ATLAS Physics Objects Status and Performance at 13 TeV

Imma Riu (IFAE Barcelona)

on behalf of the ATLAS collaboration

TOP2015 Workshop

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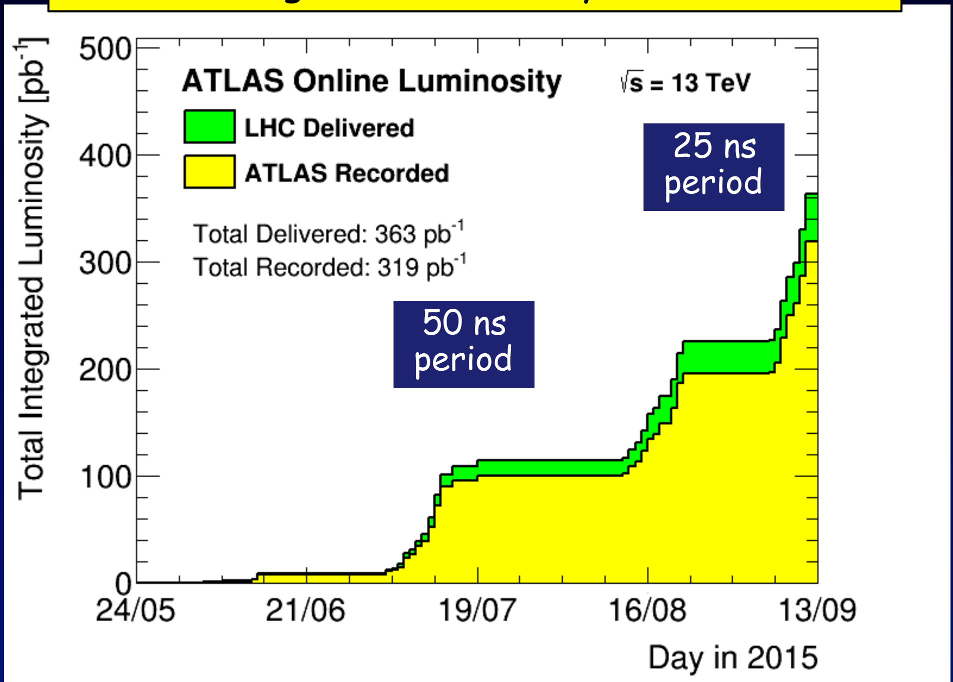
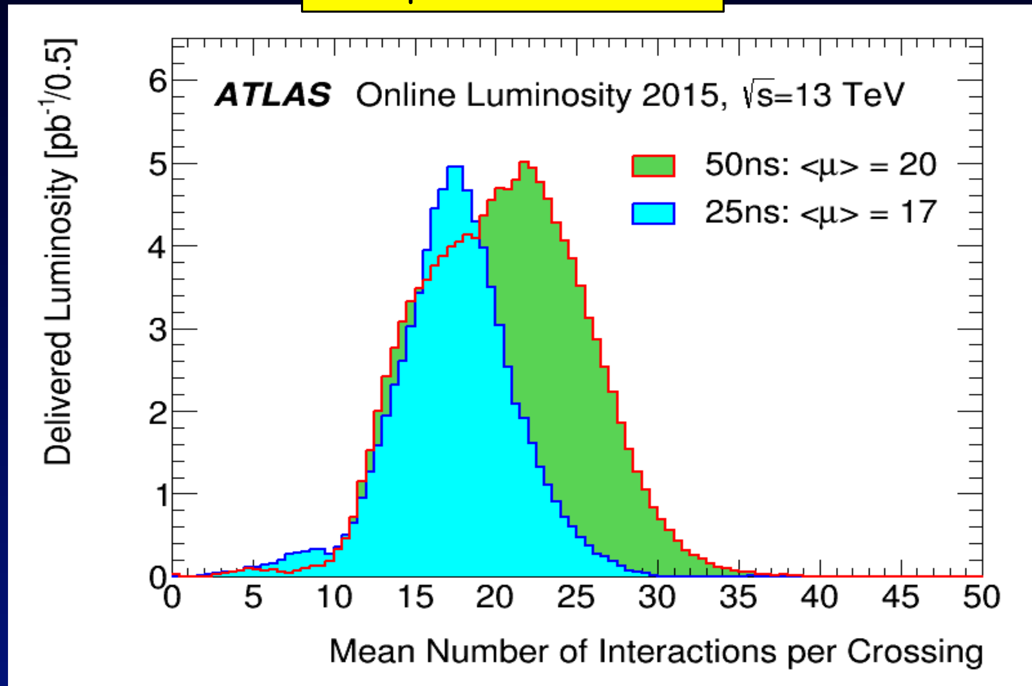
Ischia, Italy

Run 2 Operations

ATLAS integrated luminosity at √s = 13 TeV



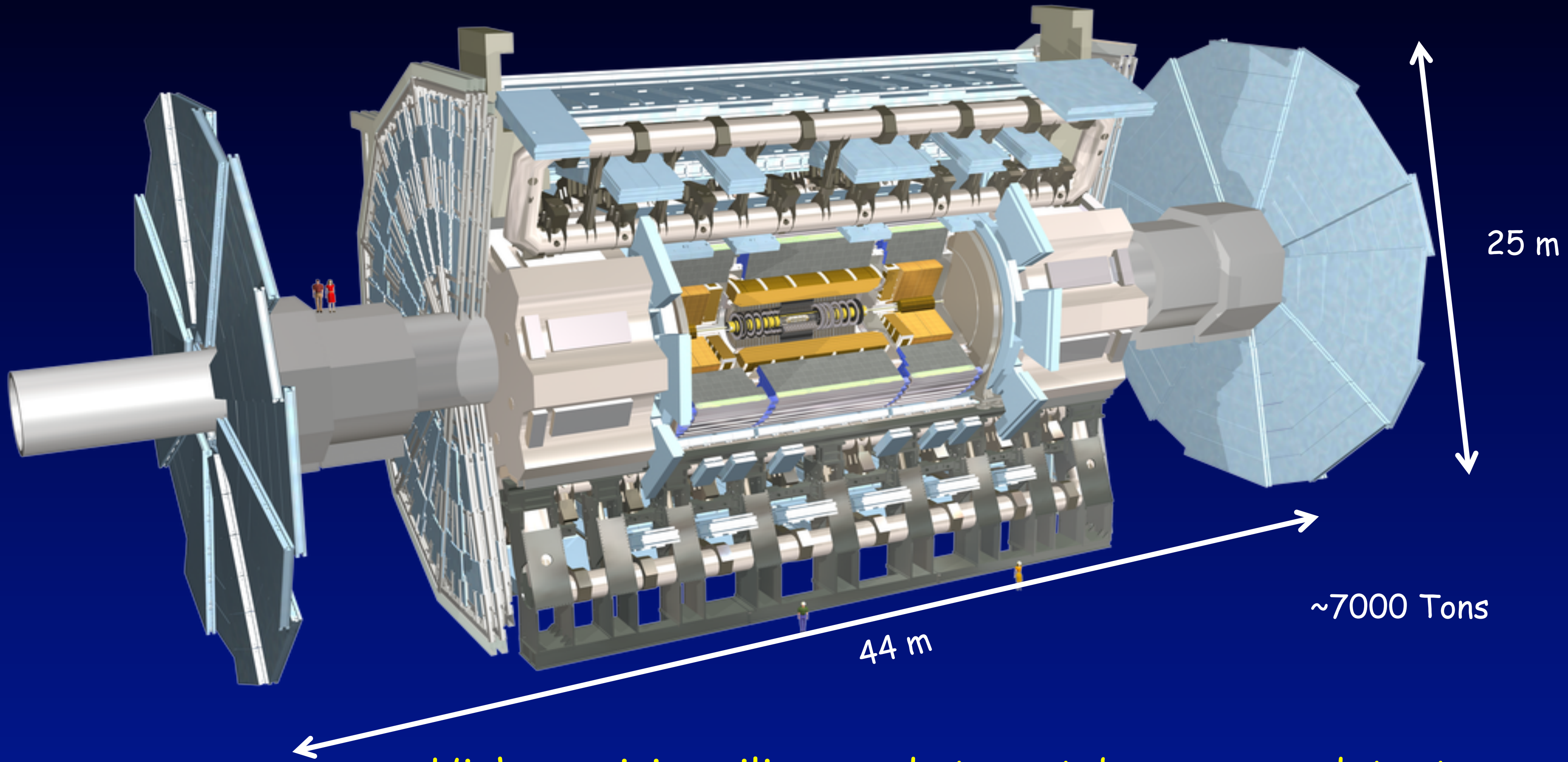
Pileup at √s = 13 TeV



- 50 ns period until July and part of August:
  - Integrated luminosity recorded: 133 pb^{-1}
- 25 ns period since August:
  - Integrated luminosity recorded: 186 pb^{-1}
- Data taking efficiency: ~90%

- 50 ns period:
  - Mean pileup: ~20 interactions per BC
- 25 ns period:
  - Mean pileup: ~17 interactions per BC

The ATLAS detector

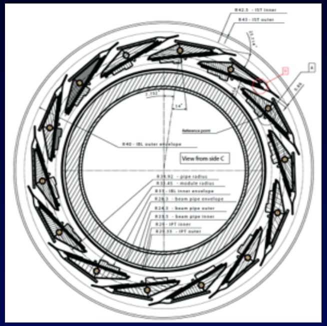


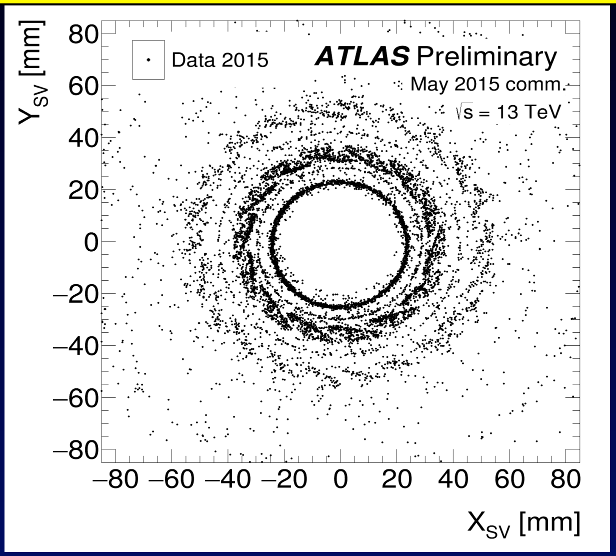
- High precision silicon and straw-tube gaseous detectors
- Fine-granularity/longitudinally segmented calorimeter
- Air-core toroid muon spectrometer

New in Run 2: Innermost pixel layer (IBL)

IBL insertion in May 2014

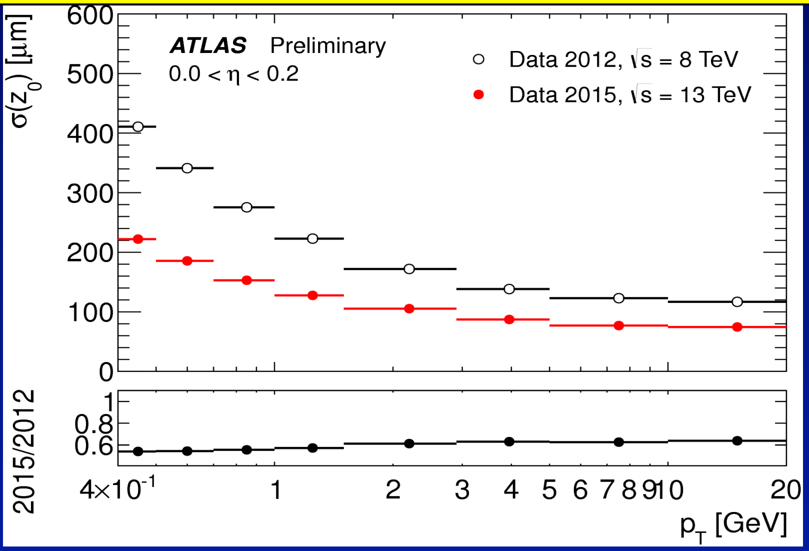
Vertex position of hadronic interaction candidates





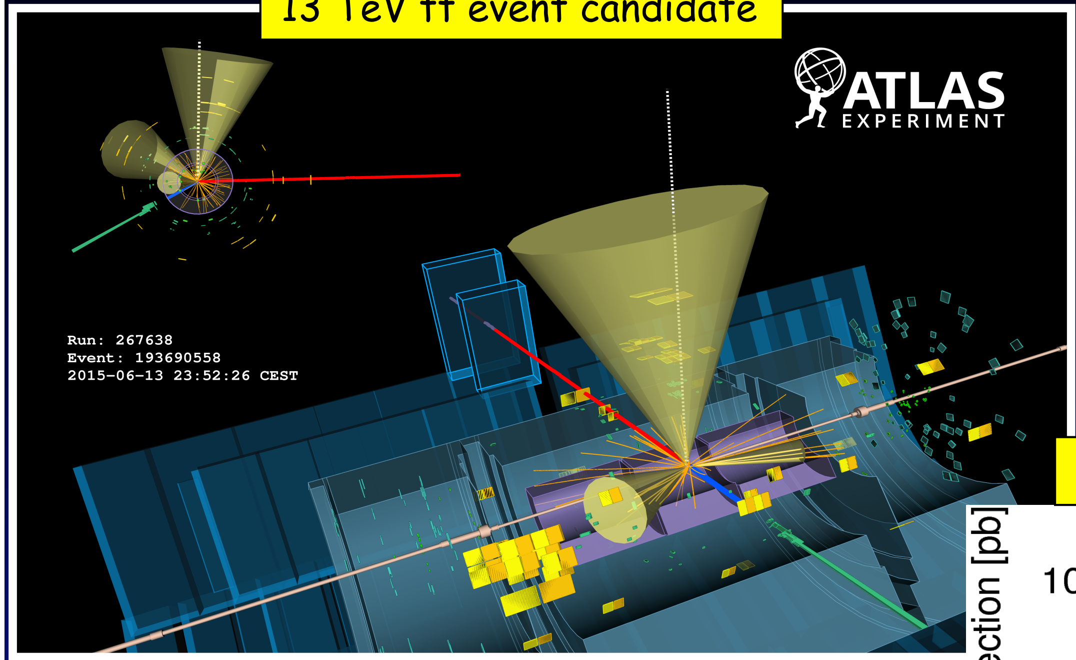
- IBL operations:
  - IBL detector is fully operational
  - Used hadronic interactions to get an initial material mapping in-situ
- Performance:
  - Significant improvement in impact parameter resolution
  - Important for improving b-tagging

