EDM4hep and PODIO

Introduction and Overview

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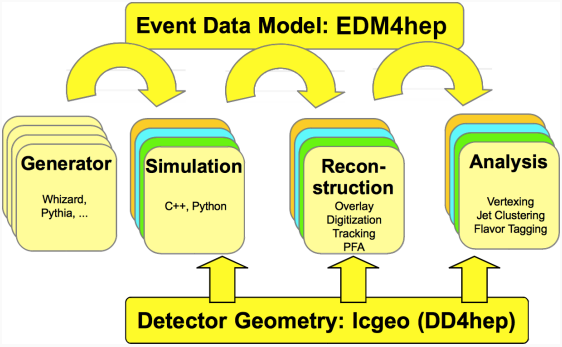
The EDM at the core of HEP software

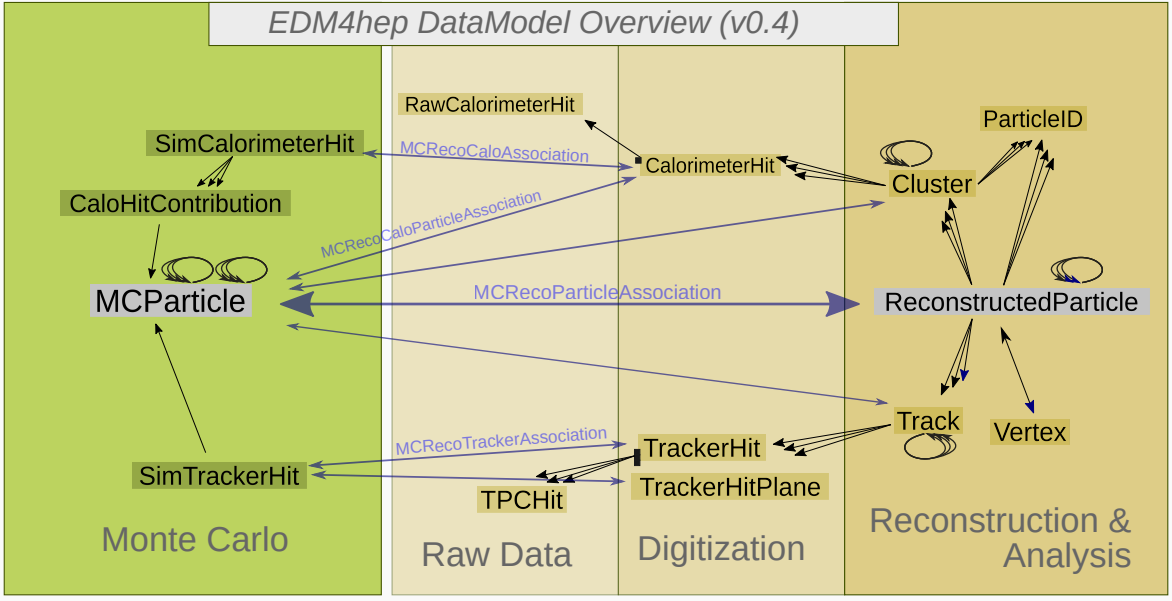


- Different components of HEP experiment software have to talk to each other
- The event data model defines the language for this communication
- Users express their ideas in the same language

EDM4hep goals

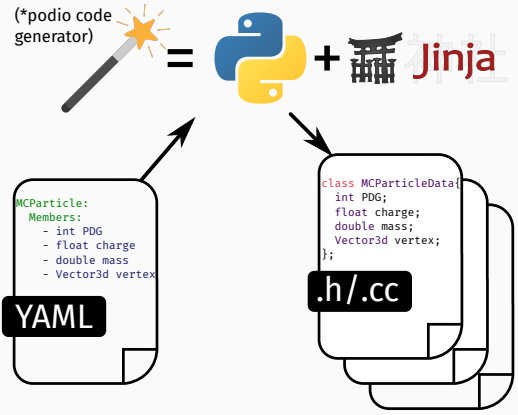
- The Key4hep project aims to define a common software stack for all future collider projects
  - Regular contributions from **ILC, CLIC, FCC-ee & FCC-hh, CEPC, EIC (ATHENA)**, ...
- EDM4hep is the **shared, common EDM** that can be used by **all communities** in the Key4hep project
- Support different use cases from these communities
  - Different collision environments lead to different requirements for an EDM
- Efficiently implemented, support multi-threading and have heterogeneous resources in mind
- Build on past experience from fcc-edm and LCIO, which has already been succesfully shared by the LC communities

