A Software Framework for FCC studies: Status and Plans

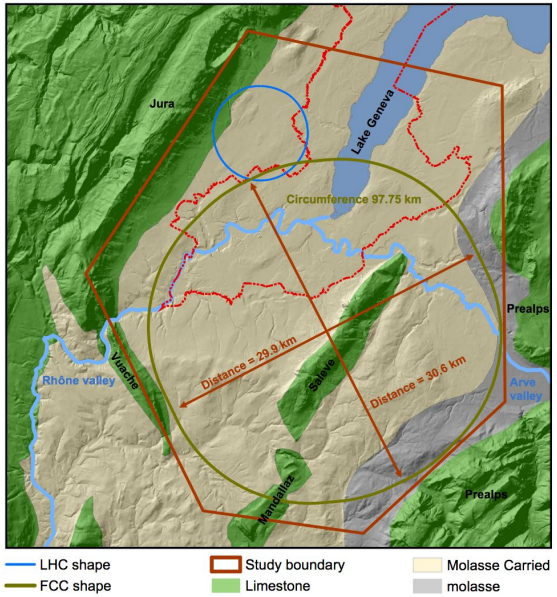
CHEP 2019, Adelaide, Australia

Nov 04, 2019

N A Tehrani, J C Villanueva, J Faltova, G Ganis,
C Helsens, J Hrdinka, C Neubüser, L Pezzotti,
M Selvaggi, V Volkl, A Zaborwska
CERN

The FCC@CERN project

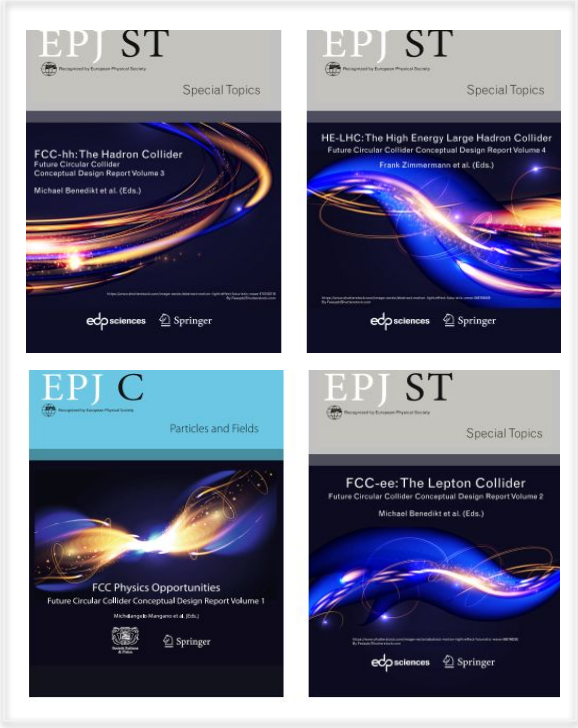
- Address main questions currently open in HEP
- Circular Collider of 97.75 km circumference
- **FCC-ee**: e^+e^-
  - $\sqrt{s} \simeq \{m_Z, 2 \cdot m_W, 240, 2 \cdot m_t\}$ GeV
  - Data taking period: ≃ **2040-2055**
- **FCC-hh**: **pp**, e^-p
  - ~100 TeV pp
  - Possibly e^-p in parallel
  - Data taking period: ≃ **2065-2090**



FCC Conceptual Design Report

- Used as input for ESPP 2019
- Using FCCSW based on
  - 150 TB of full simulated data
  - 100 TB of Delphes events

- https://cern.ch/fcc-cdr



FCC Software Outlook

- Started in 2014, target the CDR
- Driving considerations
  - One software stack to support all the cases, all the detector concepts
    - Need to support broad range of event complexity (e^+e^-,pp,e^-p)
  - Need to support physics and detector studies
    - Parametrised, fast and full simulation (and mixture of the three)
  - Allow for evolution
    - Component parts can be improved separately
  - Allow multi-paradigm for analysis
    - C++ and Python at the same level

