

Commissioning of the ATLAS Level-1 Central Trigger

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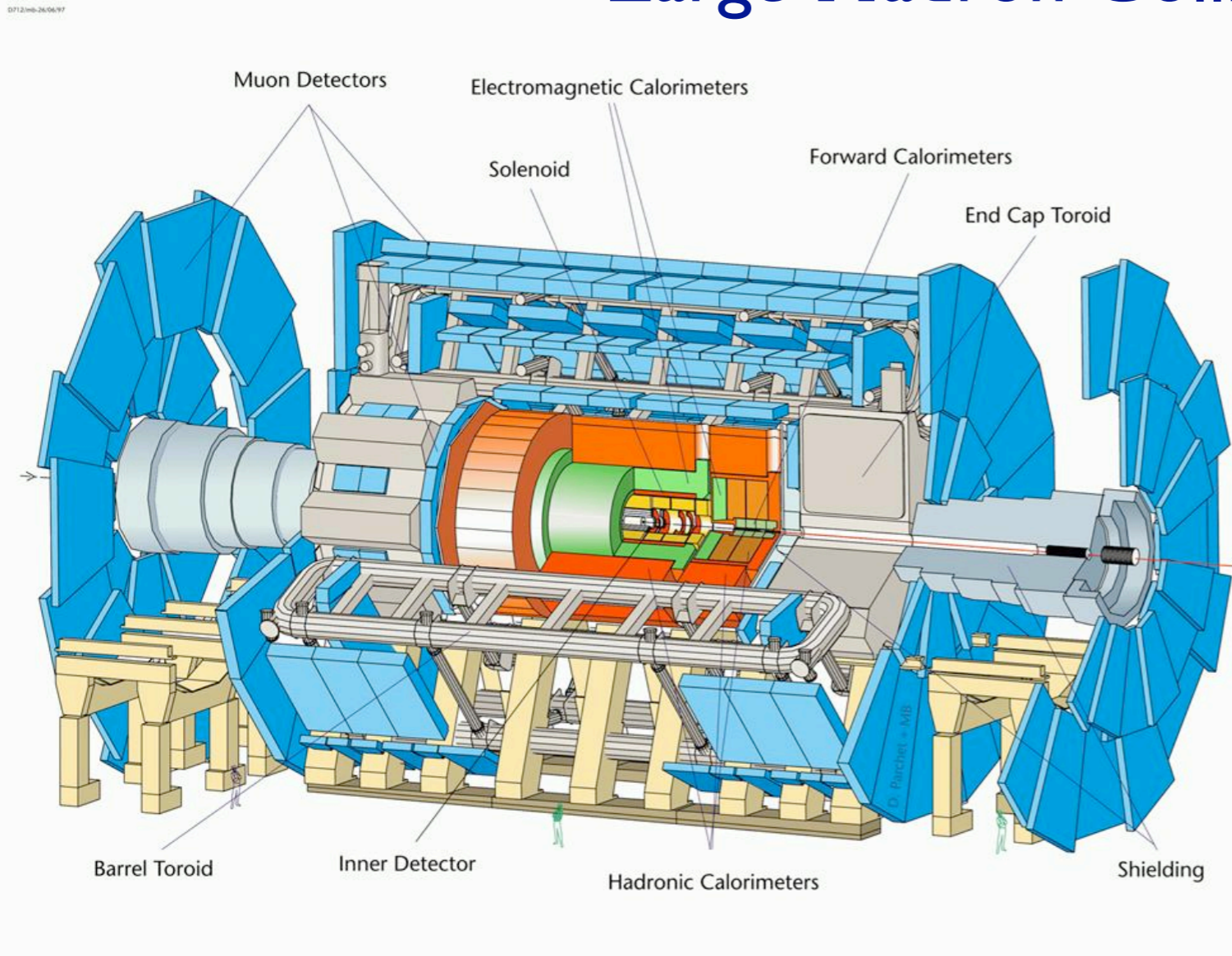
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TWEPP08 - Naxos, Greece
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General-purpose experiment at the CERN's Large Hadron Collider (LHC)



- Proton-proton collision @ 14 TeV center-of-mass energy
=> $\sigma \sim 100 \text{ mb}$
New Physics $\sigma < \text{pb}$
- ~ 25 interaction per bunch crossing @ $10^{34} \text{ cm}^{-2}\text{s}^{-1}$; bunch crossing @ 40MHz (25 ns)
=> interaction rate $\sim 1 \text{ GHz}$
- storage rate $\sim 200 \text{ Hz}$



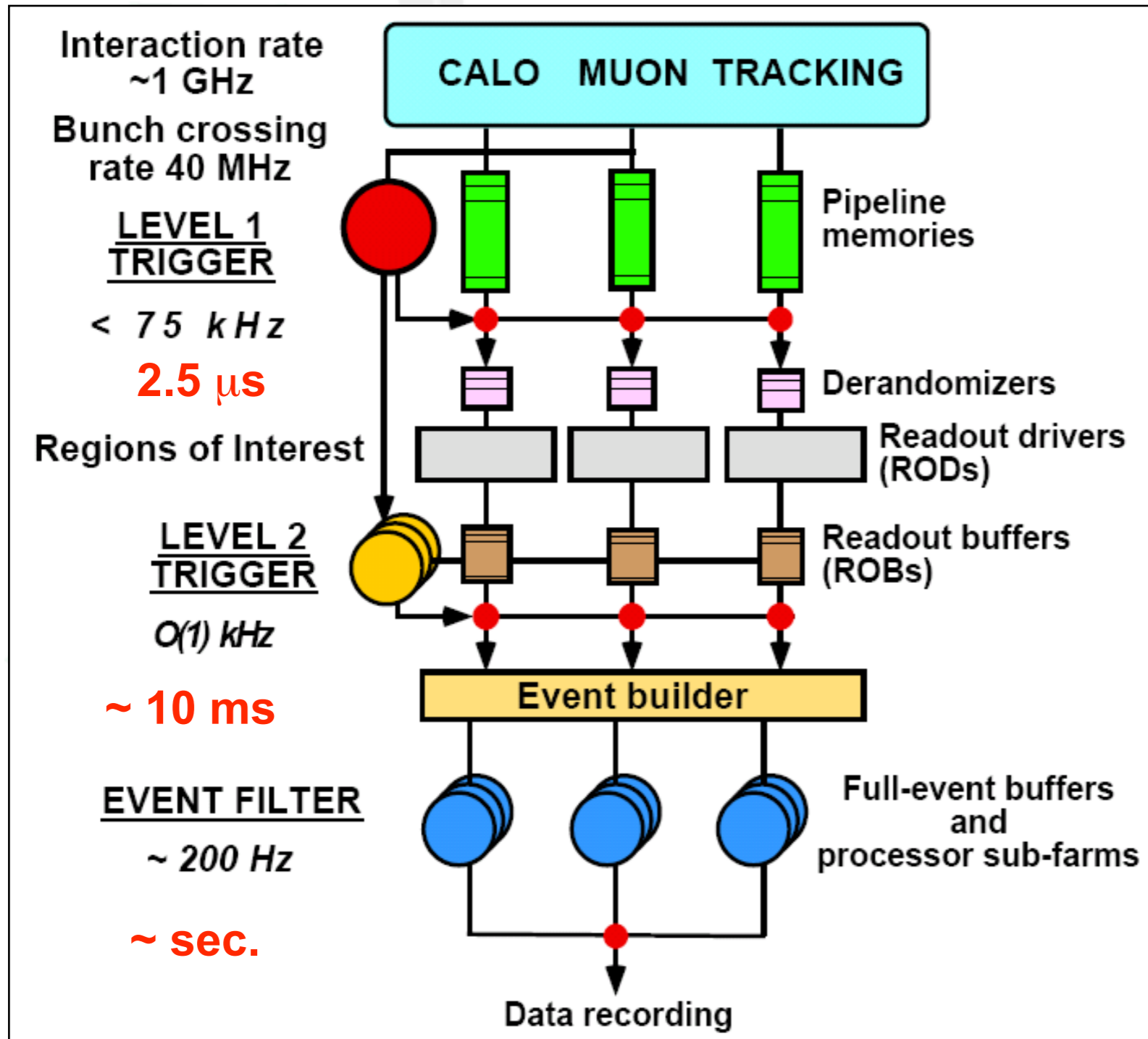
Powerful trigger system

- large rate reduction (200Hz/1GHz)
- high granularity (25 interactions/25ns)
- high efficiency

EXPERIMENT
<http://atlas.ch>

first beam event seen in ATLAS

The Trigger/DAQ System

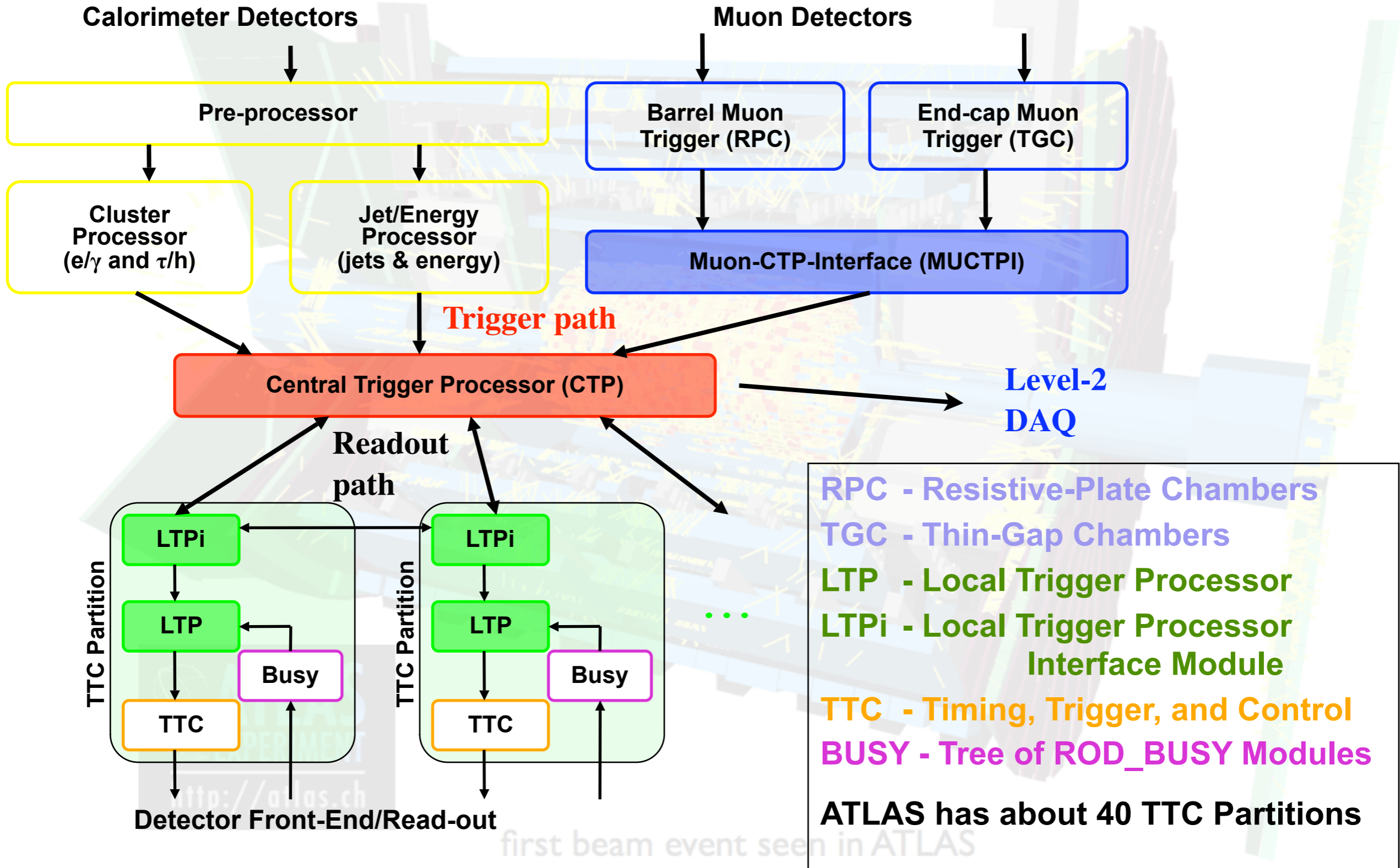


- 1) **LVL1** decision based on data from calorimeters and muon trigger chambers; synchronous at 40 MHz
- 2) **LVL2** uses Regions of Interest identified by LVL1 ($< 10\%$ of full event) with full granularity from all detectors
- 2) **Event Filter** has access to full event and can perform more refined event reconstruction

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The Level 1 Trigger System



MIOCT

(Octant Module)

receives and aligns muon candidates from 208 trigger sector logics, resolves overlaps sends results to MIBAK. Snapshot/test memory.

