Track Fitting in Belle II

The GENFIT Library and its Performance

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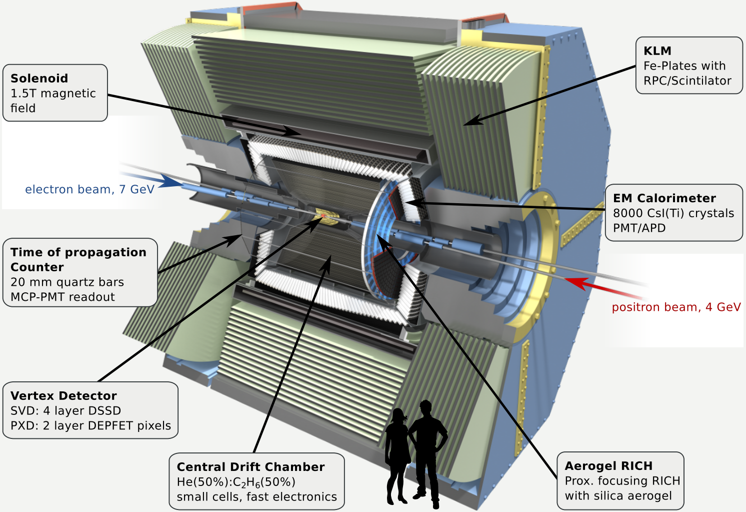
The Belle II Experiment

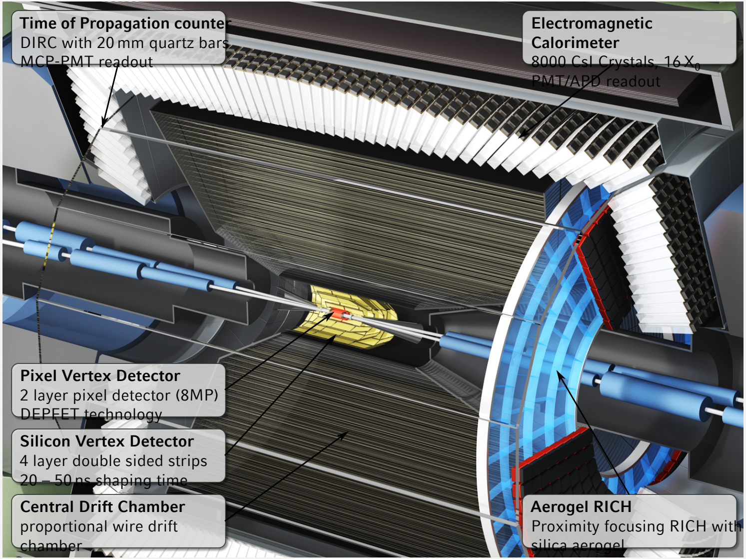


Currently being set up at KEK, Japan.

- B-factory experiment
- first beam 2016
- physics from 2018
- instantaneous luminosity goal $L = 8 \times 10^{35}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ (40 times Belle, KEKB)

See talks by Z. Dolezal, J. Wiechczyski

Tracking Detectors in Belle II



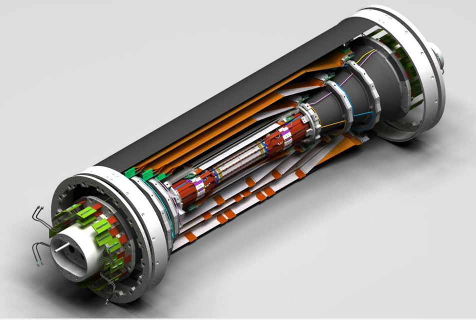
Aims:

- Momentum range: 50 MeV – –5 GeV
- background resistant
- high resolution

Detector choices:

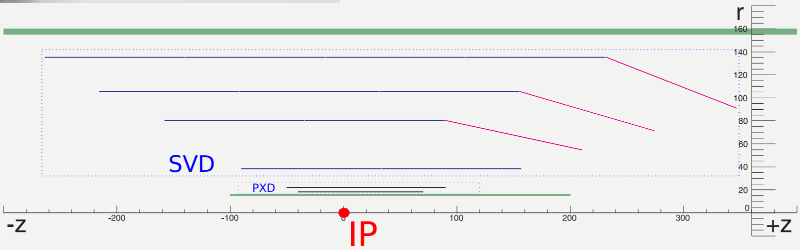
- Vertex detector: six layers of silicon
- Drift chamber: 56 wire layers, divided into 9 sueprlayers

Vertex Detector



The Belle II Vertex Detector

- two layers of DEPFET pixels (PXD)
- four layers of double-sided silicon strip detectors (SVD)



Discussed in G. Casarosa's talk.

Large Volume Drift Chamber CDC

Figure: Drift Chamber CDC

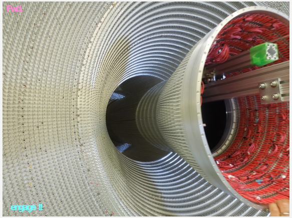


Figure: Drift Chamber End Plate

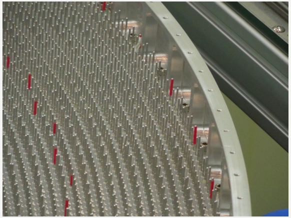
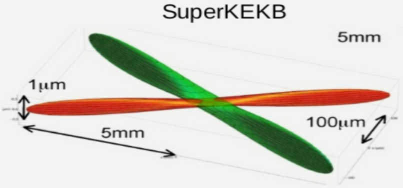


