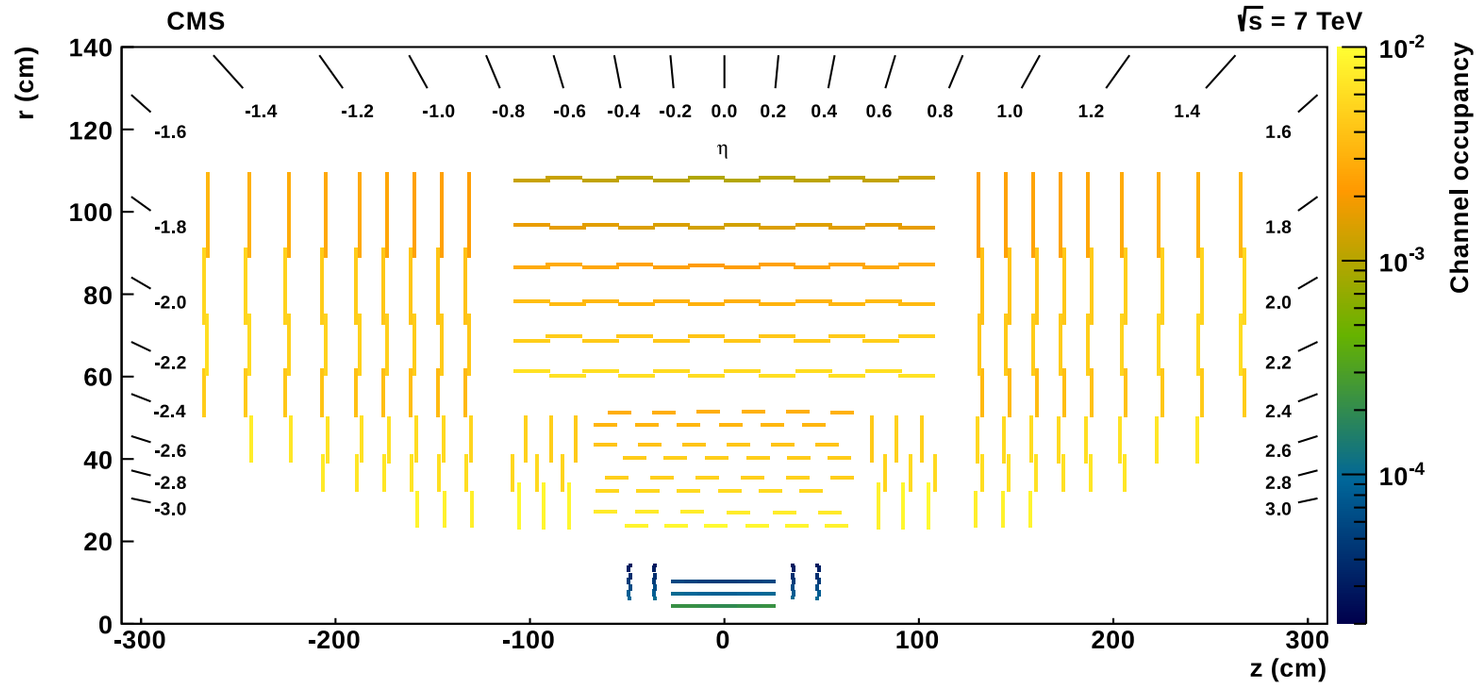
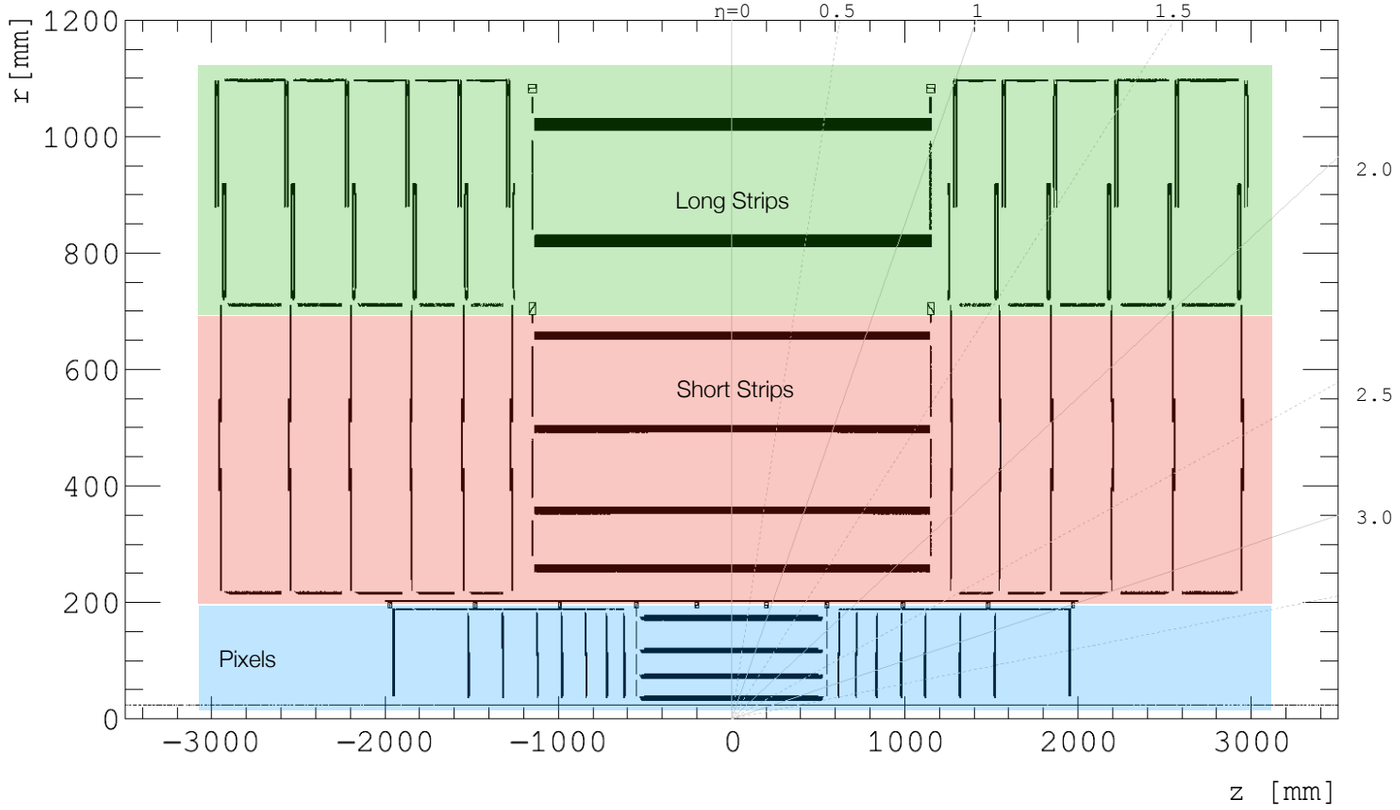
Cellular Automaton based end-cap track finder in ACTS

Ivan Kisel

Johann Wolfgang Goethe-Universität Frankfurt am Main

ACTS Detector System



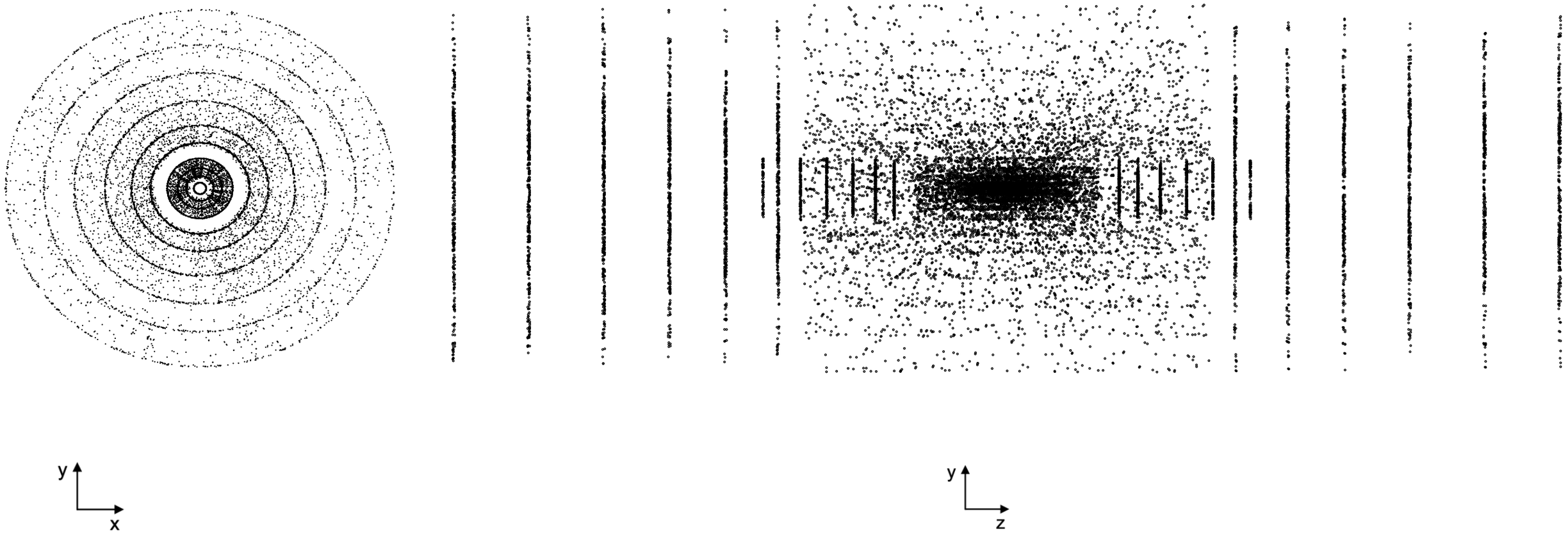


- The task is to create a track finder based on the cellular automaton for the end-cap part of the universal ACTS detector system.

