Parallel 4-Dimensional Cellular Automaton Track Finder for the CBM Experiment

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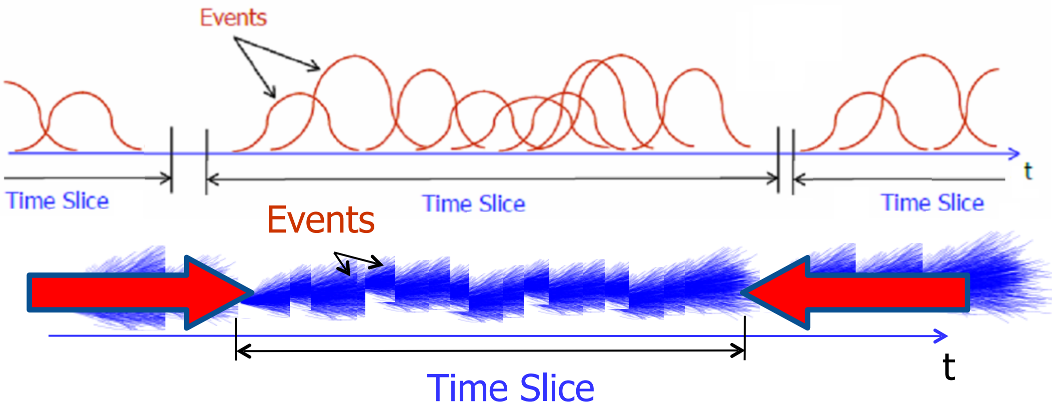
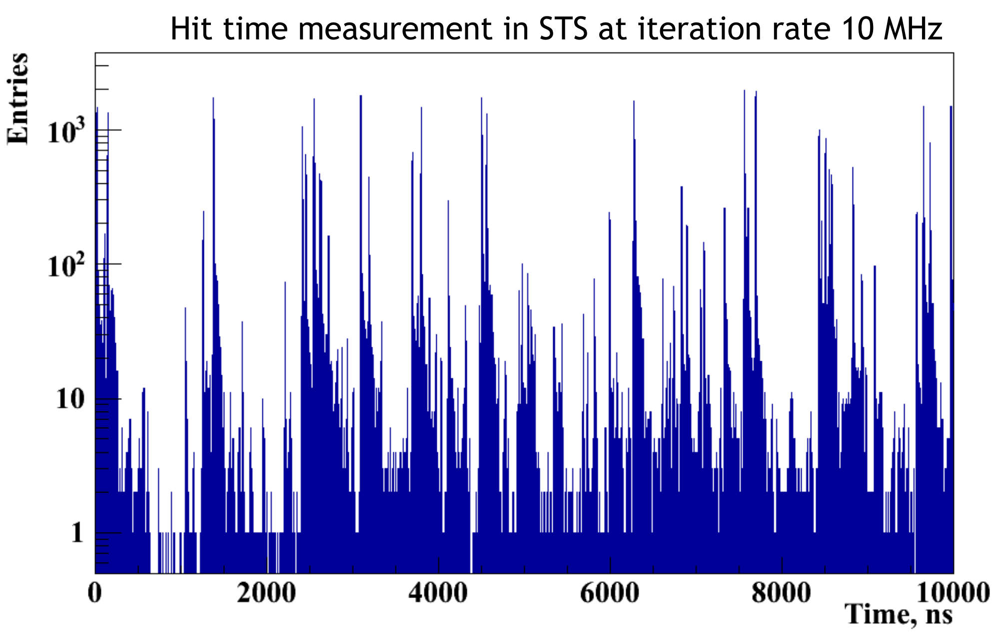
Reconstruction Challenge in CBM





- Interaction rate up to 10 MHz
- free-streaming data
- self-triggered front-end electronics
- no hardware trigger

