Status of Event Reconstruction with Cellular Automaton and KF Particle

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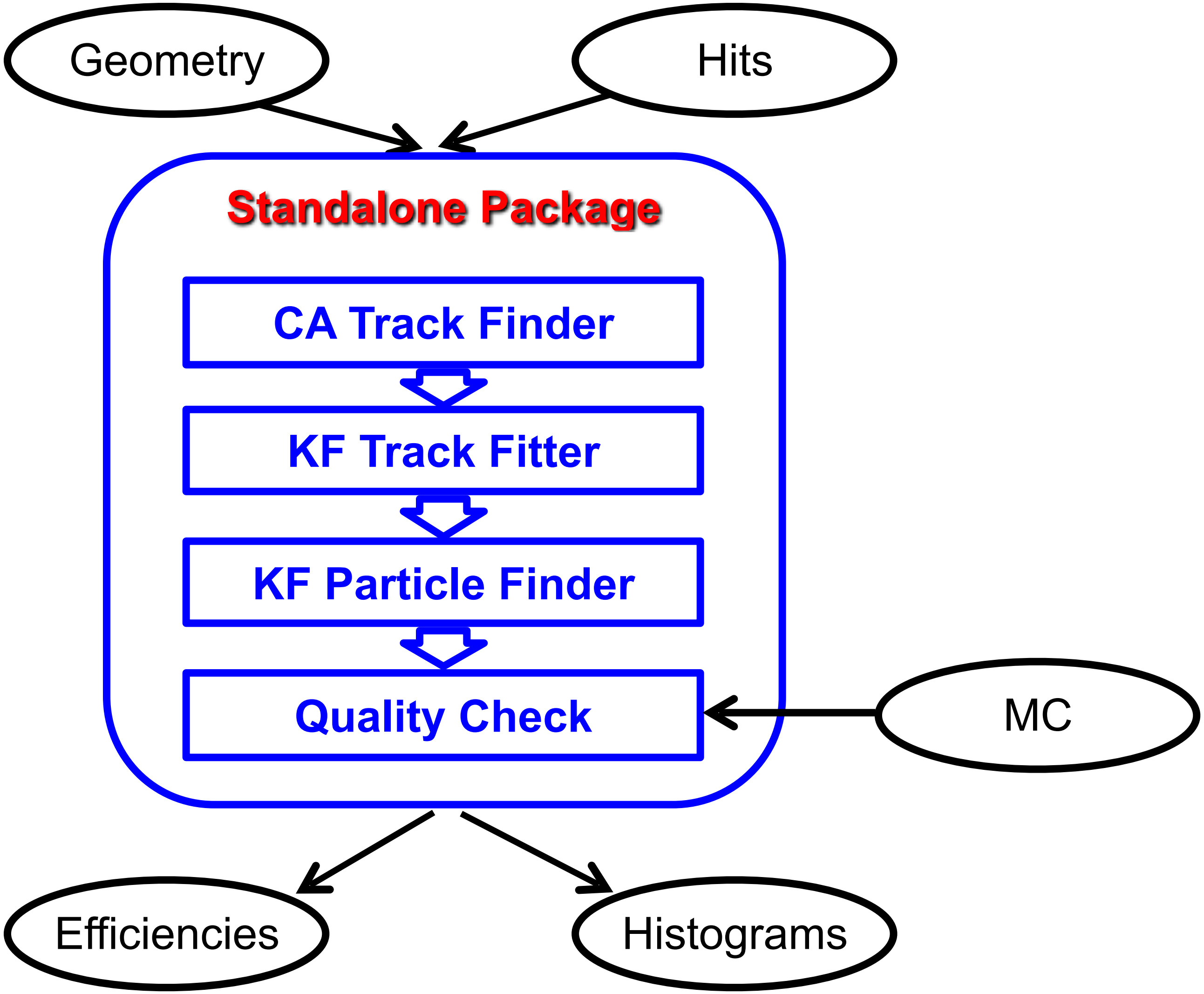
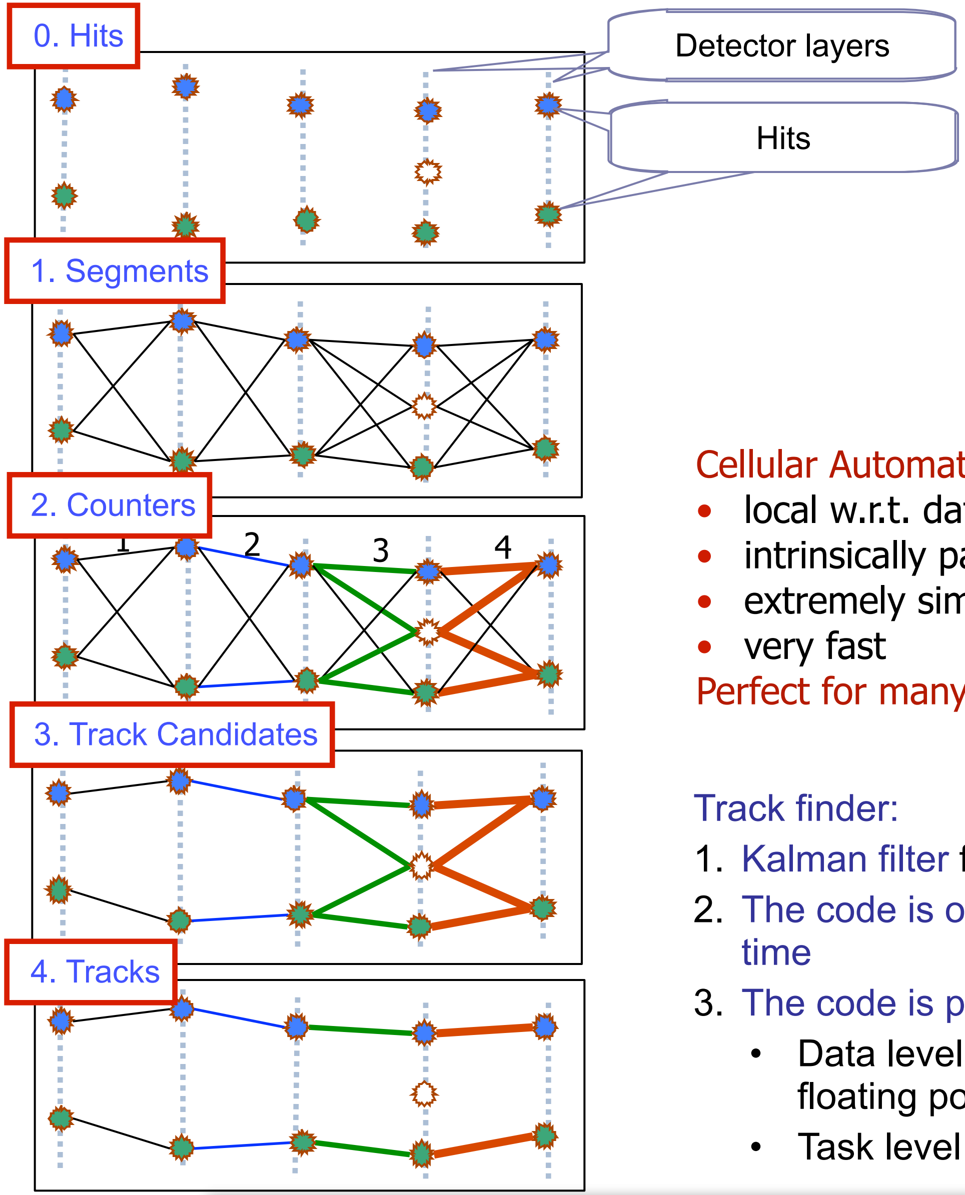
The Structure of the Standalone Package



