Multi-Event Buffering and Local Event Building for the ALICE Transition Radiation Detector

As an integral part of ALICE, the dedicated heavy ion experiment at CERN's Large Hadron Collider, the Transition Radiation Detector (TRD) contributes to the experiment's tracking, triggering and particle identification. Central element in the TRD's processing chain is its trigger and readout processor, the Global Tracking Unit (GTU). The GTU implements fast triggers on various signatures, which rely on the reconstruction of up to 20 000 particle track segments to global tracks, and performs the buffering and processing of event raw data as part of a complex detector readout tree.

The high data rates the system has to handle and its dual use as trigger and readout processor with shared resources and interwoven processing paths require the GTU to be a unique, high-performance parallel processing system. To achieve high data taking efficiency, all elements of the GTU are optimized for high running stability and low dead time.

The solutions presented in this thesis for the handling of readout data in the GTU, from the initial reception to the final assembly and transmission to the High-Level Trigger computer farm, address all these aspects. The presented concepts employ multi-event buffering, in-stream data processing, extensive embedded diagnostics, and advanced features of modern FPGAs to build a robust high-performance system that can conduct the high-bandwidth readout of the TRD with maximum stability and minimized dead time. The work summarized here not only includes the complete process from the conceptual layout of the multi-event data handling and segment control, but also its implementation, simulation, verification, operation and commissioning. It also covers the system upgrade for the second data taking period and presents an analysis of the actual system performance.

The presented design of the GTU's input stage, which is comprised of 90 FPGA-based nodes, is built to support multi-event buffering for the data received from the 18 TRD supermodules on 1080 optical links at the full sender aggregate net bandwidth of 2.16 Tbit/s. With careful design of the control logic and the overall data path, the readout on the 18 concentrator nodes of the supermodule stage can utilize an effective aggregate output bandwidth of initially 3.33 GiB/s, and, after the successful readout bandwidth upgrade, 6.50 GiB/s via 18 optical links. The high possible readout link utilization of more than 99 % and the intermediate buffering of events on the GTU helps to keep the dead time associated with the local event building and readout typically below 10 %. The GTU has been used for production data taking since start-up of the experiment and ever since performs the event buffering, local event building and readout for the TRD in a correct, efficient and highly dependable fashion.