CEPC Software Status and Plan

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- Simulation
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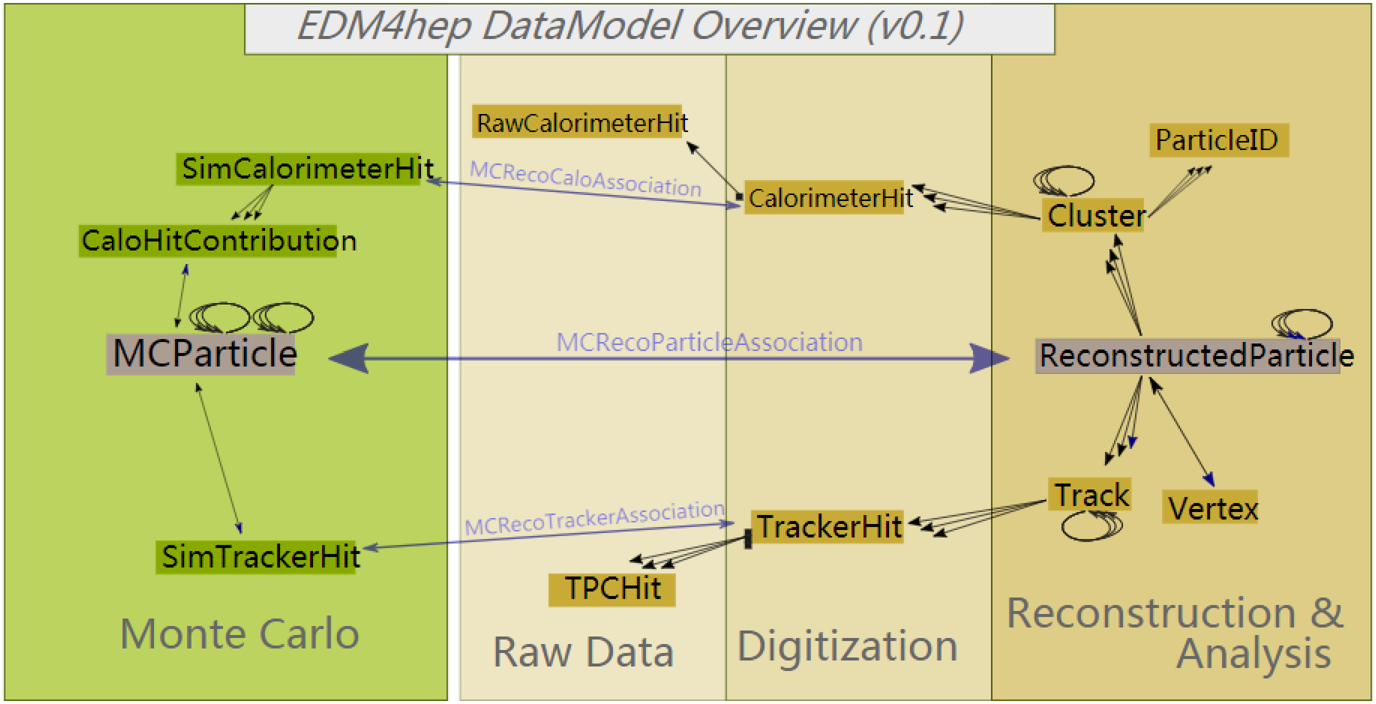
Event Data Model: EDM4hep

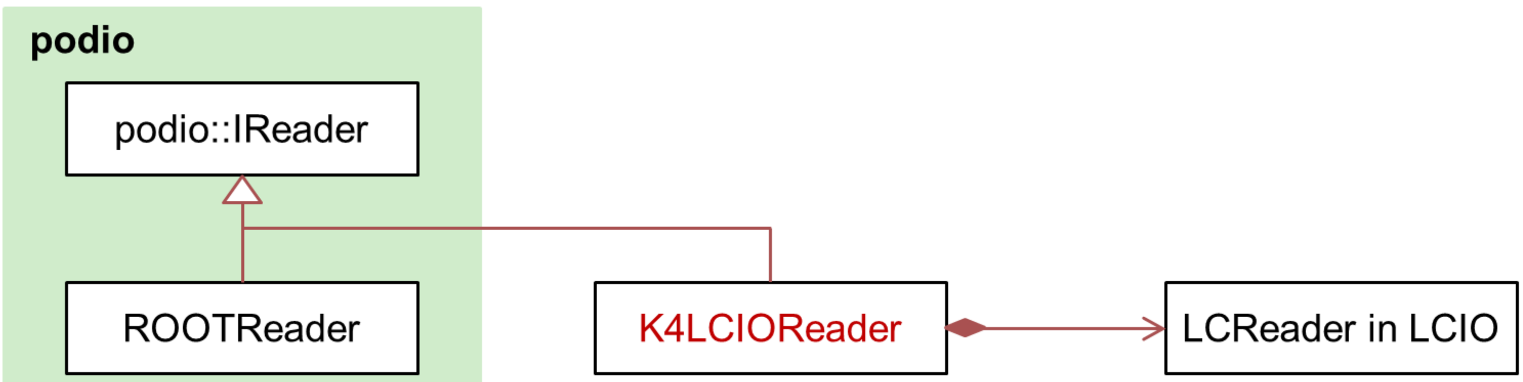
- EDM4hep: official and common EDM in Key4HEP
  - The first version (v0.1) has been released recently
  - Close to plcio, which we are using in the CEPCSW prototype



