The ATLAS Level-1 Central Trigger

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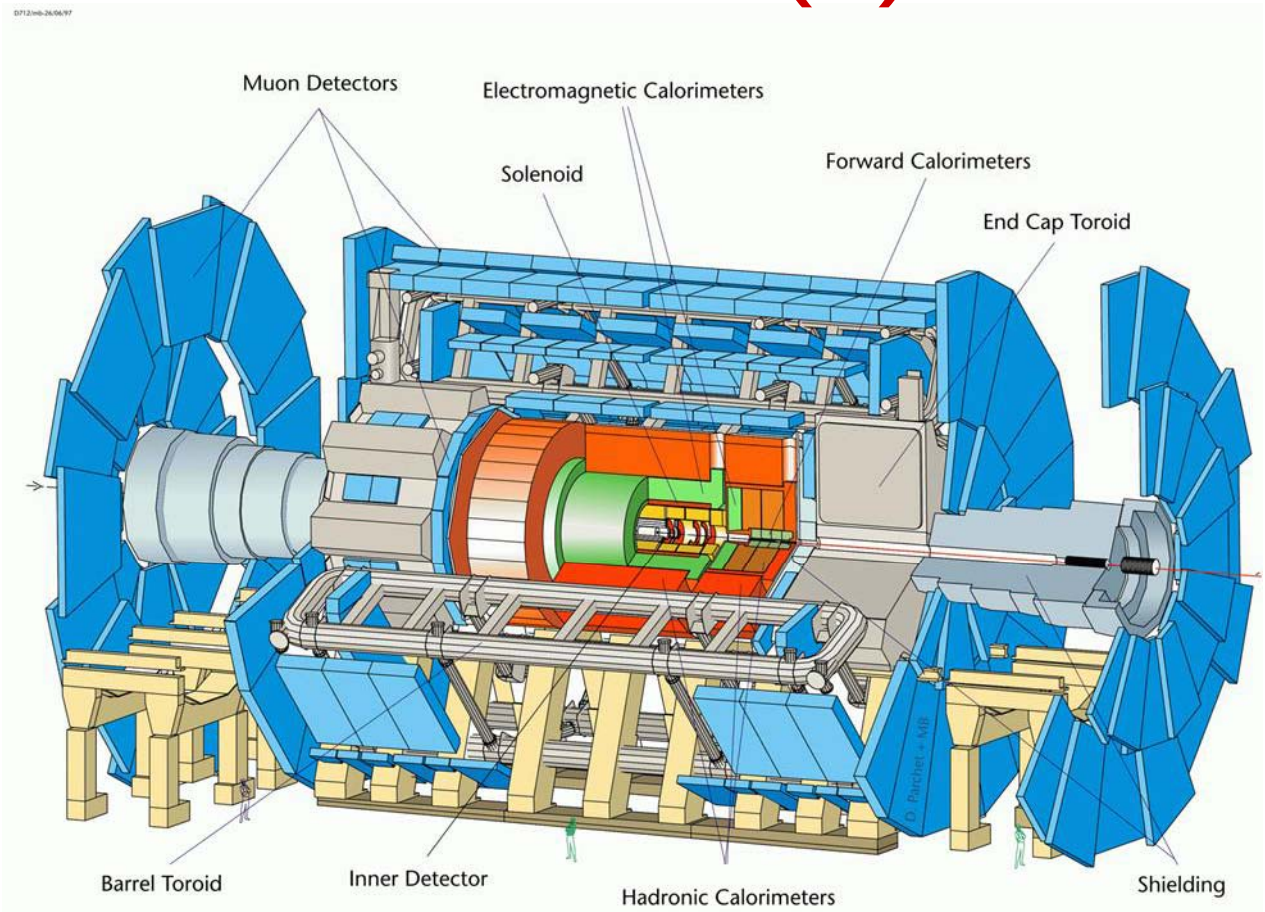
Outline

- **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**

ATLAS (1)



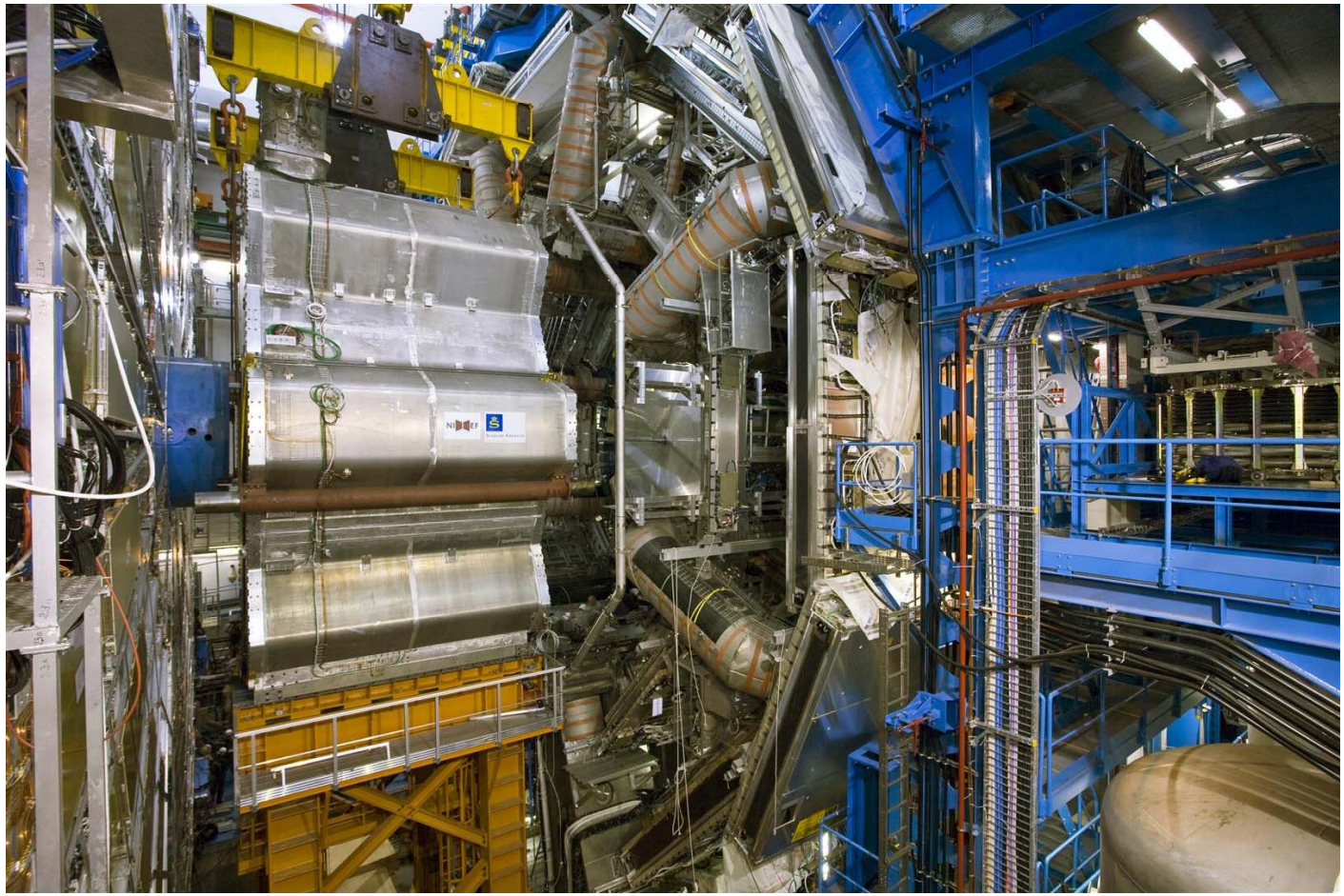
General-purpose Experiment at CERN's **Large Hadron Collider (LHC)**:

Proton-proton collisions at 14 TeV centre-of-mass energy

About 25 collisions per bunch crossing (**BC**) every 25 ns (40 MHz)

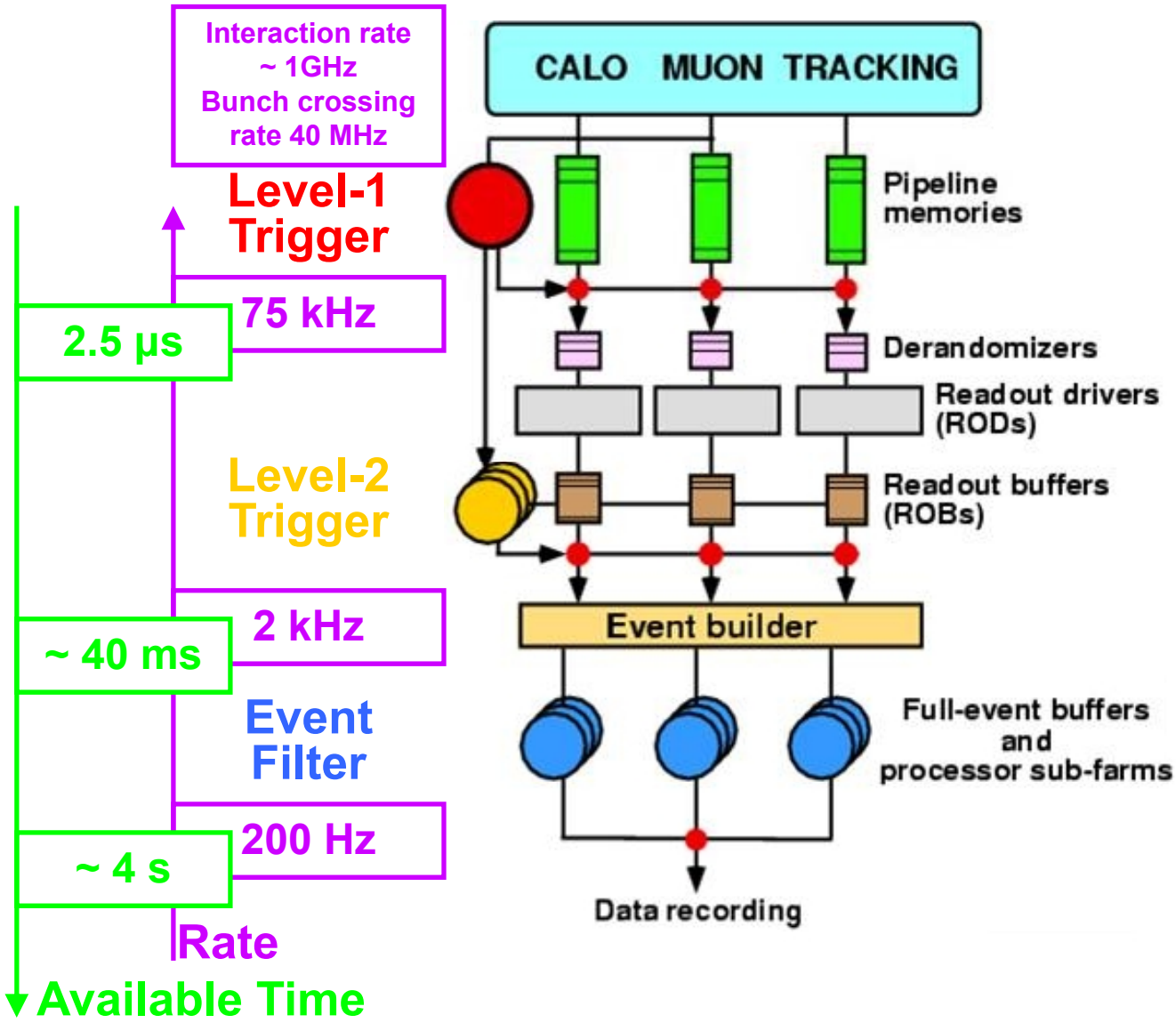
⇒ **Interaction rate of 1 GHz**

ATLAS (2)



