

AIDA-2020

Advanced European Infrastructures for Detectors at Accelerators

Presentation

Detector Simulations with DD4hep

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11 October 2016



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DETECTOR SIMULATIONS WITH DD4hep

CHEP 2016

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On behalf of the CLICdp and ILD collaborations



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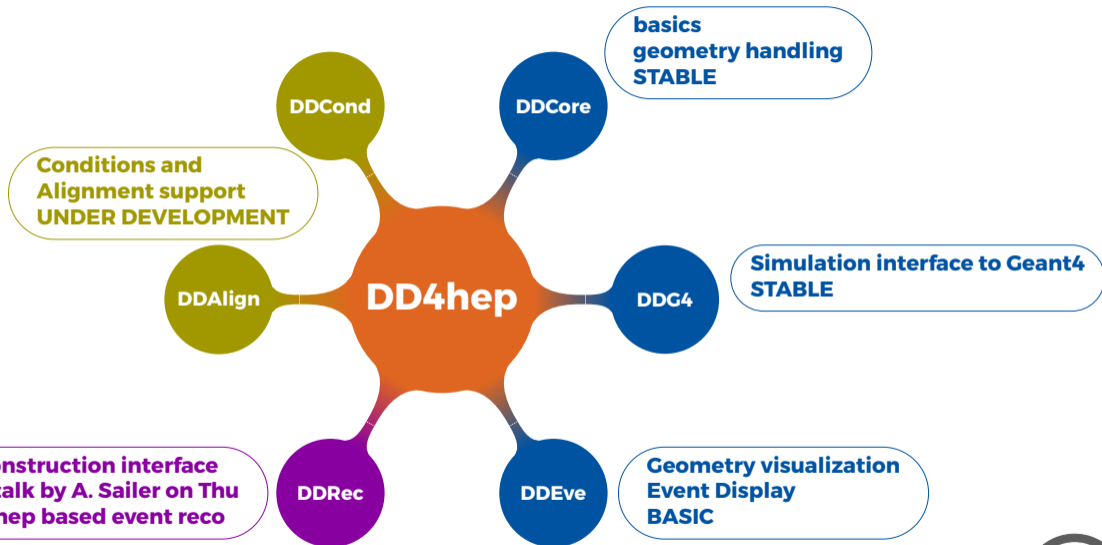
AIDA²⁰²⁰

San Francisco, 11 October 2016

Overview

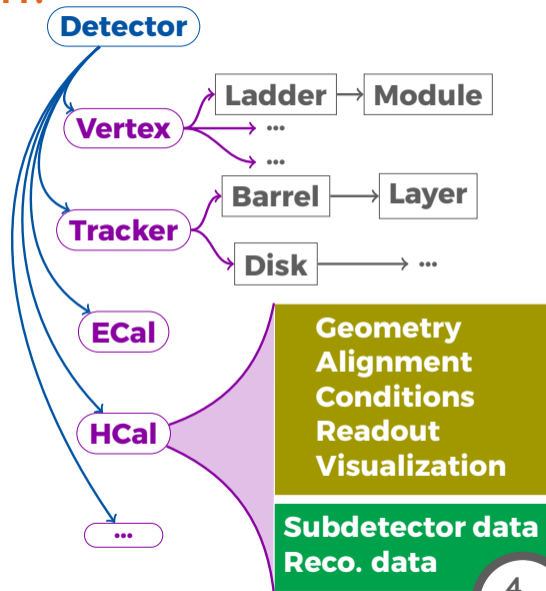
- ▶ **Complete Detector Description**
 - ▶ Providing geometry, materials, visualization, readout, alignment, calibration...
- ▶ **Supports full experiment life cycle**
 - ▶ Detector concept development, detector optimization, construction, operation
 - ▶ Facile transition from one stage to the next
- ▶ **Single source of information → consistent description**
 - ▶ Use in simulation, reconstruction, analysis, etc.
- ▶ **Ease of Use**
- ▶ **Few places for entering information**
- ▶ **Minimal dependencies**

