Report from the Trigger and DAQ Group:

October 10, 2016

T. Bose (Boston University), H. Chen (BNL)

Parallel XI: Trigger & Data Acquisition

- Overview of TDAQ system of major HEP experiments
  - Rainer Schwemmer (CERN)
  - Wesley Smith (Univ. of Wisconsin)
  - Wader Fisher (Michigan State Univ.)
  - Remi Mommsen (FNAL)
  - Jinlong Zhang (ANL)
  - Giovanna Lehmann Miotto (CERN)
  - Eric Church (PNNL)
- Lab Roadmap on trigger, DAQ and readout electronics
  - Robert Wagner (ANL)
  - Kai Chen (BNL)
  - Tiehui Liu (FNAL)
  - Ryan Herbst (SLAC)
- Optical Ring Resonators
  - Steve Kuhlmann (ANL)
- Many thanks to excellent presentations from speakers

Findings

- LHCb Upgraded Trigger/DAQ Architecture – R. Schwemmer
  - LHCb plans to move to (hardware)trigger-less readout in 2019/2020.
  - DAQ network will be separated into Event Building and Filter network
  - Using PCIe readout board to eliminate issues with current architecture
  - R&D for upgrade is well underway, with PCIe-40 second prototype and first implementation of 100 Gb/s event builder
- Optical Ring Resonators as Tracking Readout or Trigger – S. Kuhlmann
  - Nanofabrication with UV lithography (<100nm process) or more precise electron beam lithography available at ANL and industries
  - Silicon photonics is an emerging technology, possible Blue-Sky applications in astrophysics and HEP DAQ with features of low mass, low power (~1uW/channel), compact (~5um/channel) and fast (>165 GHz)
  - Need to check sensitivity to magnetic field, large scale production (cost)