MIBAK

(Backplane)

Forms total multiplicity for 6 programmable p_T thresholds, transfers readout data from MIOCT to MIROD, distributes timing and trigger signals

MICTP

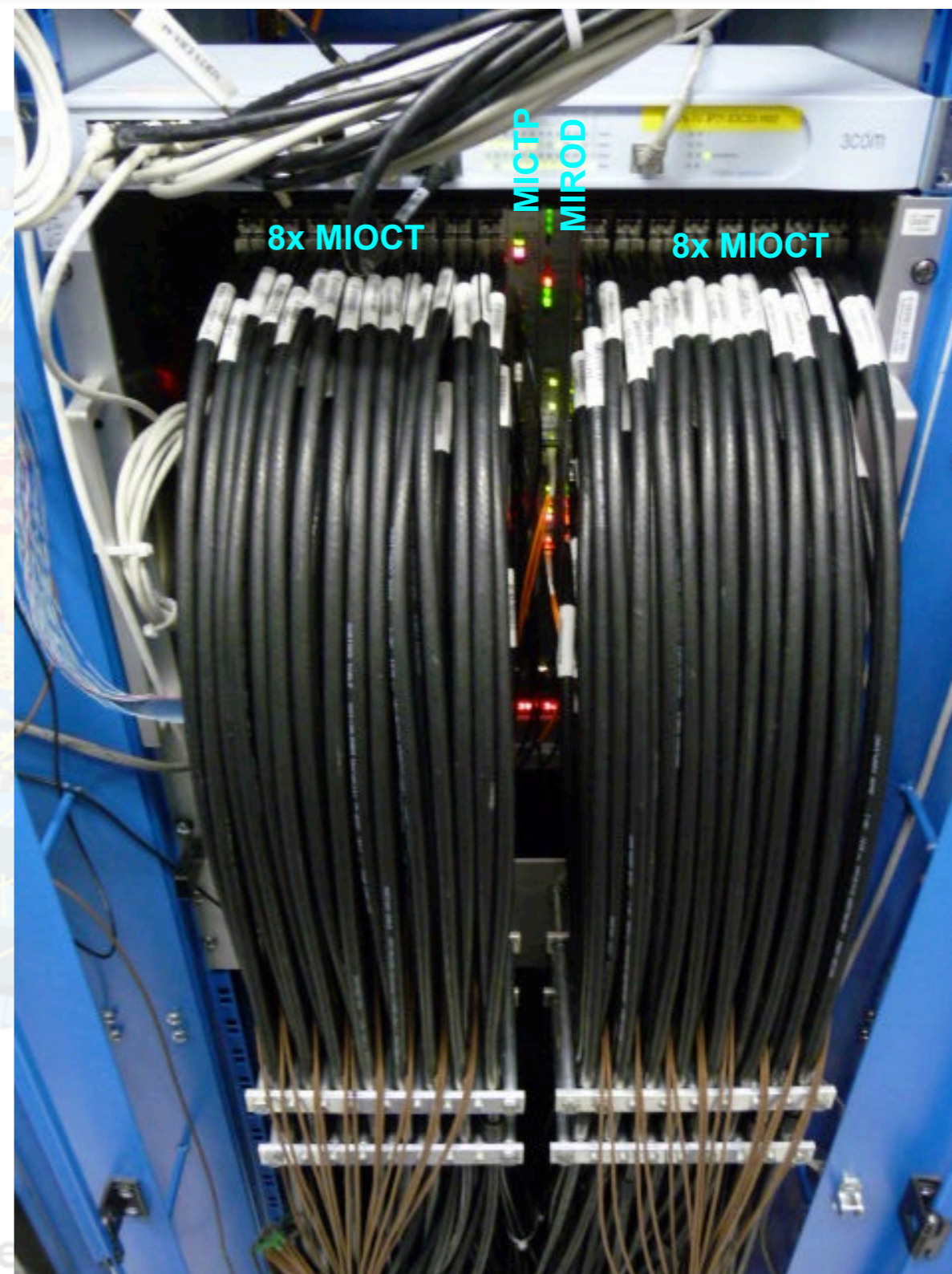
(CTP interface)

Sends total multiplicity to the CTP, receives timing and trigger signals

MIROD

(Readout driver)

Sends summary information to Level-2 and DAQ





The Central Trigger Processor



- Receives and aligns trigger inputs
- Receives (generates) timing signals from the machine
- Forms the Level-1 decision and generates dead-time
- Monitors input trigger rates (calculation of overall dead-time and luminosity)
- distributes timing signals and trigger decision to all sub-detectors
- Sends summary information to Level-2 and DAQ



first beam event seen in ATLAS



CTP: Trigger inputs

The Level 1 trigger decision is based on several trigger inputs:

- ✓ Candidate multiplicity from calorimeter and Muon Trigger:
 - ELECTRON/PHOTONS, TAUS/HADRONS, JETS, and MUONS
- ✓ Energy flags from the calorimeter trigger:
 - Sum E_T , E_T Miss, ΣE_T Jet
- ✓ Calibration requests from sub-detectors
- ✓ Specialized triggers:
 - Beam pick-ups
 - Minimum Bias Scintillators
 - Beam Condition Monitors
 - Luminosity counters
 - Forward detectors

Up to a maximum of 160 trigger inputs at any given time

- ✓ Additional internal triggers:
 - 2 Randoms, 2 Prescaled clocks, 8 bunch-crossing groups group



Trigger configuration tool

- According to a programmable Level-1 trigger menu 256 trigger items are created by combining one or more conditions on trigger inputs:
 - ✓ IEM10 = at least one electron/photon with $E_T > 10$ GeV
- Each trigger item has a mask, a priority and a pre-scaling factor
 - ✓ priority is used in the algorithm to generate the preventive dead-time:
 - high priority items see as little dead-time as possible
 - low priority items see comparatively high dead-time
- The L1A is the OR of all trigger items

Add L1 Item | Compile L1 from names | Clear Cables | L1

<input type="checkbox"/>	L1_LUCID_C	0
<input type="checkbox"/>	L1_LUCID_A_C	0
<input type="checkbox"/>	L1_RD0	0
<input checked="" type="checkbox"/>	L1_RD1	0
Comment: test comment CTP ID: 240 Priority: LOW Trigger Type: 10000001 Definition: (1)		
1x	<input type="checkbox"/>	RNDM1
830	2008-09-05 14:55:45.0	paul
<input checked="" type="checkbox"/>	L1_BPTX0_0	0
Comment: test comment CTP ID: 241 Priority: LOW Trigger Type: 10000010 Definition: (1&2)		
1x	<input type="checkbox"/>	BPTX0
1x	<input type="checkbox"/>	BGRPO



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Central Trigger Processor

CTPIN

(CTP input)

receives, synchronizes and aligns trigger inputs and sends them to the PIT bus.
Monitoring scaler of trigger inputs

CTPCORE

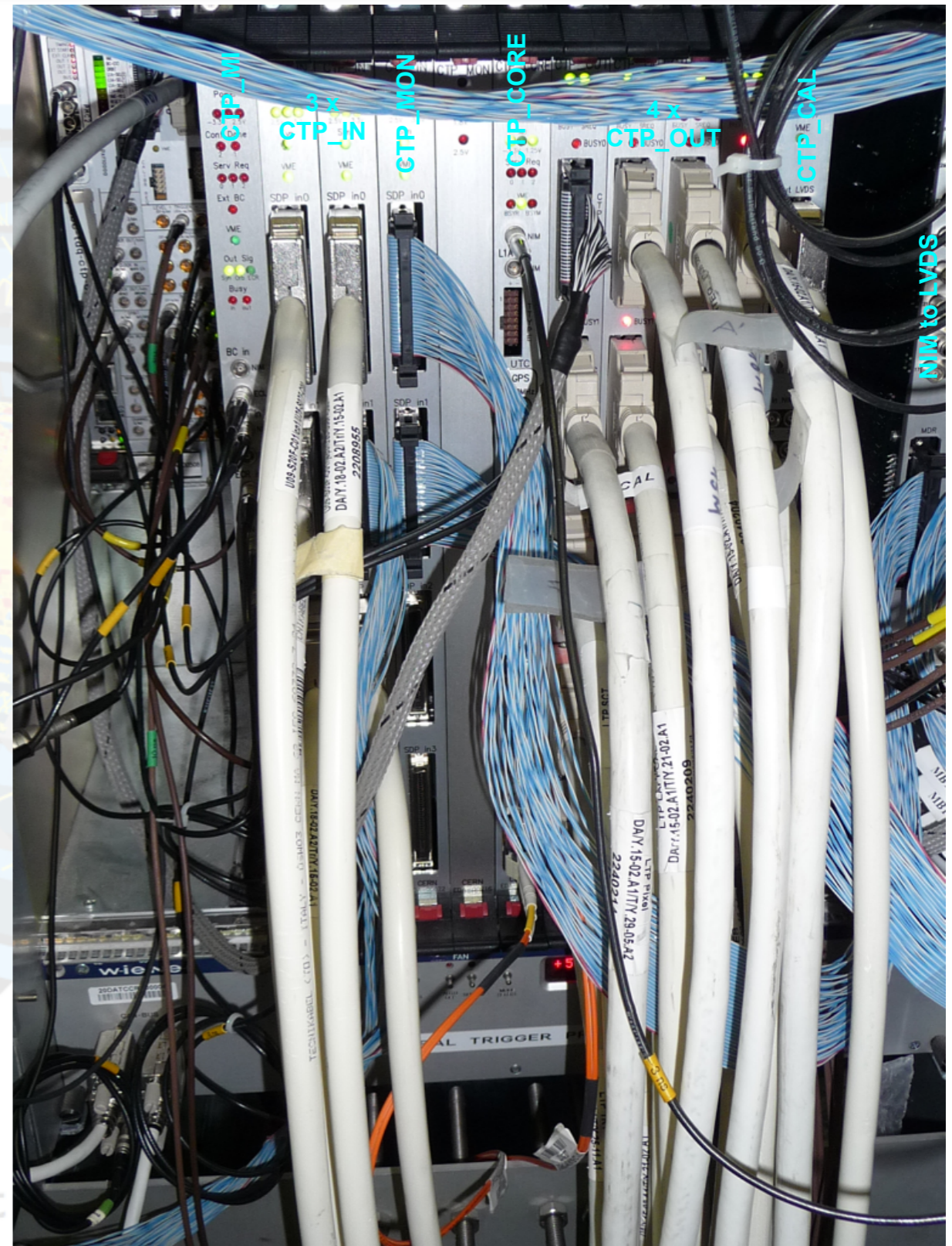
(CTP core)

receives PIT data, forms trigger items.
Applies trigger mask, pre-scales, dead-time, generates internal triggers and forms LIA. Sends summary information to DAQ and Level-2. Monitoring scalers.

CTPOUT

(CTP output)

sends LIA and timing signals to LTPs,
receives BUSYs and calibration requests.



