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Radiation-damage-effects and mitigation strategies in Silicon Photomultipliers

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Silicon Photomultipliers (SiPMs) are single-photon sensitive detectors that continue to attract increasing interest in several industrial and scientific applications that require fast detection speed, high sensitivity, compactness, insensitivity to magnetic fields and low bias voltages.
SiPMs are also replacing photomultiplier tubes (PMTs), hybrid photodiodes (HPDs), or other in high-energy physics (HEP) experiments, and for the readout of scintillators in gamma-ray detectors for space. In such applications they receive a significant dose of particles (e.g. protons and neutrons) and X and gamma rays.
While the effects of radiation in silicon detectors are well-studied [6], the literature is not as much concerning Avalanche Photodiodes (APDs) and photon-counting detector, working in Geiger-mode (like SPADs and SiPMs). Indeed, there has been recently an increasing interest in assessing such effects on both SPAD-arrays and SiPMs for HEP and space-experiments.
During the last years, at FBK (Trento, Italy) we have been developing many different technologies for SiPMs and SPADs, optimized for different applications. Such technologies are based on different silicon starting-materials (with different doping species), made with different internal structures and cell pitch (i.e. SPAD pitch).
Given the big interest in SiPM for harsh radiation environment application, we irradiated many different SiPM technologies with protons and with X-rays, to directly study and compare the effects of radiation damage in terms of Ionizing Energy Loss (IEL) and Non-Ionizing Energy Loss (NIEL). Based on the main findings on previous irradiation campaigns, we studied, developed and tested with irradiation, new SiPM structures with active trench bias and charge-draining, which demonstrated to be more radiation tolerant to ionizing-radiation effects. The structure of these new SiPM structures and the performance under irradiation will be described in detail in this contribution.

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