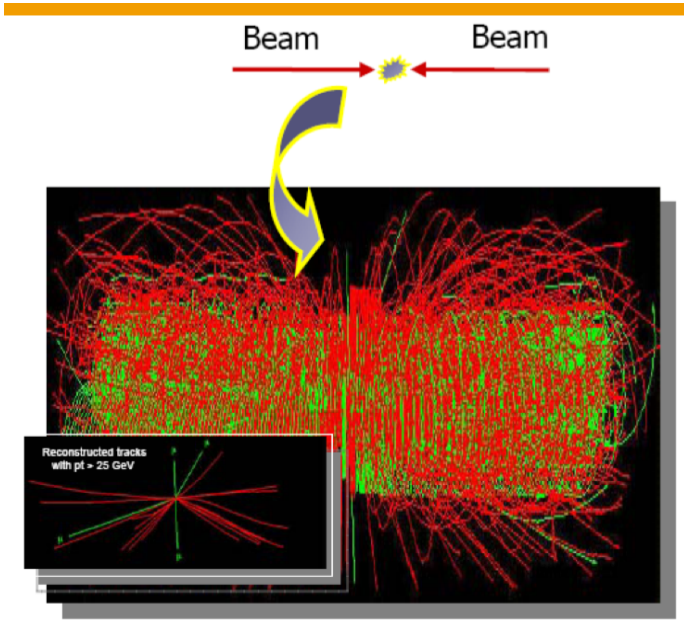
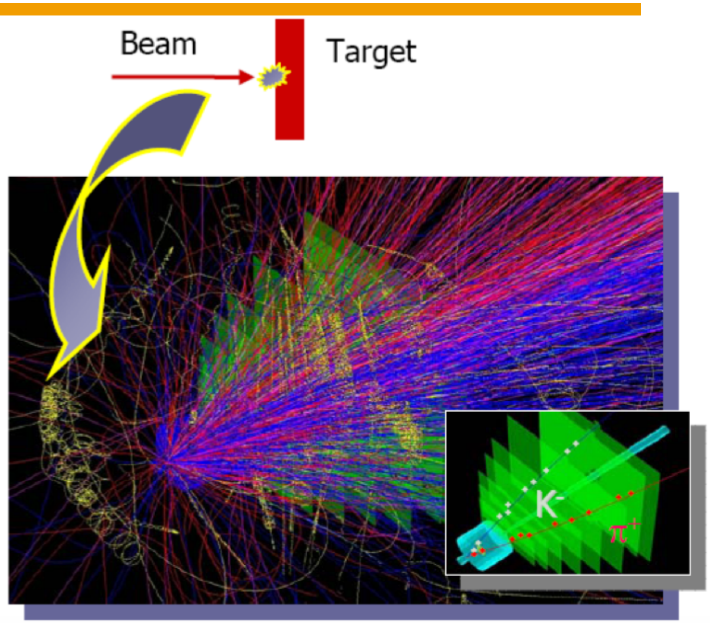
HEP Experiments: Collider and Fixed-Target



