Detector Description and Reconstruction Performance of Silicon Tracker

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(on behalf of the CepC Software group)

The 2021 International Workshop on the High Energy Circular Electron Positron Collider

Nanjing, November 11

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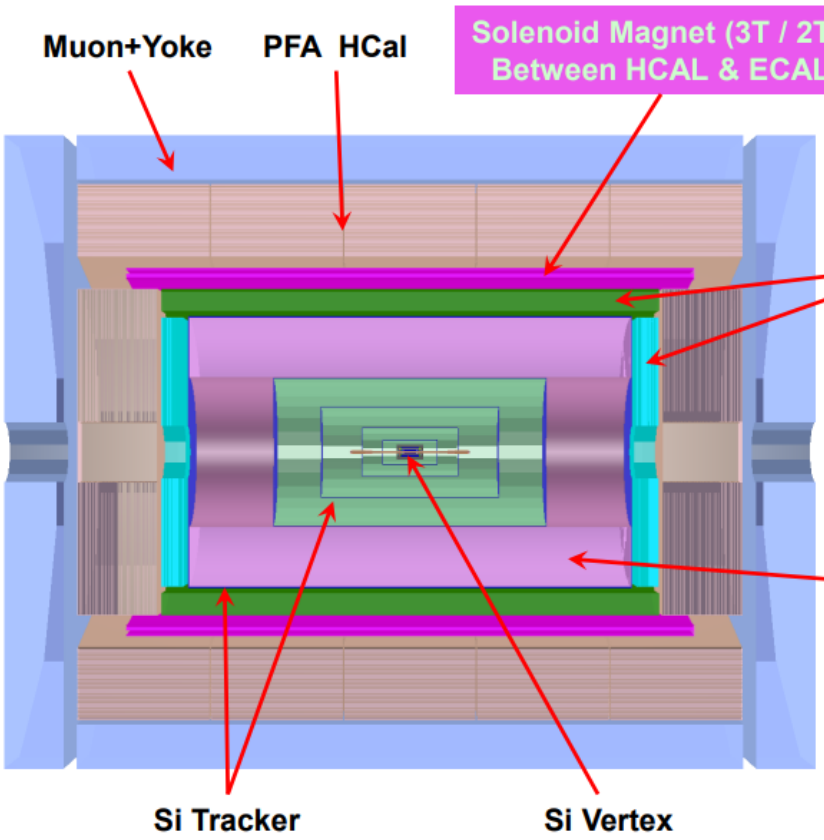
Introduction

- The 4th Conceptual Detector Design



Advantage: the HCAL absorbers act as part of the magnet return yoke.

Challenges: thin enough not to affect the jet resolution (e.g. BMR); stability.

Transverse Crystal bar ECAL

Advantage: better π^0/γ reconstruction.

Challenges: minimum number of readout channels; compatible with PFA calorimeter; maintain good jet resolution.

Drift chamber that is optimized for PID

Advantage: Work at high luminosity Z runs

Challenges: sufficient PID power; thin enough not to affect the moment resolution.

- The CDR detector has been implemented into CEPCSW and tracking has been migrated into CEPCSW from Marlin framework before Yangzhou workshop, and we can study and update based on these.

Beam pipe

- CDR like → new MDI
  - Support cooling through sub-layer structure of pipe

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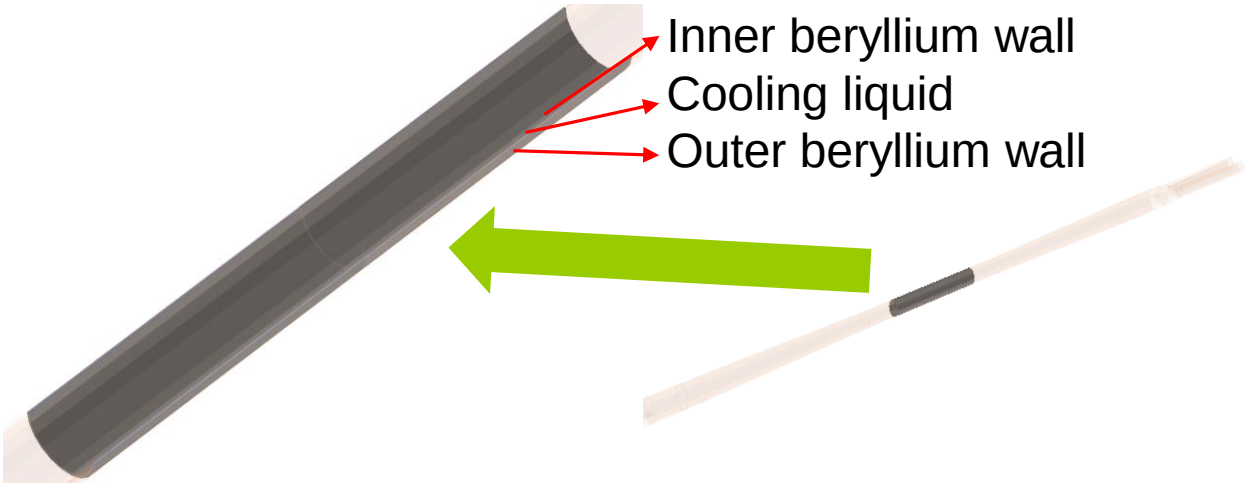
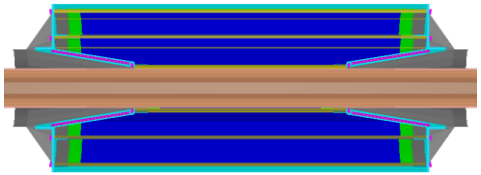
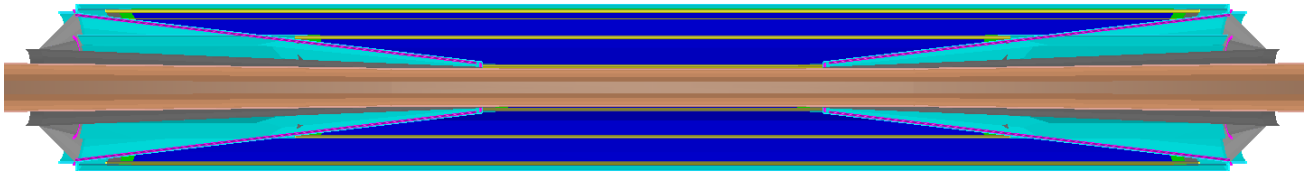


Vertex Detector

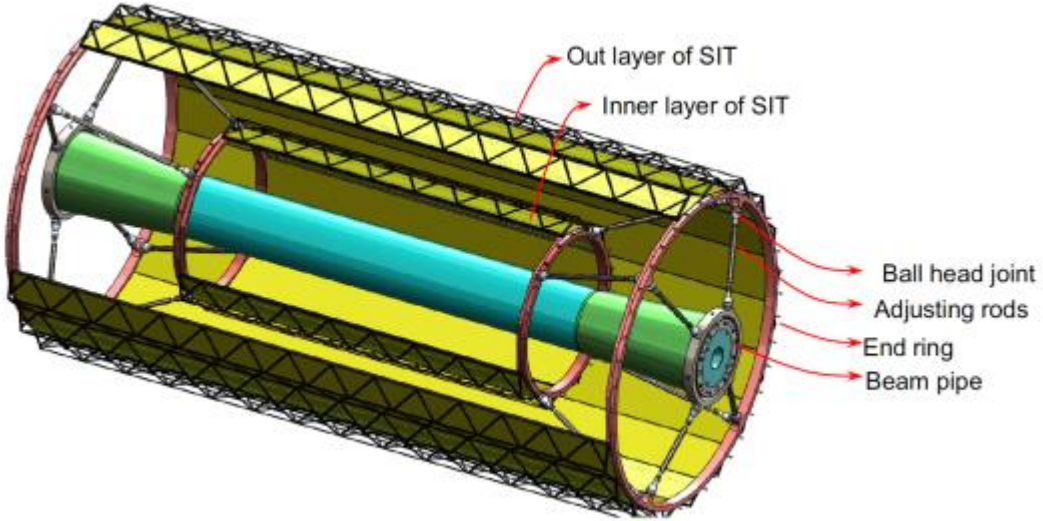
- CDR like
  - Optional layers
  - Expand in Z



