Commissioning of ATLAS Electron and Photon Trigger selection

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Outline

- *ATLAS detector and trigger*
- *Electron and Photon trigger strategy*
- *Results from first 7 TeV proton-proton collision data*
- *Commissioning steps and near future plans*

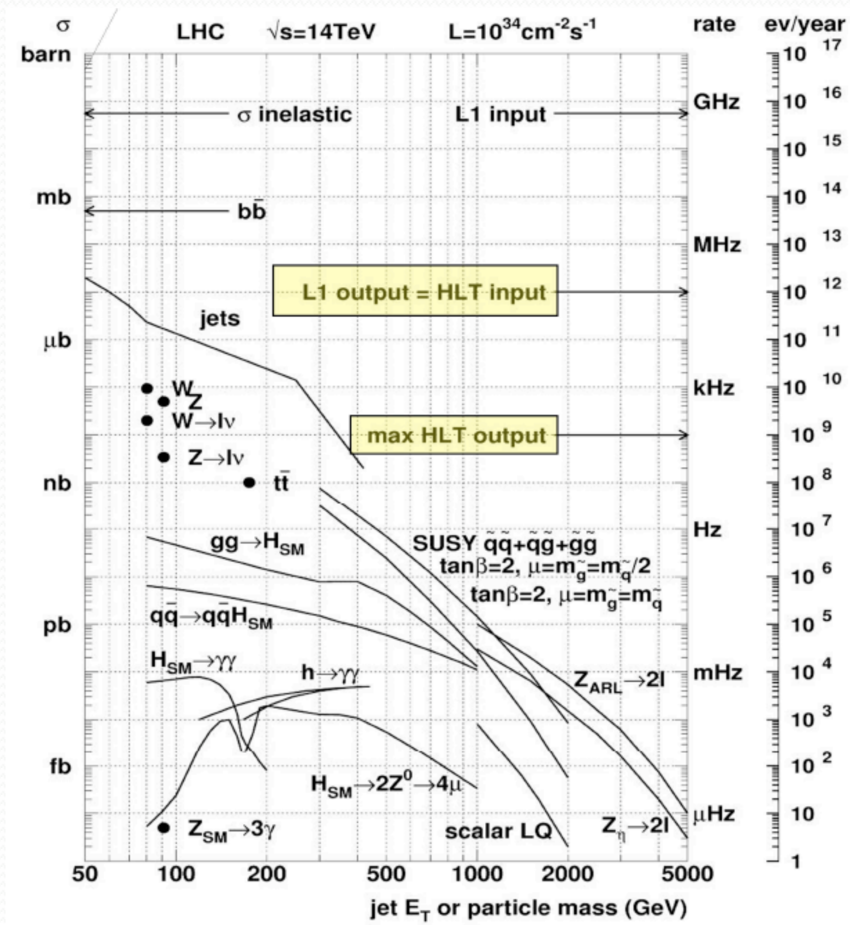
Physics motivations/requirements

- *Electrons and photons* are typical signatures of many key physics process:
  - *J/ψ, B physics* → low p_T electrons [5 – 20 GeV]
  - *Z, W, Higgs, SUSY, top, prompt γ* → medium p_T electrons and photons [20 – 100 GeV]
  - *exotics, G, Z'* → high p_T electrons and photons [>100 GeV]

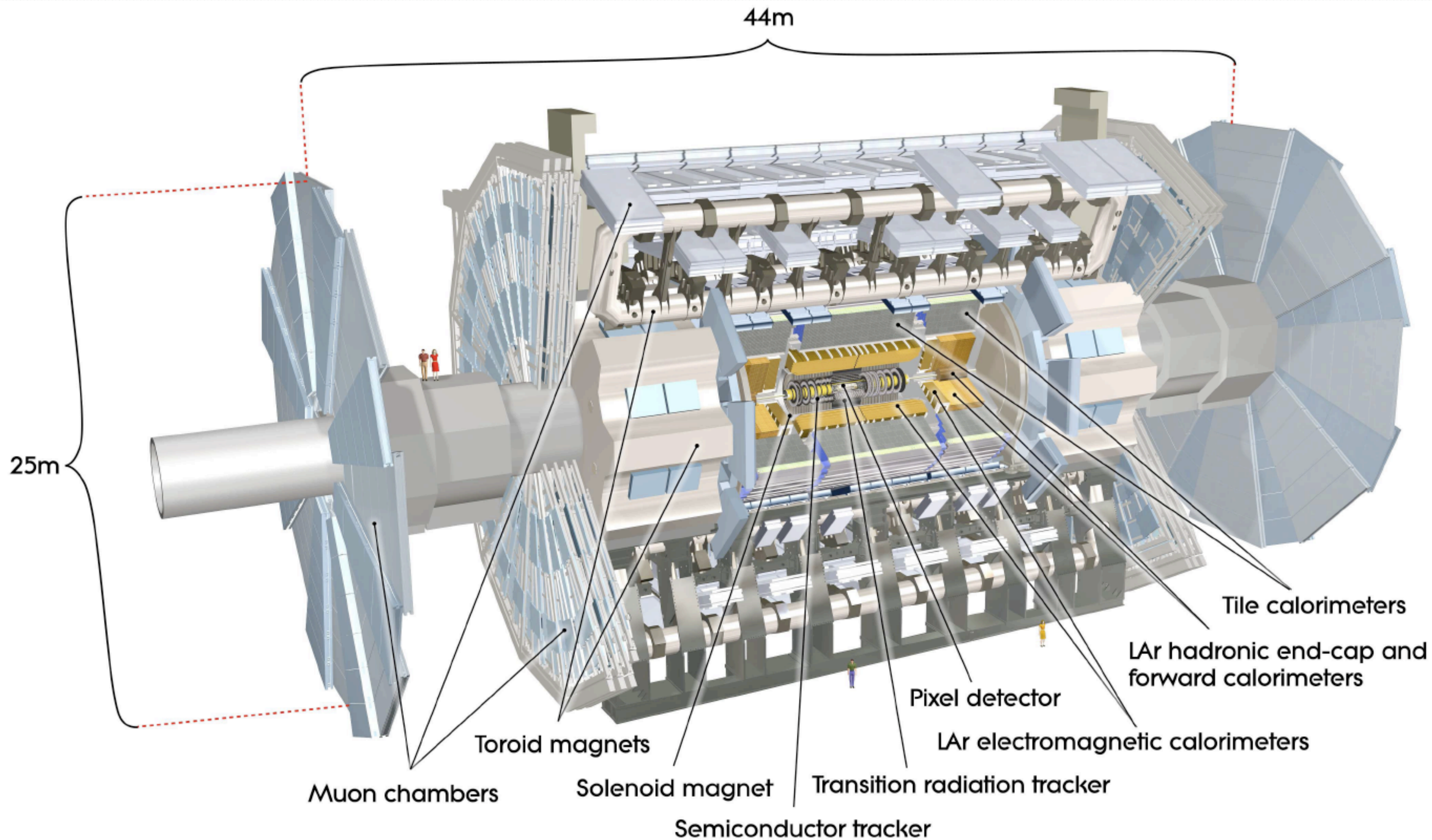
- At nominal LHC conditions:
  - bunch crossing *every 25 ns* (40 MHz rate)
  - cross section dominated by soft pp interactions
  - on average 20 interactions per bunch crossing (pile up) 10^{34} cm^{-2}s^{-1}

