Yet another CDC cosmics track finder

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Overview

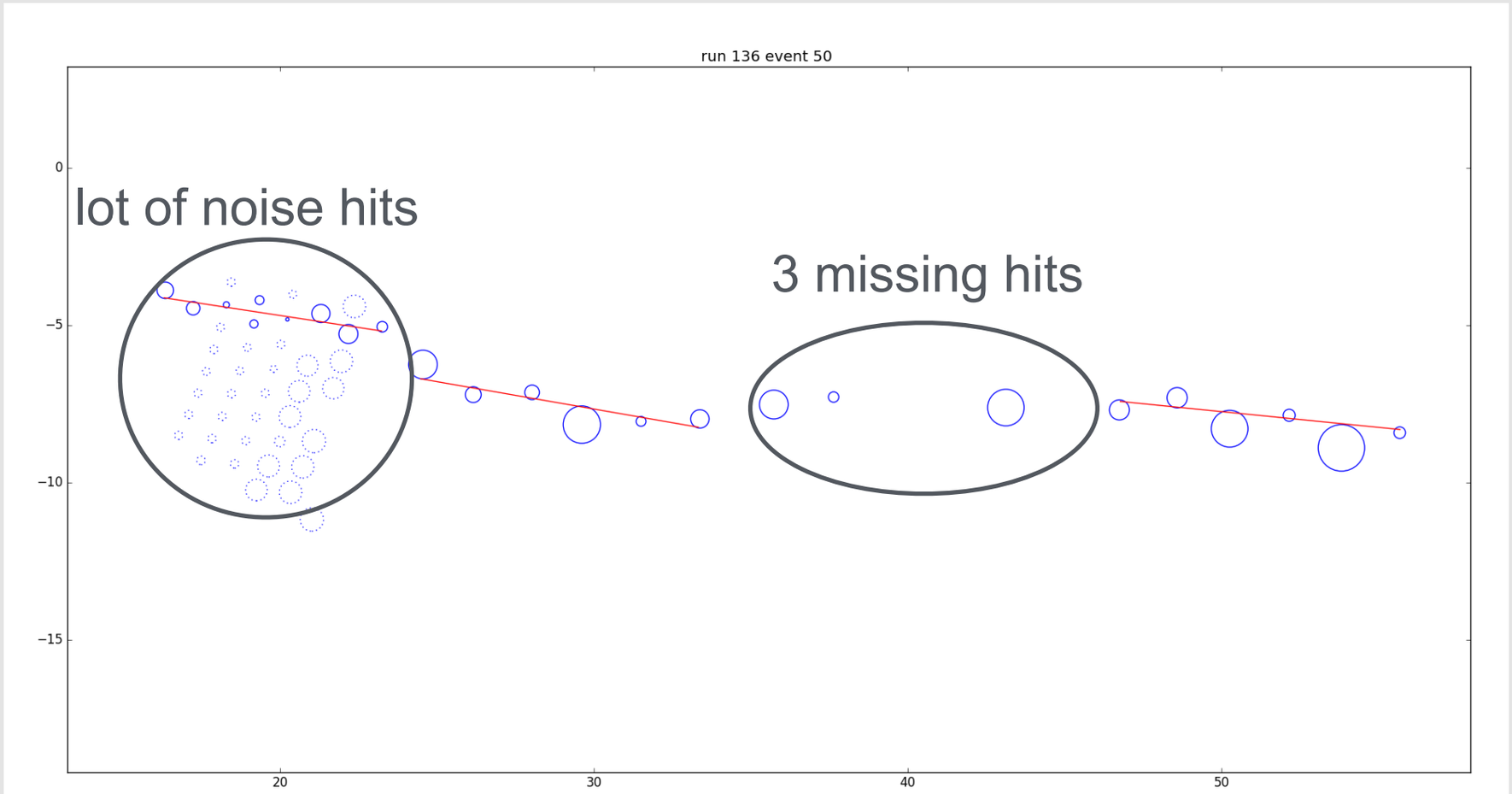
- Motivation
- First look at data
- Track and drift model
- Segment finding
- Segment linking
- Track combination
- Look at MC data

Motivation

- ⋆ Get experience with first 'real' CDC data
  - Cosmics 2016: B=0, single or double leg
- ⋆ Test alignment and calibration with GBL, MPII
- ⋆ Lightweight setup for development and testing
  - Use Python for coding, no basf2 overhead
  - Data: raw hit information in text file (from Oliver)
  - Geometry: from hits, corrections from text file
  - XT-relation: derived from data, param. in text file
  - Still work in progress

First look at data

- Simply scanned events, prominent features
  - Some (super) layers with low single hit efficiency
  - Some noise hits: TDC but no ADC information



Track and drift model

- Track is helix (B=const) or straight line (B=0)
  - Parameters at point of closest approach:
    κ, φ_0, d_0, $\tan\lambda$, z_0
- Hit position from drift time, wire position '$\mathbf{p}_w$'
  - Drift distance 'd' as function of drift time 't' is linear plus higher order corrections
  - Drift direction '$\mathbf{e}_d$' is perpendicular to wire direction and track direction
  - Hit position for drift side 's' (± 1):
    $\mathbf{p}_{hit} = \mathbf{p}_w(z) + s \cdot d(t) \cdot \mathbf{e}_d$

Segment finding

- ★ Basics
  - Independently for each super layer
  - Assuming 3 parameters + redundancy (ndf>0) → need at least 4 hits, prepare for 2 missing layers
  - Gaps are difficult for triplets → use road search
  - Assume little curvature → use straight line
    - ✦ Need only two seeding hits
  - Start with assumption Z=0

