A new methodology of clock phase adjustment in a large-scale clock distribution system for HL-LHC ATLAS TGC front-end electronics

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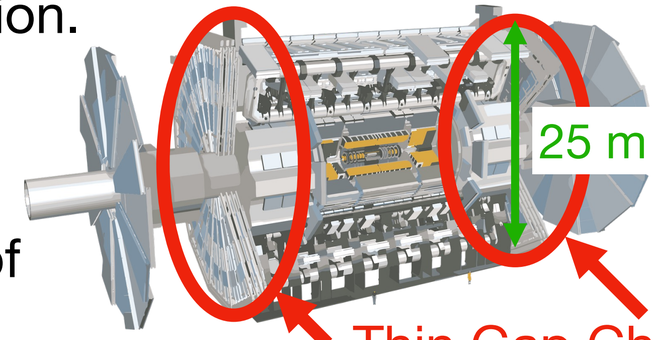
1. Thin Gap Chamber (TGC) electronics system for HL-LHC ATLAS

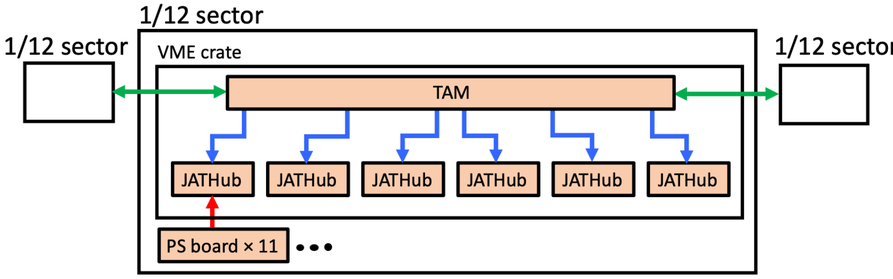
- The TGC system performs fast online muon reconstruction.
- Large-scale detector
  - Size: 25 m in diameter. Readout channels: 320,000
- For precise bunch-crossing identification, clock phase of 1,434 front-end electronics must be aligned with an accuracy of O(1) ns.



Multi-wire promotional chamber (MWPC)
320,000 channels

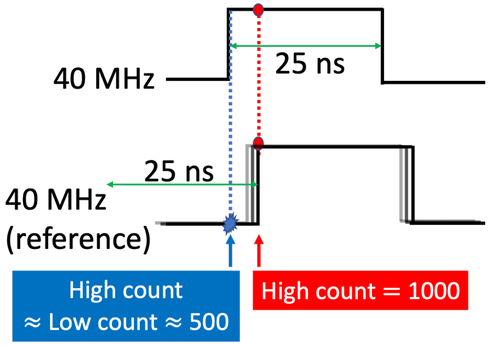
2. Methodology of phase adjustment

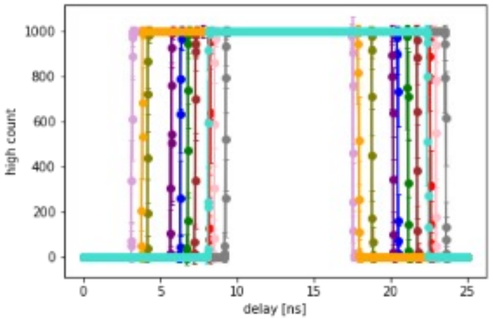
- Two custom modules (TAM and JATHub) are developed.
- By taking advantage of SoC devices, phase adjustment and monitoring of large-scale electronics system can be done remotely and simply.



3. Low-level implementation in FPGA and SoC

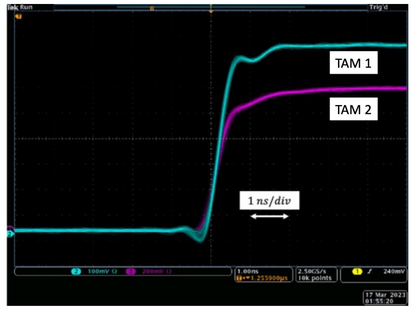
- Clock distribution and reconstruction with fixed latency
- Variable phase shift (25 ns step and 18 ps step)
- Phase monitoring

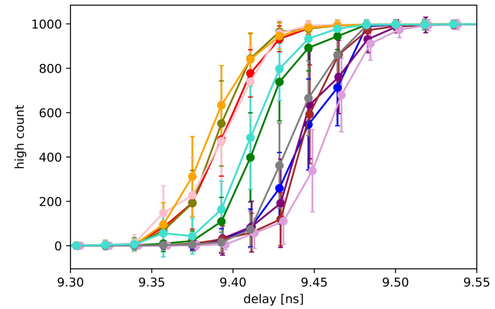




4. Demonstration of phase adjustment

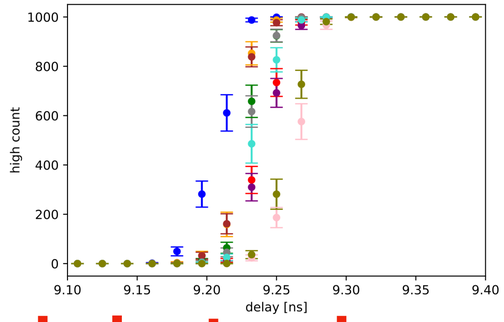
- All procedures can be done remotely and automatically in situ.
- These demonstrations ensure low-skew clock distribution and phase adjustment in 1,434 front-end electronics





5. Reproducibility and uncertainty with measurement-driven estimation

- Reproducibility of clock reconstruction with fixed latency is estimated.
- Skew and systematic uncertainty are also estimated with measurement-driven estimation method.



We conclude that phase adjustment of 1.434 front-end electronics can be done with an accuracy of ~ 50 ps (sufficient accuracy for our purpose).