Boosted top tagging in ATLAS

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Recent public results

- **Run 1 data paper** JHEP 06 (2016) 093
  - ✦ Simple jet substructure variable based taggers, HEPTopTagger, Shower Deconstruction
  - ✦ data/MC comparisons in $t\bar{t}$ and dijets + efficiency measurements
  - ✦ MC-performance comparisons
- **Run 2 smooth tagger** ATL-PHYS-PUB-2015-053
  - ✦ m_{Jet} and τ_{32} tagger with constant signal efficiencies (50% & 80%)
- **Run 2 data/MC** comparison plots JETM-2016-005
- **Variable R jets** for top tagging, see Aparajita's and Qi's talks for W and H ATL-PHYS-PUB-2016-013

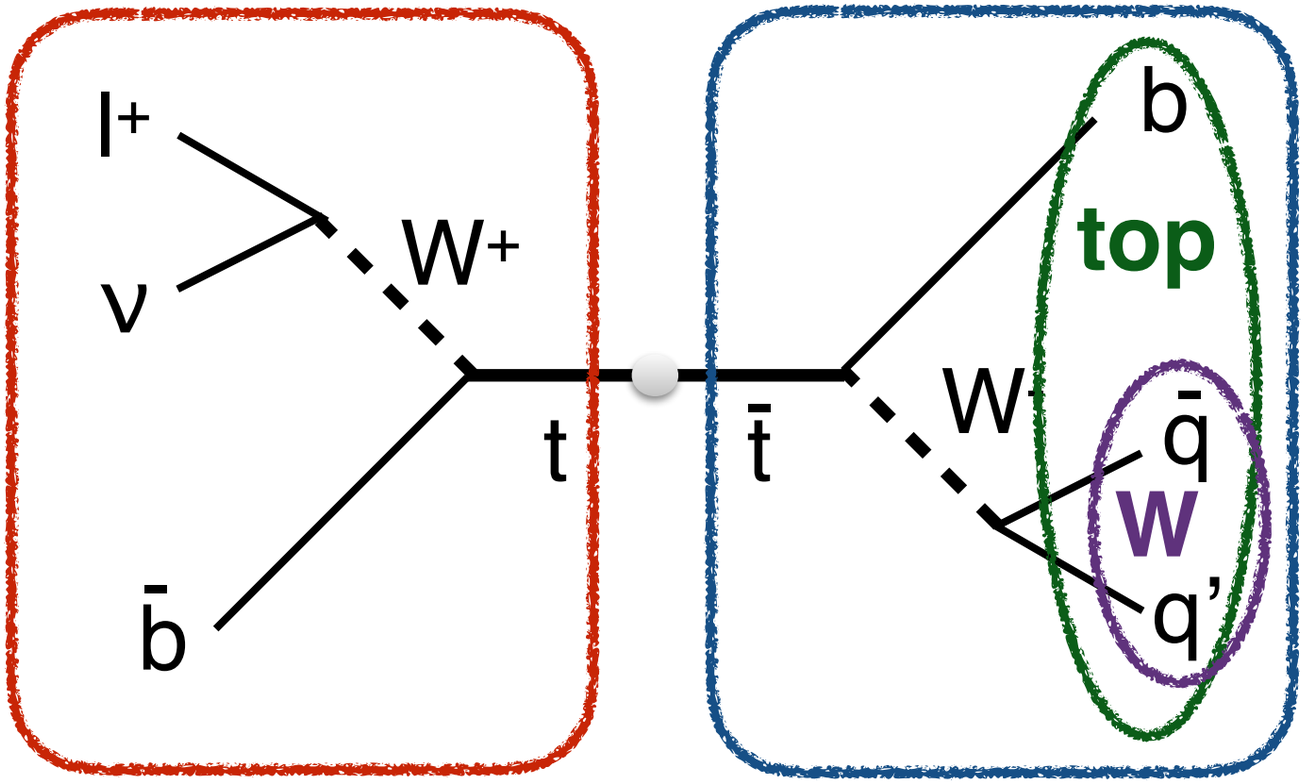
HTT: Plehn et al; JHEP 1010:078,2010

SD: Soper, Spannowski; arXiv:1211.3140 [hep-ph] N-subjettiness: Thaler, Van Tilburg; JHEP 1103:015,2011

