

Key4hep and Future Collider Software

Parallel 9 – Computing

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CERN / University of Bonn

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A Turnkey Software Stack for HEP

Imagine this:

- You want to do a new HEP project study
- All the software is already installed
- Build a detector with a couple lines of text
- Full Geant4 simulation directly available
- Basic event reconstruction already set up
- Detector performance plots also

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 - Implement a tracking algorithm
 - Test new AI-based particle flow
 - Or “just” do full-sim analysis

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Impossible?

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Impossible? No!

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Towards a Turnkey Software Stack for HEP Experiments

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Abstract. Future HEP experiments require detailed simulation and advanced reconstruction algorithms to explore the physics reach of their proposed machines and to design, optimise, and study the detector geometry and performance. To synergize the development of the CLIC and FCC software efforts, the CERN EP R&D roadmap proposes the creation of a “Turnkey Software Stack”, which is foreseen to provide all the necessary ingredients, from simulation to analysis, for future experiments; not only CLIC and FCC, but also for proposed Super-tau-charm factories, CEPC, and ILC. The software stack will facilitate writing specific software for experiments ensuring coherency and maximising the re-use of established packages to benefit from existing solutions and community developments, for example, ROOT, Geant4, DD4hep, Gaudi and podio. As a showcase for the software stack, the existing CLIC reconstruction software, written for iLCSoft, is being to be ported to Gaudi. In parallel, the back-end of the LCIO event data model can be replaced by an implementation in podio. These changes will enable the sharing of the algorithms with other users of the software stack.

We will present the current status and plans of the turnkey software stack, with a focus of the adaptation of the CLIC reconstruction chain to Gaudi and podio, and detail the plans for future developments to generalise their applicability to FCC and beyond.

The Common Software Vision: Key4hep

Common event data model EDM4hep

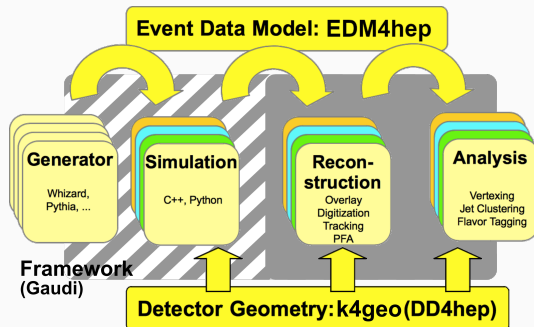
- Consistent interface enabling easy exchange and re-use of algorithms

Complete set of tools for

- Generation, simulation, reconstruction, analysis
- Develop, build, package, test, deploy, run

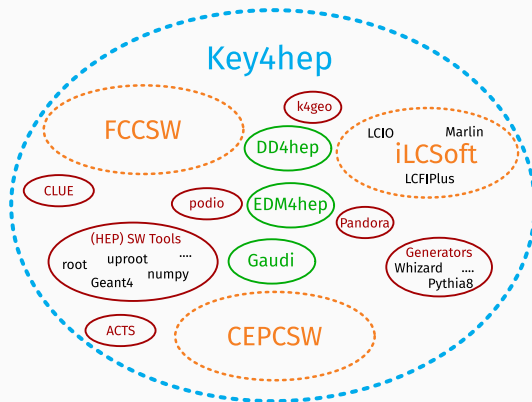
Current core ingredients

- PODIO for EDM4hep (LCIO+FCC-EDM)
- Gaudi framework (ATLAS/LHCb)
- DD4hep for geometry (detector plug&play)



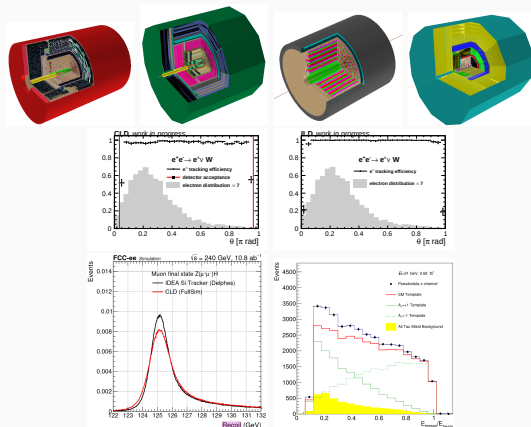
The Key4hep Ecosystem

- Mostly curating existing tools, only develop whats needed
- Central repositories for user-generated content (geometries, reconstruction algorithms, plotting scripts, etc.)
- Stable releases + nightly builds
- All made available together on CVMFS
- `/cvmfs/sw.hsf.org/key4hep/setup.sh`



Present Usage

- All current future collider studies done with Key4hep
- C3, CEPC, CLIC, FCC, ILC, LCF, MuCol, 10 TeV Plasma Wakefield Collider
- Other experiments: EIC, LUXE
- ECFA Higgs/EW/Top factory study
- DRDs, CALICE, LCTPC, EUDAQ
- Balance: fast-results vs. upstreaming developments
- Many users still in transition from Marlin/LCIOO



Key4hep Organisation

- No formal structure
- Open [mailing list](#) via CERN e-group
- [Weekly open meeting](#) with minutes, alternating between framework and EDM
- Decisions made by consensus
- [Github Org](#)
- New: yearly [in-person meeting](#) for medium/long-term planning

Discussions on common HEP software stack, including the definition of a common EDM (EDM4hep)

June 2025

 Jun 10 [EDM4hep Discussion](#) **NEW**

May 2025

 May 30 [Tracking discussion](#)

 May 27 [EDM4hep Discussion](#)

 May 20 [Key4hep Discussion](#)

 May 13 [EDM4hep Discussion](#)

 May 06 [Key4hep Discussion](#)

There are 264 events in the past. [Show](#)

Approximate FTE for core Key4hep developments/operation (*projection)

Year	2020	2021	2022	2023	2024	2025	2026*
Total FTE	3.5	4	3.5	3.5	4	3	0.5
Permanent FTE	0.1	0.1	0.1	0.6	0.5	0.3	0.3

- Primarily AIDAInnova and CERN EP R&D funded PostDocs, supplemented by CERN and DESY base funds
- Challenging knowledge retention between non-overlapping "generations"
- Both sources of R&D funding are expiring soon, no replacement secured yet
- At the same time Key4hep usage and support needs are growing!
- Even the current funding level barely keeps the project afloat

Summary

- Widespread adoption proves the readiness of the community to take a significant step towards a shared software ecosystem
- Collaboration across different communities and a consensus-based decision-making process have proven effective
- Key4hep has successfully become *the* standard for future collider physics studies
- Growing demand of support and maintenance exceeds the scope of R&D funding
- Sustained funding and long-term institutional commitment is crucial and needed *now* to keep up

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