Future of the EIC Argonne Software Toolkit

Whitney Armstrong, David Blyth, Sergei Chekanov, Ian Cloët, Adam Freese,
Sereres Johnston, Mohammad Hattawy, José Repond
and the Argonne EIC Collaboration

Argonne National Laboratory
Funded by ANL LDRD

October 16, 2017

Outline

Full Simulation and Reconstruction Tasks

Basic tasks:

1. **Event Generation** - Produce the simulation input events
2. **Detector Simulation** - Particle transport through detectors (Geant4)
3. **Digitization** - Turn *Sim Hits* into realistic hits
4. **Reconstruction** - Track, vertex, PID, PFA, and primary reconstruction
5. **Performance Analysis** - Collection of benchmark analyses used to tune the overall design

Frameworks

Question: What is the best software framework?

frame·work

/frām ˌwərk/

noun

an essential supporting structure of a building, vehicle, or object.
"a conservatory in a delicate framework of iron"
synonyms: frame, substructure, infrastructure, structure, skeleton, chassis, shell, body, bodywork; More

- a basic structure underlying a system, concept, or text.
  "the theoretical framework of political sociology"
  synonyms: structure, shape, fabric, order, scheme, system, organization, construction, configuration, composition, warp and woof; *informal* makeup
  "the framework of society"

Frameworks

Question: What is the best software framework?

frame·work

/frām ˌwərk/

noun

an essential supporting structure of a building, vehicle, or object.
"a conservatory in a delicate framework of iron"
synonyms: frame, substructure, infrastructure, structure, skeleton, chassis, shell, body, bodywork; More

- a basic structure underlying a system, concept, or text.
  "the theoretical framework of political sociology"
  synonyms: structure, shape, fabric, order, scheme, system, organization, construction, configuration, composition, warp and woof; *informal* makeup
  "the framework of society"

Trick question. The best framework is having **no framework!**

The Argonne software toolkit follows the idea that large frameworks are bad and should be avoided.

No Frameworks

Classic case of "less is more"

Why is this better?

- Fewer dependencies (always good)
- More freedom of choice
- Nested frameworks result in more rigid larger frameworks
- Precludes certain ideas/uses (often addressed by refactoring)

Frameworks are unavoidable. Examples:

- operating system + compiler
- language
- ROOT, GEANT4

Many frameworks we implicitly accept or take for granted, e.g., `x86_64`

Argonne EIC Software Toolkit

Some software tools: (in no particular order)

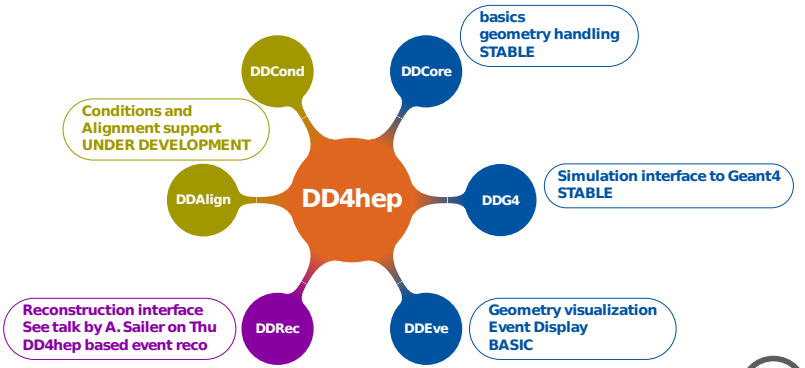
- HepSim
- GEANT4
- ROOT
- DD4hep (S.Chekanov's talk)
- LCIO, ProMC, proio, podio, fcc-edm, ...
- ~~SLIC~~ + ~~lcsim~~ → evochain (D.Blyth's talk) → **This talk**
  NPdet + a collection of tools
- parameic : light weight parameter passing tool (under development)

Outline

DD4hep

The result of a study from the *Advanced European Infrastructures for Detectors at Accelerators* (EU AIDA 2020) initiative.

Structure and packages



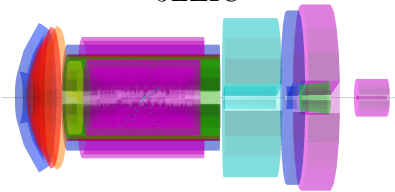
- Thoughtfully designed
- Interface to Geant4
- **Single source of geometry**
- Simple geometry hook → **better algorithm development**
- Full concept detector described in human readable text file
- Easily used in a root/python scripts

Nuclear Physics Detector Library (NPDet)

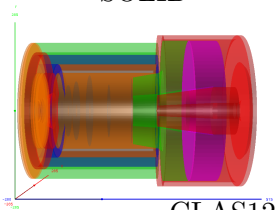
NPDet is a **collection of parameterized detectors** (using DD4hep) which can be used to construct full concept detectors in a single text file.

