Study of GEM-TPC Performance in Magnetic Fields

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Progress since Paris LCWS

- 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/$\sigma_0 = 5$)

- ☐ To check effect of pad width, we built a new readout board replacing 2 mm pads with 1.2 mm pads

2 mm $\times$ 7mm

1.2 mm $\times$ 7mm
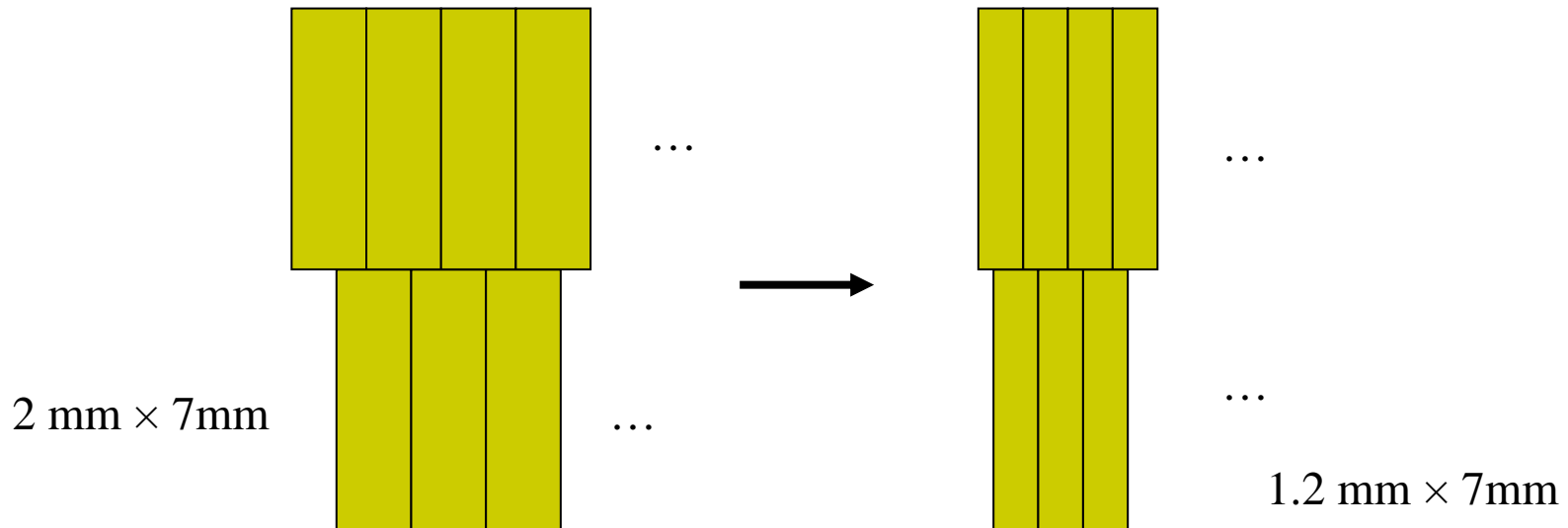
Micromegas readout plane

- 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

Micromegas on loan from Paul Colas
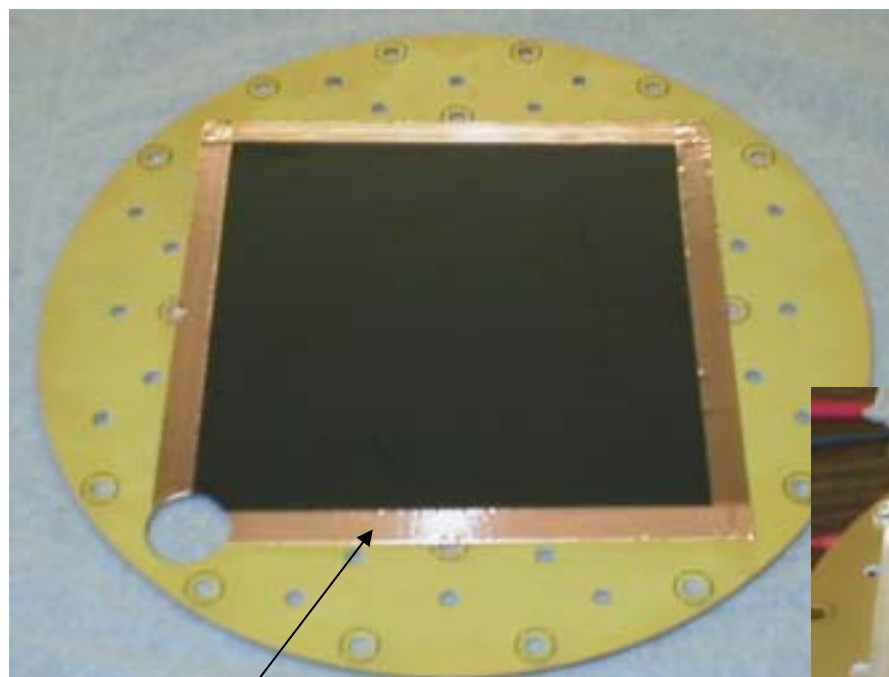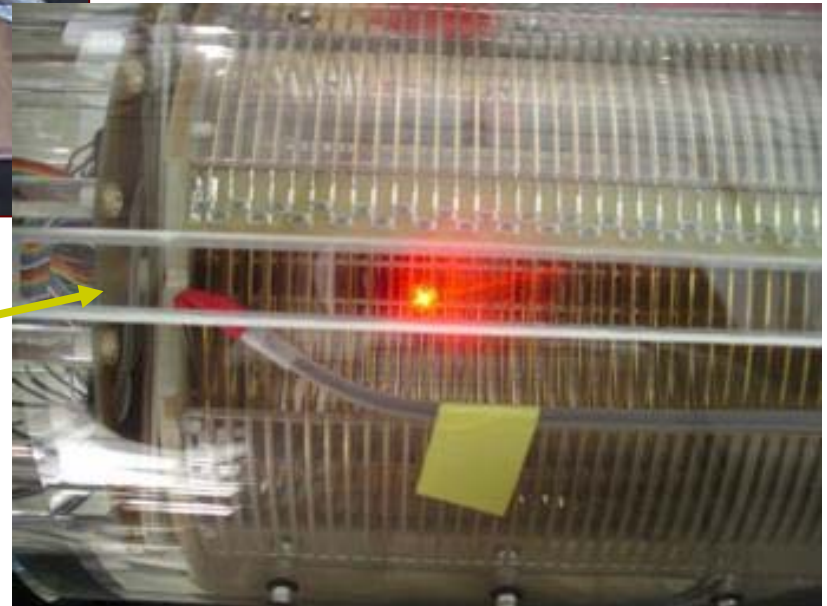
grounding resistive foil
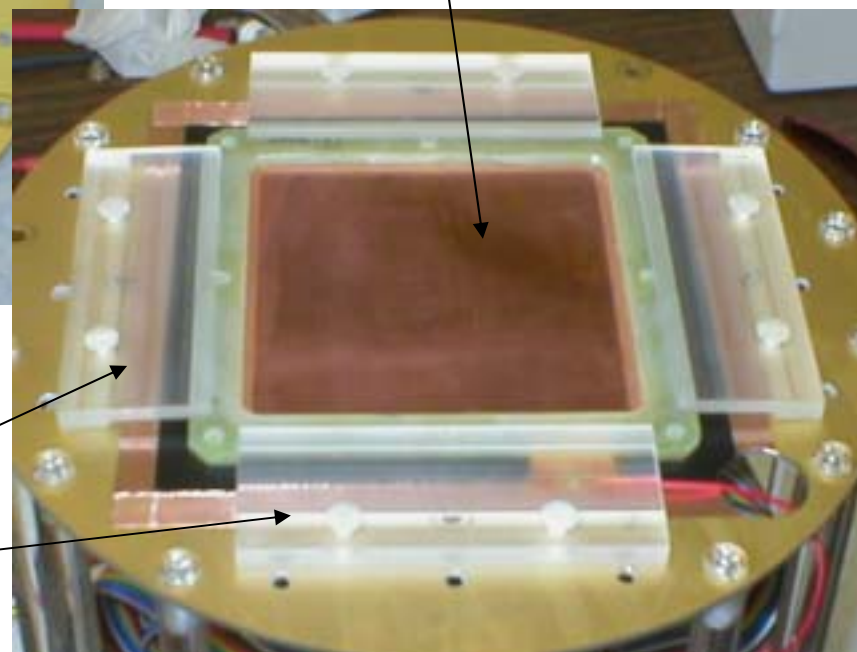
Plastic clamps to hold Micromegas in place

