Tracking with ACTS

Yee Chinn Yap (DESY)

Steps

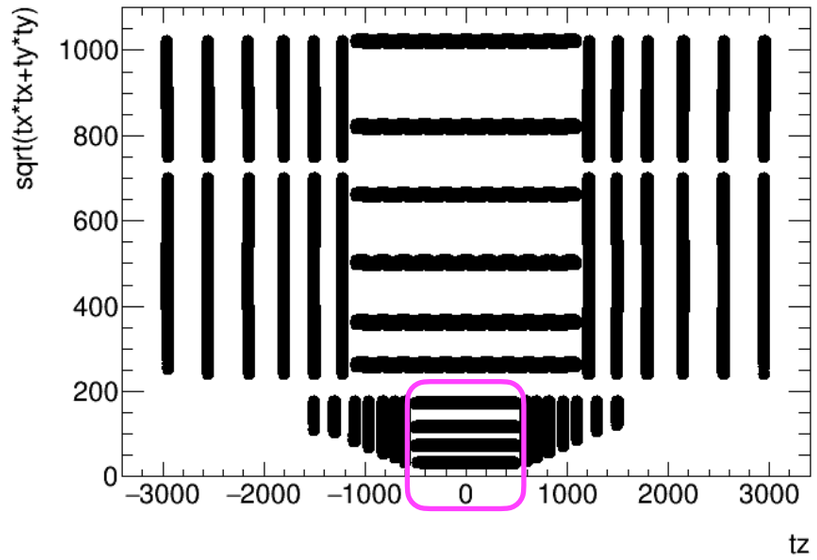
- Build tracking geometry, then propagate particles through the geometry.
- Digitise and smear hits.
- Find seeds. Seeds yield an initial estimate of track parameters that can be used to propagate the track to other parts of the detector where additional hits will be searched for.
- Track finding and fitting.

TrackParameter: (l_1, l_2, ϕ, θ, q/p, t)

- l_1, l_2: Coordinate in local surface frame
- p, ϕ, θ: Momentum and direction
- q: Charge
- t: Per-track timing info