Run 1 top tagging in $t\bar{t}$ events

Identify

events with leptonic decay



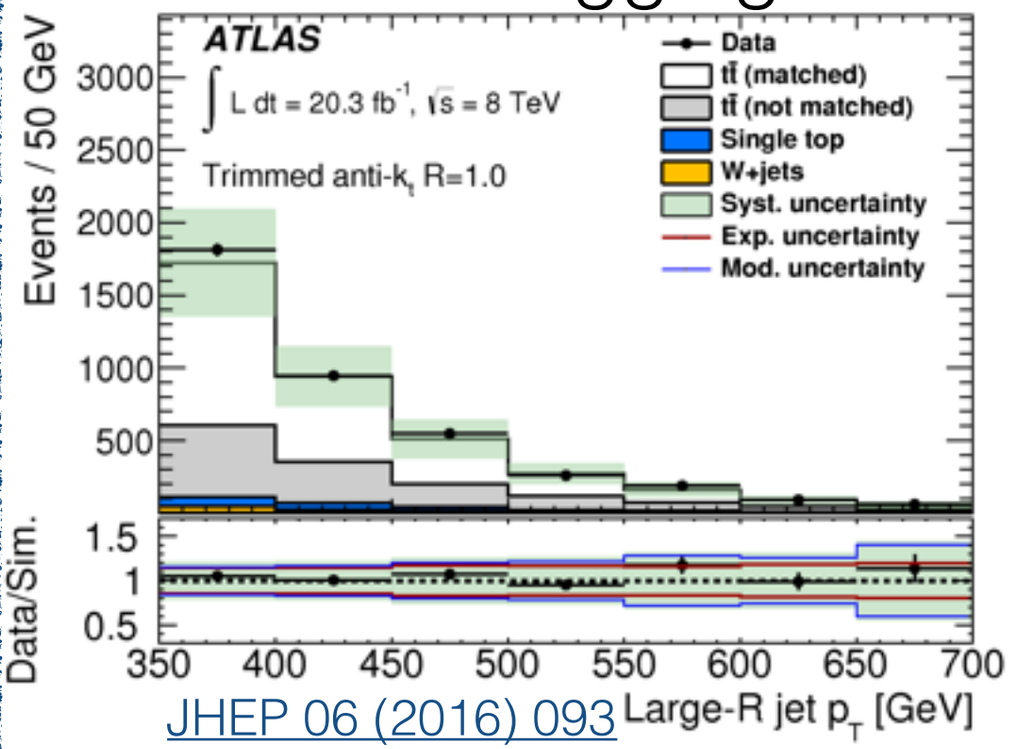
Study

large R jets and top (W) taggers with hadronic decay

Tagger	Jet algorithm	Grooming	Radius parameter	p_T range	$\|\eta\|$ range
Tagger I–V W' top tagger Shower Deconstruction	anti-k_t	trimming (R_{sub} = 0.3, f_{cut} = 0.05)	R = 1.0	> 350 GeV	< 2
HEPTopTagger	C/A	none	R = 1.5	> 200 GeV	< 2

Trimming: Krohn, Thaler, Wang; JHEP 1002:084,2010

Before tagging:



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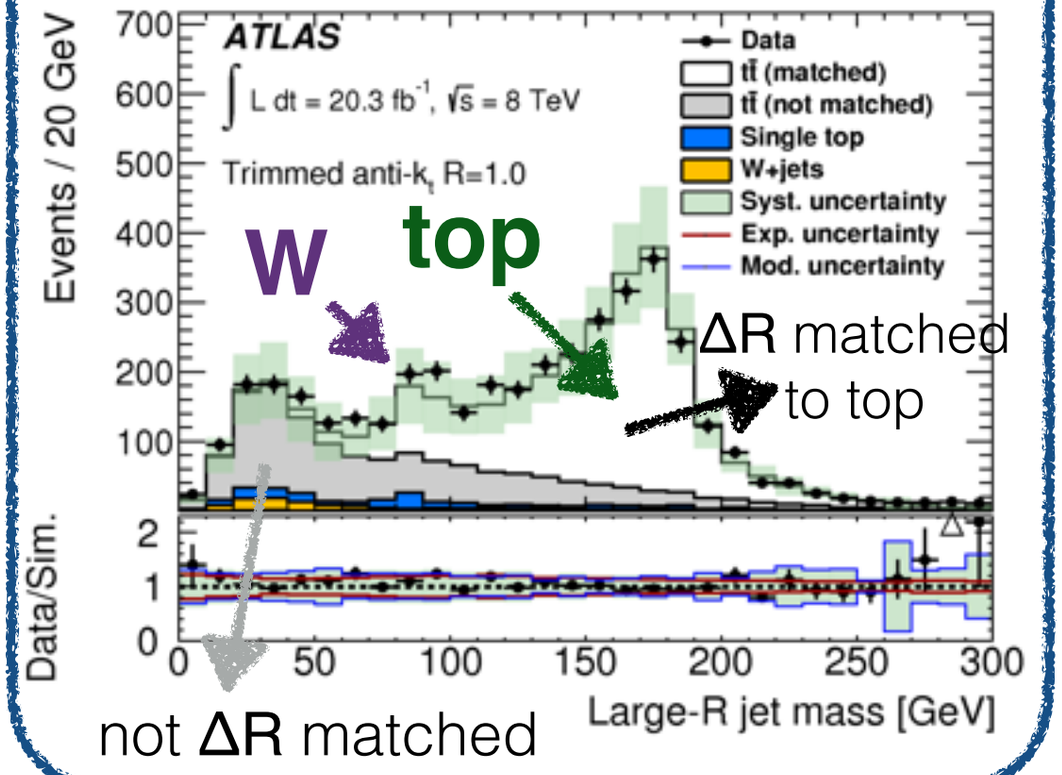