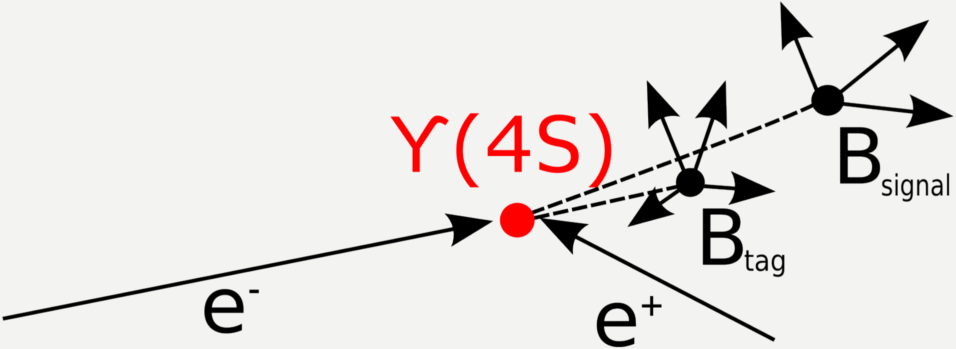
Figure: Drift Chamber Detail

- 14k sense wires
- 42k field wires
- 8000 ℓ gas volume, outer radius 1.25 m
- 56 layers, divided into 9 superlayers (5 axial wires, 4 stereo wires)

Event Topology



- e^+e^- are brought into collision in the tiny beamspot
- $\Upsilon(4s)$ is produced, decays into $B\bar{B}$ pair
- these propagate $O(100\,\mu\text{m})$ ($p_{\text{LAB}} = 1.5\,\text{GeV}$) …
- …before decaying into a total of $O(10)$ tracks
- most important observable: separation of B decay vertices along boost direction



Online, Offline

Trigger, Readout

See C. Li's talk

- CDC trigger does very coarse tracking (hardware trigger)
- complete offline TF is used in high-level trigger, used for background suppression in PXD

Offline

Stand-alone trackfinding in subdetectors

- vertex detector: cellular automaton, Hopfield network for candidate evaluation
- drift chamber: Legendre-based global track finder, cellular automaton-based local track finding

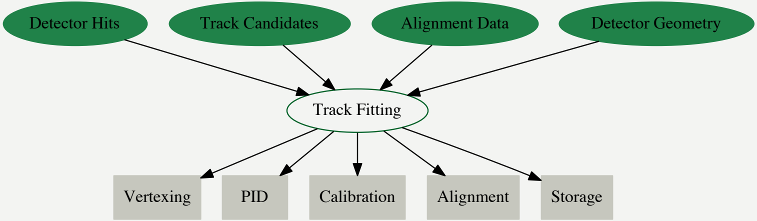
Combination of subdetectors

- found tracks are merged if fitted parameters agree at subdetector boundary
- cross-detector searches, extrapolations for additional hits (under development)

Track Fitting

Convergence Point

Track fitting is the convergence point of many things.



Track Fitting

Convergence Point

Track fitting is the convergence point of many things.

The GenFit Library

- Belle II initially based its track fitting on the experiment-independent GenFit library (arXiv:0911.1008)
- this turned out to be fairly limited, the track fitting software was essentially rewritten while keeping in spirit with the original library
- the new GenFit library is now used by the Belle II collaboration as well as the PANDA and SHiP collaborations (arXiv:1410.3698)

The Complete Track Fitting Package

GENFIT handles all aspects of track fitting

Inputs

- flexible hit classes
- track candidate handling
- interfaces for interaction between hits, tracks, alignment info (e.g. wire sag)

Processing

- extrapolation code
- pluggable fitting algorithms (Kalman filter, DAF, GBL)
- combined handling of several particle hypotheses

Output

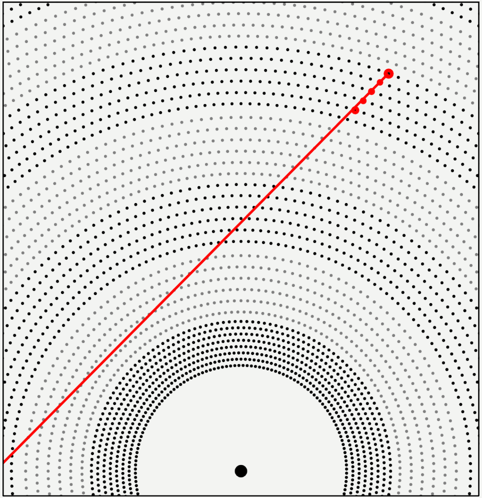
- flexible convergence criteria (e.g. were there rejected outliers?)
- storage with configurable detail (ROOT)
- interfaces to Millipede II (alignment), RAVE (vertexing)

All Detectors Tested

In 2014 we had a beam test where we could successfully establish the complete dataflow for the vertex detector including online reconstruction. (G. Casarosa's talk)
This year, we are having a cosmic ray test of the CDC.

- very promising, data from a single read-out board could be reconstructed successfully
- tracks through the entire detector expected later this year

GENFIT can handle real detector data without alignment, calibrations fine.



Actual Cosmic Data with Track Candidate

Track Fitting Algorithms

Kalman Fitter

- standard track fitting algorithm
- sequential
- equivalent to LSM

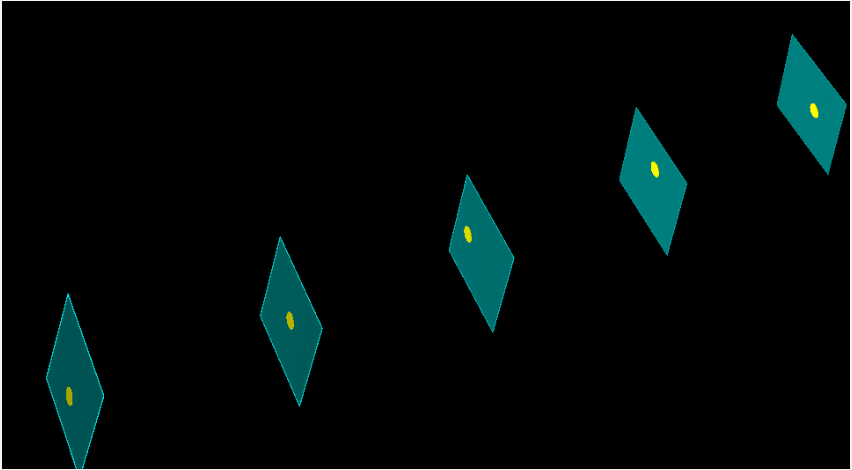
Deterministic Annealing Filter (DAF)

