GEM TPC Resolution

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TPC Setup

15 cm drift distance

cosmic ray particles

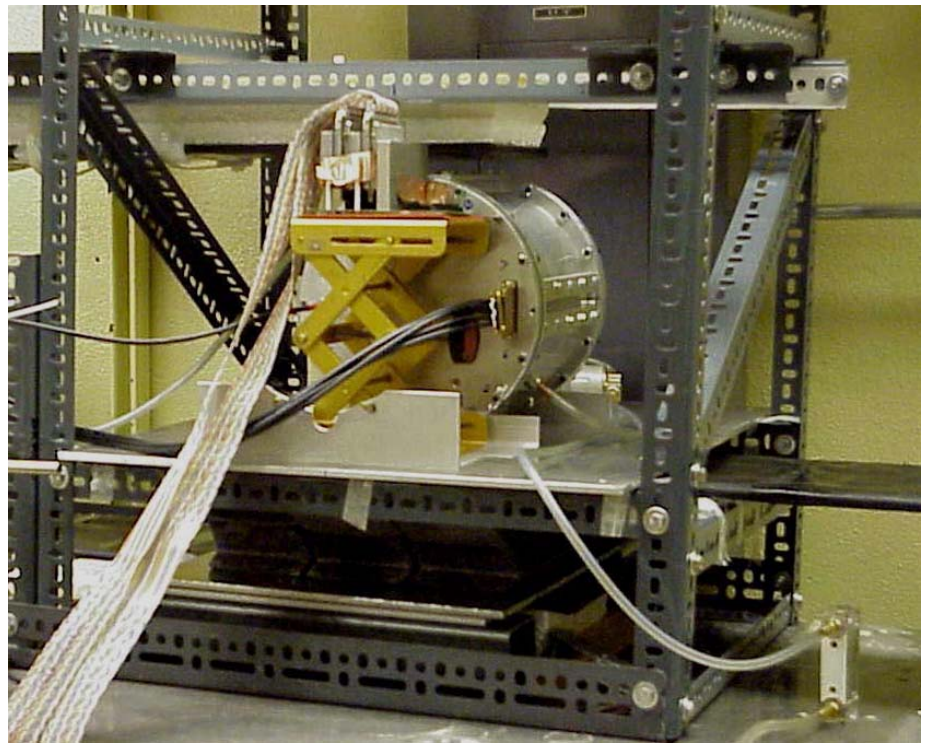
gas: Ar:CO_2 (90:10); P10

ALEPH preamplifier

custom FADC, 200 MHz
University of Montreal

track resolution
as function of

- position within pad
- pad width
- drift distance
- track angle
- amplitude



Pad Layout

pad layout:

