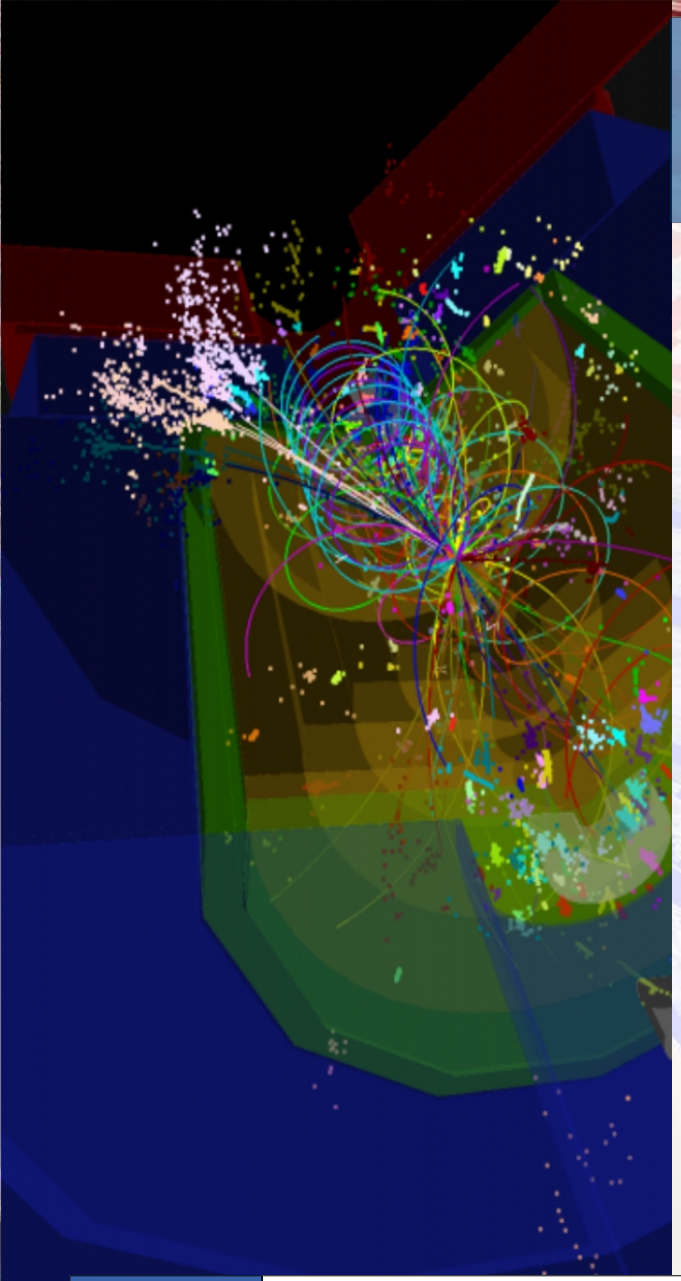

DD4hep

Notes about Experience of DD4hep in CMS and LHCb

- Core
- Simulation
- Conditions
- Alignments

M.Frank

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement no. 654168.

AIDA 2020

Motivation and Goal

DD4hep

- **Develop a detector description**
  - **For the full experiment life cycle**
    - **detector concept development, optimization**
    - **detector construction and operation**
    - **“Anticipate the unforeseen”**
  - **Consistent description, single source, supporting**
    - **simulation, reconstruction, analysis**
  - **Full description, including**
    - **Geometry, readout, alignment, calibration etc.**

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AIDA 2020

Philosophy of DD4hep & Co

DD4hep

- DD4hep is the “glue”
  - Bring together what belongs together:

    Detector structure, geometry, simulation, conditions, etc
  - Reuse existing modules: TGeo, Geant4, Assimp, etc
  - CAD support

Main Entities (1)

