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Introduction to 3D Digital SiPM and Latest Results for Particle Physics

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Conventional analog SiPMs are increasingly used in medical imaging such as positron emission tomography (PET) and are good candidates for particle physics detectors such as nEXO and DarkSide. A new generation of photon counting device called 3D digital SiPM (3DdSiPM) addresses the main limitations of conventional SiPM and offers even more flexibility and signal processing capability. The concept is to integrate in the vertical axis an array of single photon avalanche diodes (SPAD) stacked over an array of microelectronics readout channels and digital signal processing. At Université de Sherbrooke, we are working on the SPAD implementation, the 3D bonding process and two flavours of CMOS microelectronic readouts. The first flavour is geared toward very low power consumption. It is dedicated to large-scale detectors for double beta decays neutrinos less and dark matter studies where the 3DdSiPMs are operated directly in liquid xenon or liquid argon. The second version of the readout is designed for extremely low single photon timing resolution, with the goal to reach sub 10 ps FWHM. This 3DdSiPM is of interest for PET using prompt photon emission or liquid xenon as scintillator. It is also relevant to study scintillation mechanisms and prompt photon emission processes of various materials. Moreover, we have recently started a new project for quantum key distribution between ground and satellite. The measured timing jitter of this readout integrated circuit is 18 ps RMS. The SPAD array measurement shows 50% photo detection efficiency at 450 nm. Also, we are working at enhancing their VUV sensitivity above 25% at 175 nm (LXe) and to allow direct detection of LAr scintillation light. The SPAD also exhibits a single photon timing resolution of 23 ps FWHM. At the conference, an overview of the systems and measured performances from the SPAD to the CMOS readout will be presented and discussed.

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