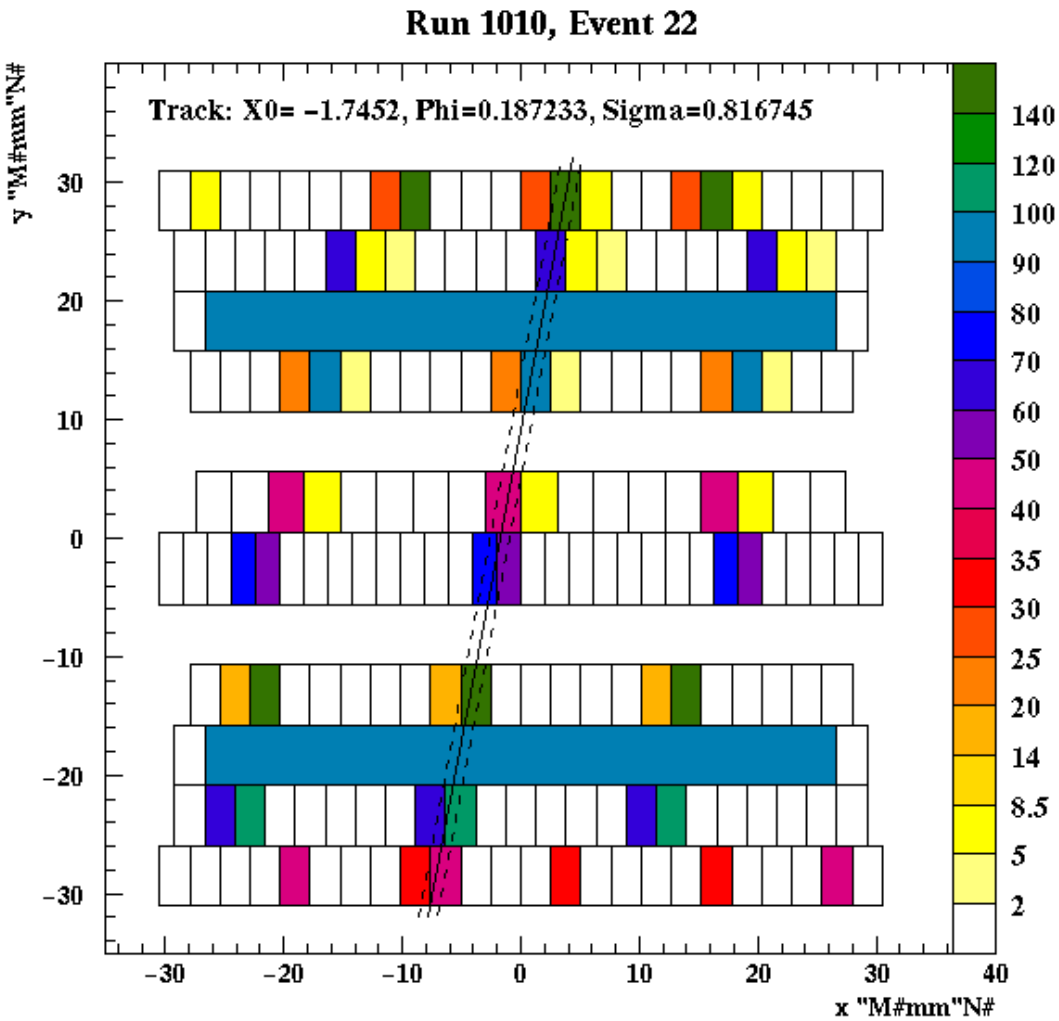
174 pads
+ trigger + veto

multiplexed ⇨ 64 channels

outer rows (1,2,4,7,9,10):
2.5 x 5 mm

row 5: 2 x 6 mm
row 6: 3 x 5 mm

all 8 rows used for track fit
1 row dropped for resolution



Pulse Reconstruction

How to get amplitude and T0 from the ADC spectrum

1) Determine *TMax*
   time of max ADC value

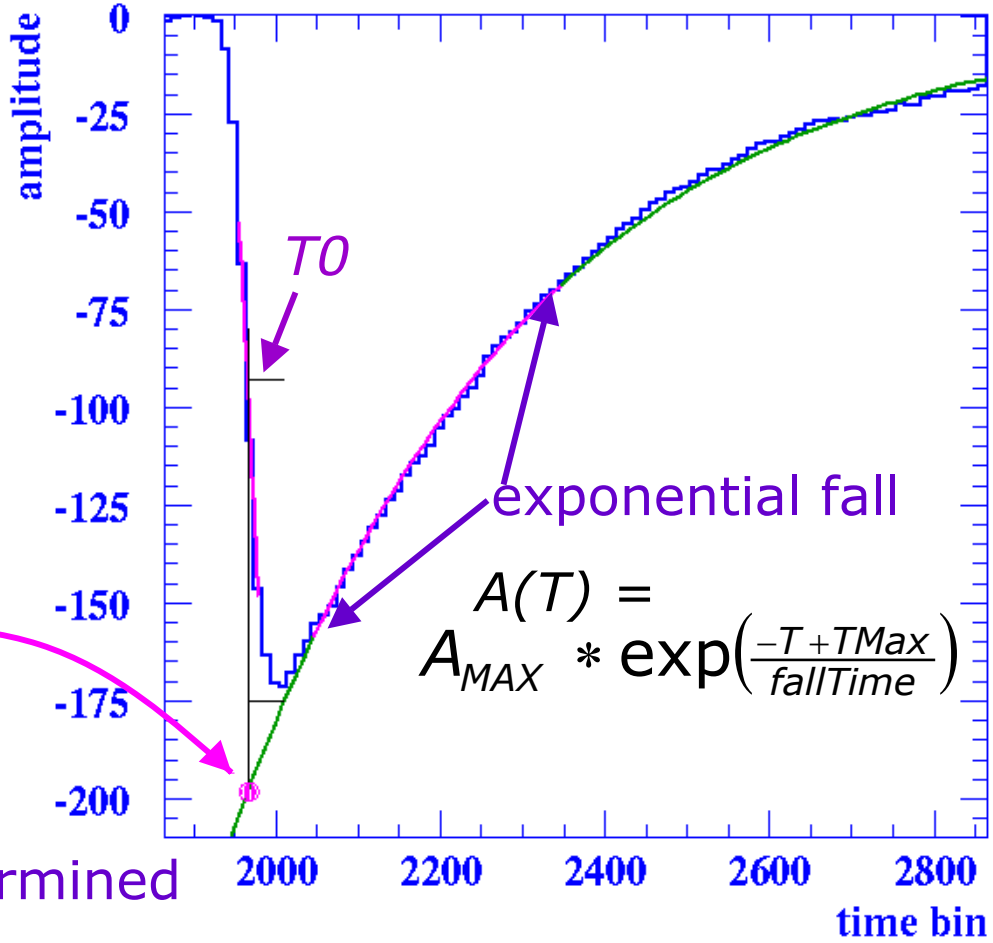
2) 'fit' exponential in range
   [TMax+50,TMax+350]
   using *fallTime(Group)*

