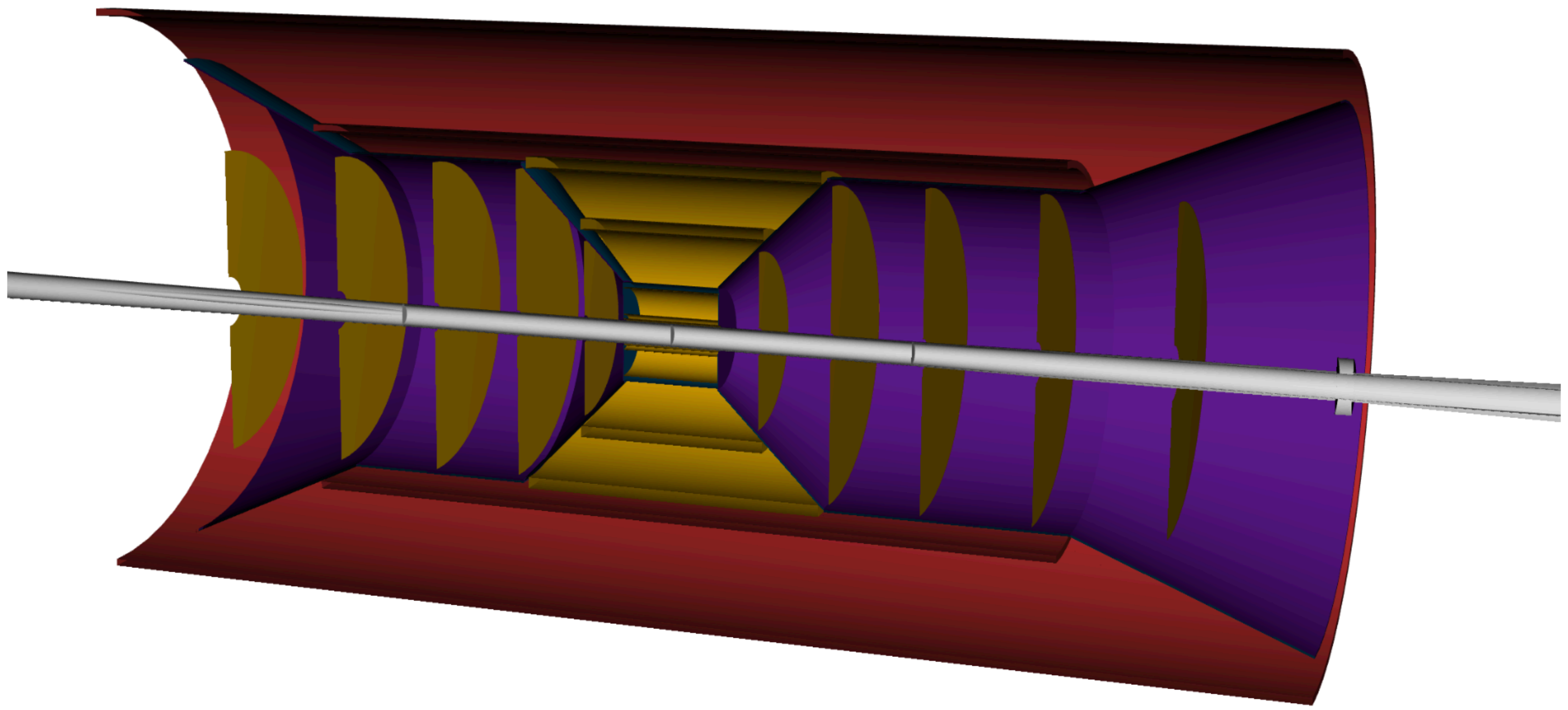
# Track Recognition and Hit Filtering

eRNST Sichtermann — LBNL

EIC Local Mtg.
February 21, 2023

# Reminder - October 2022 Geometry



Updated barrel reference geometry:

- 2 curved silicon vertex layers, r = 36, 48 mm, l = 270mm
- 1 curved silicon dual purpose layer r = 120mm, l = 270mm
- 1 stave-based sagita layer r = 270 mm, l = 540 mm
- 1 stave-based outer layer r = 420 mm, l = 840 mm

Updated disk reference geometry:

- 5 disks on either side of the nominal IP,
  - z = -250, -450, -650, -900, -1150 mm
  - z = 250, 450, 700, 1000, 1350 mm
  - inner radii >= 36 mm, outer radii <= 430 mm

The simulation implementation of the disks has a (near-) **circular** and **centered** beam openings that surround the beam pipes. They are **not** "minimal envelopes" around the beam-pipes. They are **not** based on the current understanding of sensor layout either. Addressing this before the March campaign would seem a decent goal, in my opinion. (Early insights can be gleaned e.g. from Stephen Maple's work with alternative radii.)

This limitation enters and affects studies, for example of low-$Q^2$ acceptance, that are now starting.

One can estimate the transverse momentum threshold for each of the detection layers "on the back of an envelope" form the (t)wiki geometry, $p_T$ [GeV/c] > ~0.3 × 1.7 [T] × r [m] / 2. This implies a **total momentum threshold** of **p > ~0.35 GeV/c** to be within the acceptance of the outermost disks.

