Key4hep and ILD software

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ILD workshop

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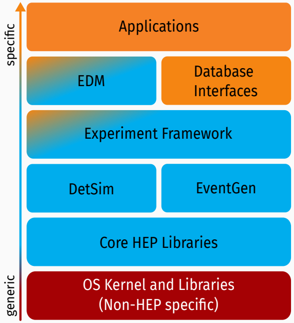
Key4hep - A (very) brief introduction

- Future detector studies rely on well maintained software for studying their potential
- Maintenance of a consistent HEP SW stack is non-trivial
    - Ecosystem of interacting components
- Sharing the burden allows everybody to reap the benefits
    - Make best use of scarce (human) resources
- **Regular contributions from ILC, CLIC, FCC, CEPC, EIC, LUXE, MuonCollider, ...**
- Support from major R&D initatives
    - CERN R&D for Future Experiments, AIDAinnova WP12, ECFA



Key4hep goals

- Provide and maintain a consistent SW stack that allows to do physics studies for **all projects**
- Ensure interoperability of the necessary building blocks
- Reuse existing solutions where possible
  - A lot of experience from LHC experiments and LC communities
- Focus new developments on future experiment specifics
- Share knowledge, processes, workflows and resources
  - Best practices, tutorials, documentation, ...

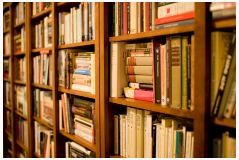
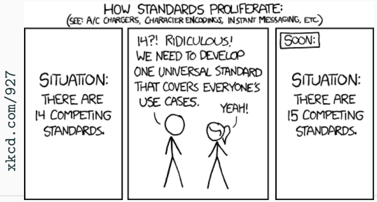


Photo by Stewart B. / CC-BY

Non-goal

- Develop and maintain project specific software and workflows

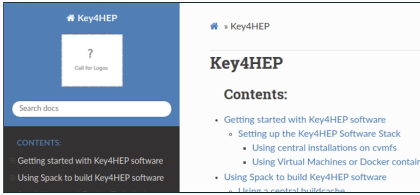

HOW STANDARDS PROLIFERATE:
(SEE: A/C CHARGERS, CHARACTER ENCODINGS, INSTANT MESSAGING, ETC.)
SITUATION: THERE ARE 14 COMPETING STANDARDS.
14?! RIDICULOUS! WE NEED TO DEVELOP ONE UNIVERSAL STANDARD THAT COVERS EVERYONE'S USE CASES.
YEAH!
SOON:
SITUATION: THERE ARE 15 COMPETING STANDARDS.
xkcd.com/927

Key4hep resources

- (Rolling) latest release of the complete Key4hep software stack

```
source /cvmfs/sw.hsf.org/key4hep/setup.sh
source /cvmfs/sw-nightlies.hsf.org/key4hep/setup.sh
source /cvmfs/ilc.desy.de/key4hep/setup.sh
```

- **Release early and release often**
  - Solicit feedback as early as possible
- Documentation available at key4hep.web.cern.ch
- Active weekly meetings ($\sim 10 - 15$ attendees)
  - https://indico.cern.ch/category/11461/



Key4HEP

CONTENTS:

Getting started with Key4HEP software

Using Spack to build Key4HEP software

» Key4HEP

Key4HEP

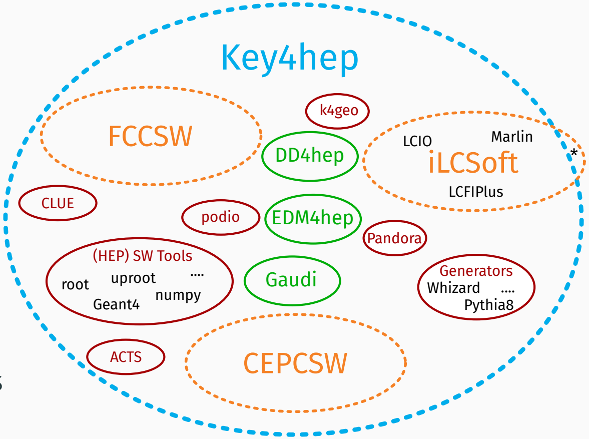
Contents:

- Getting started with Key4HEP software
  - Setting up the Key4HEP Software Stack
    - Using central installations on cvmfs
    - Using Virtual Machines or Docker contair
- Using Spack to build Key4HEP software

- **Feedback and contributions are greatly appreciated** (We really need a logo!)