3) Determine *T0* as
   $ADC(T0) = A_{MAX}/2$
   from line to rising edge

4) Amplitude = *A(T0)*

fast to calculate and
close to full fit

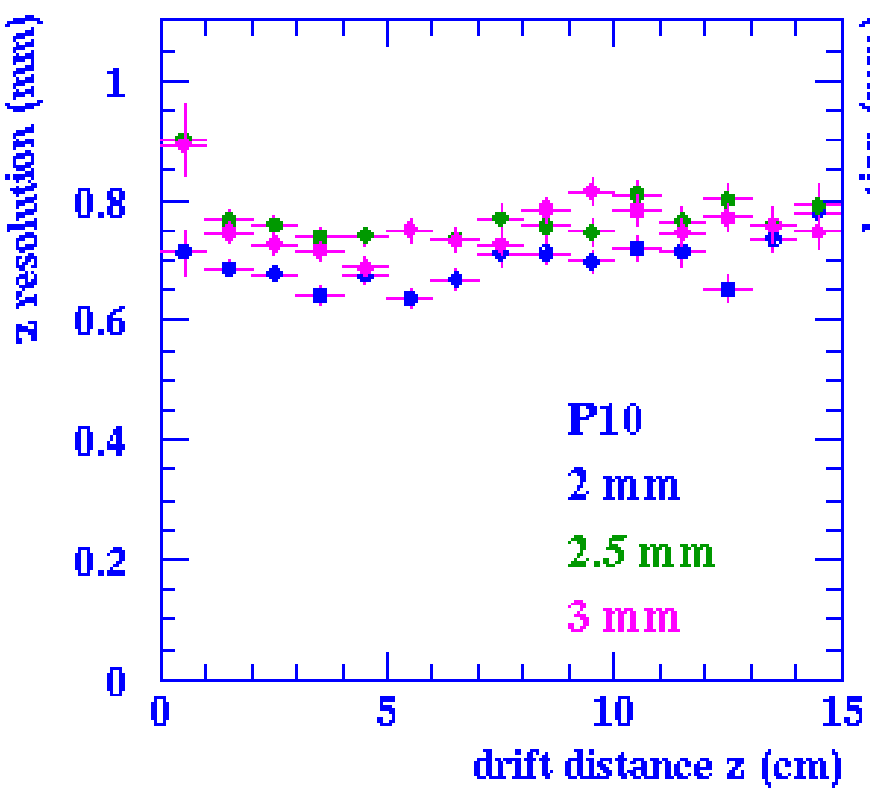
pedestal and fallTime are determined
in calibration runs

