LCWS 05

Study of GEM-TPC Performance in Magnetic Fields

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Progress since Paris LCWS

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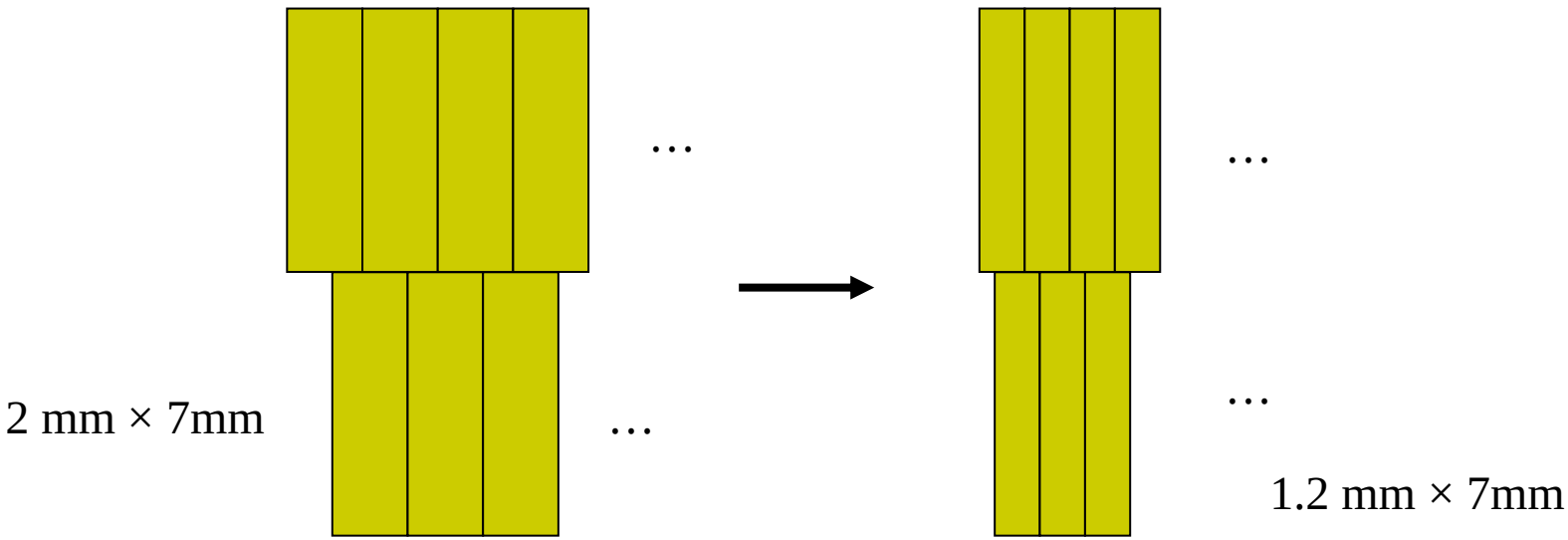
- Large dataset collected in 2004 in DESY magnet
  - UV laser system incorporated
    - single/double beams available under remote control
  - New readout plane with narrower pads
    - data taken with both sets of pads
  - Readout plane for Micromegas with resistive foil
- New full simulation of cosmic rays in DESY setup
  - cosmic ray generator (courtesy Rob McPherson, UVic)
  - GEANT3 propagation of particles in the magnetic field
    - energy loss info used as input to jtpc package
- FAR TOO MUCH TO SHOW IN 15 MINUTES!

Narrower readout plane

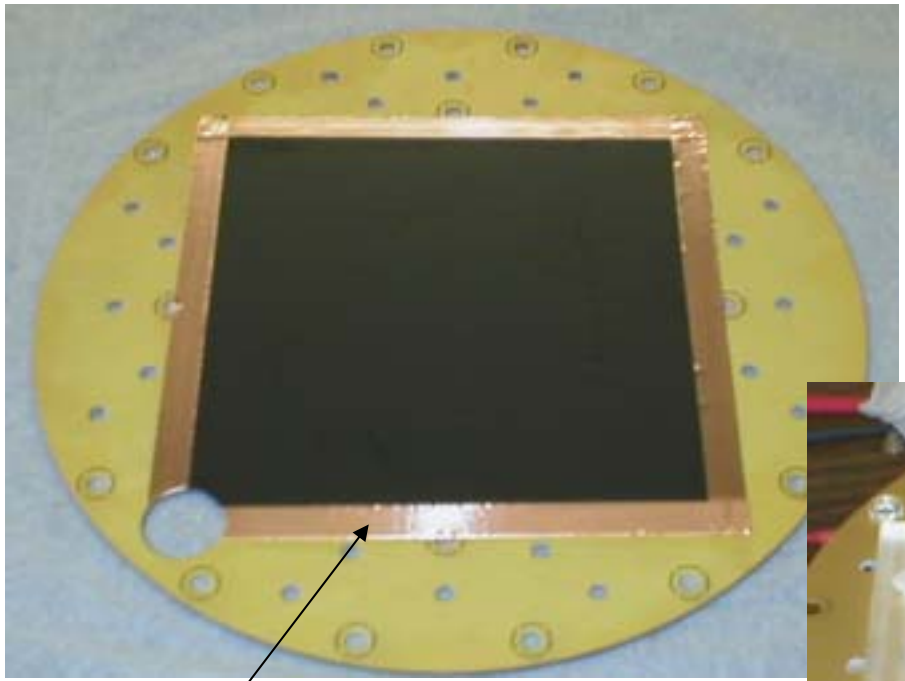
- At Paris, our results show defocusing in P5 or TDR gas of around 0.4 mm at 4 T.
  - too small for our 2 mm pads (width/σ_0 = 5)
- To check effect of pad width, we built a new readout board replacing 2 mm pads with 1.2 mm pads



Micromegas readout plane

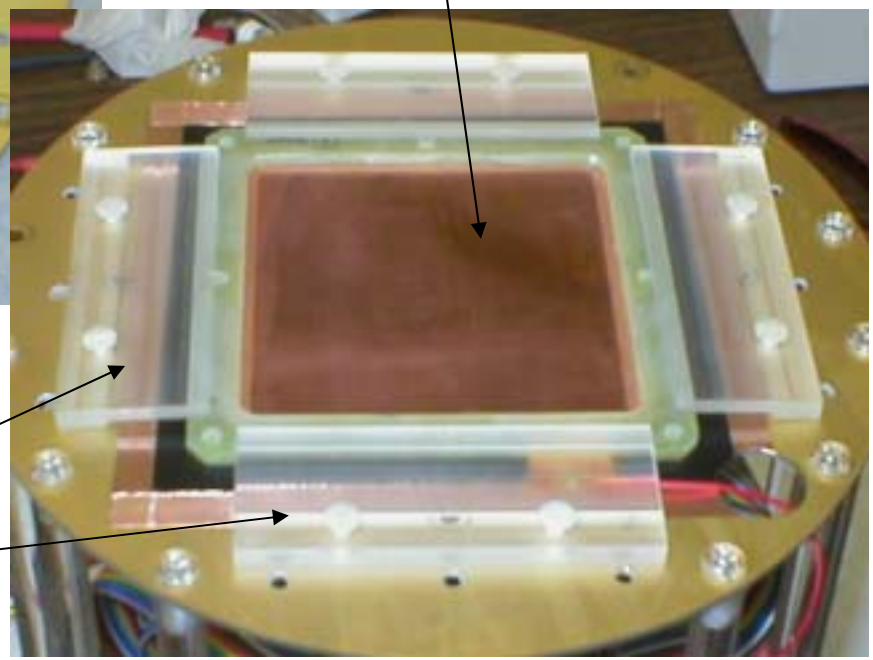
- Shorter pads (6 mm instead of 7 mm) in order to fit them all within the Micromegas frame provided to us by Paul Colas
- Resistive foil (carbon loaded kapton) provided by Madhu Dixit
- Resistive foil affixed to readout plane through baking a 50 μm sheet adhesive at high pressure
  - nice uniform gluing technique
- Unfortunately micromegas failed in P5… we were using a poorer quality MM

Micromegas installation



grounding resistive foil

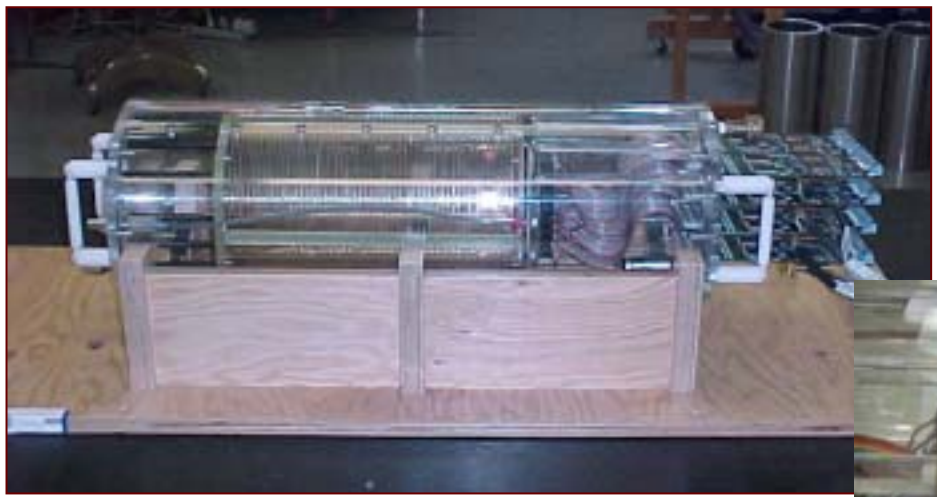
Micromegas on loan from Paul Colas

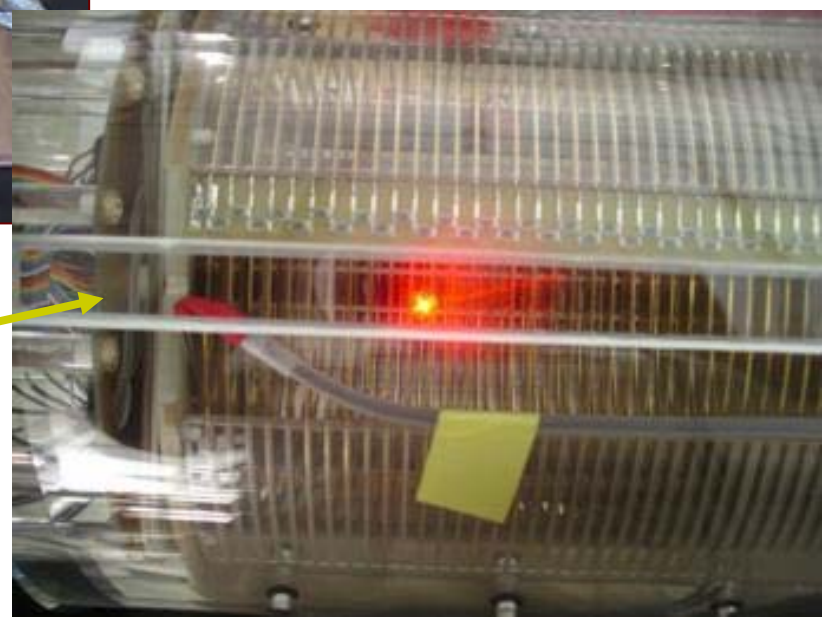


Plastic clamps to hold Micromegas in place

TPC modifications for UV laser

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





quartz window

Laser beam delivery system

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- Goal:
  - study resolution and track distortions with single beam
  - study two track resolution and ion feedback with two beams
- Challenges:
  - Deliver 1 and 2 laser beams to TPC while inserted in the DESY 5 T magnet
  - Magnet area is inaccessible while magnet on
    - magnet takes 30 minutes to ramp up or down
  - UV laser light must be contained within laser area
- Solution:
  - build a remotely controlled beam delivery system

