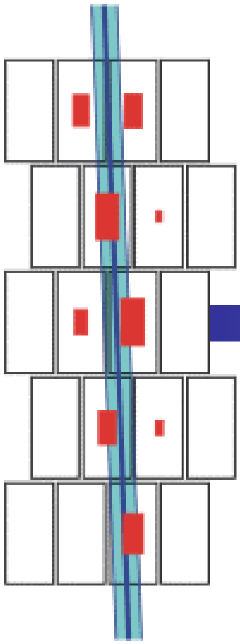


Cosmic tracking results from the Carleton GEM TPC

LC TPC meeting
CERN, December 12, 2001

Dean Karlen
Carleton University

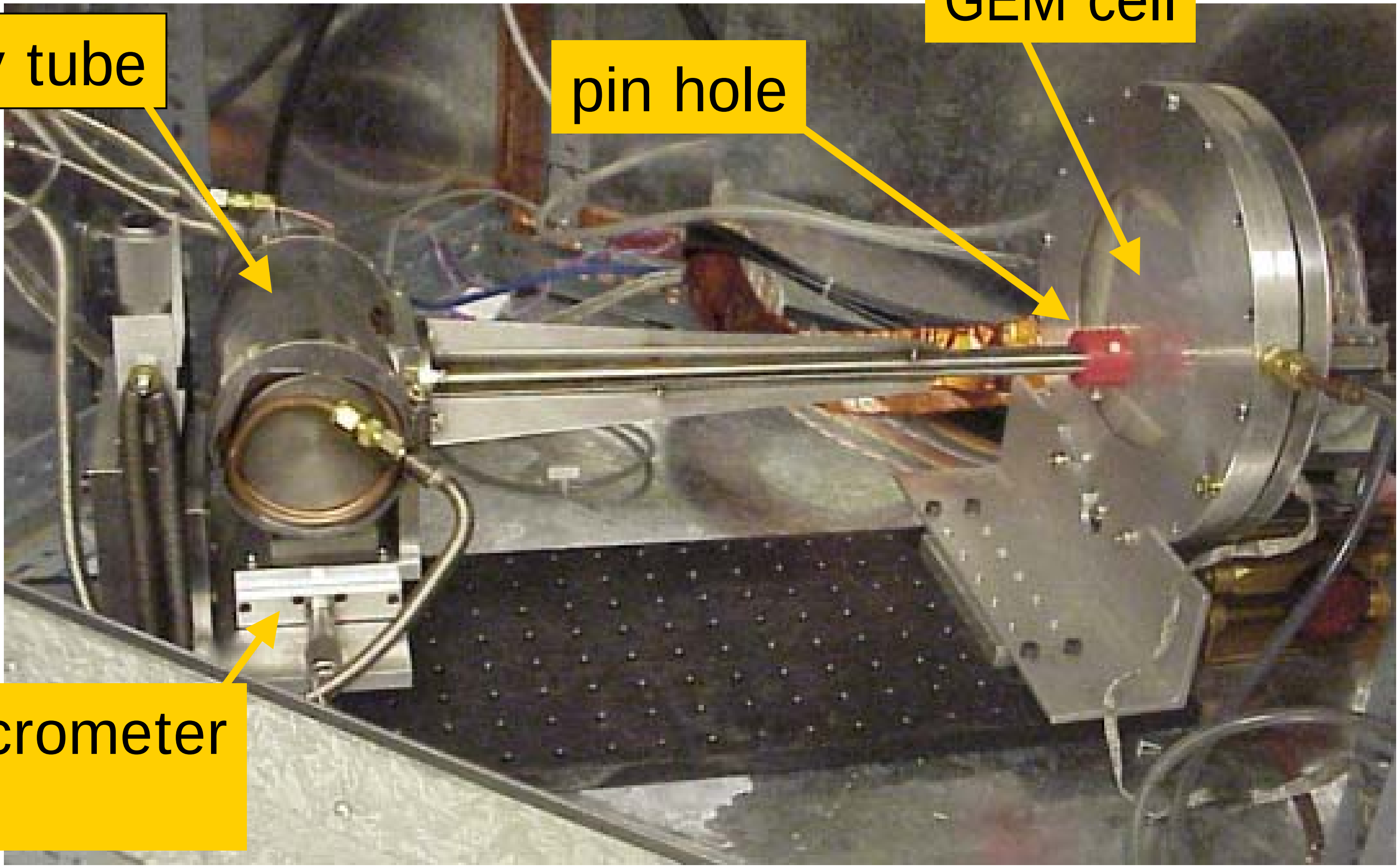
Carleton GEM/TPC group: Bob Carnegie, Jacques Dubeau, Madhu Dixit, D.K., Hans Mes
+students: Thorston Lux, Roberta Kelly

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

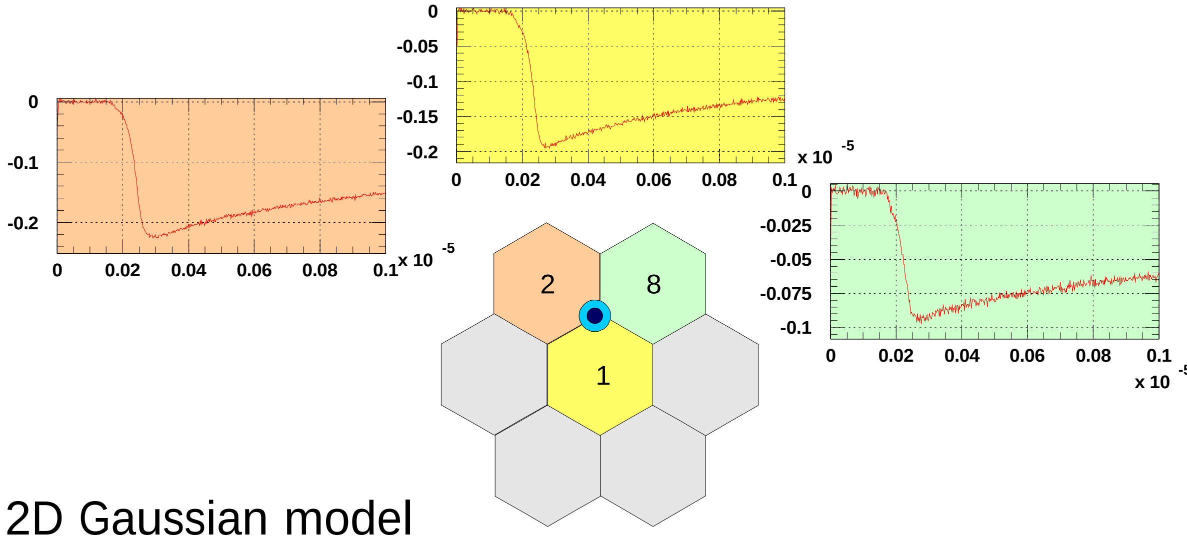
Overview of Carleton TPC R&D

- Focus on readout schemes and resolution studies
  - compared “charge-sharing” and induced signals resolutions
  - simulations of induced signals
  - new ideas to enhance induced signals
- This talk: only “charge-sharing” results presented:
  - space point resolution (x-rays) – brief review
  - tracking resolution (cosmics) – new!

