lcio2edm4hep converter and applications

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for the Key4hep developers

ECFA Higgs Factories

Topical meeting on Reconstruction

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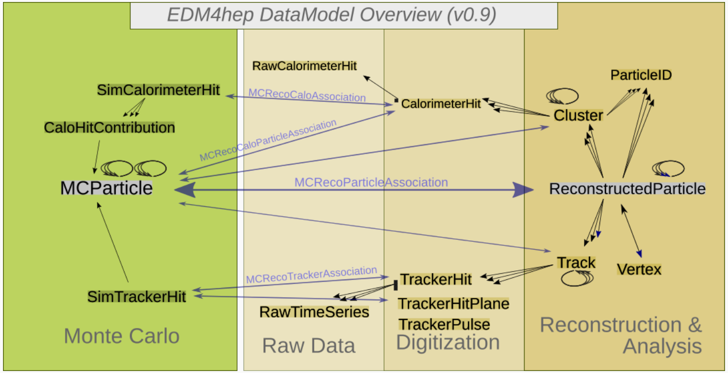
EDM4hep - The common EDM for Key4hep



- Based on `LCIO` and `FCC-edm`
  - Focus on usability in analysis
- Quite stable over the last two years
- Addition of datatypes for **CEPC drift chamber study**
- Can easily be extended
  - Used by EDM4eic
  - Main purpose: prototyping
- Generated via `podio`

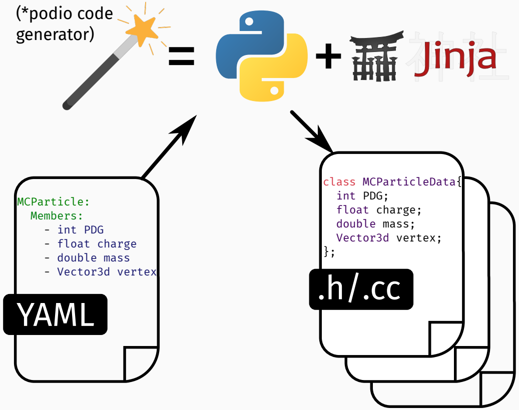
key4hep/EDM4hep

edm4hep.web.cern.ch

AIDASoft/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
  - key4hep/EDM4hep
  - eic/EDM4eic
- **Finishing schema evolution for v1.0**



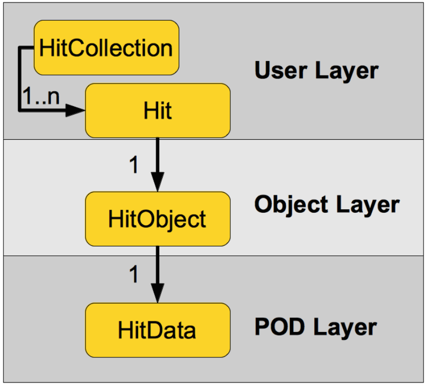
```
MCParticle:
  Members:
    - int PDG
    - float charge
    - double mass
    - Vector3d vertex
```

```
class MCParticleData{
  int PDG;
  float charge;
  double mass;
  Vector3d vertex;
};
```

AIDASoft/podio

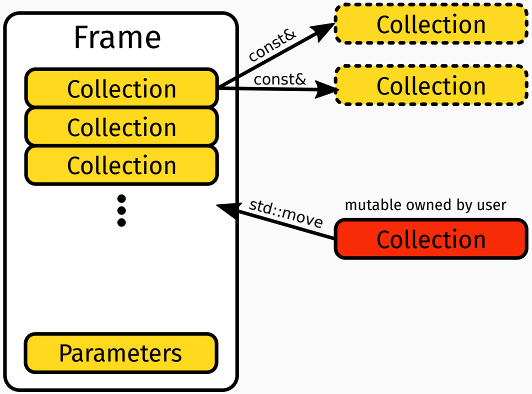
The three layers of podio

- 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



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

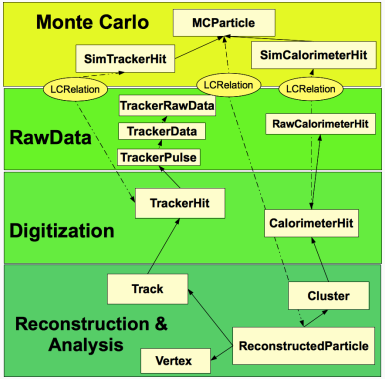
- Replaces deprecated `EventStore`
- *Type erased* container aggregating all relevant data
- Defines an *interval of validity* / category for contained data
  - Event, Run, readout frame, ...
- Easy to use and thread safe interface for data access
  - Immuatable read access only
  - Ownership model reflected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



