Tracking for Silicon Tracker in CEPCSW

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(on behalf of the CepC software working group)

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* ❖ Tracking software for silicon tracker

* ❖ Performance validation for the CDR baseline detector

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Introduction

- ❖ Track requirements of CepC
  - ● ~100% efficiency within the energy & solid angle acceptance
  - ● Momentum resolution $a \oplus \frac{b}{p_T \sin^{1/2}\theta}$
    - ■ σ_{1/p_T}: $a \approx 2 \times 10^{-5}[\text{GeV/c}]^{-1}, b \approx 1 \times 10^{-3}$
    - ■ σ_{D_0}: $\quad a \approx 3 \ \mu\text{m}, b \approx 10 \ \mu\text{m·GeV/c}$
- ❖ CepC Software (CEPCSW) based on Gaudi is being developed for current TDR study and more future study.
  - ● EDM4hep: event data model
  - ● DD4hep: detector description and reconstruction support
- ❖ More detector designs join in study: CDR baseline detector, FST/FST2, IDEA, Reference detector, toward 4th conceptual detector now
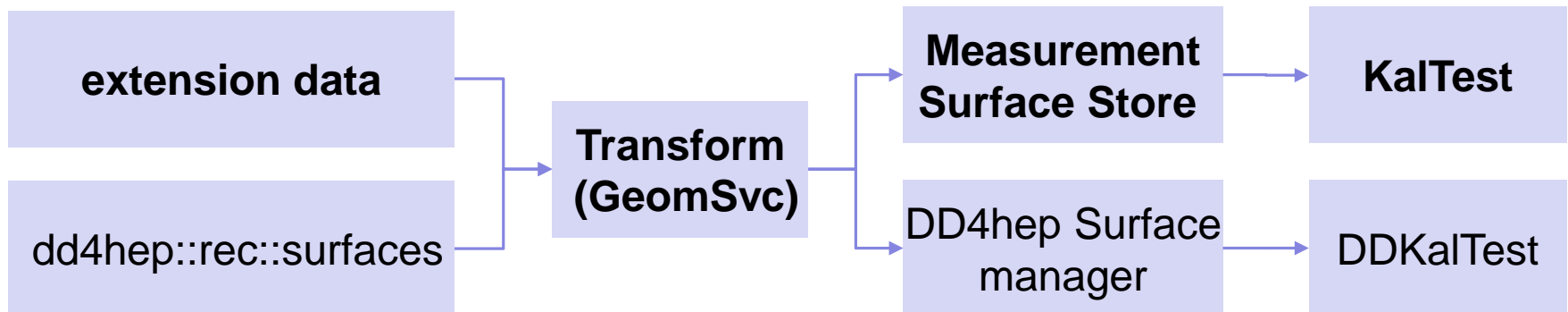- ❖ Silicon tracker always is designed as one part of trackers in all detector concept

Tracking Processor in CEPCSW

❖ Both one job (Sim→Rec) and two jobs (Sim→EDM4hep→Rec) for reconstructing simulated data are available

❖ multiple standalone tracking works for difference combinations
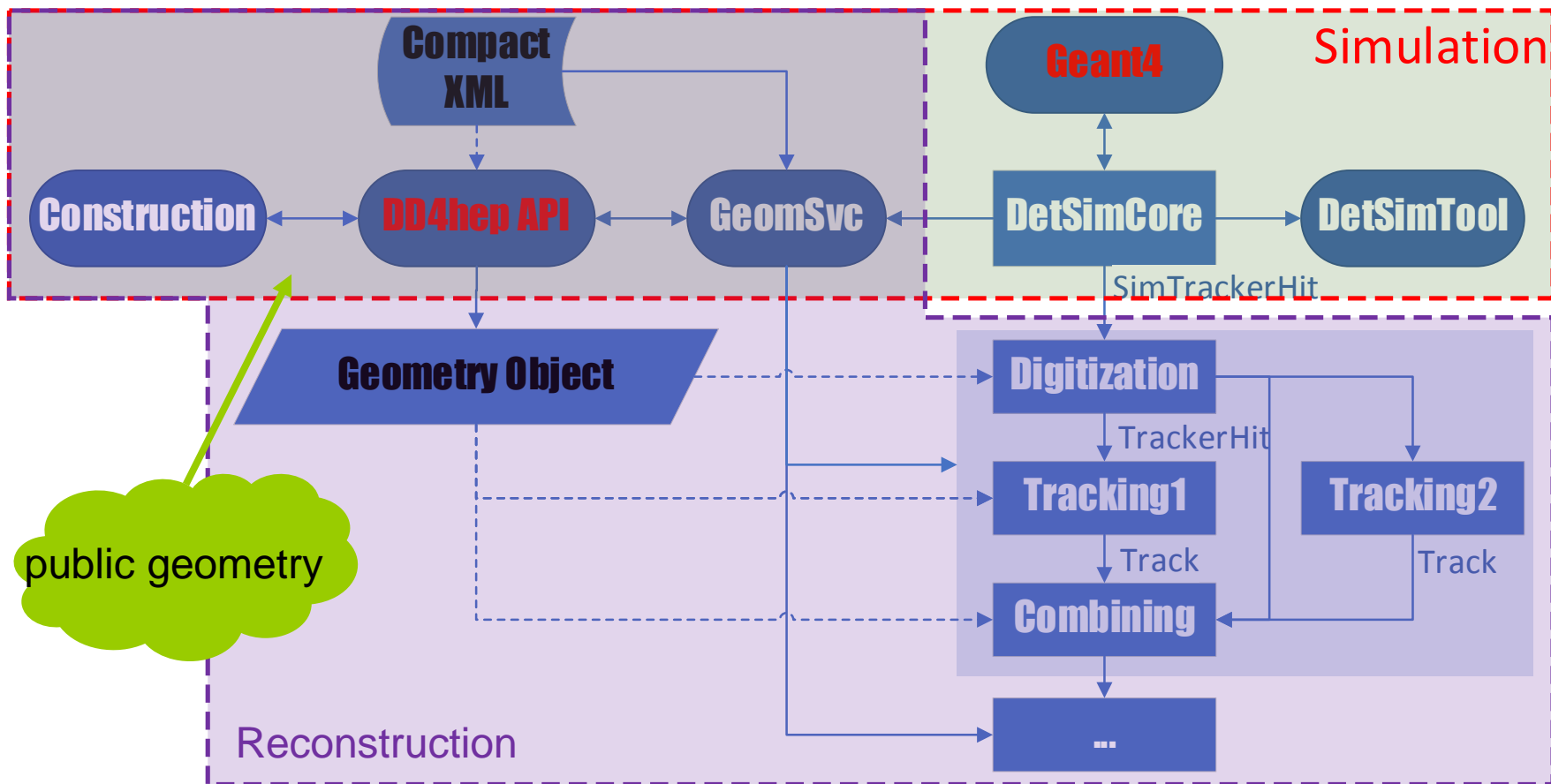
Geometry

