RECONSTRUCTION WITH KEY4HEP

Overview of Key4hep reconstruction tooling

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for the Key4hep developers

CERN

First ECFA Workshop on e^+e^- Higgs / Electroweek / Top Factories

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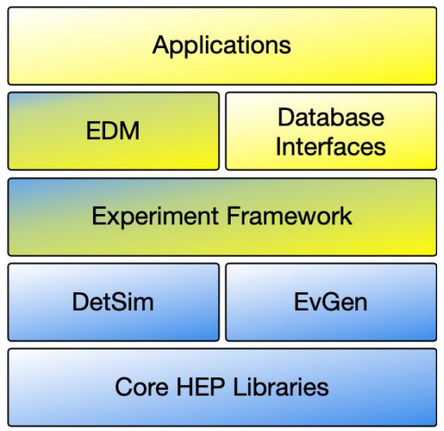
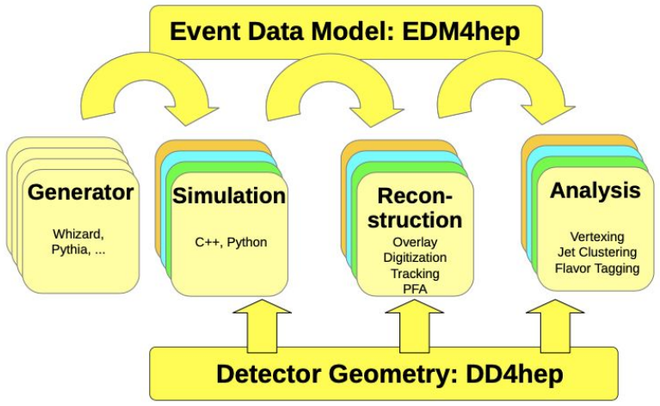
KEY4HEP

- Set of common software packages, tools, and standards for different Detector concepts
- Common for FCC, CLIC/ILC, CEPC, EIC, …
- Individual participants can mix and match their stack
- Main ingredients:
  - Data processing framework: Gaudi
  - Event data model: EDM4hep
  - Detector description: DD4hep
  - Software distribution: Spack

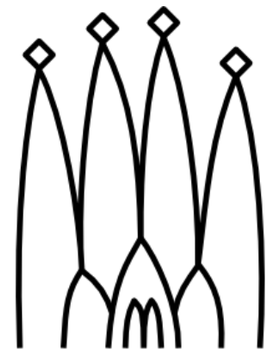


OS Kernel and Libraries (Non-HEP specific)



GAUDI

- Data processing framework
  - Stitches and steers various algorithms together
  - Controls event loop
  - Manages transient storage and I/O
- Used by live experiments: ATLAS, LHCb
- Allows concurrency, new developments: `Gaudi::Functional`
- Key4hep started life by attempting to reuse algorithms already developed
- Need for convertors/wrappers: k4MarlinWrapper, k4CLUE, k4Pandora, …



Hello World in Gaudi:

```
from Gaudi.Configuration import *
from Configurables import HelloWorl

alg = HelloWorldEx()

ApplicationMgr(
    EvtMax = 10,
    EvtSel = 'NONE',
    HistogramPersistency = 'NONE',
    TopAlg = [alg],
)
```

Source: Gaudi

RUNNING THE RECONSTRUCTION

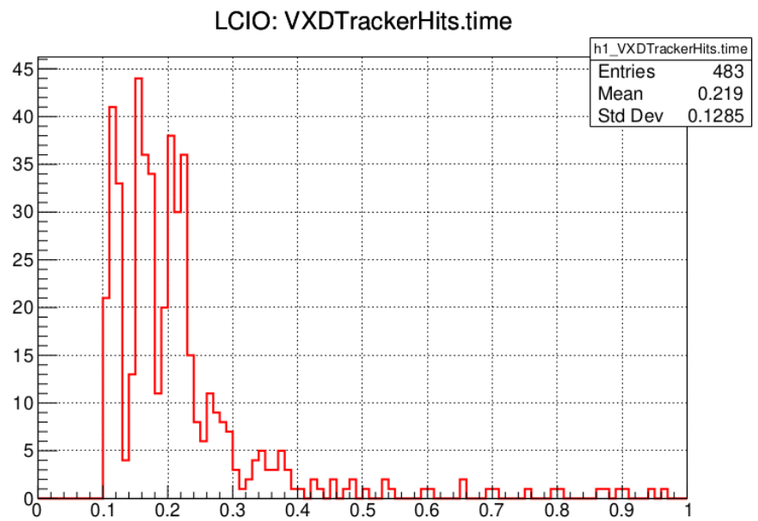
- Multiple possibilities how to run:
  - As part of the larger steering
    - Input from: k4SimGeant4, k4SimDelphes
  - As a separate step
    - Input from: … + DDSim
- In both cases I/O needs to be handled (PODIO)
  - Reading event data from in EDM4HEP ROOT files
  - LCIO Conversion: k4LCIOReader
- Algorithms developed for Marlin needs to be wrapped
  - Also here LCIO conversion is required
  - iLCSoft repository
- Detector description and instantiation is done with DD4hep
  - XML + C++ code
- Easiest way to access the stack is from CVMFS:

```
source /cvmfs/sw.hsf.org/key4hep/setup.sh
```

