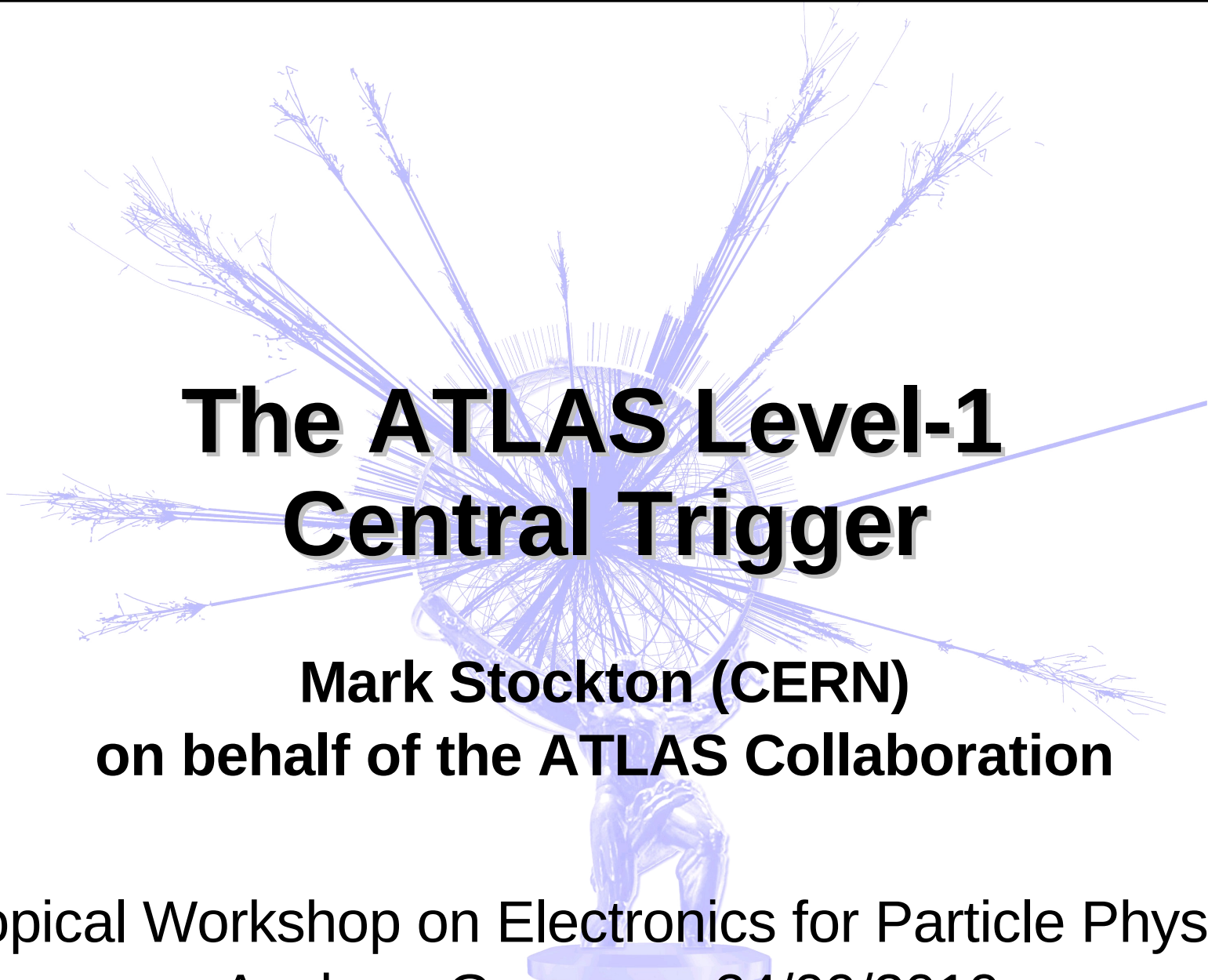
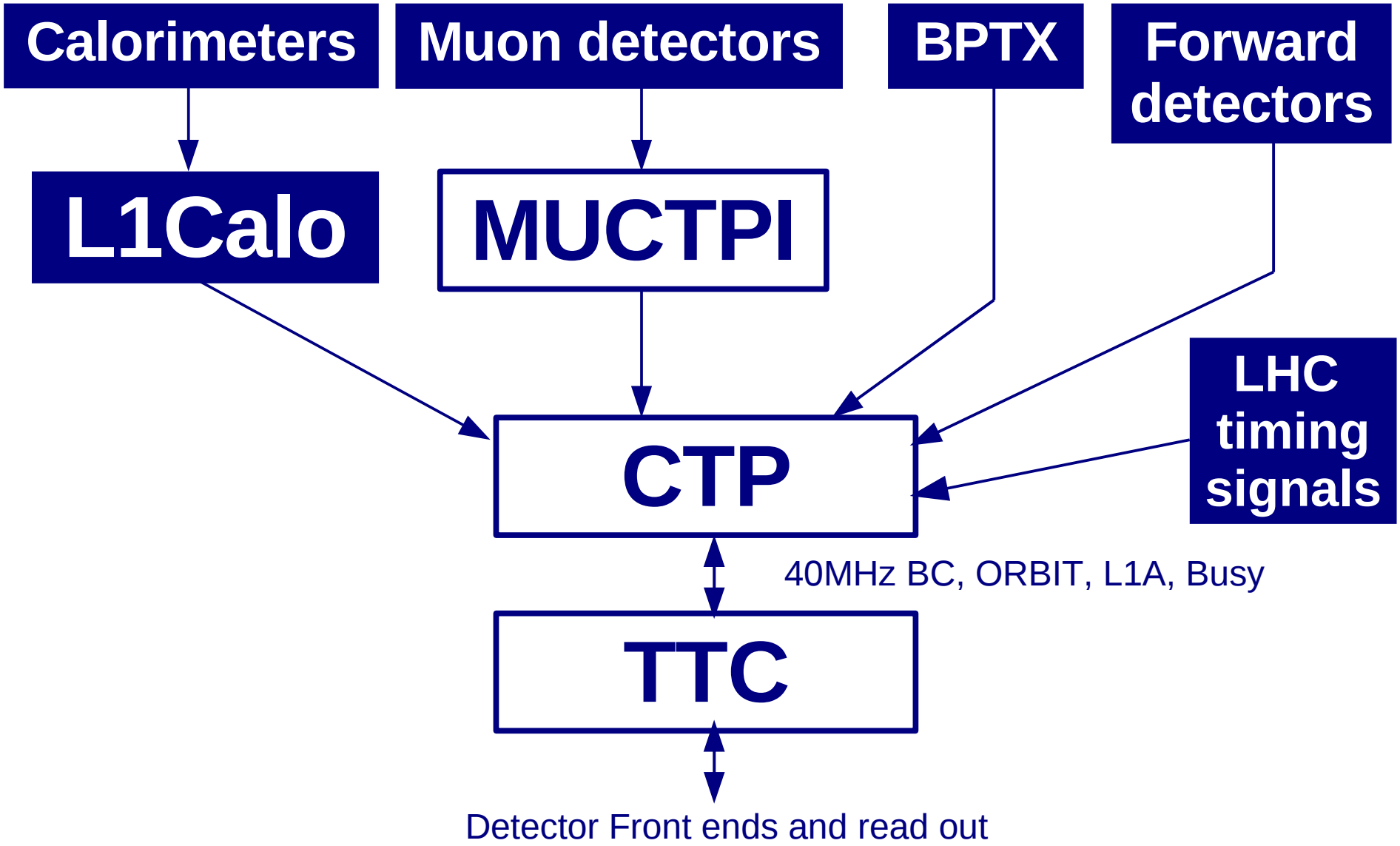