- sequence of Kalmans
- annealing procedure for outlier rejection, ambiguity resolution
- equivalent to LSM

Generalized Broken Lines

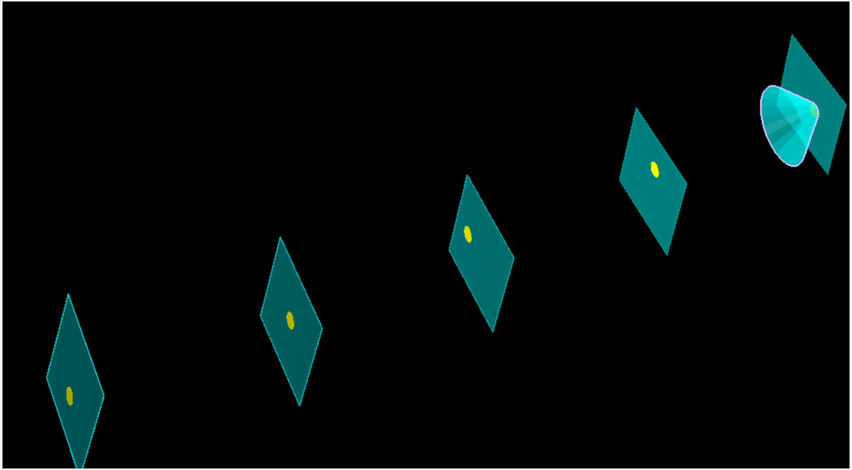
- alternaitve to Kalman
- well suited to Millipede alignment

Kalman Filter



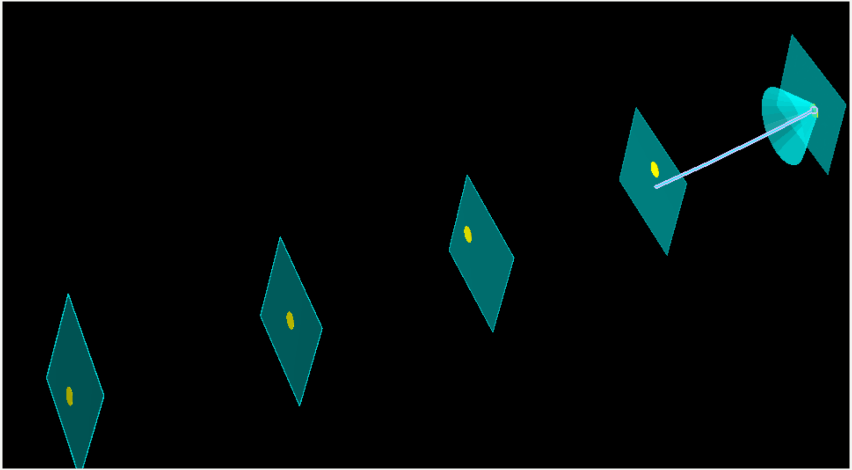
Series of noisy measurements.

Kalman Filter



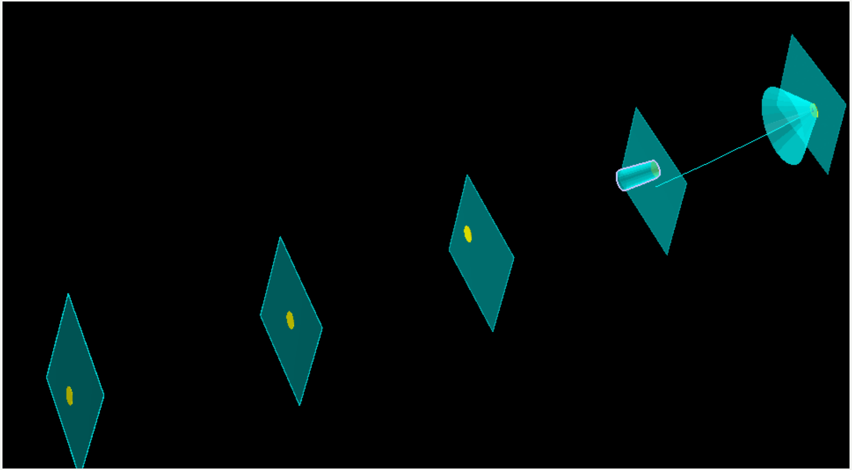
First update of the forward fit.
Position determined by first measurement.

Kalman Filter



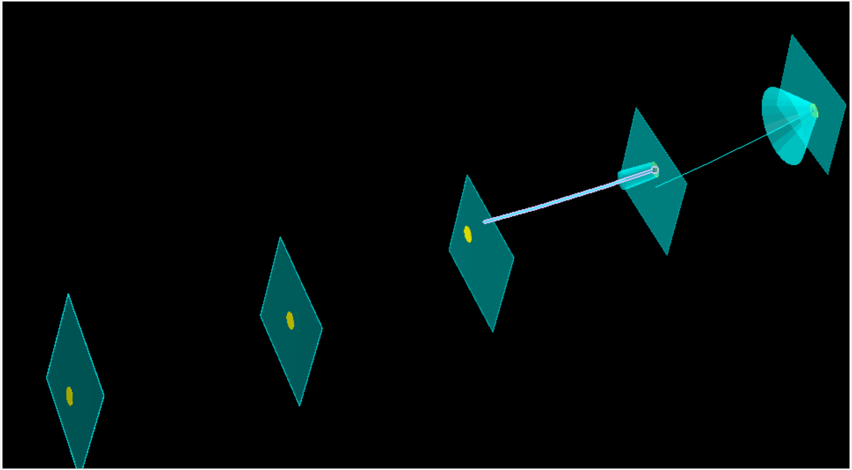
Prediction.

