ACTS in Key4hep

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CERN & University of Bonn

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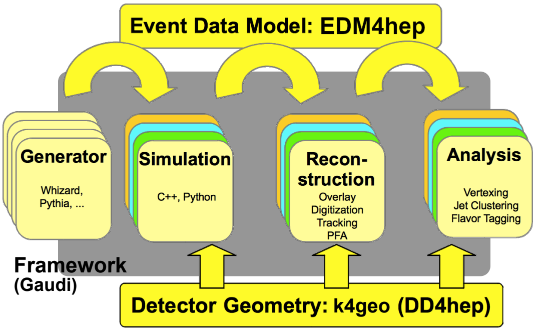
Agenda

- Brief introduction to Key4hep reconstruction and ACTS
- Status of ACTS in the Key4hep framework
- Plans for the future

Reconstruction in Key4hep

- Reconstruction is performed by a chain of Gaudi algorithms
- Algorithms can be easily put together if they take in and put out data in a common format: EDM4hep
- Geometry dependent algorithms can be re-used for different detector models if the there is a standardized description of the geometry: DD4hep
- Usually: one algorithm per task, e.g. digitization, track finding/fitting, vertexing



ACTS

- A(cts) Common Tracking Software
- Initially a modern from scratch rewrite of the ATLAS tracking Software
- Now a ‘generic’ tracking framework
- ATLAS inspired EDM
- Very fast geometry navigation and import of DD4hep geometries is possible*

*terms and conditions may apply

ACTS usage in (or related to) Key4hep

As far as I know:

- EIC: in `Juggler/JugTrack`. Usage of ACTS in Gaudi, but algorithms do not interface via EDM4hep. Loads geometry using ACTS' DD4hep plugin.
- Muon collider: `MuonColliderSoft/ACTSTracking` Marlin/LCIO based.
- LUXE: Fork of `MuonColliderSoft/ACTSTracking`
- Key4hep "proper": `k4ActsTracking`

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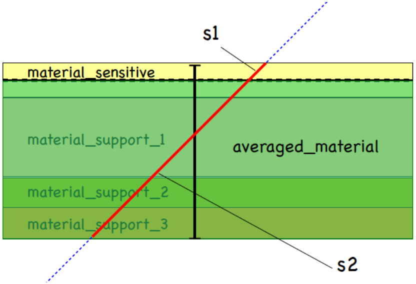
key4hep/k4ActsTracking

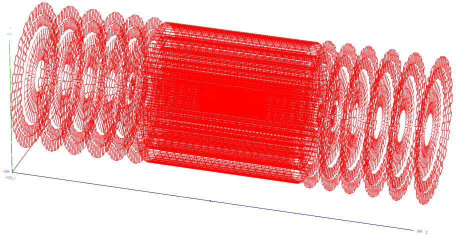
- Goal: provide general purpose Gaudi algorithms for ACTS usage with plain EDM4hep interface for easy plug-and-play
- More details in a couple of slides

Tracking ingredients

Geometry

- Tracking algorithms need access to geometry information
- Used to estimate energy losses and to extrapolate to the next possible hit position
- Usually not the 'full' Geant4 model but surfaces averaging the material
- Surface representation 'automatically' generated from the full model





Tracking ingredients

Event data model (EDM)

- The language your tracking algorithm uses to communicate with the other parts of the reconstruction
- As input: some kind of 'digitised' tracker hits
- As output: a track, usually a set of 5 parameters describing a helix
- Sometimes translation is required

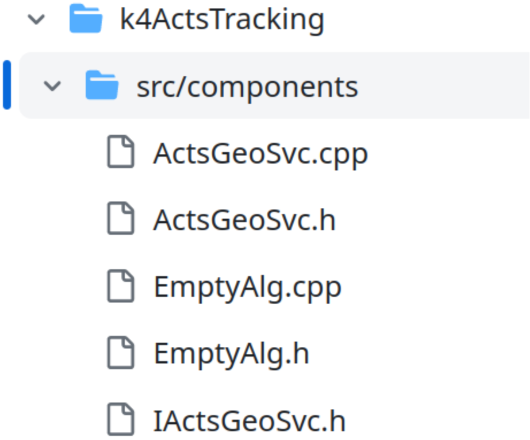
Track parameters

- EDM4hep: $(d_0, \phi, \Omega, z_0, \tan\lambda, t)$
- ACTS: $(l_0, l_1, \phi, \theta, q/p, t)$
- Requires geometry information to translate

Status of `k4ActsTracking`

What is there?

