1st Tracking Experience for MPGD TPC readout with Charge Dispersion on a Resistive Anode

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Worldwide Study of the Physics and Detectors for Future Linear $e^+ e^-$ Colliders

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Introduction

- Transverse diffusion sets ultimate limit on the resolution of a TPC
- Operating TPCs have not reached this limit:
  wire/pad TPC: *E x B* systematic effects
  MPGD TPC have the potential, but not proven yet
- Not enough charge sharing between pads for small transverse diffusion limits resolution; centroid calculation is not fully effective.

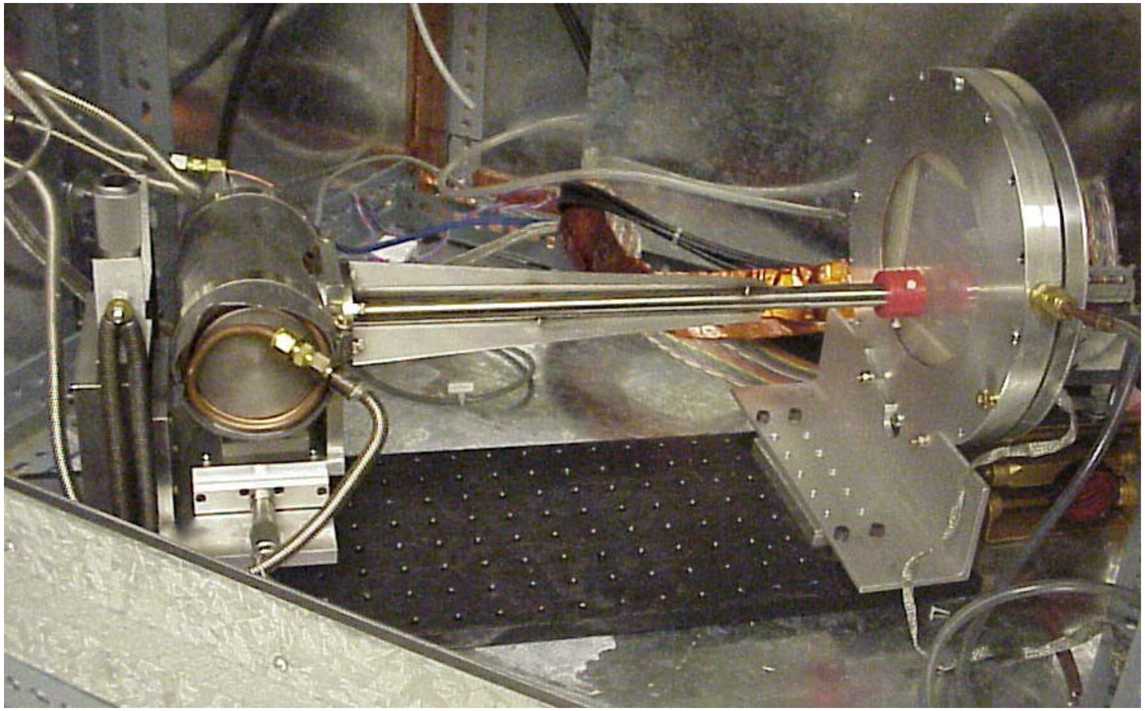
Solution:

- (very) small pads ⇨ many readout channels
- spread charge/signal after gain:
  GEM can be operated with large diffusion in gaps.
  Published: *R.K.Carnegie et.al.*, LCWS'02, physics/0402054 (sub. to NIM.)
- resistive anode: concept and 1st tests are published:
  M.S.Dixit et.al., NIM A518 (2004) 721 and presented previously.
  New results for track reconstruction and resolution.

1st Test of Principle

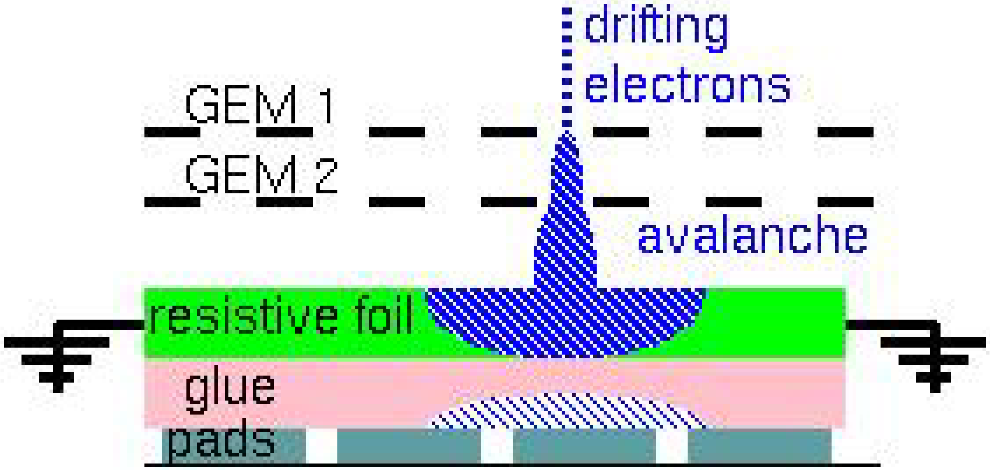
Published:
M.S.Dixit et.al.,
NIM A518 (2004) 721

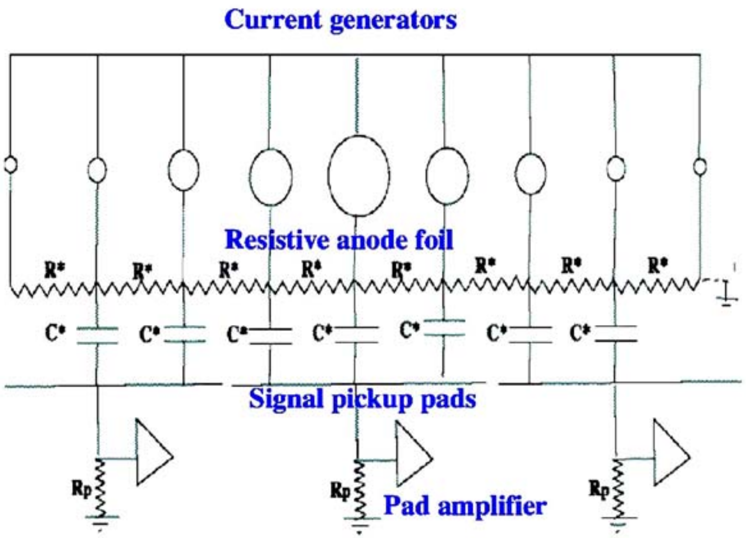
Presented previously:
R.K.Carnegie et.al.,
ALCPG (SLAC) 1/04
IEEE (Portland) 10/03



