CEPC Software: Status and Plan

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CEPC Day meeting

20-May-2024

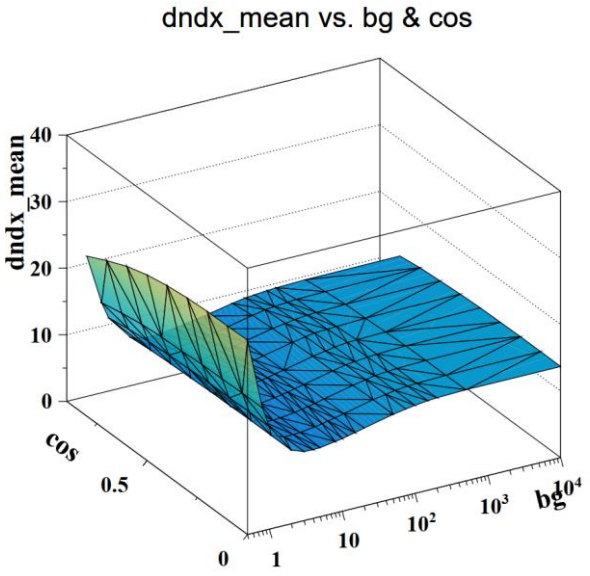
Software Releases

- Plans of TDR versions (see #1)
  - **April version (DONE)**: Background mixing, silicon, drift chamber, TPC
  - **May version (Ongoing)**: PID, Muon
- The TDR April version (tdr24.4.1) is released on May 6 (release note).
  - **Geometry**: Reference detector geometry update (Chengdong, MR !13, !16, !17, !19)
  - **Background mixing**: Support rates (Tao, MR !12) and ROOT based input (Fangyi, MR !15)
  - **Drift chamber**: CKF based tracking algorithm (Mengyao, MR !6; Tao, MR !20, !21).
- The TDR May version (tdr24.5) is under preparation.
  - **Event Data Model for PID**: `edm4hep::RecDqdx` for dN/dx (already merged) and `edm4hep::RecTof` for TOF (under review).
  - **PID software**: both dN/dx and TOF reconstruction algorithms are developed.
  - **Muon software**: focus on the geometry and detector simulation.

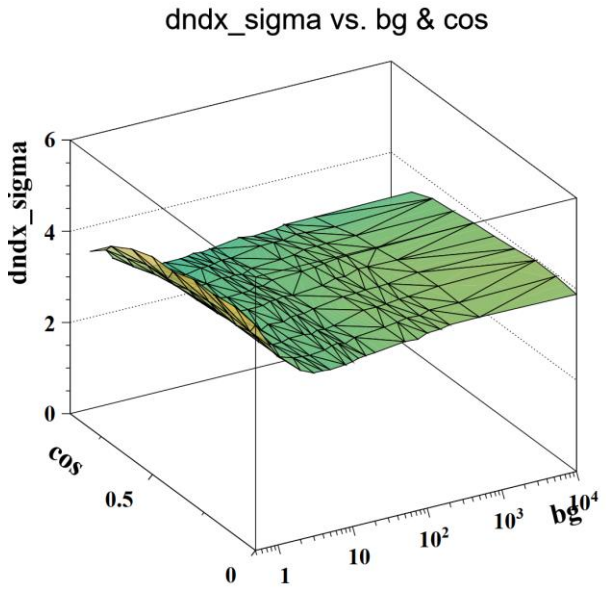
PID Software

- dN/dx in gaseous detectors (TPC and DCH)
  - Track-level dN/dx by parameterization from Garfield++-based full simulation
    - dN/dx mean vs. $\beta\gamma$ and $\cos\theta$
    - dN/dx sigma vs. $\beta\gamma$ and $\cos\theta$ (for 1 cm track length)
  - Track length calculation based on reconstructed track helices
  - dN/dx reconstruction
    - Sampling dN/dx from the mean and sigma functions, under (e, μ, π, K, p) hypotheses

