Status of CEPCSW

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(on behalf of CEPC software group)

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Outline

- Introduction
- Overview of CEPCSW
  - Detector description
  - Simulation
  - Reconstruction
- Towards Reference Detector TDR (short-term tasks)
  - Requirements
  - Software Releases
- Plans (long-term tasks)
- Summary

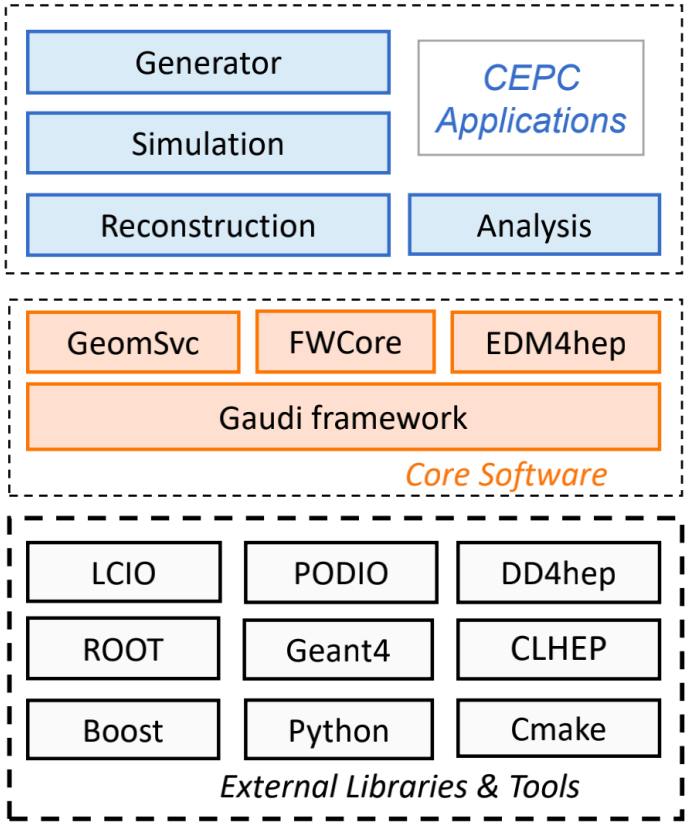
Introduction

- The CEPC software development first started with the iLCSoft
  - Reused most software modules: Marlin, LCIO, MokkaC, Gear
  - Developed CEPC’ s software components for simulation and reconstruction
  - Massive M.C. data produced for detector and physics potential studies
  - CDR was released in Nov, 2018, based on results from the iLCSoft
- New CEPC software (CEPCSW) prototype was proposed at the Oxford workshop in April 2019
- The consensus among CEPC, CLIC, FCC, ILC and other future experiments was reached at the Bologna workshop in June 2019
  - Develop a Common Turnkey Software Stack (Key4hep) for future collider experiments
  - Maximize the sharing of software components among different experiments

Overview of CEPCSW

- CEPCSW software structure
  - Core software
  - Applications: simulation, reconstruction and analysis
  - External libraries
- Core software
  - Gaudi/Gaudi Hive: defines interfaces to all software components and controls their execution
  - EDM4hep: generic event data model
  - K4FWCore: manages the event data
  - DD4hep: geometry description
  - CEPC-specific framework software: generator, Geant4 simulation, beam background mixing, fast simulation, machine learning interface, etc.

Core software: Wenxing Fang, Xingtao Huang, Teng Li, Weidong Li, Tao Lin, Jiaheng Zou *etc.*



https://github.com/cepc/CEPCSW

https://code.ihep.ac.cn/cepc/CEPCSW

Detector Description

- DD4hep is adopted to provide the full detector description with a single source of information.
- Different detector options are managed in a git repository.
  - Easy to track the changes of detectors and compare between different options.
- Available options in CEPCSW
  - CEPCv4: baseline detector in Conceptual Design Report
  - CRD: CEPC Reference Detector

