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Radiation hardness and annealing study of neutron-irradiated silicon photomultipliers

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Silicon photomultipliers (SiPMs) are semiconductor photodetectors increasingly used in high-energy physics experiments. In the planned upgrade of the Large Hadron Collider beauty (LHCb) experiment, they are considered to be used to detect Cherenkov photons in the Ring Imaging Cherenkov (RICH) detectors. In this application, the biggest drawback of current SiPMs is their susceptibility to radiation damage, where the dark count rate (DCR), typically on the order of 10^5 Hz/mm² at room temperature, significantly increases proportionally with the irradiation fluence, which hindered the single photon detection beyond 10^9 neq/cm². In this contribution, 3 x 3 mm² SiPMs of different cell sizes and producers, Hamamatsu (50 µm), Ketek (25 µm and 50 µm), Broadcom (50 µm), AdvanSiD (40 µm), and SensL (35 µm) as well as 1 x 1 mm² SiPMs from SensL (35 µm) and FBK (15 µm), were characterized. The SiPMs were irradiated at the Jožef Stefan Institute TRIGA nuclear reactor with fluences from 10^9 neq/cm² up to 10^{13} neq/cm². The main objective was to determine the temperature at which irradiated SiPMs can still be useful in future RICH detectors. Besides, it was explored how the high-temperature annealing can improve the SiPM performance post-irradiation. For the SiPM characterization in all the cases, current-voltage (I-V curve) measurements, DCR measurements, and waveform analysis, including single photon time resolution (SPTR), were carried out at different controlled temperature steps from room temperature down to the liquid nitrogen temperature.

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