Status and Plans of the Belle-II Tracking Software

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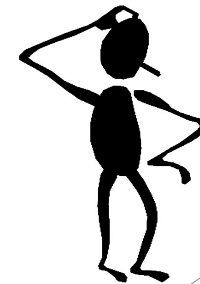
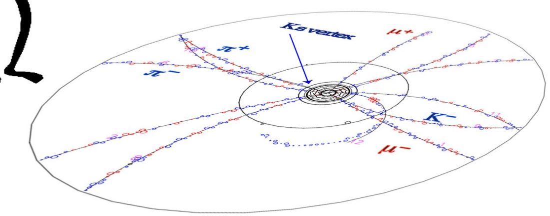
Overview

- Status of Low Momentum Track Finding
- Discussion Material on dE/dx
- Status in basf2
- Summary

Challenges





- 40x higher physics rate than in Belle
- High background
  → lots of data
- [Trigger rates up to 30kHz handled by the SVD]
  → in case of online usage

- Charged particles down to a radius of ~11cm (50 MeV p_T, Belle: 22cm) must be tracked
- Only 4 layers are available for online pattern recognition
  → even less layers are within the 11 cm!
  → AND non-recognized tracks are lost for PXD!

Track finder overview

Low Momentum track finder consists of 4 major parts:

- A **cellular automaton track finder**, searches for segments (connecting lines between two track hits) which could be part of a track.
- A **track candidate collector**, its job is to find all possible tracks and lose none.
- A **Kalman filter**, calculates quality indicators for each overbooked track candidate.
- A **neuronal network** (Hopfield network), uses those quality indicators to find the best unique combination of track candidates among the overbooked track candidates.

Simulation setup

- Vienna group currently works with MathLab based simulation, not the official basf2.
- simplified geometry of Belle II Si-detectors
- 4&6 layers – no distinction between PXDs & SVDs
- cylindrical layers @ Belle II-radii (1.3 2.2 3.8 8 11.5 14 (cm))
- thickness of Si layers: 0.5 0.5 0.5 0.5 0.5 0.5 (mm) 1mm Si ~ 0.0107 radiation lengths
- B_z = 1.5 T

Simulation setup II

- Energy loss (Bethe-Bloch formula) and multiple scattering (Highland formula) activated
- Range of track parameters:
  - Φ between 0 and 2π at random
  - Θ between π/4 and 3π/4 at random
  - z between -0.1m and 0.1m at random
  - $p_T = p * \sin\Theta$ between 0.08 GeV/c at random. (limited by simulator)
- Resolution of position measurement error in
  - $\sigma_{R\Phi}$: 15 15 10 15 15 15 (μm)
  - σ_z: 20 20 30 50 50 50 (μm)
- No noise included and no dead spots in our layers