One can also to count the number of traversed layers, N, within the acceptance "on the back of that same envelope." The acceptance of the innermost vertex layer is **$|\eta|$ < 2.0**. The inner radius of the innermost disks corresponds to **$|\eta|$ ~ 2.6**. With these arrays of five disks, one should not expect to traverse more than four detection layers for **$|\eta|$ > 2.6**. One should not expect to traverse more than three detection layers for **$|\eta|$ > 3.2**. One should not expect to track beyond **$|\eta|$ ~ 3.6** (in both directions) with this type of configuration.

There is not really a "free lunch" in disk placement; one way to think about this is that the inner and outer radii "couple" acceptance (outside of the cone region).

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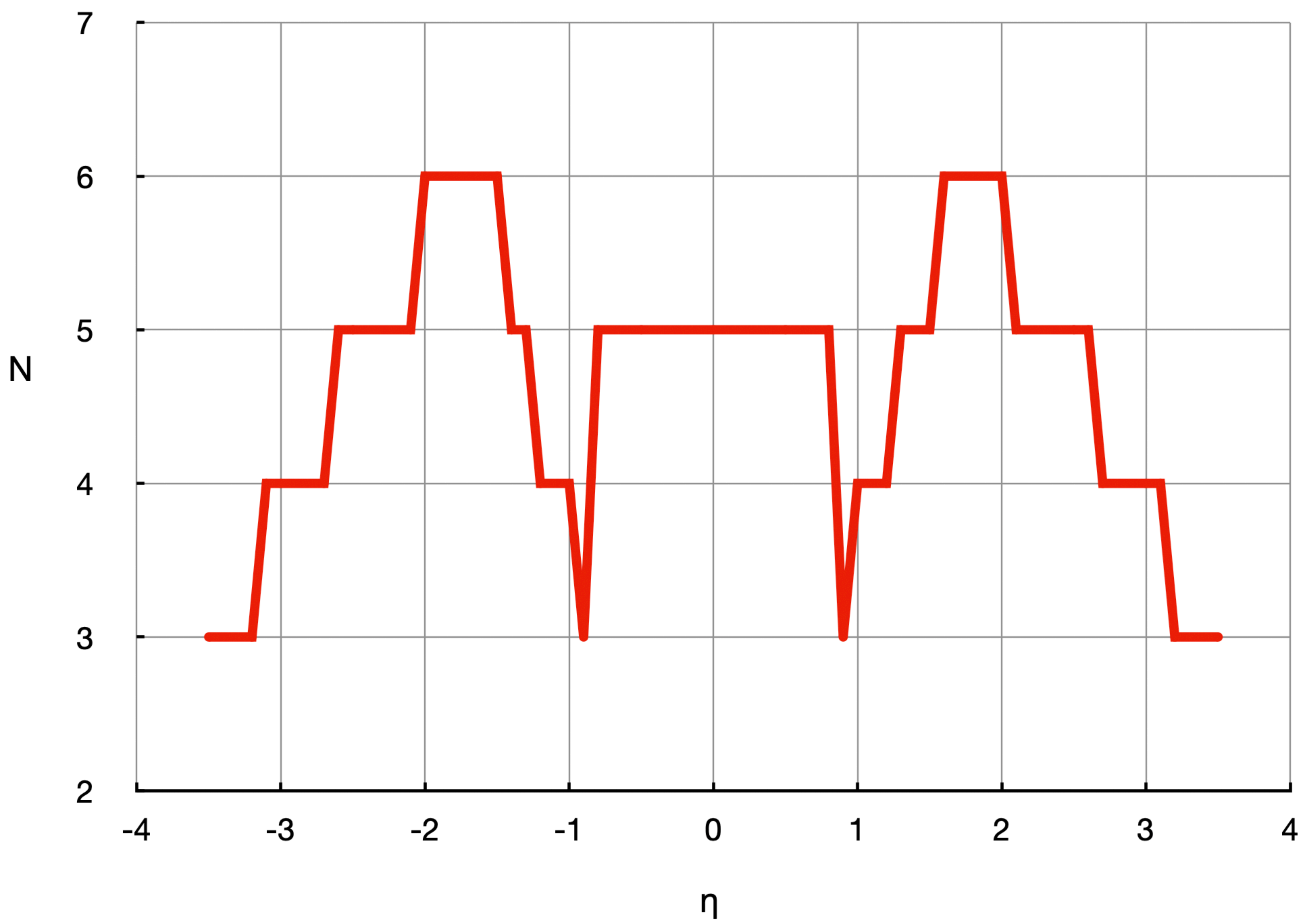


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One can also to count the number of traversed layers, N, within the acceptance “on the back of that same envelope.” The acceptance of the innermost vertex layer is **$|\eta| < 2.0$**. The inner radius of the innermost disks corresponds to **$|\eta| \sim 2.6$**. With these arrays of five disks, one should not expect to traverse more than four detection layers for **$|\eta| > 2.6$**. One should not expect to traverse more than three detection layers for **$|\eta| > 3.2$**. One should not expect to track beyond **$|\eta| \sim 3.6$** (in both directions) with this type of configuration.