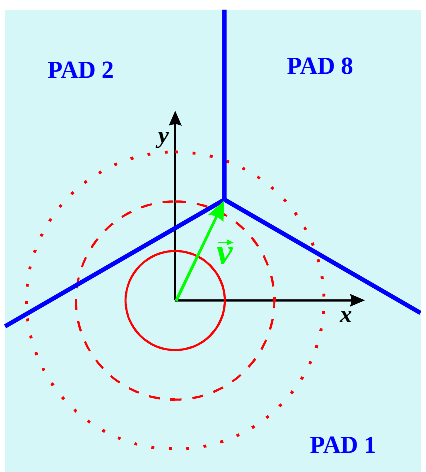
Point resolution studies at Carleton

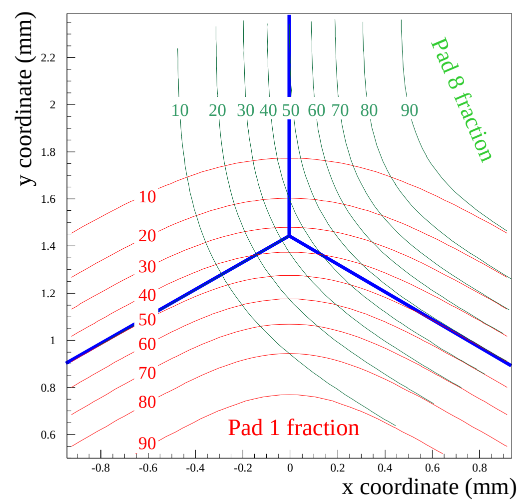


Localization from charge sharing



2D Gaussian model



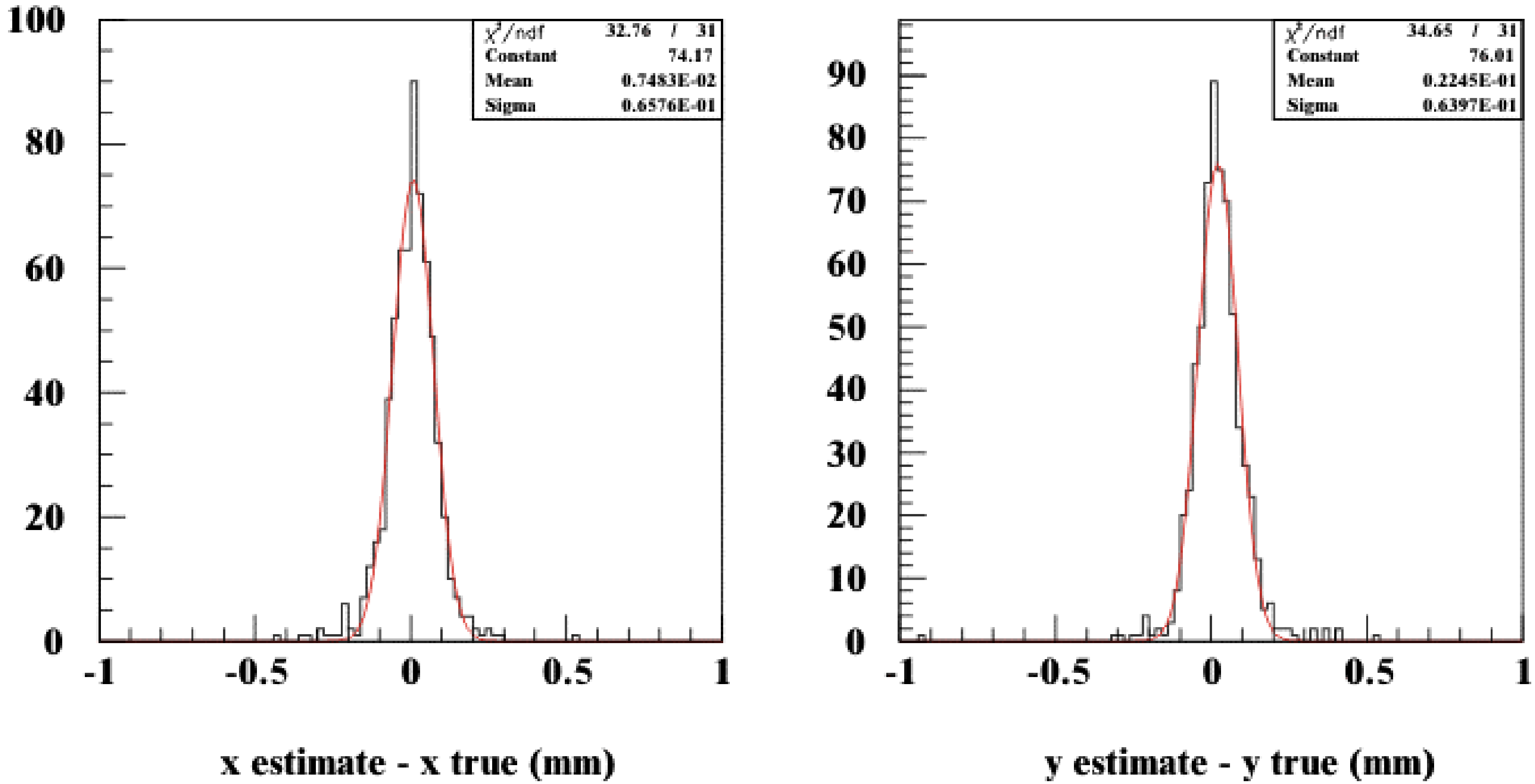


Charge sharing result – P10

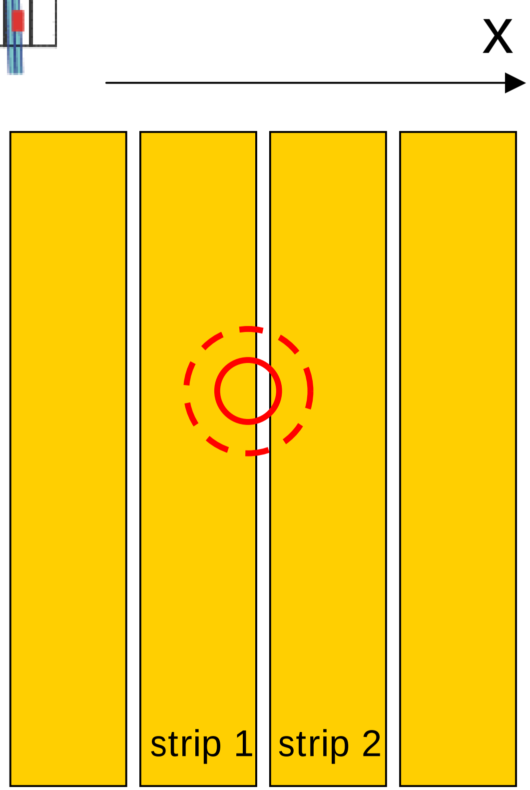
$(x,y)_{col}$ = (0.4,1.243) mm

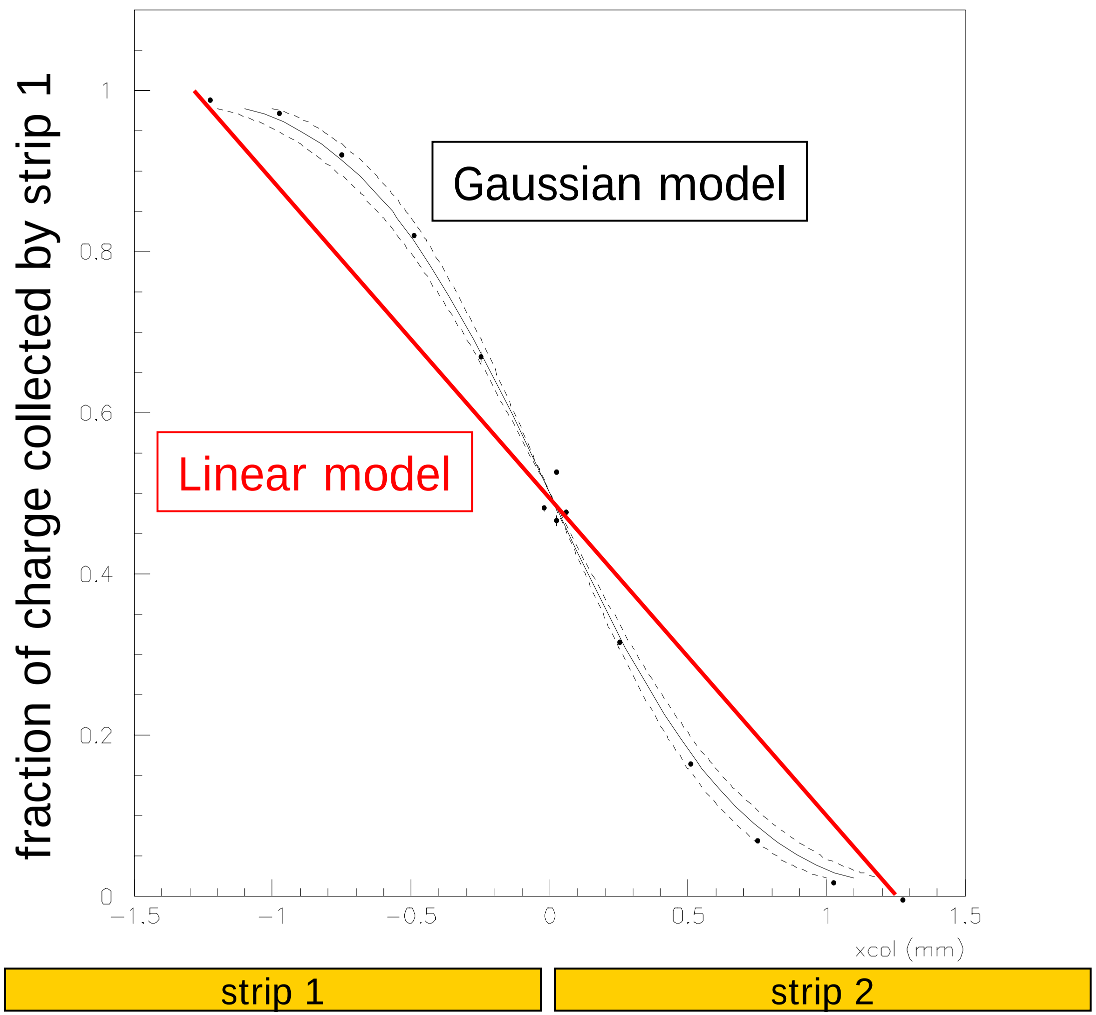
$\bar{x}$ = 0.408 mm
σ_x = 0.066 mm

$\bar{y}$ = 1.265 mm
σ_y = 0.064 mm



Strip geometry – charge sharing

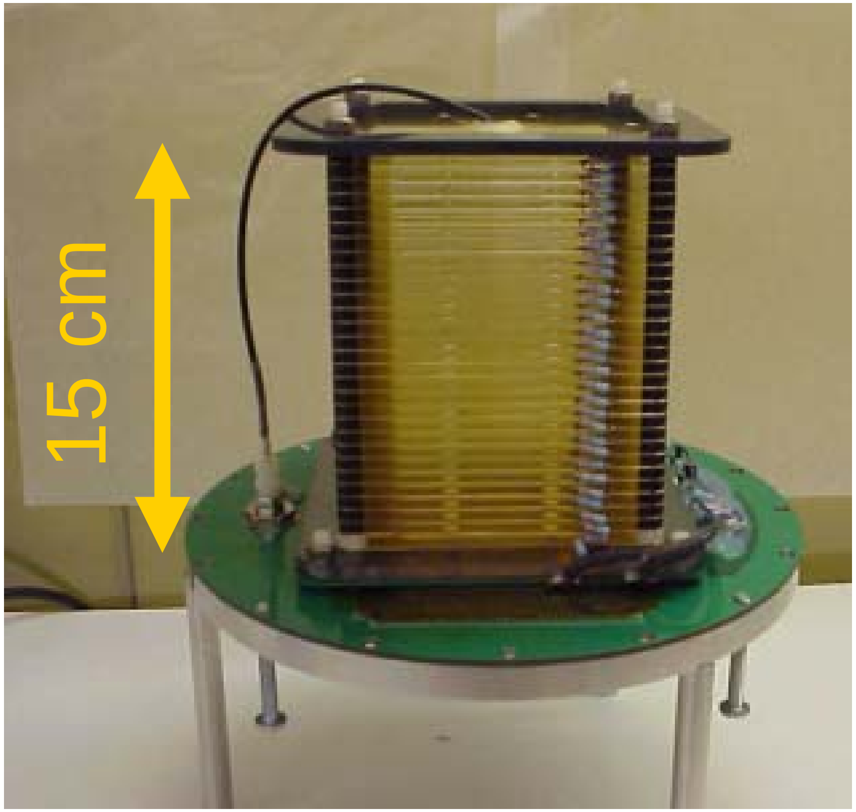


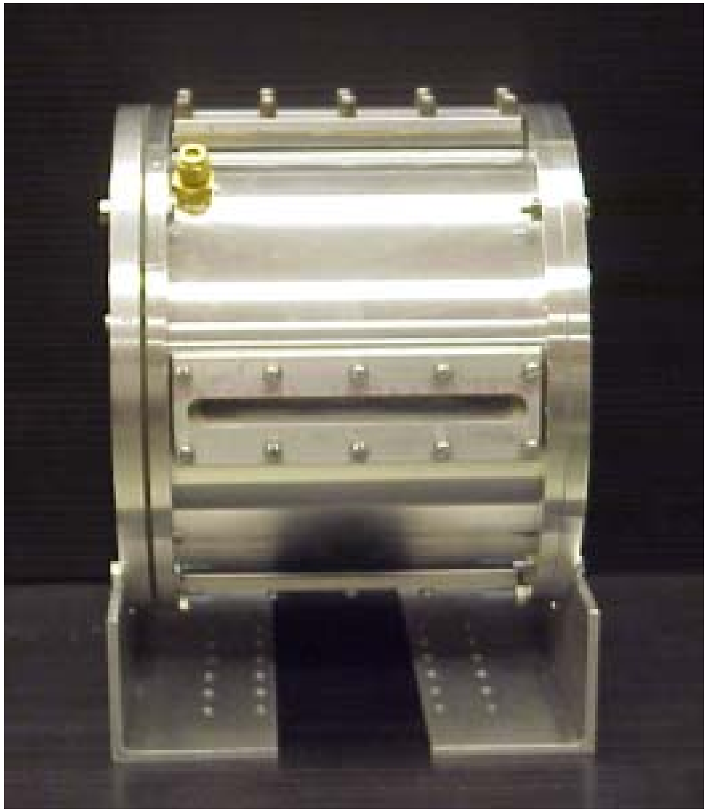


- With P10 gas:
  - x standard deviation: ~70 μm

Track resolution studies

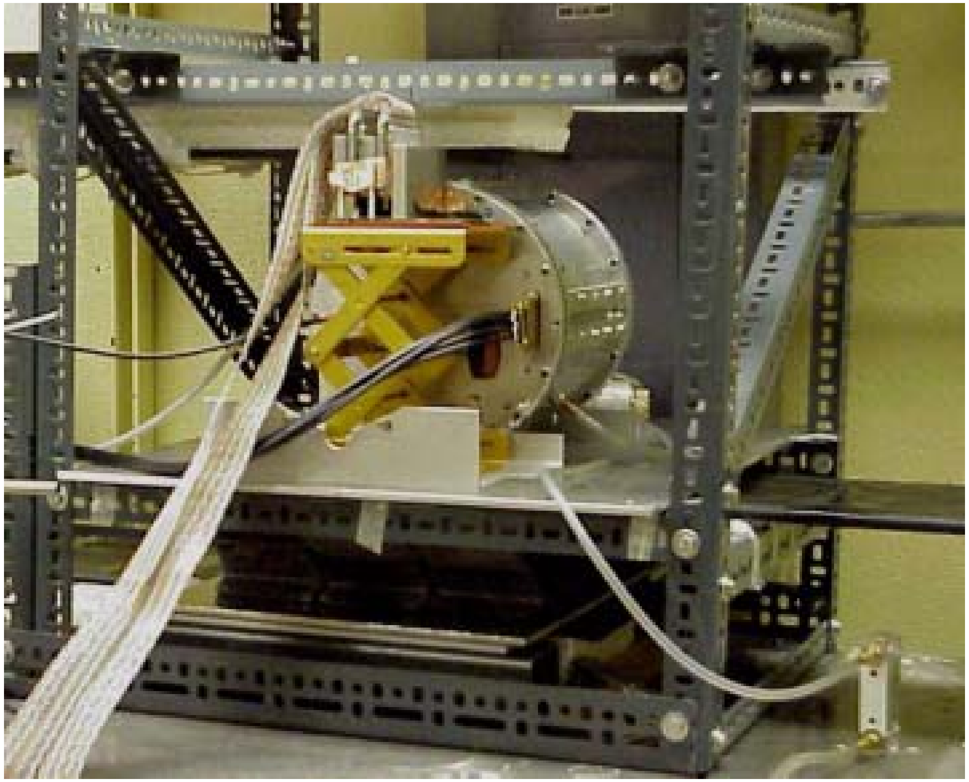
- Mini-TPC constructed



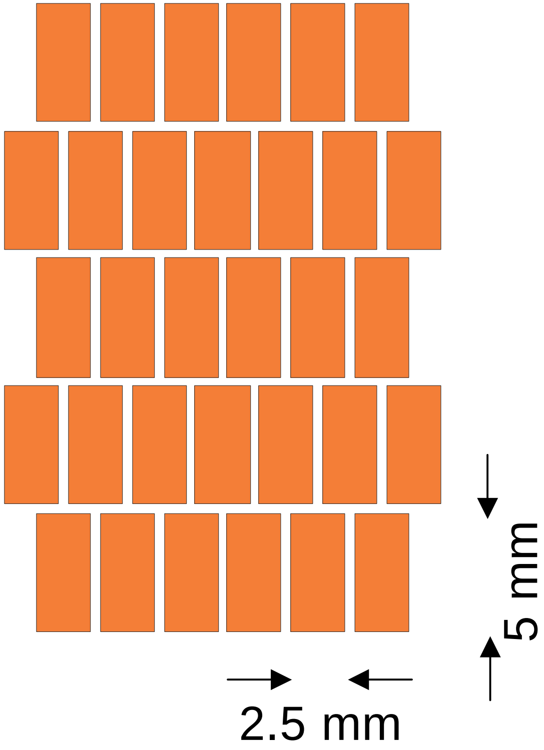


Tracking studies

- Cosmic ray telescope



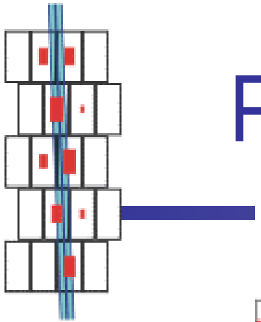
- Readout pad layout

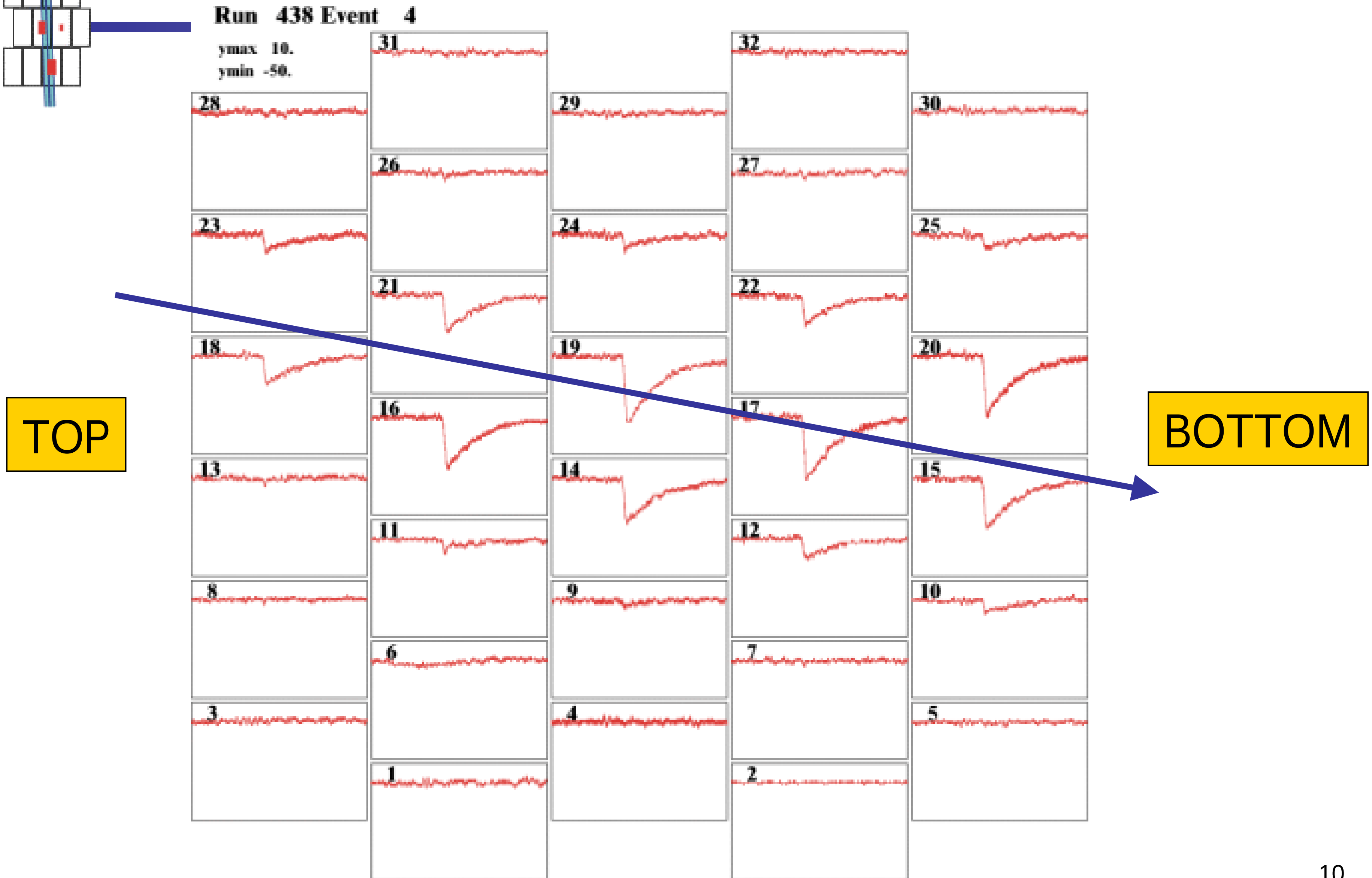


Details – cosmic data taking

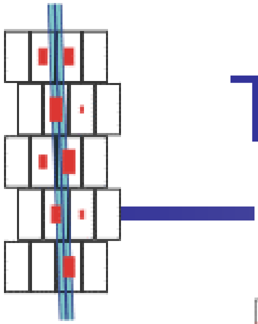
- Gases: Ar CH_4 (90:10) and Ar CO_2 (90:10)
- Drift field: 135 V/cm, GEM gain: ~5000
- pre-amps: ALEPH TPC pre-amp
- readout: 32 channel custom FADC
  - 200 MHz sampling
  - 8 bit
- trigger rates:
  - cosmic telescope: 0.4 Hz
  - require at least one pad hit: 0.04 Hz
- Data:
  - Ar CH_4 : 6 days of running (October, 2001)
  - Ar CO_2 : 23 days of running (Nov/Dec, 2001)

