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# Tracking with ACTS in Key4hep

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# Introduction

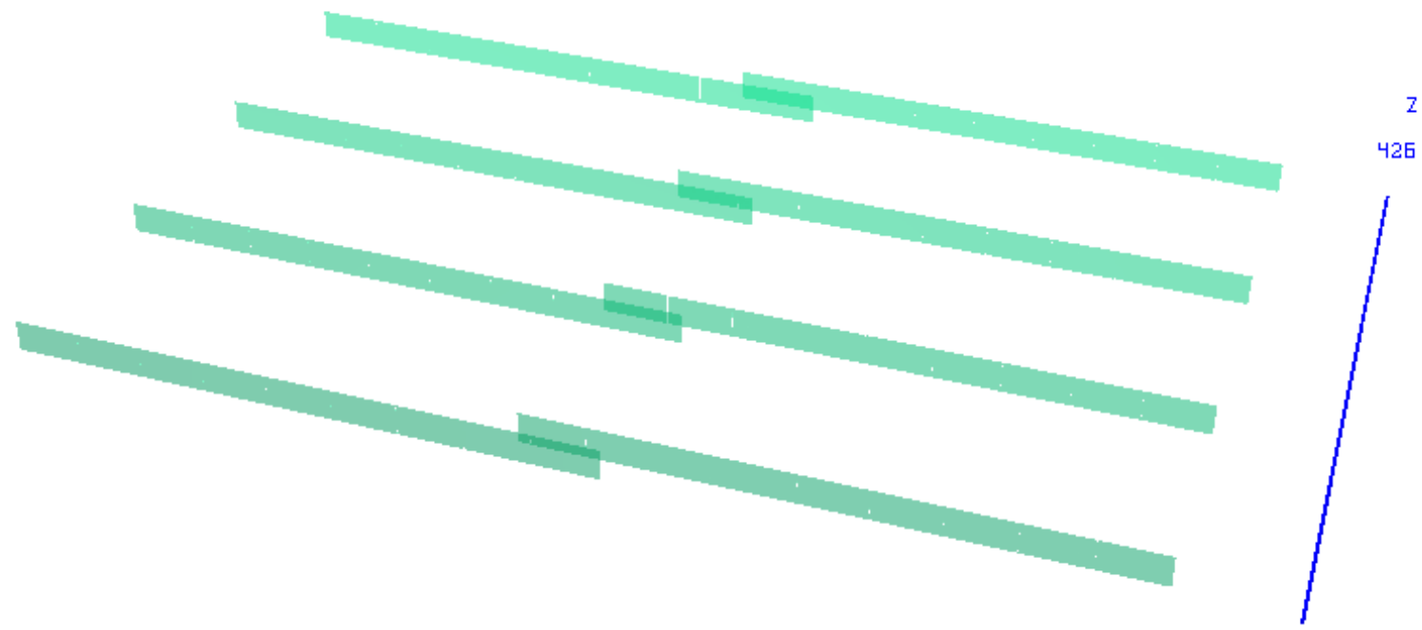
- Key4hep as a common software framework.
- Reminder: https://indico.desy.de/event/38402/contributions/139605/attachments/80569/105363/20230306-YeeY-LUXEsoft.pdf
  - Initial work done to implement simple tracker geometry in simulation and smearing-based digitisation.
- This talk extends that to the reconstruction (tracking).

# ACTSTracking

- Marlin-based, adapted from Muon Collider software.
- Using ACTS version 13.0.0
- My implementation in https://github.com/yeechinn/ACTSTracking. To be migrated to LUXE's GitHub.