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# Track Recognition and Hit Filtering

In what follows, I will focus on an angle of 175$^o$, corresponding to $\eta \sim -3.1$. This is in the electron direction. Charged tracks at this $\eta$ are within the acceptance of the four disks at most negative z. The innermost disk has no acceptance for this $\eta$; same for the vertex layers.

The event samples are single charged-pion tracks with random energies in the range of 1—5 GeV (1), 0.5 — 1 GeV (2), and 10 GeV (3). The charge-sign is randomly positive or negative. The azimuthal angle is randomized between 0 and 360$^o$. The hits in these events originate from fast simulations and include multiple scattering (the energy preserving part), as well as digitization (10 $\mu$m pitch).

The disks within the acceptance have an outer radius of 0.43 m. Their area is ~0.58 m$^2$. For a pixel pitch of 10 × 10 $\mu$m, this implies that the disks have approximately 5.8 × 10$^9$ pixels. In any given event, one may thus expect some spurious hits from noise (in addition and separate from any backgrounds).

It is up to the collaboration to demonstrate that the instrument can accomplish the science. The question if the number of disks is sufficient from a track finding point of view is thus valid. We are being asked that question and related questions, and are facing challenges in getting to answers with the ePIC software stack.

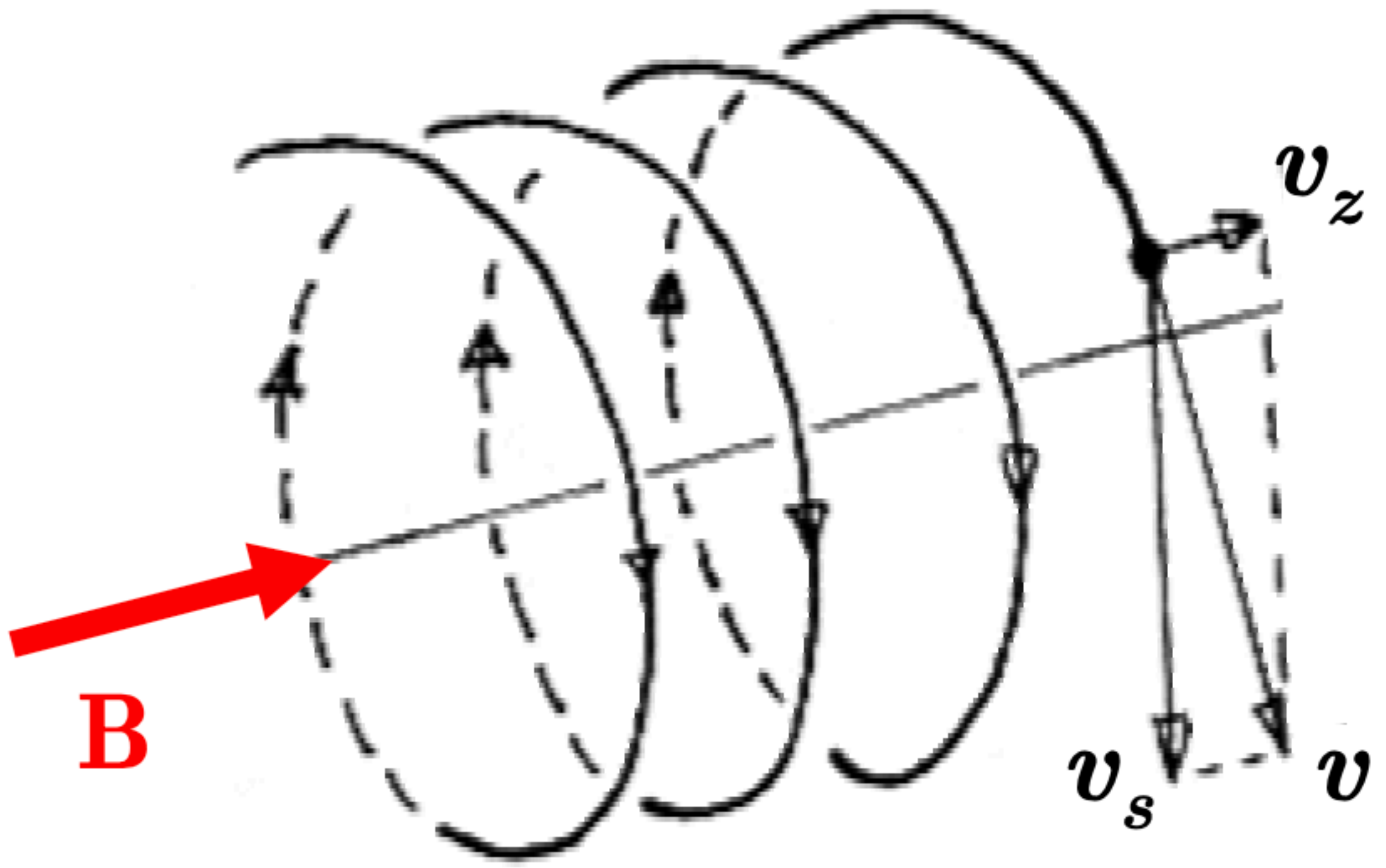
These answers are needed, on increasingly tight timelines. My goal is not to criticize that stack, ACTS, or your favorite tool, but I did consider it timely to revisit my notes from an early phase of the generic R&D and consider an alternative.

