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AIDA-2020

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Presentation

DD4hep: a Detector Description Solution for High Energy Physics Experiments

Nikiforou, N. (CERN) *et al*

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DD4hep: a Detector Description Solution for High Energy Physics Experiments

M.Frank[1], F.Gaede[2], S.Lu[2], N.Nikiforou[1], M.Petric[1], A.Sailer[1]

[1]CERN, [2]DESY

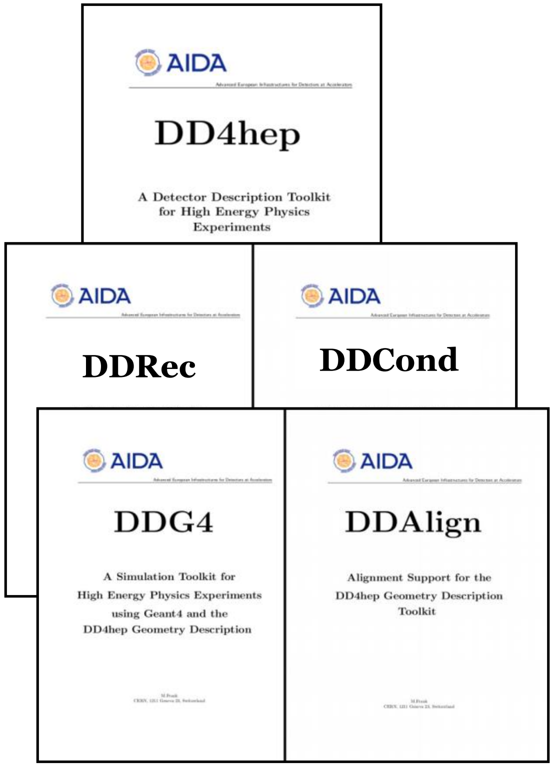
Motivation and goals

- Complete Detector Description
  - Includes geometry, materials, visualization, readout, alignment, calibration, etc.
- Support Full Experiment life cycle
  - Detector concept development, detector optimization, construction, operation
  - Easy transition from one phase to the next
- Consistent Description, Single source of information
  - Use in simulation, reconstruction, analysis, etc.
- Ease of Use
- Few places to enter information
- Minimal dependencies

DD4hep Components

- **DD4hep**: basics/core
  - Basically stable
- **DDG4**: Simulation using Geant4
  - Validation ongoing
- **DDRec**: Reconstruction support
  - Driven by LC Community
- **DDAlign, DDCond** : Alignment and Conditions support
  - Being developed

- **http://aidasoft.web.cern.ch/DD4hep**



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DD4hep

A Detector Description Toolkit for High Energy Physics Experiments

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DDRec

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DDCond

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DDG4

A Simulation Toolkit for High Energy Physics Experiments using Geant4 and the DD4hep Geometry Description

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DDAlign

Alignment Support for the DD4hep Geometry Description Toolkit

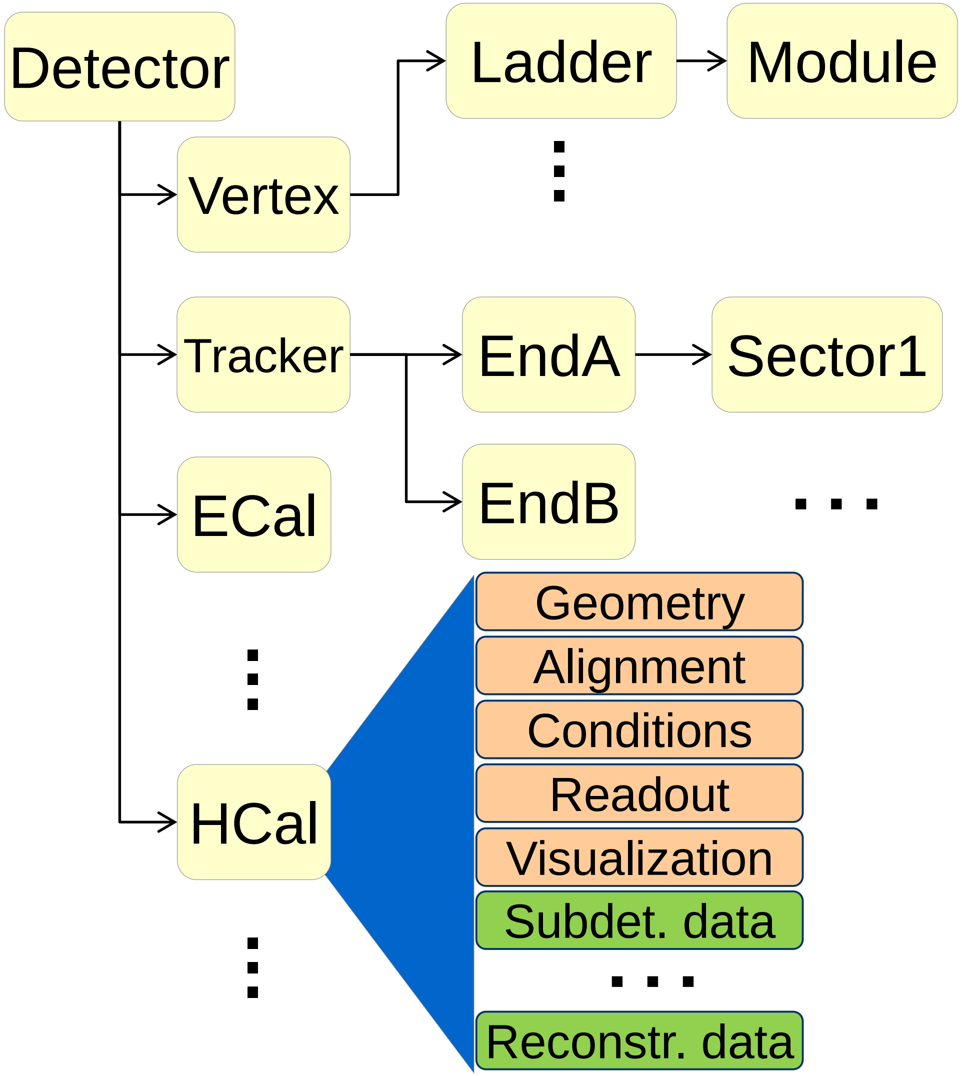
Current Toolkit Users

		DD4hep	DDG4
ILD	F. Gaede et al., ported complete model ILD_o1_v05 from previous simulation framework (Mokka)	✓	✓
CLICdp	New detector model being implemented after CDR, geometry under optimization	✓	✓
FCC-eh	P. Kostka et al.	✓	✓
FCC-hh	A. Salzburger et al.	✓	

Feedback from users is invaluable and helps shaping DD4hep!

