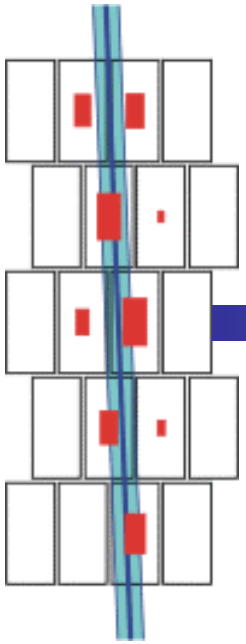


Linear Collider TPC R&D at Carleton University

ECFA-DESY Linear Collider Workshop

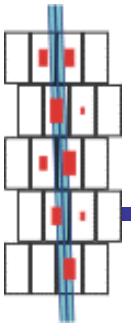
St. Malo, France

April 12-15, 2002

Dean Karlen / Carleton University

Carleton/Montreal GEM/TPC group: Bob Carnegie, Madhu Dixit, D.K., Ernie Neuheimer, Hans Mes, Jean-Pierre Martin, Kirsten Sachs

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

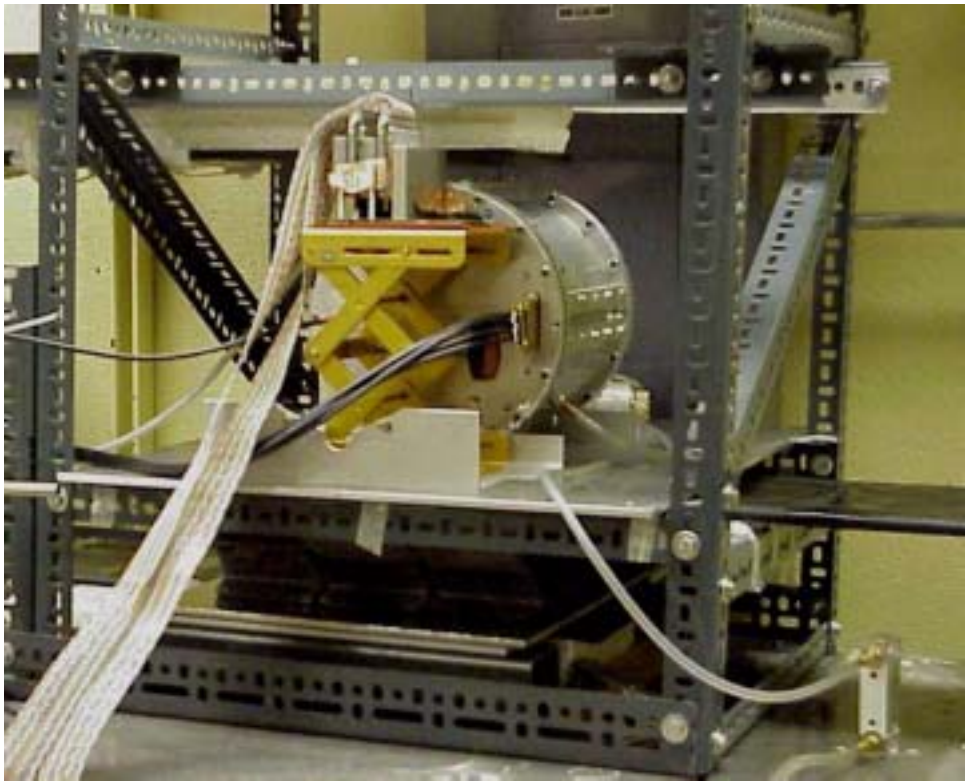


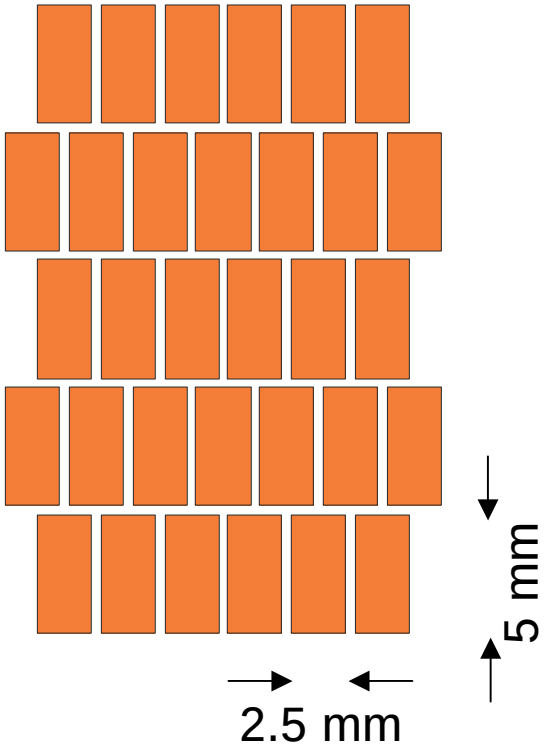
TPC R&D: recent results & plans

- Cosmic ray tracking studies (TPC#1)
  - data from Oct-Dec 2001
  - new fitting algorithm
- Simulation program
  - demonstration
  - comparison of data and MC
- Plans for new layout for readout pads
- Plans for new TPC (TPC#2)
  - concept / drawings
- Resistive Anode Studies

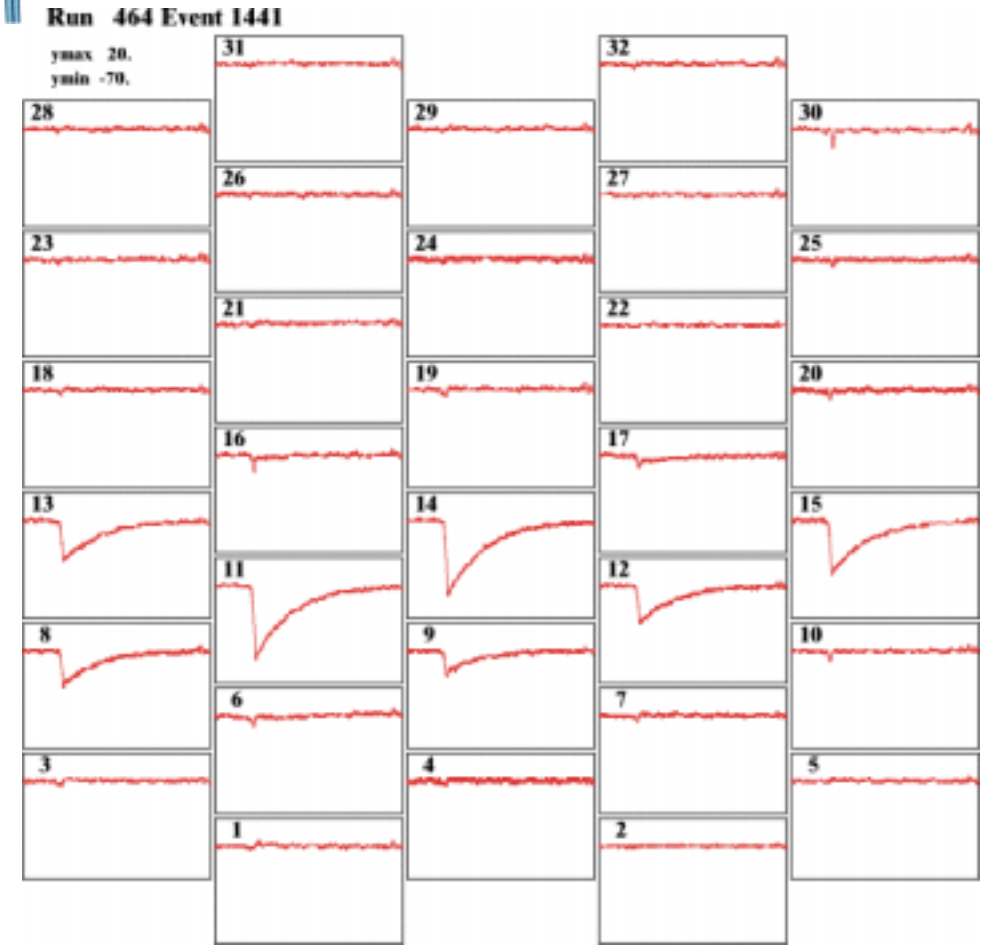
Tracking studies

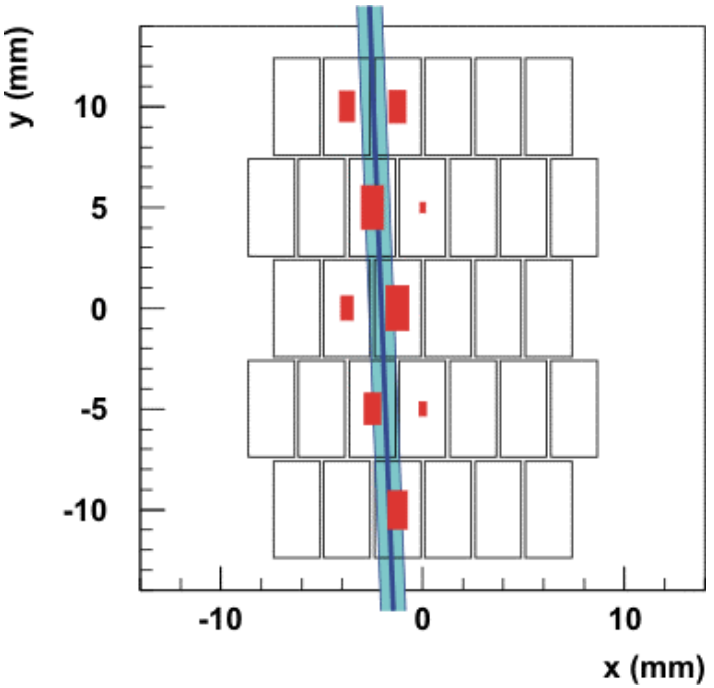
- Cosmic ray telescope
- Readout pad layout



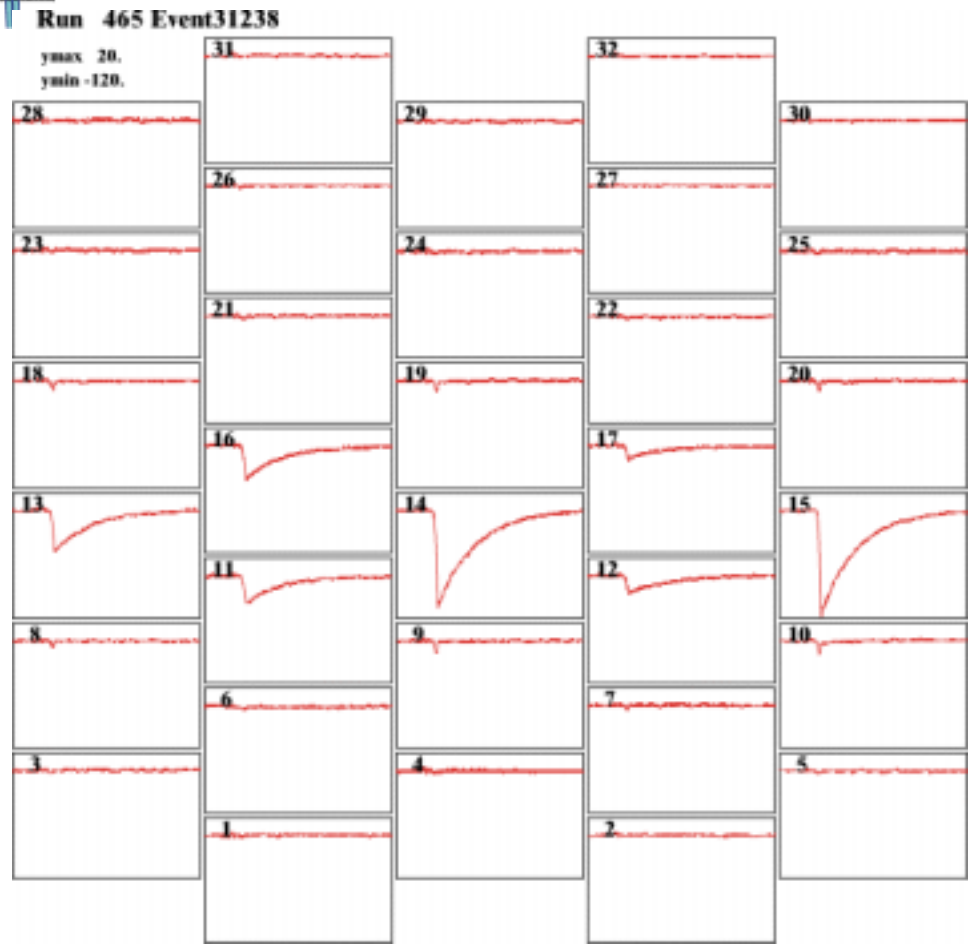


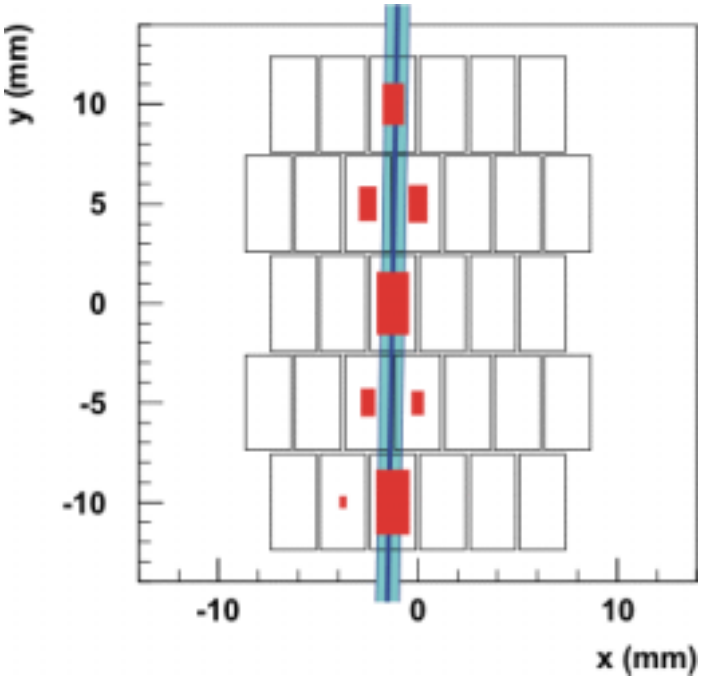
Sample events (P10, z<10 mm, |ϕ|<0.05)





