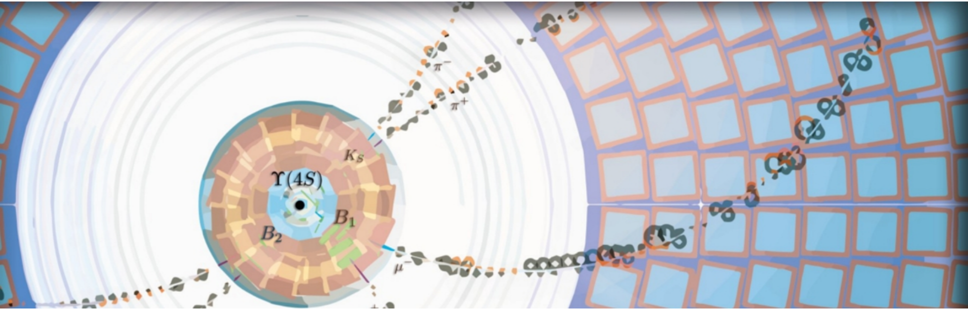
A local tracking algorithm for the Central Drift Chamber of Belle II.

F2F Meeting - Pisa



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Outline

- Weighted Cellular Automaton $\leftrightarrow$ Kalman Filter
- Optimization in the segment combination stage
- Plans

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General building block of local algorithms

Graph diagramm

○ θ_i $\longrightarrow$ w_{ij} $\ast$ E_i

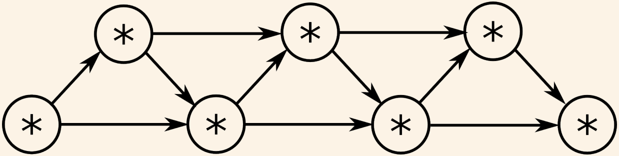
Variables

- $\theta_i :=$ suspected positions = initial state in combinations of observations (cell)
- $w_{ij} :=$ suspected transitions = propagational weight (edges)
- $E_i :=$ final states - to be generated

Various possible interpretations!

Cellular automaton

Graph diagramm



Variables

- $\theta_i :=$ goodness of fit / number of hits
- $w_{ij} :=$ compatibility / overlap penalty
- $E_i :=$ accumulated goodness of fit / number of hits until this point

Final state generation

Update rule

- State updated like

$$E_j = \max_{\text{neighbor } j} (\theta_j + w_{ij} + E_i)$$

  where E_i, θ_j and w_{ij} are real numbers.
- Accumulates goods of fit
- Track parameters are not propagated
- Applied only once per cell (loop free condition)
- Chain of high state cells make up the largest track.
- Apply multiple times for more tracks from the graph.

General final state generation

Generalized update rule

- E_i, θ_j and w_{ij} can be choosen more complex
- max and $+$ can be choosen accordingly

$$E_j = \text{vote}_{\text{neighbor } i}(\text{update}(\theta_j, \text{propagate}(w_{ij}, E_i)))$$

- Iterate until stablization is reached.
- Possibly with multipass or annealing sheme.

Kalman filter

Graph diagramm

$$\circledast \longrightarrow \circledast \longrightarrow \circledast \longrightarrow \circledast$$

Variables

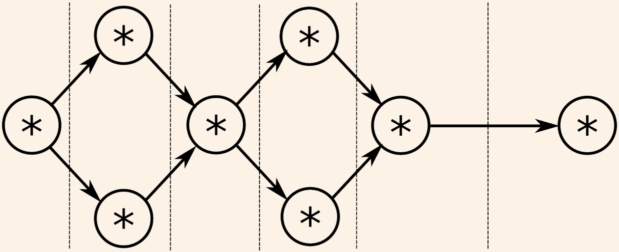
$$\begin{aligned} \theta_i &= \text{Measurement aka. RecoHit} \\ w_{ij} &= \text{Propagation matrix} \\ E_i &= \text{Track state at measurement} \end{aligned}$$

Update rule

Full state propagation including covariances. No Vote part.

Dynamic annealing filter

Graph diagramm - layered arrangement



Variables

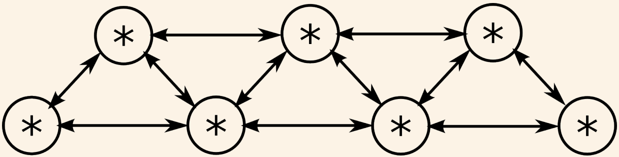
Same as Kalman filter

Update rule

Vote part is a mean with weights mitigated by stepfunctions (+ annealing)

Hopfield network

Graph diagramm - symmetrical edges



Variables

$$\theta_i = \text{External excitation - a priori probability of being in the track}$$
$$w_{ij} = \text{Mutal support between cells}$$
$$E_i (= s_i) = \text{Posterior probability of being in the track}$$

Hopfield network

Update rule

$$s_j = \text{step}\left(\sum_i w_{ij} \cdot s_i + \theta_j\right)$$

+ annealing sheme

Similarity to cellular automaton

- Minimizes the same energy function
- While hopfield network states agreement with neighbors, cellular automaton sums agreement over maximal paths
- Hopfield network is differential to cellular automaton.

