Line Segment Tracking

A highly parallelizable algorithm for track building

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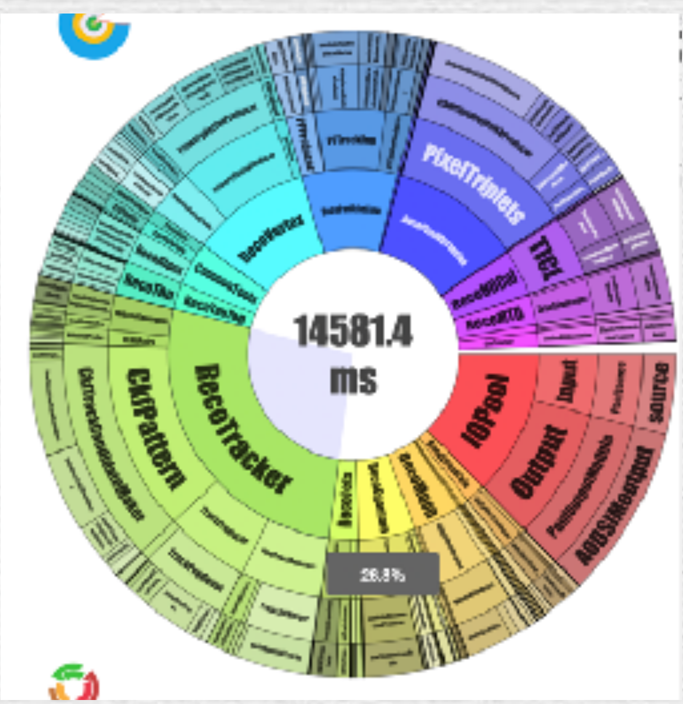
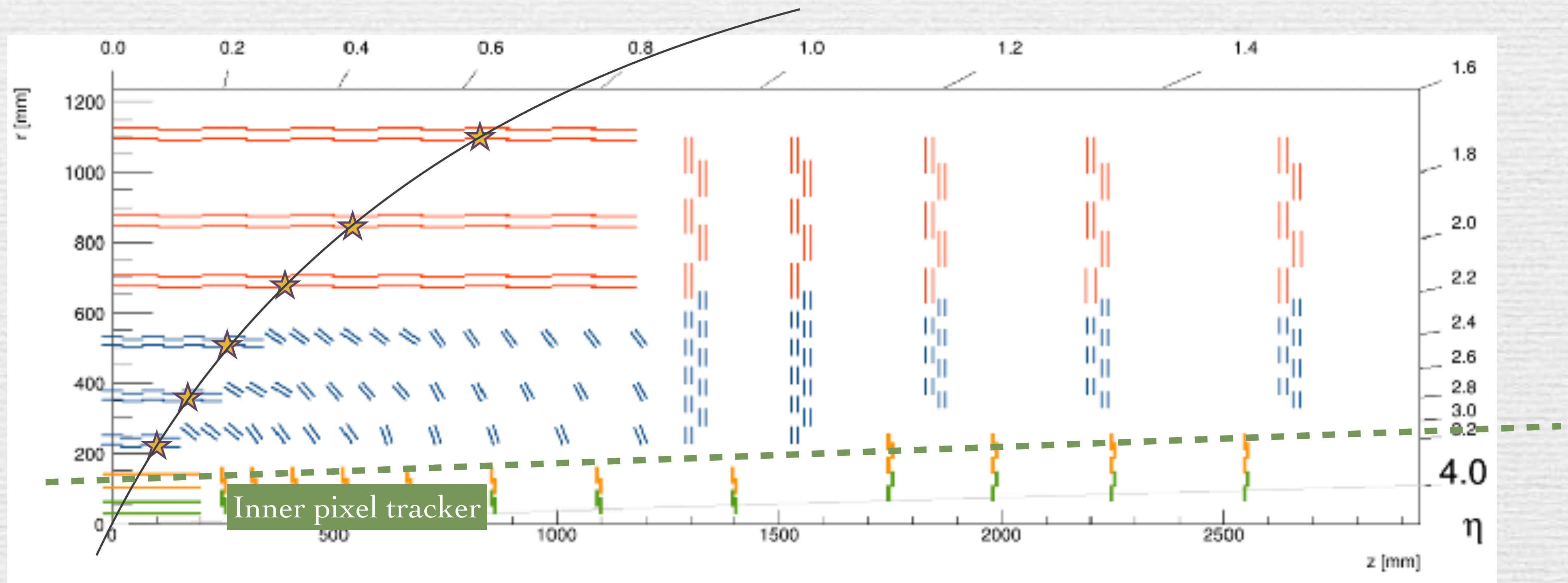
On behalf of the LST team

