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Testing of the HCC and AMAC functionality and radiation tolerance for the HL-LHC ATLAS ITk Strip Detector

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A new silicon-strip charged-particle detector (ITk Strip) is a major subdetector of the future upgrade of the ATLAS experiment for the HL-LHC. The HCC and AMAC chip are radiation-tolerant ASICs that contribute to the front-end readout, monitoring and control of the ITk Strip subdetector. Comprehensive probe station testing procedures have been developed to guarantee the reliability of each ASIC before installation. In addition, to ensure the operation of the HCC and AMAC under a radiation heavy environment, gamma, heavy ions and proton irradiation campaigns have been successfully conducted.

Summary (500 words)

The HL-LHC is an upgrade of the LHC that will significantly increase the instantaneous luminosity by a factor of five. The implication is a much busier charged-particle environment that requires faster data readout, finer granularity and higher radiation tolerance. To achieve these, the current ATLAS tracking detector is going to be upgraded with the Inner Tracker (ITk), an all-silicon based charged-particle detector composed of the ITk Pixel and ITk Strip subdetectors. The ATLAS Binary Chip (ABC), Hybrid Control Chip (HCC) and Autonomous Monitoring and Control Chip (AMAC) are the three custom application-specific integrated circuits (ASICs) designed for the readout, monitoring and control of the ITk Strip.

The ITk Strip upgrade project will require approximately 18,000 AMACs and 25,500 HCCs. All of the chips that are going to be installed in the ITk Strip need to be tested to ensure the reliability of the system. Functionality tests were created and verified on single chip setups to have a comprehensive characterization and testing of a chip in a few minutes. In addition to the testing suite, a probe station and an ASIC dependent probe card allow for the testing of large quantities of HCCs and AMACs at the wafer level which contains 557 HCC and 487 AMACs. The measured yield of good ASICs per wafer is above 90\%, exceeding requirements.

Furthermore, the performance of the radiation protections in the design of these ASICs is tested by subjecting them to total irradiation doses equivalent to that expected over the HL-LHC's lifetime. The different effects of radiation on silicon based ASICs is tested by exposing the HCC and AMAC to 3 types of radiation: gamma, heavy ions and protons. Gamma irradiation is mainly used to study the effects of total ionizing dose such as the increase in current leakage due to electron-hole buildups on the p-n junction of the chip's transistors. The gamma irradiation campaigns showed that the HCC and AMAC significant current increase as a function of total ionizing dose quickly dissipates after a few Mrad. Heavy ions and proton irradiation are both used to study single event effects (SEEs) produced by the charge deposition from particles passing through different parts of the ASIC's circuity. Proton beams are used to study SEEs under more realistic HL-LHC conditions and to understand nuclear interactions within the ASICs. Heavy ions of various LETs are used to provide higher statistics of rarer effects that may be seen at the HL-LHC. It was found that the ASICs triplicated voters used for protecting against SEEs were extremely effective, allowing both HCC and AMAC to successfully operate under very high LET ion beams.

In general, the ASICs high probe station yields and successful irradiation campaigns show that these two ASIC designs are optimal for operating under HL-LHC conditions. I will present detailed measurement results.

Primary authors: GUTIERREZ ZAGAZETA, Luis Felipe (University of Pennsylvania (US)); ASHMANSKAS, William (University of Pennsylvania (US)); DANDOY, Jeff (University of Pennsylvania (US)); DRESSNANDT, Nandor (University of Pennsylvania (US)); GOSART, Thomas Christopher (University of Pennsylvania (US)); KEENER, Paul (University of Pennsylvania (US)); KRIZKA, Karol (Lawrence Berkeley National Lab. (US)); KROLL, Joseph Ira (University of Pennsylvania (US)); LU, Sicong (University of Pennsylvania (US)); MAYERS, Godwin (University of Pennsylvania); MCGOVERN, Bobby (University of Pennsylvania (US)); NEWCOMER, Mitchell Franck (University of Pennsylvania (US)); THOMSON, Evelyn Jean (University of Pennsylvania (US)); WALL, Andie (University of Pennsylvania (US)); NIKOLICA, Adrian (University of Pennsylvania); REILLY, Michael Bendl (University of Pennsylvania (US))

Presenter: GUTIERREZ ZAGAZETA, Luis Felipe (University of Pennsylvania (US))

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