ACTS Simulated Event

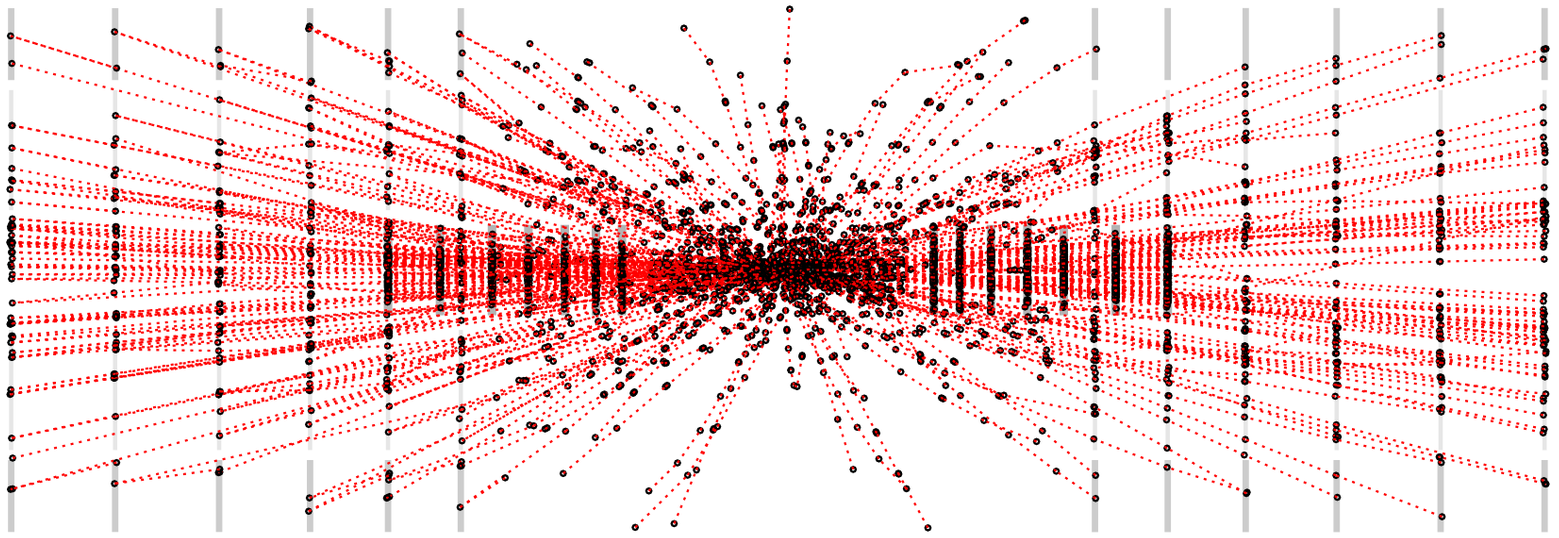
Front view

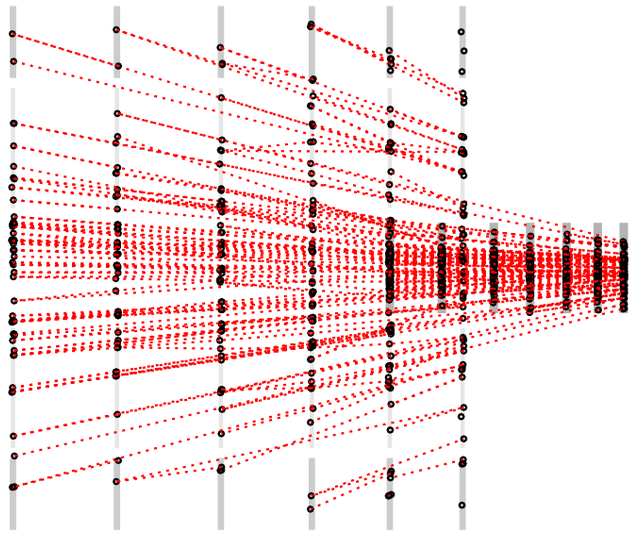
Side view

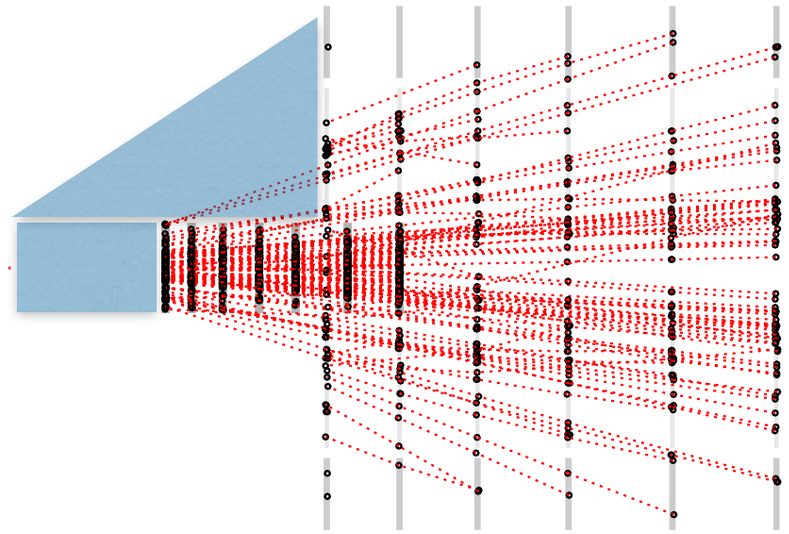


- Hits of a simulated event in the full ACTS detector system is shown

ACTS Simulated Event



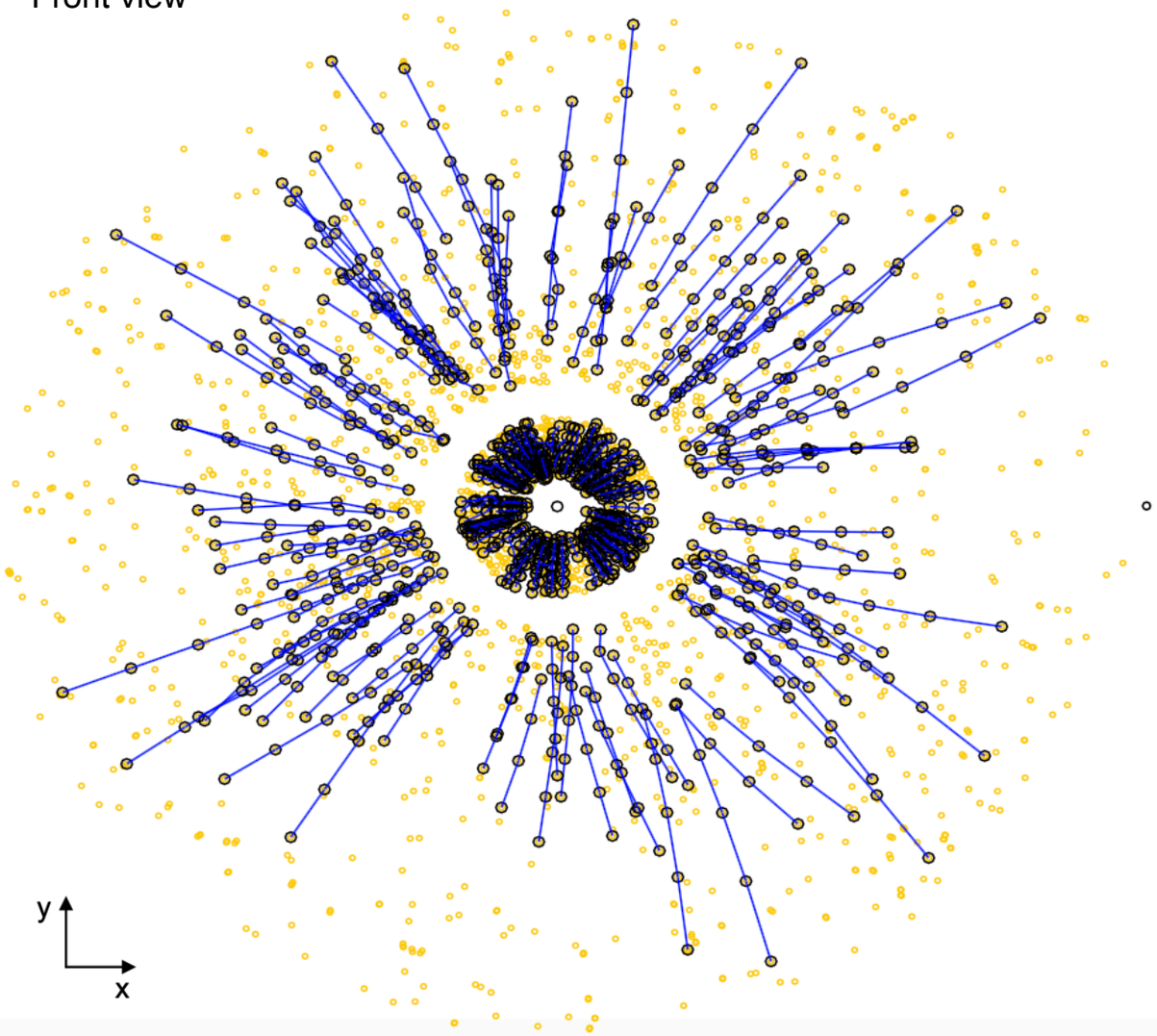




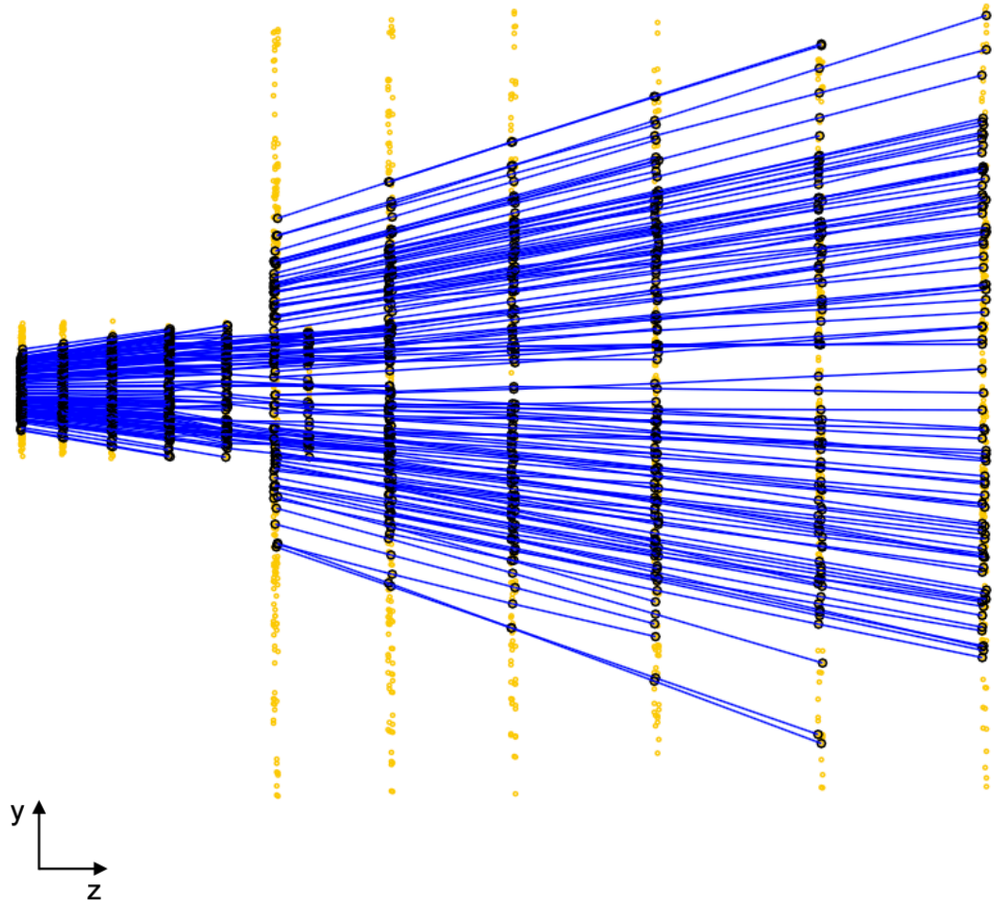
- Simulated tracks in the full/end-cap detector system shown.
- The barrel and the end-cap parts of the detector system have common acceptance.
- There is significant dependence between the acceptances of both parts.

ACTS Cellular Automaton Track Finder

Front view

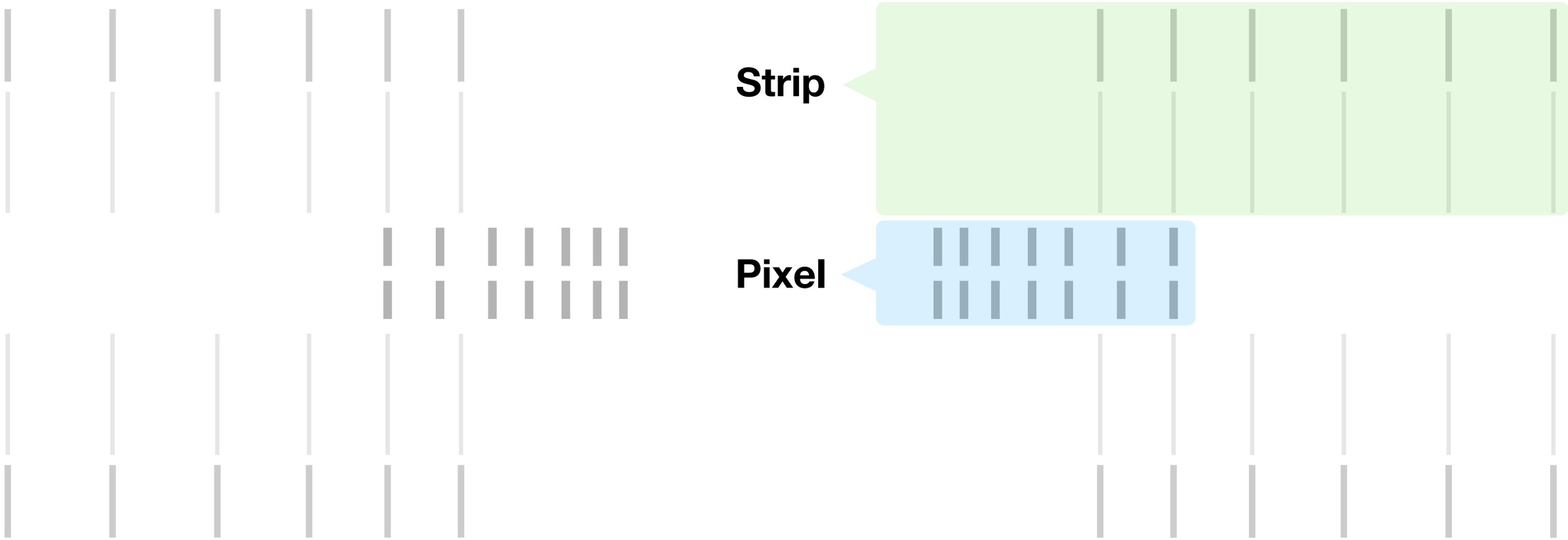


Side view



- Integration of the Cellular Automaton track finder into the ACTS framework
- Track reconstruction in the end-cap detector system (only the right part is shown)
- Small overlap of inner and outer sub-detectors acceptances
- Requires precise Kalman Filter track fit of segments within the track finder

ACTS::GenericDetector - end-cap



- The inner part of the detector system build of pixel stations.
- The outer part of the detector system build of strip stations.
- Common approach in CA track finder and KF track fitter to both detector systems.

CA Track Finder in ACTS

Common structure:

ACTS_source_folder/

- …
- Examples/
  - Algorithms/
    - **L1/ActsExamples/**
      - **L1Algo/**
        - **vectors/**
      - **L1Functions/**
      - **L1Performance/**
    - …
  - Run/
    - L1/
- …

Internal classes and functions of the L1 (Level-1, online) library. Provides a direct process of searching and fitting tracks. Does not use ACTS functions and is a standalone library (excluding ROOT classes for drawing and timer).

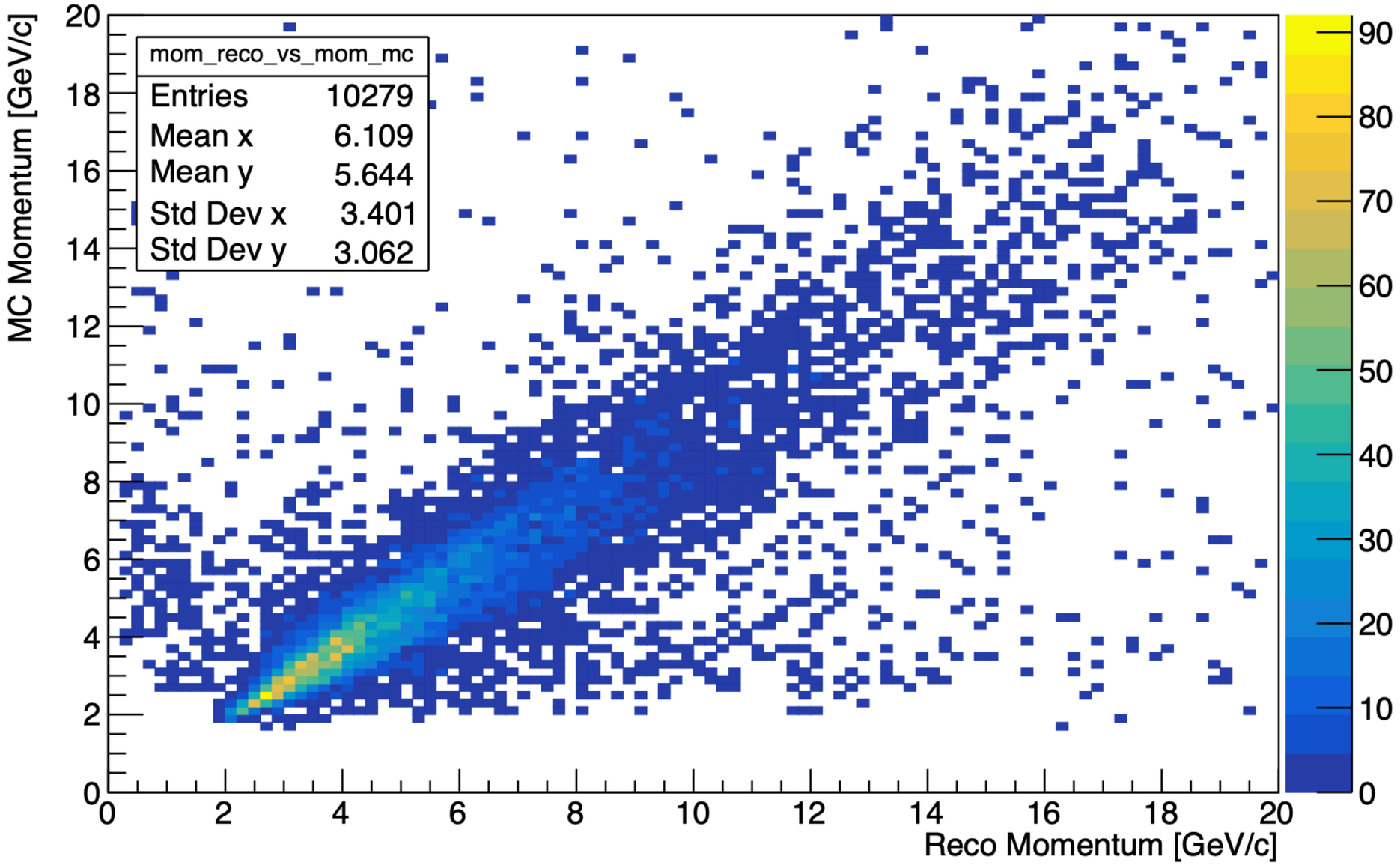
Headers for overloading of SSE SIMD intrinsics.

ACTS interfaces for working with L1 functionality. Load input data, run functions, store results.

Collecting statistics and evaluating the quality of tracking and fitting.