Geometry: Chengdong Fu

Model	Description	MainTracker	Ecal	Hcal	Status
CRD_o1_v01	coil inside simulation model	SIT+DC+SET	crystal	RPC	developing
CRD_o1_v02	strip SET	SIT+DC+SET	crystal	RPC	developing
CRD_o1_v03	MOST2 vertex	SIT+DC+SET	crystal	RPC	developing
CRD_o1_v04	smaller center beam pipe	SIT+DC+SET	crystal	RPC	developing
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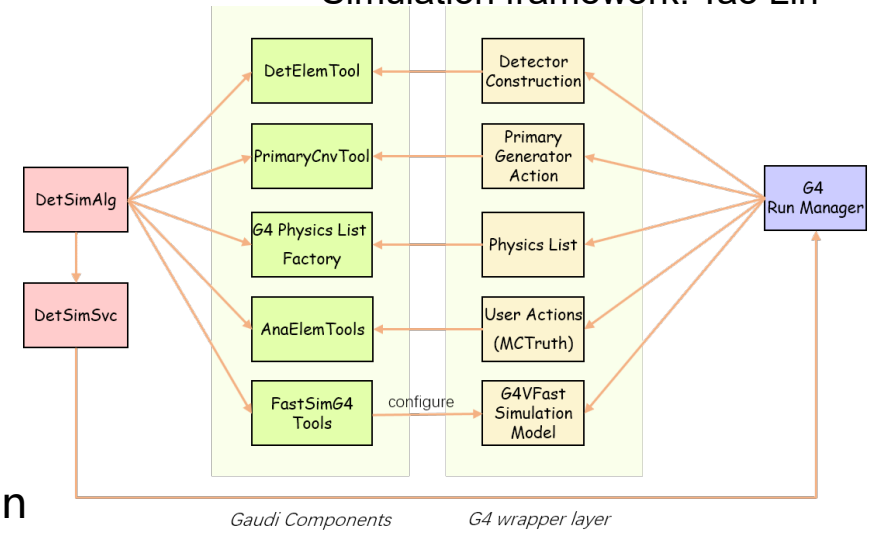
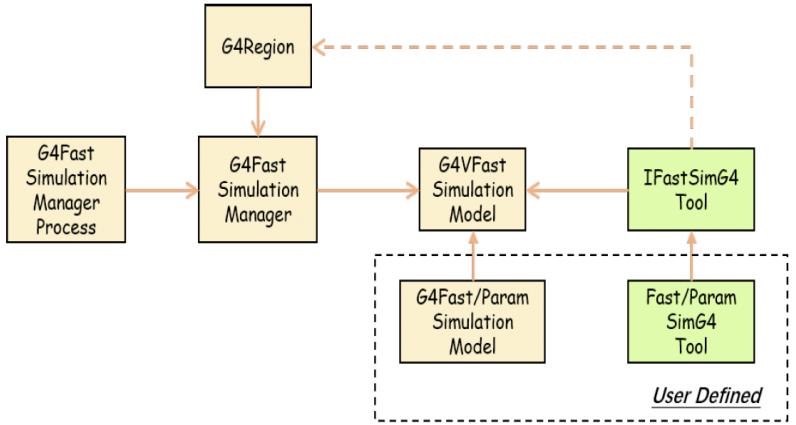
Detector Simulation (1)

- Full detector simulation has been developed based on Geant4.
  - A unified simulation framework: integrate Geant4 and Gaudi.
  - Event data: SimTrackerHit and SimCalorimeterHit
  - Generator interfaces: HepMC, LCIO, StdHep, Beam background, Particle Gun
  - Fast simulation interfaces: Geant4 Region based.
  - Detector responses: trackers, DC, TPC, calorimeter
  - Monte Carlo truth: association between hits and MC particles
- The background mixing algorithm is under development.

Simulation framework: Tao Lin

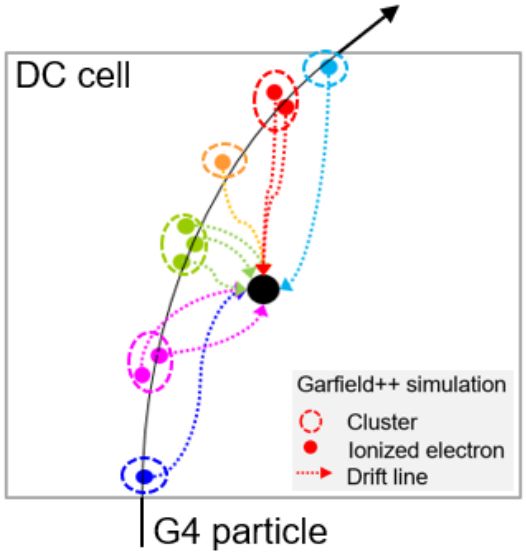




Detector Simulation (2)

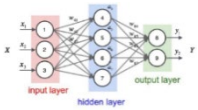
- The simulation software supports the software development of both DC and ECAL.

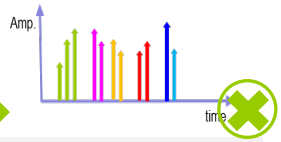
DC simulation: Mengyao Liu, Wenxing Fang *etc.*



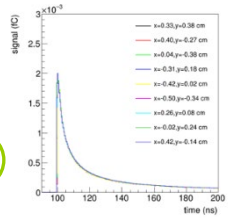
Garfield++ waveform simulation, highly time-consuming

