Task 12.2 - Turnkey Software

AIDAinnova, annual meeting

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HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

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AIDA innova

CERN

DESY.

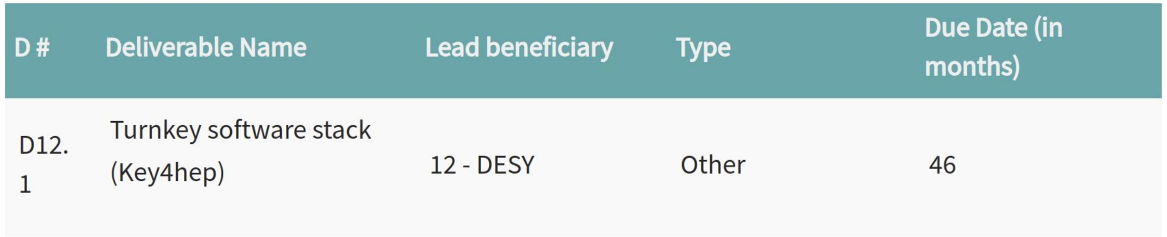
Task 12.2 - Turnkey Software

Overview

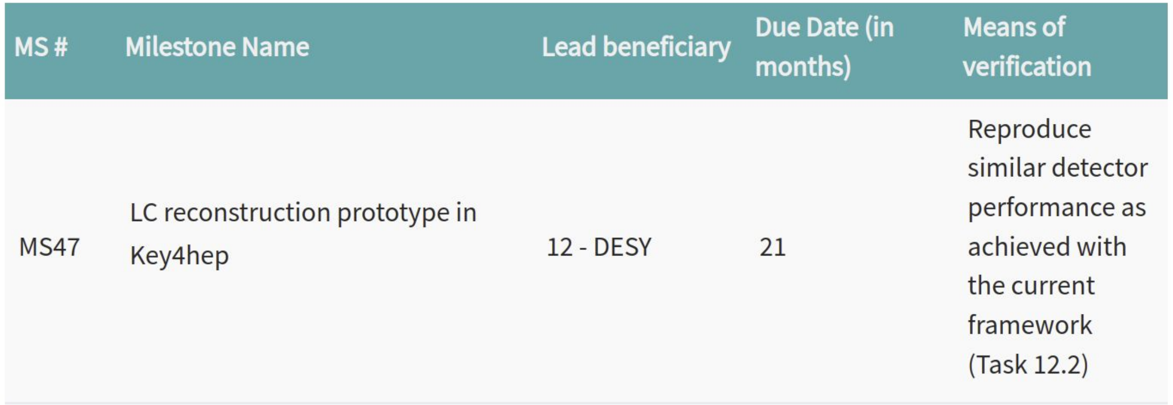
- Integrated Turnkey Software Stack, for physics and performance studies
- Simplified data model toolkit for modern hardware platforms
- Digitisation extensions for geometry toolkit
- R&D study on frameworks to manage heterogeneous resources

DESY (lead), CERN,
INFN-PI, (INFN-PD, INFN-BA, INFN-BO - unfunded)
IHEP, SDU - associated

Symbols on coming slides:
✅ Done
👷 Ongoing or planned



D #	Deliverable Name	Lead beneficiary	Type	Due Date (in months)
D12.1	Turnkey software stack (Key4hep)	12 - DESY	Other	46