Installation of the 2nd end-cap toroid magnet in July 2007

Trigger/DAQ System



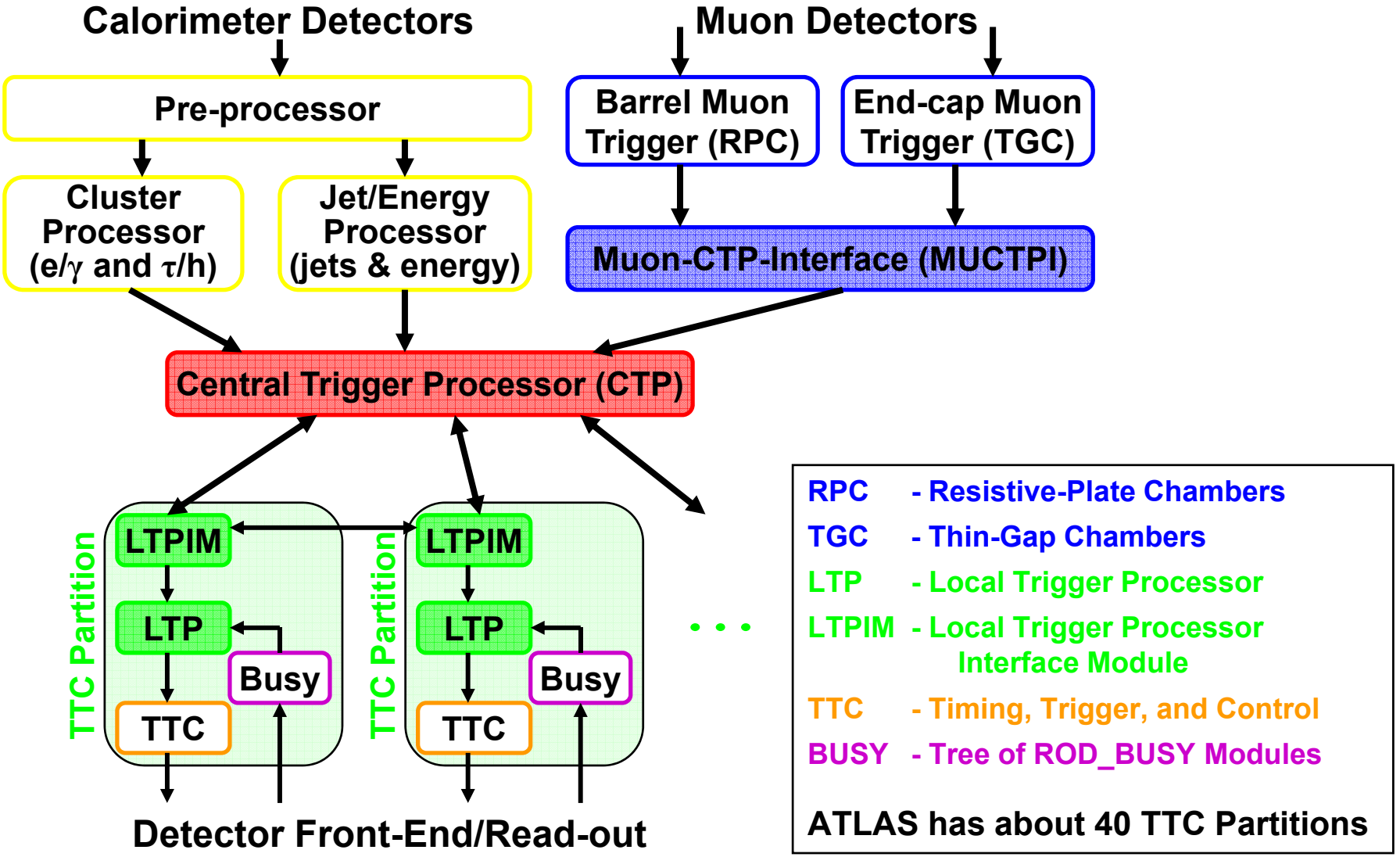
Level-1 Trigger:
Electronics + Firmware

Level-2 Trigger

+ Event Filter:

Computers + Networks + Software

Level-1 Trigger System



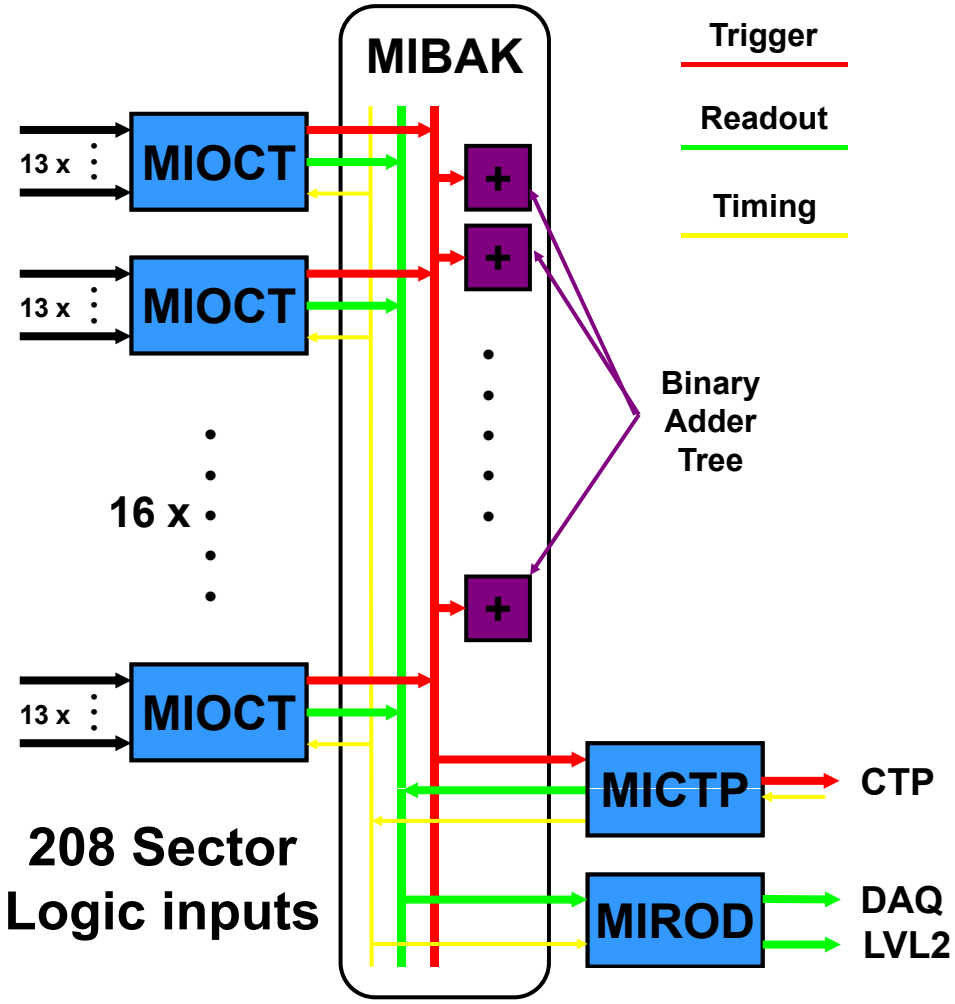
MUCTPI (1)

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**
  $\Rightarrow$ avoid double counting
- **Send summary information to Level-2 and to DAQ**
  $\Rightarrow$ identify regions of interest for Level-2 trigger processing
- **Take snapshot of incoming sector data (diagnostics); accumulate rates of incoming muon candidates (monitoring)**

