



Background Analysis and Digitization of CEPC Vertex Detector

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Vertex Detector

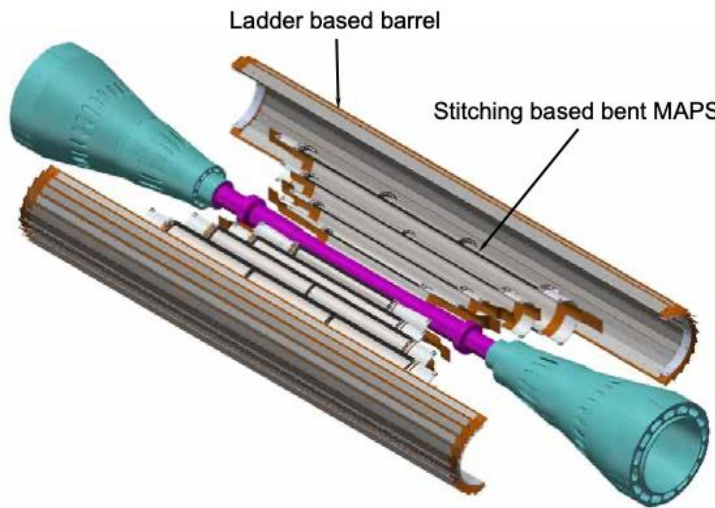
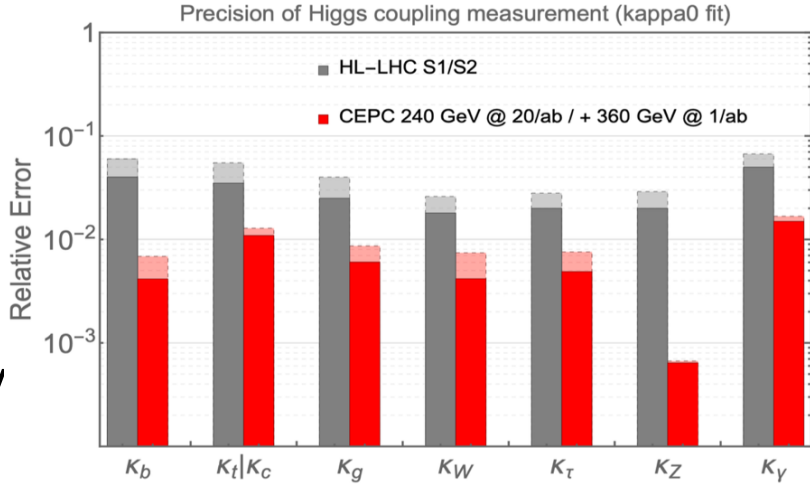
- As the next generation collider, CEPC is far beyond a Higgs factory:
- Searching for exotic or rare decays of H, Z, B and τ , and new physics
 - Huge measurement potential for precision tests of SM: Higgs, electroweak physics, flavor physics, QCD/Top

Whether it is flavor physics or Higgs physics, precise vertex measurement is an essential requirement for achieving the CEPC's physics goals.

For we have no precise digital model, the accuracy of model particularly in the forward region of the long barrel is not high, **we conducted beam test at BRSF and explored and established the TaichuPix digital model based on the results of the beam tests.**

Specification	Index
Pixel size	$25\mu\text{m} \times 25\mu\text{m}$
Dimension	$15.9\text{mm} \times 25.7\text{mm}$
Techonology	CIS 180nm
Dead time	$< 500\text{ns}$
Power density	$< 200\text{mWcm}^{-2}$
Max. Hit rate	$36 \times 10^6\text{cm}^{-2}\text{s}^{-1}$

