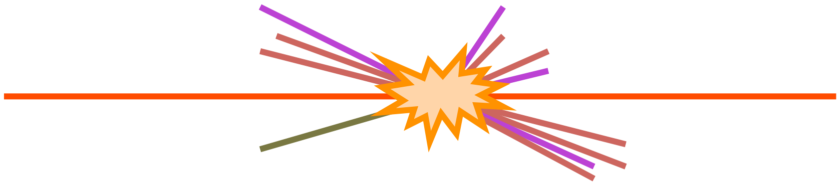
Top-quark observables at particle level



W. H. Bell
Université de Genève

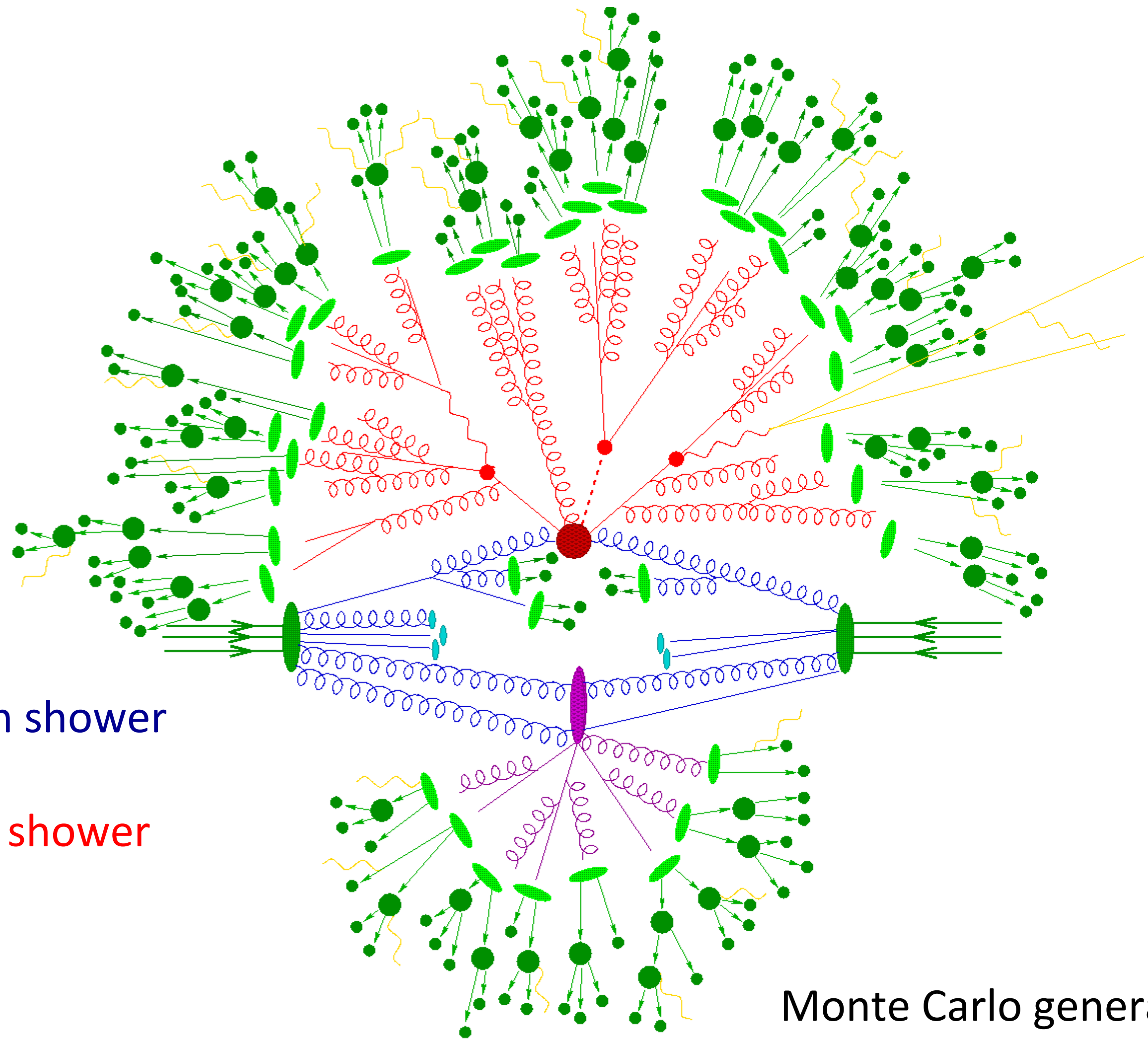
T. Dorland
DESY

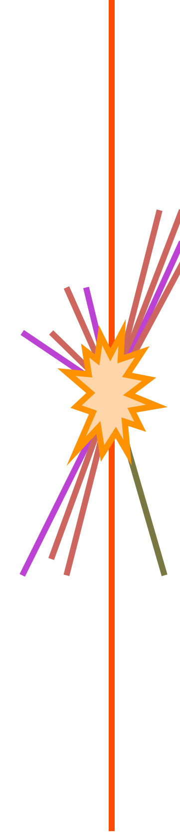
On behalf of the ATLAS and CMS collaborations

Outline

- Motivation
- Lepton selection
- Common object definitions
- Common event selections
- Pseudo-top definitions
- Conclusions

A proton-proton collision





Initial state parton shower
Signal process
Final state parton shower
Fragmentation
Hadron decays
Beam remnants
Underlying event

Monte Carlo generator representation
Sherpa

Leptons (e,μ)

- Detector reconstruction includes isolation (p_T and E_T, ΔR sum).
  - Heavy flavour decays are excluded and modelled as a background component.
- The leading lepton in a W/Z inclusive selection is mostly from the W/Z decay.
  - Leading lepton is used in RIVET versions, which does not match implementation used in ATLAS/CMS jet clustering.
- 20% of leading leptons in ttbar decays are from b-decays.
  - Effect is significant for W+HF and VH to bb+lx decays too.
  - Excluding just b-decay leptons would leave leptons from charm, dalitz decays, etc..

Leptons (e,μ)

- Cannot require particle-level isolation, since experimentally determine lepton efficiencies from inclusive Z to ll decays.
  - The lepton efficiencies include underlying event radiation and are calibrated against the inclusive set of Z to ll decays.
- Cannot use W/Z boson matching or ATLAS SHERPA hack
  - Interference effects or off-shell masses within matrix element calculation.
  - Need a longer term fix for all cases of V to leptons.
- Suggest "parent is not a hadron or quark" in lepton selection
  - Check one step up in the generator record.
  - Safe since 'experimentally' observable particles.

