<u>Spatial resolution of a MPGD TPC using</u> <u>the charge dispersion signal</u>

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## **MPGD-TPC** resolution with charge dispersion

•ILC TPC challenge: Using ~ 2 mm wide pads, measure ~ 200 points with ~ 100  $\mu$ m resolution for all tracks (max. TPC drift length ~ 2.5 m).

•Transverse diffusion sets the ultimate limit on TPC resolution.

•ILC tracker resolution goal is near the ultimate limit from diffusion for a gaseous TPC.

Conventional TPCs with proportional wir/cathode pad endcap readout systems limited by ExB & track angle systematics.
A TPC read out with a MPGD endcap could achieve the ILC resolution goal with ~ 2 mm wide pads if the precision of pad charge centroid determination could be improved.

•Ideas to improve the MPGD TPC resolution:

Narrower pads would lead to increased complexity & a larger number of readout channels.

Controlled dispersal of track avalanche charge after over a larger area to improve determination of pad centroids with wide pads.

# Charge dispersion in a MPGD with a resistive anode

•Modified MPGD anode with a high resistivity film bonded to a 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. d = 0 d

•Time dependent anode charge density sampled by readout pads. Equation for surface charge density function on the 2-dim. continuous RC network:

$$\frac{\partial \rho}{\partial t} = \frac{1}{RC} \left[ \frac{\partial^2 \rho}{\partial r^2} + \frac{1}{r} \frac{\partial \rho}{\partial r} \right]$$
$$\Rightarrow \rho(r,t) = \frac{RC}{2t} e^{\frac{-r^2 RC}{4t}}$$



## Cosmic ray resolution of a MPGD-TPC

•15 cm drift length with GEM or Micromegas readout, B = 0•Ar:CO<sub>2</sub>/90:10 chosen to simulate low transverse diffusion conditions in a high magnetic field. •Aleph charge preamps.  $\tau_{\text{Rise}} = 40 \text{ ns}, \tau_{\text{Fall}} = 2 \mu \text{s}.$ •Digitization effectively at 25 MHz by combining 200 MHz FADC time bins. •60 tracking pads (2 x 6 mm<sup>2</sup>) + 2 trigger pads (24 x 6 mm<sup>2</sup>).

The GEM-TPC resolution was first measured with conventional direct charge TPC readout.



The resolution was next measured with a charge dispersion resistive anode readout with a double-GEM & with a Micromegas endcap.

## **Resistive anode Micromegas**

530 k $\Omega/\Box$  Carbon loaded Kapton resistive anode was used with GEM. This was replaced with more uniform higher resistivity 1 M $\Omega/\Box$  Cermet for Micromegas.



#### Simulation - GEM TPC cosmic event with charge dispersion (track Z drift distance ~ 67 mm, Ar/CO, 90/10 gas)

Detailed model simulation including longitudinal & transverse diffusion, gas gain, detector pulse formation, charge dispersion & preamp rise & fall time effects.





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

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# The pad response function (PRF)

- The PRF is a measure of signal size as a function of track position relative to the pad.
- For charge dispersion non charge collecting pads have signals in contrast to conventional direct charge readout.
- Unusual highly variable charge dispersion pulse shape; both the rise time & pulse amplitude depend on track position.
- We use pulse shape information to optimize the PRF.
- The PRF can, in principle, be determined from simulation.
- However, system RC nonuniformities & geometrical effects introduce bias in absolute position determination.
- The position bias can be corrected by calibration.
- PRF and bias determined empirically using a subset of data which was used for calibration. The remaining data was used for resolution studies.

#### GEM & Micromegas PRFs for TPC track Ar:CO<sub>2</sub> (90:10) 2x6 mm<sup>2</sup> pads

The pad response function maximum for longer drift distances is lower due to Z dependent normalization.



Micromegas PRF is narrower due to the use of higher resistivity anode & smaller diffusion after avalanche gain

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## PRFs with the GEM & the Micromegas readout

- The PRFs are not Gaussian.
- The PRF depends on track position relative to the pad.
  PRF = PRF(x,z)
- PRF can be characterized by its FWHM  $\Gamma(z)$  & base width  $\Delta(z)$ .
- PRFs determined from the data have been fitted to a functional form consisting of a ratio of two symmetric 4th order polynomials.

$$PRF[x,\Gamma(z),\Delta,a,b] = \frac{(1+a_2x^2+a_4x^4)}{(1+b_2x^2+b_4x^4)}$$

a<sub>2</sub> a<sub>4</sub> b<sub>2</sub> & b<sub>4</sub> can be written down in terms of  $\Gamma$  and  $\Delta$  & two scale parameters a & b.