- Data saving rate limited by offline processing time and storage capability to *~ 200 Hz*

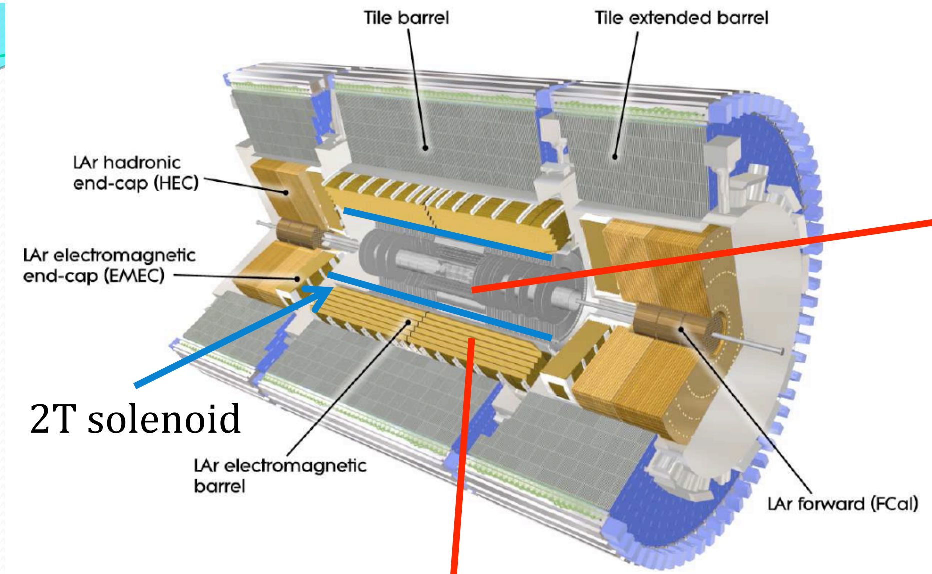
- Trigger 'requirement': *reducing rate by factor of 200000 while retaining events with interesting physics objects*



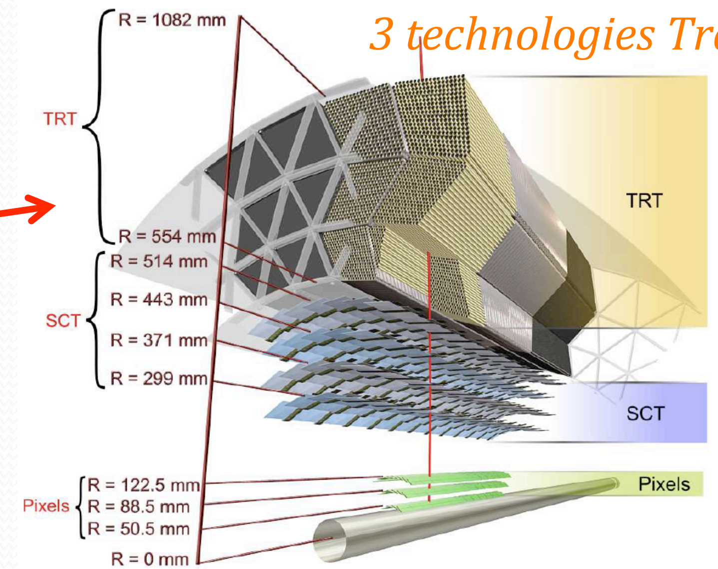
The ATLAS detector

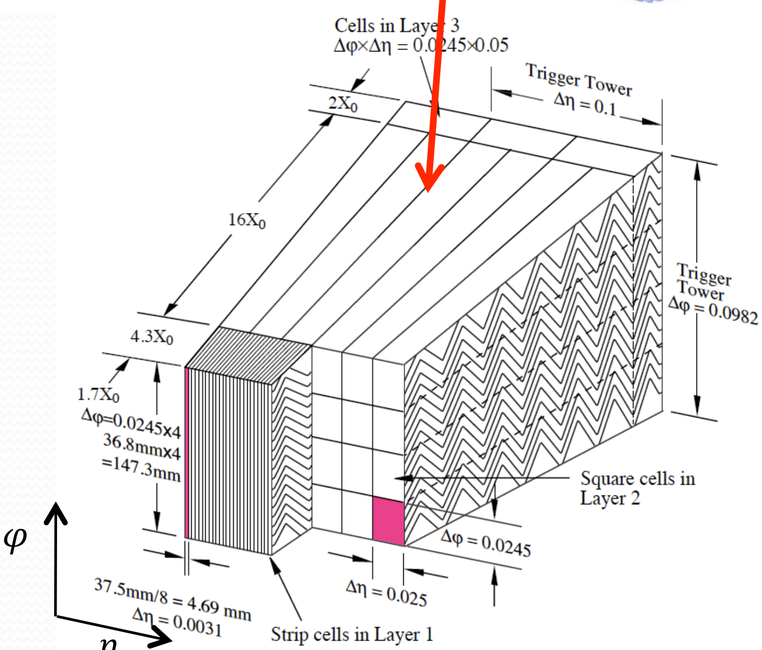


sub-detectors for egamma triggers



3 technologies Tracker





$|\eta| < 2.0$

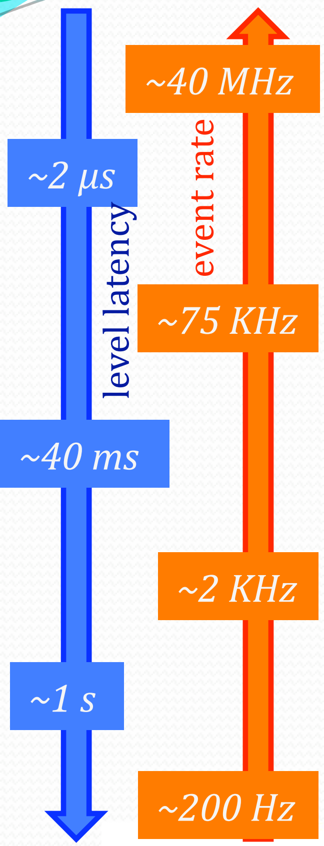
- 3 Si pixel layer
- 8 Si strips layer (4 space point)
- straw TRT detector (~36 hits per track) electron PID capability