FCC Software Outlook

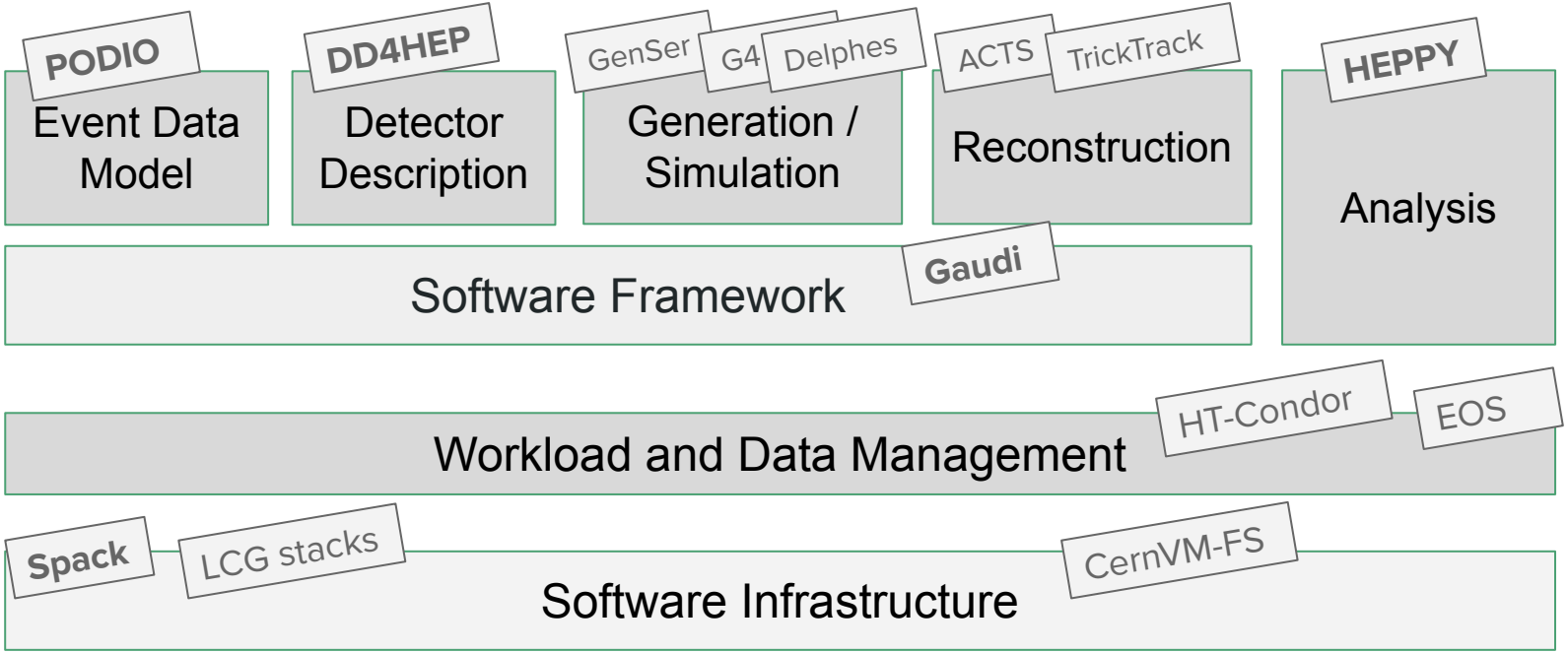
- Adopted Strategy
  - Adapt existing solutions from LHC
  - Look at ongoing common projects (AIDA)
  - Invest in streamlining of event data model

Next Slides

- Future: towards a common software for future experiments
  - Bologna workshop, June 2019
    - Present: LHC, ILC, CLIC, FCC, CEPC, SCTF, HSF
  - Agreed to:
    - Investigate the possibility to have a common event data model (EDM4hep)
    - Contribute to the development of a Common Turnkey Software Stack (Key4hep)
      - One framework (Gaudi best candidate), DD4hep, EDM4hep, Geant4, ROOT, …

