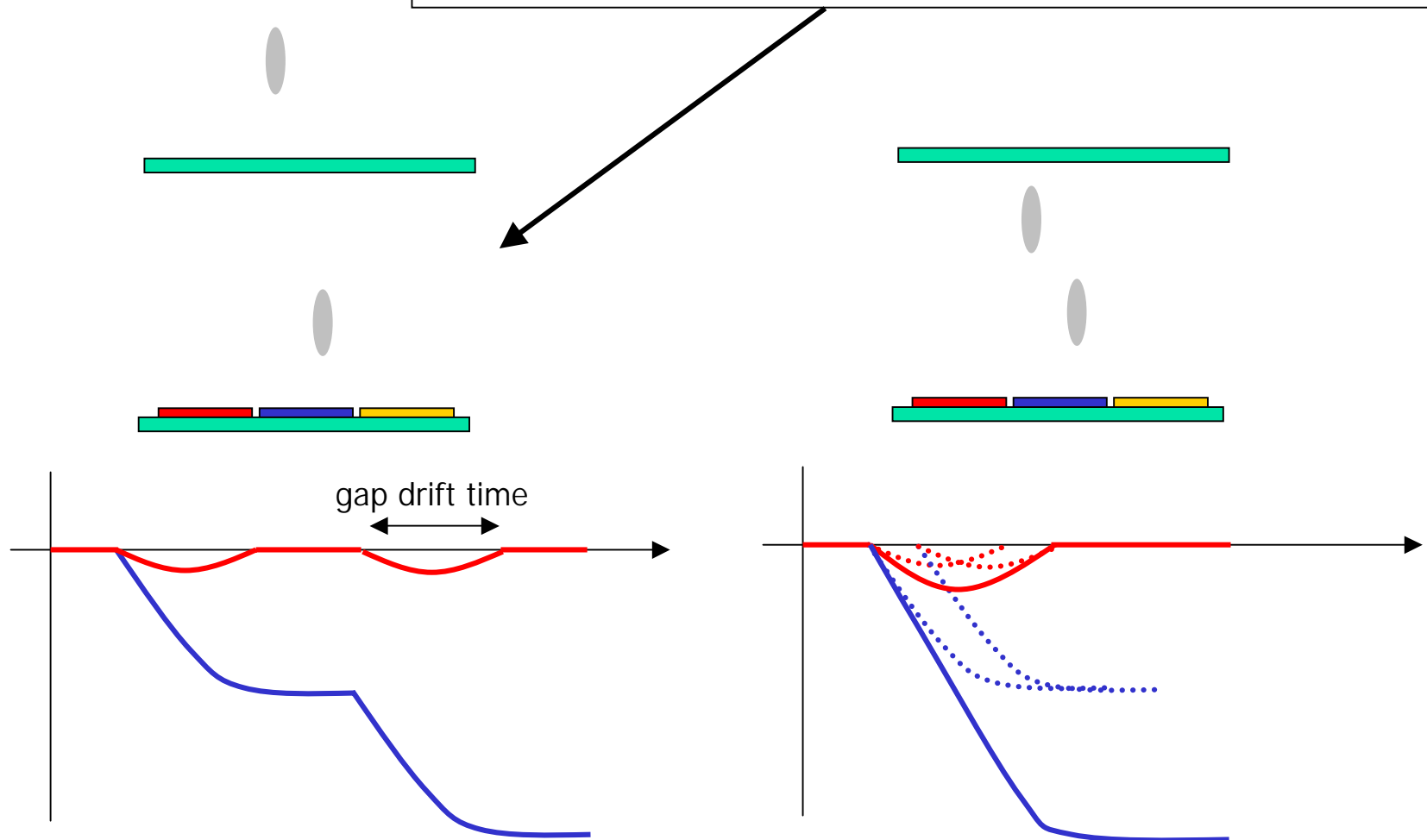


Induced pulses in staggered geometry



Induced pulse: complications

induction pulses do not add if separated





Final gap considerations

- Good to have slow drift velocity in final gap:
 - Induction pulses
 - wider pulses (can use slower electronics)
 - more induction pulse pile up (larger amplitude)
 - Charge sharing pulses
 - larger transverse diffusion (after gain), so acts as a diffuser (more charge sharing)
 - adds a constant cloud width
 - uniform cloud width is important for rectangular pads, less so for chevrons



Summary

- Interesting results:
 - relatively large pads (2.5 mm diameter) can give excellent space point resolution (of order $70\text{ }\mu\text{m}$) by using charge sharing
 - large pads are necessary for TPC application to keep the electronics channel count to a reasonable level
 - induction pulses can provide similar resolution, but readout is more challenging
 - recovers lost resolution for clusters without charge sharing