The Key4hep turnkey software stack

ICHEP 2022

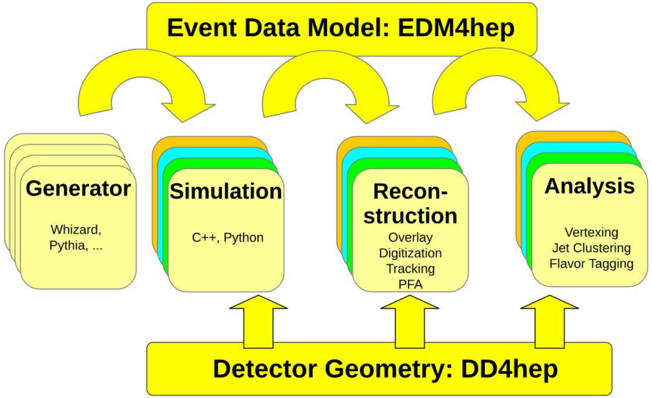
July 09th, 2022
Valentin Volkl, for the Key4hep SW group
CERN

This work benefited from support by the CERN Strategic R&D Programme on Technologies for Future Experiments (https://cds.cern.ch/record/2649646/, CERN-OPEN-2018-006).

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

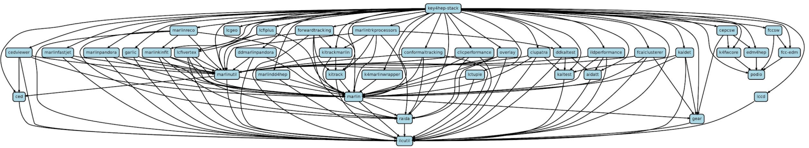
Software stack that connects and extends packages to provide a complete data processing framework, comprising fast and full simulation, reconstruction, and analysis.

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



Building the Key4hep software stack

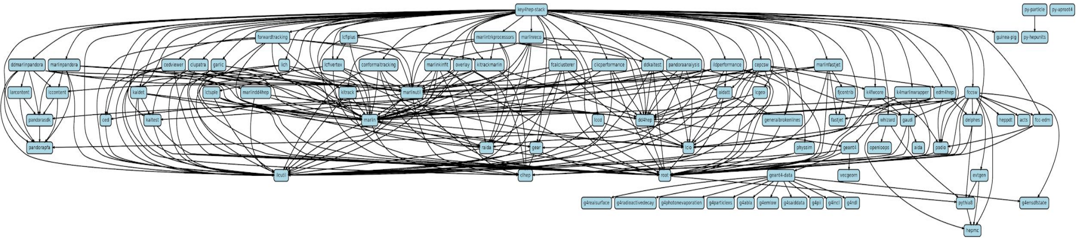
Experiment-specific Packages



- Use *Spack* package manager to deal with complexities of large software stack
    - Better adapted to scientific software than traditional package managers: Coexisting versions, reproducibility, build for different microarchitectures …
    - Strong community adoption helps share maintenance burden
    - Could be useful to developers as well to flexibly set up dependencies

Building the Key4hep software stack

Experiment-specific Packages + HEP-specific packages



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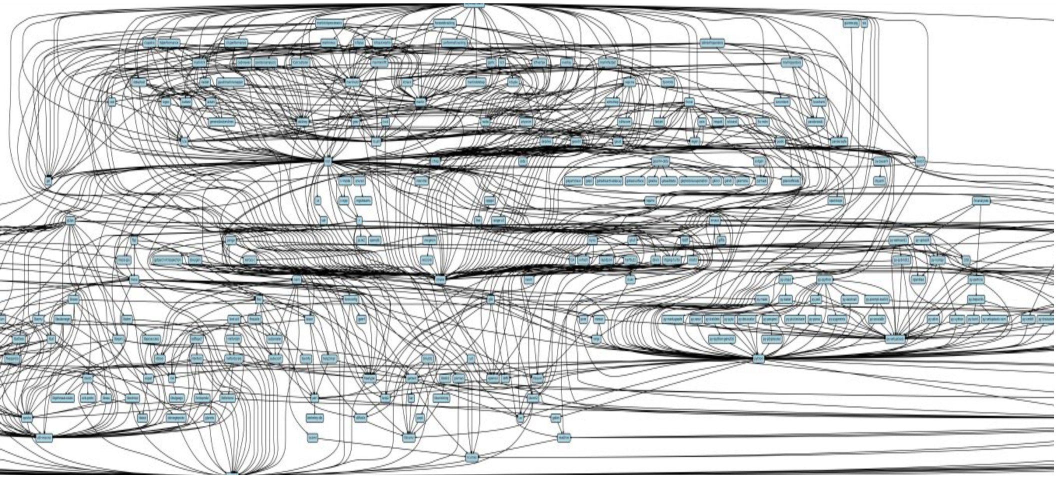
Experiment-specific Packages + HEP-specific Packages + General Purpose Libraries



