Common Objects and Backgrounds: Calibration and Performance at Atlas

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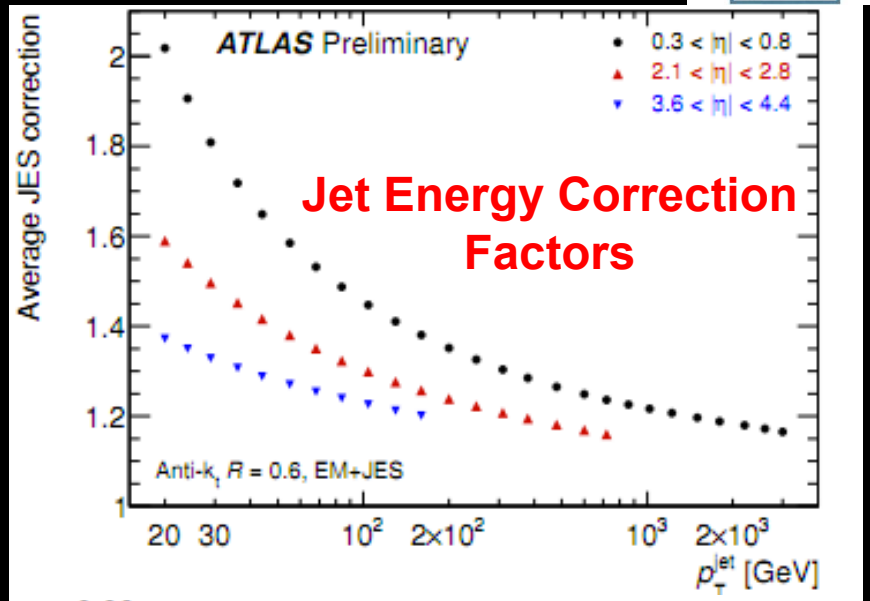
(on behalf of the Atlas Collaboration)

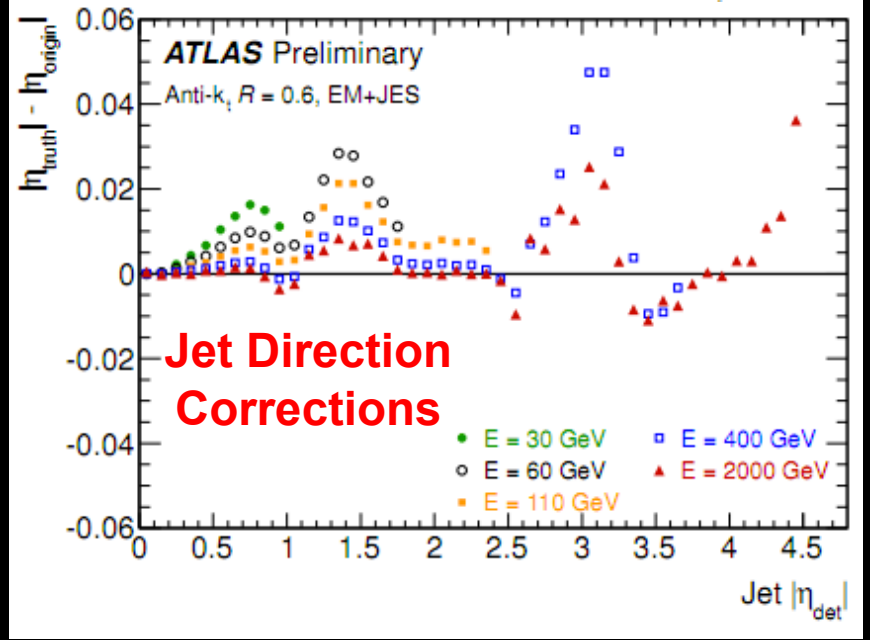
Introduction

- Top analyses rely on common work from many groups studying performance and backgrounds
- Will detail performance, calibrations, and uncertainties at Atlas of …
  - Jet, electron, muon, tau objects and triggers
  - Missing transverse energy
  - *b*-tagging
  - Finish with some thoughts about future luminosity challenges
- Several of these topics could easily fill the entire half hour
  - We'll do our best with 1-3 slides each

Jet Reconstruction

- Anti-kT reconstruction, cone-size 0.4
  - Initially EM-scale, then corrected to hadronic-scale
    - Tuned to agree with MC truth jets
  - Direction altered to point at PV
    - Further corrected to account for detection biases
  - Energy from multiple-interactions subtracted
- Veto fake jets
  - Remove jet if within $\Delta R < 0.2$ of analysis electron (isolated, $E_T >$ 25 GeV)
  - If jet has unphysical timing or shape event is rejected
    - Removes noise spikes, cosmics

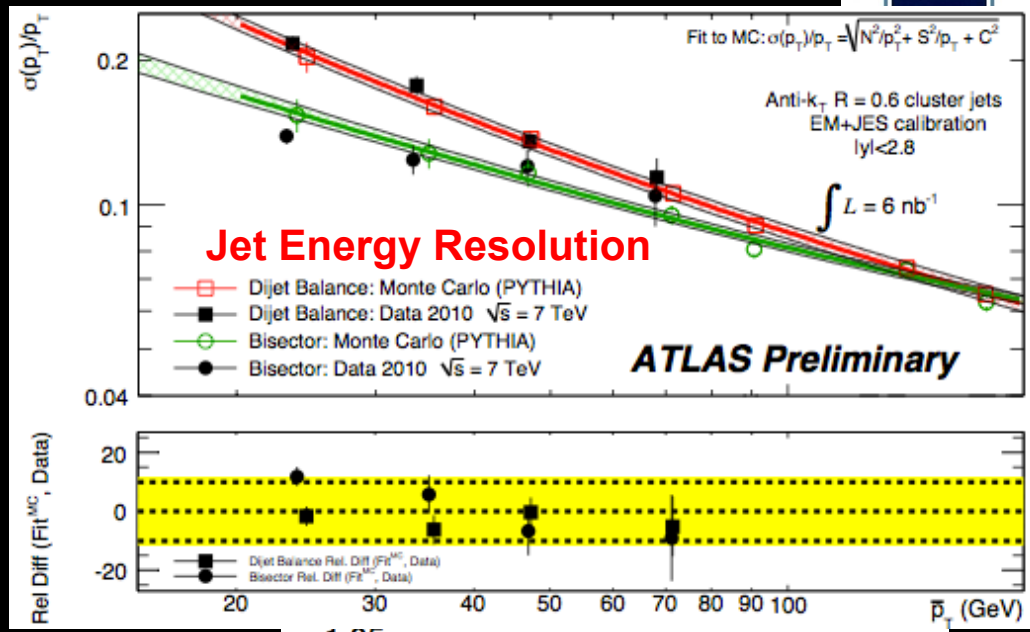


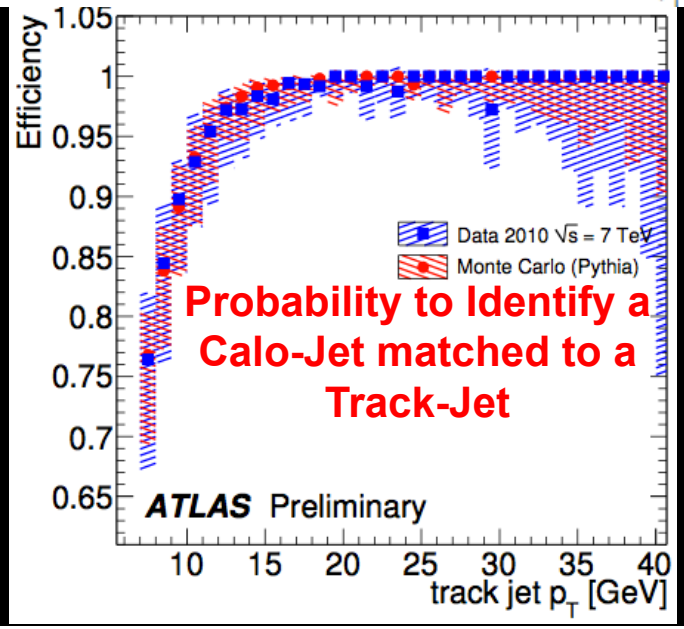


Jet Efficiency and Resolution

- Jet resolution
  - Measured in two dijet analyses
    - Sensitive to different syst. uncertainties
    - Results consistent to within 2%
  - Smear MC jets within uncertainties to get systematic

