CA Track Finder

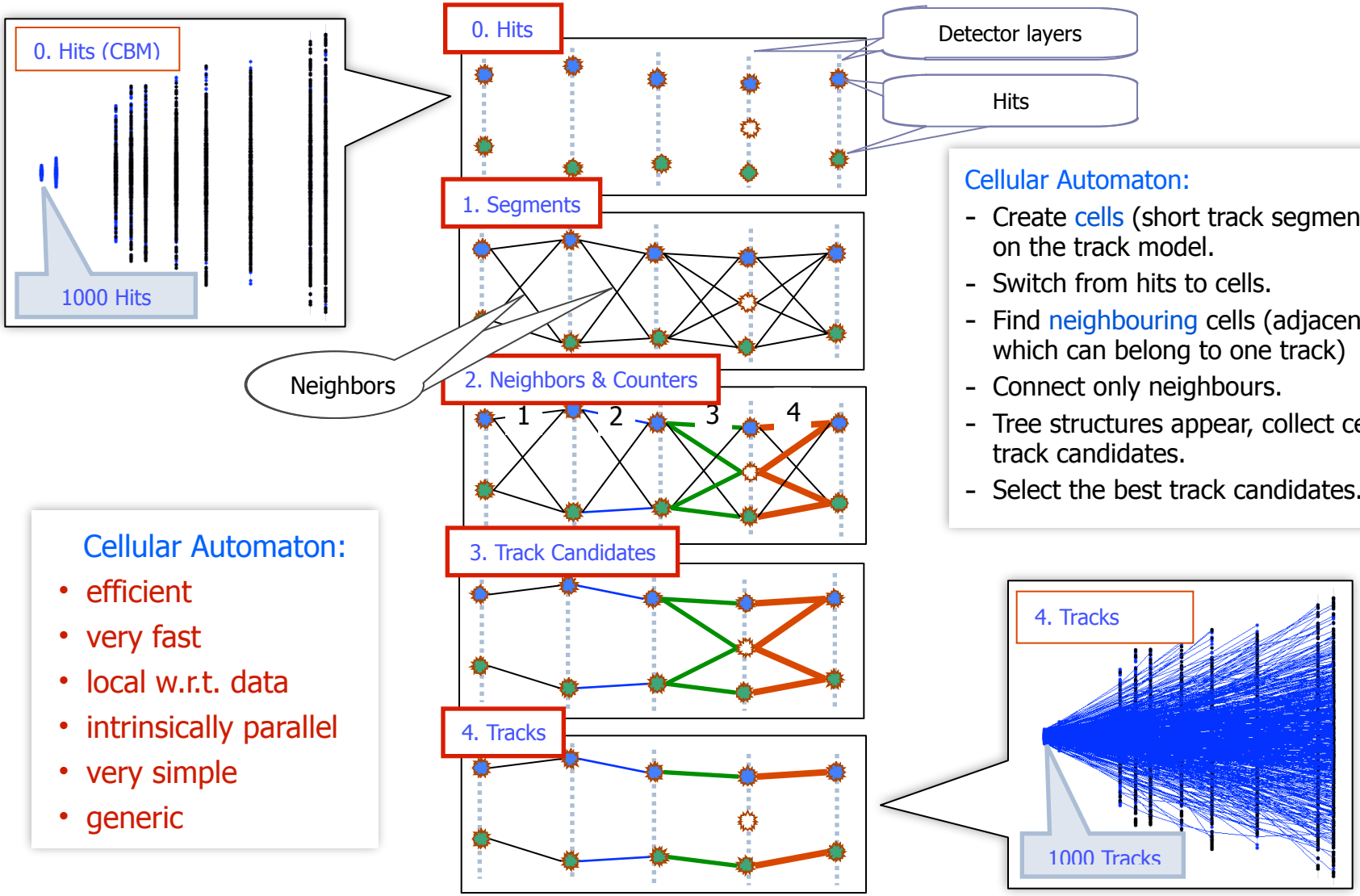
Akishina Valentina, Kisel Ivan, Kulakov Igor

13 May 2014
FCTTC
FIAS, Frankfurt

Cellular Automaton (CA) Based Track Finding

Track Finder: Group hits into tracks.

Cellular Automaton: Create short track segments basing on the track model, collect segments into track.



Cellular Automaton:

- Create cells (short track segments) basing on the track model.
- Switch from hits to cells.
- Find neighbouring cells (adjacent cells which can belong to one track)
- Connect only neighbours.
- Tree structures appear, collect cells into track candidates.
- Select the best track candidates.

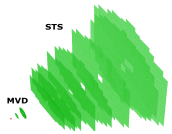
Cellular Automaton:

- efficient
- very fast
- local w.r.t. data
- intrinsically parallel
- very simple
- generic

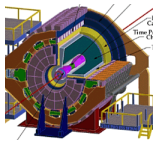
CA Track Finder with Different Detectors

- ✓ Different implementations of CA have been used with success in such experiments as CBM, HERA-B, NEMO, ALICE and STAR

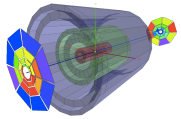
CBM L1 CA



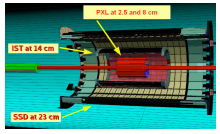
STAR TPC CA



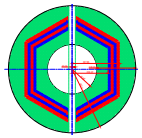
ALICE ITS



STAR HFT



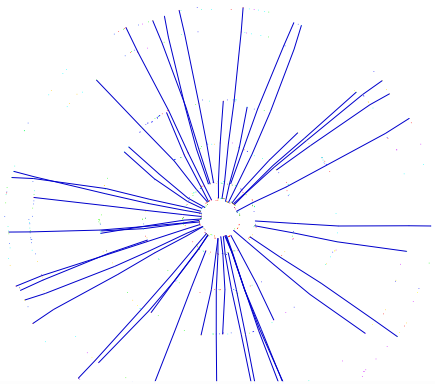
PANDA STT

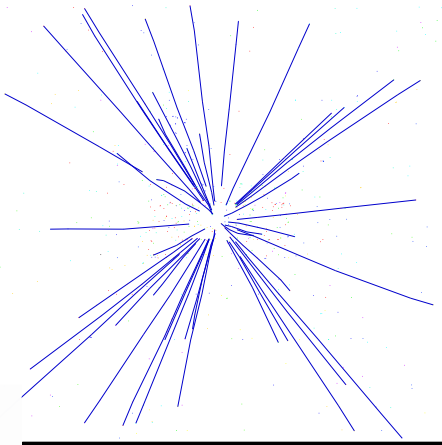


- ✓ Track Finder is Cellular Automaton (CA) and Kalman Filter (KF) based
- ✓ CA has the same code for STAR HFT, ALICE ITS, PANDA STT
- ✓ KF has the same code for STAR HFT, ALICE ITS, PANDA STT, STAR TPC (all barrel detectors)

