Study of GEM-TPC Performance in Magnetic Fields

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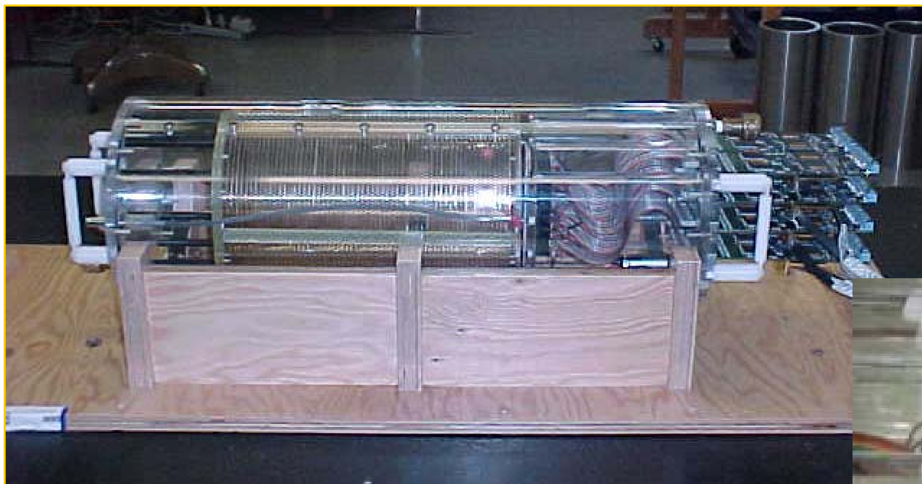
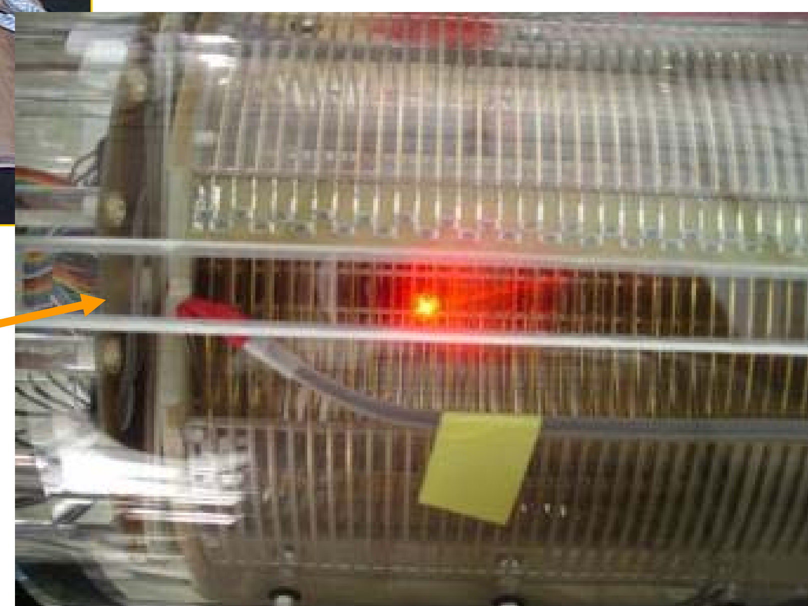
Outline

- TPC prototype test in DESY magnet (2004)
  - UV laser system incorporated
    - single/double beams available under remote control
  - New readout plane with narrower pads
    - data taken with both sets of pads
- Cosmic ray simulation for DESY setup
- Results from 2004 data sample:
  - gas properties
  - dE/dx
  - resolution
  - two particle separation

TPC modifications for UV laser

- New outer acrylic vessel made with windows for laser entry – quartz glass inserted





