Tracking in CEPC Silicon Detector

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Outline

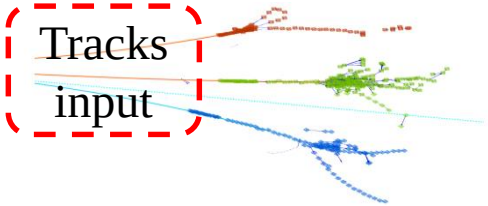
- Introduction
- Tracking software
- Tracking detectors and tracking finding
- Performance
- Summary

Introduction

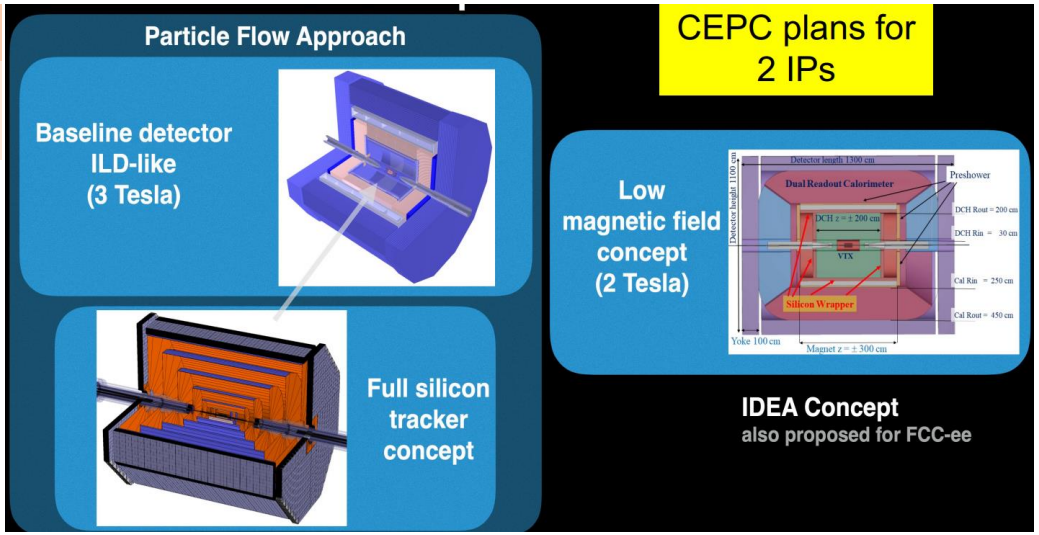
Physics process	Measurands	Requirement on tracker
ZH, $Z\to e^+e^-(\mu^+\mu^-)$, $H\to\mu^+\mu^-$	m_H, $\sigma(ZH)$, BR($H\to\mu^+\mu^-$)	$\Delta(1/p_T) = 2\times10^{-5} \oplus \frac{0.001}{p(GeV)\sin^{3/2}\theta}$

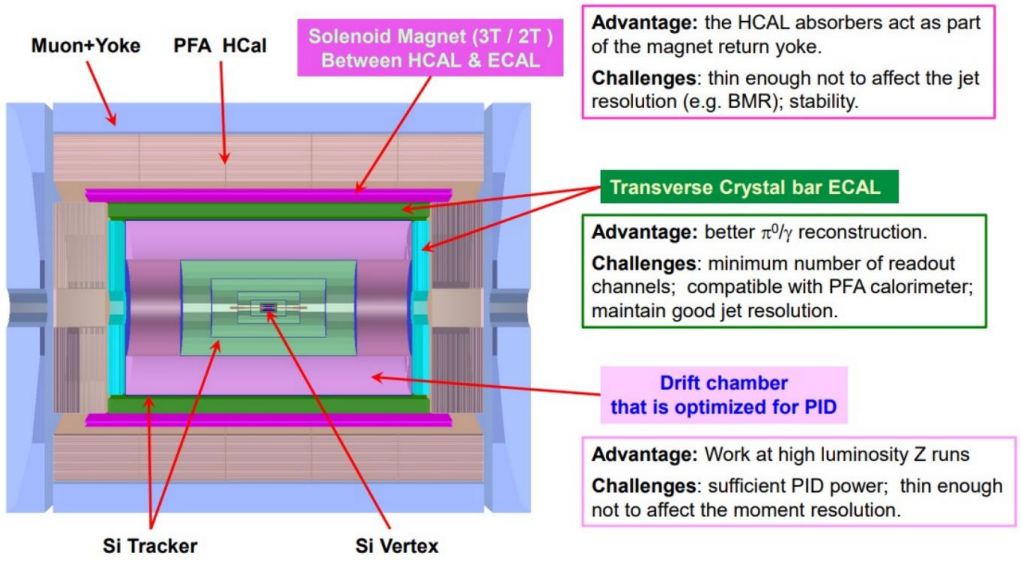
- CEPC being designed as Higgs&Z factory, has basic physics requirements, such as tracking resolution.
- Three detector concepts were designed at CDR stage, and the 4th conceptual detector design has been proposed since 2021.
- Track reconstruction for estimation on detector performance at post age of CDR, exactly as at CDR stage

- Tracker design: track performance estimation
- As PFA input



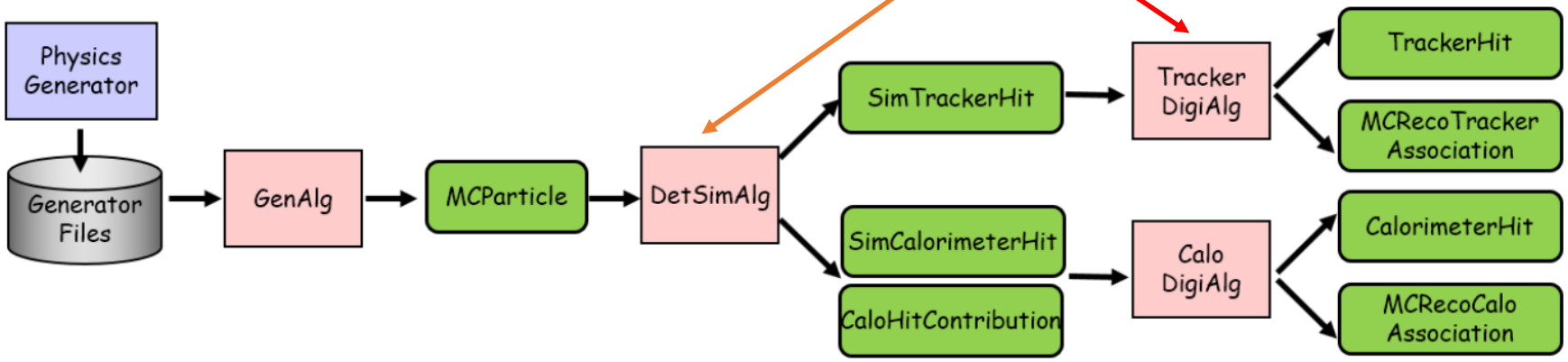
- The silicon detectors are designed as part of all detector concept!





