the ATLAS Experiment

ATLAS Physics Objects Status and Performance in Run2

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On the Physics in LHC Run2

Introduction

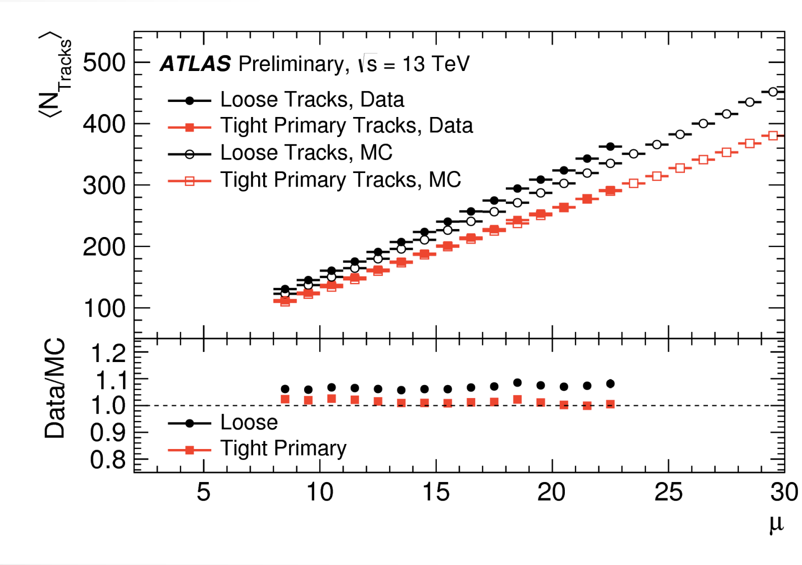
- The ATLAS detector in LHC Run2
  - Covered by the earlier talk on the ATLAS status
- ATLAS physics object reconstruction, identification and calibration are well developed and improved for LHC Run 2
  - New detectors (such as IBL and muon chambers), and improved algorithms (such as b-tagging) during LS-1
- Preliminary object performance at $\sqrt{s}$ =13 TeV was already demonstrated for the physics results released for summer conferences, now improved results based on full luminosity are becoming available
- Will focus on the key performance of the physics objects
  - Tracks, Electrons & photons, muons, taus, jets & boosted objects, missing E_T, and btagging

Tracking Performance

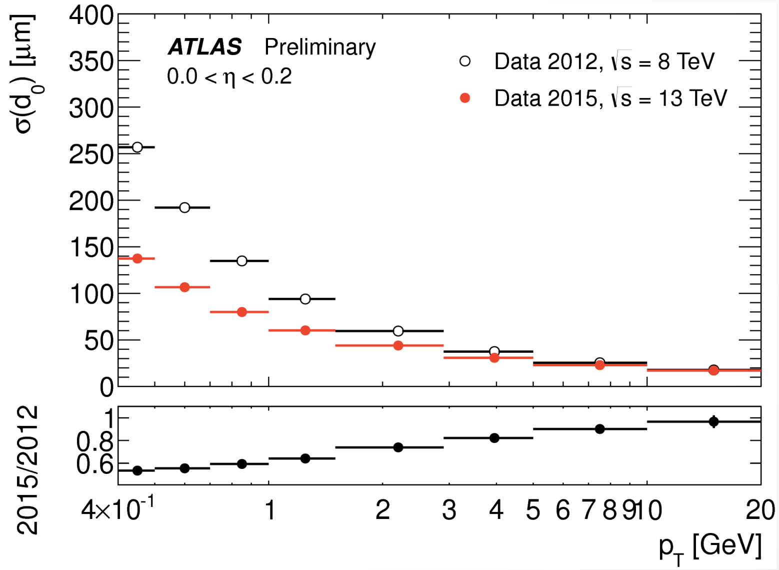
Details in ATLAS Tracking Performance twiki

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/InDetTrackingPerformanceApprovedPlots

- Performance improved with new IBL; Detector description updated after survey with hadronic interactions and photon conversions
- Alignment of main distortion modes done
- 2 working points: Loose and Tight selections for different efficiency and fake rates



Ave number of reconstructed tracks as a function of μ for data and MC w/ Loose and Tight selections

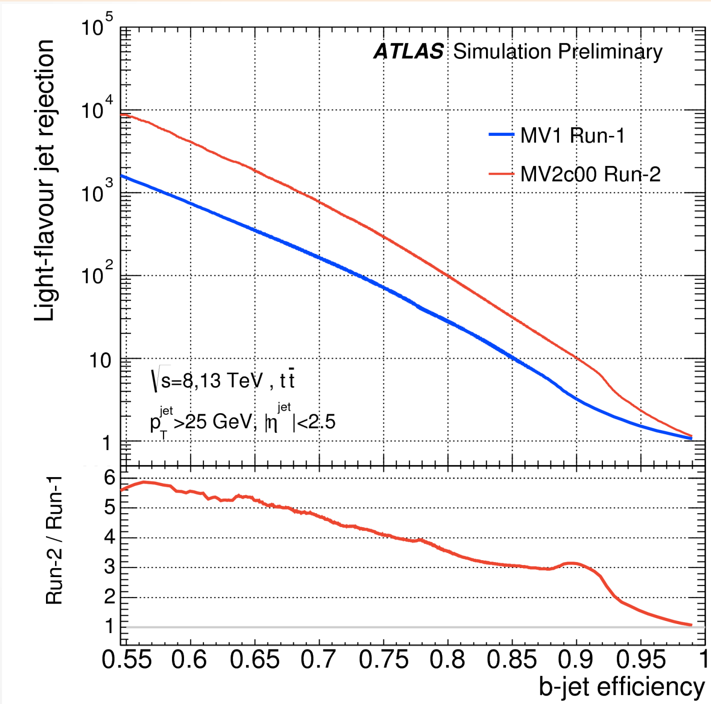


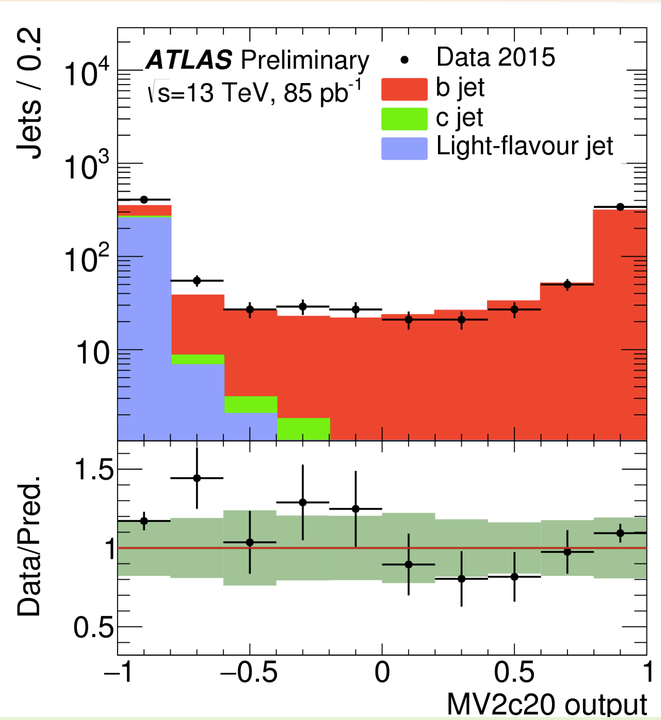
Unfolded trans. impact parameter resolution in 2015 w/ IBL compared to that in 2012 w/o IBL

b-tagging

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/FlavourTaggingPublicResultsCollisionData

- IBL (new pixel layer) improves impact parameter and vtx resolution
- MV2c20 (an improved b-tagging algorithm) combines three b-tagging algorithm outputs using a boosted decision tree.





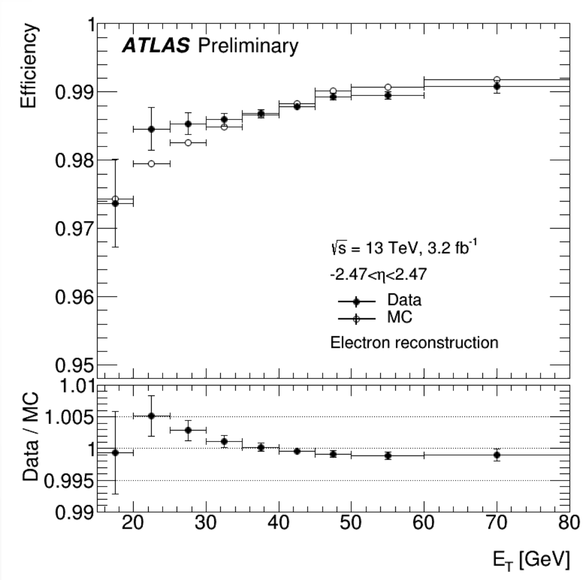
Comparison of Run1/Run 2 performance
At 75% bjet efficiency, 4X more rejection of light quark jets.

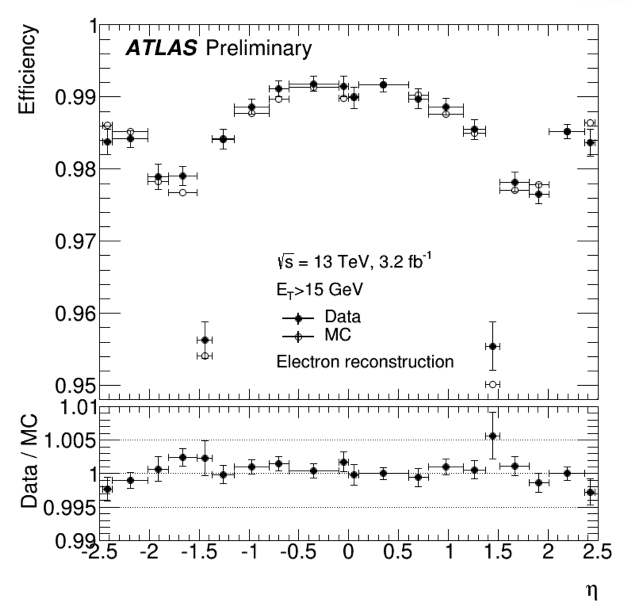
The output distribution of the MV2c20 algorithm applied to jets from the tt-bar dominated eμ sample.