Leptons (e,μ)

- Lepton definition used for jet clustering must match lepton definition for event selection.
  - Should not hide a different lepton definition within particle filter.
- SM analyses (jet, W/Z) have presented jet results including muons and neutrinos from non-W/Z decay processes.

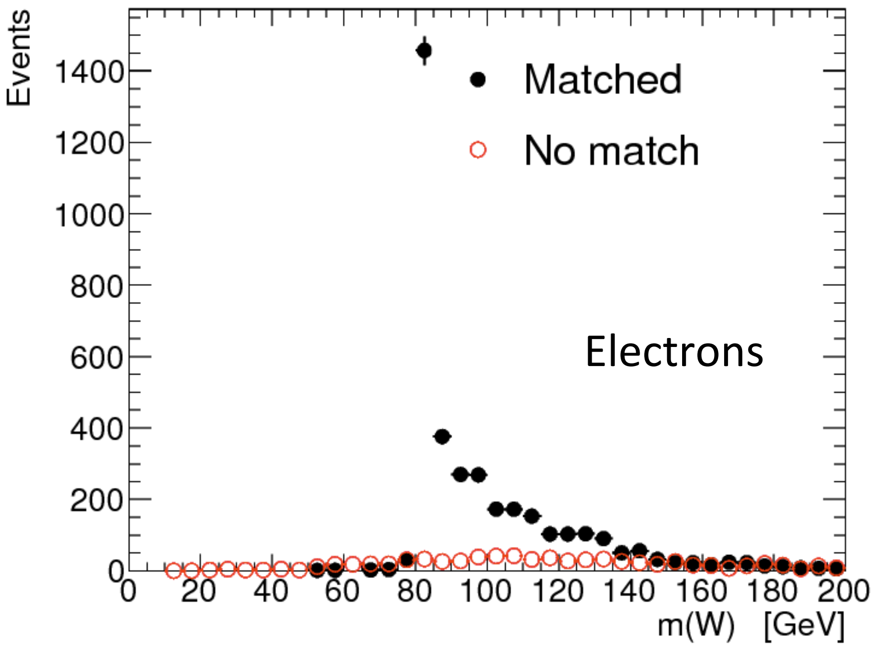
m(W) from leading lepton

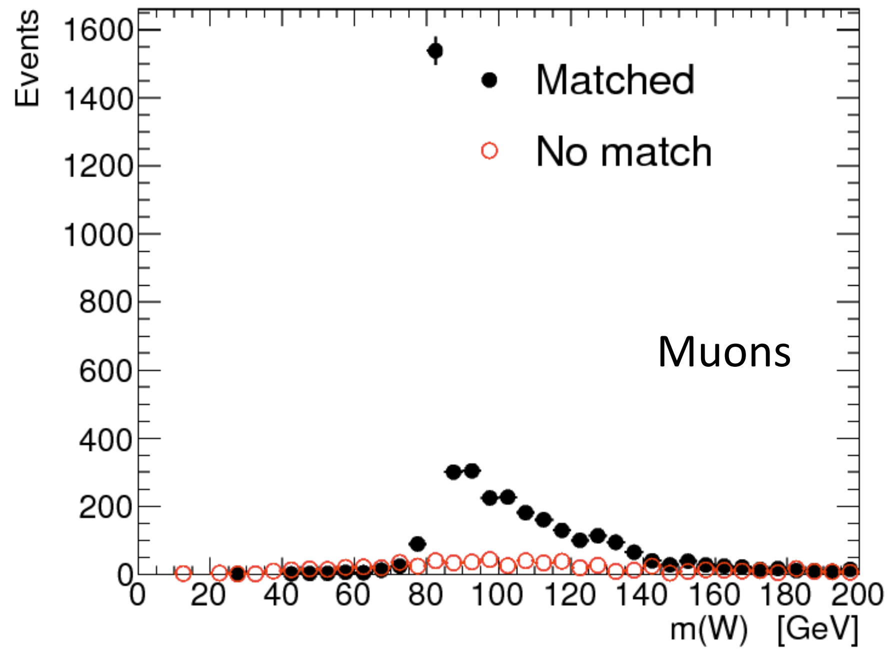
ALPGEN+HERWIG ttbar lnqq Np0 test sample

"Matched" implies generator record match.

Object selection only. No overlap removal. Leading electron or muon.

Electrons and muons dressed with photons within a $\Delta R = 0.1$ cone.





