Tracking in TPC and Silicon Detectors

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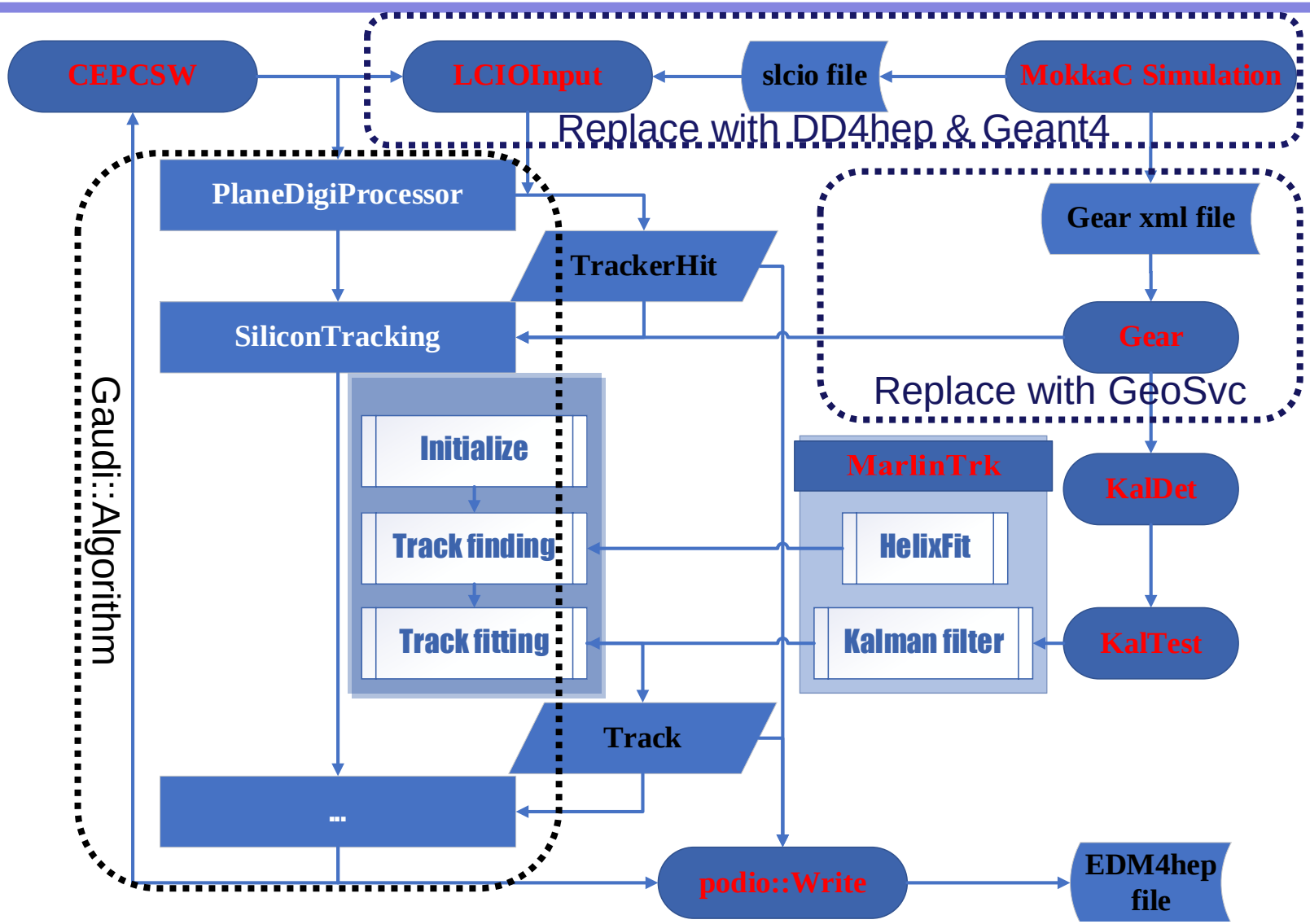
Introduction