Inelastic collisions
$10^7 - 10^9$

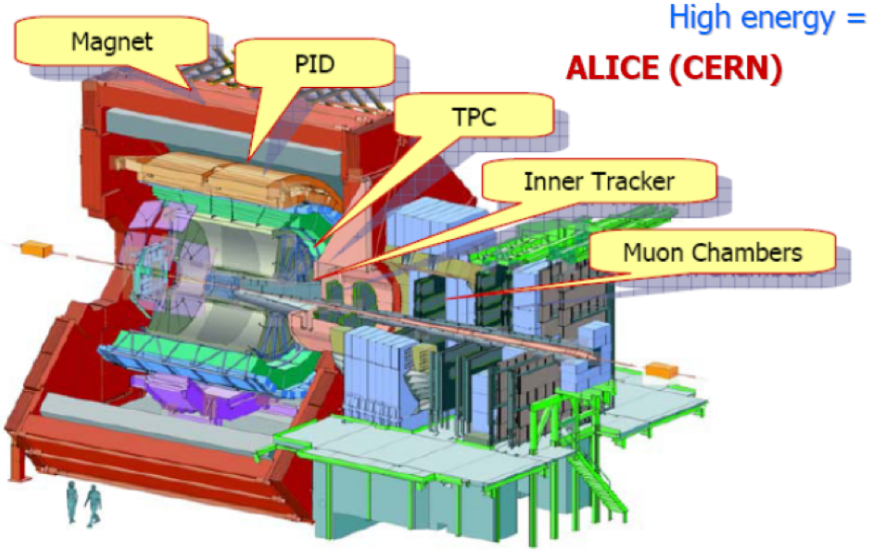
10^{11}

Signal events
$10^2 - 10^{-2}$

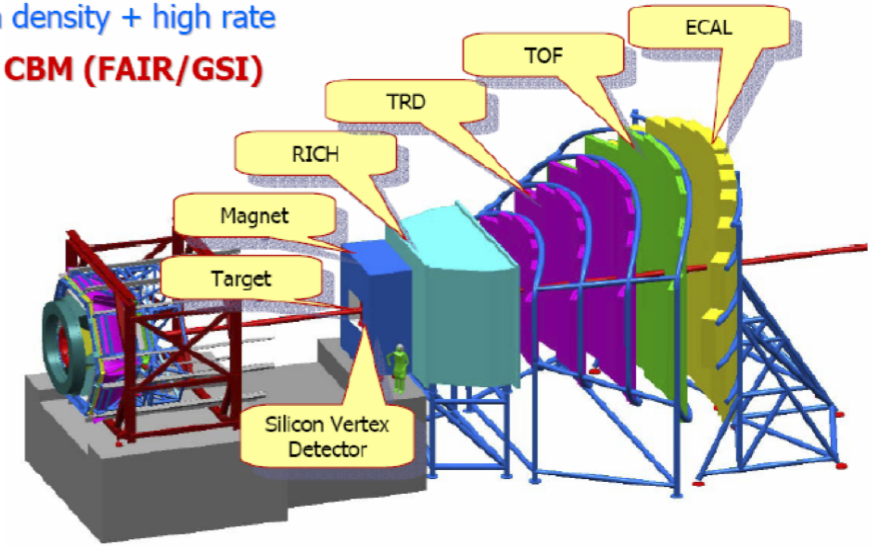


High energy = high density + high rate

ALICE (CERN)

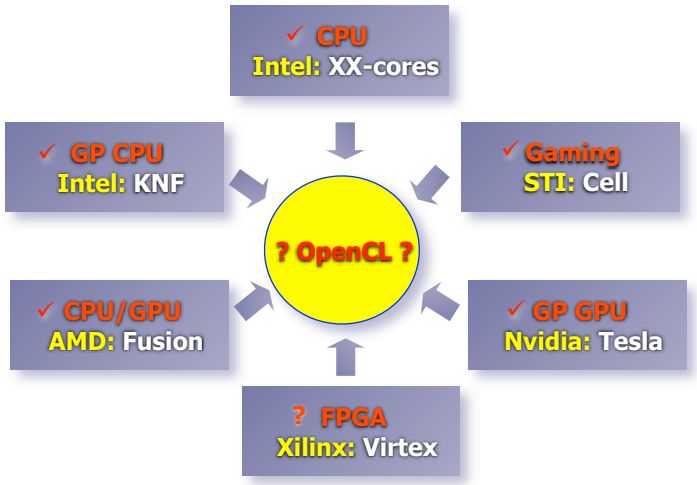


CBM (FAIR/GSI)



