



# Investigation of GEM space point resolution for a TPC tracker

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Carleton GEM group:

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

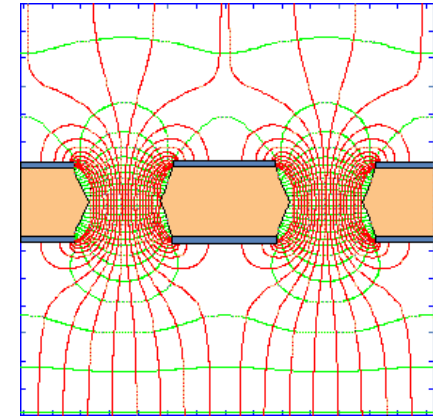
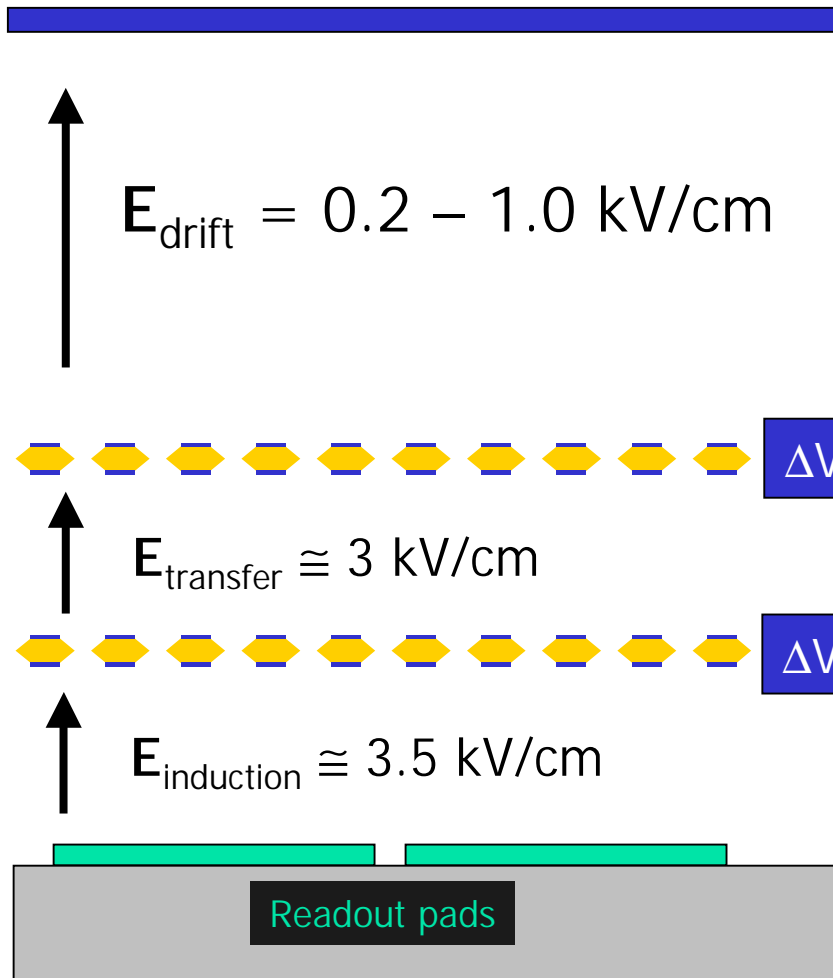


# Outline

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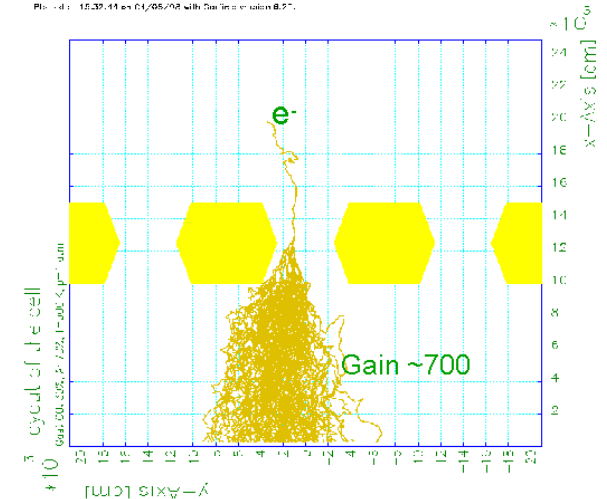
- What is a GEM?
- Why use GEMs in a TPC?
- Point resolution studies at Carleton
  - experimental setup – hexagonal pads
  - data and results – Ar CO<sub>2</sub> and P10
  - simulation work
- Future plans
- Summary

# Gas Electron Multiplier (GEM)



**Avalanche in Ar(70%) - CO<sub>2</sub>(30%)**  
 Garfield simulation by V. Avati & R. Ostonen

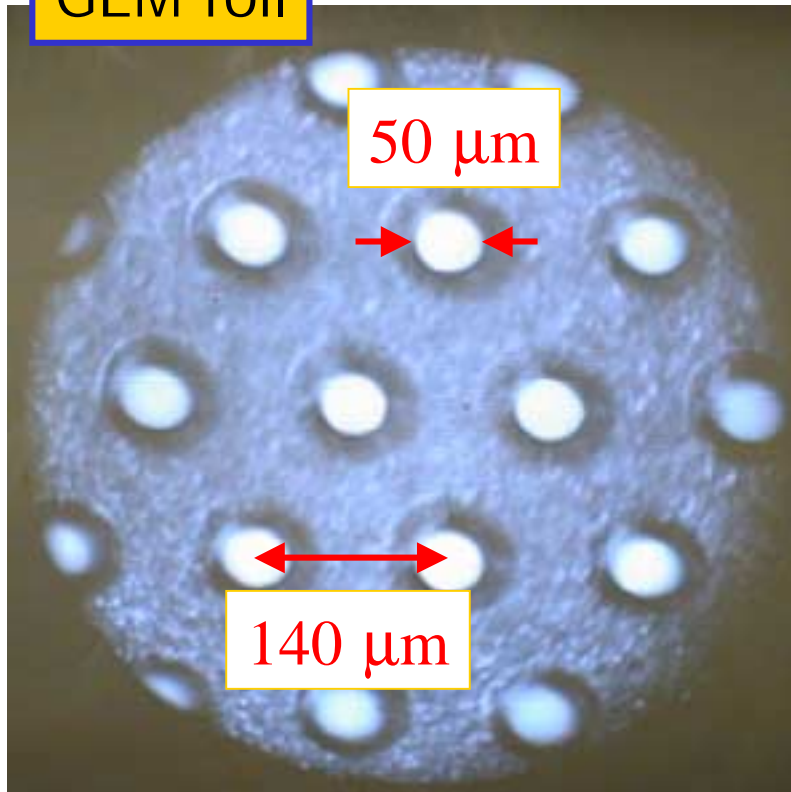
Fig. 1-41: 18.09.11 en 03/05/08 with Garfield version B.27.