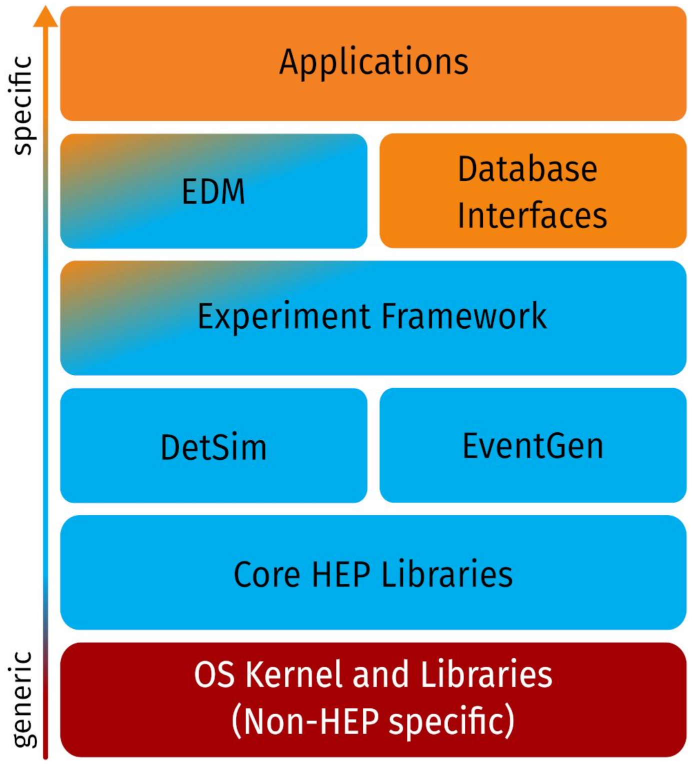


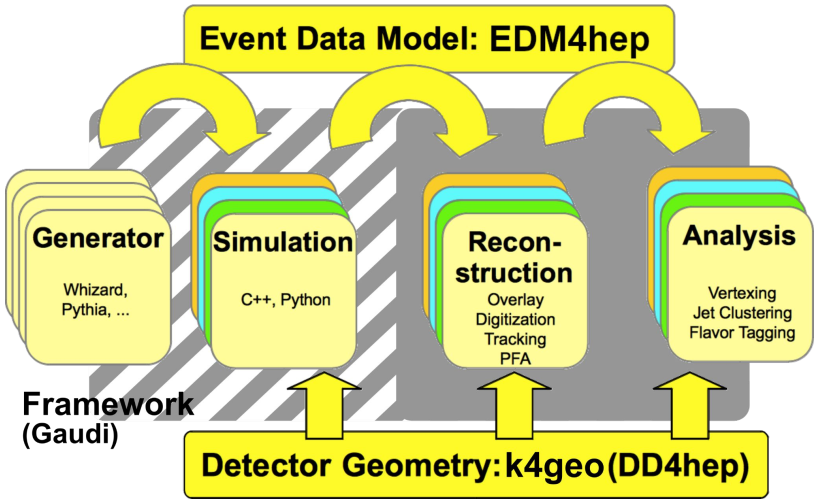
	MS #	Milestone Name	Lead beneficiary	Due Date (in months)	Means of verification
✅	MS47	LC reconstruction prototype in Key4hep	12 - DESY	21	Reproduce similar detector performance as achieved with the current framework (Task 12.2)

Key4hep

Turnkey software stack for all future collider projects

- Develop a **common turnkey software stack** for future collider studies
- Take existing tools where possible, provide necessary interfaces and contribute to the development
  - A lot of existing software from the shared **iLCSoft** developed by ILC and CLIC for many years
- Develop new tools or libraries where necessary
- All major players involved: CEPC, CLIC, FCC, ILC, EIC, …
- Provide a complete data processing framework
  - Shared components reduce overhead for all users
- Make things as easy to use as possible for everybody (librarians, developers, users)
- Supported by **HSF**, **CERN** and **AIDAinnova**





PODIO

github.com/AIDASoft/podio

The event data model toolkit

- Generate code from simple YAML definition of EDM4hep
- Based on using and storing POD (plain old data) structures
- Thread-safe and potential to target multiple I/O backends

✅ **Schema evolution** of generated EDMs (basic use cases, extend as necessary)

✅ RNTuple based backend ✅ Improved python bindings

✅ Stable collection IDs (necessary for multithreading)

✅ Interface types (inheritance free interfaces)

✅ First version of Julia code generation (main feature: machinery, templates still WIP)

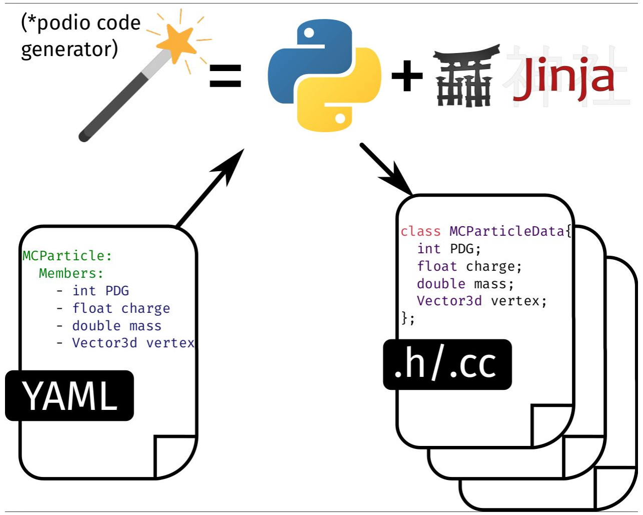
✅ Fixed subtle memory issues (present for quite some time, hard to trigger)