Fast simulation

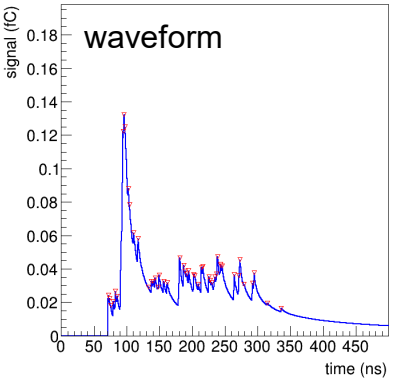




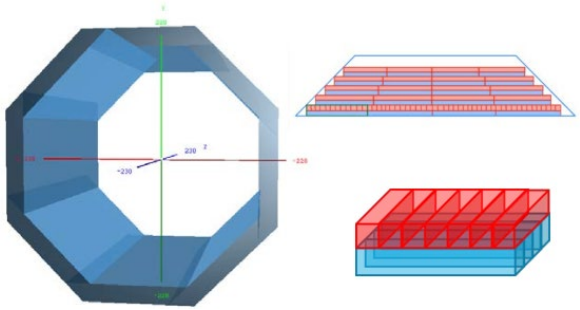
NN simulates the pulse's time and amplitude

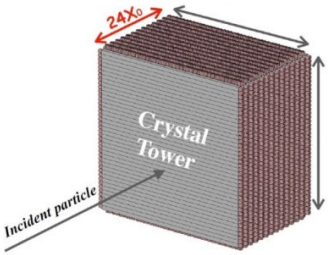


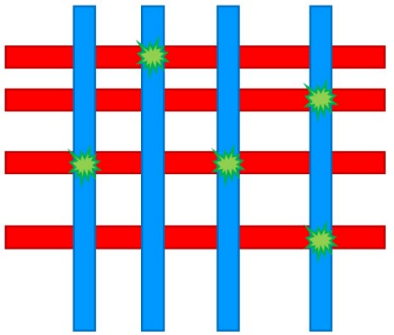
Pulse shape template



ECAL Simulation: Fangyi Guo, Yang Zhang, Shengsen Sun etc.







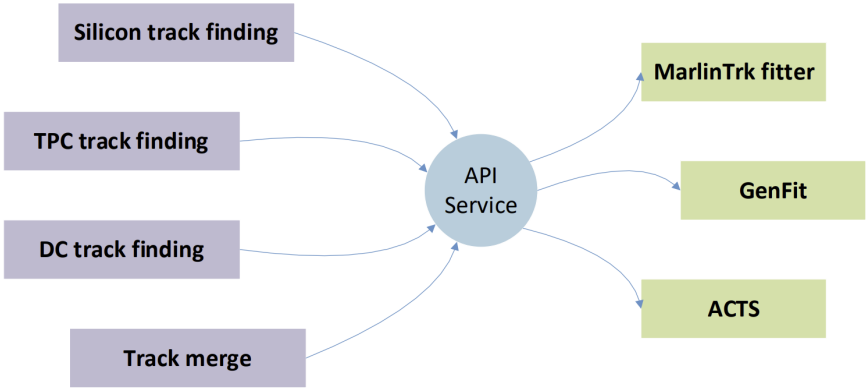
Reconstruction (1)

- Existing algorithms are migrated from Marlin to CEPCSW.
- New reconstruction algorithms are developed as well.

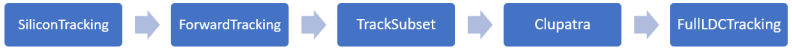
Detector	Package	Status
Silicon	SiliconTracking	Migration Done
	ForwardTracking	Migration Done
	TrackSubset	Migration Done
	FullLDCTracking	Migration Done
TPC	Clupatra	Migration Done
DC	RecGenfitAlg	Under development
ECAL/HCAL	CRDEcalRec	Under development
Muon		Under development

Reconstruction (2)

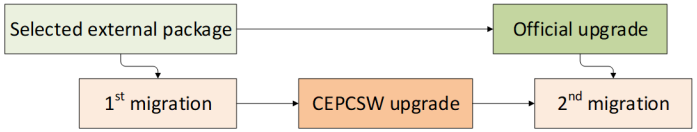
- Tracking software
  - A complete tracking chain.
  - Configure the tracking algorithms for different detectors and perform the merging algorithm.
  - For silicon tracker: SiliconTracking, ForwardTracking, TrackSubset, ConformalTracking
  - For TPC: Clupatra, ArborTracking



Migration/Implementation



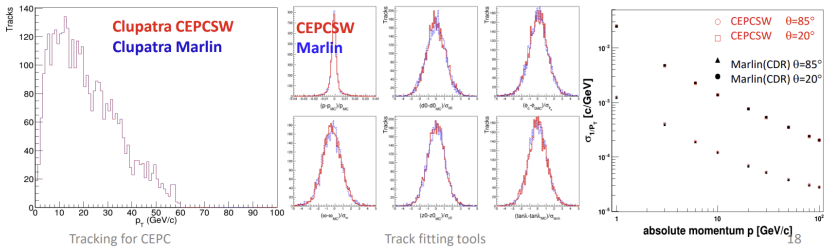
- Migrated full tracking chain from Marlin
  - Switch class to GaudiAlgorithm
  - Switch data model to EDM4hep (first realized)



