Reconstruction and Selection of Physics Objects in the ATLAS High Level Trigger

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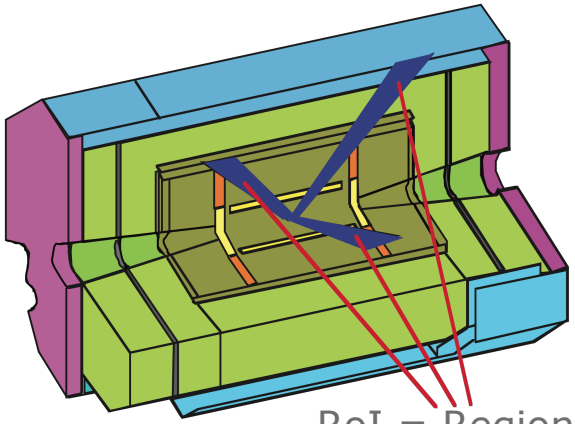
On behalf of the ATLAS collaboration

Outline

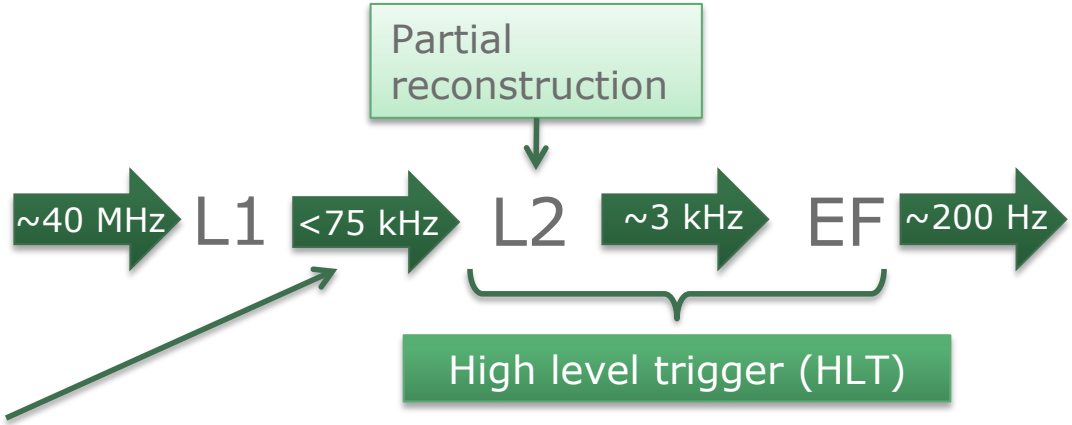
- Topics for today
  - Commisioning status
  - Performance of trigger selections
  - Evolution towards higher luminosities

- Will be presenting 900 GeV and 7 TeV data.

Introduction



RoI = Region(s) of interest: (η,φ)



- List of physics signatures (menu):
  - Electrons
  - Photons
  - Jets
  - Tau
  - Missing E_T
  - Muons
  - B-physics
  - B-jets

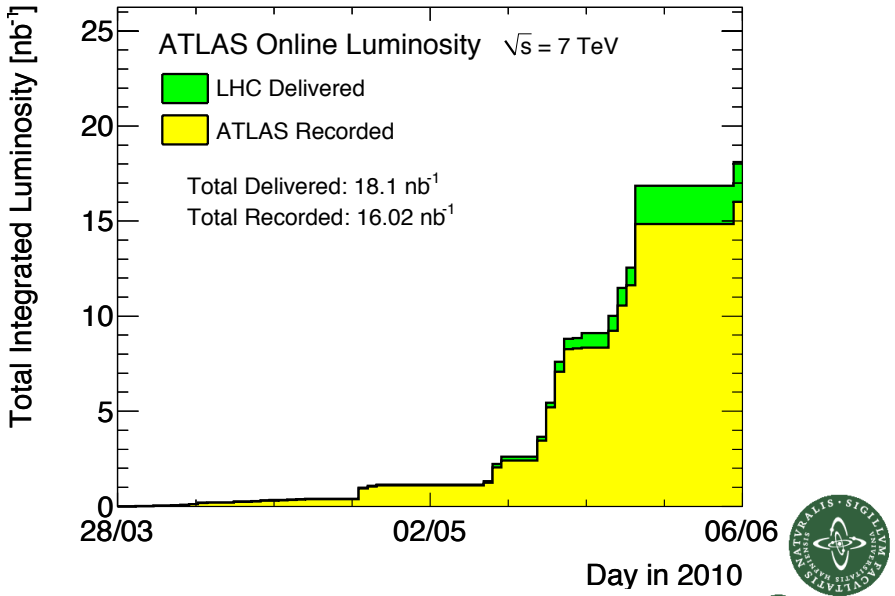
Menu is composed of ~500 signatures based on ~250 L1 items.

Poster advertisements:
ATLAS High-Level Calorimeter Trigger Algorithms Performance with First LHC pp Collisions (Pavel Jez)
Performance of the ATLAS Inner Detector Trigger algorithms in p-p collisions at centre-of-mass energies of 900 GeV and 7 TeV (Andrea Ferretto)

Current Status of the ATLAS trigger

- Running a commissioning trigger menu:
  - Lowest E_T thresholds have been written un-prescaled to disk
  - Physics HLT has been commissioned in monitoring mode (no rejection)
  - Minimum bias triggers have been running in rejection mode for some time
- At ~10^{29} $cm^{-2}s^{-1}$ the first physics triggers (lowest threshold electron and photon) were enabled for active selection.
- More signatures to come

