FCC Software Overview

FCC LHCb software discussion

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CERN-EP

FCC Software (FCCSW) today

- FCCSW is still largely what was used for the CDR
- Good modular structure based on Gaudi (LHCb, ATLAS)
  - Base for Key4hep
- Provide support for all the required functionality
  - Event Data Model (EDM), Generators, Detector geometry, Fast/Full simulation, Reconstruction, ...
- Current main limitations are in the implemented functionality
  - Available generators, in particular for FCC-ee
  - Palette of detector concepts with parametrized description
    - Quality of the description
  - Palette of detectors with detailed geometry description
    - Digitisation of their signal
  - Reconstruction algorithms

FCC Software tomorrow

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) and contribute to the development of a Common Turnkey Software Stack (Key4hep)
    - One framework (Gaudi best candidate), DD4hep, EDM4hep, Geant4, ROOT, …

- Follow-up in Hong Kong, 17 January 2020
  - Present: ILC, CLIC, FCC, CEPC
  - Agreed to set-up regular weekly meetings, a GitHub repository, documentation, deployment area on CVMFS, …
    - Get quickly first version of EDM4hep and Key4hep available

Today status: {EDM4hep v0.2, Key4hep v0.1}; ready to start testing

Mandate for the after-CDR FCC software

- Support for more detailed studies, in particular for e+e-, focusing on
  - Completeness
    - State-of-Art generators, MDI support, reconstruction / analysis algorithms, …
  - Flexible detector description
    - Easy switch/ replace sub-detectors, change dimensions / layout, …
  - Easy-of-use
    - Low usability thresholds and fast / easy learning curve
  - Adequate computing support and CPU / storage resources
  - Extensive documentation and regular training
- Ensure that SW is part-and-parcels of the Turnkey Software Stack
- Foster development and use in
  - Physics studies, Detector optimization, Machine-Detector Interface
- Foster / support substantial participation for FCC institutes worldwide

Experimental challenges for FCC-ee (on software)

- Ref: A Blondel @ FCC Physics on March 30th and case studies
- Requirements on detector understanding O(1-2) better than LEP
  - Need to simulate a lot of (reliable) data
- Priority is to have **as soon as possible**
  - Flexible **full** simulation and reconstruction for case and detector design studies
    - b-tagging, reconstruction and vertex geometry, tracking, PID etc.
  - Flexible **fast** simulation to support case studies
    - And also generator-level studies, or brain activity
- Independent of Snowmass
  - But Snowmass may be instrumental to foster activities and provide synergies
- Possible computing efficiency issue (in particular @ Z)
  - Interplay fast / full simulation may be required to mitigate

What can we do for FCC-ee with what we have today?

Monte Carlo Generators and FCCSW

- Generators repository: GenSer @ LCG software stacks
  - Generator Service hosted by EP-SFT @ CERN

    Collaboration with the authors and with the LHC experiments to prepare validated code for communities at the LHC
  - Actively used by ATLAS, LHCb, SWAN and some SME experiments
  - Deployed via CernVM-FS
- MC generators are typically standalone codes
  - Noticeable exception is Pythia8, which provides a callable interface
- FCCSW interoperates MC generators mostly through common data formats
  - HepMC, LHEF
- Pythia8 used to read HepMC, LHEF files

MC Generators: status and areas of work

- GenSer generators palette biased towards LHC
  - Good for FCC-hh, incomplete for FCC-ee
- General purpose generators such as Pythia8, Whizard, MadGraph5 available
  - But we need to get experience on how to use them effectively for FCC-ee
- Old LEP generators (KKMC, BHLUMI, MCSANC, BabaYaga, …)
  - Not available yet, but (often) still State-Of-Art
  - Wrappers to produce HepMC and/or LHEF output required

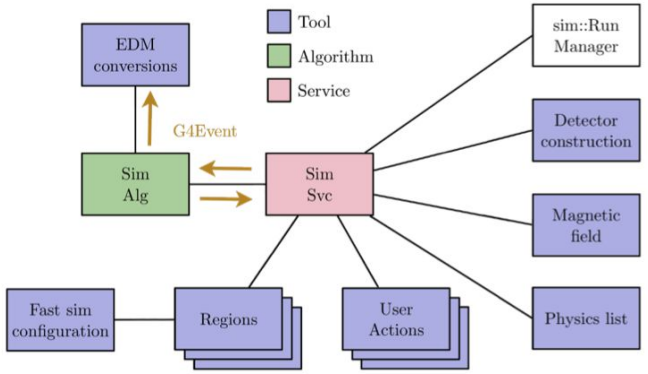
Contributions welcome/required on interfacing and testing

