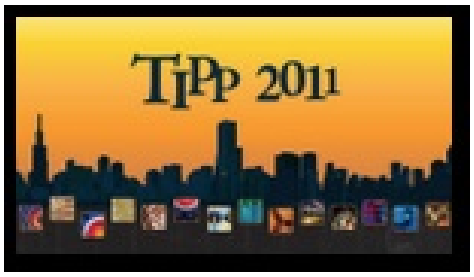

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Radiation-Hard 3D Silicon Detectors for the HL-LHC

The luminosity upgrade of CERN's Large Hadron Collider (LHC) to the High-Luminosity-LHC (HL-LHC) will mean a massive increase in radiation levels, in particular for the tracking detectors close to the interaction point. The development of ultra-radiation hard silicon detectors, capable of withstanding particle fluences in the range of a few 10E16 Neutron-equivalent per cm2, is required for the innermost tracking layers. One promising concept for radiation-hard silicon sensors is the 3D technology, where columnar electrodes are etched deep into the silicon bulk. This technology results in a short charge collection distance, which is desirable to limit the adverse consequences of radiation-induced charge trapping, the dominating radiation damage effect at these high fluences. In addition, the 3D design significantly reduces the depletion voltage compared to planar sensor designs. We have developed 3D sensors together with several manufacturers, and will report on simulation, design and processing of the sensors. A large number of 3D sensors were studied in probe-station, lab and test-beam measurements both before and after irradiation to a range of HL-LHC fluences. These results are completed by simulation studies.
A set of different sensors, in particular 3D strip designs, have been connected to LHC readout electronics, and were then tested with an IR-laser system, with a Sr90-beta-source setup and in a beam of minimum-ionising particles at CERN. The results obtained show that 3D silicon detectors have sufficient radiation hardness for the innermost tracking layers. We also found clear evidence of charge multiplication effects in some irradiated 3D sensors. Based on dynamical simulations, we have very strong indications that the charge multiplication observed originates from avalanche multiplication in the high field regions around the columnar electrodes. The charge multiplication results in a significant increase in the charge collection efficiency. A similar effect has been observed in some planar detector designs, however, the high field occurring in the 3D design means that charge multiplication occurs already at comparatively low bias voltages around 200V, whereas significantly more than 1kV is required for multiplication to start in planar detectors.

In our presentation, we will describe and summarise the results from 3D detector measurements, and discuss the maturity of the 3D technology as well as the feasibility to use 3D sensors as inner tracking detectors in the High-Luminosity Upgrades of LHC experiments.

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Track Classification: Semiconductor Detectors