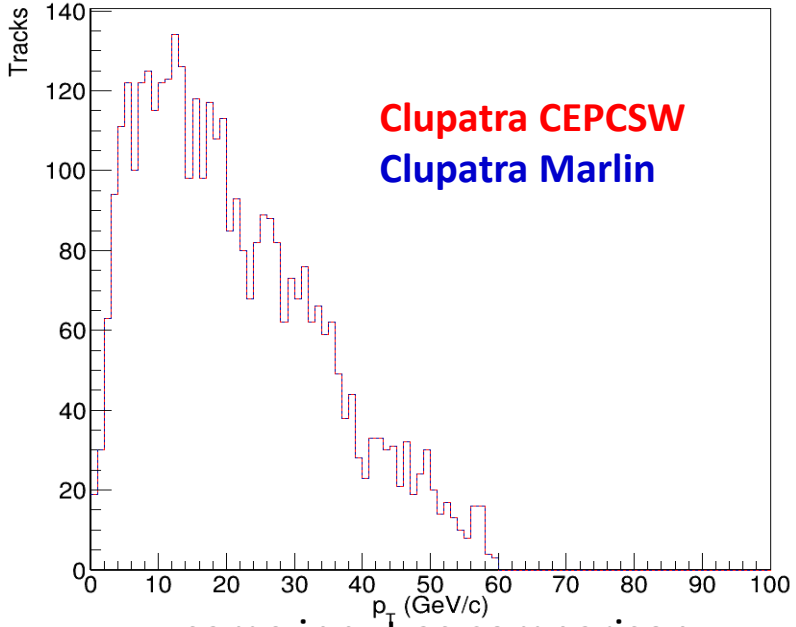
CEPCSW & Input

- CEPCSW is a Gaudi-based framework
  - Core software, application, external libraries
- EDM4hep for event data model
- DD4hep for detector description
  - Originally developed for ILC and CLIC but with all of HEP in mind
  - Covering the full life cycle of an experiment
    - ✓ Detector concepts, optimization, construction and operation
  - DDG4 provides API from xml compact files and DD4hep constructor to Geant4 geometry, DDCore for interface to DD4hep geometry (DetElement, Surface, etc) & Gear geometry
    - ✓ a single source of information for Geometry, materials, visualization, readout, alignment, calibration, reconstruction etc

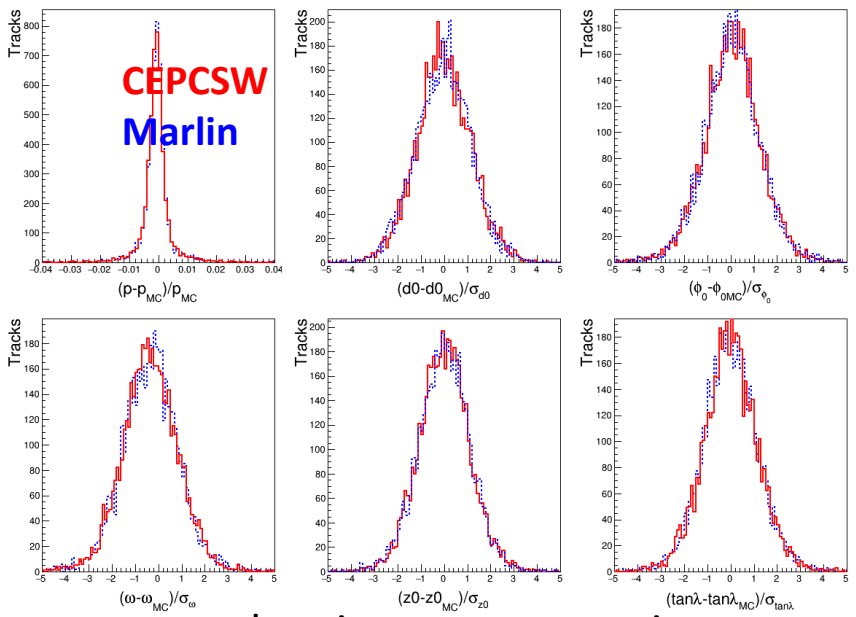


Tracking in CEPCSW

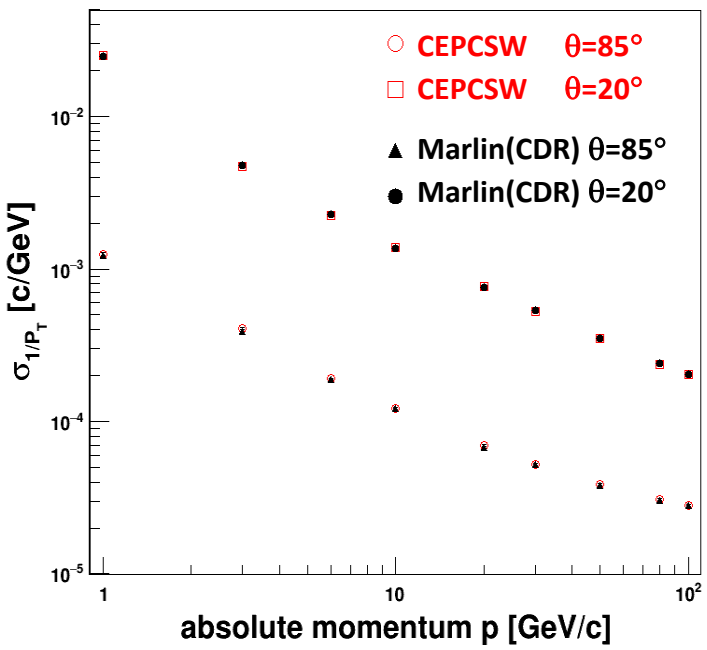
- Migrated from Marlin processor (cepcsoft/ILCSoft) to Gaudi algorithm
  - Geometry: DD4hep extension → Gear
  - Interface to call fitter
  - Switch data model to EDM4hep
- Repeat the CDR tracking chain: ILD tracking, ConformalTracking
  - Consistent tracking performance between Marlin and CEPCSW
  - Possible to continue the CDR study in CEPCSW



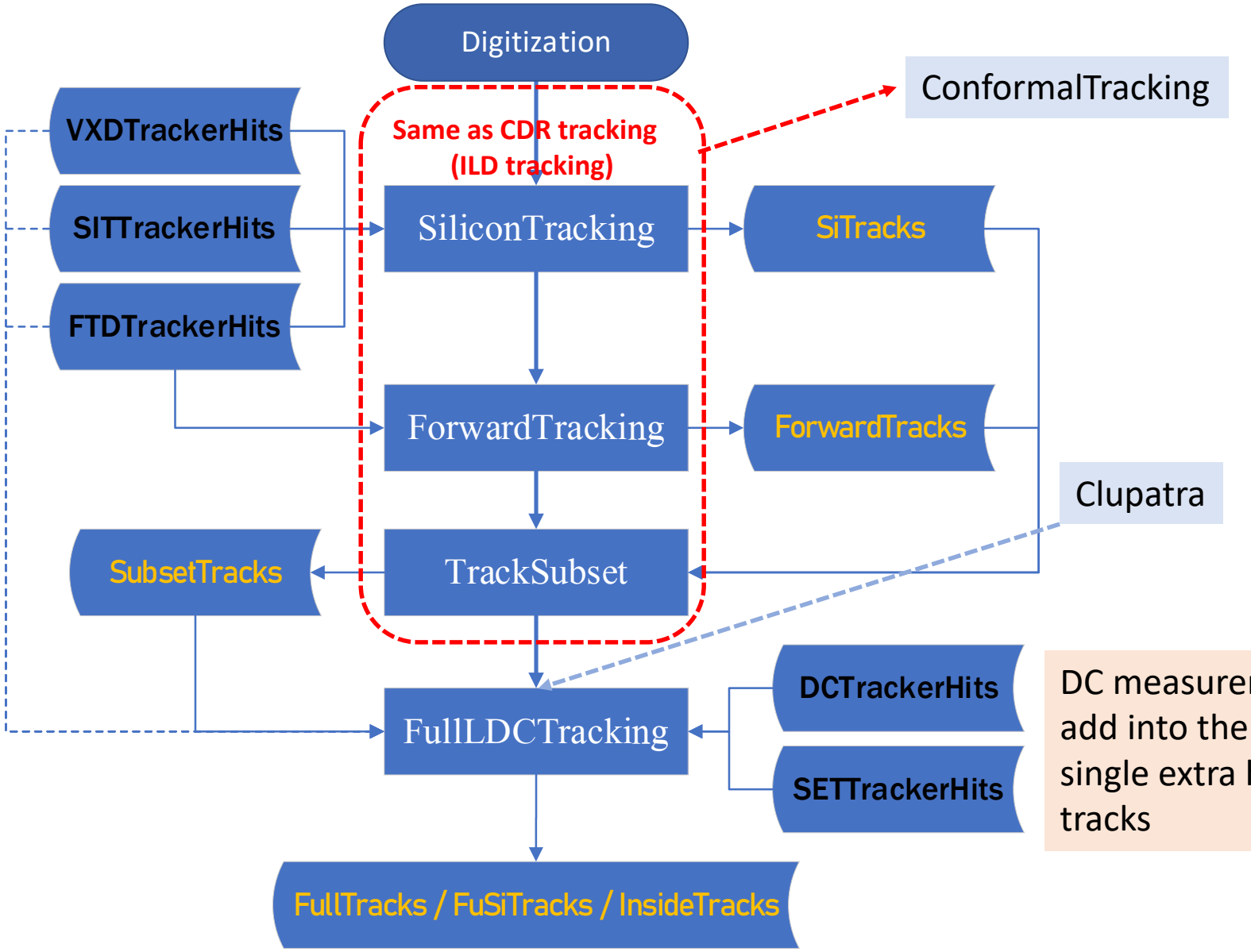
same input as comparison



random input as comparison



Tracking Chain



DC measurements is possible to add into the silicon tracks as single extra hit or complete DC tracks