Data-taking efficiency with stable beams: 89 %

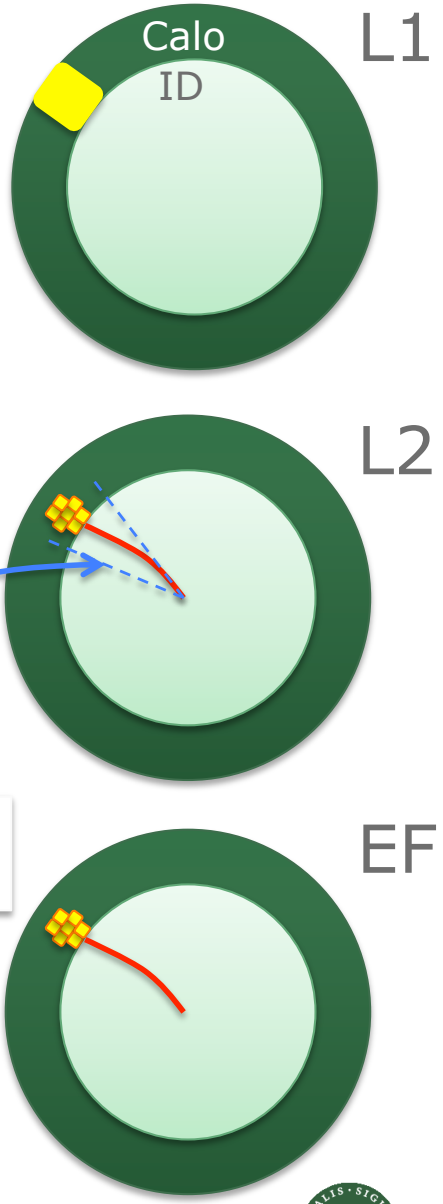


Iwona Grabowska-Bold (UC Irvine): Commissioning and performance of the ATLAS trigger with proton collisions at the LHC (Given yesterday)

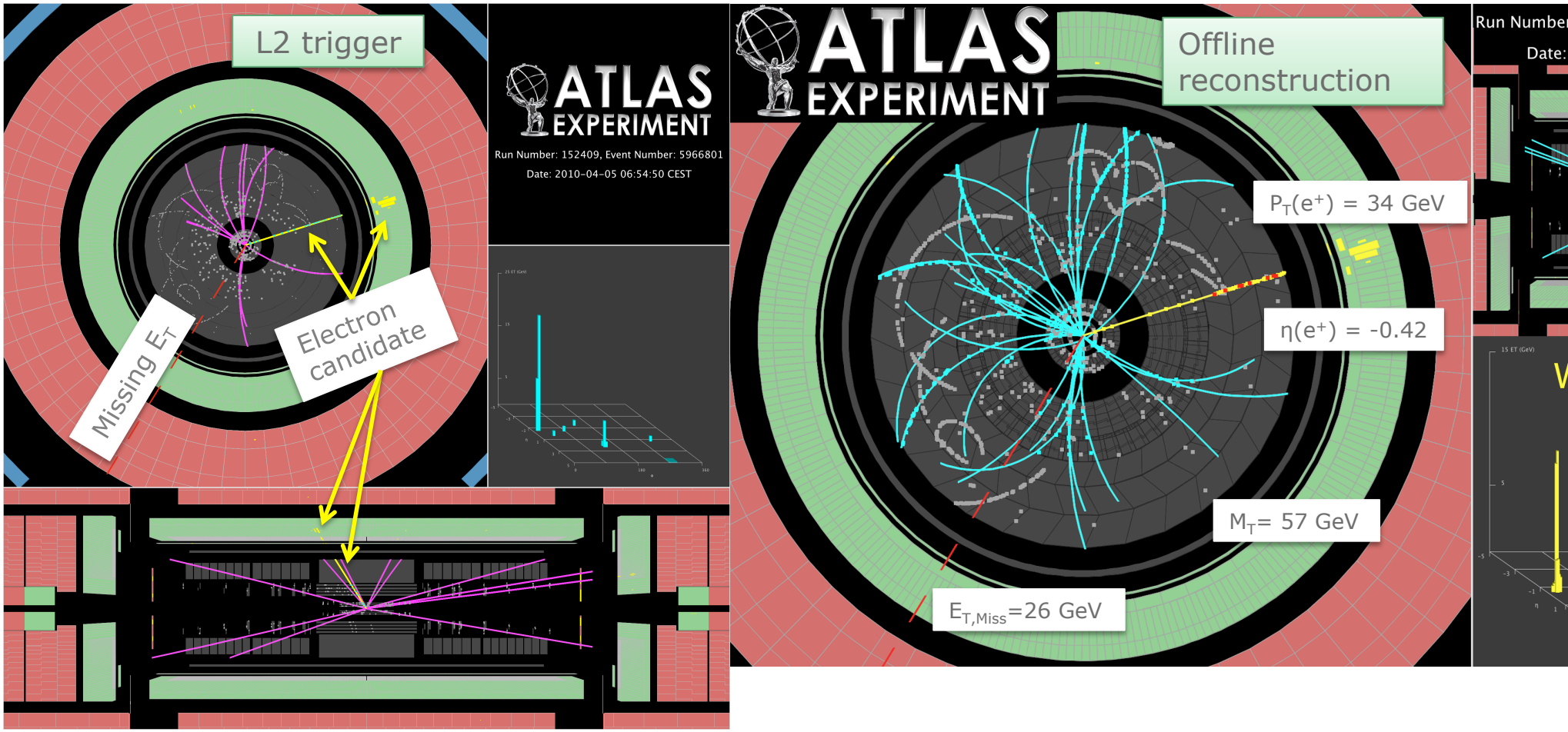
Electron and photon selection

- Physics case:
  - 3-20 GeV: b/c/tau decays, SUSY, turn-on curves (J/ψ, Υ…)
  - 20-100 GeV: W/Z/top/Higgs physics
  - > 100 GeV: Exotica (Z' and friends)
- Level 2:
  - L1 RoI →
  - Calorimeter clustering
  - Tracking
  - Cluster shape cuts and cluster track matching

  Detector partially read out
- Event Filter
  - Reco still in RoI →
  - Full event available
  - Offline algorithms used ← No conversion finding or brem recovery.
  - Calorimeter clustering
  - Tracking
  - Cluster shape cuts and cluster track matching
- Photon signatures are a superset of electron signatures (no tracking)
- Same selection variables used online and offline



First W→eν candidate in ATLAS

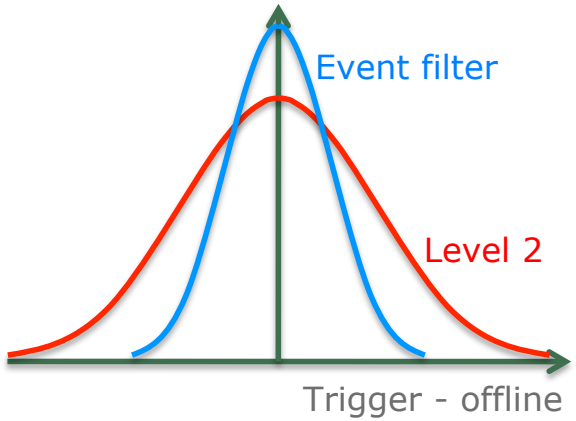


Evaluating trigger performance

L2: Fast custom algorithms, loose cuts ~ 40 ms

EF: Mostly offline algorithms with selections approaching (but looser than) offline. ~ 4 s