Structure and packages

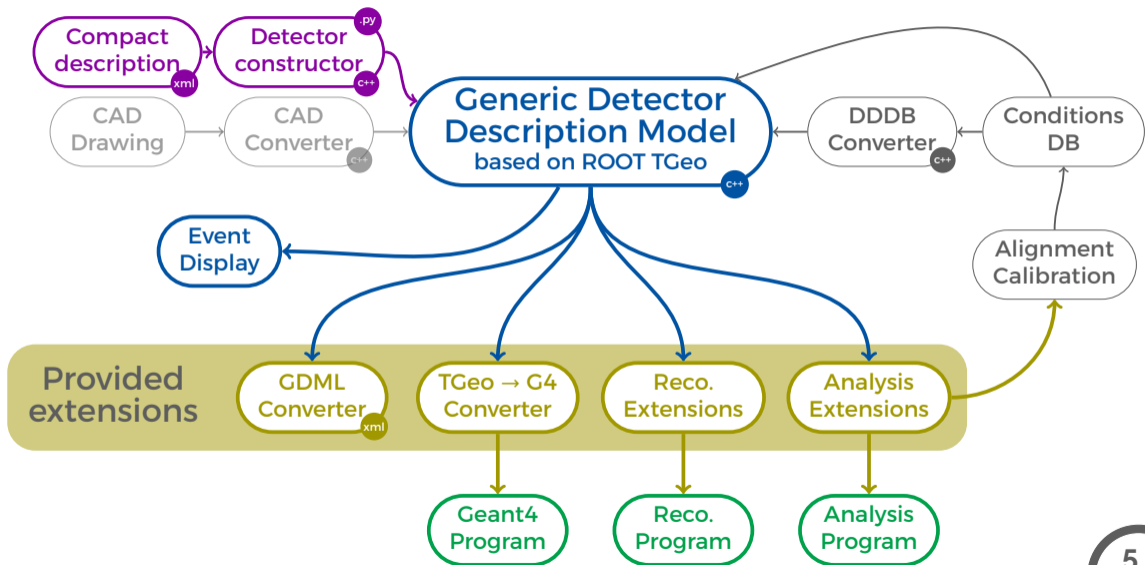


What is Detector description?

- ▶ Description of a tree-like hierarchy of 'detector elements'
 - ▶ Sub-detectors 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...



The Big Picture



The Generic Detector Palette

- ▶ Generic driver available → scalable and flexible
- ▶ Parameters are provided in compact XML files, e.g.

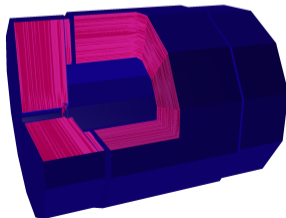
```
<detector id="15" name="HCal" type="GenericCalBarrel_o1_v01" readout="HCalCollection">
  <envelope vis="HCalVis">
    <shape type="PolyhedraRegular" numsides="HCal_sym" rmin="HCal_rmin" rmax="HCal_rmax" dz="HCal_dz" material="Air"/>
    <rotation x="0*deg" y="0*deg" z="90*deg-180*deg/HCal_symmetry"/>
  </envelope>
  <dimensions numsides="HCal_sym" rmin="HCal_rmin" z="HCal_dz*2"/>
  <layer repeat="(int) HCal_layers" vis="HCalLayerVis">
    <slice material="Steel235" thickness="0.5*mm" vis="HCalAbsorberVis" radiator="yes"/>
    <slice material="Steel235" thickness="19*mm" vis="HCalAbsorberVis" radiator="yes"/>
    <slice material="Polystyrene" thickness="3*mm" sensitive="yes" limits="cal_limits"/>
    <slice material="Copper" thickness="0.1*mm" vis="HCalCopperVis"/>
    <slice material="PCB" thickness="0.7*mm" vis="HCalPCBVis"/>
    <slice material="Steel235" thickness="0.5*mm" vis="HCalAbsorberVis" radiator="yes"/>
    <slice material="Air" thickness="2.7*mm" vis="InvisibleNoDaughters"/>
  </layer>
</detector>
```

- ▶ You can scale, change layers, radii and compositions...
- ▶ Propagate visualization attributes to Display

Your Detector Palette

```
static Ref_t create_detector(LCDD& lcdd,  
    xml_h e, SensitiveDetector sens) {  
  
    xml_det_t x_det = e;  
    Layering layering(x_det);  
    xml_comp_t staves = x_det.staves();  
    xml_dim_t dim = x_det.dimensions();  
    DetElement sdet(det_name, x_det.id());  
    Volume motherVol = lcdd.pickMotherVolume(sdet);  
  
    PolyhedraRegular polyhedra(numSides, rmin, rmax, detZ);  
    Volume envelopeVol(det_name, polyhedra, air);  
  
    for (xml_coll_t c(x_det, _U(layer)); c; ++c) {  
        xml_comp_t x_layer = c;  
        int n_repeat = x_layer.repeat();  
        const Layer* lay = layering.layer(layer_num - 1);  
        for (int j = 0; j < n_repeat; j++) {  
            string layer_name = _toString(layer_num, "layer%d");  
            double layer_thickness = lay->thickness();  
            DetElement layer(stave, layer_name, layer_num);
```