HEP Experiments: select interesting physics on-line

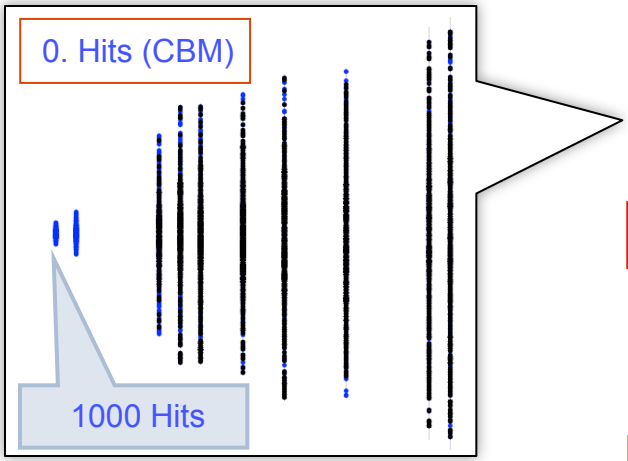
CPU/GPU Programming Frameworks

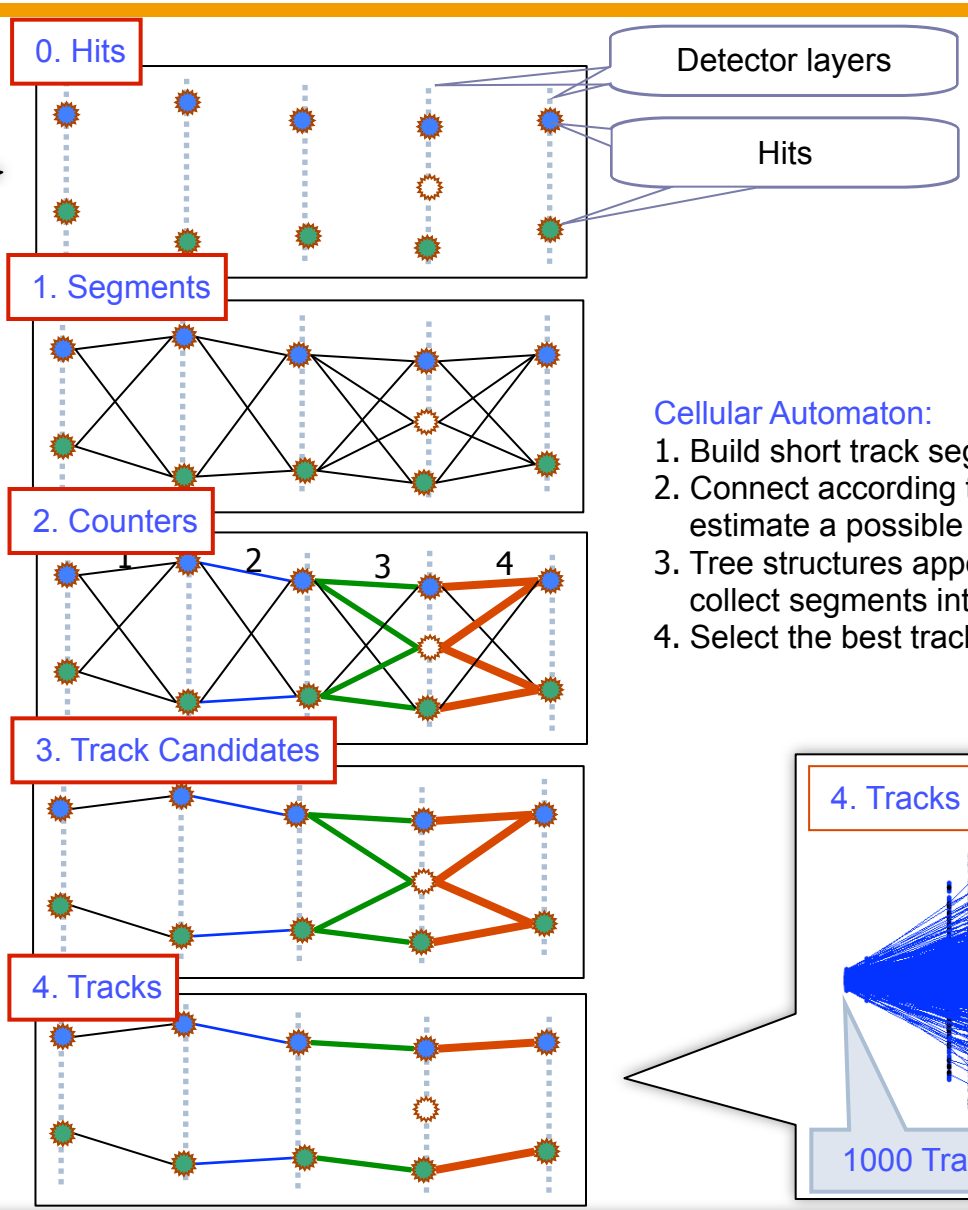


- Intel Ct (C for throughput), ArBB (Array Building Blocks)
  - Extension to the C language
  - Intel CPU/GPU specific
  - SIMD exploitation for automatic parallelism
- NVIDIA CUDA (Compute Unified Device Architecture)
  - Defines hardware platform
  - Generic programming
  - Extension to the C language
  - Explicit memory management
  - Programming on thread level
- OpenCL (Open Computing Language)
  - Open standard for generic programming
  - Extension to the C language
  - Supposed to work on any hardware
  - Usage of specific hardware capabilities by extensions
- Vector classes (Vc)
  - Overload of C operators with SIMD/SIMT instructions
  - Uniform approach to all CPU/GPU families
  - Uni-Frankfurt/FIAS/GSI

Choice of CPU/GPU/Programming is a practical question

Cellular Automaton as Track Finder





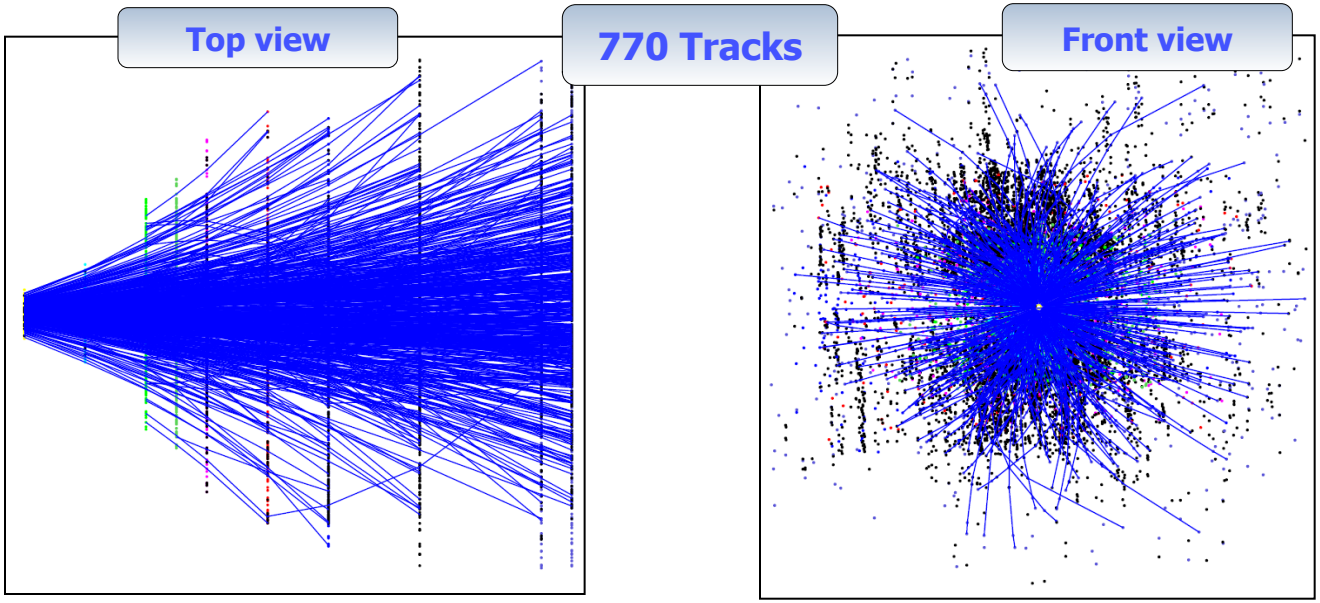
Cellular Automaton:
1. Build short track segments.
2. Connect according to the track model, estimate a possible position on a track.
3. Tree structures appear, collect segments into track candidates.
4. Select the best track candidates.

