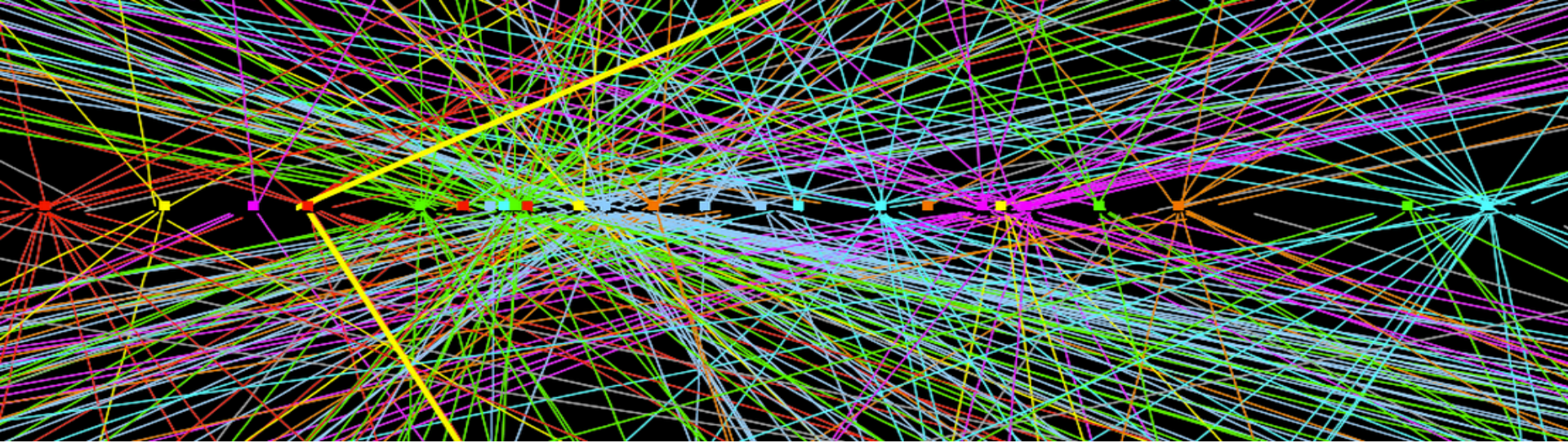
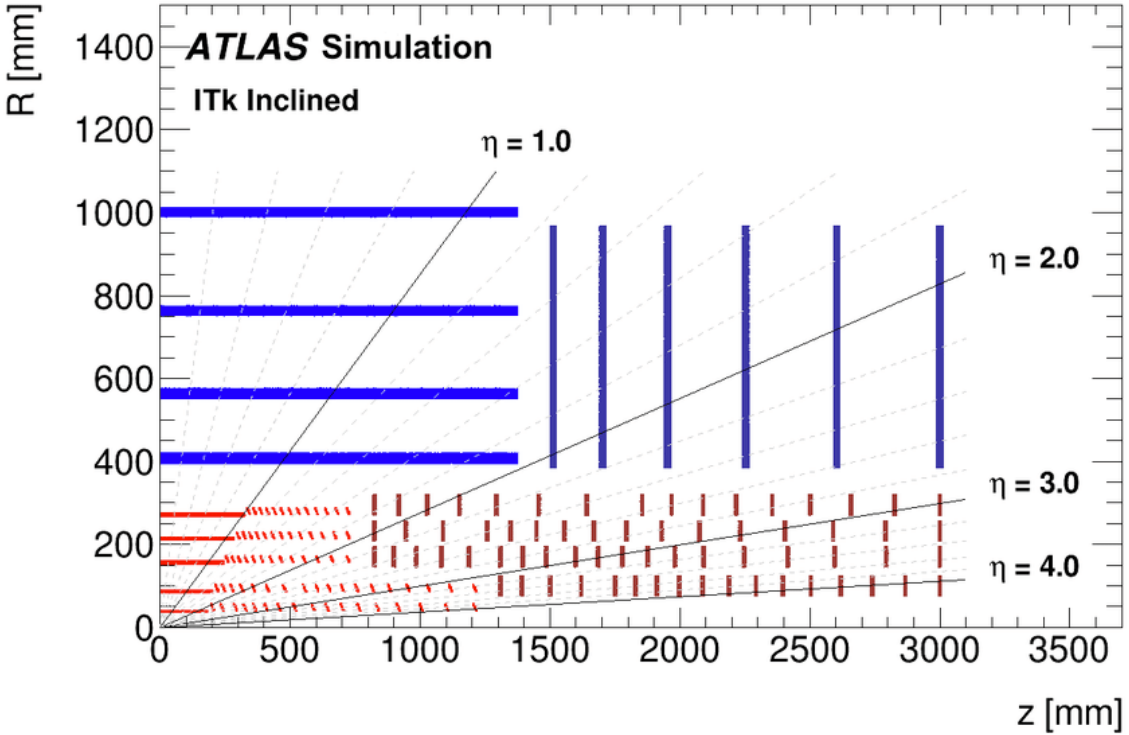