❖ Frozen CDR baseline detector (CEPC_v4)

- Silicon tracker: VXD, SIT, SET, FTD
- TPC

❖ Developing the Fourth Conceptual Detector

- Silicon tracker: VXD, SIT/SOT, EIT/EOT
- Drift chamber (DC)

❖ For tracking

```
extension data ──┐
                 ├──► Transform ──┬──► Measurement ──► KalTest
                 │    (GeomSvc)   │    Surface Store
dd4hep::rec::surfaces ┘           └──► DD4hep Surface ──► DDKalTest
                                       manager
```

Data Input

❖ Digitization from SimTrackerHit to TrackerHit

- ● SimTrackerHit: id, x, y, z, de
- ● TrackerHit:　　　id, x_new, y_new, z_new, de, covariance matrix

❖ Current digitization PlanarDigiAlg for silicon tracker

- ● Pixel: two dimensions, σ_U & σ_V
- ● Strip: one dimension, σ_U

❖ Additional algorithm for strip to build one space pointer (TrackerHit, σ_x, σ_y, σ_z) from two one-dimension hits (TrackerHit) in close strip layers
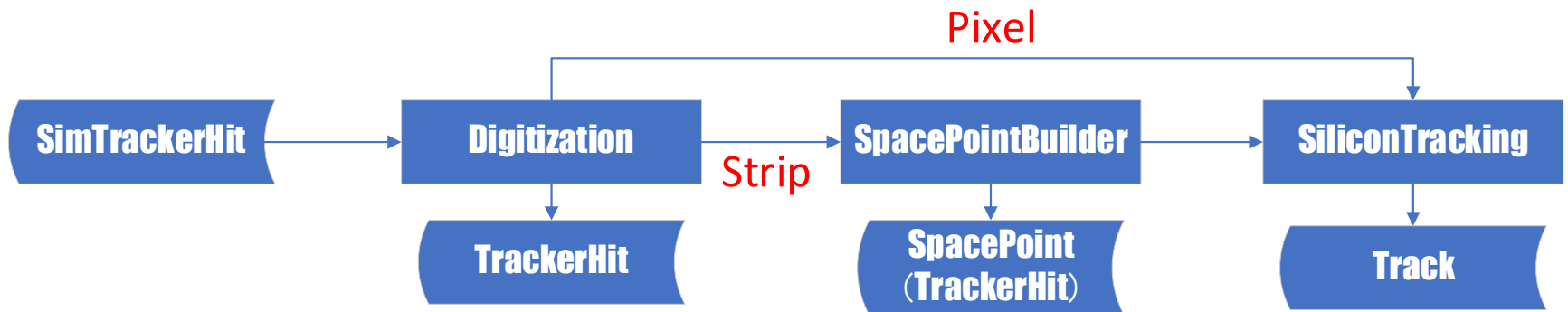
Standalone Tracking

❖ Each track finding followed by common Kalman fitting to output Track (EDM4hep), optional output collection names

❖ Optional output for each track collection according to analysis requirement
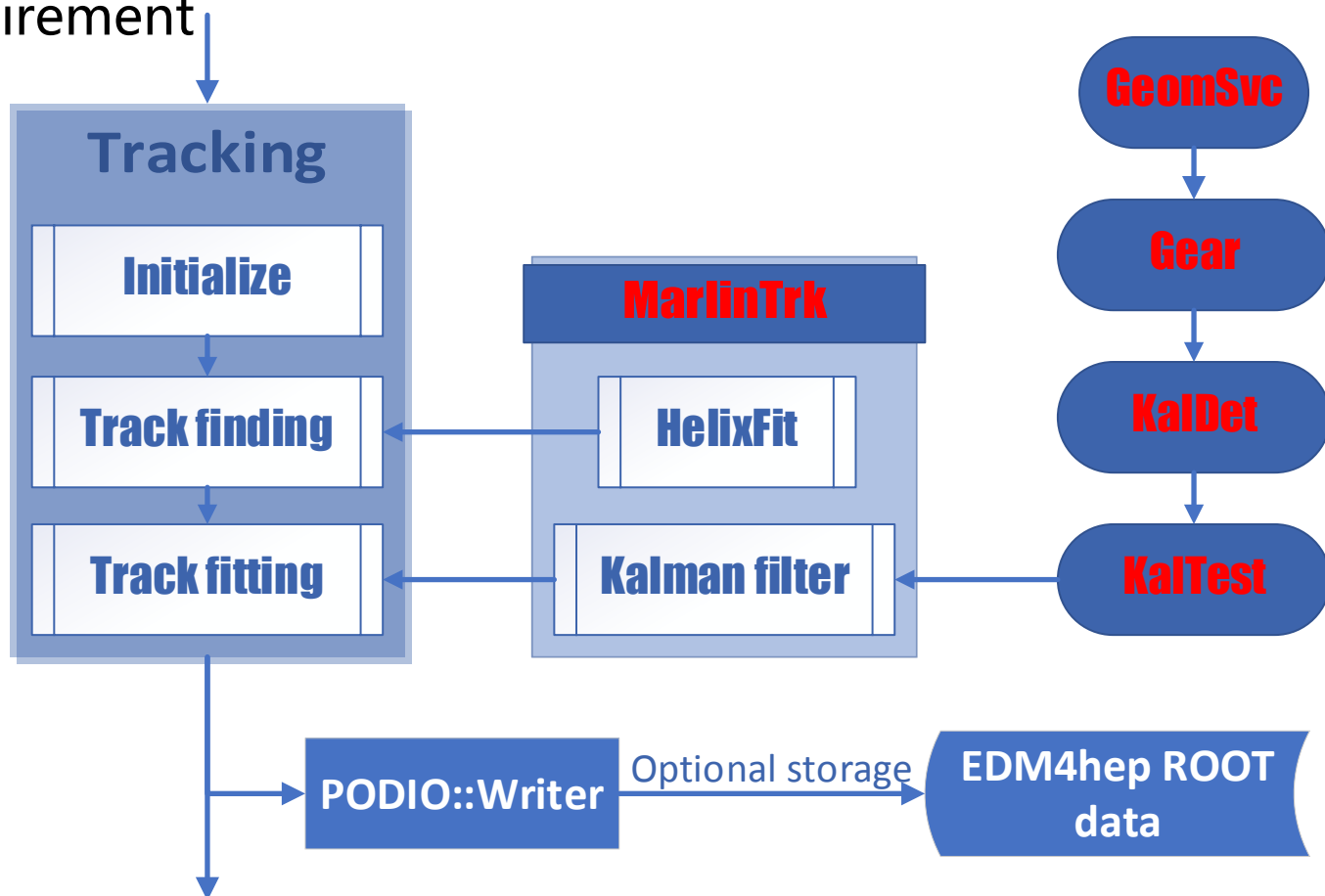
Tracking Algorithm