A Sailer, TX, Tue, 17h45

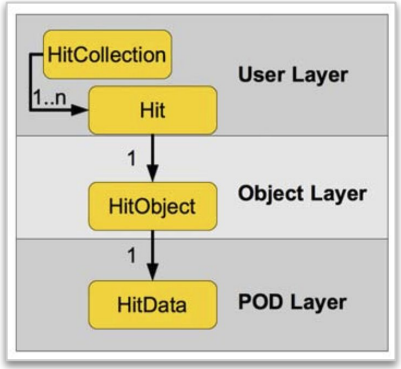
FCC Software current ingredients



Event Data Model and PODIO

- LHC experiments / LC studies solutions suffering (partly) from
  - Overly complex data models with deep object-hierarchies
  - Unfavorable I/O performance
- **PODIO**: an EDM toolkit (AIDA2020 project)
  - Plain Old Data, automatic code generation, support for different backends
    - Keep memory model simple, enabling fast I/O and efficient vectorization
    - Consistent / homogeneous implementation, minimizes mistakes
  - High-level description in YAML format
  - Three-layers
    - User: handles objects and collections
    - Object: transient, relations between objects
    - POD: actual data structures
  - Follow-up for next AIDA being prepared
    - Schema evolution, memory and I/O optimizations

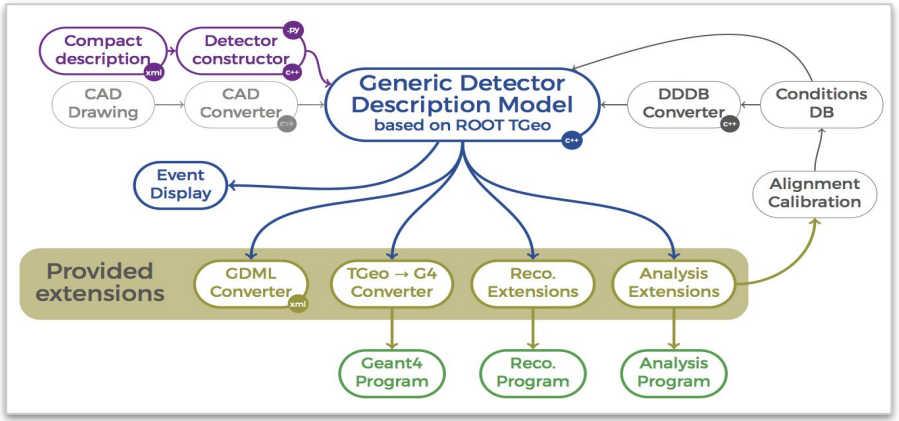
F Gaede, T5 Thu, 11h45



Detector Description: DD4hep

F Gaede, T2
Tue, 16h30

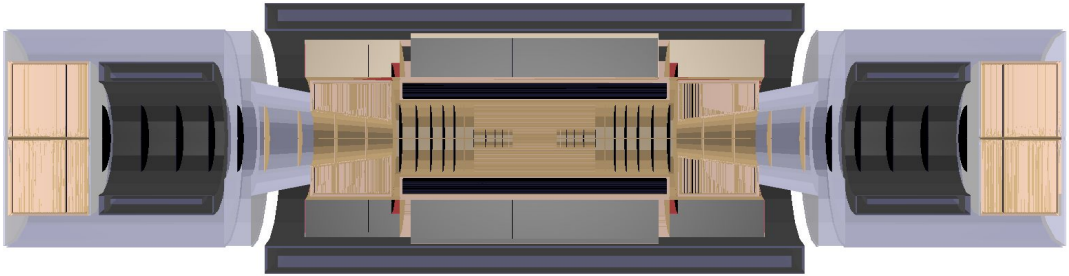
- Generic detector view appropriate to support
  - simulation, reconstruction, analysis, …
- Design goals
  - Complete
  - Single source of information
  - Easy of use



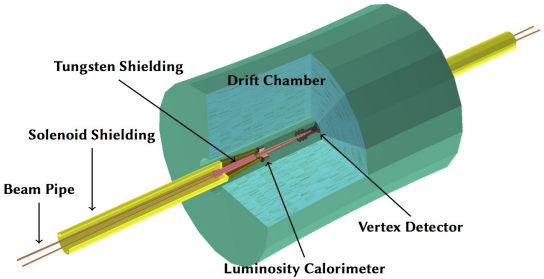
- Part of AIDA2020
- Used by CLIC, ILC, FCC, LHCb, CMS, SCT