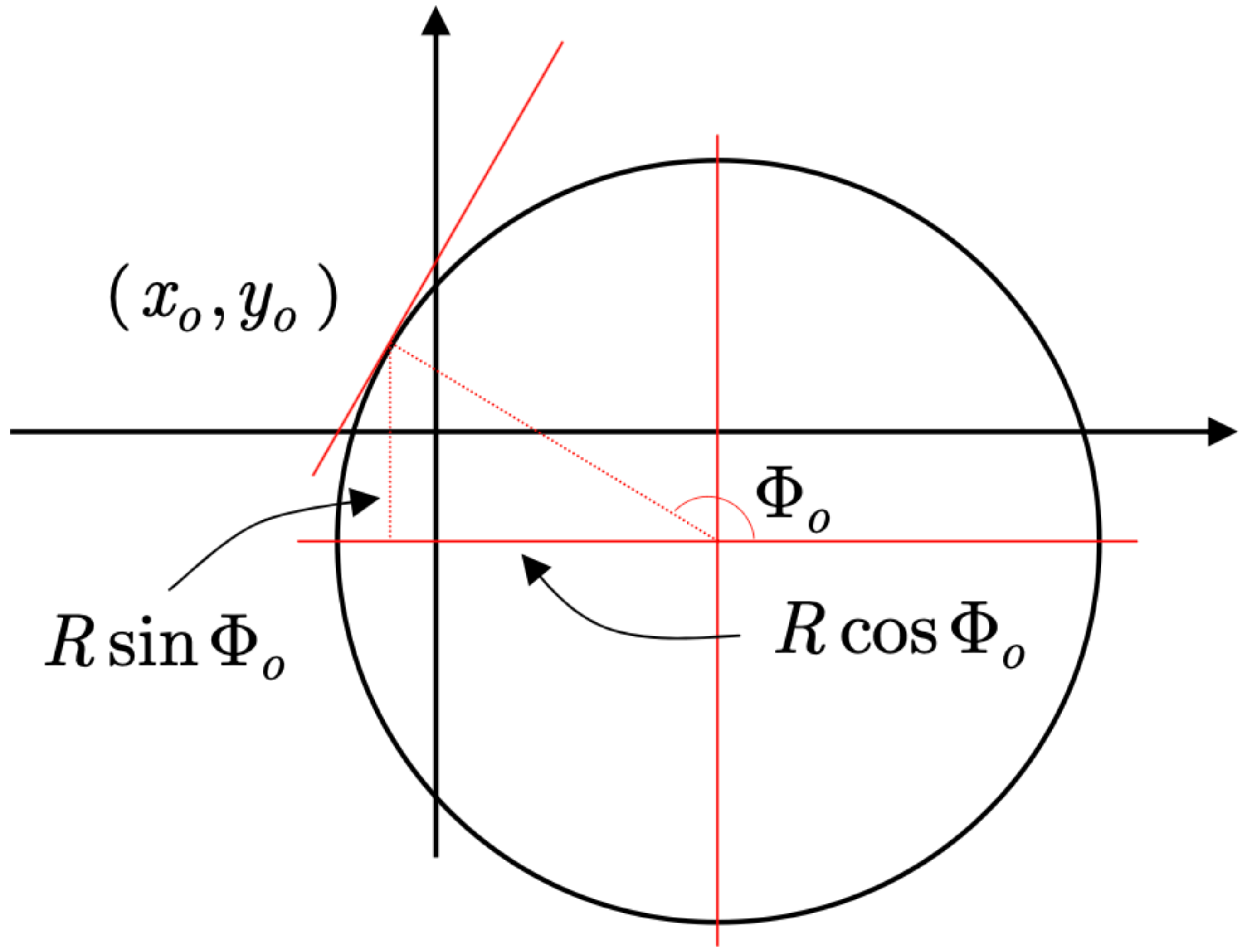
# Track Recognition and Hit Filtering

We know that tracks are helical, at least approximately. Typical radii near $\eta \sim -3.1$ are $r \sim p_T/(0.3 \times B) \sim 1.7$ m for (total) $p \sim 10$ GeV. The pitch of the helix is (well) beyond the path-length within the acceptance.

With the z-axis along the beam-line, the projection onto x-y plane is thus a circle (segment). The projections onto x-z and y-z are sinusoidal and out of phase.

Among the "standard" approaches, at least since UA1 — see e.g. V. Karimaki UA1/TN/82-24 (1982) — is to consider a conformal transformation in the x-y plane to straighten the circle segments. This would then be followed by line-recognition. A helix is, furthermore, a straight line in the s-z plane with s the path length along the helix.