LAr EM calorimeter: more on this in H. Zhang talk

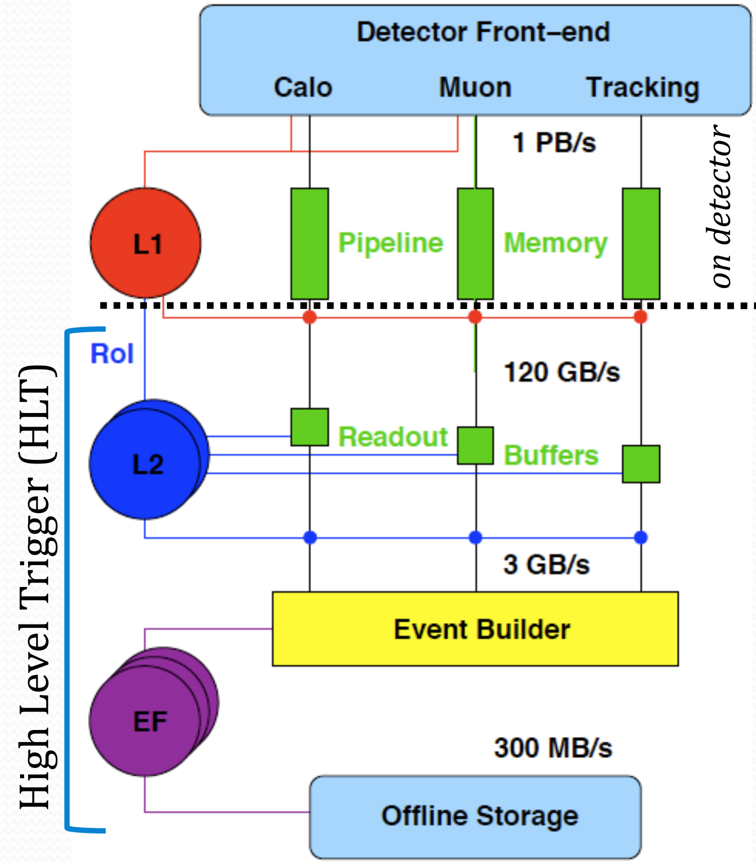
- coverage $|\eta|<3.2$ (precision meas. $|\eta|< 2.5$)
- total thickness: 24 X_0 (3 longitudinal layers)
- different granularity in each layer

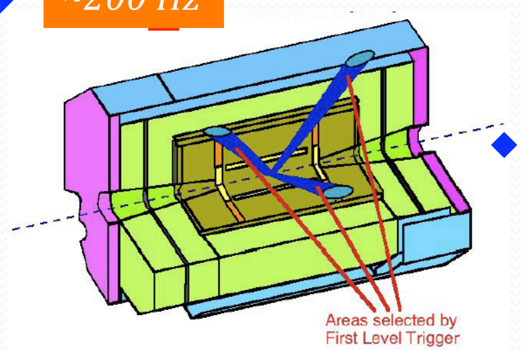
The ATLAS trigger system

A 3 level trigger system:



- *Level 1* (L1):
  - hardware based
  - only muon and calo information
  - reduced granularity
- *Level 2* (L2):
  - software based
  - all detectors available (*RoI approach*)
  - dedicated algorithms and calibration
- *Event Filter* (EF):
  - software based
  - full event information available
  - 'quasi' offline algorithms

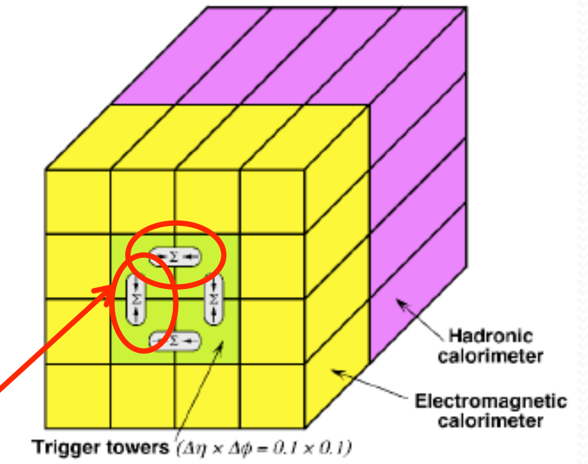


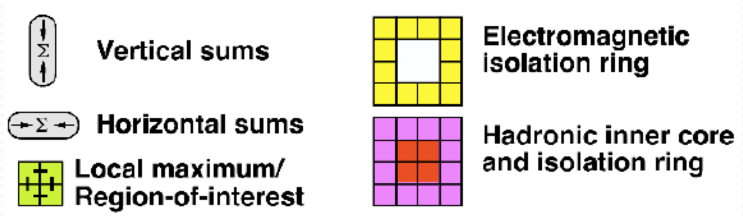


- Region of Interest (*RoI*) concept:
  only detector information contained in an angular region around directions triggered by L1 (em objects, jets and muons) are processed by next level (*increase speed and reduce network load*)

Egamma trigger: L1

- *Only calorimetric information available*
- Granularity (*Trigger Tower*): summing up EM cells energy in region ΔηxΔφ = 0.1x0.1
- *Sliding window* clustering algorithm (4x4 Trigger Tower)
- E_T calculation with ADC conversions:
  - at output *1 count ~ 1 GeV*
  - linear up to ~ 250 GeV
- E_T threshold applied to highest energy 1x2 or 2x1 T.T. combination inside the window





Naming convention example: L1_(2)EM3

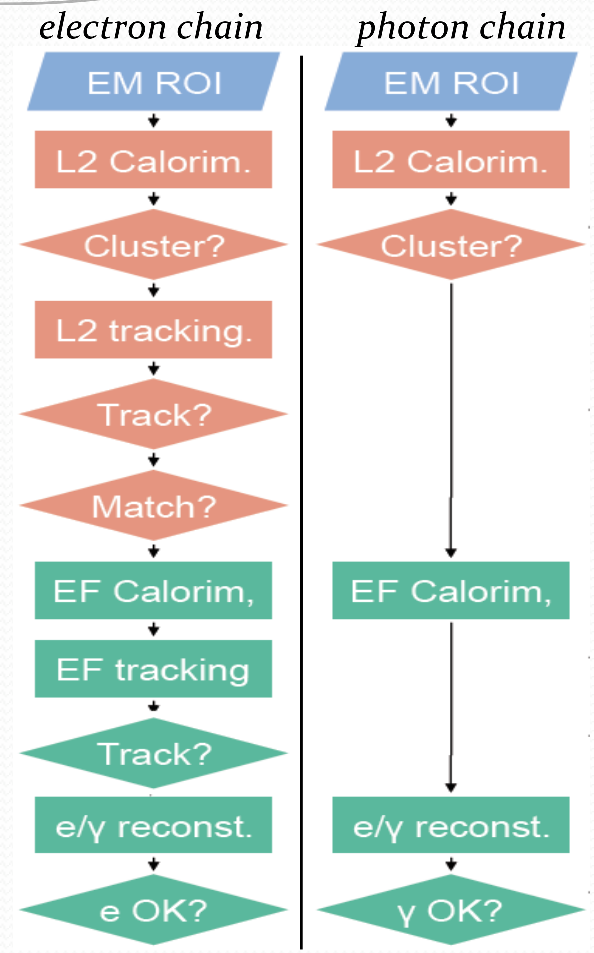
- minimal number of objects passing the selection
- EM object: no distinction between electrons and photons
- E_T threshold (on ADC counts) >3 counts → $E_T \geq$ ~4 GeV

Egamma trigger: HLT

- HLT selection consists of a *series of steps:*
  - performed in parallel on each RoI at L2
  - aim for the *earliest possible rejection*

: *Feature EXtraction ("FEX") algorithm* builds the object (track, cluster, ….)

