The Kalman filter based track fit in TPC detector

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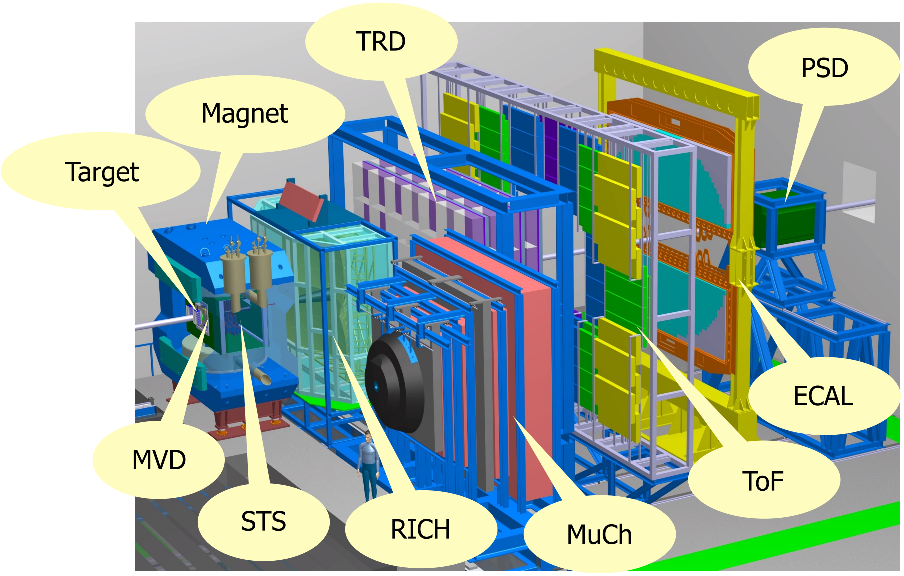
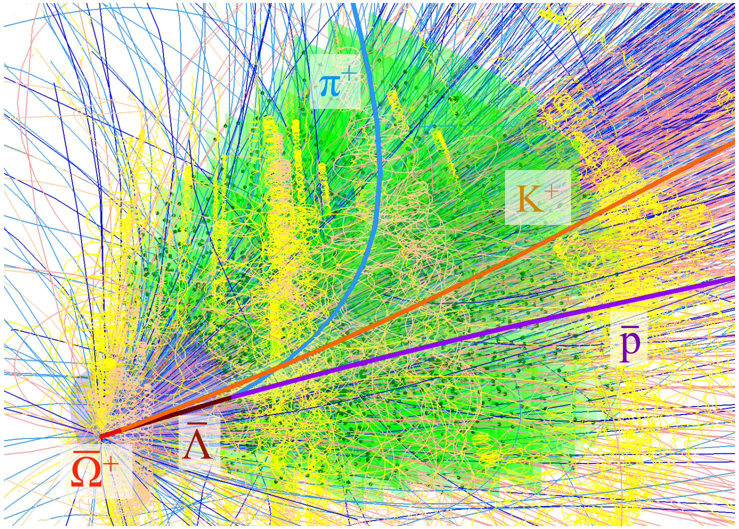
DPG Spring Meeting, Bochum, 01.03.2018