4D Tracking

Ariel Schwartzman

SLAC Fast Timing R&D Meeting
14-Apr-2021

4D pixels in LS4 ITk



3 key ideas:

Improve track reconstruction:

Speed, efficiency, purity, and IP resolution

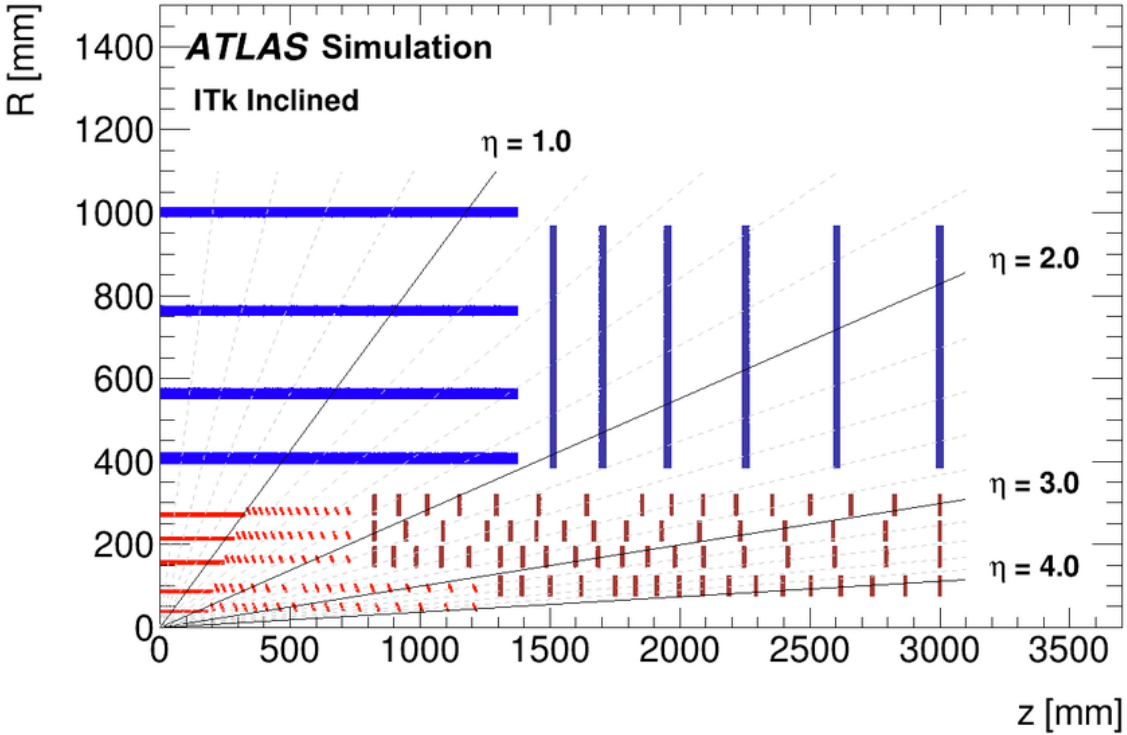
Improve physics reconstruction by reducing pileup effects:

Pileup jet suppression, particle flow, b-tagging (track-to-vertex association)

Improve forward jets (VBF):

Provide vertex t_0 for HGTD

4D pixels in LS4 ITk



3 key ideas:

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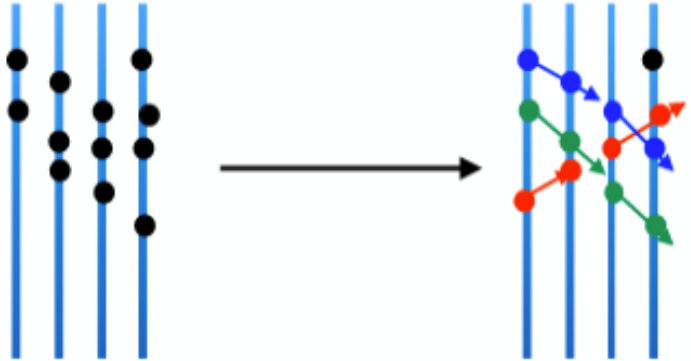
4D pixels in LS4 ITk



3 key ideas:

Improve track reconstruction:

Speed, efficiency, purity, and IP resolution

Use pixel hit time in track pattern recognition:

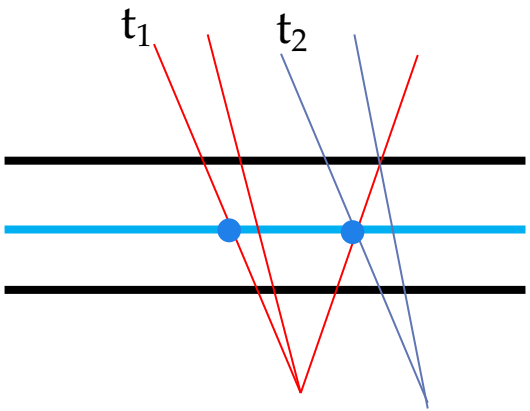
- Reduce combinatorics:
  - Improve efficiency and purity → IP resolution
- Speed up tracking reconstruction

4D Vertexing

This concept requires timing hits in multiple layers (at least 2)

What could one do if we only instrument one layer with timing information?

4D pixels in LS4 ITk



3 key ideas:

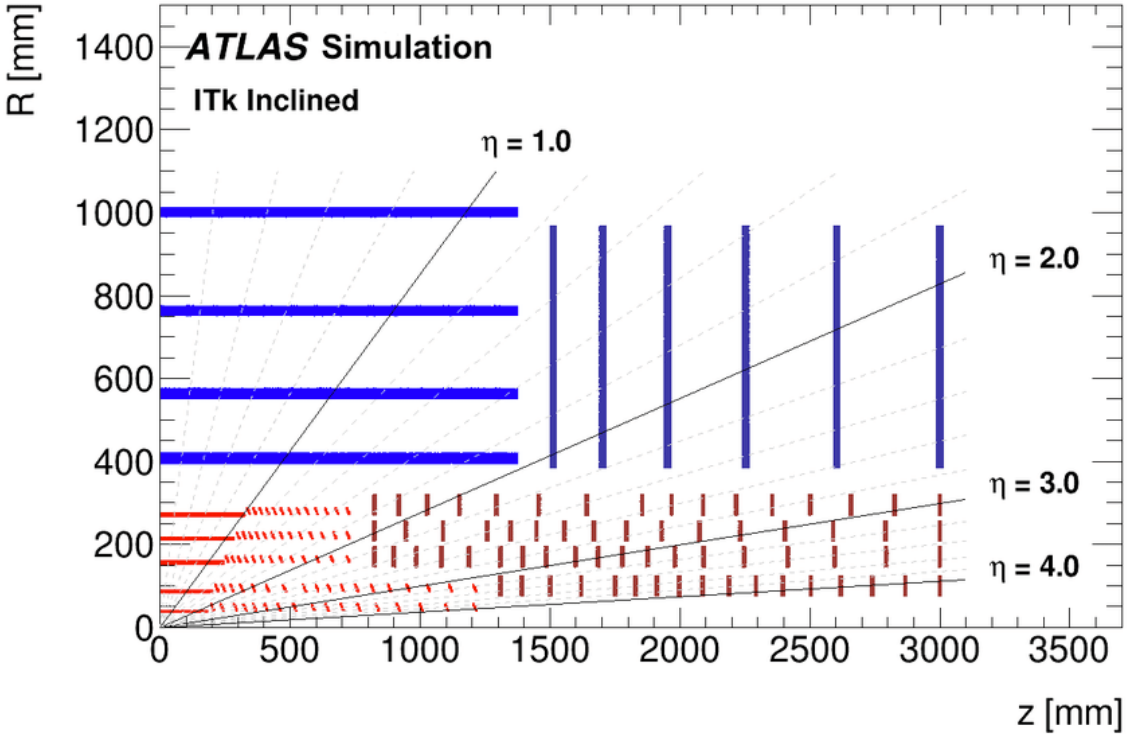
Improve track reconstruction:

Speed, efficiency, purity, and IP resolution

1. Find 1 (high quality) track → assign t_1
2. Find additional tracks with time compatibility → refine average time
3. Select all hits with a 2-3 sigma window and find all tracks from a common vertex
4. Iterate