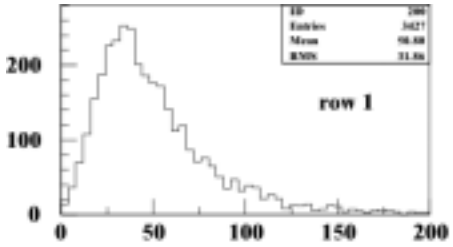
Sample events (P10, z<10 mm, |ϕ|<0.05)

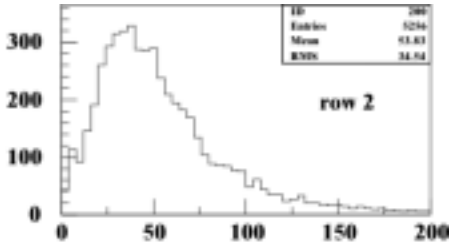


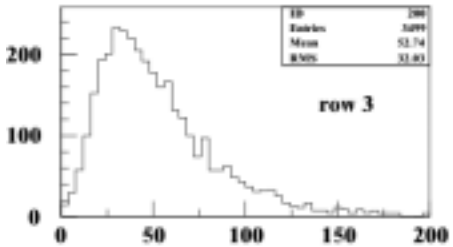


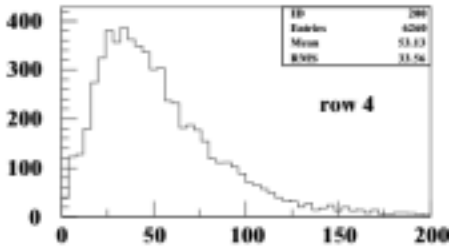
Gain stability – P10

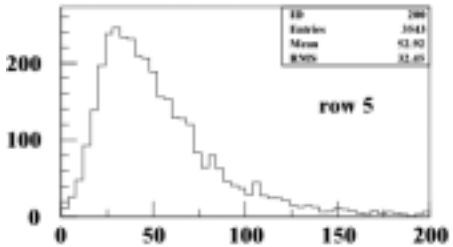
- Charge per row



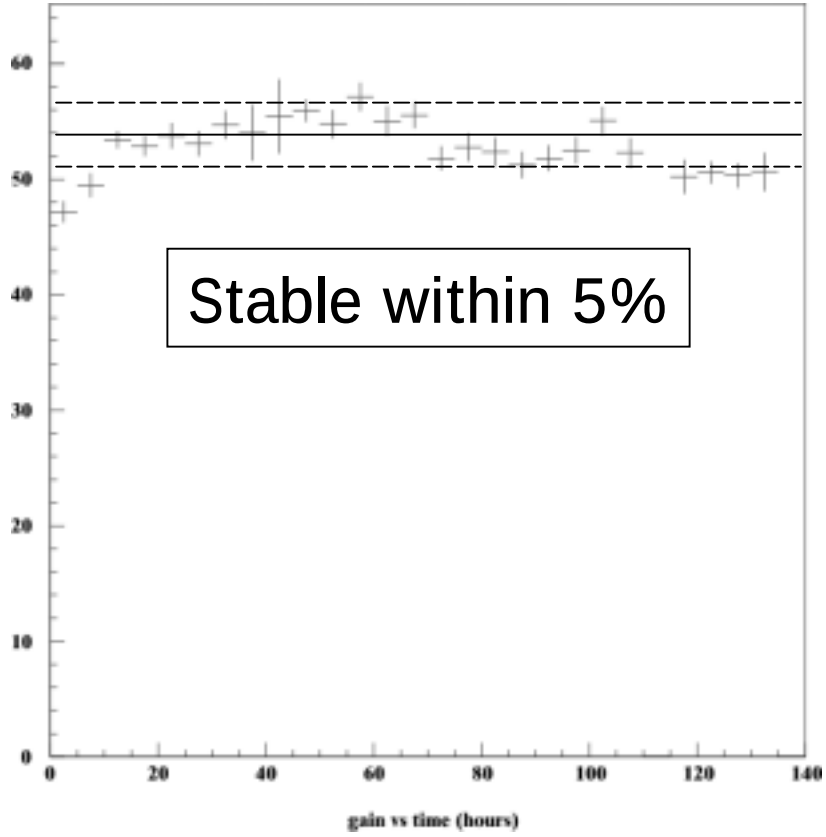






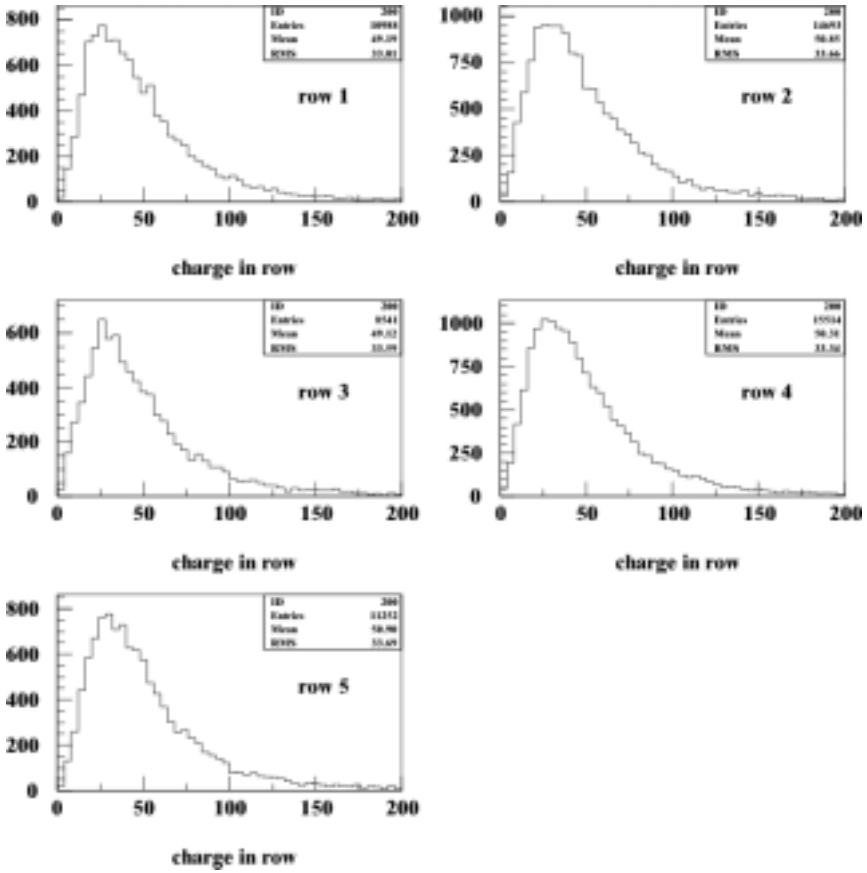


- Charge vs time

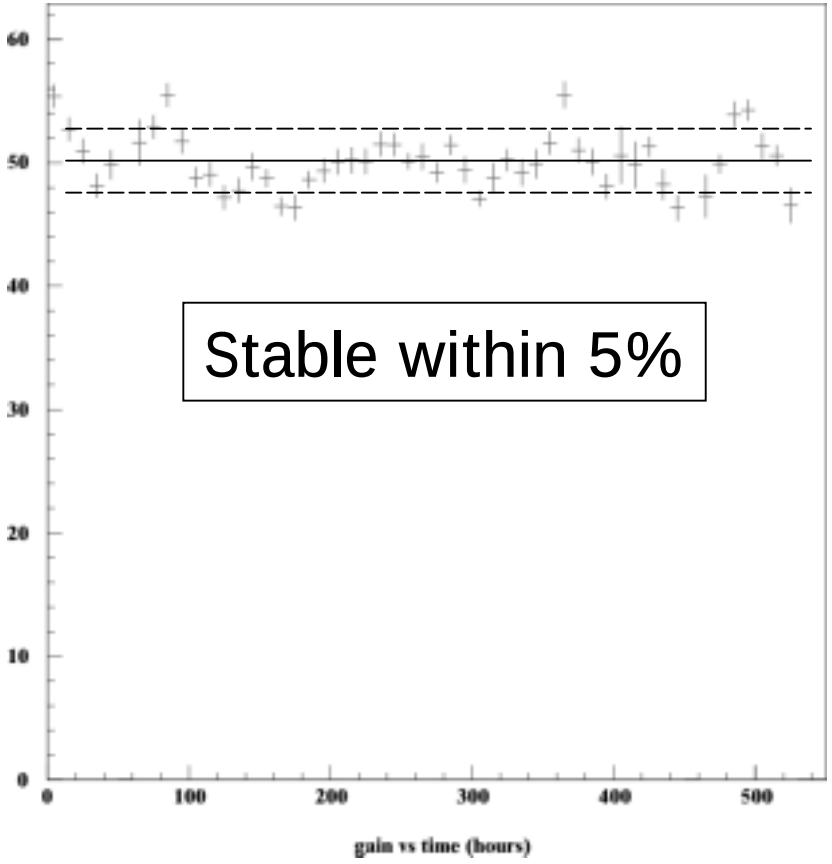


Gain stability – Ar CO_2

- Charge per row

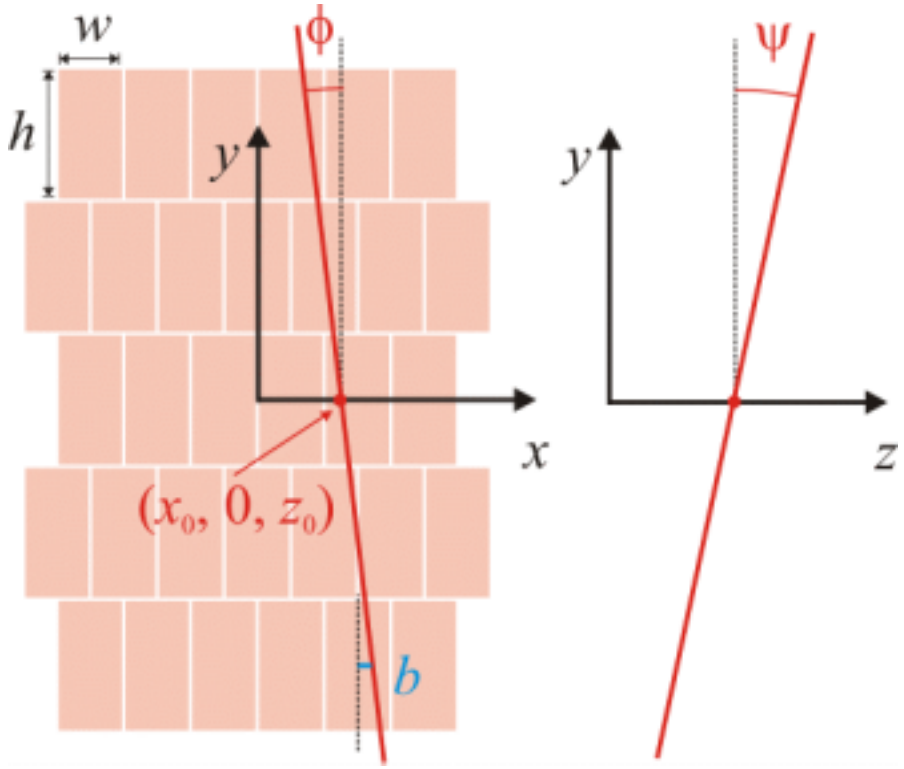


- Charge vs time



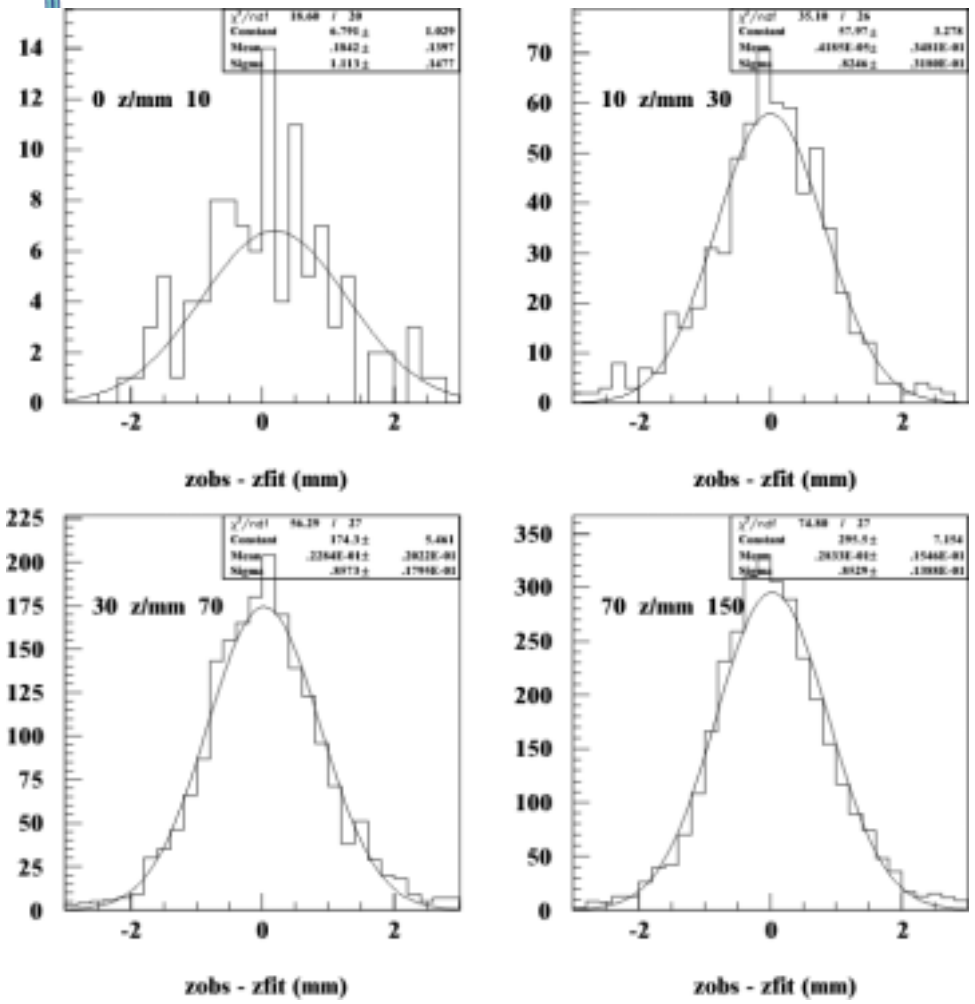
Tracking studies

- Fit x-y and y-z separately



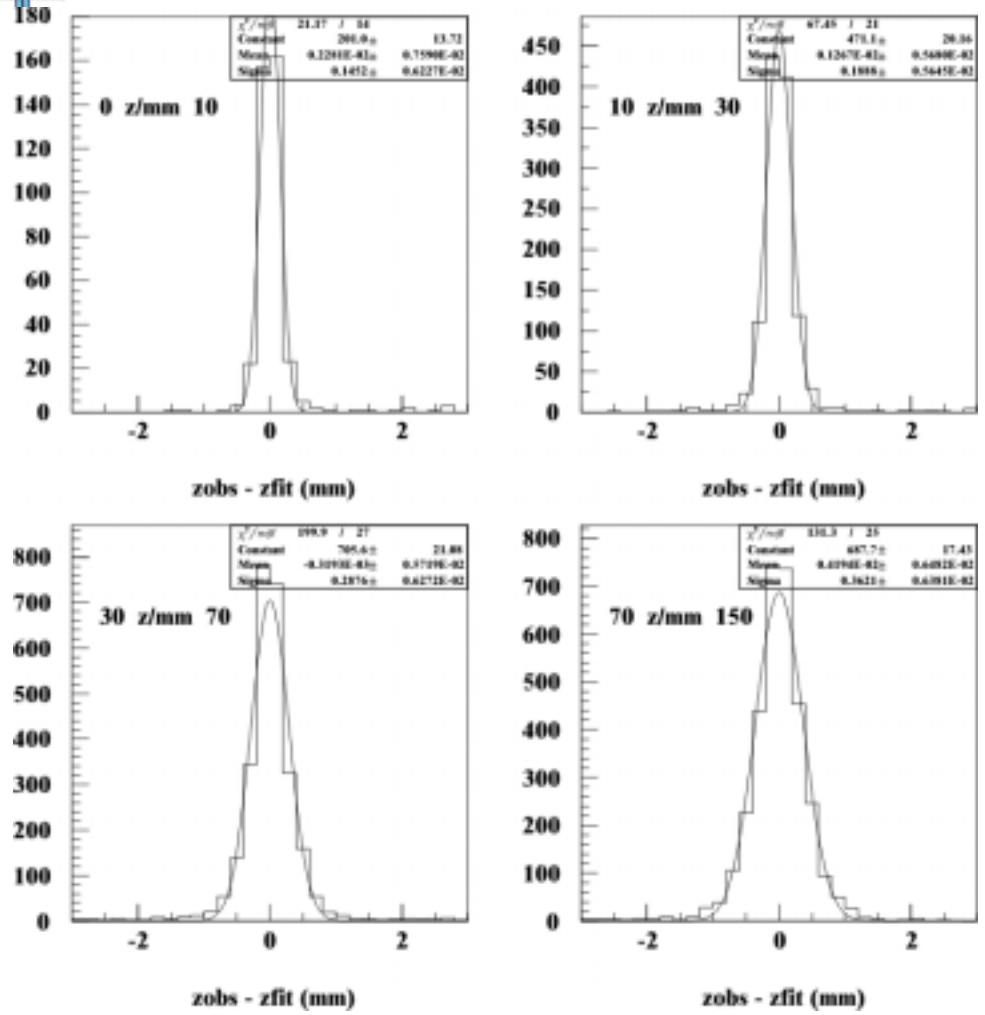
- y-z fit:
  - for each row form weighted average of pulse arrival time
  - perform unweighted linear fit of the 5 row y-coordinates vs row times
  - pulse arrival time (50% rise) dependant on pulse amplitude
    - needs further study

y-z fit results – P10



