Calorimetry triggering in ATLAS

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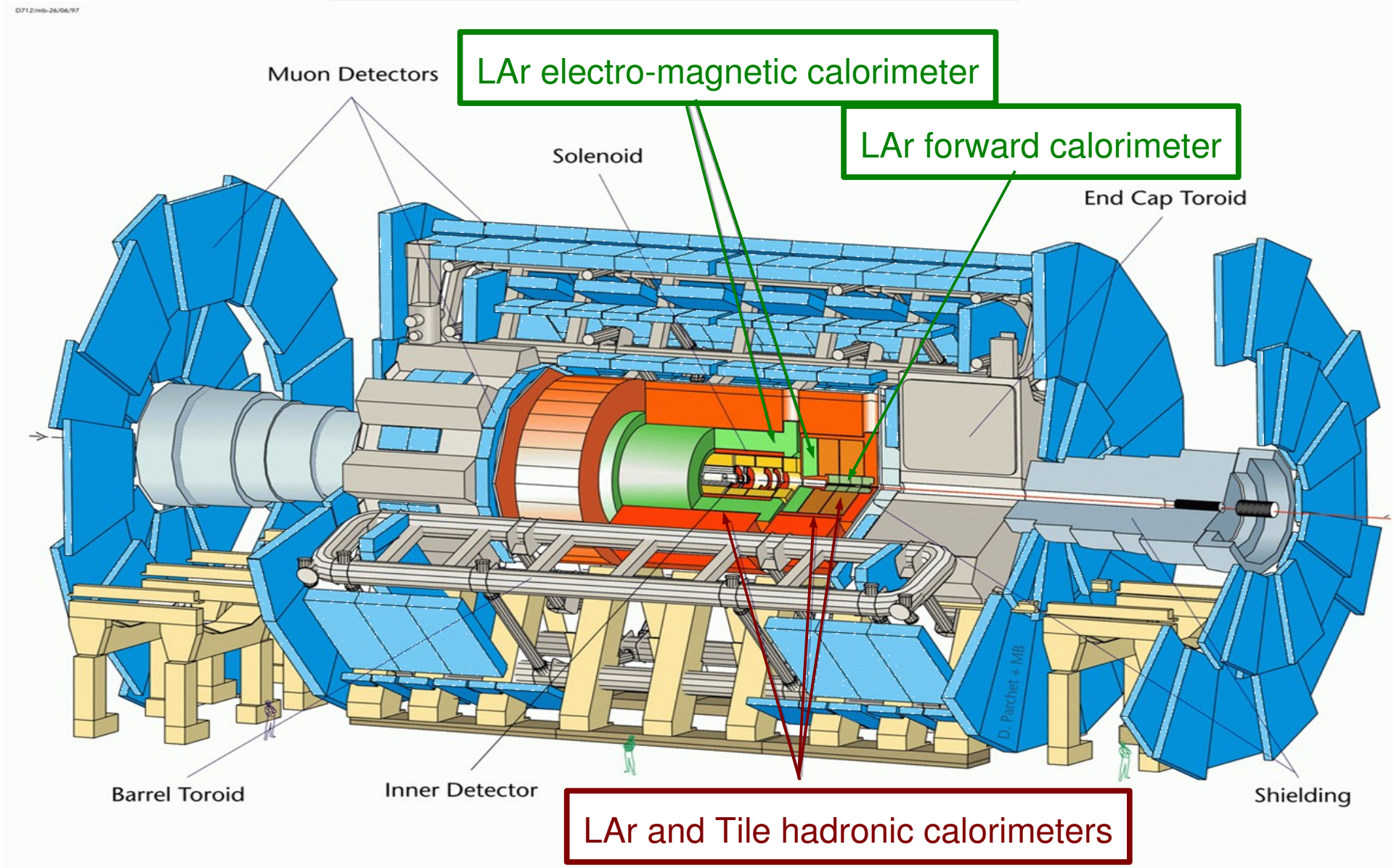
on behalf of ATLAS TDAQ collaboration

- ATLAS calorimeter
- ATLAS Trigger and DAQ overview
- Triggers for Electrons, Photons, Jets, Taus and Missing ET
- Results from cosmics and technical runs
- Preparation for data taking

ATLAS Calorimeters



Trigger Objective

- ATLAS is multipurpose spectrometer with a multipurpose trigger:

Electrons

Photons

Muons

Jets

Missing ET

Taus

Signature	L1 rate (Hz)	HLT rate (Hz)	Comments
Minimum bias	Up to 10000	10	Pre-scaled trigger item
e10	5000	21	$b, c \rightarrow e$, W, Z, Drell-Yan, $t\bar{t}$
2e5	6500	6	Drell-Yan, J/ψ, Υ, Z
γ20	370	6	Direct photons, γ-jet balance
2γ15	100	< 1	Photon pairs
μ10	360	19	W, Z, $t\bar{t}$
2μ4	70	3	B-physics, Drell-Yan, J/ψ, Υ, Z
μ4 + J/$\psi(\mu\mu)$	1800	< 1	B-physics
j120	9	9	QCD and other high-p_T jet final states
4j23	8	5	Multi-jet final states
τ20i + xE30	5000 (see text)	10	W, $t\bar{t}$
τ20i + e10	130	1	$Z \rightarrow \tau\tau$
τ20i + μ6	20	3	$Z \rightarrow \tau\tau$

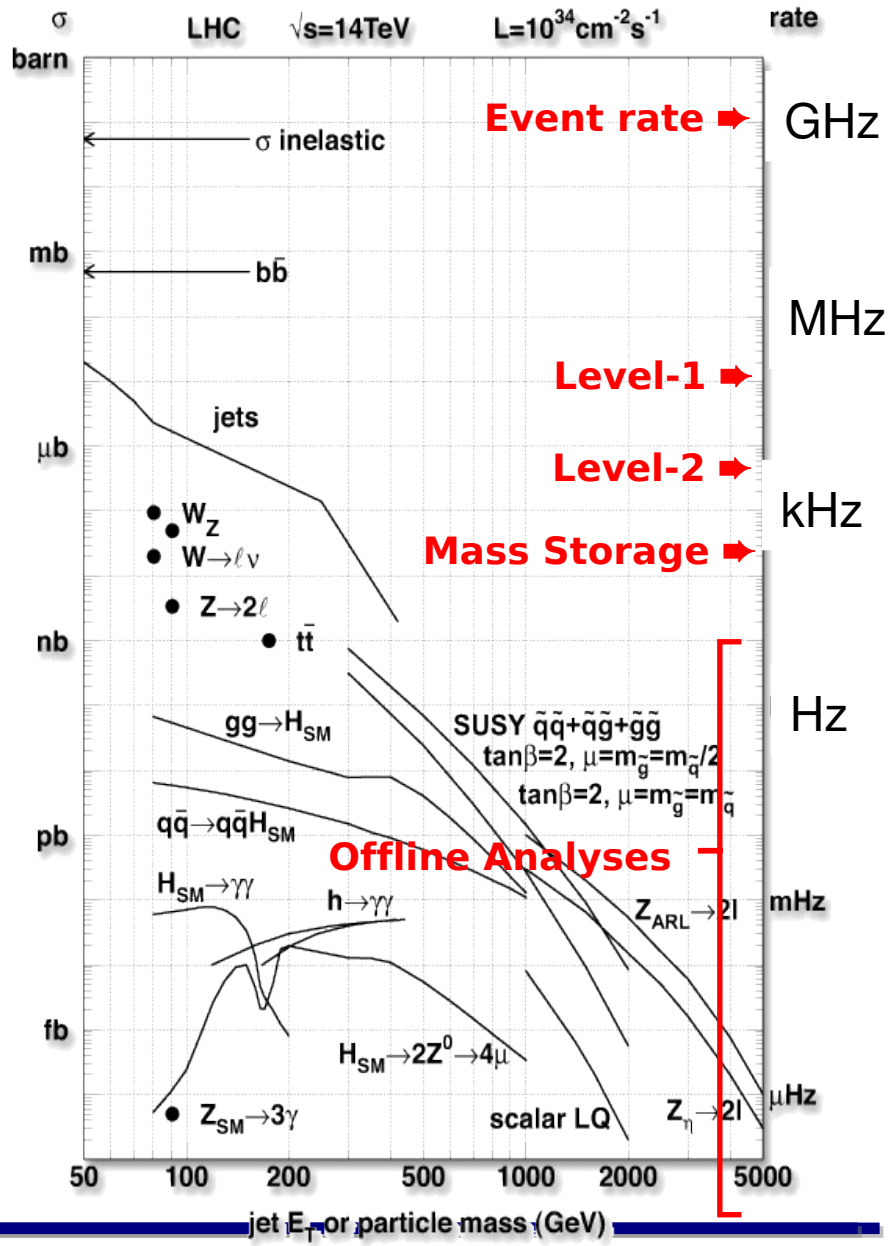
Table 64. Subset of items from an illustrative trigger menu at 10^{31} cm^{-2} s^{-1}.