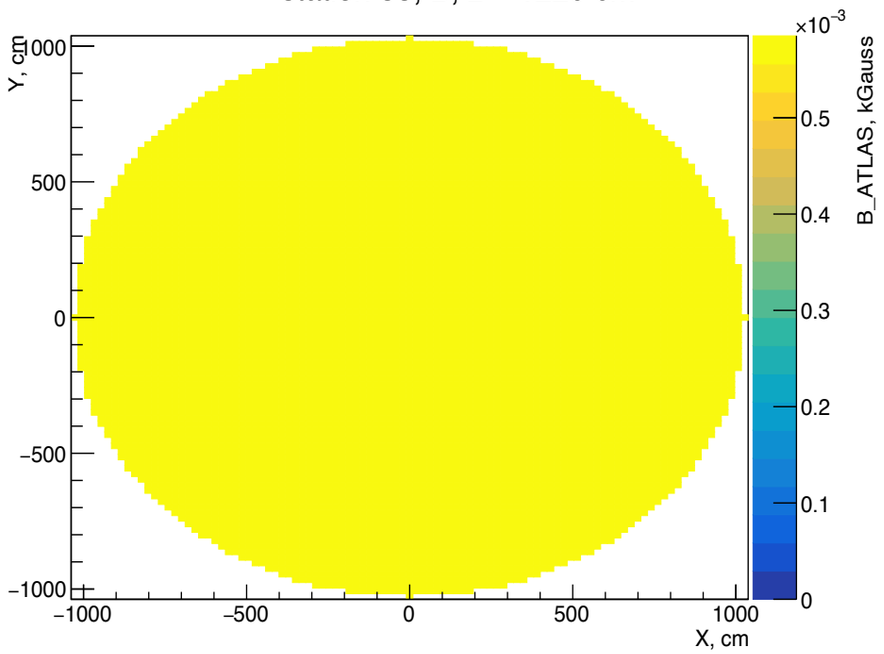
Test macro to start the reconstruction chain.

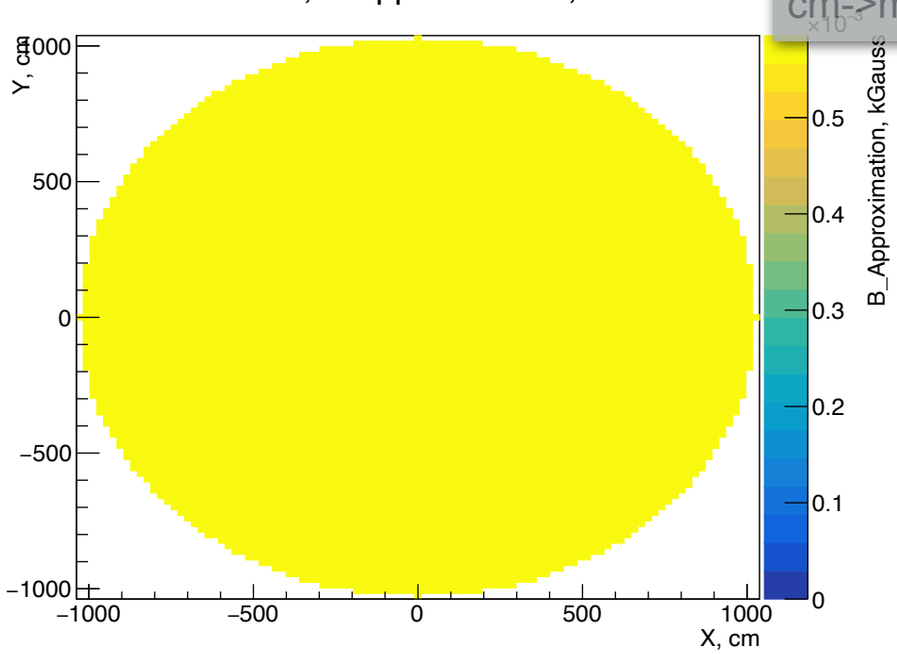
ACTS Kalman Filter Track Fit

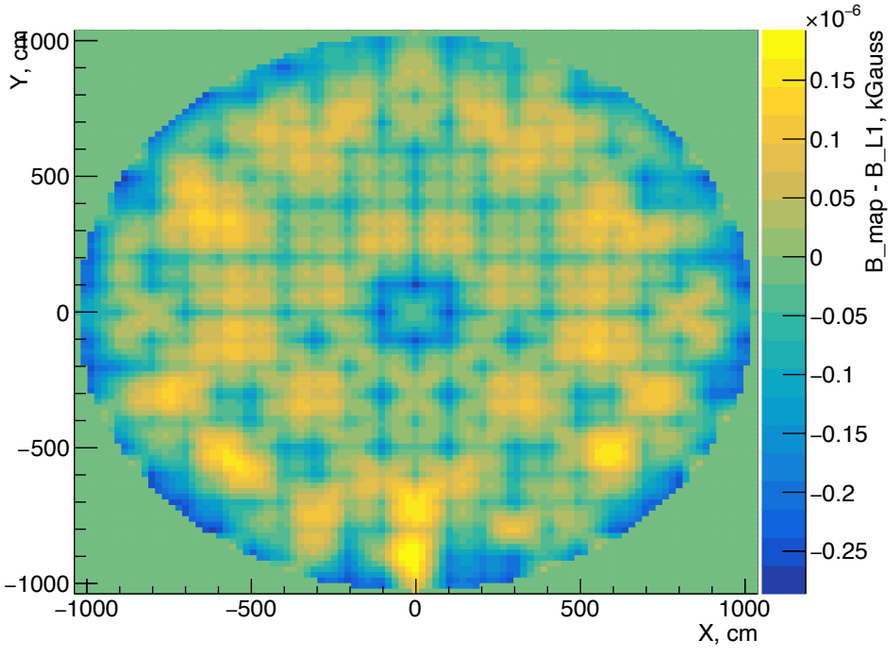


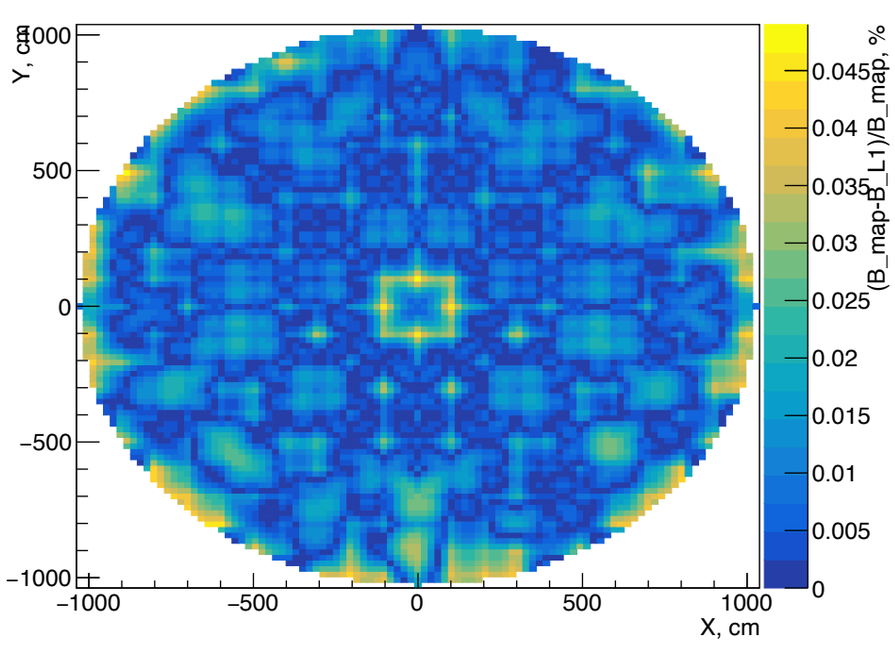
- An ideal track finder was implemented to test all steps of the reconstruction procedure.
- We also adapted the ACTS Kalman Filter track fit for use in the CA track finder.
- A strong correlation between the simulated and reconstructed moments of (real) reconstructed tracks was shown.

ACTS Magnetic Field



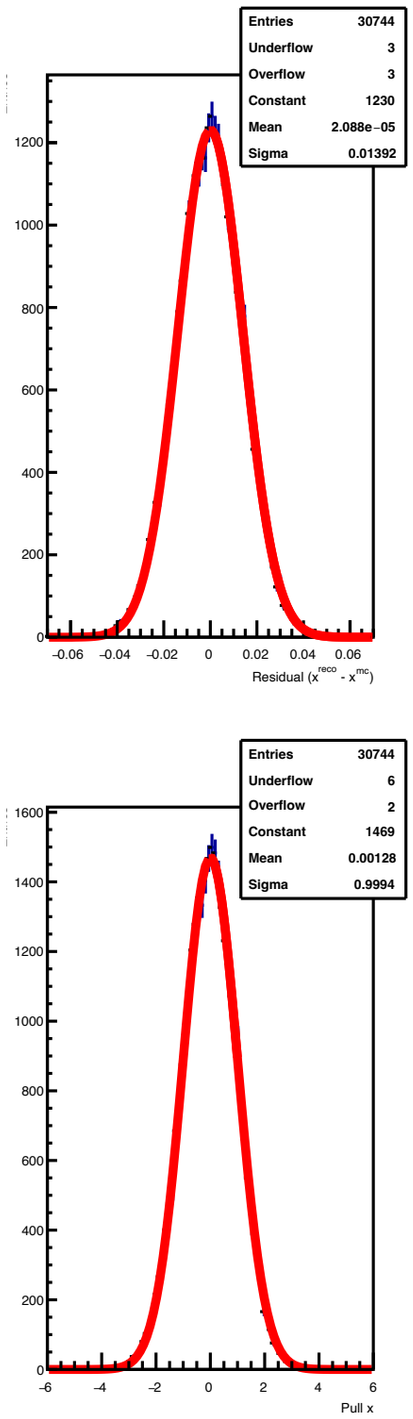


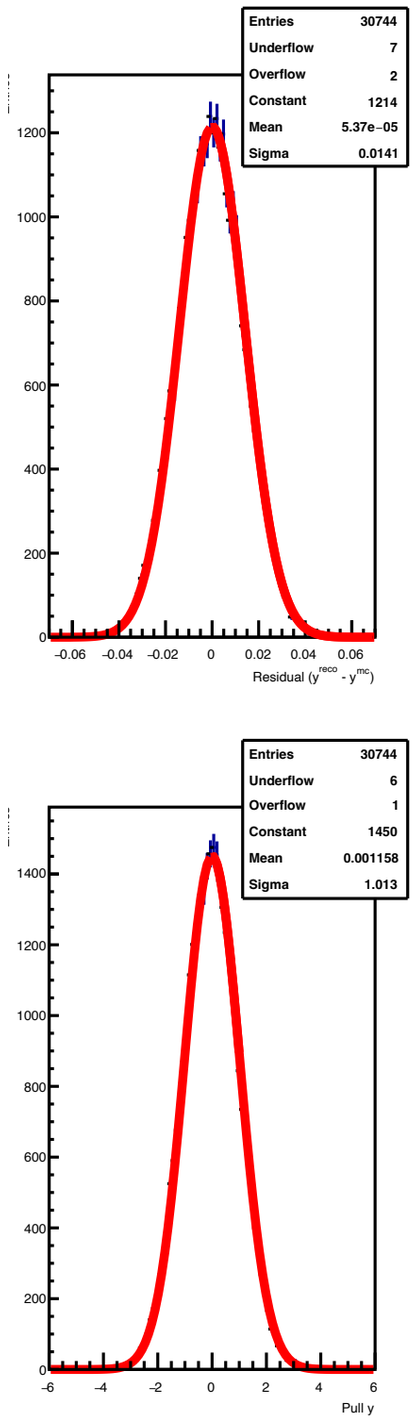


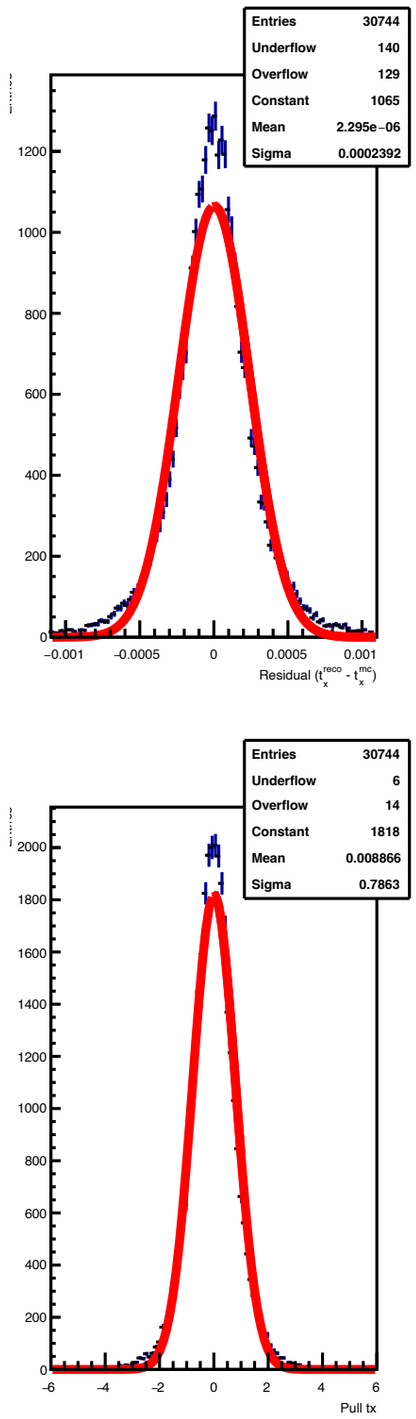


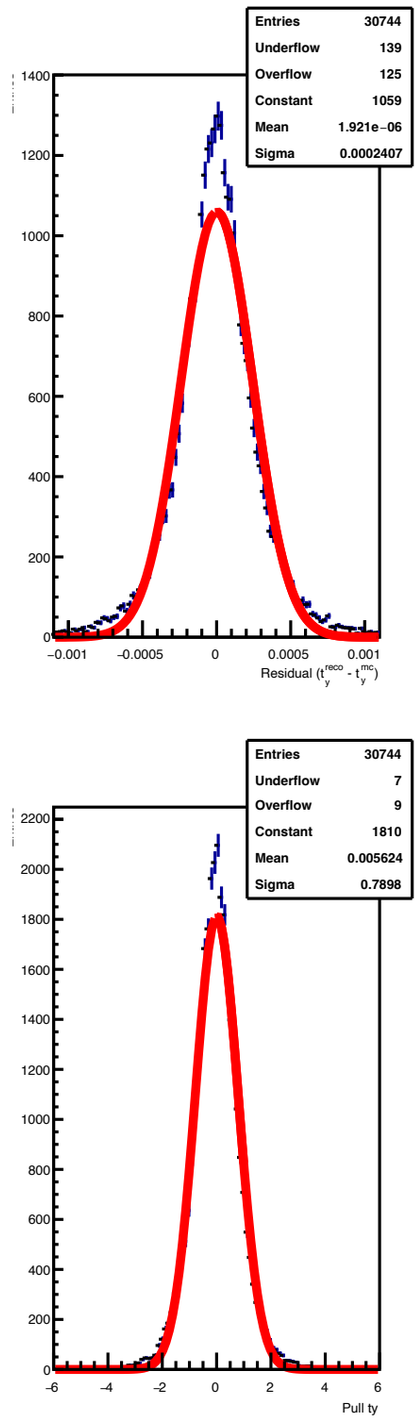
- Magnetic field is approximated locally at each station
- Approximation with 5-th order polynomial
- Magnetic field between stations is calculated using parabola (triplet fit)

