EDM4hep and PODIO

Introduction and Overview

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LUXE Computing & DAQ meeting

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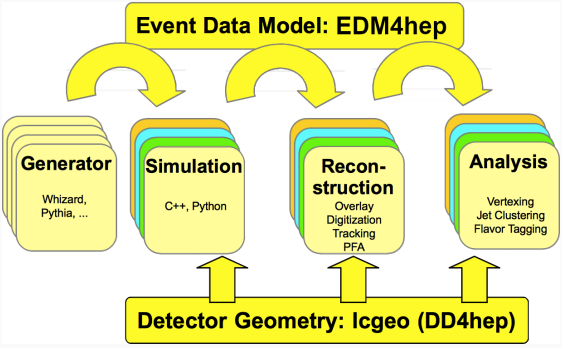
The EDM at the core of HEP software

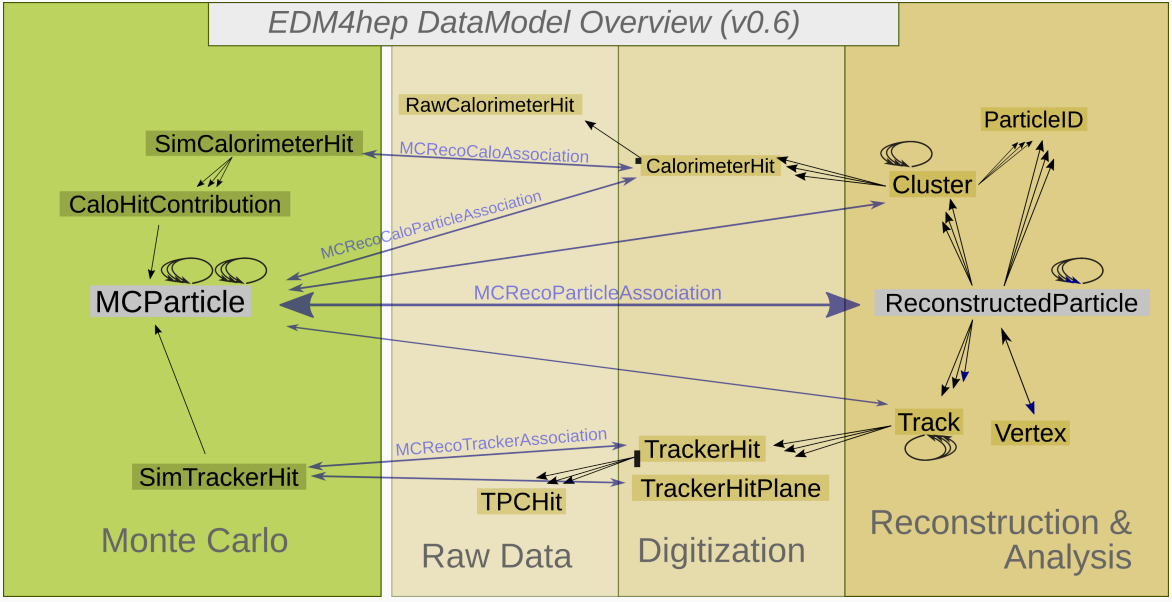


- Different components of HEP experiment software have to talk to each other
- The event data model defines the language for this communication
- Users express their ideas in the same language

EDM4hep - Goals & Motivation

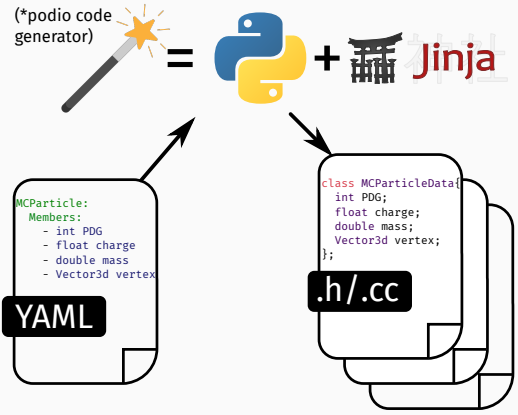
- The Key4hep project aims to develop a common software stack for all future collider projects
  - ILC, CLIC, FCC-ee & FCC-hh, CEPC, EIC, ...
- EDM4hep is the **shared, common EDM** that can be used by **all communities** in the Key4hep project (and others)
- EDM4hep has to uspport different use cases from these communities
- Efficiently implemented, support for multi-threading and with usage on heterogeneous resources in mind
- Built on experience from the “past” - mainly **LCIO**, which has been successfully shared by the LC communities