DCH



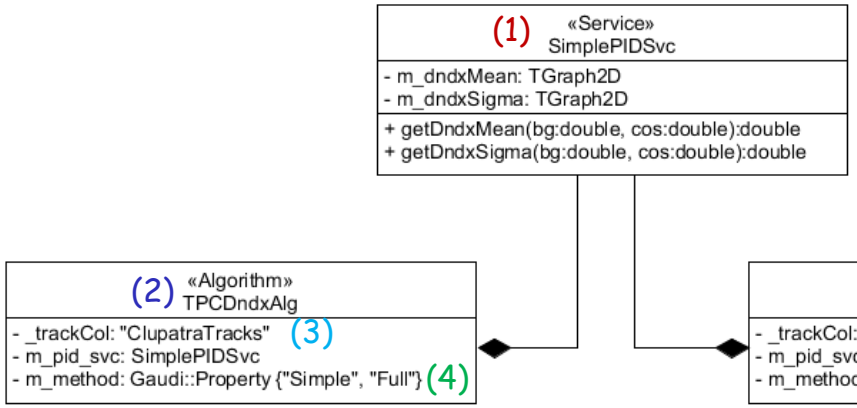
dN/dx mean



dN/dx sigma

PID Software (II)

- CEPCSW implementation
  - Developed 2 Gaudi ALGORITHMs for TPC and DCH dN/dx reconstruction
    - TPC and DCH have different readout schemas
  - Developed a single Gaudi SERVICE for the track-level parameterization
    - For track-level reconstruction, TPC and DCH have the same parameterization interface
  - Reserved an interface for future hit-level reconstruction
    - Configured by the Gaudi Property
- Status
  - Code development is about to finish
  - Tests are ongoing
  - Will be released soon



SERVICE for parameterization

ALGORITHM for dN/dx rec.

Input data collection

Interface for hit-level rec.

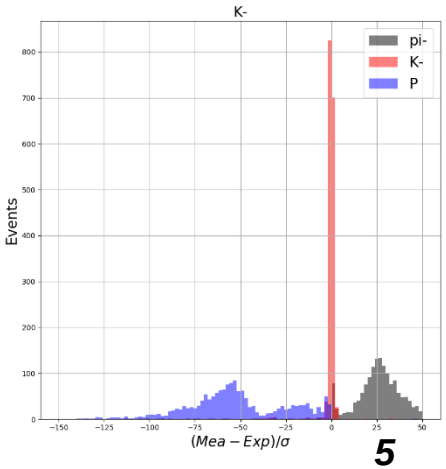
PID Software (III)

- A proposal of ToF event data model for EDM4hep

```
784 + #-------------  RecTof
785 + edm4hep::RecTof:
786 +   Description: "Reconstructed TOF (time of flight) info."
787 +   Author: "EDM4hep authors"
788 +   Members:
789 +     - float time [ns]                      // time measurement
790 +     - std::array<float, 5> timeExp [ns]    // expected time for e(0),mu(1),pi(2),K(3),p(4)
791 +     - float sigma                          // time resolution
792 +     - std::array<float, 5> pathLength [mm] // length of flight for e(0),mu(1),pi(2),K(3),p(4)
793 +     - edm4hep::Vector3d position [mm]      // extrapolated hit position
794 +   OneToOneRelations:
795 +     - edm4hep::Track track                 // the corresponding track
796 +
```

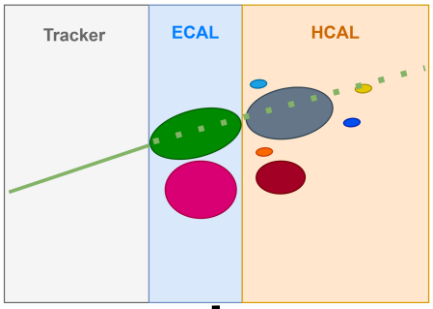
Pull Request #299: https://github.com/key4hep/EDM4hep/pull/299

- Developed a Gaudi Algorithm for ToF reconstruction
  - Geometry: R=1850mm, L/2=2350mm, and B=3T (will be updated based on newest geometry)
  - ToF model: $t_{mea} = tof_{truth} + Gaus(0, t_{bunch} = 20\text{ps}) + Gaus(0, \sigma = 50\text{ps})$
  - Provide expected ToF information for e, μ, π, K, p hypotheses
  - Will be released soon