All but muon and Bphysics triggers are Calorimeter based triggers

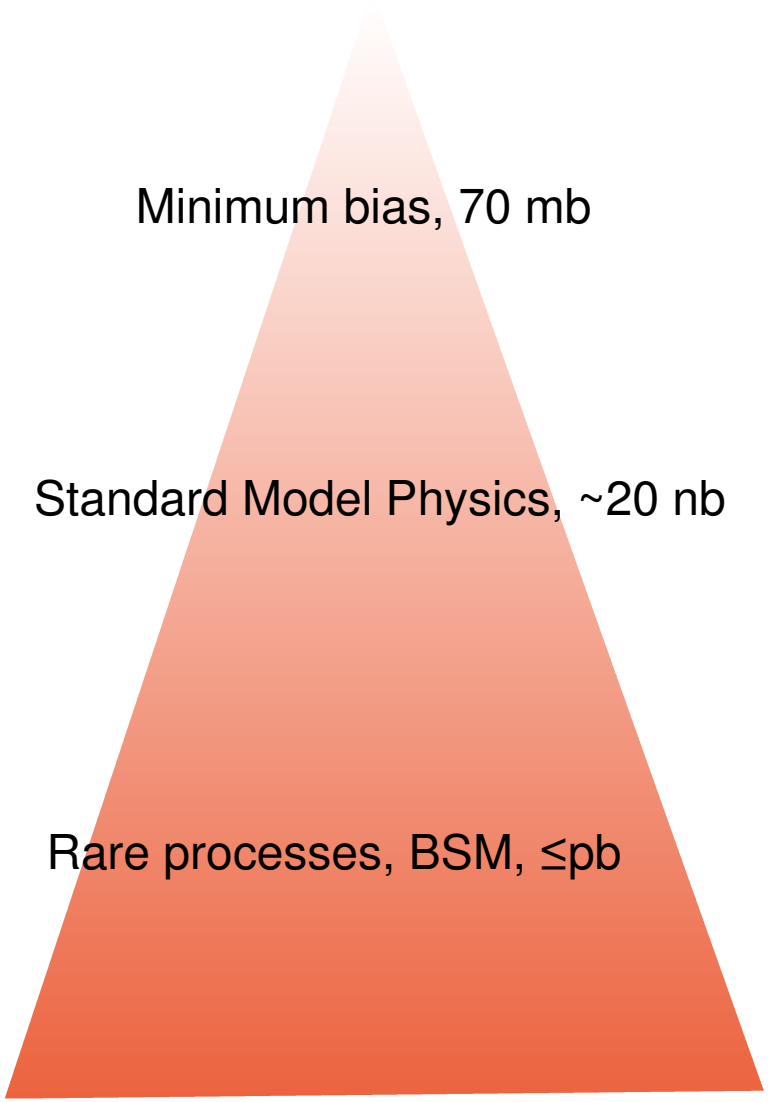
Trigger Challenge

- LHC bunch crossing 40 MHz
  - ~23 interaction/bunch at high luminocity
    - ATLAS raw event size is ~ 1.5MB (140M channels)
      - if every event is stored - ~50 TB/sec
- The design output rate is 200 Hz which is limited by storage capacity

Have to achieve more that 10^5 rejection at trigger level



Trigger Challenge



40 MHz, 1 PB/sec

Level 1: Coarse calorimeter data and muon trigger chambers

75 kHz, >100 GB/sec

Level 2: Full information from all detectors in regions of interest

1 kHz, 1.5 GB/sec

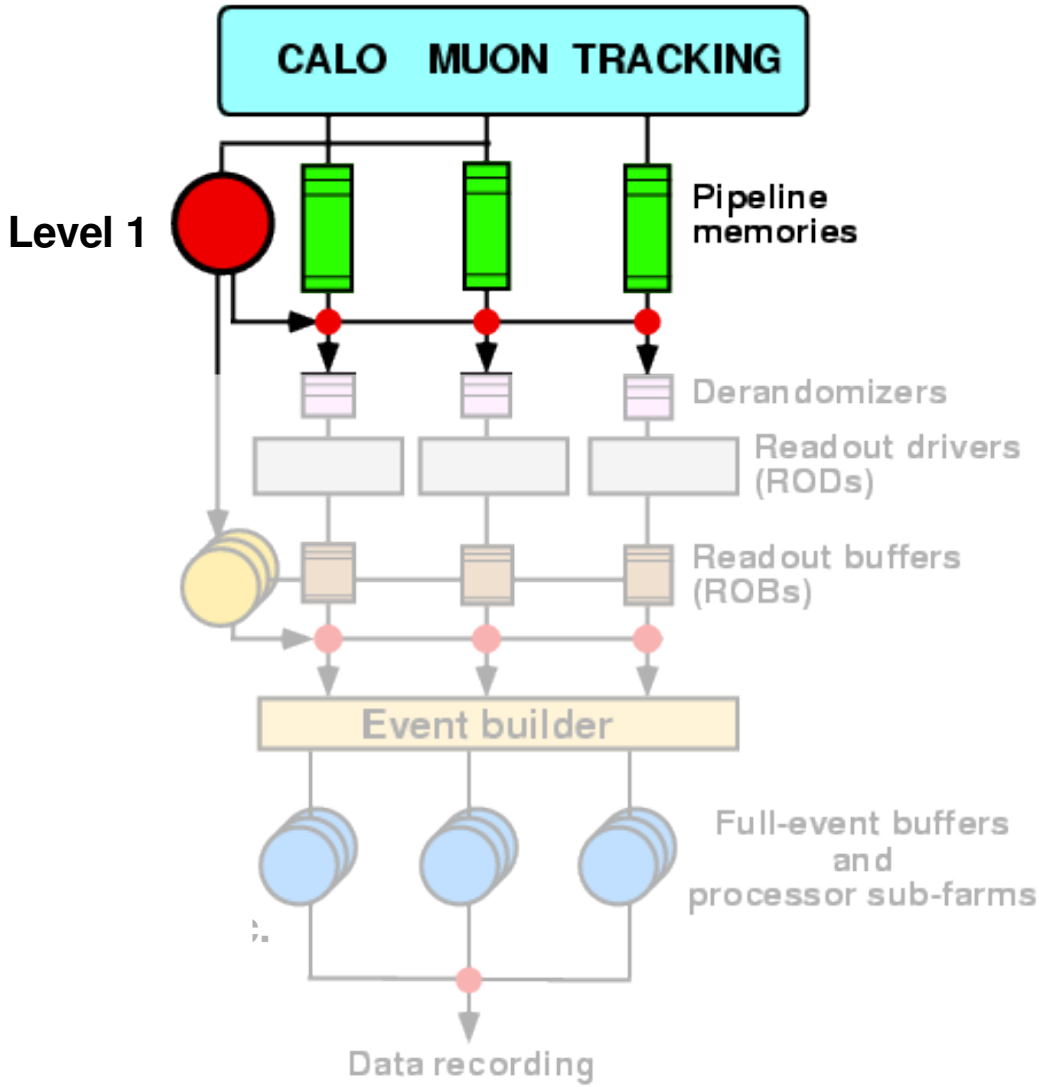
Event Filter: Reconstruction of complete event using latest alignment and calibration data

200 Hz, ~300 MB/sec

Level 1 trigger

- LVL1 Trigger
  - Hardware based (FPGAs ASICs)
  - coarse granularity calo/muon data
  - maxium latency 2.5 μs
  - output rate 75 KHz

