Performance of the ATLAS trigger system

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on behalf of the ATLAS Collaboration

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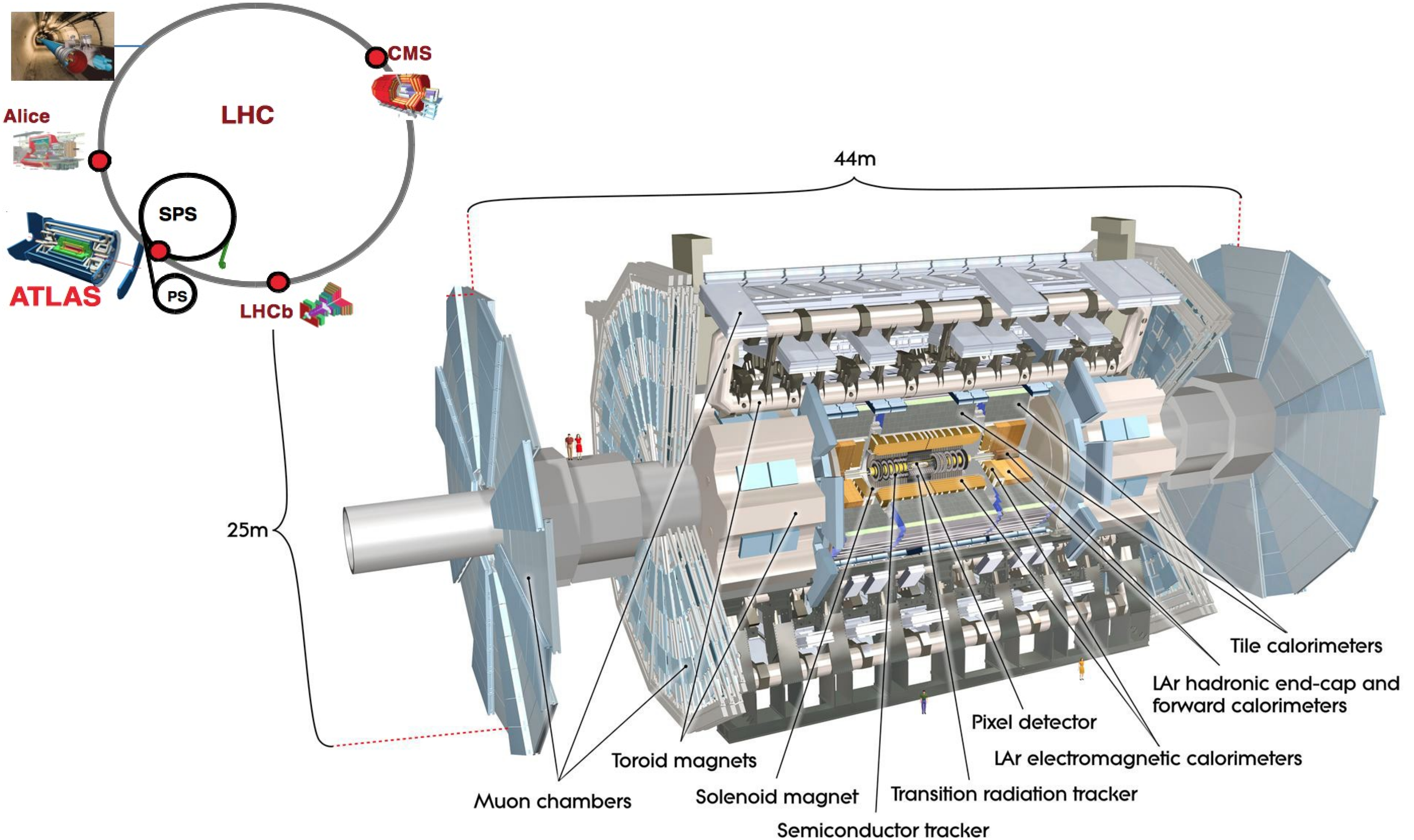
Overview

- The ATLAS trigger operated successfully during 2009-2011 LHC running at centre of mass energies between 900 GeV and 7 TeV
  - Here we focus on 2011 performance and prospects for 2012
- 3-level trigger system
  - 40 MHz bunch-crossing rate ➞ ~300 Hz average recording rate
  - L1 uses custom electronics
  - High-Level Trigger = L2 + Event Filter ➞ software-based triggers
- The trigger system selects events by identifying interesting signatures
  - More details in the following pages and in several talks/posters
- ATLAS is currently taking data with proton beams at 4+4 TeV

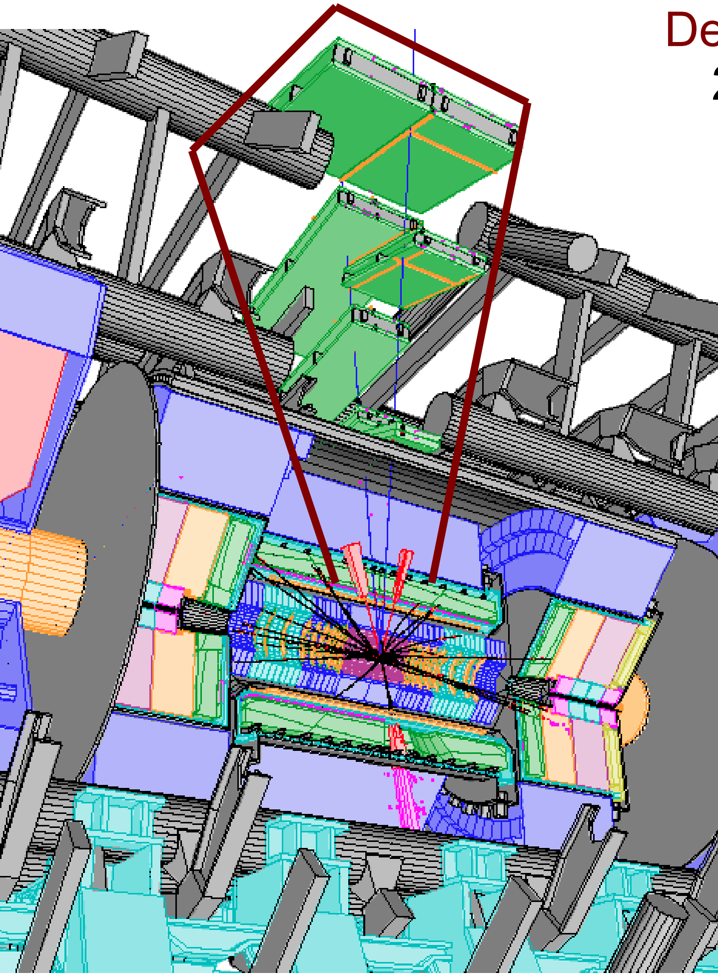
The ATLAS detector



The trigger and data acquisition system

(More details on talks by Andrea Negri)

Region of Interest (RoI) in (η, φ)



