Track Resolution Measurements for a TPC with GEM Readout

IEEE NSS 2003
Portland, USA

Dean Karlen[1,2], P. Poffenberger[1], G. Rosenbaum[1],
R. Carnegie[3], M. Dixit[3,2], H. Mes[3], K. Sachs[3],
J.-P. Martin[4]

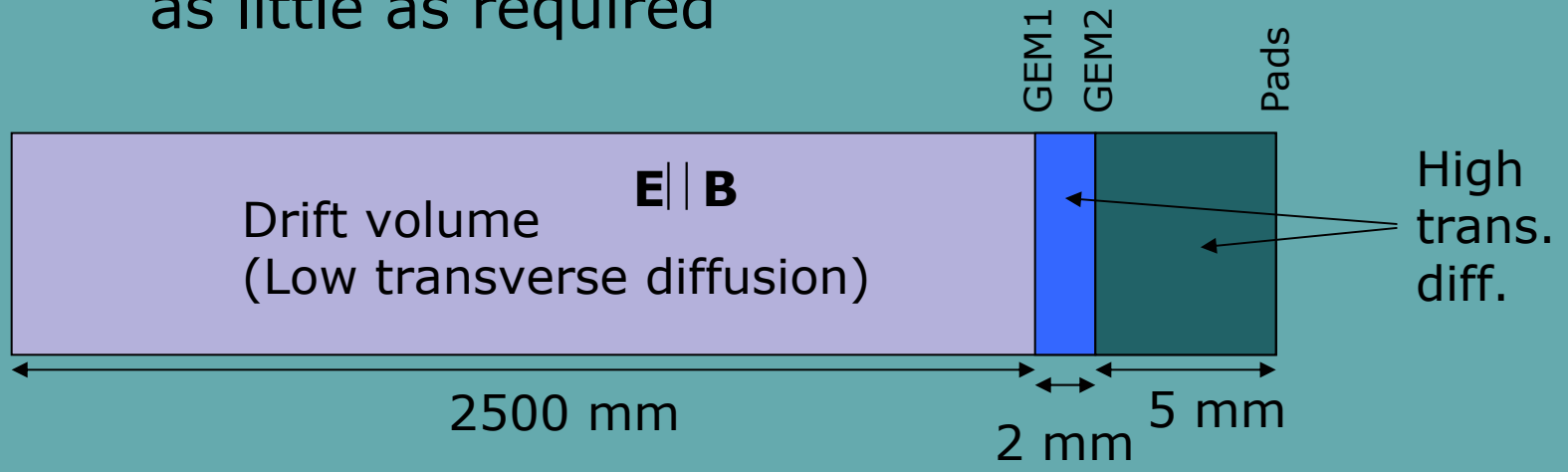
[1]*University of Victoria*; [2]*TRIUMF*;
[3]*Carleton University*; [4]*University of Montreal*

