Common Software Tools for Reconstruction

FCC Week 2022

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Valentin Volkl, for the Key4hep + FCC SW groups
CERN

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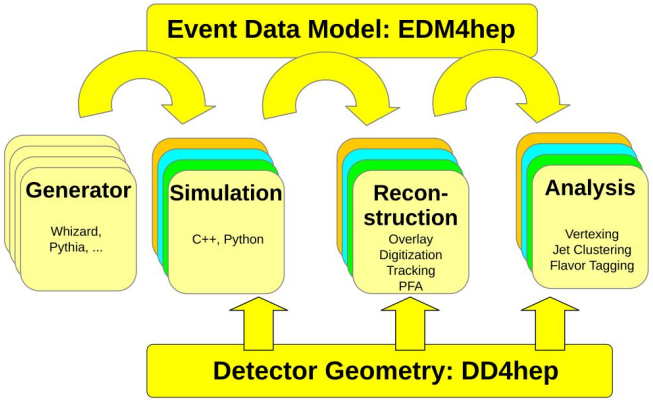
Common software tools for future colliders - a.k.a. Key4hep

Software stack that connects and extends packages to provide a complete data processing framework, comprising fast and full simulation, reconstruction, and analysis.

- Contributions from different Future Collider communities
  - FCC, CLIC, ILC, CEPC, EIC, ...
- Consistent choice of technologies for interoperability
  - EDM4hep: datamodel
  - Gaudi: framework
  - DD4hep: geometry information
  - Spack: package manager
- Ease of use for librarians, developers and users
- Provide examples, documentation, templates and comm practices



This talk highlights only some efforts:

- iLCSoft with k4MarlinWrapper
- Acts
- LAr Calorimetry Reconstruction and k4Pandora
- k4Clue

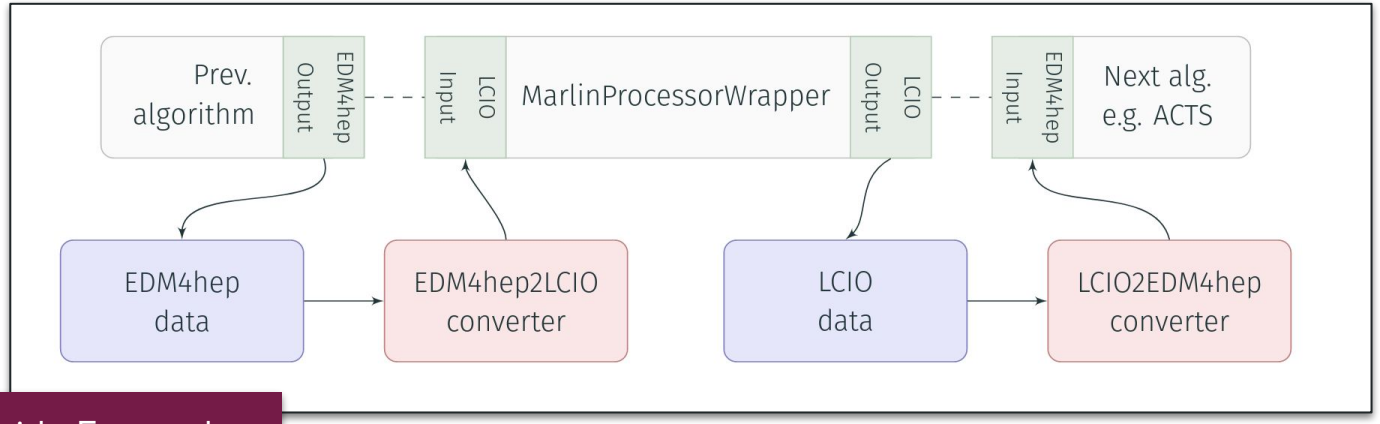
iLCSoft reconstruction chain

See talk on CLD by Andre Sailer

- Standard reconstruction for CLD:
  - Background Overlay, Digitisation
  - Track Pattern Recognition (*ConformalTracking*), track fit
  - Particle Flow Reconstruction (*PandoraPFA*)
  - Vertexing and Flavour Tagging (*LCFIplus*)

... and more (FastJet, KinematicFitting, particle ID ...) available

- iLCSoft Reconstruction chain available through **k4MarlinWrapper**
  - Allows running all existing *Marlin* processors from iLCSoft in the Key4hep Gaudi framework