Kalman Filter



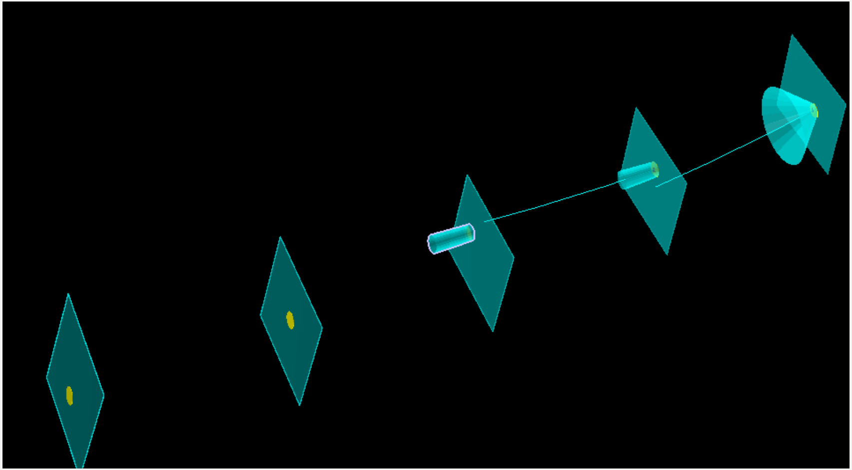
Update.
Direction determined by fist two measurements.

Kalman Filter



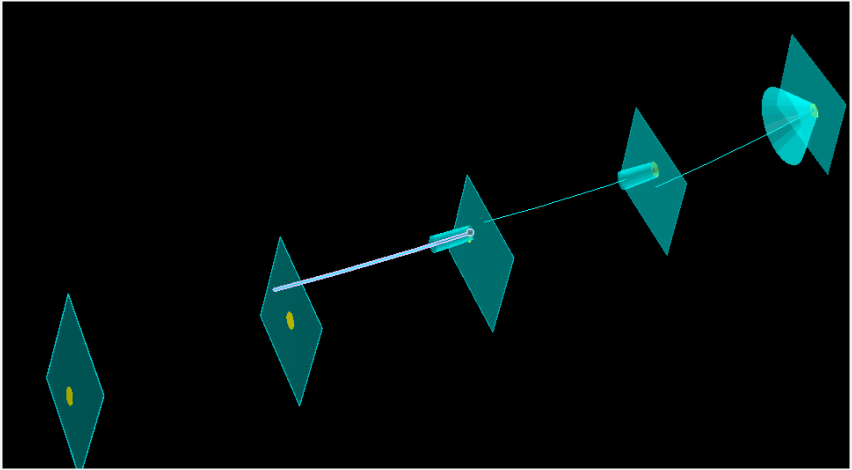
Prediction.

Kalman Filter



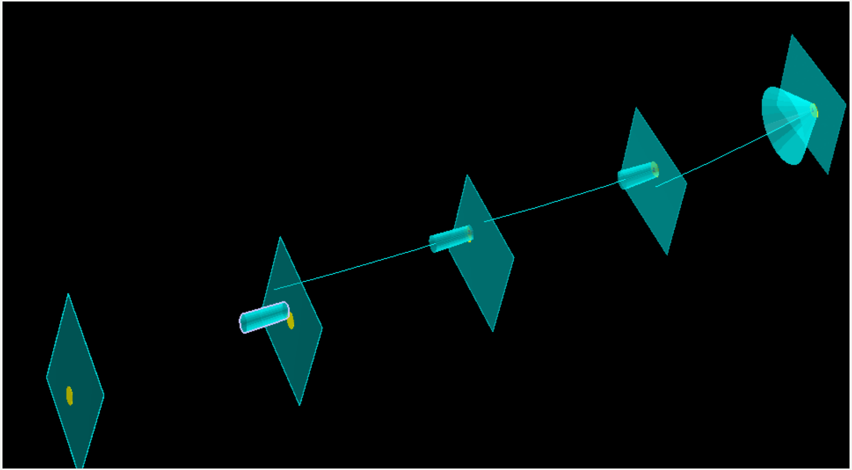
Update.
Curvature can be determined.

Kalman Filter



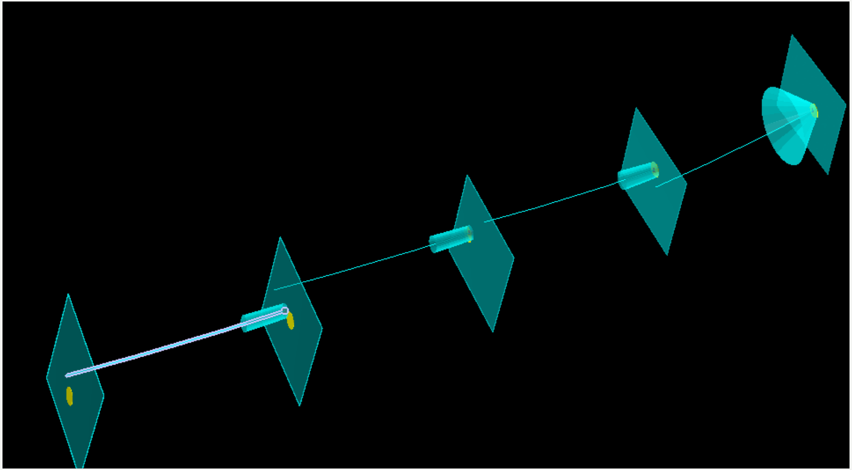
Prediction.