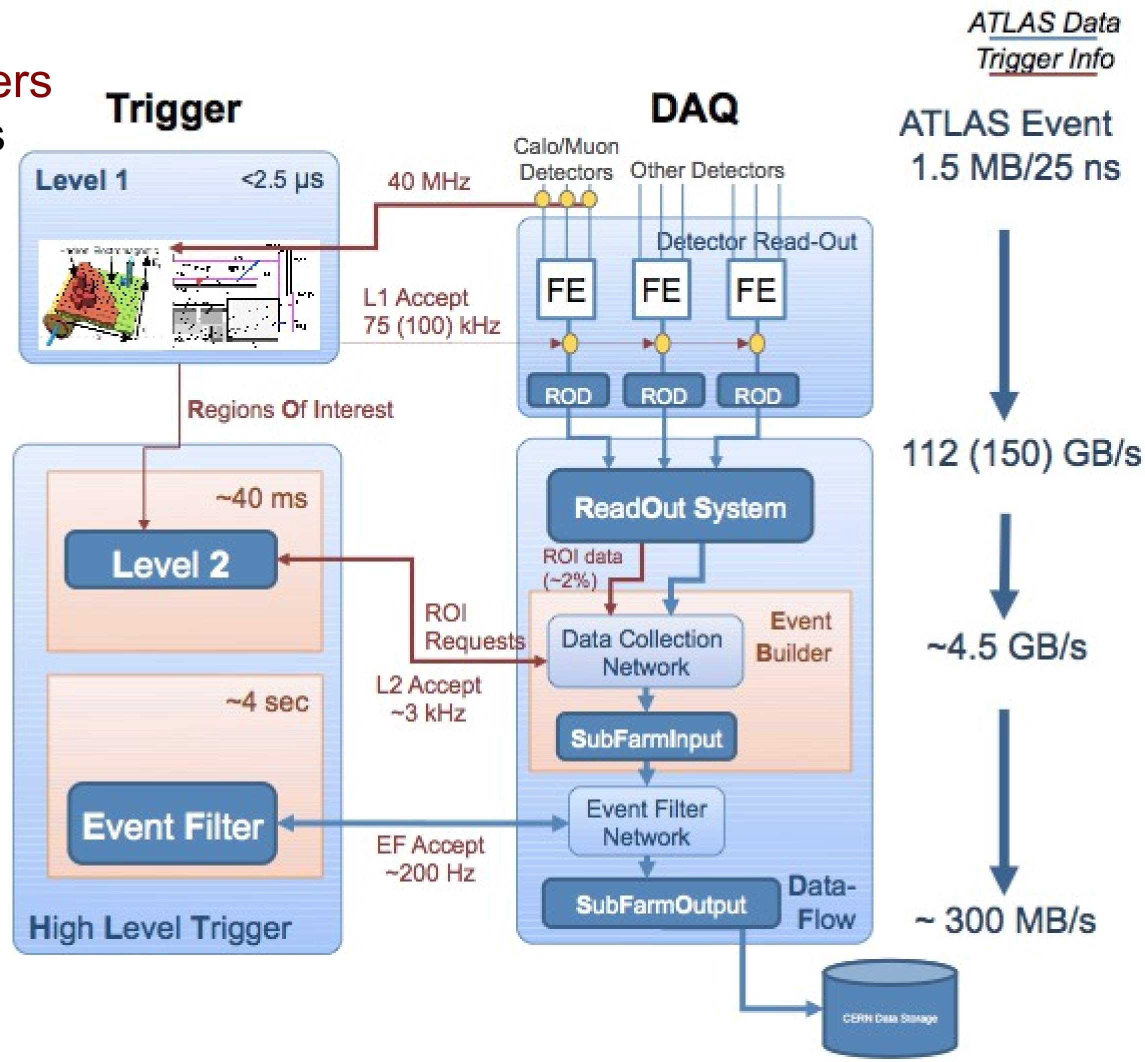
Design numbers
2011 values

40 MHz

75 (100) kHz
50-60 kHz

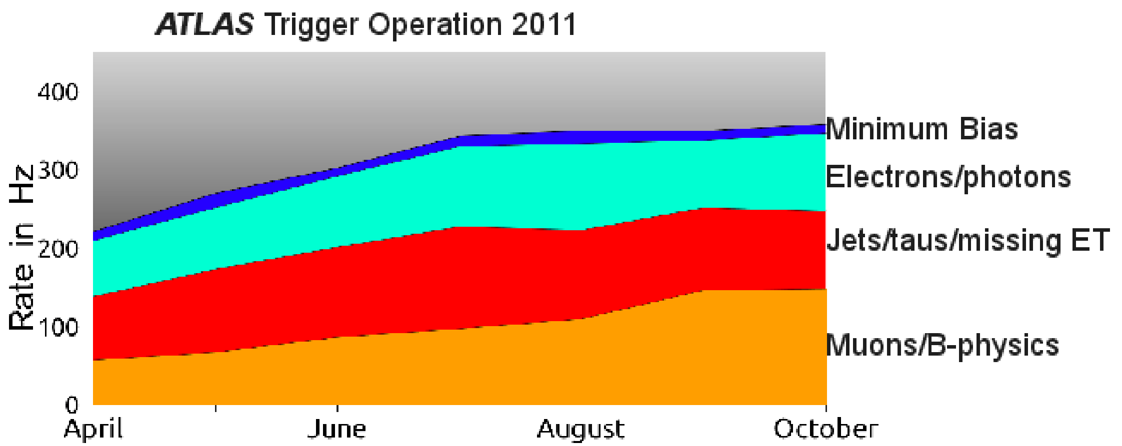
~ 3 kHz
4-5 kHz

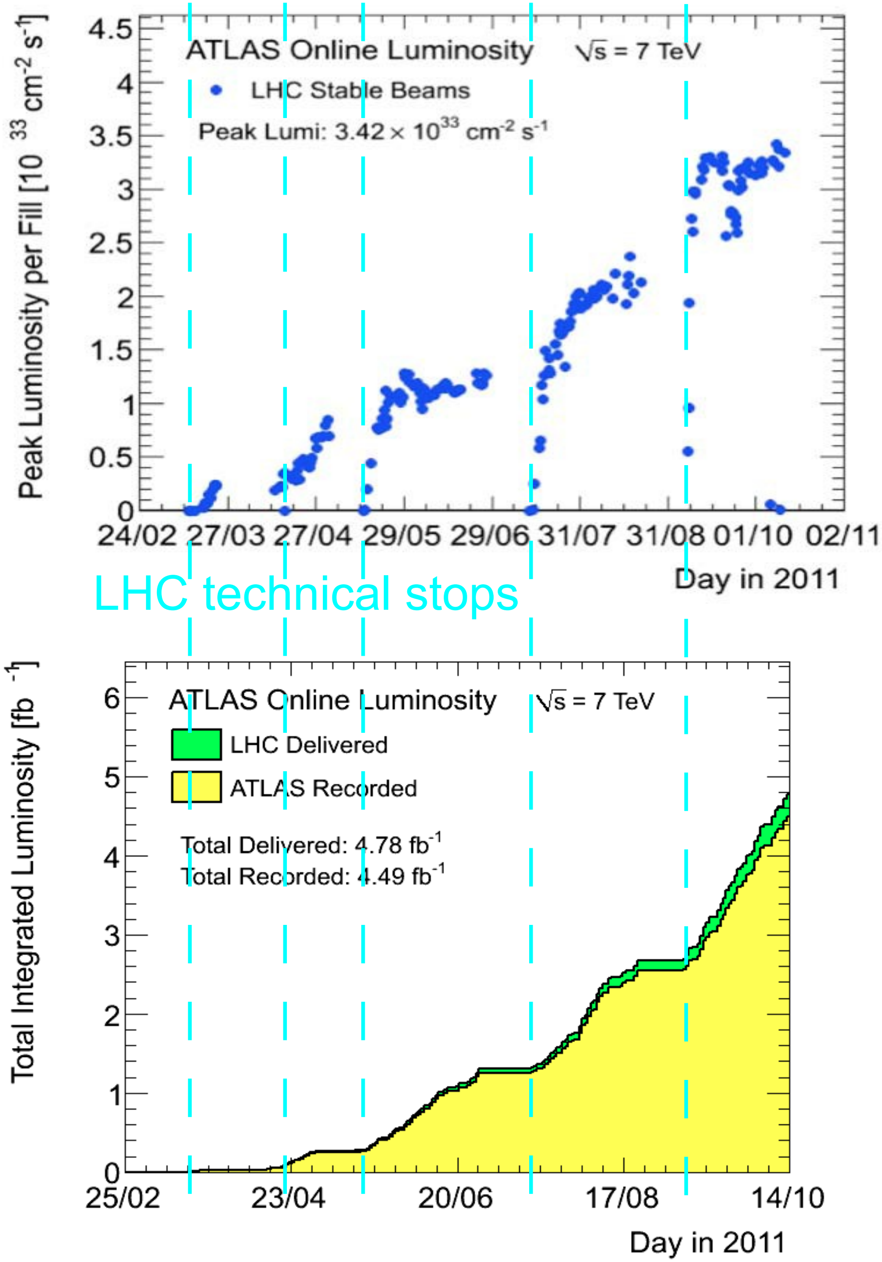
~ 200 Hz
300-400 Hz



ATLAS data taking in 2011

- ATLAS data taking efficiency: ~95%
  - 8–17 interactions/bunch crossing
  - High pile-up run with peak of 32.5 int/BC used to study config for 2012
- 3.5 + 3.5 TeV in 2011, 4 + 4 TeV in 2012