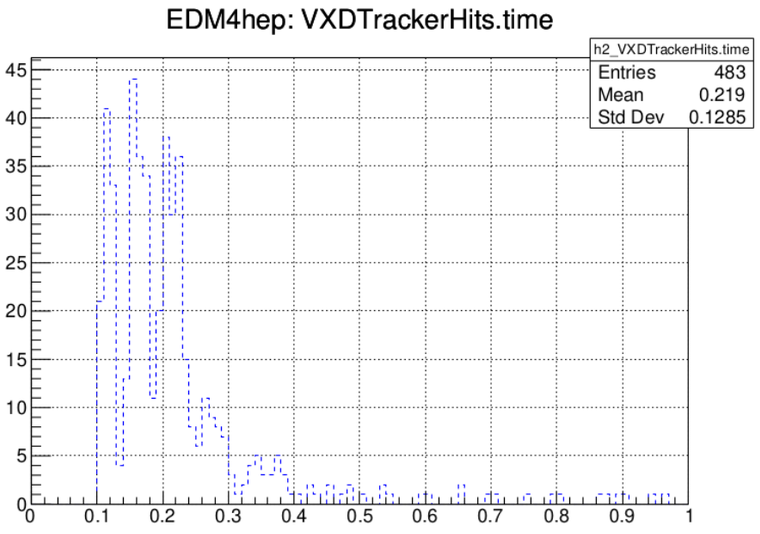
DIGITIZATION

- The digitization could be done as
  - Last simulation step
  - First step of reconstruction
- Detector specific, two main EDM4HEP datatypes

  `SimTrackerHit`, `SimCalorimeterHit`
- Simple approach in case of k4RecCalorimeter: Sum hit in a cell

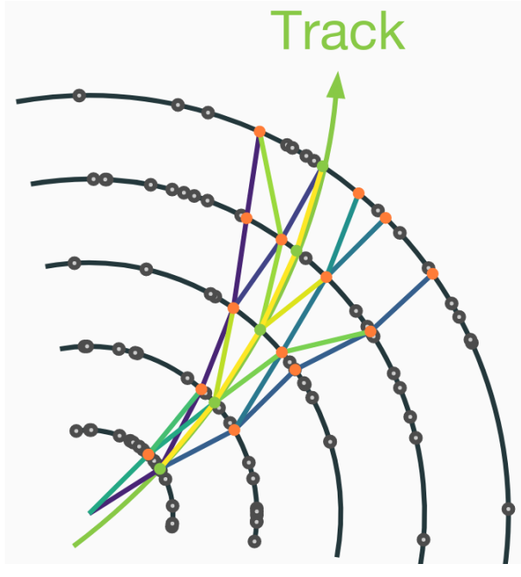


- More involved solutions in MarlinReco
  - TrackDigi and CaloDigi
- Recent highlight: Effort to add generic digitization components into DD4hep (DDDigi)
- Recent highlight: Conversion of DDPlanarDigiProcessor