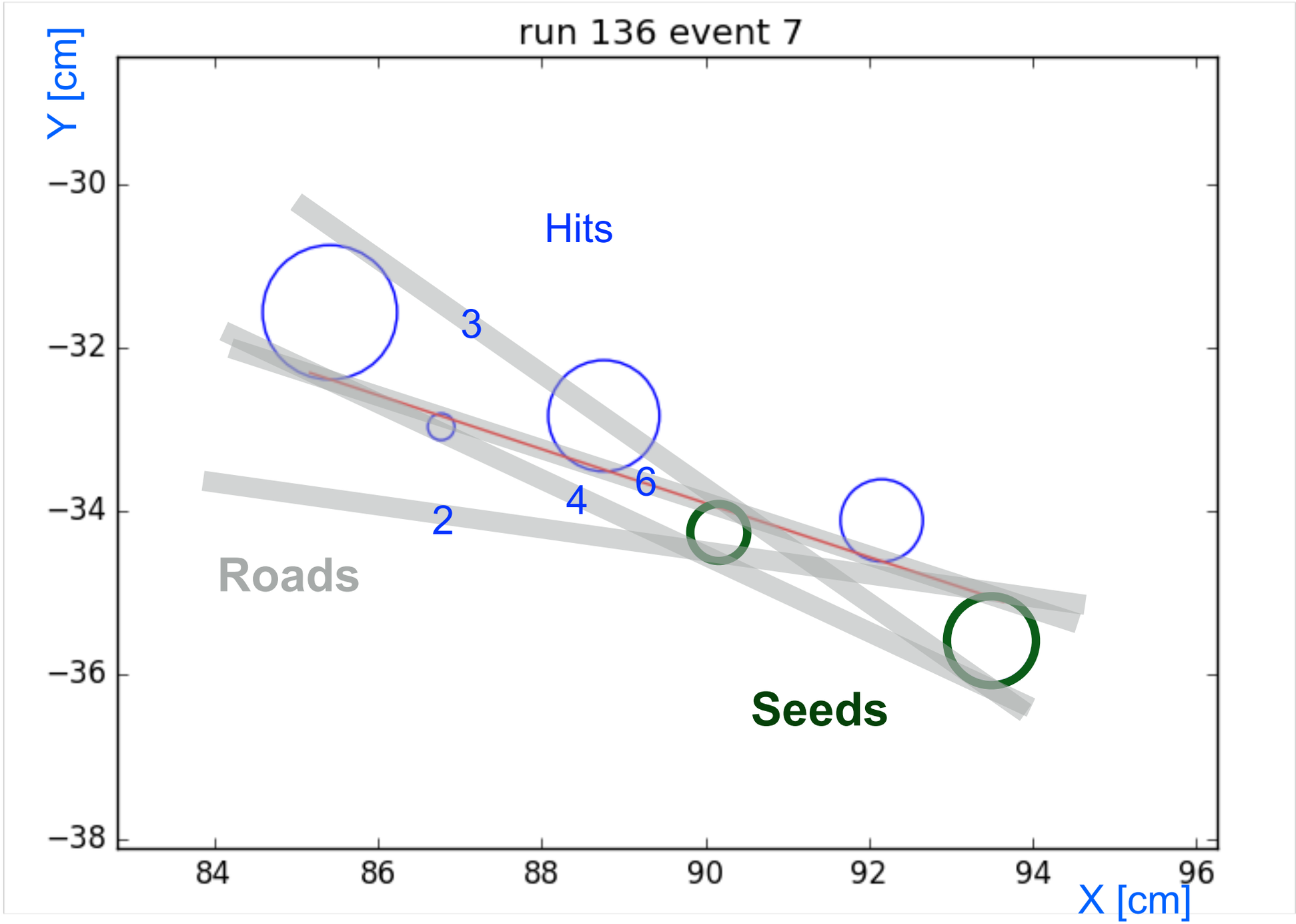
Road search (I)

- ⋆ Prepare hits
  - Take only hits with ADC information
  - Order hits by drift distance significance (d/σ_d)
- ⋆ Define seeds
  - Select hit pairs from list (in decreasing order) with 'reasonable' distance
    - ✦ e.g. $2 \leq \max(|\text{layer1}-\text{layer2}|, |\text{cell1}-\text{cell2}|) \leq 10$
  - Accounting for the drift side ambiguities they define four straight lines as search roads

Road search (II)

