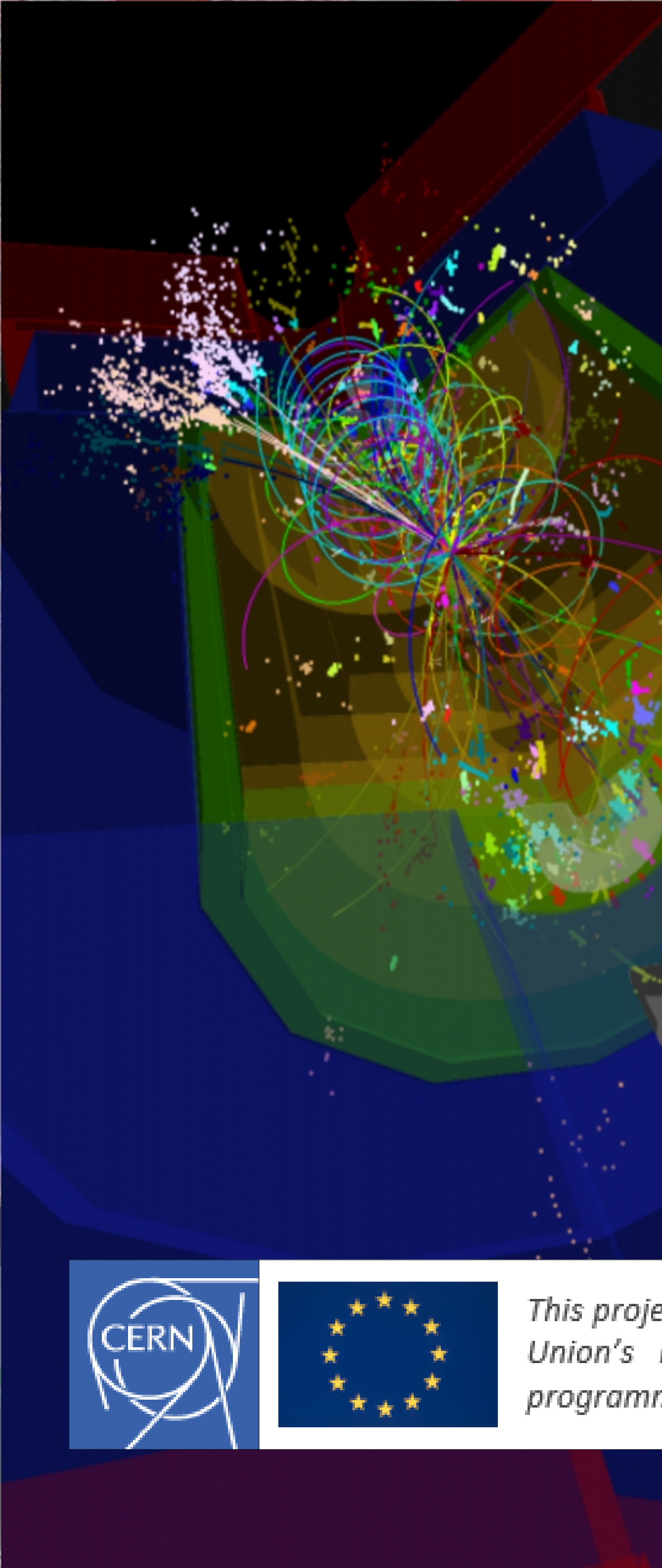


DD4hep

HEP detector description supporting the full experiment life cycle

M.Frank, F.Gaede, M.Petric, A.Sailer

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.**

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

AIDA 2020

Philosophy of DD4hep & Co

DD4hep

- **Effort of very few people with a simple, humble and comprehensive vision**

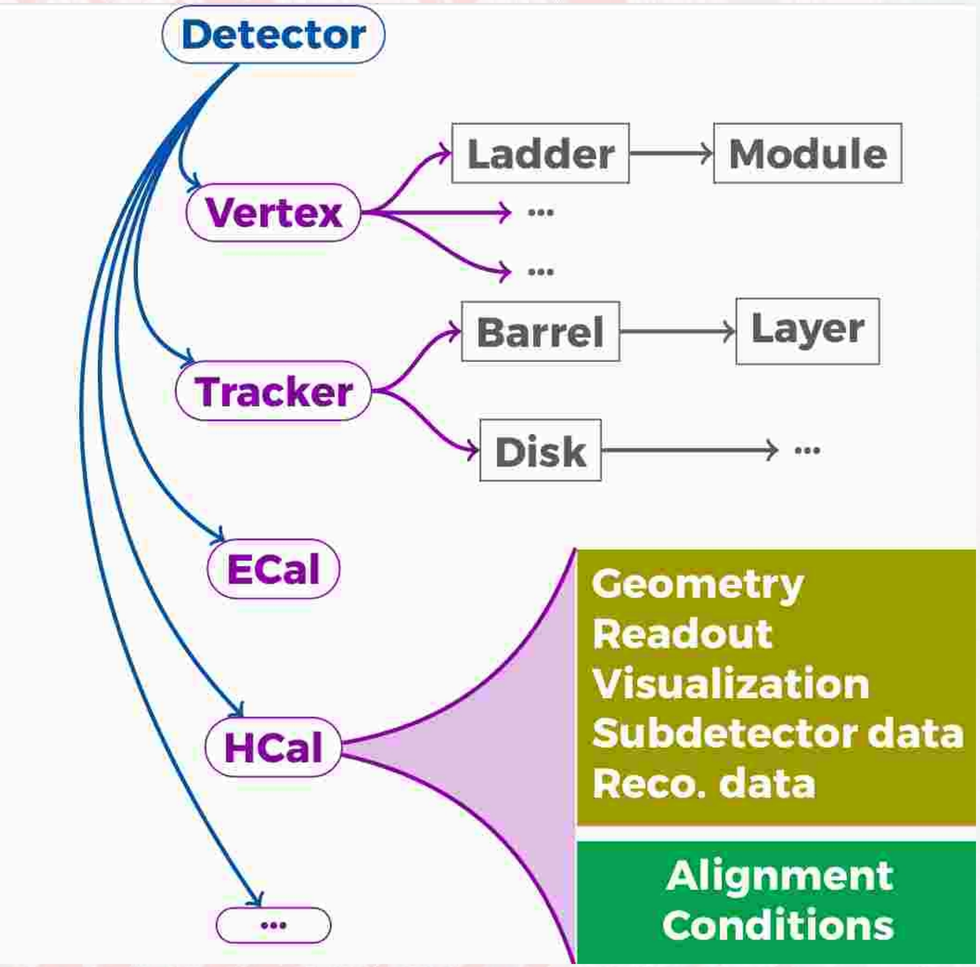
Detector description for the lazy
Minimal effort, pragmatic, no technical restrictions,
No obstacles induced by religious wars

- **DD4hep is the "glue"**
  - **Bring together what belongs together:**
    Detector structure, geometry, simulation, conditions, etc
  - **Reuse existing modules: TGeo, Geant4, GitCondDB, etc**
- **'Responsible' users highly welcome**
- **Contributions even more!**

What is Detector Description ?

DD4hep

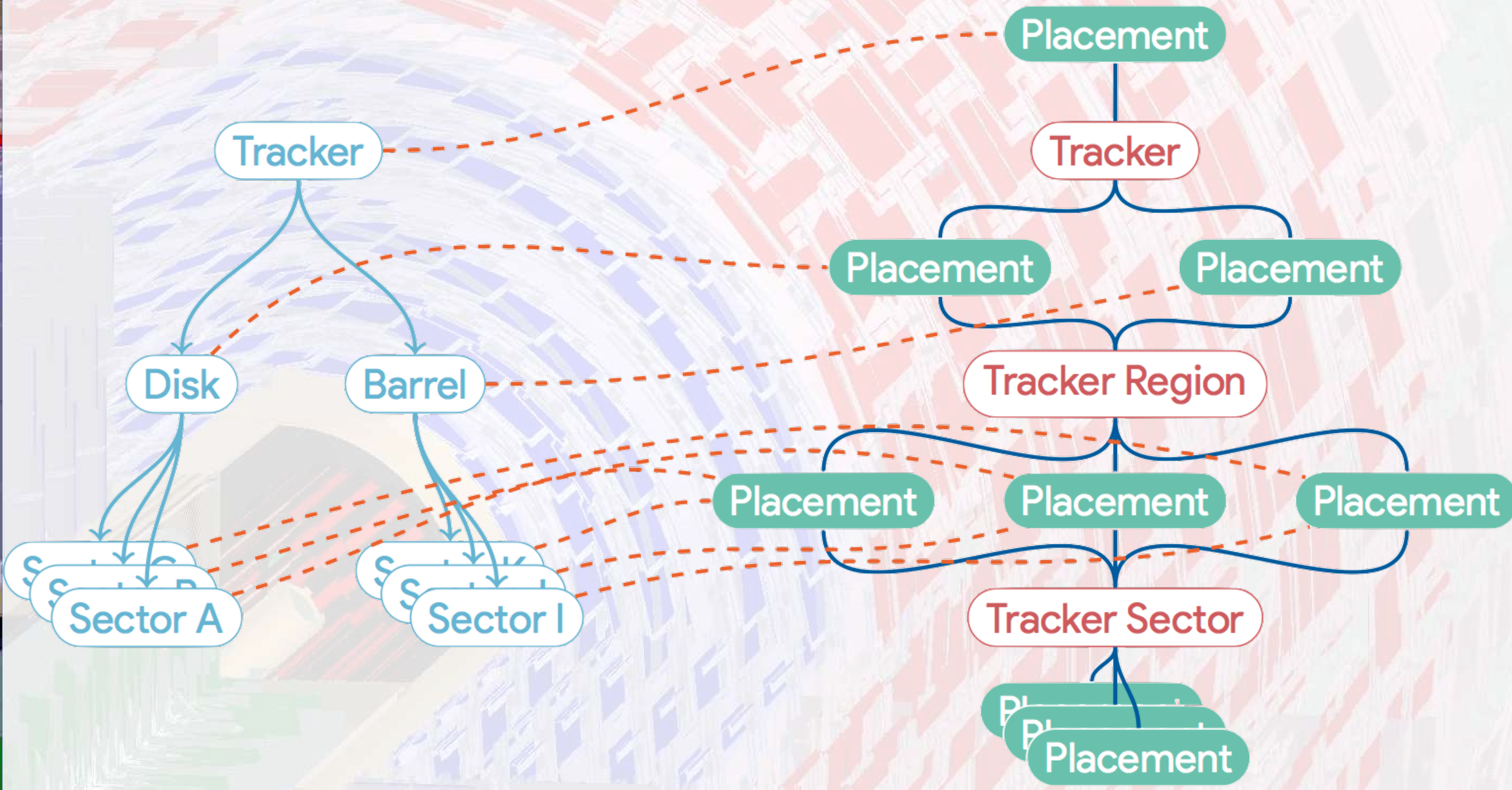
- Tree-like hierarchy of “detector elements”
  - Macroscopic (ie. not a strip)
  - Subdetectors or parts of subdetectors
- Detector Element
  - Geometry
  - Properties to process events
    - Environmental data
    - Alignments
    - Derivatives of these
  - Optionally experiment, sub-detector or activity specific data



