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Irradiation of VFAT3: A 128-channel charge-sensitive front-end chip for the CMS GEM phase-2 upgrade

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VFAT3 is the 128-channel charge-sensitive front-end chip explicitly designed for the CMS GEM phase-2 upgrades. LHC is undergoing major upgrades for HL-LHC where the particle rate is expected to increase up to 5 times. It is therefore necessary to monitor the evolution of the VFAT3 response due to aging in the radiation environment by total ionizing dose (TID) tests. The device operation could also be interrupted by a single high-energy particle. Thus, the estimation of the single event upset (SEU) cross-section is essential as well. We summarize irradiation test results that validate the suitability of VFAT3 for CMS GEM upgrades.

Summary (500 words)

The VFAT3 is a 128-channel charge readout ASIC specifically designed for CMS GEM detector charge readout. Two different radiation characterization campaigns were launched to qualify the chip for CMS operation: TID and SEU tests. TID tests have been conducted at the CERN micro-electronics X-ray facility, and VFAT3 was irradiated with a monochromatic beam of X-rays at 1.8 Mrad/hr for several hours of beam time. The chip response was measured for possible variation in its internal parameters. VFAT3 was exposed up to 70 Mrad of TID with a mono-energetic X-ray beam and showed excellent robustness to the radiation. No significant deterioration is observed in the core device functionality during the test. However, the I/O block of the chip showed sensitivity towards the TID. A frequent communication break was observed after 35 Mrad of TID. In CMS, the GEM detectors would receive a maximum of 1 Mrad of TID in the HL-LHC. The TID results show that neither aging nor communication performance degradation is expected to disturb VFAT3 operation in CMS GEMs. The SEU tests were performed at Louvain-La-Neuve heavy-ion facility (HIF). The ions of varying stopping powers were used to irradiate the VFAT3, and corresponding upsets in the device registers were recorded. The SEU cross-sections and extrapolations to the HL-LHC conditions are also established. The VFAT3 registers are triplicated and showed low statistics of bit-flips (saturation cross-section: 6.1 X10ˆ-10 cm2/bit), a good indication of the robustness of the device against SEU effects. A communication breakdown issue is also experienced during the SEU test, like the TID test. A related cross-section is calculated for this process, and the observed frequency of synchronization break is found more significant than register SEU rates. The worst-case scenario was found for the most forward GEM station, ME0, which would receive the maximum particle flux (up to 378 kHz/cmˆ2). There, a synchronization loss is expected in the system, after every 2.3 hrs at HL-LHC. This frequency is well below CMS global reset request frequency for the muon stations. The results show that VFAT3 would perform well in all the three GEM stations for the whole ten years of GEM operation without any significant radiation damage.

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