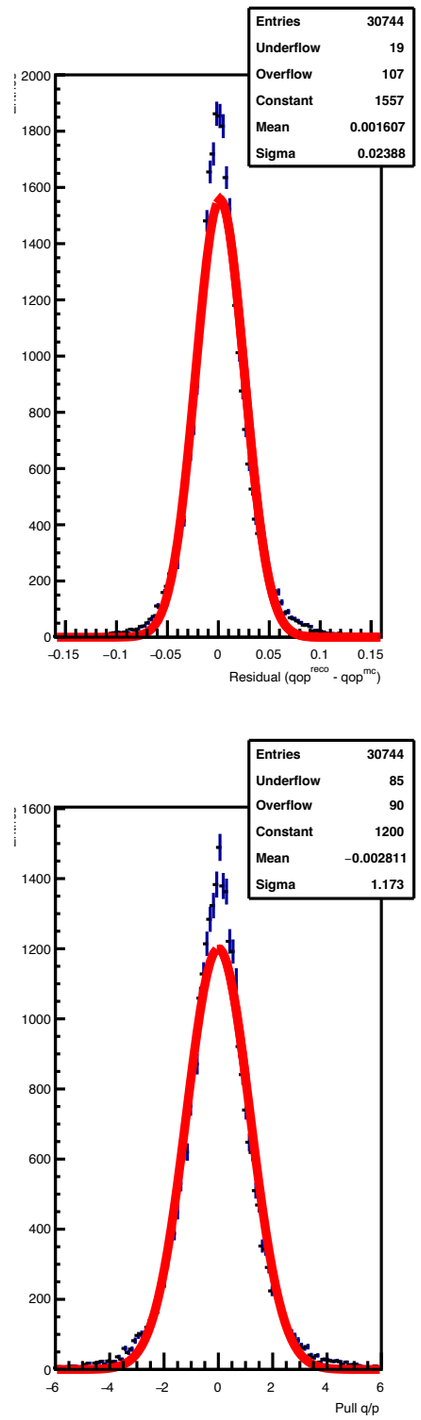
Kalman Filter - last pont - 1 iteration - Pixel detector - Scalar



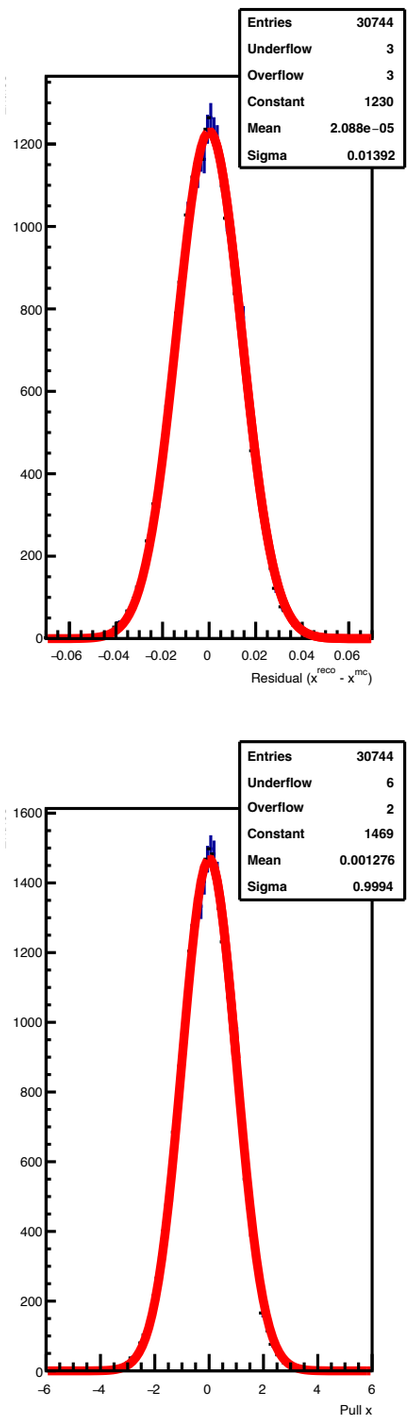


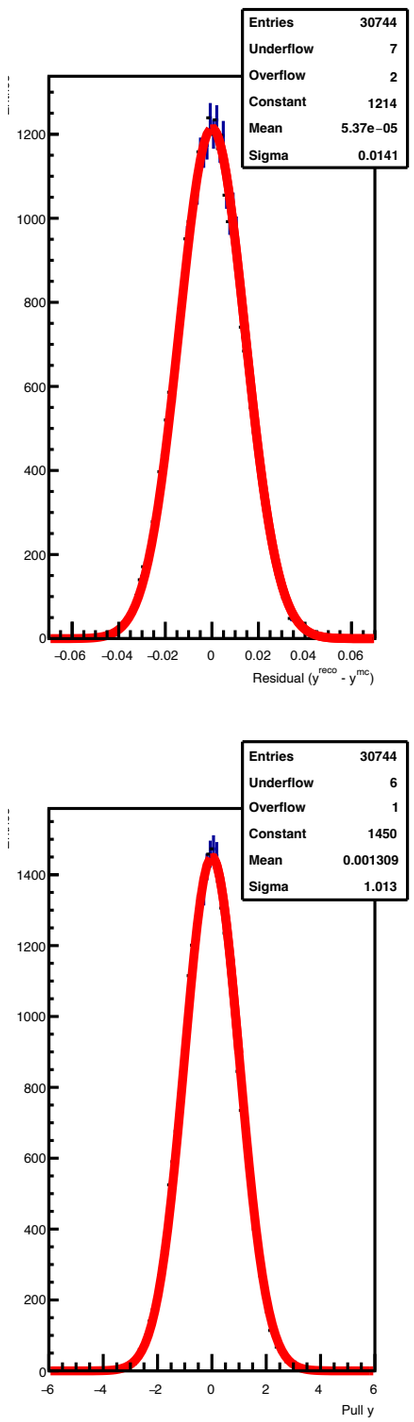


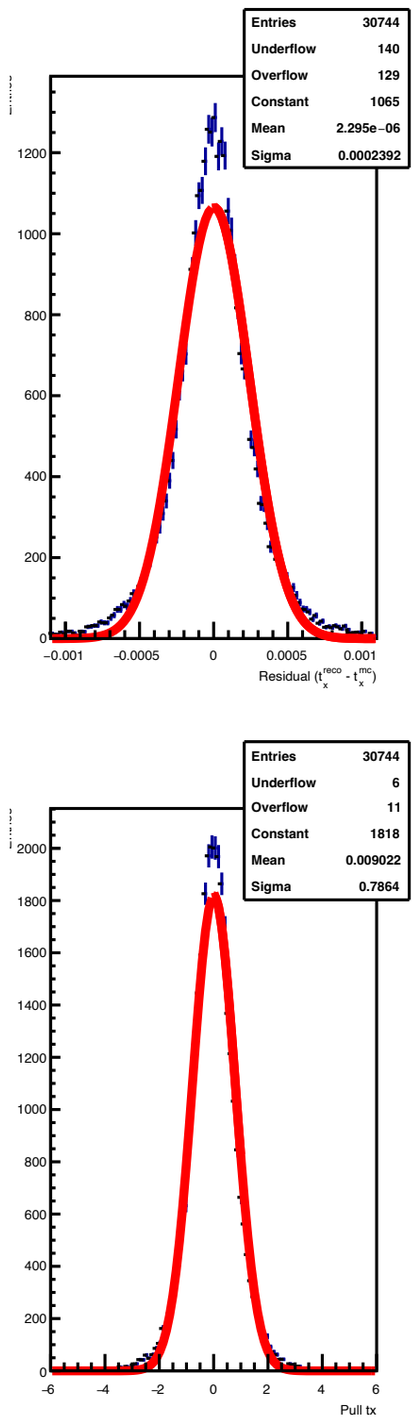


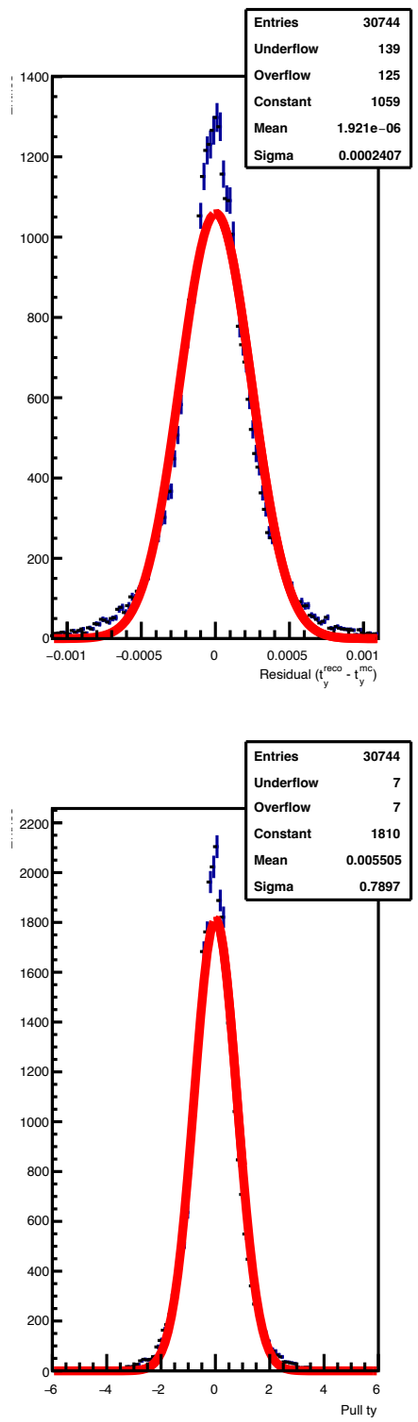


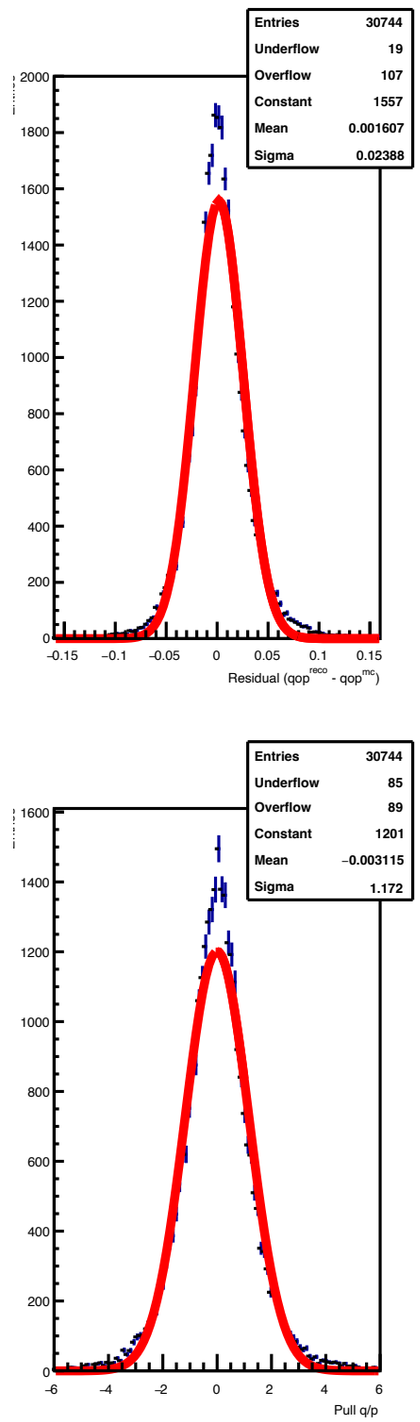
Kalman Filter - last pont - 1 iteration - Pixel detector - SIMD