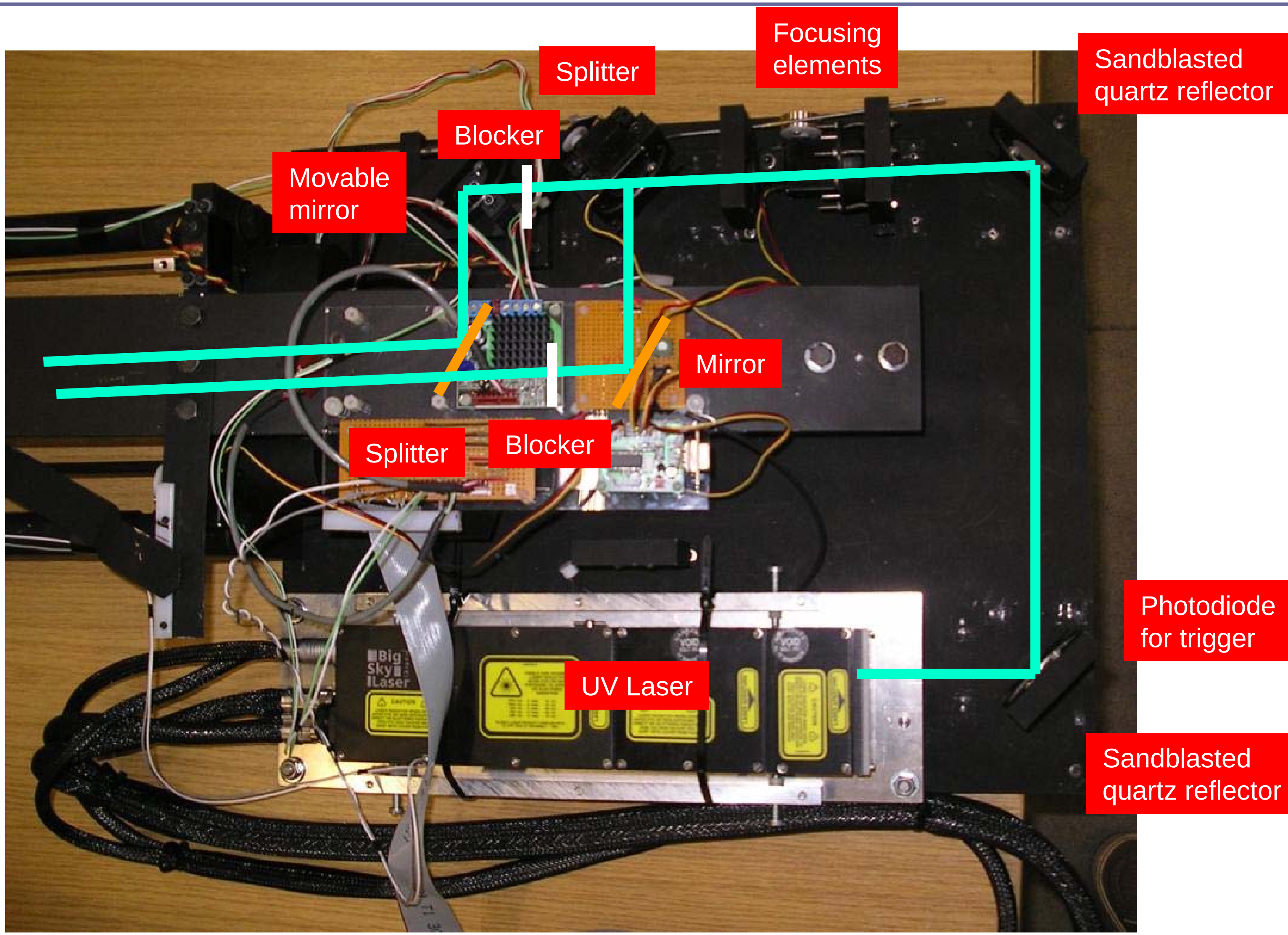
quartz window

Laser beam delivery system

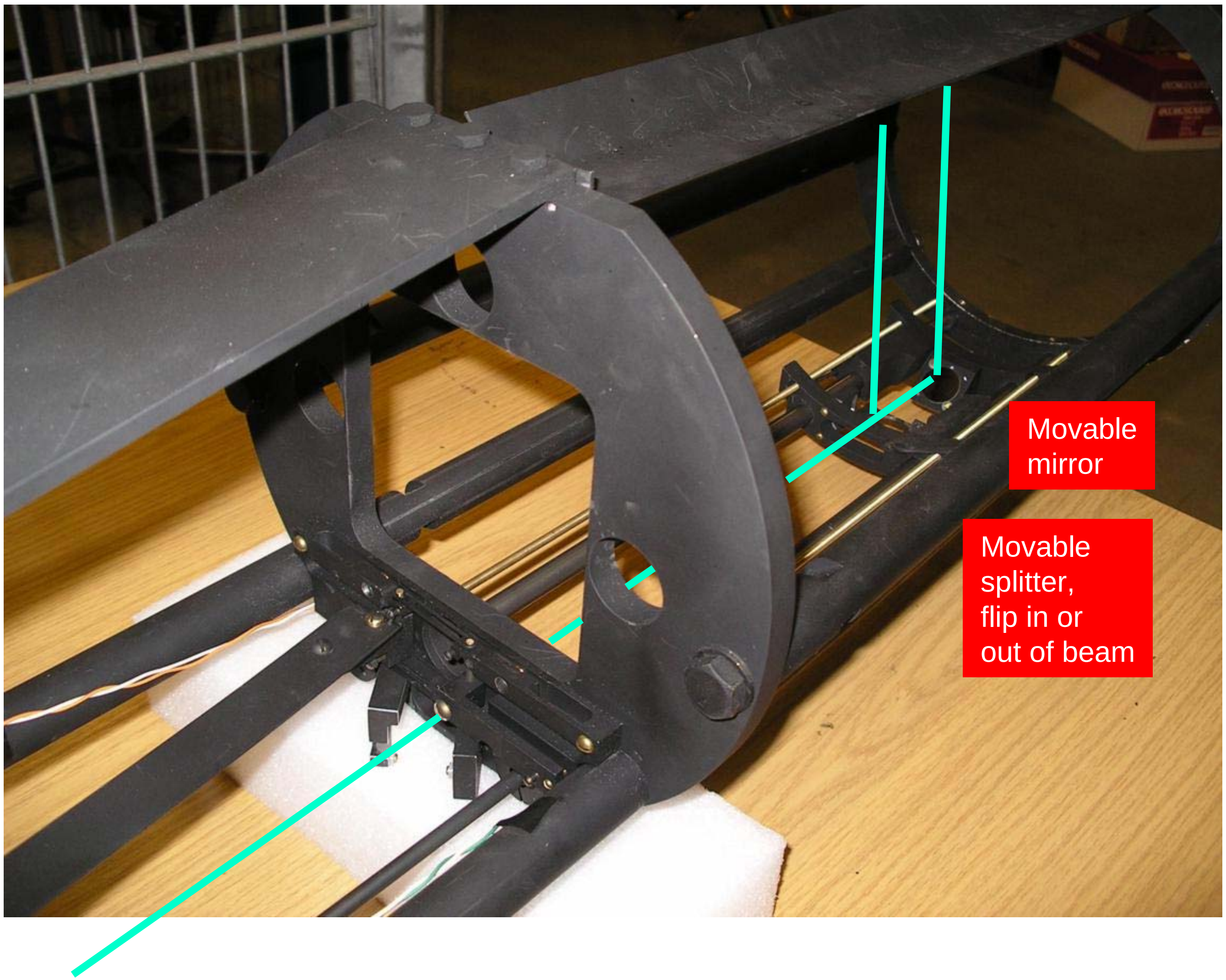
- Approx. 2 m long to reach into magnet

Engineering by
Mark Lenkowksi
Univeristy of Victoria

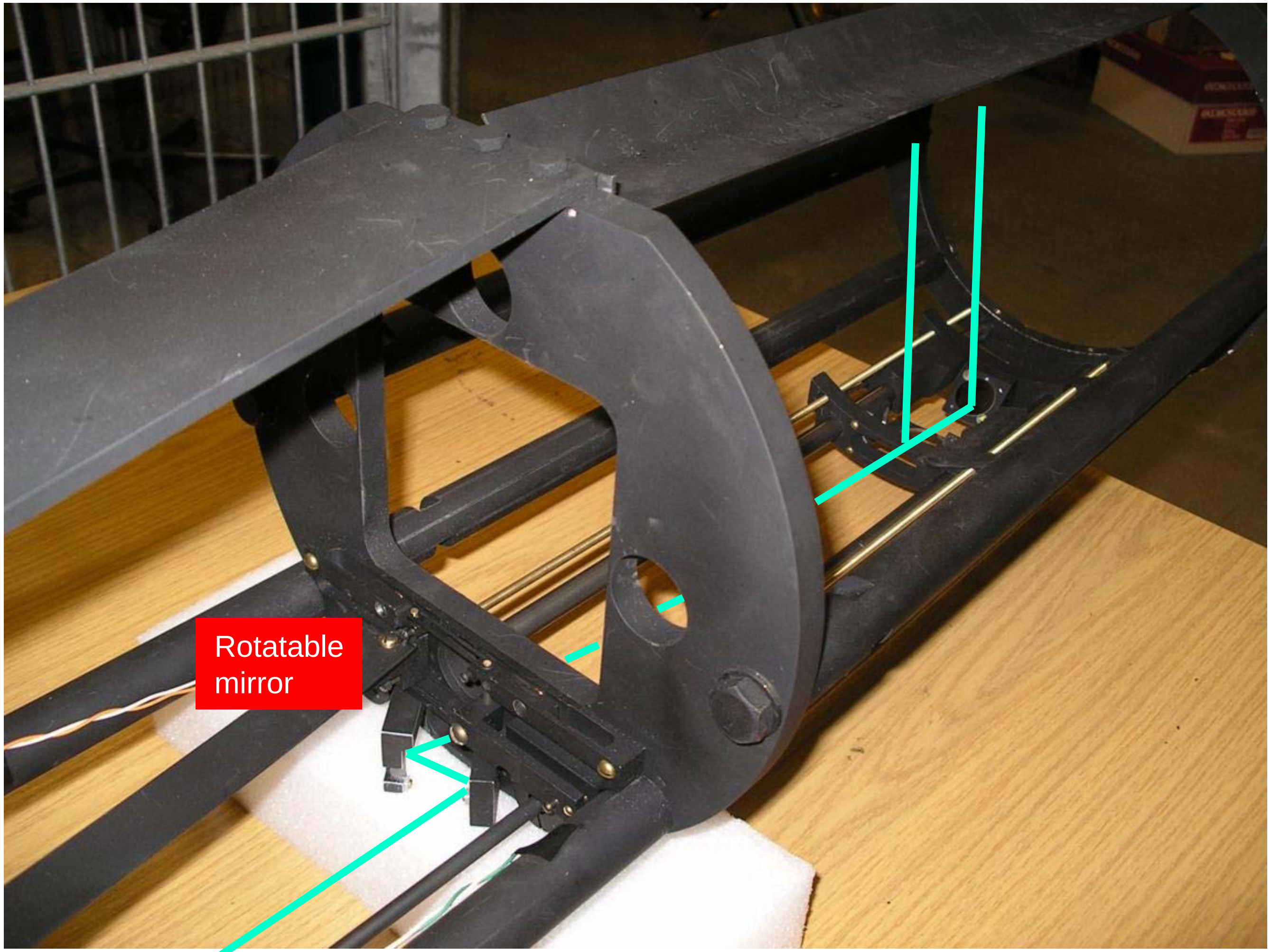
Laser optics



Beam delivery



Beam delivery – offset in x and z

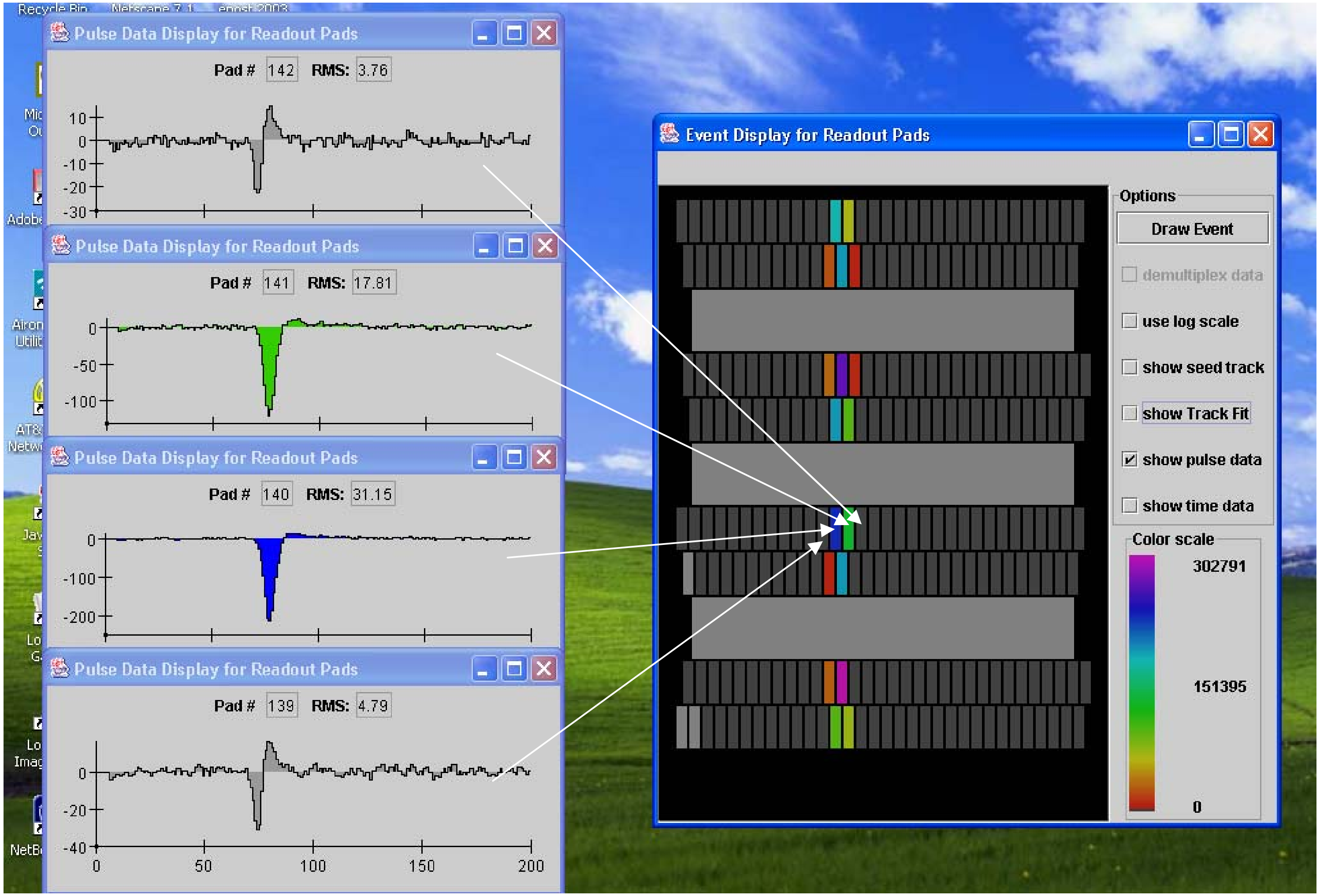


Setup with the DESY magnet

- For safety reasons, the UV laser must be contained within a light tight box

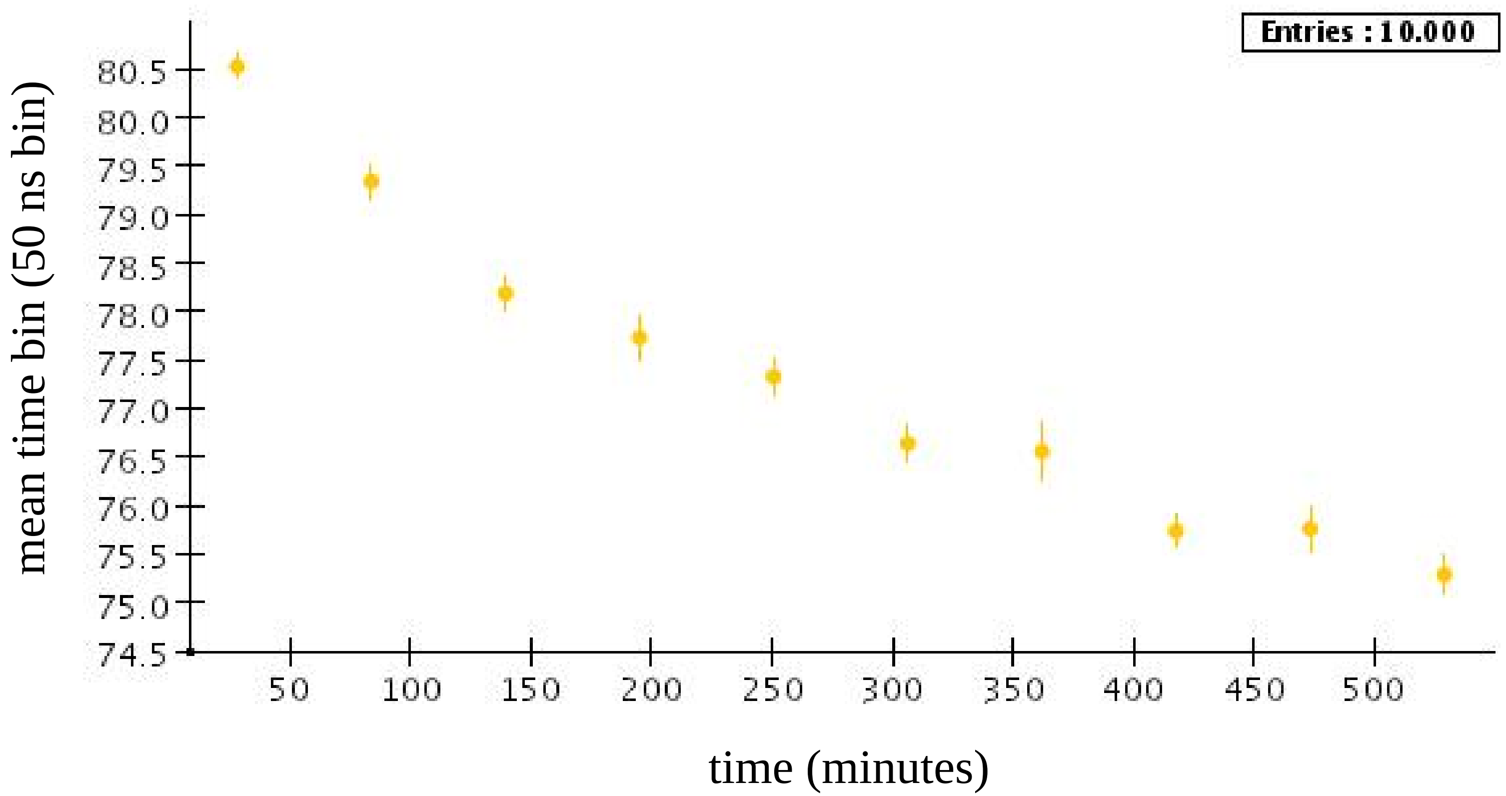
Example laser event at 4 T in P5

- Single laser track:



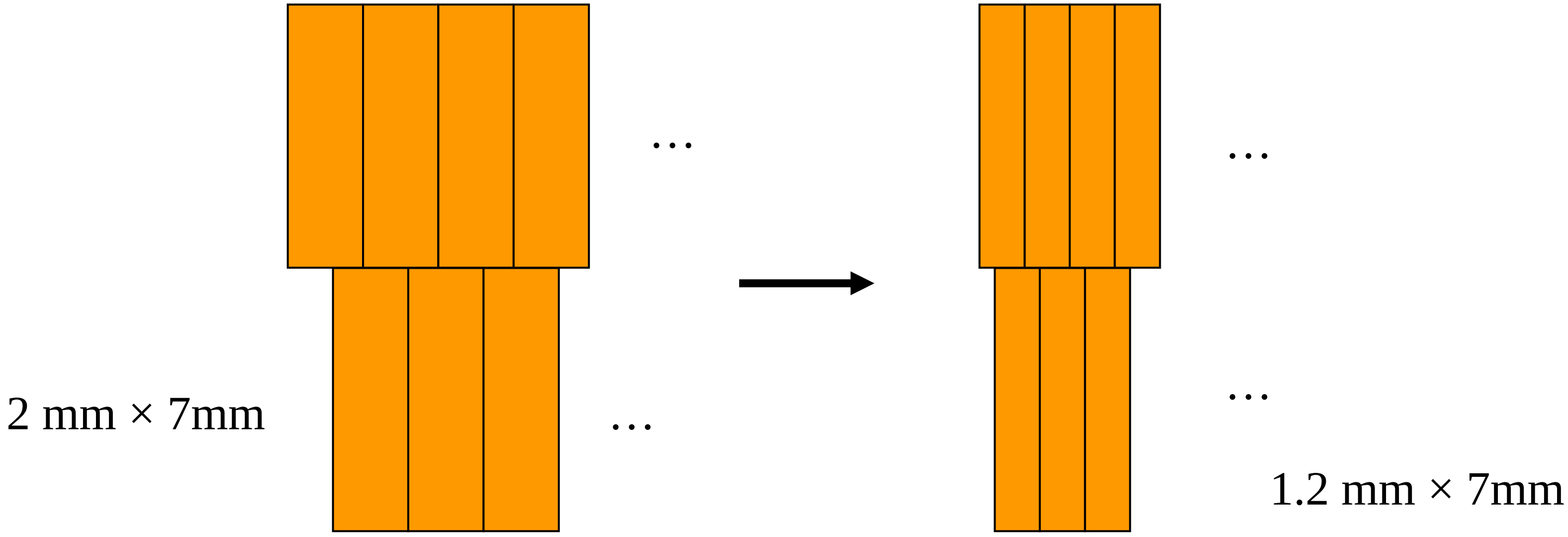
