Update of Victoria TPC R&D

Dean Karlen, Thanos Michailopoulos, Chris Nell,
Paul Poffenberger, Gabe Rosenbaum

University of Victoria and TRIUMF, Canada

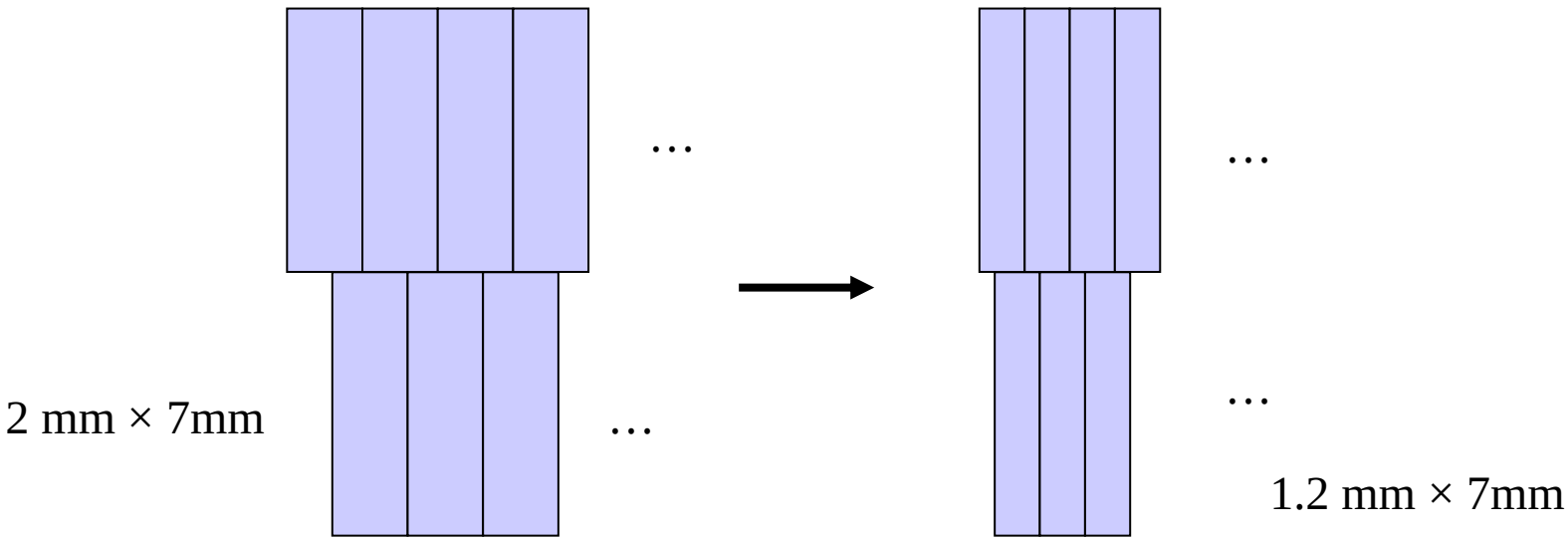
ECFA Workshop on Physics and Detectors for a Linear Collider
Durham, England September 1 – September 4, 2004

Progress since Paris LCWS

- Preparations completed for 2004 DESY magnet run
  - New readout plane with narrower pads
  - Readout plane for Micromegas with resistive foil
  - TPC modifications for UV laser
  - Remote control laser beam delivery system built
- DESY magnet run
  - Arrived at DESY on August 10
  - Dealt with problems… got first laser tracks August 15
  - After some further repairs, data collection underway August 18 – September 8 (Gabe on his own…)
    - GEM (2 sets of pads), MM, cosmics and laser tracks

Narrower readout plane

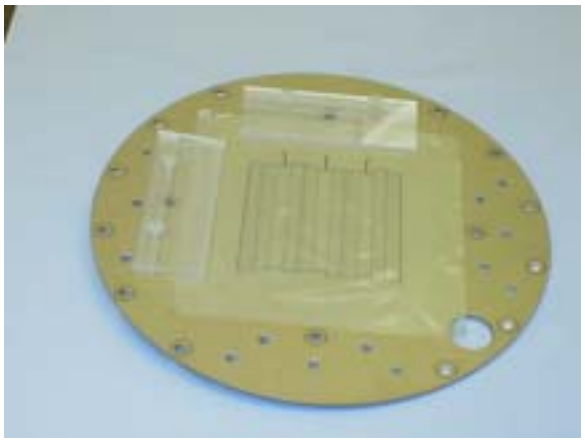
- At Paris, our results show defocusing in P5 or TDR gas of around 0.4 mm at 4 T.
  - too small for our 2 mm pads (width/σ_0 = 5)
- To check effect of pad width, we built a new readout board replacing 2 mm pads with 1.2 mm pads

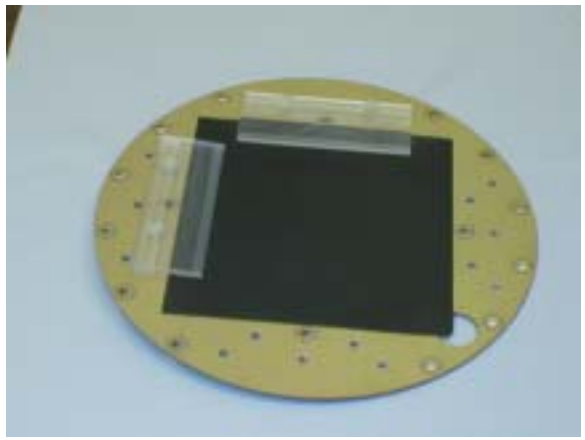


Micromegas readout plane

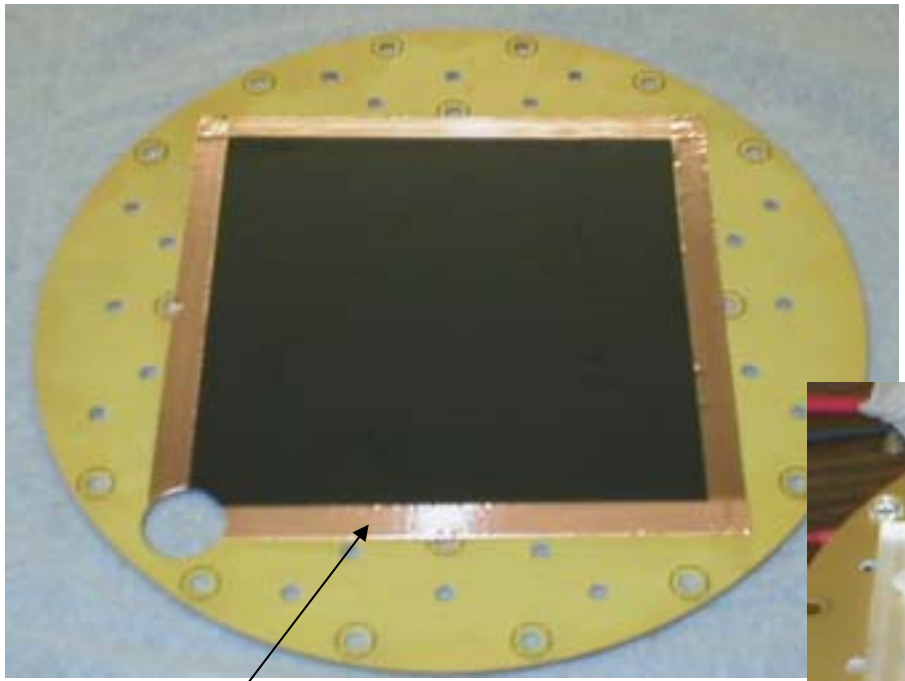
- Shorter pads (6 mm instead of 7 mm) in order to fit them all within the Micromegas frame provided to us by Paul Colas
- Resistive foil (carbon loaded kapton) provided by Madhu Dixit
- Resistive foil affixed to readout plane through baking a 50 μm sheet adhesive at high pressure
  - nice uniform gluing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

