Poster #49

Design of AC-LGAD for CEPC Outer Tracker (OTK)

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The Circular Electron Positron Collider (CEPC) is a future collider experiment which has huge potential for the precision measurement of standard model and exploration for the new physics. The Gas detector (dE/dx) for CEPC suffers separation problem for k/pi and k/p at low energy range which is important for the flavor physics. **Timing detector** based on the LGAD technology is proposed to improve the separation ability which is complementary to gas detector. The timing detector would have **30 ps to 50 ps** timing resolution and the **10 μm** spatial resolution at the same time due to application of the AC-LGAD technology. **Low Gain Avalanche Diode** (LGAD) has **high-precision time performance**, and the time resolution can reach 30 ps, IHEP has designed a LGAD strip prototype to verify the technical validity.

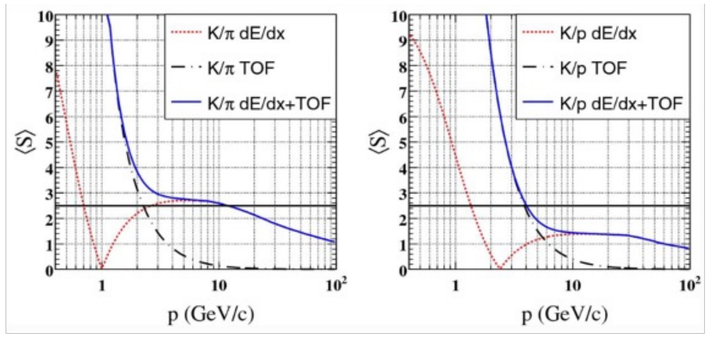
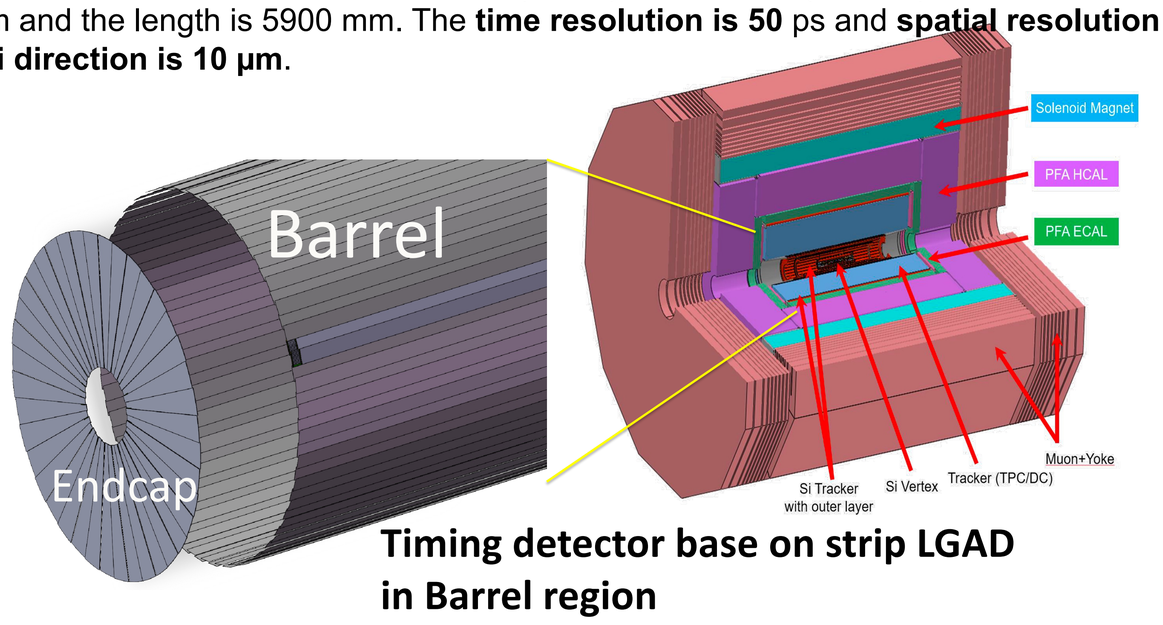
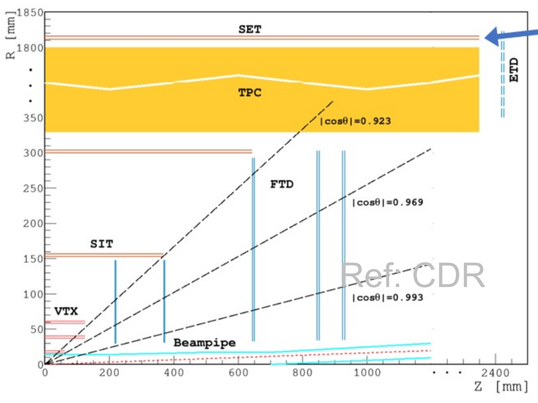