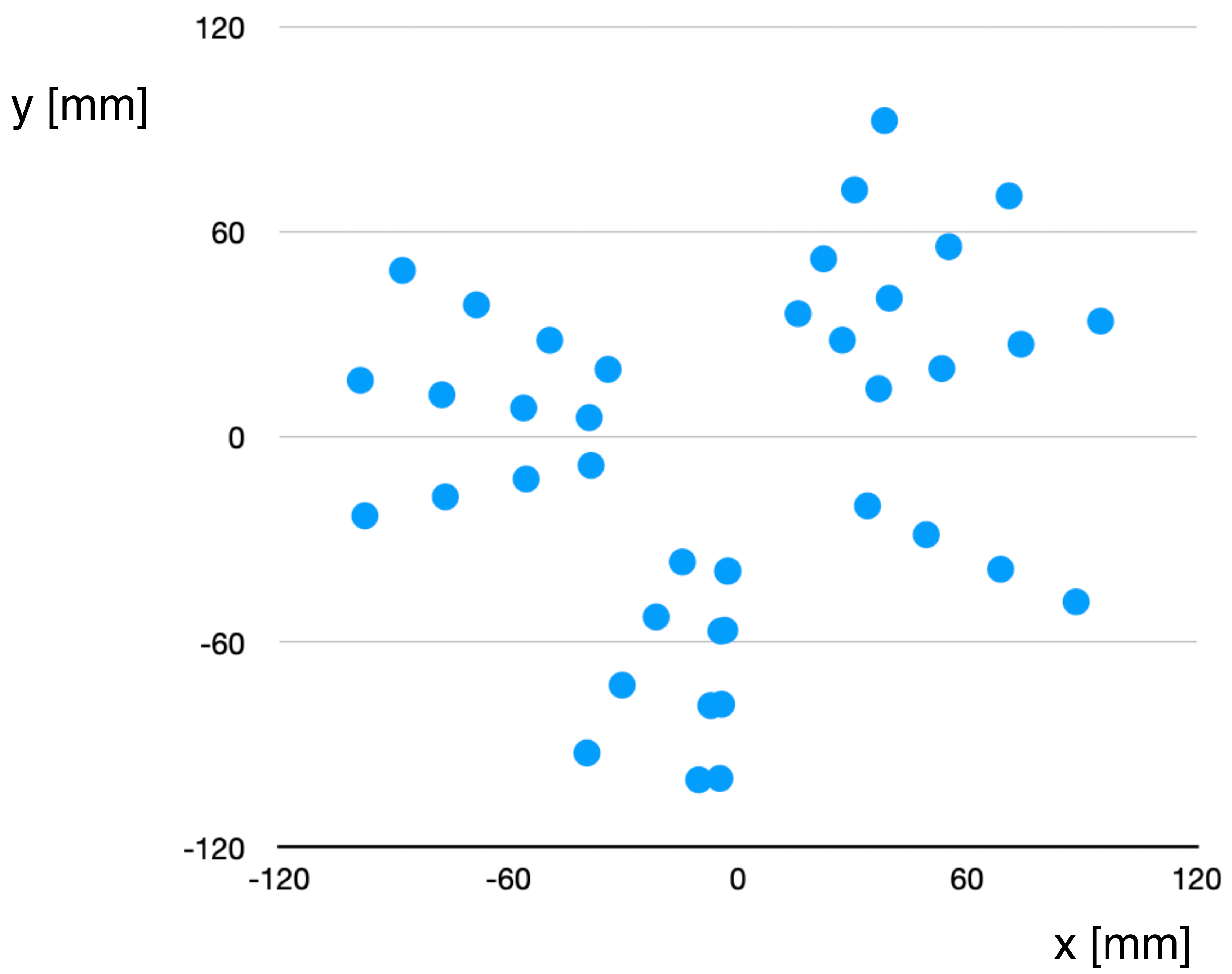

A priori, we do not know the origin of the helix, nor its radius, etc.