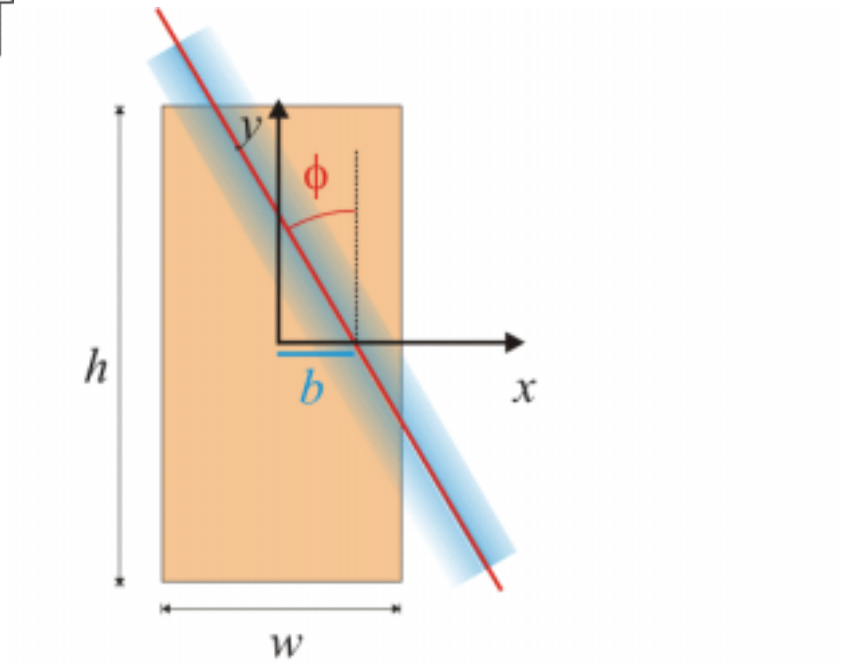
- Not diffusion limited
  - pulse arrival time definition needs improving
  - 800 micron resolution independent of drift length
  - v_d ~ 50 μm/ns

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 ~ 9 μm/ns

x-y fit



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

$$= \eta(b,\phi,\sigma,h,w) - \eta(b,\phi,\sigma,-h,w) + \eta(b,\phi,\sigma,-h,-w) - \eta(b,\phi,\sigma,h,-w)$$

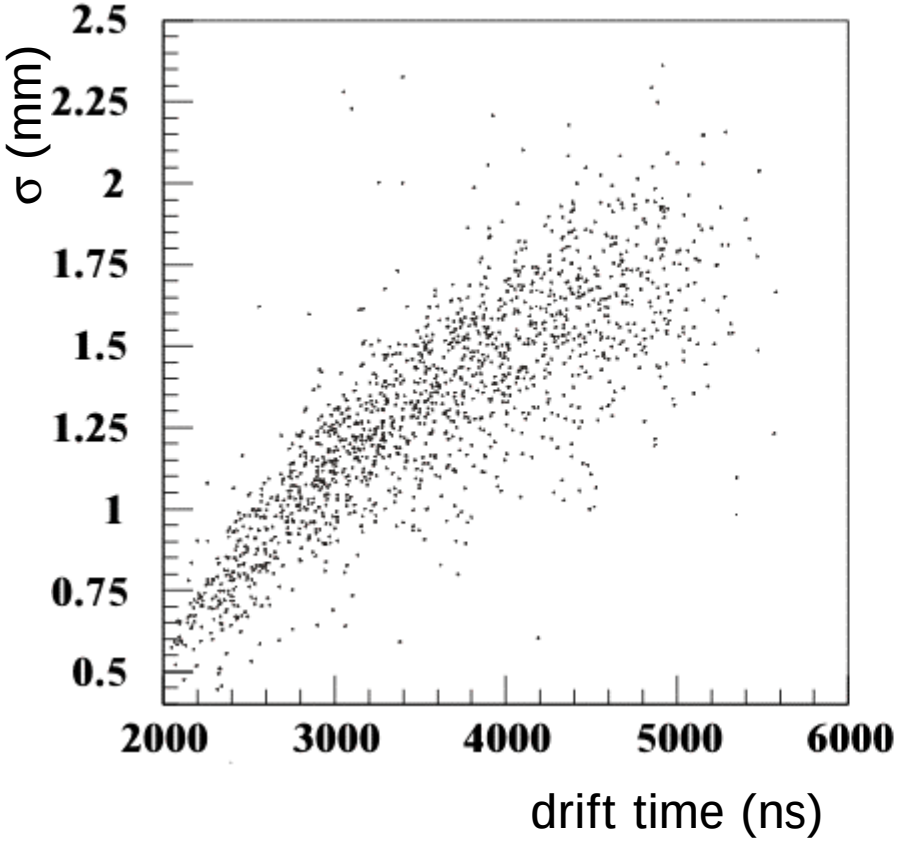
$$\eta(b,\phi,\sigma,h,w) = \frac{1}{\cos\phi \sin\phi} \xi\left((b+\frac{w}{2})\cos\phi + \frac{h}{2}\sin\phi, \sigma\right)$$

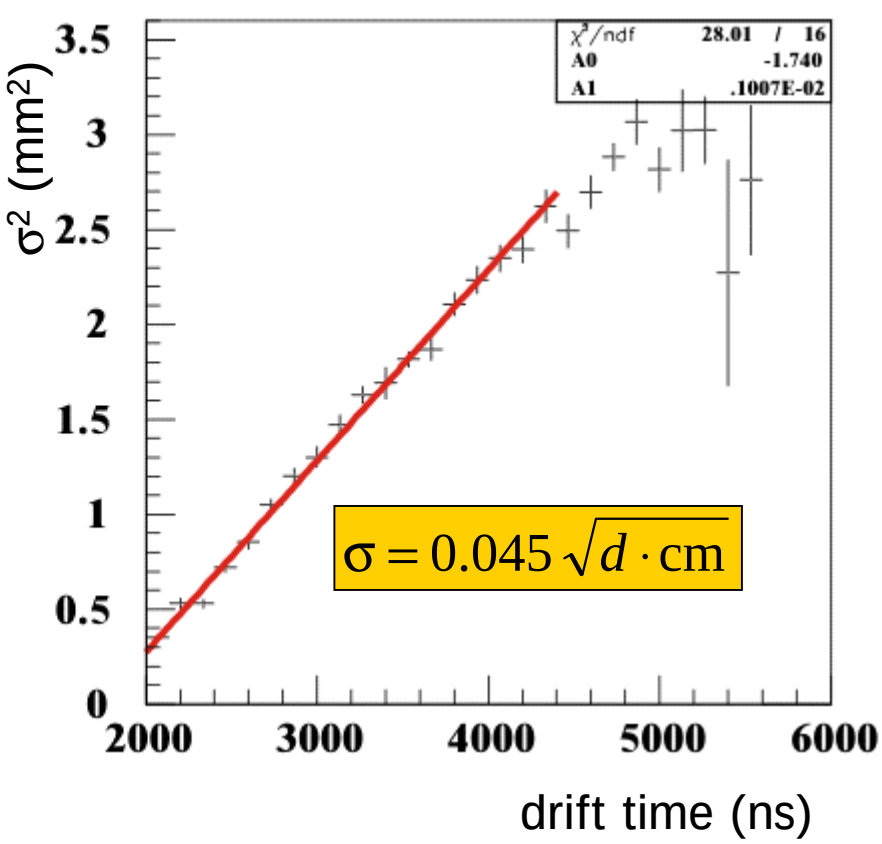
$$\xi(u,\sigma) = \frac{u}{2}\mathrm{erf}\left(\frac{u}{\sqrt{2}\sigma}\right) + \frac{\sigma}{\sqrt{2\pi}}\exp\left(\frac{-u^2}{2\sigma^2}\right)$$

- 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

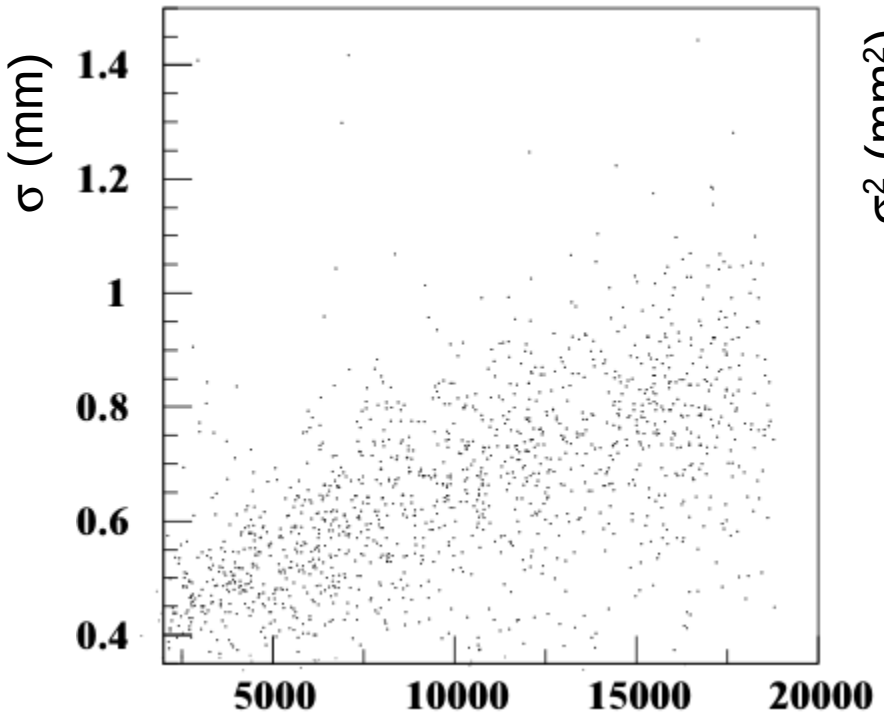
- Results from fit of data: diffusion apparent