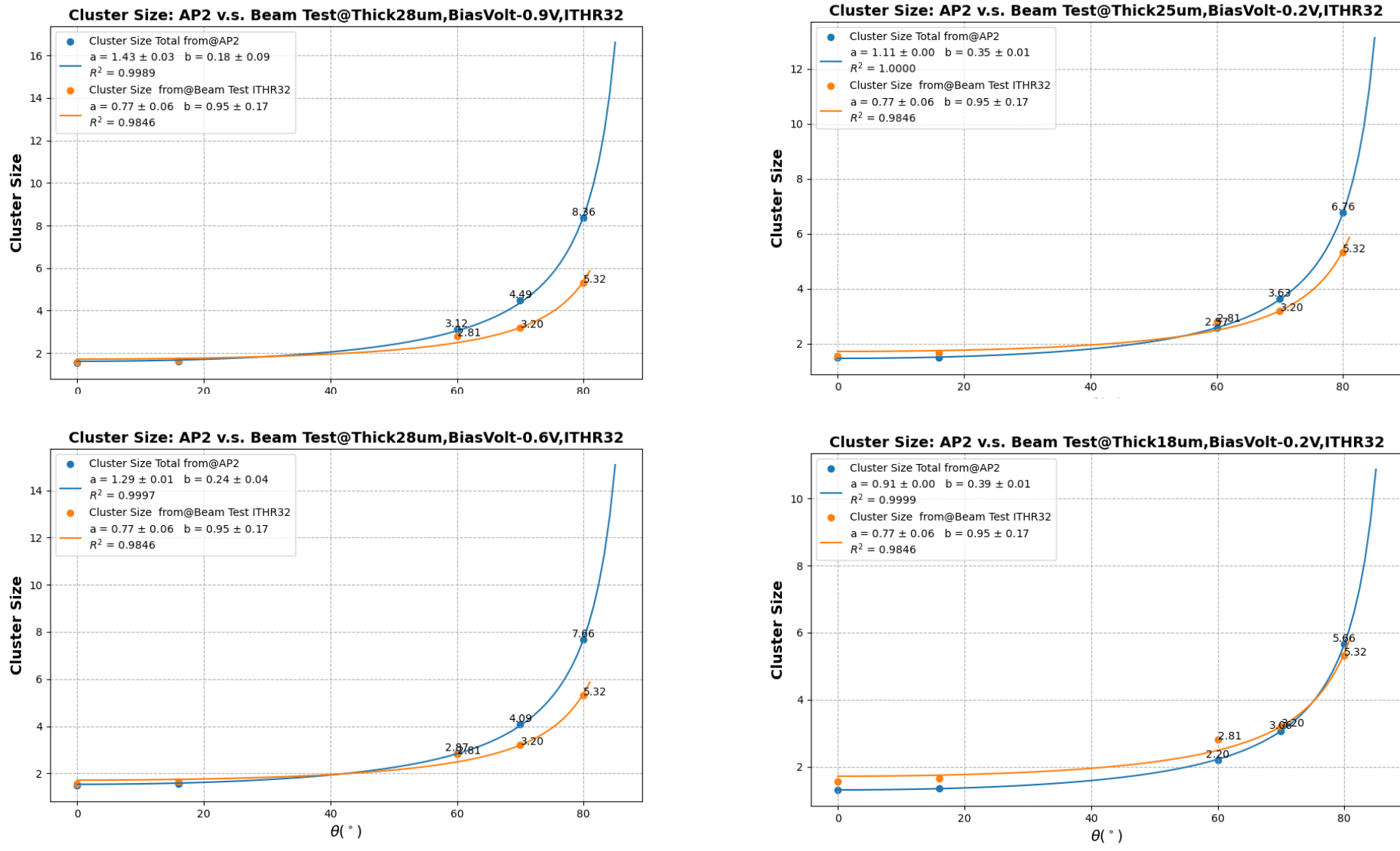
TaichuPix-3 Performance Index



Baseline scheme of CEPC vertex detector

Beam Test Result v.s. Simulation

Then we try to change the parameters and results show as below.



The simulation results from AIPix-2 are acceptable in comparison to the experimental measurement results.

