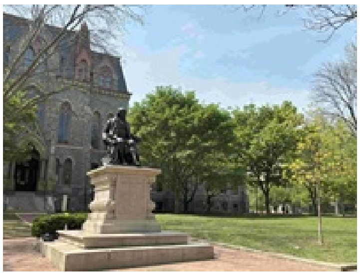

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Novel High-Performance Single-Photon Detectors for Next Generation HEP Applications

Wednesday 8 October 2025 16:50 (20 minutes)

High energy physics (HEP) experiments require high-performance detectors to advance the energy, luminosity, and cosmology frontiers. Photomultiplier tubes (PMTs) have been extensively used to detect scintillation light. In recent years, silicon photomultipliers (SiPMs), an array of single photon avalanche diodes (SPADs), have become preferable as a solid-state alternative to PMTs due to their invulnerability to magnetic fields, compactness, low operating voltage, robustness, and lower cost. Furthermore, SiPMs implemented in a standard CMOS process, as opposed to a dedicated optical process, allow the optical sensor to be coupled on the same chip with the readout electronics. This results in a compact, low-cost, and low-bias voltage SiPM detector. However, SiPMs tend to rapidly degrade in high irradiation environments, making them unsuitable for some collider experiments, particularly given the trend towards higher luminosities and therefore higher irradiation levels. One of the major challenges of SiPM in such high-radiation environments is their noise performance. In addition, CMOS detectors have been developed for precision position (ps time resolution) measurements in HEP due to their compactness and spatial granularity. The goal is to develop a new class of SiPM detectors that provides an order-of-magnitude improvement in key performance metrics, namely timing resolution and noise. High energy physics (HEP) experiments require high-performance detectors to advance the energy, luminosity, and cosmology frontiers. Photomultiplier tubes (PMTs) have been extensively used to detect scintillation light. In recent years, silicon photomultipliers (SiPMs), an array of single photon avalanche diodes (SPADs), have become preferable as a solid-state alternative to PMTs due to their invulnerability to magnetic fields, compactness, low operating voltage, robustness, and lower cost. Furthermore, SiPMs implemented in a standard CMOS process, as opposed to a dedicated optical process, allow the optical sensor to be coupled on the same chip with the readout electronics. This results in a compact, low-cost, and low-bias voltage SiPM detector. However, SiPMs tend to rapidly degrade in high irradiation environments, making them unsuitable for some collider experiments, particularly given the trend towards higher luminosities and therefore higher irradiation levels. One of the major challenges of SiPM in such high-radiation environments is their noise performance. In addition, CMOS detectors have been developed for precision position (ps time resolution) measurements in HEP due to their compactness and spatial granularity. The goal is to develop a new class of SiPM detectors that provides an order-of-magnitude improvement in key performance metrics, namely timing resolution and noise. This idea involves integrating field-modulating gates into SPADs within commercial CMOS processes to create perimeter-gated SPADs. Preliminary work has shown that the field modulating gate reduces the noise (dark count) of regular SPADs and SPAD-based SiPM detectors. To improve the timing resolution, we will design new front-end readout circuits at the pixel level.

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