Andre Sailer, Placido Fernandez

ACTS A Common Tracking Software

Project to preserve and enhance LHC track reconstruction software for future **detectors**

A flexible, **open source R&D testbed**:

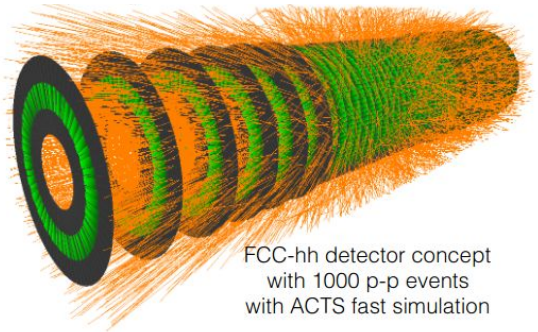
- Facilitate collaboration across experiments and external contributors, e.g. machine learning experts
- Allow for novel algorithms and detector components (e.g. timing, tracklets)

A high-performant toolbox for track reconstruction based on LHC experience

- Modern code and software concepts to allow for concurrent computing
- Support high luminosity and high precision tracking algorithms

Very active ongoing efforts:

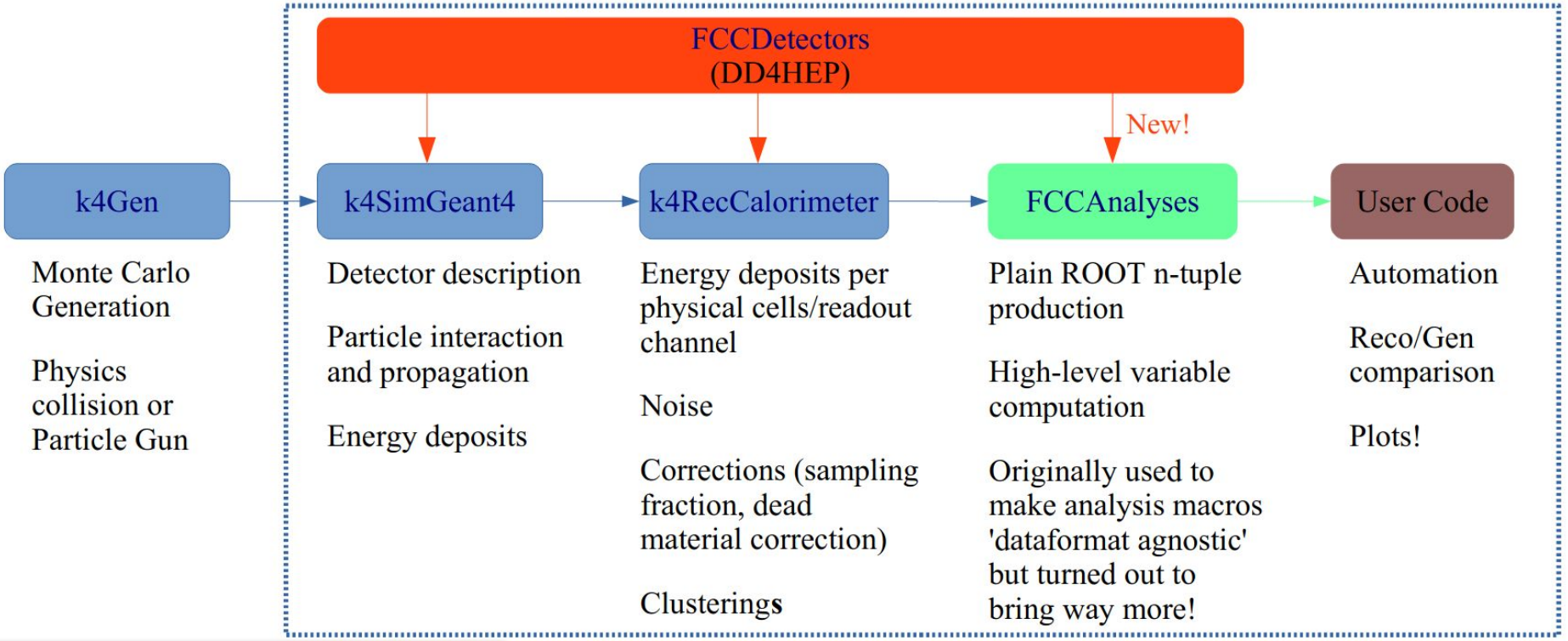
- Updating geometry loading for seamless use with FCC detector models
- Include existing EIC framework components