Laser beam delivery system

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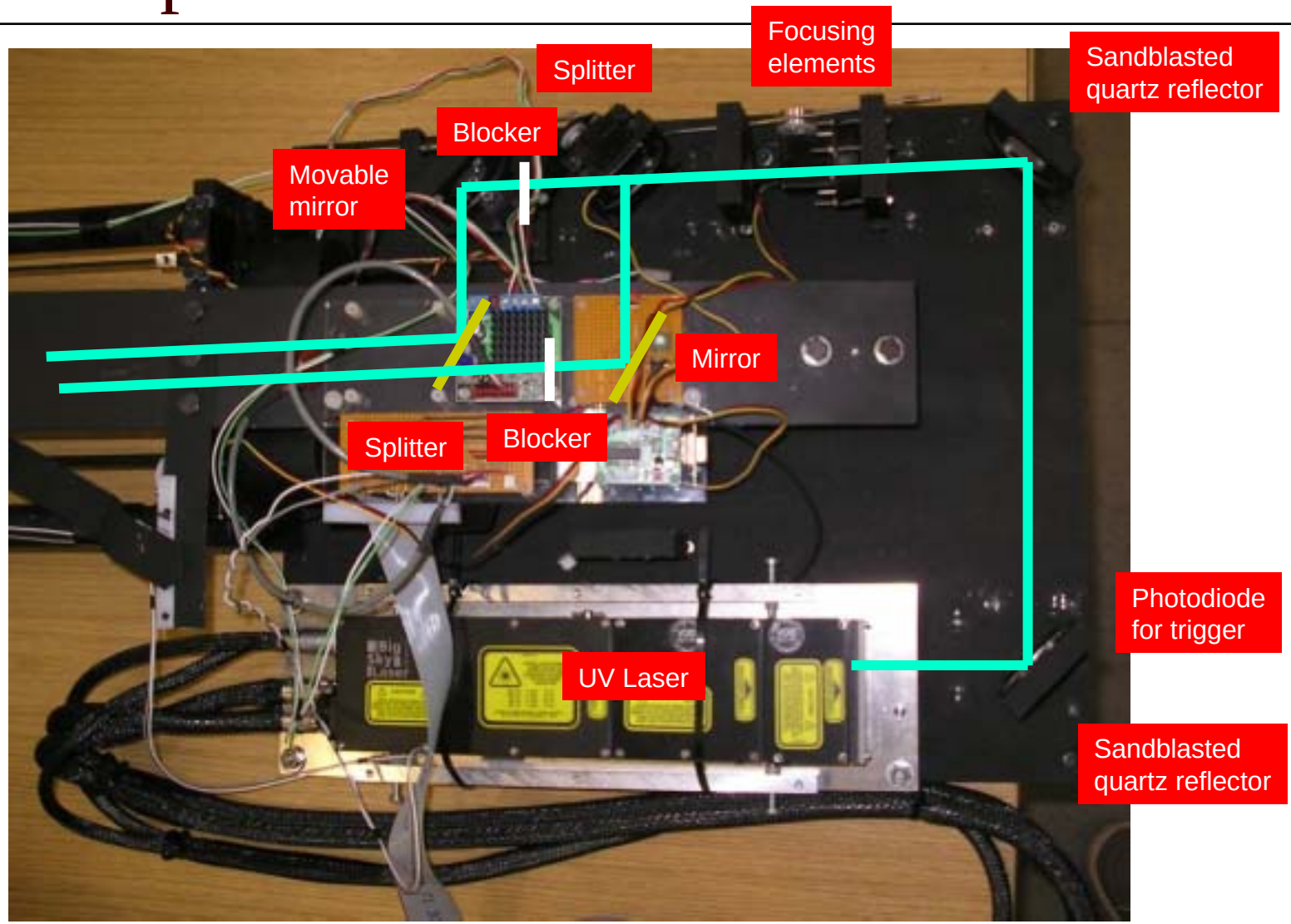
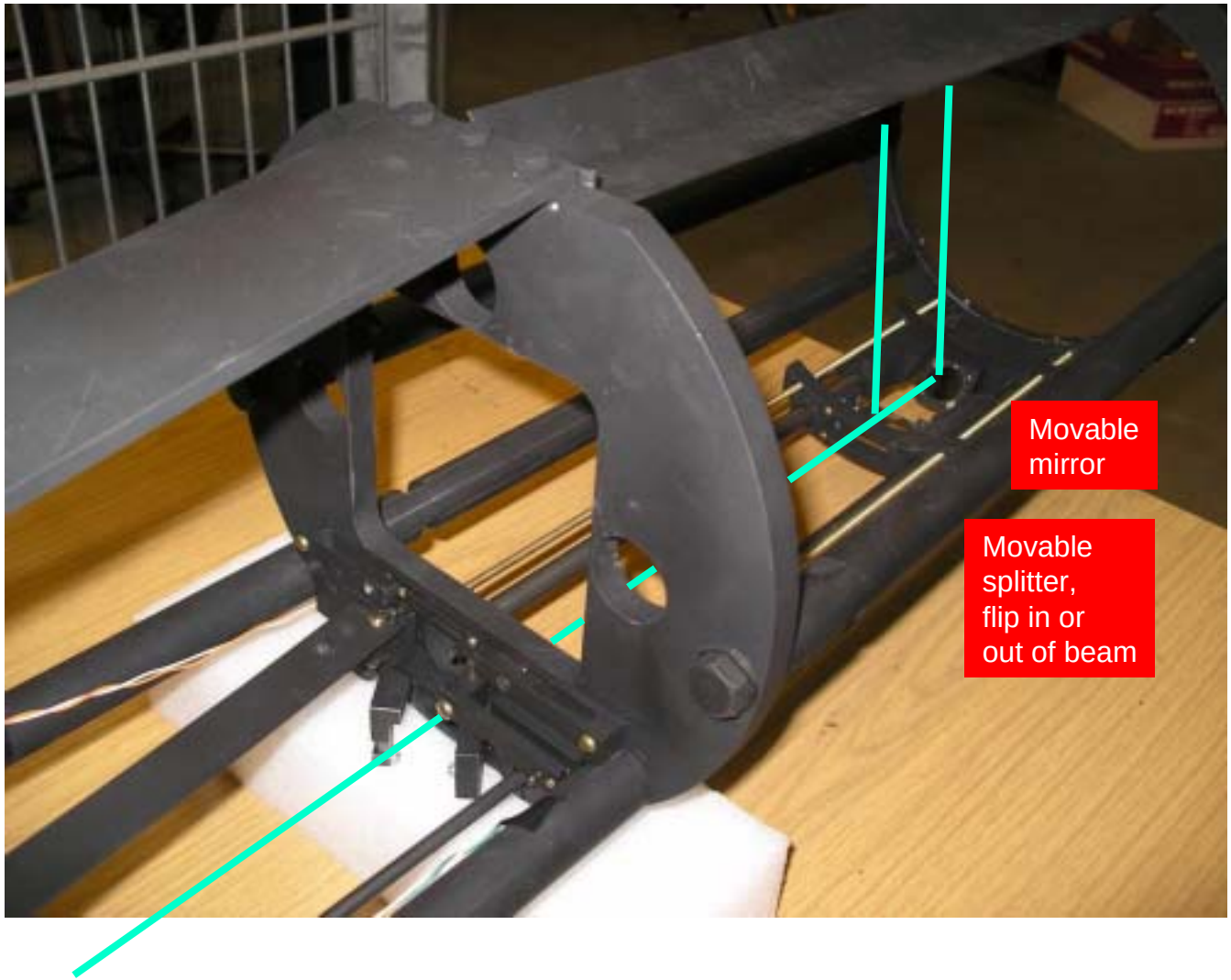
- Approx. 2 m long to reach into magnet