TPCs with MPGD readout

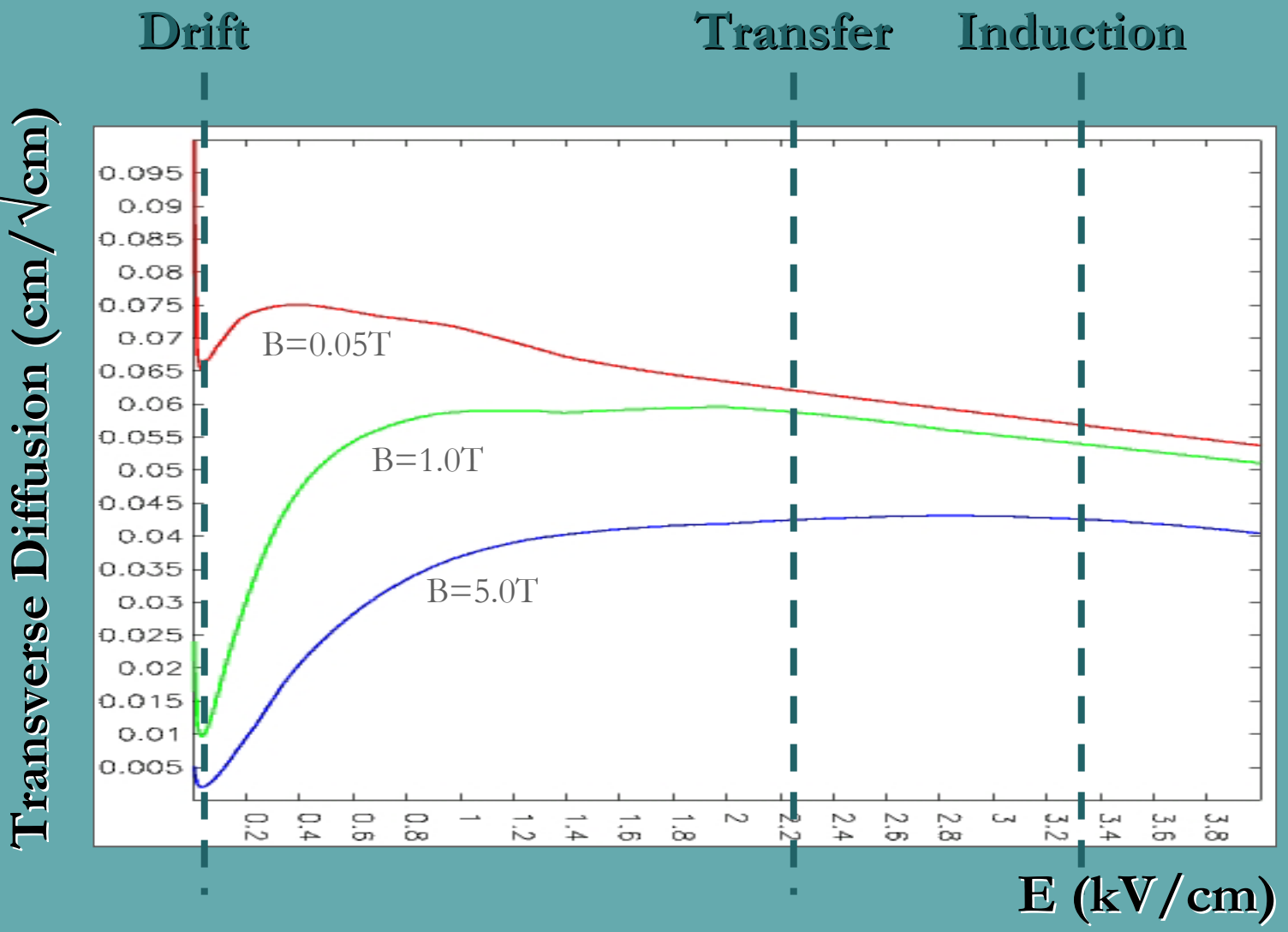
- MPGDs offer significant advantages for TPC readout
  - Reduced $\mathbf{E} \times \mathbf{B} \Rightarrow$ better resolution
  - Faster signals $\Rightarrow$ better z separation
  - Narrower signals $\Rightarrow$ better r-ϕ separation
  - Particularly well suited for a LC
- Narrow signals present a new challenge for large scale TPCs:
  - How to accurately determine the centroid of the narrow charge distribution with a reasonable number of channels

TPCs with GEM readout

- GEMs offer a solution:
  - Use gas diffusion between the GEMs to spread the charge over a larger region
    - Since the defocusing occurs during and after the gain stage, the track resolution is not sacrificed
    - For the best two-particle separation, defocus as little as required



Example: P5


Drift
Transfer
Induction
Transverse Diffusion (cm/√cm)
0.095
0.09
0.085
0.08
0.075
0.07
0.065
0.06
0.055
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
B=0.05T
B=1.0T
B=5.0T
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4
3.6
3.8
E (kV/cm)

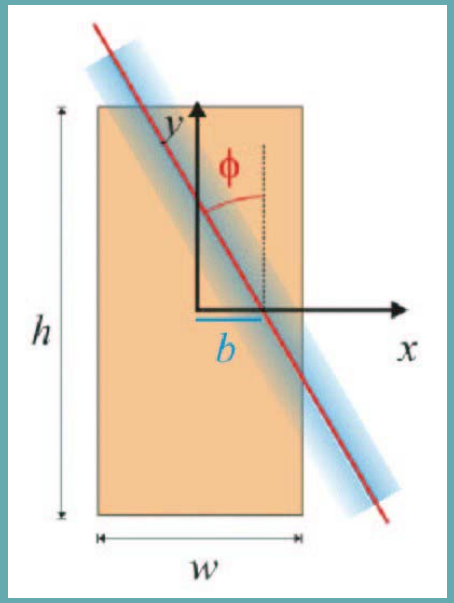
Limited defocusing

- Minimum defocusing required to retain track resolution:

$$\sigma \approx \tfrac{1}{4}\,\text{pad width}$$

- Charge sharing typically over 2 pads:
  - Important to account for non-linear sharing
  - Track fitting is performed by maximum likelihood:

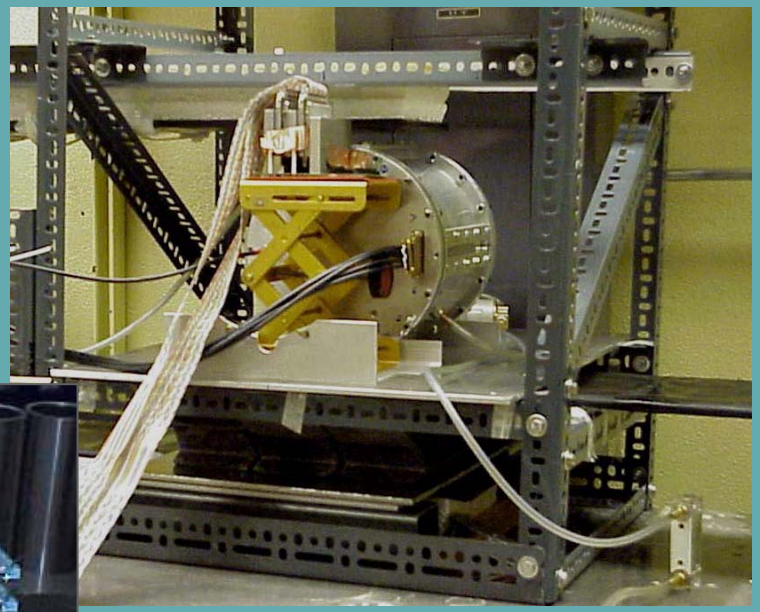
$$x_0, \phi_0, \sigma, r^{-1}$$

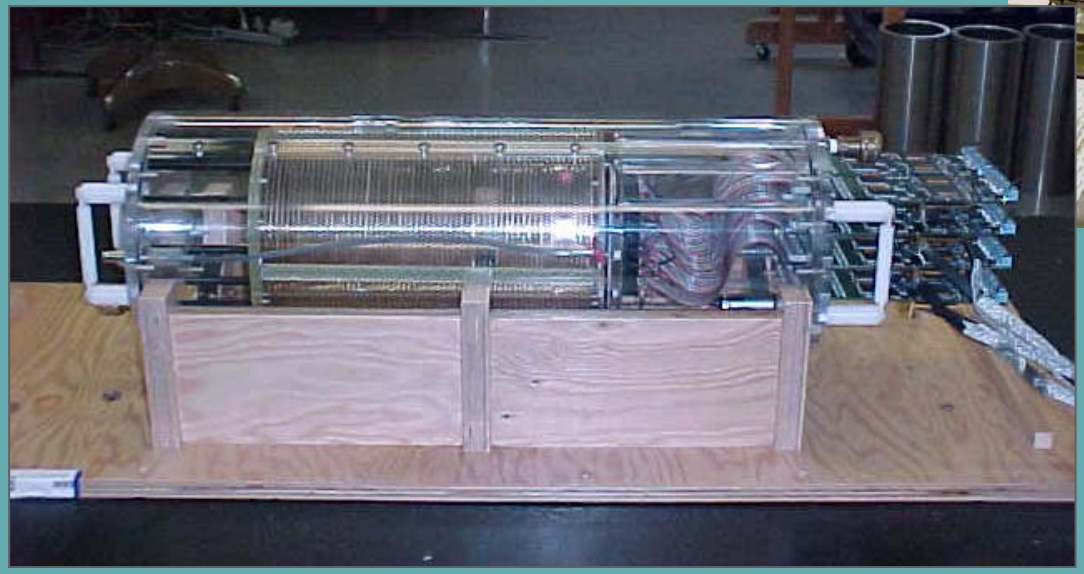


Demonstrations of defocusing

- Two small TPCs with GEM readout for cosmic ray tests:

TPC1 (Carleton University)
15 cm drift
Without magnetic field
2mm × 6 mm pads

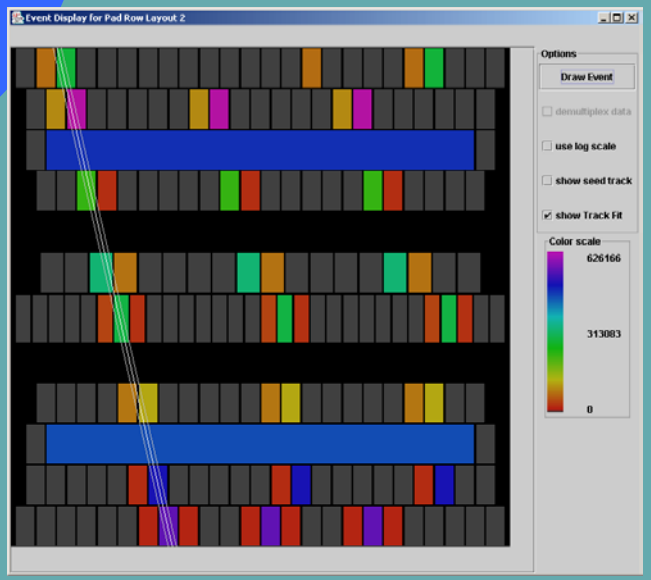




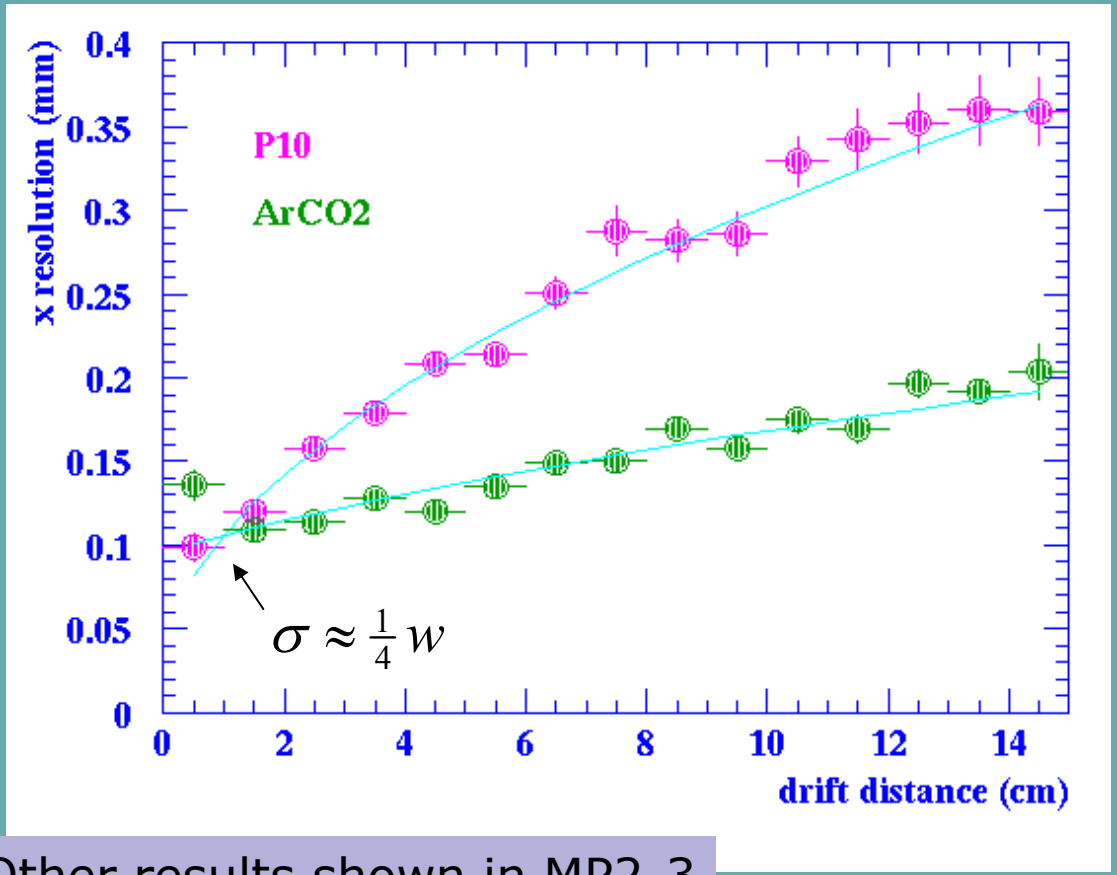
TPC2 (U. Victoria)
30 cm drift
With magnetic field
2mm × 7 mm pads

TPC1: no B field, P10 and $ArCO_2$ (90:10)

- $ArCO_2$ / short drift distances mimic high magnetic field operation



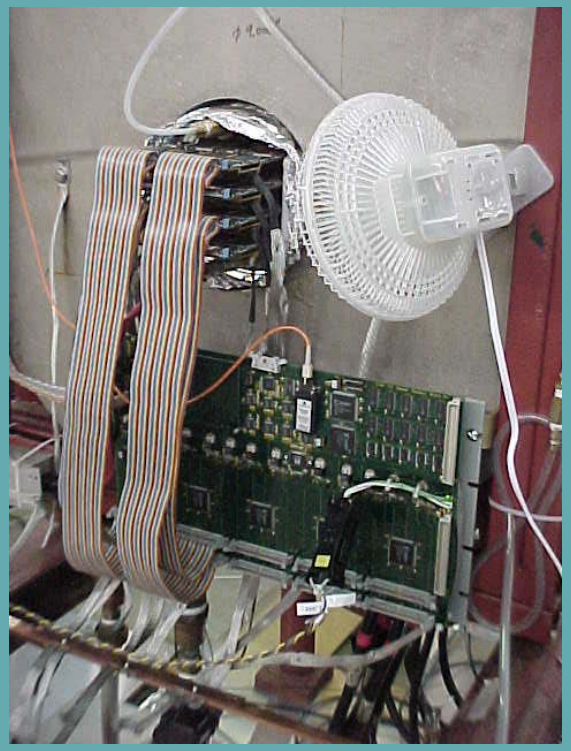
2mm × 6 mm pads
~ 100 μm resolution



Other results shown in MP2-3

TPC2: First GEM-TPC tracking in B fields

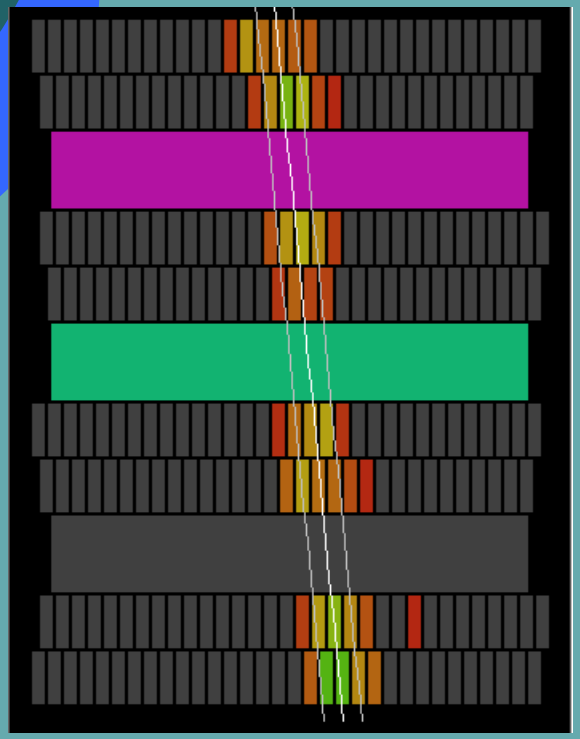
- TRIUMF tests (0 – 0.9 T)



