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

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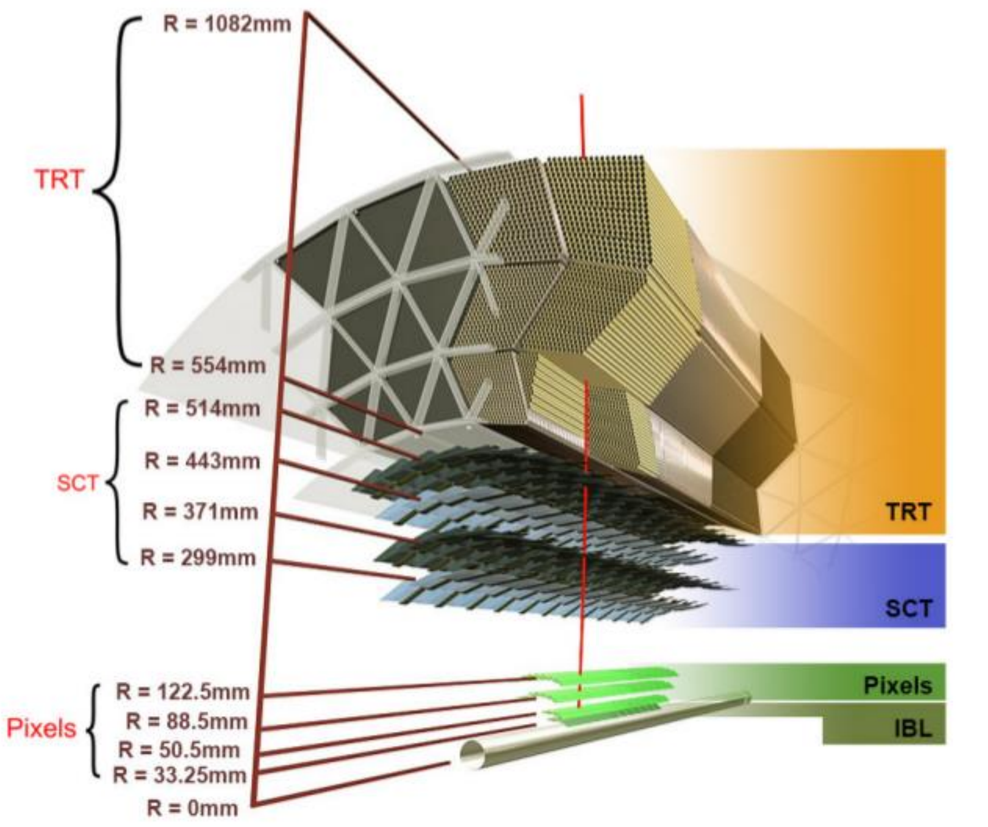
Introduction