- Trigger selections motivated by physics requirements, developed & tuned using Monte Carlo (MC) simulations
- To build confidence in selections we need to check:
  - Good offline / trigger correspondence of selection variables:



  - Good MC description of data at trigger and reconstruction level

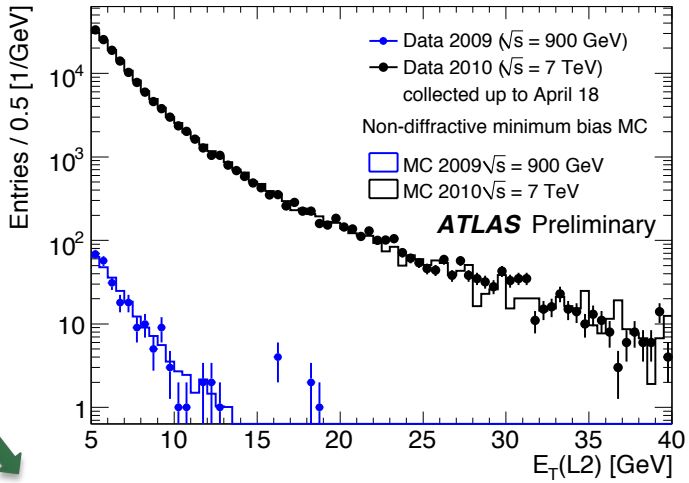
Electron and photon performance

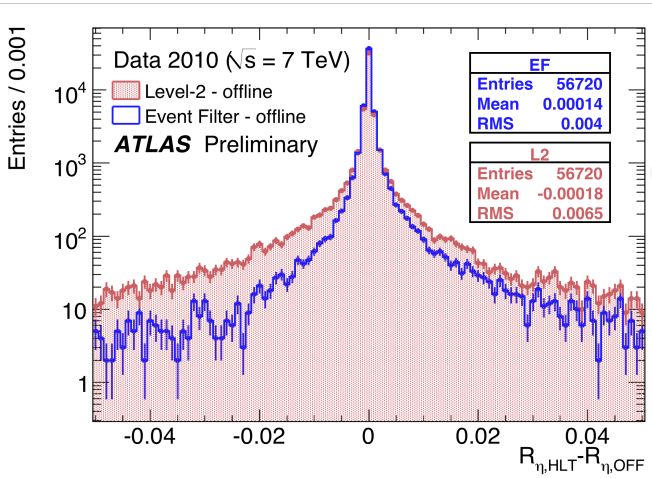
- E_T spectrum of EM clusters: (Level 2)
- Shower shape in 2nd EM layer: (Event filter)

Cell units: η×φ=0.025 × 0.025

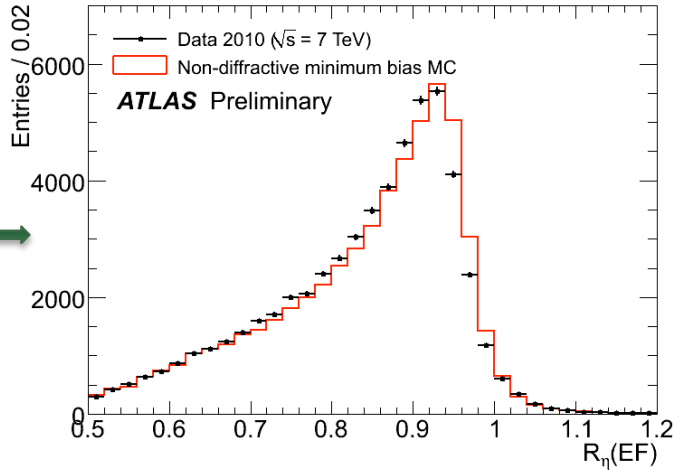
$$R_\eta = \frac{E(3\times 7)}{E(7\times 7)}$$

Should be 1 for electrons





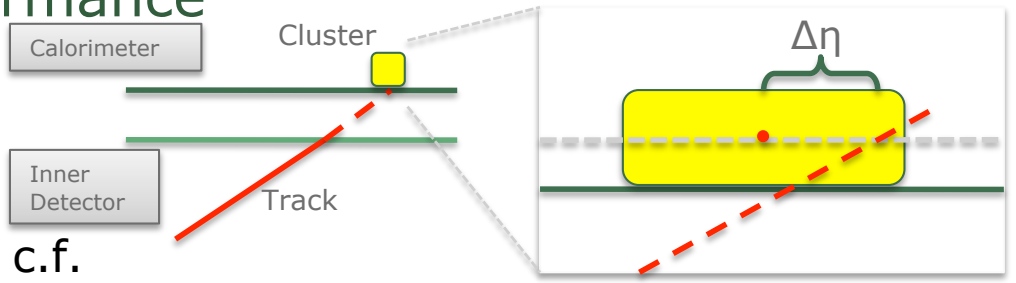
- Good offline / HLT agreement
- Reasonable data/ MC agreement