What is Detector Description

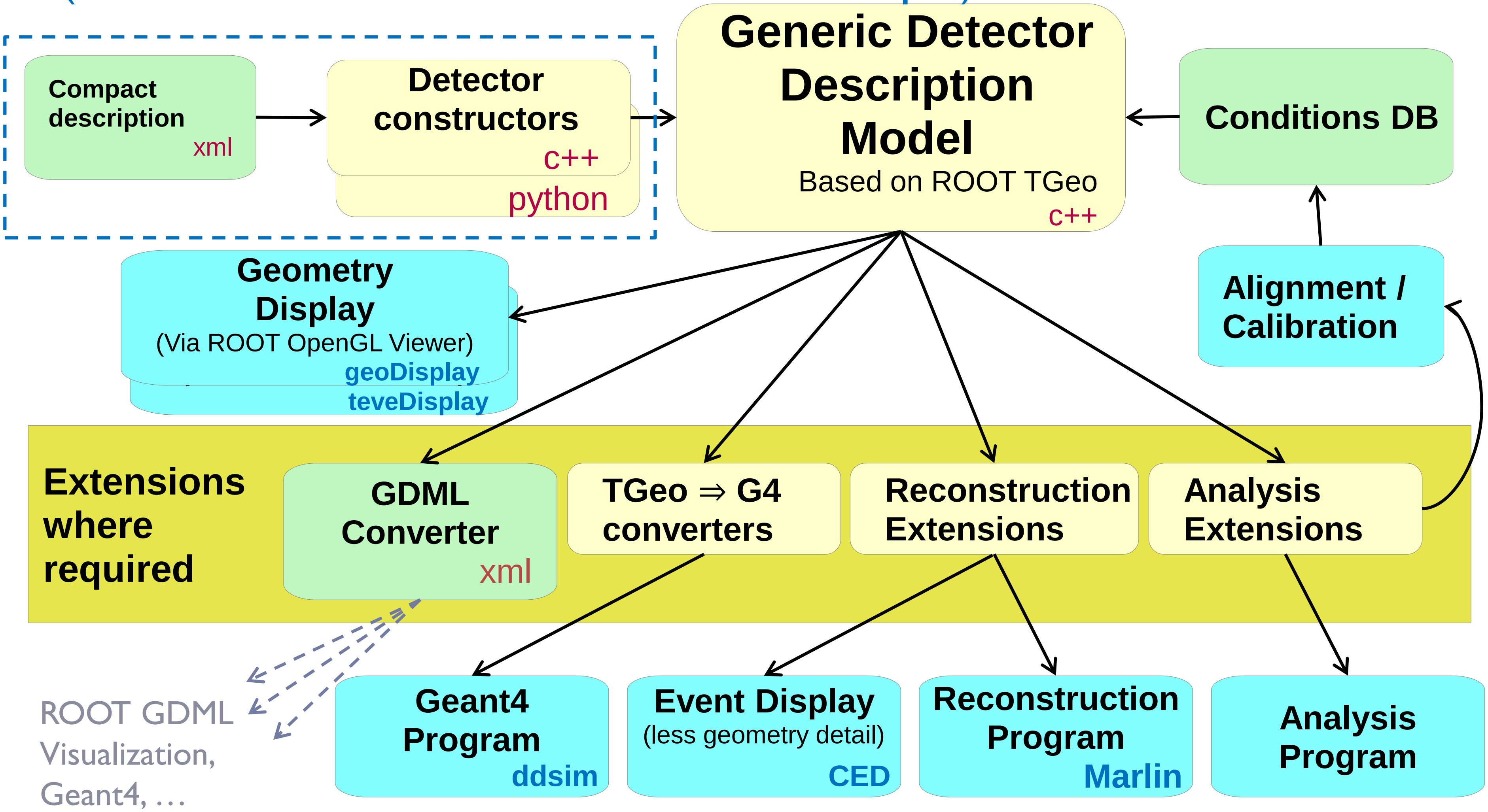
- Description of a tree-like hierarchy of **“detector elements”**
  - Subdetectors or parts of subdetectors
- Detector Element describes
  - Geometry
  - Environmental conditions
  - Properties required to process event data
  - Extensions (optionally): experiment, sub-detector or activity specific data, measurement surfaces, …



M. Frank

DD4hep – The Big Picture

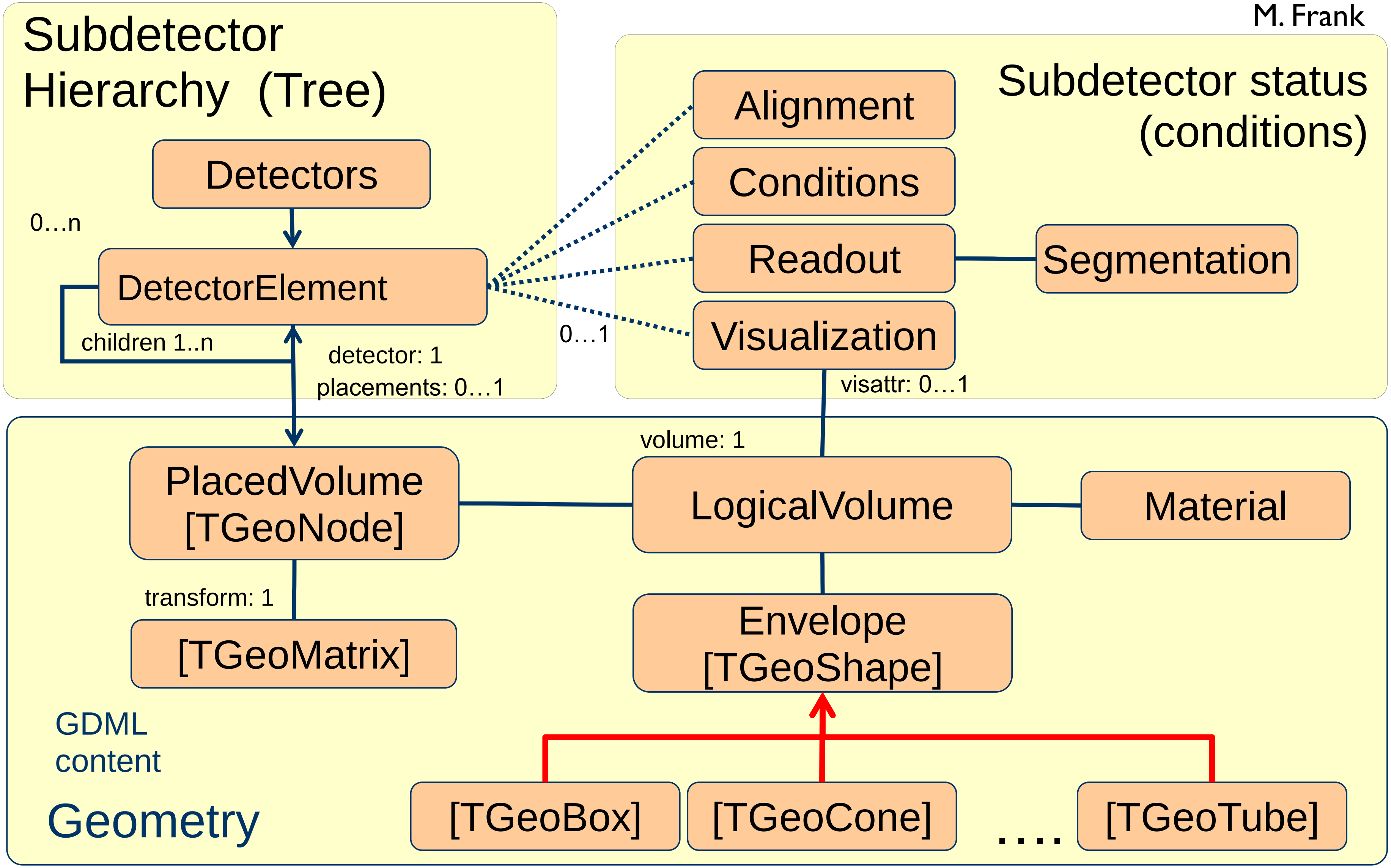
(With the CLIC/ILD use case as an example)