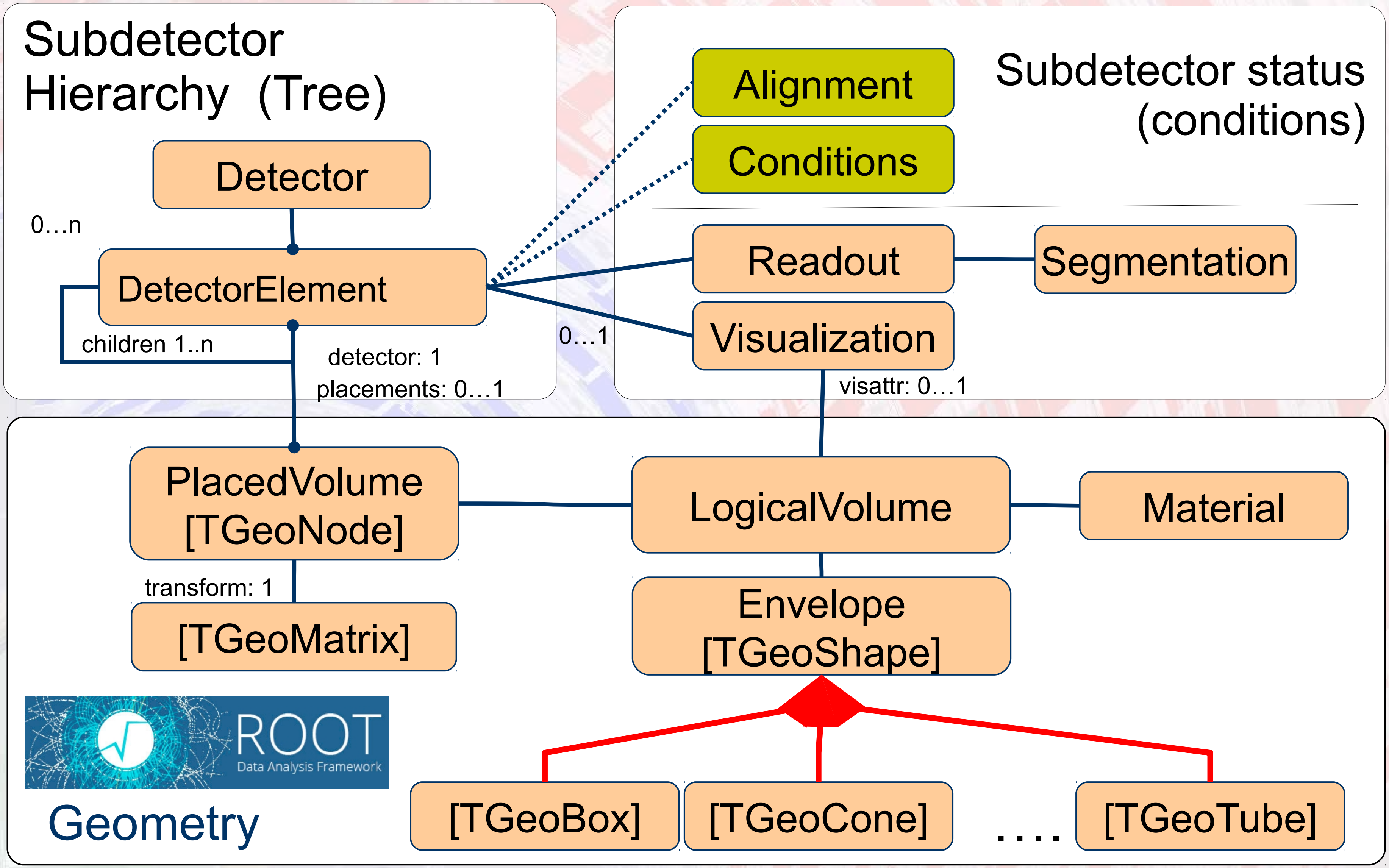
Detector Description is not Geometry
(Please update your glossary)

DD4hep

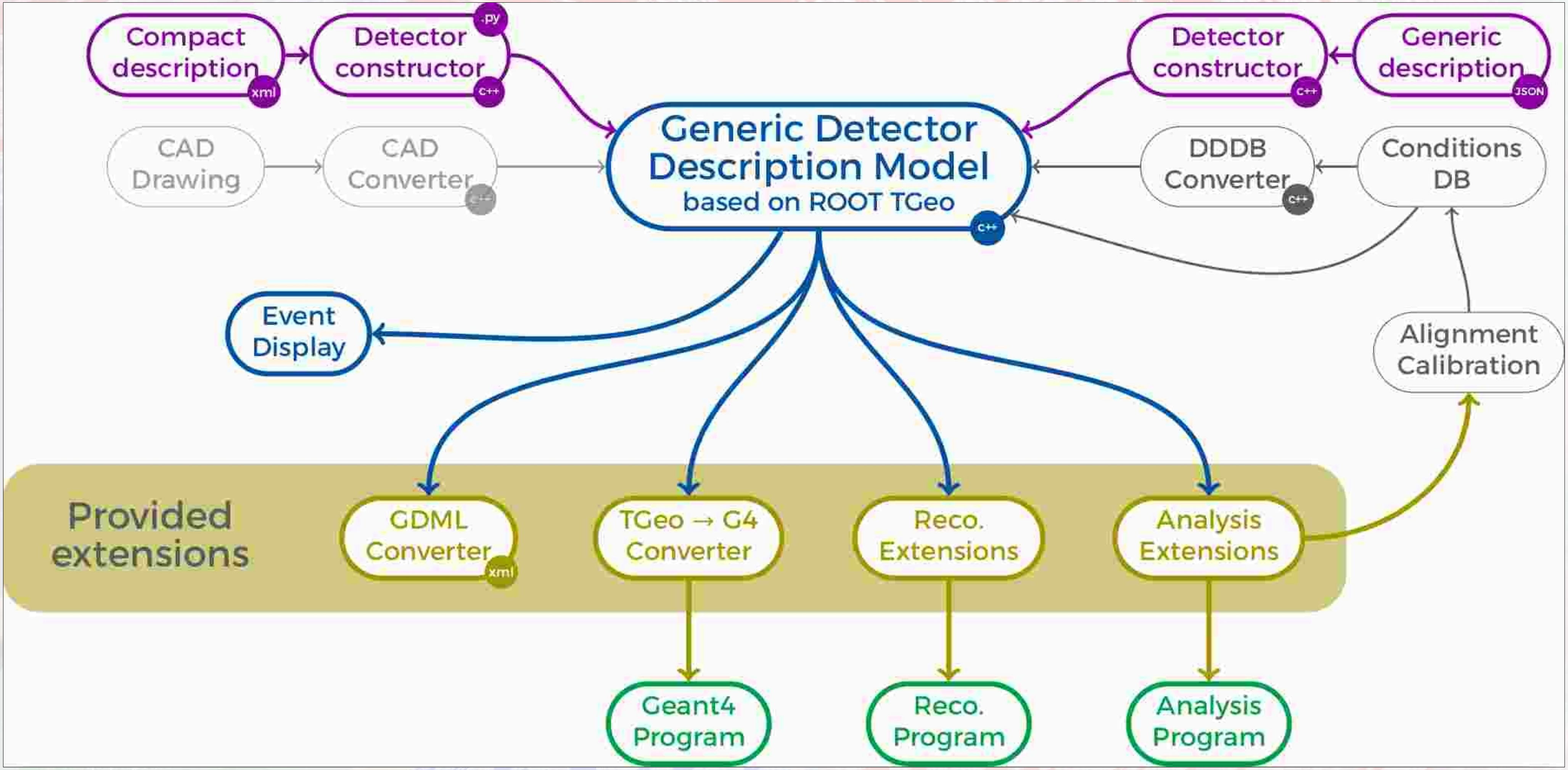
- **Detector element tree**
- **Geometry (pseudo-)tree**