Output

edm4hep::Track

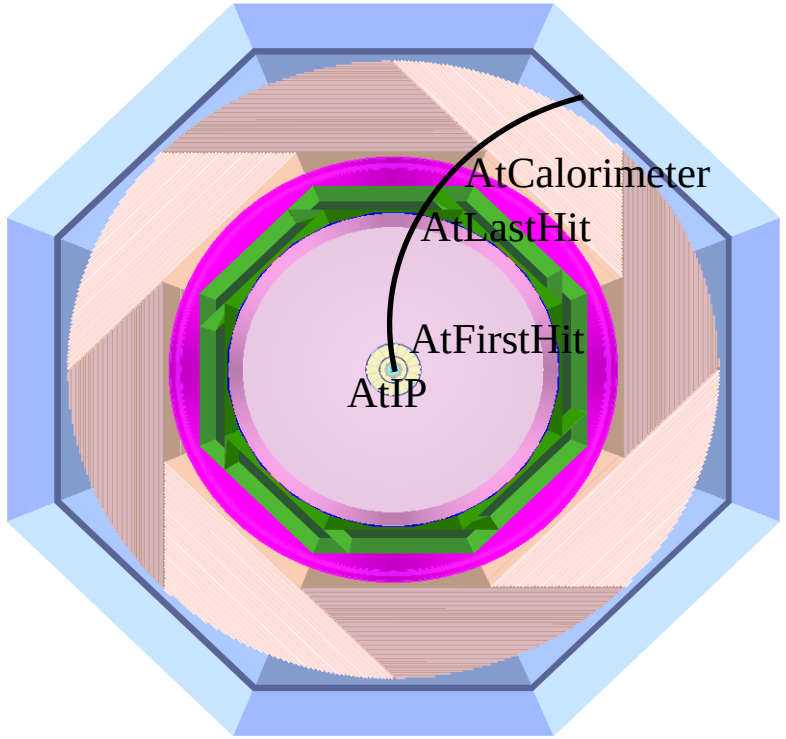
.....

edm4hep::TrackerHit s

.....

edm4hep::TrackState s

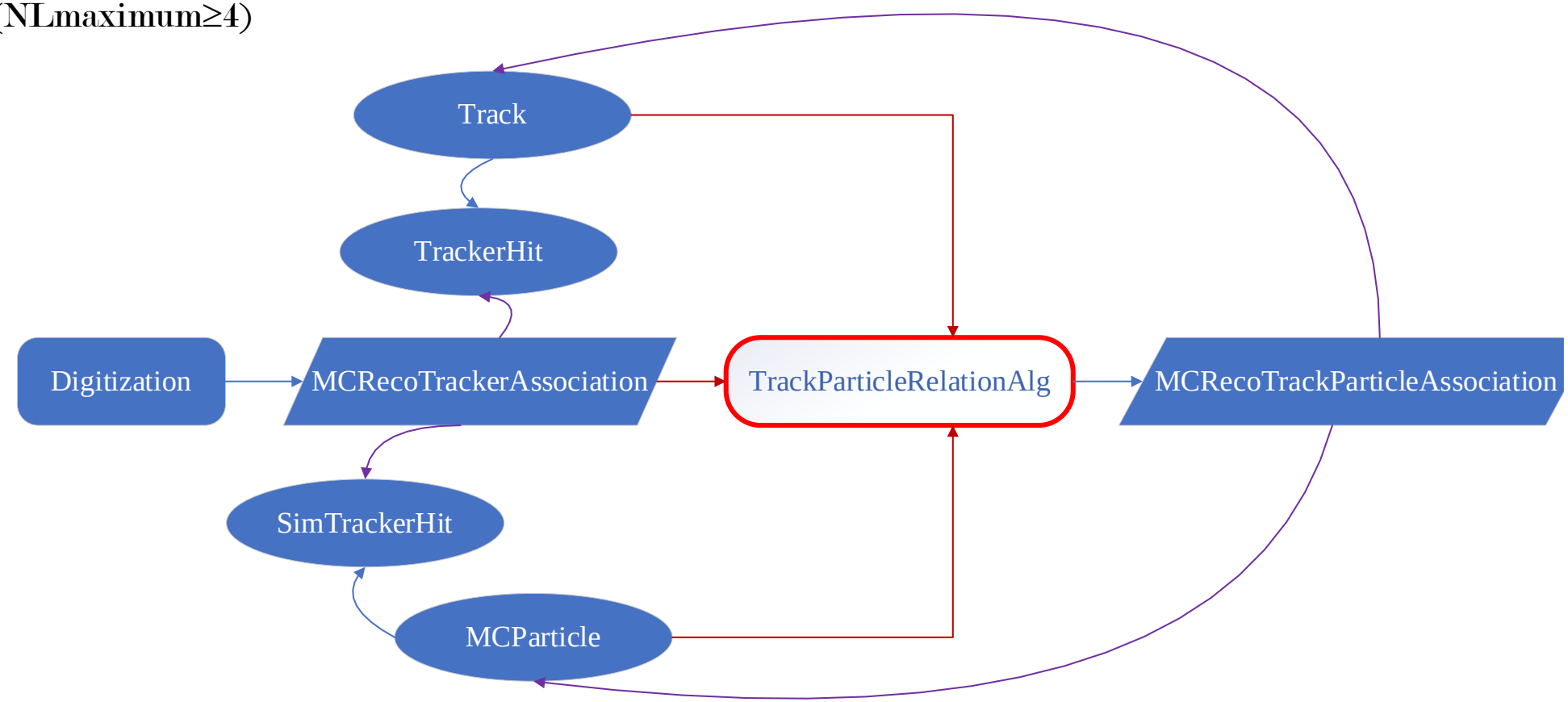
- std::int32_t location
- float D0
- float phi
- float omega
- float Z0
- float tanLambda
- float time
- edm4hep::Vector3f referencePoint
- std::array<float, 21> covMatrix



Currently, four TrackStates are in storage:
if(location==edm4hep::TrackState::AtIP)
if(location==edm4hep::TrackState::AtFirstHit)
if(location==edm4hep::TrackState::AtLastHit)
if(location==edm4hep::TrackState::AtCalorimeter)

Association

- MCRecoTrackParticleAssociation
  - Track
  - MCParticle
  - weight: number of tracker hit linked between MCParticle and Track (NL), for a particle, found track (NLmaximum≥4)