Digital Model

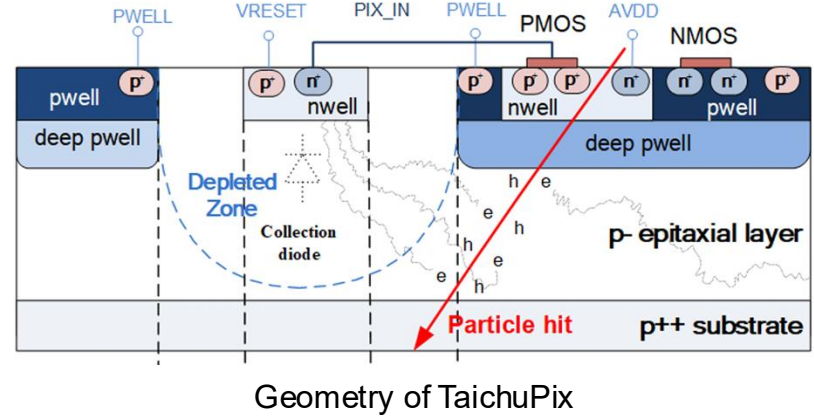
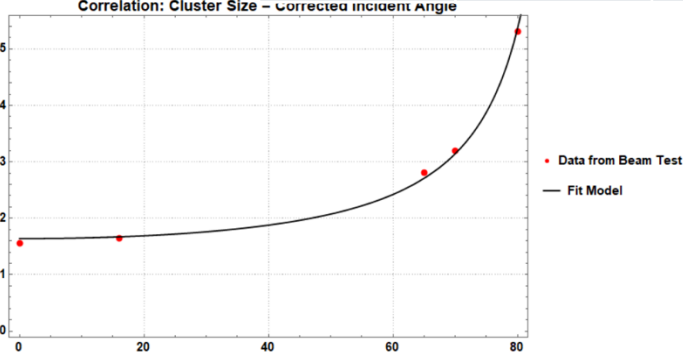
- Considering the issues:
- Low accuracy in the forward region.
 - The performance simulation does not include the complete physical processes

A model based on beam test result and AP2 simulation is developed to estimate cluster size.

$$C = a \sec \theta + b$$

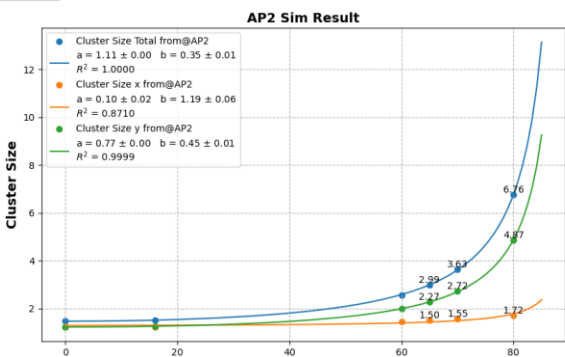
C is the Cluster Size, and θ is the incident angle

Param	Estimate	Std Error	RSquared
a	0.783	0.022	0.9995
b	0.856	0.069	

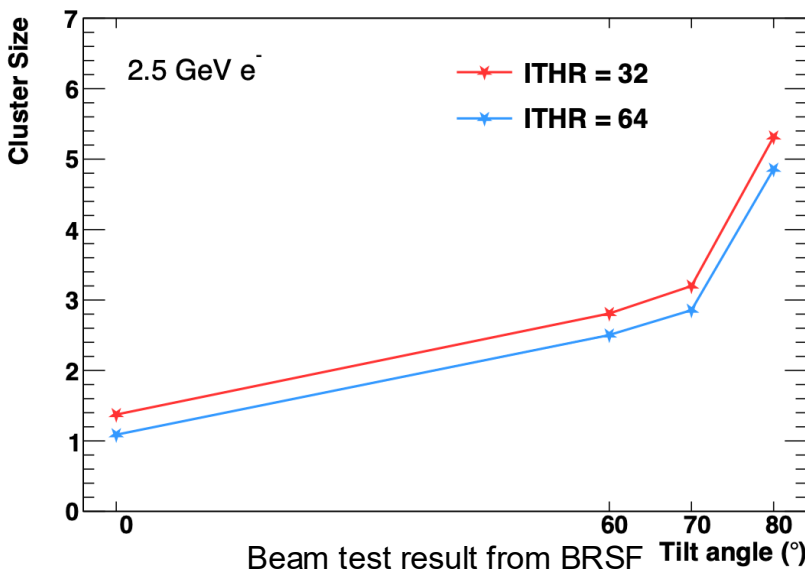


Geometry of TaichuPix

Fitting result of beam test(left fig& table) and simulation(right fig) shows that the model is reasonable.