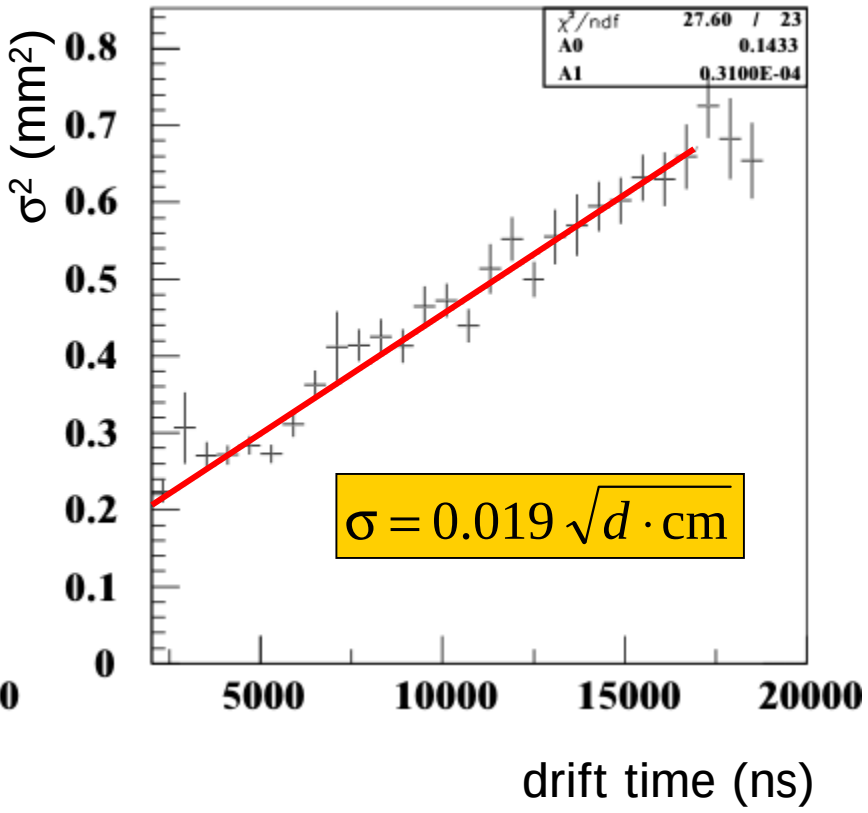




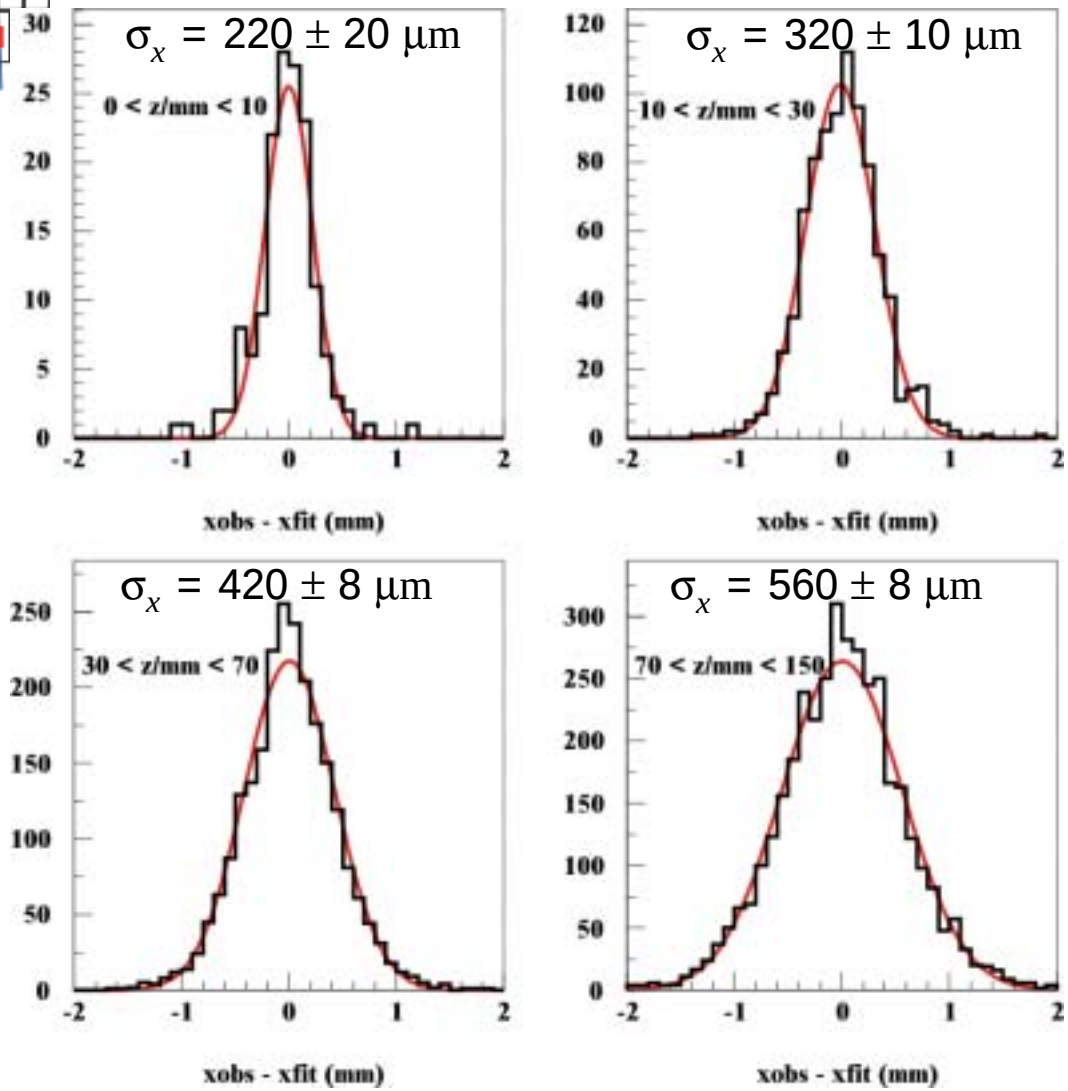
Line charge width – Ar CO_2

- Results from fit of data: diffusion apparent



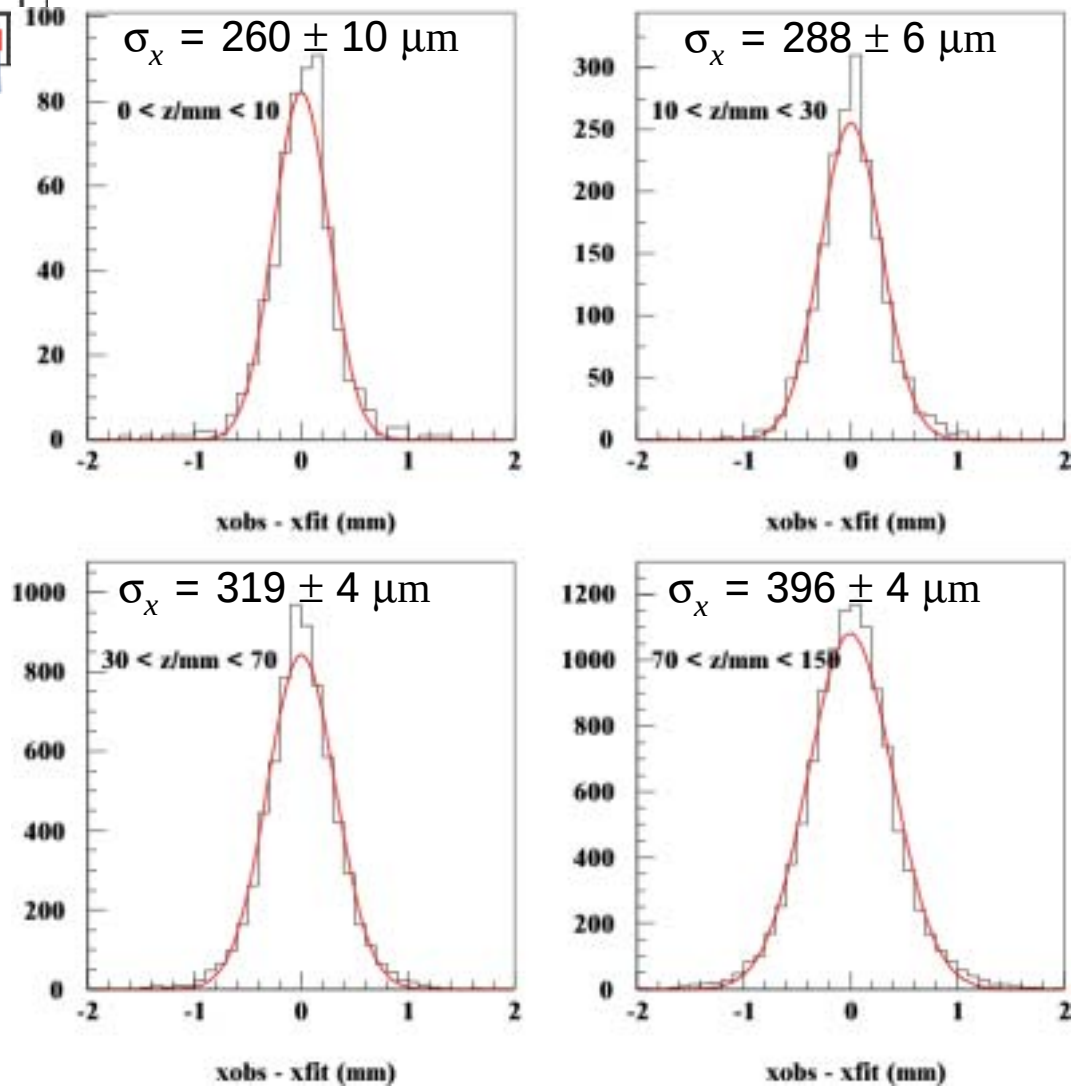


Track x_0 resolution – P10



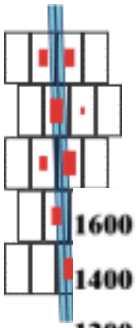
- x_0 resolution from single row:
  - do fit excluding the row: x_0, ϕ, σ free
  - do fit for single row: only x_0 free
  - compare 1 row x_0 to 4 row x_0

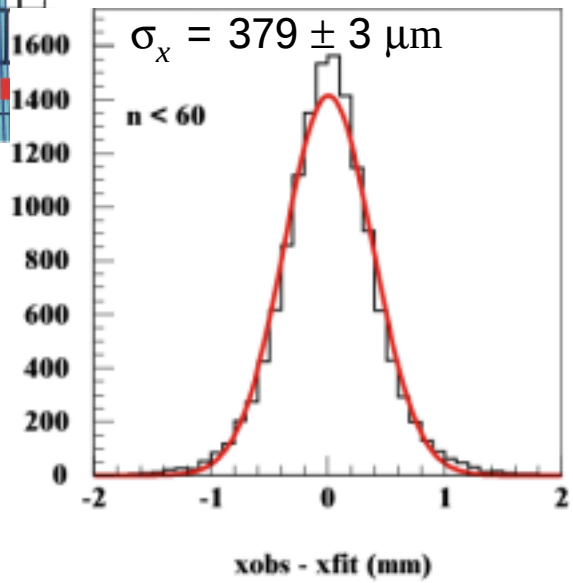
Track x_0 resolution – Ar CO_2

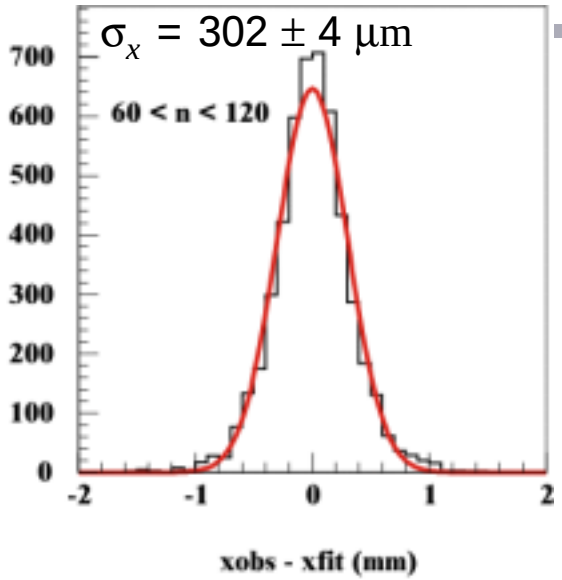


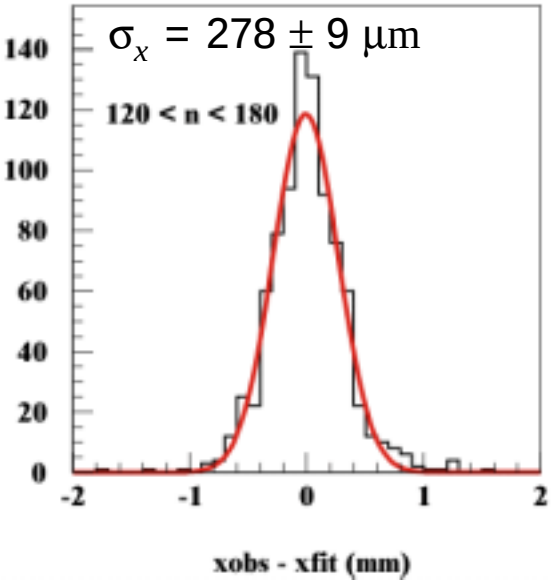
- x_0 resolution from single row:
  - do fit excluding the row:
    - x_0, ϕ free
    - σ fixed
  - do fit for single row: only x_0 free
  - compare 1 row x_0 to 4 row x_0