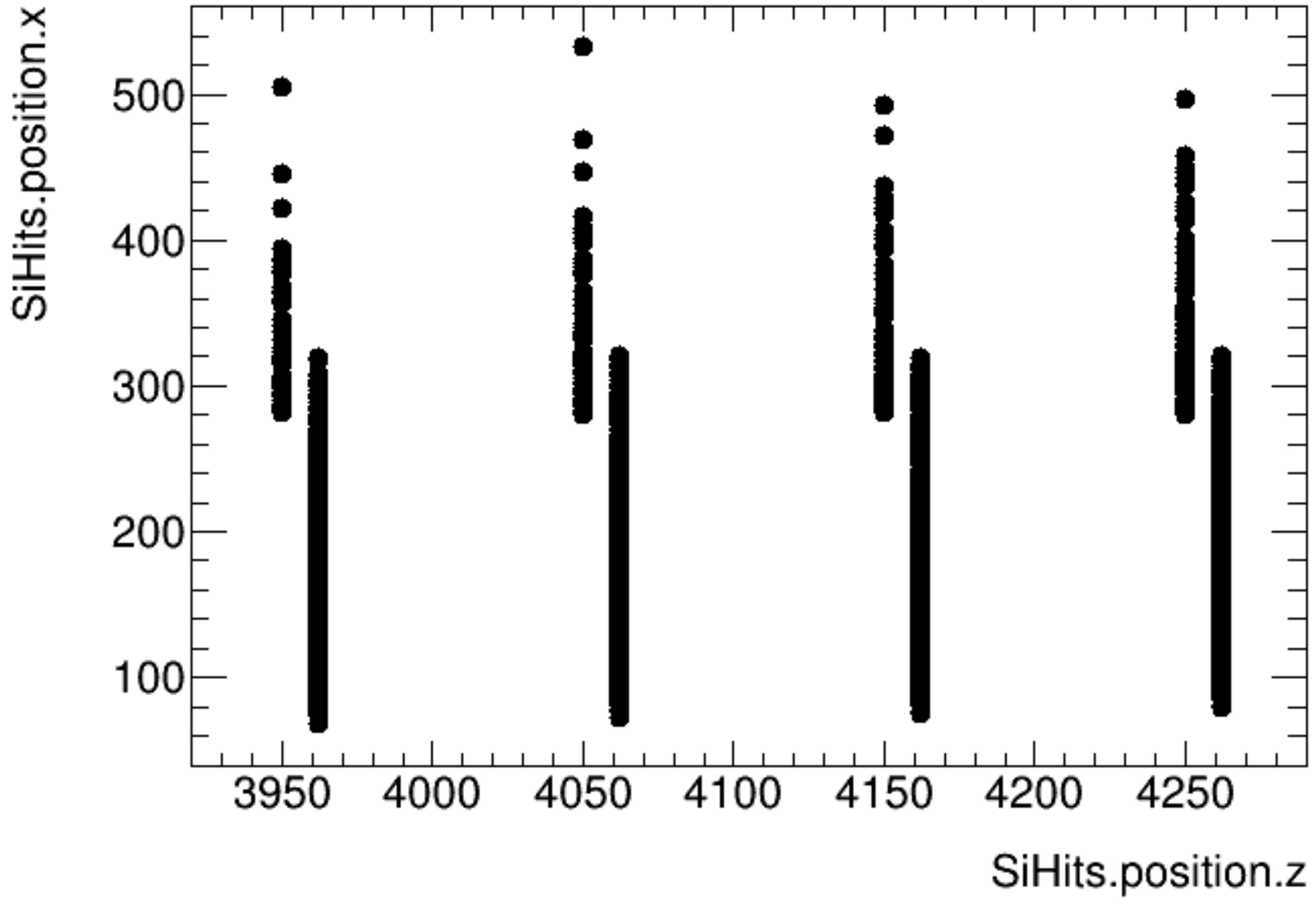
# Tracker geometry and simulation

- Instead of the geometry in luxegeo, redefine tracker as an endcap to enable automatic conversion from DD4hep geometry to ACTS tracking geometry.
- Floating silicon sensors, no support.
- Run simulation in DD4hep from PTARMIGAN signal input, with only dipole field and tracker simulated.
  - Converted available (https://github.com/LUXEsoftware/utility/blob/main/h5_to_slcio.py)
- Simulation time: a few seconds for an event with O(1000) positrons.