NPdet/src/
- GenericDetectors
- SiEIC
- JLEIC
- CLAS12
- SOLID

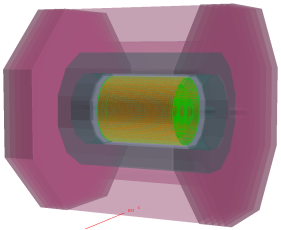
JLEIC



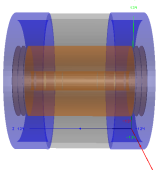
SOLID



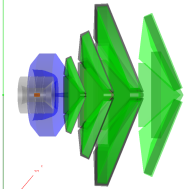
SiEIC



eRHIC



CLAS12



Add a new detector

```
static Ref_t build_detector(Detector& det, xml_h e, SensitiveDetector sens)
{
  xml_det_t   x_det     = e;
  Material    air       = det.air();
  double z_offset = dd4hep::getAttrOrDefault(x_det, _Unicode(zoffset), 10.0*dd4hep::cm);
... [ Build geometry ]
}
DECLARE_DETELEMENT(SimpleRomanPot, build_detector)
```

```
<detector id="1" name="MyRomanPot" type="SimpleRomanPot"
          vis="RedVis" readout="RomanPotHits" zoffset="1.0*m">
</detector>
[...]
<readouts>
  <readout name="RomanPotHits">
    <segmentation type="CartesianGridXY" grid_size_x="1.0*mm" grid_size_y="1.0*cm" />
    <id>system:5,layer:9,module:14,x:32:-16,y:-16</id>
  </readout>
</readouts>
```

GEANT + DD4hep

The largest framework in the toolkit

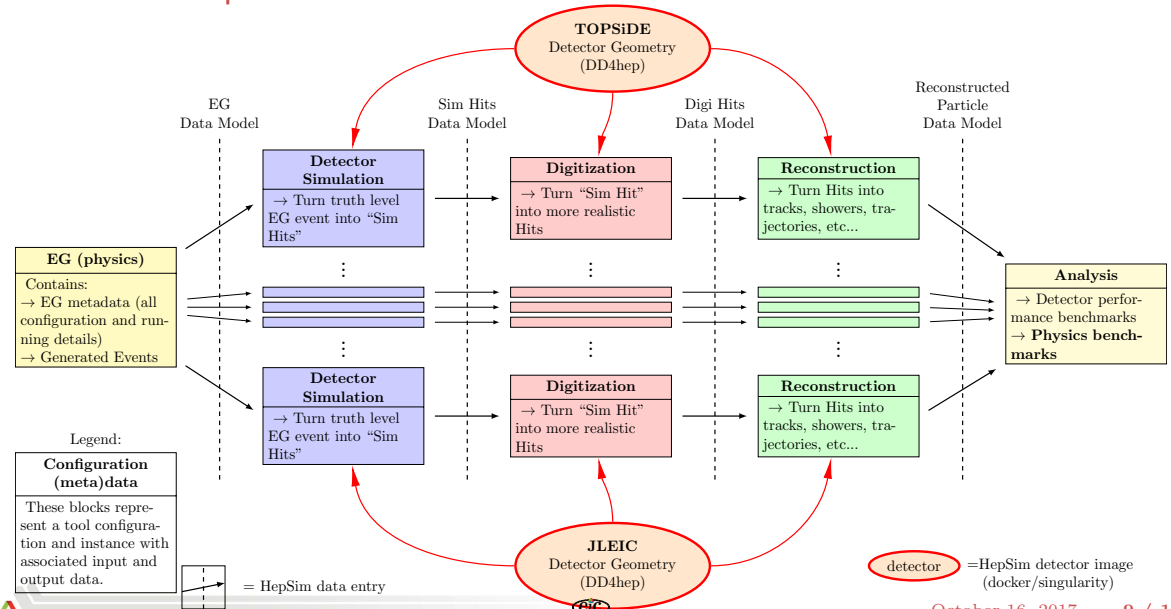
DD4hep provides a **single geometry source** used in both simulation and reconstruction