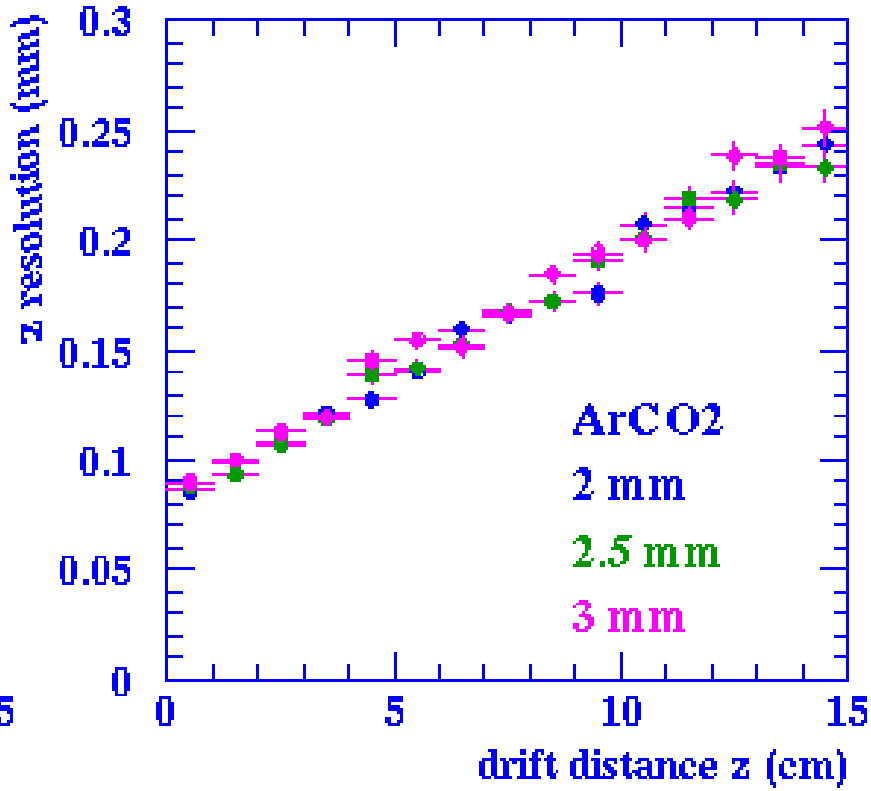


Z Resolution

Intrinsic time resolution
~13ns for P10
~9ns for $ArCO_2$

$ArCO_2$ very slow
longitudinal diffusion visible
effect is linear with drift distance ?!?

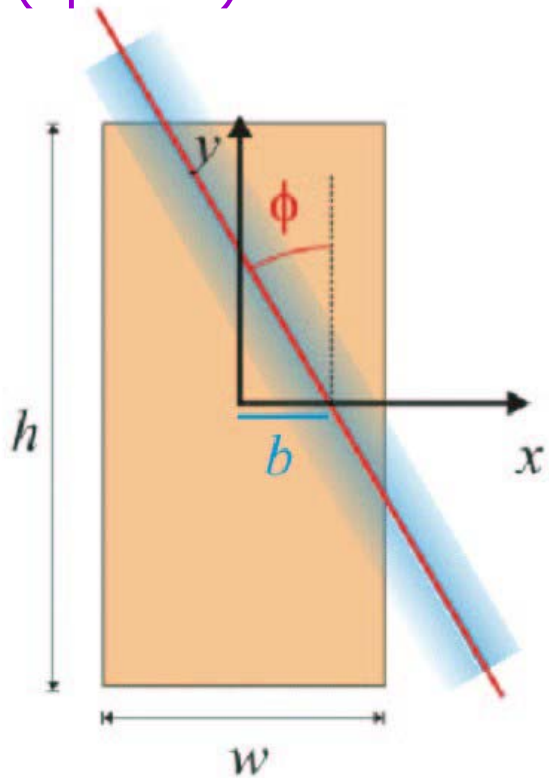




Track Fit

Dean Karlens method

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



assume uniform line of charge with Gaussian spread σ

integral over pad ⇨ expected charge

normalized expectation across row gives probability

Likelihood = Π probability * Amplitude

Resolution ***s***:
fit only x_0 to one row, compare to track
row included in track fit ⇨ $\boldsymbol{s}_{in}$ too small
row excluded in track fit ⇨ $\boldsymbol{s}_{ex}$ too large

Proper estimate of resolution:

$$\boldsymbol{s}^2 = \boldsymbol{s}_{in} * \boldsymbol{s}_{ex}$$

Naïve Theory

Charge width σ_{track}:

$$\sigma_{track}^2 = \sigma_0^2 + C_D^2 \cdot z$$

$$\sigma_0^2 = \sigma_{hex}^2 + \sigma_{intern}^2 + \sigma_{other}^2$$

hex: 37 μm intern: ~ 300 μm

Charge width σ_x across a row:

$$\sigma_x^2 = \sigma_0^2 + \sigma_D^2 + \sigma_\phi^2$$

$$\sigma_D = C_D \sqrt{z} / \cos\phi$$

$$\sigma_\phi = L / \sqrt{12} \tan\phi$$

X resolution s_x:

$$s_x^2 = s_0^2 + s_D^2 + s_\phi^2$$

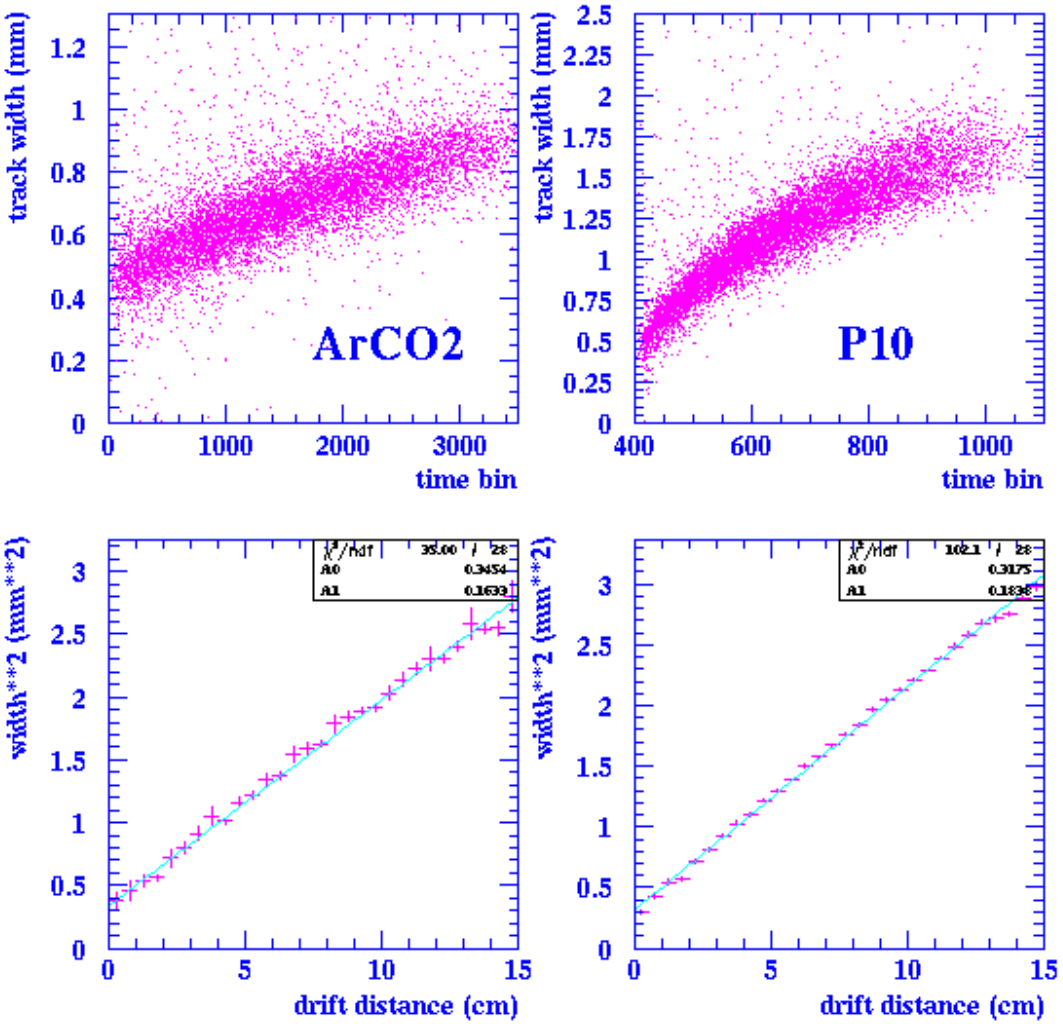
$$s_0 = \frac{\sigma_{hex}}{N_h} + \frac{\sigma_{intern}^2}{G_1 G_2 T N_t} + s_{other}^2$$

transverse diffusion: $s_D = \sigma_D / \sqrt{R \cdot N_t}$

track angle effect: $s_\phi = \sigma_\phi / \sqrt{N_{cl}^\varepsilon}$

N_t number of electrons
N_{cl} number of clusters
R Ratio
ε exponent [Blum]

Track Width



determine
transverse diffusion C_D
from track width

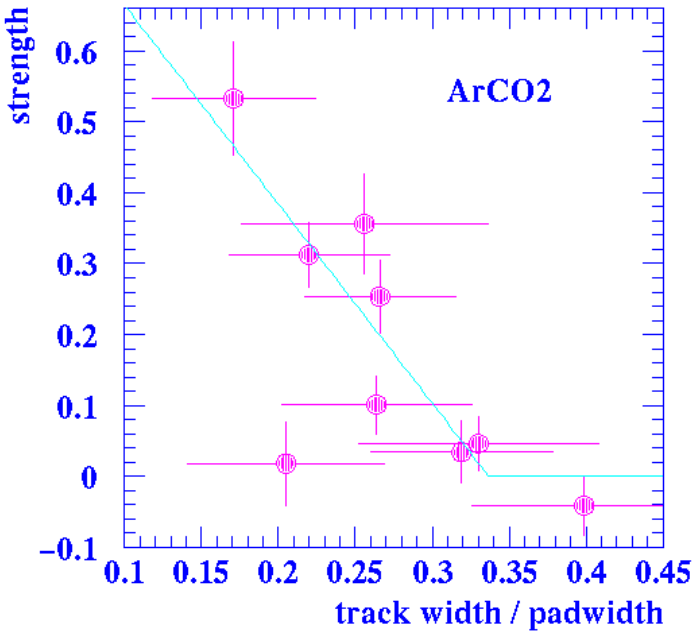
$$\sigma^2_{track} = \sigma^2_0 + C^2_D \cdot z$$