Number of events
Matched: 3591, not matched: 757

Number of events
Matched: 3783, not matched: 688

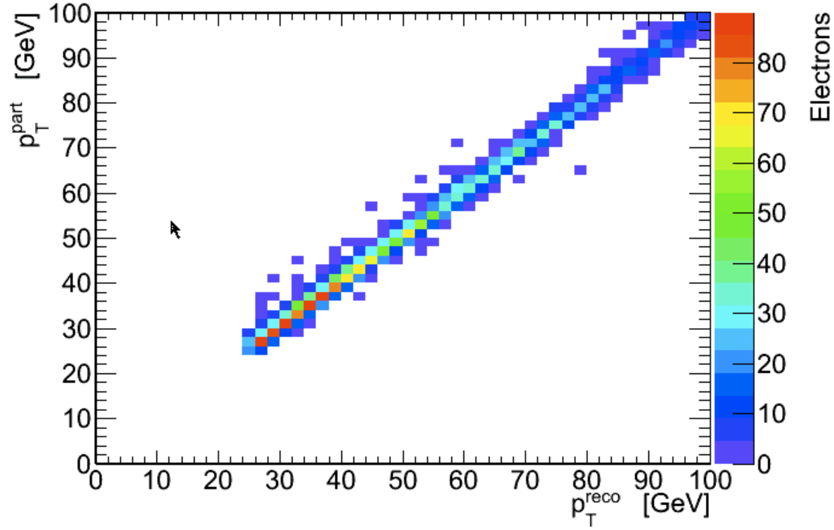
Common objects definitions

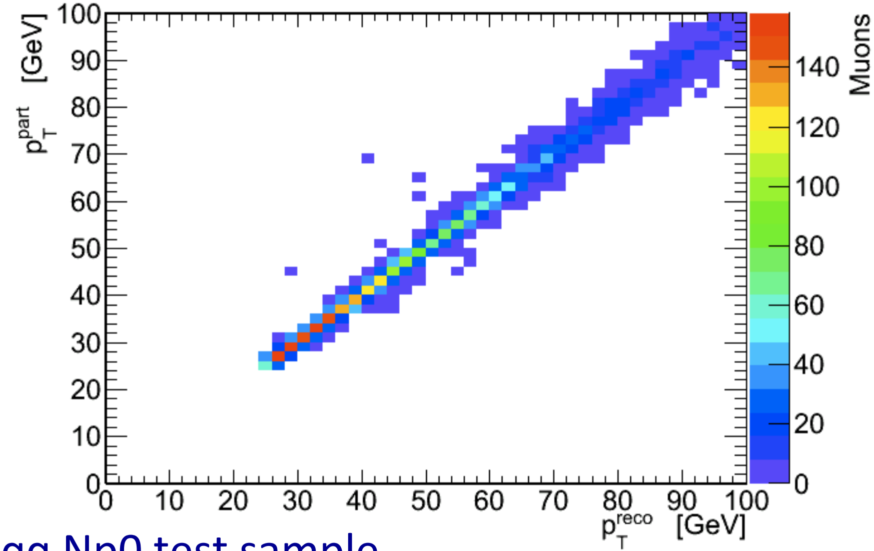
- Define objects from stable particles ($\tau > 0.3 \times 10^{-10}$ s).
  - Match reconstructed object definitions as closely as possible.
  - Objects required to be within observed pseudorapidity range.
- **Electrons**: stable electron and four-vector sum with photons within a ΔR cone of 0.1
  - Require lepton to be from W/Z decay*, excluding tau decays
- **Muons**: stable muon and four-vector sum with photons within a ΔR cone of 0.1
  - Require lepton to be from W/Z decay*, excluding tau decays.
- **Jets**: anti-k_t jets of stable particles with radius parameter 0.4/0.5
  - Cluster all particles (inc. muons and neutrinos) which are not from W/Z decay* into jets.
- **E_T^{Miss}**: four-vector sum of neutrinos from W/Z-boson decays*
  - Then use the transverse component and azimuth.
  - Including tau decays.
- **B-tag**: re-cluster the jet including B-hadrons with $p_T \approx 0$
  - b-hadron $p_T > 5$ GeV to improve correlations.
- **Overlap removal**: jet-electron, muon-jet, electron-muon, electron-jet

$$\Delta R = \sqrt{\Delta\phi^2 + \Delta\eta^2}$$

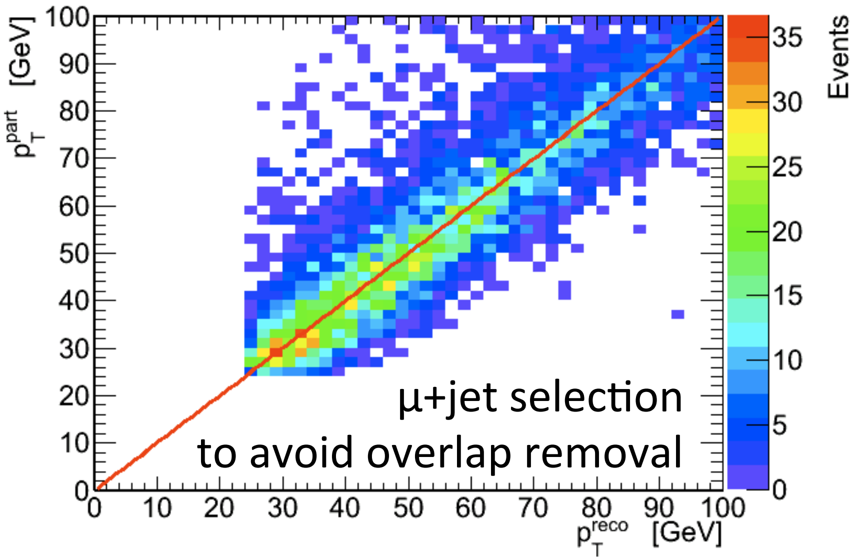
* - refers to parent is not a hadron or quark