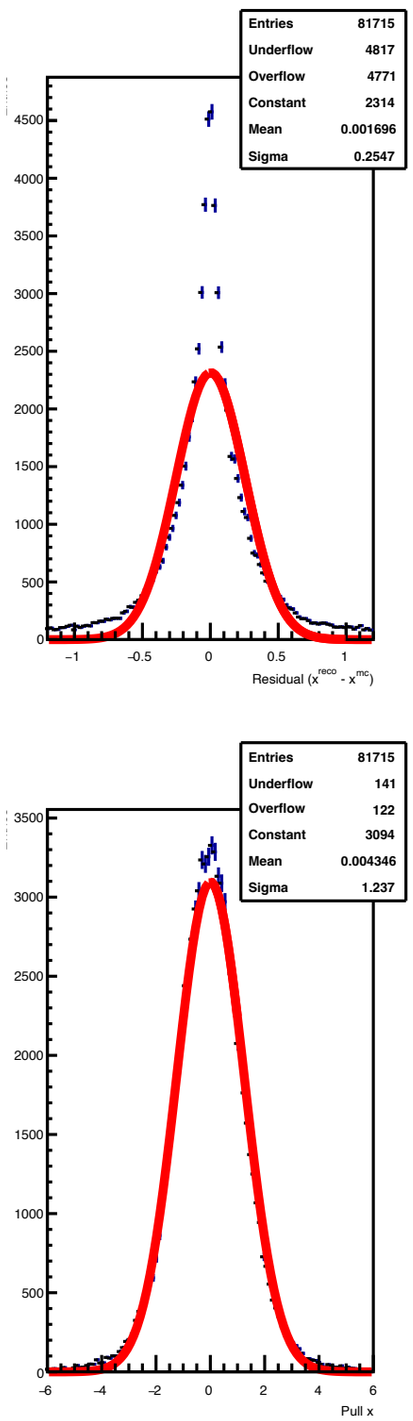


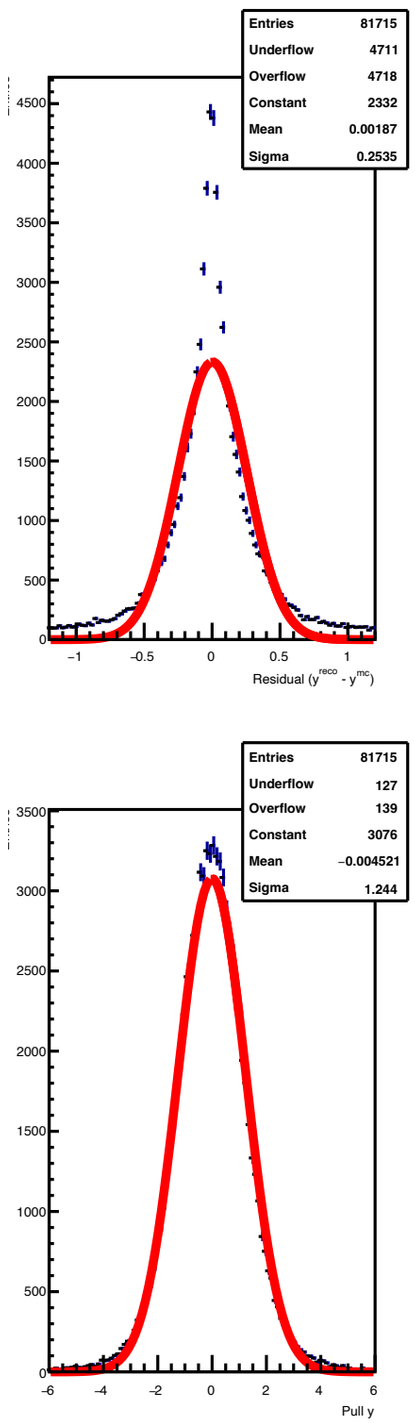


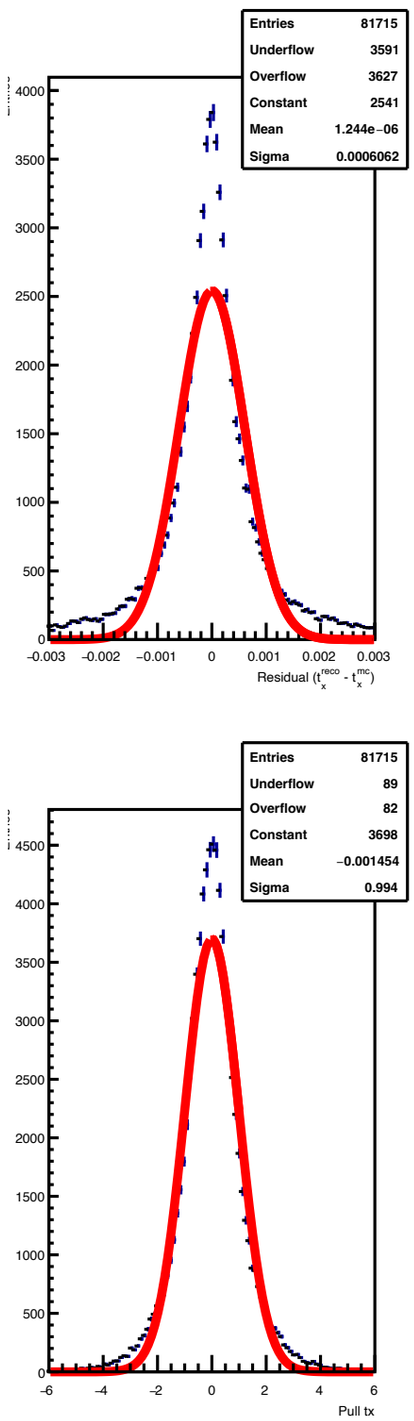


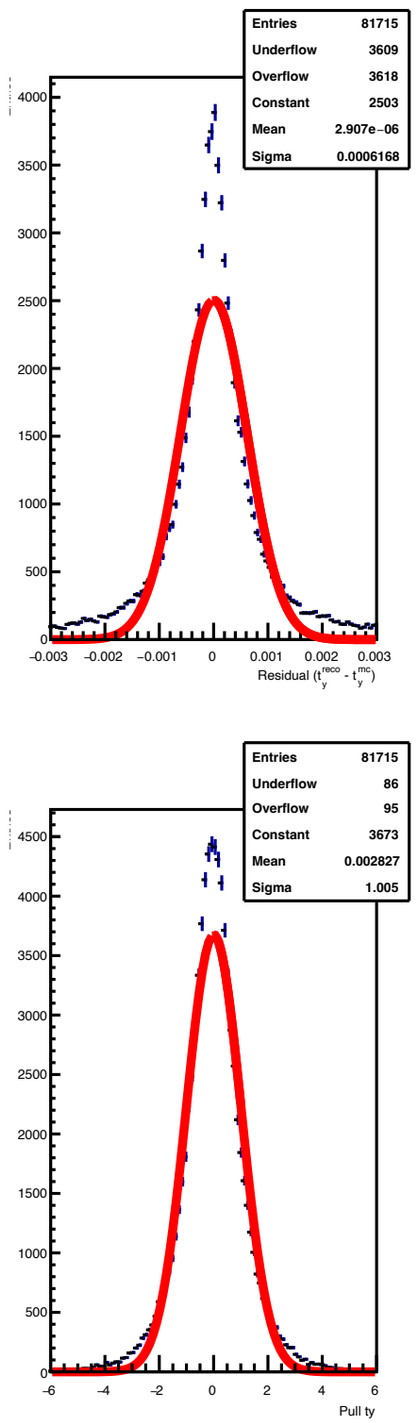


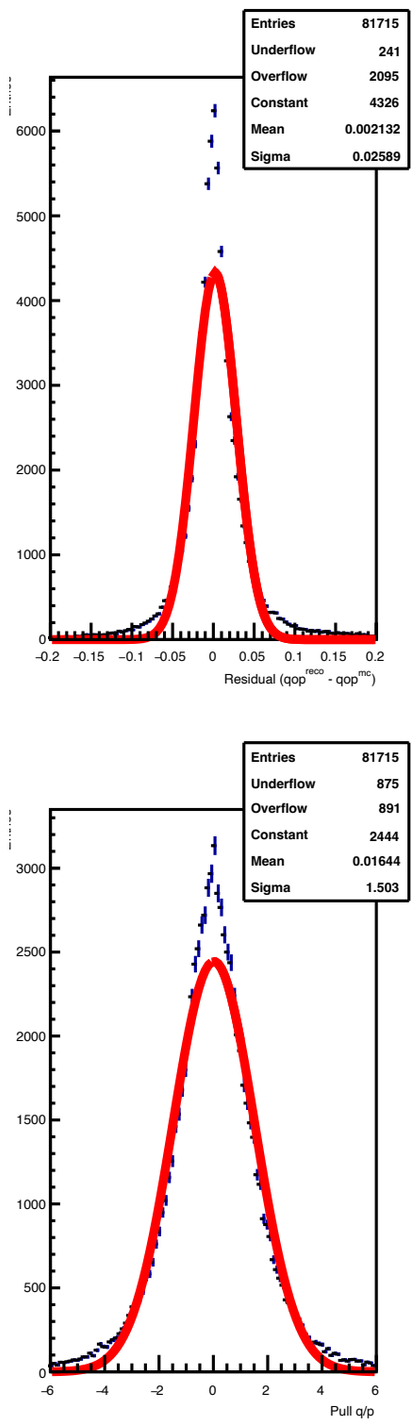
Kalman Filter - last pont - 1 iteration - Strip detector - Scalar



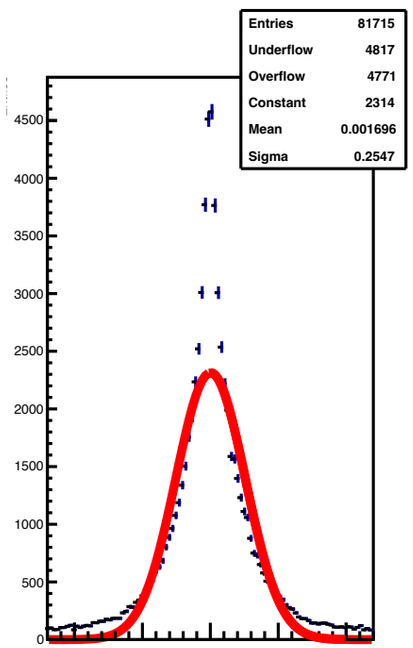


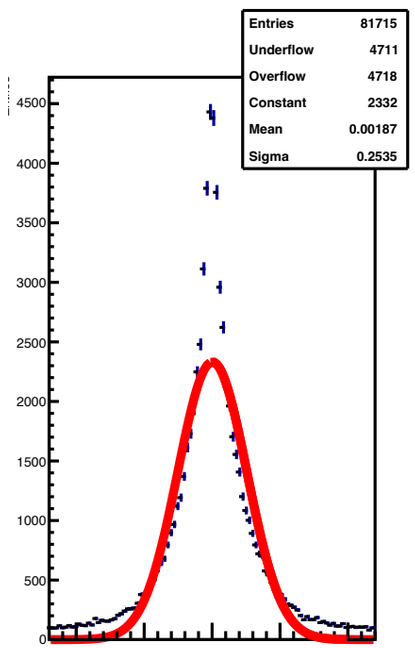


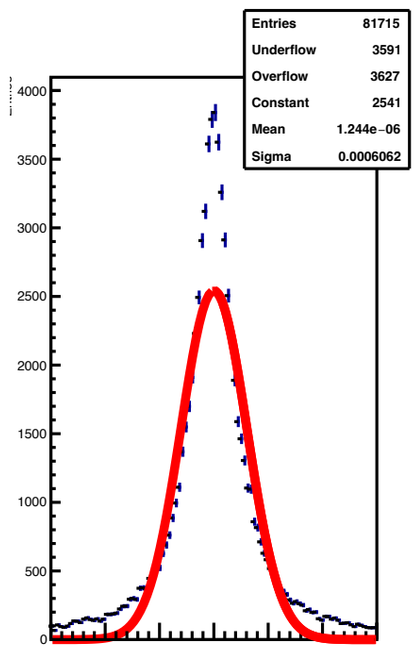


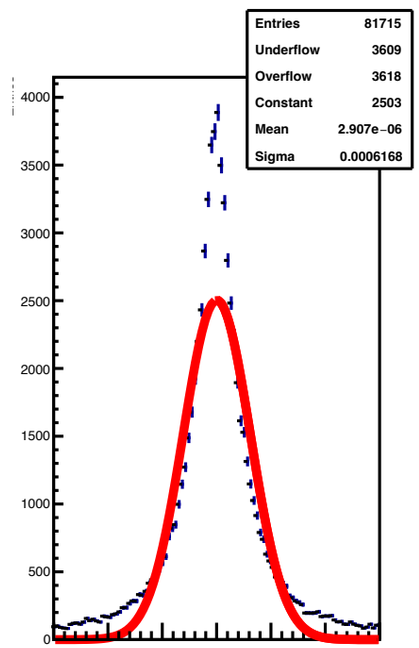


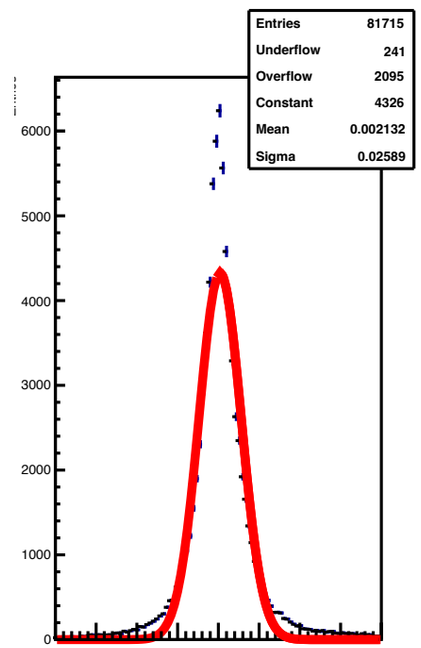
Kalman Filter - last pont - 1 iteration - Strip detector - SIMD