- Another implement way is in considering, to test coversion cost
  - Create a GaudiAlgorithm to covert data model and call
    - ✓ EDM4hep→LCIO→call event loop function→LCIO→EDM4hep
- Key4hep (best) in plan
  - CallingAlg to call prepared API
  - event model support with same code is important

Phase I: Migrated MarlinTrk

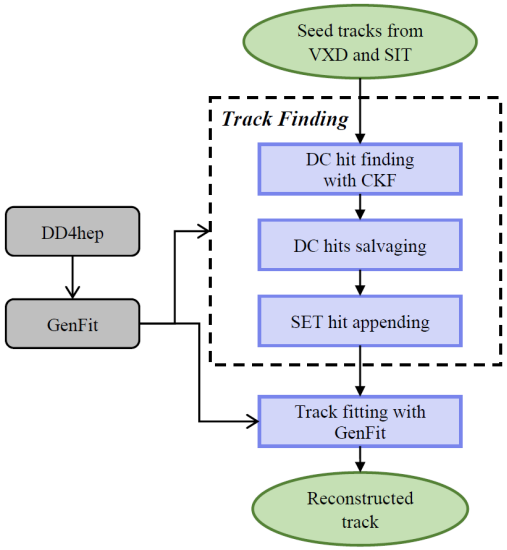
- Create service to convert DD4hep extension to Gear as KalTest geometry input
- Create service to create MarlinKalTest object, called by tracking algorithm
- Switch data model to EDM4hep
- After migration
  - Fully identical on same digitized input
  - consistent on different input (different random)
- Upgrade to DD4hep surface (DDKalTest) is in plan

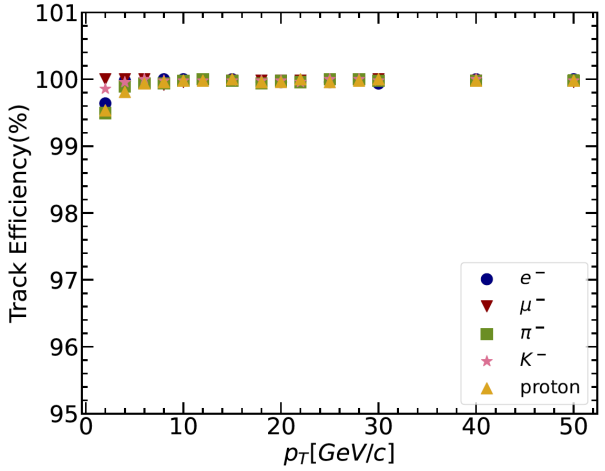


Reconstruction (3)

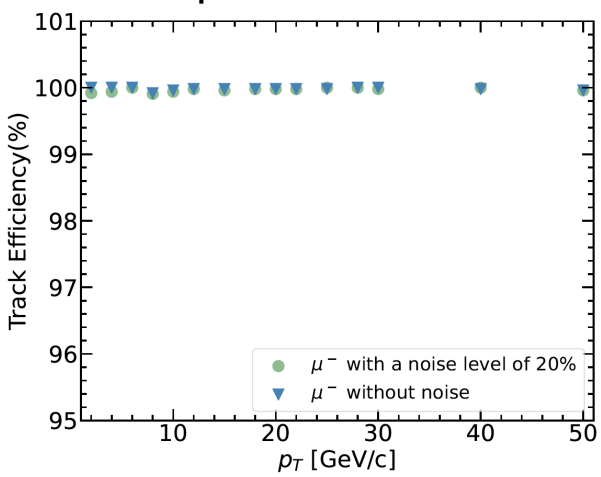
Mengyao Liu, Weidong Li, Xingtao Huang, Yao Zhang, Ye Yuan *etc.*

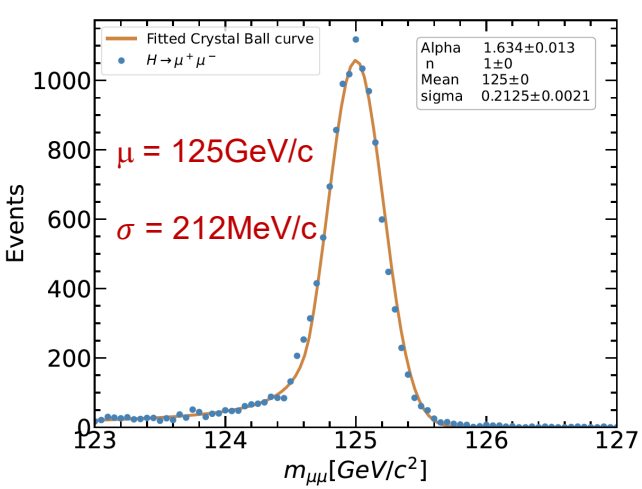
- DC Reconstruction
  - Track Finding with Combinatorial Kalman Filter
    - Migrate from Belle2
  - Track Fitting with GenFit
    - Using DAF Kalman filter
  - Implementation
    - Extrapolation based on GenFit
    - Field, material and geometry from DD4hep
    - A data format converter from EDM4hep
  - Performance validation completed