Central Trigger Processor

CTPMI

(CTP machine interface)

receives timing signals from LHC,
generates additional timing and sends
all to the COM bus

CTPMON

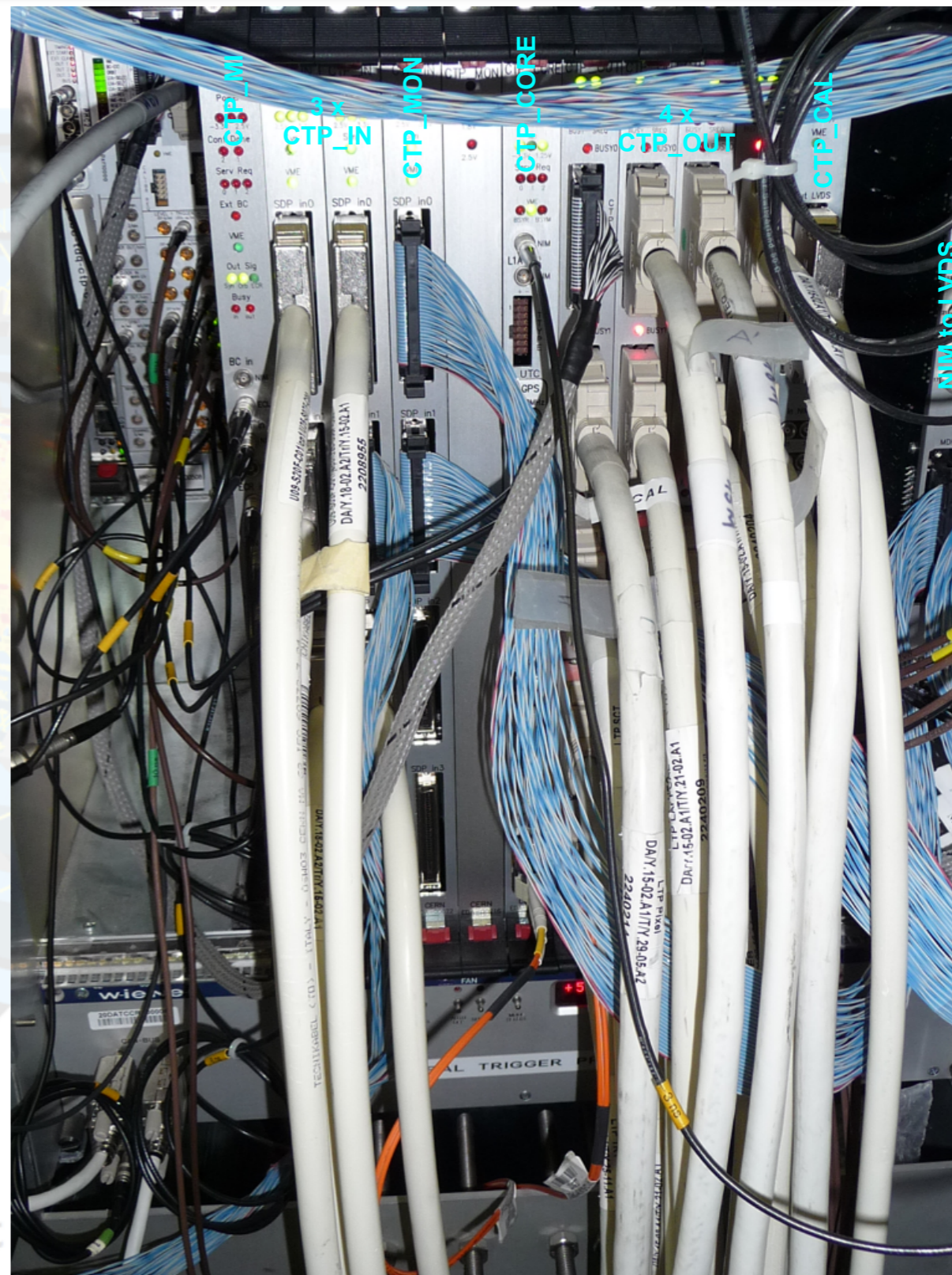
(CTP machine interface)

Decodes trigger inputs and does bunch-
per-bunch monitoring

CTPCAL/NIM2LVDS

(ctp calibration request / NIM to LVDS)

receives and time-multiplex calibration
request, receives additional NIM trigger
inputs, sends then as input to the CTPIN



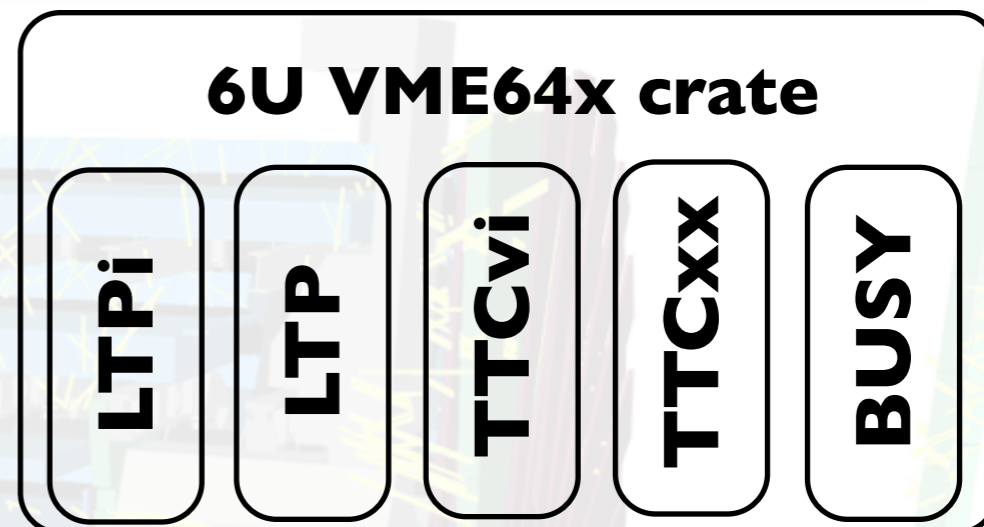
first beam event



The TTC crate

TTC system

timing trigger and control system
Distributes timing signals (BC, Orbit),
trigger signals (LIA), trigger type (8-bit),
commands (bunch counter reset (BCR),
event counter reset (ECR)) to the front
end readout. The TTC system is divided
in 40 partitions to allow concurrent runs
of sub-detectors.



LTP

Local trigger processor
Receives TTC signals from the CTP.
Sends partition busy to the CTP.
Generates TTC signals when running
standalone.

TTCex

Multiplex TTC signal and sends them
optically to the front-end

TTCvi

Time Trigger Control VME interface
Generates the BCR signal.

BUSY

Collects busy signals from the front-
end, sends the OR to the LTP

first beam event seen in ATLAS

The LTPi

LTPi

(LTP interface)

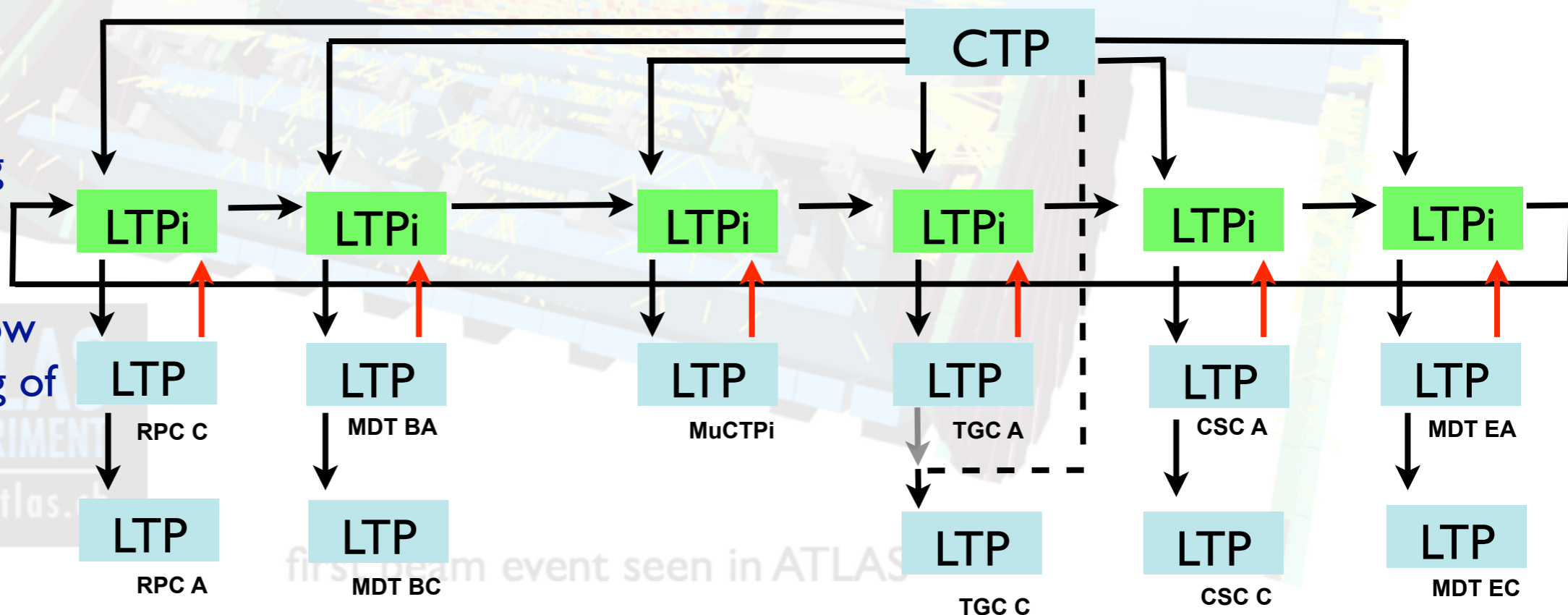
Switch module for TTC signals.

- 3 in/out CTP, LTPi (LVDS), local (NIM)
- Active equalizers for the LVDS inputs
- Delay chips (delay25) to compensate cable skew and adjust the phase of signals to the LTP
- Generates trigger type word according to test-trigger inputs



Almost all sub-detectors are using LTPi modules.

Three loop connections to allow concurrent running of groups of sub-detectors:





Commissioning with cosmics

- The MUCTPI and the CTP are being used since 2 years to provide triggers to an increasing number of sub-detectors.
- Since few months the system has been running in its final configuration:
 - ✓ receiving all foreseen trigger inputs (muon, calorimeter and forward detectors)
 - ✓ providing triggers to all sub-detector
- cosmic runs particularly relevant for:
 - ✓ synchronize distribution of timing signals to sub-detectors
 - ✓ timing-in trigger inputs (cosmic timing-in different from beam)
 - ✓ exercise the system
 - ✓ improve monitoring capabilities
 - ✓ spotting problems