✅ Removal of deprecated EventStore → Only Frame based I/O

👷 **Version 1.0** (effectively done, cleaning up minor issues & documentation now)

👷 Some prototyping and testing on heterogeneous resources

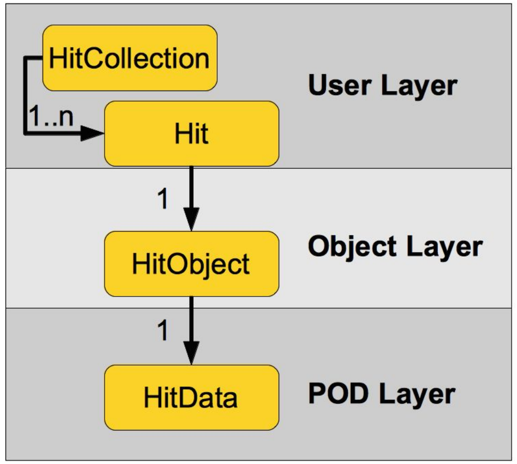
👷 Additional features (already a few on the wish list: e.g. streaming of Frames)



(*podio code generator)

```
MCParticle:
  Members:
    - int PDG
    - float charge
    - double mass
    - Vector3d vertex
```

```
class MCParticleData{
  int PDG;
  float charge;
  double mass;
  Vector3d vertex;
};
```

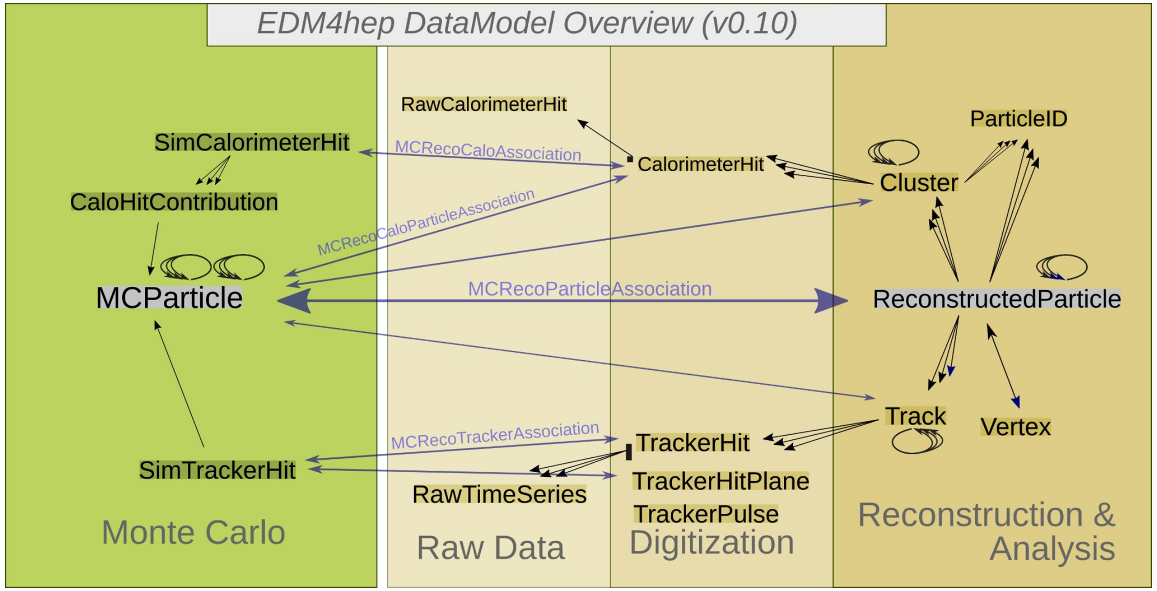


github.com/key4hep/EDM4hep
edm4hep.web.cern.ch

EDM4hep

The common event data model

- EDM4hep defines the common *language* for all Key4hep components to communicate
- Heavily inspired by LCIO that has been successfully shared by ILC and CLIC
- Generated by the PODIO EDM toolkit
  - EDM4hep and EICD main customers of PODIO