M. Frank

Geometry Implementation

M. Frank



Subdetector Hierarchy (Tree)

Detectors

0…n

DetectorElement

children 1..n

detector: 1

placements: 0…1

0…1

Subdetector status (conditions)

Alignment

Conditions

Readout

Segmentation

Visualization

visattr: 0…1

volume: 1

PlacedVolume [TGeoNode]

LogicalVolume

Material

transform: 1

[TGeoMatrix]

Envelope [TGeoShape]

GDML content

Geometry

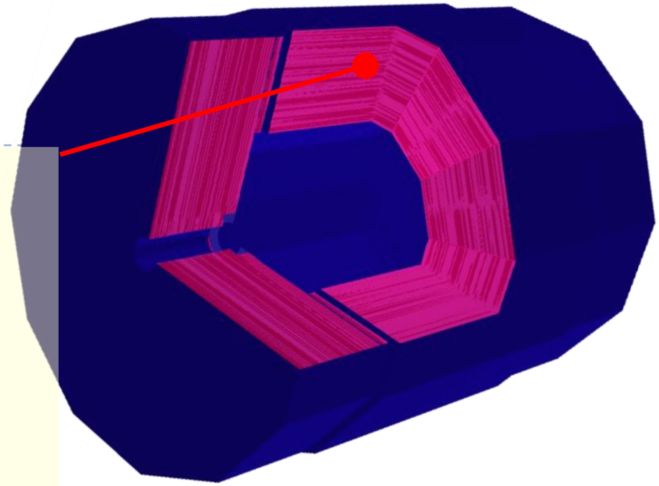
[TGeoBox]

[TGeoCone]

….

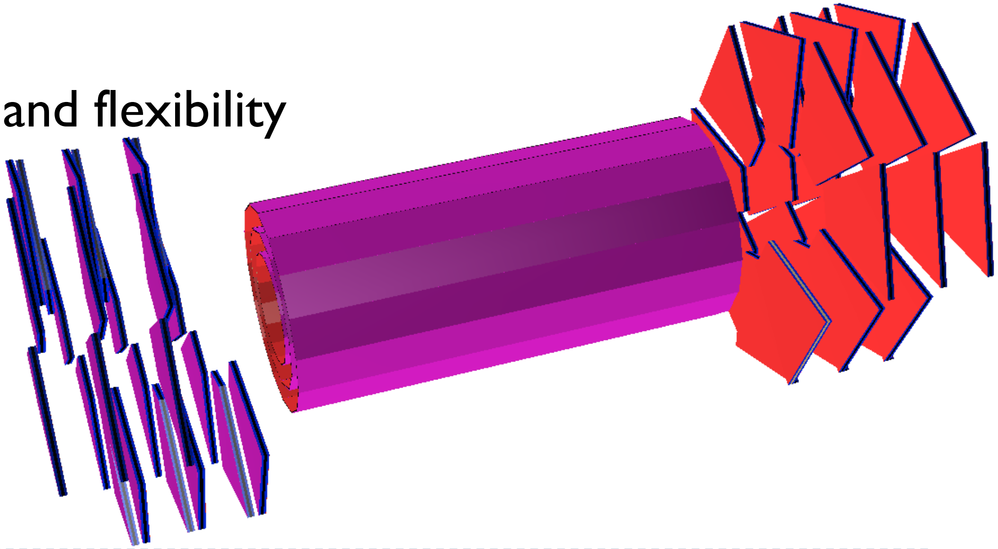
[TGeoTube]

Detector examples



```xml
<detector id="DetID_HCAL_Barrel" name="HCalBarrel" type="HCalBarrel_o1_v01"
readout="HCalBarrelHits" vis="HCALVis" >
 <dimensions nsides="HCal_symm" rmin="HCal_Rin" z="HCal_Z" />
 <layer repeat="(int) HCal_layers" vis="HCalLayerVis" >
  <slice material="Steel235" thickness="0.5*mm" vis="AbsVis"/>
  <slice material="Steel235" thickness="19*mm" vis="AbsVis"/>
  <slice material="Polysterene" thickness="3*mm" sensitive="yes"/>
  <slice material="PCB" thickness="0.7*mm"/>
  <slice material="Steel235" thickness="0.5*mm" vis="AbsVis"/>
  <slice material="Air" thickness="2.7*mm"/>
  </layer>
</detector>
```

- Fairly scalable and flexible drivers (Generic driver palette available)
- Visualization, Radii, Layer/module composition in compact xml, volume building in C++ driver
- User decides balance between detail and flexibility
- Usually could do a lot just by modifying the xml. For example:
  - Scale detector
  - Create double layers
  - Create "spiral" endcap geometry
  - …



Envelopes

- Good practice: each subdetector should be contained in an **envelope** defining its boundaries

