The ATLAS beam pick-up monitoring software

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Overview

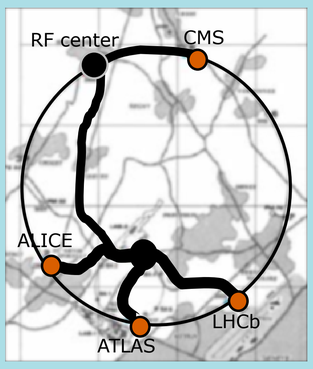
The ATLAS experiment [1] at the Large Hadron Collider (LHC) [2] must be synchronized to the collisions to ensure the quality of the event data recorded by its subdetectors. On both sides of ATLAS, 175 m upstream from the interaction point, beam pick-up detectors are installed along the LHC beam pipe. They are used

- to monitor the phase between the collisions and the LHC clock signals that drive the ATLAS electronics
- to monitor the structure and uniformity of the LHC beams
- as input to the trigger system

This contribution describes the monitoring of the LHC beams and timing signals.

LHC timing signals

The LHC provides beam related timing signals to the experiments via optical fibers [3]. The phase of the clock signals can change, e.g. due to temperature fluctuations, causing front-end electronics to sample at non-optimal working point. The figure to the left shows how the timing signals are distributed from the RF center of the LHC to the experiments.



The BPTX detectors

The BPTX stations are extra beam position monitors provided by the LHC machine, but operated by experiments for timing purposes. The BPTX stations are comprised of four electrostatic button pick-up detectors, arranged symmetrically in the transverse plane around the LHC beam pipe. When a charge distribution passes the pick-up, an analog signal is produced and transmitted to the underground counting room *USA15* via a 220 m low-loss cable. The photograph on the right shows the installed BPTX station for beam 2 on the C-side of ATLAS.

References

[1] The ATLAS Collaboration. The ATLAS Experiment at the CERN Large Hadron Collider. *JINST 3 (2008) S08003*

[2] L. Evans and P. Bryant (editors). LHC Machine. *JINST 3 (2008) S08001*

[3] S. Baron TTC challenges and upgrade for the LHC. *Article / p125 in report CERN 2005-011.*

[4] T. Pauly et al. ATLAS Level-1 Trigger Timing-In Strategies. *11th Workshop on Electronics for LHC and Future Experiments, Heidelberg, Germany, 12 - 16 Sep 2005, pp.274-278*

[5] C. Ohm. Phase and Intensity Monitoring of the Particle Beams at the ATLAS Experiment. Master Thesis *Linköping University, Sweden, LITH-IFM-EX–07/1808–SE*

Monitoring of the LHC beams and timing signals

The analog signals from the BPTX stations and the LHC timing signals are digitized using an oscilliscope with ethernet capabilities, and analyzed by a computer (see Figure 1) [4, 5]. The monitoring framework can be divided into the three major parts described in the following sections.

BPTX Read-out

By periodically reading out the BPTX and LHC timing signals over a time period corresponding to a full LHC turn (89 μs), the the phase between timing signals and each bunch passing through ATLAS can be monitored. The waveforms acquired from the BPTX stations are scanned for bipolar pulses corresponding to LHC particle bunches. The identified pulses are analyzed further by fit algorithms that extract measurements of the arrival time, intensity and longitudinal length of each bunch individually. The LHC timing signals are also processed and clock and orbit pulse edges are determined with high accuracy. By combining the extracted information, each bunch can be assigned a phase and a *bunch crossing identifier* (BCID).

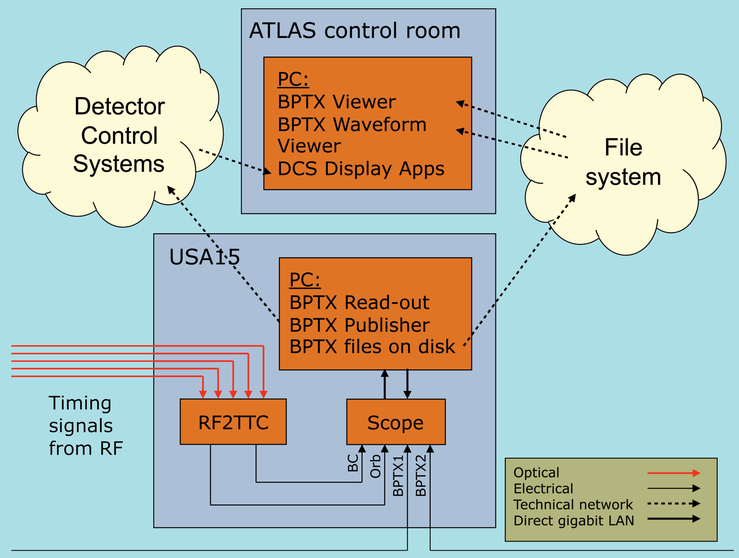


Figure 1: Overview of the information flow in the monitoring system.

BPTX Viewer

In the ATLAS control room, the *BPTX Viewer* application lets the shifter monitor

- the phase between the timing signals and the collisions
- the beam structure and potential of out-of-time bunches
- individual bunch properties, e.g. intensity, phase and longitudinal length, both bunch-by-bunch and over time

Figures 2 and 3 show *BPTX Viewer* running on simulated data with nominal LHC filling scheme.