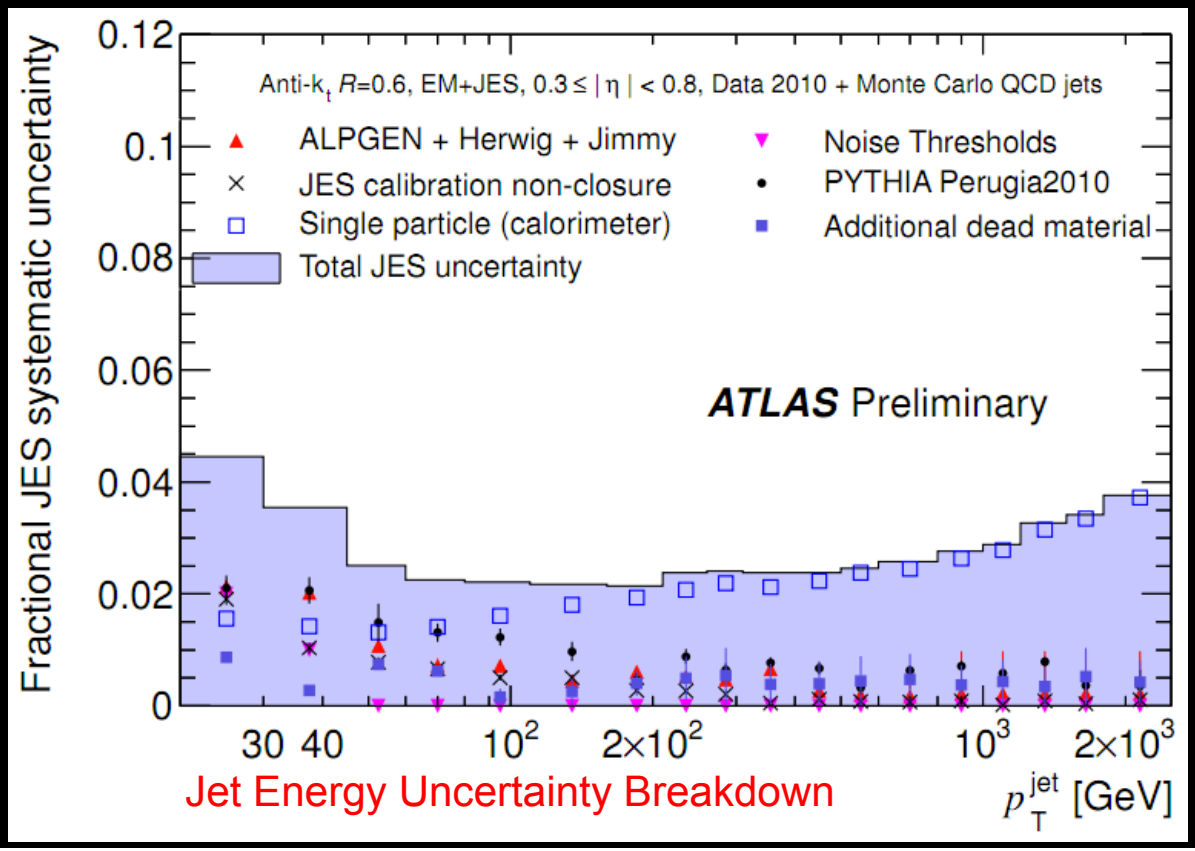
- Jet reconstruction efficiency (~97% for top jets)
  - Determined from fraction of time track jet matches calo jet
  - Data-MC agreement to ~1% level





Jet Energy Scale

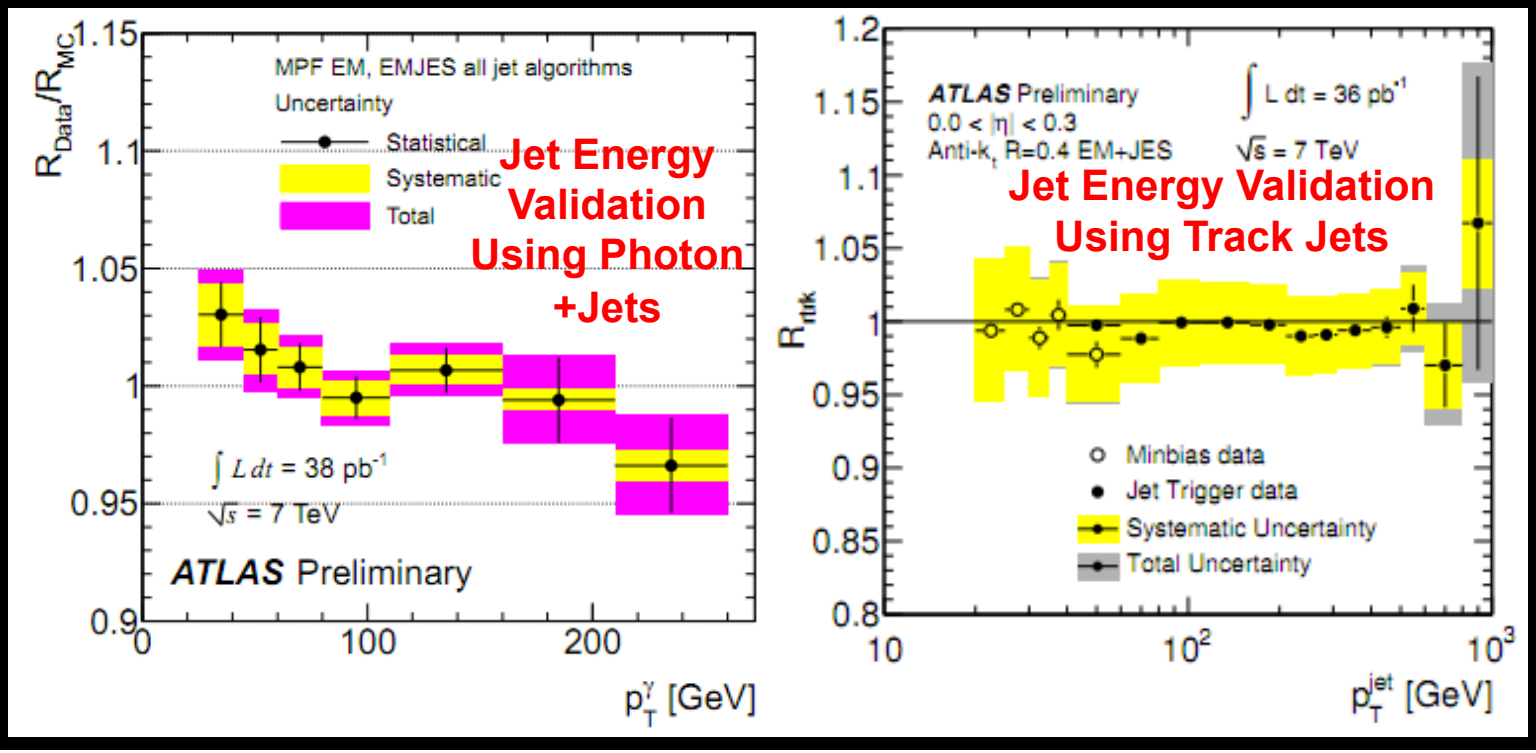
- Many categories of uncertainty, mostly measured from studies in MC
  - Flavor: Gluon vs quark jet composition, *b*-jet energy
  - Detector material, Calorimeter noise
  - Calorimeter response: from test beam, track-vs-calo comparisons
  - Calibration projections to high-eta
  - Pileup: 0% (high jet p_T, central) – 7% (low jet p_T, forward)