- Github repository: https://github.com/key4hep/EDM4hep

Event Data Model: Reading LCIO Data

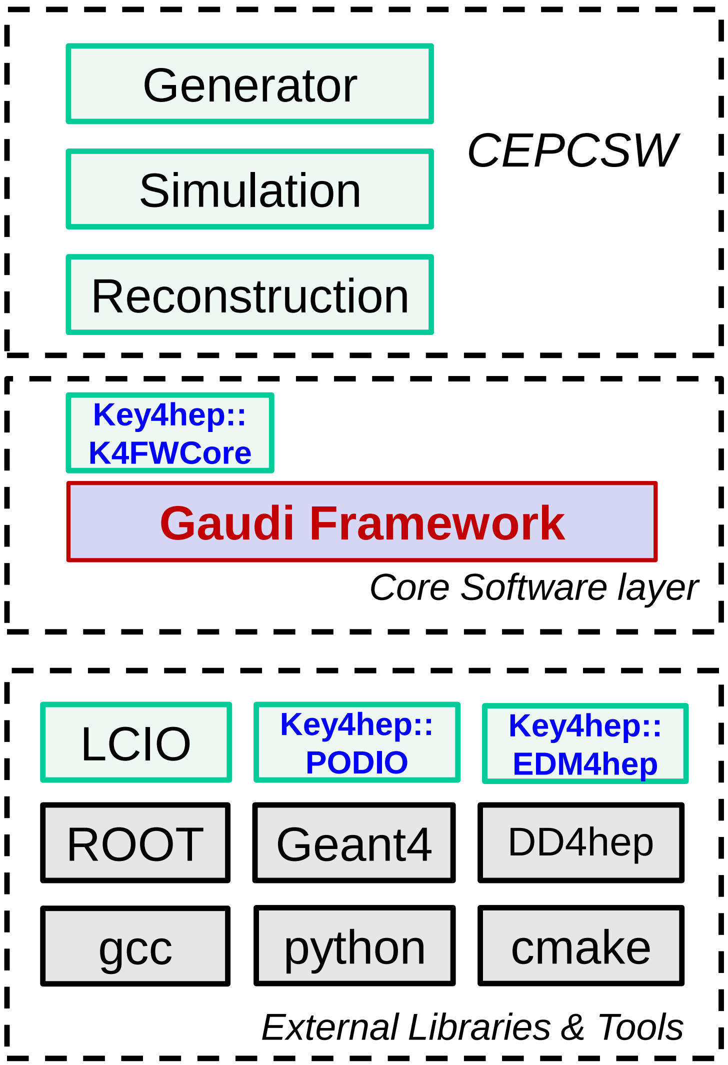
- **K4LCIOReader**: https://github.com/ihep-sft-group/K4LCIOReader
  - Generate EDM4hep data collections from LCIO format data
  - A standalone package that can be used without Gaudi



- **LCIOInput**: https://github.com/ihep-sft-group/LCIOInput
  - A Gaudi algorithm wrapper of K4LCIOReader
  - Read LCIO data in Key4HEP modules

Event Data Model: Testing at CEPC (1)

- Common tools
  - CMake: building & deployment
    - Gaudi cmake macros
  - Spack: Package manager
    - K4spack: https://github.com/key4hep/k4-spack
  - Git: version control
    - http://cepcgit.ihep.ac.cn/cepc-prototype
  - CVMFS: software distribution
    - CEPC specific: /cvmfs/cepcsw.ihep.ac.cn/prototype
- Layered External Libraries
  - CEPC specific libraries
  - Key4HEP libraries
  - LCG libraries (from CERN CVMFS)
  - FCC libraries (optional)



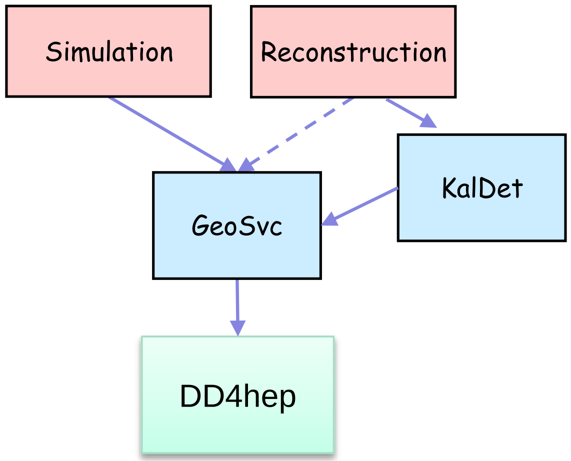
Event Data Model: Testing at CEPC (2)

- In order to use Key4HEP
  - migrated to the official LCG 97 (SLC6 version)
  - original CEPC software based on FCC's extension of LCG 94