EDM4hep schema



podio as generator for EDM4hep

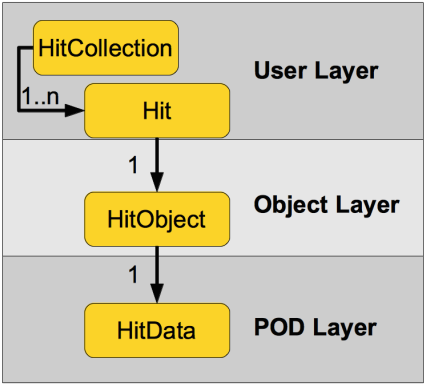
- Traditionally HEP c++ EDMs are heavily Object Oriented
- Use `podio` to generate thread safe code starting from a high level description
- Provide an easy to use interface to the users



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

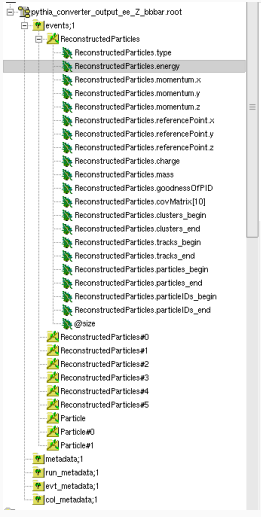
```python
recos = ReconstructedParticleCollection()
#... fill ...
for reco in recos:
  vtx = reco.getStartVertex()
  for rp in reco.getParticles():
    mom = rp.getMomentum()
```

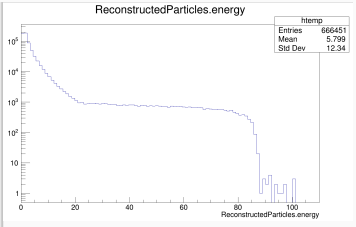
```python
d = ROOT.RDataFrame('events', 'events.root')
h = (d.Define('abs_pdg', 'abs(Particle.PDG)')
      .Define('mu_sel', 'abs_pdg == 13')
      .Define('mu_px',
              'Particle.momentum.x[mu_sel]')
      .Histo1D('mu_px'))
h.DrawCopy()
```

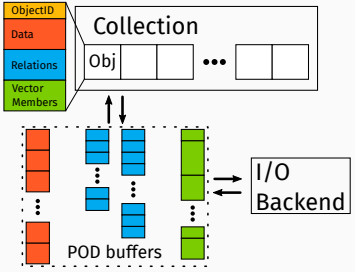
← Using `RDataFrame` to read ROOT files

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

podio support in framework(s)

- podio has been used by `fcc-edm`
- key4hep/k4FWCore provides Gaudi integration for podio generated EDMs
  - Originally developed for FCCSW, now adapted by Key4hep
- juggler has essentially the same functionality as `k4FWCore`
  - Developed in the context of ATHENA
- Essentially re-implementation(s) of “standalone” ROOT writers/readers of podio
  - Including some differences that snuck in over time

Currently ongoing work

- Schema evolution of generated EDMs
  - Leverage existing code generation facilities
  - Allow for user intervention for non-trivial cases (e.g. change of coordinate system)
  - Incrementally implement required features
  - Foresee the possibility to exploit existing schema evolution from I/O backend (e.g. ROOT)
- `podio::Frame` - a generalized (event) data container
  - Offer a flexible mechanism for organizing data into different categories (e.g. Run, Event, ...)
  - Easy to use, thread-safe interface