✅ (Standalone) conversion from LCIO

✅ Improved python bindings

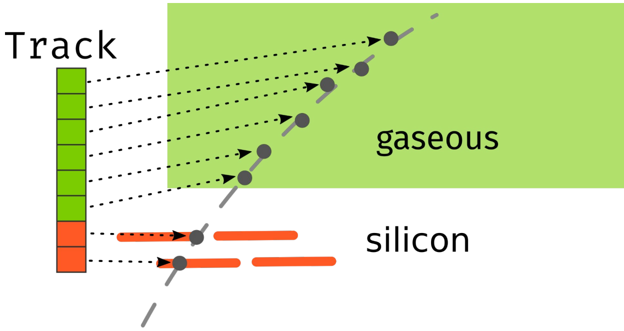
✅ Introduction of TrackerHit interface (covering TrackerHit3D and TrackerHitPlane)

✅ Cleanup of type inconsistencies / naming / documentation

👷 **Version 1.0** (backwards compatible from then on, almost there)

👷 Conceptual changes w.r.t. LCIO

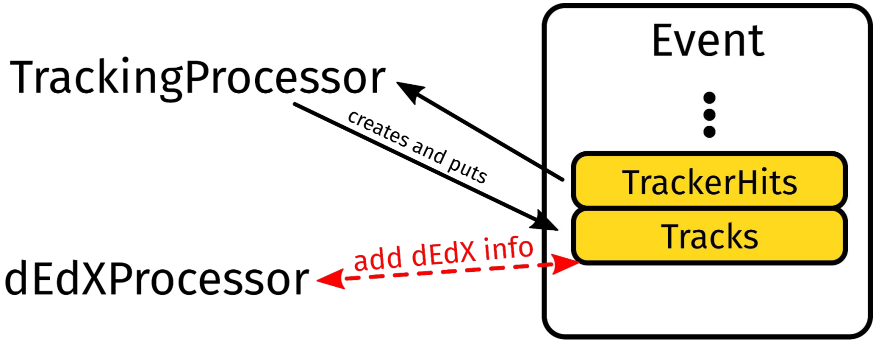
👷 Utility functionality as necessary

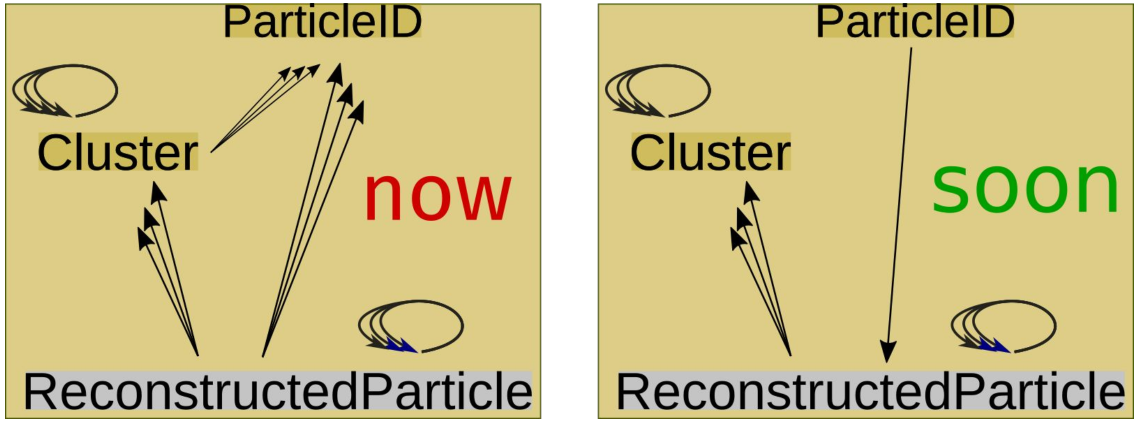


EDM4hep v1.0

The last missing pieces

- Breaking things without intention of doing schema evolution
  - Too many things that do not have an easy evolution mechanism
- **Consistent mutability concept**
  - Some inconsistencies inherited from LCIO
  - Very big conceptual change
  - Requires substantial work in conversion
  - Requires new utilities for users
- Many things already addressed
  - TrackerHit interface
  - Multiple EventWeights
  - Consistent relation naming
- Keeping track in [EDM4hep v1.0 github project]()

