GEM TPC R&D

GEM TPC R&D in Canada

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GEM TPC R&D

2 Main Points of Interest

Test-cell:

- improve space-point resolution
- spread signal over several readout pads
- charge dispersion on resistive foil
- match pad response function to diffusion

TPC (15 cm drift distance):

- track resolution
- hit efficiencies
- multiplexing
- Compare gas: P10 ↔ Ar CO_2

GEM TPC D&R D

Space-Point Resolution

Problem:

if typical dimension of charge cloud ~0.5 mm
and typical dimension of pad size ~2 mm

⇨ signals on adjacent pads too small

⇨ poor centroid calculation

⇨ degraded resolution

Ideas for solutions:

spread signal over several (2-3) readout pads

- complex shapes, e.g. chevrons
- small pads + multiplexing
- increase size of charge cloud

✓ increase size of signal

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Resistive Anode Studies

Test-cell:

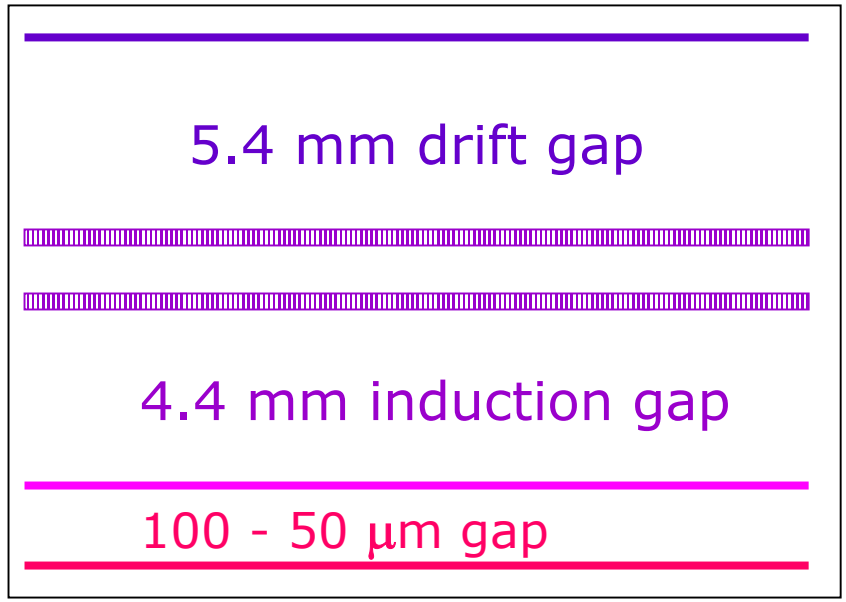
drift plane

small drift distance

double GEM — GEM1, GEM2

resistive foil (kΩ - MΩ/❑)

readout pads



readout:

8 channel digital scope
future: 32 channel FADC

signal:

collimated X-ray source

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Charge Dispersion

Idea: charge spread on resistive foil
signal distributed over several pads

Telegraph equation:

differential equation — solution (point charge)

1 dim: $\left(\cancel{\frac{L}{R}\frac{\partial^2 Q}{\partial t^2}} + \right)\frac{\partial Q}{\partial t} = \frac{1}{RC}\frac{\partial^2 Q}{\partial x^2}$ $\qquad Q(x,t) = \sqrt{\frac{RC}{4\pi t}}\, e^{\frac{-x^2 RC}{4t}}$

2 dim: $\frac{\partial Q}{\partial t} = \frac{1}{RC}\left[\frac{\partial^2 Q}{\partial x^2} + \frac{1}{x}\frac{\partial Q}{\partial x}\right]$ $\qquad Q(x,t) = \frac{RC}{2t}\, e^{\frac{-x^2 RC}{4t}}$

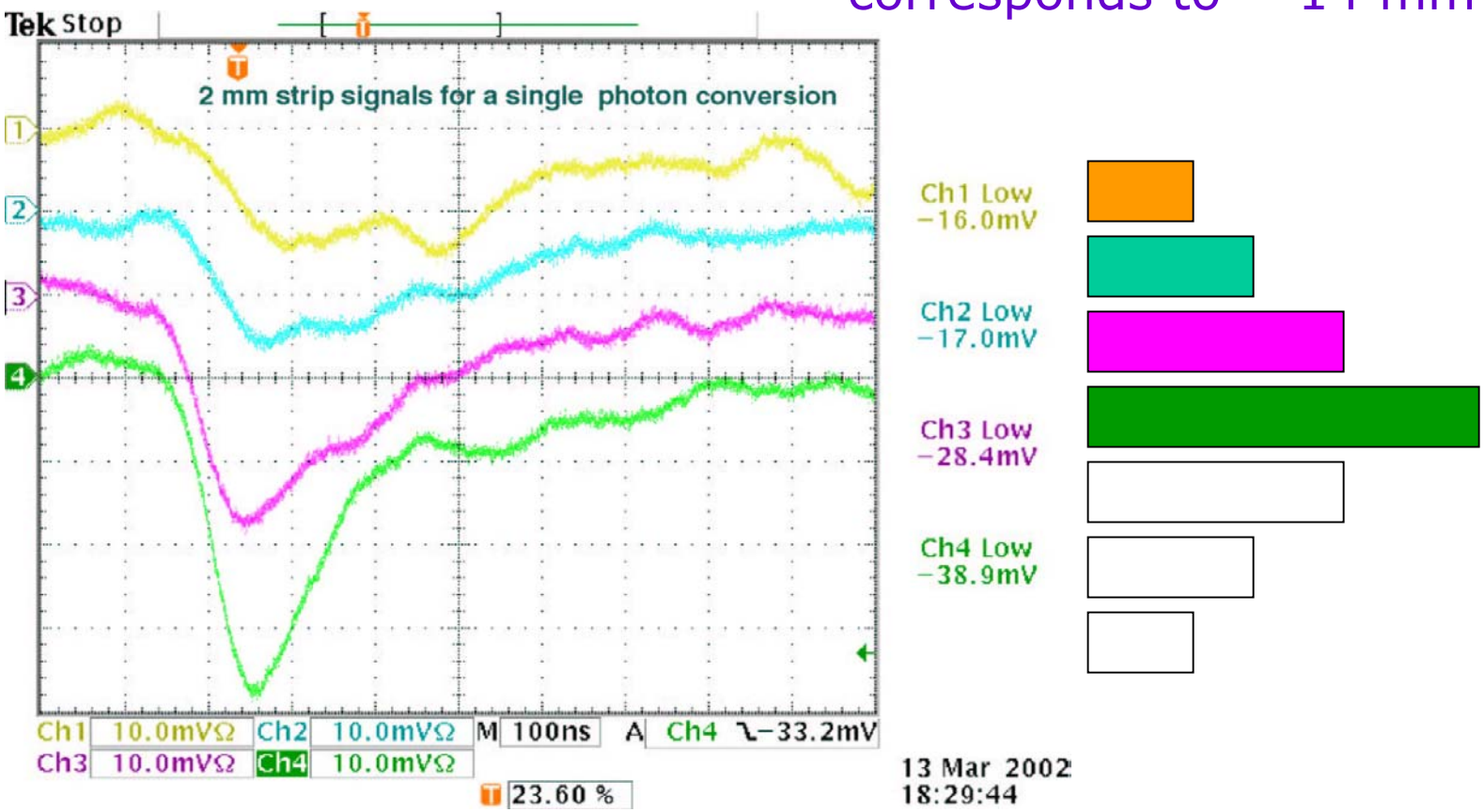
Q: charge density ; t: time ; x: coordinate
C: capacity ; L: inductivity ; R: resistivity