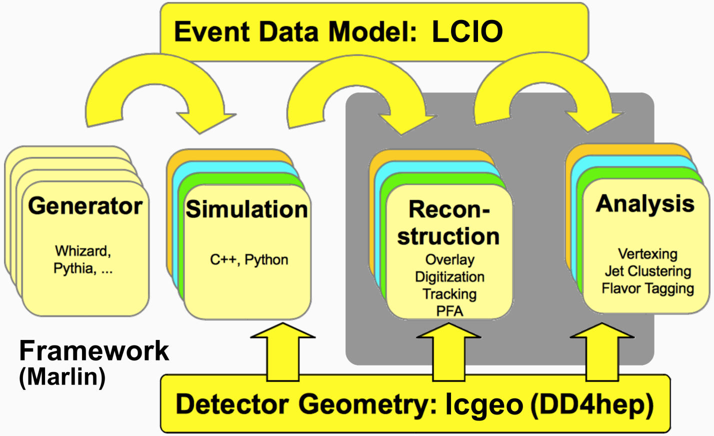
iLCSoft in Key4hep

- **iLCSoft is contained in Key4hep**
  - Things "just keep working"
  - Standard workflows, developing iLCSoft packages, ...
- `iLCInstall` vs `spack`
  - **Only build artifacts in Key4hep**
- No equivalent iLCSoft and Key4hep release yet
  - Key4hep with latest iLCSoft package versions
  - Different external package versions (ROOT, Geant4, ...)
  - Different tool chains (compilers, python, ...)



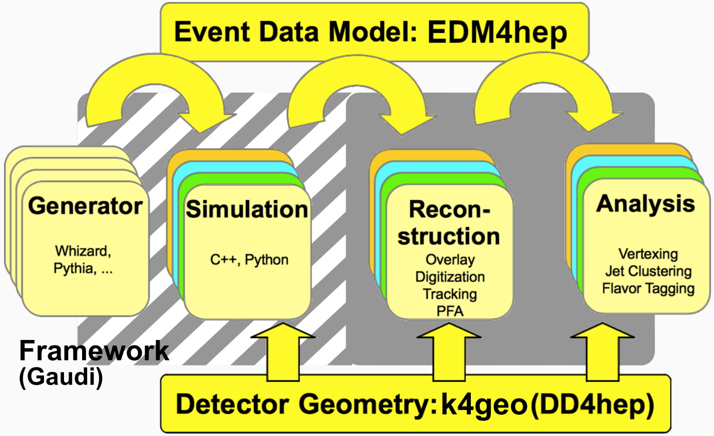
*Few testbeam packages not available

Standard workflow in iLCSoft



- Generators and simulation (`ddsim`) run outside of framework
- Reconstruction & (parts of) Analysis via `Marlin`
- **This works unchanged in a Key4hep environment!**