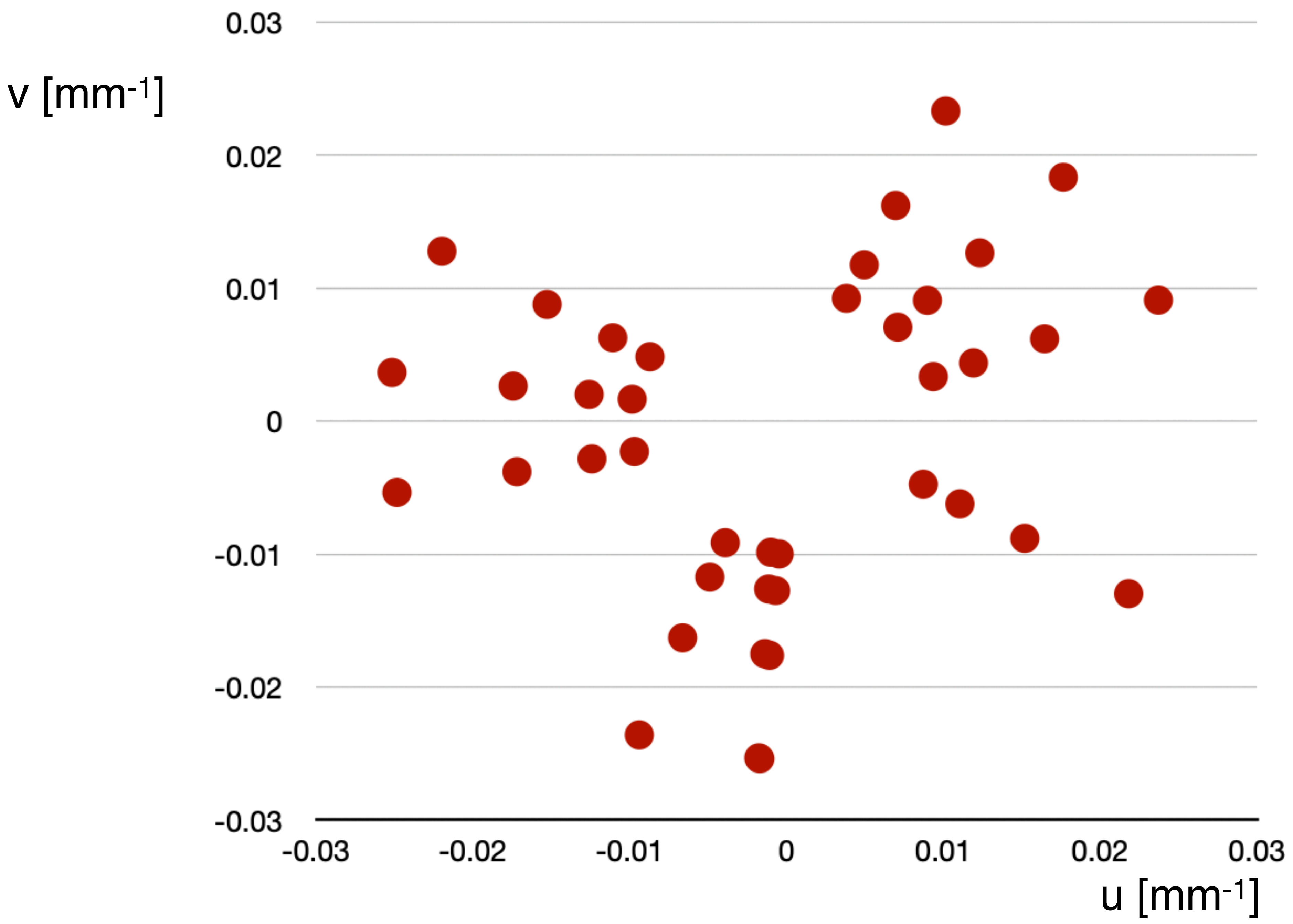
# Track Recognition and Hit Filtering

To arrive at some answers “on a clock”, I made some crude shortcuts (and wrote some minimally viable C code),

Specifically, I considered a conformal mapping in the x-y plane with (0,0) as the origin — which is in effect a (weak) beam line constraint — and use the *r*-z plane instead of the *s*-z plane. The r-z plane is lossy in the azimuthal angle; the dependence is reasonably linear (at least more so than x-z or y-z).

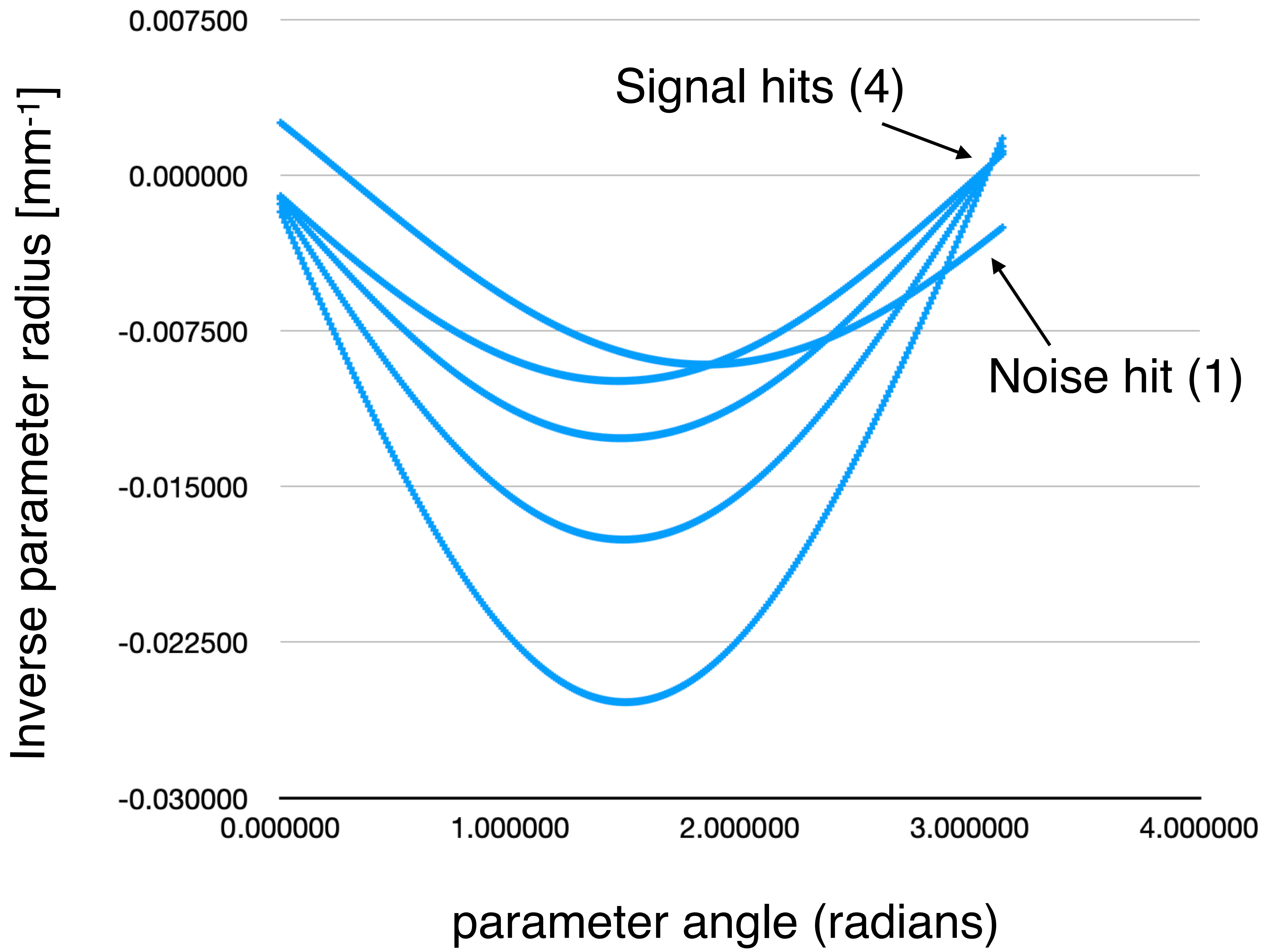
Ten events in x-y (left) and u-v (right). Yes, the lines on the left are curved and the ones on the right do not go through the origin.