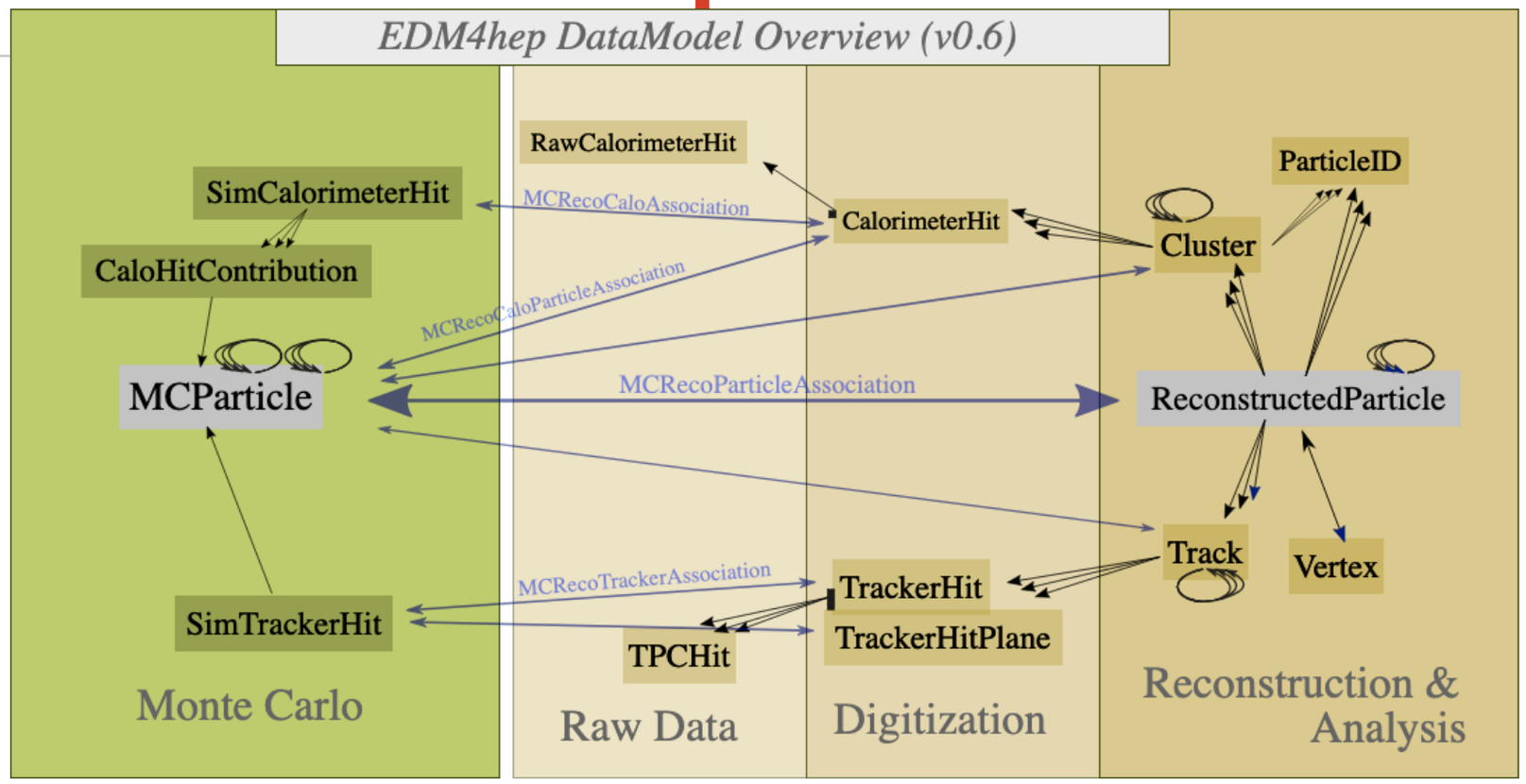
# Simulation output

- E-laser, phase-0, ξ=4



# Simulation output

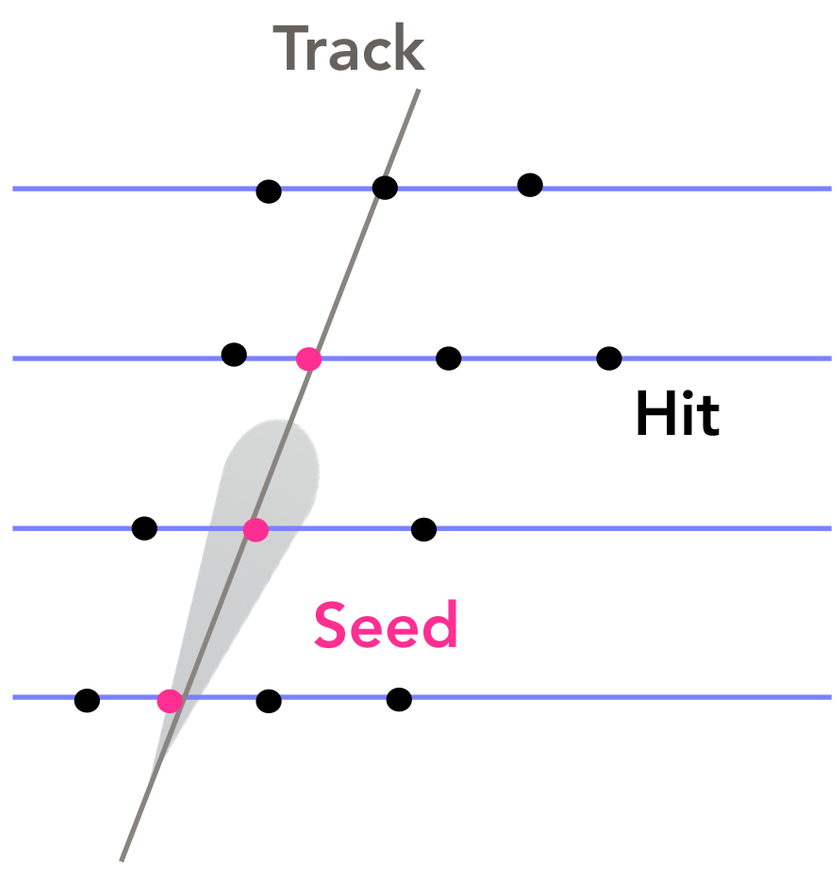
- From SimTrackerHit, need digitisation to get TrackerHit.




- Not to duplicate work, took a fast simple digitiser from key4hep as a temporary solution.
  - Gaussian smearing of tracker hits with a resolution of 5 microns.
- TrackerHit used as input in tracking.