- `ActsGeoSvc`: instantiates an ACTS tracking geometry from DD4hep and lets other algorithms use it
- Caveat: unable to load the CLD model, so I use the OpenDataDetector (ODD) for development
- MC-truth based tracking in preparation
- EIC people are looking to upstream some of their developments



k4ActsTracking::TruthTracking

- Goal: create all ‘true’ tracks
- Take all reconstructed hits of a `MCParticle` and fit them with the ACTS Kalman filter
- Good test of all the necessary parts
- Status: first track fits achieved!
- Missing: conversion from ACTS to EDM4hep tracks, flexible number of input collections
- Code not on Github yet

```
INFO Hello from event: 1
INFO track fit ok :)
INFO track momentum: 1.00842
INFO Hello from event: 2
INFO track fit ok :)
INFO track momentum: 0.947415
INFO Hello from event: 3
INFO track fit ok :)
INFO track momentum: 1.02946
```

What is still missing

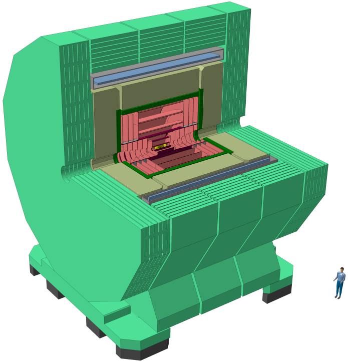
- `Refit`: Will be almost for free once `TruthTracking` works, at the moment waiting for EDM4hep interface types **PR#252**
- More geometries, ACTS has a new (better) way to load DD4hep geometries that I still need to try out
- Any kind of track finding/pattern recognition

Interlude: (re-)using iLCSoft tools

Used by CLD:

- `MarlinTrkProcessors`
  - A collection of processor for digitization, track finding and fitting.
  - `DDPlanarDigiProcessor`, `RefitFinal`, `ClonesAndSplitTracksFinder`
- `MarlinTrk`
  - Provides track factory and interface to different fitters (`DDKalTest`, `aidaTT`)
- `ConformalTracking`
  - Finds and fits tracks using a conformal mapping[1]

More details: **FCC SW meeting** and **1st ECFA Reco WS**



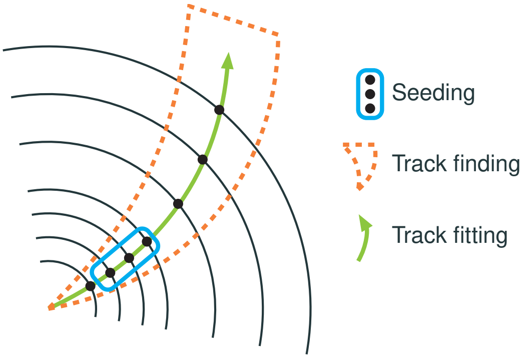
Using `k4ActsTracking` together with Key4hep

Some geometry requirements

- The DD4hep geometry of your detector needs to be loadable by ACTS
- 'Special' detector ID scheme if you want to reuse digitisers (e.g. `DDPlanarDigiProcessor`), track finding (e.g. `ConformalTracking`) etc. from ilcsoft
- (Search k4Geo for GlobalTrackerReadoutID)

How can you help

- Implement any kind of ‘real’ track finding
- An algorithm using the ACTS combinatorial Kalman filter will be relatively easy
- More sophisticated pattern recognition will require more work
- Vertex finding, digitisation or other things using ACTS



[ACTS documentation]

Future plans

Short-term:

- TruthTracking algorithm

Medium-term:

- New geometry loading
- Refit algorithm
- Also Gaussian sum filters for fitting

Long-term:

- Add more things, developed by **you**

Summary

- The ACTS integration into Key4hep is progressing
- The main hurdles are geometry loading and EDM conversion (and lacking ACTS documentation)
- First track fits were achieved and a Gaudi algorithm for truth tracking and refits will be ready soon
- Additional person power will be needed to also cover track finding/seeding (pattern recognition)

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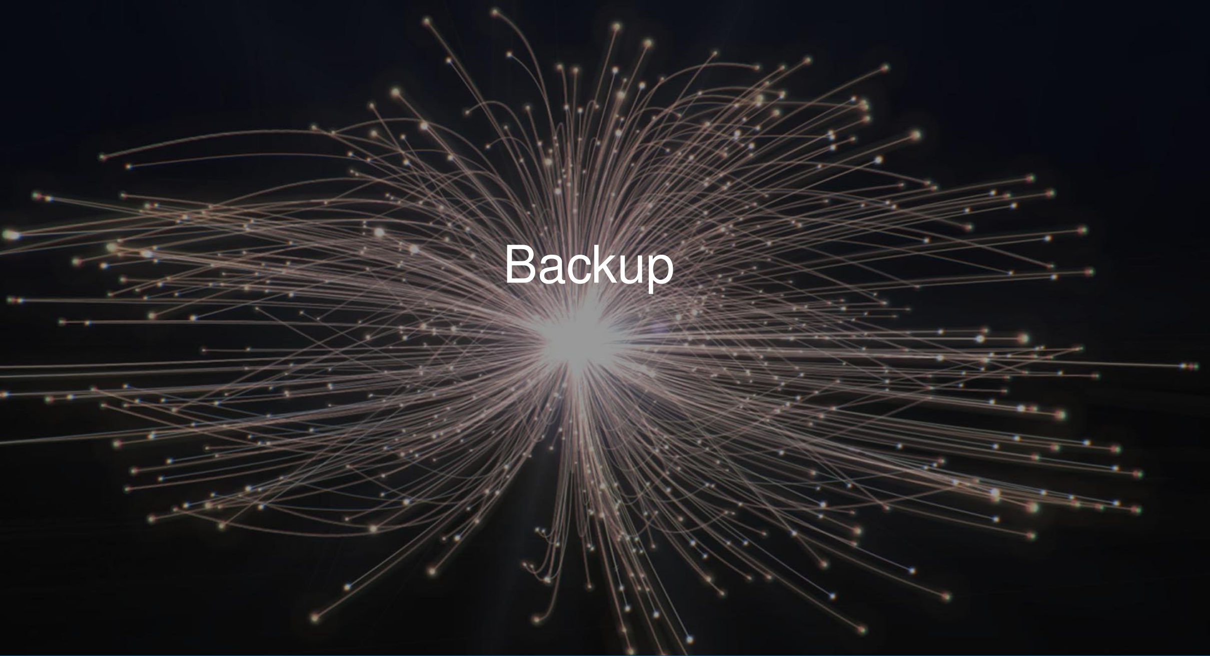

