Cellular Automaton Track Finder for Belle II

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AIDA Workshop
TU Wien, March 27,1014

Motivation

ILC

- Robin Glattauer developed CA track finder for forward disks in ILC
- Delivered code end of 2012

Belle II

- Jakob Lettenbichler continued to develop CA track finder (VXDTF) for Belle II vertex detector
- Applied to simulated data and beam test data so far
- Code is currently being refactored

Common ground

- Both applications for a "small" number of silicon sensors
- Joint presentation at VCI 2013

Motivation

Related efforts

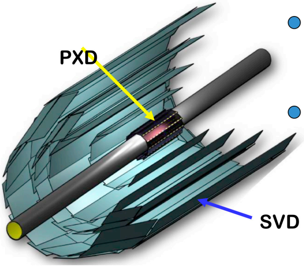
- CMS works on seeding with CA
- Belle II works on CA for track finding in the Central Drift Chamber
- CBM has CA track finder code for CPU and GPU

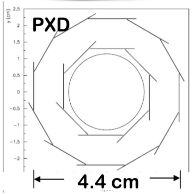
A Cellular Automaton Toolbox?

- Identify the basic building blocks
- Refactor and import existing code
- Define interfaces between generic parts and experiment-specific parts
- Write a framework for generating sector maps, testing and optimization
- **Does a toolbox make sense?**

The Belle II VXD

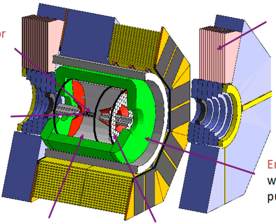
Nano beam option: 1 cm radius of beam pipe



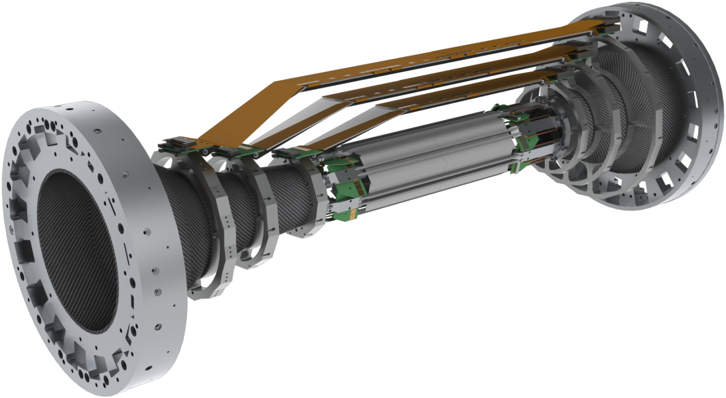


„PXD“

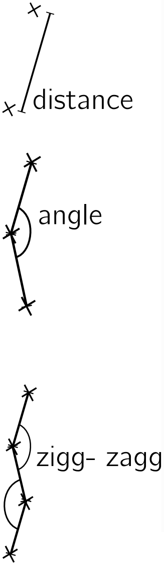
- **2 layer Si pixel detector (DEPFET technology)**
  (R = 1.3, 2.2 cm) monolithic sensor
  thickness 50 μm (!), pixel size ~50 x 50 μm²
- **4 layer Si strip detector (DSSD)** ← **„SVD“**
  (R = 3.8, 8.0, 11.5, 14.0 cm)

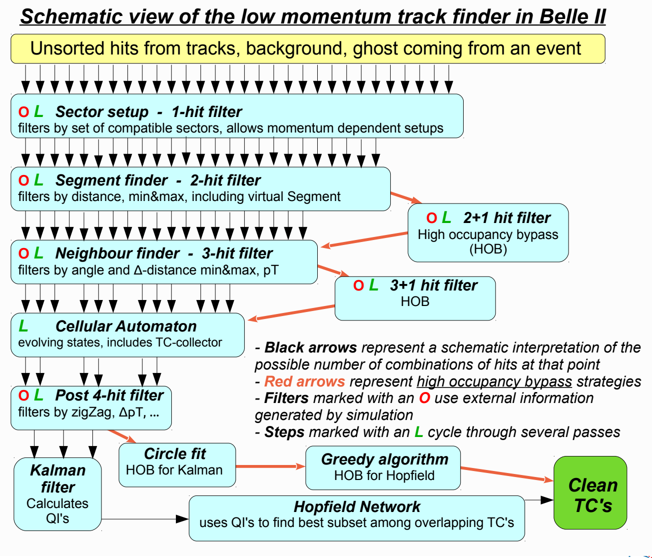


The Belle II SVD



Flow of the algorithm





For a better understanding...

Vocabulary

Sector Smallest detector unit known to CA: sensor, part of a sensor, drift cell,. . .

Hit Space point in a sector

Cell Track segment connecting two hits

Friend Inner one of two compatible sectors

Neighbour Inner one of two compatible segment

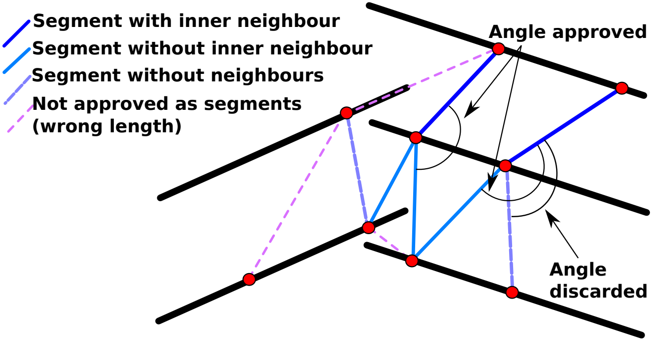
Filter Cut applied to segments and neighbours in order to reduce combinatorics