TPC modifications for UV laser

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

quartz window

Laser beam delivery system

- 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

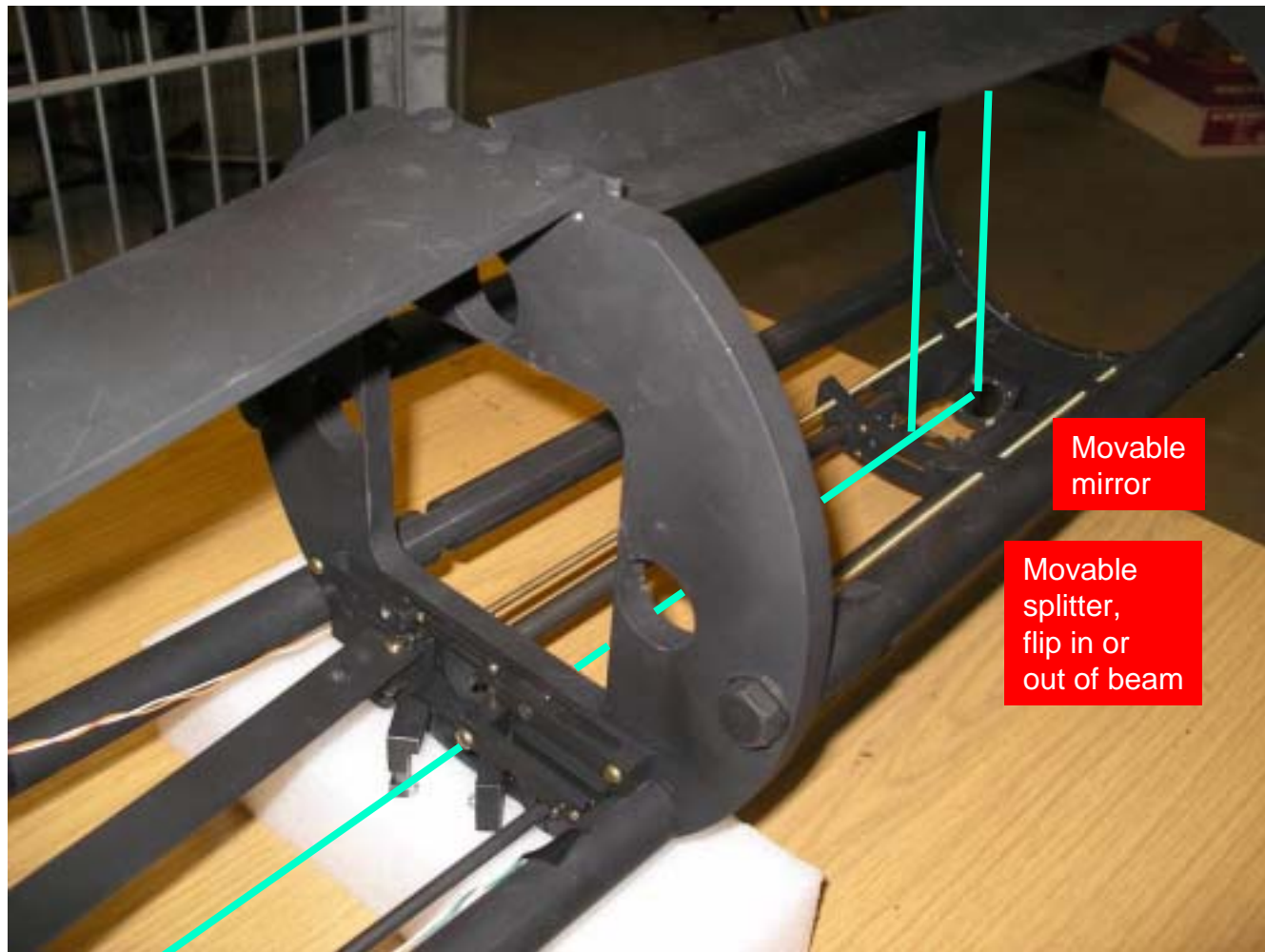- Approx. 2 m long to reach into magnet

laser + optics

laser power supply

TPC holder

Engineering by
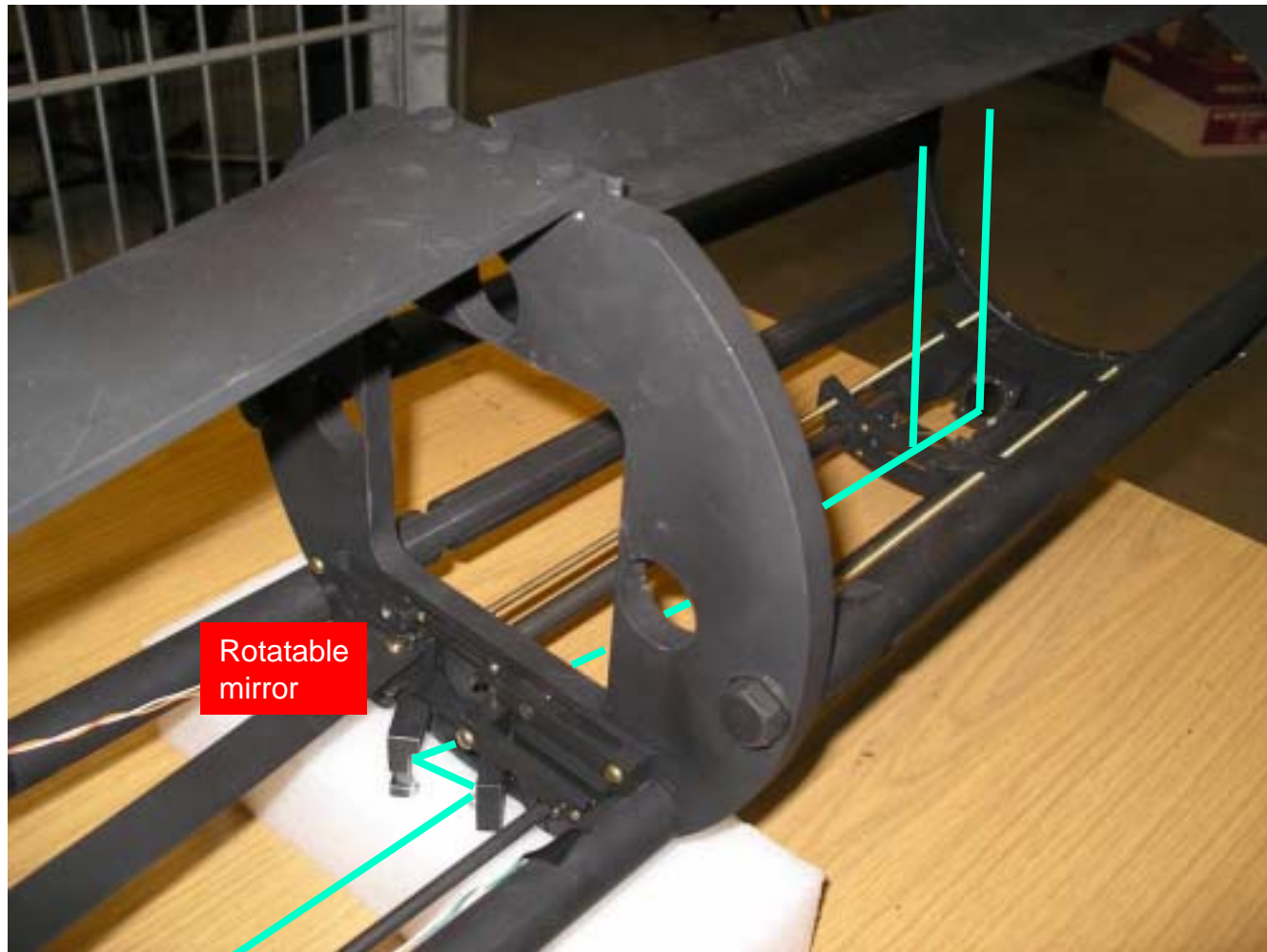Mark Lenkowksi
Univeristy of Victoria

Laser optics

Focusing elements

Splitter

Blocker

Movable mirror

Sandblasted quartz reflector

Mirror

Splitter

Blocker

Photodiode for trigger

UV Laser

Sandblasted quartz reflector

Beam delivery

Movable mirror

Movable splitter, flip in or out of beam
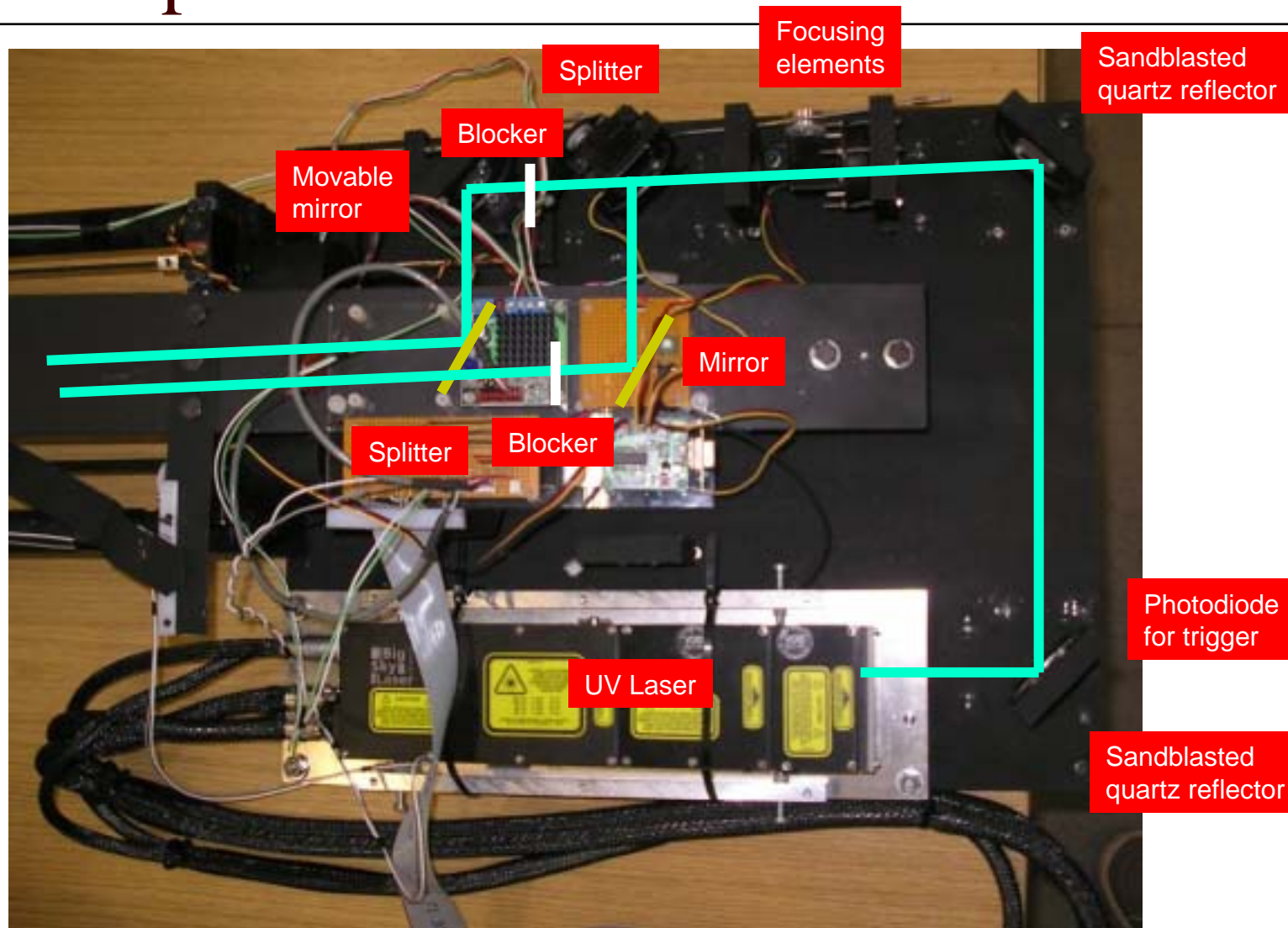
Beam delivery – offset in x and z

Rotatable mirror

Study of GEM-TPC Performance in Magnetic Fields : Dean Karlen

Setup with the DESY magnet

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

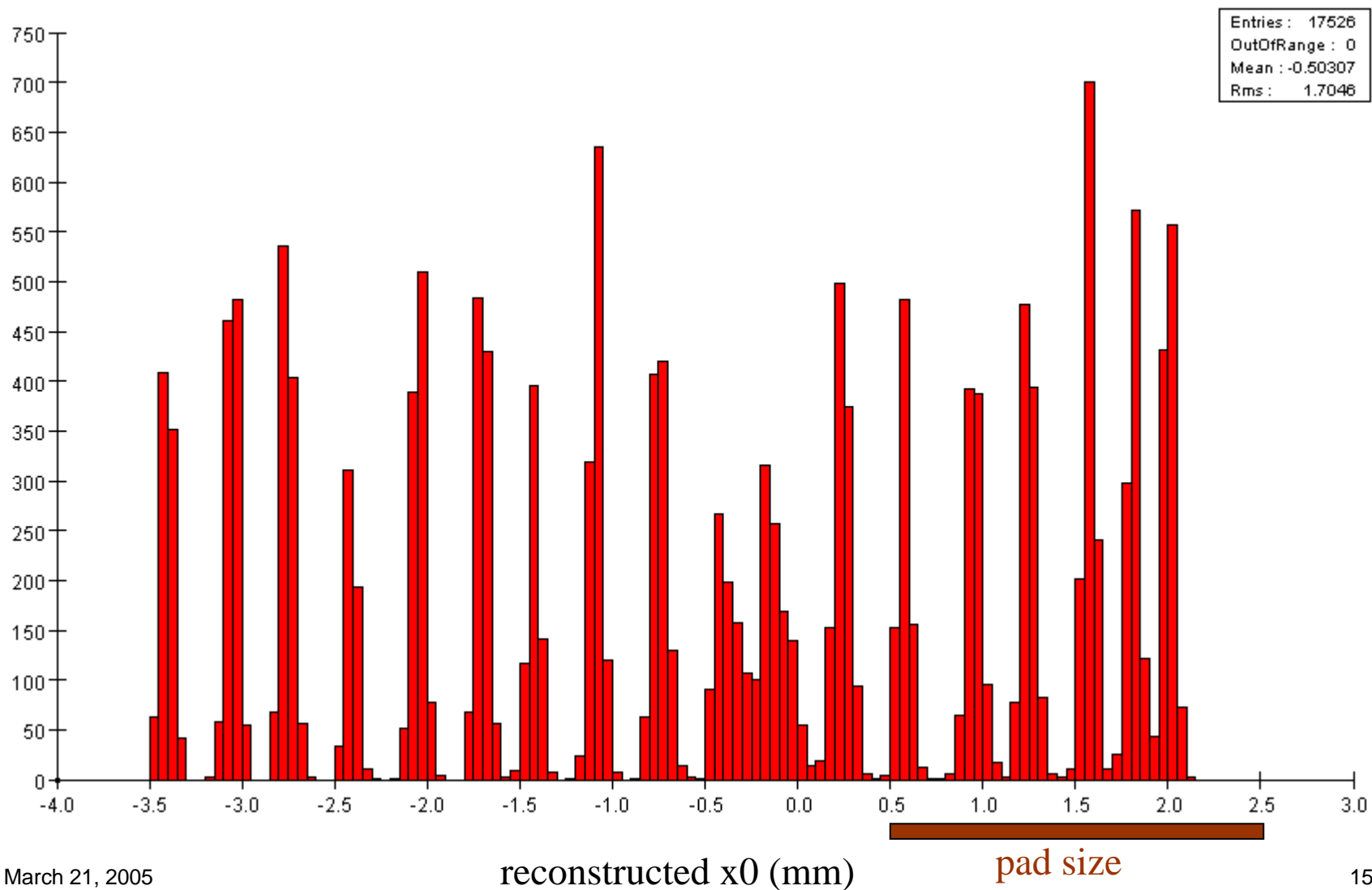# Laser event with 2 mm pads at 4 T in P5