Experience needed for interfacing: FORTRAN, FORTRAN&C++ interplay

For testing: ability/willingness to understand settings of a given generator

Simulation

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



Reconstruction

- Challenges: algorithm detector concept independent
  - Full flexibility, avoid duplication
- Tracking
  - Track seeding (Silicon tracker, FCC-hh), Hough Transform (drift chambers, FCC-ee)
  - Under development / investigation: ACTS integration, Conformal tracking
- Calorimeters
  - Sliding window (rectangular/ellipse), Topo-clustering
  - Under development / investigation: ML techniques

Possible contributions: tracking, vertexing, ACTS, ML, particle ID

Experience needed: familiarity with reconstruction algorithms, Gaudi, C++

End-User Physics Analysis

- Output of previous steps are ROOT TTrees
- High-level interfaces, typically python-based, proved to be convenient
  - E.g. HEPPY, modular python framework for the analysis of collision events (CMS)
  - Flexible but (very) slow
- ROOT RDataFrame replacement of HEPPY available
  - Users being pushed to use it
- Room for development and introduction of new technologies
  - E.g. efficient python-steered ecosystems, e.g. numpy, awkward arrays

Possible contributions: develop HEPPY replacement based on RDataFrame or other fast technology (e.g. awkward arrays)

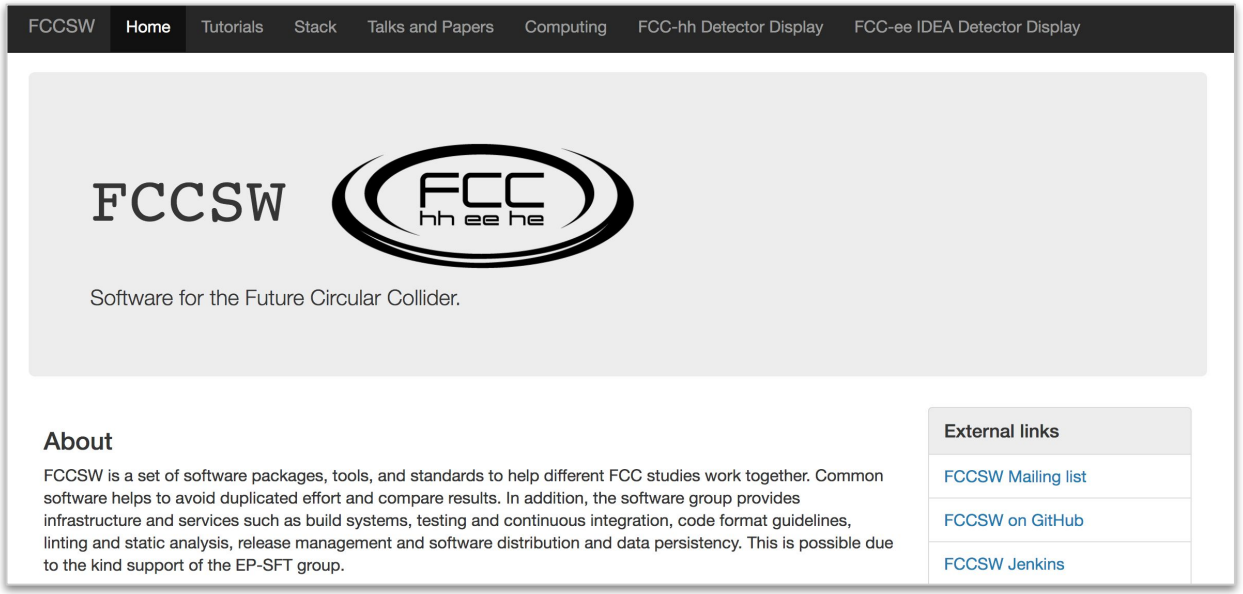
Experience needed: familiarity with ROOT and RDataFrame; advanced Python