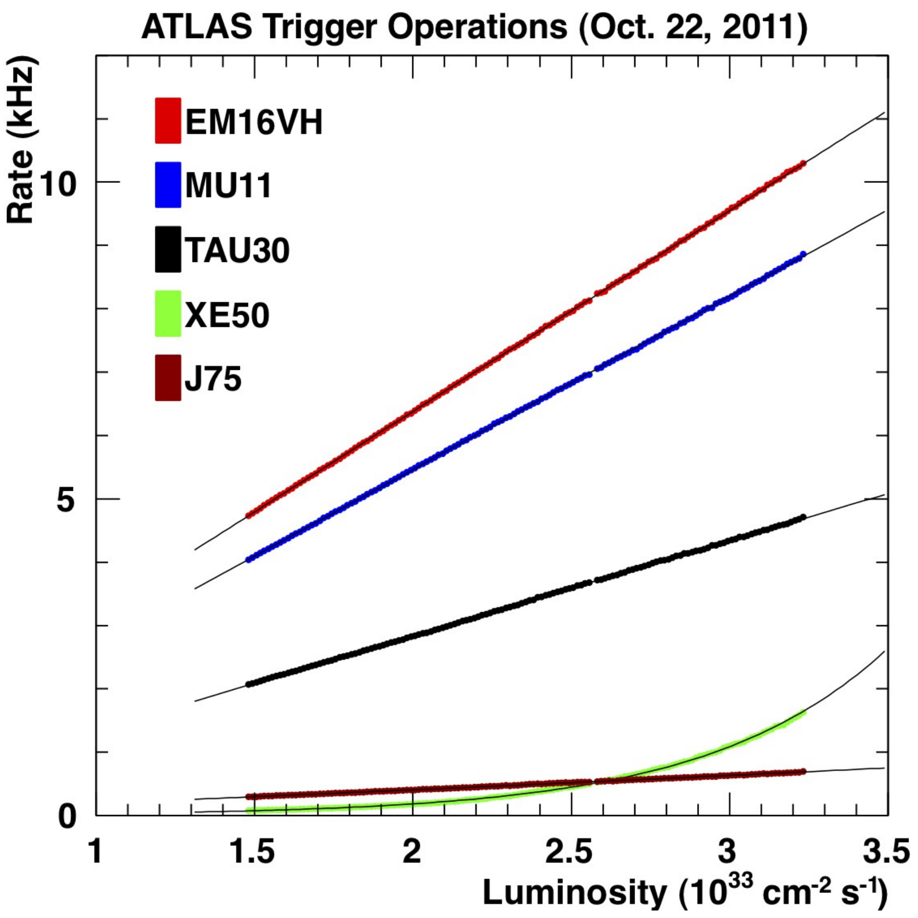


L1			HLT						
Muon	Calo	CTP	electron	photon	muon	tau	jet	b-jet	missing E_T
99.0	100	99.8	99.3	99.3	100	99.9	98.6	99.9	99.3

Luminosity weighted relative trigger quality delivery during 2011 stable beams in pp collisions at √s=7 TeV between 13 March and 31 October (in %).

Families of trigger signatures

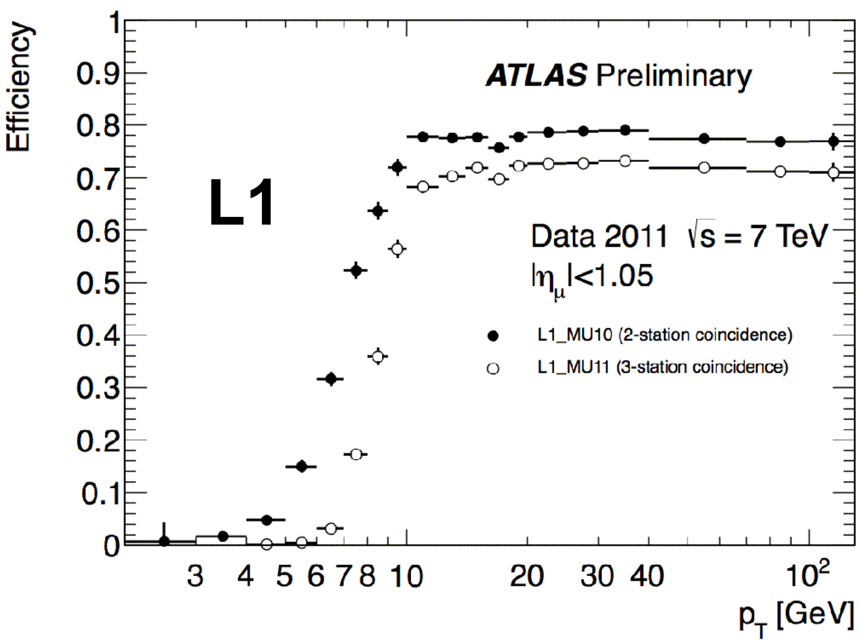
- Calorimeter triggers
  - Standalone:
    - Jets and forward jets; photons
    - Vector and scalar sums of transverse-energies
  - Combined:
    - Electron
    - Tau
    - b-jet
- Muon triggers
  - Standalone, combined, calo
  - B-physics
- Other triggers
  - Zero-bias
  - Minimum-bias
  - Forward

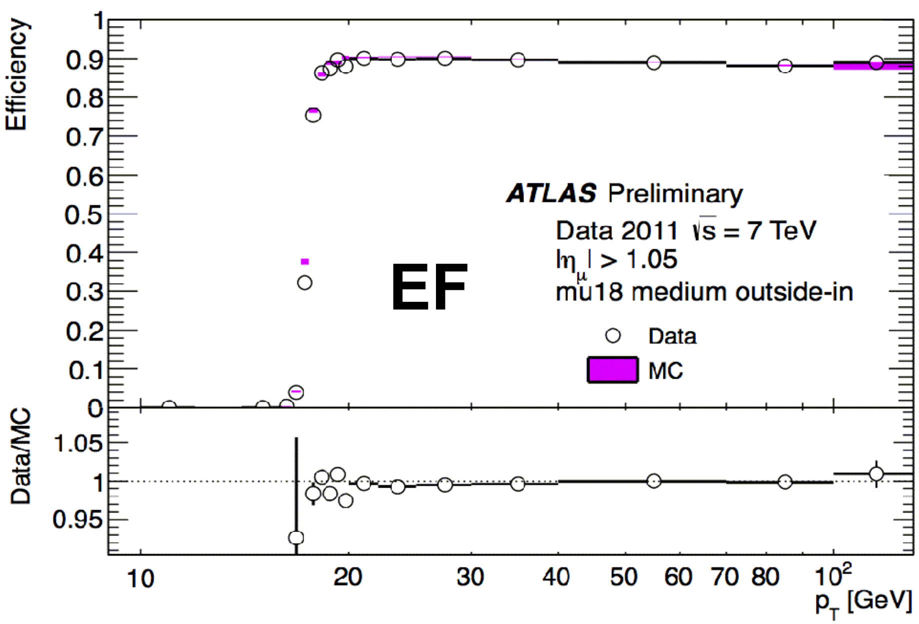


Muon triggers

- Single-muon triggers with constant EF threshold at 18 GeV for entire 2011
  - L1 required p_T > 10 GeV and 2-stations coincidence with 75 ns bunch separation, then 3-stations with 50 ns separation
- Di-muon triggers with 10 GeV threshold for entire 2011
  - Logics to solve fake di-muons at chamber boundary activated at L1 and L2
- Isolation not required in 2011 for muon triggers
  - Enabled for 2012

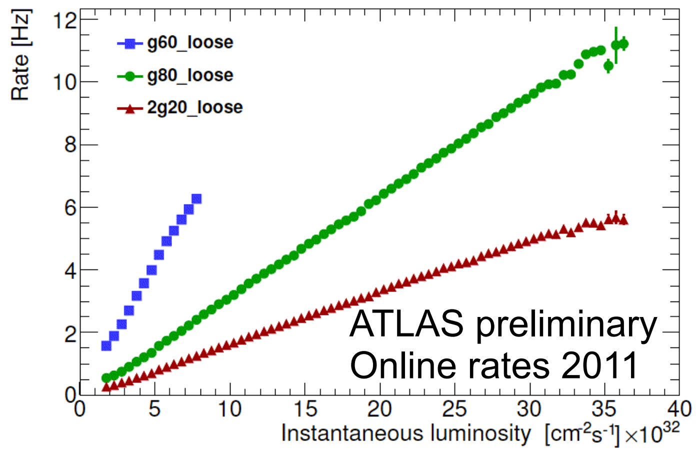
(More details on poster by Alexander Oh)





