Cellular Automaton Tracking in STT and MVD

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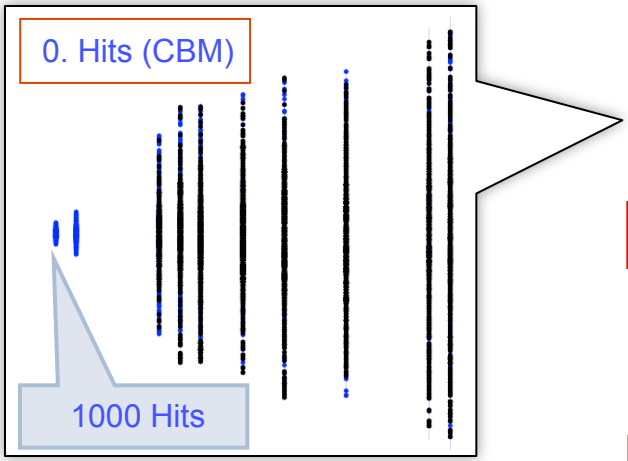
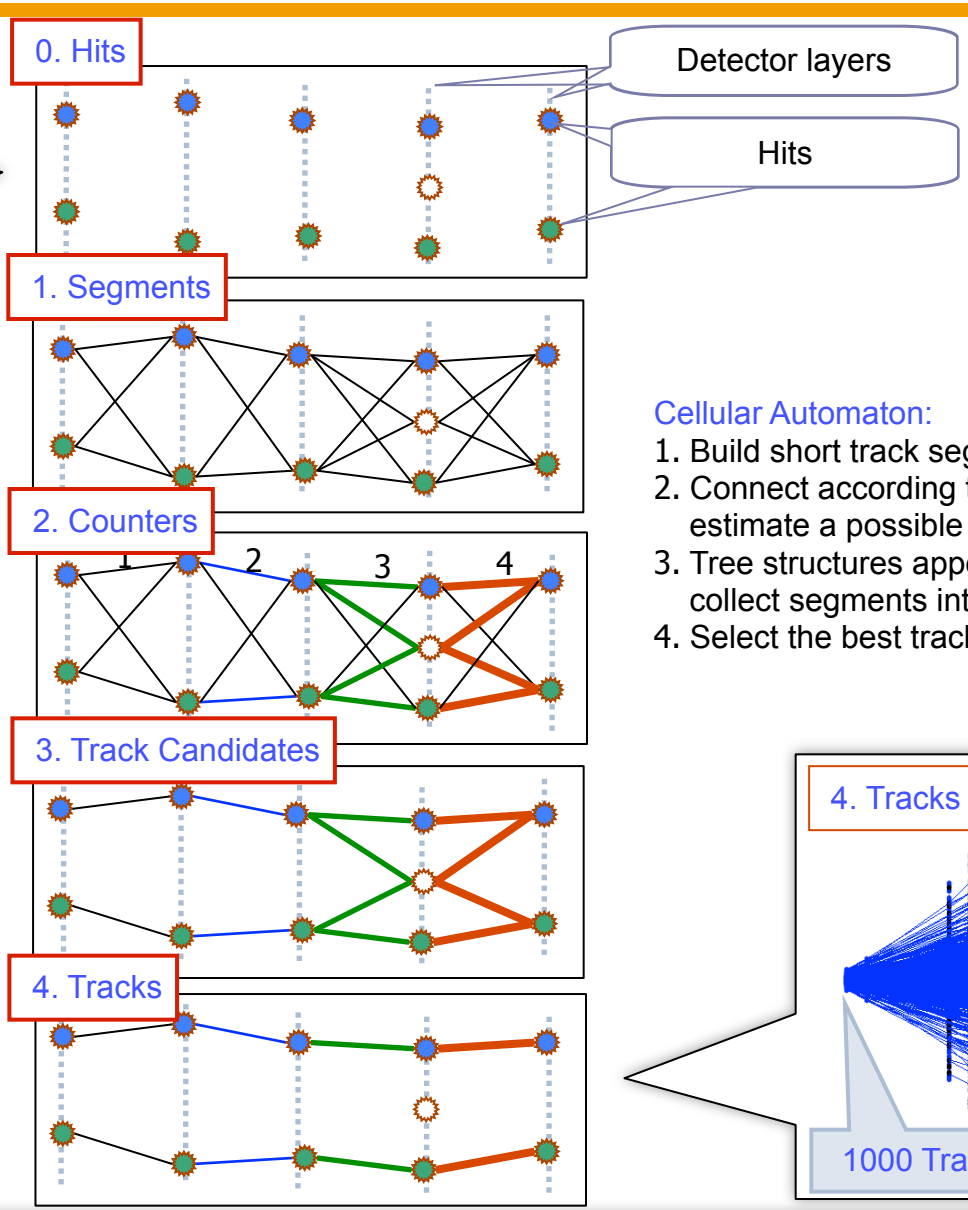
Cellular Automaton as Track Finder





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.