Jet Energy Uncertainty Breakdown

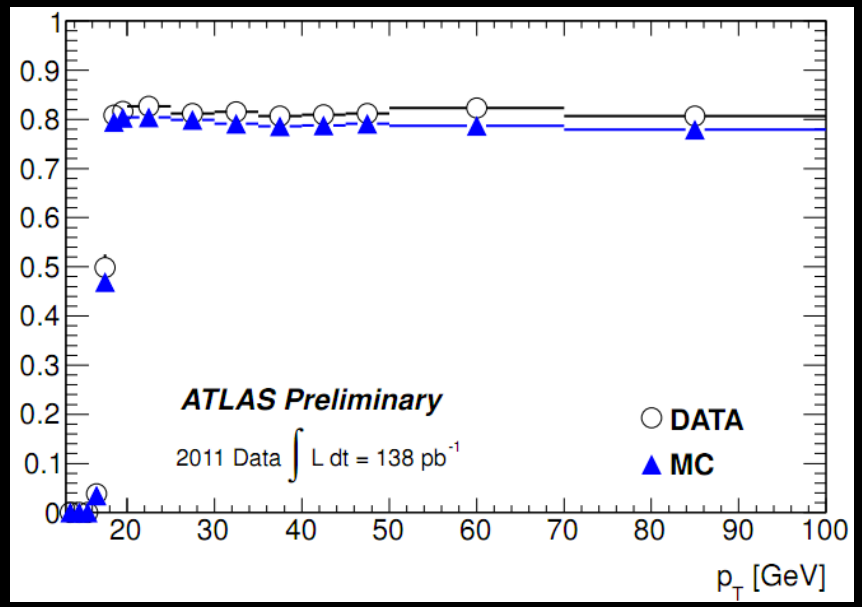
Jet Energy Cross-Checks

- Photon+jet balance
  - Assuming MET in photon+jet event comes from jet mismeasurement, calibrate
- Track-Jets
  - Use track-jets to cross-check calorimeter jet energies, compare between data and MC
- All cross-check results consistent within uncertainties



Atlas Muons

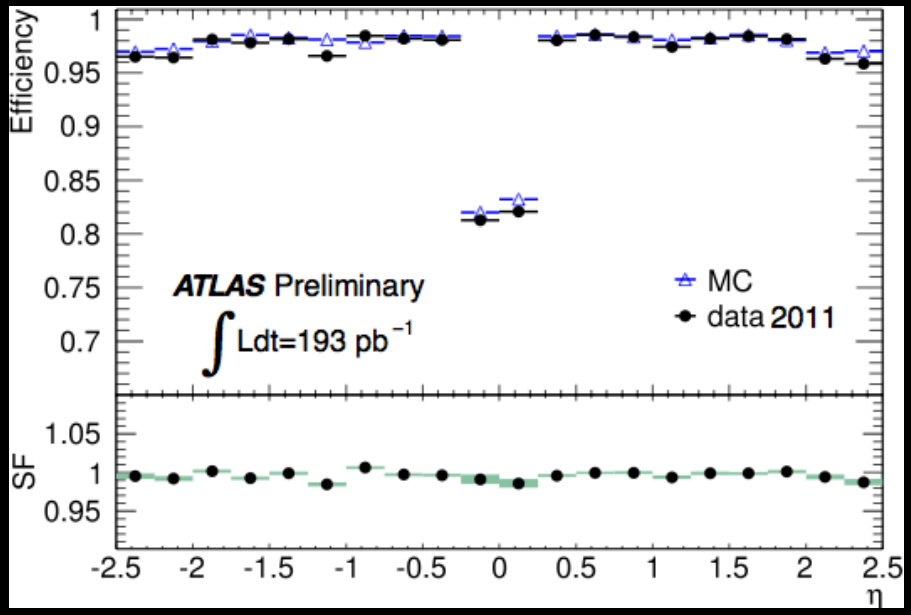
- μ's trigger on p_T > 18 GeV
  - Offline 20 GeV cut to be in plateau
  - Geometry requires |η| < 2.5
  - Offline/online muons must match ΔR < 0.15
- Offline μ reconstruction
  - Fit separately in inner-tracker/μ system
    - Then combined fit to all muon hits
  - Accept μ's up to |η| < 2.5
  - Require isolation in both tracker and calorimeter



Atlas Muon Trigger Efficiency

Muon Efficiency Calibration

- Similar calibrations for e's, μ's:
  - "tag-and-probe": find one lepton from a Z, how often is the second one identified inside mass window?
  - Binning in η needed
- μ's calibrated in three steps:
  - Trigger: how often is second μ identified by trigger?
  - Reconstruction: how often is hard track identified as μ?
  - ID: How often does reco-muon pass isolation cuts?



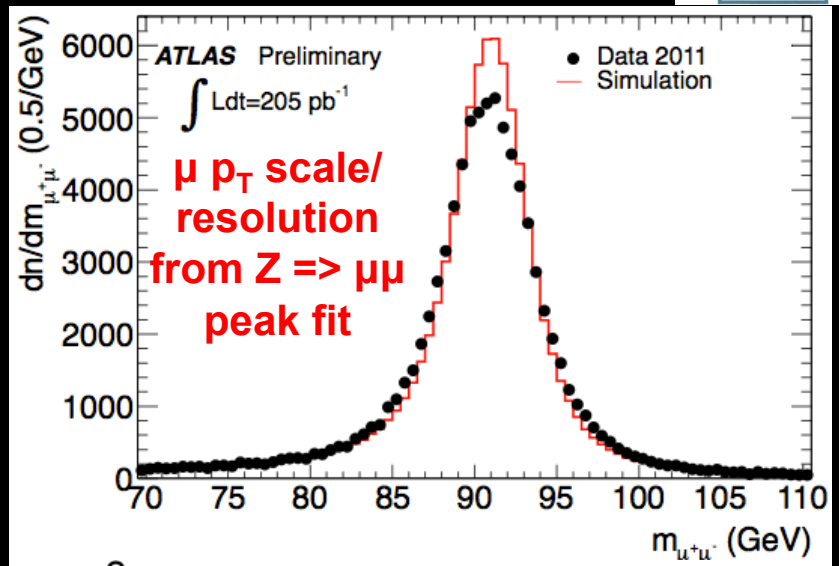
Efficiency to identify μ given inner-detector track

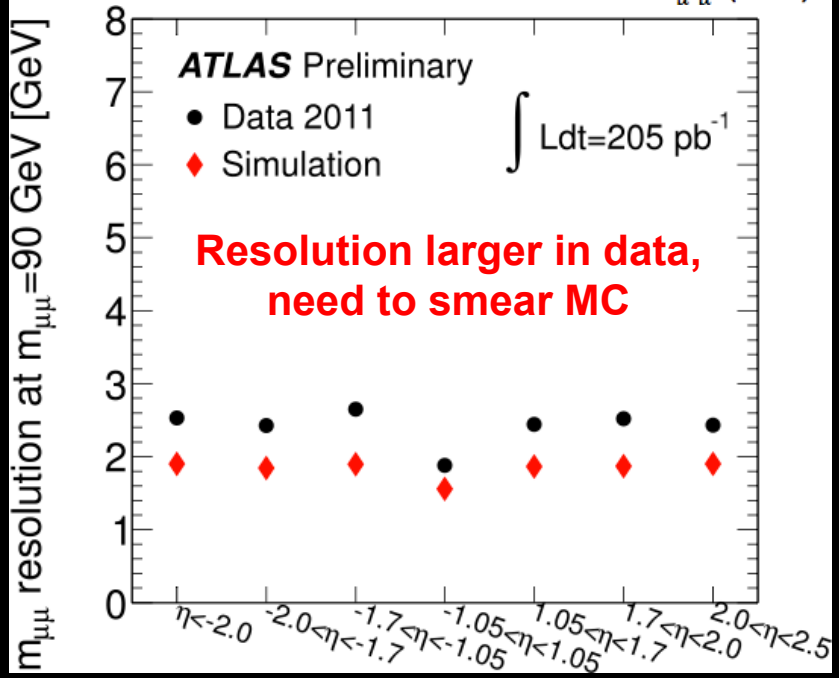
Single-Muon Efficiency Calculation:

$$\epsilon_\mu^{full} = \epsilon_\mu^{trig} \epsilon_\mu^{reco} \epsilon_\mu^{id}$$