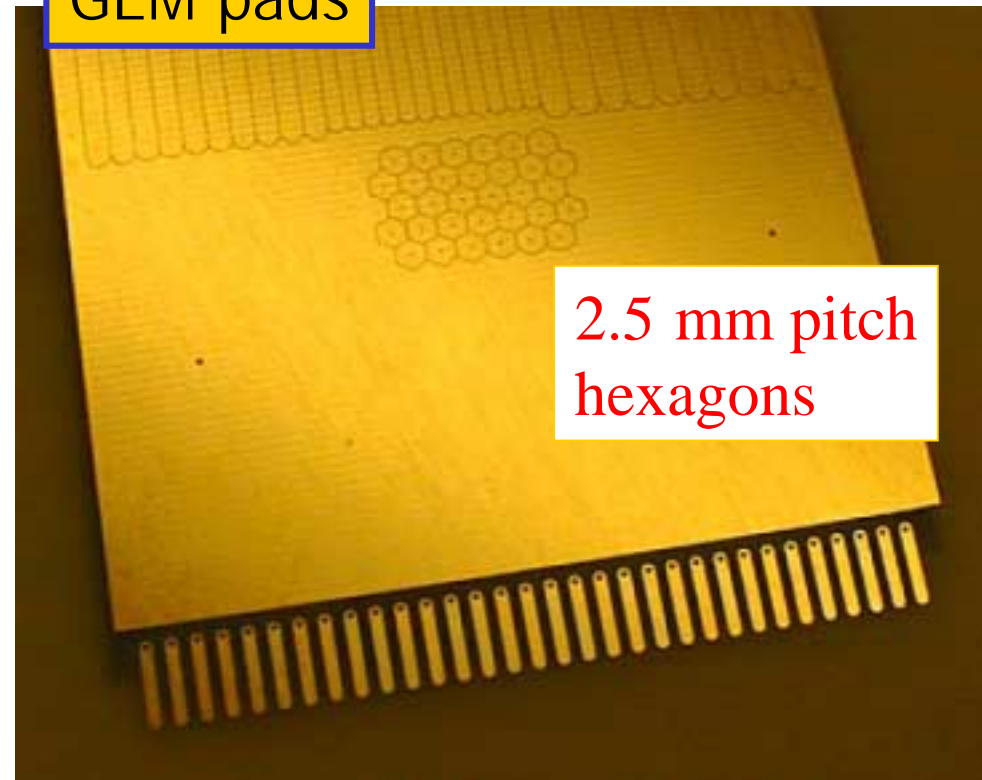
# GEM foils and pads for this study

fabricated at the CERN PCB workshop

GEM foil

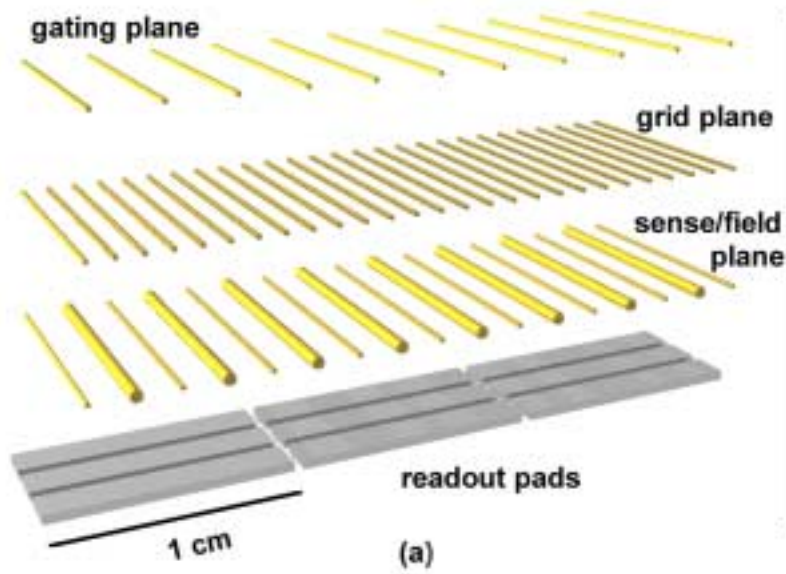


GEM pads

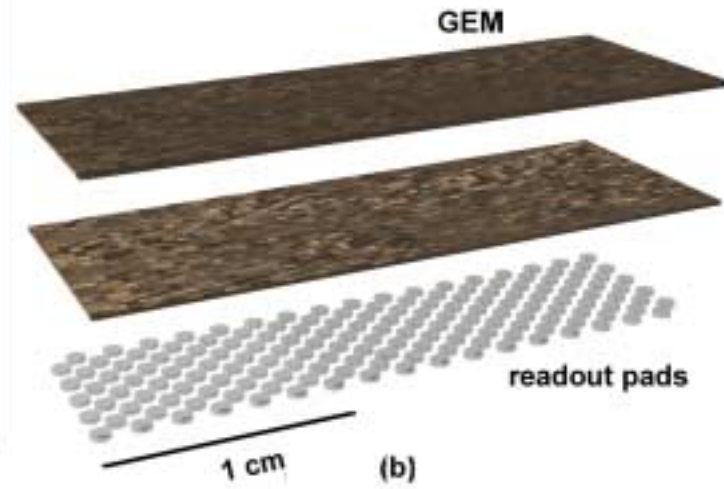


# Using a GEM in a TPC

Conventional TPC  
readout



GEM TPC  
readout



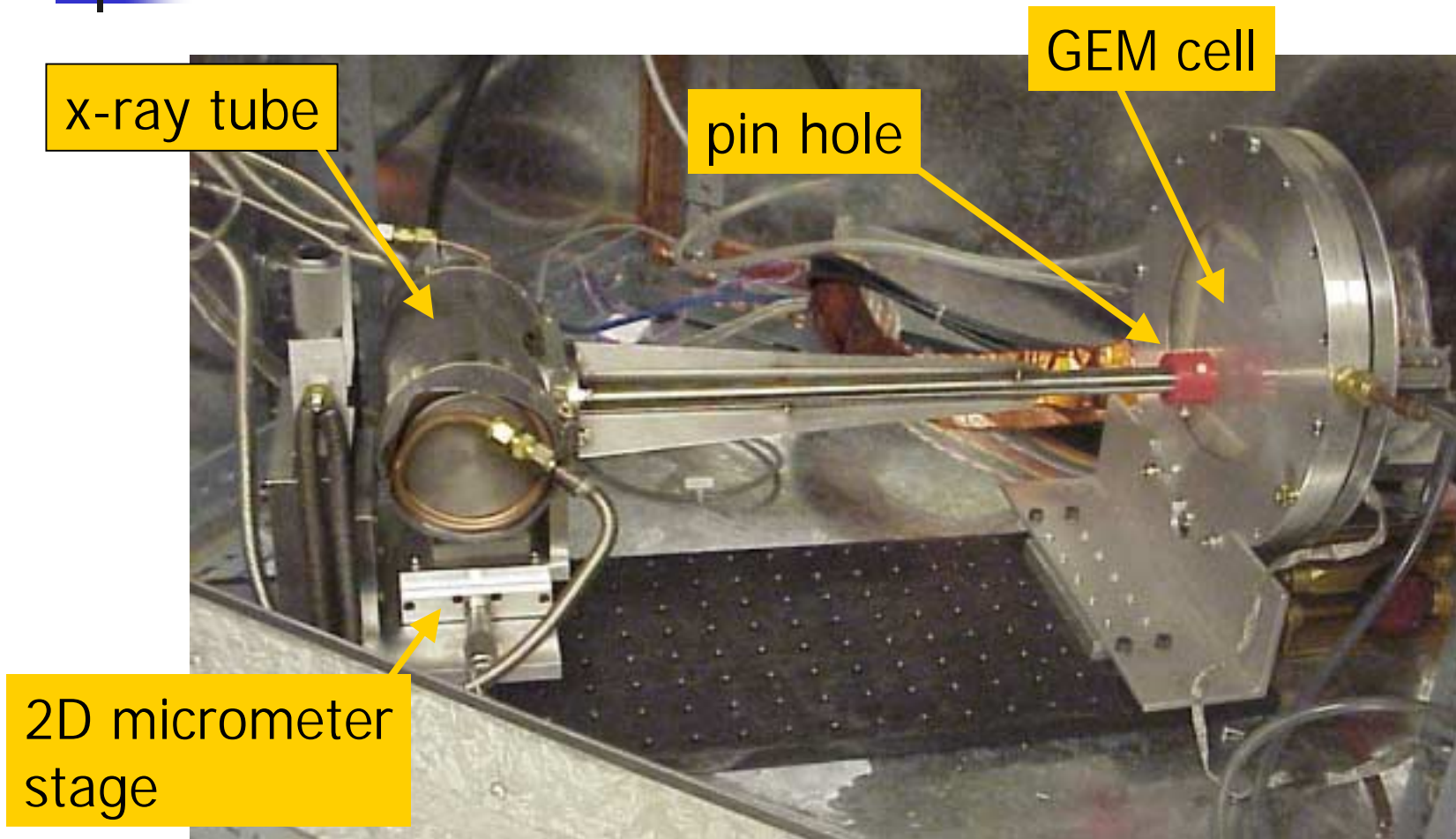


# Potential advantages for GEM readout

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- Improved space point resolution
  - $\mathbf{E} \times \mathbf{B}$  and track angle systematics suppressed
- Improved two particle separation power
  - $r - \phi$  : signals distributed over smaller area
  - $z$  : faster induction pulses ( $v_e > v_{ion}$ )
- Natural ion feedback suppression
  - no gating required (non-triggered expt.)
- Less mass in TPC endcap
  - no wires held under tension