Summary

- Software is essential during this phase of the project
  - No CDR+/TDR without a robust software
  - Should be carefully designed for long term usage
  - The current software stack, assembled using as much as possible existing components, served well the purposes of the CDRs
- New phase very challenging
  - Unprecedented level of precision expected at FCC-ee
  - Potentially orders of magnitude more Monte-Carlo than LHC
- Try to get as much as possible from the community
  - Following closely, participate-to, collaborate-w/ common activities {Key4hep, EDM4hep}
- Everyone should feel concerned
  - Immediate areas of work identified

Thank you!

- Web site https://cern.ch/fccsw



Backup

Areas of work summary

- MC generators
  - Interfacing, testing
- MDI
  - Shared formats
  - GuineaPig++ integration
  - Overlay of MDI/signal events
- Detector concepts
  - IDEA DR Calo full simulation
  - IDEA Muon system full sim
  - Validation of LAr Ecal for FCC-ee
  - Enabling of CLD in FCCSW/k4h
- Validation/testing of Delphes cards
- Reconstruction
  - Tracking algorithms
  - Vertex reconstruction
  - ACTS integration
  - ML for calo reconstruction
- Identification
  - e, mu, tau, c, b tagging / ID
- Analysis tools
  - RDataFrame based analysis
- AoB
  - Porting to other OSs
  - ...

FCC detector concept palette for Delphes

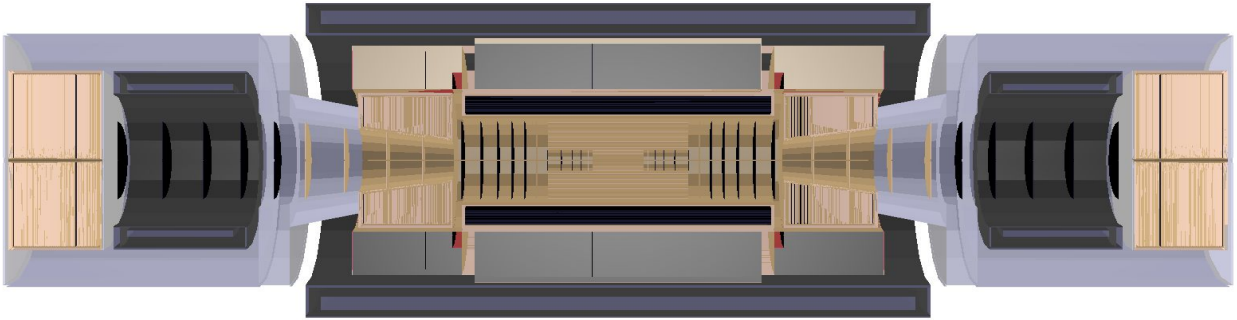
- Validated and used for CDR
  - FCC-hh baseline, HL-HELHC baseline
- IDEA, CLICDet and others available for FCC-ee
  - Not extensively used, need validation
- Latest version of Delphes includes TrackCovariance, dEdx, ParticleDensity
  - Enable simulation vertexing, b-tagging, …
  - Help developing/understanding algorithms

Possible contributions: testing, validation, fine tuning of existing cards; scripts or tool to easy variate relevant dimensions

Experience needed: familiarity with Delphes, Gaudi, simulation

FCC detector palette in DD4hep: FCC-hh

FCC-hh CDR baseline



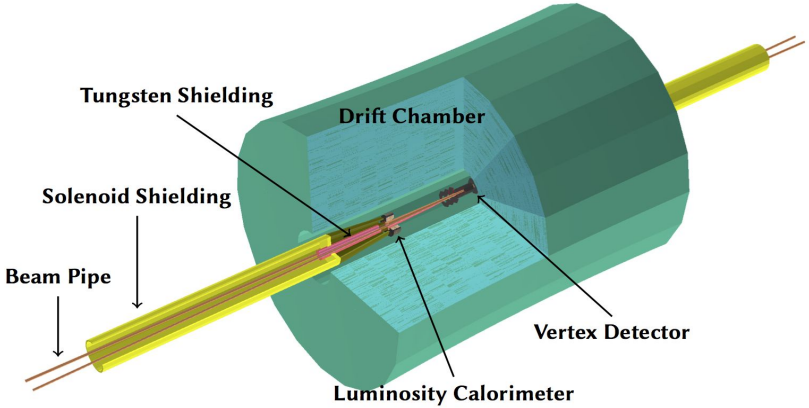
- Barrel, Endcap, Forward
- Beam Pipe, Shielding, Magnet solenoid
- Silicon Tracker
- LAr ECal, Tile HCal
- Muon System