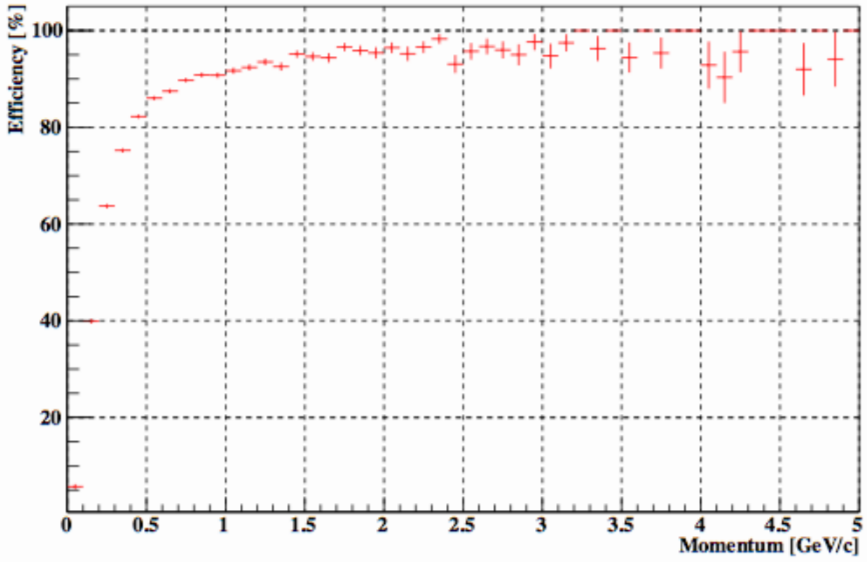
Different experiments similar reconstruction approaches

ALICE ITS CA Track Finder Performance





Hits are smeared around MC position according to gaussian distribution with width 1 mm.



Efficiency and ratios, %	
Fast Primary	98
All Tracks	75,2
Clone	0
Ghost	1,4
Tracks/ev	8
Time, ms/ev	2

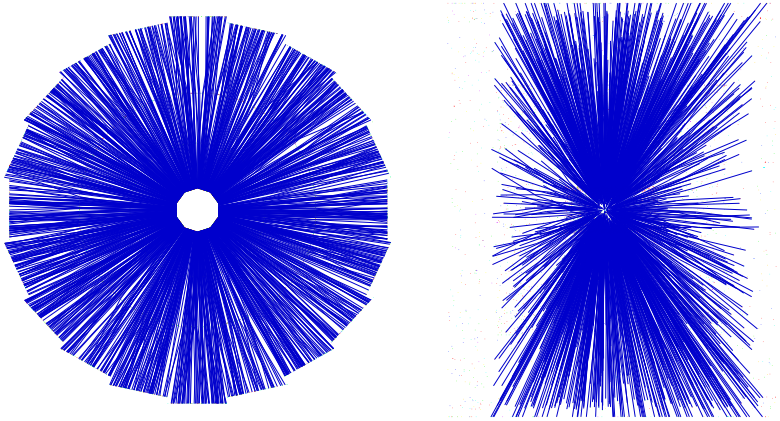
p+p events, 7TeV; Statistic: 8000 events
1 core of Intel Core i7, 2 GHz, 4 MB L3 cache, 8 GB RAM

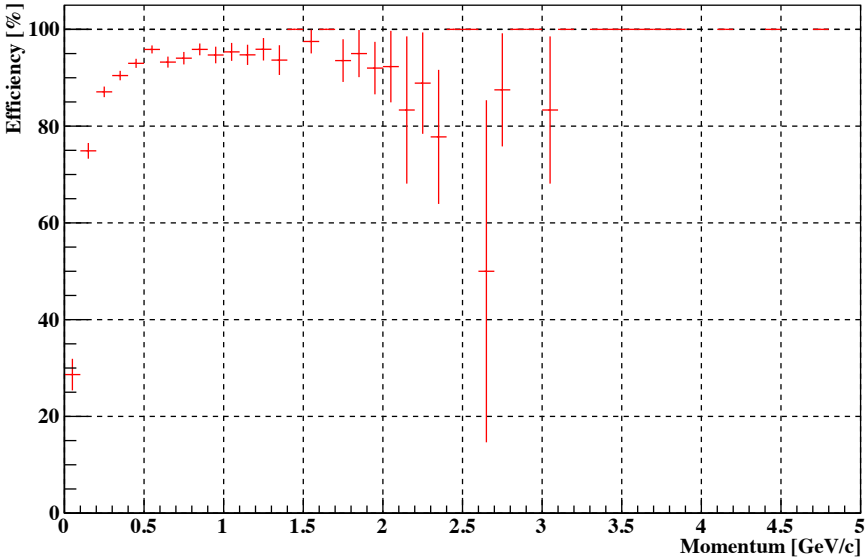
Reconstructable track:
4 consecutive MC points

All set: $p \geq 0.05$ GeV/c
Fast set: $p \geq 1$ GeV/c
Ghost: purity < 70%

The ALICE ITS CA Track Finder shows 98 % efficiency for signal tracks

STAR HFT CA Track Finder Performance





AuAu 200 GeV central; Statistic: 5 events
1 core of Intel Core i7, 2 GHz, 4 MB L3 cache, 8 GB RAM

Efficiency and ratios, %	
Fast Primary	95,3
All Tracks	88,4
Clone	0
Ghost	5,2
Tracks/ev	1055
Time, s/ev	1,72

Reconstructable track:
4 consecutive MC points

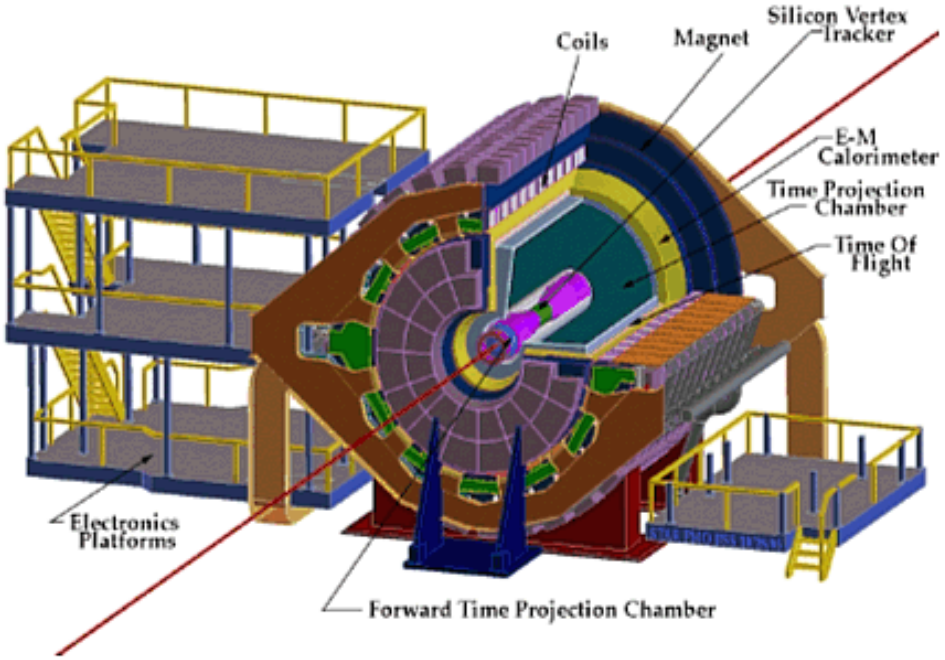
All set: $p \geq 0.05$ GeV/c
Fast set: $p \geq 1$ GeV/c
Ghost: purity < 70%

The STAR HFT CA Track Finder shows 95 % efficiency for signal tracks

STAR TPC Detector

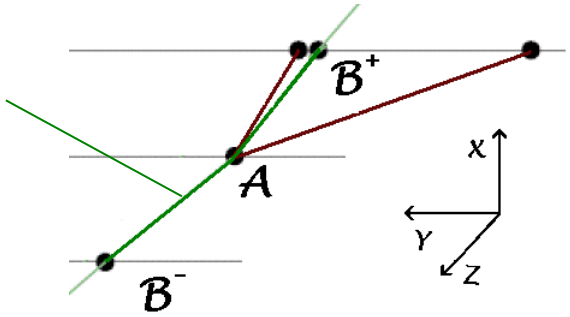
STAR:

- Collider experiment at RHIC, BNL (USA)
- Main tracking detector – TPC



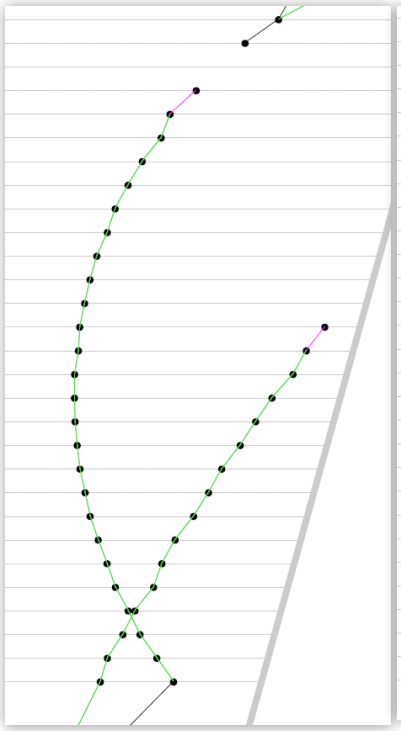
CA Track Finder Algorithm in STAR TPC

1. Reconstruction of track segments in each TPC sector:
   a) Find and link neighbours hits
   b) Clean links
   c) Create segments by fitting chains and adding outer hits
   d) Refit tracks and add inner hits
   e) Selection of tracks
2. Merge sector tracks into TPC global tracks.

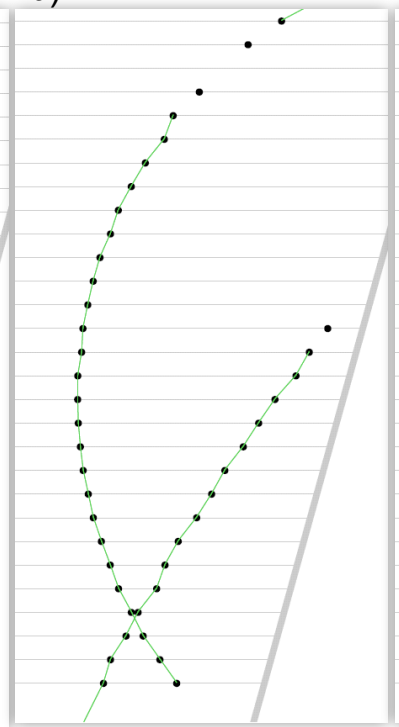


e)

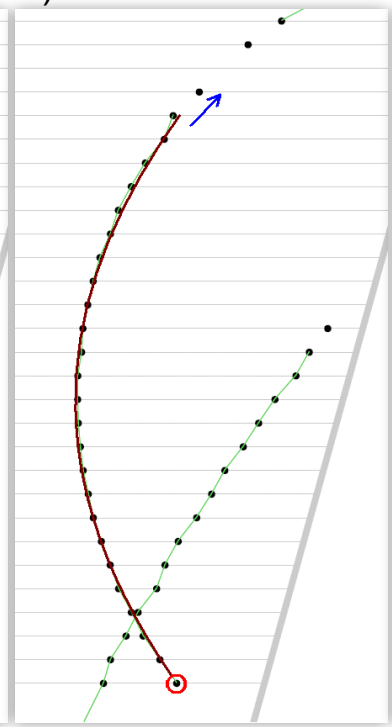
a)



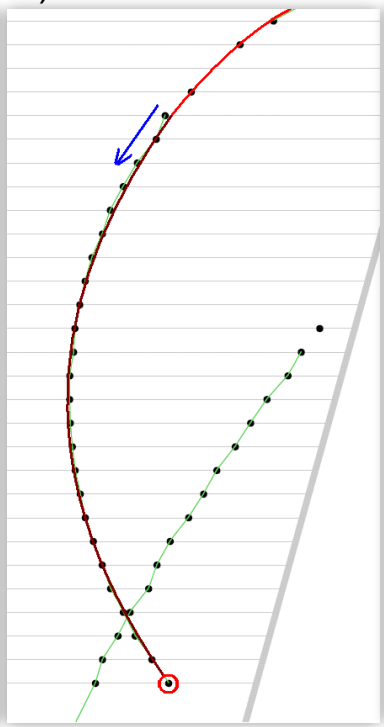
b)

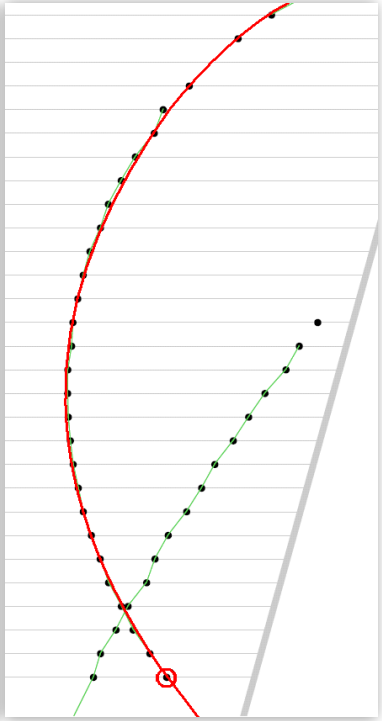


c)



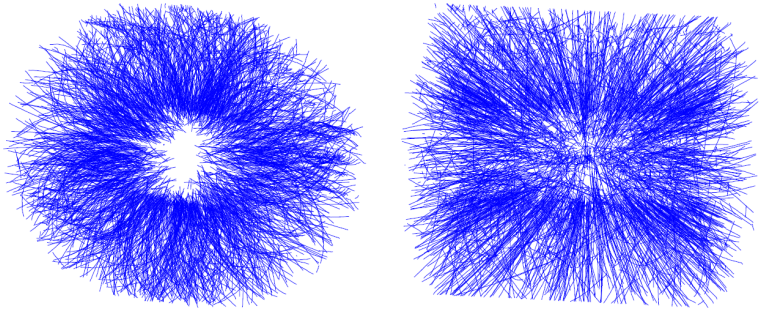
d)