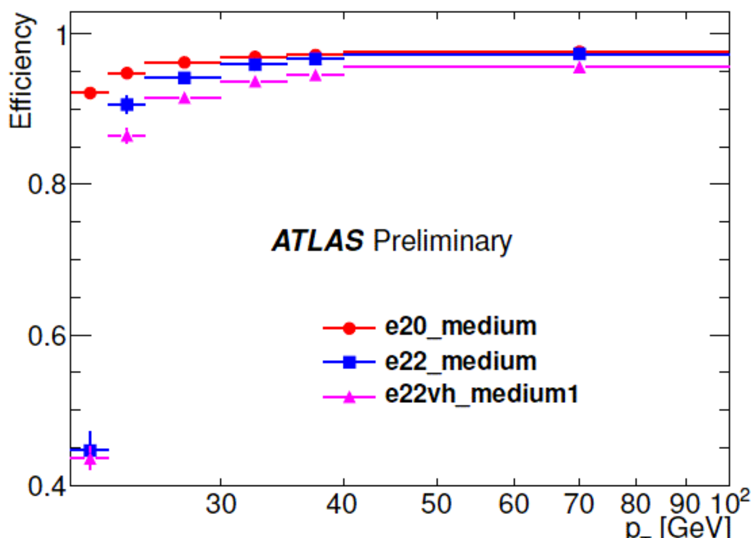
Electron and photon triggers

- Electron triggers evolved in 2011 to keep high efficiency and low pile-up dependence
  - Higher thresholds for single-electron triggers
    - 14 → 16 GeV at L1, 20 → 22 GeV at EF
  - Tighter selection (less rate with ~ same eff)
    - Hadronic leakage cut at L1 (H)
    - Coarse-granularity L1 dead-material correction (V)
    - More stringent identification at HLT

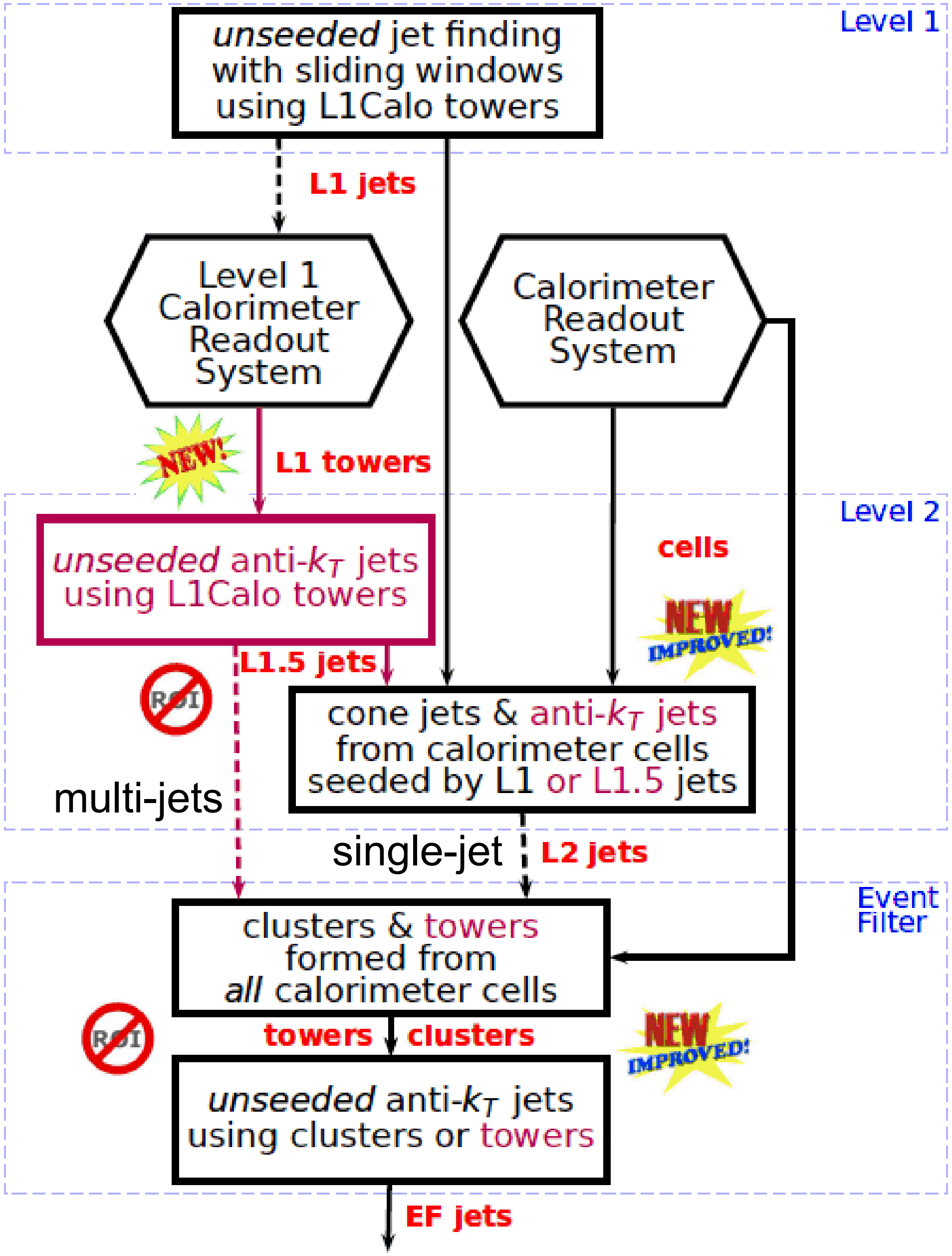


(More details on poster by Liam Duguid)

- Photon triggers in 2011
  - No change for di-gamma trigger (2×20 GeV), whose efficiency remained stable (>98%)
  - Single-photon EF threshold 60 → 80 GeV
- Higher thresholds and tighter selection in 2012



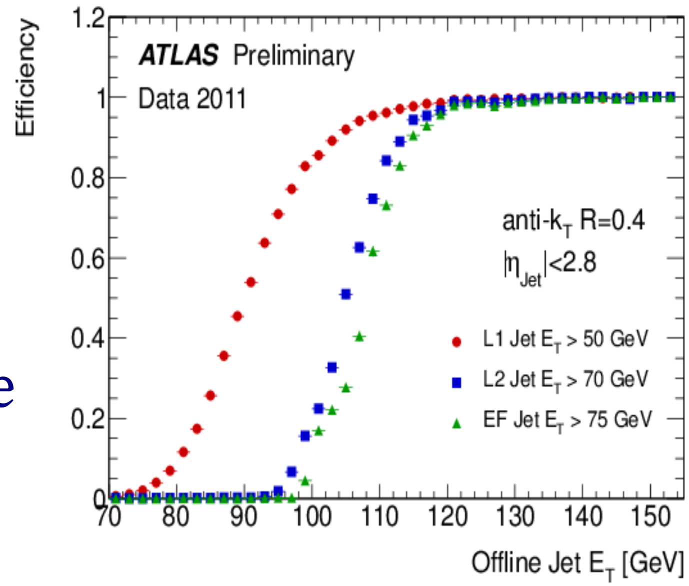
Jet triggers in 2011 and 2012

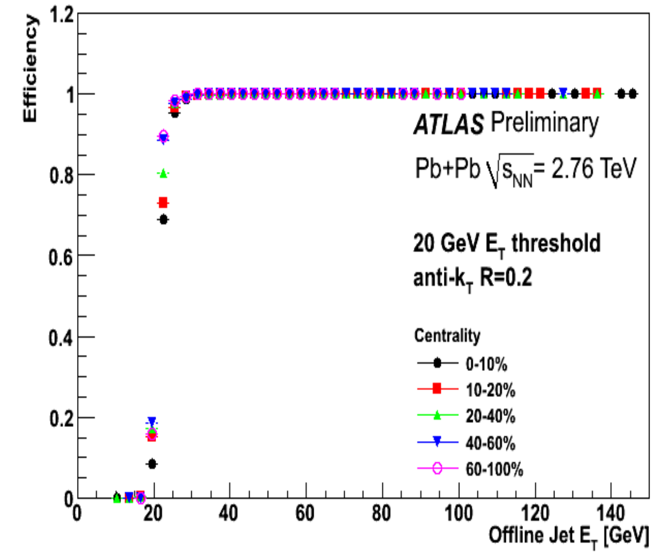


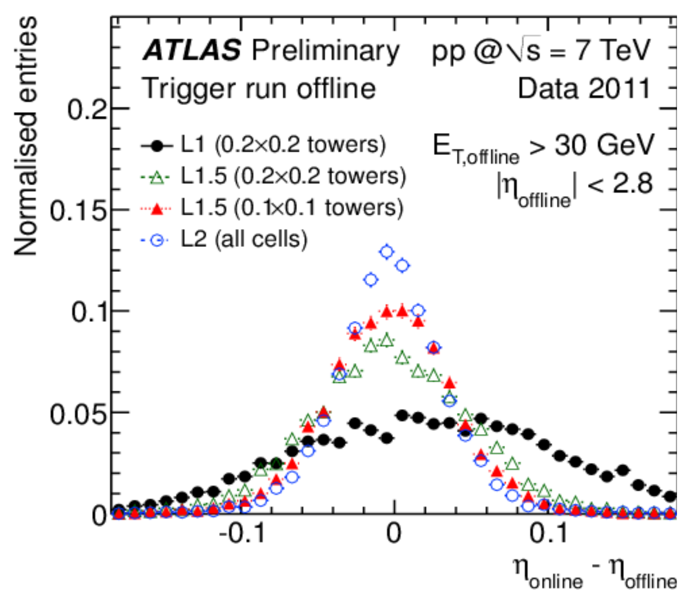
- Trigger towers at L1
  - Analog sums of cells aligned along the same direction
- L2 old: cone jets with cells in ROI
- L2 new: anti-k_T jets with trigger towers
  - Faster (allows full-scan)
  - Can be refined with cells if needed
- EF: full-scan with anti-k_T jets using topological clusters
  - Cluster seed: cell with |E| > 4 noise RMS
  - Add neighbouring cells with |E| > 2 RMS, then all neighbouring cells