LCWS 05

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

March 21, 2005

Scan of laser in x

Entries: 8349
OutOfRange: 0
Mean: 0.58202
Rms: 4.3160

reconstructed x0 (mm)

pad size

Fine scan of laser in x

Entries: 17526
OutOfRange: 0
Mean: -0.50307
Rms: 1.7046

reconstructed x0 (mm)

pad size
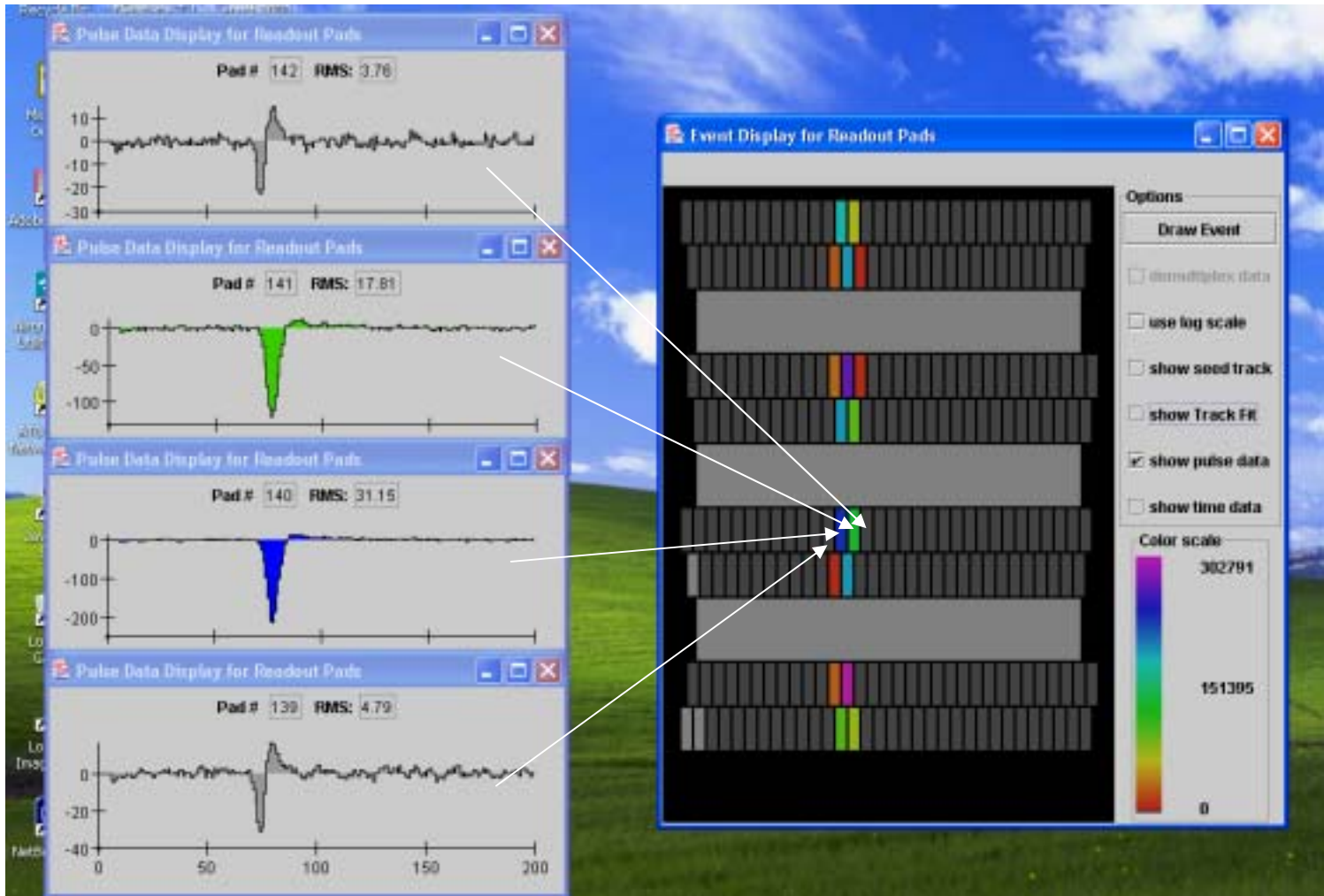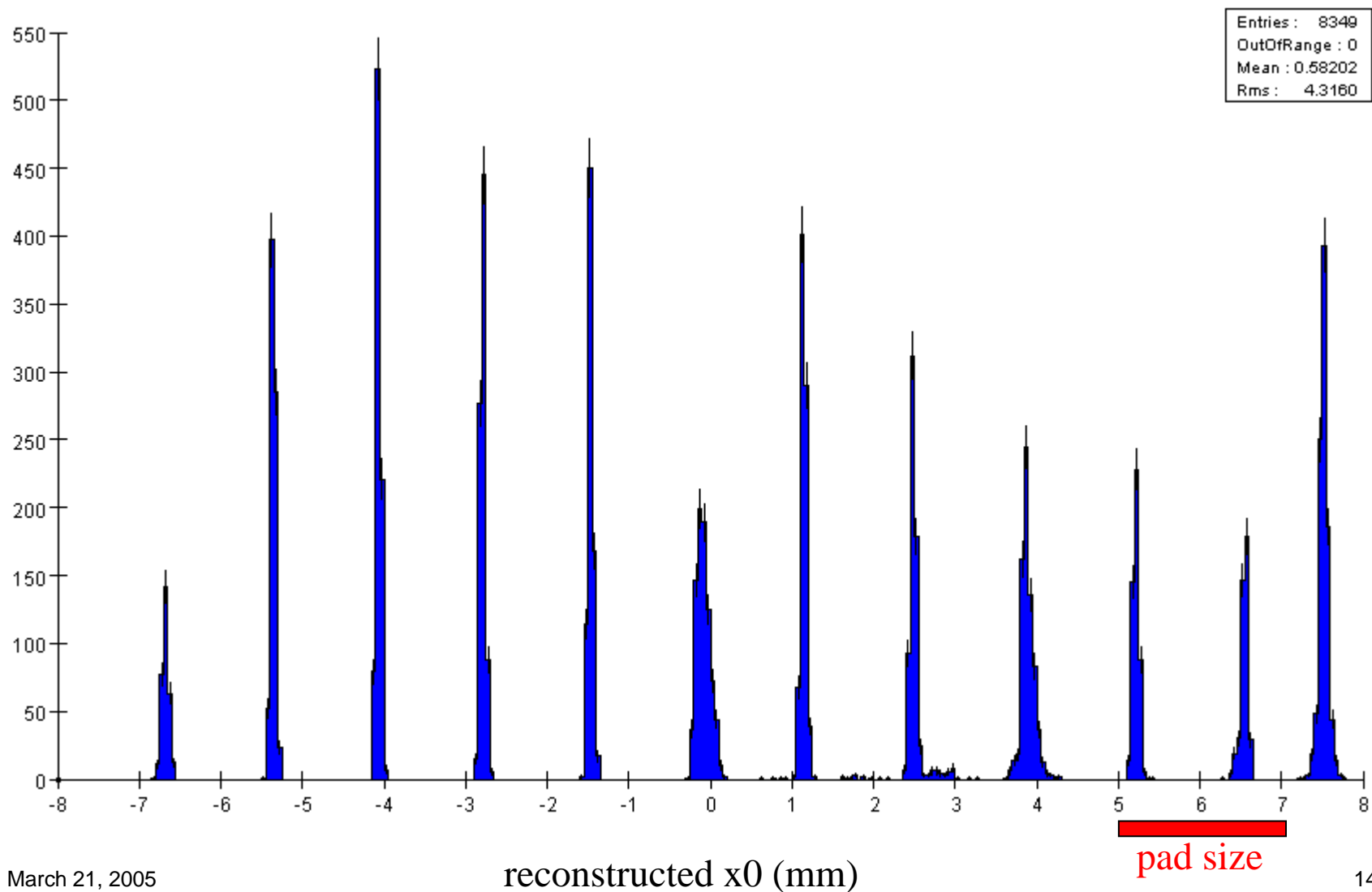
Laser track resolution studies

- ☐ Laser beam position is very stable, typical result from an overnight low rep. rate run:

  - ■ drifted ± 6 µm over a period of 12 hours
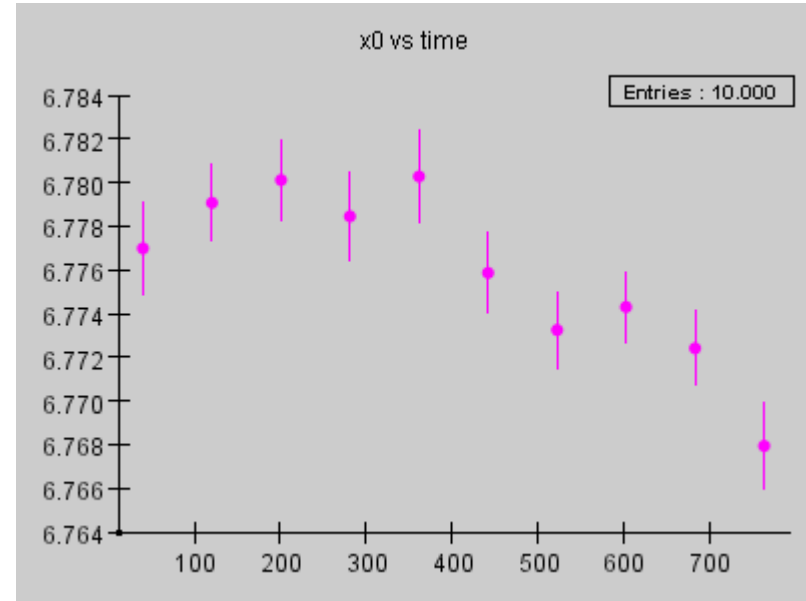
- ☐ Fit laser tracks to straight lines

  - ■ 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)