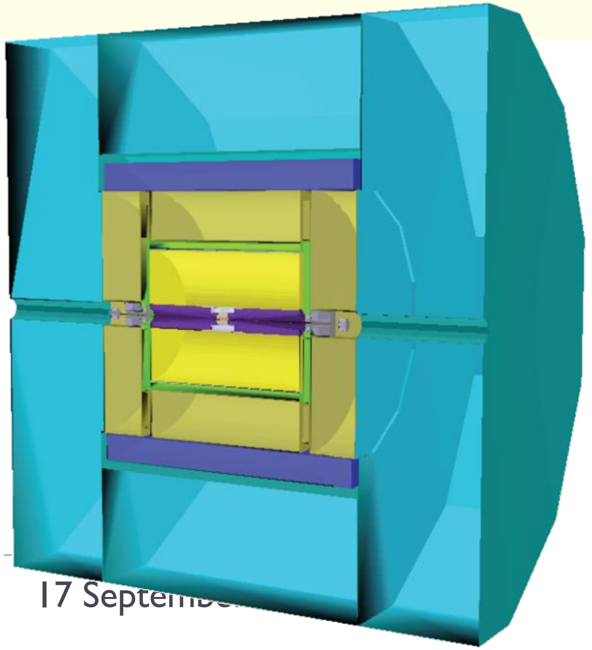
- Fairly complex envelopes can be fully described in the XML
- Using high-level parameters
  - e.g Inner/outer radius

```xml
<envelope vis="ILD_ECALVis">
 <shape type="BooleanShape" operation="Subtraction" material="Air">
  <shape type="BooleanShape" operation="Subtraction" material="Air">
   <shape type="BooleanShape" operation="Intersection" material="Air">
    <shape type="Box" dx="R_out" dy="R_out" dz="Z_max"/>
    <shape type="PolyhedraRegular" numsides="symmetry" rmin="0"
          rmax="R_out" dz="2.0*Z_max"/>
    <rotation x="0*deg" y="0*deg" z="90*deg-180*deg/symmetry"/>
   </shape>
   <shape type="Box" dx="R_in" dy="R_in" dz="Z_max"/>
  </shape>
  <shape type="Box" dx="R_out" dy="R_out" dz="Z_min"/>
 </shape>
</envelope>
```

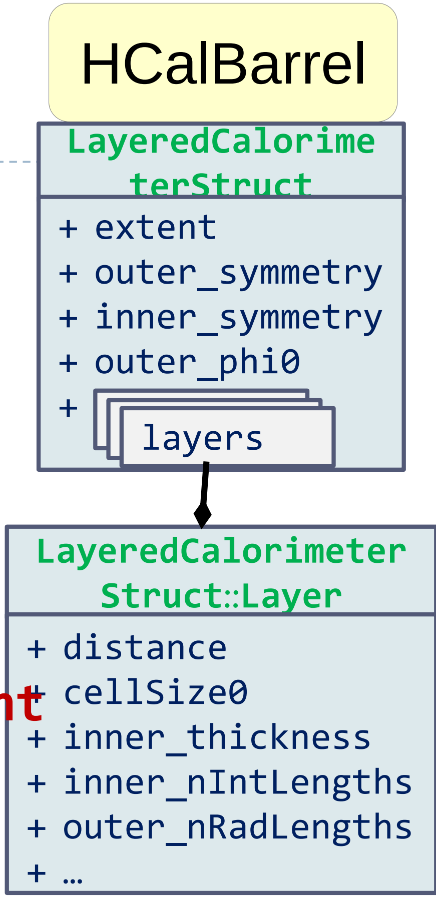
- Envelope placed with a single line in the C++ driver

```cpp
Volume envelope = XML::createPlacedEnvelope(lcdd, element, sdet);
if (lcdd.buildType()==BUILD_ENVELOPE) return sdet;
```

- Use flag in `geoDisplay` to build a simplified geometry using only the envelopes
  - e.g. ILD Detector envelopes



DDRec: Reconstruction extensions



HCalBarrel

LayeredCalorimeterStruct

+ extent
+ outer_symmetry
+ inner_symmetry
+ outer_phi0
+ layers

LayeredCalorimeterStruct::Layer

+ distance
+ cellSize0
+ inner_thickness
+ inner_nIntLengths
+ outer_nRadLengths
+ …

Extend subdetector driver with arbitrary user data

- Summary of more *abstract* information useful for **reconstruction**
- Populate during driver construction
  - Driver has the all the information
  - Take advantage of material map
- e.g: attach a LayeredCalorimeterStruct to the DetElement for HCalBarrel

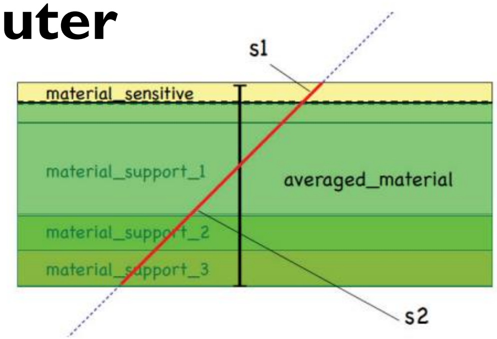
```
sdet.addExtension<DDRec::LayeredCalorimeterData>(caloData);
```

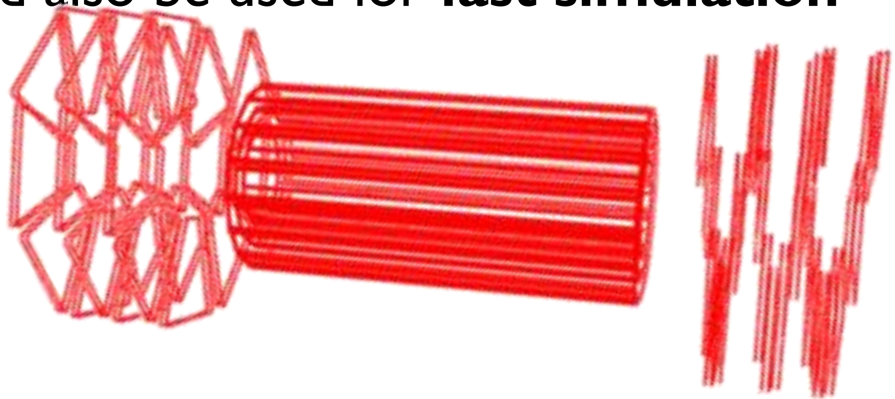
- Additional *simple* data structures available
- Users can even attach their own more complicated objects
- Other use cases: auxiliary information for tracking, slimmed-down geometry for a faster event display (e.g. CED[†])

[†] http://ilcsoft.desy.de/portal/software_packages/ced/

Measurement Surfaces

- Special type of extension, used primarily in **tracking**
  - Did not find an implementation in TGeo
  - Implemented in DDRec
- Attached to `DetElements` and `Volumes` (defining their boundaries)
  - Can be added to drivers via **plugins** without modifying detector constructor
- They hold **u**,**v**,**n**ormal and **o**rigin vectors and **inner/outer thicknesses**
- Material properties **averaged automatically**
- Could also be used for **fast simulation**



