Application of the fast vectorised Kalman filter based track fit to the STAR experiment

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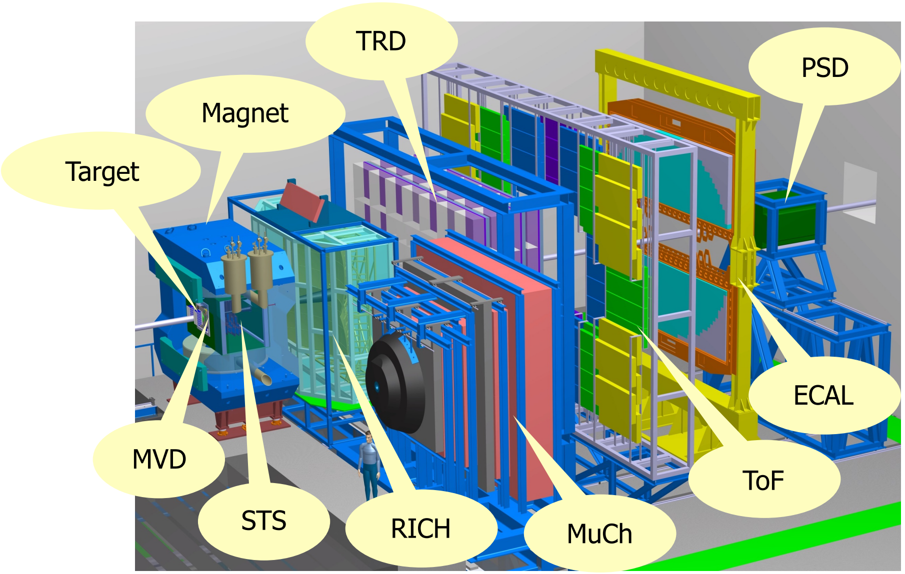
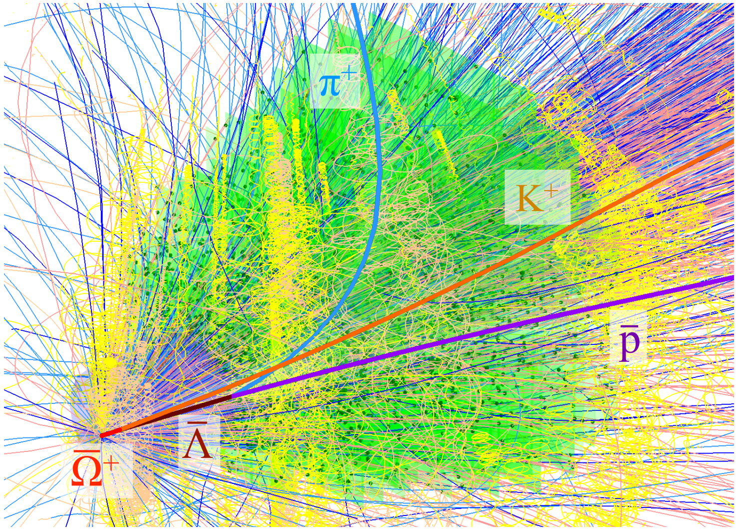
DPG Spring Meeting, München, 20.03.2019