Class Diagram: Detector Element
Sort of Standard…

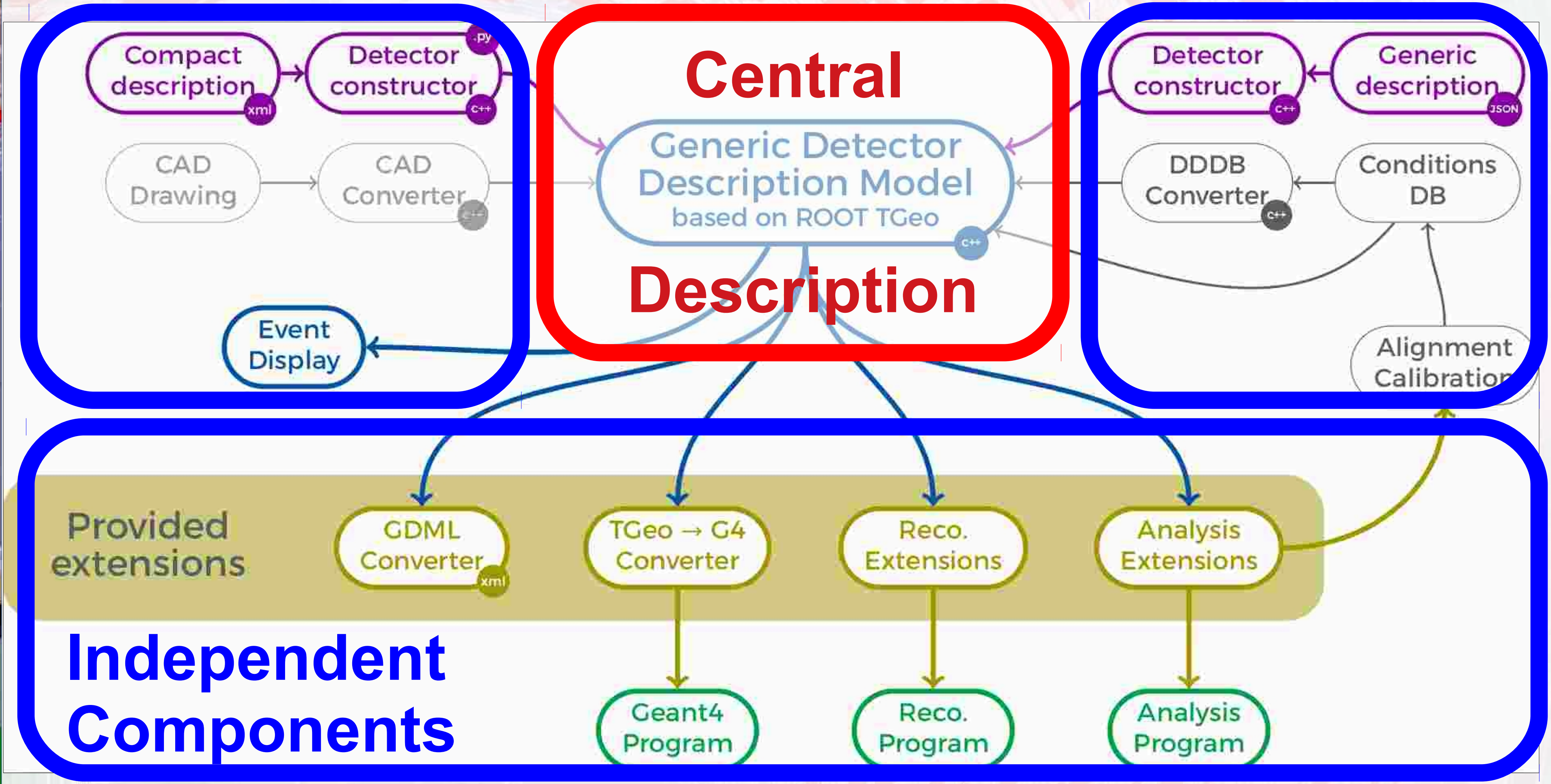


DD4Hep - The Big Picture



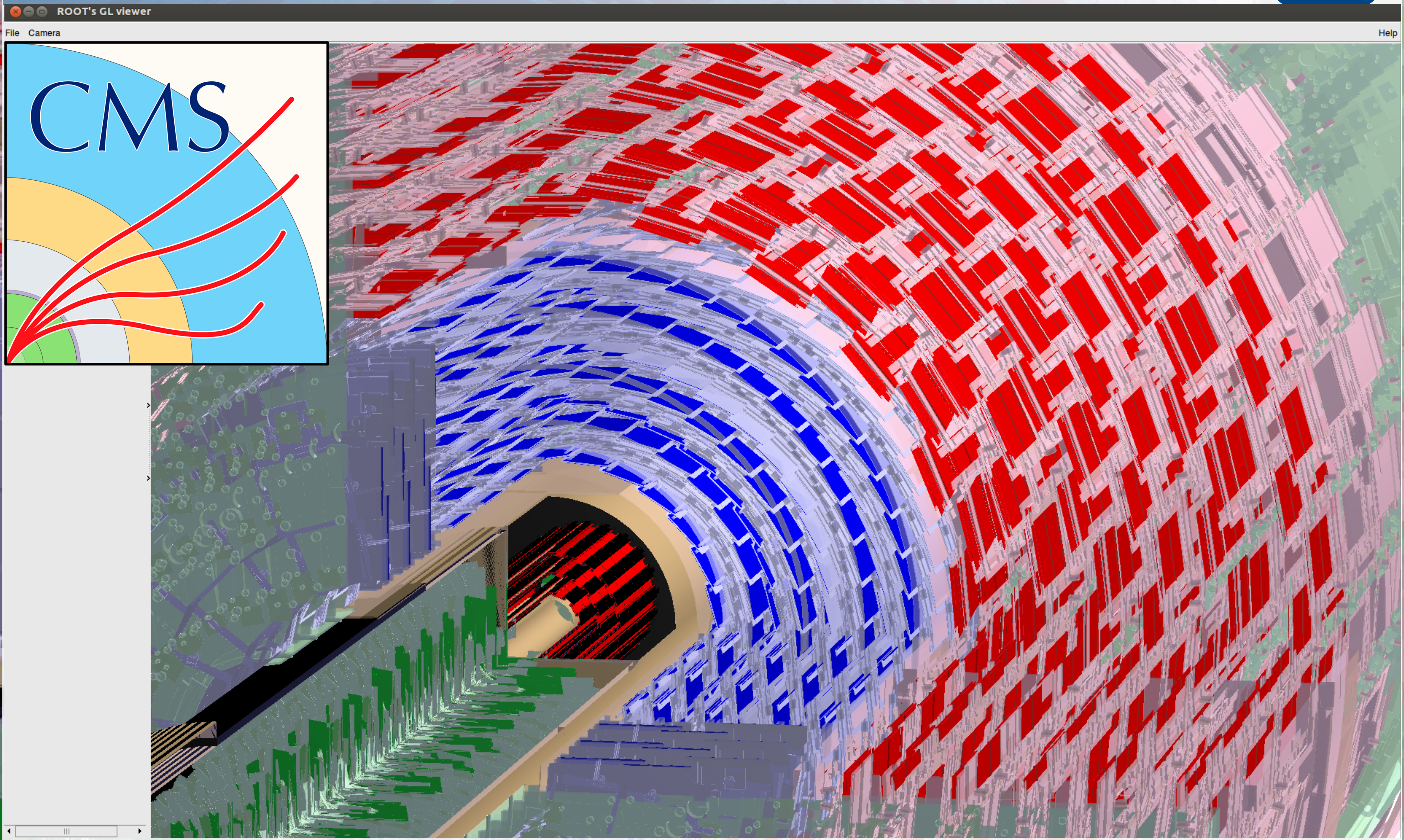
DD4Hep - The Big Picture

DD4hep



PR: CMS Trackers

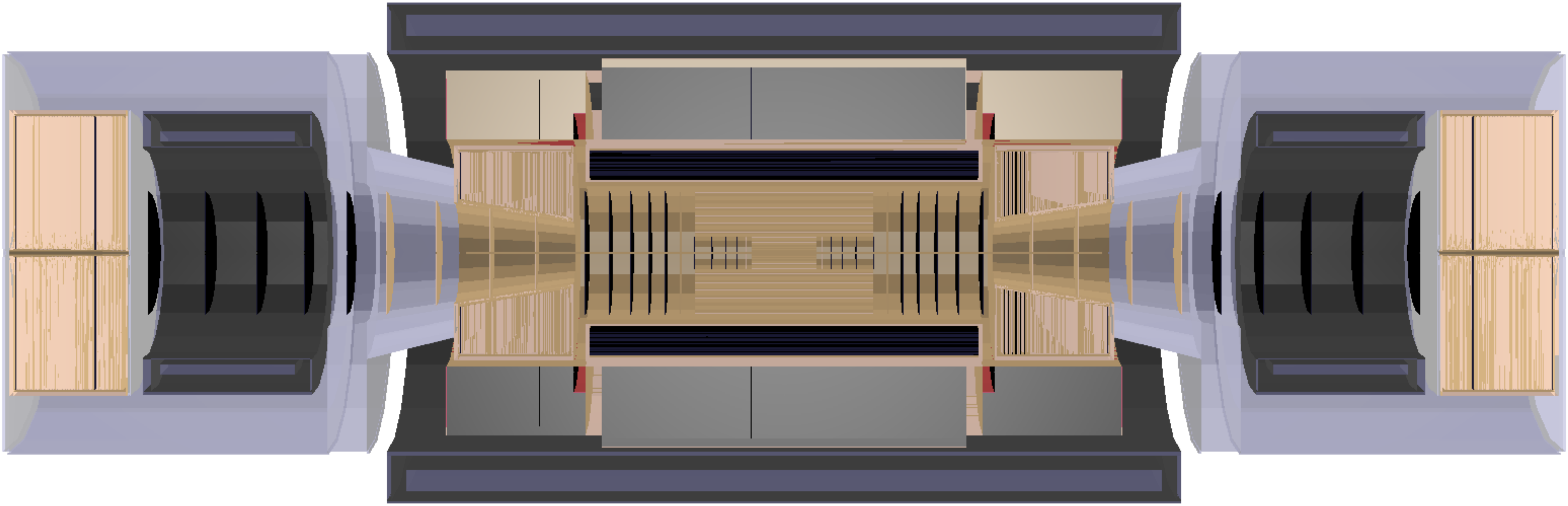
DD4hep



PR: FCC Design Study

DD4hep

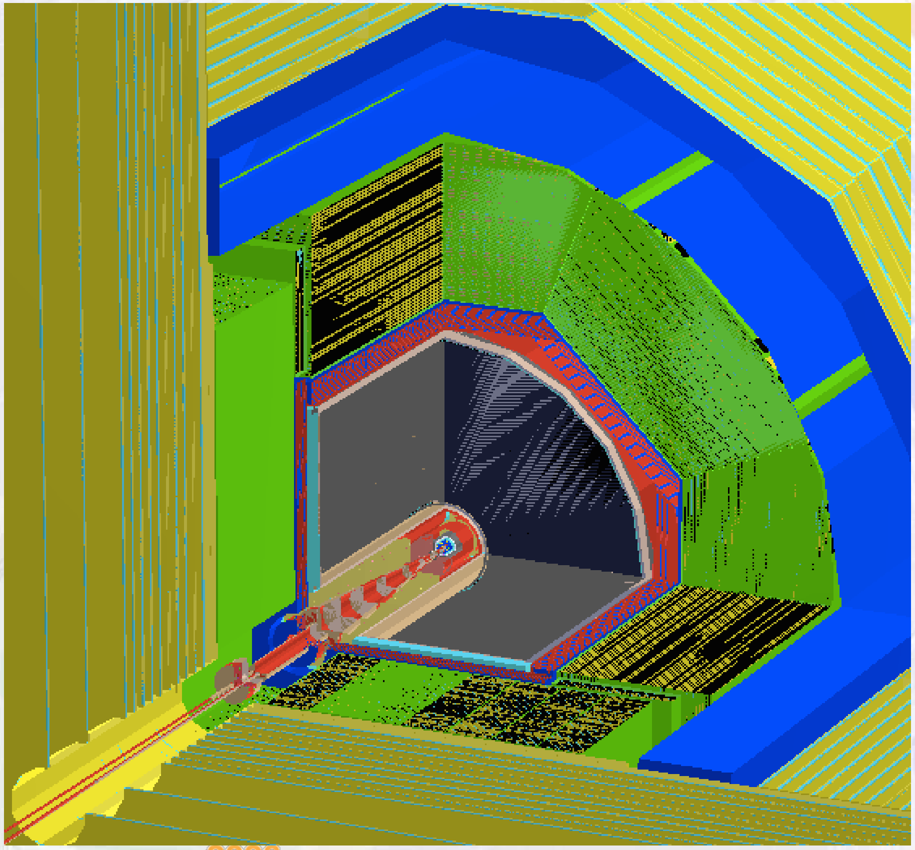
FCC
hh ee he

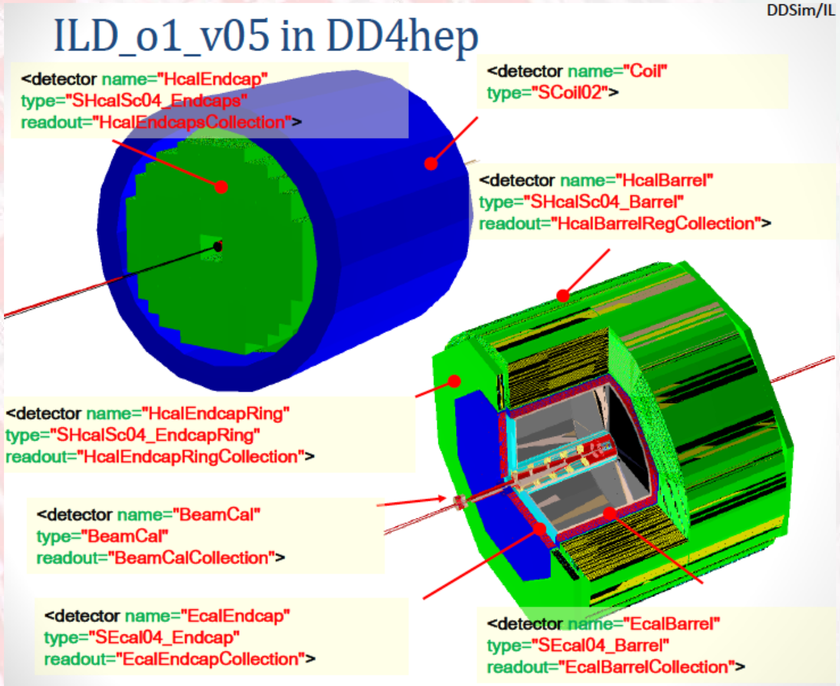


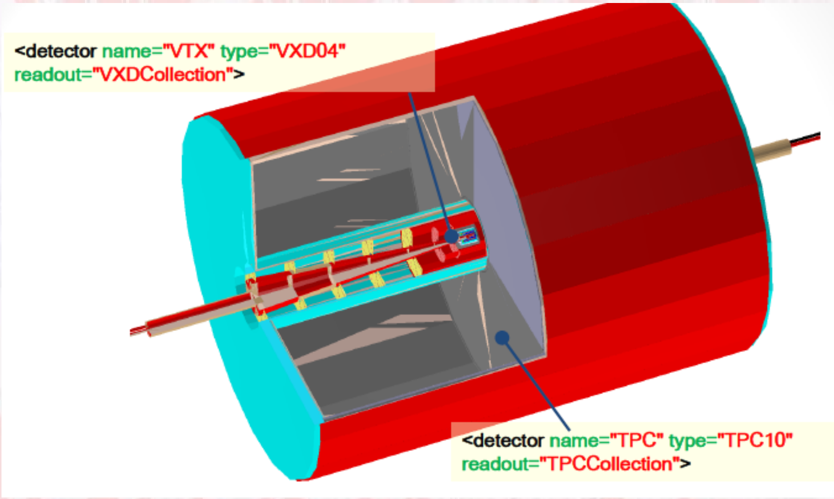
PR: ILD Model ILD_o1_v05
(F.Gaede, L.Shaojun)