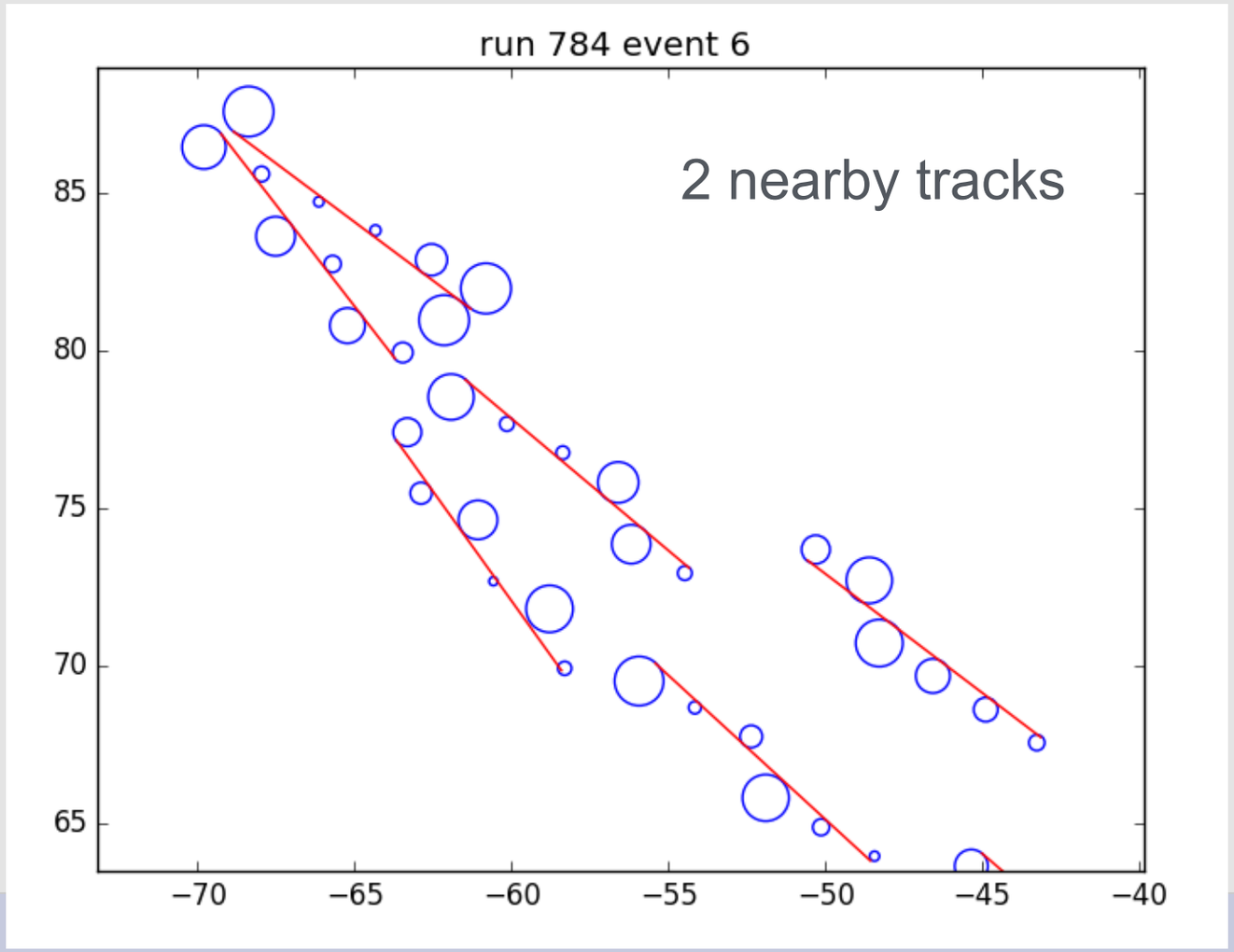
- Collect hits
  - For all unused hits check distance Δ for both drift sides to each of the four roads
  - Assign hit to all roads where distance for at least one drift side is below cut (e.g. 1 mm)
- Select candidate
  - From all roads with at least 4 hits select the one with most hits (and smallest $\sum\Delta^2$)
  - Create segment from hits of that road, mark hits as used and restart road search

Road search (III)