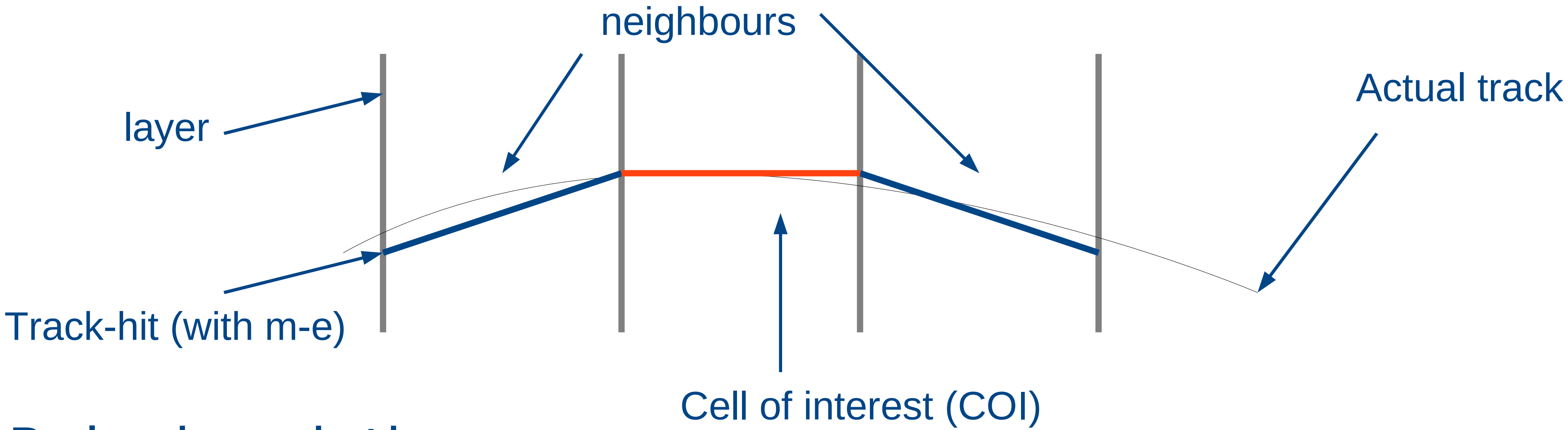
Cellular Automaton

- CA - A dynamical system with discrete space and time evolution
- Discrete space: *segment-based-cells with following properties*
  - Position (segment connects two track-hits in neighbouring layers)
  - State – in our case 0,1,2,3,4 (depending on number of layers)
  - neighbours – which cells are connected?
  - Rules – global rules, local situation

Cellular Automaton II

- Discrete time evolution:
  - All cells start with state 0
  - In each “time”-step the same rule is executed for each cell
  - Result is depending on local situation for each cell
  - After applying the rule all cells per layer are updated simultaneously
  - time evolves from outer to inner layers
  - CA runs until all cells have reached their final state.