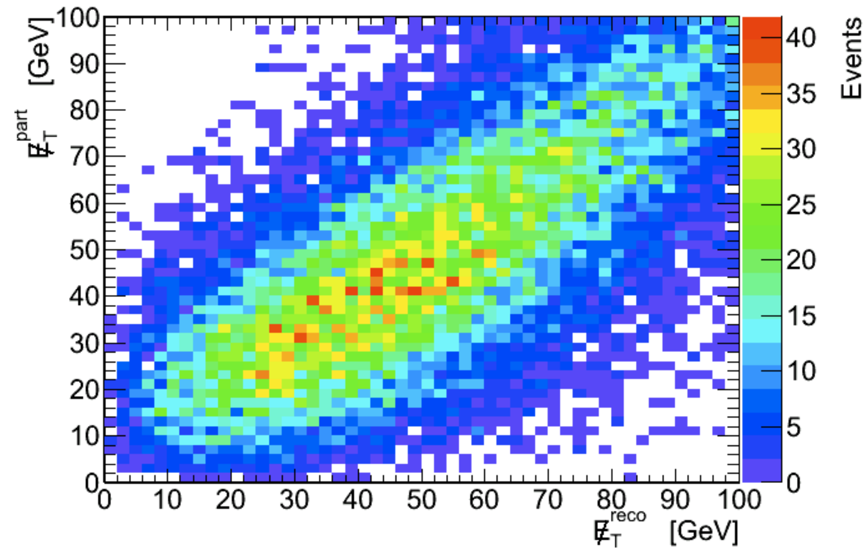
Object correlations after ΔR match



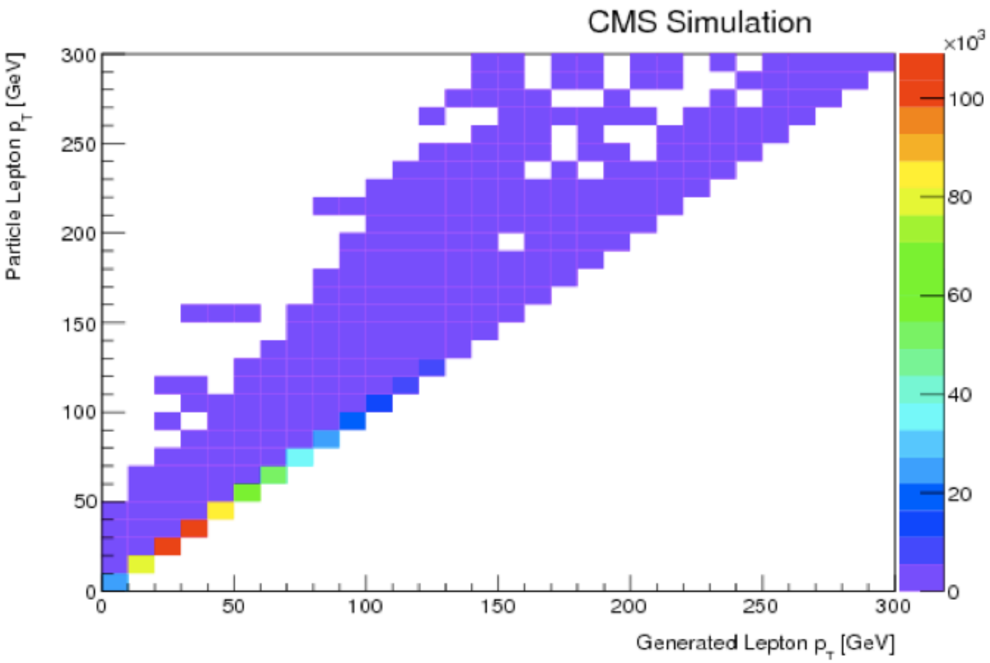


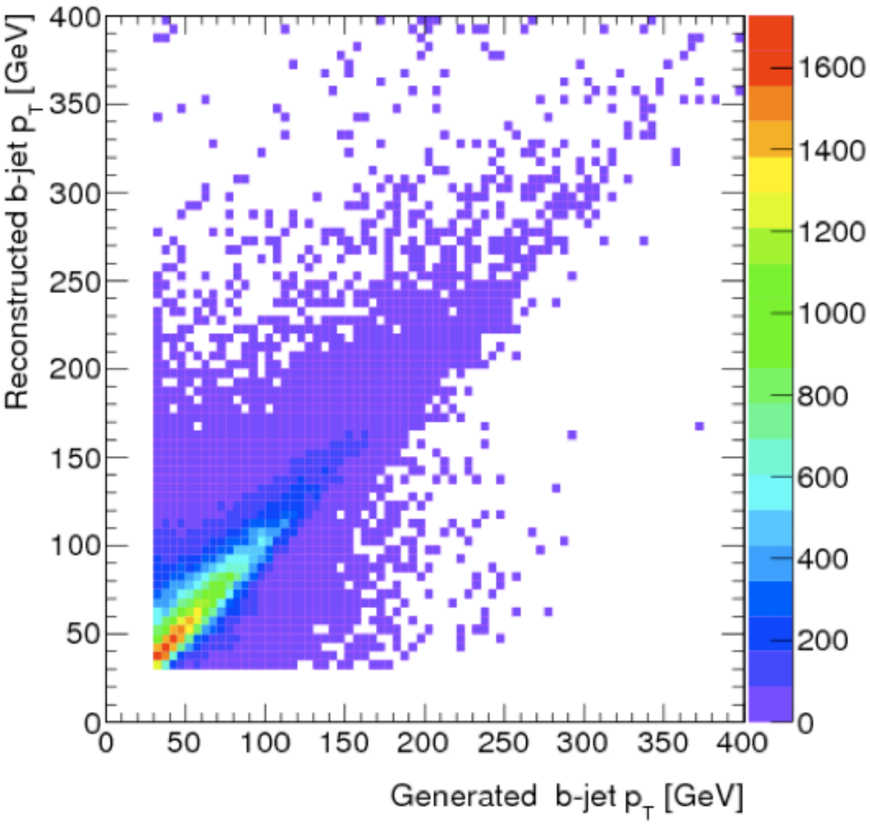
ALPGEN+HERWIG ttbar lnqq Np0 test sample