- Point resolution
  50 μm collimated
  X-ray source
- TPC test cell, 5mm drift distance, gas: Ar:CO_2 (90:10)
  60 pads, 2 x 6 mm^2
- Readout: ALEPH TPC preamplifiers
  8 channel digital scope

Concept of Charge Dispersion





Amplification: GEM or microMegas

- charge is collected on resistive foil glued to PCB, glue = insulating spacer
- 2dim *RC* network defined by geometry ⇨ charge spreads on foil surface
- capacitively coupled signals observed on PCB readout pads below

2dim telegraph equation for charge density q:

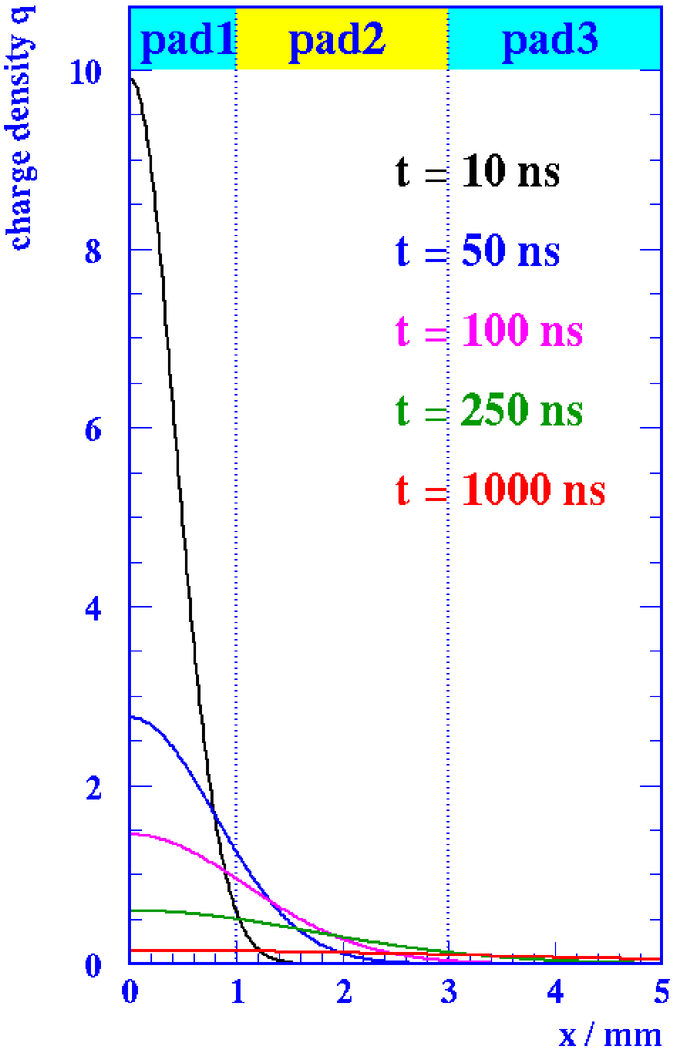
$$\frac{\partial q}{\partial t} = \frac{1}{RC}\left[\frac{\partial^2 q}{\partial x^2} + \frac{1}{x}\frac{\partial q}{\partial x}\right]$$

$$q(x,t) = \frac{RC}{2t} e^{\frac{-x^2 RC}{4t}}$$

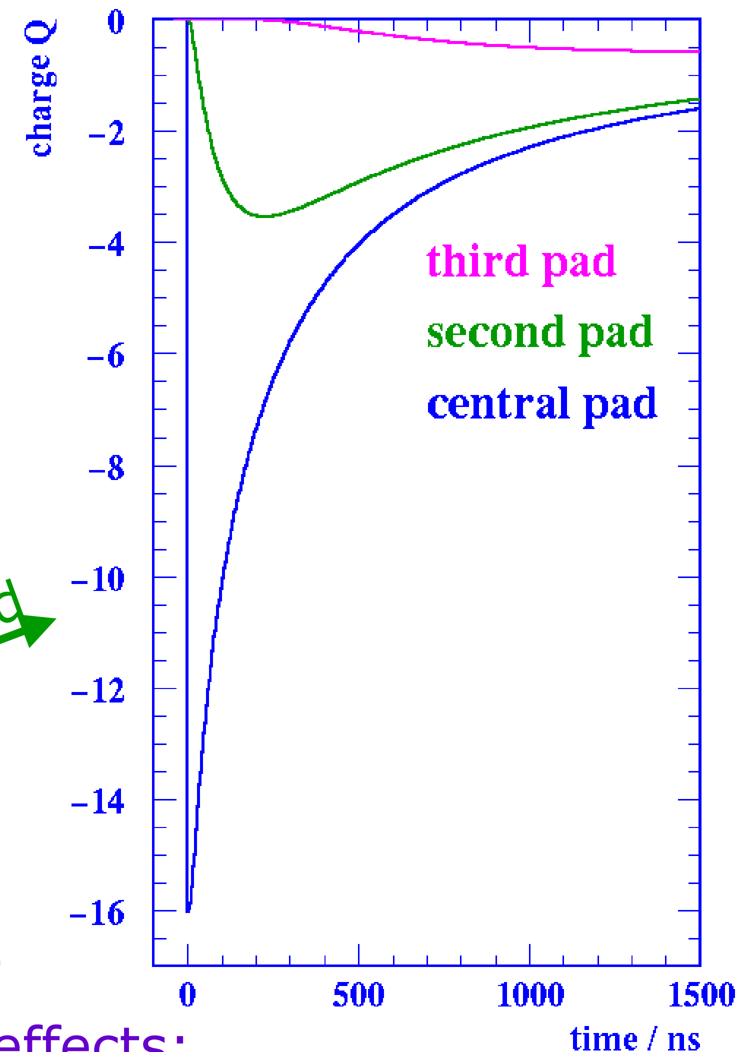
δ point source

Charge Dispersion

Finite size charge cluster after transverse diffusion that is deposited instantaneously at x=0 will spread with time.