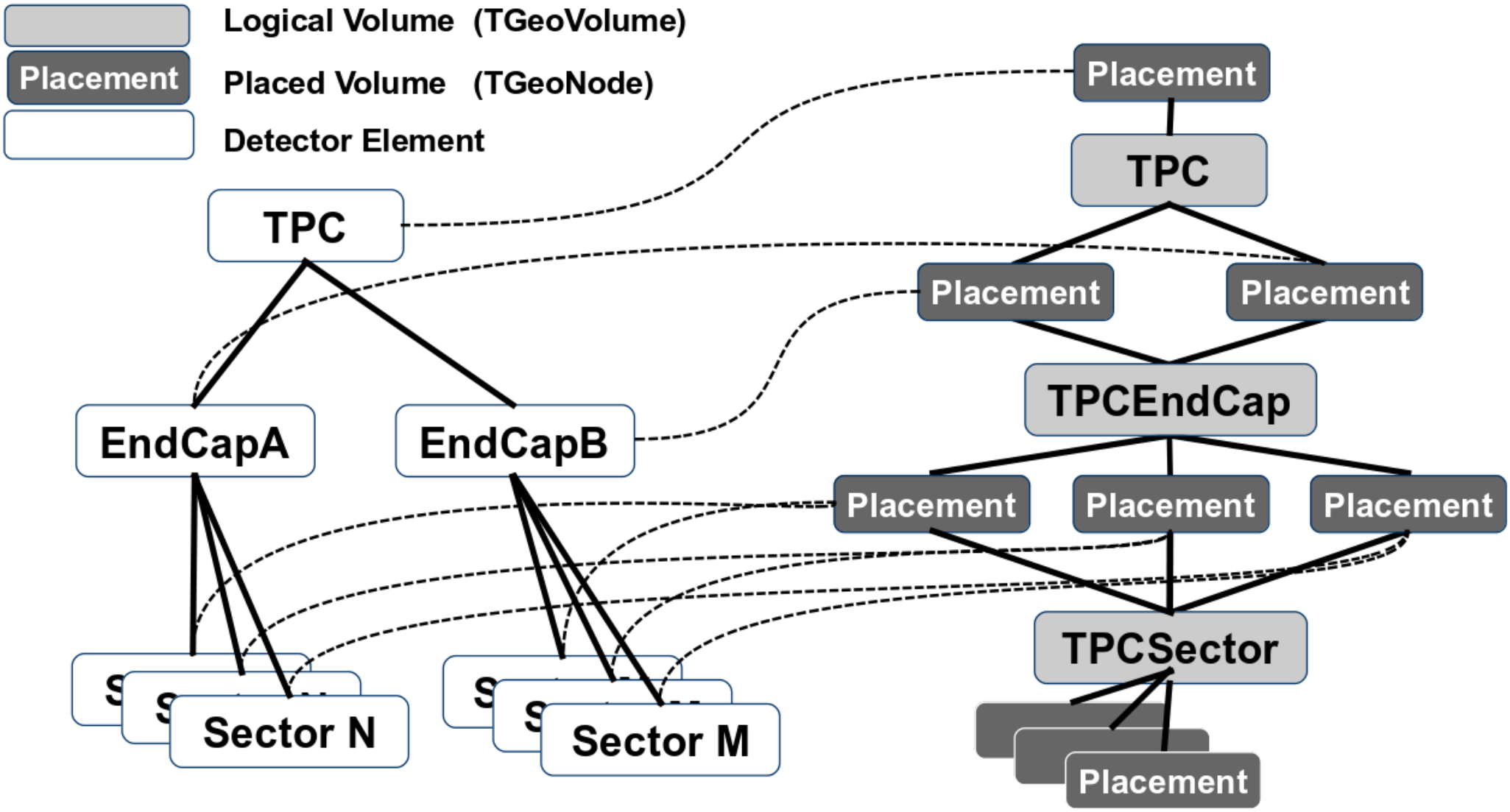
Detector description is not only geometry!

DD4hep

- **Geometrical hierarchy**
  - **Volume:** Shape + material
  - **PlacedVolume** Volume + placement matrix → mother
- **Structural hierarchy**
  - **Detector** Experiment
  - **DetElement** Parts of the experiment
- **Simulation**
  - **Geometry translation**
  - **Full simulation program with sensitive detectors etc.**
- **Conditions**

Structural and Geometrical Hierarchy

DD4hep



Main Entities (2)

Detector description is not only geometry!