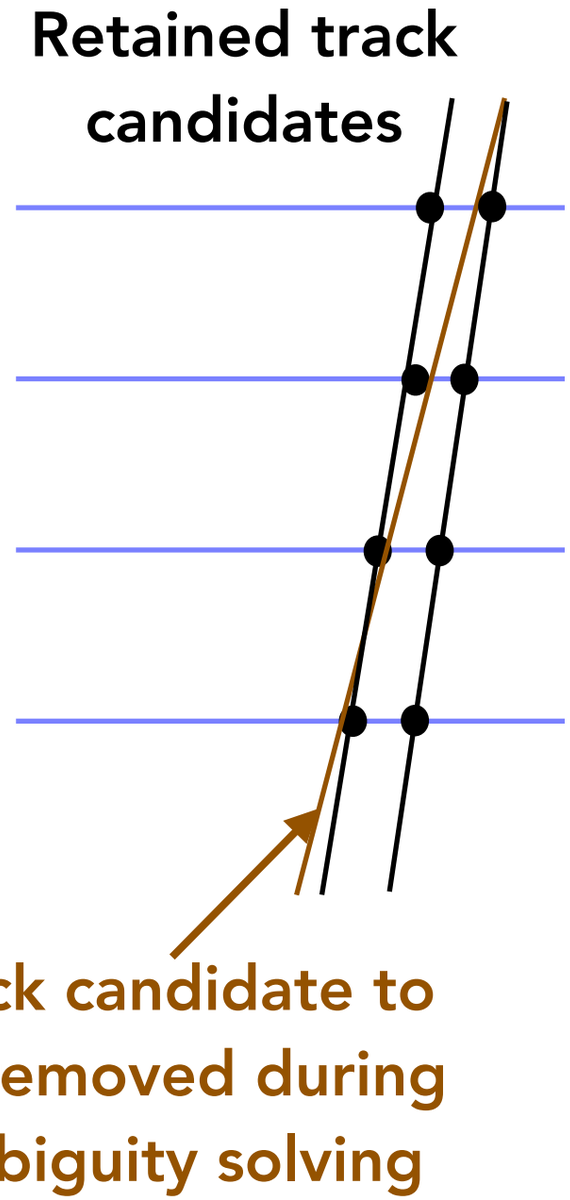
# Tracking

- Seeding:
  - Hits from first 3 layers used to form track seeds.
  - Apply selection based on expected angles for signal particles from IP.
- Track finding:
  - Combinatorial Kalman Filter (CKF) technique.
  - Initial estimate of track parameters from seed is used to predict next hit and updated progressively
  - Measurement search performed at the same time as the fit.



# Track selection

- Track candidates may share hits.
- Ambiguity solving is needed to remove duplicates (tracks matched to same particle) and fake tracks.
  - Procedure: remove low quality track candidates sharing hits with other track candidates, starting with the most shared hits, and keep removing until no shared hits left
  - Much stricter than needs to be.
- Tracks must have 4 hits. >50 % of the hits must be from the same particle to be considered matched.