- All analysis selection cuts derived from MC studies before start-up

➔ Collision data affirms that the selections will work efficiently online

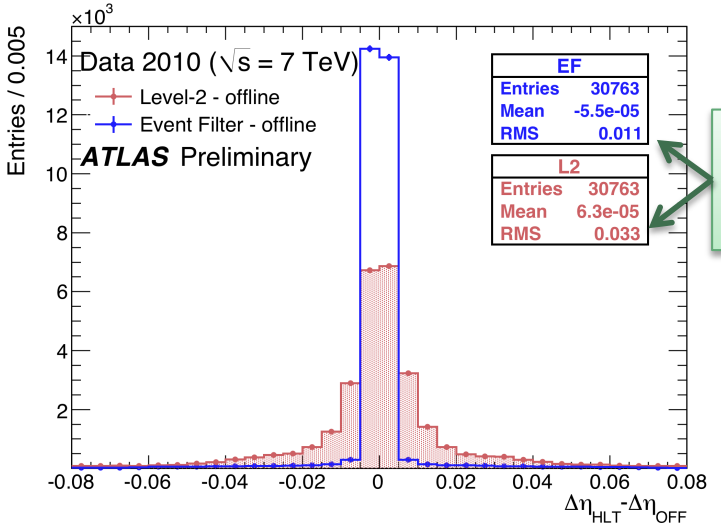
Electron and photon performance



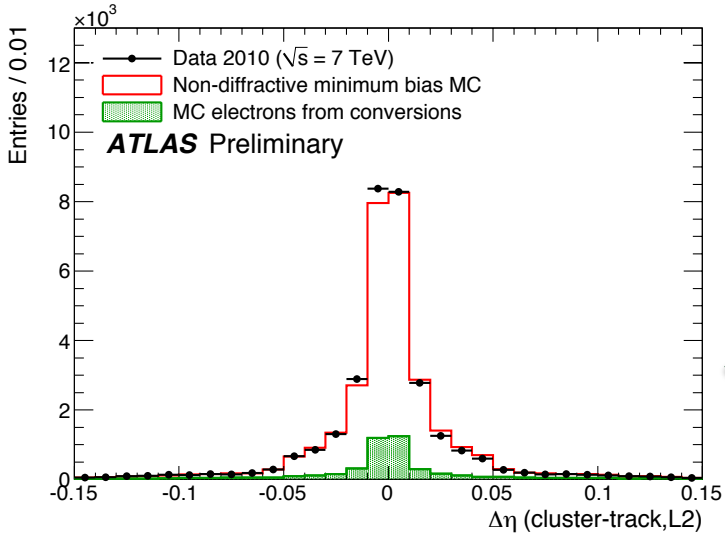
Track / cluster matching:

L2: Different (faster) algorithms c.f. offline ➔ somewhat coarser resolution

EF: Offline tools with special trigger configuration ➔ approaching offline resolution



RMS Factor of 3



Good MC/data agreement ➔
Good understanding of L2 performance (EF similar)

e/γ HLT rejection recently enabled!

Muon selection

Physics case:

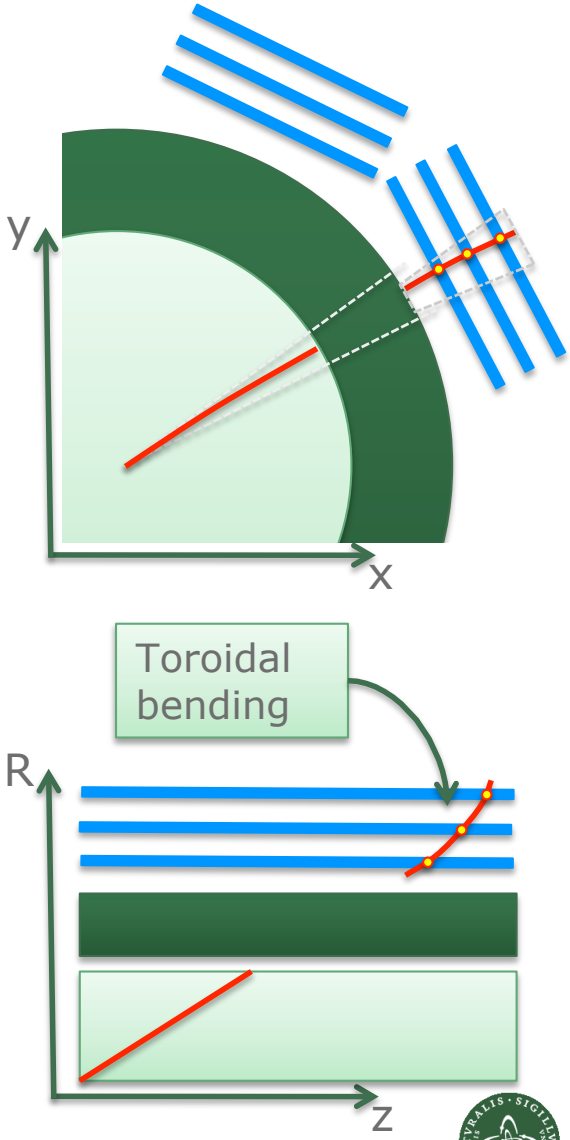
- Single muon:
  - Low P_T: J/psi, Upsilon and B-physics
  - High P_T: H/Z/W/tau → μ

Level 2:

- Track reconstruction in the Muon Spectrometer
- Combination with ID track
- (Calorimeter isolation)← higher luminosities

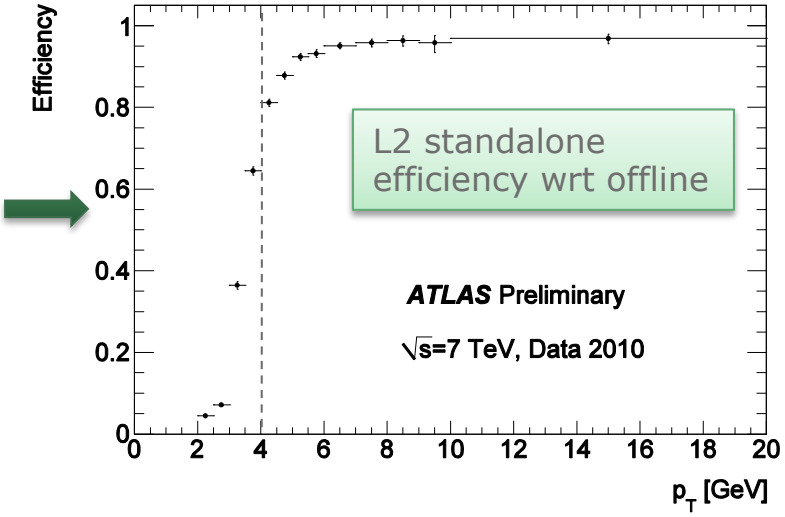
Event Filter:

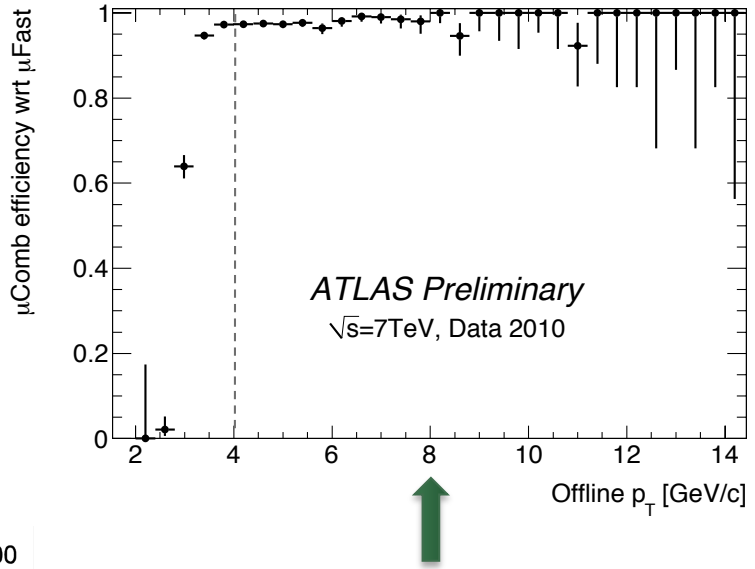
- Access to full event.
- Offline reconstruction tools running on RoI



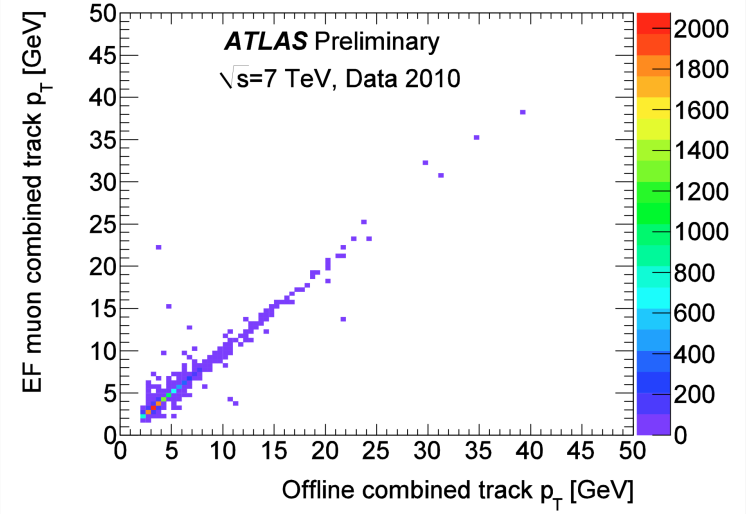
Muon performance

4 GeV P_T cut





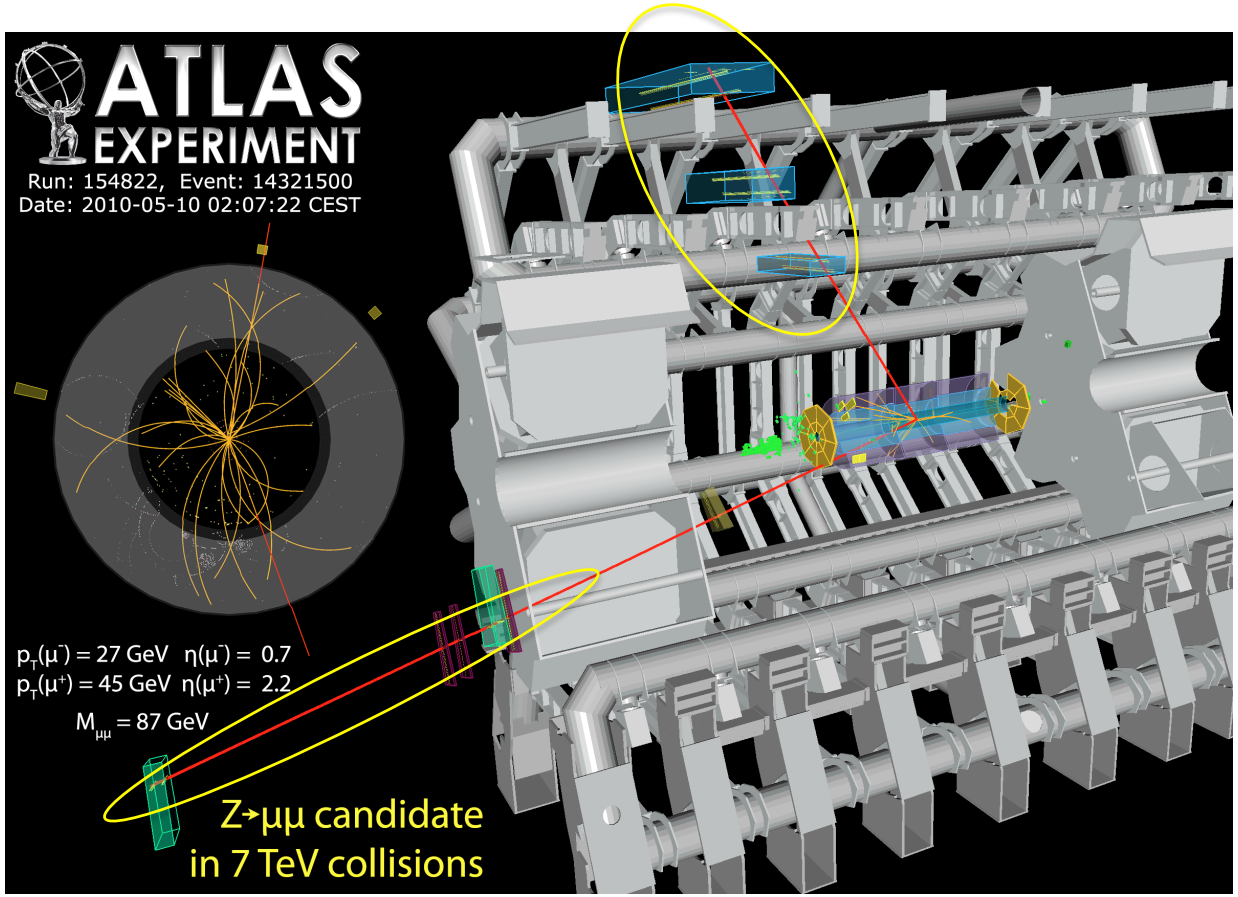
L2 barrel track combination efficiency vs muon standalone. (|η|<1.05)