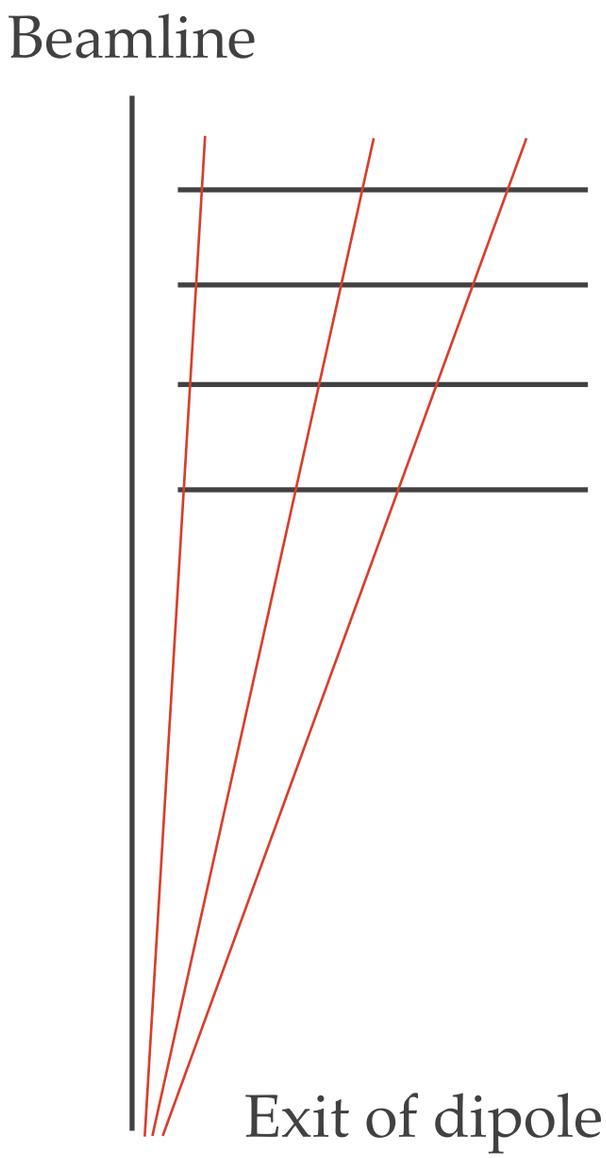
Simulation

- Fatras (FAst TRAck Simulation)
- Tracking geometry:
  - DD4hepPlugin converts full detector description into ACTS tracking geometry (surface-based).
  - XML DD4hep input adapted from OpenDataDetector (based on TrackML detector) implementation in DD4hep. Strip off everything but the four pixel layers using only one long stave (located at $\phi=\pi/2$) per layer with LUXE-like dimensions.



  - 4 layers of silicon pixel 10cm apart with the first layer 100cm away from the beam source.
  - 5cm away from the beam line.
  - Pixel size 27x29μm^2.
  - In each stave, there are 18 modules of size 15x30x0.05mm^3, with gaps of 0.1mm in between.

