# Geometric Optimization Simulation of the CEPC Vertex Detector

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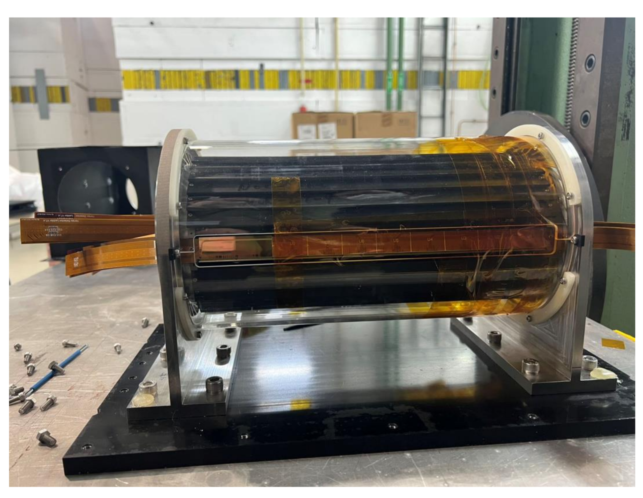
## Introduction

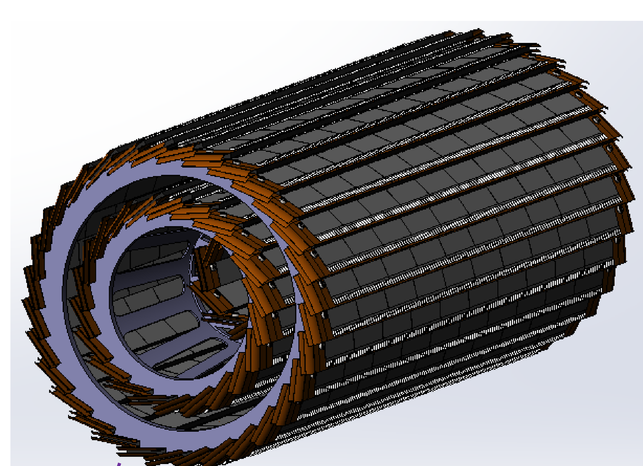
The identification of heavy-flavored quarks and τ leptons is an important physics goal of the Circular Electron Positron Collider(CEPC). The vertex detector of the CEPC is capable of obtaining precise track parameters of charged particles in the vicinity of the Interaction Point to reconstruct the decay vertex of short-lived particles. The CEPC vertex detector currently adopts two schemes, one based on the MOST2 prototype Long Barrel scheme, and the other based on the bent MAPS Stitching Mixing scheme. Both structures currently cover a polar angle of 8.1° along the length of the z-direction using a chip with a single-point spatial resolution of 5um. Based on the radius of the beam pipe of 10 mm in the CEPC-TDR, the minimum radii for the Long Barrel scheme and the Stitching scheme are 12um and 11.06um, respectively.