CDR vertex



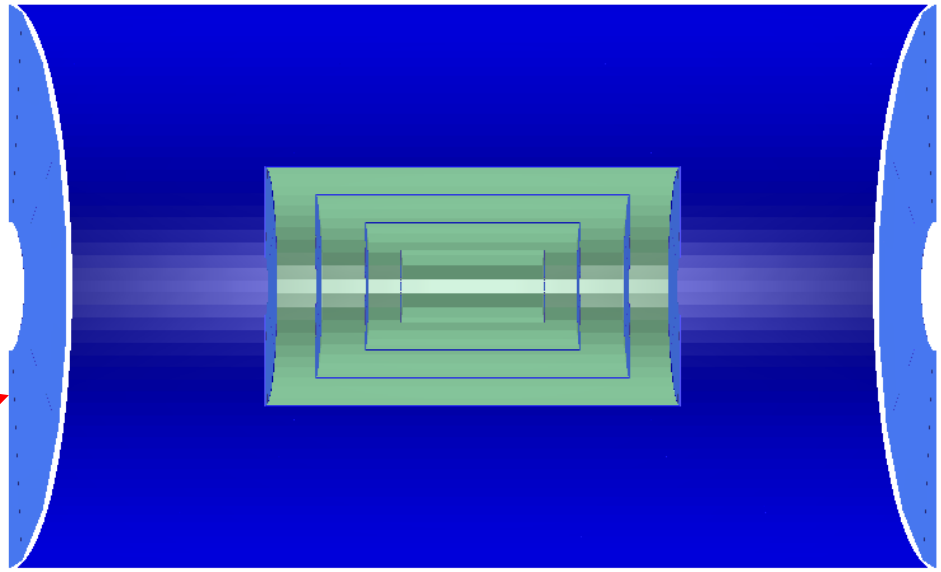
- In progress
  - New design by vertex working group



Designing vertex

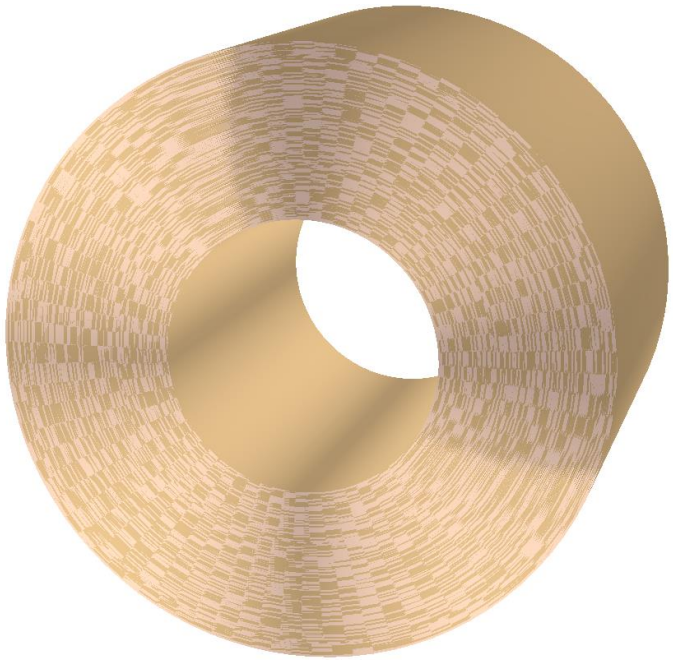
Silicon Tracker

- CDR like barrel silicon tracker, optional
  - Layer number
  - Layer position
  - Layer material budget (support + sensitive)
    - approximate for different types (CMOS etc.) temporarily
  - Pixel or strip choice
- New endcap silicon tracker: SiTrackerSkewRing
  - Layer number
  - Layer position
  - multi-components layer
  - Skew angle



Drift Chamber

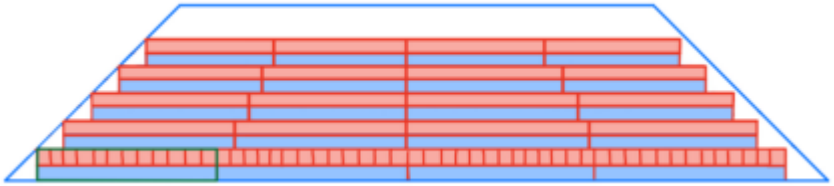
- Simple crylinder → multi-cells chamber with wires
- Optimize CPU time
- Apply API model through special region
  - Closed temporarily
  - Fix ongoing

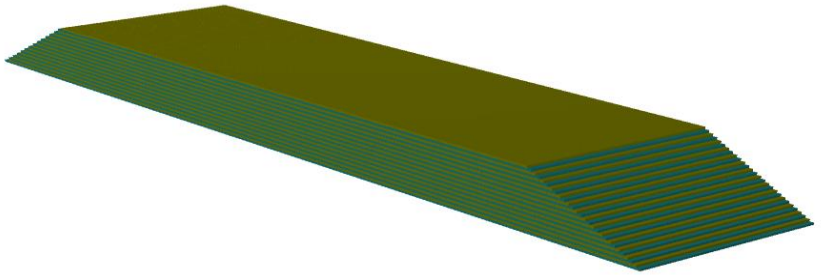


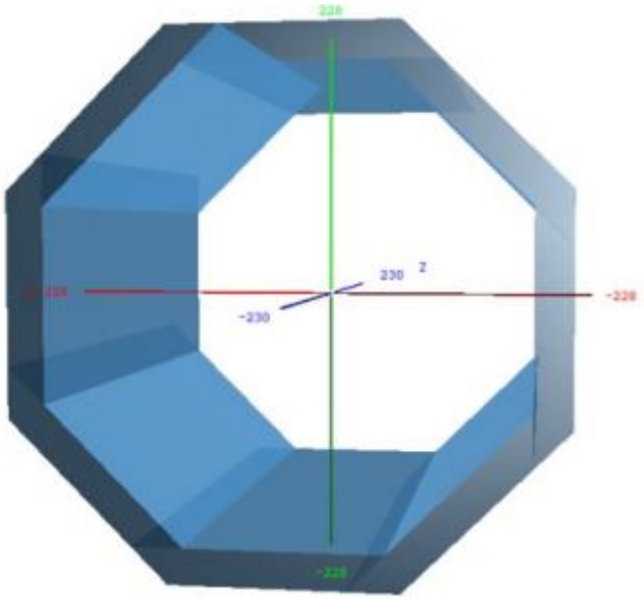
More detail in ZHANG Yao‘s talk

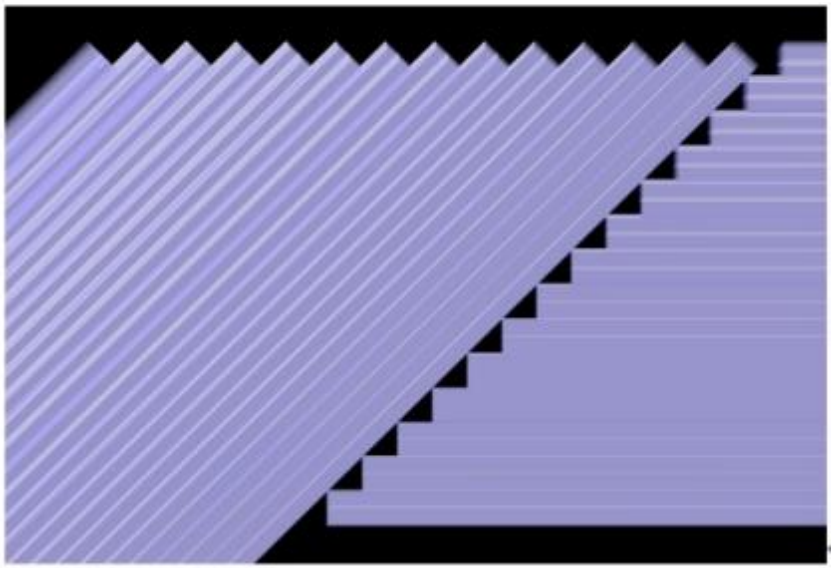
High Granularity Crystal Calorimetry

- Optimized geometry to reduce CPU time while simulating
- Current 8 staves in R-phi
  - Toward 12 staves (optional) geometry ongoing