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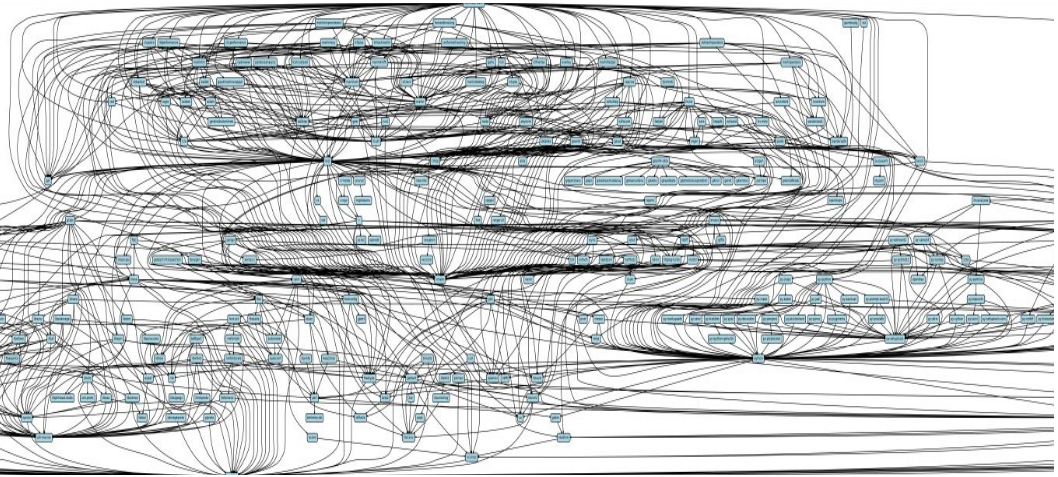

Deployed to CVMFS:

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

to set up the latest release.

