Status of Geometry: DD4Hep

AIDA 1st Annual Meeting, 28-30 March 2012, DESY

Pere Mato / CERN

28/3/2012

Outline

- Geometry Task Goals
- Requirements
- Design Elements
- Prototype
- Deliverable

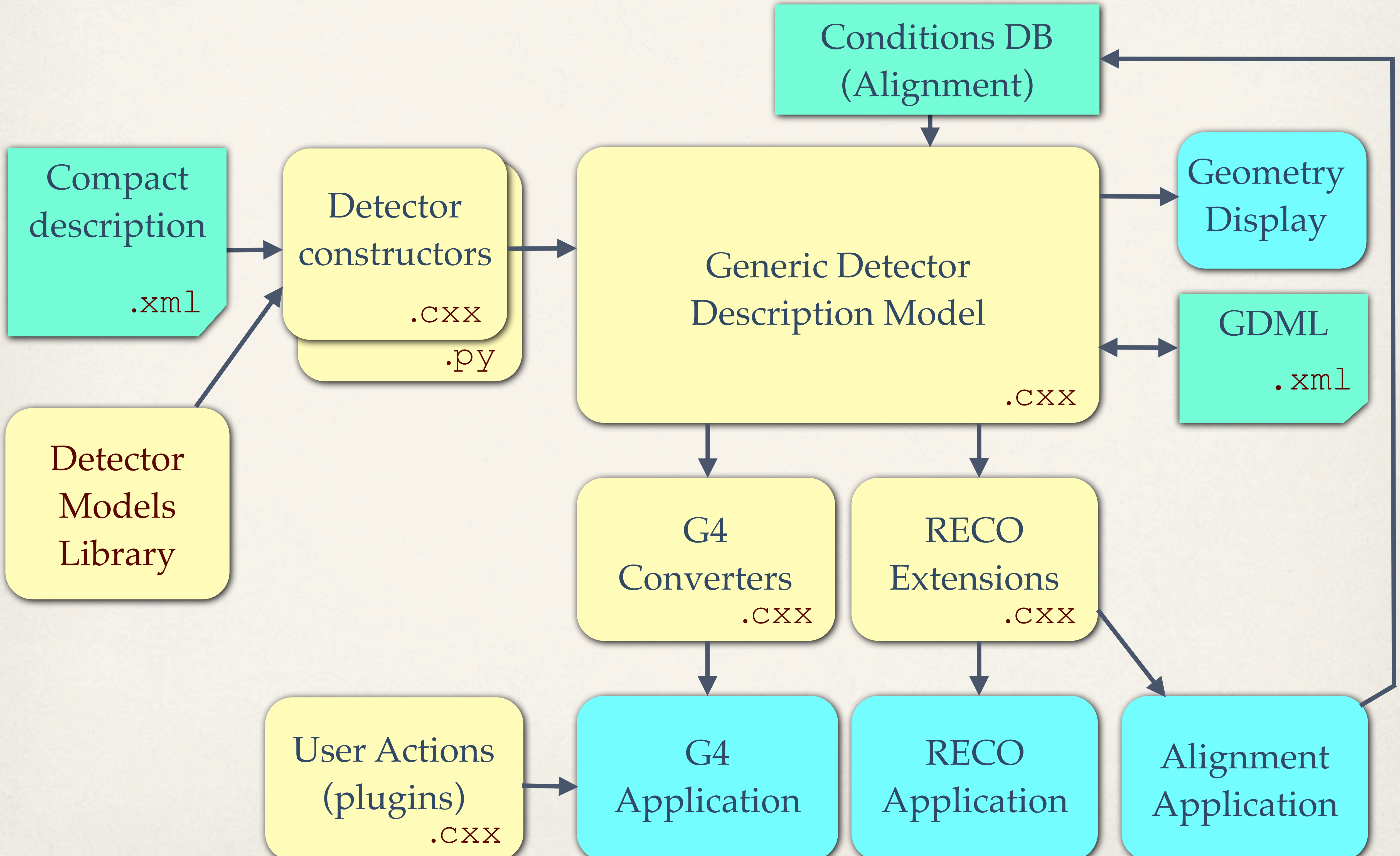
AIDA-WP2 Geometry Tasks

- Geometry Toolkit
  - Set of software tools which can describe the geometry of the detector, the material it is made from and different ways of detecting particles
  - High/Low level descriptions, primitives library, interchange formats, API for reconstruction, simulation, alignment support, etc.
  - Repository of generic detectors types
- Started the development of a prototype (DD4Hep)
  - Useful to clarify required functionality
  - Evaluation of design choices

Toolkit Main Requirements

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

Current Ideas: The Big Picture



Compact Description

- Reusing the idea of "compact detector description" from SiD software
- Human readable and compact geometry description in XML format
- Used as the main input to the detector description system
- Extendable with new generic detector types together with very specific ones

```
<detector name="VXD" type="ILDExVXD"
          vis="VXDVis" id="1">

  <layer id="1" vis="VXDLayerVis">
    <support thickness="0.01*mm"
             material="Carbon"
             vis="VXDSupportVis"/>
    <ladder  zhalf="65*mm"
             radius="16*mm" offset="-2*mm"
             thickness="0.01*mm"
             material="Silicon" number="10"/>
  </layer>

  <layer id="2"  vis="VXDLayerVis">
    <support thickness="0.01*mm"
             material="Carbon"
             vis="VXDSupportVis"/>