Engineering by
Mark Lenkowksi
Univeristy of Victoria

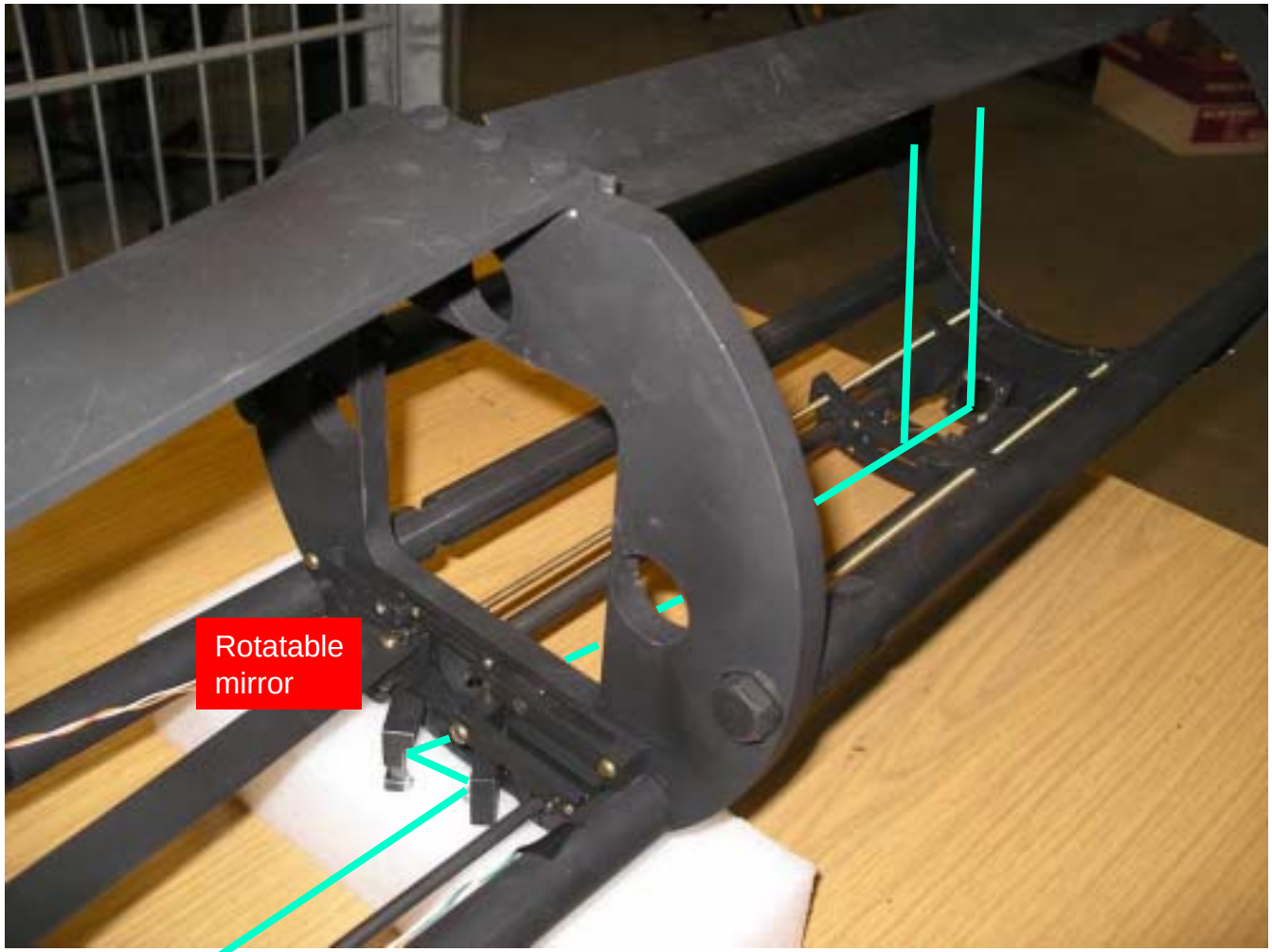
Laser optics



Beam delivery



Beam delivery – offset in x and z

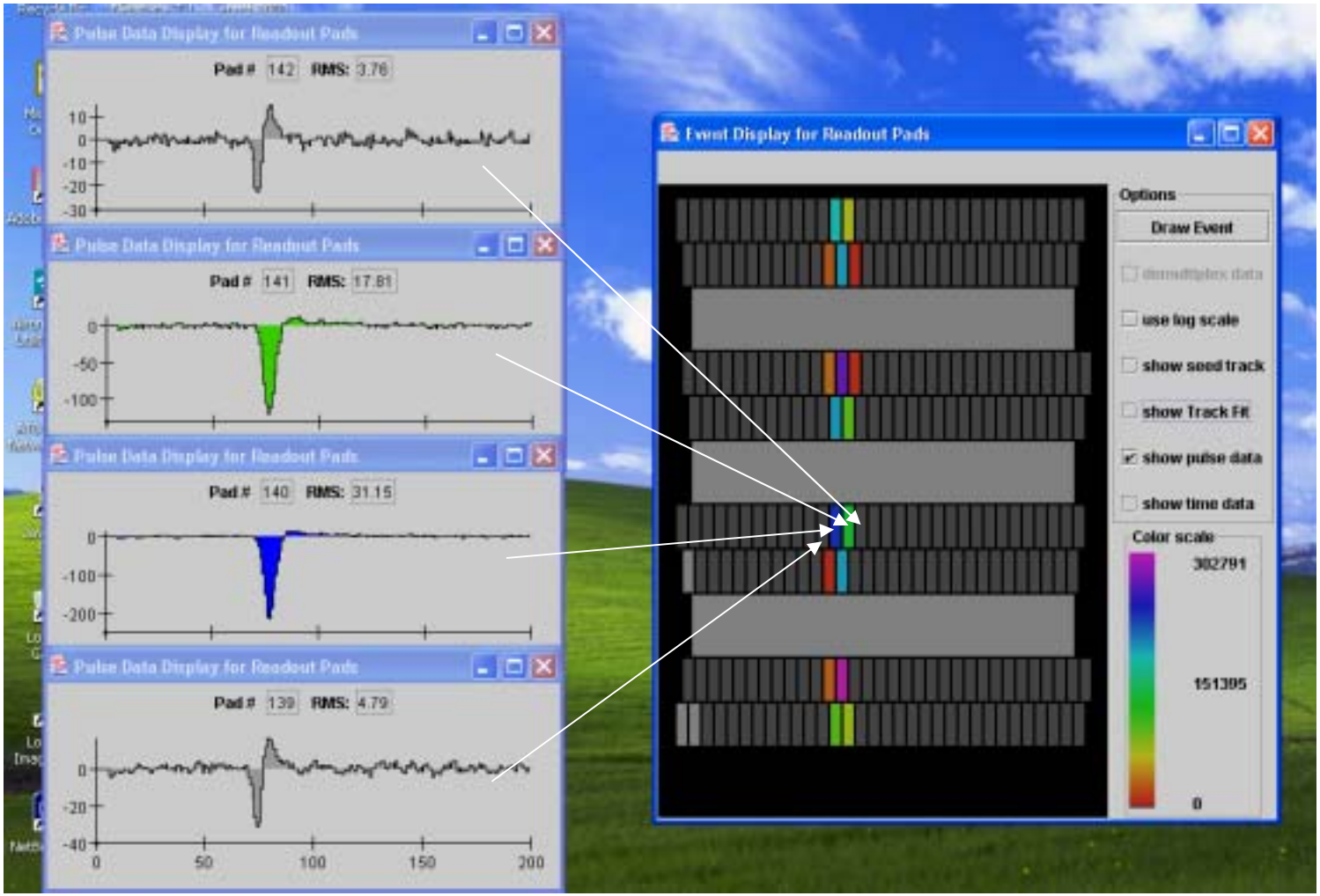


Setup with the DESY magnet

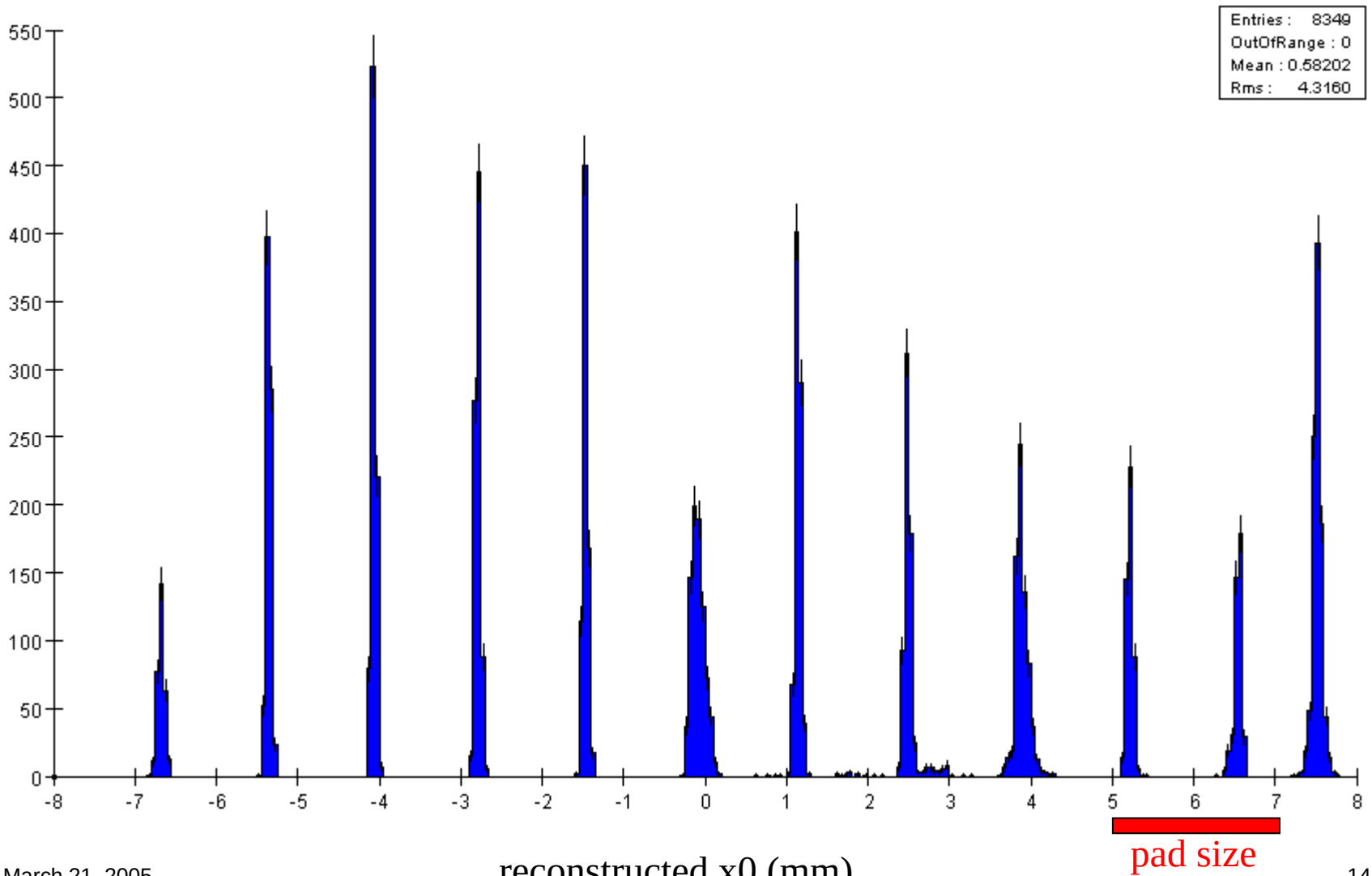
- For safety reasons, the UV laser must be contained within a light tight box

Laser event with 2 mm pads at 4 T in P5

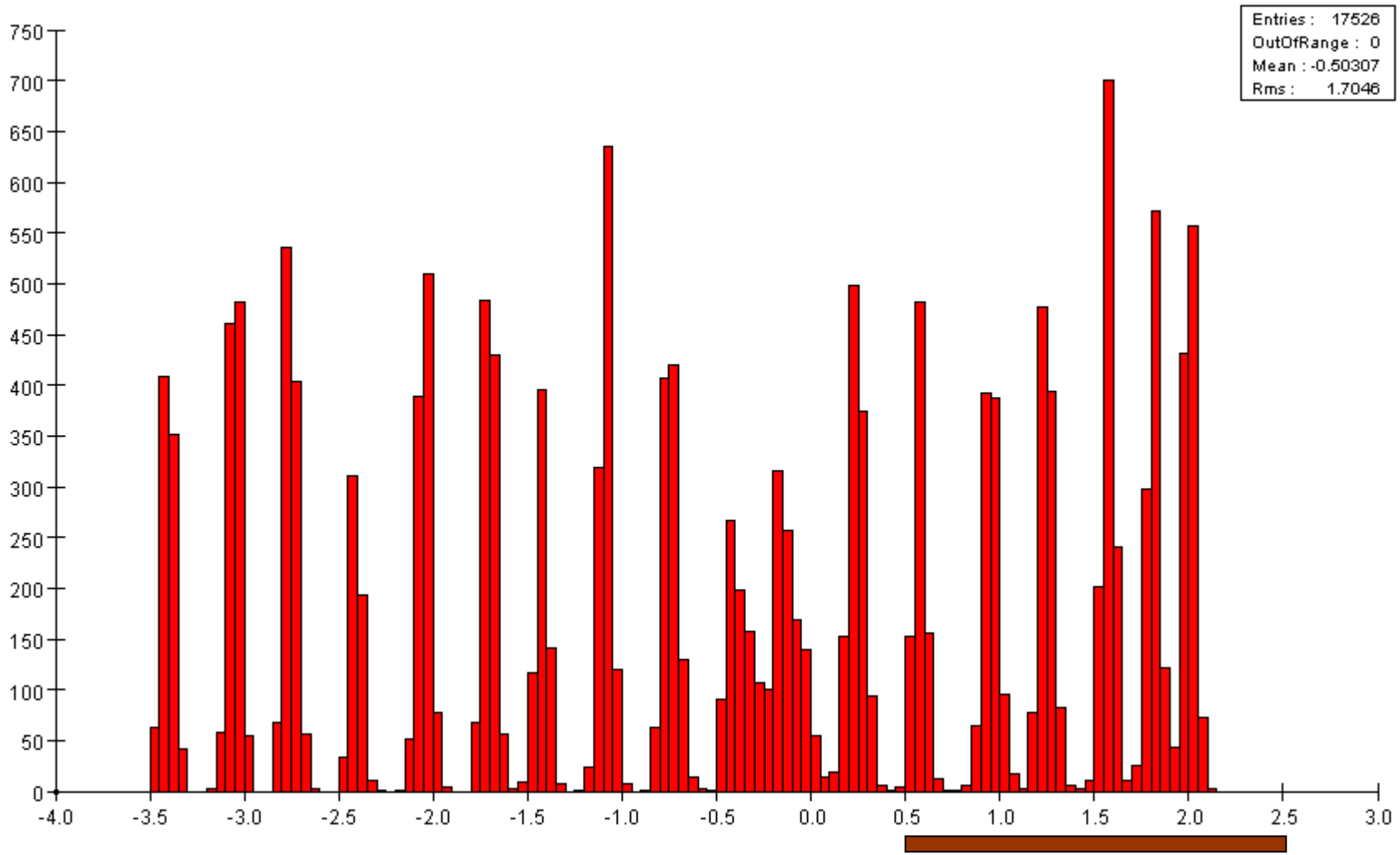
- Single laser track seen by 2 mm pads and P5 gas