Future plans

- Release v1.0 with backwards compatibility from then on
  - After schema evolution and Frame have been implemented / merged
- Consolidate the different I/O implementations (“standalone” vs. different framework implementations)
- Implement missing features (from our perspective)
  - User defined relations/associations between arbitrary types
  - *Interface types* that allow for easier high level workflows (e.g. tracker hits for different technologies)
- Implement existing feature requests from community
  - Make it possible to extend an existing EDM (AIDASoft/podio#263)
  - Allow for default initialization values in datatypes (AIDASoft/podio#266)
- Start exploring usage on heterogeneous resources

Experience using EDM4hep and podio

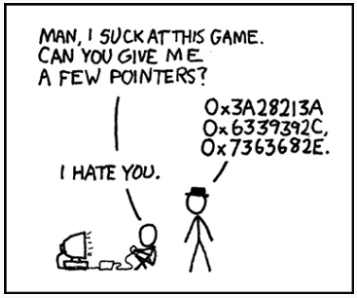
- EDM4hep is actively used for physics and detector studies and the main "customer" of podio
- "Re-implemented" by `eicd`
  - Adapted EDM4hep after first using their own podio generated EDM
  - Defines a few extra data types
- Biweekly meetings to discuss podio and EDM4hep
  - indico.cern.ch/category/11461/ - Tuesdays at 9:00AM (CEST), but US friendly timeslot possible
- Community effort is very successful
  - No showstoppers observed so far
  - Problems / issues are usually resolved quickly
  - Biggest issue so far has been missing schema evolution

Summary

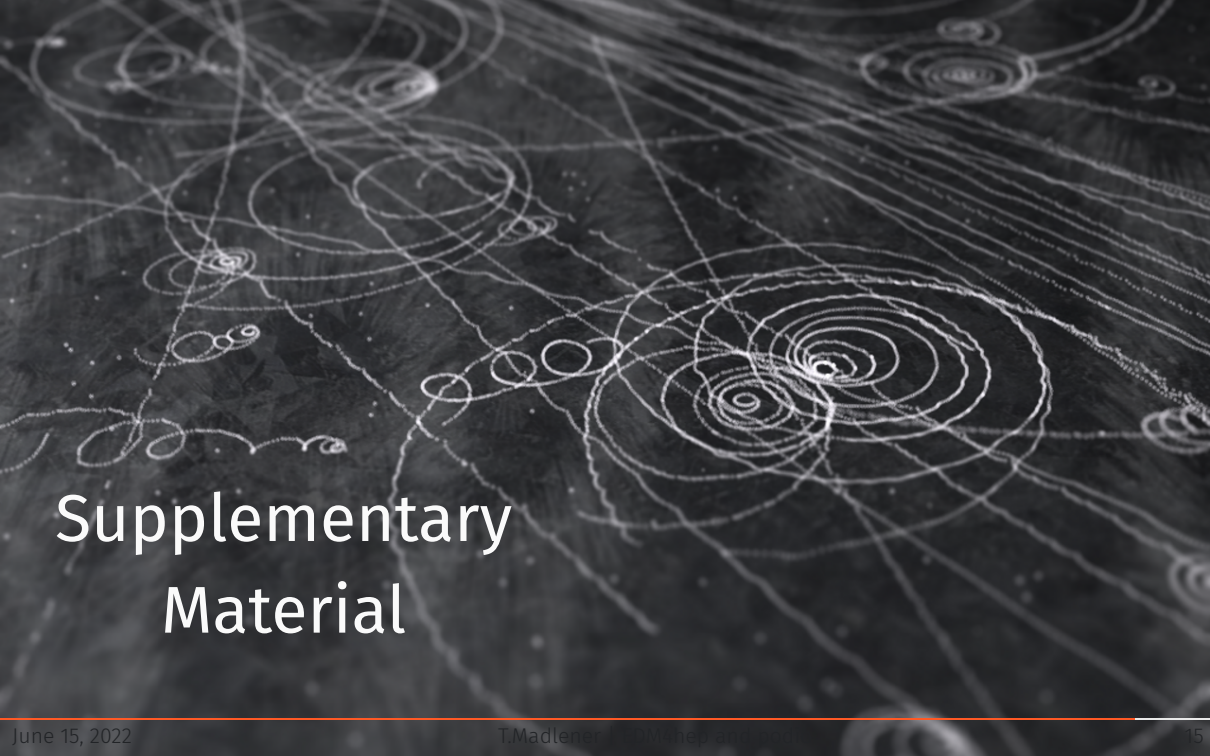
- EDM4hep is the shared, common EDM for the Key4hep project
- It is generated via the podio EDM toolkit
- Tackling schema evolution and adding the `Frame` are the major milestones for podio v1.0
  - Some additional features will be tackled after that
- EDM4hep is successfully used for physics and detector studies
- Community effort is a success
  - Also happy to welcome new contributors and communities