Drift velocity monitor

- Laser very nice to monitor drift velocity (after changing gas or opening the detector):



Narrower readout plane

- The analysis of 2003 data set showed defocusing in P5 or TDR gas of around 0.4 mm at 4 T.
  - too small for our 2 mm pads (width/σ_0 = 5)
- To check effect of pad width, we built a new readout board replacing 2 mm pads with 1.2 mm pads



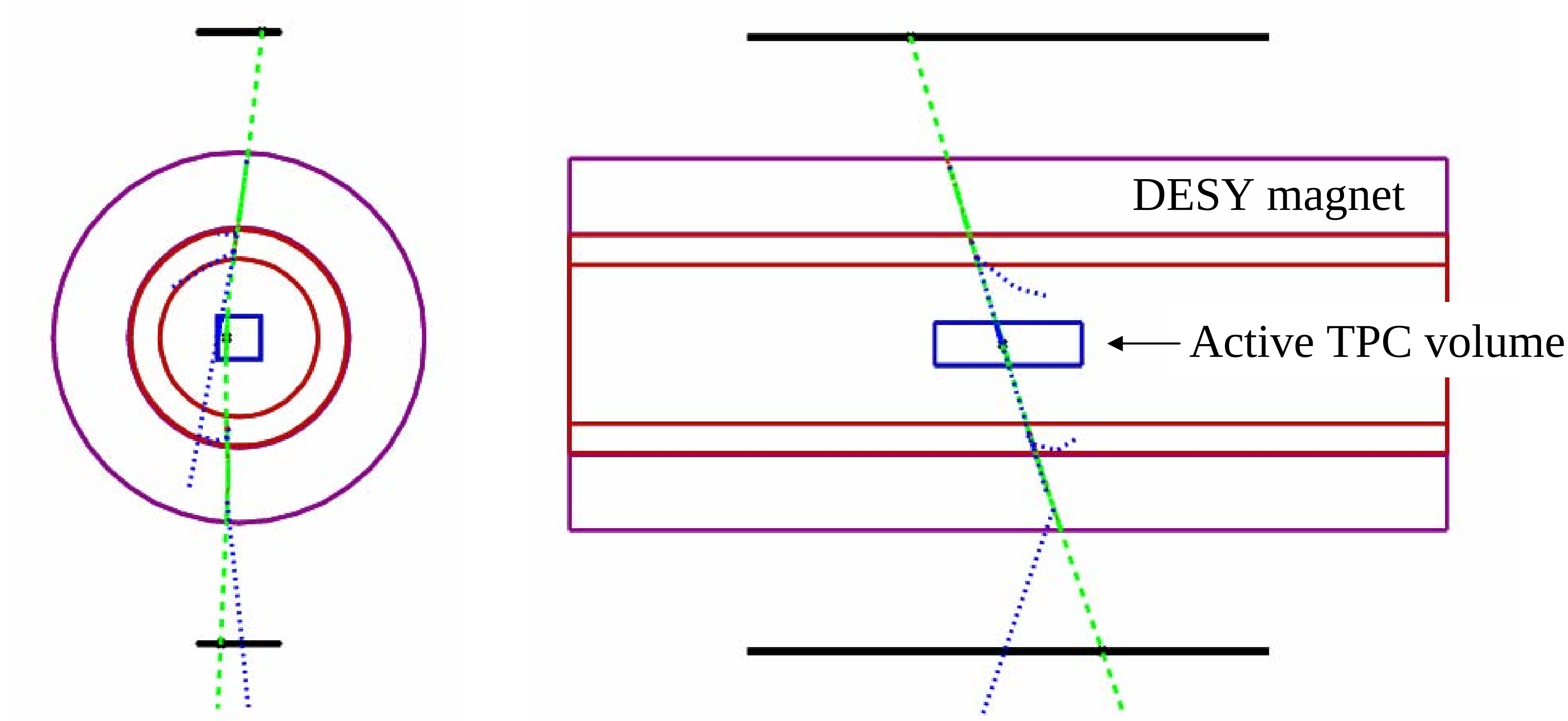
Cosmic data sets collected in 2004

Name	Gas	B [T]	Pad pitch [mm]	Drift field [V/cm]
p5B4w	“P5”	4	2	160
tdrB4w	TDR	4	2	230
p5B4n	P5	4	1.2	90
tdrB4n	TDR	4	1.2	230
tdrB1n	TDR	1	1.2	230
tdrB0n	TDR	0	1.2	230