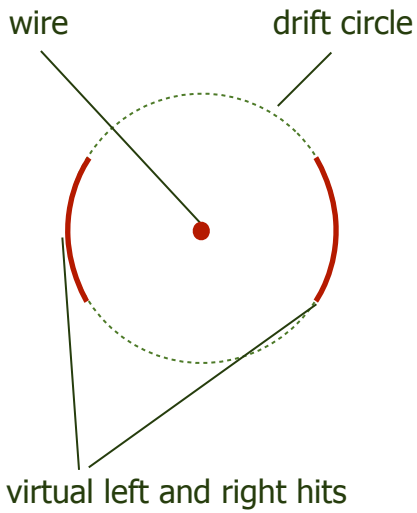
Cellular Automaton:
- local w.r.t. data
- intrinsically parallel
- extremely simple
- very fast

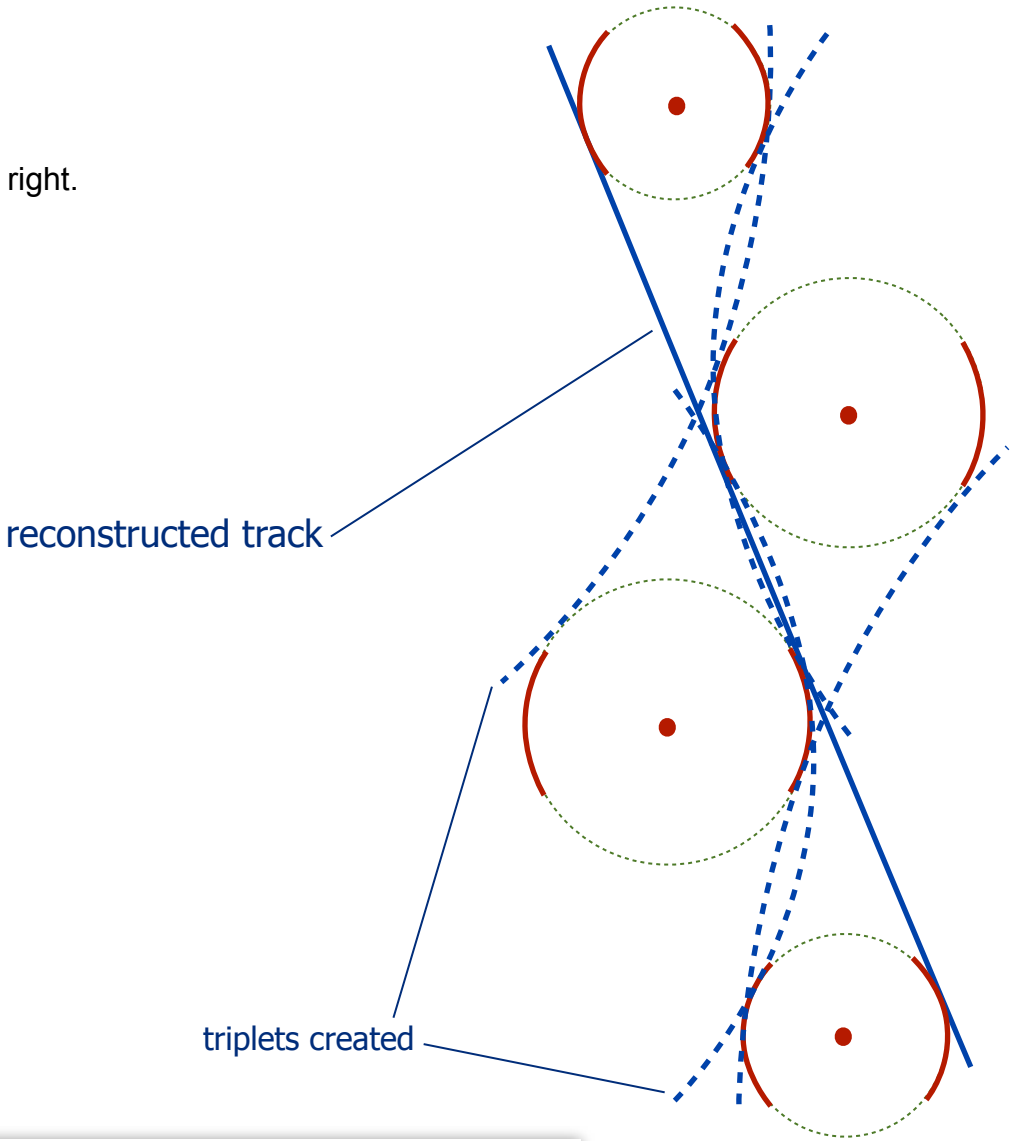
Perfect for many-core CPU/GPU !