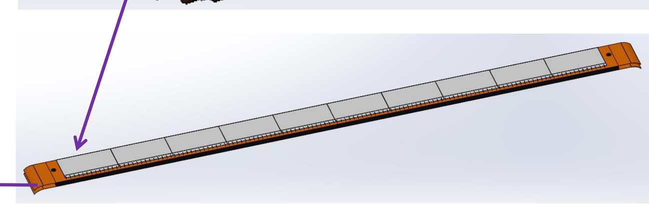
## Structure

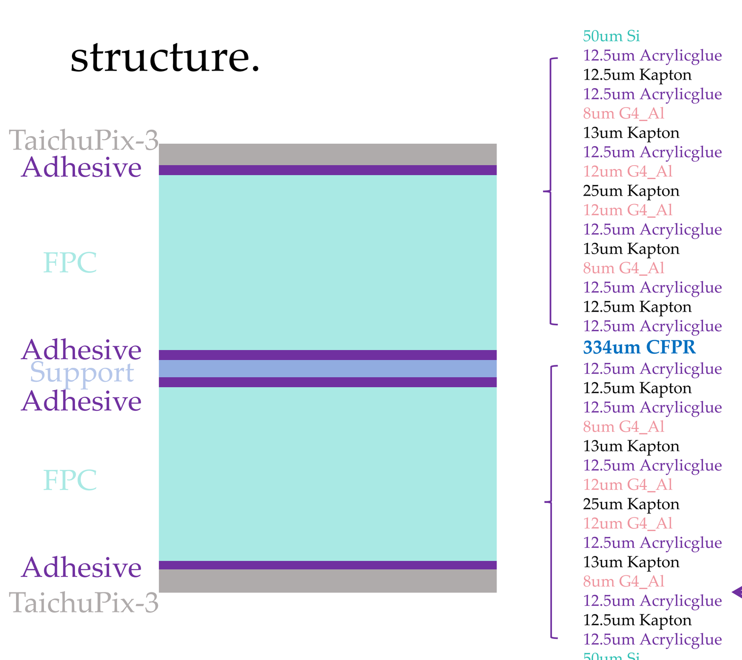
**Long Barrel scheme**

- Ladders using TaichuPix-3 chips **on both sides** as repeating units for each layer;
- TaichuPix-3 adopts a 180 nm CIS process with sizes of 15.9mm * 25.7mm;
- Carbon fiber, along with flexible circuit boards, is affixed to both sides as a support structure.



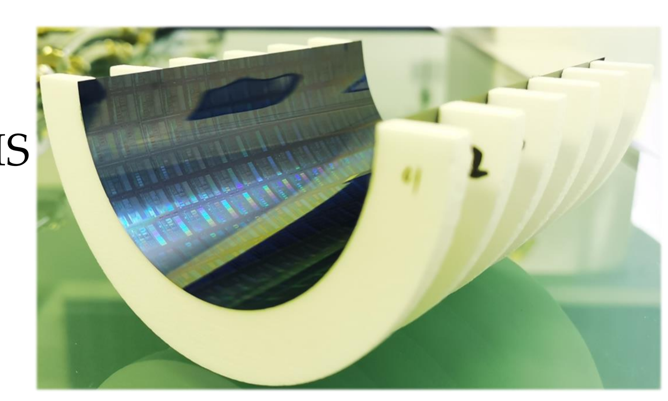







**Stitching Mixing scheme**

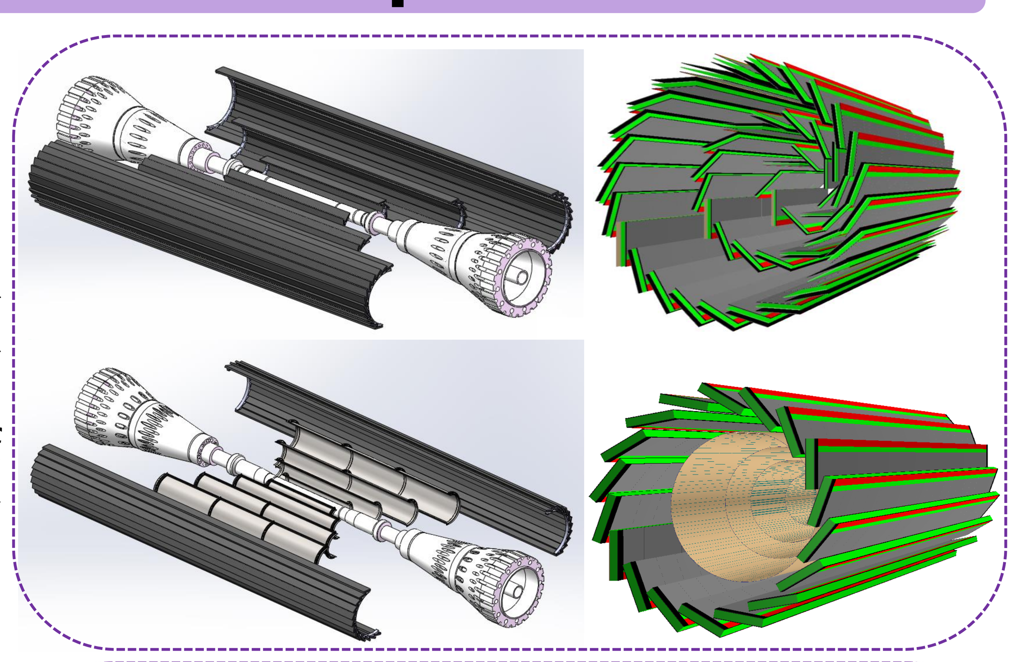
- A bent MAPS sensor adopts a 65nm CIS process with sizes of 17.277 mm * 20.2mm;
- Chips are fixed on the support.



