Investigation of GEM space point resolution for a TPC tracker

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Carleton GEM group:

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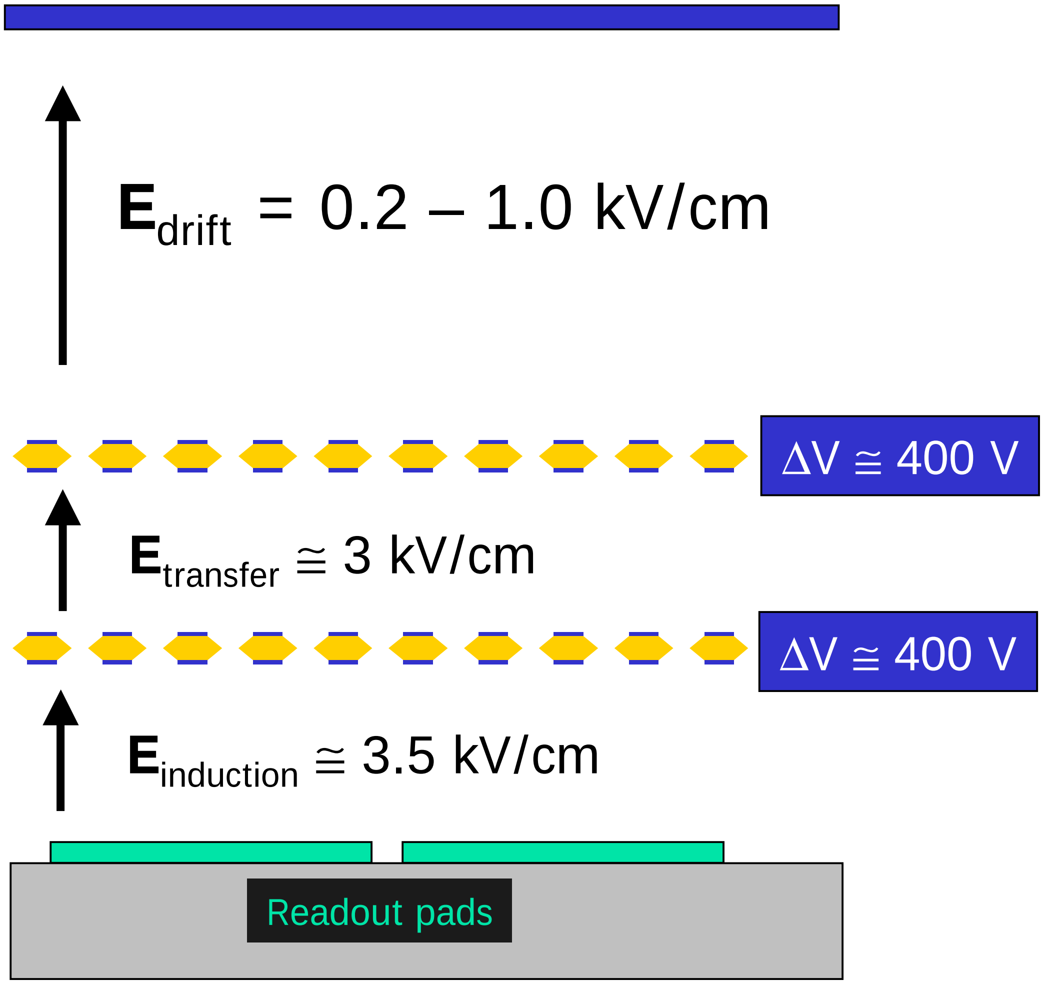
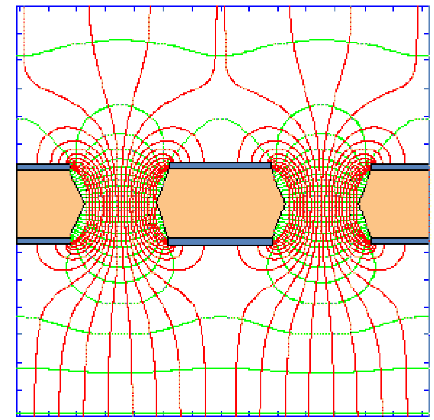
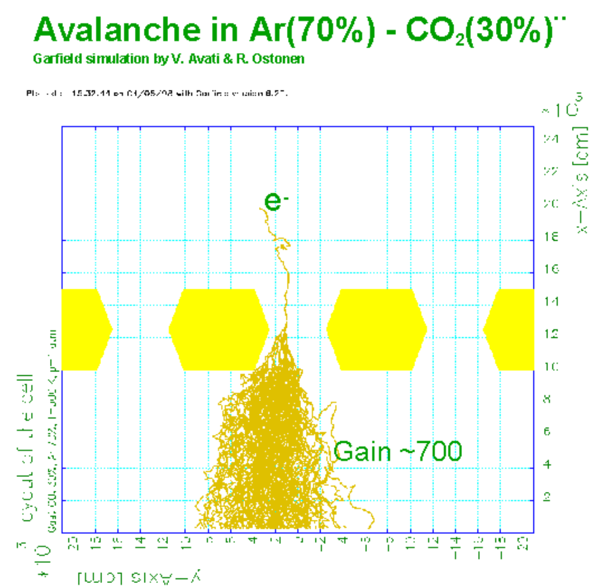
Outline

- What is a GEM?
- Why use GEMs in a TPC?
- Point resolution studies at Carleton
  - experimental setup – hexagonal pads
  - data and results – Ar CO_2 and P10
  - simulation work
- Future plans
- Summary

Gas Electron Multiplier (GEM)