Example events at ~ 25 cm drift

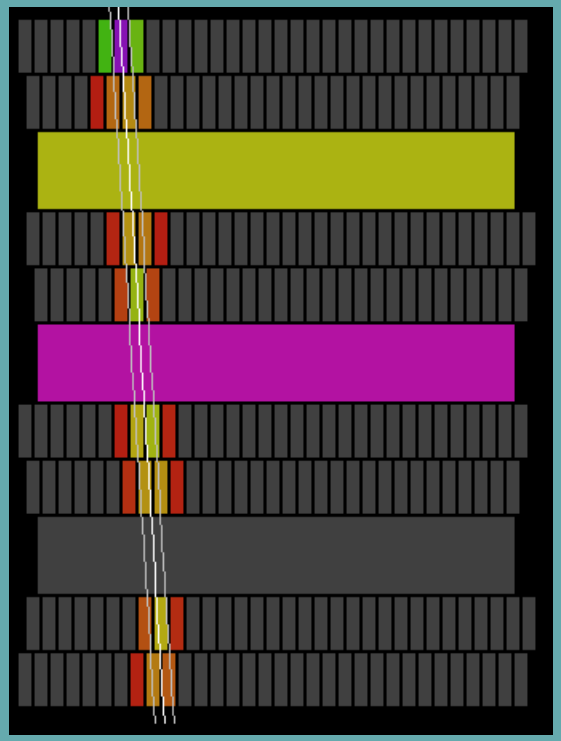
- Gas: P10

0 Tesla



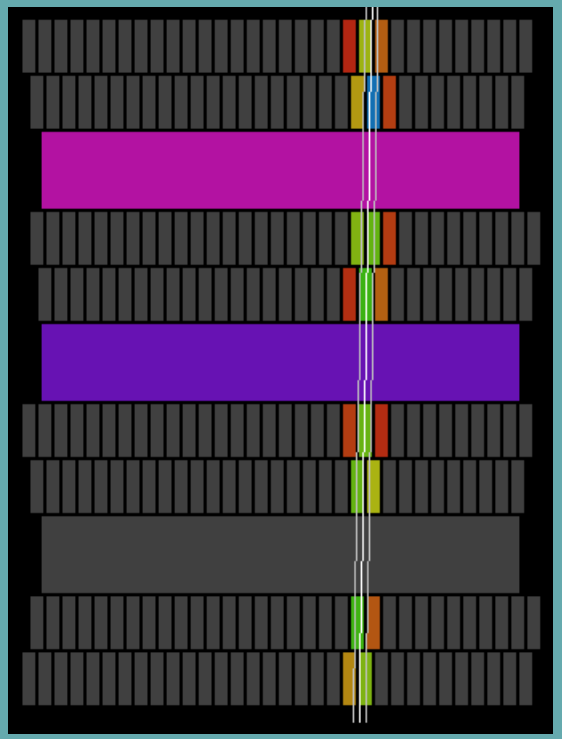
σ = 2.3 mm

0.45 Tesla