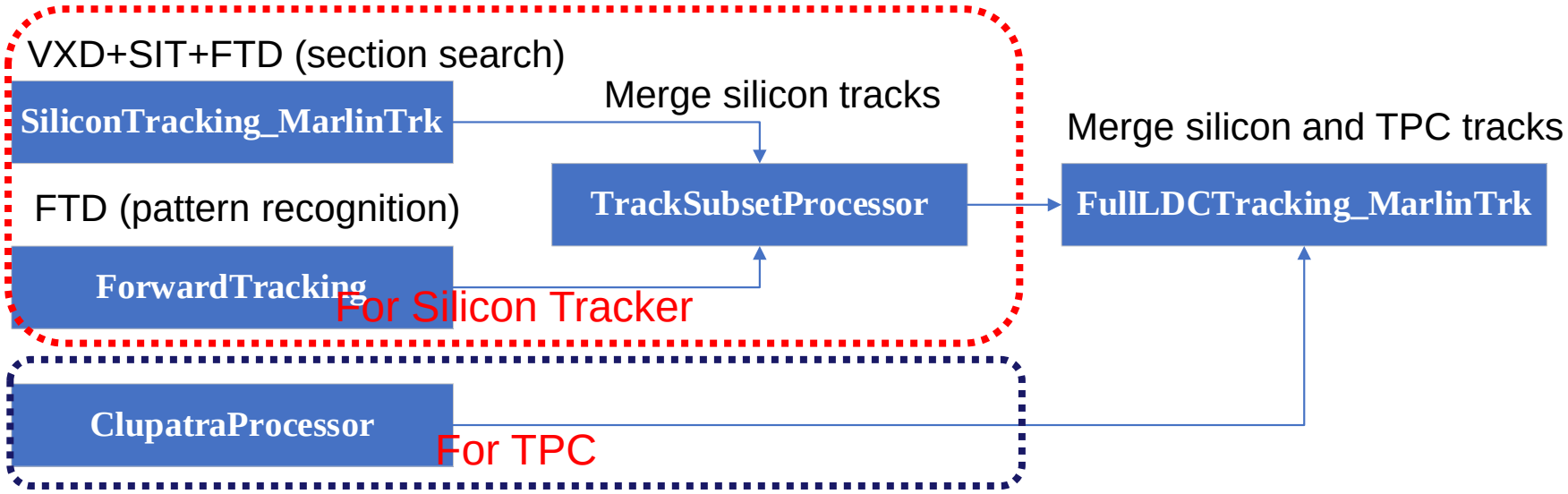
- Track requirements of CepC (from Manqi's)
  - ~100% efficiency within the energy & solid angle acceptance
  - Momentum resolution ~0.1% for Higgs with di-muon final state, <0.1% better for narrow hadrons in the flavor program
- CepC Software (CEPCSW) based on Gaudi is being developed for current TDR study and more future study.
  - Key4hep: benefit from international cooperation
  - EDM4hep: event data model
  - DD4hep: detector description and reconstruction support
  - etc.
- Reconstruction in Marlin framework (many thanks ilcsoft) has been used for CDR study, therefore, implementing them into CEPCSW can be regarded as quick start for CEPCSW and validates this new framework.
- More detector designs are joining into study: CDR baseline (CEPC_v4), FST/FST2, DC+DualReadoutCalorimeter, Reference detector …

