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FBK SiPM roadmap for ultimate timing performance

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Optimization of the timing resolution in the scintillation light readout has been one of the most important challenges in the SiPM field since the beginning of their development. Several sensor parameters contribute to the timing performance achieved in the application. The latest iteration of the NUV-HD SiPM technology developed at FBK feature Photon Detection Efficiency (PDE) in excess of 60% at 410 nm, Dark Count Rate around 60 kHz/mm² and Single-photon Time resolution (SPTR) of 90 ps FWHM for a 4x4 mm2 device with 40 μm cells, when coupled to a discrete, high-frequency readout. Thanks to these parameters, it was possible to measure an excellent Coincidence Resolving Time (CRT) of 58 ps FWHM in the readout of a 2x2x3 mm³ LSO:Ce:Ca coupled to a 4x4 mm² SiPM with 40 μm cells (98 ps FWHM with a 2x2x20 mm³ LSO:Ca:Ce). Ongoing developments include the use of metal-filled deep trench isolation, which allows reducing the optical crosstalk probability to 10% with a PDE of 60% (bare die). On the other hand, photon-starved applications, such as BGO readout with the timing resolution enhanced by the detection of Cherenkov photons, further underline the importance of improving the SPTR of the SiPMs. In the current generation of devices, this parameter is heavily affected by both the output capacitance of the sensor and by the characteristics of the front-end electronics reading it. Considering that incremental improvements between subsequent generations of SiPMs are reaching saturation, a deeper redesign of the device structure is needed. In this context, FBK is working on the development of the next-generation of SiPMs, with a strong focus on 3D integration, such as SiPMs featuring fine-pitch Through Silicon Vias and Backside-illuminated (BSI) devices. A fine segmentation of the sensitive area in separated mini-SiPMs, each one connected to a dedicated readout channel through a low-impedance interconnection, will reduce output capacitance and optimize signal integrity. BSI-SiPMs will potentially bring additional advantages, such as reaching a PDE close to 100%, reduced output capacitance, enhanced radiation hardness, single-cell connection to the readout electronics and a uniform light entrance window, suitable for the most advanced optical stacks. In the presentation, FBK roadmap towards 3D integrated SiPMs and the preliminary result obtained so far will be discussed.

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