- ▶ Users can easily write their own detector drivers, if needed
- ▶ Detector geometry extendable with additional info.
- ▶ C++ model of separation of 'data' and 'behavior'
 - ▶ Classes consist of a single 'reference' to the data object



DDG4 – Gateway to Geant4

- ▶ In-memory translation of geometry from TGeo to Geant4
 - ▶ Materials, Solids, Limit sets, Regions
 - ▶ Logical volumes, placed volumes and physical volumes
- ▶ External configuration:
 - ▶ Plugin mechanism
 - ▶ Property mechanism to configure plugin instances
 - ▶ Supports configuration via **XML**, **Python** or **ROOT-AClick**
- ▶ Use plugin mechanism to configure: Generation, Event Action, Tracking Action, Stepping Action, SensitiveDetector, PhysicsList...
- ▶ **Provides out of the box MC truth handling w/o record reduction**

DDG4 – Configuration example

- ▶ DDG4 is highly modular
- ▶ Very easily configurable through python

```
#...  
gen = DDG4.GeneratorAction( kernel , "LCIOInputAction/LCIO1" )  
gen.Input = "LCIOFileReader|" + inputFile  
#...
```

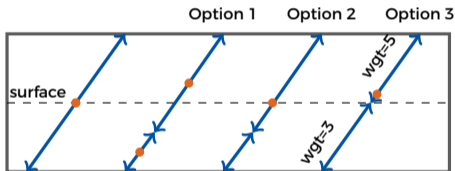
- ▶ Or configure actions, filters, sequences, cuts

```
#...  
part = DDG4.GeneratorAction(kernel, "Geant4ParticleHandler/ParticleHandler")  
kernel.generatorAction().adopt(part)  
part.SaveProcesses = ['Decay']  
part.MinimalKineticEnergy = 1*MeV  
part.KeepAllParticles = False  
#...  
user = DDG4.GeneratorAction(kernel, "Geant4TCUserParticleHandler/UserParticleHandler")  
user.TrackingVolume_Zmax = DDG4.tracker_region_zmax  
user.TrackingVolume_Rmax = DDG4.tracker_region_rmax  
#...
```

Plugin Palettes

- ▶ Providing input handlers, sensitive detectors for most cases...
- ▶ Hard to provide Geant4 Sensitive Detectors for all cases
 - ▶ Couples detector 'construction' to reconstruction, MC truth and Hit production
 - ▶ Too dependent on technology and user needs

e.g. several possibilities
for tracker



- ▶ Providing palette of most 'common' sensitive components for trackers and calorimeters
- ▶ Physics lists, Physics/particle constructors etc.
 - ▶ Wrapped factory plugins directly taken from Geant4
 - ▶ Users extend physics list (e.g. QGSP)
- ▶ Several IO handlers (LCIO, ROOT, StdHep, HepEvt, HepMC)