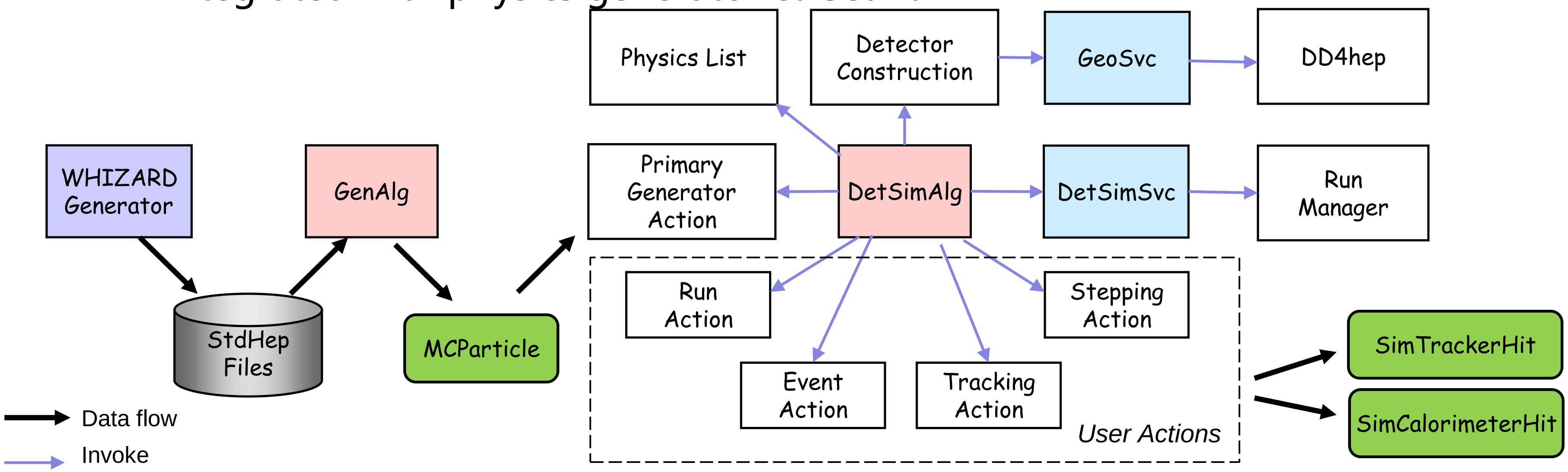
- Status
  - Define a new directory hierarchy using new naming convention.
    - /cvmfs/cepcsw.ihep.ac.cn/prototype/releases/externals/97.0.1
  - 7 external libraries were built with C++ 17 standards.
    - EDM4HEP master, Gaudi v33r1, GEAR 1.8 (CEPC modified), LCIO 2.13.3, plcio 0.1 (CEPC modified), podio master, Pandora (PFA 3.13.3, SDK 3.3.3, LC Content 3.1.4)
  - A dedicated branch was created for development & validation.
    - http://cepcgit.ihep.ac.cn/cepc-prototype/CEPCSW/tree/lcg97
    - Most of changes are due to changes of Gaudi.

Geometry data management (1)

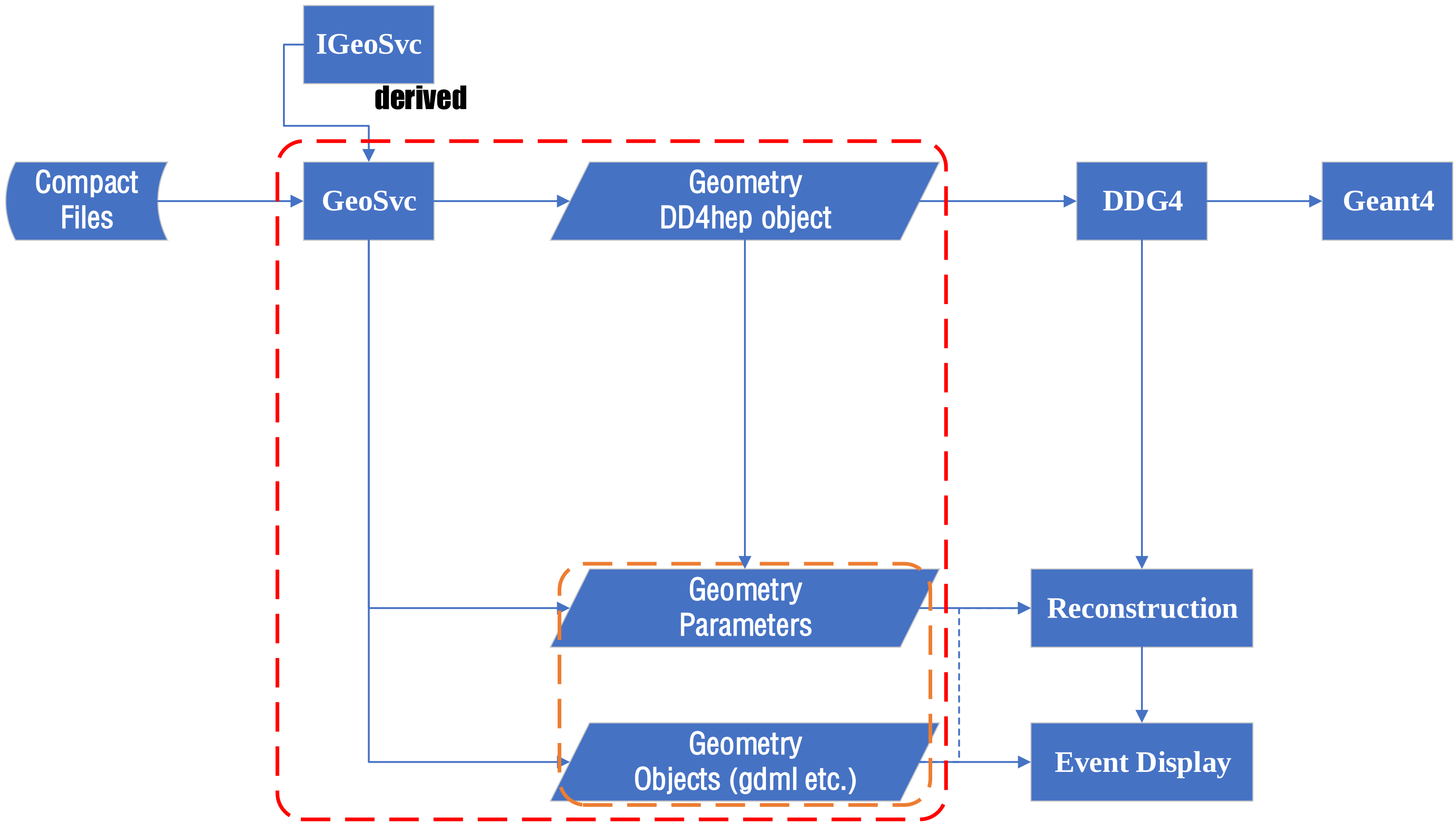
- Unified Geometry Service
  - Interfaced to DD4HEP
  - Used by simulation and reconstruction
  - To keep compatible during migration, KalDet is kept but the underlying geometry information is from GeoSvc.