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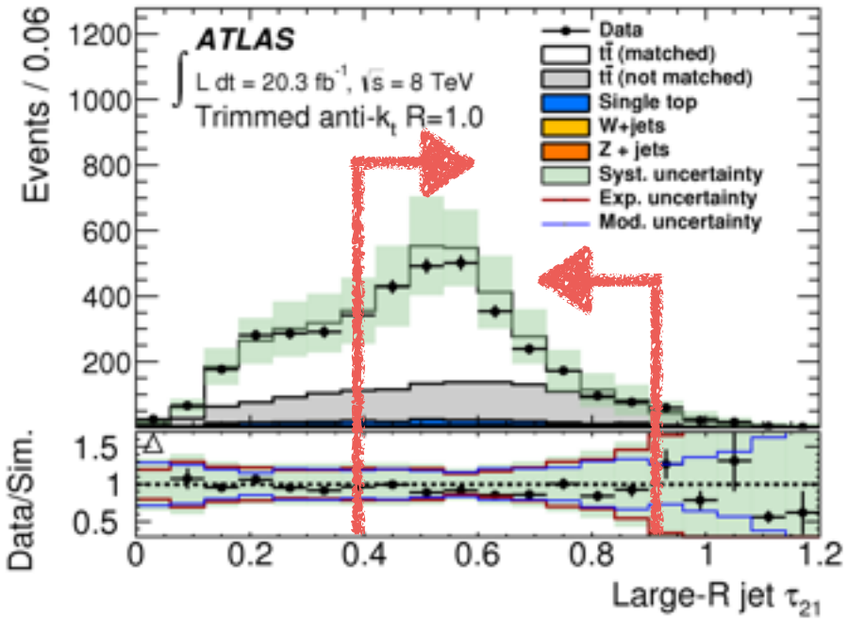
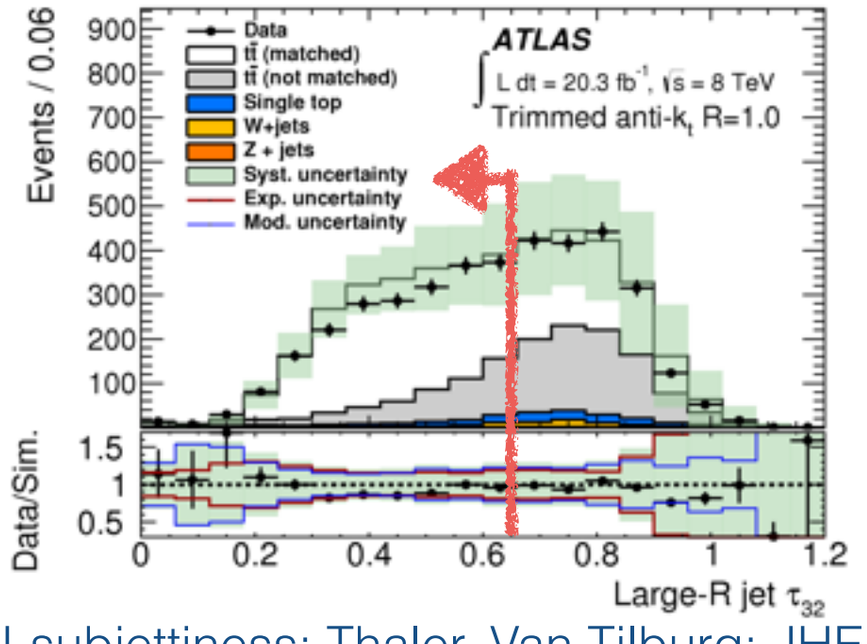
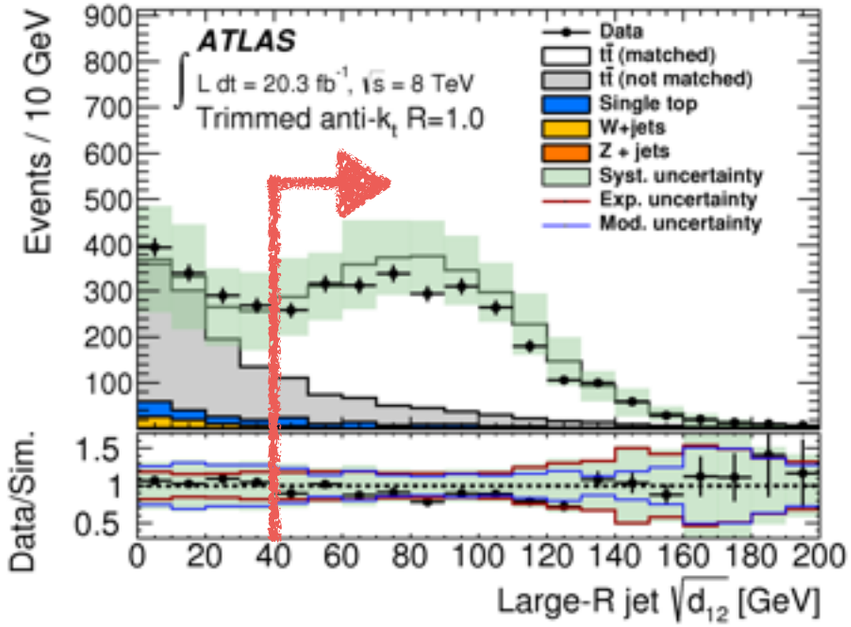
Simple taggers