Object correlations

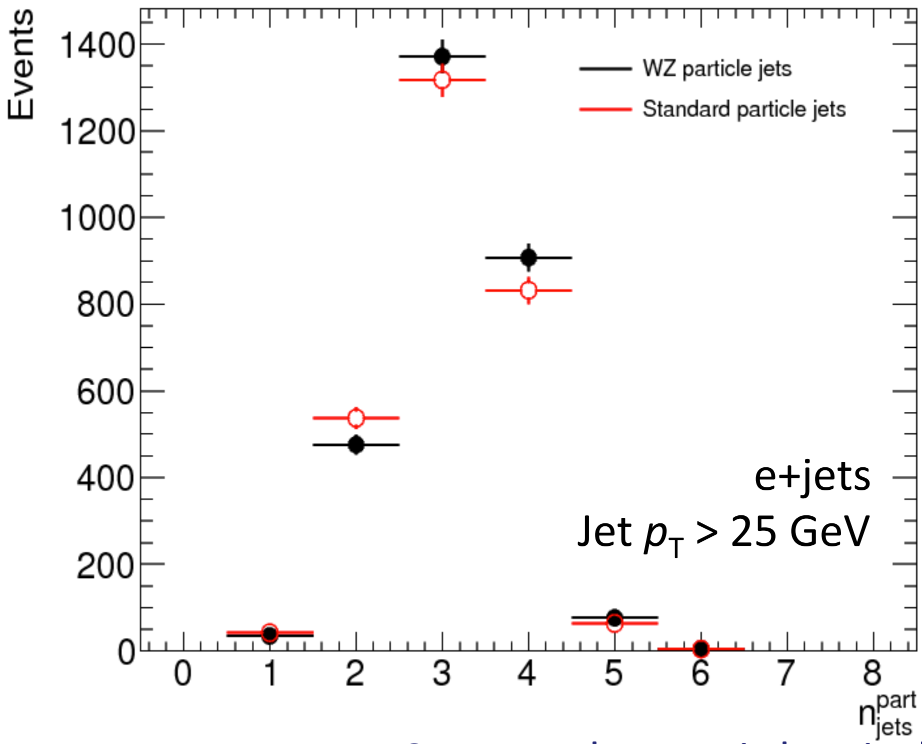


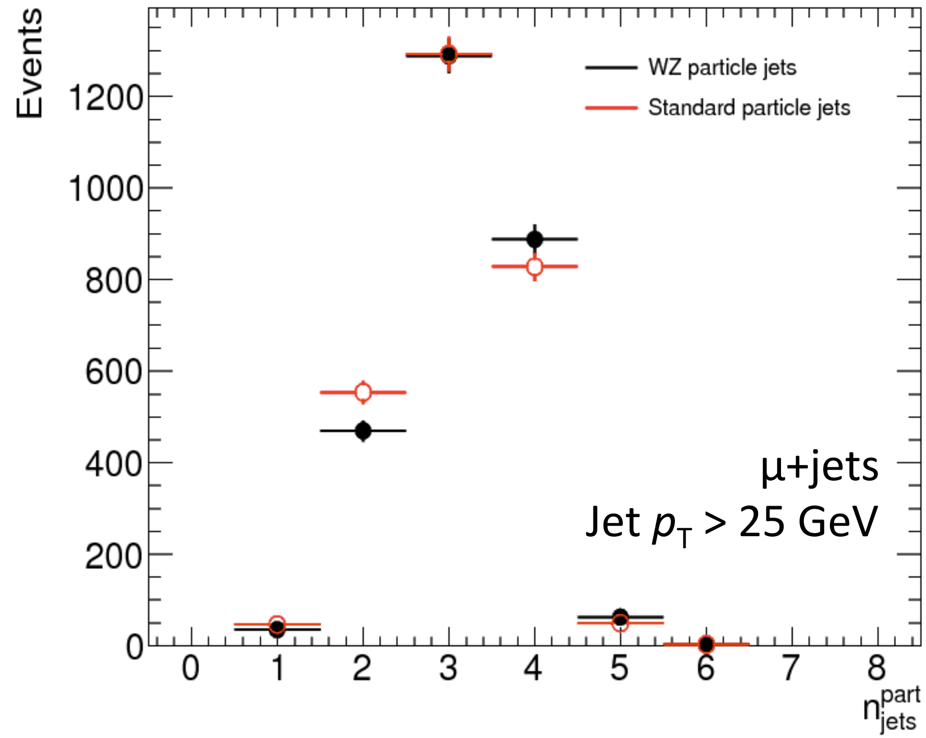


Particle-jet multiplicity

Using jets without (standard) with (WZ) muons and neutrinos.

Full particle-level event selection (single b-tag) except jet multiplicity requirement
ALPGEN+HERWIG tbar lnqq Np0 test sample



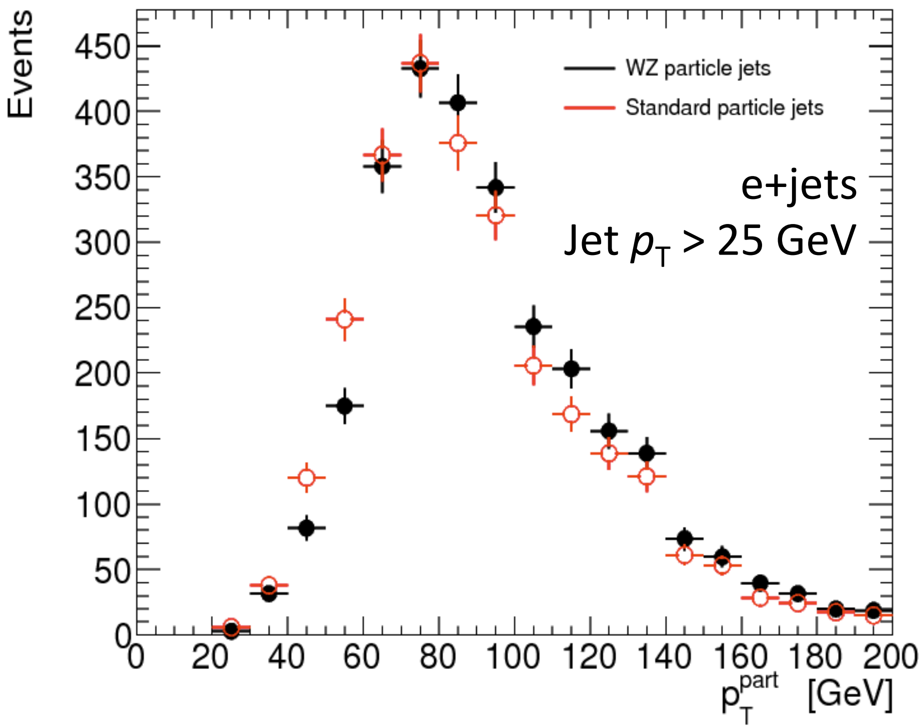


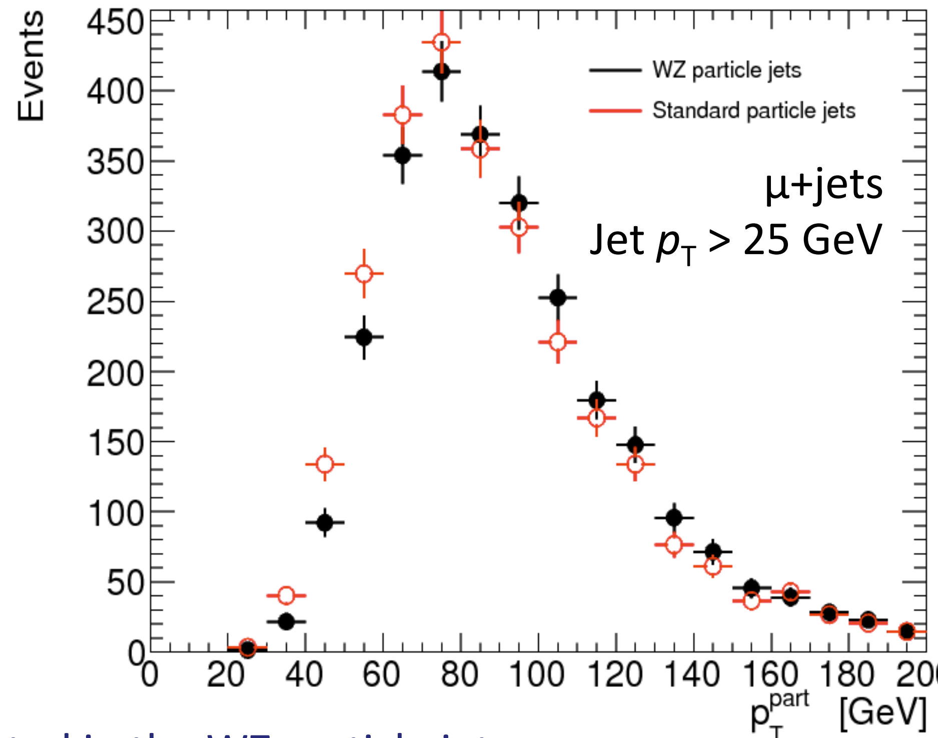
Suspect electron is less isolated in the WZ particle jet case.
Jet-muon overlap removal isolates muons to a greater extent.
(Dressed muons with FSR above 25GeV only accepted in WZ particle jet case.) *ATLAS*

