MPGD-TPC resolution from charge dispersion on a resistive anode

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MPGD-TPC resolution with charge dispersion

- Electron statistics & transverse diffusion set the fundamental limit on the best achievable TPC resolution.
- **ExB** & track angle systematic effects prevent the anode wire/cathode pad TPC in a magnetic field from getting close to the diffusion limit.
- With negligible **ExB** effects, the Micro Pattern Gas Detector (MPGD) readout could do much better but for the lack of precision in charge centroid determination with conventional ~ mm width TPC readout pads.
- The MPGD-TPC could get better resolution with sub-mm width pads at the expense of a large increase in the detector cost & complexity.

▪For better resolution with ~ mm width TPC pads, the avalanche cluster charge can be dispersed to improve pad centroid precision.

  - ➢For the GEM, added diffusion in the transfer & induction gap does disperse the cluster charge. Prototype GEM-TPCs have so far not got close to the limit of resolution from diffusion & electron statistics.
  - ➢A MPGD with a resistive anode disperses the avalanche charge & may improve the TPC resolution both with the GEM and the Micromegas.

➢The concept, the progress & the status of MPGD-TPC resolution studies with charge dispersion on a resistive anode presented here.

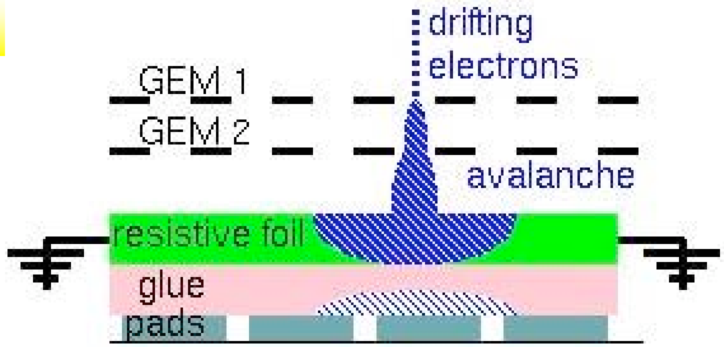
The concept of charge dispersion in a MPGD with a resistive anode

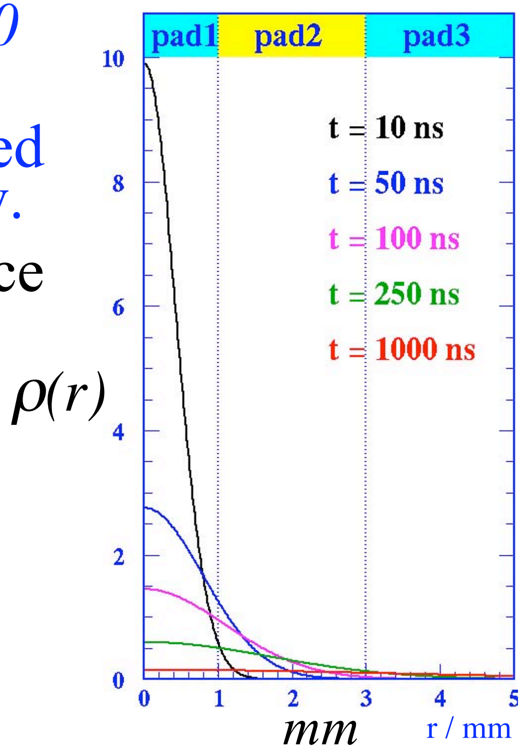
- Modified GEM anode structure with a high resistivity film bonded to the readout plane with an insulating spacer.
- 2-dimensional continuous RC network defined by material properties & geometry.
- Point charge at $r = 0$ & $t = 0$ disperses with time.
- Measure capacitively coupled charge signals on pads below.

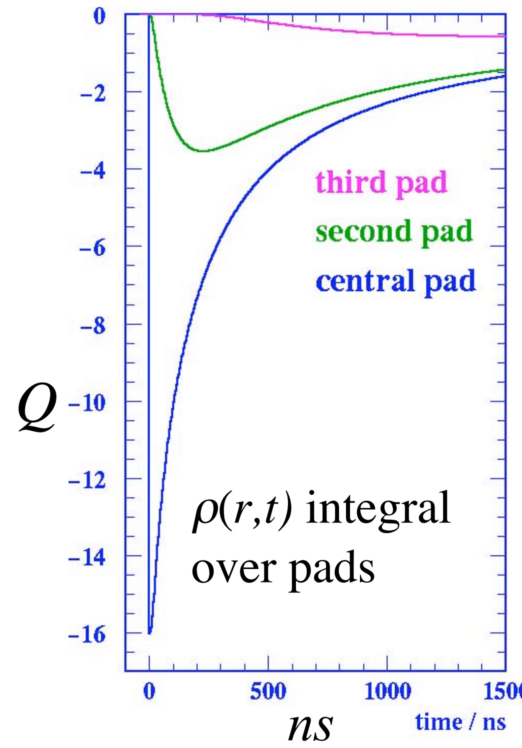
Telegraph equation for surface charge density on the 2-dim. continuous RC network:

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

$$\Rightarrow \rho(r,t) = \frac{RC}{2t} e^{\frac{-r^2 RC}{4t}}$$

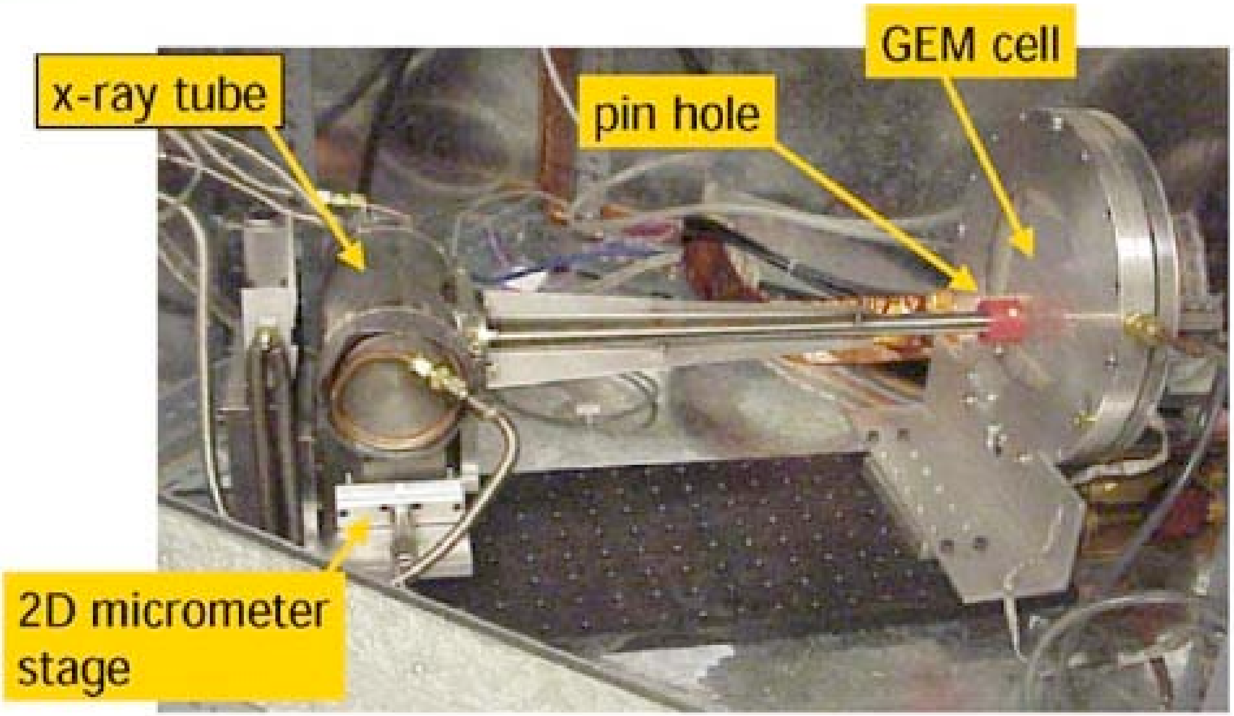






Setup for MPGD x-ray studies with a resistive anode

Concept & first results:M.S.Dixit et.al., Nucl. Instrum. Methods ***A518*** *(2004) 721.*



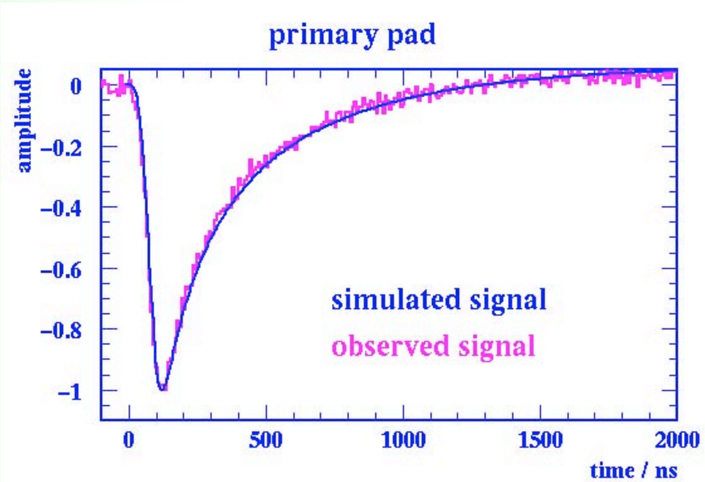
- Point source ~ 50 μm collimated 4.5 keV x rays.
- 2 mm x 6 mm pads.
- Aleph TPC preamps. $\tau_{Rise} = 40$ ns, $\tau_{Fall} = 2$ μs.
- DAQ - 500 MHz Tektronix digital scope.
- Anode resistivity ~ 530 kΩ/☐, C ~ 0.22 pF/mm^2.

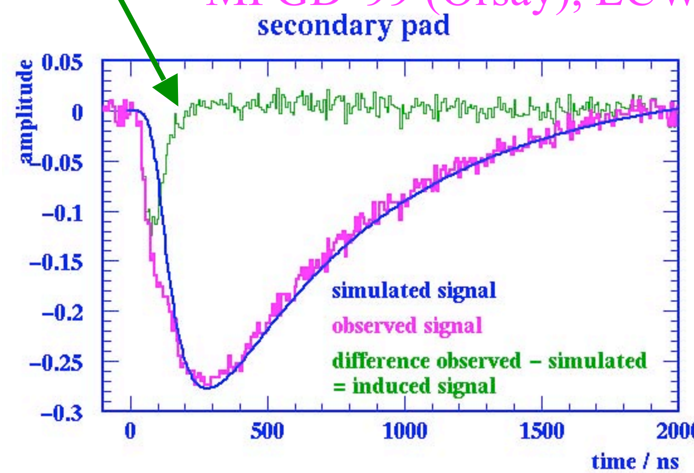
The GEM charge dispersion signal
Simulation versus measurement

(2 mm x 6 mm pads) Collimated ~ 50 μm 4.5 keV x-ray spot on pad centre.

Detailed simulation includes effects of, longitudinal & transverse diffusion, gas gain, detector pulse formation, charge dispersion & preamplifier rise and fall time effects. For tracks, include effects of unequal primary clusters.

Difference = induced signal (not included in simulation) studied previously: MPGD '99 (Orsay), LCWS '00

