Tracking with **A C**ommon **T**racking **S**oftware

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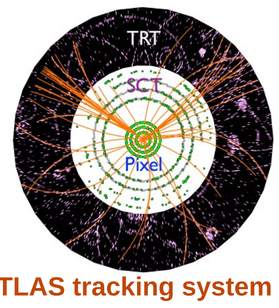
Institution: UC Berkeley

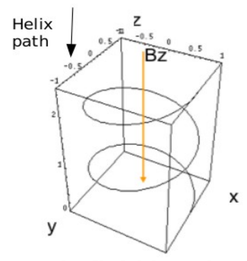
http://acts.web.cern.ch/ACTS/

What is tracking ?

- Reconstruct charged particle trajectories from detector (tracker) signals
- Determine the properties of those charged particles present
  - momentum, origin etc.



ATLAS tracking system

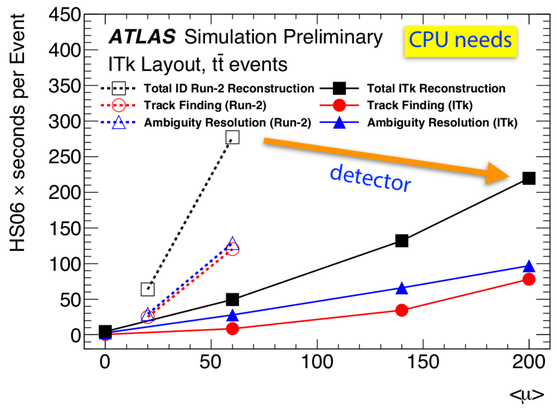


Magnetic field bends the charged trajectory

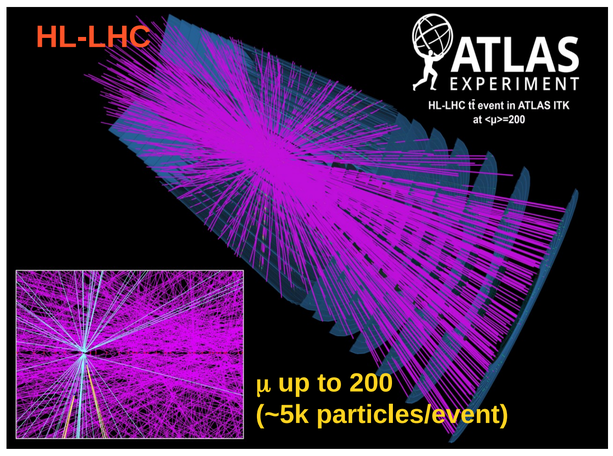
- **Input data preparation**
  - Raw data converted to cluster/drift circle
  - Formation of 3D SpacePoint
- **Track finding**
  - Identify the group of hits corresponding to a track
    - Global or local approach
- **Track fitting**
  - Estimate track parameter
    - Least squares estimation
    - KalmanFilter(could be merged with track finding)
- **Vertexing**
  - Associate sets of tracks to the same interaction point
  - Estimate vertex properties

Why is tracking a concern?

- Exponential growth of tracking time and CPU at future colliders
  - Scales in ~quadrature with pileup[1]



[1]: number of proton-proton collision point per bunch crossing, μ



- Limited performance gain from detector optimization
- Fast, accurate and efficient tracking software is crucial for physics program
  - Flavor tagging, missing E_T resolution etc.

The A Common Tracking Software (ACTS) project [2]

[2]: arXiv:1910.03128v2, DPF2019 proceedings: ACTS

A 'modern' open-source tracking toolkit to preserve and improve LHC tracking for future detectors with world-wide collaboration

Components and functionality

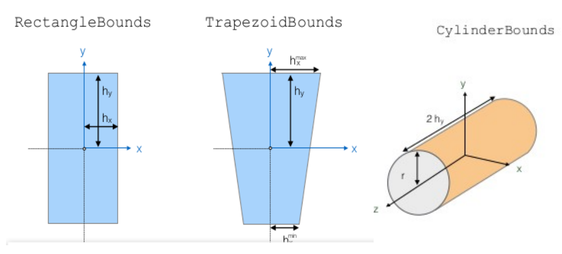
acts-core

- C++ concepts
- Thread-safe design
- Support contextual alignment, calibration, magnetic field
- Unit tests

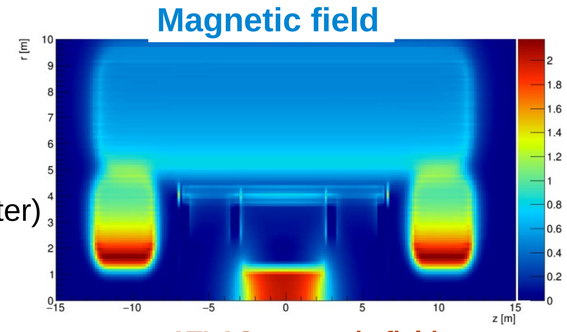
Tracking Tools

- Track seeding
- Track finding (Combinatorial KalmanFilter)
- Track fitting (KalmanFilter, GaussianSumFilter)
- Vertex Finding and fitting