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 !

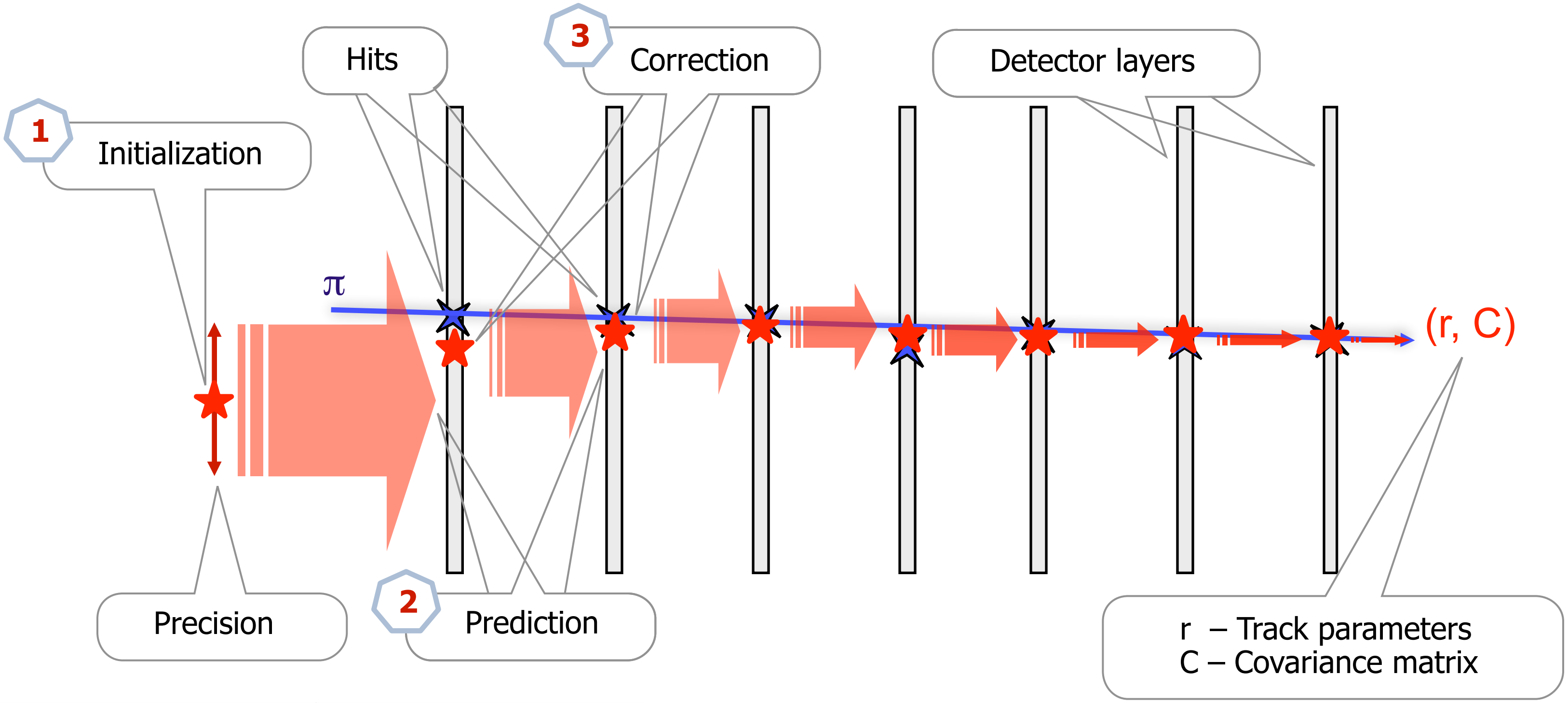
Track finder:

1. Kalman filter for track segments fit
2. The code is optimised with respect to both efficiency and time
3. The code is parallelised
   - Data level (SIMD instructions, 4 single-precision floating point calculations in parallel)
   - Task level (ITBB, parallelisation between cores)

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

Kalman Filter Track Fit

Track fit: Estimation of the track parameters at one or more hits along the track – Kalman Filter (KF)



1 Initialization

Hits

3 Correction

Detector layers

Precision

2 Prediction

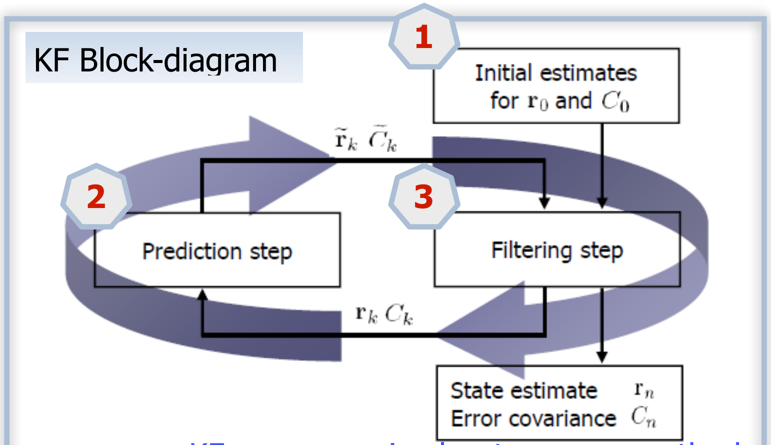
r – Track parameters
C – Covariance matrix