EDM4hep schema



podio as generator for EDM4hep

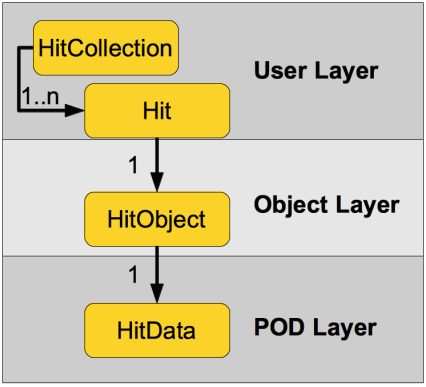
- Traditionally HEP c++ EDMs are heavily Object Oriented
- Use `podio` to generate thread safe code starting from a high level description
- Provide an easy to use interface to the users



AIDASoft/podio

The three layers of podio

- podio favors **composition over inheritance** and uses **plain-old-data (POD)** types wherever possible
- Layered design allows for efficient memory layout and performant I/O implementation



podio - datamodel definition

```yaml
components:
  edm4hep::Vector3f:
    Members: [float x, float y, float z]

datatypes:
  edm4hep::ReconstructedParticle:
    Description: "Reconstructed Particle"
    Author : "F.Gaede, DESY"
    Members:
      - edm4hep::Vector3f     momentum   // [GeV] particle momentum
      - std::array<float, 10> covMatrix  // energy-momentum covariance
    OneToOneRelations:
      - edm4hep::Vertex startVertex // start vertex associated to this particle
    OneToManyRelations:
      - edm4hep::Cluster clusters  // clusters that have been used for this particle
      - edm4hep::ReconstructedParticle particles // associated particles
    ExtraCode:
      declaration: "bool isCompund() const { return particles_size() > 0; }\n"

  edm4hep::ParticleID:
    VectorMembers:
      - float parameters // hypothesis params
```

*extracted from edm4hep.yaml

- Reusable components
- Fixed sized arrays as members
- *VectorMembers* for variable sized array members
- 1 – 1 and 1 – N relations
- Additional user-provided code

podio - features of generated code

```cpp
auto recos = ReconstructedParticleCollection();
// ... fill ...
for (auto reco : recos) {
  auto vtx = reco.getStartVertex();
  for (auto rp : reco.getParticles()) {
    auto mom = rp.getMomentum();
  }
}
```

← c++17 code with “value semantics”

↓ Python bindings via PyROOT

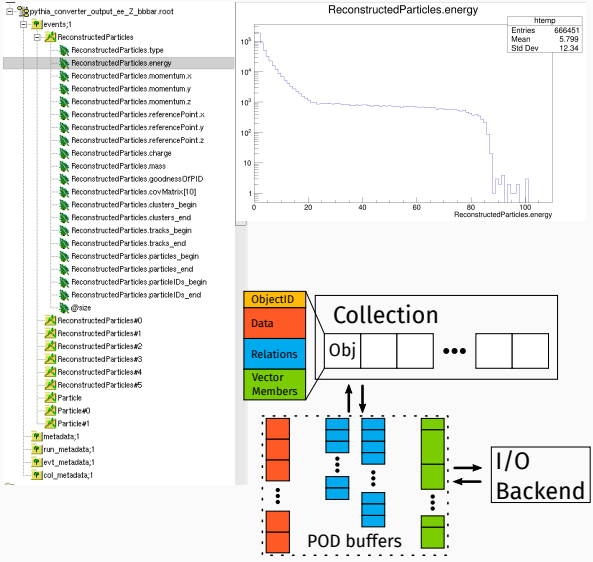
```python
recos = ReconstructedParticleCollection()
#... fill ...
for reco in recos:
  vtx = reco.getStartVertex()
  for rp in reco.getParticles():
    mom = rp.getMomentum()
```

```python
d = ROOT.RDataFrame('events', 'events.root')
h = (d.Define('abs_pdg', 'abs(Particle.PDG)')
      .Define('mu_sel', 'abs_pdg == 13')
      .Define('mu_px',
              'Particle.momentum.x[mu_sel]')
      .Histo1D('mu_px'))
h.DrawCopy()
```

