Performance of the ATLAS Trigger with Proton Collisions at the LHC

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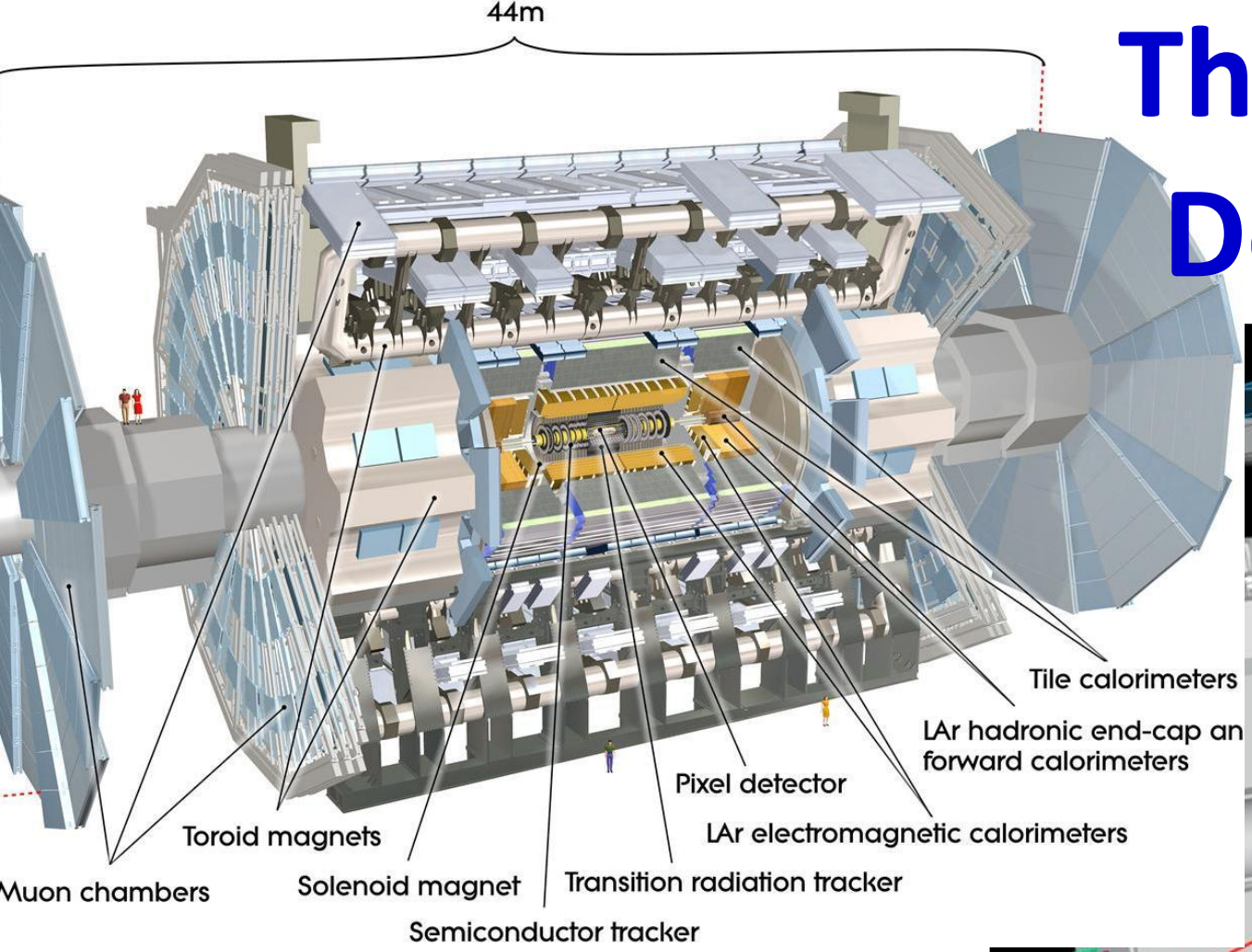
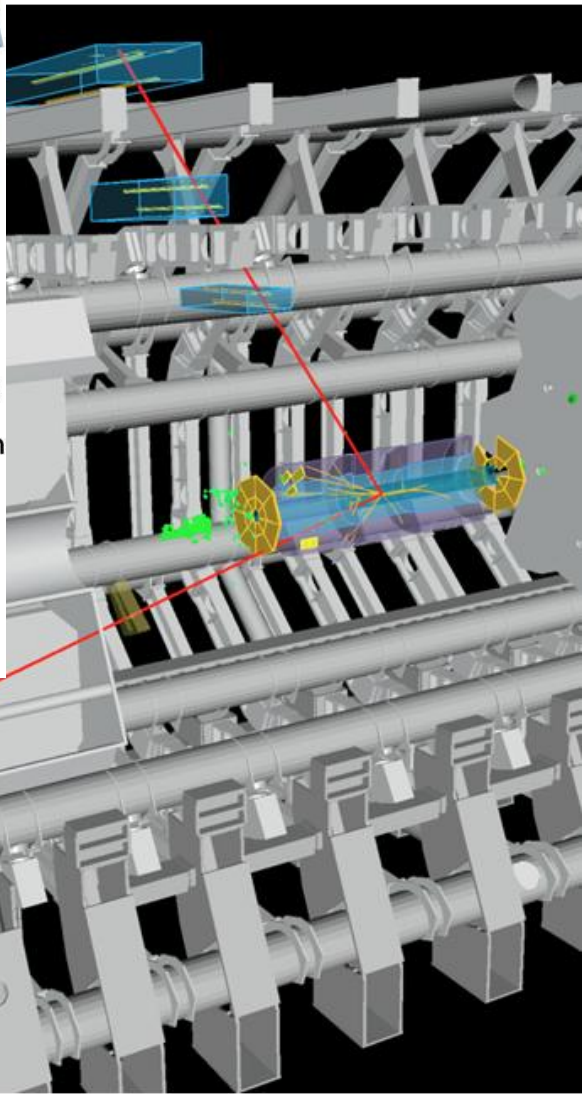
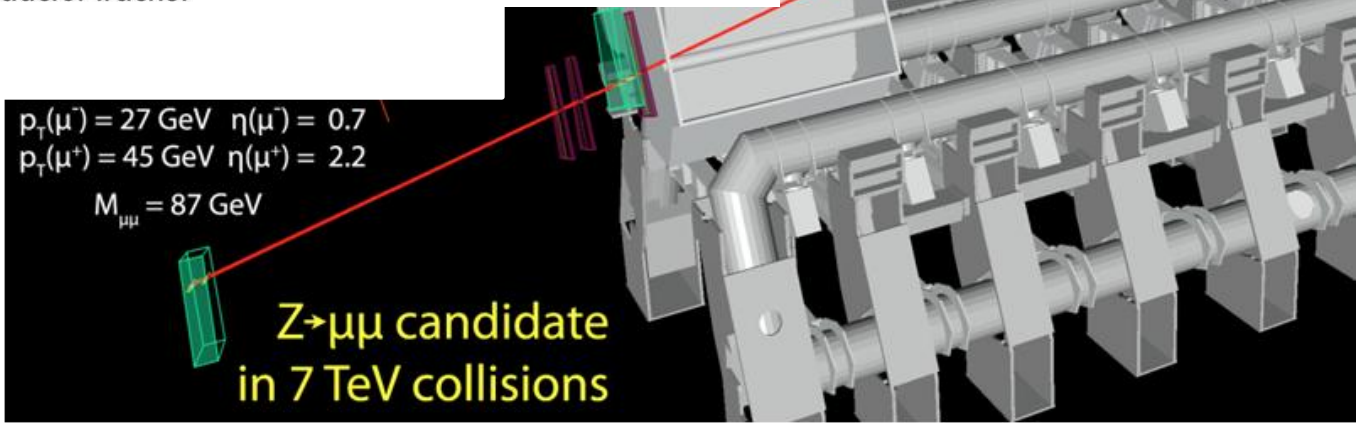
Science & Technology Facilities Council
Rutherford Appleton Laboratory PPd

The ATLAS Detector







The ATLAS Trigger

Level 1 (LVL1)

- Fast Custom-built electronics

Level 2 & Level 3 (Event Filter):

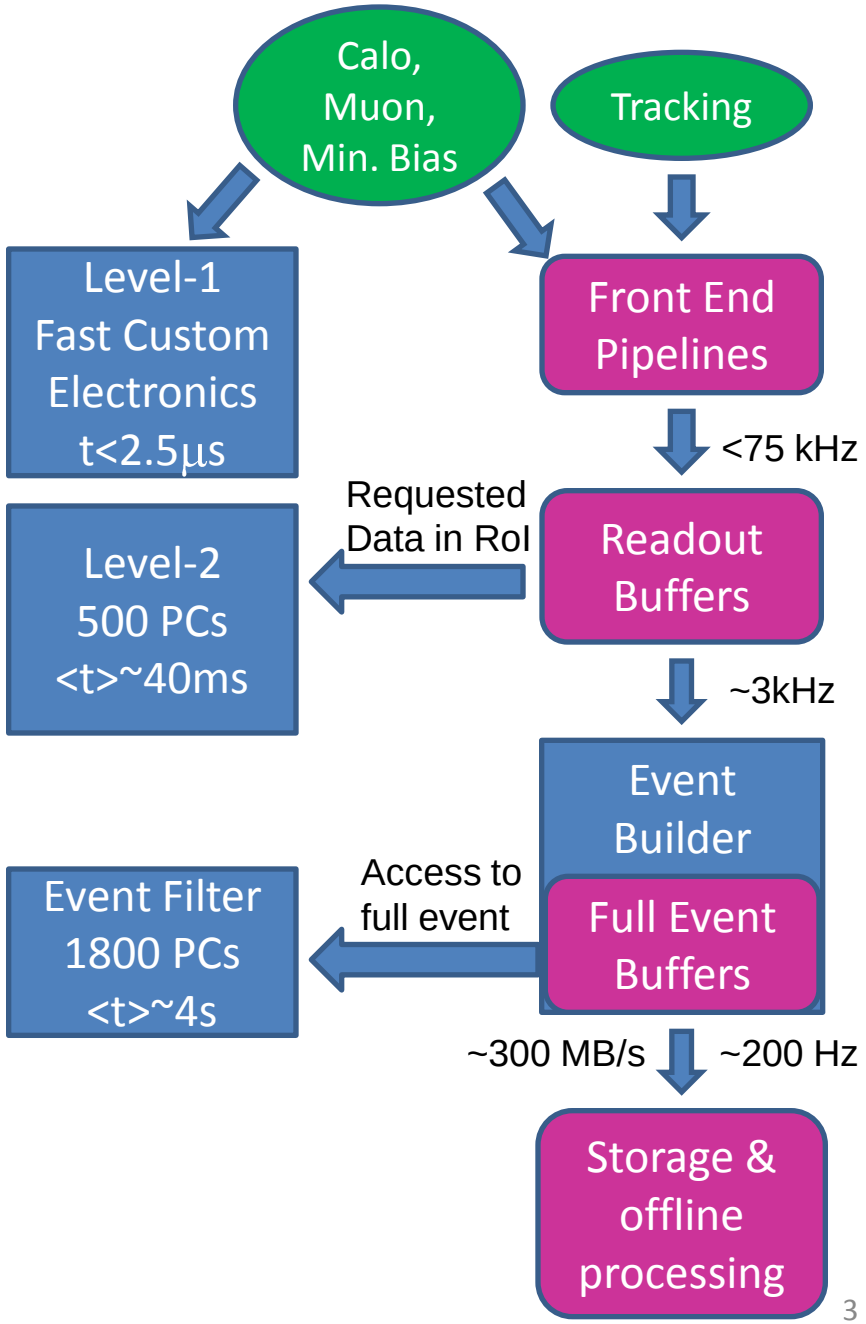
- Software based running on large PC farm