Challenges in CBM

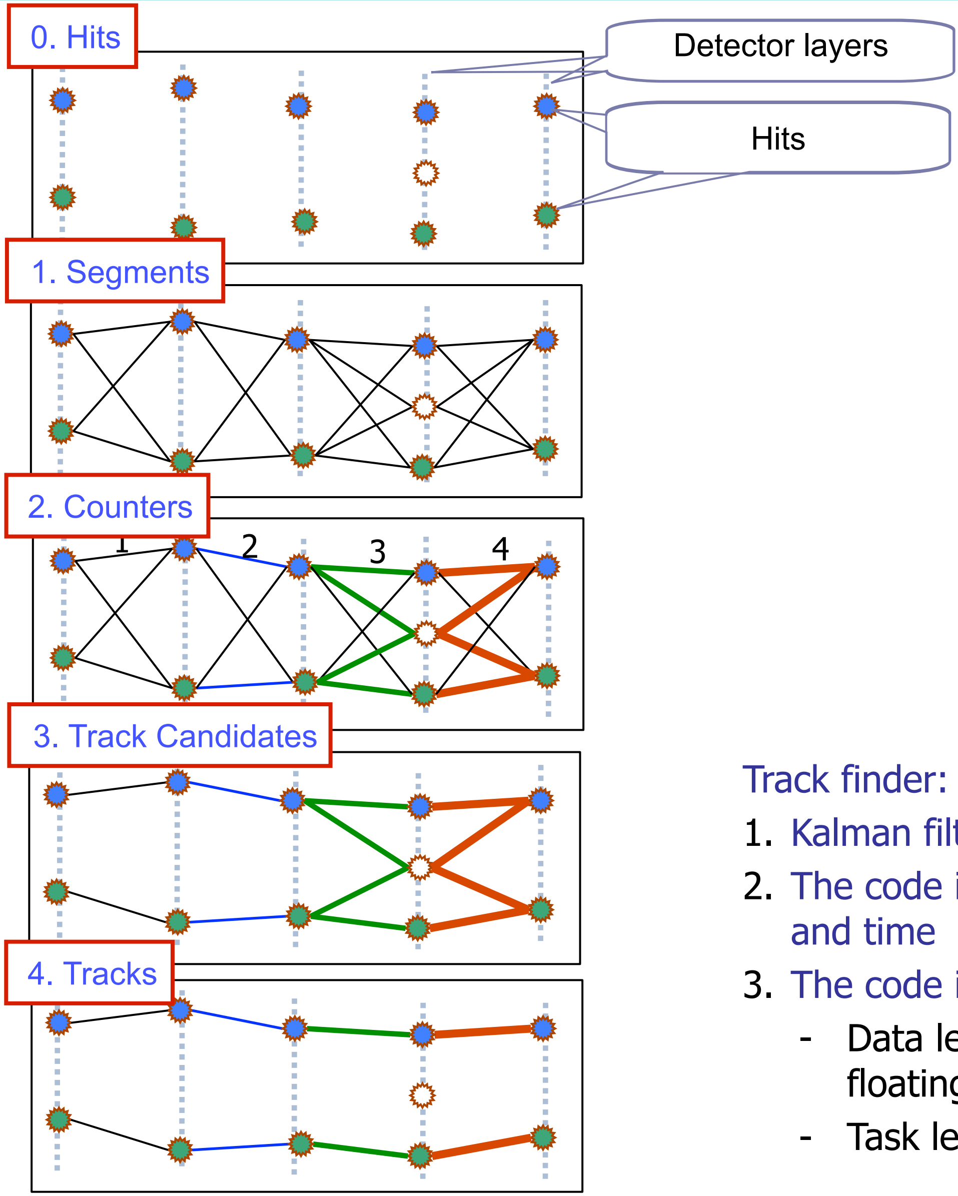


- CBM — a future fixed-target heavy-ion experiment at FAIR, Darmstadt, Germany.
- 10^5-10^7 collisions per second.
- Up to 1000 charged particles/collision.
- Free streaming data.
- No hardware triggers.
- Online time-based event reconstruction and selection is required in the first trigger level.

- On-line reconstruction at the on-line farm with 60.000 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 !