DD4hep

- Geometrical hierarchy
- Structural hierarchy
- Simulation
- Conditions
  - Static conditions (measurements)
  - Derived conditions
  - Alignments
  - DetectorElements (not by DD4hep)

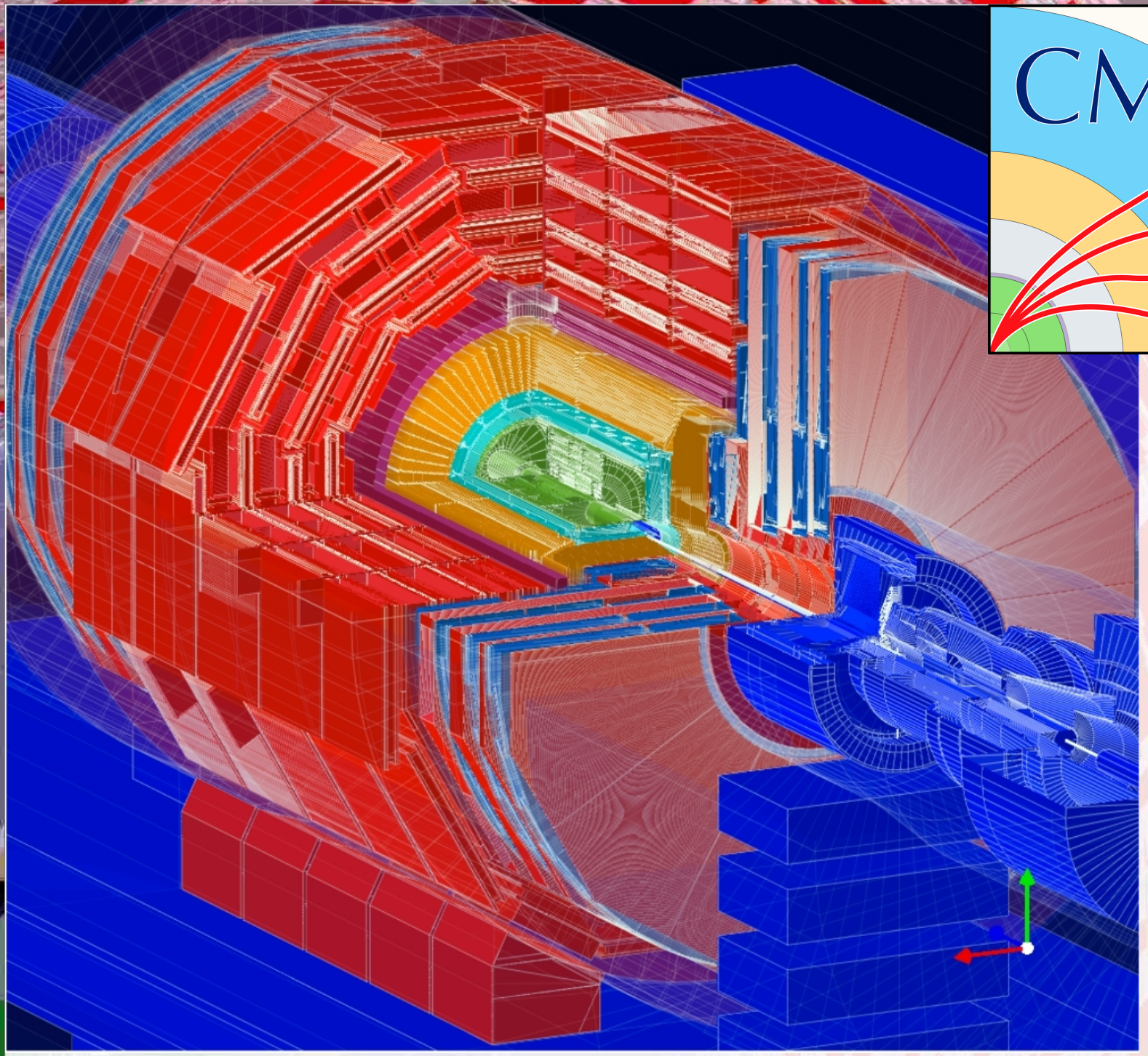
Main Entities (3)

Detector description is not only geometry!

DD4hep

- **Geometrical hierarchy**
- **Structural hierarchy**
- **Simulation**
- **Conditions**

Take your pick !