Kalman Filter



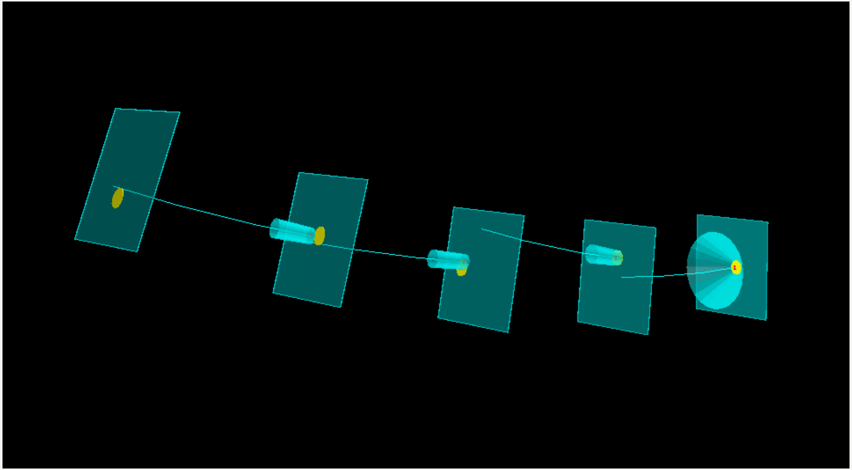
Update.

Kalman Filter



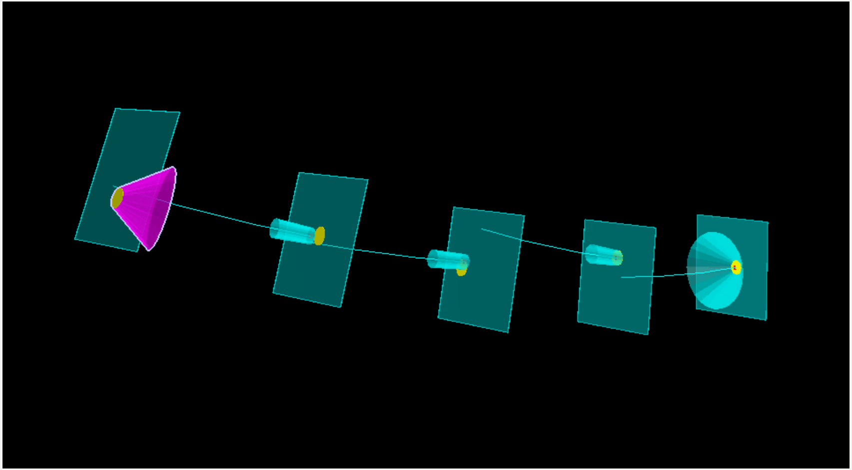
Prediction.

Kalman Filter



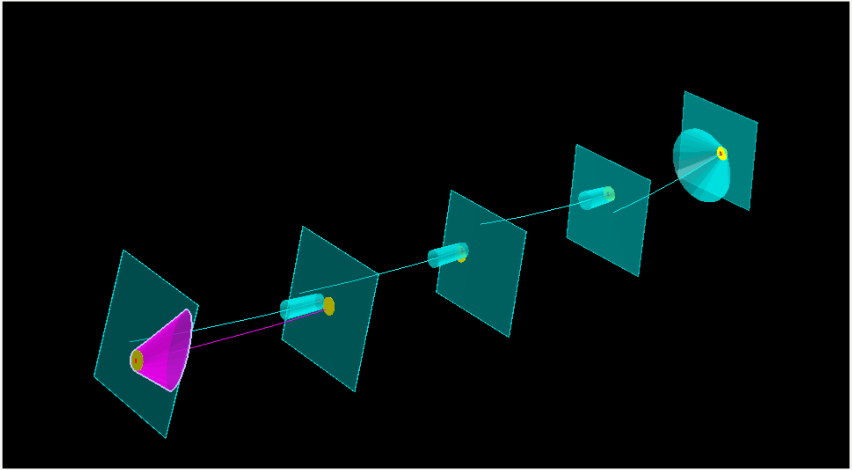
Forward fit.

Kalman Filter



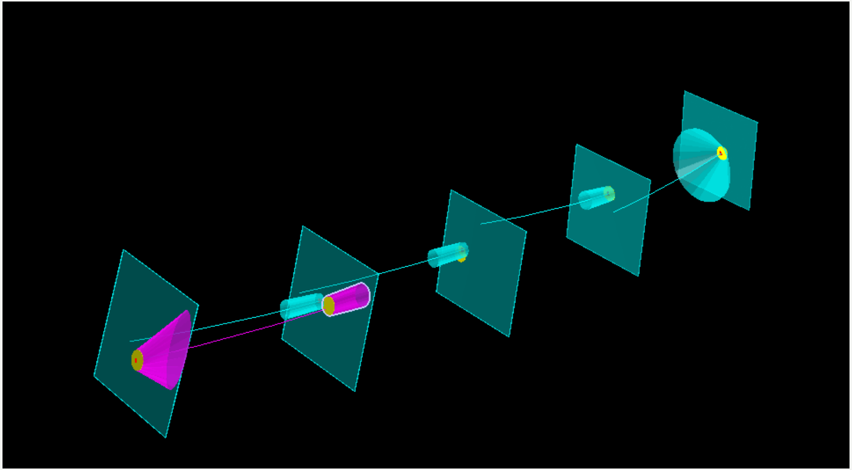
First update of the backward fit.
Direction and momentum from forward fit used as starting value.

Kalman Filter



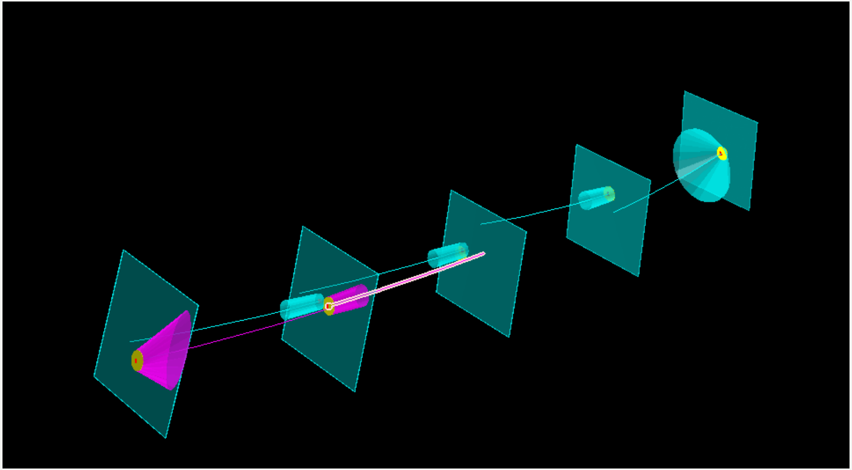
Prediction.