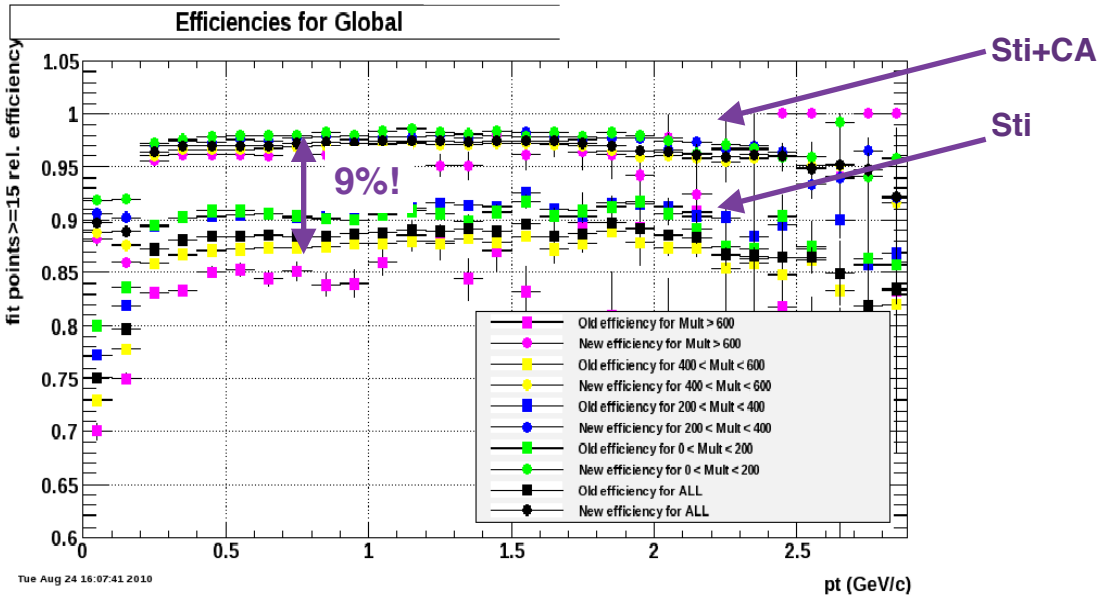




Based on the ALICE HLT TPC CA Track Finder

STAR TPC CA Track Finder Performance





Au+Au 200 AGeV; Real Data

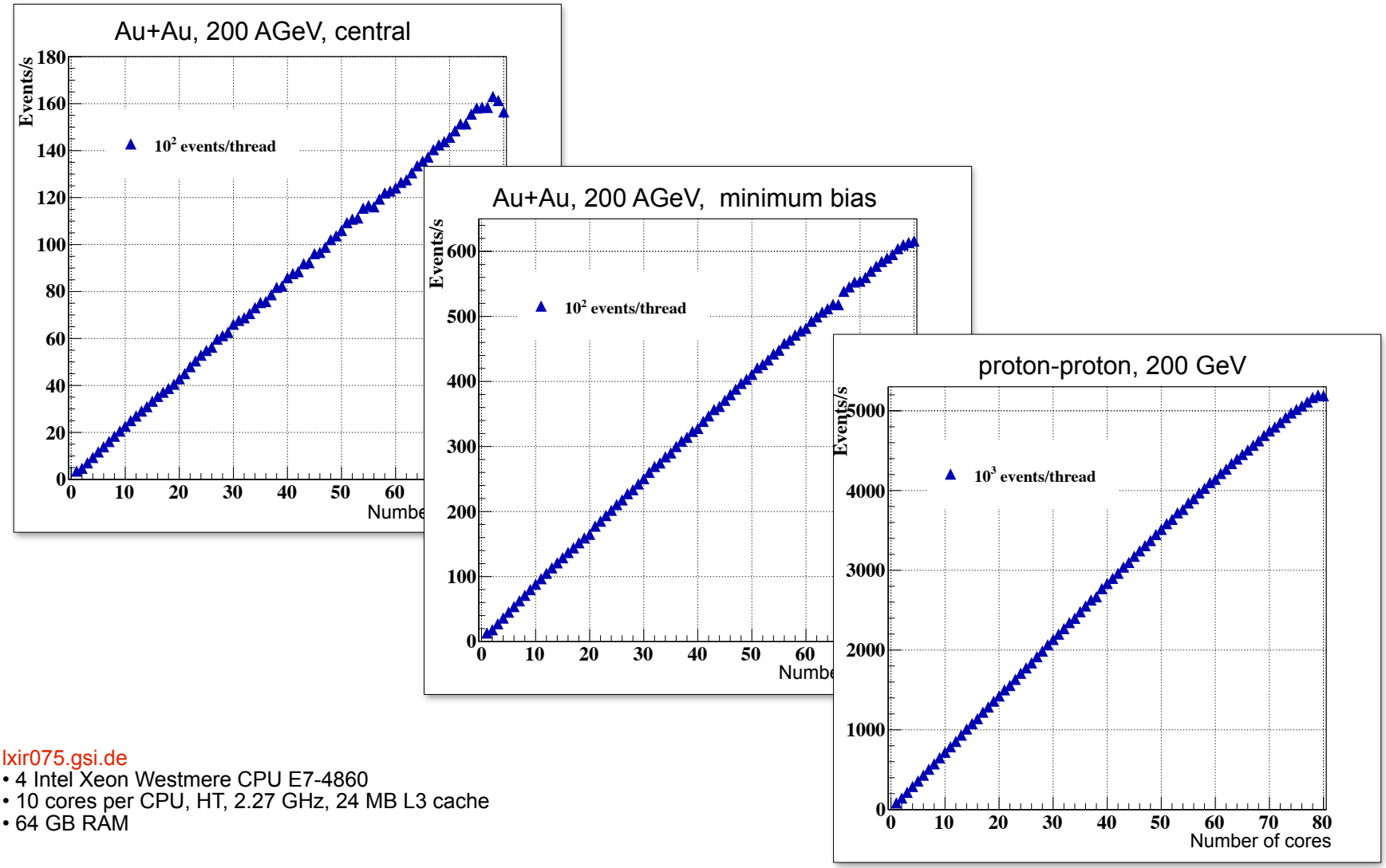
Efficiency and ratios, %	
Fast Set	96.6
All Set	88.6
Clone	10.6
Ghost	12.6
Tracks/ev	659
Time/ev, ms	47

Reconstructable track:
≥ 10 MC points

All set: p ≥ 0.05 GeV/c
Fast set: p ≥ 1 GeV/c
Ghost: purity < 90%

The execution time of STAR TPC CA track finder is 47 ms with efficiency of 96.6 %

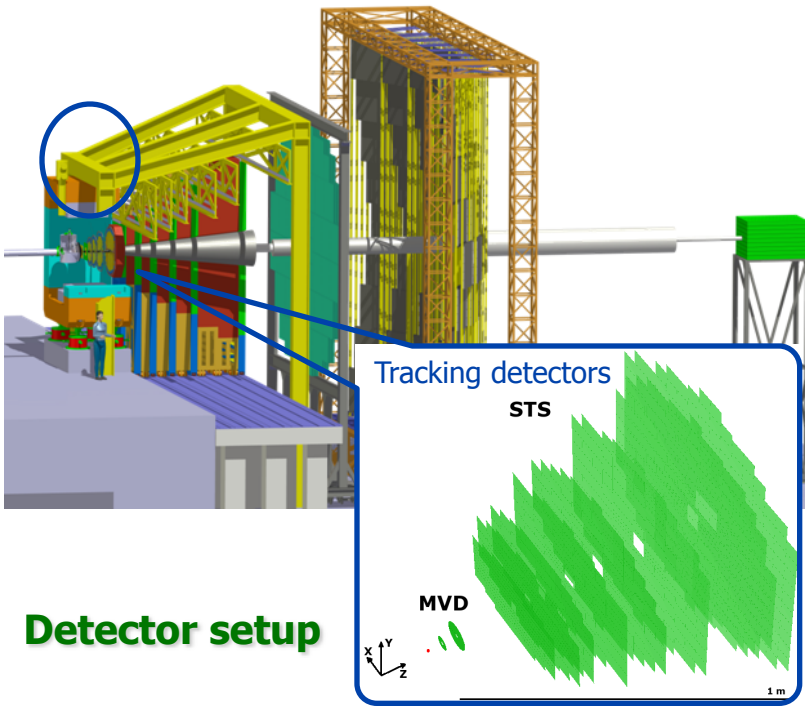
Investigation of CA Event-Level Parallelism



lxir075.gsi.de
- 4 Intel Xeon Westmere CPU E7-4860
- 10 cores per CPU, HT, 2.27 GHz, 24 MB L3 cache
- 64 GB RAM