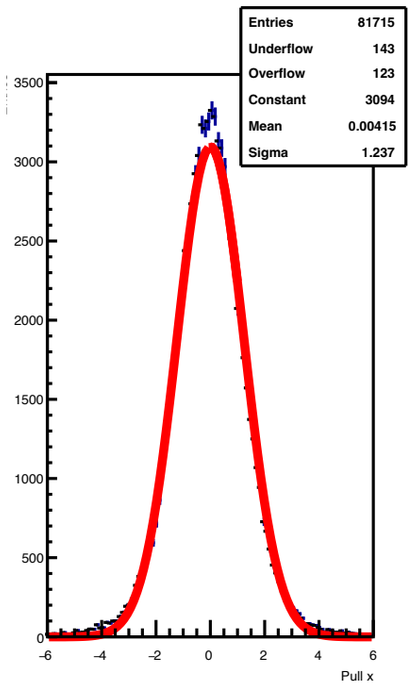


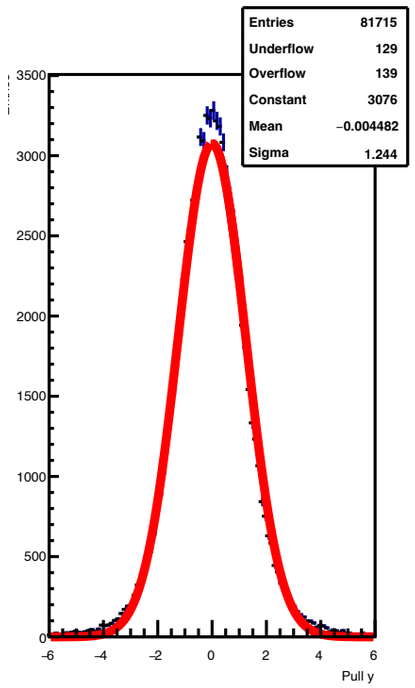


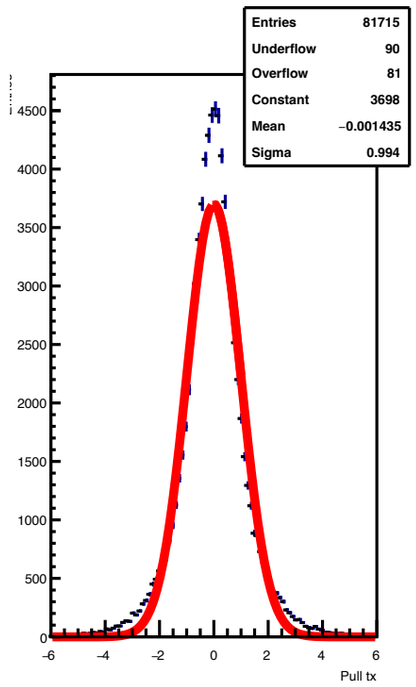


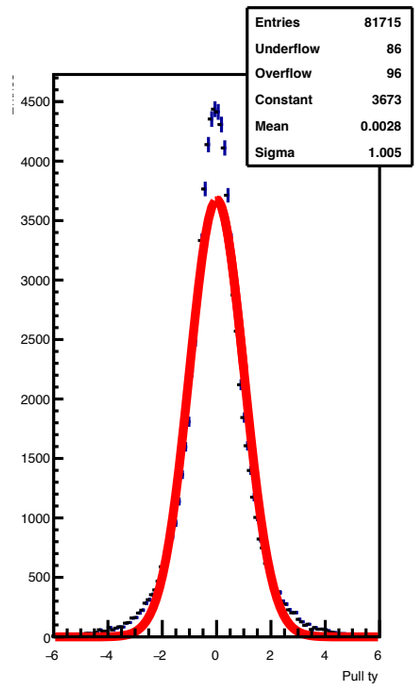


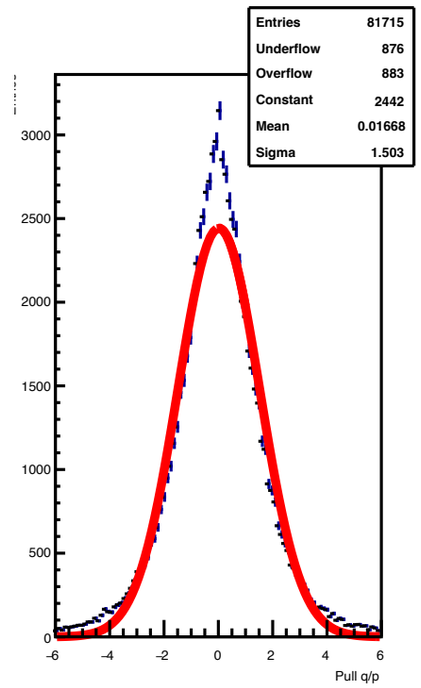






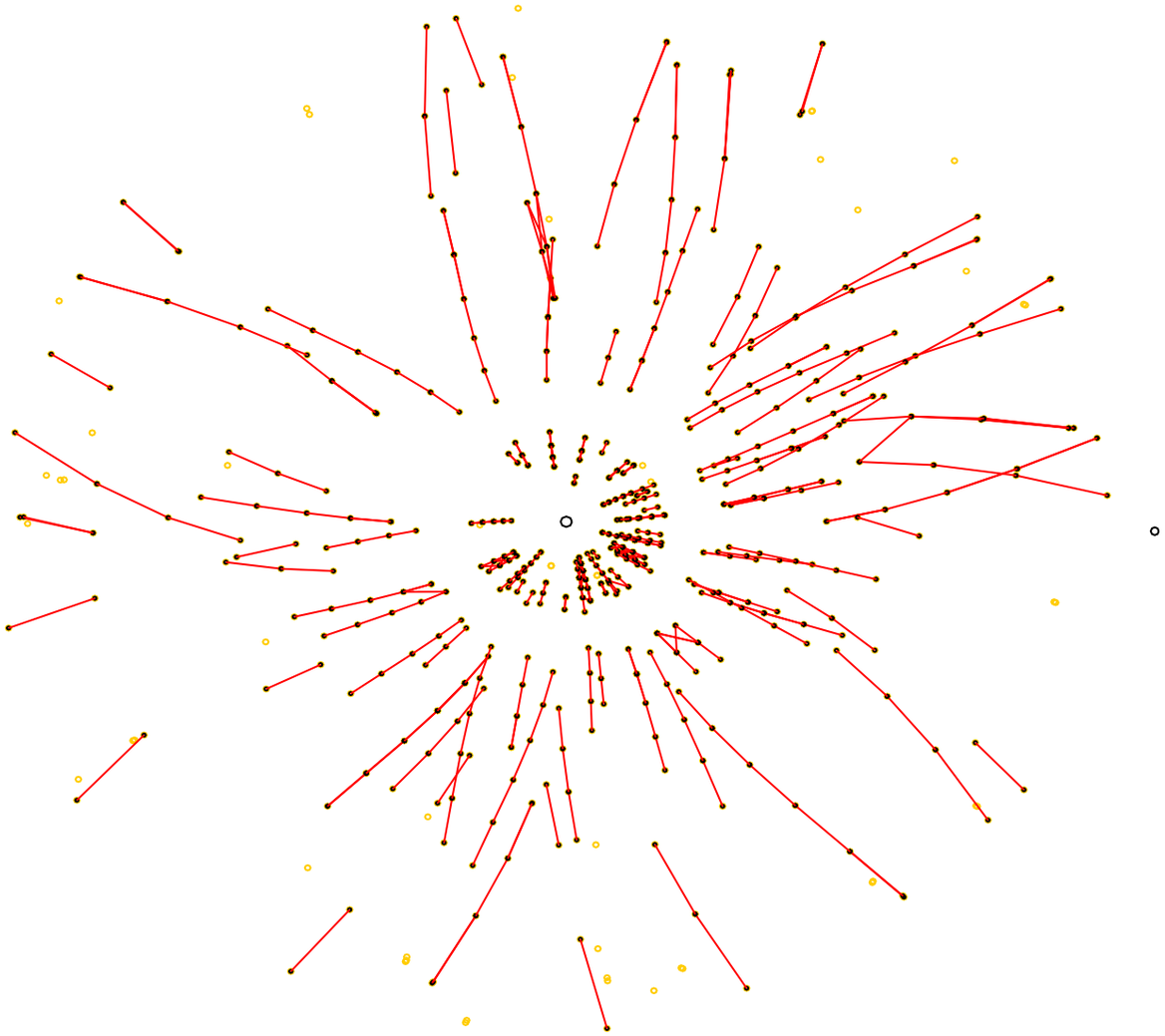


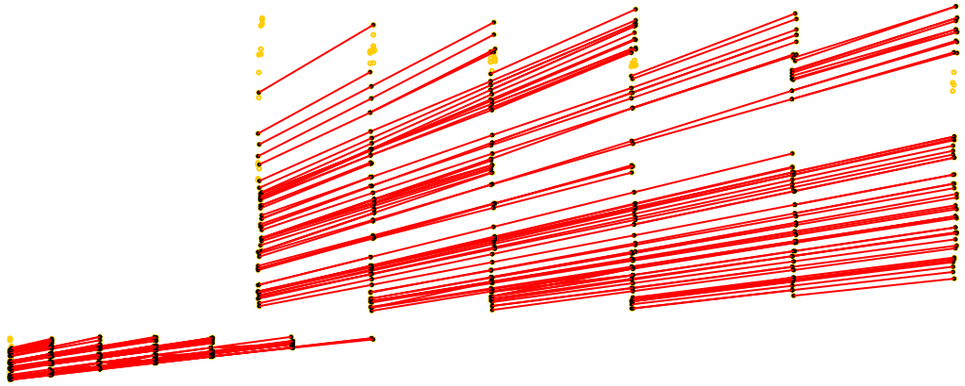




ACTS Reconstructed Event (Dublets/Scalar)

Low track multiplicity

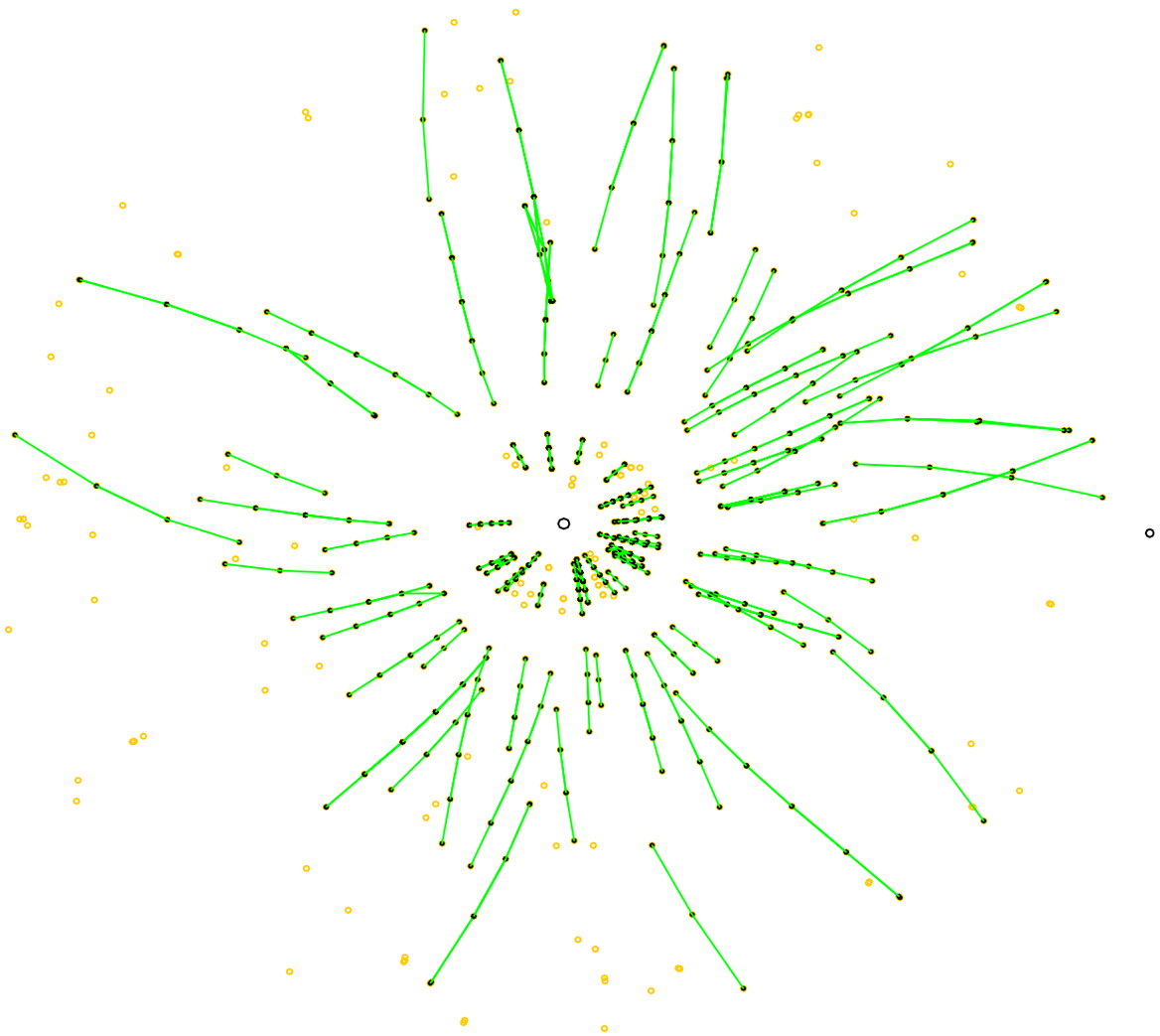


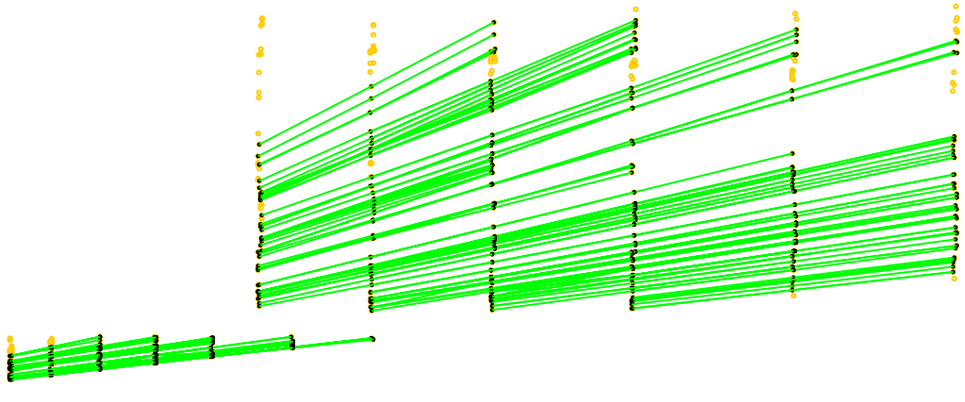


- SIMD and OpenMP CA track finder implemented as well

ACTS Reconstructed Event (Triplets/Scalar)

Low track multiplicity

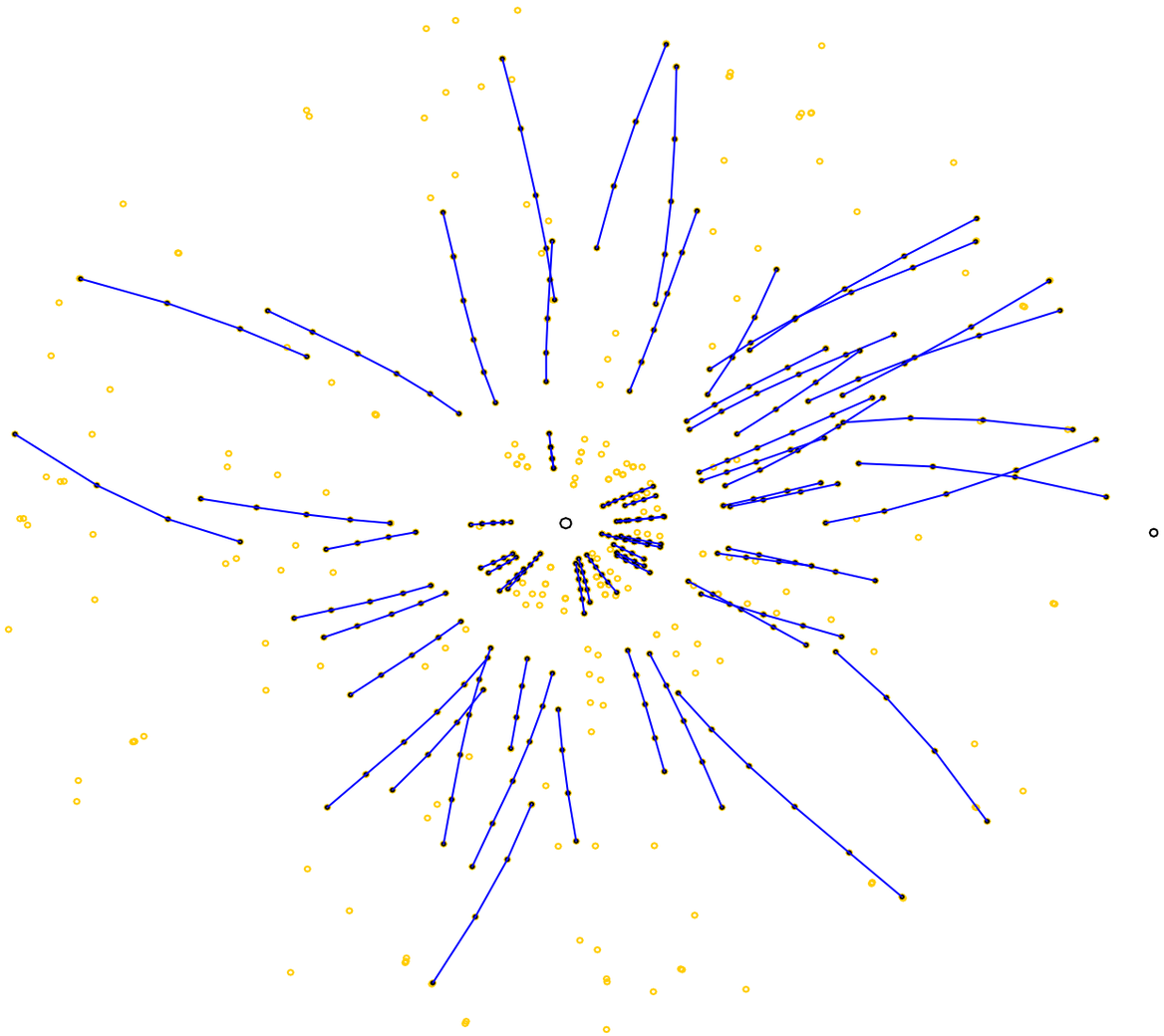


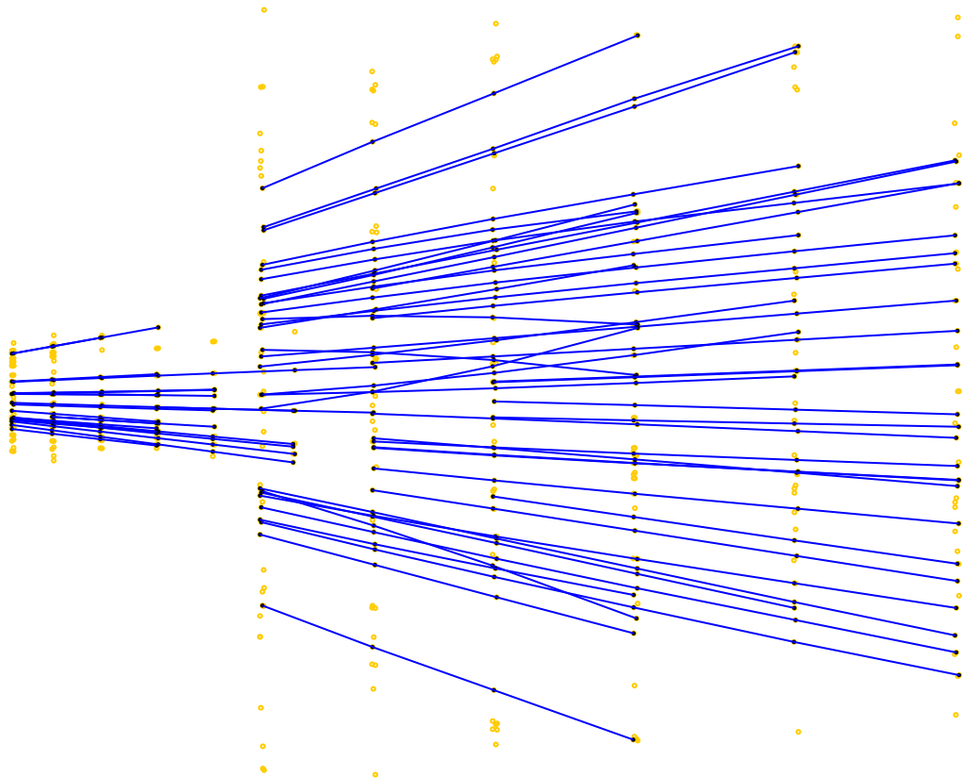


- SIMD and OpenMP CA track finder implemented as well

ACTS Reconstructed Event (Tracks/Scalar)