Applying the resistive foil



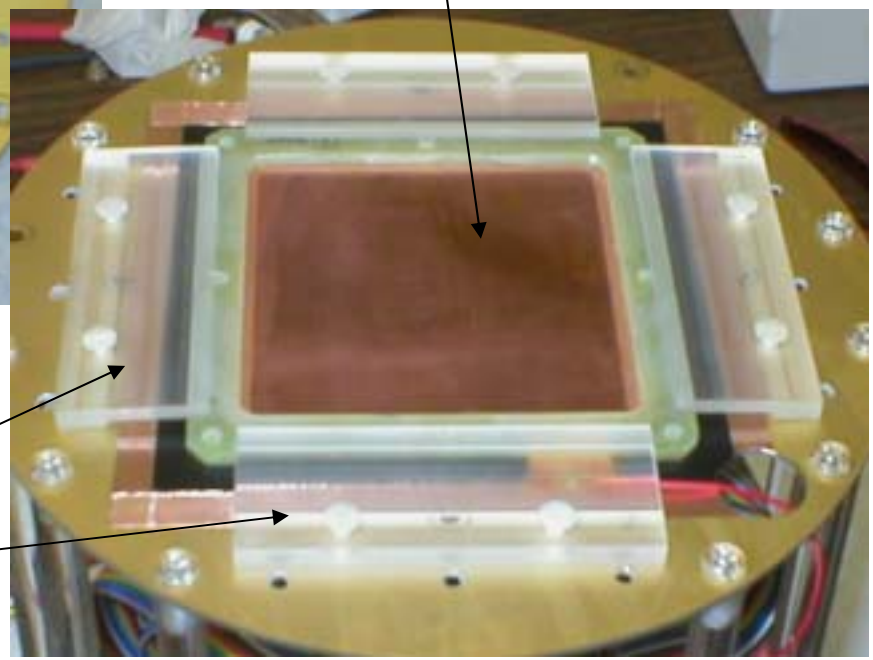


Micromegas installation



grounding resistive foil

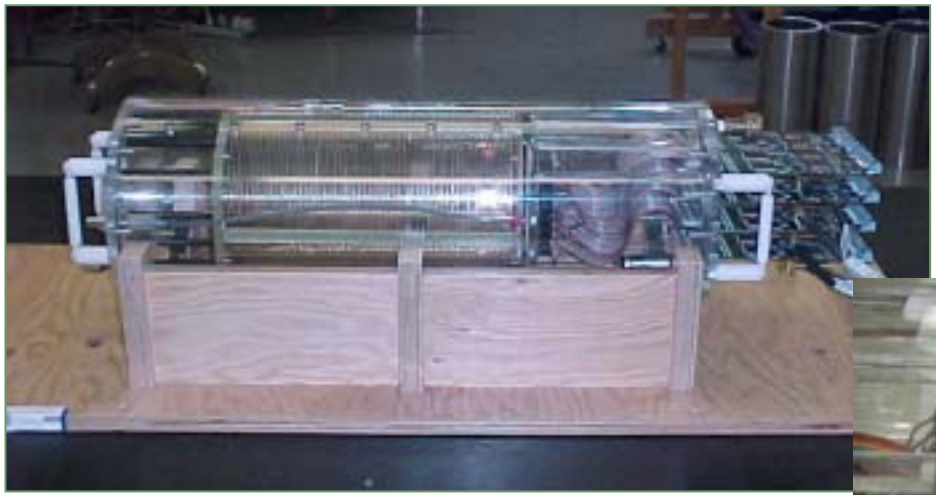
Micromegas on loan from Paul Colas

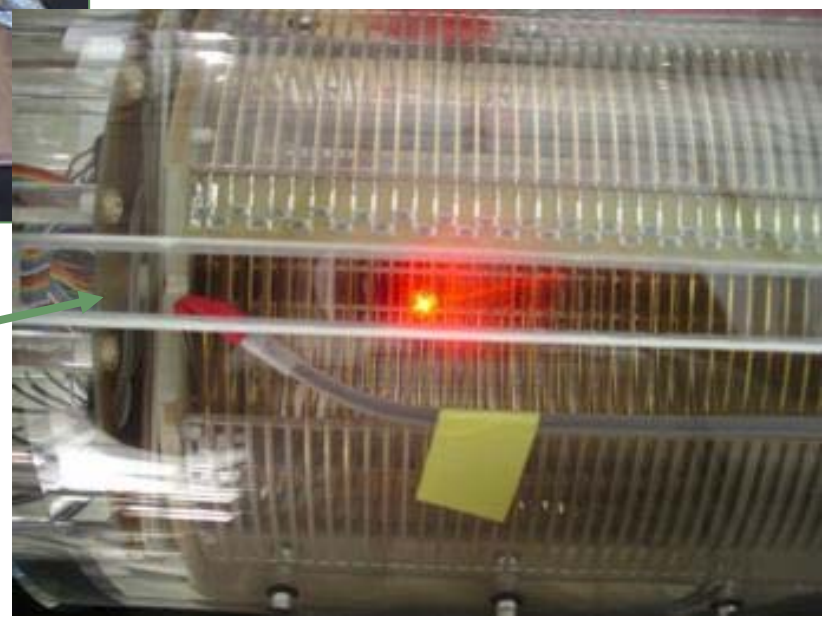


Plastic clamps to hold Micromegas in place

TPC modifications

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





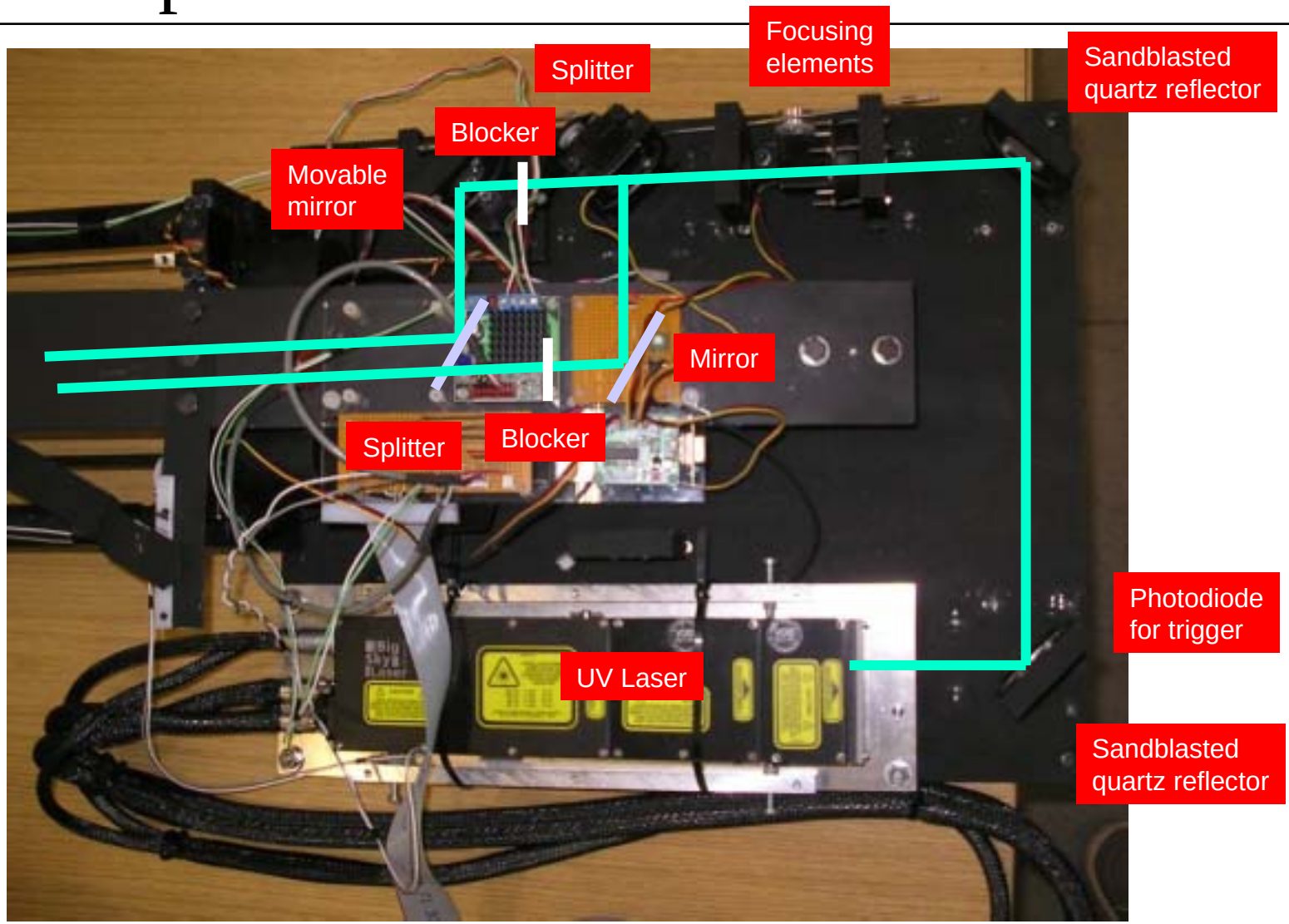
Laser beam delivery system

- 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

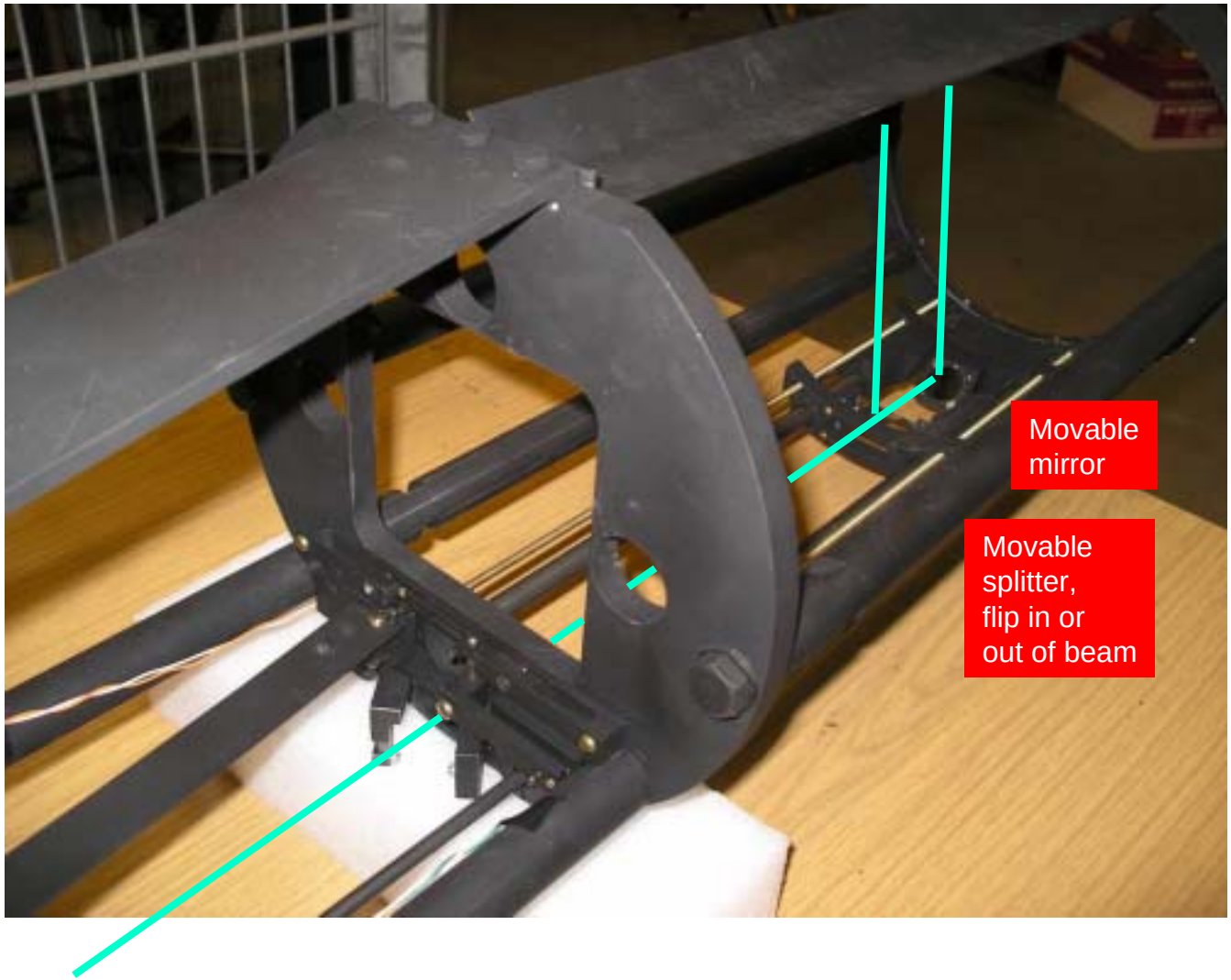
Laser beam delivery system