# Point resolution studies at Carleton





# Details

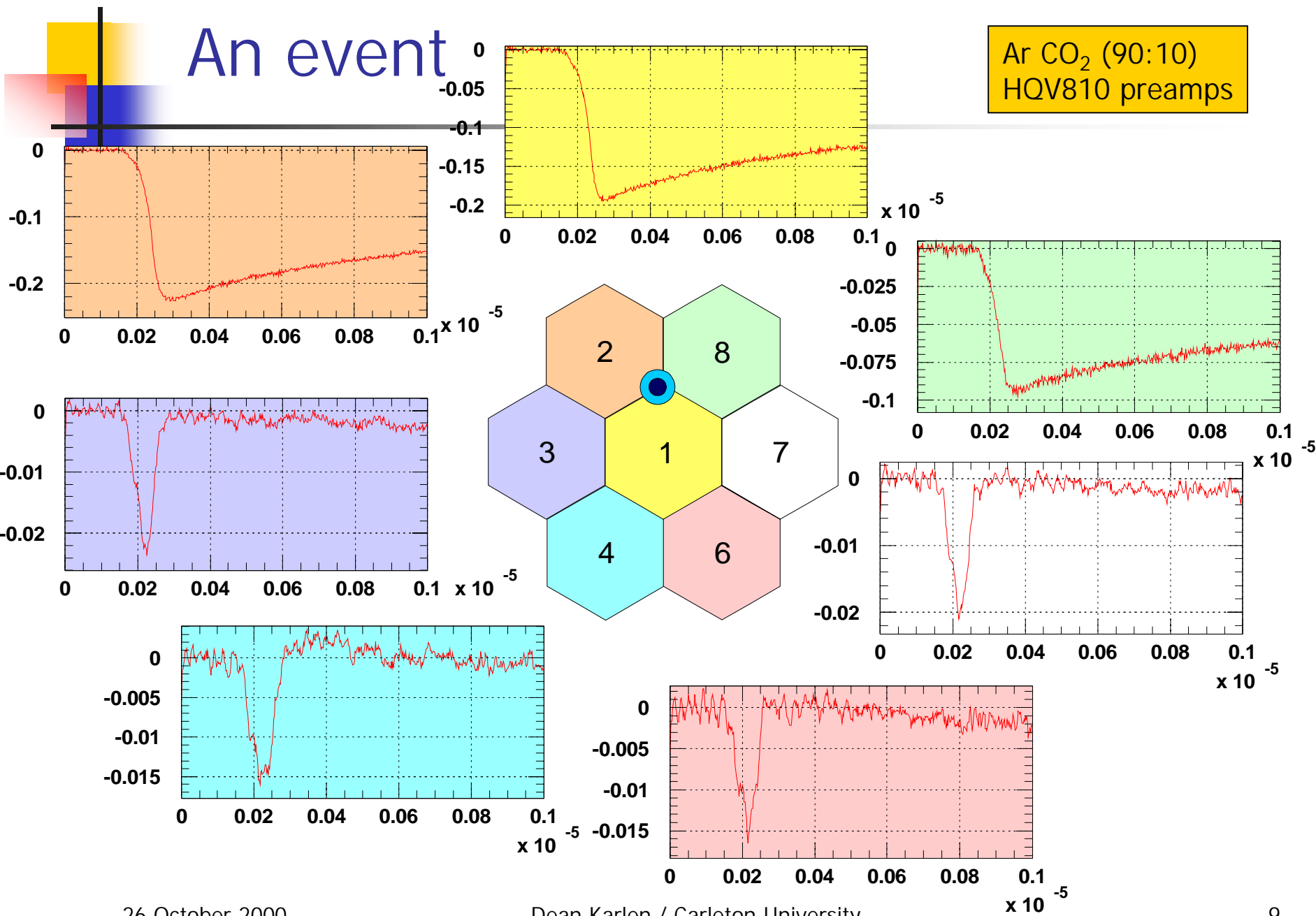
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- x-ray mean energy: 4.5 keV
- pinhole diameter: 50  $\mu\text{m}$
- Gas: Ar CO<sub>2</sub> (~90:10) / P10 : Ar CH<sub>4</sub> (90:10)
- pre-amps:
  - fast Lecroy HQV 810 with Ar CO<sub>2</sub>
  - slower ALEPH TPC pre-amp with P10
- readout:
  - two 4-channel digital scopes (9 bit ADC)
    - 500 MHz sampling for HQV 810
    - 125 MHz sampling for ALEPH preamps