Low track multiplicity

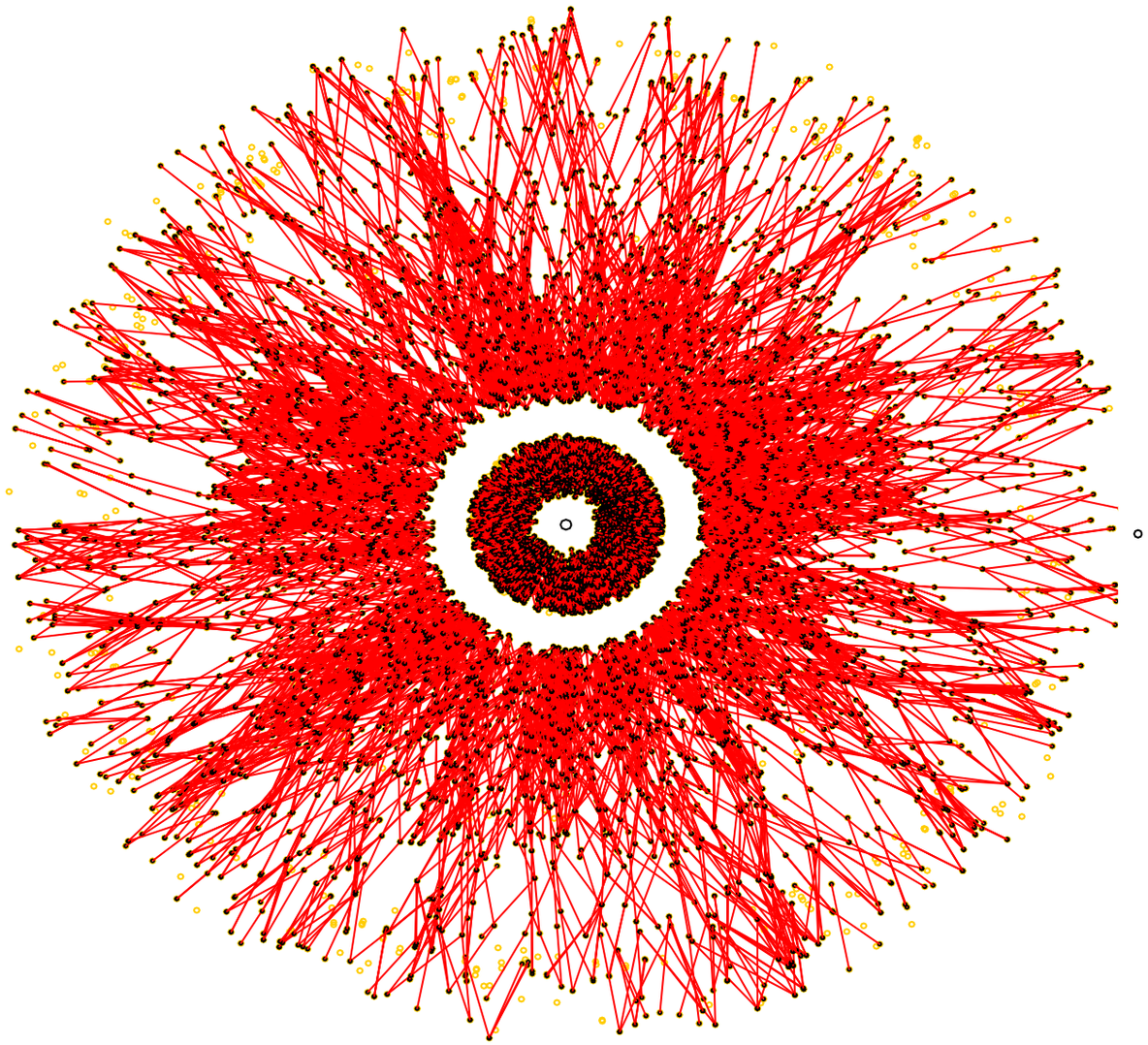


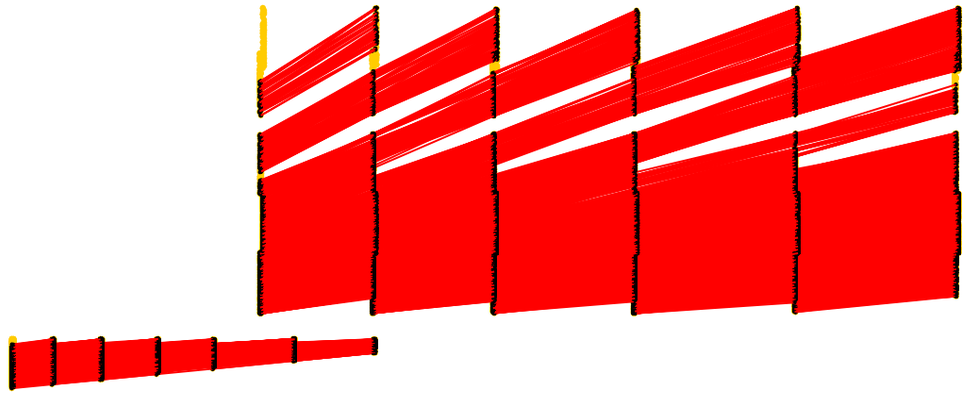


- SIMD and OpenMP CA track finder implemented as well

ACTS Reconstructed Event (Dublets/Scalar)

High track multiplicity

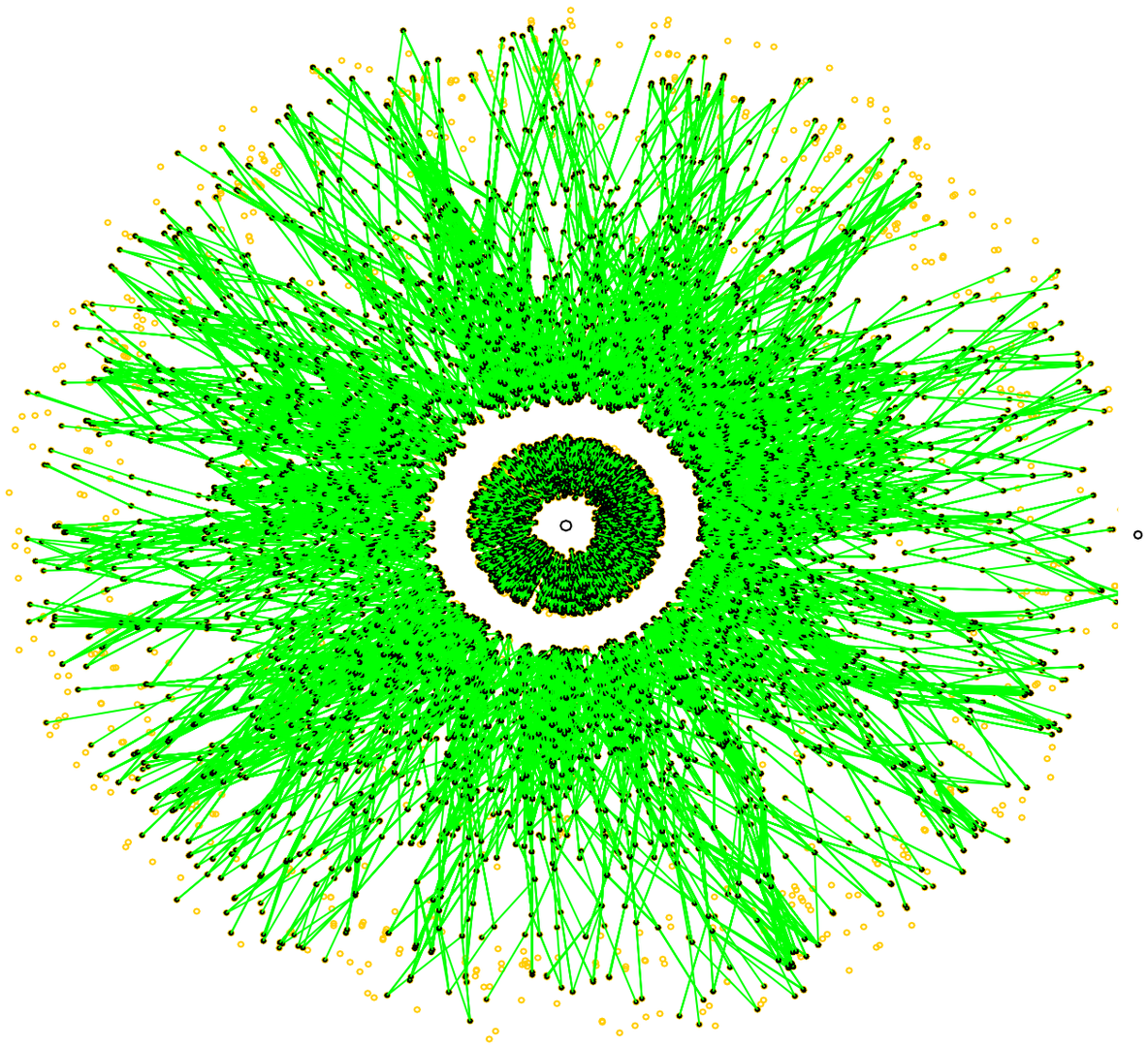


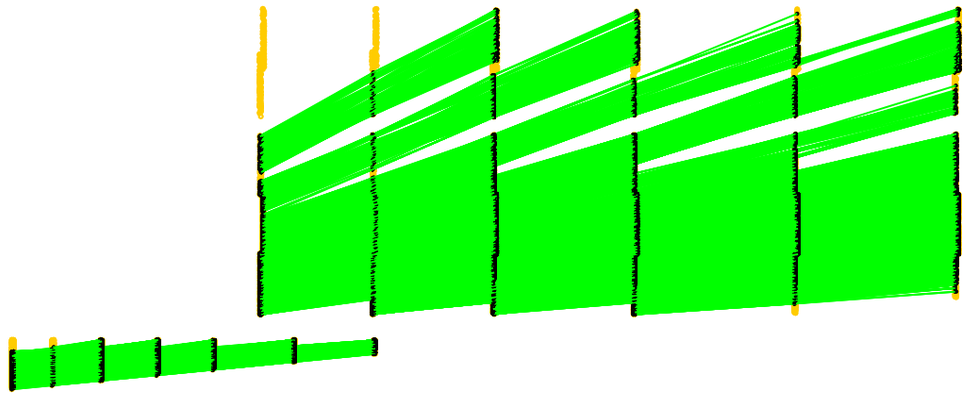


- SIMD and OpenMP CA track finder implemented as well

ACTS Reconstructed Event (Triplets/Scalar)

