Abstract:

Silicon radiation detectors have a wide range of applications in high-energy physics and synchrotron science, where accurate spatial and temporal measurements must be made under extreme radiation environments. The next generation of collider experiments, including the High-Luminosity Large Hadron Collider (HL-LHC) and the Electron–Ion Collider (EIC), demands detector technologies capable of delivering < 50 picosecond timing resolution, high spatial granularity, and long-term radiation tolerance within a single integrated platform.

This thesis focuses on the development of low-gain avalanche detectors (LGADs) for implementation in such environments. Since these efforts are being pursued worldwide, we extended our collaboration with various institutes and semiconductor foundries to contribute collectively to the development and characterization of suitable detectors. The radiation hardness and timing performance of the LGADs with varied detector thicknesses and detector design is investigated. A major contribution of this work addresses the challenge of achieving high granularity and enhanced fill factor in pixelated timing detectors. In this context, trench-isolated LGADs (Ti-LGADs) are developed and studied as a segmentation strategy compatible with TimePix and MediPix readout architectures. The optimization of fill factor for both high- and low-penetrating particles is investigated, balancing electric field uniformity, charge multiplication efficiency, and inter-pixel isolation.

Looking toward future facilities such as the Future Circular Collider (FCC), where radiation levels will exceed those of the HL-LHC, the 3D detectors proved to be a sustainable technology in terms of radiation hardness. Their timing performance is evaluated in this work using a double-sided fabrication process for timing applications, based on different pixel geometries. Overall, this work comprises electrical and laser characterizations, device design and simulations, and the fabrication of various detector configurations, each tailored to address a specific issue in high- and low-energy physics.