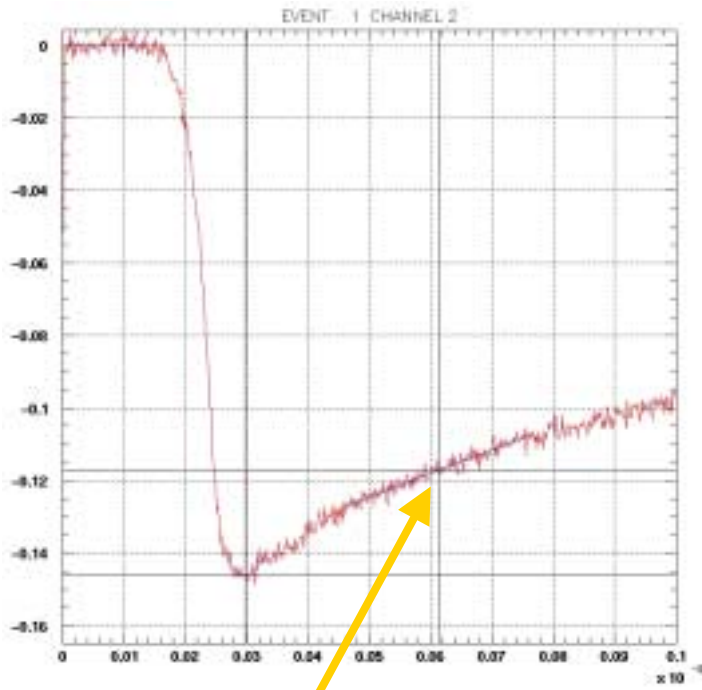
# An event

Ar CO<sub>2</sub> (90:10)  
HQV810 preamps



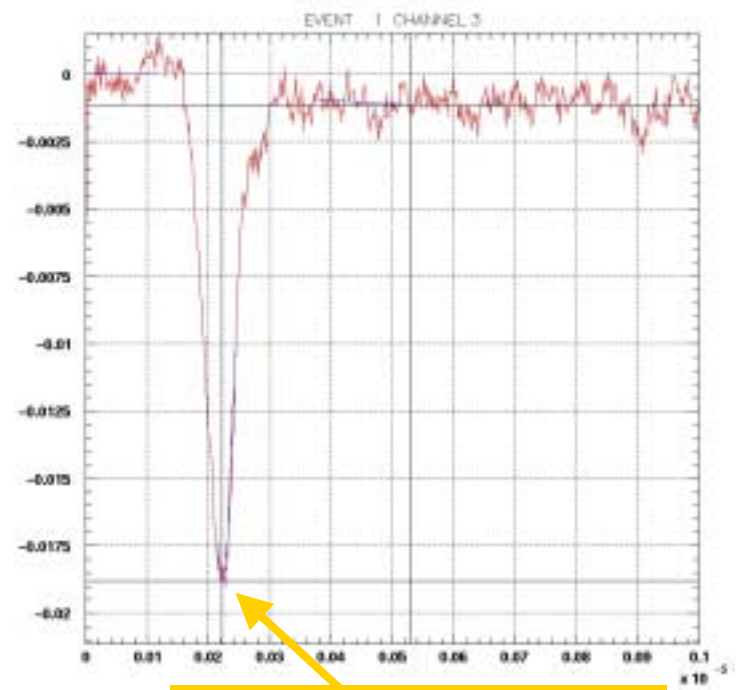
# Analysis

Direct pulse



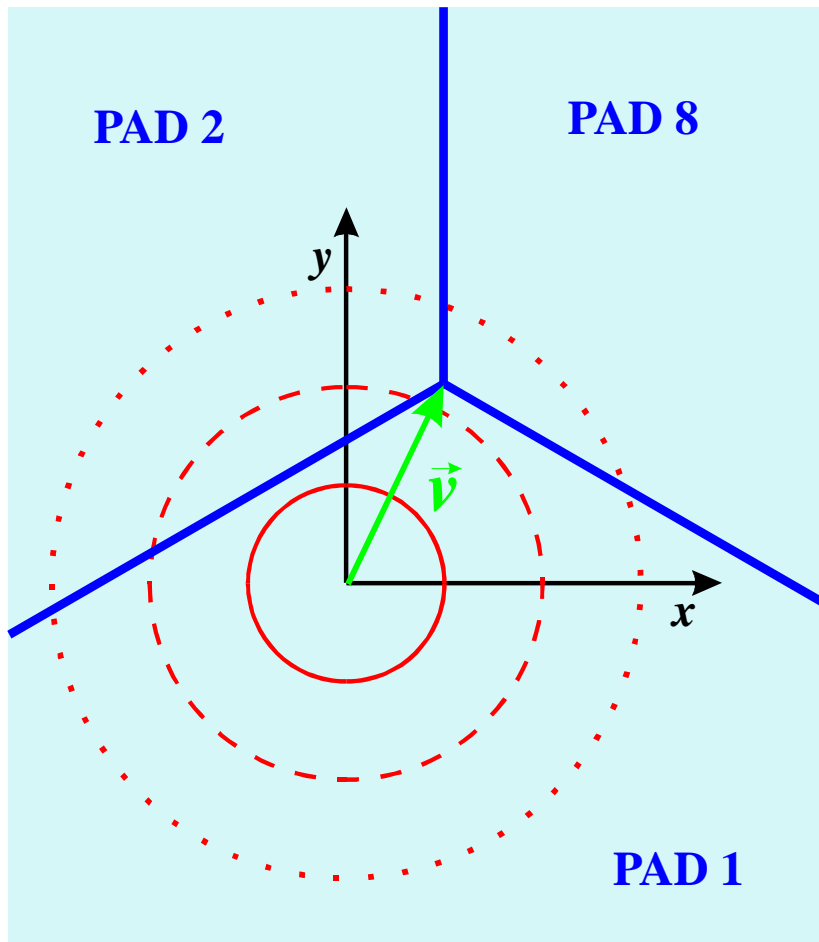
direct charge deduced from tail

Induced pulse



peak value used

# Localization using charge sharing



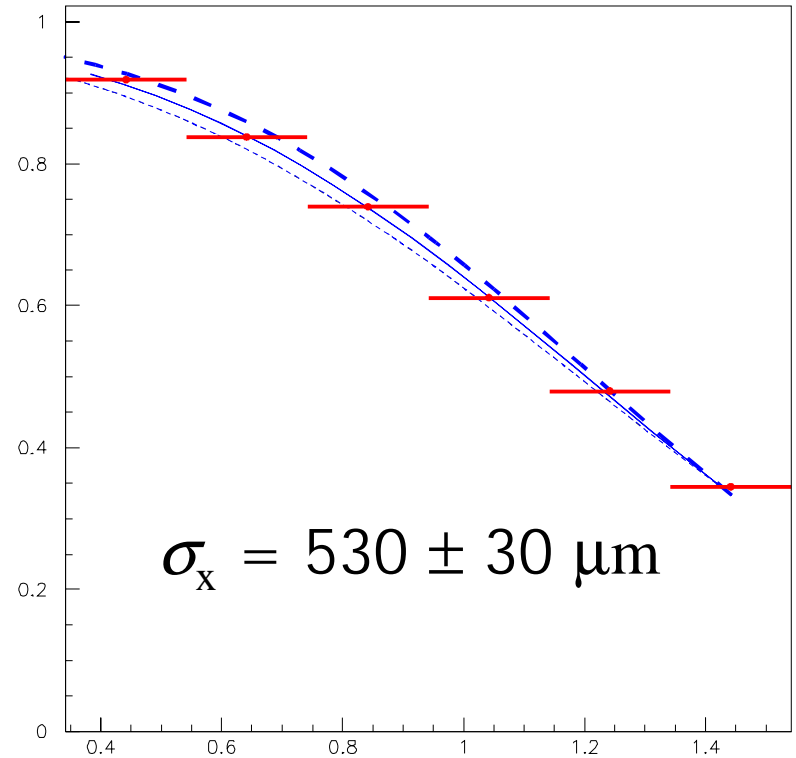
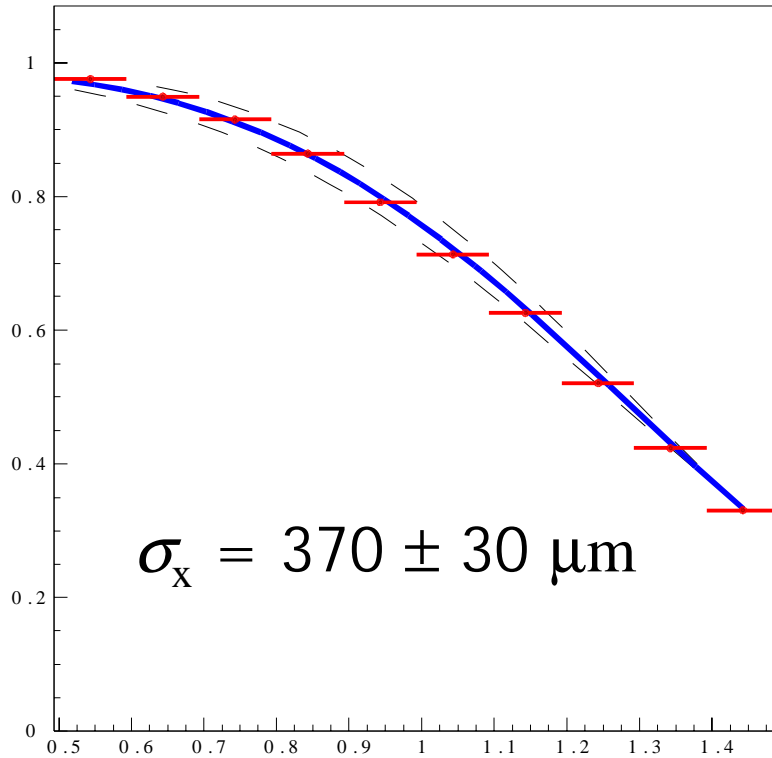
- assume electron cloud is 2D Gaussian
- charge fraction is given by integral over pad area
- 1 to 1 mapping between  $\vec{v}$  and  $(f_1, f_8)$
- One free parameter – cloud size

# Determining cloud size

Ar CO<sub>2</sub> (~90:10)

P10: Ar CH<sub>4</sub> (90:10)