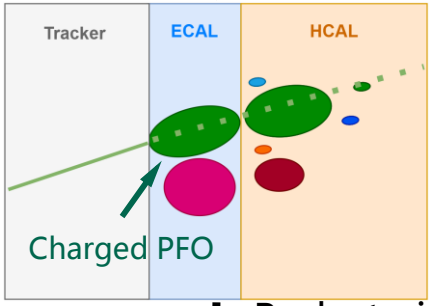


Improvement of PFA Algorithm

- BMR is improved to ~4.2% by optimization of ECAL-HCAL Matching Algorithm

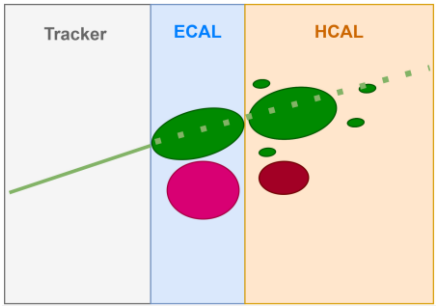


Track Extrapolating

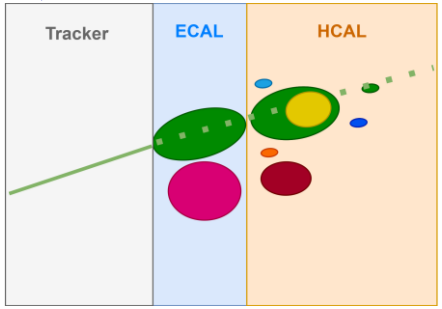


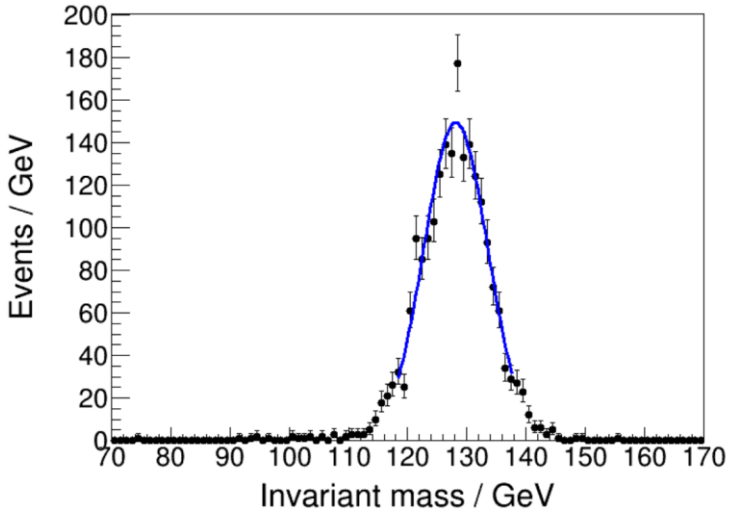
Reclustering

If $E_{track} > E_{ECAL+HCAL}$:
Merge nearby clusters to charged PFO



If $E_{track} < E_{ECAL+HCAL}$:
Split a neutral cluster from charged PFO



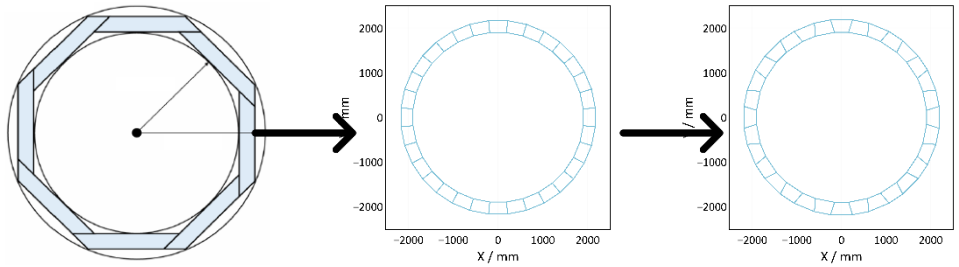


$$\text{BMR} = 4.21 \pm 0.13\%$$
$$\text{mean} = 128.14 \pm 0.15 \text{ GeV}$$
$$\sigma = 5.40 \pm 0.16 \text{ GeV}$$

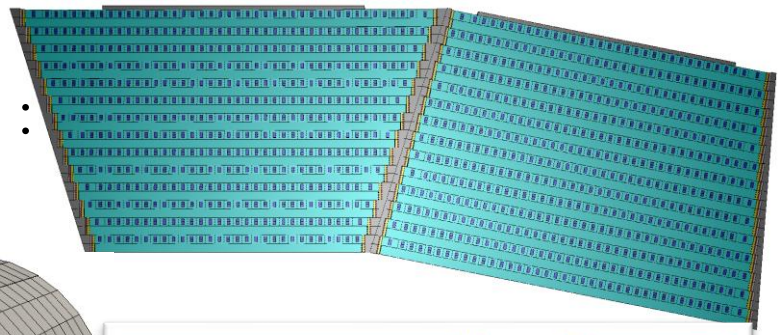
Fit with Gaussian function.
Fit range: 118.41~137.68 GeV
(90% events in fitting range)

