IF04 White Papers and Overlap with CompF4

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Instrumentation Frontier: Trigger and Data Acquisition (TDAQ)

- TDAQ systems collect data at the very front-end of detectors, reduce the volume of data selection algorithms and summarizing data into high-level quantities, and store the data for later transfer and processing.
- The next generation of physics detectors faces requirements to handle an enormous throughput of data, have high reliability and uptime in extreme environments, and accommodate fast timing and precise synchronization.
- Our interests include:
  - High-speed data links and transfers, including radiation-hard and low-power links
  - Real-time processing hardware, like low-power hardware capable of working in extreme environments like high radiation or cryogenic temperatures, and **real-time hardware capable of real-time feature extraction, including fast inference for machine-learning algorithms**
  - **Online processing and high-level trigger and reconstruction algorithms, including use of heterogeneous computing in** commodity hardware for both triggered and 'streaming' DAQ systems
  - Autonomous operation, control, and calibration of detector systems, including fast anomaly detection and fault recovery
  - Precise timing synchronization, for both improved triggering and event reconstruction and for distribution across large areas

Current Submitted IF04 White Papers

1. **“A fast method for particle tracking and triggering using small-radius silicon detectors”,** A. V. Kotwal, https://arxiv.org/abs/1910.14149
2. “**Track-Based Triggers for Exotic Signatures**”, K. F. Di Petrillo, J. N. Farr, C. Guo, T. R. Holmes, J. Nelson, and K. Pachal, https://arxiv.org/abs/2203.07314
3. **"Applications and Techniques for Fast Machine Learning in Science",** N. Tran and A. Deiana (editors), https://arxiv.org/abs/2110.13041
4. **“Readout Technologies for Future Detectors”,** M. Begel, J. Eisch, M. Garcia-Sciveres, A. Paramanov, M. Trovato, and J. Zhang, https://arxiv.org/abs/2203.14894
5. **“Innovations in trigger and data acquisition systems for next-generation physics facilities”,** R. Bartoldus, C. Bernius, and D. W. Miller, https://arxiv.org/abs/2203.07620

White Papers with no Overlap

- **#2:** Focused on track-based triggers for anomalous (e.g. displaced) charged particle trajectories. No overlap anticipated.
- **#4:** Focused on development of readout links of appropriate speed and radiation hardness. No overlap anticipated.

Overlaps

- **Biggest overlap, #3:** We have been considering this review paper as a white paper for IF04, and this is also included in CompF4.
  - The paper discusses use of "fast" ML at the LHC and in other scientific fields, including implementations for trigger, analysis, simulation and reconstruction.
  - It further covers areas of overlap and a section on hardware architectures.
  - The TDAQ group is primarily interested in trigger/data acquisition implementations.

- #**1:** This white paper describes the use of point-cloud-based unsupervised machine learning on FPGAs to reconstruct/trigger on charged particle trajectories in the LHC.
  - Use of point clouds for charged-particle trajectory reconstruction is mentioned in #3/CompF4, but not in terms of trigger/online. Some conceptual overlap, but different focus.

- **#5:** Focused broadly on next-generation TDAQ innovations.
  - Subsections on fast-tracking triggers, AI hardware/edge computing, and trigger-focused AI inferences.
  - The focus remains on trigger applications.