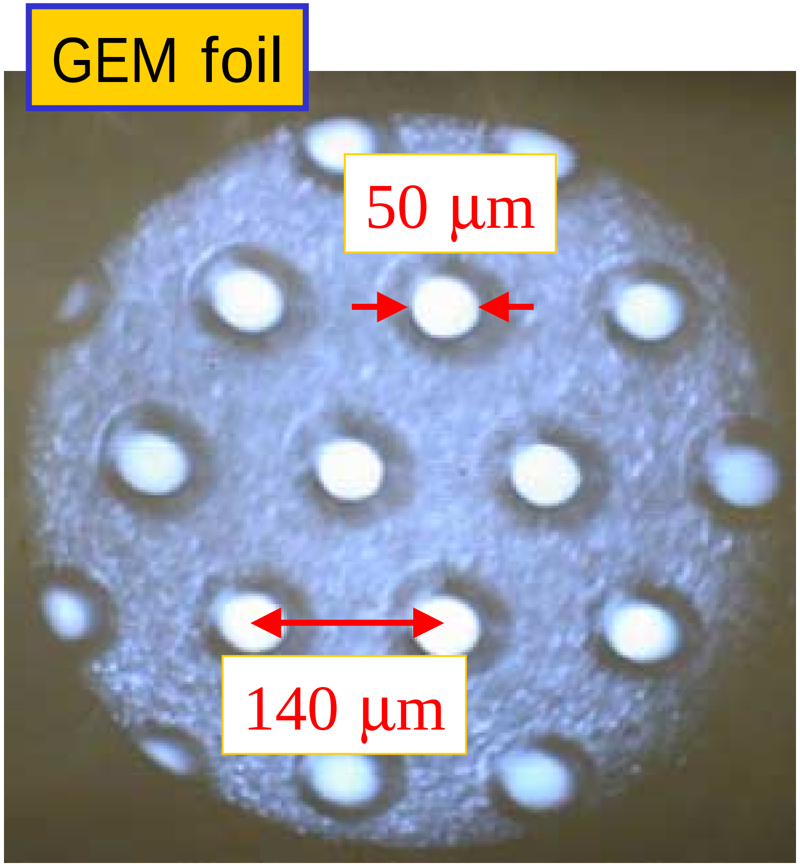


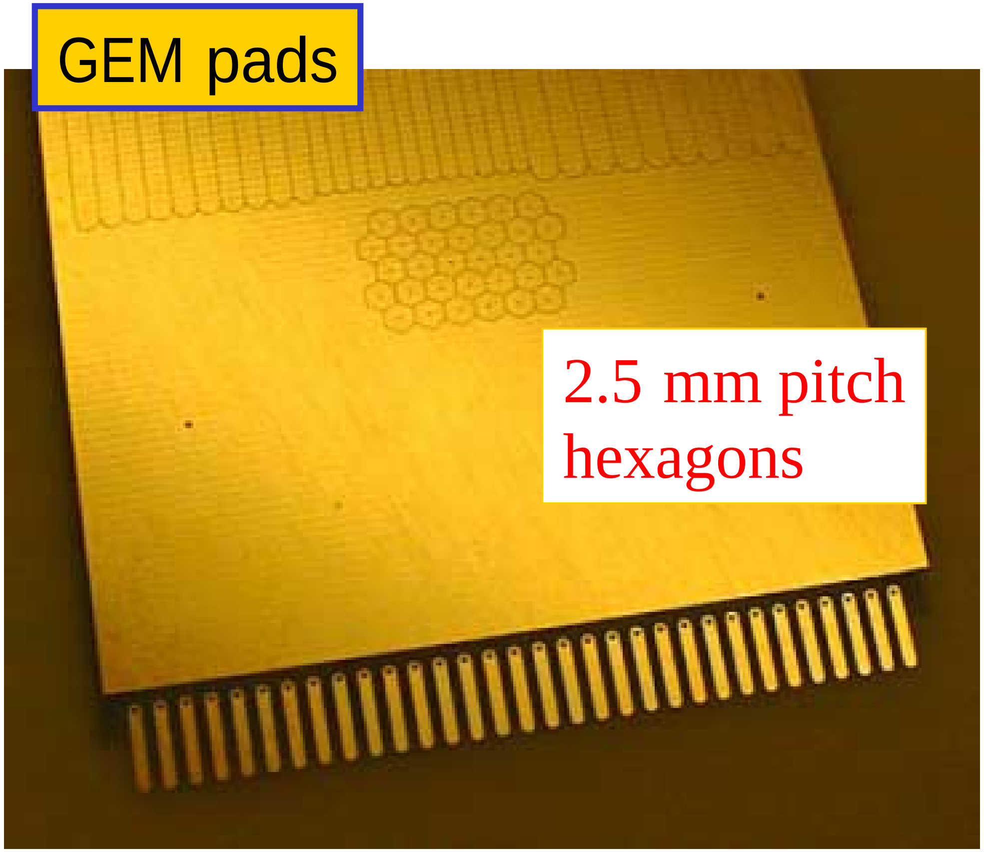




GEM foils and pads for this study

fabricated at the CERN PCB workshop

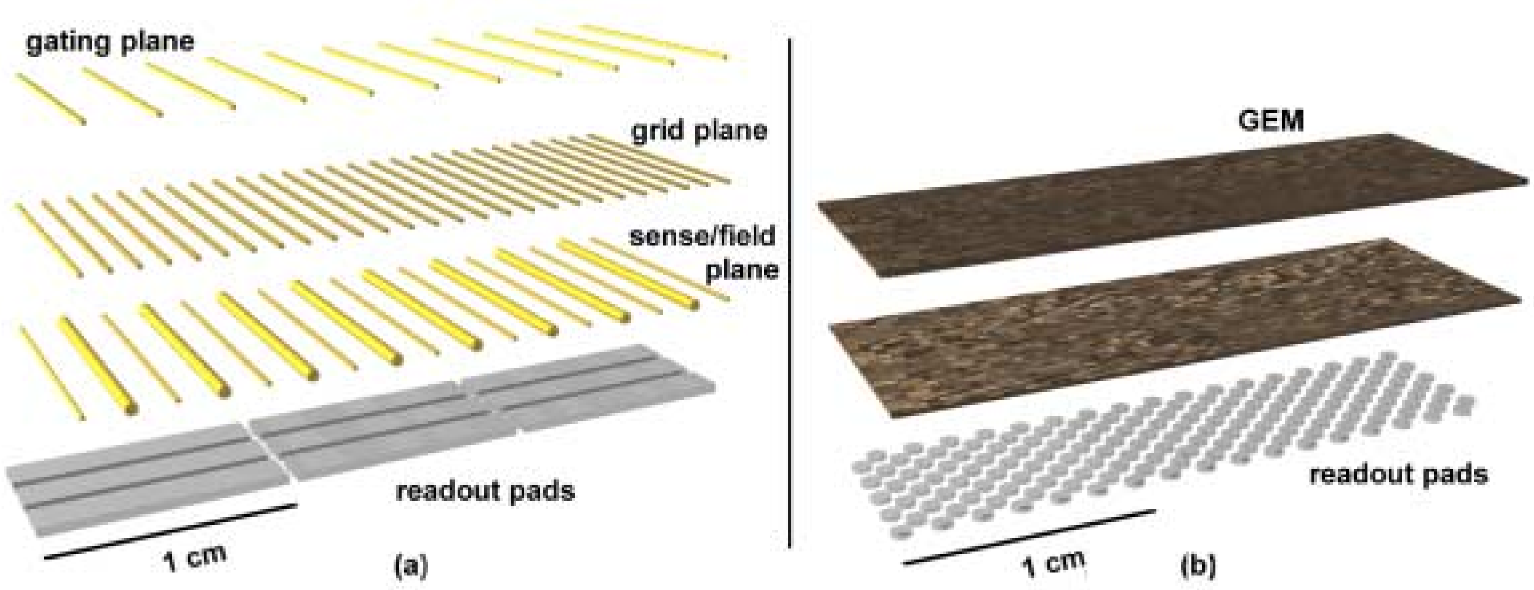




Using a GEM in a TPC

Conventional TPC readout

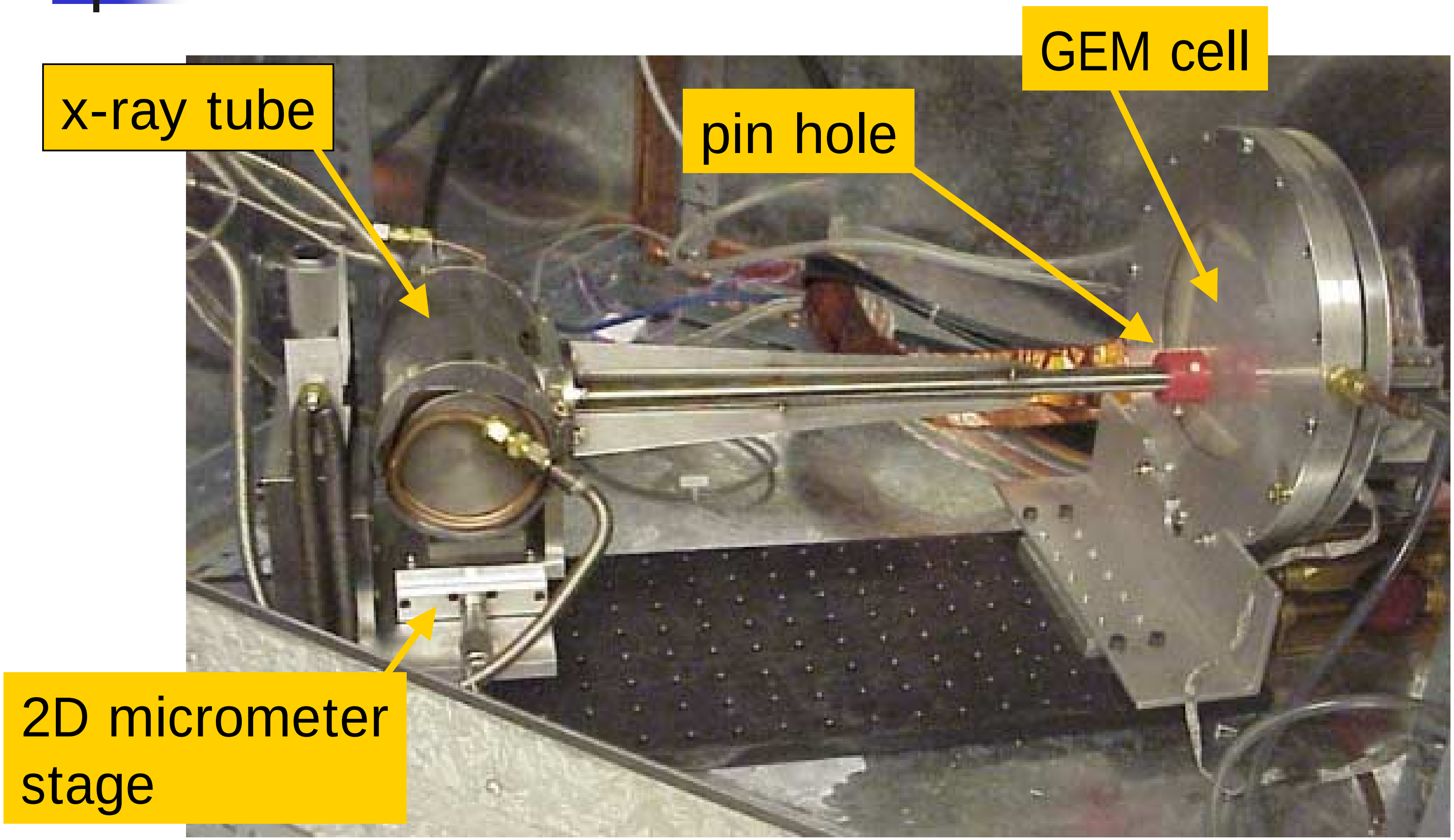
GEM TPC readout



Potential advantages for GEM readout

- Improved space point resolution
  - **E**×**B** and track angle systematics suppressed
- Improved two particle separation power
  - r -ϕ : 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