FCC-hh detector concept
with 1000 p-p events
with ACTS fast simulation

k4Acts: Andreas Salzburger, Paul Gessinger, Andreas Steffl

LAr Full Calo Sim: in a nutshell



Brieuc Francois, Jana Faltova

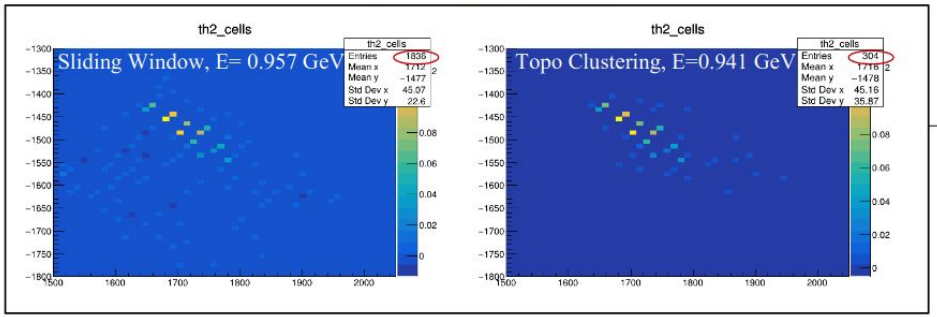
LAr Full Calo Sim: Clustering

Workshop on GranuLAr noble liquid argon detectors

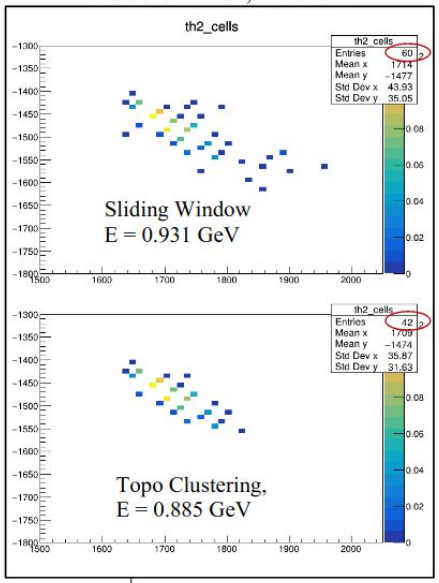
- Two clustering algorithms available
  - CreateCaloClustersSlidingWindow
    - Simple sliding window with fixed size
  - CaloTopoCluster
    - Find seeds and iteratively collects cells in several steps of S/N thresholds
    - Needs two maps: cell ID ↔ neighbors ID and cell ID ↔ noise value
      - Derived in a separated step and stored in a rootfile
    - Not well implemented (should be refactored at some point) but it works...
- Will soon try out the standalone CLUE algorithm

k4RecCalorimeter

1 GeV electron, **with noise**



1 GeV electron, **no noise**



x/y axis are x/y cell positions, z is the cell energy (binning ≠ cell granularity)

Only filling cells actually attached to the cluster, others are set to 0 by Root

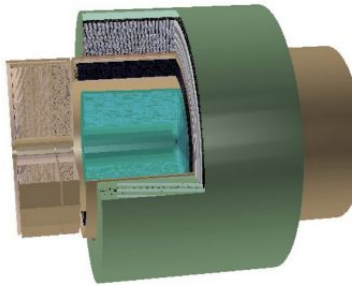
No dead material correction applied

Brieuc Francois, Jana Faltova

LAr Full Calo Sim: What do we need more?

Workshop on GranuLAr noble liquid argon detectors

- Is there anything missing?
  - Yes, quite a lot!
  - **Cross-talk emulation**
  - Detector non uniformities (can this be done easily in DD4HEP?)
  - Proper digitization
  - Central algorithm deriving cluster axis and shape variable
  - Many algorithms still rely on η detector segmentation and should be moved to a cos(Θ) segmentation
  - **Particle Flow** (see Juraj's talk!)
    - **A comprehensive detector optimization (especially for the granularity) can not be done without this**
  - A complete detector with tracks and physics objects reconstruction
  - A stable and 'high resolution' **visualization tool**
    - Helps a lot for detector geometry validation
      - Need to check tiny features (e.g. LAr gap widening, segmentation)