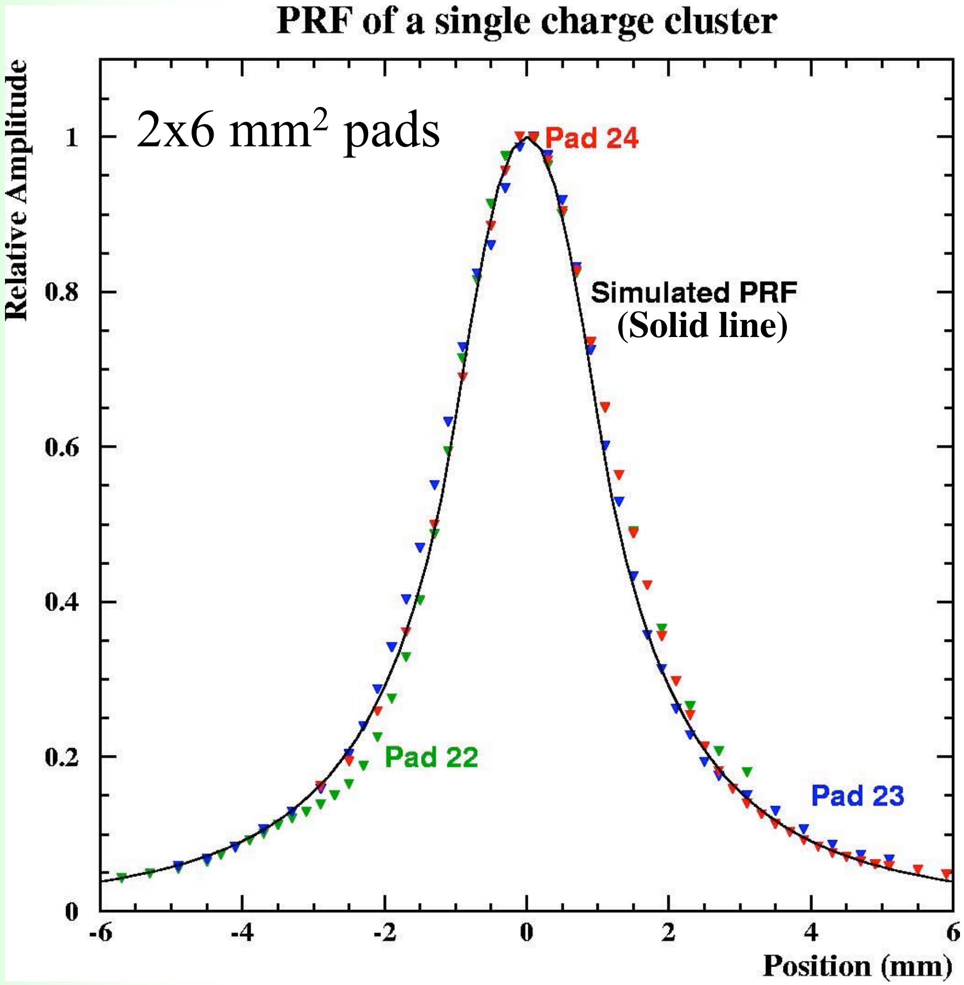




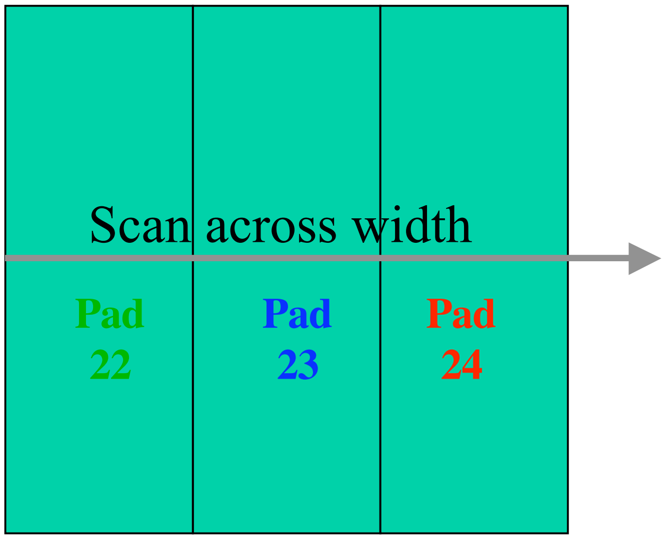
Primary signal: Fast large amplitude main pulse on charge collecting pad. Simulated primary pulse is normalized to the data.

Secondary signal: The dispersion pulse on the neighboring pad is slower & smaller. Simulated secondary pulse normalization is the same as for the primary.

GEM pad response function for a single charge cluster
Simulation versus measurement



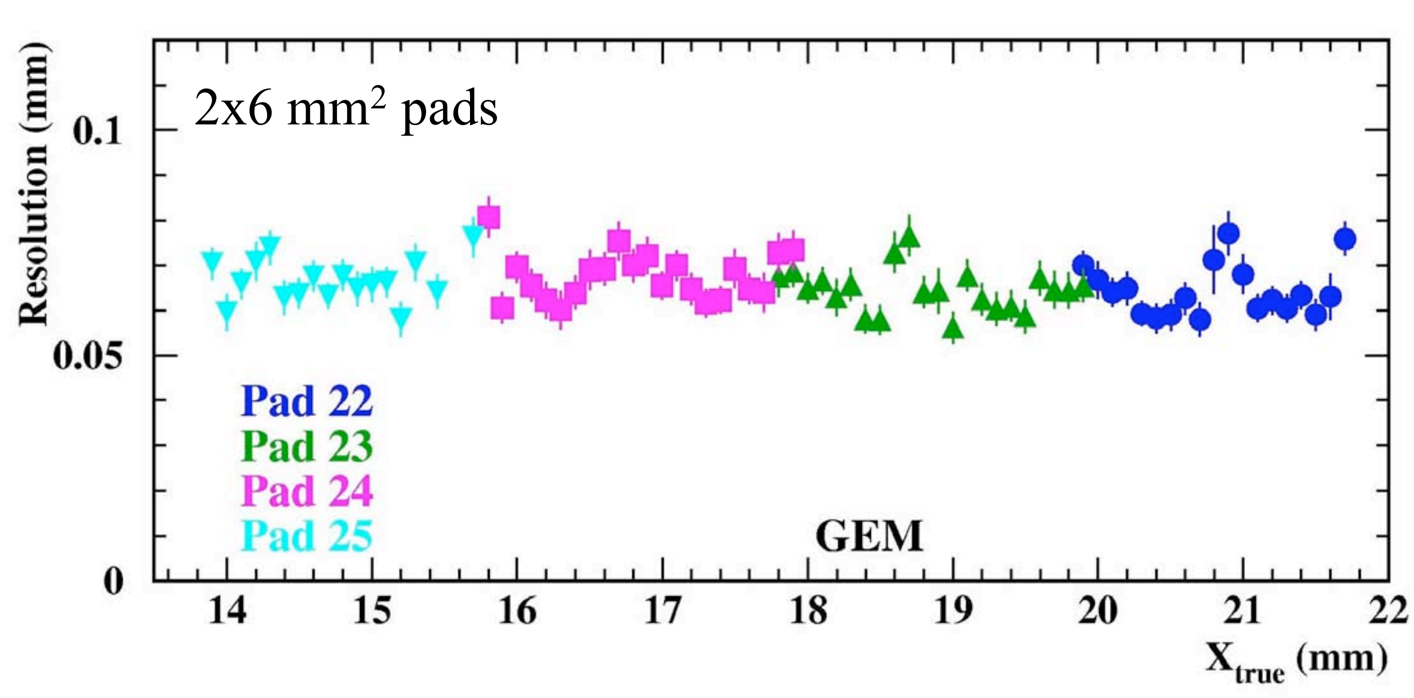
Ionization from 50 µm collimated x-rays.