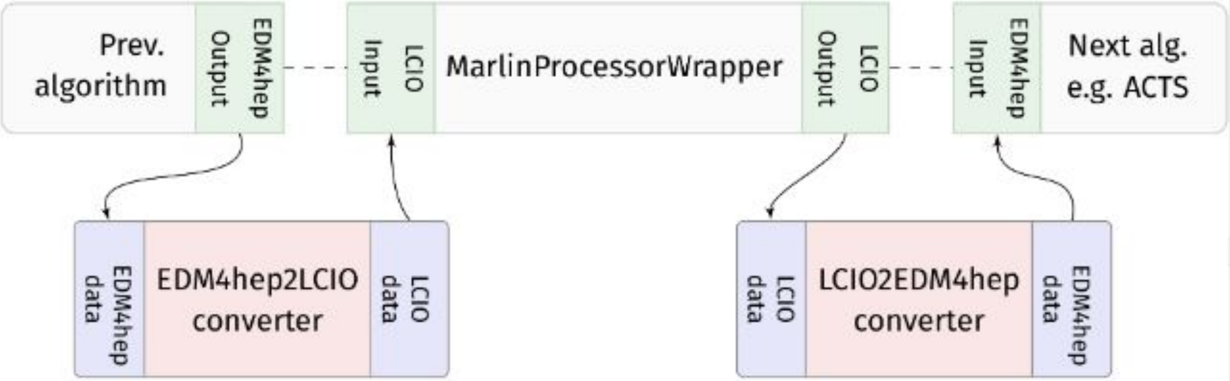




k4MarlinWrapper & EDM converters

Bridging old and new

- Run unchanged Marlin Processors via Wrapper
- Configurable on-demand conversion between LCIO and EDM4hep (and vice versa)
- Steering file conversion script



✅ Unified all EDM4hep ↔ LCIO converters in one library

✅ Added basic unit-test like converter tests

✅ Generalized relation resolving mechanism

✅ Keep track of all converted objects in an event (effectively incrementally build up parallel EDM4hep & LCIO events)

✅ Improved ergonomics (e.g. always convert EventHeader)

👷 Finalize conversion after EDM4hep v1.0

Key4hep Framework & Services

Core services & algorithms

github.com/key4hep
key4hep.web.cern.ch

- Gaudi based core framework
  - **k4FWCore** provides I/O for PODIO based EDMs
- Core services and tools for CI and development

✅ Switch FW core to use podio Frames (+removal of legacy EventStore)

✅ Thread safe way for handling metadata

✅ **Support for Gaudi Functional algorithms**

✅ Improved k4run (better error & help messages)

✅ Builds for multiple OSs

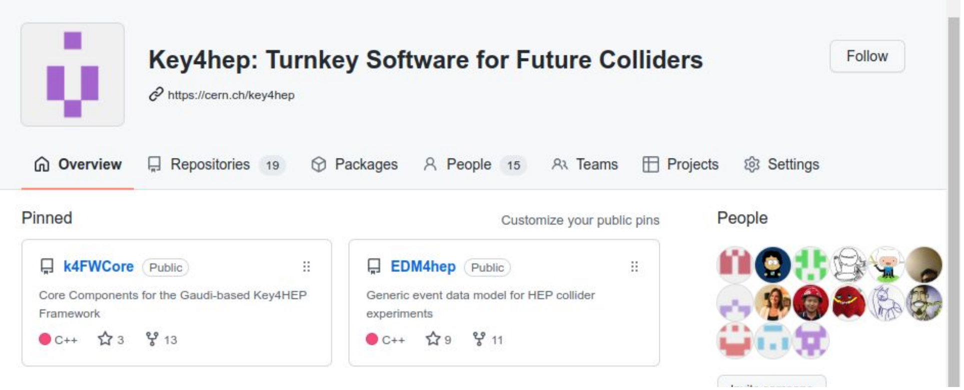
✅ New github actions to facilitate CI for Key4hep packages

✅ Convenience improvements (e.g. read all collections by default)

👷 Proper multithreading support for Functional algorithms

👷 Integration of ACTS (requires TrackerHit interface)

👷 Consolidation of simulation approaches (postponed for now)