❖ Tracking in CDR: completely repeat these processes in CEPCSW

- SiliconTracking_MarlinTrk → SiliconTrackingAlg √
- ForwardTracking → ForwardTrackingAlg √
- TrackSubsetProcessor → TrackSubsetAlg √
- ClupatraProcessor → ClupatraAlg √
- FullLDCTracking_MarlinTrk → FullLDCTrackingAlg √

❖ Optional tracking combination:

- SiliconTrackingAlg→TrackSubsetAlg→FullLDCTrackingAlg
- SiliconTrackingAlg→TrackSubsetAlg→ClupatraAlg→FullLDCTrackingAlg

VXD+SIT+FTD (dictionary)

SiliconTracking_MarlinTrk

Merge silicon tracks

FTD (pattern recognition)

TrackSubsetProcessor

ForwardTracking

For Silicon Tracker

Merge silicon and TPC tracks
+SET/ETD

FullLDCTracking_MarlinTrk

ClupatraProcessor

For TPC
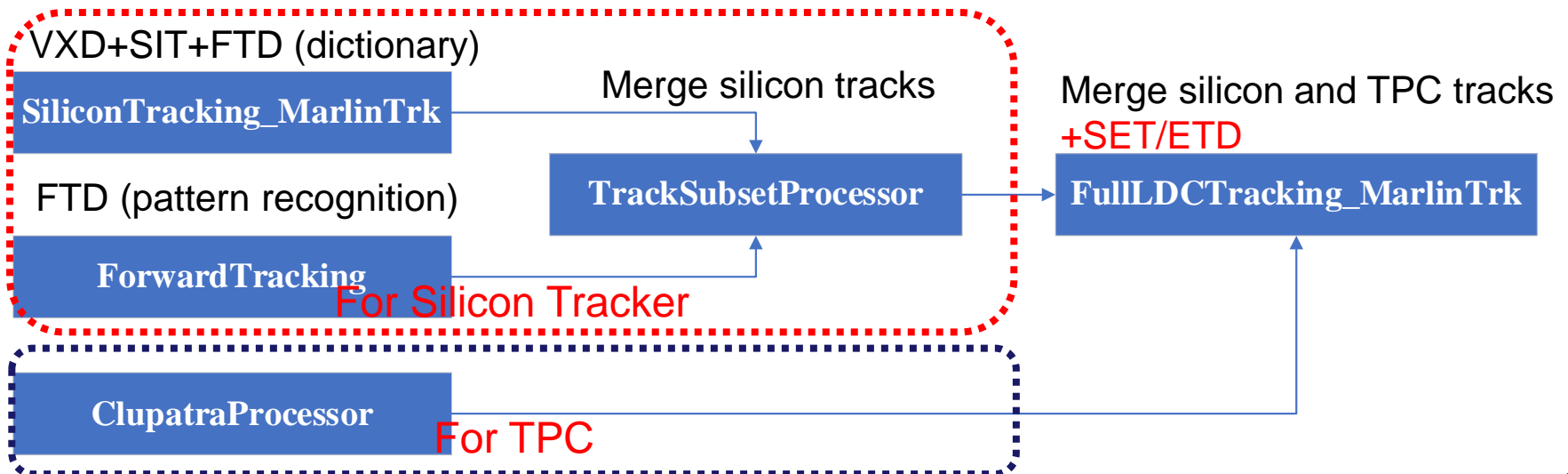
Status

❖ Migrated tracking algorithm from ILCSoft (Marlin & LCIO) to CEPCSW (Gaudi & EDM4hep)

- http://gitbub.com/cepc/CEPCSW
- Validated by track performance

❖ Tracking options

- default options work at most time
- CDR baseline detector: whole tracking chain, Examples/option
- Reference detector: silicon tracking chain, Detector/DetCRD/script
  - CRD_o1_v01: strip SIT
  - CRD_o1_v02: pixel SIT
- Fourth conceptual detector
  - Setting up

Midway concept

❖ Support for tracker optimization

- Layout options in simulation: material, position, number
- Resolution options in digitization

CDR Baseline Tracker
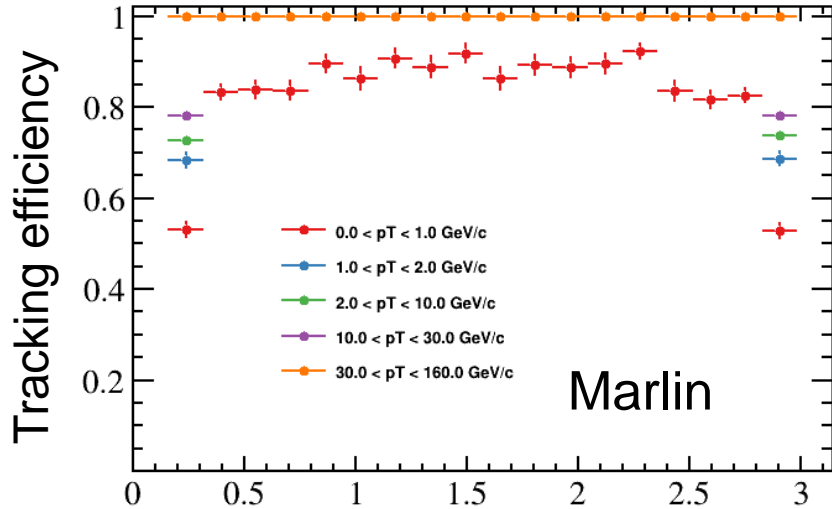
❖ Geometry description by DD4hep