Scan of laser in x

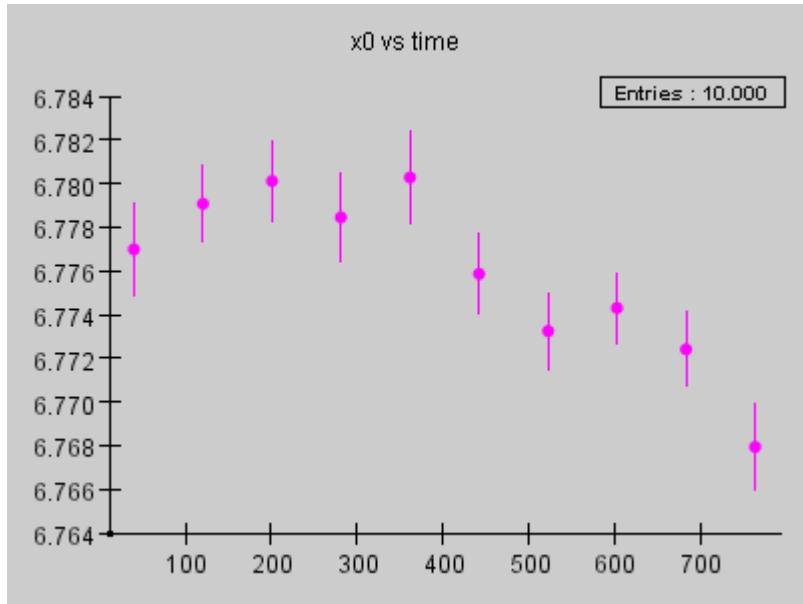


Fine scan of laser in x



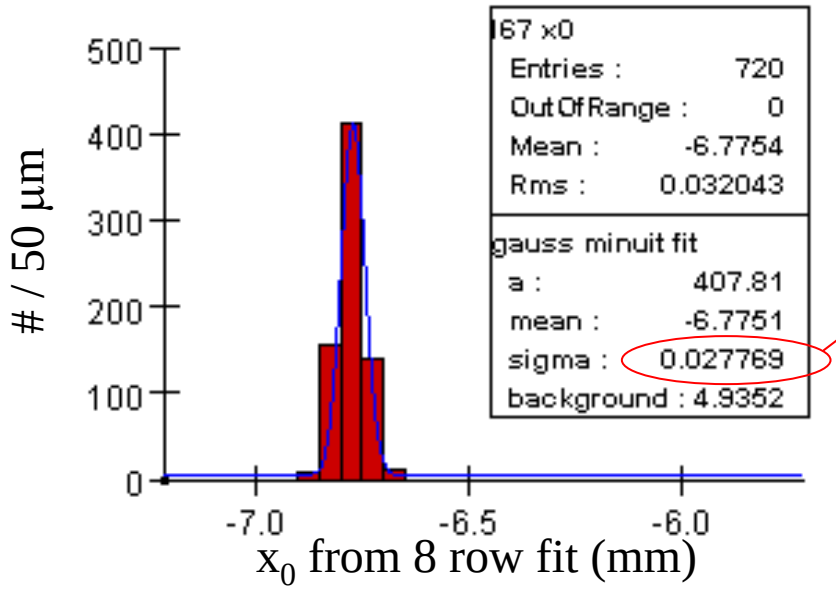
Laser track resolution studies

- Laser beam position is very stable, typical result from an overnight low rep. rate run:
  - drifted ± 6 μm over a period of 12 hours



- Fit laser tracks to straight lines
  - Fit x_0 distribution to Gaussian to estimate resolution
  - Compare this to resolution estimate from residuals
    - check that resolution estimated from the residuals is valid (ie. check the method used for cosmics)

Laser track resolution example: run 67

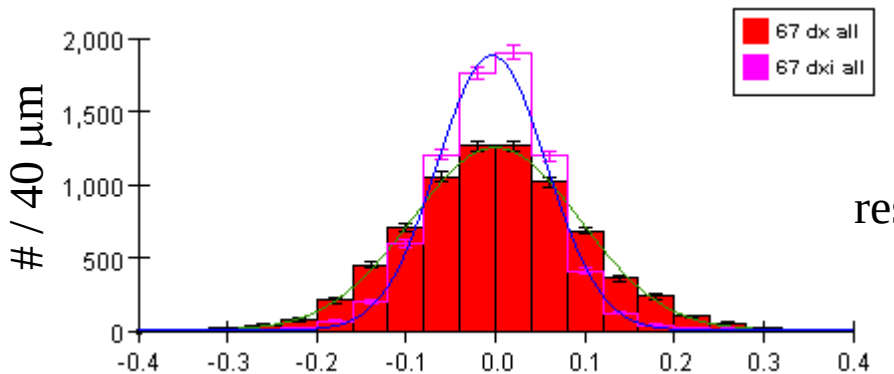


Straight track fits

8 row fit: 28 µm resolution

→ 1 row resolution = √8 × 28 µm

= 78.5 µm



reference fit excludes row: 95.2 µm
reference fit includes row: 61.6 µm

resolution (geometric mean): 76.6 ± 0.6 µm

Good agreement!

Laser resolution cross check

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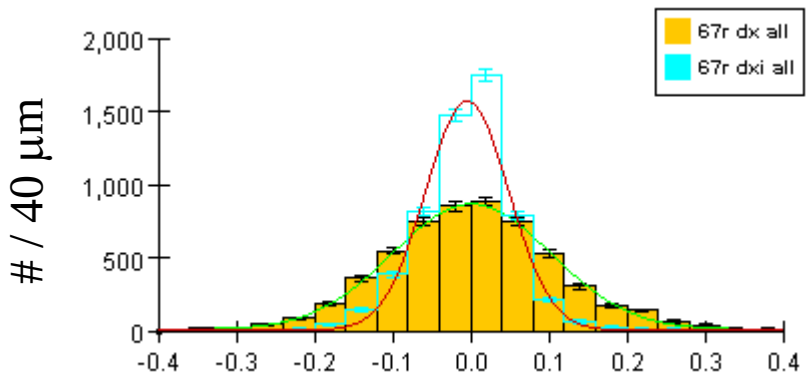
- For cosmics one must use curved track finding
  - to check if this affects the resolution estimator, apply curved track fitting to the same laser data



residual of 1 row fit to reference fit (mm)

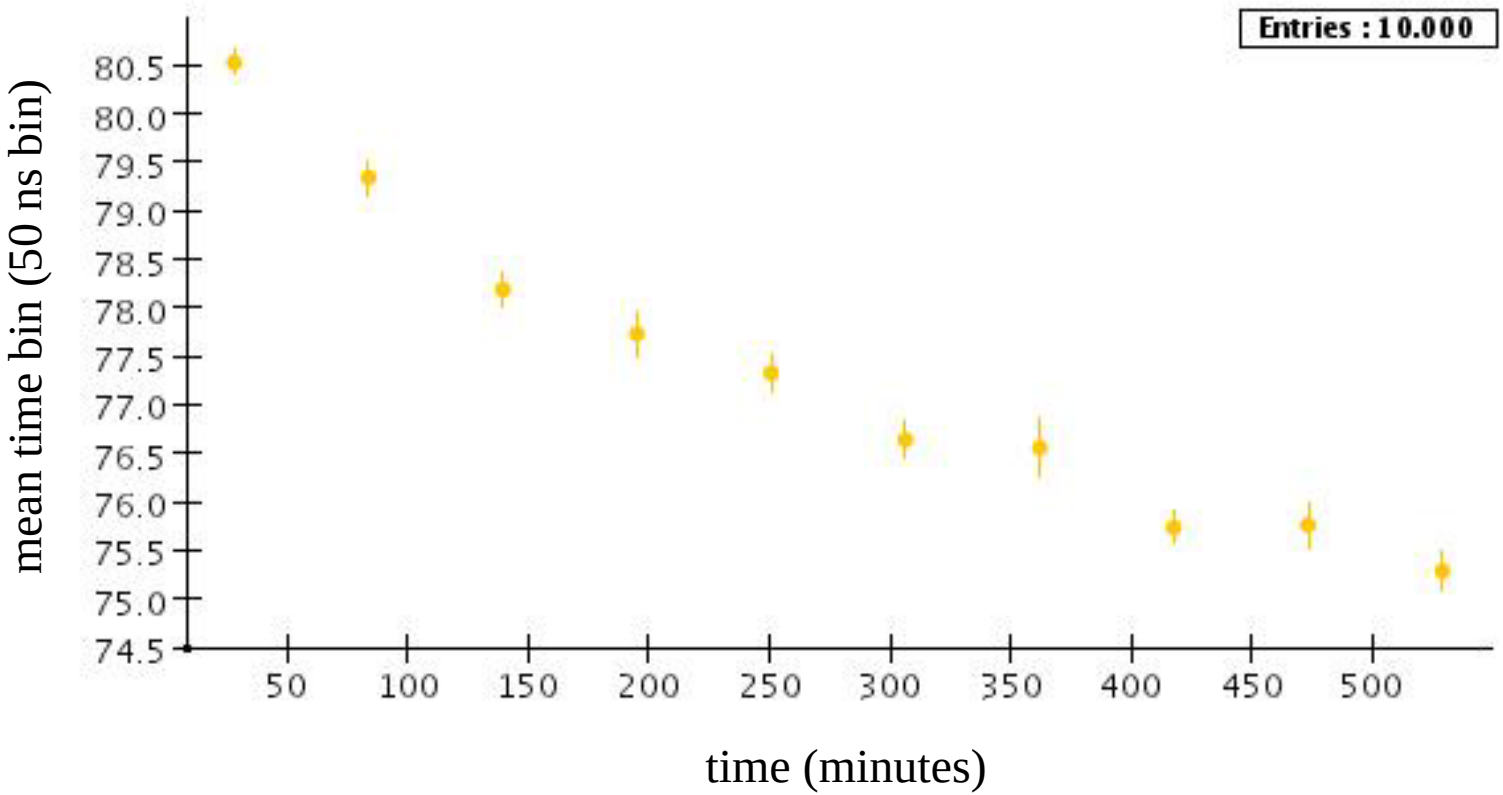
reference fit excludes row: 101.5 μm
reference fit includes row: 53.4 μm

resolution (geometric mean): 73.6 ± 0.7 μm

resolution estimate low by about 5%

Drift velocity monitor

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



Two track resolution studies: P5 gas at 4 T

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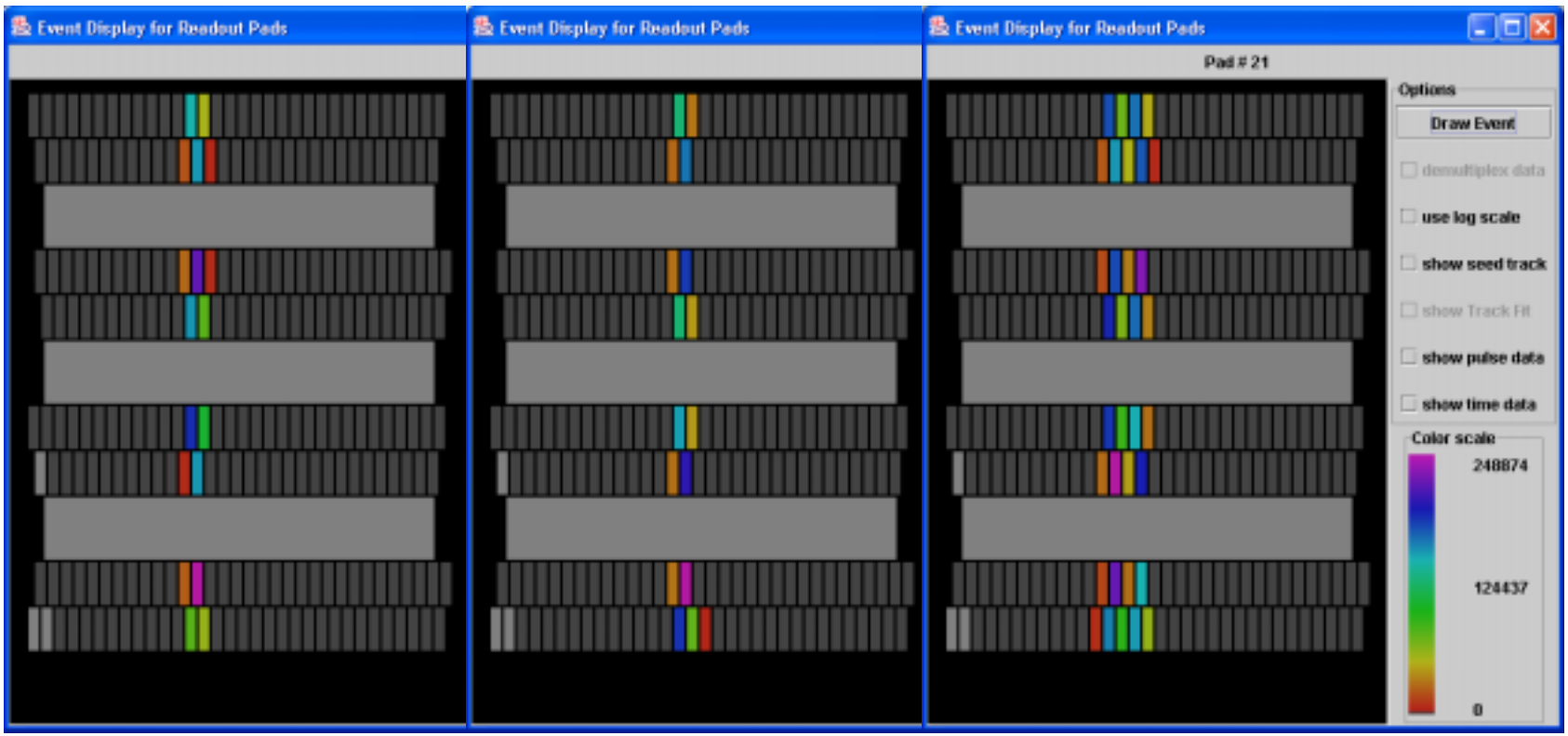
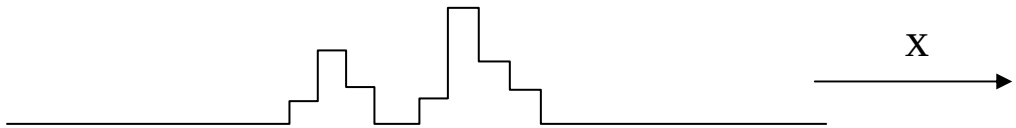
- Bring two laser beams close together **at same z**
  - example (runs 67-69): 3.8 mm separation, σ = 0.5 mm