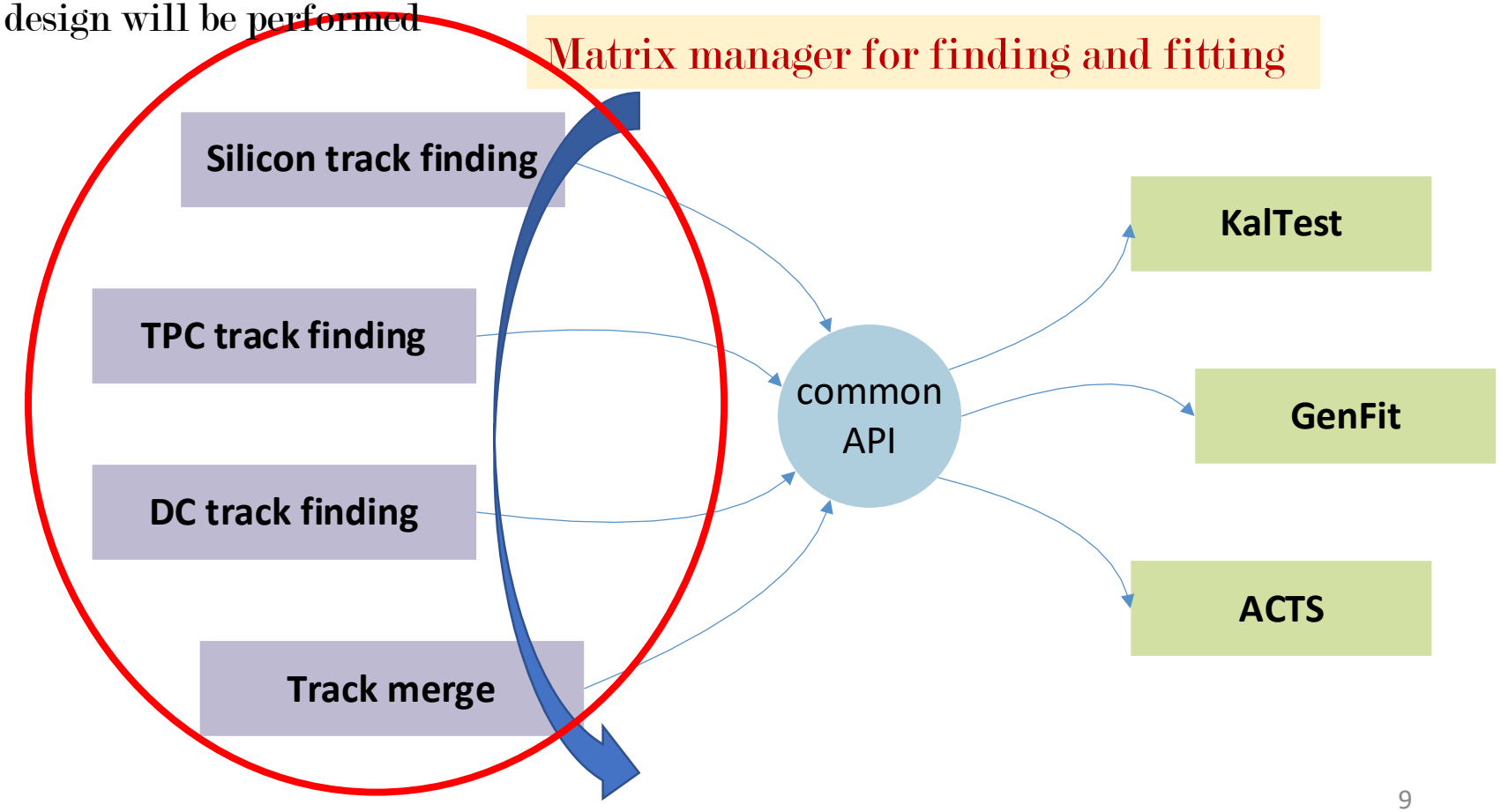


Propose of Tracking Chain

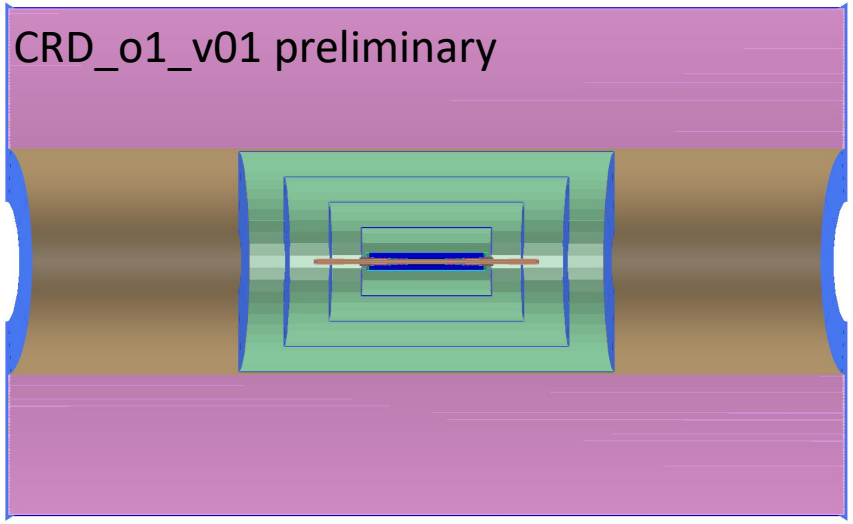
- Call the common API after track finding in all algorithm, and choose fitter according to option
- To choice best combination of track finding and fitting
  - For middle tracking, low CPU time
  - For final tracking, high performance
- Comparison on same detector design will be performed

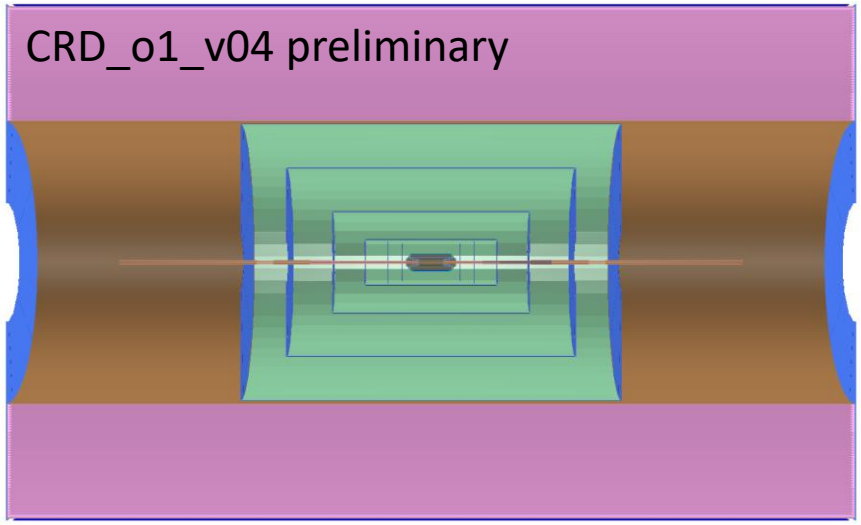
BEST: appropriate performance and CPU time

- Status
  - ConformalTracking has used the common API
    - ✓ KalTest done
    - ✓ DDKalTest, GenFit, ACTS ongoing
  - Other tracking algorithms ongoing



Tracking System (developing)