FCC detector palette in DD4hep: FCC-ee

FCC-ee IDEA

CLD

- Beam Pipe, Beam instrumentation
- Lumical, HOM Absorber
- Vertex detector
- Drift Chamber
- Dual Readout Calorimeter
- Muon System



DR calo full simulation available in “standalone”. Integration in FCCSW/Key4hep requires:

- Translation of geometry in DD4hep format
  - Requires support for optical properties, available in DD4hep since 11/2019
- Integration of digitisation

FCC detector palette in DD4hep: FCC-ee

Possible alternatives for FCC-ee

- "IDEA" tracker with reduced version of LAr ECal + Tile HCal
  - First DD4hep description available for testing
- CLD
  - Geometry description in DD4hep exists: https://github.com/iLCSoft/lcgeo
  - Requires integration in FCCSW (digitisation modules exists in iLCSoft)
  - Work in Progress

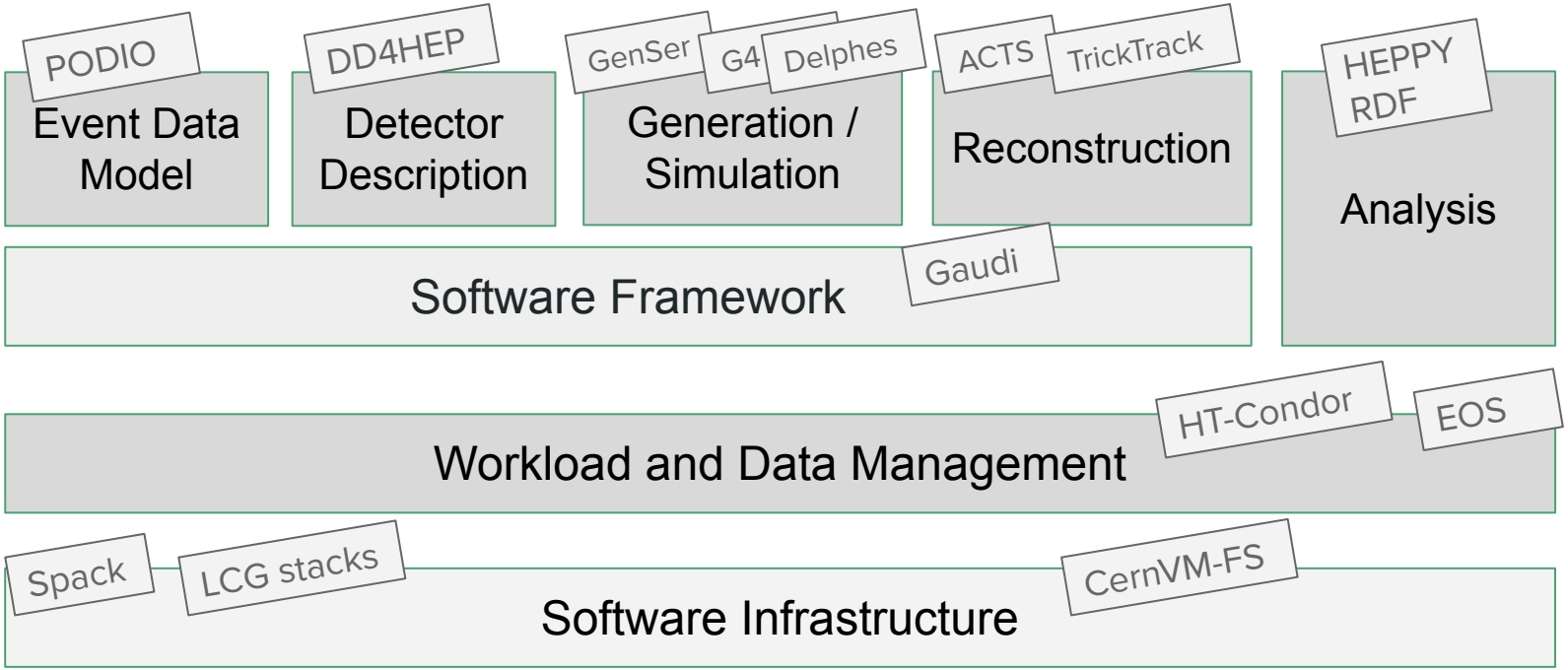
Contributions welcome/required on:
- IDEA: cross-check/complete existing stuff or provide (DR calo, muon) DD4hep descriptions and digitization
- Enabling of CLD in FCCSW: digitisation, ...