Kalman Filter



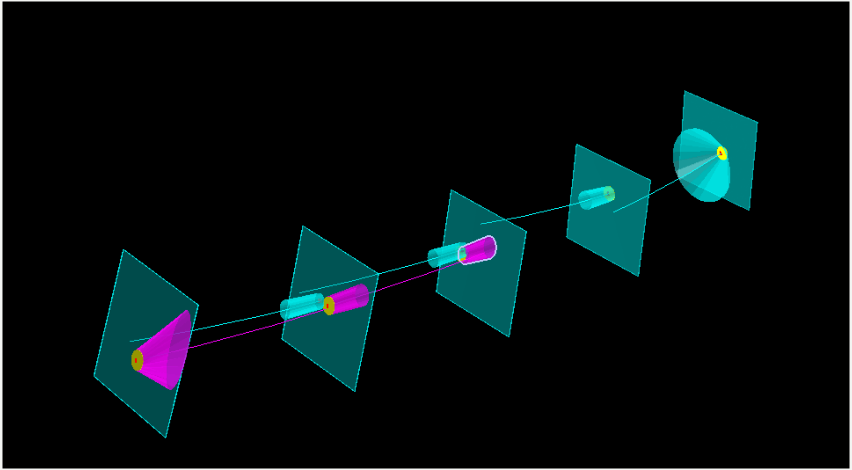
Update.
Direction determined by last two measurements.

Kalman Filter



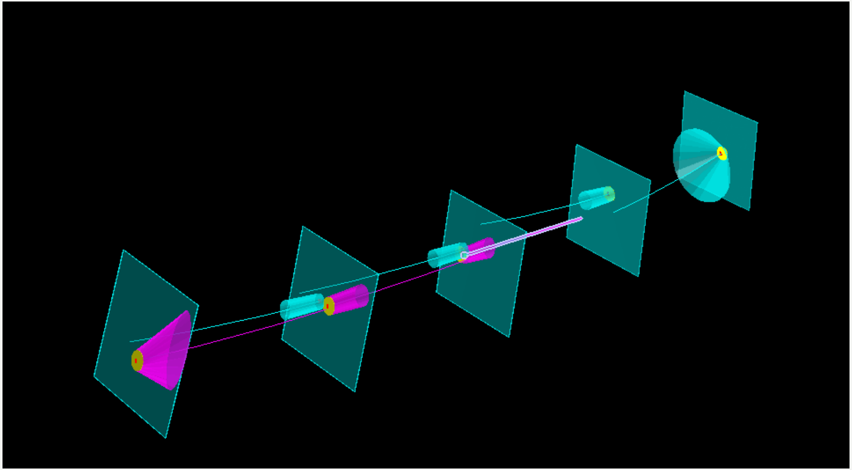
Prediction.

Kalman Filter



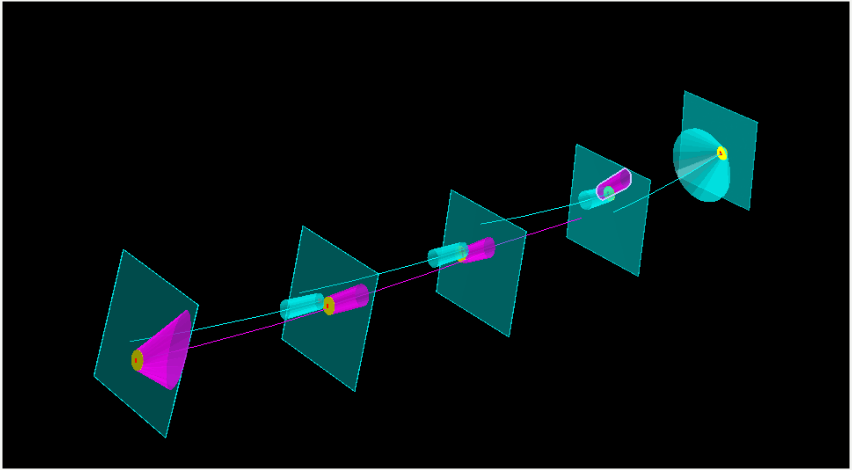
Update.
Curvature can be determined.

Kalman Filter



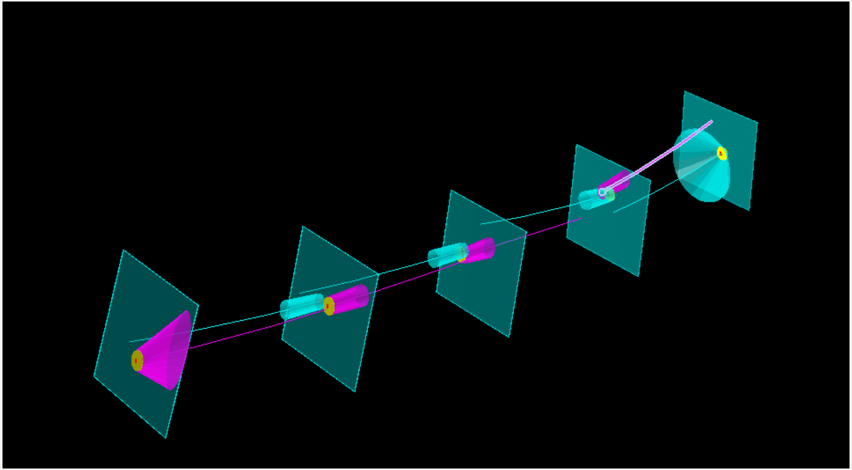
Prediction.