- Approx. 2 m long to reach into magnet

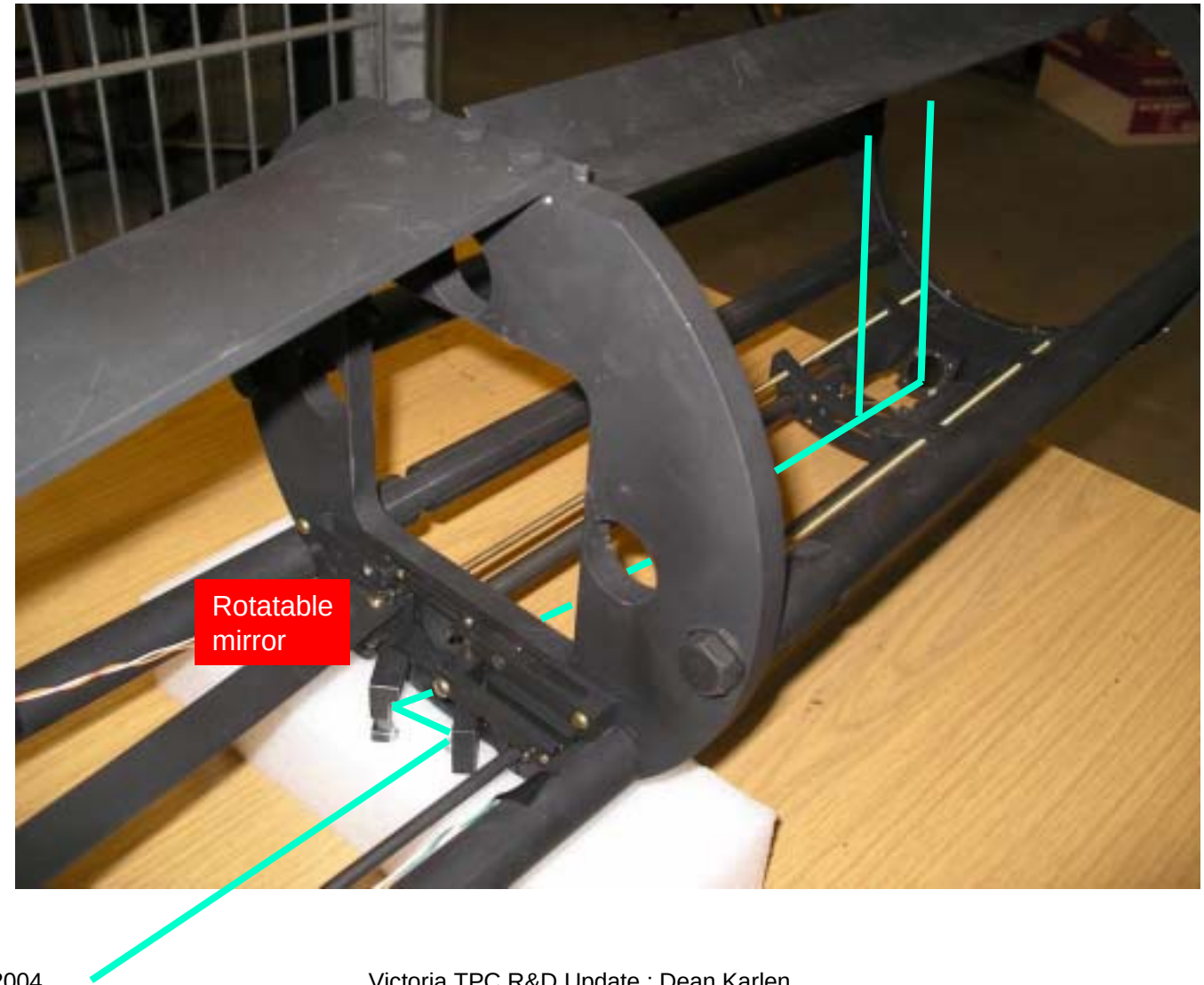
Laser optics



Beam delivery



Beam delivery – offset in x and z

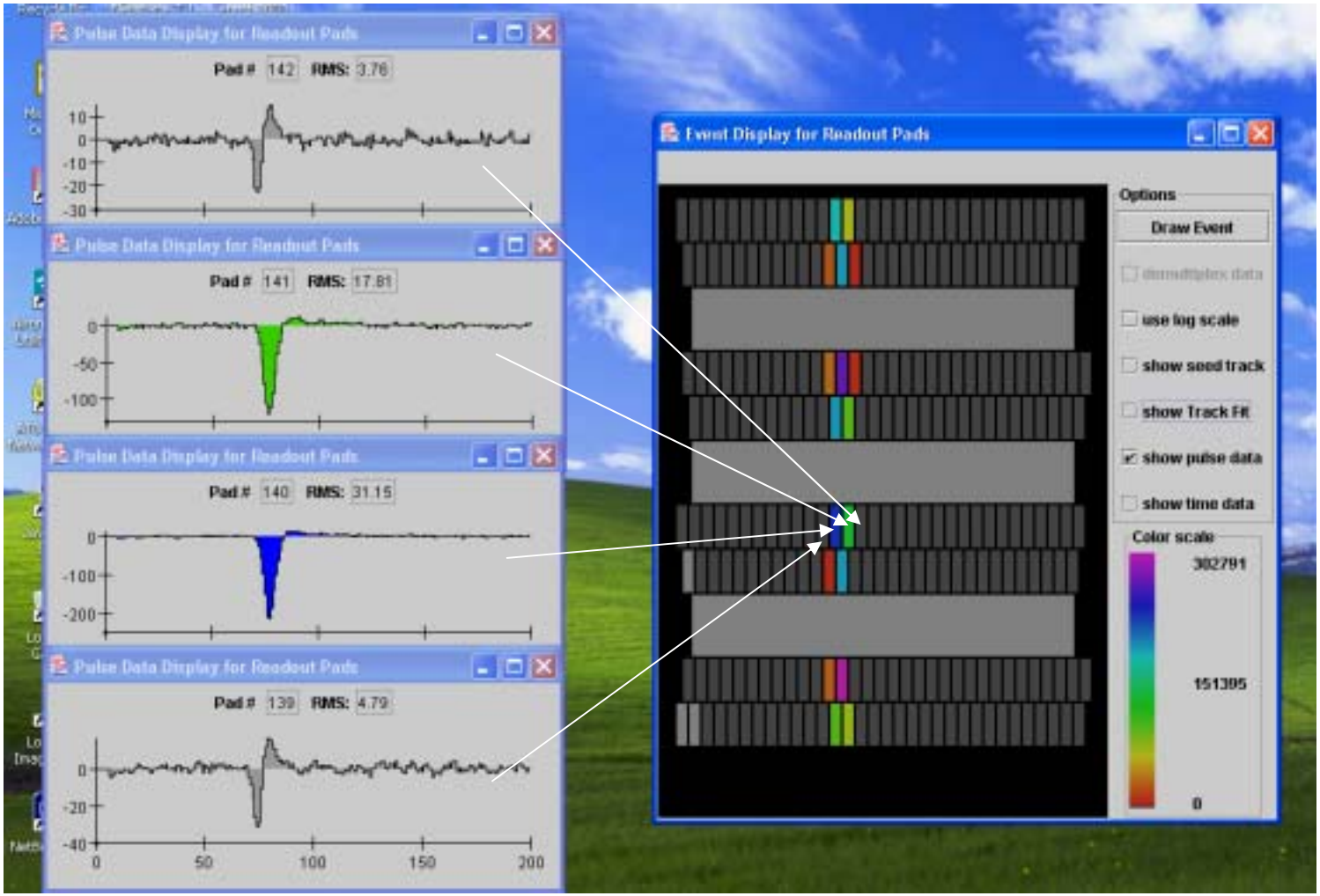


Setup with the DESY magnet

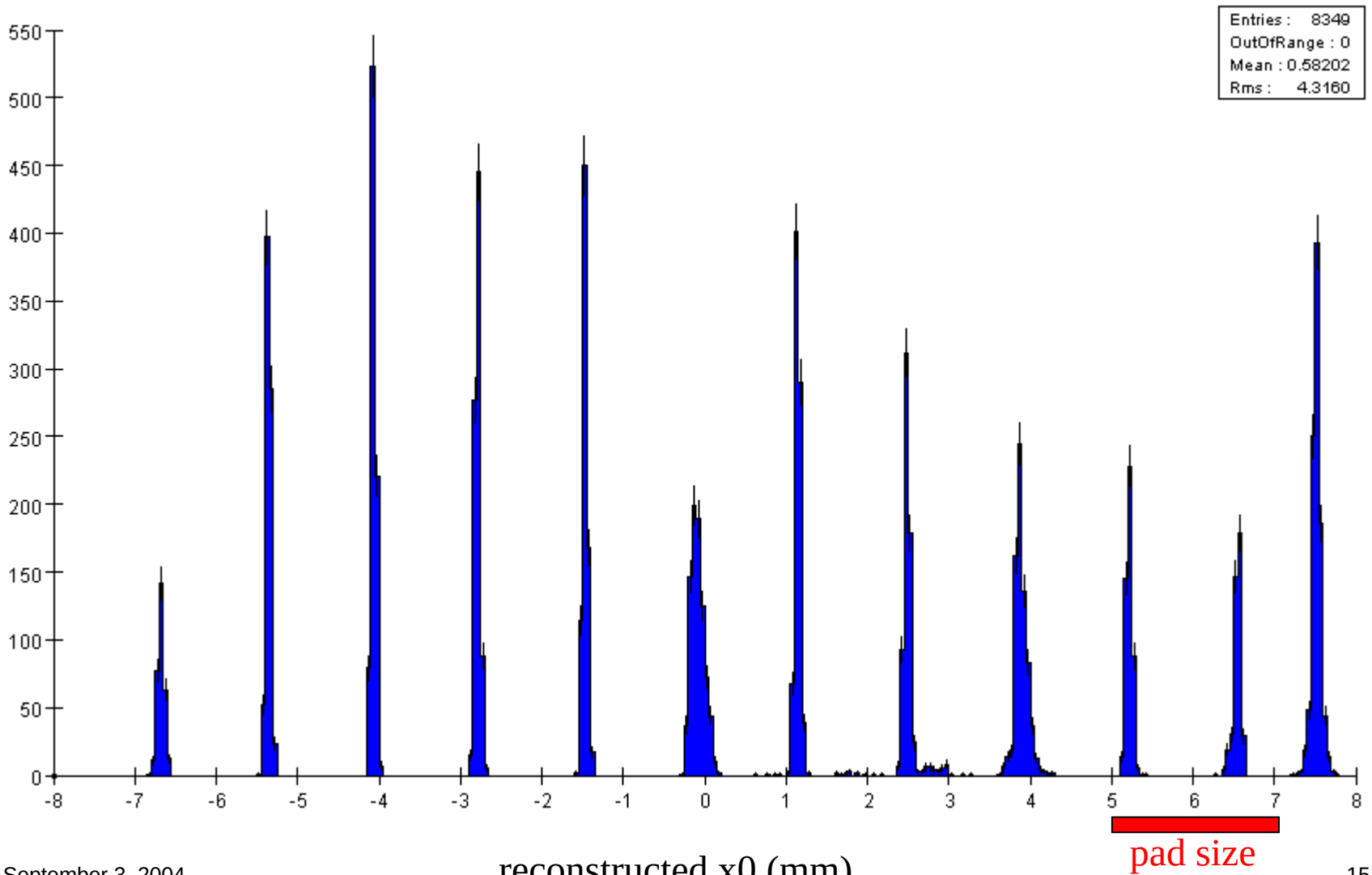
- For safety reasons, the UV laser must be contained within a light tight box

DESY run at 4 T

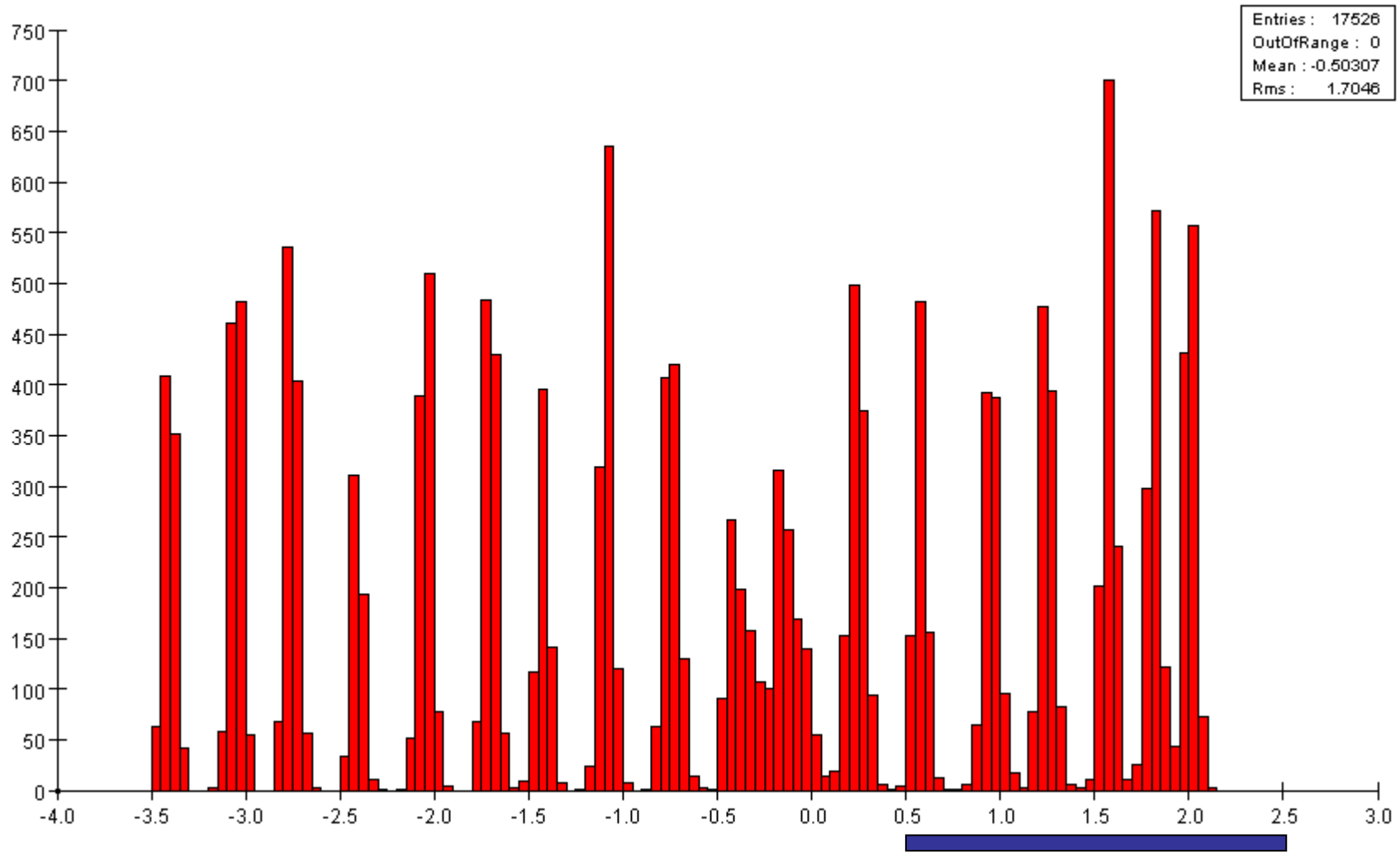
- Single laser track seen by 2 mm pads and P5 gas



Scan of laser in x



Fine scan of laser in x

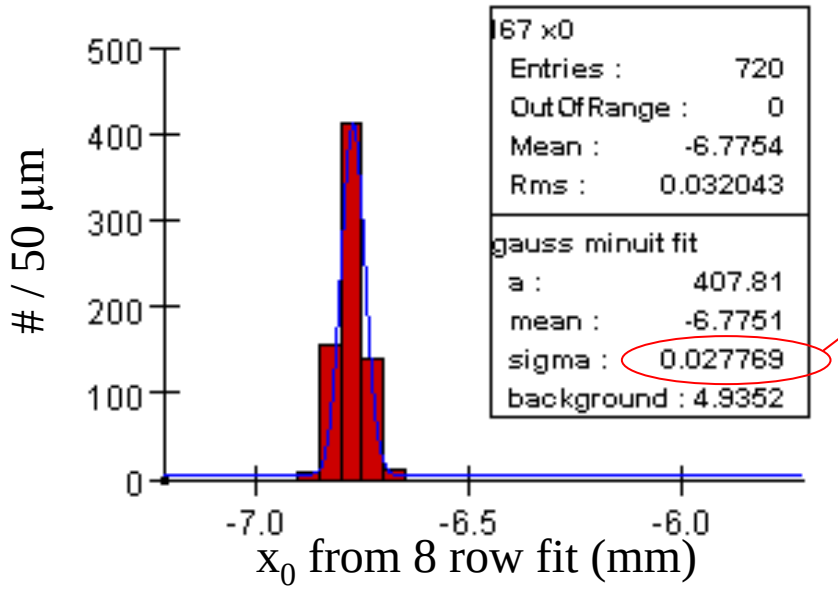


Laser track resolution studies

