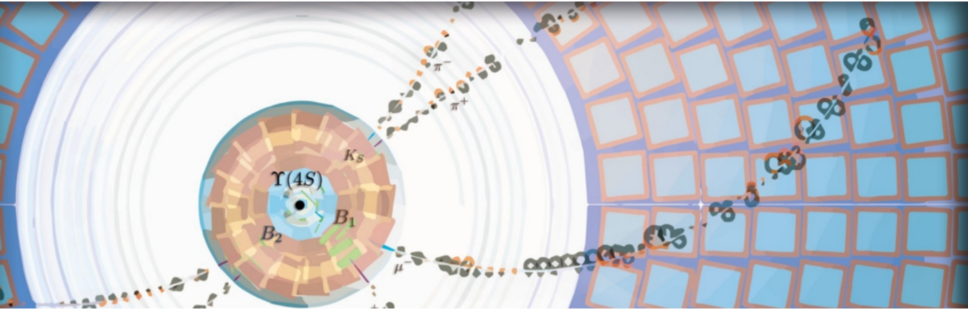
Tales of Riemann.

F2F tracking meeting - Pisa



Oliver Frost
Deutsches Elektronensynchrotron
29th September 2014

DESY
HELMHOLTZ ASSOCIATION
Belle II

Overview

- Two dimensional fitting
- Three dimensional fitting
- Planes

- Two dimensional fitting
- Three dimensional fitting
- Planes

Versions of the Riemann fit

Distance measure - fits to points

$$\epsilon = n_0 + n_1 \cdot x + n_2 \cdot y + n_3 \cdot r^2$$

(Frühwirth)

Distance measure - fits to drift circles of radius l

$$\epsilon = n_0 + n_1 \cdot x + n_2 \cdot y + n_3 \cdot r^2 - a \cdot l$$

This requires some prior knowledge of the right left passage hypotheses *a* as seen by the particle.

CDC measurements are drift circles

This difference is not neglectable especially for rather short segments.
Only using the drift length and the correct right left passage hypotheses yields accurate results.

Versions of the Riemann fit

Distance measure - fits to points

$$\epsilon = n_0 + n_1 \cdot x + n_2 \cdot y + n_3 \cdot r^2$$

(Frühwirth)

Distance measure - fits to drift circles of radius l

$$\epsilon = n_0 + n_1 \cdot x + n_2 \cdot y + n_3 \cdot r^2 - a \cdot l$$

This requires some prior knowledge of the right left passage hypotheses *a* as seen by the particle.

CDC measurements are drift circles

This difference is not neglectable especially for rather short segments.
Only using the drift length and the correct right left passage hypotheses yields accurate results.

Versions of the Riemann fit

Distance measure - fits to points

$$\epsilon = n_0 + n_1 \cdot x + n_2 \cdot y + n_3 \cdot r^2$$

(Frühwirth)

Distance measure - fits to drift circles of radius l

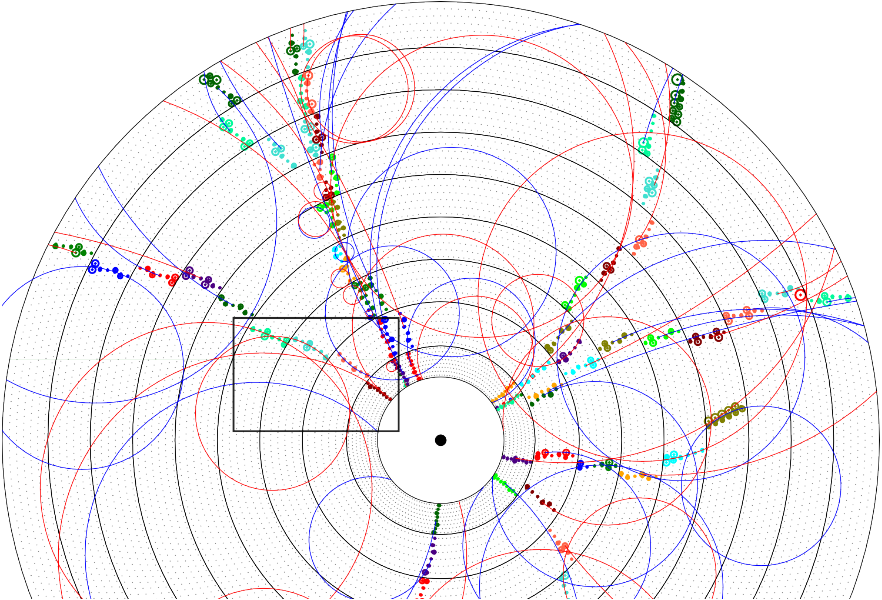
$$\epsilon = n_0 + n_1 \cdot x + n_2 \cdot y + n_3 \cdot r^2 - a \cdot l$$