Pointers to software (re)sources

- Key4hep
  - key4hep.github.io/key4hep-doc
  - key4hep - github organisation
- EDM4hep
  - key4hep/EDM4hep
  - cern.ch/edm4hep
- podio
  - AIDASoft/podio
- k4MarlinWrapper
  - key4hep/k4MarlinWrapper
- FCCAnalyses
  - HEP-FCC/FCCAnalyses

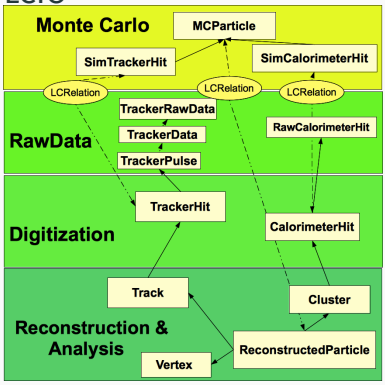


xkcd.com/138

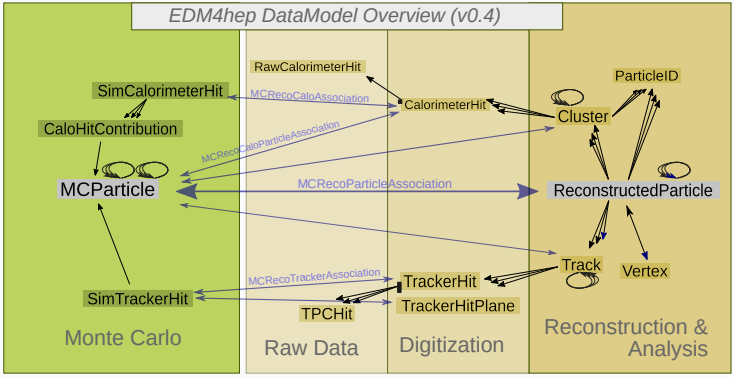

Supplementary
Material

LCIO vs EDM4hep

LCIO

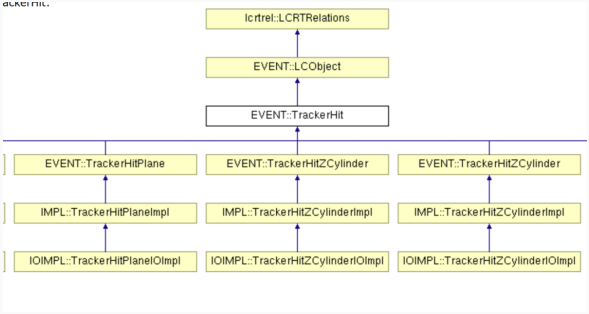


EDM4hep



- 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

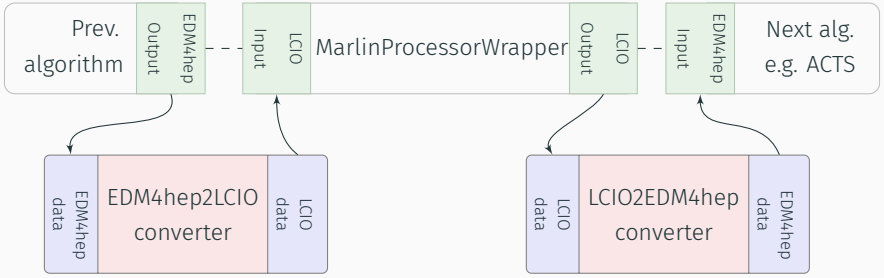
Interface types



- 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)

k4MarlinWrapper

- Wraps **Marlin processor** in a Gaudi algorithm and allows to **run them unchanged**
  - Can run a full ILD / CLIC reconstruction and analysis chain via Gaudi
- Converter script to turn Marlin XML steering files into Gaudi python option files
- Automatic, on-the-fly conversion between LCIO and EDM4hep
  - Allows to “mix and match” existing Marlin processors with Gaudi algorithms



