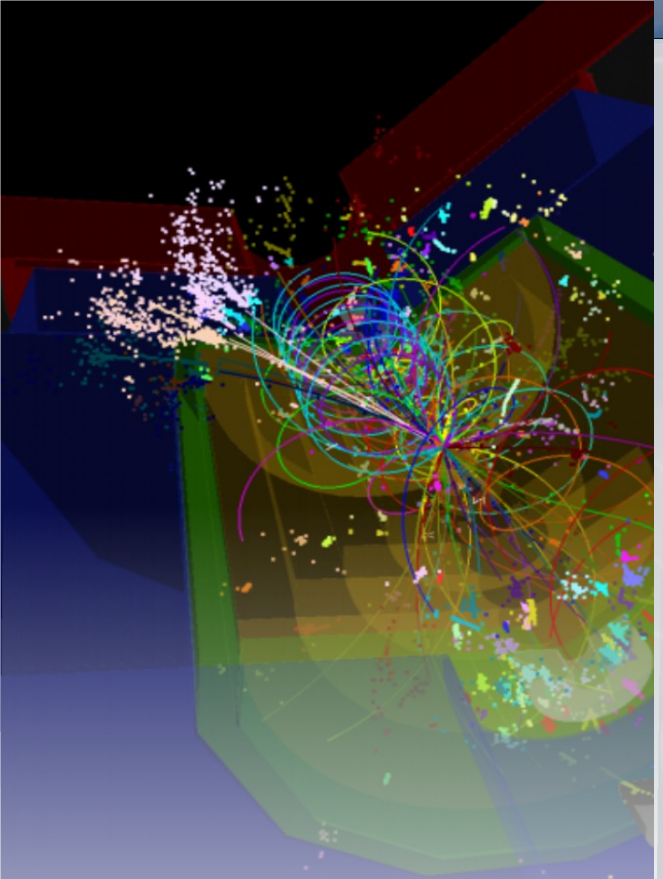


DDG4

A Simulation Framework Based on DD4hep[a] and Geant4

M.Frank[1], F.Gaede[1,2], N.Nikiforou[1], M.Petric[1], A.Sailer[1]
[1]CERN [2] Desy

[a] DD4hep: A General Purpose Detector Description Toolkit, CHEP2013, Amsterdam, NL

April 16th., 2015

- **Motivation, goals and the grand picture**

  => Introduction / Reminders

- **Concepts and Design**
- **Side remarks: Users and extensions**
- **Summary**

Motivation and Goal

DD4hep: a detector description

- For the full experiment life cycle
  - concept development, optimization, construction and operation
  - 'Anticipate the unforeseen'
- Consistent description, single source of information
  - Support for simulation, reconstruction, analysis
- Full description, including
  - Geometry, readout, alignment, calibration etc.

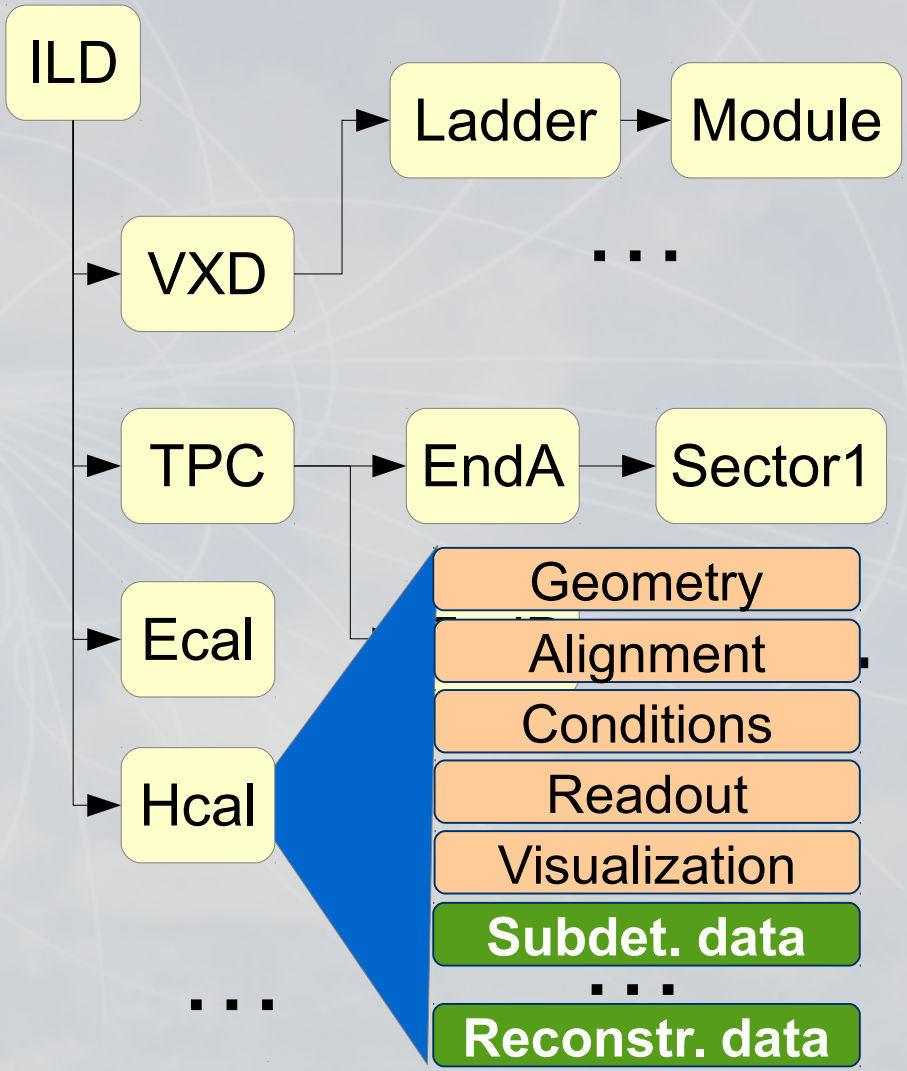
DDG4[(1)]: Simulation support for DD4hep