Muon p_T Calibrations

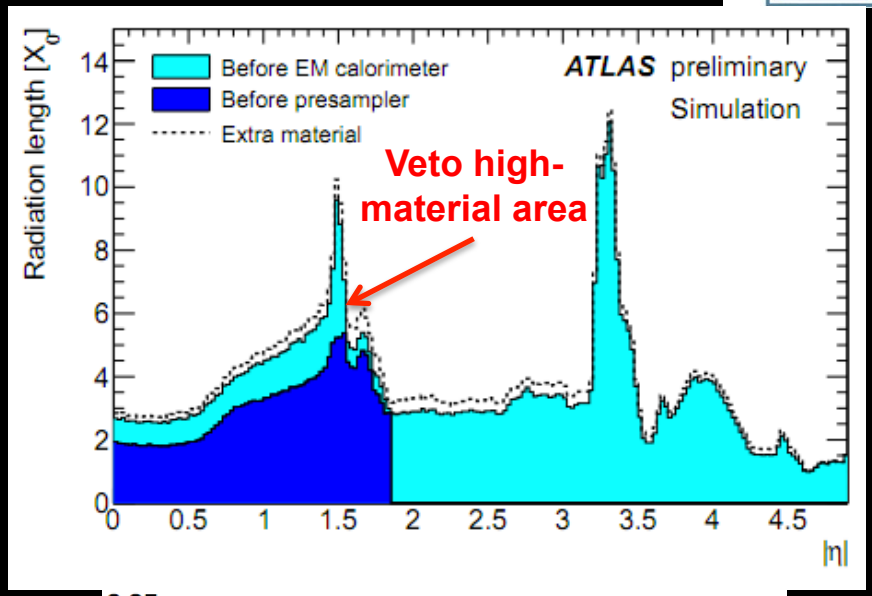
- Calibrate μ p_T scale and resolution with Z-mass fit
  - And W=>μ ν decays, comparing inner-detector and muon-system tracks
- Resolution larger in data than in simulation
  - Mostly because of misalignment of inner detector and muon system
  - Fixed in upcoming software update
- These results: rescale and smear μ's in MC to match data resolution

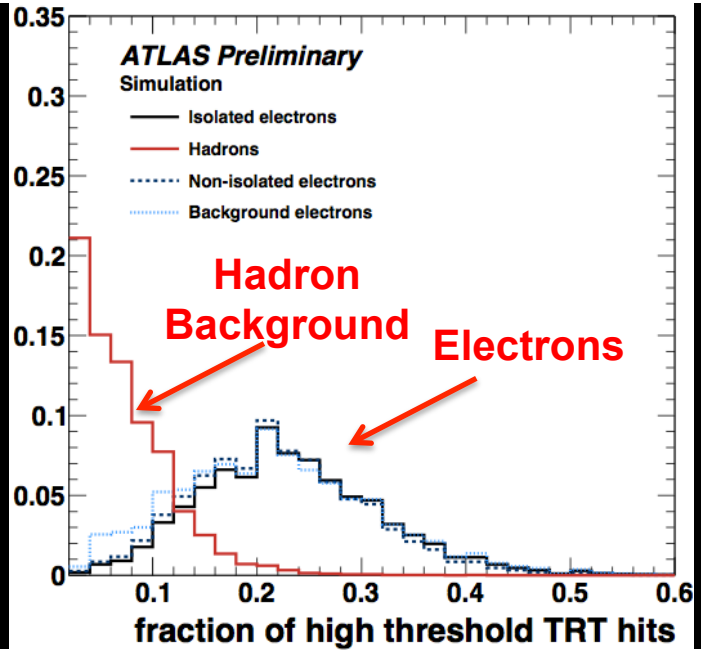




Atlas Electrons

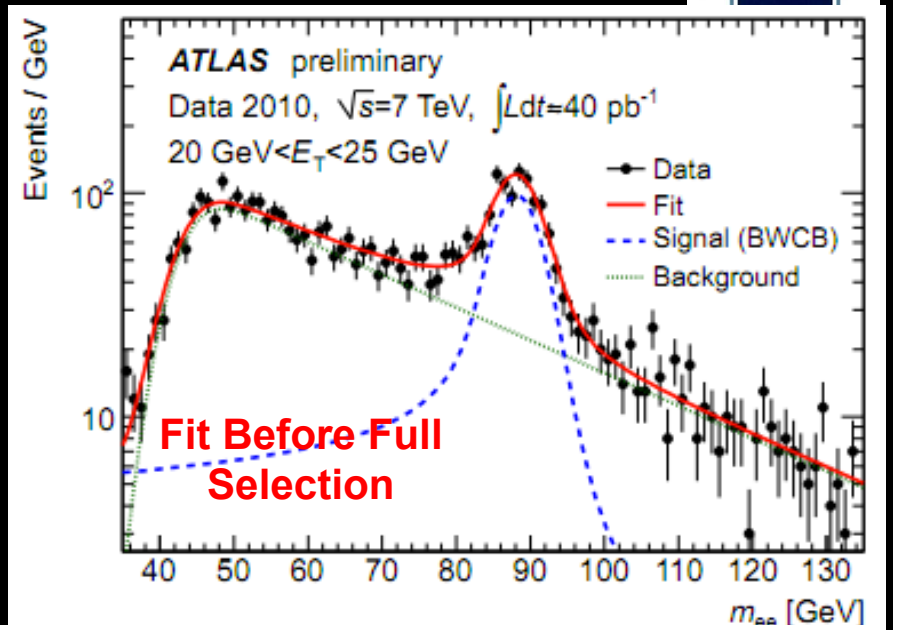
- Electrons trigger on p_T > 20 GeV
  - Offline select E_T > 25 GeV
  - |η| < 2.47 and not in transition region
  - Must match trigger
- Unusual trick at Atlas: Require electron-like "transition radiation" in tracker
  - Fraction of hits above higher threshold
- Other common quality cuts:
  - Must be isolated in calorimeter
    - After correcting for electron deposit and pileup
  - Cluster shape and depth
  - Leakage into hadronic calorimeter < ~1%
  - pT and direction matching to track
  - Conversion veto

