Boosted Boson Tagging

The ATLAS perspective

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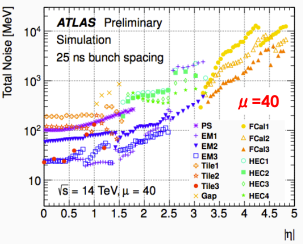
Topics

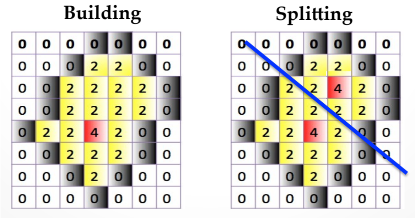
The purpose of this session is to have a lively discussion! We have prepared these slides to help guide the conversation, but by no means are we bound to this outline.

- Jet inputs
  - → Topological Clusters
- Jet reconstruction and grooming
  - → $R = 0.4$ anti-k_t is the standard. Many variants with anti-k_t and C/A
- Correcting jets - calibration and PU removal
  - → Areas Subtraction; Jet Vertex Fraction/Tagger
- Calorimeter-based tagging
  - → The standard in ATLAS; n-subjetiness, splitting scales, etc.
- Track-based substructure
  - → Ghost-match tracks to jets. Some unique to tracking, e.g. jet charge.
- Systematic Uncertainties
  - → Calo/track double ratio as the standard.

Jet Inputs: Topological clusters

- Topoclsuters ∼ follow shower development
- Building: 3D Nearest neighbor algorithm.
  - Seed with cells with $E > 4\sigma_{\text{noise}}$
  - Expand with cells with $E > 2\sigma_{\text{noise}}$
  - Finish with cells with $E > 0\sigma_{\text{noise}}$
- Splitting (right)
  - High multiplicity → large cells
  - Split into clusters around local maxima





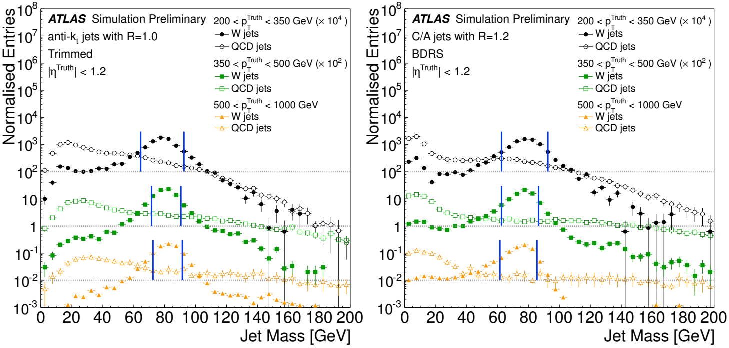
σ is the sum of electronic and pileup noise, which is adjusted with μ.

2010: $\sigma(\mu=0)$
2011: $\sigma(\mu=8)$
2012: $\sigma(\mu=30)$

Jet reconstruction and grooming

ATLAS Standards for large-R jets:

- $R = 1.0$ anti-k_t trimmed ($R_{\text{sub}} = 0.3$, $f_{\text{cut}} = 5\%$)
- $R = 1.2$ C/A BDRS ($\mu_{12} < 2/3$, $\sqrt{y_f} > 0.3$)



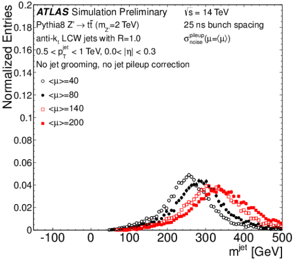
Correcting jets - calibration and PU removal

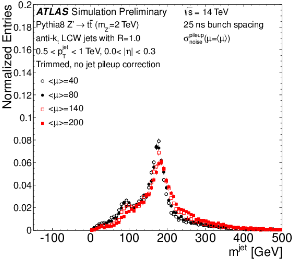
For the nominal $R = 0.4$ jets, areas-correction is the standard

- Also documented for other R values: ATLAS-CONF-2013-083
- For substructure variables: ATLAS-CONF-2013-085