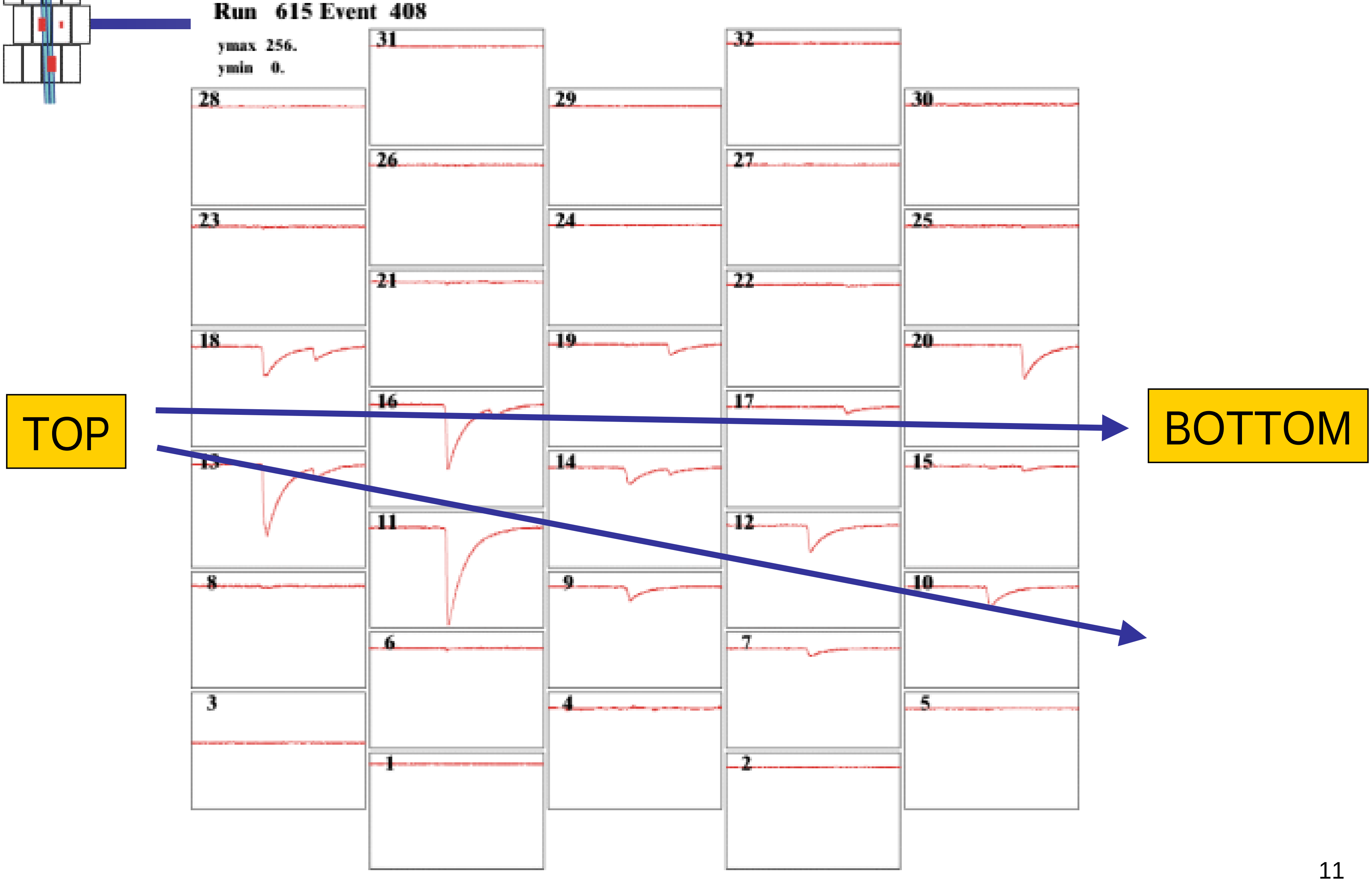
First event – P10





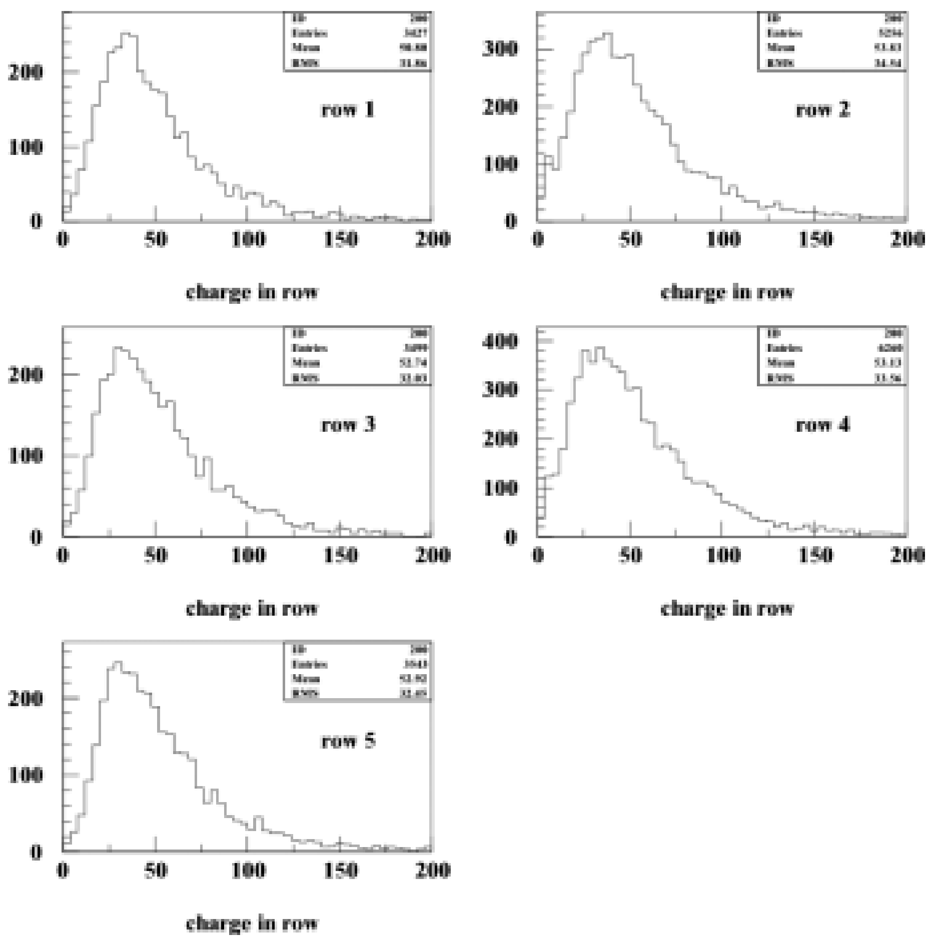
Two track event – Ar CO_2

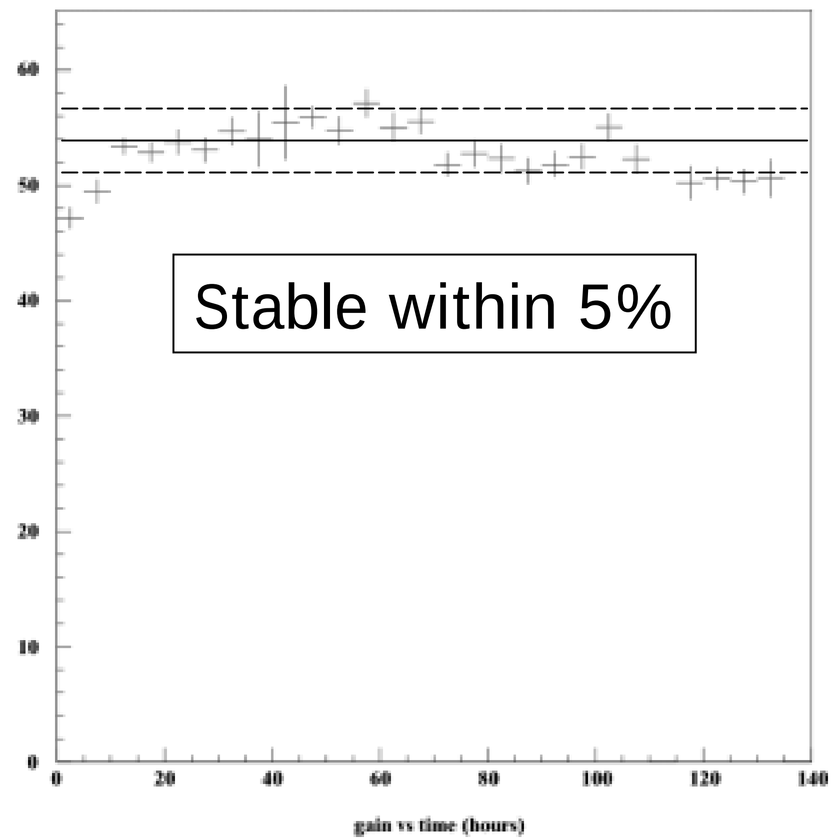




Gain stability – P10

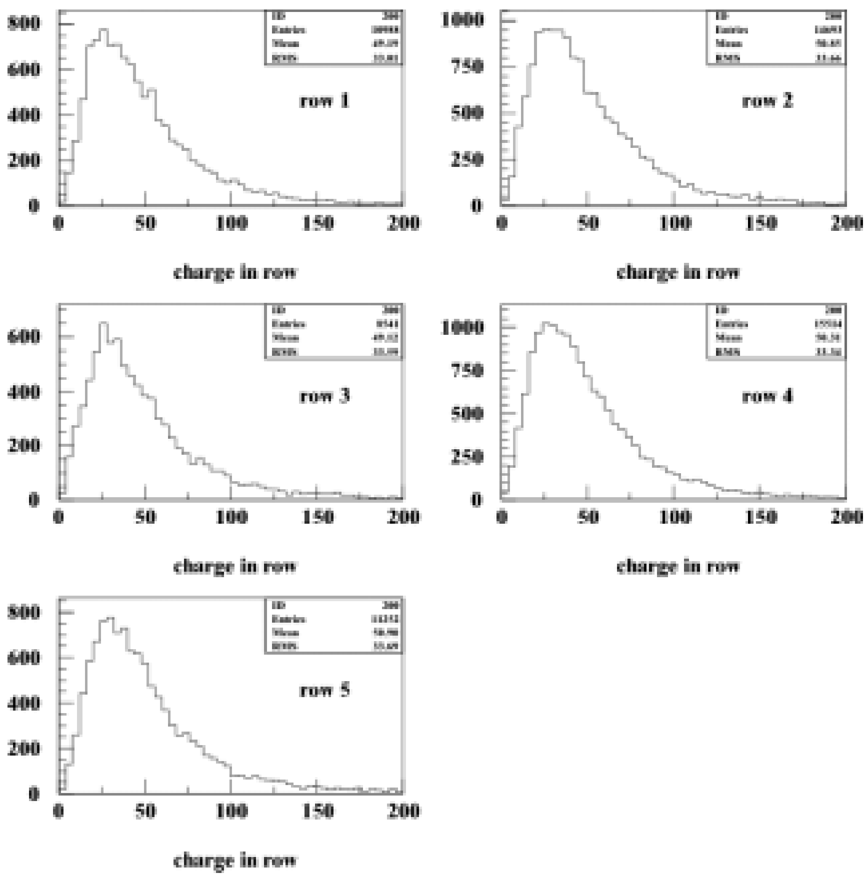
- Charge per row
- Charge vs time



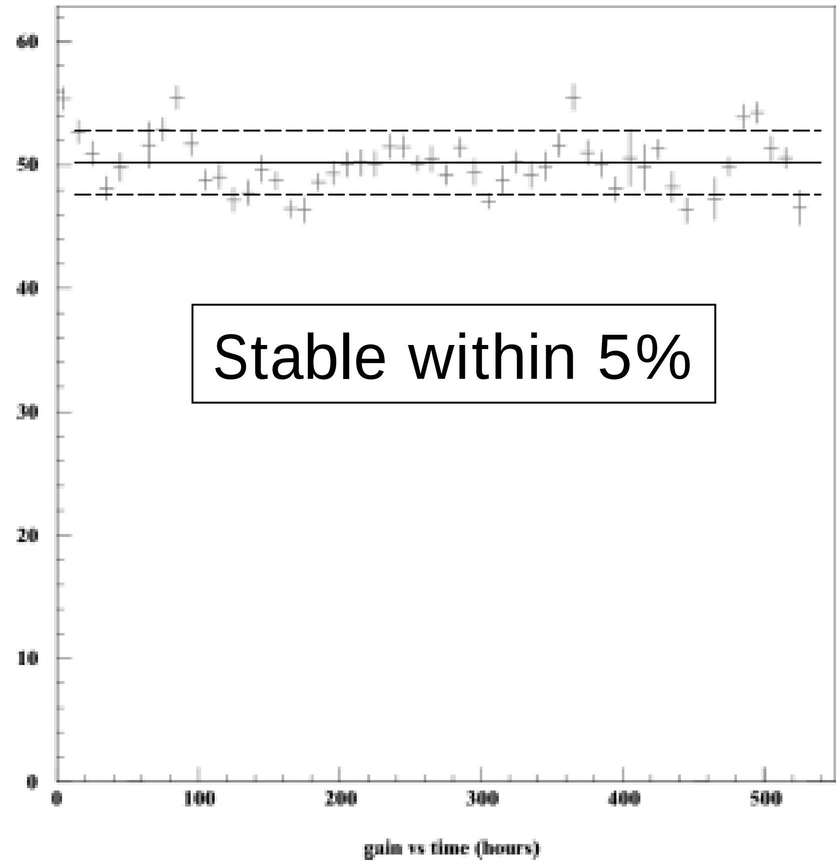


Gain stability – Ar CO_2

- Charge per row

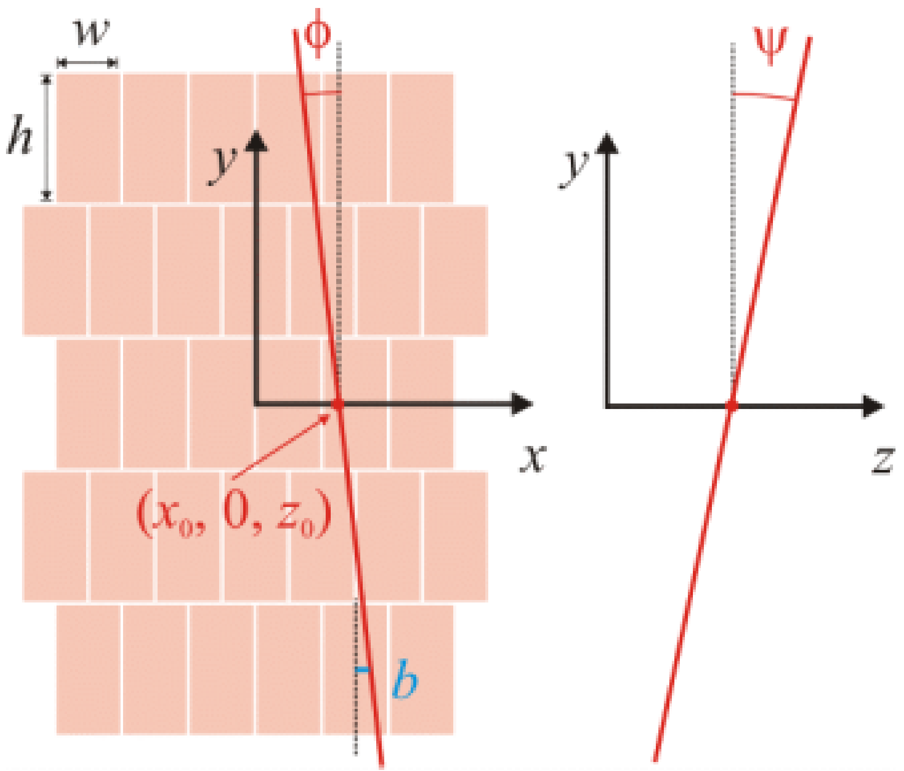


- Charge vs time



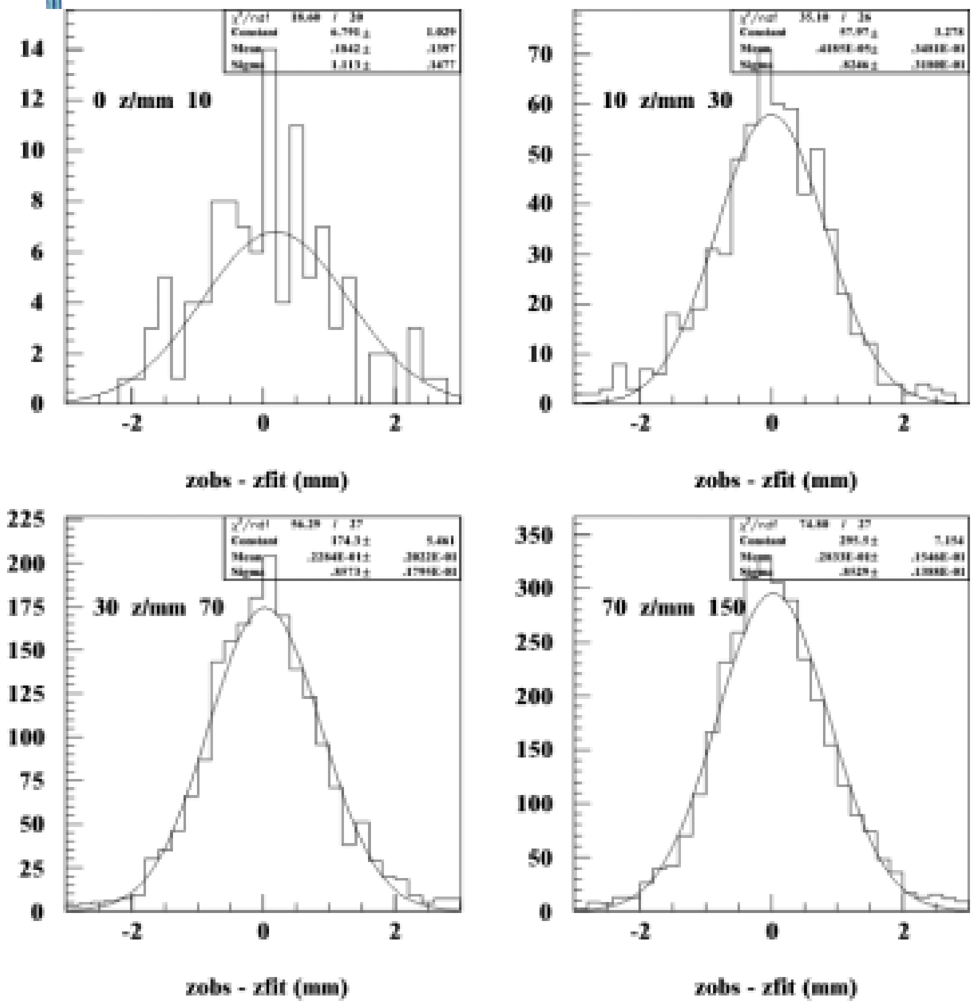
Tracking studies

- Fit x-y and y-z separately



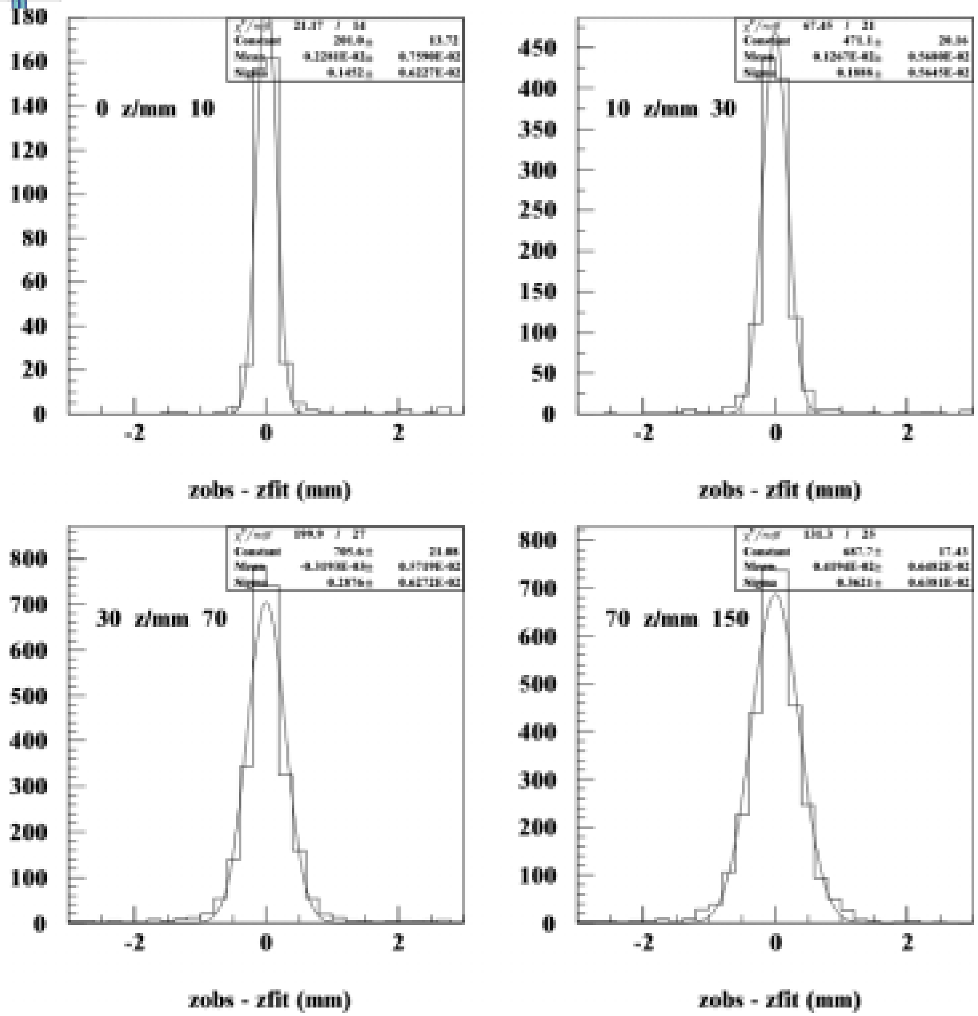
- y-z fit:
  - for each row form weighted average of pulse arrival time
  - perform unweighted linear fit of the 5 row y-coordinates vs row times
  - pulse arrival time (50% rise) dependant on pulse amplitude
    - needs further study

y-z fit results – P10



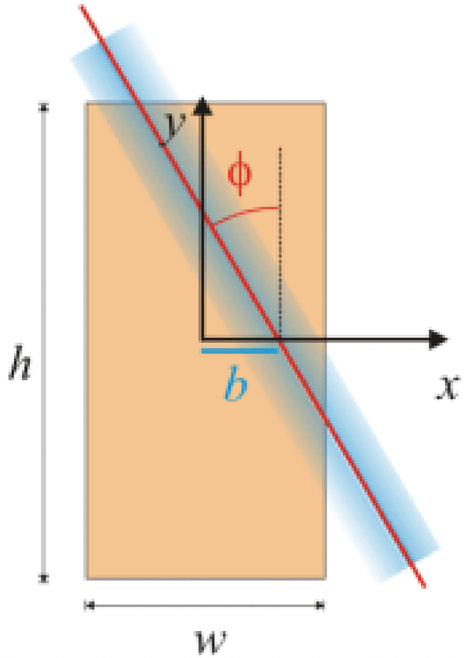
- Not diffusion limited
  - pulse arrival time definition needs improving
  - 800 micron resolution independent of drift length
  - $v_d \sim 50\ \mu m/ns$

y-z fit results – Ar CO_2



- Diffusion limited
  - less sensitive to pulse arrival time problem because of slow drift