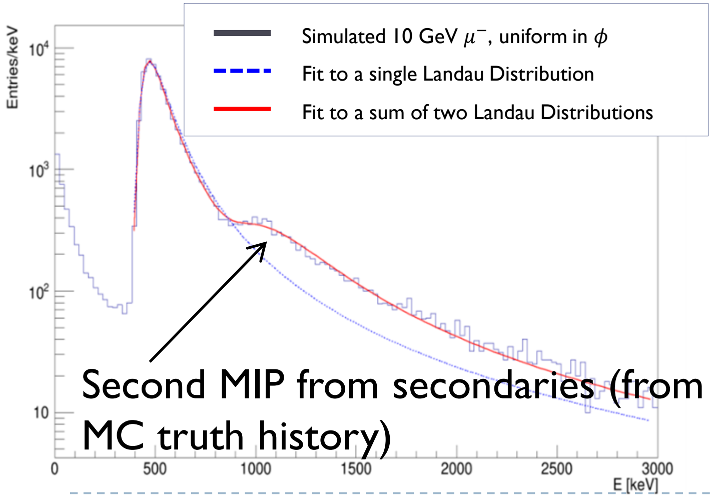


- Outlines of surfaces drawn in `teveDisplay` for CLICdp Vertex Barrel and Spiral Endcaps

DDG4: Gateway to Geant4

- DD4hep facilitates **in-memory translation of geometry** from TGeo to Geant4
- Plugin Mechanism:
  - Sensitive detectors, **segmentations** and configurable actions, …
- Configuration mechanism (via python, XML, CINT)
  - Physics lists, regions, limits, fields, …
- All shared with **Reconstruction**

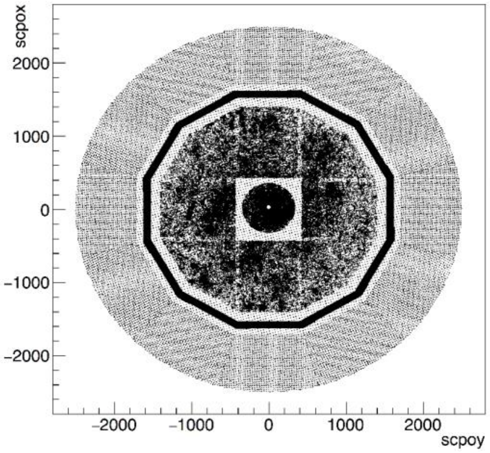
Deposited energy per hit in the CLIC det. HCal



Second MIP from secondaries (from MC truth history)

- Detailed validation underway
- Already simulating realistic physics events to develop/test tracking and particle flow-based reconstruction

Hit map from 100 Hνν events in CLIC det.



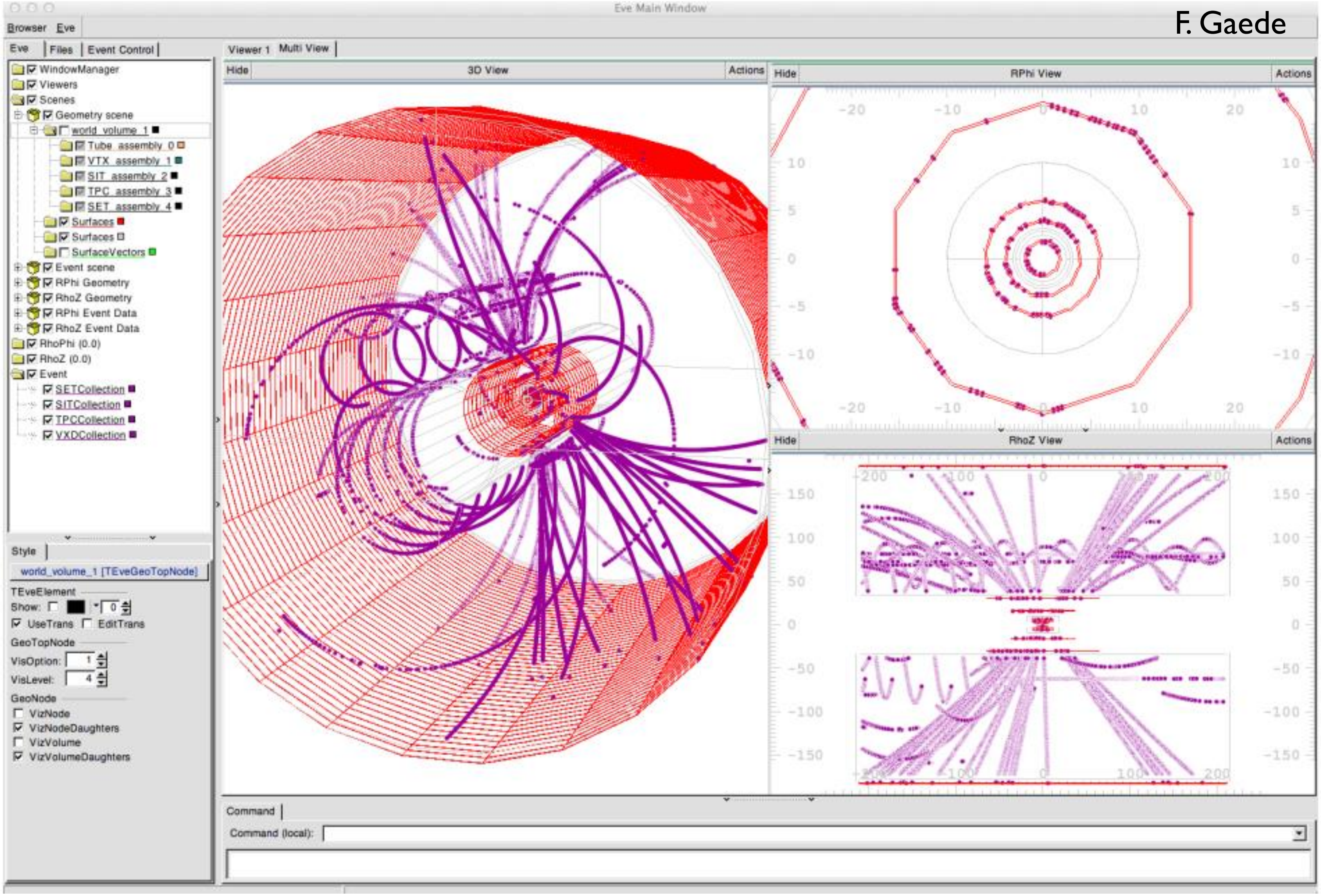
The TGeo Advantage

- Visualize and check the geometry in detail outside Geant4 first with ROOT's OpenGL viewers
  - Easier manipulation of the scene (rotate, pan, clip, …)
  - Tools (overlap check, independent GDML dump, …)