Geometry hooks allow for development of **flexible and unified** reconstruction

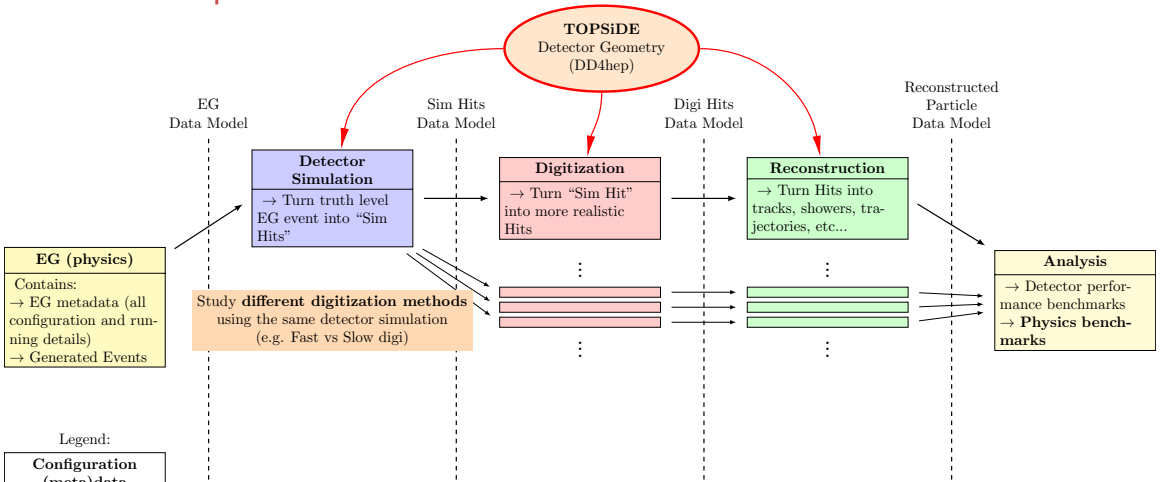
- Allows easier development of algorithms
- Generic algorithms become the focus of development
- **No large framework to battle** and integrate with

Outline

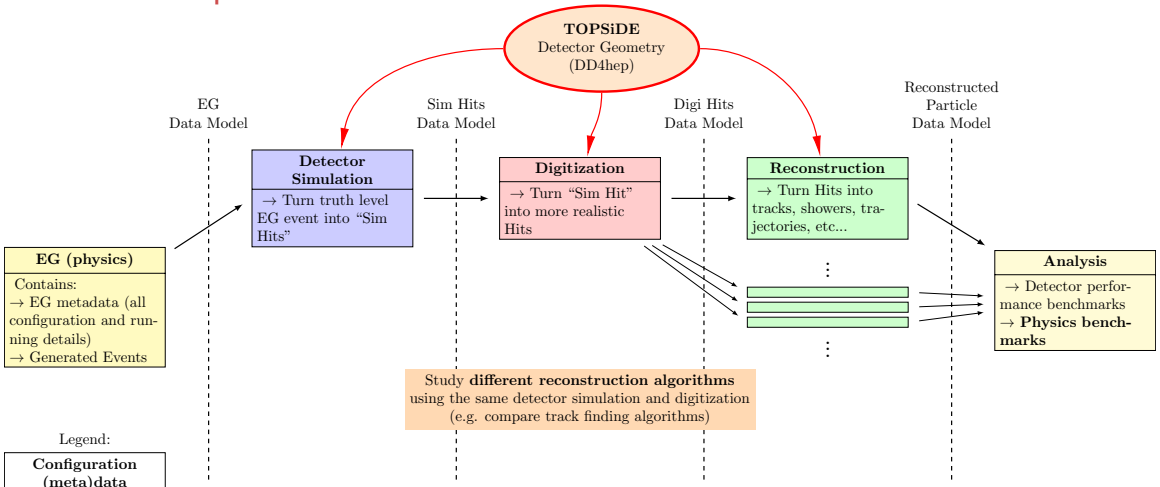
Data-flow Map



Data-flow Map



Data-flow Map



DD4hep Geometry Hooks

C++ in a ROOT script

```
dd4hep::Detector& detector = dd4hep::Detector::getInstance();  // Get the DD4hep instance
detector.fromCompact("my_awesome_detector.xml");               // Load the compact XML file
dd4hep::rec::CellIDPositionConverter converter(detector);      // Position/cellid converter tool
[...]
    for(const auto& h: hits) {
      auto cell     = h->cellID;                       // Unique segment/volume identifier
      auto pos1     = converter.position(cell);        // The segmentation hit postion
      auto cell_dim = converter.celldimensions(cell); // Dimensions of segment/volume
      [...]
      }
[...]
auto    bField = detector.field().magneticField(pos); // Get the magnetic field
double  Bz     = bField.z()/dd4hep::tesla;
```

That's it.