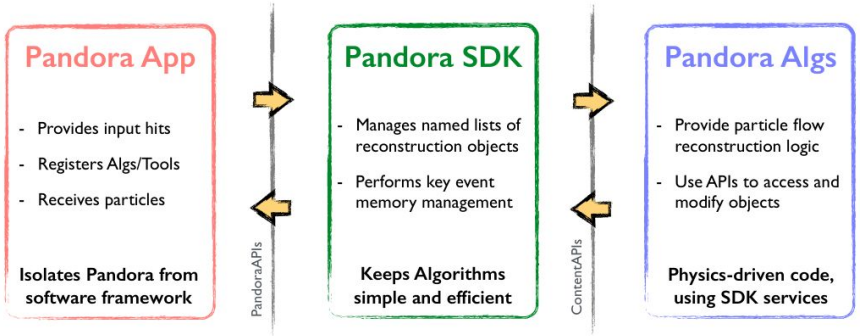
Jana Faltova (GeoDisplay)

Brieuc Francois, Juraj Smiesko

k4Pandora

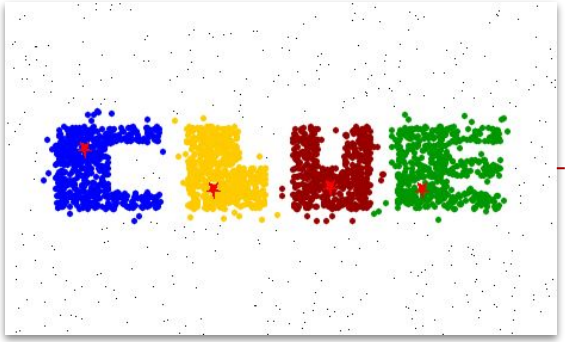
First step towards particle flow: use existing components with some conversions

`k4MarlinWrapper` ↔ `DDMarlinPandora` ↔ **Pandora**

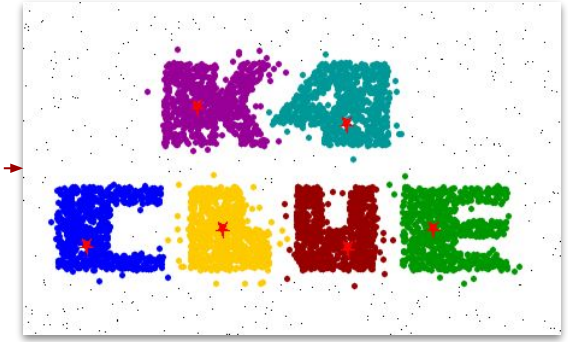



```
from Configurables import MarlinProcessorWrapper

pandora = MarlinProcessorWrapper('DDMarlinPandora')
pandora.OutputLevel = DEBUG
pandora.ProcessorType = 'DDPandoraPFANewProcessor'
pandora.Parameters = {
    'Verbosity': ['WARNING'],
    'PandoraSettingsXmlFile': ['/some/path'],
    'CreateGaps': [False],
    'ECalCaloHitCollections': ['ECalBarrelCells']
}
ApplicationMgr().TopAlg += [pandora]
```