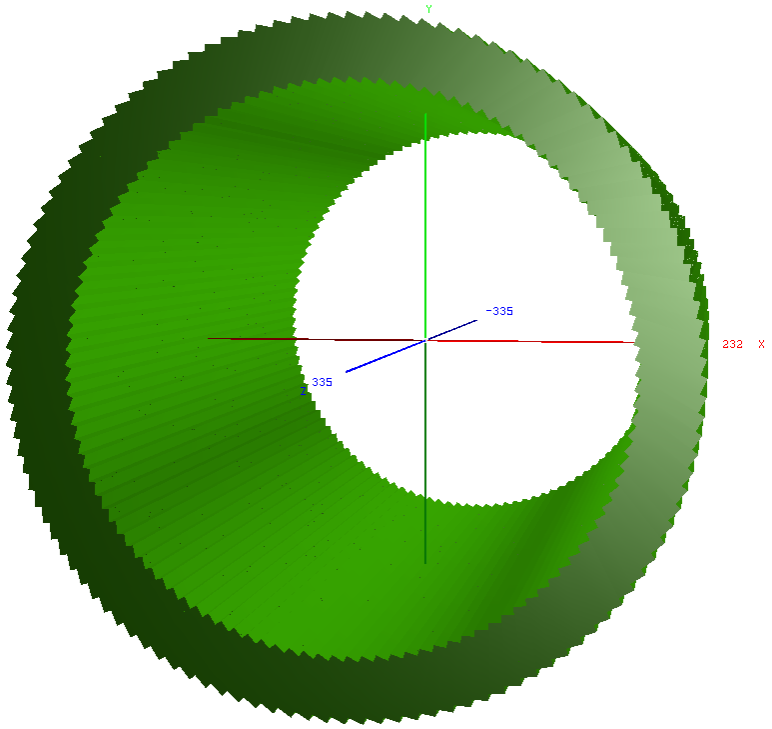




More detail in GUO Fangyi's talk

Rotated Crystal Calorimeter

- According to ZHANG Huaqiao's design, a new type of calorimeter has been implemented into CEPCSW
  - Nphi
  - Nz
  - Angle rotated by Z-axis
- Simulated hits are valid
- As standalone module

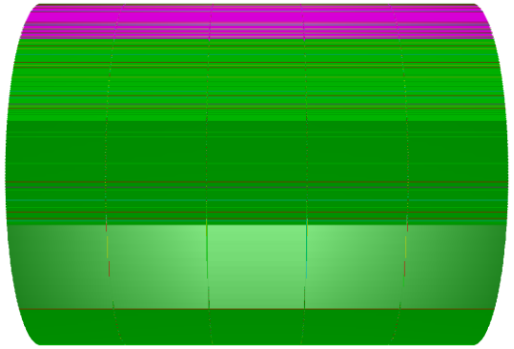


View of conceptual design with less crystals than real

Hcal

- SDHcal
  - SHcalRpc01_Barrel → SHcalRpc02_Barrel
  - (fixed octahedral) (optional)
  - SHcalRpc01_Endcaps
- AHcal
  - SHcalSc04_Barrel_v04
  - SHcalSc04_Endcaps_v01
    - TODO: unify modules

Support SD-A Hcal



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```
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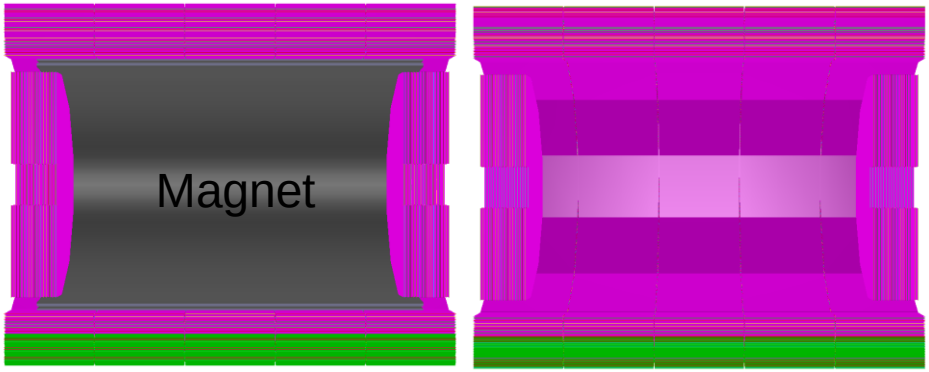
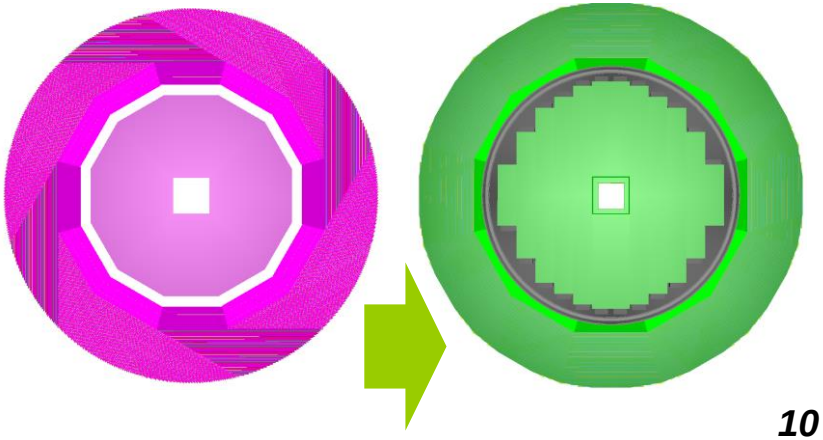
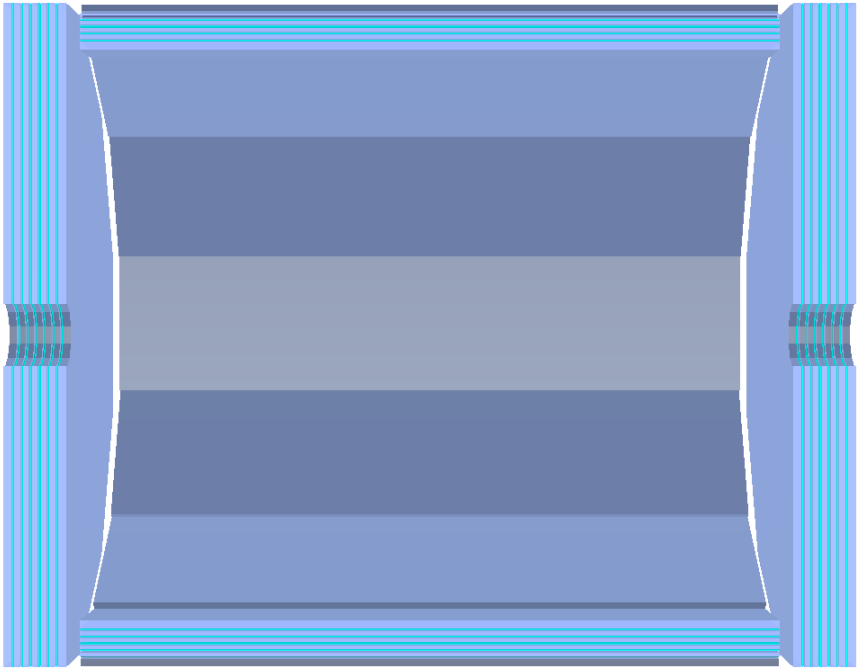
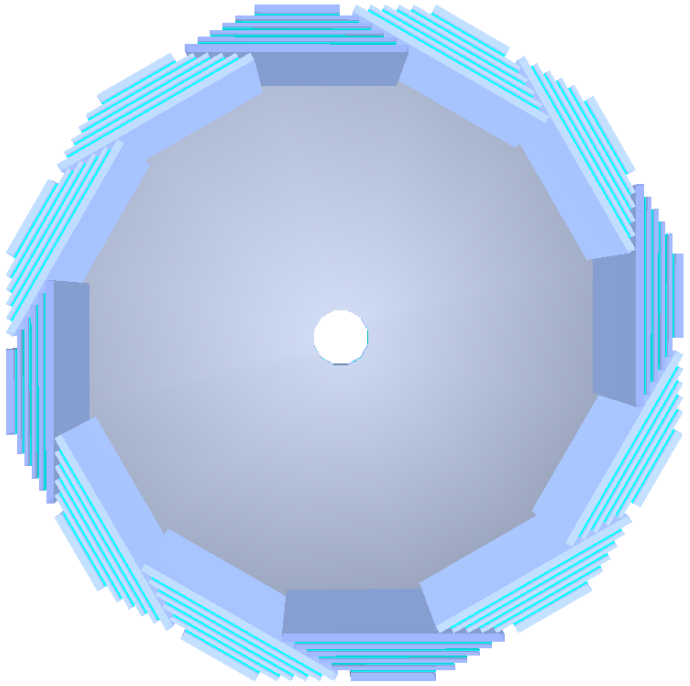




