Status of EDM4hep

Thomas Madlener

7th FCC physics workshop

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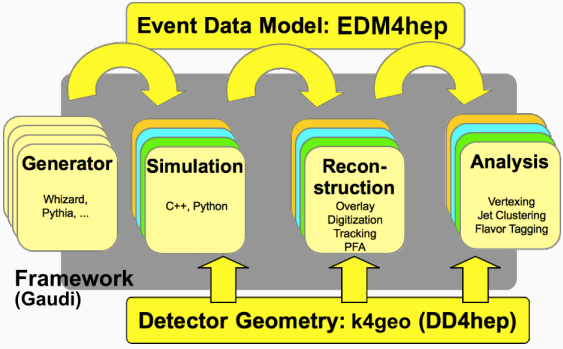
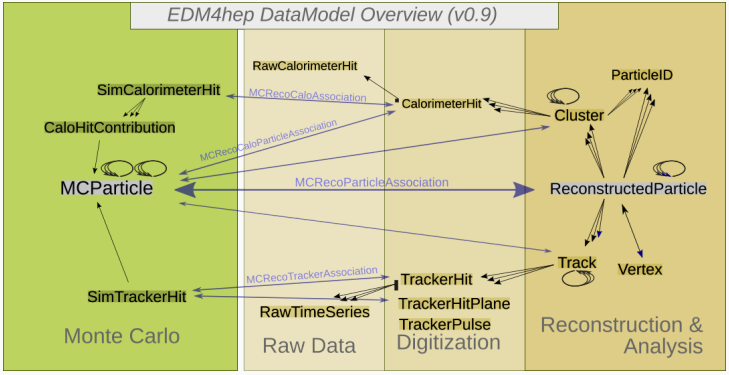
The EDM at the core of HEP software



- Different components of 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 - The common EDM for Key4hep



key4hep/EDM4hep

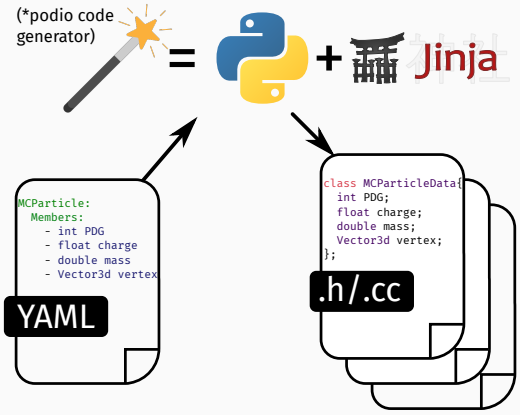
edm4hep.web.cern.ch

AIDASoft/podio

- Based on `LCIO` and `FCC-edm`
  - Focus on usability in analysis
- Quite stable over the last two years
  - **Some breaking changes foreseen for v1.0!**
- Can easily be extended
  - Used by EDM4eic
  - Prototyping!
- Generated via `podio`

The podio EDM toolkit

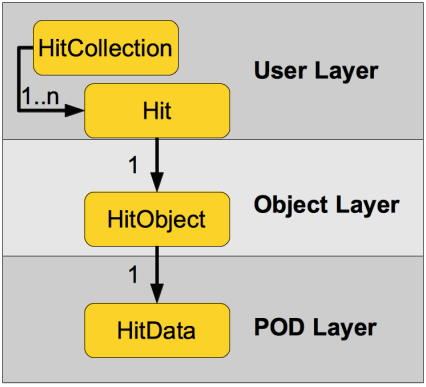
- Implementing a performant event data model (EDM) is non-trivial
- Use `podio` to generate code starting from a high level description
- Provide an easy to use interface to the users
- Main customers and feature drivers
  - key4hep/EDM4hep
  - eic/EDM4eic