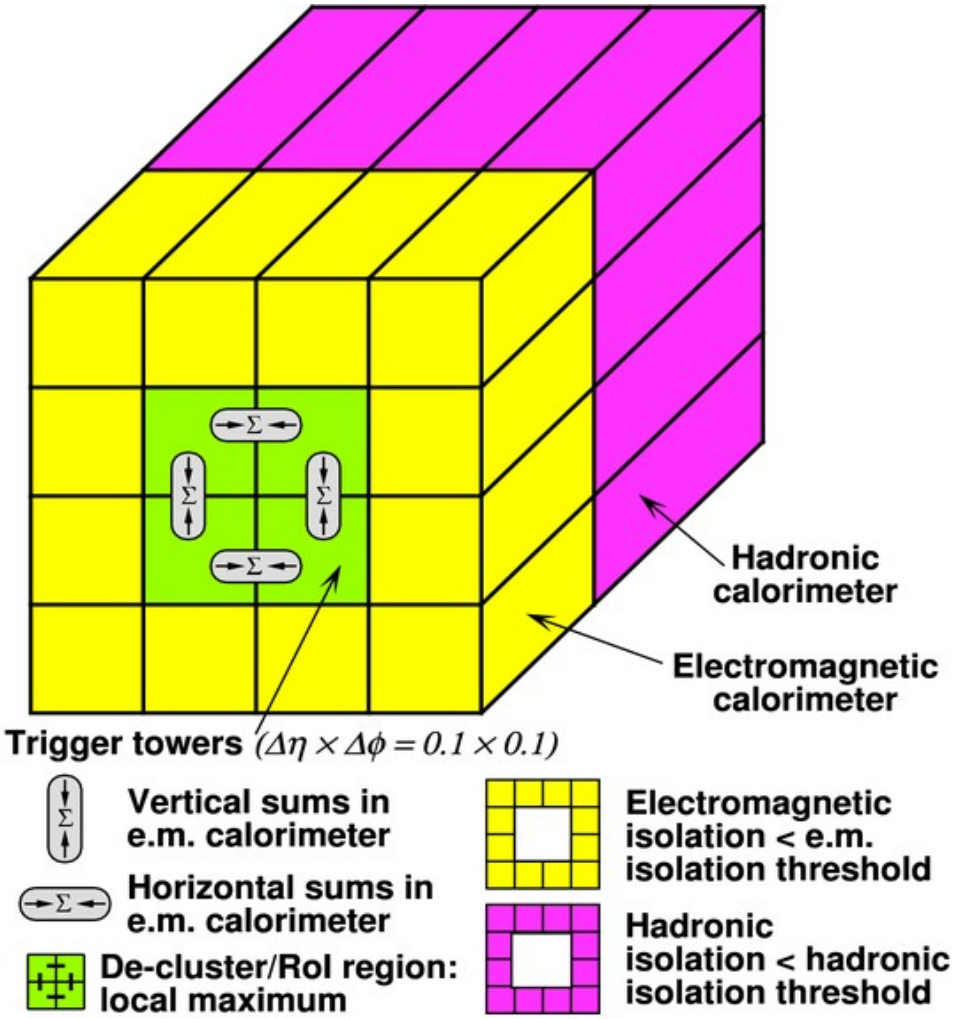
Calorimeter L1 trigger accounts for 70% of total L1 bandwidth



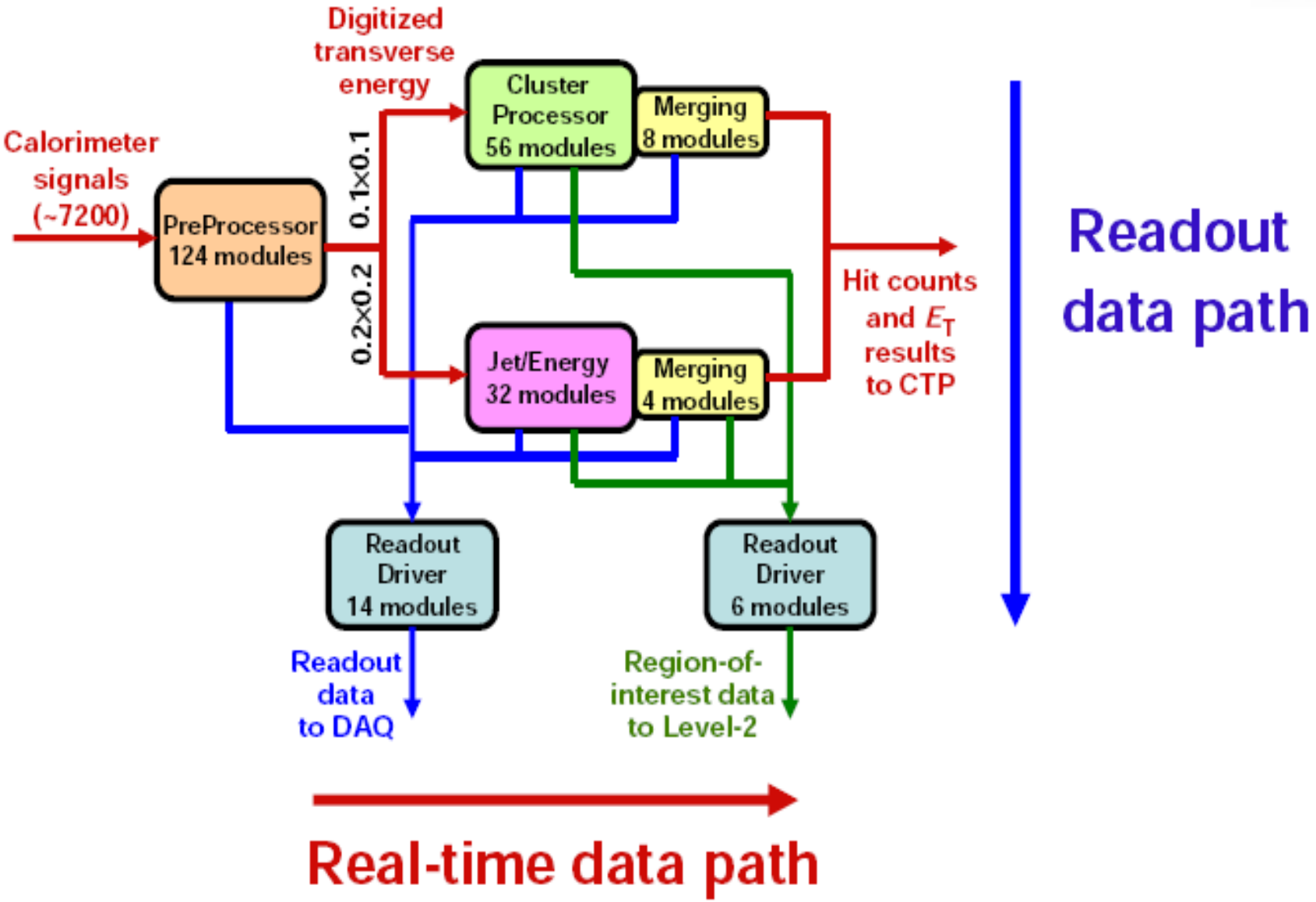
Level 1 Calorimeter trigger

- Level 1 Calorimeter selectes :
  - Electro-magnetic objects: (isolated EM only deposit) – electrons and photons
  - hadronic objects: (isolated EM+HAD deposits) - taus
  - jets:

    (high pT EM+HAD deposits)
  - events with large missing transverse energy or sum of all Calo objects: (everything)