# Track fit using the the PRF

Track at:  $x_{track} = x_0 + tan(\phi) y_{row}$  $\chi^2 = \sum_{\text{rows i=pads}} \left[ \frac{(A_i - PRF_i)}{\partial A_i} \right]^2$ Determine  $x_0 \& \phi$  by minimizing  $\chi^2$  for the entire event • One parameter fit for  $x_{row}$  (track position for a given row) using  $\phi$ Bias = Mean of residuals  $(x_{row}-x_{track})$ as a function of  $x_{track}$ Resolution =  $\sigma$  of track residuals for tracks with  $|\phi| < 5^{\circ}$ 

6 mm

2 mm

X

# **Bias corrections with GEM & with Micromegas**





Micromegas

GEM

## What is the diffusion limit of resolution for a gaseous TPC?

Resolution depends on electron statistics. Electron number N fluctuates from event to event.



$$\sigma_x^2 = \sigma_0^2 + \frac{C_d^2 \cdot z}{N_{eff}}$$

 $\sigma_0$  includes noise & systematic effects.  $C_d = diffusion constant; z = drift distance$ 

 $N_{eff} \neq \langle N \rangle$  the average number of electrons =  $1/\langle 1/N \rangle$  the inverse of average of 1/NGain fluctuations also affect  $N_{eff}$ 

### Simulation to determine N<sub>eff</sub> 2 mm x 6 mm pads - Ar/CO<sub>2</sub> 90/10

Cosmic ray momentum spectrum

dE/dx in Argon

Measured pad pulse height distribution



Statistics of primary ionization & cluster size distribution.
dE/dx dependence on momentum.

•Account for track angle & detector acceptance effects.

- •Use simulation to scale measured pulse heights to electron number.
- • $N_{eff} = 1/\langle 1/N \rangle$  determined from pulse height distribution.

• $N_{eff} \approx 38.9 \pm 10\% \ (N_{average} = 57)$ 

## Measured TPC transverse resolution for Ar: CO<sub>2</sub> (90:10)



$$\sqrt{\sigma_0^2 + \frac{C_D^2}{N_e} z}$$
 [N<sub>eff</sub> = 38.9]

Compared to conventional readout, resistive readout gives better resolution for the GEM and the Micromegas readout. The z dependence follows the expectations from transverse diffusion & electron statistics.

## What's next?

- Beam test at KEK in October 2005 to demonstrate good resolution in a magnetic field using ~ 2 mm wide pads.
- Two TPCs will be tested in the 1.2 T Jacee magnet.
  - Carleton TPC with a Micromegas with a resistive anode using a new 128 pad PCB designed for tracking in a magnetic field.

Ron Settles (MPI) has designed a TPC to facilitate comparison of different readout options under similar conditions. The MPI-TPC will also be tested at KEK using a resistive anode readout both with GEMs and the Micromegas.

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### A cosmic ray event in the new Carleton 128 pad TPC

#### **Relative amplitudes**

	1																	
19	18	17	16	15	14	13	12	11	10	9	a	7	6	5	4	з	2	
37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	
55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38	
120	121	122	123	124	125	126	127	128	64	63	62	61	60	59	58	57	56	
102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	
84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	
66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	
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#### Resolution for cosmic ray tracks for the new 128 pad TPC



The new 128 pad TPC is ready for KEK beam test

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# Summary & outlook

- Using 2 mm wide pads, we have demonstrated better GEM/Micromegas-TPC resolution with a resistive anode readout than has been achieved with conventional MPGD TPC readout systems.
- The resolution is near the diffusion limit of resolution for a gaseous TPC. In cosmic tests with no magnetic field, the measured resolution follows the expectations from transverse diffusion & electron statistics.
- Beam tests in a magnet next to demonstrate good resolution for a TPC in a magnetic field.
- A resolution of ~ 100 µm for all tracks (2.5 m drift) using
   ~ 2 mm wide pads appears feasible for the ILC TPC.