LUXE technical meeting, 8th June 2023

ACTS tracking in Key4hep for LUXE

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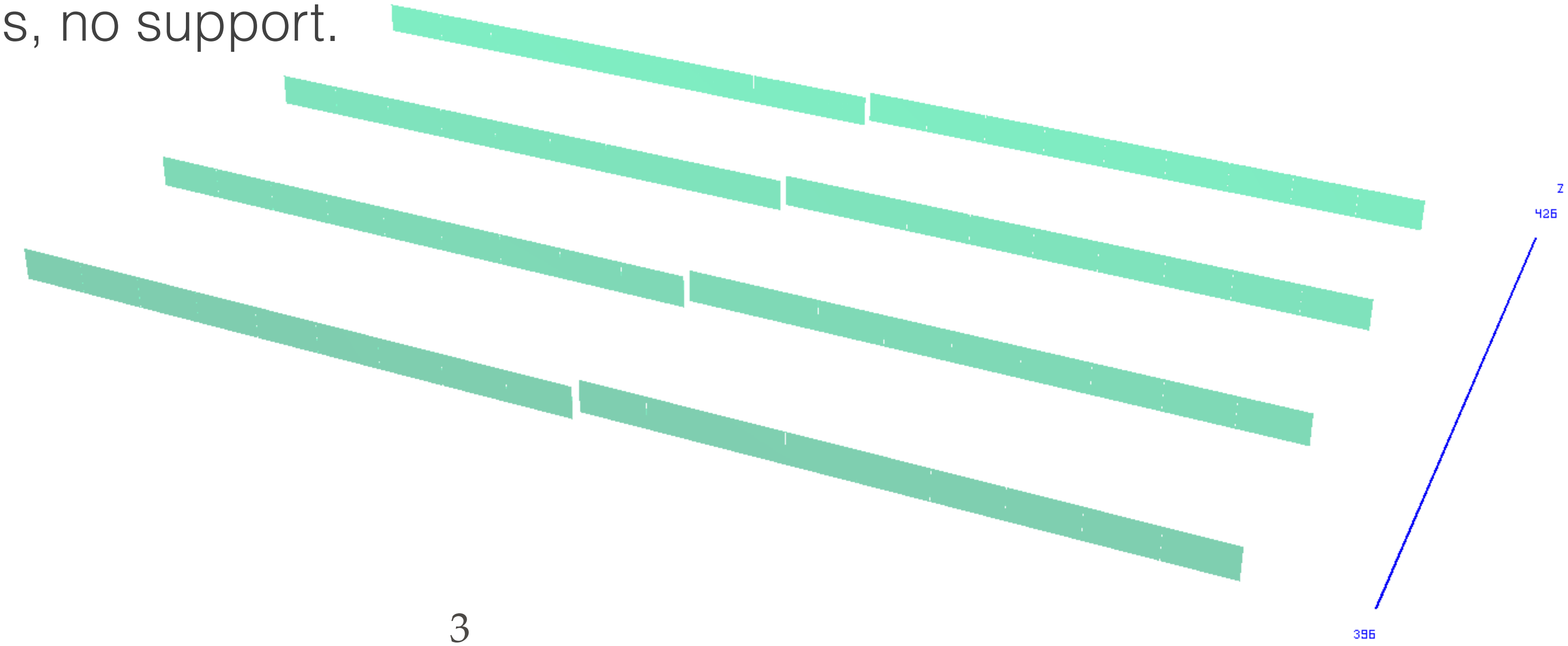
Introduction

- Reminder: https://indico.desy.de/event/38402/contributions/139605/attachments/80569/105363/20230306-YeeY-LUXEsoft.pdf
- 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.

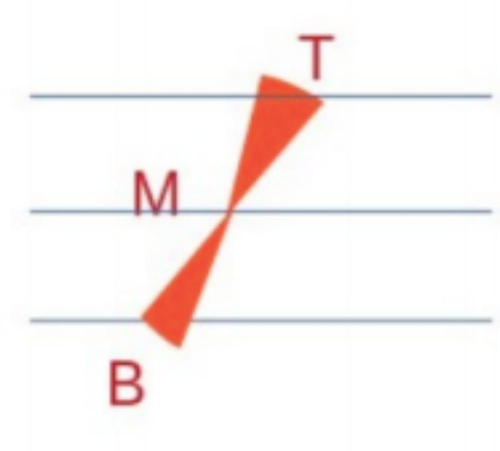
Geometry

- Features:
  - Tracker needs to be defined as barrel/endcap in DD4hep to ensure automatic conversion of DD4hep geometry to ACTS tracking geometry.
  - Requires an intermediate conversion to TGeo in this version of ACTSTracking.
- Cannot use what I defined in luxegeo. Instead define LUXE tracker as endcap. XML definition only, no additional C++ code. Using existing standard “TrackerEndcap_o2_v06” definition (lengthy xml).
- Floating silicon sensors, no support.