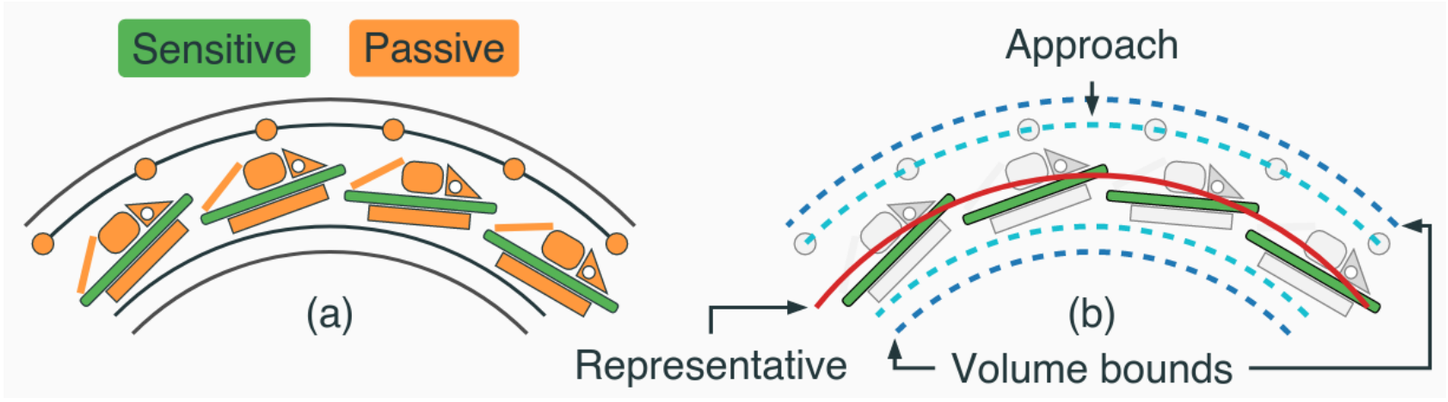


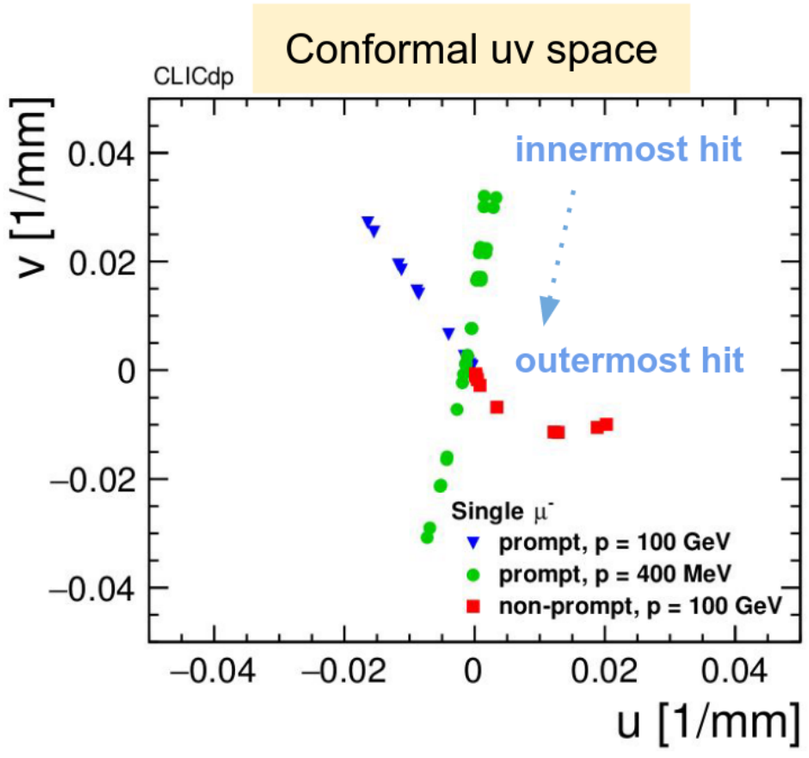
TRACKING

- Work on integrating ACTS into the Key4hep underway
  - State-of-the-art track reconstruction
  - Project was spawned from tracking code of ATLAS
  - The Key4hep wrapper: `k4ActsTracking`
  - Recent highlights:
    - Seamless loading of FCC detector models
    - Inclusion of EIC framework components



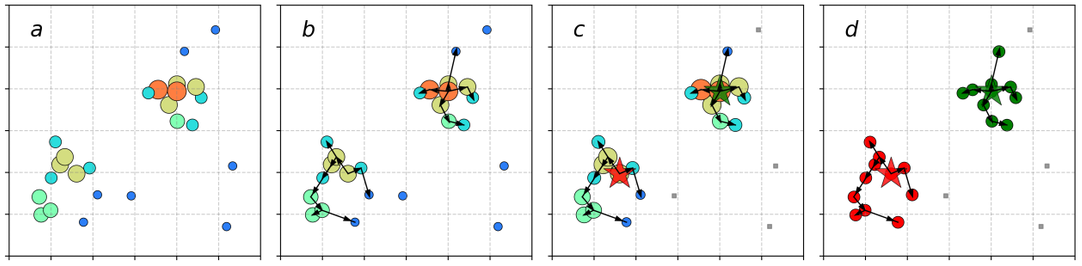
- Available as Marlin processors:
  - Conformal tracking
  - Clupatra
  - ForwardTracking for the FTD

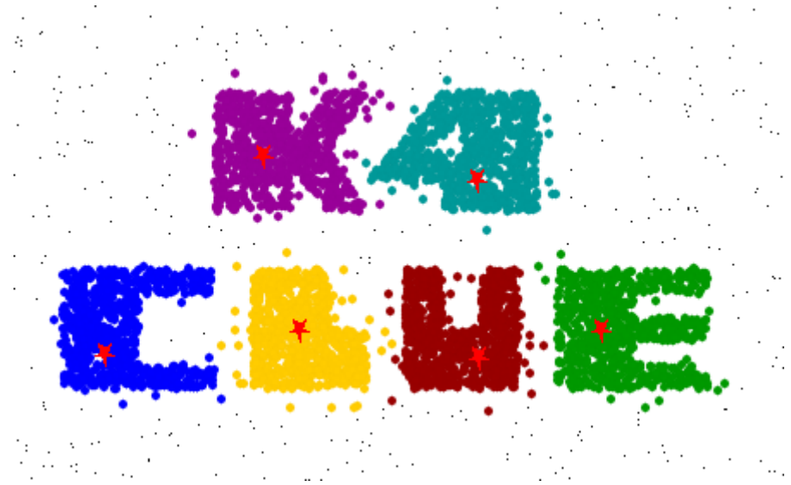




CLUSTERING

- CLUE: CLUstering of Energy
  - Intergrated in Key4hep as k4CLUE
  - Uses energy density to define ranking, seeding thresholds, …