Experience needed: familiarity/willingness to learn: DD4hep, detector geometry, Geant4

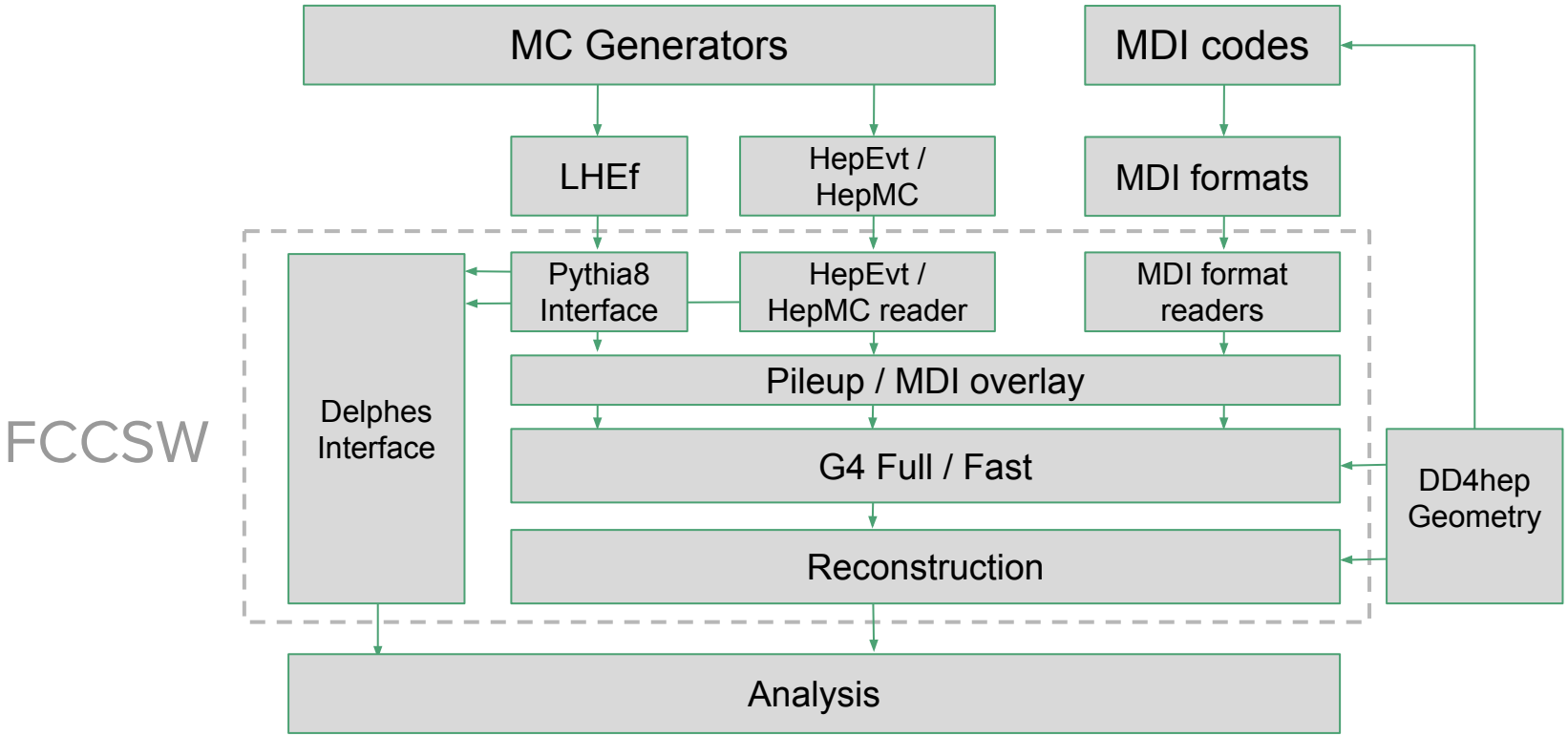
Key4hep/EDM4hep and Delphes

- EDM4hep v0.2 available
  - Should be OK for FCC-ee
- Key4hep v0.1 includes K4FWCore steering component
  - Equivalent, and derived from, to FWCore in FCCSW
- Prioritization of the DelphesInterface module addition under discussion
  - Derived from FCCSW SimDelphesInterface

Available components



Typical workflows

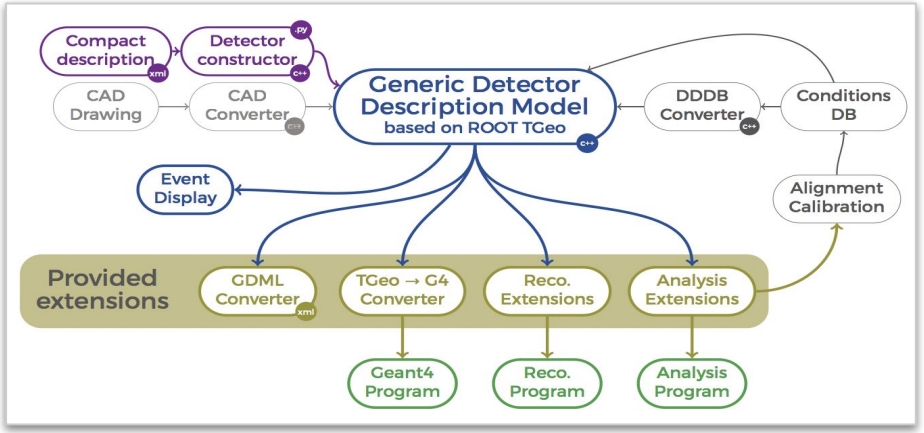


Event Data Model

- Current FCC-EDM
  - Event/Run: EventInfo
  - MC truth: MCParticle, GenVertex, GenJet
  - Tracker: Track (PositionedTrackHit, TrackCluster, TrackState)
  - Calorimeter: CaloCluster (PositionedCaloHit)
  - Associations: ParticleMCParticleAssociation, DigiTrackHitAssociation, CaloHitAssociation, CaloHitMCParticleAssociation
  - High-Level objects: TaggedParticle, Vertex (WeightedTrack), TaggedJet, ResolvedJet, MET
- Tuned on the needs of FCC-hh
  - High-level objects of LHC inspiration
- TaggedParticle contains cross association between tracks and calo objects