Level-2:

- Fast custom algorithms
- reconstruction mainly in Regions of Interest (RoI)=> limited data access

Level 3 = Event Filter (EF)

- Offline tools inside custom wrappers,
- Access to full event information



Trigger Selection

Trigger chain:

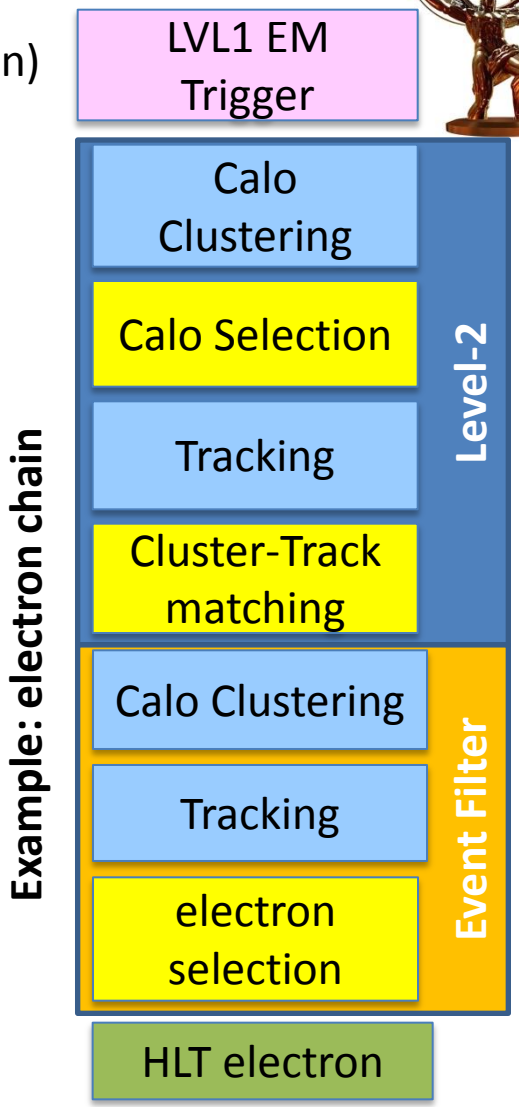
- Sequence of reconstruction and selection algorithms (~10 per chain)
- Chains for each trigger physics object and threshold i.e.

Trigger physics objects	Lowest p_T or E_T Thresholds (GeV) $L<2x10^{30}$ $cm^{-2}s^{-1}$	
	LVL1	HLT
Electron/photon	2	3
Tau	5	12
Muon	4	4
Missing energy (MET)	10	20
Jet	5	20
Total energy (SumET)	10	90

Also chains for B-tagged jets & B-physics signatures

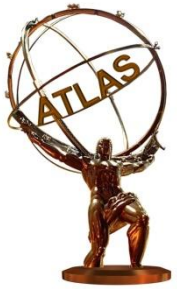
Trigger menu:

- collection of trigger signatures : ~200-500 chains in current menus
- also defines pre-scale factors
- evolves to match LHC luminosity & physics requirements



Talk(Track 13): The ATLAS High Level Trigger Configuration and Steering Software: Experience with 7 TeV Collisions: S. George

Trigger Commissioning & Evolution



Commissioning with cosmics, single-beam 2008 & 2009:

- Initial timing in of Level-1 signals, ready for first collisions

First Collisions : Dec 2009 : 900 GeV; Mar 2010 : 2.36 TeV; April & May 2010 : 7 TeV

- Level-1 active
- HLT running online in monitoring mode - no HLT rejection*:
  - Validation of HLT ready to activate when needed
  - Online beam-spot determination using Level-2 Tracking

Luminosity $cm^{-2}s^{-1}$

10^{27} $2x10^{27}$ $5x10^{27}$ 10^{28} $2x10^{28}$ $5x10^{28}$ 10^{29} $2x10^{29}$ $5x10^{29}$ 10^{30} $2x10^{30}$ $5x10^{30}$ 10^{31}

2010	April	May	June	July	August onwards
	Level-1 Active HLT Monitoring Mode		**Progressively activate HLT**		**HLT active**
	Min. Bias trigger records all collisions	Min. Bias pre-scaled e, γ, Jet, τ, μ and MET not pre-scaled	1.5 x 10^{29} : e & γ $4x10^{29}$: τ $6x10^{29}$: forward μ $1x10^{30}$: MET		**Physics menu deployed:** Shift focus from commissioning to physics

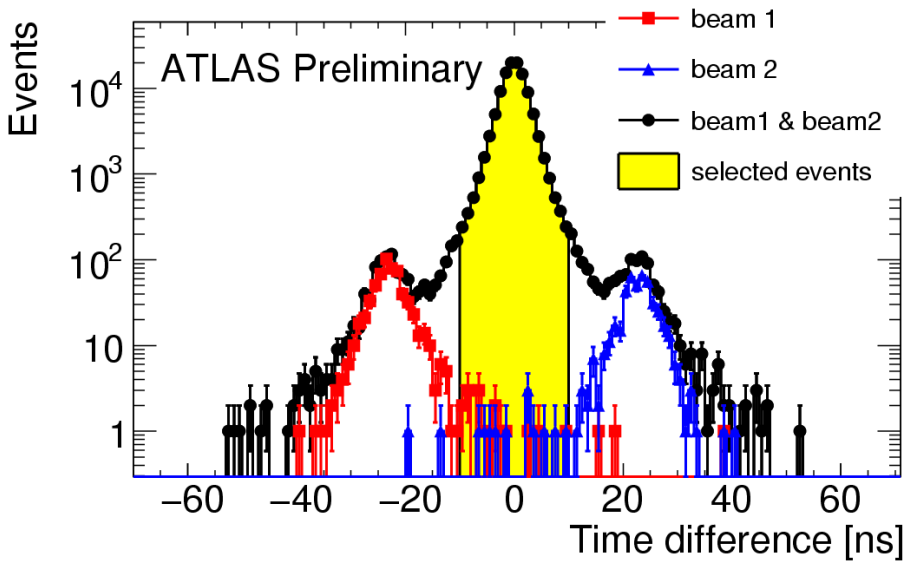
Progressive activation of HLT :

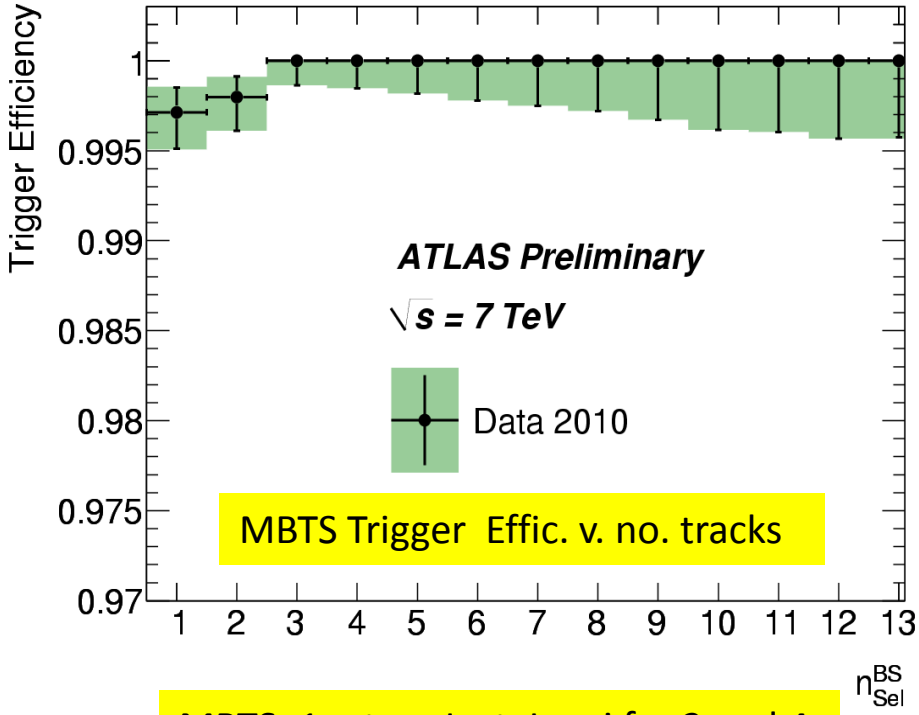
- Prescale sets pre-generated covering fixed luminosity ranges:
  - ➢ Can be updated before or during the run to match machine conditions.

* Control Trigger: Random Bunch crossing + In. Det. Hits at HLT – 1st trigger actively rejecting - already in 2009.