Tracking challenge

- Tracking is a large time consuming component of the event reconstruction already as of today.
- Most of CPU time is used on tracking, while track building takes a lot of time.
- Due to massive number of collisions and tracks, we are exploring GPU solutions for HL-LHC outer track finding, with good efficiency, low fake rate, and competitive timing.



CMS event reconstruction time

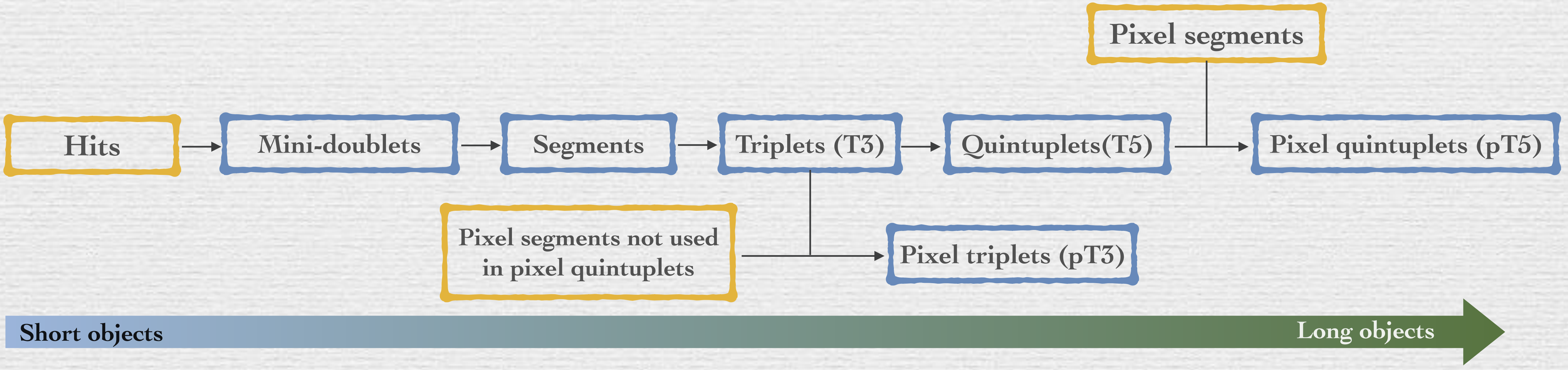


CMS tracker layout, CMSSW12

Line segment tracking on GPU

LST is a highly parallelizable track building algorithm designed to exploit GPU capabilities

- Localization: Starting from local hits and connecting neighboring objects to build short tracks
- Growth: Link shorter tracks and get longer tracks, select a subset of output tracks from the intermediate collections as final track candidate
- Parallelization: Each linking step is parallelizable on GPU