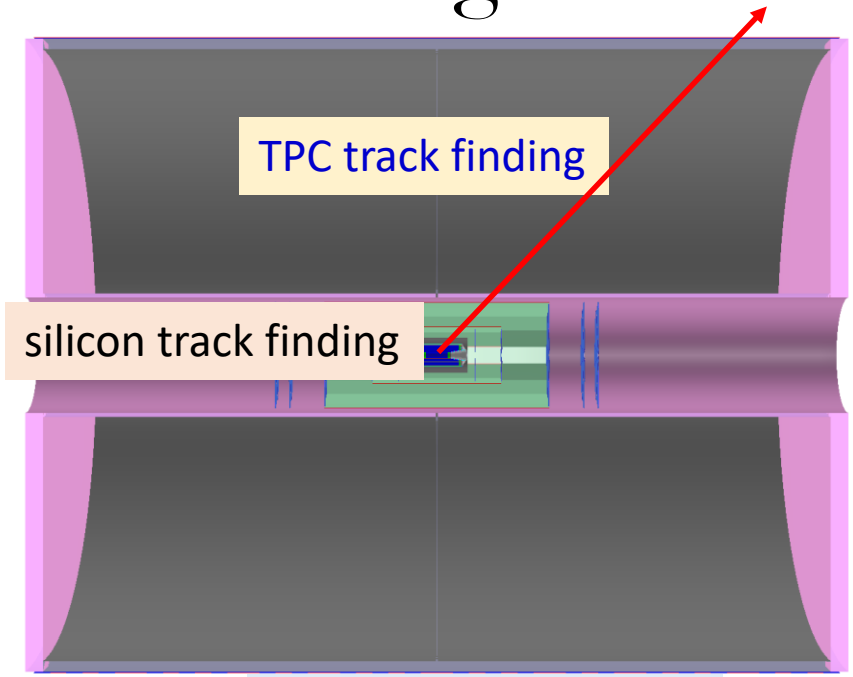


- Vertex detector (VXD): 6 pixel layers
  - $\sigma_{rphi,z}$=2.8μm, 6μm, 4μm, 4μm, 4μm, 4μm
- Silicon inside/internal DC tracker (SIT): 4 or 3 pixel layers
  - σ_{rphi} =7.2μm, σ_z=86μm
- Silicon outside/external DC tracker (SOT/SET): 1 pixel layer
  - σ_{rphi} =7.2μm, σ_z=86μm
- Endcap tracker (EIT&EOT/FTD): 2 + 3 pixel layers
  - $\sigma_{x,y}$=3μm, 3μm, 7.2μm, 7.2μm, 7.2μm
- Drift chamber (DC): 18mm or 10 mm cell size
  - σ_{rphi} =100μm, σ_z=2.828mm

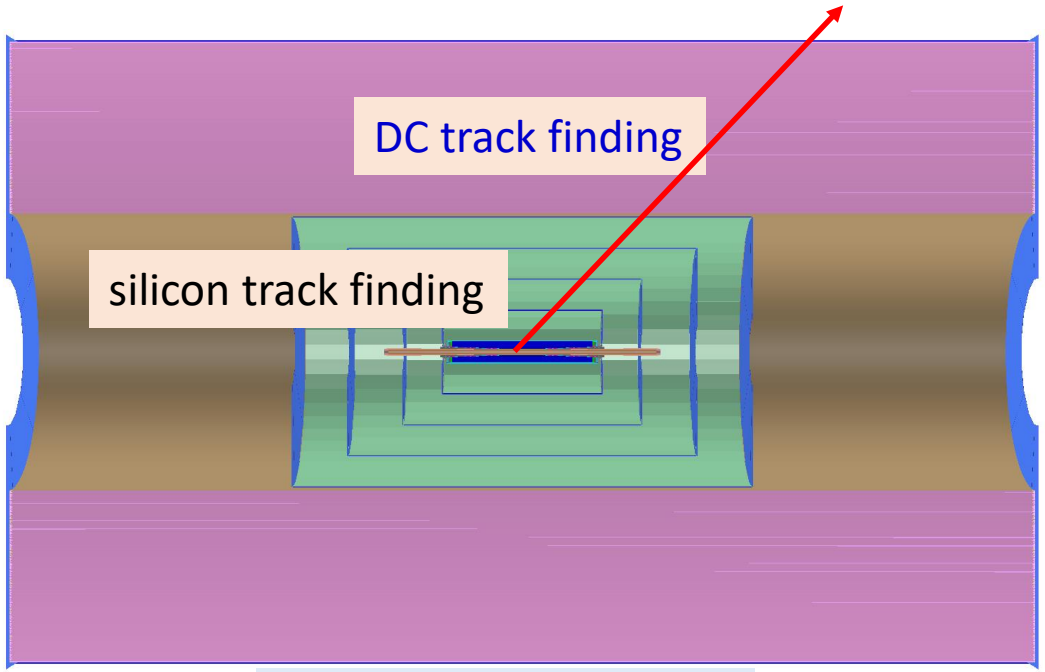
Digitization

- PlanarDigiAlg
  - Gaussian smearing at measurement dimension (u,v)
  - pixel: 2D (u,v)
  - strip: 1D (u,0) or (0, v), two doubly layer hits → one space point by SpacePointBuilder
  - TrackerHit: dU and dV saved in std::array<float, 6>& CovMatrix, interface to convert
  - Surface in reconstruction: PlanarMeasLayer
  - future: TrackerHitPlane, but should solve different types of hits in fitting
- CylinderDigiAlg
  - prepared for bent CMOS sensor
  - Gaussian smearing at (Rϕ,z)
  - TrackerHit: std::array<float, 6>& CovMatrix
  - Surface in reconstruction: CylinderMeasLayer

Track Finding



CDR Baseline detector

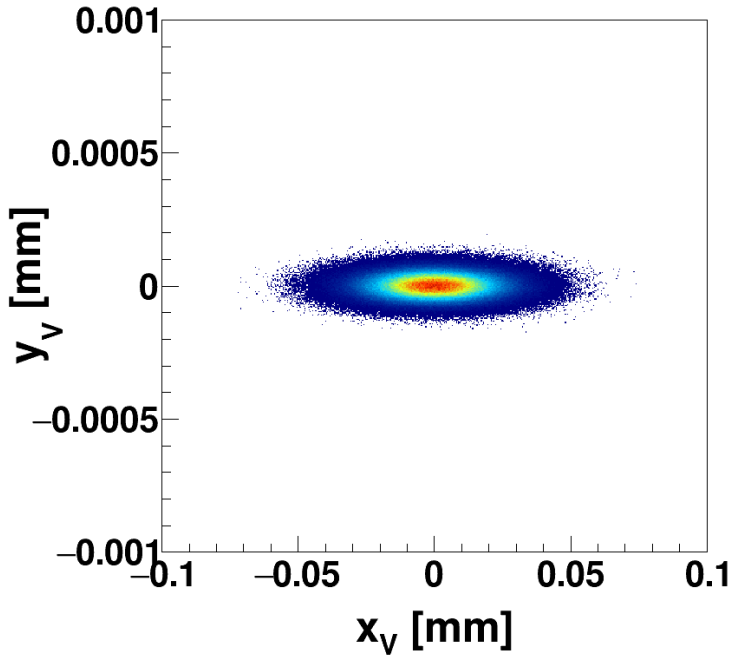


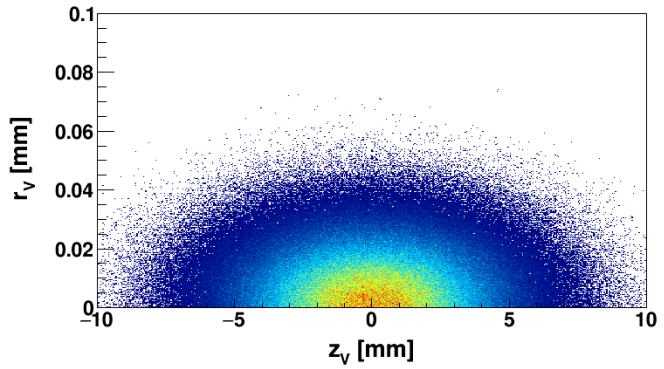
4th conceptual detector

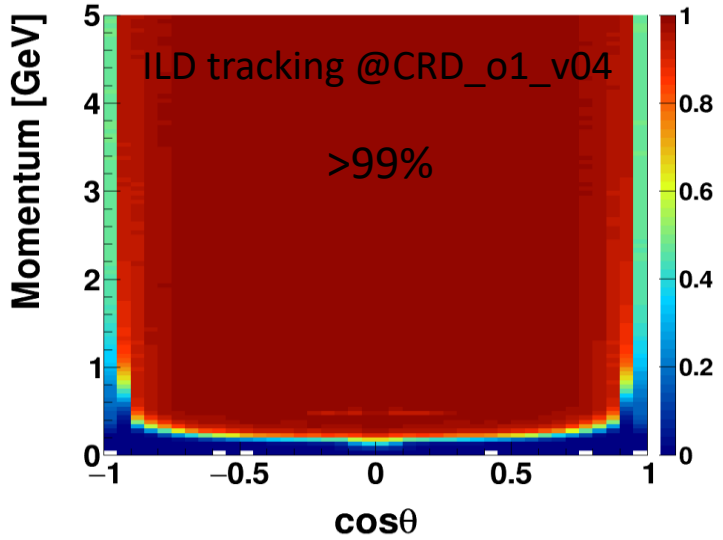
- Different pattern recognition for gas tracker and silicon tracker
  - CDR baseline detector
    - ✓ better resolution from TPC track → TPC track as base
  - 4th conceptual detector
    - ✓ worse resolution from DC track → silicon track as base
    - ✓ same silicon tracking can be performed on the full silicon tracker
- Same pattern recognition in once time is in consider

