Time of Flight Detector for circular electron positron collider

The Circular Electron Positron Collider (CEPC) is a large international scientific facility proposed [1,2] to probe the Standard Model (SM) and potentially uncover new physics beyond the SM (BSM). The CEPC program spans a wide range of center-of-mass energies and beams luminosities to achieve the highest yields of Higgs, W, and Z bosons produced in the exceptionally clean environment of an e^+e^- collider. The vast amount of bottom quarks, charm quarks, and τ-leptons produced in the decays of the Z bosons also makes the CEPC an effective B-factory and τ-charm factory. Hence, the CEPC offers an unmatched opportunity for precision measurements for flavor physics.

The identification of K/π is essential for the CEPC flavor physics program. In the CEPC full-silicon detector concept, a silicon-based time-of-flight detector is required for particle identification. The time of flight detector is expected to install between silicon tracker and calorimetry (r = 1.5 -1.8 m). CEPC Timing detector needs to perform K/π separation with 2 σ significance for particles with $p < 10$ GeV. This drives the need for a high-precision timing detector with a low material budget and moderate spatial resolution. The detailed requirements of the CEPC time of flight detector is listed below.

Excellent Time Resolution About 10 ps per track
Moderate Spatial Resolution < 10 - 20 μm
Fluence $> 1\times10^{12}$ $\mathrm{n_{eq}/cm^2}$
The total ionizing dose (TID) > 1 MRad
Material budget $< 0.5\%$ $\mathrm{X_0}$

Questions

The Snowmass 2021 provides a great opportunity for international collaborations on silicon-based timing detector R&D for the future electron-positron collider. This letter outlines several major ongoing research tasks on the CEPC timing detector, as listed below:

Physics Requirements Quantify the timing detector performance requirement towards the CEPC flavor physics program via benchmark physics measurements and analyses.

Fast Silicon Sensors Ultra-fast silicon sensor based on Low Gain Avalanche Diodes (LGAD) technology is suitable for the CEPC timing detector. LGAD sensors have been developed for ATLAS and CMS timing detector project and have been demonstrated that its timing resolution can reach 20-30 ps [3–5]. However, more R&Ds are needed to be performed in order to make it applicable to future electron-positron colliders.

- R&Ds are needed for LGAD sensors to improve its timing resolution further. The option of reducing the active thickness to $20\mu m$ - $30\mu m$ for suppressing Landau fluctuations is under study.
- R&Ds of Resistive silicon detectors (RSDs), also known as AC-coupled LGADs (AC-LGADs) [6, 7], has been considered to improve its spatial resolution. AC-LGADs are LGAD-based devices with an unsegmented gain layer, which has the potential to reach 100% fill factor. Although AC-LGADs has been demonstrated the good potential to reach high spatial and timing resolution in small sensor prototype, a careful study on the irradiation of large scale AC-LGADs sensors are needed.

Fast readout ASIC Fast readout ASICs with a few ps resolutions have been developed for ATLAS and CMS timing detector project [3, 4]. R&Ds are still needed to develop ASIC, which can operate together with AC-LGADs, especially the ASICs needed to be optimized for charge sharing calculation to reach good spatial and time resolutions.

Contacts

The contact people from the CEPC timing detector studies to the Snowmass 2021 study groups are as follows:

Vertex Detector Zhijun Liang (IHEP,CAS), Xin Shi (IHEP,CAS), João Guimarães da Costa (IHEP,CAS)

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