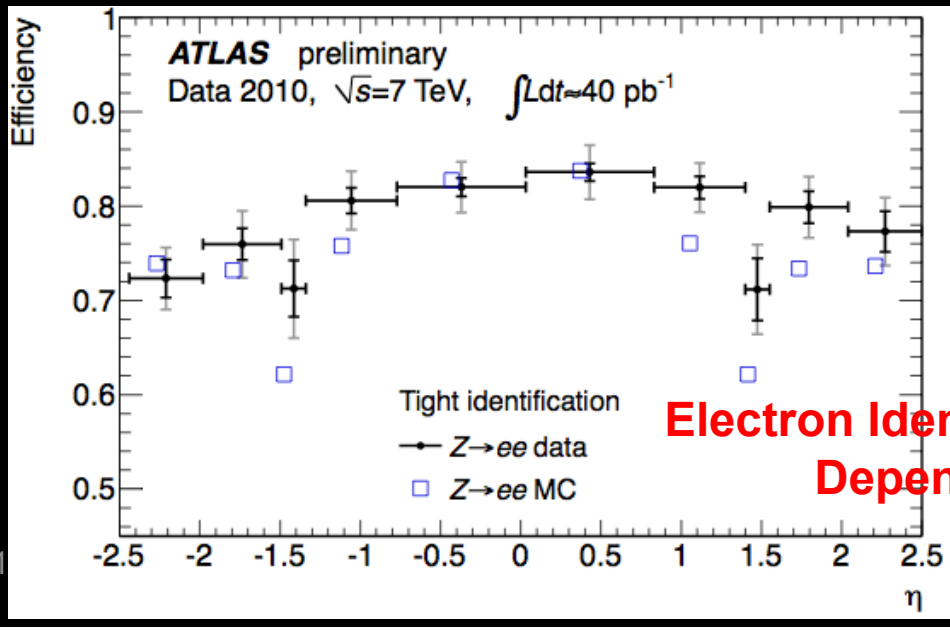


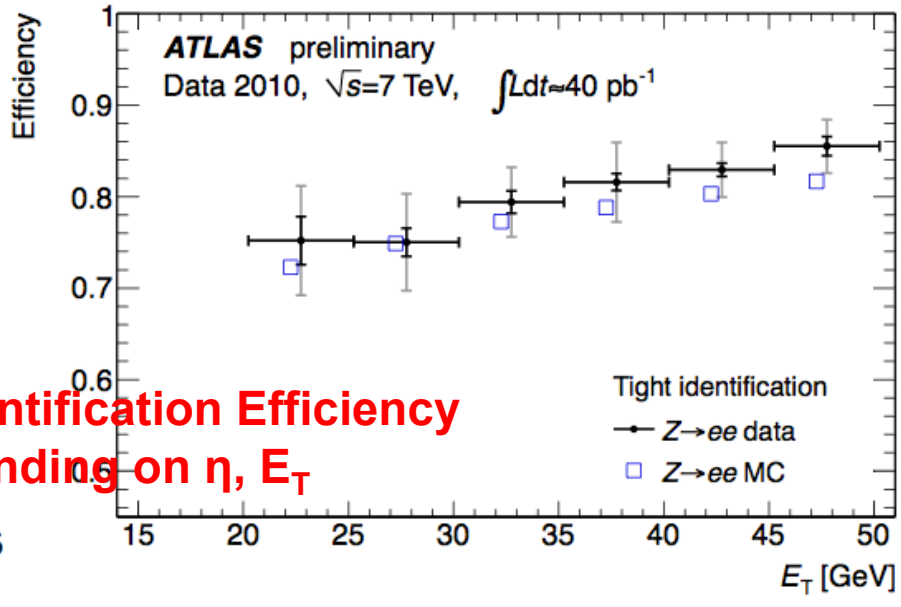


Electron Efficiency Calibrations

- Calibrate with J/ψ, Z => ee, W => eν data
  - Fit to determine number before/after selection cuts







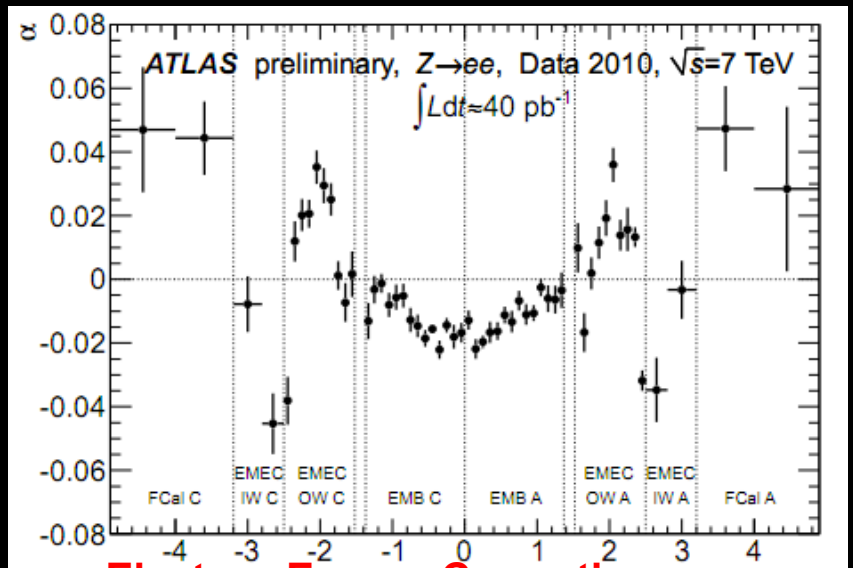
Electron Identification Efficiency Depending on η, E_T

Electron Energy

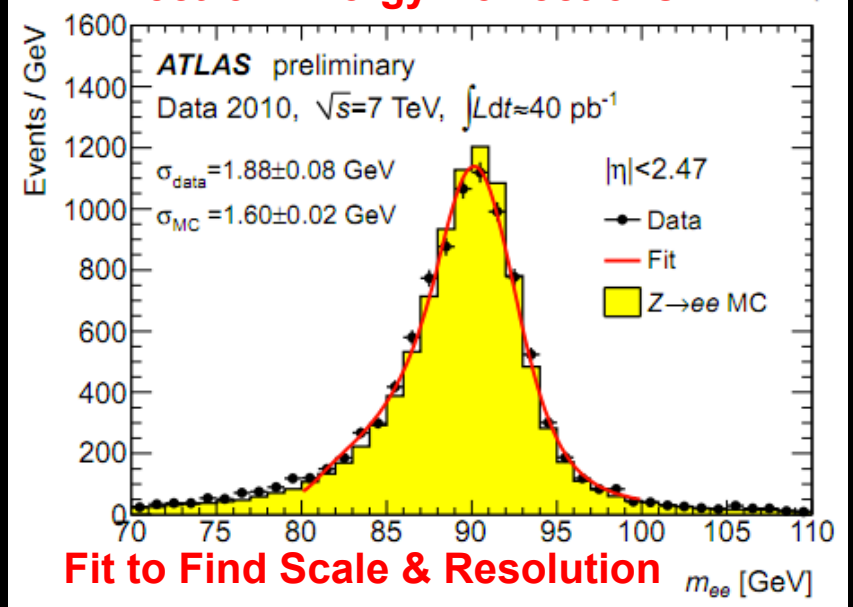
- Electron energy scale & resolution parameterized by

$$E^{true} = \frac{E^{meas}}{1+\alpha_i} \qquad \frac{\sigma_E}{E} = \frac{a}{\sqrt{E}} \oplus \frac{b}{E} \oplus c$$

- Scale and resolution determined from fit to Z-mass peak
  - Resolution is larger in data
    - smear MC
  - Cross-check with fit to low-p_T J/ψ's, track p_T comparisons
  - Scale uncertainties < ~1%