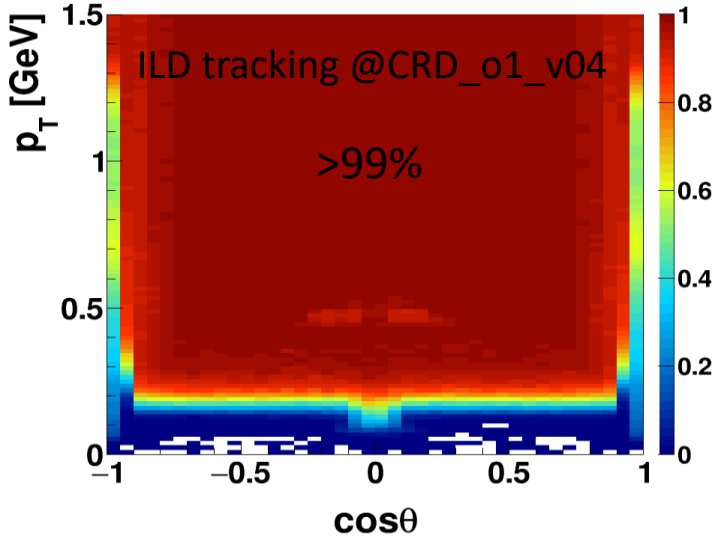
Tracking in ParticleGun

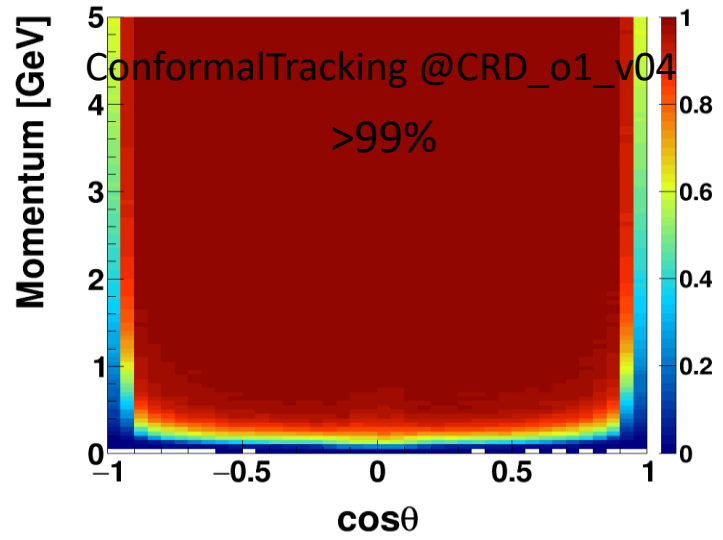
- 20 prongs: p∈(0,5)GeV, θ∈(5°,175°)