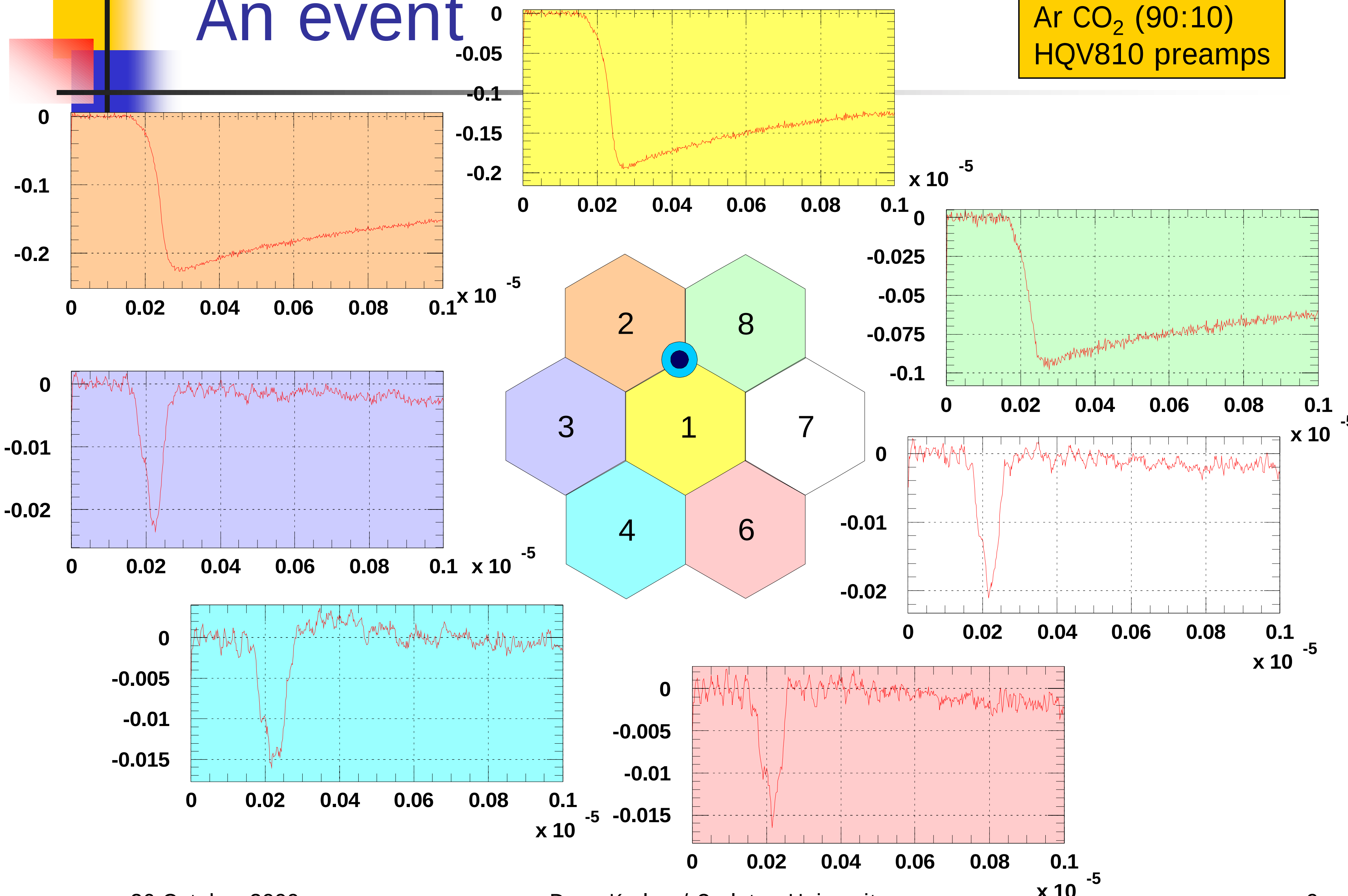


Details

- x-ray mean energy: 4.5 keV
- pinhole diameter: 50 μm
- Gas: Ar CO_2 (~90:10) / P10 : Ar CH_4 (90:10)
- pre-amps:
  - fast Lecroy HQV 810 with Ar CO_2
  - 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