AIDASoft/podio

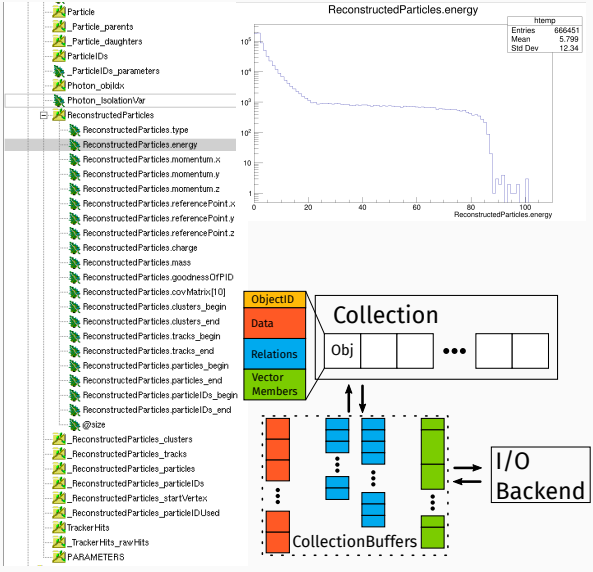
The three layers of podio

- 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



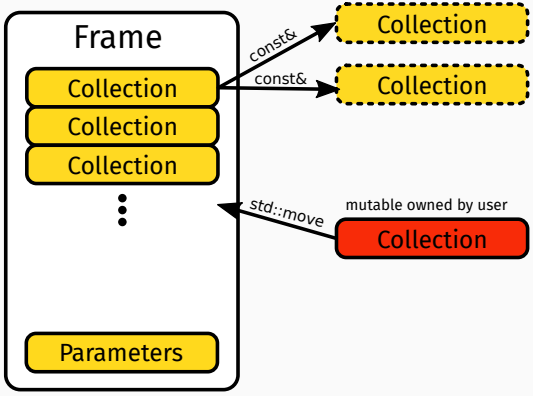
podio supports different I/O backends

- Default **ROOT** backend
  - Effectively flat ntuples (`TTree` / `RNTuple`)
  - Files can be interpreted **without EDM library**(!)
  - **Intelligble names** NEW Jun 23
  - Can be used in `RDataFrame` (**FCCAnalyses**) or with `uproot`
- Adding more I/O backends is possible
  - Alternative SIO backend exists
- **Many features only available through generated interfaces**



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

- *Type erased* 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
  - Immutable read access only
  - Ownership model reflected in API
- Decouples I/O from operating on the data
- Old `EventStore` has been removed!



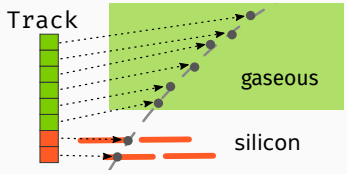

```
template<typename CollT>
const CollT& get(const std::string& name) const;

template<typename CollT, /*enable_if*/>
const CollT& put(CollT&& collection,
                 const std::string& name);
```

Schema evolution


```
Comparing datamodel versions v2 and v1

Found 3 schema changes:
 - 'ex2::NamespaceStruct' has an addded member 'y'
 - 'ex2::NamespaceStruct' has a dropped member 'y_old'
 - 'ExampleStruct.x' changed type from 'int' to 'double'

Warnings:
 - Definition 'ex2::NamespaceStruct' has a potential [...]

ERRORS:
 - Forbidden schema change in 'ExampleStruct' for 'x' [...]
```

- Allow to read old versions of an EDM from file and convert “on-the-fly”
- Hard problem with many considerations
  - Leverage backend if possible
  - Allow user defined evolution
- **Evolution always directly to current version**
- Detect potential problems at code generation
  - Expand available automatic evolutions as necessary
- **Machinery in place**; “whatever ROOT can do” for now

Interface types and their use in EDM4hep



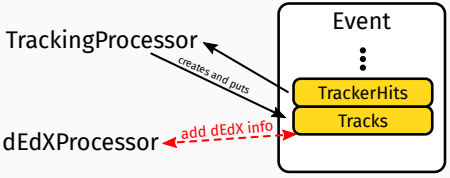

```yaml
interfaces:
  edm4hep::TrackerHit:
    Types: [edm4hep::TrackerHit3D, edm4hep::TrackerHitPlane]
    Members:
      - edm4hep::Vector3f position [mm] // hit position

datatypes:
  edm4hep::Track:
    OneToManyRelations:
      - edm4hep::TrackerHit trackerHits // hits of this track
```

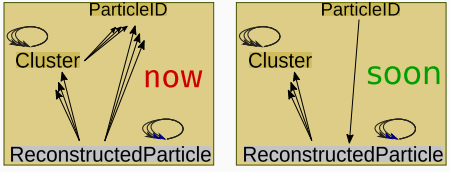
```cpp
auto track = edm4hep::Track{};
track.addHit(edm4hep::TrackerHit3D{});
track.addHit(edm4hep::TrackerHitPlane{});

const auto hits = track.getHits();
hits[0].isA<edm4hep::TrackerHit3D>();       // <-- true
hits[0].getValue<edm4hep::TrackerHit3D>(); // <-- "cast back"
hits[1].isA<edm4hep::TrackerHit3D>();       // <-- false
hits[1].getValue<edm4hep::TrackerHit3D>(); // <-- exception!
```