https://gitlab.cern.ch/kalos/clue

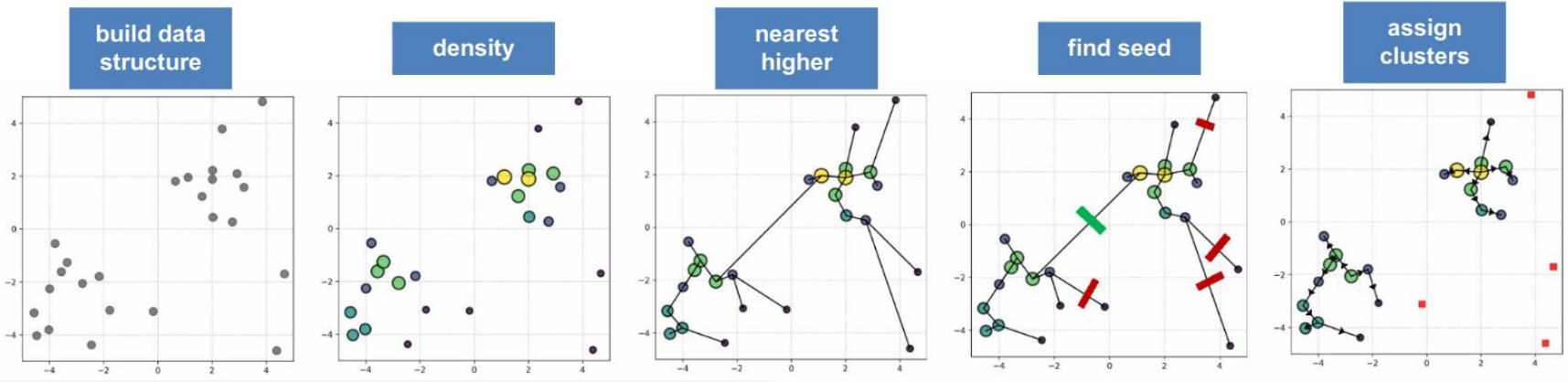


https://github.com/key4hep/k4Clue

Erica Brondolin, Marco Rovere, Felice Pantaleo

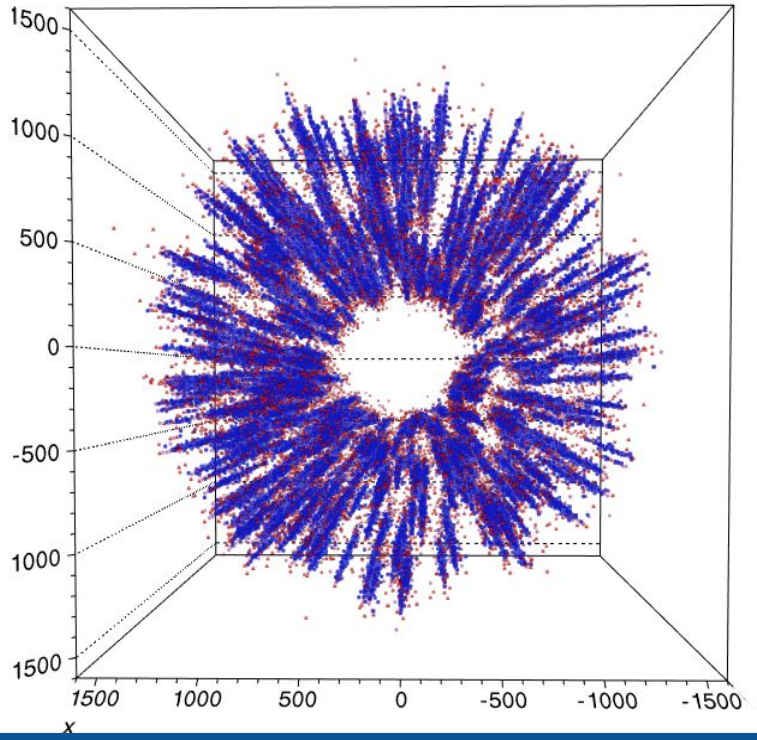
2D Clusters with CLUE

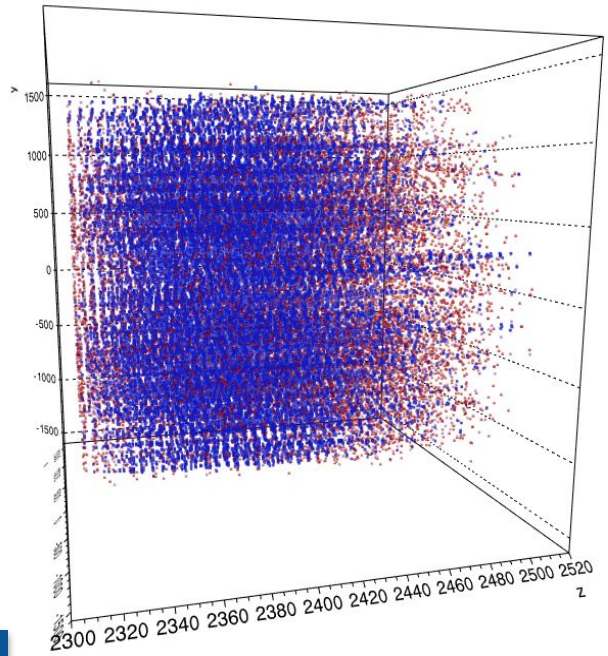
- CLUE (**CLUstering by Energy**) is an algorithm inspired by “Clustering by fast search and find of density peaks” (Ref.)
- Main characteristic:
  - *Energy density* - rather than individual cell energy - used to define ranking, seeding threshold, etc…
- GPU-friendly, i.e. suitable for the upcoming era of heterogeneous computing in HEP