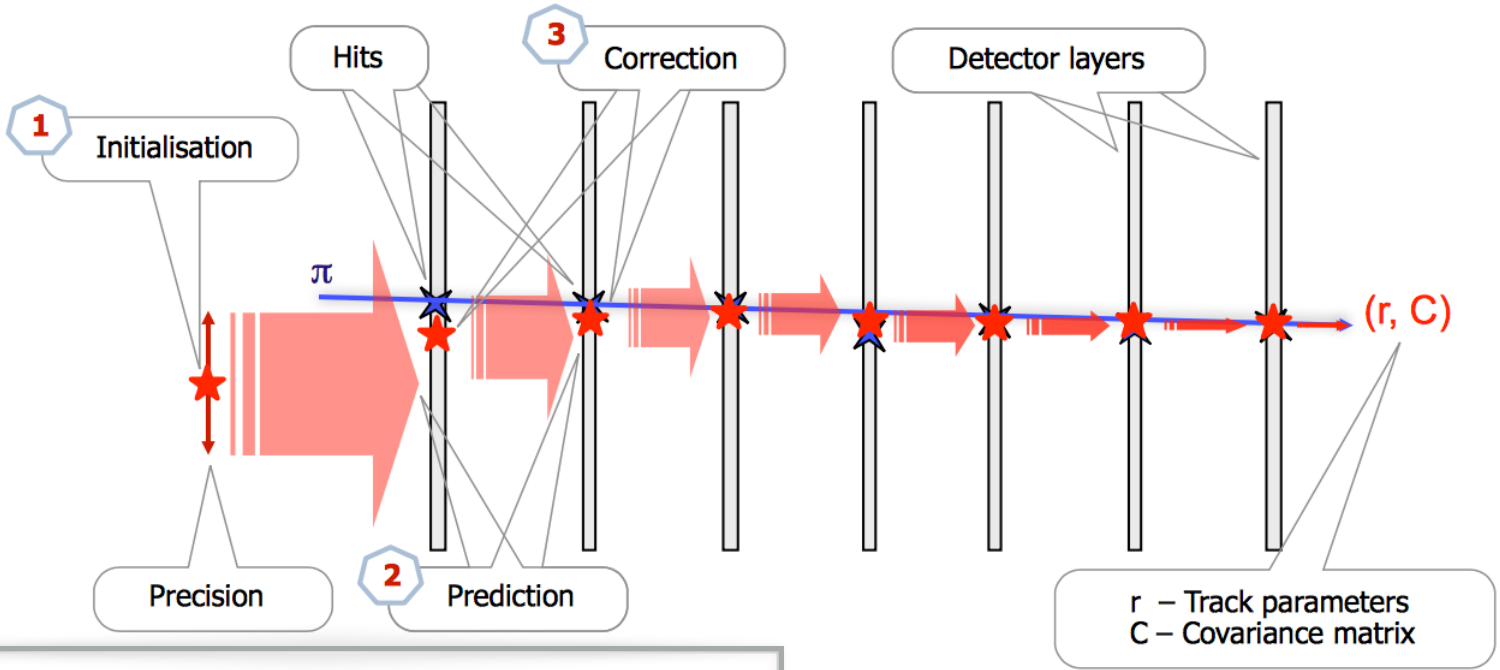
Track finder:

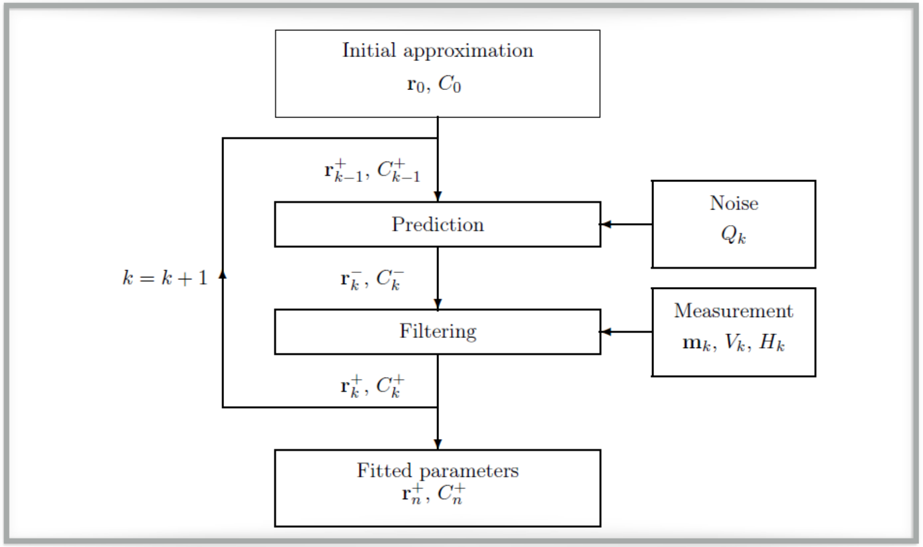
1. Kalman filter for track segments fit
2. The code is optimised with respect to both efficiency and time
3. The code is parallelised
   - Data level (SIMD instructions, 4 single-precision floating point calculations in parallel)
   - Task level (ITBB, parallelisation between cores)