- Can implement Event Displays using TEve
- Implement toggling of display of subdetectors on the fly, chose to show just envelopes, just surfaces, …

- Nice treatment of assemblies (especially assemblies-in-assemblies)

Surfaces and Hits in teveDisplay



F. Gaede

- ☑ WindowManager
- ☑ Viewers
- ☑ Scenes
  - ☑ Geometry scene
    - ☐ world_volume_1
      - ☑ Tube_assembly_0
      - ☑ VTX_assembly_1
      - ☑ SIT_assembly_2
      - ☑ TPC_assembly_3
      - ☑ SET_assembly_4
    - ☑ Surfaces
    - ☑ Surfaces
    - ☐ SurfaceVectors
  - ☑ Event scene
  - ☑ RPhi Geometry
  - ☑ RhoZ Geometry
  - ☑ RPhi Event Data
  - ☑ RhoZ Event Data
- ☑ RhoPhi (0.0)
- ☑ RhoZ (0.0)
- ☑ Event
  - ☑ SETCollection
  - ☑ SITCollection
  - ☑ TPCCollection
  - ☑ VXDCollection

world_volume_1 [TEveGeoTopNode]

TEveElement

Show: ☐ 0

☑ UseTrans ☐ EditTrans

GeoTopNode

VisOption: 1

VisLevel: 4

GeoNode

☐ VizNode

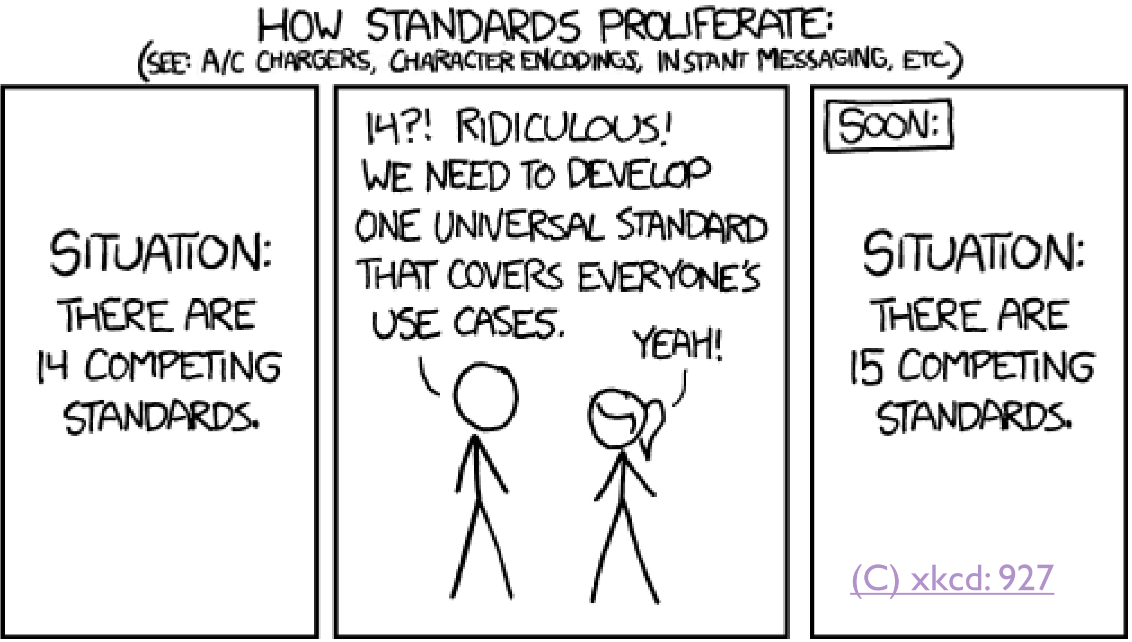
☑ VizNodeDaughters

☐ VizVolume

☑ VizVolumeDaughters

Minor inconveniences

- Variety conventions ⇒ can be confusing for the user
- Different conventions between TGeo and Geant4 shape constructors
  - E.g. `phi1` and `phi2` vs `phi1` and `dphi`
- Different units between TGeo and Geant4
  - Degrees/radians, mm/cm, …
  - **Introduced "DD4hep units" (dd4hep::mm, dd4hep::rad, …)**
  - We ***require*** users to use units explicitly in the compact xml


HOW STANDARDS PROLIFERATE:
(SEE: A/C CHARGERS, CHARACTER ENCODINGS, INSTANT MESSAGING, ETC)
SITUATION: THERE ARE 14 COMPETING STANDARDS.
14?! RIDICULOUS! WE NEED TO DEVELOP ONE UNIVERSAL STANDARD THAT COVERS EVERYONE'S USE CASES.
YEAH!
SOON:
SITUATION: THERE ARE 15 COMPETING STANDARDS.

(C) xkcd: 927

DD4hep, ROOT 6 and the Future

- Necessary changes implemented, initial tests show that DD4hep compiles and **works** with ROOT 6 and clang/cling
  - LC Community are still using ROOT 5: **transitioning to ROOT 6 by end of year**
- **Major issues encountered:**
  - **Abandonment of `PluginService` (needed for DD4hep by design)**
    - **Solution: Use the Gaudi plugin service**
  - **Problems with OpenGL on ubuntu (?)**
    - **Already under investigation by developers**
- **TGeo ⇒ VecGeom: Should not affect us**
  - **Assuming TGeo interfaces remain the same**

Summary and Outlook

- DD4hep provides consistent single source of detector geometry for simulation, reconstruction, analysis
- Takes full advantage of ROOT's TGeo
- Already in use by LC and FCC Communities
  - Full integration with iLCsoft software framework underway