❖ Implement TPC + silicon tracker of CEPC_v4 by modified lcgeo

- VXD
- FTD
- SIT
- TPC
- SET
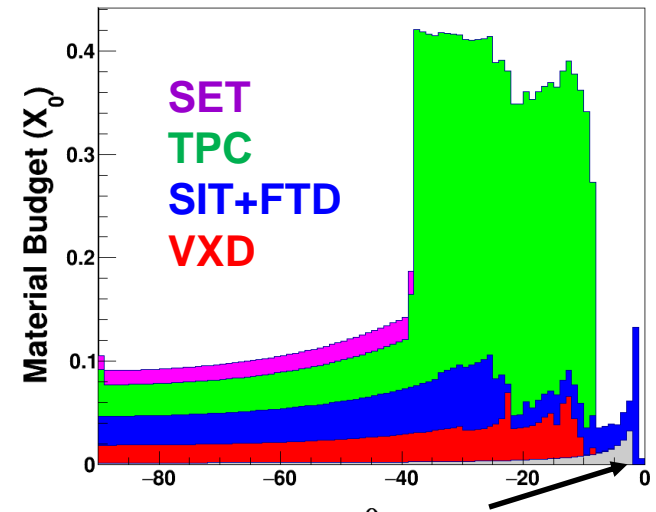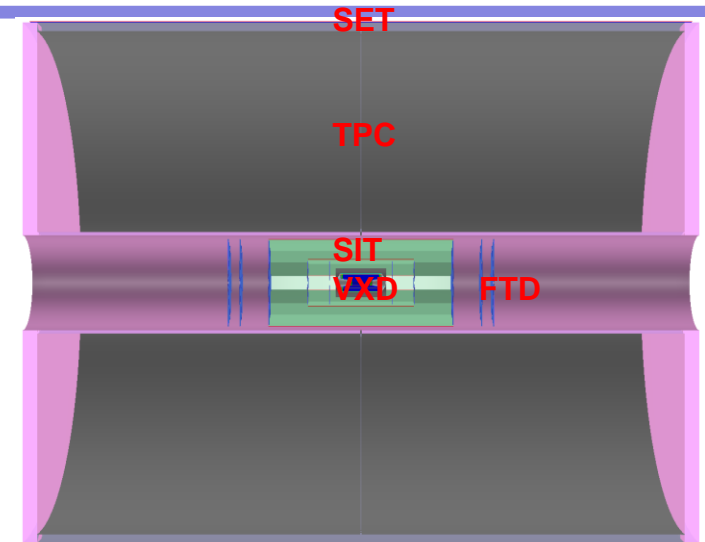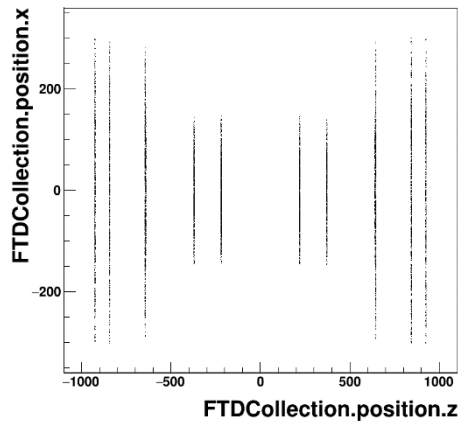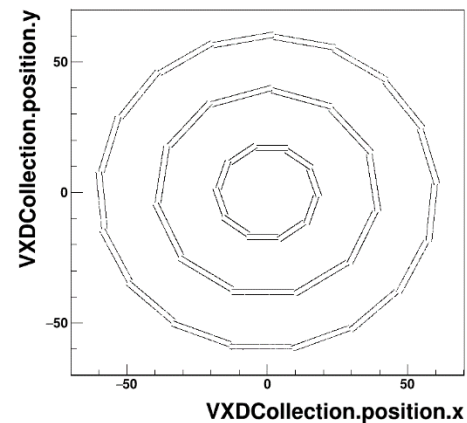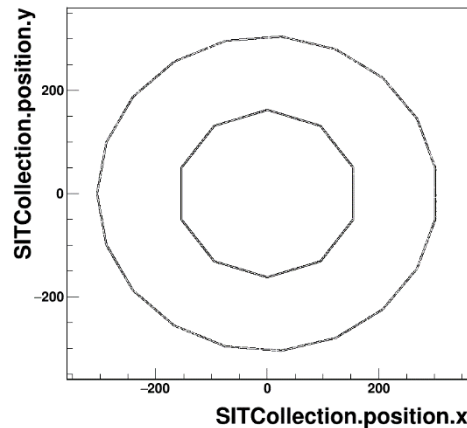
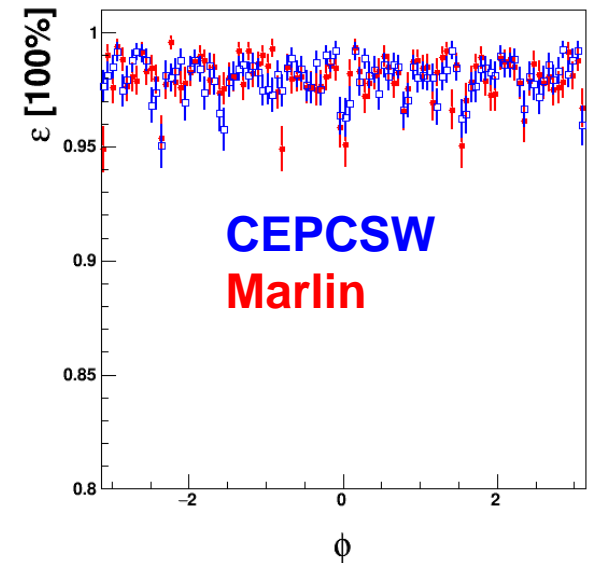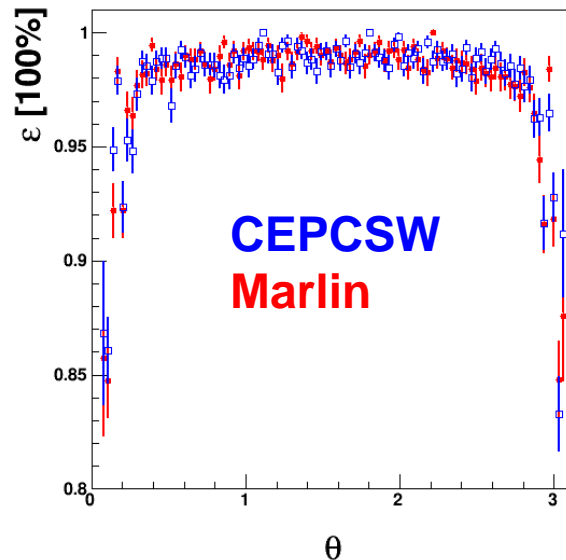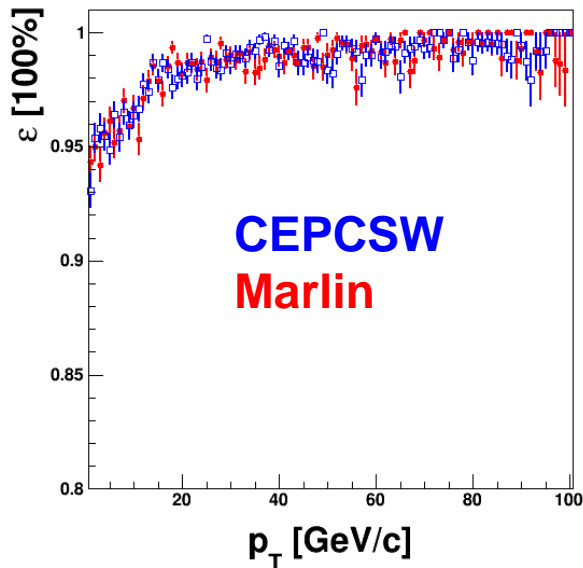Only z=0→700mm beam pipe implemented currently