Kalman Filter



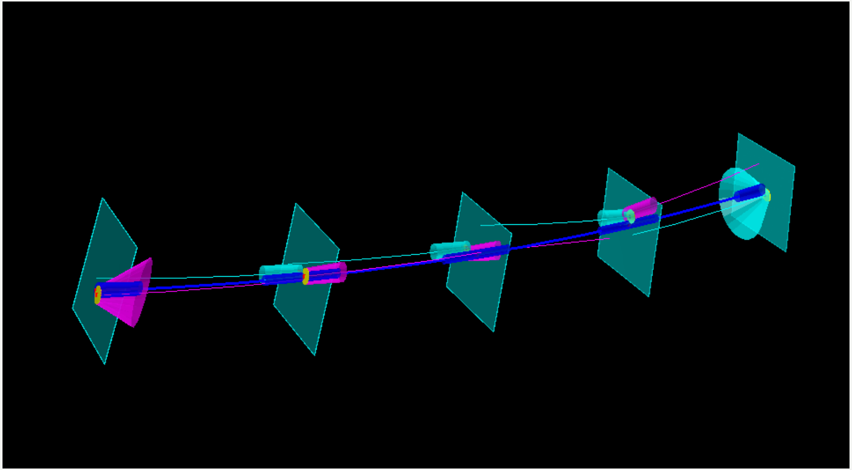
Update.

Kalman Filter



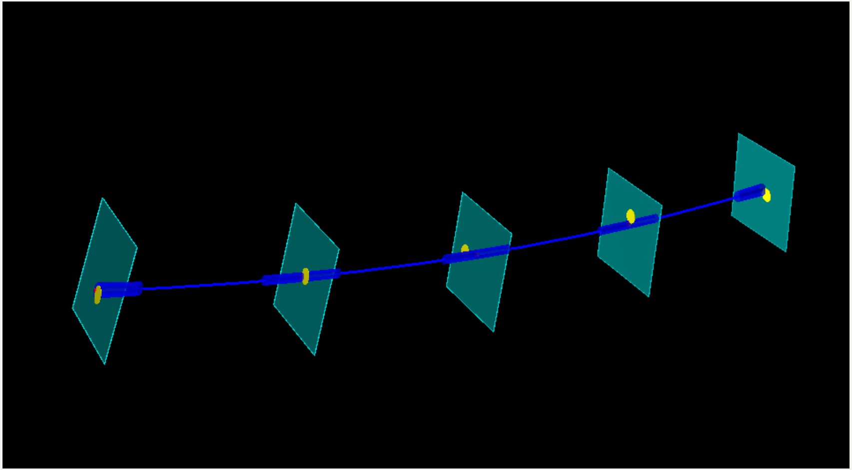
Prediction.

Kalman Filter



Smoothed track: weighted average between forward fit and backward fit.

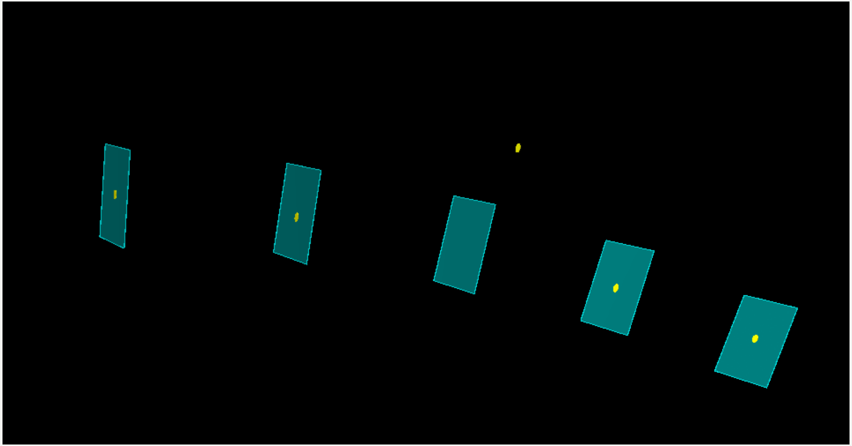
Kalman Filter



Smoothed track.

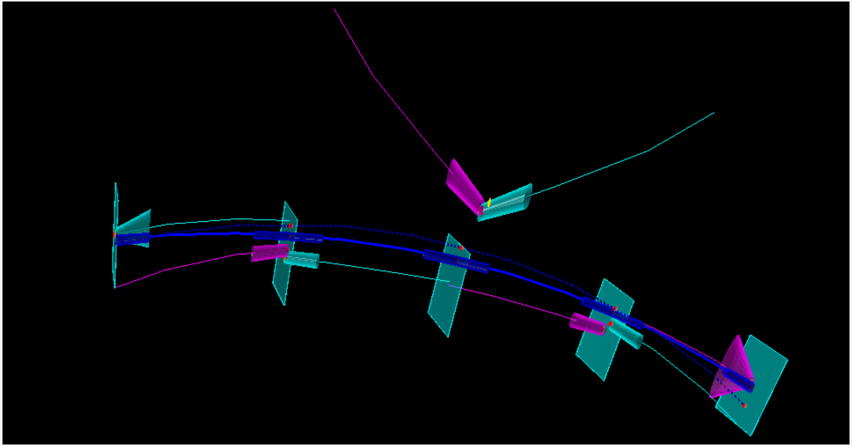
Outlier Rejection -- the DAF

Outlier - Fitted with the DAF



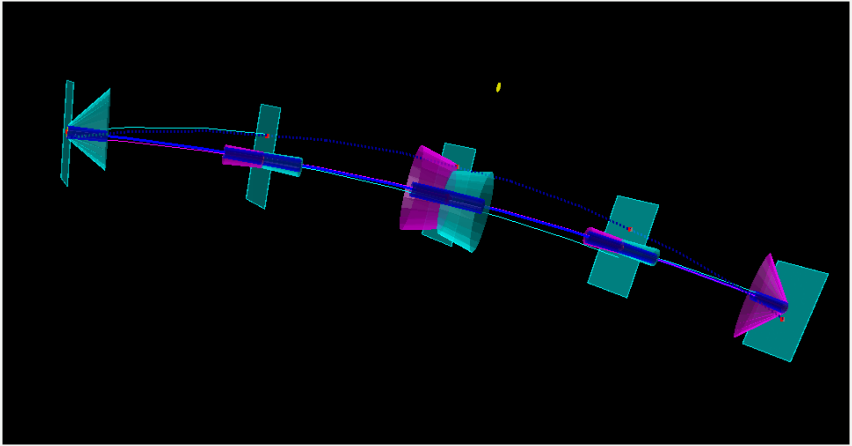
$\beta = 100$	initial weights:	1	1	1	1	1
$\log_{10} \beta = 2$	new weights:	0.4960	0.4238	0.1940	0.4310	0.5003

