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Timing properties measurements of STMicroelectronics Silicon Photomultipliers for time-of-flight PET scanners

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Positron Emission Tomography (PET) is a medical imaging technique able to observe functional processes in vivo. It is based on the simultaneous back-to-back emission of the two 511 keV photons following positron annihilation by a chemical tracer doped with appropriate radioisotopes. The possibility to use high timing resolution detectors allows to localize the emission source with higher precision along the line defined by the two gammas. This technique, usually known as time-of-flight (TOF) PET requires photo-sensors with an optimal time resolution. Silicon photomultipliers (SiPM) are potentially promising devices for such applications, due to their small size and insensitivity to magnetic fields. Several progresses have been made in recent years to improve also their timing properties, which is the main point of concern.
This contribution describes the setup and preliminary results obtained during a study of the energy resolution and timing properties of recent SiPM devices produced by STMicroelectronics. A study of the dependence of energy and timing resolution in PET-like applications on different SiPM's layout parameters (total area, number of microcells, geometrical fill factor) is under way. The SiPM structures investigated in this work are fabricated on silicon epitaxial p-type wafers and formed from planar N+-P microcells. The quenching resistor, made from low-doped polysilicon, is integrated inside the cell. Thin optical trenches filled with oxide and metal surround the microcell active area in order to reduce electro-optical coupling effects (crosstalk) between contiguous pixels. A suitable double-layer antireflective coating is deposited on the surface of the device to enhance its spectral response in the blue and near ultraviolet wavelength ranges.
In order to measure the time resolution of individual SiPM's with the two 511 keV photons detected in two LYSO crystals, a dedicated setup was designed and built in our lab, to allow for an easy handling of the different devices under test. All the setup is enclosed in a dark box to shield from ambient light.
Preliminary measurements were carried out by means of standard NIM and CAMAC electronics. Signals from the detectors are sent, either directly or through low-gain fast amplifiers, to Constant Fraction Discriminators (CFD) to provide start and stop signals to a CAMAC TDC. Amplitude information was collected as well, employing two CAMAC QDCs, for off-line data processing. Binary files collected during the measurements are further processed and analyzed by the ROOT data analysis package to carry out multidimensional data analysis. To characterize the SiPM response in a wide energy range, measure their energy resolution and study non-linearity effects, different gamma sources (22Na, 137Cs, 54Mn, 65Zn) were employed.
To characterize the timing response of such devices, coincidence measurements are better carried out by means of a high performance digital oscilloscope. In our case a Tektronix DPO7254 2.5 GHz, 20 Gs/s per channel was used, allowing to sample the signals of the two SIPMs with 50 ps steps. Various algorithms for a digital processing of the signals are being tested, in order to optimize the time resolution. The value of the unfolded time resolution was extracted by a set of measurements performed at different bias voltages by a proper selection of the photoelectric peaks in the amplitude spectra. Further developments are in progress and will be reported during the Conference.

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