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Studies of radiation damage and mitigation strategies for the SiPM of the ePIC-dRICH detector at the EIC

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The dual-radiator (dRICH) detector of the ePIC experiment at the future Electron-Ion Collider (EIC) will make use of a large array of silicon photomultipliers (SiPM) sensors for the detection of the emitted Cherenkov light. The photodetector surface will cover ~ 3 m2 with 3x3 mm2 pixels, for a total of more than 300 k readout channels. SiPM is the emerging solid-state technology for photon detection and the application of SiPM for RICH at the EIC will be the first use of SiPM for single-photon detection in a HEP experiment. SiPMs show significant advantages when compared to vacuum-based photodetector technologies, owing to their high photon detection efficiency also in high-magnetic field environments. This is a top asset for the ePIC experiment at the EIC, where the magnetic field at the location of the dRICH photodetector surface is high (~ 1 T). It is on the other hand known that SiPMs are sensitive to radiation damage and require rigorous testing to ensure that their single-photon counting capabilities and dark count rates (DCR) are kept under control over the years of running of the ePIC experiment. The DCR can be maintained to an acceptable rate, below ~ 100 kHz/mm2 as required for this application, by reducing the SiPM operating temperature and by recovering the radiation damage with high-temperature annealing cycles. Moreover, the background from the sensor DCR can be reduced by using the excellent SiPM timing capabilities coupling it with high-precision fast TDC electronics.

In this talk we present an overview of the current status of the R&D and the results of studies performed on significant samples of commercial and prototype SiPM sensors. The devices have undergone proton and neutron irradiations aimed at studying the device performance with increasing non-ionising energy loss (NIEL) doses up to 1011 1-MeV neq/cm2, the device recovery with long high-temperature annealing cycles and the reproducibility of the performance in repeated irradiation-annealing cycles. We studied the use of the self-heating capabilities of the SiPM to exploit the Joule effect as a potential effective way to perform the high-temperature annealing "in-situ". We also report on the results obtained from two beam tests performed in October 2022 and in October 2023, where the SiPM sensors were mounted on the optical plane of the dRICH detector prototype and successfully recorded Cherenkov photon rings at the CERN PS accelerator. The data have been collected with a complete chain of front-end and readout electronics based on the first 32-channel prototypes of the ALCOR chip, a newly designed ASIC for SiPM readout.

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