See NPDet examples for a tutorial (work in progress).

Where are we going with this?

Use geometry hooks to **develop generic** digitization and reconstruction **algorithms**

Not detector concept specific...

```
dd4hep::Detector& detector = dd4hep::Detector::getInstance();  // Get the DD4hep instance
detector.fromCompact("my_awesome_detector.xml");               // Load the compact XML file
dd4hep::rec::CellIDPositionConverter converter(detector);      // Position/cellid converter tool
[...]
    for(const auto& h: hits) {
      auto cell     = h->cellID;                 // Unique segment/volume identifier
      auto pos1     = converter.position(cell);  // The segmentation hit postion
      auto cell_dim = converter.celldimensions(cell); // Dimensions of segment/volume
      [...]
    }
[...]
auto    bField = detector.field().magneticField(pos); // Get the magnetic field
double  Bz     = bField.z()/dd4hep::tesla;
```

- Digitization Algorithms
- Tracking Finding Algorithms
- Track Fitting Algorithms
- Algorithms, Algorithms, Algorithms

Focus on the algorithm development

- The product of effort is high quality algorithm (not a bigger framework)
- Many existing algorithms are embedded in tightly coupled frameworks

Can easily collaborate and get contributions from other R&D Consortia!

Outline

Tracking Example

Developing good algorithms is the goal!

A note about recent ROOT developments

TDataFrame is awesome! Check it out.

```
[=](const std::vector<lcio2::TrackerHitData>& hits) {
  HoughTransform ht(captured_params);
  std::vector<std::vector<lcio2::TrackerHitData>> res = ht(vec_hits);
  return res;
  };

[&](const std::vector<std::vector<lcio2::TrackerHitData>>& possible_tracks) {
  std::vector<lcio2::TrackData> result_tracks;
  for(const auto& track_seed : possible_tracks) {
   [GenFit...]
  }
  return result_tracks;
};
```

Frameworks come and go, algorithms are forever...

Moving Forward

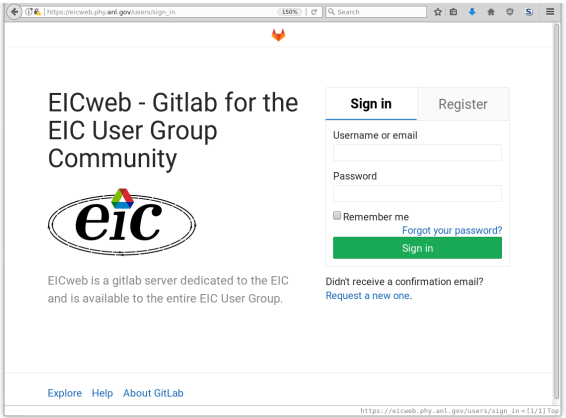
Extracting algorithms from existing frameworks

- We want to build a collection of **generic algorithms**
- Currently there are many excellent algorithms embedded in tightly coupled frameworks will extracted
- These can be made more general with DD4hep hooks
- Individual detector experts are most familiar their operation → best people to characterize its digitization

Outline

Links and References

- **HepSim**
- **EICweb** (eicweb.phy.anl.gov) - EIC dedicated gitlab server (publicly available to EIC UG)
- **Singularity**
- **DD4hep**
- **lcgeo**



DD4hep Presentations

Detector Simulations with DD4hep - Marko Petric
DD4hep Based Event Reconstruction - Andre Sailer
The FCC software: how to keep SW experiment independent - A. Zaborowska

Summary

EIC Argonne Software Toolchain (EAST)

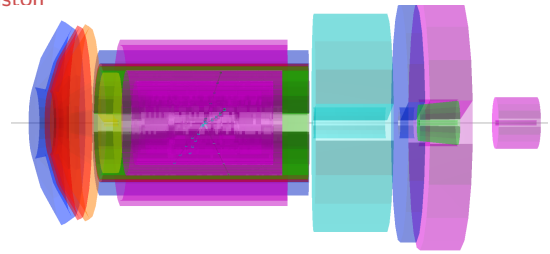
- We are shedding tightly coupled frameworks for a flexible toolkit
- Focusing on algorithm development – not framework development

- **Collaboration tools** for the **EIC User Group** are available now.
- **We want to invite the entire EIC User Group to collaborate.**
  - Contribute new EG data (physics) – Let's see what detectors work best
  - Add detectors to NPDet detector library – Make your detector technology available
  - Add reconstruction data for a new concept detector
  - Write benchmarks (detector and physics) – Optimise your concept detector to physics
  - Suggest ideas for improvement! – **We want EIC UG feedback**