The Linear Collider Case

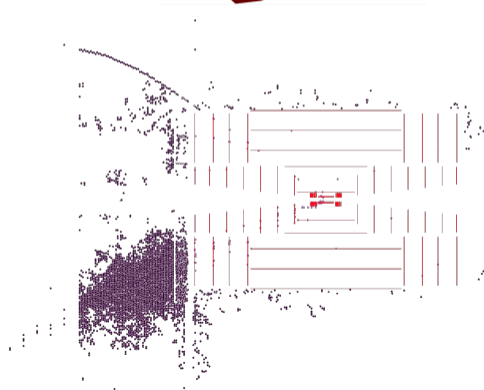
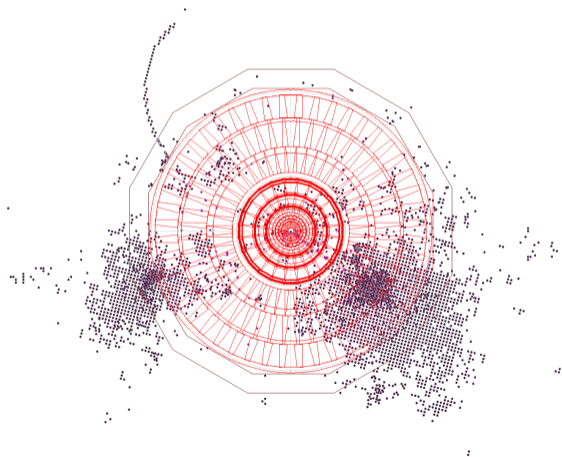
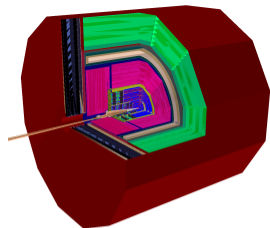
- ▶ ddsim python executable part of lcgeo and the latest iLCsoft release
- ▶ Get steering file `ddsim --dumpSteeringFile > mySteer.py`
 - ▶ Steering file includes documentation for parameters and examples
 - ▶ The python file contains a `DD4hepSimulation` object at global scope
 - ▶ Configure simulation directly from commandline

```
from DDSim.DD4hepSimulation import DD4hepSimulation
from SystemOfUnits import mm, GeV, MeV, keV
SIM = DD4hepSimulation()
SIM.compactFile = "CLIC_o3_v06.xml"
SIM.runType = "batch"
SIM.numberOfEvents = 2
SIM.inputFile = "electrons.HEPEvt"
SIM.part.minimalKineticEnergy = 1*MeV
SIM.filter.filters ['edep3kev'] =
dict (name="EnergyDepositMinimumCut/3keV" ,
      parameter={"Cut" : 3.0*keV} )
```

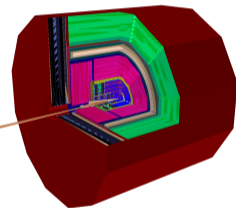
```
$ ddsim
--action.calo
--action.mapActions
--action.tracker
--compactFile
--crossingAngleBoost
--dump
--dumpParameter
--dumpSteeringFile
--enableDetailedShowerMode
--enableGun
--field.delta_chord
--field.delta_intersection
--field.delta_one_step
--field.eps_max
--field.eps_min
--field.equation
--field.largest_step
--field.min_chord_step
--field.stepper
--filter.calo
--filter.filters
--filter.mapDetFilter
--filter.tracker
-G
--gun.direction
--gun.energy
--gun.isotrop
--gun.multiplicity
--gun.particle
--gun.position
-h
--help
-I
--inputFiles
-M
--macroFile
-N
--numberOfEvents
-O
--outputFile
--output.inputStage
--output.kernel
--output.part
--output.random
--part.keepAllParticles
--part.minimalKineticEnergy
--part.printEndTracking
--part.printStartTracking
--part.saveProcesses
--physics.decays
--physics.list
--physicsList
--physics.rangecut
--printLevel
--random.file
--random.luxury
--random.replace_gRandom
--random.seed
--random.type
--runType
-S
--skipNEvents
--steeringFile
-v
--vertexOffset
--vertexSigma
```

CLIC Example

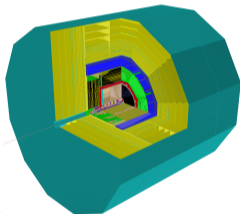
- ▶ The CLIC Detector Model
- ▶ $e^+e^- \rightarrow H(\rightarrow b\bar{b})\nu\nu$



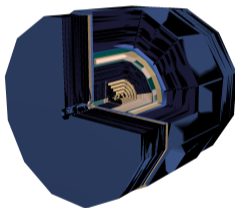
Users of DD4hep



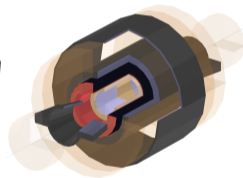
DD4hep
DDG4



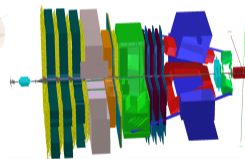
DD4hep
DDG4



DD4hep
DDG4



DD4hep



Under
investigation

► The user base for DD4hep is growing

Summary and Conclusion

- ▶ DD4hep provides a consistent single source of detector geometry for simulation, reconstruction, analysis
- ▶ Enables full simulation w/ Geant4 of particle collisions in detectors with minimal effort: simple, easy, flexible
- ▶ The DD4hep toolkit is getting accepted by wider HEP community
 - ▶ Used by CLIC, ILC, FCC detector communities
- ▶ Development continues in parallel with validation
- ▶ DD4hep can host user plugins: extensible
- ▶ Continued plugin suite development to cover all simulation needs (I/O, MC truth, etc)
- ▶ Find us at <https://github.com/AIDAsoft/DD4hep>