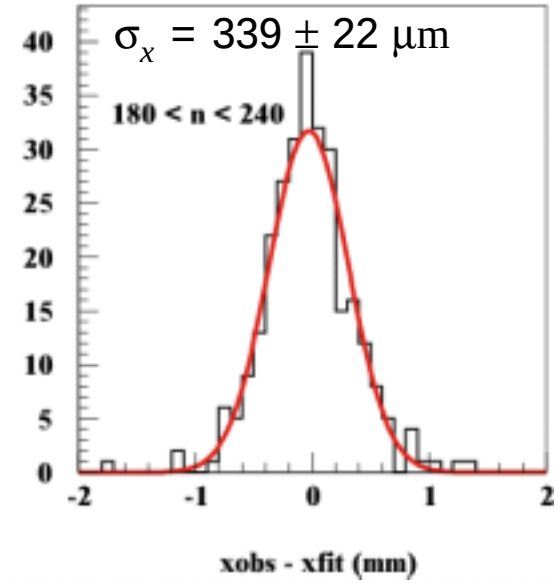
Primary ionization effect – Ar CO_2



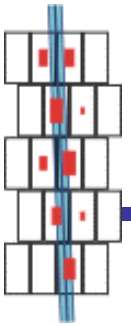








- improvement of resolution with primary electron statistics
- for large ionisation resolution degrades
  - delta-rays



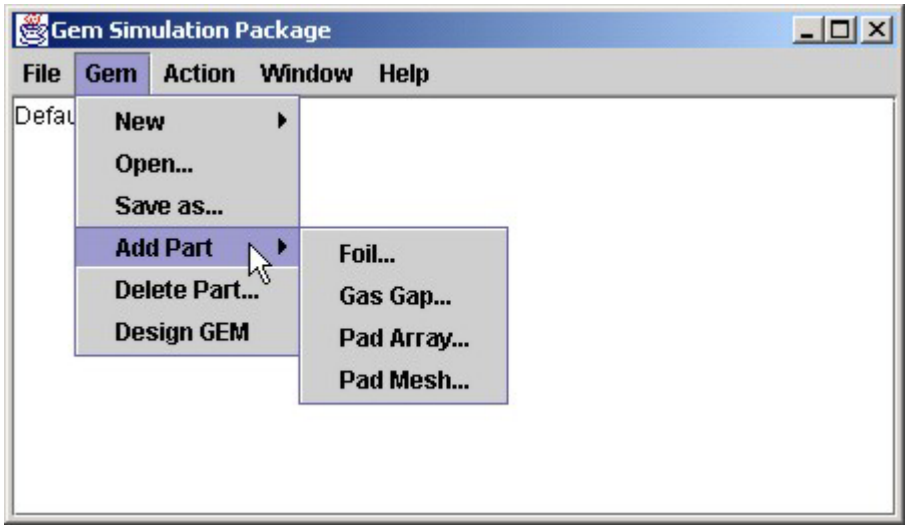
New fitting algorithm

- First fitting algorithm minimized χ^2 of comparison between observed and expected charge fractions in each row
  - observed fractions are correlated (ignored)
  - covariance depends on number of primary electrons observed (ignored)
- New scheme: use multinomial likelihood

$$\log L = \sum_{i=1}^{npad} n_i \log(p_i) + \text{constant}$$

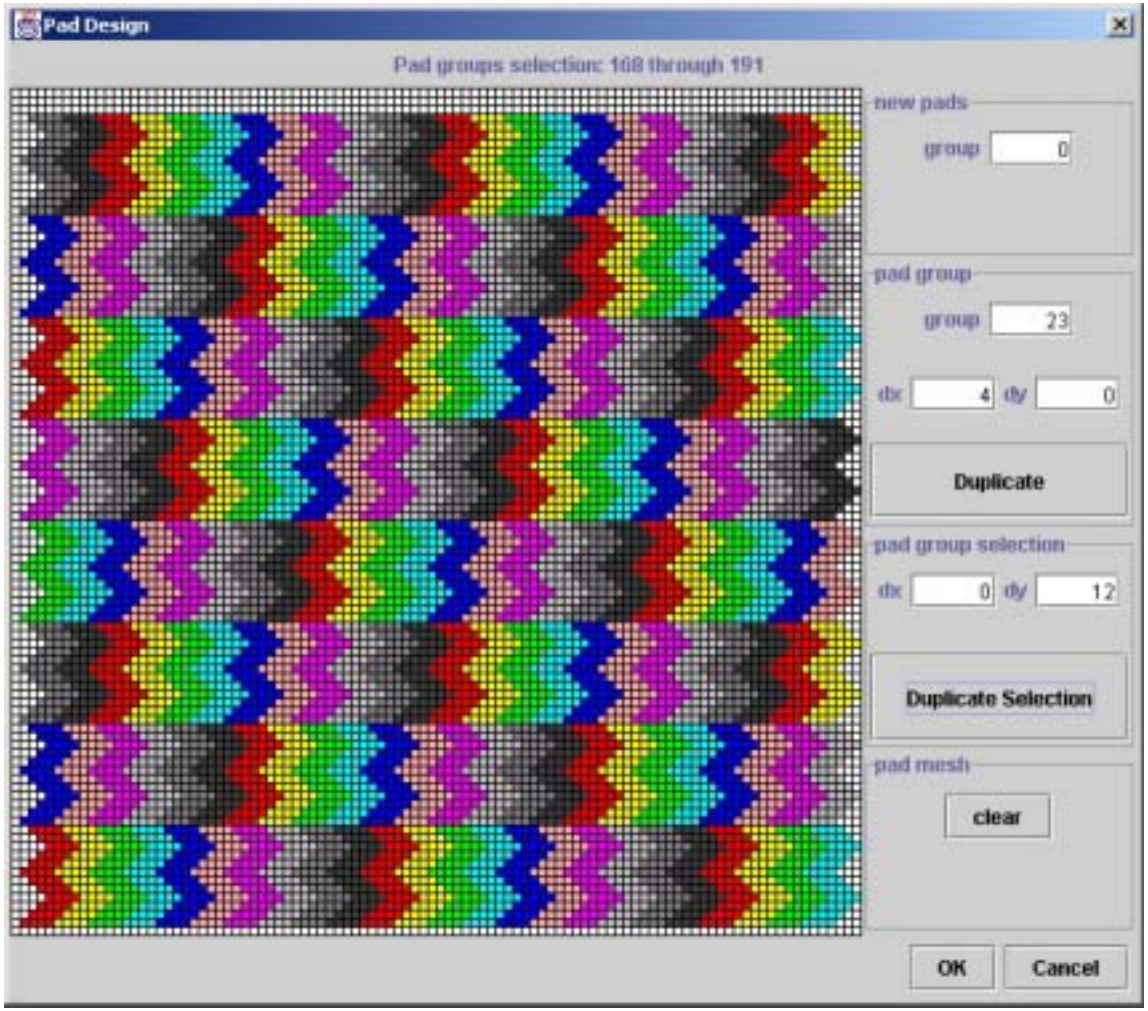
GEM simulation package

- written in java
- simulates any planar GEM system
  - version 1.0 (alpha) released
  - see: www.physics.carleton.ca/~karlen/gem



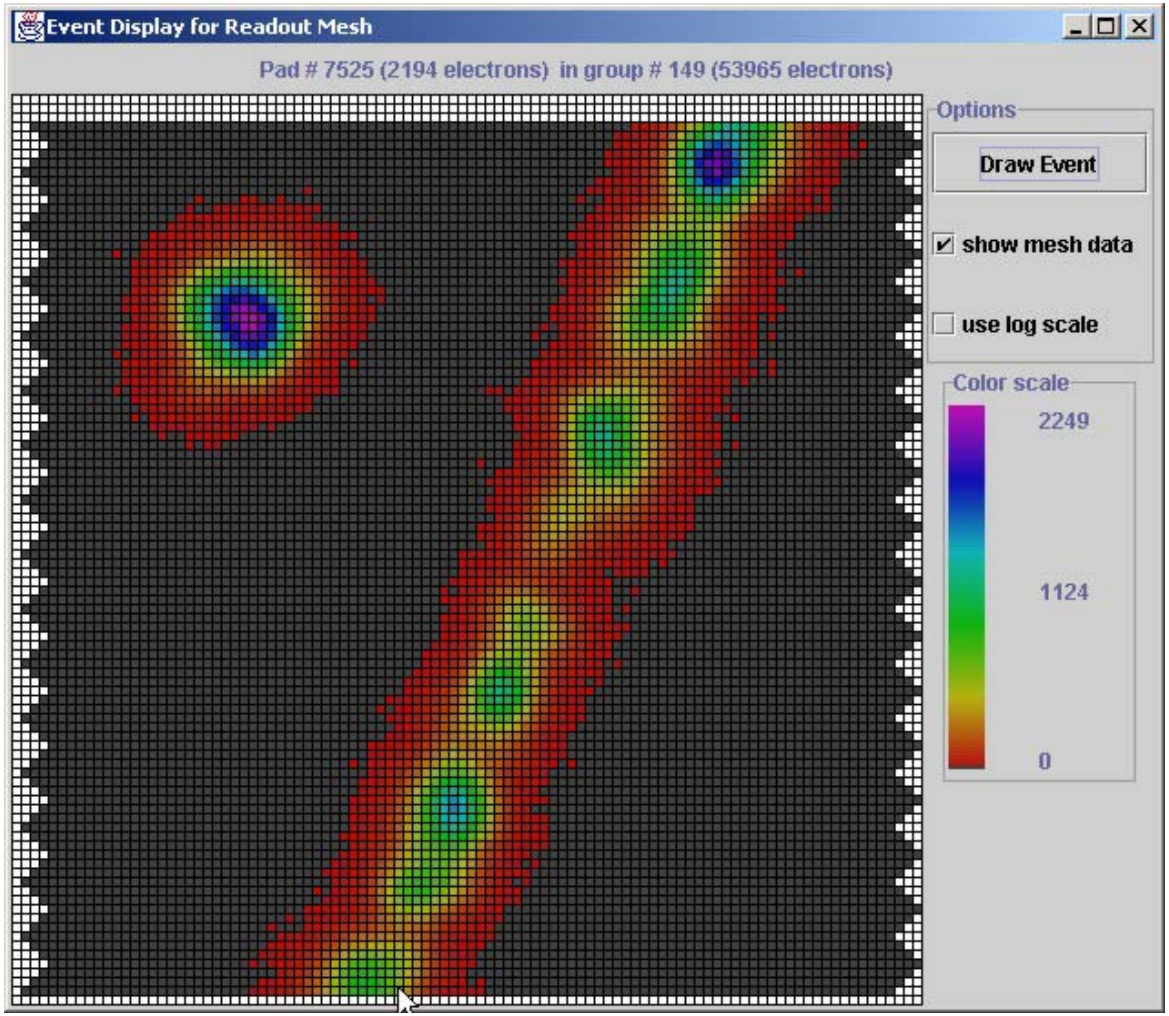
GEM simulation package

- Arbitrary pad designs can be defined:



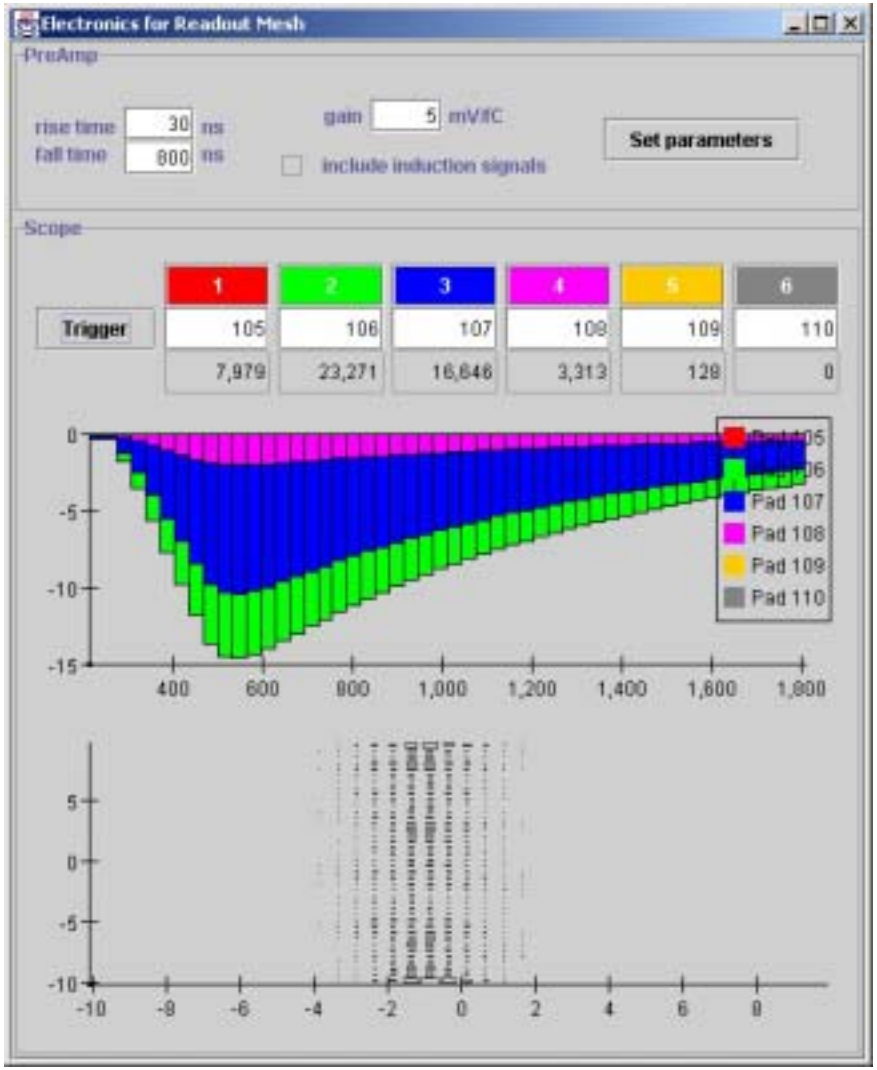
GEM simulation package

- Example of line charge and electron cloud (viewed with 0.2 mm elements).