LCIO Input from Mokka Simulation
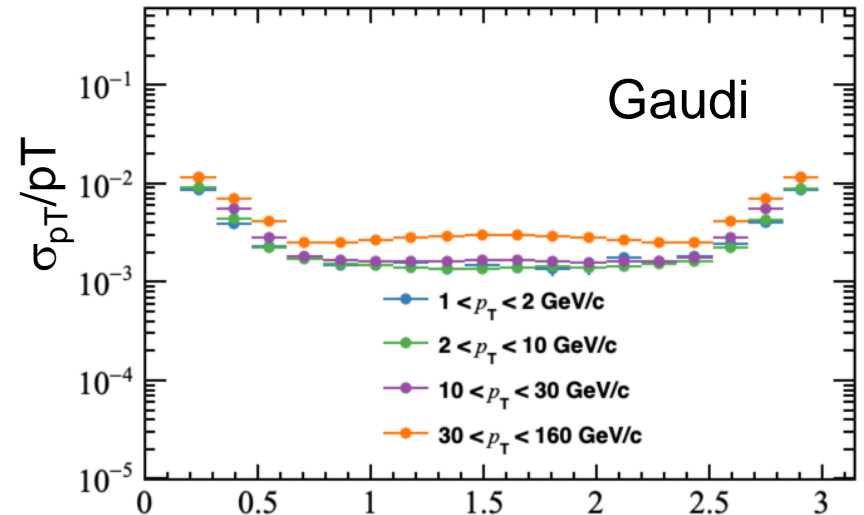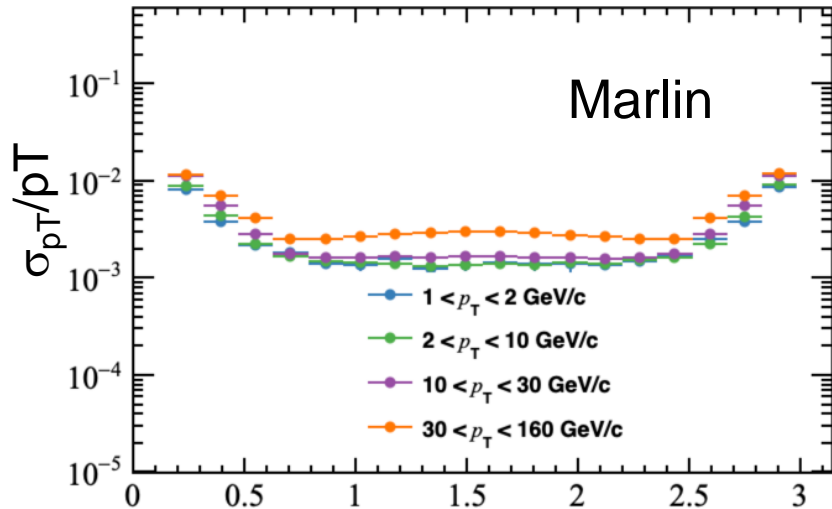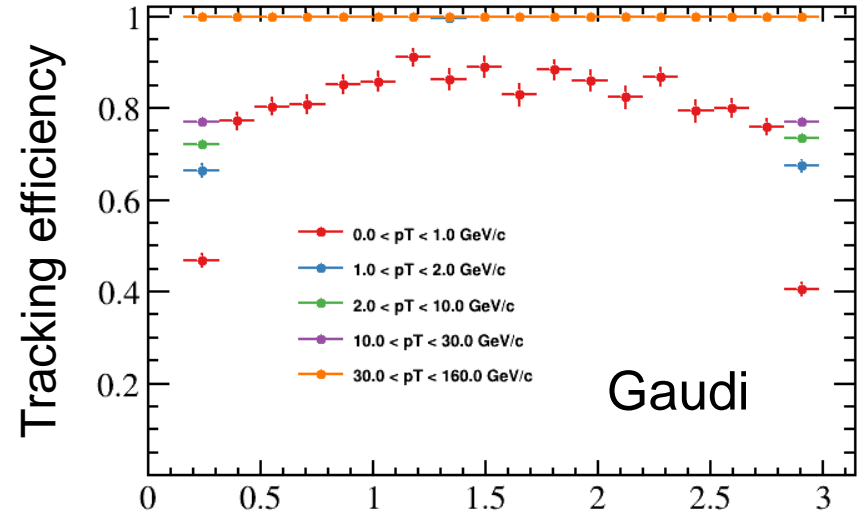
CEPCSW Simulation

- ❖ Fake tracking efficiency definition denotes tracking×detecting in fact

  - $\varepsilon = N_{macthed\_track}/N_{MC(primary)}$

  - $|par_{fit}-par_{MC}|<5\sigma_{par}$ (par=d0, phi0, ω, z0, tanλ)