Measured PRF deviates from simulation due to anode RC nonuniformities.

Resistive anode double-GEM spatial resolution

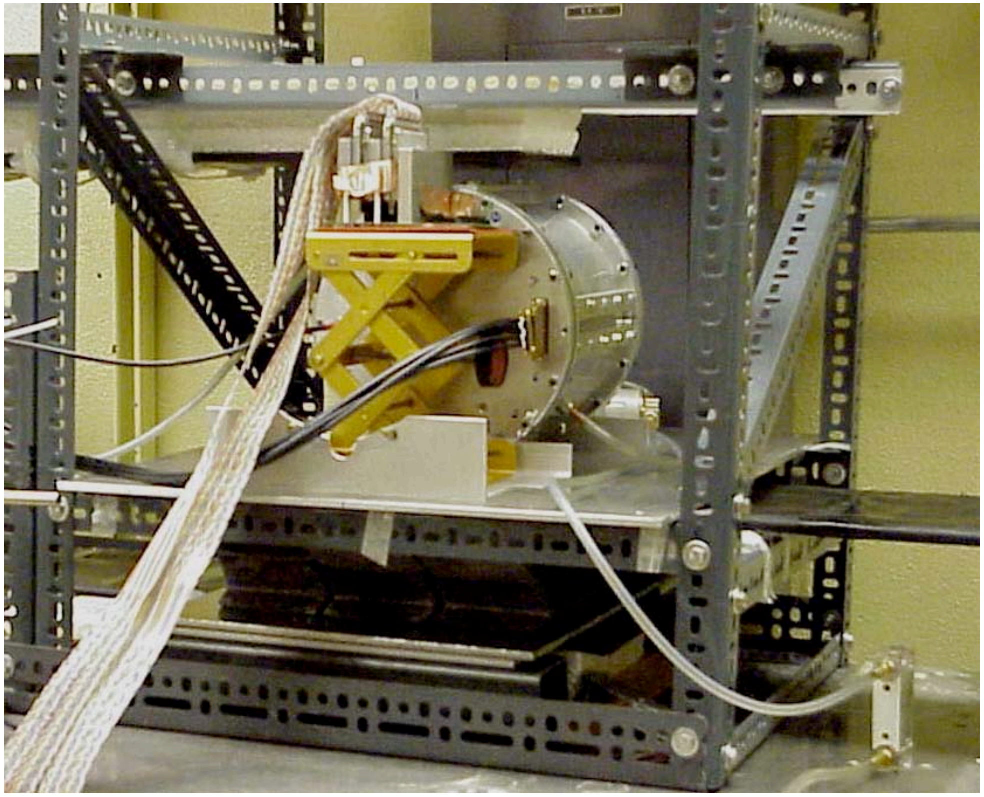
Collimated ~ 50 µm x-ray spot



- GEM resolution ~ 70 µm.
- Similar resolution measured for a Micromegas with a resistive anode readout using 2 mm x 6 mm pads

Cosmic ray track resolution of a GEM readout TPC

- 15 cm drift length TPC with double-GEM endcap readout.
- No magnetic field.
- Low diffusion gases chosen- Ar:CO_2/90:10 & Ar:CO_2 /80:20 to simulate reduced transverse diffusion in a magnetic field.
- LEP-Aleph TPC wire preamps.
- 200 MHz custom 8 bit FADCs.
- 60 tracking pads (2 x 6 mm^2) + 2 trigger pads (6 x 24 mm^2).



The GEM-TPC resolution was first measured with conventional TPC pad charge readout electronics for Ar/CO_2 (90/10).

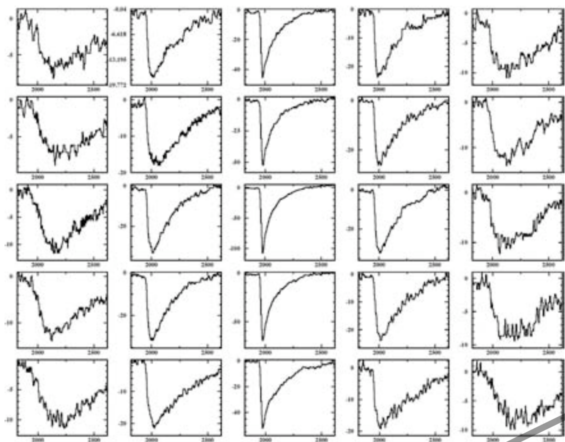
The GEM-TPC resolution was next measured with a resistive anode readout. The resistive anode was the same as was used for x-ray tests.

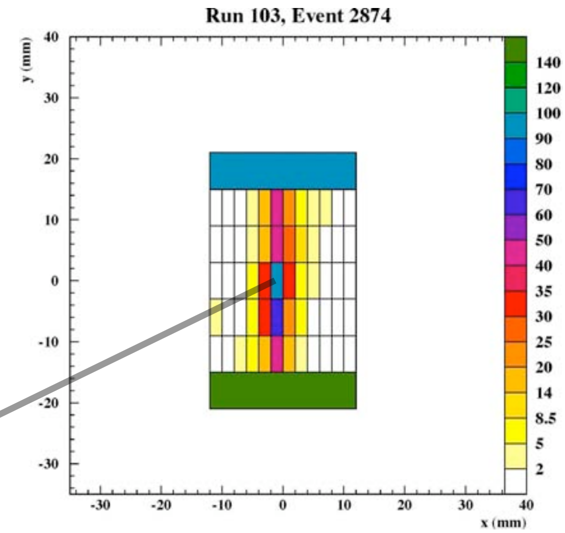
Cosmic ray simulation with charge dispersion - versus track data