Migration from Marlin to CEPCSW



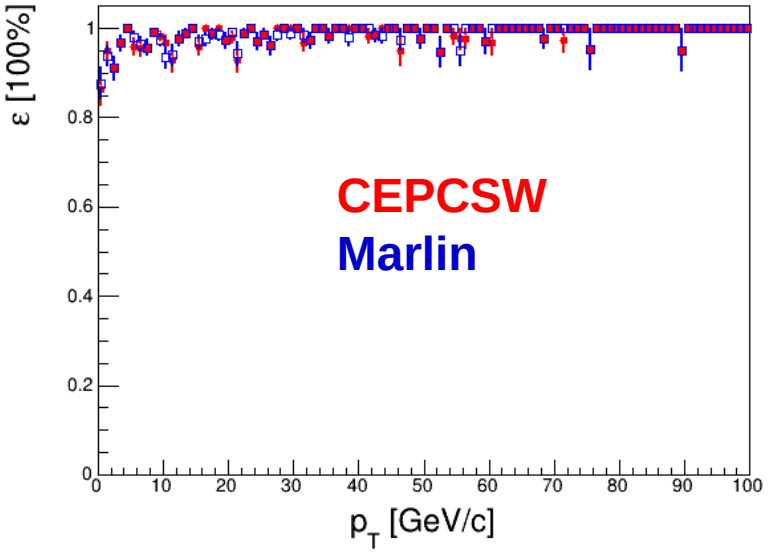
Progress of Migration

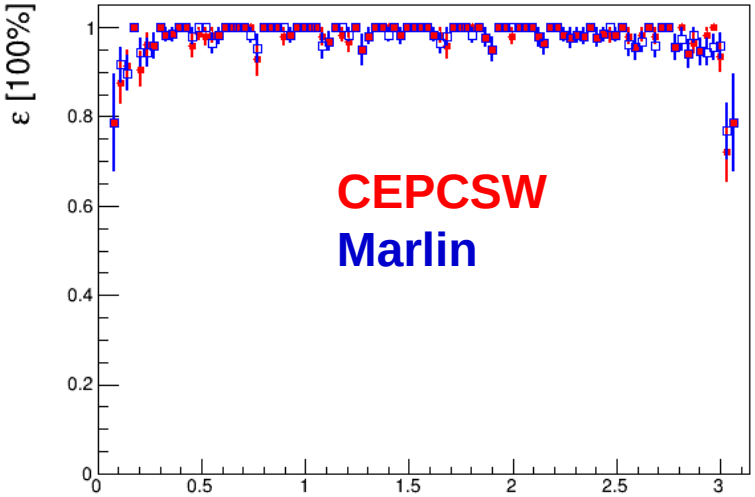
- Tracking processes in CDR: completely repeat these processes in CEPCSW
  - SiliconTracking_MarlinTrk → SiliconTrackingAlg √
  - ForwardTracking → ForwardTrackingAlg √
  - TrackSubsetProcessor → TrackSubsetAlg √
  - ClupatraProcessor → ClupatraAlg √
  - FullLDCTracking_MarlinTrk → FullLDCTrackingAlg √



Tracking Efficiency

- Fake tracking efficiency definition
  - $\varepsilon = N_{macthed\_track}/N_{MC(primary)}$
  - $|par_{fit}-par_{MC}| < 5\sigma_{par}$ (par=d0, phi0, ω, z0, $\tan\lambda$)
- Same muon sample (5000) by MokkaC (developed version of Mokka)
  - CEPC_v4 detector model
  - $p \in [0.5, 100.5]$ GeV/c
  - $\theta \in [5°, 175°]$
  - $\phi \in [0°, 360°]$
- Same reconstruction options
- Fake rate:
  - CEPCSW: (1.65±0.19)%
  - Marlin: (1.59±0.18)%