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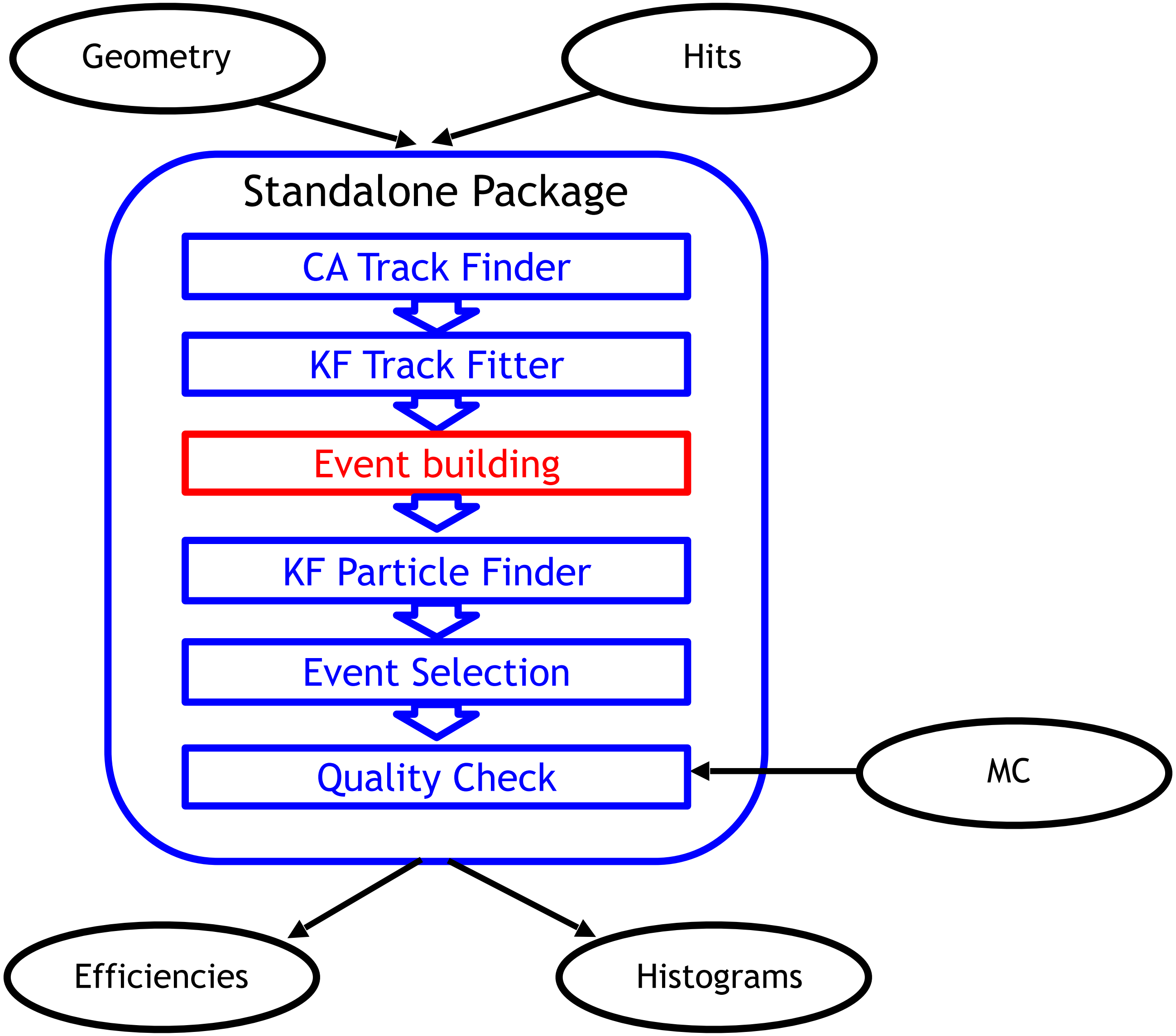
- Time-slice reconstruction rather than event-by-event
- Time-based tracking: 4D (x, y, z, t)