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Laser track resolution example: run 67


```
67 x0
Entries :          720
OutOfRange :         0
Mean :         -6.7754
Rms :          0.032043

gauss minuit fit
a :             407.81
mean :         -6.7751
sigma :       0.027769
background : 4.9352
```

x_0 from 8 row fit (mm)
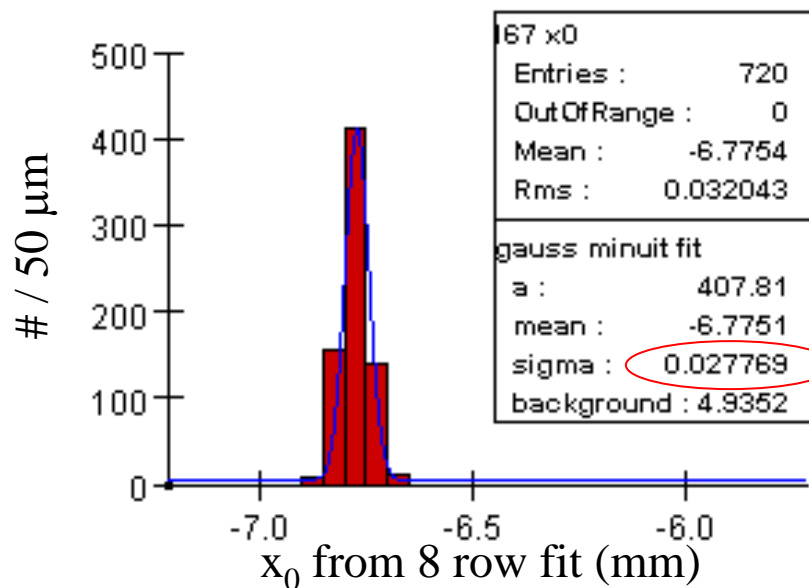
Straight track fits

8 row fit: 28 μm resolution

$\rightarrow$ 1 row resolution = $\sqrt{8} \times 28$ μm

= 78.5 μm

67 dx all
67 dxi all

residual of 1 row fit to reference fit (mm)
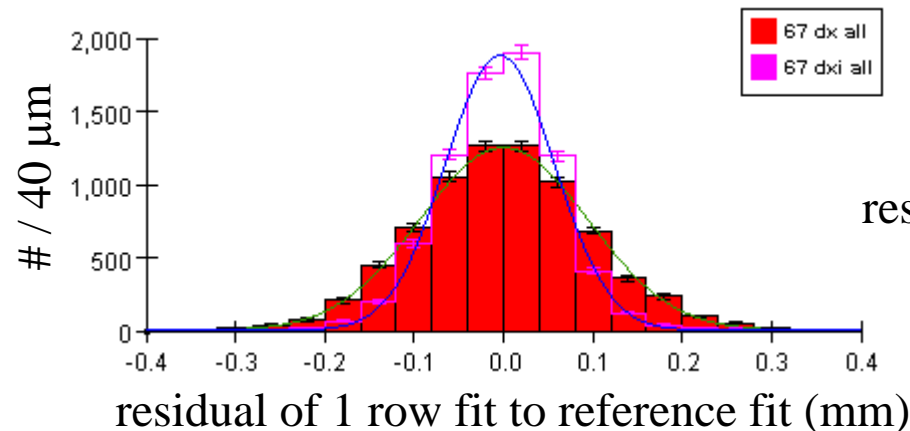
reference fit excludes row: 95.2 μm
reference fit includes row: 61.6 μm

resolution (geometric mean): 76.6 ± 0.6 μm

Good agreement!

Laser resolution cross check

- ☐ 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)
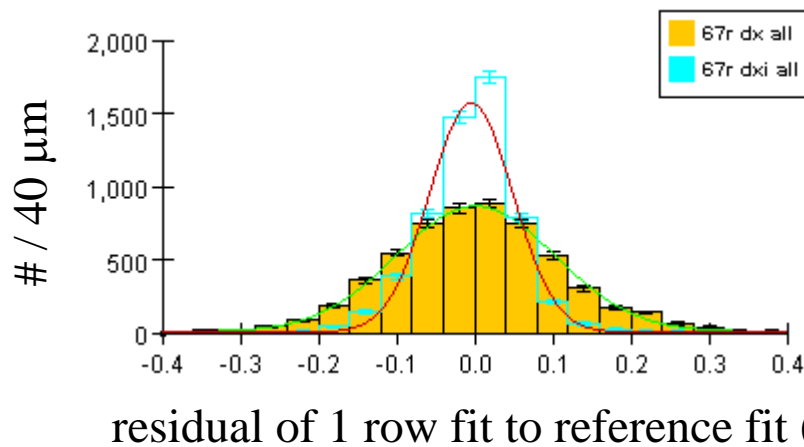
reference fit excludes row: 101.5 µm
reference fit includes row: 53.4 µm

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):

time (minutes)
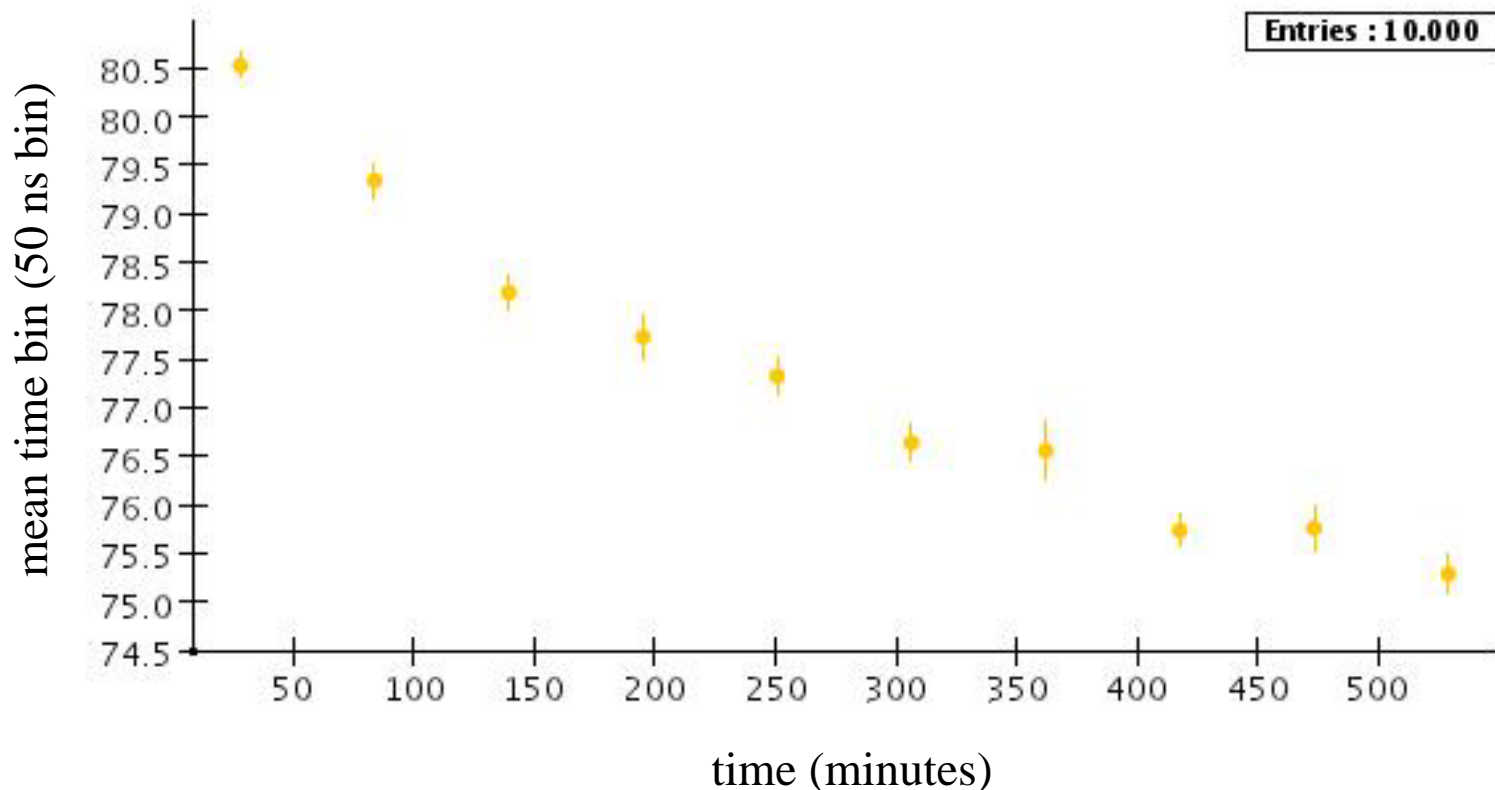
Two track resolution studies: P5 gas at 4 T

- ☐ Bring two laser beams close together **at same z**

  - ◼ example (runs 67-69): 3.8 mm separation, $\sigma = 0.5$ mm

Beam 1 only   Beam 2 only   Beam 1 and 2
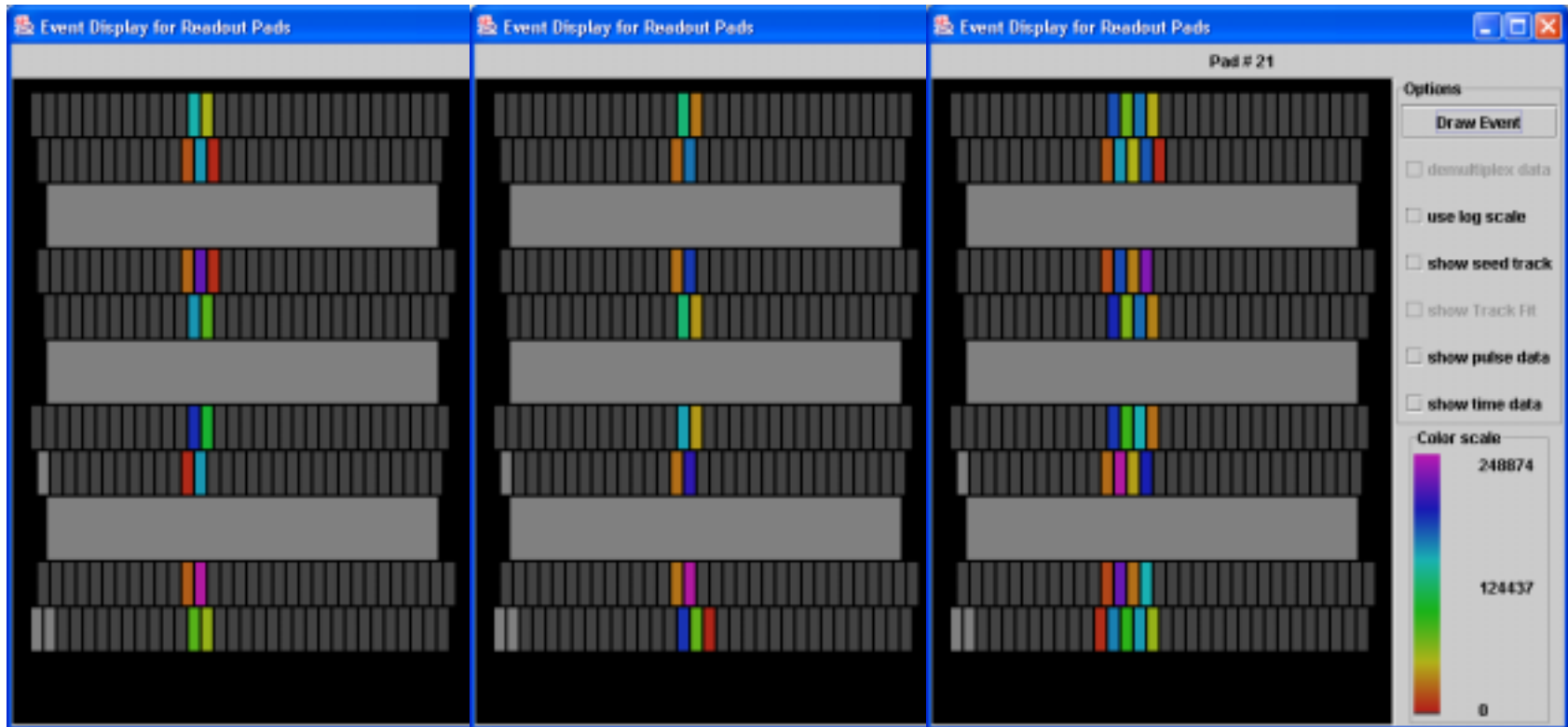
Two track likelihood fit