Integrate over pad



For simulation of pulses add time effects: longitudinal diffusion, detector rise-time, electronics effects

Charge Dispersion Signals

Collimated X-ray source

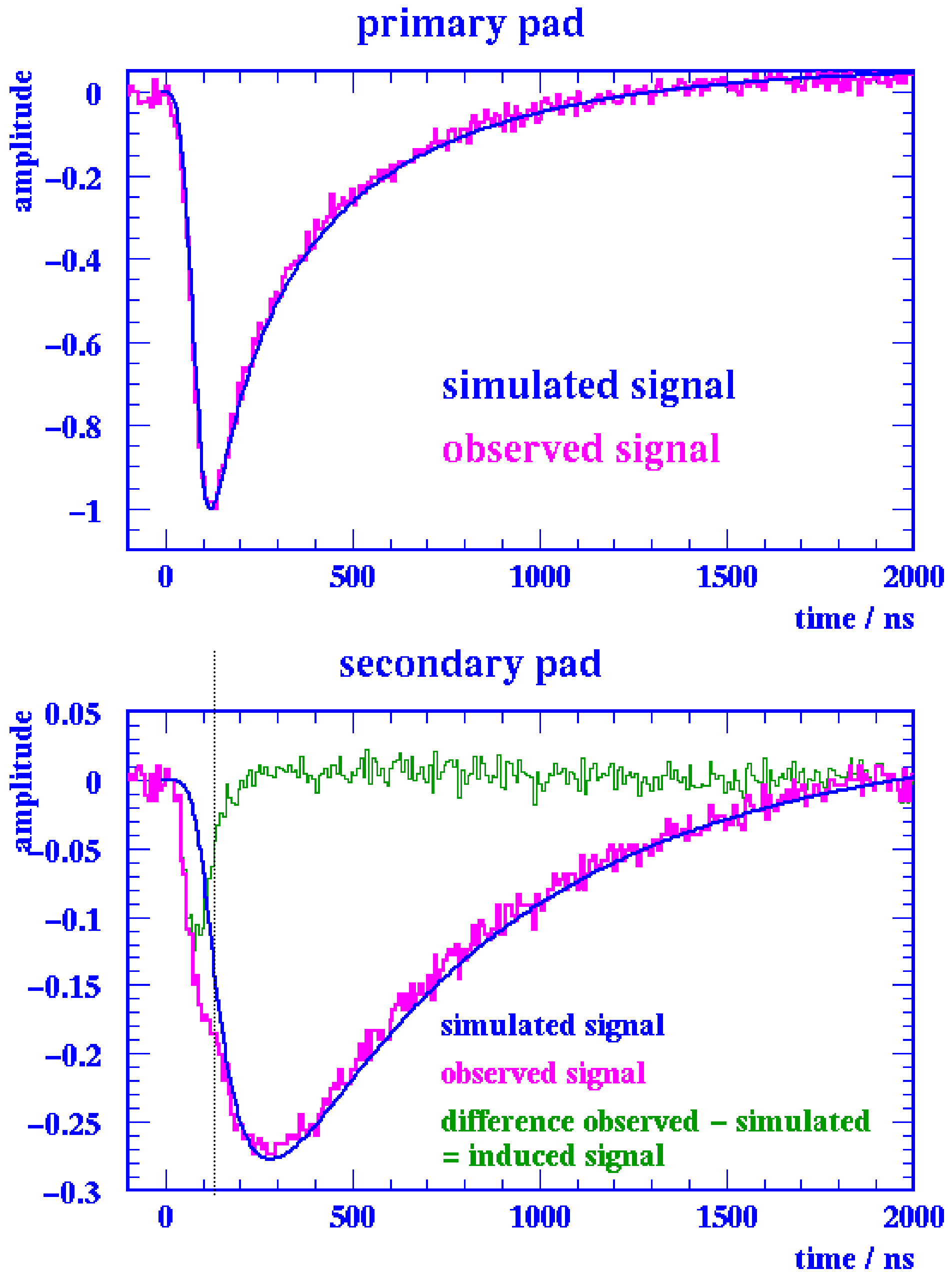
Signals from charge dispersion ar
observed on neighboring pads

Peak at later time (~150 ns)
different pulse shape

Simulation of signals available
(analytical calculation) NEW!

describes pulse shapes / PRF

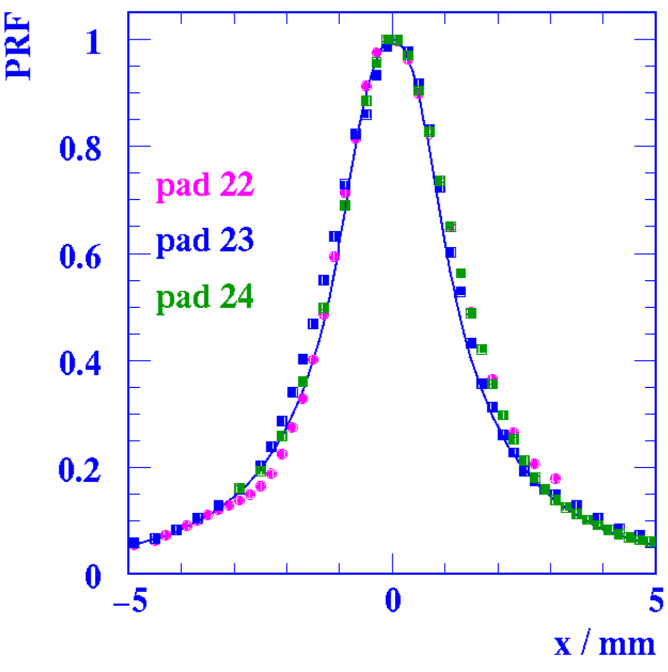
Induced signal studied previously:
MPGD '99 (Orsay), LCWS '00