## Details of the two schemes placements

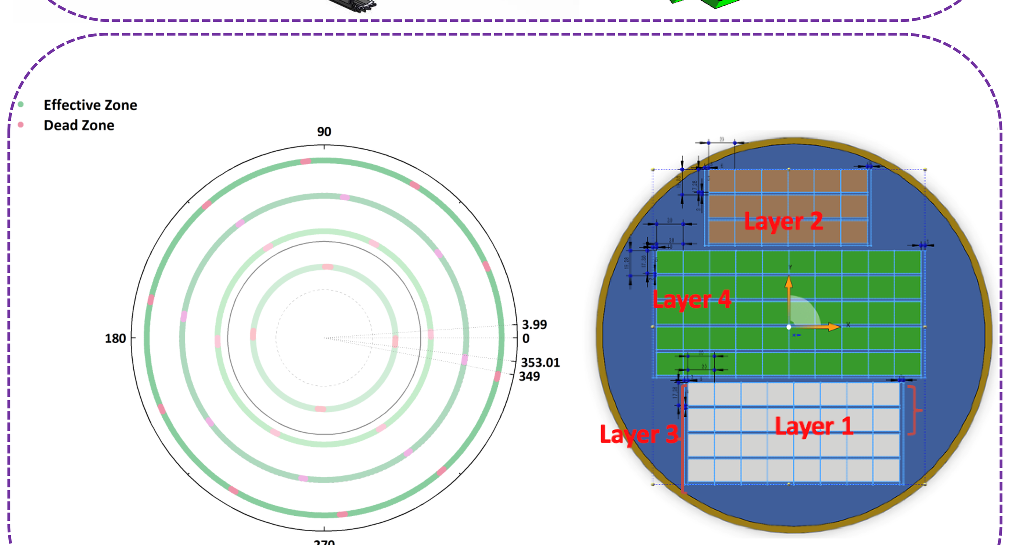
**Long Barrel features:**

- Innermost layer radius: ~12mm;
- Three layers of ladder from inside to outside (total of six layers of chips);
- Different thicknesses of support structure for load-bearing consideration.



**Stitching Mixing features:**

- Innermost layer radius: ~11mm;
- Specific starting angle for each chip layer to ensure that outgoing particles pass through at most one dead zone in a straight line;
- Utilizing four layers of curved chips and one ladder layer.



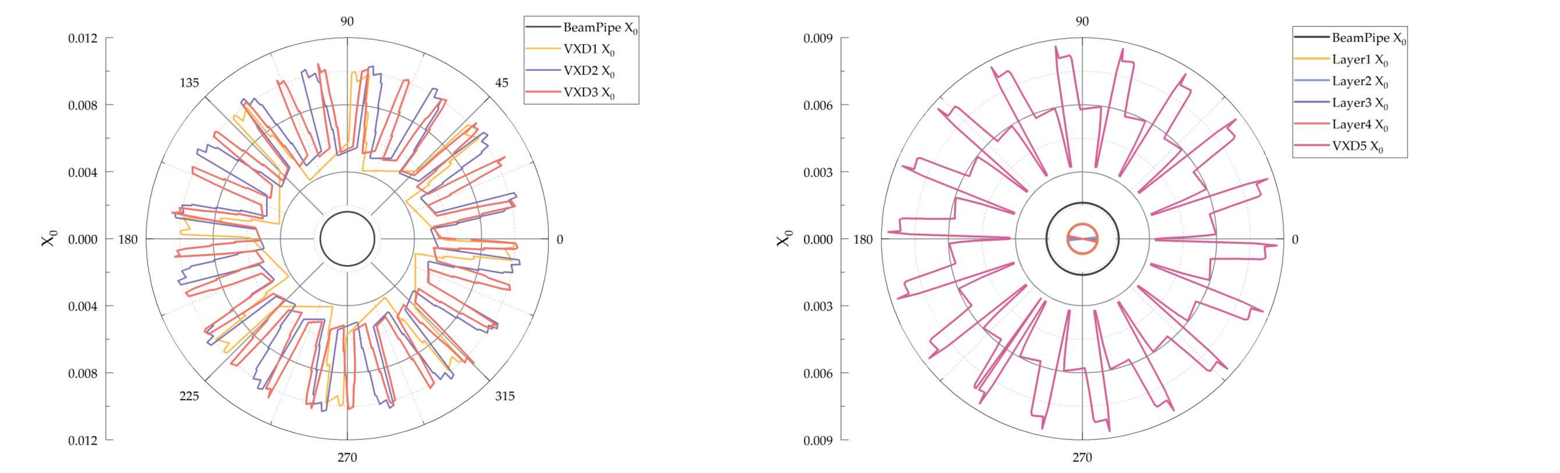

Schematic diagram of the Inner layer placement of the vertex detector stitching scheme.

