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Design and Optimization of the CEPC Tracking System

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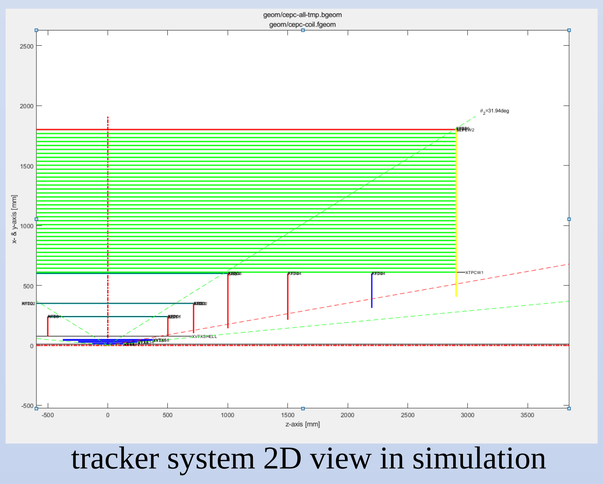
Abstract

The Circular Electron Positron Collider (CEPC) is specifically designed for in-depth studies of Higgs, W, and Z bosons, as well as heavy flavor particles. The precision tracking system is pivotal for the success of these physics studies. This presentation will delve into the software tools include fast simulation as well as optimization standards that have been meticulously selected, and applied it to achieve best performance. The presentation will showcase the impact of these optimizations on key performance indicators such as momentum resolution, tracking efficiency, and the robustness of the track fitting process.

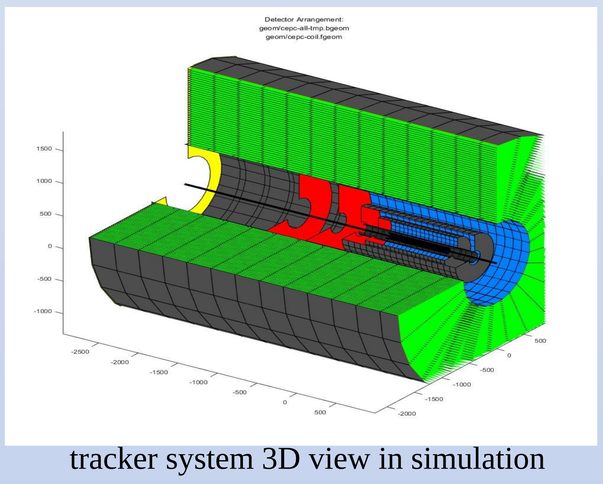
Details

Simulation Tool

Introduction: The "LiC Detector Toy" (LDT) software tool which has been developed for detector design studies, aiming at investigating the resolution of reconstructed track parameters for the purpose of comparing and optimizing detector set-ups. It consists of a simplified simulation of the detector measurements, based on a helix track model and taking into account multiple scattering, followed by full single track reconstruction using the Kalman filter. The software runs under Matlab and Octave, with an integrated GUI.



tracker system 2D view in simulation



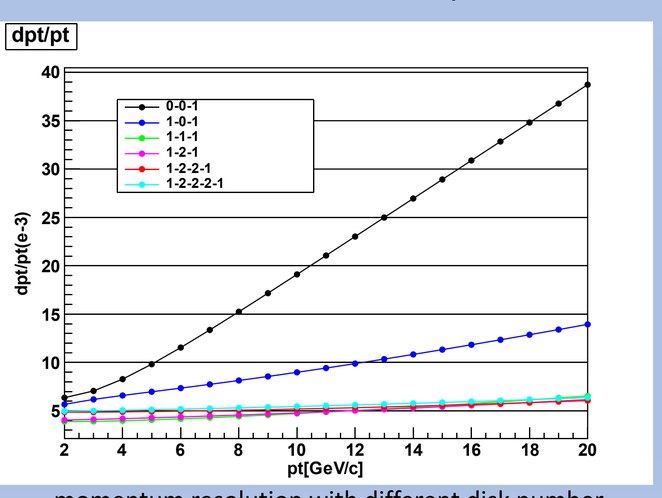
tracker system 3D view in simulation

Simulation method: Based on LDT software, we can change the layout, material budgets, spatial resolution, and hit efficiency of each sub-detector in the tracking system to achieve optimal performance.