Electron Reconstruction

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ElectronGammaPublicCollisionResults

- Seeded by a fixed-size calo cluster, matched to a track
- Dedicated track pattern recognition and fit are used to account for bremsstrahlung in material
- Discriminate against converted photons

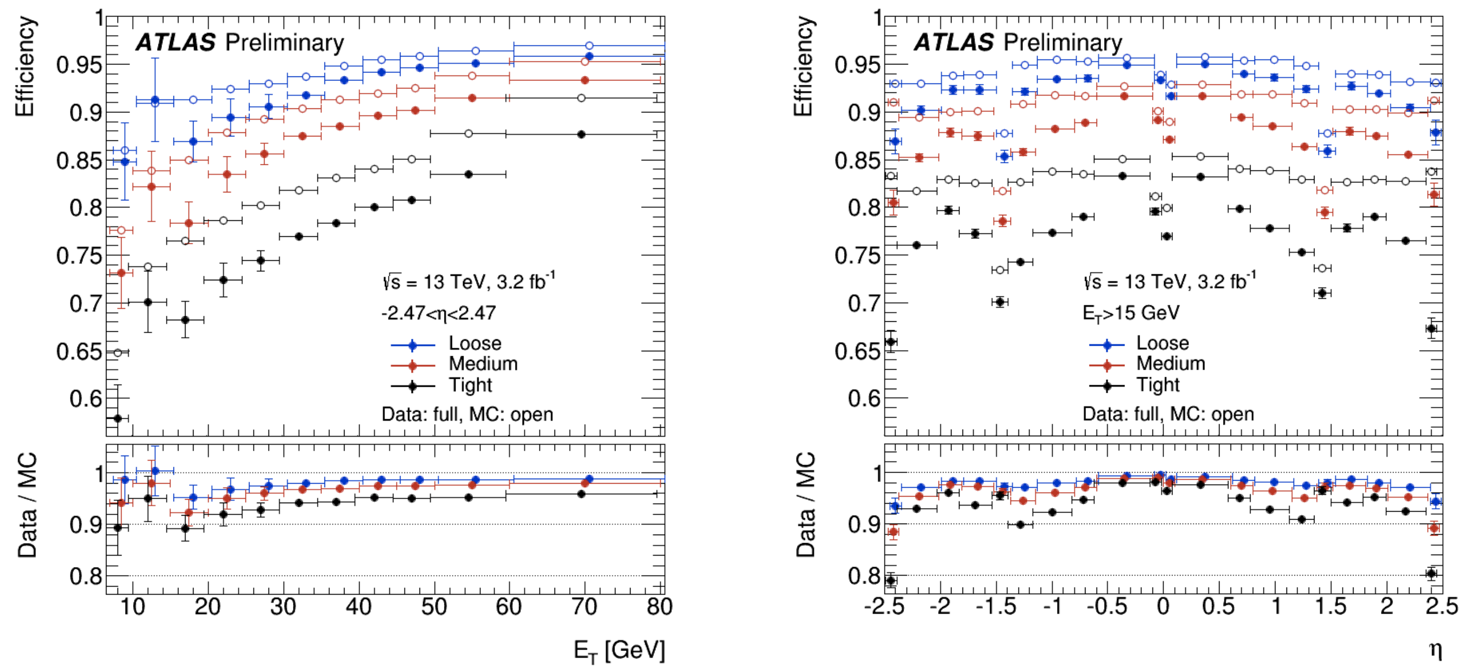




Electron reconstruction efficiencies are measured by Z→ee candidates

Electron Identification Efficiency

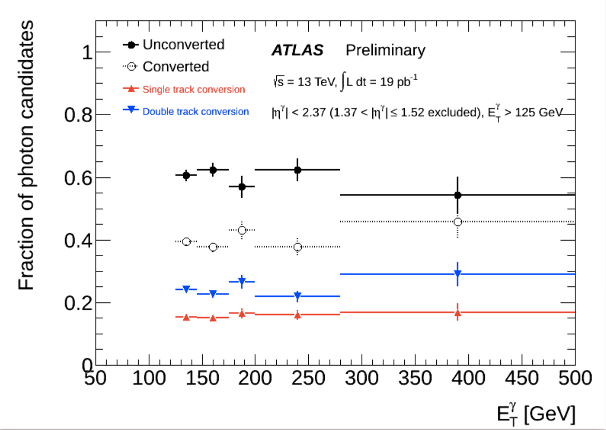
- Based on a likelihood using various discriminating variables: shower shapes, track properties, track-cluster matching, etc.
- Three levels: loose, medium and tight
- Identification efficiencies determined by J/$\psi \rightarrow$ee or Z$\rightarrow$ee events



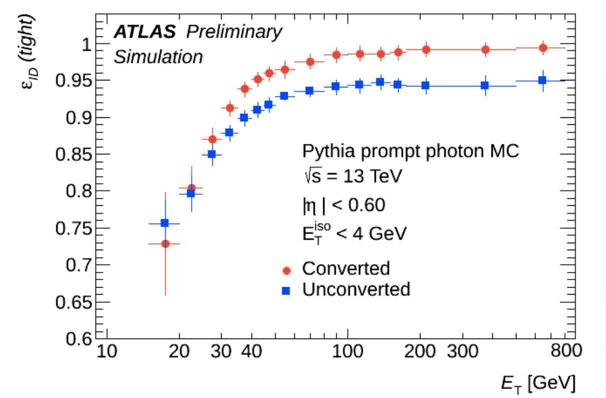
Data/MC differences are mainly due to mismodelling in calorimeter shower shape in Geant4, and corrected for MC.

Photon Reconstruction and ID

- Calorimeter clusters similar to that for electrons.
- Unconverted photons:
  - Clusters without track match
- Converted photons:
  - Clusters matched to a pair of tracks
  - Clusters matched to a track without inner-most pixel hit
- Current photon reconstruction and ID are based on Run 1 analysis, updated for the new detector and running conditions, with additional systematics
- Electron performance in Run 2 data indirectly confirms the photon performance



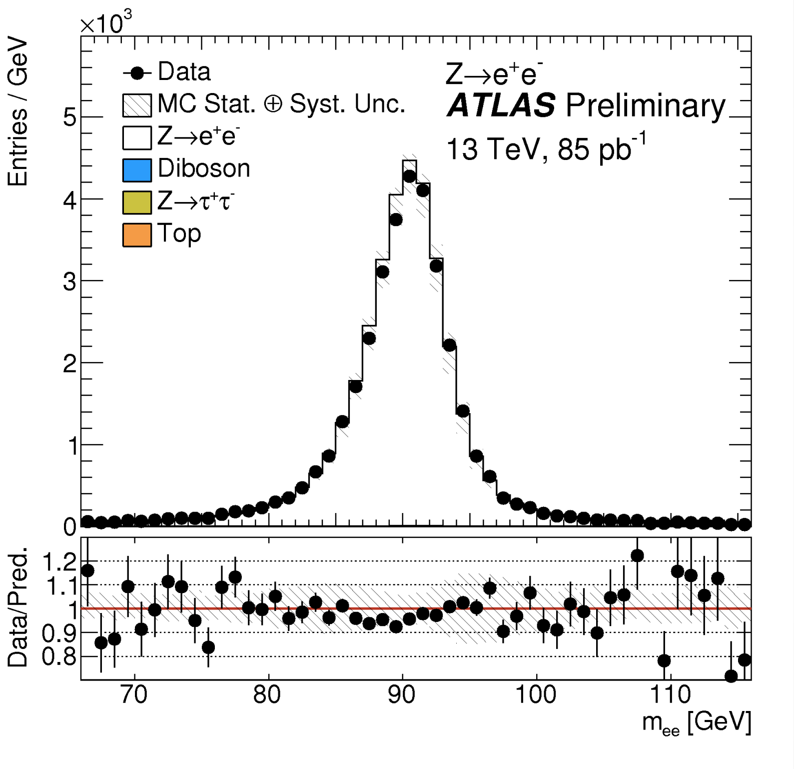
Converted and unconverted photon in Run 2 data



Expected Photon efficiency in Run 2 based on MC.