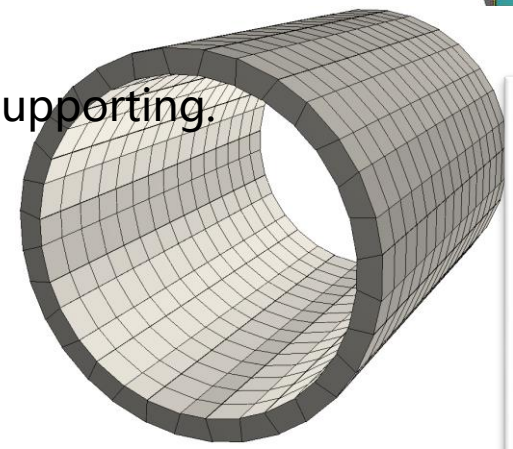
Preliminary geometry and material description of ECAL

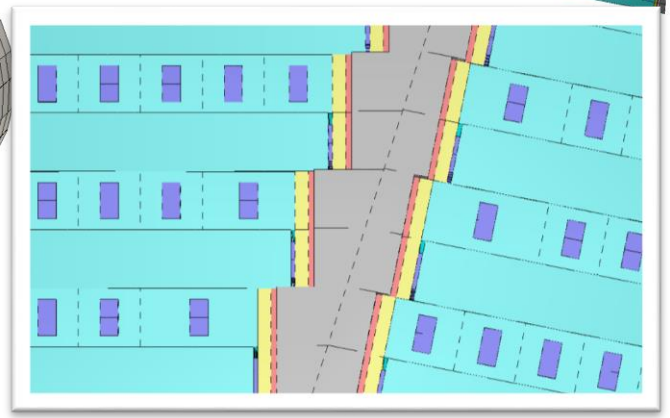
- Optimized 32-side ECAL geometry :
  - Smaller HCAL inner radius.
  - Avoid particles escaping from ECAL.
  - Minimized cracks between modules.
  - Deliver a clear shower structure.



- Fine geometry and material description :
  - Crystal, wrap, and SiPM.
  - Front-end electronics.
  - Cooling and mechanical supporting.