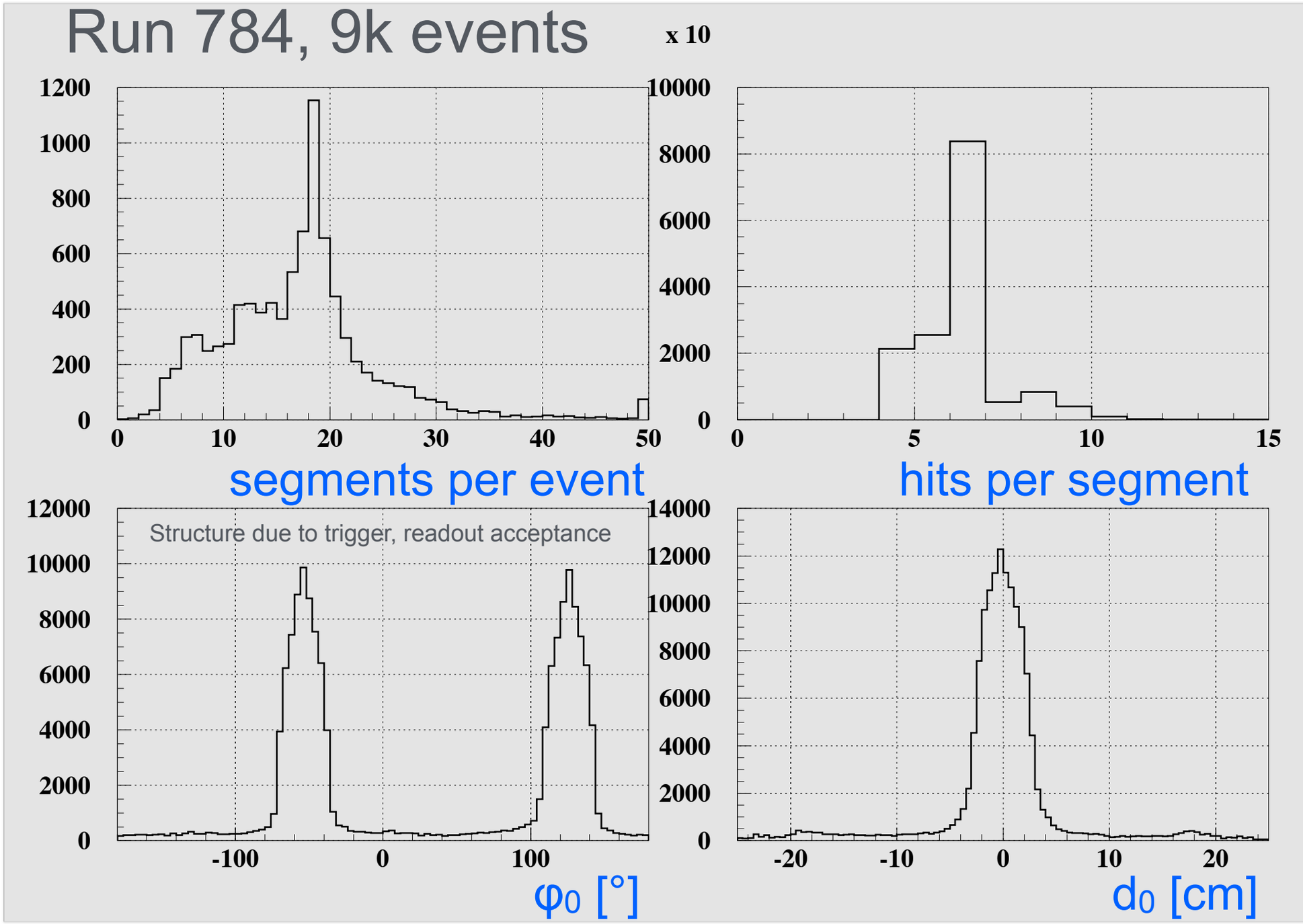


Track segments (I)

- ★ Straight line (in XY at Z=0)
  - Parameters: φ_0, d_0, t_0
    - ✦ Fit t_0 correction to account for flight and propagation time and trigger time for cosmics
  - Hits selected with both drift sides
    - ✦ Set side to '0'
    - ✦ Wire as hit position
    - ✦ Inflated error σ_d^2 += d^2



Track segments (II)



Segment linking

- ★ Basics
  - Use Fast Hough Transformation
    - Tolerant with respect to missing segments
    - Require some axial and stereo segments
  - Transform 2D segments to 5D (4D for B=0) tracks
    - $\mathbf{p}_{seg} \rightarrow \mathbf{p}_{track}$: φ_0, $d_0 \rightarrow$ (κ,) φ_0, d_0, $\tan\lambda$, z_0
    - With arc length 's_{arc}', average Z-component 'ζ' of drift directions of segment (and small curvature)

$$\frac{\partial \mathbf{p}_{seg}}{\partial \mathbf{p}_{track}} = \begin{pmatrix} s_{arc} & 1 & 0 & \zeta & 0 \\ \frac{1}{2} s_{arc}^2 & 0 & 1 & 0 & -\zeta \end{pmatrix}$$