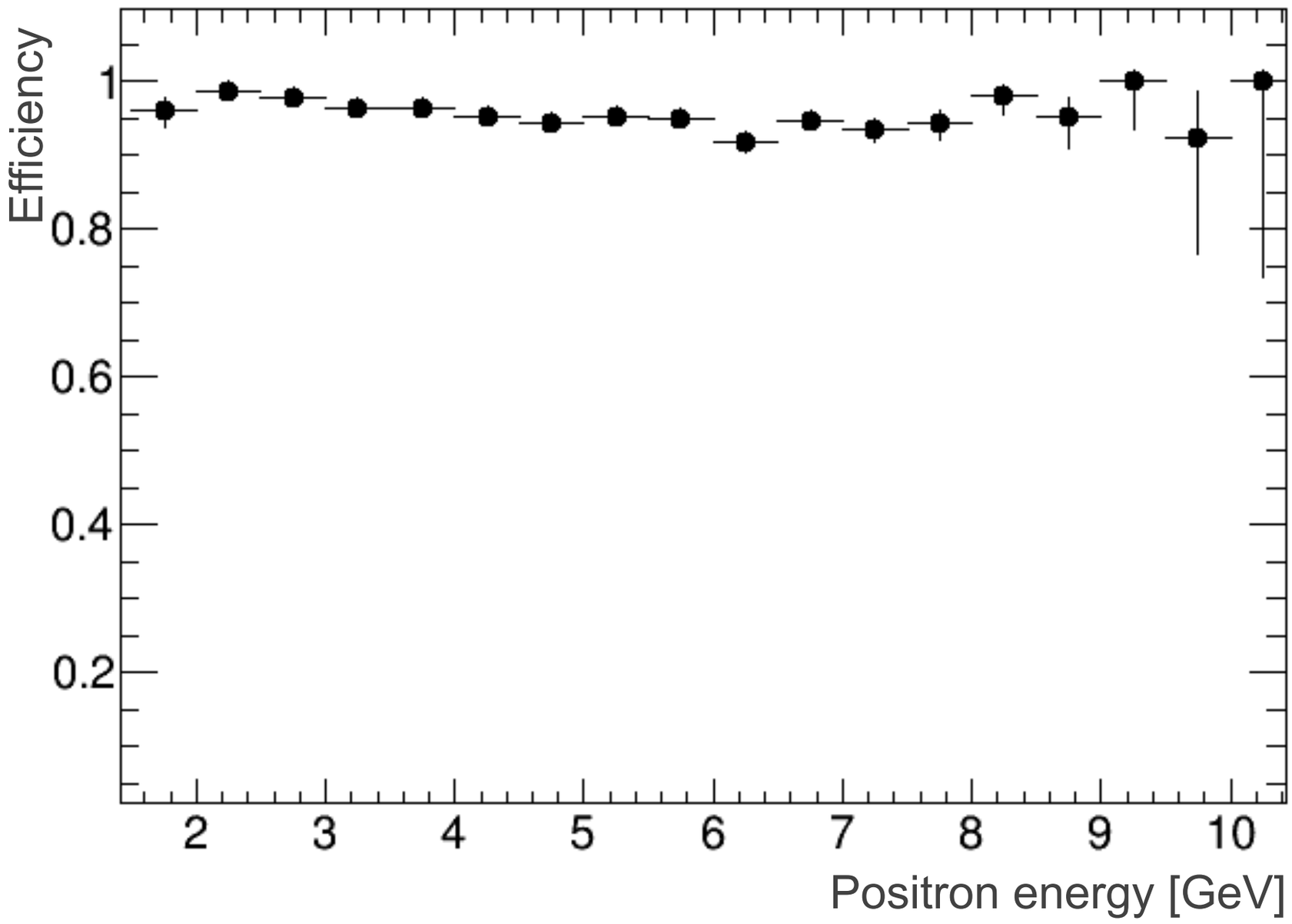


# Performance

- Test on one bunch crossing at xi=3, 4 and 5 for e-laser, phase-0.

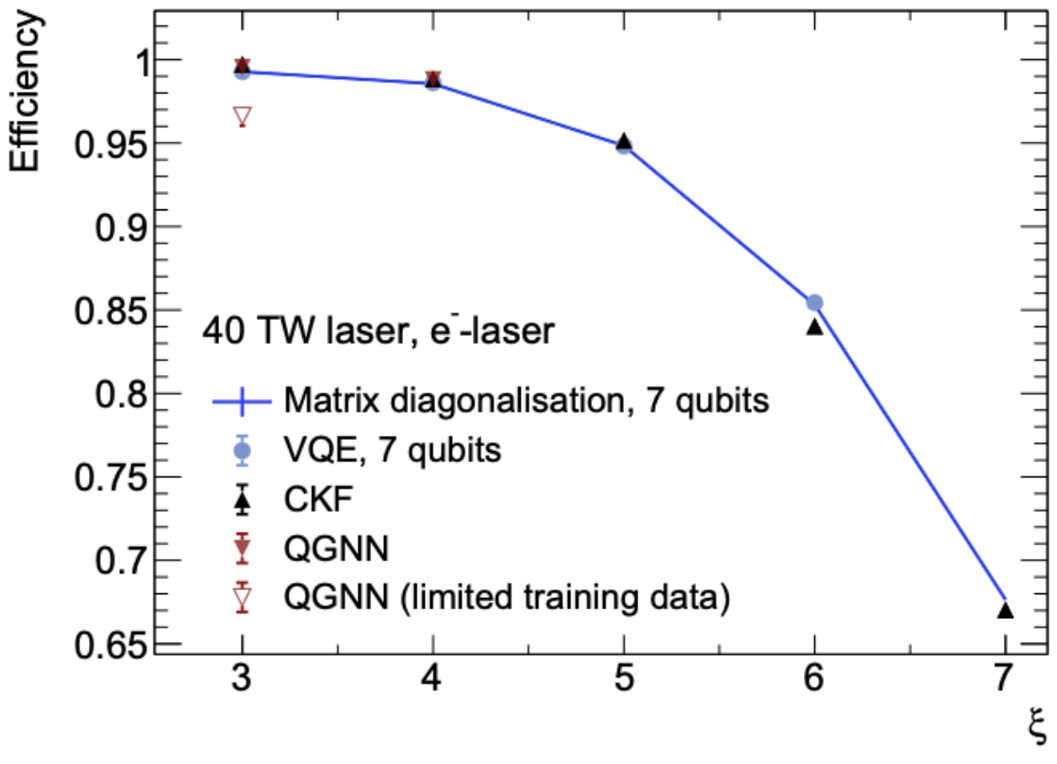
| $\xi$ | # particles | # particles which hit at least 3 layers | # selected tracks | # matched tracks | Efficiency / % | Fake rate / % |
|---|---|---|---|---|---|---|
| 3 | 141 | 140 | 137 | 137 | 97.2 | 0.0 |
| 4 | 2124 | 2115 | 2051 | 2045 | 96.3 | 0.3 |
| 5 | 10408 | 10336 | 10080 | 9873 | 94.9 | 2.1 |