Particle jet: leading p_T

Using jets without (standard) with (WZ) muons and neutrinos.

Full particle-level event selection (single b-tag) except jet multiplicity requirement
ALPGEN+HERWIG tbar lnqq Np0 test sample





Suspect electron is less isolated in the WZ particle jet case.
Jet-muon overlap removal isolates muons to a greater extent.
(Dressed muons with FSR above 25GeV only accepted in WZ particle jet case.) *ATLAS*

Common event selection: single lepton

Match the event selection used to select the data with reconstructed objects.

Synchronise the electron and muon channels to allow combinations within the selected kinematic range.

Electron channel

- Exactly one selected electron (|η|<2.4 & p_T > 30GeV)
- No selected muons (|η|<2.5 & p_T>15 GeV)
- No more selected electron (|η|<2.5 p_T>15GeV)
- Neutrino sum p_T > 30GeV
- m_T(W) > 30GeV

- At least two b-tagged jets (|η|<2.4 & p_T>30GeV)
- At least four particle jets (|η|<2.4 & p_T>30GeV)

Muon channel

- Exactly one selected muon (|η|<2.4 & p_T>30GeV)
- No selected electrons (|η|<2.5 p_T>15GeV)
- No more selected muon (|η|<2.5 p_T>15GeV)
- Neutrino sum p_T > 30GeV
- m_T(W) > 30GeV

- At least two b-tagged jets (|η|<2.4 & p_T>30GeV)
- At least four particle jets (|η|<2.4 & p_T>30GeV)

$$m_T(W) = \sqrt{2 p_T^l p_T^\nu (1 - \cos(\phi^l - \phi^\nu))}$$

Common event selection: dilepton

Match the event selection used to select the data with reconstructed objects.

ATLAS uses an HT cut on the reconstructed objects,
but not within the particle definition.

- At least two selected leptons (ee,eμ,μμ) ($|\eta|<2.4$ & p_T > 30GeV)
- For ee/μμ channels neutrino sum p_T > 60GeV
  - Extrapolate ee/μμ for combination with eμ
- At least two b-tagged jets ($|\eta|<2.4$ & p_T>30GeV)
- At least two particle jets ($|\eta|<2.4$ & p_T>30GeV)

Pseudo-top construction

- Construct pseudo-top using double-tag requirement, to minimise the non-resolution term in the unfolding.
  - ATLAS and CMS both use double-tag requirement
- Dileptonic pseudo-top, simpler if the neutrinos are used directly, rather than the MET sum.
  - Need a recipe to resolve the ambiguity.

Pseudo-top: single lepton

1. Require exactly one lepton, at least four jets and at least two of the jets to be b-tagged.
2. Assume the leading and sub-leading p_T b-tagged jets are from the top decay (top b jets).
3. Form a hadronic pseudo-W from the two highest p_T jets remaining.
4. Choose the best top b-jet, hadronic pseudo-W combination with respect to the top mass (172.5 GeV)
5. Form the leptonic pseudo-W by solving for p_z assuming the W mass.
   – Highest p_z from two-fold ambiguity
6. Form leptonic pseudo-top from pseudo-W and remaining top b-jet.

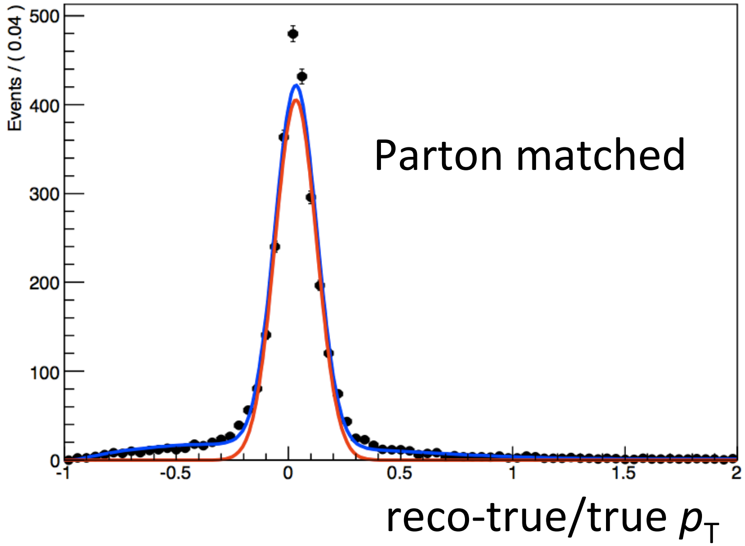
Pseudo-top correlation: single lepton

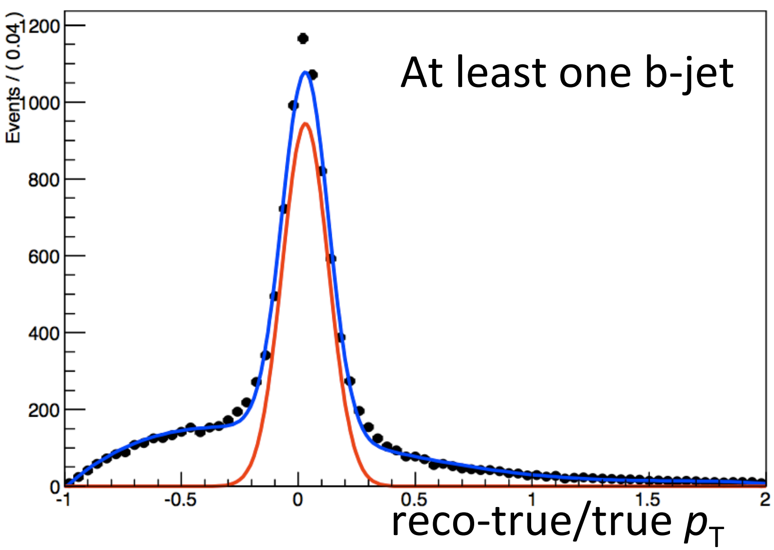
ALPGEN+HERWIG ttbar (lnqq/lnln Np0-5)
Hadronic pseudo-top p_T : pull distributions

