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Characterization of COTS ADC radiation properties for ATLAS LAr calorimeter readout upgrade

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The ATLAS LAr calorimeters plan to upgrade the readout electronics for both Phase-I and Phase-II LHC luminosity upgrades. Detector signals will be digitized at the front-end, and data will be streamed out to the back-end system continuously. Therefore, radiation tolerant ADCs are key components for both upgrade phases.

This presentation will report on irradiation test results of commercial-off-the-shelf (COTS) ADCs that have potentials to be used in the readout electronics upgrade. Total-ionization-dose (TID) irradiation test results will be described, which has been used to pre-screen COTS ADCs for further studies. Various SEE studies of a candidate ADC with both neutron and proton beams will be presented. Finally, annealing studies following ATLAS policy on radiation tolerant electronics will be reported.

Summary

The Liquid Argon Calorimeter trigger readout electronics will be upgraded in the Phase-I ATLAS upgrade. All of the ~40,000 super-cell signals will be digitized at the front-end and streamed to the back-end digital signal processing system. In the Phase-II ATLAS upgrade all front-end boards will be replaced to digitize all of the 200,000 channels enabling for continuous streaming of data to the read out drivers. For both upgrade phases, a radiation tolerant analog-to-digital converter (ADC) is required in the front-end electronics. In the past 5 years many commercial-of-the-shelf (COTS) ADCs that fit our needs and which are manufactured in 180 nm or smaller feature sized technology became available. As smaller feature size devices appear to have larger radiation resistance we embarked on a test program to evaluate ADCs from different manufacturers.
The test strategy was to initially test candidates selected on the basis of their electric characteristics to total ionizing dose (TID). At a second stage we tested the candidates with the best performance to single event effects (SEE). TID tests were performed at the BNL Solid State Gamma Irradiation Facility. In total, 17 different ADCs were tested, with six of them surviving doses larger than 1 MRad(Si) with ADS5272 being the top performer. This component is particularly interesting as it has the shortest pipeline latency (162.5 ns), which is an important parameter to minimize the Level-1 trigger latency.
Based on these results we decided to perform an SEE test with ADS5272. To measure the single event upset rate we have performed an initial test at the Los Alamos National Laboratory LANSCE-WNR facility. This facility produces a neutron beam that nearly matches the expected neutron spectra at the position of the ATLAS LAr electronics with the maximum energy of 800 MeV. During the test we identified 13 SEU events for a total fluence of ~2x10^11 n/cm^2 with one of them classified as a Single Event Function Interrupt (SEFI). After an occurrence of a SEFI the device becomes inoperable and if it cannot be reset easily, devising mitigation techniques becomes a tall task. The observation of SEFI led to a more detailed investigation of SEE properties at a much higher particle flux facilities, namely the IUCF and Boston MGH cyclotron facilities.

At the IUCF and MGH facilities three ADCs were irradiated with ~200 MeV protons to measure both SEU and SEFI cross sections. The ADCs were operated with and without periodical hardware reset, in order to study the effectiveness of mitigation.
The test results performed with high intensity proton beams revealed the presence of two different types of SEFI. One that can be reset externally and a second requires a power cycle. The latter happens infrequently at doses less than 130 kRad, with cross sections increasing steadily after this point. The SEFI cross section is ~8 x 10^-13 cm^2 when TID is less than 130 kRad. The SEU, or bit-flip happens randomly and it is not a function of deposited dose.

As the expected radiation field for the ATLAS LAr electronics is low but has a high flux of high energy neutrons, this results suggests that this ADC is a good candidate to be used in the ATLAS LAr calorimeter Phase I and Phase II upgrades. We will discuss the test results and mitigation strategies to cope with the occurrence of SEFIs. Discussion of low-dose-rate effects will also be made.

Primary author: TAKAI, Helio (Brookhaven National Laboratory (US))

Presenter: TAKAI, Helio (Brookhaven National Laboratory (US))

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