Geometry



Magnetic field

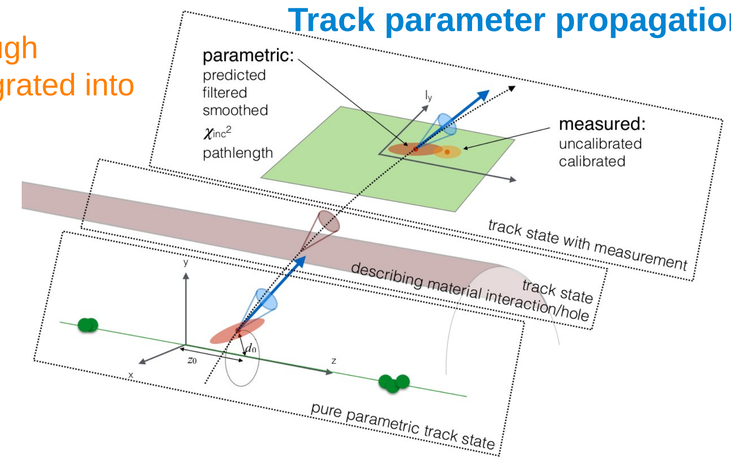


ATLAS magnetic field

acts-fatras

Fast simulation engine, simulate particle trajectories through detector, re-integrated into acts-core

Track parameter propagation



acts-framework

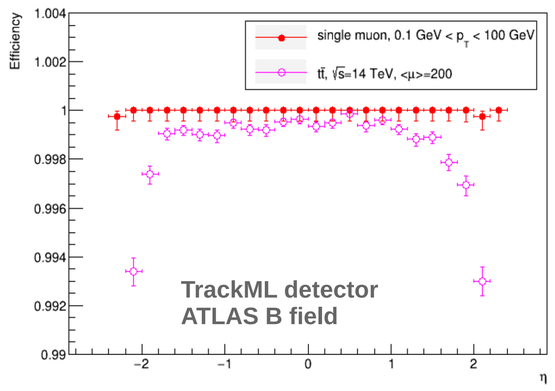
A light-weight Gaudi[3]-style framework for event processing, integration and concurrency test

[3]: Computer Physics Communications 140. 45 (2001)

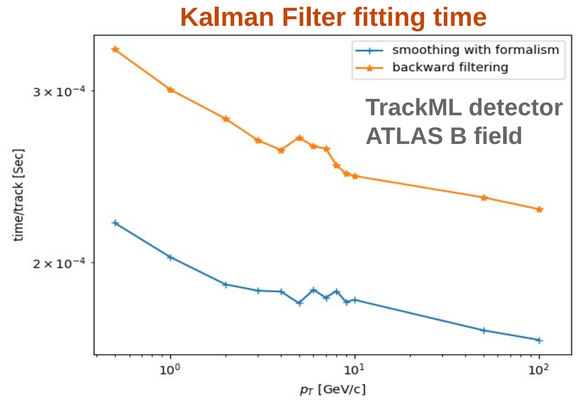
Tracking fitting and finding performance

- A full solution Kalman Filter implementation with performance well validated
  - Close to 100% efficiency. Fast fitting
  - Support hole search and outlier rejection during the fitting

