DD4hep Based Event Reconstruction

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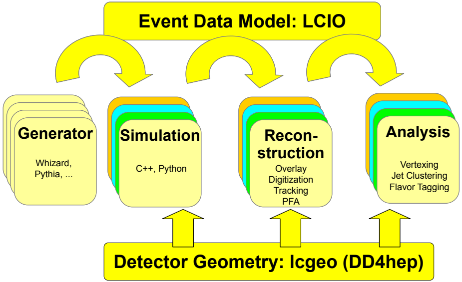
Introduction

- Linear collider community has used and developed **common software** for many years
  - Event data model: LCIO [1, 2]
  - Particle flow reconstruction: PandoraPFA [3]
- Adopted DD4Hep geometry description to develop more common software based on the DD4Hep geometry information
- Needs to be usable ***at least*** by all linear collider detector collaborations
  - Interface generic reconstruction packages via thin wrappers to linear collider framework



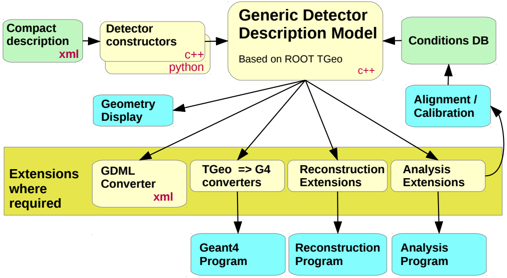
DD4HEP Geometry Framework

DD4HEP is the **single source** of geometry information for simulation, reconstruction, analysis

- Avoid duplicate implementation of geometry for different purpose or inconsistencies are almost certain

Further information:

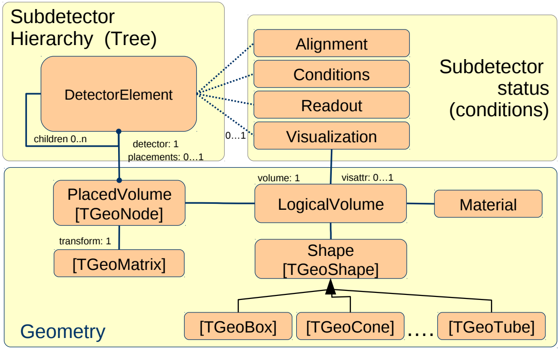
- Presentation on Detector Simulation with DD4hep
- DD4hep framework [4]
- DDG4: The DD4HEP gateway to Geant4 [5]



Geometry Tree

In DD4HEP detectors are a tree of `DetElements`

- A `DetElement` is a sub-detector or a significant part of a sub-detector
- `DetElement` points to placed logical volumes
- Extensions can be attached to `DetElements` to **provide additional views of the geometry information**



Detector XML Example

- XML structure to set parameters for detectors
- `C++` driver to interpret XML parameters and create `DetElements` and `Volumes`
  - Define sensitive parts (attached with `SensitiveDetector`) and radiator, which has to be known for reconstruction purposes
- Attach sensitive detector readout, defined elsewhere in XML

```
<readout name="ECB">
  <segmentation type="CartesianGridXY"
                grid_size_x="ECal_cell_size"
                grid_size_y="ECal_cell_size" />
  <id>...x:32:-16,y:-16 </id>
</readout>
```

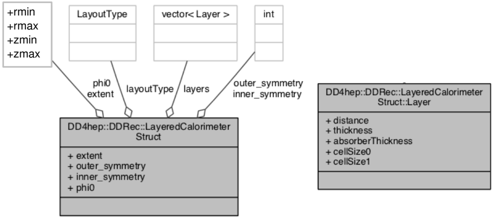
```
<detector
    name="ECalBarrel"
    type="GenericCalBarrel_o1_v01"
    id="42" readout="ECB">
  <dimensions
      numsides="ECalBarrel_symmetry"
      rmin="ECalBarrel_inner_radius"
      z="ECalBarrel_half_length*2" />
  <layer repeat="25" >
    <slice material="Tungsten"
           thickness="2.40*mm"
           radiator="yes"/>
    <slice material="Air"
           thickness="0.25*mm" />
    <slice material="Silicon"
           thickness="0.50*mm"
           sensitive="yes"/>
  </layer>
</detector>
```