This requires some prior knowledge of the right left passage hypotheses *a* as seen by the particle.

CDC measurements are drift circles

This difference is not neglectable especially for rather short segments.
Only using the drift length and the correct right left passage hypotheses yields accurate results.

Segment fits to wire position - display



Segment fits to wire position - detailed display

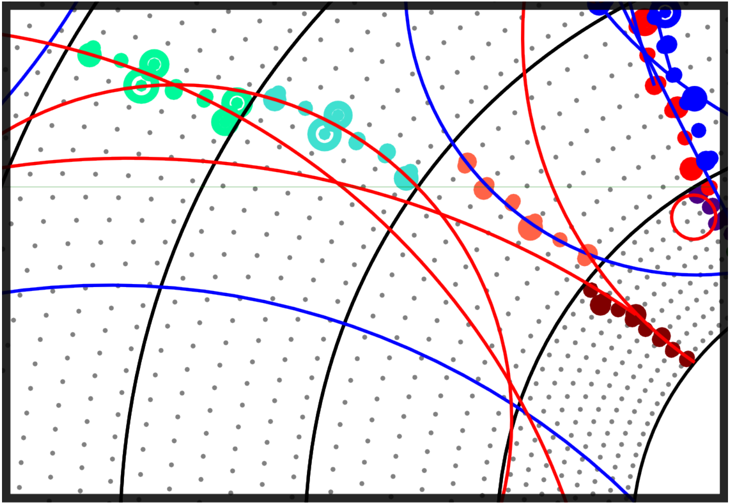
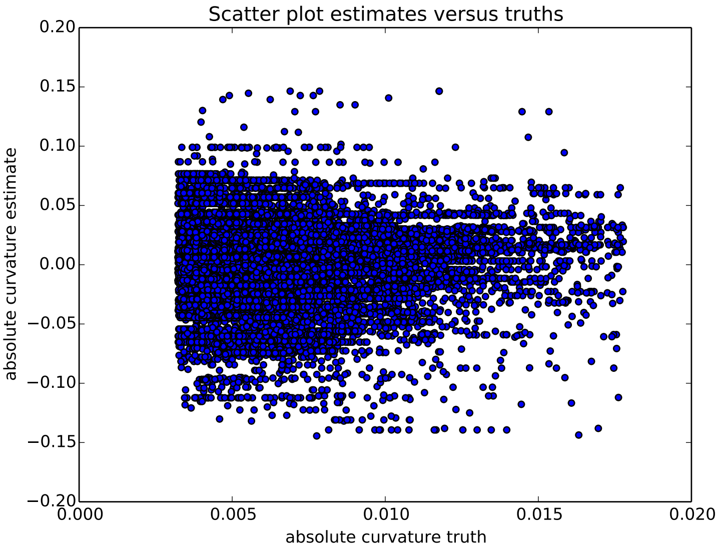
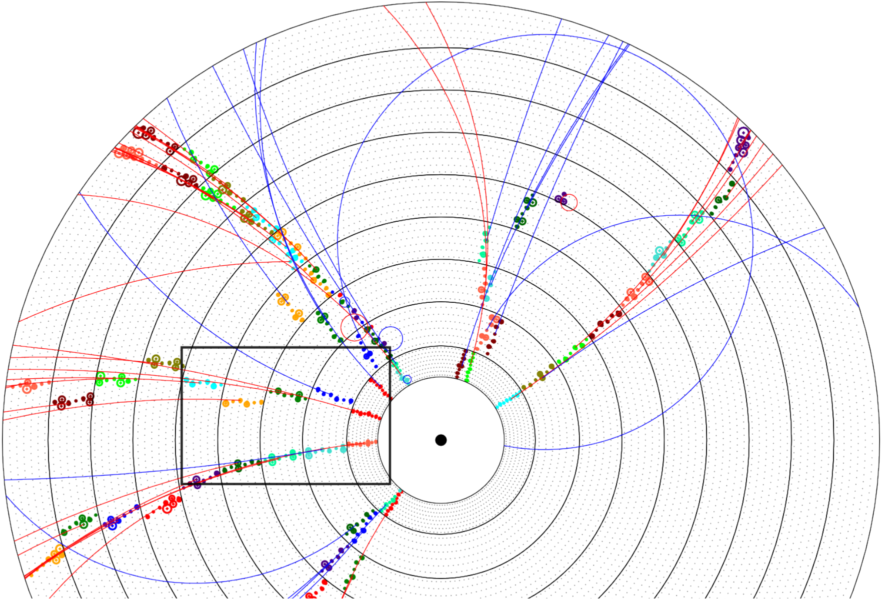