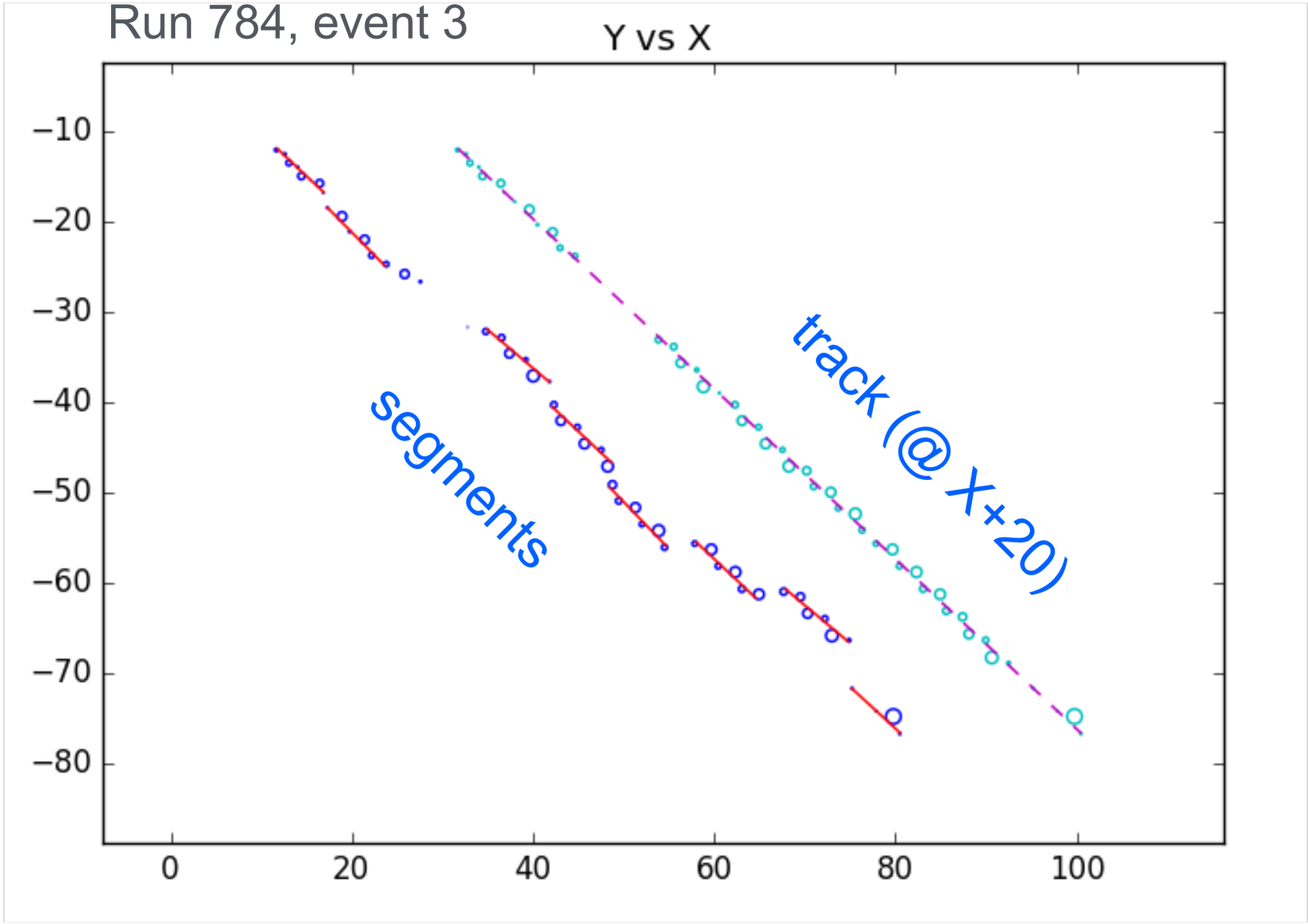
Parameter space

- ★ FHT needs predefined parameter space
  - Especially for azimuth φ_0
- ★ Use dynamic azimuth sectors of size $\Delta\varphi=1$
  - From unused segments build sorted list of φ_0
    - Add segments with $\varphi_0 < \Delta\varphi-\pi$ a second time at $\varphi_0+2\pi$ to bridge gap at $\pm\pi$
  - With sliding window find azimuth sector containing largest number of segments
  - Run FHT on azimuth sector
    - Centered at $\langle\varphi_0\rangle$, median(d_0) from contained segments

Track definition

- Requirements for FHT solution
  - Minimum number of segments, e.g. 5
  - Minimum number of segment types (AUV), e.g. 2
- Prefer long tracks
  - Iterate number of segments cut
    - Start with maximum number of super layers available in azimuth sector, reduce until minimum if no solution found
- Accept solution as track
  - Segments marked as used, commonly fitted
  - Restart FHT for sector, restart sector definition

Track found example



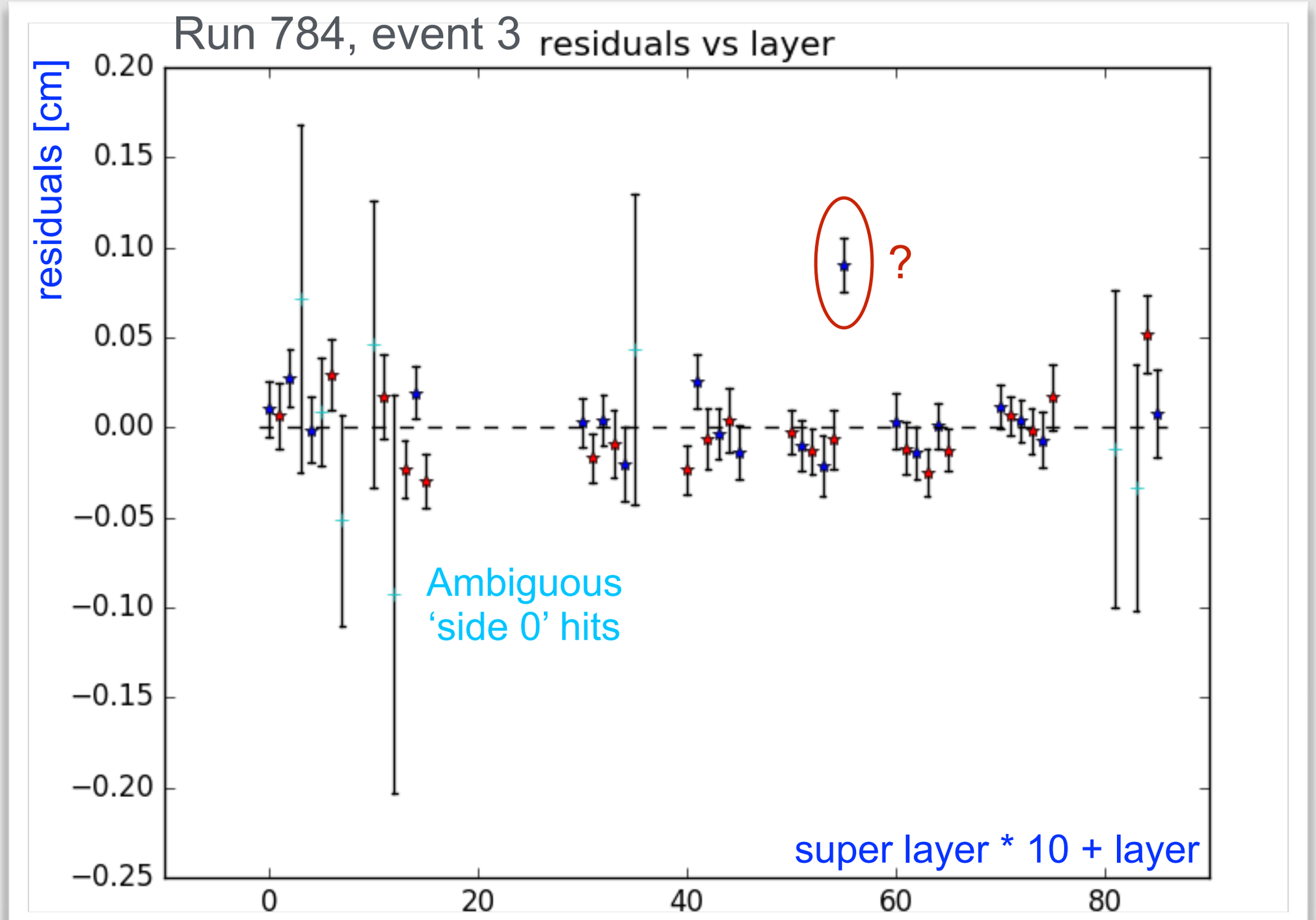
Track fitting

- Simple linear least square fit
  - 5 (4 for B=0) track parameters and optionally t_0