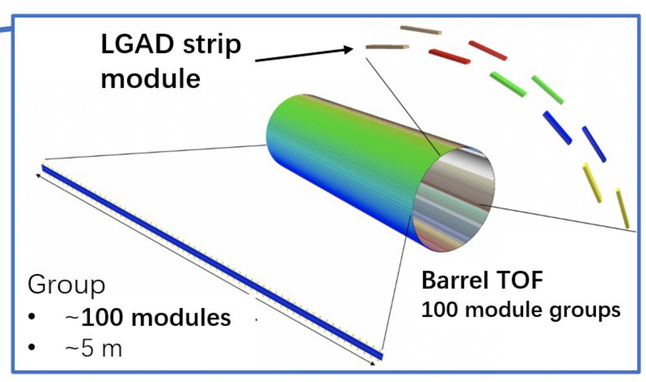
Figure 1:（left）Simulation results of the separation power for the K/pi with and without ToF，
（right）Simulation results of the separation power for the K/p with and without ToF.
(From CEPC simulation group)

Time of flight & out Tracker would be placed between the TPC and ECAL which could provide the time and spatial information for the particle track. The total coverage area would be **~90 m²** which included **70 m²** (barrel) and **~20 m²** (endcap). The radius is 1800 mm and the length is 5900 mm. The **time resolution is 50** ps and **spatial resolution at r-phi direction is 10 μm**.



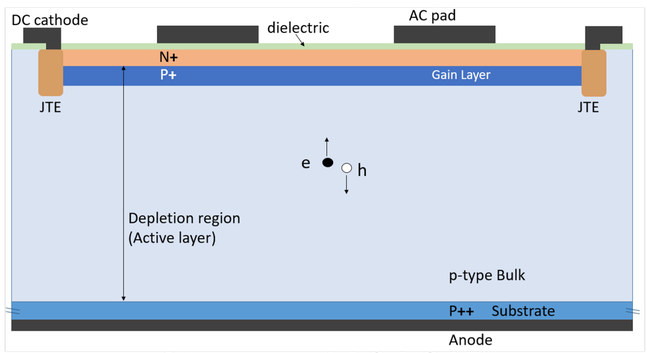
Timing detector base on strip LGAD in Barrel region



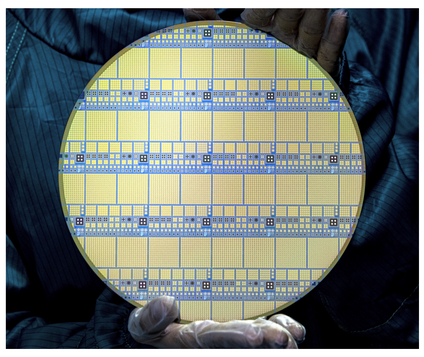


AC-LGAD (AC-coupled LGAD)

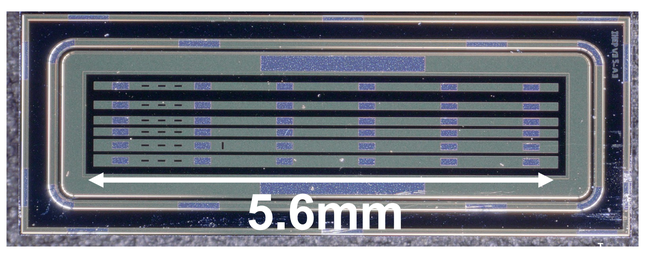
Continuous gain layer



Structure of AC-LGAD



IHEP-IME LGAD wafer



Strip AC-LGAD

Testing Results

The left figure shows the relationship between the laser intensity used for testing and the distance. The laser spot diameter is approximately 3 micrometers. The right image shows the signal waveforms read from four channels when the laser hits on the sensor surface. It can be observed that the signal peak values differ due to the varying distances between the laser incidence point and the strips.