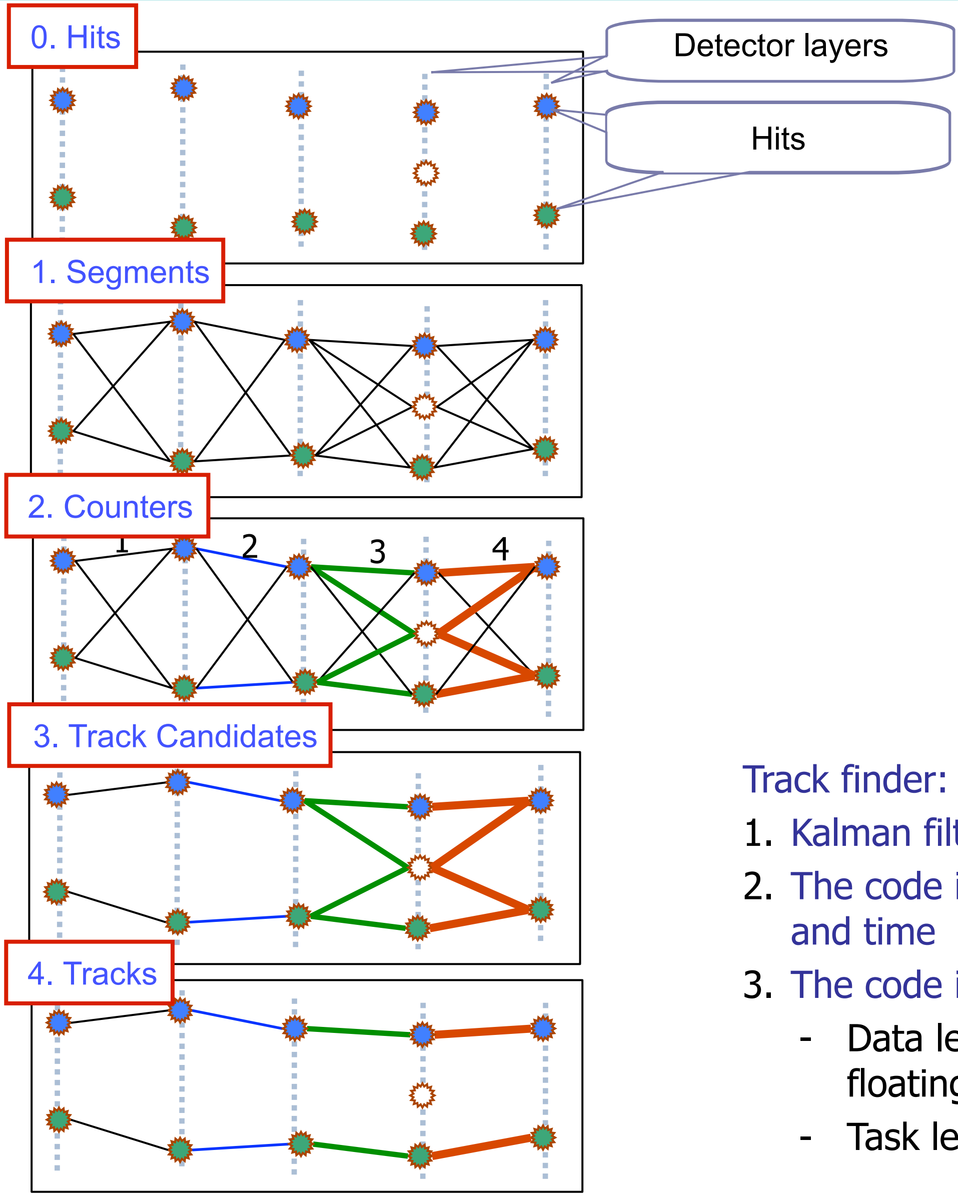


- CBM — future fixed-target heavy-ion experiment at FAIR, Darmstadt, Germany.
- 10^5-10^7 collisions per second.
- Up to 1000 charged particles/collision.
- Free streaming data.
- No hardware triggers.
- On-line time-based event reconstruction and selection is required in the first trigger level.

- On-line reconstruction at the on-line farm with 60000 CPU equivalent cores.
- High speed and efficiency of the reconstruction algorithms are required.
- The algorithms have to be highly parallelised and scalable.
- CBM event reconstruction: Kalman Filter and Cellular Automaton.



Cellular Automaton Track Finder



Cellular Automaton:

1. Build short track segments.
2. Connect according to the track model, estimate a possible position on a track.
3. Tree structures appear, collect segments into track candidates.
4. Select the best track candidates.

Cellular Automaton:

- local w.r.t. data
- intrinsically parallel
- extremely simple
- very fast

Perfect for many-core CPU/GPU !