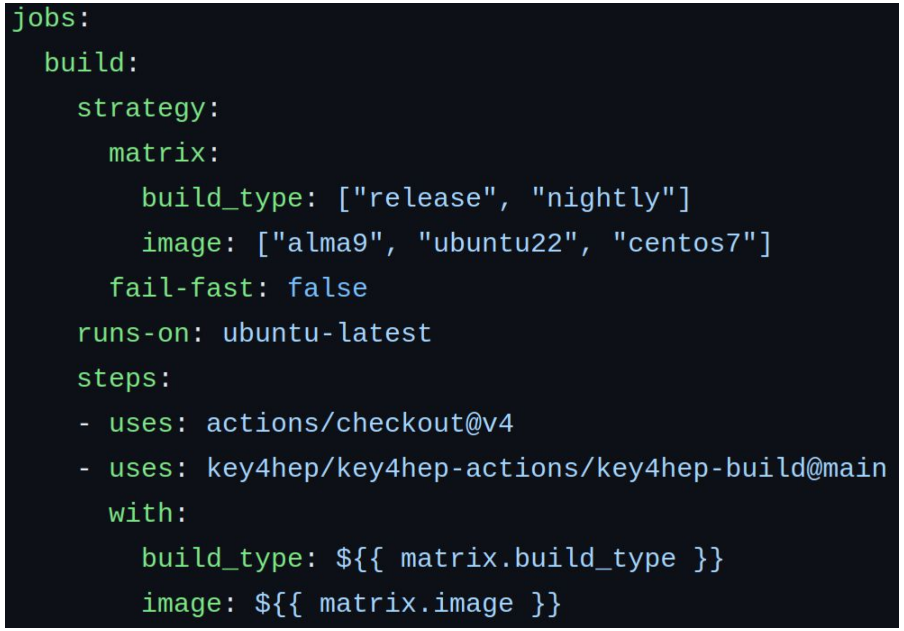
Key4hep: Turnkey Software for Future Colliders

https://cern.ch/key4hep

Pinned

k4FWCore Public
Core Components for the Gaudi-based Key4HEP Framework
C++ ☆ 3 13

EDM4hep Public
Generic event data model for HEP collider experiments
C++ ☆ 9 11



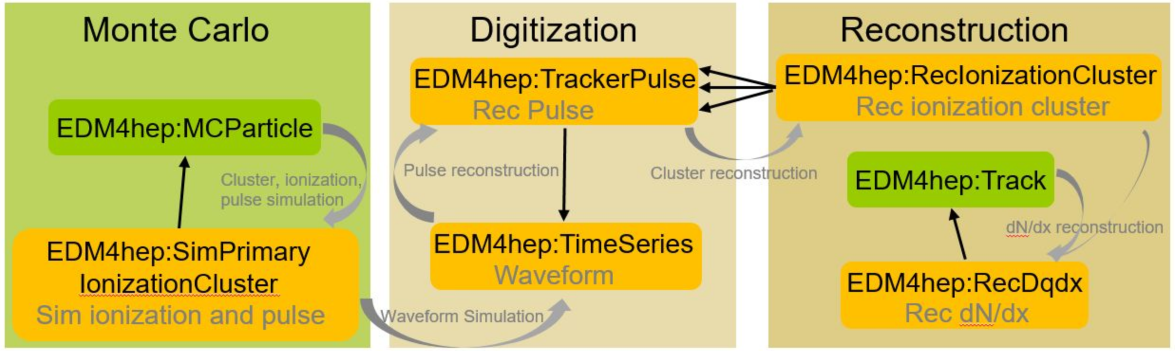
```
jobs:
  build:
    strategy:
      matrix:
        build_type: ["release", "nightly"]
        image: ["alma9", "ubuntu22", "centos7"]
      fail-fast: false
    runs-on: ubuntu-latest
    steps:
    - uses: actions/checkout@v4
    - uses: key4hep/key4hep-actions/key4hep-build@main
      with:
        build_type: ${{ matrix.build_type }}
        image: ${{ matrix.image }}
```

Work at INFN

R&D study on framework to manage heterogeneous resources

- No applicant on second call for dedicated position
  - Despite trying to advertise it as widely as possible
- Competing against numerous other more attractive software/computing positions
  - Both money and career prospects
- Decision to not have a third call, but rather try to re-direct the funds
  - No final decision yet on where the allocation might go

Report from IHEP group



Monte Carlo

EDM4hep:MCParticle

Cluster, ionization, pulse simulation

EDM4hep:SimPrimaryIonizationCluster
Sim ionization and pulse

Digitization

EDM4hep:TrackerPulse
Rec Pulse

Pulse reconstruction

EDM4hep:TimeSeries
Waveform

Waveform Simulation

Reconstruction

EDM4hep:RecIonizationCluster
Rec ionization cluster

Cluster reconstruction

EDM4hep:Track

dN/dx reconstruction

EDM4hep:RecDqdx
Rec dN/dx

✅ Extend EDM4hep to support ongoing activities in CEPC

- Reconstruction of number of primary ionizations in drift chamber
- Analysis of test beam data for vertex detector prototype