Backup Slides

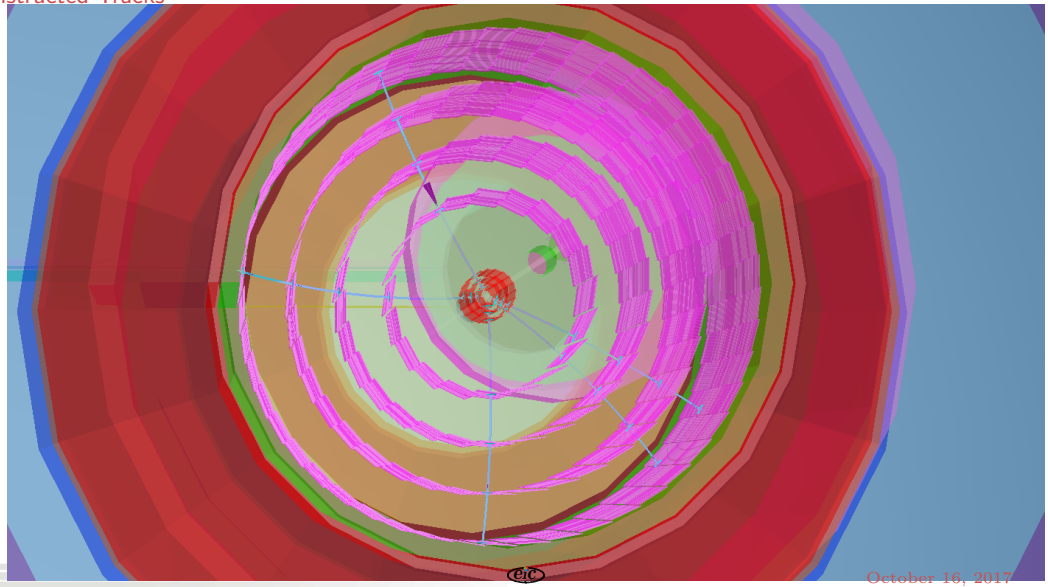
JLEIC

Sereres Johnston



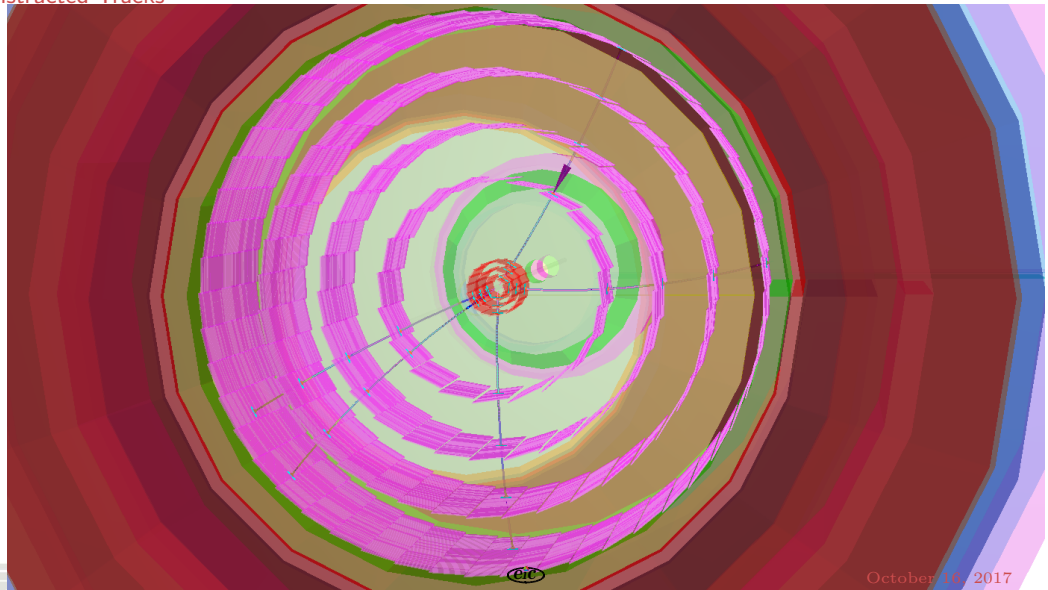
JLEIC

Reconstructed Tracks



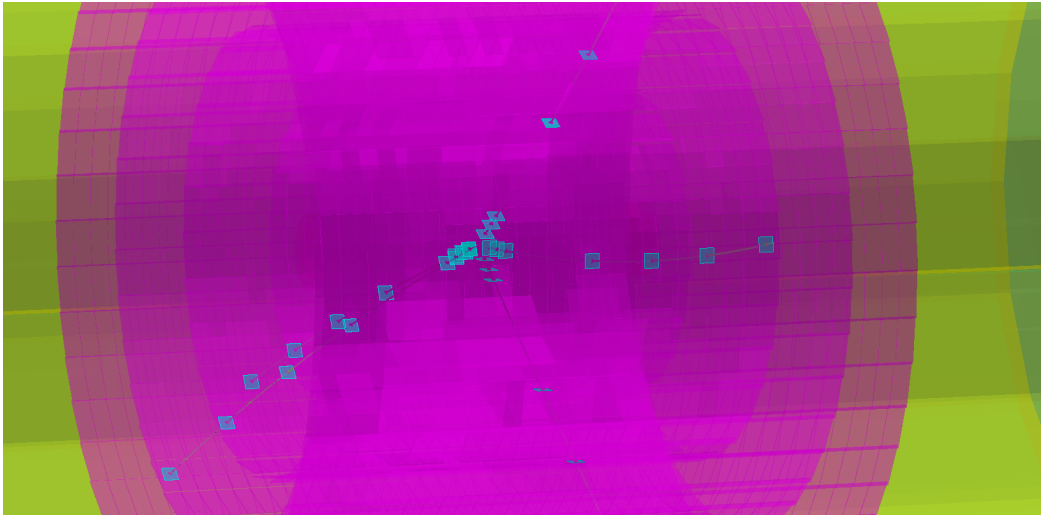
JLEIC

Reconstructed Tracks

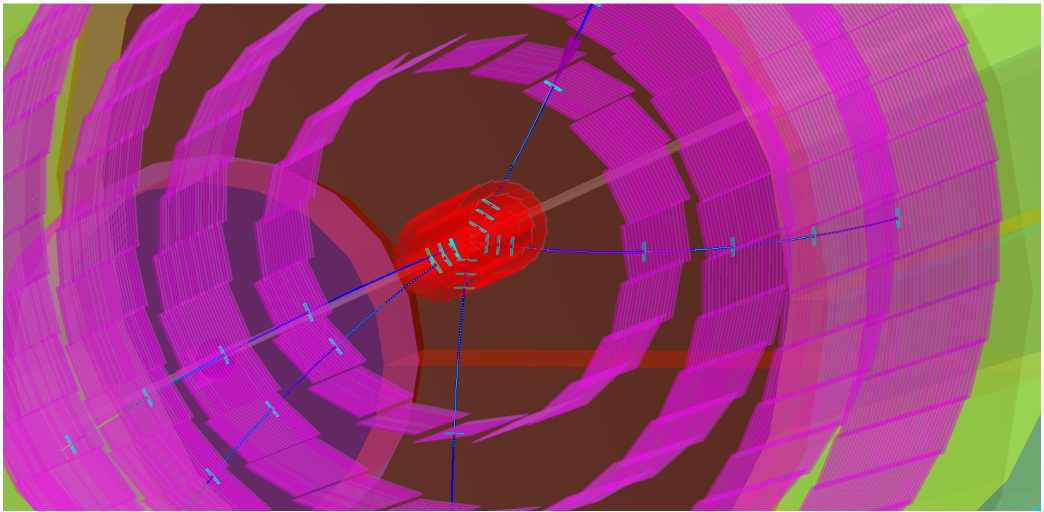


JLEIC

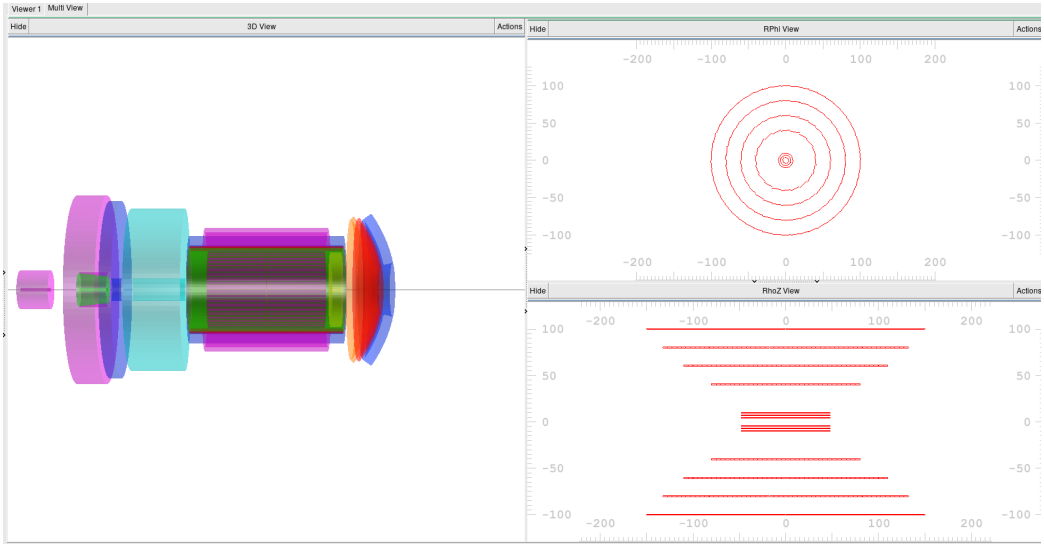