Yoke and Muon Detector

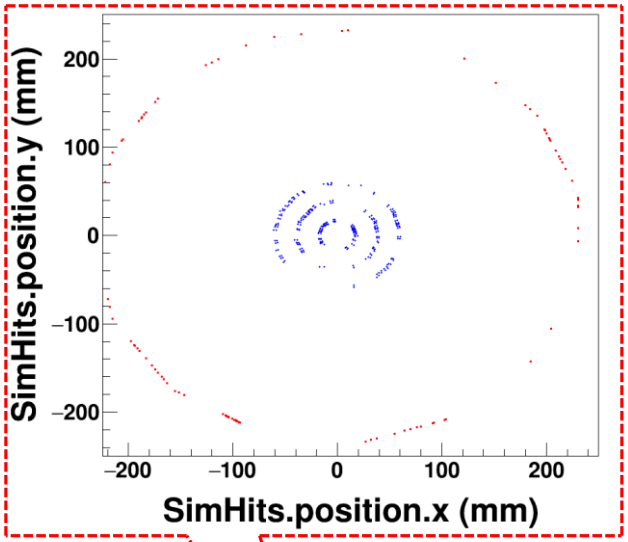
- CDR like → RotatedPolyhedraBarrelCalorimeter + PolyhedraEndcapCalorimeter2
  - Optional staves (baseline: 12)
  - Iron-Air-module-Air-Iron
    - Optional components and thicknesses

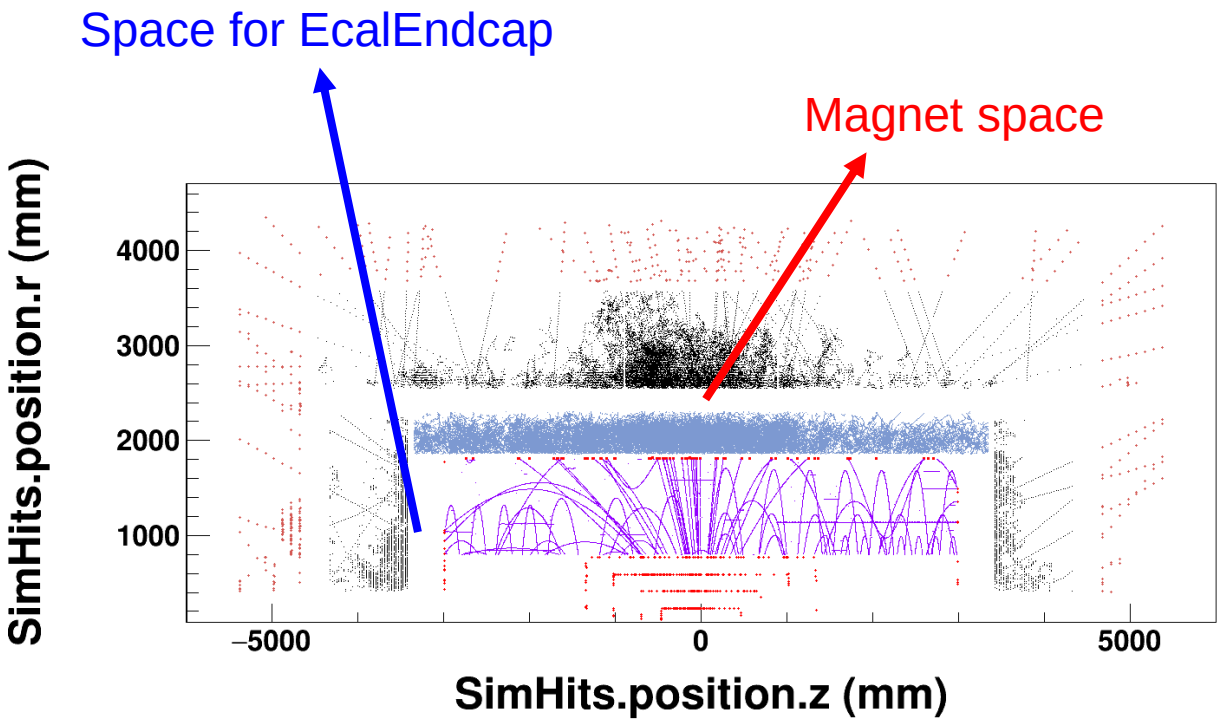


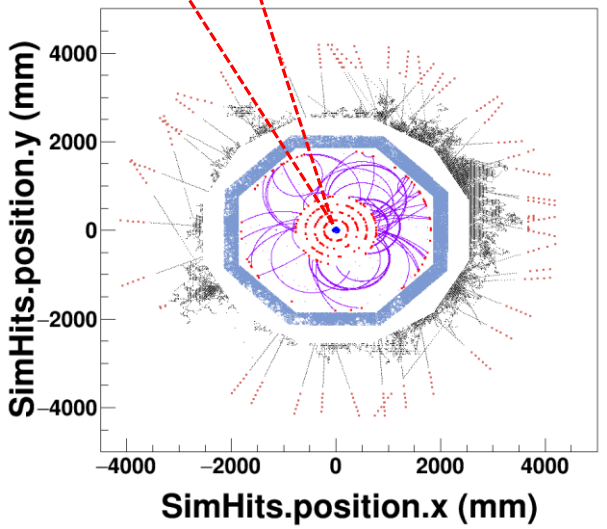


Simulated Hits

- Example of one event
  - E250.Pbbh_X_e0_p0 by whizard195
  - CDR-like EcalEndcap not include

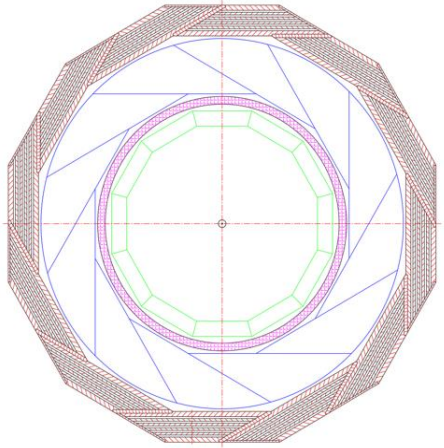


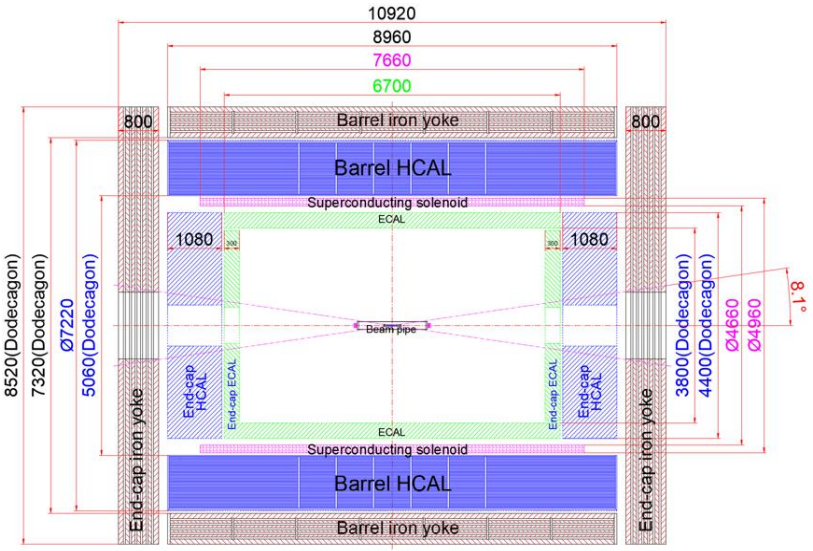




Summary and Plan

- At least one module for each sub-detector is valid as baseline for the 4th conceptual detector design, matching with mechanics size
- Implement more modules in future
  - From MokkaC
    - CSCal: crystal-silicon calorimeter
    - Simple calorimeter
  - New modules from sub-detector working group
    - Vertex
    - Silicon tracker
    - etc.
  - Update
    - Adjust options to optimized design
- View
  - DD4hep for display: bottleneck