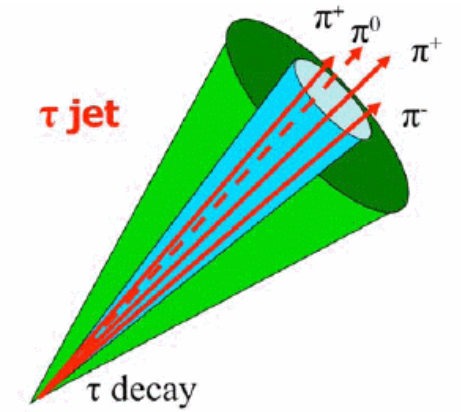
- Efficiencies derived from minimum bias data.
- Combined muon algorithms being commissioned

Z→μμ candidate

Two muon triggers fired



Tau selection



- Physics case:
  - W/Z → tau
  - SM and MSSM Higgs
  - SUSY with light stau
  - Exotics
- ~65% of taus decay hadronically in 1 or 3 prong decays

➔ Need to look for narrow jet in calorimeters

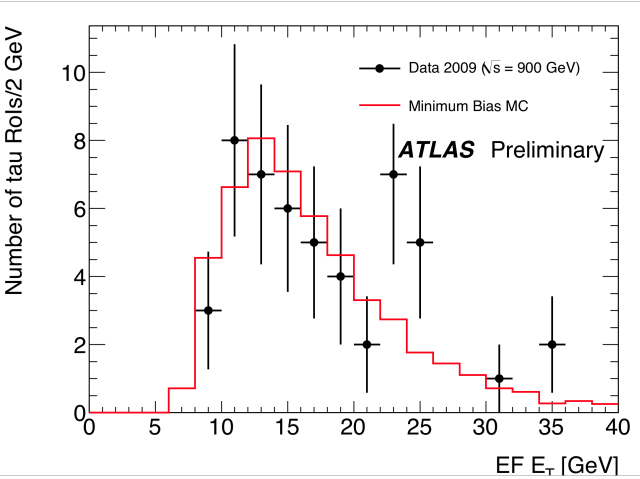
- Level2:
  - Starting point is a hadronic cluster from L1
  - Clustering + tracking in RoI
  - Cluster shape cuts and track/cluster matching
  - Track multiplicity and properties
- Event Filter
  - Acess to full event but reconstruction seeded from RoI
  - Using offline tau reconstruction

Tau performance in 900 GeV collisions

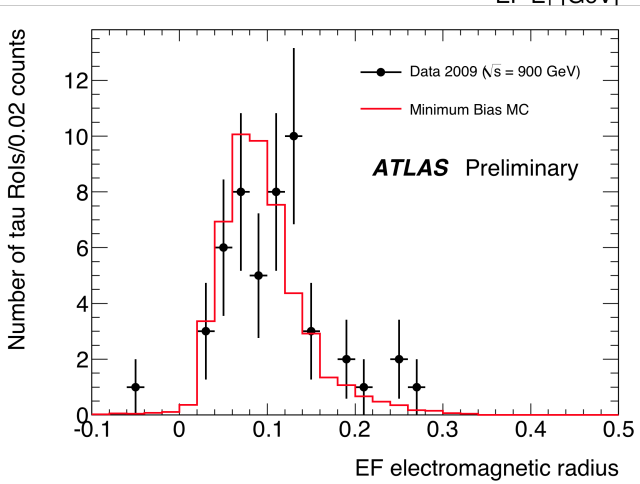
- Parameters:
  - EF E_T spectrum
  - Electromagnetic radius:

Calculated wrt a *seed* cluster in a 0.3 x 0.3 η,φ window.

$$R_{EM} = \frac{\sum E_{T,cell} R_{cell}}{\sum E_{T,cell}}, \qquad R_{cell} = \sqrt{(\Delta\eta)^2 + (\Delta\varphi)^2}$$

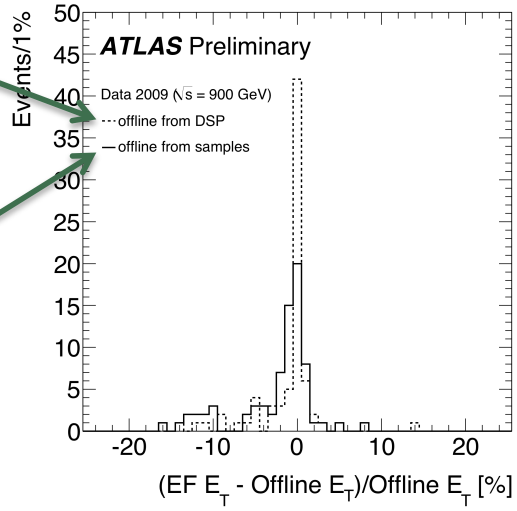


- Decent data/MC agreement
- Trigger and offline compatible:



Matches HLT approach

More precise



- Don't yet have real, identified taus
- Commissioning with jets

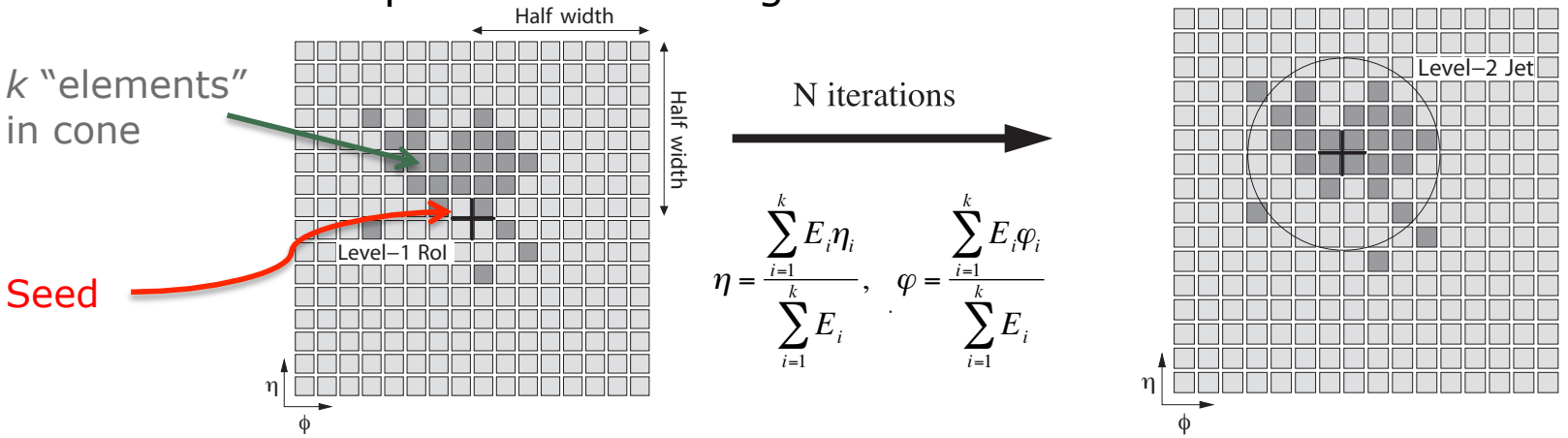
Jet selection

Physics case

- QCD studies (important in just about any analysis)
- Multijet triggers for SUSY, top and generic searches (pp → XX, X → jj)
- Forward jets for VBF

Level 2:

- Simplified iterative algorithm with R<0.4

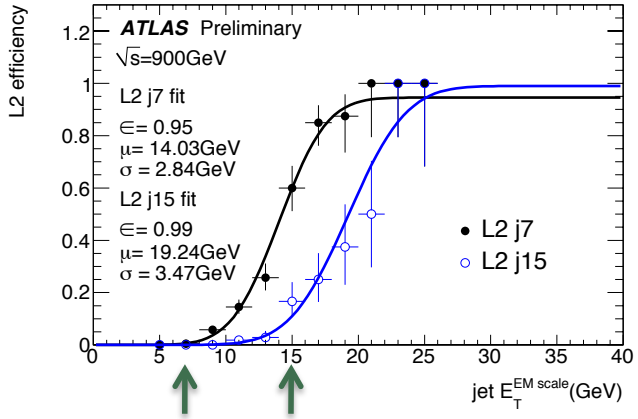


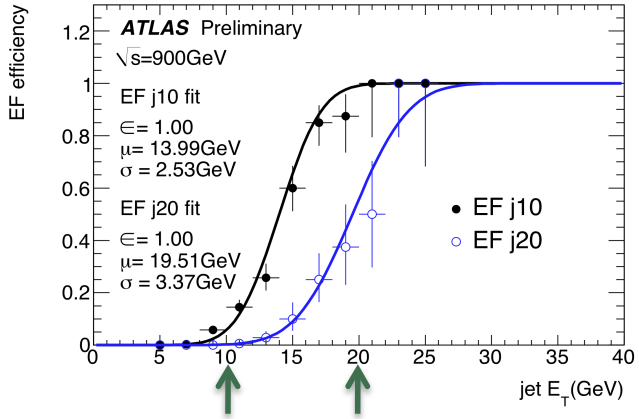
Event Filter:

- Cone jet algorithm with R<0.7 on full event
- Investigating move to anti-k_T as in offline reconstruction

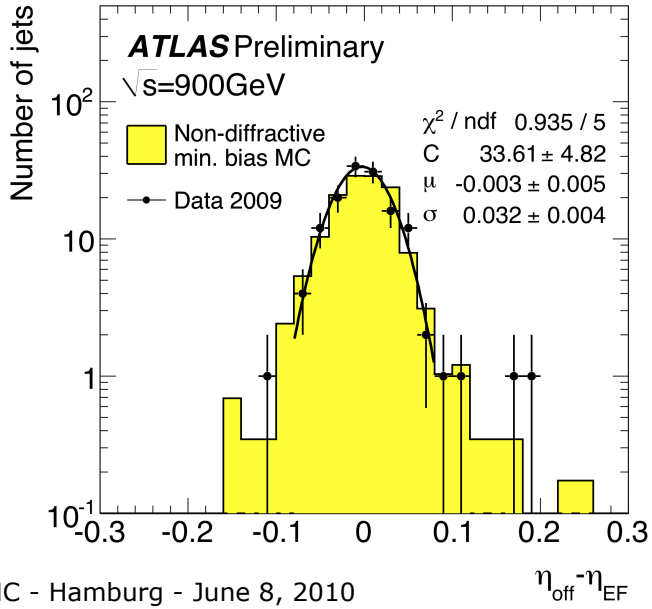
Jet performance

Efficiencies:

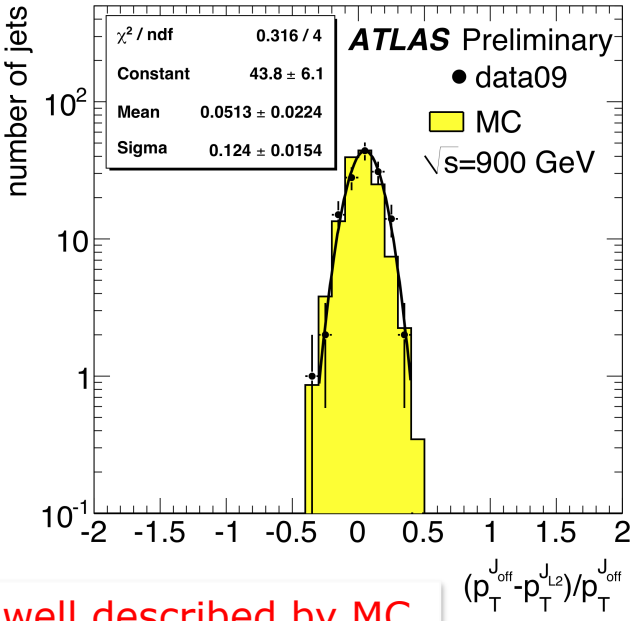




Spatial resolution, EF:



E_T resolution at L2:



Data well described by MC

Missing Transverse Energy

Physics case

- WIMPs appear in many BSM scenarios (e.g. neutralinos in SUSY)
- Precision EW measurements require well-understood MET
- MET trigger serves as orthogonal trigger for many trigger efficiency studies
- It also allows to probe softer regions of phase space (e.g. W → τν)