- Require minimal user effort

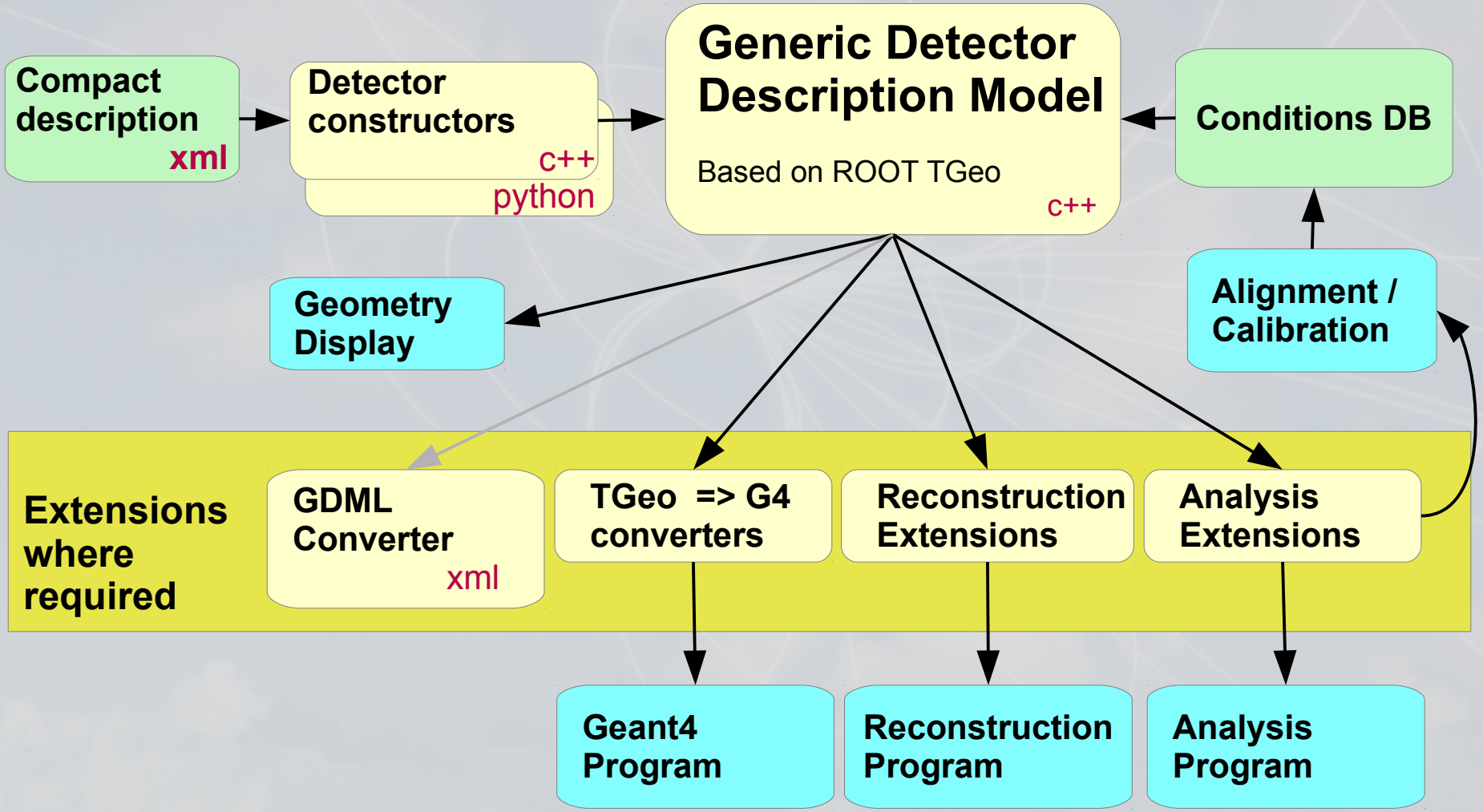
[(1)]AIDA-2020 project/Horizon-2020: WP3 Advanced Software

What is Detector Description ?