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

Left-Right Ambiguity

Create for each fired tube two virtual hits - left and right.

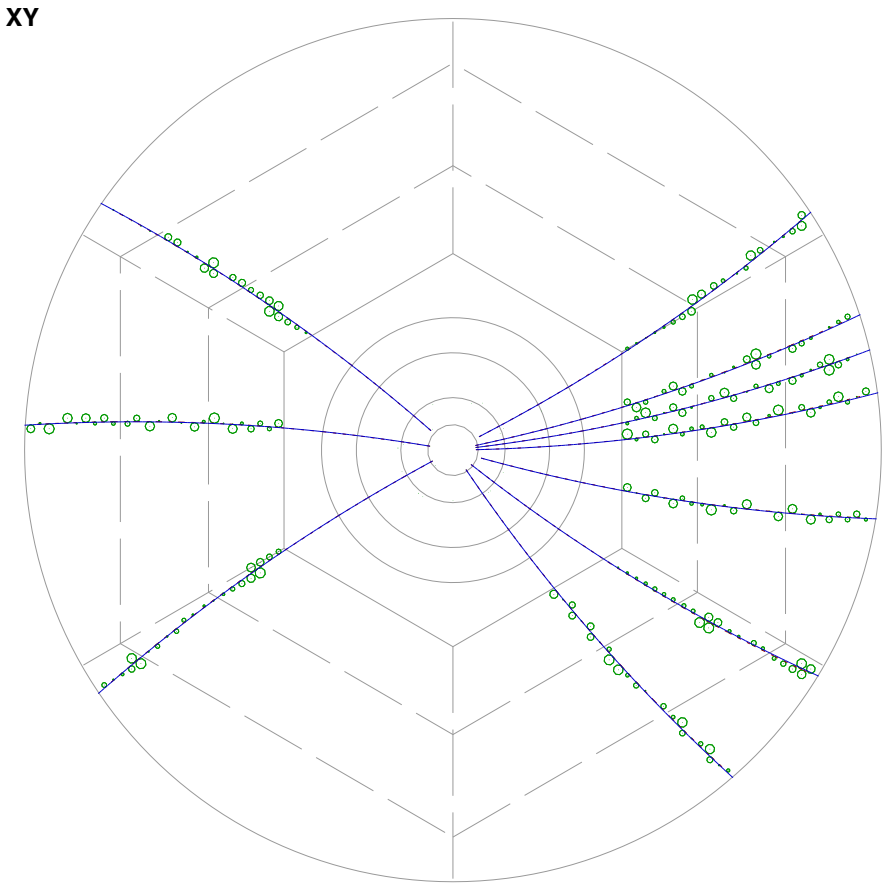


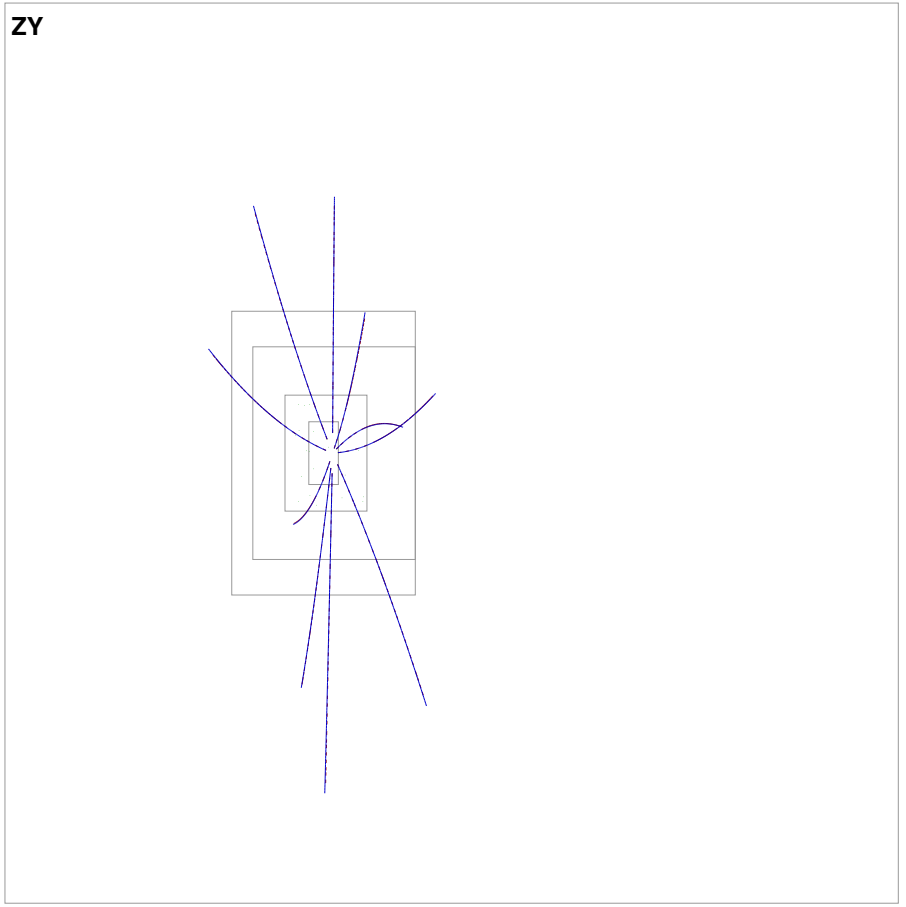


Left-right ambiguity is solved at the track finder stage

Event Display

10 primary tracks with pt = 1GeV/c