DD4HEP and FCCSW

- FCC-hh
  - Reference detector complete



- FCC-ee
  - IDEA Concept
    - Beam Pipe, instrumentation
    - Vertex Detector, Drift Chamber
    - DREAM Calorimeter (under dev)
  - LAr+Tile calorimeter (under dev)
  - CLiCDP



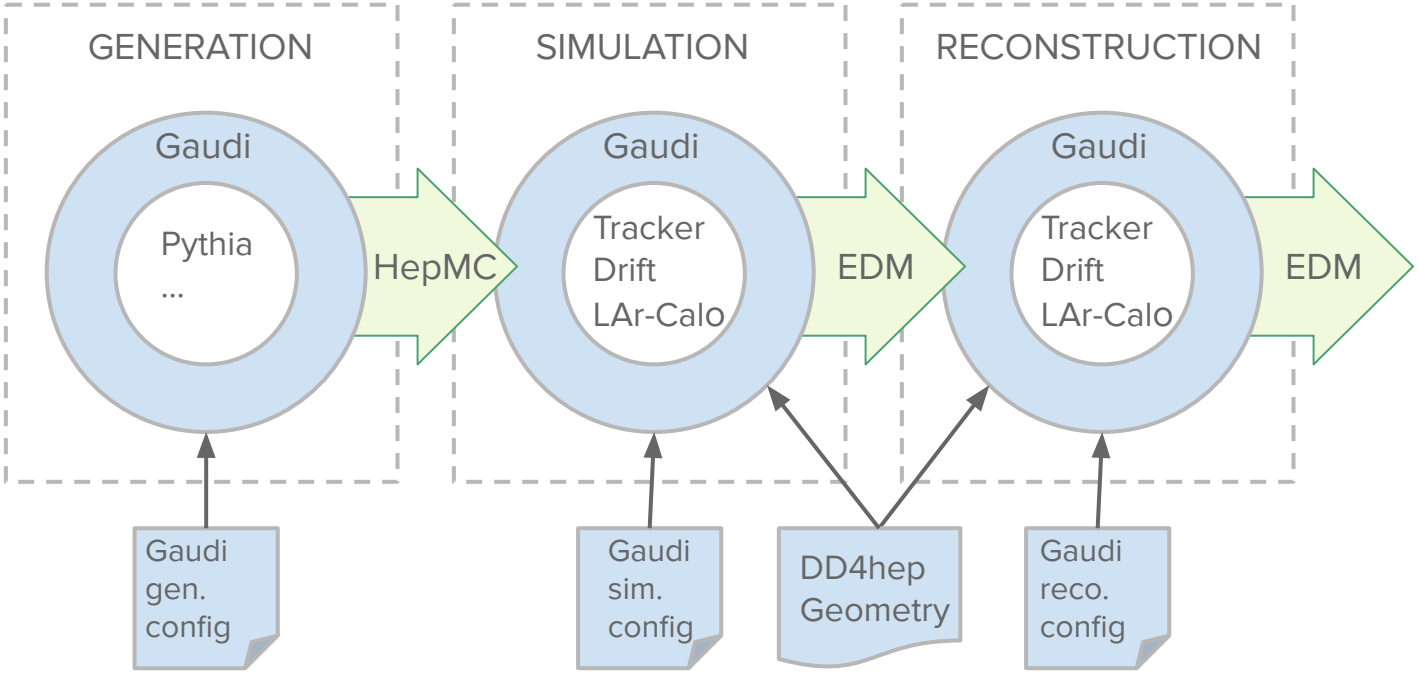
Software Framework: Gaudi

- "*The Gaudi project is a **open project for providing the necessary interfaces and services** for building HEP experiment frameworks in the domain of event data processing applications. The Gaudi framework is **experiment independent**.*"

- Data processing framework designed to manage experiment workflows
  - Separate data and algorithms; well defined interfaces
  - User's code encapsulated in Algorithm's, Tool's / Interface's, Service's
  - Different persistent and transient views of data
  - C++, with Python configuration
- Originating from LHCb, adopted by ATLAS, Daya Bay, GLAST, LZ, …