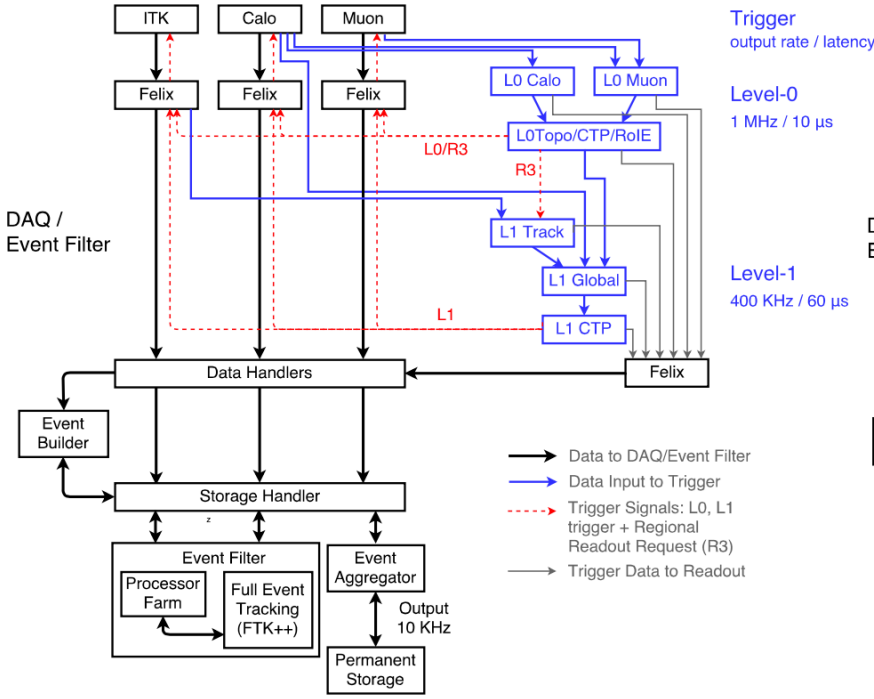
Findings

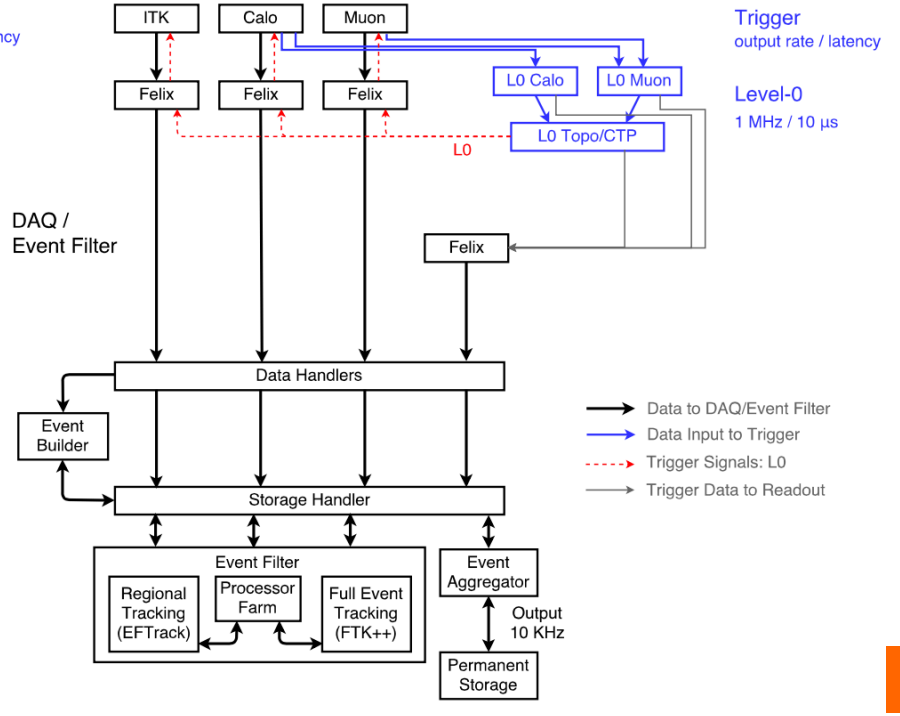
- CMS HL-LHC Trigger Upgrade – W. Smith

  Architecture:
  - Level-1 Accept: 500 kHz @ 140 PU, 750 kHz @ 200 PU
  - Level-1 Latency: 12.5 μsec
  - HLT Output rate: 5 kHz @ 140 PU, 7.5 kHz @ 200 PU
  - Features:
  - Level-1 Track Trigger
  - Track Trigger combined with L1A rate maintains overall physics performance e.g. thresholds near what are running now
  - L1 Track Finding is contained within the Tracker, with L1 Trigger performing correlation of produced track with muon and calorimeter trigger information.
  - Logic is based on adaptation of Particle Flow ideas to L1
  - Upgraded Calorimeter, Muon, Global Triggers

Findings

- ATLAS Trigger Upgrades – W. Fisher
  - ATLAS Phase-I trigger provides basis for Phase-II trigger
  - Two-level hardware trigger option based on Regions of Interest
  - Single level trigger option is also being considered
  - Track info from inner tracker crucial in subsequent levels, option to have regional tracking in either second hardware level or as coprocessor to Event Filter





Findings

- Overview of CMS DAQ Upgrade – R. Mommsen
  - Run 3 DAQ will be based on current, will replace network infrastructure and evaluate event building network technology
  - Phase-II DAQ will use common DAQ-TCDS (Timing & Control Distribution System) hub based on ATCA
  - Evaluate high performance event-builder node with non-volatile memory (3D XPoint)
  - New ideas are being developed (exploring GPUs at High-Level Trigger, 40MHz scouting, hybrid CPU+FPGA)
- ATLAS DAQ Upgrade – J. Zhang
  - Introducing FELIX (Front End LInk eXchange) in Phase-I upgrade to enable transition from custom hardware to COTS as early as possible
  - Introducing a large storage area before filtering in Phase-II upgrade to decouple event filtering operation from LHC cycle
  - Take advantage of arising technologies for implementation of event building and filtering

Findings

- Overview of (Proto)DUNE Trigger/DAQ System – G. Lehmann Miotto
  - DUNE experiment requires high up-time (>99%) to trigger/DAQ system, collect beam + atmospheric neutrinos as well as proton decay candidates with high resolution and no dead-time
  - DUNE DAQ is combining ideas of continuous readout system and triggered system
  - ProtoDUNE is to test and validate technologies and design applied to the DUNE far detector
- SBN DAQ Trigger and Timing System – E. Church
  - LArTPCs (MicroBooNE, SBND, ICARUS) will be used in the SBN program for sterile neutrino search
  - Trigger, DAQ and timing systems design is centered on building events on the fly from a few asynchronous running detector sub-systems
  - White rabbit and artDAQ are being used by both SBND and ICARUS