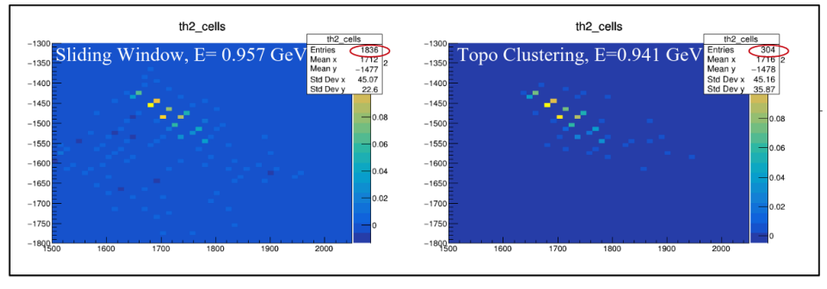


- LAr Calorimeter Reconstruction:

  `k4RecCalorimeter`

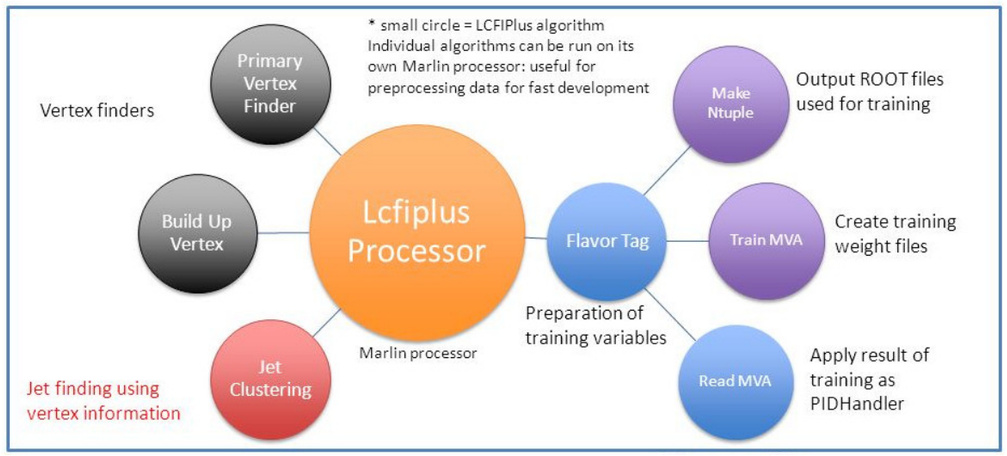
  - Sliding Window and TopoCluster based algorithms
  - Algorithm developed in proto Key4hep environment