Events overlap on hit level

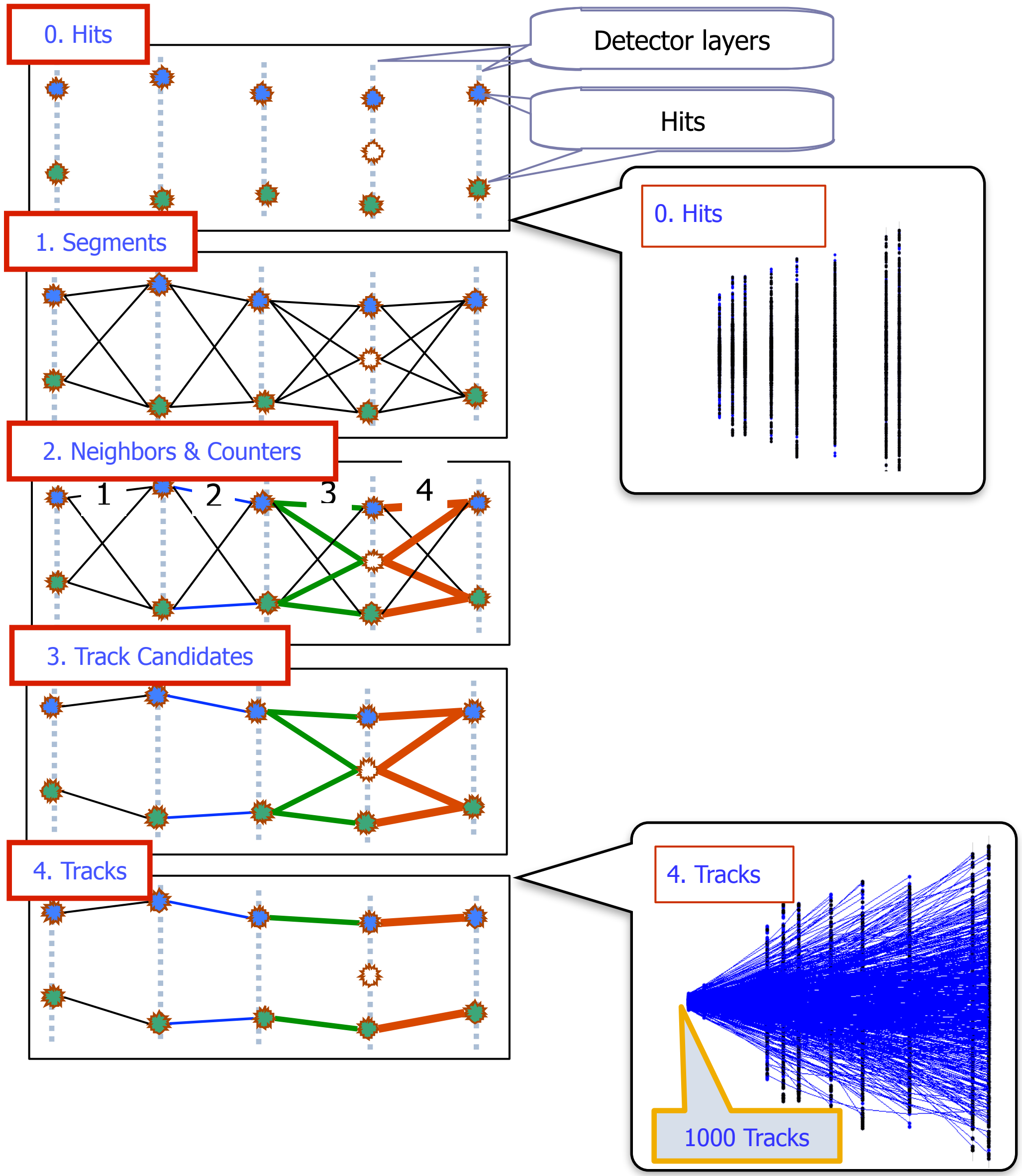
Correct procedure of event building from time-slices is crucial for right physics interpretation

First Level Event Selection Package (FLES)



Event building as a part of FLES package

Cellular Automaton (CA) Track Finder



Cellular Automaton:
- local w.r.t. data
- intrinsically parallel
- simple
- very fast

Perfect for many-core CPU/GPU !

