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Overview of 3D Integrated Photon-to-Digital Converters for Particle Physics and Medical Imaging

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The advent of Silicon Photomultipliers (SiPMs) has significantly enhanced radiation detection instrumentation, gradually replacing Photomultiplier Tubes (PMTs) in various applications. SiPMs have notably improved performance in timing-critical applications. However, their typical analog readouts face limitations, such as high power consumption, and challenges in signal integrity associated with digitization.

Our group proposes to leverage the Boolean nature of Single-Photon Avalanche Diodes (SPADs) in SiPMs to maintain the readout entirely in the digital domain, hence the term Photon-to-Digital Converter (PDC). This approach enhances the timing resolution of SPAD arrays by individually digitizing their output and actively quenching them. The SPADS can therefore be configured with different hold-off and recharge times to optimize detector performances.

PDCs are 3D integrated devices featuring a dedicated SPAD layer atop a CMOS readout ASIC, maximizing both photosensitive area and signal processing capabilities. We are collaborating with Teledyne Dalsa, an industry leader in MEMS and CCD fabrication, and using TSMC for CMOS wafers. By using major industry leaders we secure the path from conceptual to production-ready state-of-the-art PDCs, a critical aspect for next-generation experiments requiring large-area photon detection systems. An overview of the fabrication process will be presented at the conference.

We seek collaborators willing to learn to use our technology, with our support, in various contexts and applications. We wish to find early adopters with whom we can interact to maximize physics outcomes and get feedback on the technology and its next developments. We hope to share our ready-to-use comprehensive scalable test platform, enabling broader dissemination of the PDC technology to a broader user base as was seen in the advent of SiPMs 15 years ago.

This contribution will present the architecture and results of our PDCs and compare our 3D integration technology with other work in the literature.

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No

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