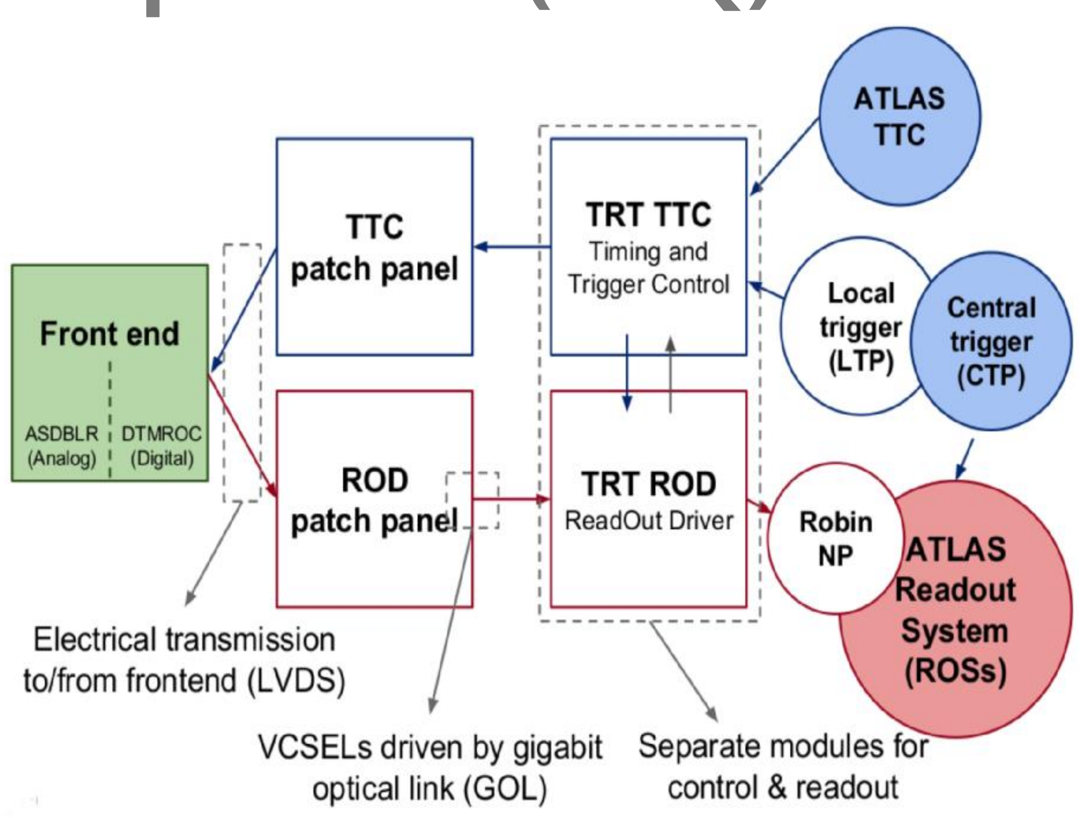
The TRT is the outermost component of the ATLAS tracking Inner Detector. In addition to charged particle tracking capabilities, the TRT functions as a transition radiation detector allowing for the discrimination between electrons and light mesons. This is accomplished with radiators between straws which emit X-ray photons when traversed by charged particles.

- Contains ~300,000 proportional-mode 2mm radius drift tubes (straws) using either Xenon/CO_2/O_2 or Argon/CO_2/O_2 as the working gas
- Electronics output: No hit, Low Threshold tracking hit (~300 eV), High Threshold particle identifying hit (~6 keV)
- Position resolution of 150 µm
- Thresholds are set such that there is 2% noise occupancy of the straws.

Data Acquisition (DAQ)

Custom front end ASICs:

- *Amplifier Shaper Discriminator, Baseline Restorer* (ASDBLR) – Amplifies and shapes output from 8 straws to generate low and high threshold signals
- *Digital Time Measurement ReadOut Chip* (DTMROC) – Measures leading edge and Time over Threshold (320 MHz sampling) for signals from 2 ASDBLRs (16 straws) as per instructions from the ATLAS and TRT timing and trigger control systems



Off detector electronics (VME Boards):

- *Timing and Trigger Control* (TTC) boards are responsible for command and control of the front end chips: resetting chips, setting thresholds, and sending triggers to start readout.
- *ReadOut Drivers* (ROD) boards control the data stream to the ATLAS ReadOut System (ROS) and use a Huffman encoding to losslessly compress the data.

Run 2 Challenges

- Higher L1 trigger rate : 75 kHz in Run 1 to 100 kHz in Run 2
- Higher occupancy due to higher LHC Luminosity (> 50% occupancy)