- Simulation tool
  - Integrated with physics generator & Geant4

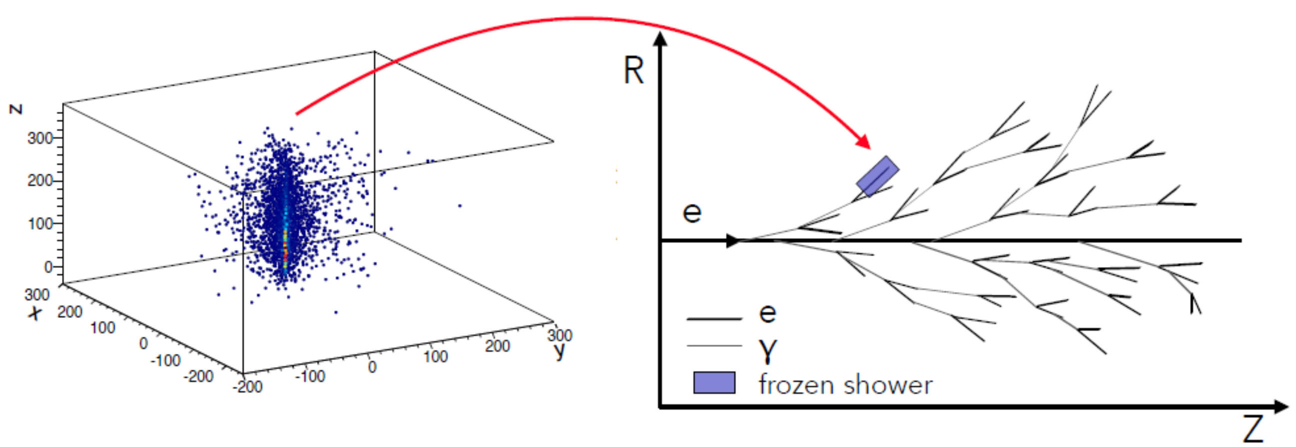


Geometry data management (2)



Simulation: fast calorimeter simulation (1)

- Developing frozen shower (FS) method for calorimeter fast simulation
- During the FS simulation the low-energy particle are substituted with pre-generated shower from the library
- The purpose of the FS library is to store the shower and the condition, with which this shower was generated
- When requested, the library should return the shower with features as close to the required, as possible
- FS in steps:
  - Library generation: need to be performed only ones. Library is created with respect of the shower properties
  - Fast simulation: showers from the library is used instead of filly simulated showers

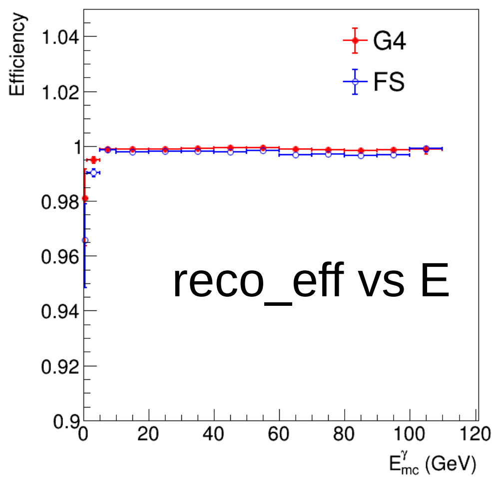


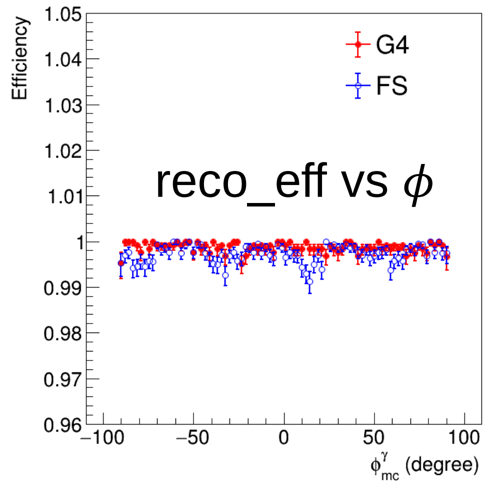
Simulation: fast calorimeter simulation (2)

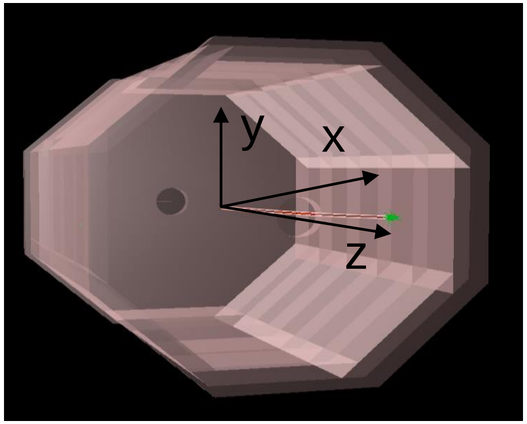
- Implementation
  - Creating the frozen shower library of electrons (or positrons) for ECAL barrel
  - Getting frozen showers with the start point as the key (E, θ, ϕ, x)
  - Adding MC hits of frozen showers to MC hit collection of the event
- Shower library binning: 1 MeV for energy (100 MeV to 1 GeV), 1 degree for $\theta(50^{\circ}$ to $90^{\circ})$, 1 degree for $\phi(-25^{\circ}$ to $25^{\circ})$, 1 mm for x (1870 to 2000 mm)
- Library size is ~ 32 GB, currently saved in uncompressed ROOT files

Simulation: fast calorimeter simulation (3)