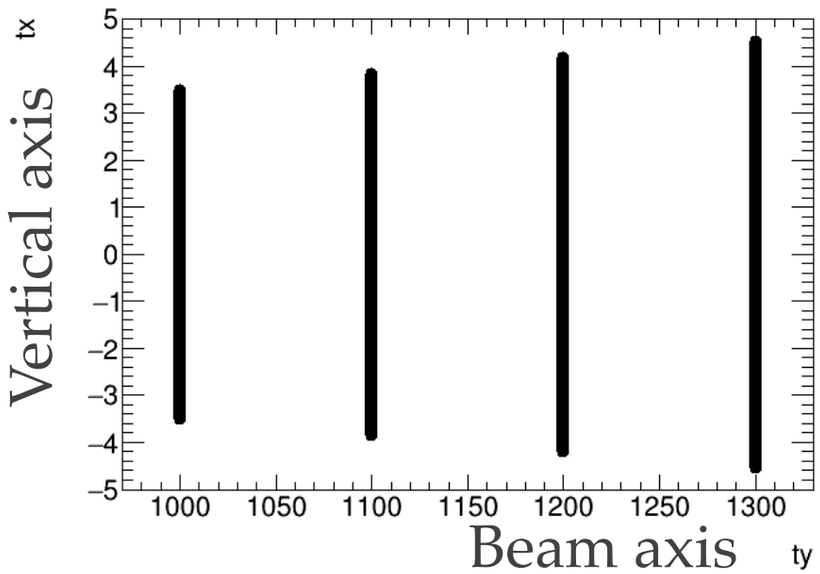
Simulation

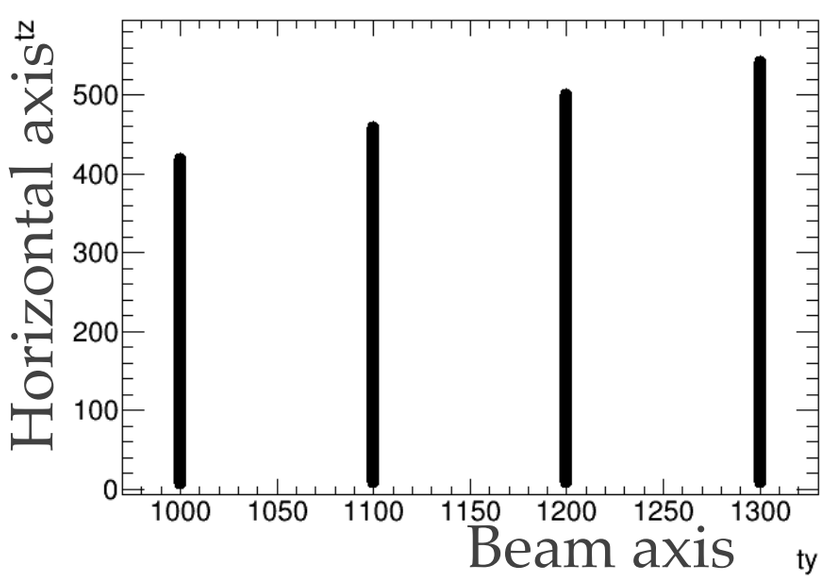


Exit of dipole magnet as beam source

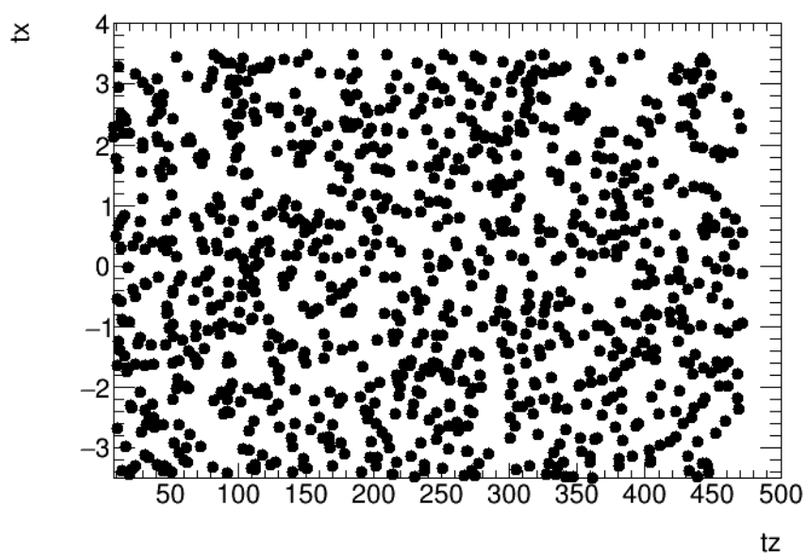
Simulation

- Due to the hacking of ODD pixel tracker, y-axis is LUXE's z-axis (z is x and x is y).
- Single event with 1000 positrons generated with phi within 0.2degrees around 90 degrees and eta within 0.001 and 0.45 (chosen such that they'd mostly hit the detector region)
- Beam source assumed gaussian with sigma=5mm.