The ATLAS Level-1 Central Trigger

Mark Stockton (CERN)
on behalf of the ATLAS Collaboration

Topical Workshop on Electronics for Particle Physics
Aachen, Germany, 24/09/2010

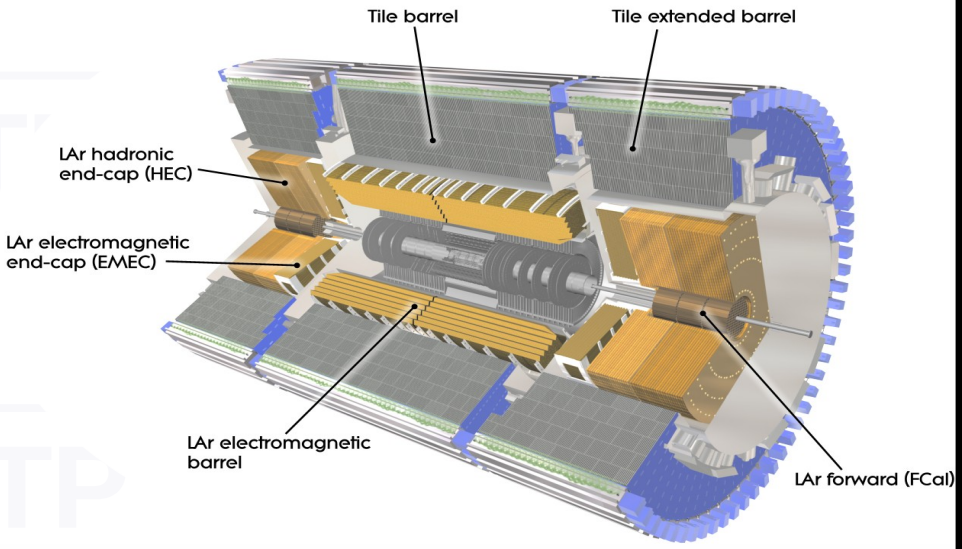


- Overview of the ATLAS Level 1 (L1) trigger

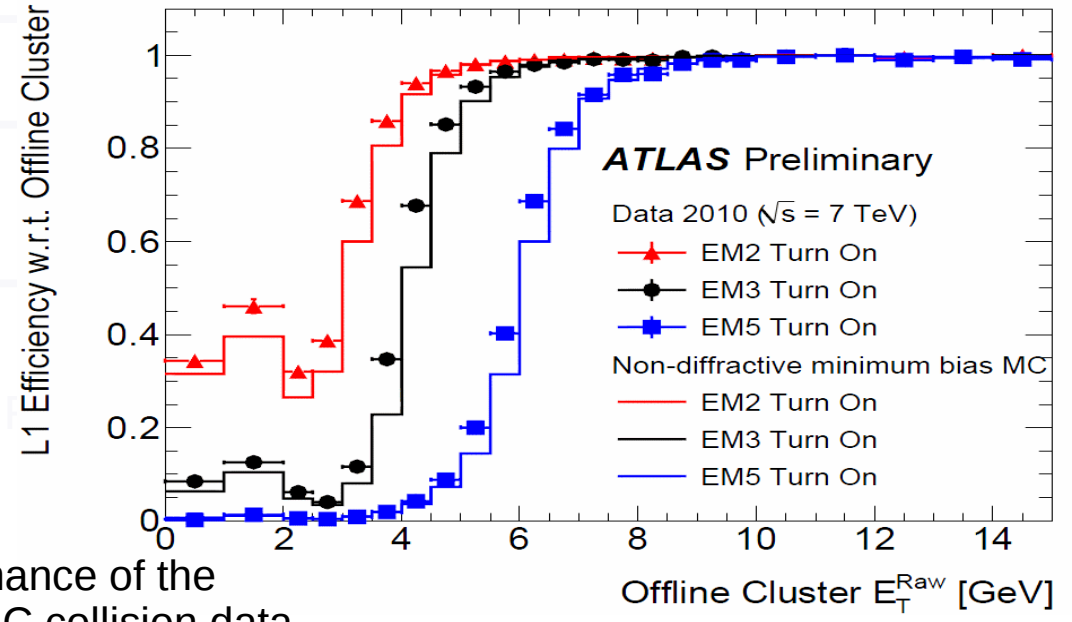
Calorimeters

L1Calo

- Split into electromagnetic and hadronic calorimeters (98.5% and 97.3% operational respectively)



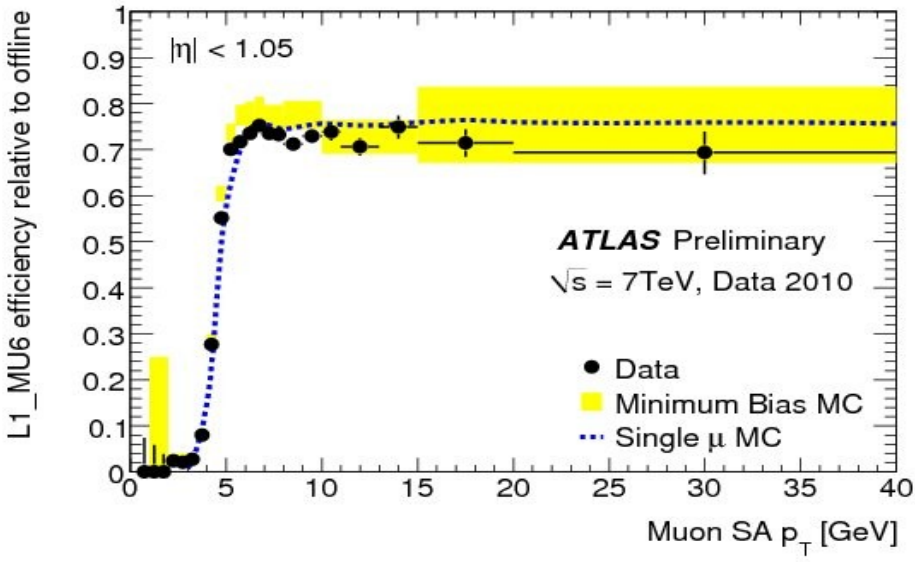
- Uses lower granularity cells to identify electrons, photons, single hadrons, jets and energy sums
- Commissioned with 99.9% of trigger towers operational