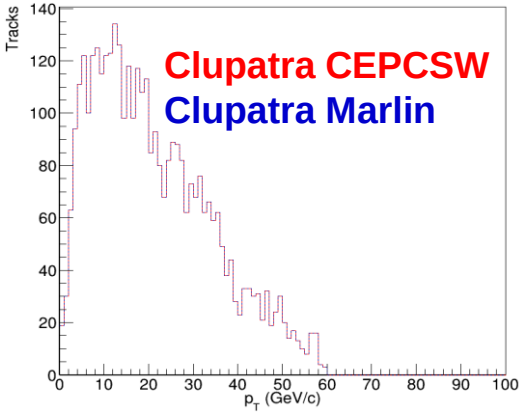


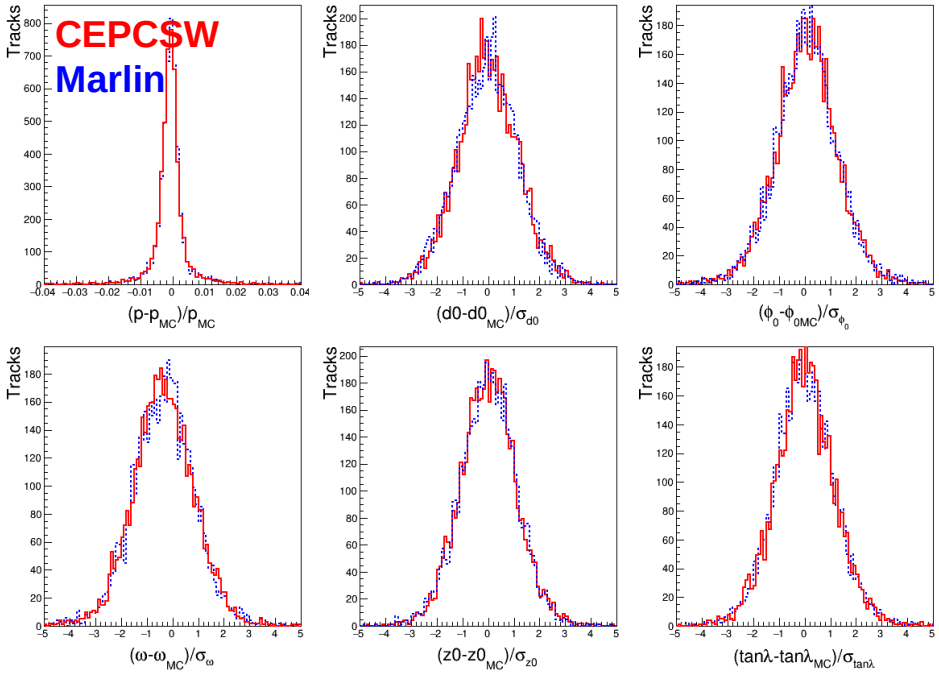


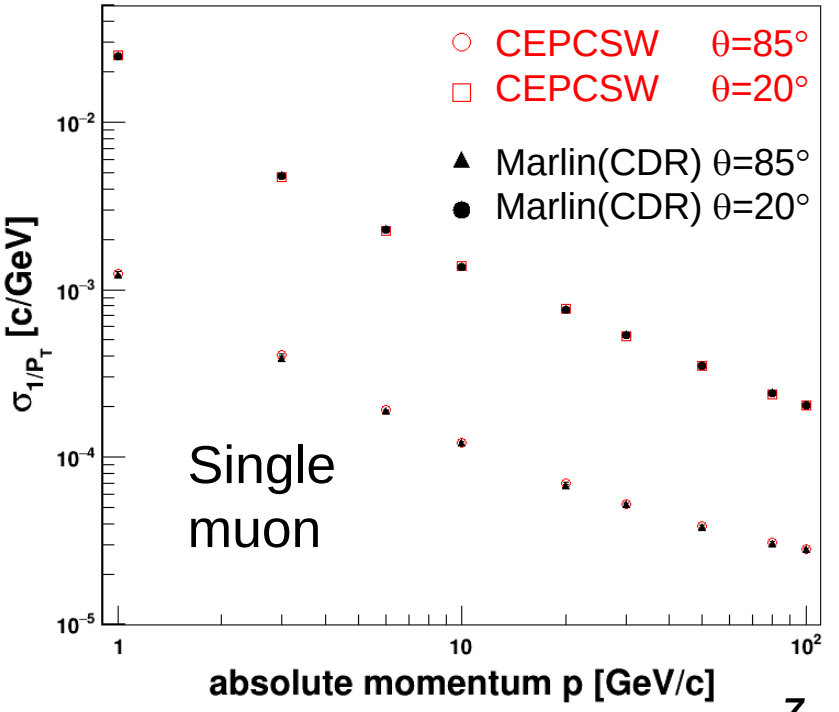
In fact, denotes tracking×detecting

TPC + Silicon Tracker

- After same digitization
  - Fully identical in CEPCSW and Marlin
- Combine to silicon tracks
  - different digitization random
  - consistent with Marlin