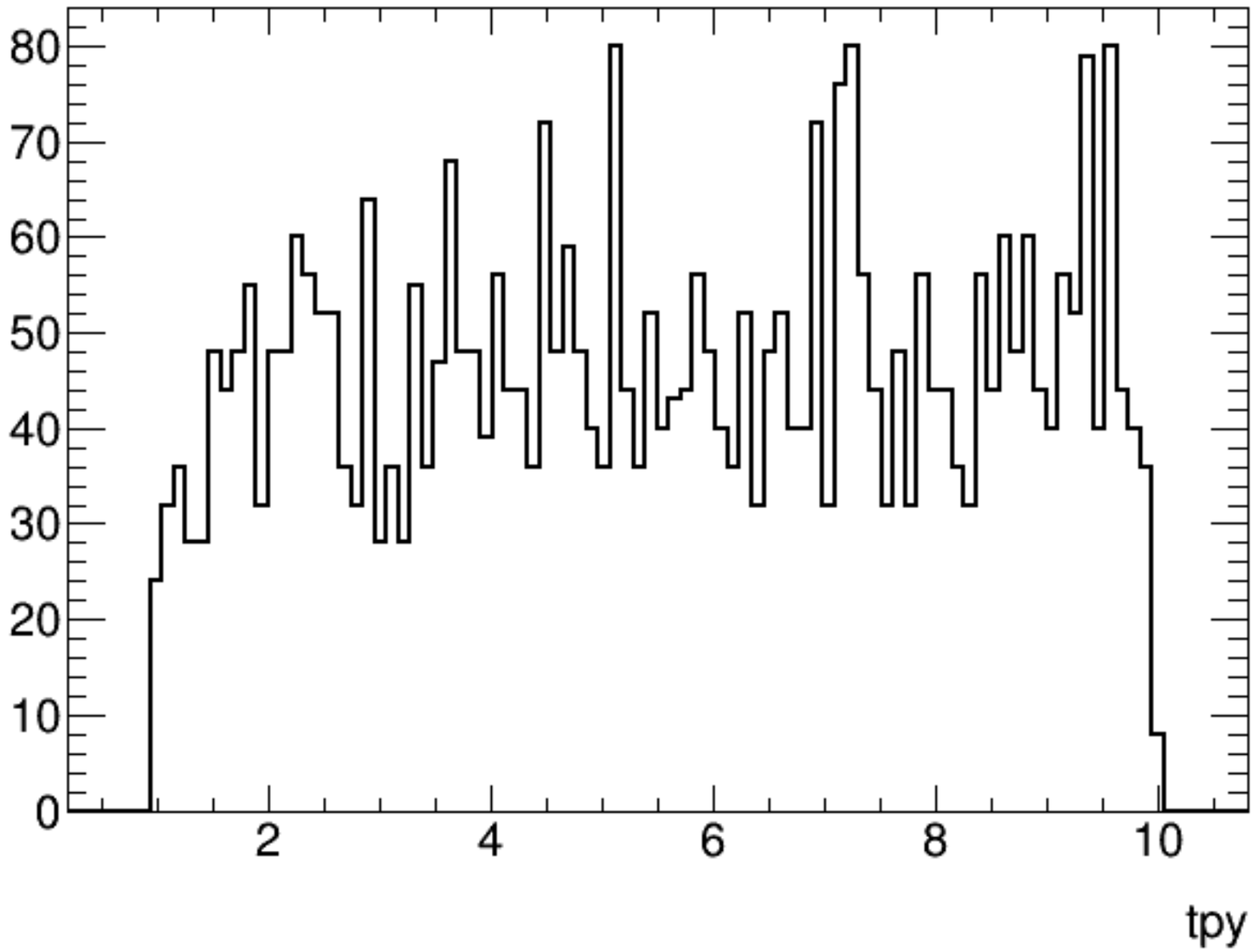


Hits distribution in first layer

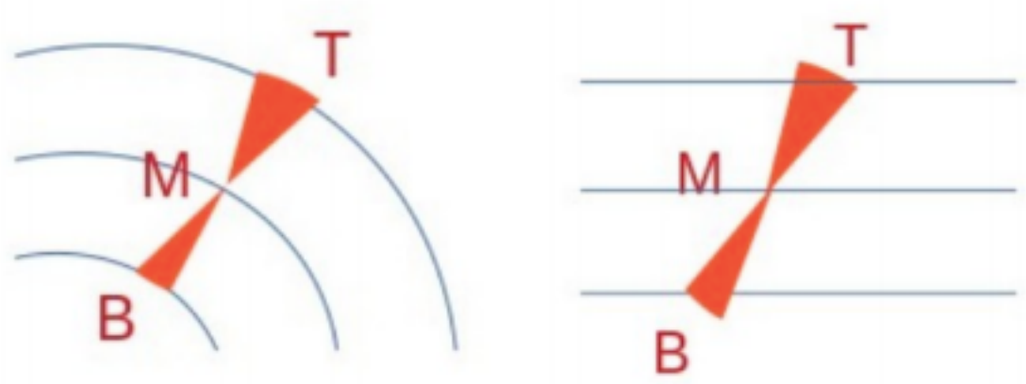


Simulation

- 1-10 GeV in longitudinal momentum with very little transverse momentum.



Seeding



- 3 spacepoints.
- For every middle SP:
  - Iterates once over bottom SP
    and then once over top SP separately. B-M and M-T tested for compatibility by applying cuts on eta (cotThetaMax), origin in z-axis (collisionRegionMin, collisionRegionMax), radial distance (deltaRMax, deltaRMin).
  - The surviving B-M and M-T are then tested together.
  - Assumes magnetic field along z=axis.
    - Helix circle calculated, from which particle energy and impact parameters can be estimated.
    - Calculates if the triplet forms a nearly straight line in the r-z plane.
- Seeds (B-M-T) are assigned weights corresponding to the likelihood that a seed is good (using impact parameter etc).

Not used, instead impose requirement on the phi direction similar to eta.

