Kalman-filter-based track fitting in non-uniform magnetic field

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Outline

1. Introduction
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   - Implementation

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   - Simulation
   - Results

The algorithm

To use the helical track model of KalTest in the non-uniform magnetic field, we have to

- assume the magnetic field between two nearby layers is uniform;
- transform the frame to make its z axis always points to the direction of magnetic field.

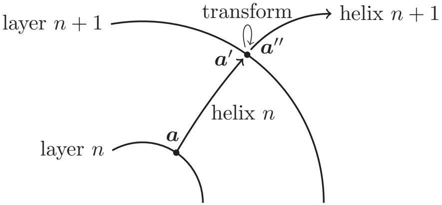


Figure 1 : Basic idea of the algorithm

Transforming the frame

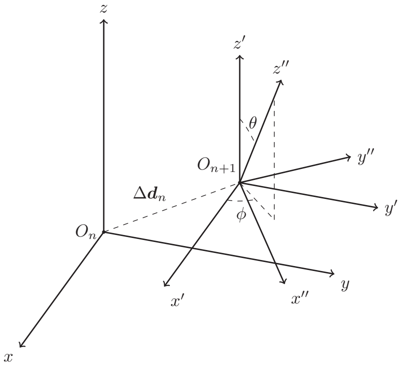


Figure 2 : Transformation

$$\boldsymbol{\Delta R} = \boldsymbol{\Delta R}_{z''}(-\phi)\boldsymbol{\Delta R}_{y''}(\theta)\boldsymbol{\Delta R}_{z'}(\phi).$$

Implementation

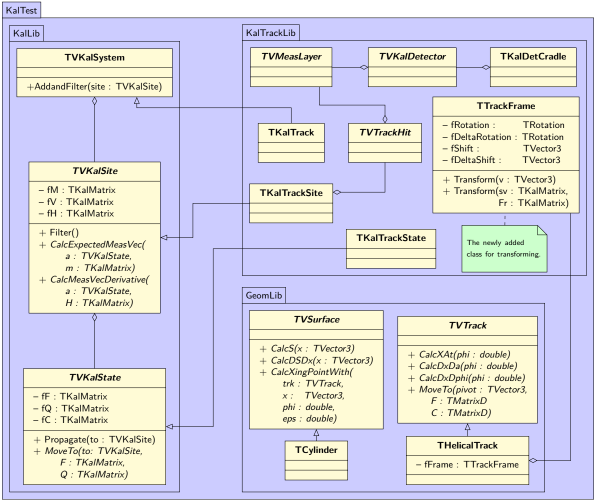


Figure 3 : Class diagram of KalTest

Simulation conditions

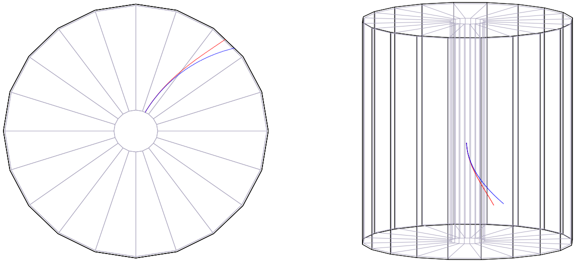
- Suppose the non-uniform magnetic field is

$$\left\{ \begin{array}{lcl} B_x & = & B_0 kxz \\ B_y & = & B_0 kyz \\ B_z & = & B_0(1 - kz^2) \end{array} \right.$$

in which, $k = \frac{k_0}{z_m r_m}$, $B_0 = 3\ \mathrm{T}$, $z_m = r_m = 3000\ \mathrm{mm}$;

- Runge-Kutta track generator;
- Track parameters: dip angle $\lambda \in [0, 0.5]$, azimuth angle $\phi \in [0, 2\pi]$;
- Detector: 251 layers, distance between two nearby layers is $6\mathrm{mm}$.

Event display



(a) xy view (b) 3D view

Figure 4 : Event display. $2\ \mathrm{GeV}$ tracks generated in uniform magnetic field (blue line), and non-uniform magnetic field (red line, $k_0 = 5$).

Momentum

- $k_0 = 1$, $p = 10$ GeV;
- Tracks are reconstructed in **uniform** magnetic field.

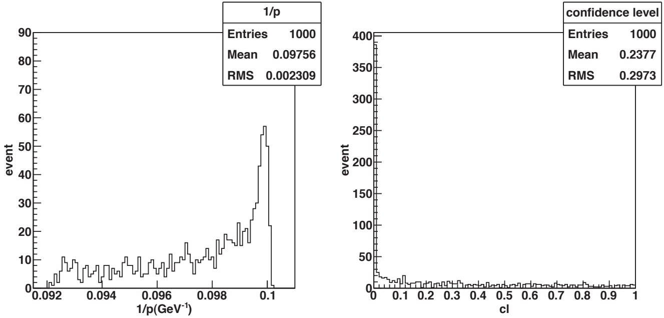


Figure 5 : Momentum and confidence level with uniform magnetic field.

Momentum

- $k_0 = 1,\ p = 10$ GeV;
- Tracks are reconstructed in **non-uniform** magnetic field.

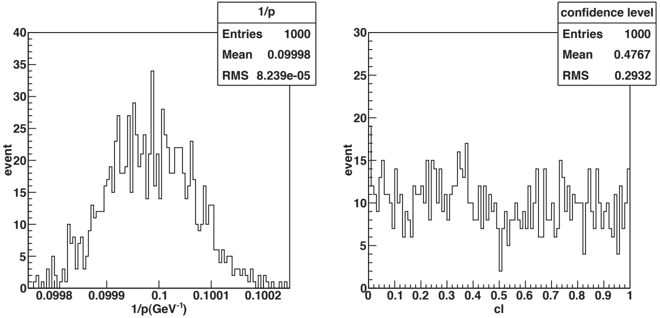


Figure 6 : Momentum and confidence level with non-uniform magnetic field.

Results with different non-uniformity and tracking step size

Table 1 : Mean and RMS of $\frac{1}{p}$ (in $10^{-1}\cdot$ GeV^{-1} and $10^{-5}\cdot$ GeV^{-1} respectively)

(a) Step size 6 mm

k_0	$\lambda = 0.1$	$\lambda = 0.3$	$\lambda = 0.5$
1	1.0000/8.03	0.9998/7.89	0.9995/7.65
2	1.0000/8.05	0.9997/8.09	0.9990/8.36
3	0.9999/8.07	0.9995/8.31	0.9984/9.20

(b) Step size 1 mm

k_0	$\lambda = 0.1$	$\lambda = 0.3$	$\lambda = 0.5$
1	1.0000/8.03	1.0000/7.89	0.9999/7.65
2	1.0000/8.05	0.9999/8.10	0.9998/8.36
3	1.0000/8.07	0.9999/8.32	0.9997/9.21

CPU expense

- MacBook Pro, OS X 10.6; 2.4 GHz Intel Core 2 Duo; 4 G Memory.
- 1,000 tracks

Table 2 : Time consumption of functions (sec.)

Function	Time expense
Total	18.82
TVKalState::Propagate	11.53
TVKalSite::Filter	7.27
TTrackFrame::TTrackFrame	0.87
TTrackFrame::TransformVector	6.59
TTrackFrame::TransformSv	2.58
TVSurface::CalcXingPointWith	5.90