DD4hep

DDSim/IL







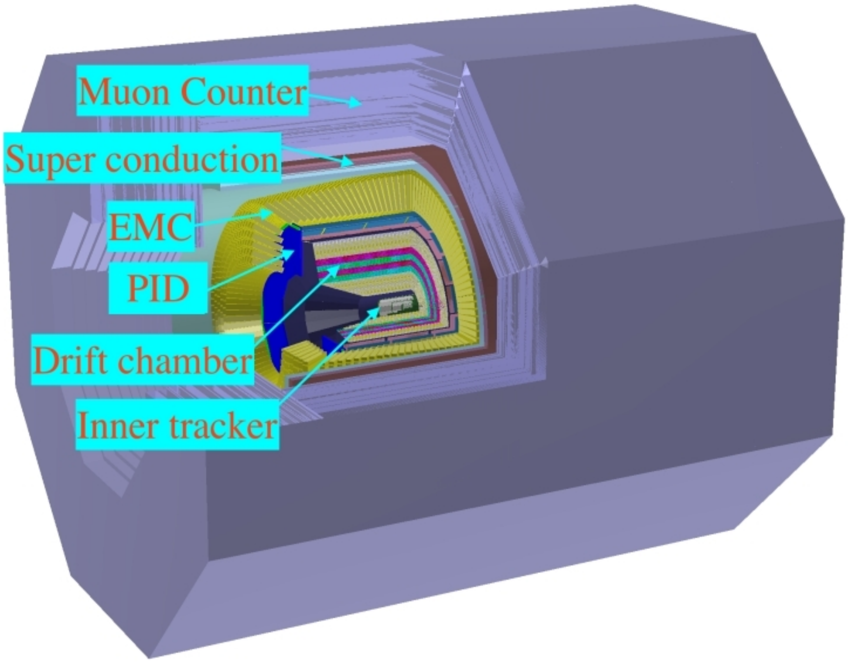
Xiaorong Zhou
State Key Laboratory of Particle Detection and Electronics
University of Science and Technology of China

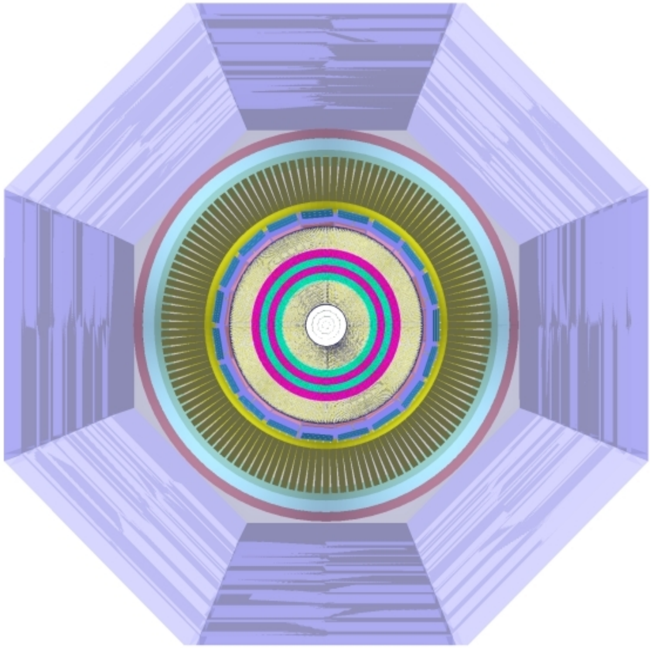
Joint Workshop on Future Tau-Charm Factory
2018.12.4-2018.12-7, Paris

DD4hep

Progress on detector simulation

- STCF software team has been formed.
- OSCAR: Offline Software of Super Tau-Charm Facility.
- Detector geometry with DD4hep.