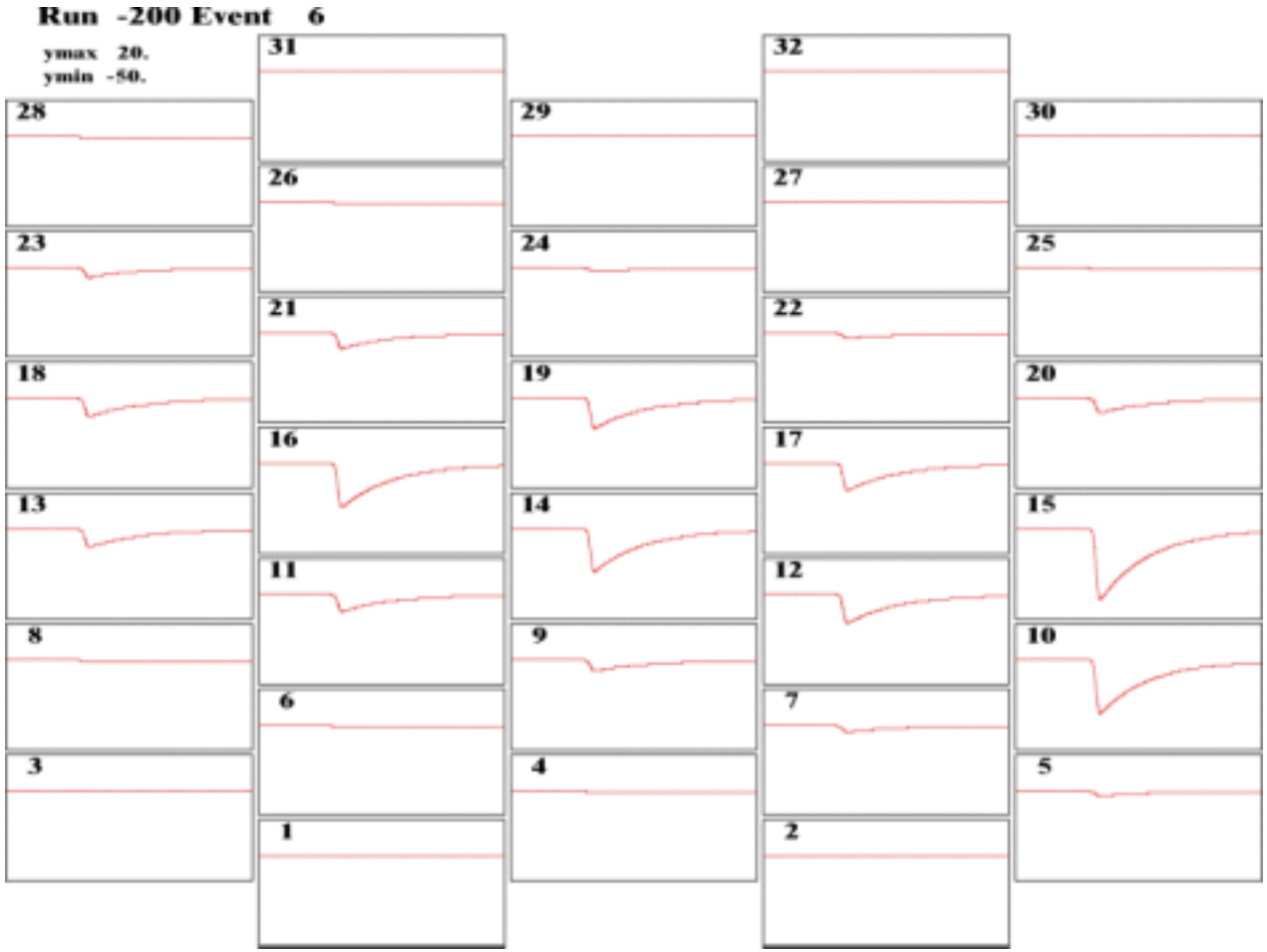
GEM simulation package

- Time structure of event shown using histogrammer from the Java Analysis Studio (Tony Johnson)



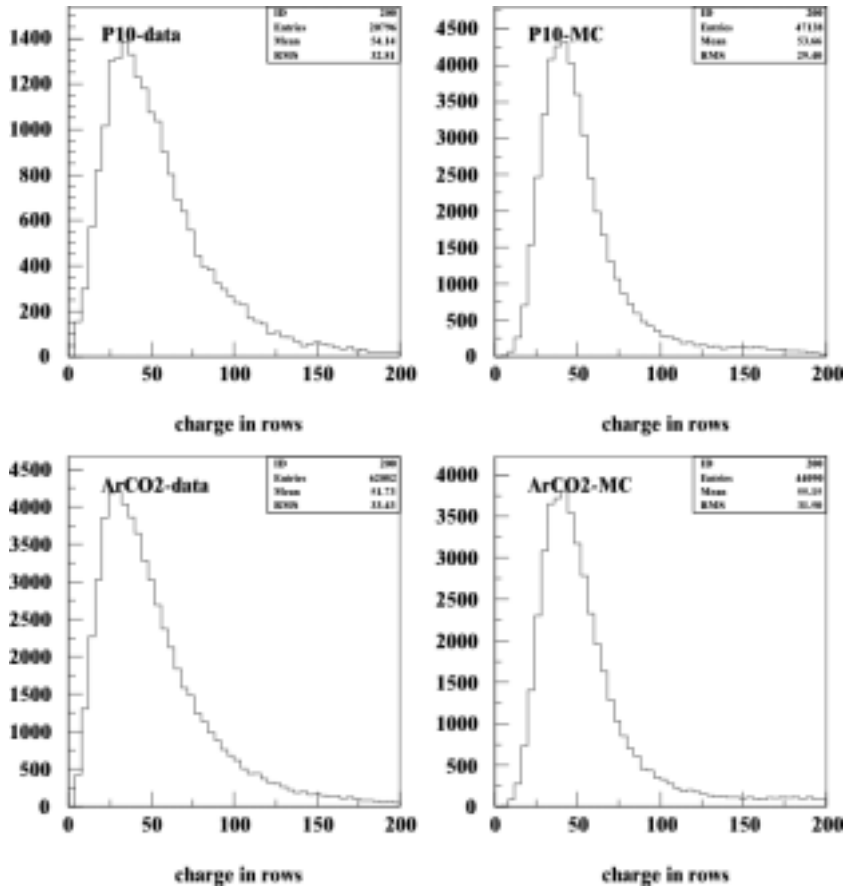
Gem simulation package

- Example event:



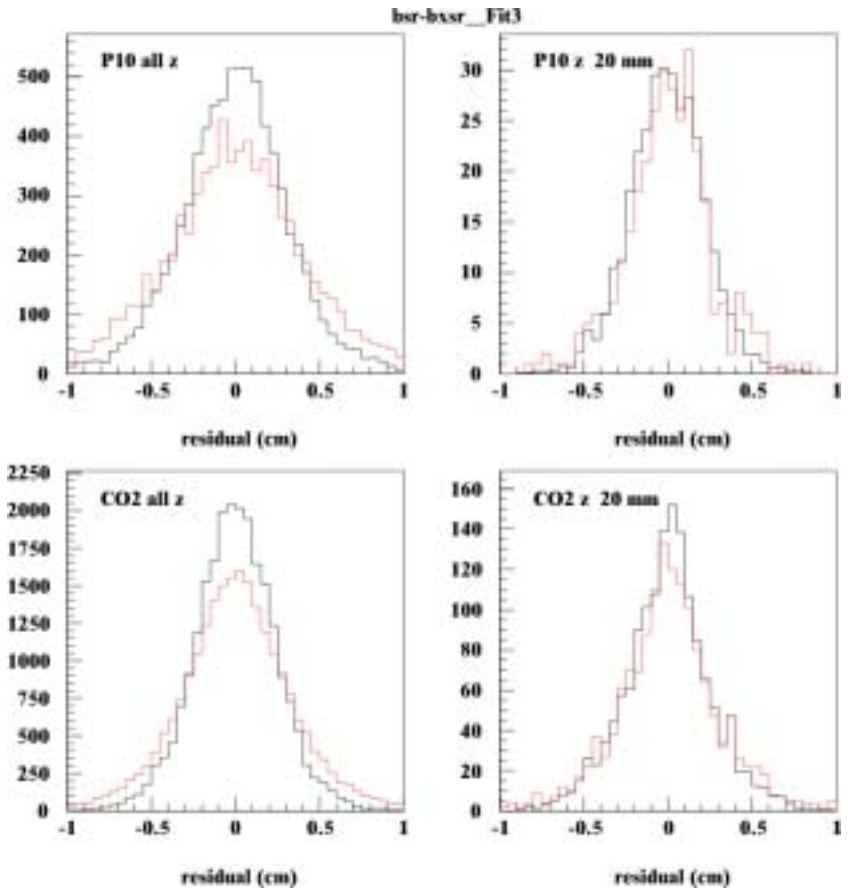
Comparison of data and MC

- Total charge collected per row:



Comparison of data and MC

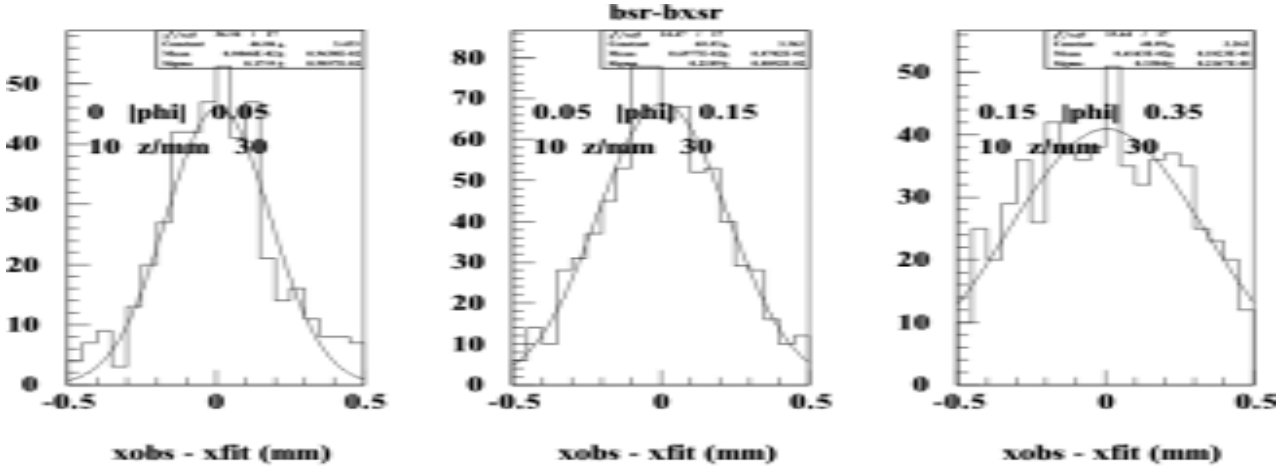
- Early stages
  - x resolution fairly well simulated
  - x resolution measurement
    - red = data
    - black = MC
  - time structure not yet well simulated



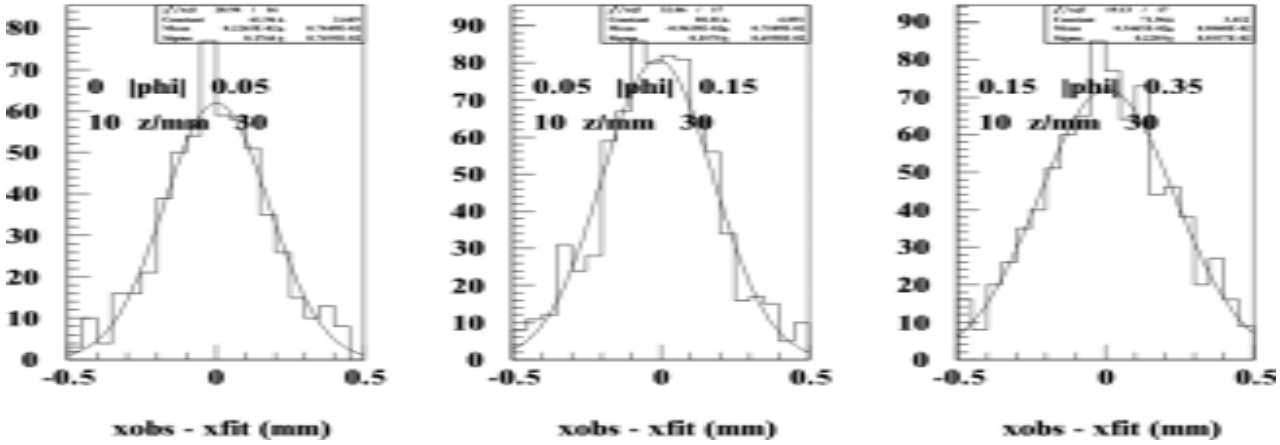
Comparison of data and MC

- Track angle effect:

Data

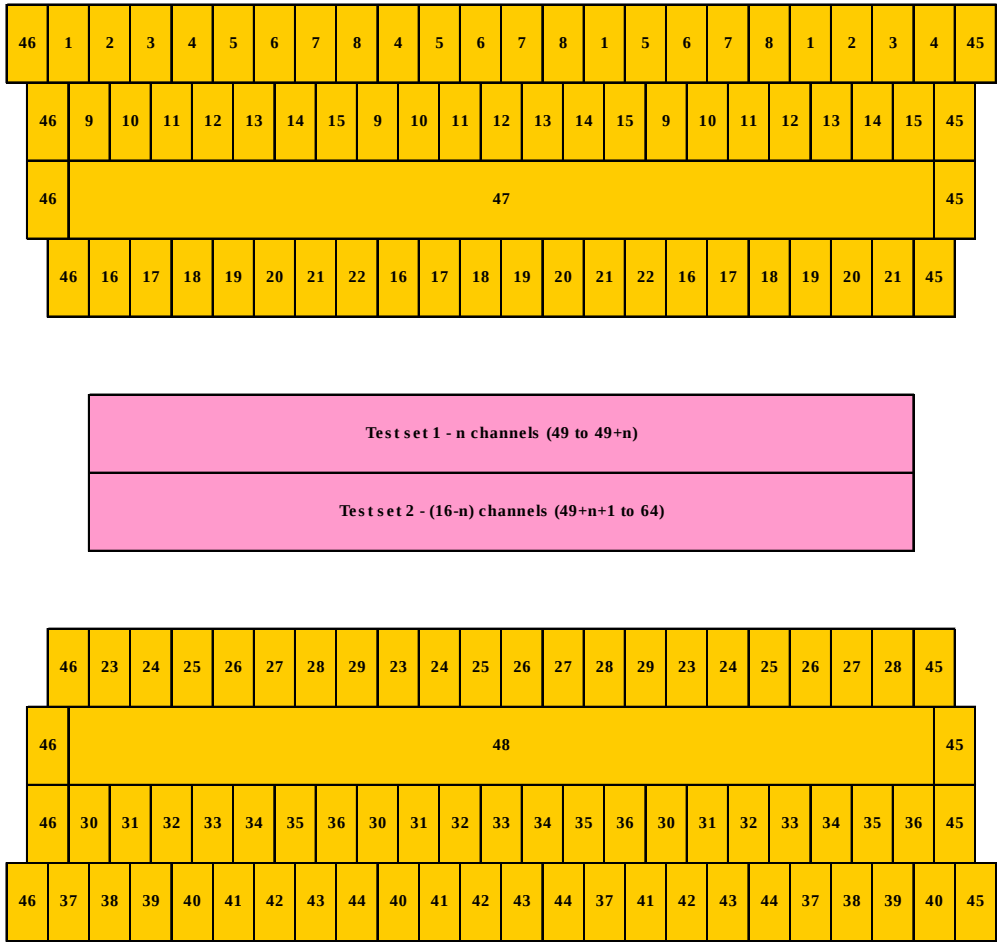


MC



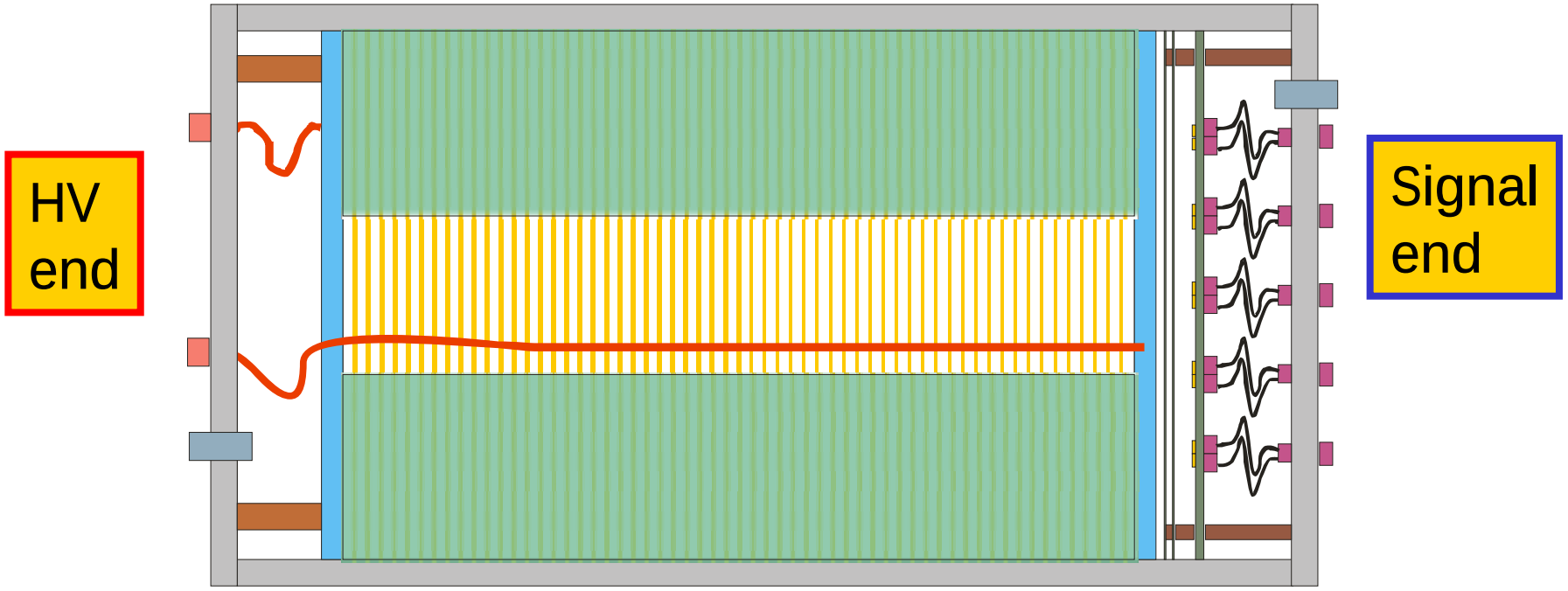
New layout for readout pads

- Plan to use 3x multiplexing to readout 192 pads with 64 channels of FADC
  - easy for cosmics, multiplicity is low!
  - should we consider multiplexing for the real TPC?
  - use long pads for triggering



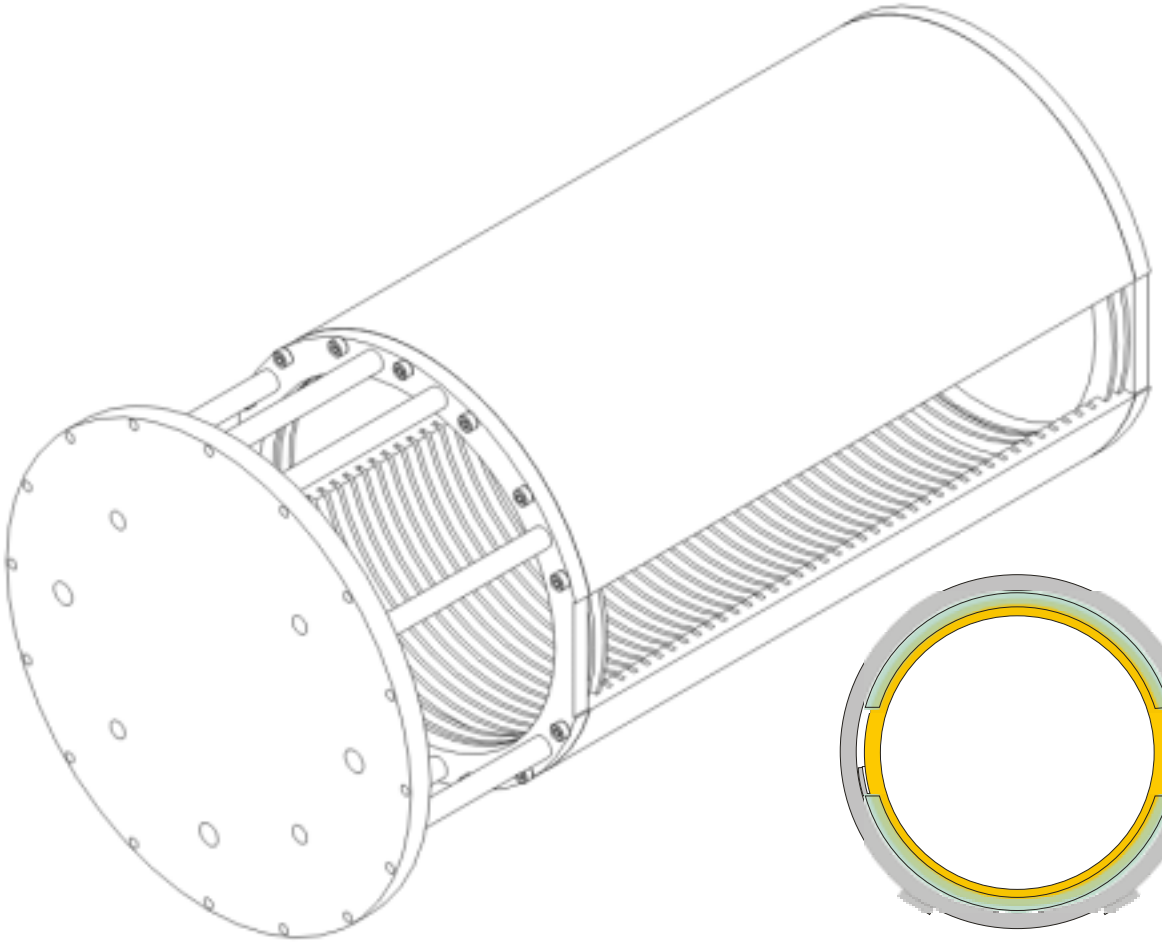
Plans for a new TPC (TPC #2)

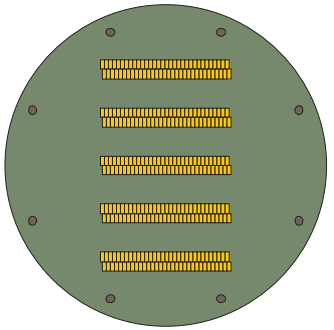
- Cylindrical, fits TRIUMF (1T) and DESY (5T) magnets
  - acrylic tubes, outer diameter 22.2 cm
- Use STAR-TPC electronics (space for 320 channels)

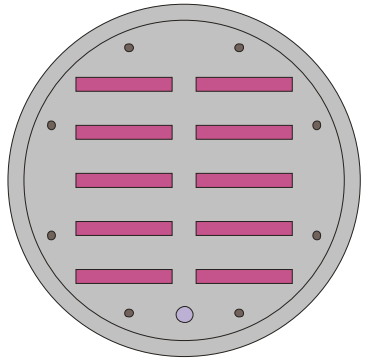


Plans for a new TPC (TPC #2)