Strong CA scalability up to 80 cores

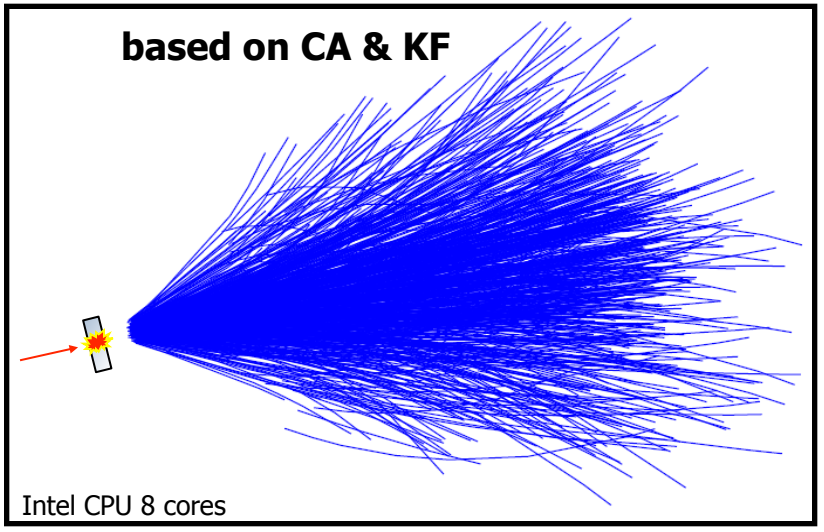
Tracking Challenge in CBM



Detector setup

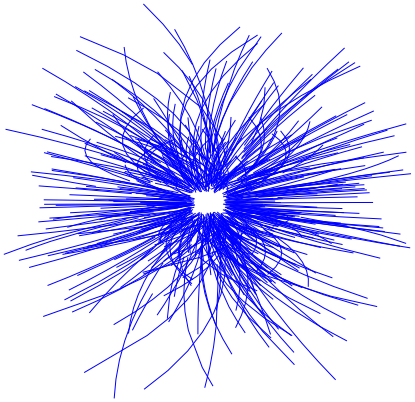
- 10^7 Au+Au collisions/sec
- Track reconstruction in STS/MVD and displaced vertex search are required in the first level trigger
- Double-sided strip detectors (85% fake space points)
- Non-homogeneous magnetic field
- 1000 charged particles per central collision

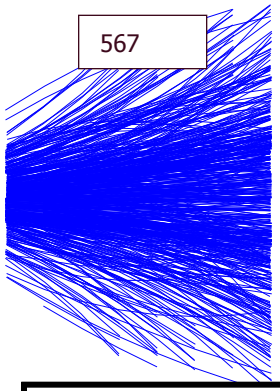
Reconstruction
in the tracking detectors

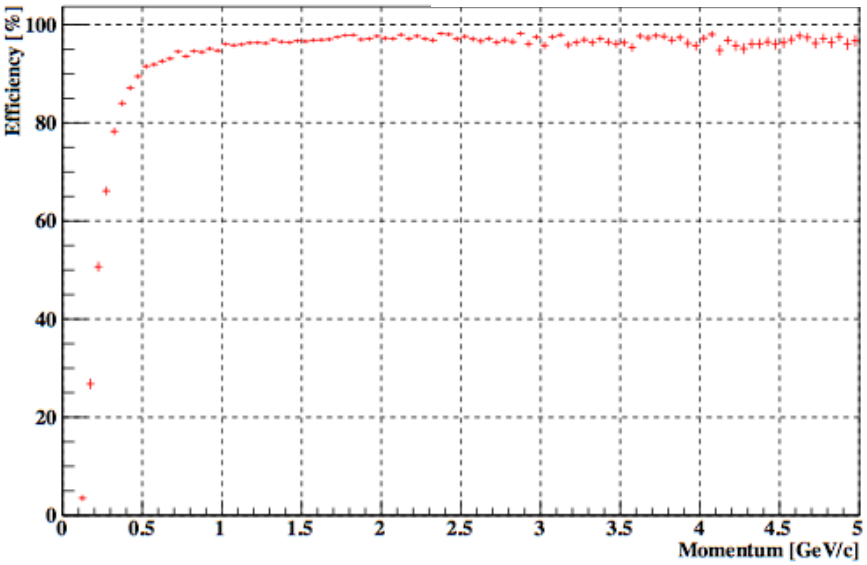


Very efficient, fast and flexible realisation of the CA track finder algorithm is required

CBM L1 CA: Track Reconstruction Quality







Efficiency and ratios, %	
Long Fast Primary	99,8
Fast Primary	97,5
All Tracks	92,1
Clone	0,3
Ghost	4,6
Quality (reco hits)	94,2
Reco Tracks/ev	131
Time, ms/ev	12

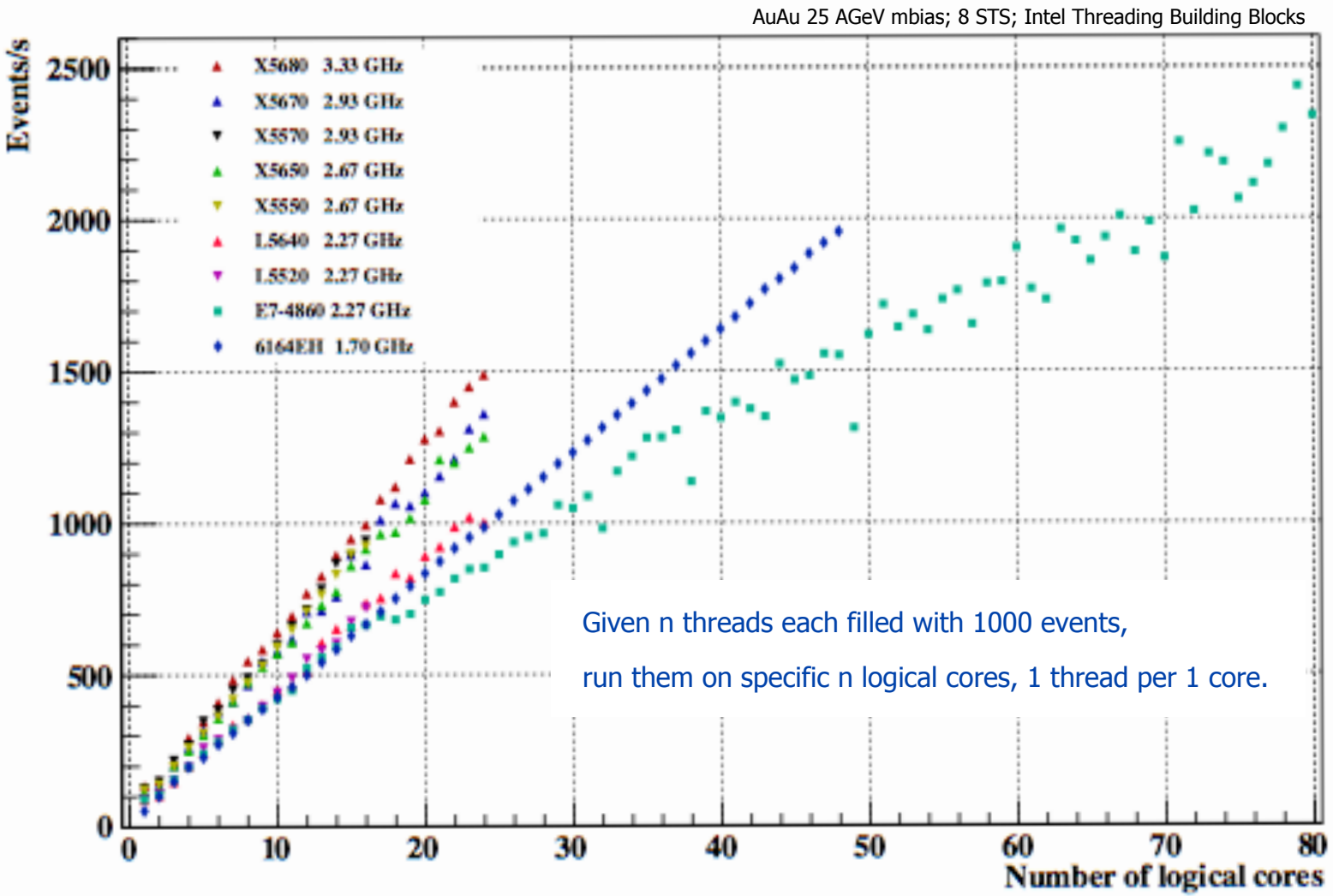
AuAu 25 AGeV mbias; 8 STS; 12b; realistic material budget; Statistic: 1000 UrQMD events
1 core of lxir039: X5550, 2.9 GHz, 16 MB L3 cache, 64 GB RAM