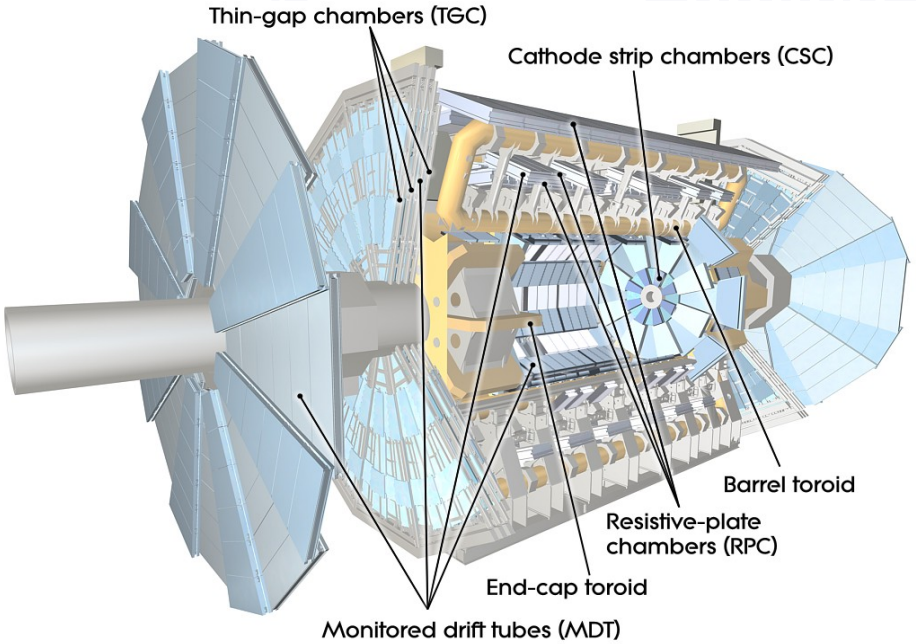


Also see talk by Juraj Bracinik: The performance of the ATLAS Level-1 Calorimeter Trigger with LHC collision data

Muon detectors

- Fast detectors are used for the L1 trigger:
- Resistive Plate Chambers: 97.0% operational, trigger 99.5%
- Thin Gap Chambers: 98.6% operational, trigger 100%
- Provide trigger candidates for different momentum thresholds



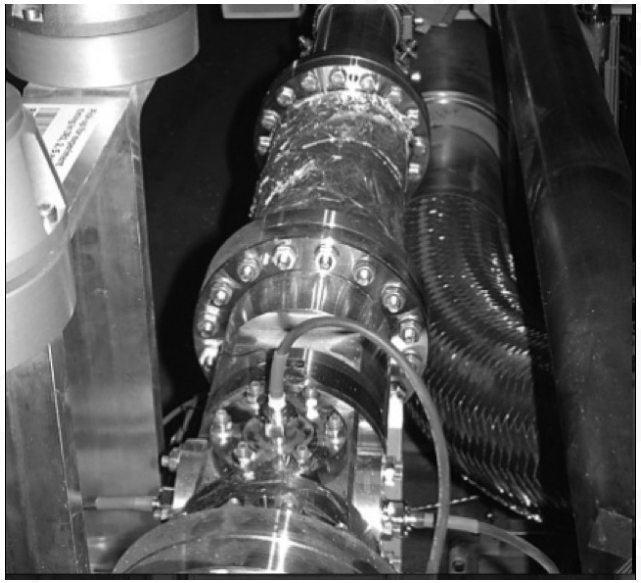


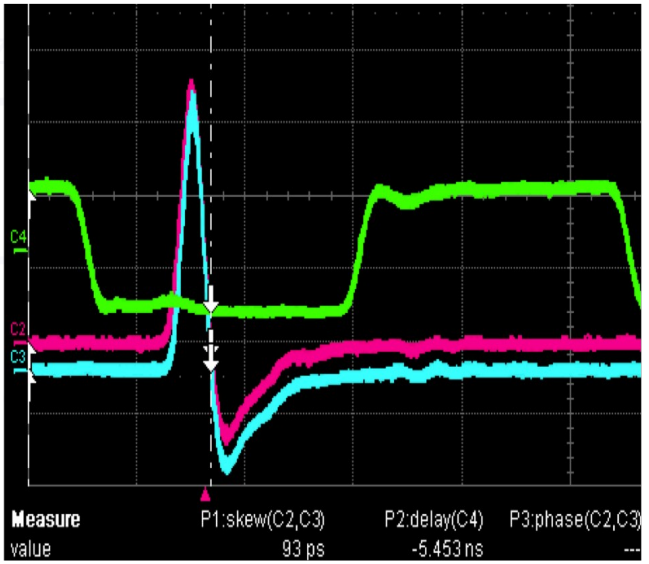
Also see poster by Takashi Hayakawa:
Detailed Performance Study of ATLAS Endcap Muon Trigger with Beam Collision Data

Beam Pick-ups

- Located 175m upstream of the interaction point
- Monitors the phase between the collisions and LHC clock, which drives the ATLAS electronics
- Originally used directly as beam triggers, now provides the LHC bunch crossing pattern used by the CTP (bunch groups)
- Monitored by a 600MHz scope with a sampling rate of 5GHz (e.g. first collisions beams blue and red with 25ns clock in green)