Longitudinal impact parameter resolution vs p_T

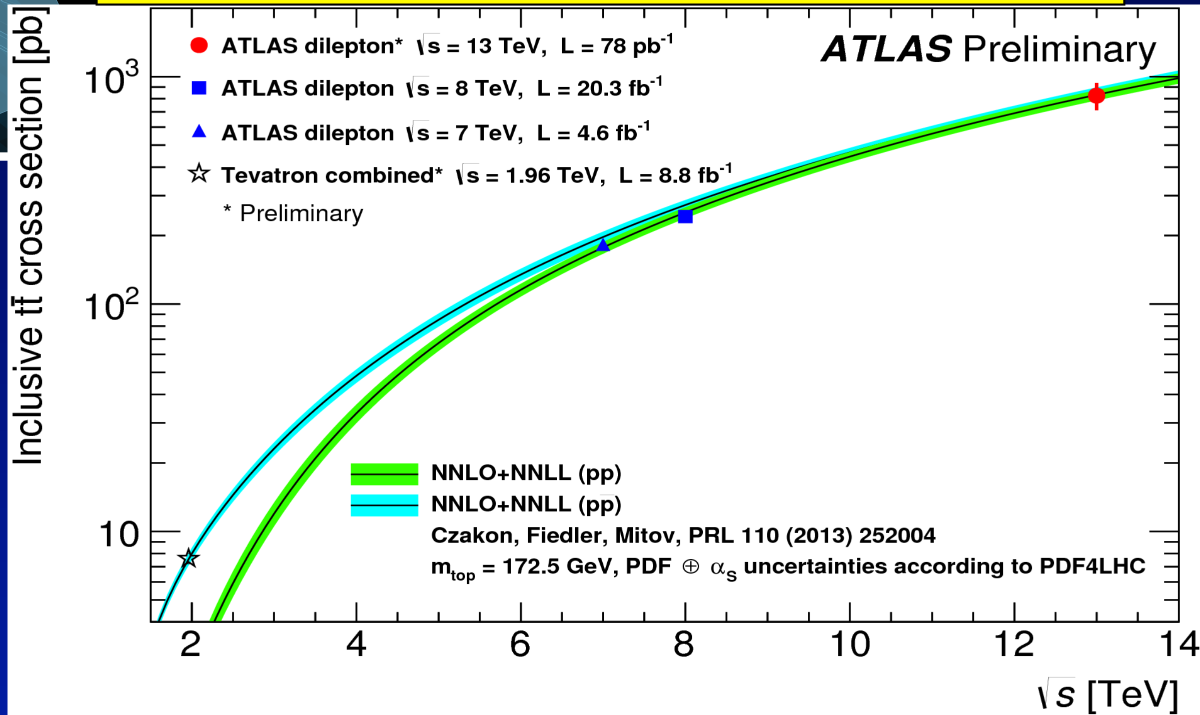


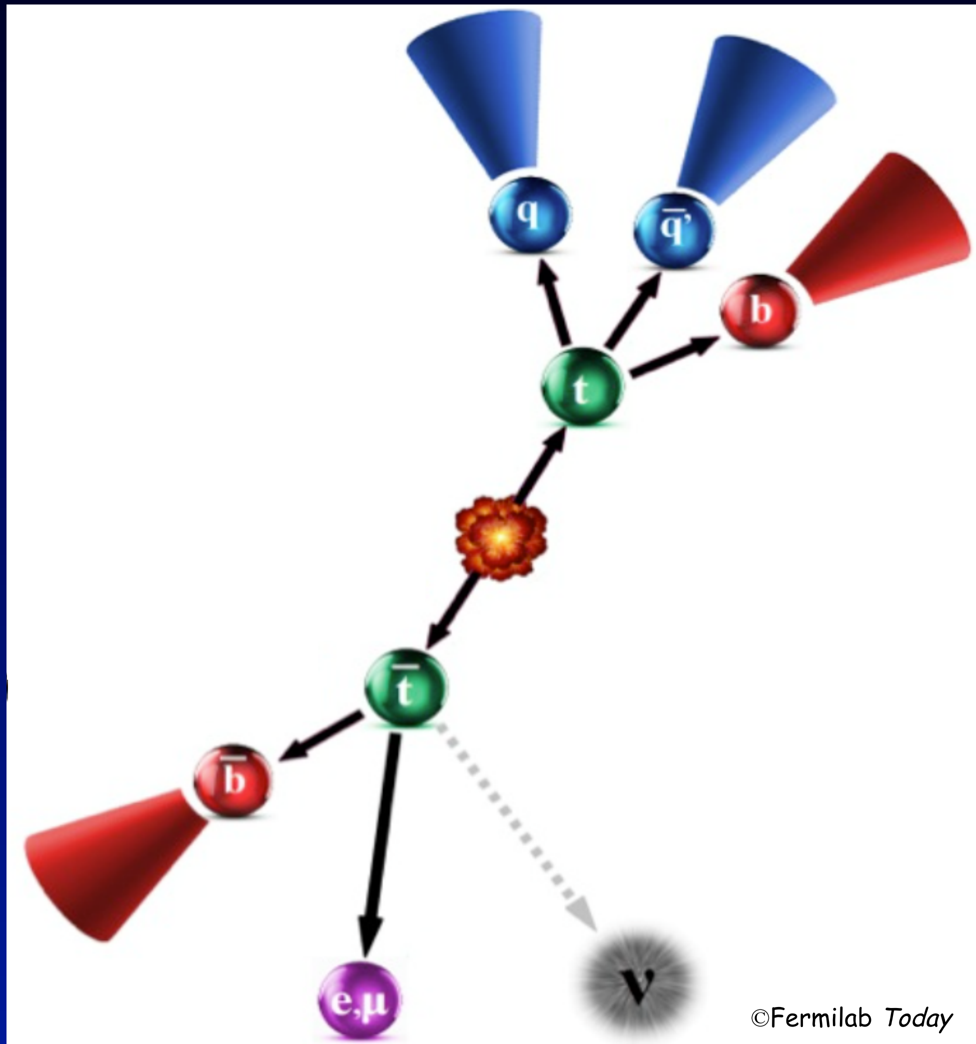
$t\bar{t}$ production in ATLAS

13 TeV $t\bar{t}$ event candidate



ATLAS inclusive $t\bar{t}$ cross-section measurements vs $\sqrt{s}$




q
q̄'
b
t
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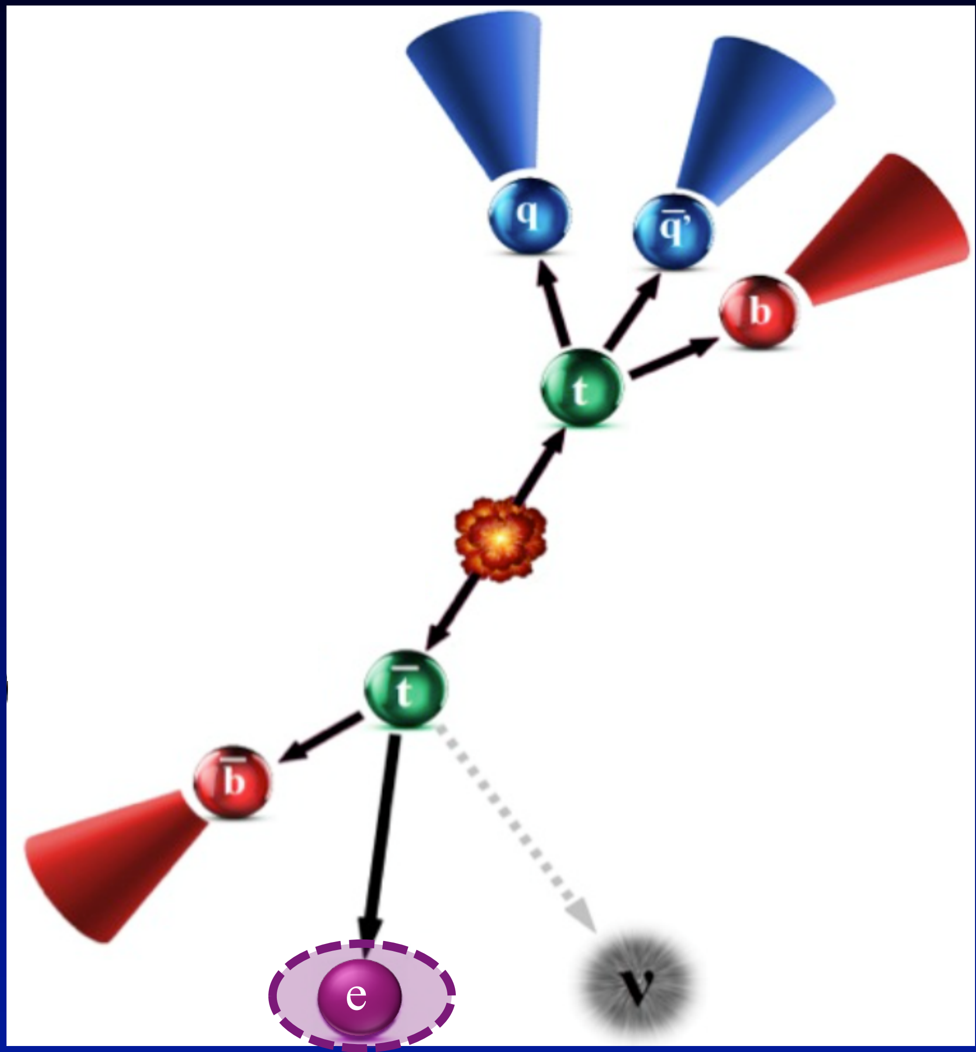
©Fermilab *Today*

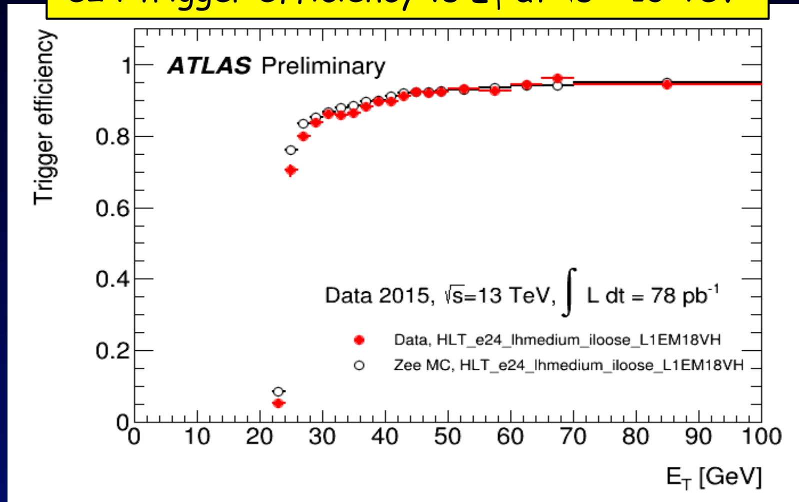
Electron objects



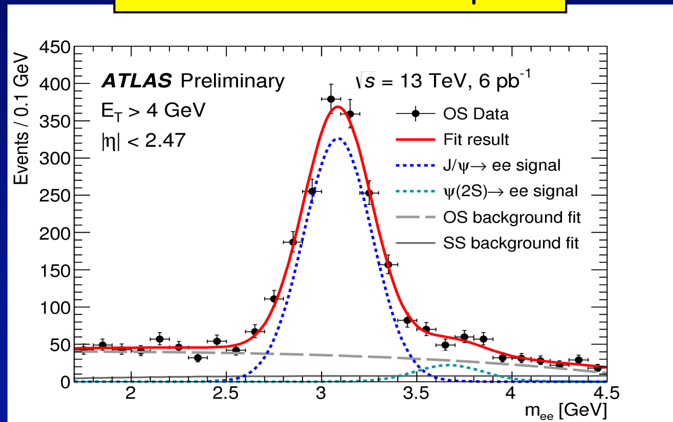
Electron trigger and reconstruction

- Electron trigger:
  - New LH-based identification used
  - Single medium (isolated) electron triggers with $E_T > 24$ GeV used so far
    - Tighter selections prepared for higher luminosities
- Electron reconstruction:
  - Use of cluster as a seed and tracks to cluster matching later
  - Dedicated track pattern and fit to account for bremsstrahlung in dead material applied
  - Discriminate electrons from unconverted photons
- Electron performance:
  - Used data samples of Z and J/ψ events
  - Reasonable energy scale and resolution

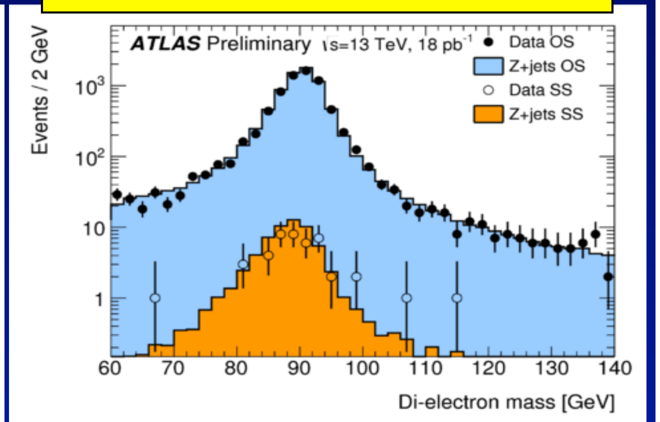
e24 trigger efficiency vs E_T at $\sqrt{s}$ = 13 TeV