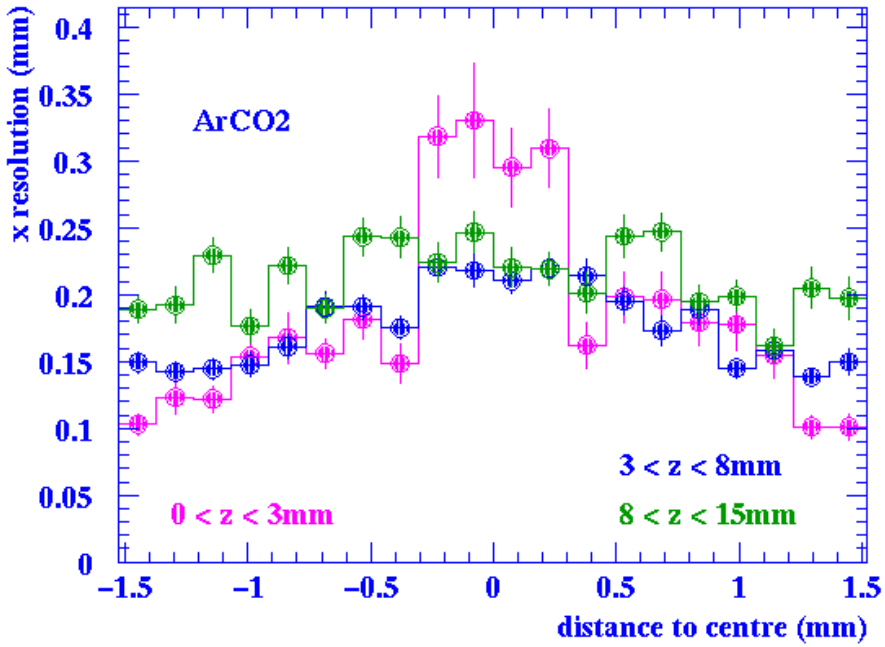
	σ_0 (mm)	C_D $\left(\frac{mm}{\sqrt{cm}}\right)$
P10	0.56	0.43
(expected)	0.33	0.39
$ArCO_2$	0.54	0.21
(expected)	0.23	0.16

Pad Width

3mm wide pads
3 ranges of drift distance
(= different charge width)

bad resolution at center of pad
for small drift / small diffusion





Fraction of rows with one hit? Can be OK!
information: no charge at neighbor pads

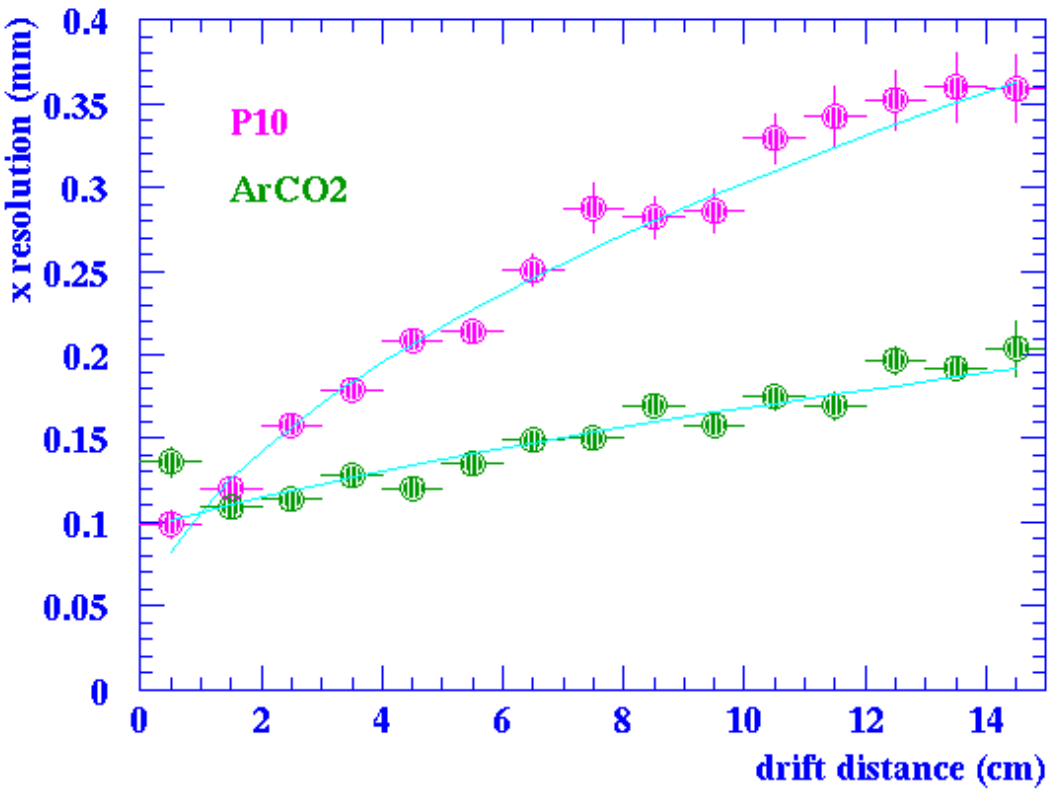
Hits not uniform distributed! Not OK!
more hits in center of pad
quantify as fraction