- ☐ Modify maximum likelihood track fitter to allow for charge coming from two tracks to contribute
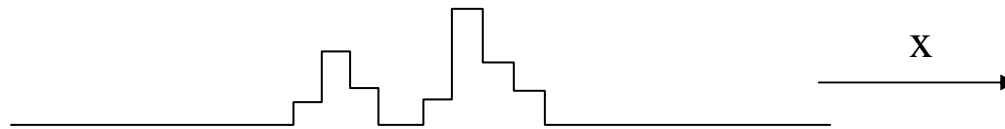
  - ■ relative amplitudes of the charges from two tracks for each row are treated as nuisance parameters (1 per row)

- ☐ 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

$\sigma = 0.5$ mm

$\Delta x = 3.8$ mm

$\Delta x = 2.0$ mm

dips between tracks

no dips
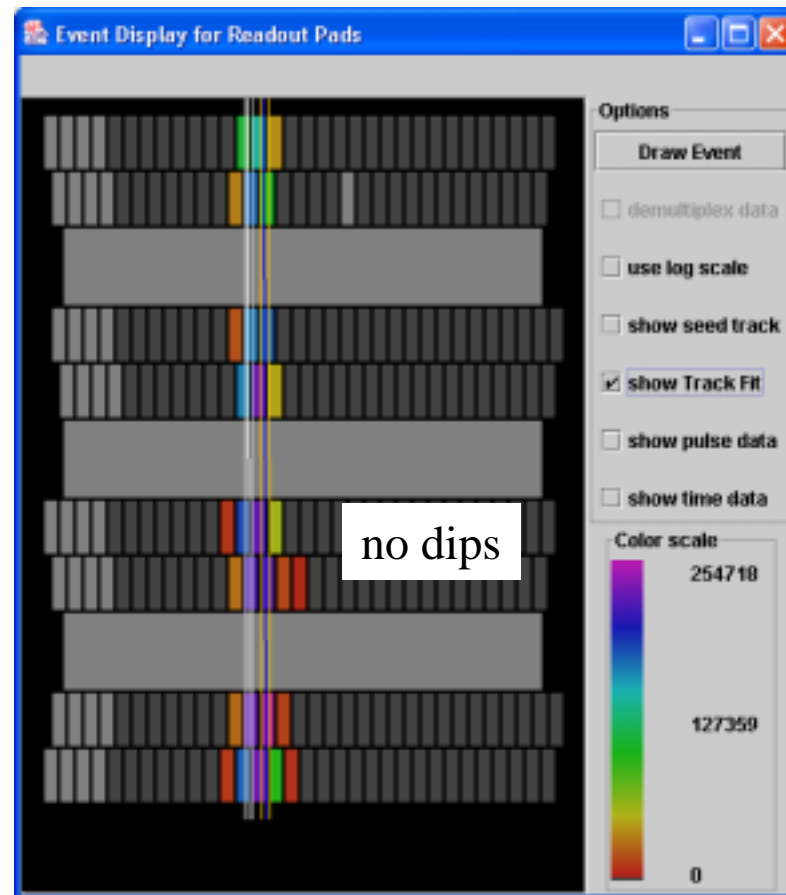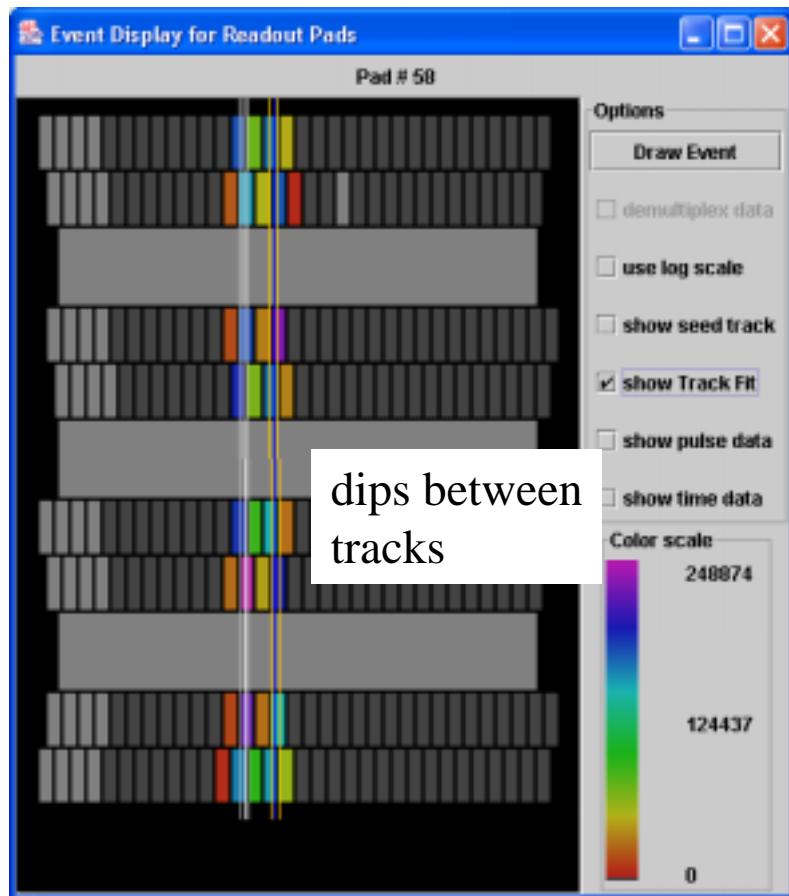
Two track fitting performance

□ Typical result:

Two track resolution at 4T

2 mm pads

(plot: single row x_0 resolution (microns) vs two track separation (mm))
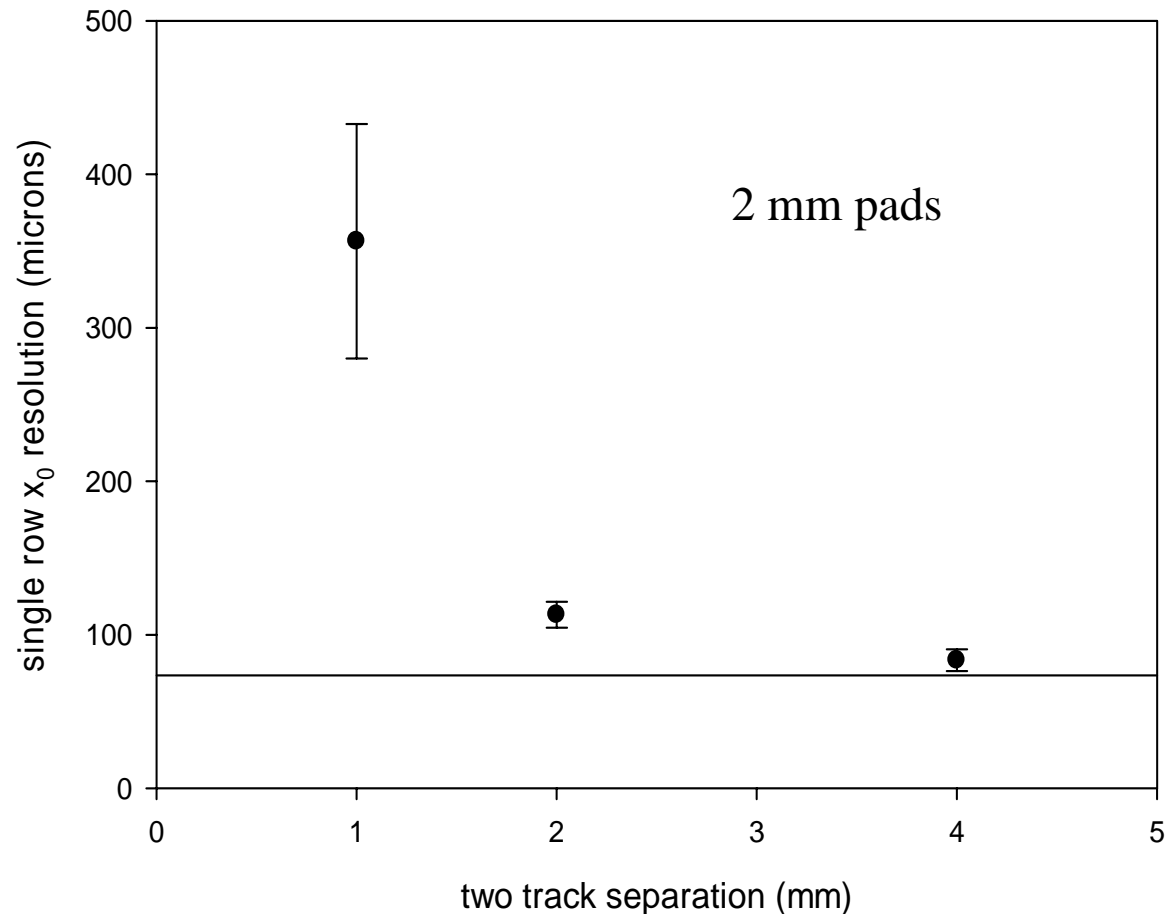
Cosmic ray tracking studies

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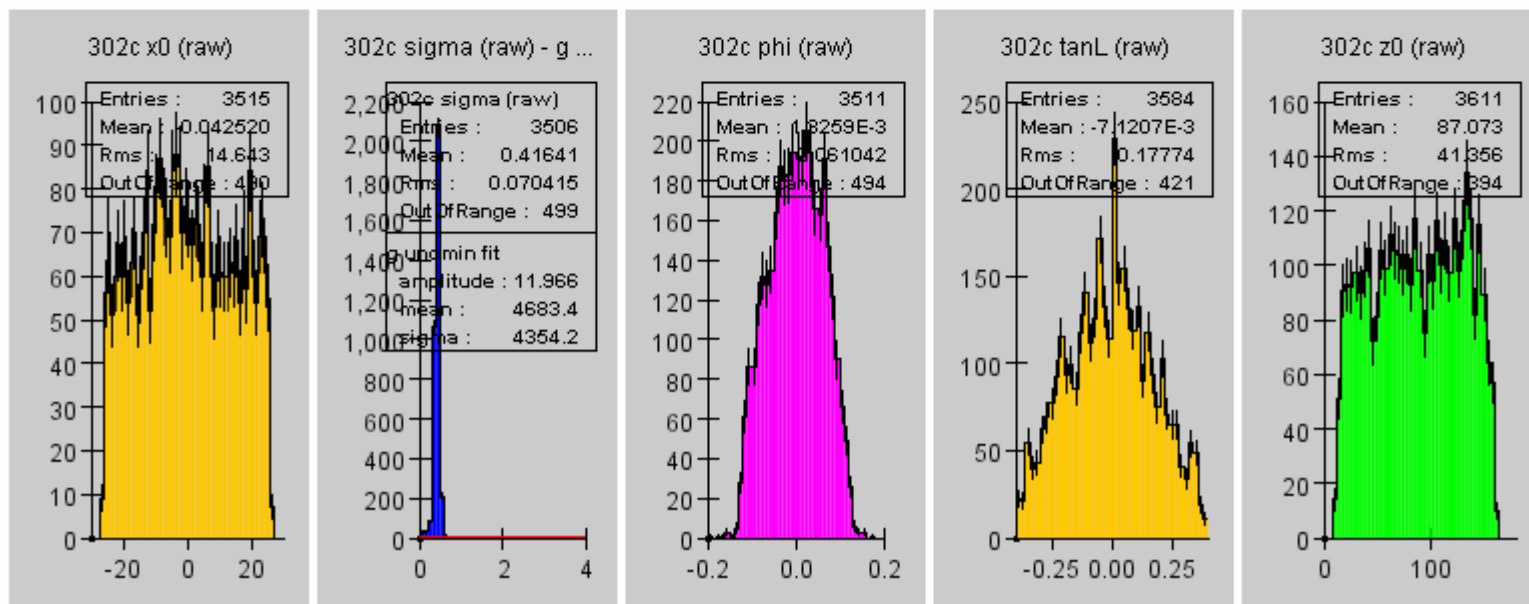