Di-electron inv. mass peak

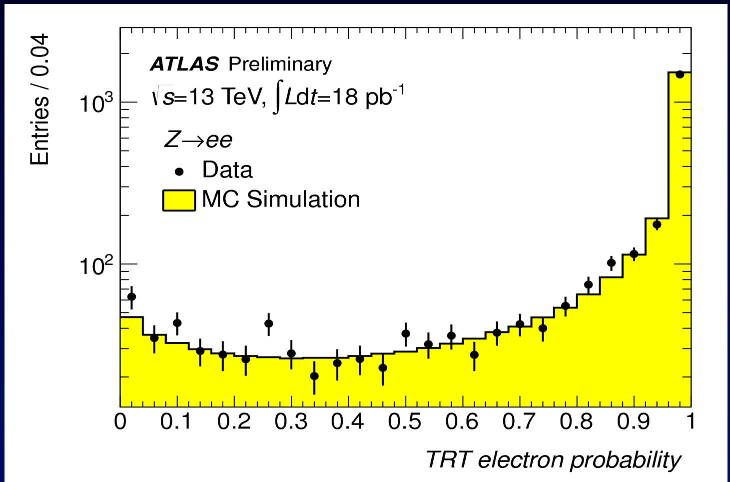


Di-electron inv. mass distribution

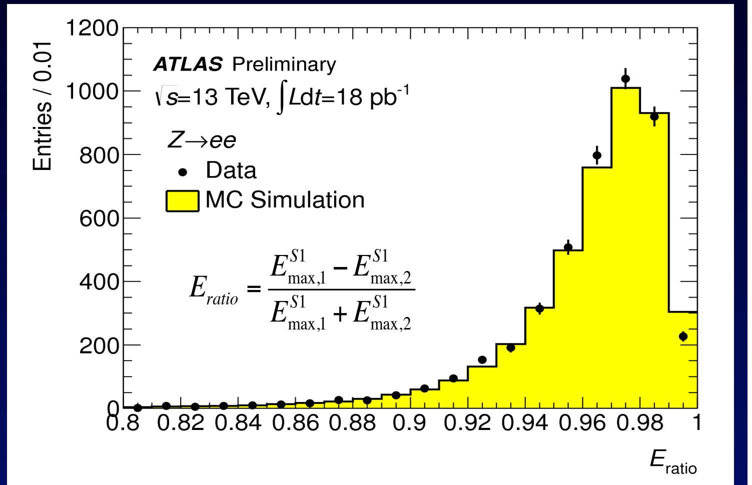


Electron identification efficiency

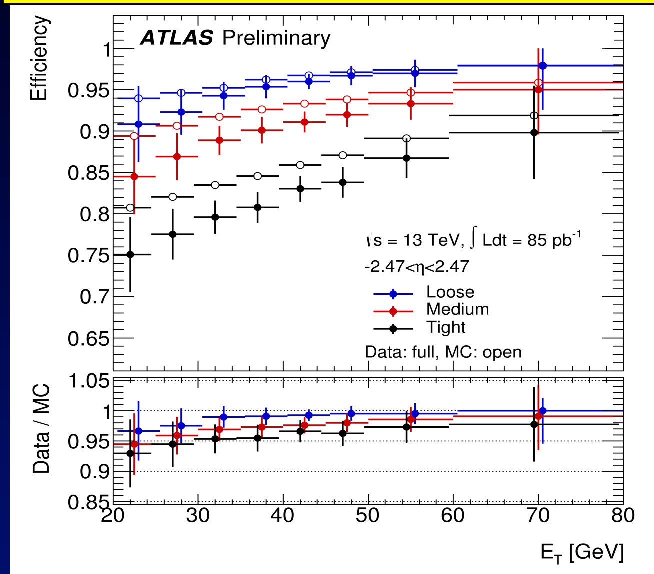
TRT electron probability



Electron shower shape variable



Electron identification efficiency vs E_T



- Electron identification:
  - Based on a likelihood obtained combining various discriminating variables:
    - Shower shapes, track properties, track-cluster matching, etc.
    - Three different identification criteria defined: loose, medium and tight
- Electron identification efficiency:
  - Measured in data
  - Efficiencies vary between 75% and 95%
    - Differences between data and MC corrected by in-situ calibration
    - Uncertainty of ~3-5%

Electron isolation

- Electron isolation definition:
  1) Calo-based E_T^{iso}:

     $\Sigma E_T^{clusters}$ ($\Delta R < 0.2$ around electron)

     Excluded cells in $\Delta\eta \times \Delta\varphi = 0.125 \times 0.175$ around e^-
     Energy corrected event-by-event using the ambient energy density to mitigate pileup effects

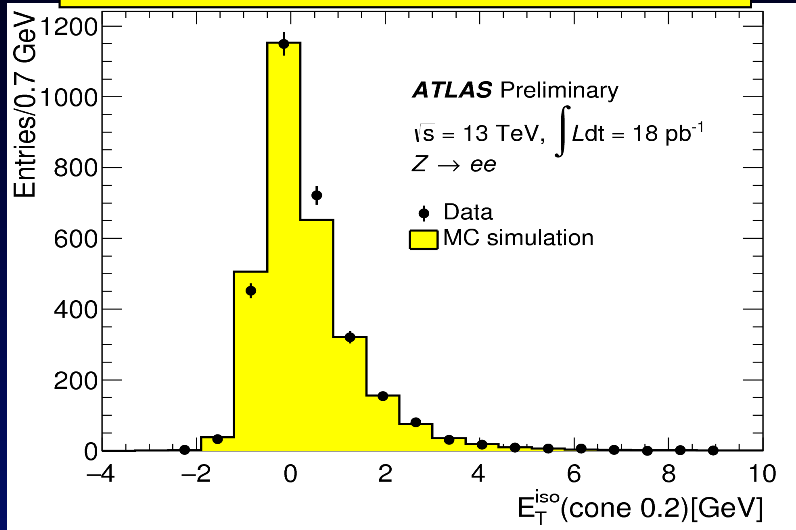
  2) Track-based p_T^{iso}:

     Σp_T^{trks} ($\Delta R = \min\{10\ \text{GeV}/E_T, 0.3\}$)

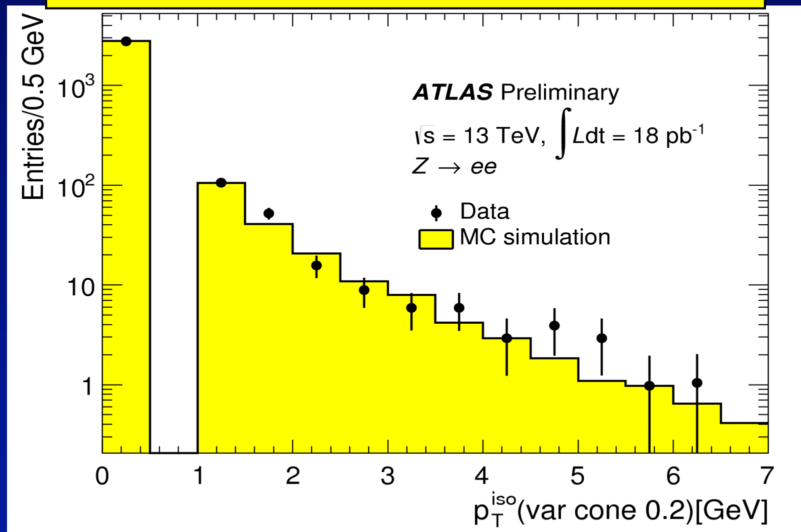
     Electron track excluded

- Performance:
  - Use of a real data sample of Z decays
  - Reasonable comparison with simulation