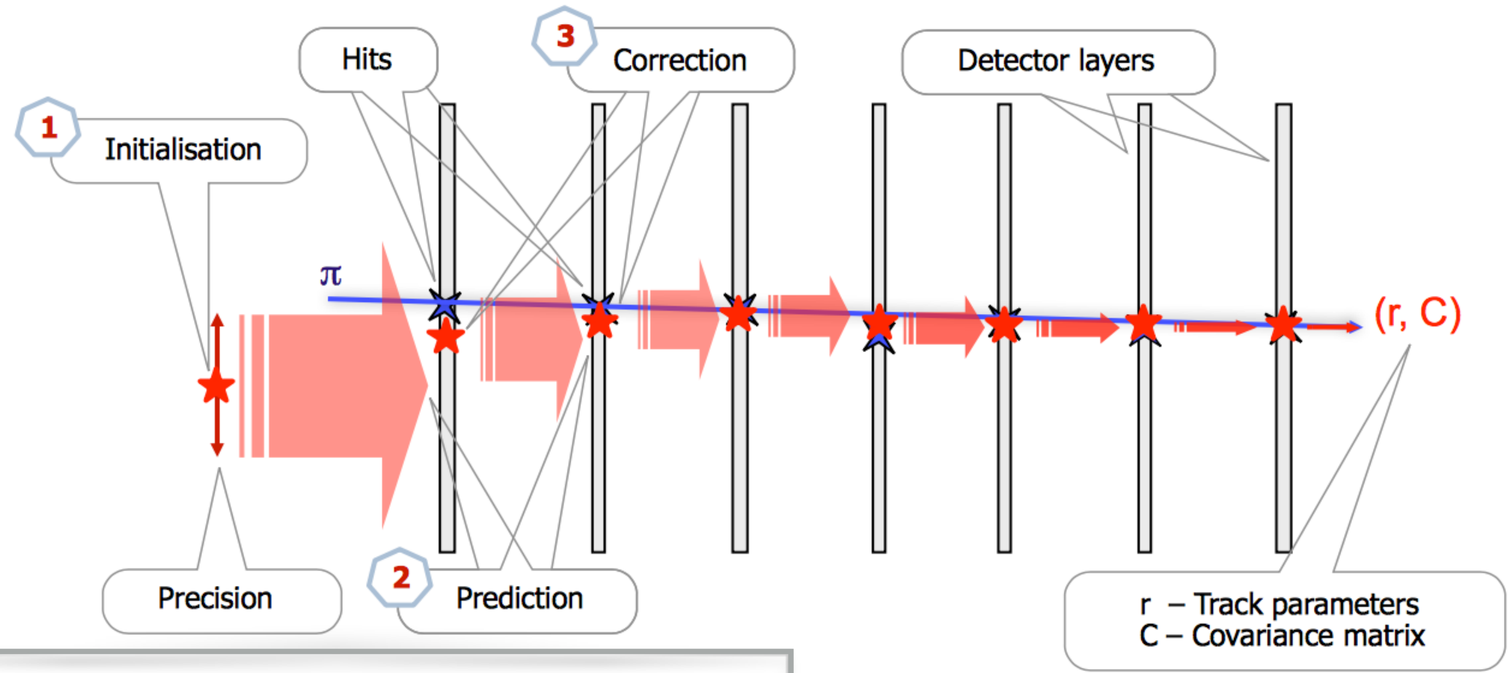
Track finder:

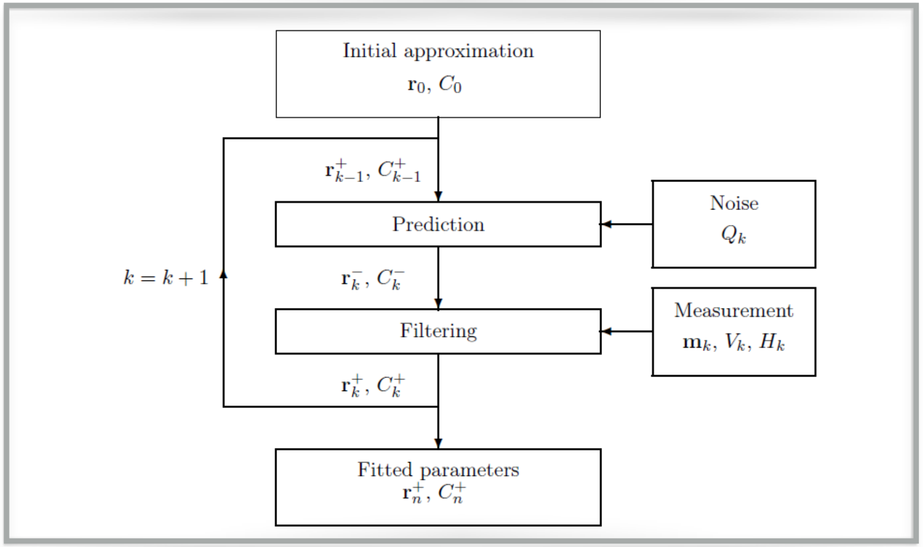
1. Kalman filter for track segments fit
2. The code is optimised with respect to both efficiency and time
3. The code is parallelised
   - Data level (SIMD instructions, 4 single-precision floating point calculations in parallel)
   - Task level (ITBB, parallelisation between cores)