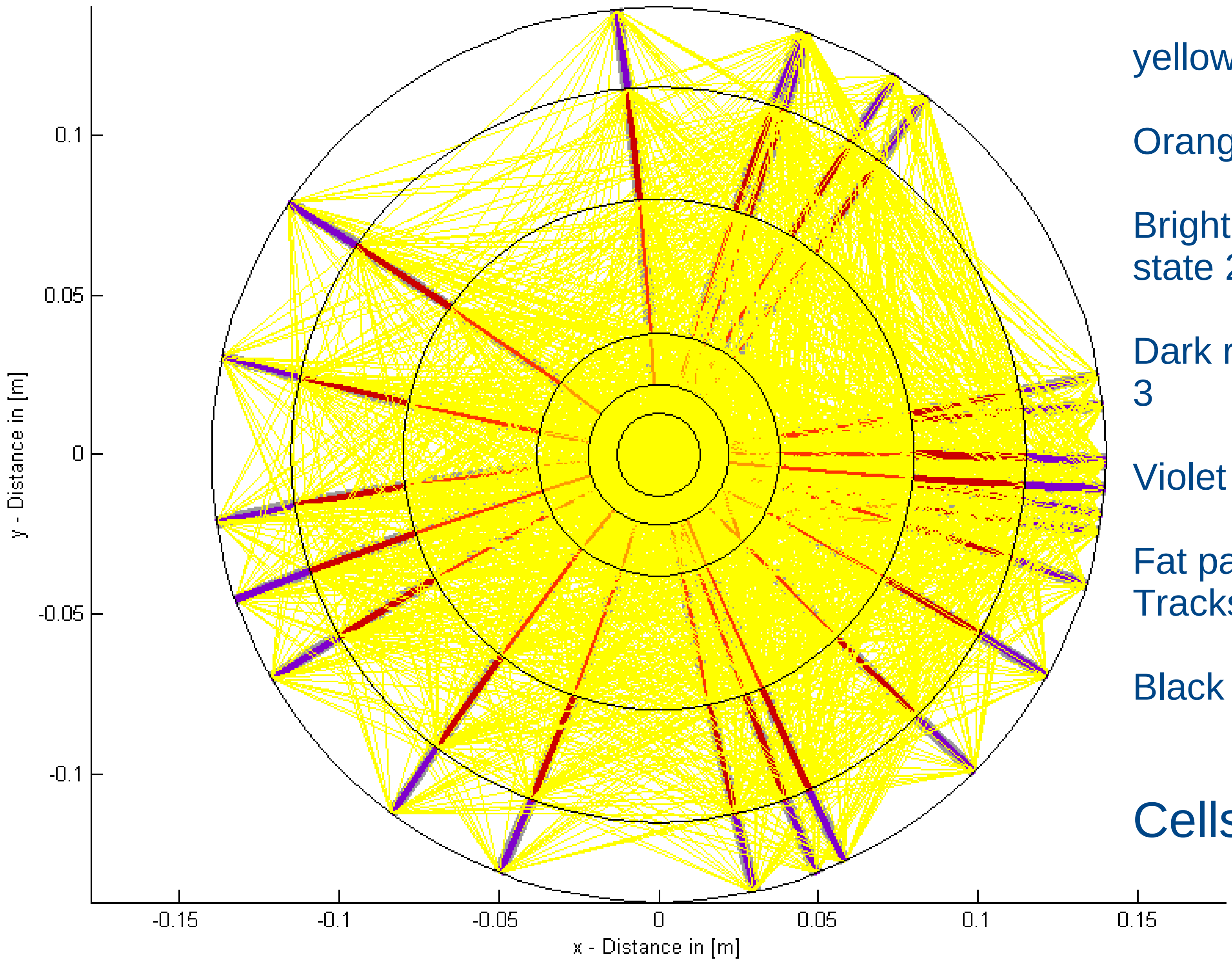
Cellular Automaton III



Rule description

- Only those cells are considered, where the length is below a layer dependent cutoff value
- Check if there is an <u>inner</u> neighbour (connected to COI and connecting angle near 180°)
- If there is an inner neighbour which state is equal to the state of COI increase state of COI +1

