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TID effects study on the monitoring system of the RD53 chip

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The High-Luminosity LHC upgrade aims to increase the instantaneous luminosity of the LHC machine to a nominal value of $5 \times 10^{34}\ cm^{-2}s^{-1}$. During the Long Shutdown 3 (2026-2028), ATLAS and CMS silicon tracking systems will be entirely replaced and the main design goals include the capability to deal with high hit and data rates, the increase in granularity, and improved radiation tolerance to cope with fluences of up to $2 \times 10^{16}\ n_{eq}/cm^2$ and a Total Ionizing Dose (TID) of up to 1 Grad.

The RD53 collaboration has been working since 2014 on the development of pixel chips for the future CMS and ATLAS upgrades. This work has recently led to the development and submission of the ATLAS RD53 production chip (ITkPixV2) which is using the 65 nm CMOS process and containing 153600 pixels of $50\ \mu m \times 50\ \mu m$.

Several TID test campaigns with Xray sources were already done on the full-size pre-production chip under low temperature (same conditions as for the inner detector) and have shown that the chip continues to work correctly up to 1 Grad. However, these tests have shown that some analog voltage and current values can shift by about 8%. It is therefore important to monitor the different sensitive voltages and currents in the chip in order to measure the variation and possibly adjust them if necessary.

The monitoring system implemented in the RD53 front-end chip is based on a 12-bit ADC associated with a multi-channel multiplexer. It allows the digitization of different sensitive parameters in the chip, particularly the voltages issued from the on-chip temperature sensors required for the off-line temperature calculation. The dependence of the ADC reference voltage (V_{refADC}) on the total ionizing dose results in a high drift of the temperature measured through the ADC, making the measurement unacceptable.

A new temperature measurement approach not dependent on the V_{refADC} shift is proposed. It provides more precise temperature measurement even at high radiation levels. Based on this, a correction method for the V_{refADC} value is foreseen to be applied regularly during the operation of the pixel detector to increase the accuracy for the digitization of voltages or currents in the RD53 chip.

The purpose of this presentation is to give a general overview of the RD53 chip architecture, in particular the monitoring system implemented inside the chip. Next, the TID test results for the monitoring bloc are presented to show that the shift of the V_{refADC} due to the TID has the most significant impact on the measurement accuracy and results in an unacceptable loss of accuracy for temperature measurement. Afterwards, the new temperature measurement approach that does not use the V_{refADC} value is presented to show that better accuracy can be achieved. Finally, the method to be followed to ensure more accurate voltages and currents monitoring despite dose effects on the ADC reference voltage is shown and discussed.

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