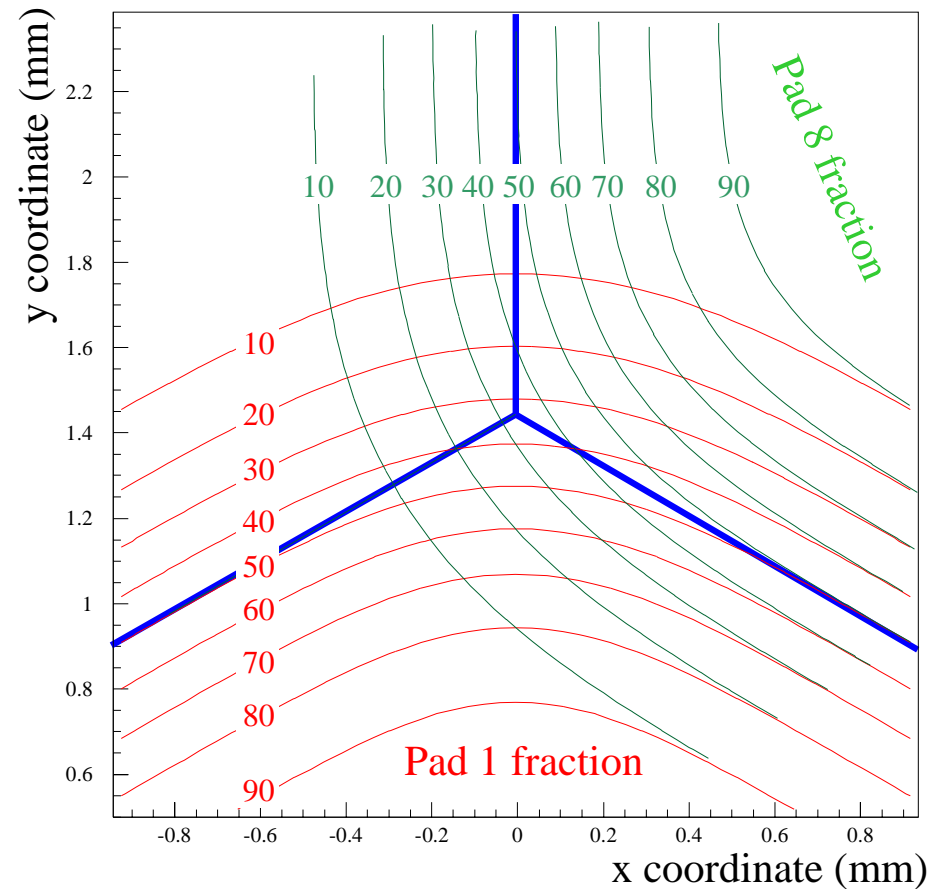
charge fraction in central pad



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  $(f_1, f_8)$

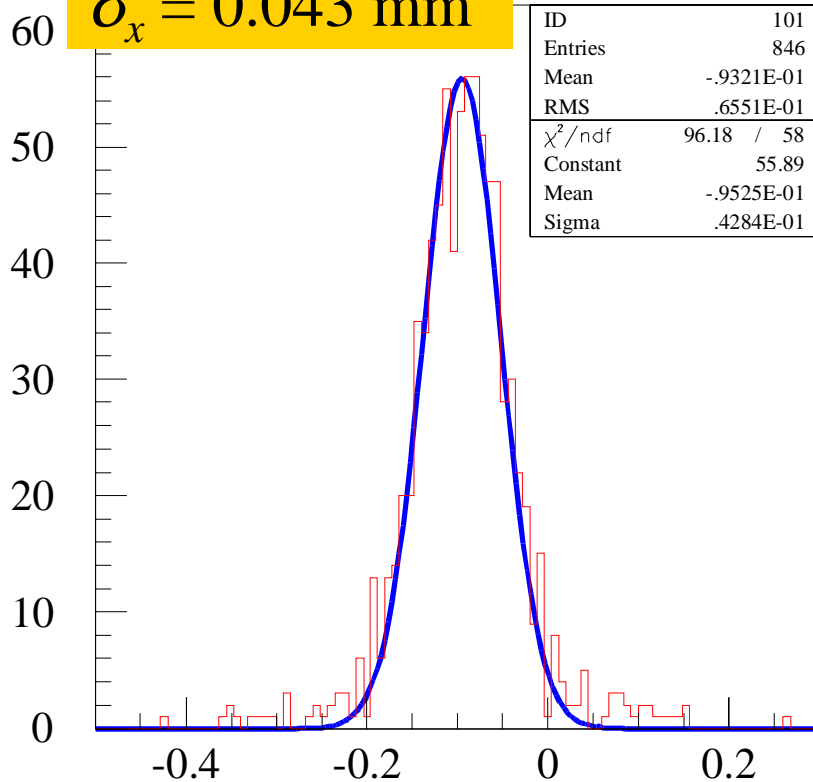


# Charge sharing result – Ar CO<sub>2</sub>

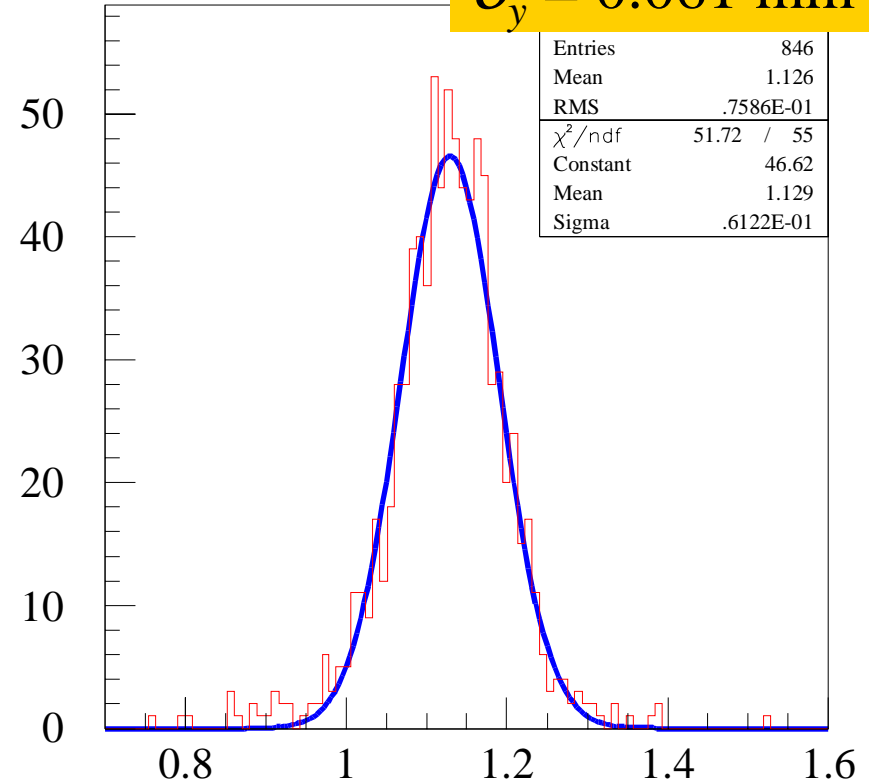
$$(x, y)_{\text{col}} = (-0.1, 1.143) \text{ mm}$$