DESY magnet

← Active TPC volume

Data (p004b4000p5.aida):
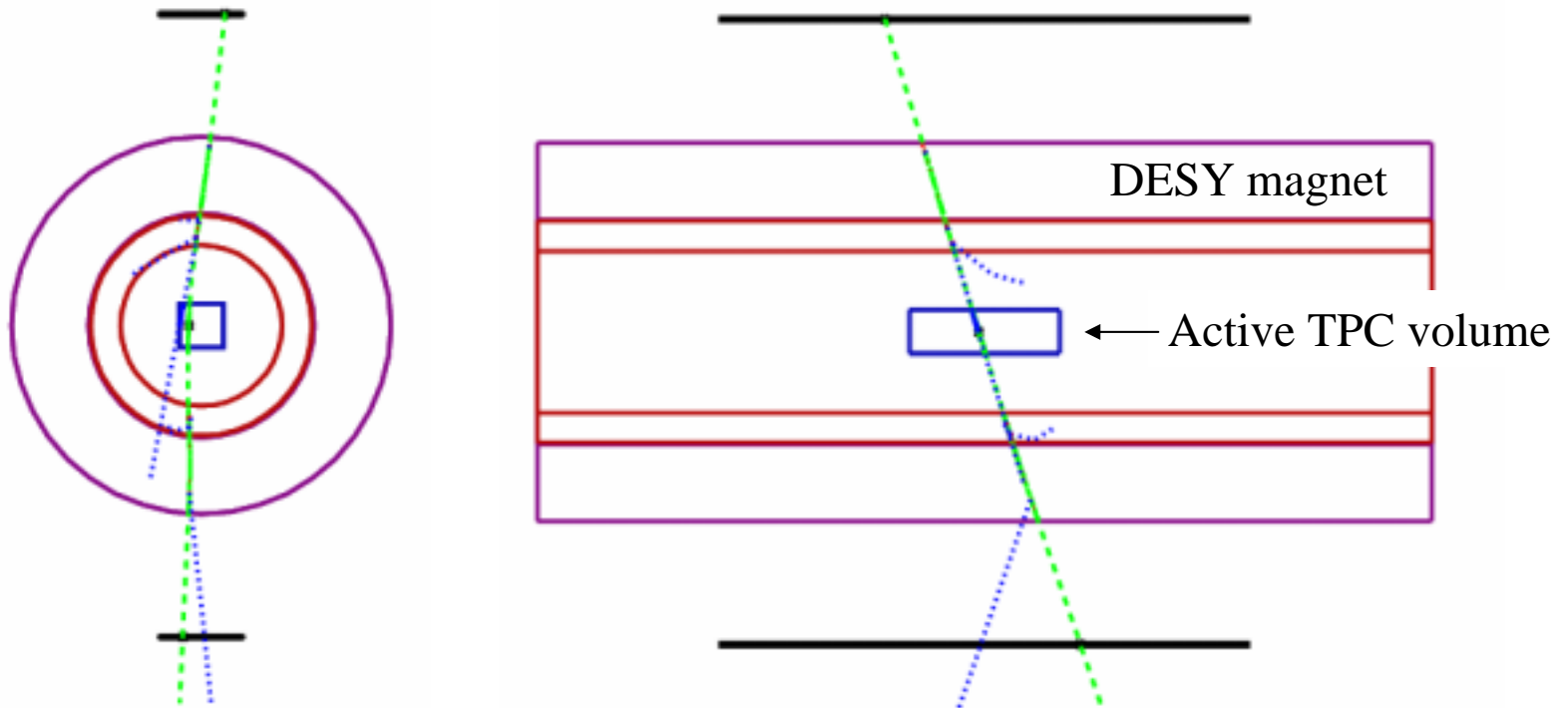
Comparison
at 4 Tesla

Data:

MC (p006mc302.aida):

MC:

Large σ events in data, not MC

sigma

Entries : 7008
× Mean : 0.42469
× Rms : 0.10957
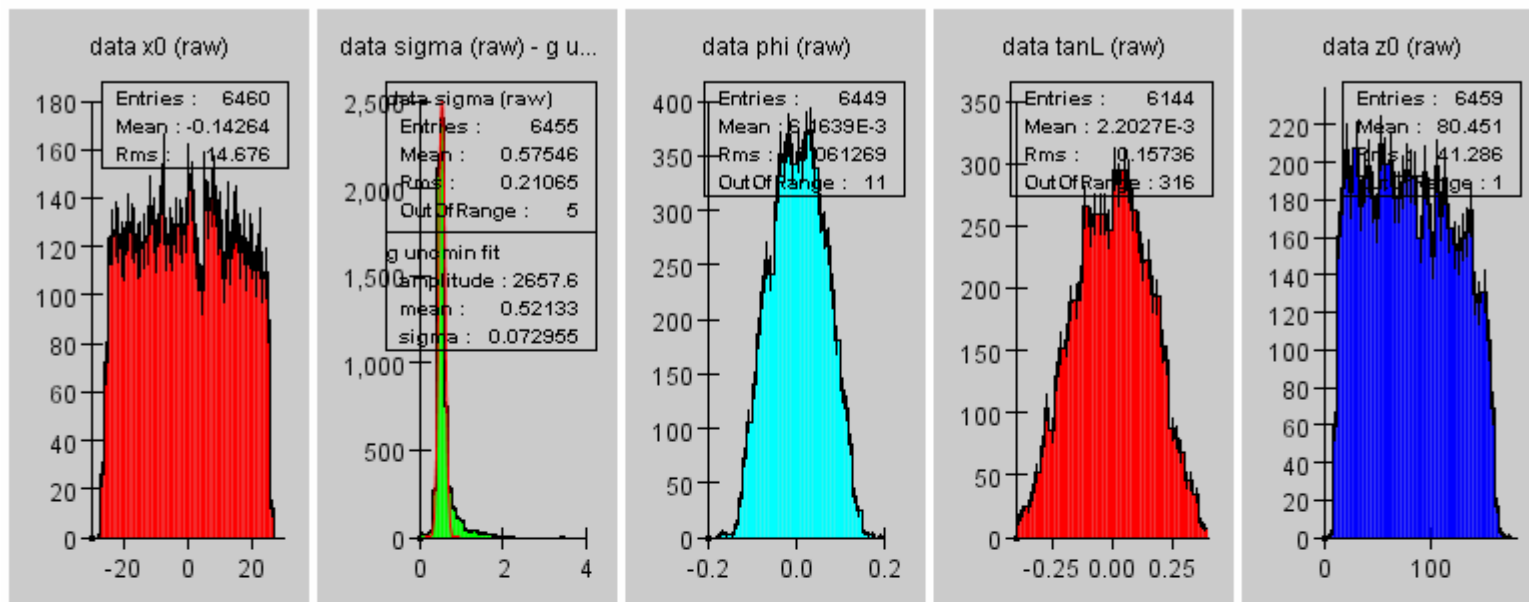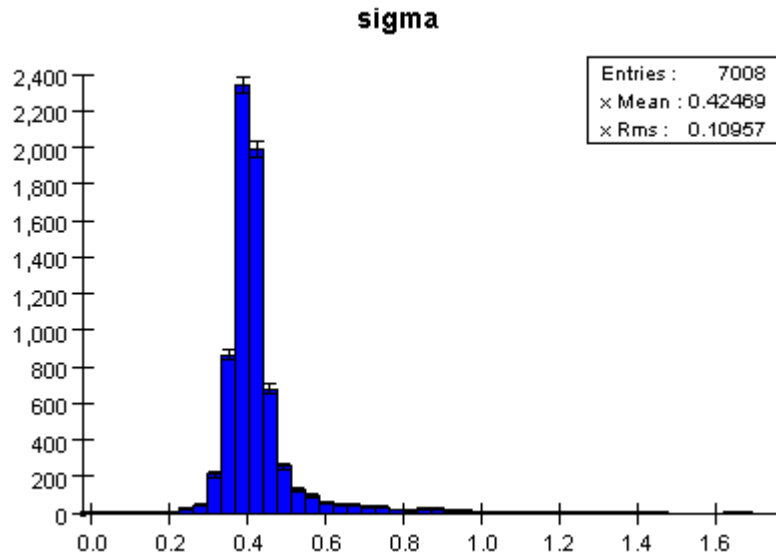
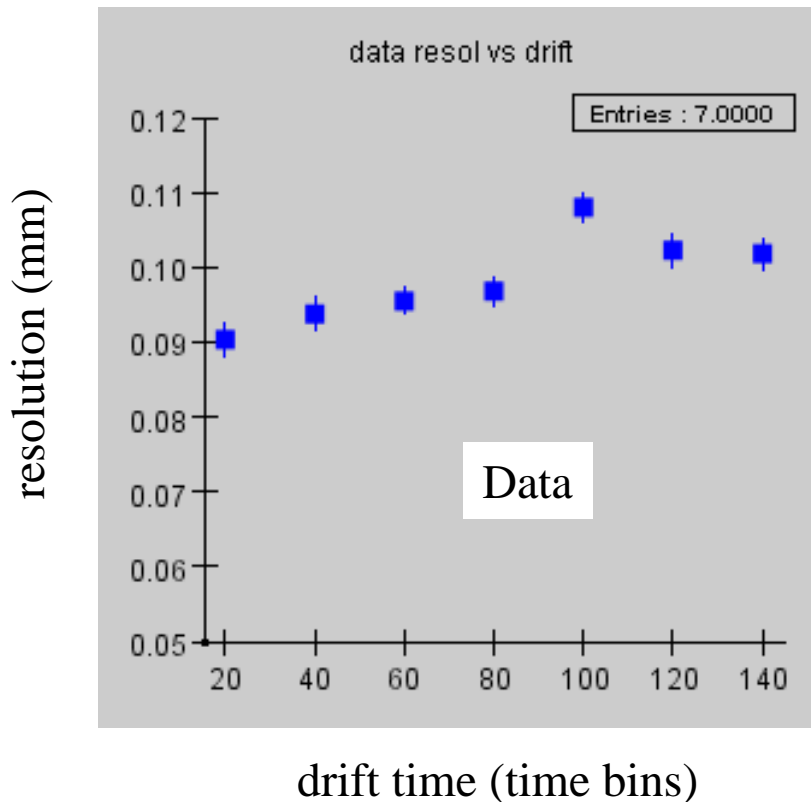Events contain very large pulse (delta ray) that generates very large induced signals. The analysis assigns charge to these pads.