CMS described with DD4hep

DD4hep baseline for Run3

CHEP 2019, Adelaide, AU

(C.Vuosalo / CMS)

CMS Picks

DD4hep

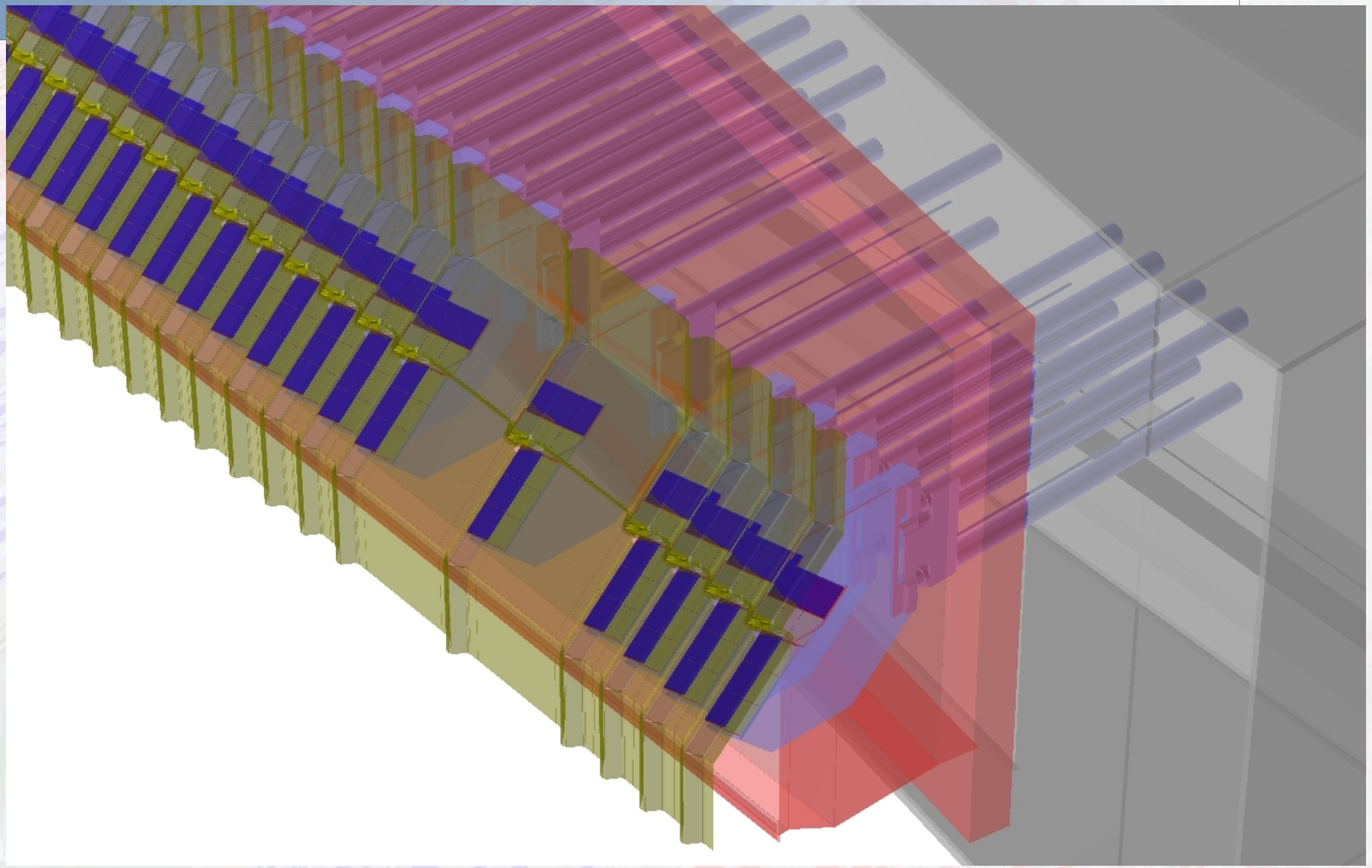
- Geometrical hierarchy
  - Volume: Shape + material
  - PlacedVolume Volume + placement matrix → mother
- Structural hierarchy
  - Detector Experiment
  - DetElement Only 1 single top element (world)
- Simulation
  - Geometry translation
    (Existing simulation program was present)