Seeding

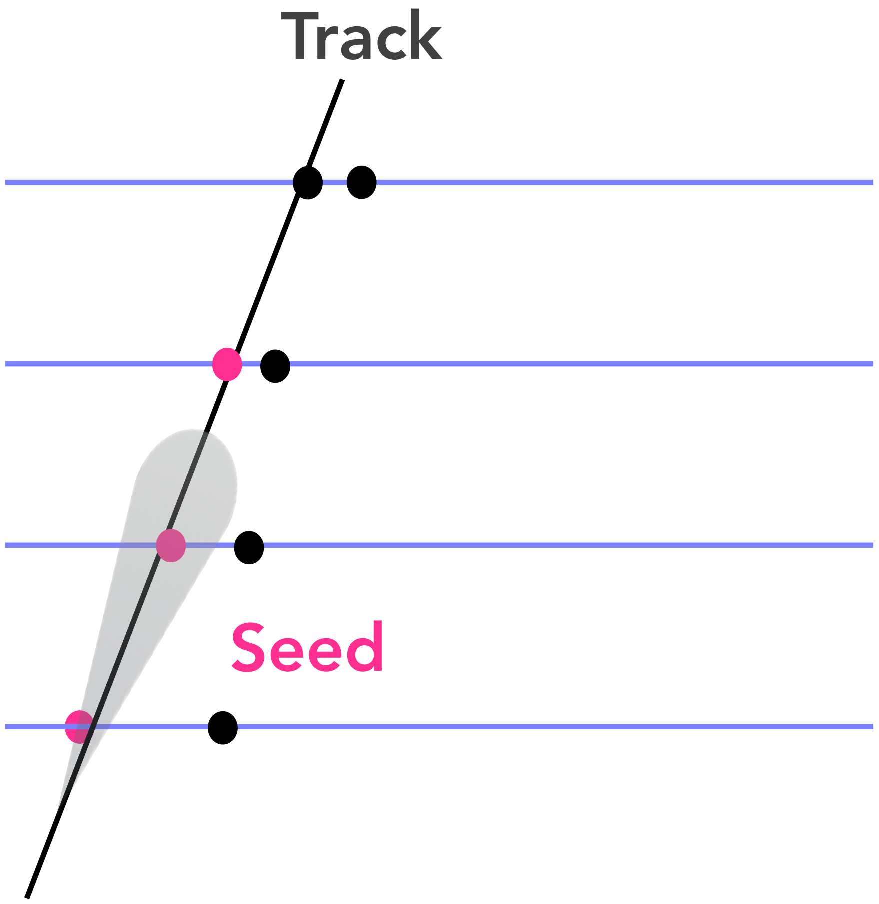
- Hits from first 3 layers used for seeding.
- Split into positive vs negative y:
  - For each middle hit, form doublets by adding top/bottom hits satisfying angle pre-selection in x and y direction.
  - Triplet selection from doublets: how much the two angles are allowed to differ between the pair of doublets due to scattering.



- Seed filtering:
  - For seeds with common bottom and middle hits, and only differing in top hit, pick the one with the straightest path.