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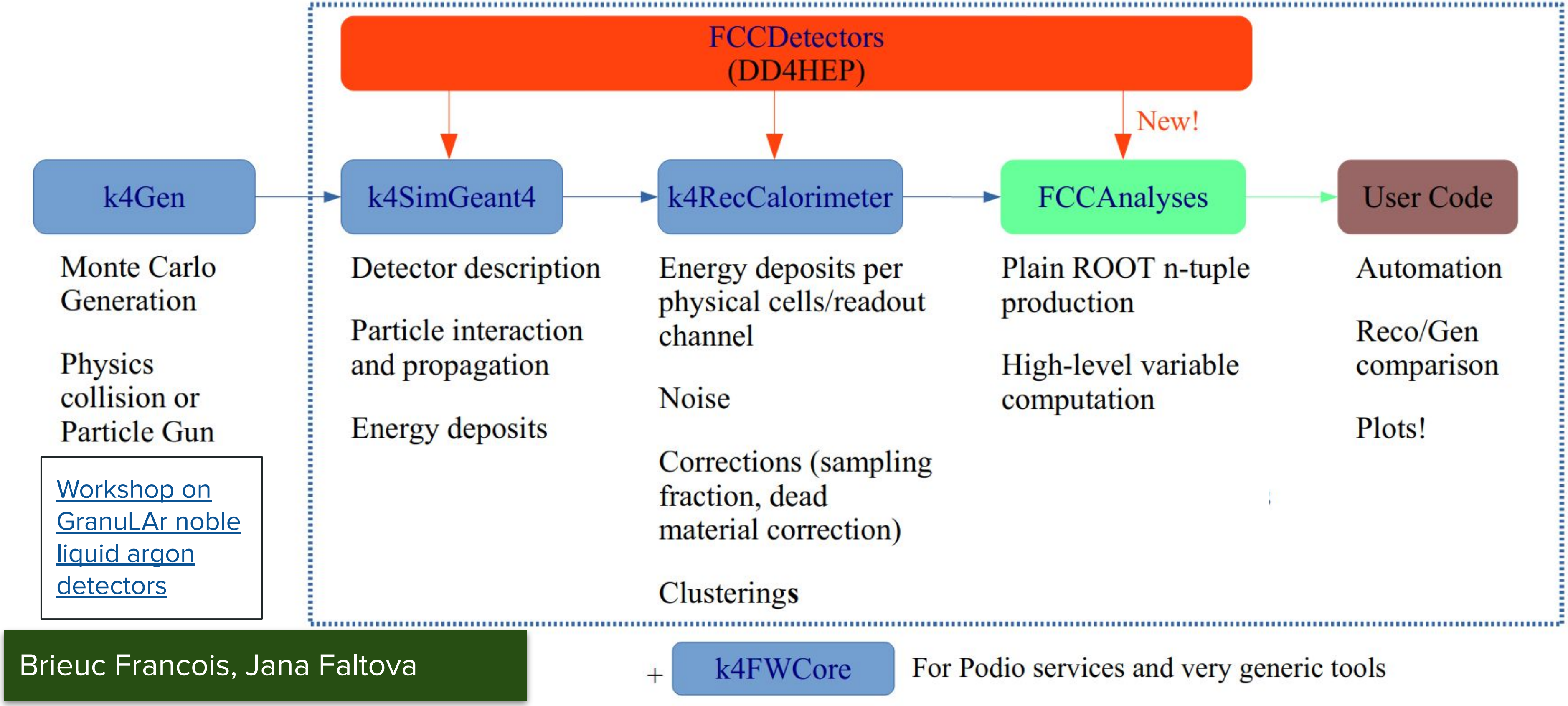
Example of a Key4hep workflow: **FCC LAr Calorimetry**



FCCDetectors
(DD4HEP)

New!

k4Gen

Monte Carlo Generation

Physics collision or Particle Gun

k4SimGeant4

Detector description

Particle interaction and propagation

Energy deposits

k4RecCalorimeter

Energy deposits per physical cells/readout channel

Noise

Corrections (sampling fraction, dead material correction)

Clusterings

FCCAnalyses

Plain ROOT n-tuple production

High-level variable computation

User Code

Automation

Reco/Gen comparison

Plots!

