ADTOBSBOX TO CATCH INSTABILITIES

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Abstract

During long shutdown II (2019-2020) the transverse observation system (ADTObsBox) in the LHC will undergo a substantial upgrade. The purpose of this upgrade is to allow for true low latency, online processing of the 16 data-streams of transverse bunch-by-bunch, turn-by-turn positional data provided by the beam position monitors in transverse feedback system in the LHC (ADT). This system makes both offline and online analysis of the data possible, where the emphasis will lie on online analysis, something that the older generation was not designed to provide. The new system provides a platform for real-time analysis applications to directly capture the data with minimal latency while also providing a heterogeneous computing platform where the applications can utilize CPUs, GPUs and dedicated FPGAs. The analysis applications include bunch-by-bunch transverse instability analysis which will profit from significant reduction of latency.

ADTOBSBOX DURING RUN II

In 2015, a system called ObsBox (Observation Box) [1] was introduced by the Radio-Frequency group at CERN which allowed for buffering of multiple high-bandwidth data-streams from the Low-Level RF systems. The main purpose of the system for the transverse plane in the LHC is to make buffers with beam data (e.g. a bunch-by-bunch transverse position) of different lengths available for users. The buffers are ranging from 2^{12} turns to analyze injection oscillation transients, to 2^{17} turns to analyze transverse beam oscillations caused for example by civil engineering works close to the LHC beam tunnel [2]. Over time, the system has evolved into an important tool providing live beam parameter and transverse stability data to the accelerator operation, and it is an absolutely vital tool for the machine development sessions, where new ideas or methods are being tested in the machines. The ObsBox machines, which analyze the data in the transverse plane from the ADT are specifically called "ADTObsBox". They have been a proving-ground to test the limits of its computing system, since the transverse plane is where the analysis has gradually moved towards online analysis (<1 second, or 11k turns latency). In 2016, an online transverse instability detection system [3, 4] was introduced that analyzed the beam positional data for exponential oscillation amplitude growths to detect an onset of transverse instability (all analysis performed bunch-by-bunch). This results in a trigger sent over the LHC Instability Trigger network (LIST) so this event is captured by other observation instruments in the LHC. This also causes an observation buffer in the ADTObsBox to be triggered for later analysis. The bunch-by-bunch instantaneous amplitude is also published and made available, e.g. for the ADT beam activity monitor which is a fixed display in the control room that has been a important operational tool during run II. The ADTObsBox instability detection system made a significant contribution to the analysis and mitigation of ongoing operational issues [5].

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ADTOBSBOX AFTER LS2

During LS2, a substantial upgrade of the ADTObsBox will take place. It will be redesigned from the ground up with new I/O cards with custom firmware, driver, servers, and applications. The main reason for this upgrade is to reduce the latency between the I/O cards until the data is available for analysis. In the older generation, this latency was 364 ms and the new generation will reduce this to 120 µs. This is achieved by moving all the pre-processing from the host server to the FPGA and creating a new driver which manages a large circular buffer which allows for asynchronous transfers. This means that the data is ready to be analysed as soon as the transfer from the FPGA is completed and thus reduces the amount of computing resources needed to receive the data.

The new I/O card can receive up to ten channels so two cards can accommodate all 16 channels which the ADT provides. This allows for all channels to be available in a single host server opening up the possibility to cross-beam and cross-plane analysis, something which was not possible in the previous system.

The new servers will allow us to continuously upgrade the ADTObsBox system with new applications during run III without being limited by computing resources. The new GIGABYTE G481-HA0 servers have 384 GB of RAM and they can run 96 threads in parallel so one server has roughly the same computing capacity as four of the older generation. There will be 3 servers with different purposes, one for real-time analysis, one for buffers, and one for development. The server dedicated for buffering will have 144 TB of local storage which will be used for a circular buffer. This will be able to store turn-by-turn and bunch-by-bunch transverse positional data for a minimum of 24 hours which can be important if an interesting event occurred which did not result in a trigger of any buffer. This can also be helpful for machine development runs where the complete data-set for the session can be stored for offline analysis at a later stage.

TRANSVERSE INSTABILITY ANALYSIS

The new system will reduce the processing latency from 364 ms to 120 µs which will make the ADTObsBox an even more powerful tool for transverse instability detection in the LHC. With the long processing delay, it can be too late for some fast rise time instabilities to be detected. If the beam is dumped due to losses on the collimators then it

would be captured by the post-mortem buffers but if not then the data could be lost. The current transverse instability detection implementation applies the Hilbert transform [6] to the bunch-by-bunch data. An instantaneous oscillation amplitude for each bunch is calculated. A growth can be detected by comparing the running average of the instantaneous amplitude for different time windows. A time window of 2^{10} turns can be seen in Fig. 1. When an instability is detected, dedicated observation buffers are triggered and saved to a storage server for further analysis. At the same time all data from the instability analysis, for example the bunch-by-bunch transverse activity is logged by the accelerator logging service (NXCALS) [7]. The implementation details of the new system have not been decided yet, but one possible solution would be to combine the data from 4 pick-ups, apply the Hilbert transform and then do an exponential curve fitting on the instantaneous amplitude. This would be performed on all bunches in the LHC and in all 4 planes so the computational resources to run this would be significant.

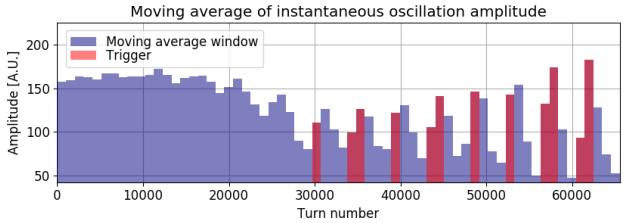

Figure 1: Moving average of instantaneous oscillation amplitudes

CONCLUSION

The upgrade of the ADTObsBox will allow for detecting instabilities while they are occurring and trigger other observation instruments in the LHC with shorter buffers. It will also allow more powerful analysis tools to be used in the future while providing a 24h circular buffer which can be used to analyze events not triggered by other instruments. In conclusion, this is a very powerful system that has proved its value during run II and will continue to do it even better during run III.

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