for simulation: + finite size of charge cloud
+ rise and fall time effects

First Attempt

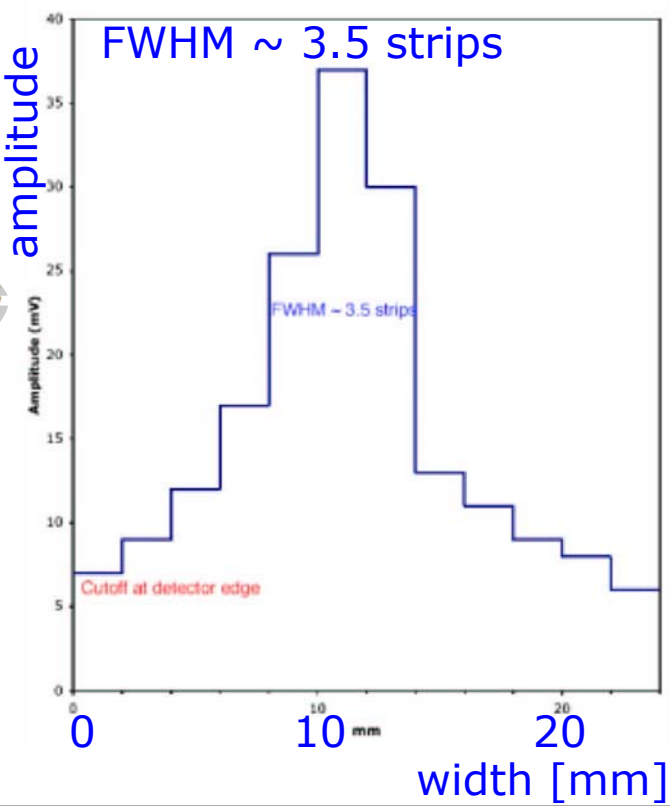
resistivity: 40 kΩ/❑
gap: ~200μm

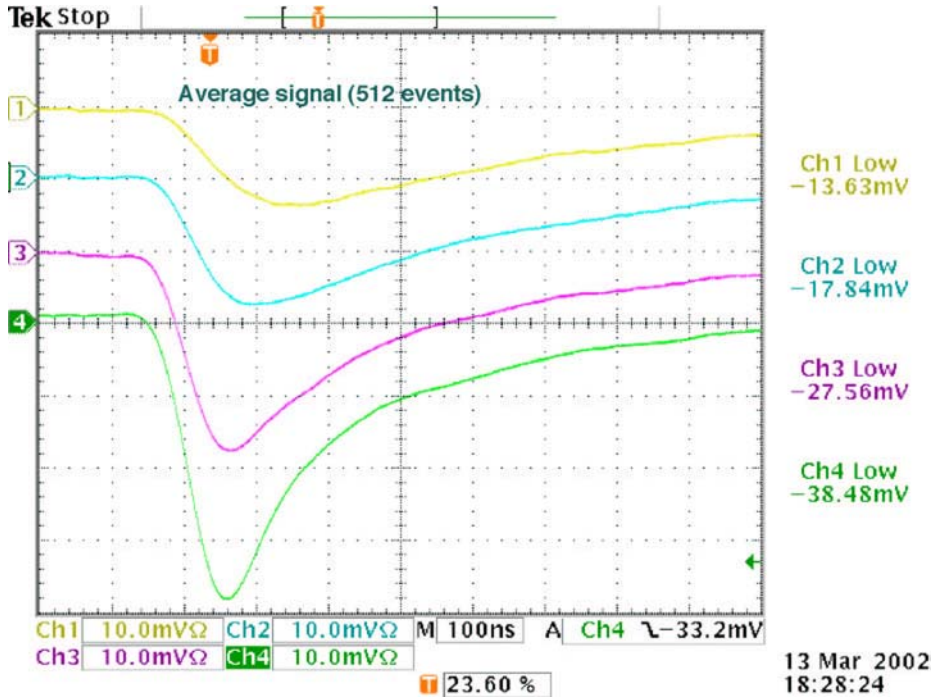
size of source: ~1 mm
signal spread over ~7 strips
corresponds to ~ 14 mm



Width of Signal

~220 μm gap
40 kΩ/❑

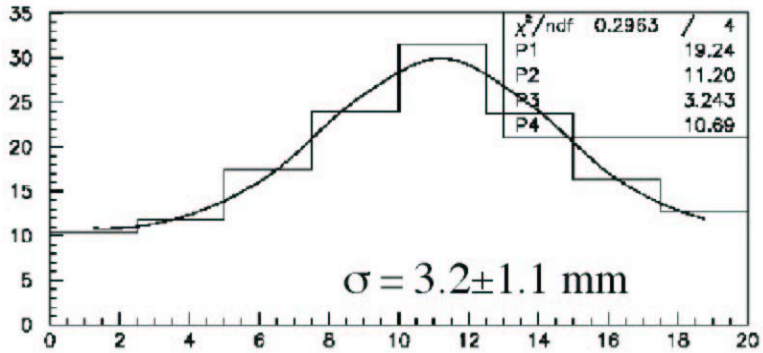




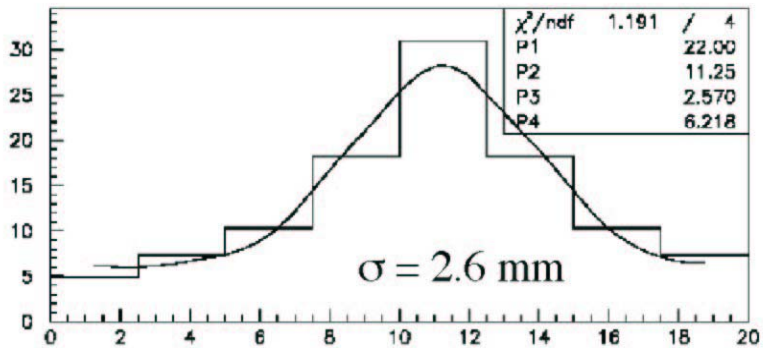
width depends on:
- resistivity of foil
- gap between foil and pads

o (RC time constant)

Pad Response Function



Measured pad response function



Simulated Pad Response Function

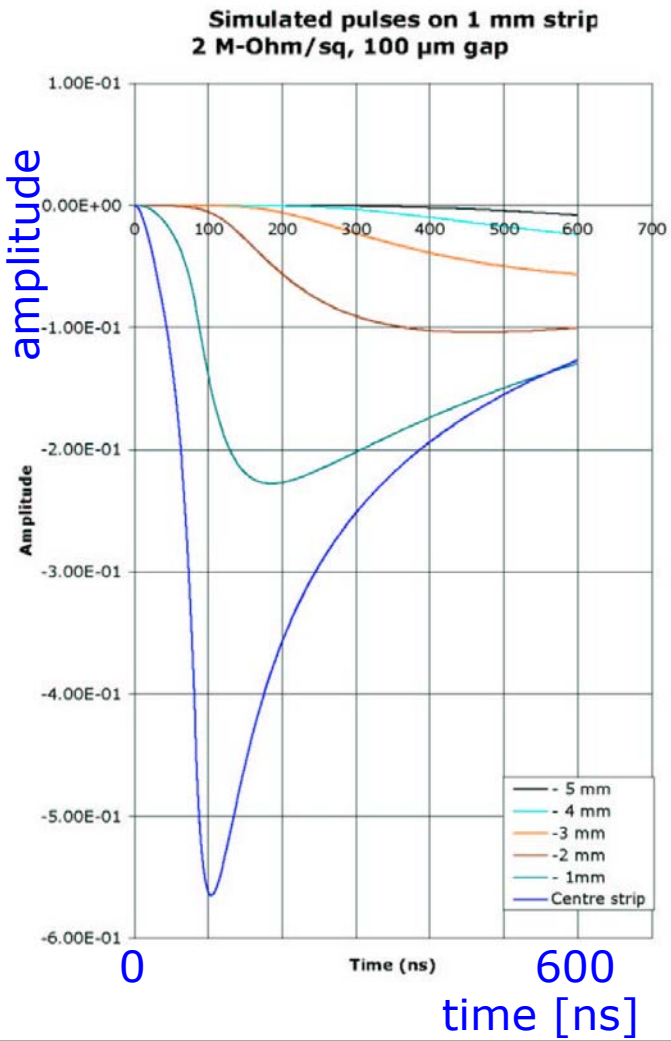
width, shape of distribution can be simulated

difference between measurement and simulation understood

optimal resolution expected for signal on 2-3 pads

2mm strips ⇨ σ ~ 0.7mm

Simulation



optimize spread according to dispersion in gas

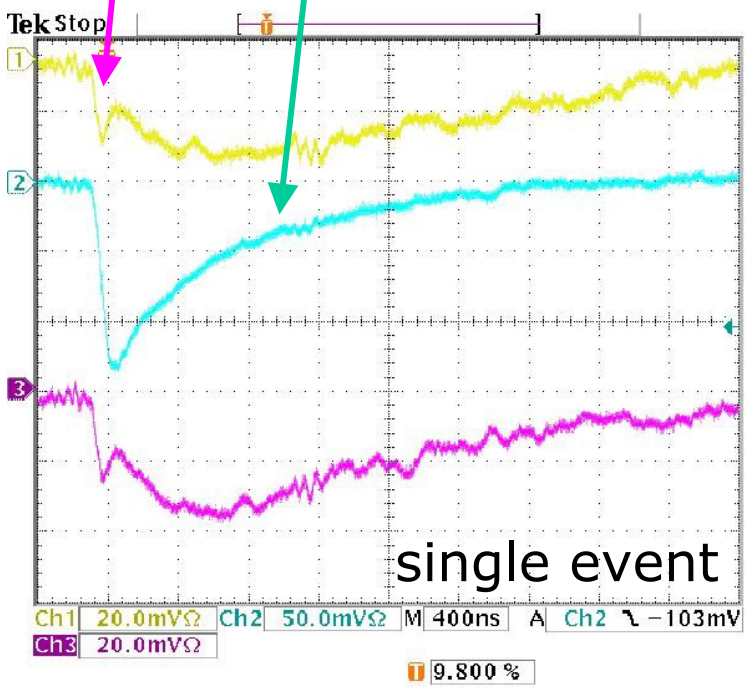
secondary pulses:
- peak delayed
- peak less pronounced