Tracking Efficiency

10 primary tracks with pt = 1GeV/c

only tracks with all (4 barrel) MVD hits are selected

	STT	STT+MVD
Efficiency	97.2	99.3
Clone	1.8	9.2
Ghost	2.5	2.5
Tracks/event	10	10
Time, ms/event	5	7

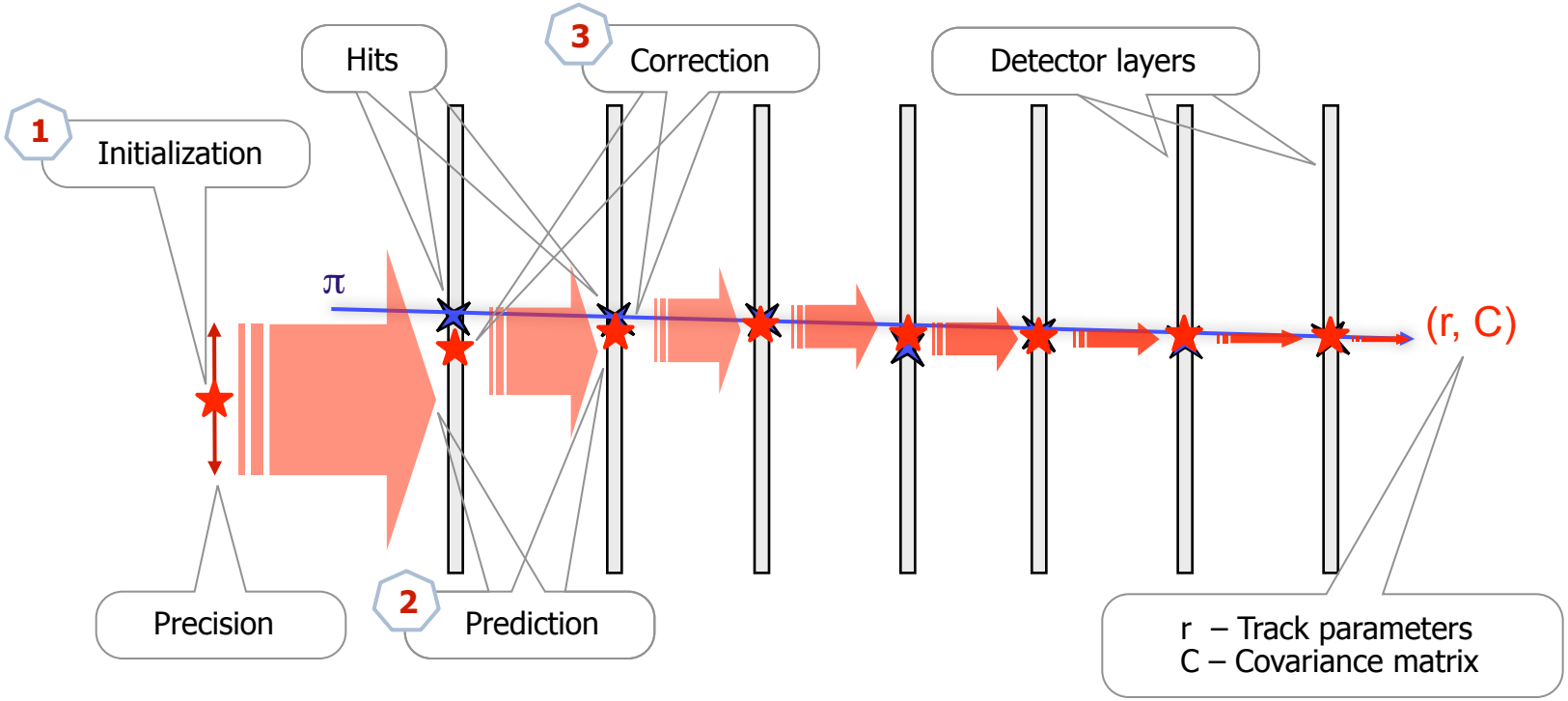
Reconstructable track: ≥ 6 consecutive MC points
Ghost: purity < 75%