Results 0.5-1 GeV



yellow lines: cells @ state 0

Orange lines: cells @ state 1

Bright Red lines: cells @ state 2

Dark red lines: cells @ state 3

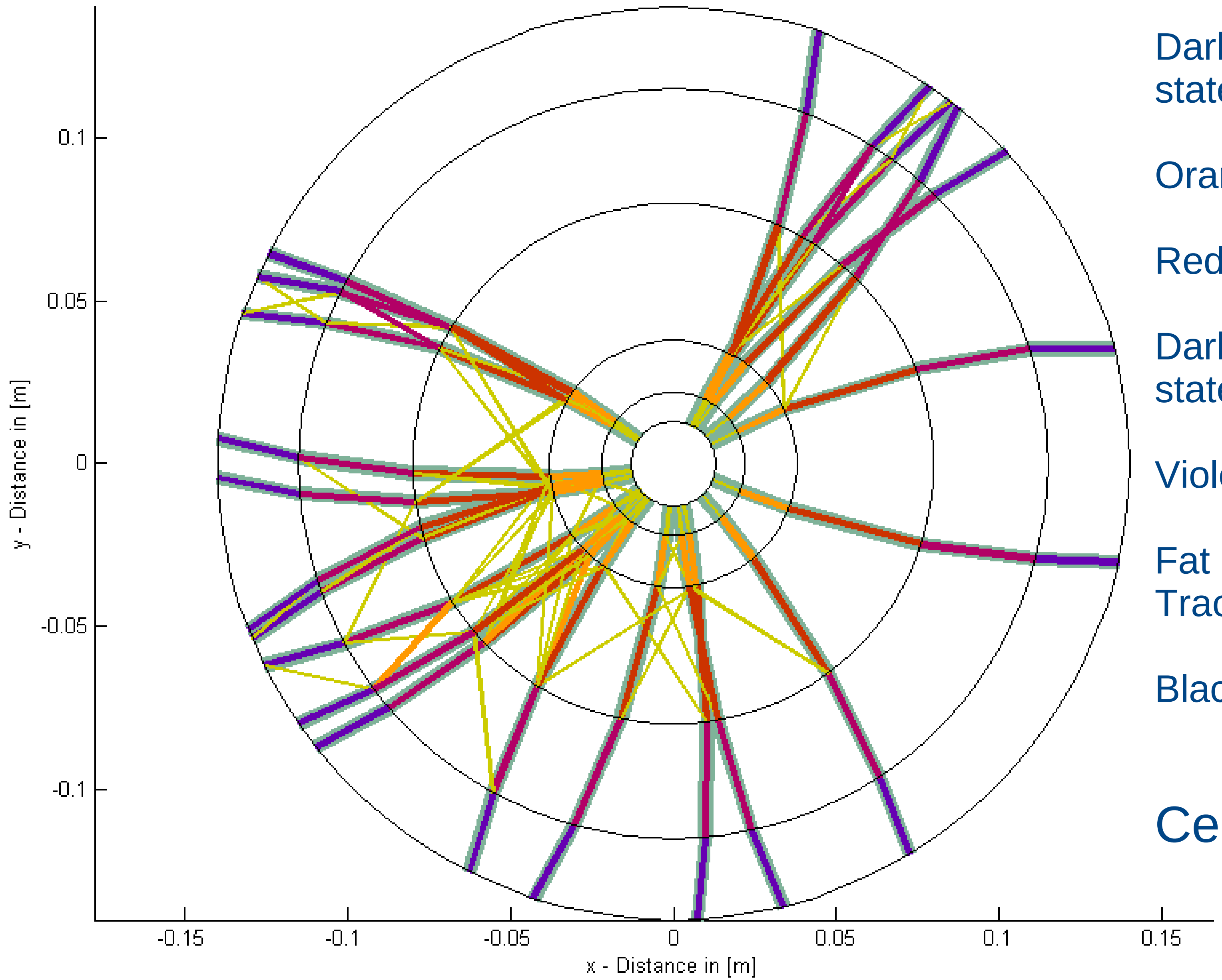
Violet lines: cells @ state 4

Fat pale green lines: original Tracks

Black circles: layers

Cells without prefilter

Results 0.1-0.2 GeV



Dark yellow lines: cells @ state 0

Orange lines: cells @ state 1

Red lines: cells @ state 2

Dark magenta lines: cells @ state 3

Violet lines: cells @ state 4

Fat pale green lines: original Tracks

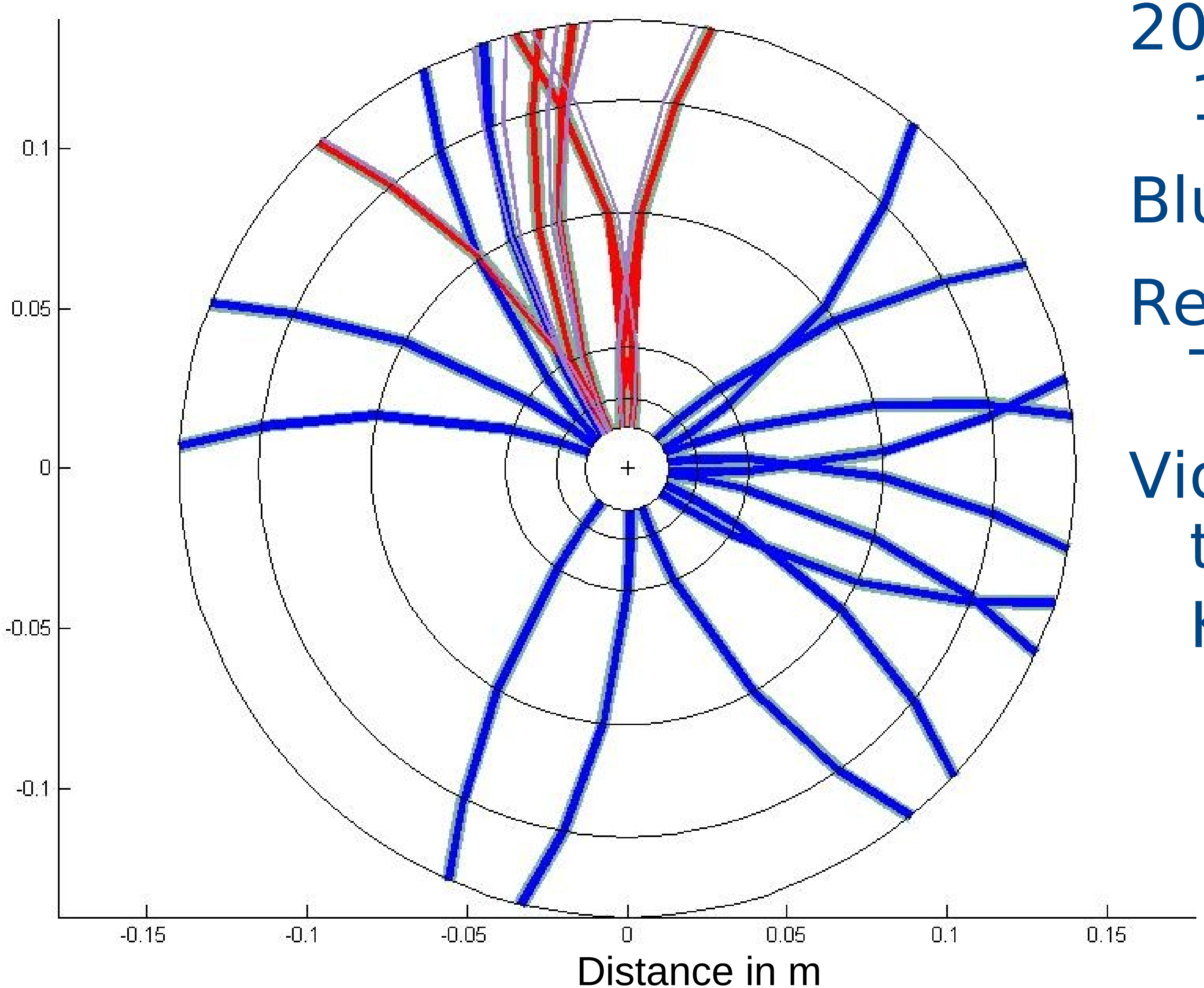
Black circles: layers

Cells with prefilter

TC-Collector

- After finishing the cellular automaton step, a track collector collects all possibilities of useful tracks
- It starts at a track seed (cells with high states, found in outer layers) and follows their tracks (via connected neighbours) inwards. At each fork it follows each way separately.
- After collecting all track candidates, there are some track-hits which were used more than once. Those are set to 'overbooked'
- Overbooked track candidates have to pass some further filters to be accepted as final track candidates

TC-Collector II



- 20 Tracks @ 100MeV
- Blue: unique TCs
- Red: overbooked TCs
- Violet: reference tracks for the Kalman filter

Final track selection

- Kalman filter computes quality indicators (p-values of total track χ^2) for each track candidate
- The Hopfield network uses those quality indicators to find the best subset of compatible tracks among the overbooked track candidates.

Simulated results

1000 events	10T - 80 Mev - 4L	20T - 80 Mev - 4L	10T - 80 Mev - 6L	20T - 80 Mev - 6L
Found tracks by CA	12.204	31.461	10.611	22.963
Compatible tracks found by CA	7.359	9.265	9.354	17.144
Real tracks found by CA	7.359	9.265	9.354	17.144
Compatible tracks found by NN	2.639	10.732	640	2827
Real tracks found by NN	2.579	10.427	607	2656
Recovered real tracks (total)	**99.38%** (of 10.000 tracks)	**98.46%** (of 20.000 tracks)	**99.61%** (of 10.000 tracks)	**99.00%** (of 20.000)

T... tracks per Event
L.... number of layers
MeV... MegaElectronVolt (indirect proportional to curvature)