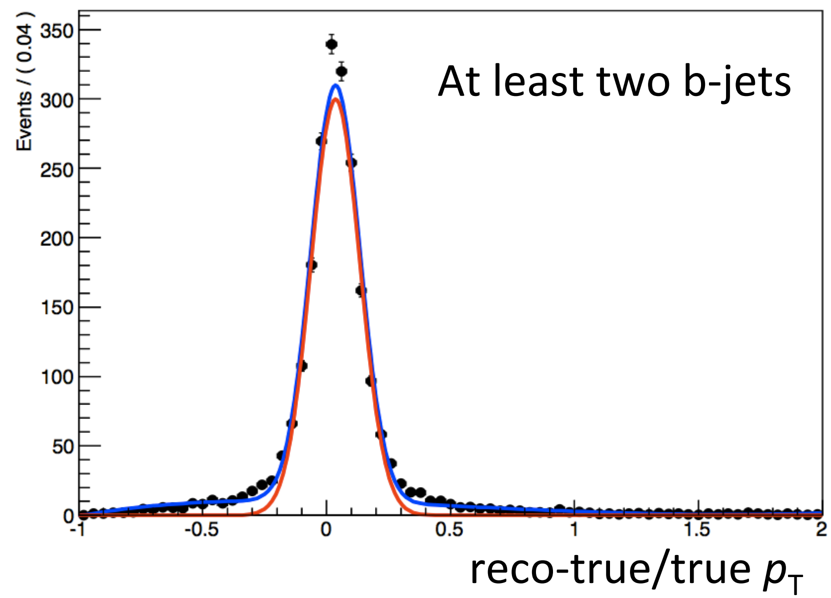
electron-channel

Motivation for double b-tag

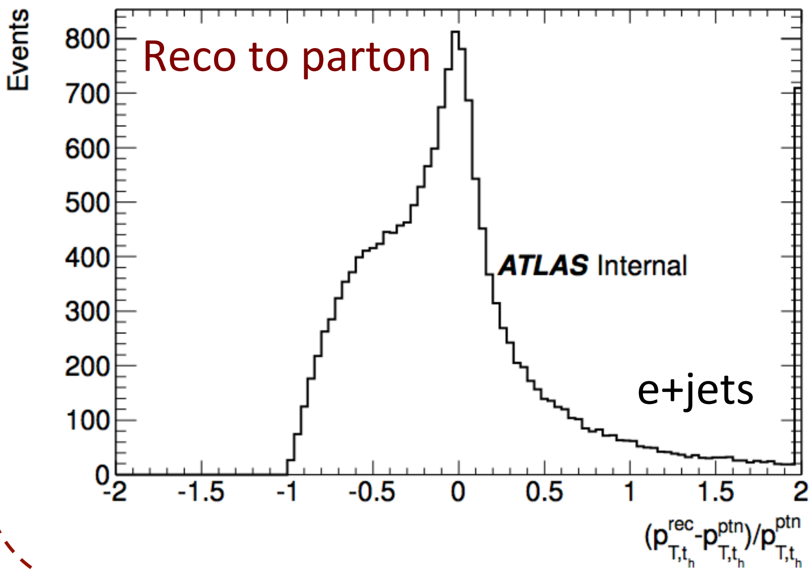
ATLAS



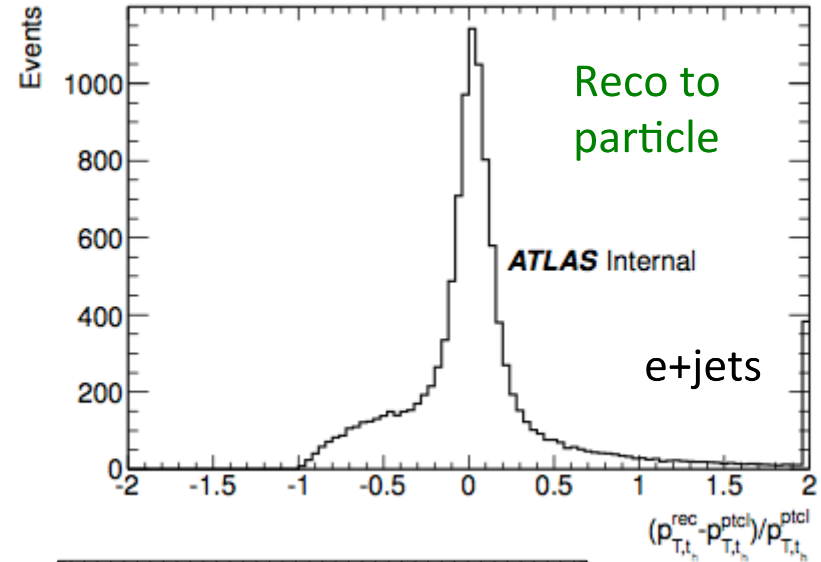




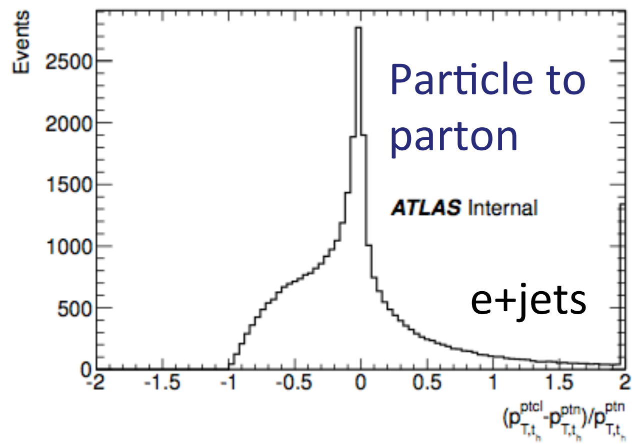
Top/pseudo-top, pull distributions: p_T



Fiducial measurement



Extrapolation



Effect of acceptance corrections to inclusive parton (p_T = 0, 4π srad.) not shown.