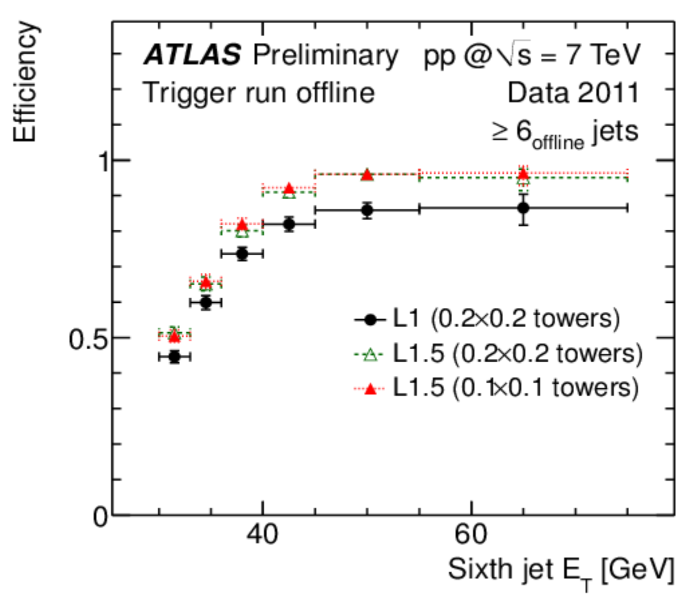
Jet trigger performance

- EF-only jet triggers used in heavy-ion run
  - No centrality dependence of the turn-on
  - New L2 tested online (not in active mode)
- High pile-up:
  - Anti-kT instead of cone at L2, EF
  - Tighter L1 calorim. noise suppression





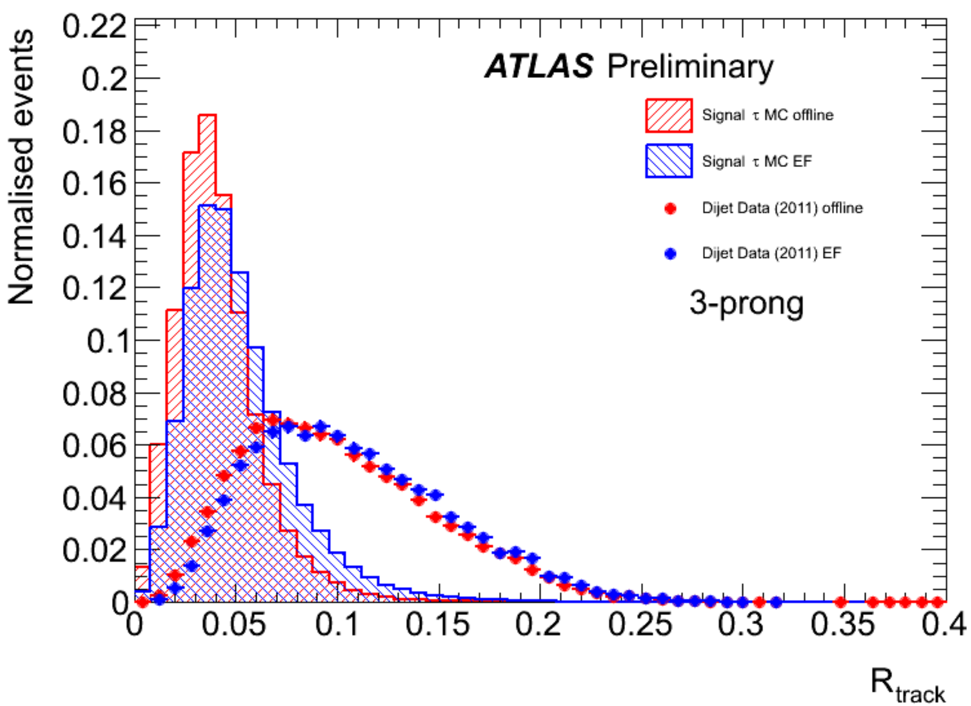


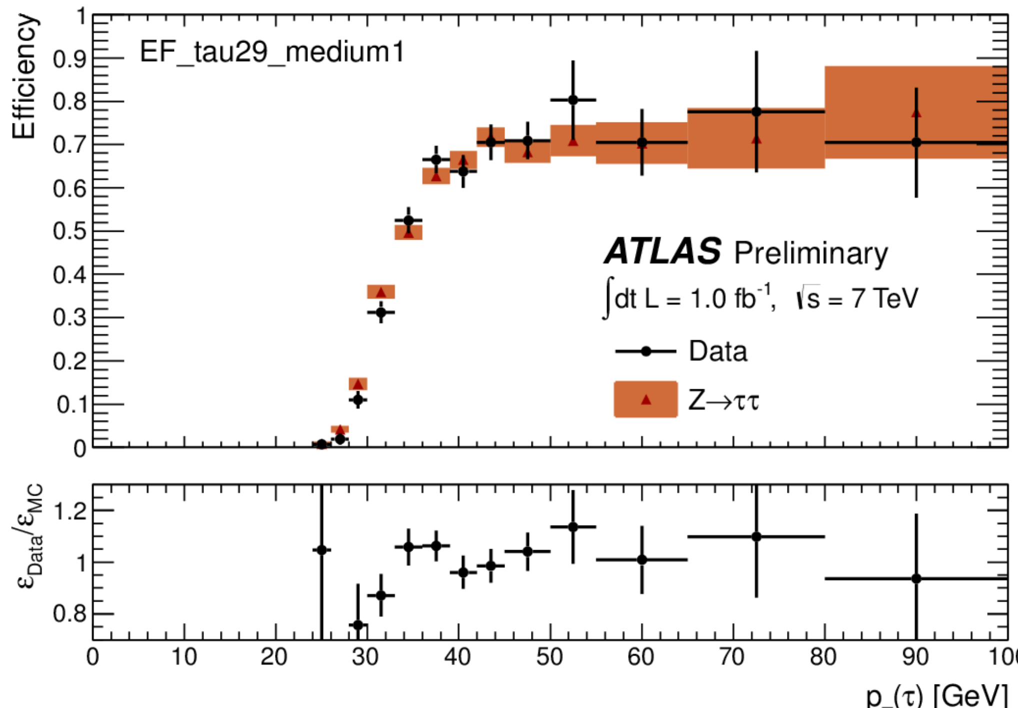


Tau triggers

- Tau triggers select hadronically decaying tau leptons
- Several improvements at HLT to be robust against pile-up in 2012
  - Reduced cone size for calo-based variables
  - Tighter track selection (max Dz = 2 mm from leading pT track)
  - New variables combining calorimeter and tracking information

(More details on poster by Patrick Czodrowski)