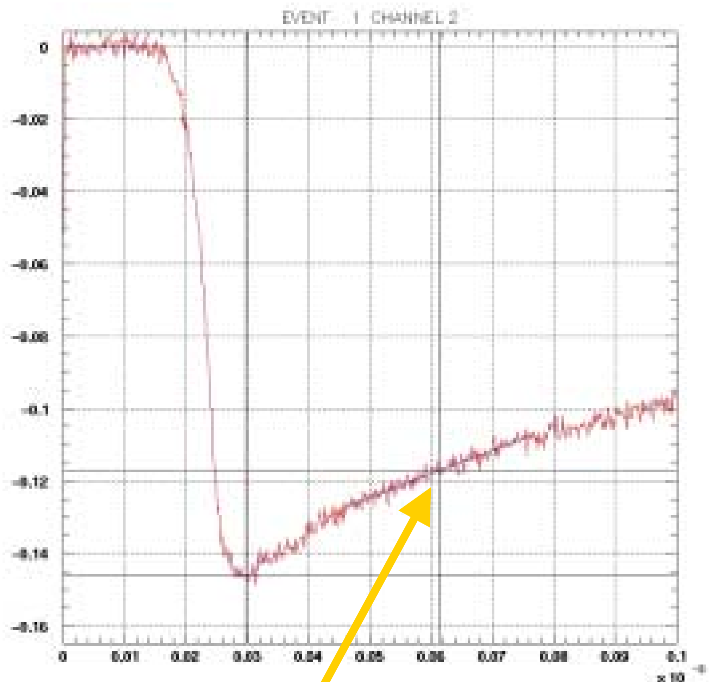
Ar CO_2 (90:10)
HQV810 preamps

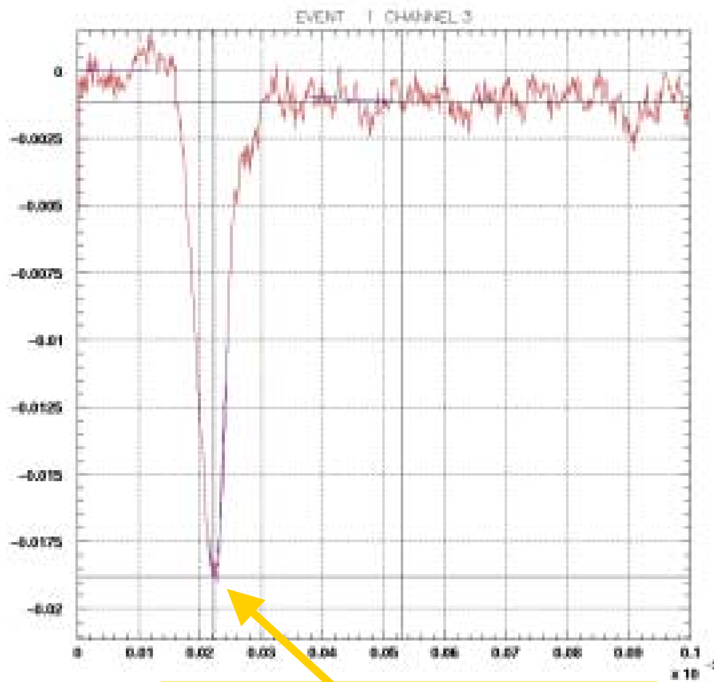


Analysis

Direct pulse

Induced pulse

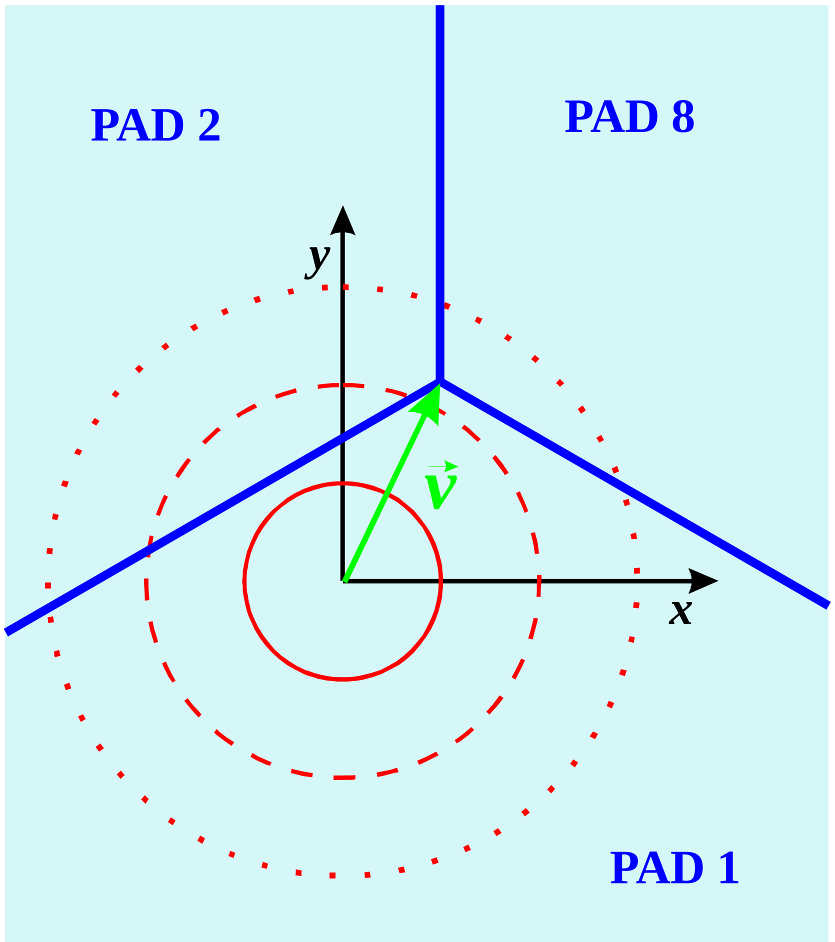




direct charge deduced from tail

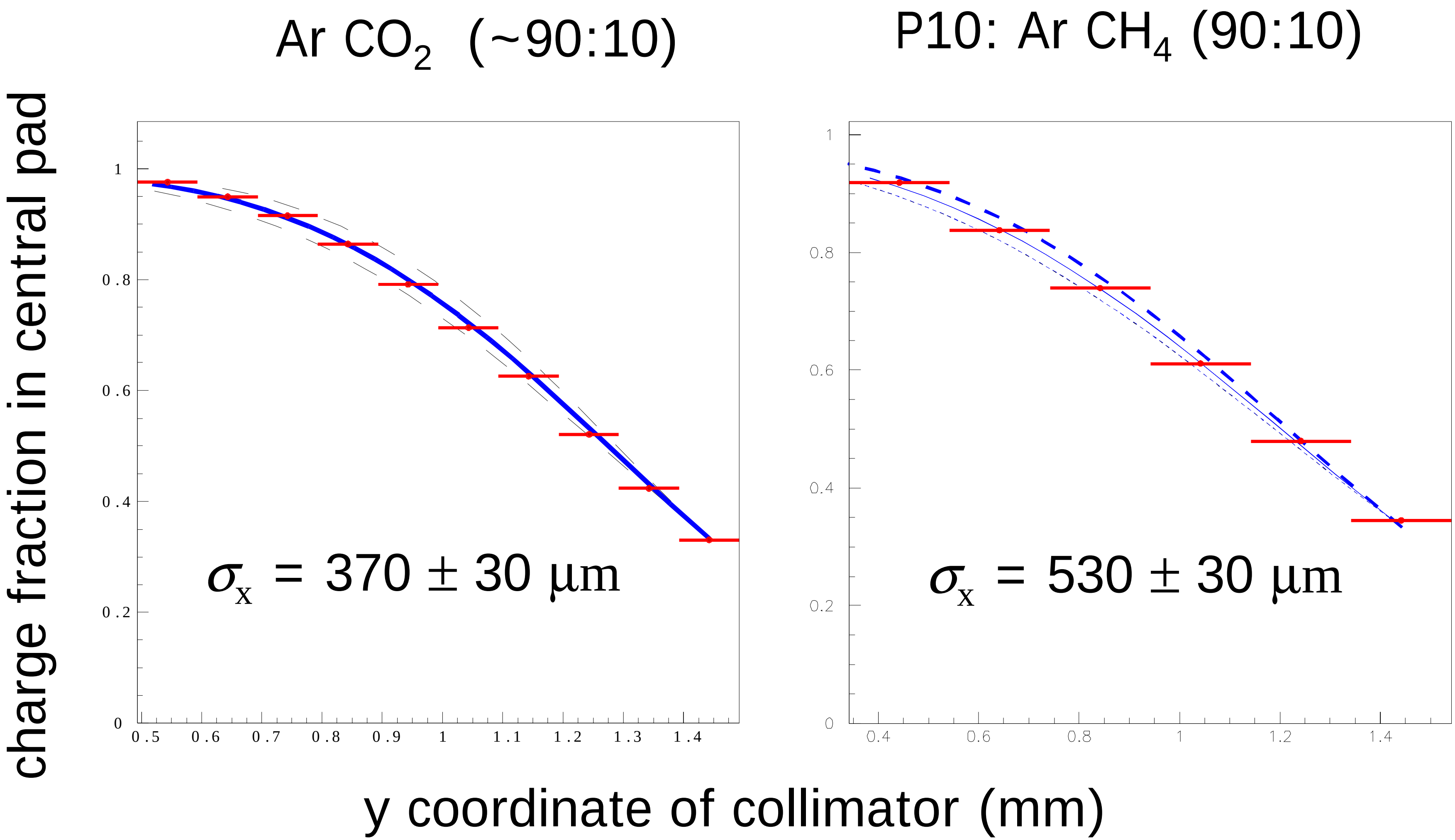
peak value used

Localization using charge sharing



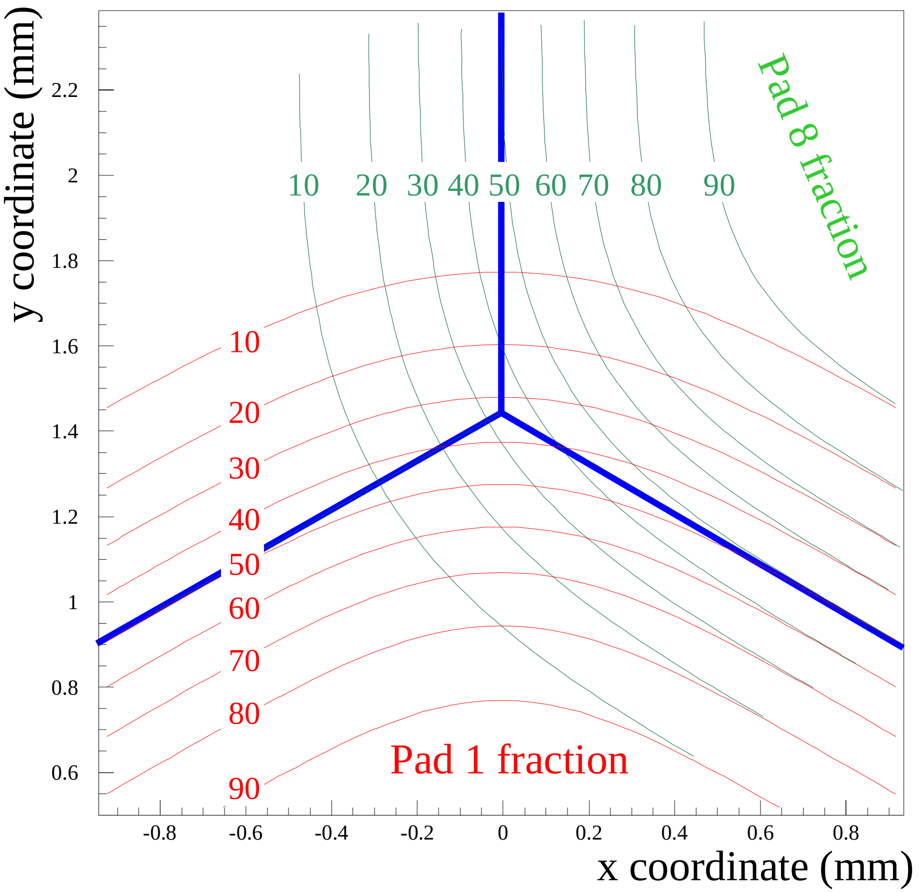
- assume electron cloud is 2D Gaussian
- charge fraction is given by integral over pad area
- 1 to 1 mapping between ***v*** and (f_1,f_8)
- One free parameter – cloud size