- **Description of a tree-like hierarchy of 'detector elements'**
  - **Subdetectors or parts of subdetectors**
- **Detector Element describes**
  - **Geometry**
  - **Environmental conditons**
  - **Properties required to process event data**
  - **Optionally: experiment, sub-detector or activity specific data**



DD4Hep - The Big Picture



- **Motivation and Goals**
- **Concepts and Design**
  - **… life is a wish-list**
  - **The design and some illustration examples**
- **Side remarks: Users and extensions**
- **Summary**

Simulation: The Wish

- **Simulation =**
  Geometry + Detector response + Physics
- **Minimalistic approach**
  - **Ideally: configuration without extra (C++) user code**

- **DDG4 Wish:**
  - **Bootstrap Geant4 from DD4hep memory model**
  - **Configure the simulation application**
  - **Run...**

Configuring Simulation Application: Concept

- Walk through the geometry and convert on the fly from ROOT to Geant4
- Hook into the Geant4 provided entry points
- Instantiate detector response (sensitive detectors) from plugin palette
- Instantiate physics list, -constructors and -processes from plugin palette
- Run...

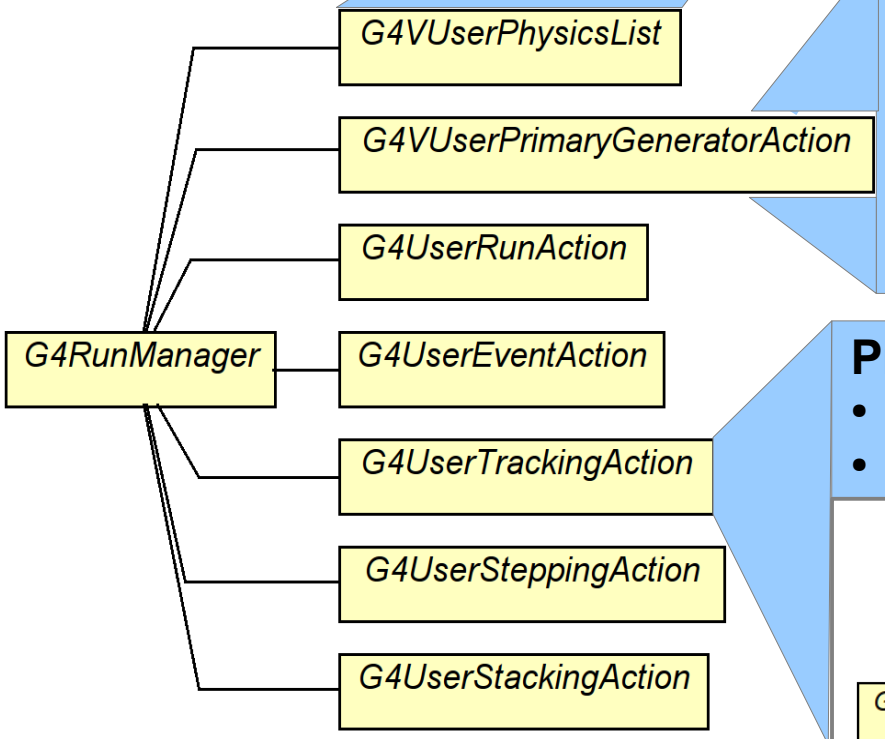
Geant4 Provided Hooks

[and what we want to do inside]

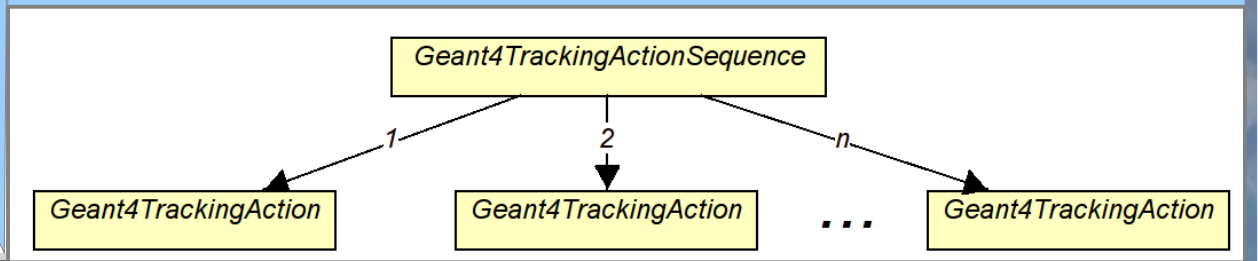
Main issue: flexible configuration

Flexible definition of the physics list
- Define particles, processes, physics constructors or use/extend predefined physics lists