CLUEHits Events display

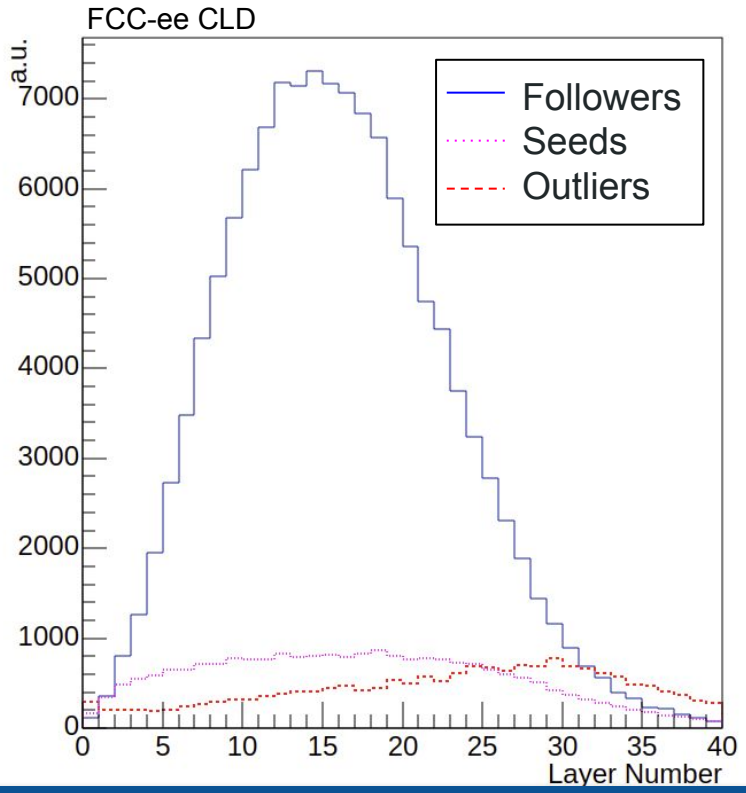
- Sample:
  - 500 events
  - single gamma generated with 10 GeV
  - 10° > θ > 30°