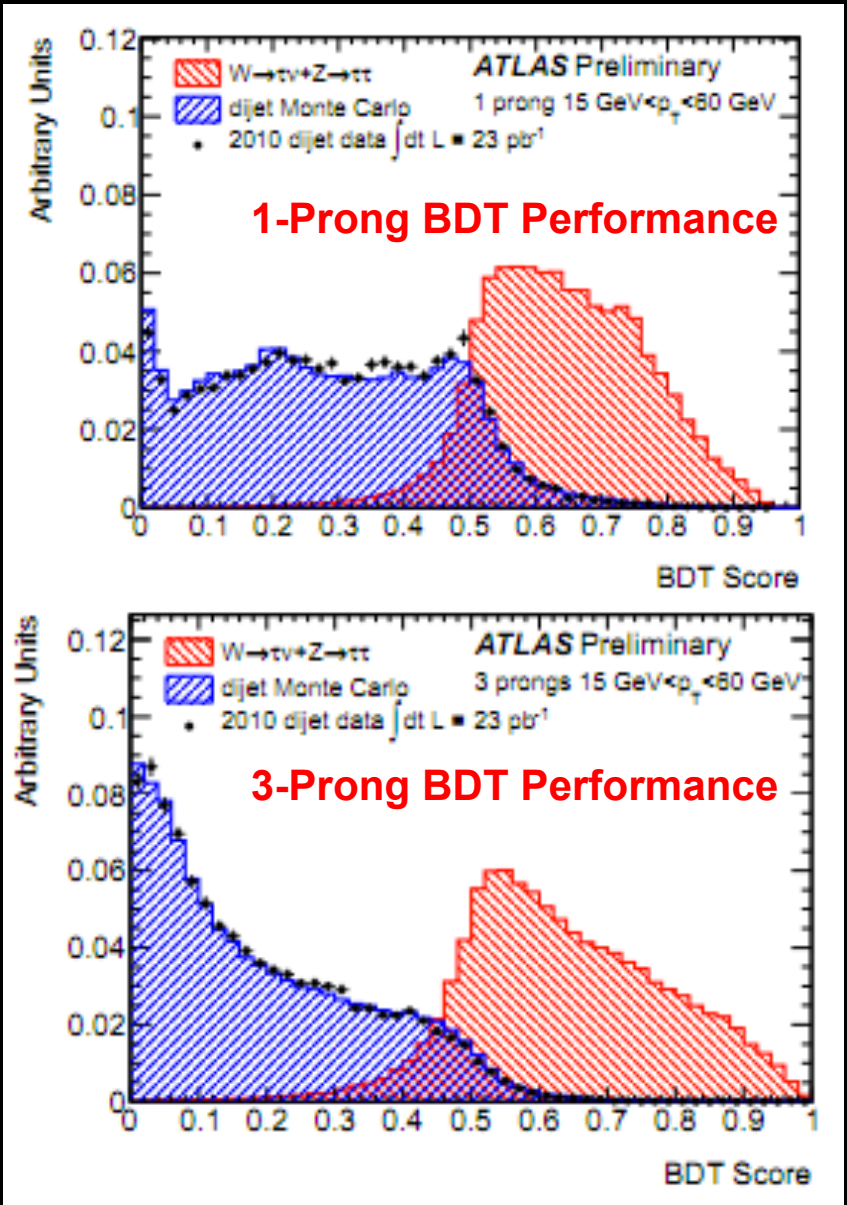
Electron Energy Corrections



Fit to Find Scale & Resolution

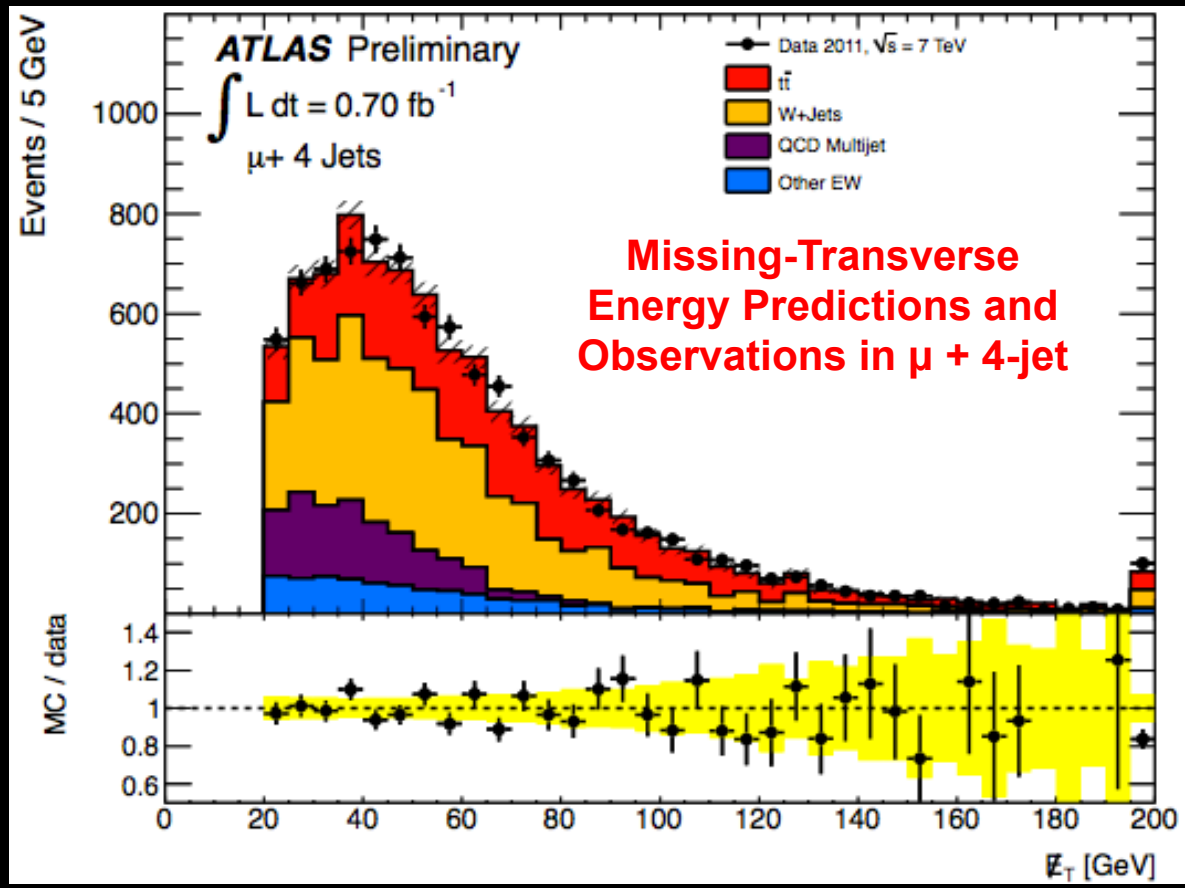
Atlas Taus

- Atlas has one analysis searching for hadronic taus in top decays
  - Seeded by jets, associated with 1 or >=3 tracks
  - Jet and Electron fakes removed with separate boosted decision trees
- Decision trees based on …
  - Shape in calorimeter and tracking
  - Transition radiation produced in tracker (1-prong)
  - Momentum of leading track
  - Displacement of vertex (3-prong)
  - Vertex mass (3-prong)



Atlas Missing Transverse Energy

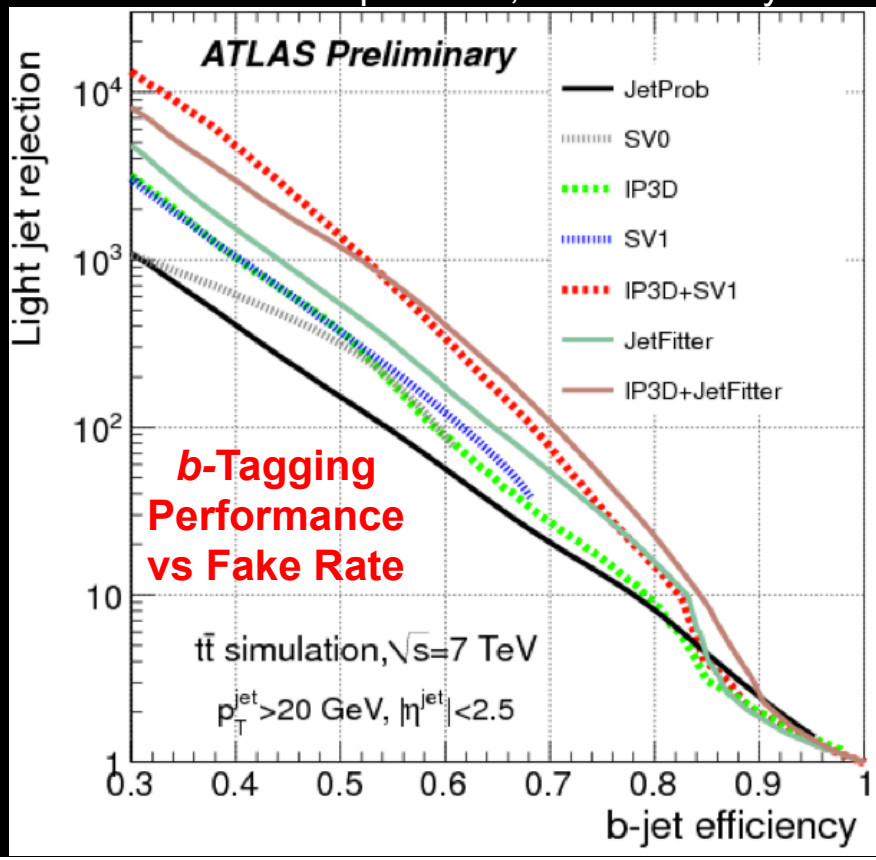
- Missing transverse energy is calculated from formula below
  - Jets corrected to hadronic scale if p_T > 20 GeV
    - Priority left-to-right: jets overlapping electrons counted at EM-scale
  - Pileup: 10% uncertainty on unclustered energy