✅ CEPC Vertex Detector tracking with ACTS

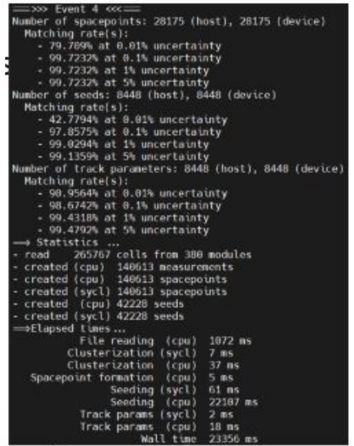
- Geometry in ACTS format (“manual” conversion from DD4hep)
- Use FATRAS and TRACCC for fast sim and tracking

✅ CEPC-on-Gaussino prototype

- Based on LHCb’s Gen/McEvent, Gaussino, CEPCS
- Geometry via DD4hepCnvSvc

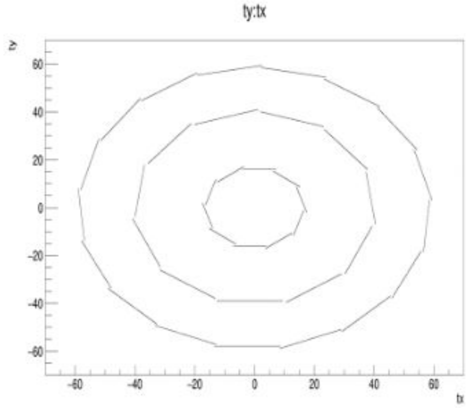
👷 Optimize data flow / communication between CPU and GPU. Investigate possibility of avoiding copies by building a connection between EDM4hep and TRACCCs vecmem

👷 Use EDM4hep for Gaussino



```
══>>> Event 4 <<<══
Number of spacepoints: 28175 (host), 28175 (device)
  Matching rate(s):
    - 79.789% at 0.01% uncertainty
    - 99.7232% at 0.1% uncertainty
    - 99.7232% at 1% uncertainty
    - 99.7232% at 5% uncertainty
Number of seeds: 8448 (host), 8448 (device)
  Matching rate(s):
    - 42.7794% at 0.01% uncertainty
    - 97.8575% at 0.1% uncertainty
    - 99.0294% at 1% uncertainty
    - 99.1359% at 5% uncertainty
Number of track parameters: 8448 (host), 8448 (device)
  Matching rate(s):
    - 90.9564% at 0.01% uncertainty
    - 98.6742% at 0.1% uncertainty
    - 99.4318% at 1% uncertainty
    - 99.4792% at 5% uncertainty
──> Statistics ...
- read    265767 cells from 380 modules
- created (cpu)  140613 measurements
- created (cpu)  140613 spacepoints
- created (sycl) 140613 spacepoints
- created  (cpu) 42228 seeds
- created (sycl) 42228 seeds
══>Elapsed times ...
              File reading  (cpu)  1072 ms
            Clusterization (sycl)  7 ms
            Clusterization  (cpu)  37 ms
     Spacepoint formation  (cpu)  5 ms
                   Seeding (sycl)  61 ms
                   Seeding  (cpu)  22187 ms
              Track params (sycl)  2 ms
              Track params  (cpu)  18 ms
                     Wall time  23356 ms
```

Computing performance of TRACCC
CPU: Intel Xeon Silver 4214 @ 2.20GHz
GPU: NVIDIA Quadro RTX 8000

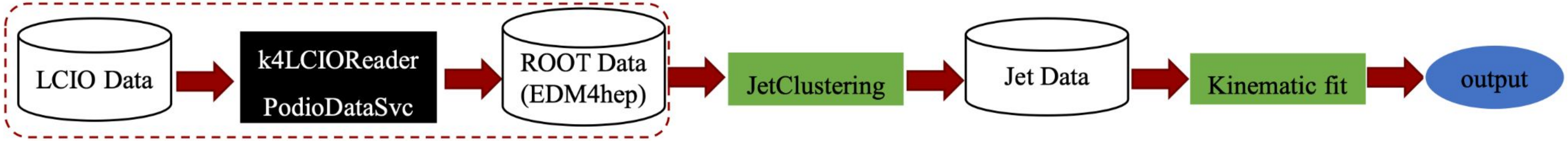


Visualization of vertex detector
(single sided)

Report from SDU group

✅ Development of an analysis toolkit based on RDataFrame

- Port of several existing tools (MarlinKinFit, JetClustering, …)