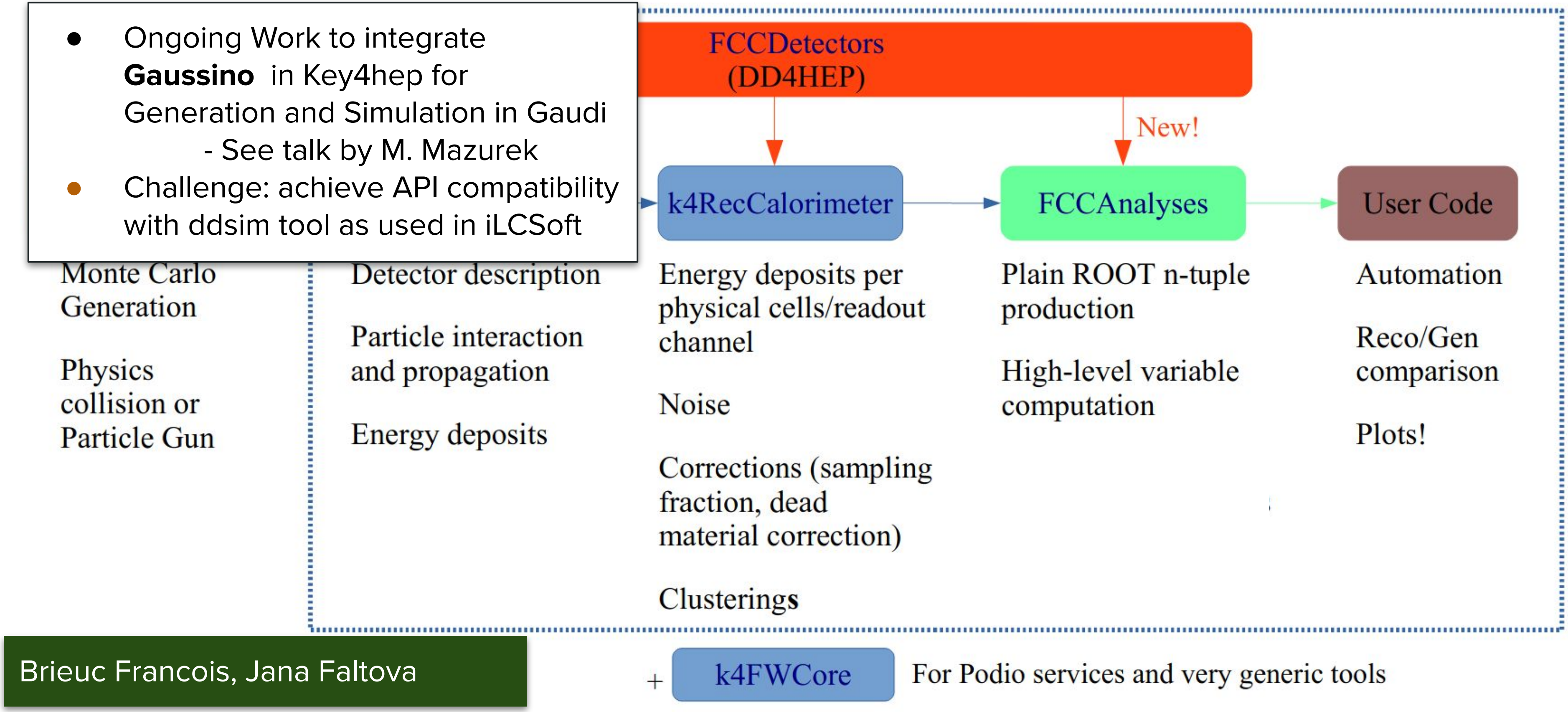
+ k4FWCore For Podio services and very generic tools

[Workshop on GranuLAr noble liquid argon detectors]

Brieuc Francois, Jana Faltova

Example of a Key4hep workflow: **FCC LAr Calorimetry**

- Ongoing Work to integrate **Gaussino** in Key4hep for Generation and Simulation in Gaudi
  - See talk by M. Mazurek
- Challenge: achieve API compatibility with ddsim tool as used in iLCSoft



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Brieuc Francois, Jana Faltova