Determining cloud size



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_2

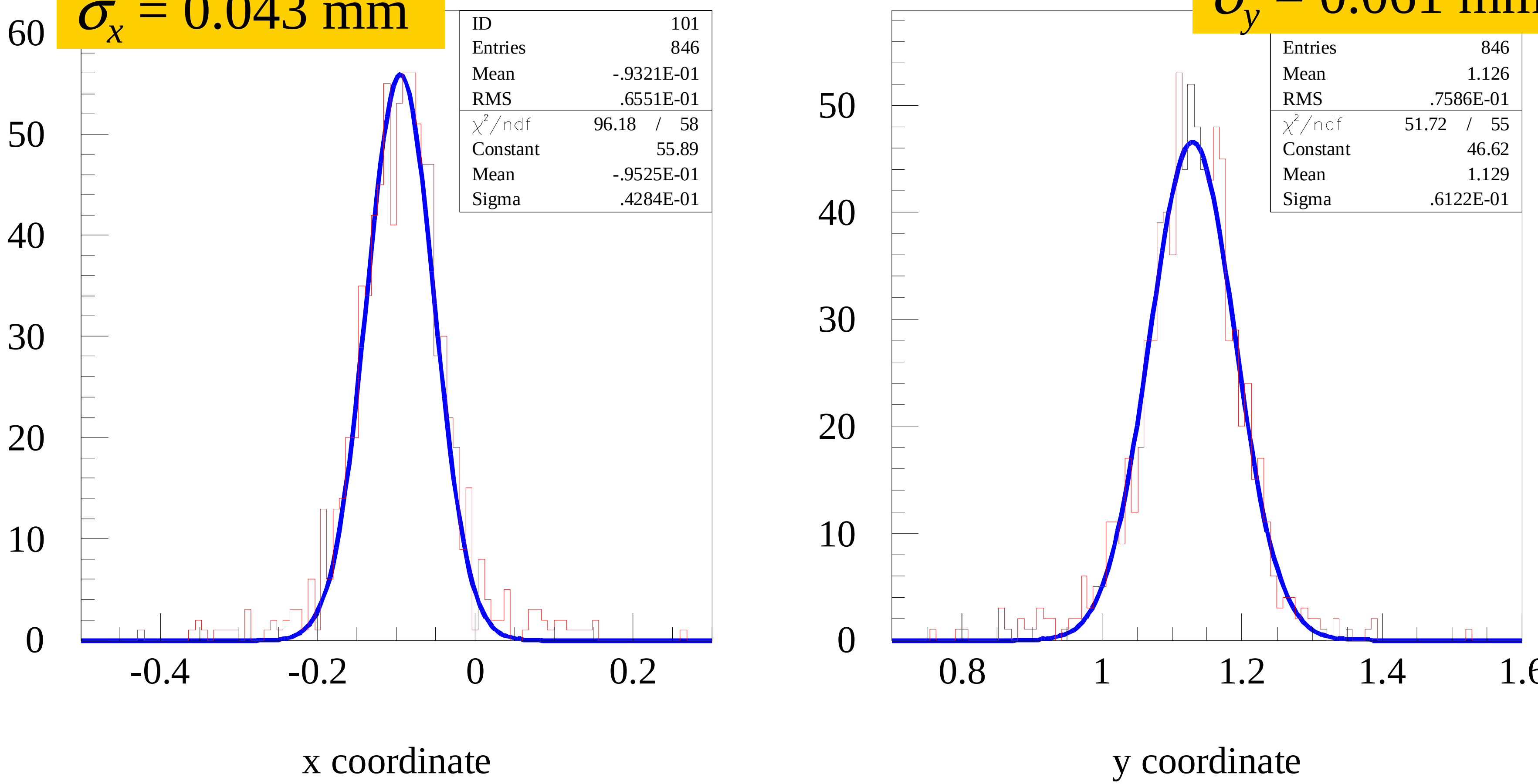
$(x,y)_{col}$ = (-0.1,1.143) mm

$\bar{x}$ = – 0.095 mm

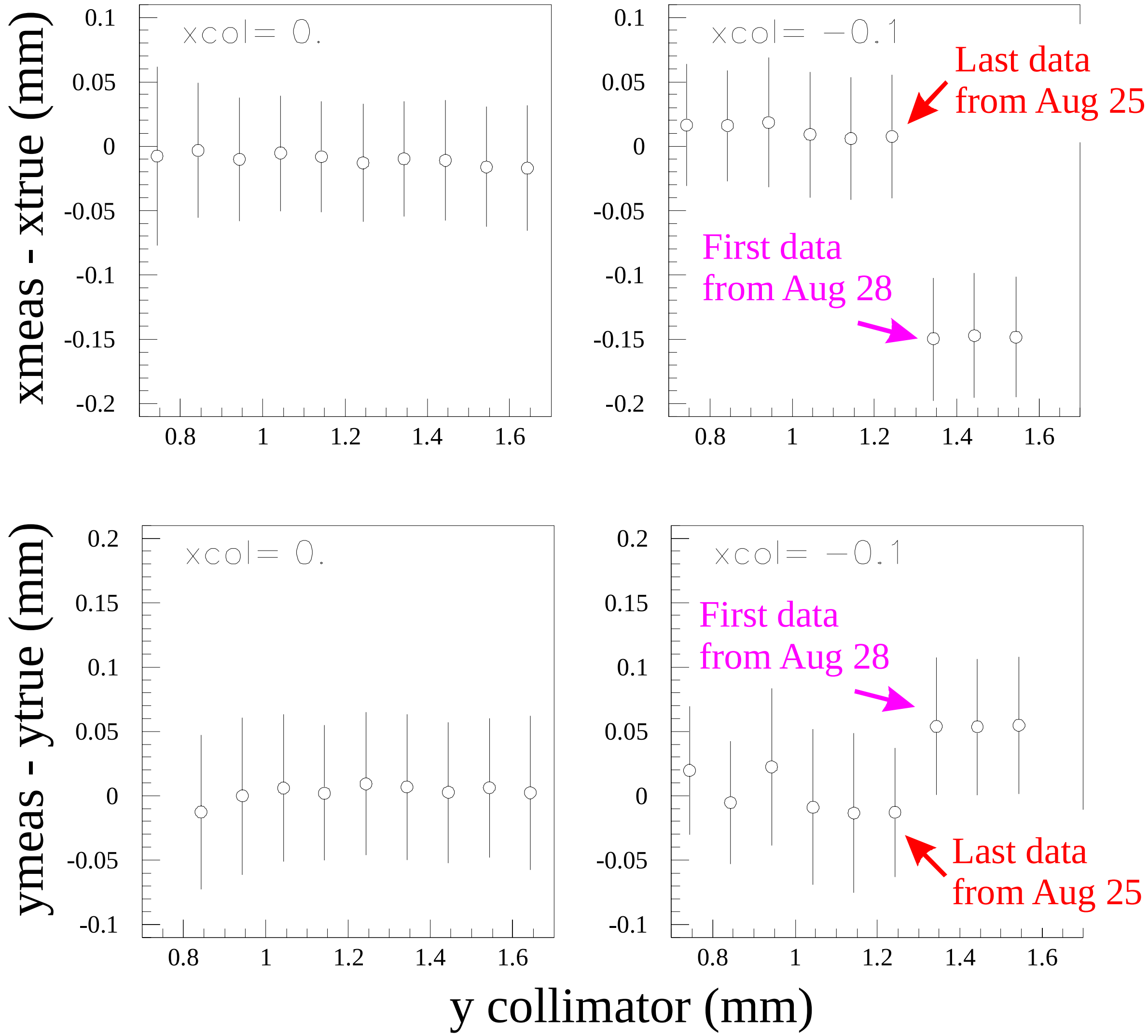
σ_x = 0.043 mm

$\bar{y}$ = 1.129 mm

σ_y = 0.061 mm

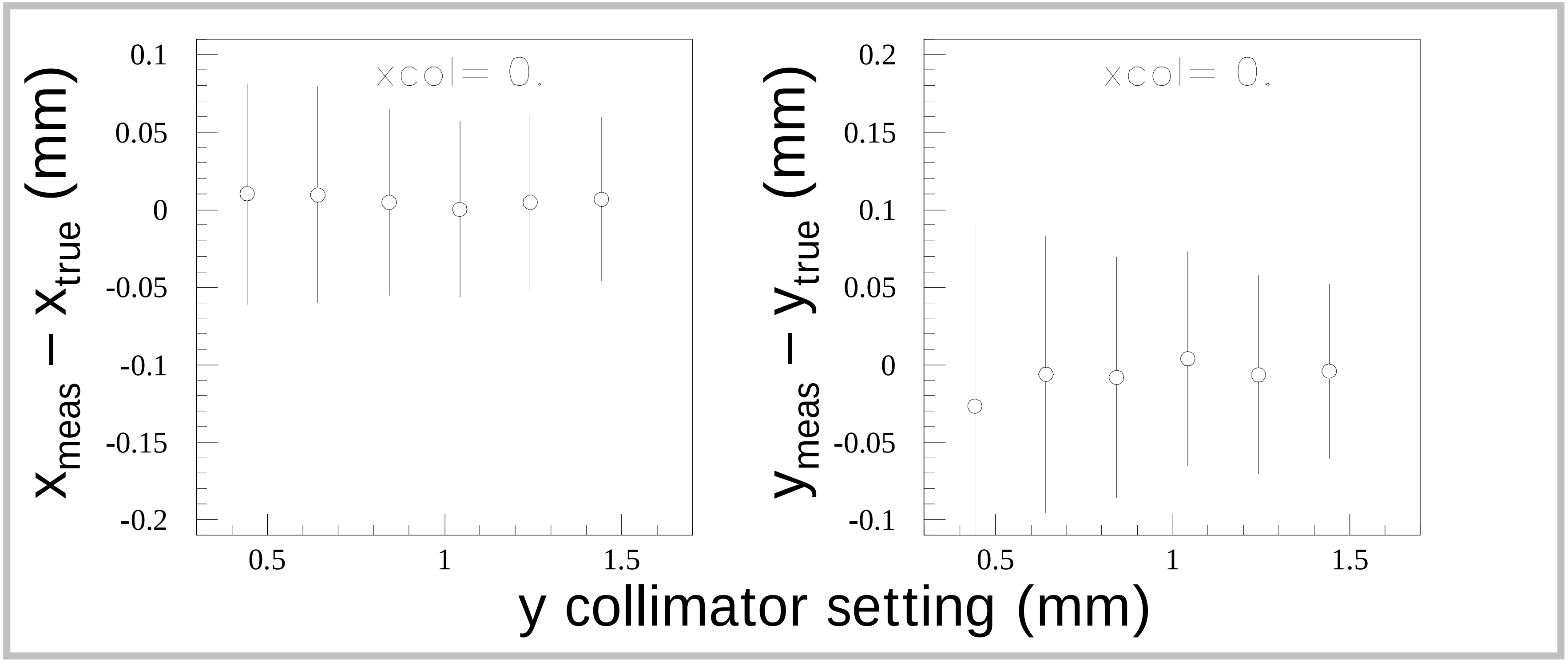


Charge sharing result – Ar CO_2



Charge sharing result – P10

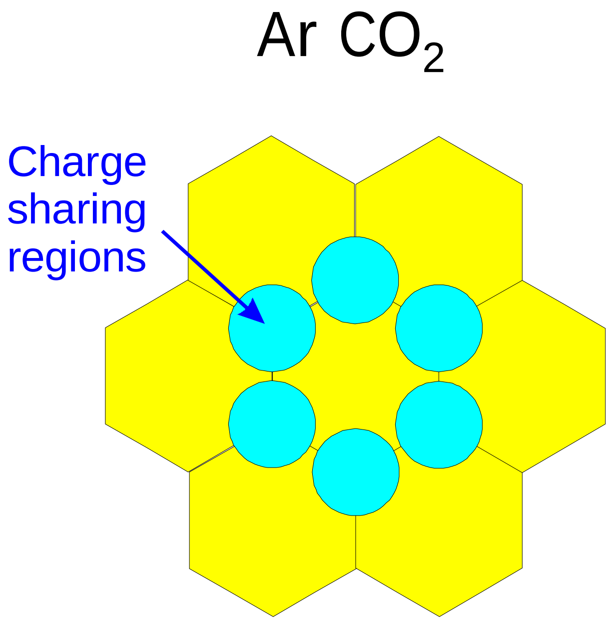
- standard deviation again 50-60 μm → not diffusion limited