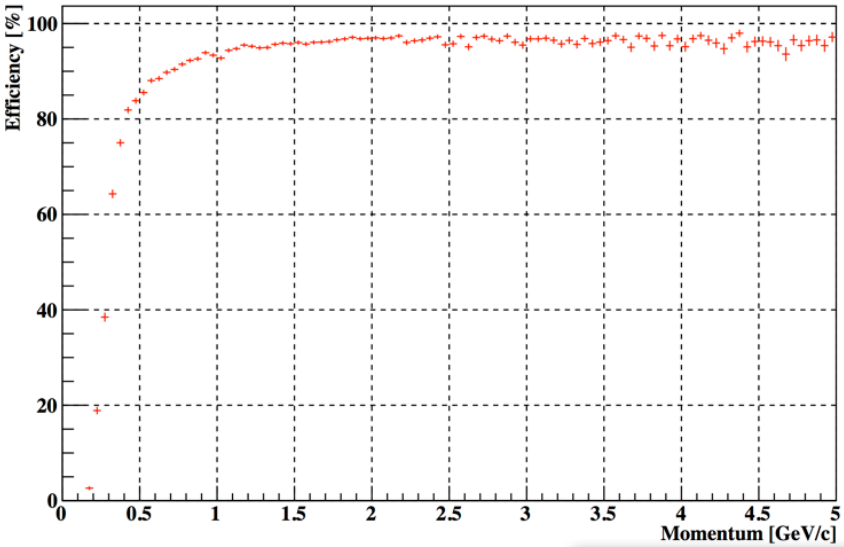
Cellular Automaton:
- local w.r.t. data
- intrinsically parallel
- extremely simple
- very fast

Perfect for many-core CPU/GPU !

Useful for complicated event topologies with large combinatorics and for parallel hardware