: 'HYPOthesis' algorithm applies identification cuts and (eventually) rejects the event



L2
- *clustering*: hottest cell approach for cluster finding, fixed cluster size
- *tracking*: 3 fast pattern recognition algorithms (*2 based on silicon hits, one on TRT standalone*)

EF
- *clustering*: sliding window for cluster finding, variable cluster size (*barrel/endcap*)
- *tracking*: optimized tuning of offline algorithms
- "as close to offline as trigger timing constraints allow": no *conversion finding, no brem recovery ….*

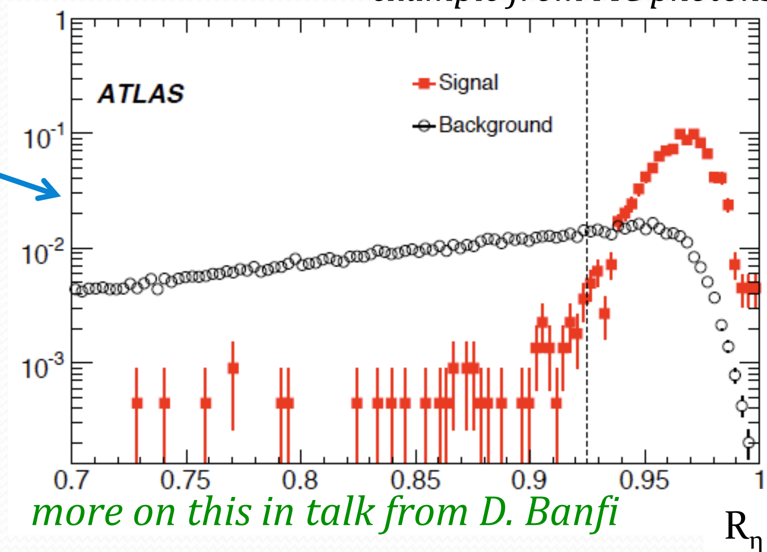
example: `(2)e5_loose`

- (2)e → electron
- 5 → $E_T \geq 5$ GeV
- loose → set of selection criteria

Egamma trigger: selection

- Electron and photon identification exploits the difference in calo shower shapes between signal and background *(signal shower are narrower)*.
- *HLT and offline use the same variables for signal identification* (*reducing trigger bias*)
- *Simple cut based identification criteria on 'well understood' variables:*
  - *calorimeter*: lateral shapes in 2nd EM layer, leakage in hadronic calorimeter, 1st EM layer variables (high granularity in η direction)
  - *tracking* (electron specific): track p_T , number of hits in silicon detectors, calo cluster-track angular match

example from MC photons



more on this in talk from D. Banfi

- Trigger cut values comes from a compromise between:
  - having sufficient rate reduction
  - being as efficient as possible with respect to events selected by offline
- *A good trigger-offline resolution is an important requirement*

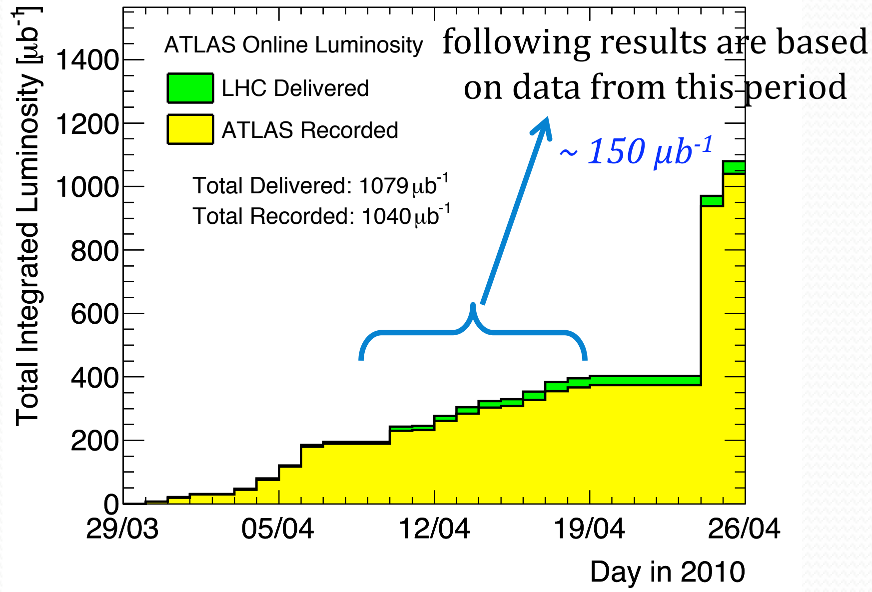
7 TeV collisions in ATLAS

2009: *collisions at 900 GeV c.m.e.*

- peak luminosity ~ 7×10^{26} cm^{-2}s^{-1}
- ~500 M collision event with stable beam

2010: *collisions at 7 TeV c.m.e.*

- first collisions on 30-03-2010
- peak luminosity ~ 2×10^{28} cm^{-2}s^{-1}
- so far ~ 1 nb^{-1} of stable beam data



- Electron/photon trigger operational mode:
  - *L1*: active and used for event streaming (relying on Minimum Bias triggers to check its performance)
  - *HLT*: running online in pass-through mode (producing objects and decisions but NOT rejecting events) during stable beam operation

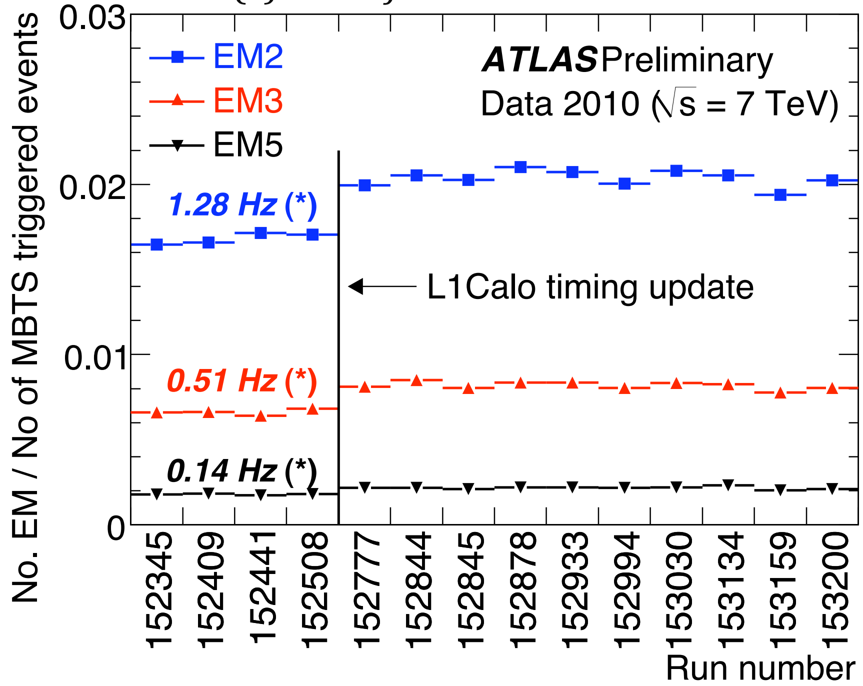
- Assessing trigger performance through:
  - comparison of trigger quantities with Monte Carlo at each level
  - evaluation of trigger resolution w.r.t. offline identification variables