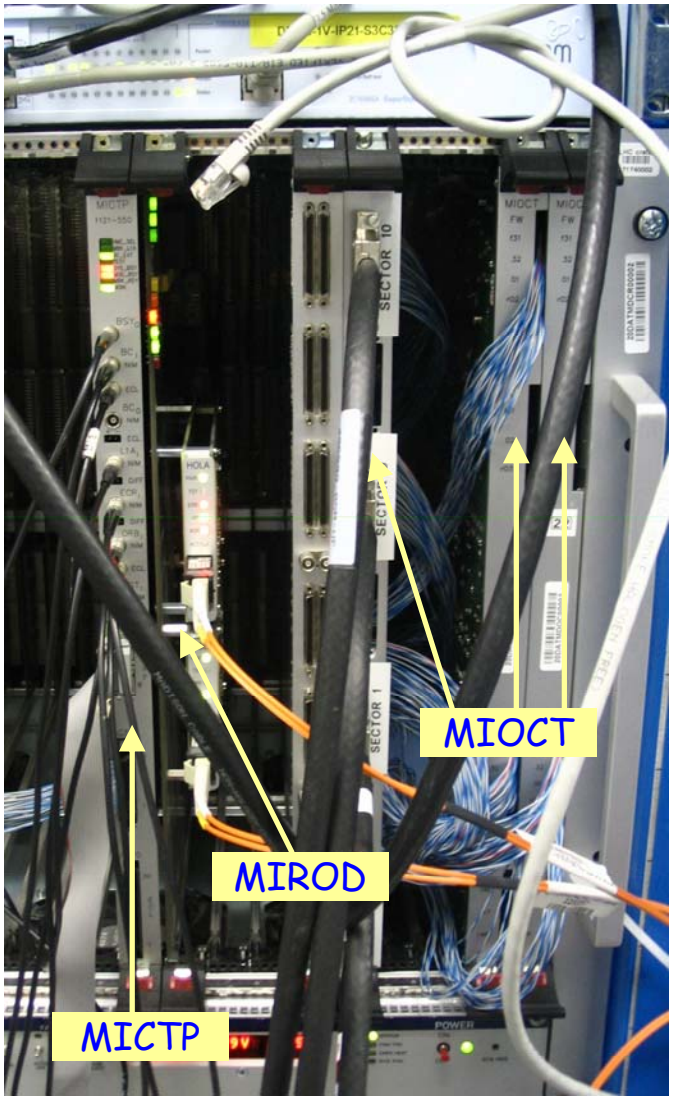
MUCTPI (2)

- **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



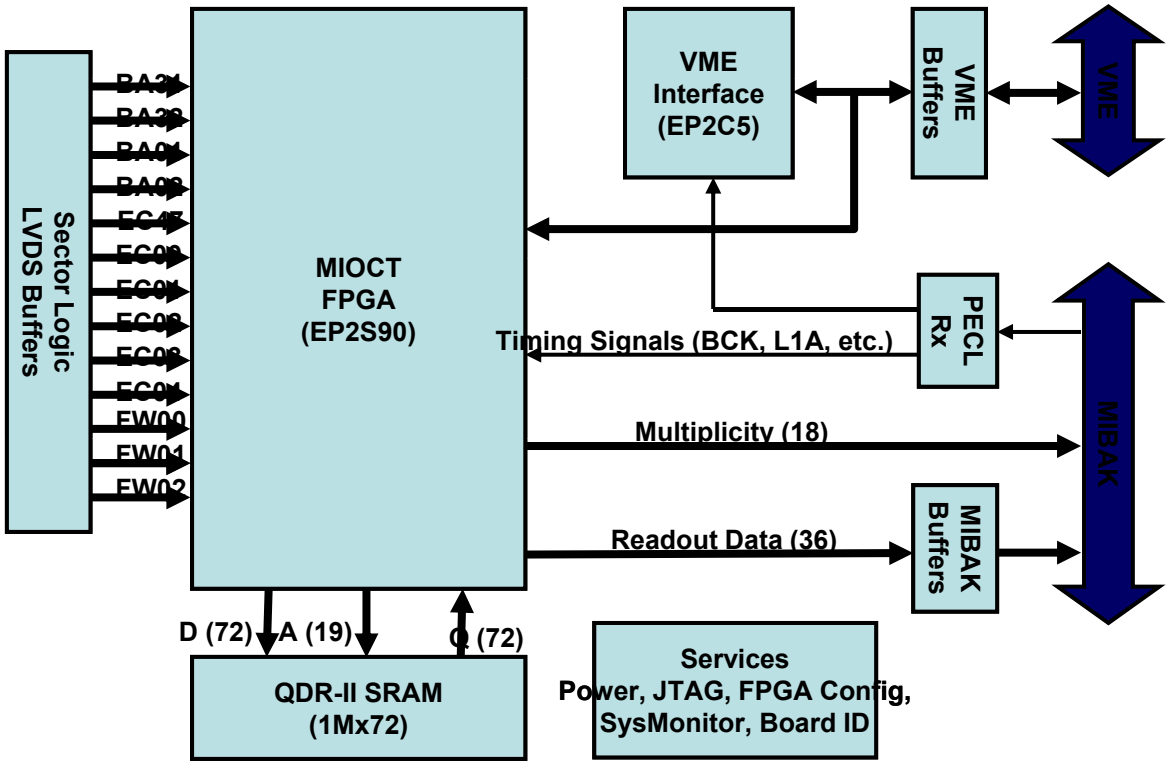
MUCTPI (3)

- **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

MUCTPI (5)

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**

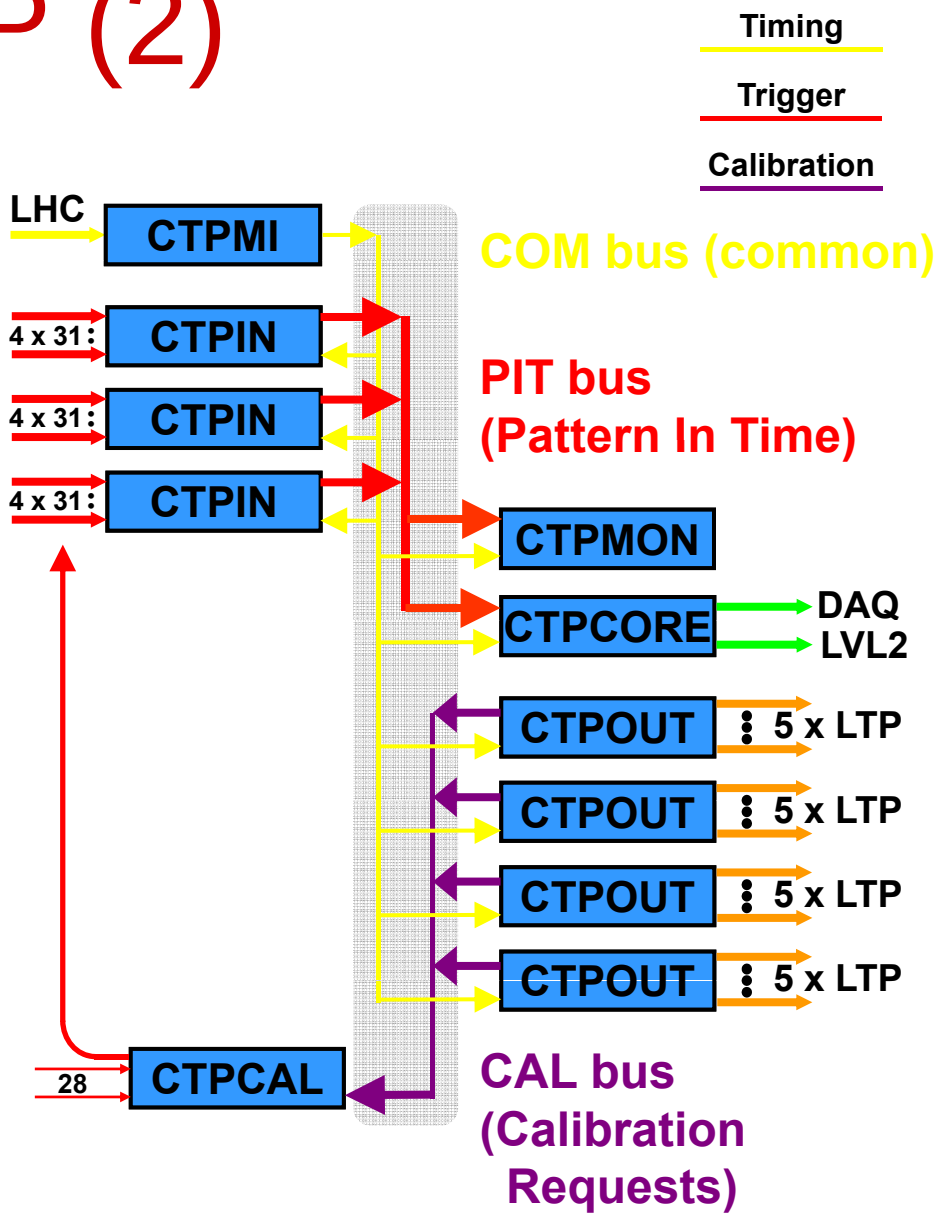
CTP (1)