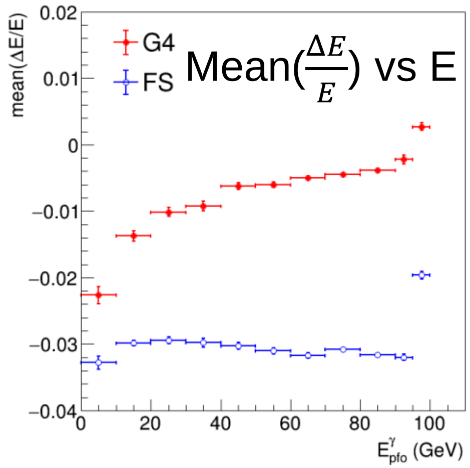
- Check physics performance of γ for the FS simulation

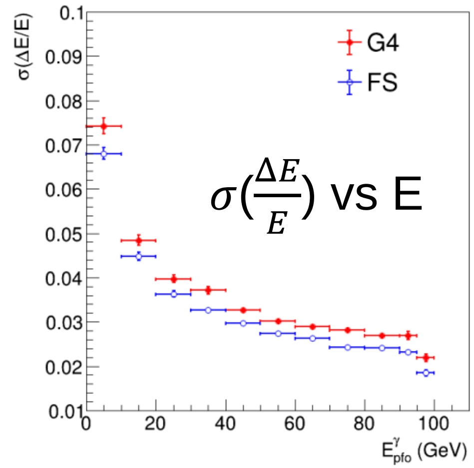






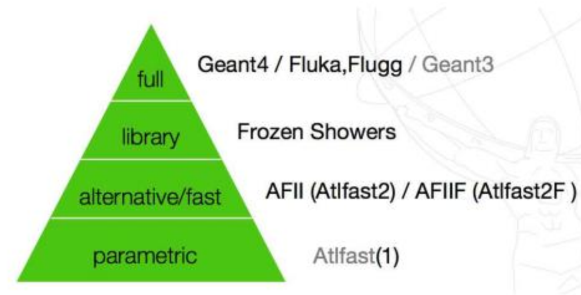
- The reconstruction efficiency is a bit lower in stave concatenation region
- Need some tuning to improve the agreement between G4 and FS results



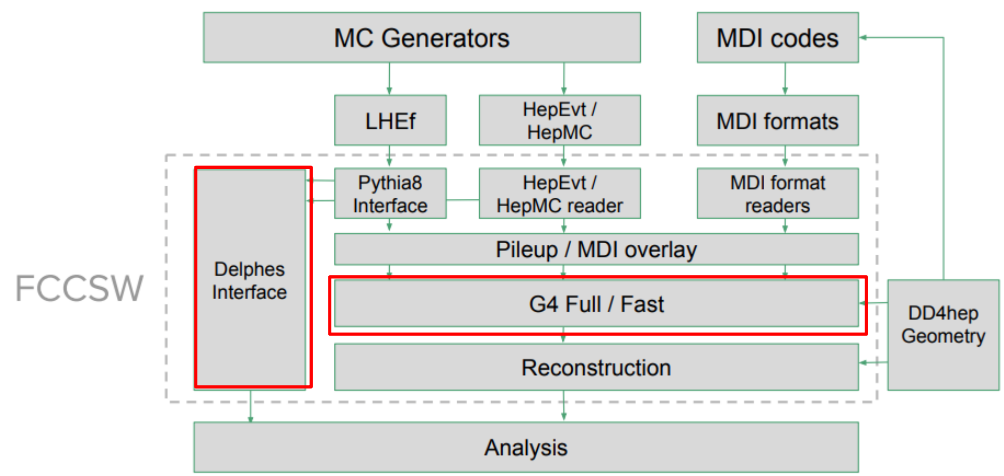


Simulation: fast simulation framework (1)

- Motivation: integrate the full and fast simulation in the same framework.
  - Full simulation (Geant4) $\mathcal{O}(1)$
  - Fast simulation $\mathcal{O}(1/100)$
  - Parametric simulation $\mathcal{O}(1/1000)$



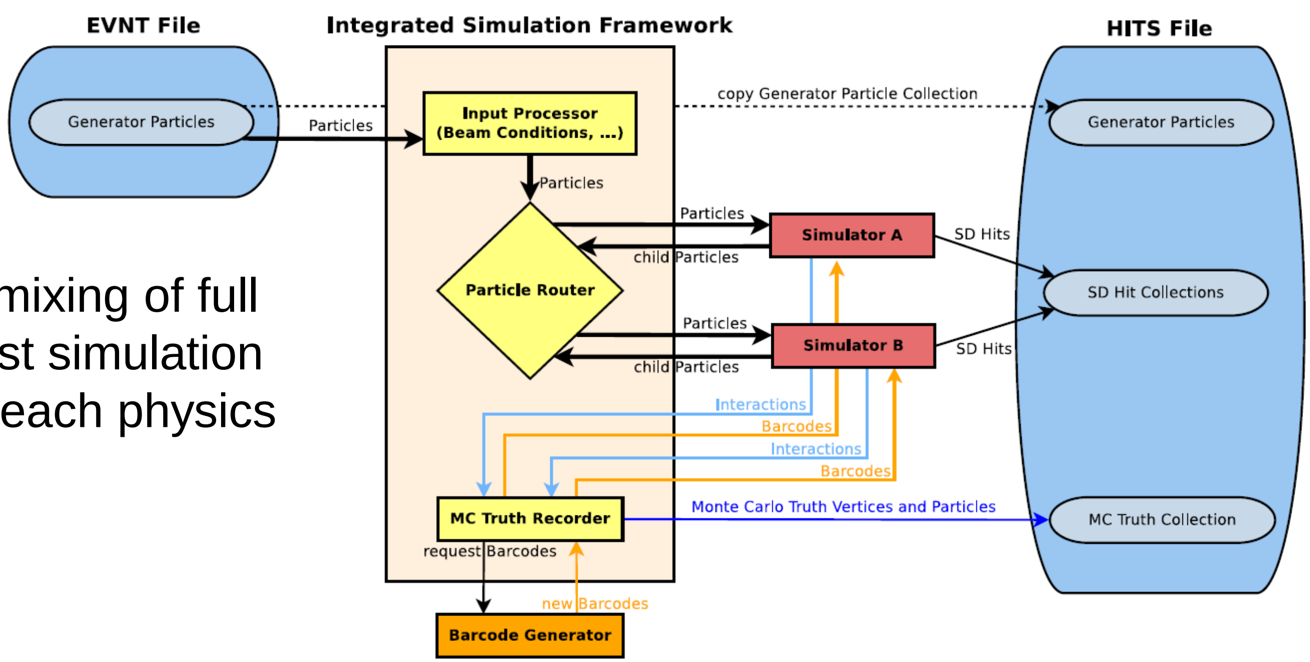
- Current status: evaluation of existing solutions
- Fast simulation in FCCSW
  - There are two types:
    - Geant4 region-based
    - Delphes-based
  - Allow mixing of full and fast simulations
  - when a particle enters a certain detector region, the user-defined simulation tool will be used.