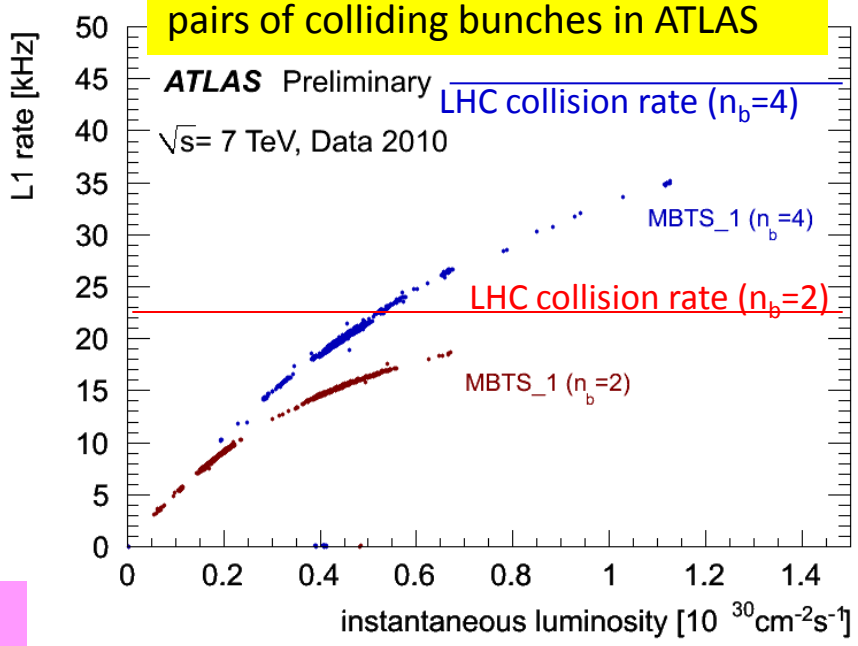
Minimum Bias Trigger

- Minimum Bias Scintillators (MBTS) installed in each end-cap ($2.09 < |\eta| < 3.84$)
- Primary Minimum Bias trigger MBTS_1:
  - ➢ at least 1 counter above thresh & filled LHC bunch
- Efficiency 99.7% for collisions with one track with $p_T > 500$ MeV
- Time Difference between forward and backward counters signal collisions events:





MBTS_1 rate v. Inst. Lumi for 2 and 4 pairs of colliding bunches in ATLAS



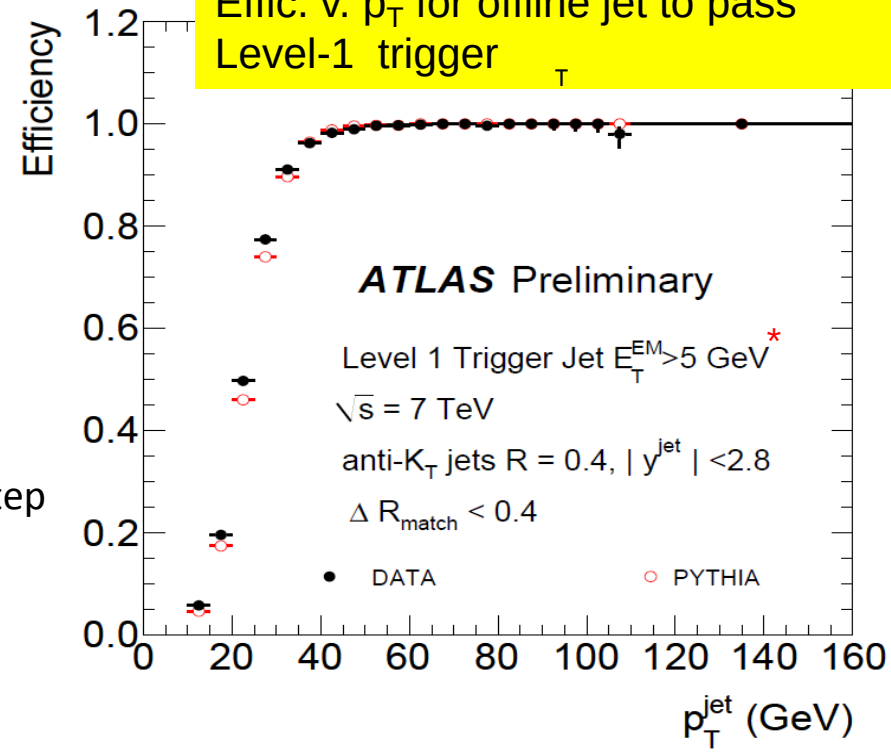
Poster: Minimum Bias Trigger in ATLAS: R. Kwee

Jet Triggers

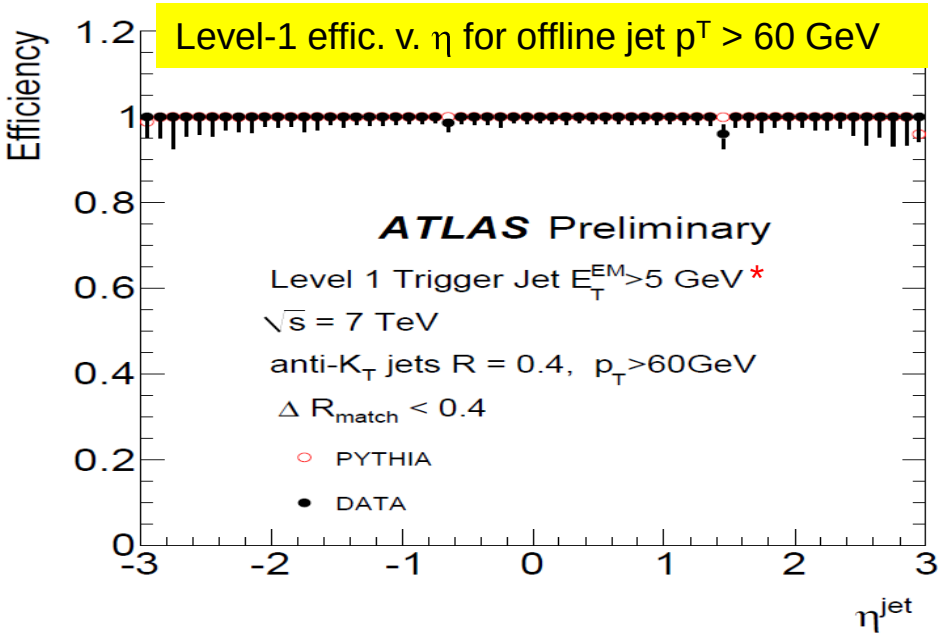
For: QCD multijet prodn., W->τν, SUSY, top, generic searches (pp → XX, X → jj), VBF

- Currently triggering based on Level-1 :
  - Sums E_T in the EM and Hadronic Calorimeters
  - sliding window of up to 0.8x0.8 in ηxϕ with 0.2 step
  - Thresholds well modelled by MC
  - 100% effic. above turn-on

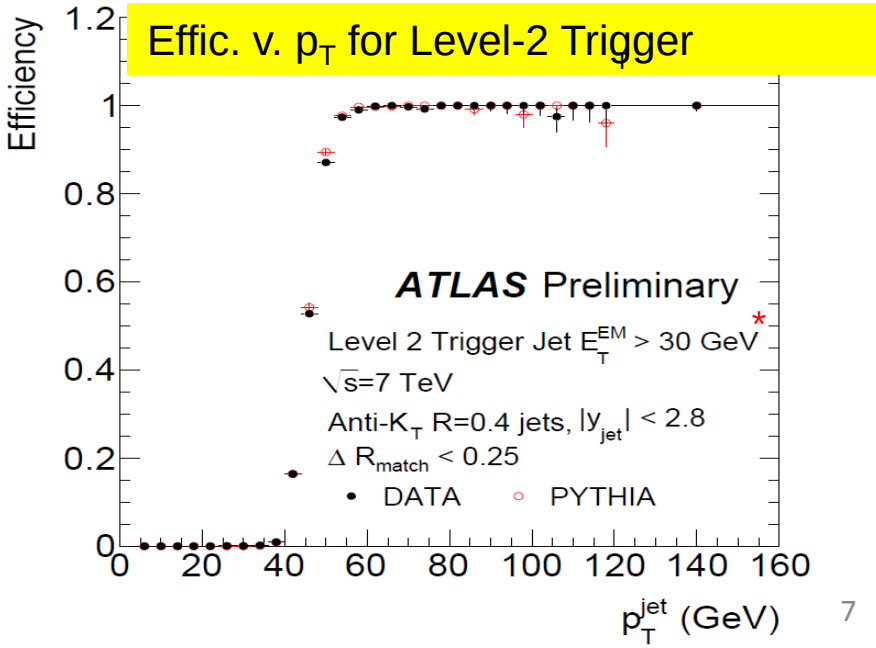
Effic. v. p_T for offline jet to pass Level-1 trigger



Level-1 effic. v. η for offline jet p^T > 60 GeV



Effic. v. p_T for Level-2 Trigger



*Level-1 & HLT use EM Energy scale

e & γ Triggers

3-20 GeV for b/c/tau decays, SUSY, turn-on curves
20-100 GeV for W/Z/top/Higgs physics
> 100 GeV for exotics

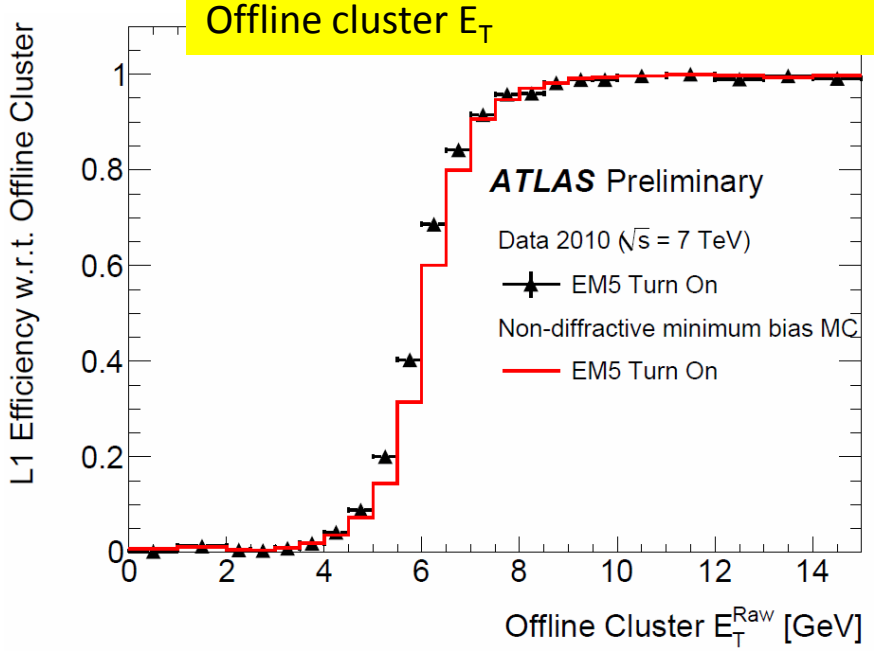
Level-1 Trigger based on Calo. energy in:

- E_T within central core : $\Delta\eta x\Delta\phi$=0.2x0.2
- Can require EM and Hadronic isolation

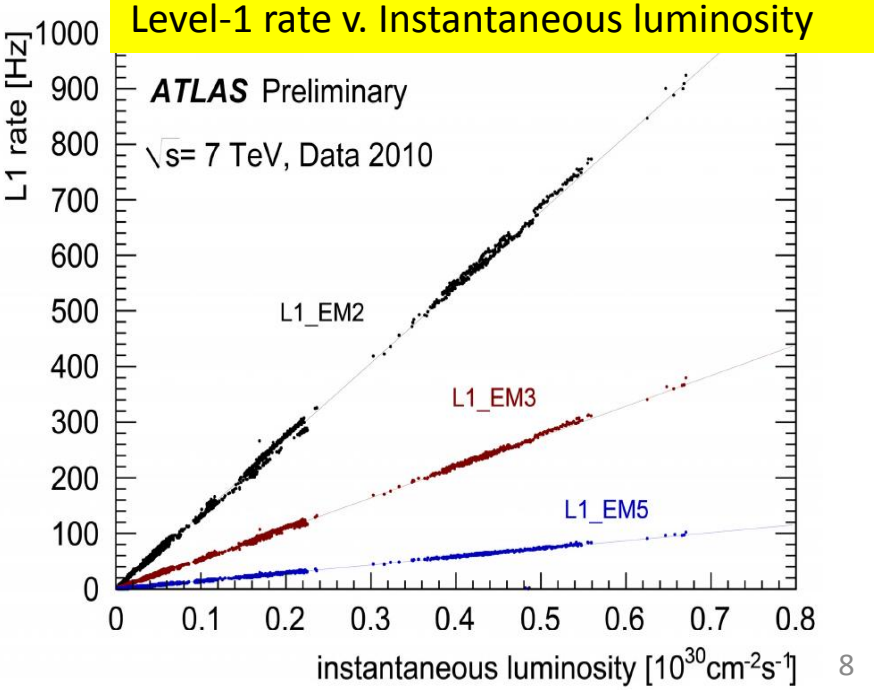
➢ Close to 100% efficient above turn-on
➢ Efficiency well modelled by Simulation

HLT Rejection enabled when L1_EM2>~200Hz
L > ~$1.5x10^{29}cm^{-2}s^{-1}$

Level-1 Efficiency w.r.t. Offline v. Offline cluster E_T

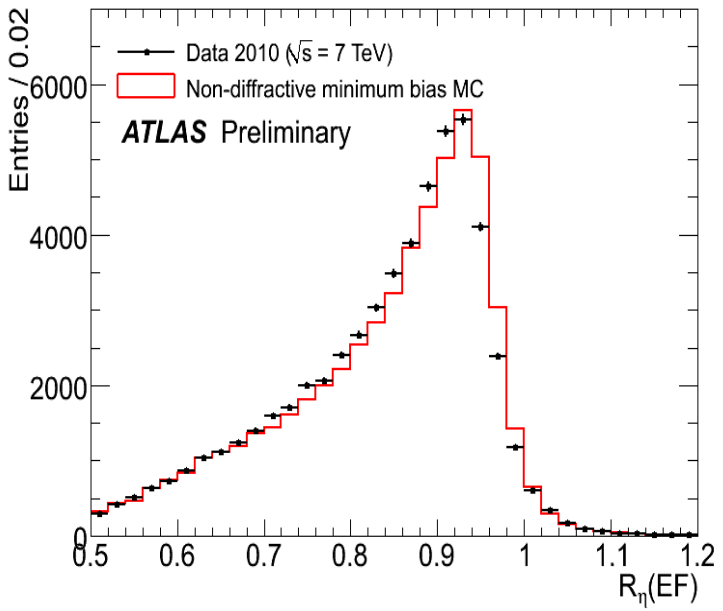


Level-1 rate v. Instantaneous luminosity



e & γ : HLT

R_η distributions for data and MC
Peaked towards 1 for e



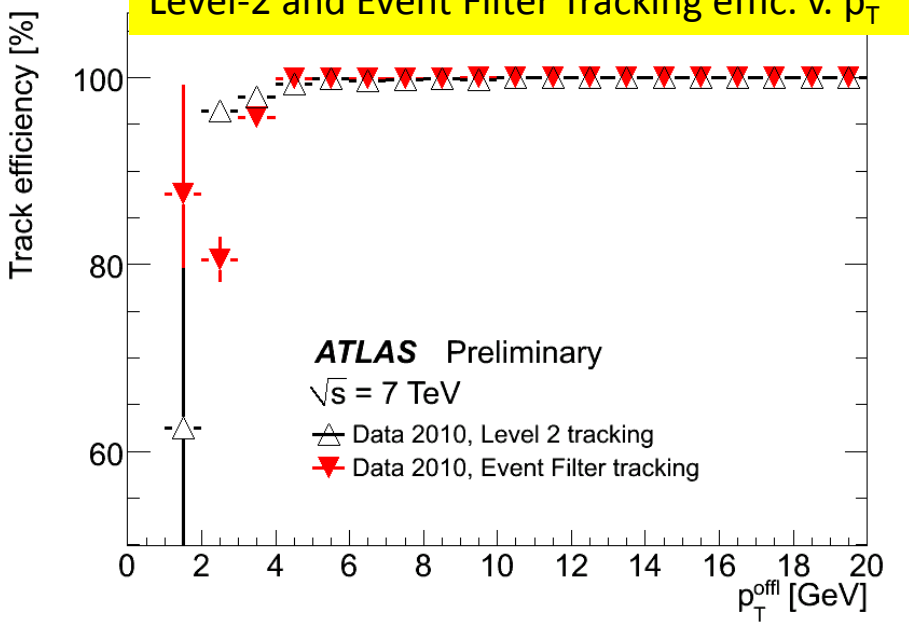
- HLT uses full granularity calo. to calculate E_T & cluster shape parameters e.g.

$$R_\eta = \frac{E(3\times 7)}{E(7\times 7)}$$

Cell units:
Δη×Δϕ= 0.025 × 0.025

- Additional rejection achieved by matching calorimeter clusters to Inner Detector Tracks

Level-2 and Event Filter Tracking effic. v. p_T



Level-1 Muon

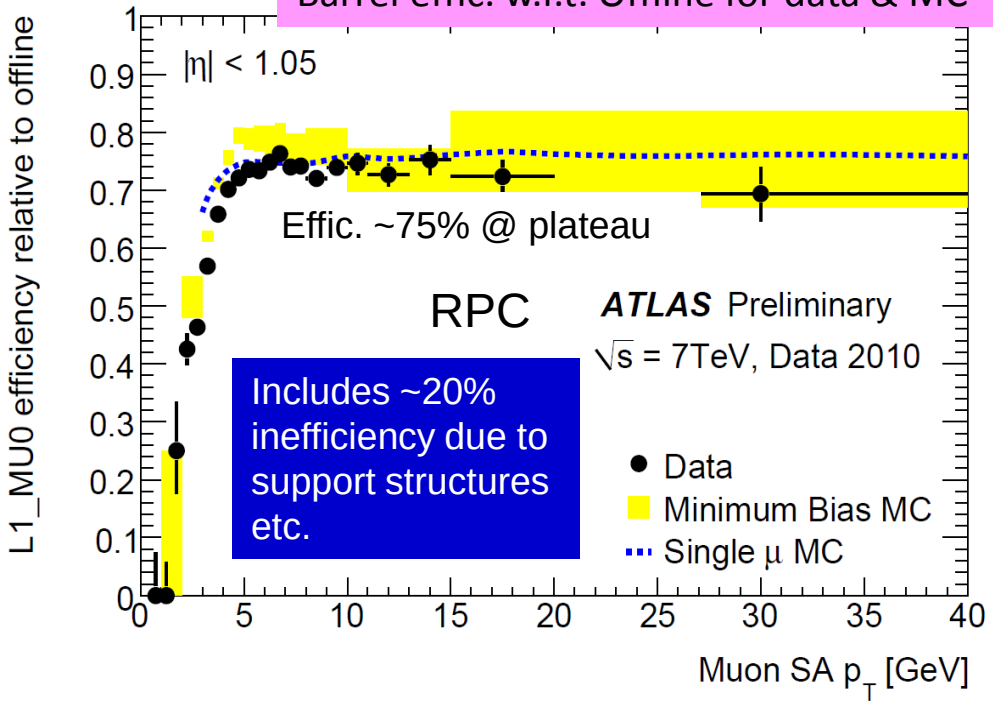
Low P_T: J/Ψ, Υ and B-physics
High P_T: H/Z/W/tau → μ