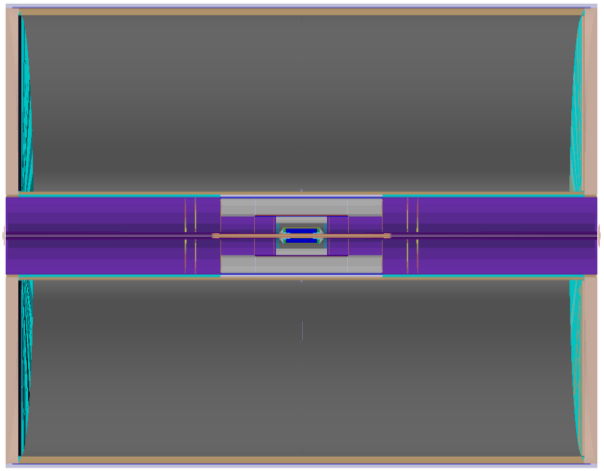


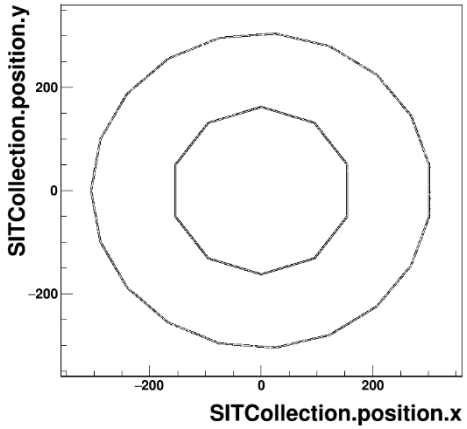


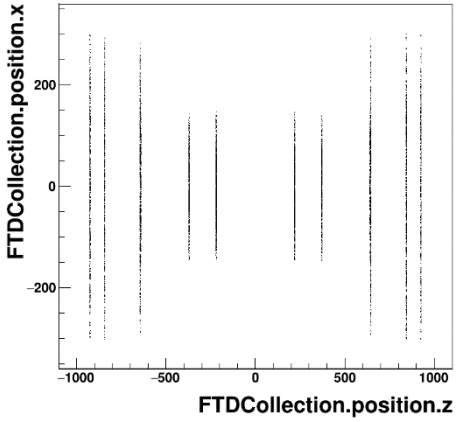


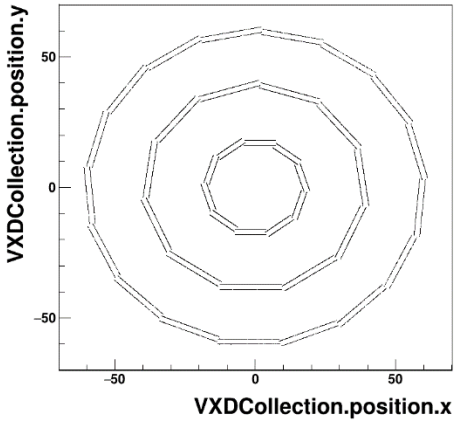
Tracker Geometry Implementation

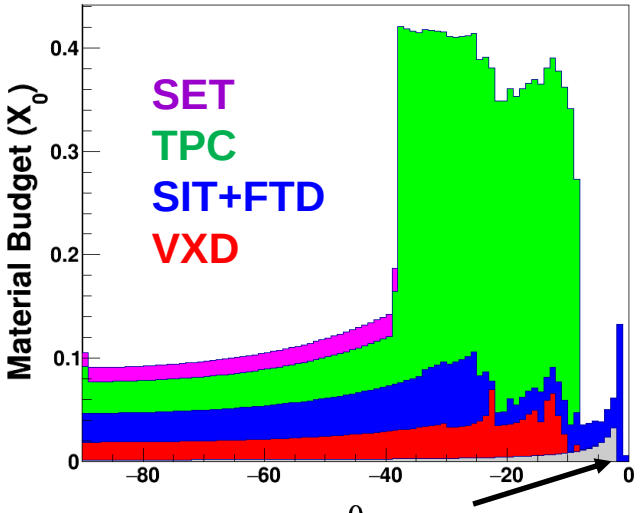
- Geometry description by DD4hep
- Implement TPC + silicon tracker of CEPC_v4 by modified lcgeo
  - VXD
  - FTD
  - SIT
  - TPC
  - SET