Not very accurate, depends on amplitude, …

Drift Distance

X resolution for small $|\phi|<5^{o}$

$$s_x^2 = s^2 + C_D^2/(R \cdot N_t)\ z$$



average number of electrons
N_t= 57 ($ArCO_2$), 55 (P10)
C_D from our data

Fit full sample:
$R\ N_t$ = 19 $\pm$ 7 (ArCO2)
20.6 $\pm$ 0.7 (P10)

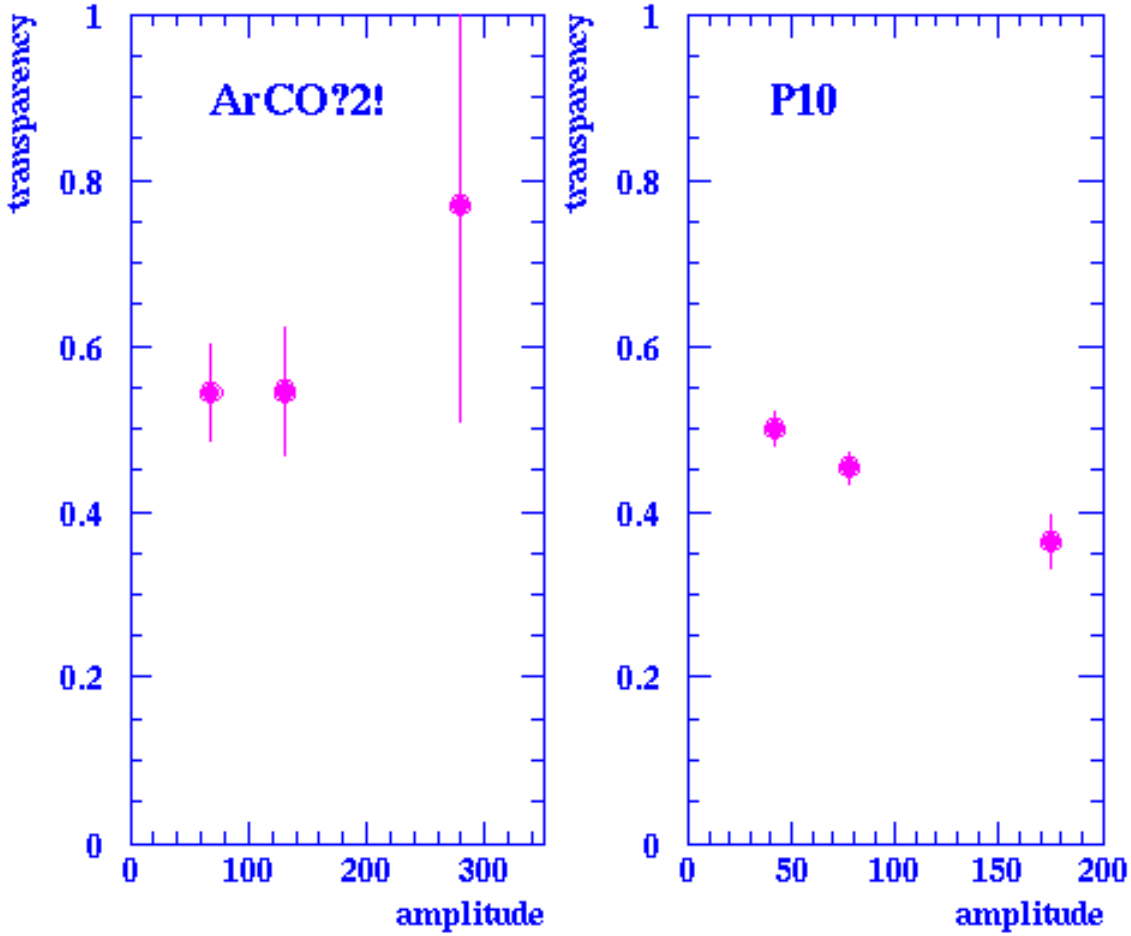
Wide range of amplitudes:

$$\langle A \rangle \cong 1.3 \Big/ \left(\left\langle 1/\sqrt{A} \right\rangle \right)^2$$