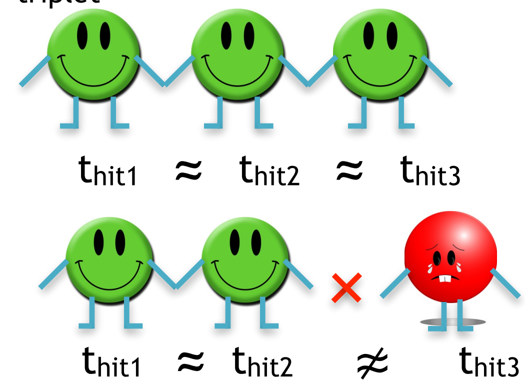
Cellular Automaton:
1. Build short track segments - triplets.
2. Mark possible neighbours while building triplets
3. Connect according to the track model, estimate a possible position on a track.
3. Tree structures appear, collect segments into track candidates.
4. Select the best track candidates.

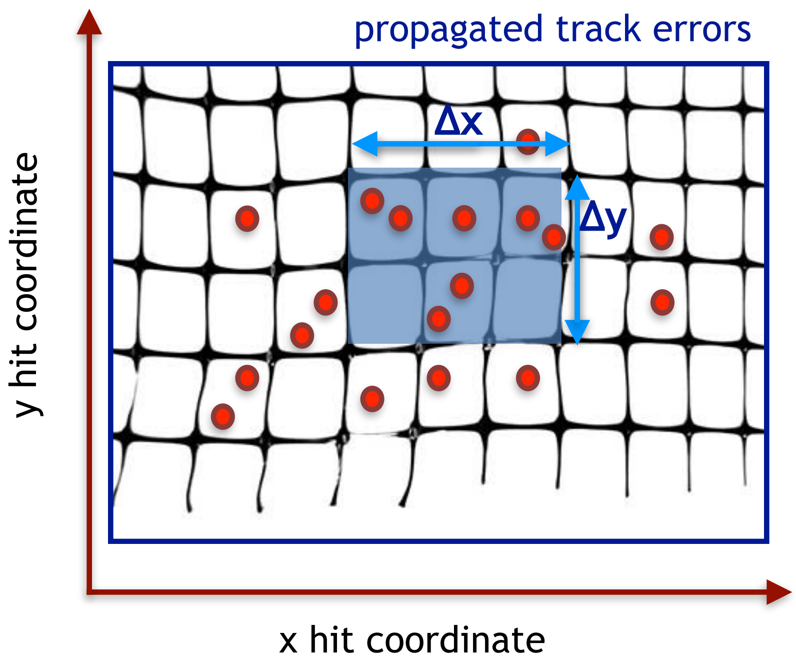
Time-based CA Track Finder

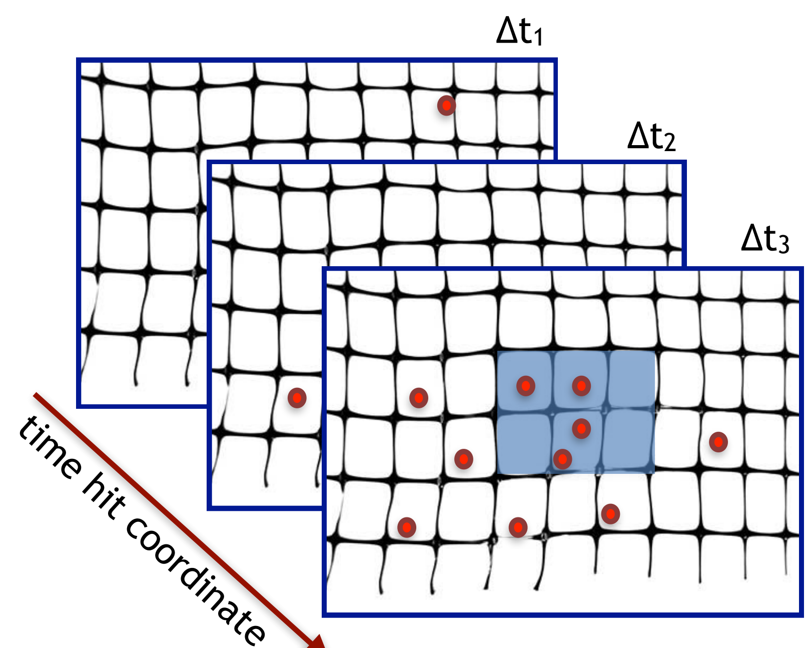
How to use time information in tracking?