Calo-based electron isolation distribution

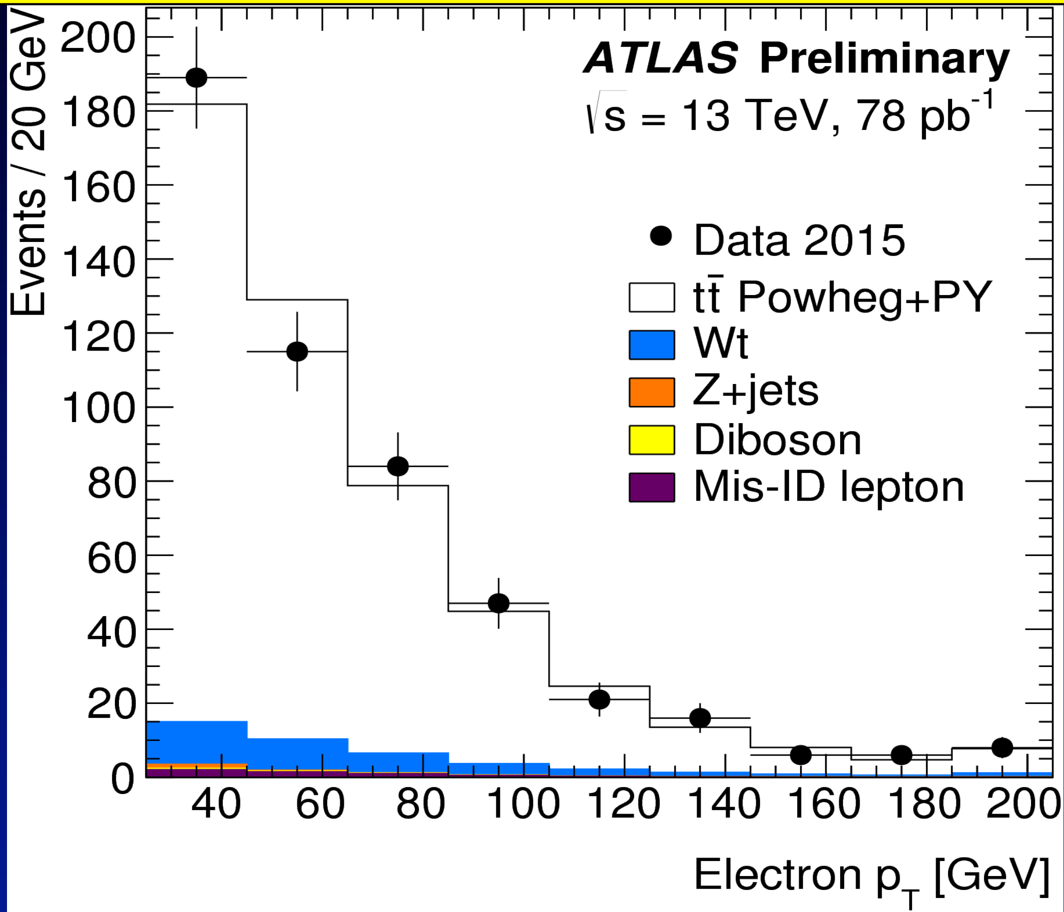


Track-based electron isolation distribution

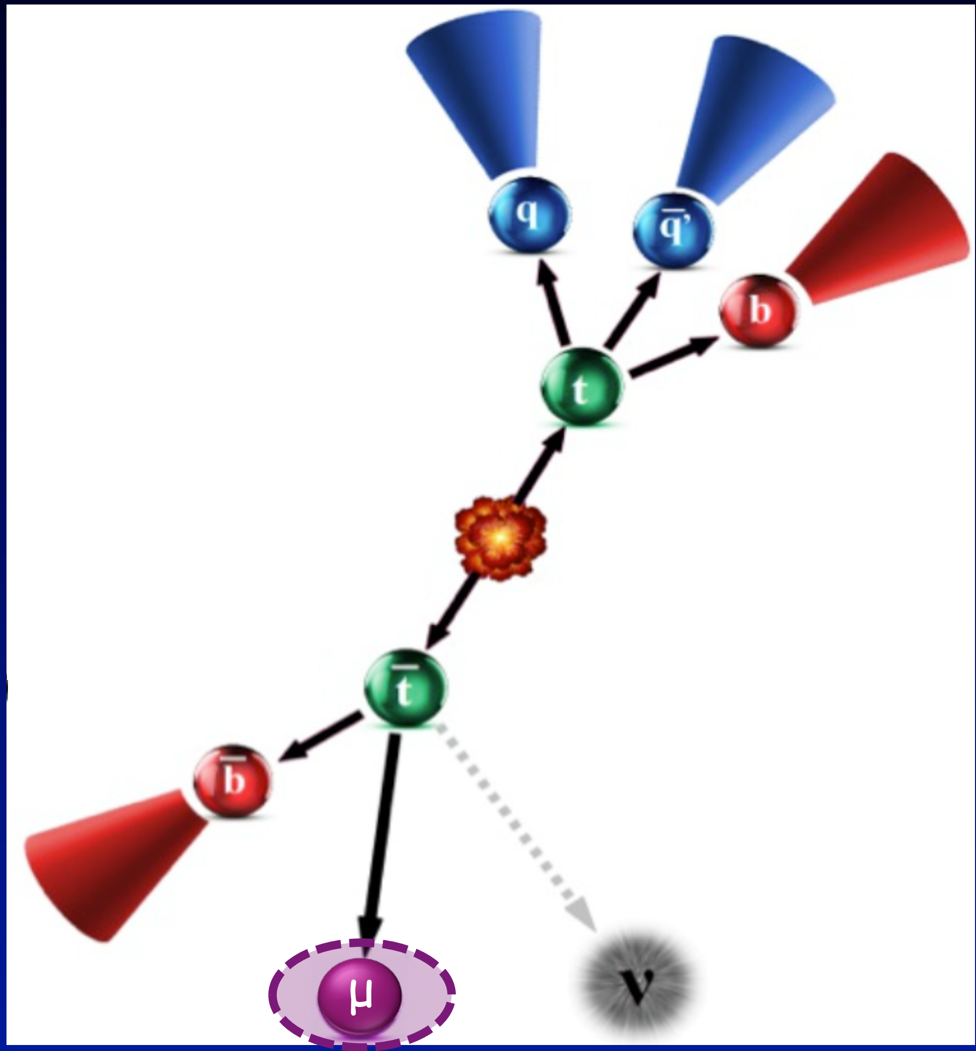


Electrons in $t\bar{t}$ enriched data sample

Electron p_T distribution in $t\bar{t} \rightarrow e\mu + \geq 1$ b-jet events

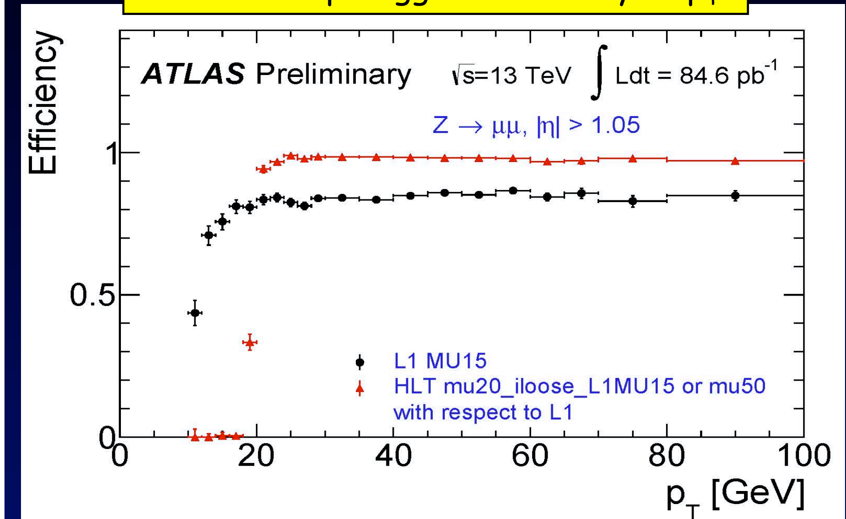


Muon objects

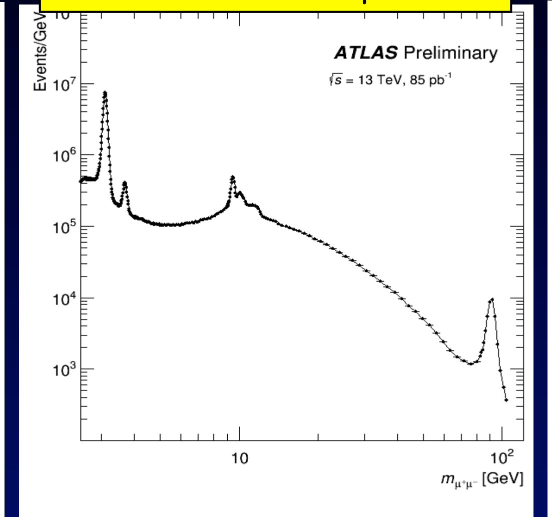


Muon trigger and reconstruction

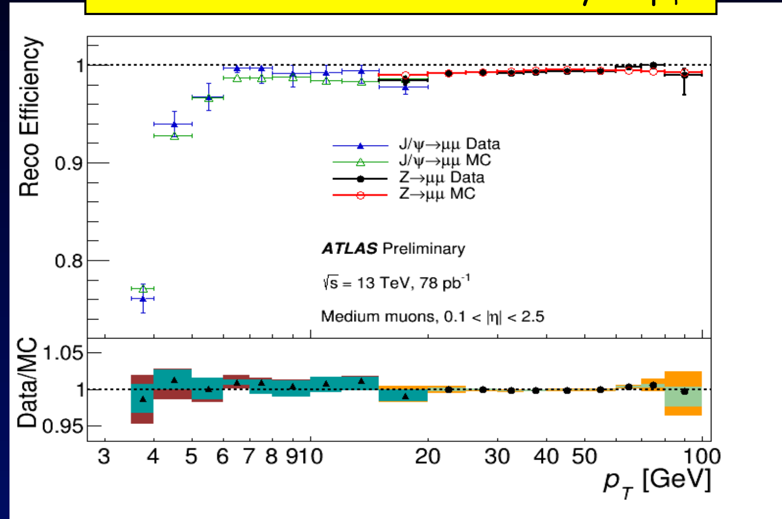
Muon endcap trigger efficiency vs p_T



Di-muon inv. mass spectrum



Muon reconstruction efficiency vs p_T



- Muon trigger:
  - Transverse momentum calculation improved using hits from new chambers in the endcaps
- Muon reconstruction:
  - Combining tracks of the ID and MS
  - Muons reconstructed at $|\eta| < 2.5$
  - Different selection categories are defined: loose, medium, tight

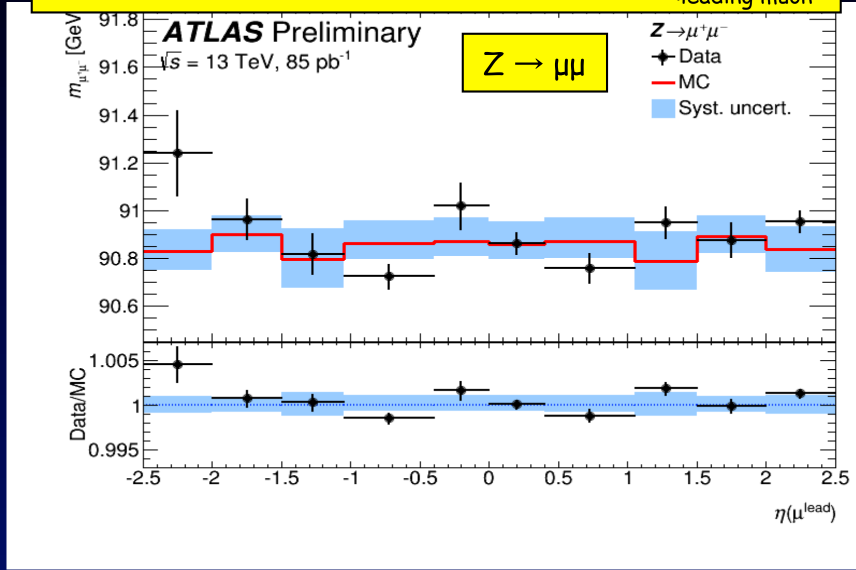
- Muon reconstruction efficiency:
  - Used data samples of J/Ψ and Z event candidates
  - Efficiency measured using a tag-and-probe method like in Run 1
  - More than 98% efficiency for muons with $p_T > 10$ GeV
    - Well modeled by simulation
  - Uncertainty < 1% for muons with $p_T > 20$ GeV

Muon momentum scale and resolution

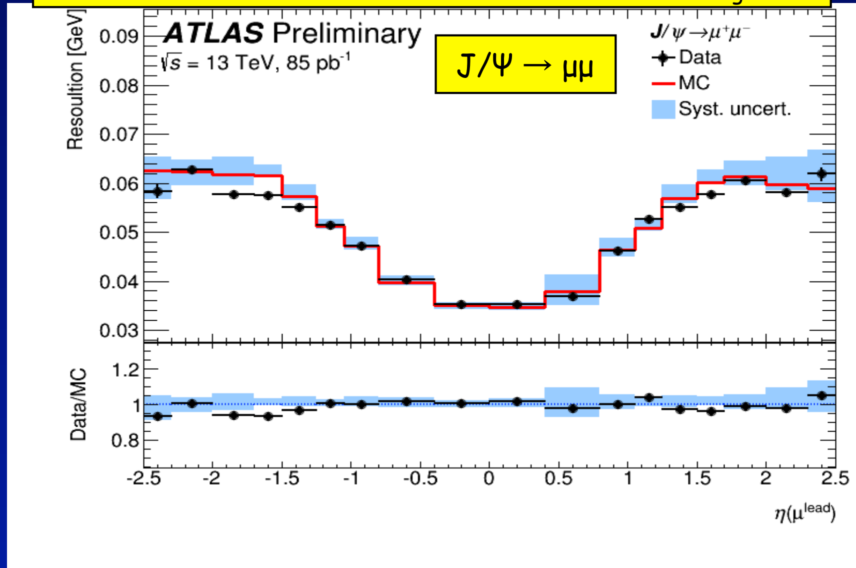
- Muon momentum scale:
  - Combines Inner Detector and Muon Spectrometer information
  - Use of J/Ψ and Z events
  - Corrections to the simulated muon momentum scale and resolution derived from a template-based likelihood fit using Z and J/Ψ decays at $\sqrt{s}$ = 8 TeV
  - Data taken at 13 TeV used to validate and update the corrections to account for changes of the detector conditions

- Performance:
  - Momentum scale already understood with a precision of ~0.2%
  - Resolution understood to within ~5% in the momentum range of the J/Ψ

Mean value of the di-muon inv. mass vs $\eta_{\text{leading muon}}$



Resolution of the di-muon inv. mass vs $\eta_{\text{leading muon}}$

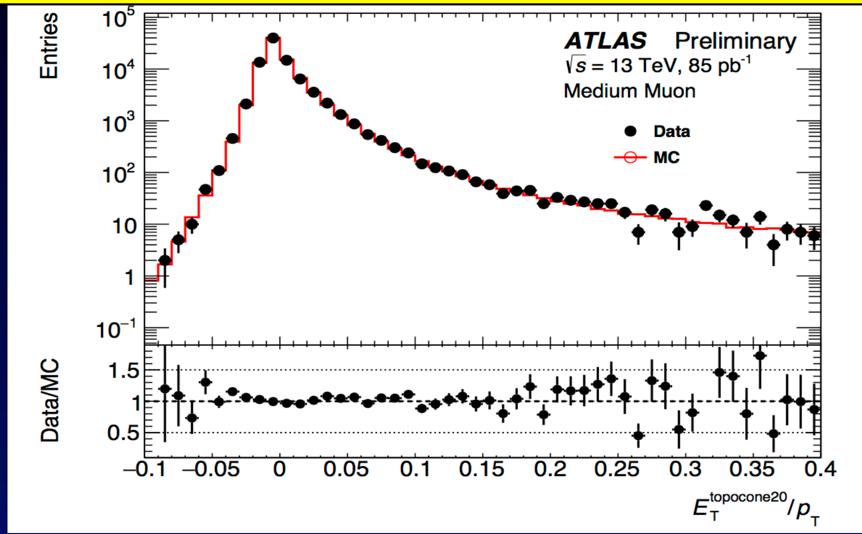


Muon isolation

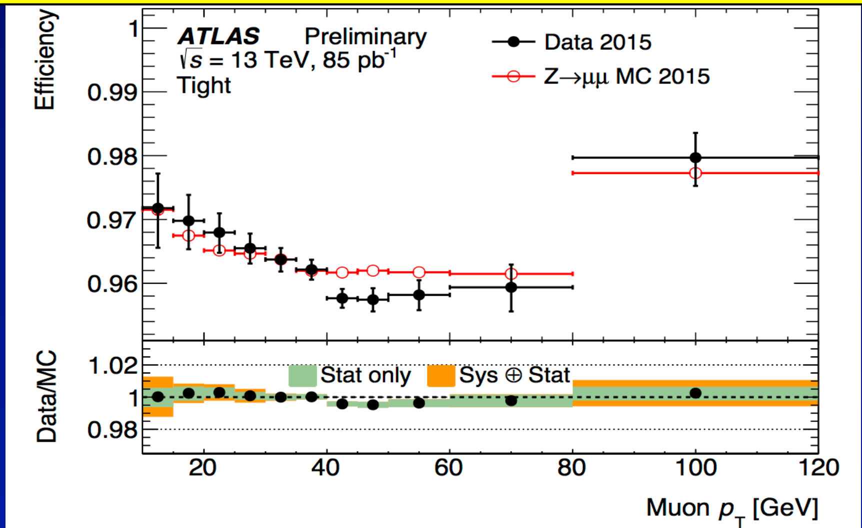
- Muon isolation definition:
  1) ΣE_T^{topo} (topoclusters $\Delta R < 0.2$) / p_T^{μ}
     Clusters $\Delta R < 0.1$ excluded
  2) Σp_T^{trks} ($\Delta R = \min\{10\ GeV/p_T, 0.3\}$) / p_T^{μ}
     Muon track excluded
     Tracks p_T dependent cone size chosen to improve performance for μ's from boosted particle decays

- Performance:
  - Use of a real data sample of Z decays
  - Using pairs of *Medium* muons w/ $\Delta R \geq 0.3$
  - Good agreement with MC

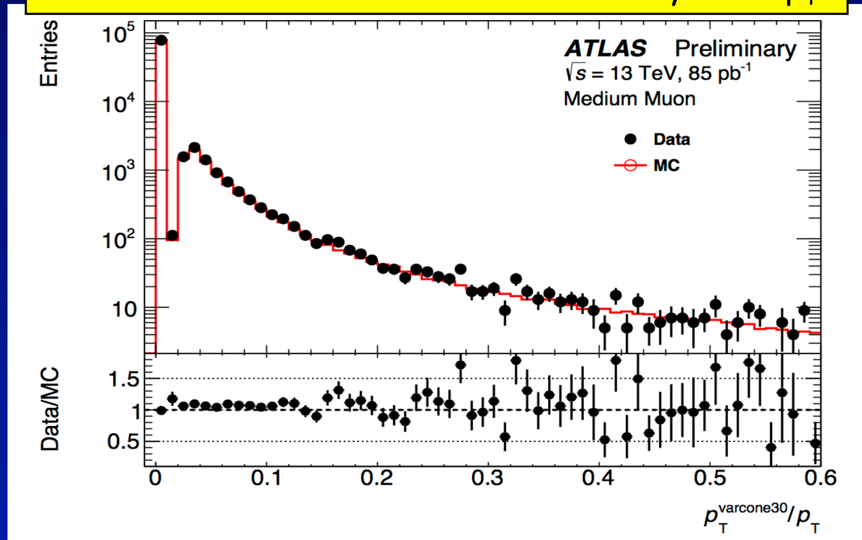
Calorimeter-based isolation variable divided by muon p_T