Conclusion

Similarities

The weighted cellular automaton can be interpreted as

- an integal (sum) form of the Hopffield network.
- a Kalman filter / DAF propagating only the best goodness of fit, but not the entire track state.

Weights

What is the best choice of weight to make it most similar to the Kalman filter?
χ^2?

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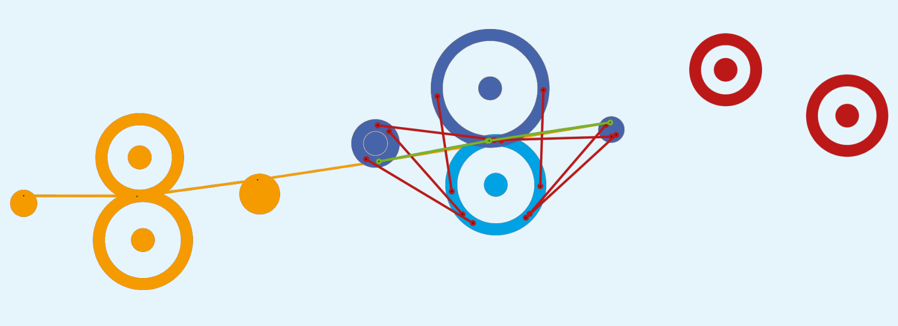
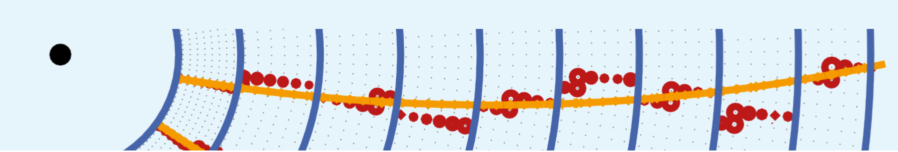
Bottom-up in two stages

Combine hits in the same superlayer to segments



Combine segments to tracks



Bottom-up in two stages

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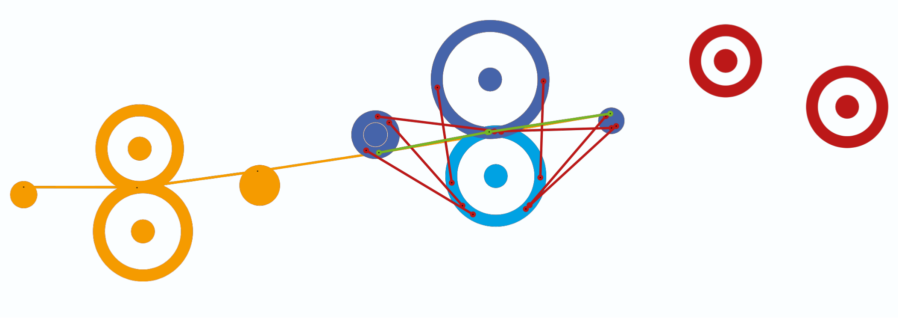

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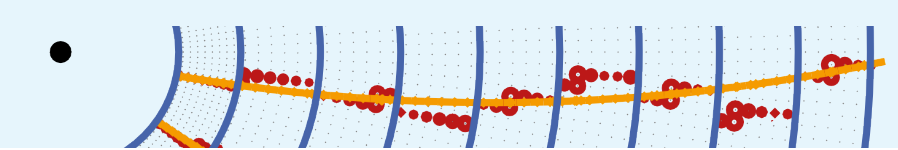


Axial segment pair creation

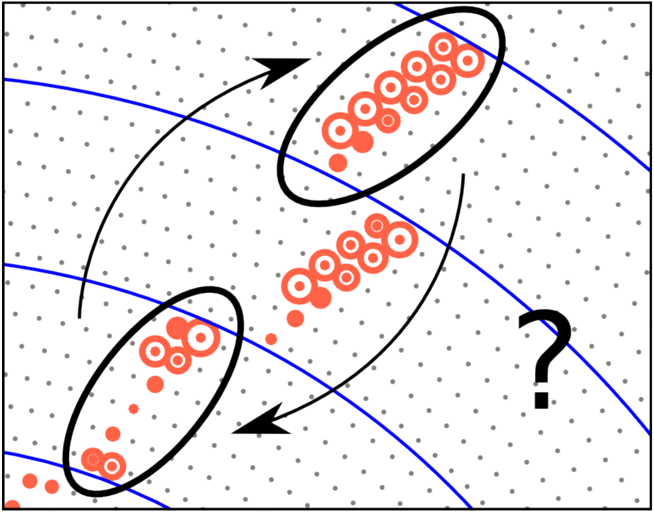


Figure: Make axial segment pairs by fitting and extrapolating with a two-dimensional circle for each segment