CBM CA Track Finder: Efficiency

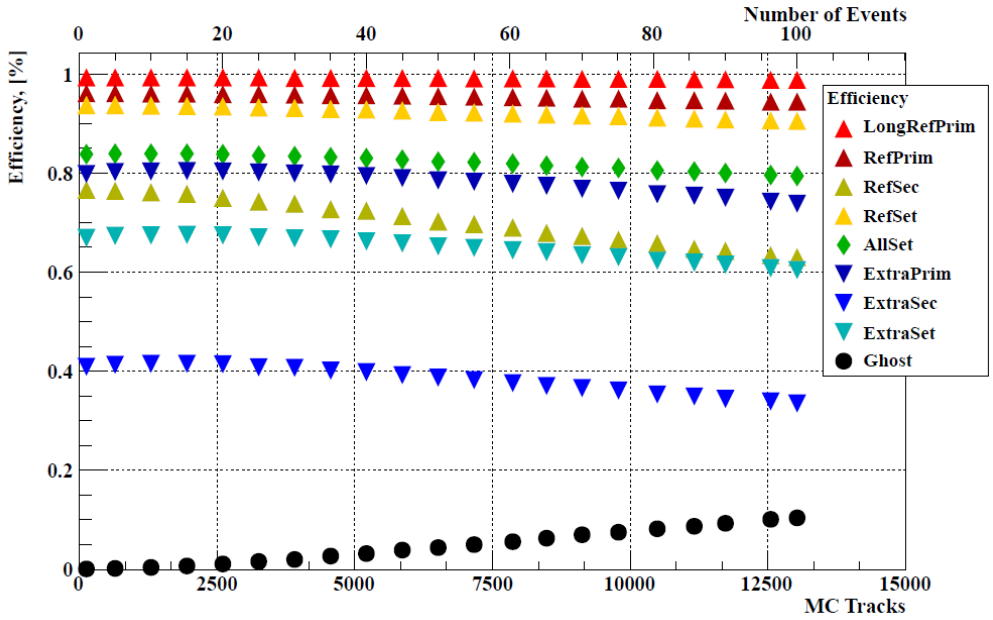


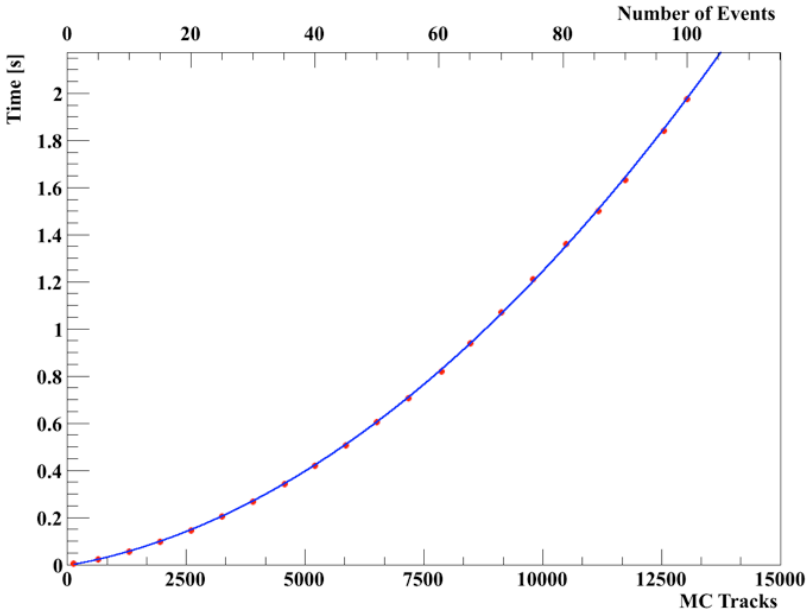


	Efficiency, %	
	mbias	central
Primary high-p tracks	97.1	96.2
Primary low-p tracks	90.4	90.7
Secondary high-p tracks	81.2	81.4
Secondary low-p tracks	51.1	50.6
All tracks	88.5	88.3
Clone level	0.2	0.2
Ghost level	0.7	1.5
Reconstructed tracks/event	120	591
Time/event/core	8.2 ms	57 ms

Efficient and stable event reconstruction

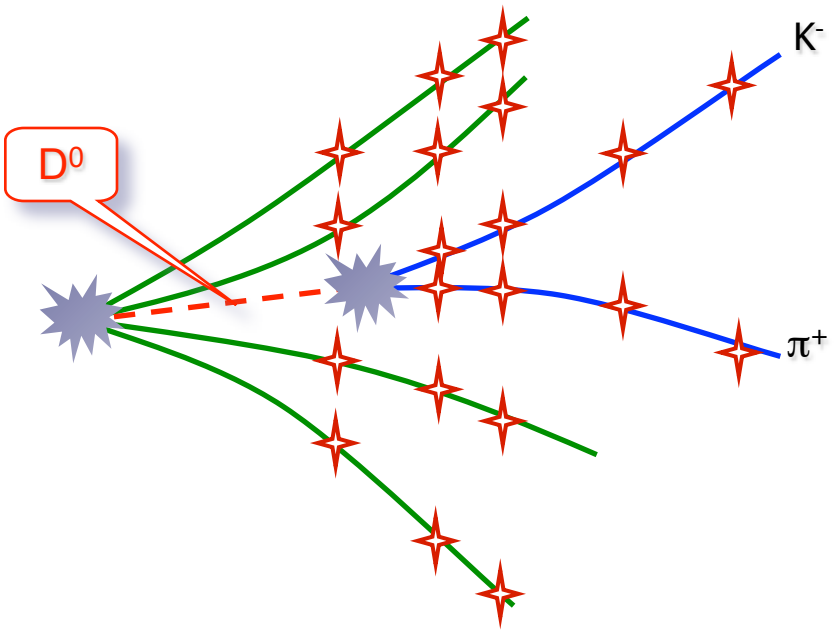
CA Track Finder: Efficiency and Time vs. Track Multiplicity





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

KFParticle: Reconstruction of Vertices and Decayed Particles



State vector

Position, direction, momentum and energy

$r = \{ x, y, z, p_x, p_y, p_z, E \}$

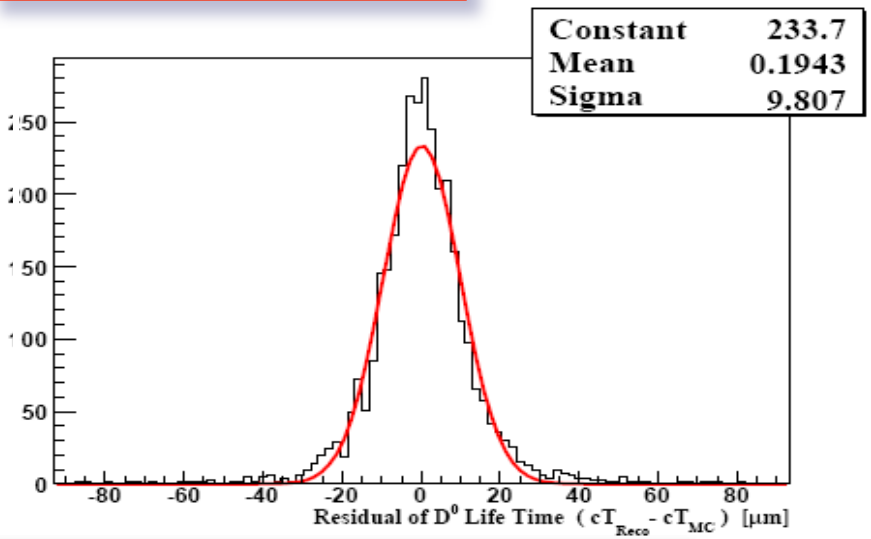
- Mother and daughter particles have the same state vector and are treated in the same way
- Geometry independent
- Kalman filter based

```
AliKFVertex PrimVtx( ESDPrimVtx );  // Set primary vertex
                                    // Set daughters
AliKFParticle K( ESDp1, -321 ), pi( ESDp2, 211 );

AliKFParticle  D0( K, pi );              // Construct mother
PrimVtx += D0;                           // Improve the primary vertex

D0.SetProductionVertex( PrimVtx ); // D0 is fully fitted
K.SetProductionVertex( D0 );       // K is fully fitted
pi.SetProductionVertex( D0 );      // pi is fully fitted
```

x, y, z, p_x, p_y, p_z, E, m, L, cτ



KFParticle provides uncomplicated approach to physics analysis (used in CBM, ALICE and STAR)