- Initial run likely with large concentration of water

Cosmic ray simulation

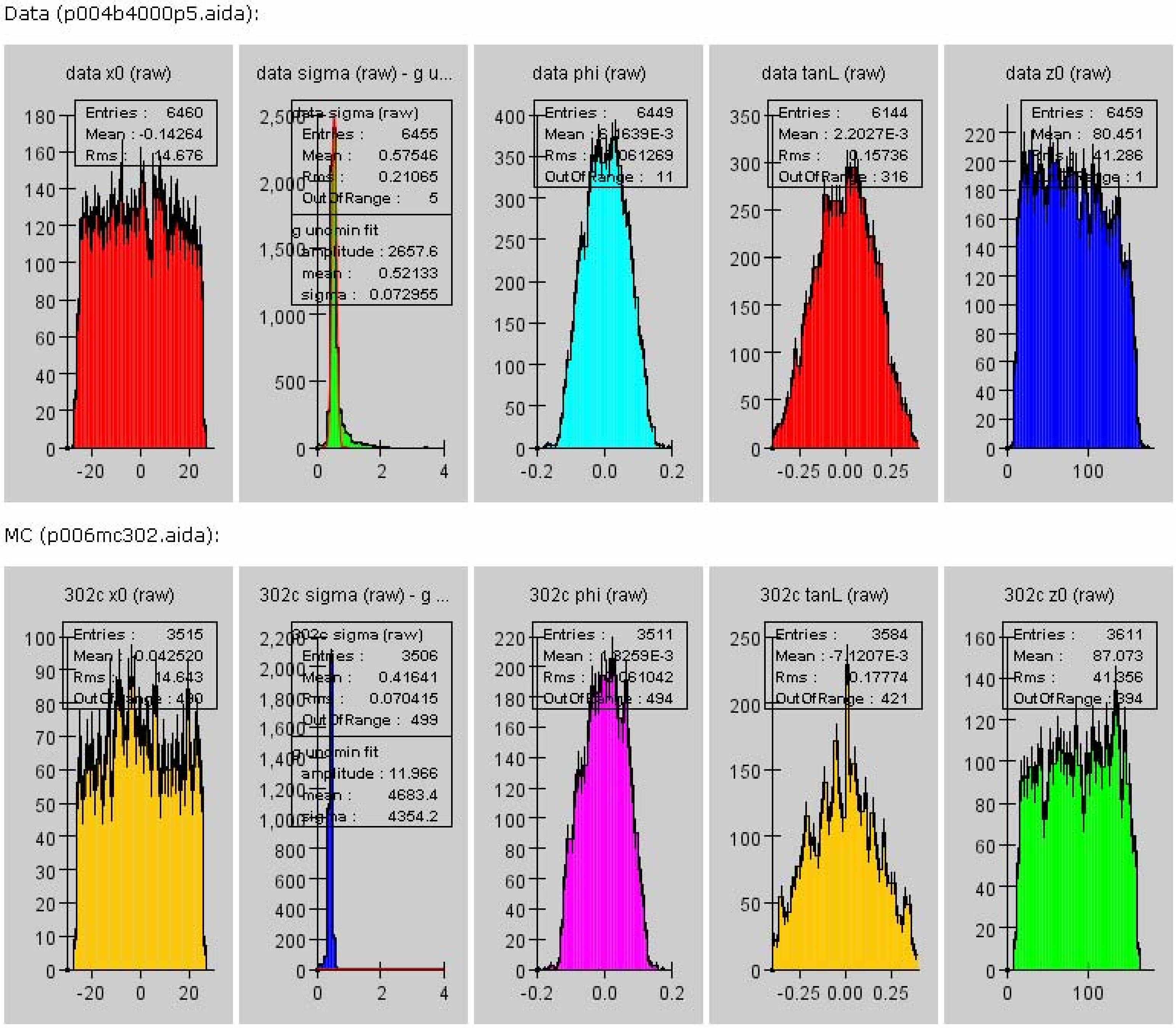
- To better understand the results from the cosmic ray samples, a full GEANT3 simulation of cosmic events was developed:



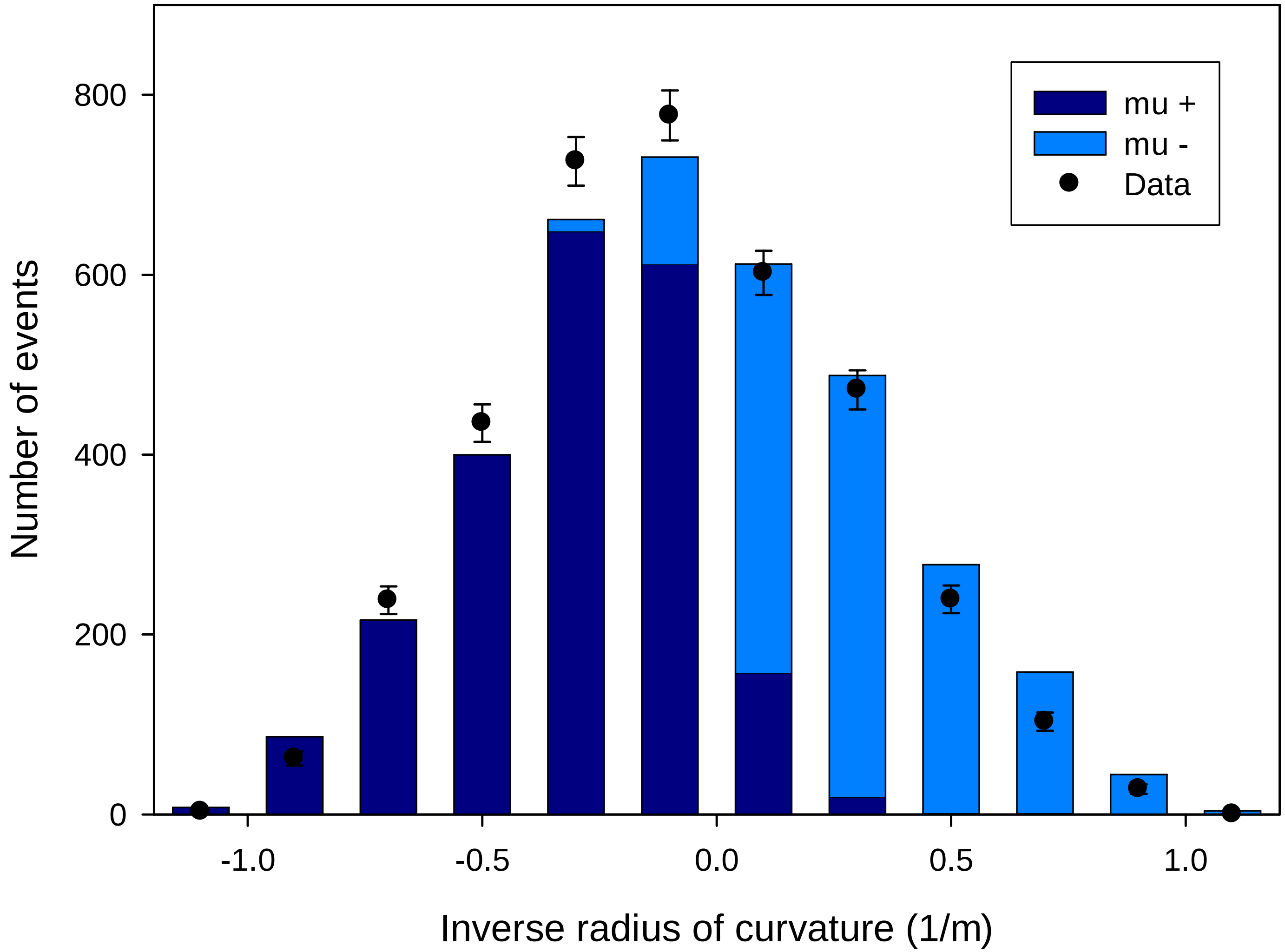
Comparison at 4 Tesla

Data:

MC:

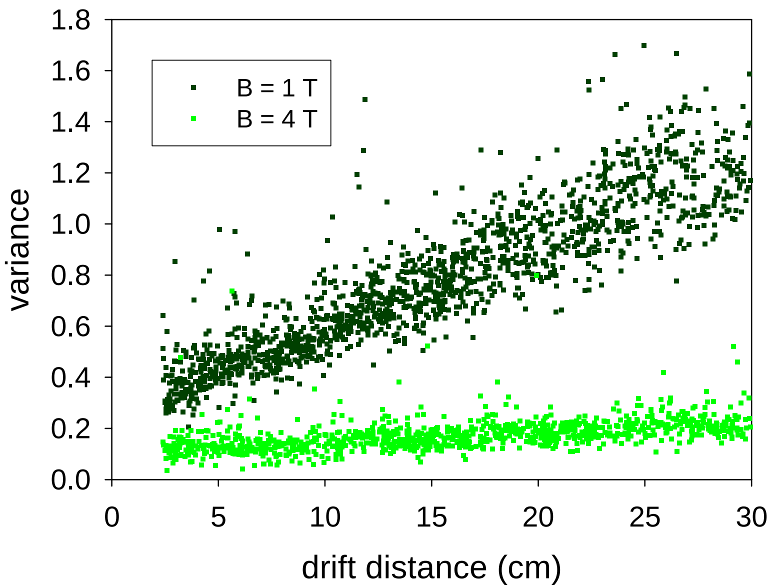


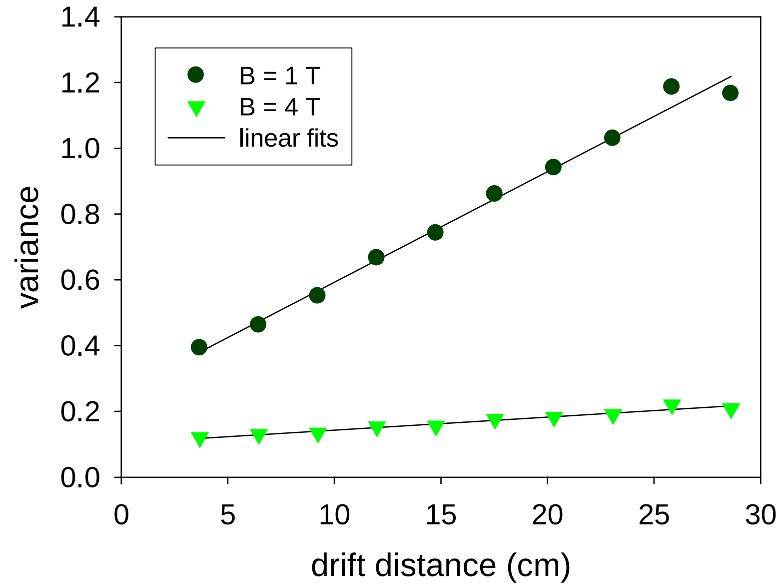
Spectrum/asymmetry of muons



Gas properties

- Diffusion measured on an event by event basis
  - σ^2 vs drift distance is linear
    - slope → diffusion constant (D)
    - intercept → defocusing term (σ_0)