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DD4hep Core

DD4hep

- **Handles the detector element functionality**
- **Basically stable**
  - **Bug fixes, enhancements**
- **Objects and sub-packages are reflective**
  - **ROOT C++ dictionary defined**
  - **Intrinsic support for cross-language development**
- **Reflection supports interactivity**
  - **Cint (Cling/AClick) and python (cppyy)**
- **CHEP 2013**

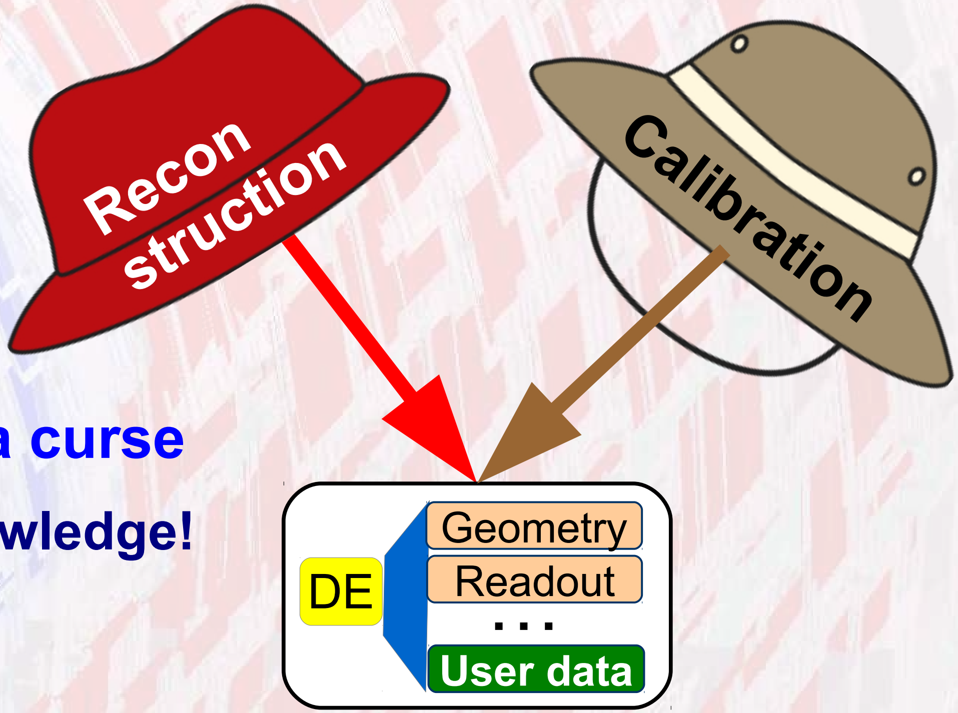
DD4hep: A Detector Description Toolkit for High Energy Physics Experiments

Views & Extensions: Users Customize Functionality

DD4hep

DD4hep is based on handles (smart pointers)

- Rarely deal with data directly
- Possibility of many views based on the same DE data
  - Same 'data' associated to different 'behaviors'
  - All views are consistent and creation is efficient: pointer-copy
- Be prudent: a blessing and a curse
  - User data are common knowledge!



Simulation: DDG4

DD4hep

- Simulation = Geometry +
  Detector response +
  Physics
- Mature status
  - Eventual bug fixes, smaller improvements
  - Phase of constant re-validation
- Automatic geometry conversion
- Palette of standard sensitive detectors
- Support for MC truth handling
- CHEP2015

  DDG4 A Simulation Framework based on the DD4hep Detector Description Toolkit

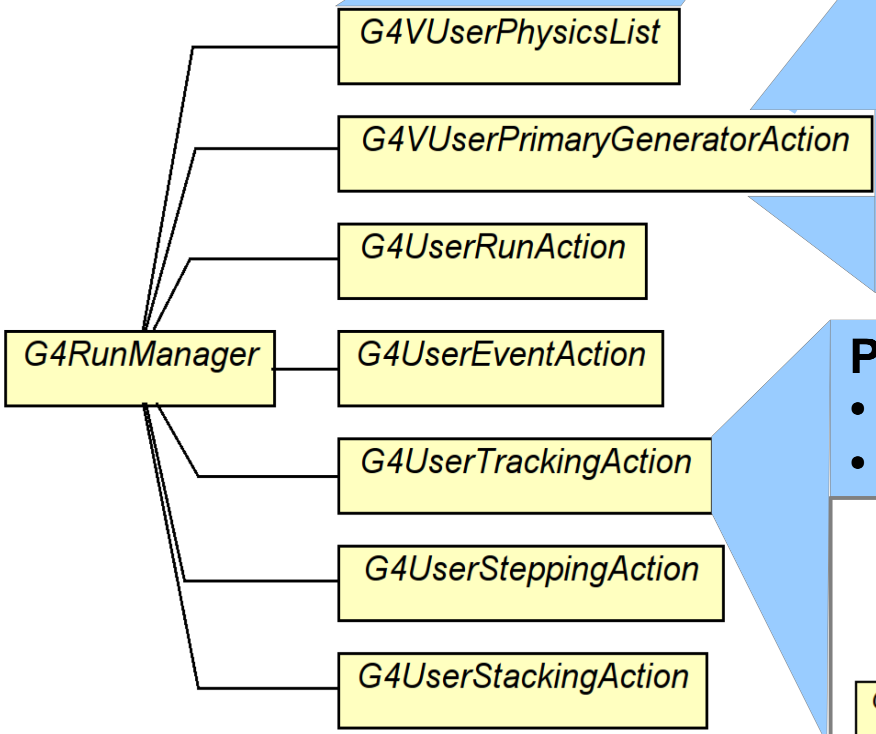
Geant4 Provided Hooks
[and what we want to do inside]

DD4hep

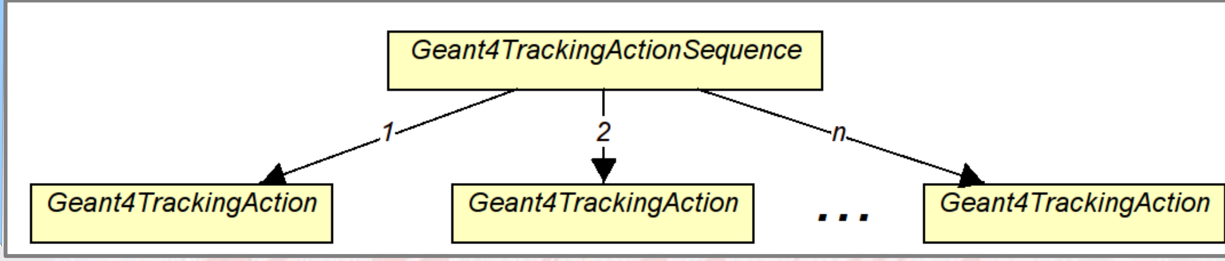
Main issue: flexible configuration

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

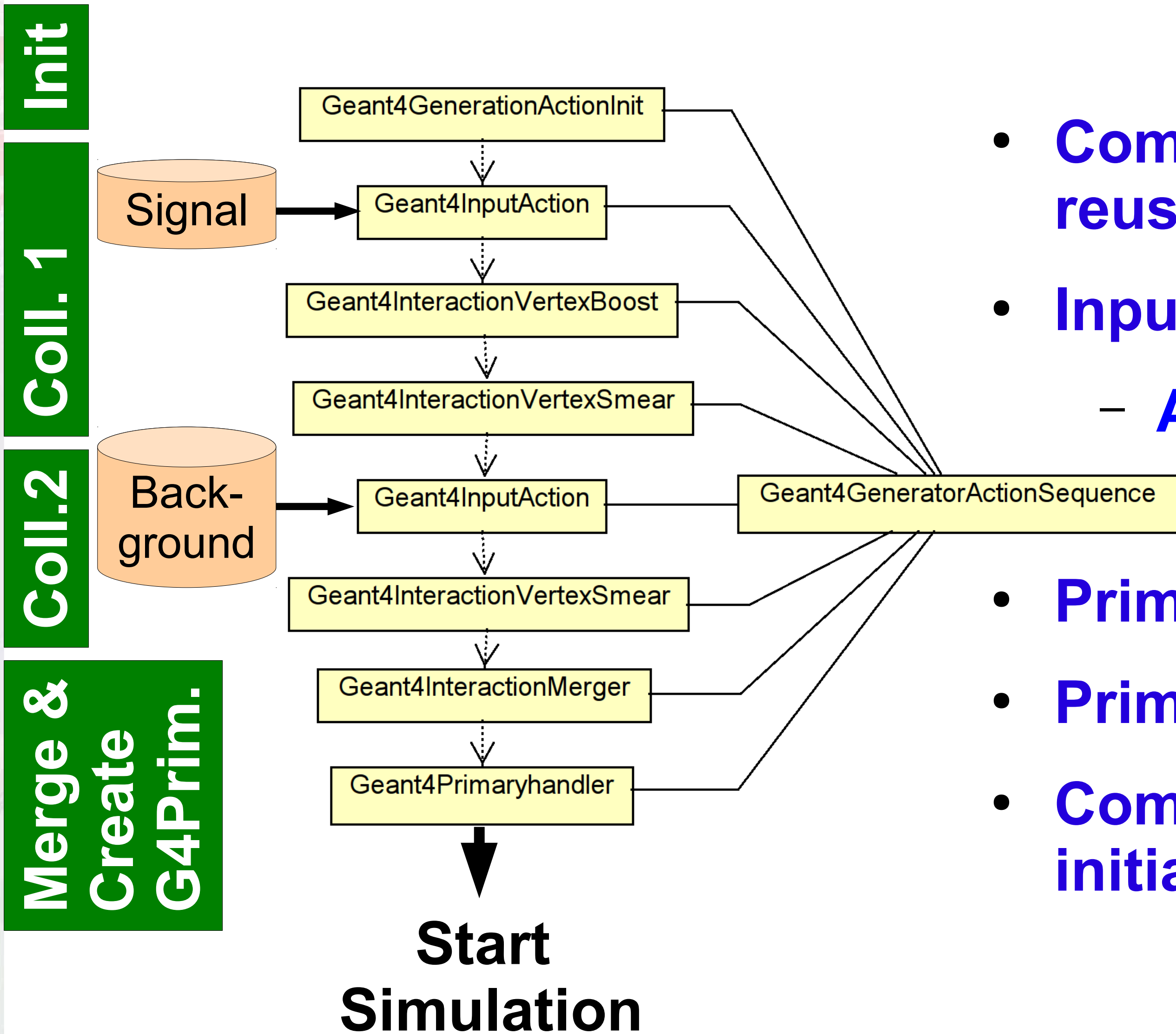


Provide user programmable sequences
- Either as explicit object type using ABC
- Or registering a member function as callback