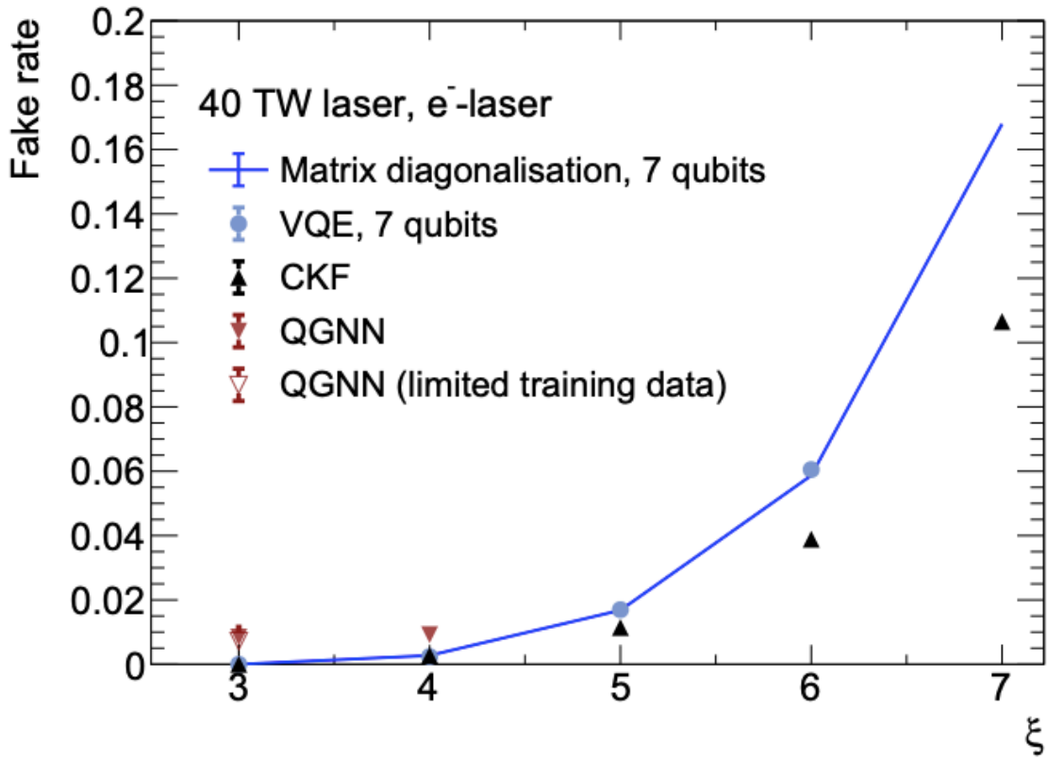
# Efficiency at $\xi$=5



# Comparison

- Performance close to the results of CKF in standalone ACTS.
  - Results taken from our group's quantum computing paper (Quantum algorithms for charged particle track reconstruction in the LUXE experiment arXiv:2304.01690) which uses a simplified fast simulation.
- In terms of timing, standalone ACTS is faster, to be investigated.



# Summary

- First implementation of tracking with ACTS within Key4hep available.
- Further study and optimisation to follow, as well as adaptation to eventual tracker geometry.
  - Following Sasha's visit to DESY, we have a plan to gradually migrate LUXE software including detector geometry simulation.