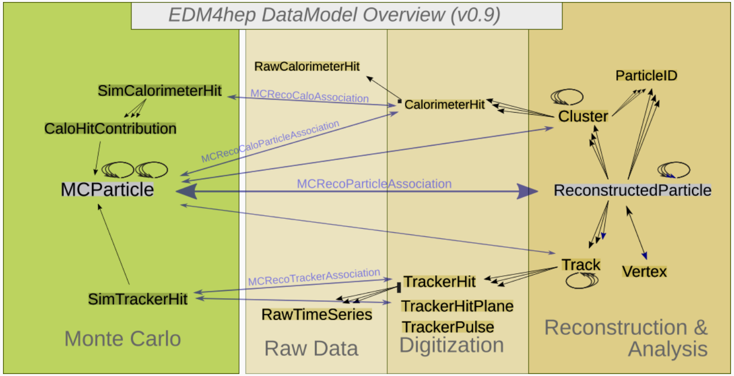
```
template<typename CollT>
const CollT& get(const std::string& name) const;

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

LCIO vs EDM4hep (at the highest level)

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 is 20 years old now. A lot of time to develop tools for it.

LCIO vs EDM4hep - High level differences

	LCIO	EDM4hep
call syntax	pointer semantics (`->`)	value semantics (`.`)
code layout	inheritance (`LCObject`)	composition
mutability	always*	creation only
external relations	`LCRelation`	dedicated `Association` types
event container	`LCEvent`	`podio::Frame` + `edm4hep::EventHeader`
run container	`LCRunHeader`	`podio::Frame`
event contents	missing collections allowed	all events with same collections†
parameters	collections & `LCEvent`	`podio::Frame` only
file format	`slcio` (SIO)	`.root` (default), SIO available

*"If you know what you are doing"

†Technically a requirement of the ROOT backend

Why another converter?

- key4hep/k4LCIOReader already provides reading of LCIO files into the Key4hep (Gaudi) world
  - Used in key4hep/k4MarlinWrapper
- **Wanted a standalone executable** (no Gaudi or Marlin)
- **Using the `podio::Frame`**
- Support all necessary functionality (e.g. subset collections)
- Easier to use shared library
- Complete overhaul of pre-existing functionality
  - Major effort from Finn Johannsen (DESY project student)
  - Shared library in key4hep/k4EDM4hep2LcioConv

How to use the standalone converter

- README
- Simplest case (complete events in LCIO)

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

- Almost simple case (e.g. non-complete events in LCIO)
  - Need some help to "patch" collections on-the-fly, e.g.

```
SETSpacePoints                TrackerHit
RecoMCTruthLink               LCRelation[ReconstructedParticle,MCParticle]
```

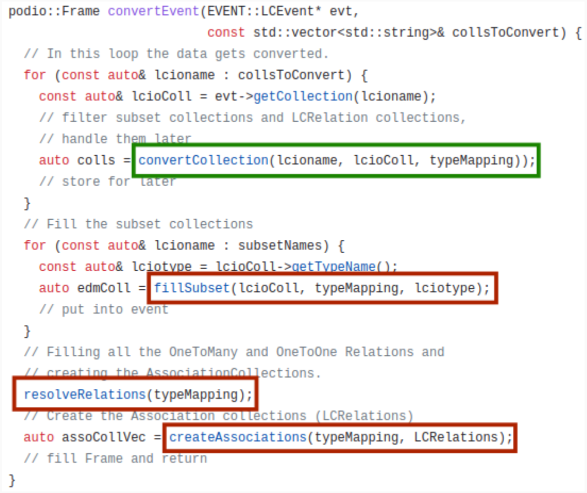
  - Don't write this yourself!