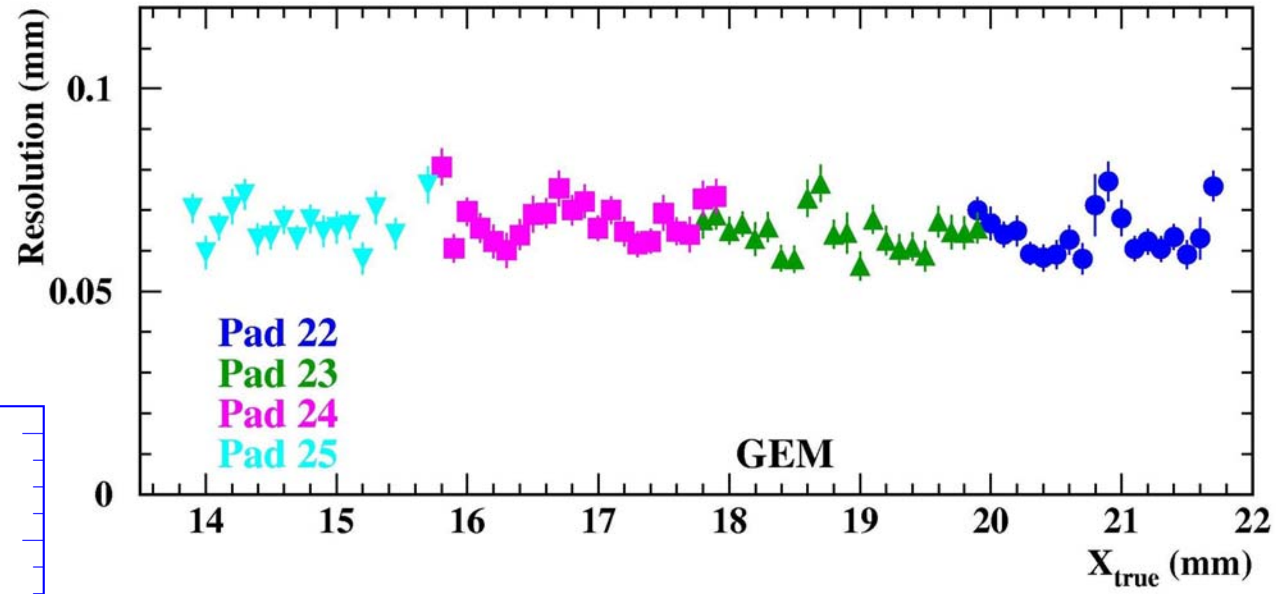


Proof of Principle

Point resolution

Pad response function
is well described
by simulation.





Achieved resolution ~ 70 μm with GEM,
microMegas should give similar result.
Previous microMegas tests were limited,
due to small frame.

New microMegas frame
is ready for mounting.

Cosmic-Ray Track Study

Track reconstruction with charge dispersion on resistive anode.

Study resolution.

GEM-TPC Setup:

15 cm drift distance

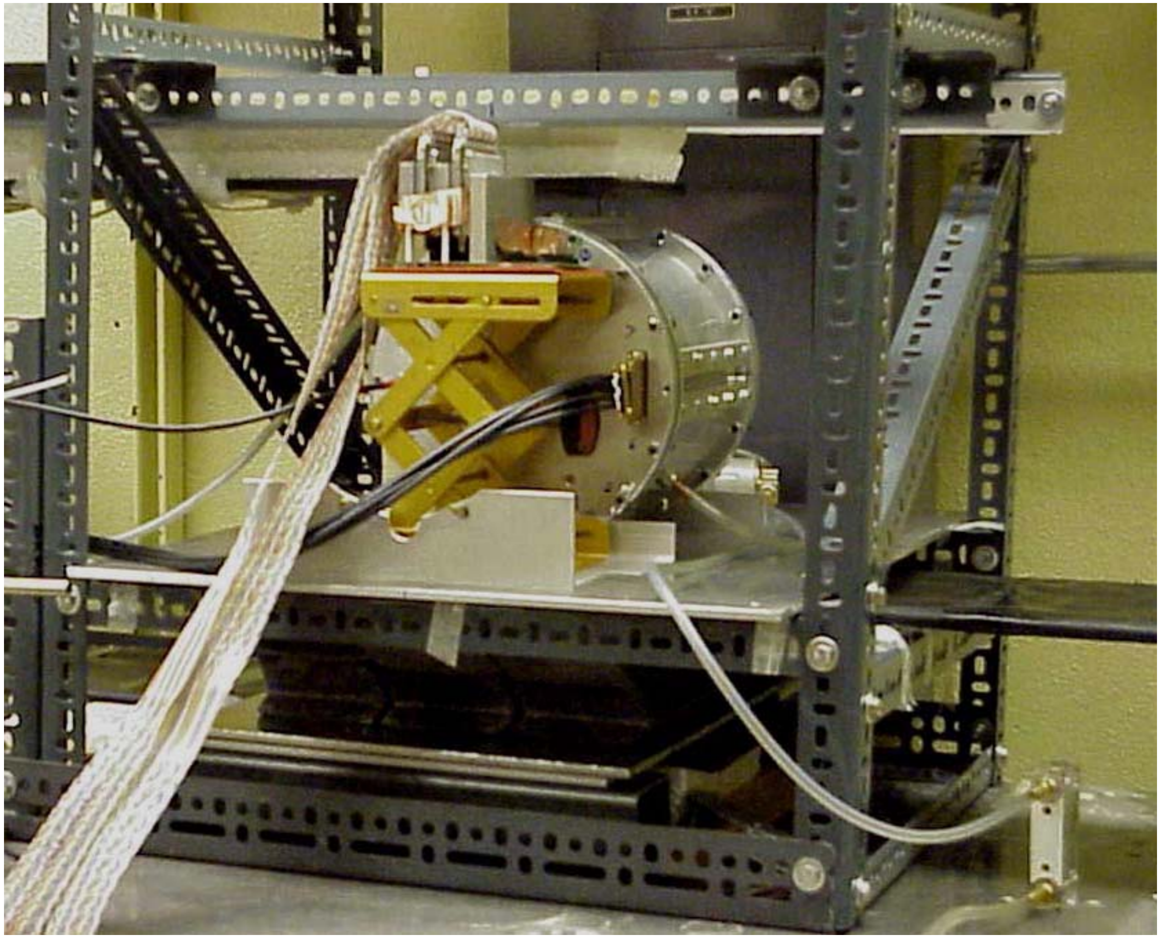
cosmic ray particles

gas: Ar:CO_2 (90:10)