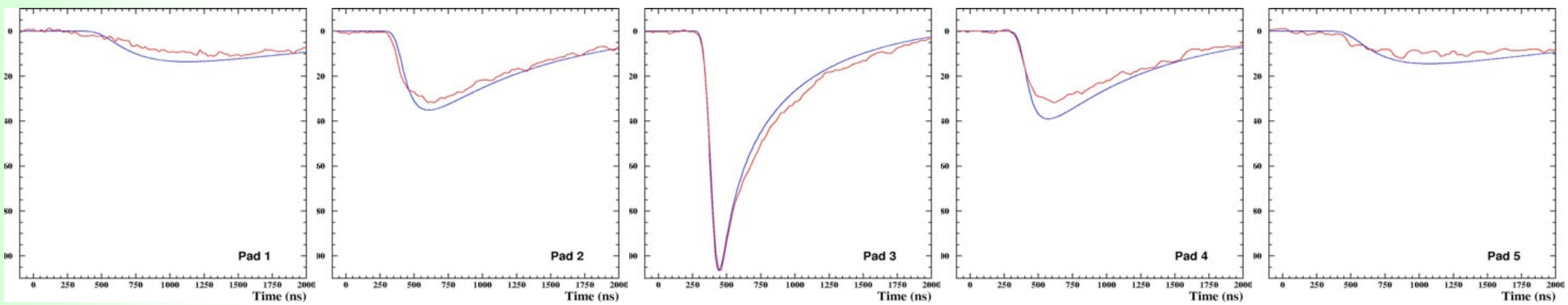
(track Z drift distance ~ 67 mm, Ar/CO_2 90/10 gas)

2x6 mm^2 pads

- An exact simulation requires specifying the position & the size of all primary clusters.
  - *We assume primary electron clusters over a pad have equal size and spacing.*

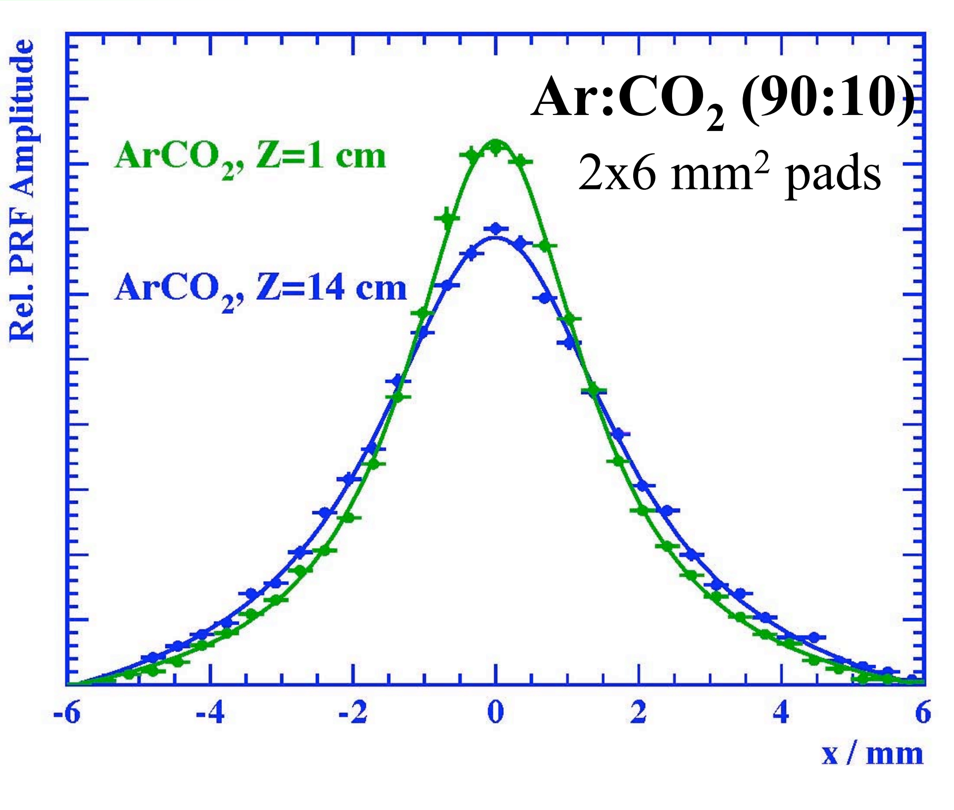






Centre pad amplitude used for normalization - no other free parameters.

Track pad response function for charge dispersion



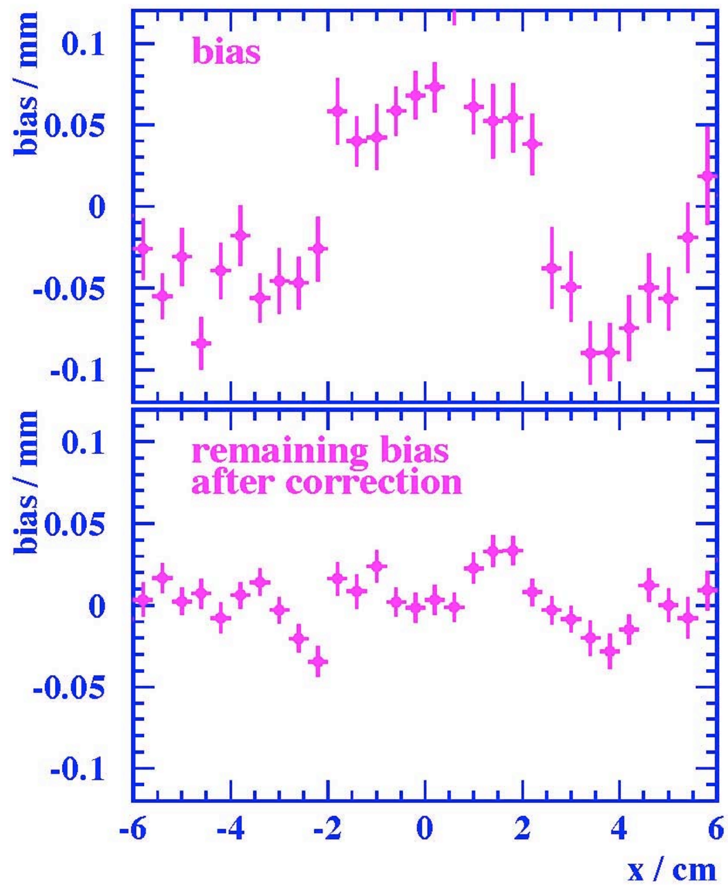
- The pad response function (PRF) was determined from the self consistency of subset of cosmic ray data used for calibration.
- The PRF can be described by a generalized Lorentzian function:

Parameters: x & FWHM $\Gamma(z)$

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

The pad response function maximum for 14 cm is lower due to Z dependent normalization.