Example of an Action Sequence

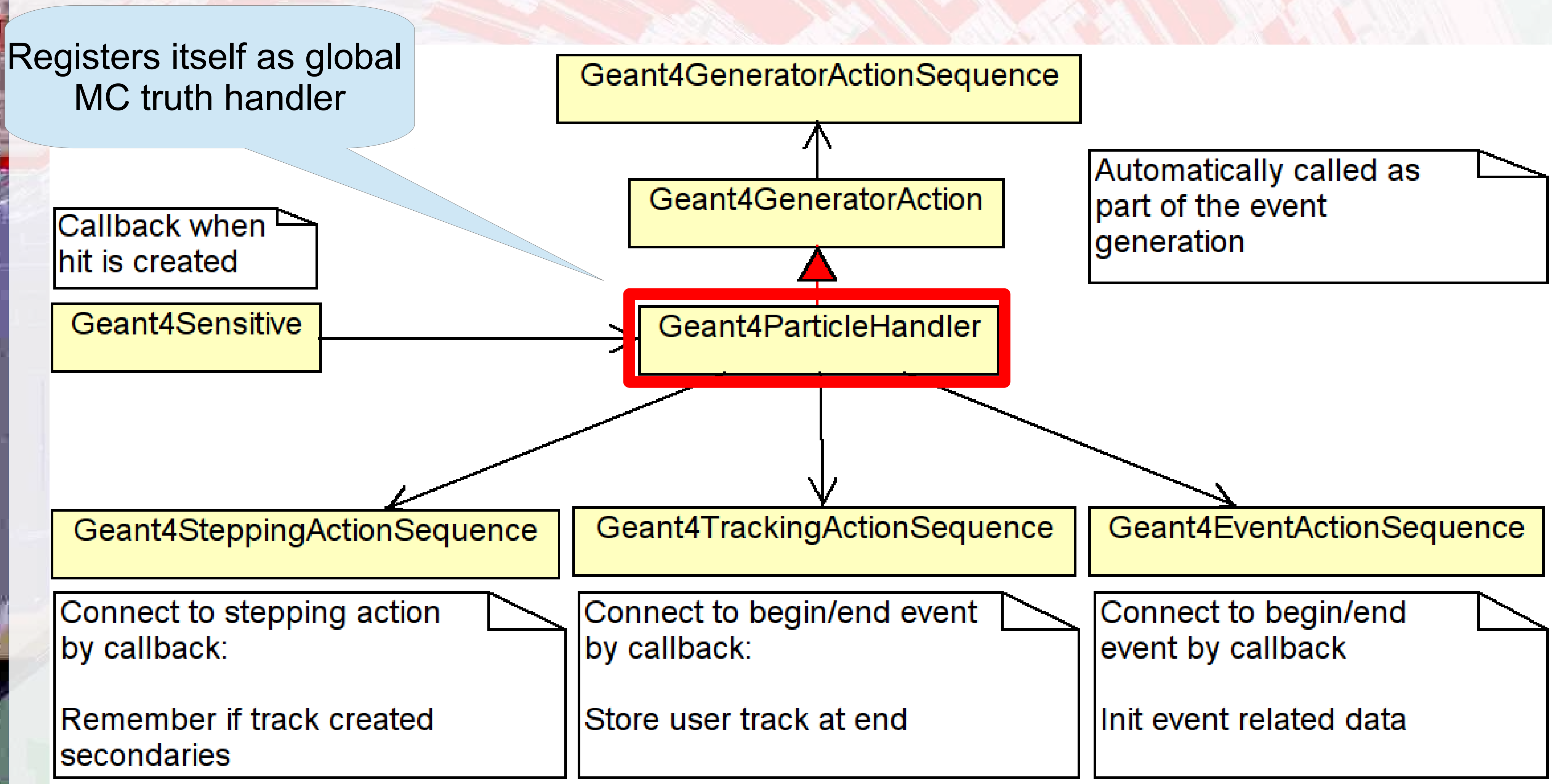
Event Overlay with Features



- 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 (LC specific algorithm)

DD4hep



External Framework Support

DD4hep

- 2 possibilities
  - DDG4 (Geant4) takes over event loop from framework
  - Framework steers event loop (overloading run manager)
- Everything is a plugin (or could be made one)
  - External frameworks can overload all central entities
  - G4RunManager
  - Geant4 action routines
  - Physics …
- External framework context
  - Typed pointer available to every user action
  - User defined structure allows to interact with any framework service: histograms, I/O, etc.

Fast Simulation & SLIC

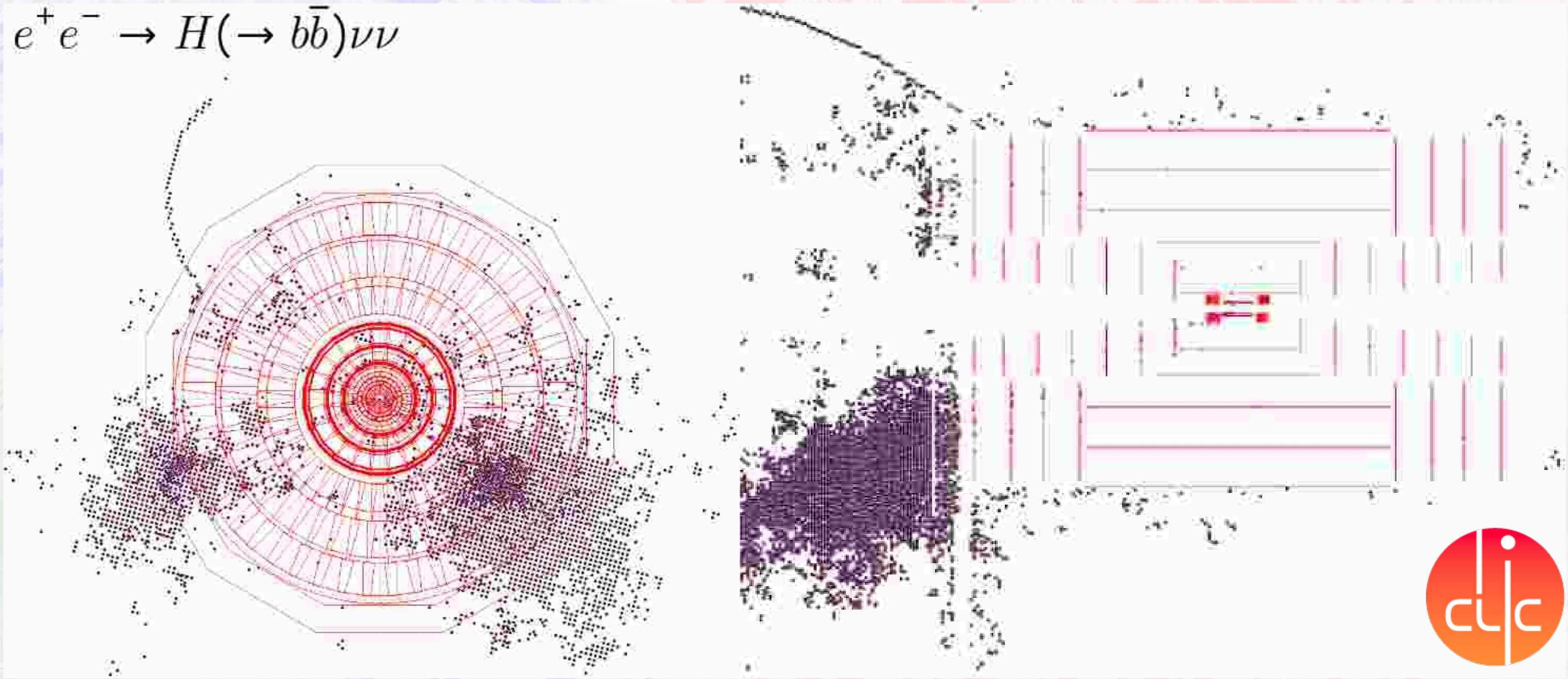
DD4hep

- Fast Simulation: Support for fast simulation provided by Geant4
  - SFT fellow working on fast simulation in Geant4
  - Some commitment to also handle DD4hep integration
  - Personal guess: Once it is understood what to do in Geant4
    Provide plugins and attach them to sensitive volumes
- SLIC
  - Abandoned (though initially written for SiD/LC)
  - Uses old GDML implementation with limited geometry support
    So much to be said for "standard"
    "EIC Geometyry Description and detector interface", page 2

DDG4 in Production

DD4hep

- **Deployed for CLICdp in DIRAC**
  - **For every detector study (now ~14) central generation**
- **ILC started mass production**



Standard Detector Palette DDDetectors

DD4hep

- Used for design studies (LC, FCC-eh)
- Origin from the SiD detector model
  - Layer based detectors
  - Tracker barrel & endcap
  - Several calorimeter constructs
- Partially with measurement surfaces (F. Gaede)
  - Uses plugin mechanism to enhance detector elements
    - Non intrusive mechanism to attach user defined optional data
      => 'anticipate the unforeseen'
- Sensitive volumes identified by CellID: up to pixel
  - Volume path reduced to 64 bit number
  - CellID in simulated hit + detector description → placement

DDCond: Conditions Data

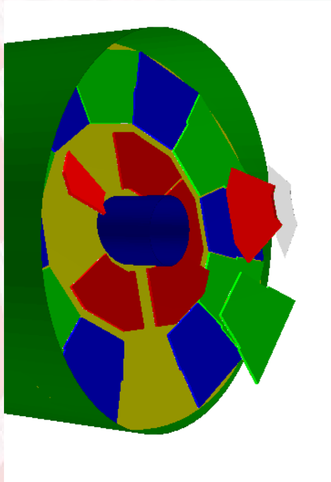
DD4hep

- Time dependent data necessary to process the detector response [of particle collisions]
  - slowly changing: every run O(1h), lumi section O(10min) ...
  - multiple conditions change in batches: require discipline
  - conditions may be the result of computation(s)
- DDCond deals with the management of these data
  - Efficient and fast, if used according to design ideas
  - Manages resources
  - Supports multi threading by design
    Well defined locking points
  - Cache where necessary but no more
- CHEP2018
  Conditions and Alignment extensions to the DD4hep Detector Description Toolkit