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

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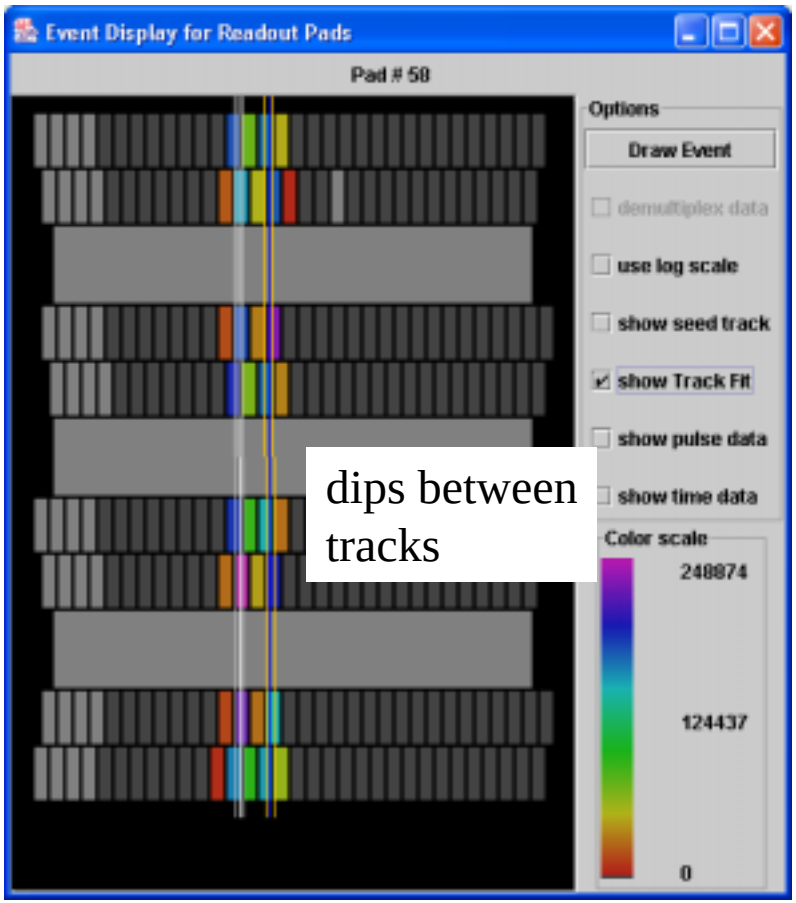
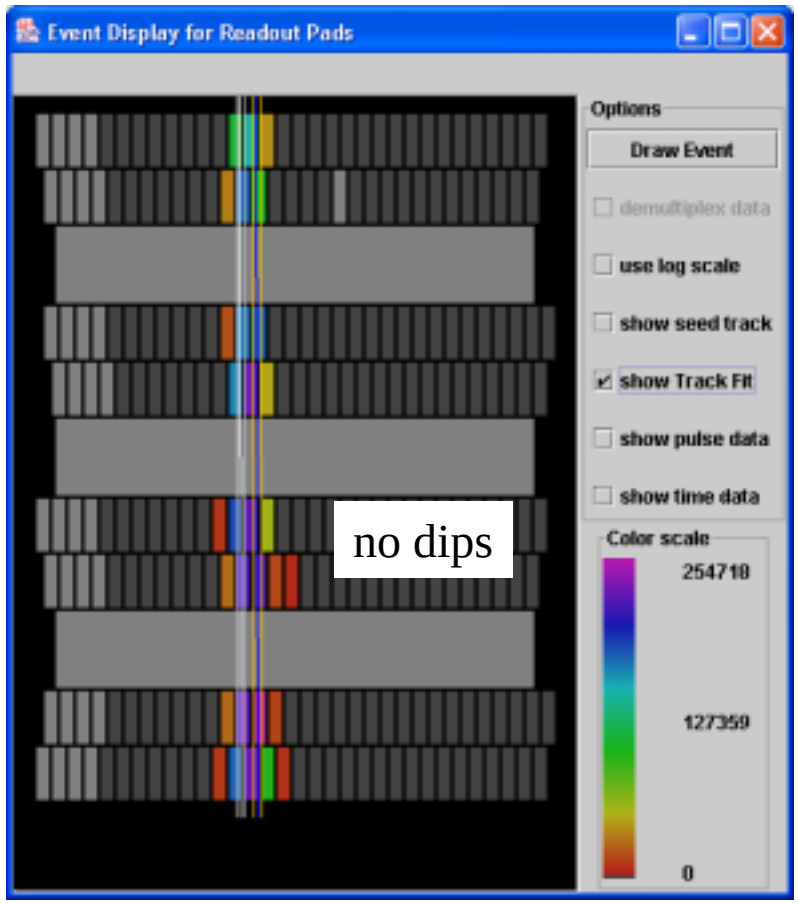
σ = 0.5 mm

Δx = 3.8 mm

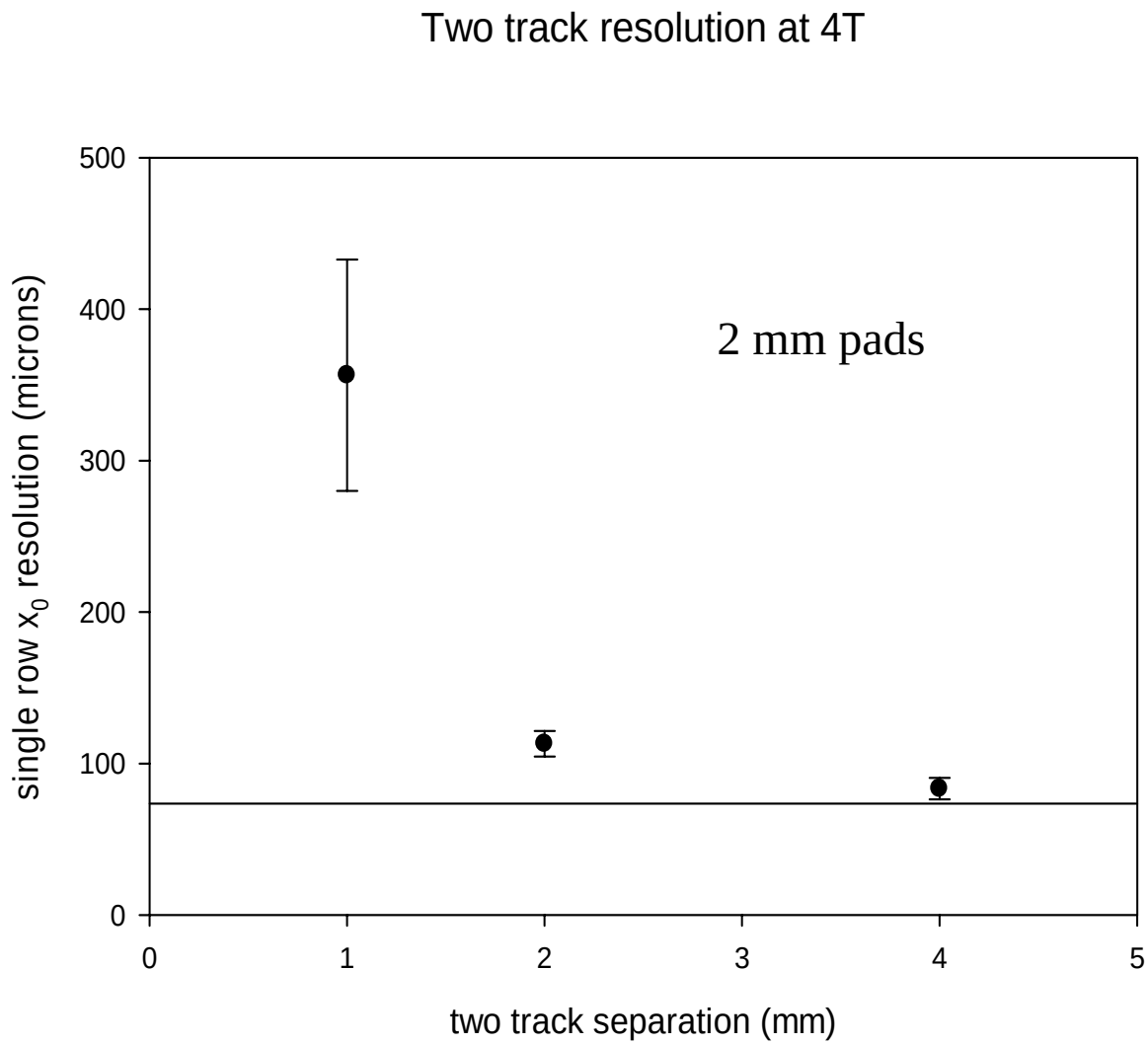


Δx = 2.0 mm



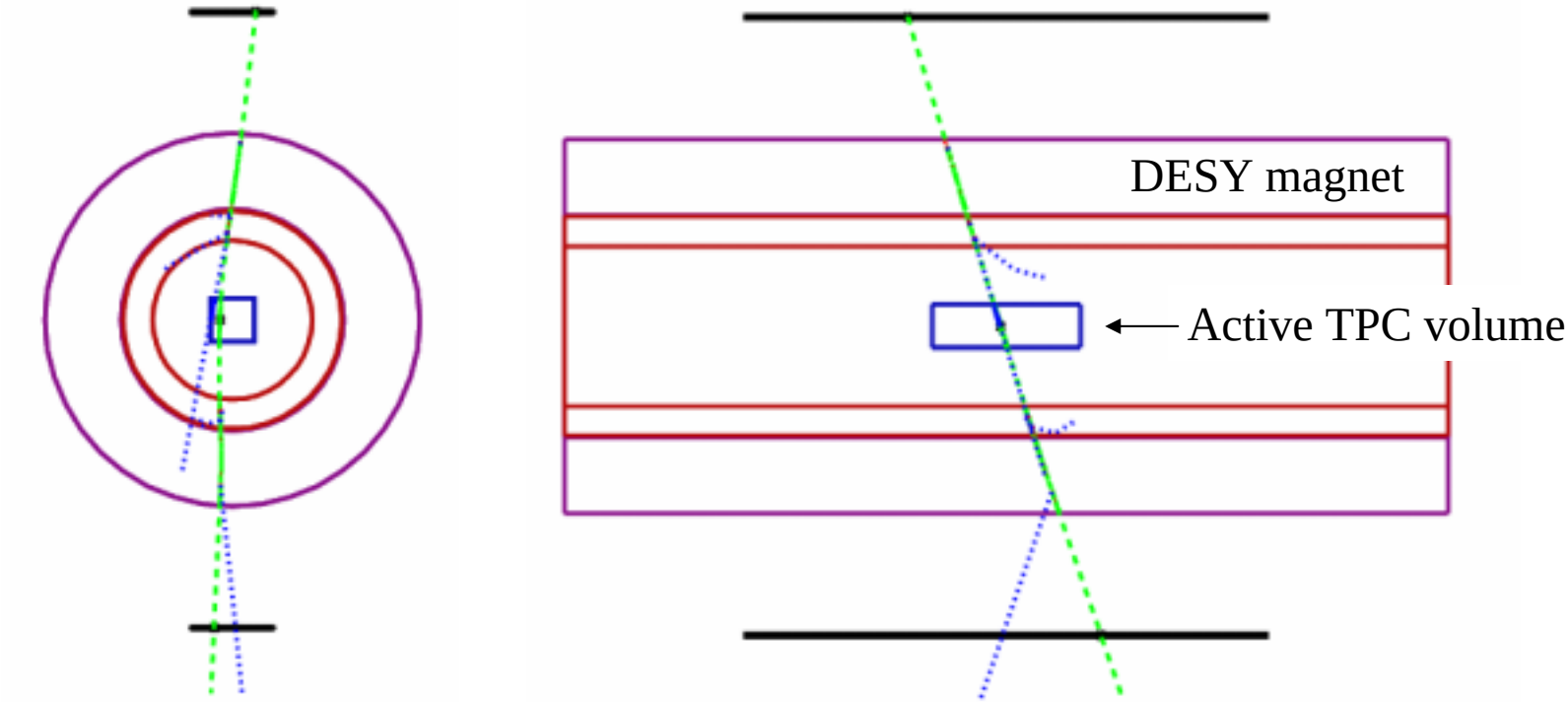
Two track fitting performance

- Typical result:



Cosmic ray tracking studies

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

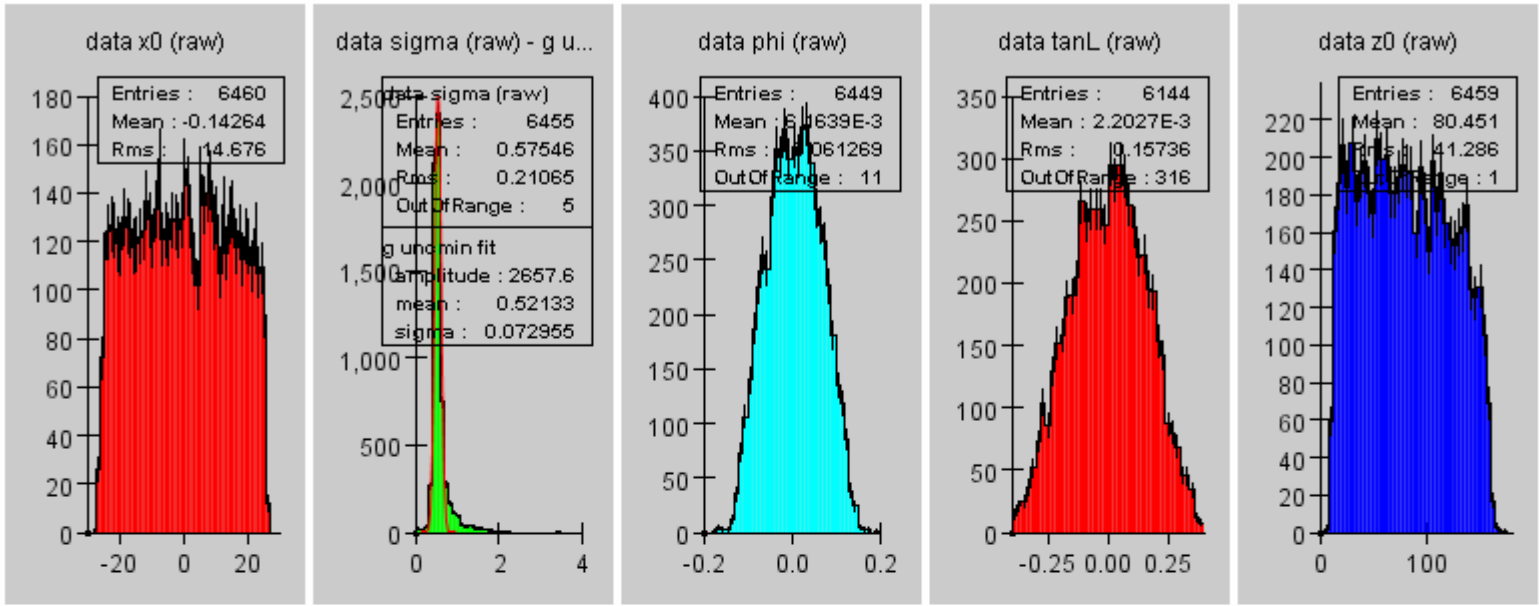


Comparison at 4 Tesla

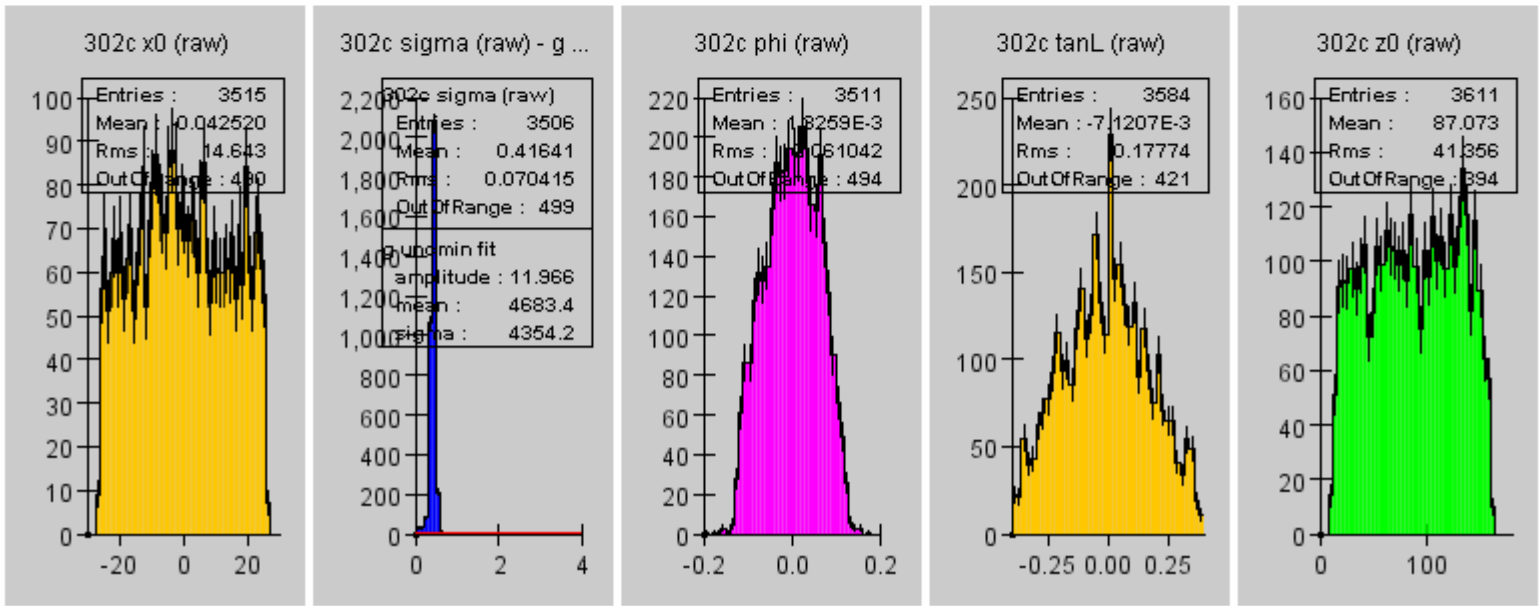
Data:

MC:

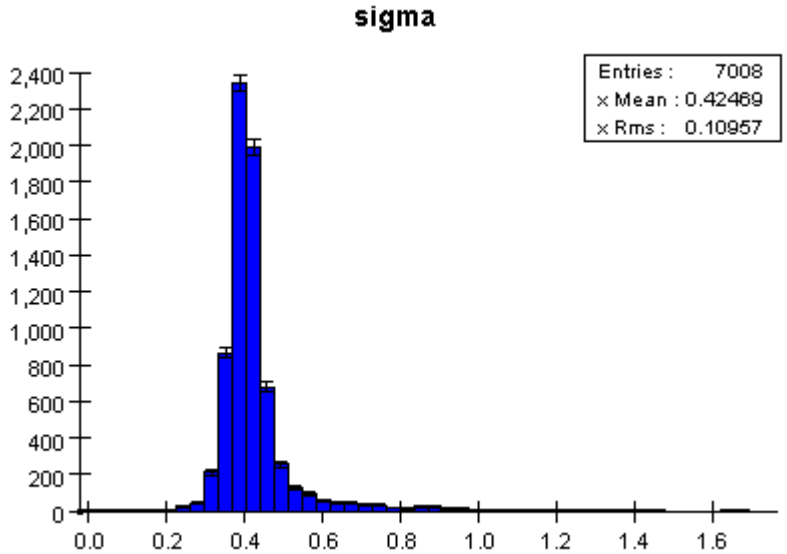
Data (p004b4000p5.aida):

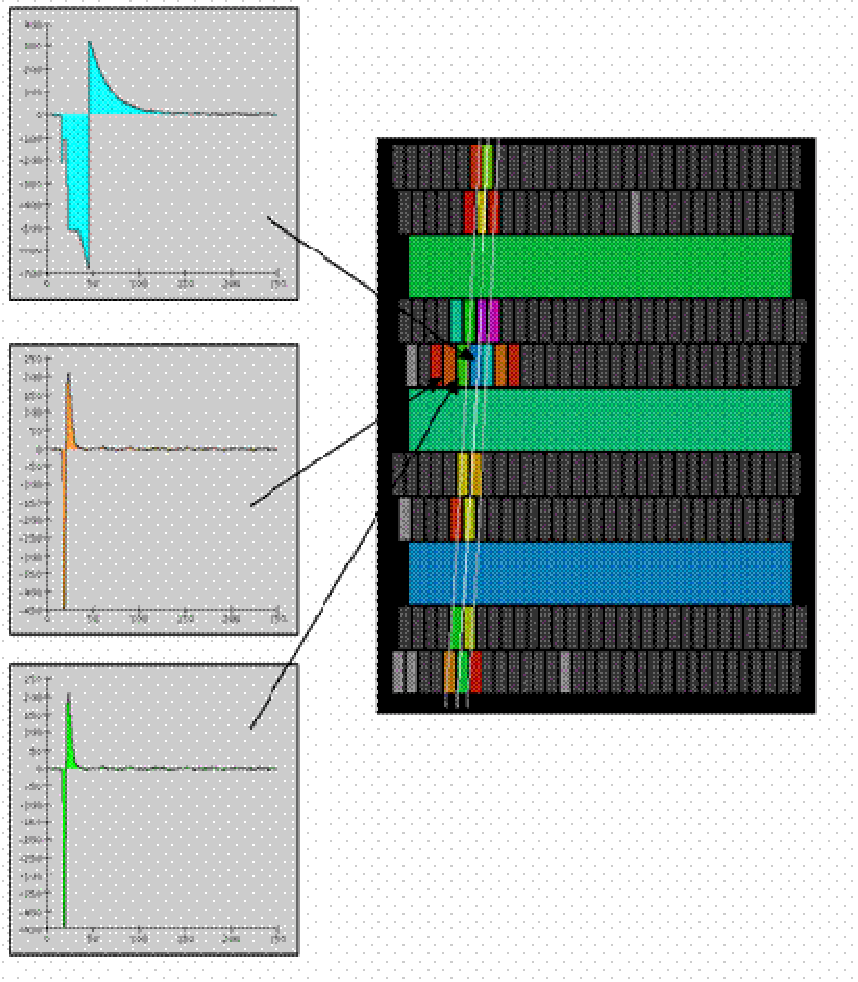


MC (p006mc302.aida):