- Laser beam position is very stable, mean reconstructed positions from runs separated by 20 minutes have RMS < 4 μm

- 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 (method used for cosmics)

Laser track resolution example: run 67

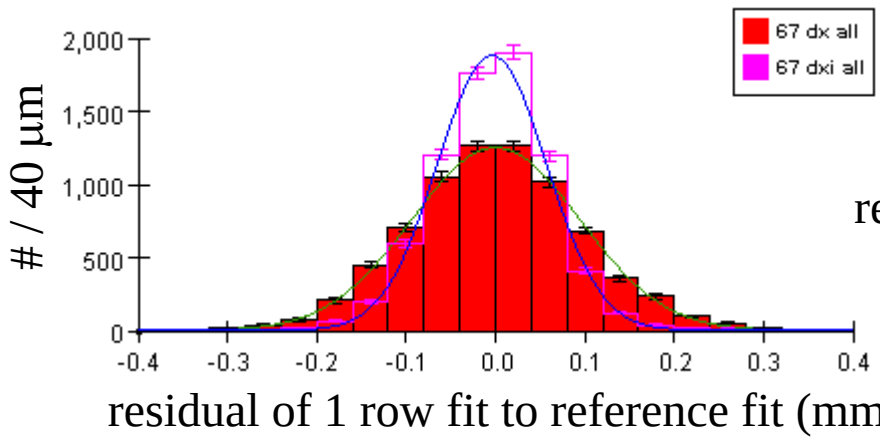


Straight track fits

8 row fit: 28 µm resolution

→ 1 row resolution = √8 × 28 µm

= 78.5 µm



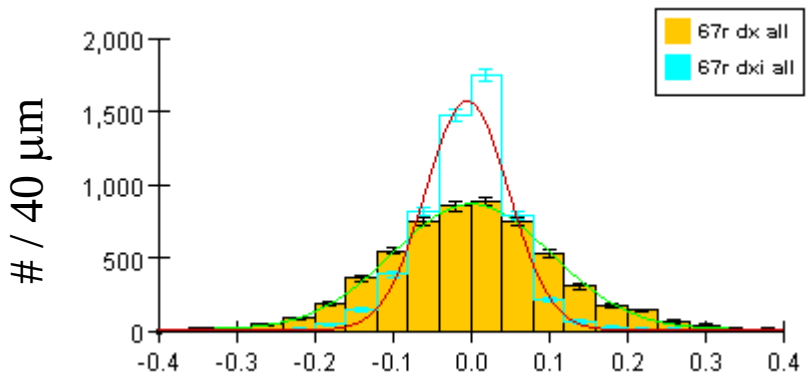
reference fit excludes row: 95.2 µm
reference fit includes row: 61.6 µm

resolution (geometric mean): 76.6 ± 0.6 µm

Good agreement!