Figure 1: Segment fits have too high curvature, more information needed to straighten trajectories.

Segment fit to wire position - estimation quality



Segment fits to drift circles - display



Segment fits to drift circles - detailed display

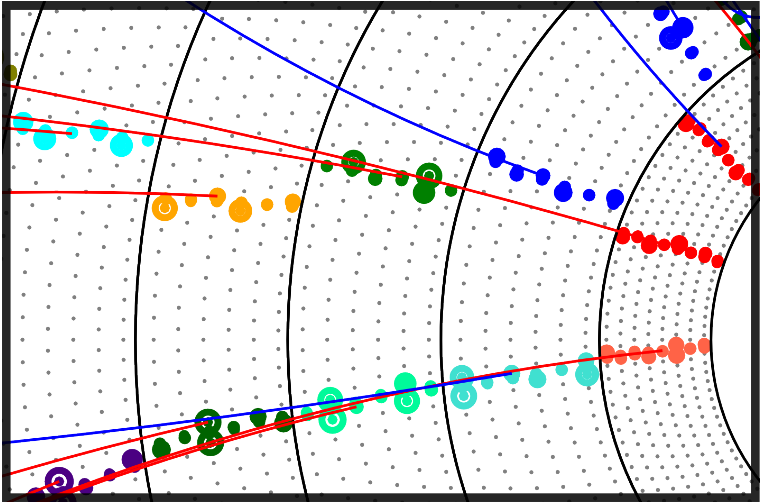
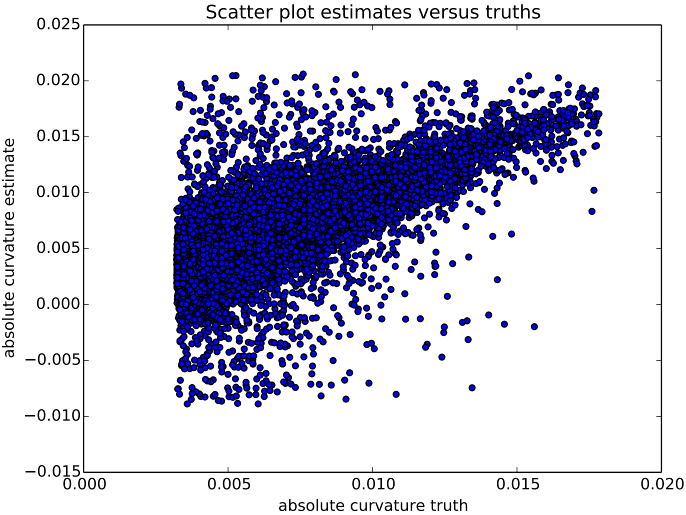


Figure 2: Using drift circles fits to axial segment yields right curvature. Fits to stereo segments have differing curvature. Here the curvature sign is opposite (blue vs. red).