- Triplets are build from the hits with the same time measurement within 3 σ of detector precision
- Fast access to the hits is provided by time-based structure: hits are sorted by time and space coordinates and stored into the time-based grid

Hits time measurement have to be the same within detector precision to build a triplet





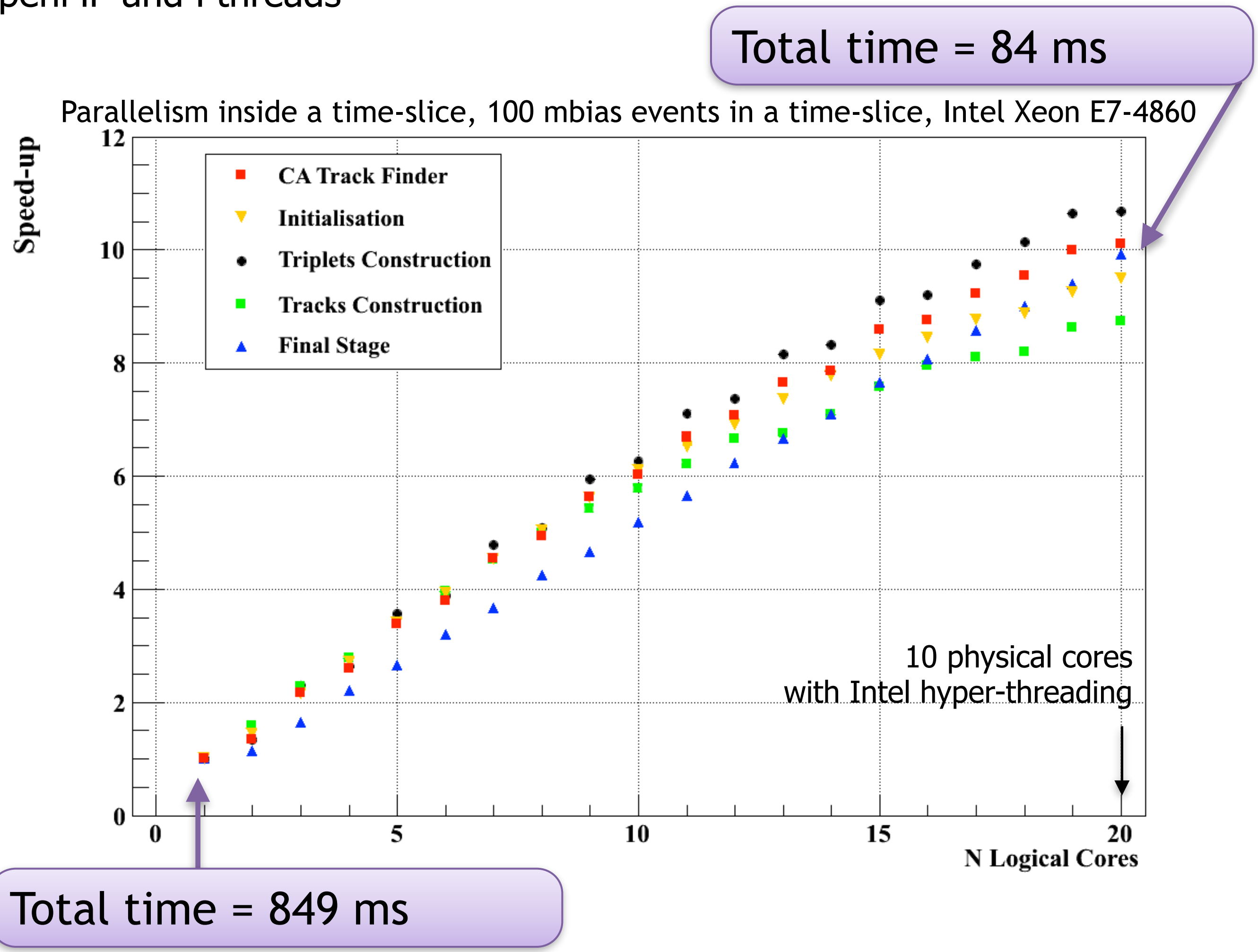


Variable time step of grid: 4D tracking in a 3D-style approach

4D CA Track Finder Scalability

Parallel implementation with OpenMP and Pthreads

Algorithm Step	% of total execution time
Initialisation	8%
Triplets construction	64%