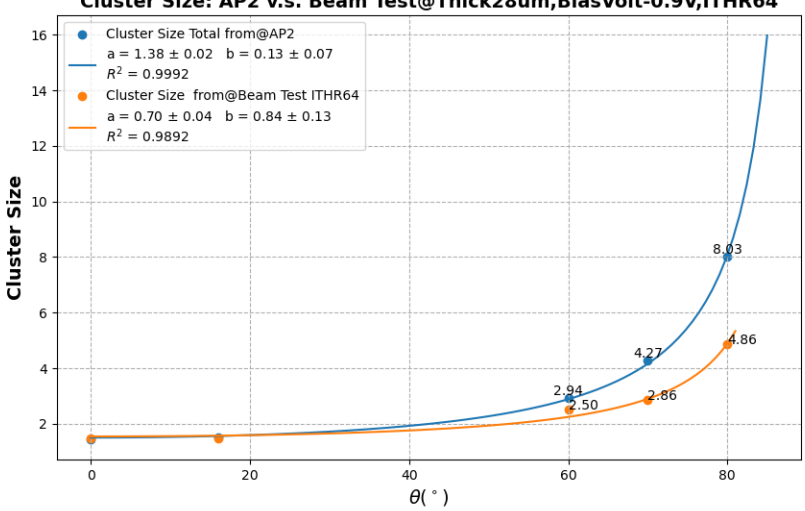
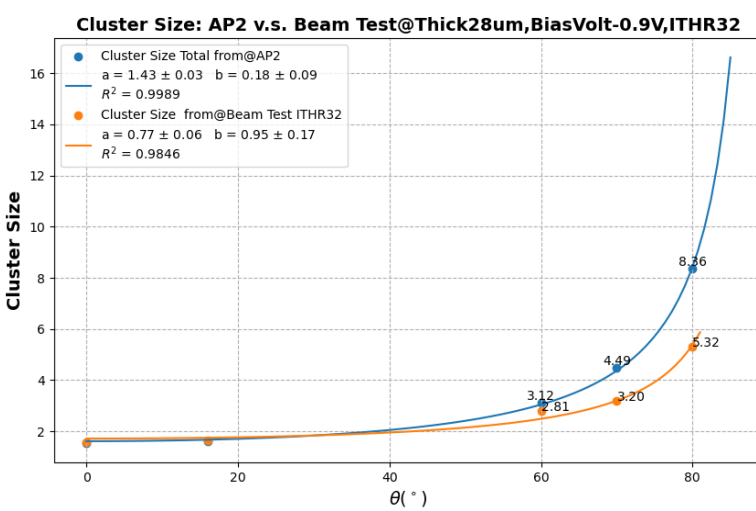


Beam Test Result v.s. Simulation



Angle	ITHR32	ITHR64
0°	1.561	1.469
16°	1.645	1.478
60°	2.809	2.504
70°	3.199	2.856
80°	5.315	4.857

The figure above presents the results of the beam tests. To make the conclusions more reliable, we also incorporated the beam test results from DESY II. By comparing the beam test results with the AP2 simulation results, we found some significant differences when the parameter settings were the same as those in the experiments.



Some significant differences under large angle.

- Here are some possible reasons:
- In AIPix-2, signals produced by the substrate do not contribute.
 - Due to electric field distributions, the effective sensitive thickness may differ from the true thickness.

Beam Background Estimation

- Signal-to-noise ratio is very low, makes background analysis very important
- Provide directions for improving geometry, estimate power consumption...