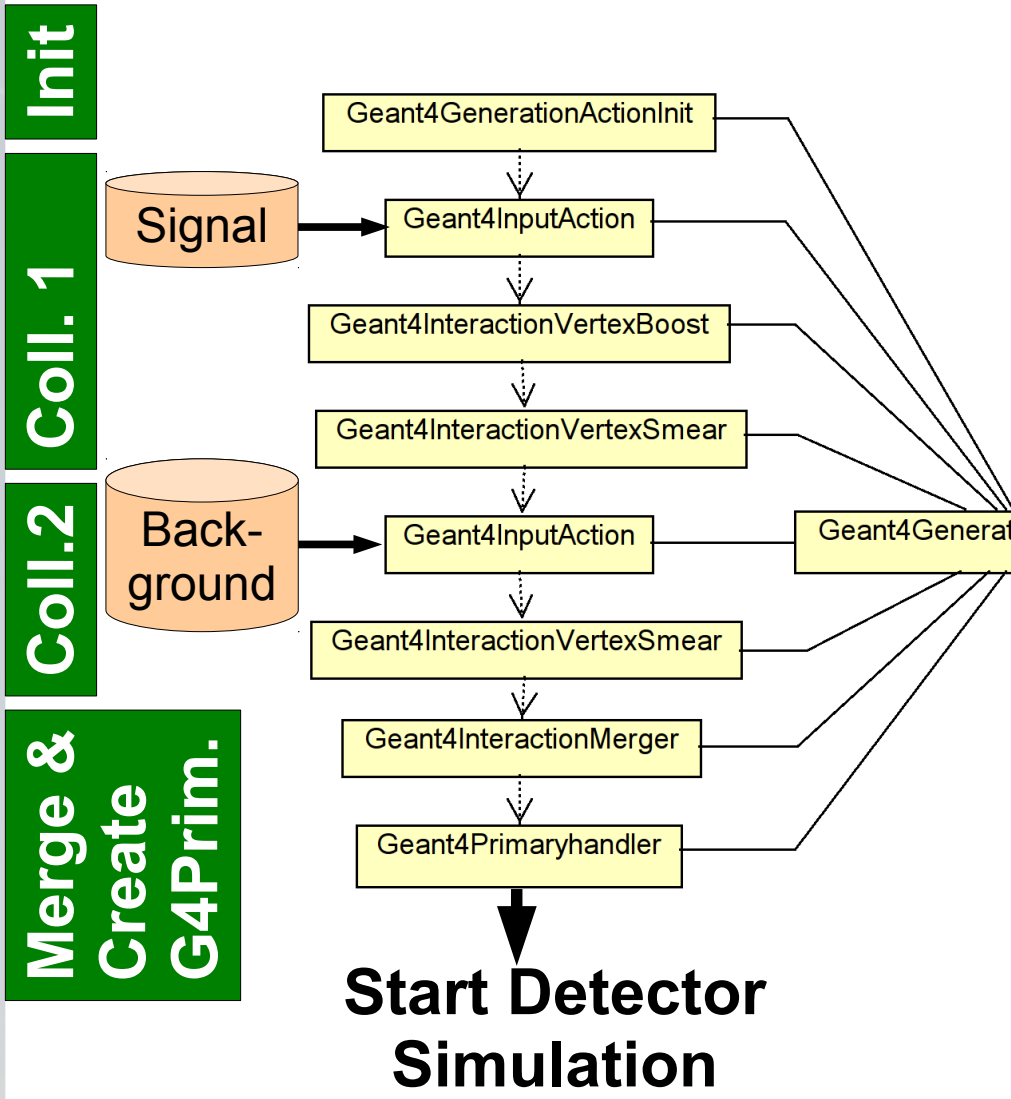
Flexible data input
- Programmable sequence. Input from particle gun, lcio, stdhep or HepMC (text) – easily extensible
- Modules to smear and boost primary vertices
- Modules to construct interaction overlays
- Further extensions may independently added



Provide user programmable sequences
- Either as explicit object type using ABC
- Or registering a member function as callback