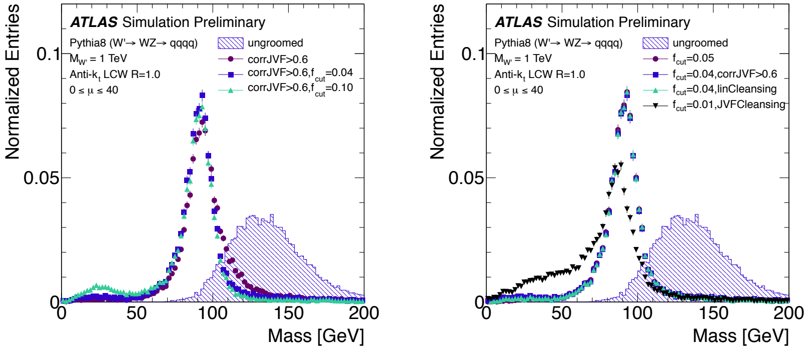
Standard in ATLAS for large R jets is to apply no further corrections beyond grooming.

- When $\langle \mu \rangle$ is not too large, this does well to remove pileup dependance (Public Plots)





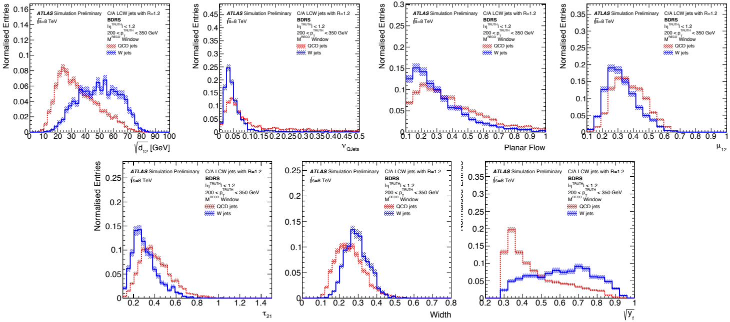
Correcting jets - calibration and PU removal II



- In fact, for Run I pileup conditions, it does not matter all that much which pileup mitigation technique is used ATL-PHYS-PUB-2014-001.

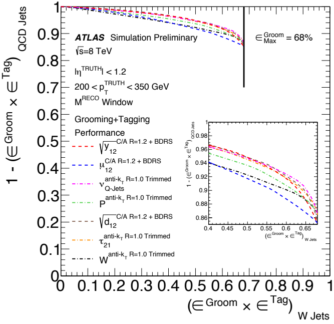
Calorimeter-based tagging

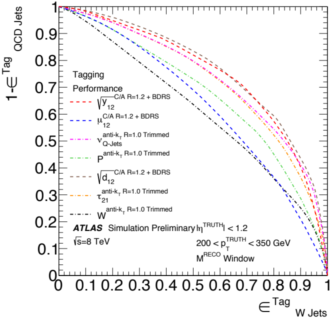
- Chose seven variables to pair with jet algorithms
  - τ_{21}, $\sqrt{d_{12}}$, μ_{12}, $\sqrt{y_{12}}$, ν_{QJets}, width, Planar Flow
- Optimal defined as maximal BG rejection at 50% Sig. eff.
- Two methods to optimize pairing of groomer+tagger
  1. Fix tagger → scan jet algorithms for optimal performance
  2. Fix jet algorithm → scan taggers for optimal performance



Calorimeter-based taggers

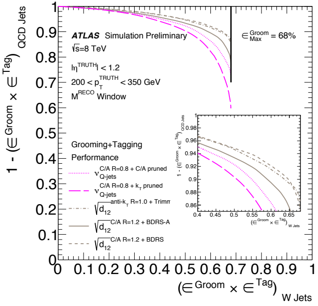
- Learn from looking at performance by considering tagger only and groomer+tagger mix
- Conclusion for method 1
  - We can say what a bad tagger is
  - It is difficult to say that any one groomer+tagger is truly optimal