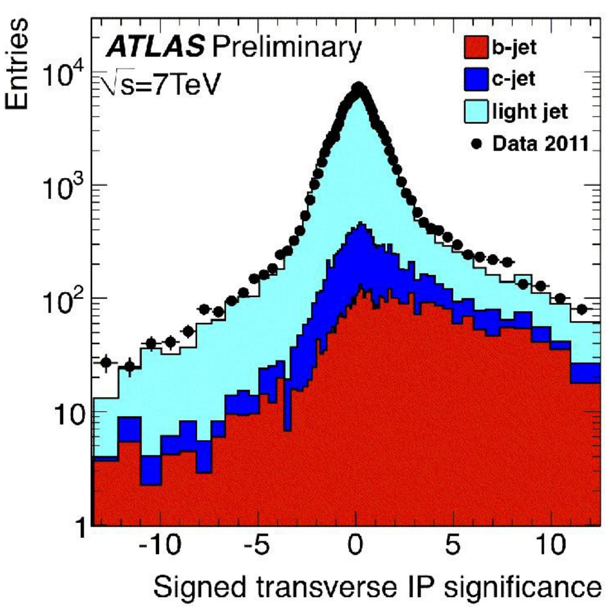


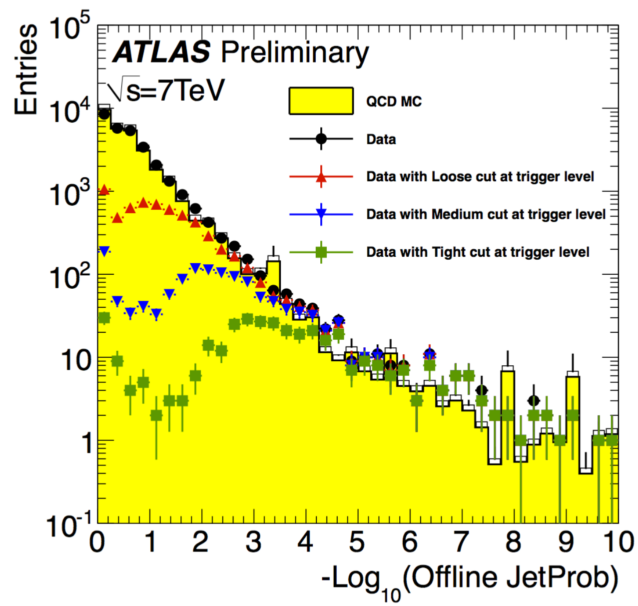


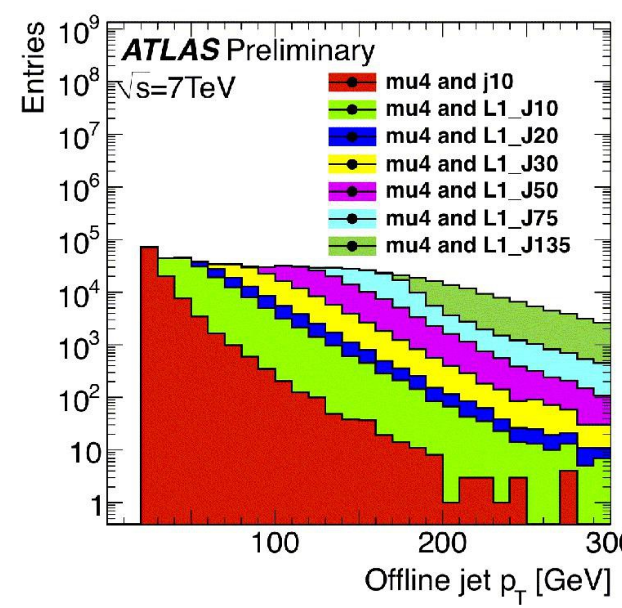
b-jets triggers

- Two main categories: lifetime and muon+jet (mainly for calib) triggers
- Rely on tracking and vertexing to tag jets at L1 (2011) and HLT (2012)
  - HLT jet triggers required to fire at high luminosity (from Sep 2011)
- Refinements for 2012:
  - Better primary vertexing
  - New L2 jets for inclusive triggers
  - Combined b-jet + MET or lepton

(More details on poster by Viviana Cavaliere)

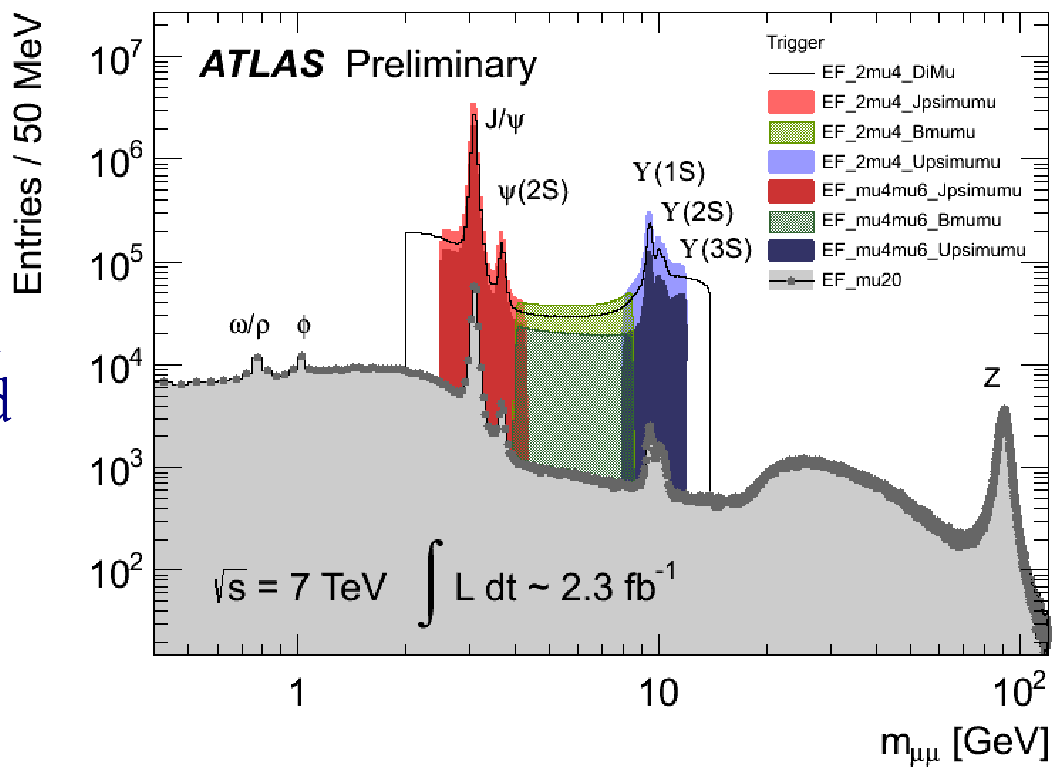






B physics

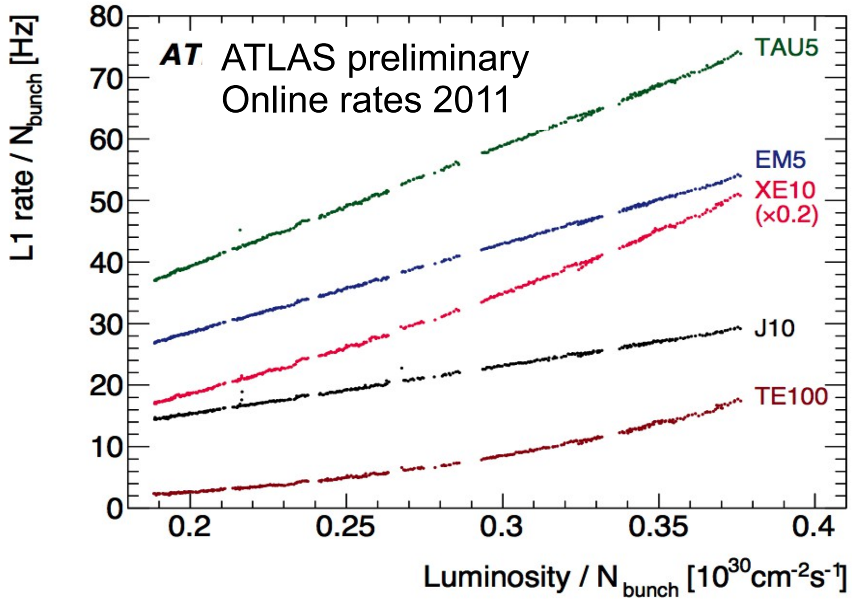
- B-physics triggers = low p_T di-muon triggers with additional mass cuts to select specific signatures (J/ψ, ϒ, Bμμ)
  - L1 lowest threshold re-optimized in Sep to allow it run unprescaled while keeping high efficiency (same EF threshold)
- 2012: EF thr. moves from 4 to 6 GeV for both muons
  - Reduced efficiency: J/Ψ (25%), ϒ(12%), Bμμ(17%)
- 2012: New L1 di-muon triggers requiring at least one muon or both muons in the barrel
  - Keep some eff for low thr (4-6 GeV)



Di-muon invariant mass

The difference between the grey (single muon trigger mu20) and the coloured histograms shows the data collected using the dedicated B-physics triggers.