```
check_missing_cols --minimal input.slcio > patch.txt
lcio2edm4hep input.slcio output.edm4hep.root patch.txt
```

- `patch.txt` file can also be used to select a subset of collections to convert

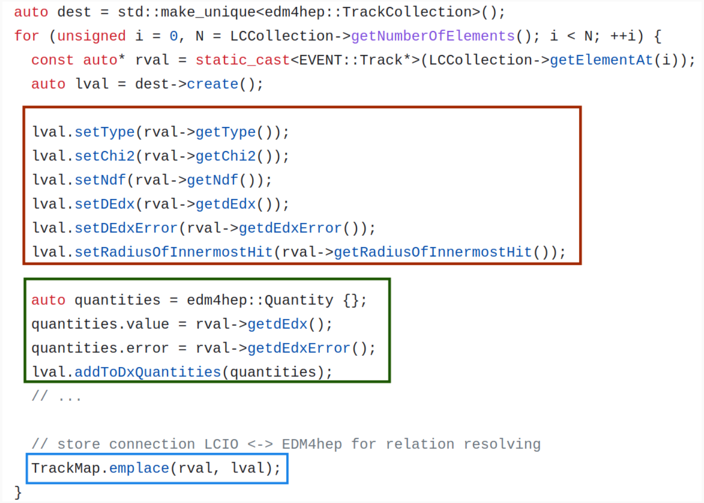
Using the shared library

- Conversion in two steps
    1. Convert data
    2. Resolve inter-object relations
- High-level functions delegate to type specific ones
- Ongoing work to integrate this into `k4MarlinWrapper`



```
podio::Frame convertEvent(EVENT::LCEvent* evt,
                          const std::vector<std::string>& collsToConvert) {
  // In this loop the data gets converted.
  for (const auto& lcioname : collsToConvert) {
    const auto& lcioColl = evt->getCollection(lcioname);
    // filter subset collections and LCRelation collections,
    // handle them later
    auto colls = convertCollection(lcioname, lcioColl, typeMapping));
    // store for later
  }
  // Fill the subset collections
  for (const auto& lcioname : subsetNames) {
    const auto& lciotype = lcioColl->getTypeName();
    auto edmColl = fillSubset(lcioColl, typeMapping, lciotype);
    // put into event
  }
  // Filling all the OneToMany and OneToOne Relations and
  // creating the AssociationCollections.
  resolveRelations(typeMapping);
  // Create the Association collections (LCRelations)
  auto assoCollVec = createAssociations(typeMapping, LCRelations);
  // fill Frame and return
}
```

LCIO to EDM4hep conversion example

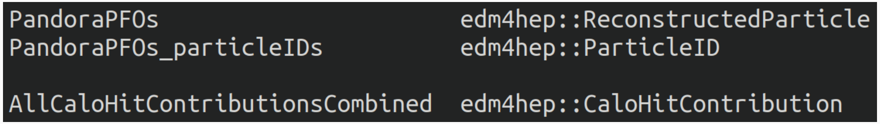


```cpp
auto dest = std::make_unique<edm4hep::TrackCollection>();
for (unsigned i = 0, N = LCCollection->getNumberOfElements(); i < N; ++i) {
  const auto* rval = static_cast<EVENT::Track*>(LCCollection->getElementAt(i));
  auto lval = dest->create();

  lval.setType(rval->getType());
  lval.setChi2(rval->getChi2());
  lval.setNdf(rval->getNdf());
  lval.setDEdx(rval->getdEdx());
  lval.setDEdxError(rval->getdEdxError());
  lval.setRadiusOfInnermostHit(rval->getRadiusOfInnermostHit());

  auto quantities = edm4hep::Quantity {};
  quantities.value = rval->getdEdx();
  quantities.error = rval->getdEdxError();
  lval.addToDxQuantities(quantities);
  // ...