Simulation: fast simulation framework (2)

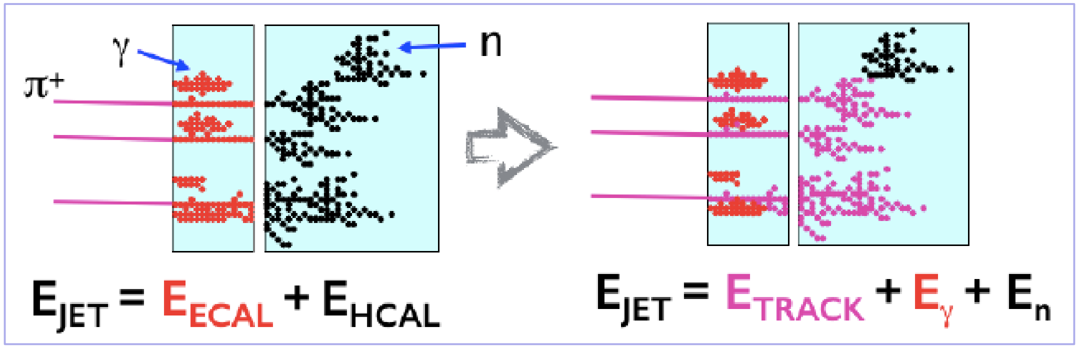
- Fast simulation in ATLAS
  - ATLAS had developed a power framework called ISF (Integrated Simulation Framework)
  - All the particles are routed by the ISF to the corresponding simulators.
    - More flexible than the Region-based solution.

Allow mixing of full and fast simulation within each physics event.



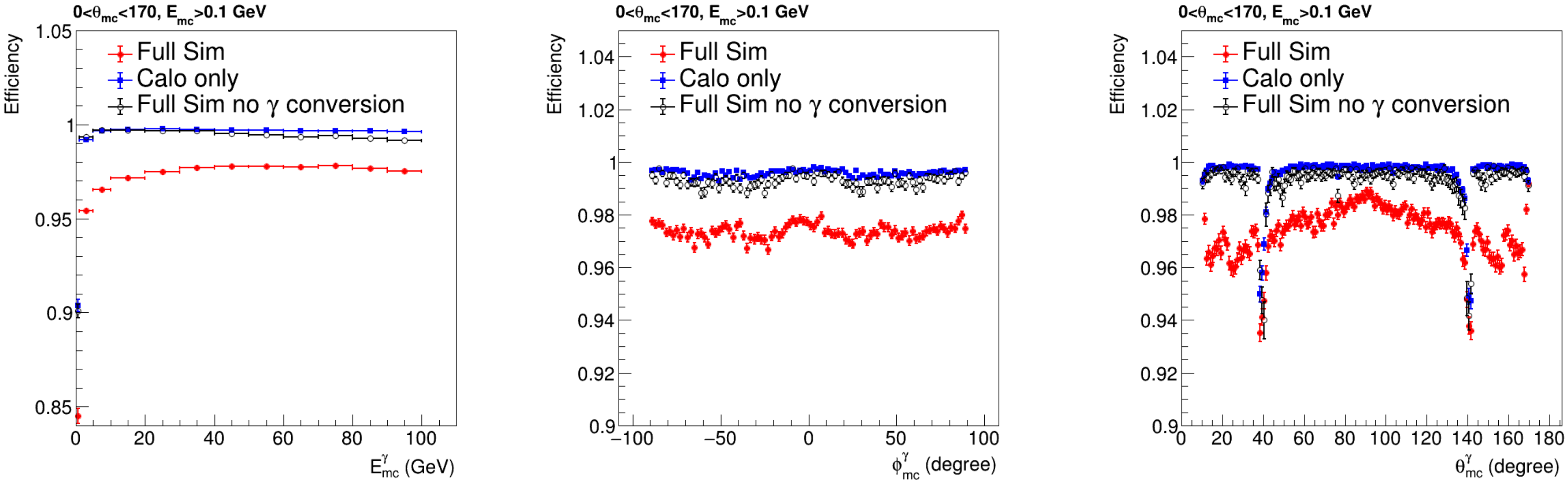
Reconstruction: Pandora

- Pandora uses dedicated pattern recognition methods to reconstruct particles in the jet
- Using Pandora, the energy of jet can be expressed by $E_{Jet} = E_{Track} + E_{\gamma} + E_{n}$. Therefore, most of energy in jet (~60%, from charged hadrons) can be measured by tracker precisely, 30% of the energy (mainly from $\pi^0 \rightarrow \gamma\gamma$) can be well measured by ECAL, and 10% of the energy (e.g. K_L) will be given by HCAL