Detector Description: DD4hep

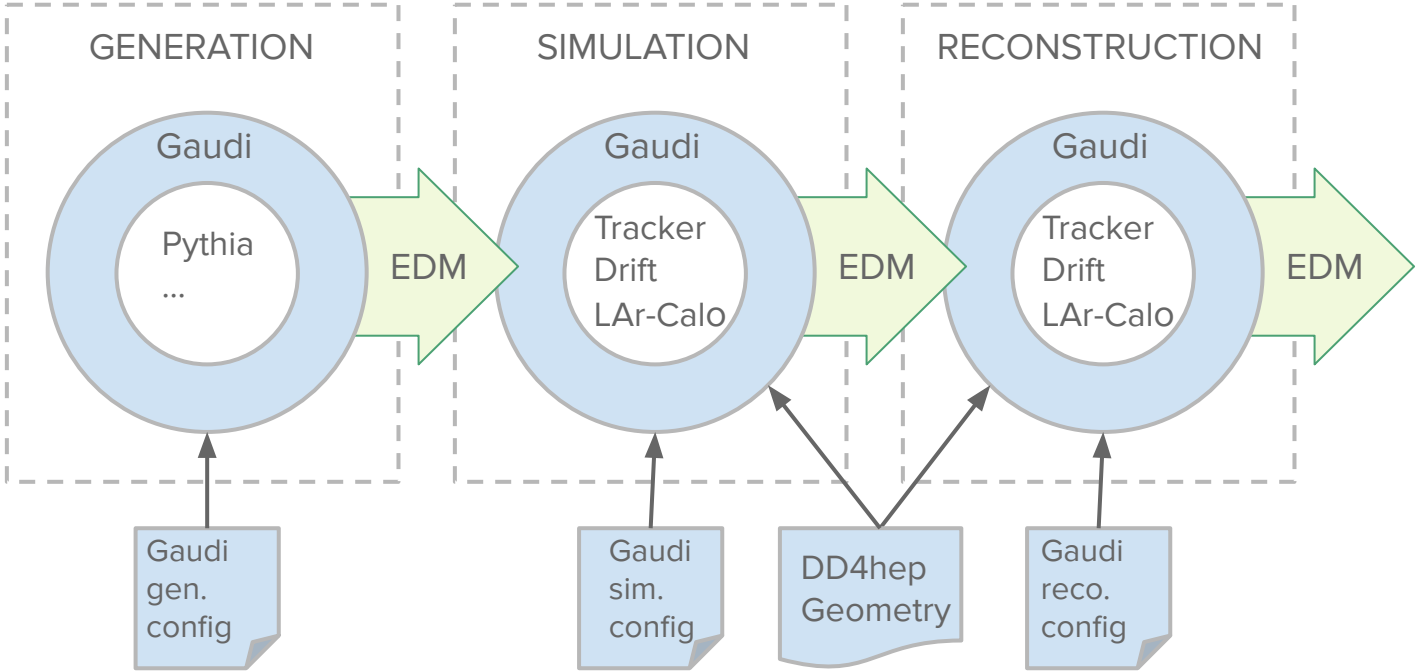
- Generic detector view appropriate to support
  - Simulation, reconstruction, analysis, …
- Design goals
  - Complete detector description
  - Single source of information
  - Support all stages of the experiment
  - Easy of use
- Part of AIDA2020
- Used by CLIC, ILC, FCC, LHCb, CMS, SCT



Software Framework: Gaudi-based

- Framework toolkit to provide required interfaces and services to build HEP experiment frameworks
  - Opensource project and 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, Gaudi is adopted also by ATLAS
  - Actively developed to face LHC Run 3 and Run 4 challenges (high PU)
- Using the latest Gaudi version (v32r2).

Gaudi and FCCSW



Software Infrastructure

- Typical HEP development workflow

- Deliverables
  - Full dedicated LCG stack
    - LCG_97a_FCC_2, LCG_97a_FCC_3
  - Full Spack managed build

- Deployment on dedicated CernVM-FS repositories
  - /cvmfs/fcc.cern.ch/
    - Also /cvmfs/fcc-nightlies.cern.ch/ for testing

FCC specific
fccsw fcc-physics fcc-edm

LCG release
Gaudi dd4hep ROOT ...

OS support

- Currently CERN-centric
- Support for the default version running on lxplus
  - CentOS 7, gcc 8, gcc 9
  - Experimental support for Ubuntu 20.04 LTS, MacOsX
- VM, based on CernVM, available to recreate equivalent environment
  - Works from everywhere but speeds depends on the network

Possible contributions: provide support for other OSs (Ubuntu, MacOsX, …)

Experience needed: familiarity with build systems, linux, ...

CERN resources and access policy

- CERN resources are available to member of institutes having signed the Memorandum of Understanding and its addendum
- EOS areas for data or large files: /eos/experiment/fcc
  - Current quota: 400 TB
  - E-group membership: fcc-eos-access (and alike)
  - Dedicated areas for ee, hh, eh, helhc, users
    - Plan to deprecate ‘users’: each CERN user has 1 TB at /eos/user/*u*/*username*
    - Needs to be enabled on Account Management page
- EOS areas for shared files: /eos/project/f/fccsw-web/www
  - Also accessible also via web
- Dedicated queue on LXBATCH
  - AccountingGroup = "group_u_FCC.local_gen" (on HTCondor)
  - E-group membership: fcc-experiments-comp