σ = 1.2 mm

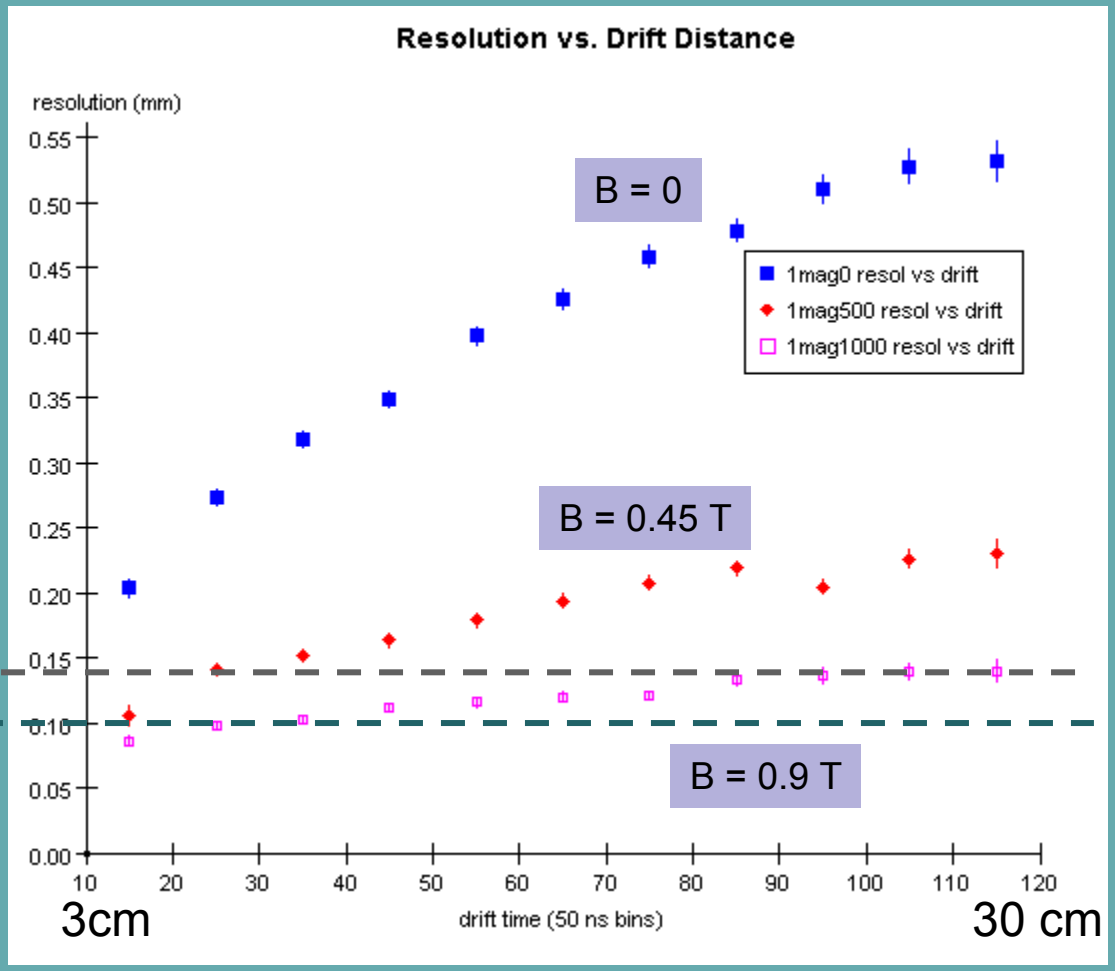
0.9 Tesla



σ = 0.8 mm

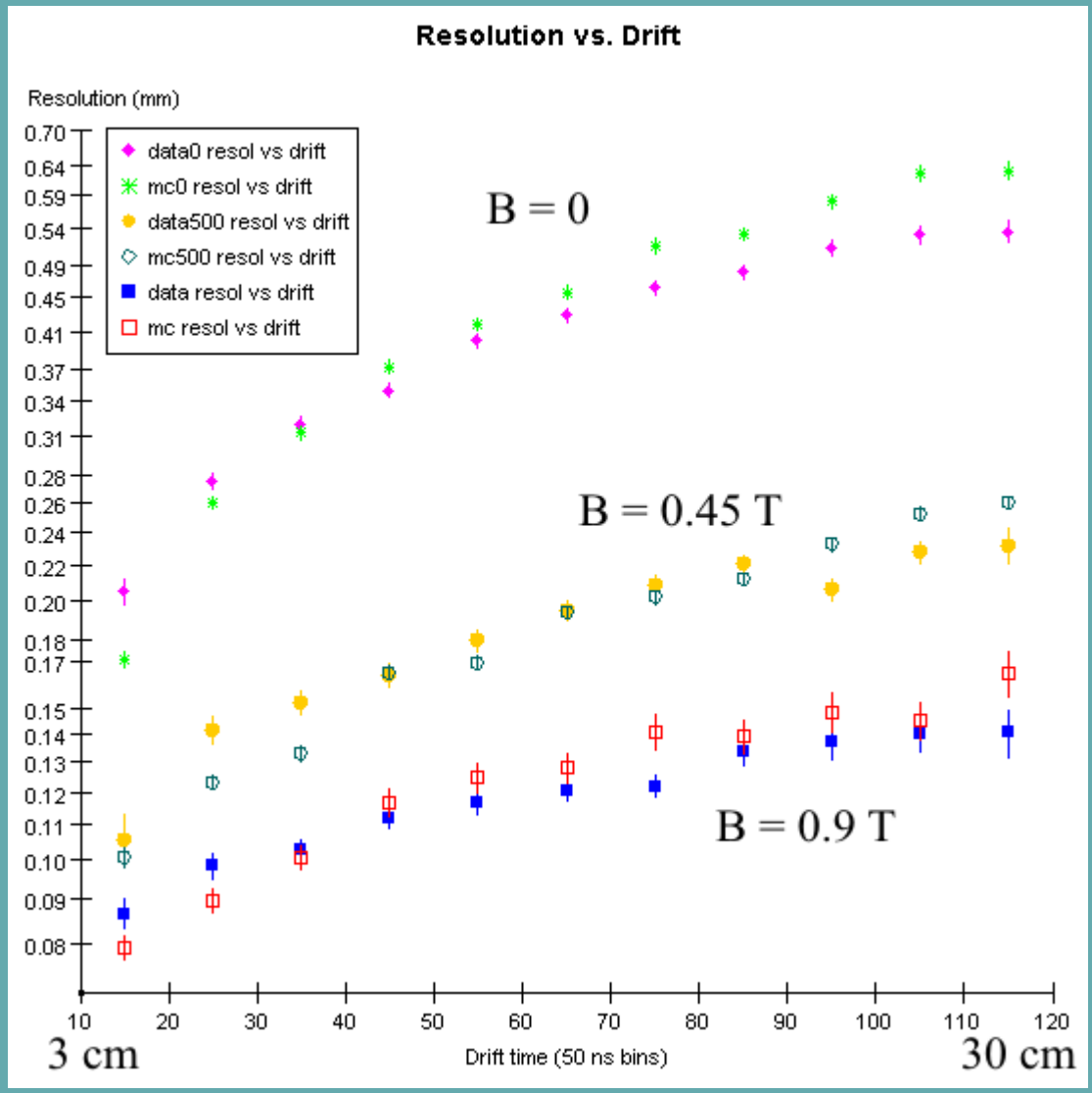
Tracking resolution (preliminary)