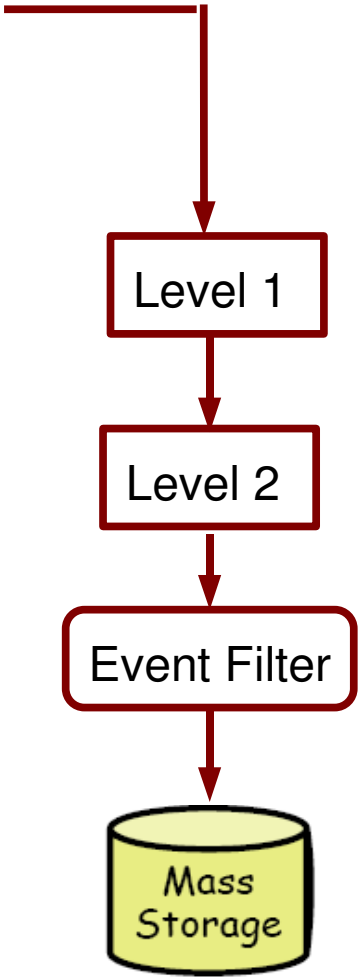


L1Calo readout



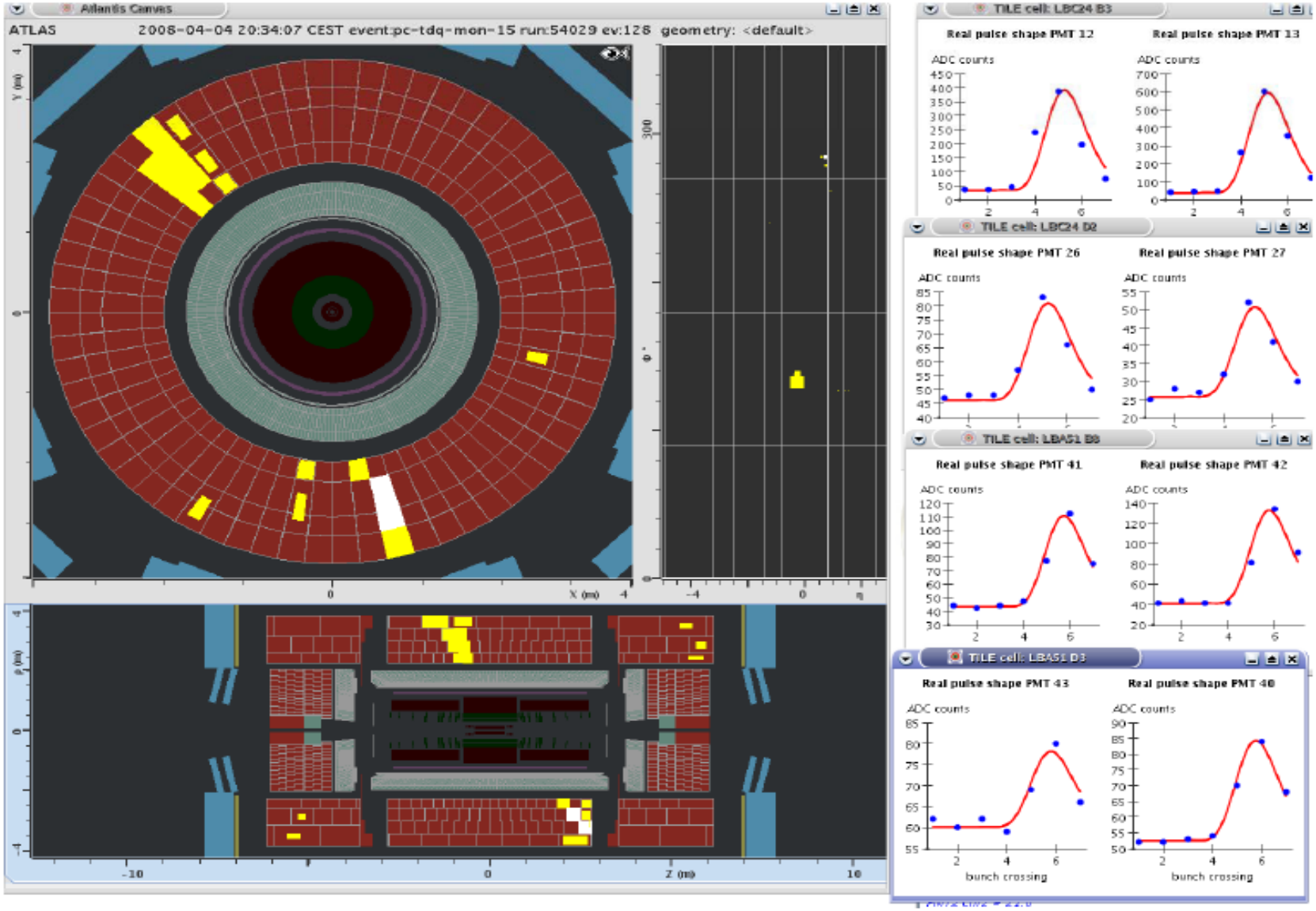
Cosmics runs

- Real data comes from detector
- Allows to test L1 and data preparation for L2,EF
- Test software with real imperfect data



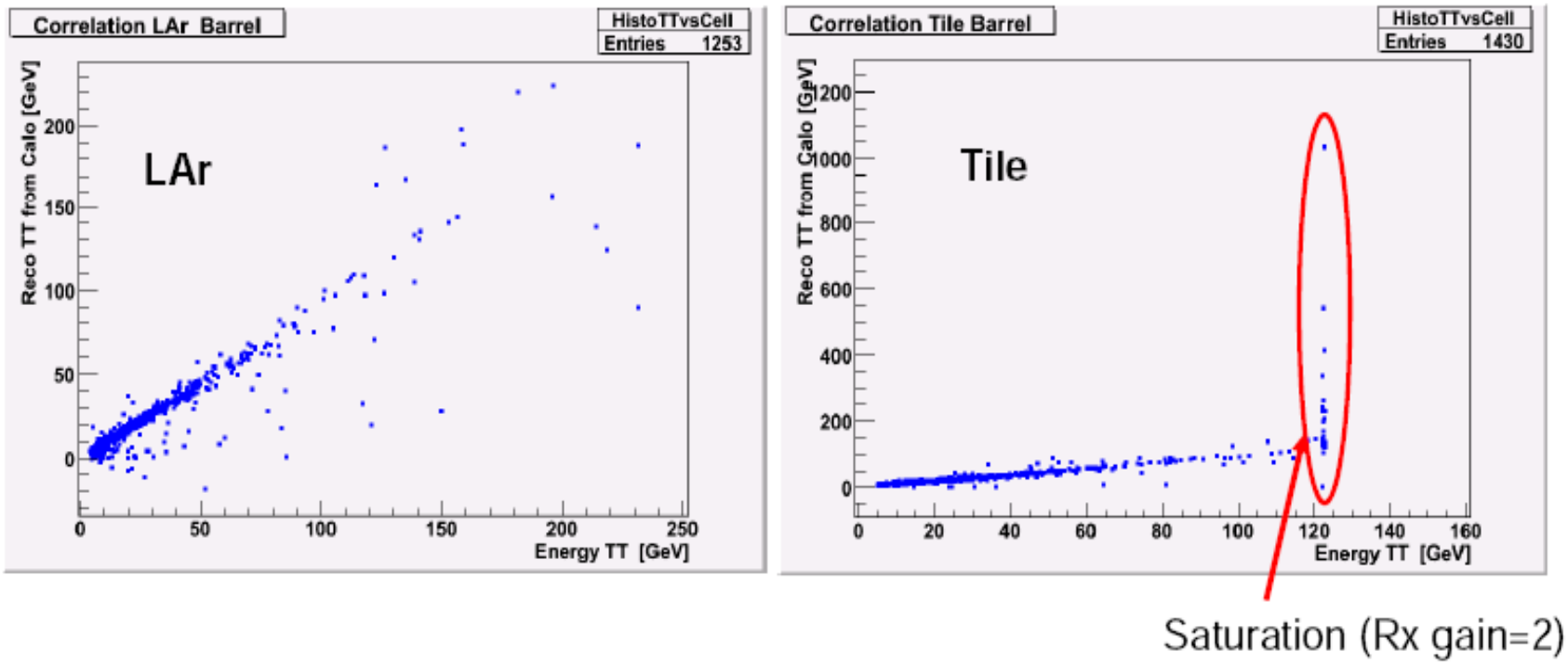
Very busy time in ATLAS control room

L1Calo trigger of cosmics rays



L1Calo energy correlation from cosmics data

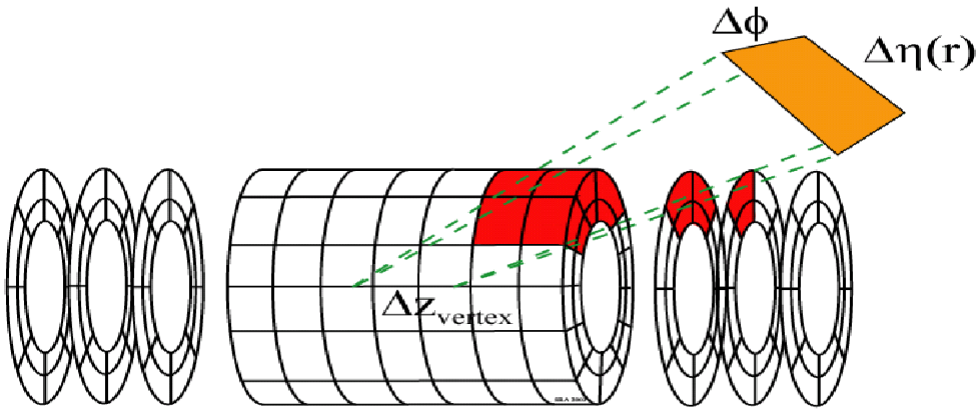
- Both timing and energy scale of the signals were checked with cosmics data in addition to tests with pulses