CMS Status

DD4hep

- Started to participate in 2017
- Declared DD4hep as baseline for Run3 at CHEP 2019
  - Since January 2022 DD4hep is used for Run3 production and reconstruction
  - Migration of Run4 development to DD4hep nearing completion, should be done by 2023
- Fruitful discussions, both sides adapting

LHCb



LHCb Picks: Nearly Everything

DD4hep

- Geometrical hierarchy
  - Volume: Shape + material
  - PlacedVolume Volume + placement matrix → mother
- Structural hierarchy
  - Detector Experiment
  - DetElement Parts of the experiment
- Simulation
  - Geometry translation (Existing simulation program)
- Conditions
  - Static conditions (measurements)
  - Derived conditions
  - Alignments

Conditions Data

DD4hep

- Provide access to a consistent set of fixed values according to a given time (measurements)
- Derived conditions as a result of computation(s)
  - Measurement conditions applied to functional object(s)
  - Example: Alignments
  - Computation/dependency resolution provided by DD4hep
  - Functional callbacks provided by LHCb
- LHCb detector elements:
  - Derived conditions at highest level
  - All data relevant to one subdetector to process collision(s)
  - Experiment and subdetector specific developments

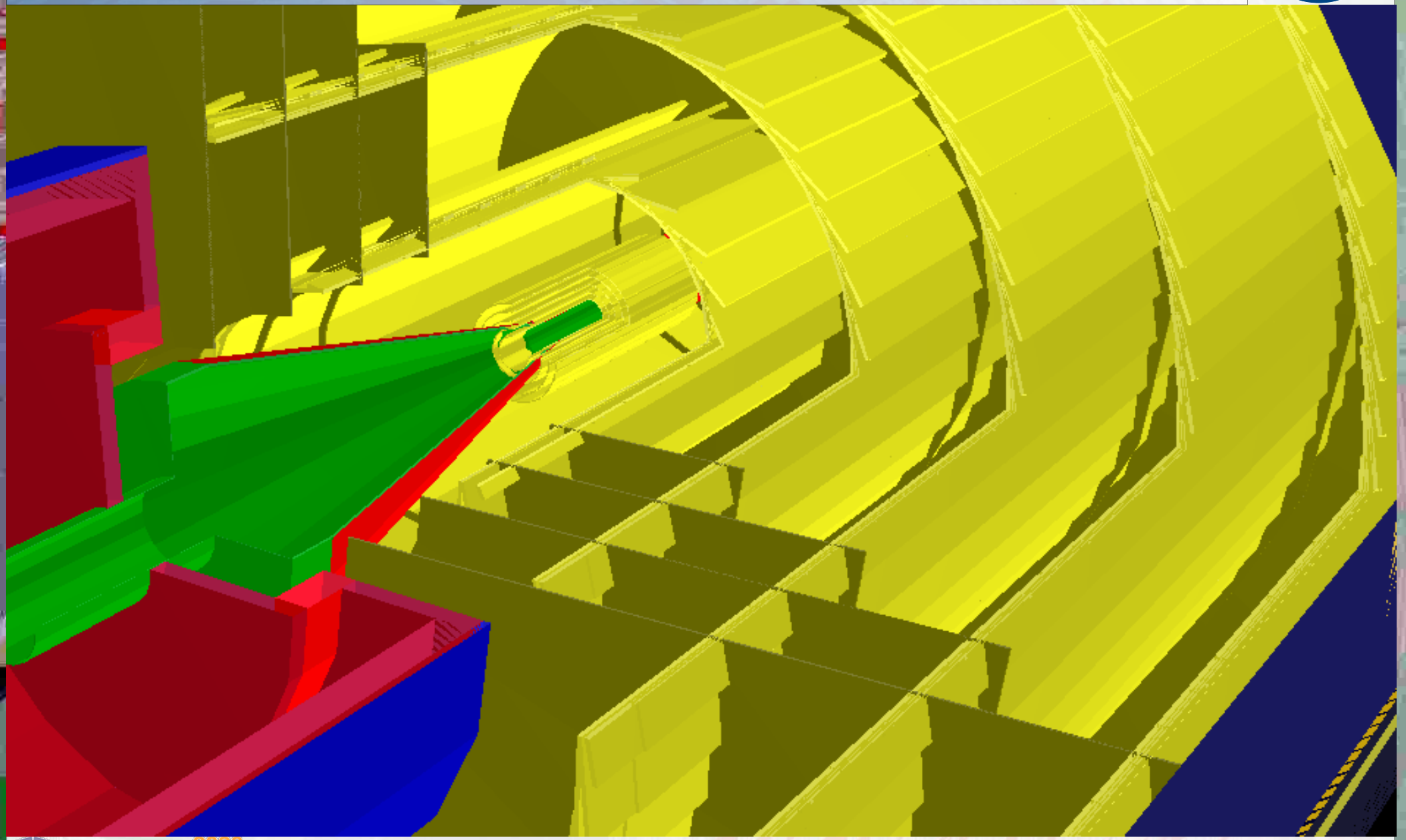
LHCb Status

DD4hep

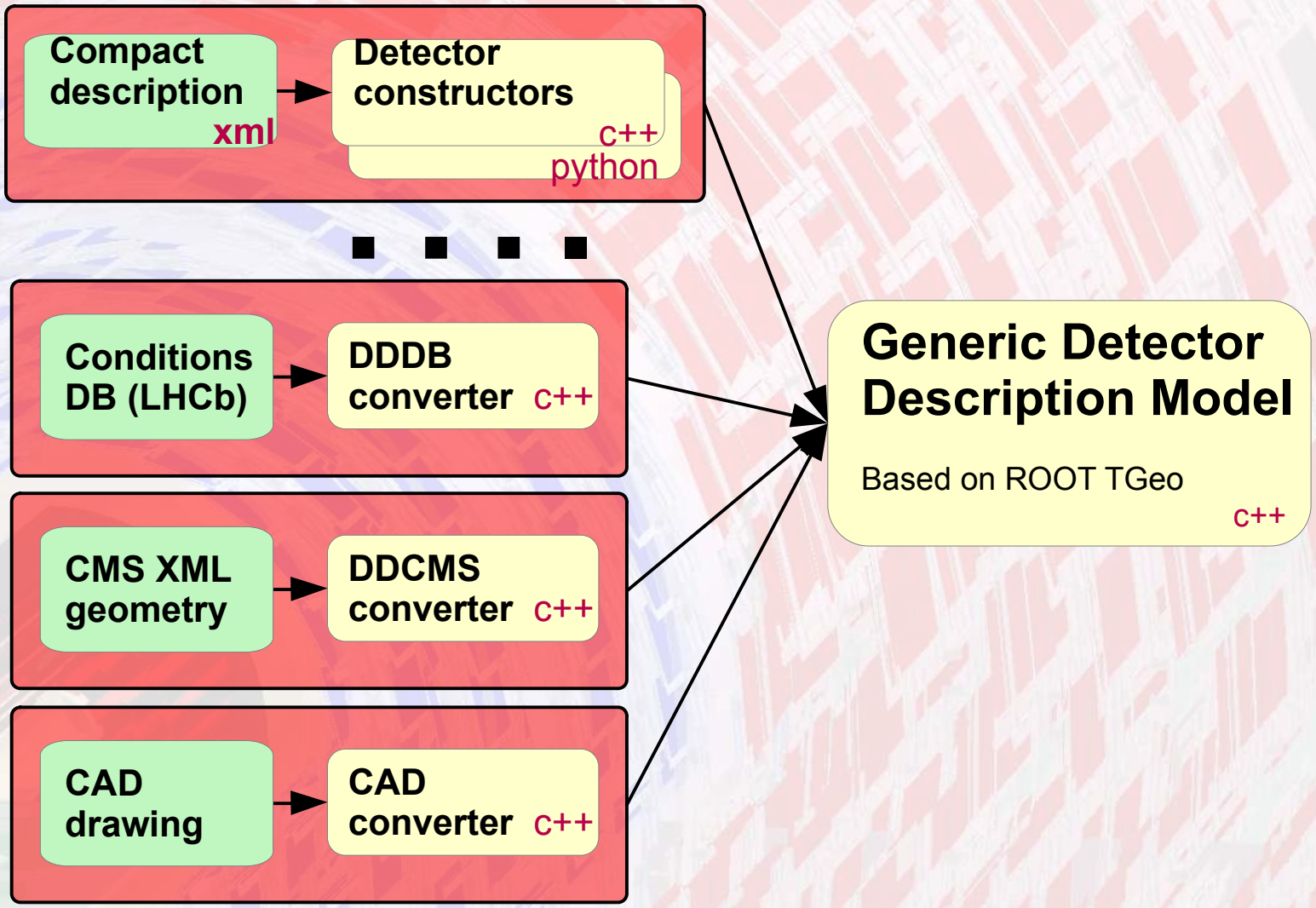
- Framework present since ~ CHEP 2019
- Geometry and structural hierarchy mostly finished for all subdetectors
- Simulation can adapt as subdetectors have finished the geometry/structure description
- Usage/implementation of conditions and detector elements vary between subdetectors
  - Some subdetectors close to completion
  - Some subdetectors at a very early stage
- High pressure at all ends (hardware and software)
  - 2022 will be a commissioning year
  - Living in interesting times