    <ladder  zhalf="65*mm" radius="18*mm"
             offset="-2*mm"
             thickness="0.01*mm"
             material="Silicon" number="10"/>
  </layer>

  ...

</detector>
```

Detector Constructors

- A set of code fragments that are able to convert the XML elements into detector description (DD) objects
  - Objects: Material, Element, VisAttributes, Limits, etc.
  - Generic Detectors: SiTrackerBarrel, CylindricalEndcapCalo, etc.
  - Specific Detectors: ILDTPC, etc.
- Prototyped two possible implementations
  - C++ functions (XercesC)
  - Python functions (PyROOT)

```
<element Z="29" formula="Cu" name="Cu" >
   <atom type="A" unit="g/mol" value="63.5456" />
</element>
```

```
def process_element(lcdd, elem):
  doc = lcdd.document()
  tab = doc.GetElementTable()
  element = tab.FindElement(elem.get('name'))
  if not element:
    atom = elem.find('atom')
    tab.AddElement(atom.get('name'),atom.get('formula'),
                   atom.getI('Z'), atom.getI('value'))
```

```
template <> Ref_t toRefObject<Atom,xml_h>(lcdd_t& lcdd, const
xml_h& e)  {
  xml_ref_t    elem(e);
  TGeoManager* mgr      = lcdd.document();
  XML::Tag_t   eltname  = elem.name();
  TGeoElementTable* tab = mgr->GetElementTable();
  TGeoElement*  element = tab->FindElement(eltname.c_str());
  if ( !element )  {
    xml_ref_t atom(elem.child(_X(atom)));
    tab->AddElement(elem.attr<string>(_A(name)).c_str(),
                    elem.attr<string>(_A(formula)).c_str(),
                    elem.attr<int>(_A(Z)),
                    atom.attr<int>(_A(value))
                    );
    element = tab->FindElement(eltname.c_str());
  }
  return Handle_t(element);
}
```

