The ATLAS
Level-1 Central Trigger

R. Spiwoks¹, S. Ask², D. Berge¹, D. Caracinha¹,³, N. Ellis¹,
P. Farthouat¹, P. Gallno¹, S. Haas¹, P. Klofver¹, A. Krasznahorhay¹,⁴,
A. Messina¹, C. Ohm¹, T. Pauly¹, M. Perantoni⁵,
H. Pessoa Lima Jr.⁵, G. Schuler¹, J. M. de Seixas⁵, T. Wengler²

¹) CERN, Switzerland
²) University of Manchester, UK
³) University of Lisbon, Portugal
⁴) University of Debrecen, Hungary
⁵) Federal University of Rio de Janeiro, Brazil
Outline

• Introduction

• Level-1 Central Trigger:
  – Muon-to-Central Trigger Processor Interface (MUCTPI)
  – Central Trigger Processor (CTP)
  – Local Trigger Processor (LTP) and Local Trigger Processor Interface Module (LTPIM)

• Commissioning & Results:
  – Setup
  – Software
  – Results

• Summary
General-purpose Experiment at CERN’s Large Hadron Collider (LHC):
Proton-proton collisions at 14 TeV centre-of-mass energy
About 25 collisions per bunch crossing (BC) every 25 ns (40 MHz)
⇒ Interaction rate of 1 GHz
Installation of the 2nd end-cap toroid magnet in July 2007
Trigger/DAQ System

Interaction rate
~ 1GHz
Bunch crossing rate 40 MHz

Level-1 Trigger:
Electronics + Firmware

Level-2 Trigger + Event Filter:
Computers + Networks + Software

Available Time

2.5 μs
75 kHz
Level-1 Trigger

~ 40 ms
2 kHz
Event Filter

~ 4 s
200 Hz

Rate

Data recording
Level-1 Trigger System

Calorimeter Detectors
- Pre-processor
  - Cluster Processor (e/\gamma and \tau/h)
  - Jet/Energy Processor (jets & energy)

Muon Detectors
- Barrel Muon Trigger (RPC)
- End-cap Muon Trigger (TGC)

Central Trigger Processor (CTP)
- Muon-CTP-Interface (MUCTPI)

LTPIM - Local Trigger Processor Interface Module
TTC - Timing, Trigger, and Control
BUSY - Tree of ROD_BUSY Modules

ATLAS has about 40 TTC Partitions
Functionality:

- **Receive all muon candidates from 208 trigger sectors and calculate multiplicities for 6 programmable $p_T$ thresholds** (results sent to CTP)

- **Resolve cases where a single muon traverses more than one sector** ⇒ avoid double counting

- **Send summary information to Level-2 and to DAQ** ⇒ identify regions of interest for Level-2 trigger processing

- **Take snapshot of incoming sector data (diagnostics); accumulate rates of incoming muon candidates (monitoring)**
• MIOCT - Octant module
  – Receive muon candidates from muon trigger sector logic
  – Resolve overlaps

• MIBAK - Backplane
  – Multiplicity summing
  – Readout data transfer
  – Timing signal distribution

• MICTP - CTP interface
  – Multiplicity output to CTP
  – Trigger & timing signals

• MIROD - Readout driver
  – Send summary information to Level-2 and DAQ
• **Prototype installed since 2005**
  – Provides almost full functionality
  – Missing some flexibility in overlap handling (MIOCT)
  – Being upgraded incrementally to the final system

• **MIOCT:**
  – Input module for one octant. Two old and one new MIOCTs installed
  – Currently 10 muon sectors (out of 208) are connected

• **MICTP:**
  – Timing distribution and trigger (muon multiplicities)
    output to CTP

• **MIROD:**
  – Output to Level-2 and DAQ using an old version of S-Link readout link (ODIN)
  – Will be replaced soon with ATLAS standard version of S-Link readout link (HOLA)

• **MIBAK:**
  – Custom active backplane for multiplicity summation and readout
MUCTPI (4)

New MIOCT Design for more flexible overlap handling:

- Prototype has been tested and is being used in the experiment
- Final production (34 modules) expected for September 2007

→ See poster by S. Haas
New MIROD/CTP Design:

• **Old MIROD was developed for old version of S-Link readout link (ODIN)**
  
  Can use newer ATLAS standard version of S-Link readout link (HOLA) with adapter card
  
  But requires more space of an additional VMEbus slot space which in the final system will be occupied by a MIOCT module
  
  ⇒ **New MIROD design with HOLA S-Link cards**

• **More recent FPGA technology**
  
  ⇒ Migrate original design into single FPGA

• **Same PCB as for MICTP**
  
  ⇒ Additional spare modules for MICTP
Functionality:

- Receive, synchronize, and align trigger inputs from calorimeter and muon trigger and others
- Generate Level-1 Accept (L1A) according to programmable trigger menu
- Additional functionality:
  - Generate trigger-type word accompanying every L1A
  - Generate preventive dead-time in order to prevent front-end buffers from overflowing
  - Generate summary information for Level-2 and DAQ
  - Generate a precise absolute time stamp (GPS, 5 ns)
  - Generate additional timing signals (ECR)
- Take snapshot of incoming trigger inputs (diagnostics); accumulate rates of incoming trigger inputs and generated trigger combinations (monitoring)
CTP (2)