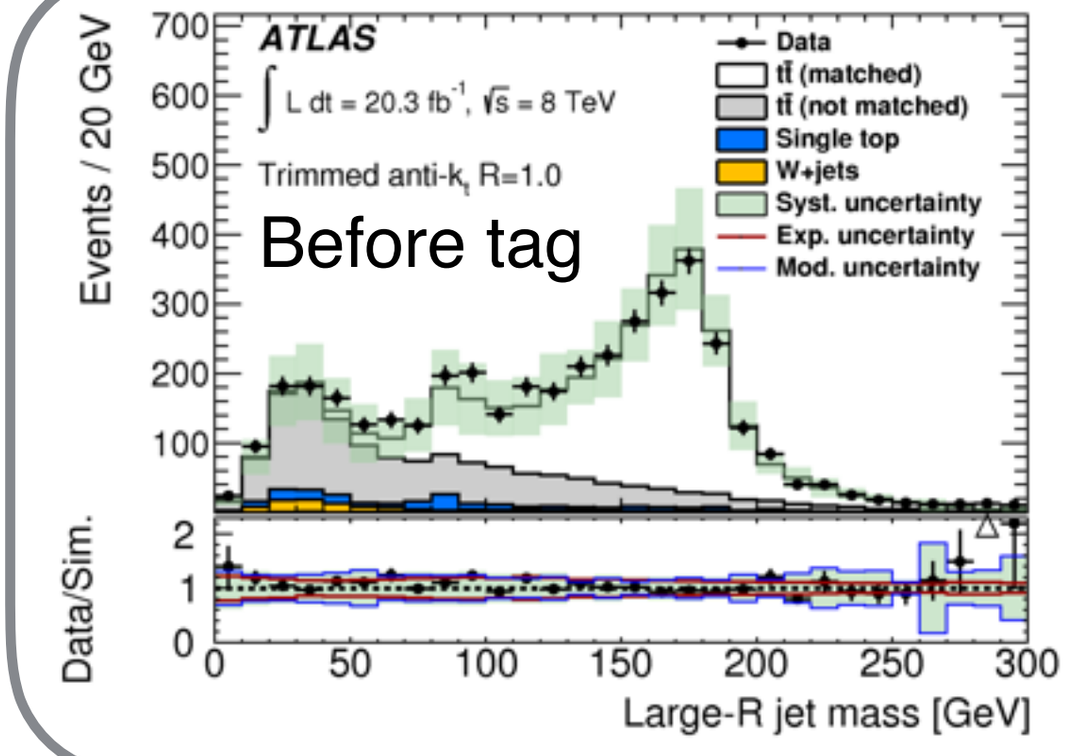
One example: ATLAS W’