80 MeV ~ 18 cm radius

Further steps

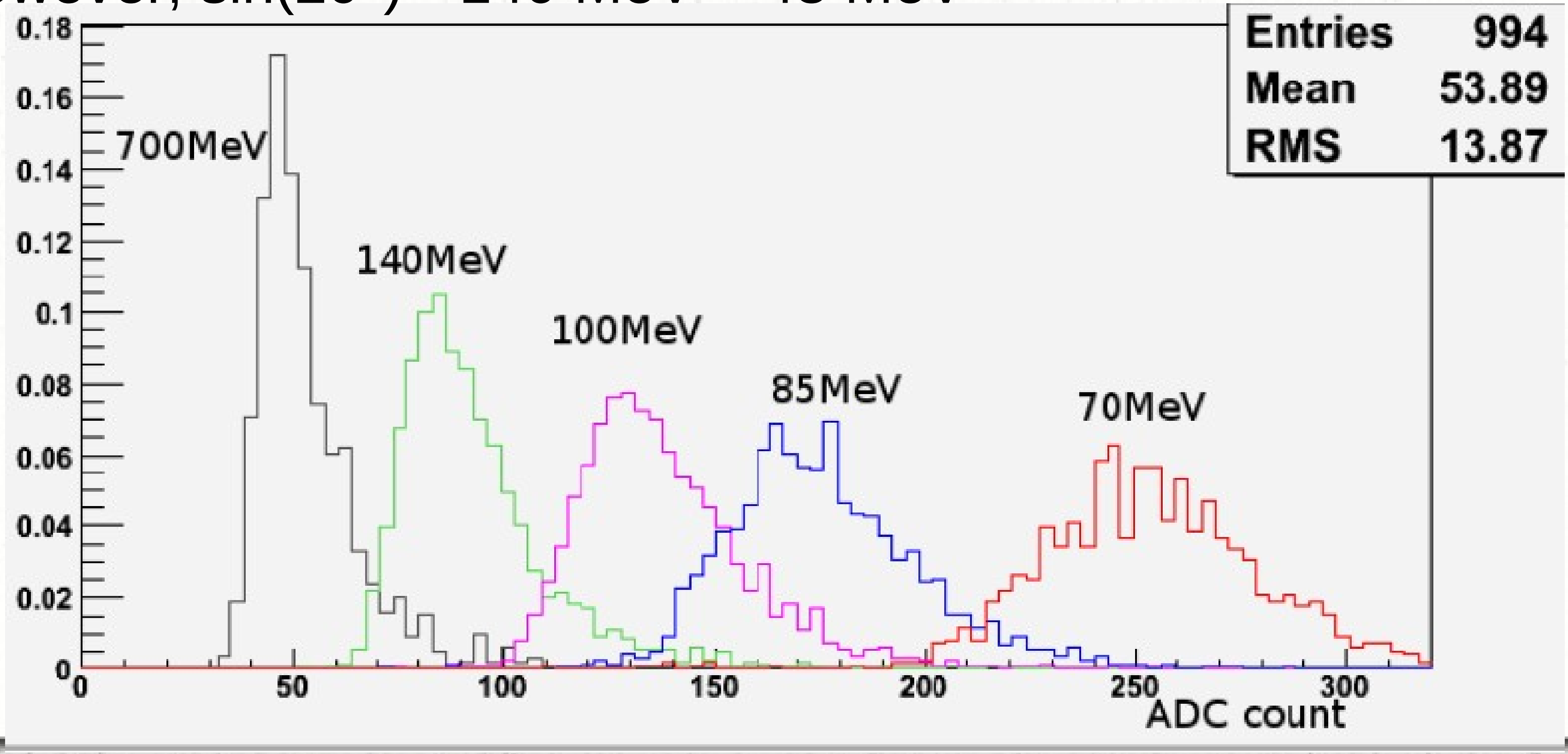
- Implementing the track finder into the Belle II-framework
- Adapting it to the real geometry of the detector
- Simulation of physics events
- Implementing algorithms for low energy tracks (<80 MeV)
- Including background into the simulation
- Tuning

Certainly the Vienna group will try to go down with the momentum range, but we should discuss dE/dx stuff nevertheless.