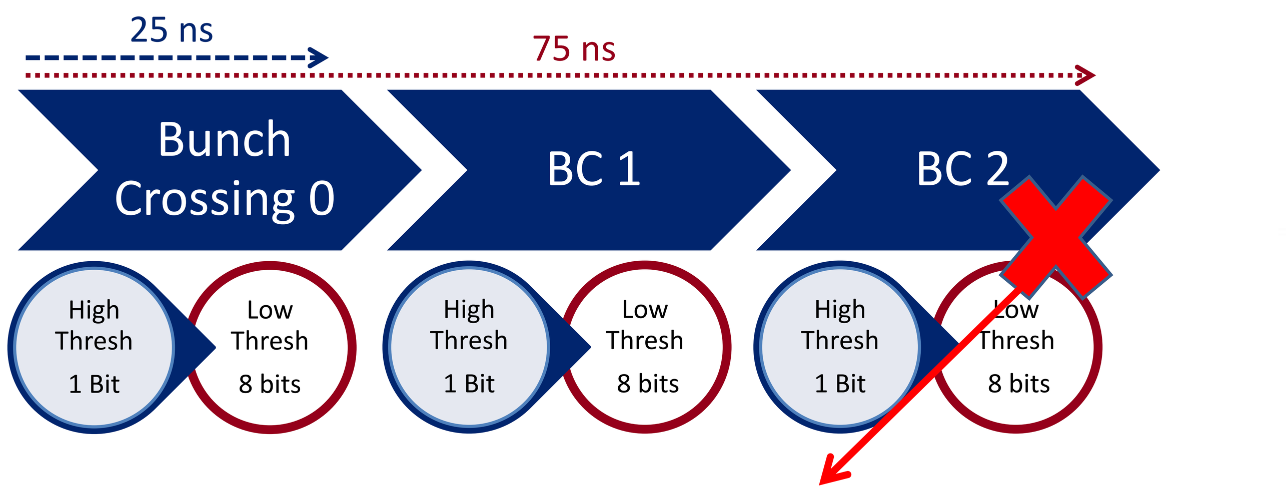
ROD firmware and software changes

- Reworked clock signals and improved stability of clock. This protects against clock jitter present in high occupancy situations that cause data corruptions.
- Lowered on-board DDR memory speed which sometimes caused board failures
- Added a suite of monitoring tools and counters including a live internal website tracking info such as ROD Busy percentage, NSE usage, errors, etc.
- Implemented simple checks such as a sendID mode where the DTMROCs send their address to the ROD FPGA for fast firmware and data line testing at up to the maximum expected data rate

TRT DAQ in Run 2

Preparing the front end to ROD path for 100 kHz:

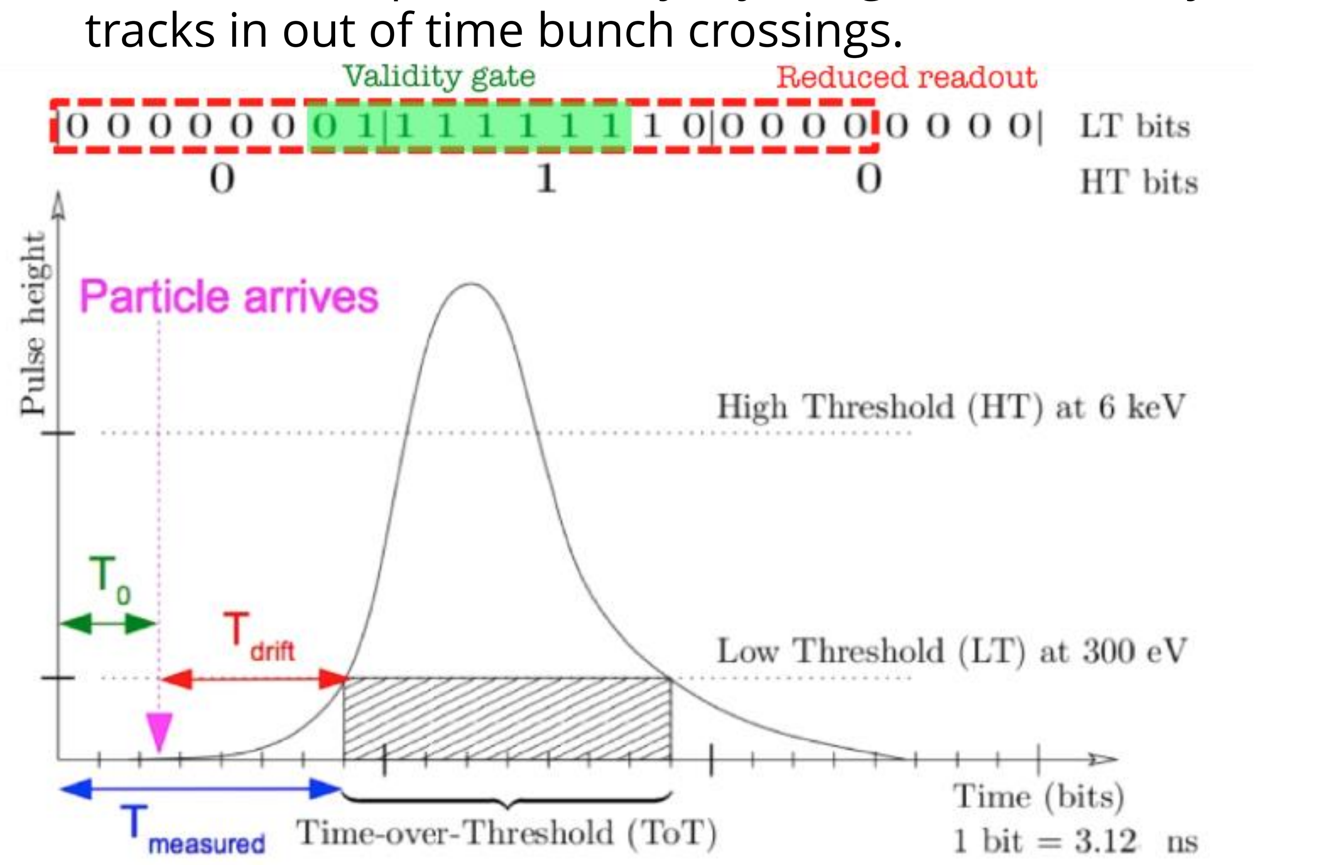
- In Run 1, the DTMROCs sent 444 bit words: 16 straws x 3 bunch crossings x 9 bits of info per crossing with an additional 12 bit header.
- Data readout format for hit straws:



- In Run 2 the last 4 bits of the last bunch crossing are not returned.
- Studies have shown this does not affect straw hit/particle identification efficiencies, and allows the TRT DAQ to reach the desired 100 kHz rate.
- This change reduces the per straw number of bit from 27 to 23 and the DTMROC bit number from 444 bits to 380 bits and is referred to as Reduced Readout mode.

ROD changes to decrease ROD time and bottleneck at the ROD to ROS path:

- An NSE (Network Search Engine) chip on the ROD compresses the full DTMROC data stream to the data stream sent to the ROSes.
- In Run 2 a hash function is implemented which stores the most common 4,000 DTMROC words and their Huffman compressed words. The NSE chip is used only if the word is not encoded via the hash table.
- A variable width timing gate is implemented to require that at least one low threshold hit falls within a certain time window, preferentially rejecting hits caused by tracks in out of time bunch crossings.