- Fit track to all but one row:
  - fix ϕ_0, $1/r$, and σ, fit to one row alone
  - x_0 residual fit to Gaussian

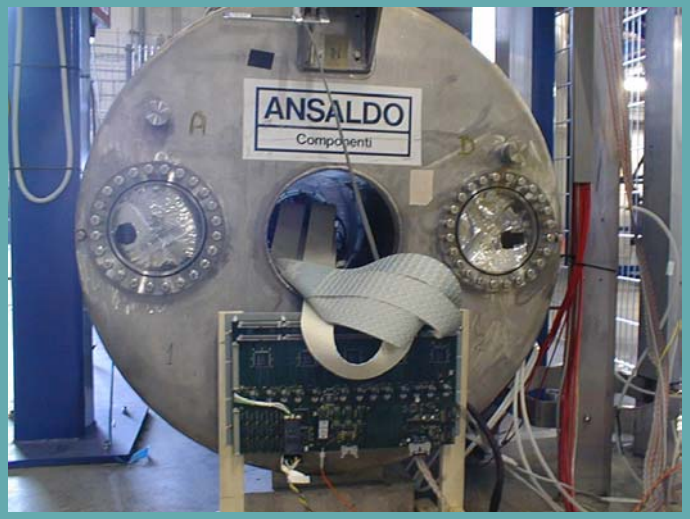


Comparison with MC simulation

- Simple simulation of GEM operation
- Good agreement with data
- Preliminary results…

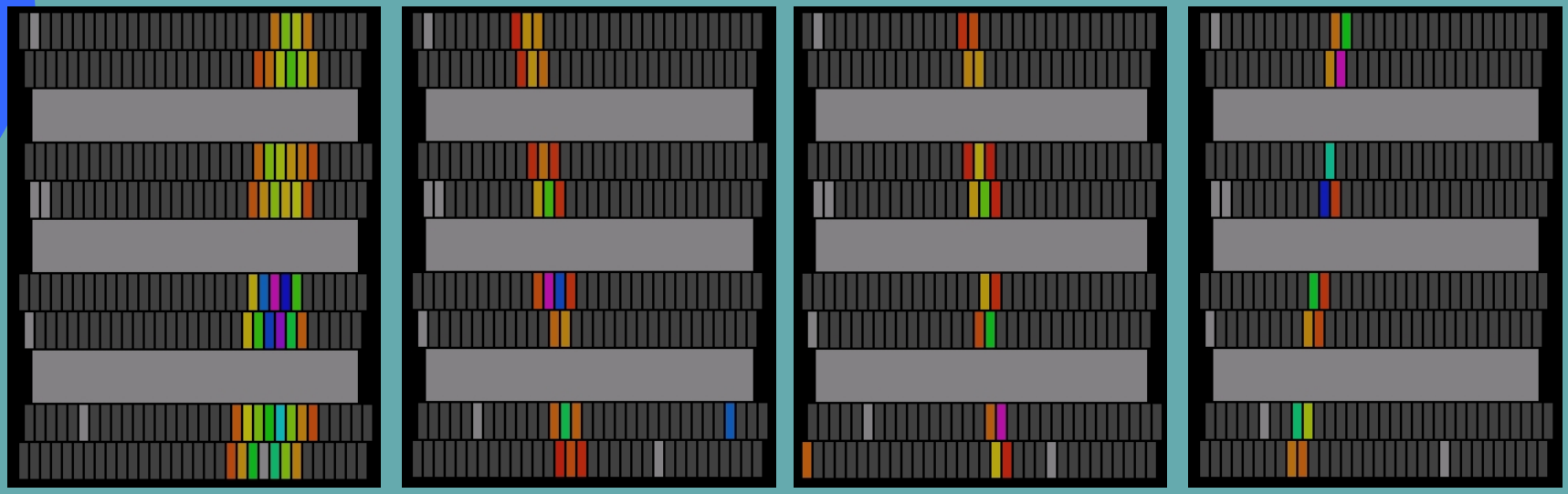


DESY tests (0 – 5.3 T)