- ❖ Single muon sample (50000) on CEPC_v4 geometry

 - $p\in[0.5, 100.5]$ GeV/c, $\theta\in[5°,175°]$, $\phi\in[0°,360°]$

Performance of Combining with TPC

❖ Simulation: MokkaC (LCIO) VS CEPCSW

- single muon

❖ Reconstruction: full tracking chain (silicon + TPC)
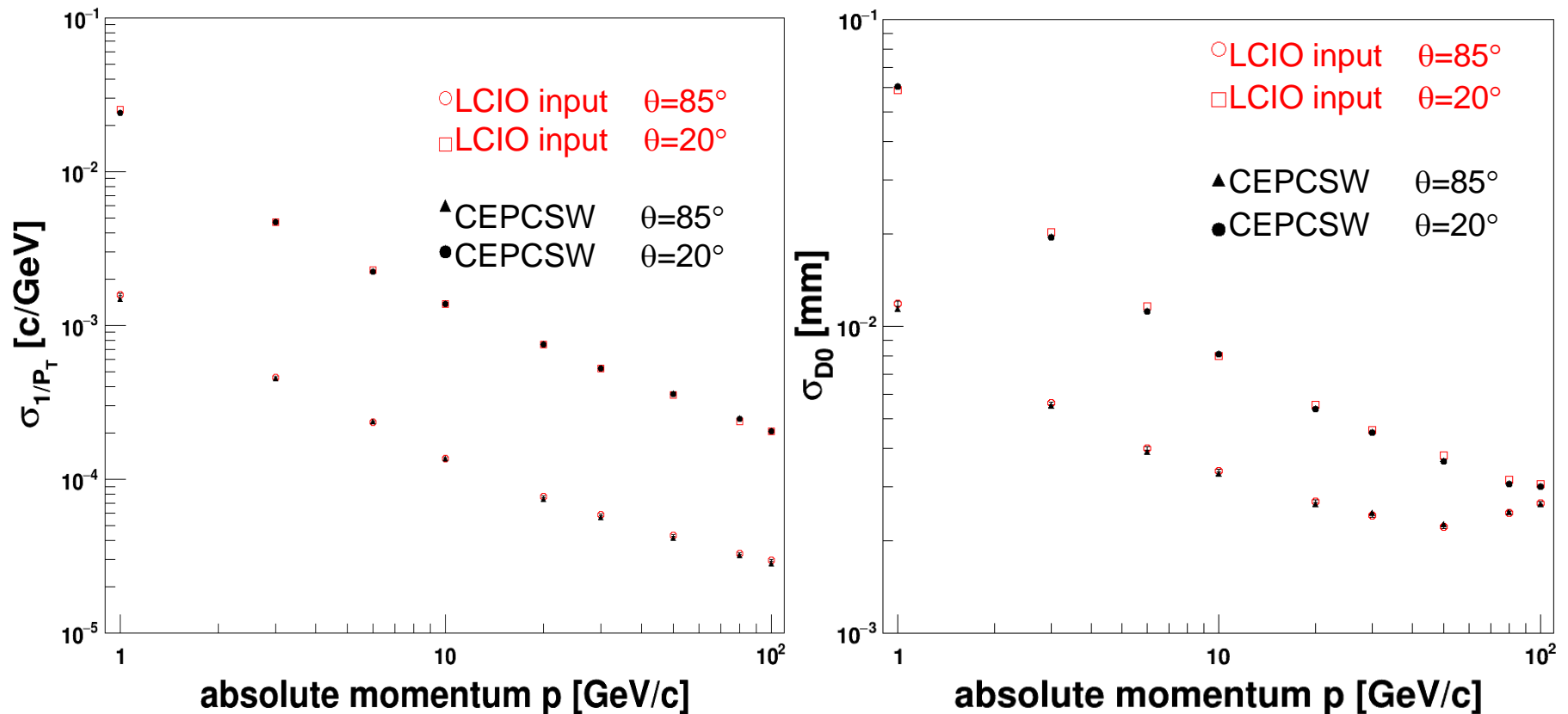
Reference and Fourth Concept

❖ Tracker design developing toward the fourth conceptual detector
- VXD
- SIT/SOT
- EIT/EOT
- DC

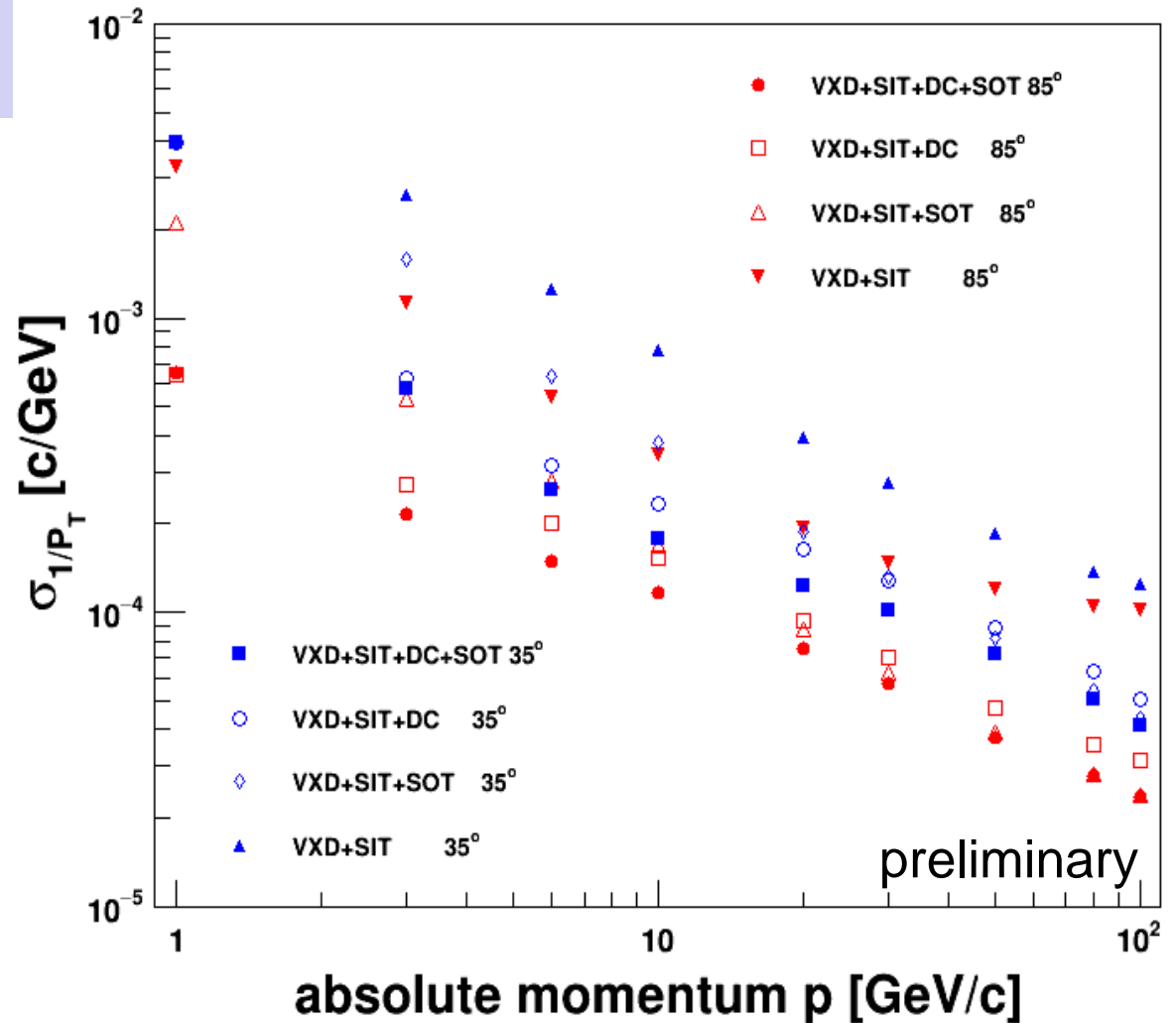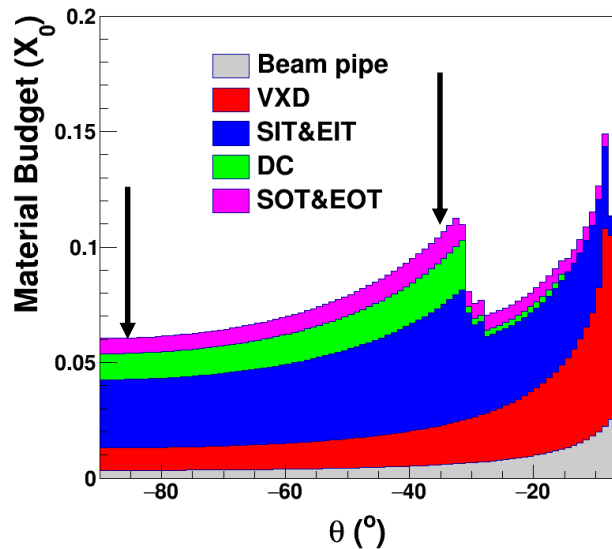❖ Tracking works through adjusting the tracking combination and tracking options, test done