KFParticle Finder for Physics Analysis and Selection

Tracks: $e^{\pm}$, $\mu^{\pm}$, $\pi^{\pm}$, $K^{\pm}$, $p^{\pm}$
secondary primary

(mbias: 1.4 ms; central: 10.5 ms)/event/core

Open-charm:
$D^0 \to \pi^+ K^-$
$D^0 \to \pi^+ \pi^+ \pi^- K^-$
$\bar{D}^0 \to \pi^- K^+$
$\bar{D}^0 \to \pi^- \pi^- \pi^+ K^+$
$D^+ \to \pi^+ \pi^+ K^-$
$D^- \to \pi^- \pi^- K^+$
$D_s^+ \to \pi^+ K^+ K^-$
$D_s^- \to \pi^- K^+ K^-$
$\Lambda_c \to \pi^+ K^- p$

Strange particles:
$K^0_s \to \pi^+ \pi^-$
$\Lambda \to p \pi^-$
$\bar{\Lambda} \to \pi^+ p^-$

Gamma:
$\gamma \to e^- e^+$
Strange resonances:
$\bar{K}^{*0} \to K^+ \pi^-$
$K^{*0} \to \pi^+ K^-$
$\bar{\Lambda}^* \to p K^-$
$\Lambda^* \to p^- K^+$
Light vector mesons:
$\rho \to e^- e^+$
$\rho \to \mu^- \mu^+$
$\omega \to e^- e^+$
$\omega \to \mu^- \mu^+$
$\varphi \to e^- e^+$
$\varphi \to \mu^- \mu^+$
$\varphi \to K^- K^+$
Charmonium:
$J/\Psi \to e^- e^+$
$J/\Psi \to \mu^- \mu^+$

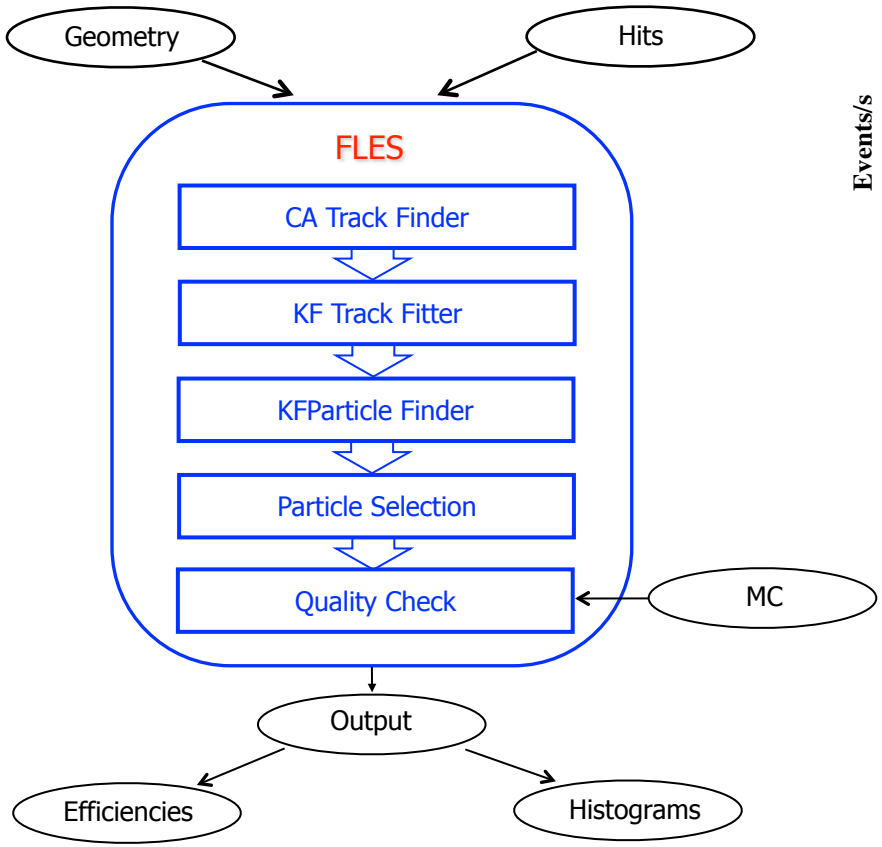
Multi-strange hyperons:
$\Xi^- \to \Lambda \pi^-$
$\bar{\Xi}^+ \to \bar{\Lambda} \pi^+$
$\Omega^- \to \Lambda K^-$
$\bar{\Omega}^+ \to \bar{\Lambda} K^+$