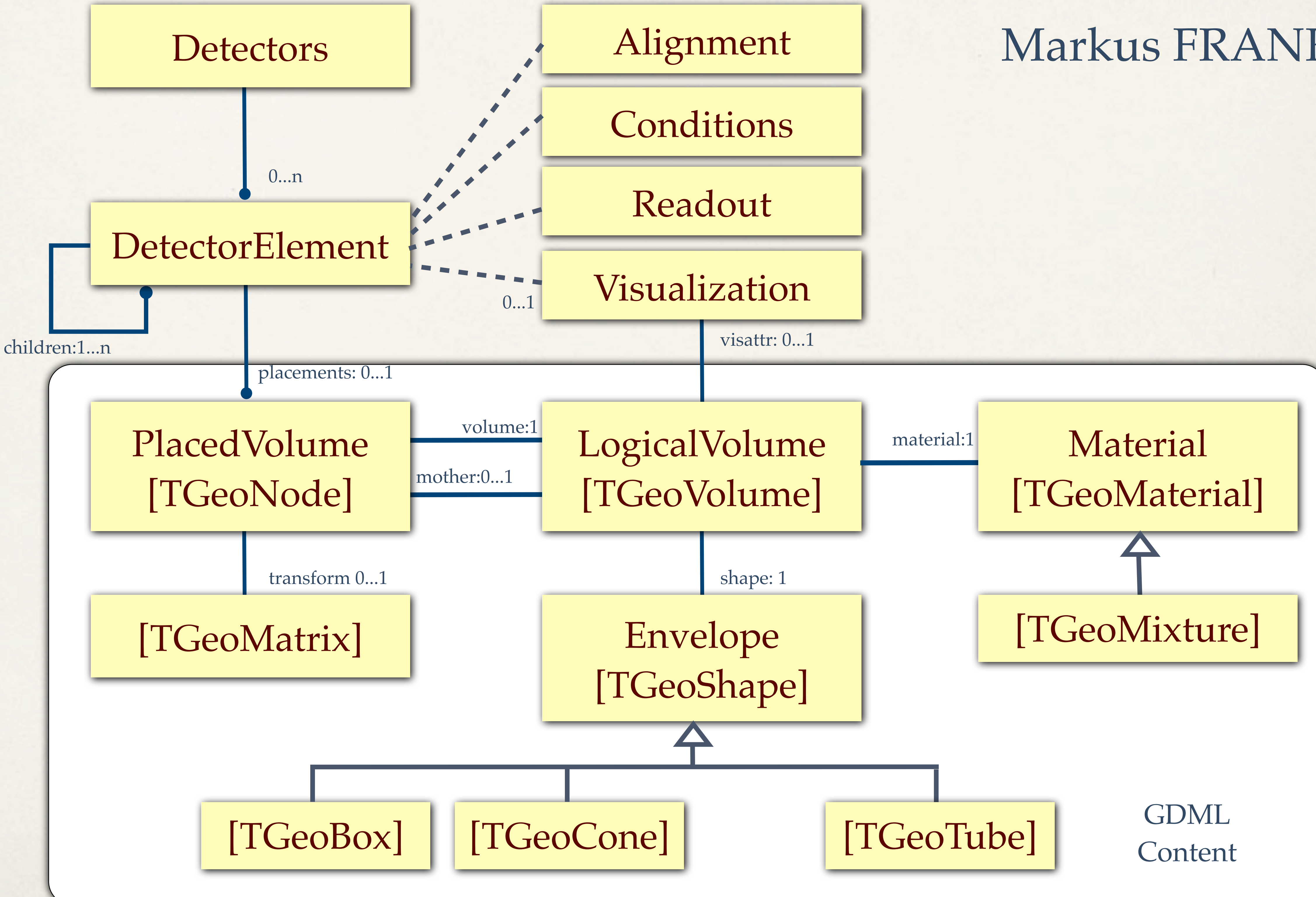
```
def detector_ILDExVXD(lcdd, det):

  vdx = DetElement(lcdd, det.name, det.type, det.id)
  mother = lcdd.worldVolume()

  for layer in det.findall('layer'):
    support = layer.find('support')
    ladder  = layer.find('ladder')
    layername = det.name + '_layer%d' % layer.id
    nLadders = ladder.getI('number')
    dphi    = 2.*pi/nLadders
    sens_thick  = ladder.thickness
    supp_thick  = support.thickness
    supp_radius = ladder.radius + sens_thick/2. + supp_thick/2.
    width       = 2.*tan(dphi/2.)*(ladder.radius-sens_thick/2.)

    ladderbox = Box(lcdd, layername+'_ladder_box',  (sens_thick+supp_thick)/2., width/2., ladder.zhalf)
    laddervol = Volume(lcdd, layername+'_ladder', ladderbox, lcdd.material('Air'))

    sensbox   = Box(lcdd, layername+'_sens_box', sens_thick/2., width/2., ladder.zhalf)
    sensvol   = Volume(lcdd, layername+'_sens', sensbox, lcdd.material(ladder.material))
    sensvol.setVisAttributes(lcdd.visAttributes(layer.vis))
    laddervol.placeVolume(sensvol, Position(-(sens_thick+supp_thick)/2.+sens_thick/2.,0,0))

    suppbox   = Box(lcdd, layername+'_supp_box', supp_thick/2.,width/2.,ladder.zhalf)
    suppvol   = Volume(lcdd,layername+'_supp', suppbox, lcdd.material(support.material))
    suppvol.setVisAttributes(lcdd.visAttributes(support.vis))
    laddervol.placeVolume(suppvol, Position(-(sens_thick+supp_thick)/2.+sens_thick/2.+supp_thick/2.,0,0))

    for j in range(nLadders):
      laddername = layername + '_ladder%d' % j
      radius = ladder.radius + ((sens_thick+supp_thick)/2. - sens_thick/2.)
      rot = Rotation(0,0,j*dphi)
      pos = Position(radius*cos(j*dphi) - ladder.offset*sin(j*dphi),
                     radius*sin(j*dphi) - ladder.offset*cos(j*dphi),0.)
      mother.placeVolume(laddervol, pos, rot)

  return vdx
```