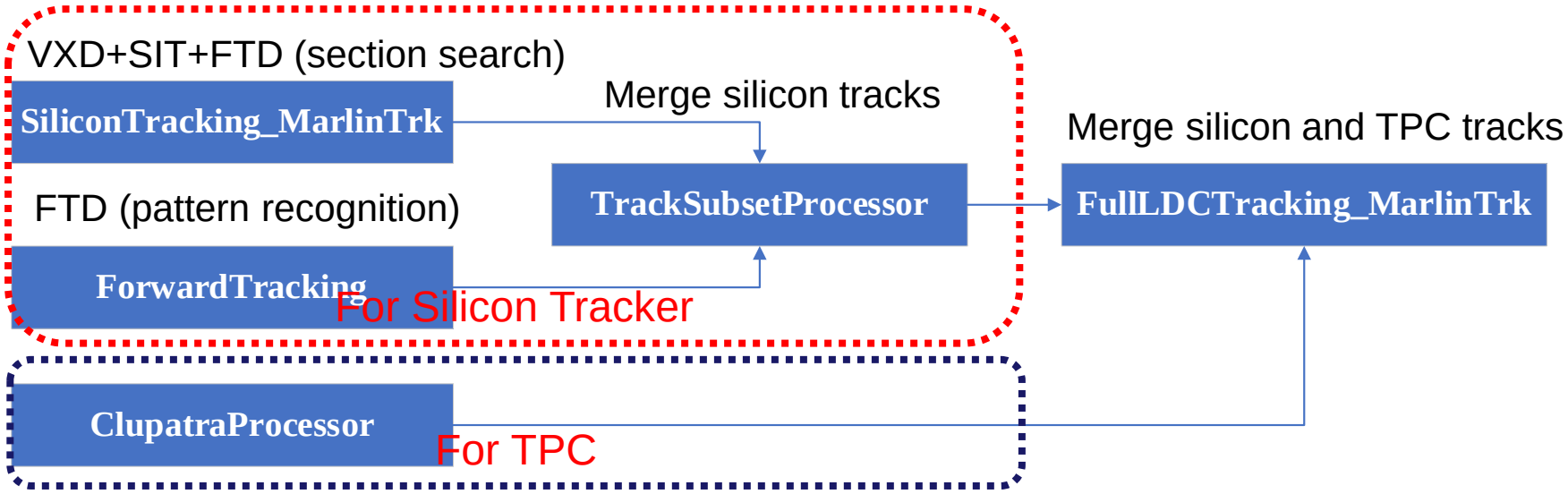




Mechanics size

Tracking for Silicon Tracker

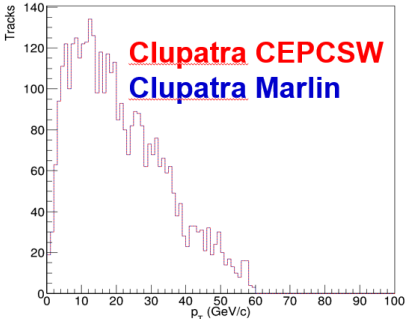
- Migrated tracking processes for CDR into CEPCSW:
  - SiliconTracking_MarlinTrk → SiliconTrackingAlg √
  - ForwardTracking → ForwardTrackingAlg √
  - TrackSubsetProcessor → TrackSubsetAlg √
  - ClupatraProcessor → ClupatraAlg √
  - FullLDCTracking_MarlinTrk → FullLDCTrackingAlg √
- Full Sim-Rec process
  - generator→simulation→digitization→tracking&fitting



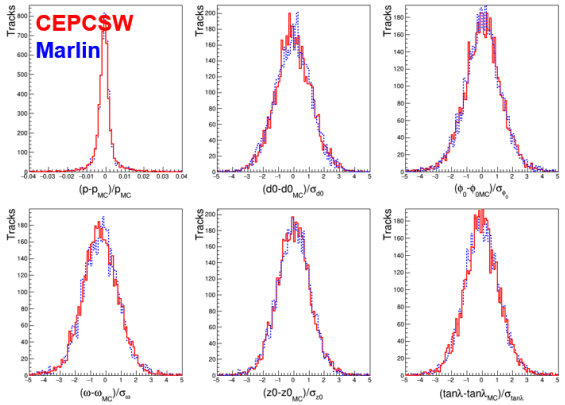
Validation

- Compare to Marlin framework with same detector (CDR)
  - simulated data (LCIO by MokkaC)→ digitization → reconstruction
  - Digitized data (LCIO by Marlin) → reconstruction
  - Different simulation: CEPCSW (EDM4hep) VS MokkaC (LCIO)

Confirm: the difference caused by random number (smear or Geant4)

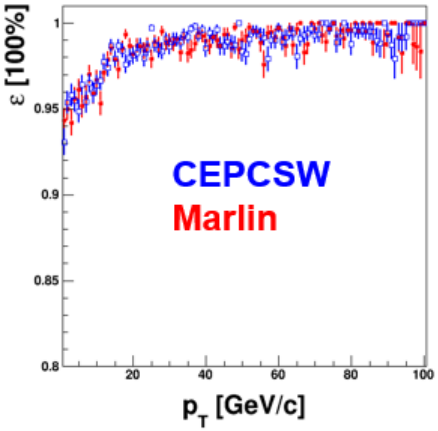


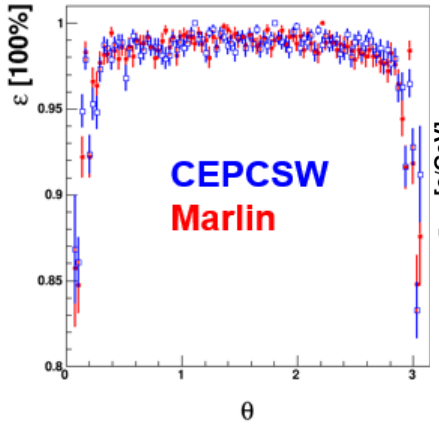
- Matching efficiency
  - Definition: $\varepsilon = N_{macthed\_track}/N_{MC(primary)}$, $|par_{fit}-par_{MC}| < 5\sigma_{par}$ (par=d0, phi0, ω, z0, tanλ)
  - single muon sample (50000): $p \in [0.5, 100.5]$ GeV/c, $\theta \in [5°,175°]$, $\phi \in [0°,360°]$