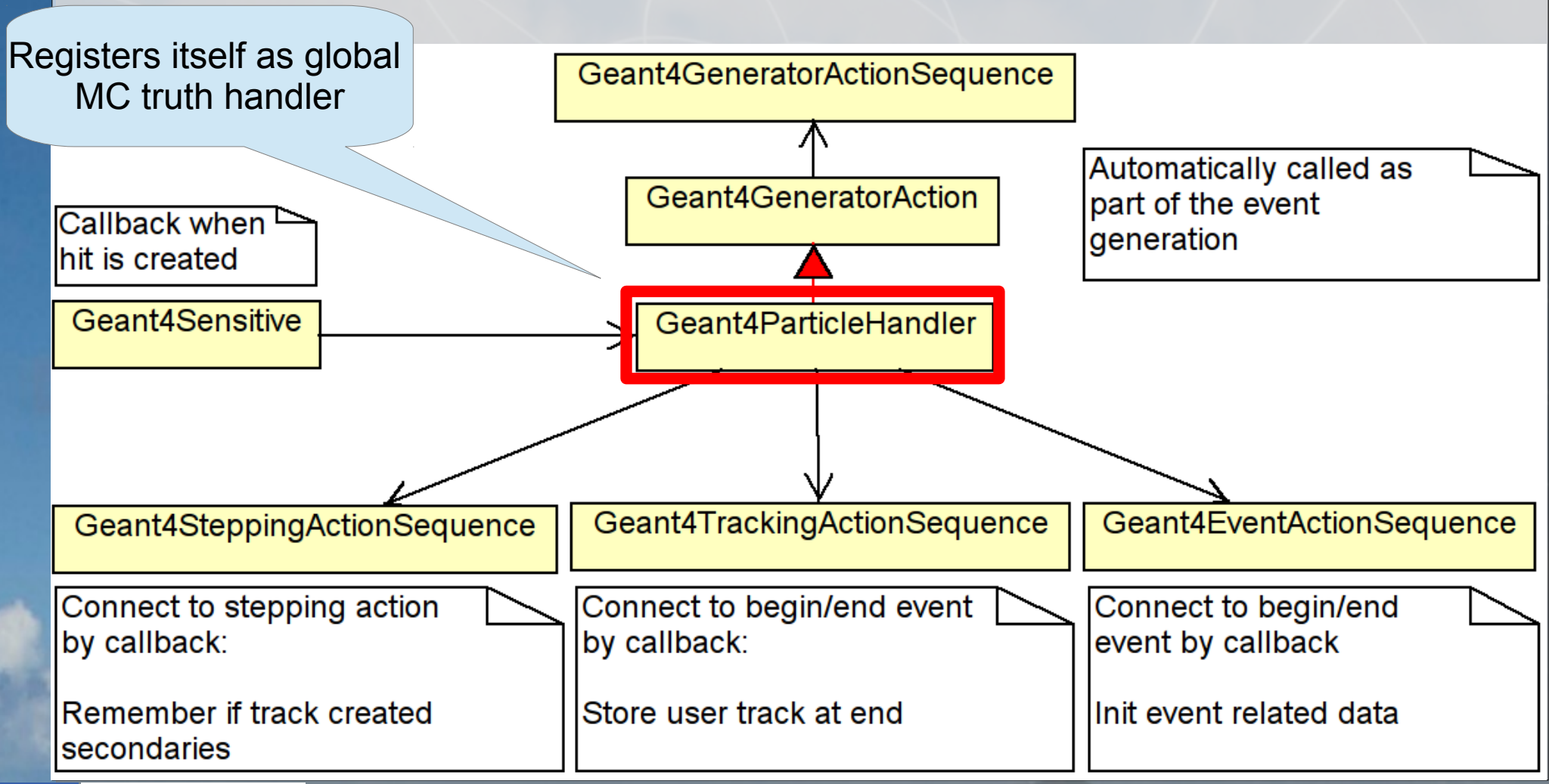


Example of an Action Sequence: Event Overlay with Features



- Combine simple and reusable modules
- Input module
  - Any data format
- Primary vertex smearing
- Primary vertex boost
- Common: initialization, final merge

Another Example: MC Truth Handling



Design Considerations

- **External configuration**

  => requires Plugin mechanism
  => requires Property mechanism to configure plugin instances
  => Allows to naturally support configuration using XML, python or ROOT-AClick

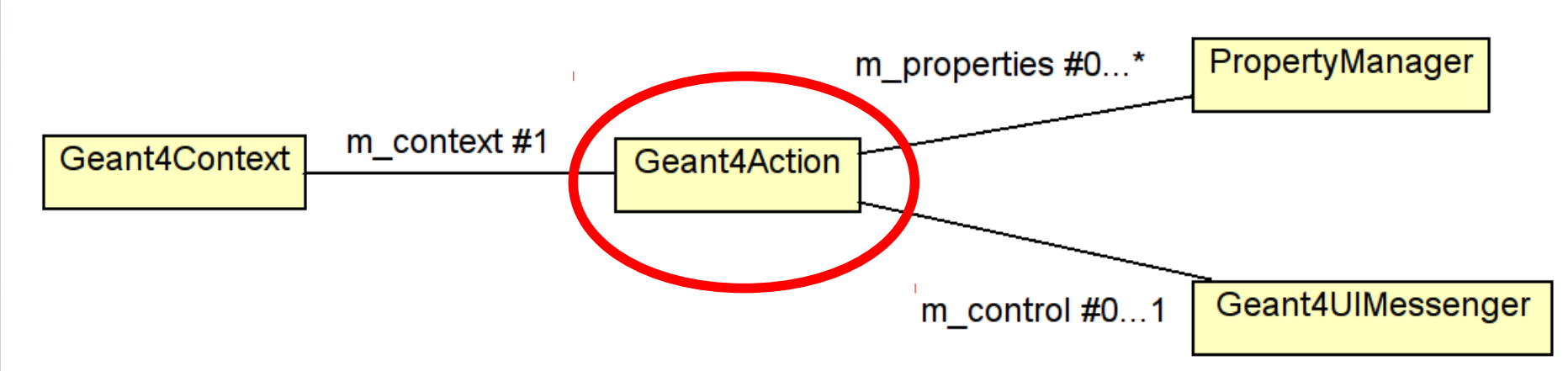
- **Interactivity in Geant4**

  => For all plugins export properties and selected member functions

- **Formalization and external setup of physics**

  => formalize construction of physics lists, physics constructors and particle type constructors in Geant4

Simple Basic Block for all Entities



- **Geant4Context**
  - **Access Geant4 internals and Geometry**
- **PropertyManager**
  - **External configuration [similar to e.g. Gaudi]**
- **Geant4UIMessenger**
  - **Interactivity from the Geant4 prompt**

Construct Specialized Components with Geant4Action as Base Class:

- Configurable physics actions (physics list)
- Configurable action sequences to handle sensitive detectors
- Configurable action sequences to handle
  - Events (e.g. event output) => Event action
  - Tracks => Tracking action
  - Simulation step => Stepping action
  - ...if the user application wants to interact with these
- And of course also provide the modules to populate these sequences!