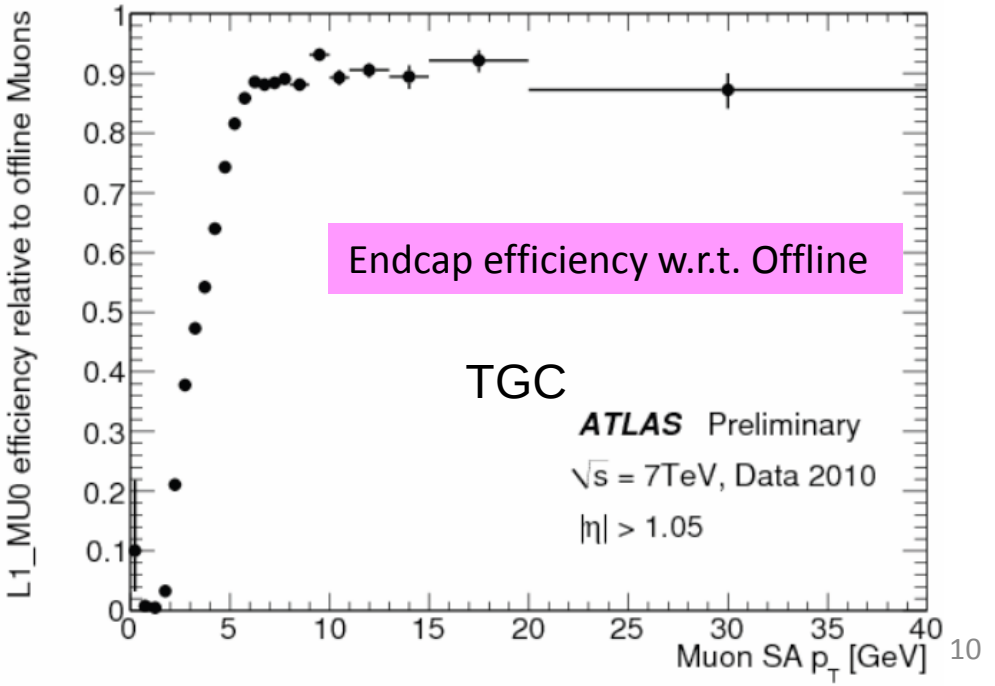
Level-1 Muon Trigger:

- Barrel: Resistive Plate Chambers
- Endcap: Thin Gap Chambers

• Performance evaluated w.r.t. offline
⇒ Close to nominal efficiency
⇒ Good agreement with Simulation

Barrel effic. w.r.t. Offline for data & MC



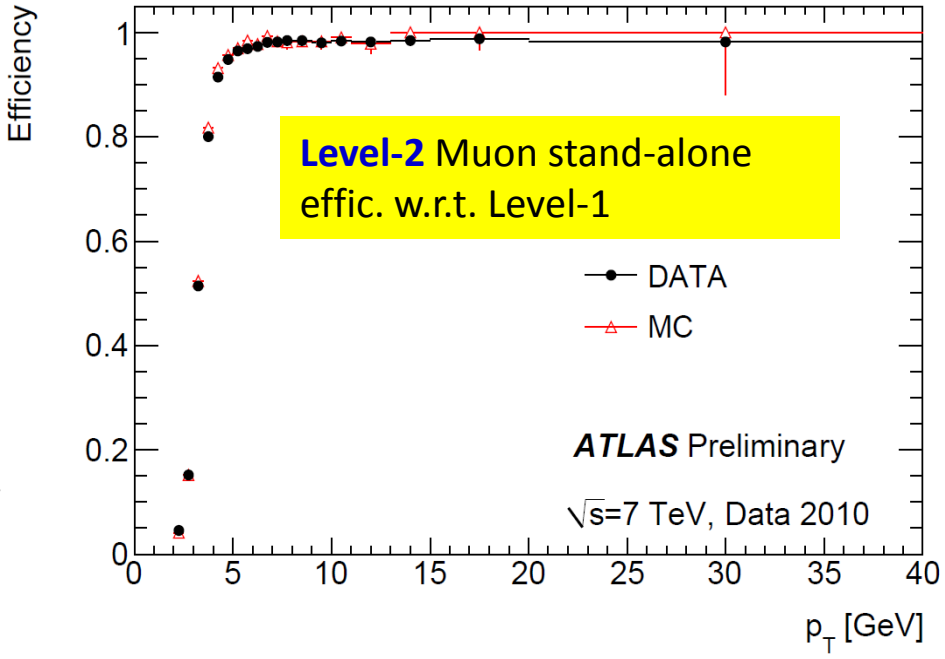


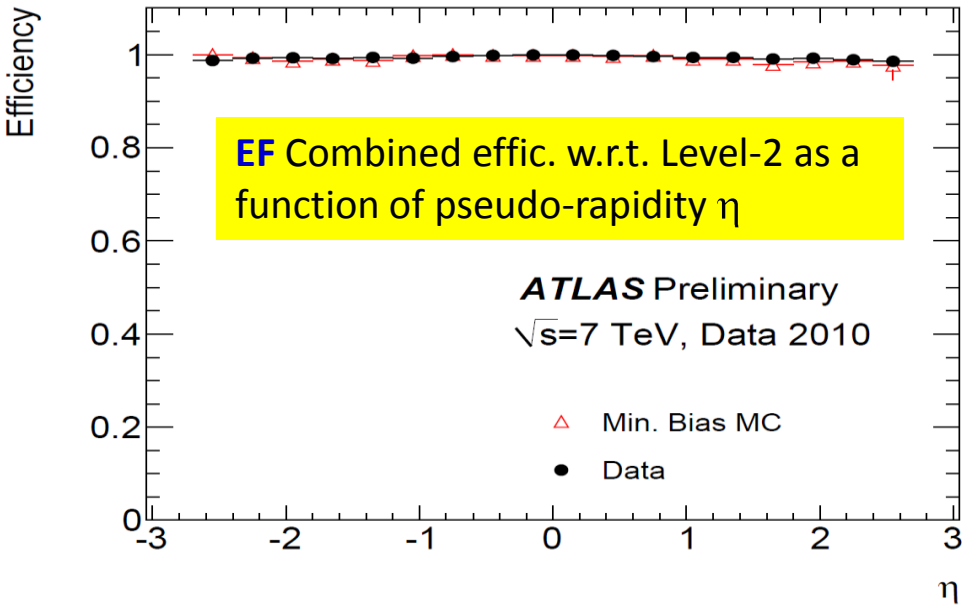
HLT Muon Trigger

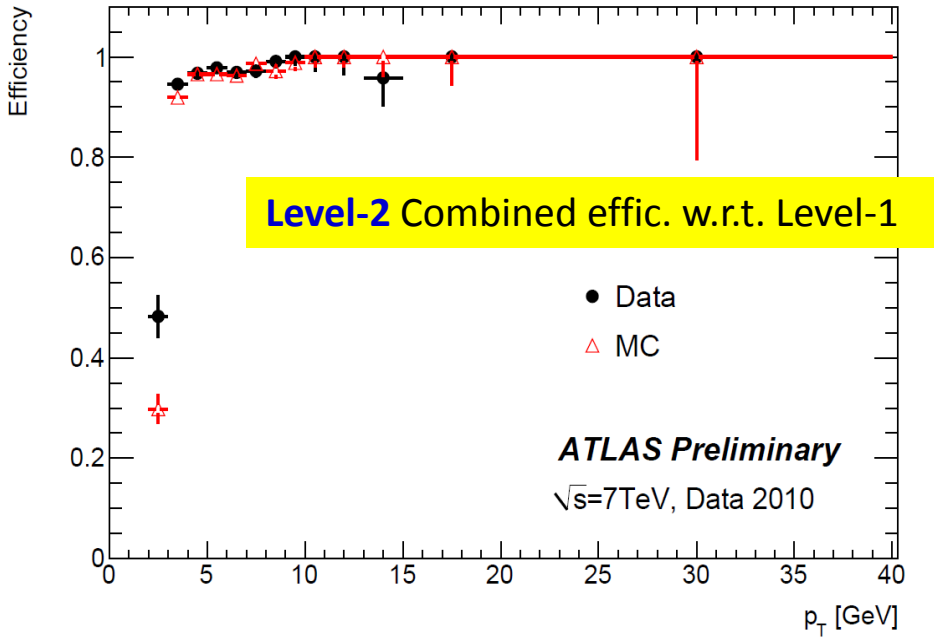
Stand-alone: Muons reconstructed at the HLT including information from the precision muon detectors

- Effic. > 98% w.r.t. Level-1 for muons p_T>4 GeV
- Good agreement with Simulation