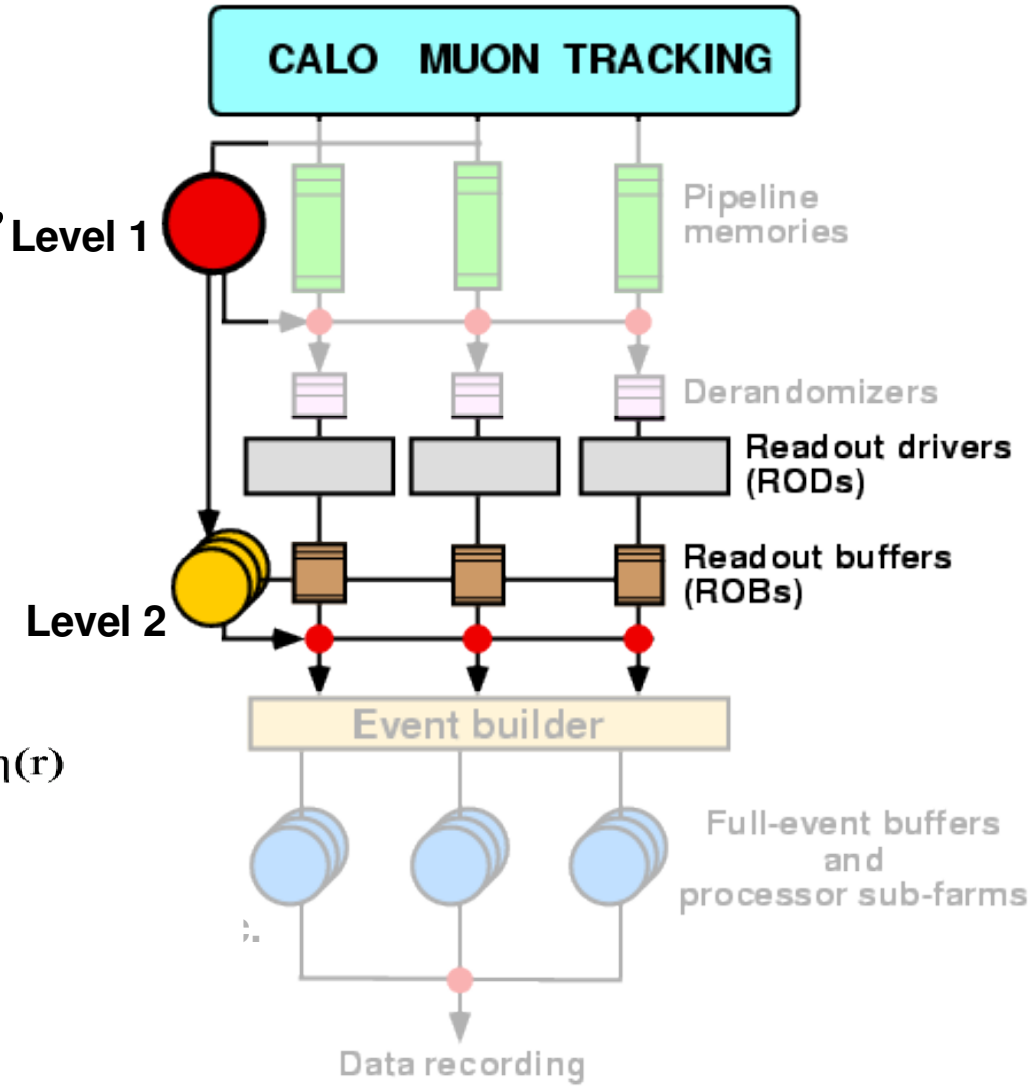


Good correlation of L1Calo energies with calorimeter readout

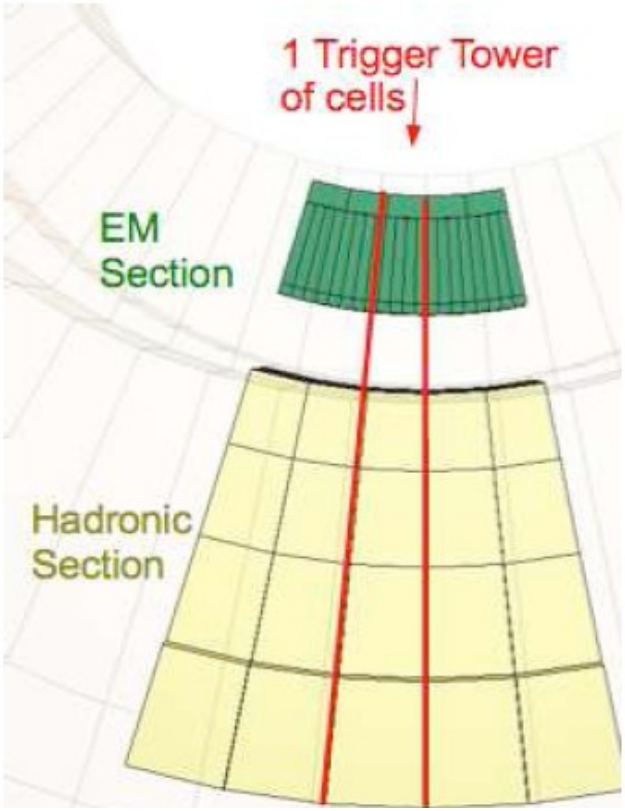
Level 2 trigger

- LVL2 Trigger
  - Software based
  - full granularity for all subdetectors, but only small region of interest is read and analysed (2% of all data per event)
  - fast rejection algorithms
  - mean event processing time - 40ms
  - output rate ~2 KHz





Level 2 trigger

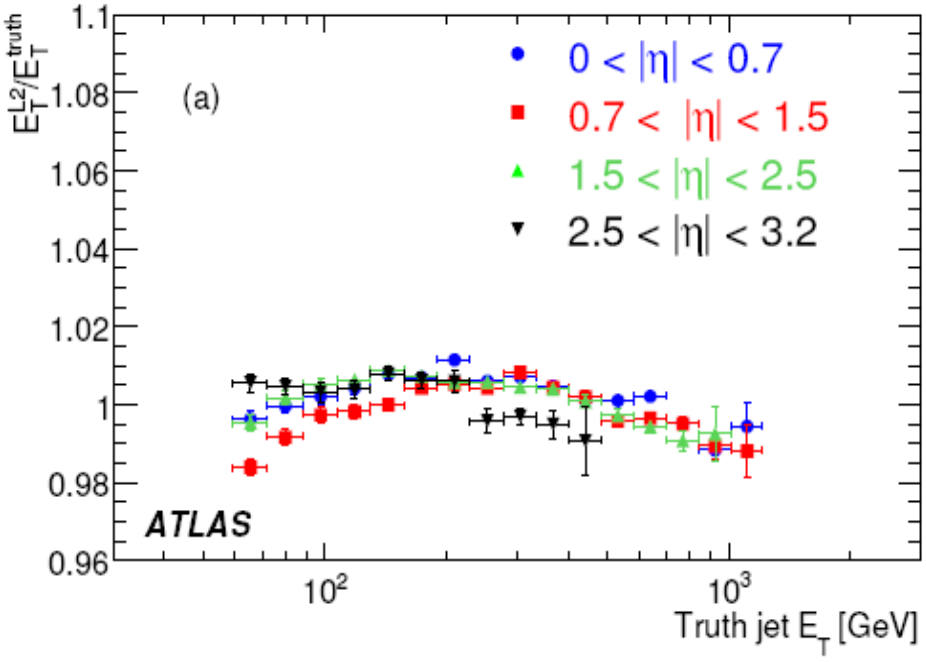


- Electrons, Photons :
  - based on 2nd LAr sampling : study shape parameters of the EM cluster; track match
- Taus (narrow hadronic cluster):
  - take shape parameters from 2nd LAr sampling; use EM+HAD to estimate total energy, check EM and track isolation requirements;
- Jets :
  - measure total energy in the large cone (EM+HAD), advanced jet calibration
- Missing ET (event property):
  - Correct L1 ET on losses due to muons (from L2 muon reconstruction)