Energy Calibration

- Calorimeter data is corrected for non-uniformities including inter-layer calibration
- Energy correction is applied to both MC and data based on MVA using detailed info about the candidate
- Final energy scale correction for data based on Z→ee events as a function of η
- Additional smearing to MC to account for MC/data diff.
- Current energy calibration is based on Run 1 analysis.



e^+e^- invariant mass of
Z→ee candidate events

Muon Reconstruction and & Identification

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/MuonPublicResults

Muon Tracks

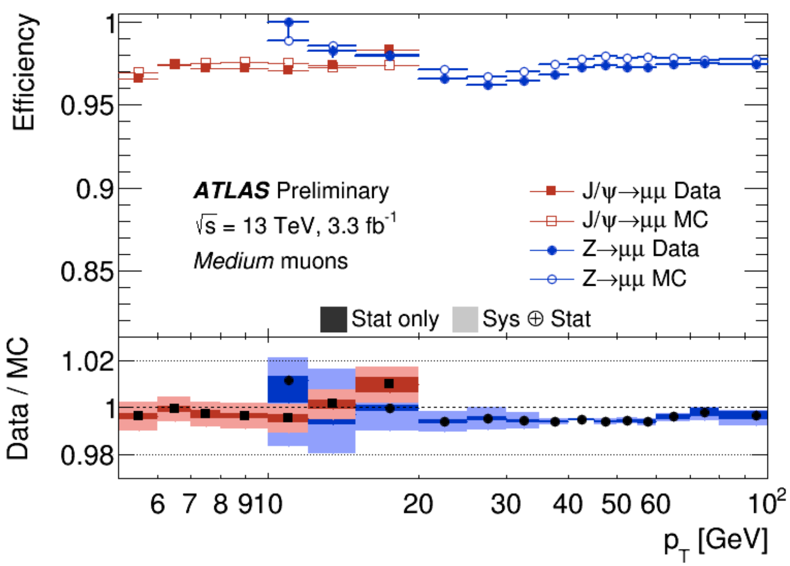
- Combined
  - ID+MS track
  - Most of μ candidates
- Standalone
  - MS track only
  - $2.5 < | \eta | < 2.7$
- Segment-tagged
  - ID track + MS Segment
  - Low p_T and special region
- Calo-tagged
  - ID track + calorimeter energy deposit

Muon Identification

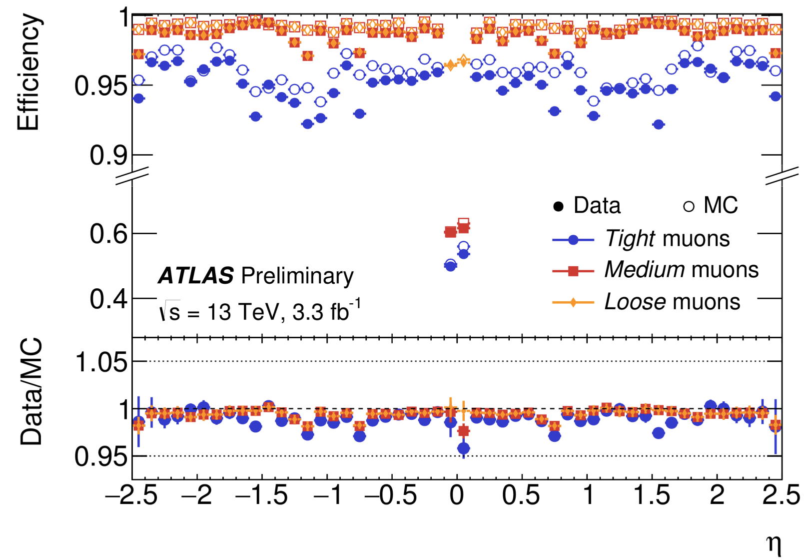
- Loose
  - Maximize efficiency
  - Uses all four types
- Medium
  - Default
  - Minimize systematics for calibrations
- Tight
  - Minimize fake muons
- High P_T
  - Optimize resolution for $P_T > 100$ GeV

Muon reconstruction efficiencies are determined by data events and compared to MC

Tag and probe method with J/ψ → μμ and Z→μμ used to determined the efficiencies

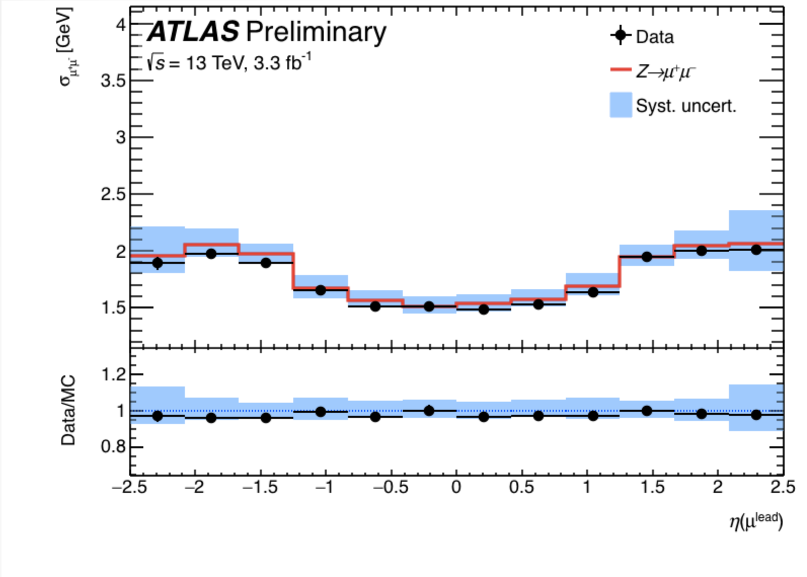


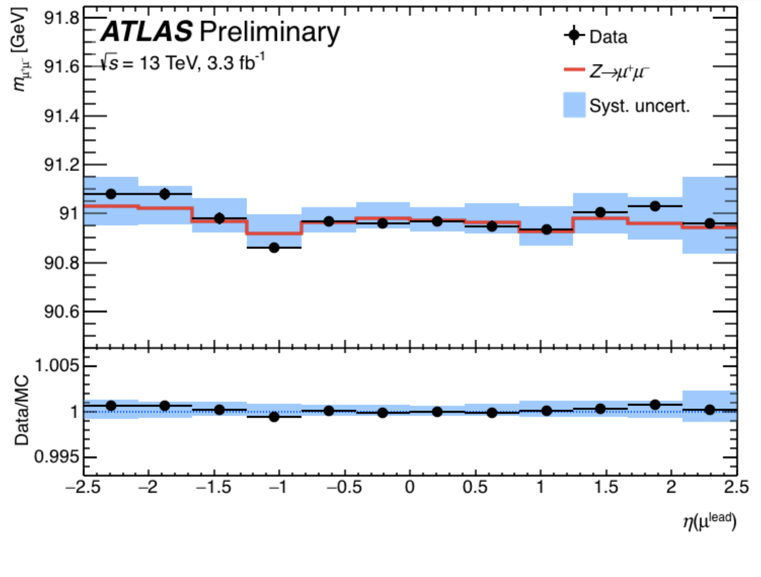
Muon reconstruction efficiencies for the Medium identification algorithm measured in $J/\psi \rightarrow \mu^+\mu^-$ and $Z \rightarrow \mu^+\mu^-$ events as a function of the muon momentum.



Muon reconstruction efficiencies for the Loose/Medium/Tight identification algorithms measured in $Z \rightarrow \mu^+\mu^-$ events as a function of η for muons with pT>10 GeV.

Muon reconstruction resolution





Muon p_T resolution as a function of η obtained from reconstructed $Z \rightarrow \mu^+\mu^-$ candidates.

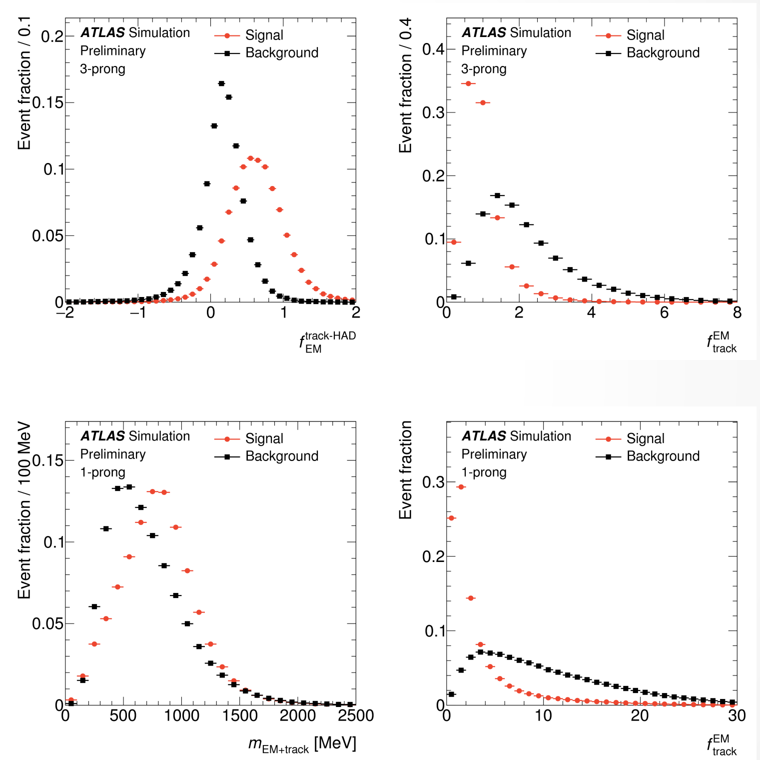
Muon p_T scale as a function of η obtained from reconstructed $Z \rightarrow \mu^+\mu^-$ candidates.

Muon p_T scale is validated by data and resolution is consistent with expectation.