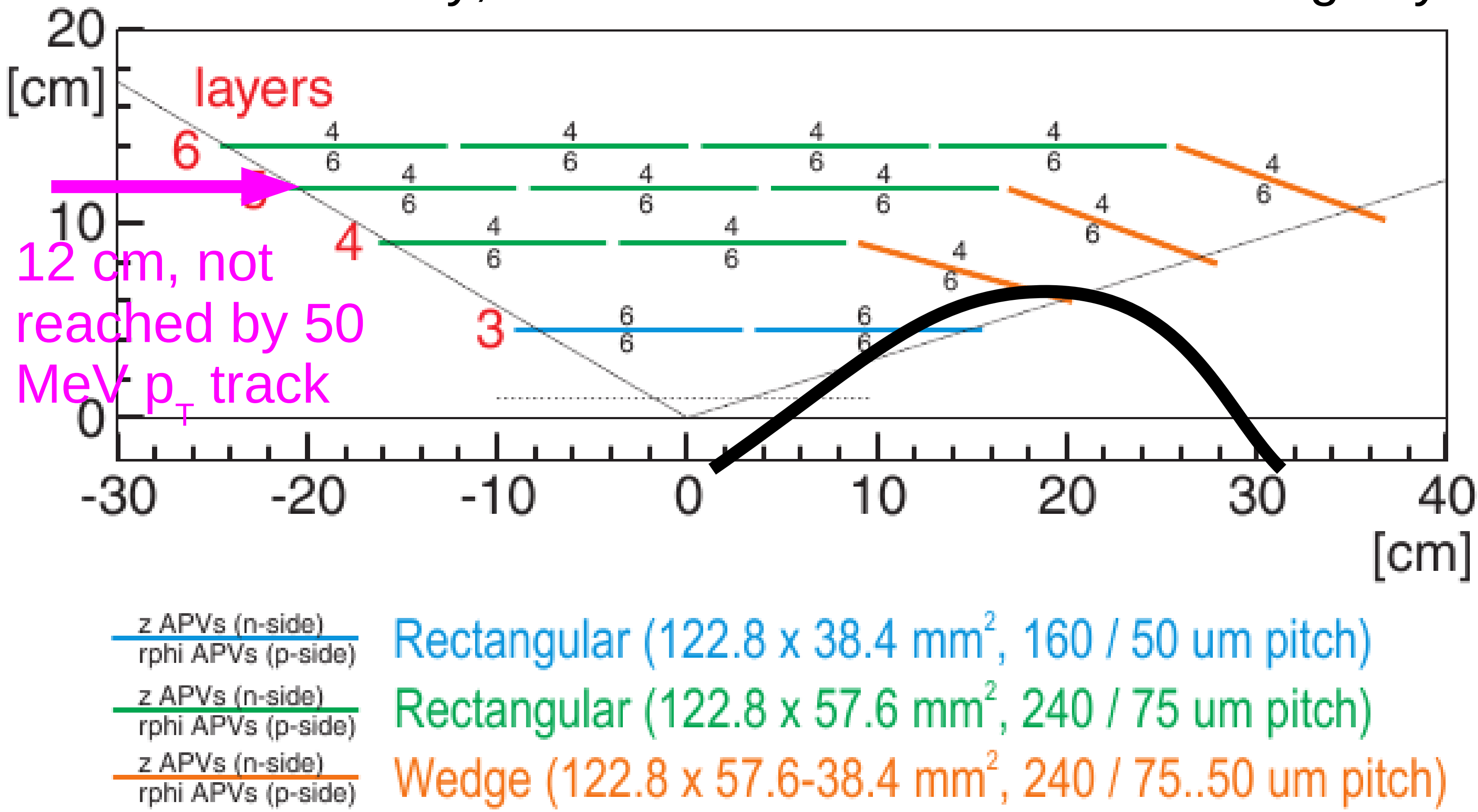
Dependent on total momentum (not p_T) there is plenty of energy deposition...

Just in case this wasn't discussed

However, sin(20°) * 140 MeV = 48 MeV



Of course cluster analysis may be applied to SVD, perhaps even more easy, but consider how these tracks migh fly:



The curve may hit just one or two SVD sensors, making it difficult to extract information

+ Redundancy is always nice.