✅ Further development of Valprod toolkit to run validation

- Running CEPC CI jobs on grid

👷 Integrate more missing analysis tools to RDataFrame

👷 Continue development of validation system

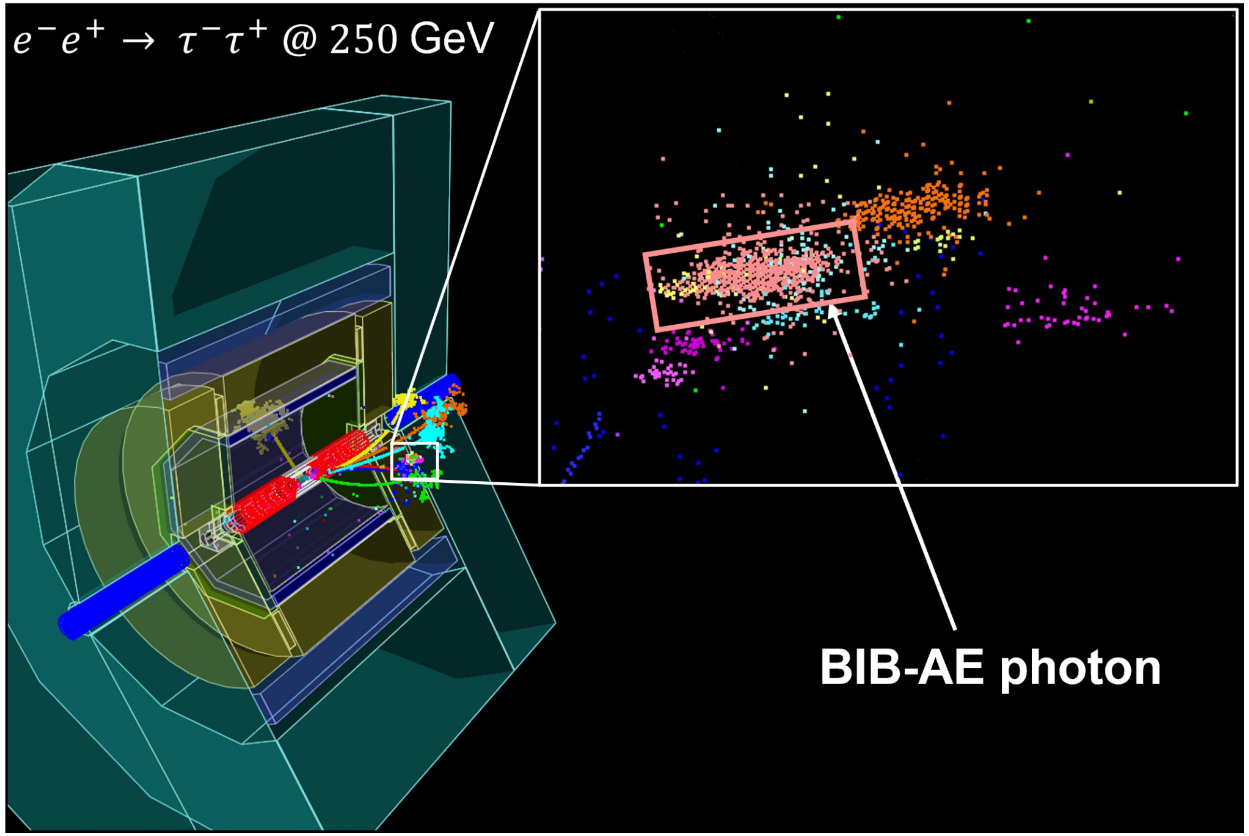
- Generalize grid resource usage possibilities

Interactions with other WPs

Integration of R&D into the software stack

- **Successfully ran simulation (ddsim) and standard reconstruction for ILD using the BIB-AE model for fast shower generation**
  - Part of the developments during last years hackathon
- ACTS integration ongoing
  - Stopped by need for TrackerHit interface in EDM4hep until recently
- PandoraPFA integration
  - Available through MarlinWrapper
  - See Swathis talk

courtesy P. McKeown



Summary / Outlook for the next year

- Finalized stable version of podio
  - Minor cleanup ongoing
- Finalizing EDM4hep v1.0
  - Some conceptual changes wrt LCIO (still ongoing)
  - Improved converter functionality
- First version of Gaudi Functional capable core components
  - Using podio functionality (no longer re-implementing readers / writers)
  - Necessary changes mostly transparent, few changes necessary for k4MarlinWrapper
  - Multi-threading support ongoing
- Integration of ML FastSim in DDML
  - Next steps: Add more models
- Tutorials and updated documentation
- Keep on working integrating more software tools and using them in simulation, reconstruction & analysis
  - Try to homogenize the approaches and avoid re-developing the same thing multiple times

Thank you