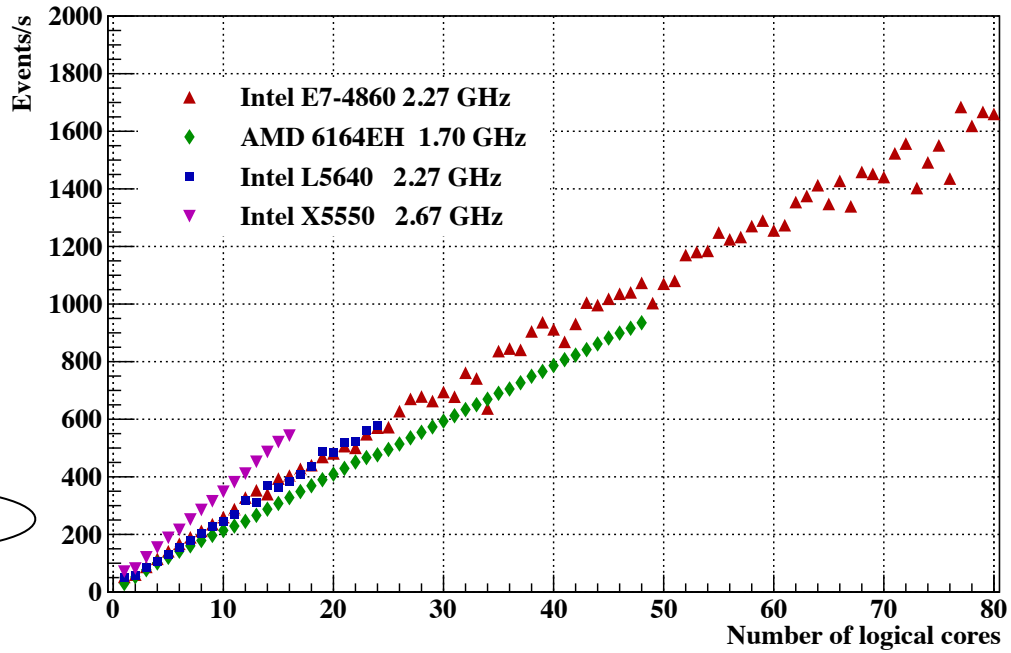
Strange and multi-strange resonances:
$\Sigma^{*+} \to \Lambda \pi^+$
$\bar{\Sigma}^{*+} \to \bar{\Lambda} \pi^-$
$\Sigma^{*-} \to \Lambda \pi^-$
$\bar{\Sigma}^{*-} \to \bar{\Lambda} \pi^+$
$K^{*-} \to K^0_s \pi^-$
$K^{*+} \to K^0_s \pi^+$
$\Xi^{*-} \to \Lambda K^-$
$\bar{\Xi}^{*+} \to \bar{\Lambda} K^+$

Open-charm resonances:
$D^{*0} \to D^+ \pi^-$
$\bar{D}^{*0} \to D^- \pi^+$
$D^{*+} \to D^0 \pi^+$
$D^{*-} \to \bar{D}^0 \pi^-$

Multi-strange resonances:
$\Xi^{*0} \to \Xi^- \pi^+$
$\bar{\Xi}^{*0} \to \bar{\Xi}^+ \pi^-$
$\Omega^{*-} \to \Xi^- \pi^+ K^-$
$\bar{\Omega}^{*+} \to \bar{\Xi}^+ \pi^- K^+$

CBM Standalone First Level Event Selection (FLES) Package





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

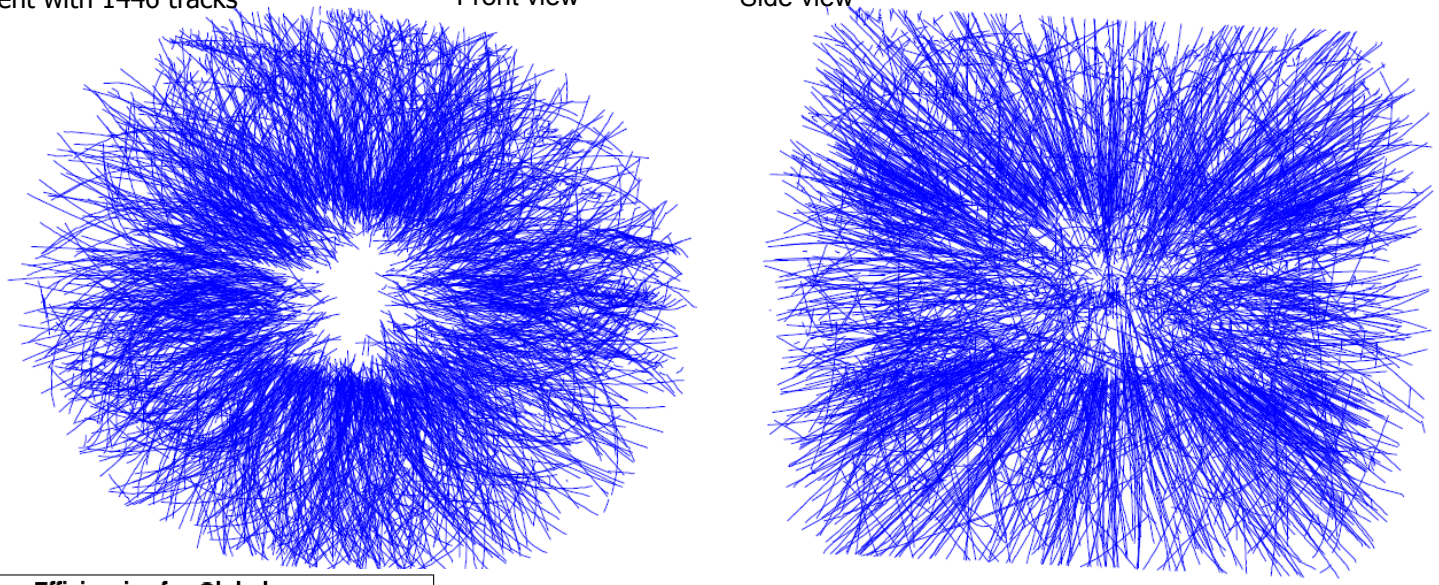
The first version of the FLES package is vectorized, parallelized, portable and scalable