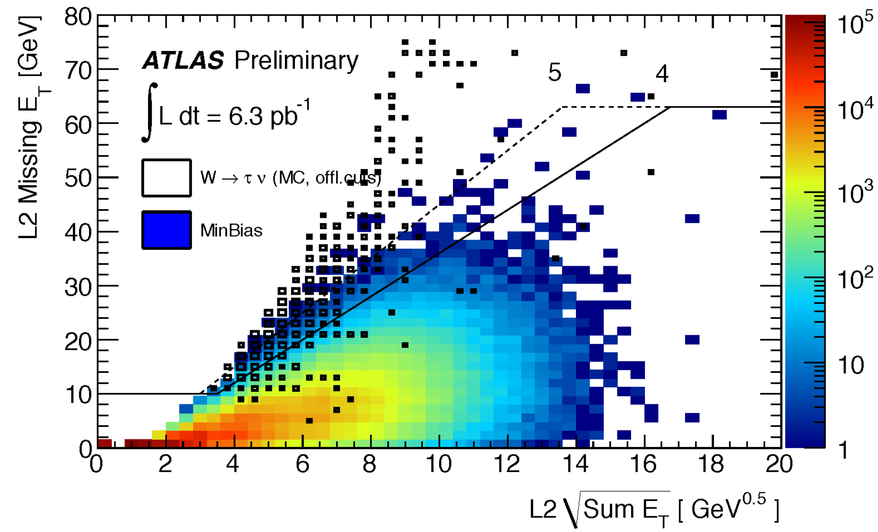
MET triggers

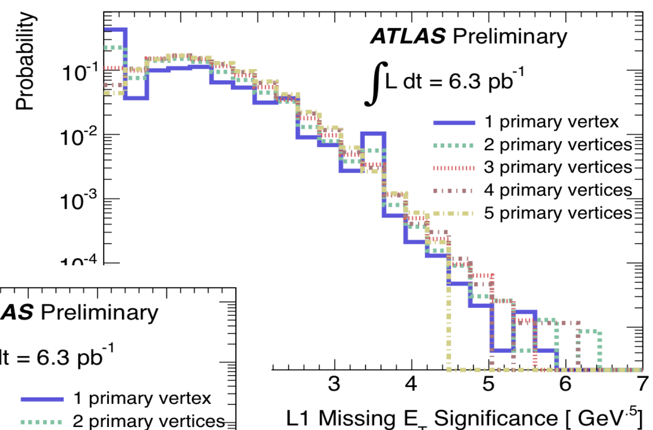


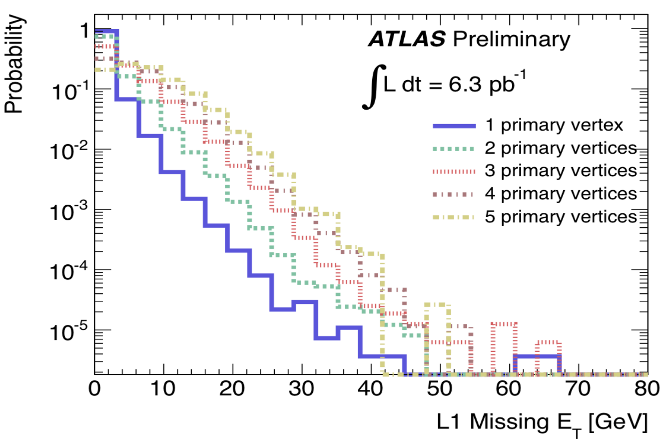
- Pile-up presents difficulties to global quantities like MET and SumET
  - Rates increase faster than linearly with increasing instantaneous luminosity
  - Thresholds have been increased several times in 2011
- Because of the ROI concept, L2 did not allow computing global quantities
  - L1 output rate = EF input rate → bottleneck
- New L2 algorithm processing summary info from calorimeters
  - Partial sums over channels connected to each front-end board
  - Active in 2012
- TDAQ upgraded in 2011 to allow accessing all front-end boards
  - Replacement of critical nodes → bandwidth increase
- New EF algorithm processing topological clusters in 2012
  - Improved resolution

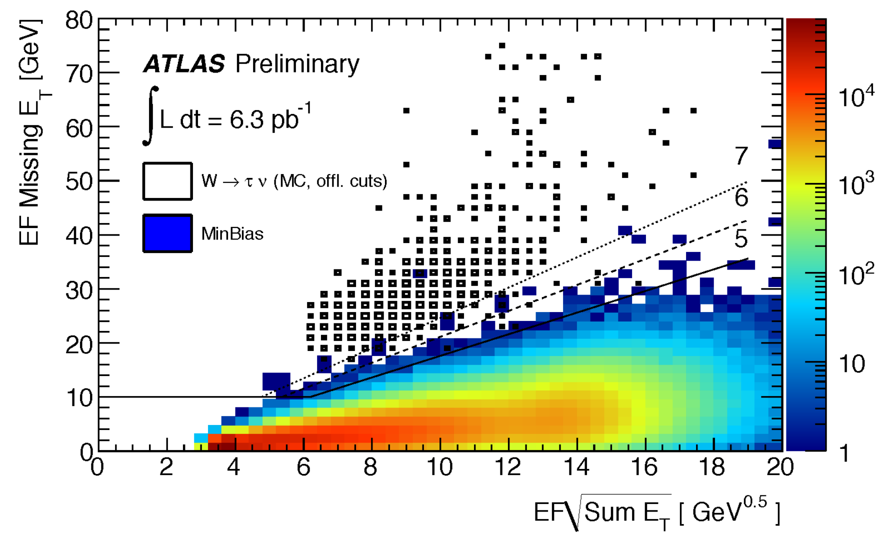
MET significance triggers

- Event selected by looking at both the vector (MET) and scalar (SumET) sum of transverse energies
- Implemented during 2010 Christmas break, active in 2011 and 2012
  - Recover some efficiency at low MET
  - Rates under control









Summary

- The ATLAS trigger operates since 2009 with very high live time
- The LHC evolution in 2011 implied adjustments in the configuration of most physics triggers
  - New triggers and techniques have also been tested
- 2011 data and initial 2012 data used to tune the configurations for this year
  - Big pile-up increase: 8-10 int/BC (min 2011) → 25-30 int/BC (max 2012)
  - All trigger signatures need to cope with it
  - Most significant changes for jet, b-jets, tau and MET triggers
- A number of talks and posters provides additional details
- THANKS A LOT

Talks and posters about the ATLAS trigger

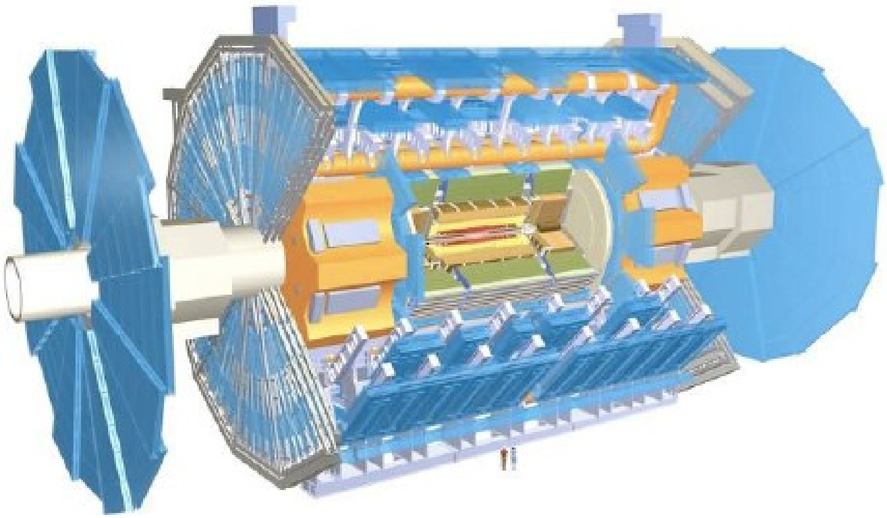
- Applications of advanced data analysis and expert system technologies in ATLAS Trigger-DAQ Controls framework, Giuseppe Avolio (talk)
- Evolution of the Trigger and Data Acquisition System for the ATLAS experiment, Andrea Negri (talk)