SectorMap A lookup-table containing pointers to friend sectors and the associated filter values

Filters

Motivation using filters:

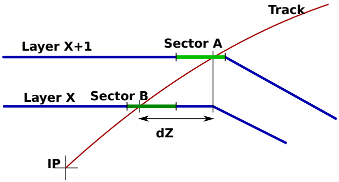
- Single hits are combined to segments which form TC's when connected → combinatorial problem
- Gradually filtering reduces combinatorics with increasing complexity
- Filter by cuts (2-hit: hit-distance, 3-hit: angle of linked segments)

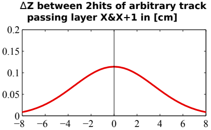


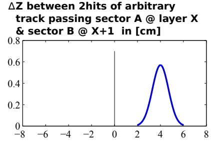
Sectors

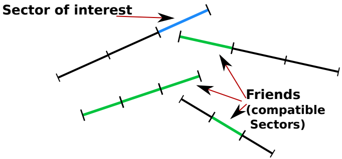
Motivation using sectors:

- Windmill structure and slanted sensors forbid simple layer-wise cuts → at least sensor-wise cuts
- Better: subdividing sensors in sectors and storing friend-lists
- → Allows customized cuts for filters to reduce combinatorics
- → Allows multipass optimizing for different momenta and curling tracks

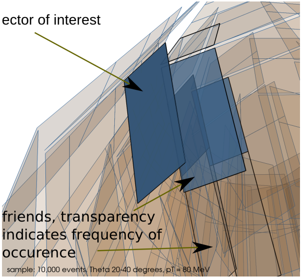


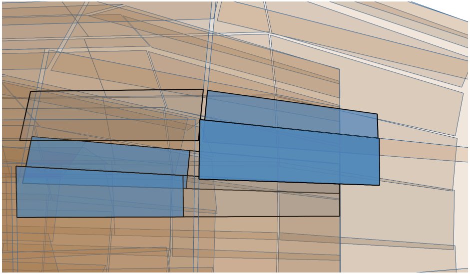






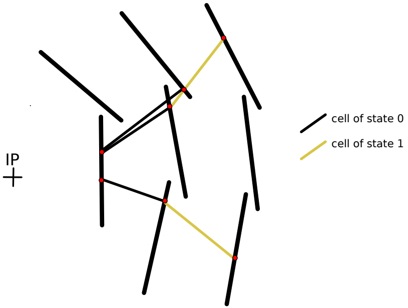
Sectors and friends



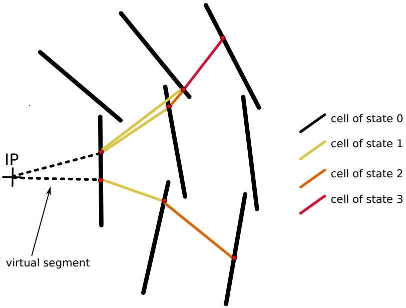


- Only hits lying in "friendly" sectors can form a cell → speed.
- Each sector carries its own information about all friends.
- Different sets of friends allow different treatment of high energy, low energy and curling tracks.

CA for 3–4 layers, virtual segment and sectors



Basic concept of cells



Extended concept using virtual segments attached to the IP and sectorMaps for segments in overlapping parts

Track candidates, quality and cleaning

Track candidate collection

- New TCs start with a seed (cells with high states), grows inwards by attaching cells with decreasing value of state
- A TC-Filter applies simple rules like zig-zag or Δp_T

Track quality

- Several algorithms for assessing track quality indicators (QI):
  - Track length
  - Kalman filter (genfit2)
  - Circle fitter
  - Helix fitter

Track candidates, quality and cleaning

Track cleaning

- QIs are used to define a non-overlapping subset of TCs by using one of the following algorithms:
  - Neuronal network of Hopfield type (highest reconstruction rate)
  - Simple greedy algorithms (faster, worse quality)

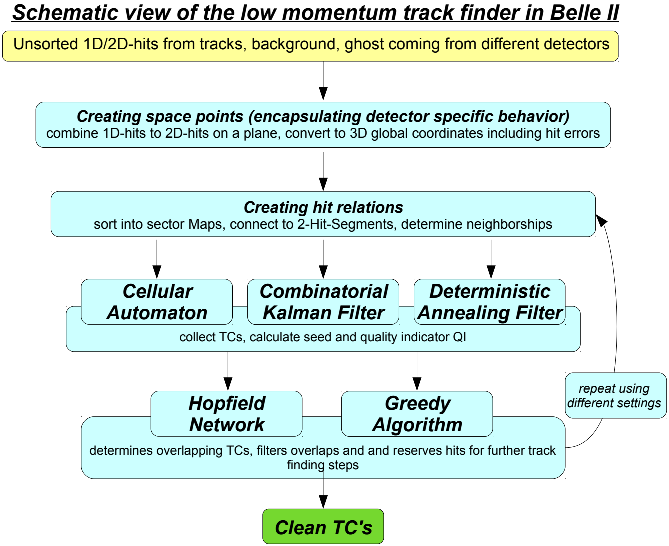
Building a toolbox

Basic components

1. Read sector maps (once per run)
2. Read hits and sort them into sectors
3. Generate segments and find neighbours
4. Run the CA (or any other kind of track finder) and collect track candidates
5. Compute quality indicators
6. Run cleaning algorithm

- Steps 3–6 can be repeated with different sector maps and different filters
- Used hits may or may not be removed

Refactoring plan



Requirements

Manpower

- 1 PhD student
- Master students (staggered by 6 months)
- Will seek cooperation with CMS, CBM etc.
- **I am looking forward to your comments!**