L2 Calibration

- Hadronic responce of calorimeter is generally smaller than electro-magnetic responce. Calibrate difference to give an original energy of the jet. At L2:
  - $E_{jet} = w_{EM} * E_{EM} + w_{HAD} * E_{HAD}$
    - $w_i = a + b * \log(E)$
      - $a, b = f(\eta)$
- More detailed calibration

  at EF/offline level

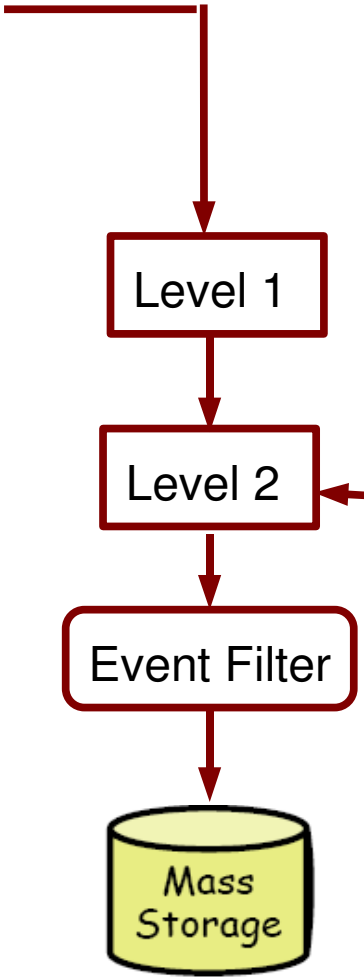


Dedicated calibration is applied to jet energy and missing ET measurements at all trigger levels. Tau uses jet calibration.

HLT technical runs

Cosmic Real Events

- Real data comes from detector
- Allows to test L1 and data preparation for L2,EF
- Test software with real imperfect data
- Not many events are accepted by physics triggers



Monte Carlo Events

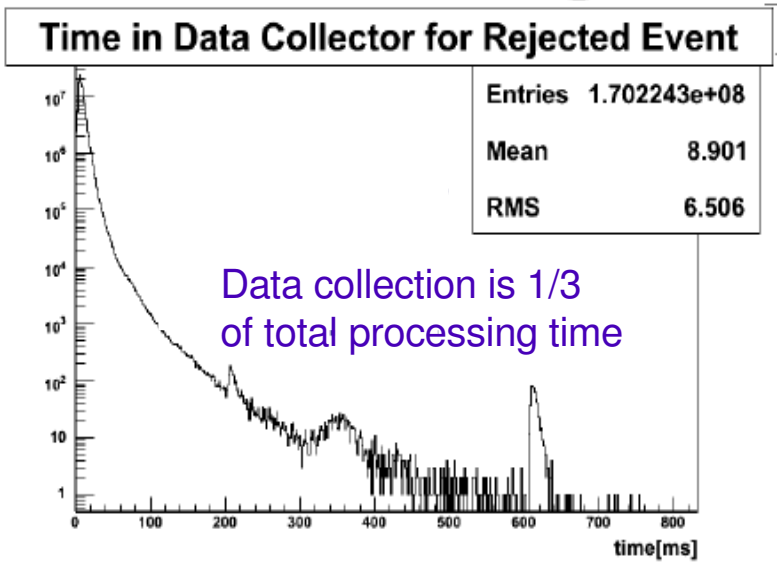
- MC or cosmics data are preloaded to readout buffer
- DAQ/HLT plays back data through the whole system except L1
- loop permanently over preloaded data
- Allow running at high rate

In the ATLAS control room

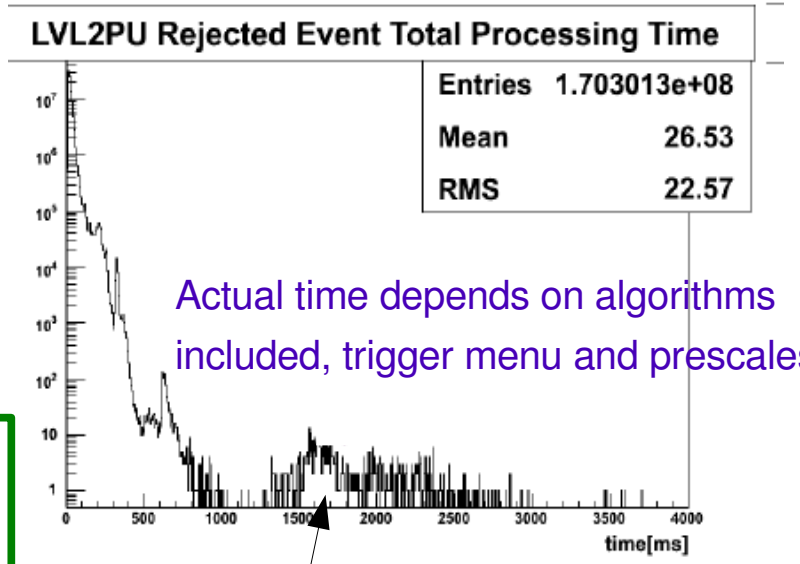
Technical runs are also a very busy period

Results of technical runs

- test of DAQ/HLT system with realistic input rate
- test of trigger robustness and stability (in spite of small number of input MC events)
- test of time used by algorithms and spend on accessing data
- validation of output stream and data acquisition system
- test of time used to configure system
- validation of Data Quality control, tools, data taking procedures



Data collection is 1/3 of total processing time



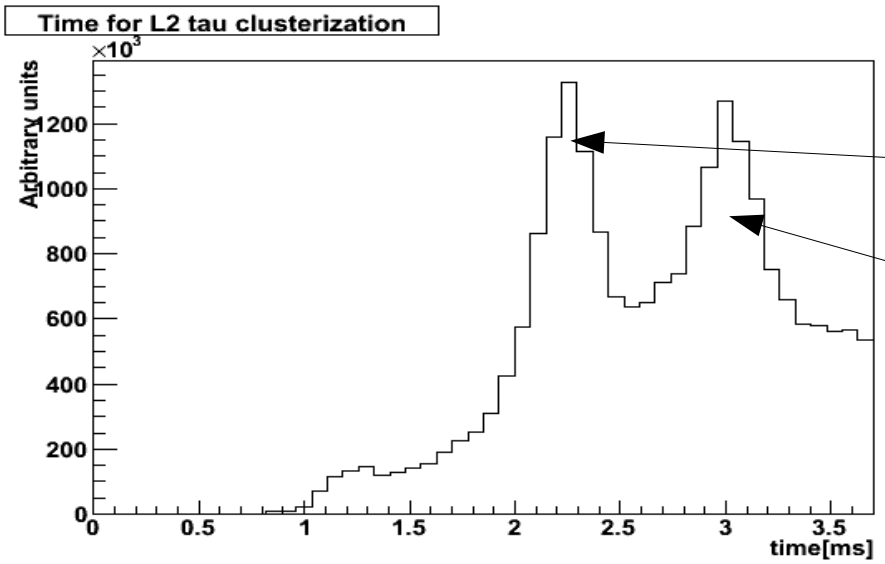
Actual time depends on algorithms included, trigger menu and prescales

First event, long configuration time

Tests with complex menu for start-up are successful,
Timing and performance is according to specifications

Data access

- Data access is a critical component of trigger system, minimize the number of requests of data :
  - use region of interest (2% of all data)
  - re-use/cache data for different triggers (e.g. electron and tau found on the same spot);
  - use early prescaling and early rejection
  - optimize number of requests for data – better big block at once than many small blocks