  - 130 micron resolution for drift length < 1cm
  - $v_d \sim 9\ \mu m/ns$

x-y fit



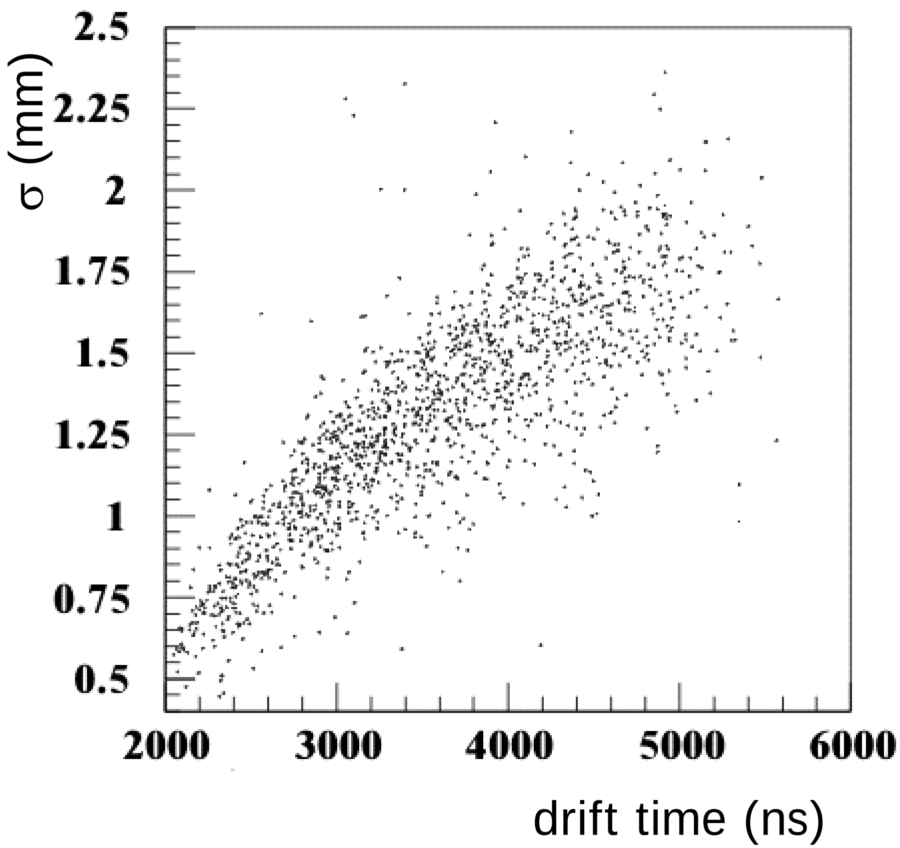
$$I(b,\phi,\sigma,h,w) = \int_{-w/2}^{w/2} dx \int_{-h/2}^{h/2} dy \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{[(x-b)\cos\phi + y\sin\phi]^2}{2\sigma^2}}$$
$$= \eta(b,\phi,\sigma,h,w) - \eta(b,\phi,\sigma,-h,w) + \eta(b,\phi,\sigma,-h,-w) - \eta(b,\phi,\sigma,h,-w)$$

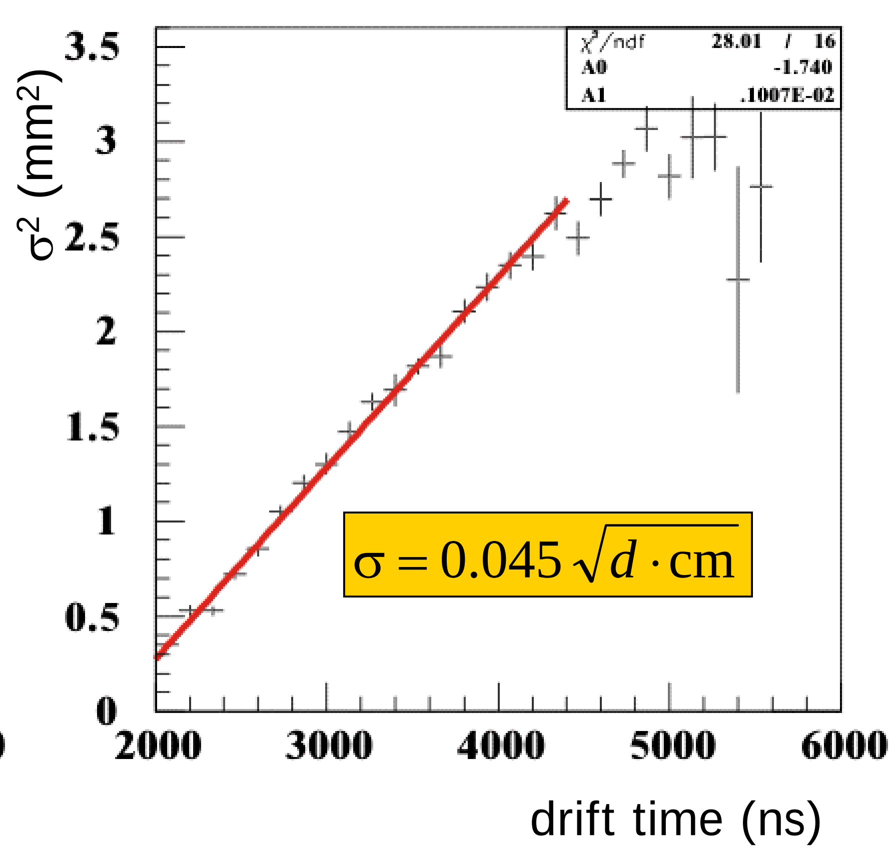
$$\eta(b,\phi,\sigma,h,w) = \frac{1}{\cos\phi\sin\phi}\xi\left((b+\frac{w}{2})\cos\phi + \frac{h}{2}\sin\phi, \sigma\right)$$
$$\xi(u,\sigma) = \frac{u}{2}\mathrm{erf}\left(\frac{u}{\sqrt{2}\sigma}\right) + \frac{\sigma}{\sqrt{2\pi}}\exp\left(\frac{-u^2}{2\sigma^2}\right)$$

- use model of uniform line of charge, with Gaussian transverse spread, σ
  - charge fractions given by integral over pad
- fit uses observed charge fractions within each row
  - min χ^2 with x_0, ϕ and σ free
- ionization fluctuations
  - not included in model
  - unimportant for $\phi = 0$
  - leads to track angle effect on resolution

Line charge width – P10

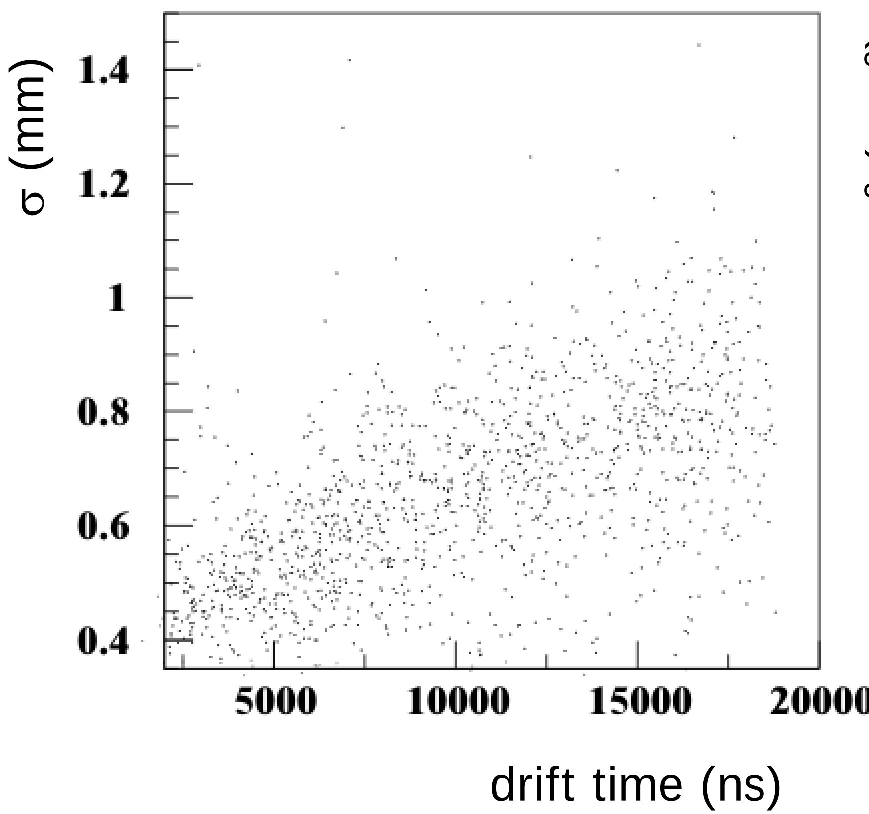
- Results from fit of data: diffusion apparent