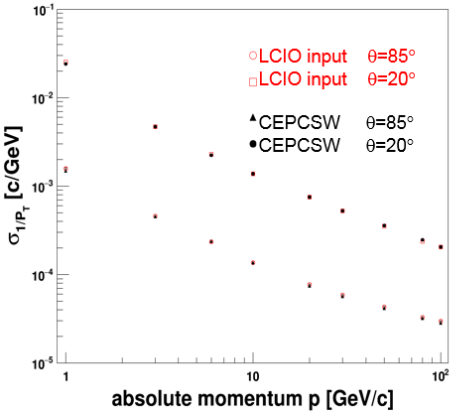


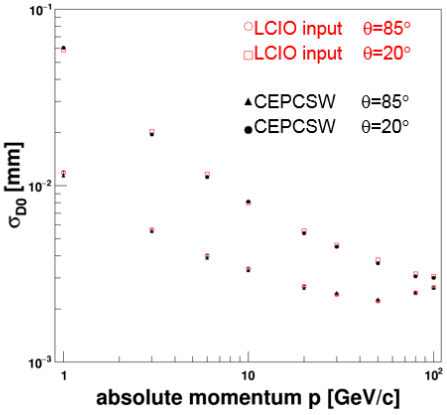
- Resolutions

Consistent with Marlin's results



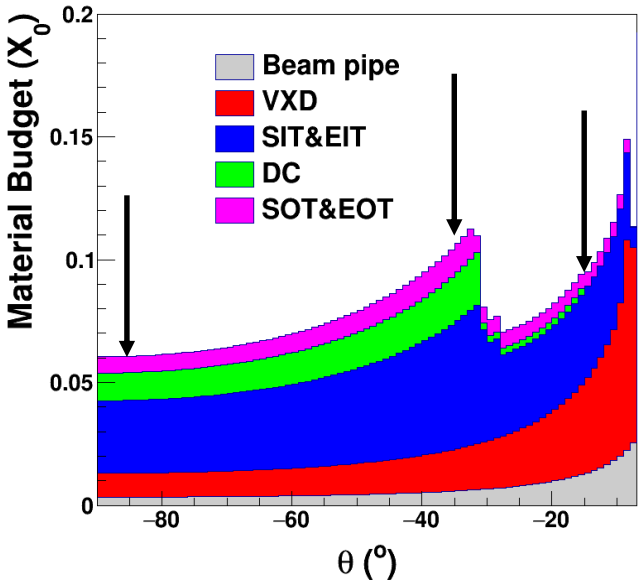




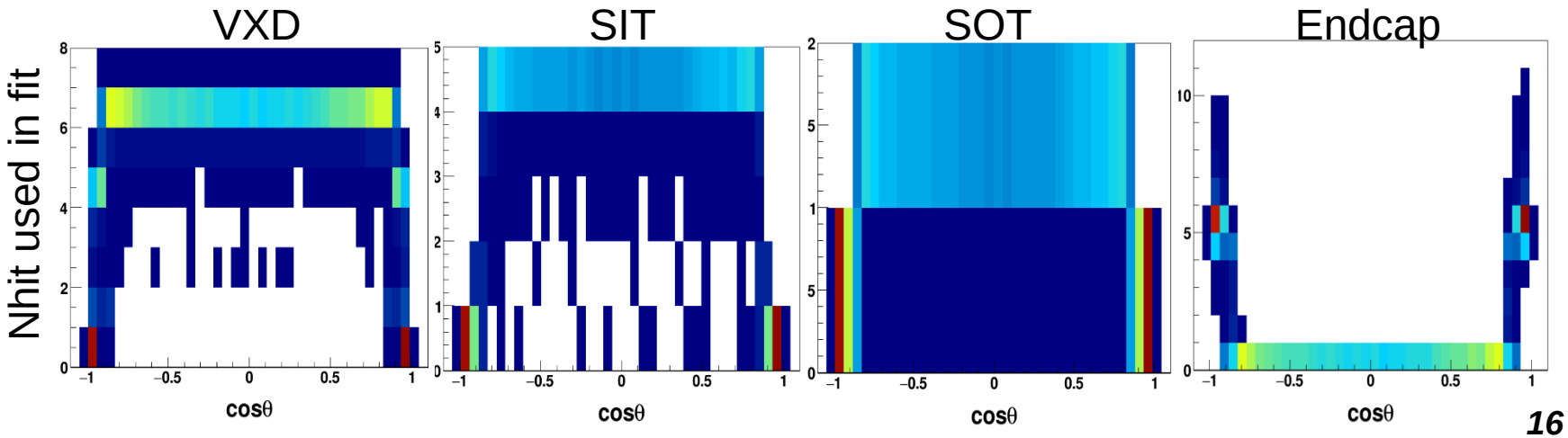


Apply to the 4th Conceptual Detector

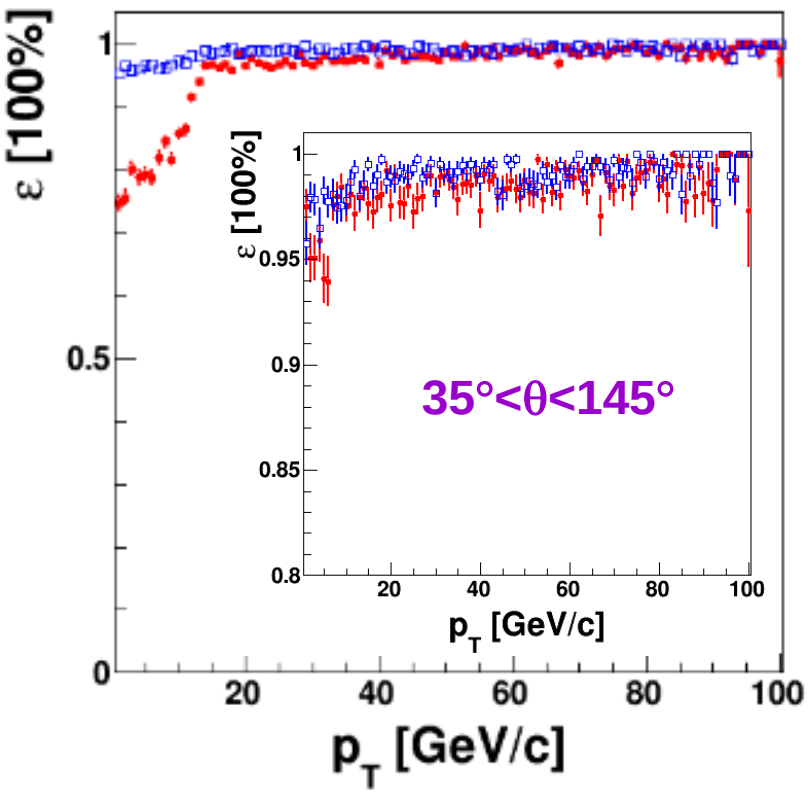
- Vertex detector (VXD): 6 pixel layers
  - $\sigma_{rphi,z}$=2.8μm, 6μm, 4μm, 4μm, 4μm, 4μm
- Silicon inside DC tracker (SIT): 4 pixel layers
  - σ_{rphi} =7.2μm, σ_z=86μm
- Silicon outside DC tracker (SOT): 1 pixel layer
  - σ_{rphi} =7.2μm, σ_z=86μm
- Endcap tracker: 2 + 3 pixel layers
  - $\sigma_{x,y}$=3μm, 3μm, 7.2μm, 7.2μm, 7.2μm