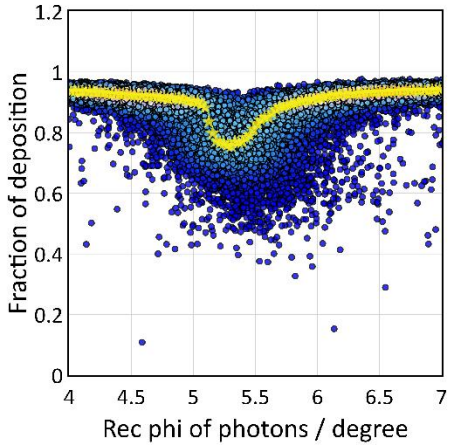


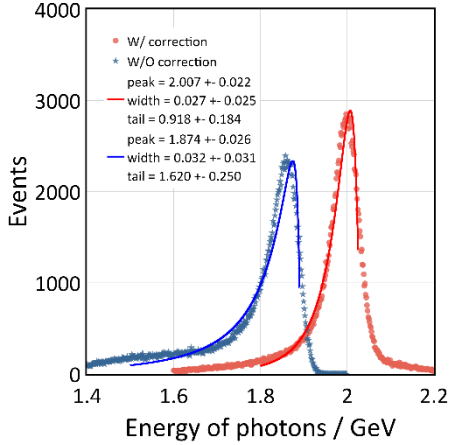


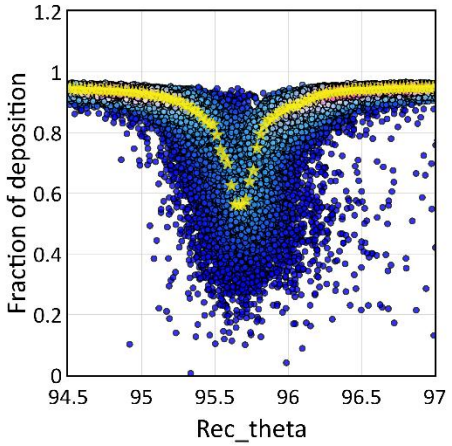


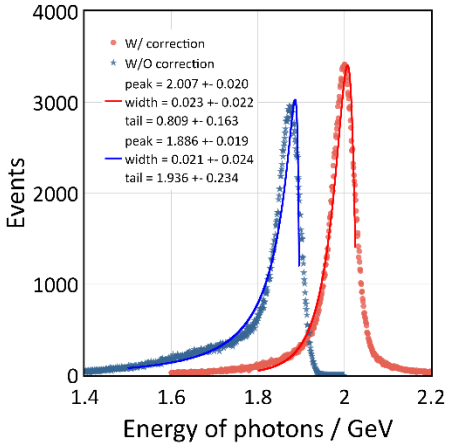
Energy correction at cracks of ECAL

- $E_{correction} = \frac{E'_{truth}}{E'_{deposition}} \times E_{depostion}$:
  - Correction factor $\frac{E'_{truth}}{E'_{deposition}}$ is obtained from simulated 2 GeV photon events.
- Energy correction algorithm:
  - Based on position reconstruction of clusters.
  - Phi and theta directions.

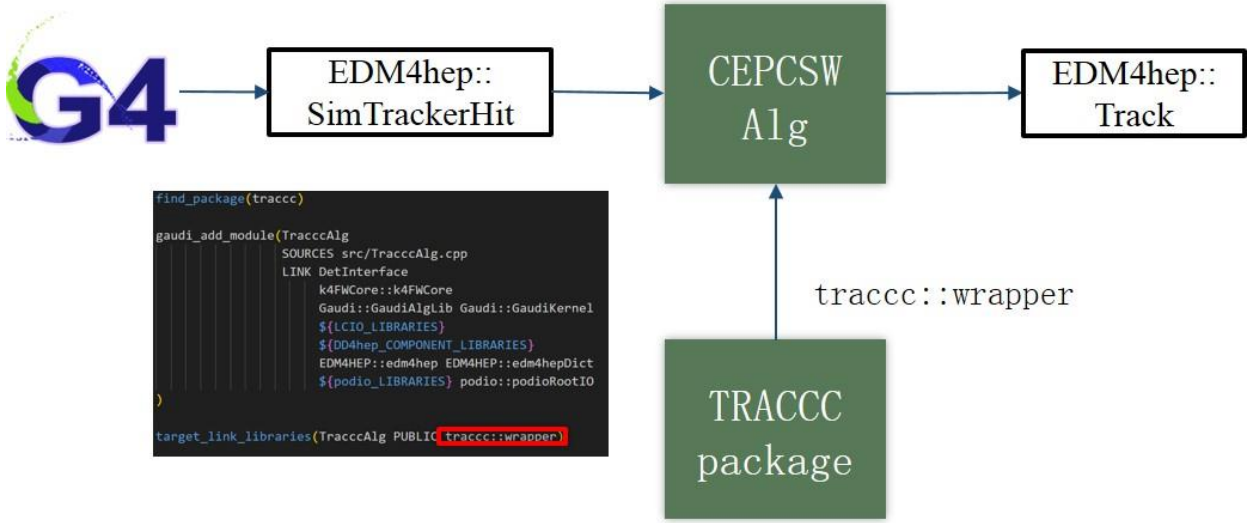








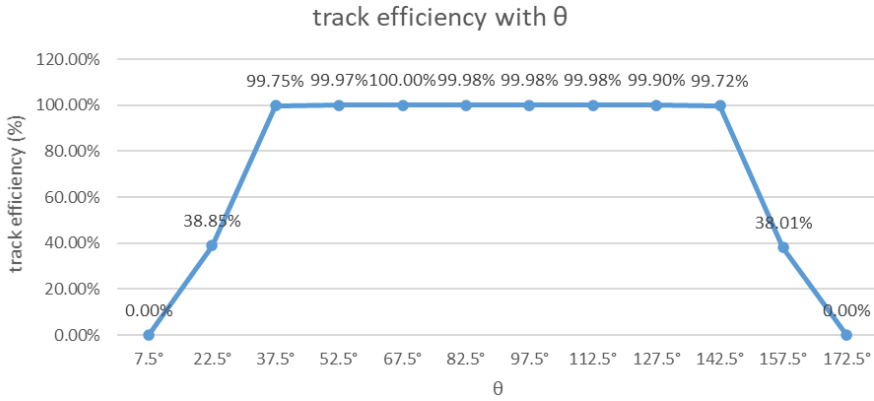
Track Finding with TRACCC (1)