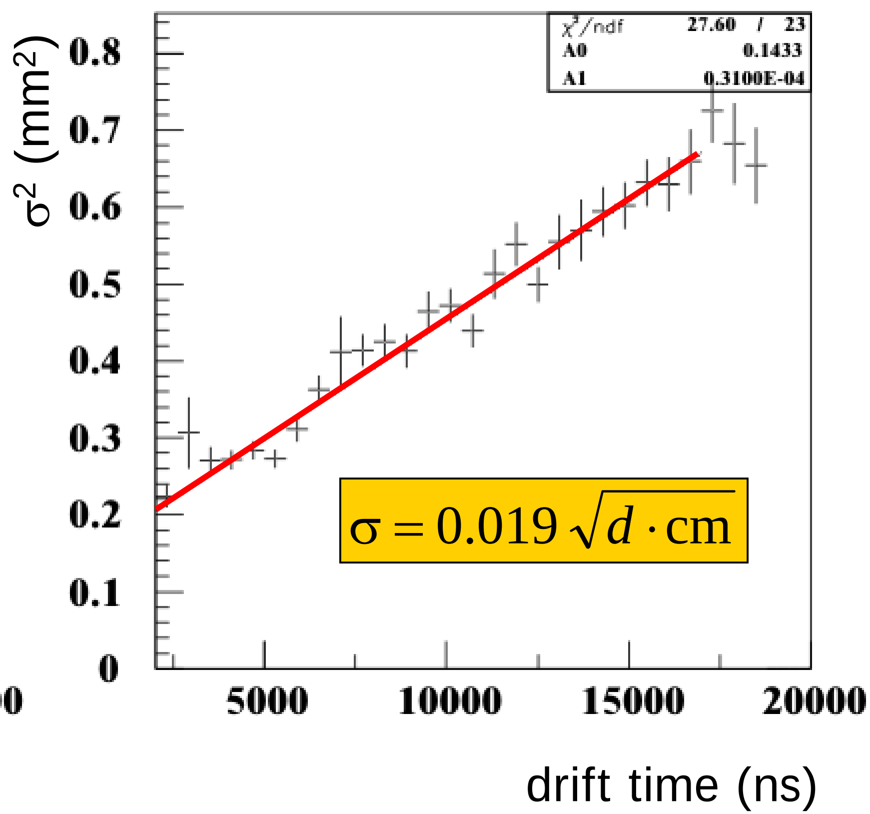




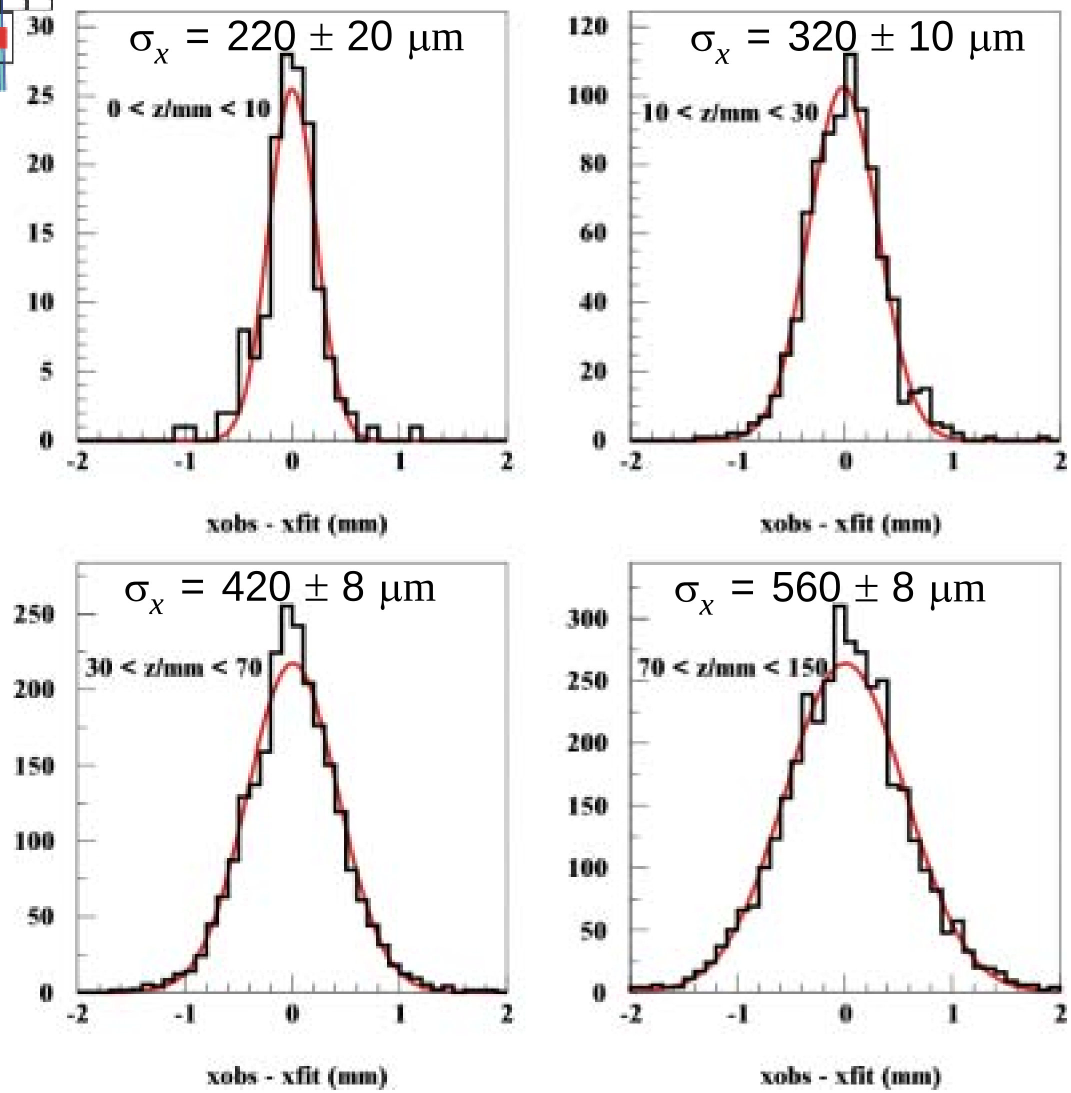
Line charge width – Ar CO_2

- Results from fit of data: diffusion apparent



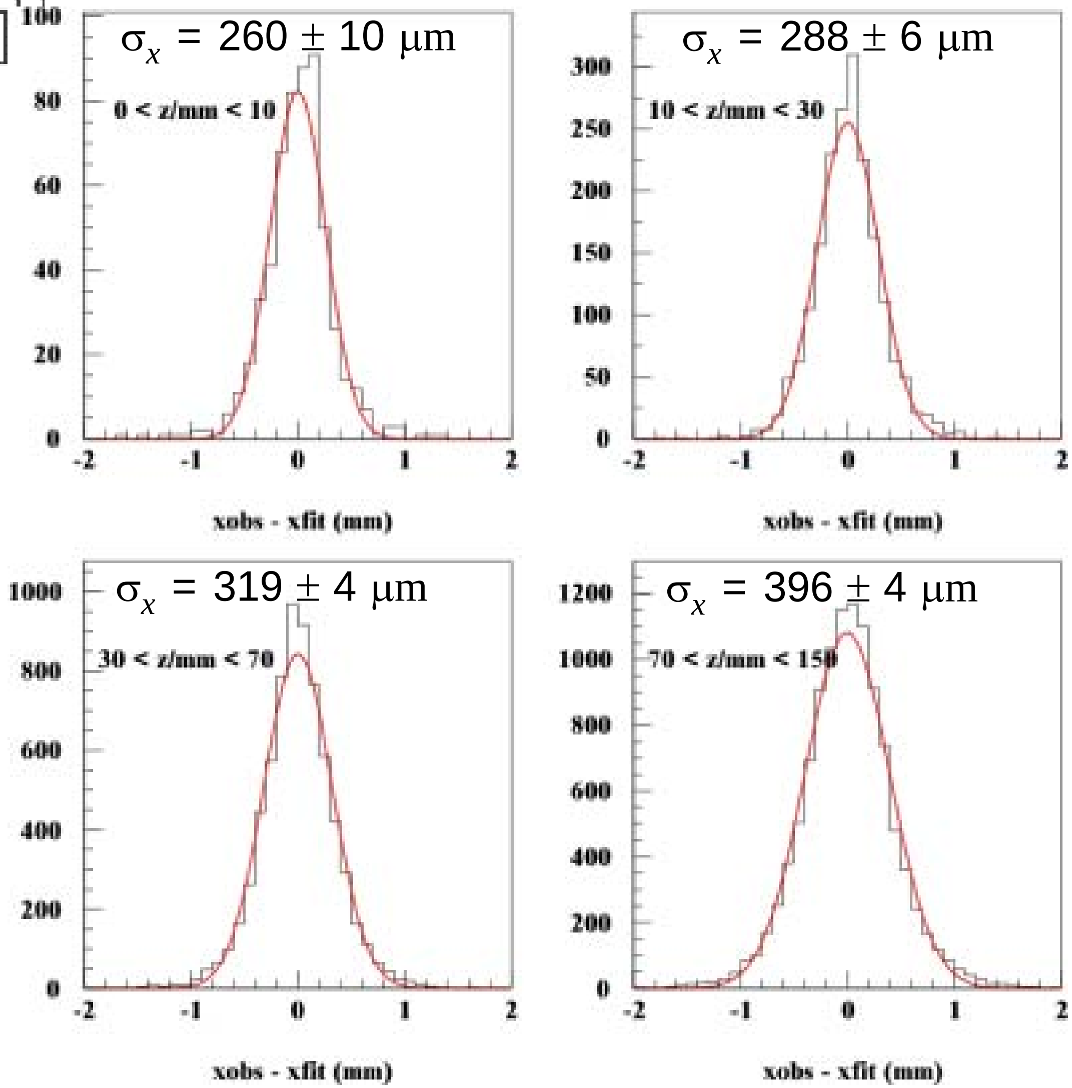


Track x_0 resolution – P10



- x_0 resolution from single row:
  - do fit excluding the row: x_0, ϕ, σ free
  - do fit for single row: only x_0 free
  - compare 1 row x_0 to 4 row x_0

Track x_0 resolution – Ar CO_2

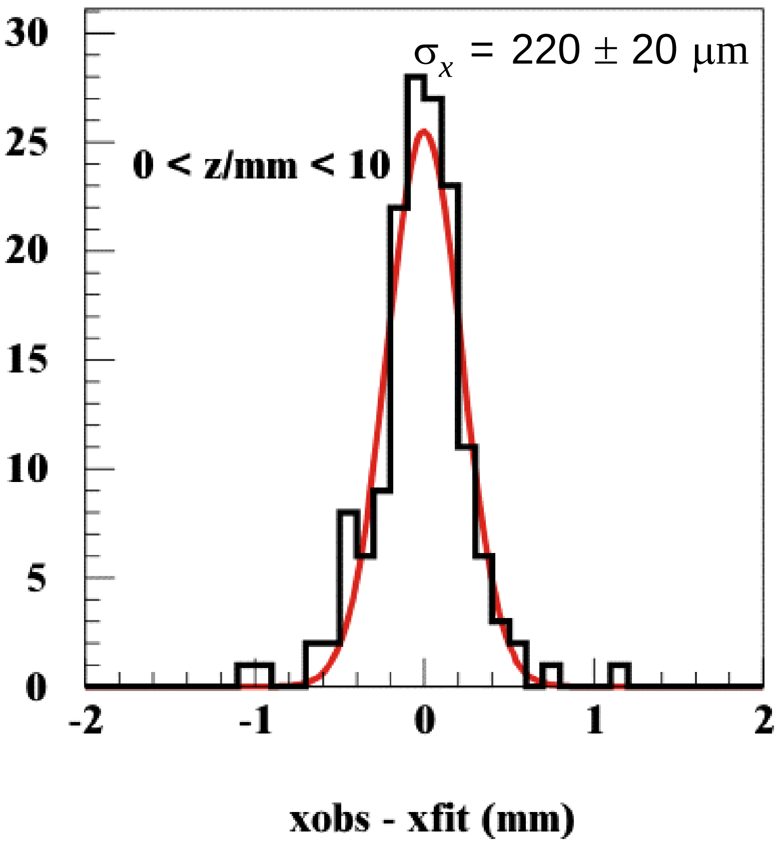


- x_0 resolution from single row:
  - do fit excluding the row:
    - x_0, ϕ free
    - σ fixed
  - do fit for single row: only x_0 free
  - compare 1 row x_0 to 4 row x_0