Laser resolution cross check

- 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)

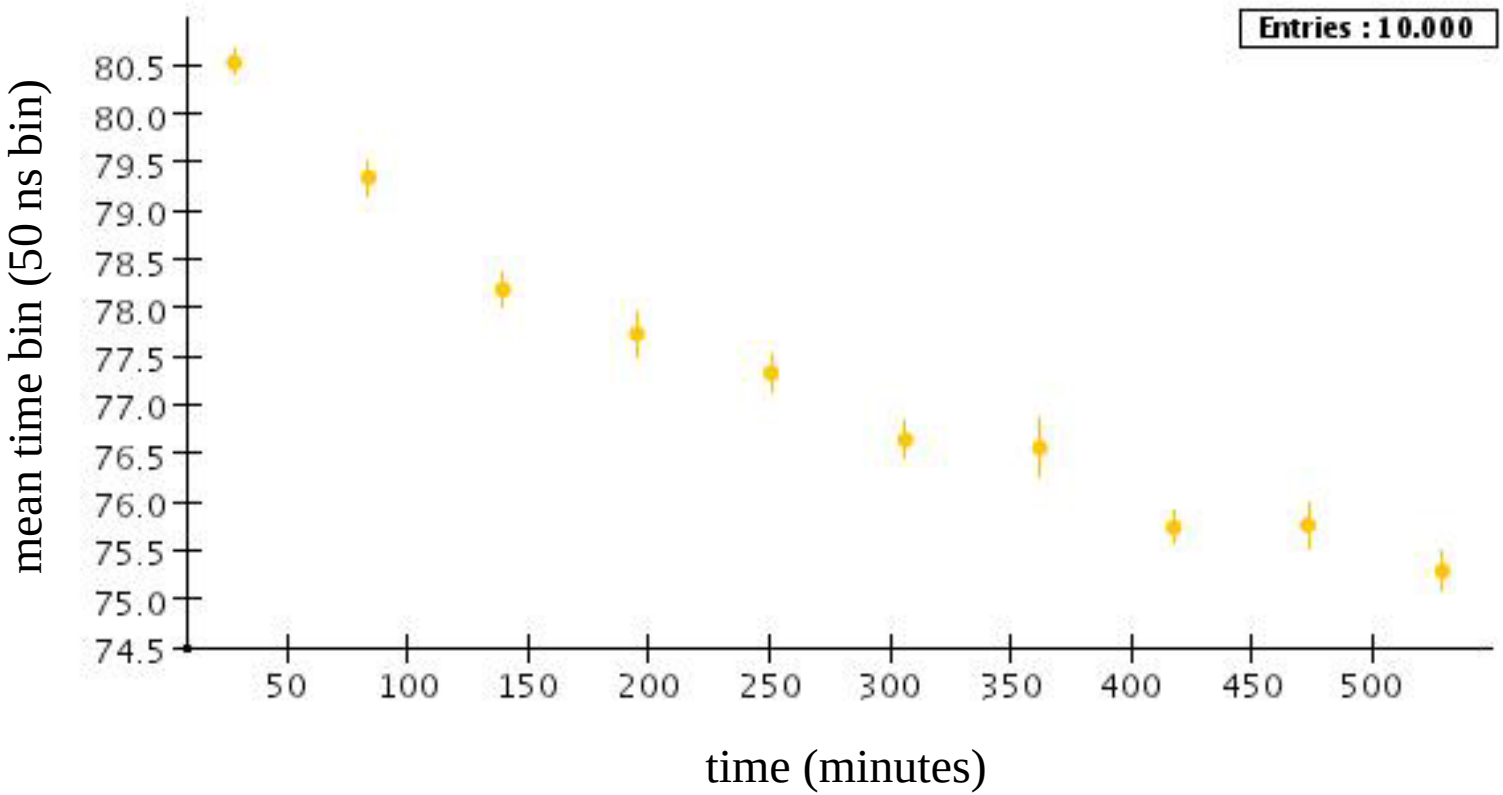
reference fit excludes row: 101.5 μm
reference fit includes row: 53.4 μm