| | layer/VXD X | radius .mm | length .mm | arc length .mm | height .mm | support thickness .um |
|---|---|---|---|---|---|---|
| Long Barrel | VXD1 | 12.46 | 260.0 | | 1.7 | 334 |
| | VXD2 | 27.89 | 494.0 | | 2.5 | 358 |
| | VXD3 | 43.79 | 749.0 | | 3.2 | 370 |
| Stitching Mixing | layer 1 | 11.06 | 161.4 | 69.108 | | 45 |
| | layer 2 | 16.56 | 242.2 | 103.662 | | 32 |
| | layer 3 | 22.06 | 323.0 | 138.216 | | 31 |
| | layer 4 | 27.56 | 403.8 | 172.770 | | 29 |
| | VXD5 | 34.74 | 500.0 | | 2.8 | 363 |

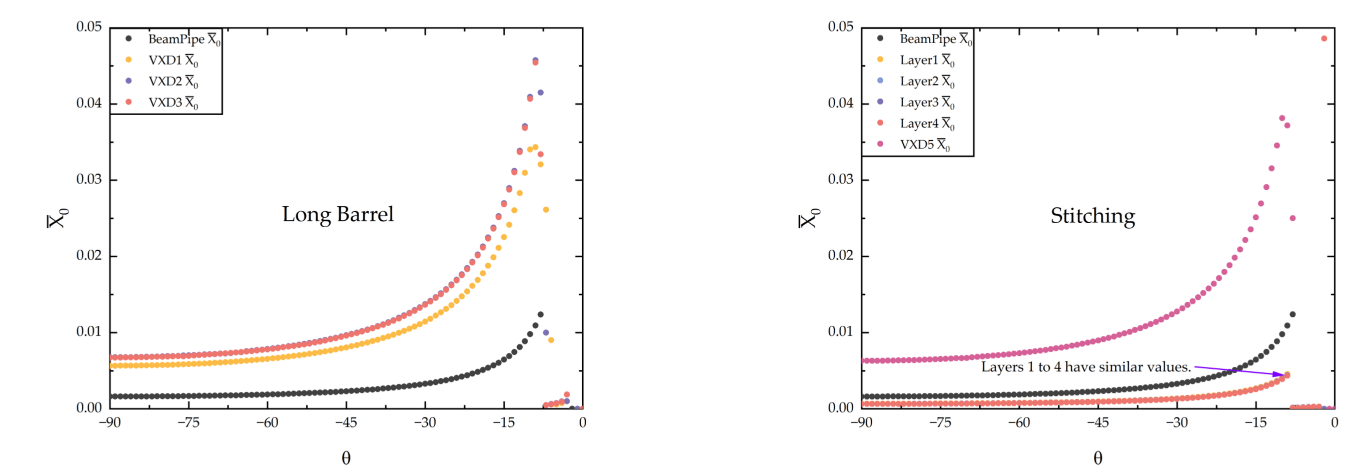
## Material budget

**Long Barrel scheme:**

- More chips used in middle and outer layers, so additional four layers of aluminum in each for stability and to prevent significant deformation.