Reconstructable track:
≥ 4 consecutive MC points

All set: p ≥ 0.1 GeV/c
Fast set: p ≥ 1 GeV/c
Ghost: purity < 70%

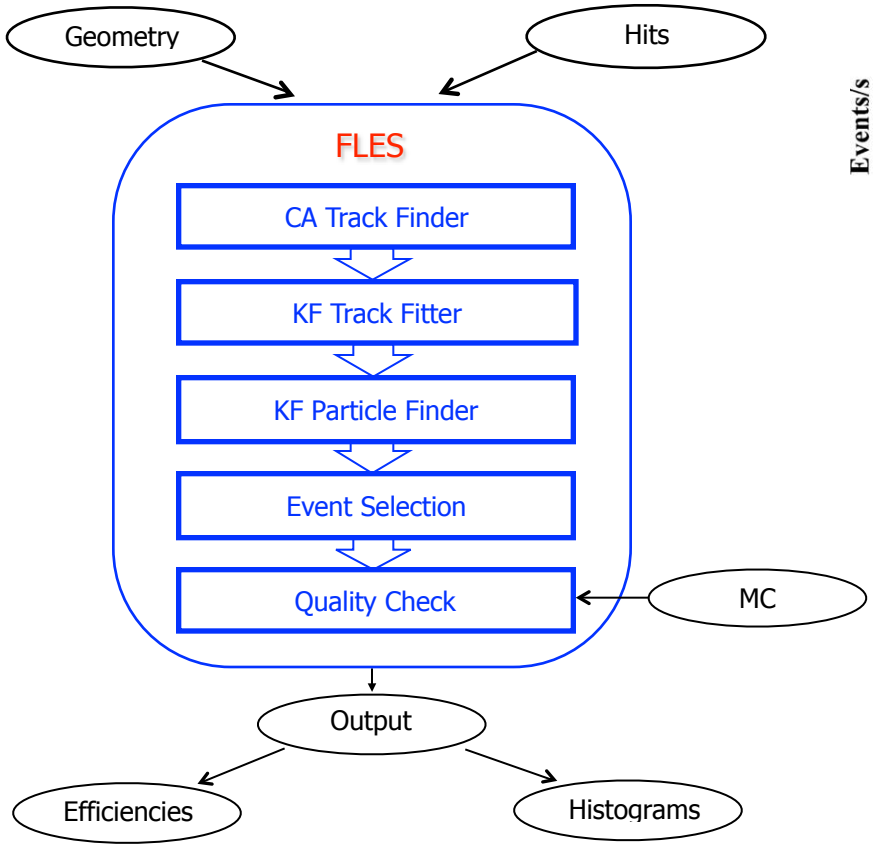
CA Track Finder shows 97.5 % efficiency for signal tracks at latest STS setup

Scalability on Many-core System



The CA Track Finder shows strong scalability on many-core system

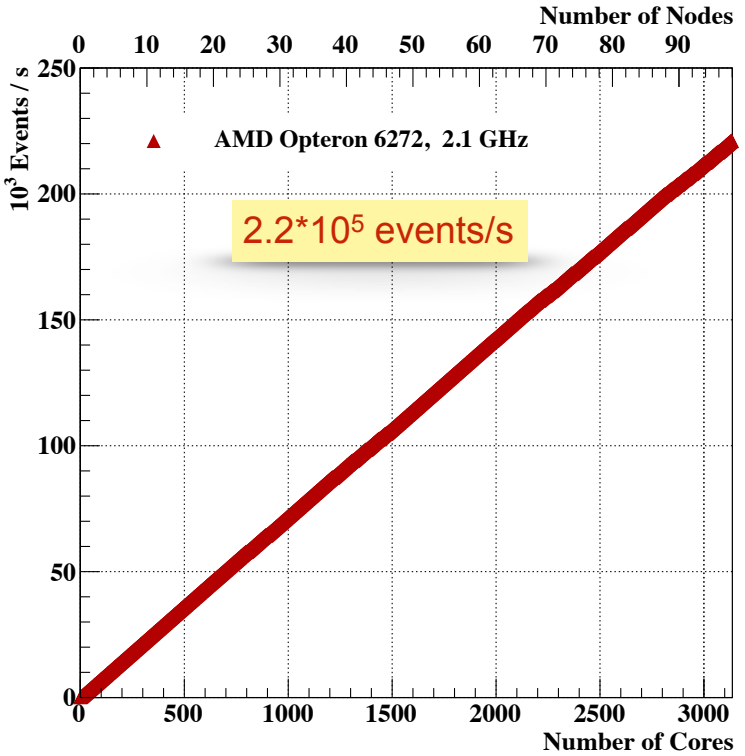
CBM Standalone First Level Event Selection (FLES) Package



Given n threads each filled with 1000 events, run them on specified n cores, thread/core.

The first version of the FLES package is vectorized, parallelized, portable and scalable

FLES Tests on ITEP Supercomputer (Event-Level Parallelism)

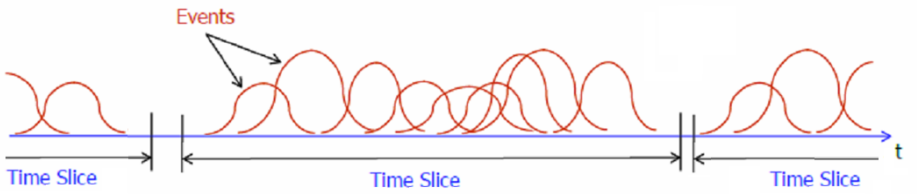


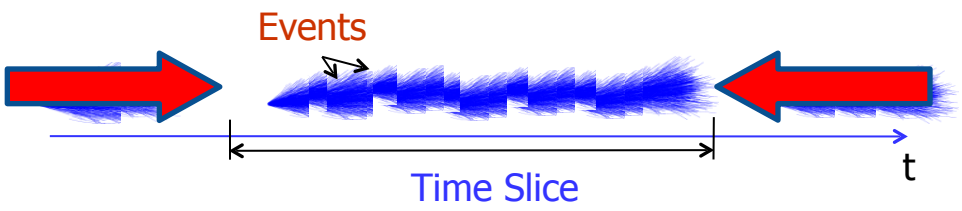
CA Track Finder: towards 4D Reconstruction

The beam in the CBM will have no bunch structure, but continuous:

Reconstruction of time slices rather then events will be needed.