DDREC: High Level Information

High level view onto the detectors through DDREC `DataStructures` extensions for `DetElements`

- C++ driver fills DDREC `DataStructures`
- Dimensions, positions, parameters for layers,. . .
- Reconstruction accesses information from `DataStructures`. **Decouples detector implementation from reconstruction algorithms**
- Detector drivers responsible to fill and attach appropriate `DataStructures` to sub-detectors

`DataStructures` contain sufficient information to provide geometry information to particle flow clustering via PANDORAPFA



Data Structure	Detector Type
`ConicalSupportData`	Cones and Tubes
`FixedPadSizeTPCData`	Cylindrical TPC
`LayeredCalorimeterData`	Sandwich Calorimeters
`ZPlanarData`	Planar Silicon Trackers
`ZDiskPetalsData`	Forward Silicon Trackers

Geometry for Track Reconstruction

Information needed for track reconstruction

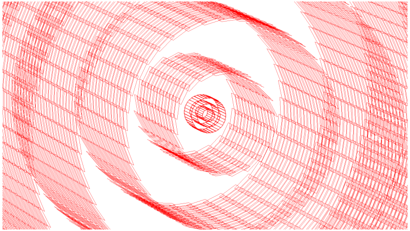
- measurement directions of hits
- local-to-global coordinate transforms
- material properties

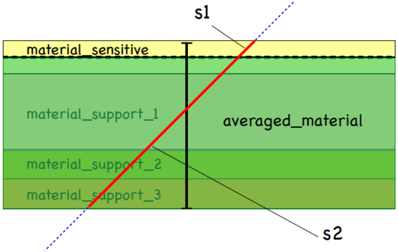
DD4HEP surfaces provide this information

- Surfaces can **automatically** added (plugin) or explicitly in the driver

```
<plugin name="DD4hep_GenericSurfaceInstallerPlugin">
  <argument value="TrackDet"/>
  <argument value="dimension=2"/>
  <argument value="u_x=-1."/>
  <argument value="v_y=-1."/>
  <argument value="n_z=1."/>
</plugin>
```

  - Plugin loops over all `DetElements` of given sub-detector and adds surfaces for sensitive elements
  - Configure surface type and direction in volume
- Surfaces automatically average materials





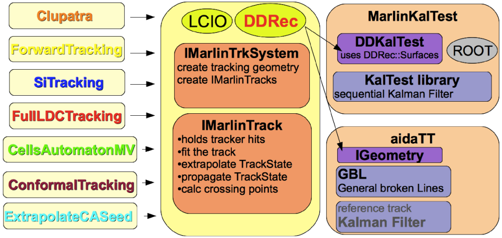
Track Reconstruction

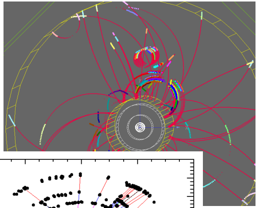
Track reconstruction for linear collider software becoming more **framework independent** by using DD4HEP surfaces

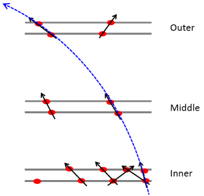
- Pattern recognition/track finding algorithms
  - From **detector specific**: *Clupatra* for TPC; mini-vector for vertex detector double layers
  - to **geometry agnostic**: pattern recognition in conformal space
- Track fitting, fairly generic: DDKALTEST, AIDATT
- Geometry: Interfaced via DDREC and Surfaces

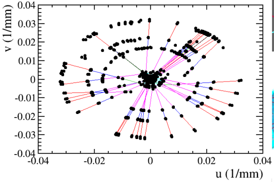
DDKALTEST using DD4HEP surfaces for track fitting

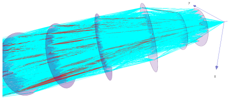
- **If detector is described in DD4HEP track reconstruction will run on it**