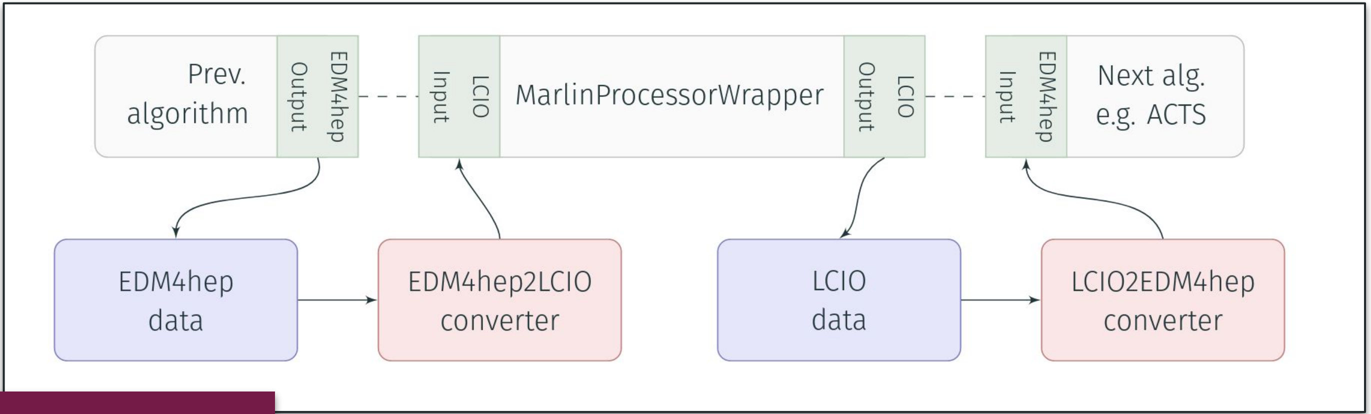
iLCSoft reconstruction chain

- 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 Flow Reconstruction …) available

Full iLCSoft Reconstruction chain in Key4hep 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**
Widely used already: ATLAS, ALICE, Belle II, sPHENIX ...

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

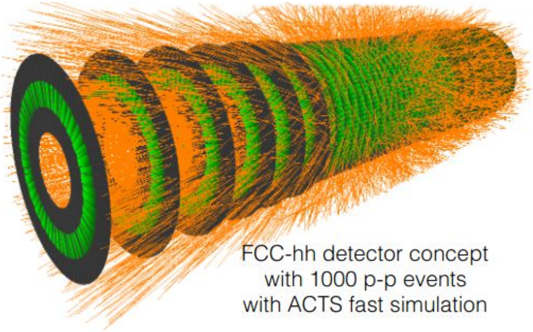
- Facilitate collaboration across experiments and external contributors, e.g. machine learning experts
- Allow for novel algorithms and detector components (e.g. timing, tracklets)

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

Integration of experiment-independent libraries:

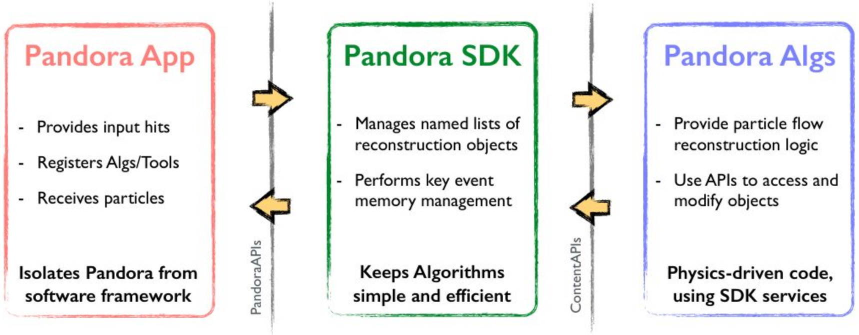
Workshop on GranuLAr noble liquid argon detectors

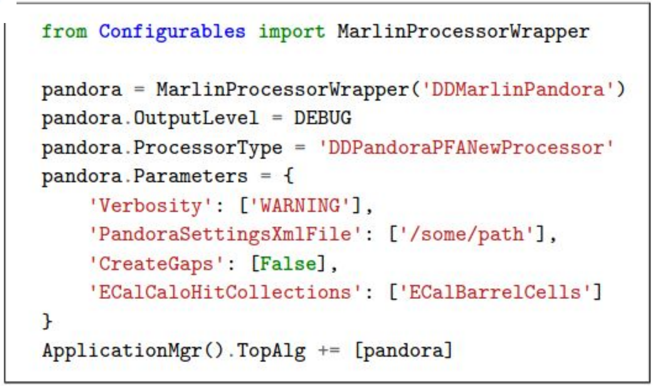
k4Pandora

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

Ongoing development of a **dedicated key4hep package** (k4Pandora, under construction)