- General interface can be useful to "gloss over some details"
- Value semantics prevent inheritance based approach
  - Pointers in interfaces break consistency
  - No base class to inherit from
- Introduce *interfaces* as new category in YAML definition
  - Define desired functionality
  - **No collections!**
  - Use like normal *datatypes*
  - "Casting back" is possible

Current developments towards EDM4hep v1.0

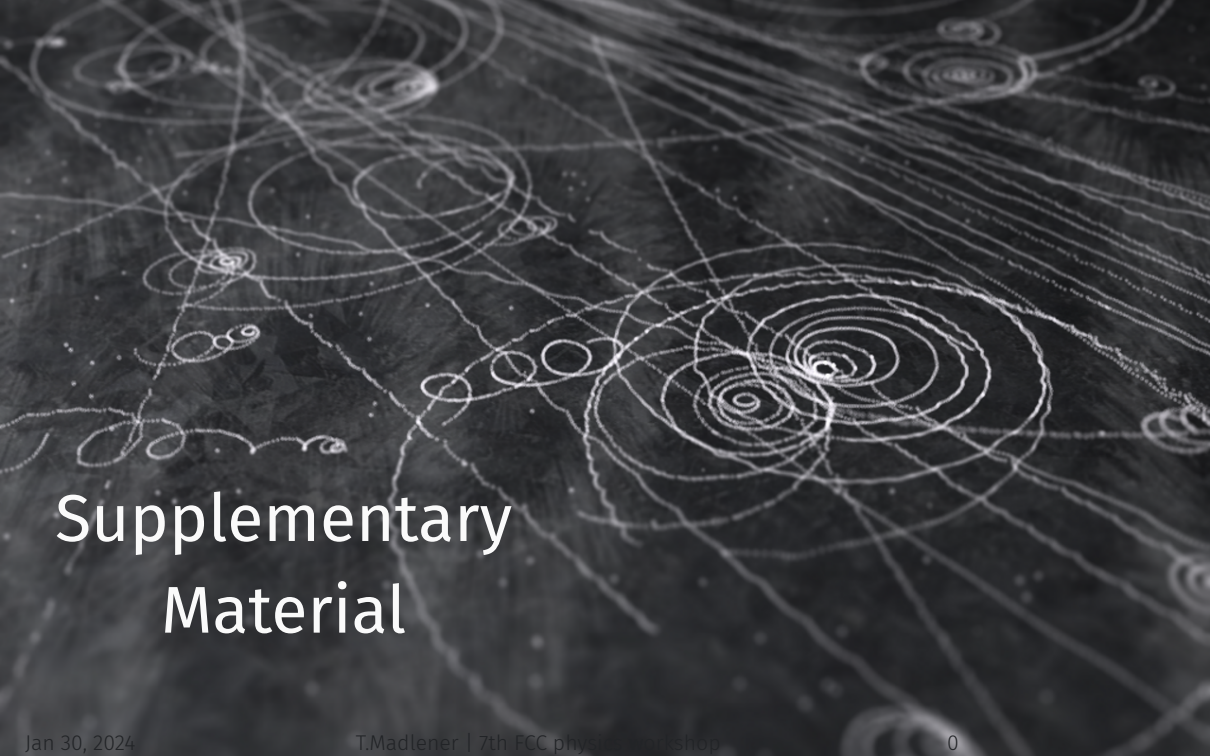
- **We are going to break some things without intention of doing schema evolution!**
- Consistent mutability concept
  - Some inconsistencies inherited from LCIO
  - Make sure to have relations “in the right direction”
  - Remove unused relations
- Introduce `TrackerHit` interface
- Add multiple weights to `EventHeader`
- Renaming of a few relations
- **Now is a good time to bring up bigger changes**
- Keeping track in EDM4hep v1.0 project