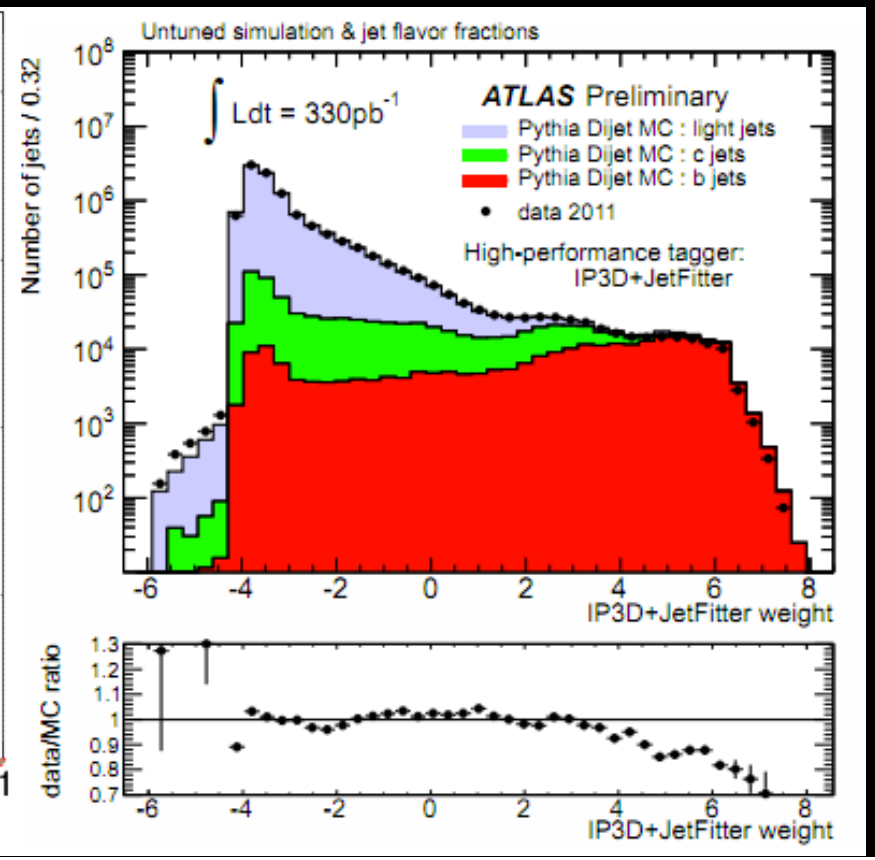


$$E_{x,y}^{Miss} = E_{x,y}^{ele} + E_{x,y}^{pho} + E_{x,y}^{tau} + E_{x,y}^{jet} + E_{x,y}^{soft-jet} + E_{x,y}^{\mu} + E_{x,y}^{cell}$$

b-Tagging

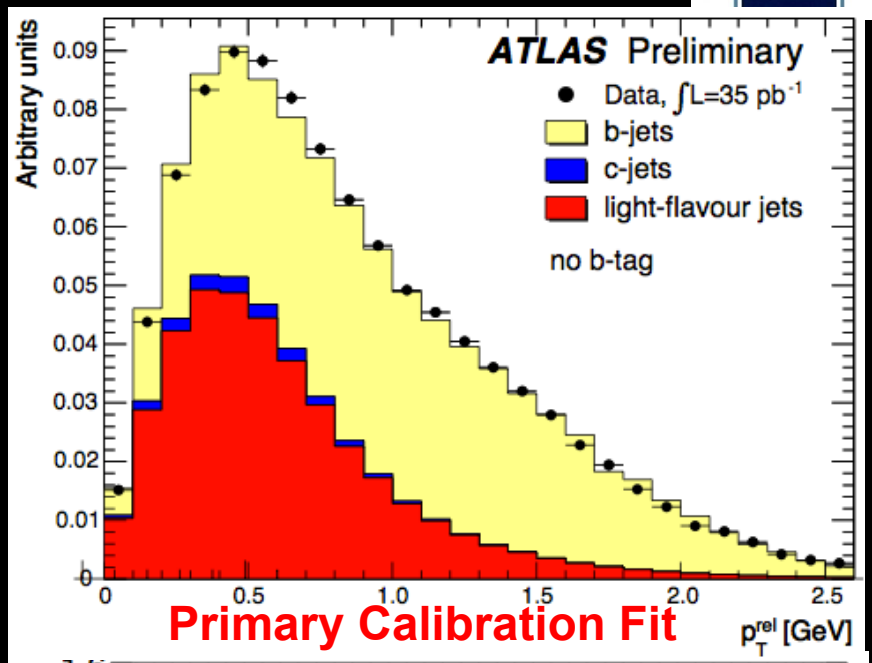
- Two *b*-tagging algorithms used for Atlas top
- "SV0": Fit displaced tracks to single vertex.
  - Tag jet if significantly displaced from Primary vertex
  - Used for 2010 results
- "IP3D+JetFitter": fit for multiple vertices and study non-vertexed tracks
  - Vertex masses, momenta, track counts, and track properties input to tagging decisions
  - Much more powerful, used for many new results



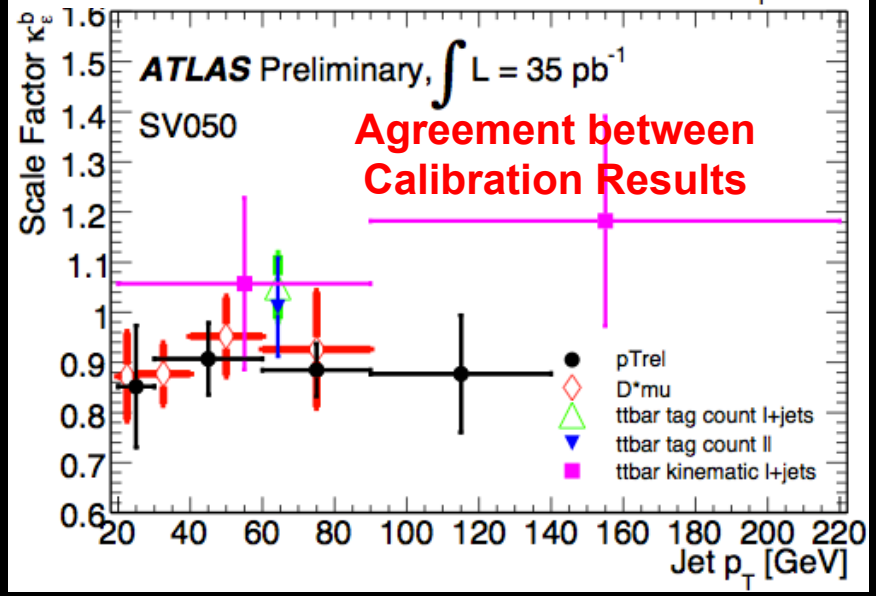


b-Tagging Calibrations

- *b*-Tagging efficiency: 5 separate calibrations
- Primary:
  - Fit to muon transverse momentum relative to jet axis
- Cross checks:
  - Fits to D*μ *b*-hadron decay peak
  - Three ttbar measurements
    - Low stats in 2010 data, but should be most sensitive calibrations in future