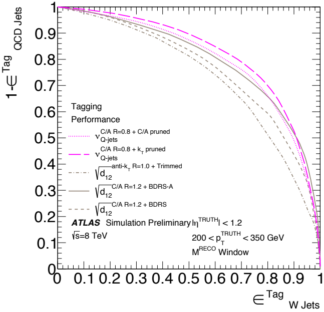




Calorimeter-based taggers II

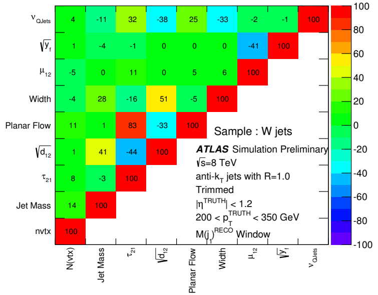
- Learn from looking at performance by considering tagger only and groomer+tagger mix
- Conclusion for method 2
  - We can say what a bad tagger is
  - It is difficult to say that any one groomer+tagger is truly optimal

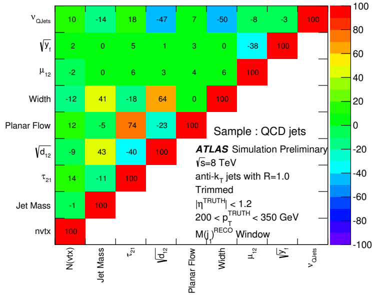




Calorimeter-based taggers III

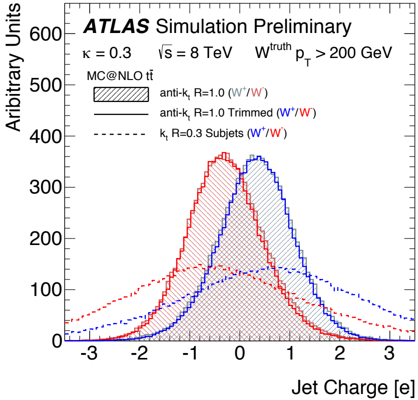
- Can further optimization be gained by leveraging correlations?
- Initial answer – no – correlations between signal and background are not drastically different
  - NOTE : More investigation required



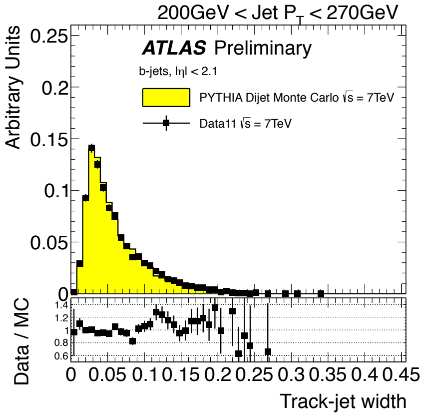


Track-based substructure

Jets are build from the calorimeter and jets are ghost associated.



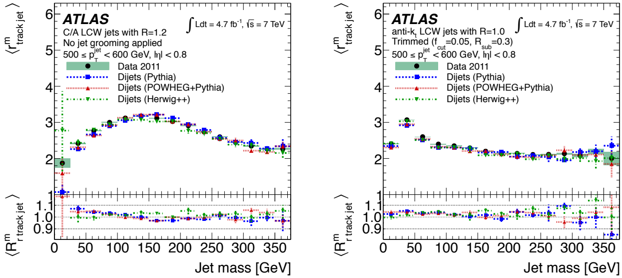
Jet Charge



Double b-hadron tagger
(tracks ΔR matched)

Systematic Uncertainties

The standard prescription in ATLAS is to compute the double ratio between track jets/MC track jets and calo jets/MC calo jets (r is the calo/track ratio).