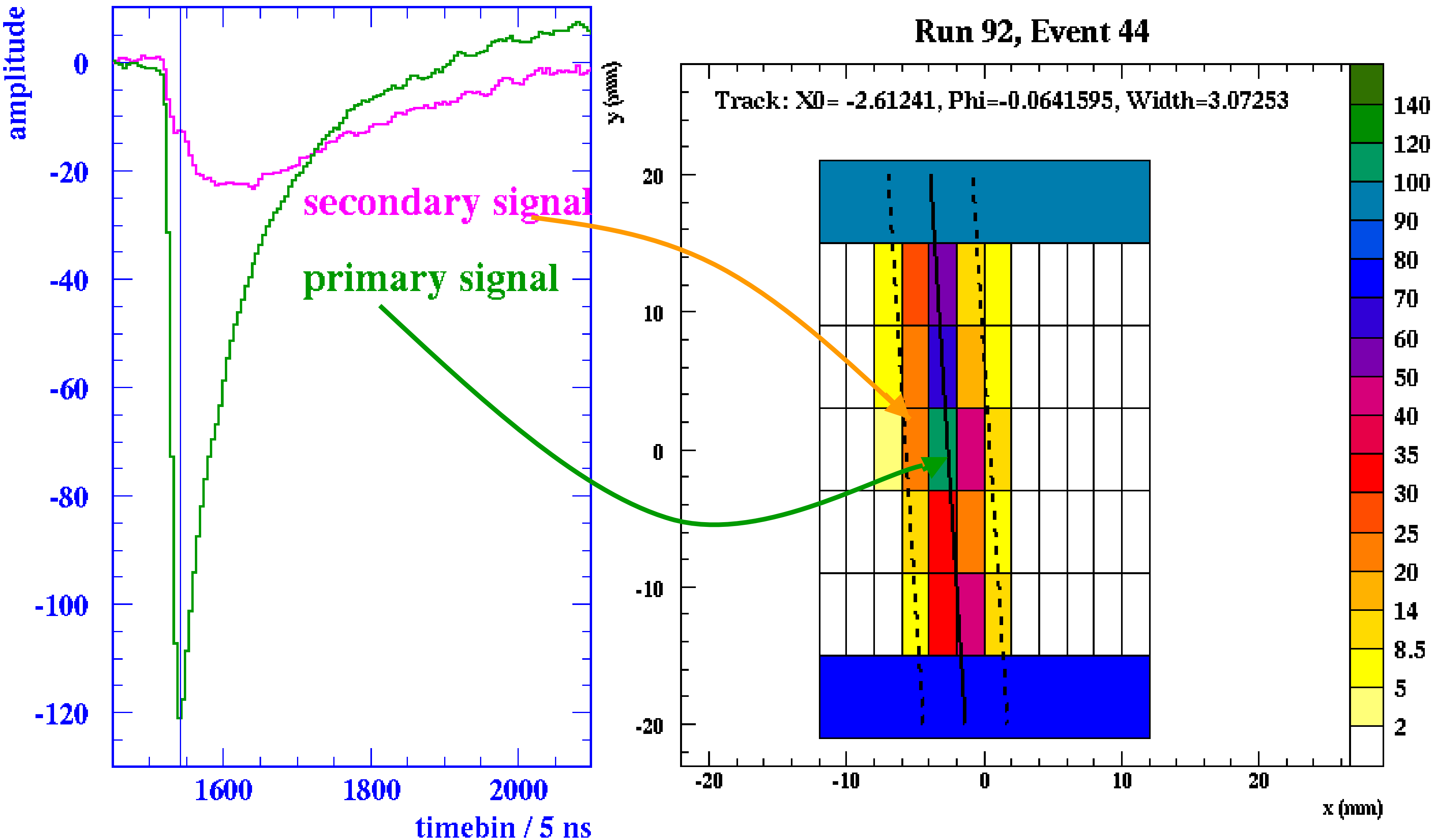
60 pads, 2 x 6 mm^2

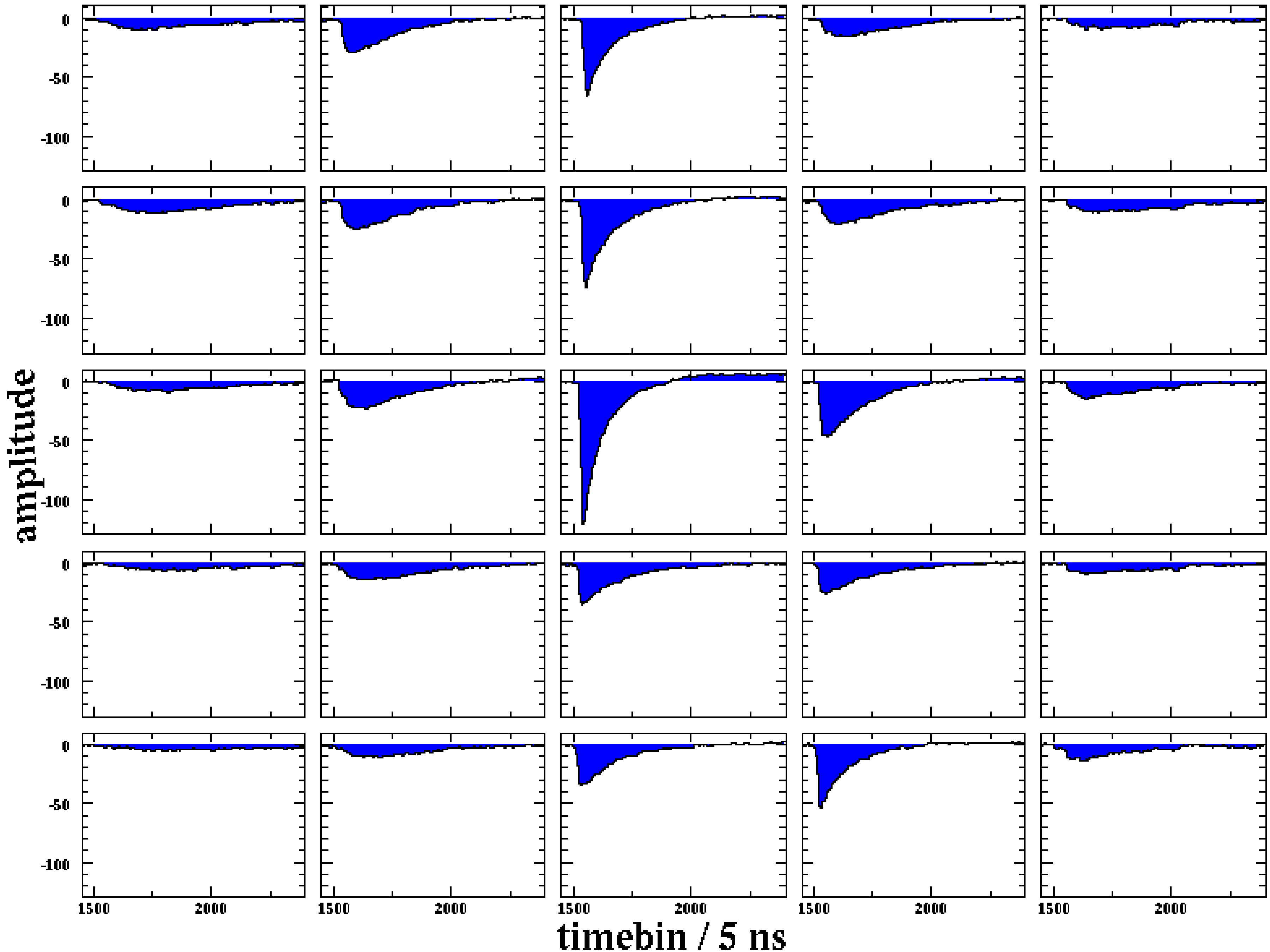
ALEPH TPC preamplifiers

custom FADC, 200 MHz University of Montreal



Event with Charge Dispersion





0
-50
-100
amplitude
1500
2000
timebin / 5 ns

Tracking with charge dispersion

Re-learn how to do signal / track reconstruction:

- different pulse shapes → what is the amplitude?
- PRF not known a priori.
- cross-talk between rows:
  dispersion is 2D → seen on next row
  can in principle be used to reduce track-angle effect

Learn from experience with point resolution
but situation is different:

- Point of charge ⇨ line of charge (cosmic-ray track)
- No external knowledge of position
  ⇨ use internal consistency of 5 rows

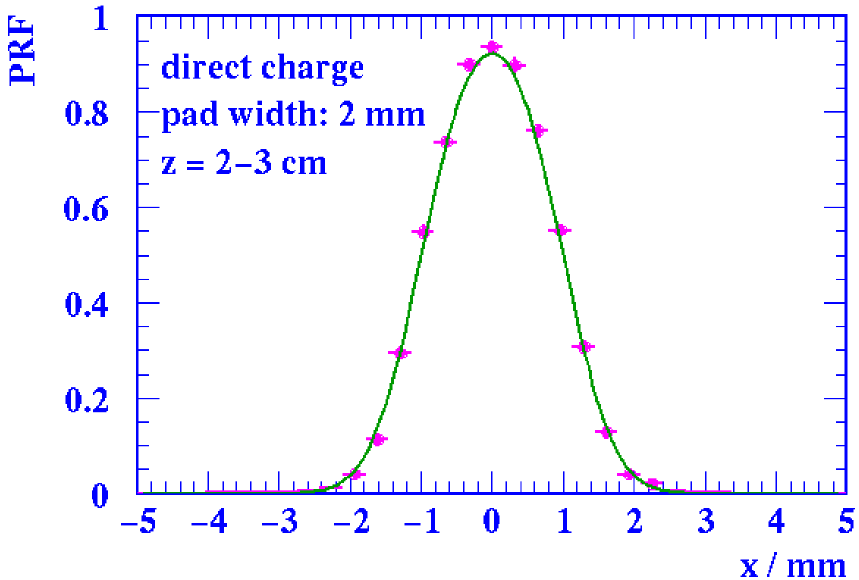
Pad Response Function

Direct charge

Charge has Gaussian profile
from transverse diffusion

$$PRF(x,\sigma,\phi) = \int_{pad} Gauss$$

Parameters: x, $\sigma(z)$, ϕ

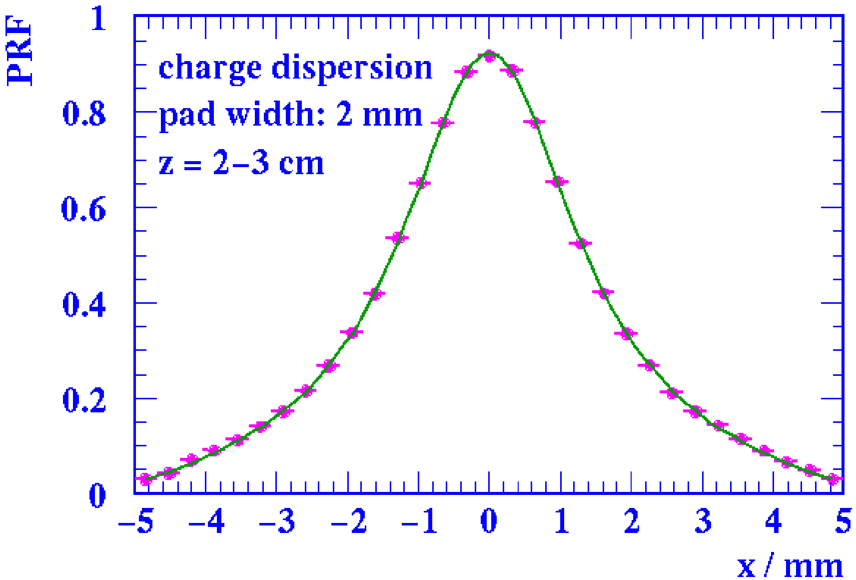


Charge dispersion

Determine PRF from data
fit to generalized Lorentzian

$$PRF(x,FWHM) = \frac{1 + a_1 x + a_2 x^2}{1 + b_1 x + b_2 x^2}$$

Parameters: x, $FWHM(z)$



PRFs describe the data well, adjust width as function of drift distance.