resolution (geometric mean): 73.6 ± 0.7 μm

resolution estimate low by about 5%

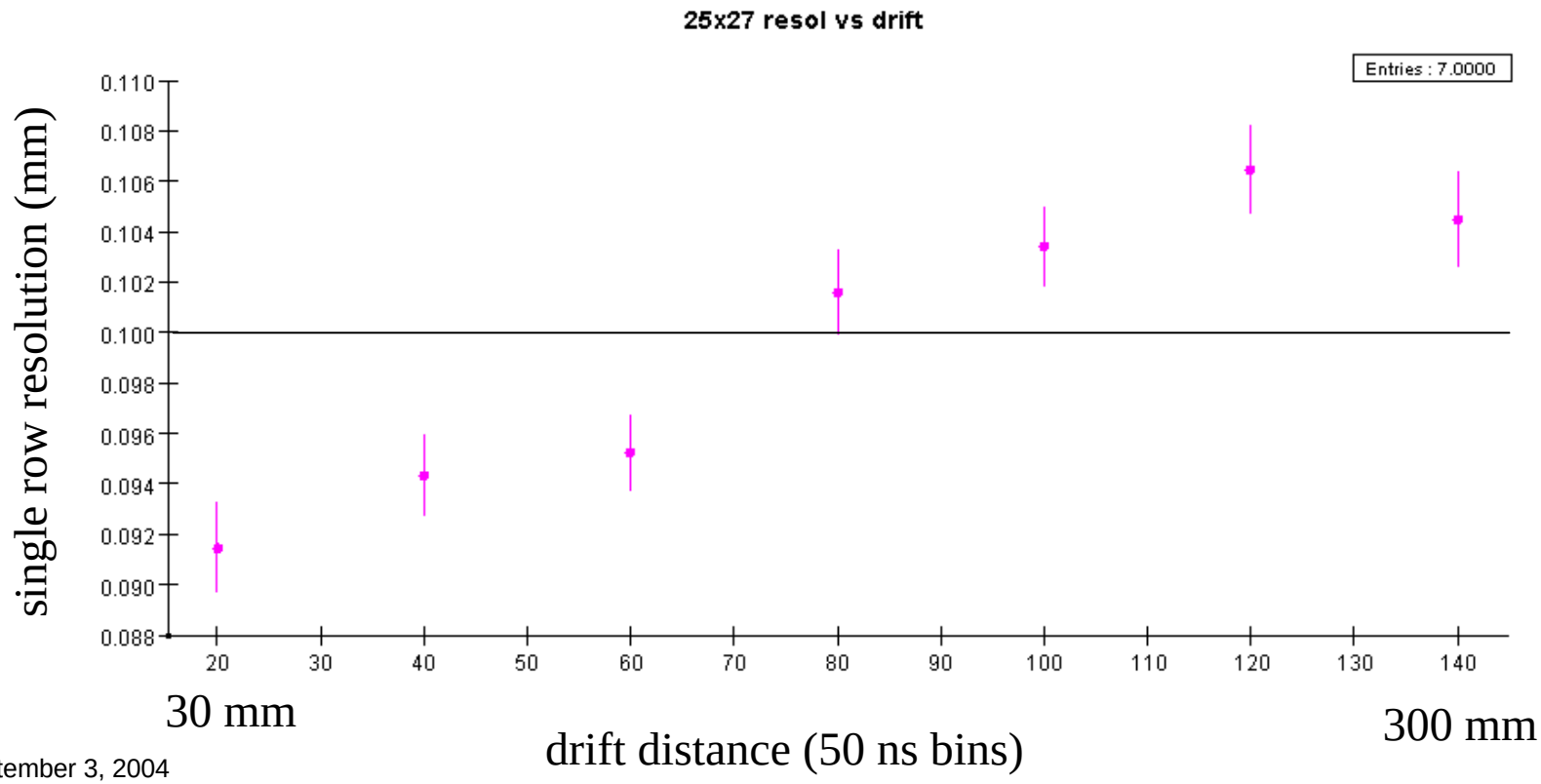
Drift velocity monitor

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

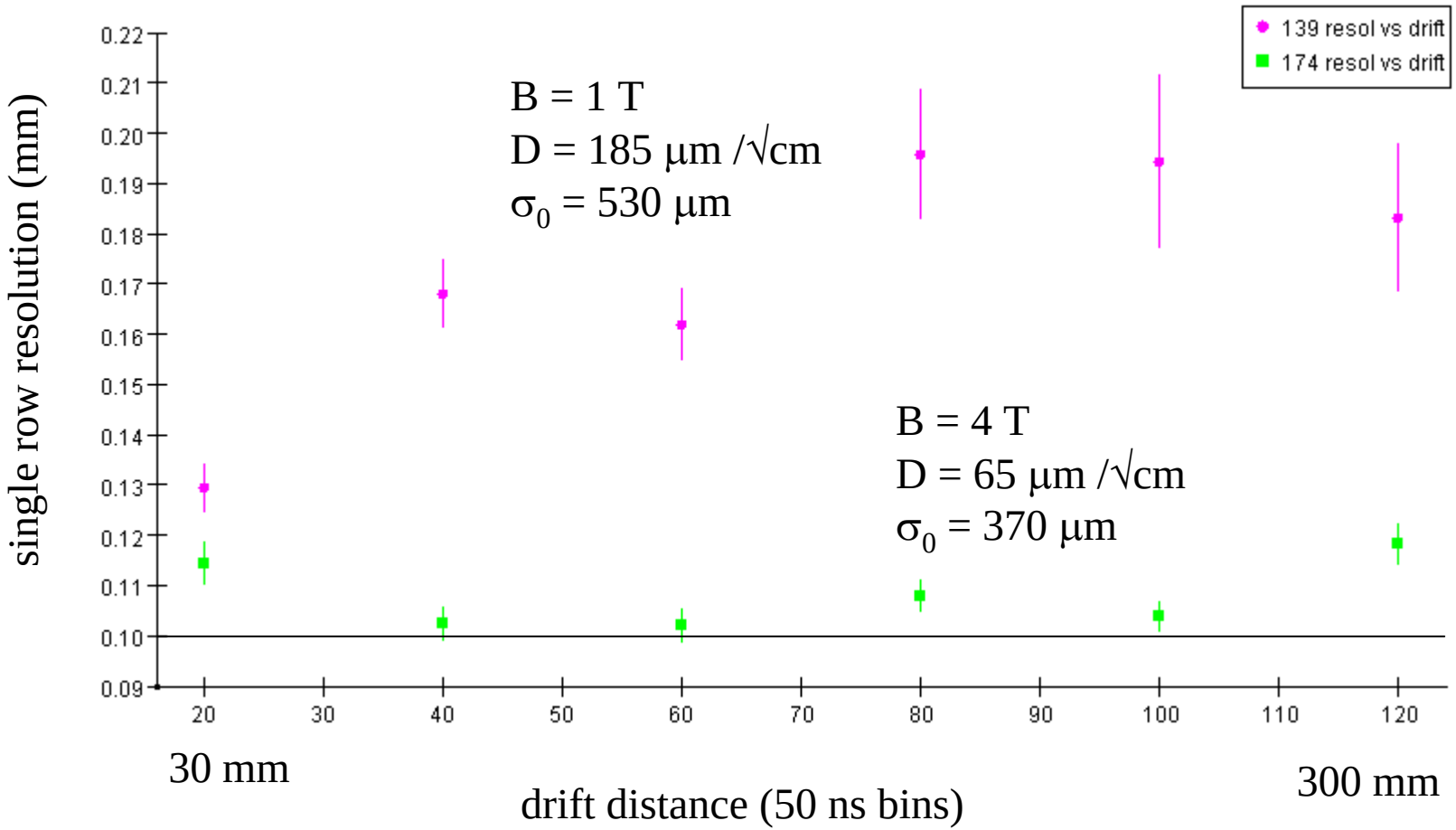


Cosmic results: P5 gas, 2 mm pads, 4 T

- P5 gas properties not quite as expected:
  - plateau of drift velocity was 160 V/cm (not 130 V/cm)
  - at this drift field diffusion measured: 77 ± 3 μm/√cm



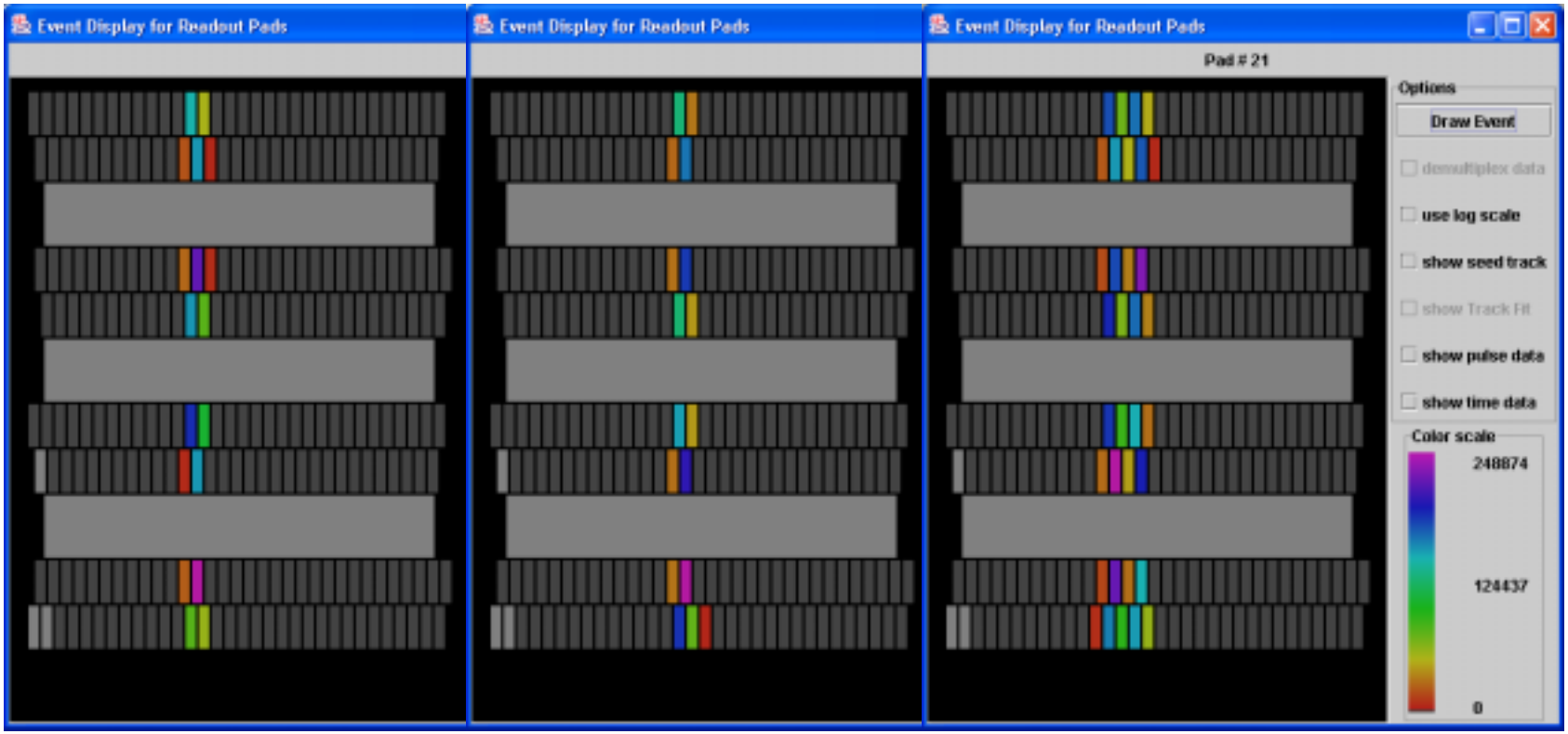
Cosmic results: TDR gas, 2mm pads



Two track resolution studies: P5 gas at 4 T

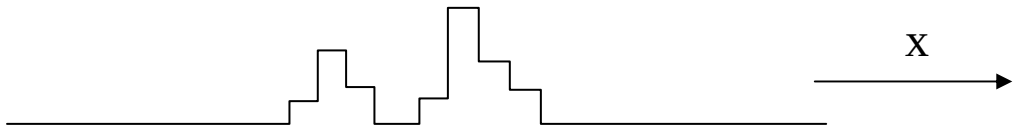
- Bring two beams close together **at same z**
  - example (runs 67-69): 3.8 mm separation, σ = 0.5 mm

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

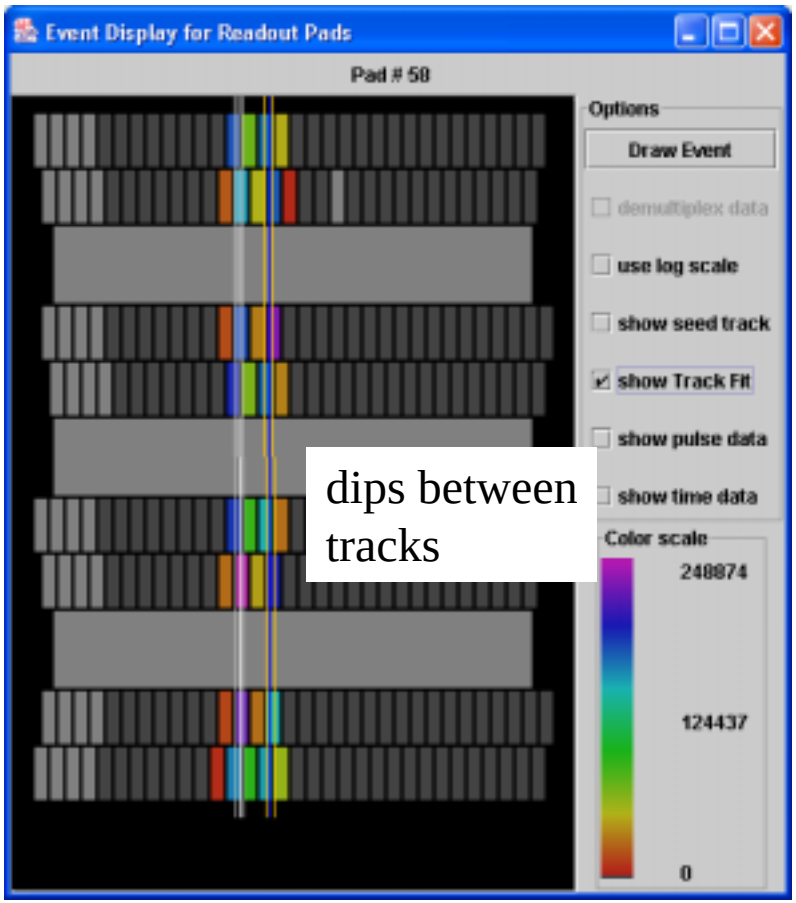


  - relative amplitudes of the charges from two tracks for each row are treated as nuisance parameters (1 per row)
- Fix sigma (known from z)
- Maximize likelihood for 4 track parameters (x_{01}, ϕ_{01}, x_{02}, ϕ_{02}) + 8 nuisance parameters
  - for MIPs the 8 nuisance parameters are independent and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