Reconstruction: porting Pandora to CEPCSW (1)

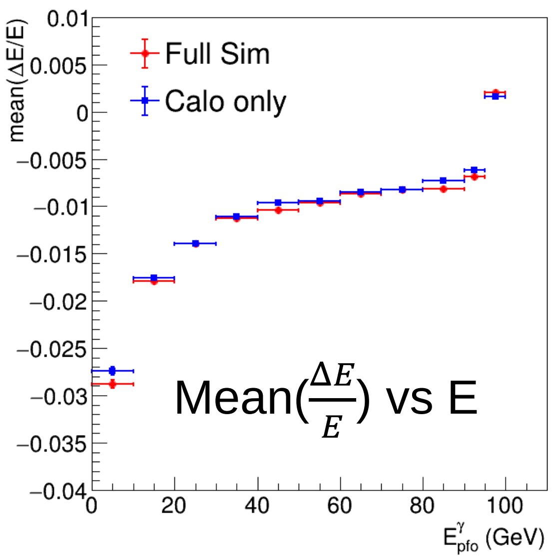
- Managed to port MarlinPandora to CEPCSW framework
- Using single γ to check the pandora performance
- Below are γ reconstruction efficiencies as function of E_{mc} , θ_{mc}, and ϕ_{mc}

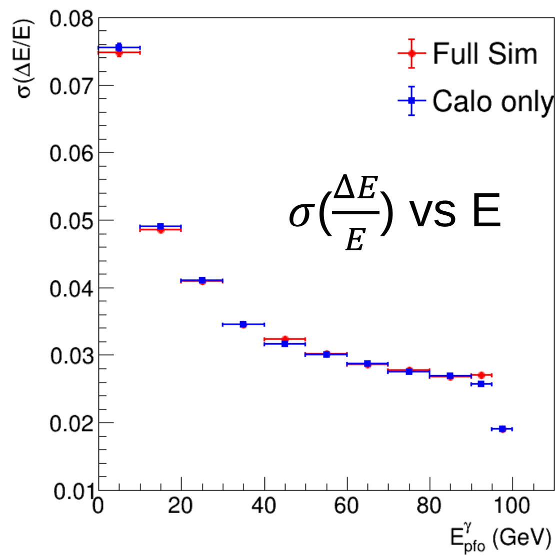


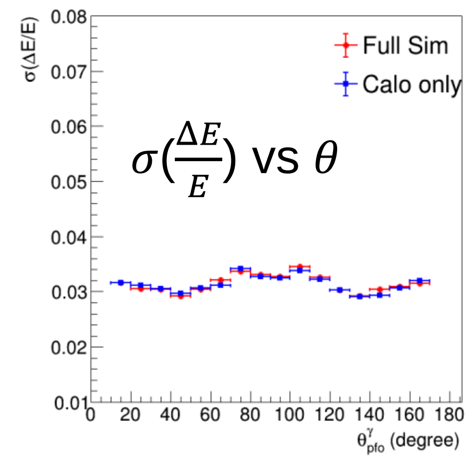
- The tracker detector before the ECAL makes the reconstruction efficiency lower. Should be improved after including reconstructed vertex information
- In high energy region, few photons are reconstructed as neutrons which are produced before calorimeter

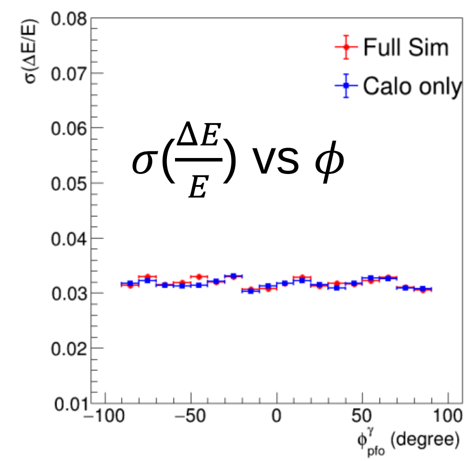
Reconstruction: porting Pandora to CEPCSW (2)

- Using single γ to check the reconstructed energy and resolution as function of E, θ, and ϕ









- Future work:
  - Performing calibration to correct the energy
  - Improving the resolution by optimizing the reconstruction algorithm

ECAL design studies with CEPCSW (1)

- By using DD4hep, it is easy to simulate different detector options in the same software framework.
- An example: BGO Crystal ECAL Matrix (based on Chunxiu Liu's)
  - 3D BGO array with 60x60x60 cells. Each cell is $1cm^3$
- A package Detector/DetEcalMatrix was developed.
  - Detector construction by DD4hep driver EcalMatrix.
  - All the parameters are defined in XML files.
  - The readout size is controlled using the segmentation.
  - The cell ID is associated with the segmentation by DD4hep.
- Pandora was used to reconstruct clusters.