[N-subjettiness: Thaler, Van Tilburg; JHEP 1103:015,2011](#)





Tagger	Top-tagging criterion
Substructure tagger I	$\sqrt{d_{12}} > 40$ GeV
Substructure tagger II	$m > 100$ GeV
Substructure tagger III	$m > 100$ GeV and $\sqrt{d_{12}} > 40$ GeV
Substructure tagger IV	$m > 100$ GeV and $\sqrt{d_{12}} > 40$ GeV and $\sqrt{d_{23}} > 10$ GeV
Substructure tagger V	$m > 100$ GeV and $\sqrt{d_{12}} > 40$ GeV and $\sqrt{d_{23}} > 20$ GeV
W' top tagger	$\sqrt{d_{12}} > 40$ GeV and $0.4 < \tau_{21} < 0.9$ and $\tau_{32} < 0.65$

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Simple taggers

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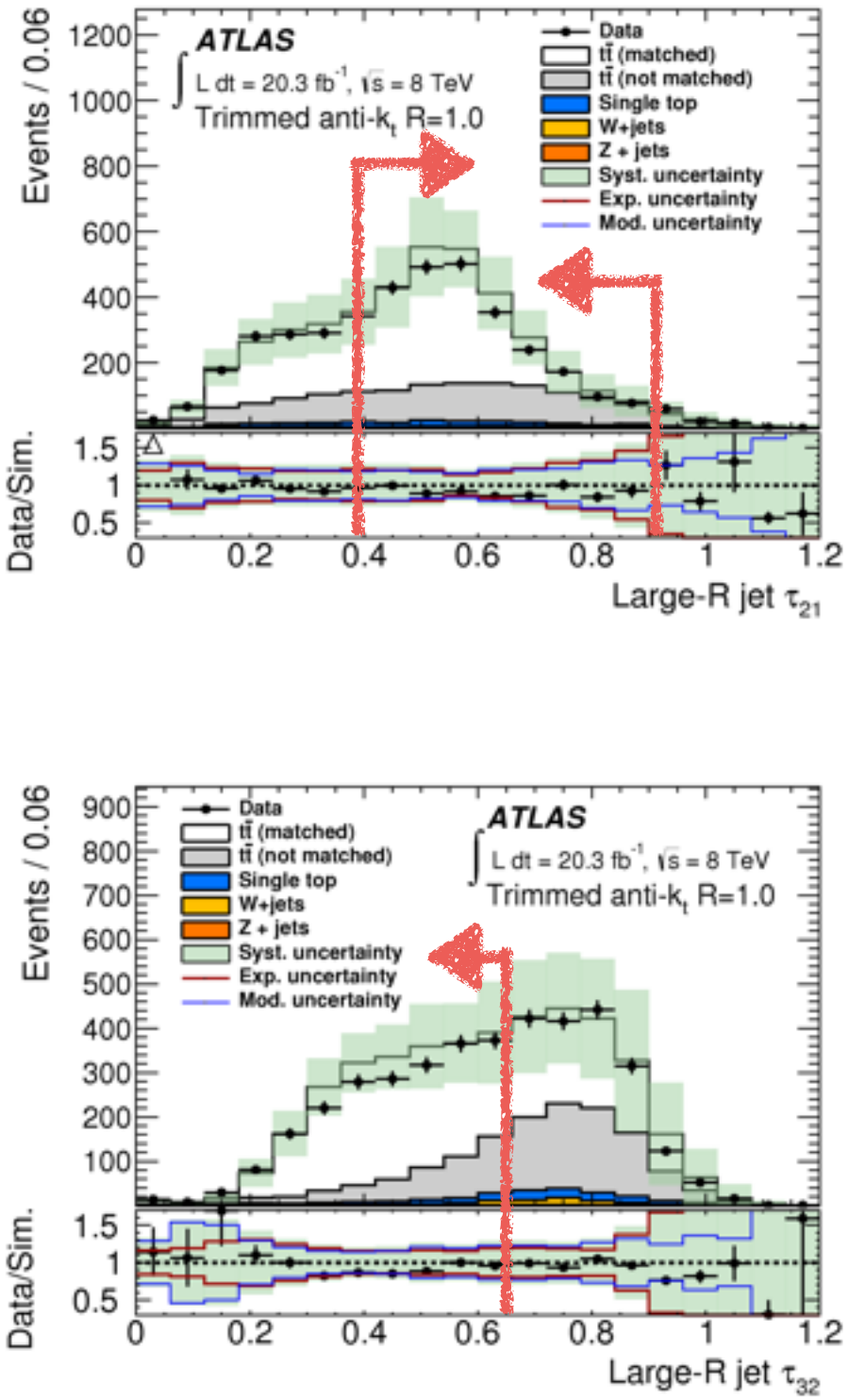