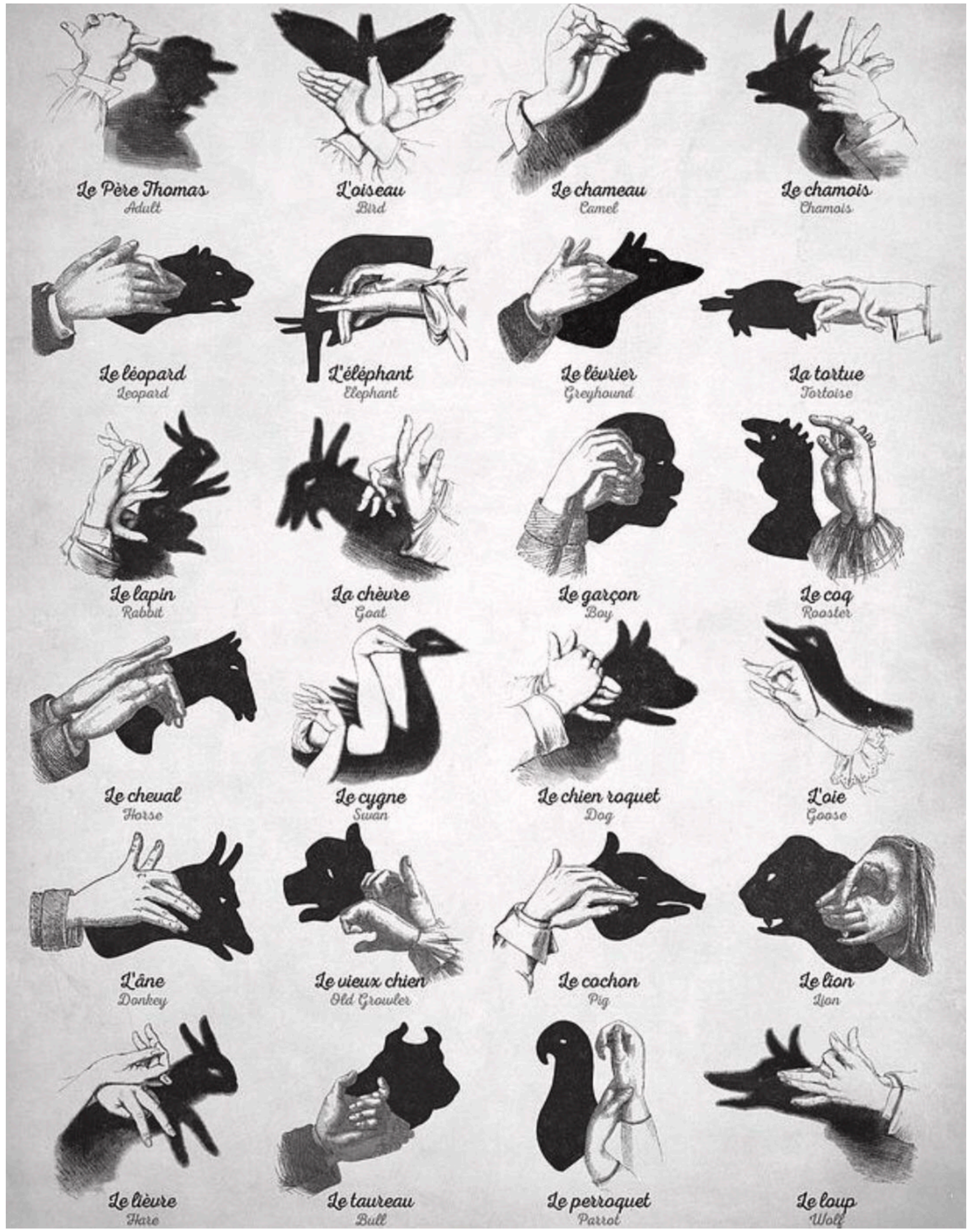


# Track Recognition and Hit Filtering

Apply Hough transforms — turning hit points into lines — to x-y and r-z *separately*. Fill histograms with the line parameters and look for values (crossings) over a threshold.