Level 1

- Direct hardware sum of L1Calo towers

Level 2

- Applies a muon correction to the L1 result

No time to read out the full calorimeter

Event Filter

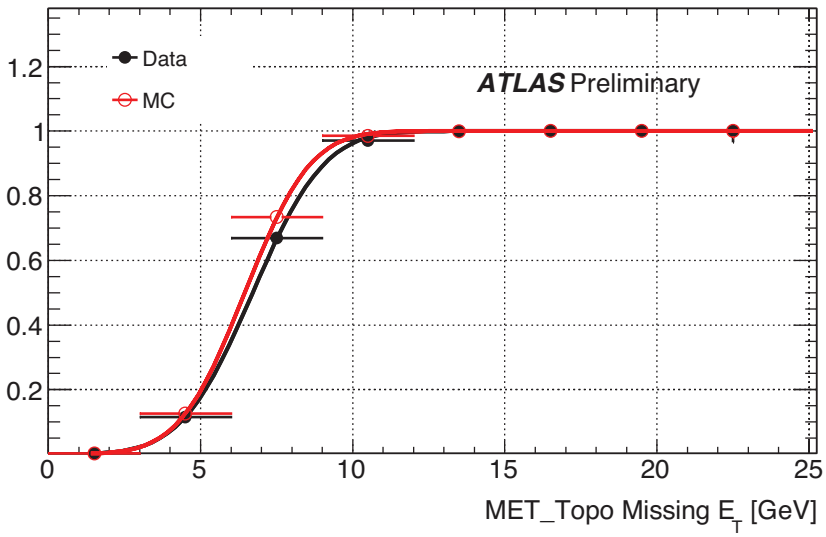
- Uses the full event to calculate the missing E_T
  - 3 σ noise suppression cut on individual cells
  - Apply simple layer-based calibration

Missing E_T performance

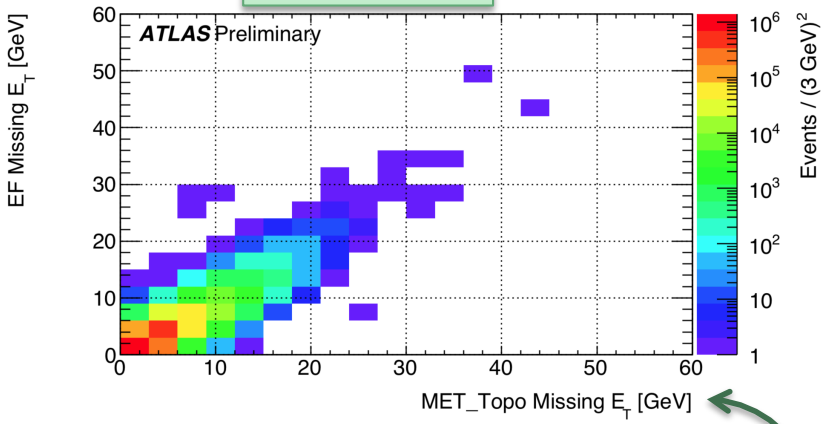
- Sharp and well-described turn-on curve (5 GeV threshold)
- Good correlation between HLT and offline
- Good MC description
- Most fake MET events don't pass L1 requirement

➔ Minimal bias on offline MET calculation

EF efficiency

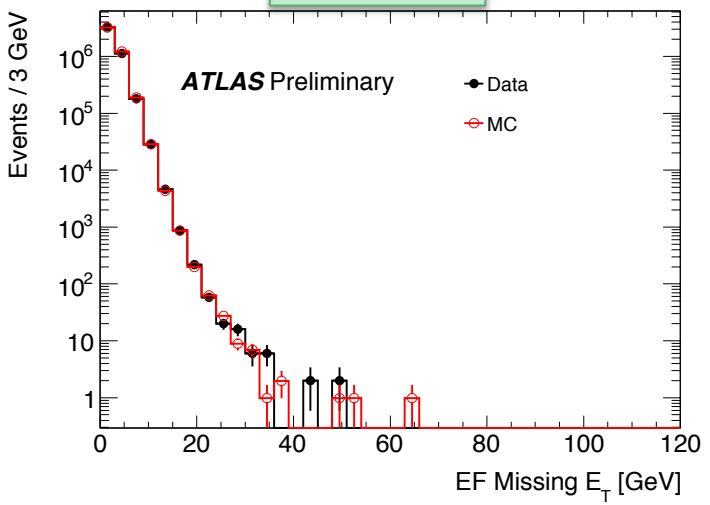


HLT vs Offline



Offline MET

Data cf. MC



Menu evolution towards 10^{31} - 10^{32} $cm^{-2}s^{-1}$

Validation steps

- Run without any HLT at all
- Run HLT offline
- Deploy HLT online without rejecting events
- Step-wise deployment of rejecting HLT when needed
- Performance studies on large signal-enriched samples

➔ Putting a full physics menu online

Well rehearsed

On-going effort

Coming…

Validation of algorithms and infrastructure

- Flexibility allows deploying one signature at a time
- Well-rehearsed system to validate code/performance offline

Any strategy from here will always be a mixture of

- Tightening cuts (increase purity)
- Raising thresholds (reduced emphasis on monitoring)
- Applying prescales (bring down rate)

Plans differ between signature groups

Key signatures

Lumi ($cm^{-2}s^{-1}$)	10^{30}	10^{31}	10^{32}
Electrons & photons	10 GeV photon	20 GeV photon	30 GeV photon
	10 GeV electron	10 GeV electron	15 GeV electron
Taus	29 GeV tau	50 GeV tau	84 GeV tau
	12 GeV tau + 20 GeV MET	12 GeV tau + 20 GeV MET	16 GeV tau + 25 GeV MET
Muons	10 GeV muon	10 GeV muon	13 GeV muon

Jets:

- Scheme of progressive prescaling
- B-jet tagging can be used to reduce thresholds

Missing ET:

- Stable until 10^{32}

Strategy covers an increase in luminosity of 3 orders of magnitude! (10^{29} → 10^{32})

Cuts:

- Loose
- Medium
- Tight

Summary

- Selections developed based on MC data have performed very well online
- There is good agreement between trigger and offline quantities and between data and MC

➔ This has given us the confidence to enable active rejection for the first time as luminosity exceeded 2 x 10^{29}

- The Trigger has worked very succesfully at both 900 GeV and 7 TeV, efficiently recording the data for physics including first J/ψ, W and Z decays
- Menus and pre-scale sets are in place in preparation for the anticipated rapid evolution in machine luminosity
- Bring it on…