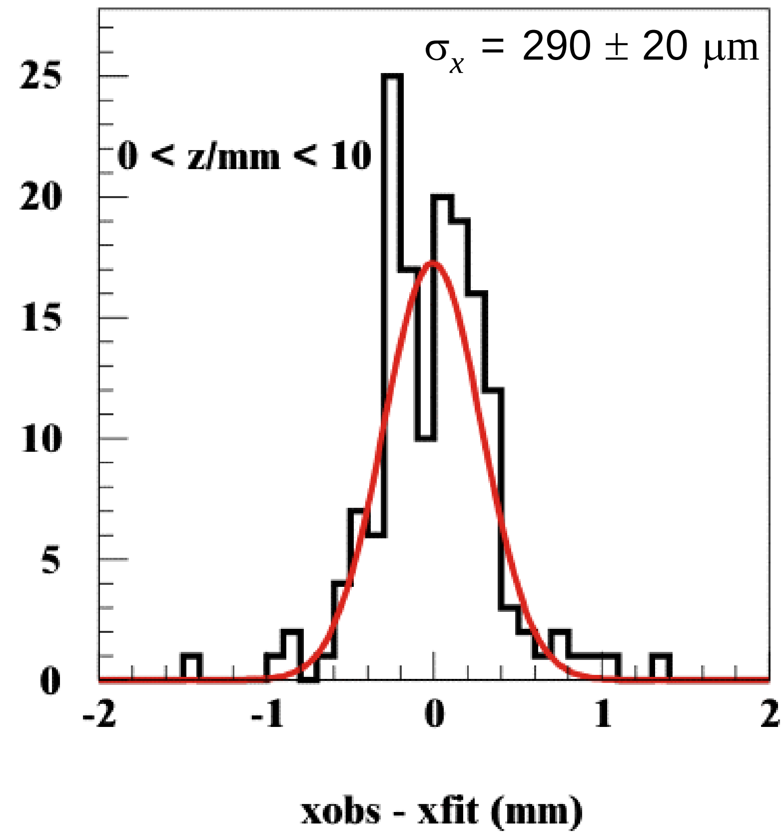
Centroid finding – P10

- Linear weighted x_0 coordinate less accurate

Gaussian model



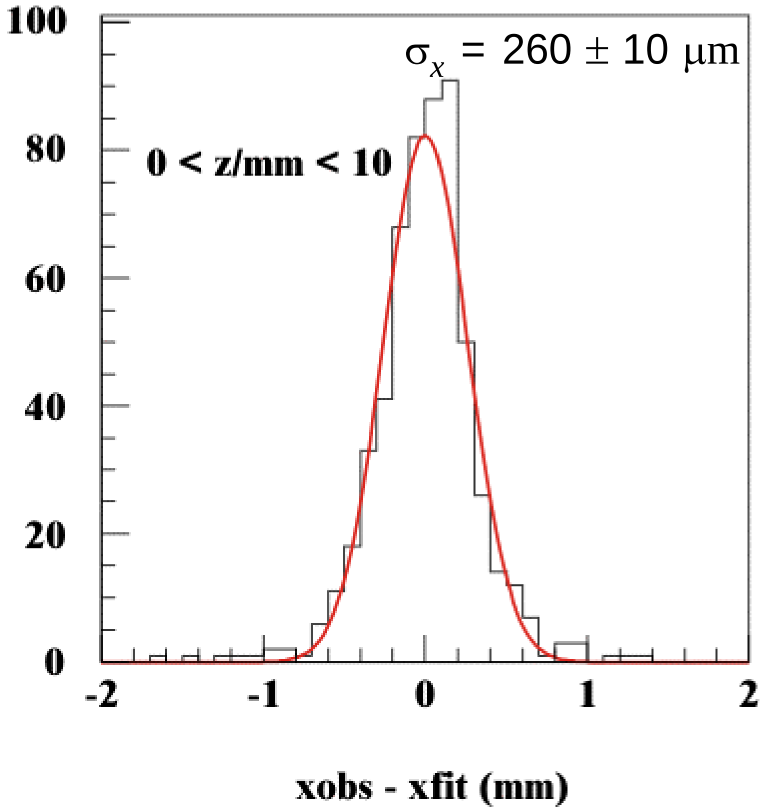
linear weighting



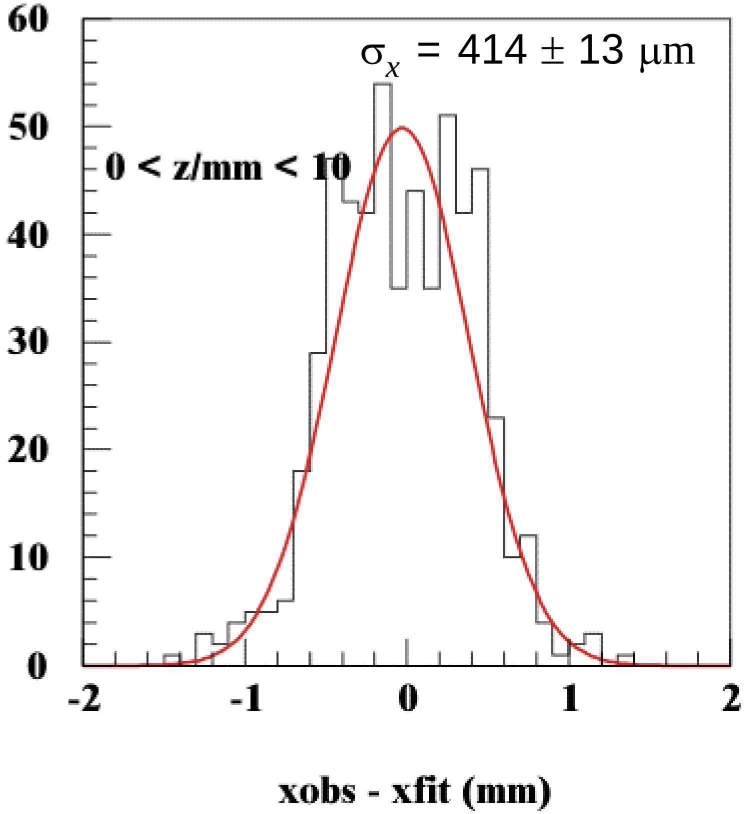
Centroid finding – Ar CO_2

- Linear weighted x_0 coordinate less accurate

Gaussian model



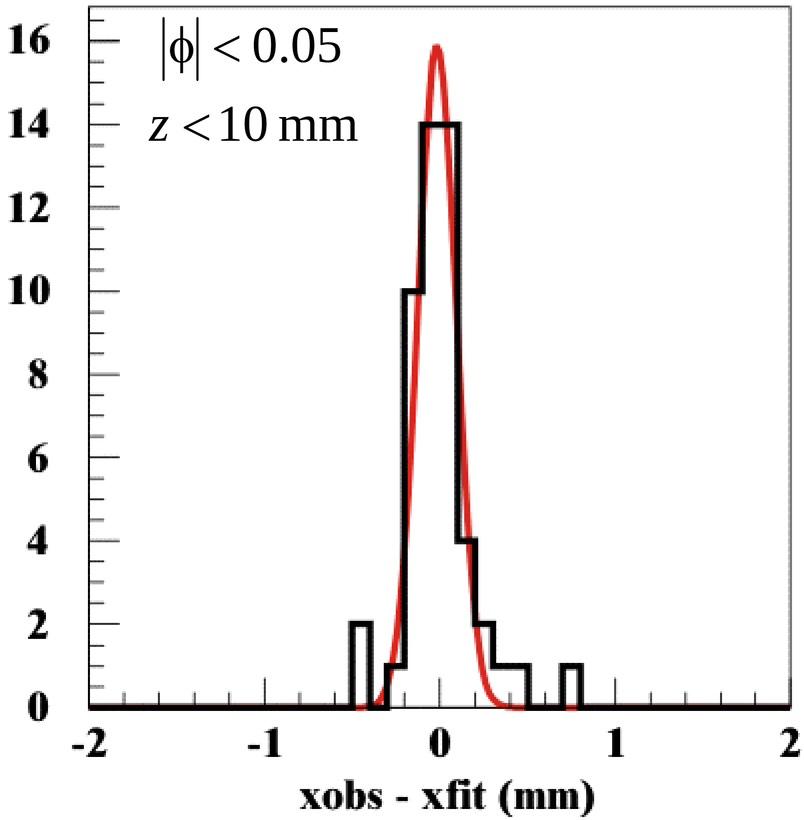
linear weighting



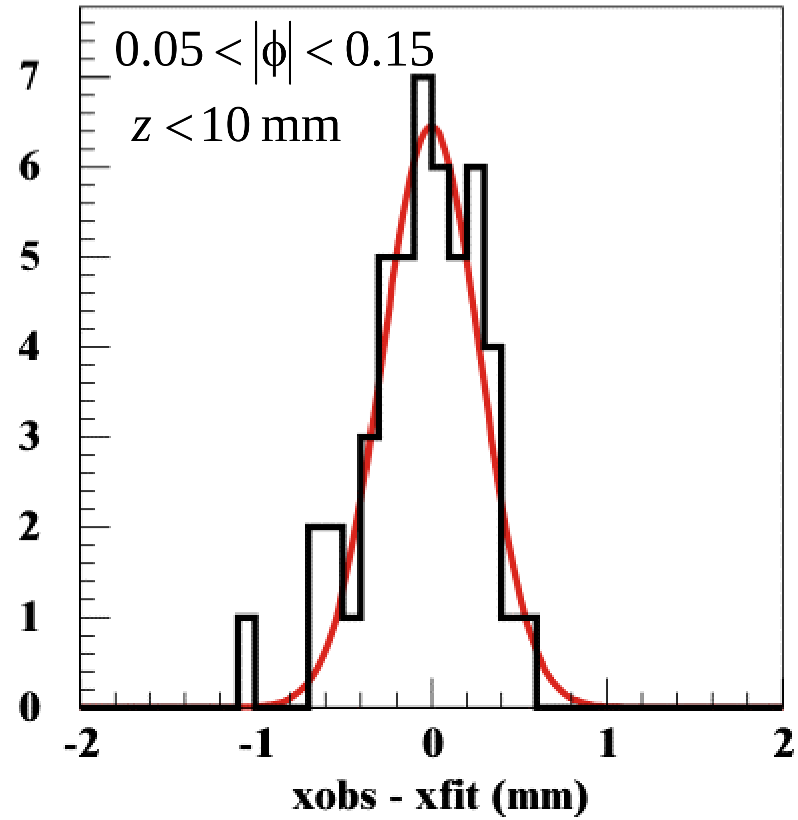
Track angle effect – P10

- Appears to be significant, but small statistics

σ_x = 110 ± 15 μm

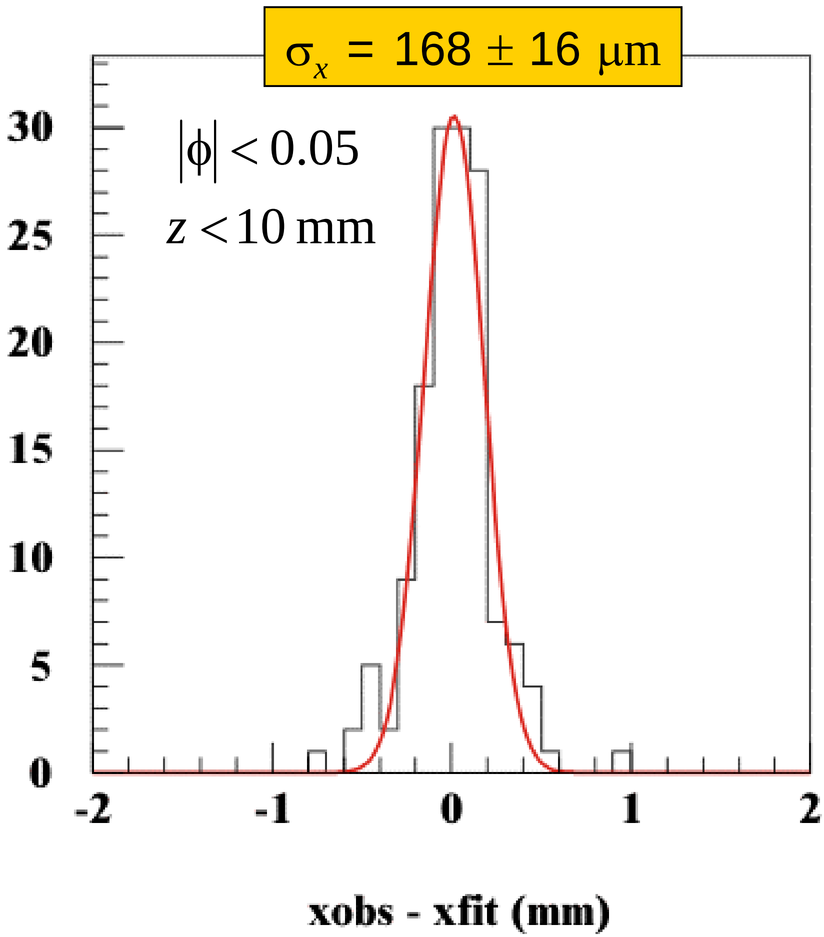


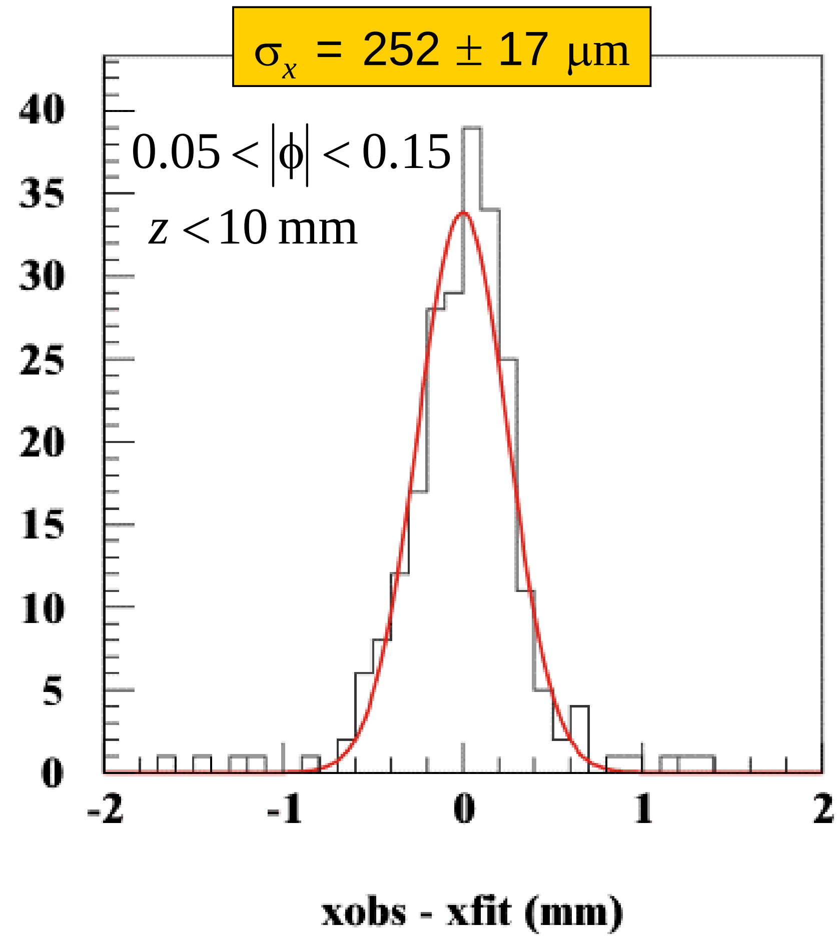
σ_x = 280 ± 50 μm

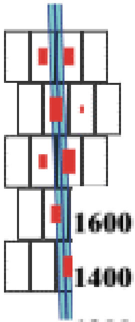


Track angle effect – Ar CO_2

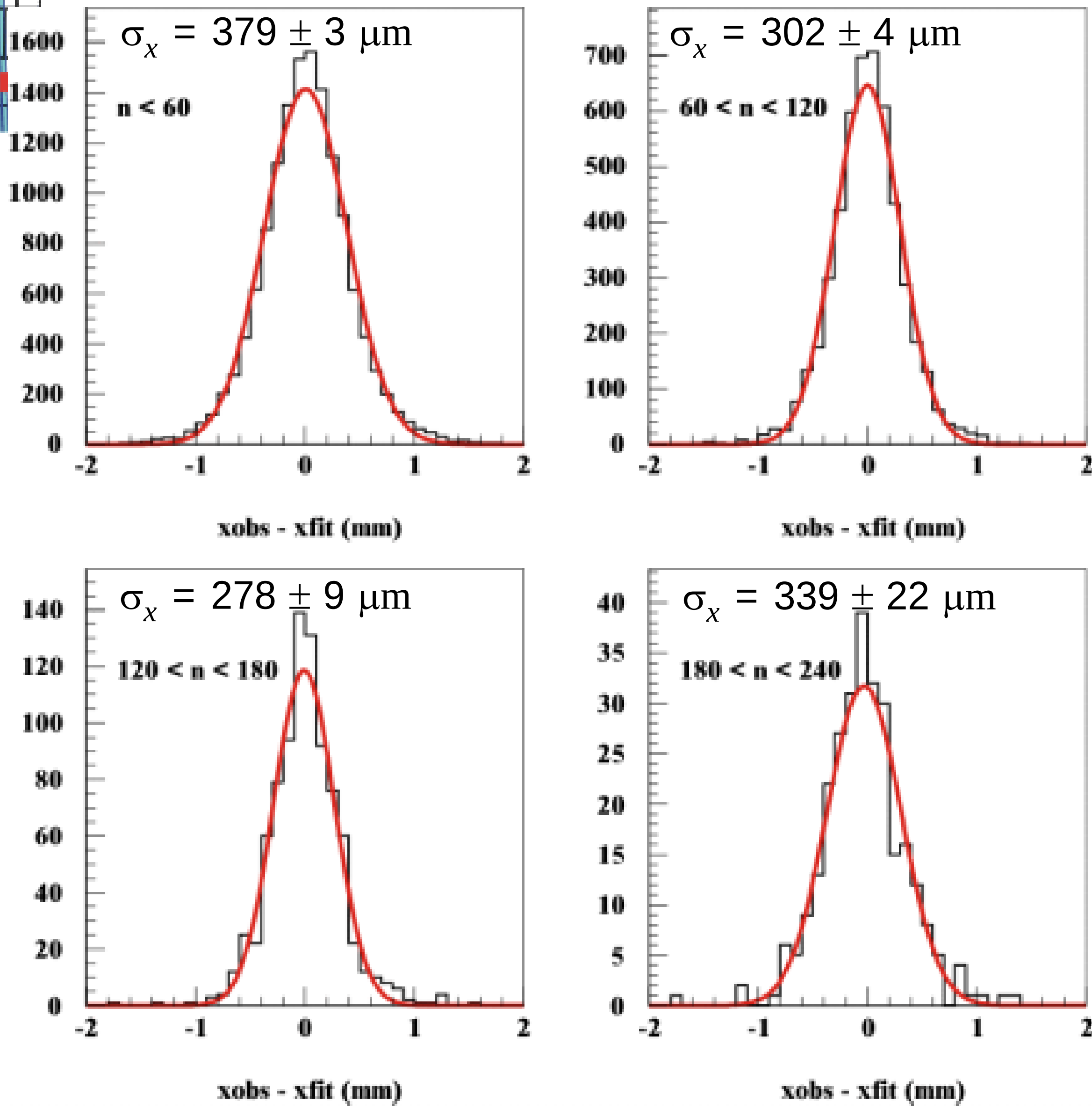
- Appears to be significant, but small statistics