Useful for complicated event topologies with large combinatorics and for parallel hardware

Kalman Filter for Track Fitting

Track fit: Estimation of the track parameters at one or more hits along the track — Kalman Filter (KF)





State vector

Position, direction and momentum

$r = \{ x, y, t_x, t_y, q/p \}$

Kalman Filter:

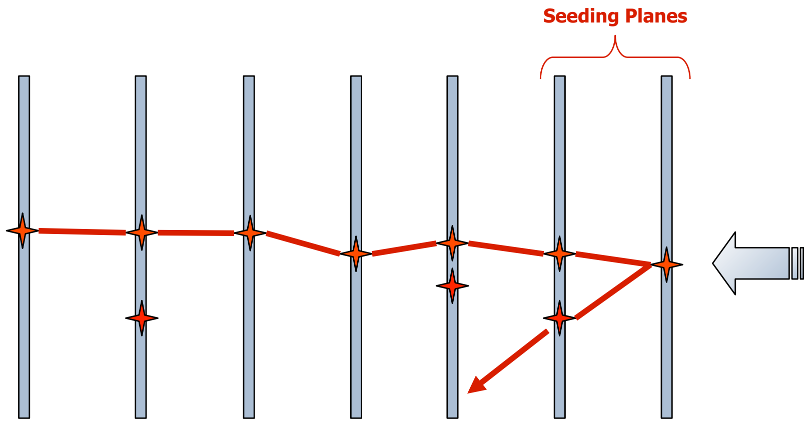
1. Start with an arbitrary initialisation.
2. Add one hit after another.
3. Improve the state vector.
4. Get the optimal parameters after the last hit.

CA based CBM global track finder

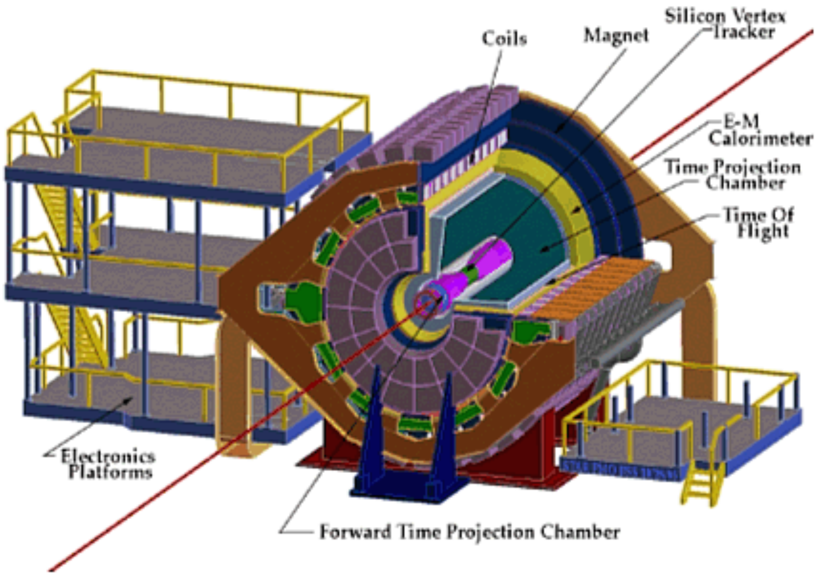
- Global track finder in CBM is based on track following.
- Disadvantages:
  - requires seeding;
  - A final track finding efficiency is limited by the seeding efficiency;
  - problems with alignment in subsystems;
  - problems with alignment of subsystems.
- Implementation of the CA based global track finder is in progress (V. Akishina, HK 46.6).