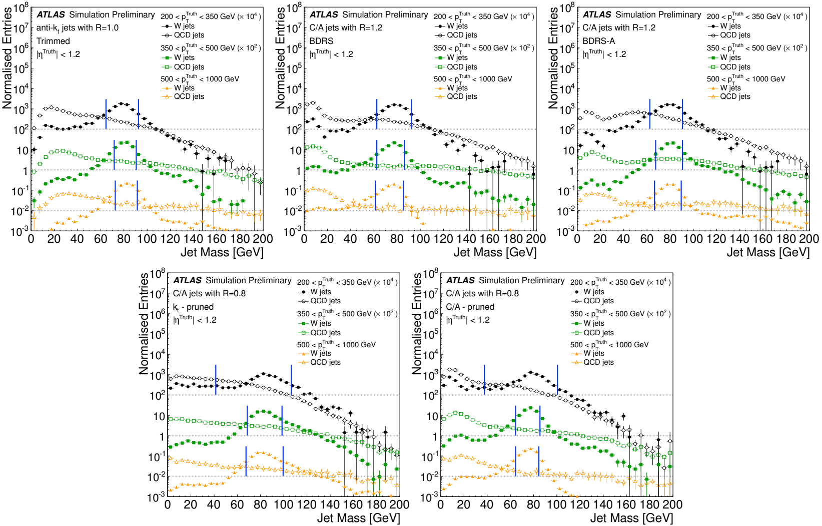


(a) C/A, $R = 1.2$ (b) anti-k_t, $R = 1.0$ (trimmed)

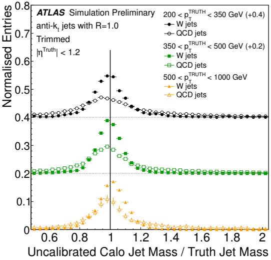
Calibrations exist in bins of m/p_T for anti-k_T 1.0 and C/A $R = 1.2$.

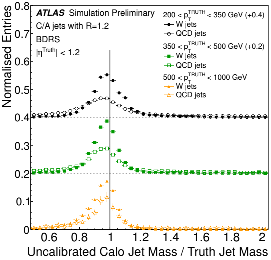
BACKUP

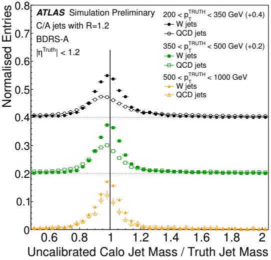
Jet Mass

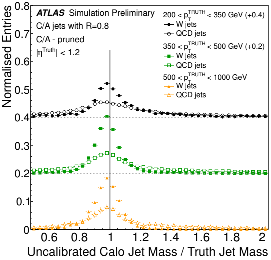

ATLAS Simulation Preliminary
anti-k_t jets with R=1.0
Trimmed
|η^Truth| < 1.2
C/A jets with R=1.2
BDRS
BDRS-A
C/A jets with R=0.8
k_t - pruned
C/A - pruned
200 < p_T^Truth < 350 GeV (× 10^4)
W jets
QCD jets
350 < p_T^Truth < 500 GeV (× 10^2)
W jets
QCD jets
500 < p_T^Truth < 1000 GeV
W jets
QCD jets
Normalised Entries
Jet Mass [GeV]