State vector

Position, direction and momentum

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

KF Block-diagram



1 Initial estimates for $\mathbf{r}_0$ and C_0

$\tilde{\mathbf{r}}_k$ $\tilde{C}_k$

2 Prediction step

3 Filtering step

$\mathbf{r}_k$ C_k

State estimate $\mathbf{r}_n$
Error covariance C_n

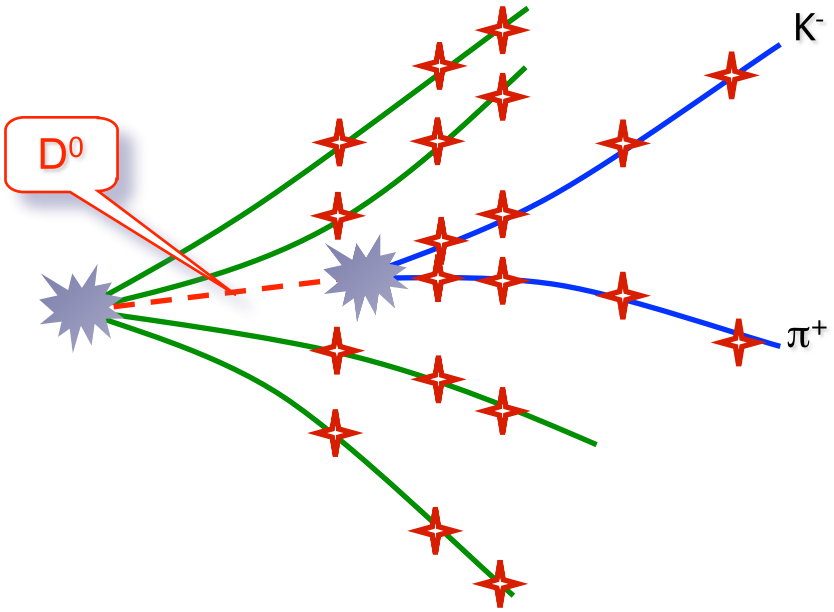
KF as a recursive least squares method

Kalman Filter:

1. Start with an arbitrary initialization.
2. Add one hit after another.
3. Improve the state vector.
4. Get the optimal parameters after the last hit.

Nowadays the Kalman Filter is used in almost all HEP experiments

KF Particle for Short-lived Particles Reconstruction



State vector

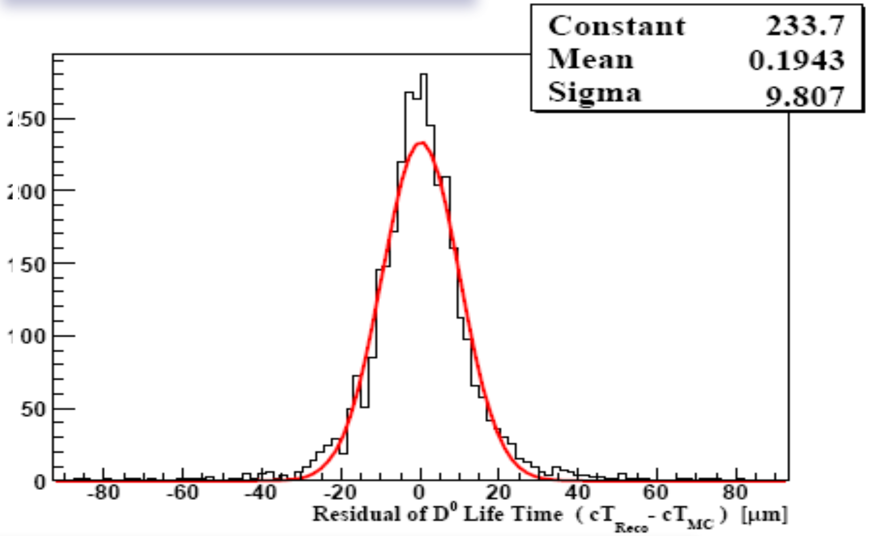
Position, direction, momentum and energy