Measurements in this case 4D (x, y, z, t).





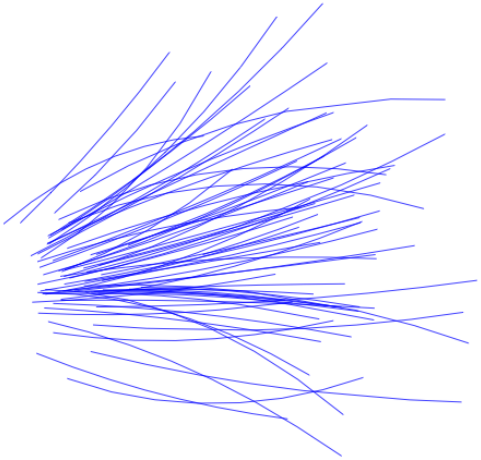
Packed groups of events:

- a number minimum bias events was grouped into one, which was treated by track finder as one event
- no time measurement was taken into account
- hits were created on the minimum bias event level

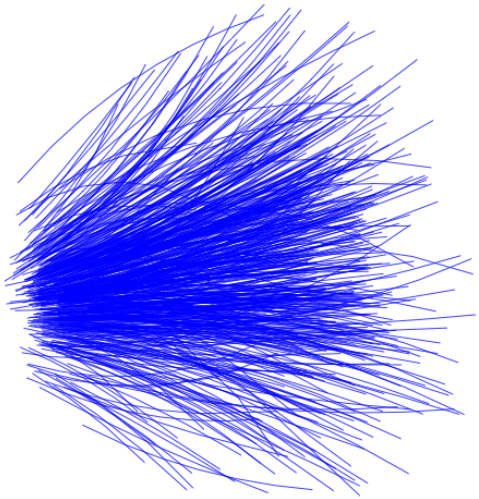
A group of minimum bias events is treated as a single event

CBM CA Track Finding at High Track Multiplicity

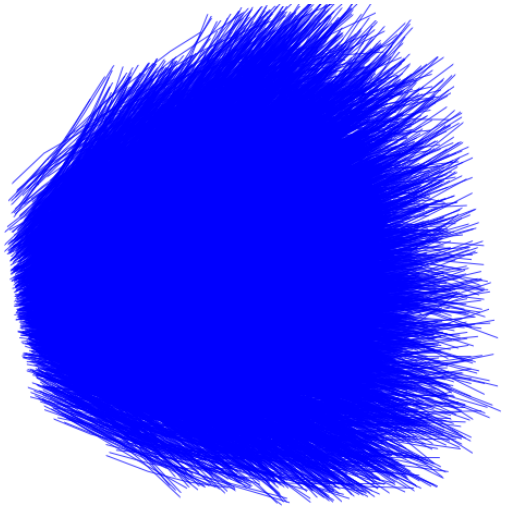
A number of minimum bias events is gathered into a group, which is then treated by the track finder as one event



1 minimum bias event
$\langle N_{reco} \rangle = 109$



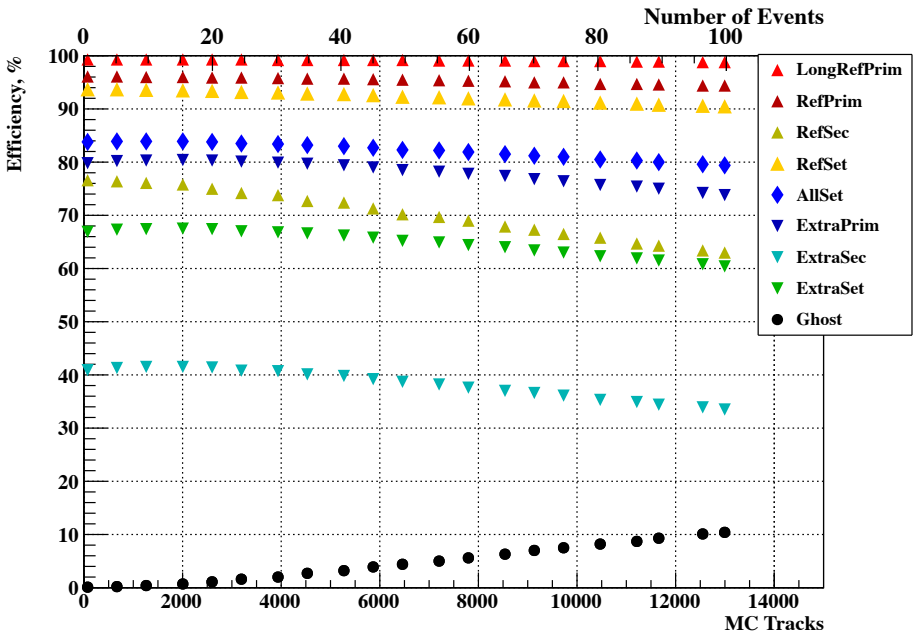
5 minimum bias events
$\langle N_{reco} \rangle = 572$