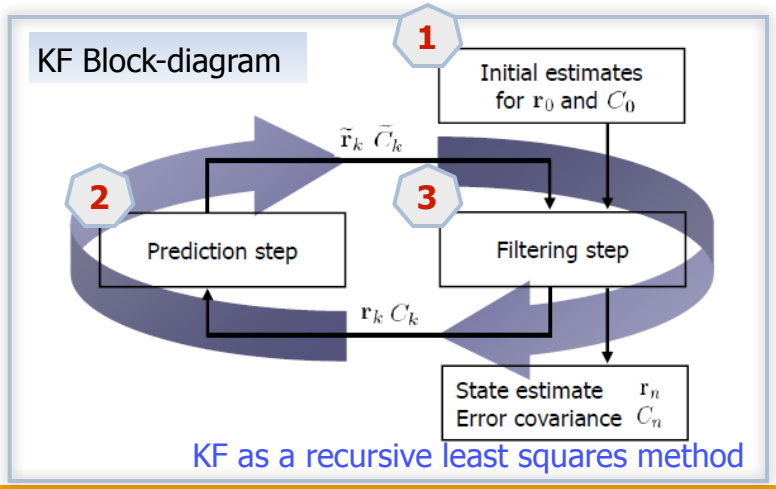
10 tracks with pt = 1 GeV/c; 100 events
1 core of Intel Core i7, 3.4 GHz, 8 MB L3 cache, 32 GB RAM