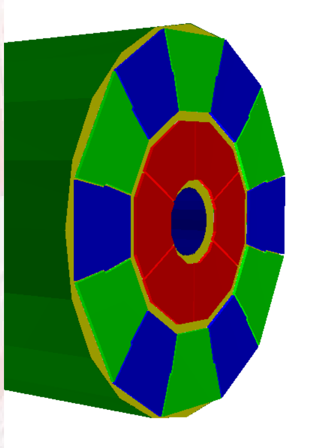
Global and Local Alignments

DD4hep

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



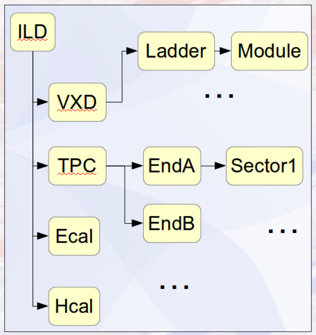
- **Local alignment corrections**
  - Geometry stays intact (either ideal or globally aligned)
  - Multi-threading supported, multiple versions
  - Local alignment corrections are conditions
  - Provide matrices from ideal geometry to world
    e.g. to adjust hit positions

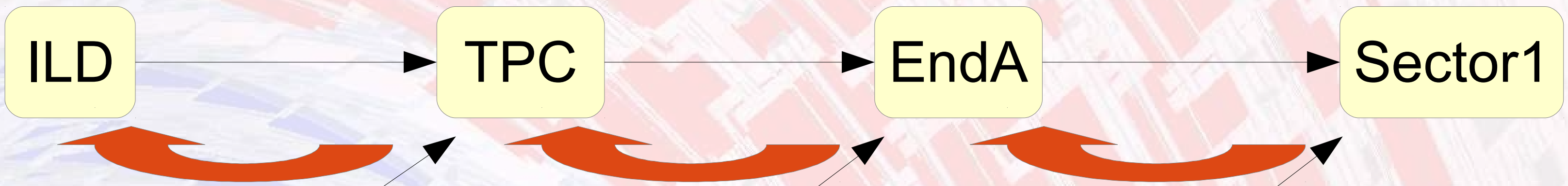


- **Both supported**

Local Alignment Δ - Parameters

DD4hep





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

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

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

- 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)

Toolkit Users

DD4hep

Increasing interest in the HEP community

- ILC F. Gaede et al.
- CLICdp A. Sailer et al.
- SiD D. Protopopescu et al.
- FCC-eh P. Kostka et al.
- FCC-hh A. Salzburger et al.
- FCC-ee O. Viazlo (CLD design), N. Alipour, G. Voutsinas
- SCTF Super-Charm-Tau Factory designs (Novosibirsk, Bejing)
- EIC Evaluation considered/started (W. Armstrong et al.)

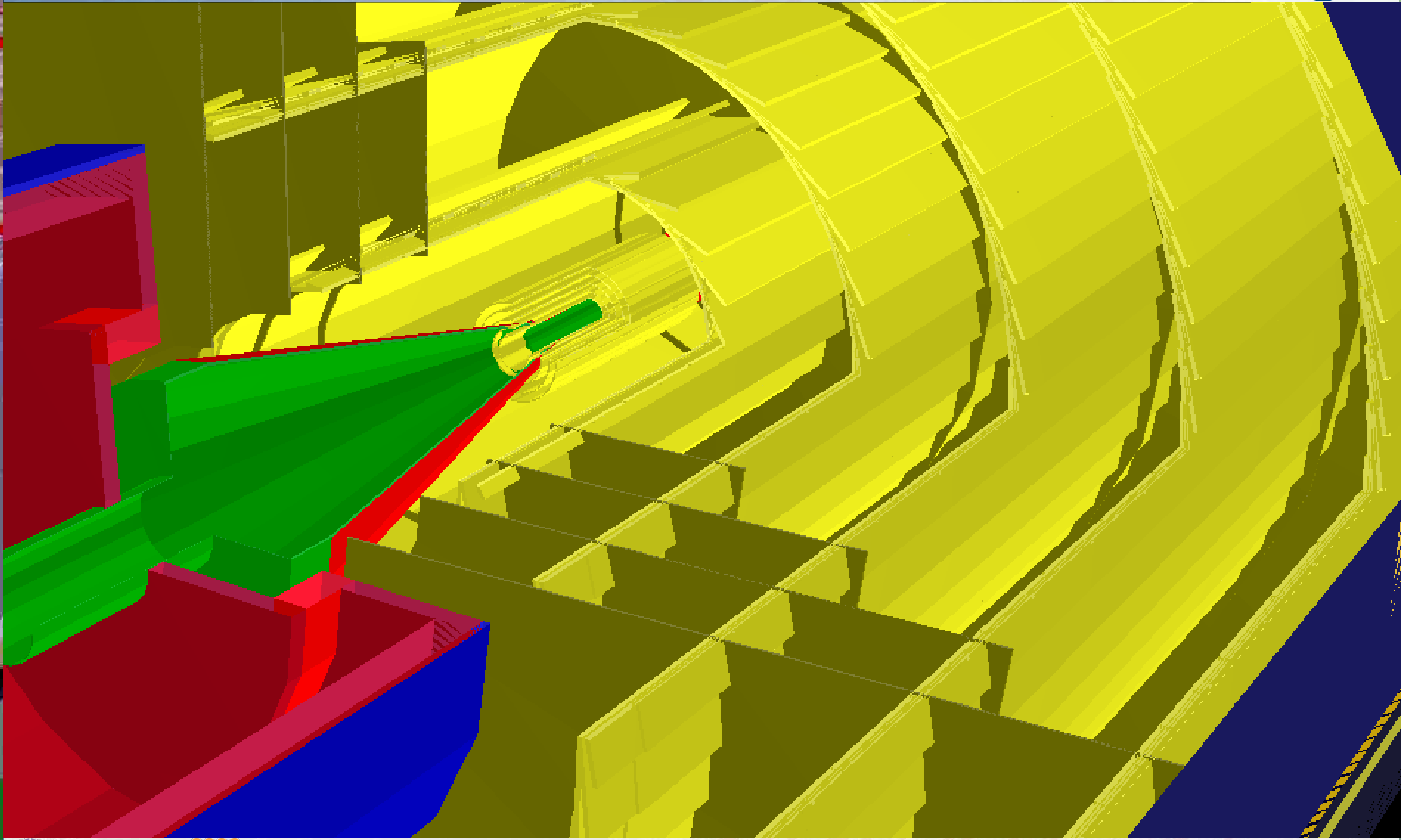
- LHCb LHCb Upgrade for Run III (B.Couturier et al.)
- CMS Evaluation for upgrade started (202x) (Y.Osborne et al.)
- CALICE Calorimeter R&D, started

Summary

DD4hep

- DD4hep is getting mature
- Flexible components interacting with user framework
- Starts being capable of handling all aspects of detector description for the lifetime of an experiment
- Increasing interest in the community and increasing number of users
- Visit us on:
  - `http://dd4hep.cern.ch`
  - Up to date doxygen information
  - User Manuals: have improved but not perfect

Questions and Answers

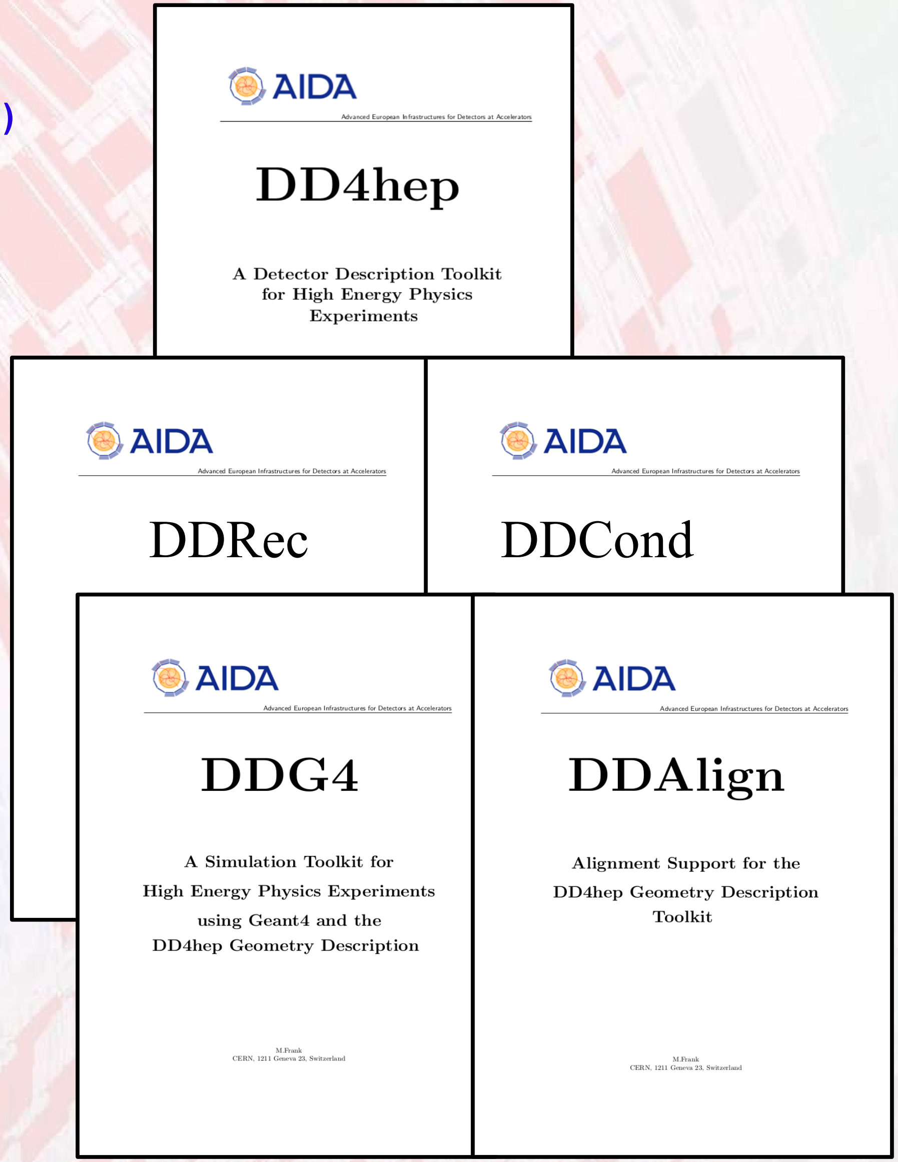


Saga in 5 Episodes

DD4hep

- DD4hep – basics/core (1)
- DDG4 – Simulation using Geant4 (1)
  - Fast simulation (4)
- DDRec – Reconstruction supp.(2)
- DDCond – Detector conditions (3)
- DDAlign – Alignment support (3)
- DDDigi – Generic Digitization (4)