Summary

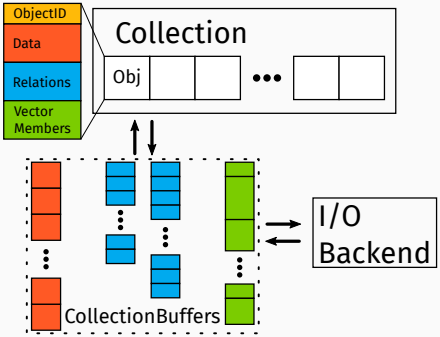
- EDM4hep is the common EDM and as such a core component of Key4hep
- Crucial developments in podio are done
  - File format frozen for quite some time now
  - Consider it *feature complete* for now
  - v1.0 soon (weeks) $\rightarrow$ backward compatible from then on
- Need to fix some conceptual issues and integrate podio latest features in EDM4hep
  - Breaking changes without plans for smooth evolution
- EDM4hep v1.0 planned to be finished soon
  - Backward compatible or transparent migration afterwards

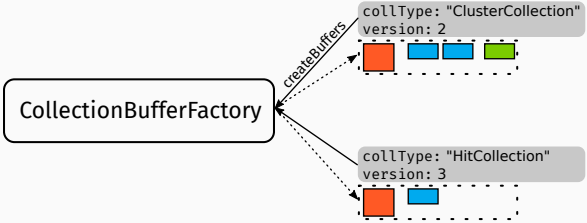


Supplementary Material

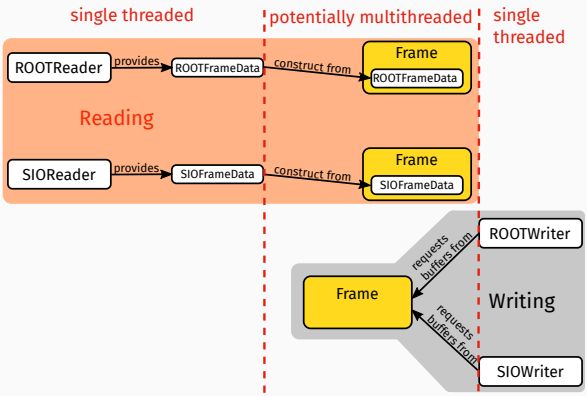
I/O low level basics

- I/O is based on collections
- `CollectionBuffer` holds all necessary data to (de)serialize a collection
  - Simple POD buffers (AoS)
  - I/O backend only needs to handle these
- `CollectionBufferFactory` creates empty buffers
  - (type, version) → `std::function`
  - Populated during datamodel library loading





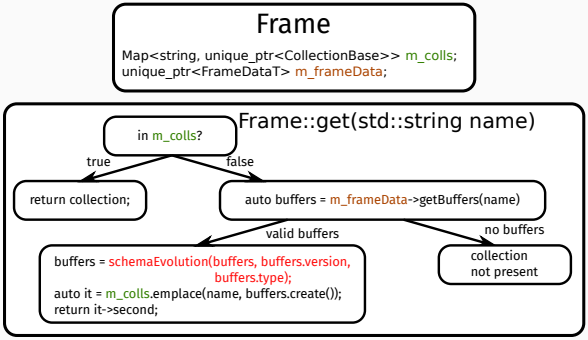
I/O on the Frame level



- Readers & Writers assumed to be single threaded
  - Low level building blocks
- Defer work as long as possible
  - Minimize time in Reader
- Frame can be constructed from "arbitrary" `FrameDataT`
  - Provides `CollectionBuffers`
  - Contain complete data for a Frame

Schema evolution - Technical details

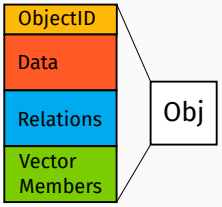
- Called as early as possible and as late as necessary
  - Earliest point where we have collection buffers from all backends is in Frame
- Schema evolution functions available from `SchemaEvolution` singleton
  - Populated during shared library loading
- Schema evolution can be a no-op



More recent transparent(-ish) changes

- Stable collection IDs
  - Initially: Insertion order into Frame
  - Now: Hash of collection name
  - 32 bits for transparent migration
- RNTuple based backend
- Storing datamodel definition in *metadata Frame*
  - Always possible to regenerate datamodel from datafile
  - Retrievable programmatically
  - Dumping via `podio-dump`
  - String literal embedded into binary

```
struct ObjectID {
  int index;
  uint32_t collectionID;
};
```




```
readelf -p .rodata libedm4hep.so | grep options
  [   368]  {"options": {<...>},
"schema_version": 1, "components": {<...>},
"datatypes": {<...>}}
```

podio - datamodel definition

```
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)

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