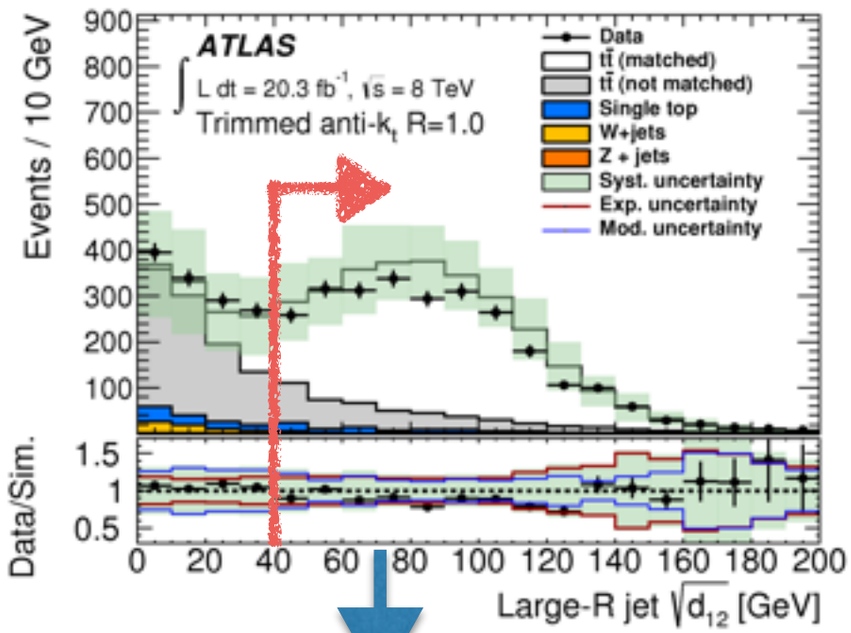

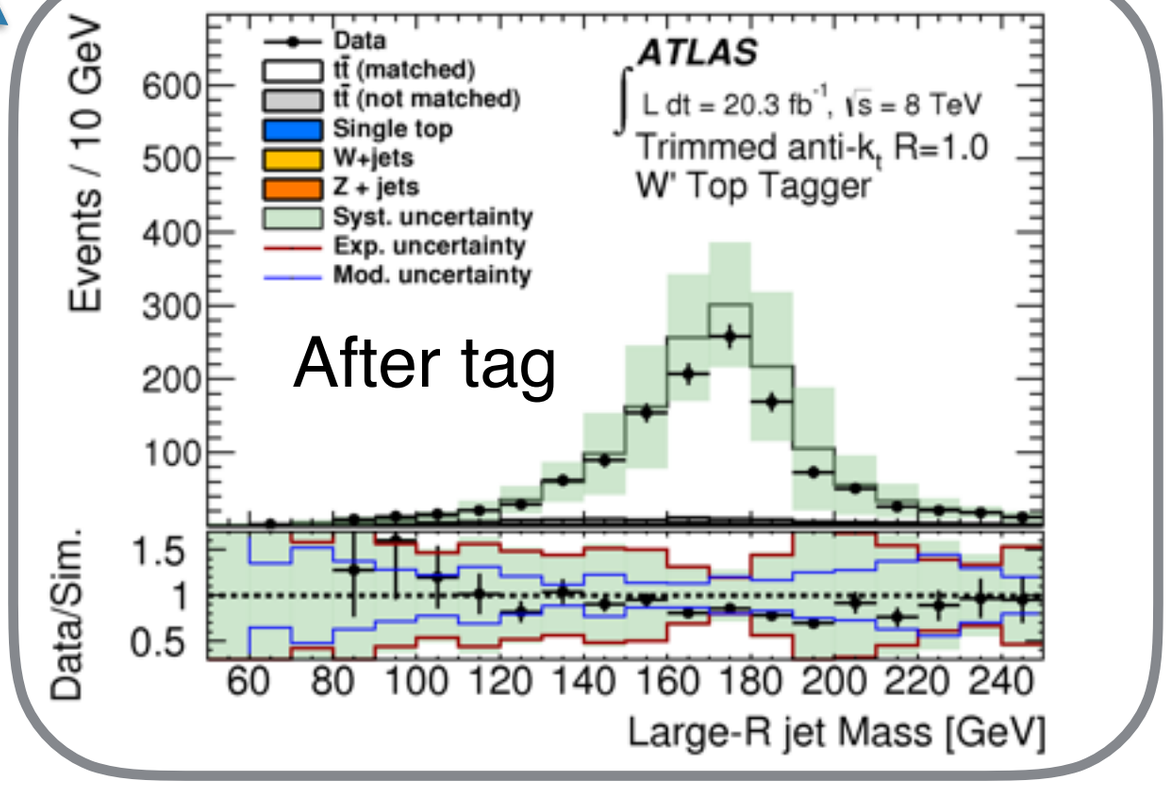

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