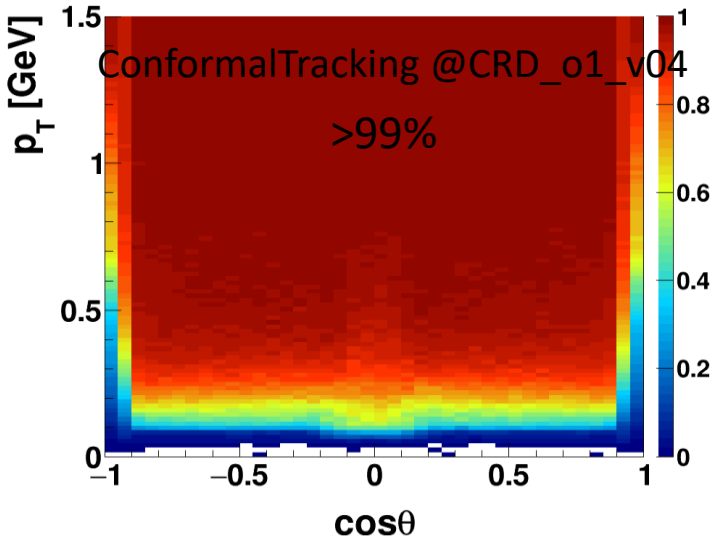






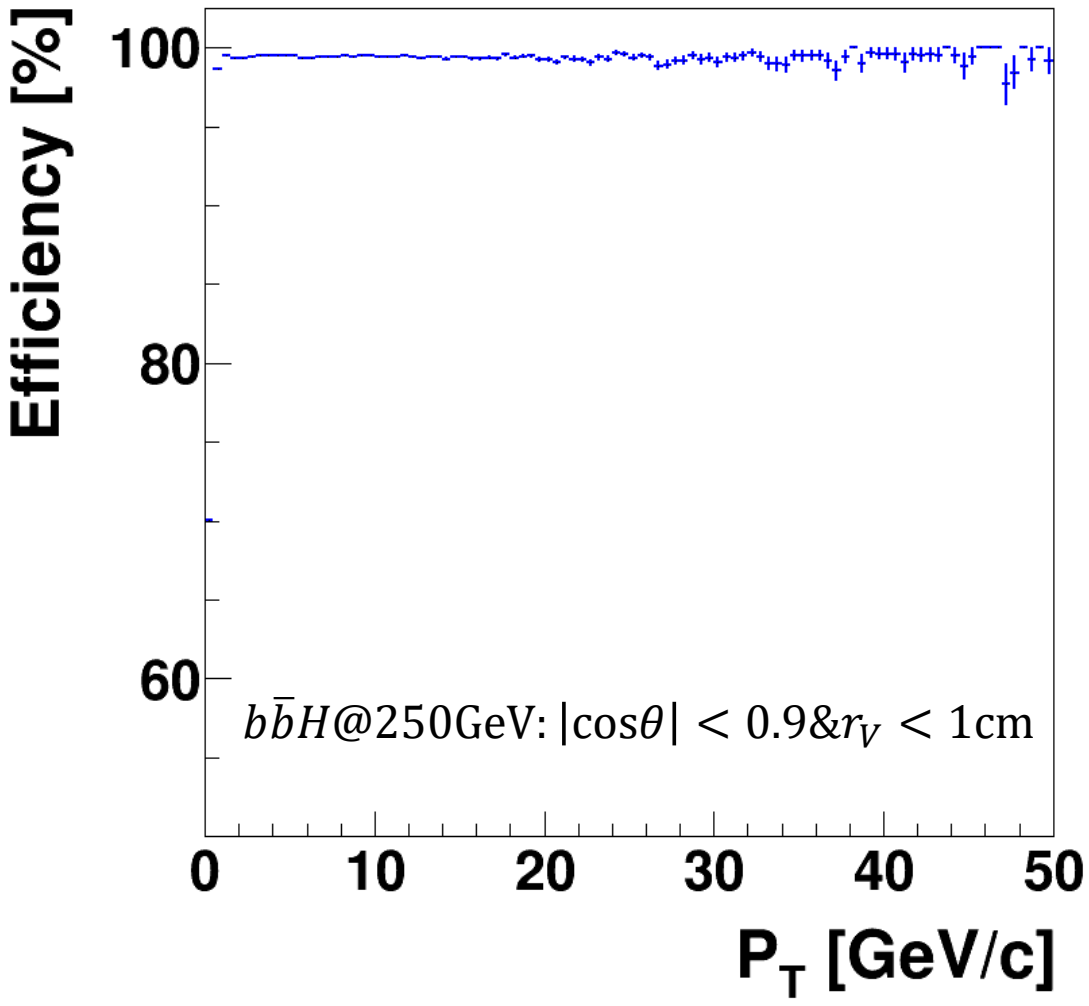


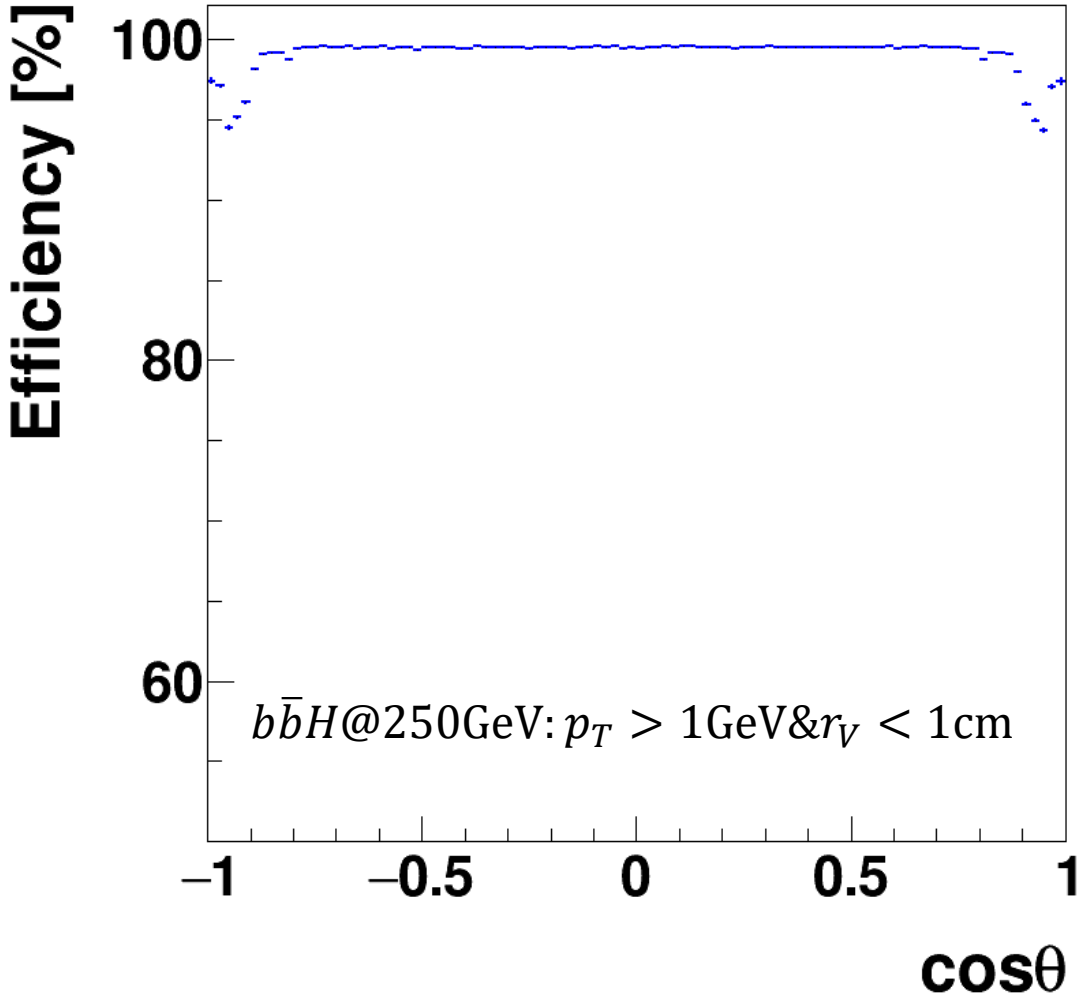




Efficiency in $b\bar{b}H$

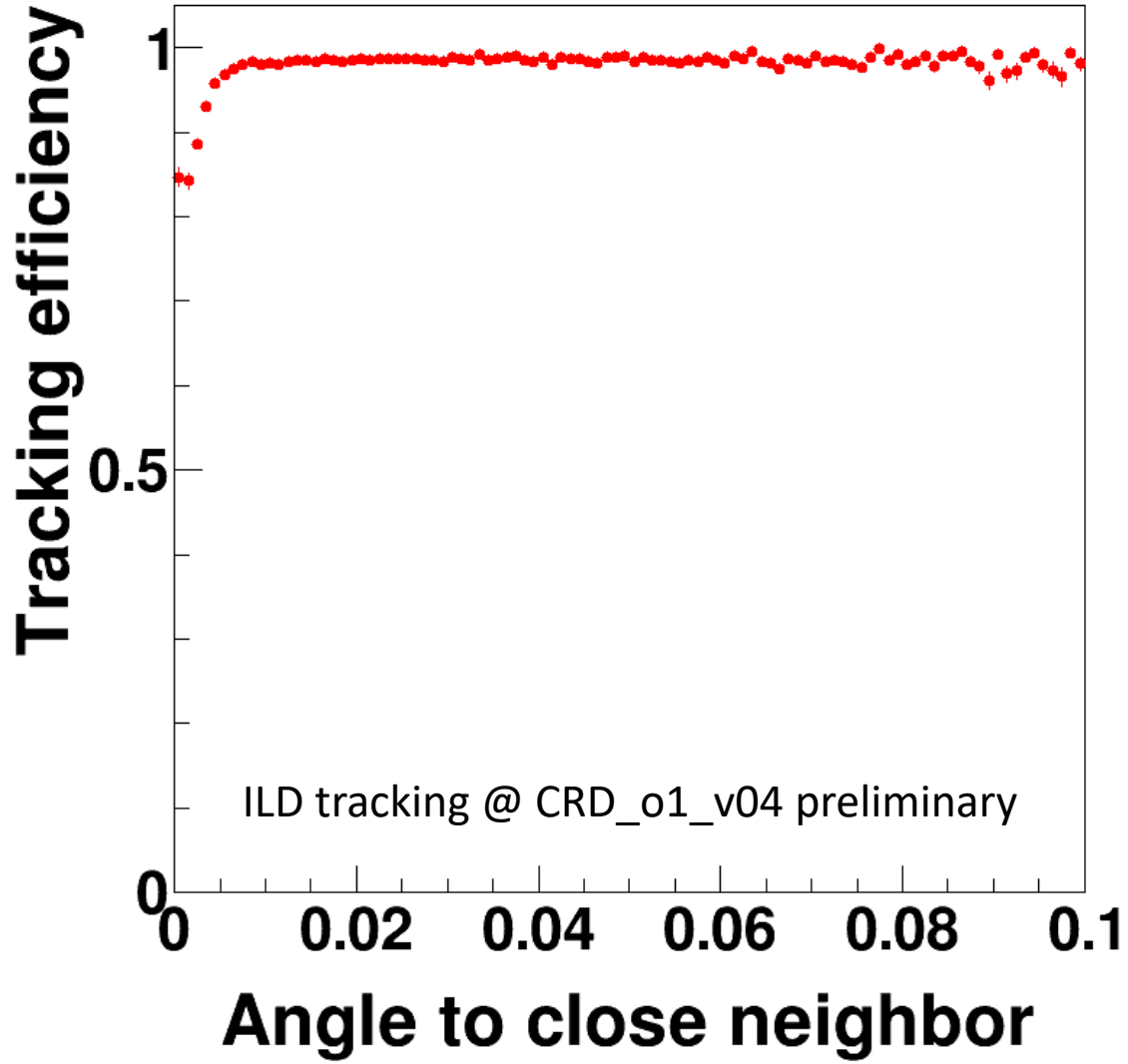
- Observe particle: has ≥6 hits in trackers