flow chart of LST algorithm

- Detailed explanation of the algorithm can be found here

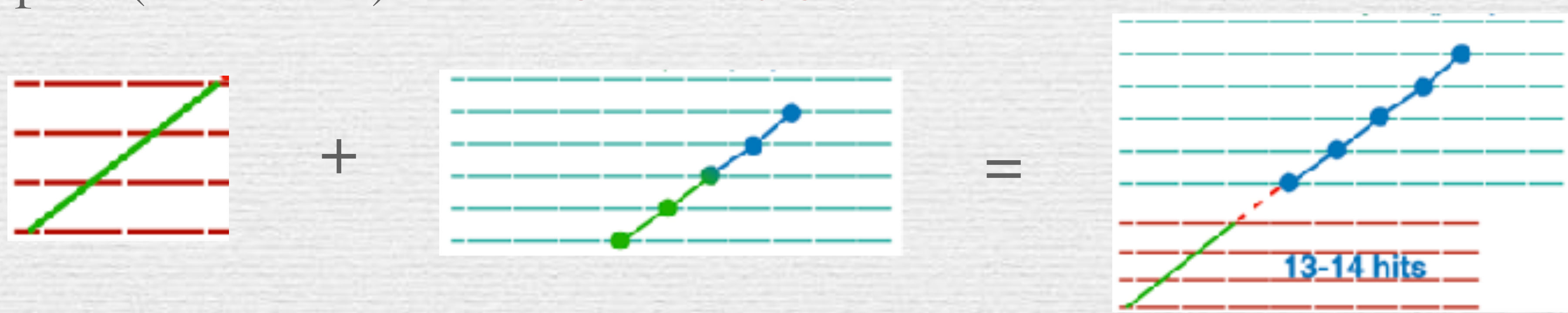
Track building : connecting the dots

From Segments to T3 (6 hits)

From T3s to T5s (10 hits)

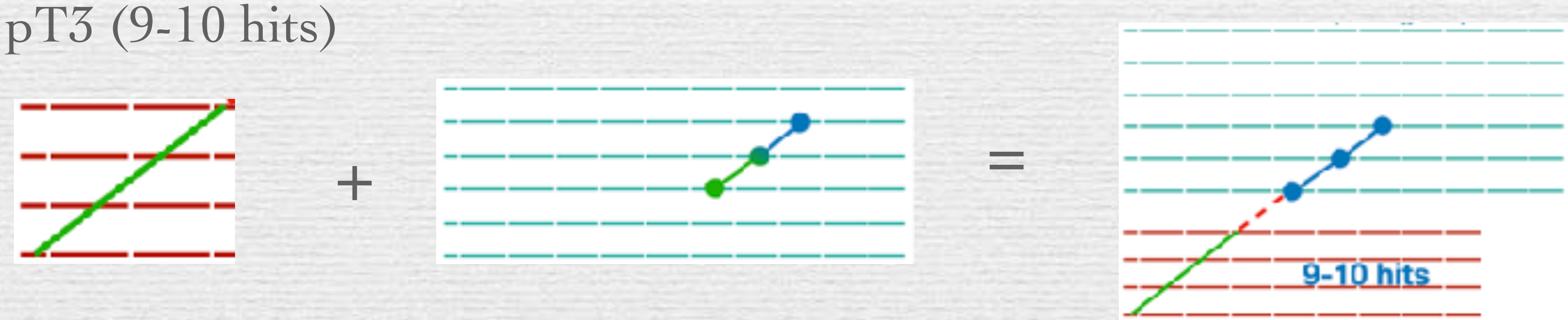
From T5s to pT5 (13-14 hits) Pixel segment may give us 3 hits or 4 hits as input

Inner tracker



From T3 to pT3 (9-10 hits)