Tracks construction	15%
Final stage	13%



Speed-up factor 10,1   Theoretically achievable factor: 13

4D Track Finder in CBMroot Framework

Efficiency, %	3D	4D	CBMROOT
All tracks	92.1	92.2	91.3
Primary high-p	97.9	97.9	99.1
Primary low-p	93.6	93.5	93.6
Secondary high-p	92.0	92.0	88.9
Secondary low-p	65.7	65.9	56.8
Clone level	2.8	3.1	3.7
Ghost level	4.9	4.2	1.9
Time/event/core	11.7 ms	13.6 ms	17.3 ms

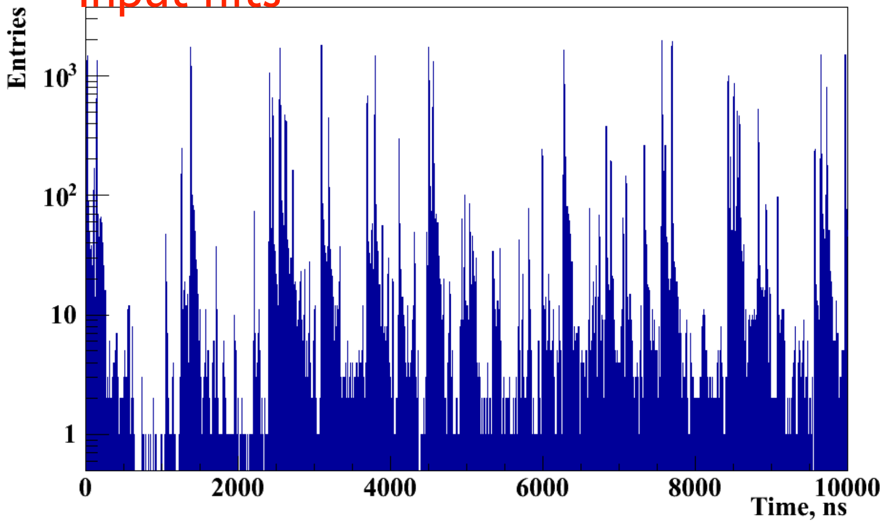
CBMroot revision 8357 (Nov 2014)

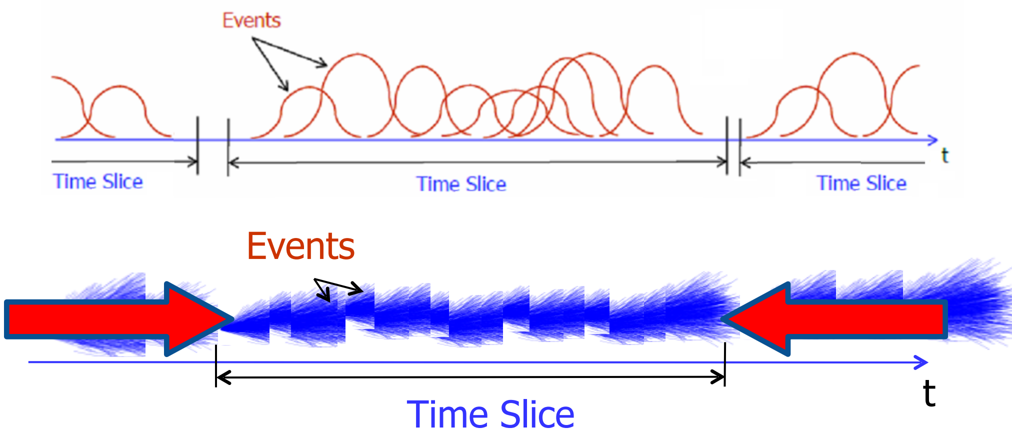
3D, 4D: AuAu 25 AGeV mbias events at 10MHz
CBMROOT: AuAu 10 AGeV mbias events at 10MHz