Segment triple creation

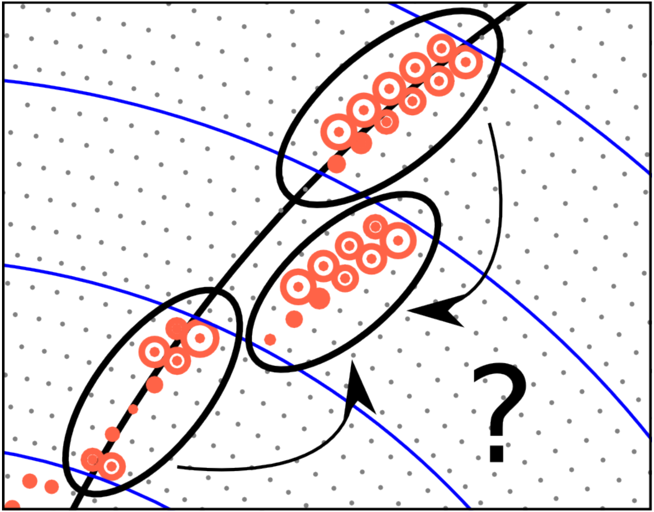


Figure: Combine axial segment pairs with intermediate stereo segment to segment triples

Segment triple connections

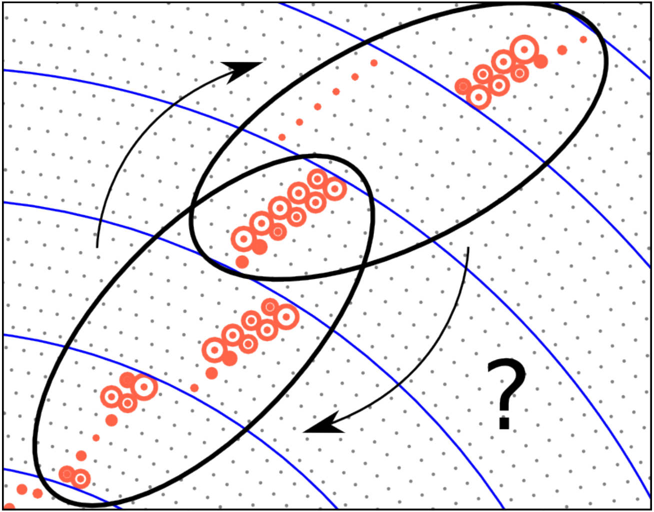
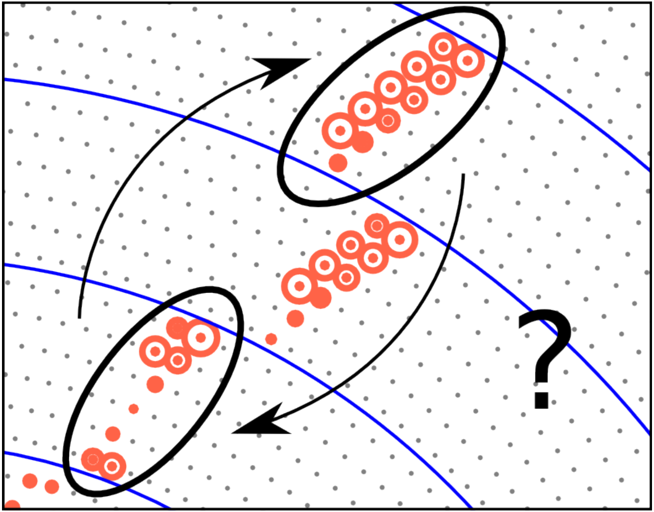


Figure: Generate connections of neighboring segment triples to form the graph edges.

Axial segment pair creation



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Achievable cut quality for axial segment pair connections

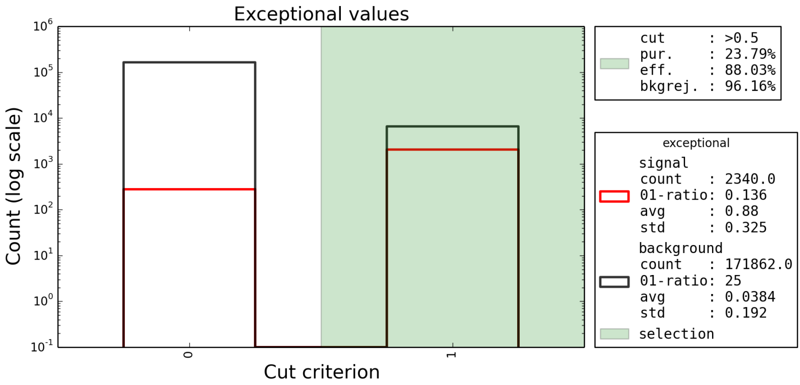

Figure: Cut using combination of parameter estimates - no error estimates calculated

Towards proper χ^2 cut

Better cut criterions

- should use χ^2 values
- need error estimates from the fits to the segment
- are valuable for the stereo layer incoperation as well

Error estimates

Frühwirt / Riemann fit

- Parameter estimation is undistored.
- Estimates of the covariance are slightly problematic, because
  - 4 parameters are fitted, where there should be only 3,
  - parameters are not gaussian distributed.

Karimäki fit

- 2D circle fit in polar coordinates
- Parameter estimates made with severer approximations.
- Estimates of the covariance
  - in gauss distributed perigee coordinates
  - are optimal and quickly calculatable.

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Near future

- Commit more documentation
- Rebrand the local finder to Cellular Automaton finder
- Implement the variance estimates