Questions and Answers

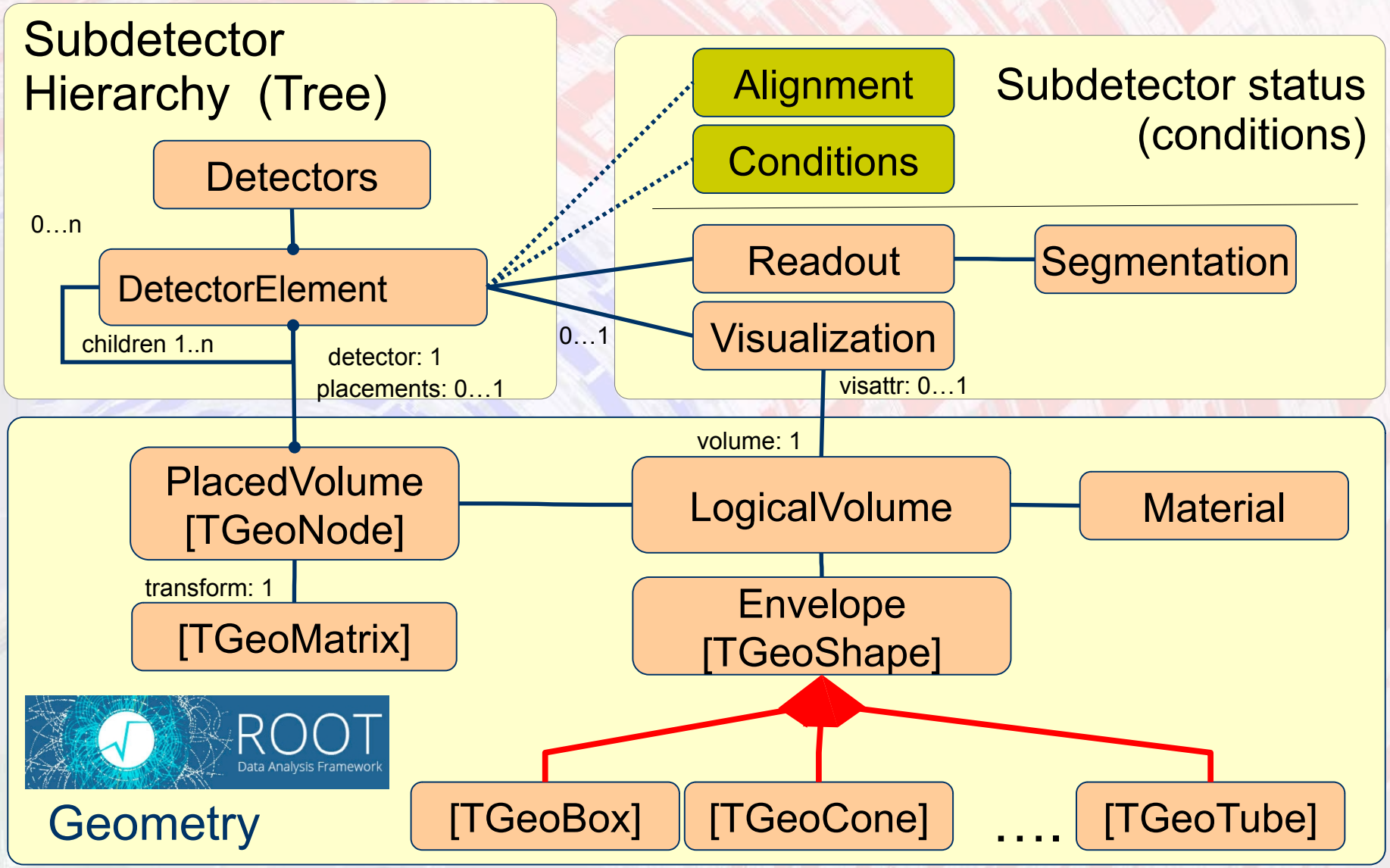
DD4hep



Multiple Input Sources



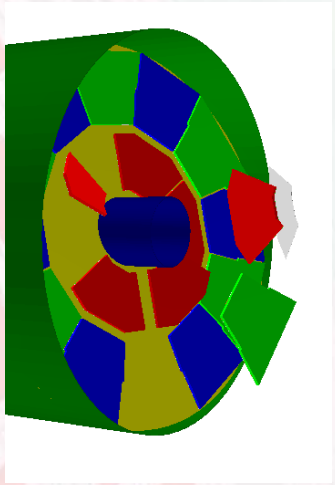
Class Diagram: Detector Element
Sort of Standard...



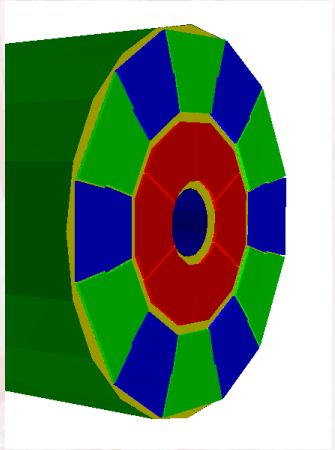
Alignments

DD4hep

- Global alignment corrections
  - Physically alters geometry
    Intrinsically supported by ROOT
  - By construction not multi-threaded
  - Possibility to simulate misaligned geometries

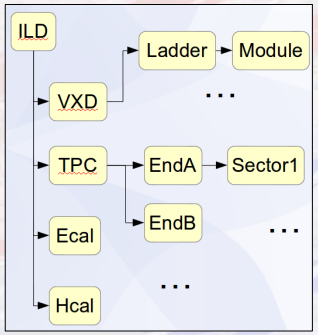


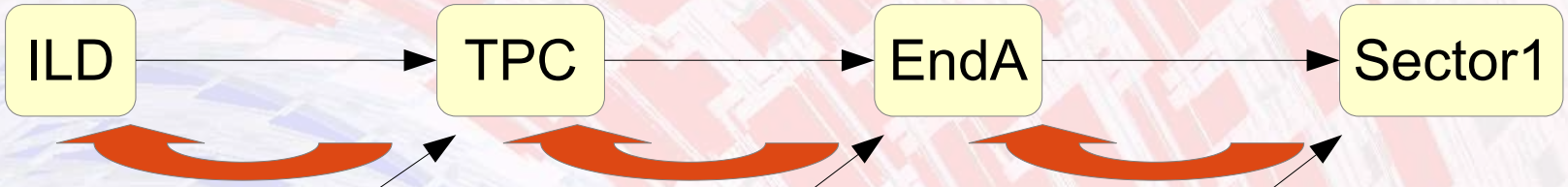
- Local alignment corrections
  - Geometry stays intact (either ideal or globally aligned)
  - Multi-threading supported, multiple versions
  - Local alignment corrections are conditions
  - Provide matrices from ideal geometry to world
    e.g. to adjust hit positions



- Both supported (global with caveat)

Local Alignment Δ - Parameters





$$Tr^{World}_{Sec\,1} = Tr^{World}_{EndA} \times \left(Tr^{Parent(EndA)}_{Sec\,1} + \Delta_{Sec\,1} \right)$$

$$Tr^{World}_{EndA} = Tr^{World}_{TPC} \times \left(Tr^{Parent(TPC)}_{EndA} + \Delta_{EndA} \right)$$

$$Tr^{World}_{TPC} = Tr^{World}_{ILD} \times \left(Tr^{Parent(ILD)}_{TPC} + \Delta_{TPC} \right)$$

- Trickle-up the hierarchy and compute the matrices the most effective way with re-use of intermediate results
- Math verified by AIDA^{2020} alignment task force (C.Burr)