Time-based tracking performance comparable with event-by-event

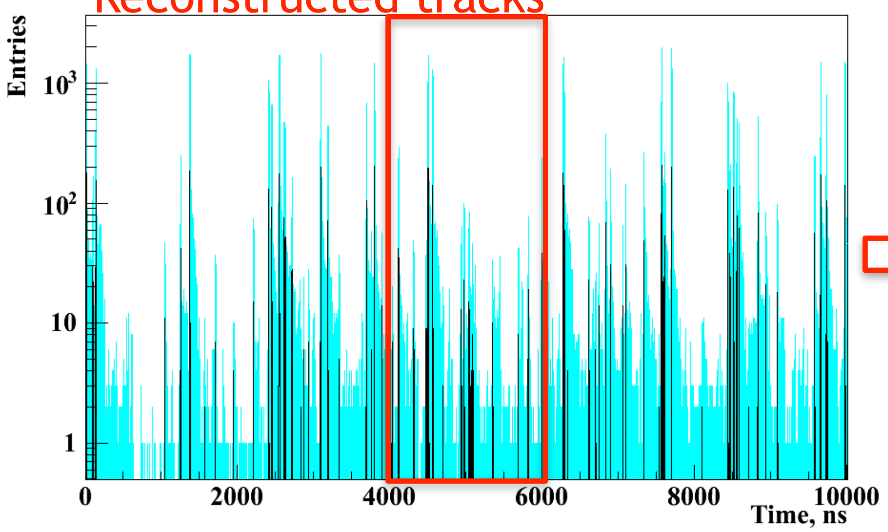
Time-based Track Reconstruction

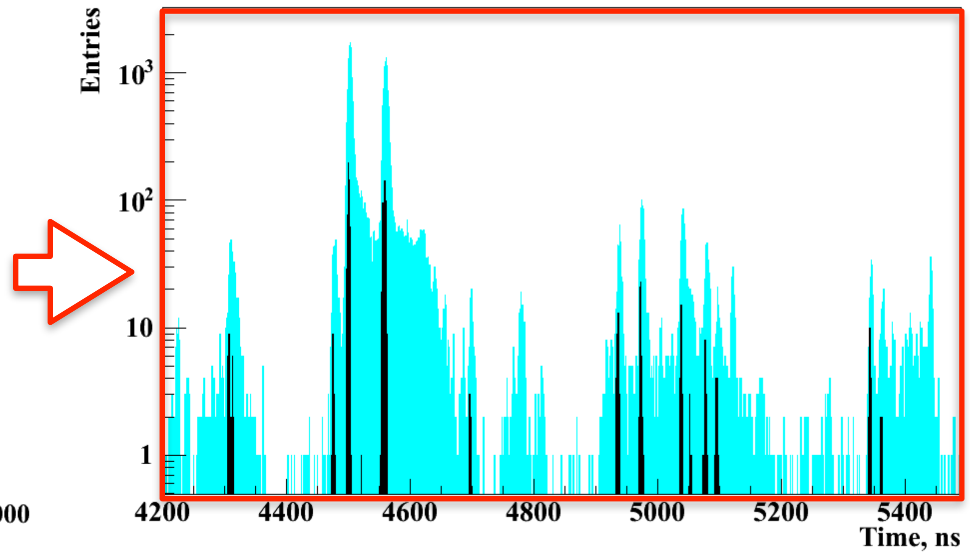
Input hits





Reconstructed tracks



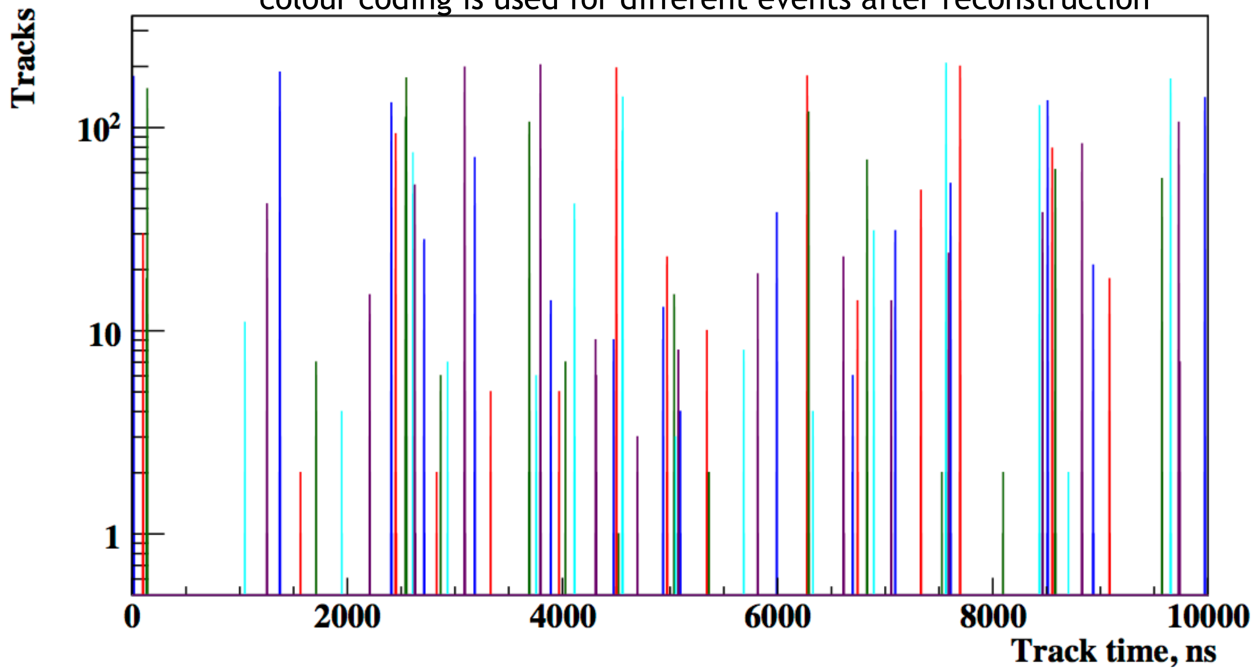


Reconstructed tracks are clearly clustered in groups representing original events

Event Building at IR = 10 MHz

Reconstructed tracks are grouped in events using histogramming:
- all tracks are filled in a time histogram with bin width of 1 ns
- neighbouring not empty bins are called an event
- gap of a 4 empty bins is a sign for event end

colour coding is used for different events after reconstruction



- 70 reco events are reconstructed one-to-one, 7 reco events are merged together.
- Primary tracks can be separated using primary vertex information.
- Search of only one primary vertex per event using KF Particle Finder package is currently implemented.
- Multi-vertex reconstruction is in progress.

7% of events are merged to be studied with multi-vertex analysis

Summary

- Event building is a necessary part of FLES package
- Time-based 4D track finder allows to reconstruct time-slices with speed and efficiency comparable to event-based approach
- 4D track finder is parallel with speed-up 10.1 out of 13 theoretically achievable within the Intel Xeon E7-4860 CPU
- A first version of event building was implemented based on the 4D tracking.

Future Plans

- Multiple primary vertices analysis
- Physics analysis