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 snap shot of incoming trigger inputs (diagnostics); accumulate rates of incoming trigger inputs and generated trigger combinations (monitoring)**

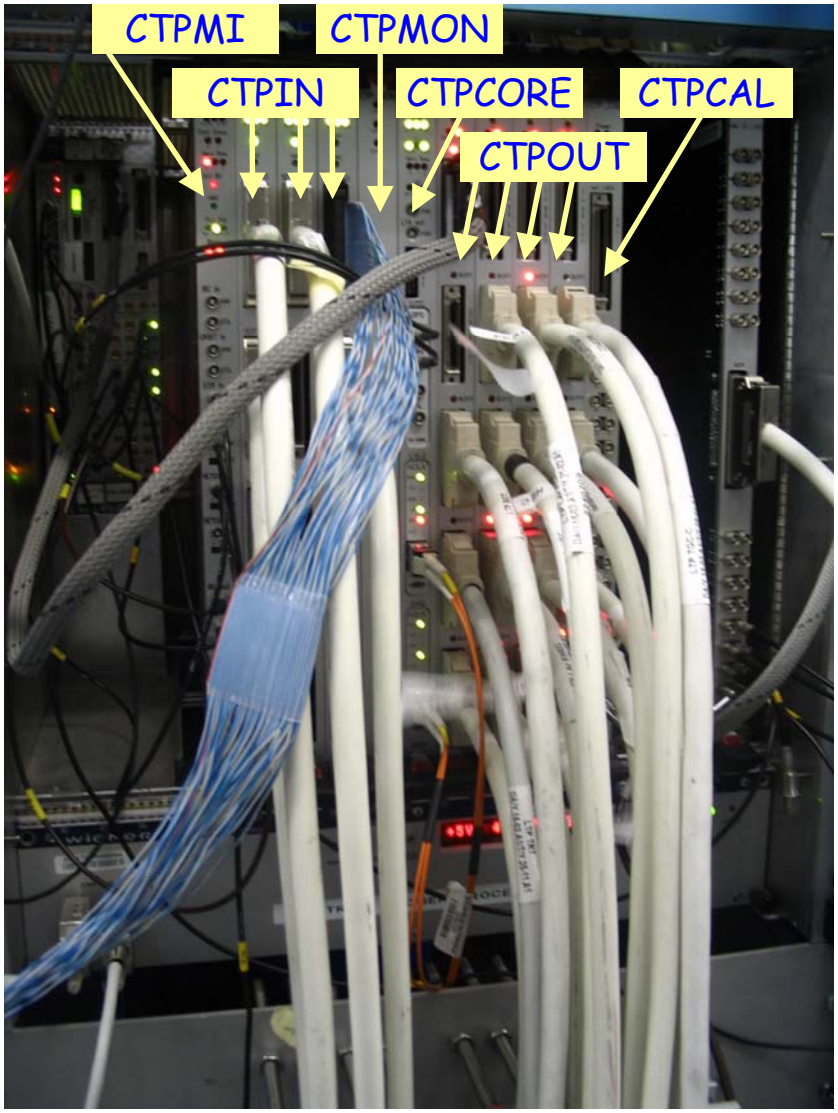
CTP (2)

- **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

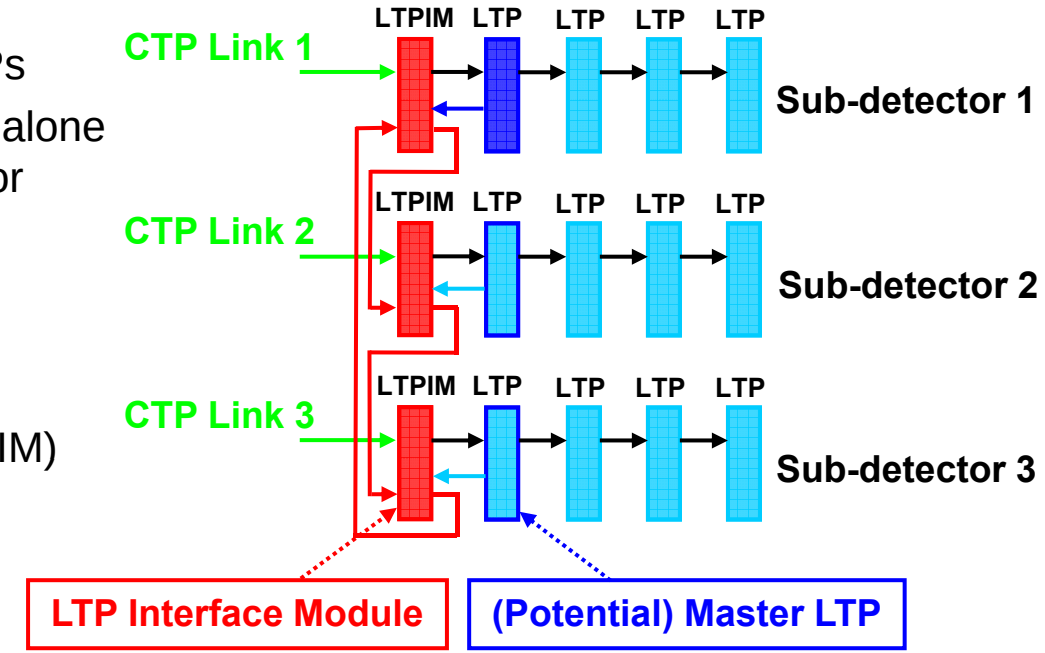
software development is well advanced, including issues such as monitoring and the luminosity block mechanism

LTP + LTPIM (1)

Functionality:

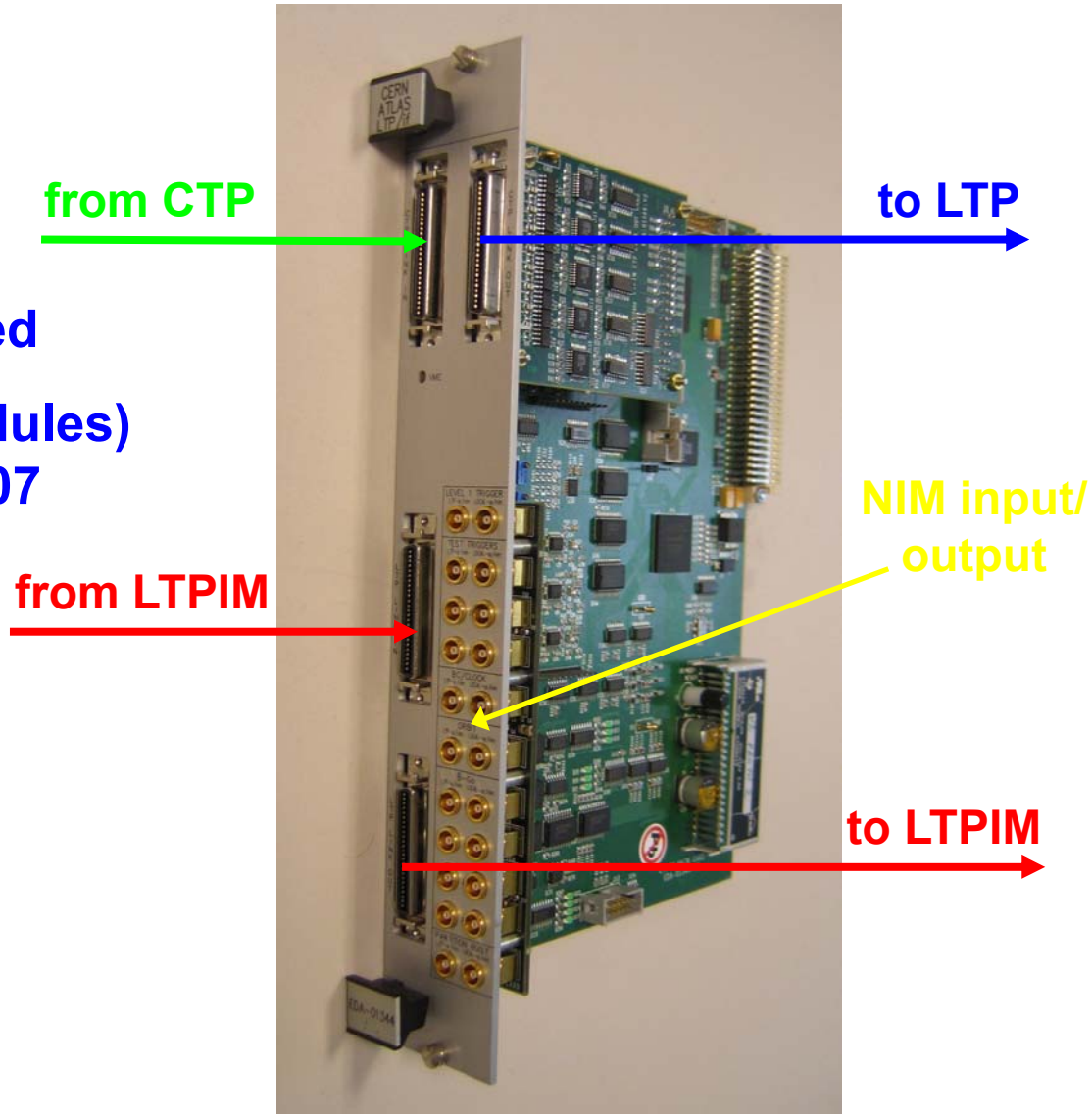
- **LTP:**
  - Connects to CTP
  - Allows to daisy-chain several LTPs
  - Replaces the CTP when in stand-alone mode: use local external signals or internal pattern generator
- **LTPIM:**
  - "Switch module" for LTP signals
  - 2 inputs (from CTP and from LTPIM)
    + local input (NIM)

    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**



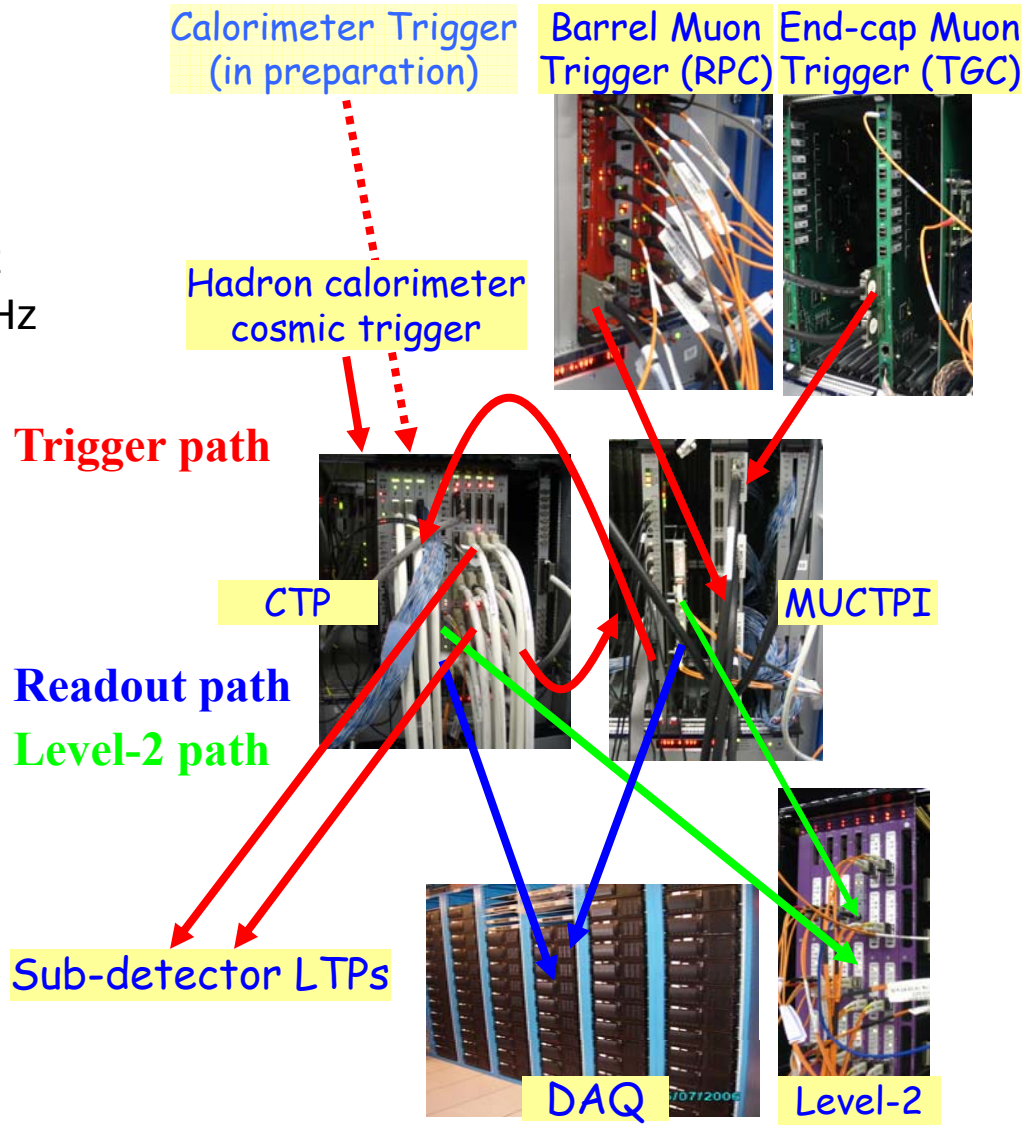
Commissioning (1)