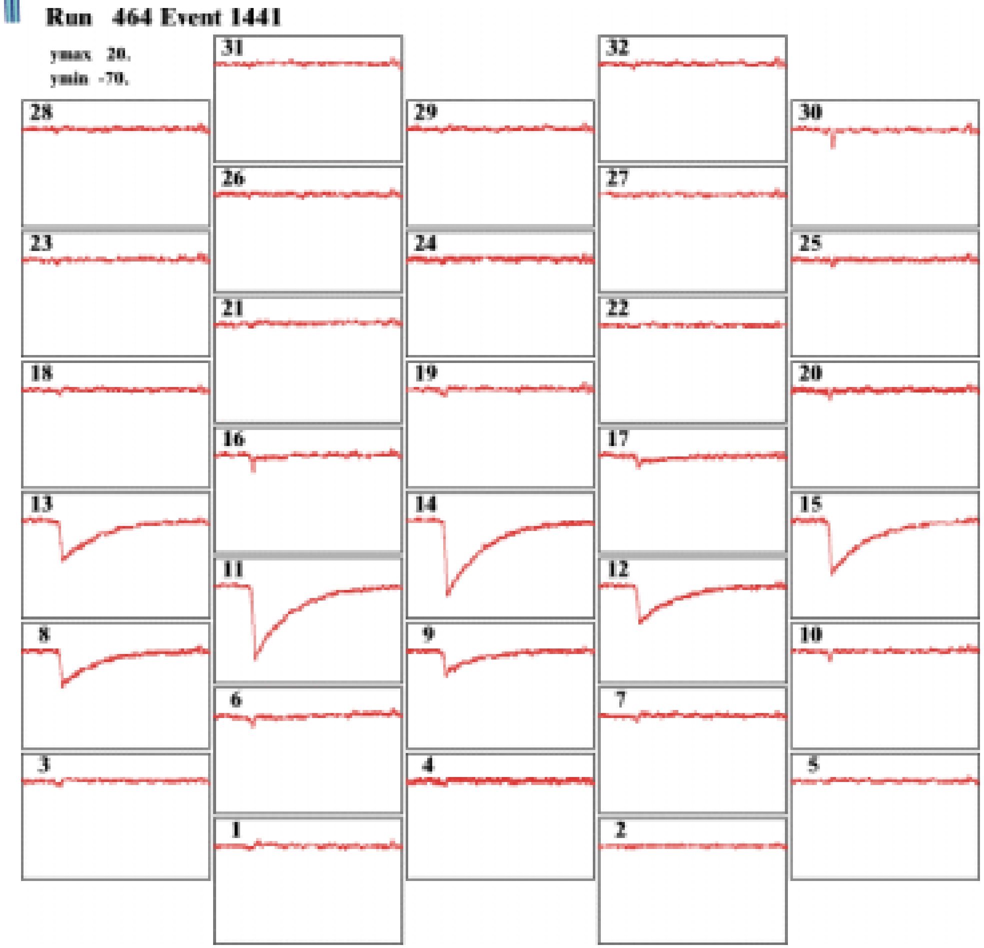


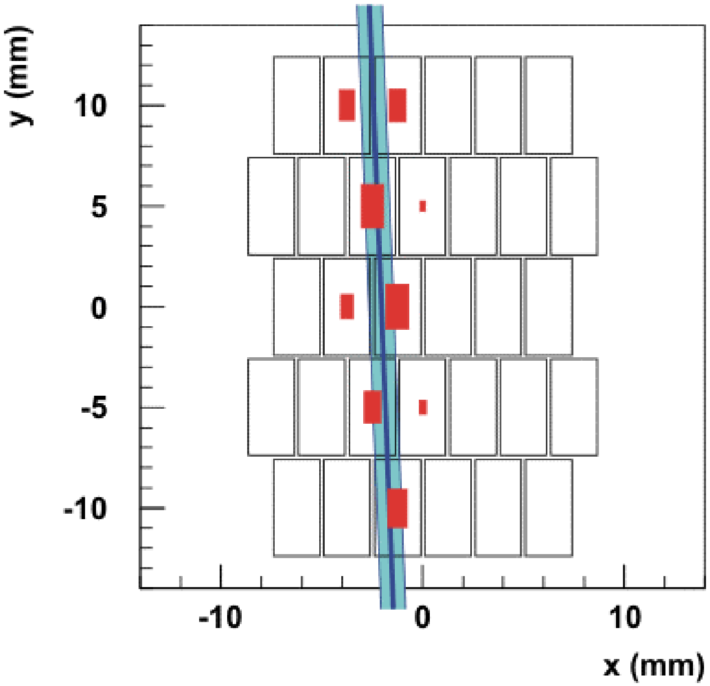
Primary ionization effect – Ar CO_2



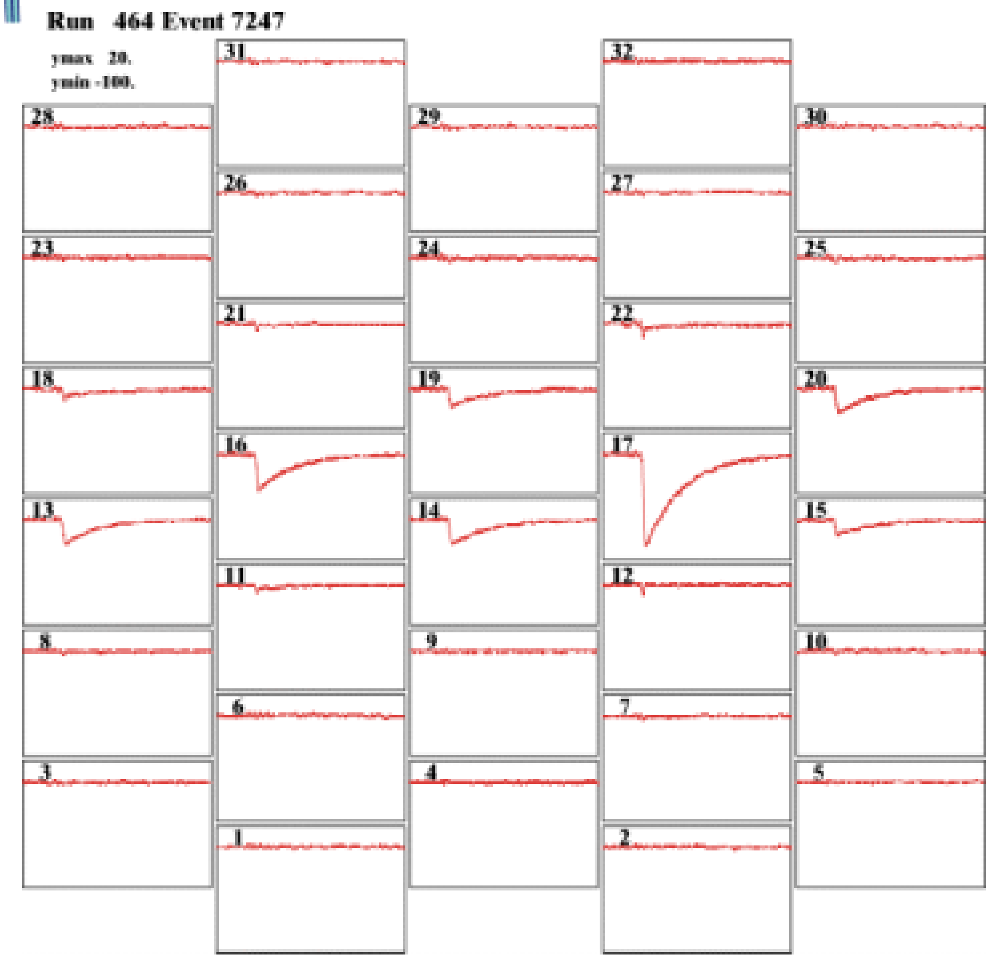
- improvement of resolution with primary electron statistics
- for large ionisation resolution degrades
  - delta-rays

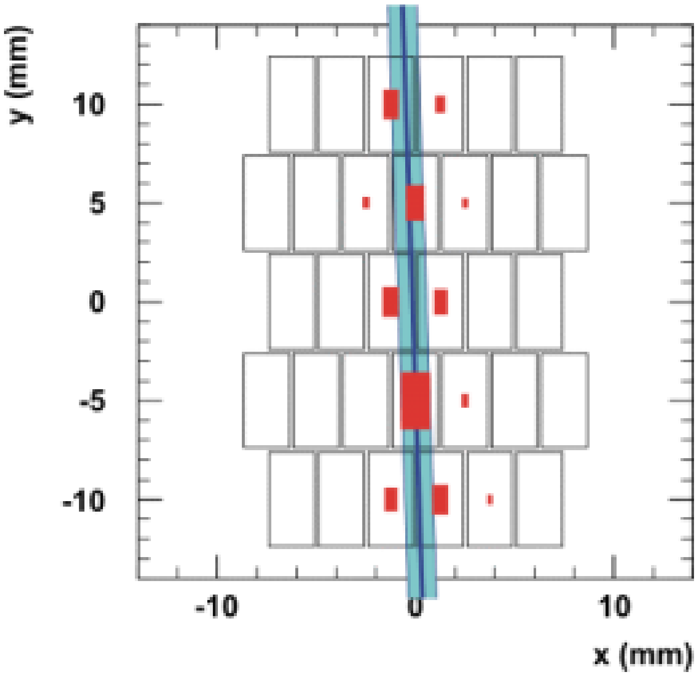
Sample events (P10, z<10 mm, |ϕ|<0.05)



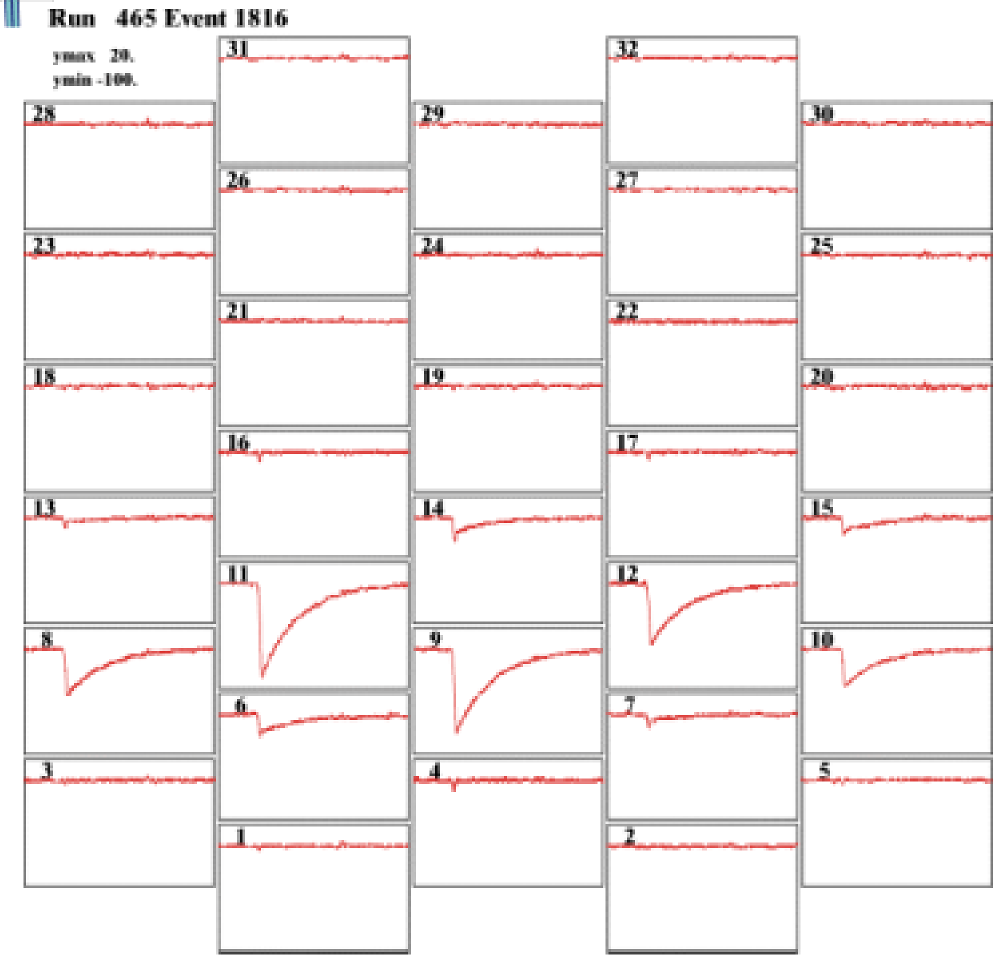


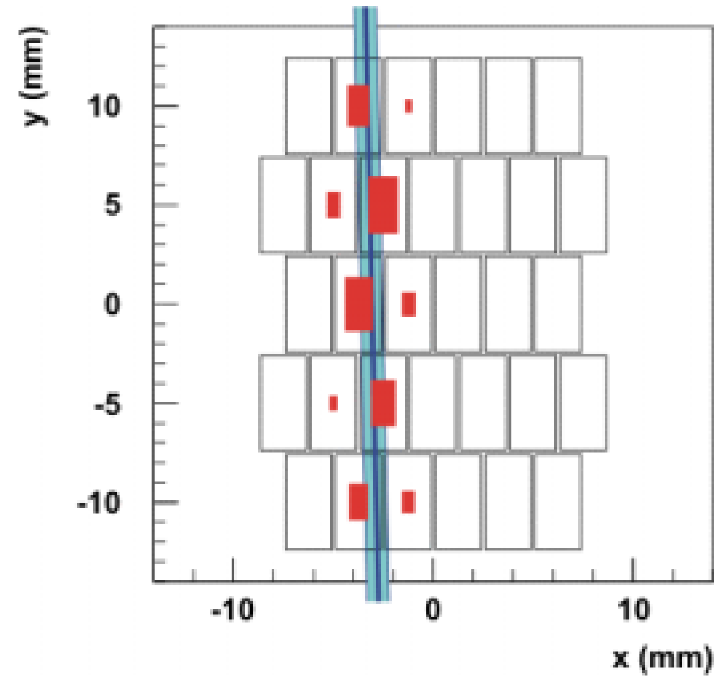
Sample events (P10, z<10 mm, |ϕ|<0.05)