without background

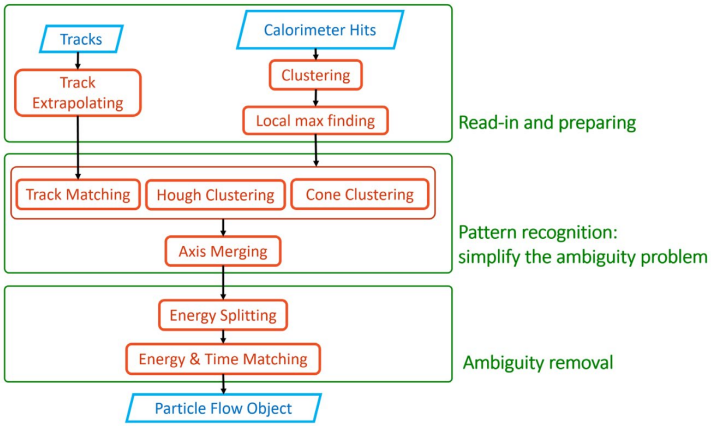


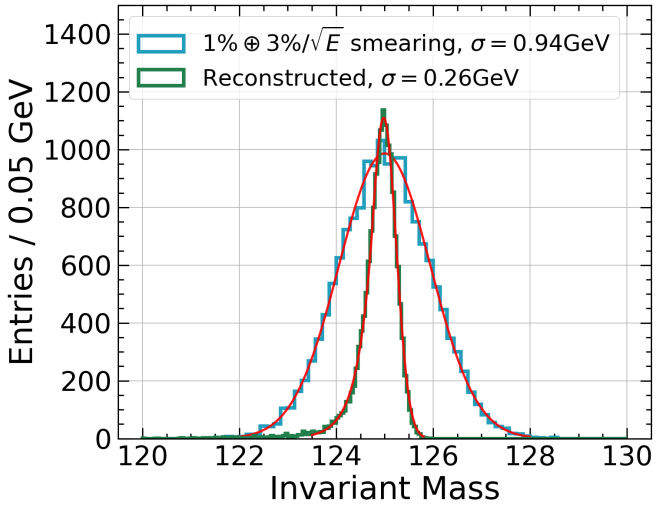


Reconstruction (4)

Fangyi Guo, Weizheng Song, Shengsen Sun, Linghui Wu, Yang Zhang *etc.*

- Long Crystal Bar ECAL
  - For details, see talk by Fangyi

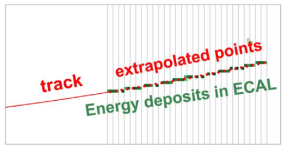


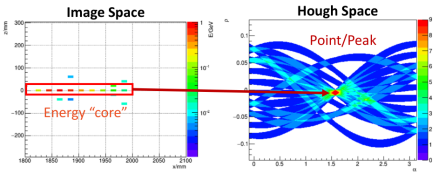


$H \rightarrow \gamma\gamma$ in CEPC

Shower Recognition

- Multiple algorithm for shower recognition:
  - Charged particle: track-matching.
  - EM shower: Hough transformation.
  - Fragment: cone-clustering.

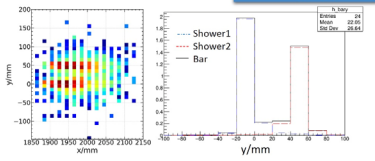




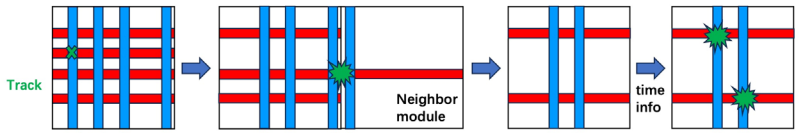
Reconstruction algorithm

Software task:
- ✓ * Clustering
- ✓ * Pattern recognition.
- ✓ * Overlap: energy splitting.
- ✓ * Ambiguity problem.

- **Splitting for the overlapped shower:**
  - Calculate the expected energy deposition from EM profile.
    - Expected energy : $E_{i\mu}^{exp} = E_{\mu}^{seed} \times f(|x_i - x_c|)$
    - Assigned weight: $w_{i\mu} = \frac{E_{i\mu}^{exp}}{\sum_{\mu} E_{i\mu}^{exp}}$



- **Ambiguity removal:**
  - Information from: track, neighbor tower, time.