Tau Reconstruction & Identification

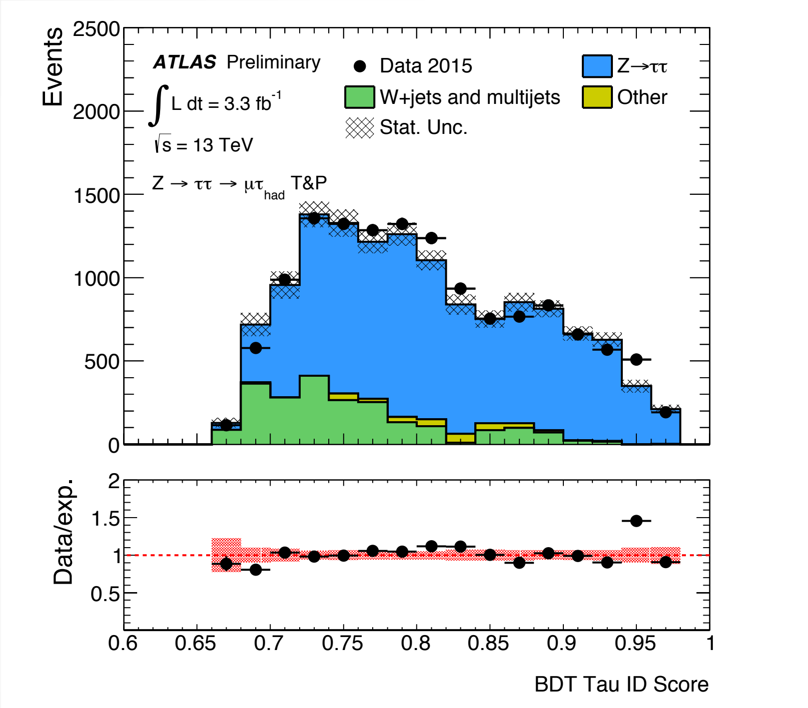
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TauPublicCollisionResults

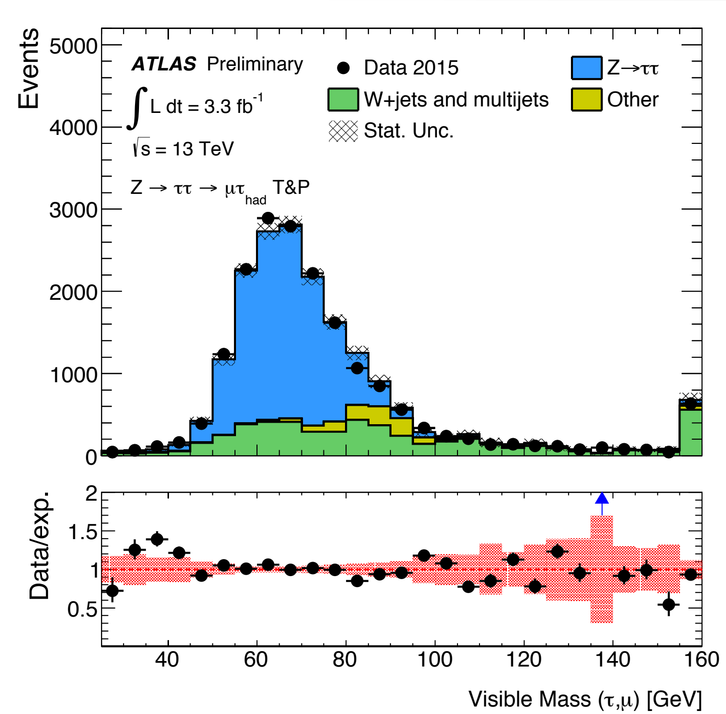
- Taus are seeded by anti-k_t jets
- Tau vertex is identified using tracks in $\Delta R<0.2$
- $P_{tau\text{-}vis} = C^*(\Sigma\ P_{clusters})$ in $\Delta R<0.2$
- Tau Identification:
  - BDT discriminant trained to reject jet backgrounds, combining calorimeter, tracking and lifetime observables.
- Tau energy scale:
  - Simulation-based recalibrating the calorimeter clusters, as a function of η, p_T, and N_{Track}



Distributions of some of the variables used in tau BDT, signal vs background

Tau performance





The visible mass reconstructed using isolated muons and offline tau candidates passing the offline medium identification requirement.

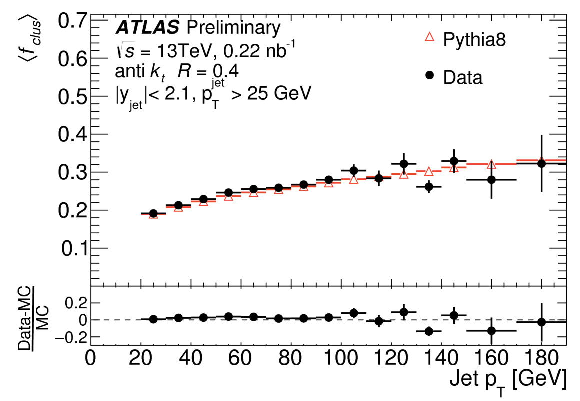
The visible mass reconstructed of $Z \to \tau\tau$ candidates using isolated muons and offline tau candidates passing the offline medium identification requirement.

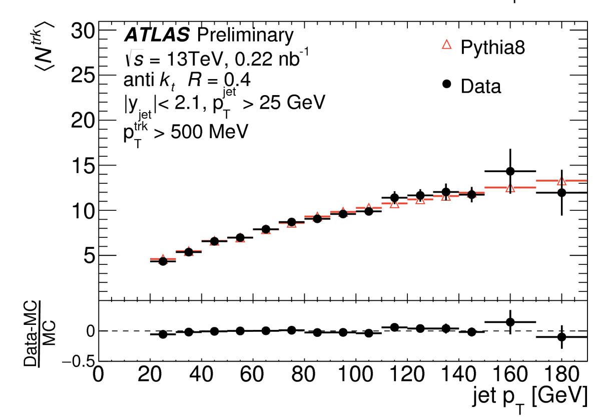
Performance of tau calibration and identification algorithms has been cross-checked with Z->tautau events in data and good agreement has been found.

Jet Reconstruction & Calibration

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/JetEtmissPublicResults

- Inputs to jet reconstruction
  - Clusters of topologically connected cells in the calorimeter
  - Clusters are formed based cell energy significance over expected noise, updated for run 2 due to LHC and calorimeter readout changes
- Jet finding algorithm: anti-k_T
- Jet identification: remove non-collision and noise background

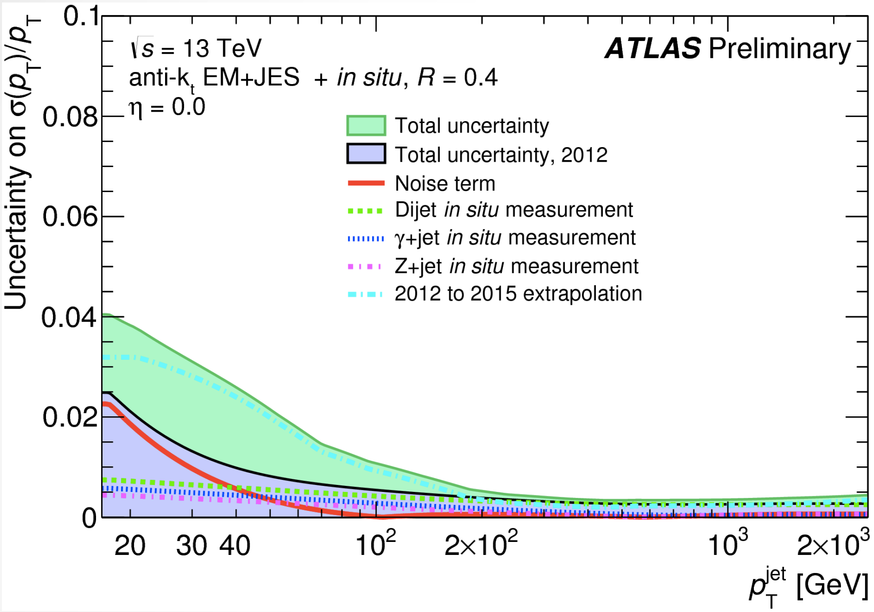


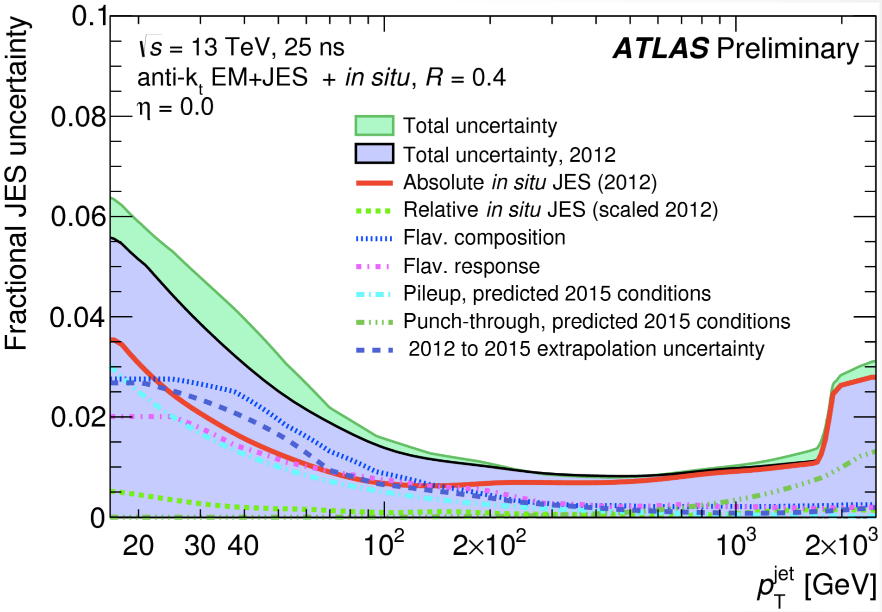


Calibration procedure consists of a sequence of steps:

Constituent scale → Pileup corrections → MC based JES → Global seq calibration → In-situ calibration → Final Jet E scale