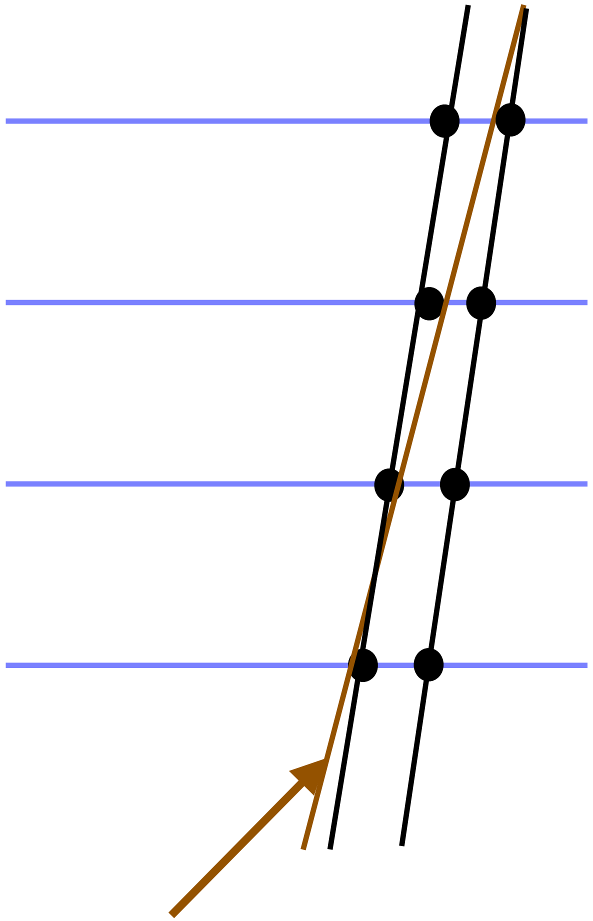
Track finding

- 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.



Ambiguity solving

- Track candidates may share hits.
- CKF is a local method, which means during the track finding process it is unaware of hits being used in another track.
- Ambiguity solving is needed to remove duplicates (tracks matched to same particle) and fake tracks.