High track multiplicity

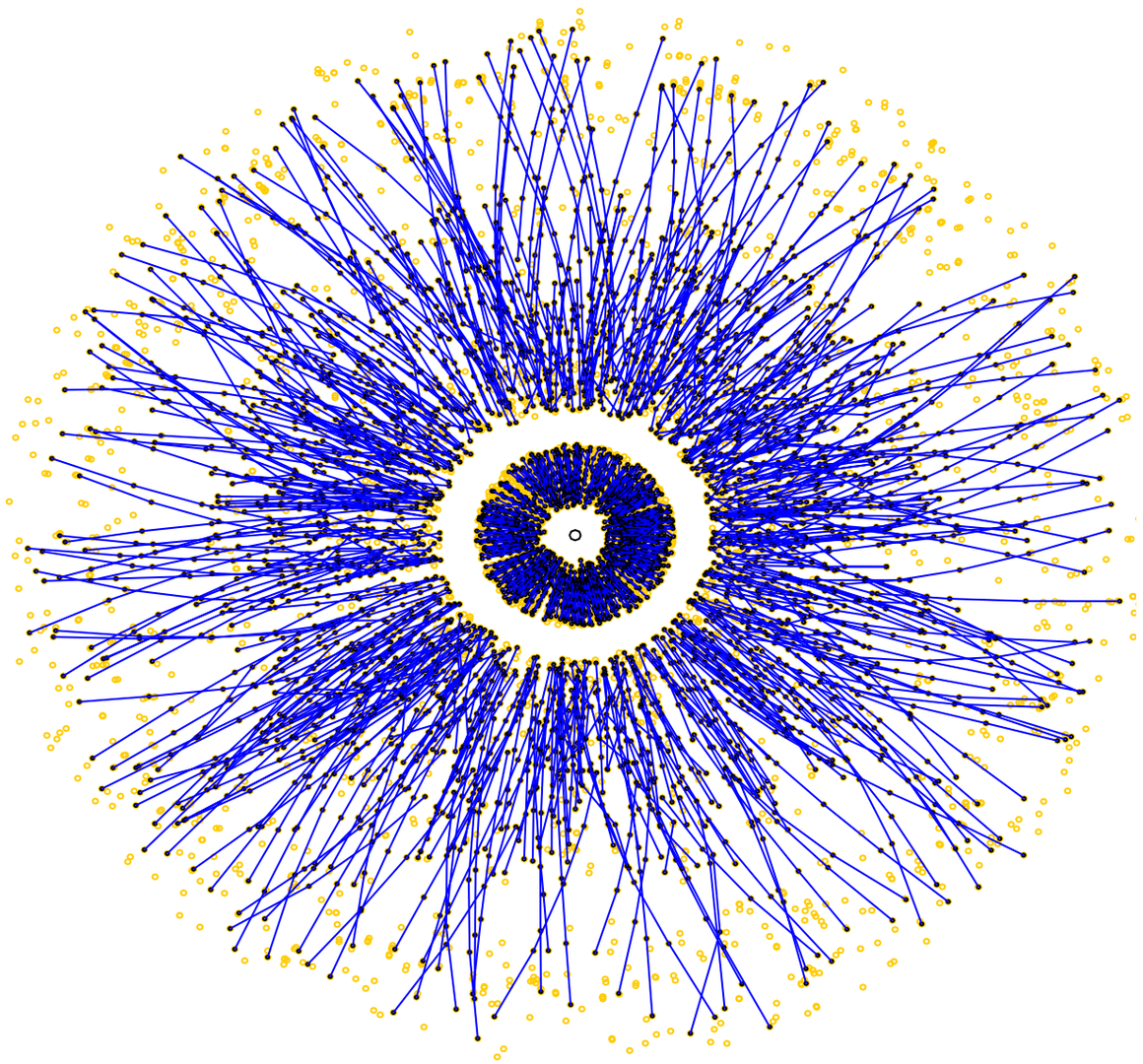


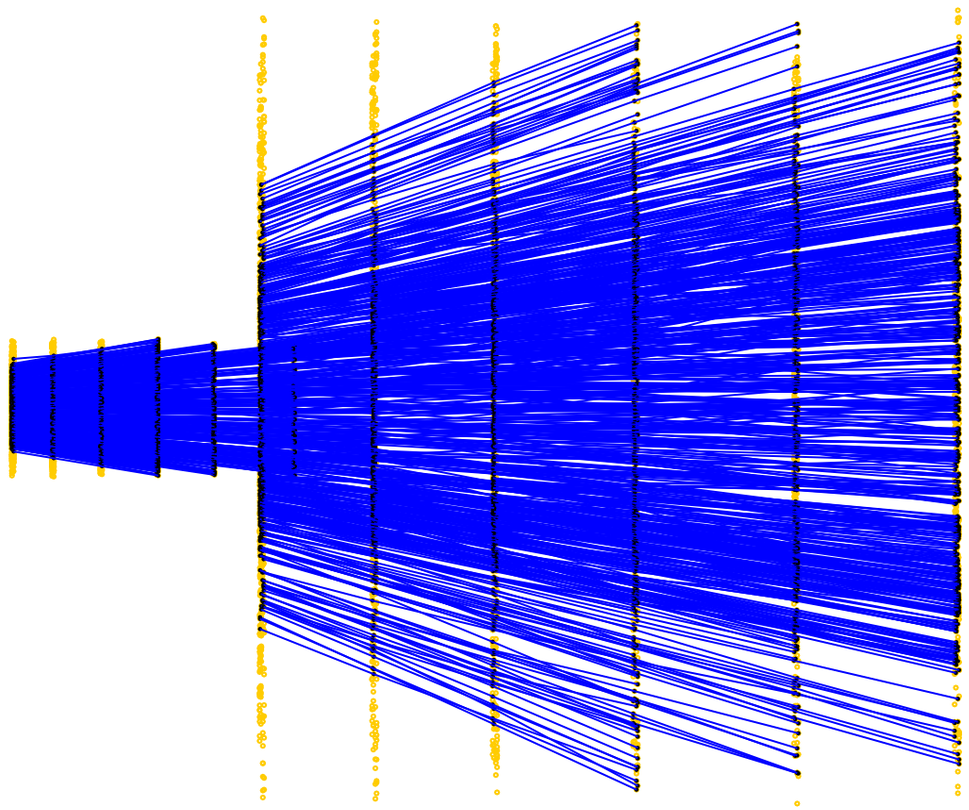


- SIMD and OpenMP CA track finder implemented as well

ACTS Reconstructed Event (Tracks/Scalar)

High track multiplicity

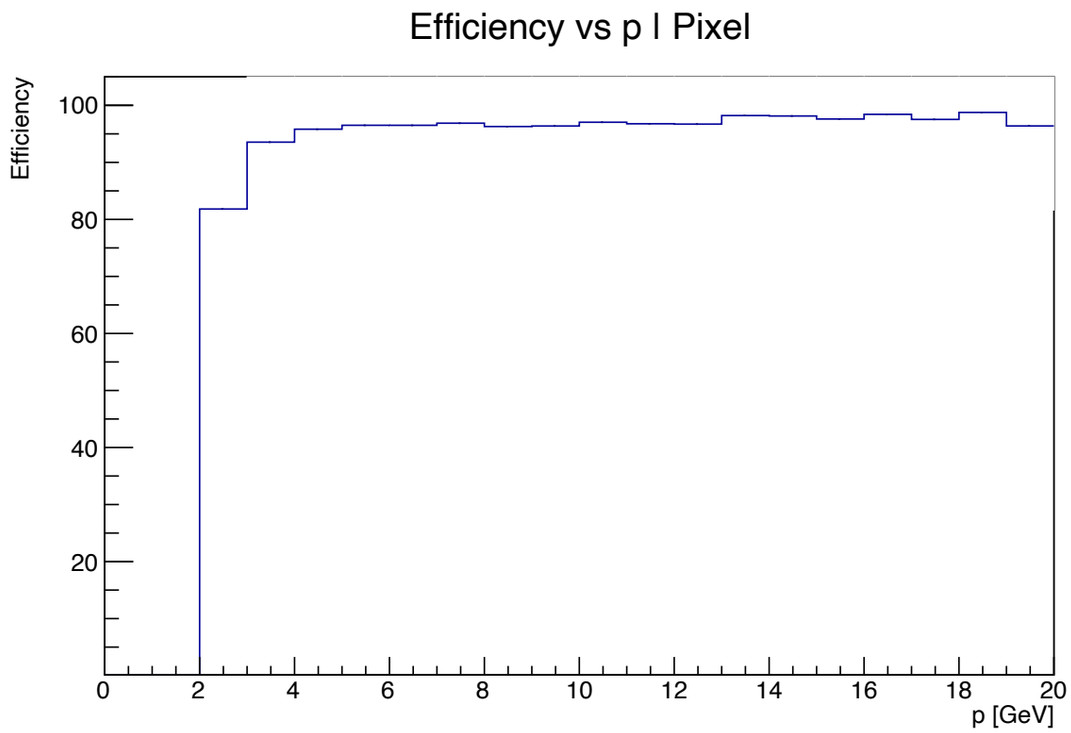


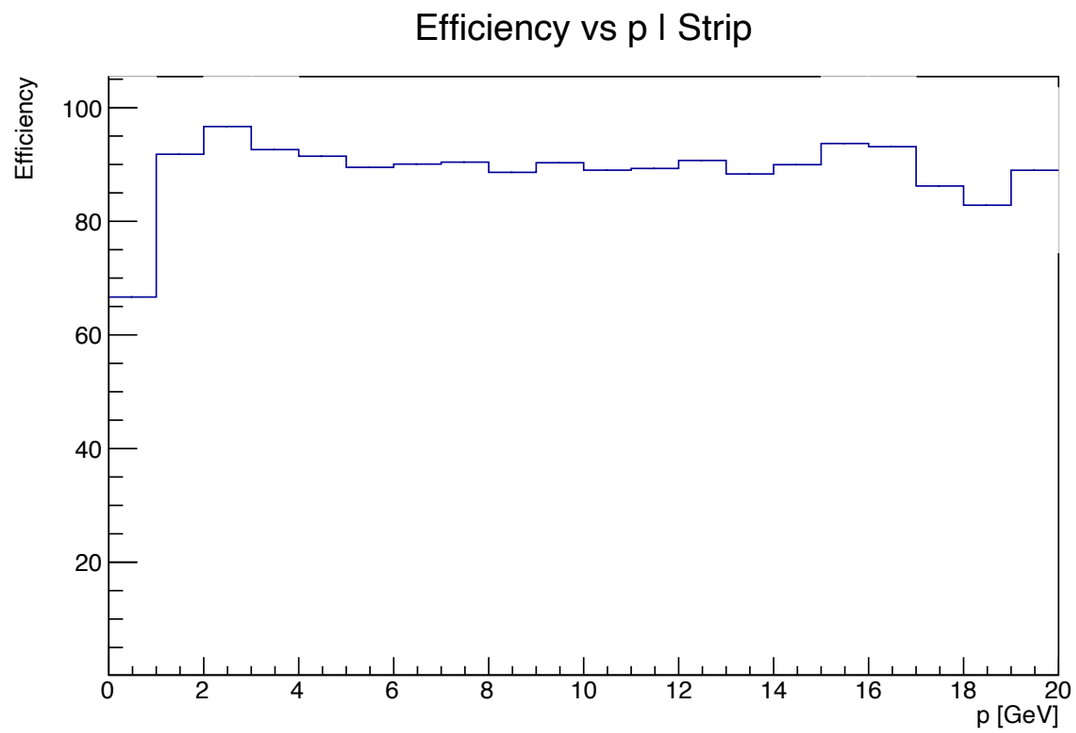


- SIMD and OpenMP CA track finder implemented as well

CA Tracking Efficiency (SIMD)

High track multiplicity





Tracking efficiency in Pixel detector. nEvents: 100

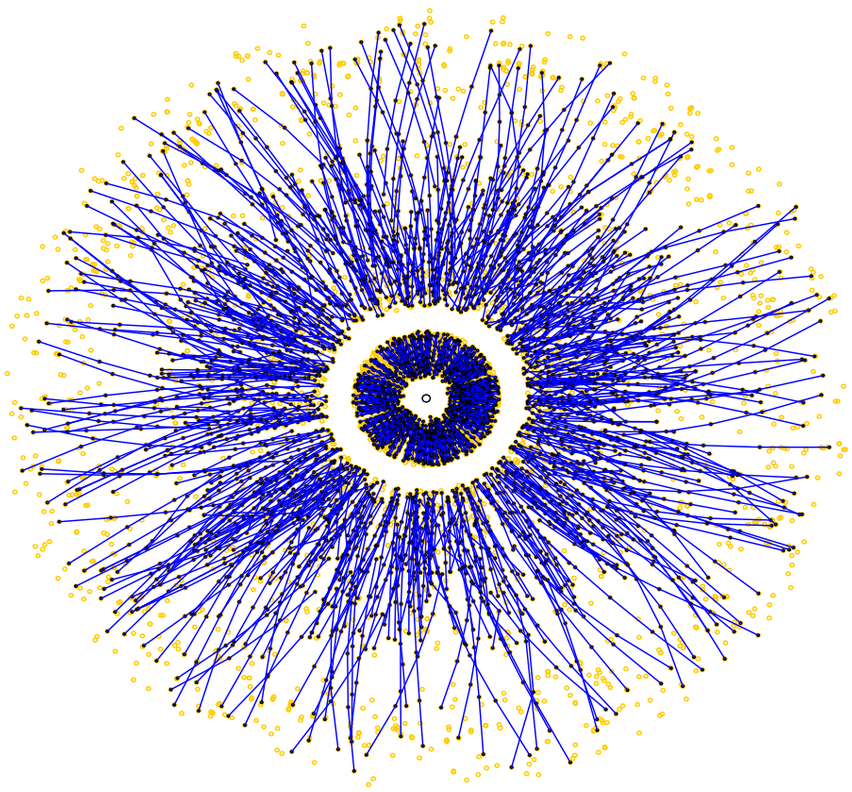
Momentum	reco / mc	efficiency
p > 0 GeV	0 / 0	0.00
p > 1 GeV	0 / 0	0.00
p > 2 GeV	270 / 330	81.81
p > 3 GeV	3405 / 3640	93.54
p > 4 GeV	5359 / 5593	95.81
p > 5 GeV	4748 / 4920	96.50
p > 6 GeV	3198 / 3314	96.49
p > 7 GeV	2413 / 2491	96.86
p > 8 GeV	1735 / 1802	96.28
p > 9 GeV	1276 / 1324	96.37
p > 10 GeV	1015 / 1046	97.03
p > 11 GeV	748 / 773	96.76
p > 12 GeV	558 / 577	96.71
p > 13 GeV	493 / 502	98.21
p > 14 GeV	368 / 375	98.13
p > 15 GeV	285 / 292	97.60
p > 16 GeV	250 / 254	98.42
p > 17 GeV	158 / 162	97.53
p > 18 GeV	159 / 161	98.75
p > 19 GeV	933 / 968	96.38
Total:	27371 / 28524	95.95
Ghost:	1153	

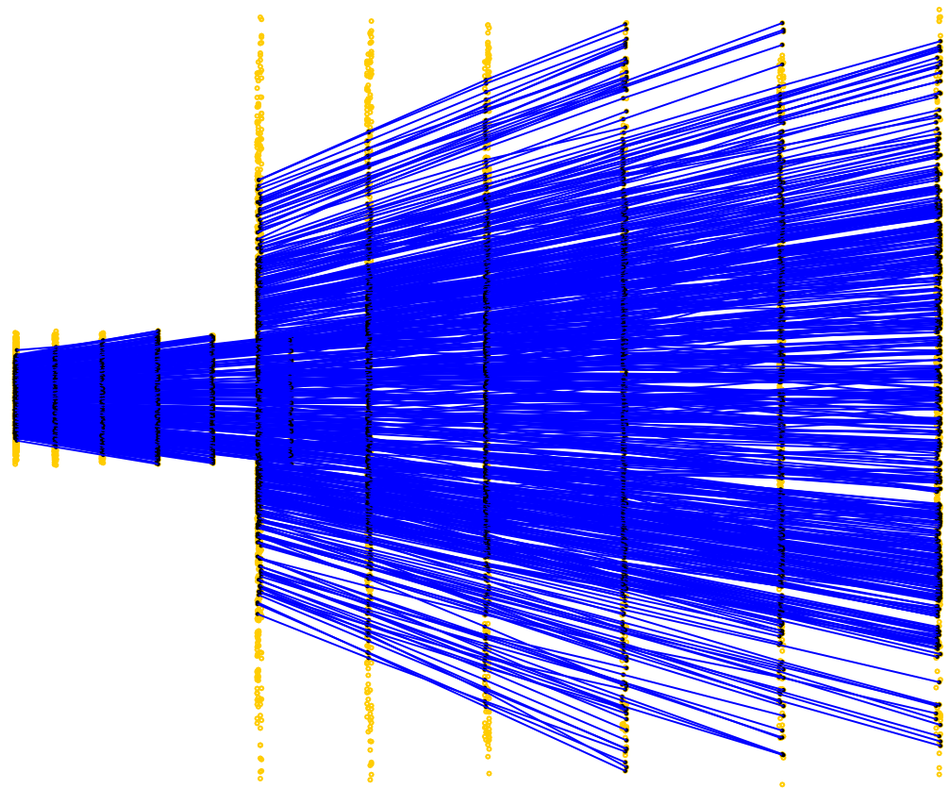
Tracking efficiency in Strip detector. nEvents: 100

Momentum	reco / mc	efficiency
p > 0 GeV	2 / 3	66.66
p > 1 GeV	6479 / 7058	91.79
p > 2 GeV	13738 / 14211	96.67
p > 3 GeV	11828 / 12771	92.61
p > 4 GeV	7950 / 8693	91.45
p > 5 GeV	4755 / 5313	89.49
p > 6 GeV	3099 / 3441	90.06
p > 7 GeV	2177 / 2408	90.41
p > 8 GeV	1447 / 1633	88.61
p > 9 GeV	1071 / 1186	90.30
p > 10 GeV	744 / 836	88.99
p > 11 GeV	559 / 626	89.29
p > 12 GeV	400 / 441	90.70
p > 13 GeV	333 / 377	88.32
p > 14 GeV	242 / 269	89.96
p > 15 GeV	178 / 190	93.68
p > 16 GeV	149 / 160	93.12
p > 17 GeV	100 / 116	86.21
p > 18 GeV	82 / 99	82.82
p > 19 GeV	549 / 617	88.97
Total:	55882 / 60448	92.44
Ghost:	4566	

Time: 137.633 ms/ev (OMP: 197.692 ms/ev)

Summary





- Developed a track finder based on the Cellular Automaton for track searching in the end-cap part of the ACTS detector.
- The procedure of track fitting based on the Kalman Filter was created.
- A procedure for approximating the magnetic field for its fast calculation during track fitting was created.
- The data structures suitable for working with parallel data streams are developed.
- The CA algorithm is vectorized (SIMD) using SSE and AVX instruction sets.
- The CA algorithm is parallelized (inside event) between CPU cores using OpenMP directives.
- Interfaces to operate with any detector systems inside ACTS are created.
- CA track finder and KF track fitter are integrated in ACTS, and documentation is also created.