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

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

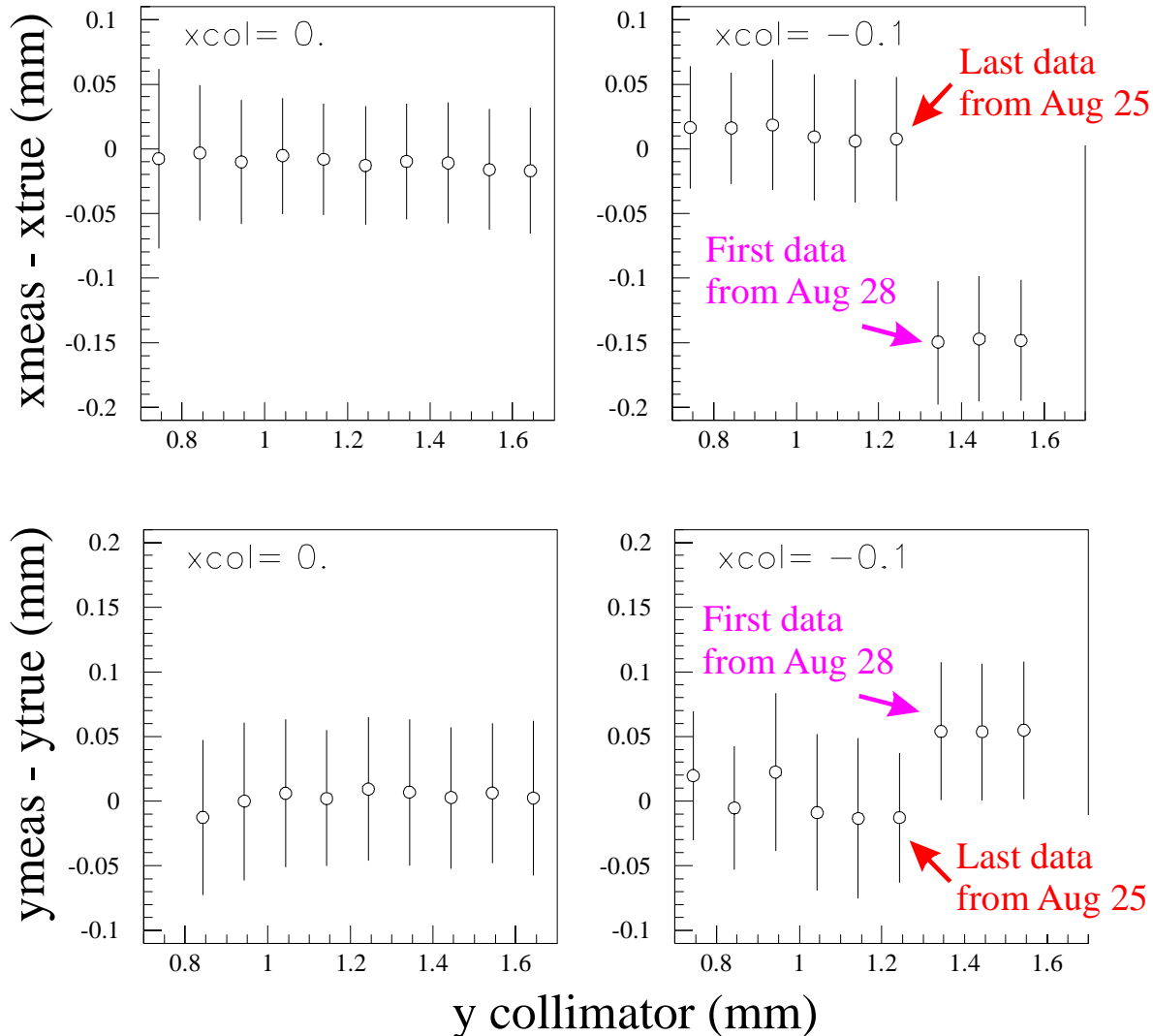


x coordinate



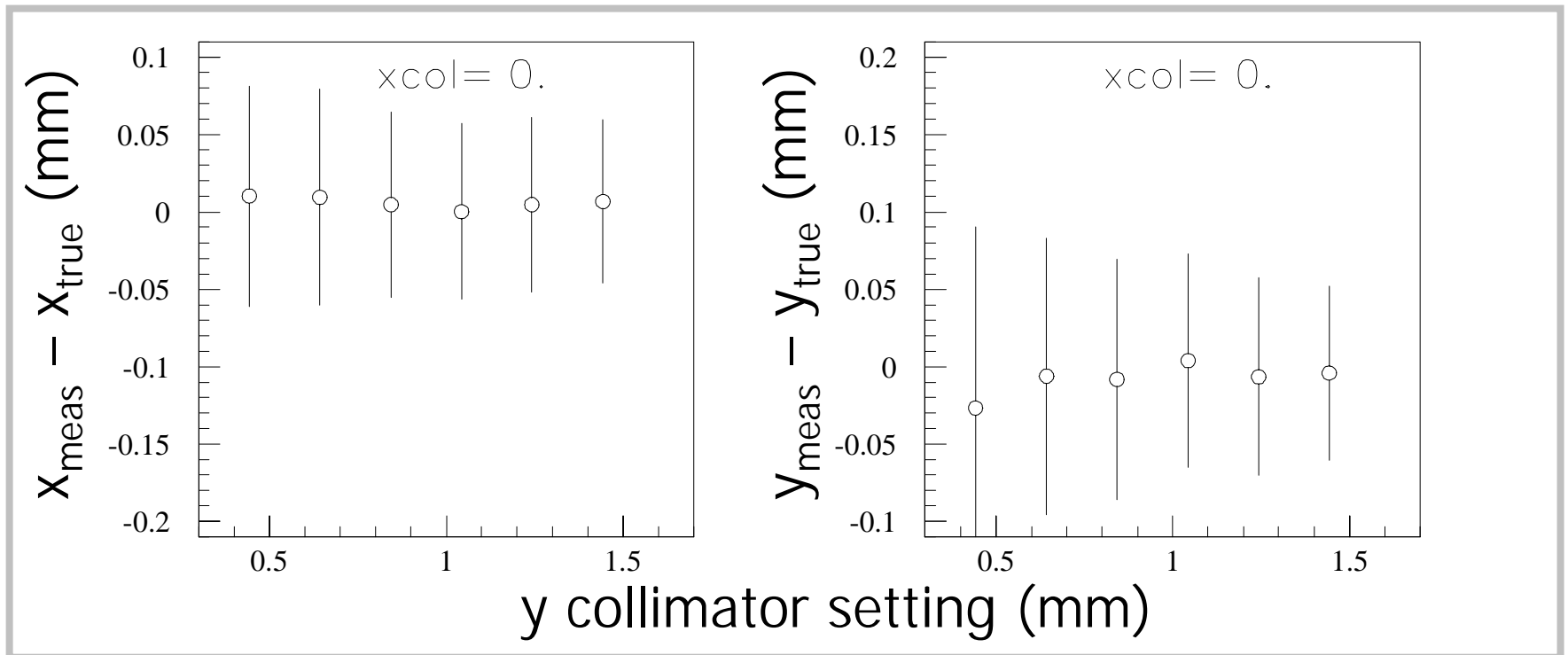
y coordinate

# Charge sharing result – Ar CO<sub>2</sub>



# Charge sharing result – P10

- standard deviation again 50-60  $\mu\text{m}$   $\rightarrow$  not diffusion limited

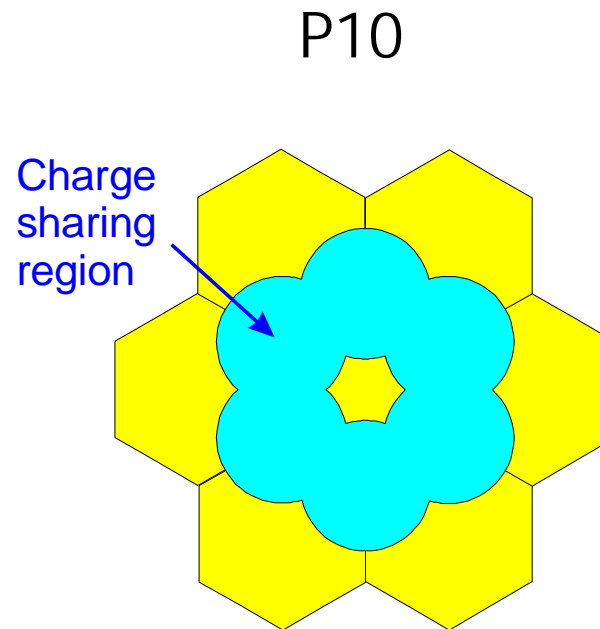
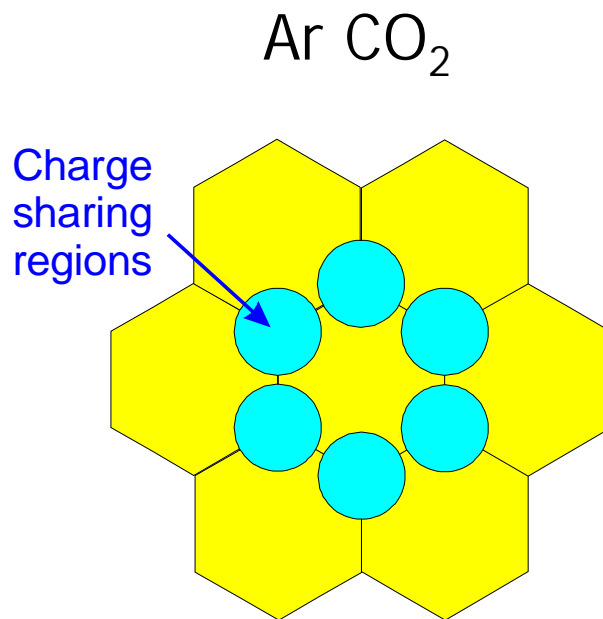


