Geometry independent
Kalman filter based track fit

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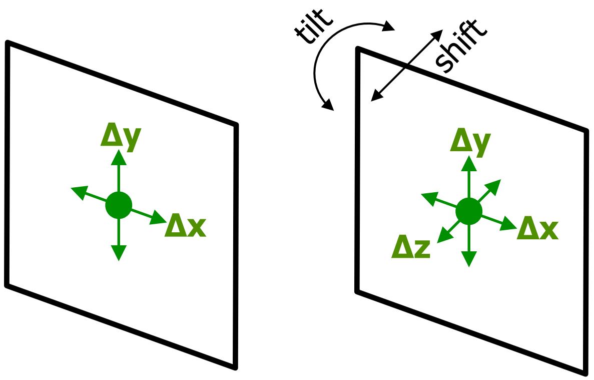
Track fit problem in case of 3D measurements

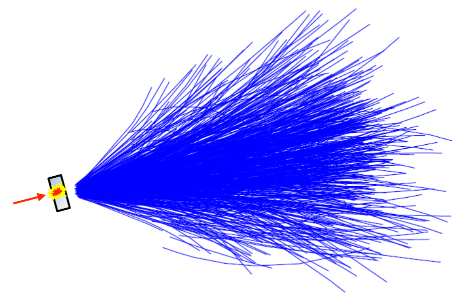
Misalignment



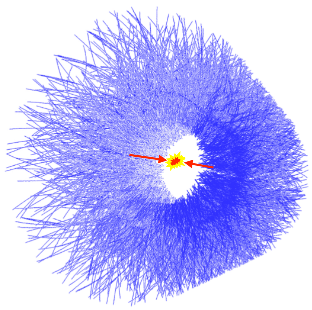
Perfectly aligned station

Misaligned station

Unification for different geometries



Fixed target geometry



Collider geometry

- In case of realistic misaligned geometry detector stations are tilted and shifted.
- The position of station is known with errors.
- Hit position is also known with errors in all 3 directions.

- Two kind of geometries require different track models and transport approaches.
- Mixed detector geometry requires approximate solutions with the conventional fit approach.

Geometry independent fit is needed for mathematically correct solutions

KF Particle for track fit

Concept:

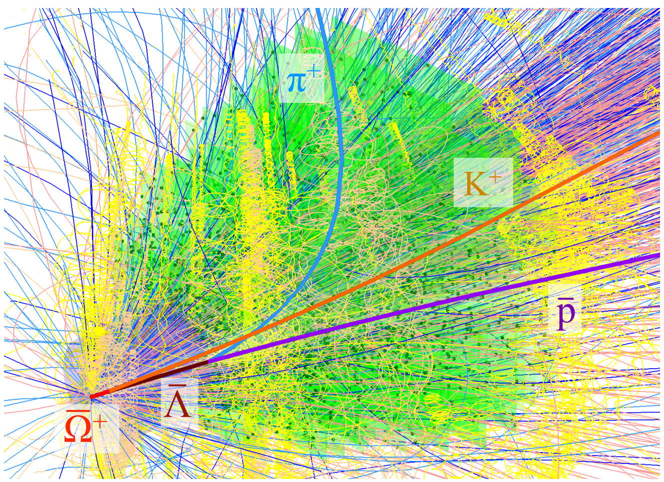
- Mother and daughter particles have the same state vector and are treated in the same way
- Geometry independent
- Kalman filter based

State vector — Position, momentum and energy

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

$$\mathbf{C} = \langle \mathbf{r}\mathbf{r}^T \rangle$$

Covariance matrix



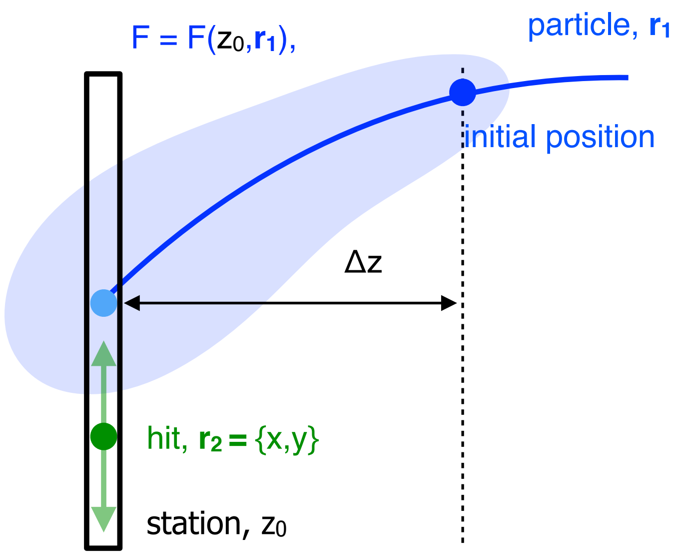
$$\bar{\Omega}^+ \rightarrow \bar{\Lambda} K^+$$
$$\bar{\Lambda} \rightarrow \bar{p} \pi^+$$