JES and JER

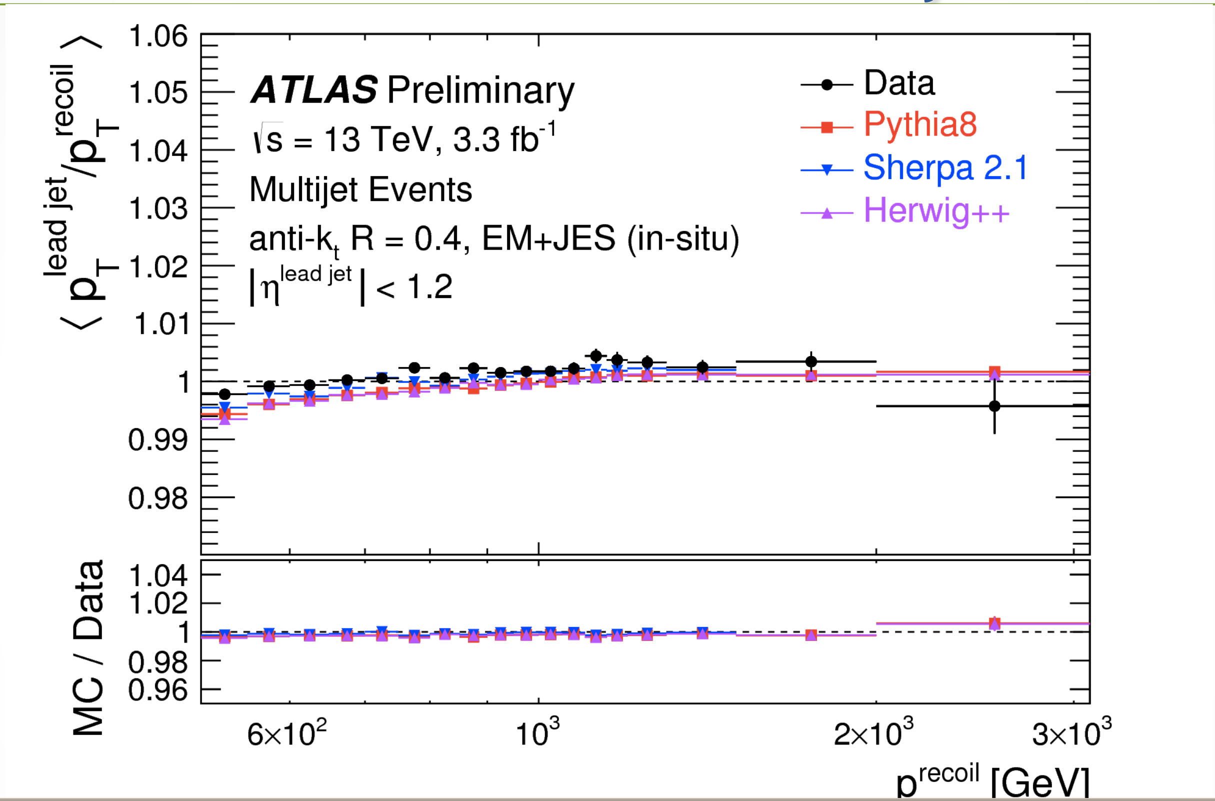




Jet energy resolution uncertainties estimated for 2015 data with 25 ns bunch spacing as a function of jet p_T for jets of η =0

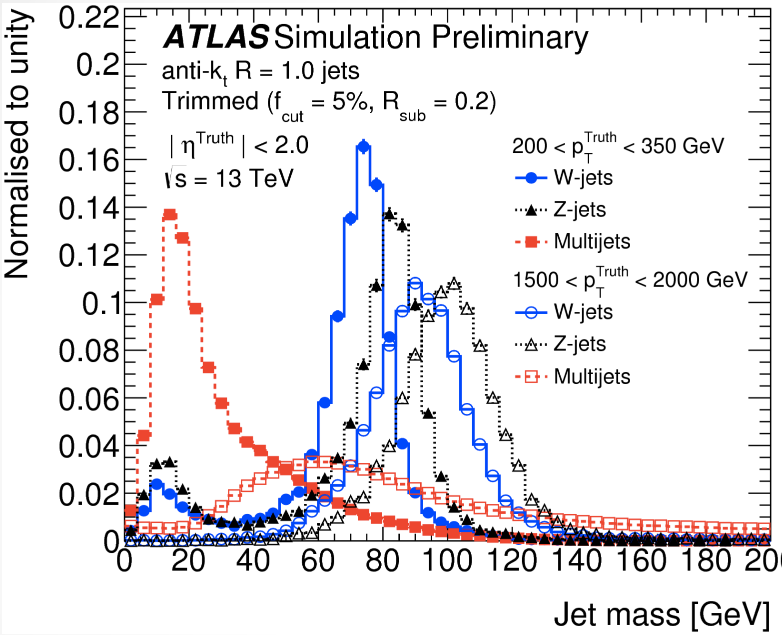
Jet energy scale uncertainties estimated for 2015 data as a function of jet *p*T for jets of η = 0

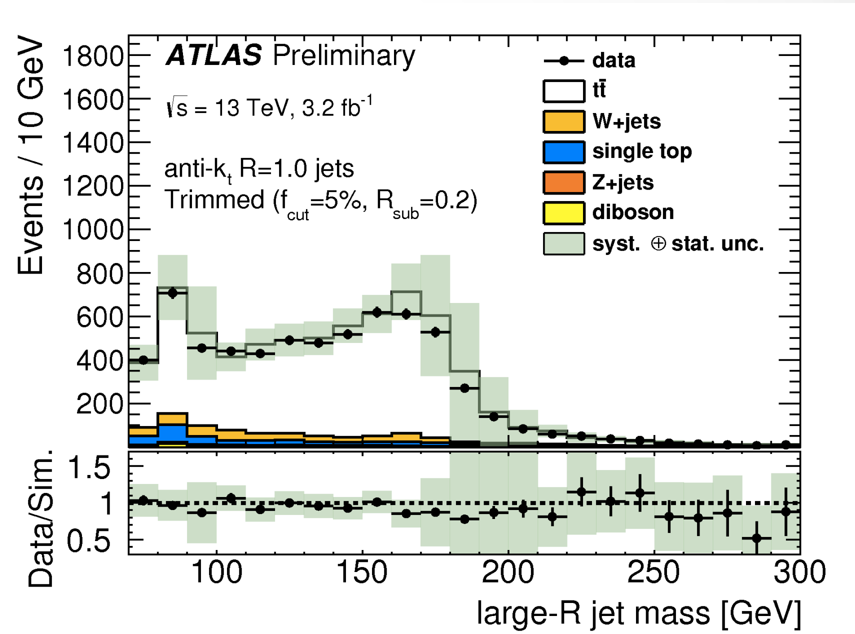
JES validation with multi-jet balance



Multijet balance distributions for data and MC simulation using anti-k_t R=0.4 jets, calibrated with the EM+JES and 2012 *in situ* corrections applied

Large-R jets and boosted objects





Expected Performance

The uncalibrated jet mass distributions for *W*-jets and *Z*-jets and background using one of the grooming configurations for leading reconstructed jets, for two p_T ranges

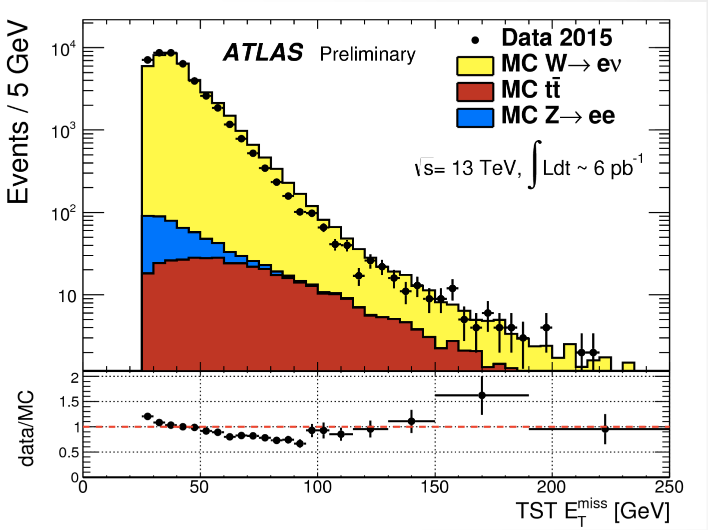
Validation

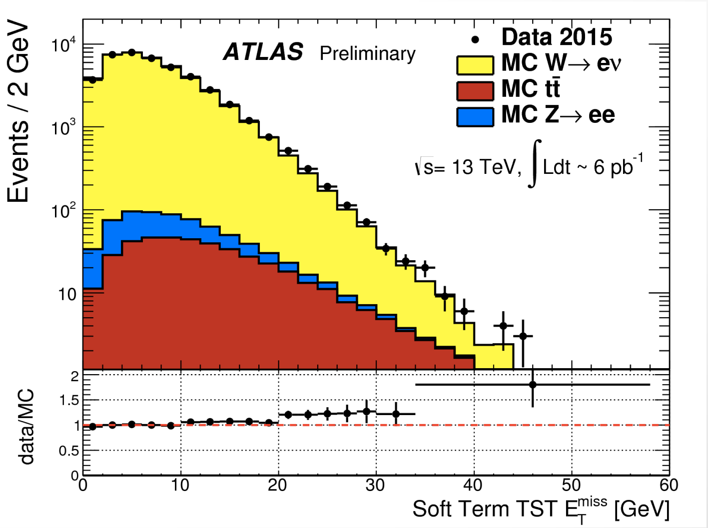
Reconstruction of boosted top all-hadronic decay with data and MC using large-R jets