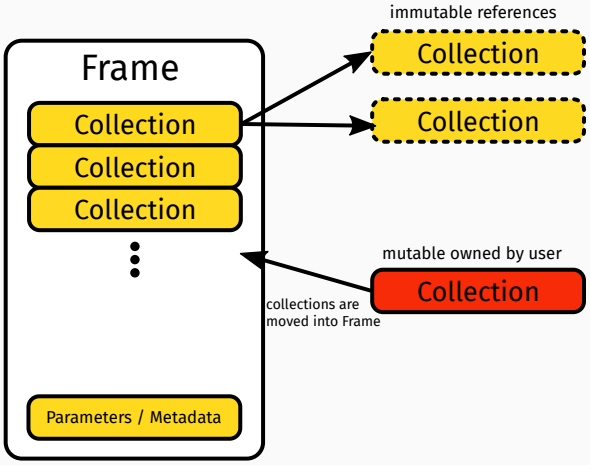
FCCAnalyses

HEP-FCC/FCCAnalyses

- `FCCAnalyses` is a python analysis framework based on `RDataFrame`
  - Comes with high level reco functionality
  - Extensible via C++
- **Not specific to FCC!** Can be run with EDM4hep inputs
- Declarative style of the analysis
- Currently being reworked for improved usability

```
(self.df
 # define an alias for muon index collection
 .Alias("Muon0", "Muon#0.index")
 # define the muon collection
 .Define("muons",  "ReconstructedParticle::get(Muon0, ReconstructedParticles)"
 #select muons on pT
 .Define("selected_muons", "ReconstructedParticle::sel_pt(10.)(muons)")
variables = {
    "mz":{"name":"zed_leptonic_m","title":"m_{Z} [GeV]","bin":125,"xmin":0,"xmax":250},
    "mz_zoom":{"name":"zed_leptonic_m","title":"m_{Z} [GeV]","bin":40,"xmin":80,"xmax":100},
    "leptonic_recoil_m":{"name":"zed_leptonic_recoil_m","title":"Z leptonic recoil [GeV]","bi
    "leptonic_recoil_m_zoom":{"name":"zed_leptonic_recoil_m","title":"Z leptonic recoil [GeV]
    "leptonic_recoil_m_zoom1":{"name":"zed_leptonic_recoil_m","title":"Z leptonic recoil [GeV
    "leptonic_recoil_m_zoom2":{"name":"zed_leptonic_recoil_m","title":"Z leptonic recoil [GeV
    "leptonic_recoil_m_zoom3":{"name":"zed_leptonic_recoil_m","title":"Z leptonic recoil [GeV
    "leptonic_recoil_m_zoom4":{"name":"zed_leptonic_recoil_m","title":"Z leptonic recoil [GeV
 # find zed candidates from  di-muon resonances
 .Define("zed_leptonic",         "ReconstructedParticle::resonanceBuilder(91)("
 # write branch with zed mass
 .Define("zed_leptonic_m",       "ReconstructedParticle::get_mass(zed_leptonic
 # write branch with zed transverse momenta
 .Define("zed_leptonic_pt",      "ReconstructedParticle::get_pt(zed_leptonic)"
 # calculate recoil of zed_leptonic
 .Define("zed_leptonic_recoil",  "ReconstructedParticle::recoilBuilder(240)(ze
 # write branch with recoil mass
 .Define("zed_leptonic_recoil_m","ReconstructedParticle::get_mass(zed_leptonic_
 .Define("zed_leptonic_charge","ReconstructedParticle::get_charge(zed_leptonic
```

podio::Frame basics



- Ownership of the data reflected in the interface
  - Immutable access only for stored data
  - Mutable user owned data has to be explicitly *moved* into the Frame
- Defines an *interval of validity* or category for the stored data (e.g. Run, Event, ...)
- Thread-safe
- First version being tested
  - AIDASoft/podio#287