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

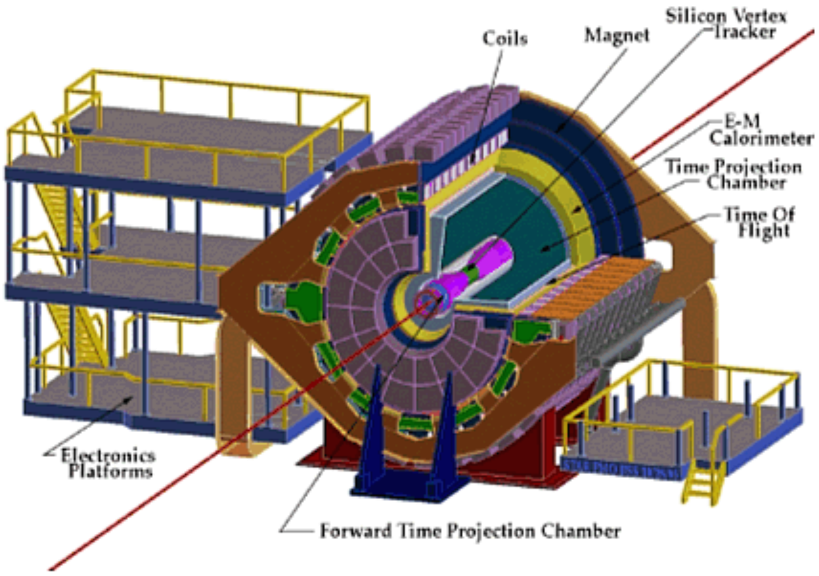
Position, direction and momentum

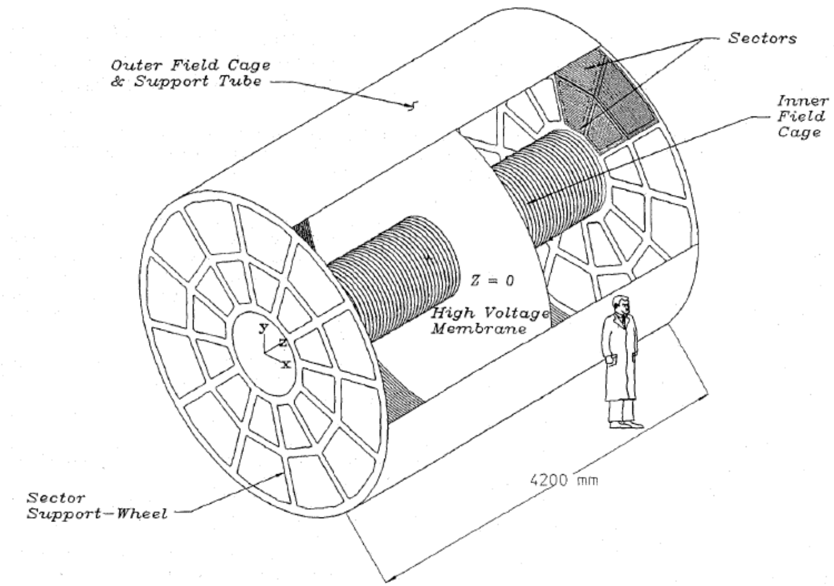
$r = \{ x, y, t_x, t_y, q/p \}$

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.

STAR at BNL





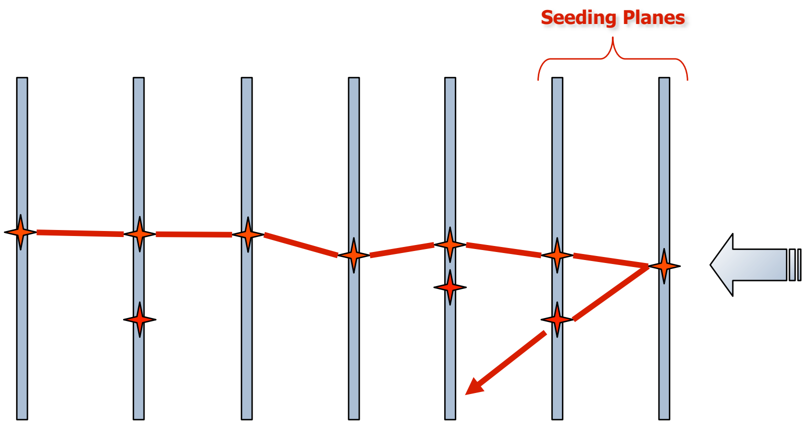
- Collider experiment at RHIC, BNL
- Up to 200 AGeV Au-Au collisions
- Main detector – TPC
- CA track finder is being developed in STAR within the FAIR Phase-0 program

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

Integration of CA into 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: integrate the **CA** track fitter instead of **Sti** -> completely exclude **Sti** from the track reconstruction procedure.