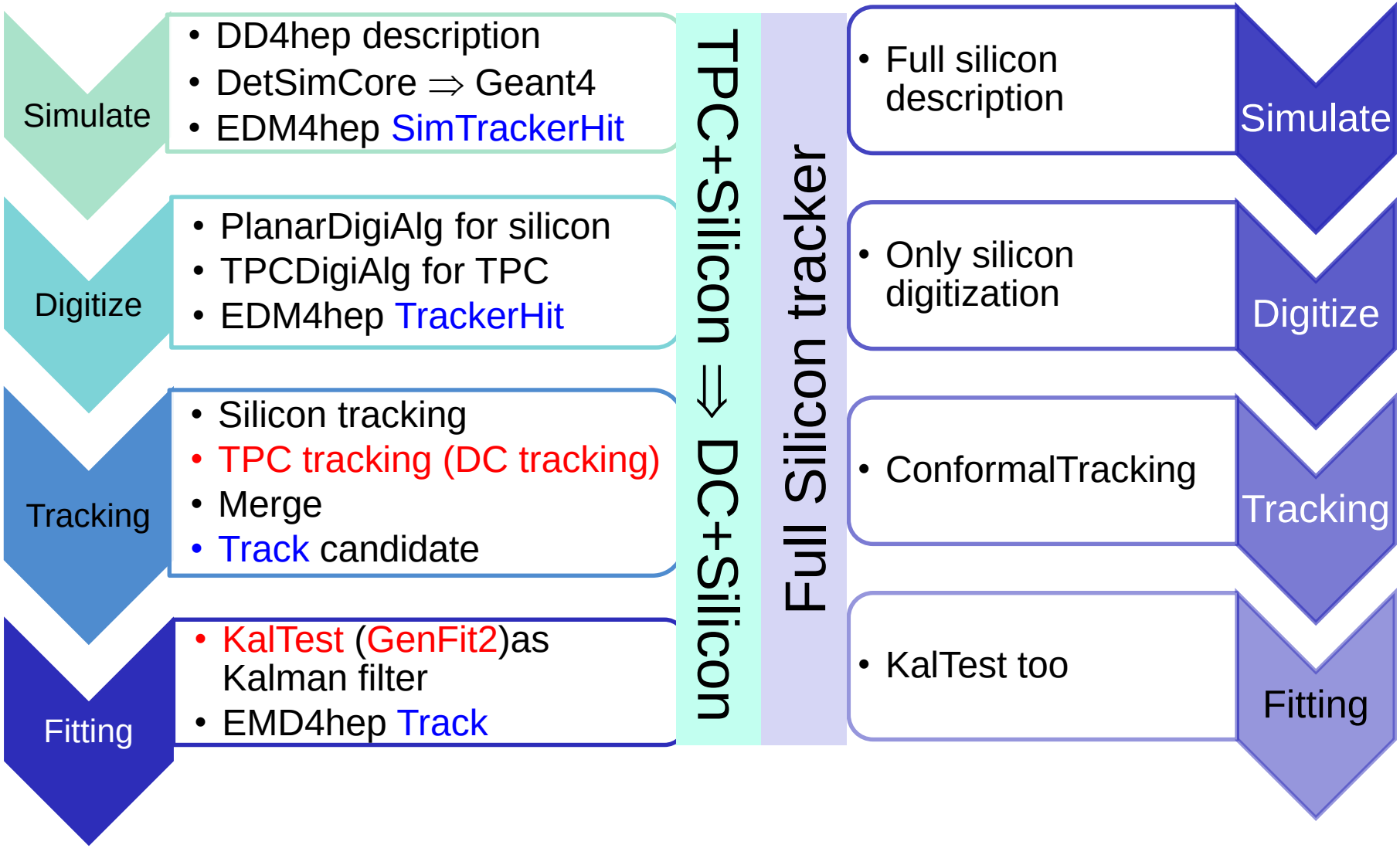






Only z=0→700mm beam pipe implemented currently

Full Sim-Rec Process



Progress of Tracking Software

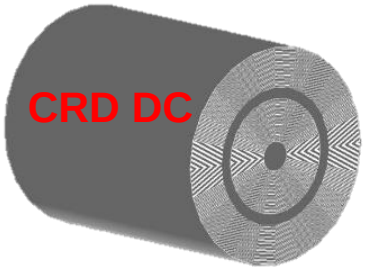
- Apply migrated digitization and tracking algorithms (from Marlin framework) onto CEPCSW simulated data (EDM4hep)
  - Start from simple SimTrackerHit and simple digitization
  - Run this full **sim→digi→tracking→fitting** chain in CEPCSW
  - **[Debug ↔ performance check]→update** are ongoing
- ConformalTracking has been also migrated
- Plan face to future
  - Realistic digitization (space charge effect, noise etc.)
  - Clustering before tracking (solve the problem on large time cost of ConformalTracking sometimes)
  - Non-uniform magnetic field study
  - Background mixing study
  - Test ACTS and consider to apply it onto fitting (KalTest brother?)

Developing for CRD Tracker

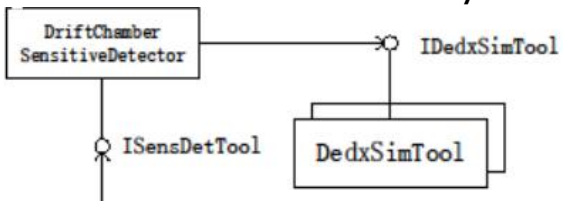
- Supported by DD4hep compact description
  - Only need to use released options or modify some optional parameters in XML file, not face to construction files (c++) generally
  - Replace TPC with DC (option on sub-detector modules)
  - Modify silicon layout (option on parameter)
  - Database (MokkaC) ⇒ XML file (current CEPCSW)
- In full reconstruction chain, TPC tracking (Clupatra) is a standalone work model, therefore it is possible to replace it with DC tracking, at the same time keeping others tracking.
- Roadmap for silicon tracker in CRD
  - SiliconTracking + TrackSubset work well for modified VXD + FTD+ SIT, but not work on too long track in silicon tracker, such as full silicon tracker, and then ConformalTracking will become alternative offer.
  - ConformalTracking works on full silicon tracker, also on vertex tracking.
  - New tracking based machine learning is also on considering.

Status of Drift Chamber Software

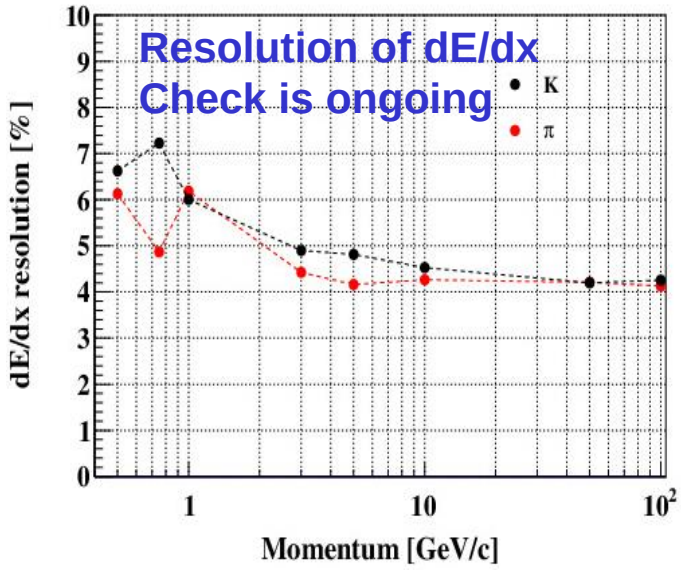
- Geometry
  - inner + outer chambers
  - Baseline: 1.8m, 130 layers, He:iC_4H_{10}=90:10
  - Cell partitioning with the segmentation method