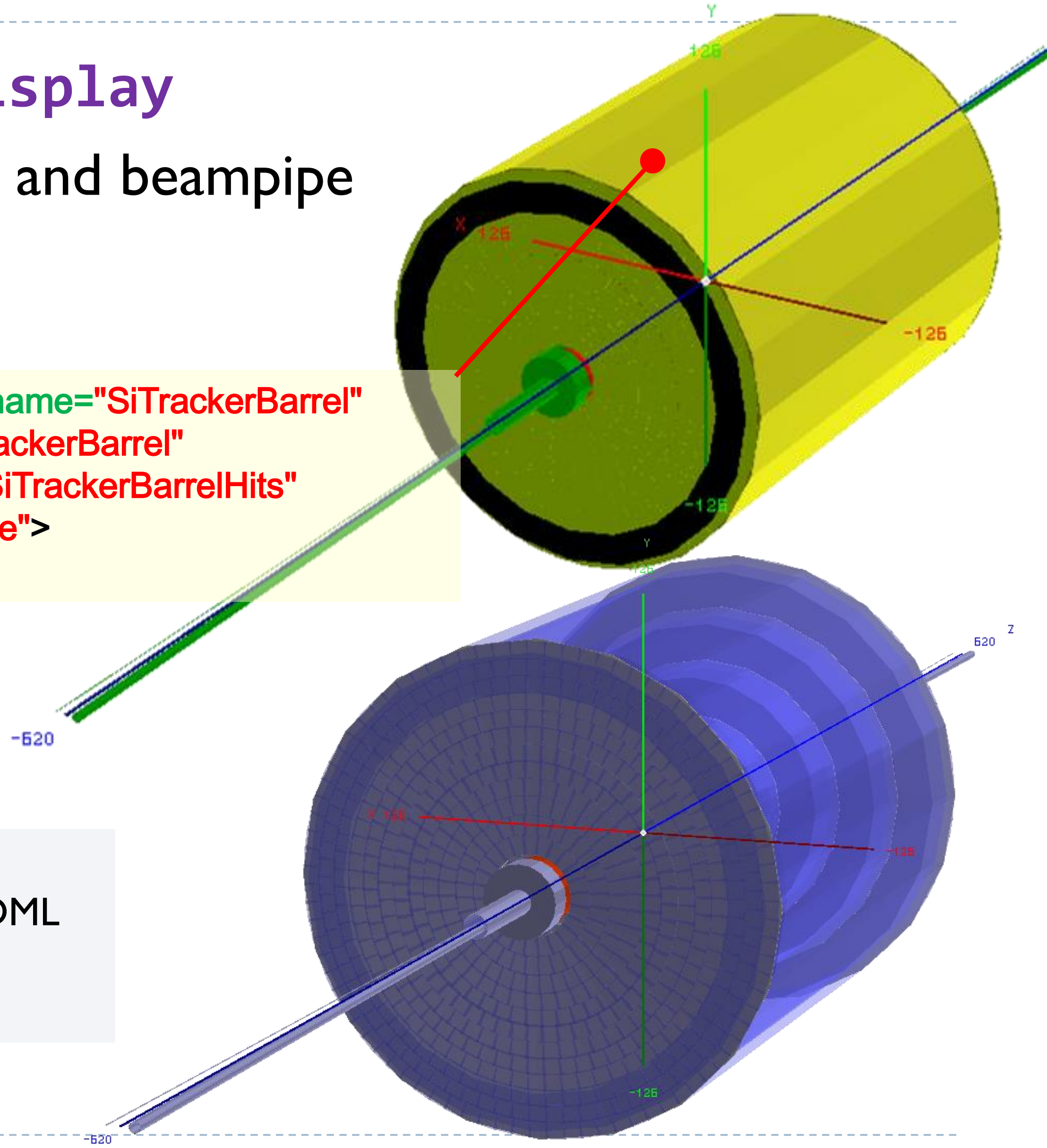
- Development continues in parallel with validation

- Compatibility with ROOT 6 demonstrated

BACKUP SLIDES

CLIC_SID_CDR Tracker

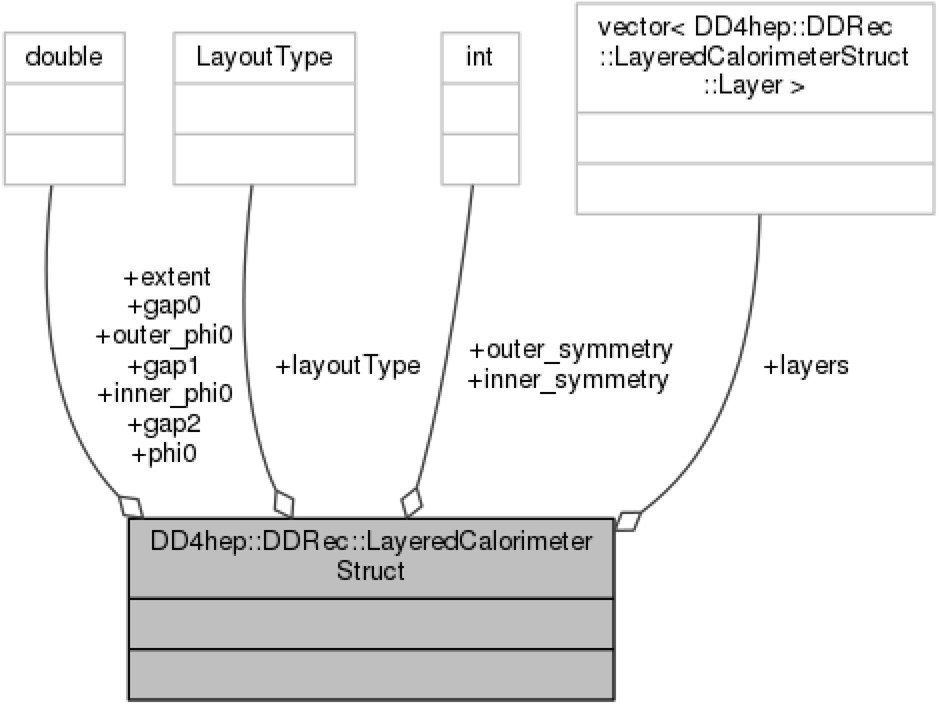
- Visualized here in **geoDisplay**
- Around Vertex Detector and beampipe