Bias in reconstructed positions from the PRF

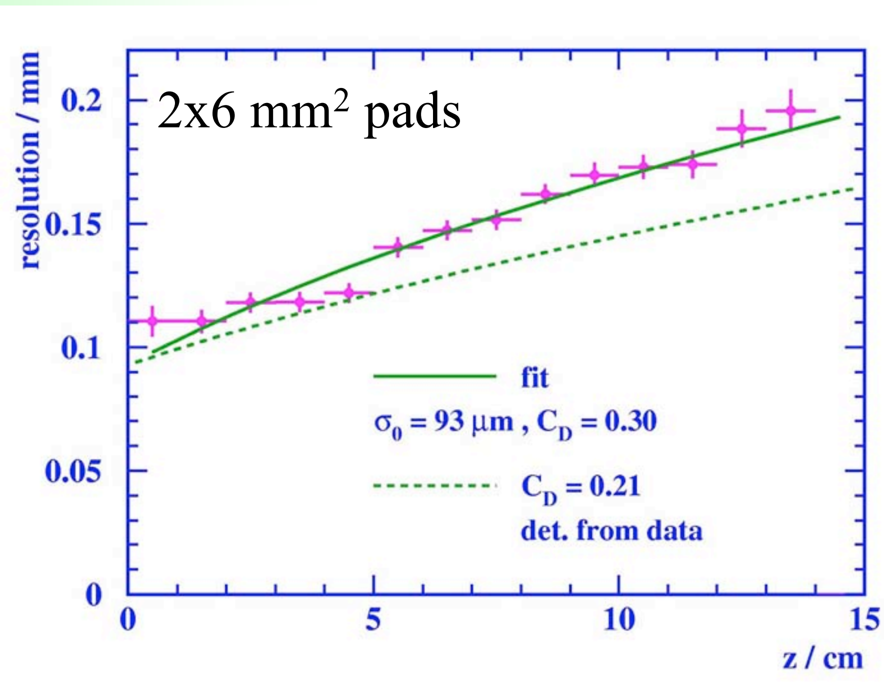


- Local non-uniformities in the anode RC lead to ~100 μm bias (systematic errors) in position determination. The bias error can be removed by calibration.
- The bias corrections were determined from the calibration data set.
- The bias corrections will be much smaller for a detector with more uniform RC properties.

Bias for row 4 in Ar:CO_2 (90:10)

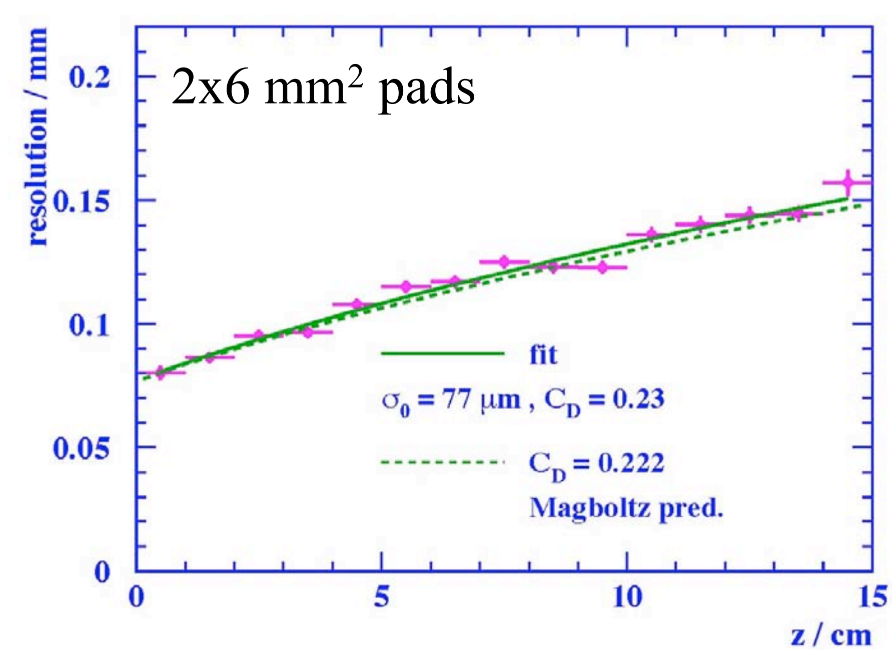
GEM-TPC transverse spatial resolution for Ar:CO_2 (90:10)

TPC resolution with conventional GEM readout



R.K.Carnegie et.al., physics/0402054 (Nucl Instrum & Methods **A** *- in press).*