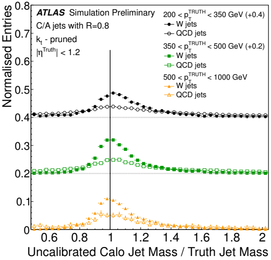
Jet Mass Ratio



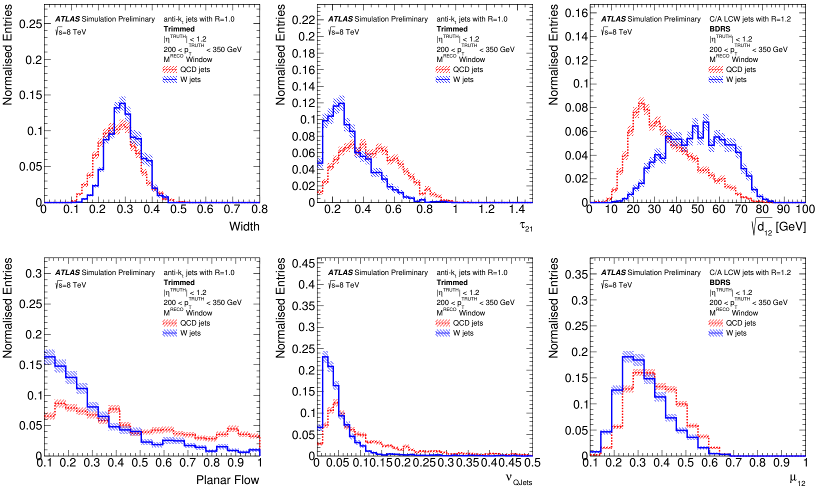




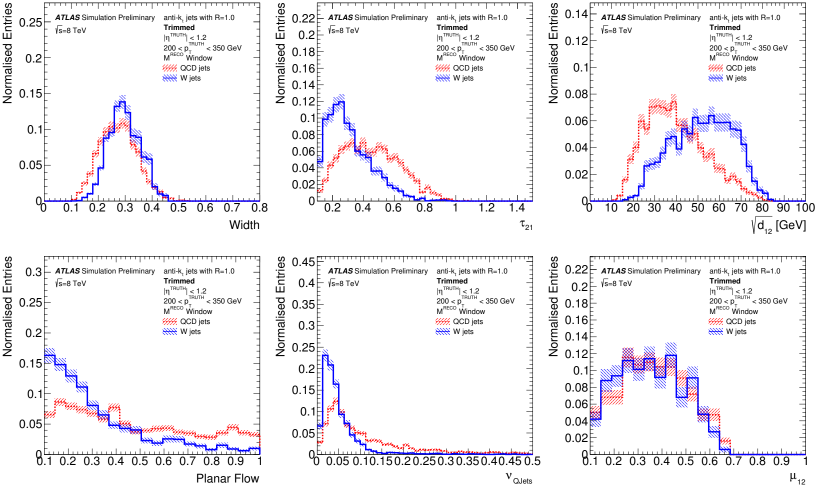




Optimal

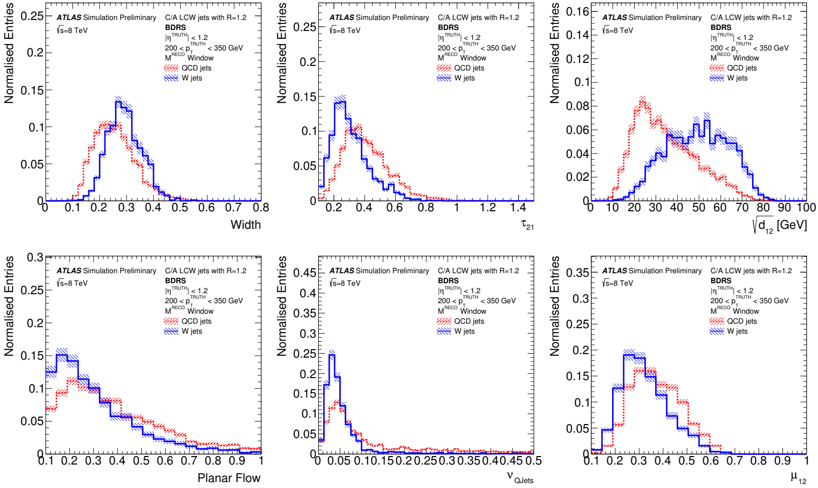

ATLAS Simulation Preliminary
√s=8 TeV
anti-k_t jets with R=1.0
Trimmed
C/A LCW jets with R=1.2
BDRS
|η^TRUTH| < 1.2
200 < p_T^TRUTH < 350 GeV
M^RECO Window
QCD jets
W jets
Normalised Entries
Width
τ21
√d12 [GeV]
Planar Flow
ν QJets
μ12

Trimmed


ATLAS Simulation Preliminary
√s=8 TeV
anti-k$_t$ jets with R=1.0
Trimmed
$|\eta^{TRUTH}| < 1.2$
$200 < p_T^{TRUTH} < 350$ GeV
M^{RECO} Window
QCD jets
W jets
Normalised Entries
Width
τ_{21}
$\sqrt{d_{12}}$ [GeV]
Planar Flow
ν_{QJets}
μ_{12}

BDRS

SLAC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M^RECO Window
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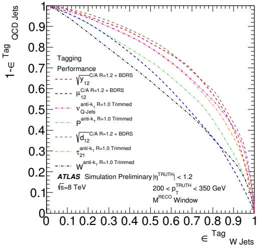
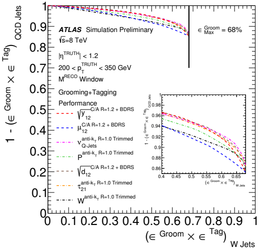
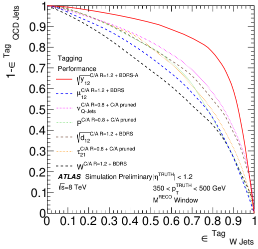
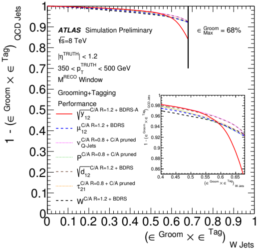
W jets
Normalised Entries
Width
τ21
√d12 [GeV]
Planar Flow
ν QJets
μ12

