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BETSEE: Testing for System-Wide Effects of Single Event Errors on ITk Strips Modules

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The Inner Tracker silicon strip detector (ITk Strips) is a part of the ATLAS upgrade for the HL-LHC. The detector readout and control is accomplished by the interaction of three on-module custom ASICs (ABCStarv1, HCCStarv1 and AMACstar). All ASICs are designed with protections against Single Event Errors. Their resilience at the system-level can be tested using the Board for Evaluation of Triple-chip Single Event Effects (BETSEE). This special places all three ASICs into the beam-spot concurrently and allows for module-like operation. The results from irradiating BETSEE with heavy ions and protons will be presented.

Summary (500 words)

The ATLAS upgrade for the HL-LHC contains a new silicon tracker called the Inner Tracker (ITk). The ITk Strip detector is a subset of the ITk with striped silicon sensors. It will employ three custom ASICs; ABC-Starv1, HCCStarv1 and AMACStar. They operate together to perform detector readout and control. Up to 11 ABCStarv1's (ATLAS Binary Chip, front-end) are connected to a single HCCStarv1 (Hybrid Controller Chip, communication with End-of-Stave). The AMACStar (Autonomous Monitor and Control Chip), among many tasks, provides single-ended control signals for the ABCStarv1/HCCStarv1 and the on-module DC/DC converter.

The ASICs will operate in a hash radiation environment. Special considerations have gone into the design to ensure reliable operation. This includes protections against digital state changes induced by transvsering ionizing particles, known as Single Event Errors (SEE). The effectiveness of the protection is typically tested by operating standalone chips inside either a proton or heavy ion beam. While good at testing the basic functionality, the single-chip tests can miss effects only present in realistic operation of the whole system. An example of a system-level effect is chip reset caused by a Single Event Transient in an AMACStar control signal. Or a loss of communication lock between the ABCStarv1 and HCCStarv1 due to spontaneous bit errors in the transmitted signal.

The Board for Evaluation of Triple-chip Single Event Effects (BETSEE) has been produced to study SEE effects on the operation of the three-chip system. The chips are connected as they would be on a module, allowing for realistic operation. The layout is such that all three chips concurrently fit into a 2 cm beamspot. The BETSEE card does not employ a sensor and contains only a single ABCStarv1.

The BETSEE card was operated in a heavy ion beam at UCLouvain and a proton beam at TRIUMF. While some SEE effects were observed in the read-out data path, none were deemed serious.

The operation was done using software written for module testing (ITSDAQ for ABCStarv1/HCCStarv1 and Powertools for AMACStar). Power supply control and monitoring was done via the labRemote library. Live monitoring was available by using the moneater program to analyze data in real-time and push results to Grafana. The test loop consisted of continuously performing
read out of all registers on all three chips,
digital signal injections and triggers,
exercise of the AMACStar monitoring functionality,
and external current monitoring.

The external current monitoring is a key view on the state of the system as it is correlated with the chip configuration. Spontaneous resets can be seen as sudden changes in power usage.

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