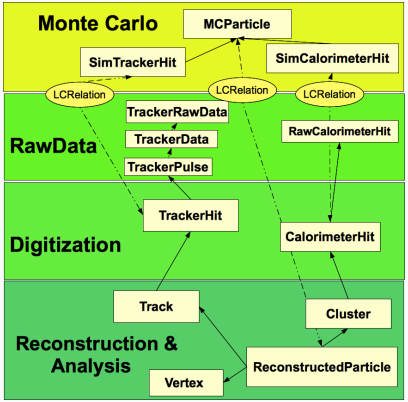
Standard workflow in Key4hep



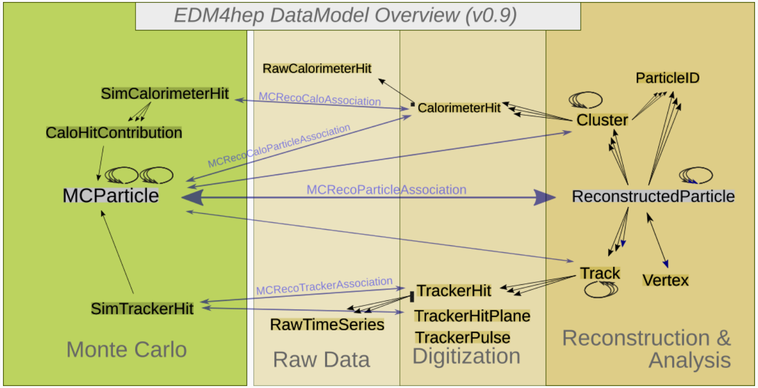
- **Conceptually the same as before** with some parts replaced
- `k4geo` (renamed from `lcgeo`) now also with first FCC geometries
- Gaudi in principle supports running Gen & Sim in FW (postponed in Key4hep)

LCIO vs EDM4hep (at the highest level)

LCIO

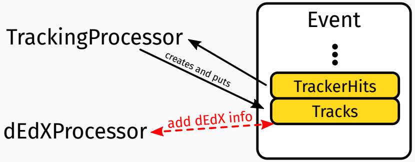


EDM4hep



- Since EDM4hep is based on LCIO the high-level structure is very similar
- Some differences in philosophy and implementation
- **Conversion in both directions available in Key4hep** as a library

LCIO vs EDM4hep (the philosophical differences)



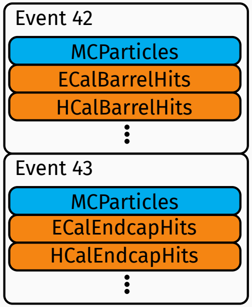
Mutability of collections and objects

- **LCIO:** Always, **EDM4hep:** Only during creation

→ Conceptual changes necessary for some workflows

→ Need to adapt EDM4hep schema

- Trivial thread-safety, improved provenance

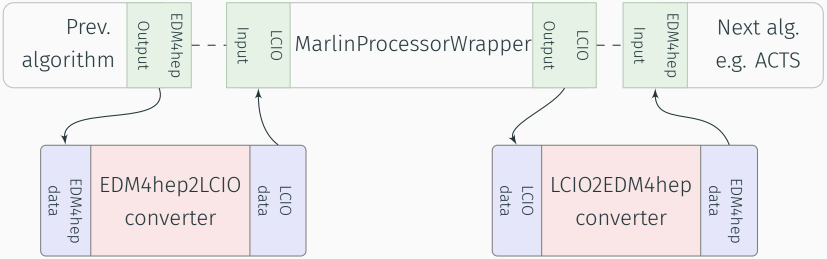


Possible event contents

- **LCIO:** Completely independent,
  EDM4hep: Consistency enforced by ROOT
- Minor impact; standard workflows switched to consistent contents

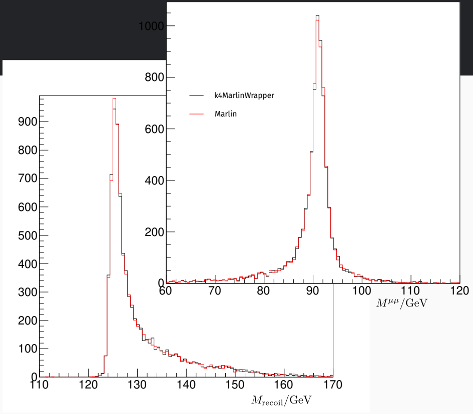
k4MarlinWrapper

- Wraps **Marlin processor** in a Gaudi algorithm and allows to **run them unchanged**
- Automatic, on-the-fly conversion between LCIO and EDM4hep
- **Allows to “mix and match” existing reconstruction algorithms with new developments**

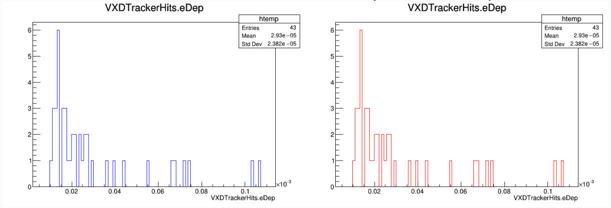


k4MarlinWrapper validation

- Full ILD, CLIC & CLD reconstruction chains have been run
    - EDM4hep inputs to EDM4hep outputs working
- Physics validation via Higgs recoil for ILD
- Converters with standalone tests
- **Ready to be used for "real" work**
    - Feedback is vital