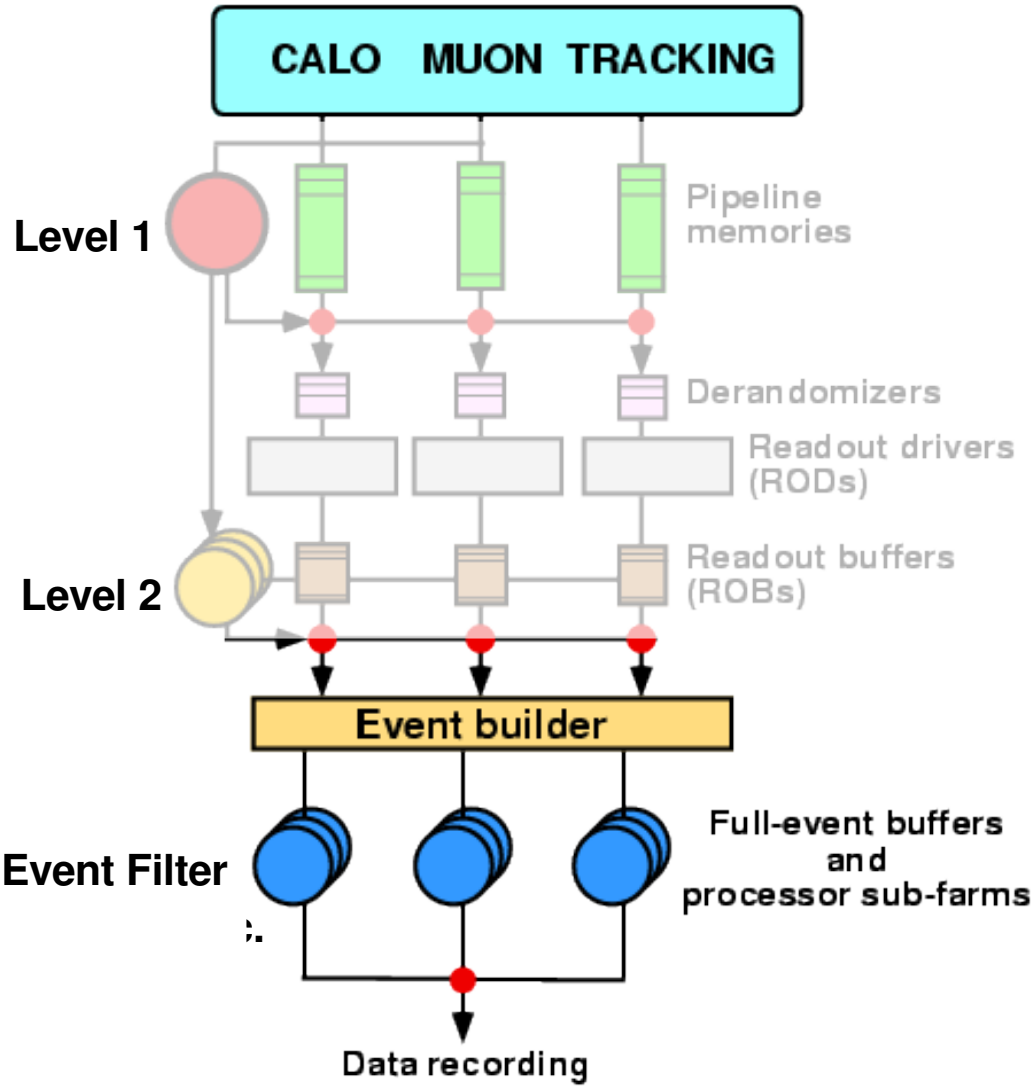


Tau & Egamma RoIs overlap,
part of data are already unpacked

Tau only RoIs

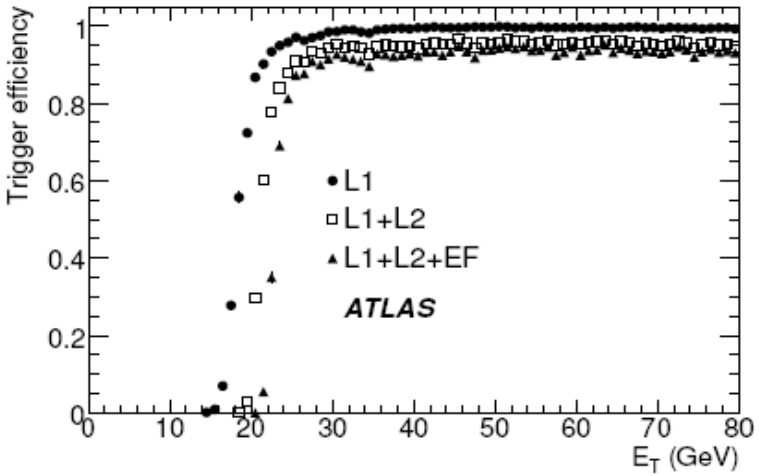
Event Filter (level3) trigger

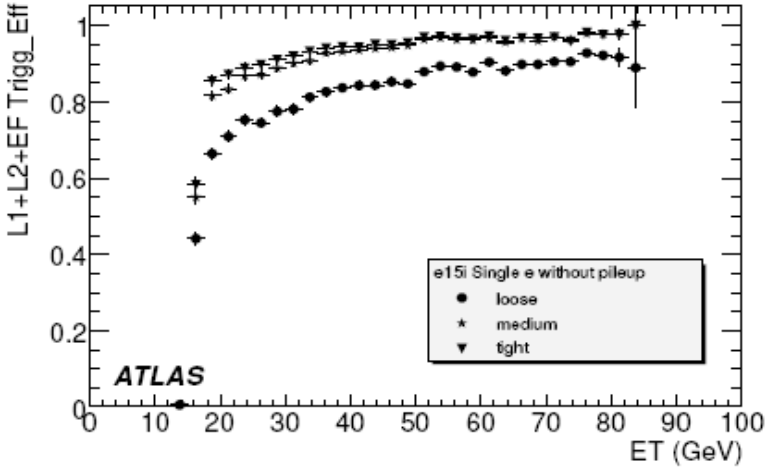
- Event Filter Trigger
  - Software based
  - potential full event access
  - *Offline*-like algorithms
  - mean event processing time ~ 4 ms
  - output rate **200 Hz**
  - data storage 300MB/s



EF performance

- Event filter runs most complex algorithms and provides accurate measurements of transverse energy of objects.
  - optimize performance to provide highest possible efficiency at affordable rates
  - use offline tools to benefit from offline development and precision
  - can use differently tight cuts for different purposes and different pt regions





Preparing trigger menu for data

- Complex trigger menu includes
  - triggers for physics
  - triggers for commissioning, calibration
  - back-up triggers (what is actual rate?)
  - triggers for efficiency measurements
  - HLT pass-through triggers
  - minimum bias

Draft of menu for 10^31, 14TeV run

Stream	Total Rate (Hz)	Unique Rate (Hz)
egamma	55	48
muon	35	29
jetTauEtmiss	104	89
minBias	10	10
express	18	0
calibration	15	13

Example: egamma part of menu

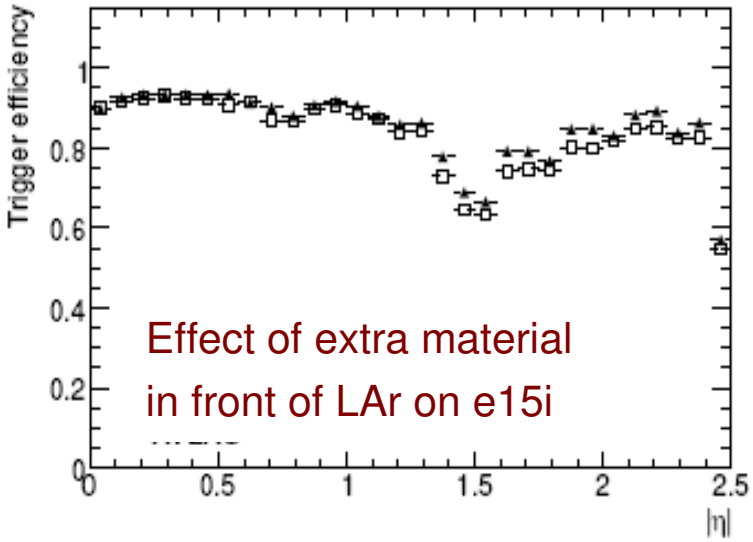
Signature	Level-1 Item	Level-1 Pre-scale	Level-1 Rate [kHz]	Event Filter Selection	Event Filter Pre-scale	Event Filter Rate [Hz]	Motivation
e5	EM3	60	0.7	medium	1	4.8 ± 0.2	$J/\Psi \to ee, Y \to ee$, Drell-Yan
2e5	2EM3	1	6.5	medium	1	6	$J/\psi \to ee, Y \to ee$, Drell-Yan
Jpsiee	2EM3	1	6.5	medium	1	1	$J/\psi \to ee, Y \to ee$
e10	EM7	1	5.0	medium	1	21	$e^{\pm}$ from b,c decays, E/p studies
γ10	EM7	1	5.0	medium	100	0.6 ± 0.1	$e^{\pm}$ direct photon cross-section, e-no-track trigger
e10_xe30	EM7_XE30	1	0.2	medium	1	0.3 ± 0.3	access low p_T-range for $W \to e\nu$
2γ10	2EM7	1	0.5	loose	1	< 0.1	di-photon cross-section
2e10	2EM7	1	0.5	loose	1	0.4 ± 0.2	$Z \to e^+e^-$
Zee	2EM7	1	0.5	loose	1	< 0.1	$Z \to e^+e^-$
2e12i_L33	2EM7	1	0.5	tight	1	< 0.1	trigger for L$\sim 10^{33}$ cm^{-2} s^{-1}
γ15	EM13	1	0.7	medium	10	1.3 ± 0.1	$e^{\pm}$ direct photon cross-section
e15_xe20	EM13_XE20	1	0.2	loose	1	1.0 ± 0.4	access low p_T-range for $W \to e\nu$
2g17i_L33	2EM13I	1	0.1	tight	1	< 0.1	trigger for L$\sim 10^{33}$ cm^{-2} s^{-1}
γ20	EM18	1	0.3	loose	1	5.4 ± 0.2	direct photons, jet calibration using γ-jet events, high-p_T physics,check tracking eff.
e20_passL2	EM18	1	0.3	loose	200	< 0.1	check L2EF performance
e20 passEF	EM18	1	0.3		125	0.1	check L2EF performance
em20_passEF	EM18	1	0.3		750	0.5 ± 0.1	check HLT performance
em20i_passEF	EM18I	1	0.1		300	0.5 ± 0.1	check L1 isolation
e22i_L33	EM18I	1	0.1	tight	1	1.2 ± 0.1	trigger for L$\sim 10^{33}$ cm^{-2} s^{-1}
γ55_L33	EM18	1	0.3	tight	1	1.2 ± 0.1	trigger for L$\sim 10^{33}$ cm^{-2} s^{-1}
em105_passHLT	EM100	1	1		1	1.0 ± 0.1	New physics, check for possible problems
γ150_passHLT	EM100	1	1		1	< 0.1	check for possible problems in express stream