Missing E_T

- Missing E_T is reconstructed from hard and identified objects + a soft term

  E_T^{miss} = hard E_T^{miss} + soft E_t^{miss}
- hard objects = e,γ,μ,τ,jet
- a track-based soft-term is optimal for high pileup running
  - p_T^{trk} > 0.4 GeV assoc. to PV
  - Includes overlap removal btw tracks and clusters associated to hard objects



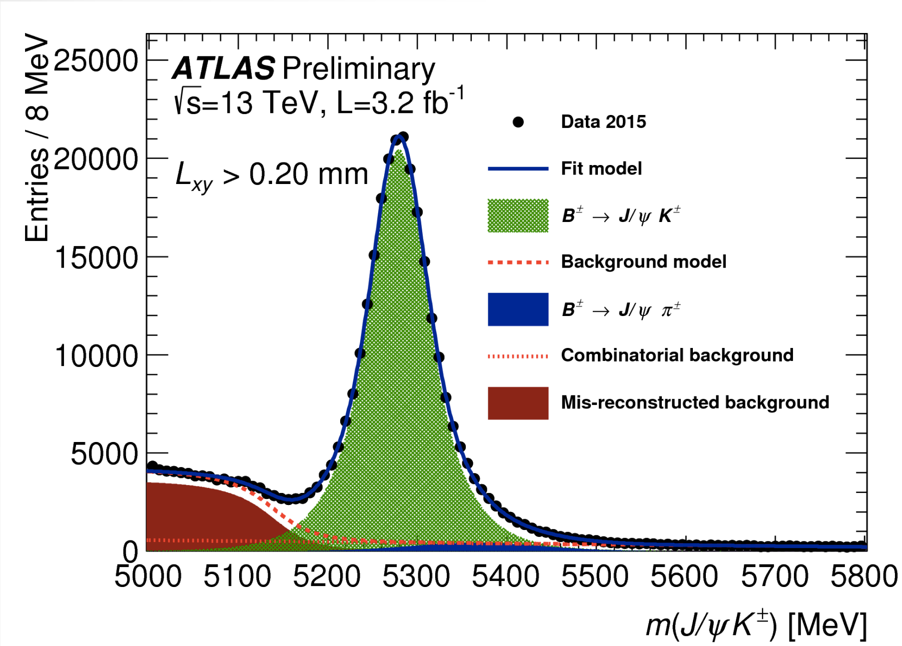


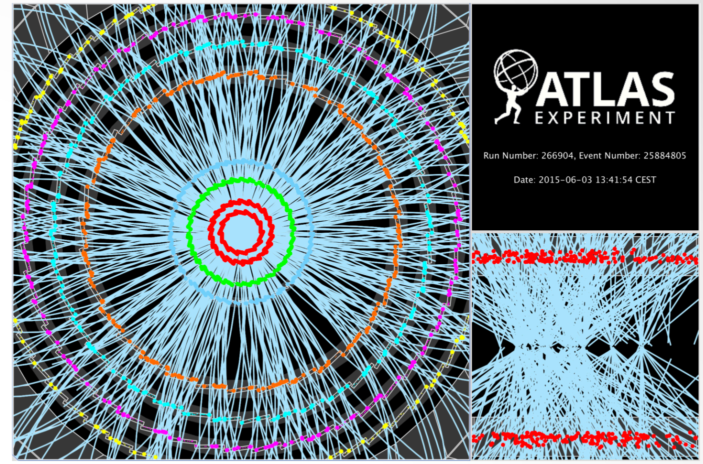
Summary

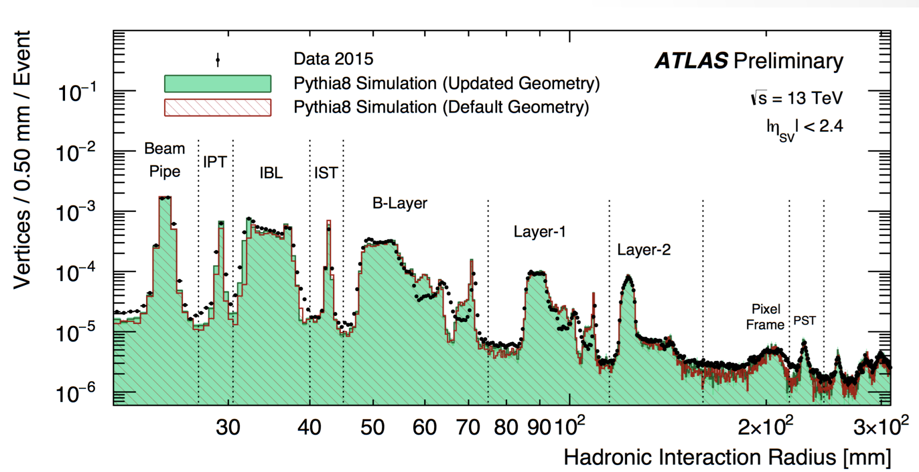
- ATLAS has successfully deployed Run 2 physics objects for the end-of-year analysis results
- Excellent physics object performance, validated by the data, enabled a large number early results for the end-of-year event last month:
  - 4 papers submitted and 24 preliminary results
  - Details are given in this twiki
    https://twiki.cern.ch/twiki/bin/view/AtlasPublic/December2015-13TeV
- Performance will be further improved as analyses are refined.

Additional Slides

Tracking





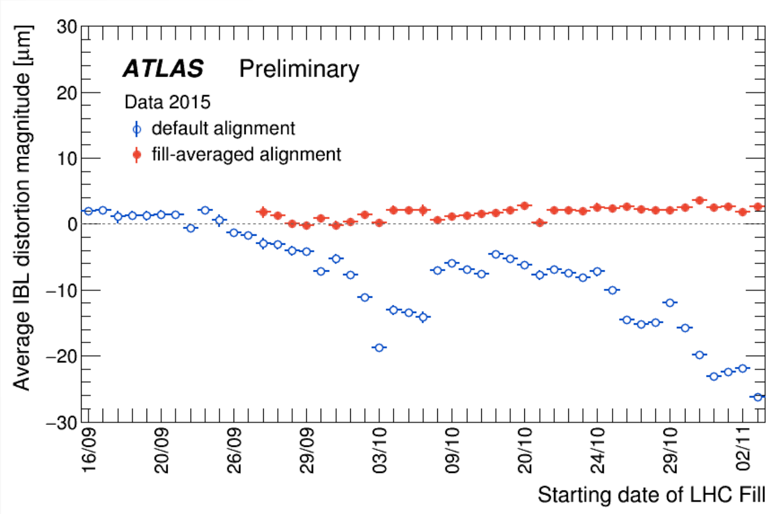


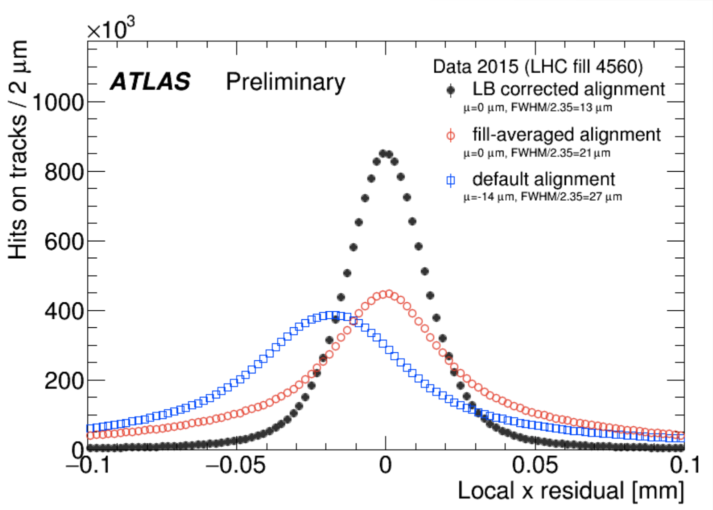
Alignment and tracking performance check with reconstructed $B^{\pm}$ mass

Comparison of the radial distribution of hadronic interaction candidates between data and simulation

Time dependent alignment corrections to IBL distortions

Additional alignment corrections on top of the `default ID alignment' are required due to an significant increase in the IBL distortion magnitude that was observed after the 26/09



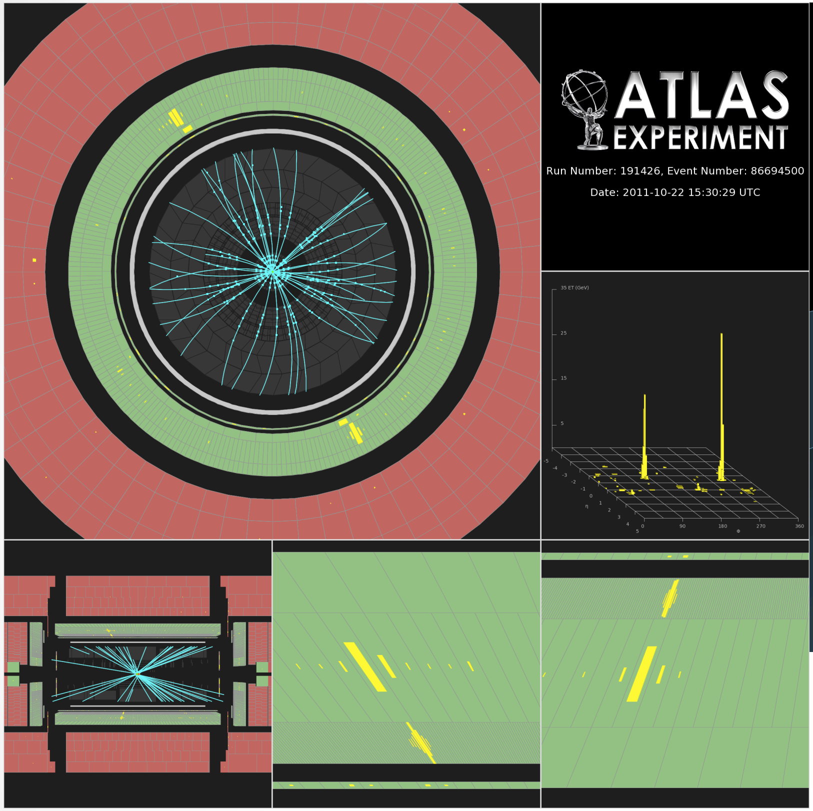


IBL distortion magnitude in the transverse plane per LHC fill averaged over all 14 IBL staves and averaged over the duration of the respective fill.