Combined: Muon track segment combined with inner detector track





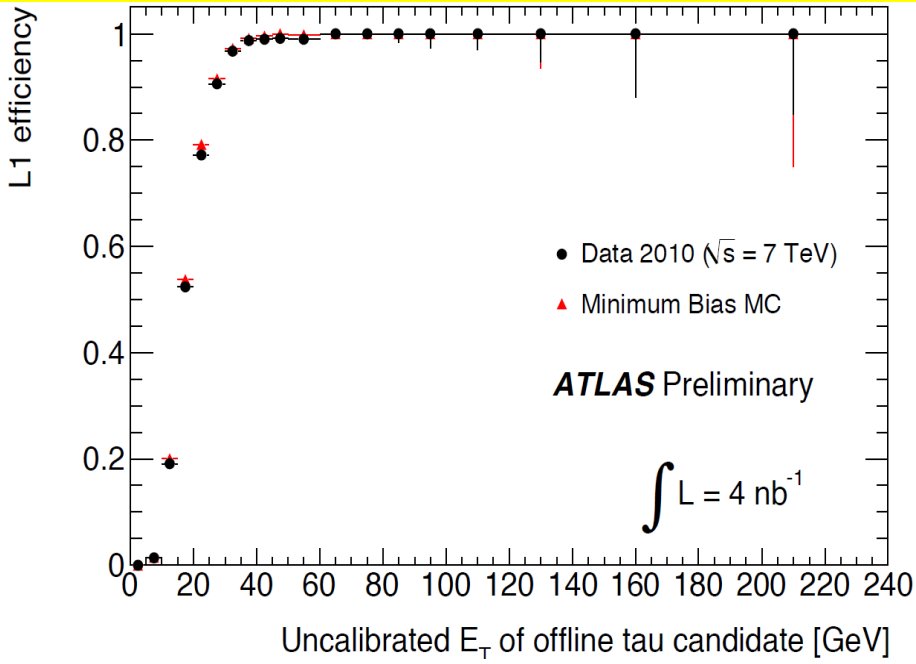


Tau Trigger

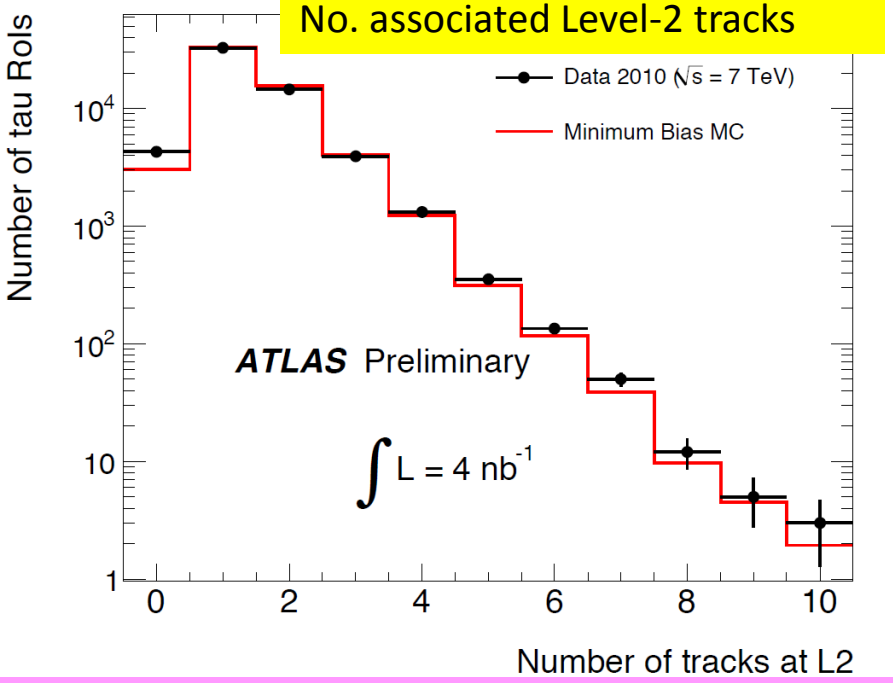
W/Z → τ, SM &MSSM Higgs, SUSY with light stau, Exotics

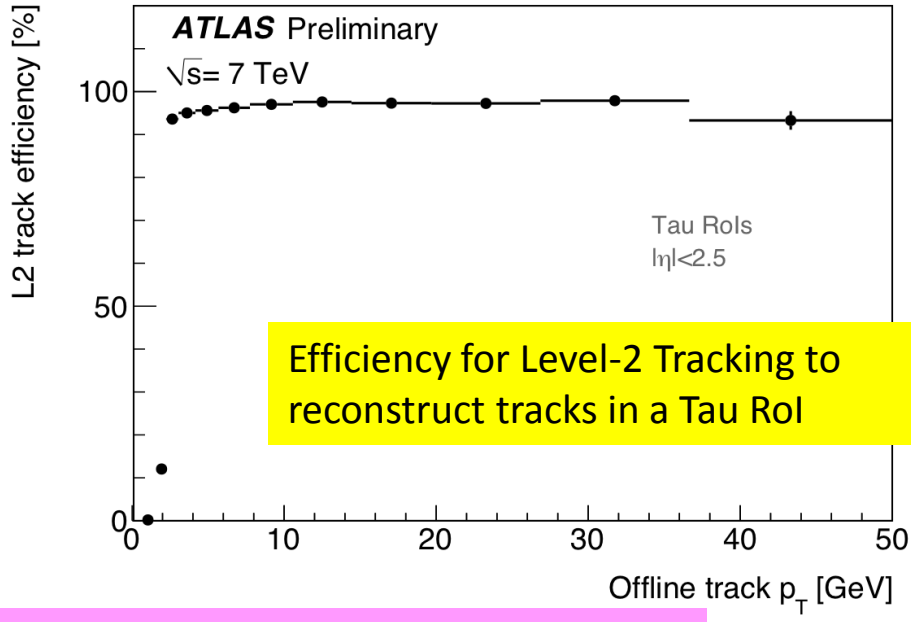
- Dedicated trigger for taus decaying to one or more hadrons
- Level-1: calculates E_T using e.m. and hadronic calo in core ($\Delta\eta x\Delta\phi$=0.2x0.2)
  - can require isolation
- HLT: Tau identified by well collimated calo. cluster with small no. of associated tracks

Level-1 Effic. v. E_T of offline τ cand. for 5 GeV threshold



No. associated Level-2 tracks





Efficiency for Level-2 Tracking to reconstruct tracks in a Tau RoI

Poster: Performance of the ATLAS tau trigger with 7 TeV collision data at the LHC: M. Shamim

Missing E_T Trigger

For: W → τν, BSM, SUSY, orthogonal trigger for efficiency studies.

Level-1: Missing E_T and Sum E_T calculated based on Calorimeter Cells

Level-2 : Add muon information

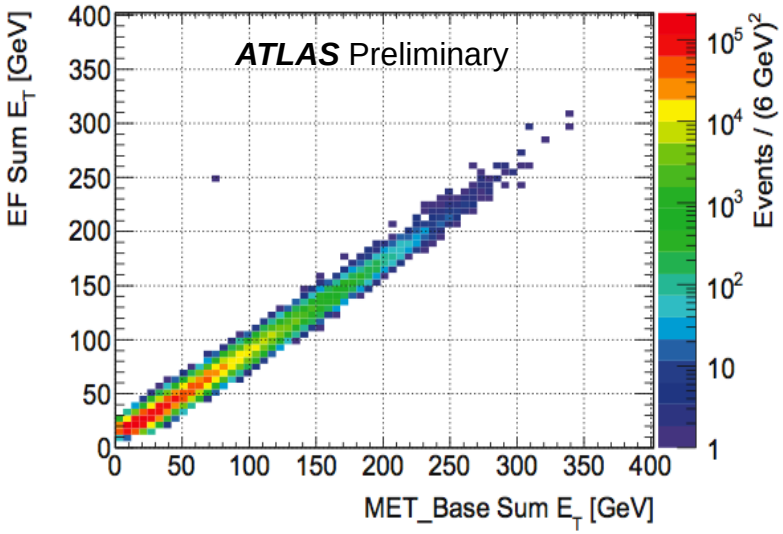
Event Filter: Recalculate using Calo. & Muon

10 GeV threshold running un-prescaled to $L \sim 10^{30} cm^{-2} s^{-1}$

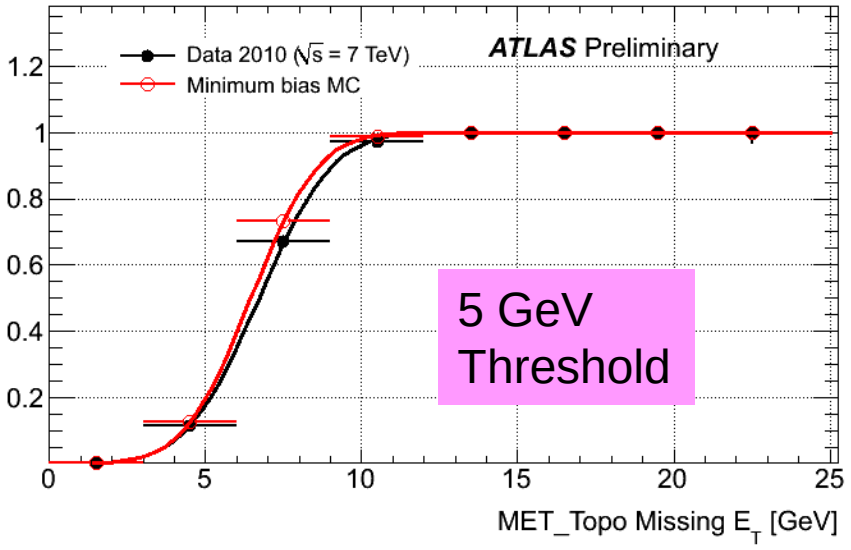
Menu also includes combined triggers :