courtesy of B. Stacey



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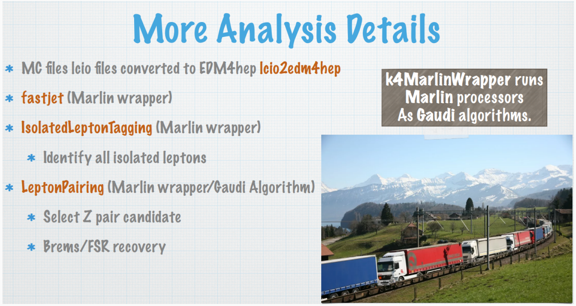
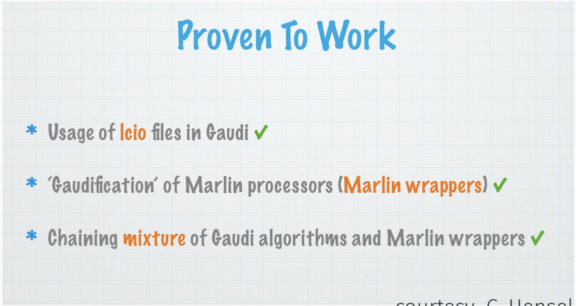


More Analysis Details

- MC files lcio files converted to EDM4hep lcio2edm4hep
- fastjet (Marlin wrapper)
- IsolatedLeptonTagging (Marlin wrapper)
    - Identify all isolated leptons
- LeptonPairing (Marlin wrapper/Gaudi Algorithm)
    - Select Z pair candidate
    - Brems/FSR recovery

k4MarlinWrapper runs Marlin processors As Gaudi algorithms.



Proven To Work

- Usage of lcio files in Gaudi ✓
- 'Gaudification' of Marlin processors (Marlin wrappers) ✓
- Chaining mixture of Gaudi algorithms and Marlin wrappers ✓