Detector Description Prototype

- Developed by Markus Frank
- C++ model separation of 'data' and 'behavior'
  - Classes consist of a only single 'reference' to the data object
  - Practical advantages concerning compile/link dependencies
  - Same 'data' can be associated to different 'behaviors'
- Implementation based on TGeo (ROOT)
  - TGeom classes directly accessible (no hiding)
  - Support for alignment

Detector Description Model

Markus FRANK



Reconstruction Extensions

- The idea is to 'extend' the DetectorElement class with specific reconstruction code
  - Be able to answer detector questions asked by the reconstruction algorithms. E.g.:
    - transform ECAL 'cell id' to local [global] coordinates
    - amount of material to next layer
- These extensions can be added as 'plug-ins'

```
struct GearTPC : public Geometry::Subdetector {
  typedef TPCData Object;
  GearTPC(const Geometry::RefHandle<TNamed>& e);

  GlobalPadIndex  getNearestPad (double c0, double c1) const;
  double getDriftVelocity () const;
  double getReadoutFrequency () const;
  double getInnerRadius() const;
  double getOuterRadius() const;
};
```

```
double GearTPC::innerRadius() const {
  Subdetector gas    = data<Object>()->gas;
  Tube        tube   = gas.volume().solid();
  return tube->GetRmin();
}
double GearTPC::outerRadius() const {
  Subdetector gas    = data<Object>()->gas;
  Tube        tube   = gas.volume().solid();
  return tube->GetRmax();
}
```

Generic Geant4 Converters

- The Geant4 detector geometry can be created from the DD model
  - Conversion of TGeom to G4Geometry (currently using VGM)
  - Similarly the way it is done with SLIC (without having to generate an intermediate GDML file since we convert C++ objects to C++ objects)
- This will be facilitated by the USolids library to obtain the exact same behavior
- Plug-ins for User Actions and Sensitive Detectors are foreseen