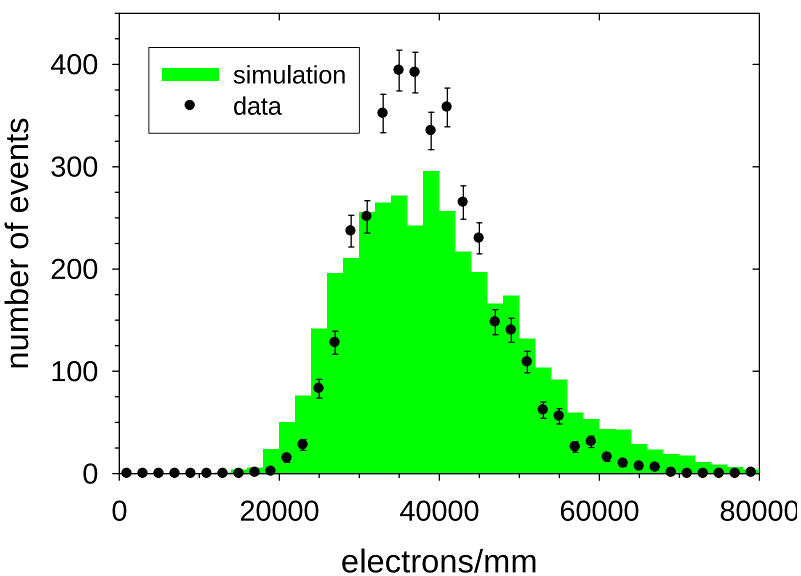


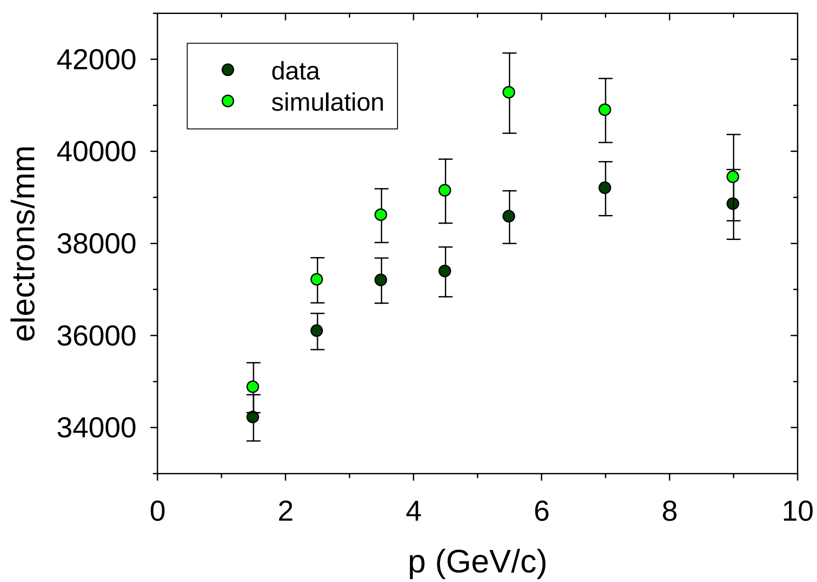
Gas properties

Data	v_d [cm/μs]	v_d sim [cm/μs]	D [μm/$\sqrt{\text{cm}}$]	D sim [μm/$\sqrt{\text{cm}}$]	σ_0 [μm]	σ_0 sim [μm]
p5B4w	3.84 ± 0.08	3.64	76 ± 5	67 ± 1	429 ± 2	350 ± 2
p5B4n	3.85 ± 0.04	4.14	34 ± 5	43 ± 1	382 ± 1	369 ± 1
tdrB4w	4.51 ± 0.05	4.52	71 ± 10	69 ± 1	367 ± 4	262 ± 1
tdrB4n	4.54 ± 0.06	4.52	70 ± 5	69 ± 1	319 ± 3	255 ± 1
tdrB1n	4.66 ± 0.06	4.52	205 ± 10	206 ± 2	509 ± 2	289 ± 2
tdrB0n	4.68 ± 0.06	4.52	348 ± 20	468 ± 10	918 ± 15	580 ± 1

dE/dx study

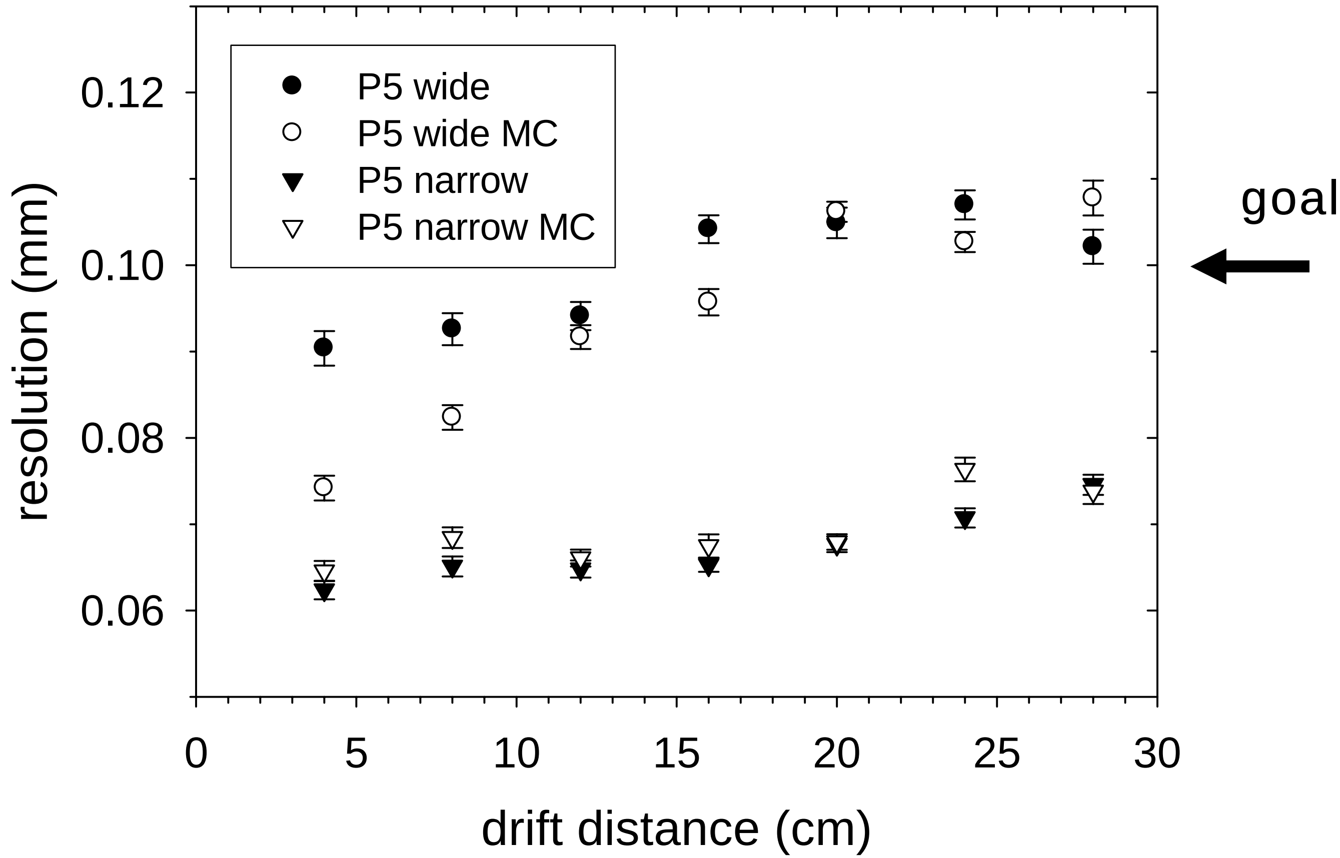
- Use all 11 rows – form truncated average number of electrons collected on the rows per mm of path length
- Overall resolution 17% (86 mm sample)
  - expected 16%





Transverse resolution (per row)

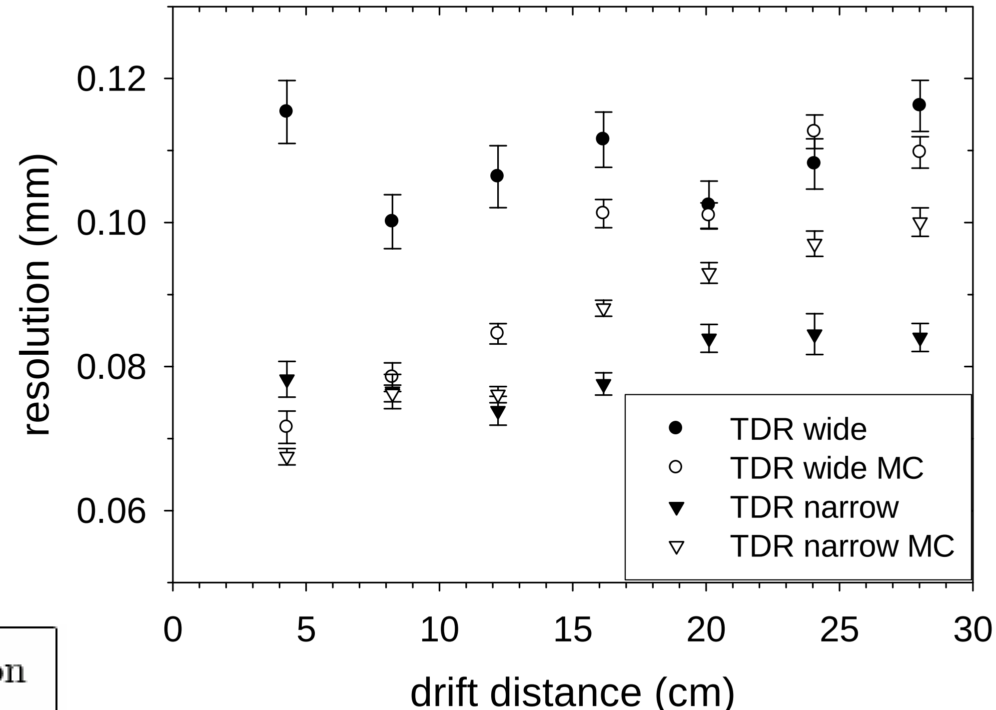
- P5 gas at 4T



- systematic biases reported at LCWS05 understood
  - narrow pads incorrectly placed in Gerber files

Transverse resolution (cont.)