- QC paper procedure: remove low quality track candidates sharing hits with other track candidates, starting with the most shared hits, until all remaining tracks have at most one shared hit.
- Current implementation: keep removing until no shared hits left, i.e. more severe than the paper.



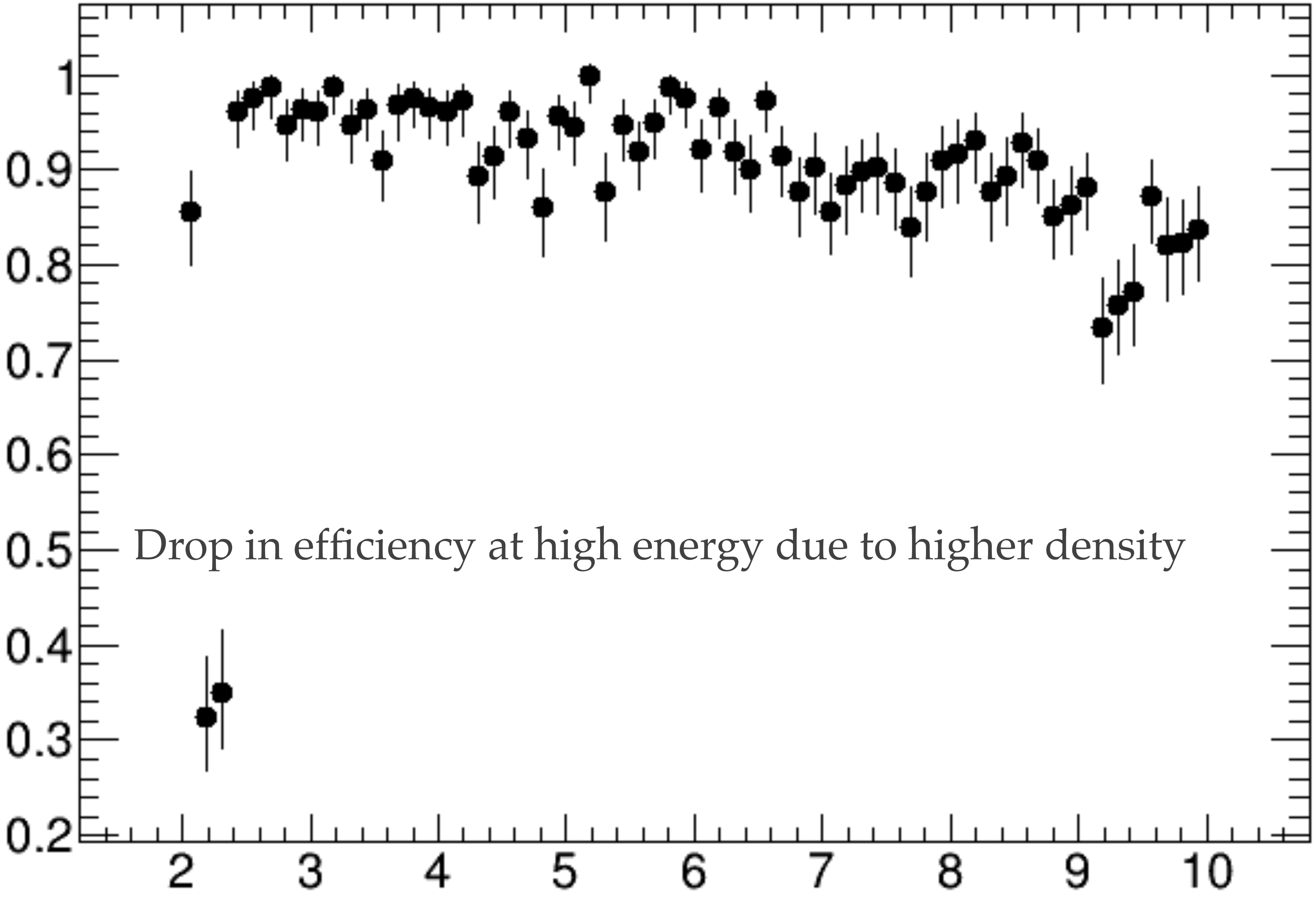
Track candidate to be removed during ambiguity solving