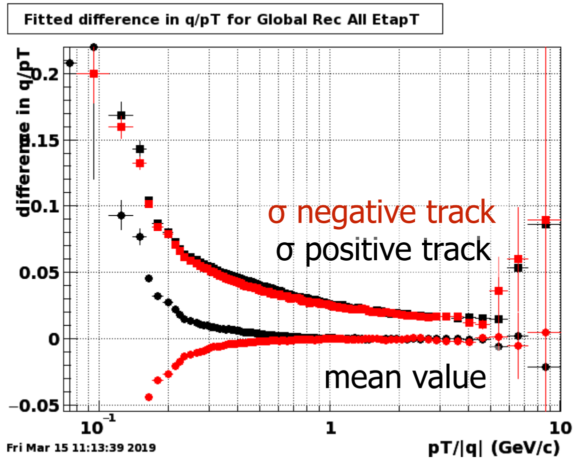
CA Track Finder in STAR

- 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.

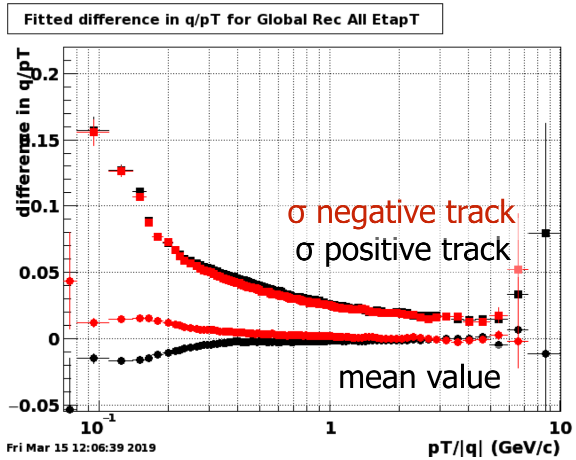
  } — optimised for TPC
- For extrapolation of tracks to outer detectors, it is necessary to take into account the non-homogeneous magnetic field and the complex material structure.

Comparison of fit quality: residual

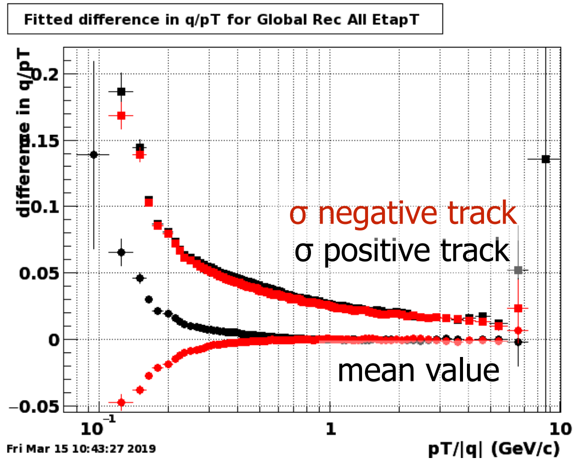
Fast CA fit



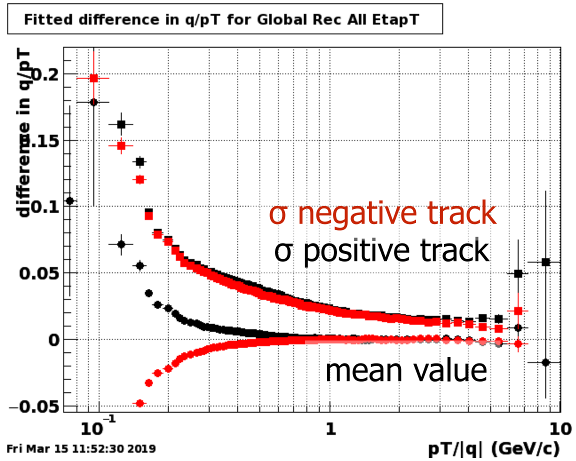
GenFit(Stx)