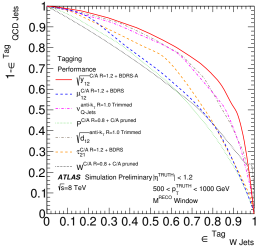
Fix Variable, Find Optimal Algorithm

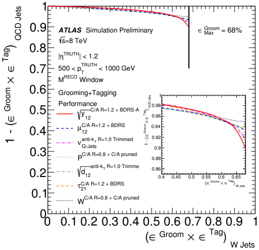






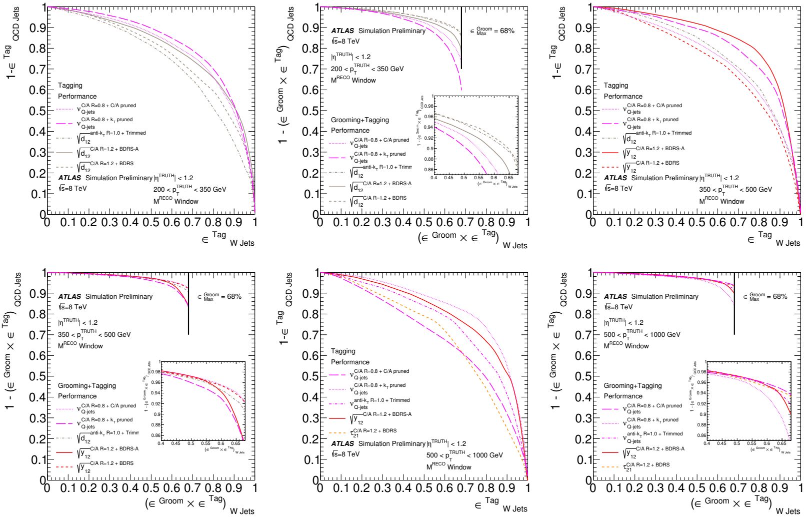




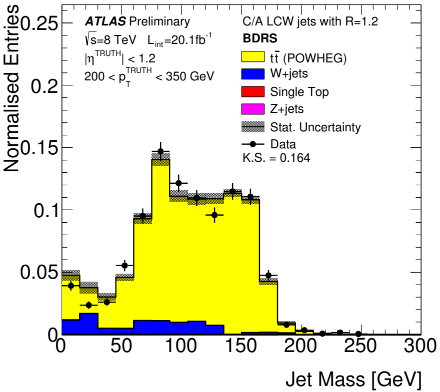


Fix Algorithm, Find Optimal Variable

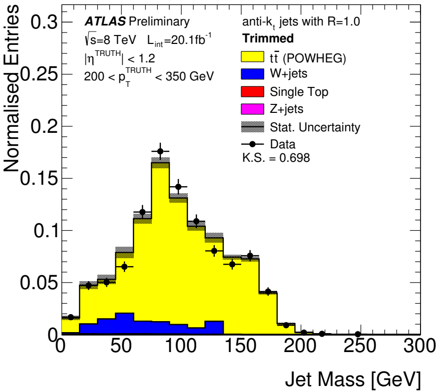
SLAC



Data/MC

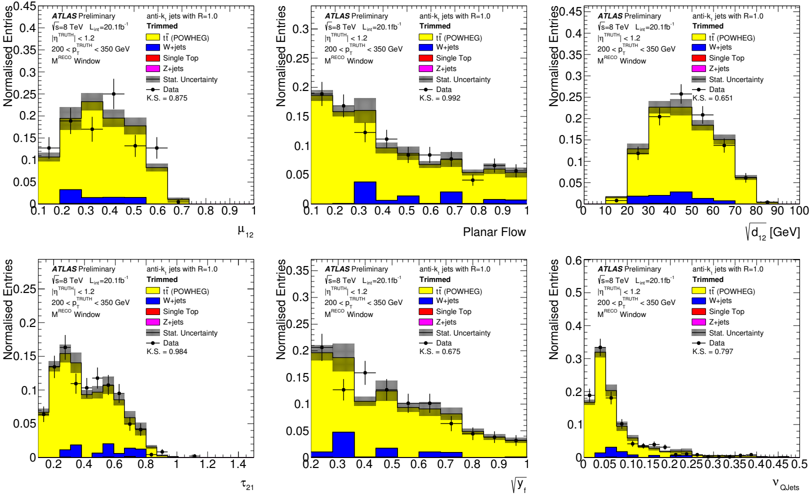


Normalised Entries
0.25
0.2
0.15
0.1
0.05
0
ATLAS Preliminary
√s=8 TeV L_int=20.1fb^-1
|η^TRUTH| < 1.2
200 < p_T^TRUTH < 350 GeV
C/A LCW jets with R=1.2
BDRS
tt̄ (POWHEG)
W+jets
Single Top
Z+jets
Stat. Uncertainty
Data
K.S. = 0.164
0
50
100
150
200
250
300
Jet Mass [GeV]

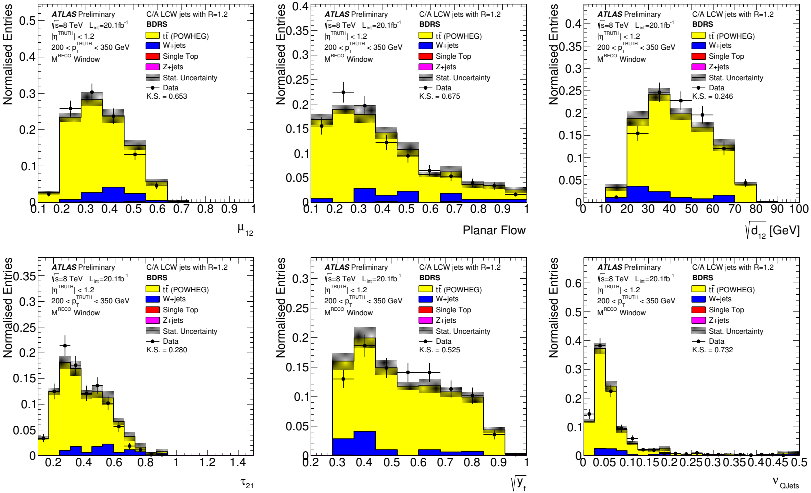


Normalised Entries
0.3
0.25
0.2
0.15
0.1
0.05
0
ATLAS Preliminary
√s=8 TeV L_int=20.1fb^-1
|η^TRUTH| < 1.2
200 < p_T^TRUTH < 350 GeV
anti-k_t jets with R=1.0