Combined track and calo isolation efficiency vs muon p_T

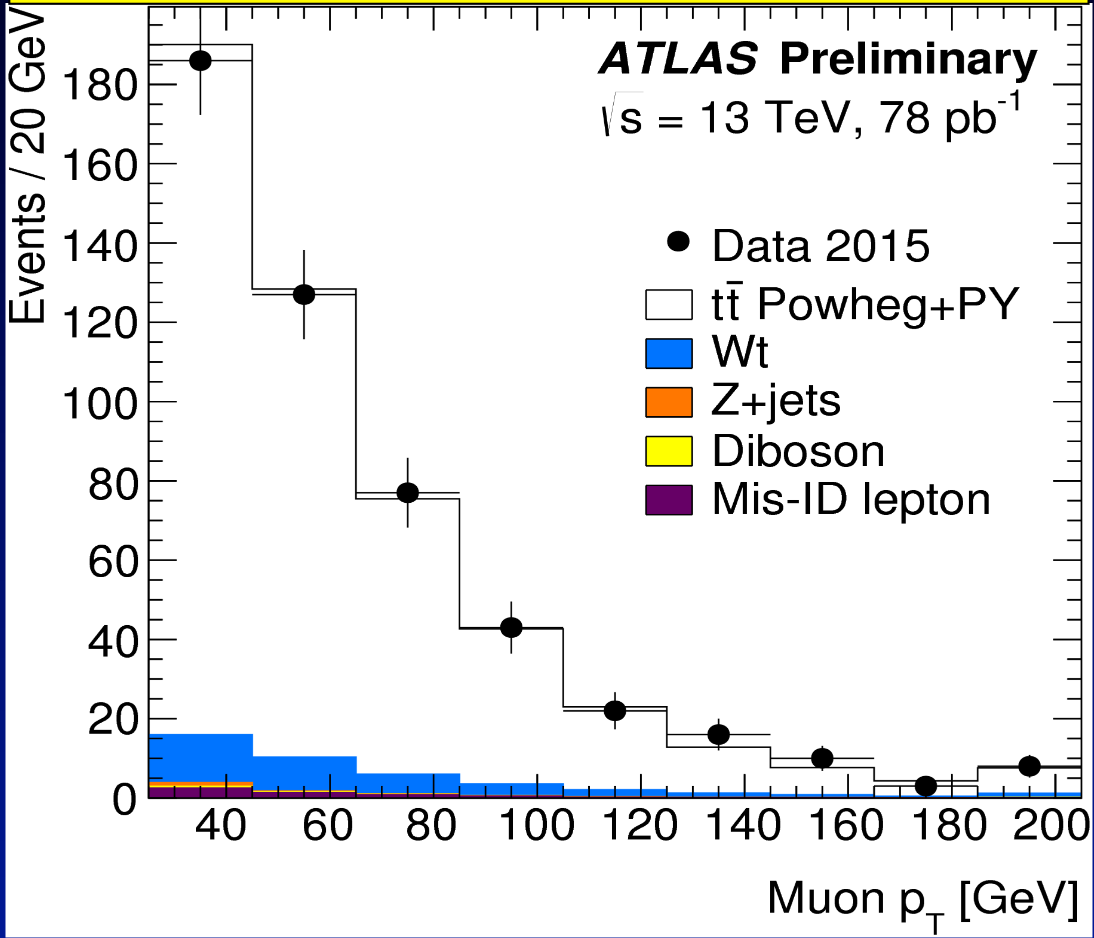


Track-based isolation variable divided by muon p_T

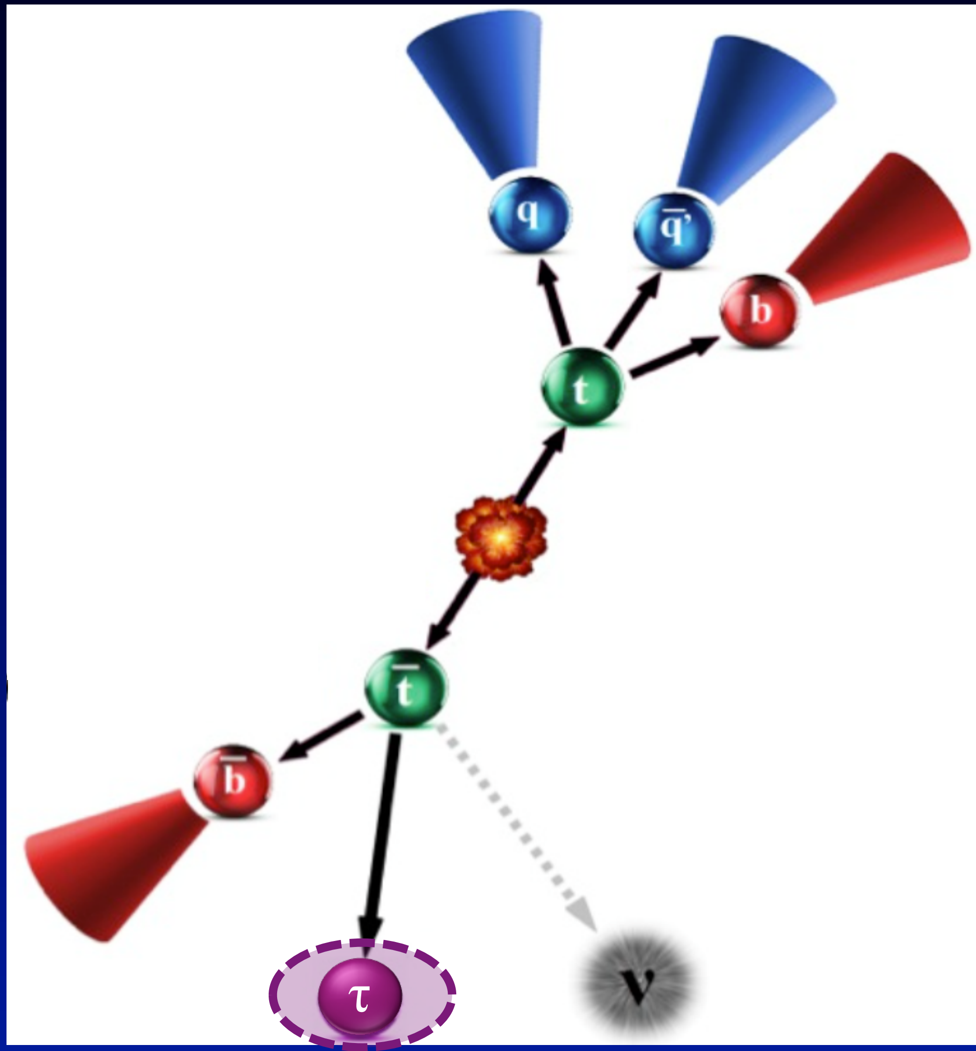


Muons in $t\bar{t}$ enriched data sample

Muon p_T distribution in $t\bar{t} \rightarrow e\mu + \geq 1$ b-jet events



Tau objects

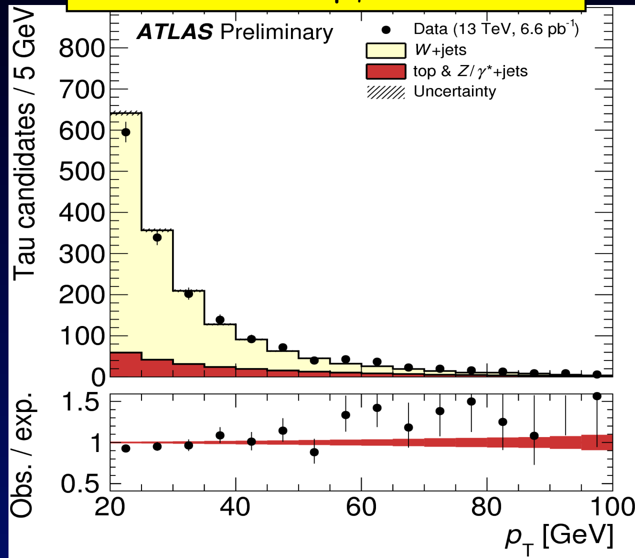


Hadronic tau commissioning

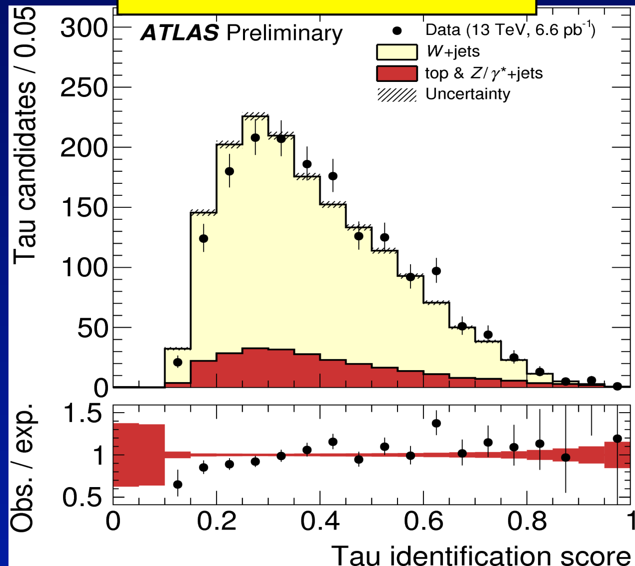
- Hadronic taus identification:
  - Like in Run 1, plan to use various discriminating variables combined in Boosted Decision Trees to reject tau-fakes from electrons and jets, modified for Run 2 conditions
  - Candidates required to be associated with 1 or 3 tracks within a core region $\Delta R < 0.2$

- Performance studies:
  - Used various samples of minimum bias, di-jets, W(μν) /Z(μμ/ee)+jets and $Z \rightarrow \tau\tau$
  - Studied various discriminating variables
  - Reasonably good agreement with simulation
  - Will use more data for detailed studies