Status in basf2

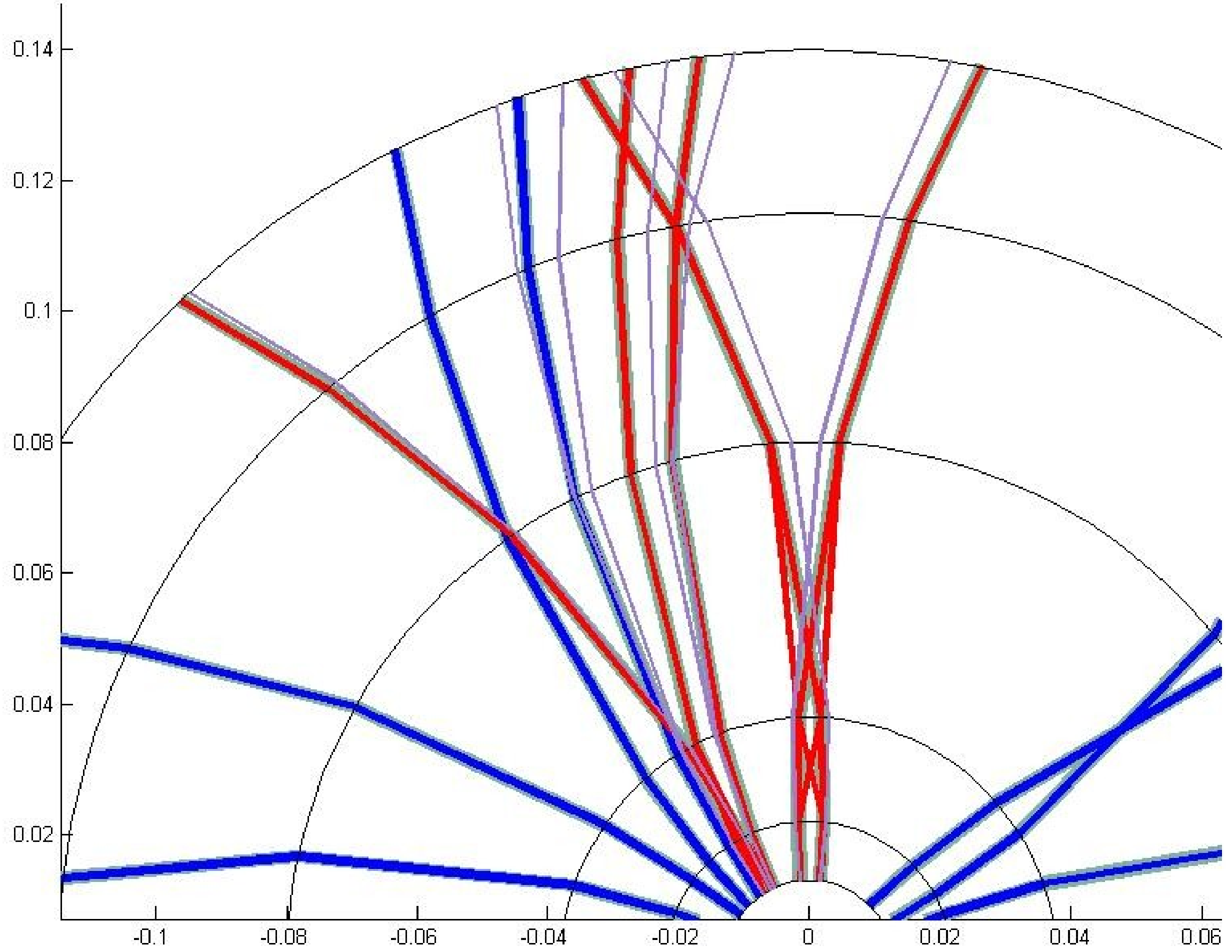
- Tracking algorithm (see Valencia meeting talk) in CDC further improved.
- MC Track Finder for CDC Hits exists, for other detectors matter of days.
- Interfacing to GENFIT as well matter of days.

Further “external” tools in the pipeline to make fast progress by just interfacing existing tools

Summary

- There is now a preferred strategy for low momentum tracking.
  - Needs to be tested with realistic background
  - Needs to be implemented in basf2
- CDC based tracking is on the way
  - Needs as well some better background estimation
- Track Fitting, Vertexing, etc. can make use of external tools, and will therefore be ready in reasonable time.

Backup


0.14
0.12
0.1
0.08
0.06
0.04
0.02
-0.1
-0.08
-0.06
-0.04
-0.02
0
0.02
0.04
0.06