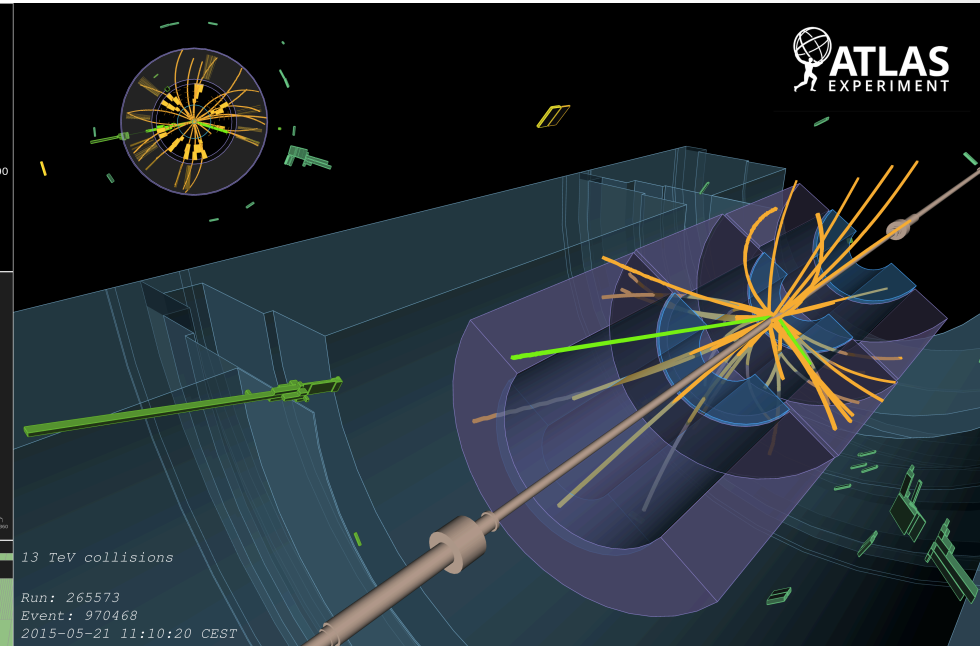
The IBL local x unbiased residual distributions for tracks that pass the Tight Primary track selection and have a transverse momentum satisfying $p^{T > 3\ \mathrm{GeV}}$.

Time dependent alignment corrections restore the precision

Electrons and Photons

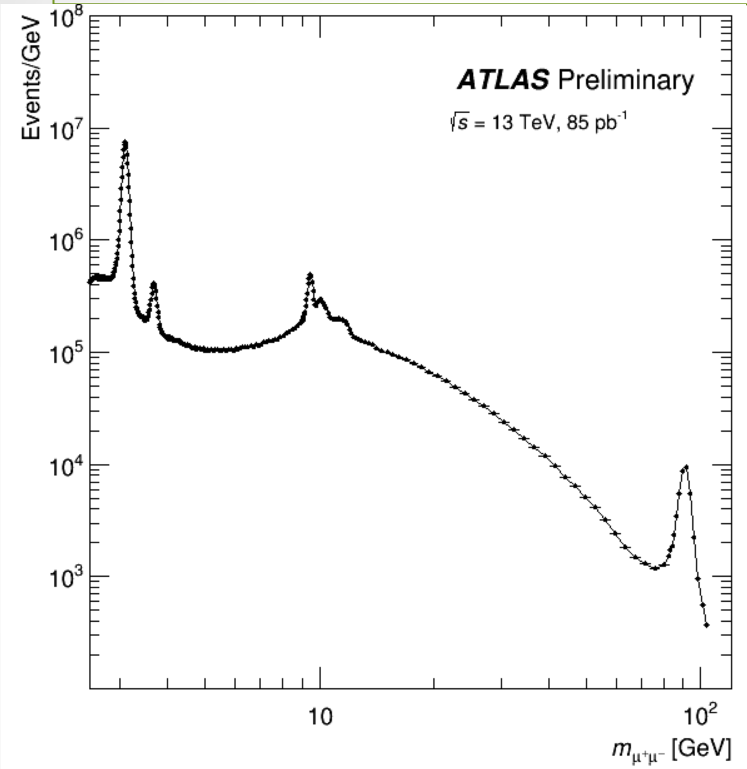


γγ event at √s = 8 TeV

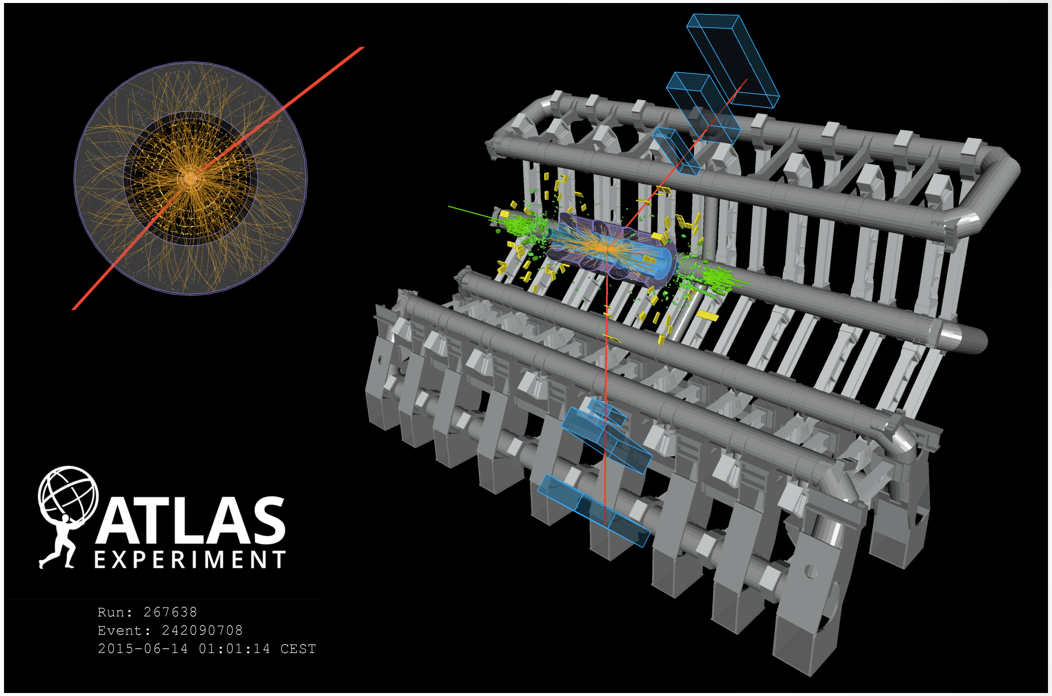


Z→ee event at √s = 13 TeV

Muons



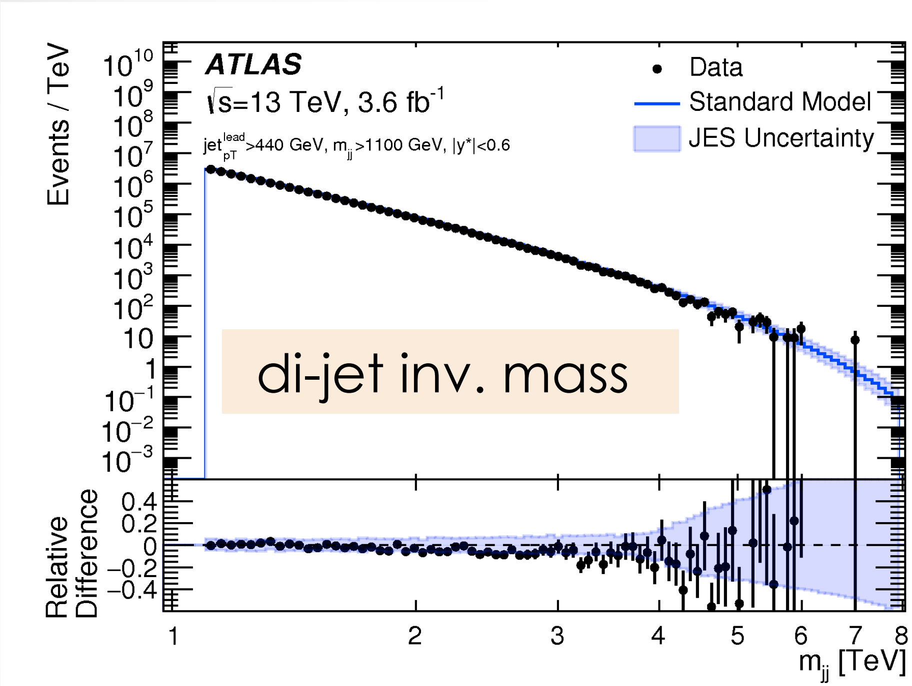
$M_{\mu\mu}$ with p_T> 4 GeV & |η| < 2.5 GeV