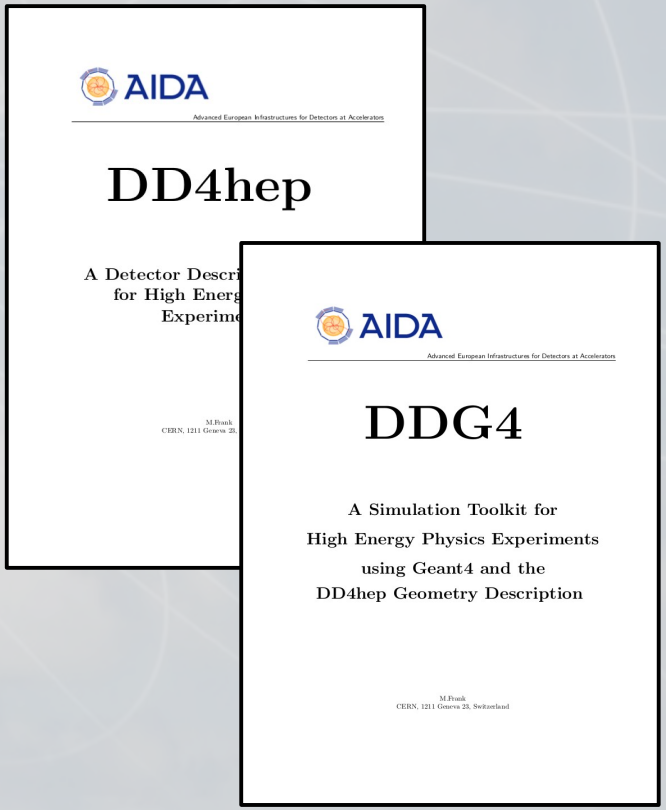
Simulation: Plugin Palettes

- Palette of sensitive detectors
  - Generic sensitive detectors for trackers & calorimeters
  - Adopt generic designs for other detector 'classes'
- Palette of IO handlers
  - Input: lcio, StdHep(lcio), HepEvt (ascii), HepMC(ascii)
  - Output: Root, lcio
- MC truth handling w/o record reduction
- Physics lists, Physics/particle constructors etc.
  - Wrapped factory plugins directly taken from Geant4
  - Users extend physics list (e.g. QGSP)

- **Motivation and Goals**
- **Concepts and Design**
- **Side remarks: Users and extensions**
- **Summary**

Documentation

- http://aidasoft.web.cern.ch/DD4hep
- https://svnsrv.desy.de/basic/aidasoft/DD4hep/trunk
- Doxygen documentation
- In svn trunk/doc:
  - DD4hep manual, ~ 40 pages
  - DDG4 manual, ~40 pages
    First issues, to be completed
  - Living documents



Known Toolkit Users

Users are mandatory for feedback to avoid developments in thin air (i.e. purely academic)

- **ILD:** F. Gaede et al., ported complete Mokka model ILD_o1_v05 (1)
- **CLICdp:** starting new design after CDR (1)
- **FCC-eh:** P. Kostka et al.
- **FCC-hh:** starting, A.Salzburger et al.
- **LHCb:** investigations by technical student

DD4hep	DDG4
X	X
X	X
X	X
X	
X	

(1) See A.Sailer's poster in Session B: "Integration of DD4hep in the Linear Collider Software Framework" Booth 6, Wednesday + Thursday https://indico.cern.ch/event/304944/session/10/contribution/290

To Keep Us Off the Street ...

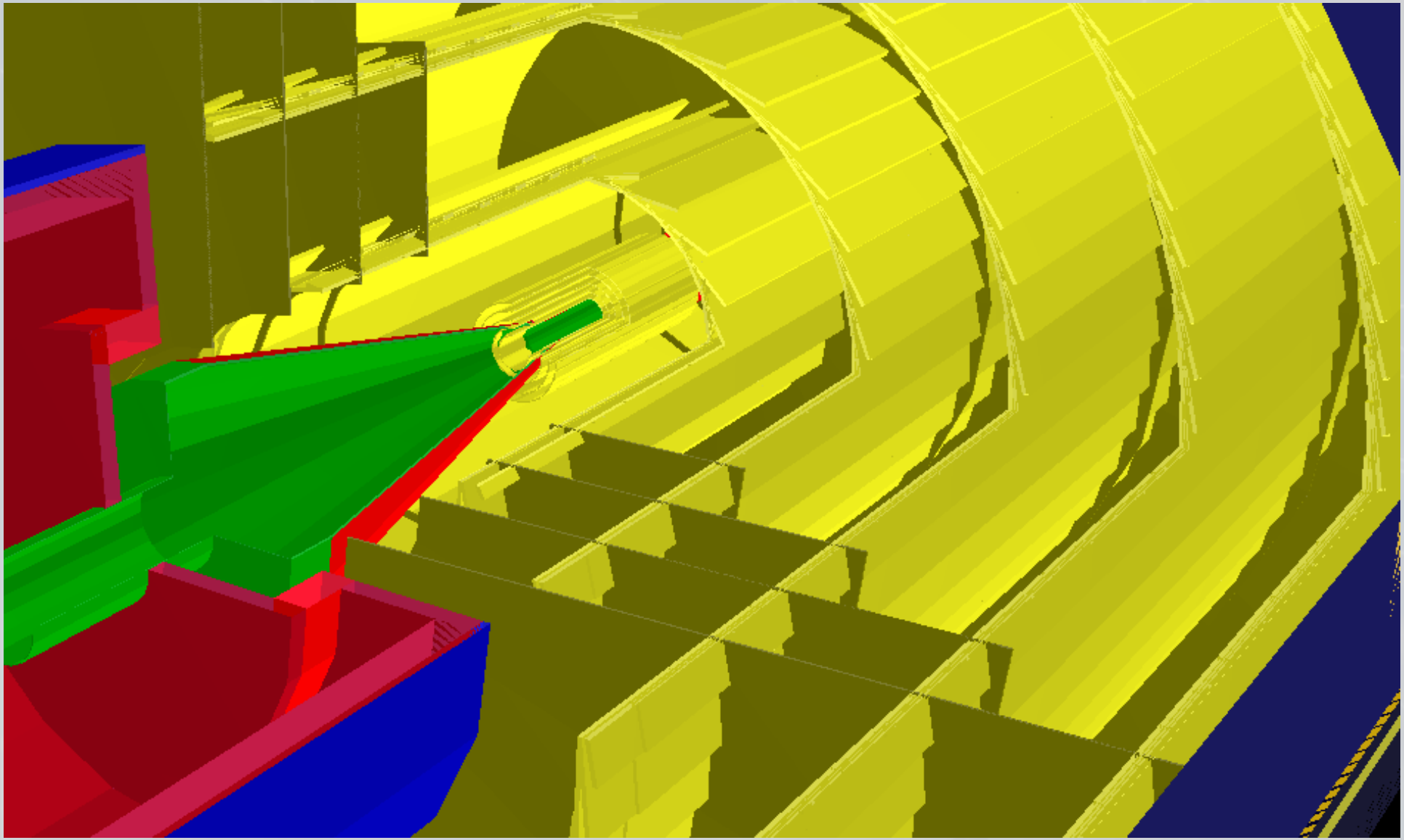
- **Possible improvements of DDG4**
  - **Support for fast and parametrized simulation**
    - **Speed-up by avoiding full Geant4 machinery**
  - **Heterogenous simulation**
    - **Full, fast and parametrized simulation depending on sensitive region**
  - **Take action on demand, hope for external contributions**