<http://atlas.ch>

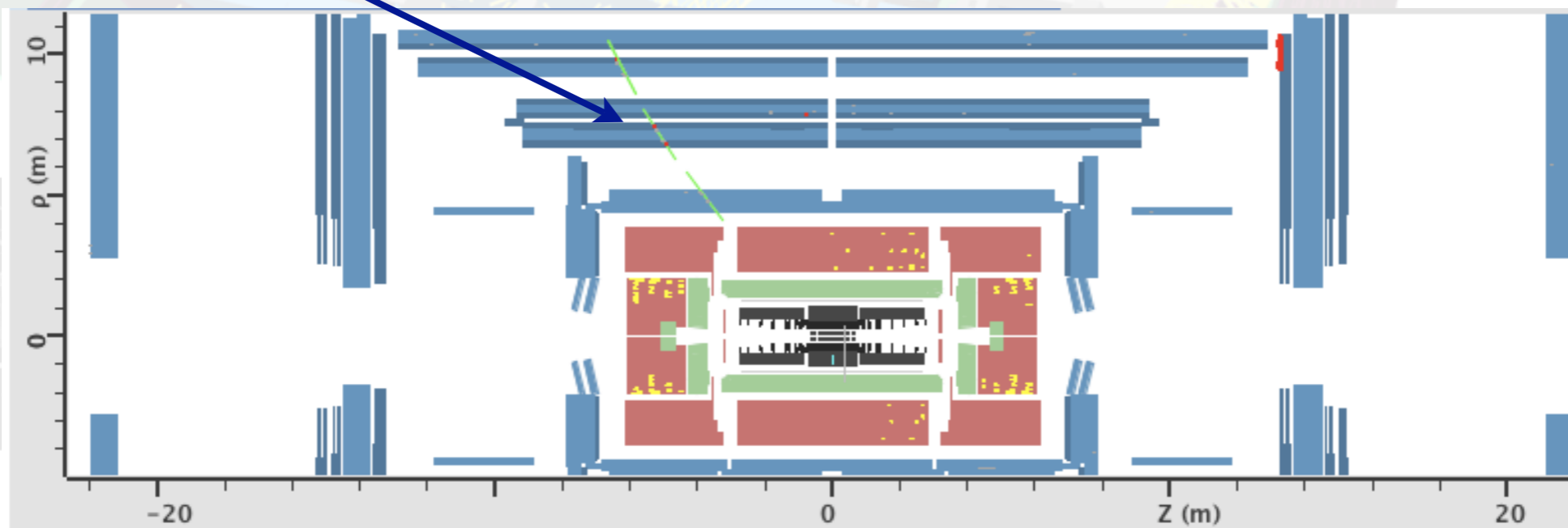
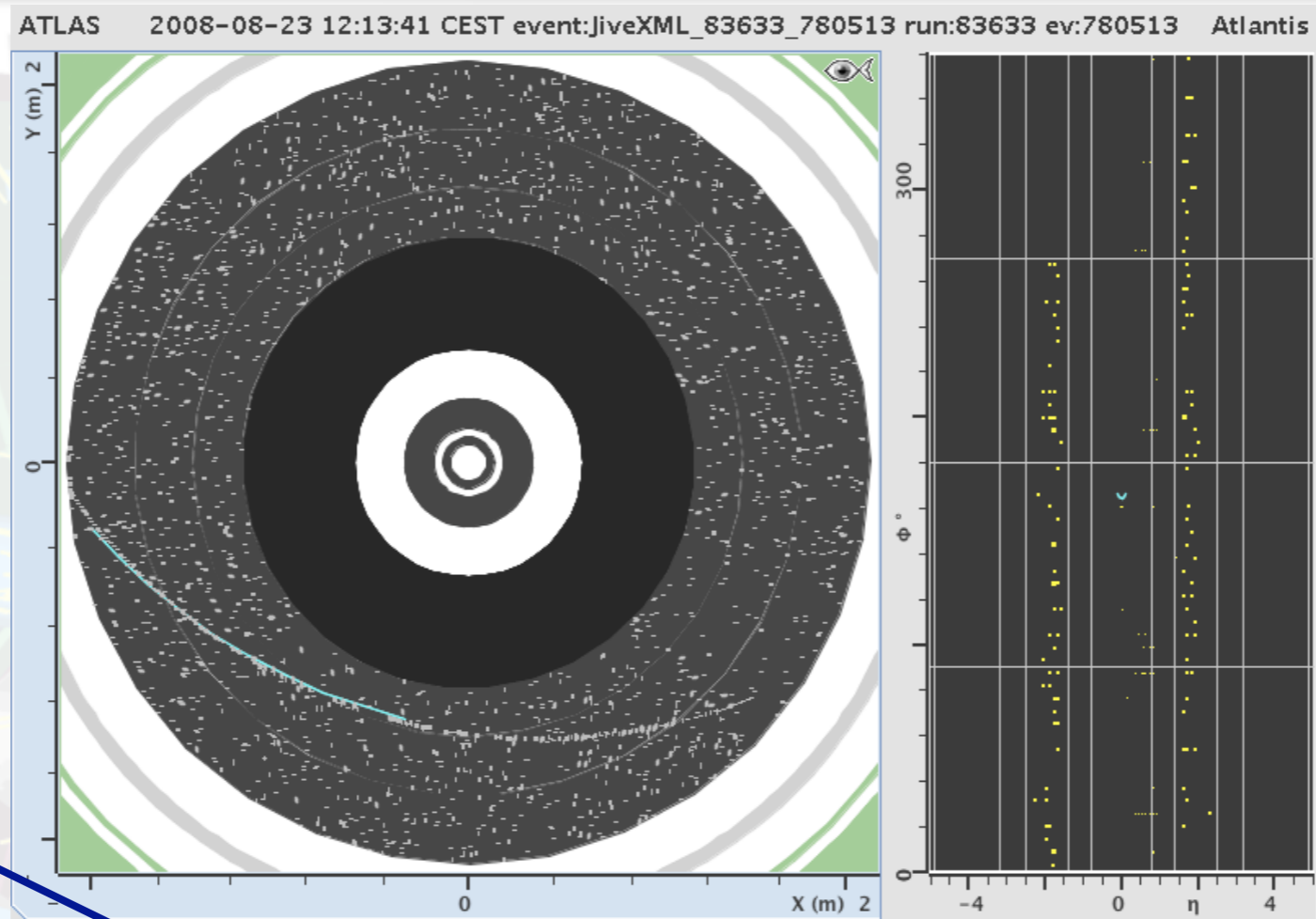
first beam event seen in ATLAS



Commissioning with cosmics

Cosmic-ray with magnetic field on

RPC trigger hits





Trigger strategy for beam

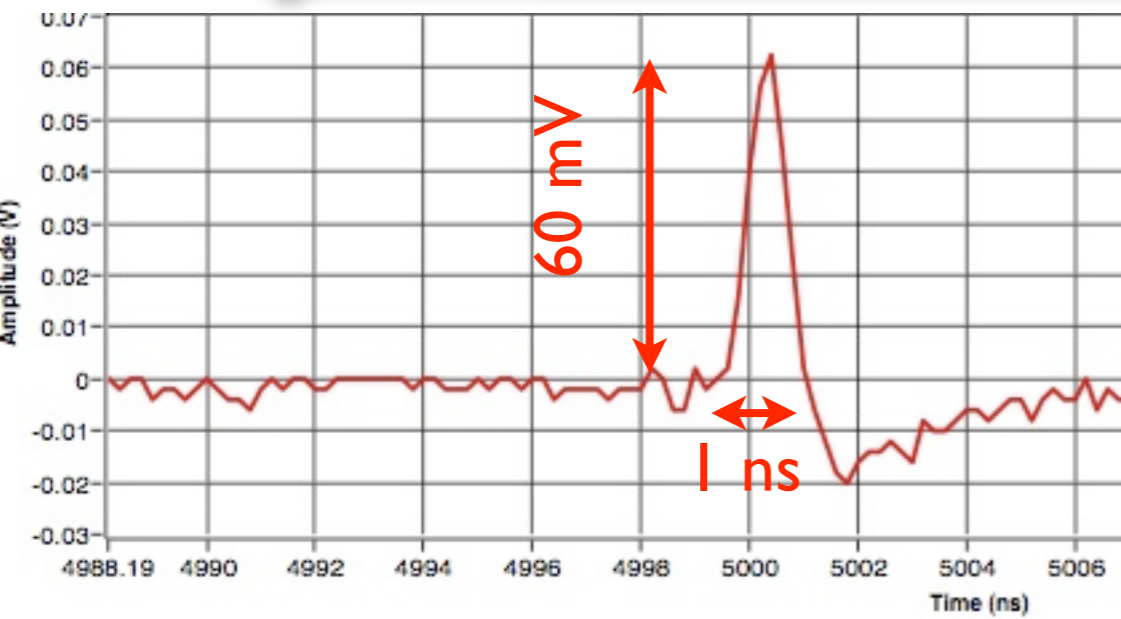


- First period: proton bunches sent onto the collimators
 - ✓ IEM3, ITAU5, IJ5, Minimum Bias Trigger Scintillators (cosmic rate <20 Hz)
 - ✓ Goal: trigger on these exceptionally high multiplicity events and correlate their time with the time of the bunches as seen by the beam pick-ups
 - ✓ Monitor rate and time of all trigger items in the CTP
- Second Period: circulating bunches
 - ✓ Phase I: trigger on the beam pick-ups, monitor and align other triggers (and detector readout). Set up timing for downstream events (similar to collision)
 - ✓ Phase II: enable other triggers in coincidence with the beam pick-up
 - ✓ Phase III: change from BPTX to bunch groups once the LHC clock will be stable and in phase with the beam

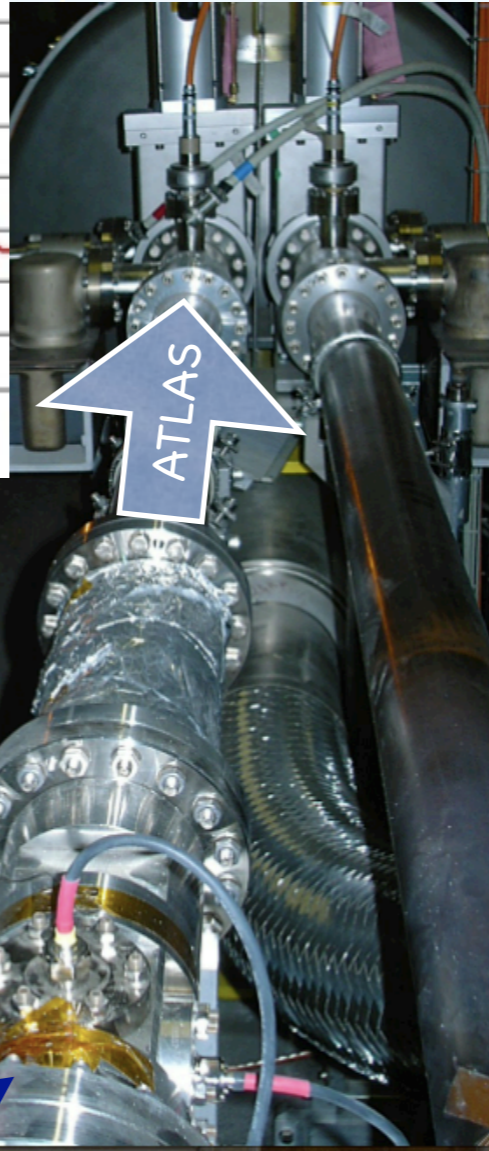


first beam event seen in ATLAS

LHC time signals



BPTX signal shape
(real beam!)

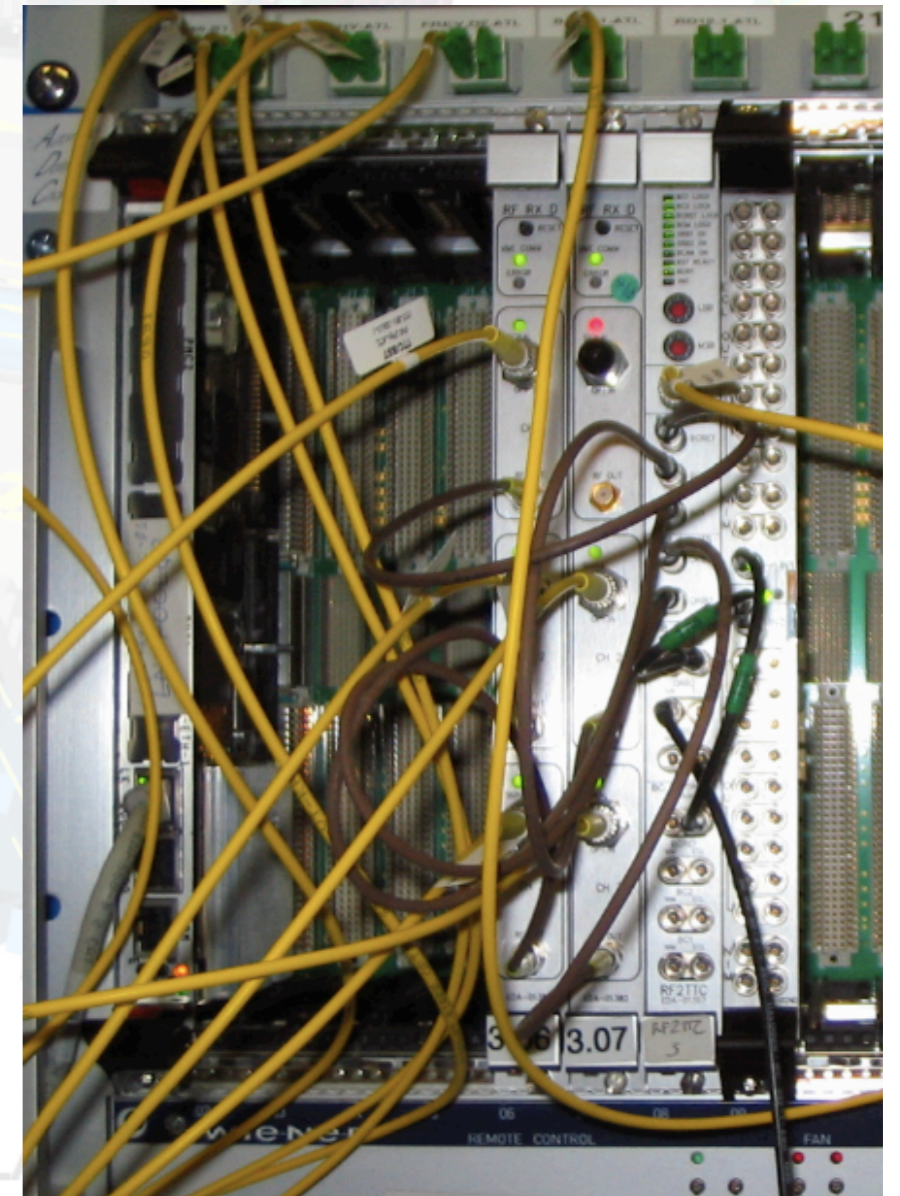


Beam pick-ups (BPTX)