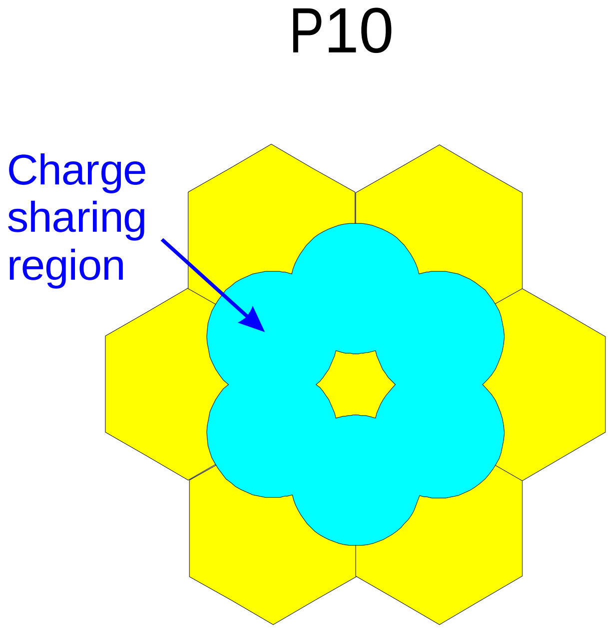


- increase in σ_y due to sensitivity of algorithm to cloud size

Localization from charge sharing

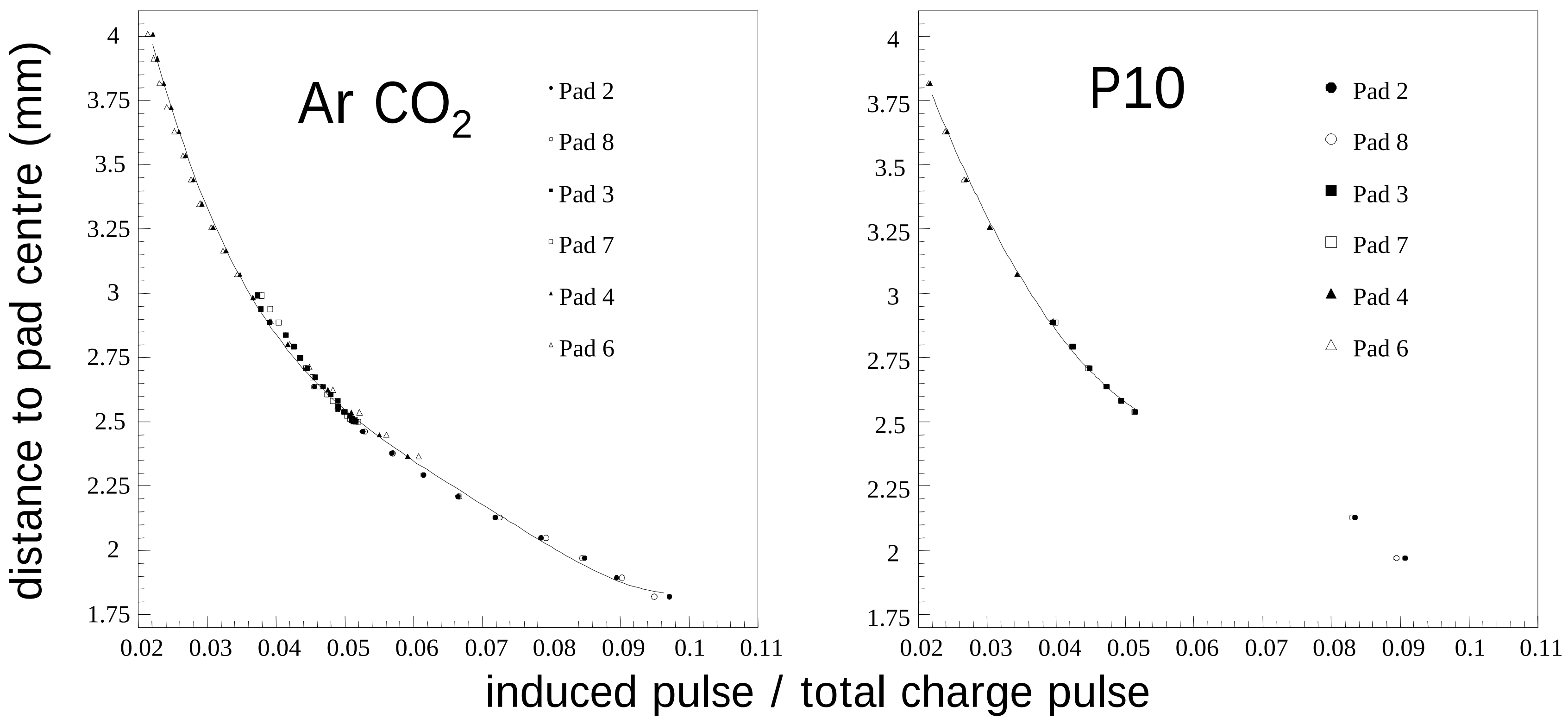
- Method only works in regions where significant charge is deposited on 3 pads