Trimmed
tt̄ (POWHEG)
W+jets
Single Top
Z+jets
Stat. Uncertainty
Data
K.S. = 0.698
0
50
100
150
200
250
300
Jet Mass [GeV]

Trimmed


ATLAS Preliminary
√s=8 TeV L_int=20.1fb^-1
|η^TRUTH| < 1.2
200 < p_T^TRUTH < 350 GeV
M^RECO Window
anti-k_t jets with R=1.0
Trimmed
tt̄ (POWHEG)
W+jets
Single Top
Z+jets
Stat. Uncertainty
Data
K.S. = 0.875
K.S. = 0.992
K.S. = 0.651
K.S. = 0.984
K.S. = 0.675
K.S. = 0.797
Normalised Entries
μ_12
Planar Flow
√d_12 [GeV]
τ_21
√y_f
ν_QJets

BDRS


ATLAS Preliminary
√s=8 TeV L_int=20.1fb^-1
|η^TRUTH| < 1.2
200 < p_T^TRUTH < 350 GeV
M^RECO Window
C/A LCW jets with R=1.2
BDRS
tt̄ (POWHEG)
W+jets
Single Top
Z+jets
Stat. Uncertainty
Data
K.S. = 0.653
K.S. = 0.675
K.S. = 0.246
K.S. = 0.280
K.S. = 0.525
K.S. = 0.732
Normalised Entries
μ12
Planar Flow
√d12 [GeV]
τ21
√yf
ν QJets