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

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

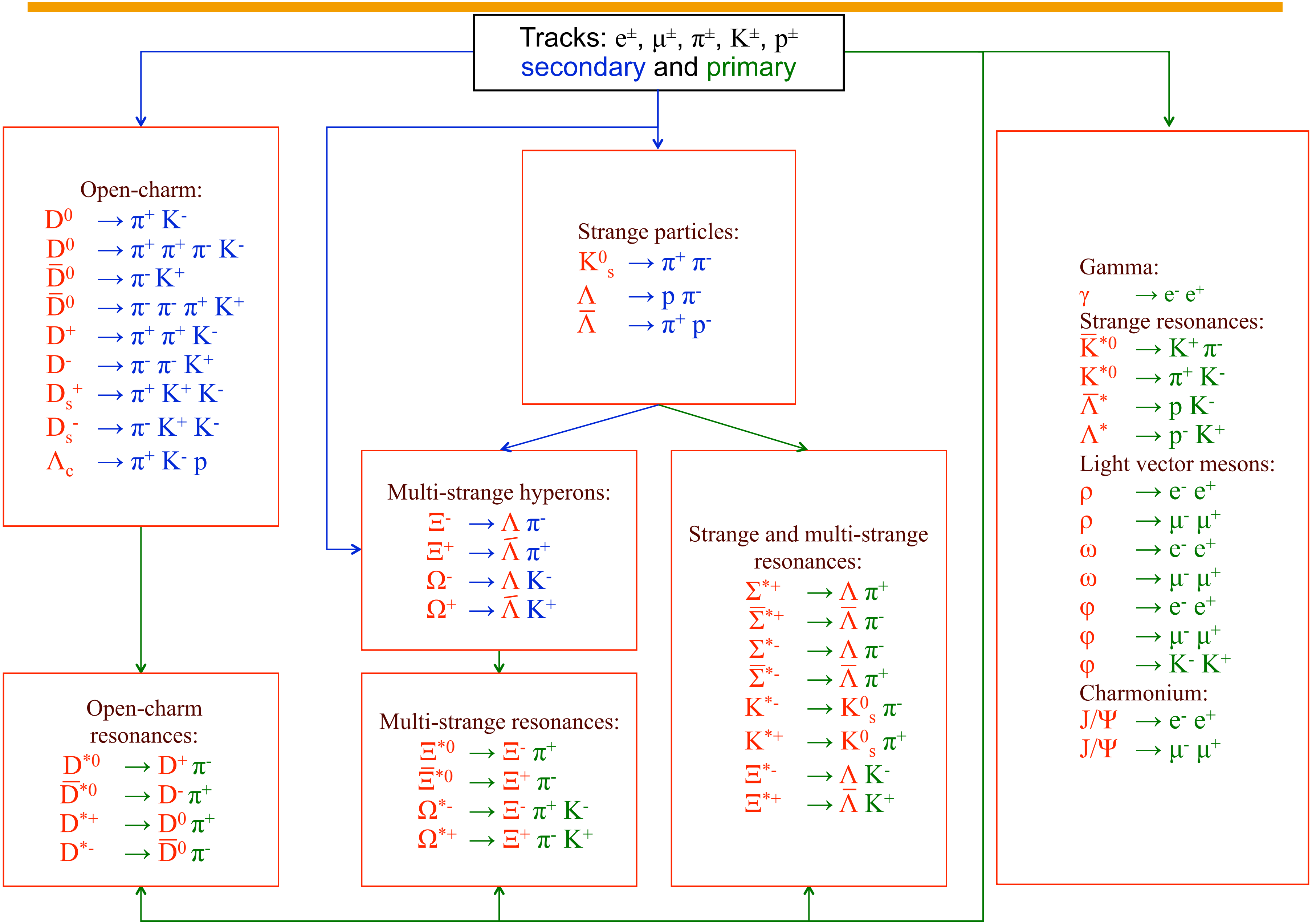
x, y, z, p_x, p_y, p_z, E, m, L, cτ

```
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
```



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

KF Particle Finder for Physics Analysis



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

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:
$J/\Psi \to e^- e^+$
$J/\Psi \to \mu^- \mu^+$