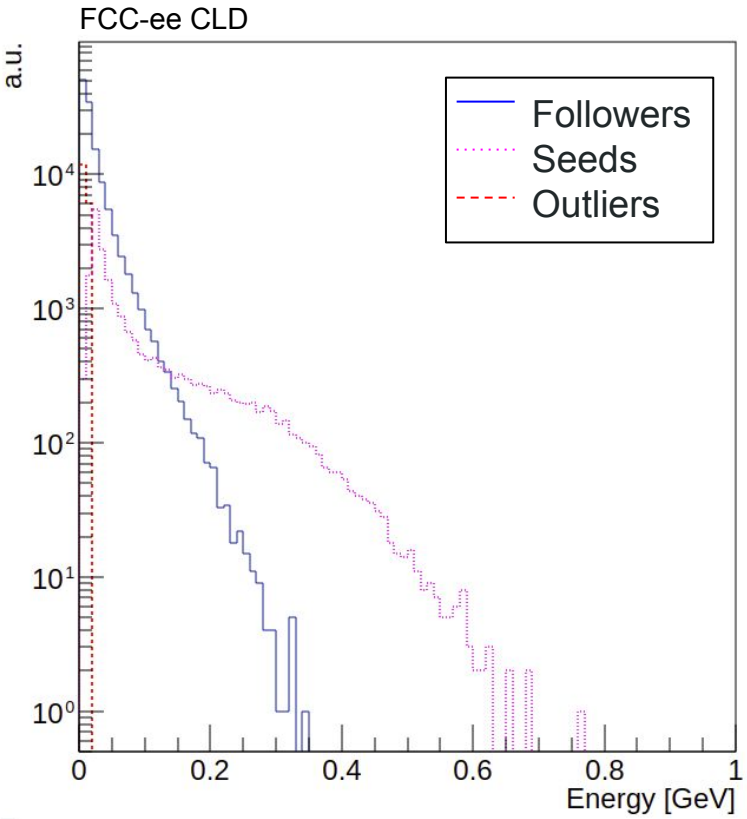




Followers
Seeds
Outliers

CLUE hits





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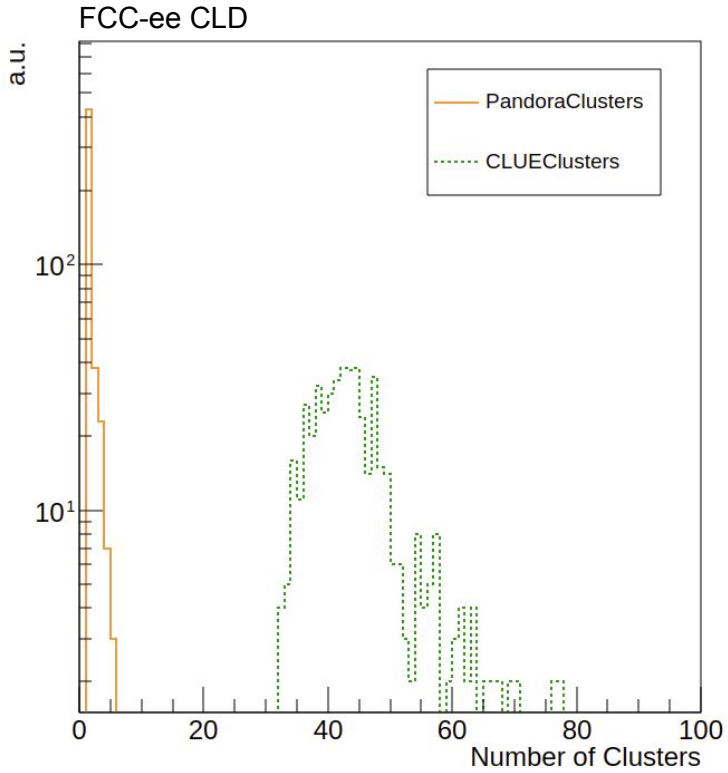
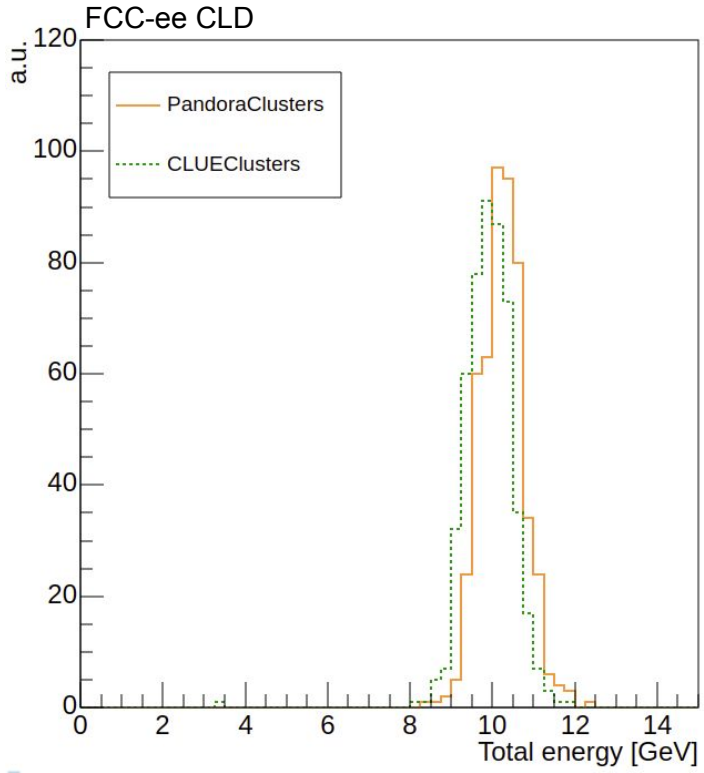
CLUEClusters

and comparison w/PandoraClusters

Reminder:

CLUEClusters are built per layer, while PandoraClusters are built in the entire detector





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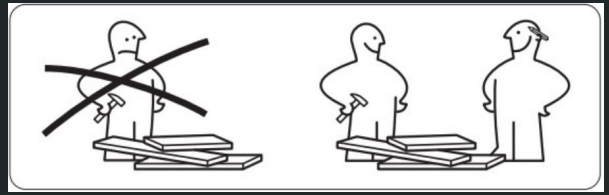
Conclusions



Key4hep provides the foundation for software collaboration among future colliders and detector models
- Common language of DD4hep + EDM4hep

Development of new algorithms as well as maintenance of established workflow
- iLCSoft via k4MarlinWrapper
- k4Acts
- LAr Calorimetry Reconstruction and particle flow
- k4Clue

... many interesting topics to collaborate on, join the Key4hep and FCC software meetings to get started!

- Documentation & links
  - cern.ch/key4hep (main documentation)
  - cern.ch/edm4hep (doxygen code reference)