- **DDG4 is the 2nd. episode of the DD saga**
  - **DD4hep, DDG4, DDRec,** DDAlign and DDCond (to come)

Summary and Outlook

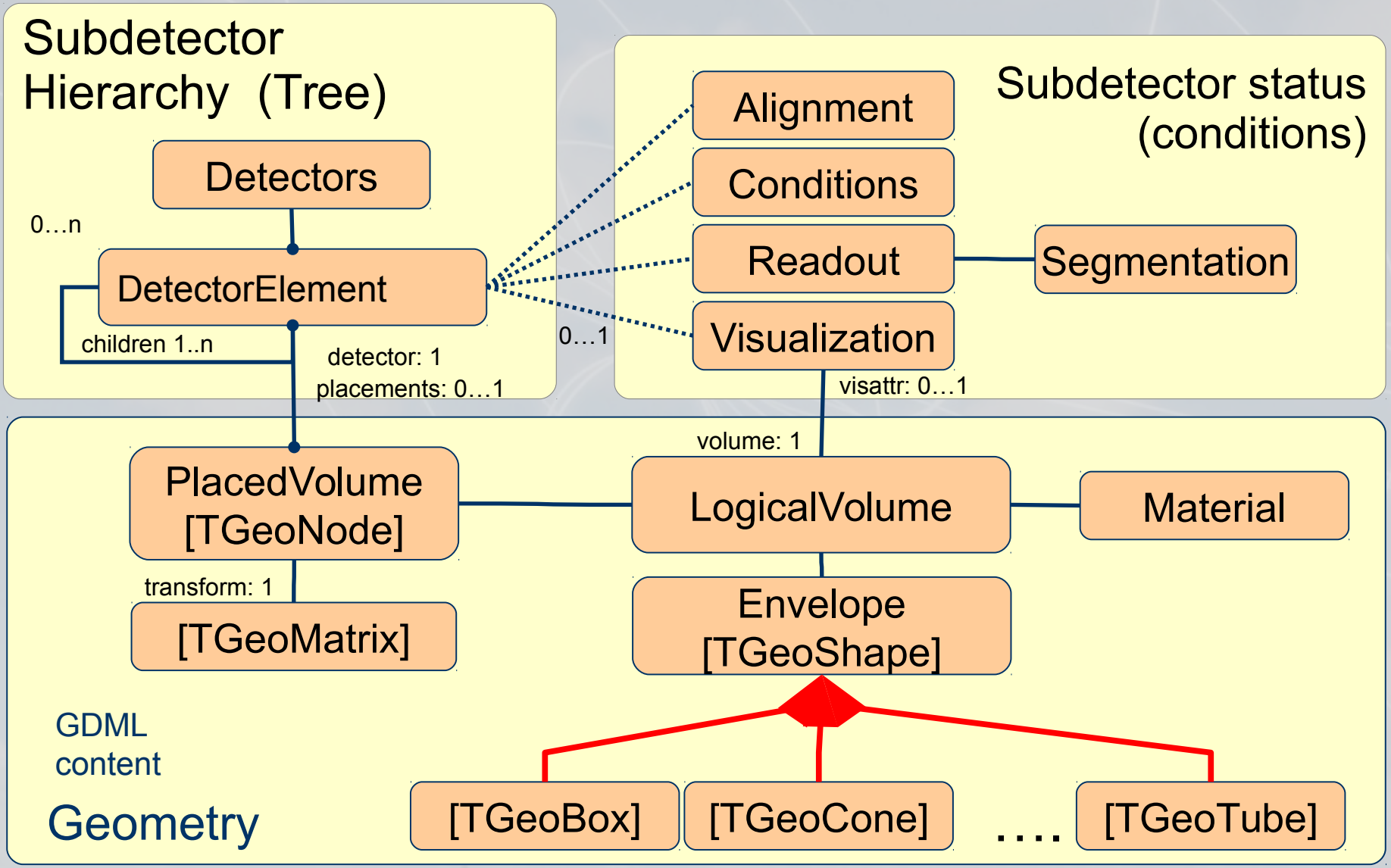
- The DD4hep toolkit (+extensions) is getting accepted:
  => Validation by users has started
- Simulation toolkit DDG4 being validated
  - Toolkit to simulate particle collisions in
    HEP detectors with minimal effort: simple, easy, flexible
  - DDG4 can host user plugins: extensible
- Basic DD4hep detector palette established
  - Hope for further user contributions
  - Hope to offer 'complete' sensitive detector palette
- Hope for contributions to complete the plugin suite to cover all simulation needs (I/O, MC truth, etc)