Towards Reference Detector TDR

- Motivation
  - Support the fast iterations of the reference detector design.
  - Release the latest versions of detectors to support physics and performance studies.

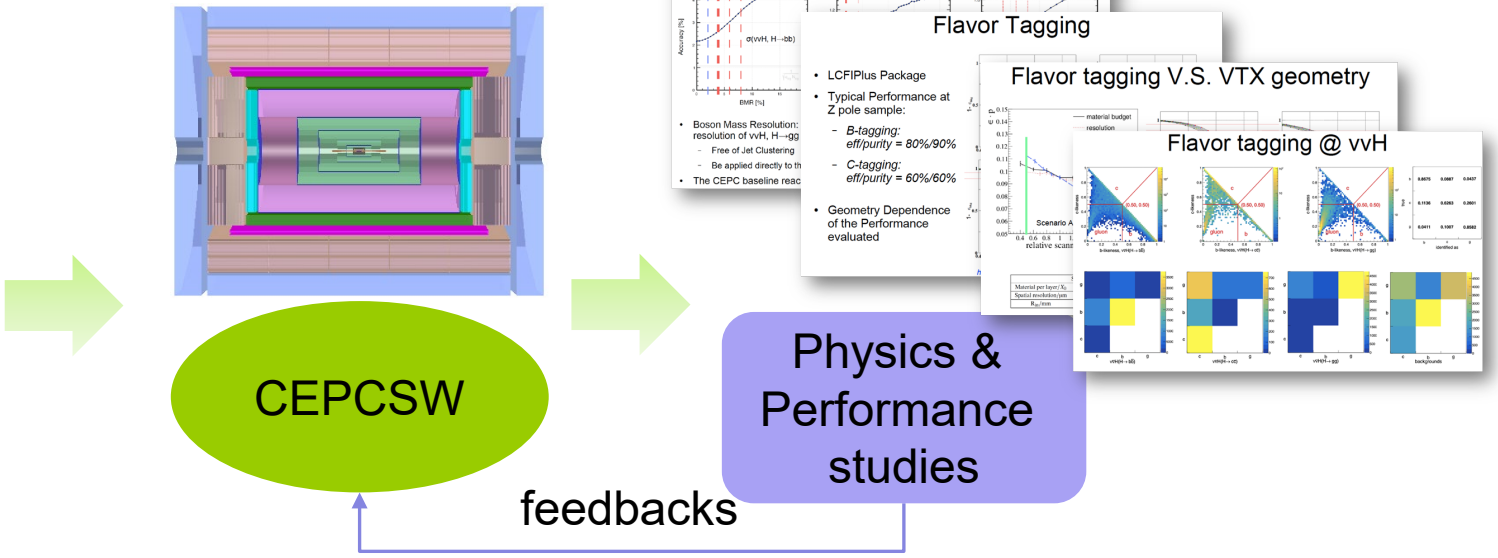
Mechanical

Vertex

Tracker

Calorimetry

Muon



Software Releases for TDR

- The software development
  - Adopt a new version scheme: tdr*YY.MM*
  - Driven by Issues and Merge Requests. Project management via milestones.
  - The repository is hosted at IHEP GitLab.
    - Source code is mirrored to GitHub.
- Short-term plans before July.

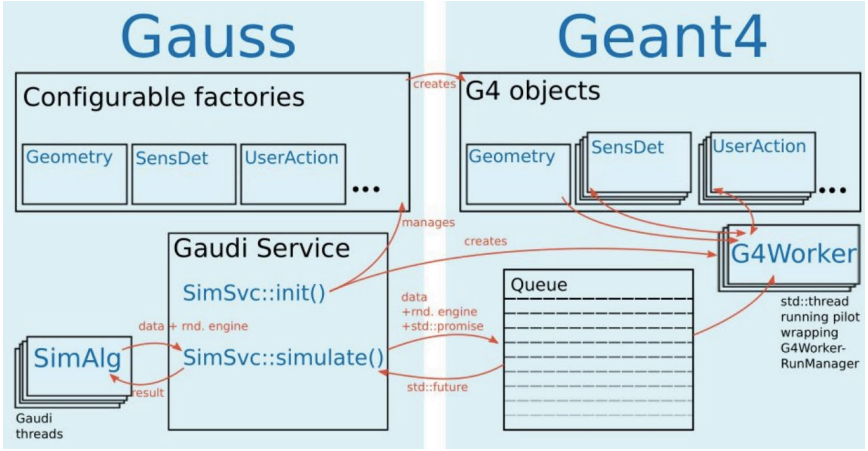
Release	Timeline	Features
tdr24.3 √	March	Core software
tdr24.4	April	Tracking and Background mixing
tdr24.5	May	PID and muon
tdr24.6	June	Calorimeters