Outlier - Fitted with the DAF



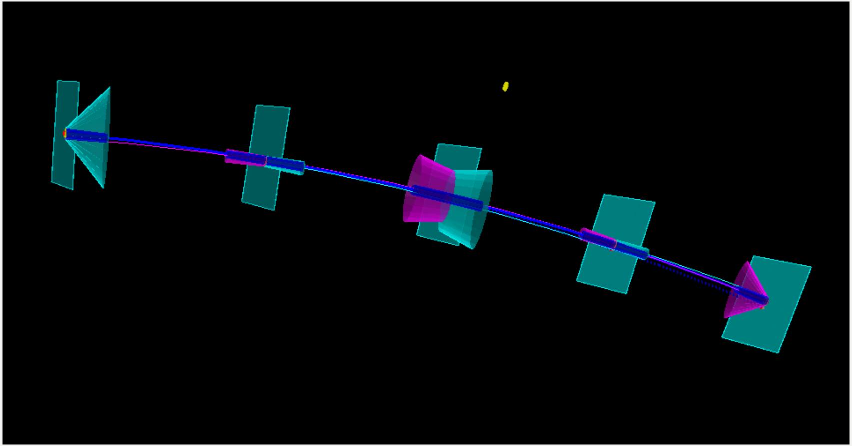
$\beta = 17.78$	initial weights:	0.4960	0.4238	0.1940	0.4310	0.5003
$\log_{10}\beta = 1.25$	new weights:	0.5426	0.3640	$6.052e-6$	0.3913	0.5470

Outlier - Fitted with the DAF



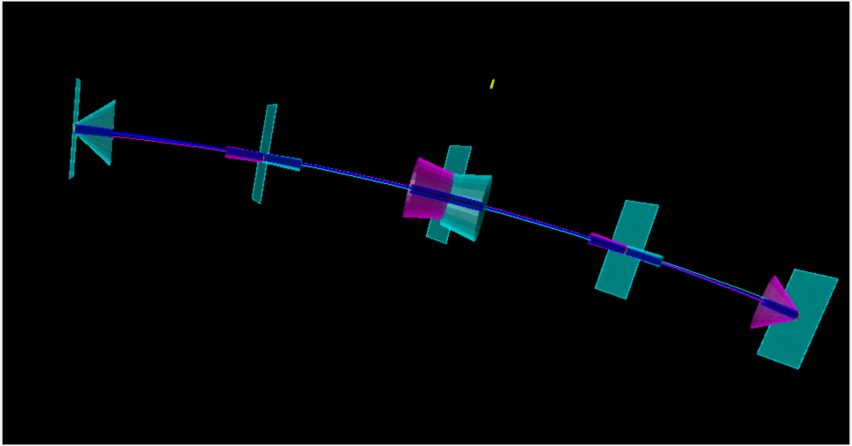
$\beta = 3.162$	initial weights:	0.5426	0.3640	$6.052e - 6$	0.3913	0.5470
$\log_{10}\beta = 0.5$	new weights:	0.8111	0.8093	$4.106e - 52$	0.8099	0.8109

Outlier - Fitted with the DAF



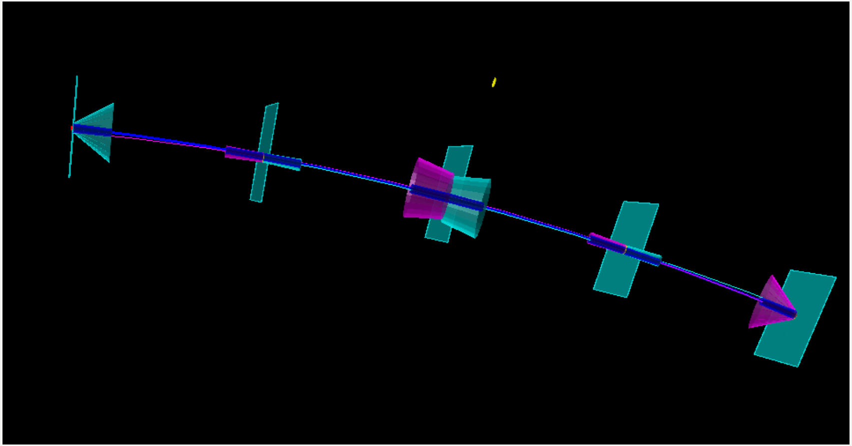
$\beta = 0.5623$	initial weights:	0.8111	0.8093	$4.106e-52$	0.8099	0.8109
$\log_{10}\beta = -0.25$	new weights:	0.9997	0.9997	$1.725e-290$	0.9997	0.1000

Outlier - Fitted with the DAF



$\beta = 0.1$	initial weights:	0.9997	0.9997	$1.725e-290$	0.9997	0.1000
$\log_{10}\beta = -1$	new weights:	1	1	0	1	1

Outlier - Fitted with the DAF



$\beta = 0.1$	initial weights:	1	1	0	1	1
$\log_{10}\beta = -1$	new weights:	1	1	0	1	1

SUMMARY, FIGURES OF MERIT

Time per track: 20 ms disk space: unpruned/pruned

Blocks

normal block

with text

alert block

with text

example block

with text