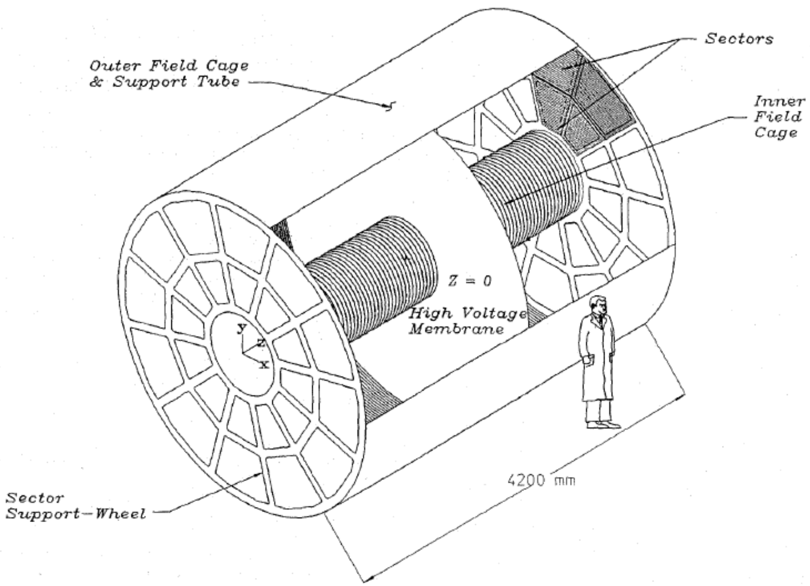
Track following:

1. Create seed
2. Extrapolate to the next station
3. Find and add hit by KF method



STAR at BNL





- CA track finder is being developed in STAR within the FAIR phase 0 program
- Collider experiment at RHIC, BNL
- Up to 200 AGeV Au-Au collisions
- Main detector – TPC

Challenges:

- Increased RHIC luminosity
- Online HLT - fast
- Global track finder has to be speed up significantly
- Upgrade the reconstruction algorithms for:
  - vectorization
  - multi-threading
  - many-core systems

CA based STAR global track finder

- Global track finder in STAR (**Sti**) is based on track following:
    1. Create seed from TPC detector.
    2. Find track in TPC detector.
    3. Extend track to the outer ToF, BEMC and MTD detectors.