1 GeV electron, **with noise**

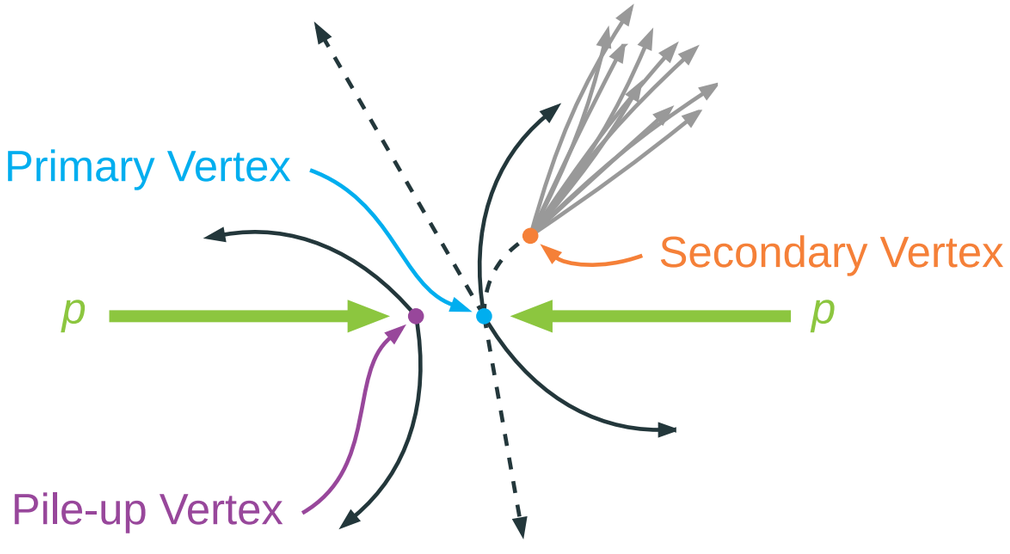


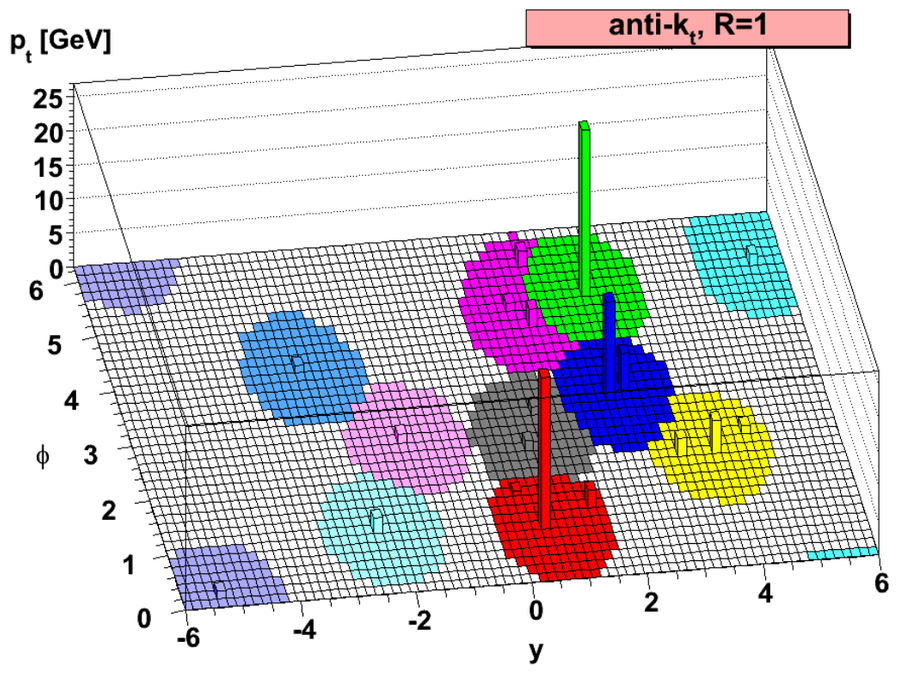
OTHER RECONSTRUCTION ALGORITHMS

- Through Marlin Wrapper are available also:
  - LCFIPlus for vertexing and flavour tagging
  - FastJet for jet clustering
  - KinematicFitting
  - Particle ID
  - Conditions



- ACTS is also capable of vertexing

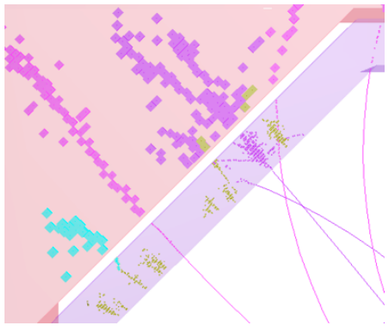


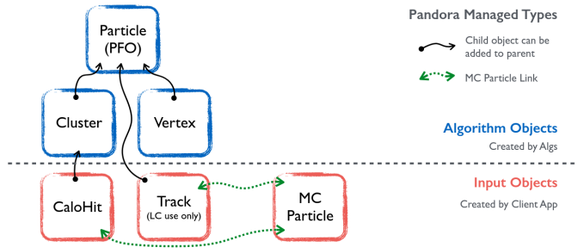


[arXiv:0802.1189]

HIGHER LEVEL RECONSTRUCTION

- PandoraPFA is a prime candidate for the integration in k4Pandora
- It integrates multitude of pattern recognition algorithms
- Developed for reimplementation of PFA at future e+e- linear collider
- Ongoing efforts revolve around developing a direct Gaudi wrapper k4Pandora or use of two existing ones k4MarlinWrapper+DDMarlinPandora
- Recent highlight: Dummy clustering achieved in k4MarlinWrapper+DDMarlinPandora