This proposal should be studied in simulation

4D pixels in LS4 ITk



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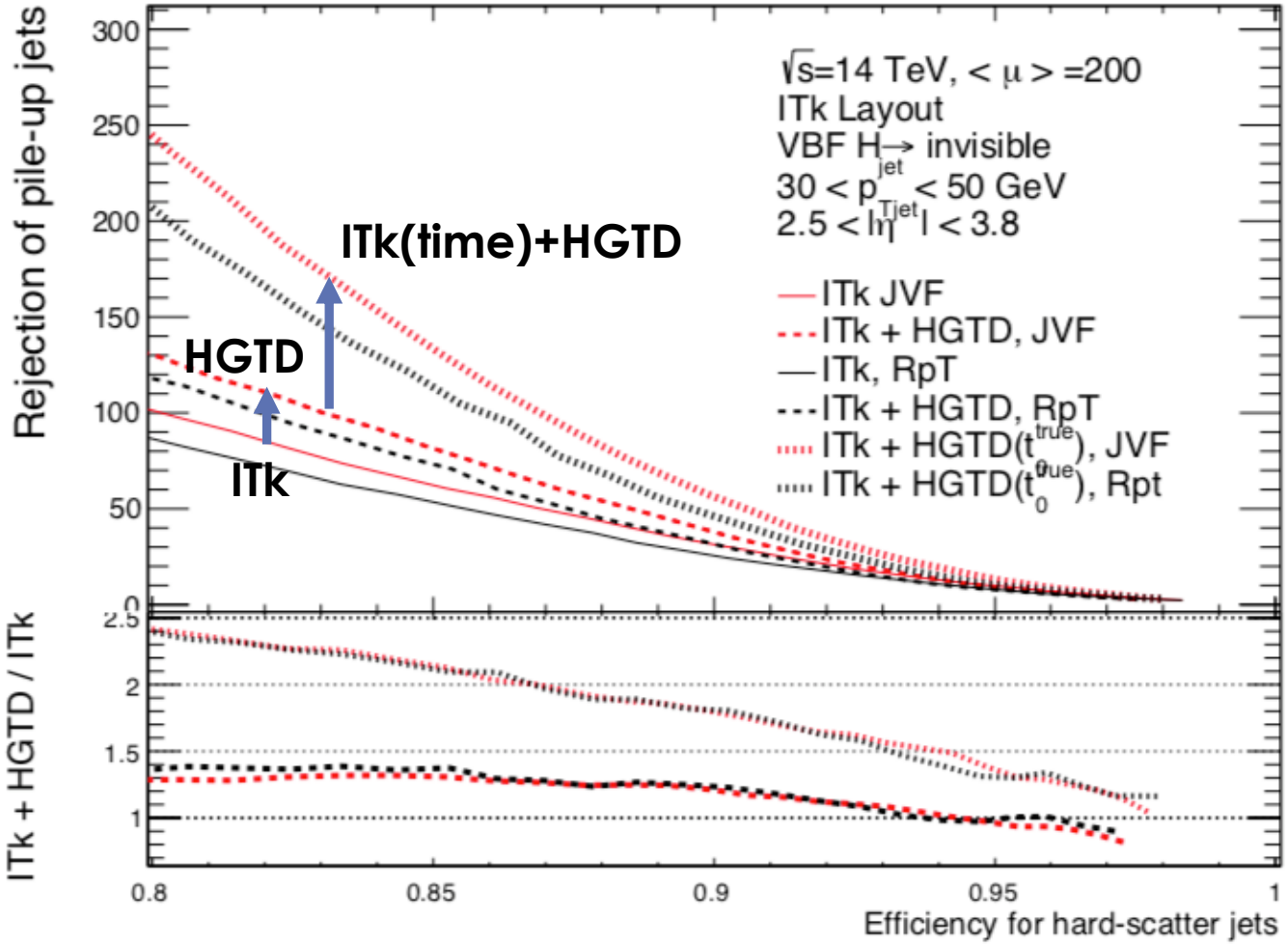
4D pixels in LS4 ITk

- Track-to-vertex association requires to compare the track time to the (primary) vertex time
- Assuming pixel time resolution = 50ps, since primary vertices have >25 tracks → vertex t_0 resolution ~ 50ps/5 < 10ps
- **This will enable precise t_0 reconstruction to be combined with HGTD 30ps track resolution in the forward region,** but might not be optimal for b-tagging/particle-flow improvements
  - This could be studied using existing Monte Carlo samples, by assigning times to tracks with an uncertainty given by the pixel time resolution


Rejection of pile-up jets
ITk + HGTD / ITk
Efficiency for hard-scatter jets
√s=14 TeV, < μ > =200
ITk Layout
VBF H→ invisible
30 < p_T^jet < 50 GeV
2.5 < |η^Tjet| < 3.8
ITk JVF
ITk + HGTD, JVF
ITk, RpT
ITk + HGTD, RpT
ITk + HGTD(t^true), JVF
ITk + HGTD(t_0^true), Rpt
ITk(time)+HGTD
HGTD
ITk

Summary and next steps

- **Implement 30-50um pitch pixel sensors in ATLAS/ACTS simulation**
  - Study track performance (CPU time, efficiency, purity, IP resolution) as a function of number of layers with instrumented time pixels
  - Requires modifications to track seeding and Kalman Filter
  - Need also to consider and investigate material budget impact

- **b-tagging, jet energy resolution, and their impact on physics (di-Higgs?) can start in parallel using existing Run 4 Monte Carlo samples**
  - Assign track times based on various assumptions about time resolution