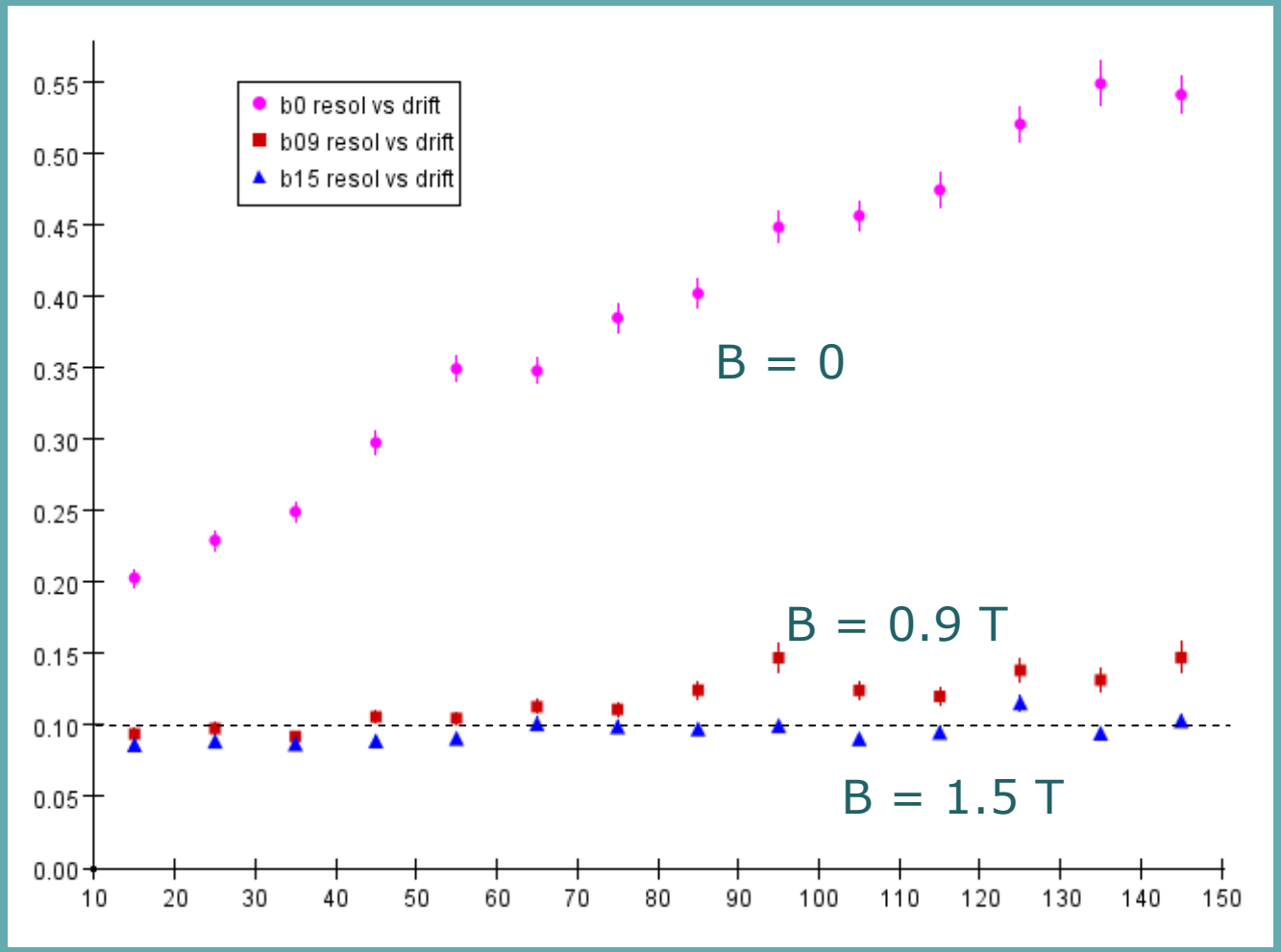
Example events at ~ 25 cm drift

- Gas: P5



B=0T B=0.9T B=2.5T B=4.5T

Tracking resolution (preliminary)



Preliminary results

- Tracking resolution ≤ 100 μm for all drift distances for B $\geq$ 1.5 T
  - Further improvement for higher fields not yet realized…
- Defocusing values larger than expected
  - Maintain $\sigma \approx \frac{1}{4} w$

B(T)	σ_0 (mm)	sim σ_0 (mm)
0.	1.14	0.21
0.9	0.66	0.43
1.5	0.60	0.42
2.5	0.52	0.40
3.5	0.53	0.38
4.5	0.55	0.36
5.3	0.51	-

Summary

- MPGD readout for TPCs offers several advantages over wire/pad readout
- Limited defocusing during/after amplification

$$\sigma \approx \frac{1}{4}\,\text{pad width}$$

  - Achievable with diffusion in GEM gaps
  - Preserves good tracking resolution and two-particle separation

Acknowledgements

- Support staff at Carleton University and University of Victoria
- LBNL – STAR electronics
- TRIUMF laboratory – 1 T magnet setup
- DESY group – 5 T magnet setup and operational support (P. Wienemann, F. Sefkow, T. Lux, …)