Functionality of the package:

- Construction of the particles from tracks or another particles
- Decay chain reconstruction
- Transport of the particles
- Simple access to the particle parameters and their errors
- Calculation of the distance to point
- Constraint on the vertex (filtration of the 3D point)

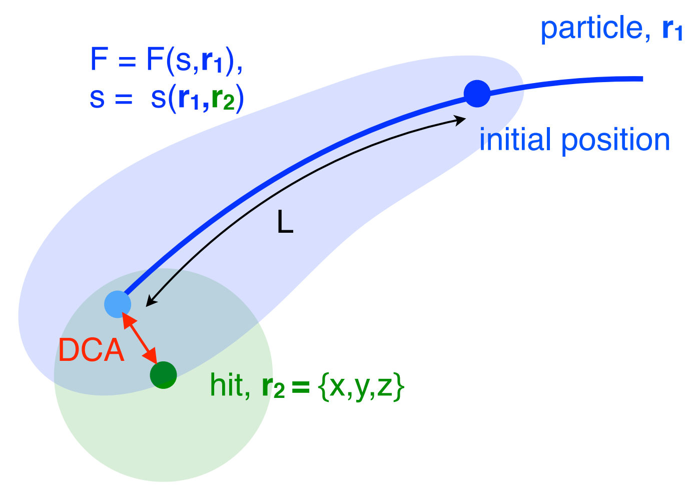
The functionality of KF Particle is perfectly suited for the first version of the geometry independent track fit

Conventional approach



- Transport to the fixed z-position, depends on the geometry.
- The transport matrix $F = F(z_0,\mathbf{r}_1)$ does not depend on the hit parameters $\mathbf{r}_2$.
- A track does not correlate with a hit.
- Conventional Kalman filter method can be applied.

Transport to the DCA point



- Transport to the DCA, does not depend on the geometry.
- The transport matrix $F = F(s,\mathbf{r}_1)$, $s = L/p$, s depends both on $\mathbf{r}_1$ and $\mathbf{r}_2$.
- Since $s = s(\mathbf{r}_1,\mathbf{r}_2)$, a particle correlates with a hit (correlation is hidden in the covariance matrix).
- The modified Kalman filter method should be applied.

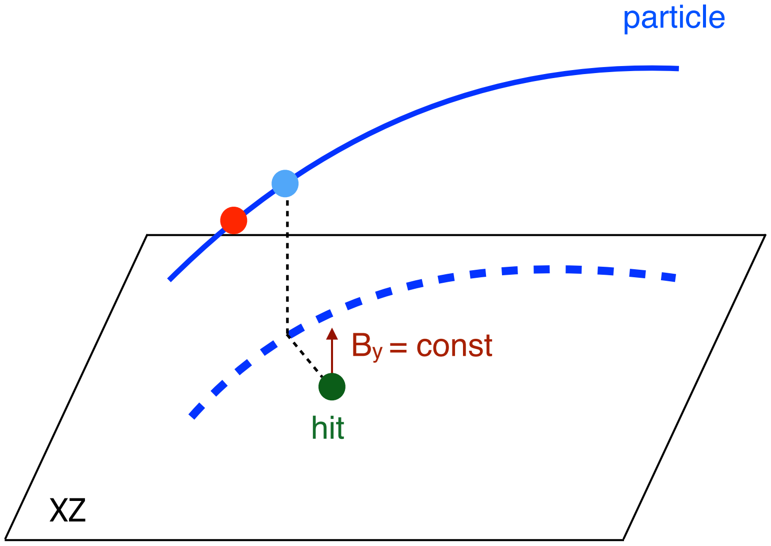
Calculation of the DCA point to a hit

Assumptions:

- distance between the point of closest approach and particle is short;
- constant one-component field B_y, works well for short distances.

Point of closest approach between a particle and a vertex:

- find point in 2D (is solved analytically);
- transport particle to that point;
- assuming small distance between 2D and 3D point, find point in 3D by Taylor expansion.



Applicability of the Kalman filter method

The Kalman filter method provide optimal solution in case of:

- Linear dynamic systems: both extrapolation and filtration equations are linear.
- State vector (vector of parameters) and measurements are independent.
- Measurements do not correlate with each other.

In case of the geometry independent fit the system is nonlinear. Even in case of the straight line fit the mathematics become highly nonlinear, therefore the Kalman filter method is approximate and should be stabilised:

- initialisation of the parameters with the meaningful values;
- correct initialisation of the covariance matrix;
- correct procedures for the operations with large numbers (for instance, addition of initially large elements of the covariance matrix with small hit errors).