- **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)

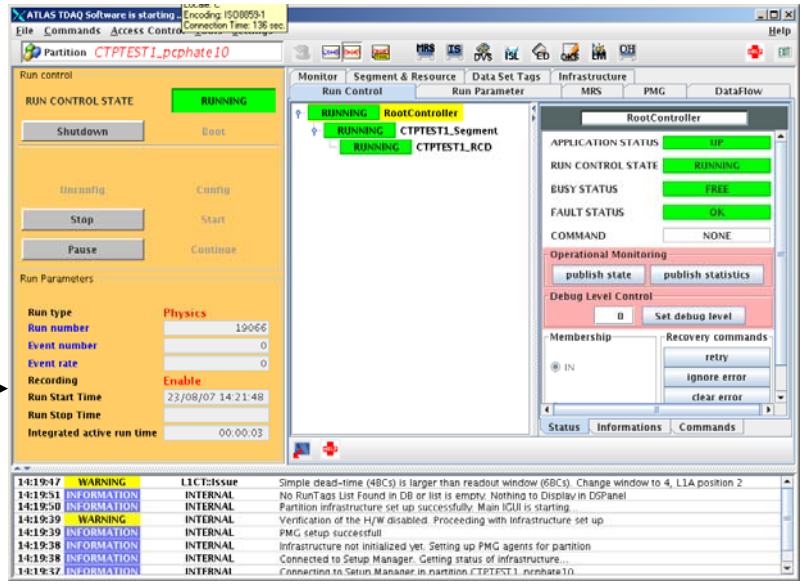
Experimental Setup:

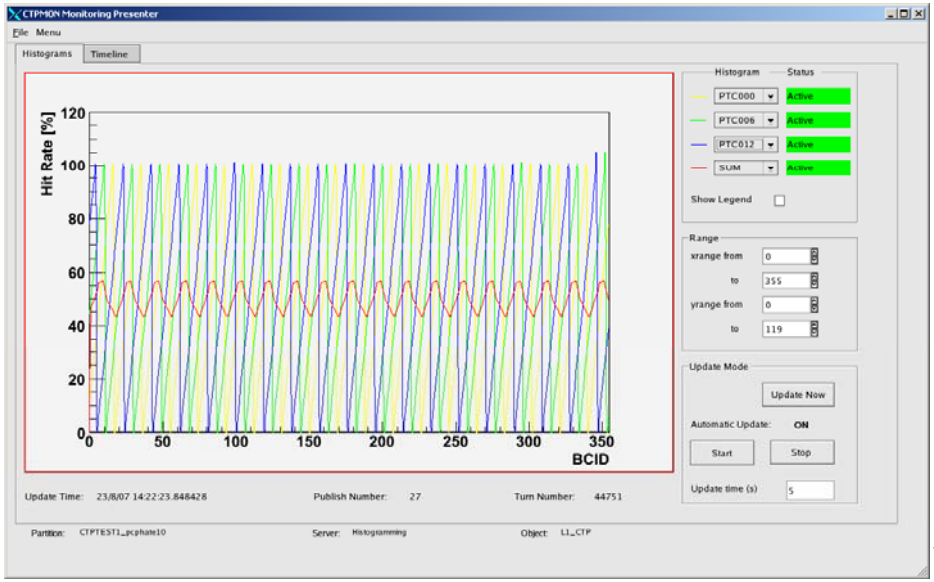
- **Trigger inputs:**
  - Muon triggers to MUCTPI:
    - 4 × Barrel (RPC) sectors: 120 Hz
    - 6 × End-cap (TGC) sectors: ~ 1 Hz
  - Temporary hadron calorimeter cosmic trigger (< 1 Hz)
  - CTP internal triggers
  - Calorimeter trigger in preparation
- **Readout:**
  - Summary information of MUCTPI and CTP to Level-2 and DAQ
- **Timing distribution:**
  - To almost all sub-detectors (via LTP, *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

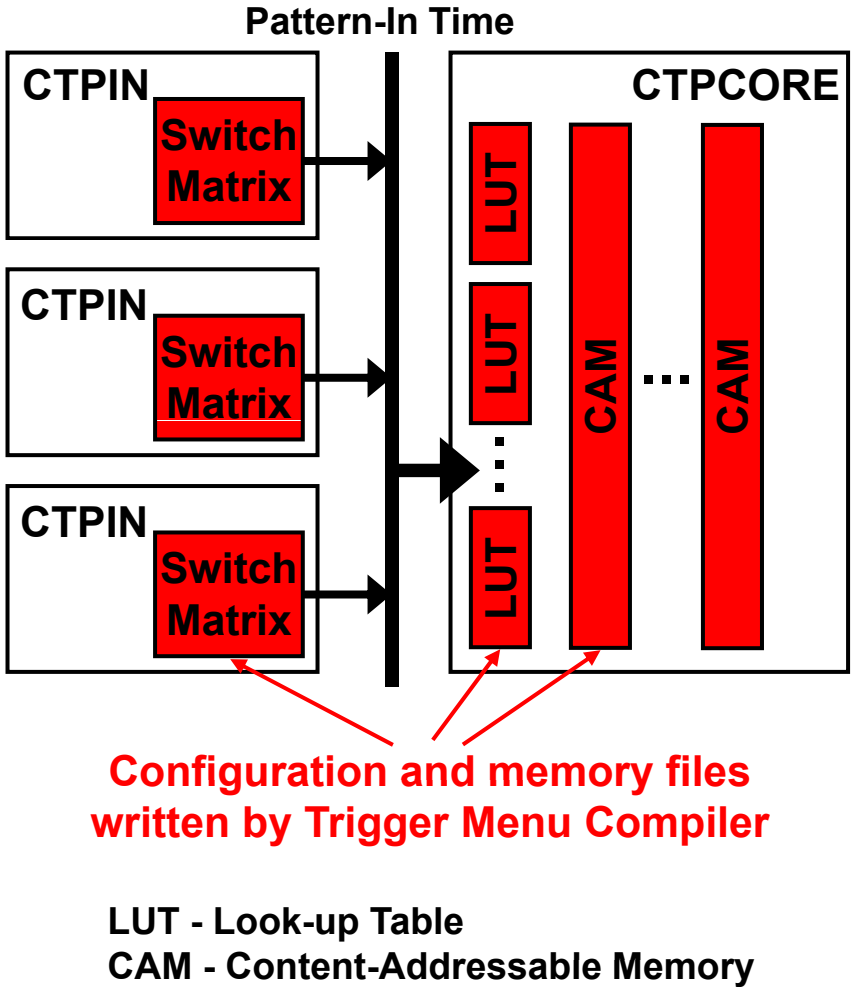
- **Trigger Database**:

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

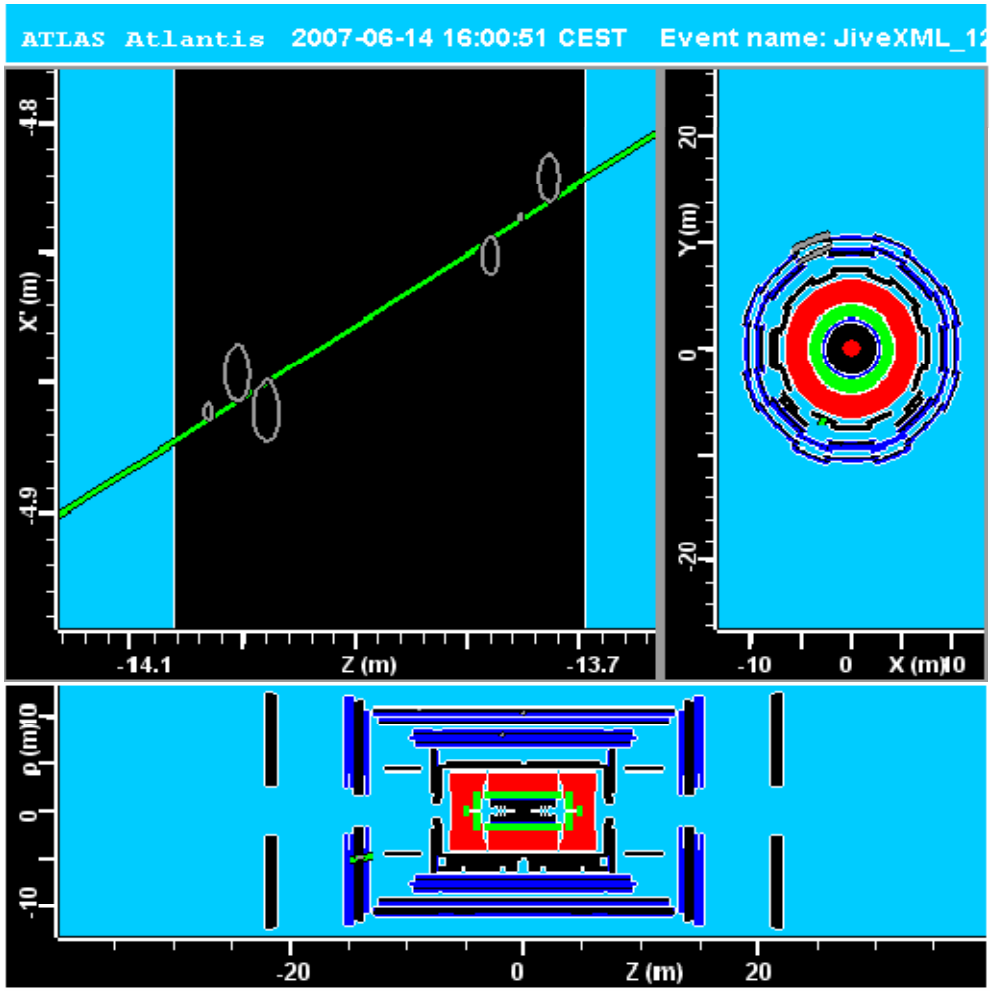
- **Trigger Menu Compiler:**

  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)

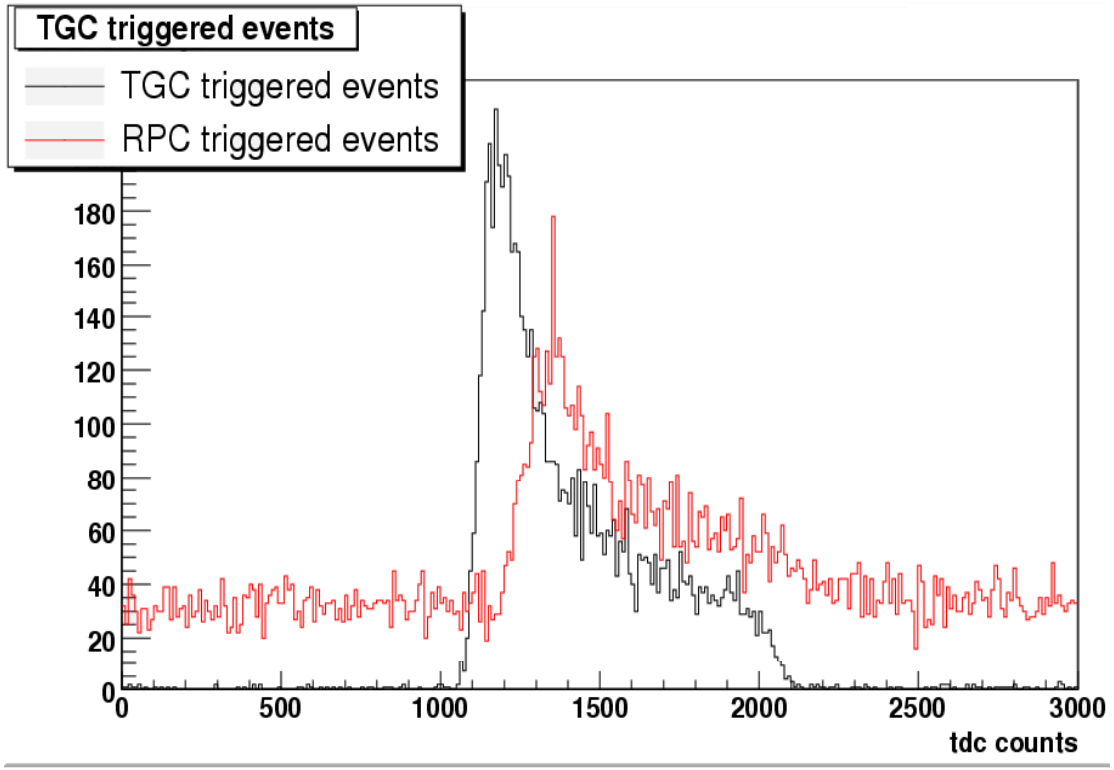


Results (1)



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**