BPTX

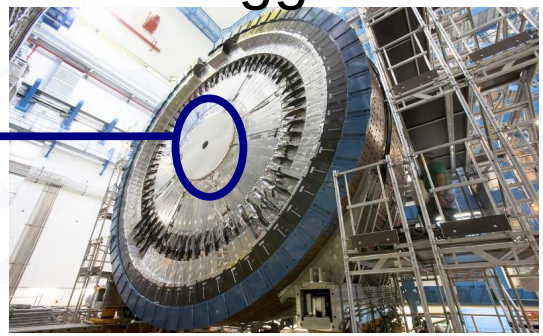


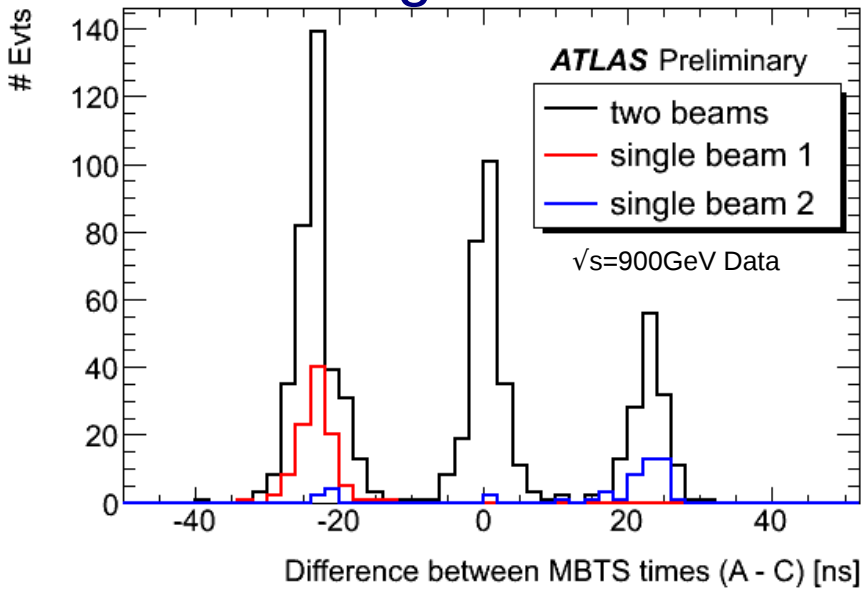


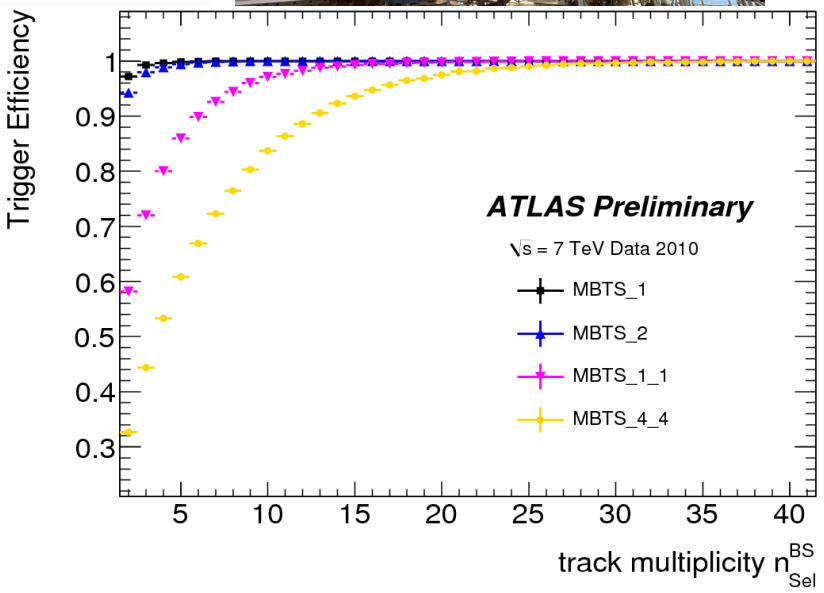
Also see talk by Thilo Pauly:
Performance of ATLAS detector and electronics under first beam conditions

Forward detectors

- Many other forward inputs:
  - Zero Degree Calorimeter,
  - Beam Conditions monitors,
  - MBTS (Minimum Bias Trigger Scintillators)
  - LUCID (LUminosity measurement using Cerenkov Integrating Detector)
- The MBTS is a relatively simple highly efficient trigger
- 2x16 scintillator pads installed in front of the LAr cryostat on both sides
- Hits on both sides gives handle on beam backgrounds