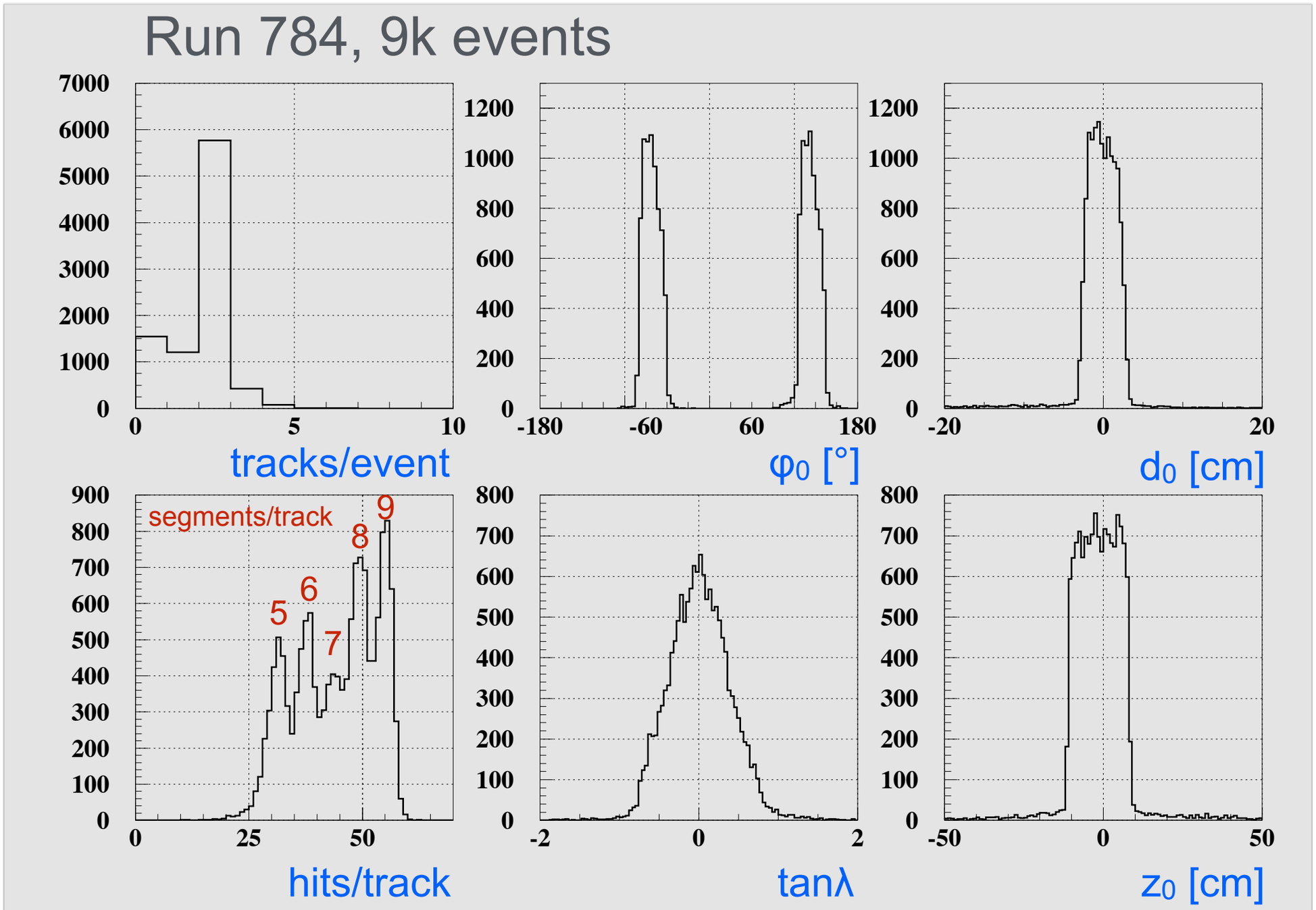
$$\frac{\partial d}{\partial \mathbf{p}_{track}} = \left(\begin{array}{ccccc} \frac{1}{2} s_{arc}^2 & s_{arc} & -1 & \zeta \cdot s_{arc} & \zeta \end{array} \right) \quad , \frac{\partial d}{\partial t_0} = s \quad \text{(side)}$$

  - Optionally use prediction to resolve drift side again for all hits or only for 'side 0' hits
- GBL
  - Refit with GBL and global derivatives for alignment and calibration
  - Write trajectory to MPII binary file