Findings

- Lab Roadmap ANL – R. Wagner
  - Argonne HEP electronics group supports HEP division experimental work, expert in high speed digital design, front end design, novel electronics system and wireless DAQ
  - Major contribution to ATLAS Tile Phase-II upgrade, FTK, L1Track trigger and FELIX
  - Collaboration with outside labs and universities is common
- Lab Roadmap BNL – K. Chen
  - Main architect of ATLAS Phase-I upgrade (LAr, NSW, TDAQ) and main contributor to ATLAS Phase-II upgrade plan/proposal
  - Natural evolution from ATLAS Phase-I to Phase-II upgrade, LAr FESOC, MDT readout and TDAQ (FELIX, trigger processor)
  - Cold electronics is enabling technology to LArTPC experiments (MicroBooNE, SBND, (Proto)DUNE)
  - Collaboration with labs and universities in both ATLAS and neutrino experiments

Findings

- Lab Roadmap FNAL – T. Liu
  - Reliable cryogenic readout electronics (COLDATA) for DUNE
  - Huge data volume per channel (MKID pixel DAQ for Dark Energy) and extremely low noise CCD readout for Dark Matter search
  - Proceed with “off-the-shelf” DAQ, leverage CAPTAN, artDAQ software and test beam experience
  - Major development of AM+FPGA based tracking trigger for CMS upgrade, close collaboration with labs and universities throgh LPC
- Lab Roadmap SLAC – R. Herbst
  - RCE platform has been used in LSST, 35ton, ProtoDUNE, Heavy Photon search, LDMX, ATLAS ITk readout test systems, LCLS-II
  - LCLS-2 high performance accelerator controls RF detectors in ATCA based platform
  - Readout electronics system for TES in ATCA platform
  - ASIC group specialized in mixed signal, low noise analog front end, noise filtering optimizaiton, ADC and DAC, high speed digital data transmission

Comments

- LHCb is moving into trigger-less readout, not possible for ATLAS and CMS in HL-LHC upgrade.
- Both ATLAS and CMS will rely on track trigger to retain trigger thresholds close to those used in Run 1 in order to fully exploit the increased luminosity of the HL-LHC.
- For HL-LHC both ATLAS and CMS plan to migrate algorithms used by higher level triggers into the Level-1 trigger.
- ATLAS, CMS and LHCb will use common readout interface to detector front end; ATLAS and LHCb will use PCIe based design, while CMS will use ATCA based design
- ATLAS, CMS and LHCb will take increasing advantage of *COTS* (*Commercial-Off-the-Shelf*) hardware

Comments

- LArTPC based neutrino experiments impose different requirements to trigger and DAQ system
- ATLAS FELIX system will be used in ProtoDUNE project, an example of development from energy frontier experiment being applied to intensity frontier experiment
- Optical links management (e.g. how to monitor links and predict errors) becomes a new challenge in experiments
- Close collaboration among labs and between labs and universities have been seen; it is important to continue with this and also maintain and strengthen ties with industry

Identification of Risks and Opportunities

- Technology advancement led by industries doesn't necessarily provide a solution to meet special requirements of HEP experiments
  - HEP experiments are rarely a driver of industrial development
- Identify specific area and develop a solution for future HEP experiments
  - High speed transmitter (> 10Gb/s), high density (> 10), low cost rad hard transceiver
  - Readout electronics operating in special environment (e.g. cryogenic temperature, radiation and magnetic field)
  - The trigger determines the physics reach of the experiment
    - The success of the track trigger in the HL-LHC upgrade of ATLAS and CMS will be crucial for the discovery of new physics

Recommendations

- Encourage the development of high-bandwidth radiation hard optical links (>10Gb/s)
- Encourage the development of scalable DAQ system to enable the transition from custom hardware to commodity networking and computing as early as possible
- Encourage the development in hybrid CPU-FPGA, GPGPU, storage, high speed optical and electrical communication
- Encourage studies of the impact of timing information in the trigger at ATLAS/CMS
- Encourage focus on emerging technologies such as photonics and wireless communication

Possible Grand Challenge Ideas

- Can trigger-less readout and DAQ system become a ***common*** solution for future large scale HEP experiments?
  - Networking, computing, data transmission, machine learning etc.
  - All hardware triggers migrate to software solution