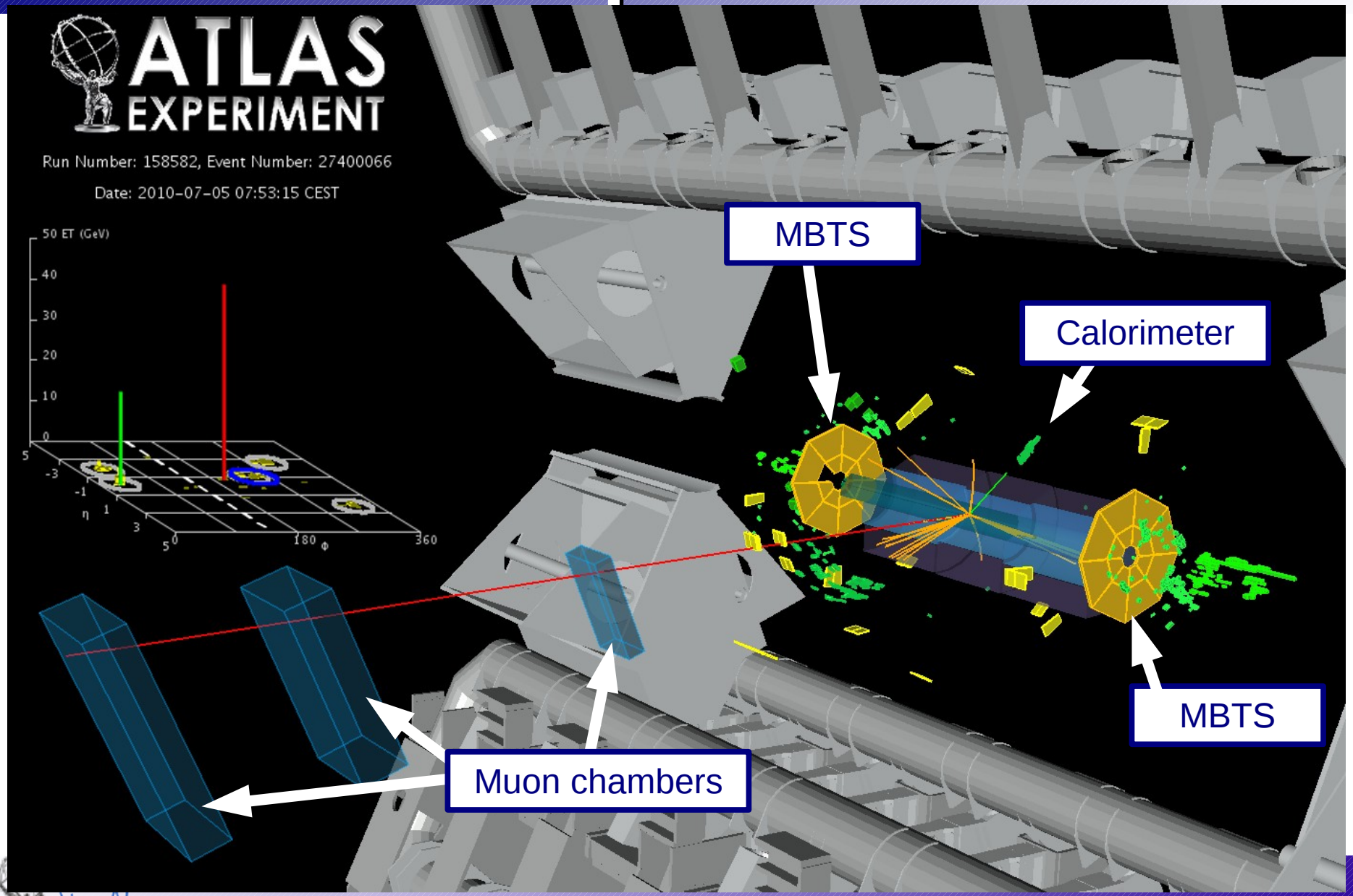






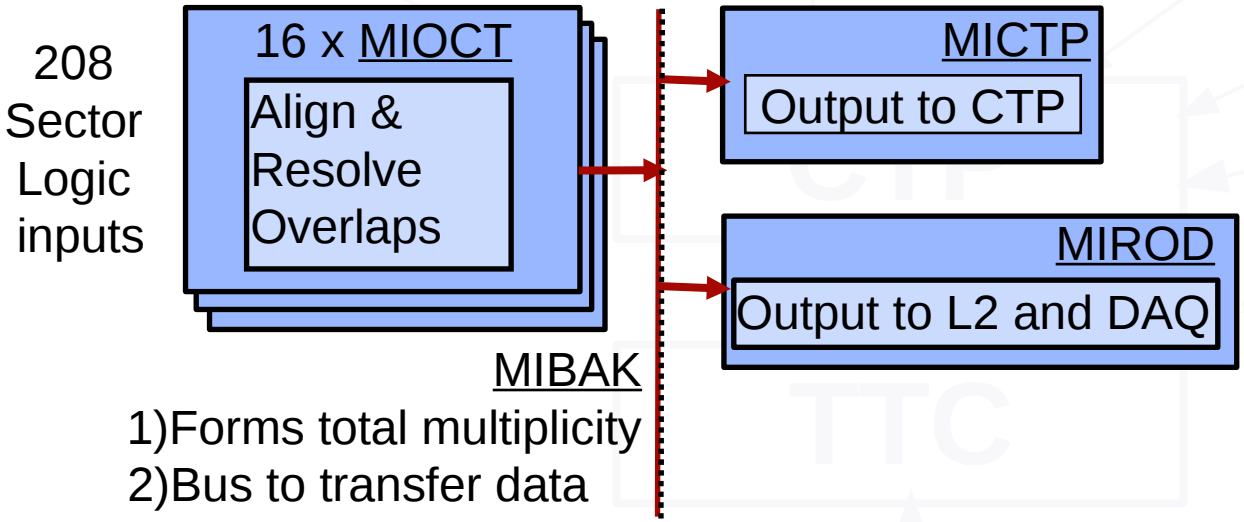
Also see poster by Tim Martin:
Development and Online Operation of Minimum Bias Triggers in ATLAS

All used in a top event candidate



Muon to CTP Interface

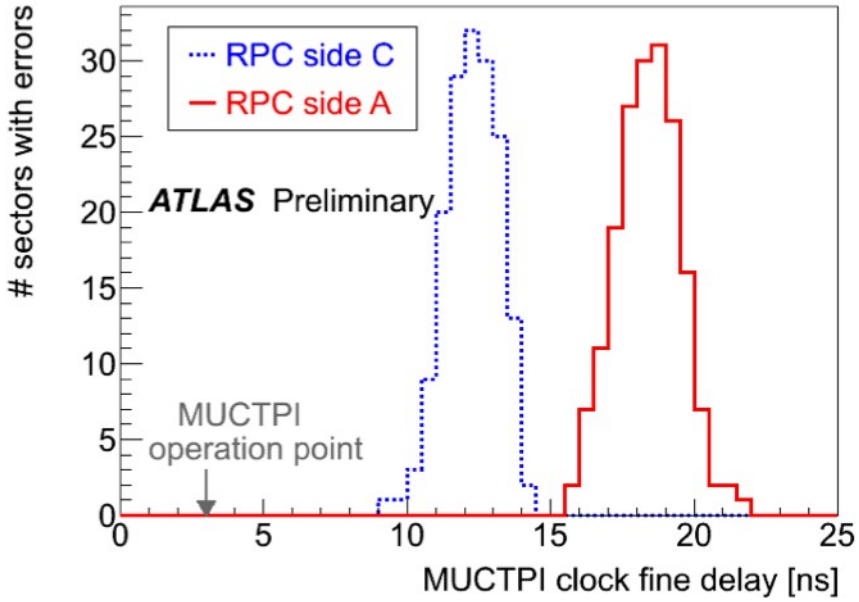
MUCTPI

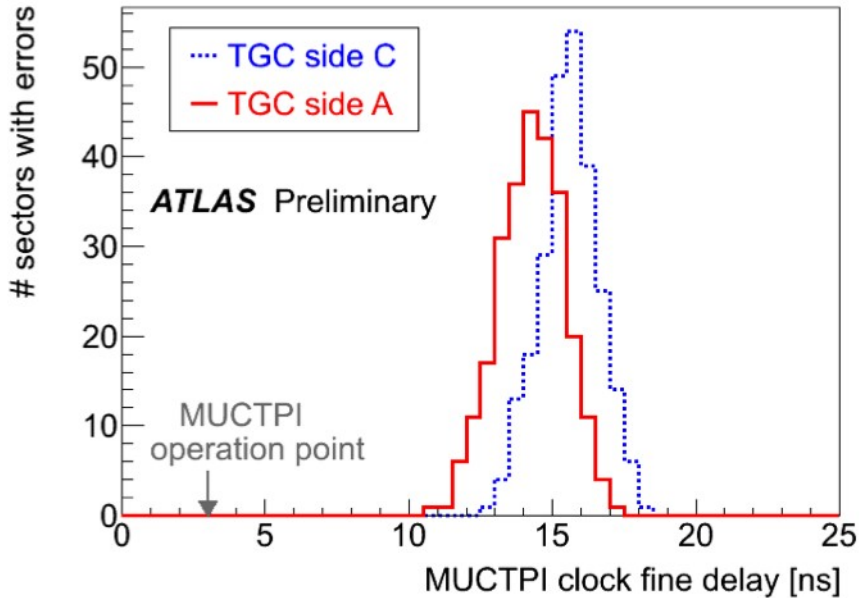


- Photo taken during installation at point 1

MUCTPI timing

- Result of a clock fine delay scan between MUCTPI and the muons trigger detectors
  - RPC (left) and TGC (right)
- Shows that at the current operating point (3ns) there are no transmission errors
  - They instead cluster further away with a width of around 5ns