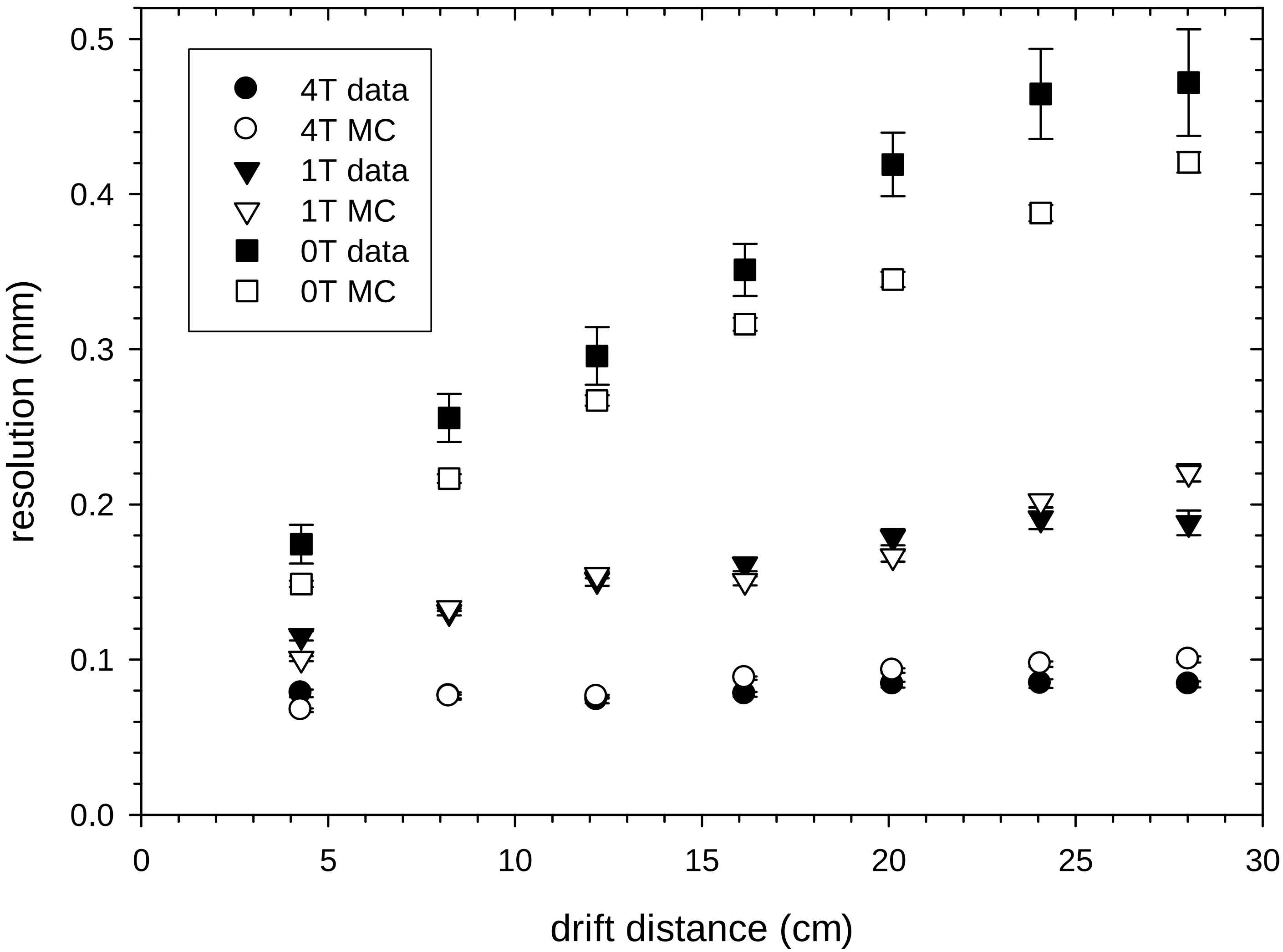
- TDR gas
  at 4T



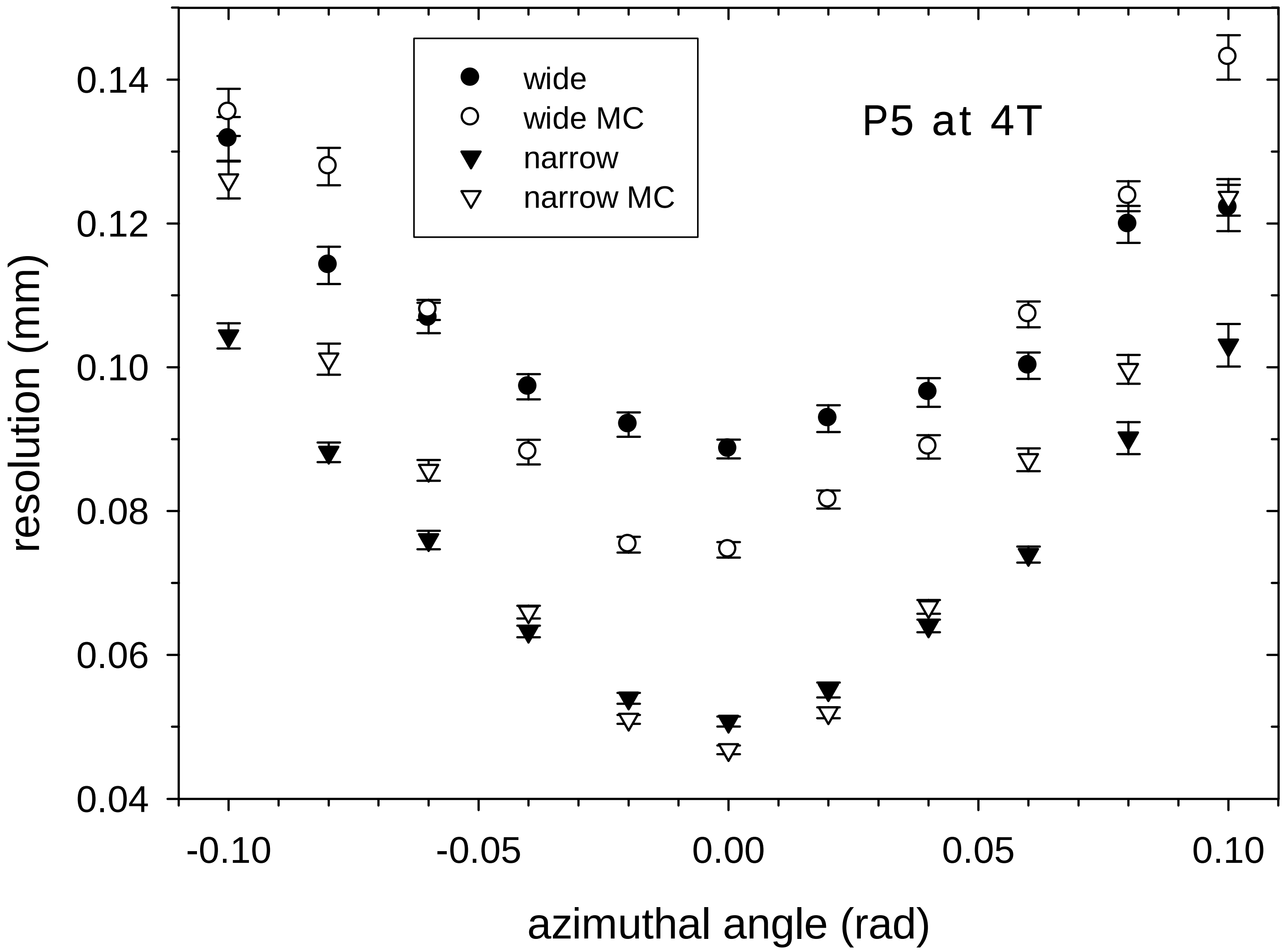
dataset	Resolution [μm] (data)	Resolution [μm] (sim.)
p5B4w	108 ± 1	92 ± 1
p5B4n	68 ± 1	68 ± 1
tdrB4w	117 ± 2	100 ± 1
tdrB4n	83 ± 1	87 ± 1

Summary for all drift distances

Transverse resolution for lower fields

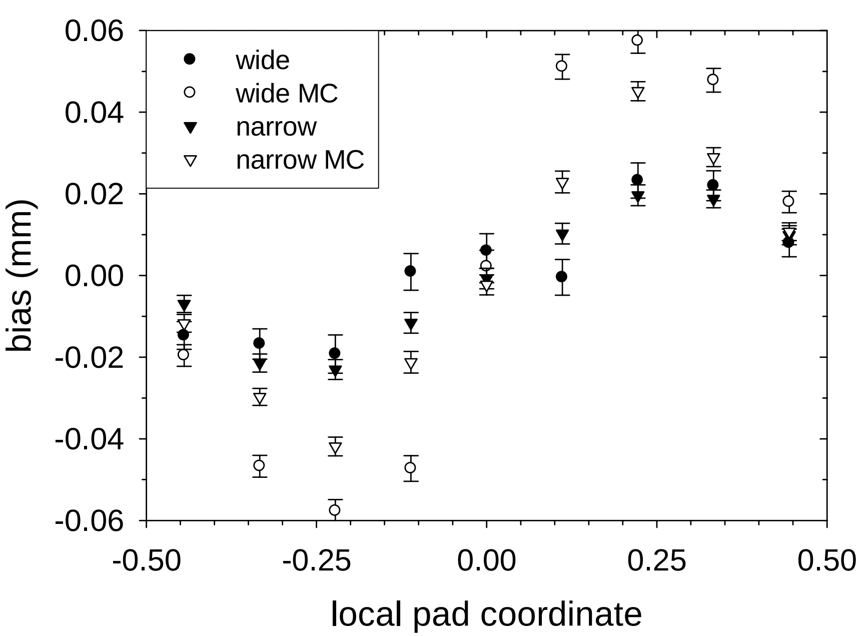


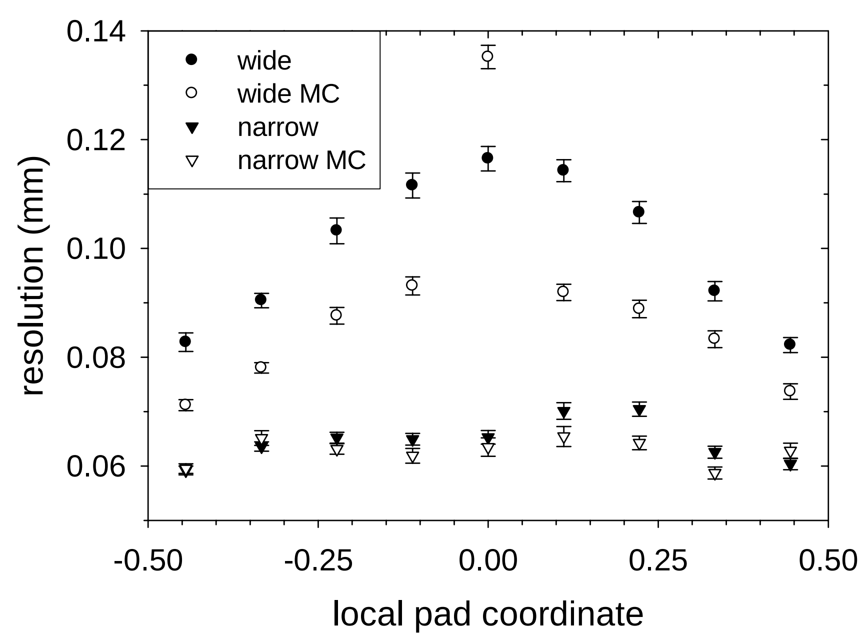
Track angle effect



Bias/resolution across a pad

- Bias function seen (and predicted) due to underestimate of cloud width
  - small enough not to affect resolution
- Resolution best near edge of pad for wide pads