- Actively developed to face LHC Run 3 and Run 4 challenges (high PU)

Gaudi and FCCSW

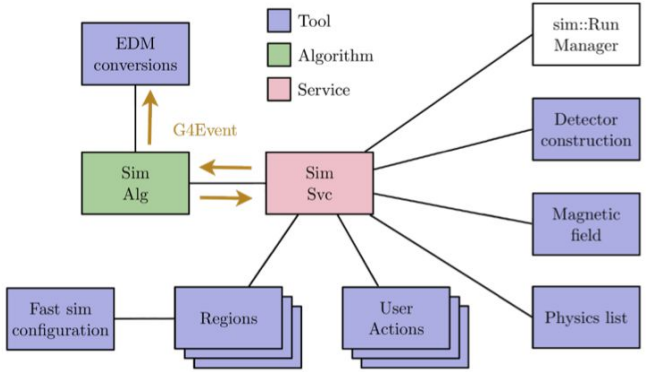


Monte Carlo Generation

- Interoperability with (Monte Carlo) generators at
  - Level 0 - common data formats
    - E.g. HepMC, Les Houches Event Files, MDI
  - Level 1 - callable interfaces
    - E.g. Pythia8
- Pythia8 also acts as LHEF event reader
  - Other converters available (HepMC, HepStd)
- Generator repository: GenSer @ LCG Stacks
  - Available in FCCSW
- MDI codes (MDISim, GuineaPig, ...) use level 0 interoperability
  - Adhoc converters under discussion

Simulation

- Geant4
  - Gaudi components exists to create
    - User Actions
    - Regions
    - Sensitive detectors
    - Selective output options
  - Mixing fast and full G4 simulation possible
    - SimG4Full / SimG4Fast
- Delphes
  - Gaudi interface
    - EDM output

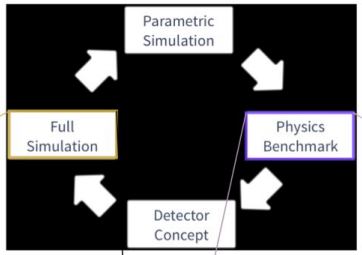


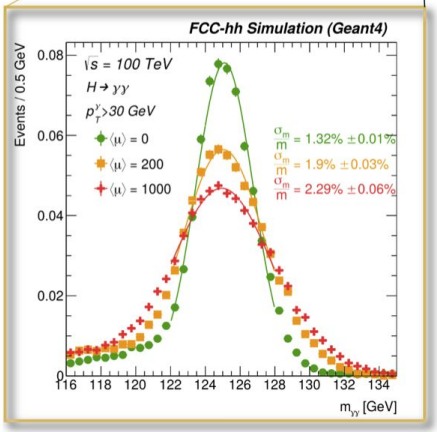
Fast / Full Simulation Interplay

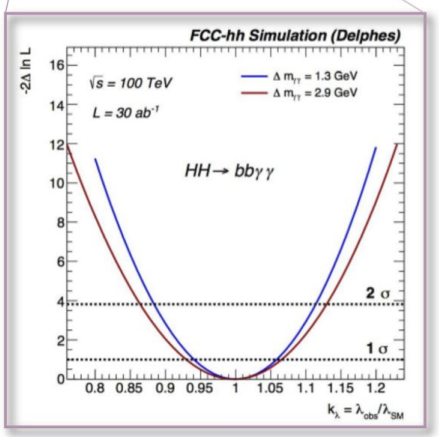
Example:

Higgs self-coupling

@ FCC-hh







Reconstruction

- Challenges: algorithm detector concept independent
  - Fully flexibility, avoid duplication
- Tracking
  - Track seeding (TrickTrack)
  - Hough Transform for drift chambers
  - Under implementation / investigation
    - ACTS integration
    - Conformal tracking
- Calorimeters
  - Sliding window (rectangular/ellipse)
  - Topo-clustering