  // store connection LCIO <-> EDM4hep for relation resolving
  TrackMap.emplace(rval, lval);
}
```

- Majority of cases is trivial
- Some minor differencs need treatment
  - EDM4hep with generalized dQ/dx treatment
  - `CellID`s always 64 bits in EDM4hep

Some visible differences after conversion

- ParticleID
  - Part of `ReconstructedParticle` and `Cluster` in LCIO
  - Dedicated type + relations in EDM4hep
  - → Additional collection in EDM4hep output
- CaloHitContribution
  - Part of `SimCalorimeterHit` in LCIO
  - Dedicated type in EDM4hep
  - → Additional (global) collection in EDM4hep output
- Transparent for reconstruction / analysis
- `TPCHit` (LCIO) → `RawTimeSeries` (EDM4hep)



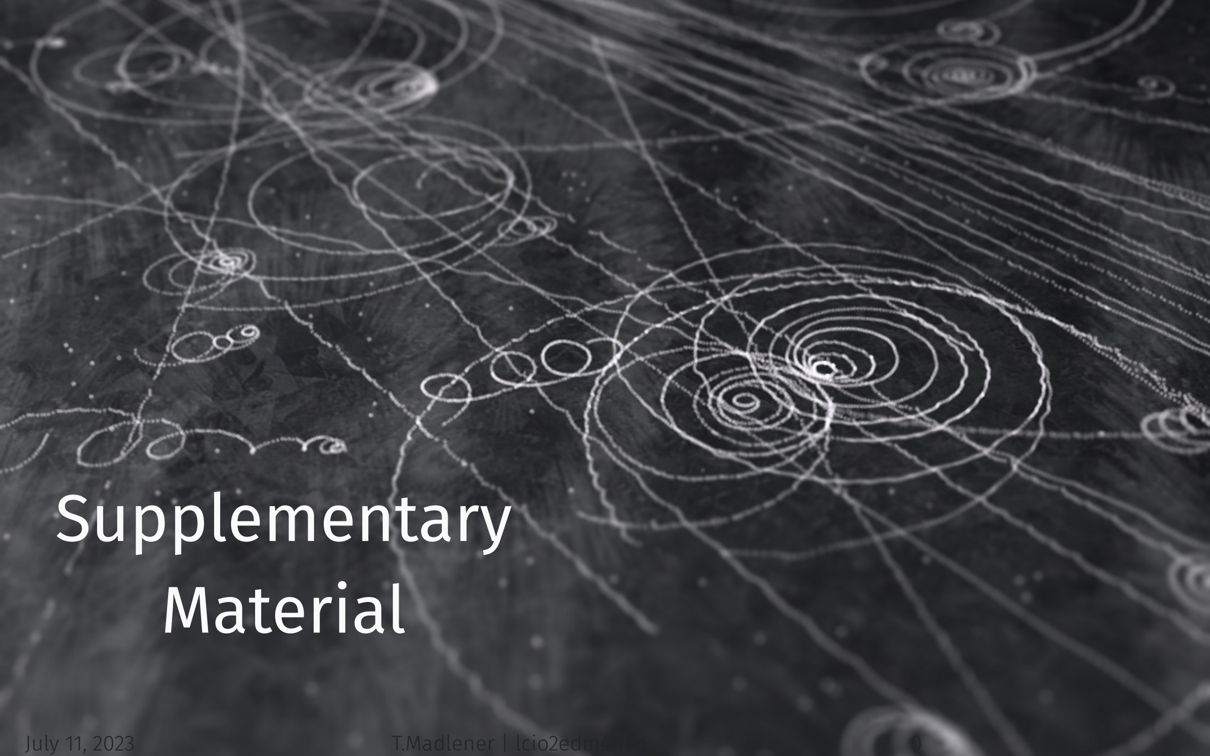
```
PandoraPFOs                      edm4hep::ReconstructedParticle
PandoraPFOs_particleIDs          edm4hep::ParticleID