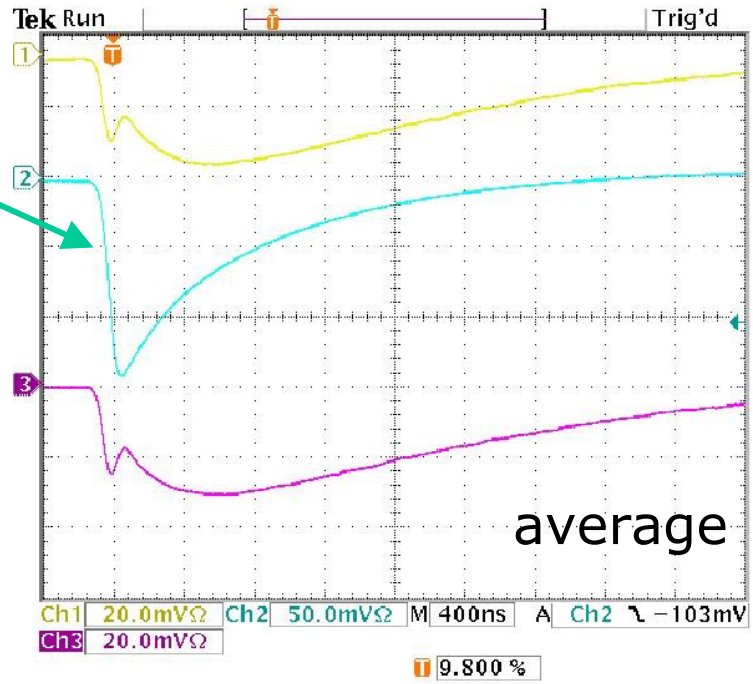
time constant for secondary pulses is longer for strips (1 dim) compared to rectangular/hex pads (2 dim)

