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Fast Timing Monolithic Silicon Pixel Sensor for TOF-PET

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Positron emission tomography (PET) is a nuclear medicine method used to observe metabolic processes in the body, by detecting pairs of photons produced by the annihilation of positrons emitted by a β^+ tracer.
The Thin-TOF PET (TT-PET) project aims at the construction of a small-animal PET scanner based on silicon monolithic pixel sensors with 30 ps time resolution for 511 keV photons. The very high time resolution allows the measurement of the time of flight information of the two photons and a significant reduction of the backgrounds. Technology CAD (TCAD) simulation was used to design a guard ring of the pixel sensor and to study the capacitance and weighting field. SiGe heterojunction bipolar transistor technology (SG13S from IHP Microelectronics with $\beta = 900$ and $f_t = 250$ GHz) was chosen to achieve fast integration (< 1 ns), low equivalent noise charge (700 electrons on 1 pF capacitance) and low power consumption ($135\ \mu\mathrm{W/mm^2}$). The scanner will be composed of 16 towers in a ring structure and each tower is composed of 60 detection modules, which are formed by a lead foil ($50\ \mu$m thick) for photon conversion, a flex circuit ($50\ \mu$m) for signal transmission and a silicon pixel sensor ($100\ \mu$m). This novel structure allows to measure the photon depth of interaction, improving the spatial resolution across the whole view of the scanner. A GEANT4 Monte Carlo simulation was implemented to extract the expected performance of the scanner.

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