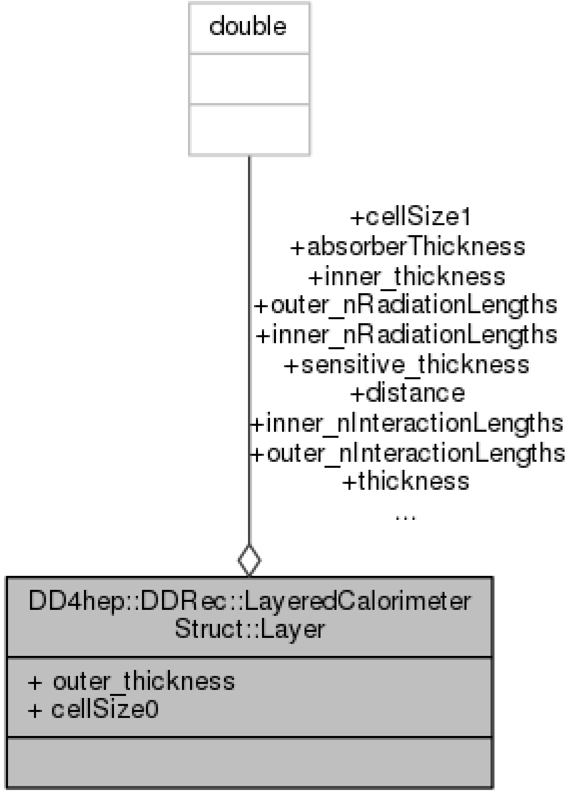


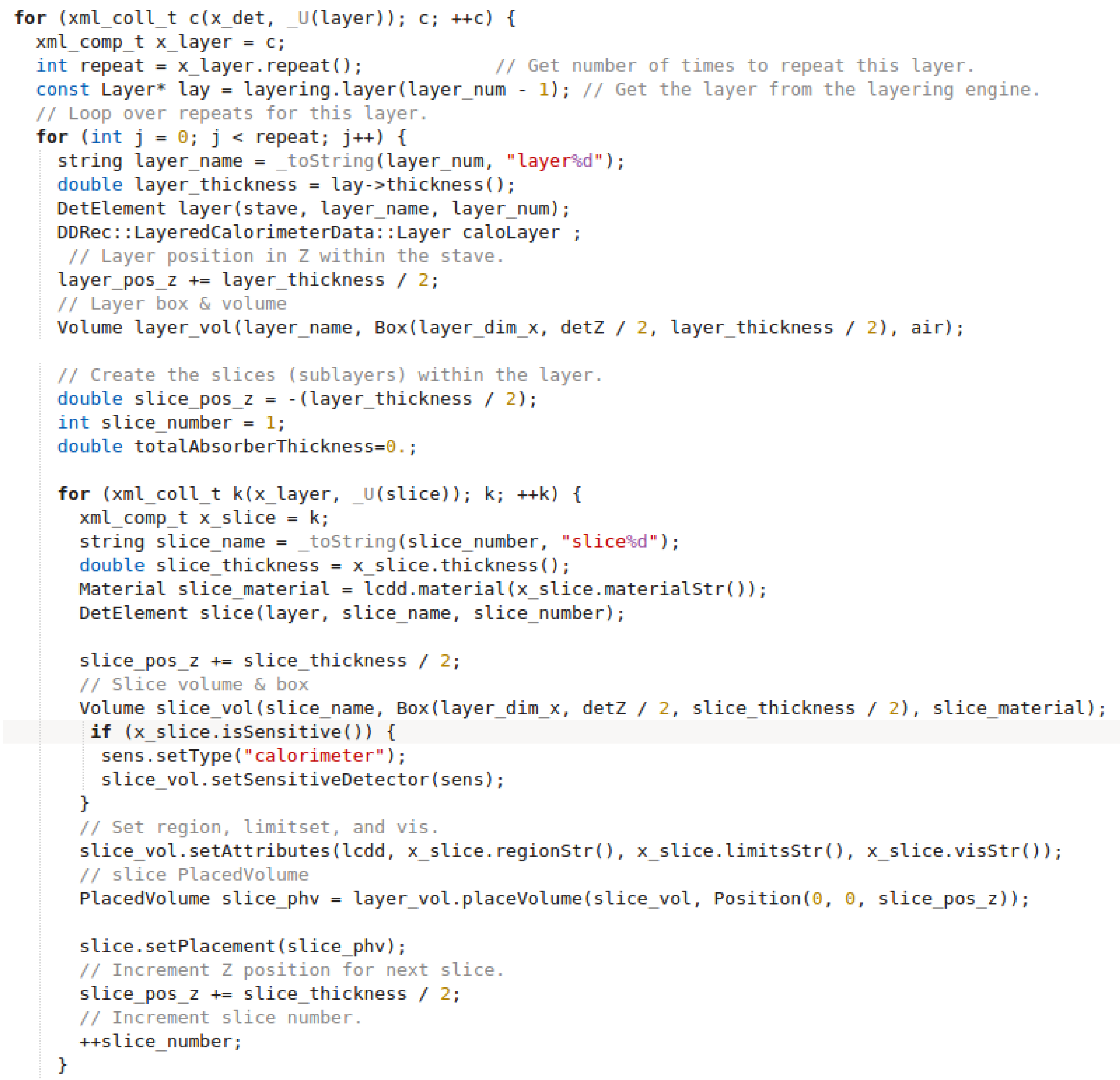
```
<detector name="SiTrackerBarrel"
type="SiTrackerBarrel"
readout="SiTrackerBarrelHits"
reflect="true">
```

The same tracker visualized with ROOT's TGeoManager using and intermediate GDML file dumped from Geant4 after loading geometry from DD4hep

LayeredCalorimeterStruct







```
for (xml_coll_t c(x_det, _U(layer)); c; ++c) {
  xml_comp_t x_layer = c;
  int repeat = x_layer.repeat();            // Get number of times to repeat this layer.
  const Layer* lay = layering.layer(layer_num - 1); // Get the layer from the layering engine.
  // Loop over repeats for this layer.
  for (int j = 0; j < repeat; j++) {
    string layer_name = _toString(layer_num, "layer%d");
    double layer_thickness = lay->thickness();
    DetElement layer(stave, layer_name, layer_num);
    DDRec::LayeredCalorimeterData::Layer caloLayer ;
     // Layer position in Z within the stave.
    layer_pos_z += layer_thickness / 2;
    // Layer box & volume
    Volume layer_vol(layer_name, Box(layer_dim_x, detZ / 2, layer_thickness / 2), air);

    // Create the slices (sublayers) within the layer.
    double slice_pos_z = -(layer_thickness / 2);
    int slice_number = 1;
    double totalAbsorberThickness=0.;

    for (xml_coll_t k(x_layer, _U(slice)); k; ++k) {
      xml_comp_t x_slice = k;
      string slice_name = _toString(slice_number, "slice%d");
      double slice_thickness = x_slice.thickness();
      Material slice_material = lcdd.material(x_slice.materialStr());
      DetElement slice(layer, slice_name, slice_number);

      slice_pos_z += slice_thickness / 2;
      // Slice volume & box
      Volume slice_vol(slice_name, Box(layer_dim_x, detZ / 2, slice_thickness / 2), slice_material);
       if (x_slice.isSensitive()) {
        sens.setType("calorimeter");
        slice_vol.setSensitiveDetector(sens);
      }
      // Set region, limitset, and vis.
      slice_vol.setAttributes(lcdd, x_slice.regionStr(), x_slice.limitsStr(), x_slice.visStr());
      // slice PlacedVolume
      PlacedVolume slice_phv = layer_vol.placeVolume(slice_vol, Position(0, 0, slice_pos_z));

      slice.setPlacement(slice_phv);
      // Increment Z position for next slice.
      slice_pos_z += slice_thickness / 2;
      // Increment slice number.
      ++slice_number;
    }
```

Example HCal Barrel Driver

- Always within a function called

```
static Ref_t create_detector(LCDD& lcdd, xml_h e, SensitiveDetector sens)
{
…
return sdet;
}
```

- Macro to declare detector constructor at the end:

```
DECLARE_DETELEMENT(HCalBarrel_o1_v01, create_detector)
```