Smaller Signal Spread

central strip: main pulse

adjacent strips with induced pulse





1.5 mm strips

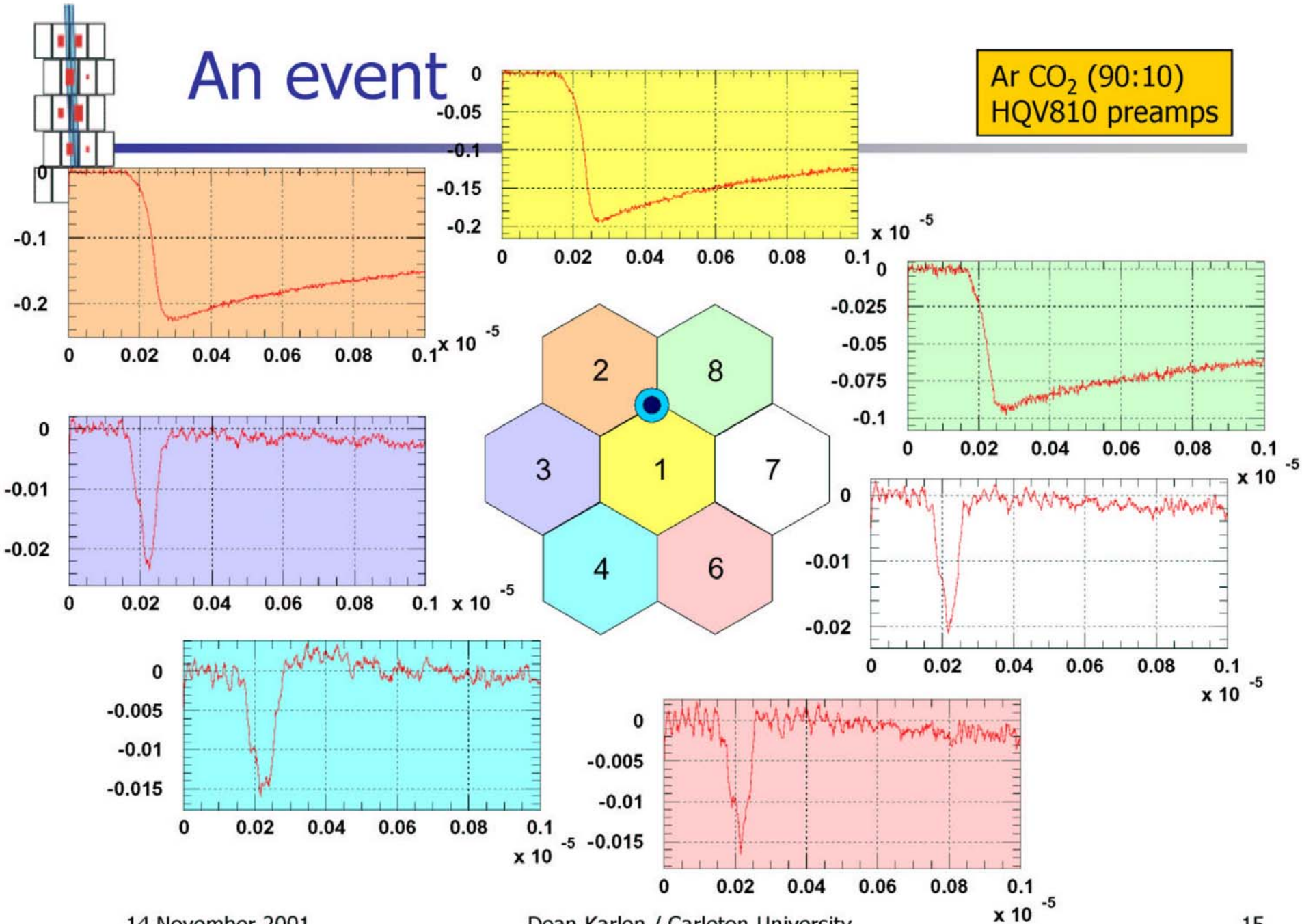
2 MΩ/❑

100 μm gap

⇨ ~0.8 mm width

An event

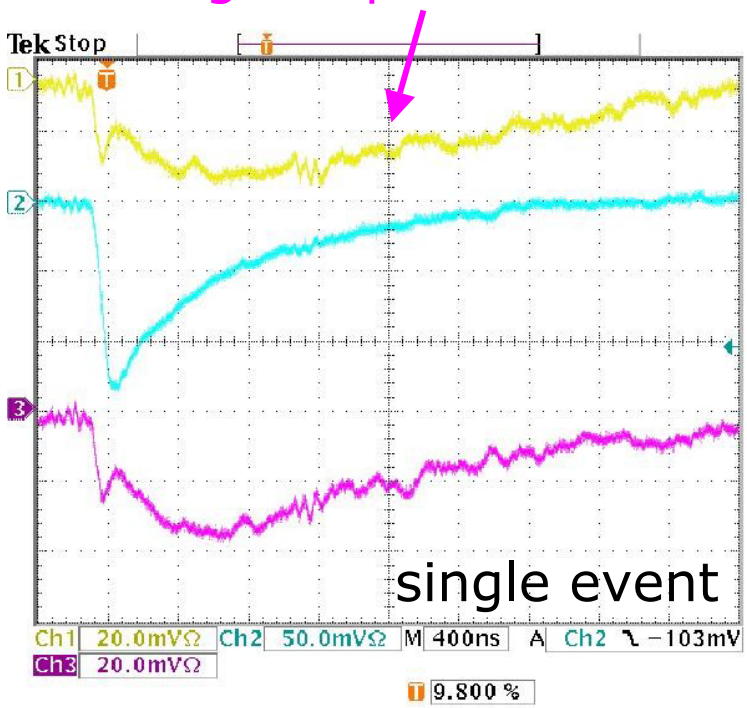
Ar CO_2 (90:10)
HQV810 preamps

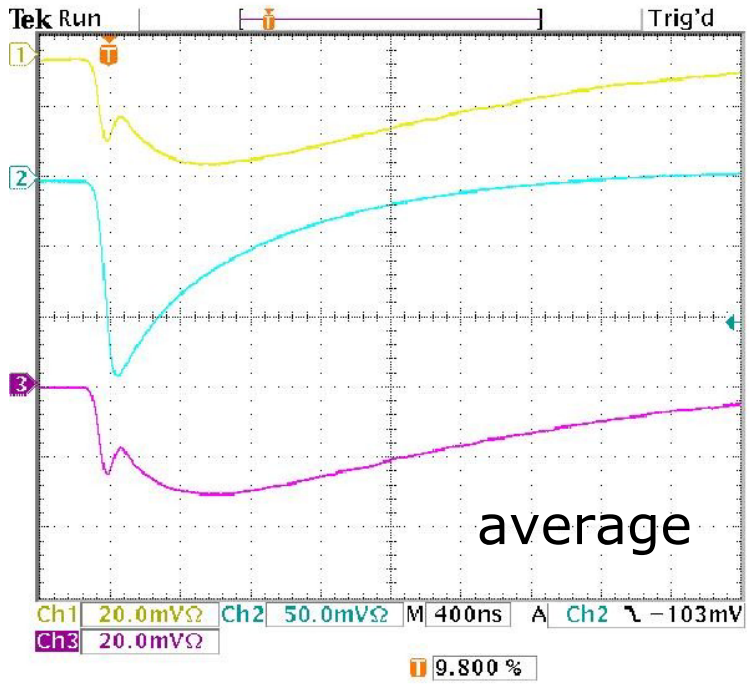


Smaller Signal Spread

central strip: main pulse

adjacent strips with induced pulse
+ charge dispersion on foil





1.5 mm strips

2 MΩ/❑
100 μm gap
⇨ ~0.8 mm width

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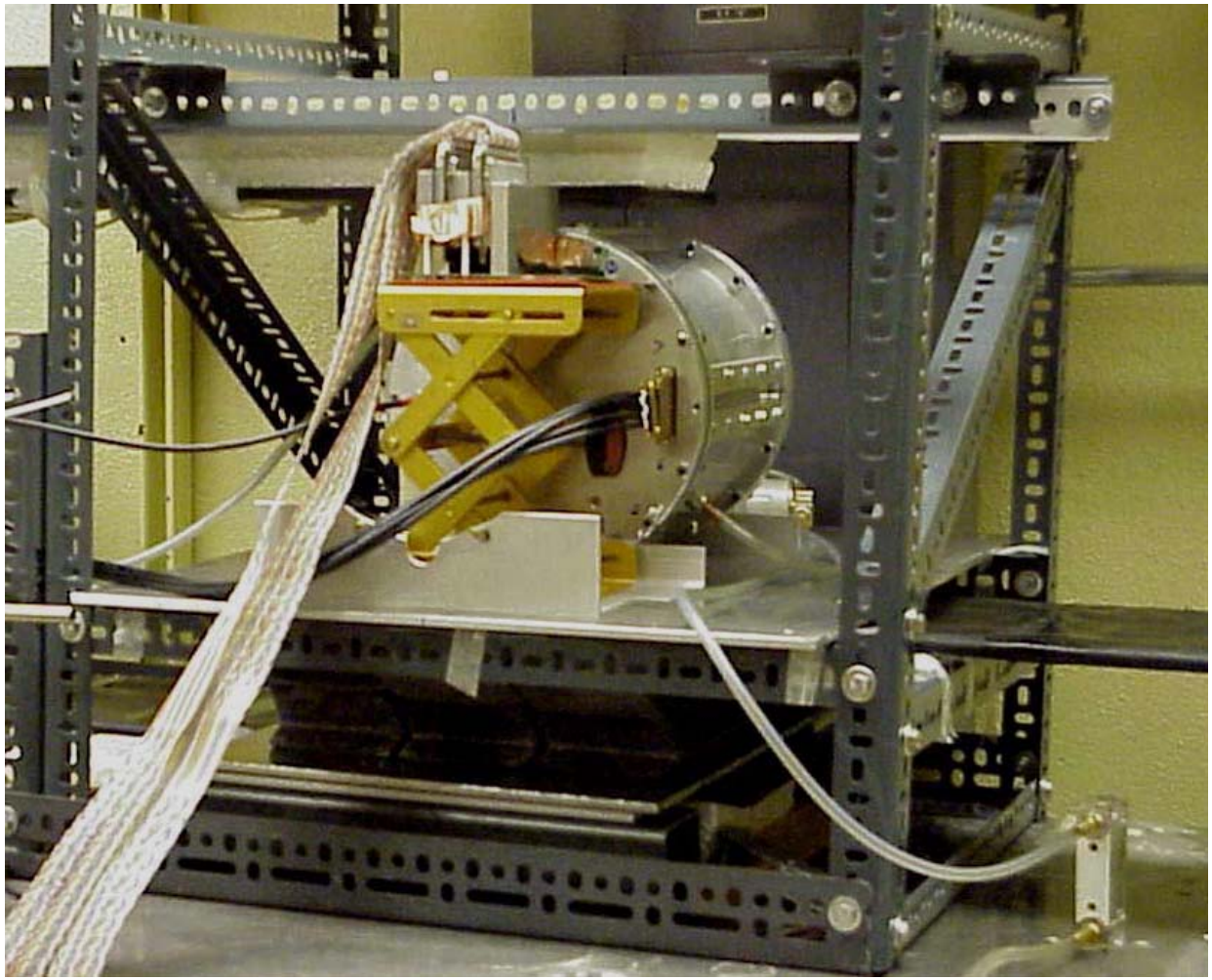
Outlook

- systematic measurements with
  strips, hexagonal and rectangular pads
- determine pad response function
- determine resolution
- verify uniformity of signal spread
- compare to simulation
  problem: measurement of resistivity of foil
- long term:
  apply to tracking studies

TPC



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TPC Setup

15 cm drift distance
cosmic ray particles
gas: Ar CO_2 ; P10

ALEPH preamplifier

custom FADC, 200 MHz
University of Montreal

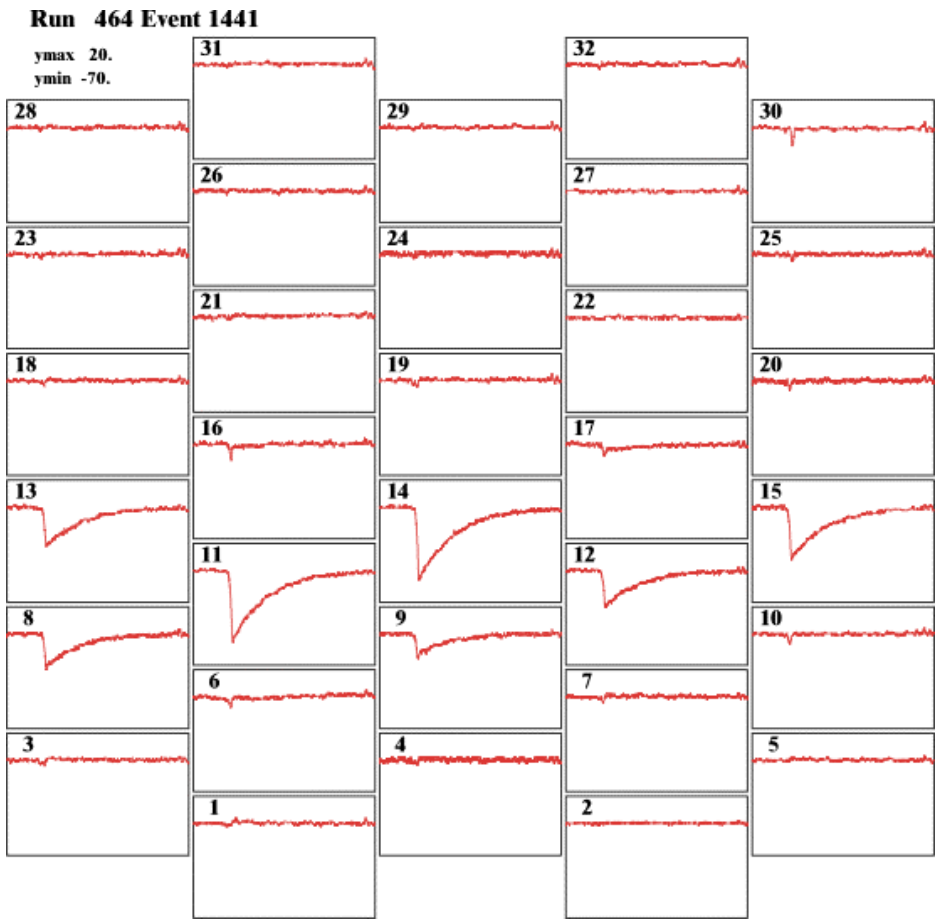
pad layout:

- old: 32 pads (2.5 x 5 mm) in 5 rows
- new: 174 pads (~2.5 x 5 mm) multiplexed + trigger + veto

studies:

- gain stability
- track resolution
- efficiency

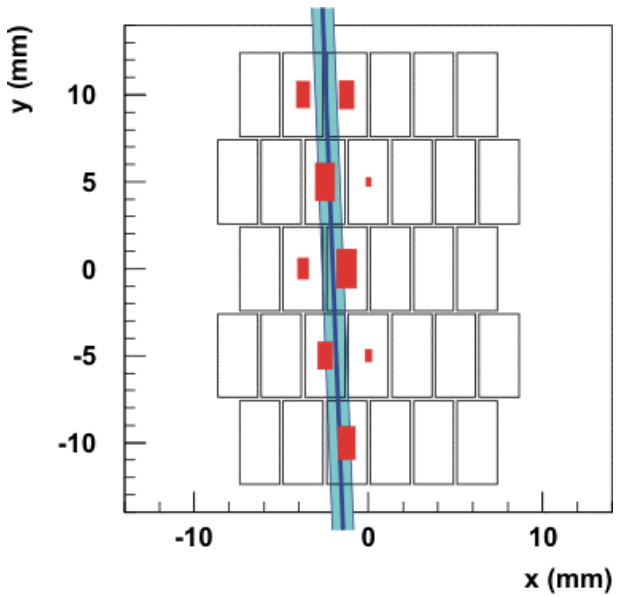
TPC Event



gas: P10

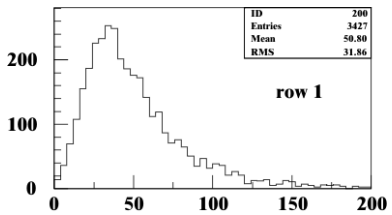
z < 10mm

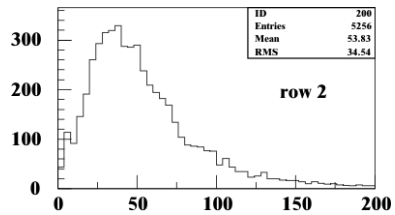
|ϕ|<0.05

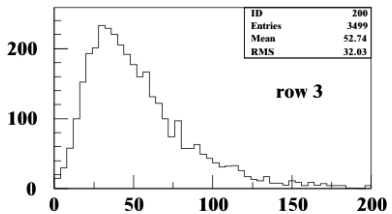


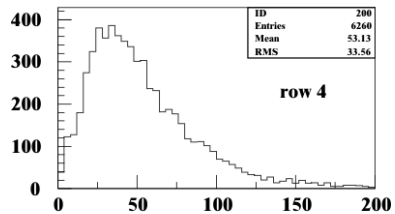
Gain Stability P10

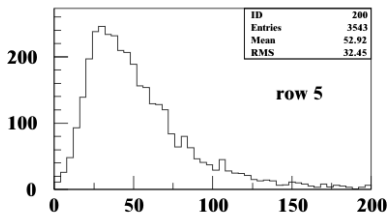
average charge in each row



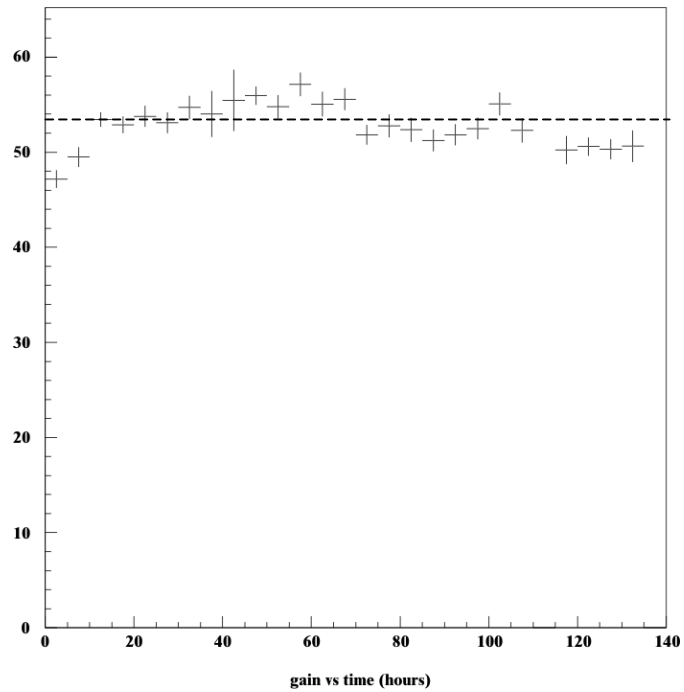








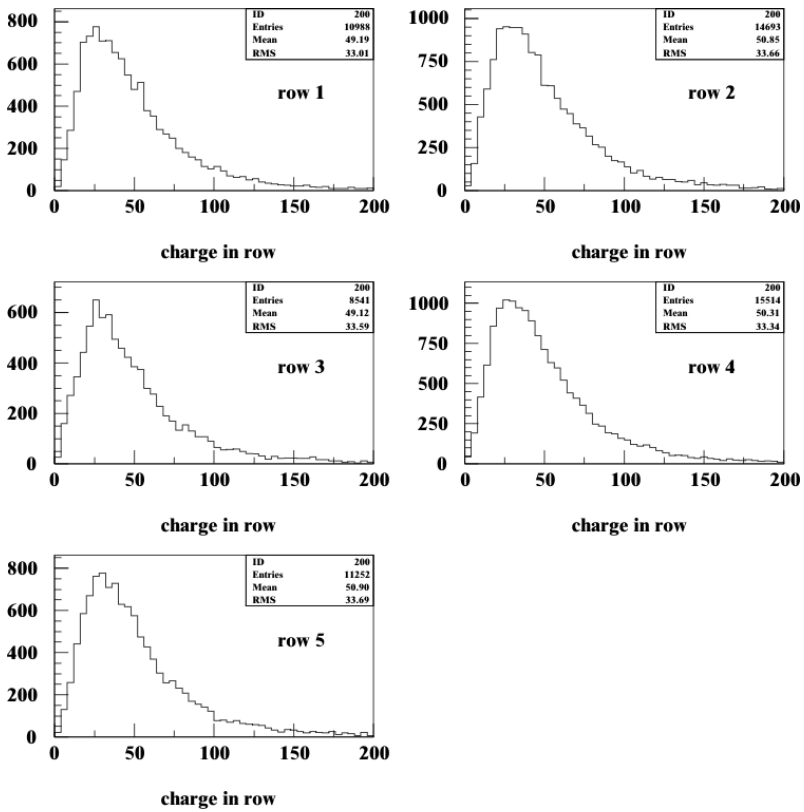
mean:
stable over 140 hours



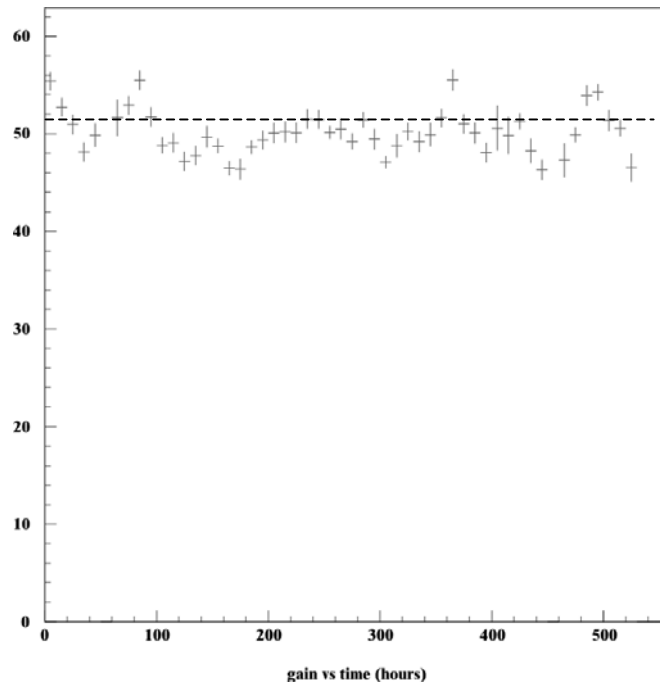
Gain Stability Ar CO_2

GEM R&D

average charge in each row

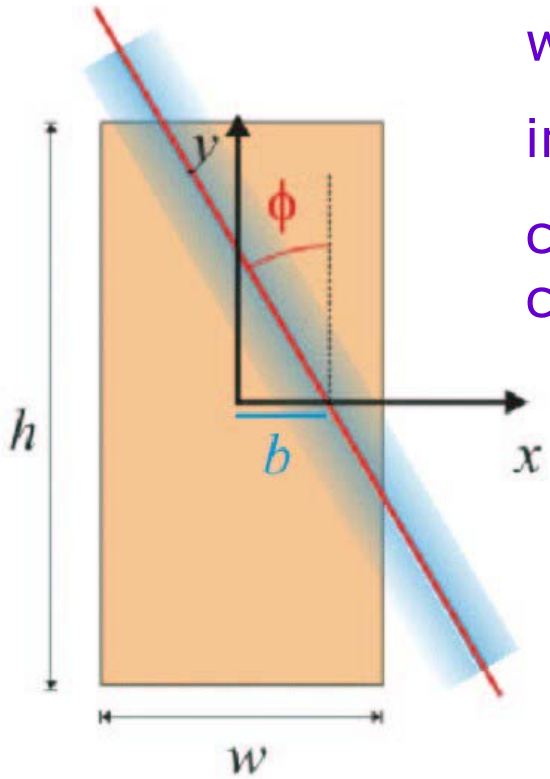


mean:
stable over 550 hours



Track Fit in x-y

3 parameter fit: x_0 (offset), ϕ (angle), σ (spread)



assume uniform line of charge with Gaussian spread σ

integral over pad ⇨ expected charge

compare to observed charge fractions in each row

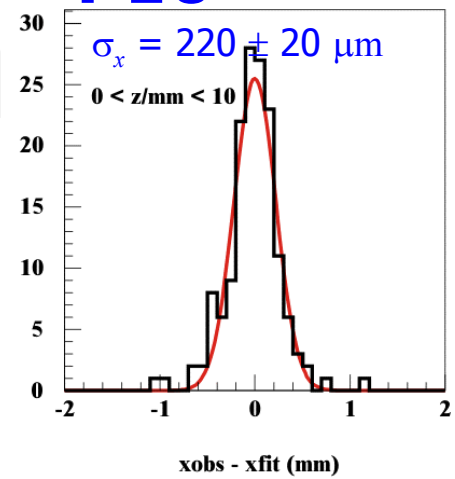
neglected:

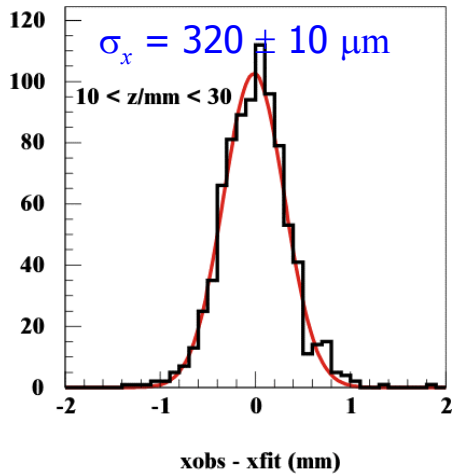
fluctuations along the track
⇨ track angle effect
for large ϕ