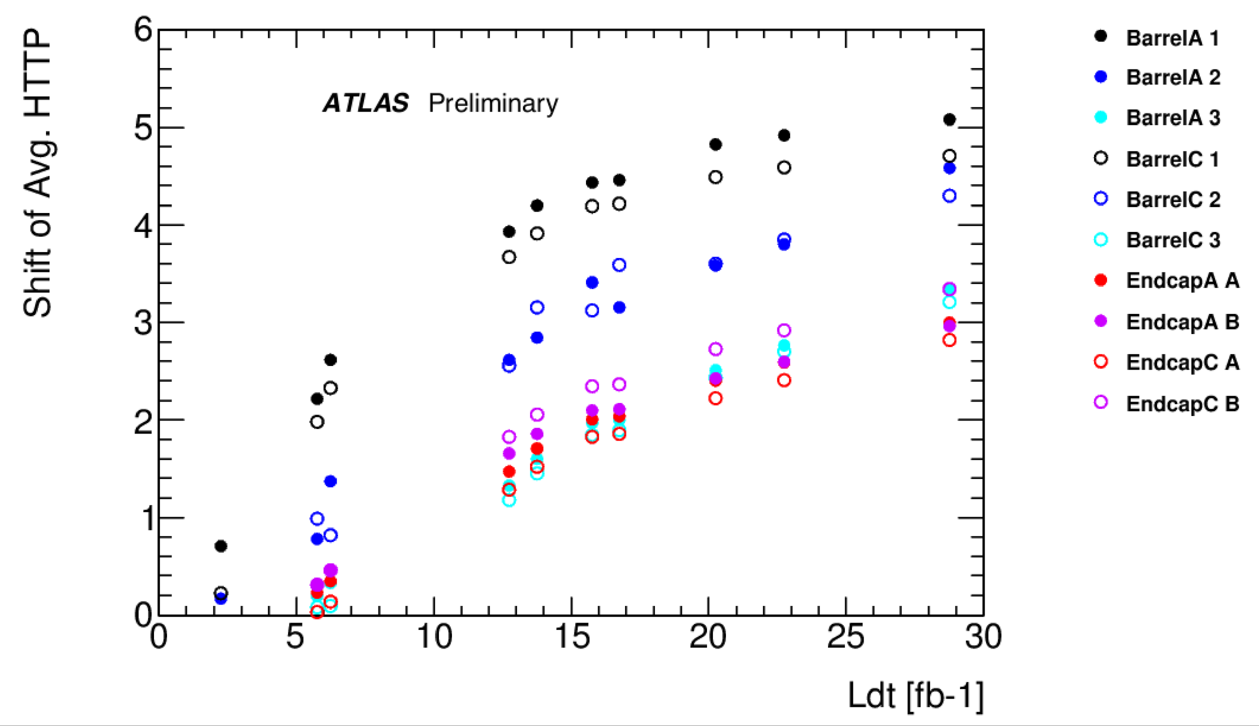
Gas Configurations

In Run 1 TRT used a Xenon working gas mixture only. For Run 2 straws are filled with either the Xenon mix or Argon mix due to leaks in the gas supply tubing.

- Argon has better tracking performance at high rates but absorbs less transition radiation (~10% less), thus leading to a loss in particle identification.
- A pressure regulation system was developed to keep leakage to a minimum.
- The ASDBLRs have a functionality built in to change the shaping parameters of the signal.
- A database is used to track the gas configuration per front end board and set the ASDBLRs appropriately.
- Currently testbeam studies are underway investigating the possibility of using a Krypton gas mixture.

Radiation Studies

During Run 1 a shift of thresholds (corresponding to the 50% occupancy threshold for a given test pulse) was seen with the innermost layers showing the largest effect. The shift for high threshold can be seen in the figure below. Additionally a loss of gain was observed (not shown). The layers receiving the highest dose during Run 1 received ~30 kRad. Sample ASDBLRs were irradiated at Brookhaven National Lab with a Co60 source to reproduce this effect.



The sample ASDBLRs were irradiated up to 500 kRads. The threshold shift was observed and found to saturate at ~ 50 kRads. The changes in threshold and gain are accounted for in a threshold calibration procedure.

Conclusions

- There have been numerous upgrades and improvements to the TRT DAQ over the course of the long shutdown one.
- Tests in ATLAS have shown that the TRT can operate successfully at a rate of 100 kHz as well as in higher occupancy conditions (> 50%) .
- The TRT DAQ team look forward to Run 2!

References

The ATLAS TRT Collaboration, *The ATLAS TRT electronics,* JINST 3 (2008) P06007
The ATLAS Collaboration, *Basic ATLAS TRT performance studies of Run 1,* ATL-INDET-PUB-2014-001