

Radiation Hard Pixel Development for the LHCb VELO Upgrade

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The upgrade of the LHCb experiment, planned for 2018, will transform the experiment to a trigger-less system reading out the full detector at 40~MHz event rate. All data reduction algorithms will be executed in a high-level software farm with access to the complete event information. This will enable the detector to run at luminosities of $2 \times 10^{33} \text{cm}^{-2} \text{s}^{-1}$ and probe physics beyond the Standard Model in the heavy flavour sector with unprecedented precision.

The Vertex Locator (VELO) is the silicon vertex detector surrounding the interaction region. The current detector will be replaced with a hybrid pixel system equipped with electronics capable of reading out at 40~MHz, designed to withstand the irradiation expected at an integrated luminosity of 50fb^{-1} and beyond. The detector will be composed of silicon pixel sensors with $55 \times 55 \mu\text{m}^2$ pitch, read out by the VeloPix ASIC which is being developed based on the TimePix/MediPix family. The hottest region will have pixel hit rates of 900 Mhits/s yielding a total data rate more than 3 Tbit/s for the upgraded VELO.

The sensors, manufactured by two different vendors and with a variety of guard ring and implant designs, have been irradiated in 5 different facilities, with both neutrons and protons, uniformly and non-uniformly. The performance post irradiation has been measured in testbeam and lab. In addition the radiation hardness of parylene coating has been investigated. The efficiency has been probed in detail within the pixel cell and a comparison made of different implant sizes, showing a difference in efficiency in the pixel corners after irradiation. The charge collection of thin and thick sensors has been compared after the full irradiation. In addition the Timepix3 has been used to investigate the time response of the sensors at a variety of angles, and also to check the regions of increased current after irradiation. The results of this sensor testing campaign, the first time that the small pixel performance after heavy irradiation has been measured, will be presented.

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