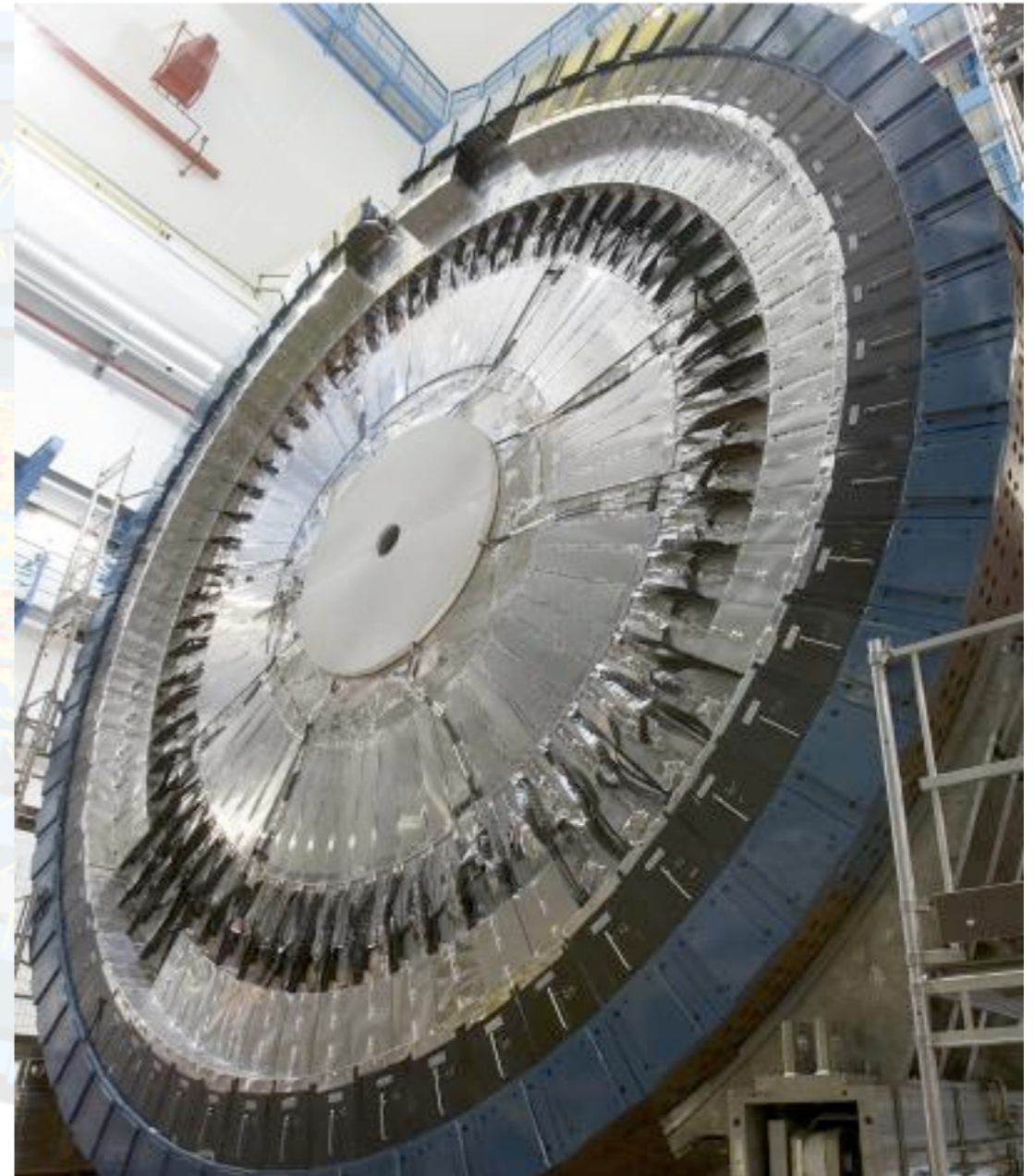
Electrodes sensitive to the passage of the beam

RF2TTC

Receives the Clock and the Orbit signal of the 2 beams and a reference clock from the LHC



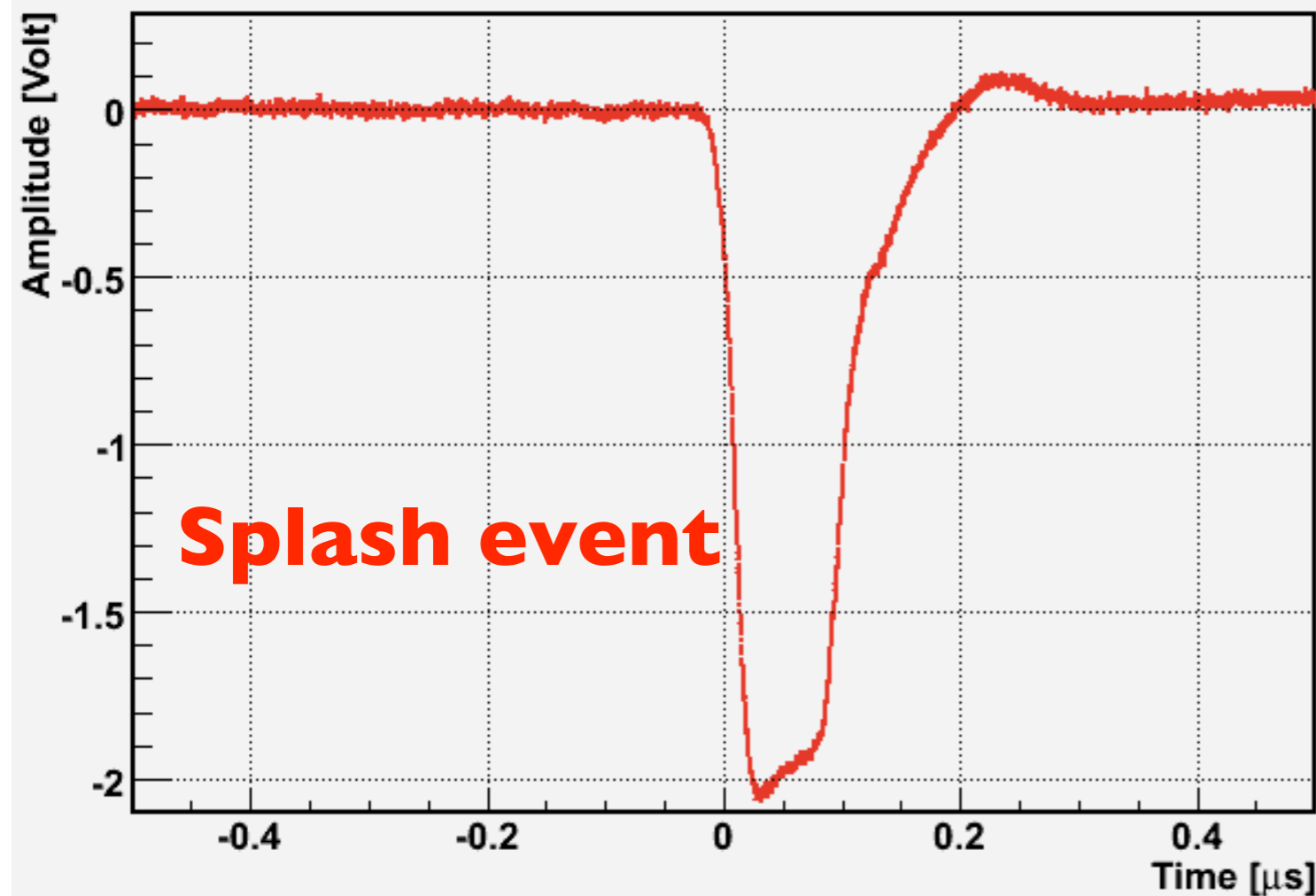
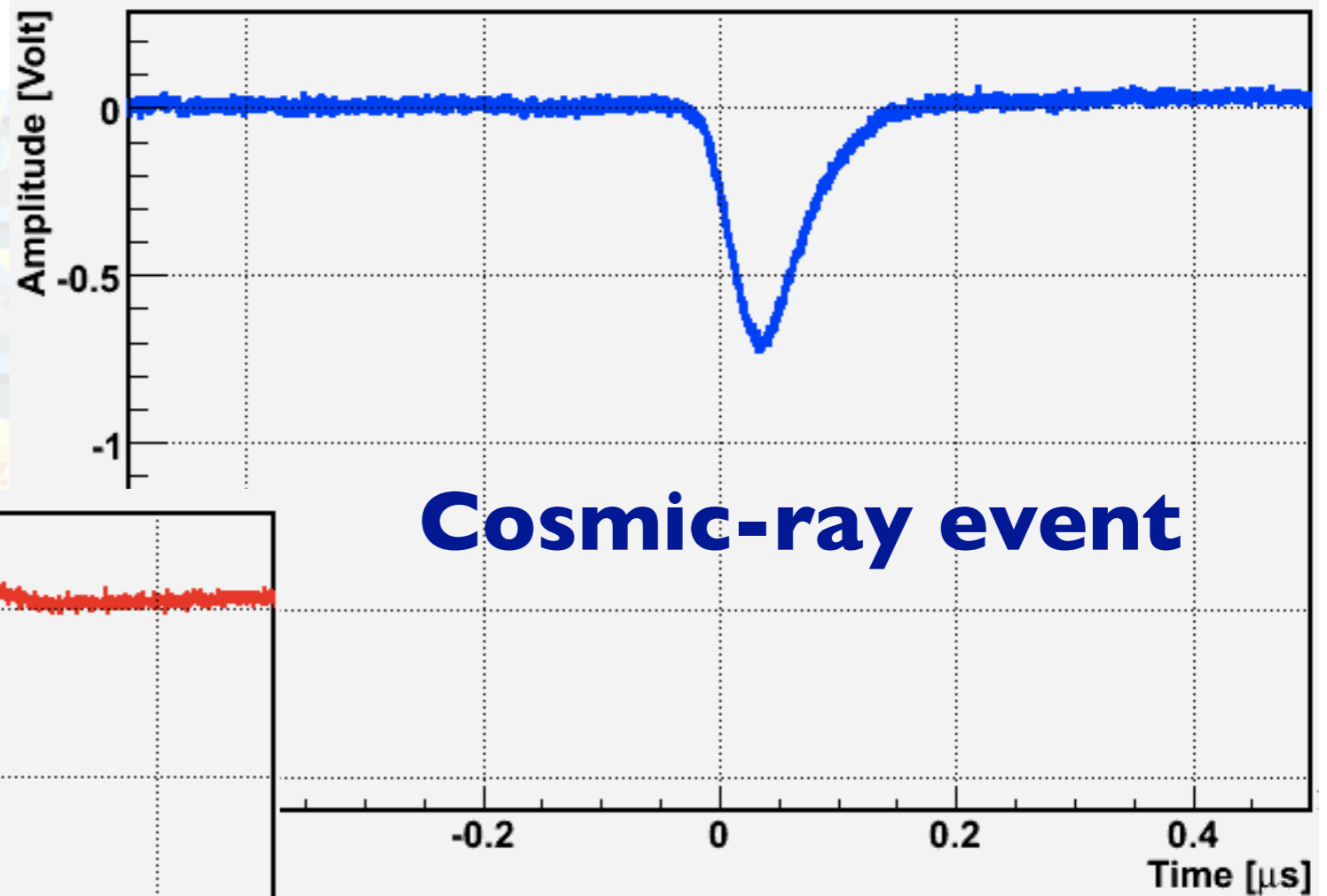
- Minimum bias trigger scintillator will be used at early days running to trigger on minimum activity in the detector. Located on LAr cryostat: 2 sides 16 modules each ($|z|=3.5\text{m}$; $R=0.15\text{--}1.2\text{m}$).
- Each signal is discriminated and fed into the CTP NIM-TO-LVDS (32 inputs)
- Very simple and robust system. Signals always monitored with a scope
- Sensitive to minimal forward activity.
- Time information is a handle to identify beam-halo, beam-gas, collisions