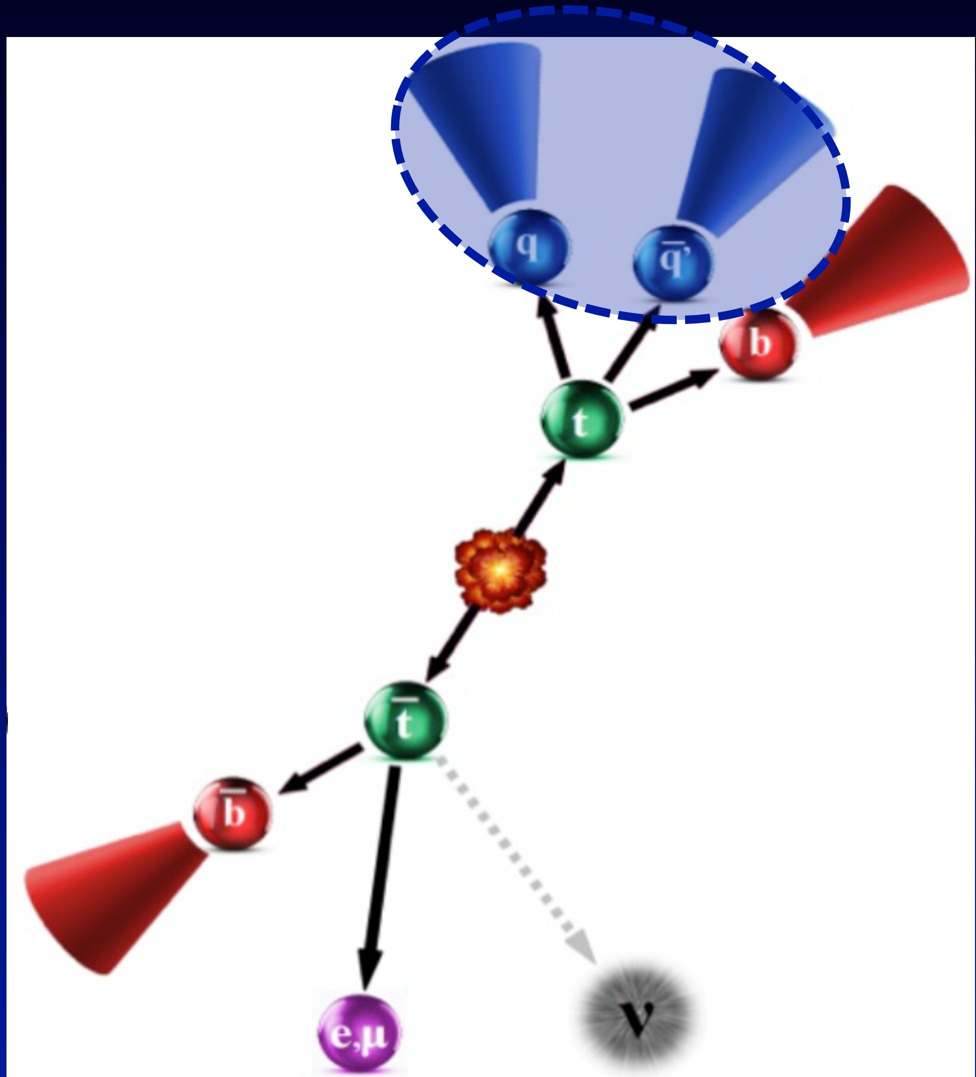
Tau candidates p_T distribution



Tau identification score



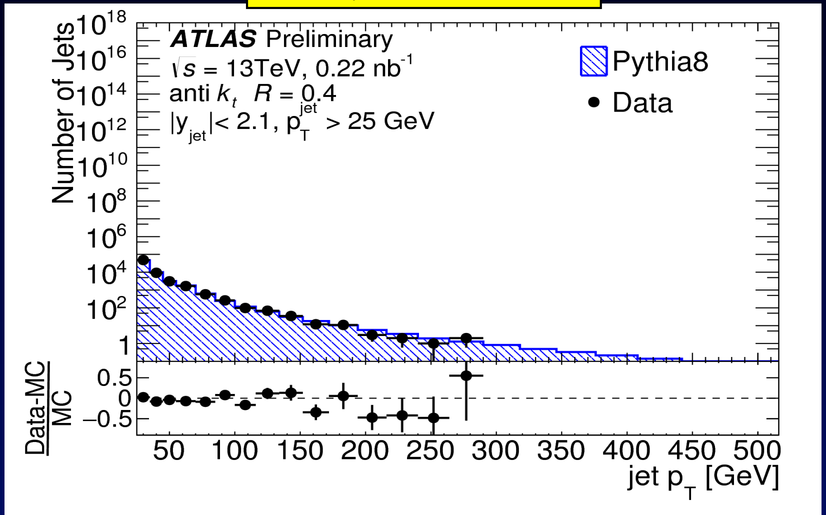
Jet objects



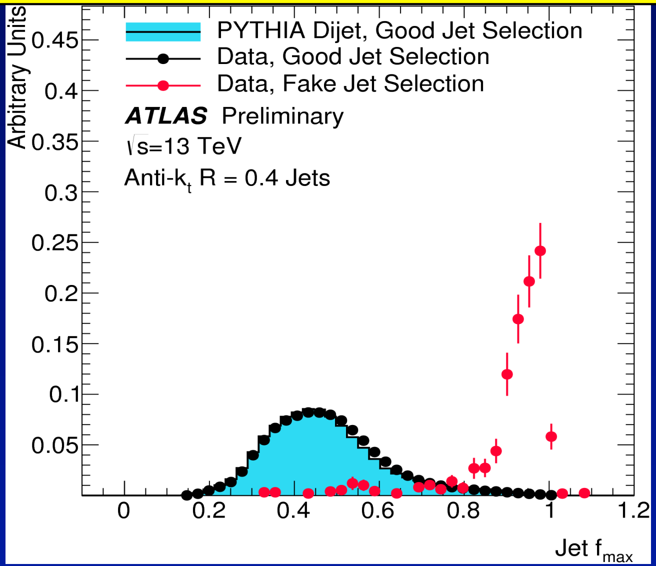
Jet reconstruction and selection

- Jet reconstruction:
  - Use anti-k_T algorithms (R = 0.4) starting from topological clusters (EM scale)
  - Jets calibrated applying MC-based p_T, η corrections for non-compensating calorimeter and inactive material as well as in-situ corrections from Run 1 data
  - Pileup subtraction applied for both in-time and out-of-time pileup
    - Use of a Jet Vertex Tagger discriminant based on the Jet Vertex Fraction and the relative jet p_T from tracks of the hard-scatter vertex
- Jet quality studies:
  - Used dedicated selections for good jets (mainly di-jet events) and fake jets (events ≥ 1 jet with unbalanced p_T)
  - Jet quality selection very similar to Run 1
  - Very good agreement with simulation

Jets p_T distribution

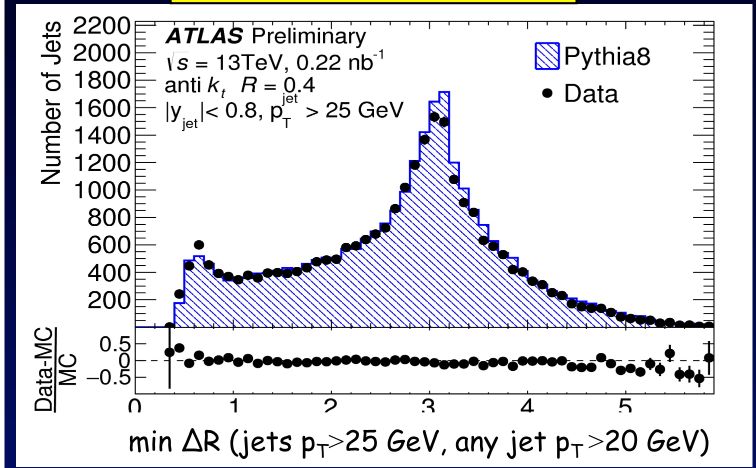


Maximum energy fraction in any single calorimeter layer

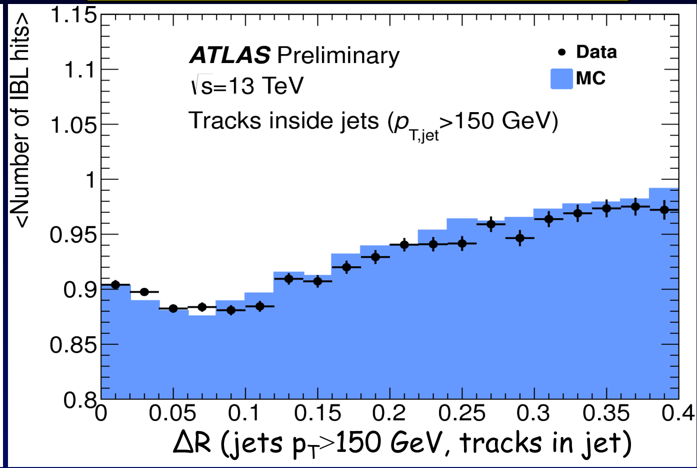


Jet performance and uncertainties

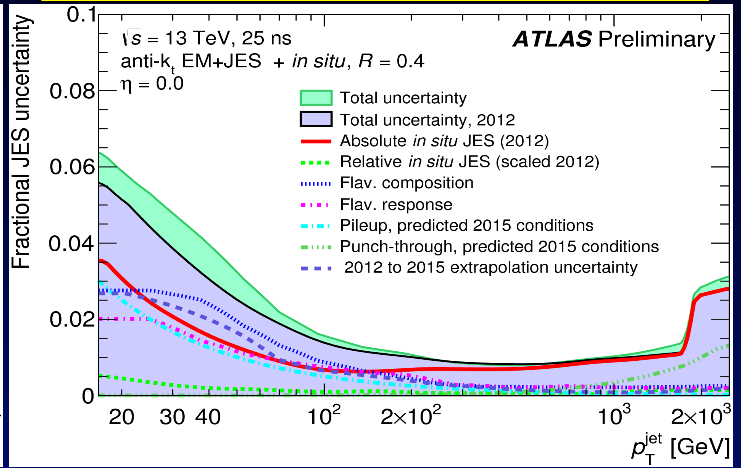
#jets vs min ΔR (jet,jet)



< #IBL hits > vs ΔR (jets, tracks)



Jet energy scale uncertainties vs jet p_T



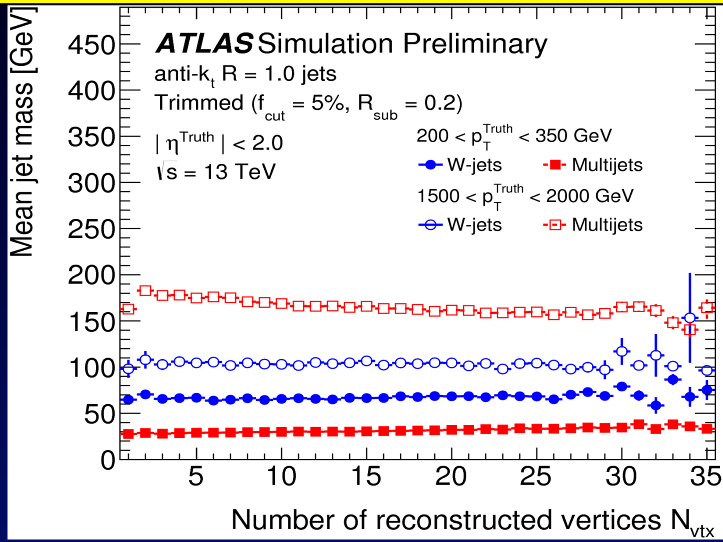
- Jet performance:
  - Studied various jet property variables
  - Generally well described by simulation with few exceptions, that are consistent with Run 1

- Jet uncertainties:
  - Estimated with 2012 data and verified with early Run 2 data
  - ~1-6% uncertainty depending on p_T and η
    - Will improve with in-situ calibrations
  - Various nuisance parameter models available for top physics analyses

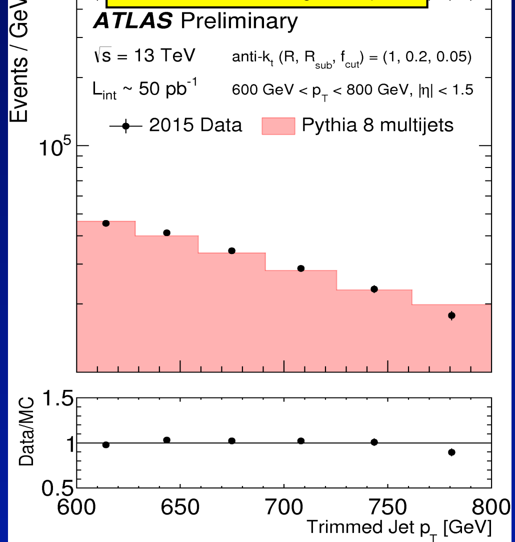
Large-R jet commissioning

- Introduction:
  - Important for high p_T objects, which are boosted and result in collimated decay products
    - Difficult to resolve small-R jets
- Reconstruction:
  - Large-R jets ($R \geq 1$)
  - Use of different grooming techniques exploiting the jet substructure like trimming/filtering/etc.
    - Distinguish between heavy particle decays from multi-jet processes
- Performance:
  - Groomed objects are less sensitive to pileup
  - Reasonably good agreement with simulation
  - Promises to be a useful tool for high p_T boson or top tagging in Run 2

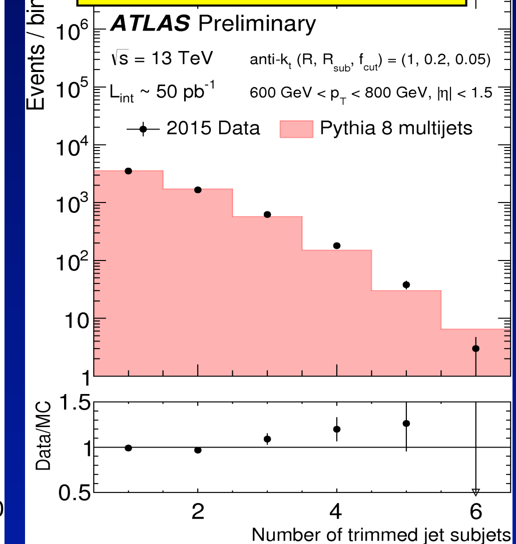
Expected pileup dependence of large-R jet mass