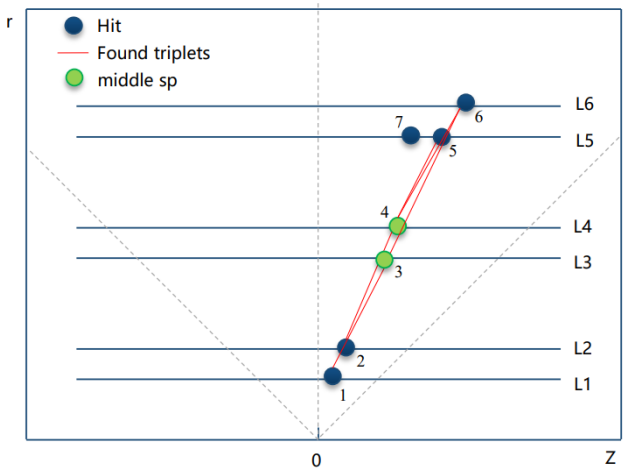
- Latest version could be found in CVMFS:
  - /cvmfs/cepcsw.ihep.ac.cn/prototype/releases/tdr24.3.1/
- Baseline performance will be released as well.

Long-term Plans in CEPCSW (1)

Xingtao Huang, Teng Li, Weidong Li,
Tao Lin, Yizhou Zhang, Jiaheng Zou

- Parallelization and Heterogeneous
  - CEPC-on-Gaussino prototype: CEPC is working with Key4hep project members re-implementing the detector simulation software based on Gaussino
  - Seeding with TRACCC: CEPC silicon detector is used as an example. Develop the 6-layer seed finding in GPU.



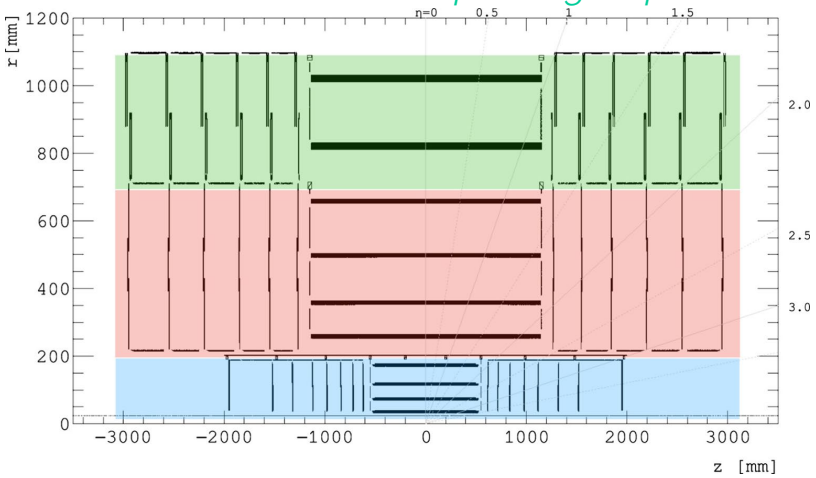


Long-term Plans in CEPCSW (2)

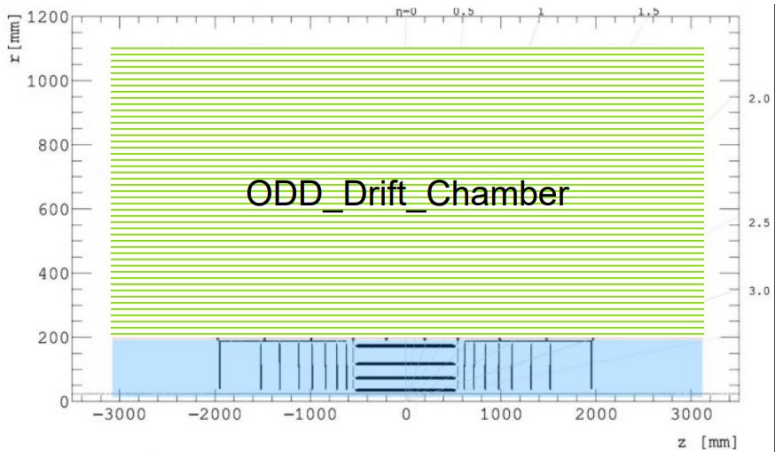
- Contribution to common software, such as ACTS
  - Adding Drift Chamber to Open Data Detector