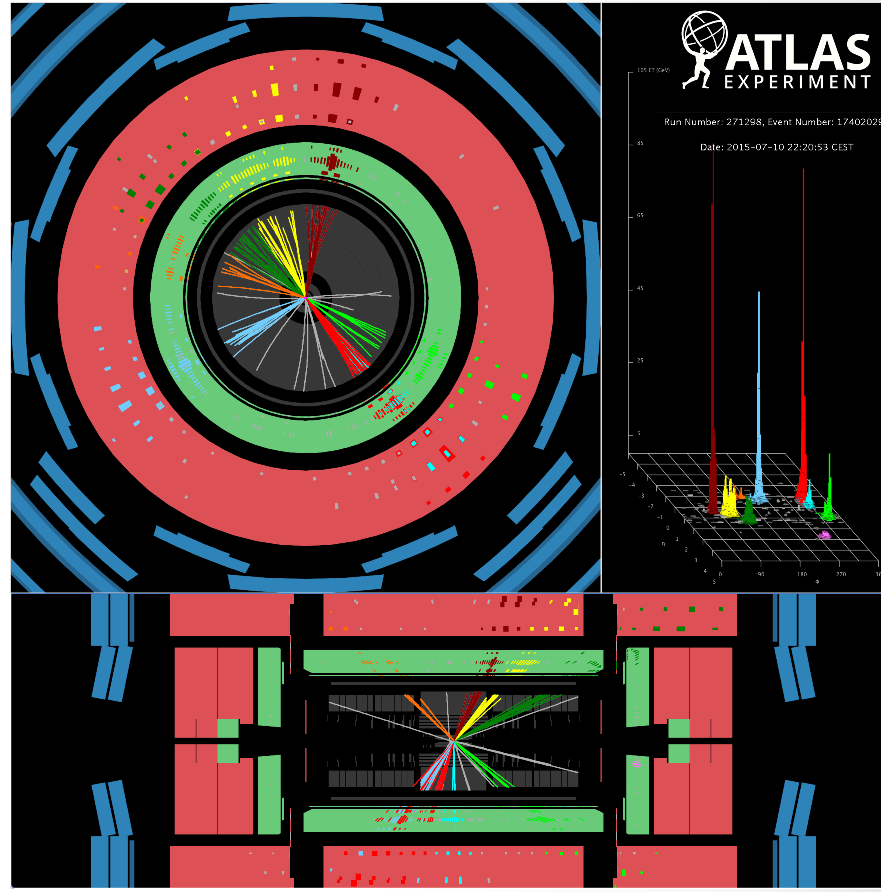


Z→μμ event at √s = 13 TeV

LS1 changes: Added chambers to complete the original design

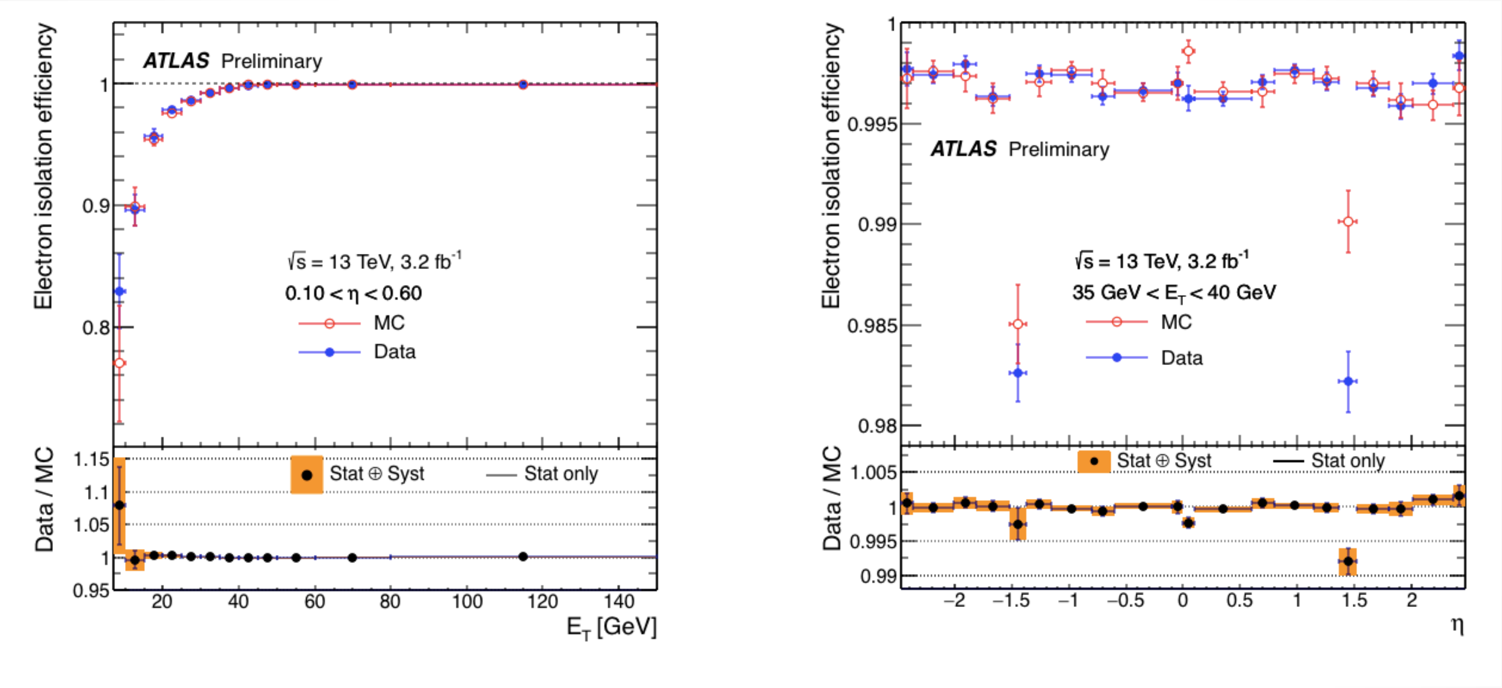
Jets





A 9-jet Event with jet $p_T > 50$GeV

Electron Isolation Efficiency



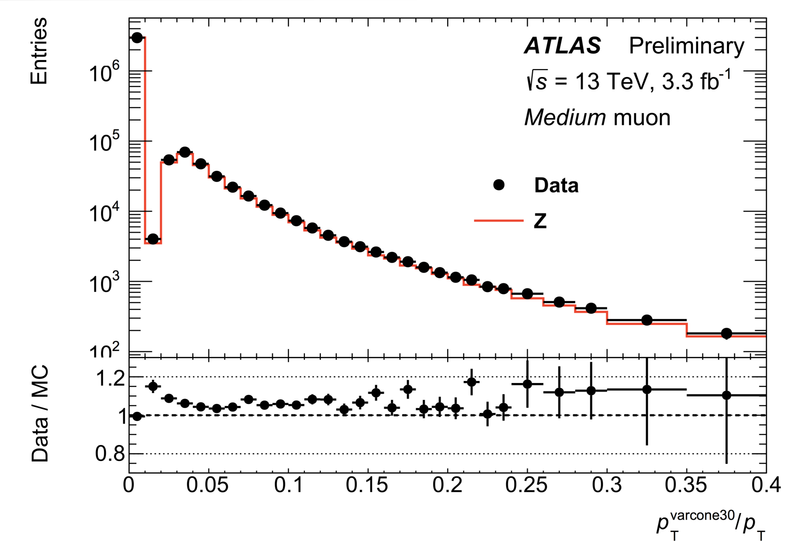
Effiiciency of the isolation requirement for tight electrons

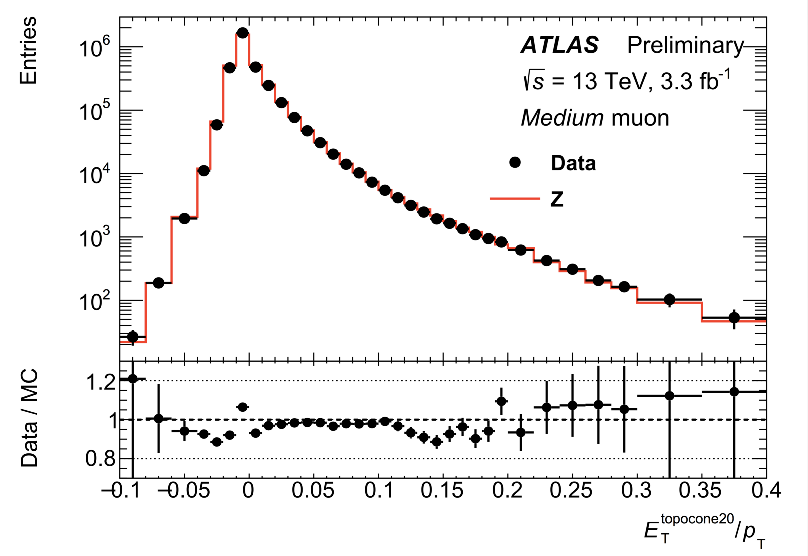
$E_{T,iso}$ (calo)/E_T < 0.2 & $E_{T,iso}$ (tracks)/E_T < 0.15

$E_{T,iso}$ (calo) = sum of E_T of clusters in $\Delta R < 0.2$

$E_{T,iso}$ (tracks) = sum of PT of tracks in $\Delta R < \min(0.2, 10\ \text{GeV}/E_T)$

Muon isolation





Distributions of the track-based (left) and the calorimeter-based (right) isolation variables, divided by the muon p_T measured in $Z \to \mu+\mu-$ events.

Data is well reproduced by MC simulation