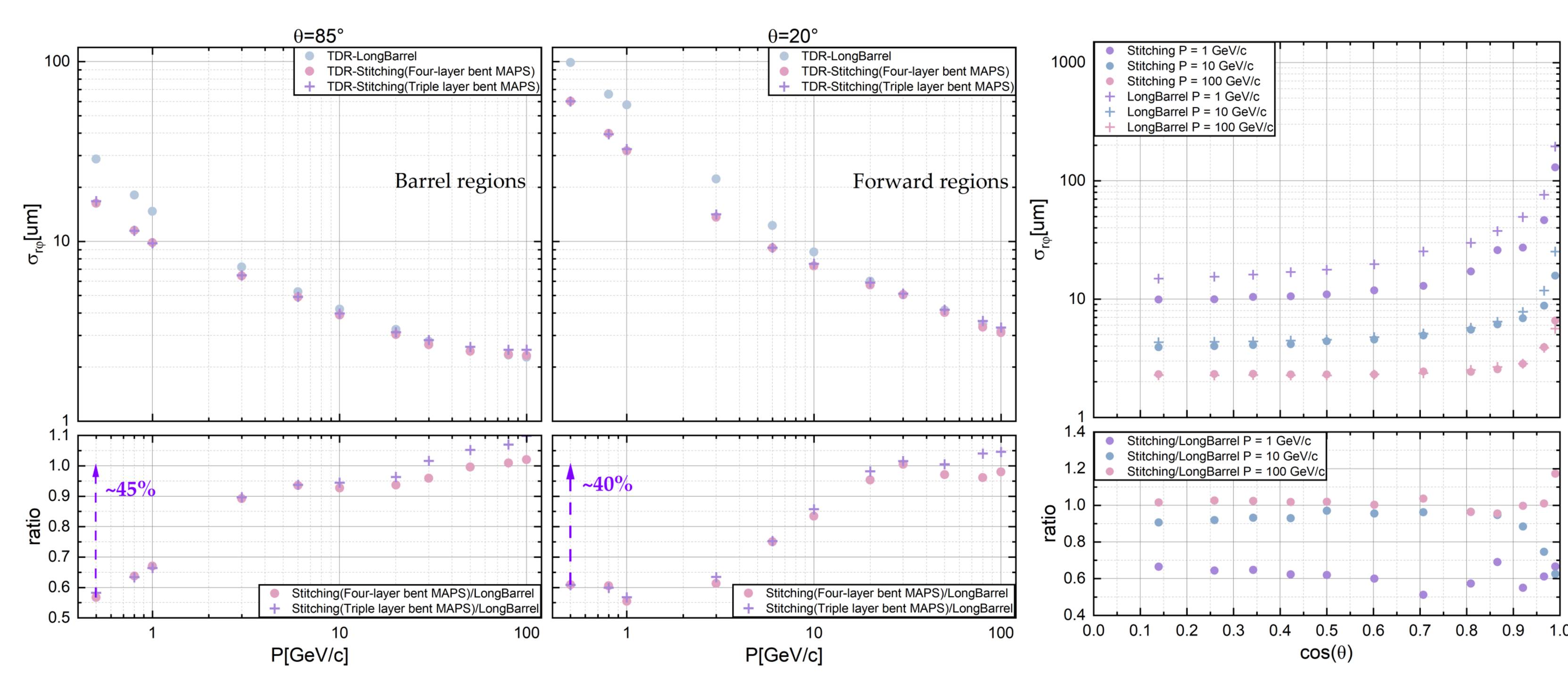
The material budget $X_0$ of two structures vary with $\varphi$ when $\theta = -90°$.




The average value $\overline{X_0}$ within the range of $\varphi \in (0, 360)$ varies with $\theta$.

| Mat | BeamPipe | Layer/VXD 1 | Layer/VXD 2 | Layer/VXD 3 | Layer 4 | VXD5 |
|---|---|---|---|---|---|---|
| Long Barrel | 0.162% | 0.565% | 0.676% | 0.672% | | |
| Stitching | 0.162% | ~0.06% | ~0.06% | ~0.06% | ~0.06% | 0.629% |

## Performance




- When the momentum of the outgoing particle $\mu^-$ is lower than 40 GeV/c, the TDR-Stitching Mixing scheme uses four-layer bent MAPS to perform better than the TDR-LongBarrel.
- The TDR-Stitching Mixing scheme employs triple-layer bent MAPS and four-layer bent MAPS in the low momentum range, with nearly identical performance in terms of the impact parameter $d_0$.
- In the low momentum range, the TDR-Stitching Mixing scheme uses four-layer bent MAPS to improve $d_0$ by nearly 40% compared to the TDR-LongBarrel for particles emitted at any angle.

## Summary

- The TDR-Stitching Mixing scheme features a reduced material budget compared to the TDR-Longbarrel scheme, resulting in a smaller $d_0$ resolution in the low momentum range;
- The TDR-Stitching Mixing scheme utilizing triple-layer bent MAPS demonstrates performance nearly equivalent to that of the four-layer MAPS;
- Further detailed simulation and optimization of the TDR-Stitching Mixing scheme are planned for the future.

## Reference

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III. http://code.ihep.ac.cn/cepc/CEPCSW


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