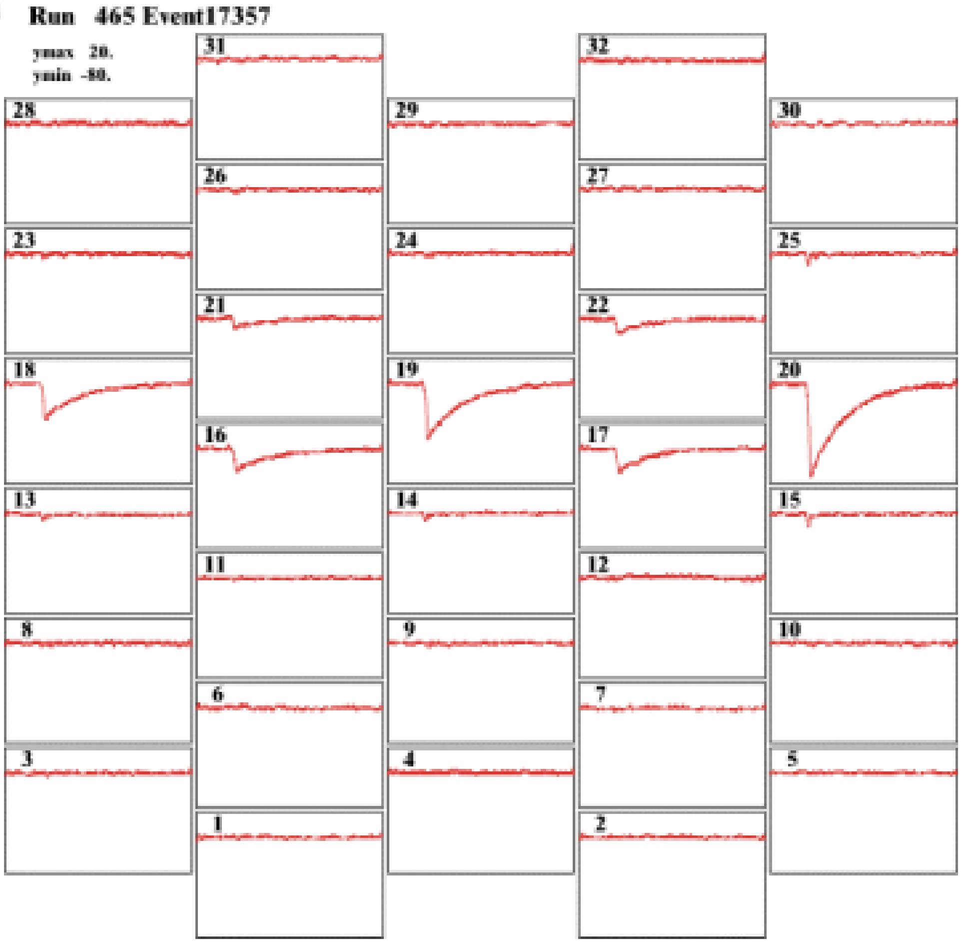


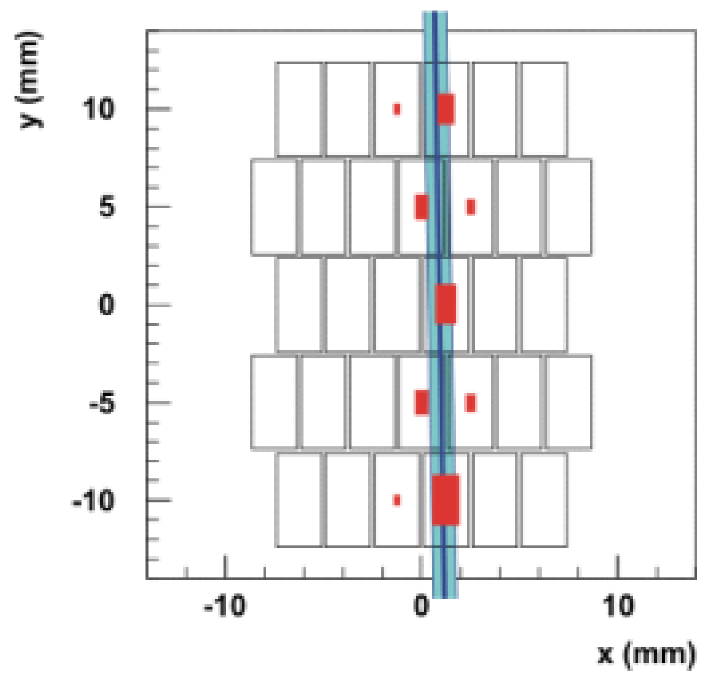
Sample events (P10, z<10 mm, $|\phi|<0.05$)



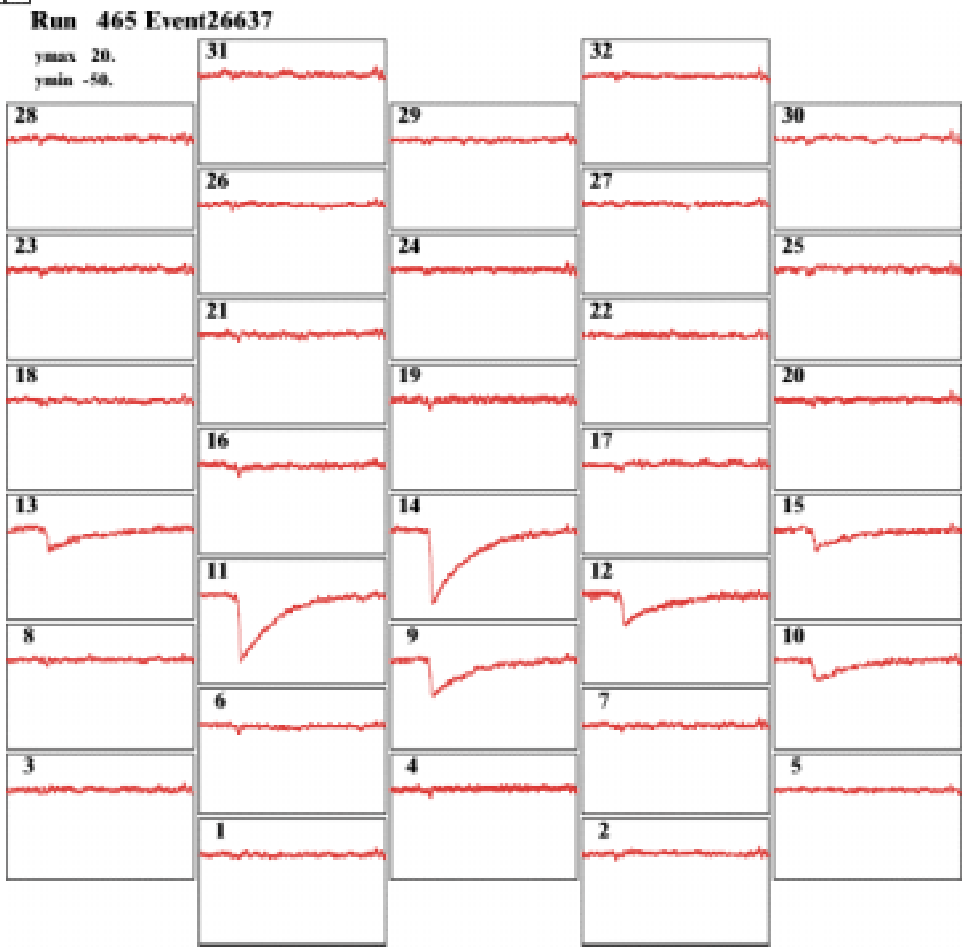


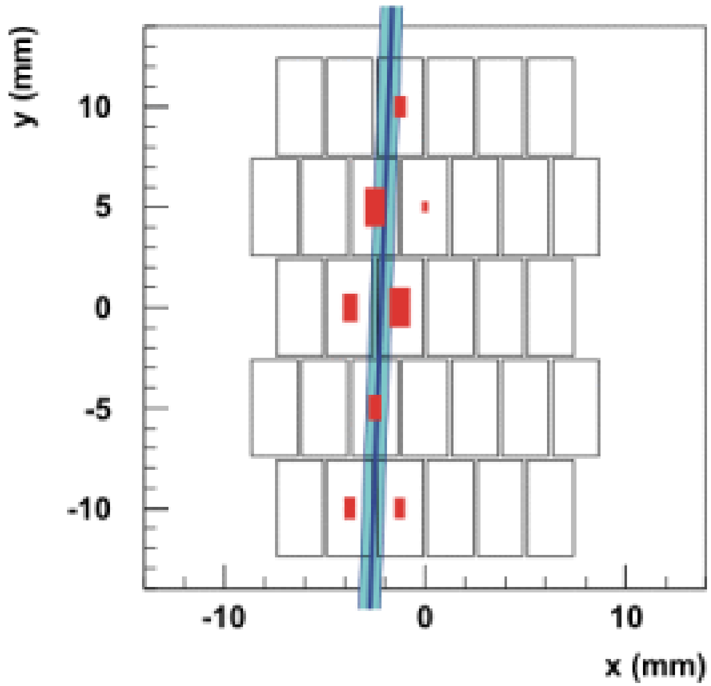
Sample events (P10, z<10 mm, |ϕ|<0.05)



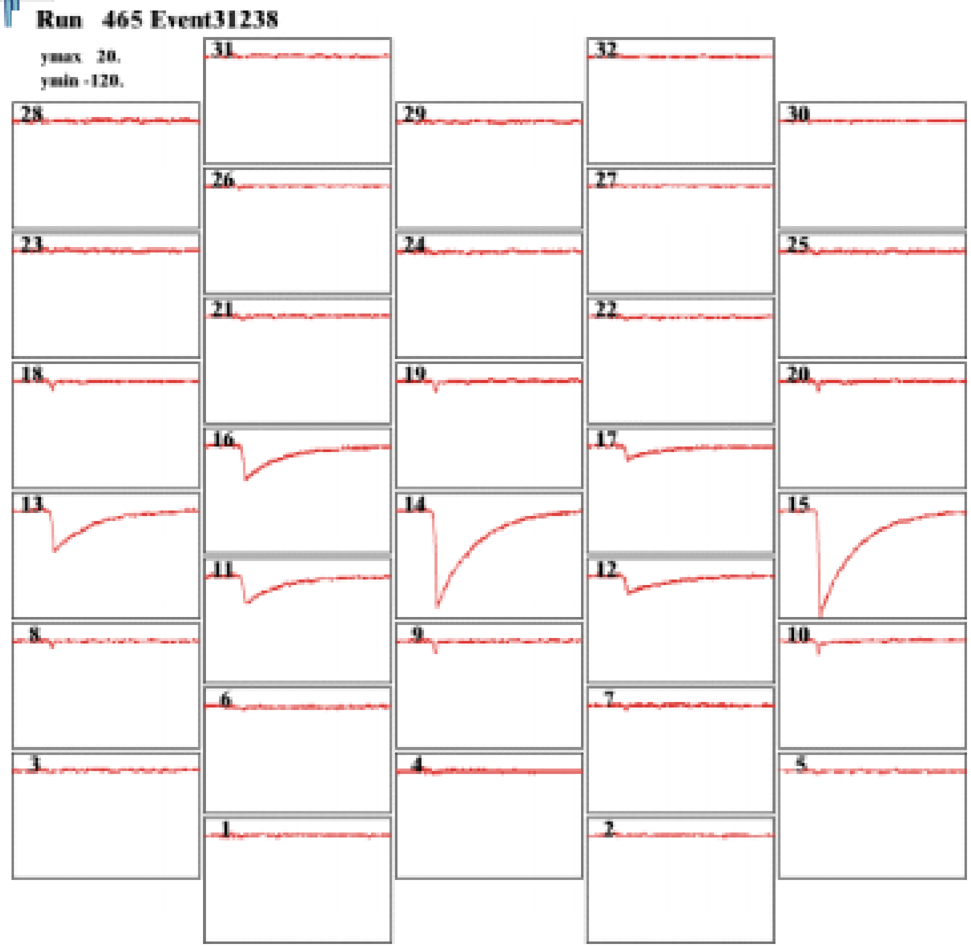


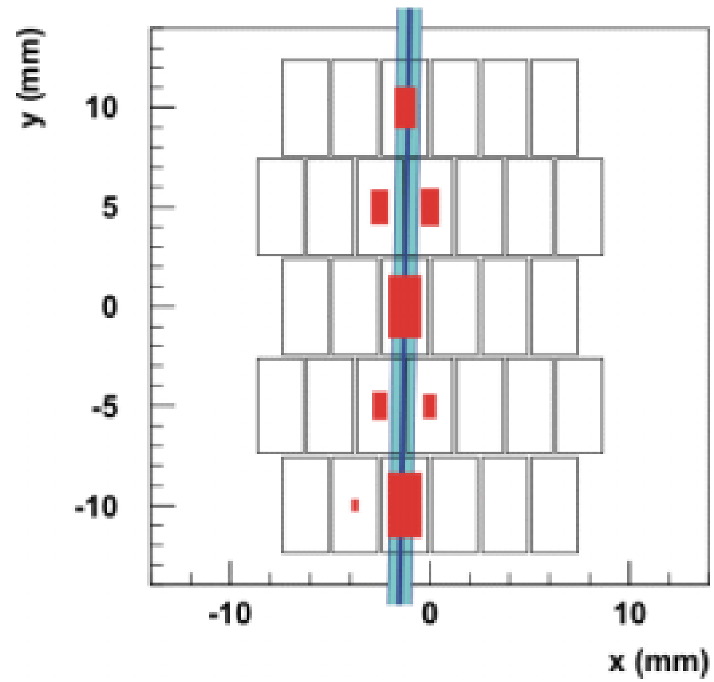
Sample events (P10, z<10 mm, |ϕ|<0.05)





Sample events (P10, z<10 mm, |ϕ|<0.05)





Future plans for Carleton studies

- Continue cosmic tracking studies
  - improve track fit program: χ^2 not done right!
    - $ArCO_2$ resolution should be better than P10!
  - comparison with simulations
  - alternative gases?
  - include calibration constants? (none so far!)
  - alternative readout pad geometries?
  - Q: can “charge sharing” signals alone provide optimal resolution and two particle separation?
  - Q: are the small induced signals helpful?
- new ideas for spreading signal over more pads
  - resistive layer above pads that absorbs charge and leave only induced signals

Summary

- Findings from charge sharing measurements:
  - Good space point resolution with relatively large pads
    - 2D Gaussian model works well
  - Good tracking resolution with relatively large pads
    - Line-Gaussian model works well
    - pad diameter ~ 4 × transverse diffusion is ok
    - do not need to increase transverse diffusion to match pad diameter!

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