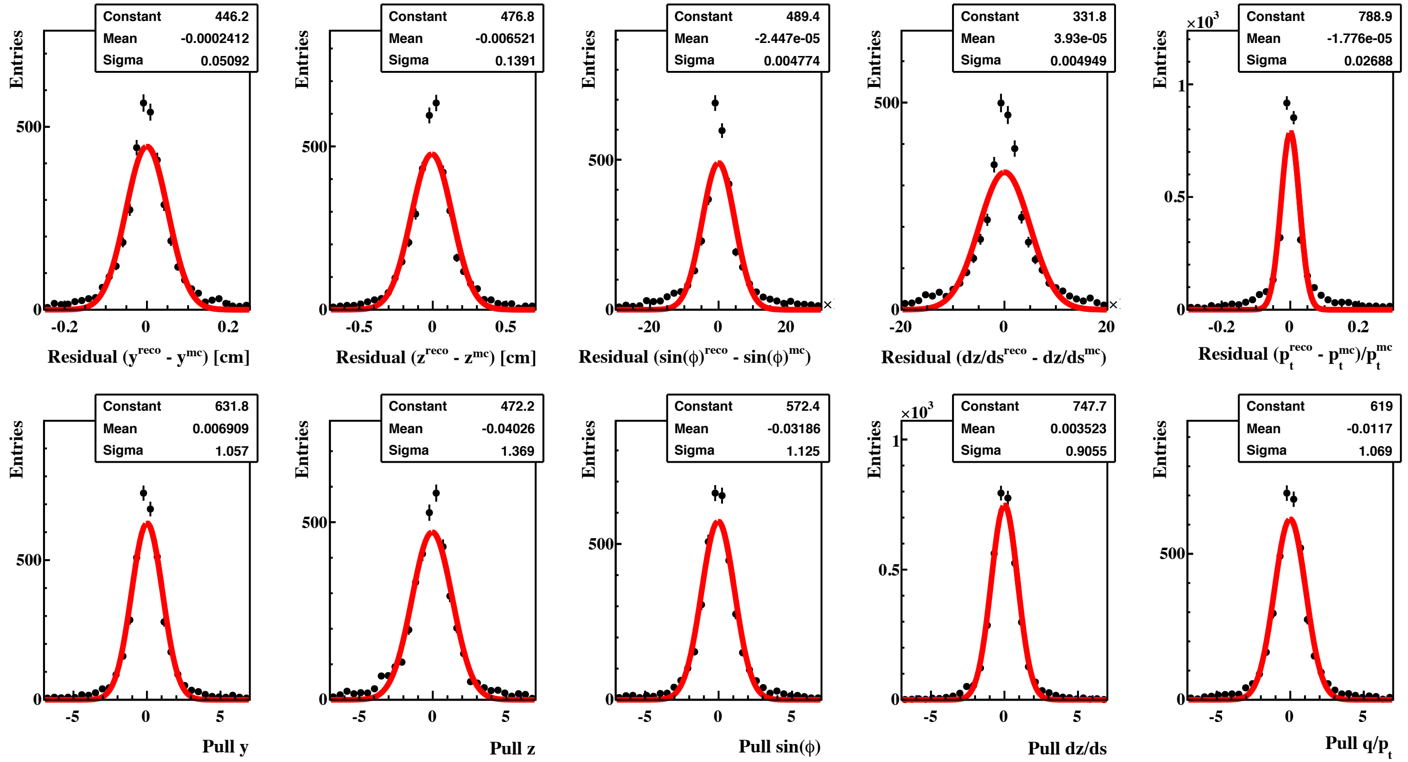
- For acceleration of the algorithm:
    - Done: integration the **CA** track finder as a seed finder for **Sti** — **StiCA** track finder.
    - Planned: extend the **CA** track finder to the outer detectors.

CA Track Finder in STAR

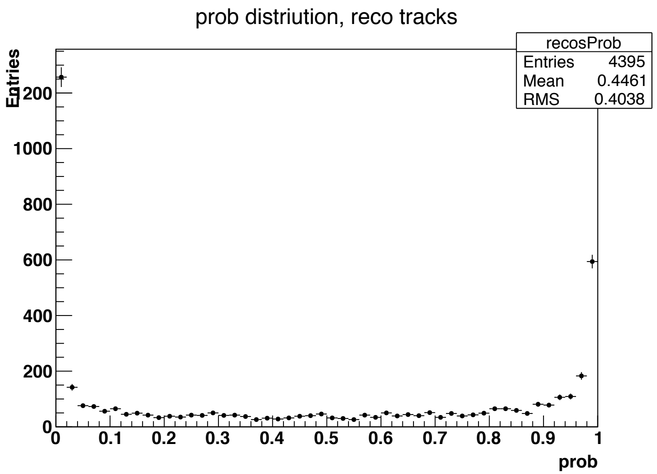
- CA track finder, being a part of StiCA, spends only **10%** of the total time of finding tracks.
- The goal is to speed up the fitting of tracks, which is performed by Sti.
- CA track finder is fully vectorised and highly optimised and includes Kalman Filter based track fitter, which assumes:
  - simplified one-component constant magnetic field;
  - simplified uniform material description.

  } — optimised for TPC
- For extrapolation of tracks to outer detectors, it is necessary to take into account not homogeneous magnetic field and complex material structure.

Results



- Exact position of pad rows
- Non homogeneous magnetic field
- Non homogeneous material



- Fitted track errors are in a good agreement with the simulated hit errors.
- Correct mathematics — as a result correct pulls (unbiased, width about 1), χ^2 and flat prob (p-value) distributions.

Summary

- The Kalman filter method for reconstruction of charged particle trajectories in the TPC CA track finder for the STAR experiment is extended for non homogeneous magnetic field and material.
- The developed Kalman filter based track fit is fully SIMDised and highly optimised
- The method shows correct distributions of track parameter residuals and pulls, and χ^2.

Plans

- Extende the SIMDised KF track fit to the outer ToF, BEMC and MTD detectors.
- Apply the developed methodology to the track fit in the CBM experiment.