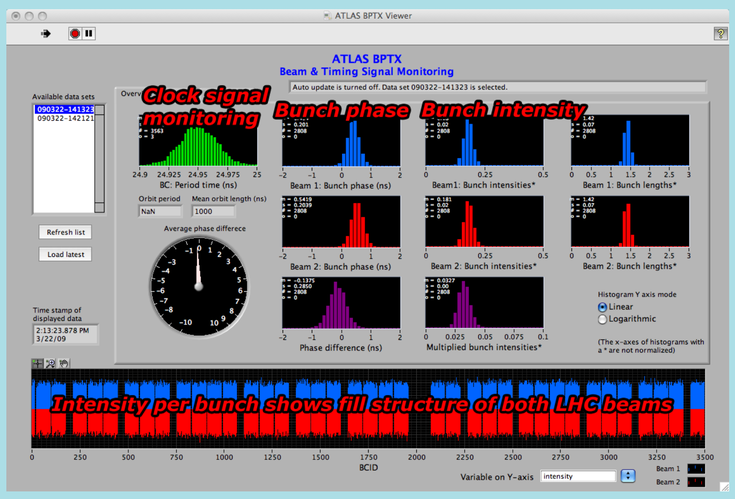


Figure 2: *BPTX Viewer* showing the LHC beam structure.

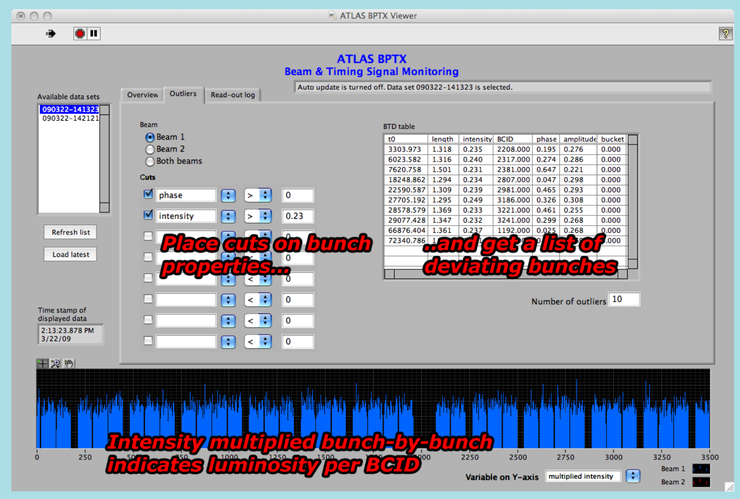


Figure 3: *BPTX Viewer* showing the outlier bunch finder.

BPTX Waveform Viewer

If deviating bunches are found with *BPTX Viewer*, the shifter can inspect the BPTX signal waveforms directly using a designated program called the *BPTX Waveform Viewer*.

Results from first beam

Figure 4 shows the first LHC bunch approaching ATLAS, recorded by the BPTX monitoring system. A few hours later, a bunch was successfully circulated 8 turns around the accelerator and seen by ATLAS as depicted in Figure 5. The pulse amplitude, which is proportional to the bunch intensity, is degrading from turn to turn, which is consistent with the beam loss and debunching expected for a beam not yet captured by the LHC RF system.

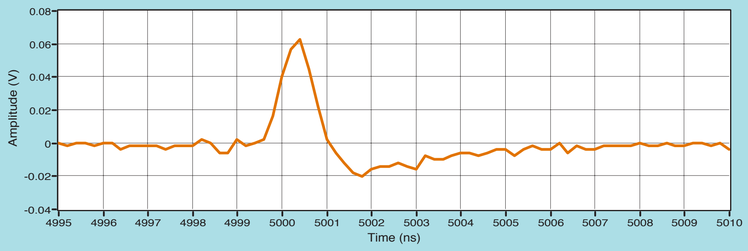


Figure 4: The first LHC bunch on its way to ATLAS.

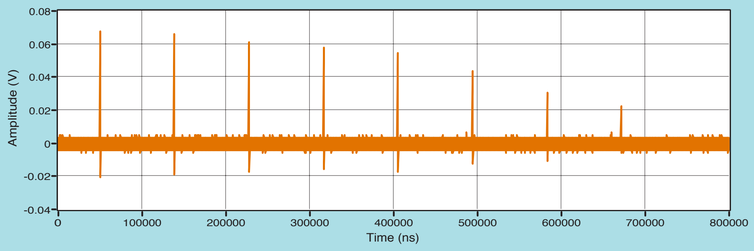


Figure 5: A bunch passing ATLAS in 8 consecutive turns.

Around 1 AM on September 12, 2008, a single bunch was circulated around the LHC for about 20 minutes after being captured by the RF system. The BPTX monitoring system measured the intensity (not yet normalized) during this period, see Figure 6. The scattering of the data points suggests that the precision is around 10%.

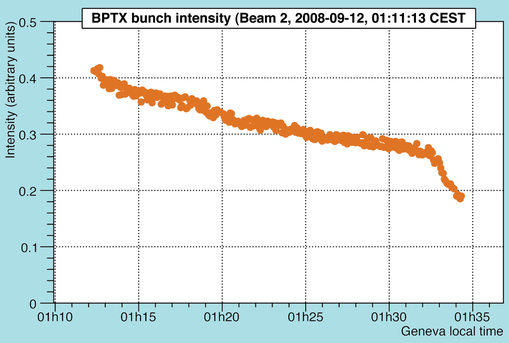


Figure 6: Beam intensity.