Track Fit

Direct charge	Charge dispersion
Maximize probability	Minimize χ^2
$\prod_{i=pads} PRF_i^{N_i}$ N_i: electrons on pad i	$\sum_{i=pads} \left(\frac{A_i - PRF_i}{\delta A_i} \right)^2$

PRF has to be normalized accordingly

Determine track parameters x_0, ϕ

$$x_{track} = x_0 + y \tan(\phi)$$

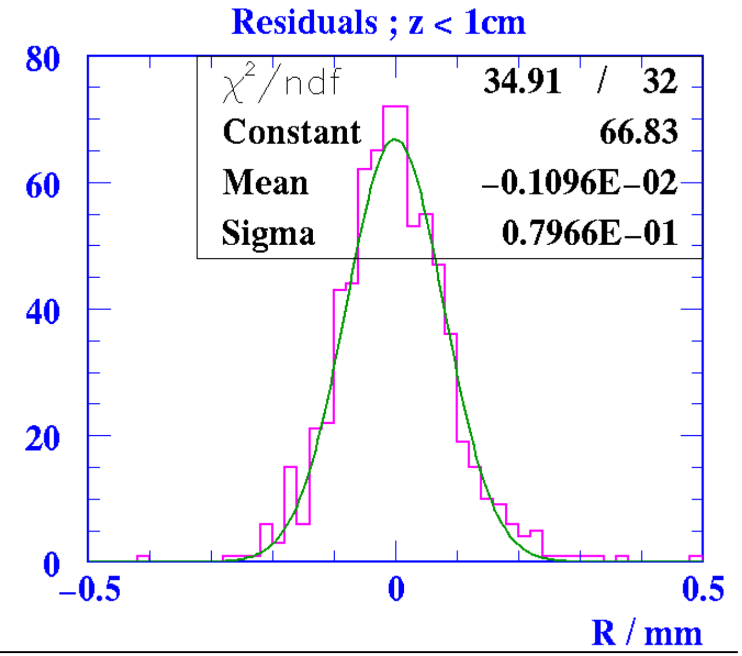
Position x_{row} in row: track fit to 1 row, other track-parameters fixed

Residuals: $R = x_{row} - x_{track}$

Bias: mean of residuals

Resolution: sigma of residuals

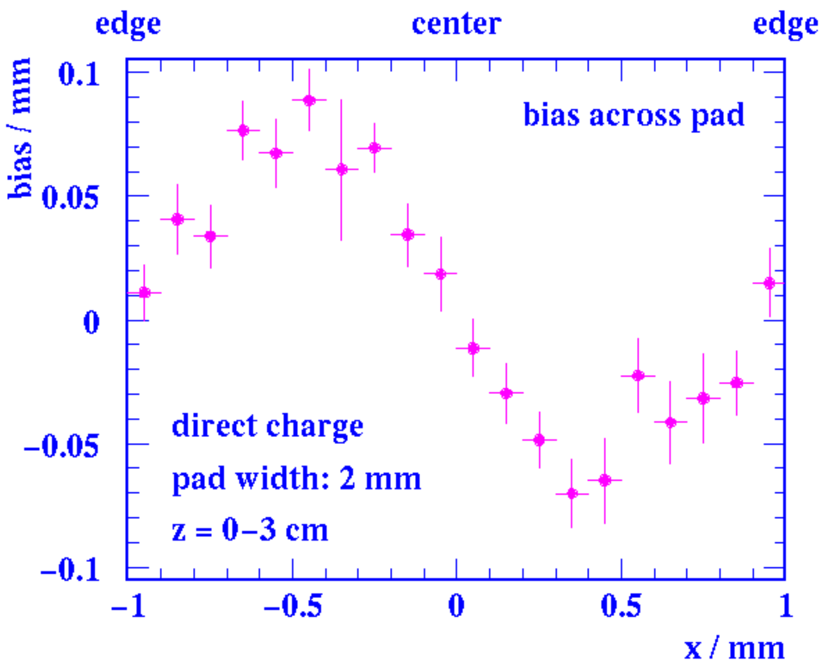
Study for tracks with $|\phi| < 5^o$.



Is there a Bias?

