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Improving radiation hardness in space-based Charge Coupled Devices through the narrowing of the charge transfer channel

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Charge-Coupled Devices (CCDs) have been the detector of choice for imaging and spectroscopy in space missions for several decades, such as those being used for the Euclid VIS instrument and baselined for the SMILE SXI. Despite the many positive properties of CCDs, such as the high quantum efficiency and low noise, when used in a space environment the detectors suffer damage from the often-harsh radiation environment. High energy particles can create defects in the silicon lattice which act to trap the signal electrons being transferred through the device, reducing the signal measured and effectively increasing the noise.

We can reduce the impact of radiation on the devices through four key methods: increased radiation shielding, device design considerations, optimisation of operating conditions and image correction. Here, we concentrate on device design operations, investigating the impact of narrowing the charge-transfer channel in the device with the aim of minimising the impact of traps during readout.

Previous studies for the Euclid VIS instrument considered two devices, the e2v CCD204 and CCD273, the serial register of the former having a 50um channel and the latter having a 20um channel. The reduction in channel width was previously modelled to give an approximate 1.6x reduction in charge storage volume, verified experimentally to have a reduction in charge transfer inefficiency of 1.7x. The methods used to simulate the reduction approximated the charge cloud to a sharp-edged volume within which the probability of capture by traps was 100%. For high signals and slow readout speeds, this is a reasonable approximation. However, for low signals and higher readout speeds, the approximation falls short.

Here we discuss a new method of simulating and calculating charge storage variations with device design changes, considering the absolute probability of capture across the pixel, bringing validity to all signal sizes and readout speeds. Using this method, we can optimise the device design to suffer minimum impact from radiation damage effects, here using detector development for the SMILE mission to demonstrate the process.

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