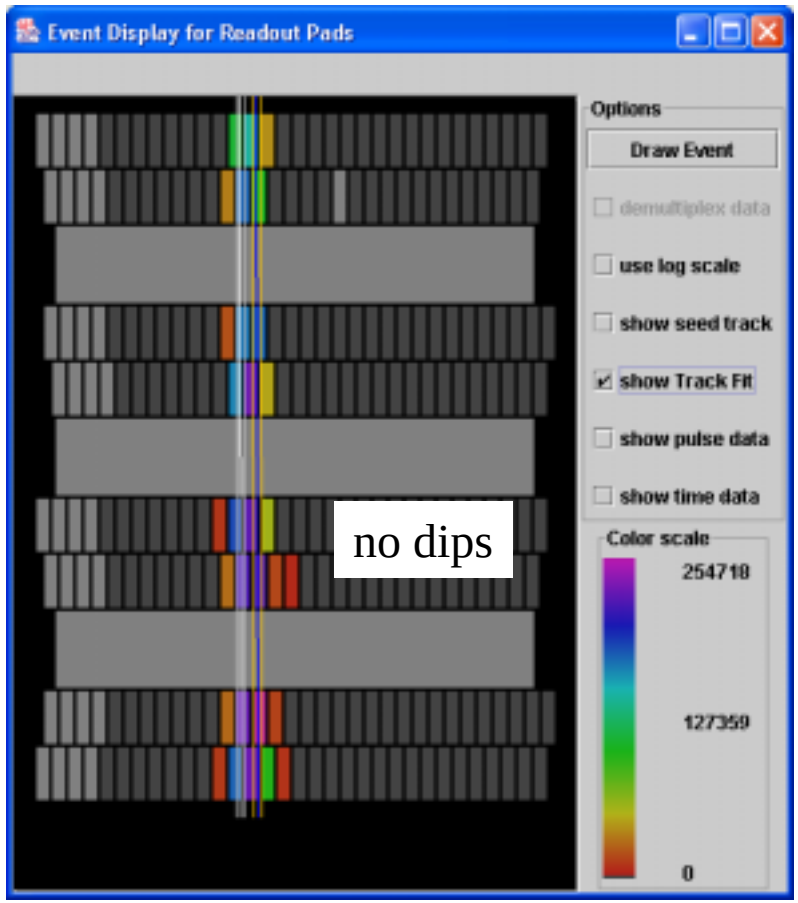
Track fits: 2mm wide pads

σ = 0.5 mm

Δx = 3.8 mm



Δx = 2.0 mm



Two track fitting performance

- For a drift distance of 150 mm:
  - resolution degrades for $\Delta x < 4$ mm, as expected, but degradation is slower than might be expected
    - information well preserved for $\Delta x = 2$ mm

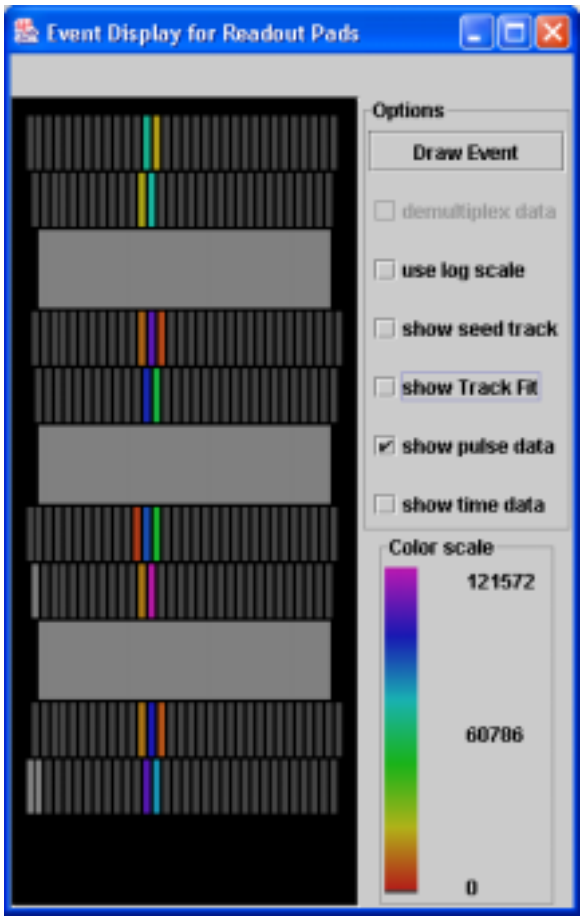
		$\Delta x = 4$mm x_0 resolution (μm)		$\Delta x = 2$ mm x_0 resolution (μm)		$\Delta x = 1$mm x_0 resolution (μm)	
B (T)	**σ (μm)**	**single**	**double**	**single**	**double**	**single**	**double**
4	500	28, 25 →	32, 27	28, 27 →	43, 37	28, 22 →	99, 153
2	690	29, 22 →	33, 26	33, 25 →	46, 39		
1	975	44, 37 →	57, 48	47, 50 →	91, 85		

    - biases in 2 track fit parameters: mostly small, no definite trend

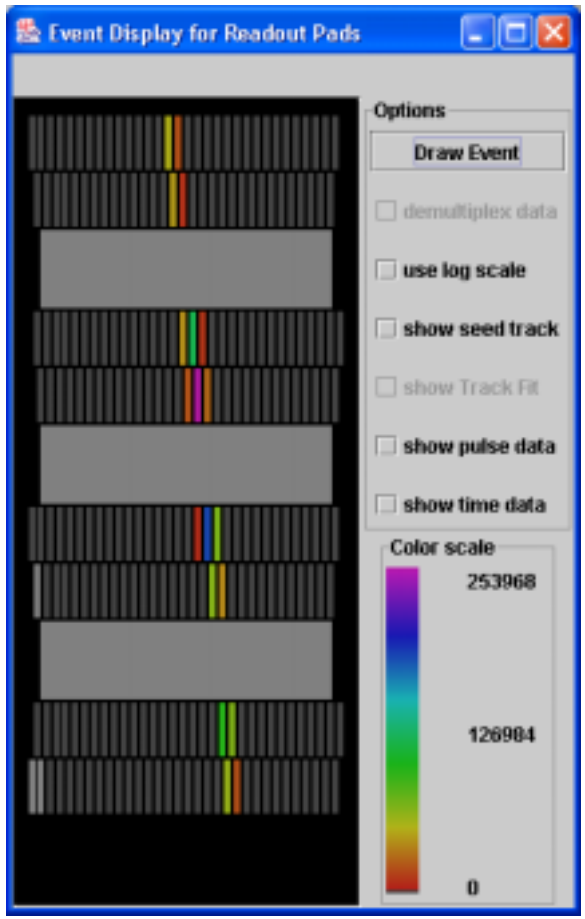
Narrower pad readout: 1.2 mm, P5 at 4 T

- Check if greater sharing improves resolution

laser event



cosmic event



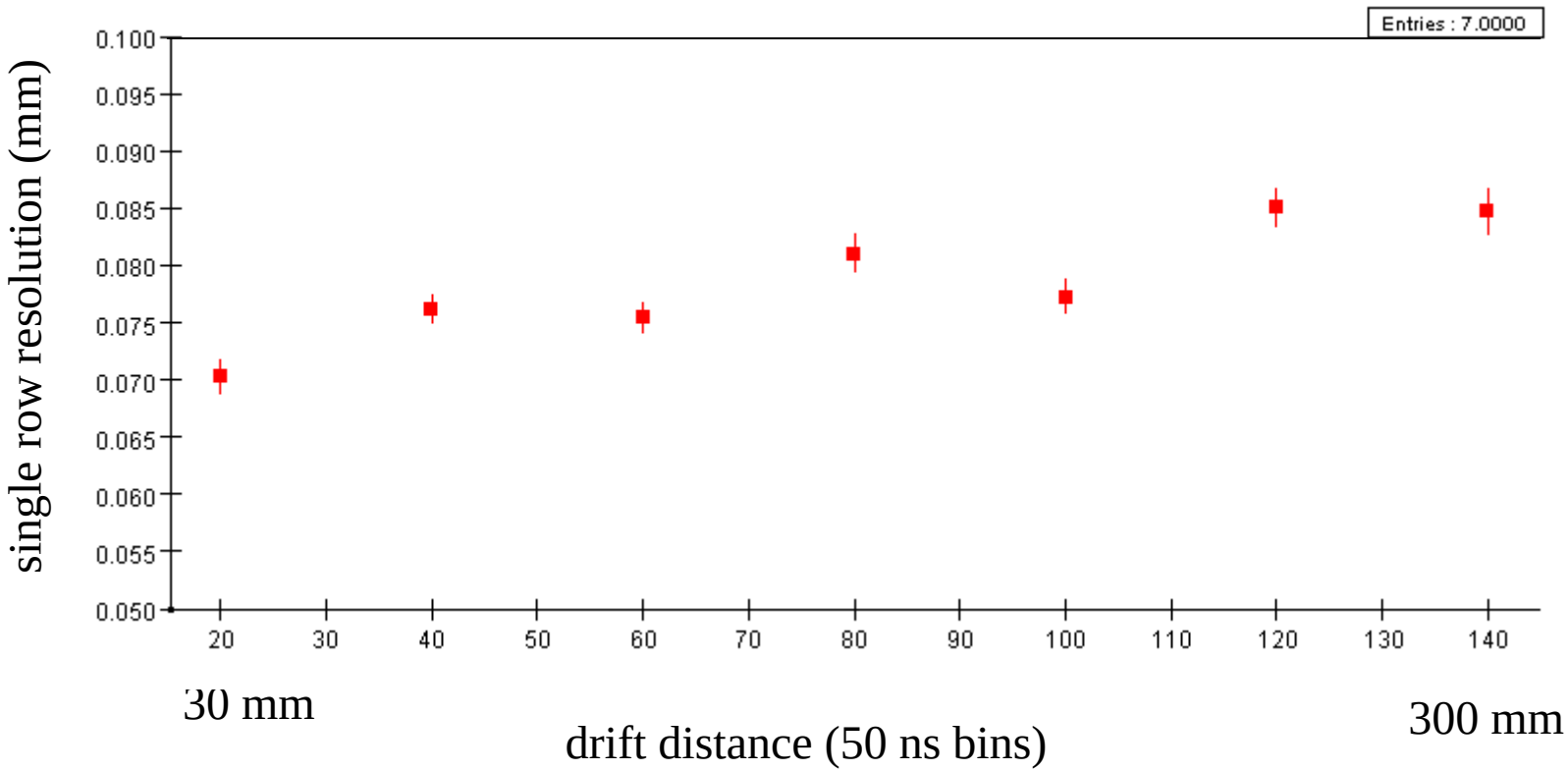
Narrower pads: initial resolution results