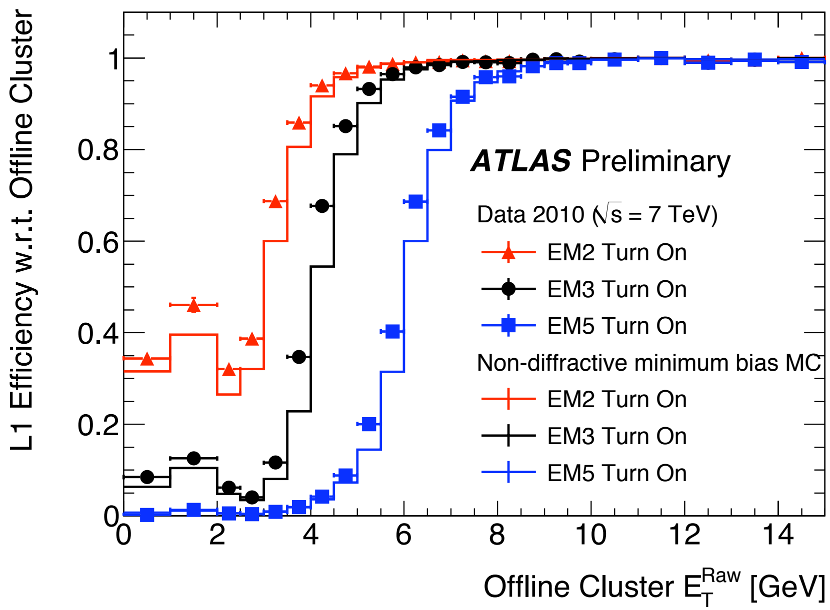
- No identification cuts applied on offline reference → *all distributions dominated by fakes*

L1 results

- Reliable operation of L1 calorimeter system
- *Rate is stable within 10 %*
- Timing calibration improved after few runs (*see talk from J.T. Childers*)
- For energy resolution studies *see talk from H. Zhang*

(*) *Rates for* $L \approx 10^{27}\ cm^{-2}s^{-1}$

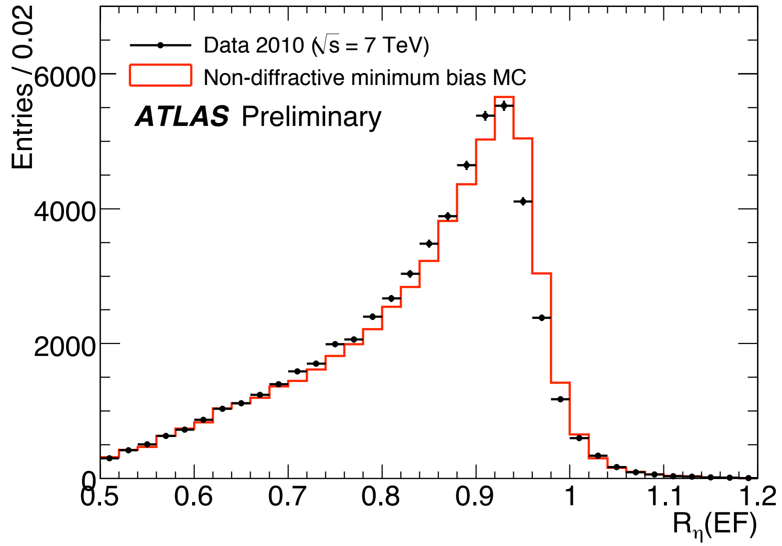


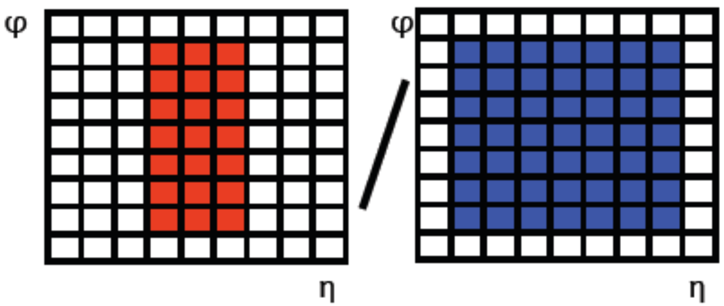


- L1 efficiency w.r.t offline:
  - excluded barrel/endcap transition region
  - general agreement in shape with MC but turn-on in data starts slightly earlier
  - reaching plateau within 1-2 GeV above L1 threshold

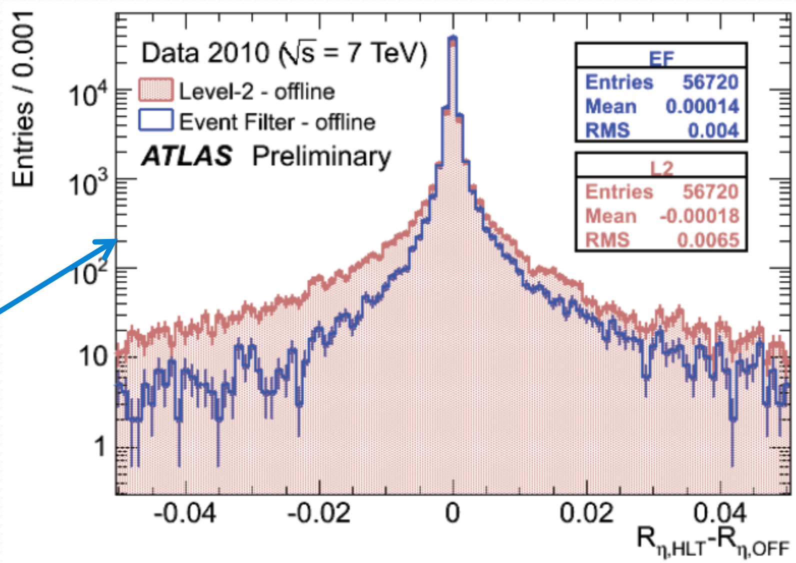
HLT: shower shapes

R_η = *energy deposition in 3x7 cells divided by energy deposition in 7x7 calo cells*
(lateral shower shape variable using 2nd sampling layer information)





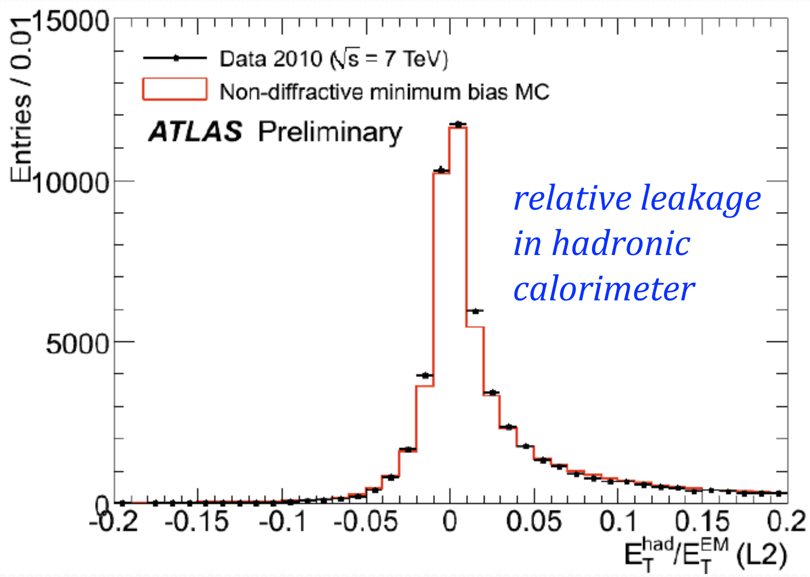
- L2 clusters matched to offline electrons
- Slight shift with respect to MC also observed at L2 and offline (*); related to description of crosstalk between cells in second layer
- Good agreement between offline and HLT: EF resolution is ~ factor 2 smaller than L2