(1) Mature state: bug-fixes and maintenance
(2) F. Gaede (WP3, Task 3.6)
(3) Work since start of AIDA2020
(4) Planned extensions


AIDA

DD4hep

A Detector Description Toolkit for High Energy Physics Experiments

AIDA

DDRec

AIDA

DDCond

AIDA

DDG4

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

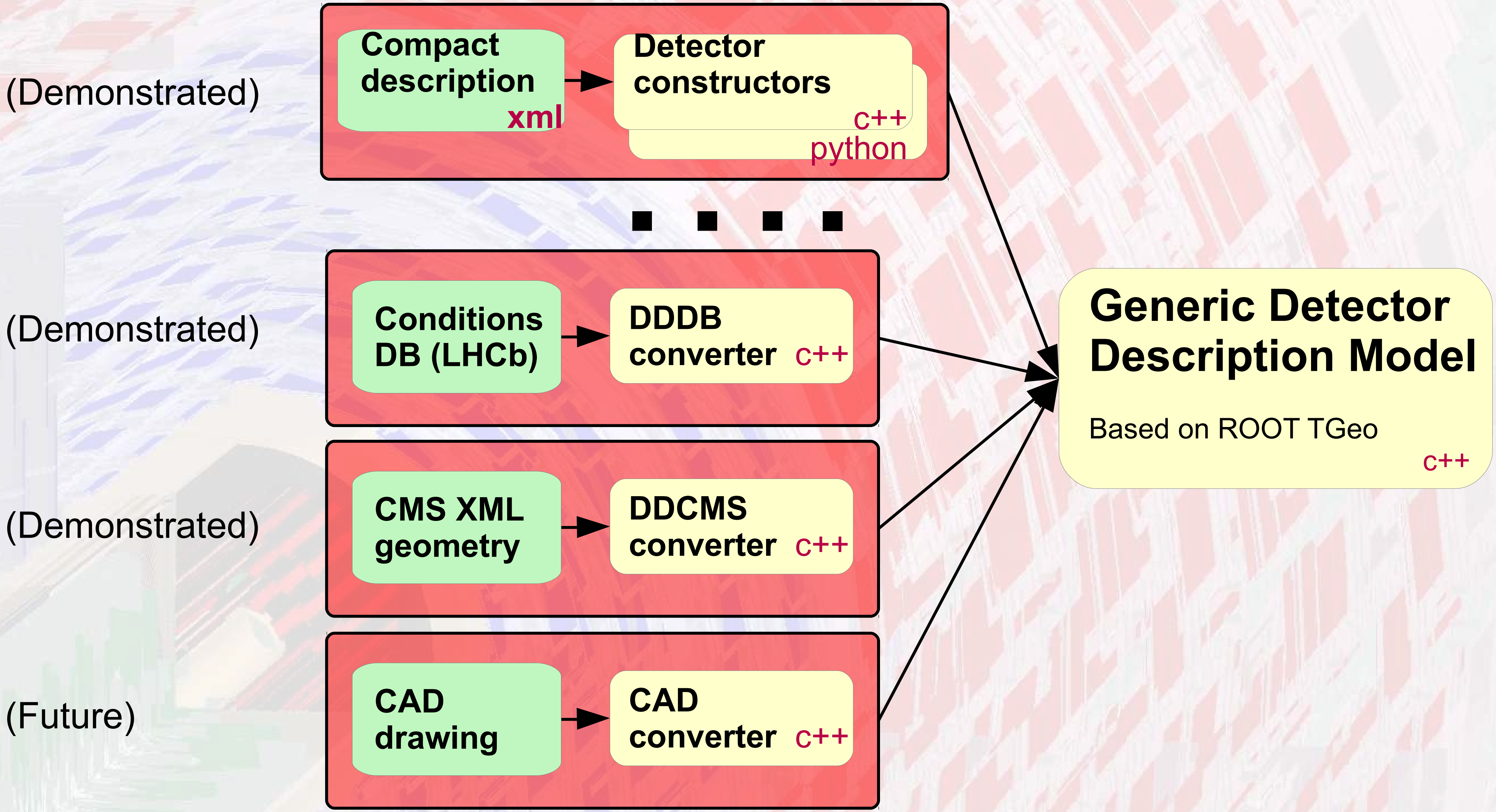
AIDA

DDAlign

Alignment Support for the DD4hep Geometry Description Toolkit

Multiple Input Sources

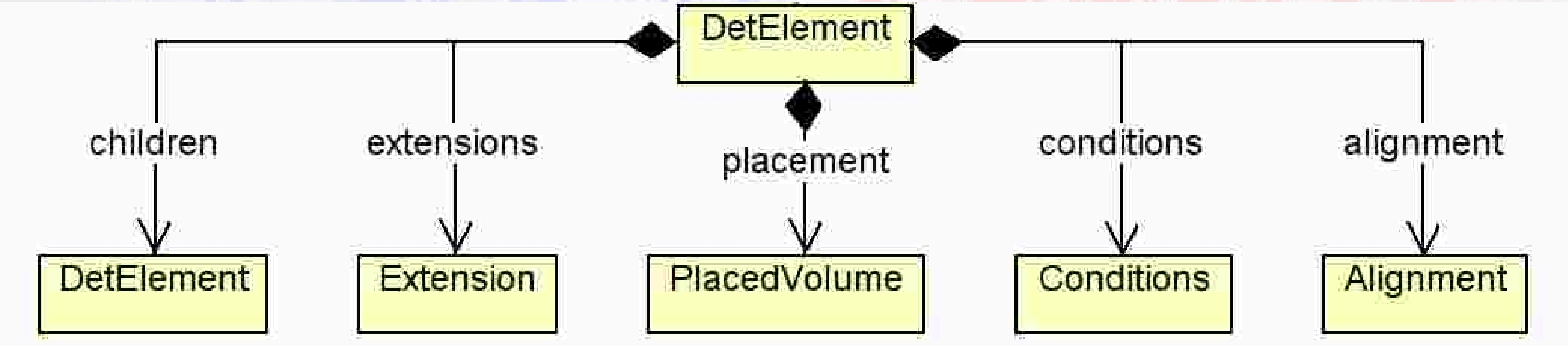
DD4hep



Conditions implementation in LHCb Velo Detector

DD4hep

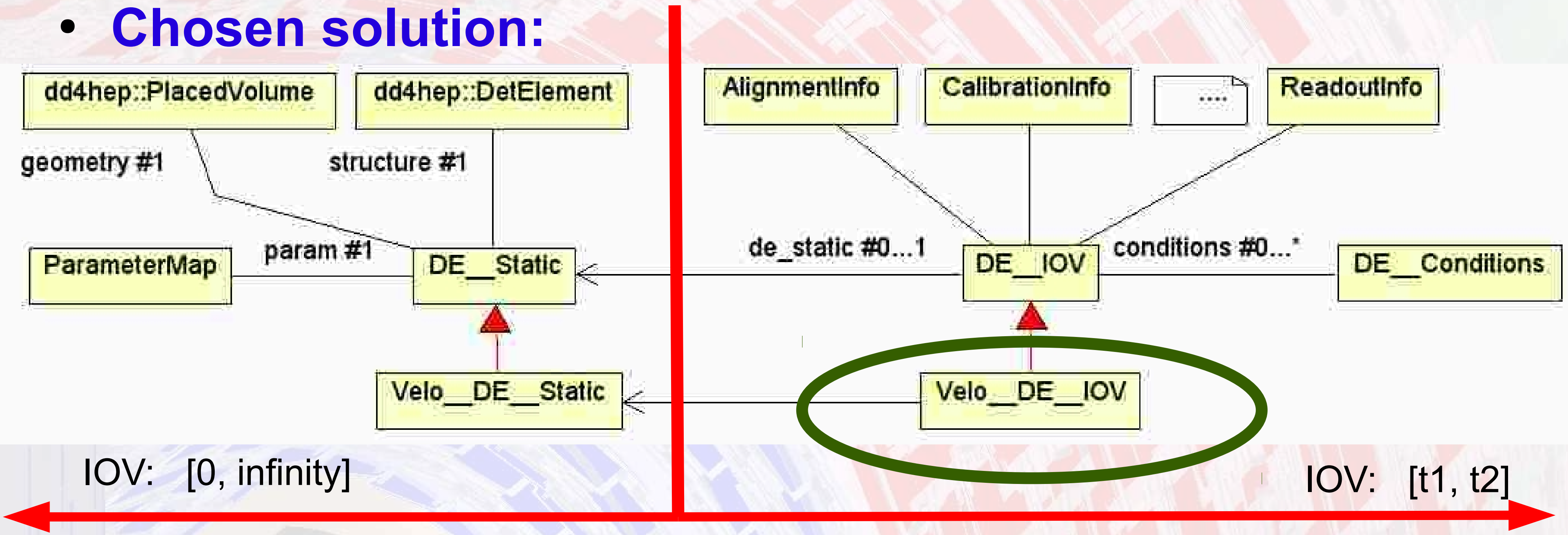
- People want to see “Detector elements”
  - Fully functional description of parts of the detector
    - Long term valid stuff (structure)
    - Short lived quantities (temperature, alignment, …)
- A “natural” aggregation would be similar to:



- Intuitive, but not good: violates multi-threading

Conditions implementation in LHCb Velo Detector

- **Chosen solution:**



- **Use IOV dependent projection for event processing**
  - **This is our new "detector element"**
  - **Keeps reference to the not changing properties**
- **Dress with facade to provide required functionality(ies)**