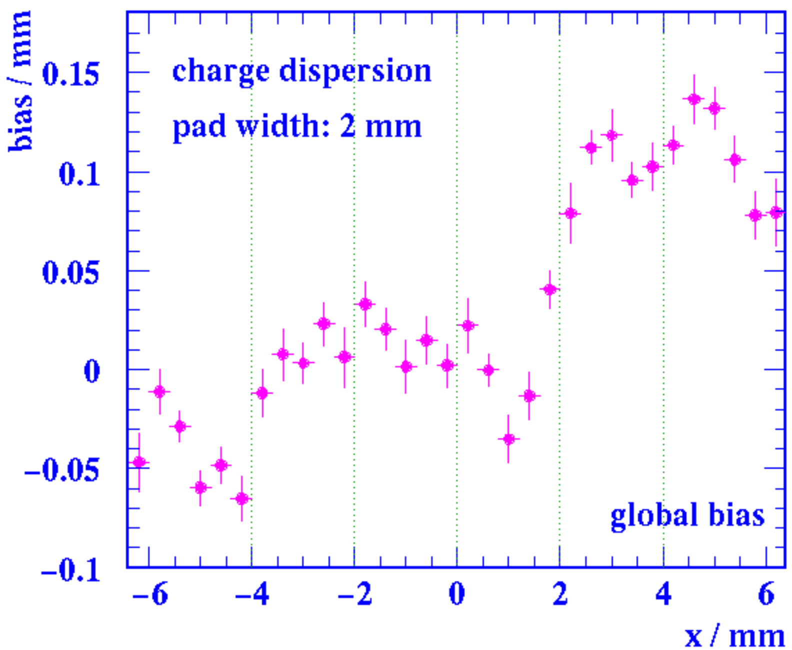
Direct charge	Charge dispersion

Bias across pad if
pad width > 3 ∗ charge width



No global bias

Global bias due to *RC* inhomogenity
time independent
→ can be corrected

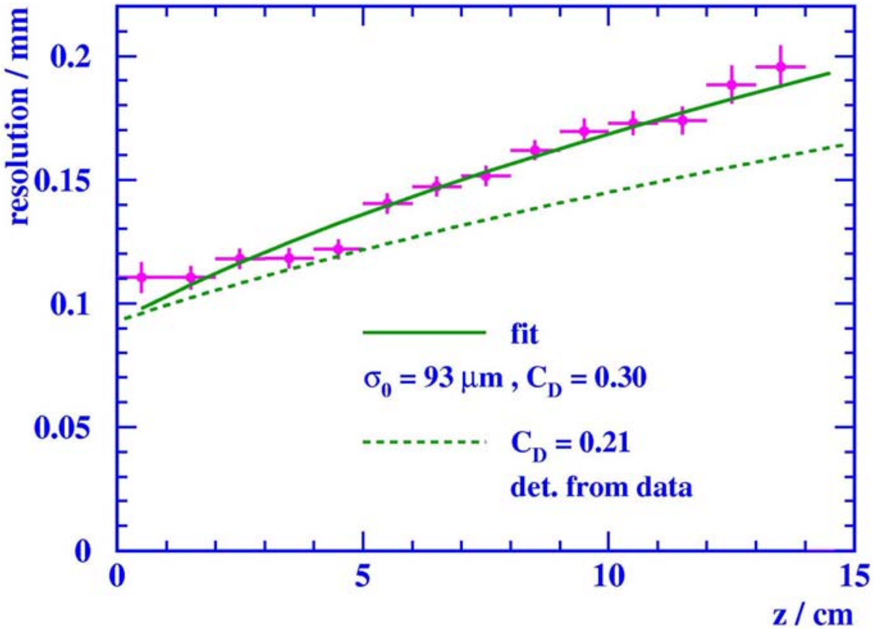


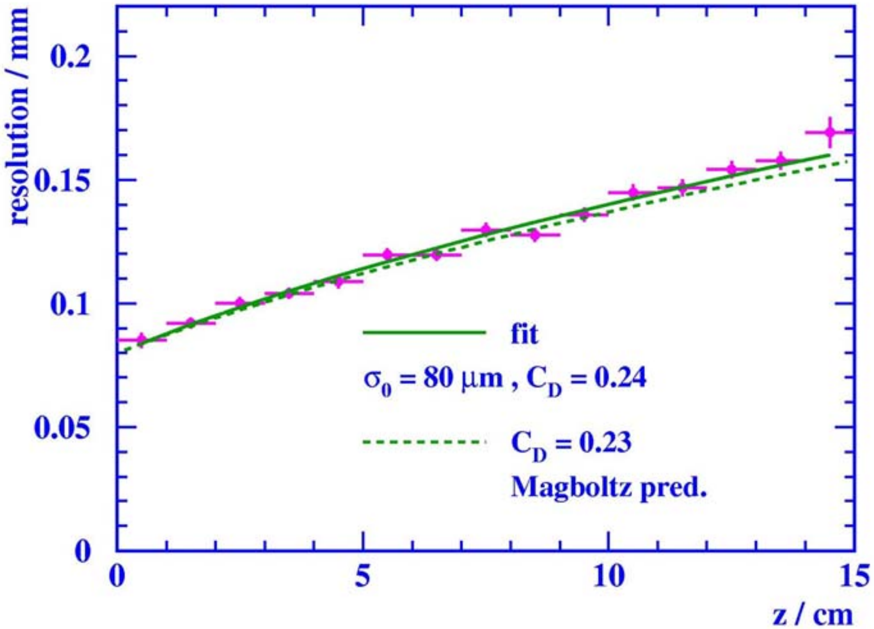
No bias modulo pad size

Resolution as Function of z

Direct charge	Charge dispersion

R.K.Carnegie et.al.,
physics/0402054 (→ NIM)





- - - - - $\sigma_0 + \frac{C_D}{\sqrt{N}} z$

Charge dispersion improves resolution even if charge is 'sufficiently' spread due to transverse diffusion.

Resolution Comparison

Direct charge	**Charge dispersion**
For small transverse diffusion (small z, B field) 2 mm wide pads don't give the best possible resolution.	Spreads signal in controlled way (geometry, not diffusion). Width is tunable, adjust *RC*. Works with GEM ***AND*** microMegas.
Not enough charge sharing.	Need good quality of resistive foil and lamination to ensure homogenous *RC*. Remaining systematic effects can be corrected.
Don't reach diffusion limit with our setup/analysis.	
Obtained resolution @ z=0: σ_0 = 93 μm 50% worse than diffusion limit	Obtained resolution @ z=0: σ_0 = 80 μm close to diffusion limit for z>0

Conclusion / Plans

Concept of charge dispersion on a resistive anode successfully tested with point charge and cosmic-ray tracks.

Global bias (~100 μm), can be corrected.

Charge dispersion improves resolution compared to normal readout.
Resolution at z=0 of 80 μm, for z>0 close to diffusion limit;
with 2 mm wide pads, Ar:CO_2 (90:10), up to 15 cm drift distance.

Will repeat this study with microMegas:

Point resolution study ⇨ uniformity / consistency.
Track resolution with microMegas and charge dispersion.
We can use ArCO_2 to fake low diffusion from magnetic field.

Further tests: magnetic field, test beam, …
Open questions: what kind of electronics can be used, …
(e.g. inexpensive 20 MHz electronics)

This is a promising start but not the end of the story … …