Primary Calibration Fit



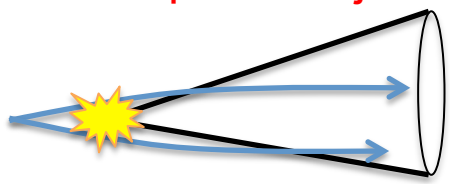
Agreement between Calibration Results

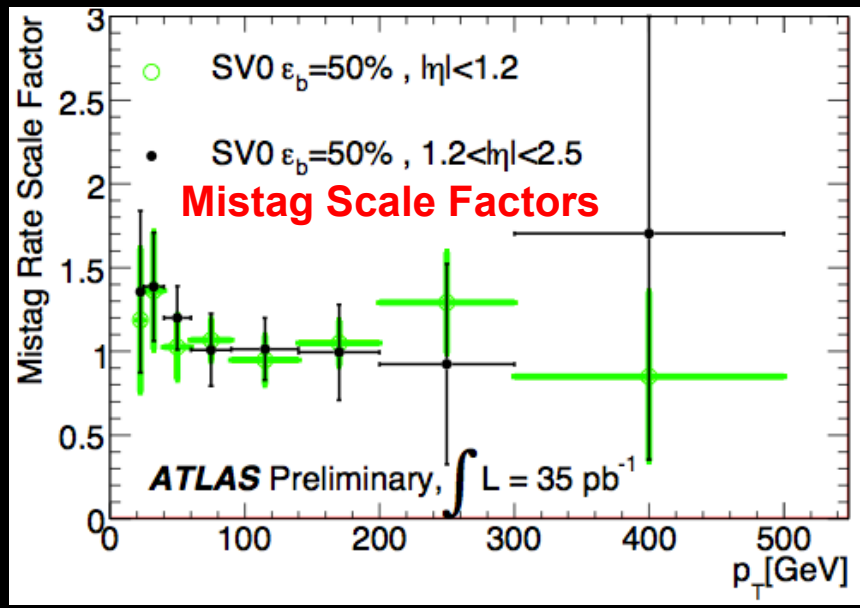
Fake *b*-Tag Calibrations

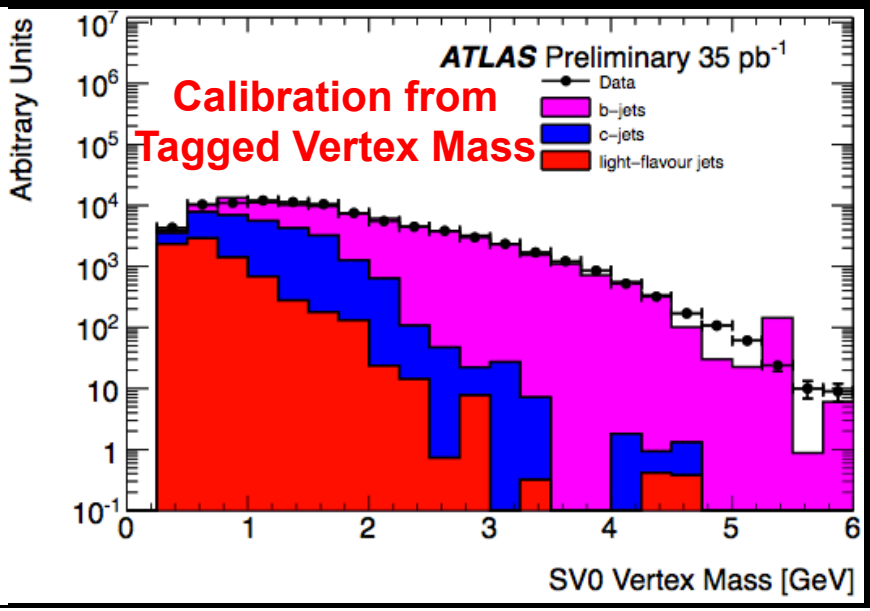
- For charm-jets:
  - Very hard to directly calibrate
  - Instead assume same scale factors as for *b*-jets, x2-uncertainty
    - Reasonable because physics similar to *b*'s
- Non-charm mistags: 2 calibrations, combined
  - Unphysical-tracking ("negative")-tag control region
  - Fits to tagged vertex mass

Calibration from "Negative-Tags" …

Uses tracks displaced on wrong side of primary vertex compared to jet

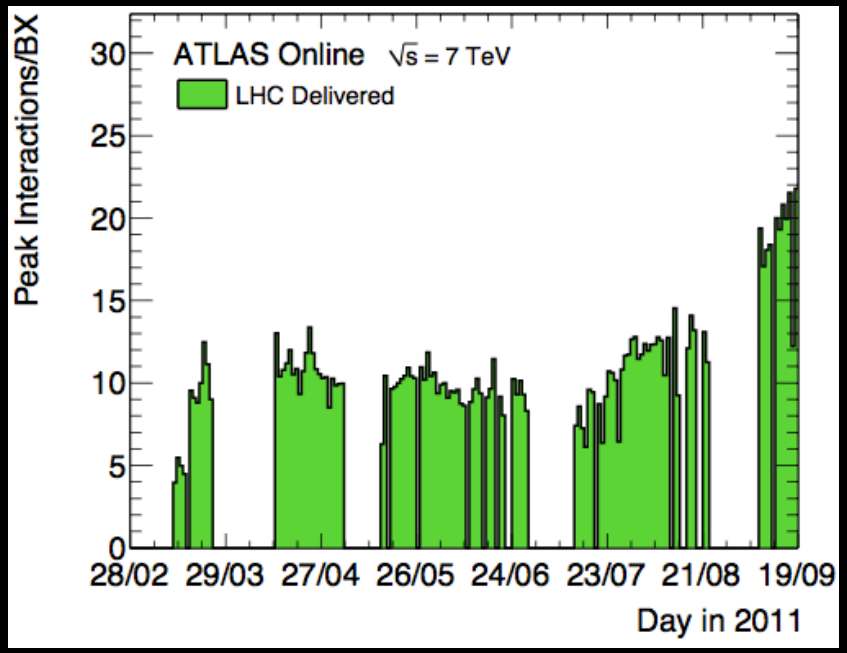






Future Luminosity Challenges

- Trigger issues:
  - Unprescaled single-lepton triggers no longer possible
  - Future strategies being discussed
- Pileup: Lepton definitions robust except for isolation cuts
  - Tracker isolation much less dependent
- Pileup jets contaminate analyses
  - Future: may veto by requiring consistency with primary vertex
  - Pileup jets not *b*-tagged. *b*-tagging fake-rate calibrations not robust unless pileup jets removed.



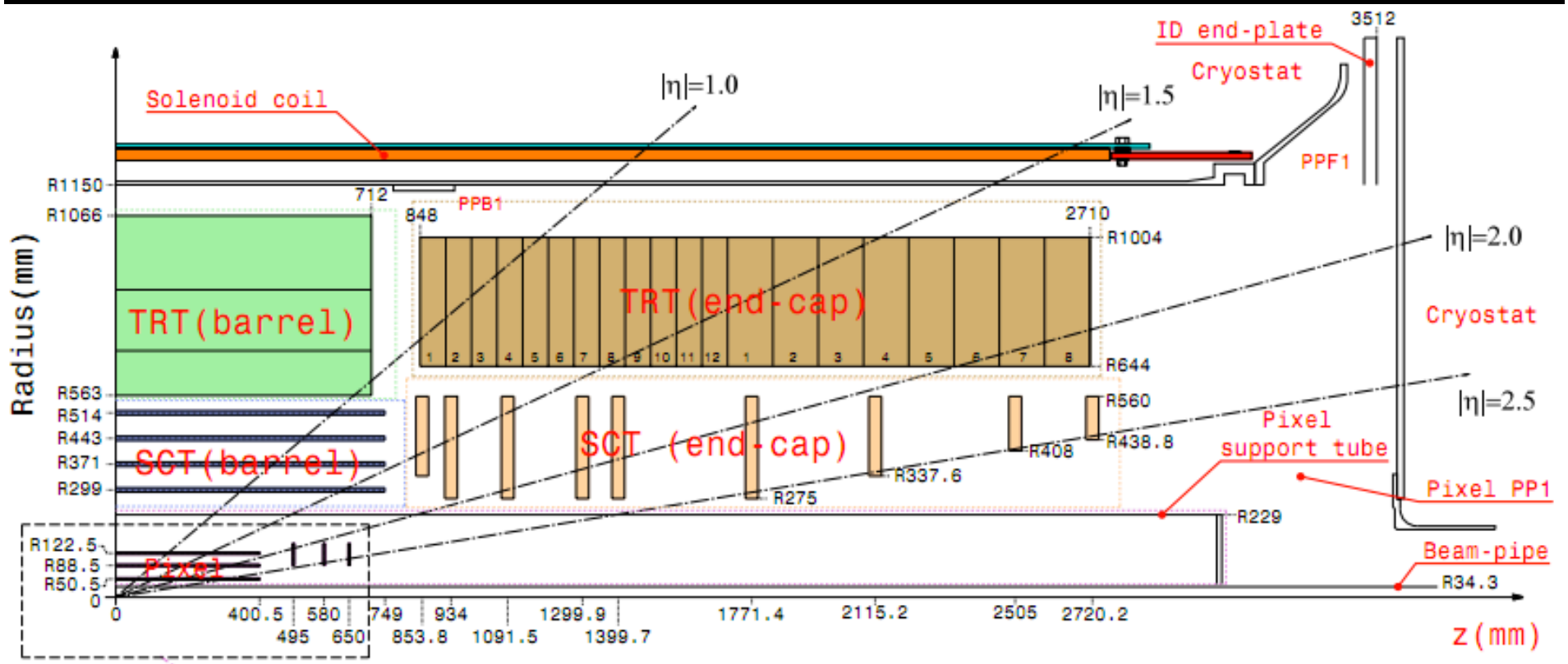
Number of Pileup Interactions Increasing over Time

Summary

- Have discussed most of the common objects and tools required for top analyses

- Some documents to explain in more detail:
  - Jet energy calibration: ATLAS-CONF-2011-032
  - Electron performance: ATLAS-PHYS-PUB-2011-007
  - Muon reconstruction: ATLAS-CONF-2011-063
  - Muon momentum calibration: ATLAS-CONF-2011-046
  - Taus: ATLAS-CONF-2011-077
  - Missing ET: CERN-PH-EP-2011-114
  - Advanced *b*-taggers: ATLAS-CONF-2011-102
  - *b*-tagger calibration: ATLAS-CONF-2011-089

Backup: Inner Detector



Atlas Inner Detector System

Most objects are limited by
tracking system limit of |η| < 2.5