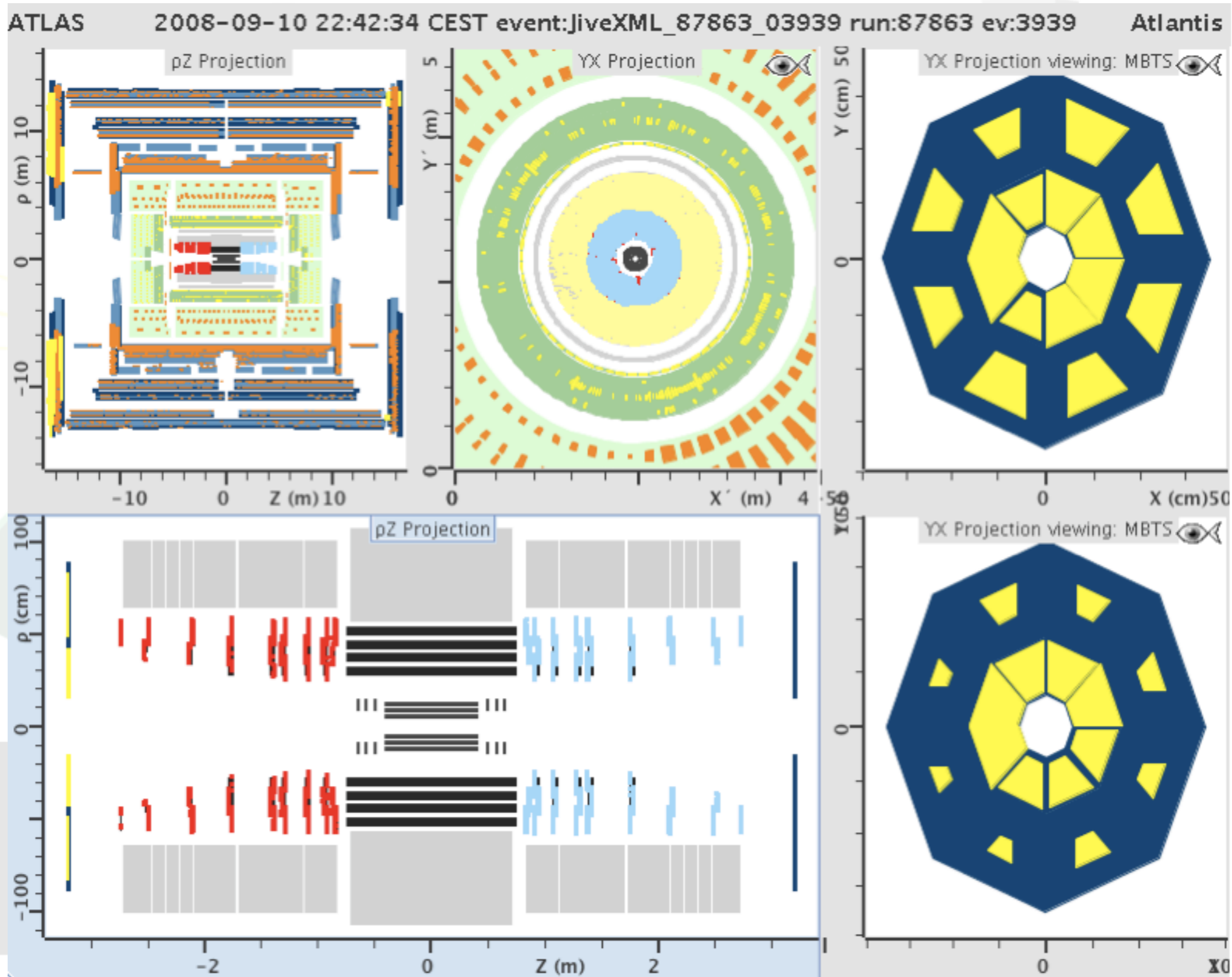


Splash event in the MBTS

Sept. 10 2008
10:34:30
Beam I
signal on the
MBTS scope



Splash event in the MBTS

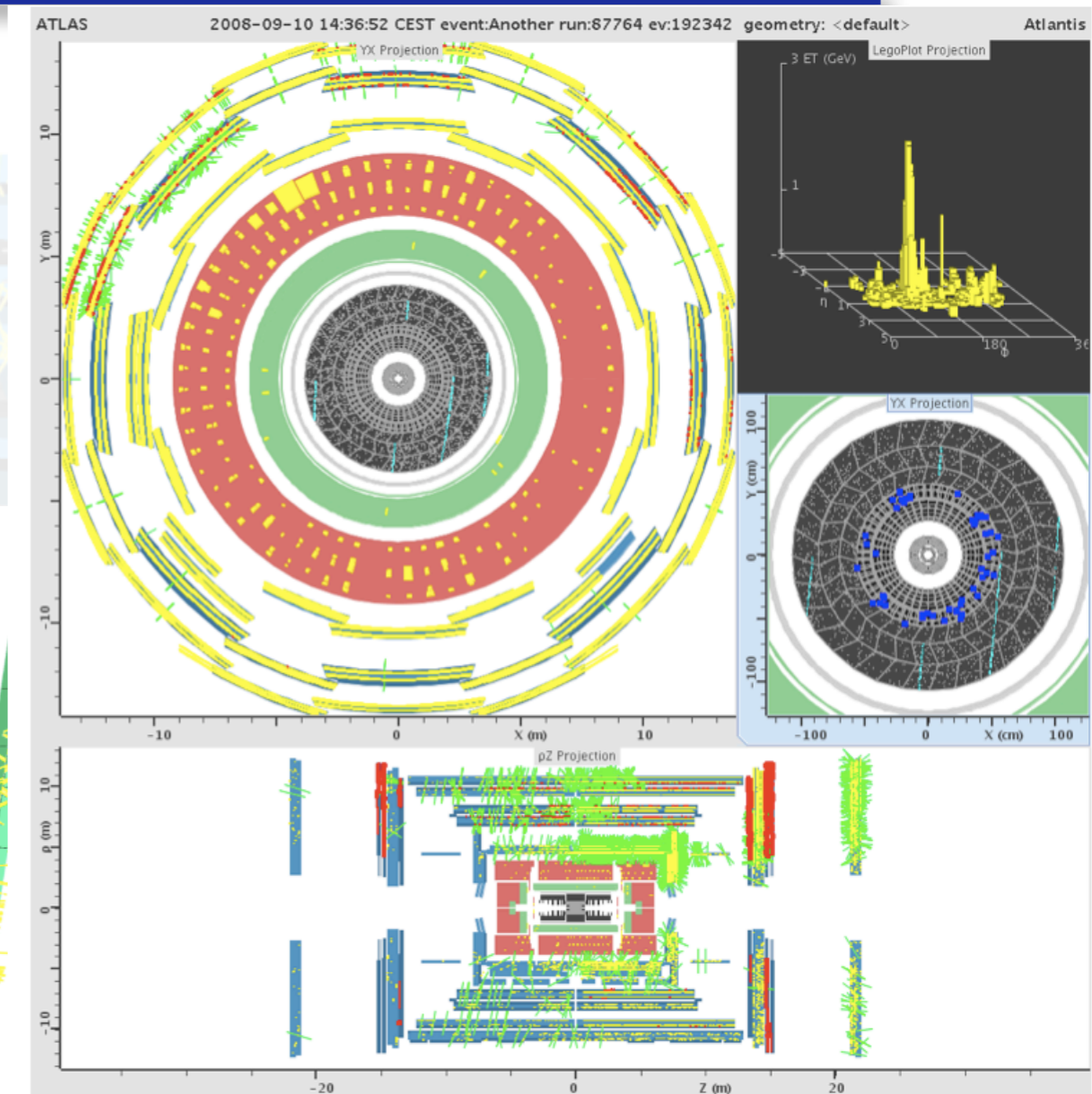
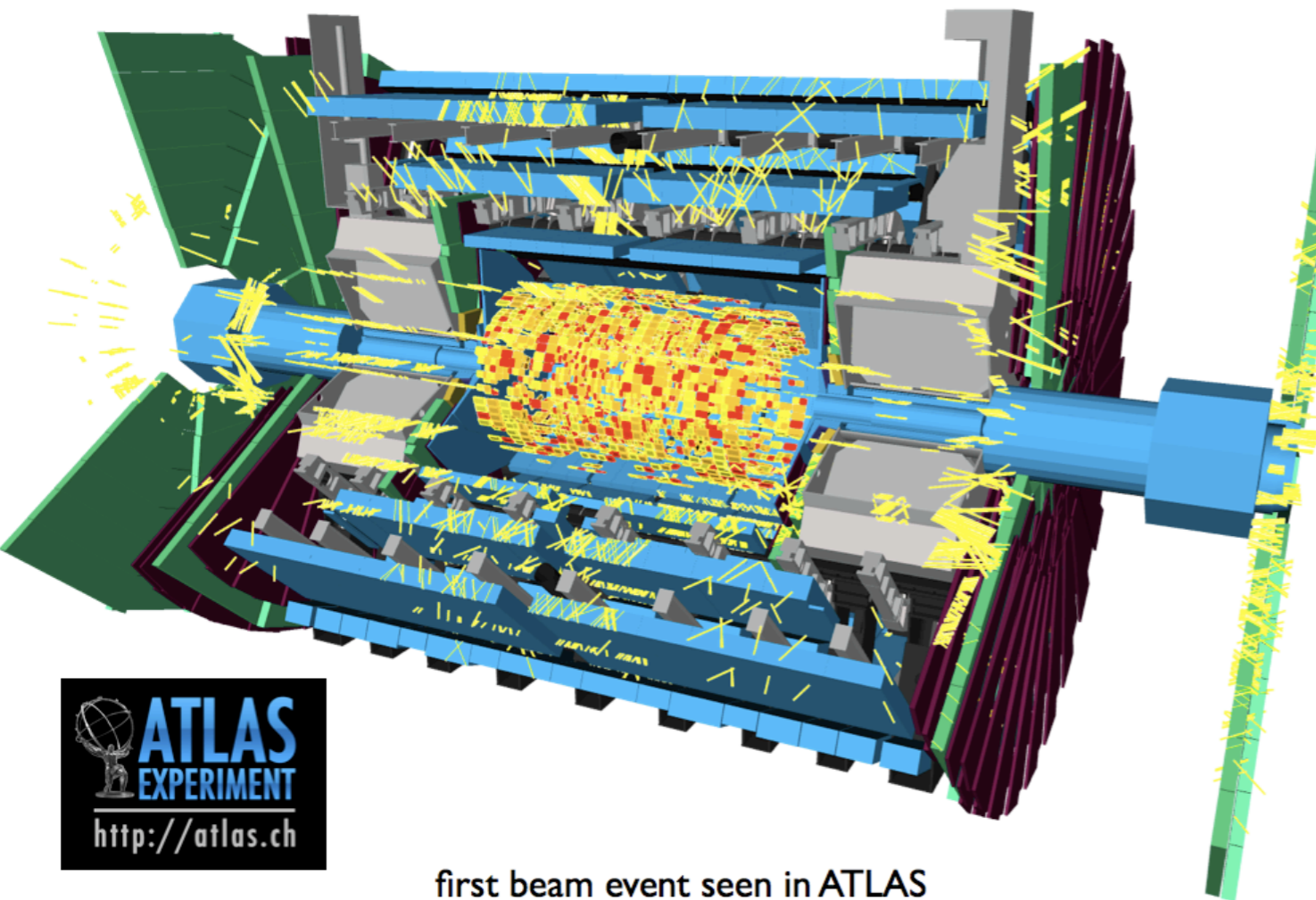




Splash Event in ATLAS



Beam dumped on the collimator upstream of ATLAS ($\sim 2 \cdot 10^9$ protons). Events triggered by calorimeter and MBTS triggers.