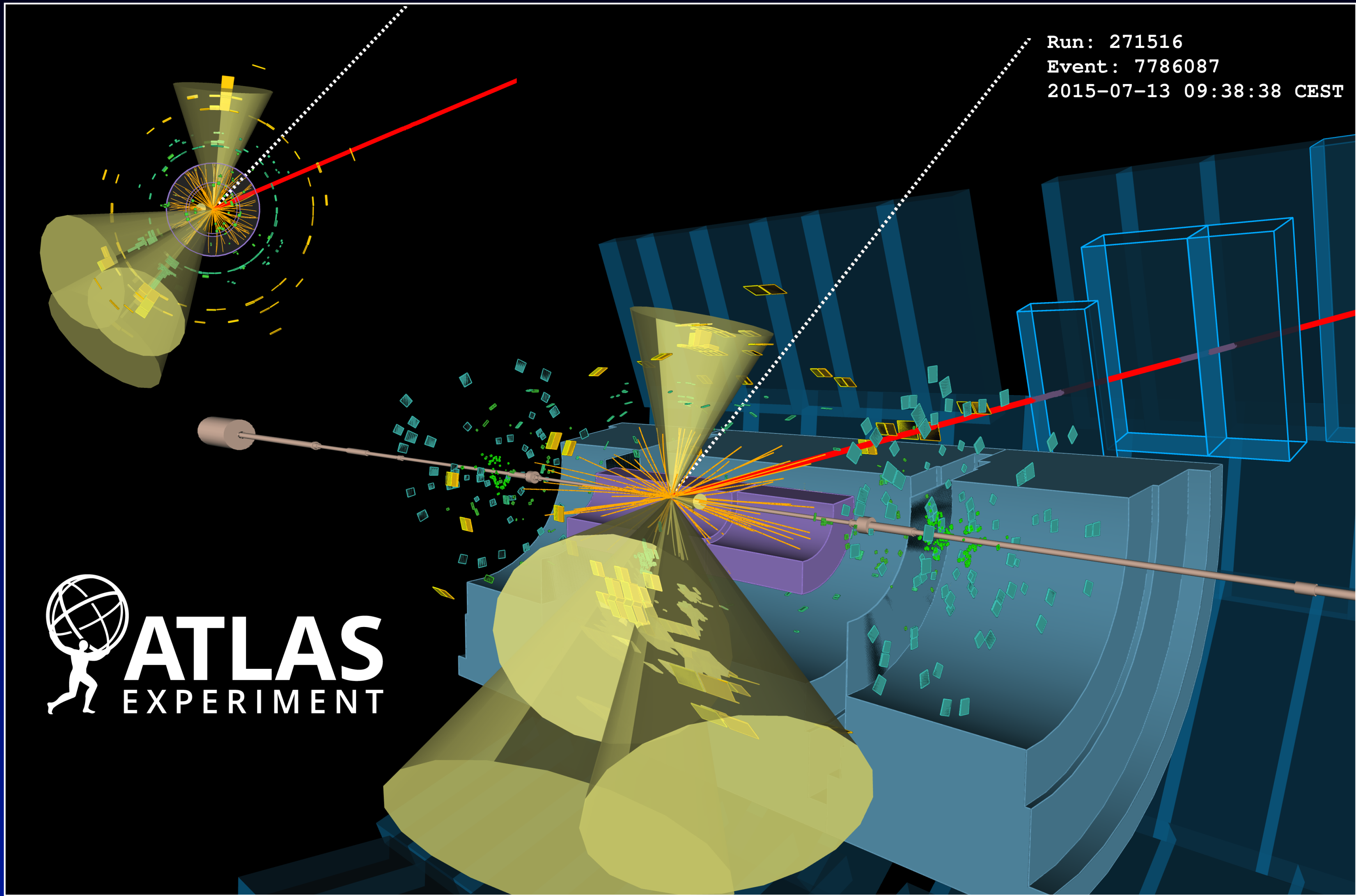
Trimmed jet p_T



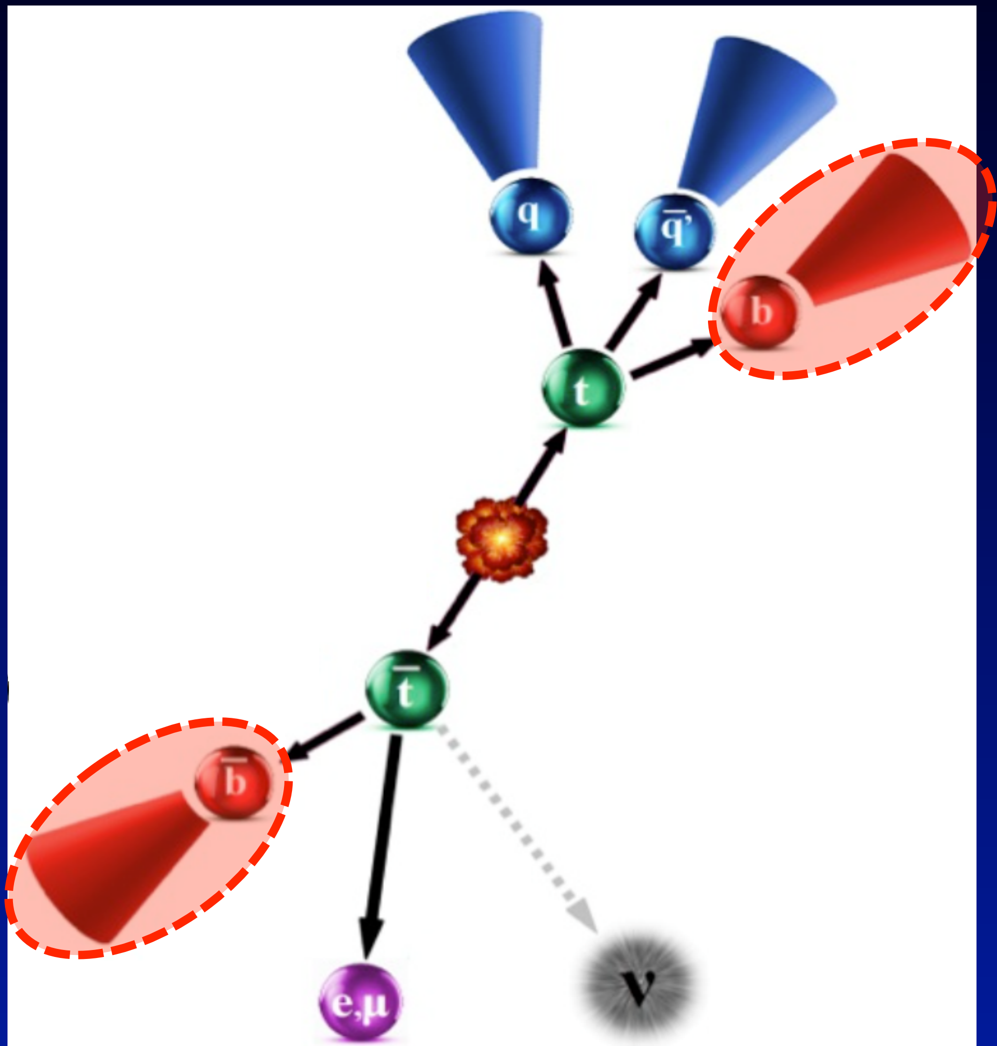
trimmed subjets



Boosted $t\bar{t}$ event candidate at 13 TeV

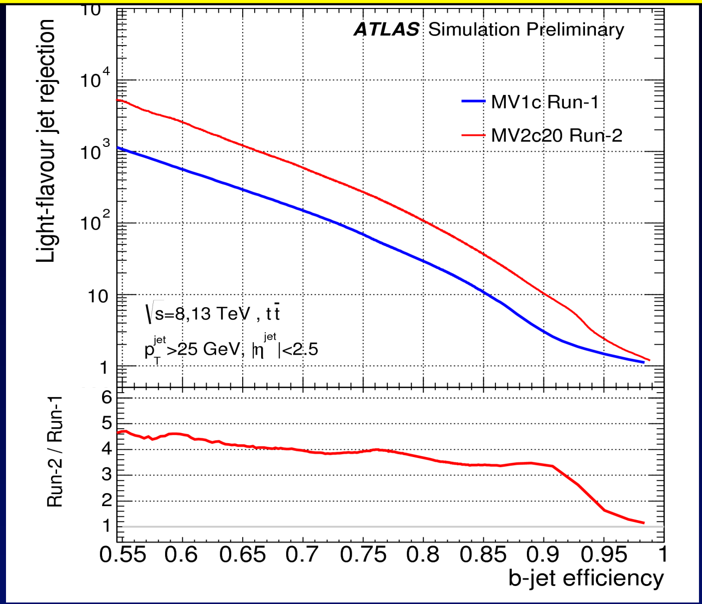


b-tagged jet objects

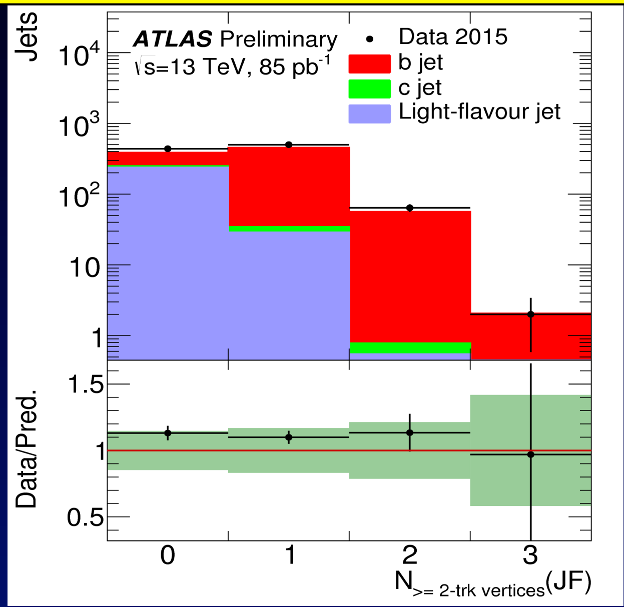


b-tagging performance

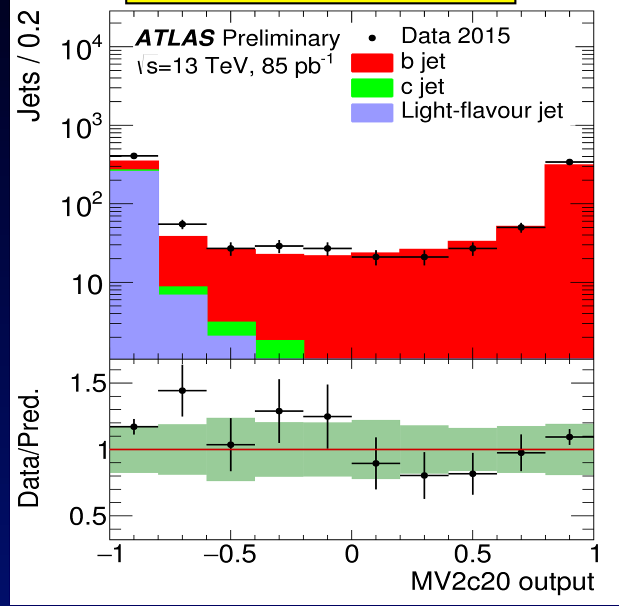
Expected light-flavour jet rejection vs b-jet eff.



#vertices w/ ≥ 2 trks in $t\bar{t} \rightarrow e\mu$ events



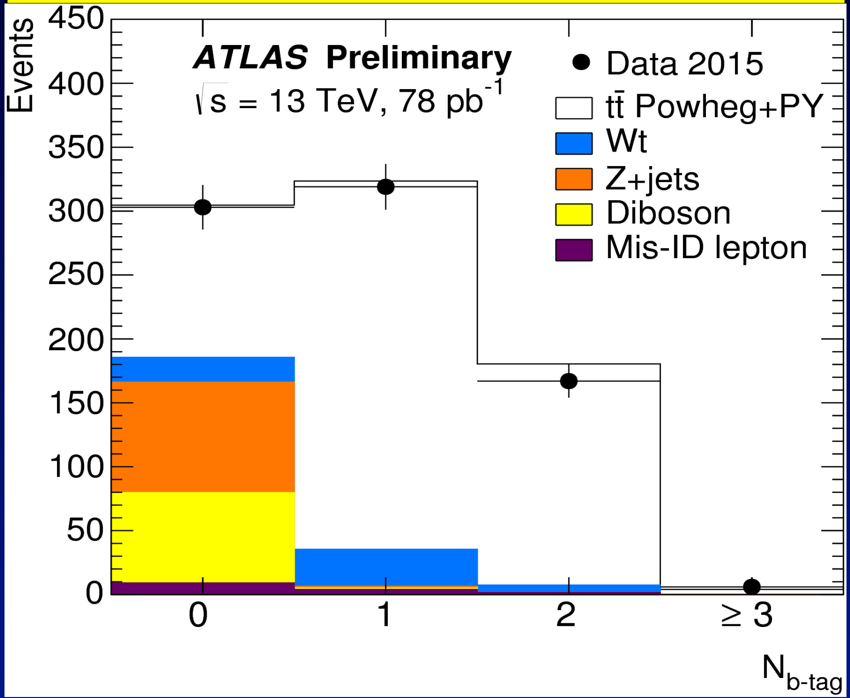
b-tagging MVA output



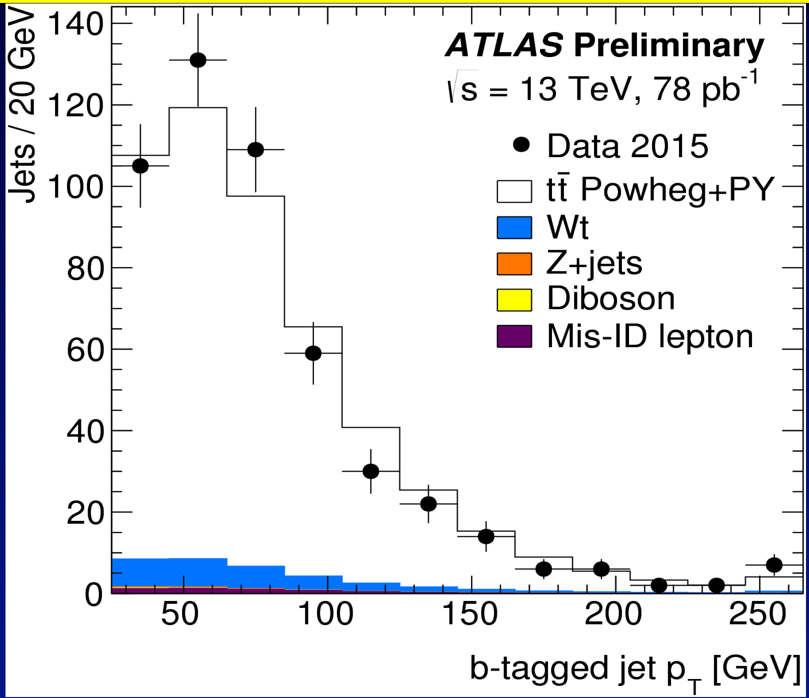
- Reconstruction:
  - Use multivariate algorithm (MVA)
    - Combine discriminating variables from three basic algorithms (IP-based, SV finding, fit of the B/D-hadron cascade decay) using a boosted decision tree
  - Many algorithmic updates in both basic taggers and final MVA
- Performance:
  - Expected a factor ~4 increase in light-jet rejection in b-tagging algorithms with respect to Run 1
    - Majority of improvement from IBL
  - First validation using a sample of jets from b-jet enriched $t\bar{t} \rightarrow e\mu$ +jets data events
    - Variables input to b-tagging MVA as well as output discriminant well described