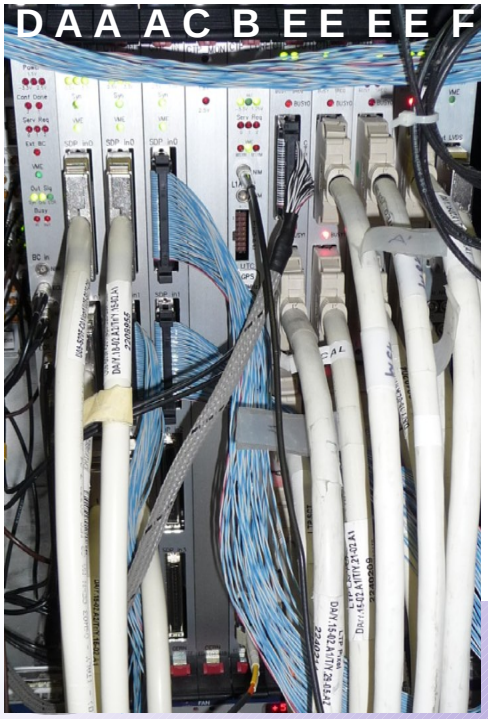


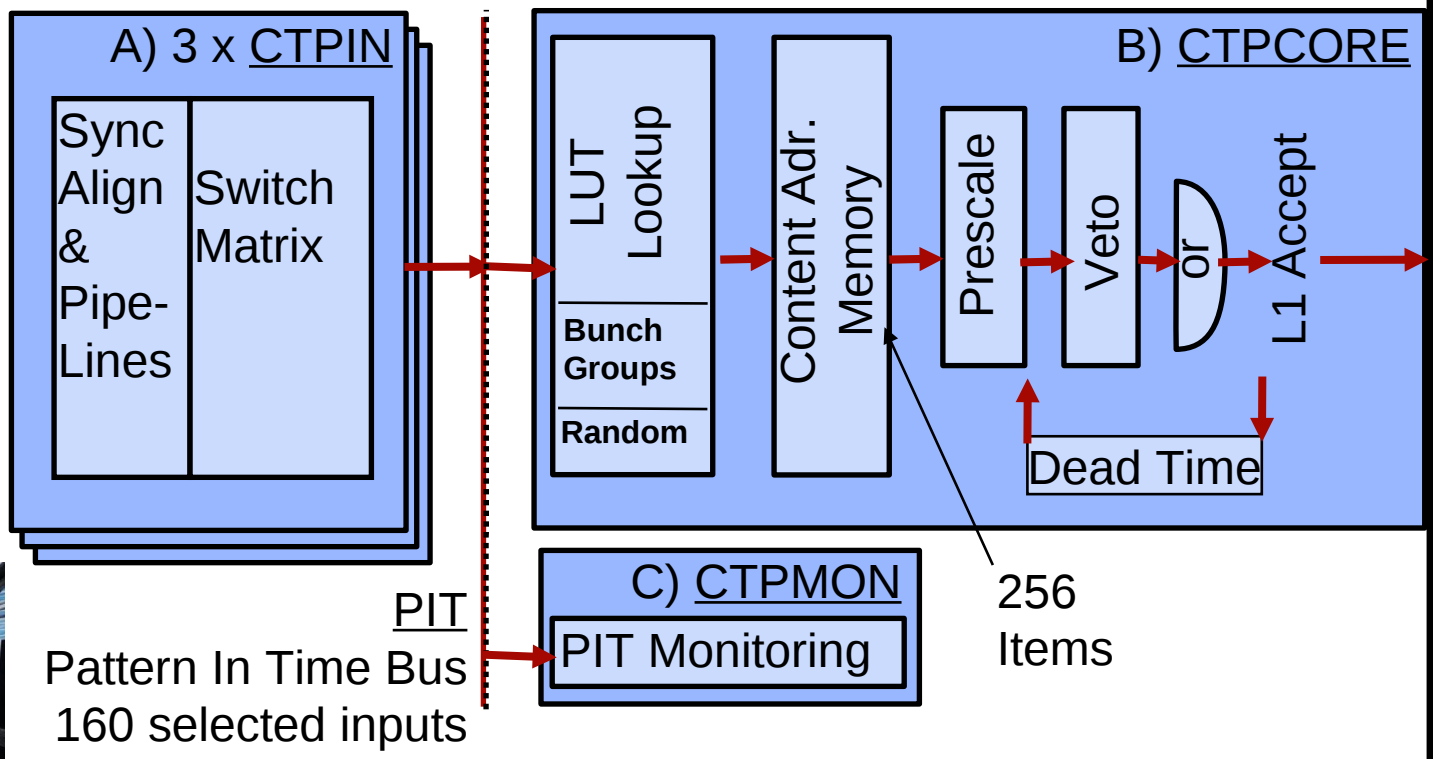
Also see poster by Takashi Hayakawa:
Detailed Performance Study of ATLAS Endcap Muon Trigger with Beam Collision Data

Trigger Timing and Control system (TTC)

- Distributes to front end readout:
  - Timing signals: bunch clock, orbit
  - Trigger signals: L1 accept
  - Commands: bunch and event counter resets
- The timing information arrives from the RF (point 4) at the CTP through the Radio-frequency to TTC (RF2TTC)
  - Coarse orbit delay to align ATLAS BCID with the LHC
  - Fine delay of 0.5ns for the bunch clock
- Collects the busy signals from the detector front ends
  - Occurs when the sub-detector buffers are almost full
  - The CTP then introduces dead-time

CTP (Central Trigger Processor)





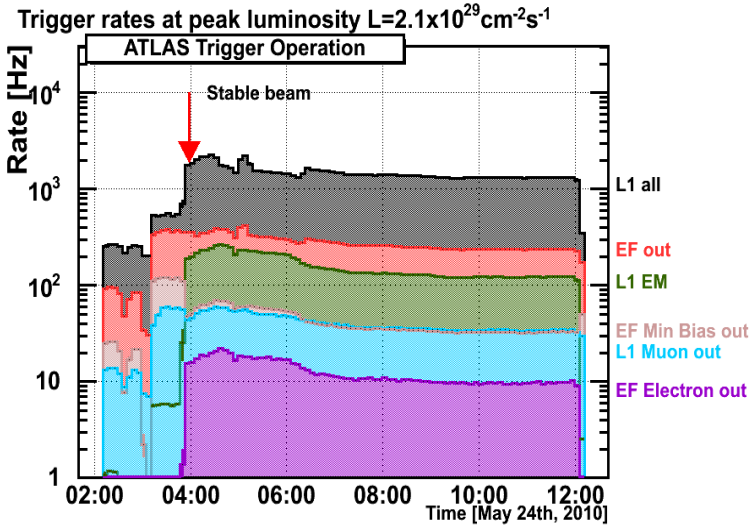
D) CTPMI: Machine Interface (timing signals from LHC)

E) CTPOUT: Output of L1A and timing signals

F) CTPCAL: Calibration requests

Operation

- Fully operational at point 1
  - Running with L1 output rates of typically around 10^4Hz
  - Using trigger menu of ~230 out of the 256 items available
  - The prescale sets are updated on average 7 times per run
  - A group of ~10 people work on the CTP, with 1 on call at all times usually receiving less than 1 call per week

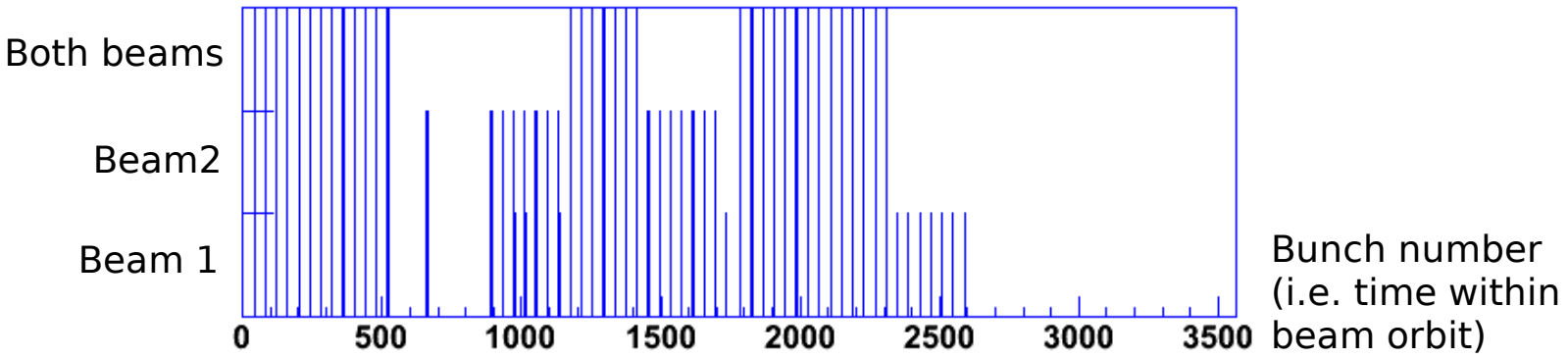


- Will now describe some of the features of the CTP that have been successfully exploited in ATLAS
  - Along with new developments, which only became clear once collisions began