Efficiency 99.3% at 7 ms per event

Kalman Filter based Track Fit

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





KF as a recursive least squares method

State vector

Position, direction and momentum

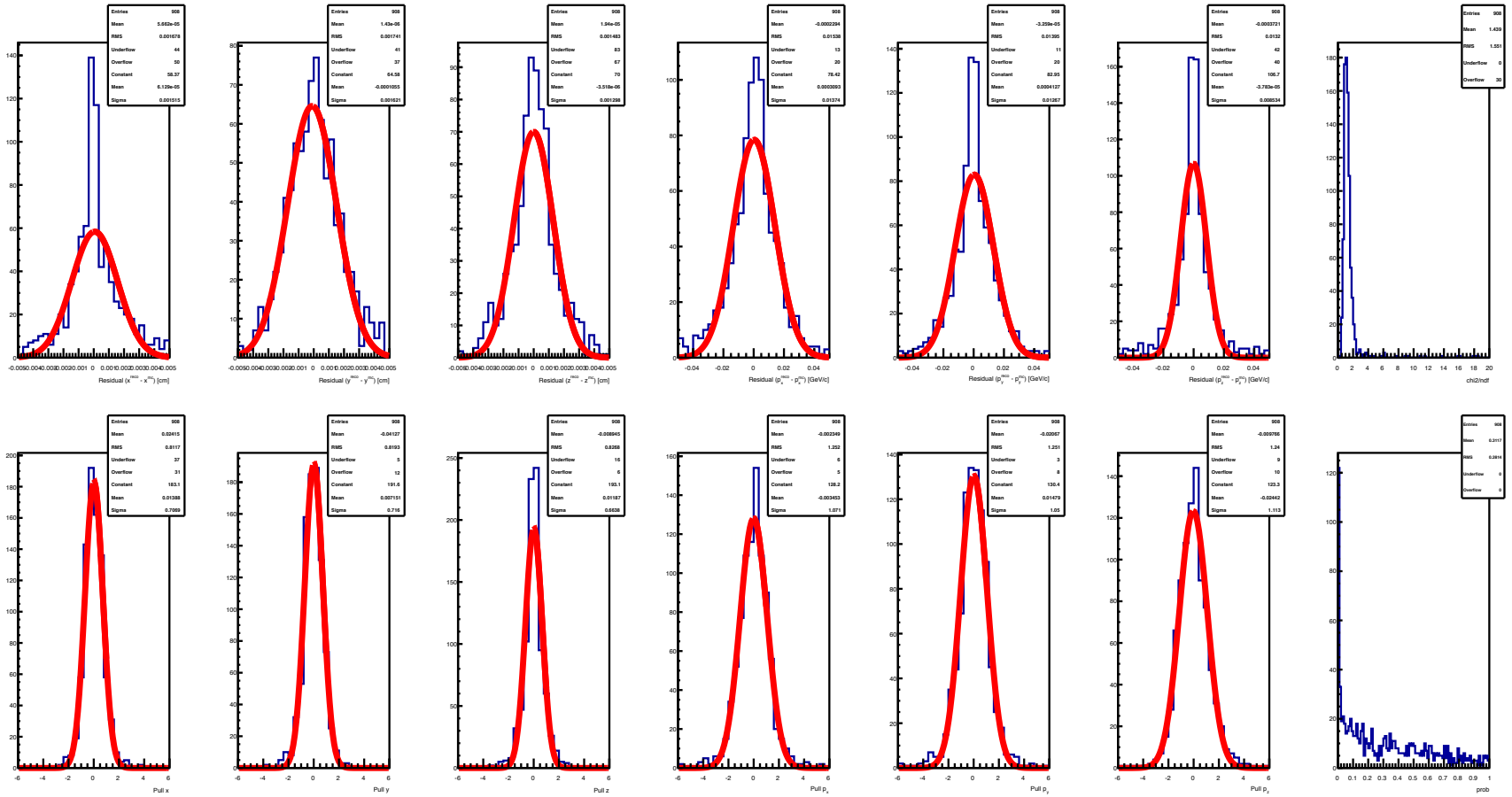
$r = \{ x, y, z, p_x, p_y, p_z \}$

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.

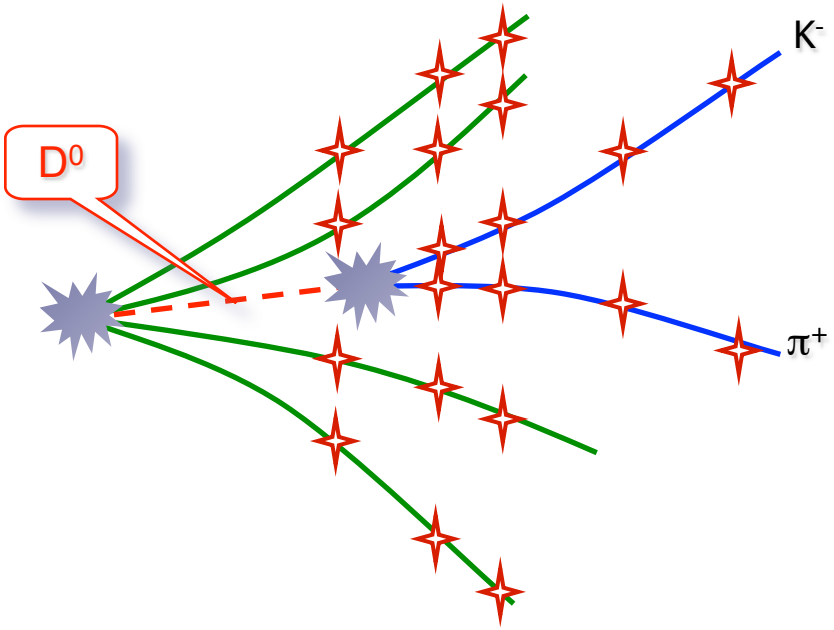
Nowadays the Kalman Filter is used in almost all HEP experiments

KF Fit Quality



	x, μm	y, μm	z, μm	p_x, MeV/c	p_y, MeV/c	p_z, MeV/c
Residual	15	16	13	14	13	9
Pull	0,7	0,7	0,7	1,1	1,1	1,1

KF Particle: Reconstruction of Vertices and Decayed Particles



State vector

Position, direction, momentum and energy

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

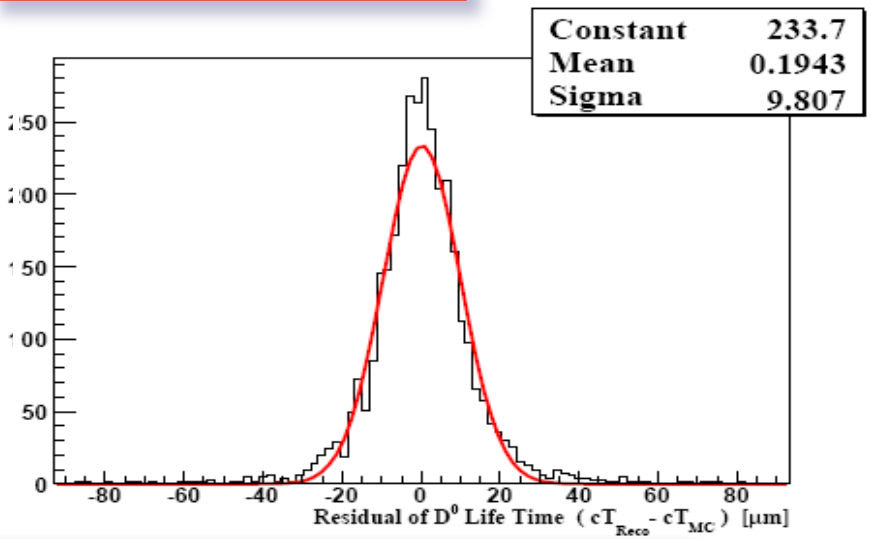
- Mother and daughter particles have the same state vector and are treated in the same way
- Geometry independent
- Kalman filter based