Reconstructed Tracks



Reconstructed Tracks

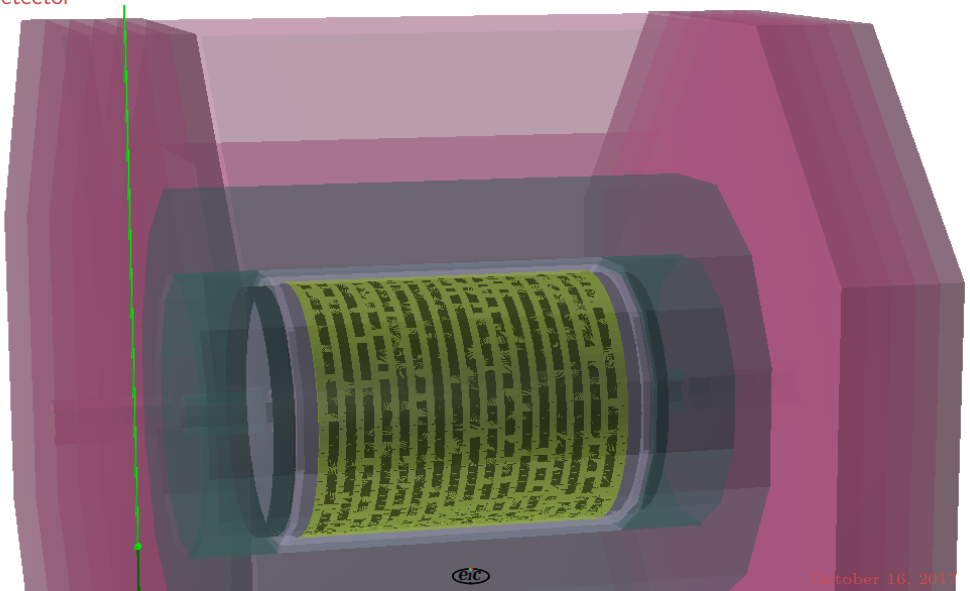


Reconstructed Tracks



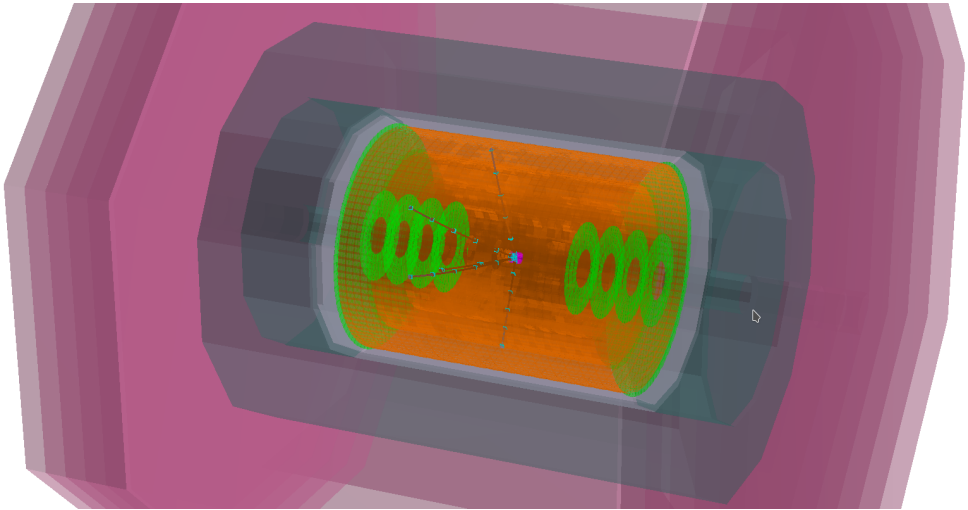
SiEIC

SiD stvle detector



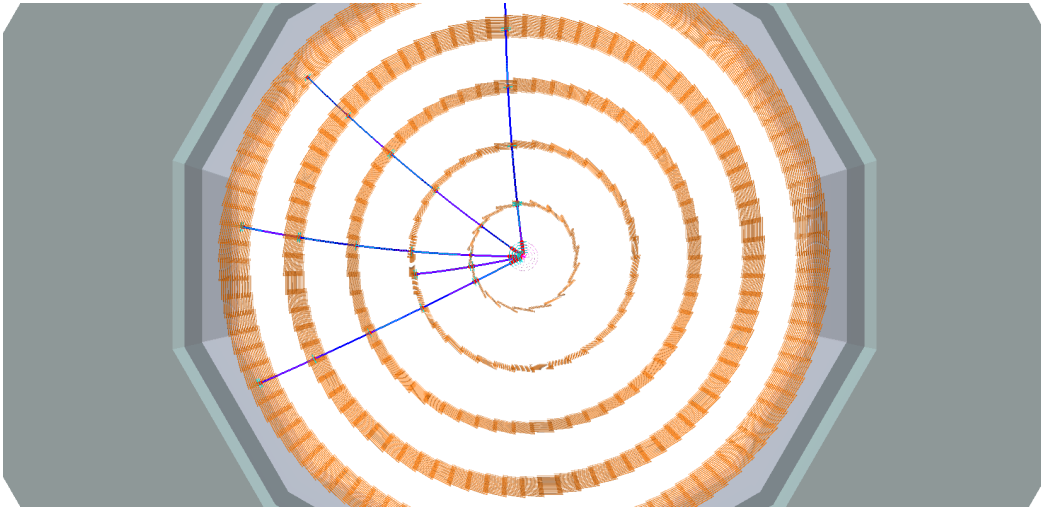
SiEIC

Reconstructed Tracks

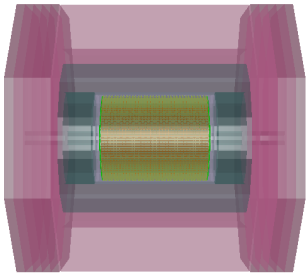


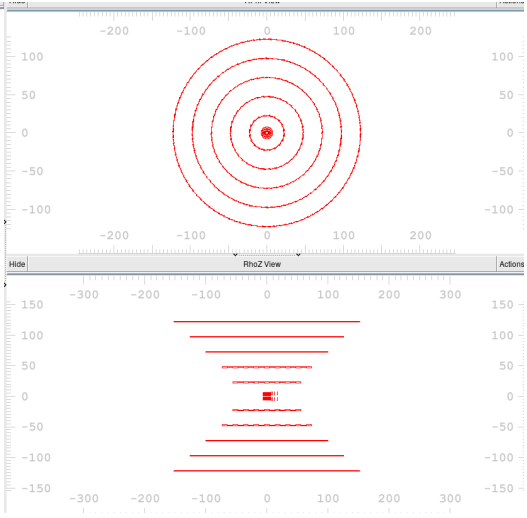