Backup

Tracking in Key4hep

Used by CLD/CLICdet:

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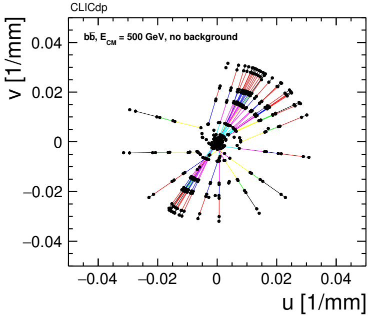
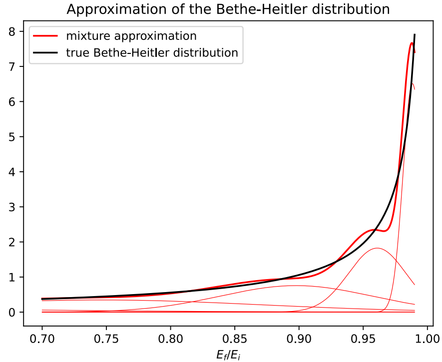


Tracks in conformal space

Gaussian sum filters (GSF)

- Approximate more complicated energy loss by a mixture of gaussians
- Successively remove or down-weight components incompatible with measurements
- Available in recent ACTS releases and actively improved on a regular basis



[ACTS documentation]

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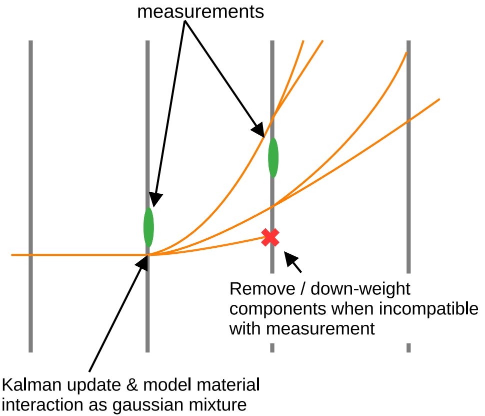
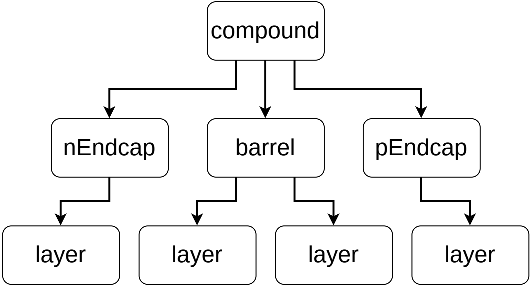


[ACTS documentation]

From DD4hep to ACTS surfaces

ACTS DD4hep plugin

- Parses the DD4hep geometry to build the ACTS tracking surfaces
- To not complicate the parser it expects a certain hierarchy of the geometry (see right)
- Most detector model implementations in `k4Geo` do not fullfil the criteria
- It is a problem to only have one endcap that is mirrored like in the DD4hep examples



DD4hep geometry definition layout expected by ACTS

Improving the performance

Idea:

- A gaussian sum filter could improve the electron track reconstruction, especially for a detector with silicon tracking like CLD
- Do not re-implement this ourselves but use a modern tracking framework that already supports GSFs: ACTS
- Bonus: maybe gain a speedup from the more sophisticated ACTS geometry navigation also for the regular Kalman filter track fit

Necessary ingredients:

- Detector geometry ✓ (ACTS DD4hepPlugin)
- Tracker hits, tracks ✓ (ACTS EDM4hepPlugin)
- Also reliable back-and-forth conversion of LCIO-EDM4hep ✓

Sounds very straightforward, maybe someone has already done it?

Tracking surfaces

- Both ACTS and the tracking algorithms already available in Key4hep use a simplified geometry
- Sensors approximated by surfaces with averaged material
- All our k4Geo/DD4hep geometries already have this DDRec surface information
- Ongoing cooperation with the ACTS authors to initialize ACTS geometry from our DDRec surfaces