$x, y, z, p_x, p_y, p_z, E, m, L, c\tau$

```
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: Functionality

Functions	CBM	ALICE, STAR, PANDA
Construction of mother particles	+	+
Addition and subtraction of the daughter particle to (from) the mother particle	+	+
+= and -= operators	+	+
Accessors to the physical parameters (mass, momentum, decay length, lifetime, rapidity, etc)	+	+
Transport: to an arbitrary point, to the decay and production points, to another particle, to a vertex, on the certain distance	+	+
Calculation of a distance: to a point, to a particle, to a vertex	+	+
Calculation of a deviation: from a point, from a particle, from a vertex	+	+
Calculation of the angle between particles	+	+
Constraints: on mass, on a production point, on a decay length	+	+
KF Particle Finder	+	+

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

CBM: KF Particle Finder for Physics Analysis and Selection

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

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

Open-charm:

$D^0 \rightarrow \pi^+ K^-$
$D^0 \rightarrow \pi^+ \pi^+ \pi^- K^-$
$\bar{D}^0 \rightarrow \pi^- K^+$
$\bar{D}^0 \rightarrow \pi^- \pi^- \pi^+ K^+$
$D^+ \rightarrow \pi^+ \pi^+ K^-$
$D^- \rightarrow \pi^- \pi^- K^+$
$D_s^+ \rightarrow \pi^+ K^+ K^-$
$D_s^- \rightarrow \pi^- K^+ K^-$
$\Lambda_c \rightarrow \pi^+ K^- p$

Strange particles:

$K^0_s \rightarrow \pi^+ \pi^-$
$\Lambda \rightarrow p \pi^-$
$\bar{\Lambda} \rightarrow \pi^+ p^-$

Gamma:

$\gamma \rightarrow e^- e^+$

Strange resonances:

$\bar{K}^{*0} \rightarrow K^+ \pi^-$
$K^{*0} \rightarrow \pi^+ K^-$
$\bar{\Lambda}^* \rightarrow p K^-$