Single positron performance

- Simulated with DDsim using particle gun.
- 5000 single positrons from {0,0,0} with E=pz={2,10} GeV (flat distribution).
- 4896 reconstructible positrons (at least 3 hits). Found 7488 seeds/tracks, 4450 matched.
- Post ambiguity solving: 4347 tracks, 4268 matched.
- Time: 28s (seeding), 532s (seed+track finding), 100s (ambiguity solving)

- Works reasonably well, but rather slow. Now compare with standalone ACTS that I have been using so far to e.g. produce results for the paper.

Efficiency vs energy



Drop in efficiency at high energy due to higher density

Comparison to standalone ACTS

	Standalone implementation	Implementation in Key4hep
Detector geometry	Simple (no overlapping stave, no gap between sensors) Implemented as barrel (90 degrees rotation)	Realistic Implemented as endcap
ACTS version	19.0.0 (roughly)	13.0.0
Detector simulation	Fast simulation from David	DDSim/G4

- Check performance using PTARMIGAN signal as input with phase-0 e-laser xi=4 sample.
  - Convert PTARMIGAN into .slcio and input into DDsim for detector simulation.
- Compare to paper results using standalone ACTS.

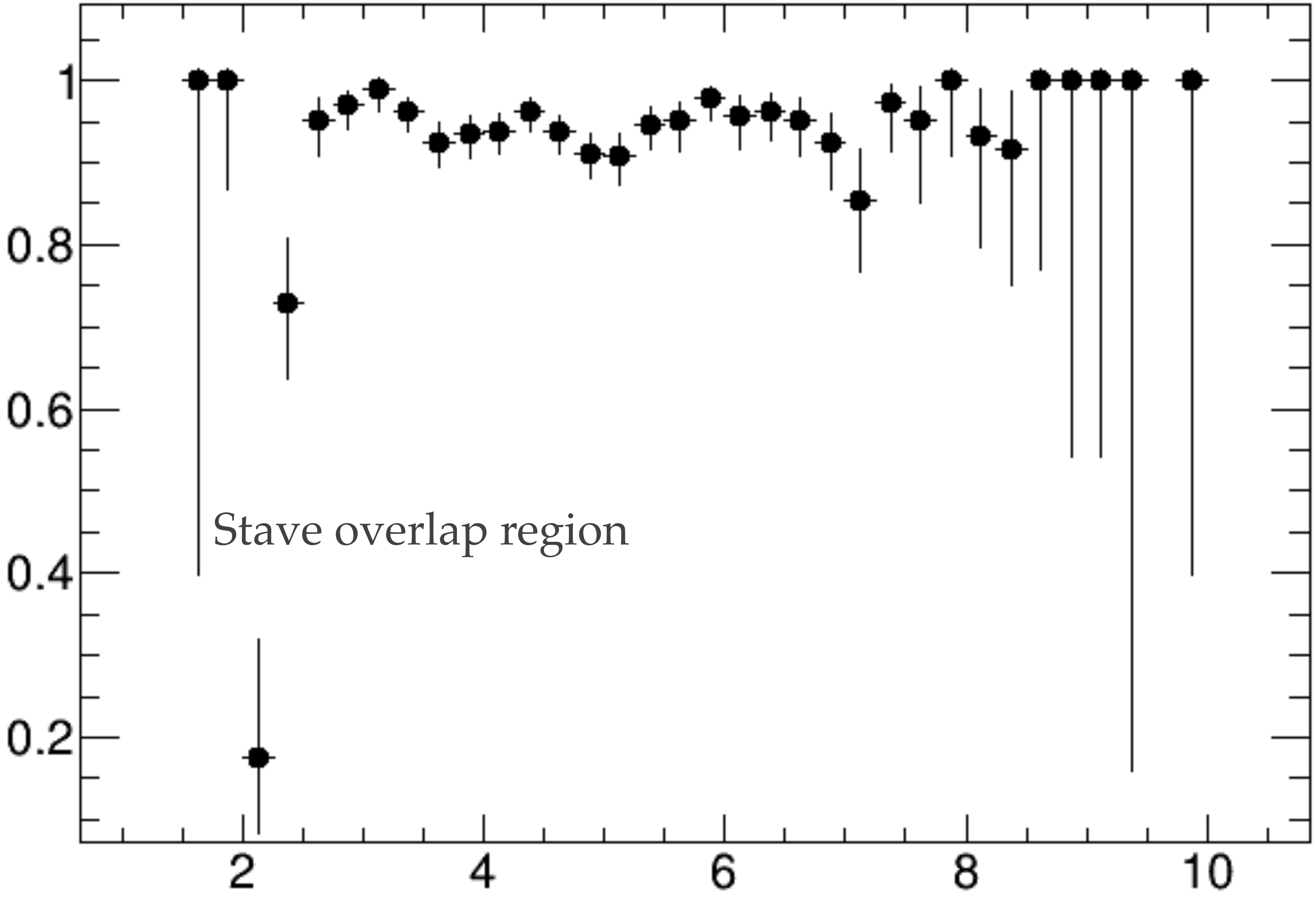
Performance

- PTARMIGAN phase-0 e-laser xi=4
    - 2124 positrons.
- In realistic simulation, 45 particles don't have hits in first 3 layers (due to gap) and seeds cannot be found. No seeds -> No tracks.

Performance

		Standalone implementation	Implementation in Key4hep
Pre ambiguity solving	# seeds found = # reconstructed track candidates	2669	2522
	# matched track candidates (majority hits) with at least 4 hits, not counting duplicates	2108	2013
Post ambiguity solving	# tracks	2104	2005
	# matched tracks	2099	1988
Time	Seeding	150ms	5s
	Tracking	800ms	80s
	Ambiguity solving	negligible	11s