Large σ events in data, not MC



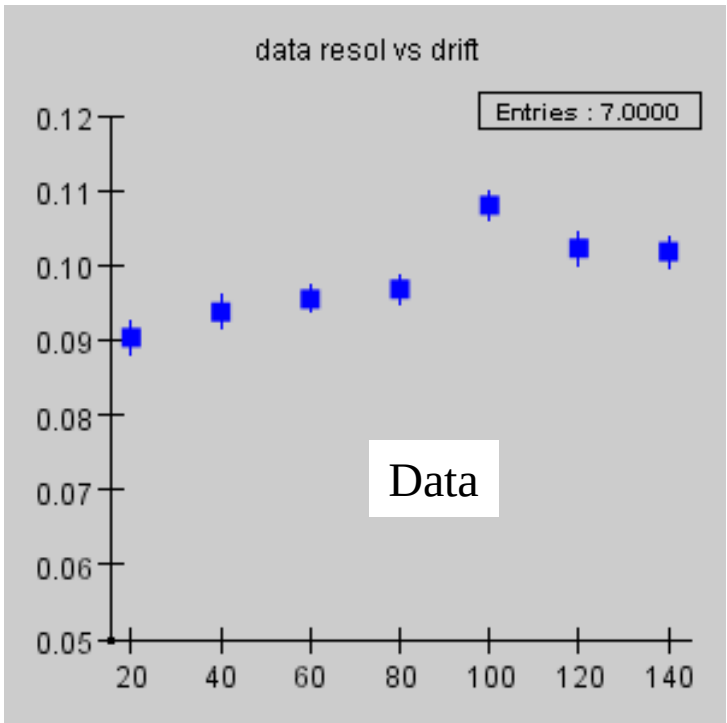


Events contain very large pulse (delta ray) that generates very large induced signals. The analysis assigns charge to these pads.

The MC includes delta rays, but does not simulate induced signals.

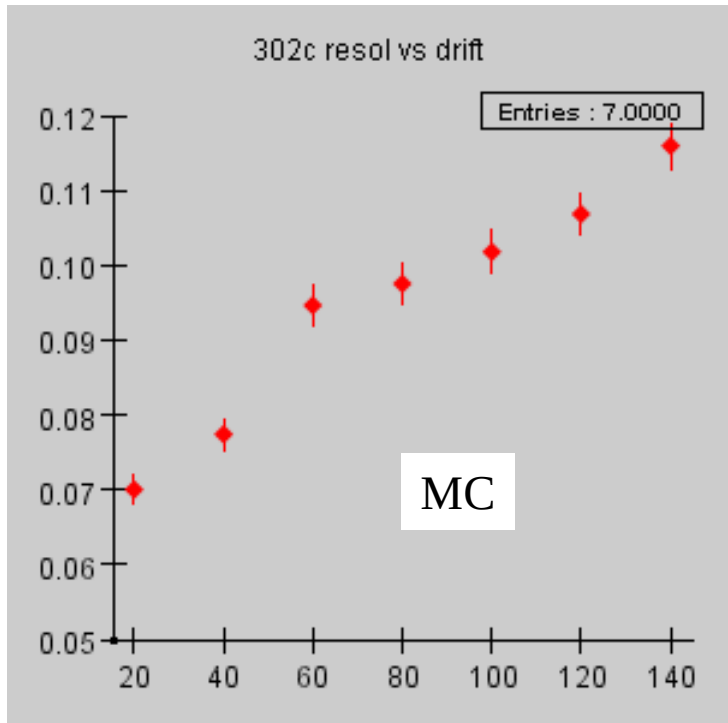
Comparison of resolution: 2 mm pads

- P5 gas not yet stabilized: diffusion constant still large: ~70 μm/√cm



resolution (mm)

drift time (time bins)

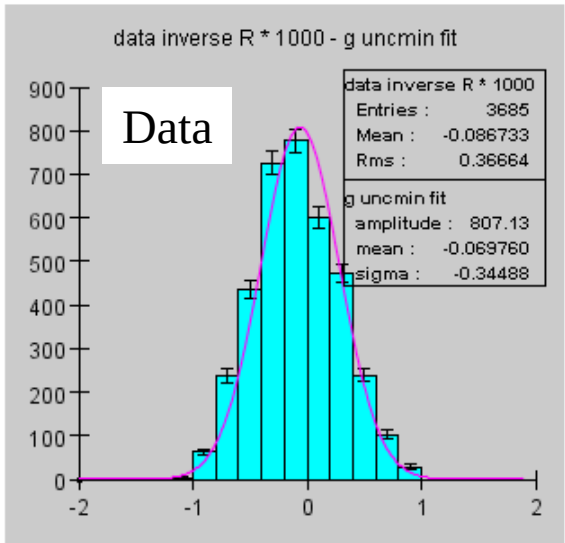


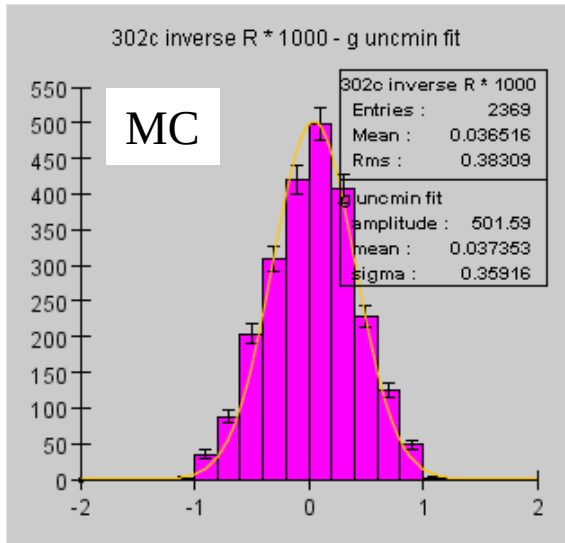
drift time (time bins)

Inverse radius of curvature

RMS of Data and MC is good agreement

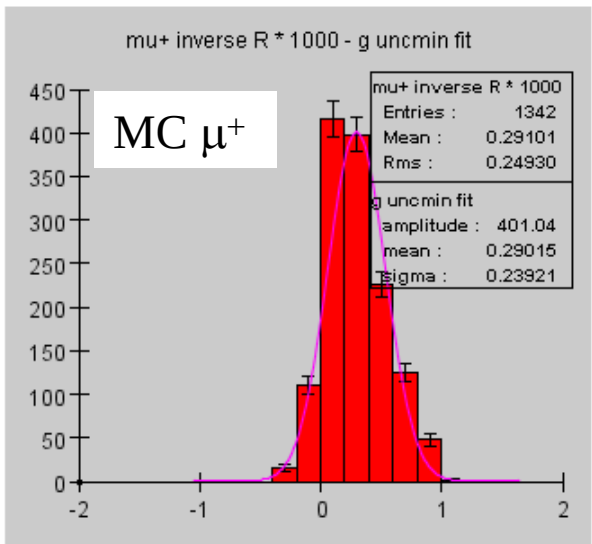
Offset in opposite direction…

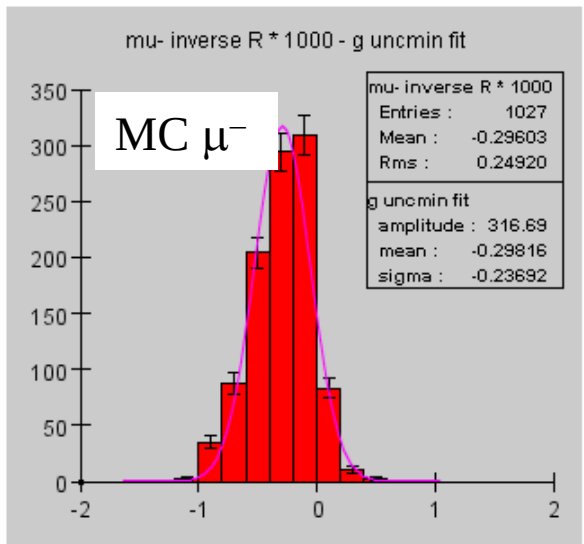




The following plots show the Monte Carlo distributions for mu+ and mu- separately:

Offset in MC due to imbalance of μ^+ and μ^-



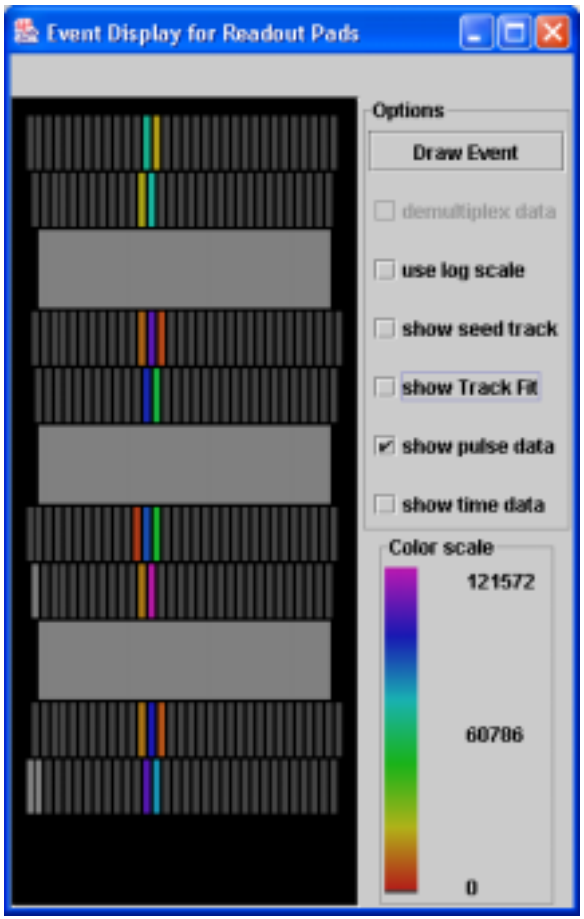


MC and data have B fields in opposite directions?