- **CTPMI - Machine interface**
  - Receive timing signals from LHC

- **CTPIN - Input module**
  - Receive trigger input signals
  - Synchronize and align signals

- **CTPMON - Monitoring module**
  - Bunch-per-bunch monitoring

- **CTPCORE - Core module**
  - Form Level-1 Accept (L1A)
  - Send summary information to Level-2 and DAQ

- **CTPOUT - Output module**
  - Send timing signals to LTPs
  - Receive calibration requests

- **CTPCAL - Calibration module**
  - Time-multiplex calibration requests
  - Receive front-panel inputs
CTP (3)

- Final system installed since 2006
- **CTPMI:**
  - Clock and orbit input
- **3 × CTPINs**
  - For up to 12 trigger input cables
- **CTPMON:**
  - Monitoring of trigger input on bunch-per-bunch basis
- **CTPCORE:**
  - Trigger decision according to trigger menu
- **4 × CTPOUTs:**
  - For up to 20 outputs to sub-detectors
- **CTPCAL:**
  - Time-multiplexing of calibration requests
  - Additional individual trigger signals
- **NIM-to-LVDS fan-in module**
  - Additional individual trigger signals
CTP (4)

• Production problems overcome:
  – Problems with FPAG mounting on CTPIN and CTPCORE solved by remounting, all modules are working correctly

• Last module CTPCAL produced:
  – Time-multiplexing of calibration requests from sub-detectors, received by CTPOUT and put on CTPCAL backplane
  – 28 additional individual trigger inputs
  – CTPCAL was tested, installed, and two spares produced

• Two more complete systems available
  – in laboratory for spare and development (firmware modification and software development)

⇒ CTP hardware is finished

software development is well advanced, including issues such as monitoring and the luminosity block mechanism
LTP + LTPIM (1)

Functionality:

• **LTP:**
  - Connects to CTP
  - Allows to daisy-chain several LTPs
  - Replaces the CTP when in stand-alone mode: use local external signals or internal pattern generator

• **LTPIM:**
  - "Switch module" for LTP signals
  - 2 inputs (from CTP and from LTPIM)
    + local input (NIM)
  - 2 outputs (to LTP and to LTPIM)
    + local output (NIM)
  - Allows several combinations of sub-detectors to run and to change combinations without re-cabling, e.g. calorimeter and calorimeter trigger
LTP + LTPIM (2)

- Prototype has been tested
- Final production (34 modules) expected for October 2007

from CTP to LTP

from LTPIM

NIM input/output

to LTP

to LTPIM
Commissioning (1)

• **Program:**
  
  – **Routine use:**
    
    • MUCTPI and CTP are routinely being used since more than one year to provide triggers to an increasing number of sub-detectors
    
    • Mainly using muon triggers (barrel and end-cap) and CTP internal triggers; basic connection tests to calorimeter trigger have been performed
    
    • Trigger and timing signals are provided to 14 sub-detectors
  
  – **Several milestone weeks during 2007:**
    
    • "M4" week from 23 AUG - 3 SEP
Commissioning (2)

Experimental Setup:

• **Trigger inputs:**
  – Muon triggers to MUCTPI:
    • 4 × Barrel (RPC) sectors: 120 Hz
    • 6 × End-cap (TGC) sectors: ~ 1 Hz
  – Temporary hadron calorimeter cosmic trigger (< 1 Hz)
  – CTP internal triggers
  – Calorimeter trigger in preparation

• **Readout:**
  – Summary information of MUCTPI and CTP to Level-2 and DAQ

• **Timing distribution:**
  – To almost all sub-detectors (via LTP, \textit{LTPIM in preparation})
Commissioning (3)

- Run control
  + configuration database
    - "Plug-in" module for run control
    - Schema in configuration database
    - ATLAS graphical user interface

- Monitoring
  - Input rates, bunch-per-bunch rates, combined trigger rates, BUSY status, etc.
  - Bunch-per-bunch monitoring, thanks to H. Schoorlemmer, summer student
Commissioning (4)

Trigger Configuration

- **Trigger Database:**
  Stores *event selection strategy* (Level-1, Level-2, Event Filter),
  **Trigger Tool** is a Graphical User Interface to browse and edit all trigger menus

- **Trigger Menu Compiler:**
  Automatic translation of *high-level description* of Level-1 trigger menu to all necessary *configuration files* of the CTP:
  
  *Input:* XML (high-level description)  
  *Output:* VHDL (Switch Matrix)  
  + memory (LUT + CAM)

**Diagram:**
- **Pattern-In Time**
  - CTPIN Switch Matrix
  - CTPCORE
  - LUT
  - CAM
  - Configuration and memory files written by Trigger Menu Compiler

LUT - Look-up Table  
CAM - Content-Addressable Memory
Display of an event triggered by end-cap muon trigger with hits in muon precision chambers
Results (2)

- Events triggered by both, end-cap and barrel muon trigger, have hits in the muon precision chambers with characteristic muon TDC spectrum.
- Trigger from barrel muon trigger reaches the muon precision chamber front-end electronics 130 ns earlier trigger than from end-cap muon trigger.
Summary

• Hardware is finished or about to be finished
  – New MIOCT: prototype tested, final production under way
  – New MIROD/CTP: prototype under test
  – LTPIM: prototype tested, final production under way

• Complete trigger and readout chain is being operated in the experiment using cosmic rays

• Effort is moving towards exploitation and operation
  – Work on online and offline software, e.g. monitoring