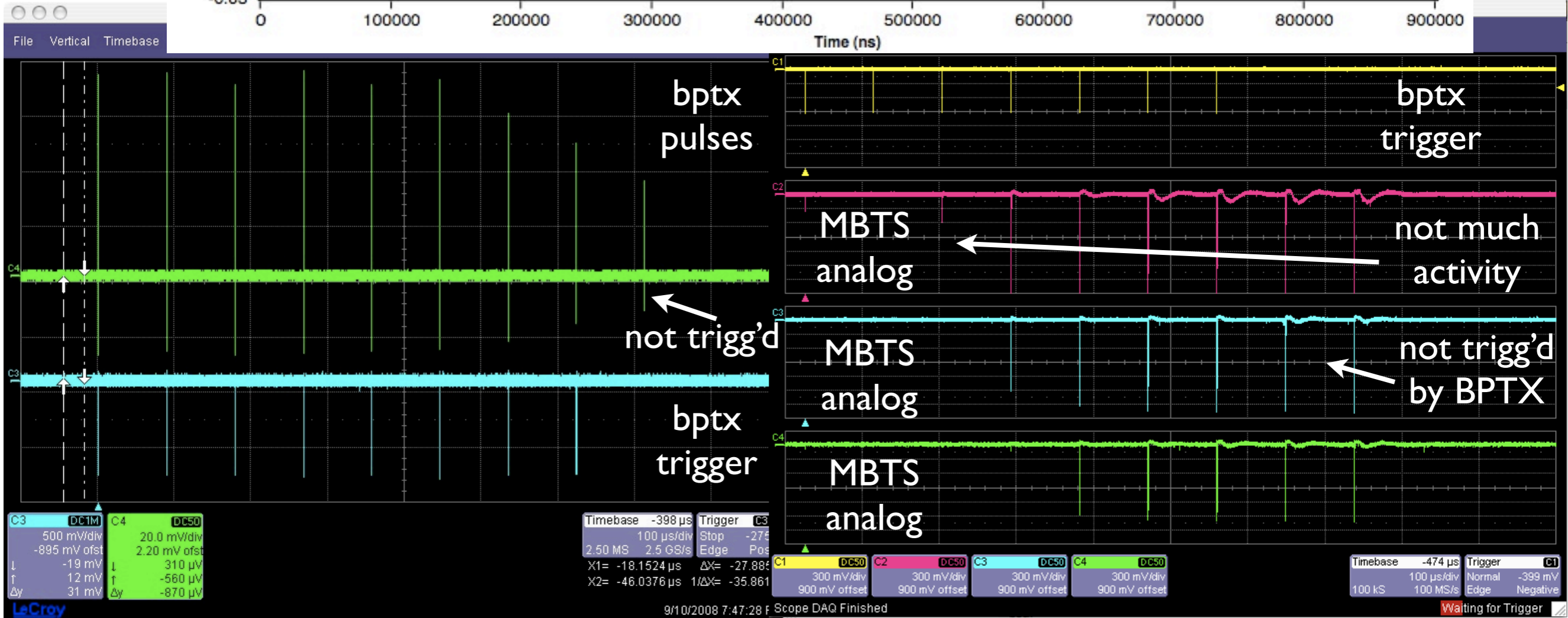
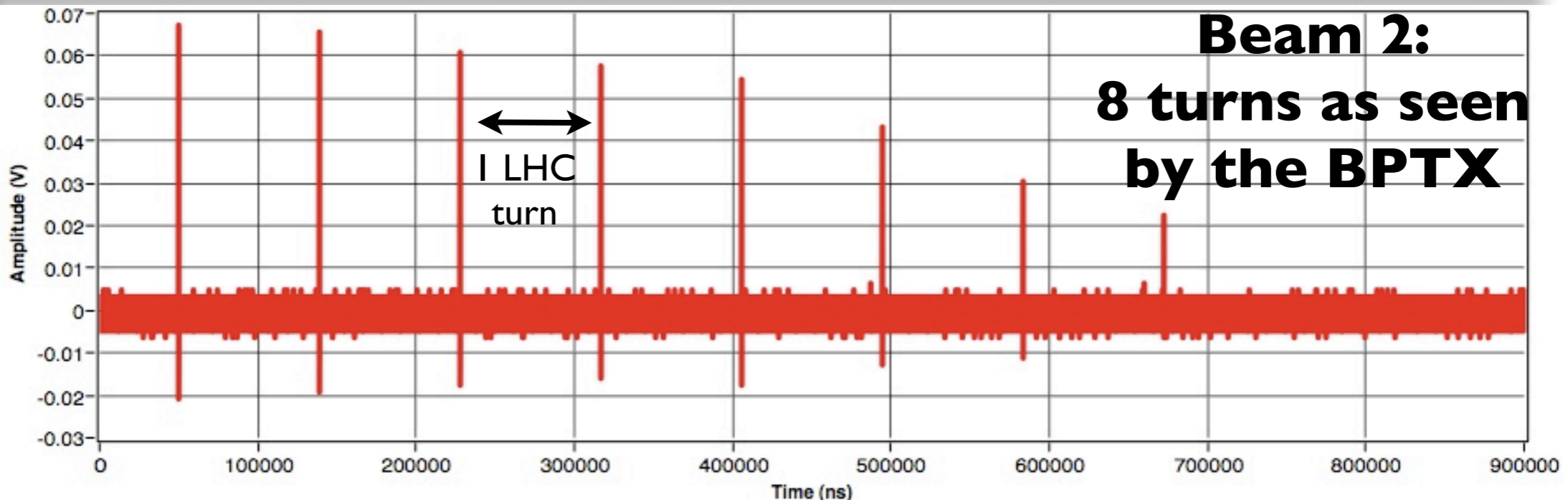


first beam event seen in ATLAS

in ATLAS



First circulating beam signals



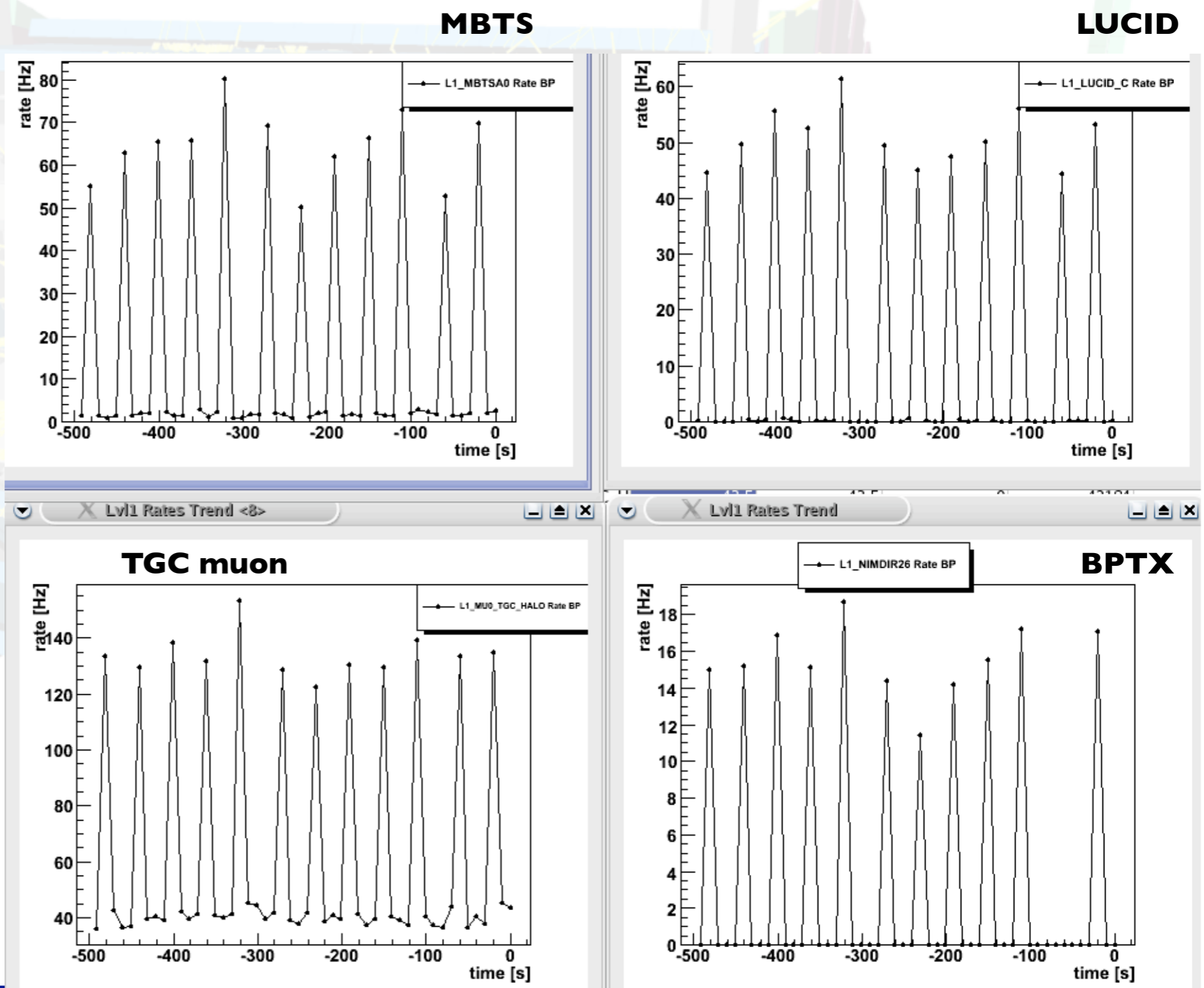


First beam triggers

The CTP input rates are constantly monitored and published on the information service.

Rates are recorded for each:

- trigger input,
- PIT line,
- trigger item before pre-scale
- trigger item after pre-scale,
- trigger item after veto.





Single Beam Event

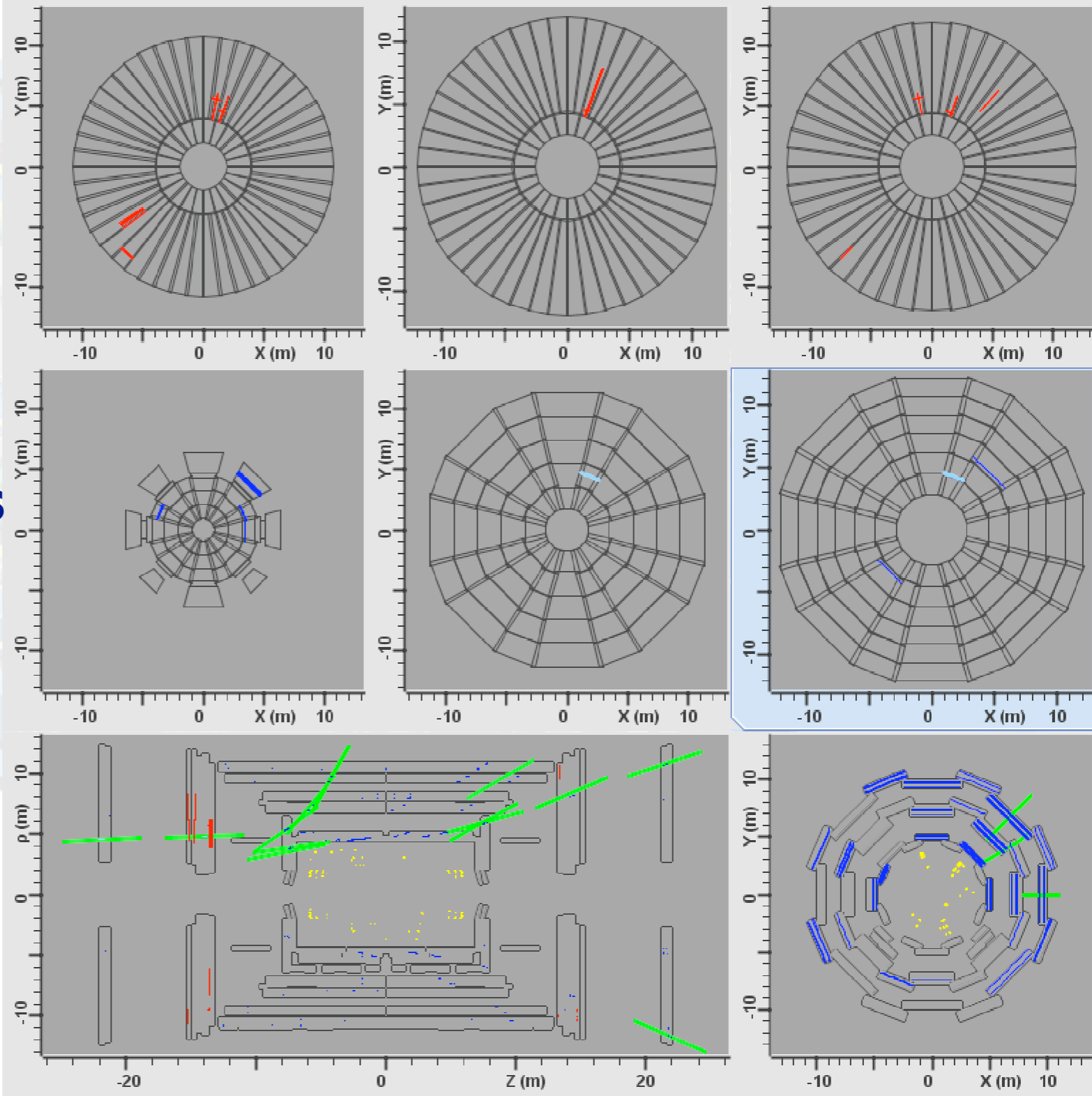
ATLAS 2008-09-10 21:31:10 CEST event:JiveXML_87863_00041 run:87863 ev:41 geometry: <default> Atlantis