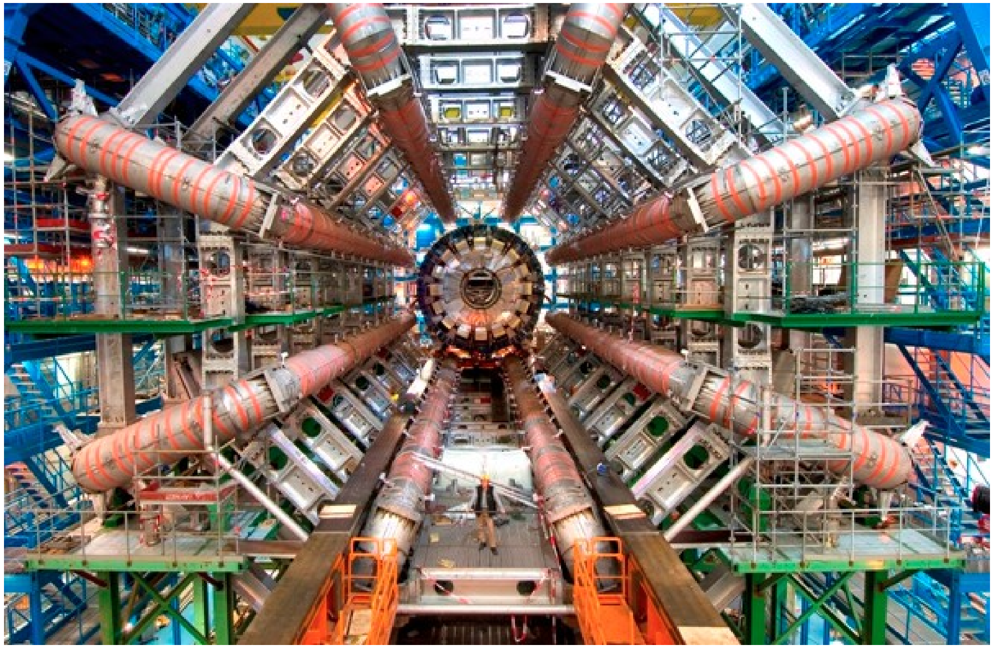
- Triggering on hadronic tau decays in ATLAS: algorithms and performance, Patrick Czodrowski
- b-jet triggering in ATLAS: from algorithm implementation to physics analyses, Viviana Cavaliere (A. Oh)
- A System for Monitoring and Tracking the LHC Beam Spot within the ATLAS High Level Trigger, Rainer Bartoldus (C. Bee)
- Upgrade and integration of the configuration and monitoring tools for the ATLAS Online farm, Sergio Ballestrero (L. Darlea)
- Tools and strategies to monitor the ATLAS online computing farm, Lavinia Darlea
- Centralised configuration tool for a large scale farm of netbooted systems, Liviu Valsan (L. Darlea)
- Resource Utilization by the ATLAS High Level Trigger during 2010 and 2011 LHC running, Doug Schaefer
- Architecture and performance of the ATLAS Inner Detector Trigger software, Pauline Bernat
- Experience with the custom-developed ATLAS trigger monitoring and reprocessing infrastructure, Valeria Bartsch (D.C.)
- The Version Control Service for ATLAS Data Acquisition System Configuration Files, Igor Soloviev
- The Electronic Logbook for the Information Storage of ATLAS Experiment at LHC, Luca Magnoni
- GPU-based algorithms for ATLAS High-Level Trigger, Jacob Howard
- Balancing the resources of the High Level Trigger farm of the ATLAS experiment, Marius Tudor Morar
- Evolution and performance of electron and photon triggers in ATLAS in the year 2011, Liam Duguid
- The ATLAS Muon Trigger at high instantaneous luminosities, Alexander Oh
- Experience with highly-parallel software for the storage system of the ATLAS Experiment at CERN, Wainer Vandelli (M. Tudor Morar)
- Designing the ATLAS trigger menu for high luminosities, Yu Nakahama Higuchi
- High-performance scalable information service for the ATLAS experiment, Sergei Kolos (G. Avolio)
- The ATLAS Level-1 Trigger System, Will Buttinger
- The First Prototype for the FastTracker Processing Unit, Andrea Negri

BACKUP

ATLAS subdetectors

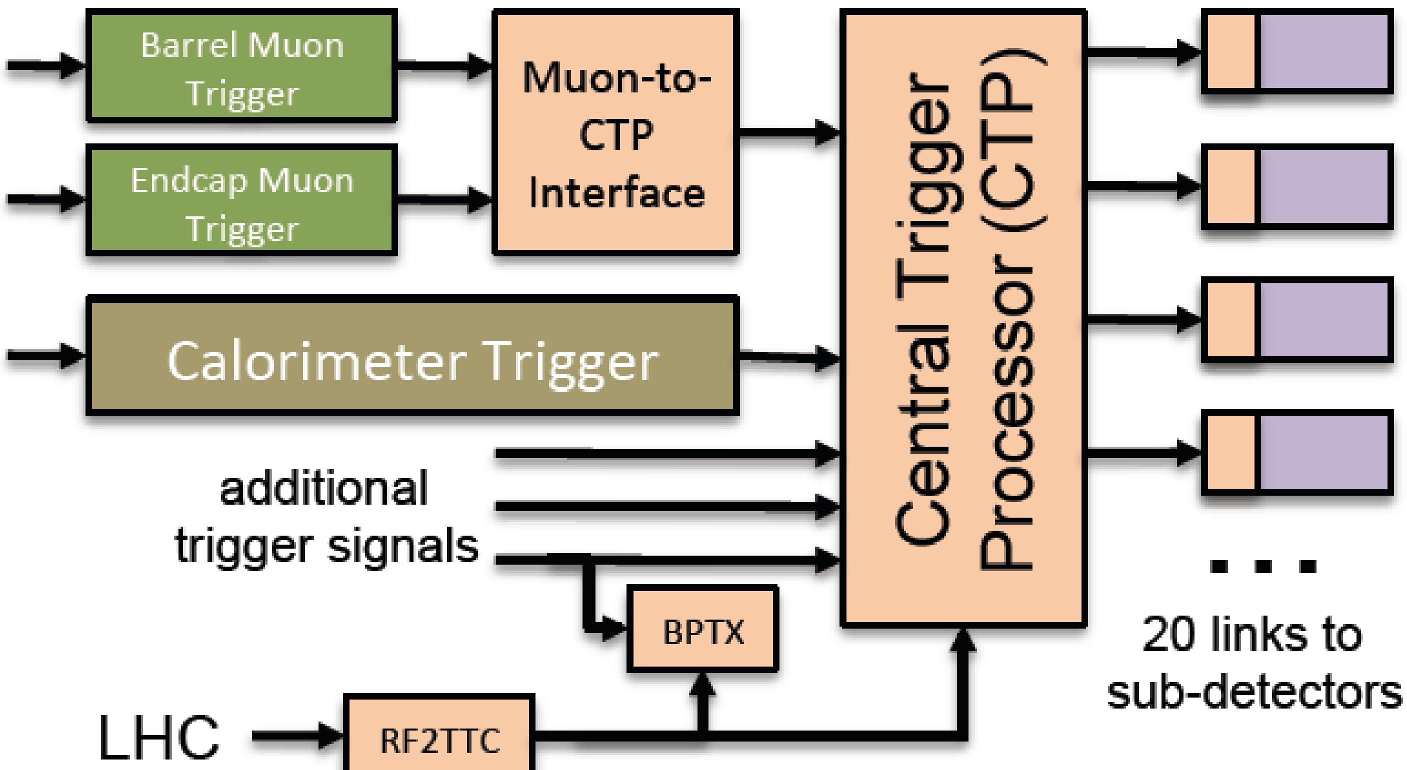
- Inner Detector: Precision Tracking & Vertexing in $|\eta| < 2.5$
  - Silicon Pixels + Silicon Strips
  - Transition Radiation Tracker
  - 2T Central Solenoid
- Calorimeters in $|\eta| < 4.9$
  - Electromagnetic: Pb/LAr calo with accordion geometry
  - Hadronic: Fe/Scintillator in barrel, Cu/LAr in end-cap
- Muon Spectrometer in $|\eta| < 2.7$
  - Resistive Plate Chambers (RPC)
  - Thin Gap Chambers (TGC)
  - Cathode Strip Chambers (CSC)
  - Muon Drift Tube Chambers (MDT) for precision tracking
  - Air Core Toroids





The first-level (L1) trigger system

- Central Trigger Processor (CTP) → L1A ("accept") signal
  - Input from calorimeters, muon spectrometer, additional signals
  - Receives LHC 40 MHz clock and distributes clock and decision to sub-system front-end electronics and to HLT



(More details on poster by Will Buttinger)

Trigger operation