mean N_t in fit is smaller by 30% from naïve guess

⇨ split sample

Statistics



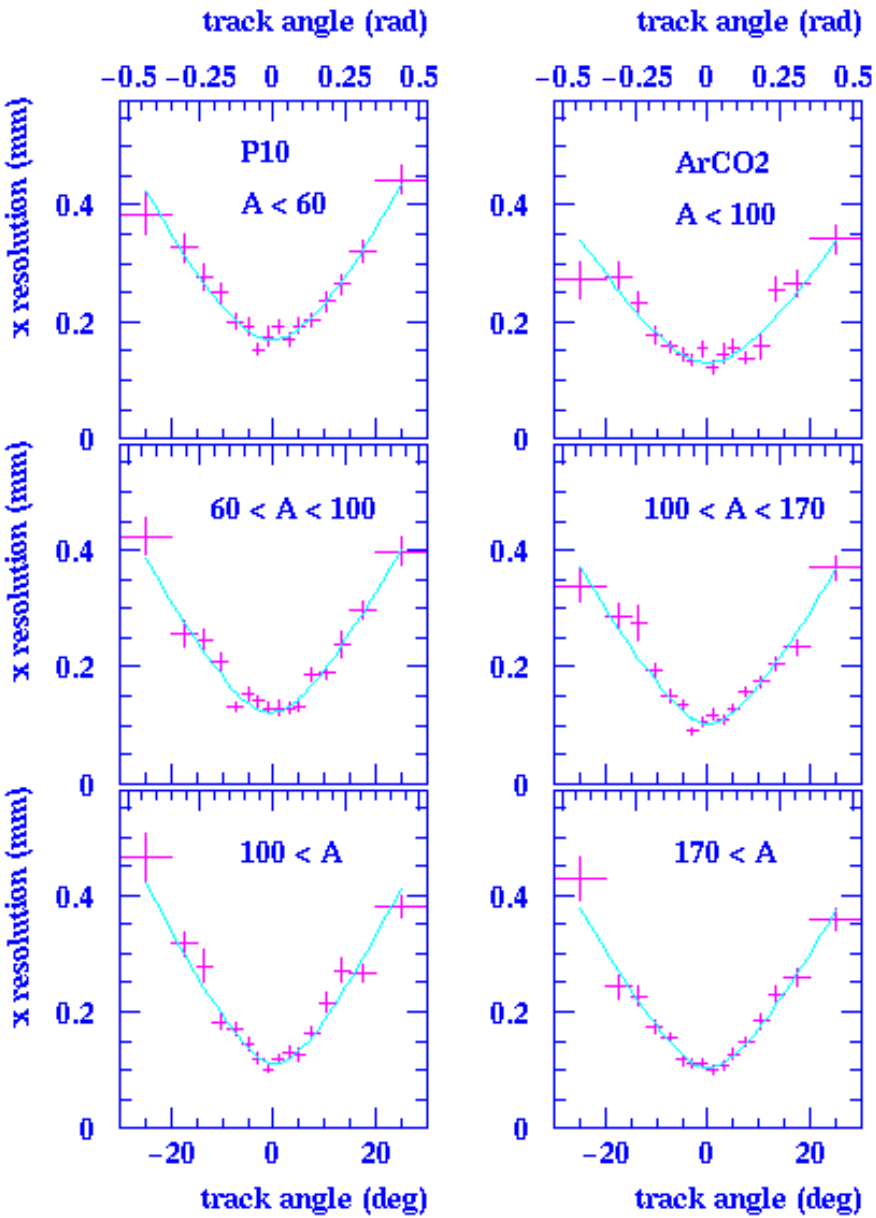
3 regions of amplitude
2 gasses

N_t too small by 10%

from fits we obtain
ratio R ≅ 50%
in naïve model

we make use of only
half the statistical power

for one reason
or another



Track Angle

small drift: z < 3 cm

$$s_x^2 = s^2 + \frac{L^2}{12 \cdot N_{cl}^{\varepsilon}} \tan^2(\phi - \varphi)$$

φ: systematic offset in ϕ
consistent with 0

ε: reduction of number of clusters
$\cong$ 0.5 no significant dependence

s: decreases with amplitude
dominated by transverse diffusion

simple model describes
the data well

no surprises

Conclusion

Comprehensive study of track resolution with GEM TPC
No magnetic field, gasses: Ar:CO_2 (90:10) and P10

- for good resolution: charge width > pad width /3
- charge width at small drift much wider than expected
  ~ 500 μm unexplained
- track angle effect
  no systematic bias in ϕ
  weak dependence on number of clusters: $s_\phi \sim 1/\sqrt[4]{N_{cl}}$
  base resolution improves with amplitude
- x resolution as function of drift distance
  for 3 regions of amplitude and both gasses
  make use of only about half the statistical power

Need to understand why resolution at large drift distance doesn't improve with statistics as expected.