Topological and Central Trigger Processor for 2014 LHC luminosities

G. Anders^{b,c}, B. Bauss^a, D. Berge^c V. Büscher^a, T. Childers^c, R.
Degele^a, E. Dobson^c, A. Ebling^a, N. Ellis^c P. Farthouat^c C.
Gabaldon^c, B. Gorini^c, S. Haas^c W. Ji^a, M. Kaneda^c, S. Mättig^d, A.
Messina^c C. Meyer^a, S. Moritz^a, E. Simioni^a, T. Pauly^c R. Pottgen^a,
U. Schäfer^a, R. Spiwoks^c S. Tapprogge^a, T. Wengler^c, V. Wenzel^a

a, Institut für Physik, Universität Mainz, Mainz, Germany

b, Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität

Heidelberg, Heidelberg, Germany

c, CERN, Geneva, Switzerland

d, DESY, Hamburg and Zeuthen, Germany

Overview

- ➊ ATLAS Level-1 Trigger 2013-2014 Upgrade
- ➋ Central trigger processor upgrade
- ➌ Topological Processor
- ➍ Topological Processor functional demonstrator test results
- ➎ Summary

ATLAS Detector

ATLAS Level-1 Trigger

- Hardware based, synchronous with LHC clock
- Pipelines 2.5 μs fixed latency system
- The output is a single bit "Level-1 Accept" (L1A) signaling to the detector front-end readout systems via the Trigger Timing and Control system (TTC)

Level-1 upgrade in 2013-2014 (Phase-0 upgrade)

Motivation:

- LHC proton collisions at 14 TeV and luminosity above $3 \times 10^{34} \text{cm}^{-2} \text{s}^{-1}$
- Higher events rate

Strategy for the Level-1 trigger upgrade:

- Use geometrical information of jets/leptons/MET and apply topology cuts (currently used @ Level-2)
- Replace the Common Merging Modules (optical connectivity)
- Add a new hardware element: Topological Processor
- Upgrade the Central Trigger Processor (optical connectivity and more resources)

See also the talk of Riccardo Vari, UPG2-2, "Upgrade project and plans for the ATLAS detector and trigger"

CTP Resource Utilisation

What	Used	Available
CTPIN input cables (partially used)	9	12
CTPIN input signals*	212	372
CTP PIT bus lines	160	160
CTPCAL calibration request **	1	19
CTPCORE trigger items	241	256
CTPCORE bunch groups	8	8
CTPCORE maximum number of AND terms ***	6	256
CTPCORE maximum number of bits in OR terms	6	12
CTPOUT output cables to TTC partitions	20	20
CTPIN integrating monitoring counters	138	768
CTPMON per-bunch monitoring counters	88	160
CTPCORE per-bunch trigger item counters	12	12

* = dedicated patch of CTPIN firmware to reduce 16 MBTS signals to 3-bit value, and some input signals are only used for CTPIN monitoring

** = only TILE sub-detector

*** = always two terms are used for bunch groups

ATLAS Phase-0 upgraded Level-1 Trigger

The main requirement is to provide optical connectivity for the TP to apply topological cuts, double the CTP trigger input (and trigger items) and add secondary trigger partitions.

Phase-0 upgrade CTP features

- Current CTP functionalities
 - Receives and aligns trigger inputs and produces trigger menu items
 - Forms the Level-1 decision and generates dead-time (L1A generation)
 - Monitors input trigger rates and applies pre-scaling and veto
 - Receives timing signals (BC, ORBIT) from the LHC
 - Sends RoI information to LVL2, and read-out data to DAQ
 - Distributes timing signals and trigger decision to all sub-detectors
- CTP new features
 - Increase resources (trigger inputs and trigger items)
 - Optical inputs to connect to Topo Processor (and MUCTPI)
 - Improved bunch group masking/monitoring (i.e. "collision bunch group" contains the BCIDs of colliding bunches)
 - Allow partitioning of Level-1 Accept generation for detector commissioning
 - CTP upgrade requires complete redesign of several modules

Phase-0 upgrade CTP Specification

- 320 trigger inputs on PIT bus backplane (now 160)
- 512 trigger items (now 256)
- 12 optical inputs using ribbon-fiber receiver
- Avago MiniPOD for compatibility with Topo Processor
- 16 bunch groups (now 8)
- 256 per-bunch counters for trigger item monitoring (now 12)
- 4 trigger partitions
 - Common trigger menu
 - Each L1A partition has selection of trigger items, and it's own deadtime handling
 - Only primary L1A partition (i.e. "physics partition") provides LVL2 and DAQ readout
 - Secondary L1A partitions used for detector commissioning, calibration, etc.

Phase-0 Topological Processor

- The Topological Processor is a new element in the trigger
- Allow for any conceivable topological algorithm
- Route a maximum fibre count / data volume into individual module / processor
 - Electrons, tau, jets, MET : 553 Gb/s
 - Muons 267 Gb/s
 - Total aggregate bandwidth 820 Gb/s
 - Achievable at 6.4Gb/s line rate
- Design
 - Fully ATCA compliant
 - Optical input from the backplane via blindmate connectors
 - High-density midboard o/e converters (AVAGO miniPOD)
 - Keep compact, with short traces and no on-board signal duplication
 - FPGA based processors (Xilinx Virtex7 XC7V485T initially)
 - Output from opto links on the front panel to the CTP

CTPCORE++ and TP modules

TP Functional Demonstrator "GOLD"

- ATCA form factor
- Input from the backplane to opto-mezzanine
- 10Gb/s (up to) AVAGO o/e converters
- High performing FPGAs (XC6VLX240T) with multiple 6.4 Gb/s transceivers
- Output from opto links on the front panel
- An useful "gym" for testing technology needed for the TP

Tests performed on "GOLD"

- Initial verification of clocks and boundary scans
- Full data path between FPGAs - o/e converter loopback and Bit Error Rate scan
- Check of signal integrity ("Eye diagrams")
- Measured error free time regions ("Bathtub profiles")
- Achieve optimization of the transceivers parameters
- Latency measurements
- Logic utilization by algorithms

Test results of the full data path at 6.4 Gb/s

- Full real time data path working at required speed

Summary

- Central Trigger Processor Phase-0 upgrade
 - Double the number of trigger inputs (160 $\rightarrow$ 320)
 - Double the number of trigger items (256 $\rightarrow$ 512)
 - Secondary trigger partitions for detector commissioning
 - Design review Sep/Oct 2012
 - First prototype in Q1 2013
 - Aim to be ready in 2014 ATLAS combined cosmics running
- Topological Processor
 - Allow to apply topological cuts at Level-1
 - Large physics potential and many simulation studies carried out
 - Design review today
 - First prototype in Q2 2013 (well in line with CTP)
 - Large campaign of tests successful performed on the TP functional demonstrator "GOLD"
 - Aim to be ready in 2014 ATLAS combined cosmics running