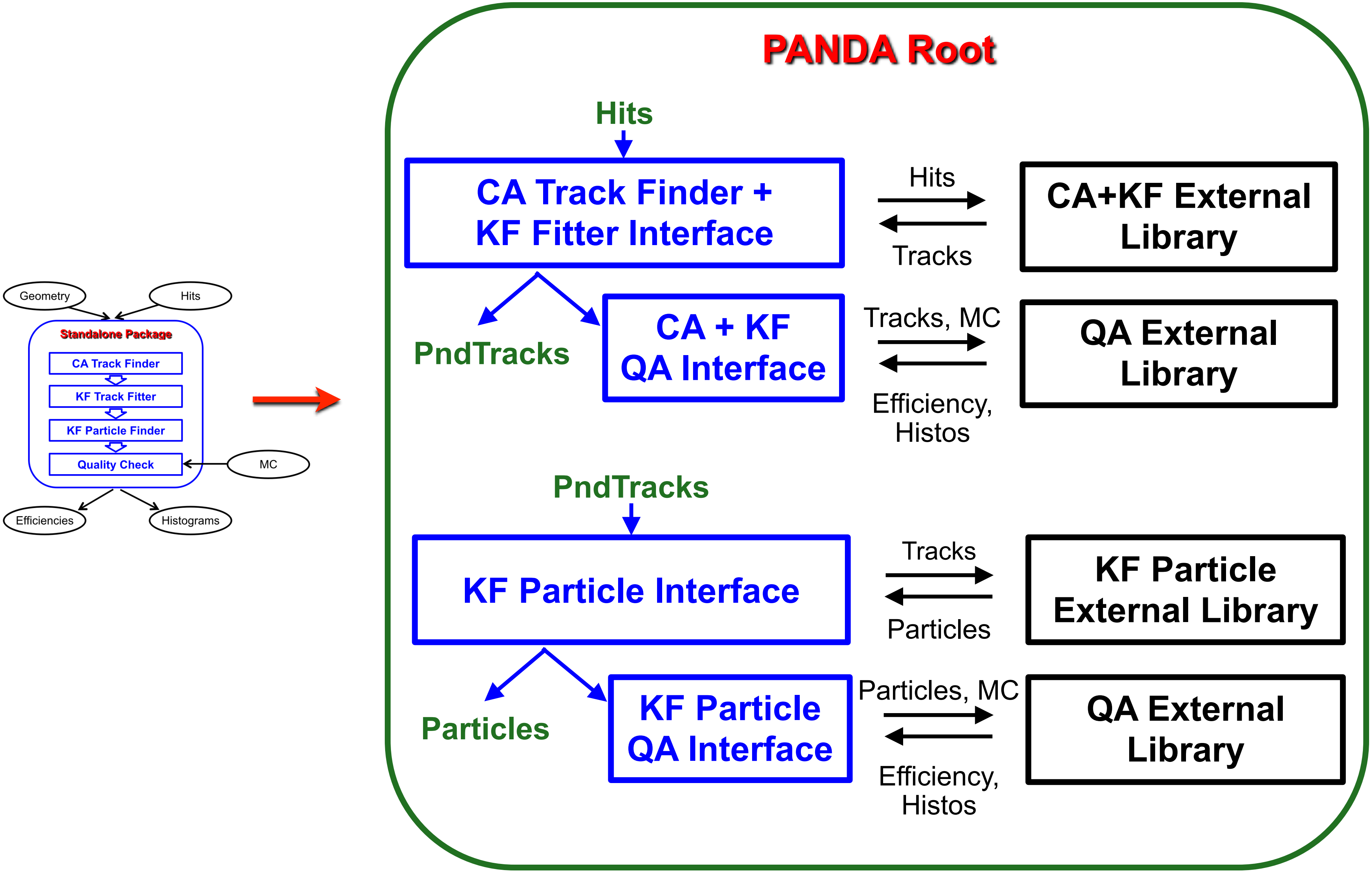
Multi-strange hyperons:
$\Xi^- \to \Lambda \pi^-$
$\Xi^+ \to \bar{\Lambda} \pi^+$
$\Omega^- \to \Lambda K^-$
$\Omega^+ \to \bar{\Lambda} K^+$