Axial segment fit to drift circles - estimation quality



Difference between axial and stereo layers

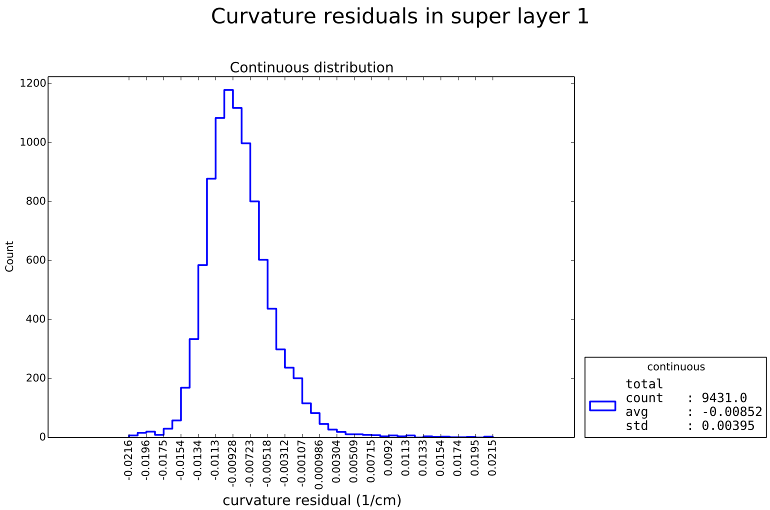
Axial layers

- Projection carried out by the wires is the xy projection.
- Curvature in xy projection is the real curvature.
- Unbiased fit in projection

Stereo layers

- Projection carried out by the wires changes with z position.
- A particle trajectory can gradually pick up additional displacement as it is moving forward/backward.
- Curvature in the projection and $\tan \lambda$ are interwined.
- This generally leads to a bias.

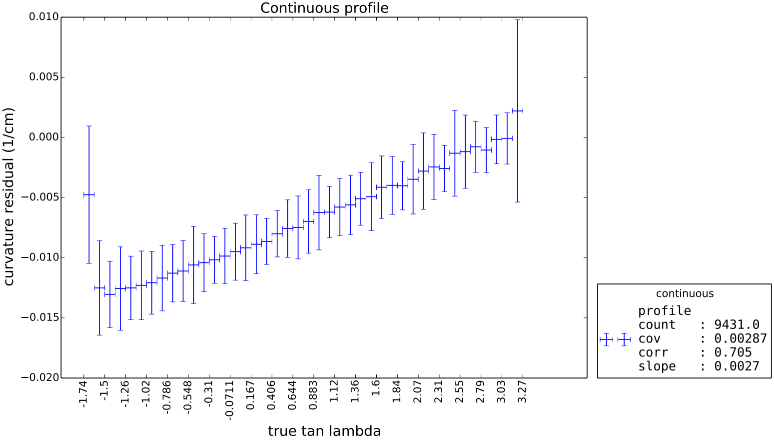
Bias in curvature residuals - stereo superlayer 1



Cause of the bias

Stereo effect influences curvature in the xy-projection

Curvature residual versus tan lambda in super layer 1



Extending the Riemann fit to estimate covariance matrices

Covariance estimation

$$V_{ij}^{-1} = \sum_k w_k \frac{d\epsilon_k}{dn_i} \frac{d\epsilon_k}{dn_j}$$

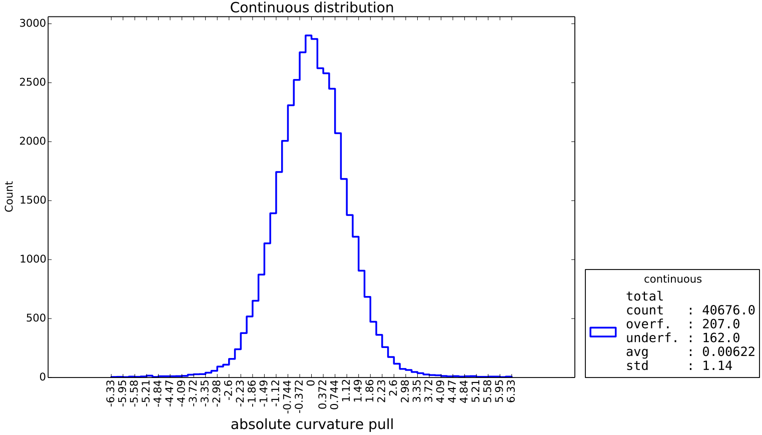
(Karimaki)

Application to Riemann fit

- Simple in normal parameters n, since they enter the distance ϵ linearly.
- Slightly complicating translation from four n parameters to three perigee parameters.

Covariance estimation quality

Distribution of absolute curvature pull (clipped)



Auxiliary implementation details.