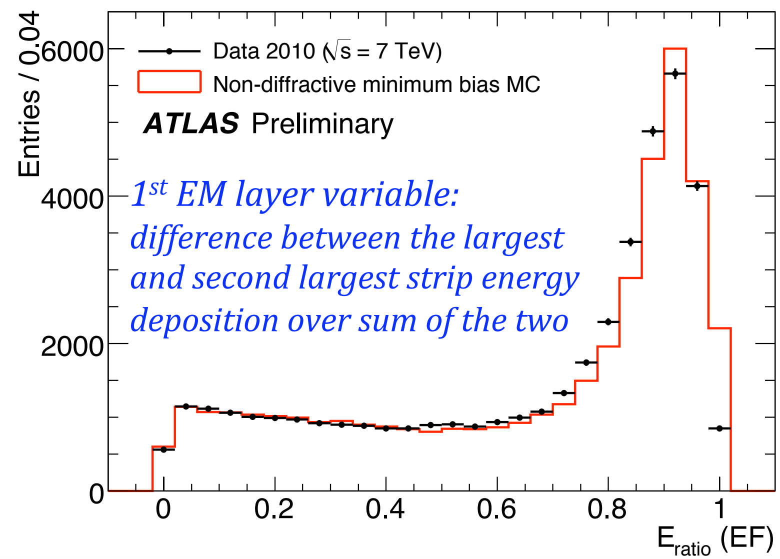


(*) plot from 900 GeV data in D. Banfi's talk

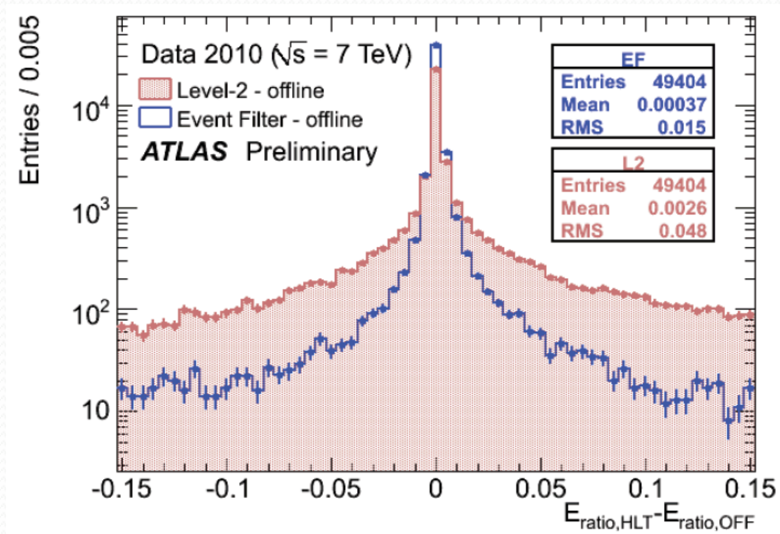
HLT: shower shapes (2)

- A few more examples ….





- General agreement with MC also for shapes variables in other layers of the EM calorimeter
- No visible bias and reasonable trigger-offline resolution
- *"the faster and simpler L2 algorithms perform adequately with respect to the more complex EF/offline reconstruction ones"*



Next steps in commissioning

- egamma trigger bandwidth is ~ 30-50 Hz
  L1_EM2 rate will reach this limit starting from a luminosity of few 10^{28} $cm^{-2}s^{-1}$

- deploying HLT in rejection mode needs many validation steps:
  - check the correct functionality on the trigger in offline reprocessing ✔
  - deploy the HLT online without active rejection ✔
  - detailed verification of HLT results w.r.t. offline *in progress*
  - measure performance on signal enriched sample (Tag&Probe on Z→ee and J/ψ→ee, MET trigger for W→eν) ultimate goal (*more data needed*)

- at higher luminosity need to prescale(*) the lowest E_T chains.
  (*) randomly accepting 1 in N triggers

- …. looking just ahead:
  the electron/photon trigger menu for 10^{31} $cm^{-2}s^{-1}$ (MC rate estimates)

primary trigger	rate (Hz)	motivation
2e5_medium	1.3	*J/ψ→ee, Υ→ee, Drell-Yan*
e10_medium	18.4	*$e^{\pm}$ from b,c decays, E/p studies*
e20_loose	2.9	*Z→ee, W→eν, high p_T phys*
g20_loose	10.5	*direct photon, γ-jet calibration*

Primary trigger: lowest unprescaled chain for a given set of identification cuts

+ many other signatures for monitoring, calibration, performance measurement

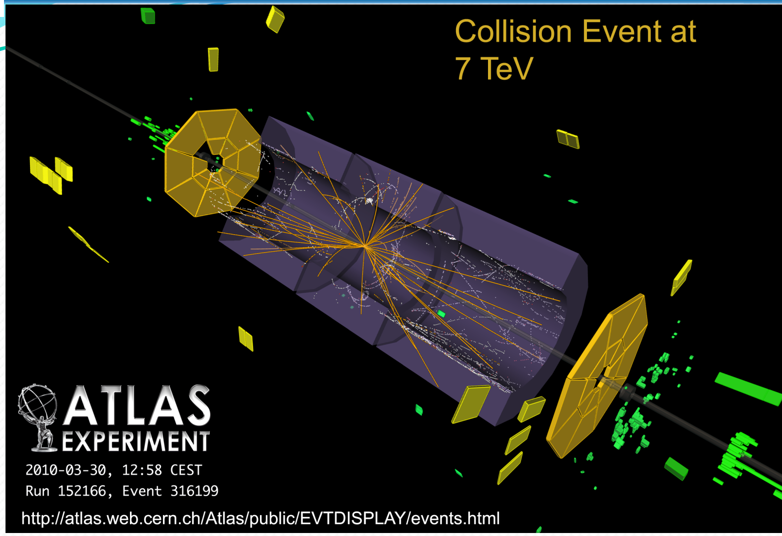
Conclusions

- The analysis of the first 7 TeV LHC collisions represented a further step in the commissioning of the electron and photon trigger in ATLAS:
  - *L1 calo trigger* system shows good performance and stability
  - *HLT electron and photon chains* (currently in pass-through mode) are working properly online

- Comparison of trigger quantities with offline references shows good agreement
- The distributions measured online are well reproduced by MonteCarlo simulation
  - *we increased our confidence in the correctness of the MC-based trigger studies and trigger optimizations (rates, efficiencies, etc ..)*

- *Electron and photon triggers will play a major role in physics analysis with increasing LHC instantaneous luminosity*