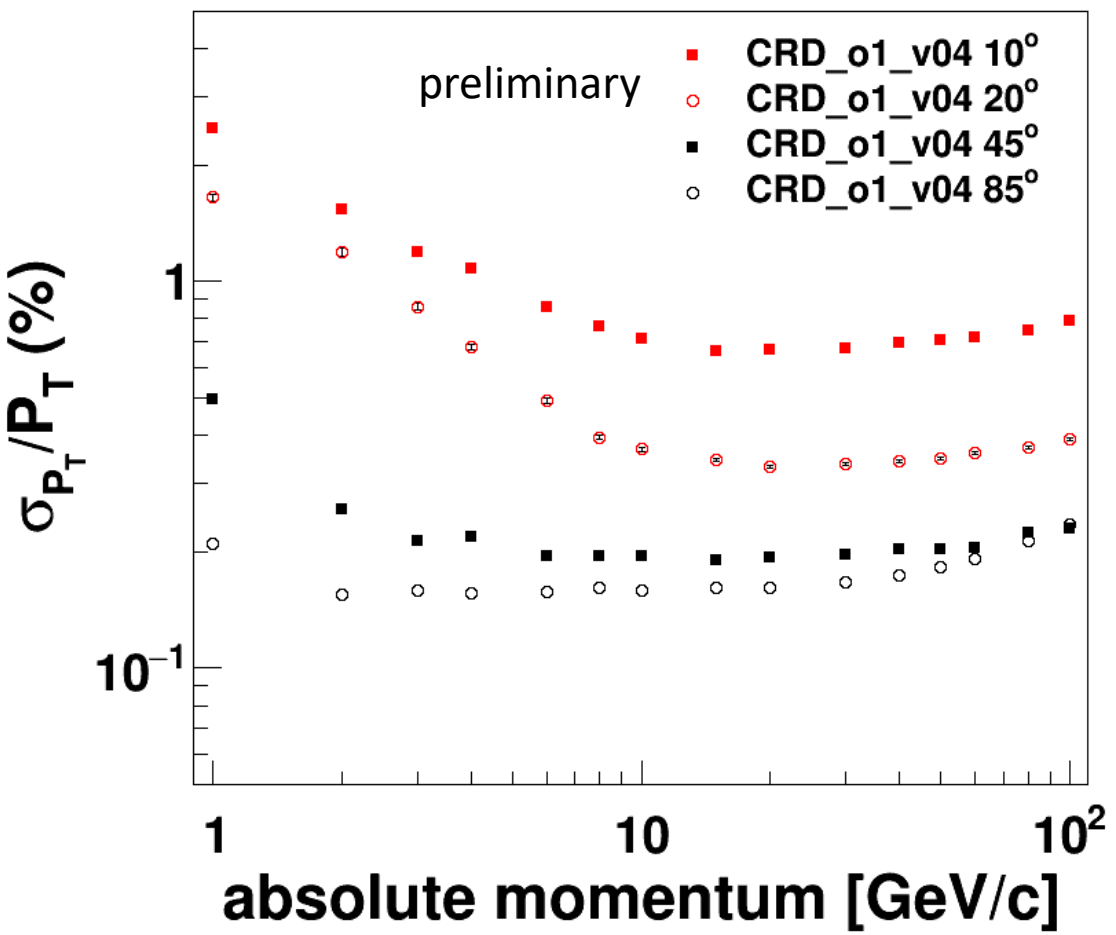
Efficiency in τ→3prong

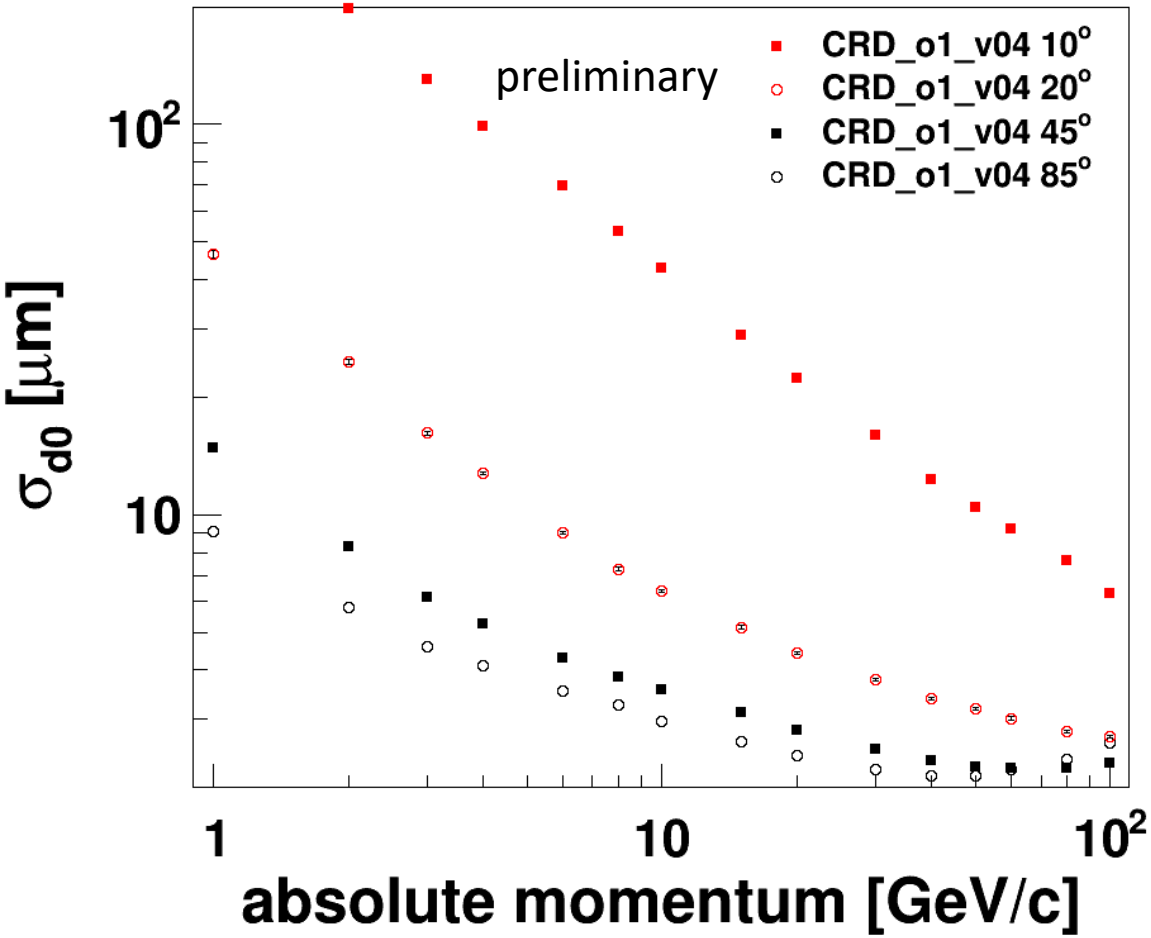
- Observed particles (N): has ≥6 linked tracker hits
  - Has linked track (Nf)
  - ε=Nf/N
- Search the close neighbor in the final state particles



Resolution

- σ_{IP}=(15μm, 36nm, 2.8mm)





Summary

- Built tracking software for the silicon detectors in CEPCSW, digitization, track finding, track fitting and assocation maker.

- Tracking chain composed of Gaudi algorithms works on multiple detector designs. There are two parallel silicon tracking (ILD tracking and ConformalTracking) in development.

- Multiple fit tools (DDKalTest, GenFit, ACTS) are ongoing to implement into same tracking algorithm through the common API. The ConformalTracking has been updated.

- More performance test (multiple particle gun, $b\bar{b}H$, $\tau \rightarrow 3prong$) has been performed.
  - Still has many improved space, such as stability of ConformalTracking.

Thanks very much for your attention!