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R&D Developments in Cherenkov Imaging Technologies for Particle Identification Systems in Future Experiments

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Cherenkov light imaging is expected to play a critical role in charged particle identification across a wide kinematic phase space in many upcoming particle and nuclear physics experiments worldwide, in particular in the filed of hadronic physics, flavor physics and for electron-positron colliders.

Extensive R&D efforts are underway on multiple fronts of Cherenkov imaging technology, including the optimization of radiator material selection, advancements in photon sensor technologies, the development of fast and reliable readout electronics, and system-level integration. The synergies between novel ideas emerging from future experimental needs and the knowledge gained from operating Cherenkov detectors, together with a broad spectrum of R&D contributions from various collaborations, are shaping the next generation of Cherenkov imaging systems.

Experiments at the Large Hadron Collider (LHC) and the Electron-Ion Collider (EIC) are among the major contributors to these R&D activities. These efforts are driven by the need to meet increasingly demanding physics requirements, which call for both innovative technological solutions and the refinement of established designs. The challenging experimental conditions play a critical role in detector design; factors such as strong magnetic fields, high radiation levels, and limited available space are key considerations.

In order to maintain the precision of Cherenkov emission angle measurements, R&D studies are focused on developing radiator materials with improved optical quality, and, most importantly, photon sensors with high photon detection efficiency and fine granularity. To effectively suppress background, accurate measurement of the Time-of-Arrival (ToA) of the detected photons is essential, which in turn requires a large number of detected photons to ensure statistical precision.

As a result, in recent years, particular attention has been directed toward sensor technologies that enable the combination of Cherenkov photon timing information with high quantum efficiency, high gain, high rate capability, and fine spatial granularity. Photon detectors capable of achieving time resolutions below 100 picoseconds for single-photon detection have therefore emerged as a focal point in detector development. These technologies hold the potential to significantly enhance the performance of particle identification systems in the challenging environments anticipated in future high-energy physics experiments.

Moreover, these fast photon sensors open the possibility of using them as Time-of-Flight (TOF) detectors by exploiting the timing properties of Cherenkov photons generated by particles passing through the detector window.

In this talk, I will present an overview of the current R&D landscape dedicated to Cherenkov imaging detectors, with a focus on the efforts from various experimental collaborations aiming to implement this technology in coming and future experimental efforts. Special emphasis will be placed on recent developments in photon sensor technologies, which are central to meeting the performance goals of the upcoming experiments.

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