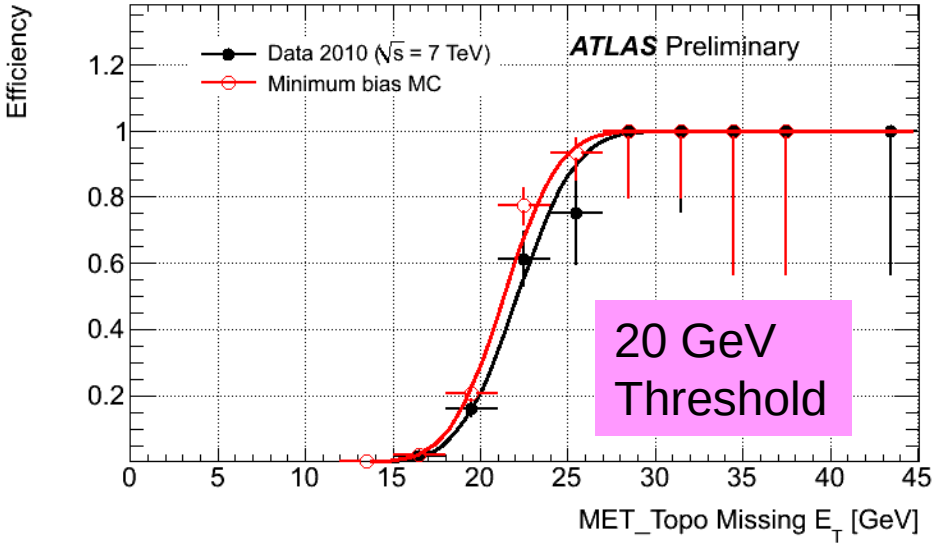
- e.g. tau + Missing E_T

Event Filter Sum E_T v. offline Sum E_T



Comparision of Event Filter Missing ET in 7 TeV Data with Simulation





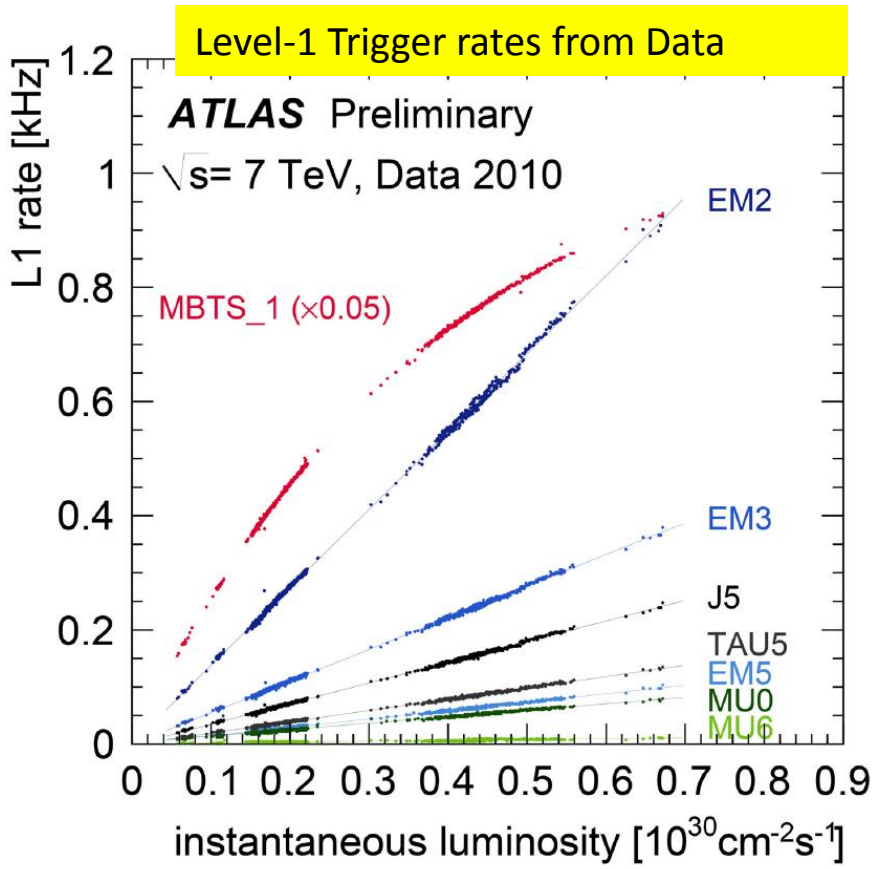
Good agreement of Missing E_T turn-on with MC

Good agreement of Online and offline quantities

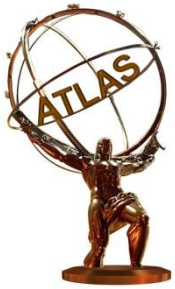
Summary

- The ATLAS Trigger has been successfully commissioned :
  - ➢ Instrumental in delivering data for first physics

- Very inclusive Level-1 based trigger to start
- Evolving to track LHC luminosity:
  - ⇒ HLT ready for activation when needed
  - ⇒ Several HLT triggers now active
- Generally excellent agreement with Offline &MC
- Continued evolution matching lumi. & physics :
  - pre-scale lower thresholds
  - move from loose to medium HLT cuts
  - use of isolation requirements
  - higher multiplicity & multi-object triggers
  - Add. Triggers: Jets with B-tagging, B-physics
- Perf. with pile-up confirmed using Data & MC

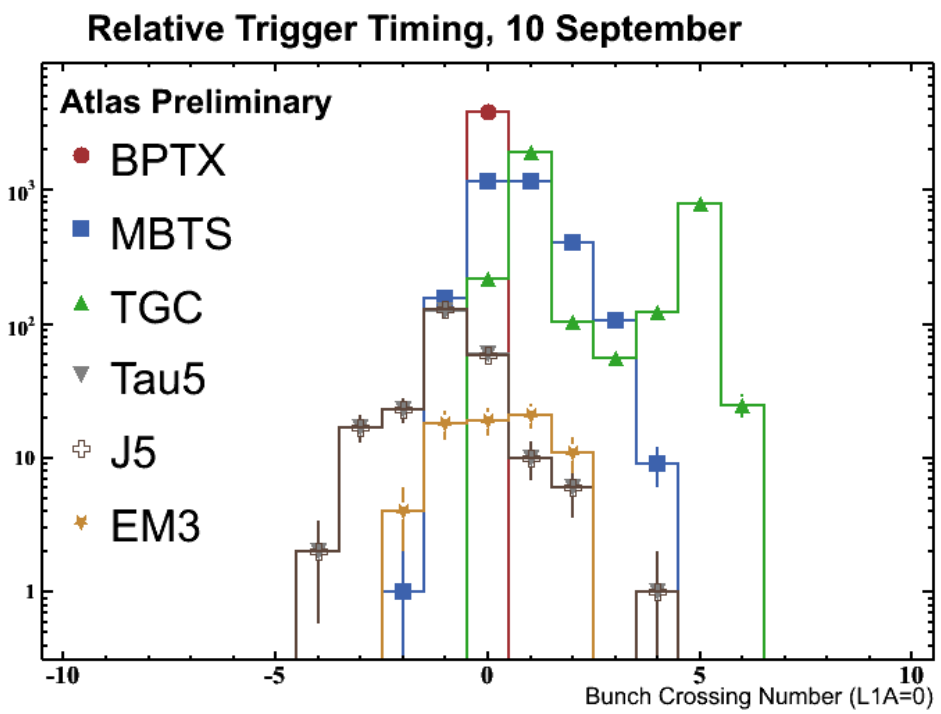


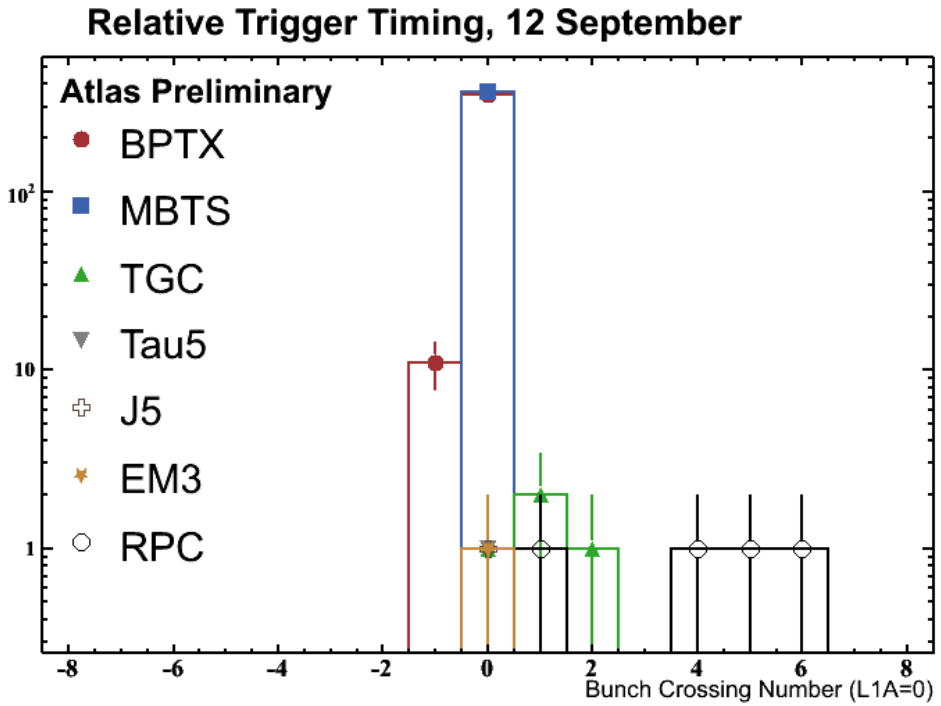
=> The ATLAS trigger is ready and able to meet the challenges ahead and deliver the data for physics in 2010/11 and beyond.



