Chasing time

Impact paragraph

In the current age of high energy physics, silicon tracking detectors have become a central component of many high energy physics experiments. The drive to improve and develop new detectors, as well as almost all instrumentation used at European Organization for Nuclear Research (CERN), leads to inventions that are applied in a wide range of fields outside of high energy physics. Perhaps the most well-known of these inventions to come from CERN is the world wide web, but other inventions such as Gas Electron Multiplier (GEM) detectors for radiotherapy have also seen dedicated use outside of high energy physics.

By adding temporal information to imaging techniques like Positron Emission Tomography (PET), or improving the time resolution of time-of-flight systems, the quality and accuracy of results from these systems can be substantially enhanced. By performing research and constructing systems to characterize, in the case of this dissertation, hybrid pixel detectors, the temporal performance of such detectors can be improved. The results obtained, and lessons learned from improving the temporal performance of hybrid pixel detectors, can aid significantly in the design of novel detectors. Another benefit is having developed dedicated systems that can test the temporal performance of such devices, enables the possibility to test detectors from outside of high energy physics.

The work presented in this dissertation focuses on the characterisation and development of planar silicon sensors, as well as Timepix3 and Timepix4 readout chips. A new characterisation system is commissioned at Nikhef, which gives researchers a tool to investigate novel silicon sensors with precise time resolution. Besides this, a new beam telescope is constructed and commissioned that allows researchers to test novel sensors, as well as candidate detector systems for the upgrade of the LHCb VErtex LOcator (VELO) in a beam environment. Besides these two systems, the temporal characteristics of planar (thin) silicon sensors have been investigated. The results of planar sensors attached to Timepix3 readout chips have been limited by the time resolution of these readout chips, and therefore can also not be applied in demanding systems in the industry. The result of a thin planar sensor attached to a Timepix4 readout chip, however, is promising, reaching a resolution of 147.4 ± 1.1 ps.

These systems are accessible for researchers within Nikhef and other institutes and collaborations and allow for the development and characterisation of next-generation sensors and ASICs. Ultimately, these developments can lead to the creation of next-generation detector systems that can be applied in for example time-of-flight measurements in mass spectrometry. Besides this, developments in characterisation systems can more easily lead to new systems that can be applied to different kinds of detectors that for example are applied in PET. Therefore, the experience gained by constructing and utilizing these systems can lead to a shortened development time for different detector systems.

To implement these detectors in the next-generation experiments at CERN, a time resolution of 50 ps is required. Therefore, the time resolution achieved with Timepix4 readout chips is not yet sufficient to be directly applied in these experiments. However, efforts are ongoing to improve both the sensor (by applying different geometries) and the readout chip. A lot of effort however still needs to be given in order to achieve the desired resolution of 50 ps in the coming years. This work, however, lays a basis to develop and characterise these sensors in the coming years.