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Development and performance of the dRICH SiPM-based photodetector for the ePIC experiment at the EIC

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The dual-radiator RICH (dRICH) detector of the ePIC experiment at the Electron-Ion Collider (EIC) will employ Silicon Photomultipliers (SiPMs) for single-photon Cherenkov light detection. Covering an area of ~ 3 m^2 with 3×3 mm^2 pixels and more than 300,000 readout channels, this will be the first collider experiment to utilize SiPMs at such a scale for single-photon applications in high-energy physics. SiPMs are chosen for their cost-effectiveness, high photon detection efficiency, and robust performance in magnetic fields (~ 1 T at the detector location). The dRICH will provide crucial particle identification over a broad momentum range ($1-50$ GeV/c) in the hadronic endcap region.

Despite their advantages, SiPMs are not radiation-hard, requiring comprehensive R&D efforts to ensure the preservation of their single-photon counting capabilities and control of dark count rates (DCR) over the experiment's lifetime. Strategies to mitigate performance degradation include operating the sensors at low temperatures, exploiting precise timing with fast time-to-digital conversion (TDC) electronics, and recovering radiation damage through high-temperature annealing cycles.

In this talk, we present an overview of the ePIC-dRICH photodetector system with highlights from the R&D performed for the operation of the SiPM optical readout in the ePIC experiment, where a large number of SiPMs were tested for usability in single-photon applications in a moderate radiation environment. Irradiated SiPMs underwent various annealing procedures to test their recovery capability from radiation damage. Particular attention was given to an annealing procedure exploiting the Joule effect, where high temperatures were achieved via self-heating of the sensor.

We will present recent beam test results of a large-area, 2048-channel detector prototype that was successfully tested with particle beams at CERN-PS in October 2023 and May 2024. The photodetector surface is modular and consists of novel photodetection units (PDUs) developed by INFN, each comprising 256 SiPM sensors, cooling infrastructure, and TDC electronics within a compact volume. The results demonstrate promising performance for the first SiPM-based Cherenkov detector in a frontier QCD experiment, paving the way for its operation at the EIC.

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