Analysis considerations

- HEPPY: High Energy Physics with PYthon
  - Modular python framework for the analysis of collision events
- Developed and still used for CMS
- In FCC is used to
  - Process EDM events, apply-preselection, produce a flat and light ROOT ntuple
  - Analyse the ROOT ntuple
    - Not the only code used for this purpose
- Flexible but slow
  - Plan to move to a C++-based analysis framework, e.g. RDataFrame

Software Infrastructure

- Typical HEP development workflow
- Deliverables
  - FCCSW
  - Externals: FCCSW specific dependencies
  - Based on LCG releases
- Deployment on dedicated CernVM-FS repositories
  /cvmfs/fcc.cern.ch, /cvmfs/fcc-nightlies.cern.ch
- Builds (nightlies, releases) managed by **Spack**
  - Good feedback to HSF packaging WG

FCCSW - Main package

FCC externals
fcc-edm fcc-physics tricktrack
heppy podio ...

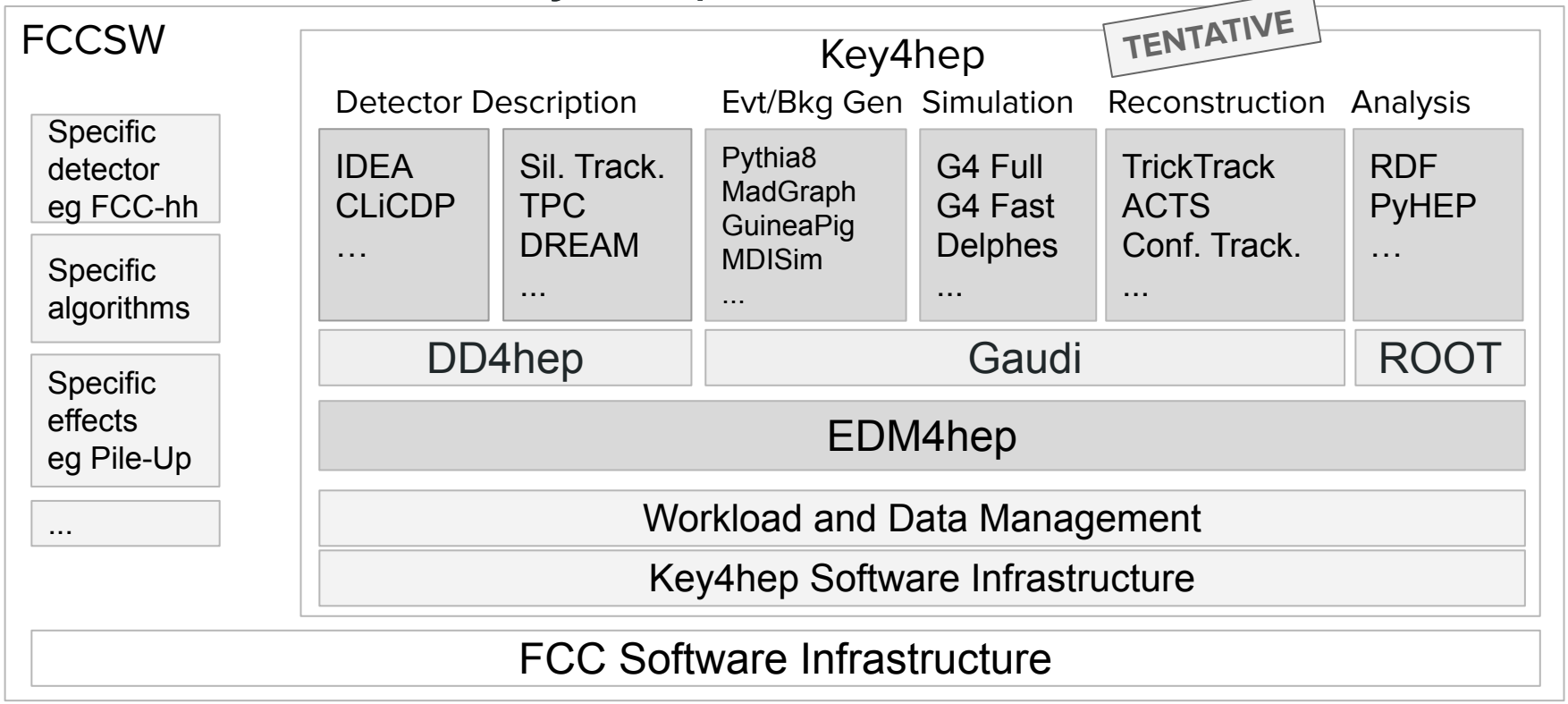
LCG release
Gaudi dd4hep ROOT ...