no layer display

preliminary

no layer display

preliminary

layer display
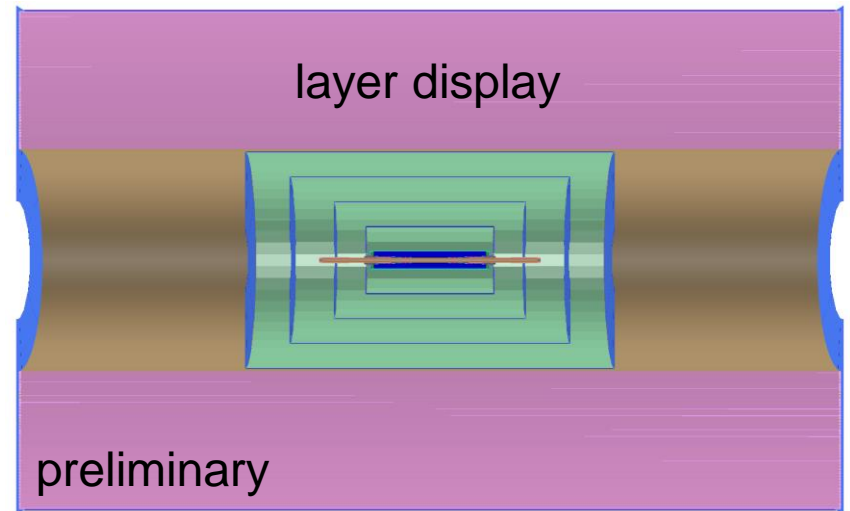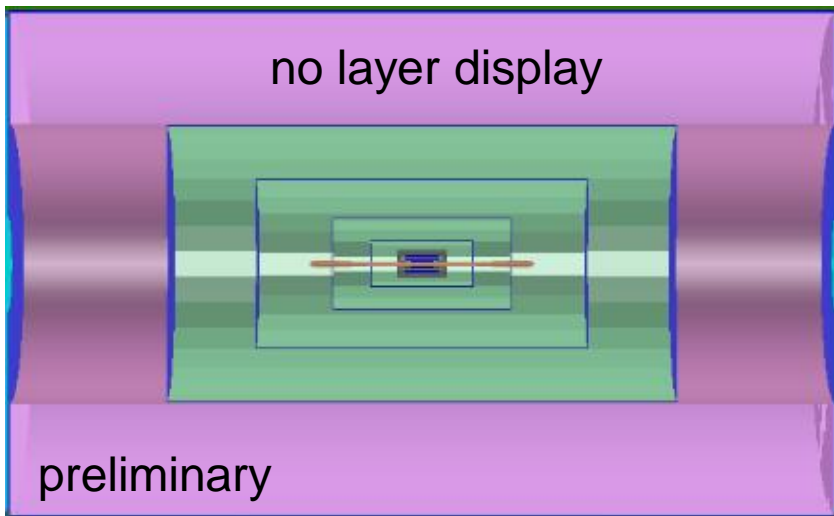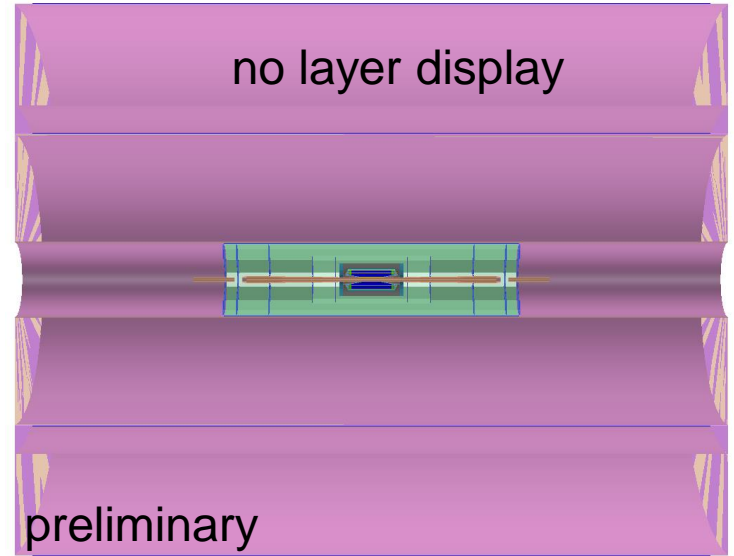
preliminary

