1 Single Event Upsets

From test beam data Single Event Upsets (SEU) are expected in the on-detector \textit{p-i-n} diodes that receive the TTC data and in the ABCD ASICs. Extrapolations of the test beam results were used to compare with the measured in-situ results \cite{1}.

1.1 \textit{p-i-n} diodes

While no direct measurements of SEU rates could be performed in-situ, the occurrence of SEUs led to a characteristic signature of synchronization errors \cite{1}. The characteristic signature for a genuine SEU is the occurrence of a burst of events which fails this synchronisation test. The correlation between the measured SEU rate and the cluster occupancy in a module in a given run is shown in fig.\cite{1} The cluster occupancy is a good proxy for particle flux, as the rate of noise hits is negligible.

The measured number of SEUs in a data set corresponding to an integrated luminosity of 8.69 fb\(^{-1}\) was 2504. The value of the SEU cross sections determined from the test beams was used to predict the number of SEUs. The value determined was 1900 which is in reasonable agreement given the uncertainties in the extrapolation \cite{1}.

1.2 ABCD registers

SEUs in the ABCD registers cannot be directly identified during ATLAS operation. However an indirect determination of SEUs in the ABCD register that sets the DAC value for the threshold. The MSB is normally set to ‘1’ and if an SEU causes it to be flipped to a ‘0’ the threshold would become below the baseline. This would then result in a very high occupancy until the register was reset. This allowed the detection of SEU bursts. To demonstrate that these candidates are
genuine SEUs, the rate was measured as a function of fluence. The results are illustrated in fig. 2 and also show the expected linear relationship. The measured number of SEU events in a data set corresponding to 20.3 fb$^{-1}$ was 3046 ± 100. Simple extrapolation of the measured SEU cross sections at test beams gave a prediction of 1000. The discrepancy is probably a reflection of the uncertainties in the extrapolation of the SEU cross sections with energy. Mitigation strategies including regular resets have reduced the data loss due to SEU to a negligible level.

2 Radiation damage in optical links

The radiation damage in the optical links was measured in-situ and compared with extrapolations of test beam data. The radiation induced damage expected at the end of run 3 can be accommodated in the links power budgets.

2.1 VCSELs

The optical power of the on-detector VCSELs was measured in special runs by measuring the photocurrents in the off-detector $p-i-n$ diodes which received the light. The optical power decreased linearly with luminosity. The decrease in optical power was measured in different regions of the SCT that were exposed to different fluences. The results of these measurements are summarised in a plot of the change in VCSEL output versus the fluence (see fig. 4). Assuming that the threshold current and slope efficiency change linearly with fluence the results can be compared to test beam data with and without annealing. As these links have had more annealing time than used in the test beam studies, the plot indicates that the radiation damage is slightly larger than expected.
2.2 \textit{p-i-n} Diodes

The radiation damage in the \textit{p-i-n} diodes was studied in-situ by measuring the photo-currents for the on-detector devices. The decrease in responsivity is not linear and tends asymptotically to a fixed value. The results of these fits are shown for one layer of the barrel in fig. ?? The other regions gave similar results and the weighted mean value for the asymptotic decrease of responsivity was \( R_{\text{eff}} = 0.731 \pm 0.027 \pm 0.046 \), which is in good agreement with the value of 0.71 obtained in test beam measurements.
Figure 4: Plot of the change in VCSEL output versus fluence for the different regions of the SCT.

References