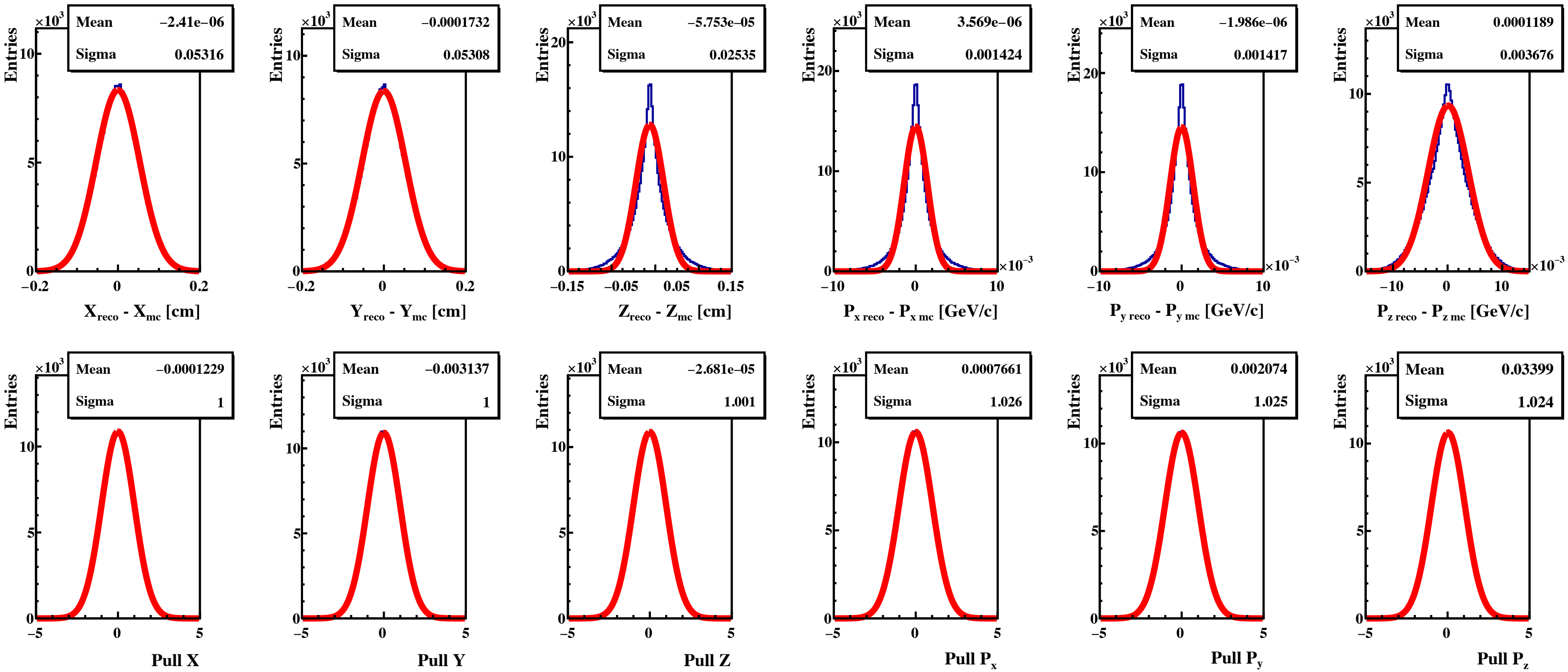
Application at the example of straight line

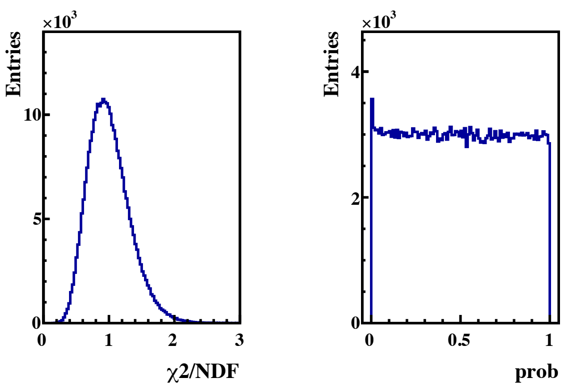
The first version of the geometry independent fit was developed at the example of the straight line:

- Particle tracks were generated as straight lines assuming zero magnetic field. Detector stations were assumed massless to exclude the multiple scattering at the first step.
- Hits were generated along the line by the smearing of all 3 coordinates (x, y, z) according to the Gaussian distribution.
- Current mathematics for filtering assumes correct errors of the track, therefore the track parameters were initialised by the simulated parameters smeared according to the Gaussian distribution with corresponding errors in the covariance matrix.

Results

Coordinates **Momentum**





- Fitted track errors are in a good agreement with the simulated hit errors.
- Correct mathematics — as a result correct pulls (unbiased, width about 1), χ^2 and flat prob (p-value) distributions.

Summary and Plans

Summary

- A first version of the geometry independent track fit is developed.
- The current implementation is stable with correct initial approximation and correct initial covariance matrix.
- The method shows high fit quality at the example of the straight line fit.

Plans

- Further develop the fit, stabilise it with respect to initial approximation.
- Apply the method for the track fit in the CBM experiment.