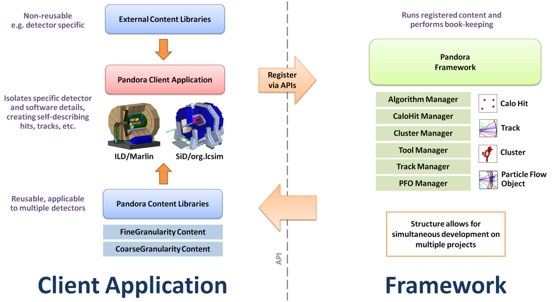
Particle Flow Reconstruction

PANDORAPFA: generic toolkit for pattern recognition algorithms in highly granular calorimeters

- Originally developed for ILC/CLIC detectors
- Extended to work in LAr-TPC reconstruction for the DUNE neutrino experiment
- Some functionality for *coarse* calorimeters exists as well

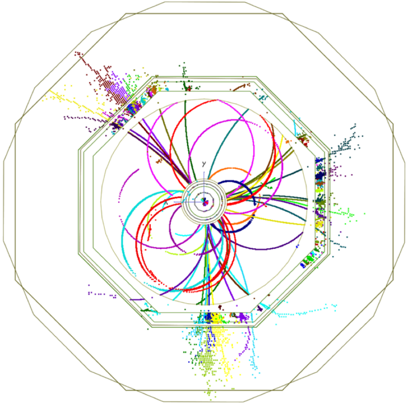
ClientApplication: DDMARLINPANDORA glues linear collider framework (Marlin), DD4HEP, and PANDORAPFA

- Passes DDREC `DataStructures` information, tracks, and calorimeter hits to PANDORAPFA
- Converts PANDORAPFA objects into LC EDM objects

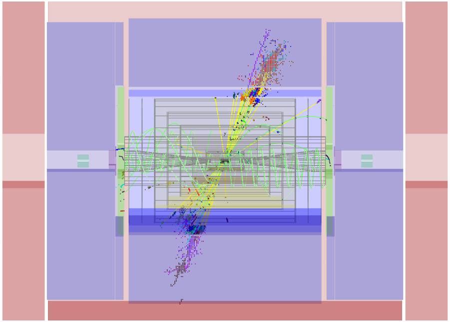


Reconstructed Events

Two events in **different** detectors **simulated and reconstructed** with previously described tracking and particle flow clustering



ILD detector, TPC and silicon tracking: $t\,\bar{t}$



CLIC detector, silicon tracking: Z to two jets

Summary

The DD4HEP detector description tool-kit offers a flexible and easy to use solution for the consistent and complete description of particle physics detectors in one single system.

- No need to define separate geometry for reconstruction, no duplication of effort, fewer bugs
- Generic reconstruction packages with *no* framework dependency: tracking toolkit (aidaTT), particle flow reconstruction (PANDORAPFA)

If the detector is described via DD4HEP, reconstruction comes almost for free

- Used by CLIC, ILD, SiD for simulation and **reconstruction**
- Only need a thin wrapper between experiment framework and geometry on one side and reconstruction package on the other
- Well suited for detector optimisation studies at other future accelerators

References

[1] F. Gaede, T. Behnke, N. Graf, and T. Johnson. LCIO - A persistency framework for linear collider simulation studies. In *Proceedings of CHEP 2003*. 2003.

[2] F. Gaede, et al. LCIO persistency and data model for LC simulation and reconstruction. In *CHEP 2004*. 2005.

[3] J. S. Marshall and M. A. Thomson. The Pandora software development kit, CHEP 2012. In *CHEP 2012*, p. 022034. 2012. AIDA-CONF-2015-003.

[4] M. Frank, F. Gaede, and P. Mato. DD4hep: A Detector Description Toolkit for High Energy Physics Experiments. In *CHEP 2013*. 2013. AIDA-CONF-2014-004.

[5] M. Frank, F. Gaede, N. Nikiforou, M. Petric, and A. Sailer. DDG4 A Simulation Framework based on the DD4hep Detector Description Toolkit. In *CHEP 2015*. 2015.