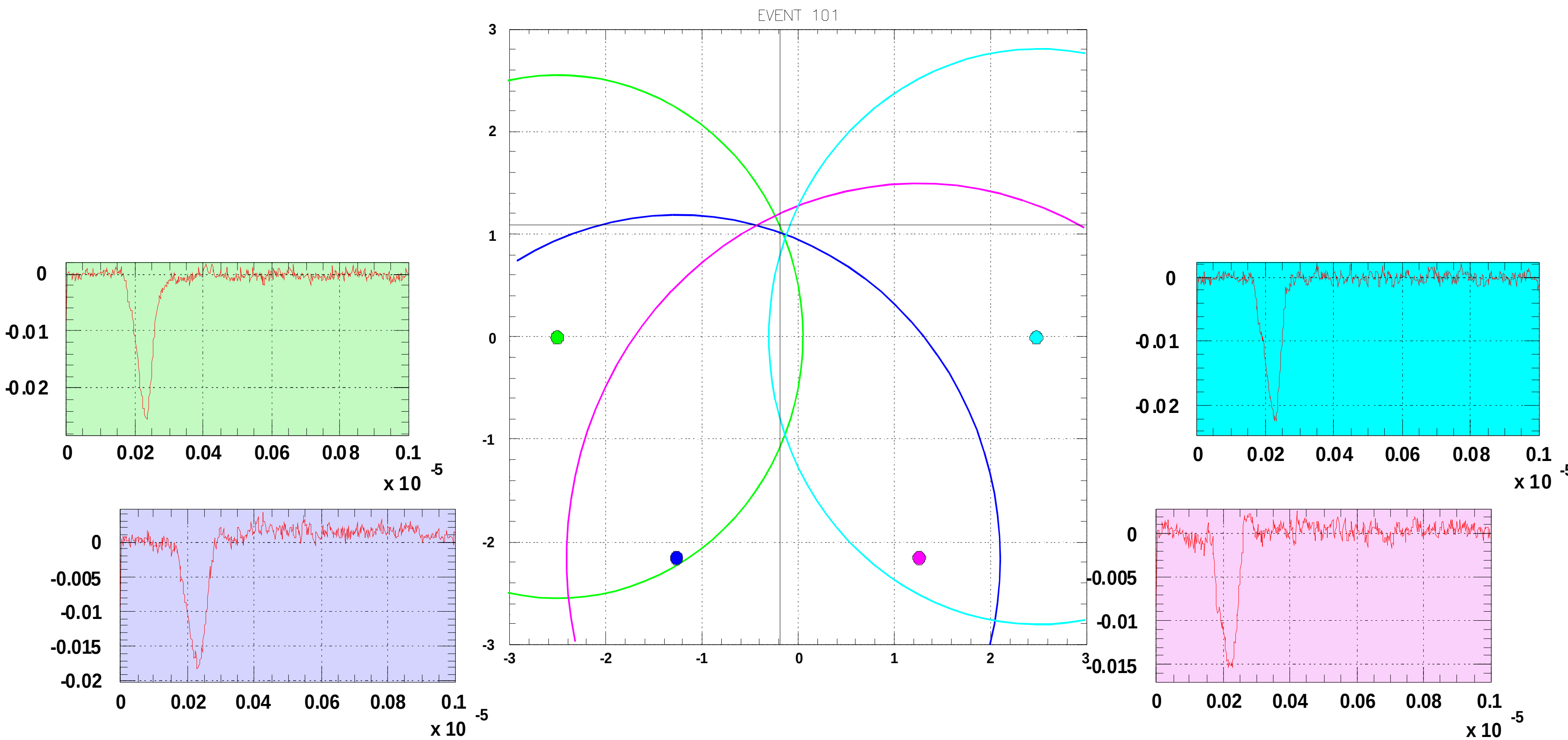
Localization from induced pulses

- 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.

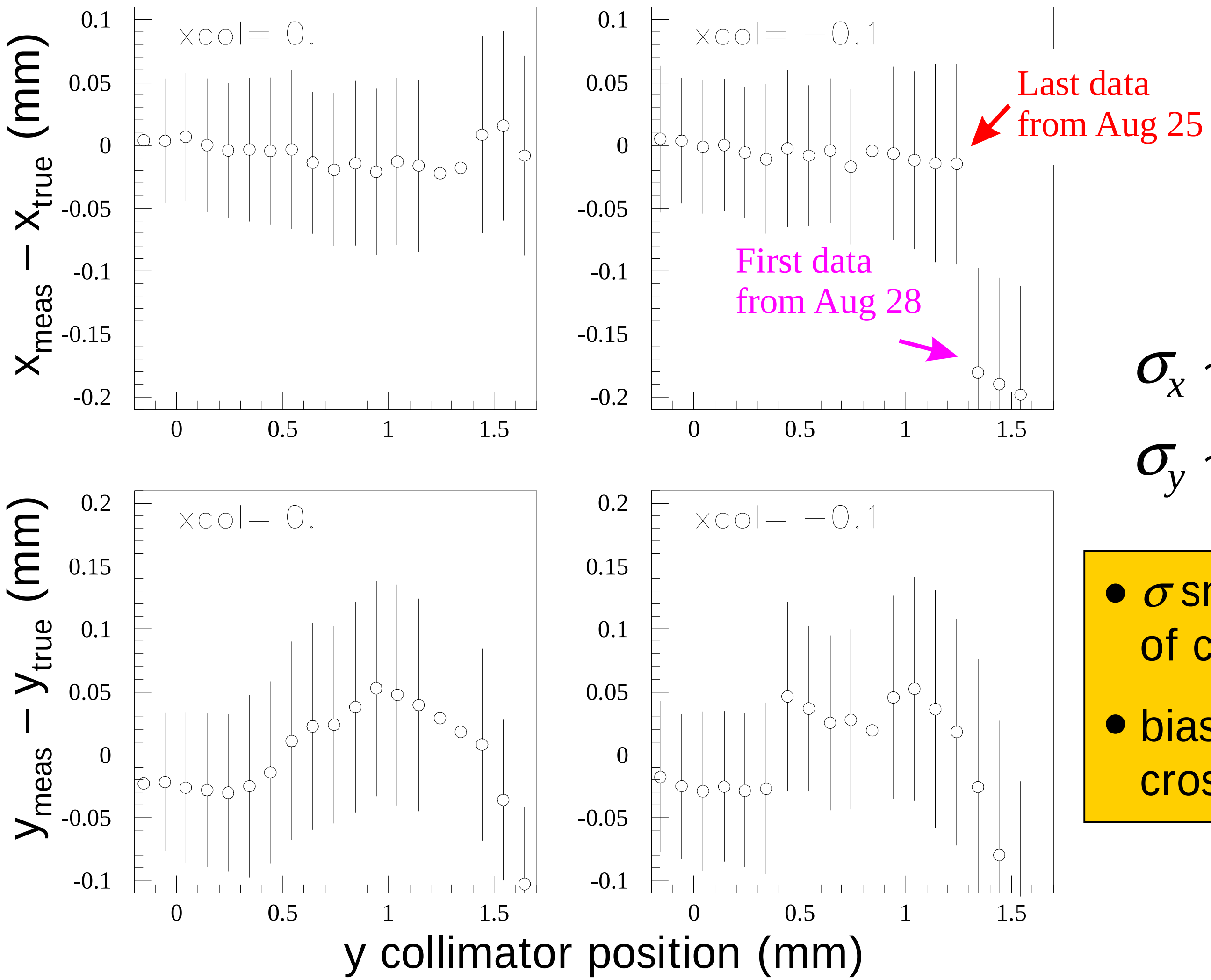


Example

- collimator location: (-0.1,1.143)