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

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

Proposed Structure Within PANDA Root



Geometry

Hits

Standalone Package

CA Track Finder

KF Track Fitter

KF Particle Finder

Quality Check

MC

Efficiencies

Histograms

PANDA Root

Hits

CA Track Finder + KF Fitter Interface

Hits

Tracks

CA+KF External Library

PndTracks

CA + KF QA Interface

Tracks, MC

Efficiency, Histos

QA External Library

PndTracks

KF Particle Interface

Tracks

Particles

KF Particle External Library

Particles

KF Particle QA Interface

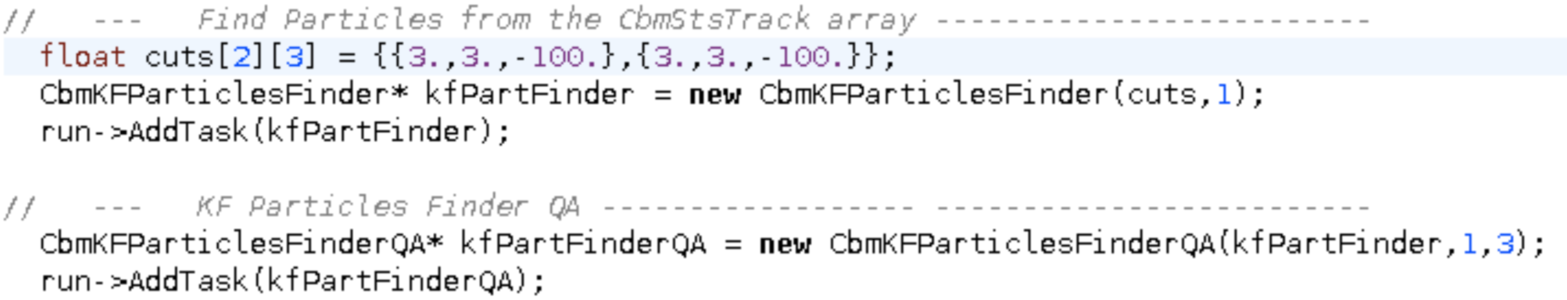
Particles, MC

Efficiency, Histos

QA External Library

Interfaces

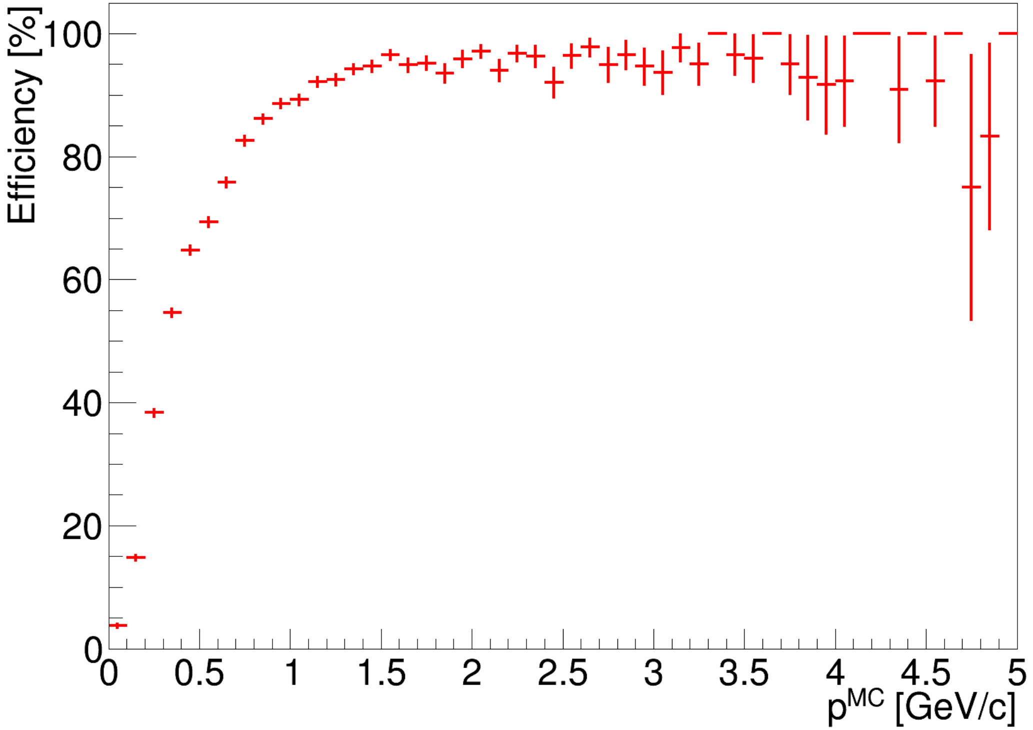
- The external libraries are proposed to be the same for the PANDA and CBM experiments (possibly, on the FAIR Root level).
- The default constructors will be prepared for each task as well as the constructors with parameters to be tuned.
- KF Particle Finder task together with a QA task on the example of the CBM experiment:



```
//   ---   Find Particles from the CbmStsTrack array -------------------------
  float cuts[2][3] = {{3.,3.,-100.},{3.,3.,-100.}};
  CbmKFParticlesFinder* kfPartFinder = new CbmKFParticlesFinder(cuts,1);
  run->AddTask(kfPartFinder);

//   ---   KF Particles Finder QA ----------------- -------------------------
  CbmKFParticlesFinderQA* kfPartFinderQA = new CbmKFParticlesFinderQA(kfPartFinder,1,3);
  run->AddTask(kfPartFinderQA);
```