The MC includes delta rays, but does not simulate induced signals.
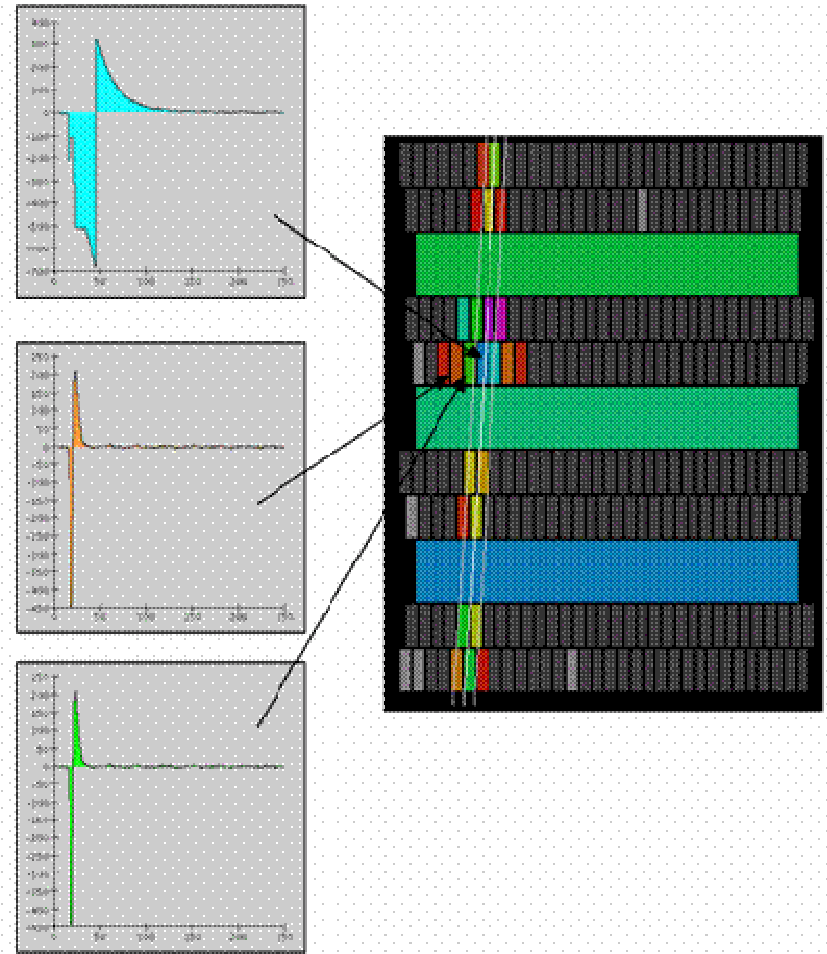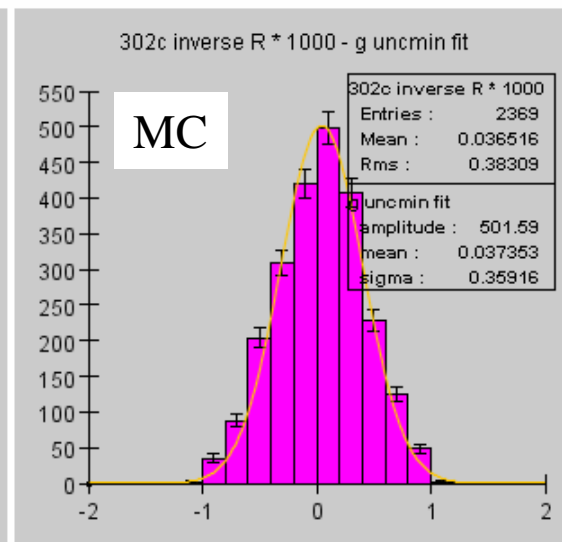
Comparison of resolution: 2 mm pads

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

Data

MC
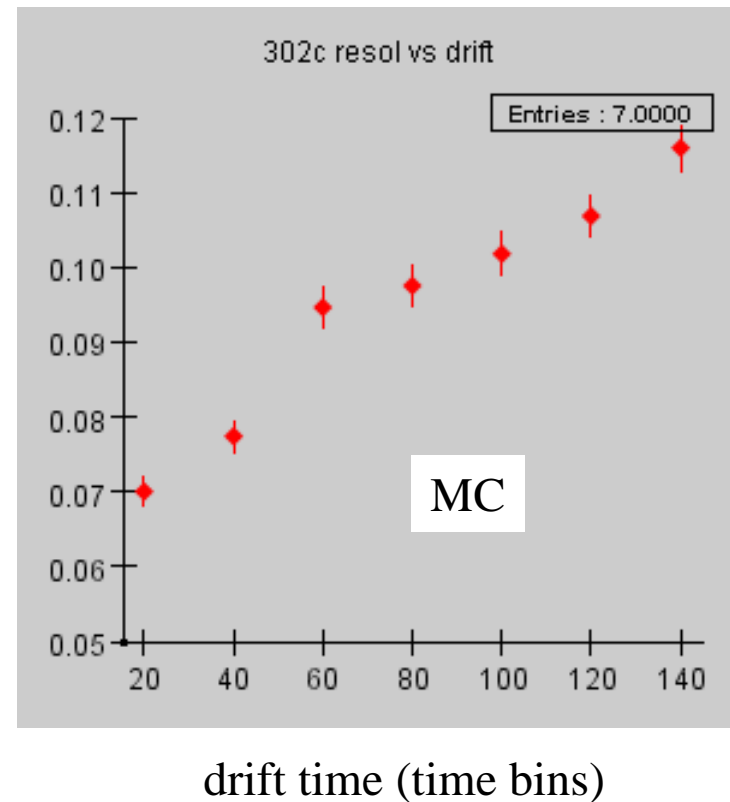
Inverse radius of curvature

RMS of Data and MC
is good agreement

Offset in opposite
direction…

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

MC and data have B
fields in opposite
directions?
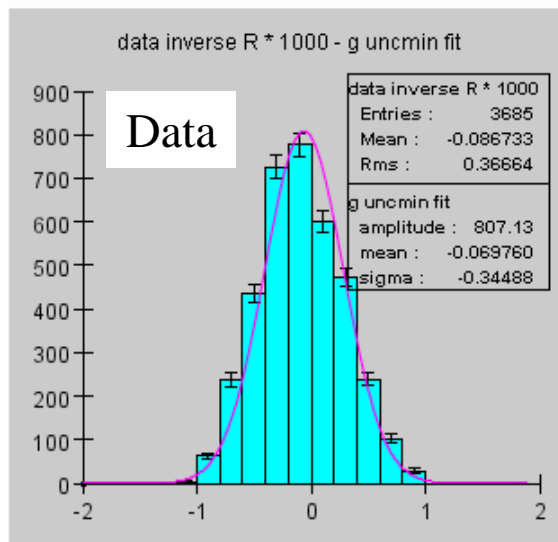
The following plots show the Monte Carlo distributions for mu+ and mu- separately:
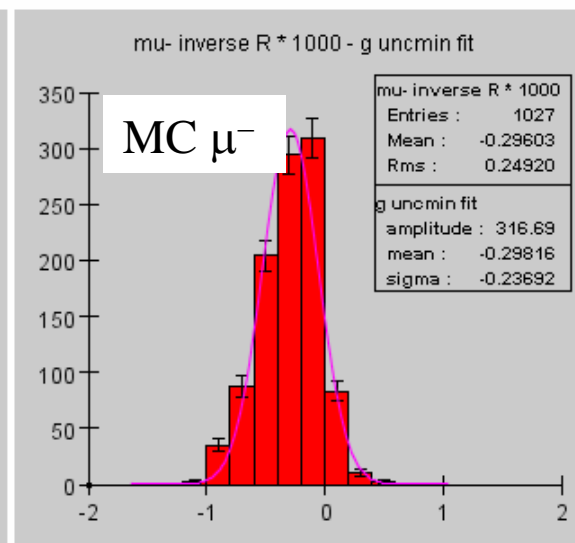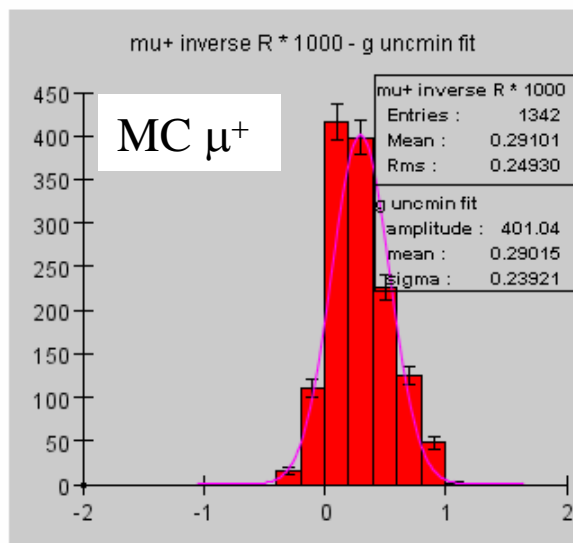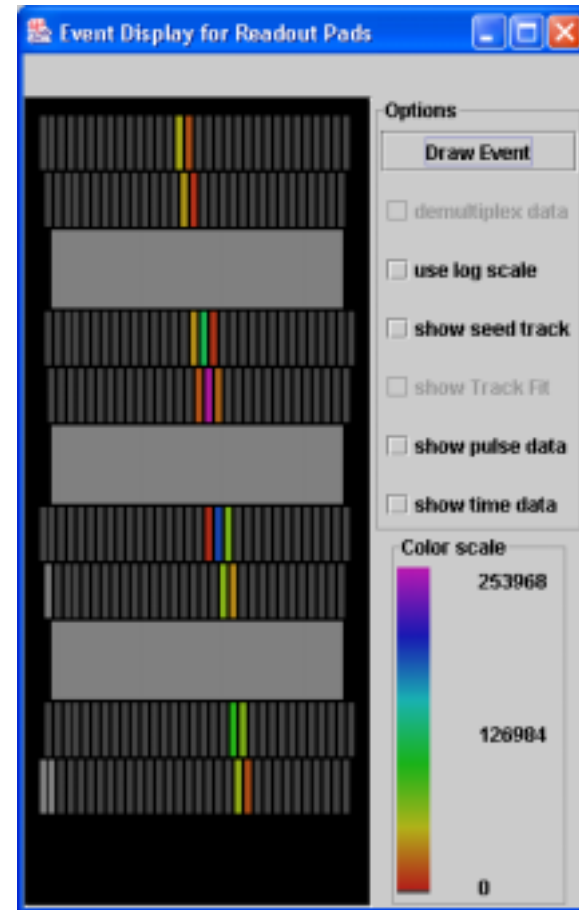
Narrower pad readout: 1.2 mm, P5 at 4 T