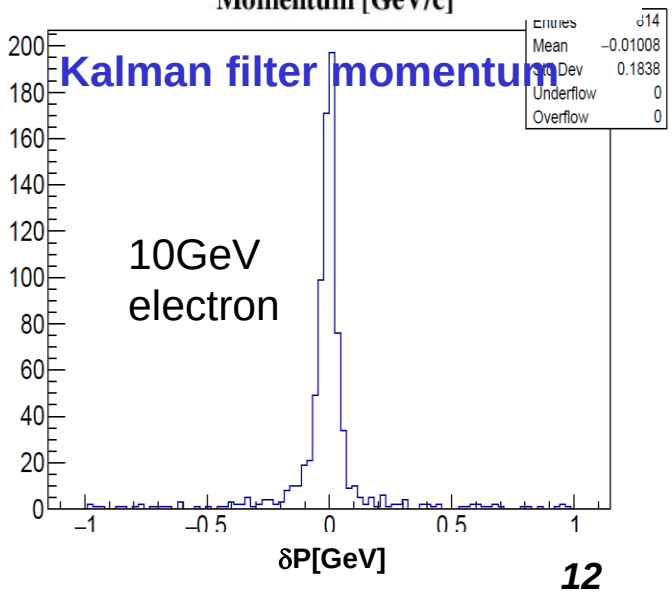


- dE/dx simulation
  - Implemented dE/dx simulation module with sampling method by Bethe Bloch Eq.
  - Configurable Gaudi tools could be used for the implementation of different dE/dx methods



- Reconstruction
  - Track fitting with Kalman filtering use standalone Genfit2, to implement
  - Space points which random selected from truth as input

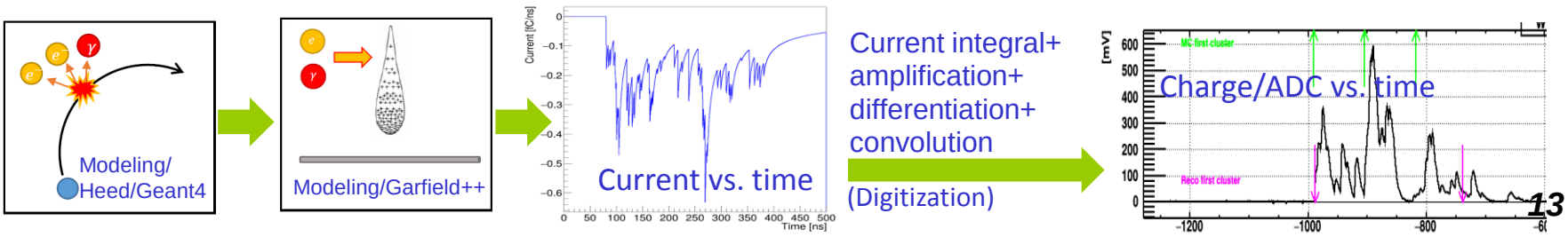




Plan of Drift Chamber Software

- First release of drift chamber software
  - Baseline with axial wires
  - Simple dE/dx simulation
  - Track fitting with wire measurement
- Simulation of geometry and waveform for cluster counting method
  - Implement sereo wires
  - Implement fast Garfield++ waveform or its parameterization as dN/dx sampling model, according to study
- Standalone drift chamber performance studies
  - cluster counting with Garfield++
  - Trackerr for momentum resolution
- Development of drift chamber tracking algorithms
  - Track fitting combine silicon and drift chamber measurments
  - Tack finding with seeding, self-tracking or machine learning method

Simulation of waveform for cluster counting method

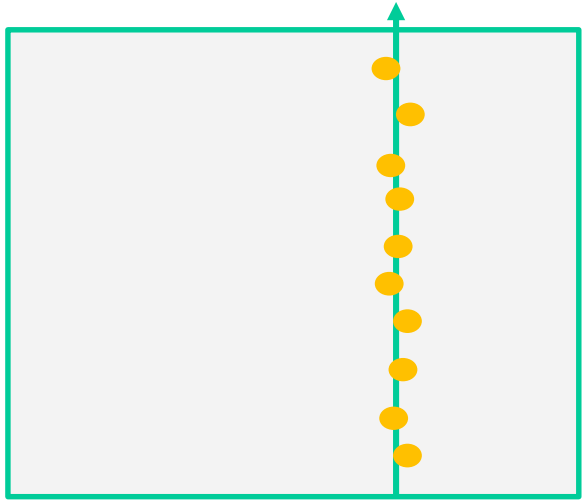


Study of Cluster Counting Method

- Particle identification is essential for Higgs, EW and flavor physics
- Cluster counting method provides a very promising approach to achieve better PID than dE/dx method for the drift chamber of CEPC reference detector
- A standalone simulation study with Garfield++ on ionization process being performed