AllCaloHitContributionsCombined  edm4hep::CaloHitContribution
```

Differences that need more work

- EDM4hep is quite a bit more restrictive compared to LCIO
  - Hyrum's Law is a thing, especially in HEP
  - Mutability of objects that are read
  - Possibilities to store data outside the EDM
- No generic Associations in EDM4hep (similar to `LCRelations`)
  - Can only convert those that are present
- Some features will not be available in EDM4hep
  - E.g. collection parameters; wild mix of *collection level metadata* and *event level collection related data* in LCIO files
- Some things will potentially need conceptual changes

Summary

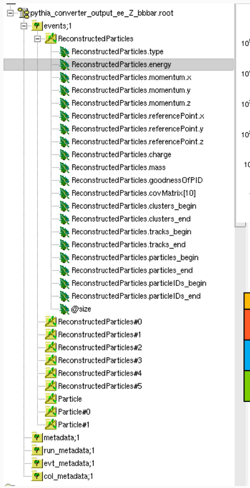
- New LCIO-to-EDM4hep conversion library & standalone `lcio2edm4hep` available
- Will be used in `k4MarlinWrapper` as well
- Covers everything we discovered during development
- Some thing still need work
- **Feedback is extremely valuable! If you find an issue, let us know!**
- Also let us know about things you want to have



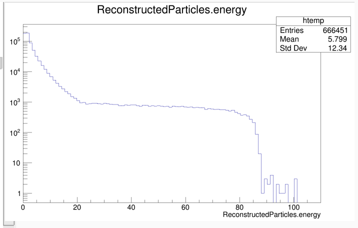
Supplementary Material

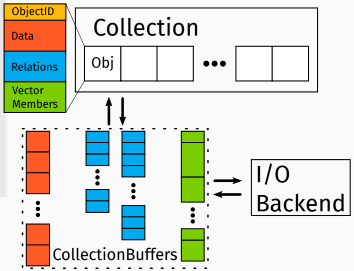
podio supports different I/O backends

- 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



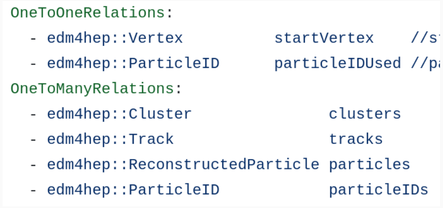
```
pythia_converter_output_ee_Z_bbbar.root
  events;1
    ReconstructedParticles
      ReconstructedParticles.type
      ReconstructedParticles.energy
      ReconstructedParticles.momentum.x
      ReconstructedParticles.momentum.y
      ReconstructedParticles.momentum.z
      ReconstructedParticles.referencePoint.x
      ReconstructedParticles.referencePoint.y
      ReconstructedParticles.referencePoint.z
      ReconstructedParticles.charge
      ReconstructedParticles.mass
      ReconstructedParticles.goodnessOfPID
      ReconstructedParticles.covMatrix[10]
      ReconstructedParticles.clusters_begin
      ReconstructedParticles.clusters_end
      ReconstructedParticles.tracks_begin
      ReconstructedParticles.tracks_end
      ReconstructedParticles.particles_begin
      ReconstructedParticles.particles_end
      ReconstructedParticles.particleIDs_begin
      ReconstructedParticles.particleIDs_end
      @size
    ReconstructedParticles#0
    ReconstructedParticles#1
    ReconstructedParticles#2
    ReconstructedParticles#3
    ReconstructedParticles#4
    ReconstructedParticles#5
    Particle
    Particle#0
    Particle#1
  metadata;1
  run_metadata;1
  evt_metadata;1
  col_metadata;1
```



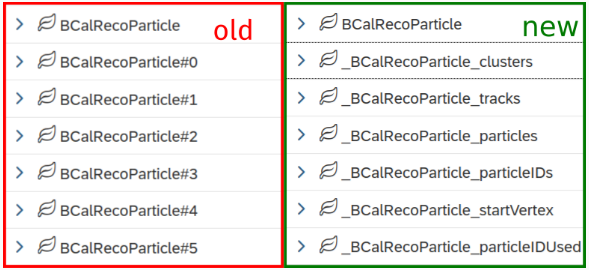


Other recent developments

- More legible branch names for relations
- Stable collection IDs based on collection names
- Ongoing efforts to have EDM4hep in coffea
  - First version based on ILD DST files



```
OneToOneRelations:
  - edm4hep::Vertex            startVertex    //s
  - edm4hep::ParticleID        particleIDUsed //p
OneToManyRelations:
  - edm4hep::Cluster                  clusters
  - edm4hep::Track                    tracks
  - edm4hep::ReconstructedParticle particles
  - edm4hep::ParticleID               particleIDs
```



old	new
BCalRecoParticle	BCalRecoParticle
BCalRecoParticle#0	_BCalRecoParticle_clusters
BCalRecoParticle#1	_BCalRecoParticle_tracks
BCalRecoParticle#2	_BCalRecoParticle_particles
BCalRecoParticle#3	_BCalRecoParticle_particleIDs
BCalRecoParticle#4	_BCalRecoParticle_startVertex
BCalRecoParticle#5	_BCalRecoParticle_particleIDUsed