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ATLAS Transition Radiation Tracker (TRT) Electronics Operation Experience at High Rates

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The ATLAS Transition Radiation Tracker (TRT) is a gaseous drift tube tracker which combines continuous tracking capabilities with particle identification based on transition radiation. The TRT Data Acquisition system uses custom front-end ASICs and boards for trigger and timing control as well as data read-out. To prepare for LHC run 2, changes were made to support the increased ATLAS trigger rate of 100 kHz, increased TRT occupancy caused by higher LHC luminosity, and gas mixture changes in some TRT straw tubes. Radiation studies were performed following an observed gain loss at the front-end during the 2012 run.

Summary

The ATLAS Transition Radiation Tracker (TRT) is the outermost of the three sub-systems of the ATLAS Inner Detector. The TRT contains ~300,000 proportional-mode drift tubes (straws). Along with providing continuous tracking by detecting ionization deposits, the TRT also provides electron identification capability through the detection of larger multi-keV deposits caused by transition radiation X-ray photons generated in radiators positioned between the straw tubes.

The TRT readout uses several custom components. Two custom-built, front-end ASICs mounted at the ends of the straws record the ionization deposits in the TRT straws: the analog Amplifier, Shaper, Discriminator, Baseline Restorer (ASDBLR) chip and the Digital Time Measurement, ReadOut Chip (DTMROC). The ASDBLR records ionization deposits using two thresholds: a track position measuring low threshold (LT) of ~300 eV and a particle identifying high threshold (HT) of ~6 keV. The DTMROC records when the low threshold and high threshold signals occur and stores them in a pipeline. The readout of the DTMROCs is performed by the TRT-specific ReadOut Drivers (RODs) that are controlled by the TRT-specific Timing, Trigger, and Control modules (TTCs). A lossless compression scheme based on Huffman encoding is used in the RODs to decrease the data size transmitted to the ATLAS Readout System (ROS).

The TRT readout chain was modified to handle the expected increased run 2 LHC luminosity and consequent higher TRT occupancy as well as the new ATLAS Level-1 trigger rate of 100 kHz (from 75 kHz). Three possible bottle-necks in the TRT readout chain were identified: The front-end to ROD readout, the ROD processing time and the ROD to ROS transmission rate. Consequently the readout window was reduced by 12.5 ns (reducing the number of bits recording the tracking time information from 24 to 20). The ROD firmware was modified for faster data compression mainly by including a hash table for efficient look-up of the most common patterns. A variable width timing gate (the "validity gate") was introduced to reject hits from neighboring collisions (this also improves track reconstruction at high occupancy). Other modifications to the ROD firmware increased robustness against data corruption.

During run 2 parts of the TRT active gas system will be filled with an Argon-based gas mixture or possibly a Krypton-based gas mixture instead of the Xenon-based gas mixture used in run 1. The ASDBLR chip provides functionality to switch between shaping functions suitable for the Xenon and Argon/Krypton gas mixtures. The software and databases were modified to allow configuration of the shaping per front-end board. We will report on first test-beam studies performed on Krypton-filled straws.

During the 2012 run, an increase of the high threshold and a resulting loss of efficiency for electron identification was observed. We reproduced this loss of gain by irradiating ASDBLR boards using a Co60 source at

Brookhaven National Laboratory. Studies indicate that the loss of gain flattens for doses not much above the run 1 dose.

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