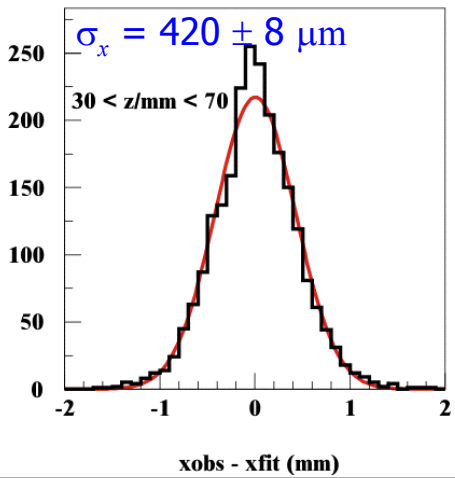
Track x_0 Resolution

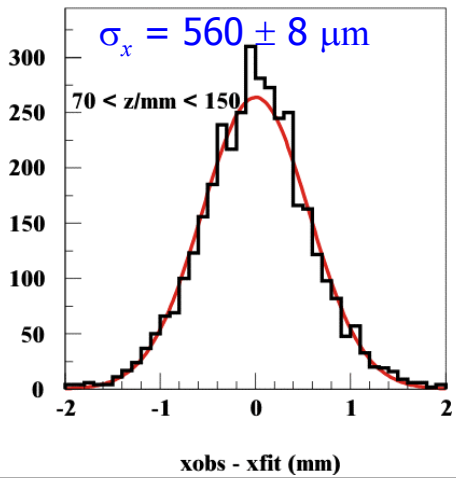
GEM R&D

P10









x_0 resolution of one row

track fit w/out row
⇨ x_0, ϕ, σ

fit single row ⇨ x_R

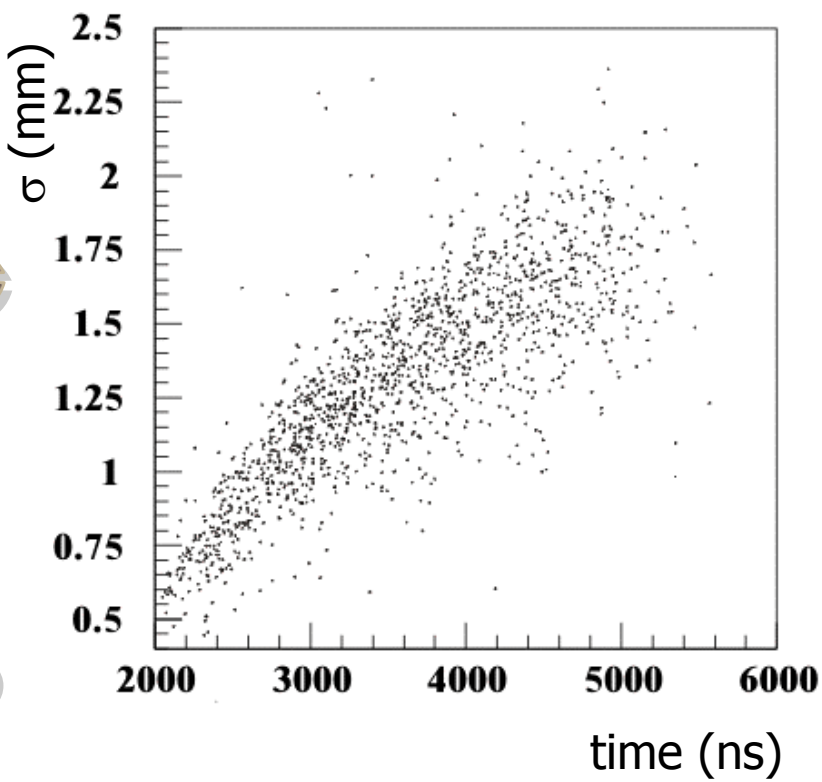
compare $x_0 \leftrightarrow x_R$

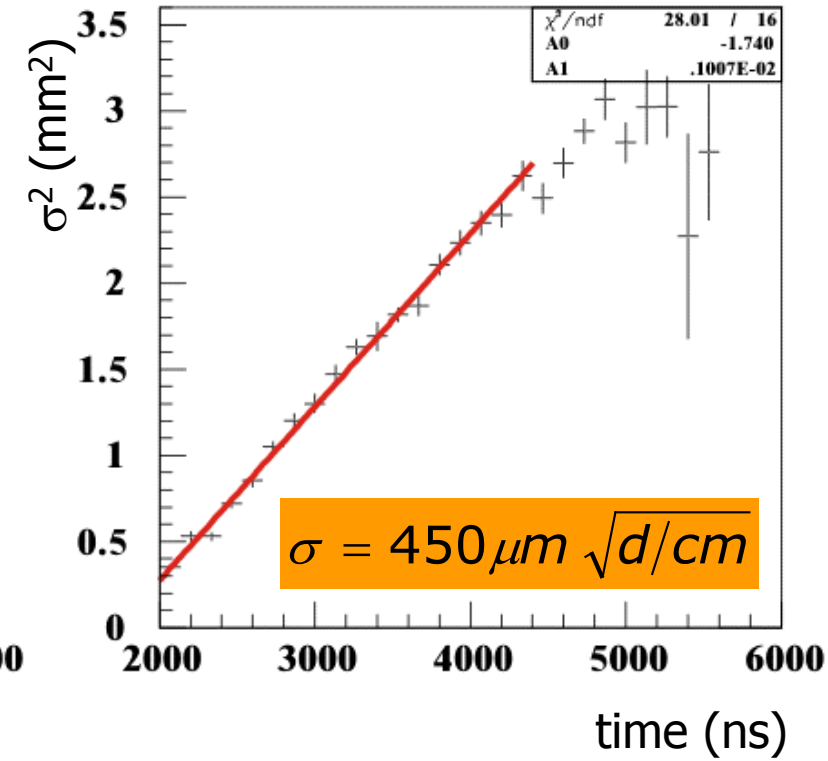
Ar CO_2:

z [mm]	σ_x [μm]
0 - 10	260 ± 10
10 - 30	288 ± 6
30 - 70	319 ± 4
70 - 150	396 ± 4

Diffusion P10

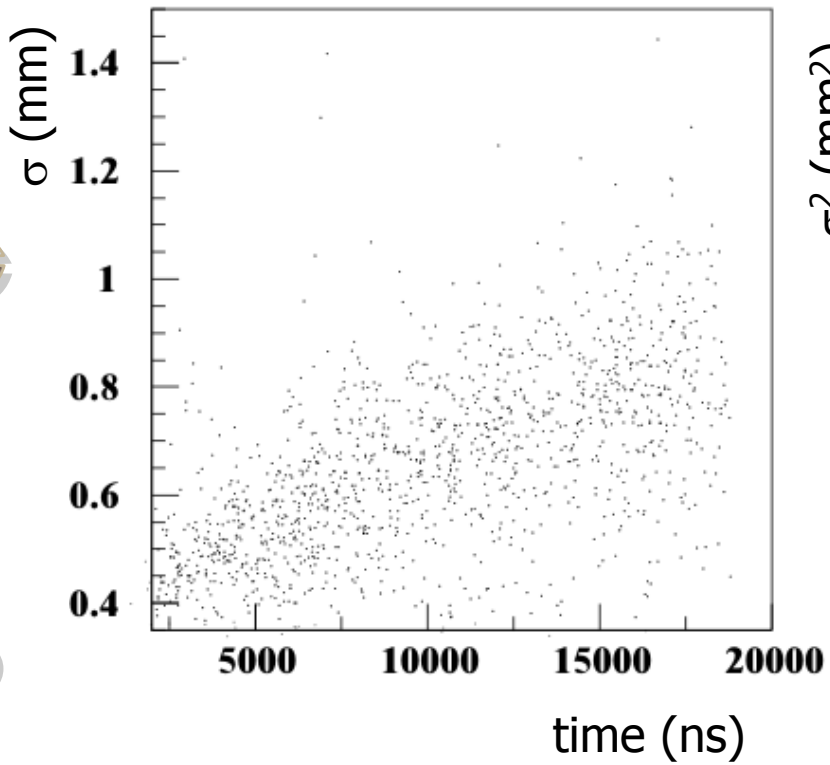
width of charge, σ, increases with drift distance *d*