Resolution with a resistive anode readout

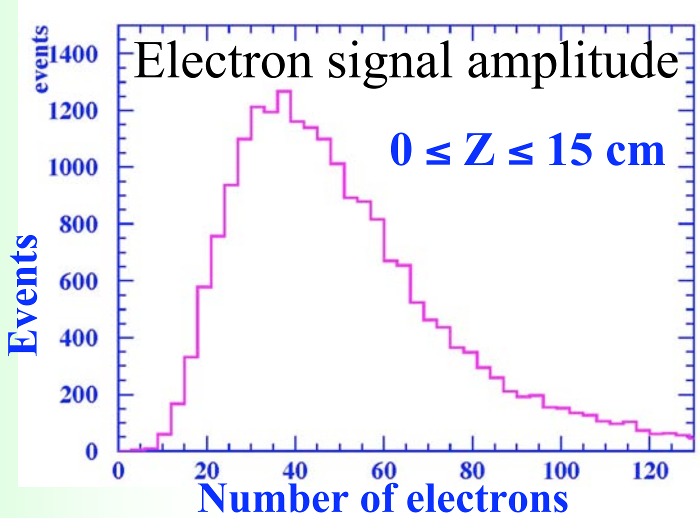


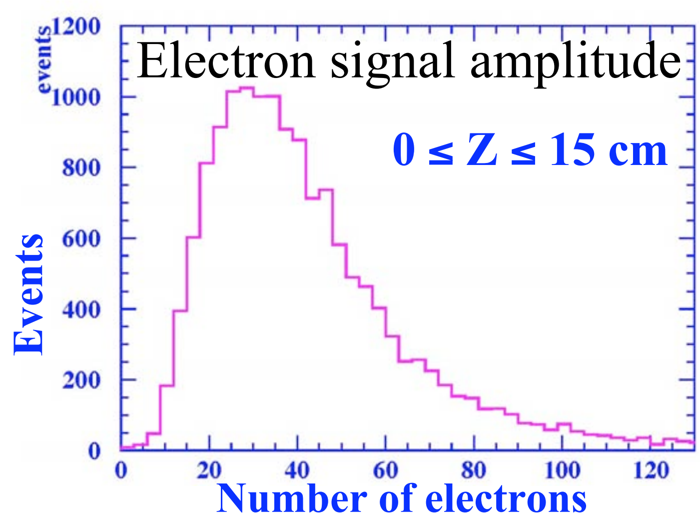
.... $\sqrt{\sigma_0^{\;2} + \frac{C_D^{\;2}}{N_e} z}$

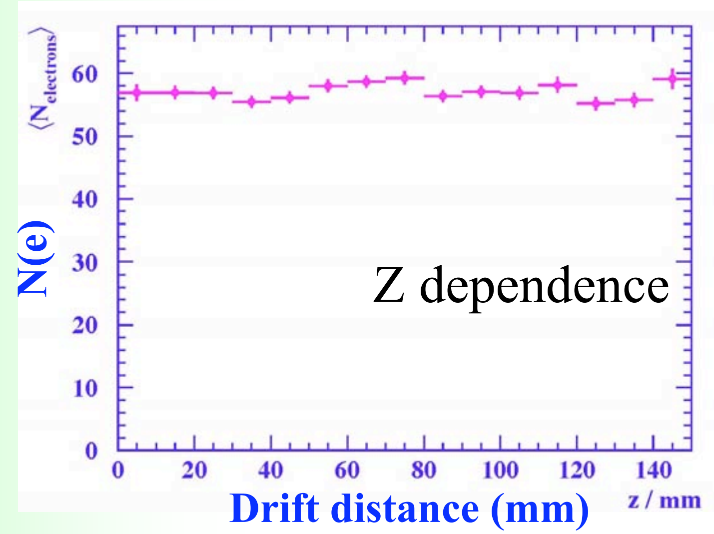
Compared to a conventional GEM readout, the resistive anode resolution is better with Z dependence consistent with diffusion & electron statistics.

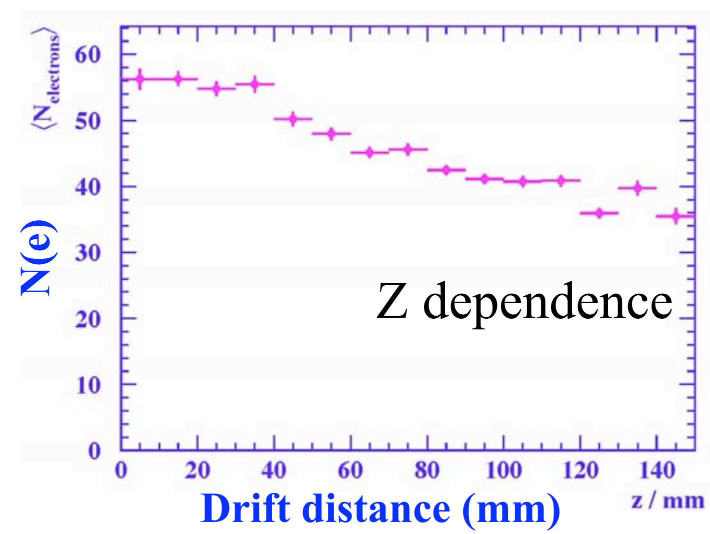
Electron loss observed for Ar:CO_2(80:20) due to attachment