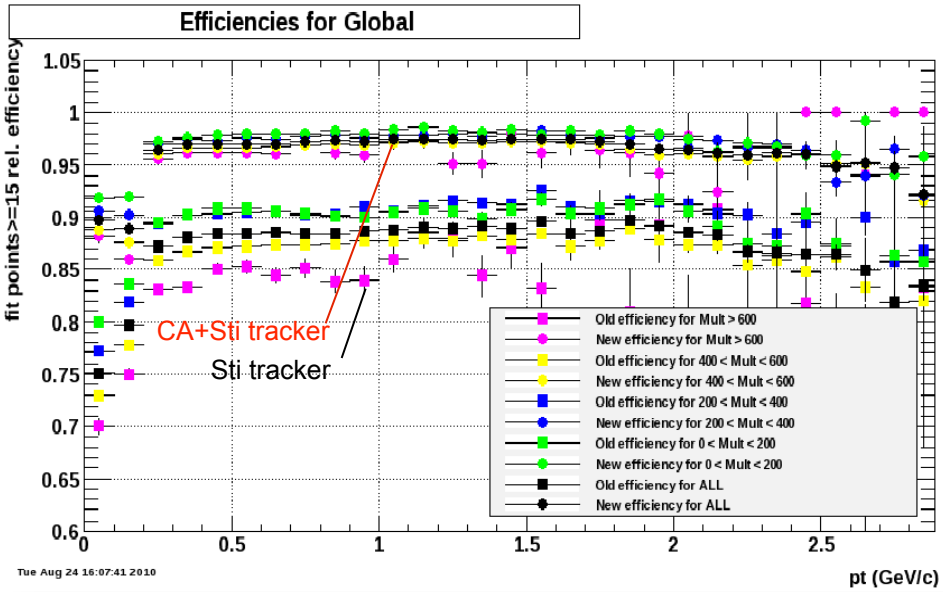
STAR TPC CA Track Finder

Au-Au event with 1446 tracks

Front view

Side view





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

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

The CA track finder is more stable w.r.t. track multiplicity and is ~10 times faster than the TF based Sti track finder.

Consolidate Efforts: Common Reconstruction Package

Uni-Frankfurt/FIAS:
Vector classes
CPU/GPU implementation

GSI:
Algorithms development
Many-core optimization

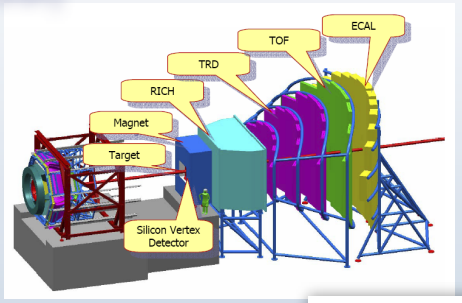
OpenLab (CERN):
Many-core optimization
Benchmarking

HEPHY (Vienna)/Uni-Gjovik:
Kalman Filter track fit
Kalman Filter vertex fit

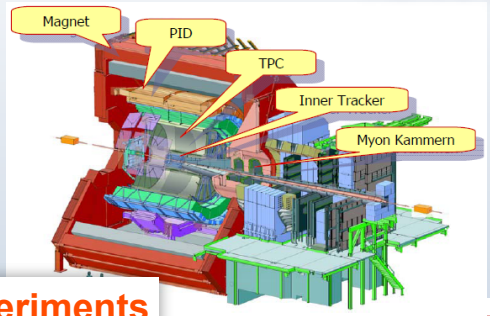
Common Reconstruction Package

Intel:
ArBB/OpenCL implementation
Benchmarking

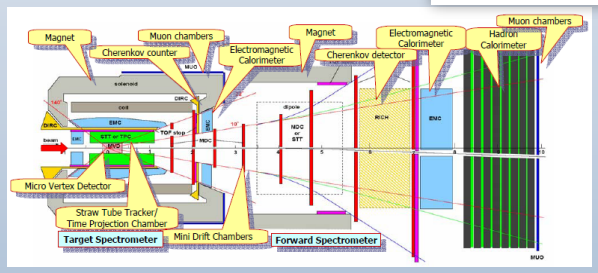
CBM (FAIR/GSI)



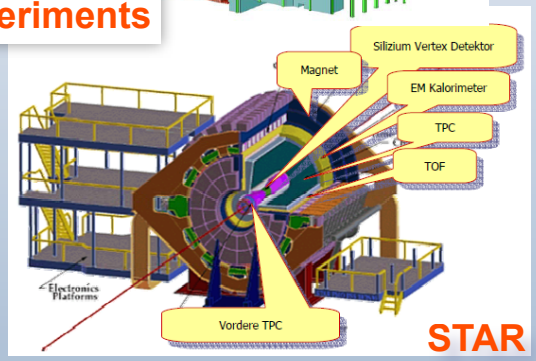
ALICE (CERN)



Host Experiments



PANDA (FAIR/GSI)



STAR (BNL)