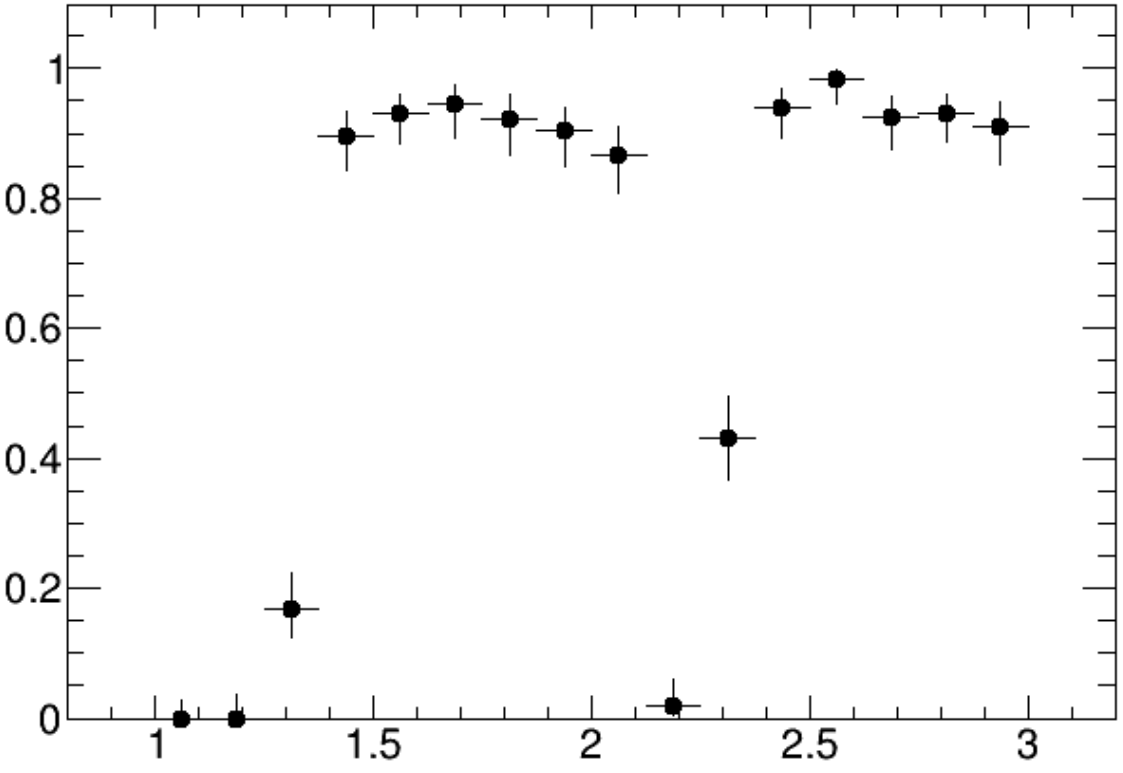
Efficiency vs energy



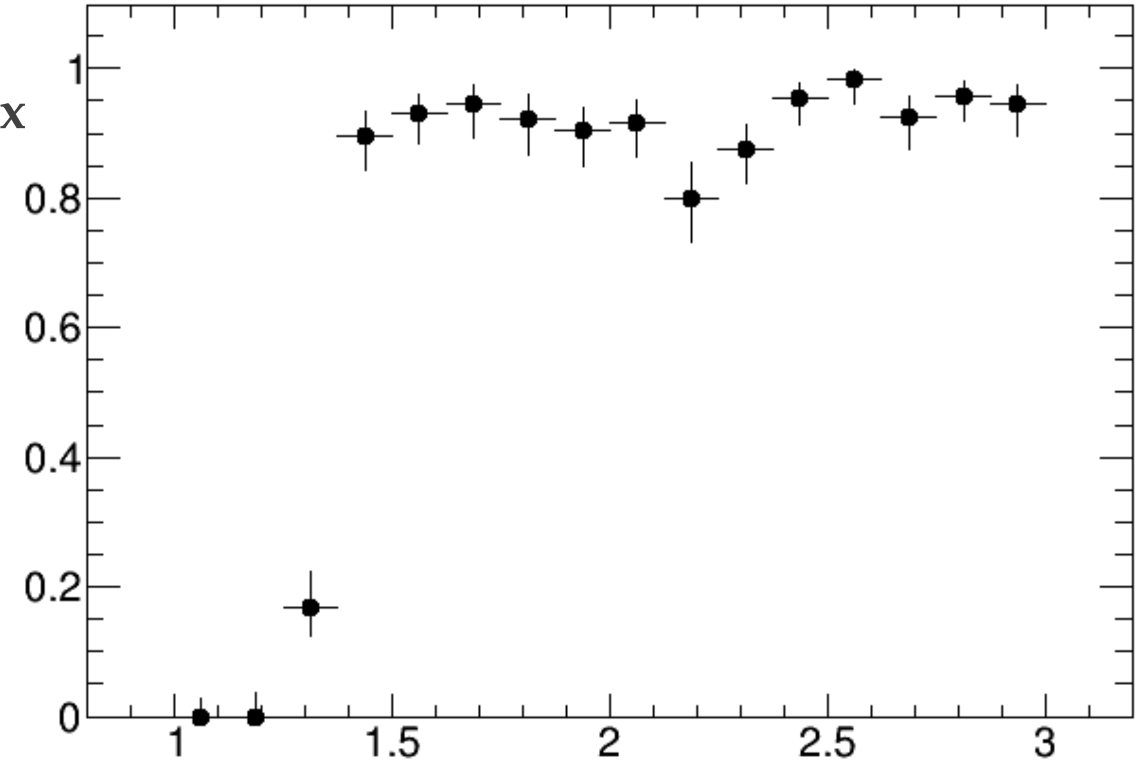
Stave overlap region

Low energy efficiency study

- 1000 single positrons with flat energy distribution between 1 and 3 GeV.