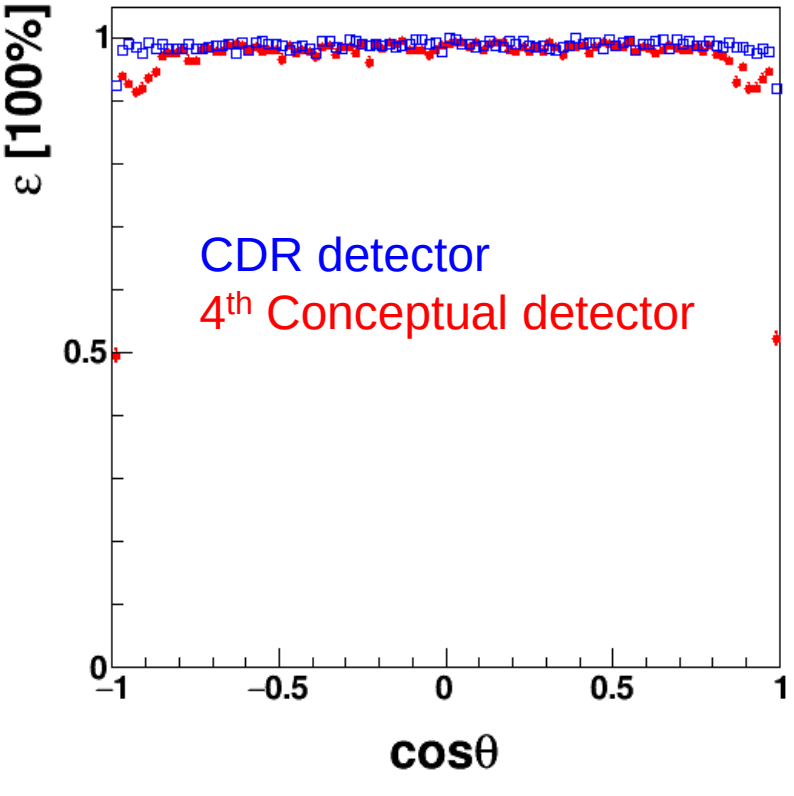


- Drift chamber (DC): 100 layers, regarded as material budget only



Matching Efficiency

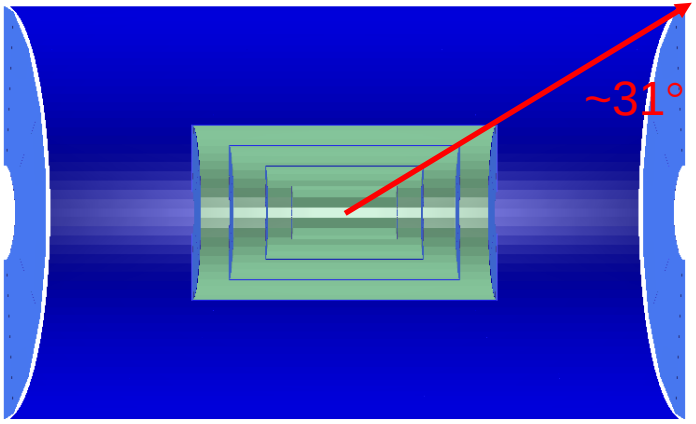


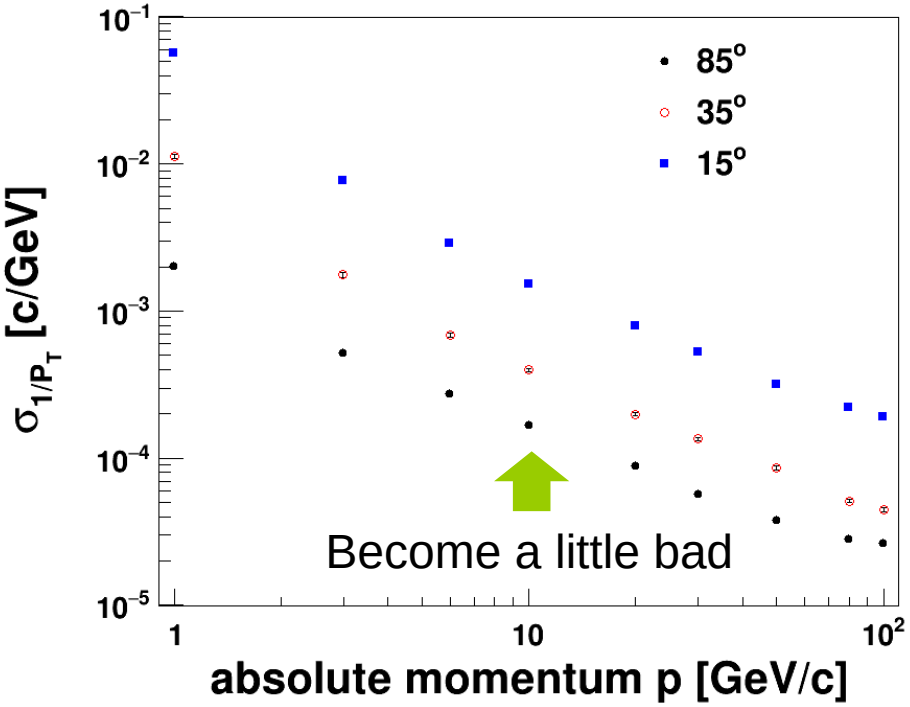


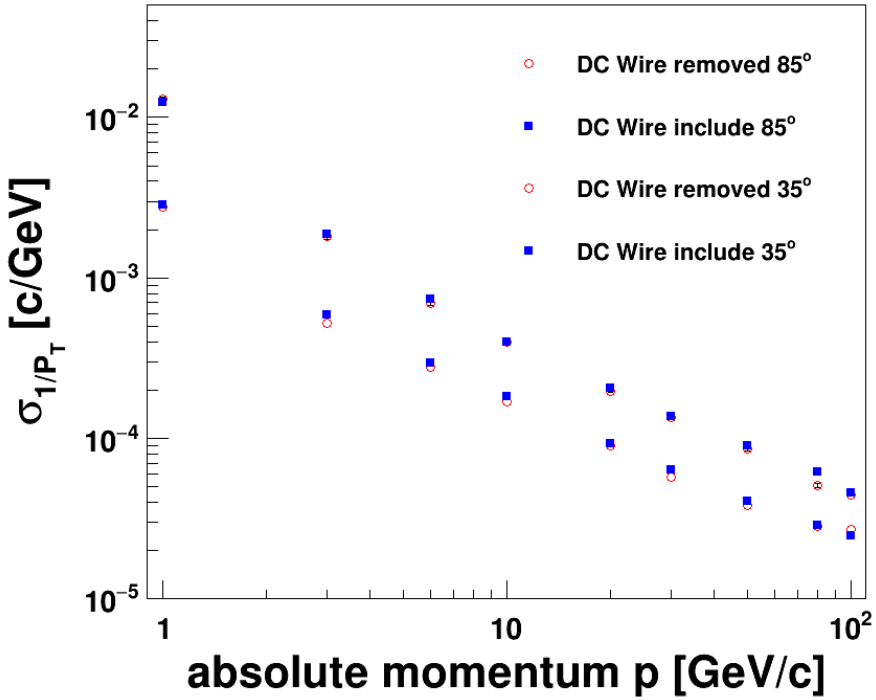
- Barrel silicon tracker has close efficiency with CDR (silicon+TPC)
- Most of lost tracks lie in endcap region, denotes the current implemented endcap design is very rough, needed to optimize

Resolution

- 85°: almost pass all barrel layers
  - The tendency is consistent with fast estimation
- 35°: close to the barrel/endcap edge
- 15°: pass endcap layers
- DC Wires affect randomly



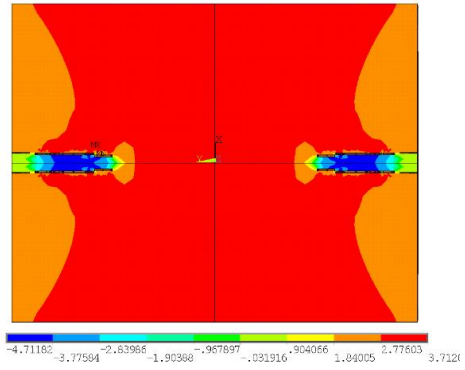




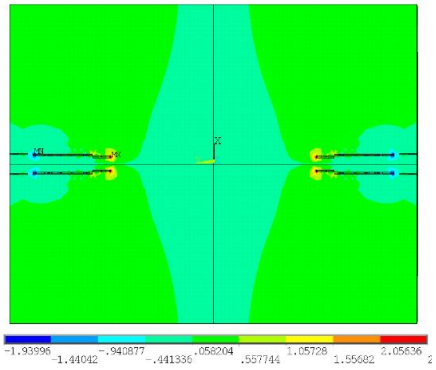
Non-uniform Field

- Include non-uniform field by map files through GenericBFieldMapBrBz in simulation
- Keep to use field value at (0,0,0) in reconstruction
  - Resolution changes very small: $(\sigma_{Pt}-\sigma_{Pt,non})/\sigma_{Pt}$ ~4%@100GeV
  - momentum departure from MC truth, to correct in future

From NING Feipeng: ~5%



Bz



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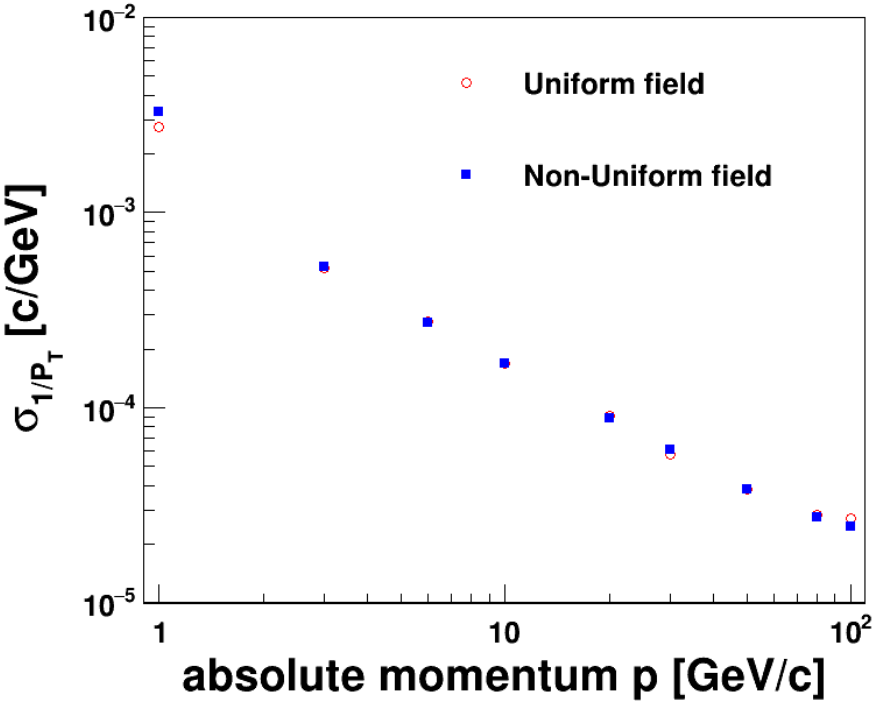
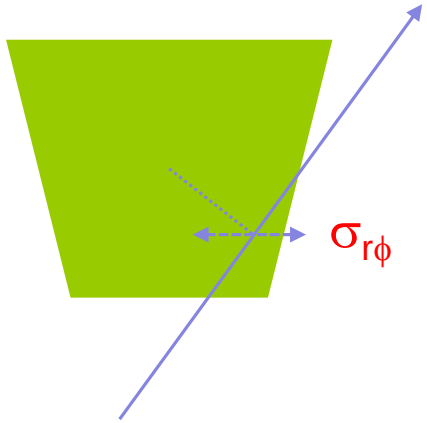
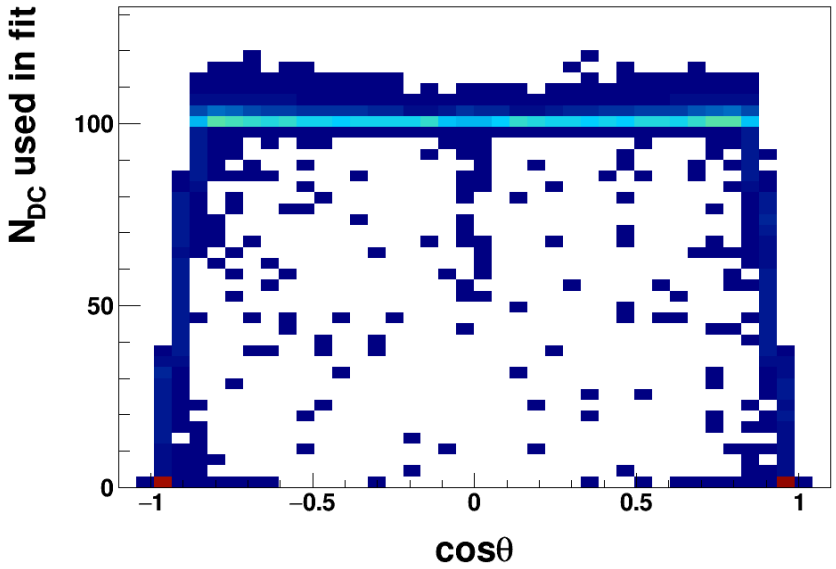