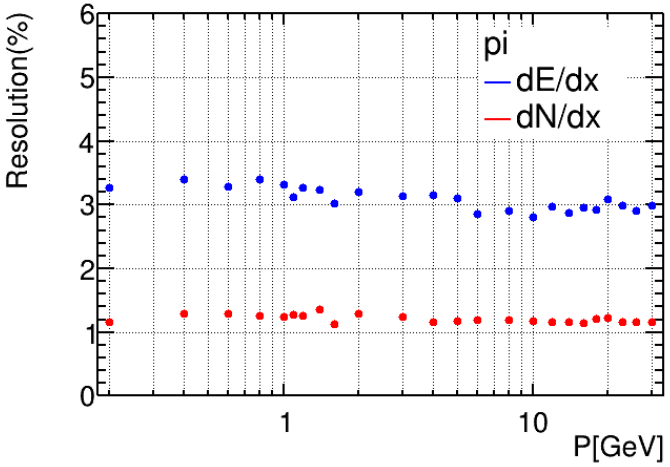
Input

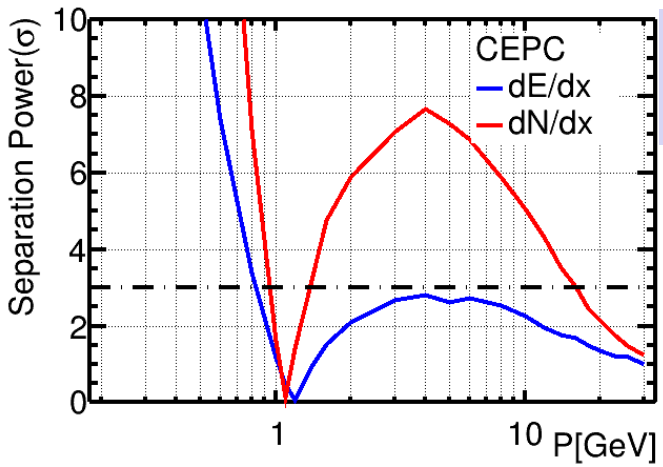
- Cell size: 1cm*1cm
- 118 layers, R from 0.3 to 1.5m (suggested by Mingyi)
- He(50%) + iC_4H_{10}(50%)
- $\cos\theta = 0$



Preliminary Results from Garfield

- Preliminary results show that the resolution and separation power with cluster counting method are significantly better than traditional dE/dx method
- To do
  - Simulate the induced signal and develop the peak finding algorithm
  - Study the performance by varying detector configurations (size, gas …)
  - Take the contribution of electronics into account
  - Develop a realistic digitization model in CEPCSW





Truncated mean cut (70%) for dE/dx

$$S = \frac{|<\frac{dE}{dx}>_{\pi} - <\frac{dE}{dx}>_{K}|}{\sqrt{\sigma\left(\frac{dE}{dx}\right)^2_{\pi} + \sigma\left(\frac{dE}{dx}\right)^2_{K}}}$$

Release Plan of Tracking Software

- First preliminary version — November 30, 2020
  - workable for CEPC_v4, for combining test with following PFA, VertexFinding, jet procedures, etc.
  - Validated TPC+Silicon tracker geometry
  - Validated TPC+Silicon simple digitization
  - Validated TPC+Silicon tracking and fitting

access to download from https://github.com/cepc/CEPCSW before official release

- Updated version — December 31, 2020
  - Implement ConformalTracking for study on full silicon tracker
  - Implement DC Geometry & fitting
- First frozen version
  - Implement DC tracking
- More according research progress
  - Digitization, background mixture, cluster counting for DC, clustering for silicon track, etc.

Summary

- Complete tracking and fitting procedure has been migrated from Marlin to CEPCSW, and results are consistent with Marlin.
- CEPC_v4's tracker has been implemented into CEPCSW, and there are two reconstruction chains, in release plan.
  - (database)→MokkaC→(saved LCIO, Gear file)→Digi→Tracking→Fitting
  - (compact)→Sim →Digi→Tracking→Fitting
- Simulation and reconstruction software for CRD are also in progress.
- Big plan besides updating current software:

Simulation	Digitization	Tracking	Fitting	Analysis
Geometry	Realistic Digi	DC tracking	ACTS etc.	Performance
Cluster counting	Background mixture	DC fitting	Surface manager	Background mixing
	Clustering	Machine learning		Non-uniform field

Thank You !

謝謝