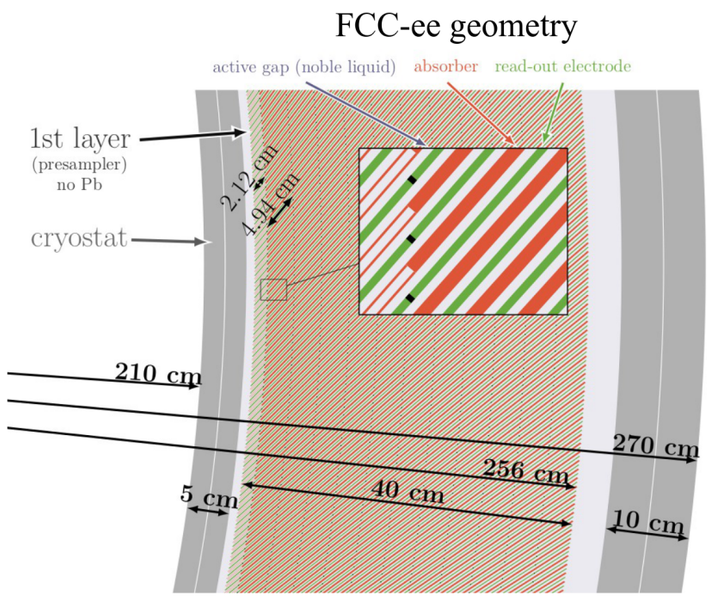


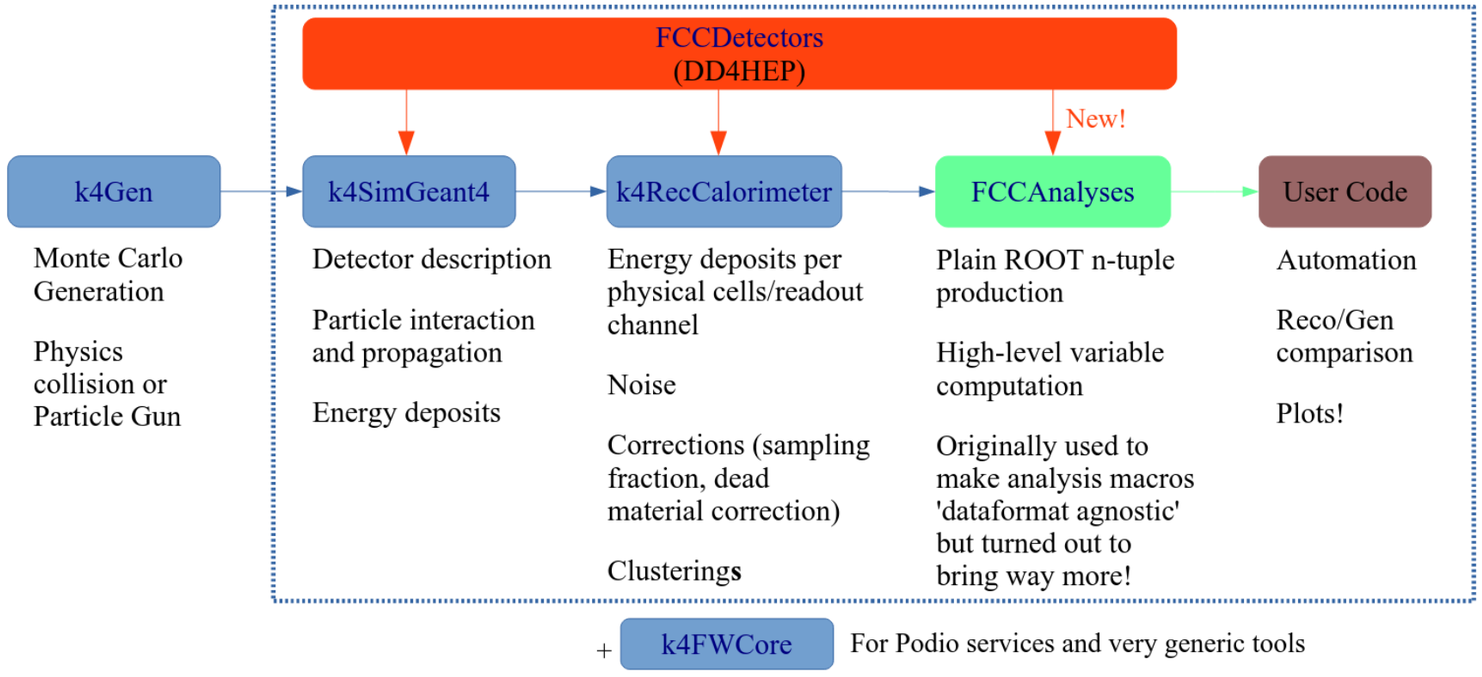
Algorithm 3 Pseudocode description of a client application for LAr TPC event reconstruction in a single drift volume

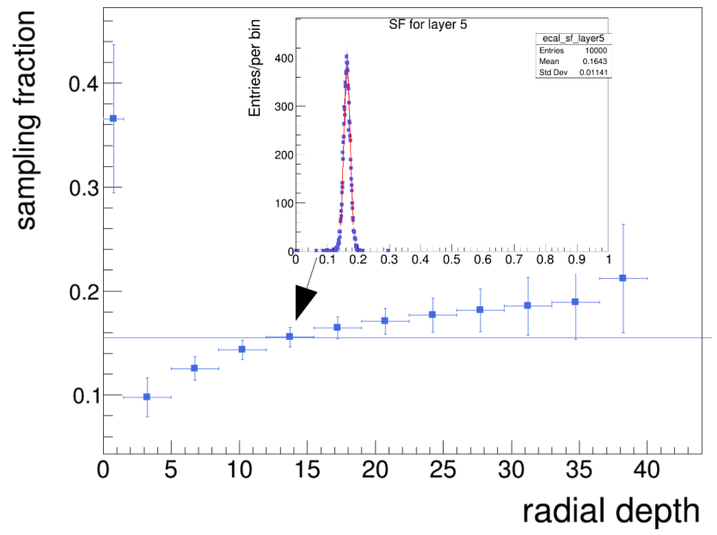
```
1:  procedure MAIN
2:      Create a Pandora instance
3:      Register Algorithms and Plugins
4:      Ask Pandora to parse XML settings file
5:      for all Events do
6:          Create CaloHit instances
7:          Create MCParticle instances
8:          Specify MCParticle-CaloHit relationships
9:          Ask Pandora to process the event
10:         Get output PFOs and write to file
11:         Reset Pandora before next event
```

EXAMPLE: LAR CALORIMETER

- Sampling Calorimeter based on LAr/LKr + Pb/W
- Simulation/Reconstruction fully steered in Gaudi
- Several Gaudi based algorithms include
  - Sampling fraction determination
  - Upstream/Downstream energy correction
  - Adding noise to Calo Cells
  - Clustering: Sliding Window or TopoCluster based