← Using `RDataFrame` to read ROOT files (`uproot` also possible)

podio supports different I/O backends

- Default **ROOT** backend
  - POD buffers are stored as branches in a `TTree`
  - Files can be interpreted **without EDM library**(!)
  - Can be used in `RDataFrame` or with `uproot`
- Alternative **SIO** backend
  - Persistency library used in `LCIO`
  - Complete events are stored as binary records
- Adding more I/O backends is possible



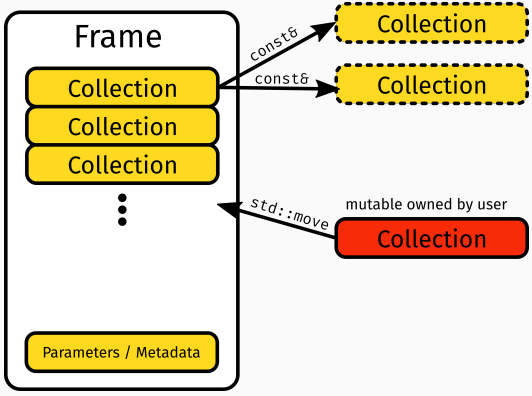
CMake interface for projects using podio

```cmake
find_package(PODIO)

# generate the c++ code from the yaml definition
PODIO_GENERATE_DATAMODEL(edm4hep edm4hep.yaml headers sources IO_BACKEND_HANDLERS "ROOT;SIO")
# compile the core data model shared library (no I/O)
PODIO_ADD_DATAMODEL_CORE_LIB(edm4hep "${headers}" "${sources}")
# generate and compile the ROOT I/O dictionary
PODIO_ADD_ROOT_IO_DICT(edm4hepDict edm4hep "${headers}" src/selection.xml)
# compile the SIOBlocks shared library for the SIO backend
PODIO_ADD_SIO_IO_BLOCKS(edm4hep "${headers}" "${sources}")

# Install the created targets
install(TARGETS edm4hep edm4hepDict edm4hepSioBlocks)
```

- Easy to use functions for integrating a podio generated EDM into a project
- Split into core EDM library and I/O handling for different backends
  - Pick what you need
  - I/O handling parts dynamically loaded by podio on startup

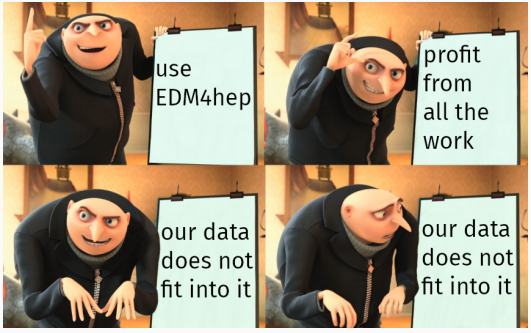
The `Frame` - A generalized (event) data container

- Container aggregating all relevant data
- Defines an *interval of validity* / category for contained data
  - Event, Run, readout frame, ...
- Easy to use and thread safe interface for data access
  - Immuatable read access only
  - Ownership model reflected in API
- Decouples I/O from operating on the data



Prototyping of new datatypes

- podio comes with a mechanism to extend existing (“upstream”) datamodels
- EDM4hep uses this for **prototyping new datatypes**
  - Have to avoid to fracture EDM4hep
  - Goal is always inclusion into EDM4hep
- Used in Key4hep for some detector prototyping
- Room for more detector concepts in EDM4hep!