Questions and Answers



Backup slides

Implementation: Geometry



Geant4 Interactivity

```
Idle> ls /ddg4
Command directory path : /ddg4/


Guidance :
Control for all named Geant4 actions

 Sub-directories :
   /ddg4/RunInit/   Control hierarchy for Geant4 action:RunInit
   /ddg4/RunAction/   Control hierarchy for Geant4 action:RunAction
   /ddg4/EventAction/   Control hierarchy for Geant4 action:EventAction
   /ddg4/LcioOutput/   Control hierarchy for Geant4 action:LcioOutput
```

```
 Sub-directories :
 Commands :
   show * Show all properties of Geant4 component:UserParticleHandler
   Control * Property item of type bool
   MinimalKineticEnergy * Property item of type double
   Name * Property item of type std::string
   OutputLevel * Property item of type int
   TrackingVolume_Rmax * Property item of type double
   TrackingVolume_Zmax * Property item of type double
   name * Property item of type std::string
Idle> /ddg4/UserParticleHandler/TrackingVolume_Rmax
Geant4UIMessenger: +++ UserParticleHandler> Unchanged property value TrackingVolume_Rmax = 1265.
Idle> /ddg4/UserParticleHandler/TrackingVolume_Rmax 1.3*m
Geant4UIMessenger: +++ UserParticleHandler> Setting property value TrackingVolume_Rmax = 1.3*m  native:1300.
Idle> /ddg4/UserParticleHandler/TrackingVolume_Rmax
Geant4UIMessenger: +++ UserParticleHandler> Unchanged property value TrackingVolume_Rmax = 1300.
Idle>
```

Geant4 interactivity interfaced to every action object

- **Enabled on request**

Actions have properties
(similar to Gaudi)

- **Interrogate properties**
- **Modify properies**

Configure DDG4 Application with python

```
kernel = DDG4.Kernel()
lcdd = kernel.lcdd()
kernel.loadGeometry("file:"+install_dir+"/DDDet
kernel.loadXML("file:"+example_dir+"/DDG4_field
DDG4.importConstants(lcdd)
```

```
Generation of isotrope tracks of a given multip
"""
# First particle generator: pi+
gen = DDG4.GeneratorAction(kernel,
          "Geant4IsotropeGenerator/IsotropPi+")
gen.Particle = 'pi+'
gen.Energy = 100 * GeV
gen.Multiplicity = 2
gen.Mask = 1
kernel.generatorAction().adopt(gen)
# Install vertex smearing for this interaction
gen = DDG4.GeneratorAction(kernel,
          "Geant4InteractionVertexSmear/SmearPi-
gen.Mask = 1
gen.Offset = (20*mm, 10*mm, 10*mm, 0*ns)
gen.Sigma = (4*mm, 1*mm, 1*mm, 0*ns)
kernel.generatorAction().adopt(gen)
```

- **Python configuration snippets**
  - **Loading geometry**
  - **Configuring actions**
  - **Steer Geant4 until it's prompt/batch**
- **C++ config ~ same**
- **Alternative: xml Load xml with lcdd**

Configure DDG4 Application from XML

```
<sequences>
  <sequence name="Geant4EventActionSequence/EventAction">
    <properties Control="true"/>
    <action name="Geant4Output2ROOT/RootOutput">
      <properties Control="true" Output="simple.root"/>
    </action>
  </sequence>
  <sequence name="Geant4GeneratorActionSequence/GeneratorAction">
    <action name="Geant4ParticleGun/Gun">
      <properties .... />
    </action>
  </sequence>
  <sequence sd="SiVertexBarrel" type="Geant4SensDetActionSequence">
    <properties Control="true"/>
    <filter name="GeantinoRejector"/>
    <filter name="EnergyDepositMinimumCut"/>
    <action name="Geant4SimpleTrackerAction/SiVertexBarrelHandler">
      <properties Control="true"/>
    </action>
  </sequence>
  ....
</sequences>
```

Geant4 event action setup

Geant4 generator action setup

Sensitive detector setup

Instance type from palette

Instance name for reference

Complete Mokka model ILD_o1_v05 ported

(F.Gaede, L.Shaojun)

- **VXD, FTD, SIT, TPC, SET, beam pipe**
- **Ecal, Hcal, Yoke, Beamcal, Lcal, LHcal**
- two generic SensitiveDetectors