Kalman Filter fitting efficiency

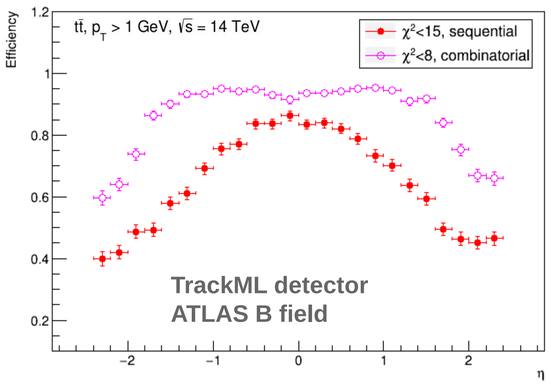


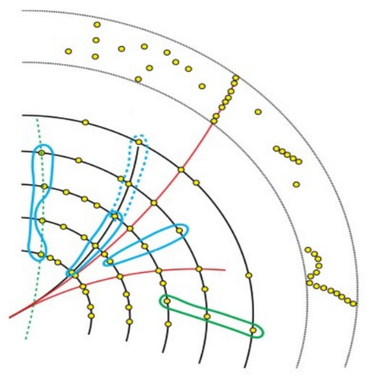
Kalman Filter fitting time

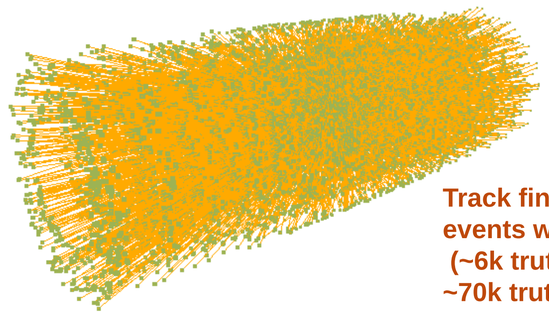


- Prototype of Combinatorial KalmanFilter for track finding
  - Simultaneous tracking fitting and finding (allow branching of tracks)
  - Improved tracking performance in dense environments

Combinatorial KalmanFilter track finding efficiency





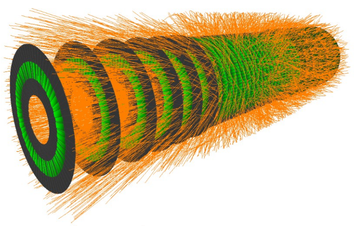


TrackML detector
ATLAS B field

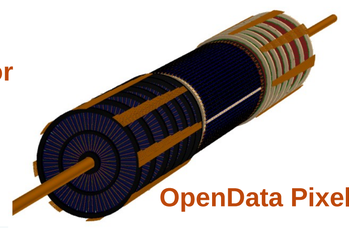
Track finding for ttbar events with μ = 200 (~6k truth particles, ~70k truth hits)

Application and R&D

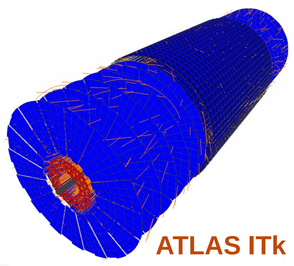
- ACTS is integrated in the athena framework; Feasibility studies ongoing for use of ACTS by Belle-II[4], sPhenix, EIC
- R&D platform for innovative tracking techniques and hardware architecture
  - TrackML[5] Challenge
  - Exploration of speed-up with multi-core, accelerators



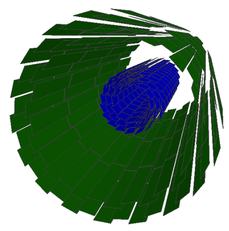
TrackML detector



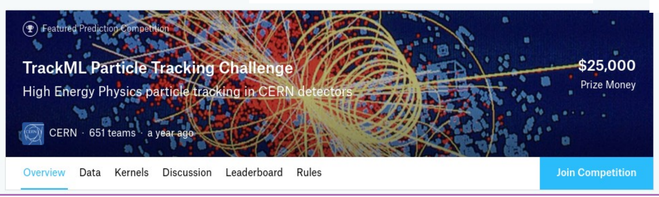
OpenData Pixel



ATLAS ITk



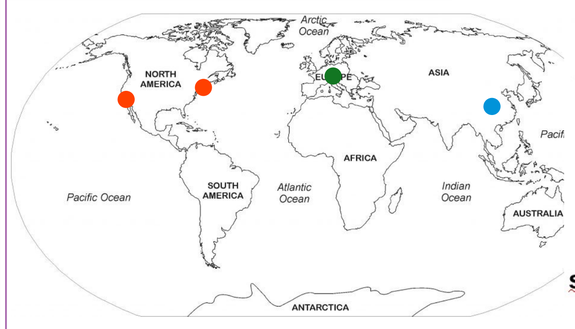
sPhenix silicon



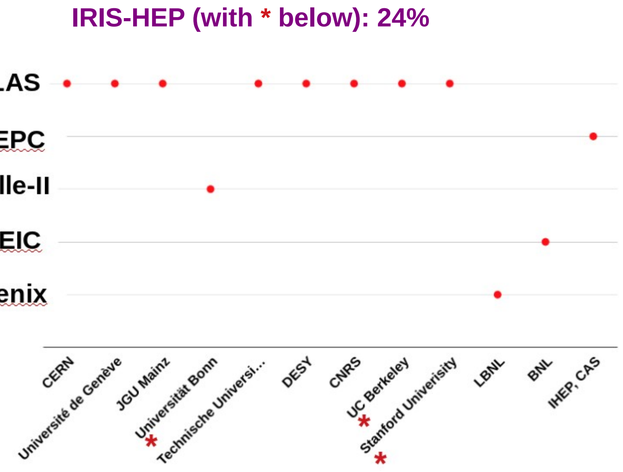
[4]: by IRIS-HEP fellow student Ralf Farkas

[5]: https://www.kaggle.com/c/trackml-particle-identification

World-wide collaboration



Estimated fraction of FTE from IRIS-HEP (with * below): 24%



Don't hesitate to get in touch if experiments are interested in collaboration with or using ACTS!

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