- increase in  $\sigma_y$  due to sensitivity of algorithm to cloud size



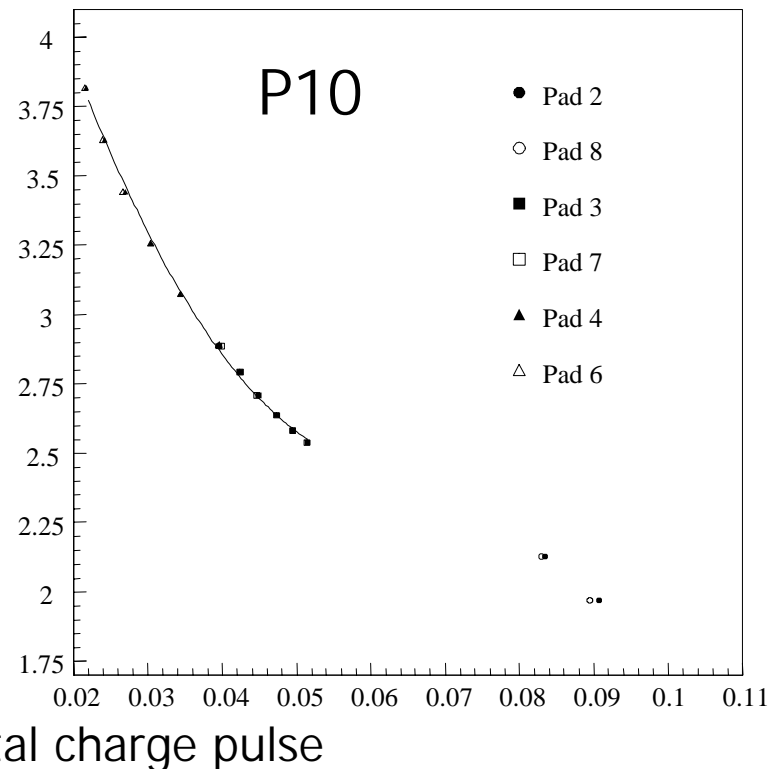
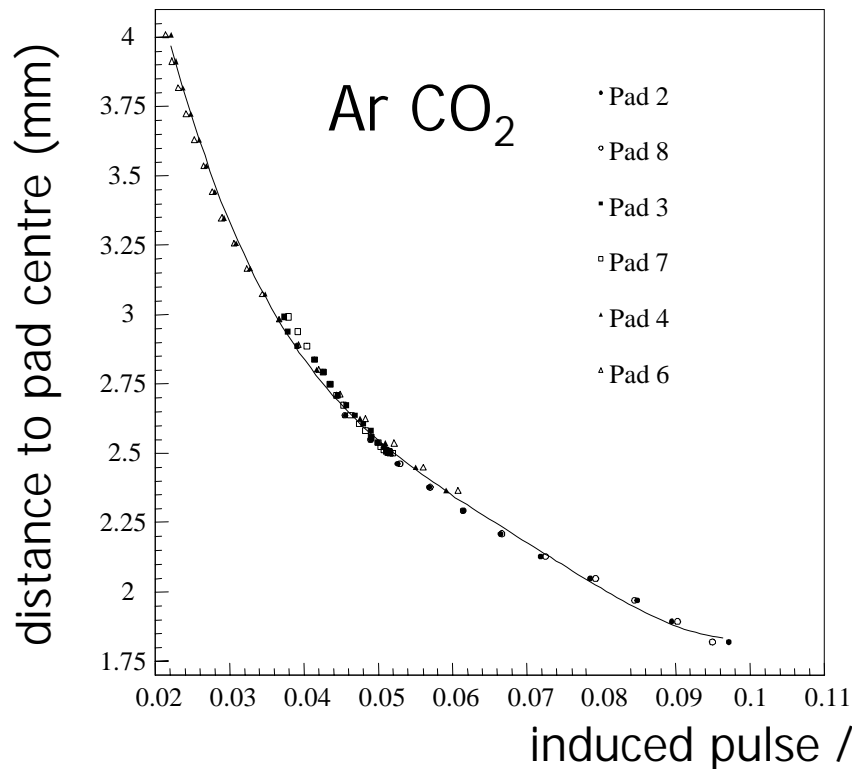
# Localization from charge sharing

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



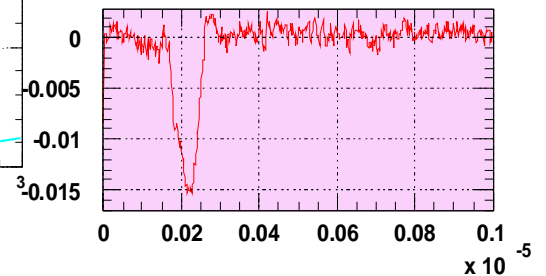
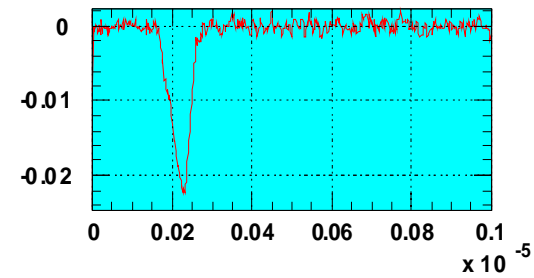
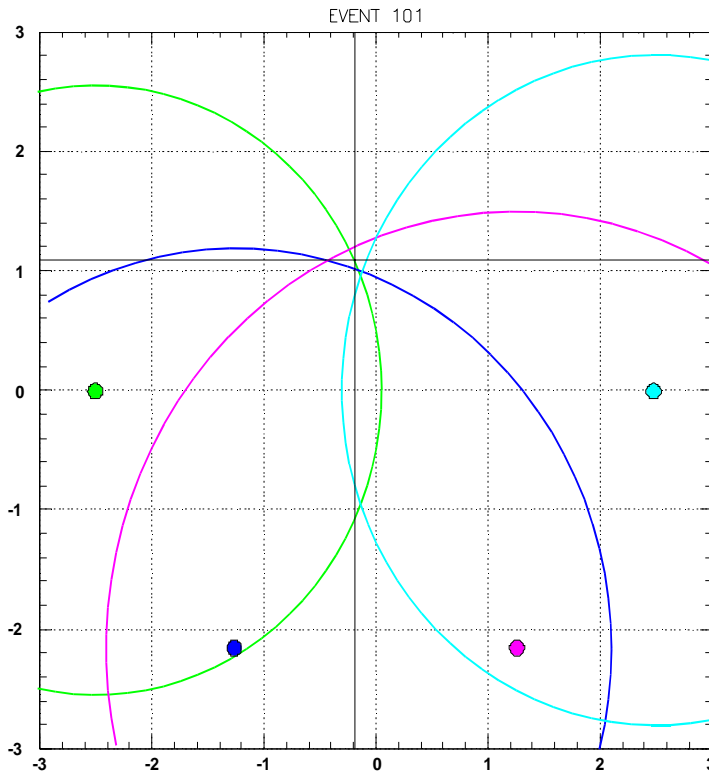
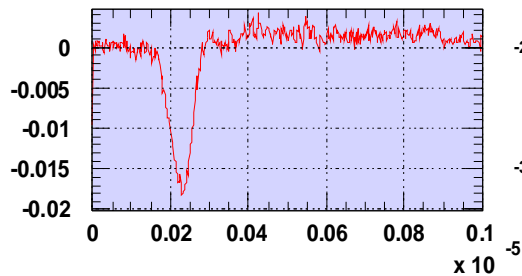
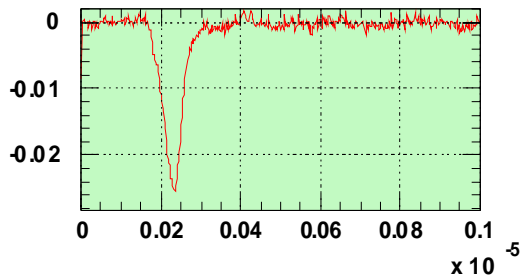
# Localization from induced pulses

- 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.