Loosen seed dx/x preselection

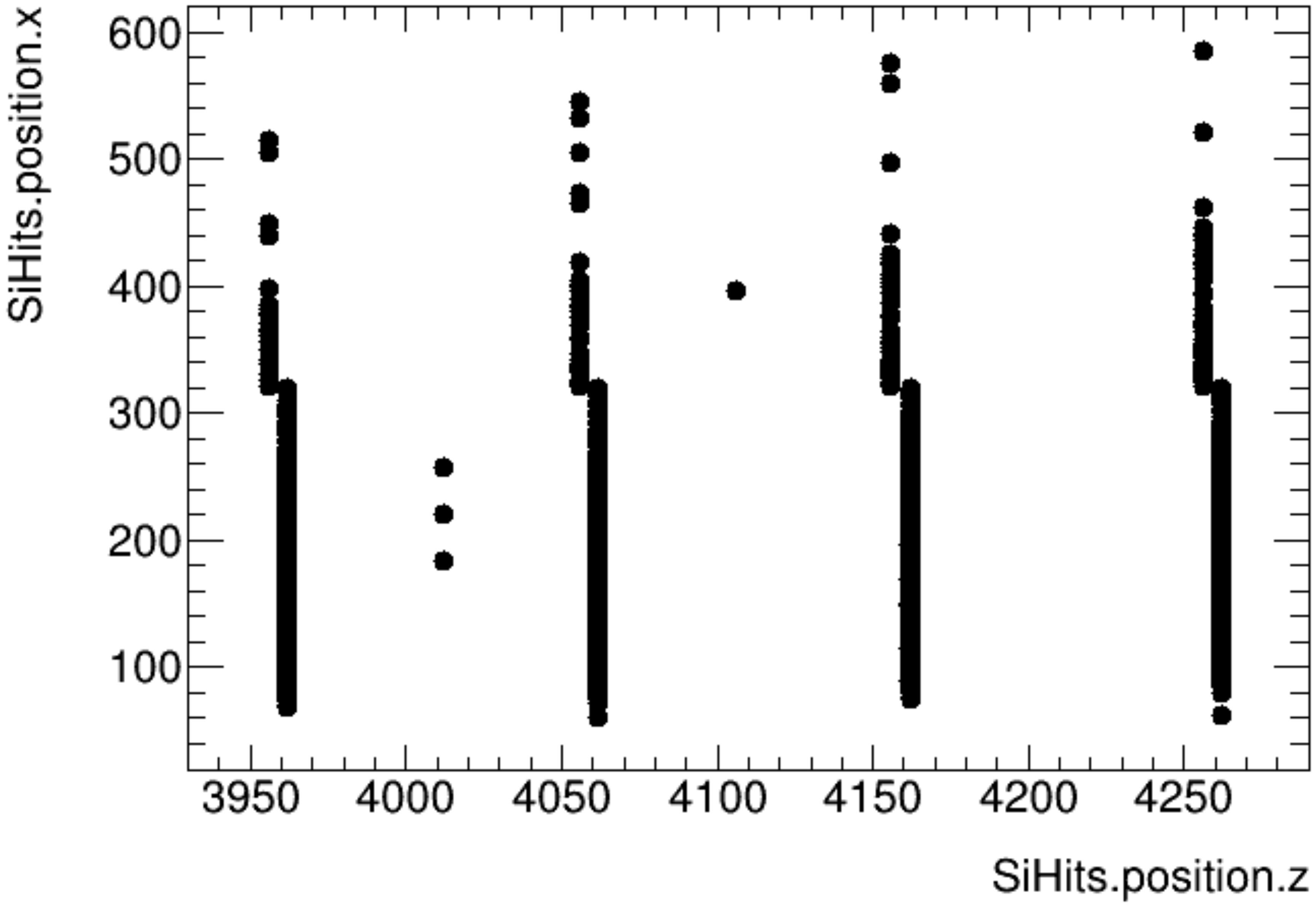


Timing

- More detailed timing calculation for standalone ACTS (get detailed timing for each algorithm while the timing in Key4hep is based on the entire processor. However, difference is significant.
- Not clear why.
    - No obvious difference seen in timing in the two versions of standalone ACTS (tested for a generic detector).
- To be investigated.

Hits position

- What’s going on between the layers?



To do

- Refine seed selection.
- Option for CSV input.
- Detailed performance study.
- Investigate difference to standalone ACTS implementation particularly vis-à-vis timing.