Ongoing work & Future plans

- Release v1.0 with backwards compatibility from then on
  - Need to finish schema evolution work first
- Propagate Frame based I/O to all currently existing “customers”
  - Framework integration, ddsim (DD4hep) output, ...
- Implement currently missing features
  - E.g. User defined associations between arbitrary types
  - *Interface types* that allow for easier high level workflows (e.g. tracker hits for different technologies)
- Start exploring work on heterogeneous resources

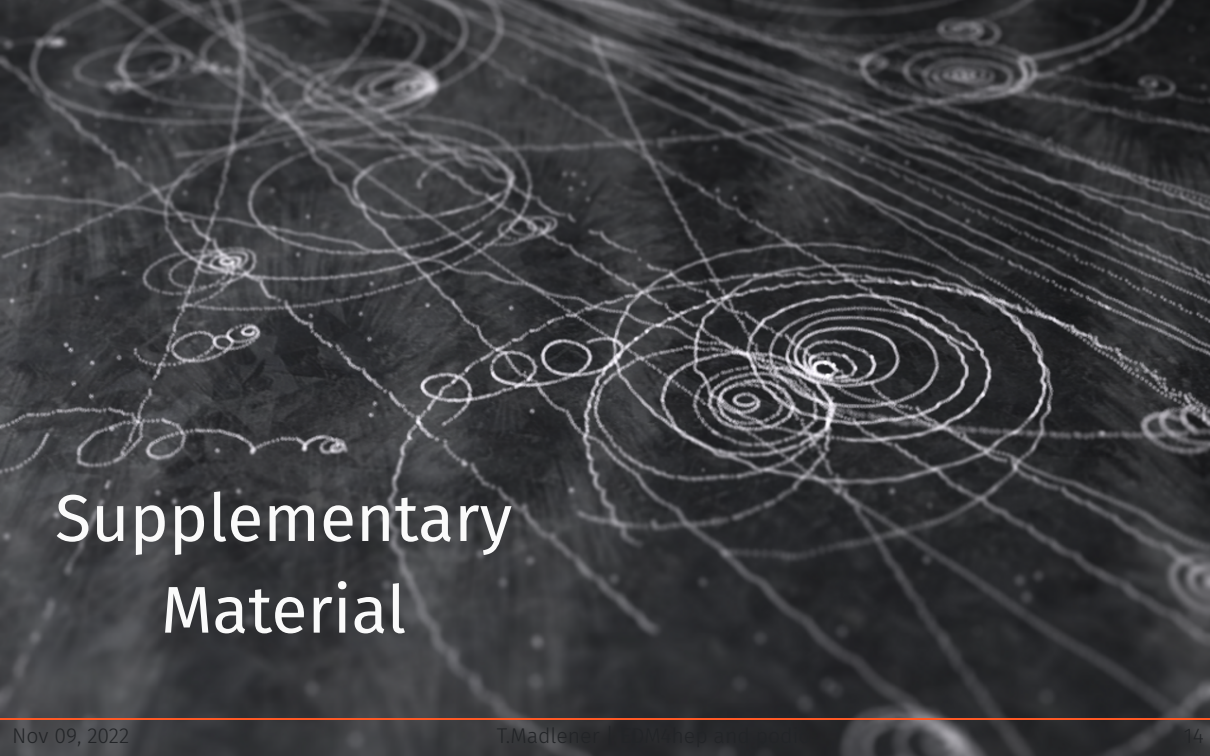
Summary

- EDM4hep is the shared, common EDM for the Key4hep project
  - Community effort is a success
- It is generated via the podio EDM toolkit
- Efficient implementation of data types and flexible I/O capabilities
- podio extension mechanism can be used to add new data types
- EDM4hep is open for new data types for not yet covered detector types

Pointers to software (re)sources

- EDM4hep
  - key4hep/EDM4hep
  - cern.ch/edm4hep
- podio
  - AIDASoft/podio
- Biweekly meetings for podio/EDM4hep discussion
  - indico.cern.ch/category/11461/