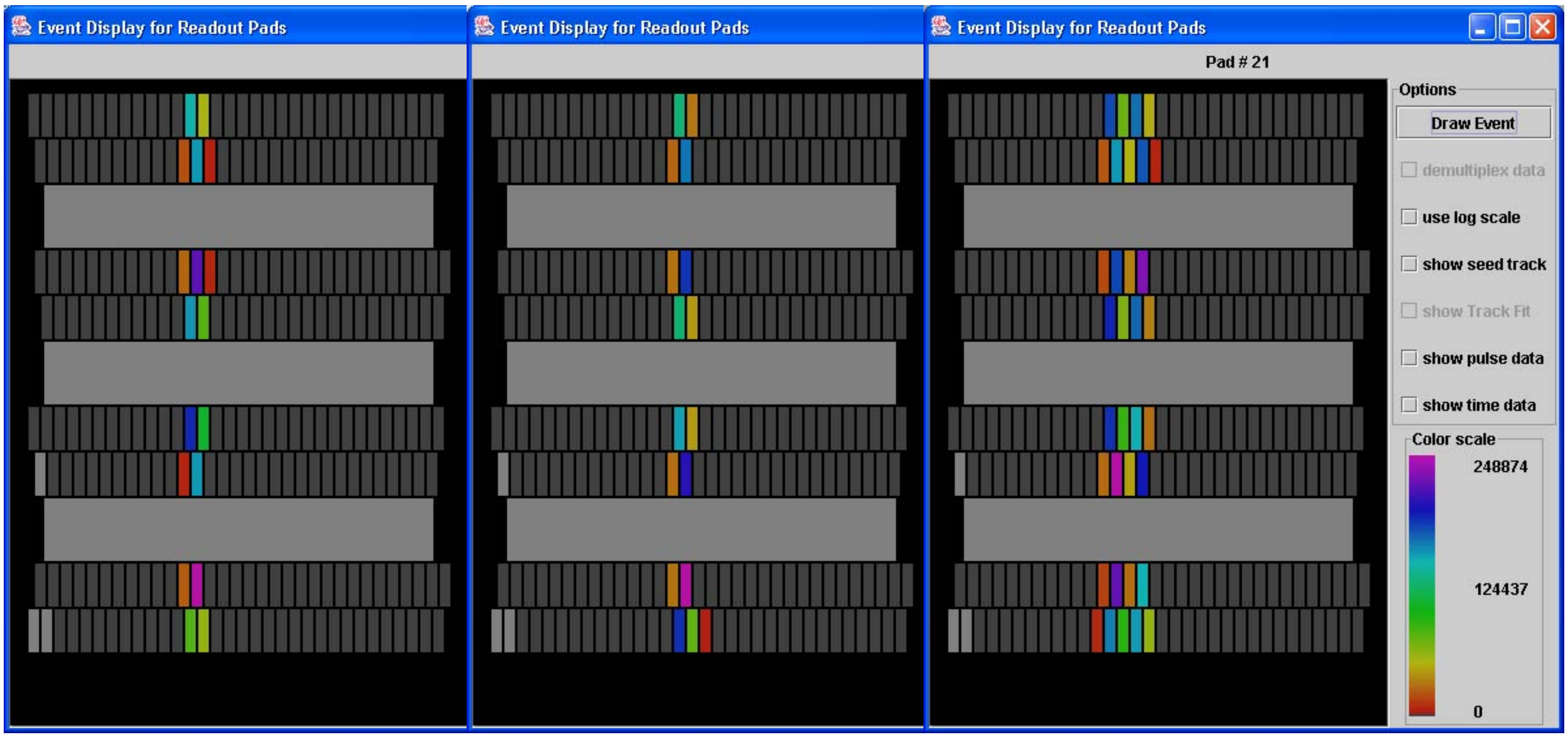




Two track resolution studies

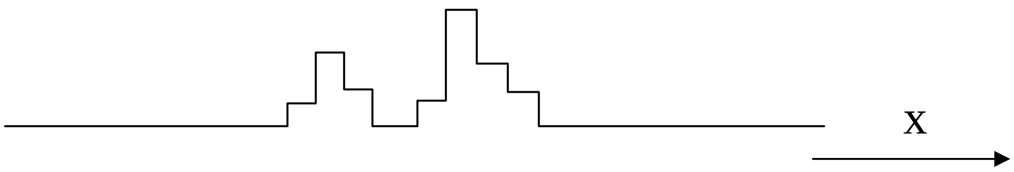
- Bring two laser beams close together **at same z**
  - example (runs 67-69): 3.8 mm separation, σ = 0.5 mm

Beam 1 only — Beam 2 only — Beam 1 and 2



Two track likelihood fit

- Modify maximum likelihood track fitter to allow for charge coming from two tracks to contribute

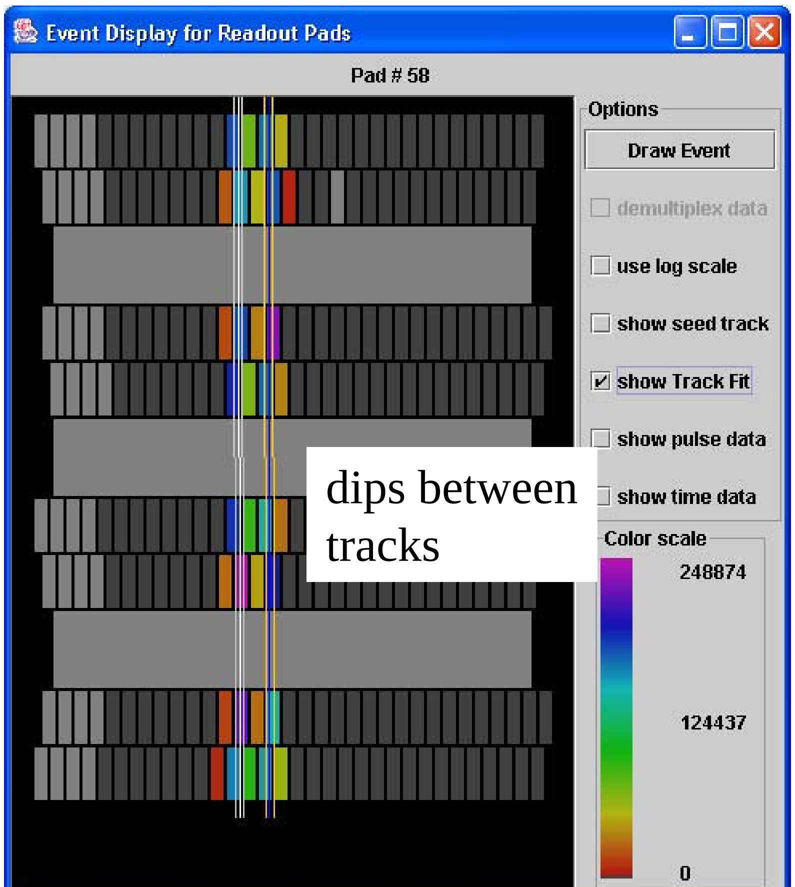


  - relative amplitudes of the charges from two tracks for each row are treated as nuisance parameters (1 per row)
- Fix sigma (known from z)
- Maximize likelihood for 4 track parameters (x_{01}, ϕ_{01}, x_{02}, ϕ_{02}) + 8 nuisance parameters
  - for MIPs the 8 nuisance parameters are independent and maximum likelihood determined by setting $\partial L / \partial \alpha_i = 0$