CA Track Finder with DPM Generator

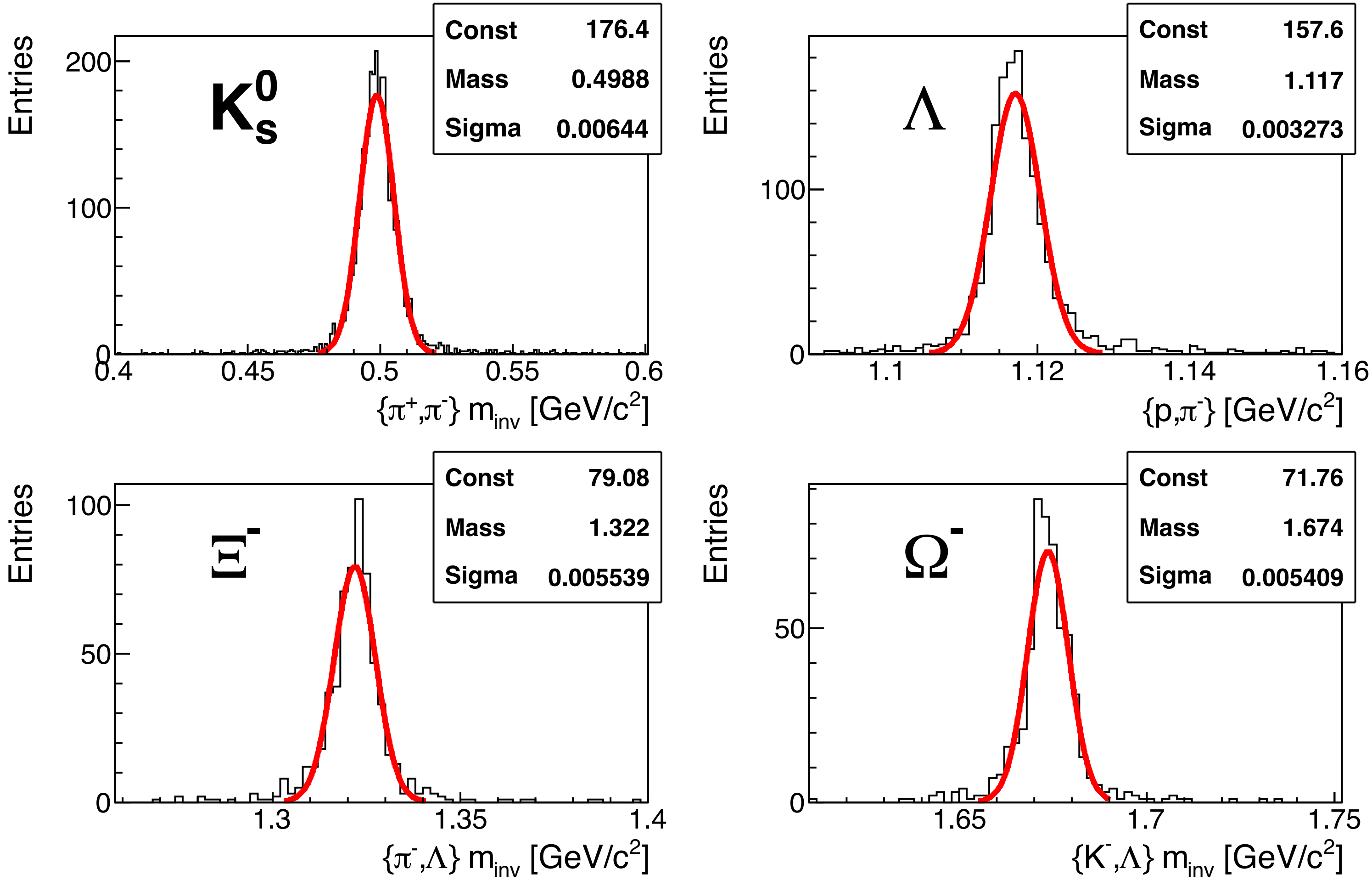
- The test with DPM generator and STT+MVD detectors were performed. The efficiency for primary tracks with p > 1 GeV is shown to be high.
- Further tests with secondary and slow tests are in progress.
- Tests within PANDA Root are needed.



Efficiencies and ratios	
Efficiency Reference (P>1 GeV/c) Primary Tracks	94,4
Clone	3,3
Ghost	23,8
Tracks/ev	2
Time, ms/ev	4.7

DPM generator with momentum 7.24 GeV/c

Reconstruction of Strange Particles with KF Particle



Particle	p_t	Efficiency	Particle	p_t	Efficiency
K	1	56,2%	Λ	1	32%
Ξ	2	14,1%	Ω	2	17,1%

10000 signal events, Ideal track finder, MC primary vertex

Summary

- The standalone package for the PANDA reconstruction was developed since last summer.
- The package includes
  - Cellular Automaton track finder;
  - Kalman filter based track fit;
  - KF Particle Finder for vertexing and short-lived particles reconstruction.
- The integration of the developed methods into the PANDA Root framework is in progress.
- The external libraries are proposed to be used, they are planed to be common for the PANDA and CBM experiments (possibly, on the FAIR Root level).
- Tests with secondary and slow tracks are in progress.