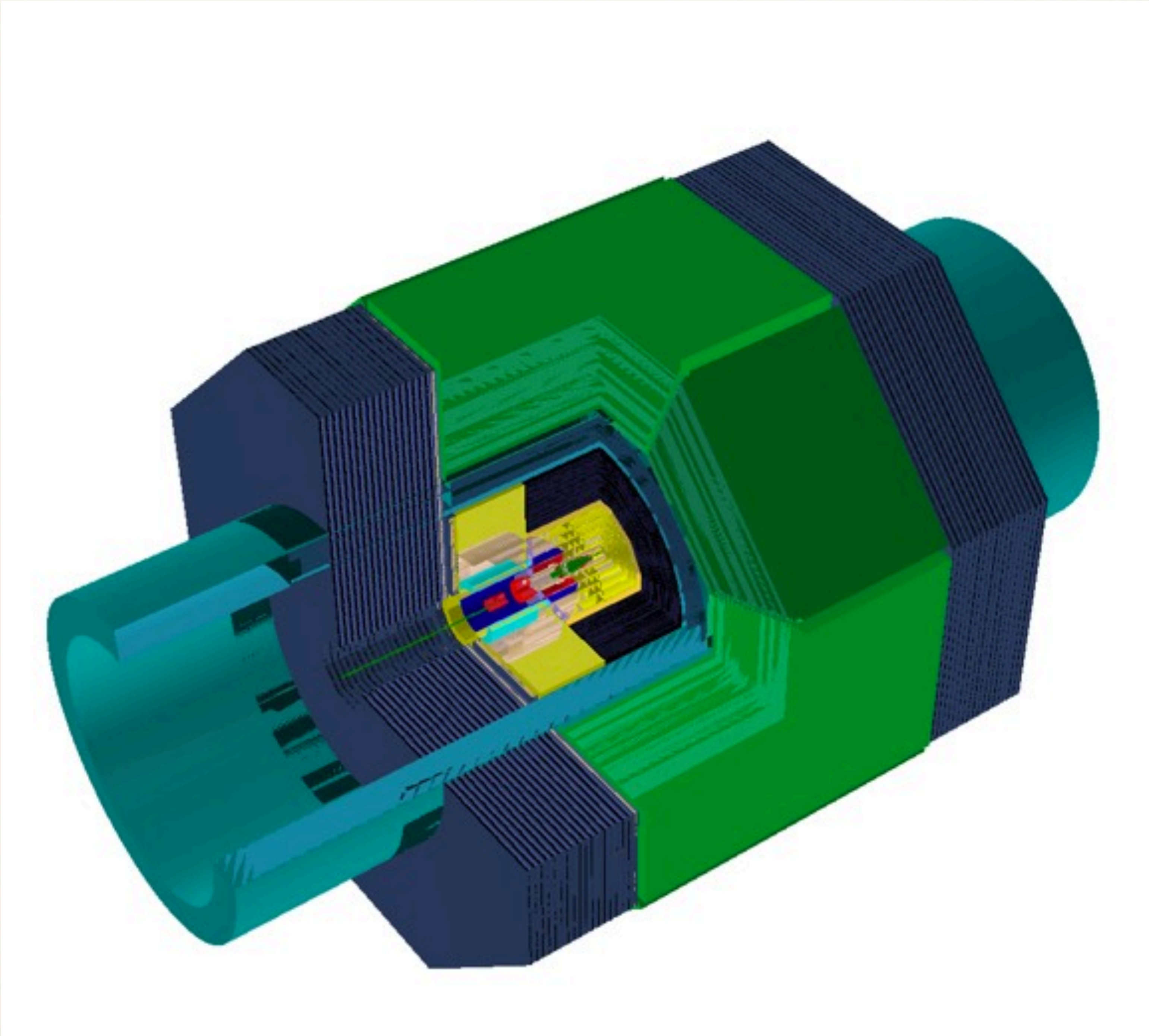
Application Code

- The entry point to the Generic DD model is an 'singleton' (e.g. LCDD)
  - Access the detector by its name (e.g. TPC)
  - Associate it to a given 'behavior' (e.g GearTPC)
  - Start using it
  - Draw it!

```
#include "LCDD.h"
#include "GearTPC.h"

int main(int argc,char** argv)  {

  LCDD& lcdd = LCDD::getInstance();

  lcdd.fromCompact(argv[1]);

  GearTPC tpc = lcdd.detector("TPC");

  cout << "Gear: Inner:" <<
           tpc.getInnerRadius() << endl;
  cout << "       Outer:" <<
           tpc.outerRadius() << endl;

  return 0;
}
```

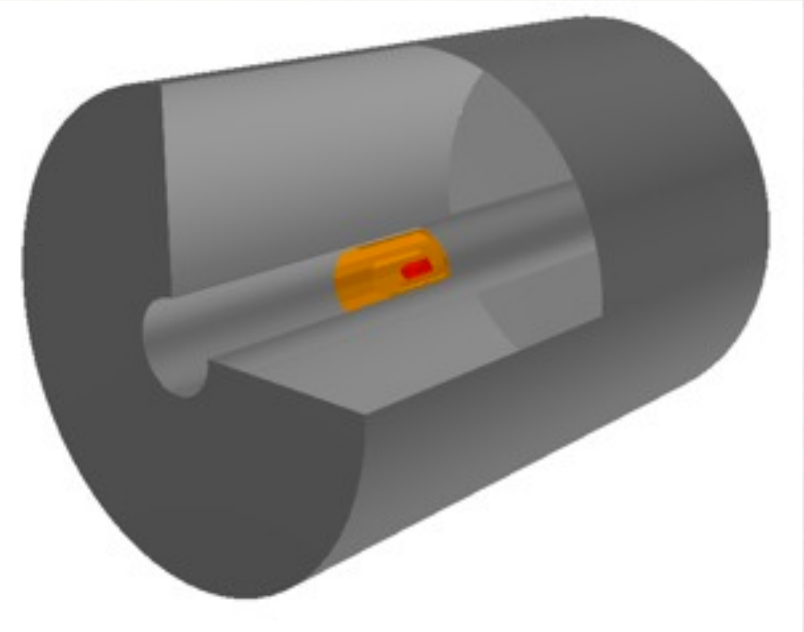
Detector Display

- Detector Display applications can be developed using native ROOT functionality (OpenGL, Eve, etc.)



Display of the DD model produced from the SiD compact description (M. Frank)

DD4Hep Prototype



- Started to implement a simple prototype consisting of a simplified structure for the ILD central tracking detectors:
  VXD, SIT, TPC (Steven Aplin)
  - Simulation program based on Geant4 example N03
- Implemented initial implementations for described components
  - Examples for simulation, reconstruction programs, display
- http://aidasoft.web.cern.ch/DD4Hep
- http://svnsrv.desy.de/viewvc/aidasoft/DD4hep/

Delivery Status

- D2.3 - Software design for geometry toolkit including the interfaces for the reconstruction toolkits
- Delayed 2 months:
  - We have made quite a lot of progress in the last two months producing a prototype to exercise some of the key design ideas (see https://aidasoft.web.cern.ch/DD4Hep)
  - We wanted to perform some cross-checks in particular in the area of the interfaces (or gateways) to the simulation and reconstruction applications before finalizing the design and producing the design document.
  - This has basically been done and now we are ready to produce the deliverable

Summary

- Started to develop a prototype to test some of the design ideas
  - Code exists in the repository
  - People are encourage to give feedback
- Usability of the prototype is currently being tested by A. Münnich by trying to add new detector types (TPC end-caps, modules and pad planes)
- Started to write the design document for D2.3 deliverable
  - Will not be very different than this few slides
  - Including the USolids part