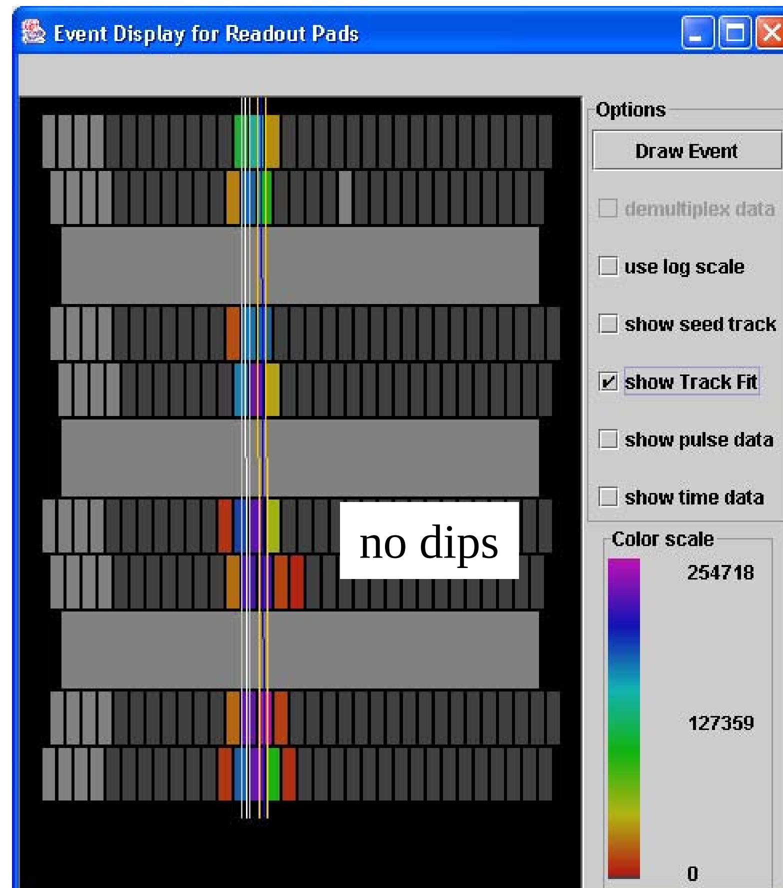
Double track fits: 2mm wide pads

σ = 0.5 mm

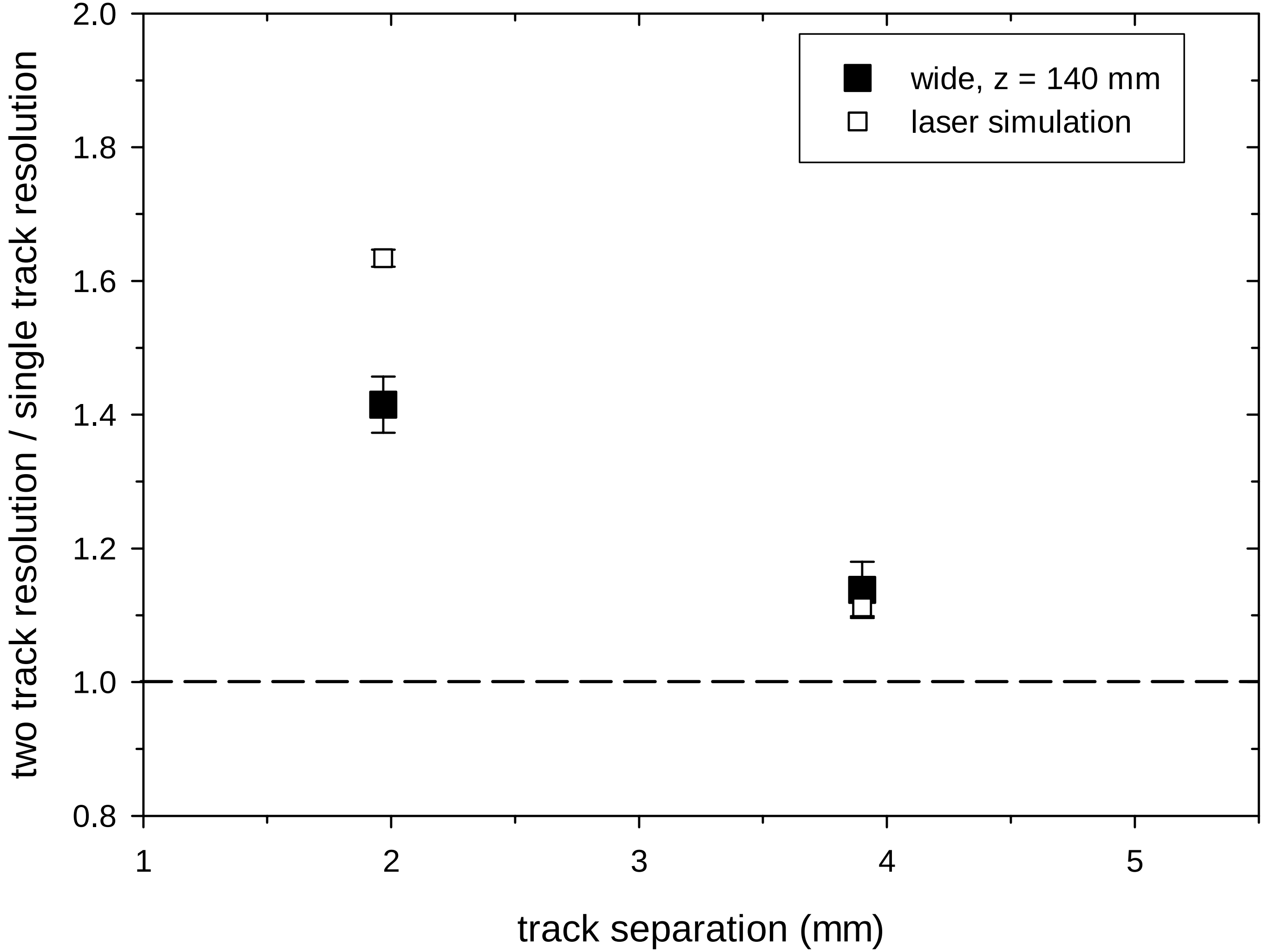
Δx = 3.8 mm



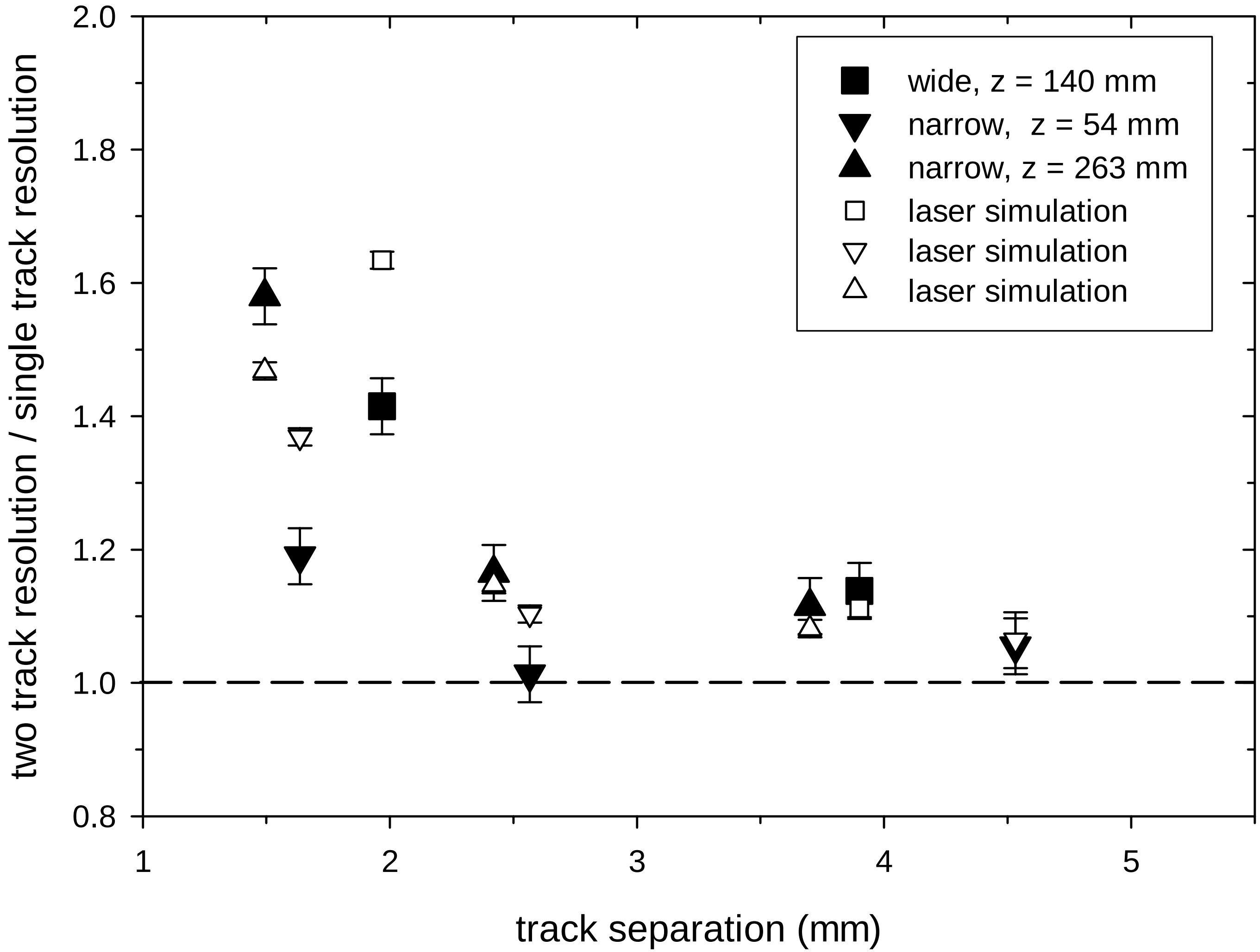
Δx = 2.0 mm



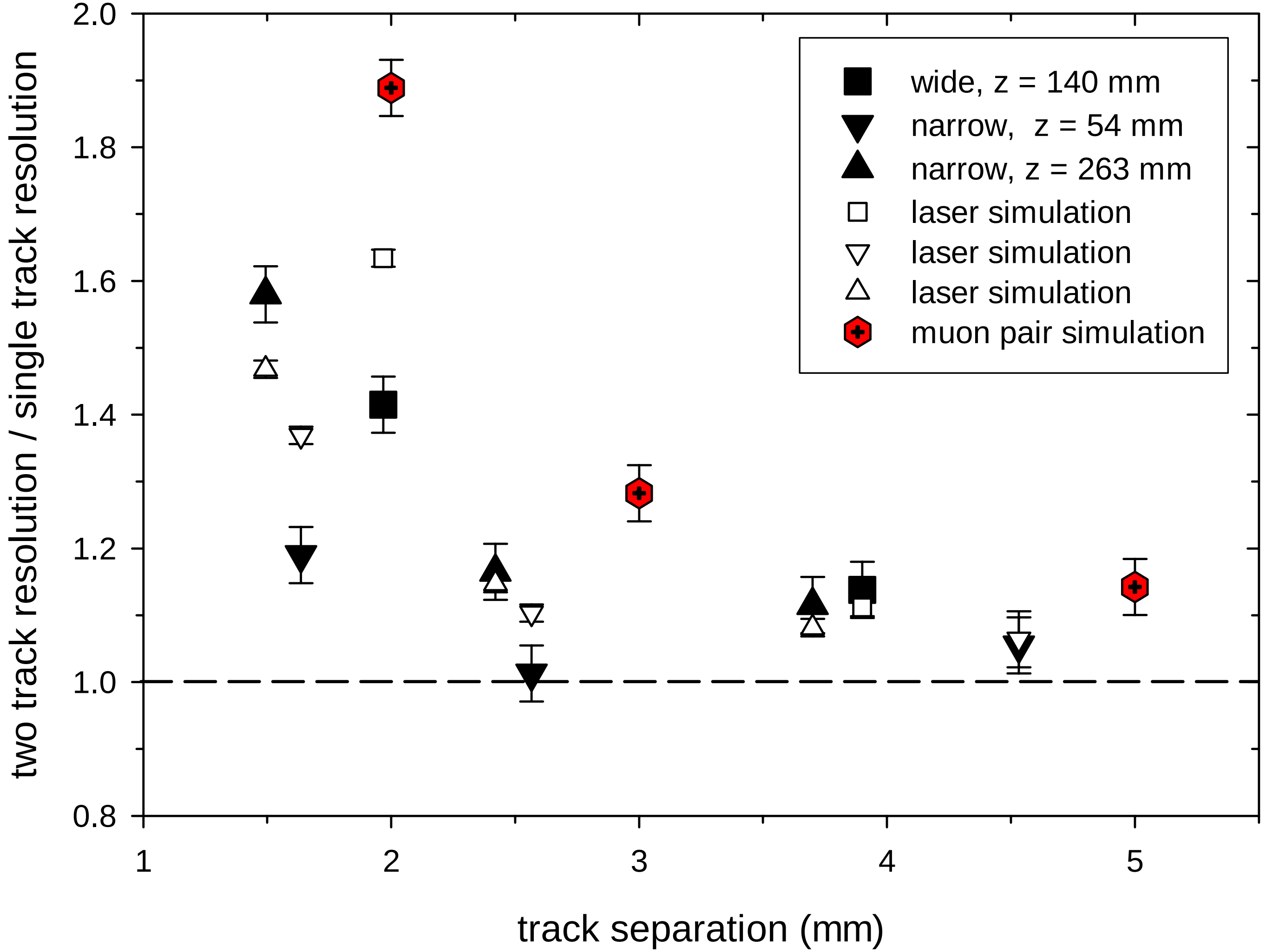
Resolution degradation (wide pads)



Resolution degradation (narrow)



Resolution degradation (muon sim)



Conclusions

- A very successful run at DESY in 2004
- Laser tracks are a useful tool for testing TPC operation
  - Our laser transport system is available for others for DESY laser tests
- GEM-TPC performance at 4T reaching design goals:
  - spatial resolution (~100 mm)
  - two track separation (~3 mm for 2 mm pads)
- Simulation roughly reproduces many features in the data
  - should be useful for optimizing TPC design parameters
- Thanks to the DESY group for the use of the magnet test facility and assistance