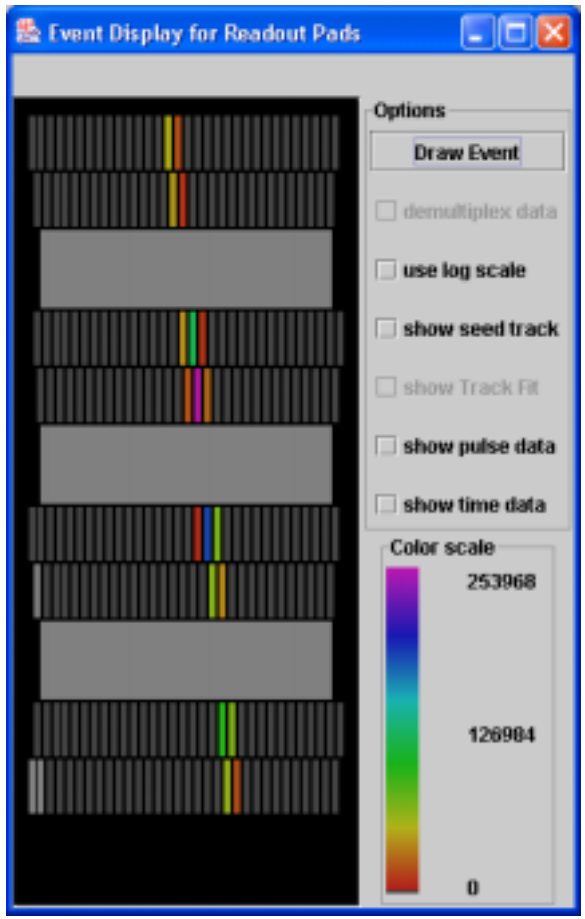
Narrower pad readout: 1.2 mm, P5 at 4 T

- Check if better sharing improves resolution

laser event



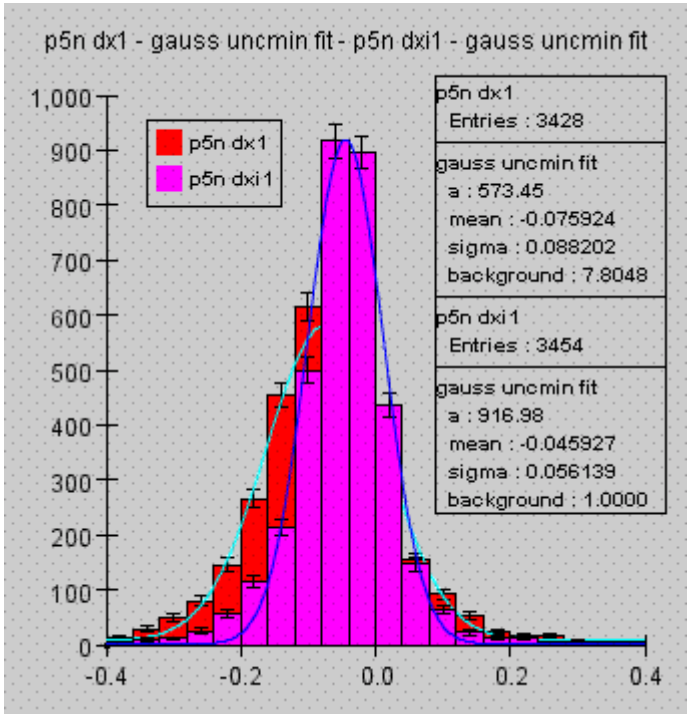
cosmic event



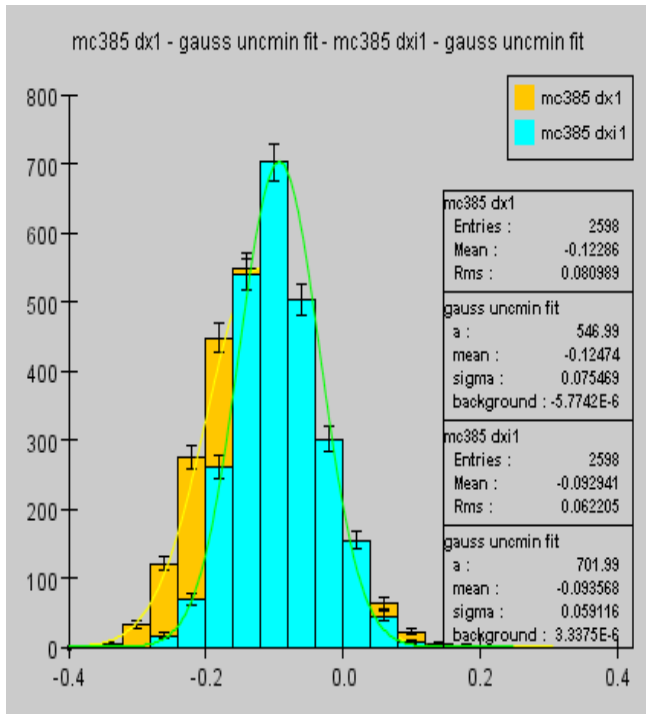
Biases seen

- significant offsets seen (not seen with 2 mm pads)
  - eg. row 1 residuals offset by ~ – 0.1 mm

Cosmic rays



Laser events

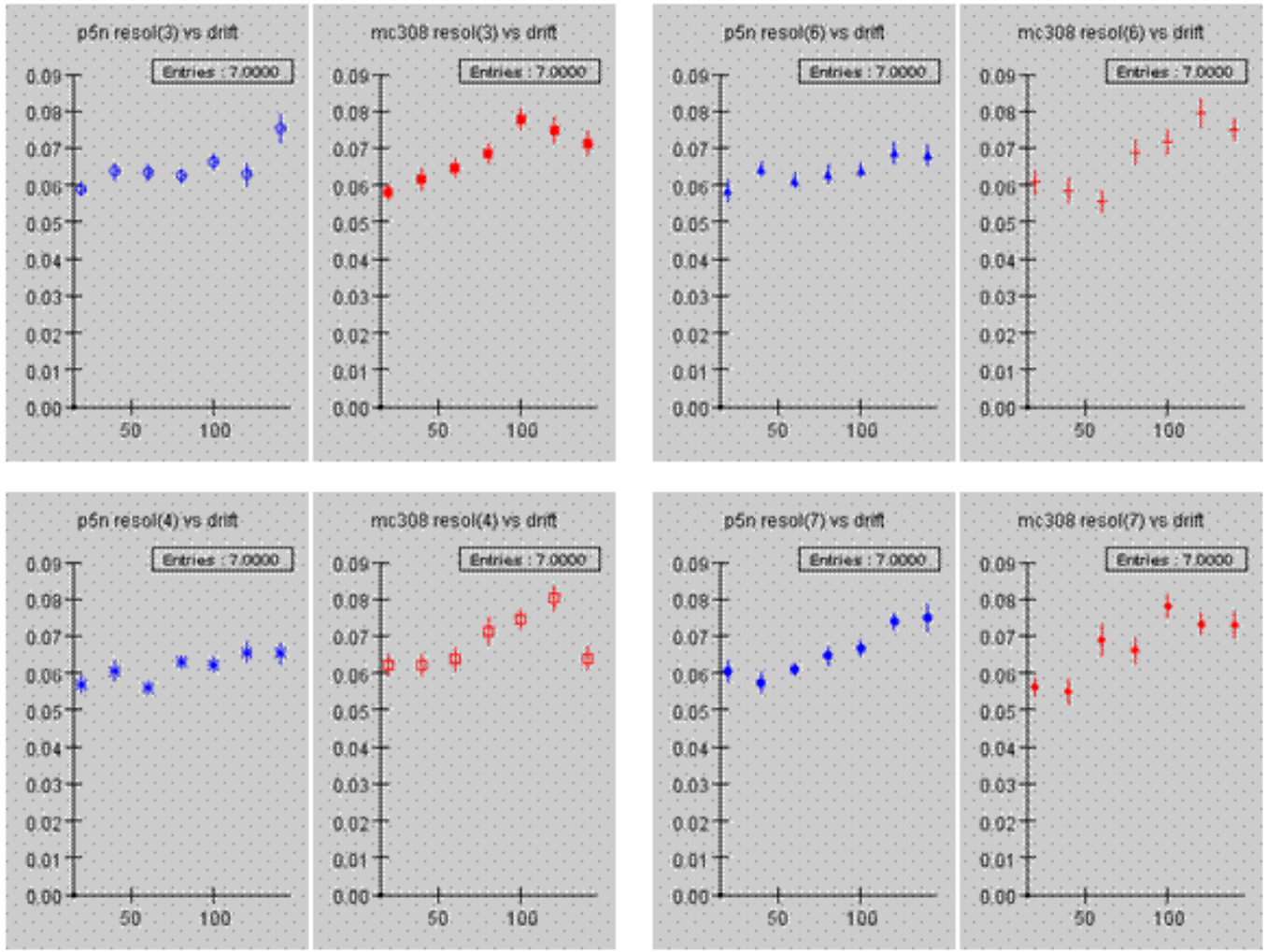


Row by row resolution

- Remarkably good agreement with MC

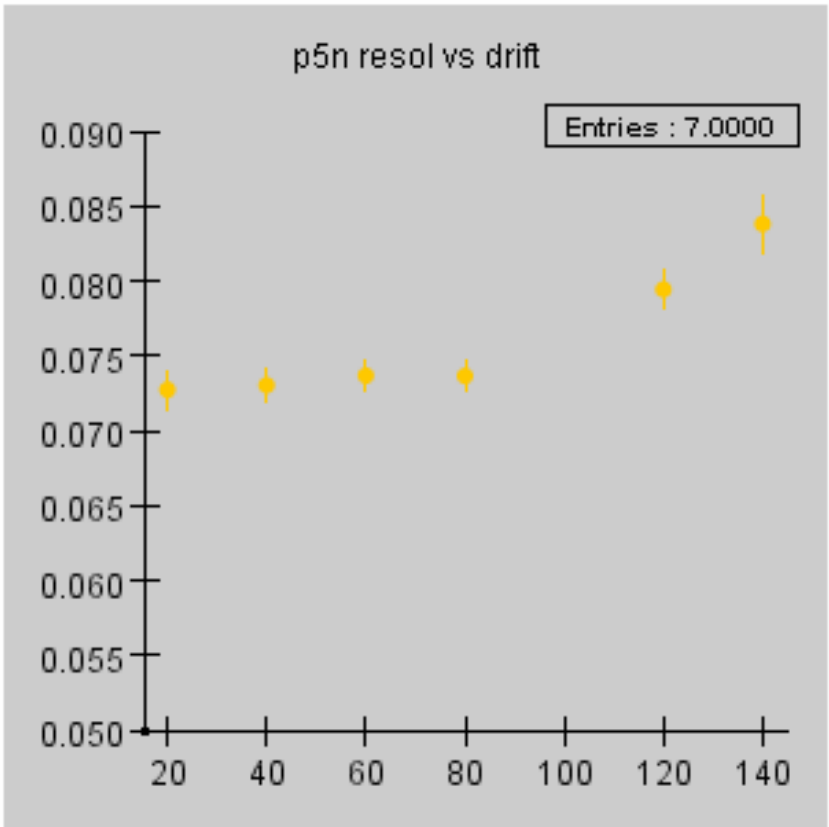
Significant improvement in resolution

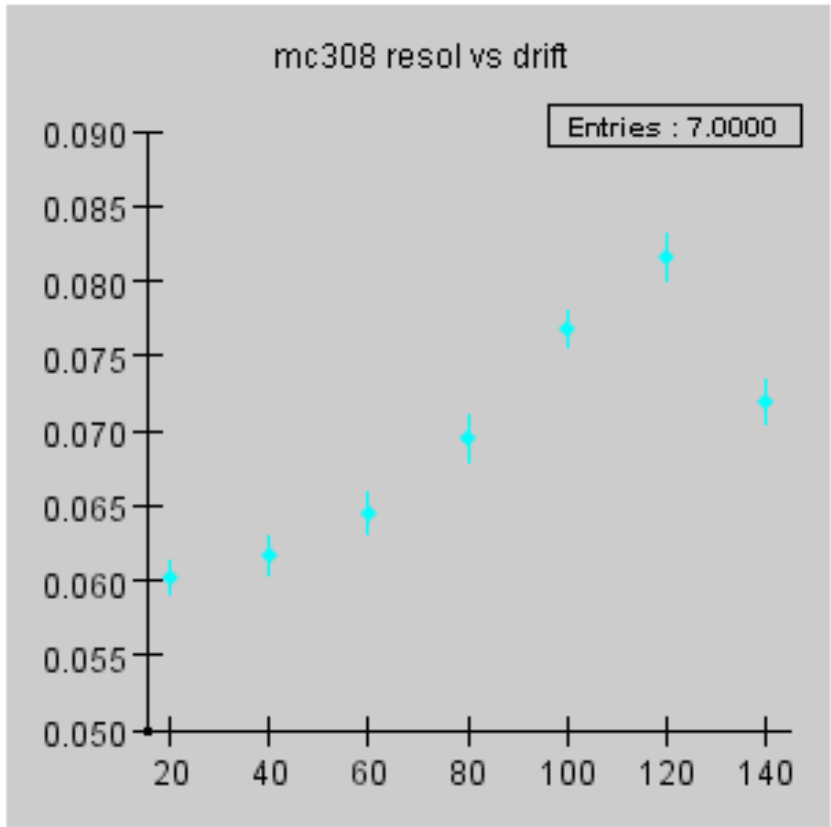
less diffusion and smaller pads



Overall resolution

- Due to systematic biases in data, overall resolution somewhat worse than MC – still it is very good!





Summary

- A very successful run at DESY in 2004
  - a lot of data – a systematic analysis is underway
- Laser tracks are very useful tool for testing TPC operation
  - Our laser transport system is available for others for DESY laser tests
- Two track resolution is quite good:
  - eg. ~2 mm for 2 mm pads
- Full simulation reproduces data resolutions reasonably well.
  - 2 mm × 7 mm pads: ~90-110 μm resolution for ~P5 gas at 4T
  - 1.2 mm × 7 mm pads: ~70-80 μm resolution for P5 gas at 4T