Sti-like CA fit

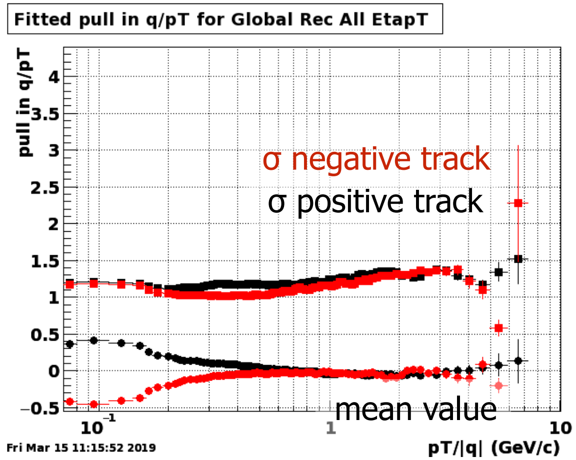


Sti fit

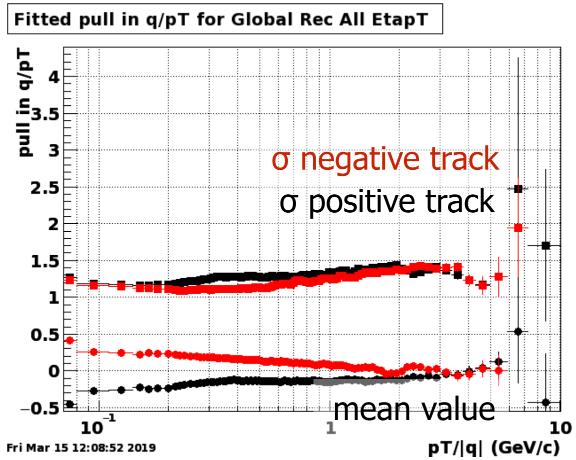


Comparison of fit quality: pulls

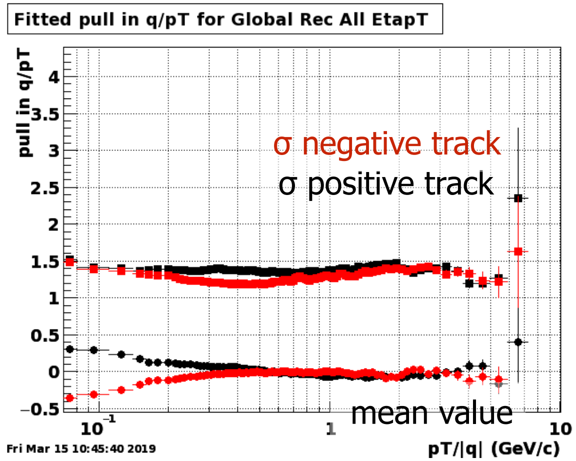
Fast CA fit



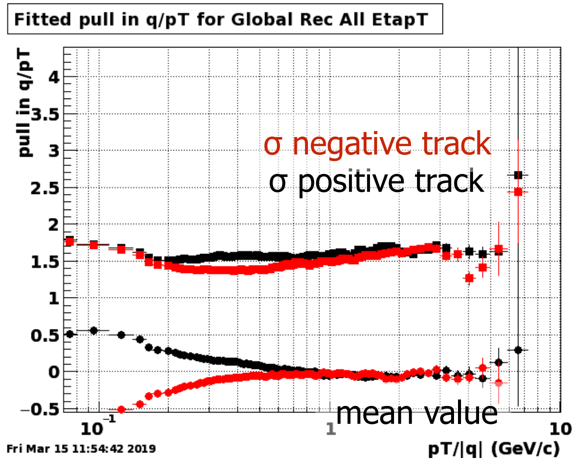
GenFit(Stx)



Sti-like CA fit



Sti fit



Measured calculation time (sec)

	Fast CA	Sti-like CA	Sti	GenFit(Stx)
Total/event	2.42	2.6	2.88	3.45
CPU/event	2.06	2.14	2.36	3.07
CA/event	0.038	0.1	0.038	0.038
Sti/event	0.44	0.52	0.76	—
Stx/event	—	—	—	1.31

Summary

- The Kalman filter method for reconstruction of charged particle trajectories in the TPC CA track finder for the STAR experiment is extended to accurately include the non-homogeneous magnetic field and detector material.
- The developed algorithm is a toolkit for the preparation of the track fitting procedure.
- The method shows correct distributions of the track parameter residuals and pulls, and χ^2.

Plans

- Further optimise and vectorise the Kalman filter based track fit without loss of accuracy.
- Extend the SIMDised KF track fit to the outer ToF, BEMC and MTD detectors.
- Apply the developed methodology to the Kalman filter track fit in the CBM experiment.