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A readout system based on SiPM for the dRICH detector at the EIC

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The ePIC experiment at the future Electron-Ion Collider aims to use silicon photomultipliers as the photodetector technology for the dual-radiator ring-imaging Cherenkov detector (d-RICH). Despite their advantages for this low light application in high magnetic fields, SiPMs are sensitive to radiation and require rigorous testing to ensure that their single-photon counting capabilities and dark count rate are kept under control over the years. The presented results show the successful use of a complete prototype readout chain based on the ALCOR chip for SiPM characterization measurements and test-beam measurements using the d-RICH prototype.

Summary (500 words)

Silicon Photomultipliers (SiPMs) are the main candidates for instrumenting the optical readout of the dual-radiator ring-imaging Cherenkov detector (d-RICH) for the particle identification of the ePIC experiment at the Brookhaven National Laboratory. In this talk we will present a full detector prototype made by coupling several vendors SiPMs with an ASIC based readout. The 32 channels ASIC, called ALCOR developed by INFN Torino, includes a regulated common-gate transimpedance amplifier frontend and 4 TDCs per channel allowing both single-photon counting and Time-over-Threshold modes, with a time resolution of 50 ps and an event rate capability of up to 5 MHz per channel. It works in a triggerless configuration, meaning that the ASIC produces a continuous stream of data that is then acquired by the data acquisition with a maximum rate of 300 kHz per channel for 300 thousands channels in the configuration of the final detector.
SiPMs represent the best solution in this low light application thanks to the high photodetection efficiency and insensitivity to magnetic fields (1 T for the d-RICH in ePIC). However, the detector will be placed in a radioactive environment with an expected dose for the entire life of the experiment of 10^{11} 1-MeV neq/cm². Radiation damages, for the expected dose, result in an increase of the dark current, reflected by an increase in the Dark Count Rate (DCR) of a factor 10000. This affects the single-photon counting capability due to pileup and readout saturation. To reduce the DCR, sensors are cooled to -30° C, which lowers it by a factor of ≈20 with respect to room temperature. The behaviour of ≈200 irradiated sensors was studied by exposing 3 x 3 mm² SiPMs from different vendors and cell sizes to increasing doses of radiation. The Hamamatsu S13650-50 SiPM was found to have the lowest brand new and after irradiation DCR, but it still reaches ≈10 MHz at 10^{11} 1-MeV neq/cm² at -30° C, which is beyond the capacity of the front-end ASIC and DAQ data rate. One can find in literature that by heating up the sensors it's possible to induce an annealing of the radiation induced defects leading to a reduction of the DCR. Thus, we studied two annealing methods to partially recover the DCR performance: an oven annealing at 150° C and direct/reverse current annealing at 175° C. Both the methods lead to DCR reduction of a factor 100, with the oven reaching it after 200 hours while the current annealing takes 1/10 of the time. A clear advantage of the latter is in the possibility to perform in-situ annealing without dismantling the detector.
Four sensor matrices irradiated up to 10^{10} neq/cm² that underwent the oven annealing were integrated in the d-RICH prototype and tested at CERN PS. The detector can acquire Cherenkov rings within a 10 ns time window reaching a time resolution of 350 ps. After showing the results of this test beam, the new design of the prototype towards the implementation of the final detector integration will be shown.

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