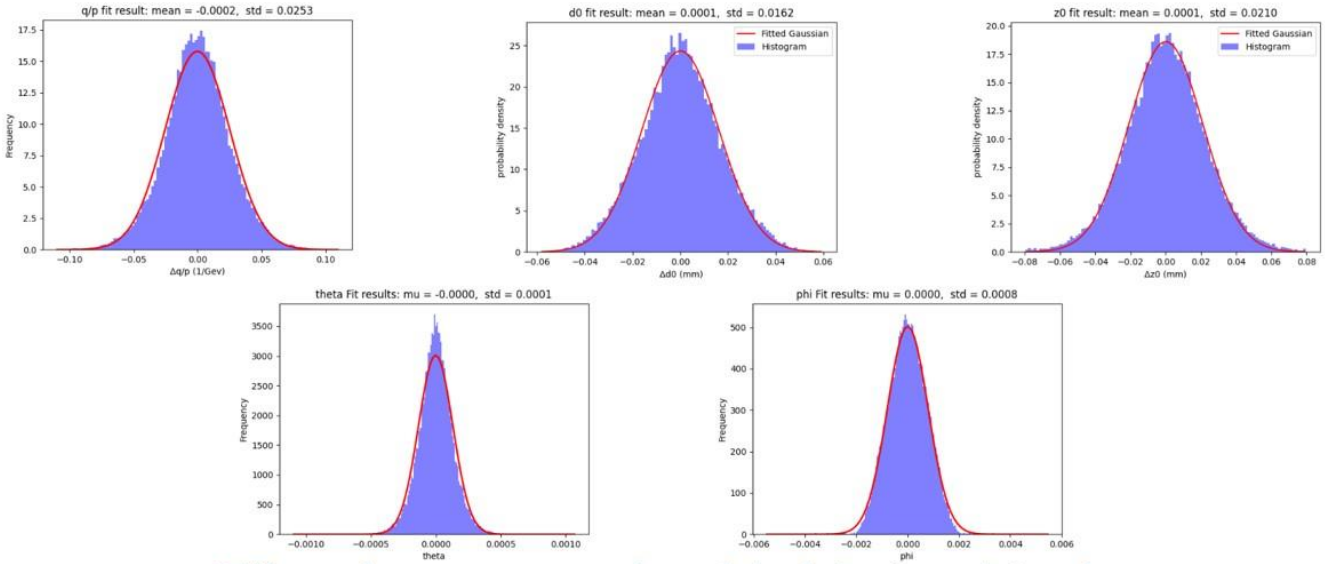


- Track finding in CEPC VTX with TRACCC
  - VTX Geometry: converting TGeo geometry to ACTS geometry
  - To accommodate the CEPC’ s specific detector structure (double-sided), the seeding algorithm was extended to have two steps:
    - Triplet finding and track seed formation
  - Also provided one common memory solution for both EDM4hep and VecMem to avoid the data copy between them

Track Finding with TRACCC (2)

- Tracking performance measured on
  - CPU: Intel(R) Xeon(R) Silver 4214 CPU @ 2.20GHz
  - GPU: NVIDIA Corporation TU102GI [Quadro RTX 8000]





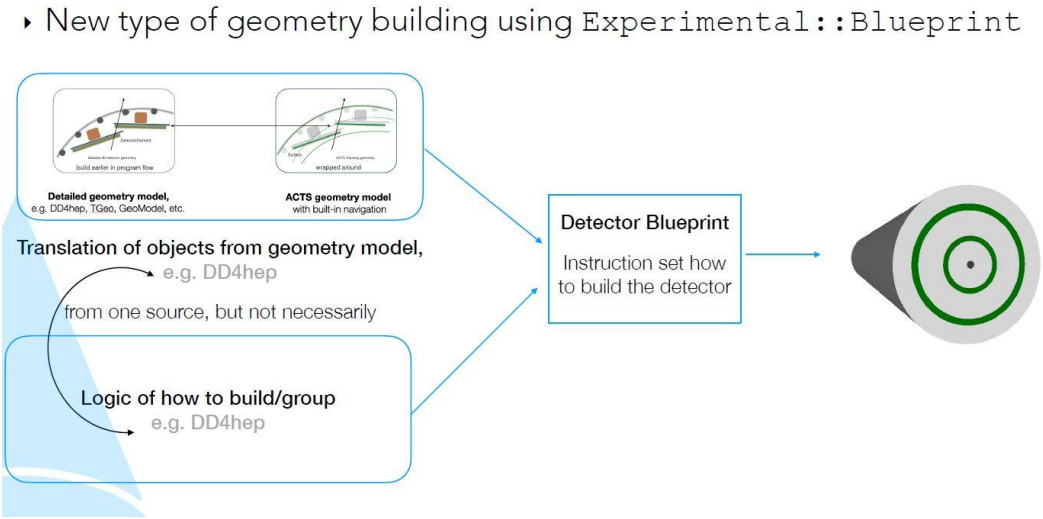
Difference between reconstruction and simulation (rec - sim) track param