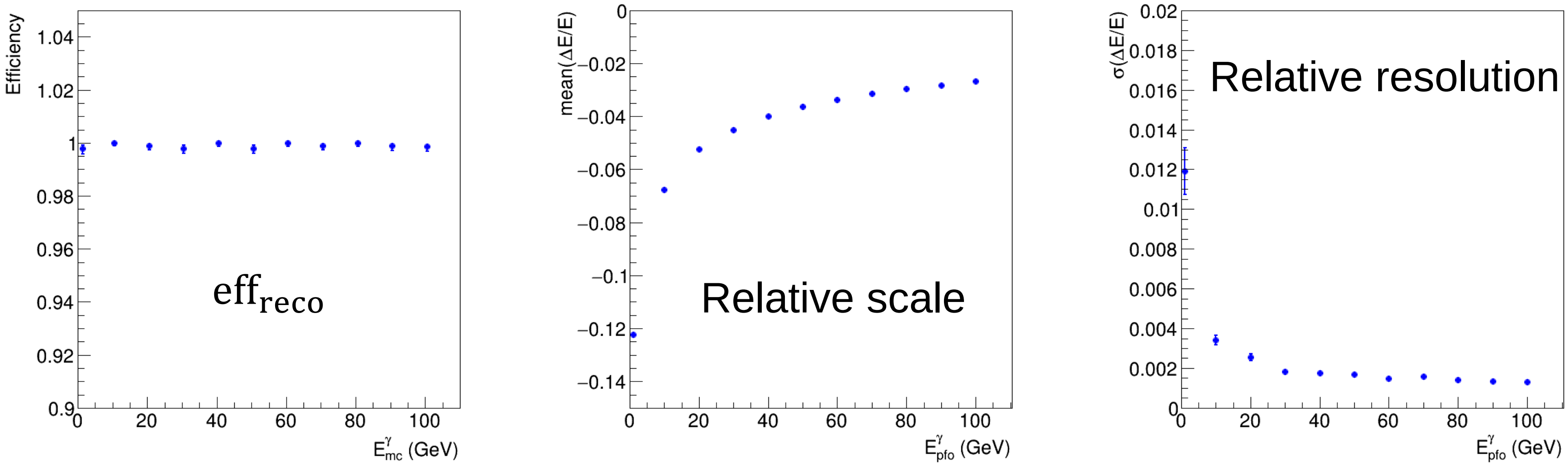
```xml
<detectors>
  <detector id="1" name="CaloDetector" type="EcalMatrix"
            readout="CaloHitsCollection" vis="VisibleGreen"
            sensitive="true">
    <position x="0"  y="0"  z="1835*mm+30*cm"/>
    <dimensions dx="30*cm"  dy="30*cm"  dz="30*cm"/>
  </detector>
</detectors>

<readouts>
  <readout name="CaloHitsCollection">
    <segmentation type="CartesianGridXYZ"
                  grid_size_x="1*cm"
                  grid_size_y="1*cm"
                  grid_size_z="1*cm"/>
    <id>system:8,x:32:-6,y:-6,z:-6</id>
  </readout>
</readouts>
```

A customized driver is developed, then the parameters are controlled in the XML file.

ECAL design studies with CEPCSW (2)

- Using single γ events for test:
  - Energy: 1, 10, 20, … , 100 GeV. $\theta = 90^{\circ}, \phi = 0^{\circ}$
- No energy calibration is performed



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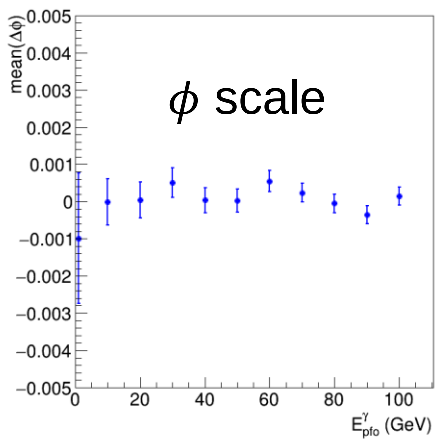

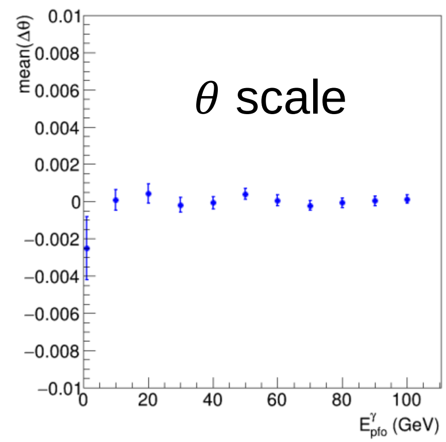

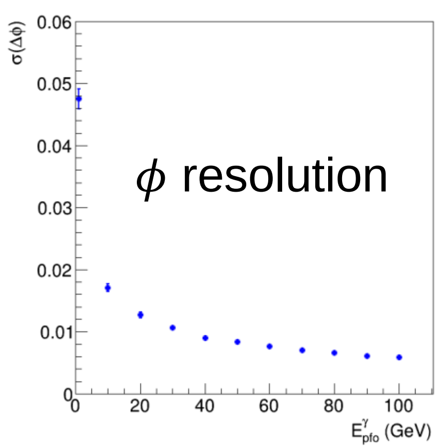

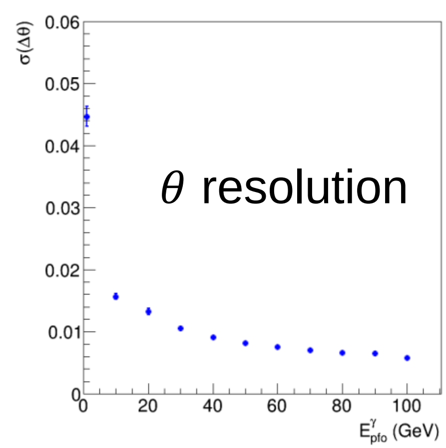

Short-term Plan

- Migrating to EDM4hep from pLCIO
- With help of three association classes
  - MCRecoCaloAssociation, MCRecoTrackAssociation and MCRecoParticleAssociation

  reconstruction performance studies can start.
- Porting ACTS algorithm to CEPCSW
- Implementing CEPC fast simulation framework

Summary

- Progress has been made since last CEPC Day meeting.
- Both event data model and geometry data management are of good shape.
- Fast simulation with frozen shower method was developed and Pandora was added to CEPCSW.
- A detector design example using CEPCSW was given and we look forward to feedbacks.

Thank You !

谢谢