*A playful word of caution on projections…*

# Track Recognition and Hit Filtering

Initial results, tabulating hit points that survive selections requiring more than 4 intersections from 4 different z-locations in uv and separately in rz space, while also requiring that the overlap has at least 4 points from 4 different locations (and a loose constraint on vertex-z determined from the r-z plane):

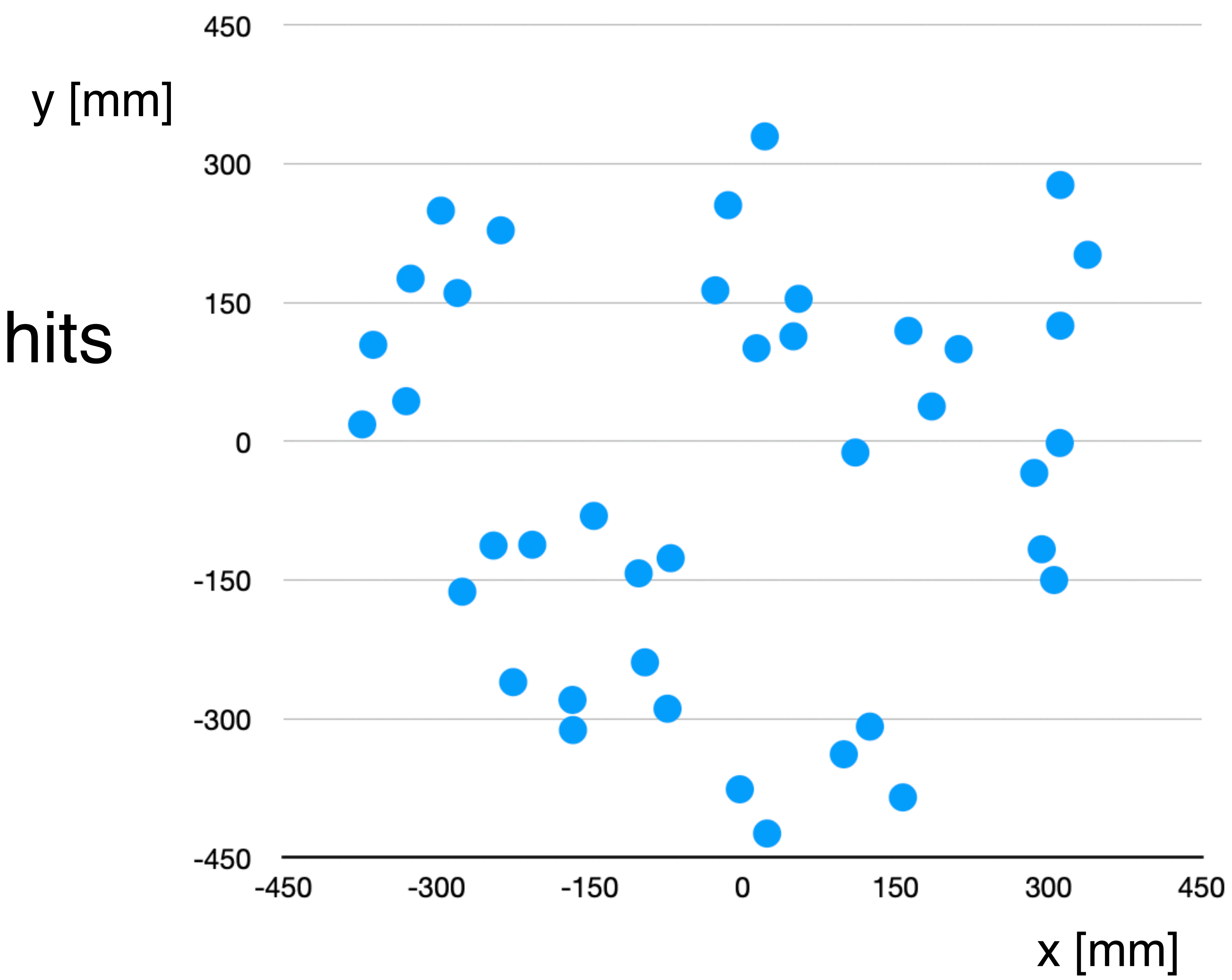
Most or all signal hits survive,

For samples with only noise hits, randomly distributed on each disk:

| | |
|---|---|
| 5 hits/disk | nothing survives |
| 10 hits/disk | 5 frames with 28 hits out of 10,000 frames with 40,000 hits |
| 25 hits/disk | 2,464 frames with 38,344 hits (out of 1M) |
| 50 hits/disk | 9,941 frames with 621,616 hits (out of 2.5M) |

If the hit on the outermost plane is constrained:

| | |
|---|---|
| 25 hits/disk | 3 frames with 13 hits |
| 50 hits/disk | 162 frames with 1,459 hits |




If a signal event is mixed with noise and the outer hit is constrained to signal, most signal is retained.

Examining "pathologies". Quite a few can very evidently be removed with an actual helix fit. Or a shortcut to restore the azimuthal correlation with z. 50 hits/disk corresponds to a $10^{-8}$ noise ratio.