Seeding

- Consider only hits in the first three layers (can also use the fourth layer for added efficiency but will have duplicate seeds).
- The three hits are required have angles consistent with expected range and z origin consistent with beam spot (exit of dipole magnet) size.
- Without smearing of truth hits:
  - Efficiency (nMatchedParticles / nAllParticles) = 0.993833 (0.989274 with 10000 particles)
  - Fake rate (nUnMatchedSeeds / nAllSeeds) = 0 (0.0147405 with 10000 particles)
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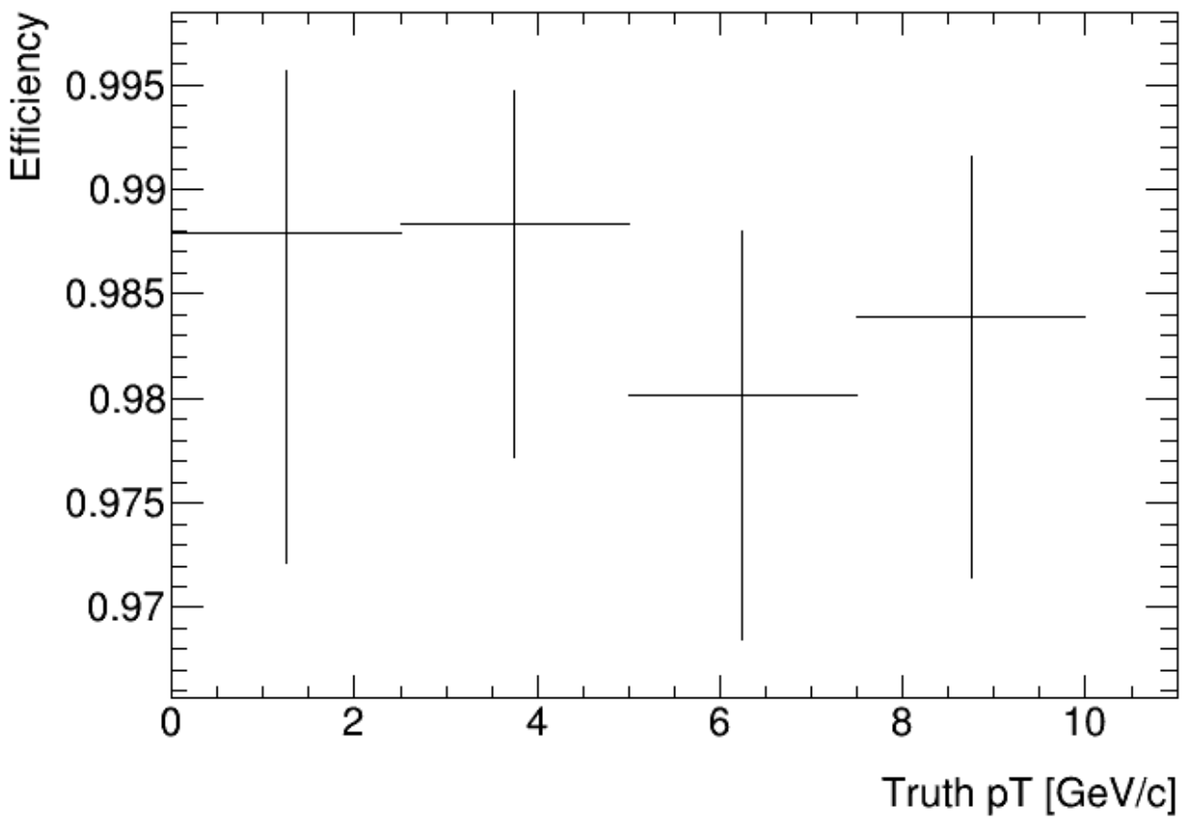
Seeding

- With smearing (std dev=0.05mm):
  - Efficiency (nMatchedParticles / nAllParticles) = 0.93628 (0.172855 with 10000 particles)
  - Fake rate (nUnMatchedSeeds / nAllSeeds) = 0.500821
- Tracking at high density becomes difficult due to combinatorial background.