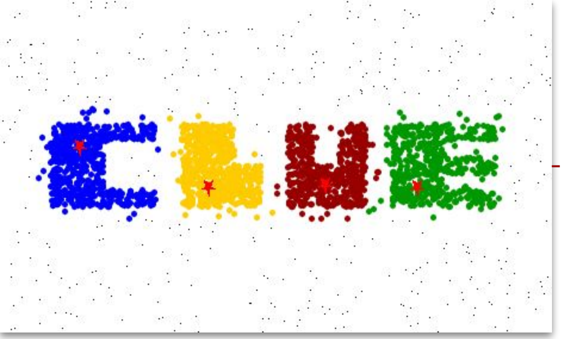
k4MarlinWrapper ↔ DDMarlinPandora ↔ **Pandora**


Pandora App
- Provides input hits
- Registers Algs/Tools
- Receives particles
Isolates Pandora from software framework
PandoraAPIs
Pandora SDK
- Manages named lists of reconstruction objects
- Performs key event memory management
Keeps Algorithms simple and efficient
ContentAPIs
Pandora Algs
- Provide particle flow reconstruction logic
- Use APIs to access and modify objects
Physics-driven code, using SDK services

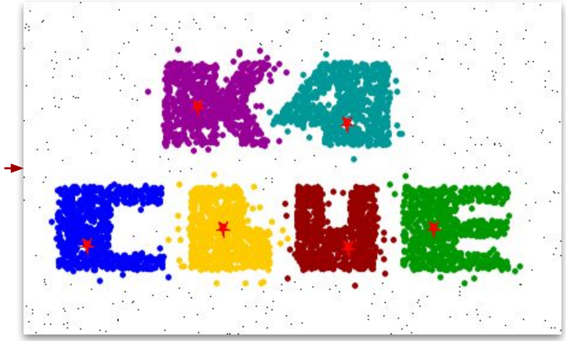

```
from Configurables import MarlinProcessorWrapper

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

Juraj Smiesko, Eduardo Ploerer

Integration of experiment-independent libraries:



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



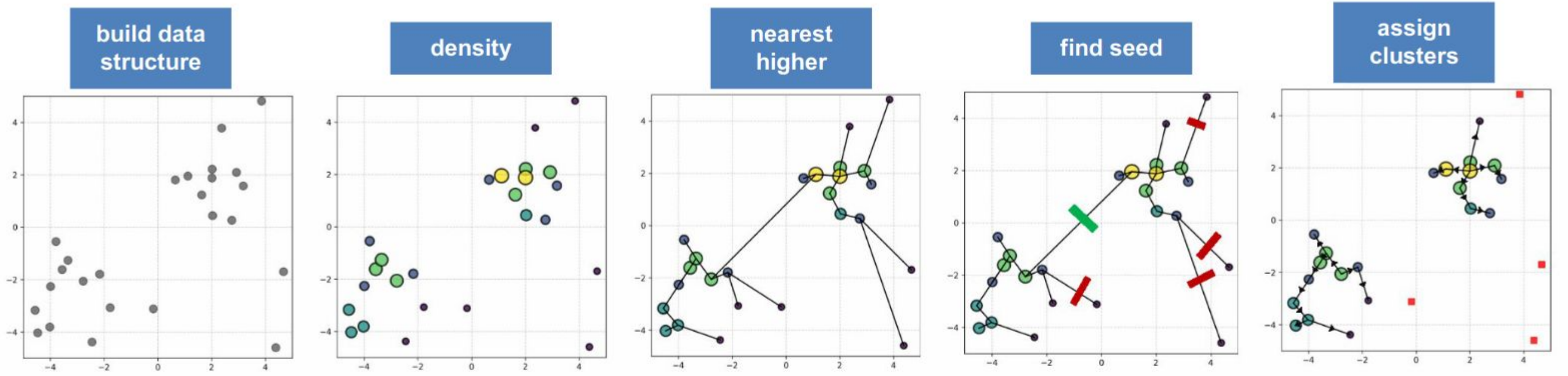
https://github.com/key4hep/k4Clue