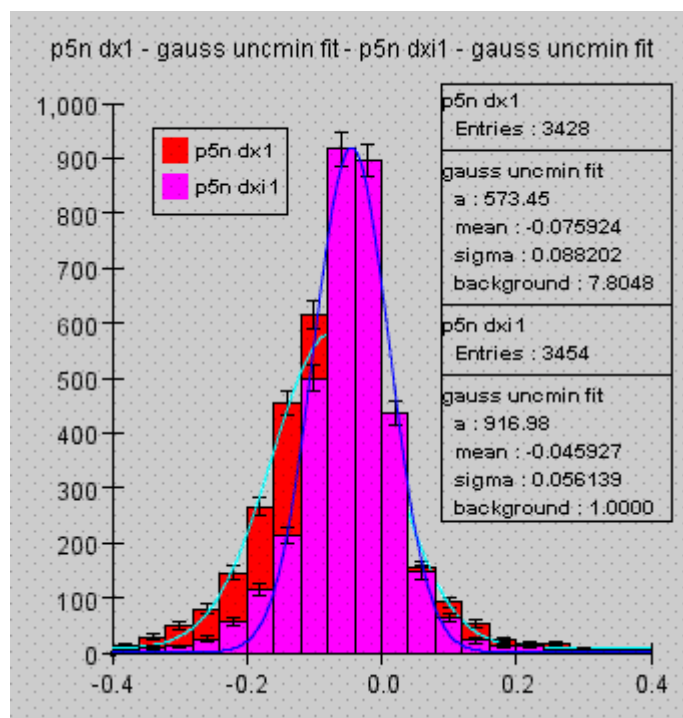□ Check if better sharing improves resolution
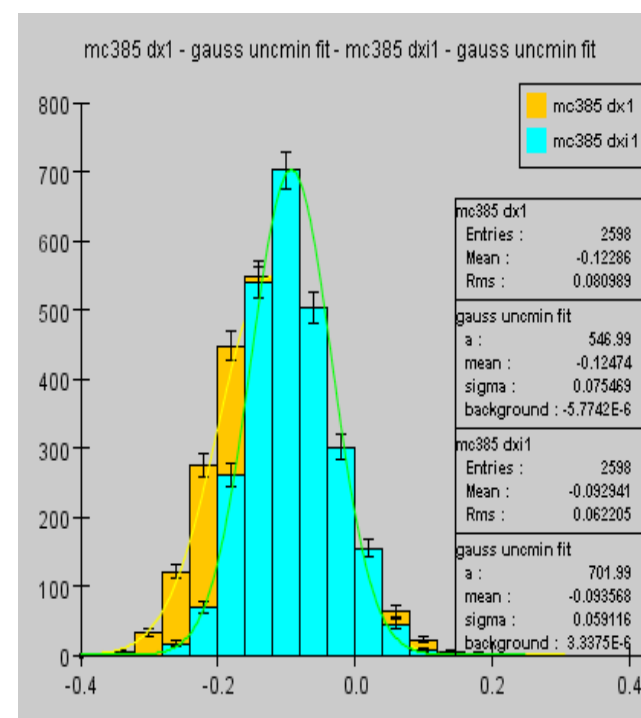
laser event
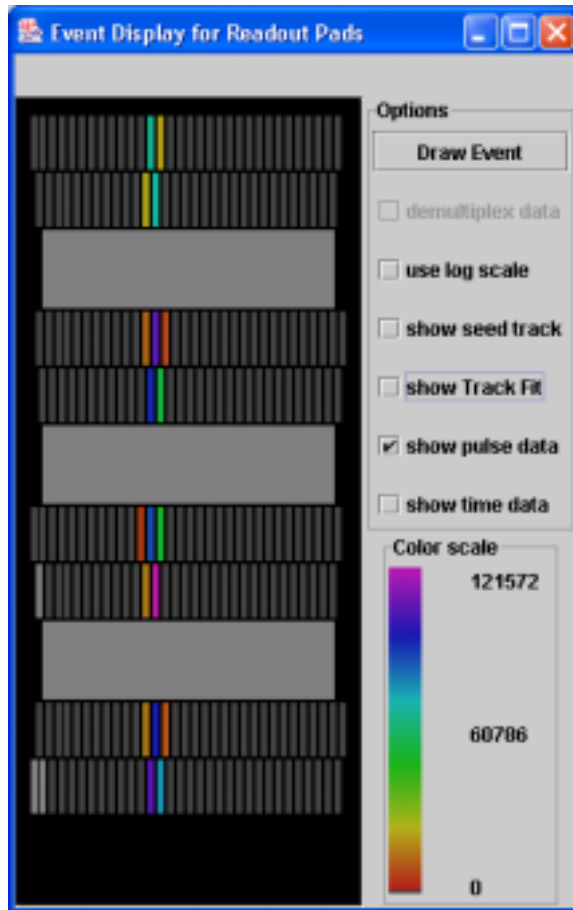
cosmic event

Biases seen

□ significant offsets seen (not seen with 2 mm pads)

   ■ eg. row 1 residuals offset by ~ -0.1 mm
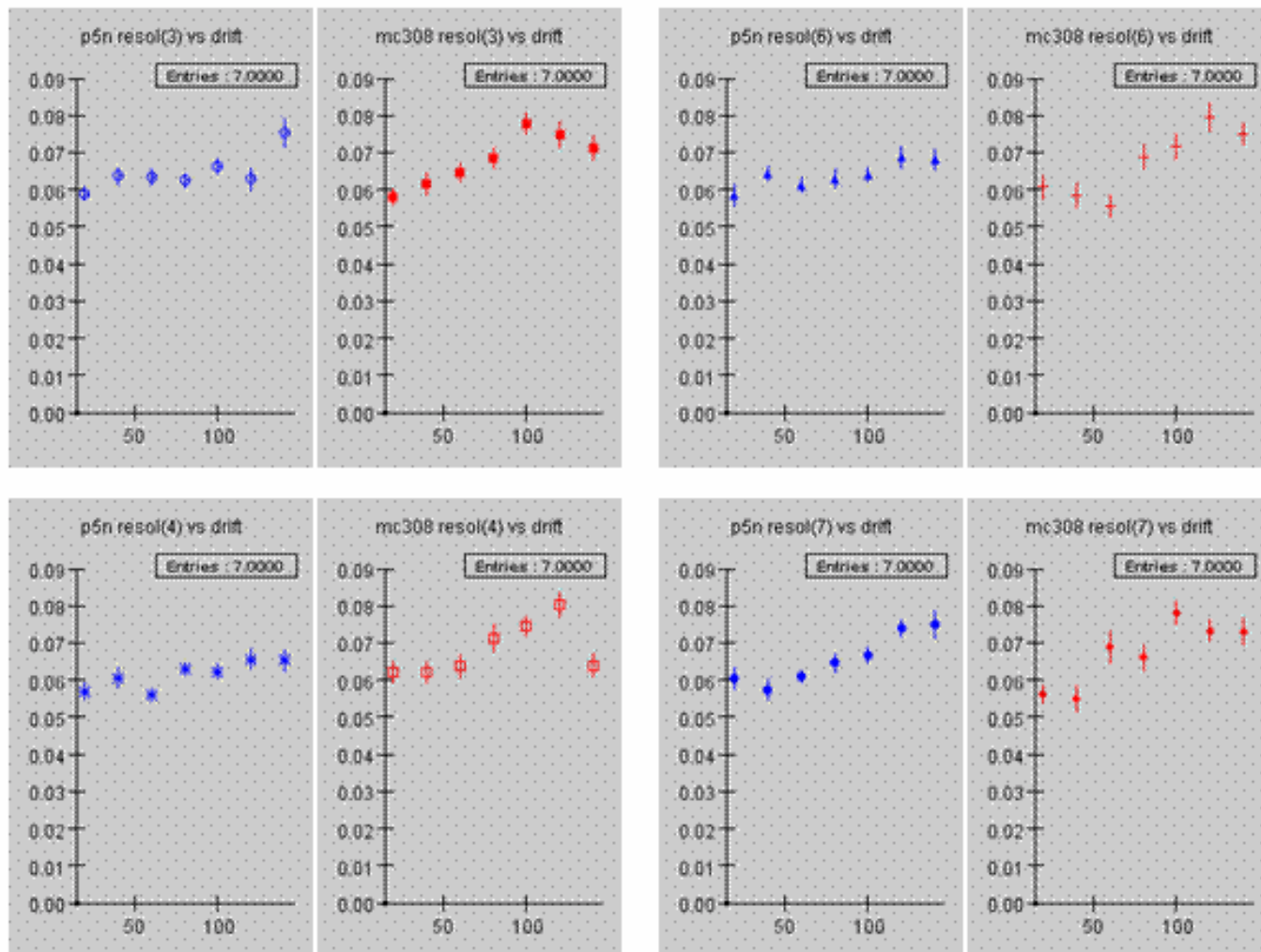
Cosmic rays

Laser events

Row by row resolution

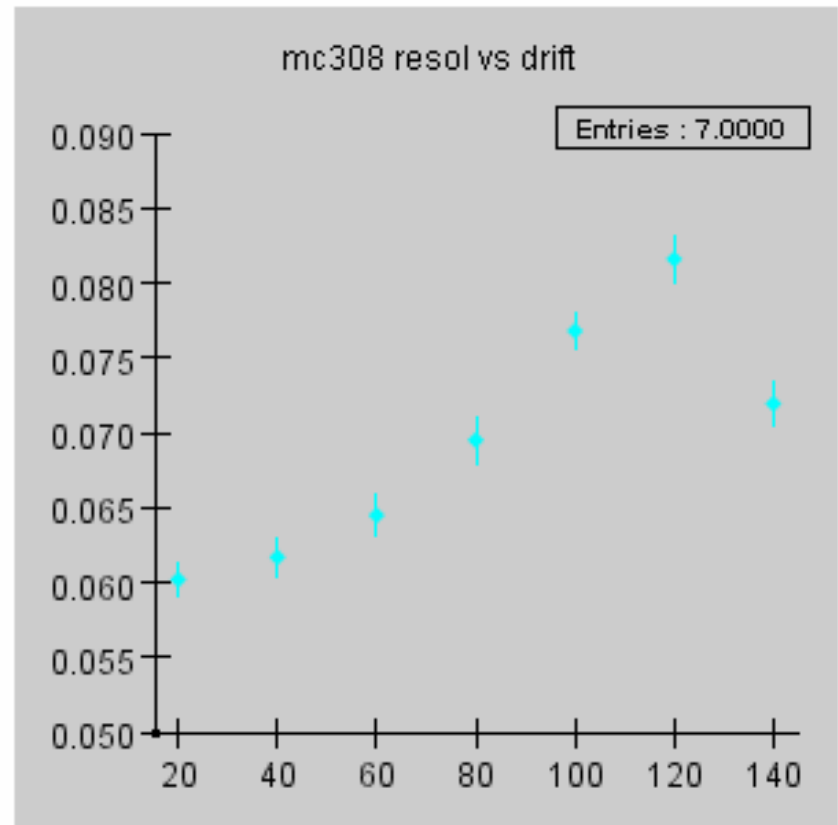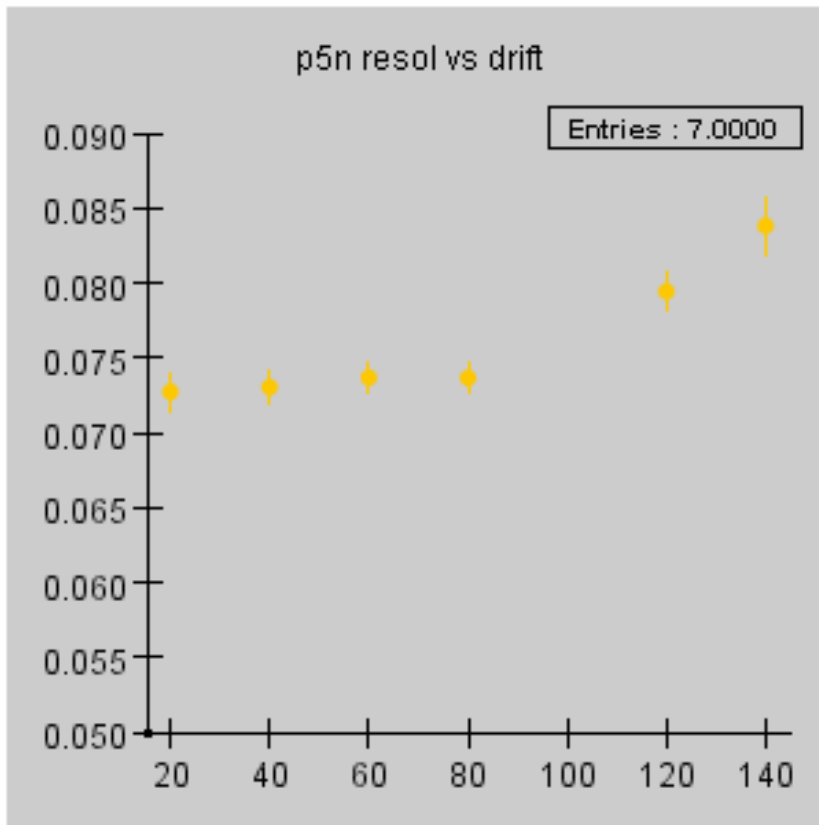□ Remarkably good agreement with MC

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