Track fitted example



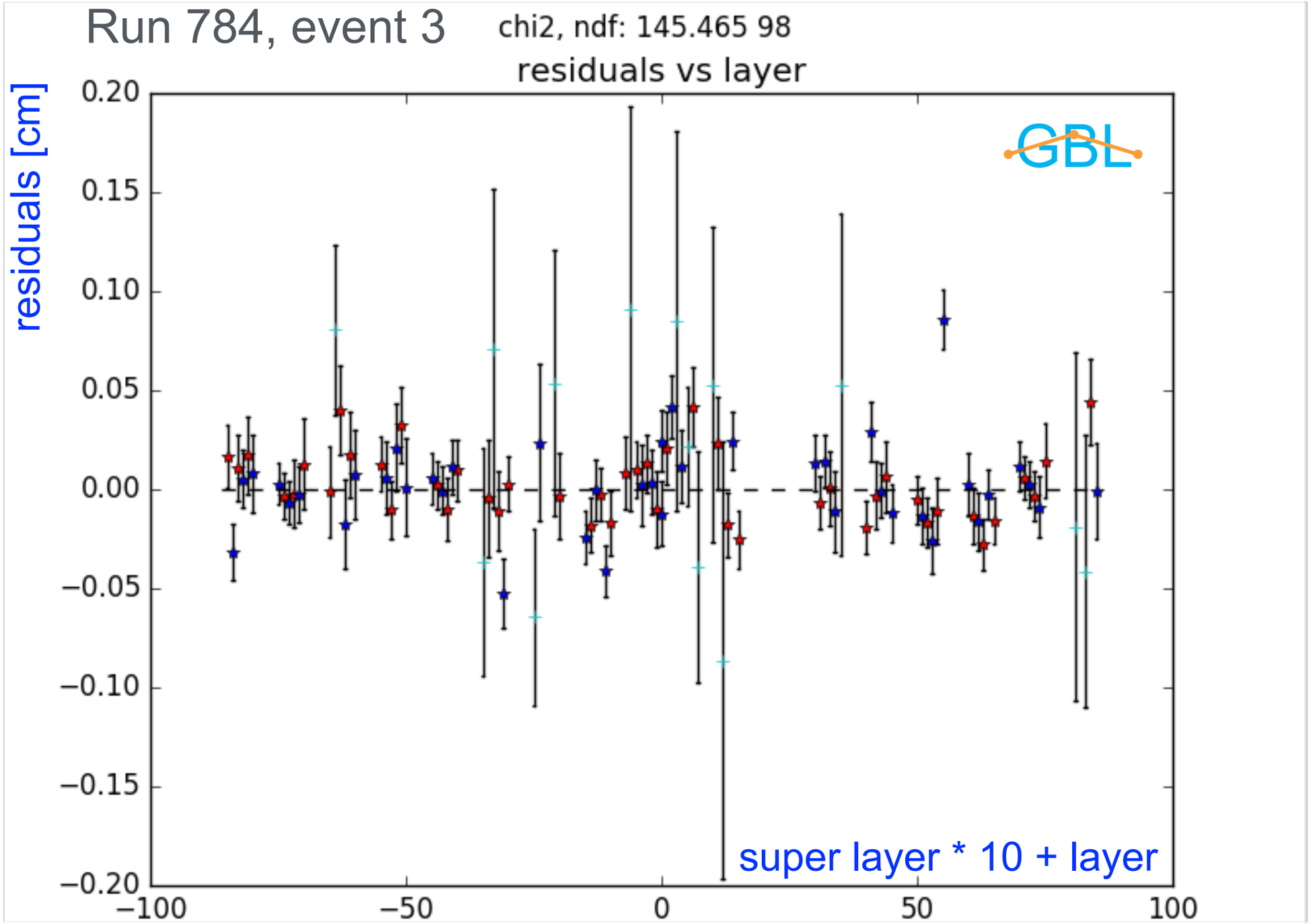
Track plots


Run 784, 9k events
tracks/event
segments/track
5
6
7
8
9
hits/track
φ_0 [°]
tanλ
d_0 [cm]
z_0 [cm]

Track combination

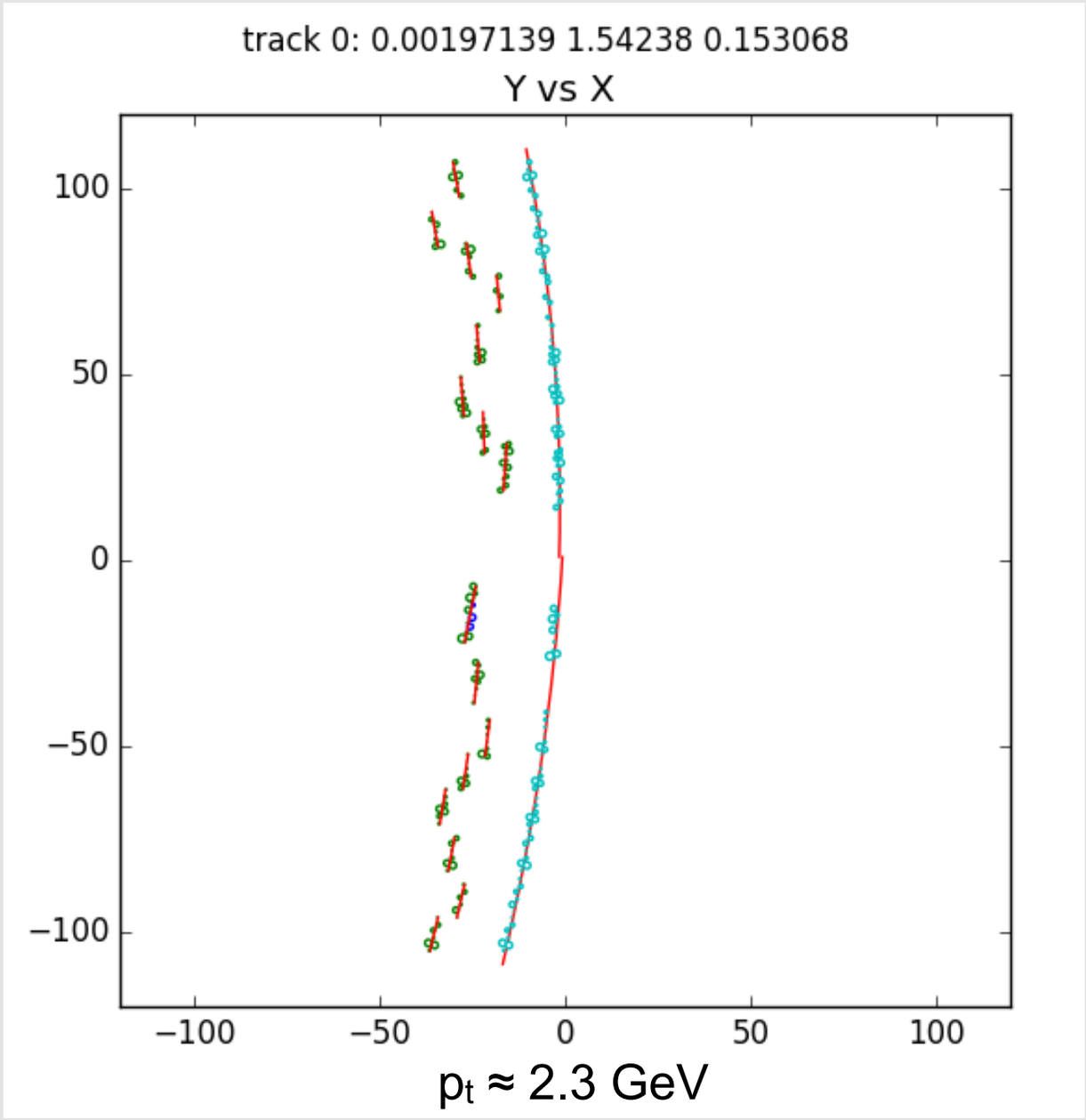
- For cosmics combine both legs into single track
  - Use all tracks with $\varphi_0>0$ as incoming tracks
  - Look for matching outgoing track ($\varphi_0<0$)
  - Cut on χ^2 from difference of track parameters and sum of covariance matrices
    - Add 3 mrad as average multiple scattering error in trigger scintillator/lead sandwich at PCA for φ, λ
  - For GBL trajectory add corresponding scatterer