- Further developments are planned, along with studies for future upgrades of the LHC

Bunch Groups

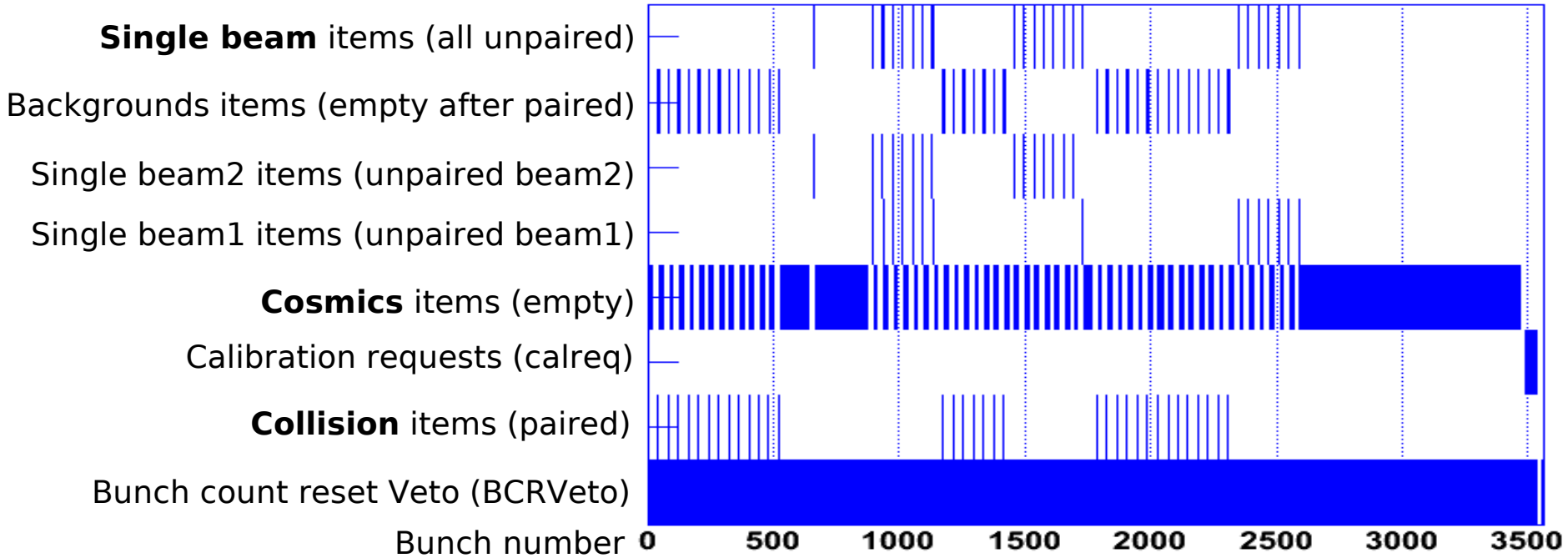
- Full turn of 3564 bunches
  - After each turn there is a bunch counter reset, for synchronisation
  - An example injection of 50 bunches in each beam, to provide 30 collisions in ATLAS:



- To define the type of event ATLAS uses 8 repetitive, fully programmable, bunch group trigger conditions
  - Applied in the CAM (in the CTPCORE)

Bunch Groups (2)

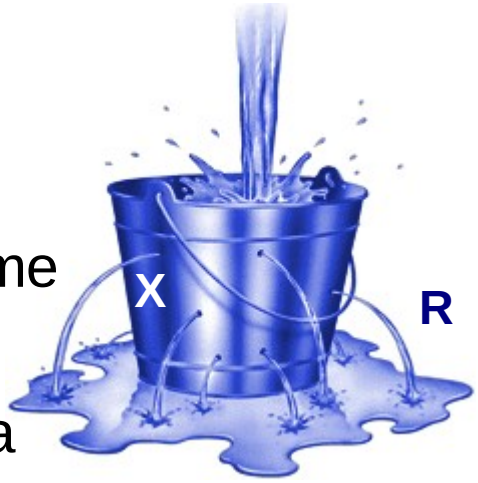
- Example bunch group for 50 bunches and 30 collisions



- The trigger items for non-collision events are then appended with the appropriate tag e.g. _EMPTY
- The BPTX suggests which bunch group to use
  - Shifter updates by the press of a button

Dead-time

- Generated by the CTP, to stop the front-end buffers from becoming full
- Fixed/Simple:
  - A programmable number of bunch crossings after each L1A
  - For example: to avoid overlapping readout windows
- Leaky bucket/Complex:
  - The leaky bucket emulates a front end buffer
  - X (in units of L1A) is the size of a bucket (i.e. the front-end buffer), when full there is dead-time
  - R (in BC) is the time it takes to leak 1 L1A
  - On average the rate is limited to X triggers in a time period of X*R bunch crossings



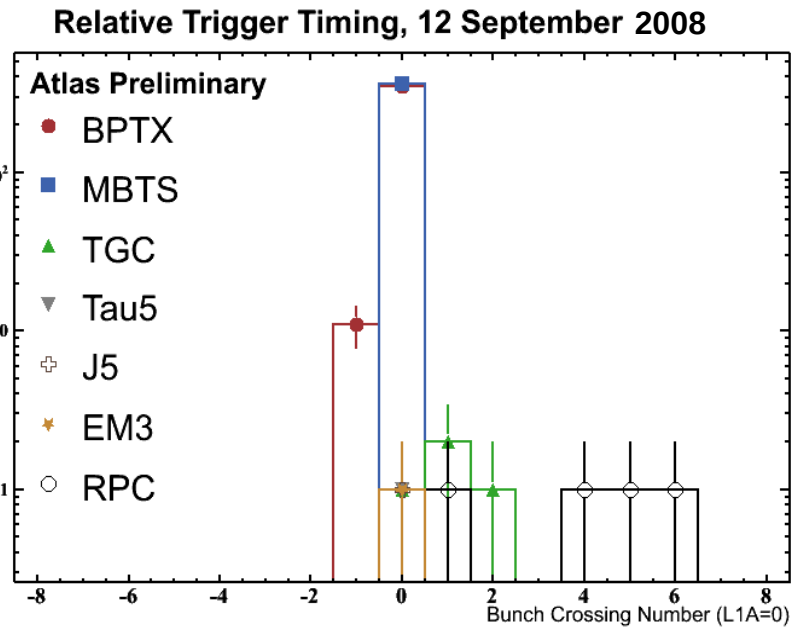
- Current settings: 5BC (simple) 7 in 72.6µs (complex)