- 3D view of drift cage

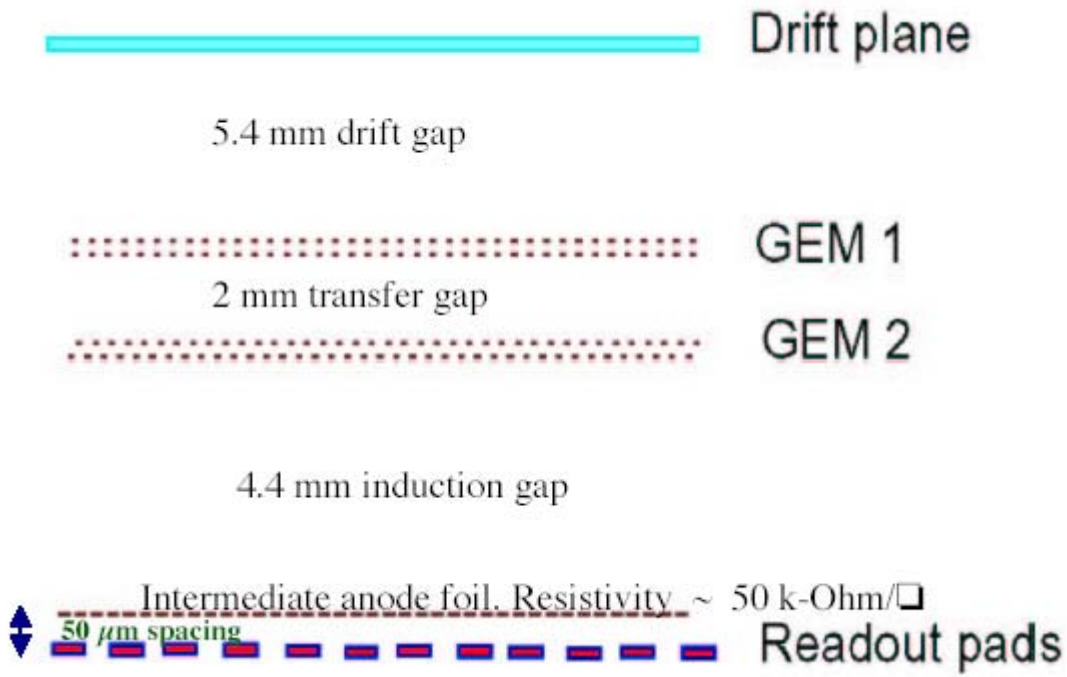


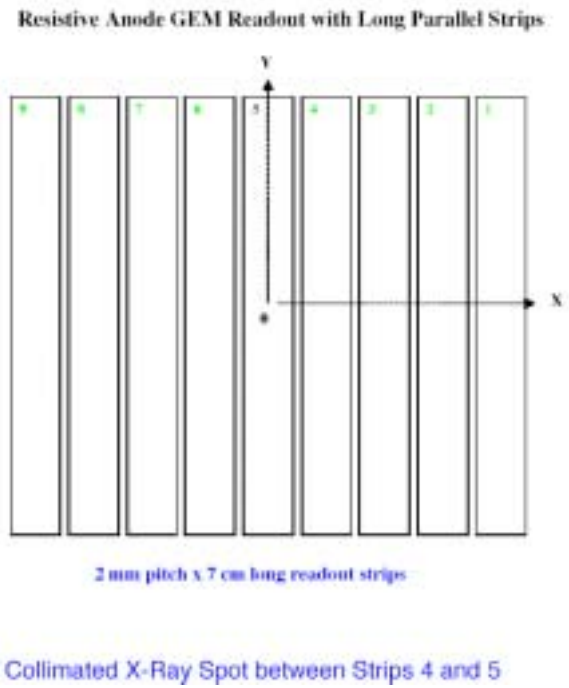




Resistive Anode Studies

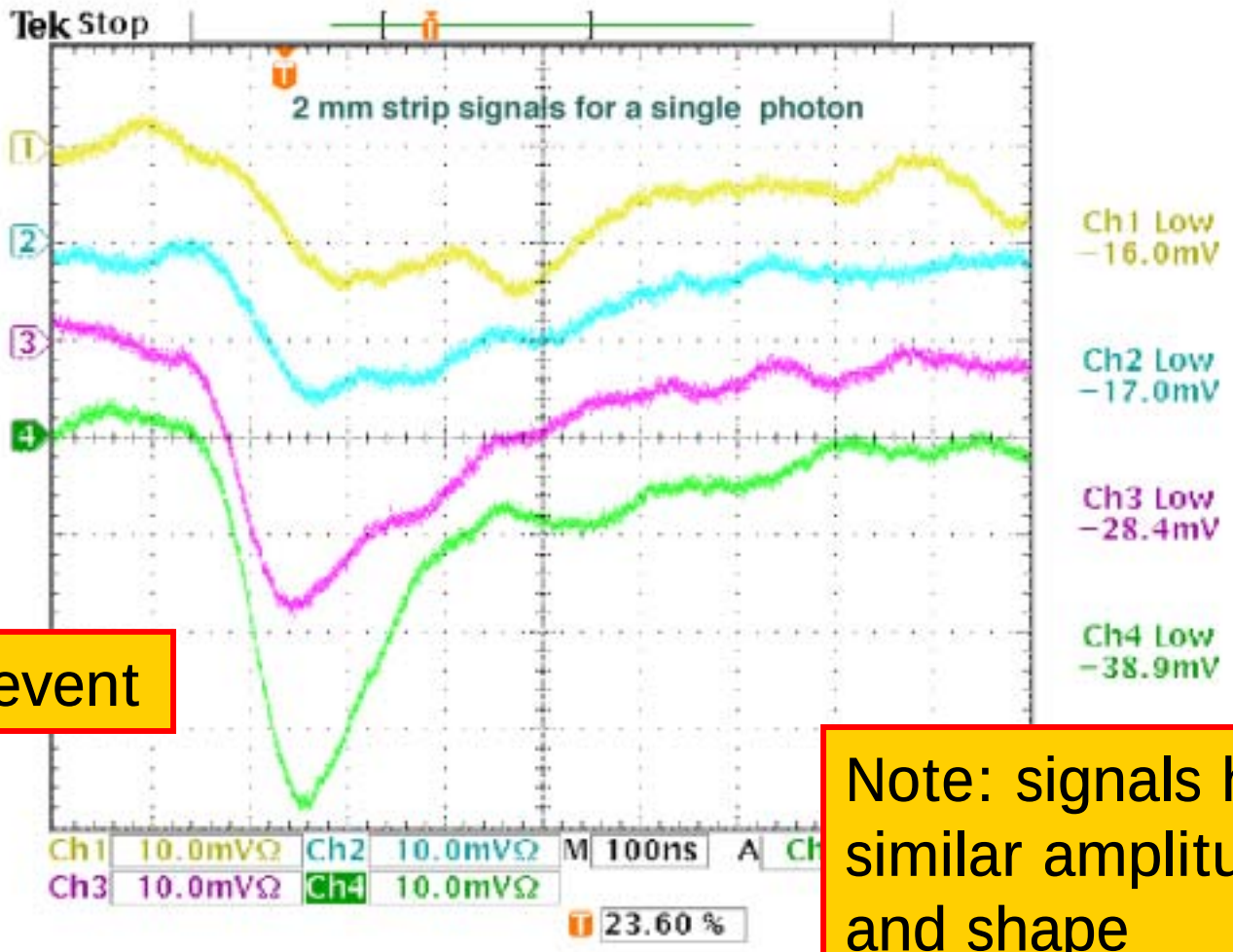
Test set-up:





Collimated X-Ray Spot between Strips 4 and 5

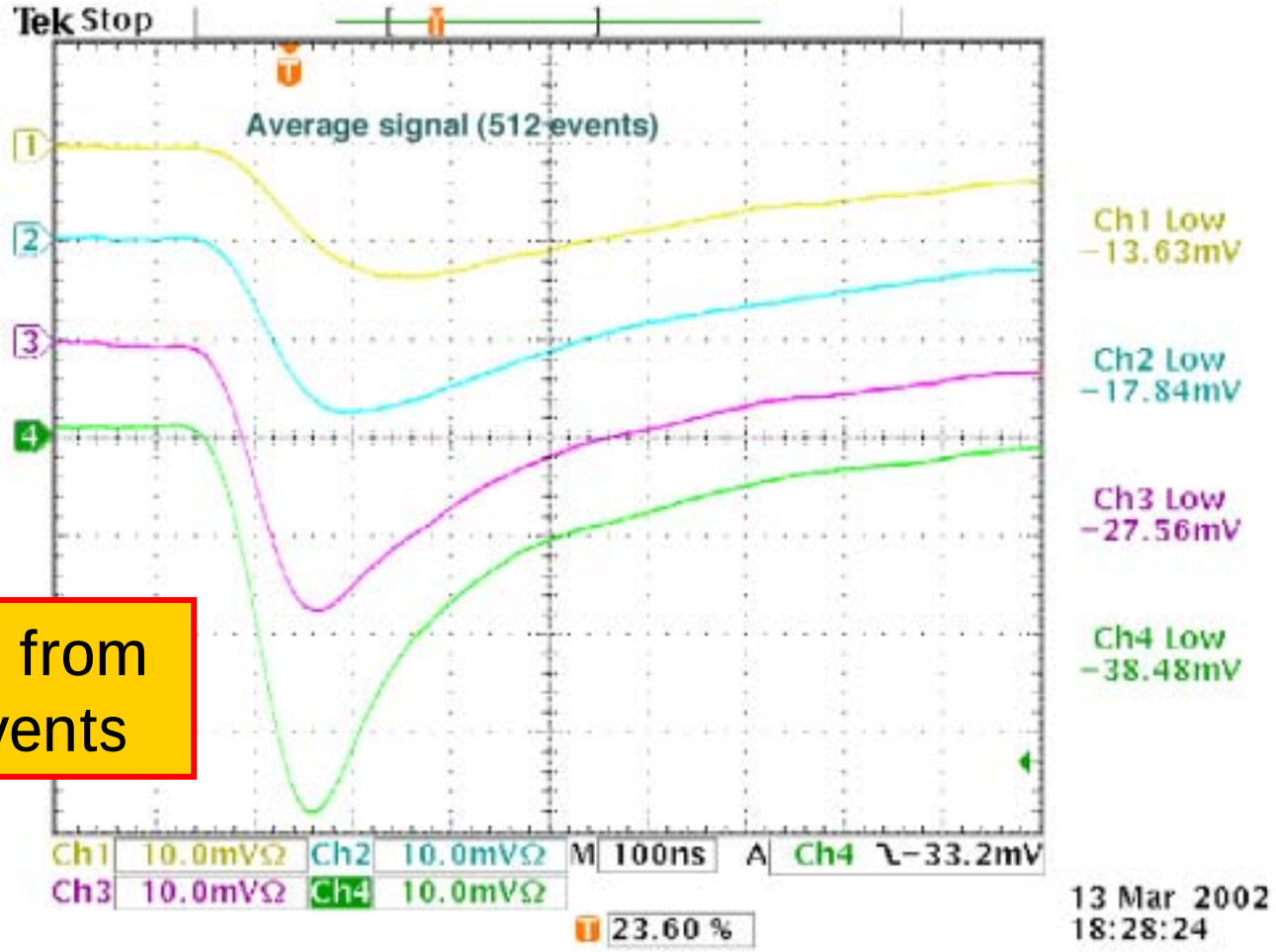
Resistive Anode Studies



Single event

Note: signals have similar amplitude and shape

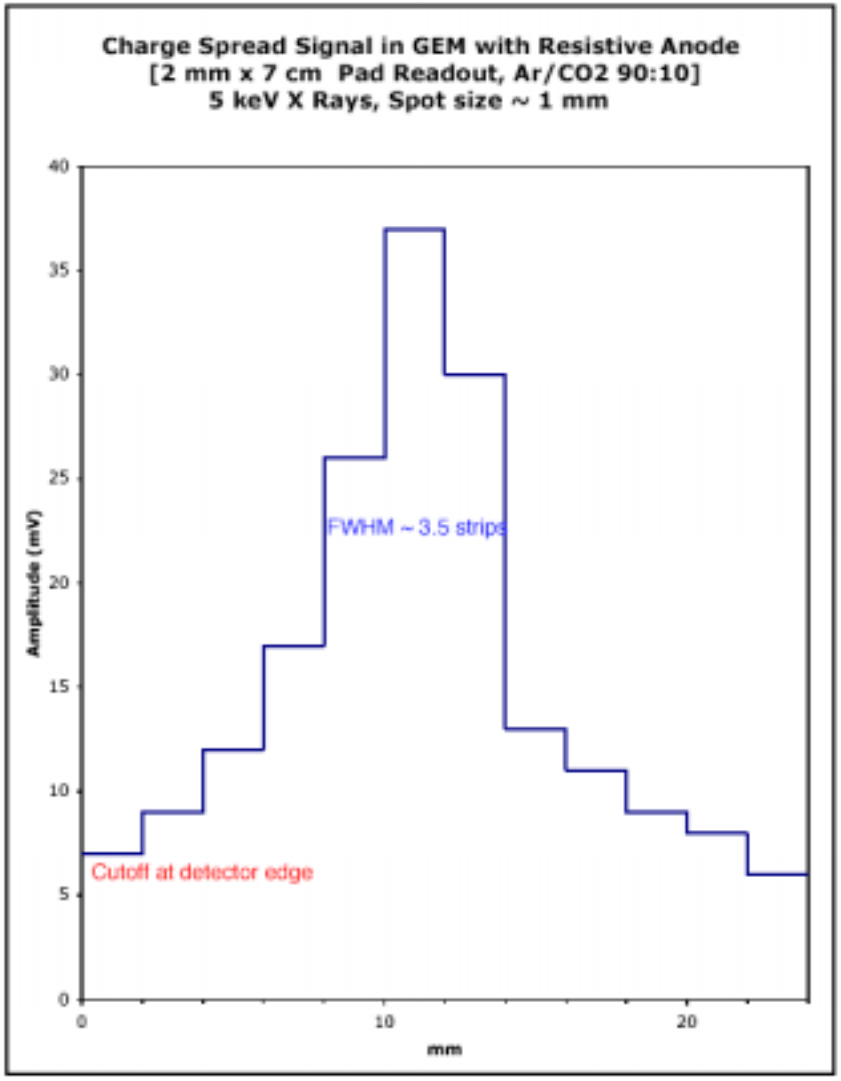
Resistive Anode Studies



Average from many events

Resistive Anode Studies

Average signal profile across 12 strips



Resistive Anode Studies

Theory

Consider a GEM with a resistive anode. Anode collects avalanche charge. Any localized charge signal will spread radially with time. The 2-D Telegraph equation:

$$\frac{\partial Q}{\partial t} = \frac{1}{RC}\left[\frac{\partial^2 Q}{\partial r^2} + \frac{1}{r}\frac{\partial Q}{\partial r}\right]$$

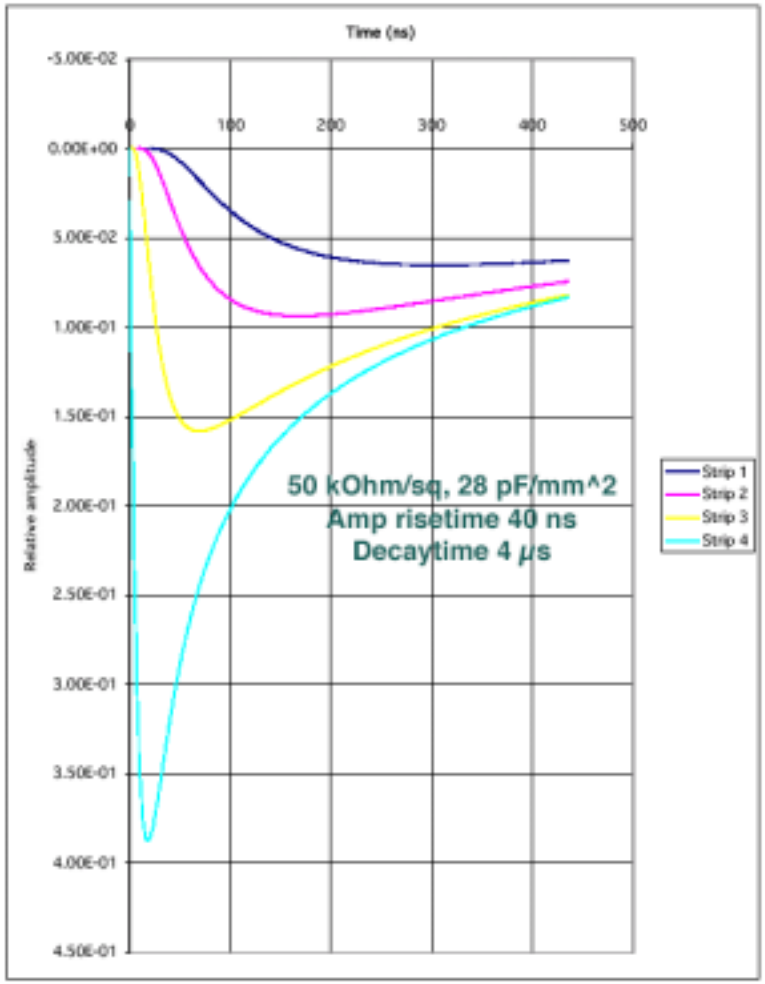
$$= k^2\left[\frac{\partial^2 Q}{\partial r^2} + \frac{1}{r}\frac{\partial Q}{\partial r}\right]$$

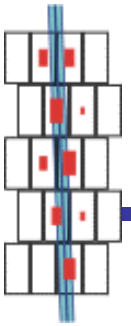
$0 < r < a$ (anode sheet radius)
C = capacitance per unit area
R = surface resistivity (Ohms/☐)
L ~ 0
$k^2 = 1/RC$

- Boundary conditions: $Q = f(r)$ at $t = 0$
  $Q = 0$ for $r = a$; $0 \le t \le \infty$
- Solution for initial point charge: Take limit $a \Rightarrow \infty$ for $Q = \delta(r)$ at $t = 0$ with $\int \delta(r)dr = 1$ is given by:

$$Q(r,t) = \frac{1}{2k^2 t} e^{-[r^2/(4k^2 t)]}$$

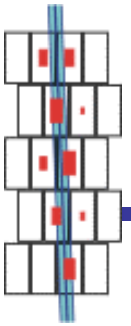
Incorporate finite size of initial charge cluster & amplifier rise & fall time effects to comare to measurement.





Resistive Anode Studies

- Plans:
  - measure space point resolution with collimated x-ray source
  - optimize resistivity and pad geometry for best space point resolution and 2 track resolving power
  - improve modelling of signals



Summary

- Continuing to make progress on many fronts:
  - cosmic tracking
    - new fitting algorithm
    - new plan for layout of readout pads with multiplexing
    - new TPC being designed to be used in TRIUMF and DESY magnets with STAR TPC electronics
  - simulation of GEM signals
    - transverse simulation is reasonably good
    - time structure simulation is poor (so far)
  - interesting results from resistive anodes for inductive signals

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