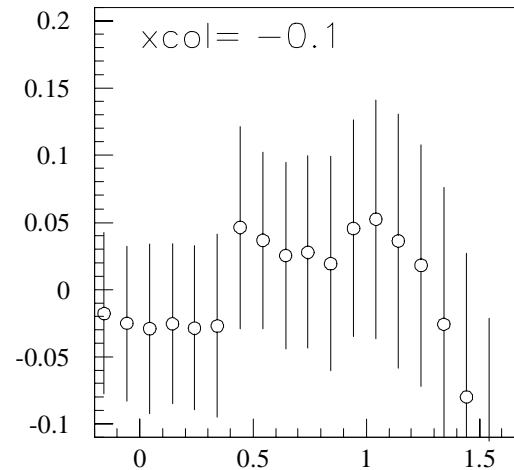
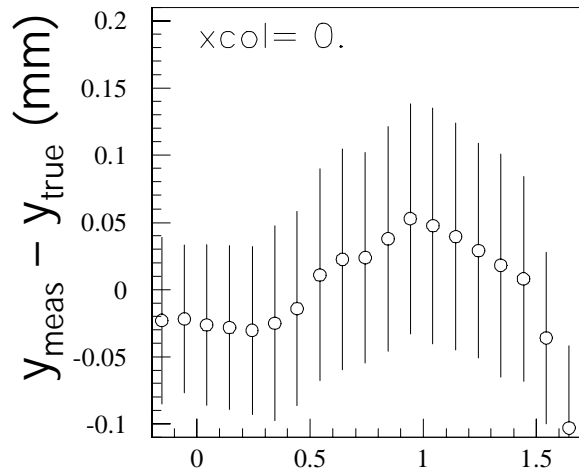
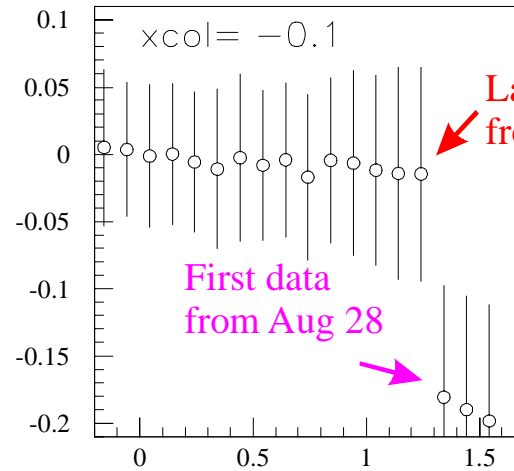
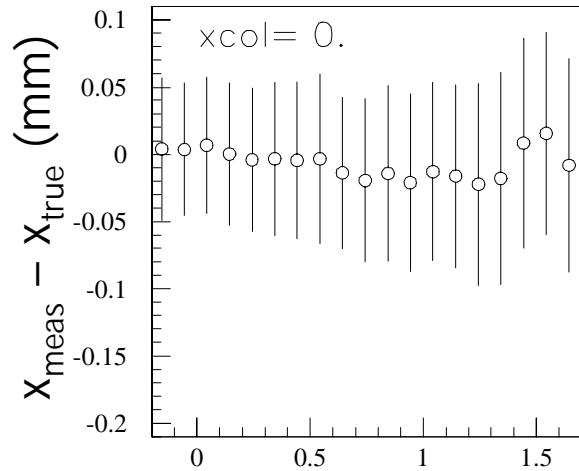


# Example

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



# Induction signal results – Ar CO<sub>2</sub>



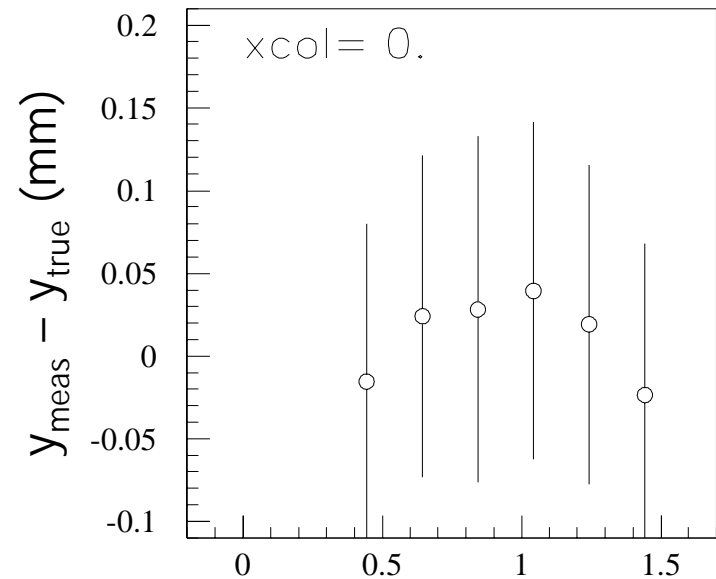
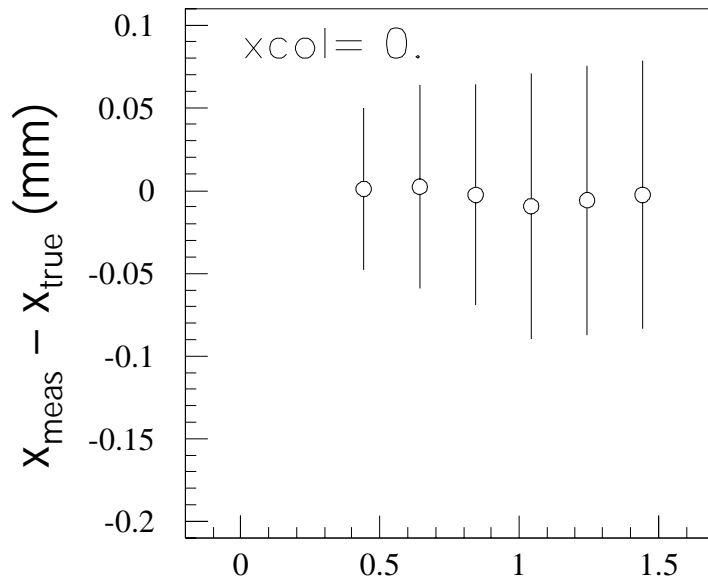
$y$  collimator position (mm)

$$\sigma_x \sim 50 - 80 \mu\text{m}$$

$$\sigma_y \sim 60 - 100 \mu\text{m}$$

- $\sigma$  smallest near centre of central pad
- biases likely due to cross-talk

# Induction signals results – P10



y collimator position (mm)

$$\sigma_x \sim 50 - 80 \mu\text{m}$$

$$\sigma_y \sim 90 - 100 \mu\text{m}$$



# Simulation work

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- Java simulation of GEM is in development
  - arbitrary GEM structure can be defined interactively
  - keeps track of electron distributions on pads
- Comparison with P10 data:
  - predicts average cloud width of 0.50 mm compared to observed value of 0.56 mm
  - confirms that diffusion contribution to measurement spread less than 25  $\mu\text{m}$
  - spread in measurements due primarily to x-ray spot size

# Simulation program

The screenshot displays a simulation program interface with several windows:

- Gas Gaps Drift Gap:** Configuration for drift gaps with parameters like Thickness (4.2 mm), Trans. diff. coeff. (648 cm<sup>2</sup>/Vsec), and Drift velocity (42 cm/sec).
- Gas Gaps Transfer Gap:** Configuration for transfer gaps with parameters like Thickness (2 mm), Trans. diff. coeff. (258 cm<sup>2</sup>/Vsec), and Drift velocity (23 cm/sec).
- Gas Gaps Induction Gap:** Configuration for induction gaps with parameters like Thickness (5.7 mm), Trans. diff. coeff. (289 cm<sup>2</sup>/Vsec), and Drift velocity (24 cm/sec).
- Pad Array Readout Pad:** Configuration for pad arrays with parameters like Pad Array layout (Grid), x and y positions, and Pad shape (Rectangle).
- Readout Pad:** Configuration for individual readout pads with parameters like Gain (100), Transparency (1), and Rectangular dimensions.
- Readout Pad Data:** A window showing charge distribution for 1,722,867 electrons, including Mean x (0.050 mm), Mean y (-0.033 mm), and Charge fractions in pads.
- Readout Pad Data:** A window showing calculator necessary for 100 events, including Mean x (0.897 mm), Mean y (-0.931 mm), and Charge fractions in pads.
- Readout Pad Data:** A window showing a histogram of charge fractions in pads, with a legend for Pad 113 (red), Pad 114 (green), Pad 115 (blue), Pad 116 (magenta), Pad 117 (yellow), and Pad 118 (black).



# Future plans

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- Further studies with hexagonal pads
- begin studies of track resolution
  - optimize GEM pad geometry for tracking
    - rectangles stretched along r direction (?)
  - small (15 cm) TPC under construction
  - FADC readout in development
- eventually a large scale TPC test in B field





# Summary

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- Interesting new results:
  - relatively large pads (2.5 mm diameter) can give excellent space point resolution (of order 50  $\mu\text{m}$ ) by using charge sharing
    - large pads are necessary for TPC application to keep the electronics channel count to a reasonable level
  - induction pulses (previously neglected) can provide similar resolution, but is more challenging
    - recovers lost resolution for clusters without charge sharing
- GEM readout for TPC looks promising!