TGC

MDT endcaps

MDT hits

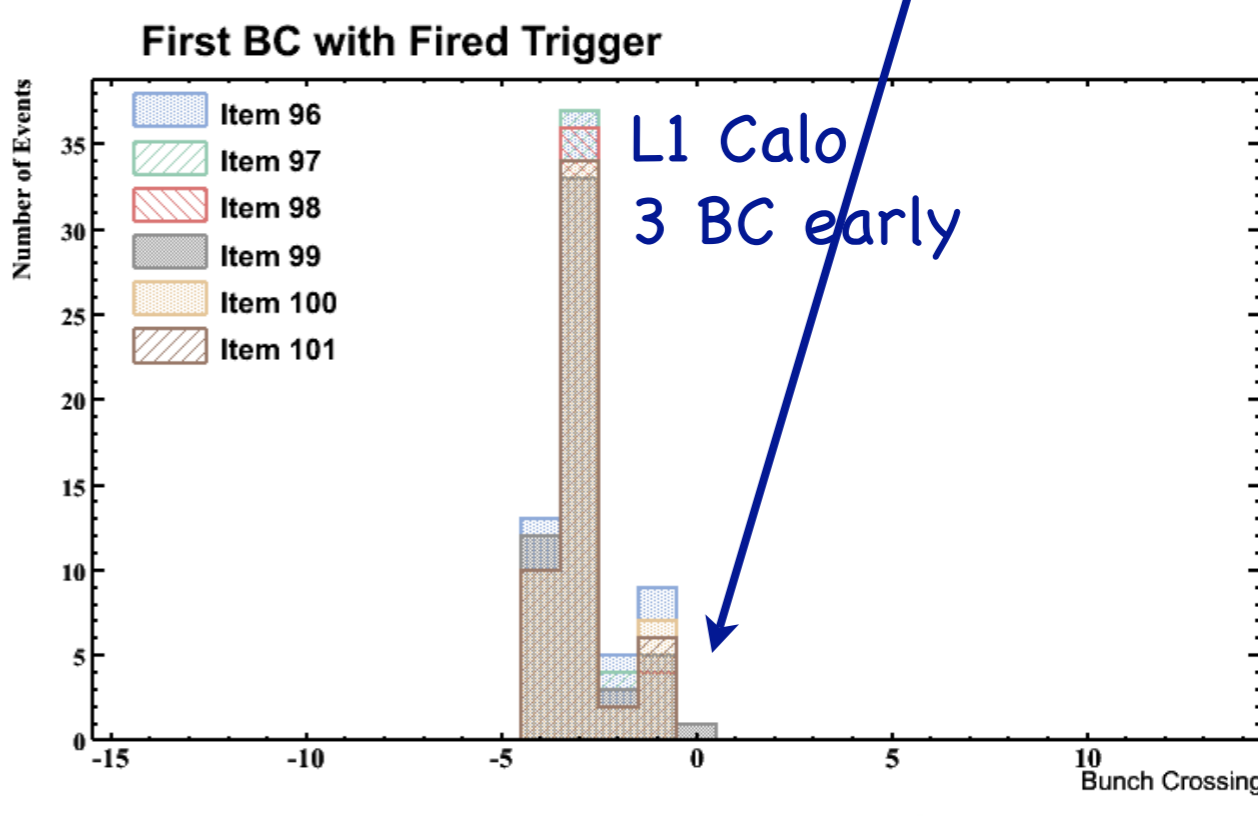
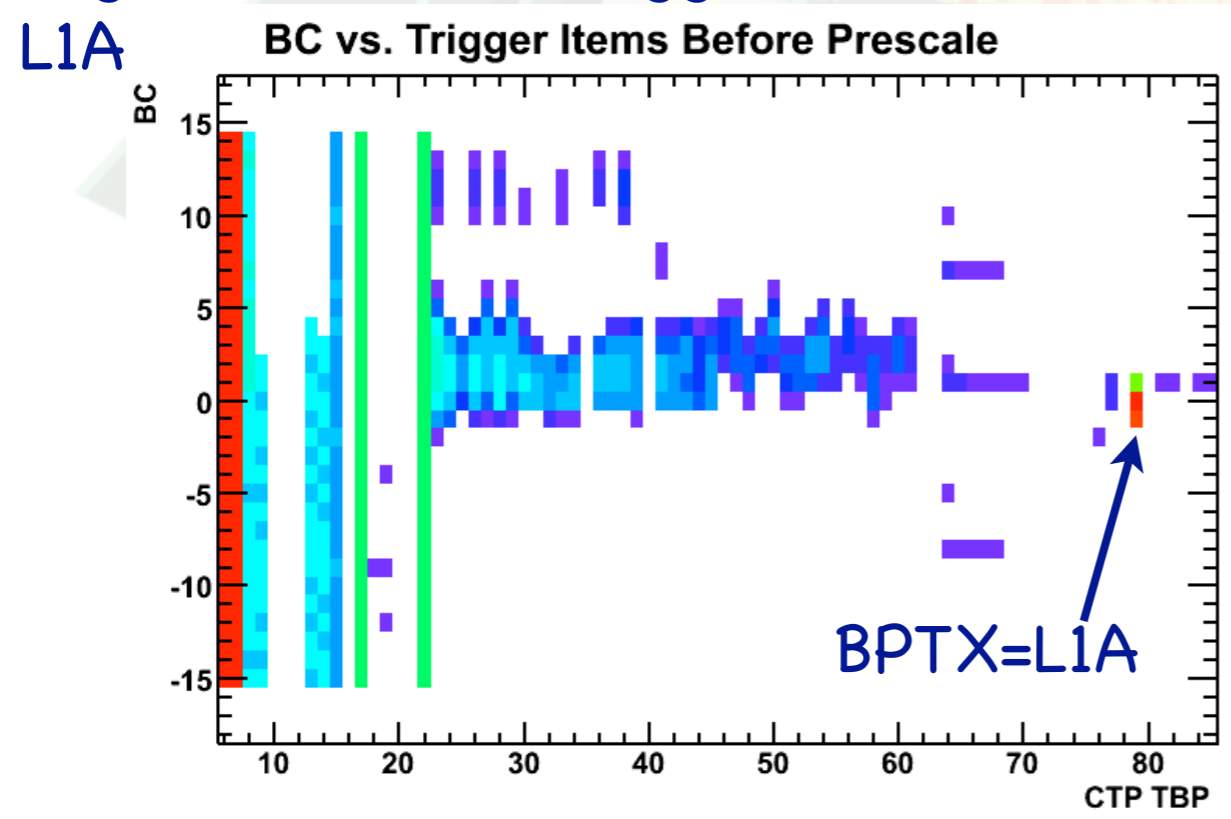
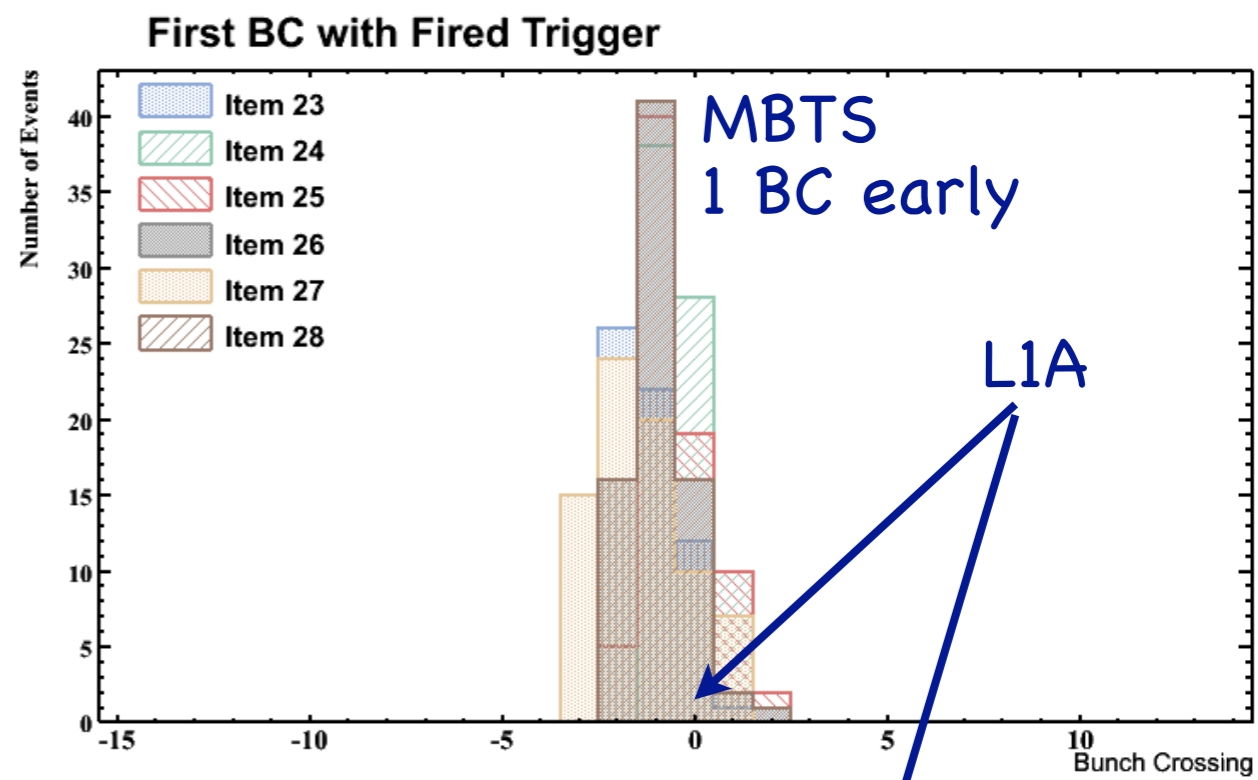
TGC hits





Trigger Timing-in strategy

- Fire L1 trigger with the filled bunch trigger (BPTX): definition of the time when a bunch is going through the detector.
- Readout CTP data for several bunch crossing (∓ 15 BC) around the L1A BC
- Adjust delay of each trigger input to be aligned with the trigger that fired the L1A





Summary



- Atlas first-level trigger is a synchronous 40MHz system based on information from the calorimeters and muon detectors
- It reduces the event rate from 1GHz to about 100KHz with a latency within than 2.5 μ s
- The system is complete and operational since a couple of months
- We have successfully triggered the first beam events!
- We have now started to timing-in of the trigger system for operation with beam



first beam event seen in ATLAS