- Fitting methods interfacing to other code easily do able.
- Transport / extrapolation of perigee covariances to new reference point.
- Helix class also doing closest approaches to points.

Summary

- Parameter and covariance matrix estimation yield reasonable results for axial layers.
- Fitting in stereo layers alone leads to a bias.
- On segment level fitting the wire position is not enough.
- **Active use of drift length is not optional.**
- The latter is **requires** the **correct right left passage hypotheses**.
- Comparision of the right left passage to the Monte Carlo truth would be desireable.

- Two dimensional fitting
- Three dimensional fitting
- Planes

Changed logic in the second stage

Pairs instead of triples

- Use pairs of segments as cells for the cellular automaton instead of triples

Benefits

- Needs only one filter in the creation step instead of two.
- Tracks are allowed to end in stereo layers.
- Fewer left over segments
- Still enough information to construct a helix with from combination of axial and stereo information

Combining the axial and stereo fit

Kalmanesk combination of parameters

Combined helix covariance

$$V^{-1} = H_a^T \cdot V_a^{-1} \cdot H_a + H_s^T \cdot V_s^{-1} \cdot H_s$$

Combined helix parameters

$$x = V \cdot (H_a^T \cdot V_a^{-1} \cdot p_a + H_s^T \cdot V_s^{-1} \cdot p_s)$$

Residuals

$$r_{a/s} = p_{a/s} - H_{a/s} \cdot x$$

Combined chi square

$$\chi^2 = r_a^T \cdot V_a^{-1} \cdot r_a + r_s^T \cdot V_s^{-1} \cdot r_s$$

with perigee parameters $p_{a/s}$, perigee covariances $V_{a/s}$ and segment ambiguity matrix $H_{a/s}$ of axial and stereo segment respectively.

Ambiguity matrix

For axial segments

$$H_a = \frac{\mathrm{d}p}{\mathrm{d}x} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \end{pmatrix}$$

For stereo segments

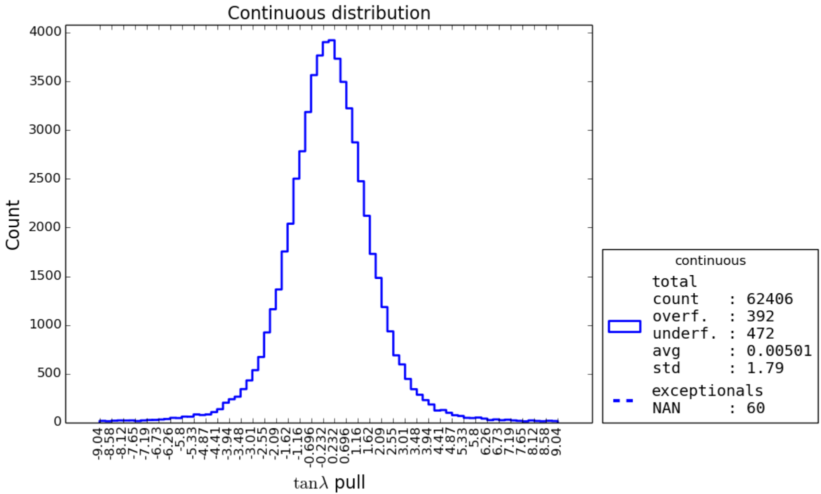
$$H_s = \frac{\mathrm{d}p}{\mathrm{d}x} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & \zeta & 0 \\ 0 & 0 & 1 & 0 & -\zeta \end{pmatrix}$$

where

$$\zeta = \frac{1}{\#\mathrm{hits}} \sum_{hits} \frac{\text{wire vector}_{xy} \cdot \text{normal to trajectoy}_{xy}}{\text{wire vector}_z}$$

Fit results

Distribution of $\tan\lambda$ pull (clipped)



- Two dimensional fitting
- Three dimensional fitting
- Planes

Things that need to be done

Obvious

- Eventually use the fit output in proper rejection of cells and neighborhoods.
- Integrate the new track model (RecoTrack).

Not so obvious

- In superlayer segment merging
- Break the forward backward symmetry.
- Merge left over segments in superlayer 0 with VXD.
- Reconstuct cycles in the cellular automaton as curlers.