Expand to Drift Chamber

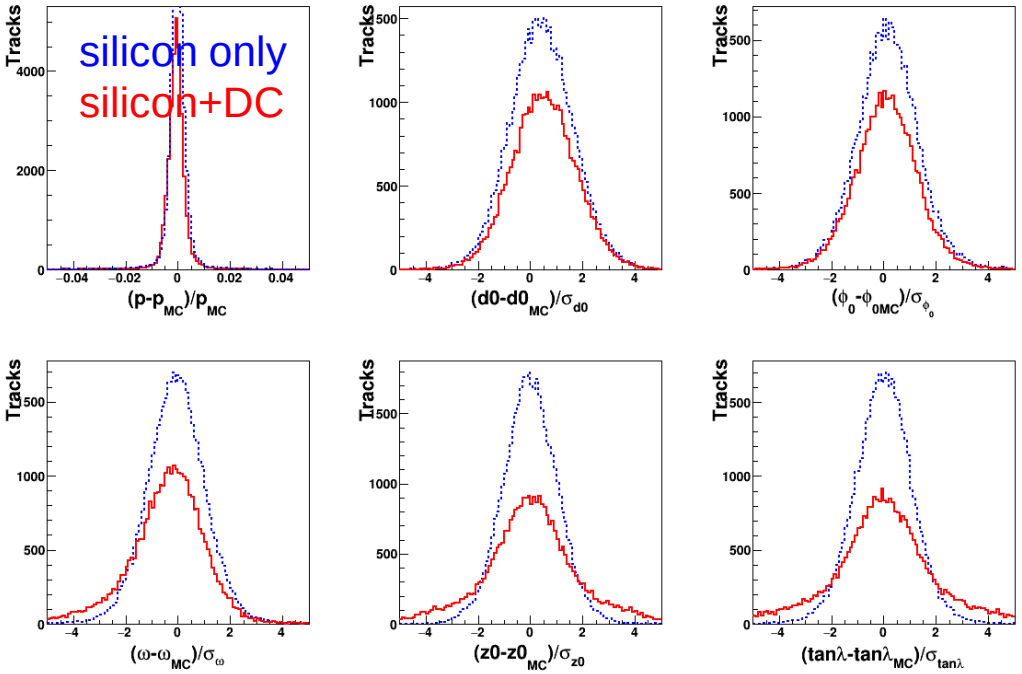
- There are another two track tools developing in CEPCSW: Genfit, ACTS
- DC hits
  - regard as CylinderHit in cylinder measurement layers
  - smear by resolution $\sigma_{r\phi}$=110μm, σ_z=1mm
- Tracking
  - Add DC hits into tracks from silicon tracking
  - Merge DC tracks with silicon tracks by FullLDCTrackingAlg does not always work, since the DC tracks have worse resolution

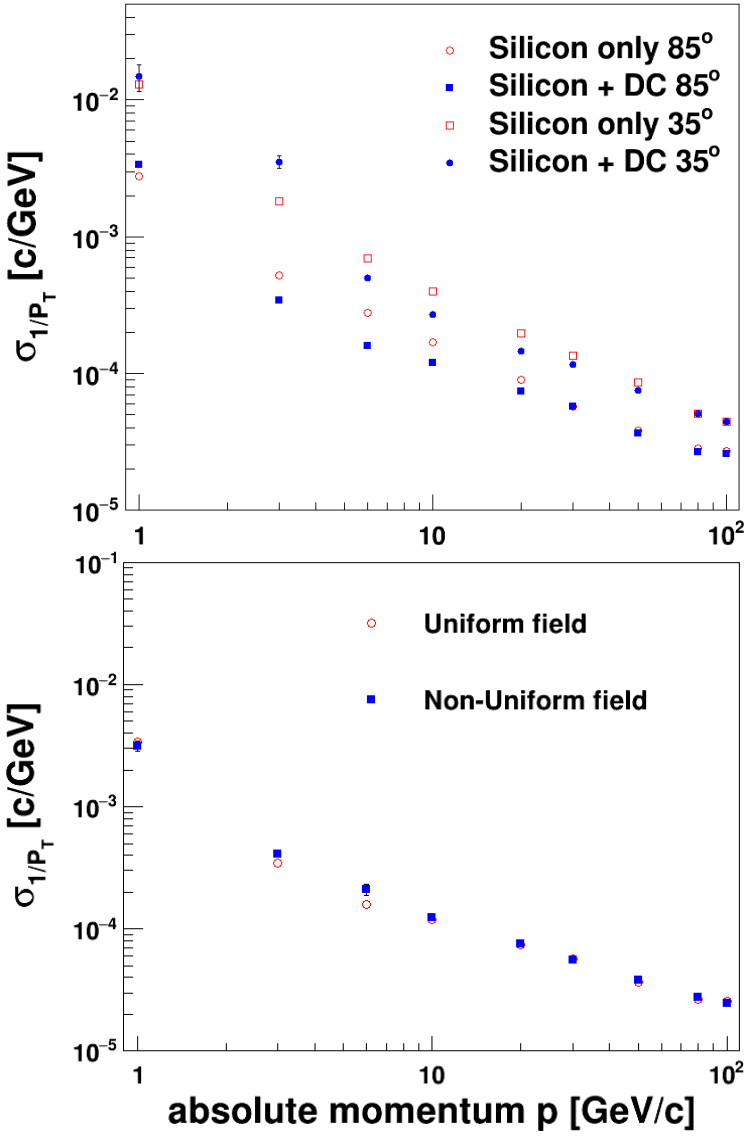




Performance with DC Hits

The pull distributions are not standard normal distribution after adding DC hits, the smeared hits are not good enough for Kalman filter, need more study





Summary

- Test tracking migrated from cepcsoft (Marlin framework, ILDSoft based) on the silicon tracker of the 4th conceptual detector
  - Performances (efficiency and resolutions) are comprehensible, consistent with the results from fast estimation (<20% for high transverse momentum)
  - Denotes endcap of silicon tracker is very rough, and need to optimize much more
- Tracking in non-uniform field is also tested, has close resolution but should be corrected
- This tracking process is valid to combine DC hits into fit, regarded as space point
  - Compare to silicon only, the resolutions in low momentum region are improved observably
  - But the estimation of error matrix (pull distribution) has some problem, to be fixed

Thank You !

謝謝