SiEIC

Reconstructed Tracks

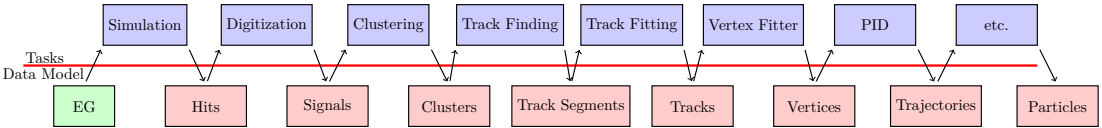


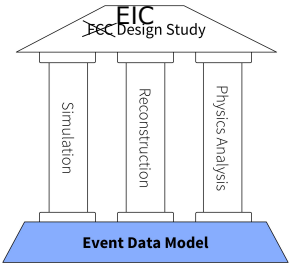
Reconstructed Tracks





Why a Data Model?





The FCC software: how to keep SW experiment independent - A. Zaborowska

- The **Data Model** is the boundaries of every task.
- A **Common** data model is the first step towards generic algorithms and tasks
- Challenge: Getting everyone to agree
- EAST initial data model: LCIO
- Note: *Data Model* does not mean *serialization tool*! It is just the data structures
- podio is a new tool which by default uses ROOT for serialization (new serialization libraries can be easily added)