Performance for Silicon Tracker

$\sigma_{rphi,z}$=2.8μm, 6μm, 4μm, 4μm, 4μm, 4μm

σ_{rphi} =7.2μm, σ_z=86μm

σ_{rphi} =110μm, σ_z=1mm

- ❖ VXD: 6 pixel layers
- ❖ SIT: 4 pixel layers
- ❖ DC: 100 layers
- ❖ SOT: 1 pixel layer

Design Comparison
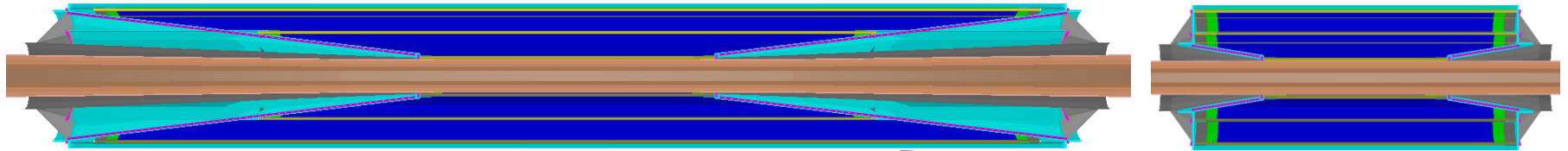
VXD: short VS long

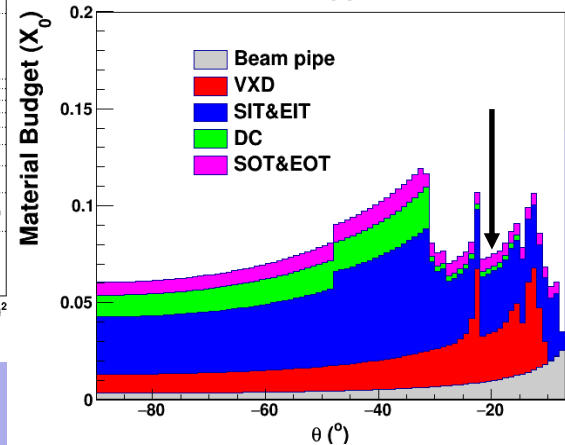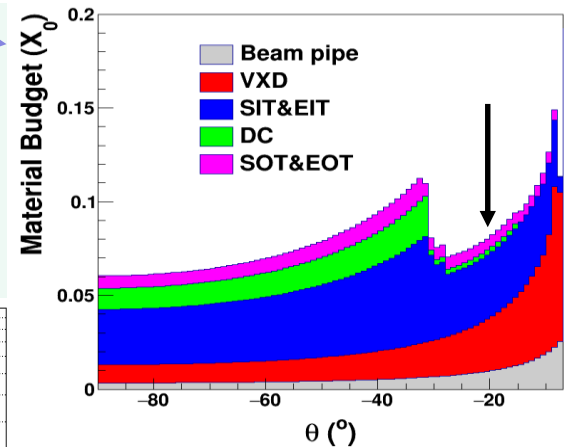|	
Geometry support	√
Preliminary tracking for endcap	√
Tracking option fro endcap	improvable

preliminary (20°)

Long
Short

preliminary (20°)

Long
Short
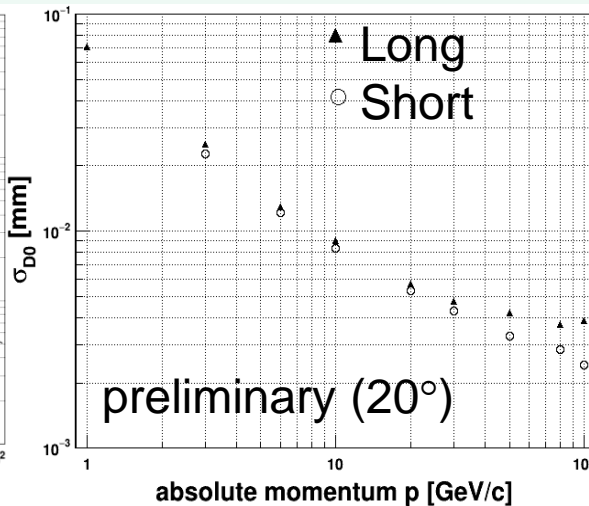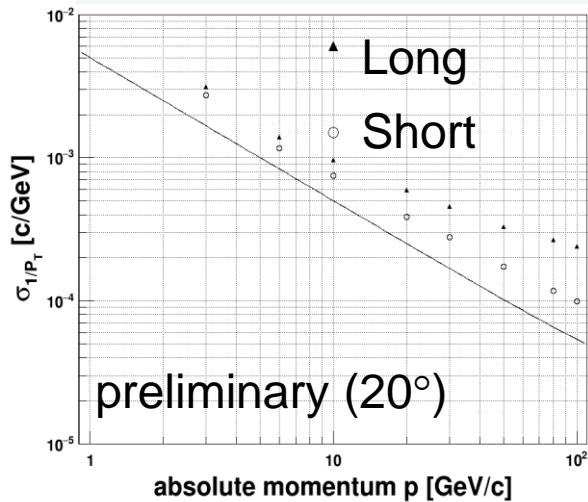
As example, possible to validate more designs
from optimization (fast simulation or estimation)

Plan

- ❖ Tracking development

  - Support for skew planar

- ❖ Study and Improvement

  - Uniform magnetic field

  - Noise mixture

- ❖ Tracking option release

  - Fourth conceptual detector

- ❖ Validate optimized tracker design by fast simulation or estimation

- ❖ Apply tracker reconstruction on physics study, probably meet more issues and fix

Summary

❖ Complete tracking and fitting procedure has been migrated from Marlin to CEPCSW, based on Gaudi and EDM4hep, and results are consistent with Marlin.

❖ CEPC_v4's tracker has been implemented into CEPCSW, and whole simulation and reconstruction chain shows consistent performance with Marlin too.

❖ Some performance tests for the Reference detector and the 4th conceptual detector in CEPCSW have been done, continuous tracking study and improvement will be performed.

❖ For most of detector designs, tracking works well, therefore, it may be considered as check for optimized tracker design, step by step together with tracking software optimization.

Thank You !
谢谢