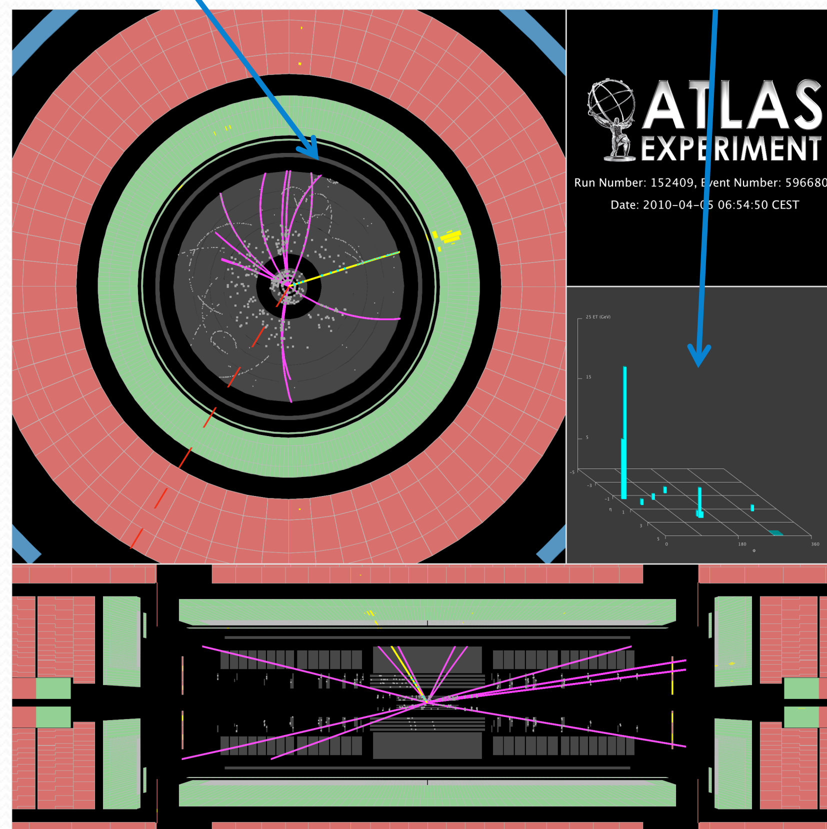
Collisions in ATLAS



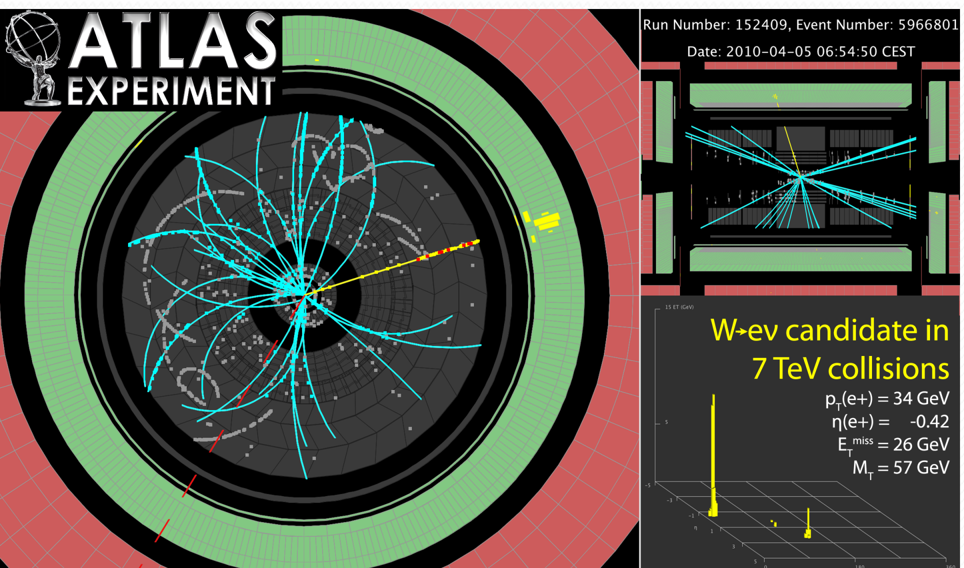
… same W candidate 'seen' also by trigger