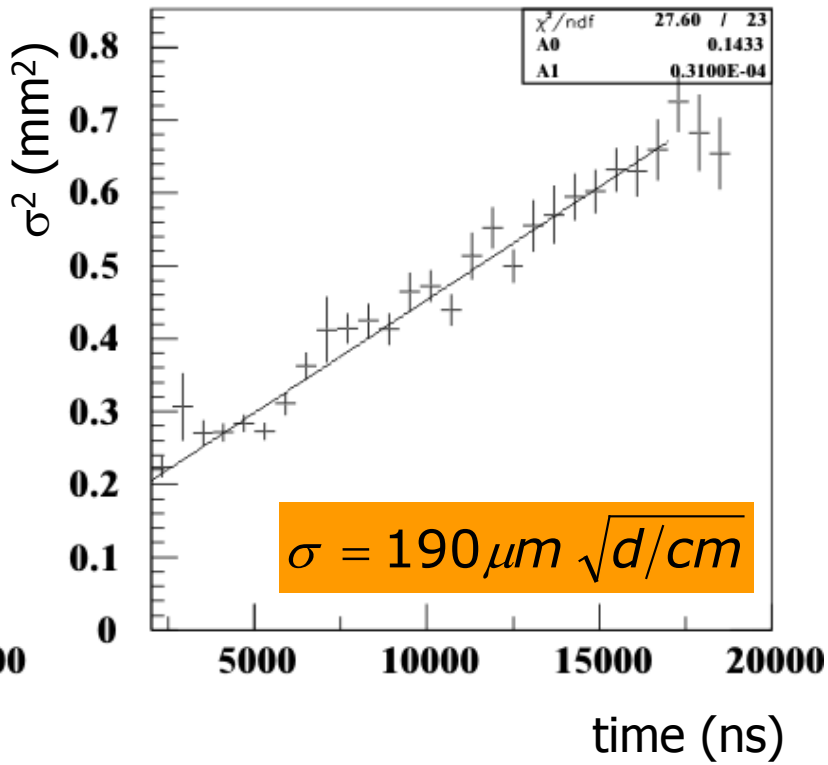




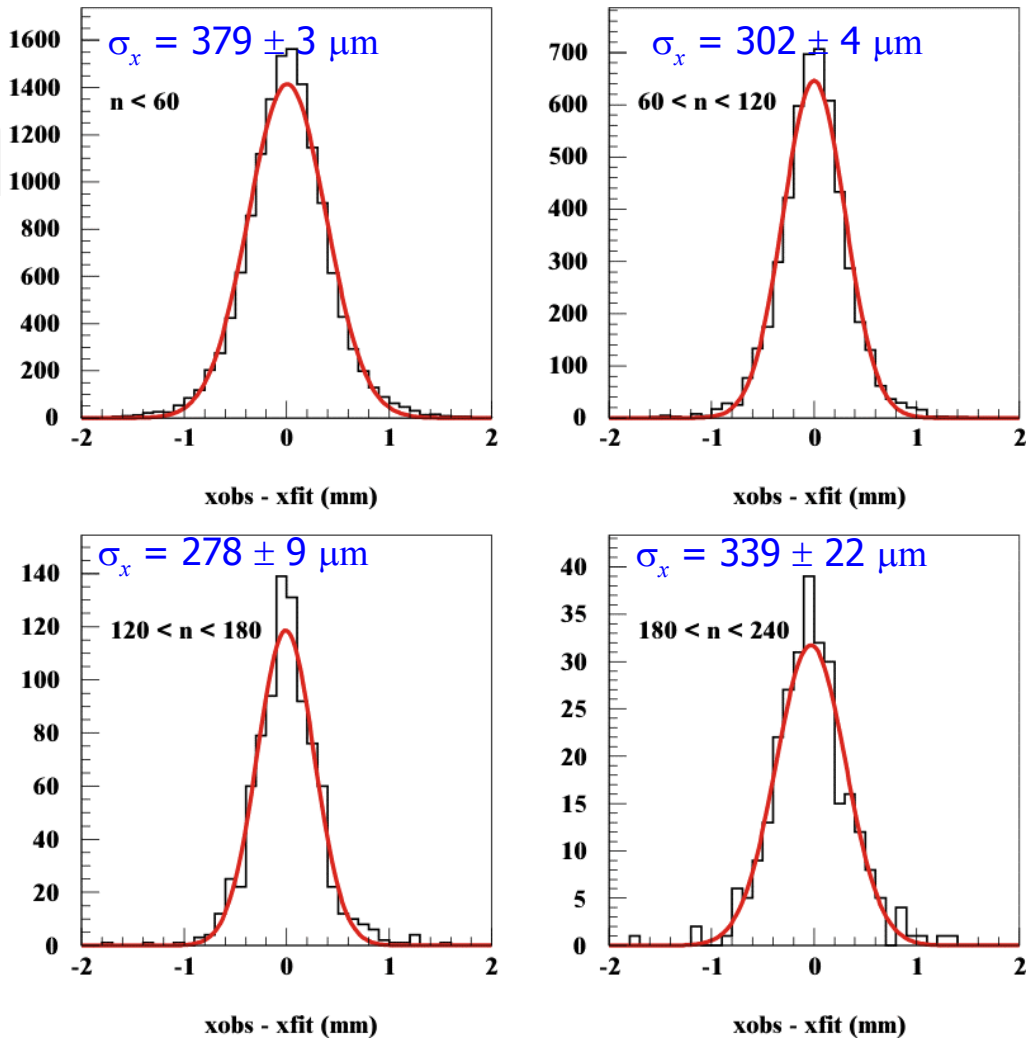
Diffusion Ar CO_2

diffusion in Ar CO_2 smaller than in P10





Ionization Effect Ar CO_2



resolution depending on total number of electrons before gain

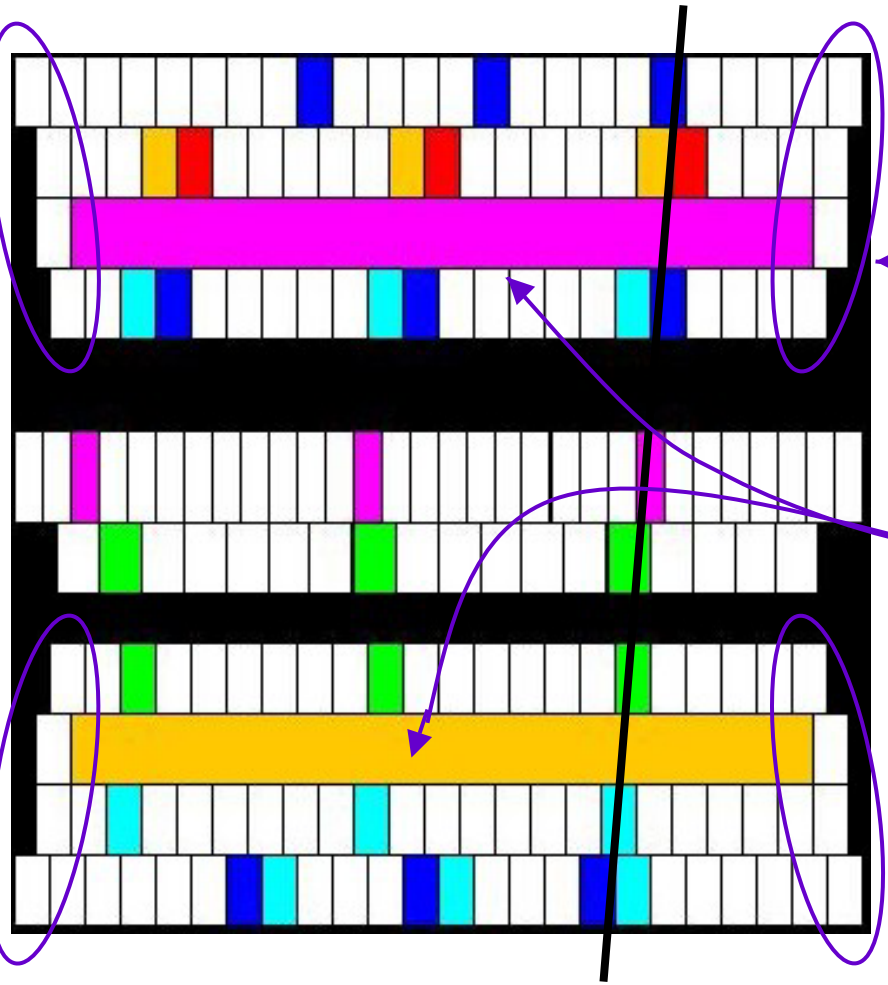
resolution improves with *n*

for very large *n*: ionization (δ-rays)

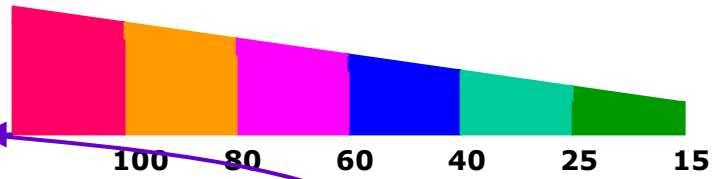
⇨

degraded resolution

New Pad Layout



amplitudes color coded:



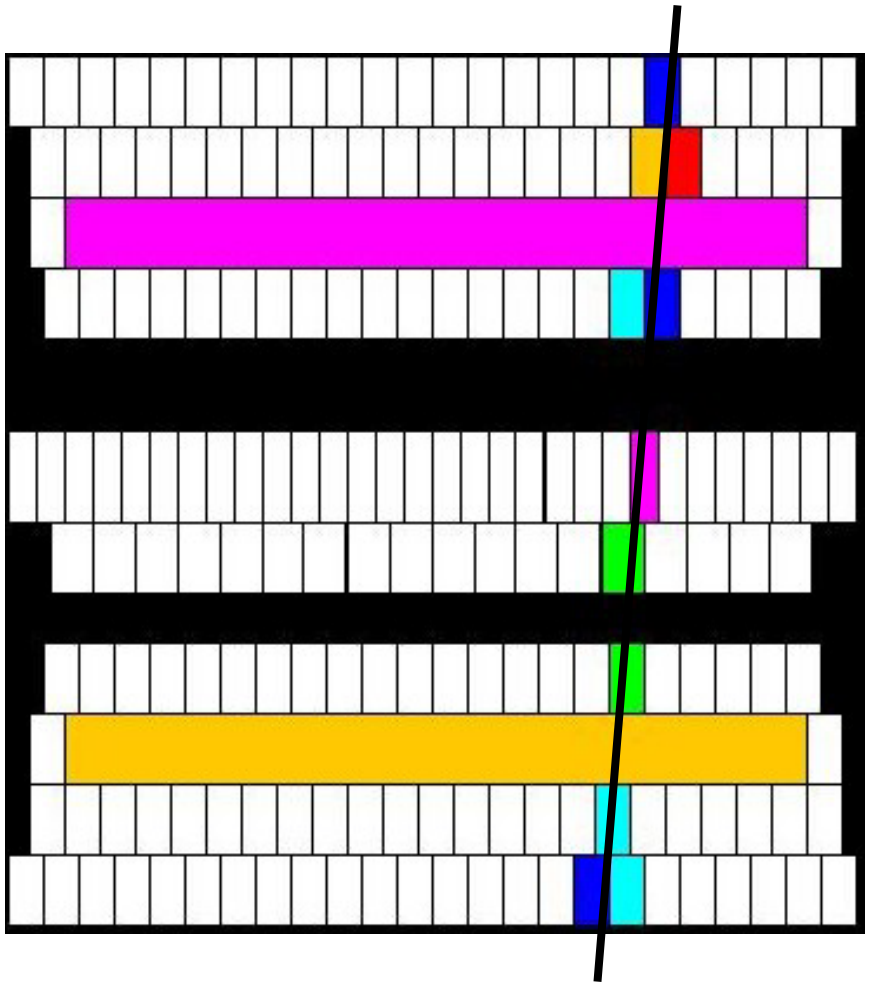
174 channels
(3 fold multiplexed)

+ 2 trigger + 4 veto

= 64 readout channels

- track reconstruction
- demultiplexing

Track Reconstruction



for event display:

high threshold
for hits

to be done:

- track fit
- studies of:
  - resolution
  - efficiency
  - .....

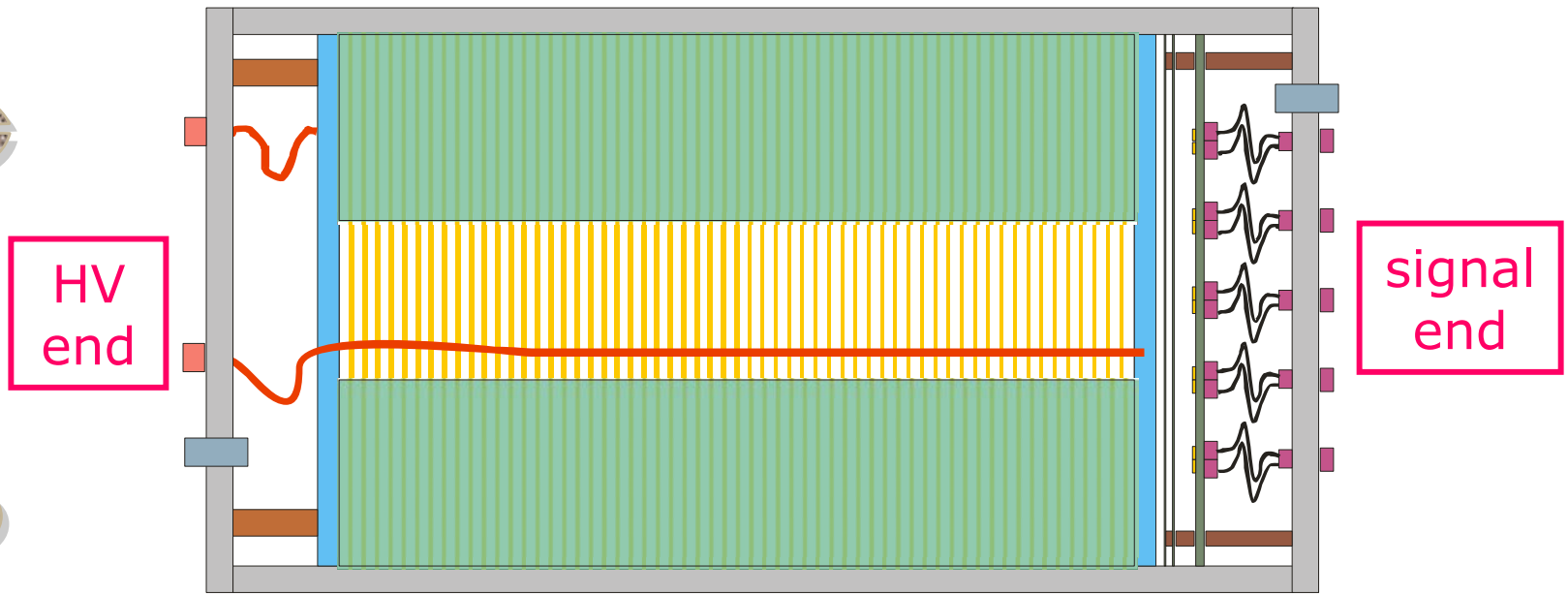
MEG TPC R&D

A New TPC (#2)

In construction:

cylindrical, outer diameter 22.2 cm, drift length 30 cm
⇨ fits TRIUMF and DESY magnets

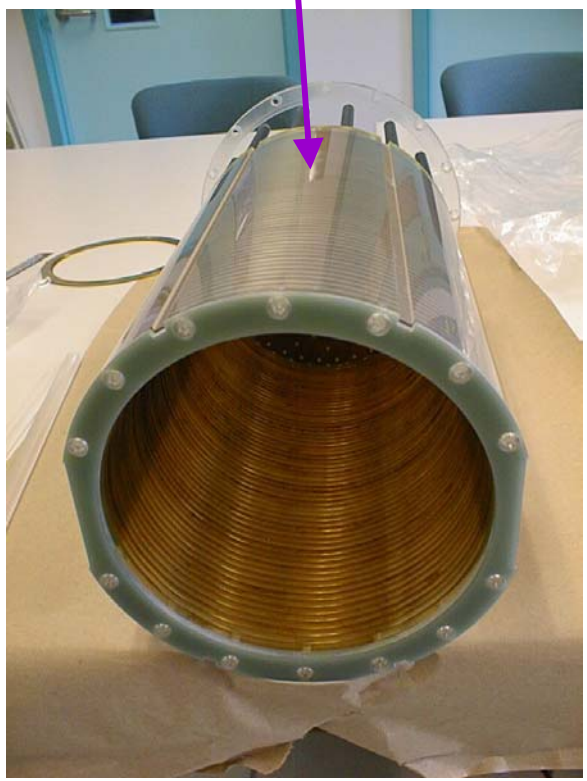
readout using STAR-TPC electronics (256 channels)

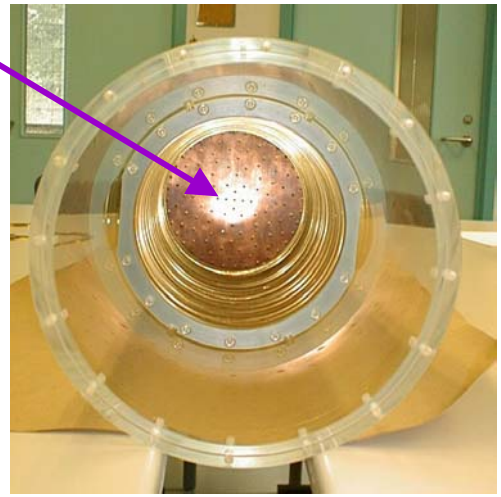


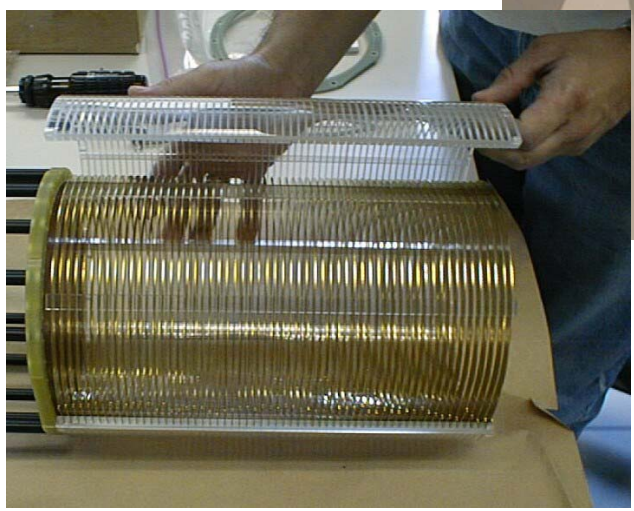
A New TPC (#2)

copper HV backplane

fieldcage: brass rings







acrylic vessel

GEM TPC R&D

Summary

Space-point resolution:

- measurements from two setups with different charge dispersion
- simulation to optimize parameters

Tracking studies:

- results on gain stability, x_0 resolution
- new pad layout with multiplexing
- new TPC being built

New web page under construction:

- http://www.physics.carleton.ca/~gmd/