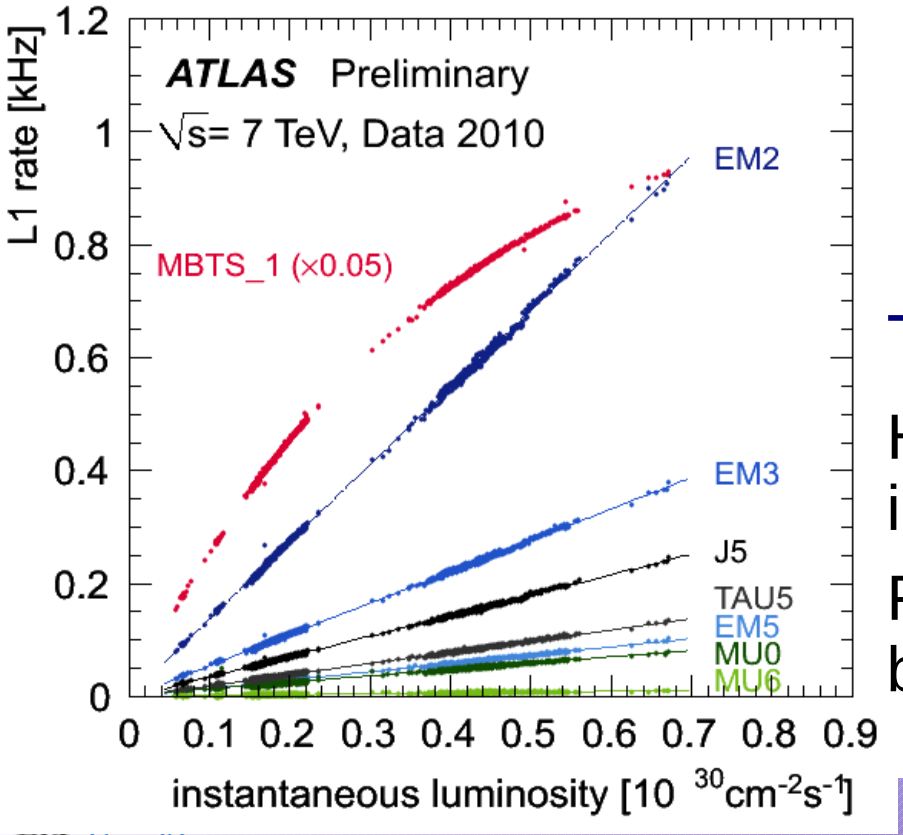
Monitoring

Timing

From the 3rd day of single beams in the LHC

- The RPC had not been tuned at all prior to this run





Trigger rates

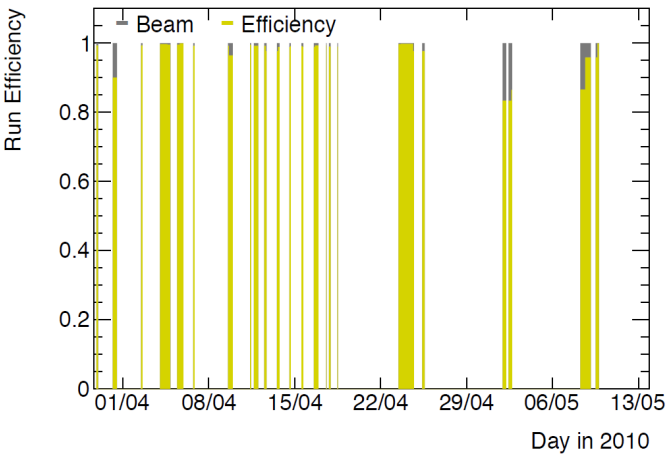
Here shown as a function of instantaneous luminosity

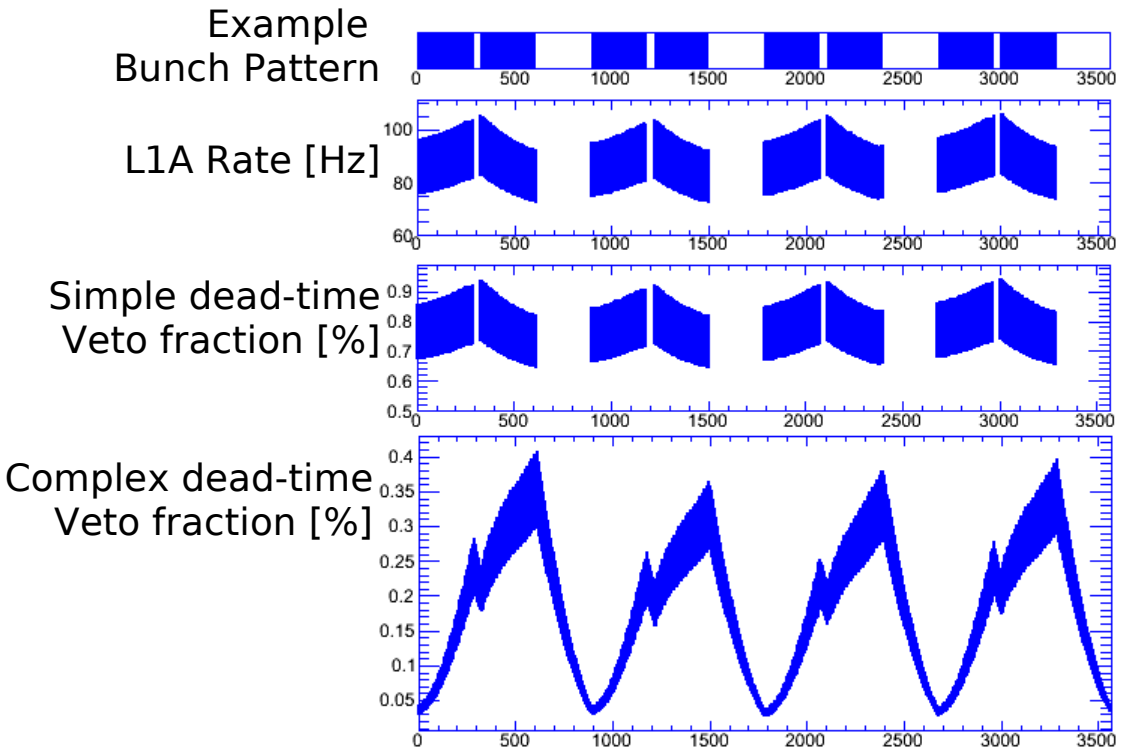
From runs with two colliding bunches in June 2010

- The MBTS rate saturates due to pileup

Monitoring (2)

- Busy and dead-time
  - Reduces the data taking efficiency
  - Here shows average percentage per 24h for runs with stable beams





- Bunch Per Bunch
  - Count number of events and dead-time per bunch in CTPCORE
  - 6 pairs of item combinations after prescale and after veto

- All of these results are fed into online plots and databases

Developments

- Zero-bias trigger (hardware)
  - Defined (in CTPIN) as having a 1-orbit delay from a selected seed trigger (currently 10GeV EM calo seed)
  - Rate scales linearly with luminosity
- Fractional prescales (hardware)
  - Implemented in the hardware of CTPCORE
  - For example it is useful for scaling a rate by 10%
- Automatic rate prescaling (software)
  - Used if an item rate passes a configurable threshold
  - CTPCORE changes prescale and stores new value, just requires approval from the shifter
- Automatic enabling (software)
  - For the CTPIN to mask inputs from disabled inputs

Summary

- The ATLAS first level trigger has been fully commissioned and well timed in
- The BPTX have been used successfully to identify the filling pattern used to define the bunch groups
- New CTP features have been developed, along with improved monitoring, which are now in use
- ATLAS has recorded 3.174pb^{-1} (on 10/09/10) of 7TeV collisions, which has provided many interesting results already