Ar:CO_2 (90:10) | **Ar:CO_2 (80:20)**

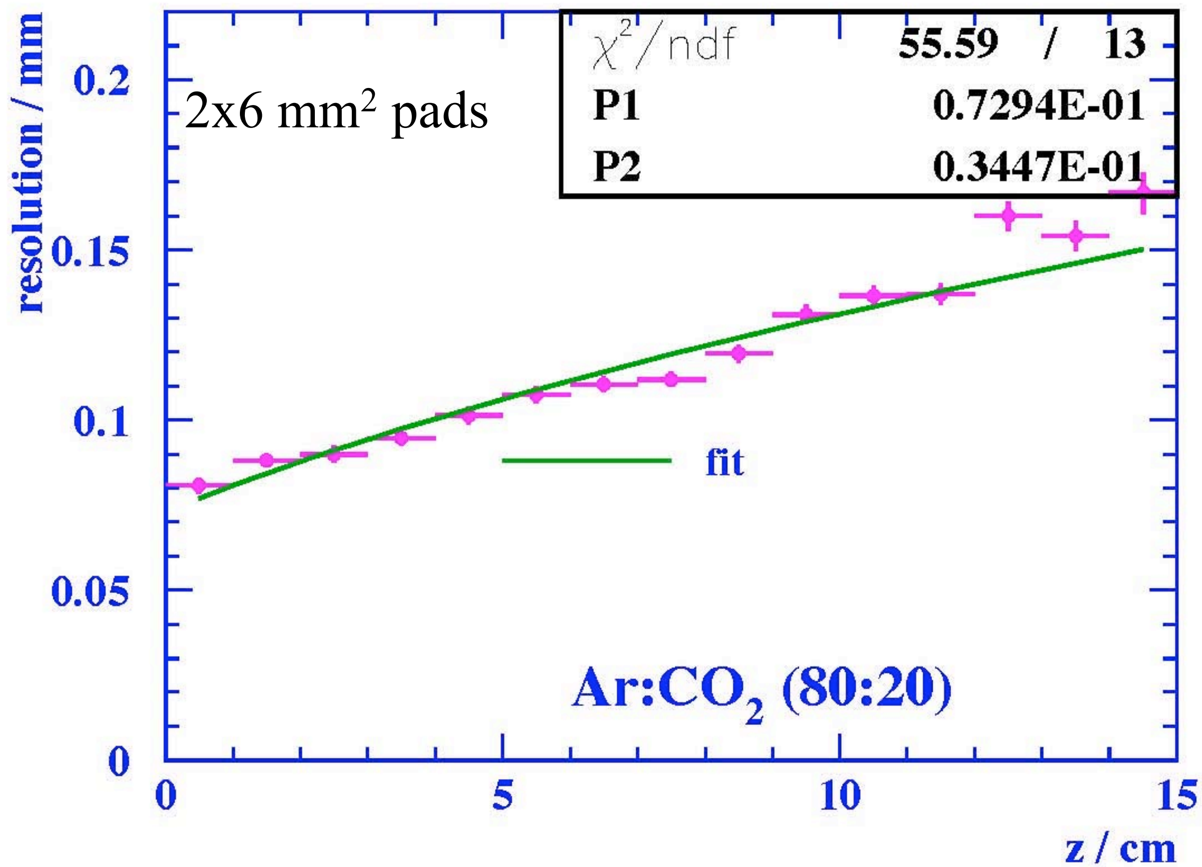








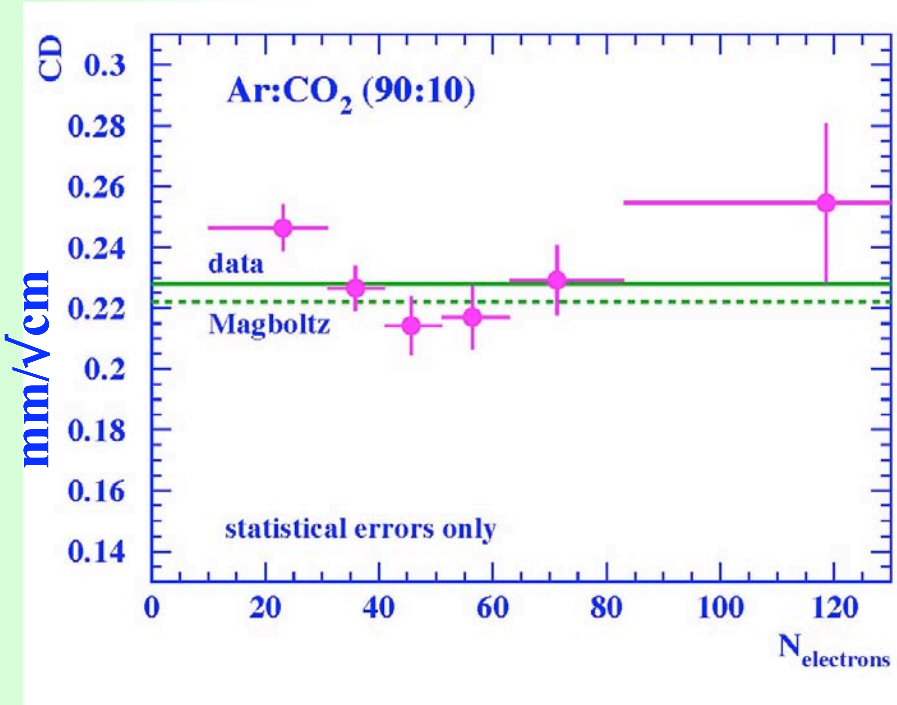
Resolution loss in Ar:CO_2 (80:20) for large drift distances due to electron attachment - Resistive anode GEM readout



Nevertheless, the Z dependence of resolution is consistent with diffusion & reduced electron statistics with increasing Z.

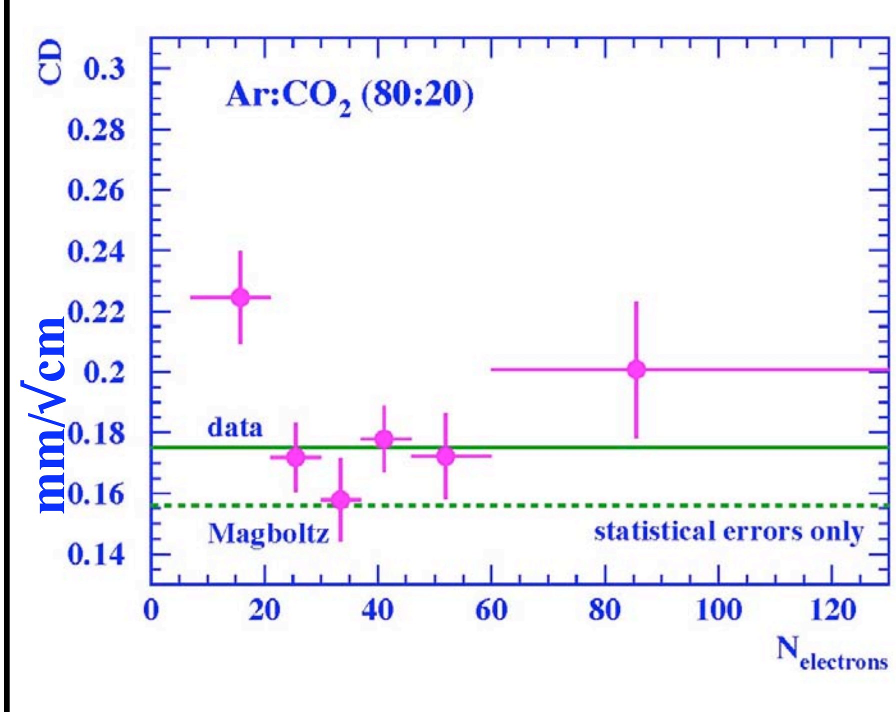
Transverse diffusion versus electron signal amplitude

$Ar:CO_2$ (90:10)



Number of electrons

$Ar:CO_2$ (80:20)



Number of electrons

Measured transverse diffusion for the two gases is reasonable.

Summary & outlook

- Better TPC resolution with GEM with a resistive anode than with a conventional GEM readout.
- The Z dependence of resolution is consistent with diffusion & electron statistics. It should be possible to reduce the ~ 75 μm constant term in the resolution with better electronics & more uniform system RC.
- We are making progress in fabricating resistive anode structures with better RC uniformity.
- We understand the complexities of charge dispersion. The simulation is in good agreement with the data.
- Plans - Micromegas tests & TPC cosmic ray & beam tests in a magnetic field using the charge dispersion signal on a resistive anode.