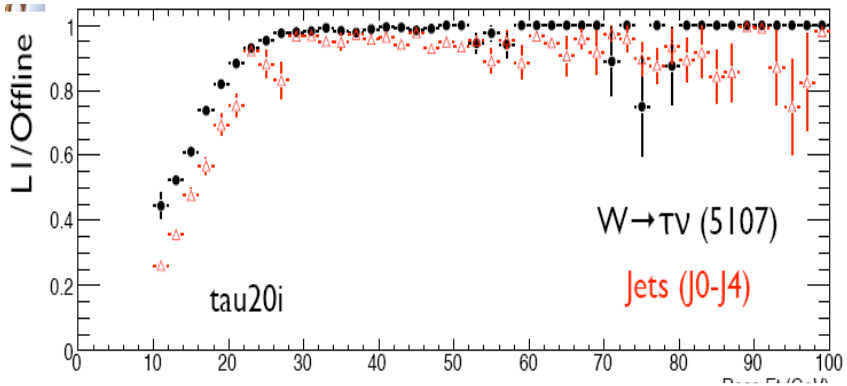
Table 12: Summary of triggers for the first physics run assuming a luminosity of L$\sim 10^{31}$ cm^{-2} s^{-1}. For each signature rates and the motivation for this trigger are given.

Rates given are estimates based on MC simulation

Preparing for data

- A lot of work went to understand and predict possible inefficiencies and biases at trigger level :
  - Effect of pile-up
  - Extra material in detector
  - Misalignment effects
  - etc
- Prepare to measure trigger efficiency from data:
  - using easy to reconstruct signals like Z->ee, ttbar
  - using well controled background (fakes)

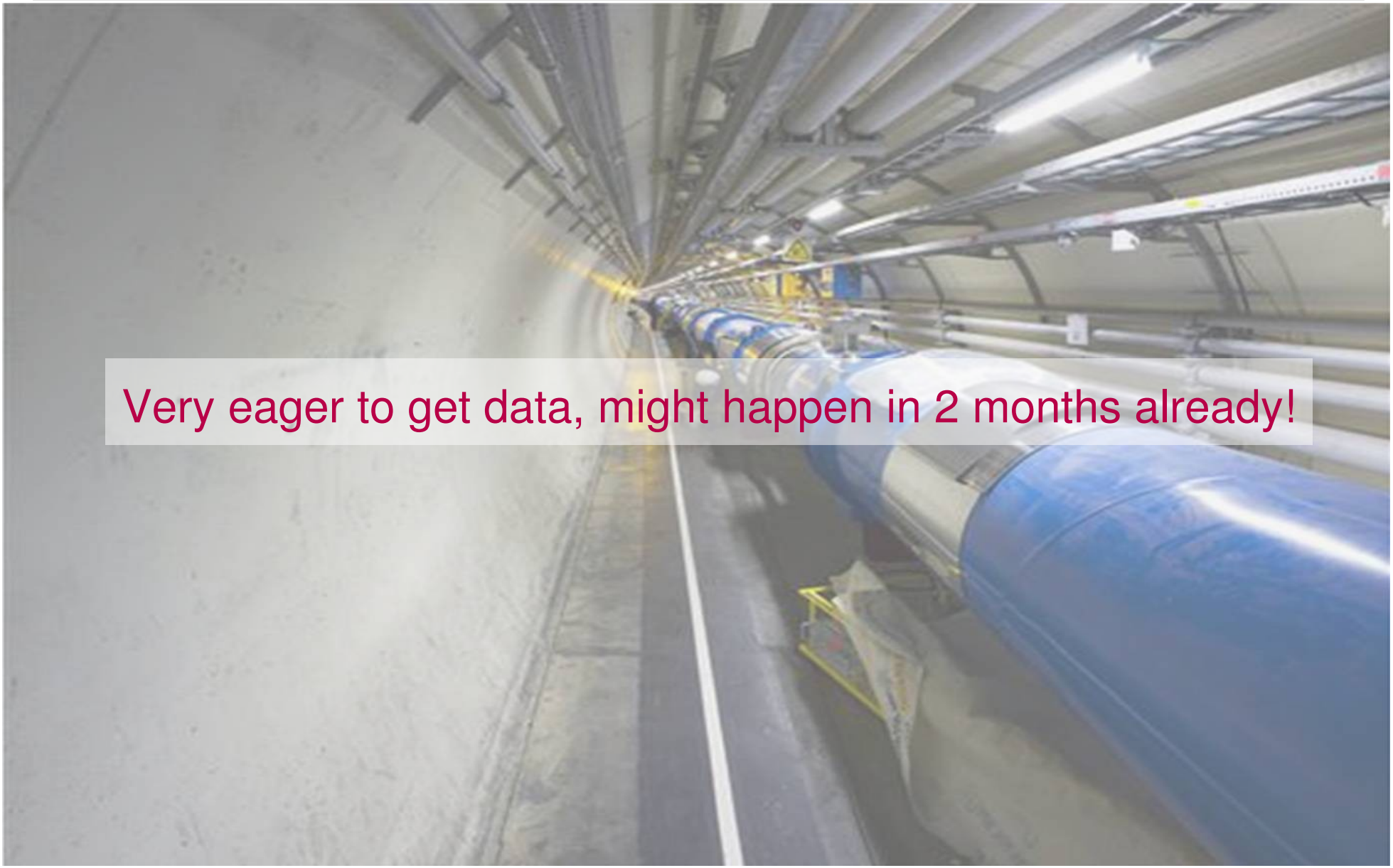




Estimates of tau efficiency from di-jet samples

Outlook

- The calorimeter is one of the main components of ATLAS trigger system, used in triggers for more that 70% of the total bandwith.
- 3 level trigger system has hardware and software components. All being installed and commissioning already now
- Cosmics tests show beautiful calorimeter signal, used for time and energy scale calibration
- Technical & cosmic runs give us the possibility to validate the HLT system and to establish procedures for algorithm tuning and data-taking
- Trigger menus are becoming mature, they include triggers for different purposes, such as physics, calibration, alignment, commissioning. Also different menus are being developed for start-up, for 10 and 14 TeV runs, and for different instant luminosities (10^31, 10^32, 10^33 /s/cm^2)
- preparation for data is ongoing, simulation of possible detector inefficiencies and systematics is applied in trigger studies


Very eager to get data, might happen in 2 months already!