Background	Generation	Tracking	Detector Simulation
Synchrotron Radiation	Geant4	Geant4	
Beamstrahlung/Pair Production	Guinea-Pig++		
Beam-Thermal Photon	PyBTH		
Beam-Gas Bremsstrahlung	PyBGB		CEPCSW/FLUKA
Beam-Gas Coulomb	BGC in SAD	SAD	
Radiative Bhabha	BBBREM		
Touschek	PyTSK with SAD		

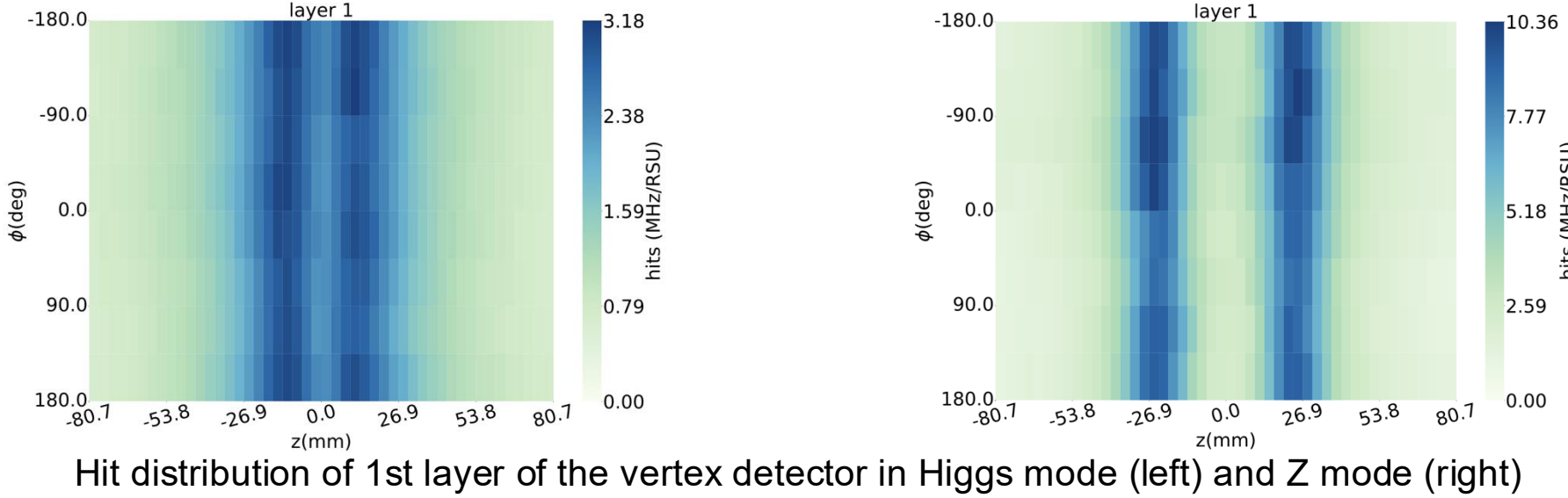
Based on the digitization model, the beam background shown as following table:

Layer	Ave. Hit Rate (MHz/cm ²)	Max. Hit Rate (MHz/cm ²)	Ave. Data Rate (Mbps/cm ²)	Max. Data Rate (Mbps/cm ²)
Higgs mode: Bunch Spacing: 277 ns, 63% Gap				
1	6.2	12	760	1500
2	0.84	1.6	87	160
3	0.17	0.36	19	38
4	0.067	0.16	8.4	19
5	0.017	0.037	2.1	4.2
6	0.013	0.026	1.6	3.7
Low-luminosity Z mode: Bunch Spacing: 69 ns, 17% Gap				
1	15	39	2700	8100
2	1.7	2.6	240	400
3	0.72	1.2	110	240
4	0.43	0.94	70	210
5	0.10	0.19	14	31
6	0.078	0.15	11	23

No trigger and error window here.

Threshold has been taken into consideration. (ITHR 32 = 368e, 1.3keV/pixel)

$$\text{Data Rate} = \text{Hit Rate} \times 32 \text{ bit} \cdot \text{pixel}^{-1} \times \text{Cluster Size}$$



Summary

To verify the performance of TaichuPix at different incident angles and provide a reference for future digitization, we conducted beam tests and established a cluster size model based on the current beam test results.

- Cluster Size at large incident angle approximately equals to 5 (3 after thined), and normal incident equals to 1.5.
- After making appropriate adjustments, the AP2 simulation results align well with the experimental results.
- The beam background was estimated based on the digital model we established.