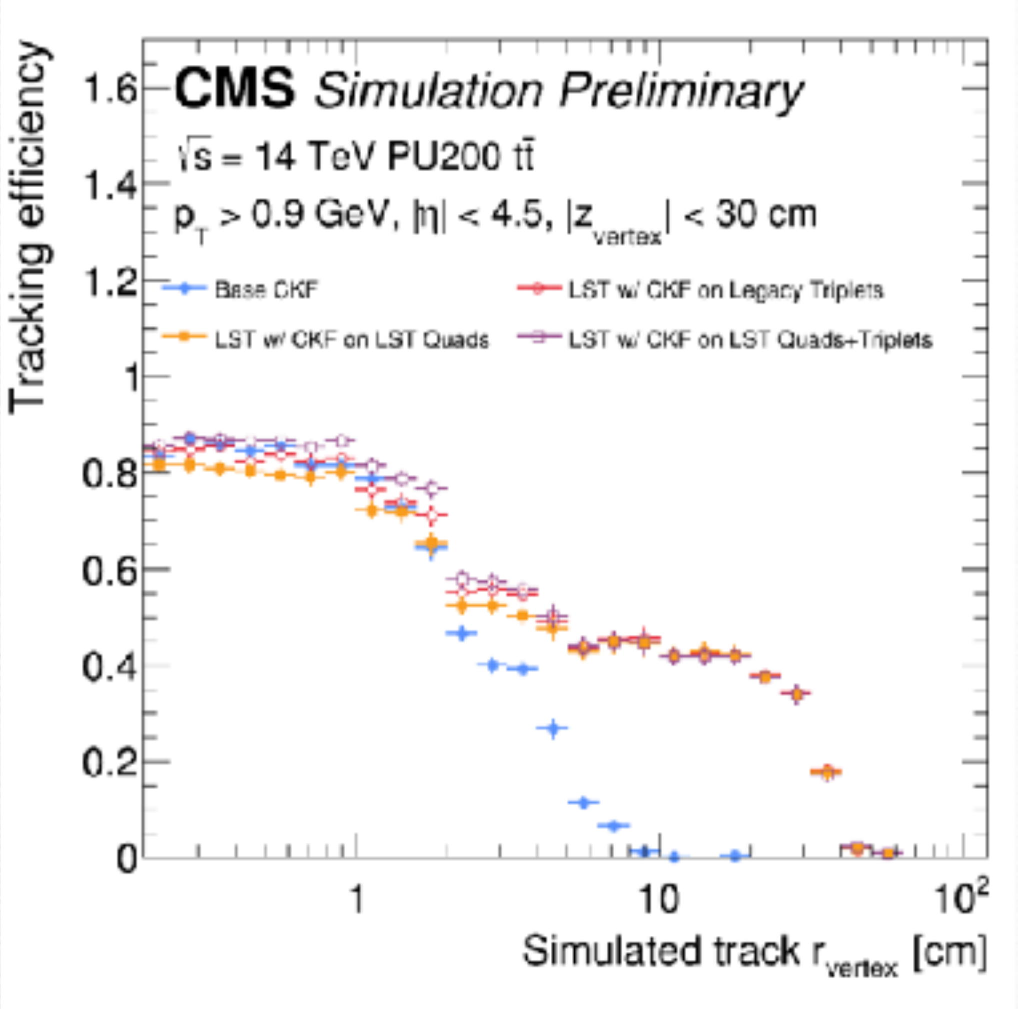
Inner tracker



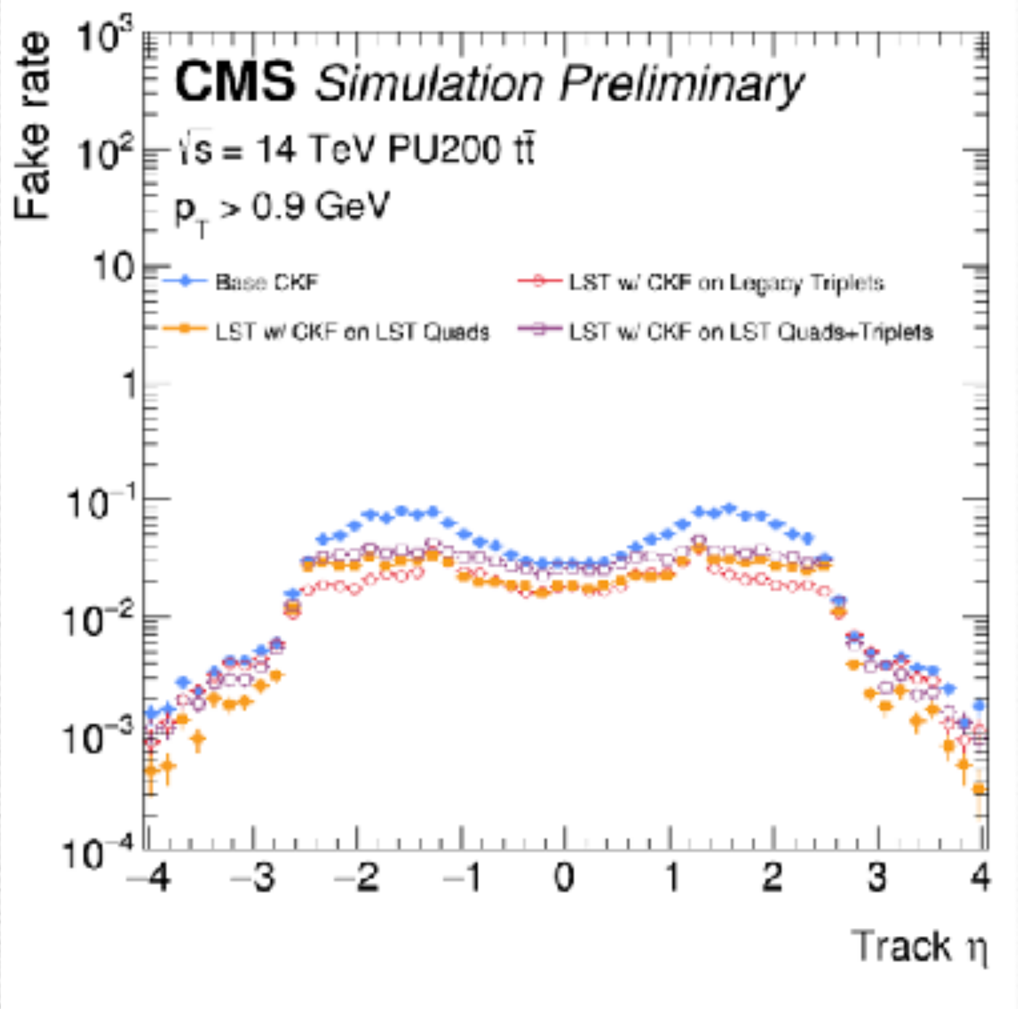
If a quad pixel seed is not used in building pT5 or pT3, will be build as pLS

Performance Improvement

- We get high efficiency, low fake rate and duplicate rate. And we are still improving and aiming for better performance
- Besides that, we get up to 35% faster than the original tracking method in online tracking



Improvement of Efficiency



Great reduction of fake rate

Tentative plans

The current performance is still far from the best we can do…

- Extension to probe phase space and build other localized objects: T4, pT2..
- Much better timing improvement in offline reconstruction.
- Better profiling performance: reduce register usage, improve GPU utilization…
- Apply pre-trained DNN matrix to true vs fake track discrimination
- ….

Reference

[1]: CMS Collaboration, “Performance of the Line Segment Tracking Algorithm in the CMS Phase-2 High Level Trigger Tracking”, CERN-CMS-DP-2024-014

[2]: CMS Collaboration, “Performance of Line Segment Tracking algorithm at HL-LHC”, CERN-CMS-DP-2023- 019.

[3]: Line Segment Tracking: Improving the Phase 2 CMS High Level Trigger Tracking with a Novel, Hardware-Agnostic Pattern Recognition Algorithm, E. Vourliotis et. al., arXiv 2407.18231 (25 Jul 2024).

[4]: Improving tracking algorithms with machine learning: a case for line-segment tracking at the High Luminosity LHC, Jonathan Guiang, Slava Krutelyov, Manos Vourliotis, Yanxi Gu, Avi Yagil, Balaji Venkat Sathia Narayanan, Matevz Tadel, Philip Chang, Mayra Silva, Gavin Niendorf, Peter Wittich, Tres Reid, Peter Elmer (for the CMS Collaboration), arXiv:2403.13166 (2023). (Submitted to CTD 2023) (Submitted to CTD 2023) (02 Feb 2023).