Induction signal results – Ar CO_2

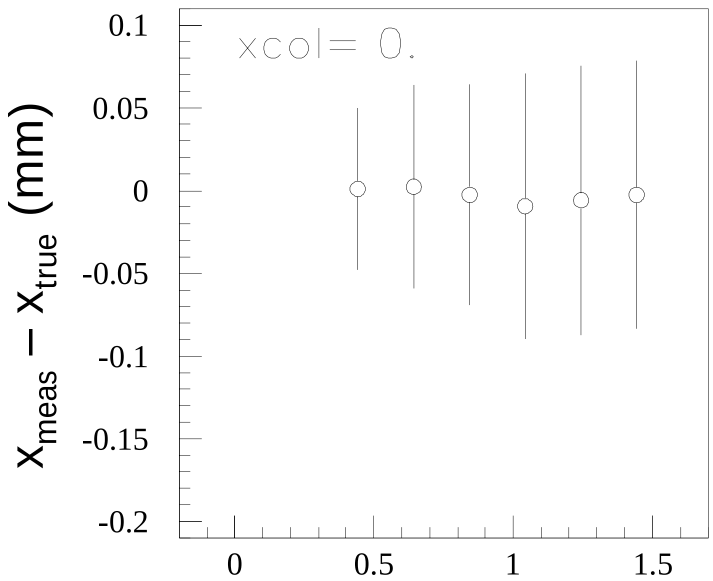


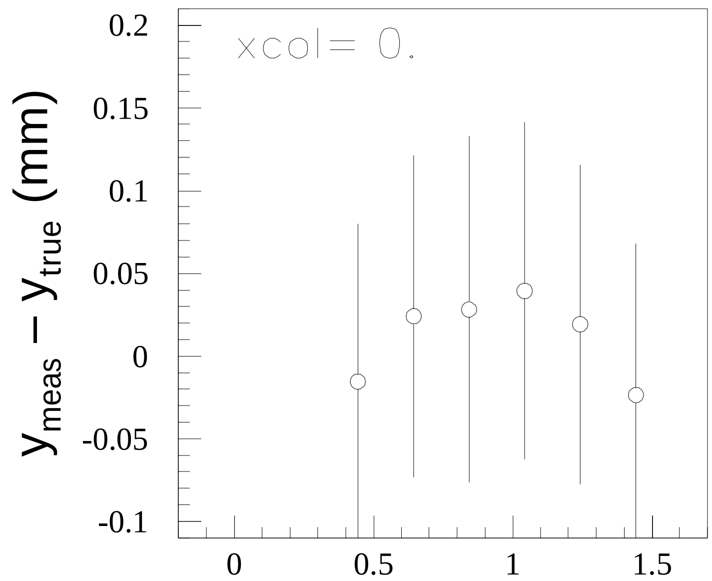
$\sigma_x \sim 50 - 80\ \mu m$

$\sigma_y \sim 60 - 100\ \mu m$

- σ smallest near centre of central pad
- biases likely due to cross-talk

Induction signals results – P10





y collimator position (mm)

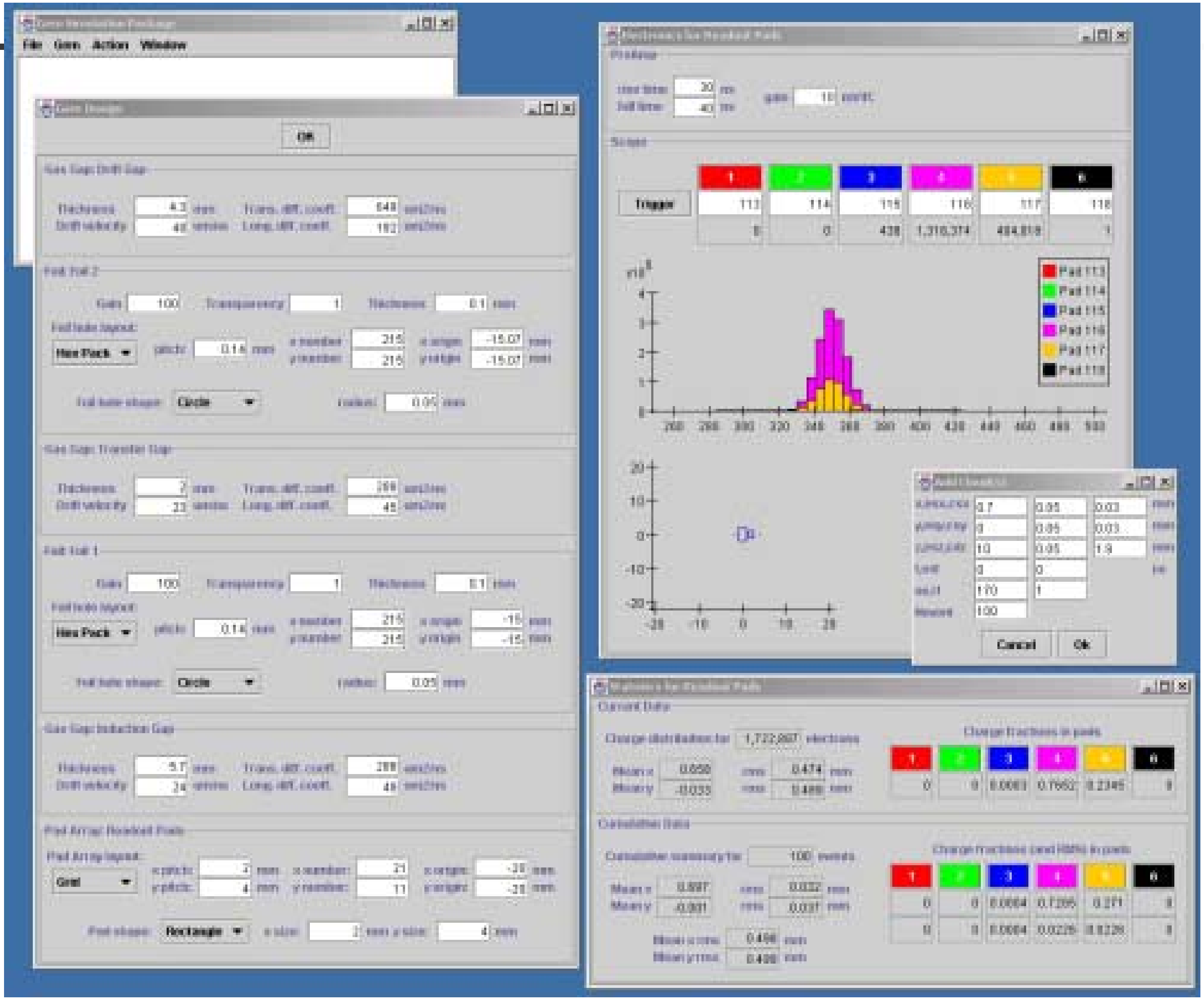
$\sigma_x \sim 50 - 80\ \mu\text{m}$

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

Simulation work

- 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 μm
  - spread in measurements due primarily to x-ray spot size

Simulation program



Future plans

- 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

- Interesting new results:
  - relatively large pads (2.5 mm diameter) can give excellent space point resolution (of order 50 μm) 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!