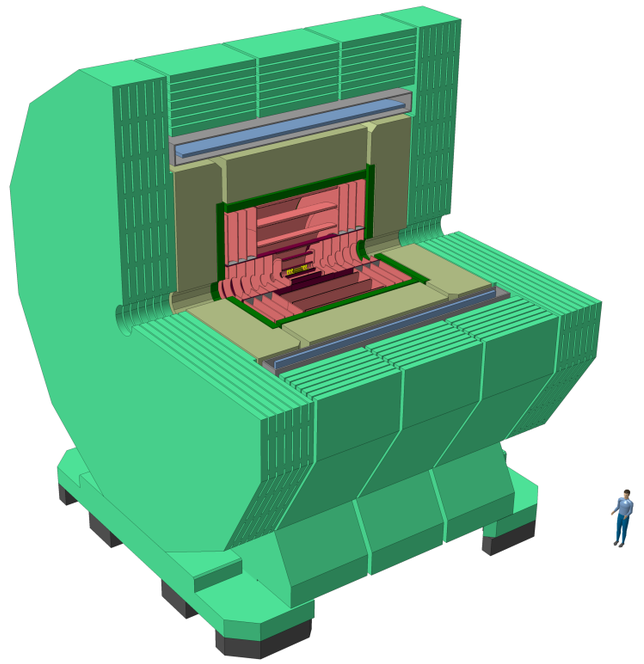


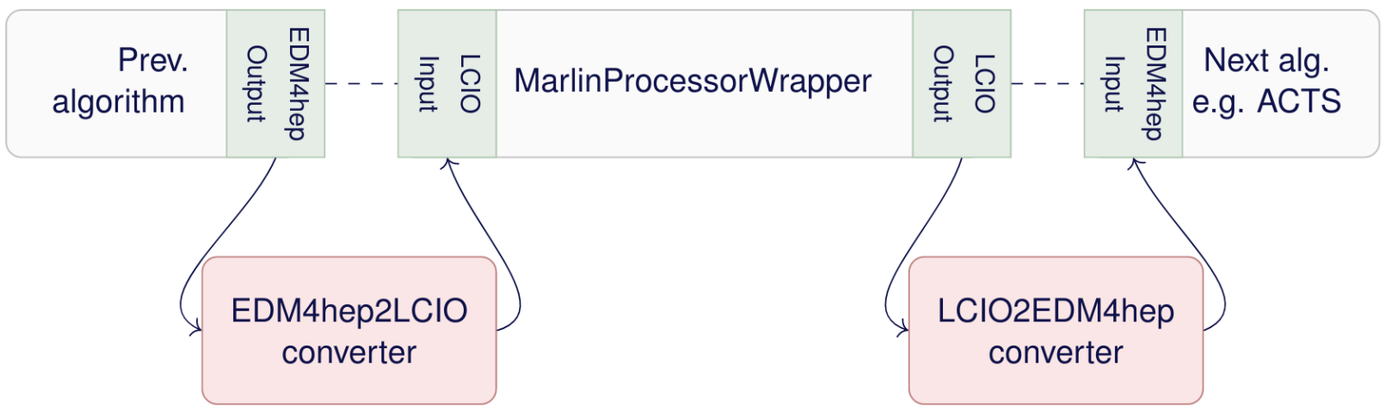


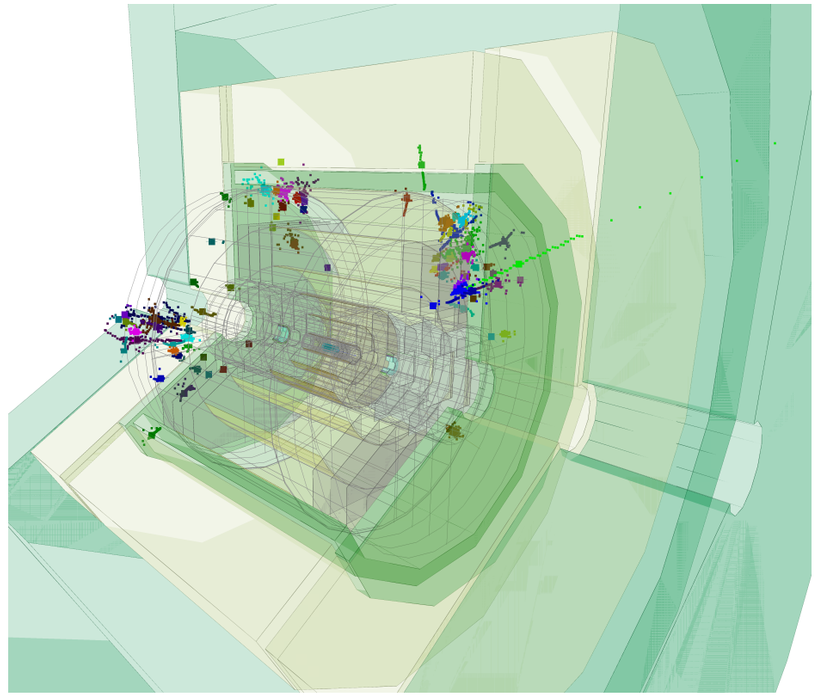


EXAMPLE: CLD

- Uses DDSim to simulate events
- Heavy use of the converters
- The reconstruction consists of
  - Background Overlay, Digitization
  - Track Pattern Reconstruction (ConformalTracking), track fit
  - Particle Flow Reconstruction (PandoraPFA)
  - Vertexing and Flavour Tagging (LCFIplus)
  - Full CLD reconstruction in gaudi
- Input and output are in EDM4hep