Xiaocong Ai, Xingtao Huang, Weidong Li, Tao Lin, ACAT 2024

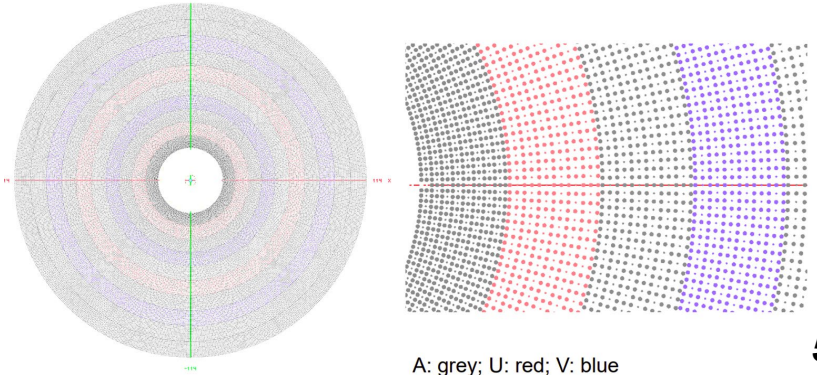
ODD: Pixel + Short Strip + Long Strip



ODD: Pixel + Drift Chamber ?



https://gitlab.cern.ch/acts/OpenDataDetector
More details here



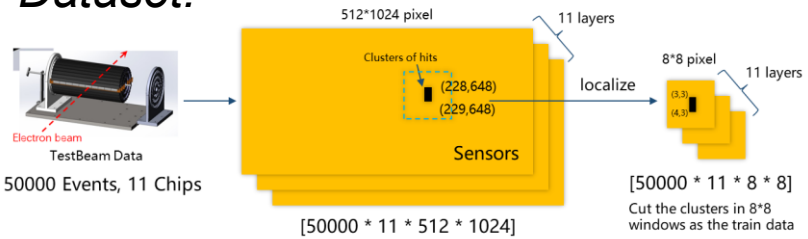
A: grey; U: red; V: blue

Long-term Plans in CEPCSW (3)

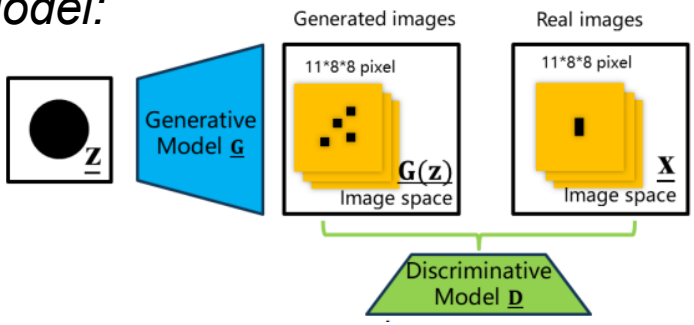
Yizhou Zhang, Xiaozhong Huang, Weidong Li *etc.*
CEPC Workshop 2023

- Machine Learning
  - ML-based digitization for CEPC vertex detector: training based on the test beam data of TaichuPix-3.

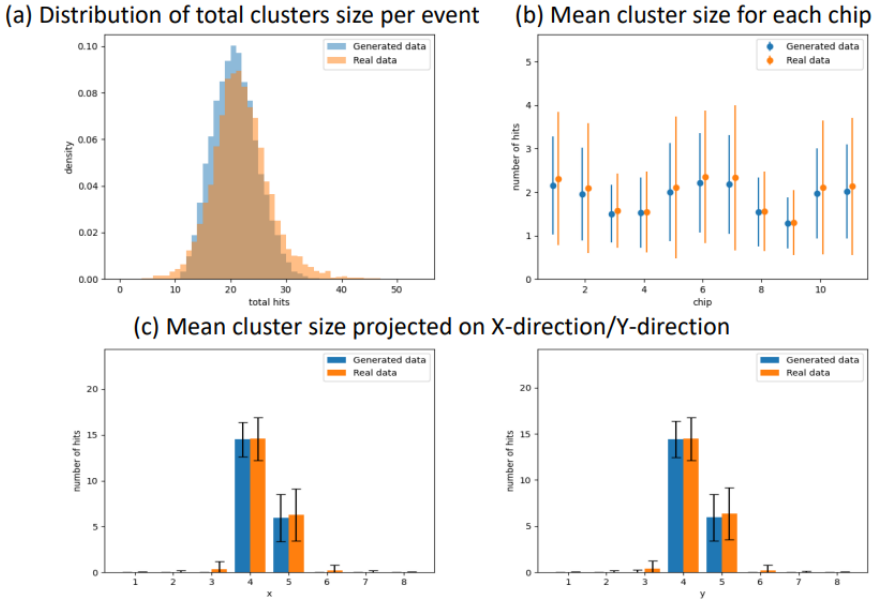
Dataset:



Model:



Evaluation:



Summary

- Towards the CEPC Reference Detector TDR, there will be four major software releases before June.
  - The March version is already released.
  - The next versions will keep optimization to follow the change of detector designs.
  - Performance plots will be released based on the latest software.
- After the choice of reference detector design, the software development will focus on the design.
- Long-term development is focus on the new technologies to boost CEPCSW performance.

Source code:	https://github.com/cepc/CEPCSW https://code.ihep.ac.cn/cepc/CEPCSW
Mailing list:	cepc_software@maillist.ihep.ac.cn

Thank you for your attention!