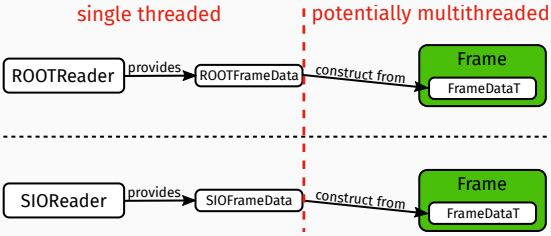
xkcd.com/138



Supplementary Material

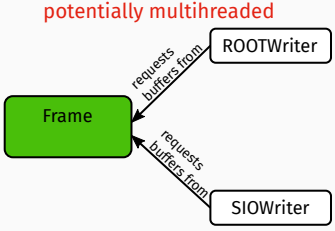
Frame I/O and multithreading model

- Readers provide data for a **complete Frame** in (almost) arbitrary format
- Assume that there is only one thread per file (i.e. Reader/Writer)



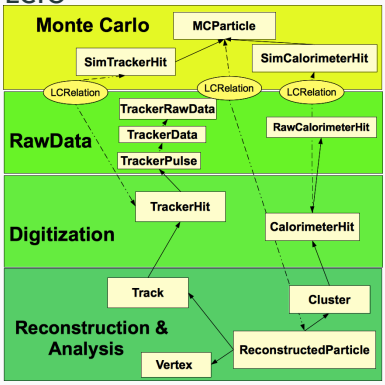
- Reading raw data and constructing a frame from it is a two step process
- Makes it possible to do unpacking on a different thread than the one that reads

- Writing can happen with multiple threads, e.g. each writer on its own thread
- Writers can write different contents, e.g. SIM & RECO into separate files
  - Need one writer “per content”

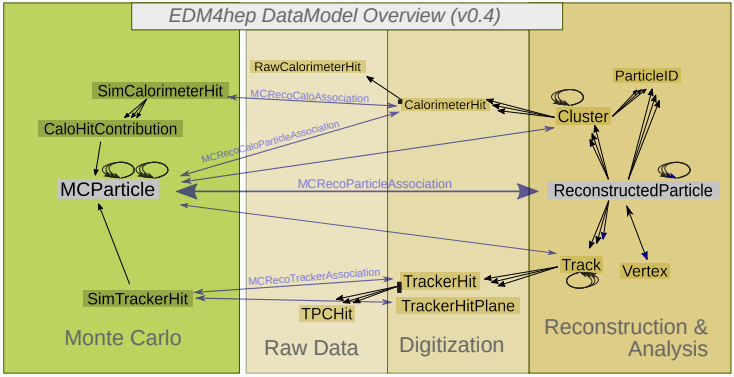


LCIO vs EDM4hep

LCIO

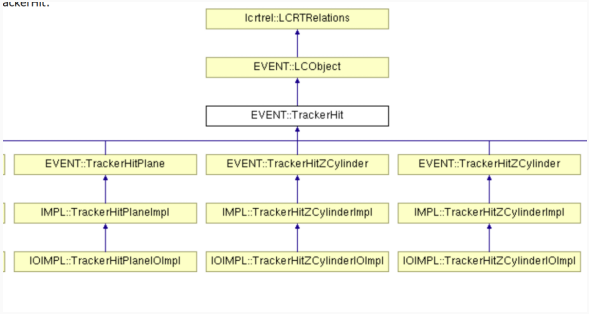


EDM4hep



- Since EDM4hep is based on LCIO the high-level structure is very similar
- Largest differences between the two are due to their implementations
- LCIO has over 15 years of usage. A lot of time to develop tools for it.
  - Not nearly as far with EDM4hep

Interface types



- LCIO uses “classic” polymorphism
  - Common `LCObject` base type for all data types
  - `Impl` classes offer the mutable interface
- This is used in some places to add some structure to data types
  - E.g. `TrackerHit` has various implementations different detector technologies
- Not solved for podio (and EDM4hep)