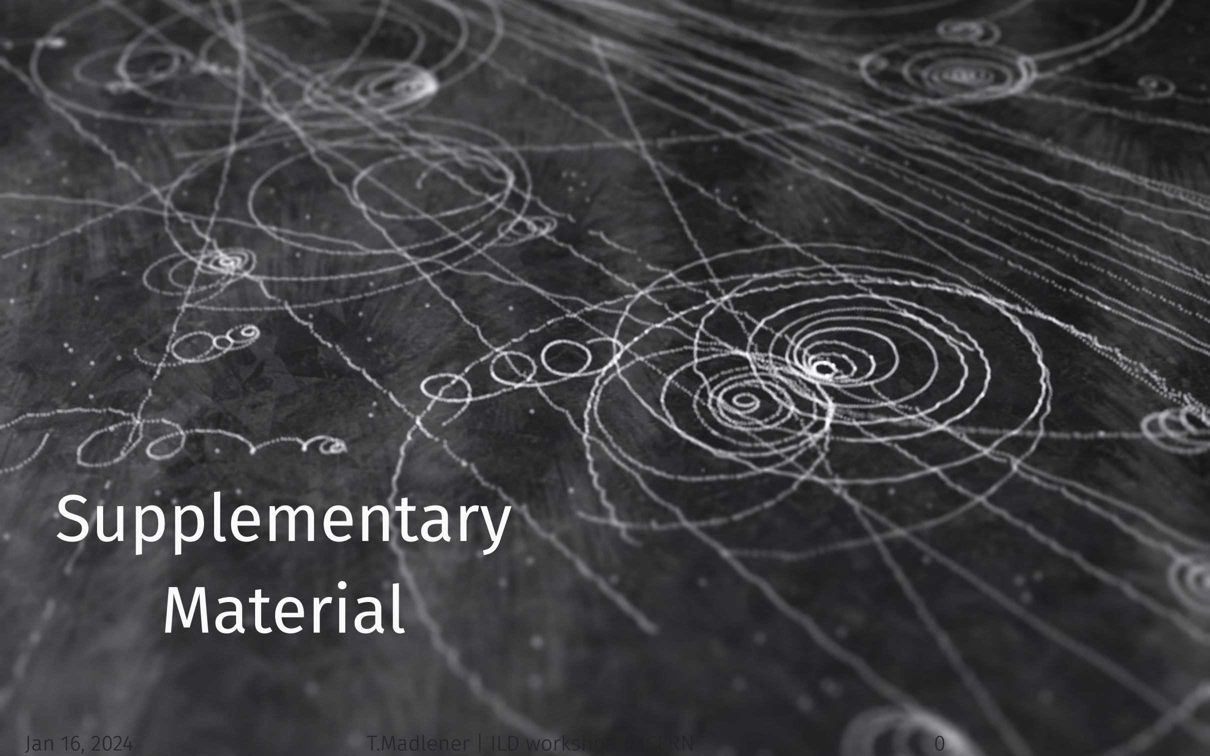
courtesy. C. Hensel

Next steps in practice

- Switch standard reco to Gaudi & MarlinWrapper (+ EDM4hep output)
  - Update (& automatize) validation to use EDM4hep
  - Use Key4hep components for new *new developments*
- Start migration of some High Level Reco (e.g. FlavorTagging) tools towards "native" Key4hep
  - Test for EDM4hep schema
  - Facilitate sharing / comparison with FCC & others
  - **(Re)-emphasize commitment of ILD to Key4hep**
- Integrate new common tools
  - e.g. ACTS for tracking (TPC possible?)
- Changes to production system & infrastructure?
- **Manpower?**

Summary

- As a community building tool Key4hep has been very successful
- **iLCSoft (components) are an integral part of Key4hep**
    - Things that work now, will also work in Key4hep
- k4MarlinWrapper and EDM converters can be / are being used for “real work”
    - **We need feedback!** (good or bad)
- Start of migration towards Key4hep components is possible



Supplementary Material

Adaption status of other projects

- FCC
  - FCCAnalyses as (high-level) analysis framework (not really using EDM4hep!)
  - Detector migration / implementation in k4geo ongoing
  - Using Key4hep as basis for developments and some productions
- CEPC
  - Started from iLCSoft but now fully switched to Gaudi & EDM4hep
  - Recent addition of drift chamber study datatypes
  - Many developments but slightly opaque
- EIC
  - Use `Jana2` framework, but try to develop framework agnostic algorithms
  - `EDM4eic` extends EDM4hep $\rightarrow$ Plan to upstream generally useful types
- MuColl
  - Partially forked iLCSoft $\rightarrow$ Plan to upstream their changes
  - Running reconstruction with Gaudi, using EDM4hep for analysis

LCIO → EDM4hep standalone converter

- Complete overhaul of pre-existing functionality
  - Major effort from Finn Johannsen (DESY project student)
  - Shared library in key4hep/k4EDM4hep2LcioConv
- Standalone executable (no Gaudi or Marlin!)

```
lcio2edm4hep input.slcio output.edm4hep.root
```

  - For all details see README
  - Available in recent nightly builds
- Support all features that are necessary for ILD

Marlin vs Gaudi

- Conceptually the two frameworks are very similar
  - Schedule different working units
  - Marshall data
- Most obvious differences in naming conventions
  - As always some differences emerge when looking at the details

	Marlin	Gaudi
language	C++	C++
working unit	Processor	Algorithm
config language	XML	Python
transient data format	LCIO	anything
set up function	`init`	`initialize`
work function	`processEvent`	`execute`
wrap up function	`end`	`finalize`

Key4hep packages

- `k4FWCore` key4hep/k4FWCore
  - Core Key4hep framework providing core functionality, e.g.
    - Data Service for EDM4hep inputs
    - Overlay for backgrounds
- `k4SimDelphes` for Delphes fast simulation key4hep/k4SimDelphes
- `k4MarlinWrapper` Marlin proc. wrapper key4hep/k4MarlinWrapper
- Many packages migrated from FCCSW to Key4hep
  - `k4SimGeant4` for Geant4 simulation integration HEP-FCC/k4SimGeant4
  - `k4Gen` for generic generator interface HEP-FCC/k4Gen
  - ...
- Ongoing work to integrate more components
  - ACTS tracking framework acts-project/acts | key4hep/k4ActsTracking
  - CLUE fast clustering algorithms .cern.ch/kalos/CLUE | key4hep/k4CLUE