L2 clusters and tracks

L1 energy deposition



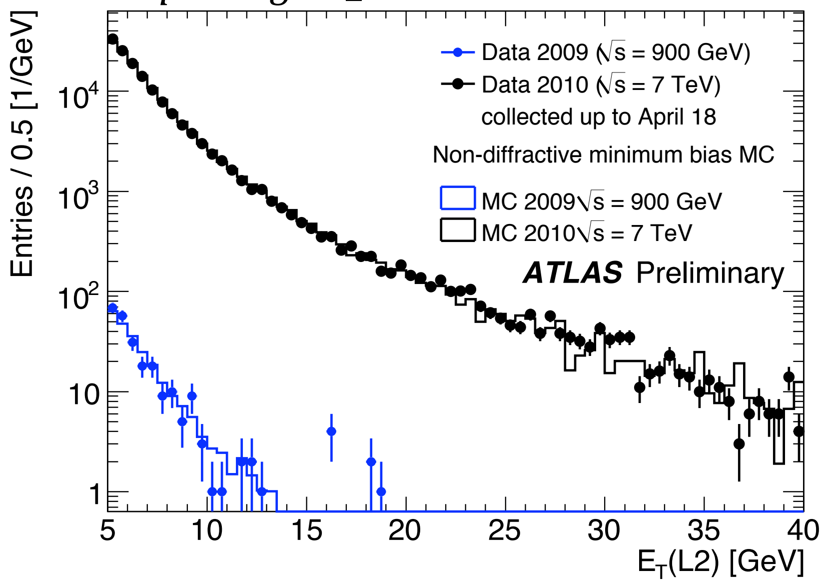
first W candidate 'seen' by offline …



backup

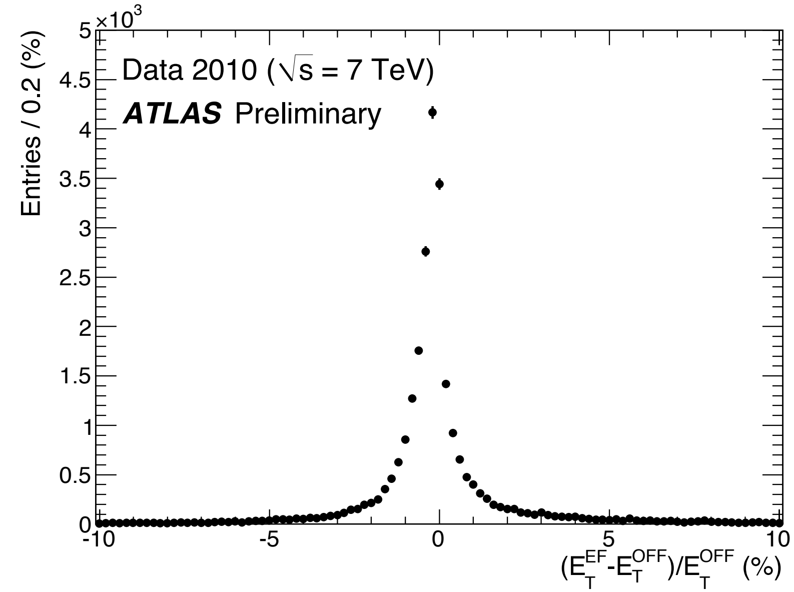
HLT: clustering

events passing L1_EM3



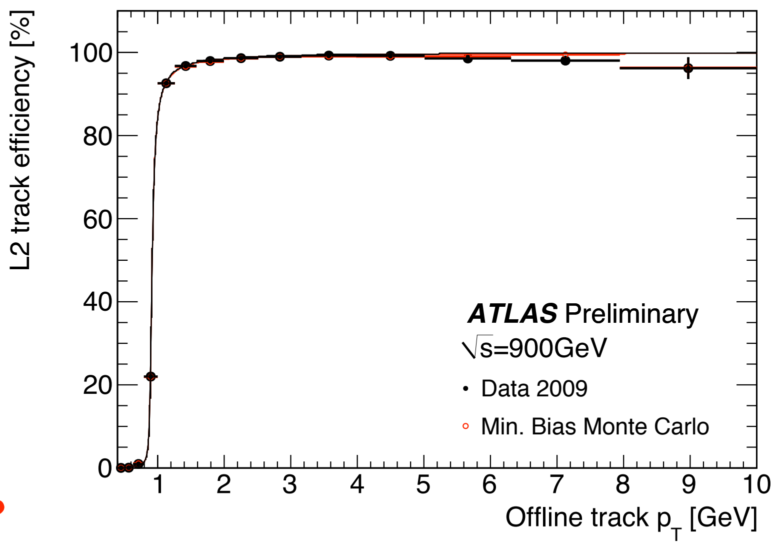
- L2 EM clusters E_T spectrum:
  - well reproduced by MC simulation
  - the same holds for angular variables distributions at both levels
  - spectrum is harder than at 900 GeV

- EF-offline energy resolution:
  - resolution at few % level
  - *in the initial running phase EF relies on real time energy calculation in DSP while offline recompute the energy with a more precise algorithm since timing calibration is not yet optimal.*

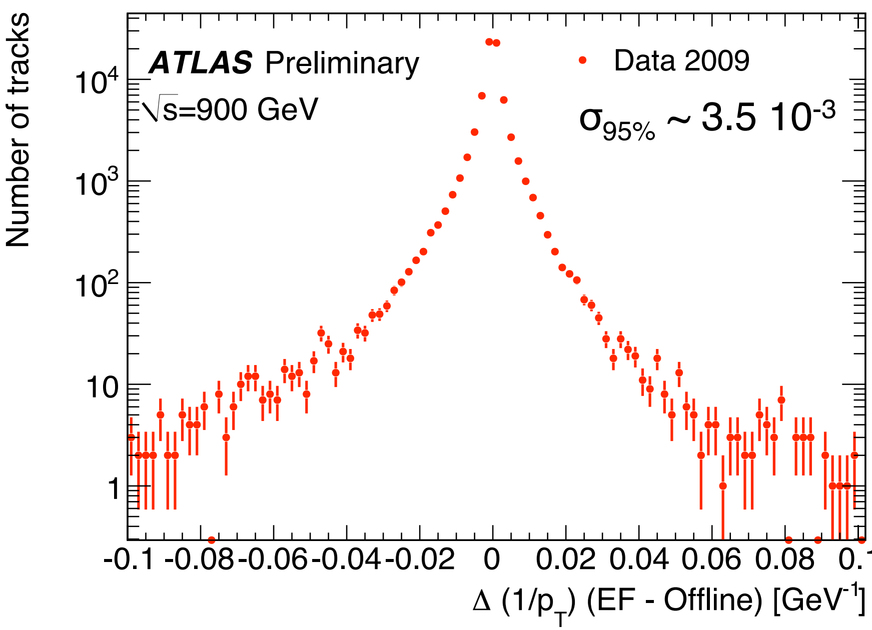


HLT: tracking

- For startup condition mainly relying on silicon hits based algorithms (both for L2 and EF).
- *Offline benchmark (#Pixel hits>0 and #SCT hits>5)*
- L2 plateau (p_T>2GeV) losses due located at high |η| region.
- EF plateau efficiency ~ 100%



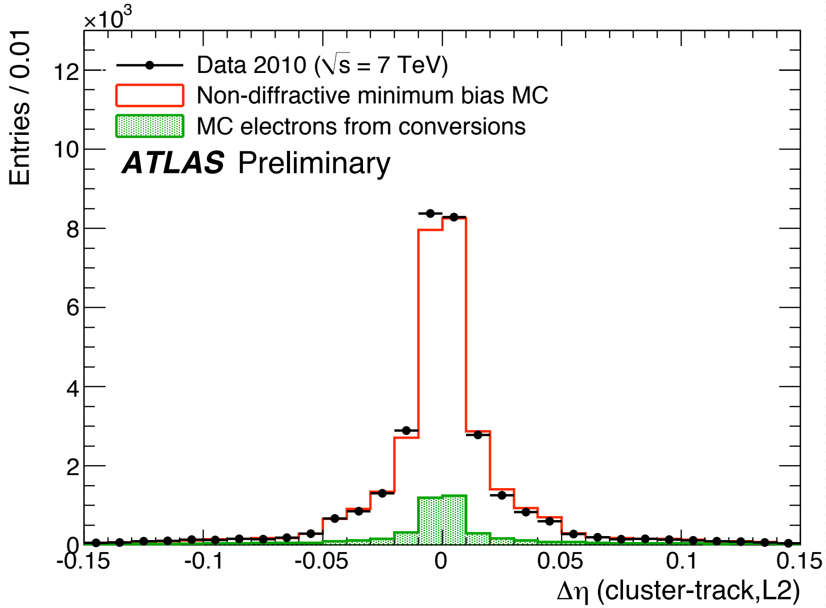
900 GeV results

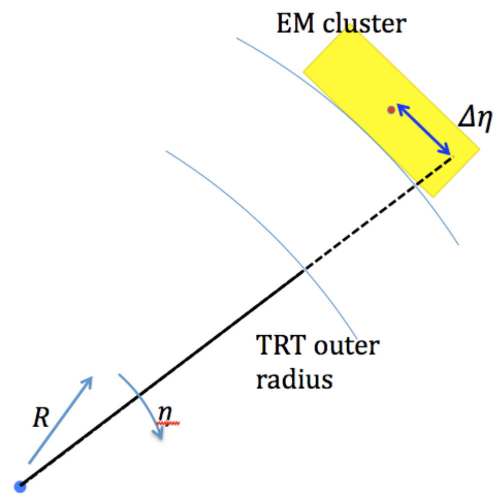


- Trigger resolution on offline track parameters:
  - *dominated by low P_T tracks*
  - d0 resolution: EF ~25 μm, L2 ~90 μm
  - $1/p_T$ resolution: EF ~3.5%, L2 ~23%
  - good agreement with MC
  - *L2 approaches EF values at higher p_T*

HLT: calo-track match

- Electron identification variable: *$\Delta\eta$ between cluster and extrapolated track*





- L2 distribution well described by MC (same observed at EF)
- *Good EF resolution w.r.t. offline*
- Larger L2 resolution due to the less sophisticated tracking algorithms