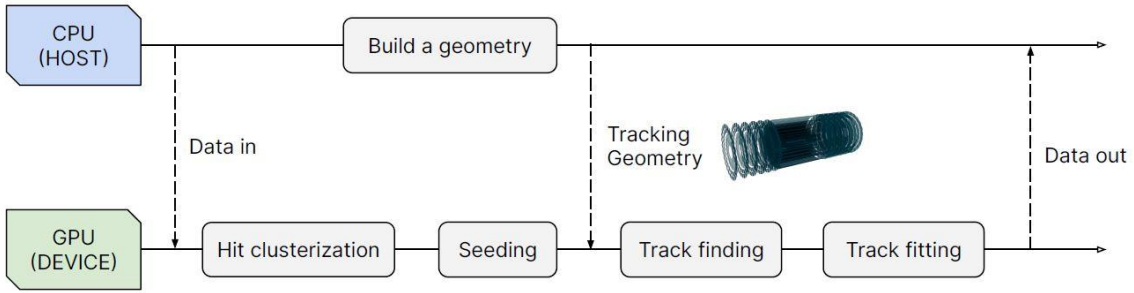
Track parameters include qoverp, d0, z0, theta, phi

Particle: mu- Energy: 5 Gev

Plan: Tracking with ACTS/TRACCC

- Tracking 2024 workshop in Zhengzhou
  - ACTS Status, Andreas Salzburger (CERN)



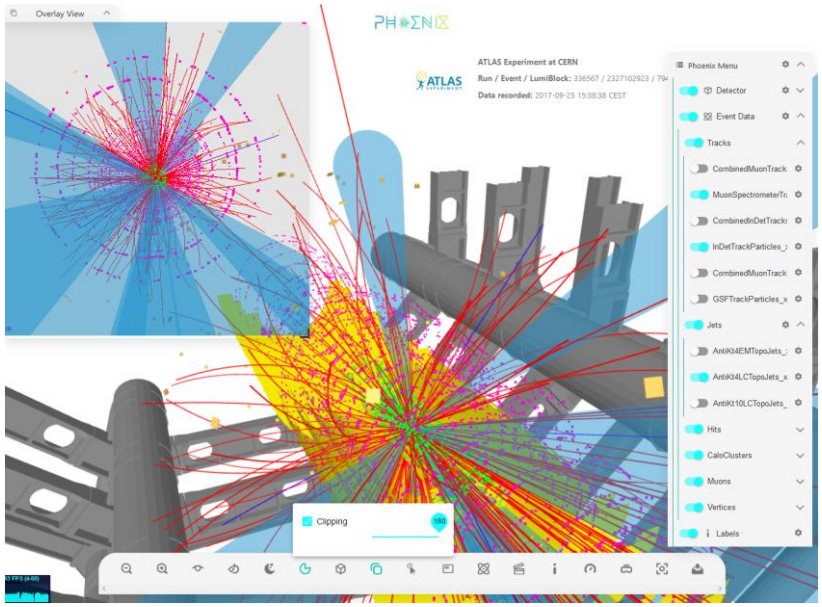


- TRACCC Status, Beomki Yeo (UC Berkeley/LBNL)

- Tracking with ACTS/TRACCC at CEPC will continue
  - implementation of tracking for the silicon strip detector

Plan: Event Display Tool

- Event display tool is important for
  - Optimizing detector design, debugging event reconstruction software and the outreach purpose
- Phoenix is a web-based event display framework supported by HEP Software Foundation
  - is being used by ATLAS, LHCb, Belle II and FCC



- SYSU is planning to work on development of event display tool with Phoenix to
  - visualize the CEPC detector with detailed geometry
  - display the CEPC event data with simplified geometry

Thank You !

謝謝