Optimizations for Momentum resolution

The momentum resolution of tracking system is influenced by various factors, among which the layout of inner tracker(ITK) is one of its important factors.

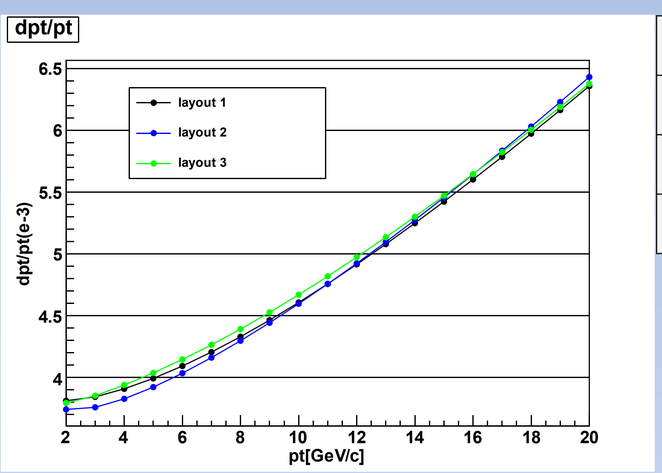
ITK endcap : The key to the impact of endcap layout on momentum resolution lies in its number and position. we tried different combinations of ITK endcap positions and numbers, compared the momentum resolution of each different combination, and selected the optimal layout.



momentum resolution with different disk number

We fixed the position of OTK and simulated the performance of different numbers of endcaps from 0 to 4. (the legend "-2" represents double layers)

The results show that no disk and one disk have poor performance; Two, three, and four disk perform well and are similar.

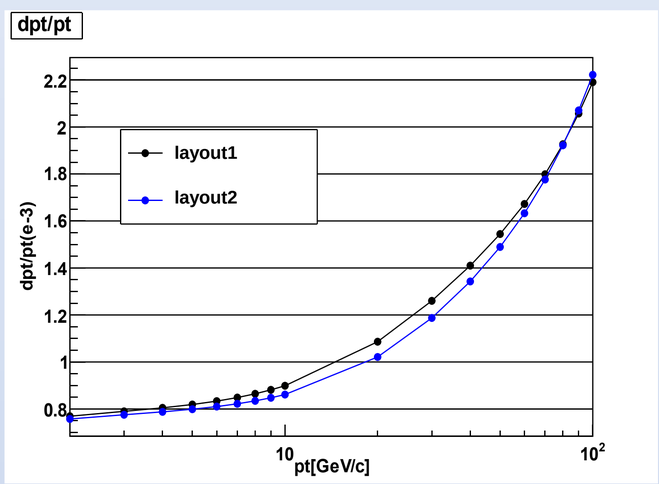


momentum resolution with optimized layout

	Disk z position(mm)		
layout1	1750	2680	2830
layout2	1125	2500	
layout3	500	1750	2680

After comparing the layouts of different combinations, we selected the best three .And they have little difference from each other

ITK barrel : Similar to endcap, we select the one with the best momentum resolution from different combinations of position numbers.