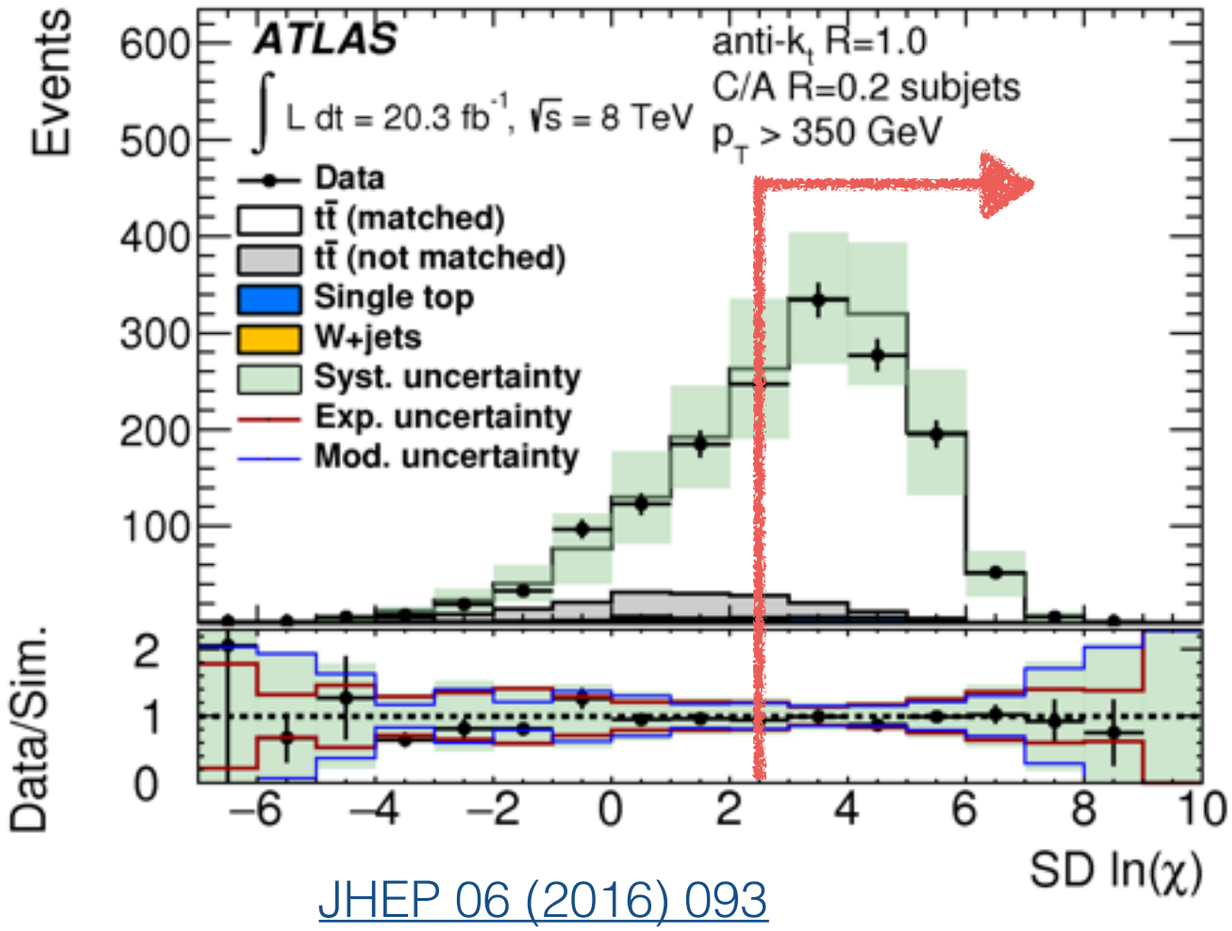
N-subjettiness: Thaler, Van Tilburg; JHEP 1103:015,2011