Track combined example

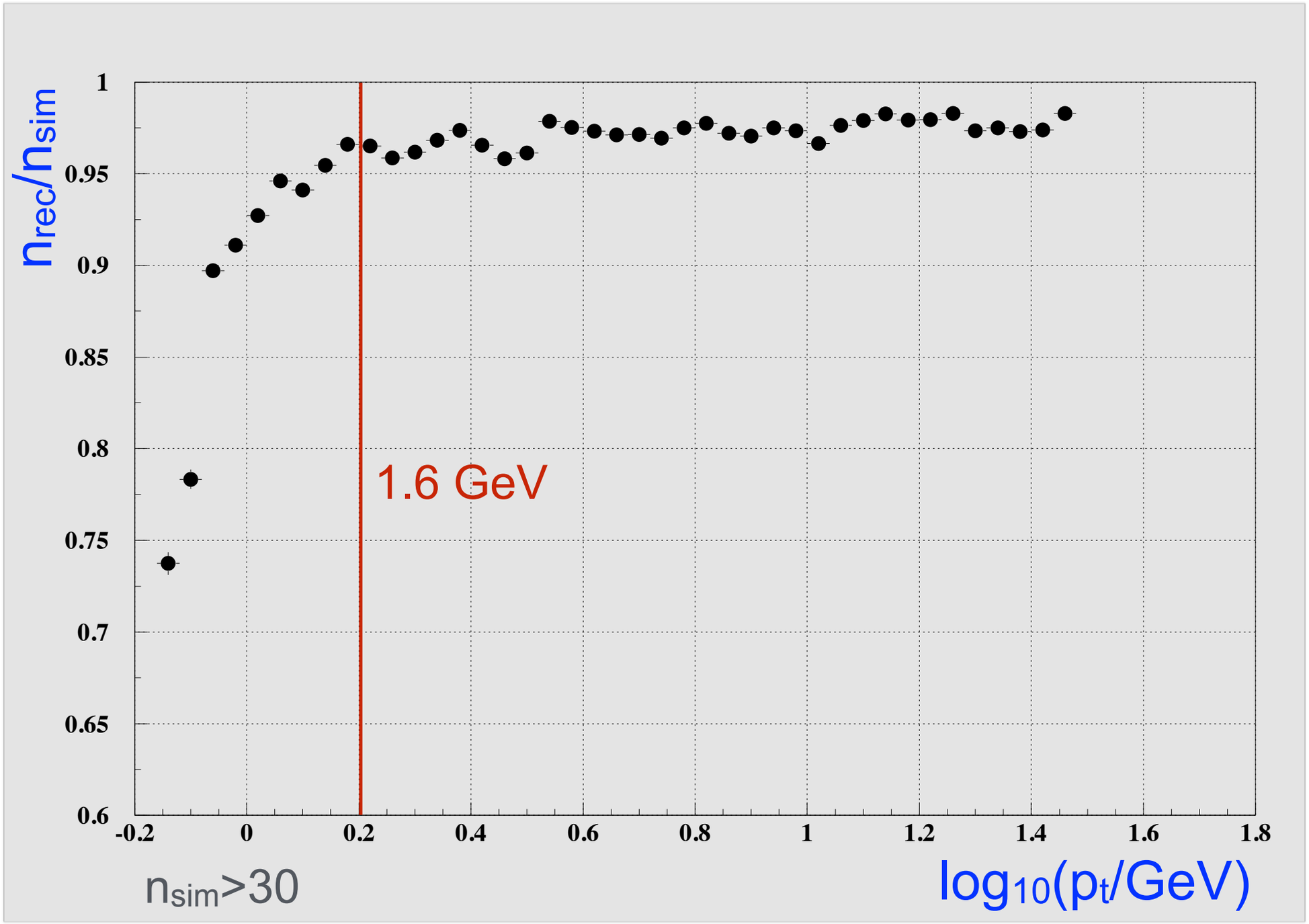


Look at MC cosmics with B on

- Straight line segments
  - Any good for B on ?
- Scanned some events
  - 'Fine' down to few GeV
- More systematic study
  - Check fraction of reconstructed to simulated hits as function of p_t



MC cosmics - hit fraction



Summary

- Track finding and fitting developed for field off cosmics in python
  - Simple road search, FHT, GBL
  - Timing: 500-600 tracks / min.
- Try too for field on cosmics (2017)
  - and other data (e.g. mu-pairs) ?
  - extend curvature acceptance ?