$\Lambda^* \rightarrow p^- K^+$

Light vector mesons:

$\rho \rightarrow e^- e^+$
$\rho \rightarrow \mu^- \mu^+$
$\omega \rightarrow e^- e^+$
$\omega \rightarrow \mu^- \mu^+$
$\varphi \rightarrow e^- e^+$
$\varphi \rightarrow \mu^- \mu^+$
$\varphi \rightarrow K^- K^+$

Charmonium:

$J/\Psi \rightarrow e^- e^+$
$J/\Psi \rightarrow \mu^- \mu^+$

Multi-strange hyperons:

$\Xi^- \rightarrow \Lambda \pi^-$
$\bar{\Xi}^+ \rightarrow \bar{\Lambda} \pi^+$
$\Omega^- \rightarrow \Lambda K^-$
$\bar{\Omega}^+ \rightarrow \bar{\Lambda} K^+$

Strange and multi-strange resonances:

$\Sigma^{*+} \rightarrow \Lambda \pi^+$
$\bar{\Sigma}^{*+} \rightarrow \bar{\Lambda} \pi^-$
$\Sigma^{*-} \rightarrow \Lambda \pi^-$
$\bar{\Sigma}^{*-} \rightarrow \bar{\Lambda} \pi^+$
$K^{*-} \rightarrow K^0_s \pi^-$
$K^{*+} \rightarrow K^0_s \pi^+$
$\Xi^{*-} \rightarrow \Lambda K^-$
$\bar{\Xi}^{*+} \rightarrow \bar{\Lambda} K^+$

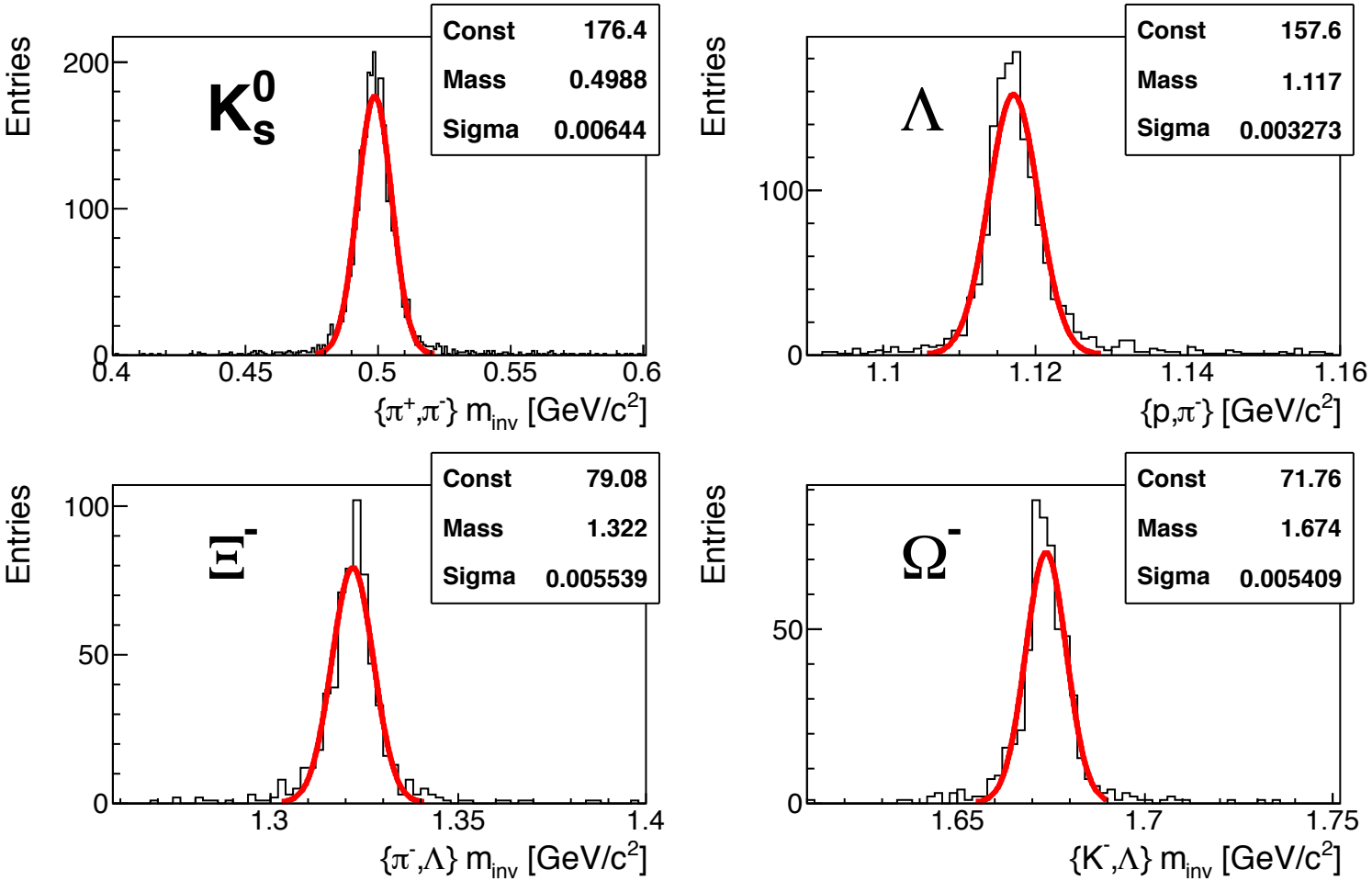
Open-charm resonances:

$D^{*0} \rightarrow D^+ \pi^-$
$\bar{D}^{*0} \rightarrow D^- \pi^+$
$D^{*+} \rightarrow D^0 \pi^+$
$D^{*-} \rightarrow \bar{D}^0 \pi^-$

Multi-strange resonances:

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

PANDA: Reconstruction of Strange Particles



Particle	p_t, GeV/c	Efficiency	Particle	p_t, GeV/c	Efficiency
K^0_s	1	56,2%	Λ	1	32,0%
Ξ^-	2	14,1%	Ω^-	2	17,1%

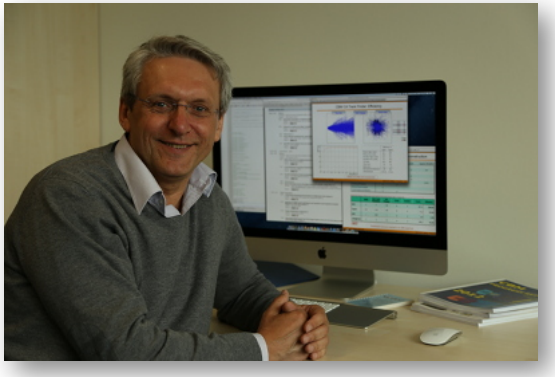
10000 signal events, Ideal track finder, MC primary vertex

Summary

A first version of

- Cellular Automaton Track Finder
- Kalman Filter Track Fitter
- Kalman Filter Particle Finder

for the STT and MVD barrel detectors has been developed



Thank you!