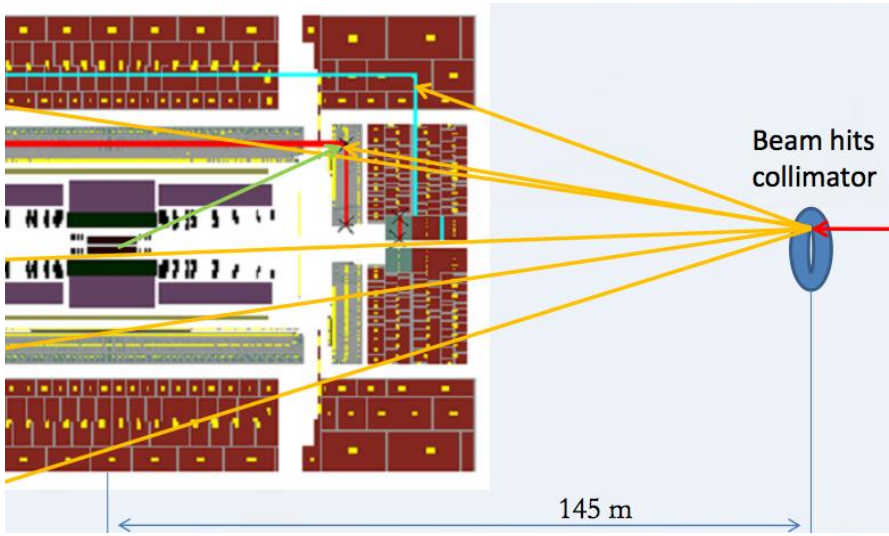
Backup

Level-1 Trigger





- Timing of LVL1 triggers determined to 5-10ns using splash events

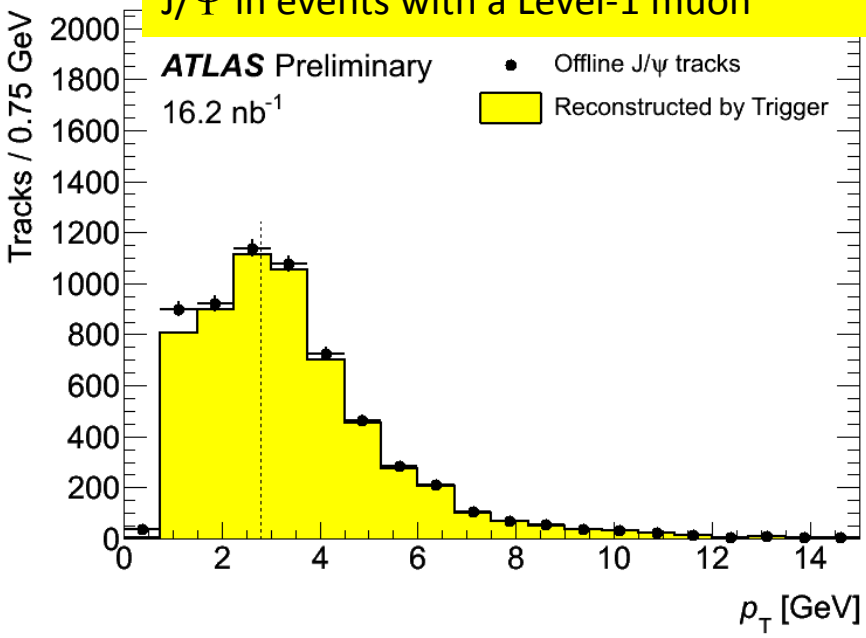


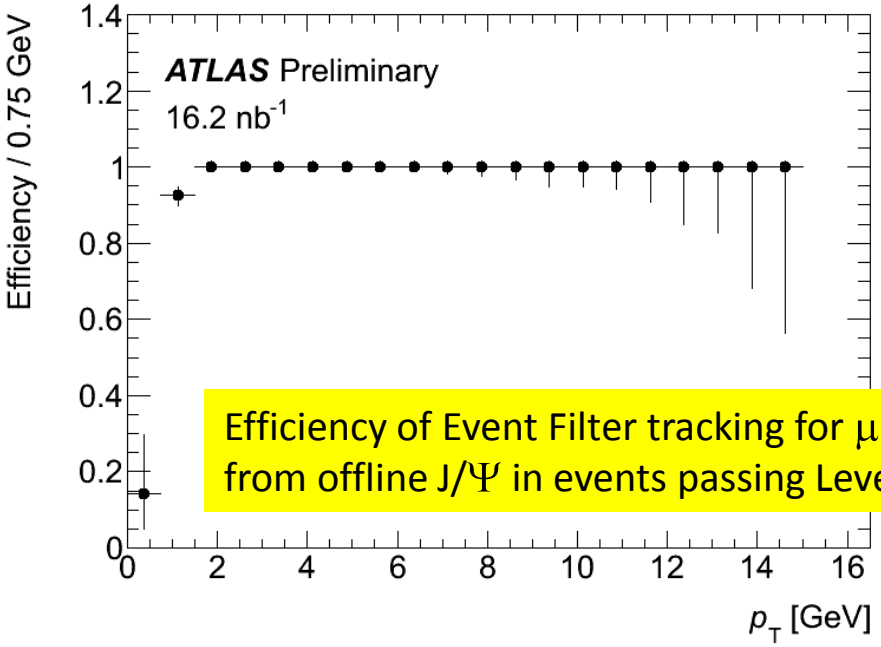
Triggers for Onia & B-Physics

- Onia & Physics analysis uses Min. Bias (early data) and Single Muon triggers
- When single muon rate becomes too high - use Dimuon Triggers:
  - Two Level-1 muons confirmed at HLT, or
  - Single Level-1 muon + second muon found at the HLT :
    - Find Inner Detector tracks in large RoI at Level-2
    - Extrapolate to associate Muon Spectrometer hits

  => Increased efficiency at low p_T

Offline and **Level-2** p_T distributions for muon tracks from offline reconstructed J/Ψ in events with a Level-1 muon





Efficiency of Event Filter tracking for μ tracks from offline J/Ψ in events passing Levels 1 & 2

ID Tracking & Online Beamspot Measurement

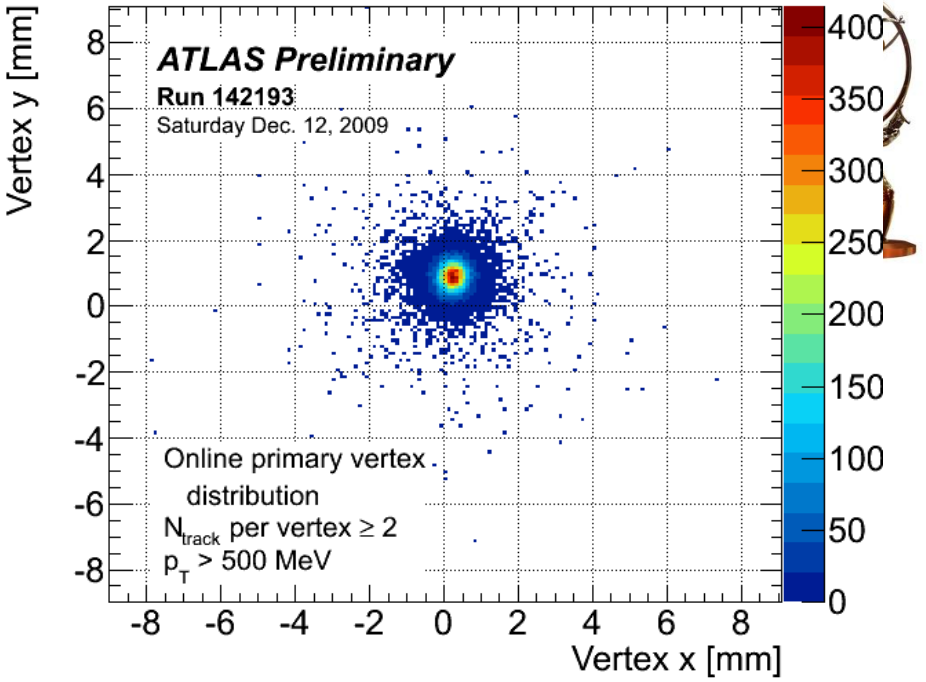
For events with a MBTS Trigger:

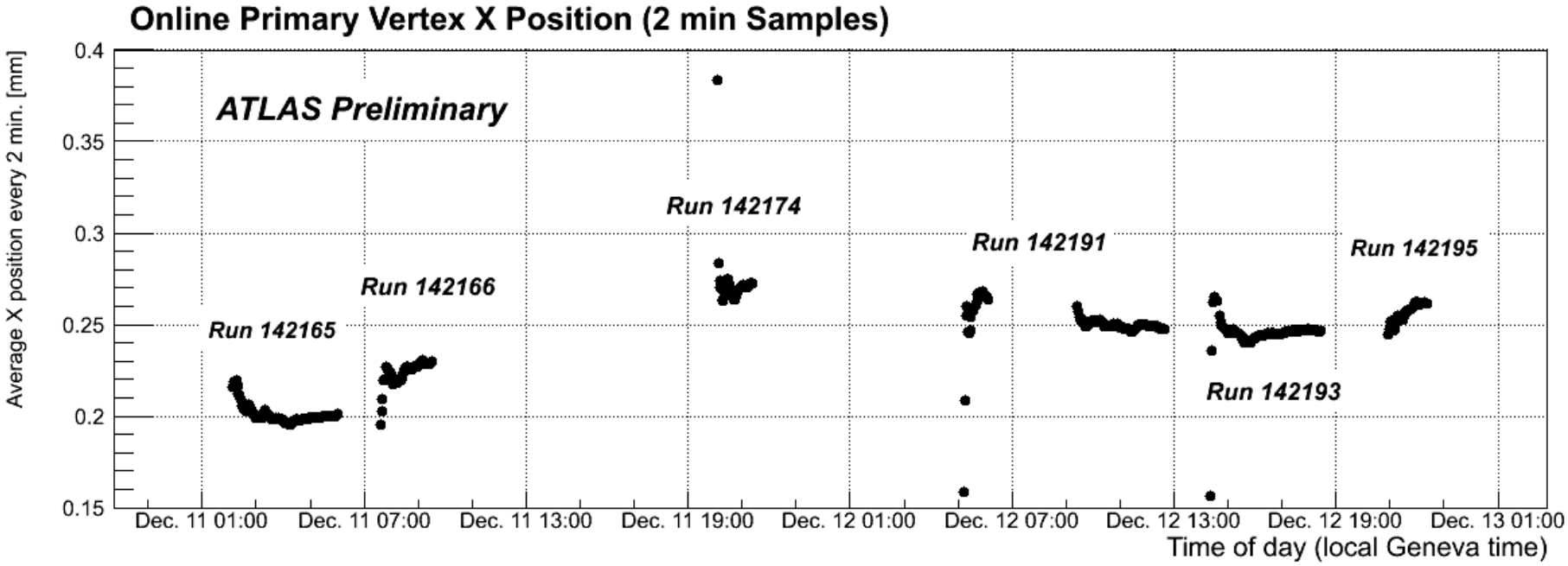
- Fast Level-2 tracking reconstructs tracks in full Inner Detector
- Primary Vertex reconstructed

⇒ Online measurement of beam position

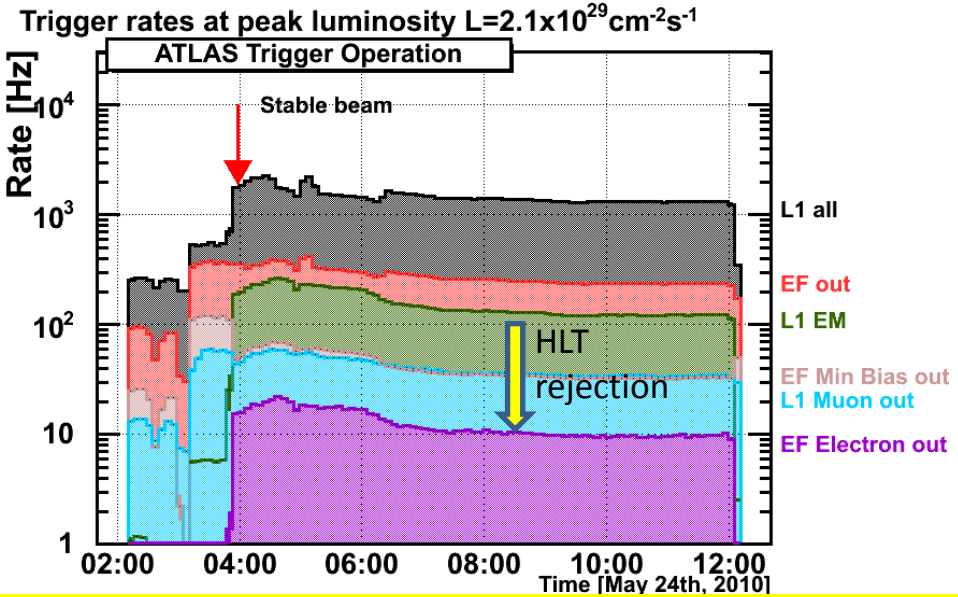
⇒ Information fed back to LHC

⇒ Can be used in trigger, e.g. Impact parameter based B-jet tagging





Activating the e & γ HLT triggers



Trigger Rates v. time with active HLT e & γ selections

First W→eν candidate in ATLAS