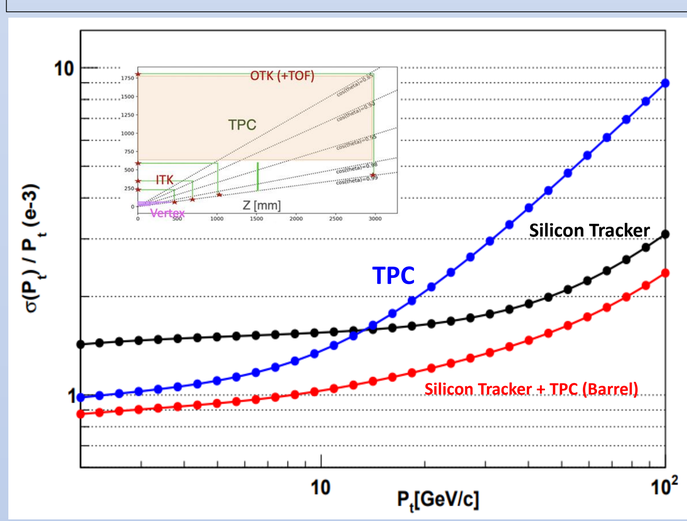


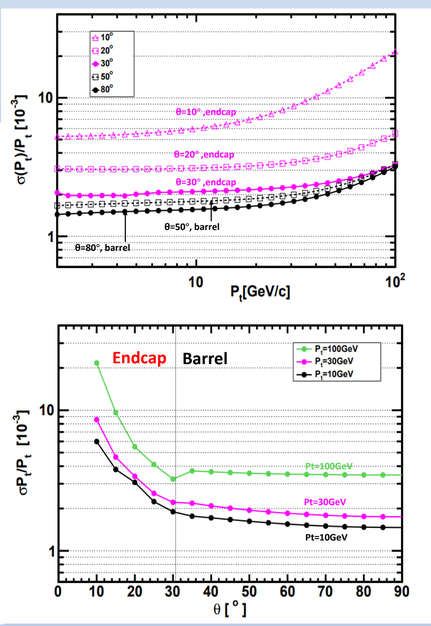
momentum resolution with different barrel layout

	ITK barrel R position(mm)		
layout1	90	364	500
layout2	90	310	400

The layout of ITK has a relatively small impact on momentum resolution, with dibarrelfferences within 0.1 ‰ for different combinations.

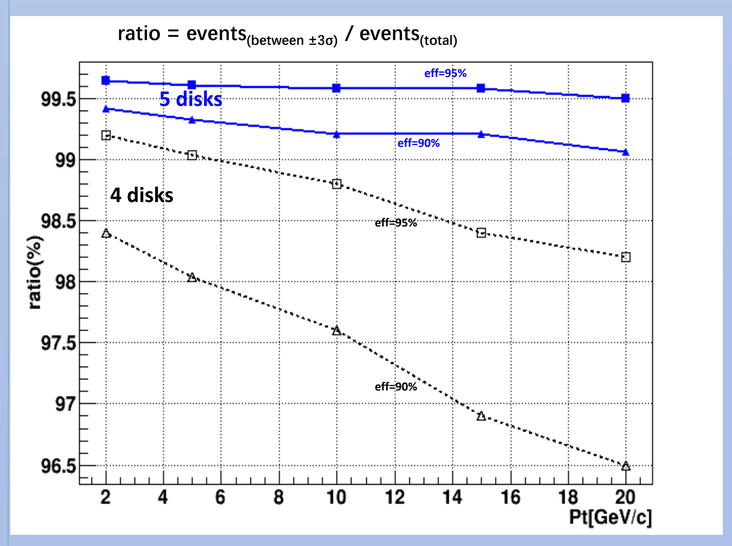
Tracking performance from fast simulation





Optimizations for tracking efficiency

For each sub-detector of tracking system, we set different hit efficiencies and observed their residual distribution of momentum resolution. Then take the events ratio within 3 σ as the tracking efficiency, and observe the impact of layout on it.



tracking efficiency in different disk number

We simulated the problem of decreased tracking efficiency caused by the loss of measurement points. And the effect of increasing the number of endcap layers on reducing this impact.

Summary:We studied the effects of different layouts on momentum resolution and tracking efficiency using fast simulation tools. For the endcap region, increasing the number of layers can improve tracking efficiency, but it can also increase scattering effects and lead to decreased resolution; Due to the presence of TPC in the barrel region, the impact of layout is relatively small. And we also give the performance of momentum resolution in current tracking systems. We will verify it through more detailed simulations in the future.