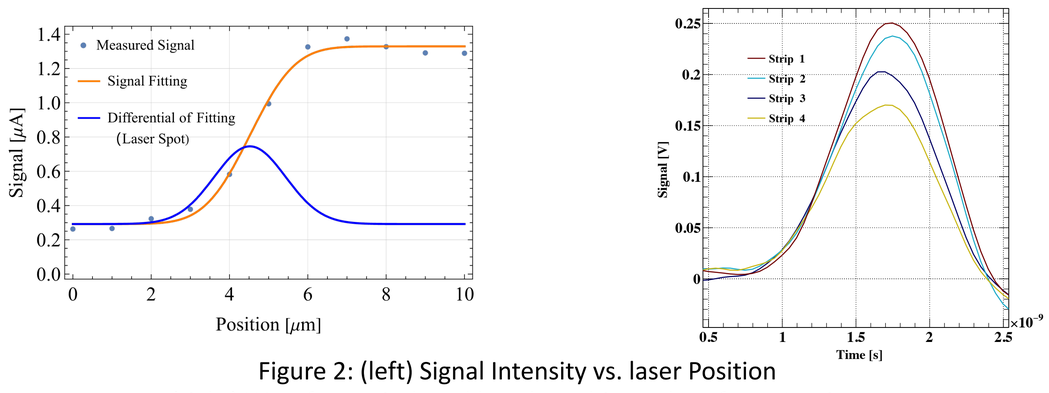
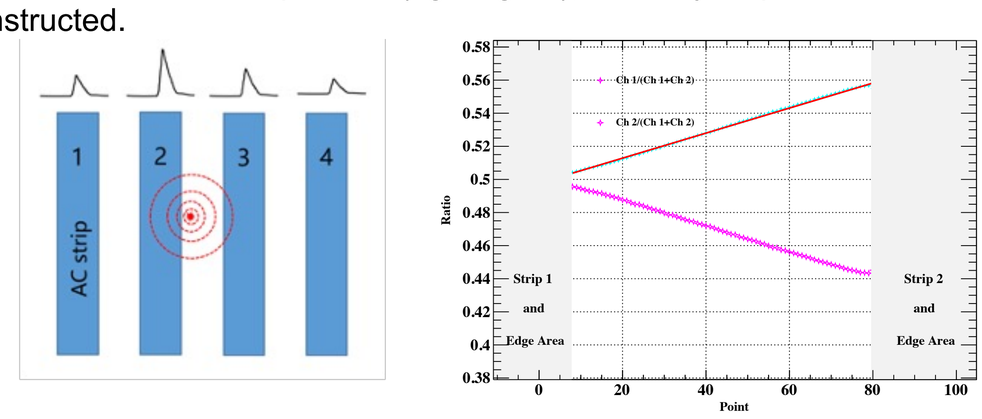


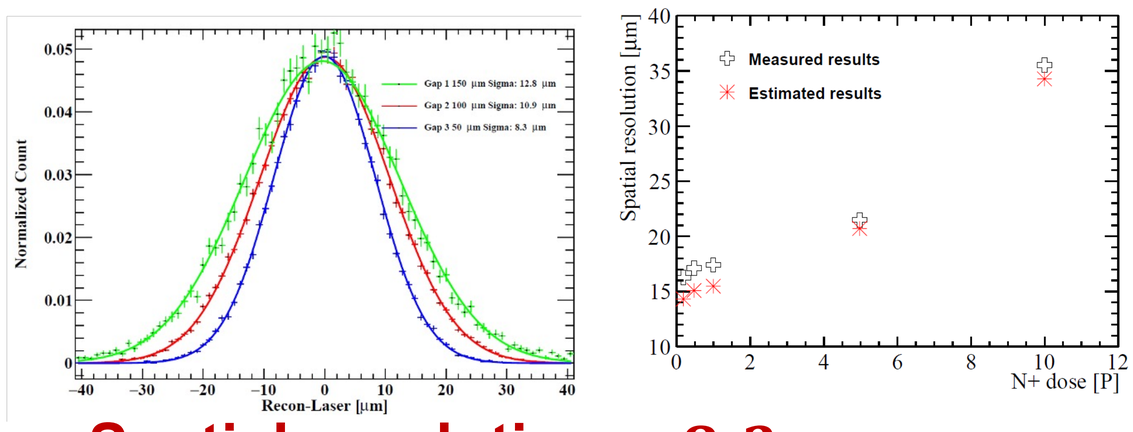
Figure 2: (left) Signal Intensity vs. laser Position
(right) Waveforms induced by a laser hit readout from 4 strips.