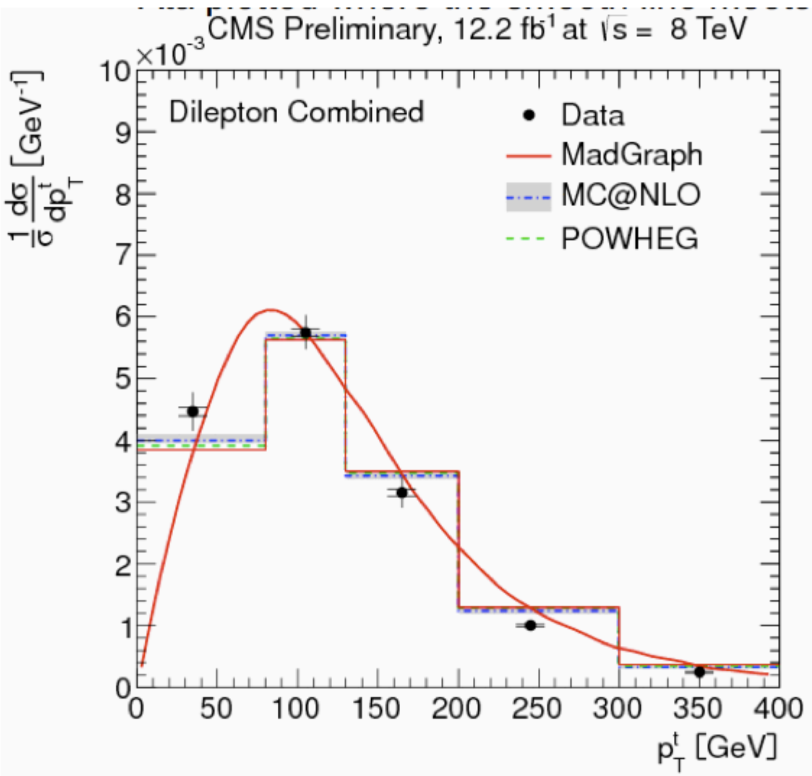
ATLAS

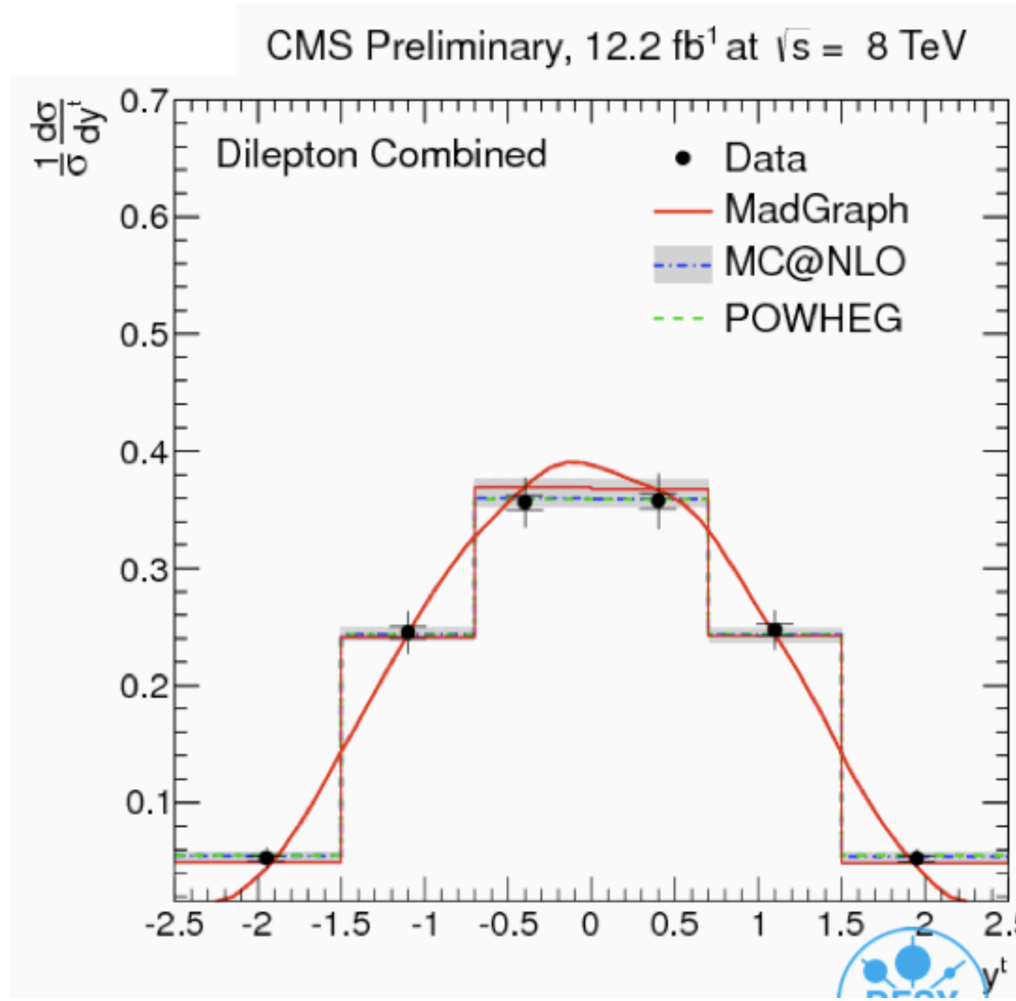
Pseudo-top: dilepton

1. Require exactly two leptons, at least two jets and at least two of the jets to be b-tagged.
2. Use all b-tagged jets to form pseudo-tops.
3. Form pseudo-W from the two best lepton-neutrino pairings with respect to the W mass.
4. Choose the best top b-jet, pseudo-W combination with respect to the top mass (172.5 GeV)

CMS cross-section results

SVD method as prescribed in TOP-12-028
Comparisons with MC@NLO and POWHEG
bin-center-correction applied





Conclusions

- Lepton problem solved with safe solution.
  - Support from generator authors (e.g. SHERPA) and from RIVET developers.
- Common definitions from overlap between CMS and ATLAS object and event selections
- Hope to see results presented in this common kinematic range soon.