CONCLUSIONS

- The reconstruction for the future colliders is slowly taking shape
- Mostly thanks to the ability to integrate specialized projects
- `k4MarlinWrapper` helps to bridge transitional period
- Future algorithms have well defined environment to count on
- Effort required to port reconstruction of already existing detector concepts to Key4hep

BACKUP

SUMMARY

RECONSTRUCTION WITH KEY4HEP I

- Key4hep: Gaudi, EDM4hep, DD4hep, Spack
- Key4hep has ability to integrate other advanced reconstruction tools/frameweworks
- `k4MarlinWrapper` helps to bridge transitional period
  - DDMarlinPandora, LCFIPlus, ConformalTracking, …
- Integration of large frameworks underway
  - K4CLUE, k4Pandora, k4ActsTracking
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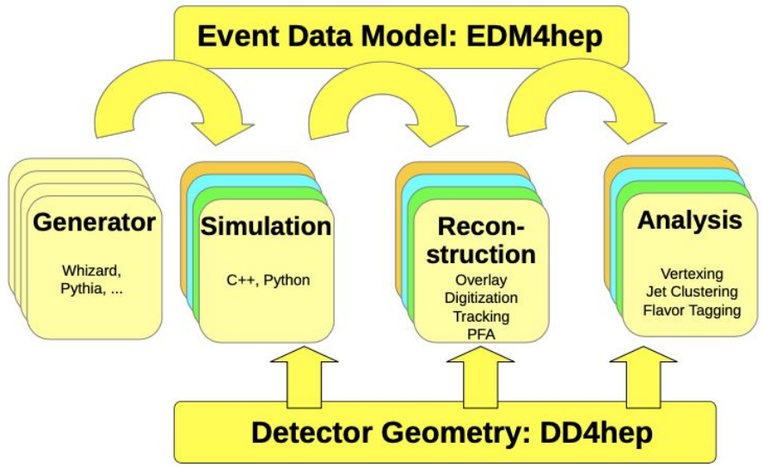

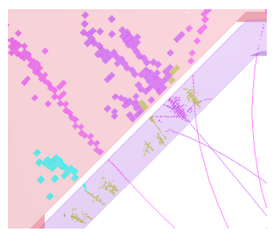

RECONSTRUCTION WITH KEY4HEP II

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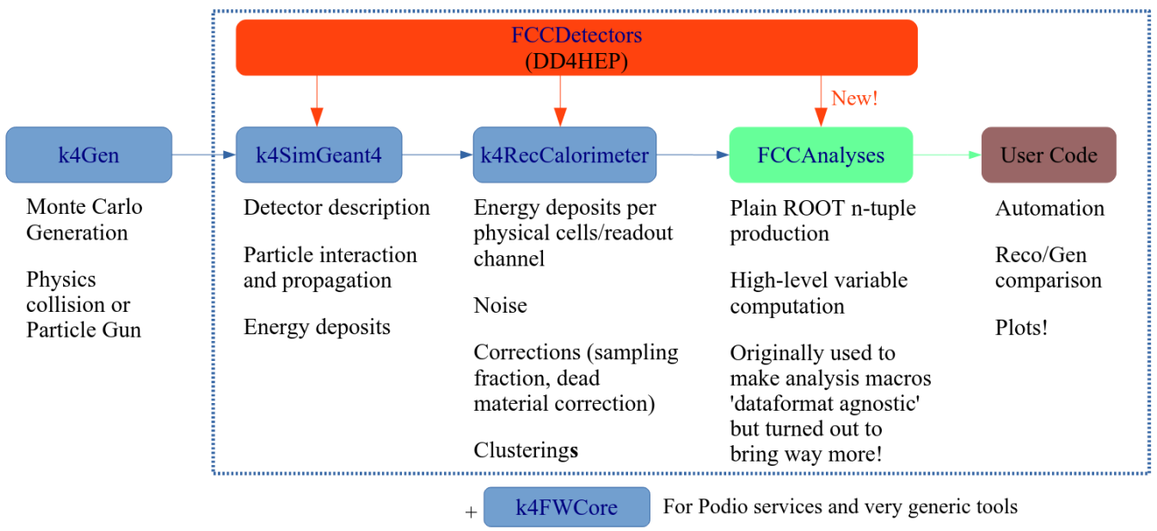

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