Erica Brondolin, Marco Rovere, Felice Pantaleo

Link for more details

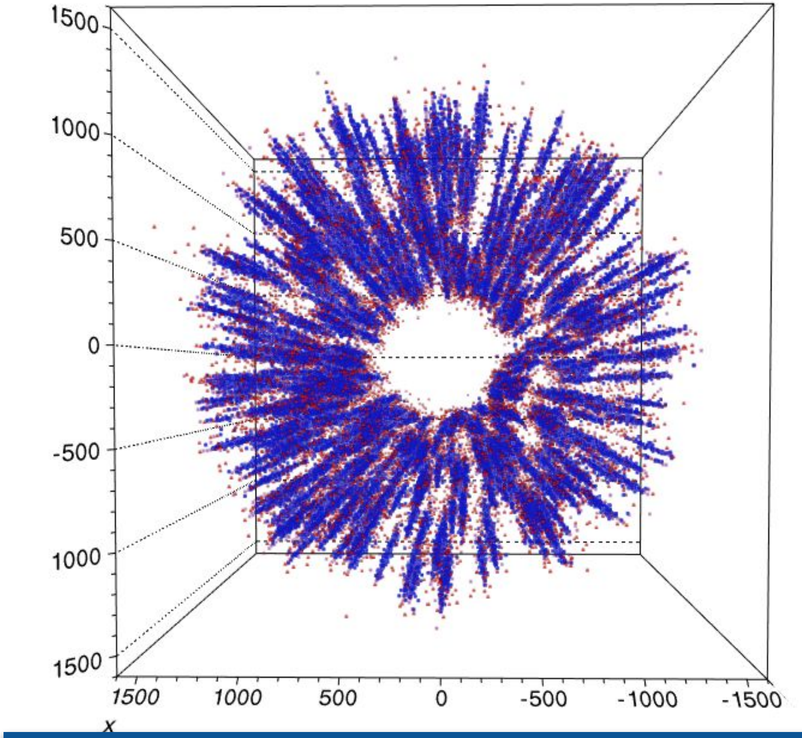
2D Clusters with CLUE

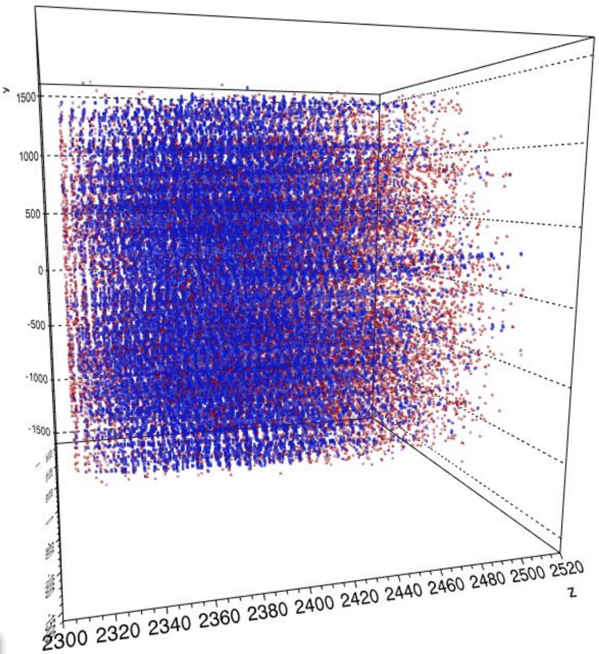
- CLUE (**CLUstering by Energy**) is an algorithm inspired by “Clustering by fast search and find of density peaks” [link to Ref.]
- Main characteristic:
  - *Energy density* - rather than individual cell energy - used to define ranking, seeding threshold, etc…
- GPU-friendly, i.e. suitable for the upcoming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



CLUEHits Events display

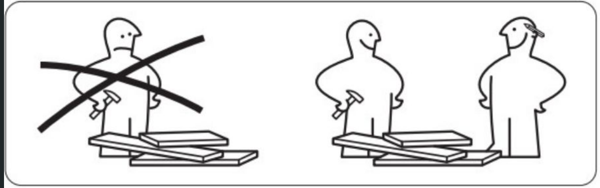
- Sample:
  - 500 events
  - single gamma generated with 10 GeV
  - 10° > θ > 30°





Followers
Seeds
Outliers

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 software meetings to get started!

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