Combinatorial Kalman Filter

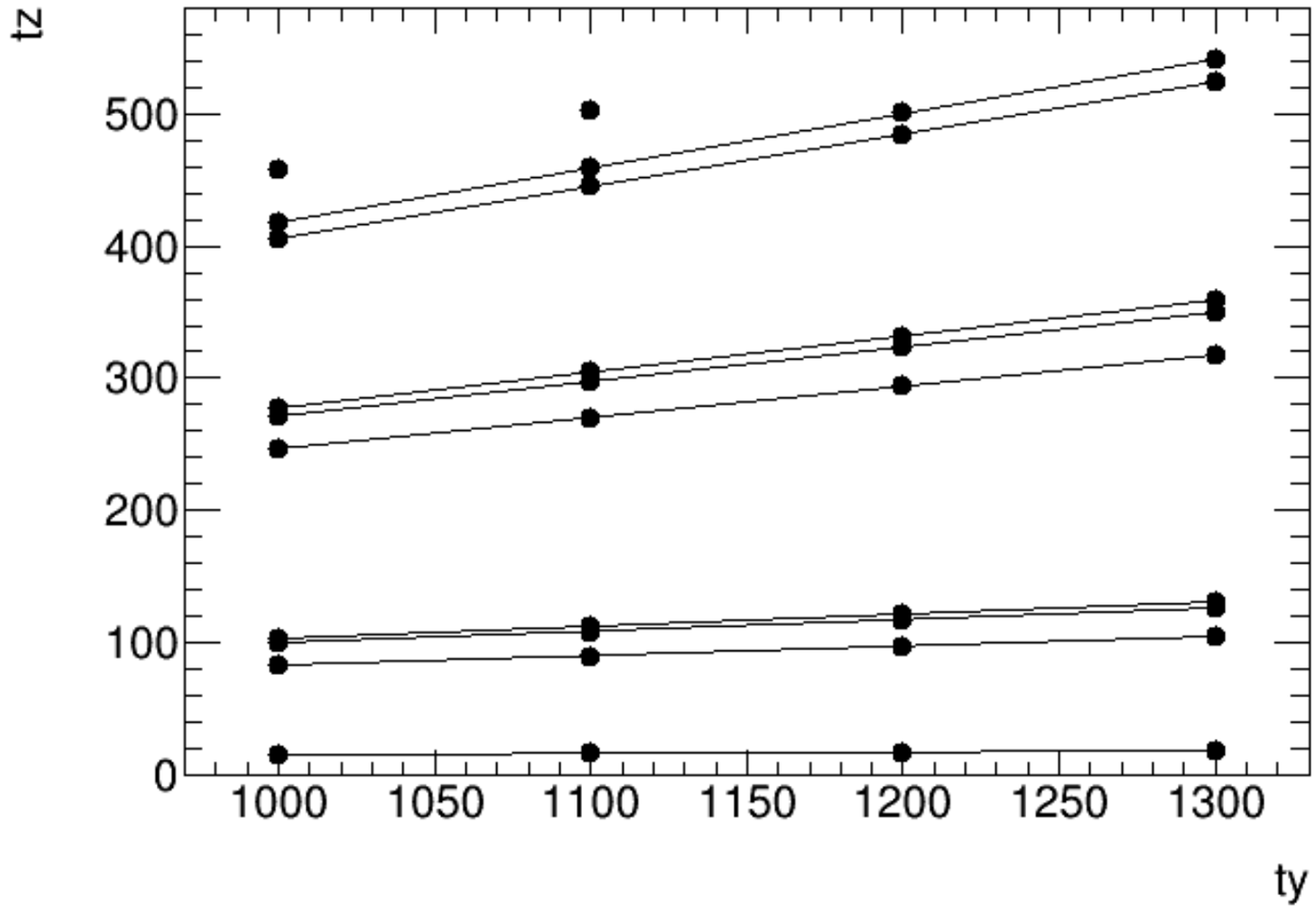
- Initial track parameters estimated from reconstructed seeds by the seeding algorithm are used to steer the CKF.
- Track parameters used to predict next hit and updated progressively.



Found 1925 tracks for 1000 particles

Combinatorial Kalman Filter

- 10 particles. One has only two hits so not considered. Found 9/9 with seeding+CKF. Performance decreases with larger number of particles.



To-do

- Improve input particles with PTARMIGAN + dipole field.
- Run tracking with David's toy MC.
- Implement a better LUXE detector model using LUXE coordinates and support (at least approximate material).
- Seeding with just two hits instead of three. More geometrical selection to lower fake rate.
- p_Z estimation from position.
- Background?