The method for position reconstruction is based on amplitude difference (left figure). Distribution of fraction of amplitude $\frac{Amp_2}{Amp_1+Amp_2}$ of adjacent strips has linear distribution based on the position (right figure), whereby hit position can be reconstructed.



Fugure 3: (Left) : Amplitude difference due to propagate distance.
(Right): Distribution of $\frac{Amp_2}{Amp_1+Amp_2}$ with position, showing a good linear relationship.

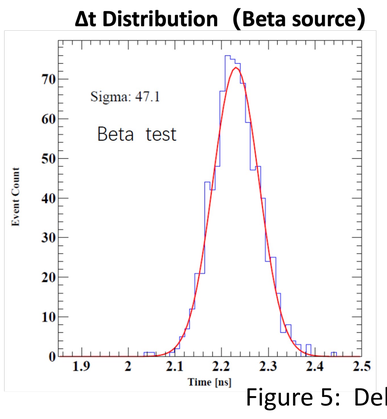
The spatial resolution of the strip AC-LGAD were tested by the Laser. The spatial resolutions of strip AC-LGADs with different pitches (150 μm, 200 μm and 250 μm) are 8.3 μm, 10.9 μm and 12.8 μm



Spatial resolution： 8.3 μm with 150 μm pitch

Figure 4: (Left) Distribution of the difference between the reconstructed position and the true position under different pitches.
(Right): Relationship between spatial resolution and gain layer concentration.

The time performance of the strip AC-LGAD were tested by the Beta source. The delta t was the difference between the arrival time of the trigger and the AC-LGAD. The sigma of the delta t distribution is combination of the time resolution of trigger and AC-LGAD. Thus according to the formula, the time resolution of **the whole AC-LGAD** is 37.5 ps.



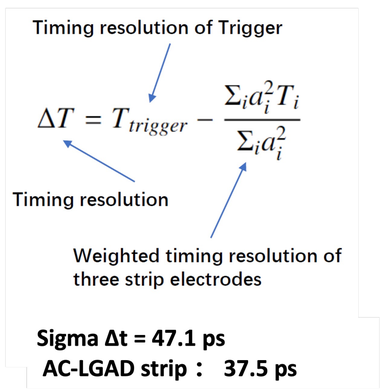


Figure 5: Delta t distribution of AC-LGAD at the Beta test

Time resolution: 37.5 ps

Summary:

AC-LGAD based Timing and out tracker detector for the CEPC is important for the flavor physics of CEPC. ToF & out tracker detector is complementary for the gas detector and help improving the k/pi,k/p separation at low energy part. It also would provide additional spatial resolution for the track due to the application of the AC-LGAD sensor technology. The total area would be about 90 m^2. The readout channels would be about 10^7. The time resolution and spatial resolution is **30-50 ps** and 10 μm (R-phi direction). In the future, the large area and very long strip AC-LGAD would be designed and produced which is very challenging.

References:

[1] CEPC Conceptual Design Report: Volume 2 - Physics & Detector
[2] Mei Zhao, et al. Low Gain Avalanche Detectors with good time resolution developed by IHEP and IME for ATLAS HGTD project.
[3] Mengzhao Li, et al. The Performance of Large-Pitch AC-LGAD With Different N+ Dose.
[4] Weiyi Sun, et al. The performance of AC-coupled Strip LGAD developed by IHEP.
[5] Weiyi Sun, et al. Development of the strip LGAD detector with double-end readout for future colliders