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Performance degradation of SiPM sensors under various irradiation fields and recovery via high-temperature annealing

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Silicon Photomultipliers (SiPMs) are widespread photon detectors in high-energy physics. Their performance degrades significantly when exposed to radiation, particularly high-energy hadrons (neutrons or protons) that induce defects in the silicon lattice. A moderate level of radiation causes damage in SiPMs, leading to an increase in dark current and dark count rate (DCR) and potentially affecting the single-photon detection capability due to pile-up and limitations in the readout electronics. At very high doses, radiation damage can also modify operational parameters (breakdown voltage, gain) and decrease photon detection efficiency (PDE). Nevertheless, several studies show that high-temperature annealing can significantly accelerate the recovery of radiation-induced defects, thereby lowering dark current and DCR.
In this talk, we report on the studies performed in the context of the R&D for the dual-radiator RICH (dRICH) detector at the future Electron-Ion Collider (EIC), where a large number of SiPMs were tested for usability in single-photon applications in a moderate radiation environment. Proton irradiation was performed at the Trento Proton Therapy Centre, delivering integrated fluences up to 1011 1-MeV neq/cm2 to the SiPMs and studying different proton energies from 18 to 138 MeV. Neutron irradiation was conducted at the CN accelerator of the INFN Legnaro National Laboratories at integrated fluences up to 1010 1-MeV neq/cm2. Gamma irradiation was performed at the CERN GIF++ facility up to 1 krad. All sensors were characterised before and after irradiation, with special focus on their low-temperature performance at -30 ℃. 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. Repeated irradiation and annealing cycles were performed to simulate a realistic experimental scenario and to assess the robustness of the sensors against such procedures.
A summary of the studies and the main results will be presented in this talk.

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