G Stewart, T5, Tue, 14h00

About the after-CDR for FCCSW

- Requirements:
  - Support more detailed studies, in particular for e+e-, focusing on
    - *Completeness*: state-of-Art generators, MDI, reconstruction / analysis algorithms, …
    - *Flexible detector description*: easy switch / replace sub-detectors, change dimensions / layout
- **Current approach** seems **adequate** to fulfill the requirements
- Foster and support
  - Participation from FCC institutes worldwide
  - Activities such as Key4HEP, which formalize and extended the FCCSW approach

Connection with Key4hep

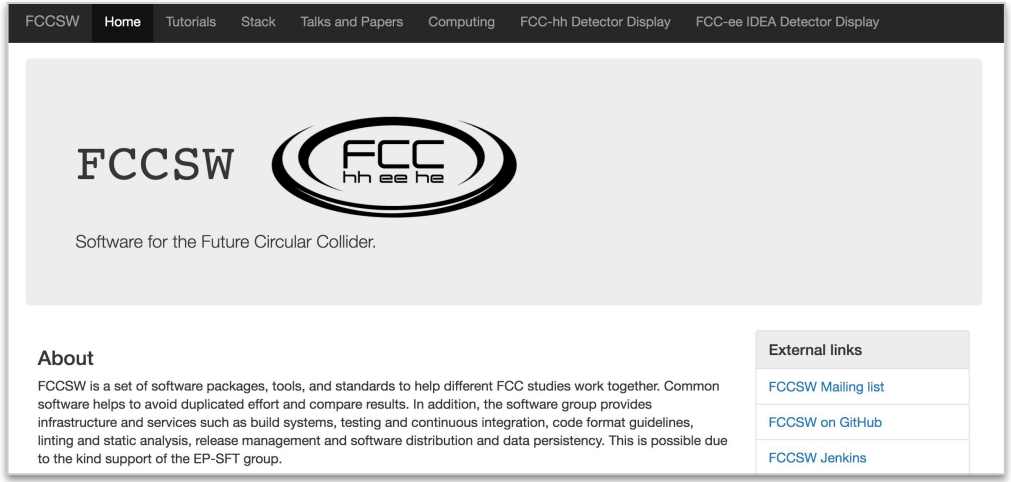


Summary

- The FCC software stack assembled using as much as possible existing components
- Served well the purposes of the CDRs
- Started a new phase to further develop to support more detailed studies, in particular for e+e-
- Follow closely, participate and collaborate new common activities {Key4hep, EDM4hep}

Thank you!

- https://cern.ch/fccsw



Backup

Gaudi and FCCSW

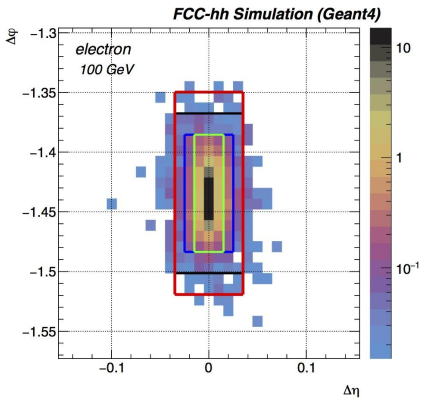
- Python scripts to configure tools and algorithms and define their processing order

```
$ fccrun \                                                  # Generic Gaudi app
      ./Examples/options/geant_fullsim_fccee_pgun.py \      # job definition
      --energyMin=10  --energyMax=10 --particleName=”mu-” \ # parameters
      --n=1000 --filename=fccee_idea_mu.root
```

- Each algorithm defines its parameters which can be overwritten of the command line

Calo Reconstruction Example

- Single 100 GeV e- reconstructed by sliding window



- Single 100 GeV pion in 8+10 layers of the E+HCal reconstructed by topo-cluster