- Looking at a few laser runs taken Wednesday, the standard deviations of the x_0 estimates from the full track fits are ~ 20 μm, as compared to ~ 28 μm for the wide pads
  - suggests that resolution is better… but not proof

- Cosmic run from Wednesday night:
  - Diffusion = 30 ± 5 μm / √cm
  - Defocusing ~ 400 μm

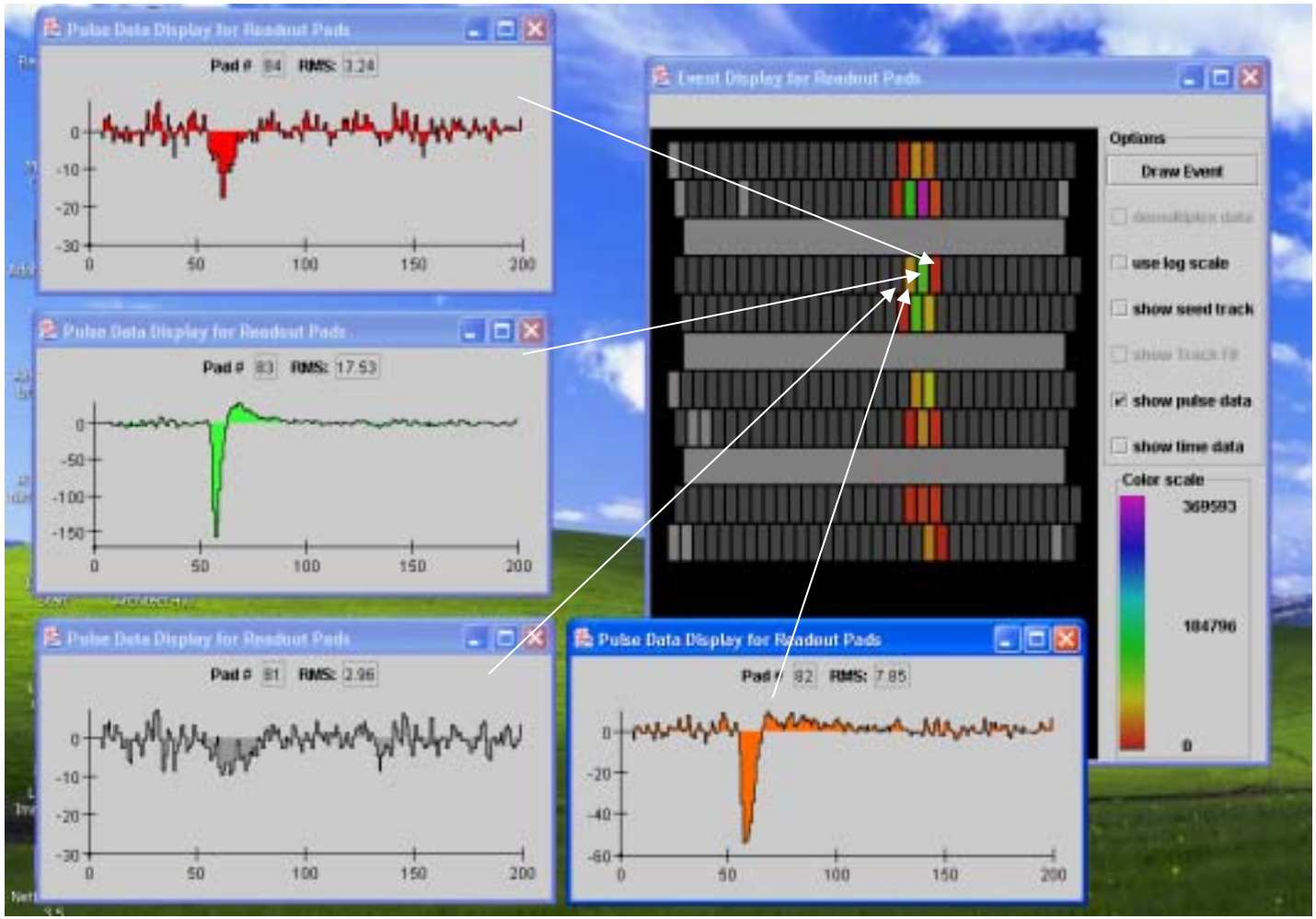
Resolution from cosmics at 4T

- From quick analysis, it appears that resolution has improved significantly…



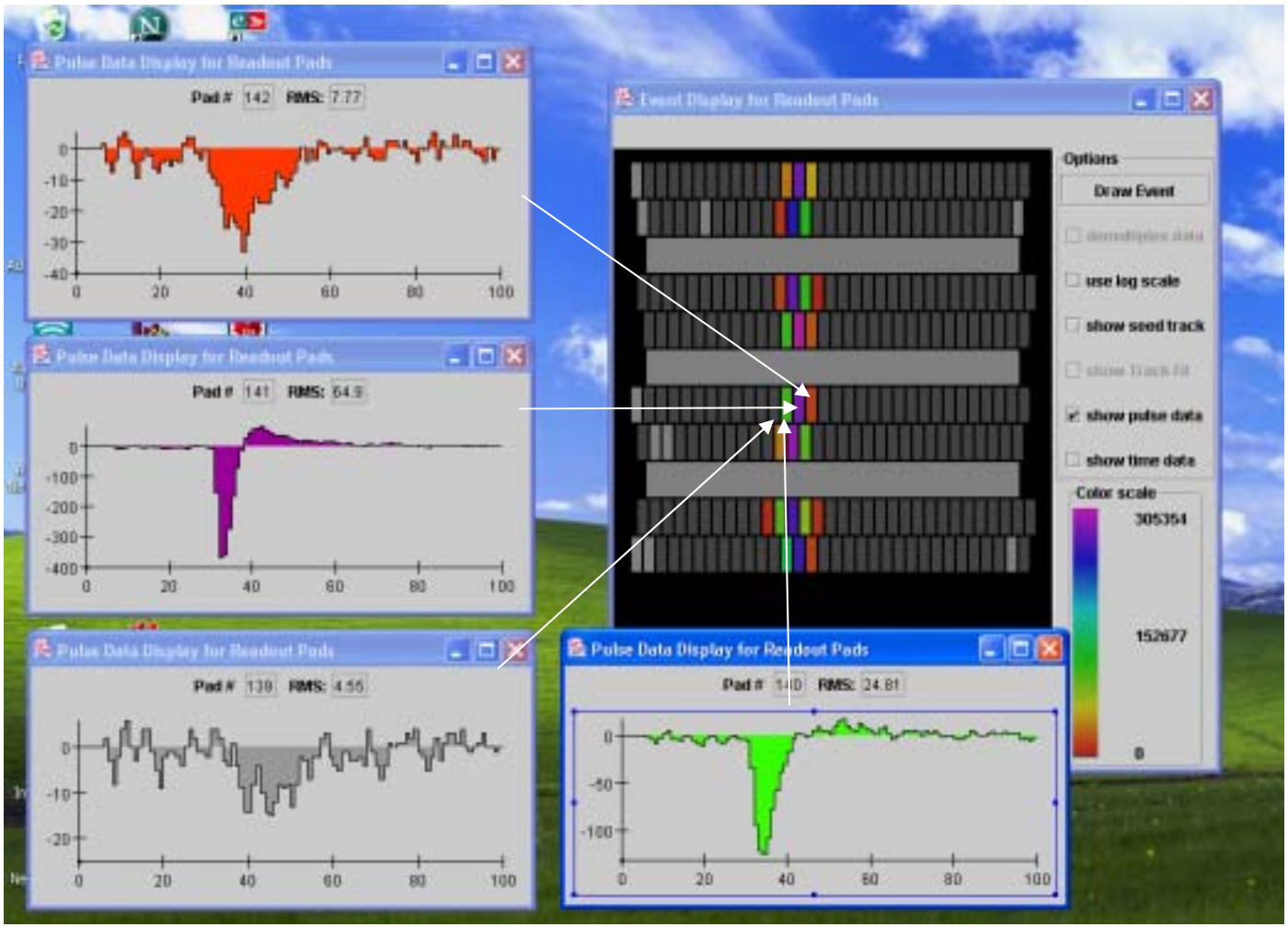
Micromegas event (Ar:Isobutane 95:5)

- A cosmic at 4 T:



Micromegas event (Ar:Isobutane 95:5)

- A laser track at 4 T:



Micromegas running

- With Ar:Isobutane (95:5), operated at 330 V to get gain of order 3000
- Changed to P5: needed 410 V to get similar gain
  - after 4 hours (20 hours since gas change) micromegas began sparking, then developed ohmic short (400 kΩ)
  - brought into air: short disappeared, but could not bring above 400 V, without constant sparking… and squealing!
  - sparks appear located about one of the pillars
- We need more experience operating micromegas

Summary

- A very successful run at DESY in 2004
  - still underway for a few more days
  - let me know if you have suggestions for further studies
- Our laser transport system is available for others to modify to fit their own needs for DESY laser tests
  - very useful tool for testing TPC operation
- Two track resolution is quite good: 2-4 mm for 2 mm pads
- With limited defocusing of P5, resolution improves by about 30% with narrower pads