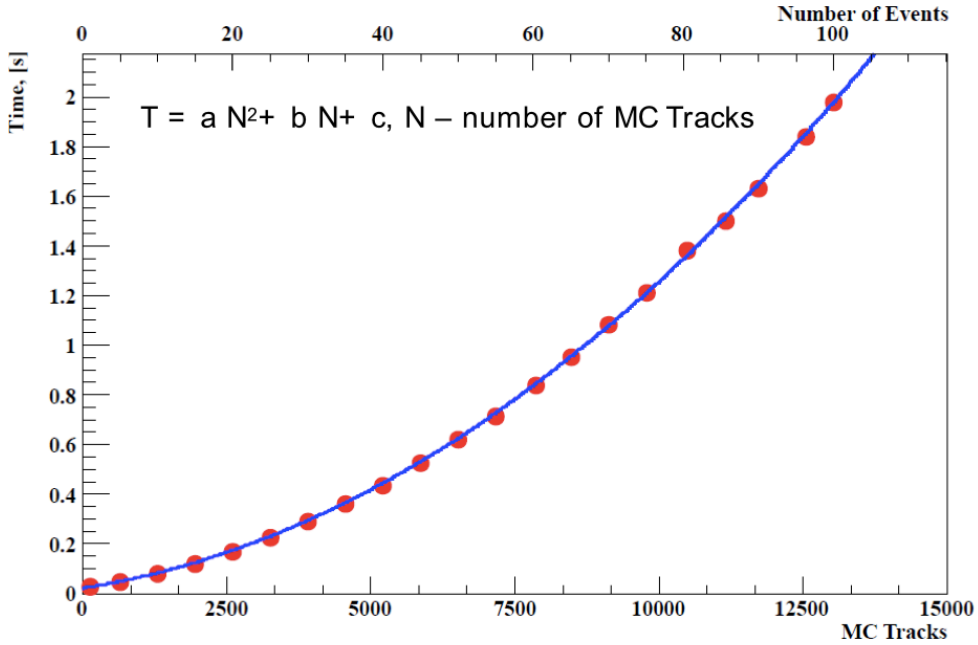


100 minimum bias events
$\langle N_{reco} \rangle = 10340$

Au+Au mbias events at 25 AGeV, 8 STS, 0 x 7,5 strip angles

Efficiency and Time vs. Track Multiplicities

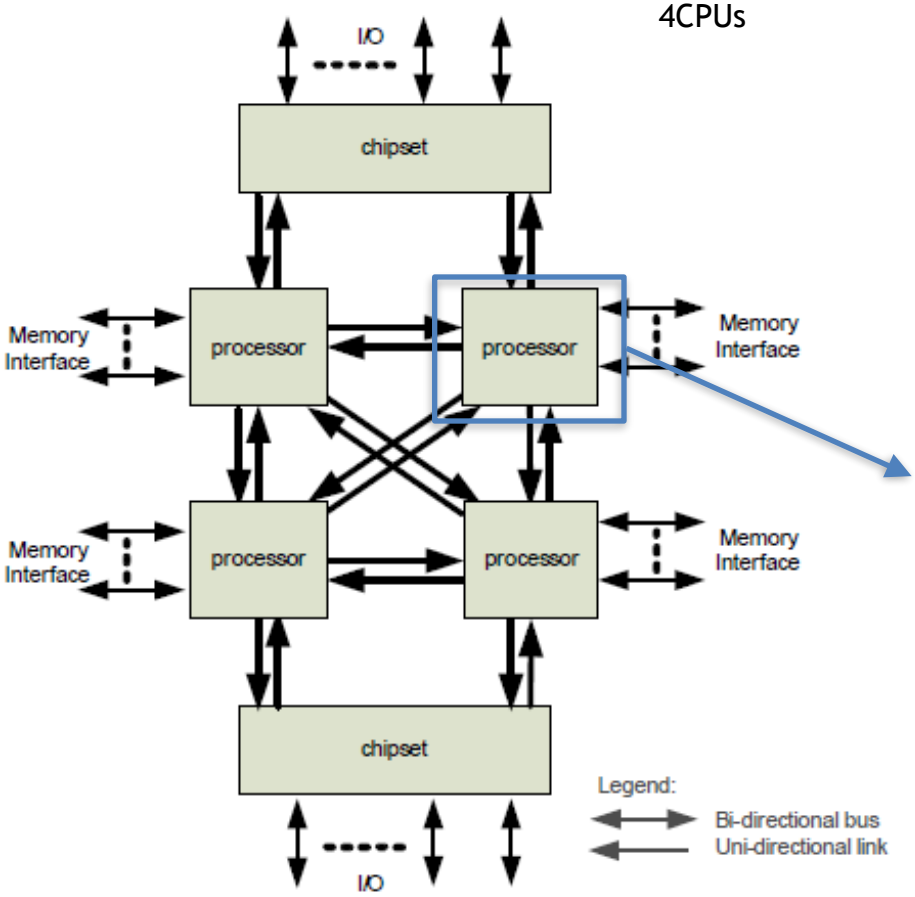




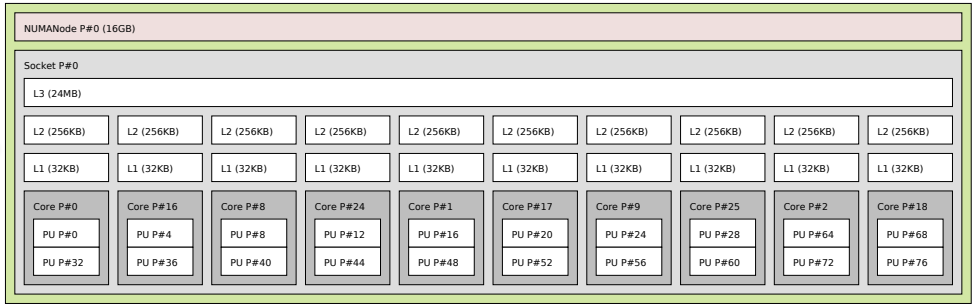
Stable reconstruction efficiency and time as a second order polynomial up to 100 minimum bias events in a group

NUMA Node architecture

lxir075 server:
Xeon E7-4860
4CPUs



Single CPU:
10 physical cores
Hyperthreading

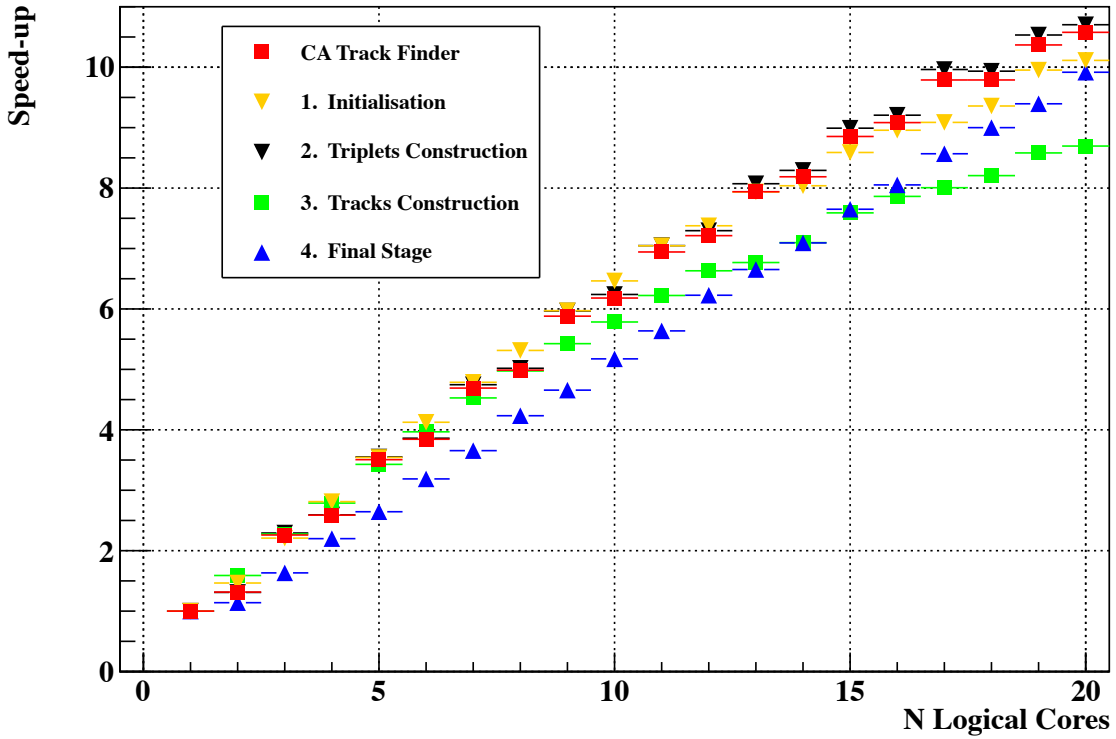


In order to optimise memory access avoid CPU communication: time slice per CPU

CA Track Finder: Speed up Factor within CPU (In-Event Parallelism)

Algorithm Step	% of total execution time
Initialisation	2%
Triplets construction	90.4%
Tracks construction	4.1%
Final stage	3.4%

Speed-up factor 10.6 Expected factor: 13



CA Track Finder was parallelized inside the event with the use of Open MP

Summary and Outlook

Summary

Cellular Automaton Track Finder is very fast and efficient, local w.r.t. data, intrinsically parallel and generic algorithm

CA Track Finder is available for STAR TPC, CBM STS, ALICE ITS, STAR HFT and PANDA STT detectors

CA Track Finder was parallelized between events and shows strong scalability up to 3k cores on ITEP computer cluster

CA Track Finder was parallelized inside the event with speed up factor of 10,6 between 10 physical cores with hyperthreading