b-tagged jets in $t\bar{t}$ enriched data sample

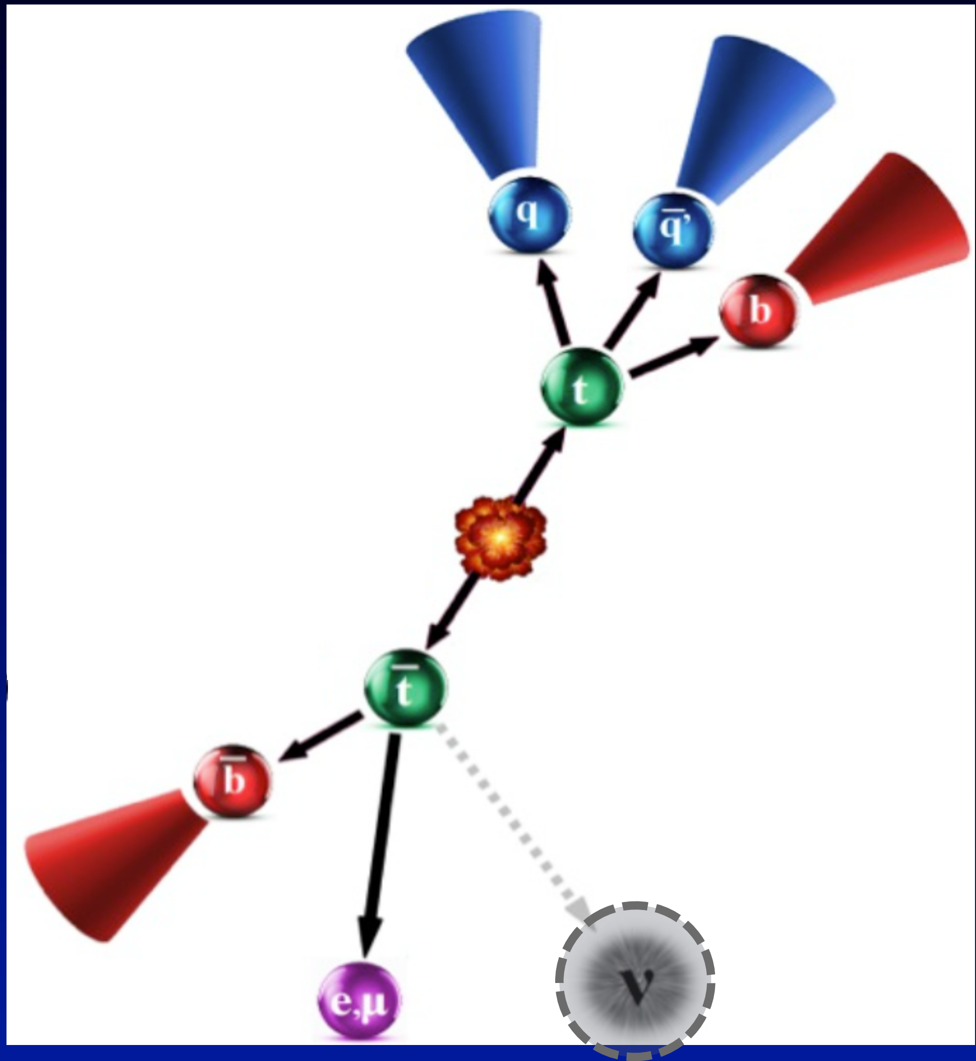
b-jet multiplicity in opposite-sign eμ events



b-jet p_T distribution in $t\bar{t} \rightarrow e\mu + \geq 1$ b-jet events



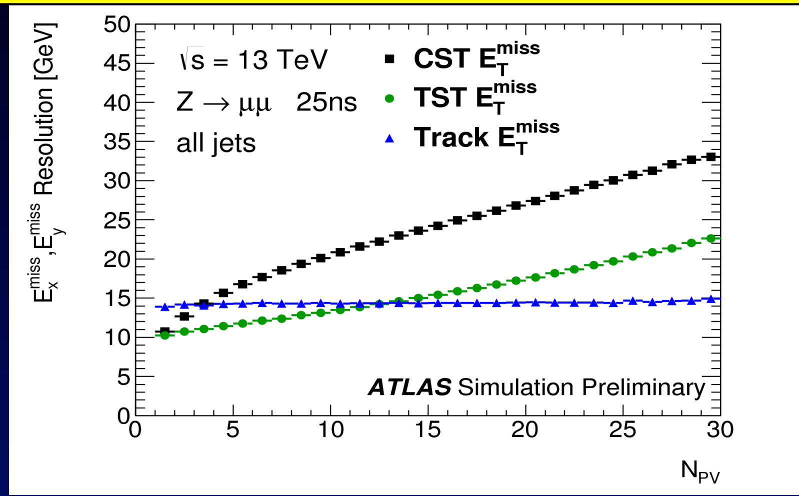
Missing transverse energy



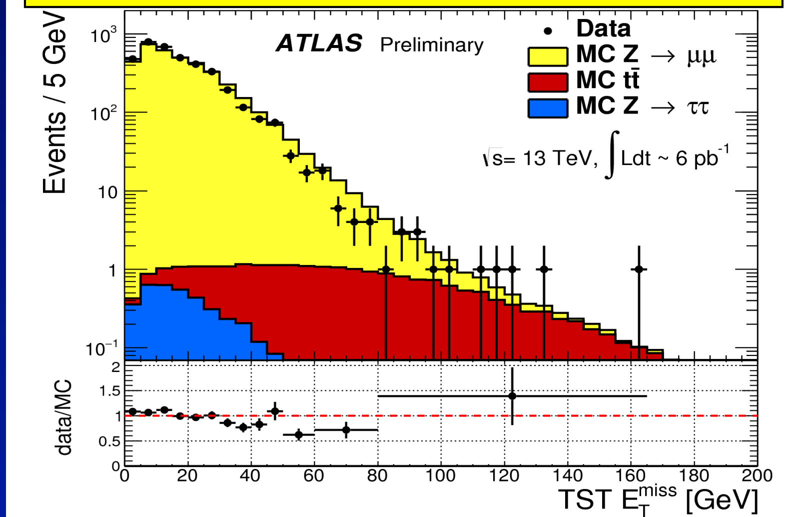
Missing transverse energy performance

- MET definition:
  - E_T^{miss} = hard E_T^{miss} + soft E_T^{miss}
  - To mitigate the effect of pileup, the soft term is track-based (TST E_T^{miss}) for these early studies
    - $p_T^{trk} > 0.4$ GeV associated to PV
    - Includes overlap removal btw tracks and clusters associated to hard objects
- MET performance:
  - Used samples of $Z\rightarrow\mu\mu$ and $W\rightarrow e\nu$
  - Agreement with MC within 20%

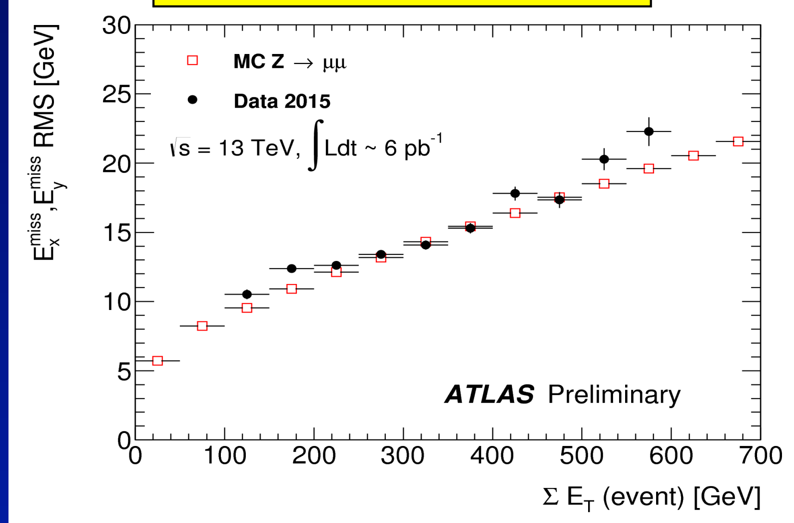
Expected resolution of E_T^{miss} vs # of primary vertices



Soft TST E_T^{miss} distribution for $Z\rightarrow\mu\mu$ events

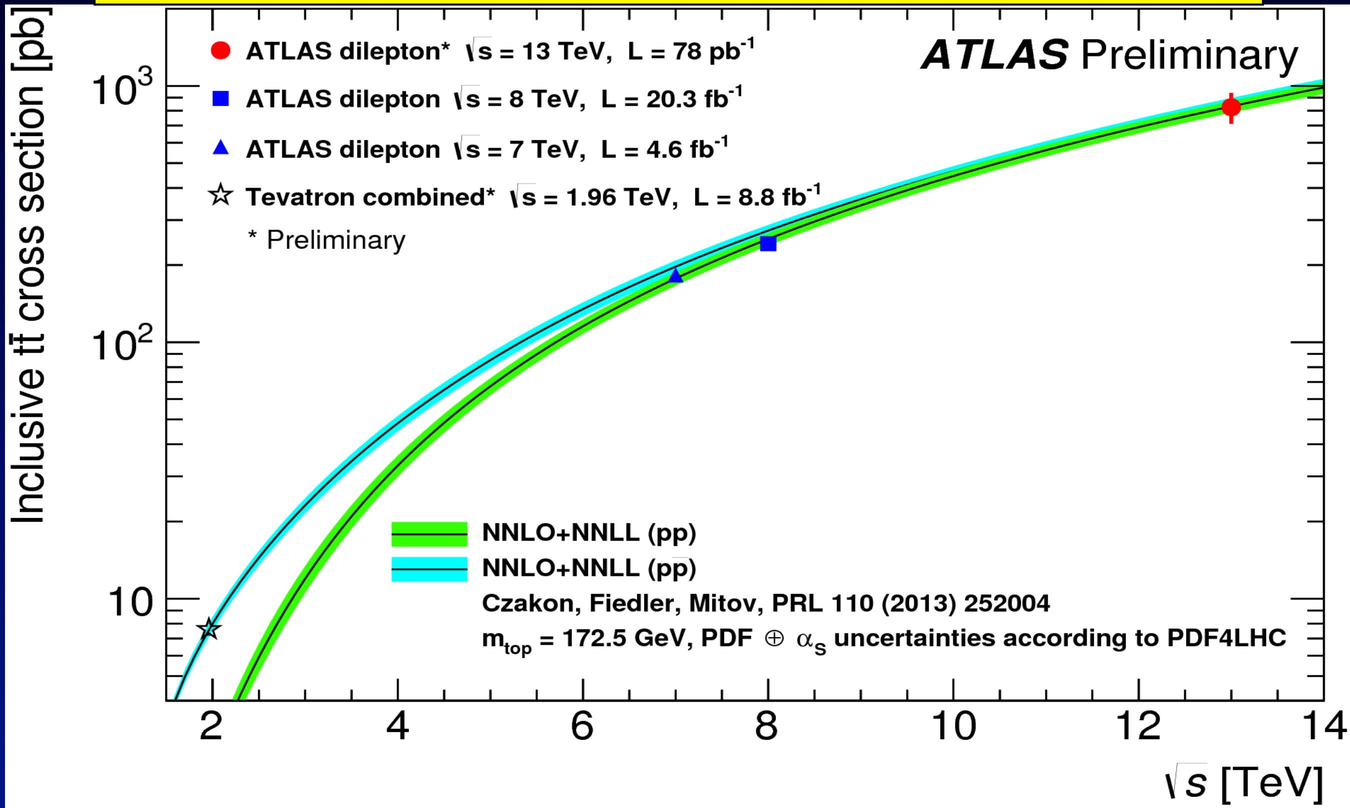


Resolution of E_T^{miss} vs sum E_T



First 13 TeV $t\bar{t}$ cross-section result

ATLAS inclusive $t\bar{t}$ cross-section measurements vs $\sqrt{s}$



- Result already shown in July at the EPS conference
- New results to be shown during this week !

Summary and outlook

- LHC has delivered this summer a good sample of both 50 and 25 ns proton-proton collisions at $\sqrt{s}$ = 13 TeV
- ATLAS is working well and has successfully commissioned the new upgrades for Run 2 including the new IBL detector
- Studied the performance of physics objects using the first data taken
  - Improvement in object reconstruction with respect to Run 1
  - Reasonable agreement with Monte Carlo predictions observed so far
  - Already small systematic uncertainties provided for physics objects
- First early physics measurements and results of physics searches already shown at the summer conferences
- Physics studies and further commissioning will continue with more 13 TeV data being acquired


THANK YOU

References

- Muons:
  - *Muon reconstruction performance in early 13 TeV data* ATL-PHYS-PUB-2015-037
- Electrons:
  - *Electron trigger performance in 2015 ATLAS data* ATL-COM-DAQ-2015-124
  - *Electron shower shapes, tracking, isolation and invariant mass distributions from $Z \rightarrow ee$ and $J/\psi \rightarrow ee$ events* ATL-COM-PHYS-2015-728
  - *Electron Efficiency Measurements in Early 2015 Data* ATL-COM-PHYS-2015-858
  - *Electron identification measurements in ATLAS using $\sqrt{s}$ = 13 TeV data with 50 ns bunch spacing* ATL-PHYS-PUB-2015-041
- Jets:
  - *Jet Calibration and Systematic Uncertainties for Jets Reconstructed in the ATLAS Detector at $\sqrt{s}$ = 13 TeV* ATL-PHYS-PUB-2015-015
  - *Identification of Boosted, Hadronically-Decaying W and Z Bosons in $\sqrt{s}$ = 13TeV Monte Carlo Simulations for ATLAS* ATL-PHYS-PUB-2015-033
  - *Properties of jets and inputs to jet reconstruction and calibration with the ATLAS detector using proton-proton collisions at $\sqrt{s}$ = 13 TeV* ATL-PHYS-PUB-2015-036
  - *Performance of jet substructure techniques in early $\sqrt{s}$ = 13 TeV pp collisions with the ATLAS detector* ATLAS-CONF-2015-035

References

- Taus:
  - *Commissioning of the reconstruction of hadronic tau lepton decays in ATLAS using pp collisions at $\sqrt{s}$ = 13 TeV* ATL-PHYS-PUB-2015-025
- b-jets:
  - *Track Reconstruction Performance of the ATLAS Inner Detector at $\sqrt{s}$ = 13 TeV* ATL-PHYS-PUB-2015-018
  - *Expected performance of the ATLAS b-tagging algorithms in Run-2* ATL-PHYS-PUB-2015-022
  - *Commissioning of the ATLAS b-tagging algorithms using $t\bar{t}$ events in early Run-2 data* ATL-PHYS-PUB-2015-039
- MET:
  - *Expected performance of missing transverse momentum reconstruction for the ATLAS detector at $\sqrt{s}$ = 13 TeV* ATL-PHYS-PUB-2015-023
  - *Performance of missing transverse momentum reconstruction for the ATLAS detector in the first p-p collisions at $\sqrt{s}$ = 13 TeV* ATL-PHYS-PUB-2015-027
- Analysis:
  - *Measurement of the $t\bar{t}$ production cross-section in pp collisions at $\sqrt{s}$ = 13 TeV using eμ events with b-tagged jets* ATLAS-CONF-2015-033