Shower deconstruction

- make small subjets (C/A R=0.2) from the clusters of the large R jet
- assume each subjet *i* comes from a certain signal (top) or background (gluon) decay particle and calculate the probability
- repeat for all possible associations
- define weight:

$$\chi = \frac{\sum_{\text{perm.}} P(p_i|\text{signal})}{\sum_{\text{perm.}} P(p_i|\text{background})}$$

SD: Soper, Spannowski; arXiv:1211.3140 [hep-ph]



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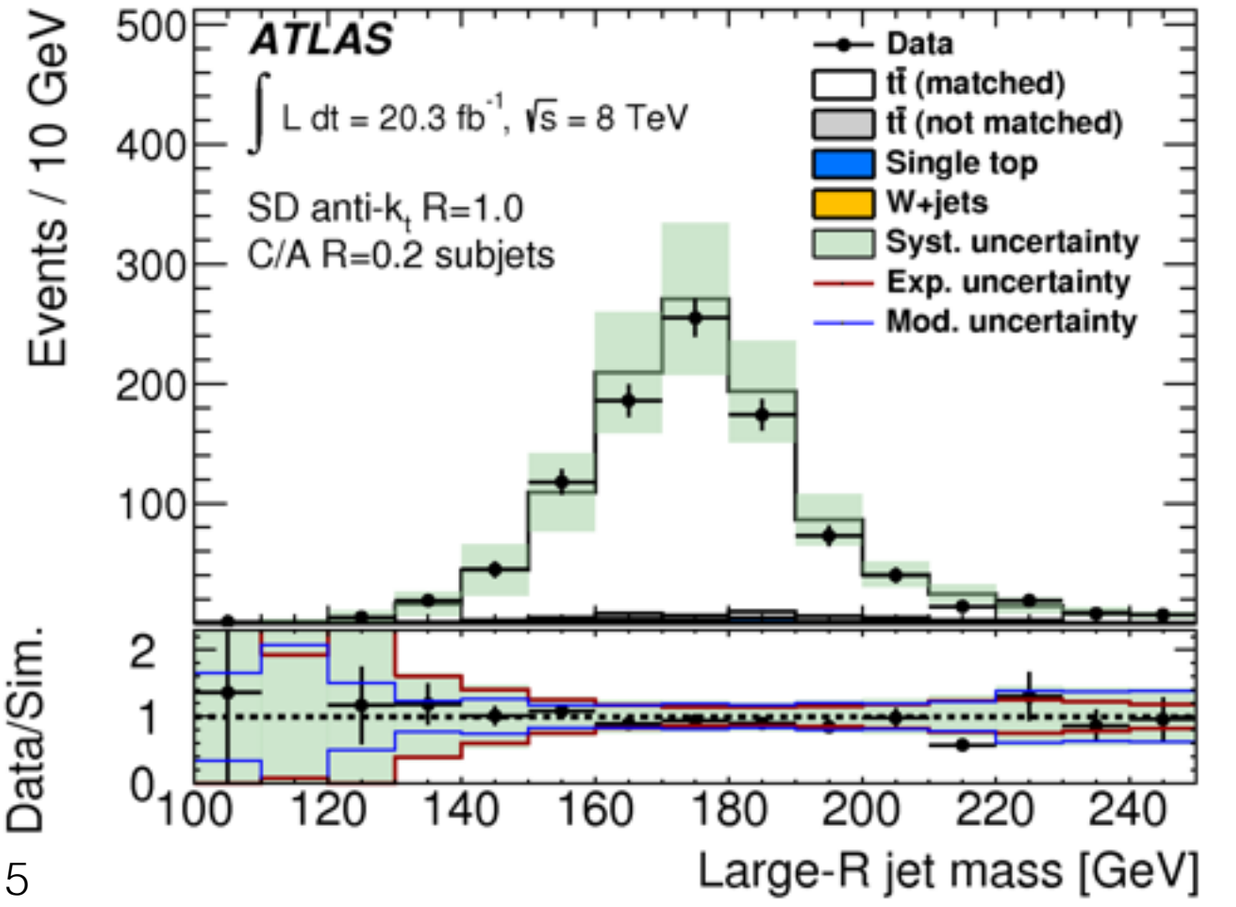
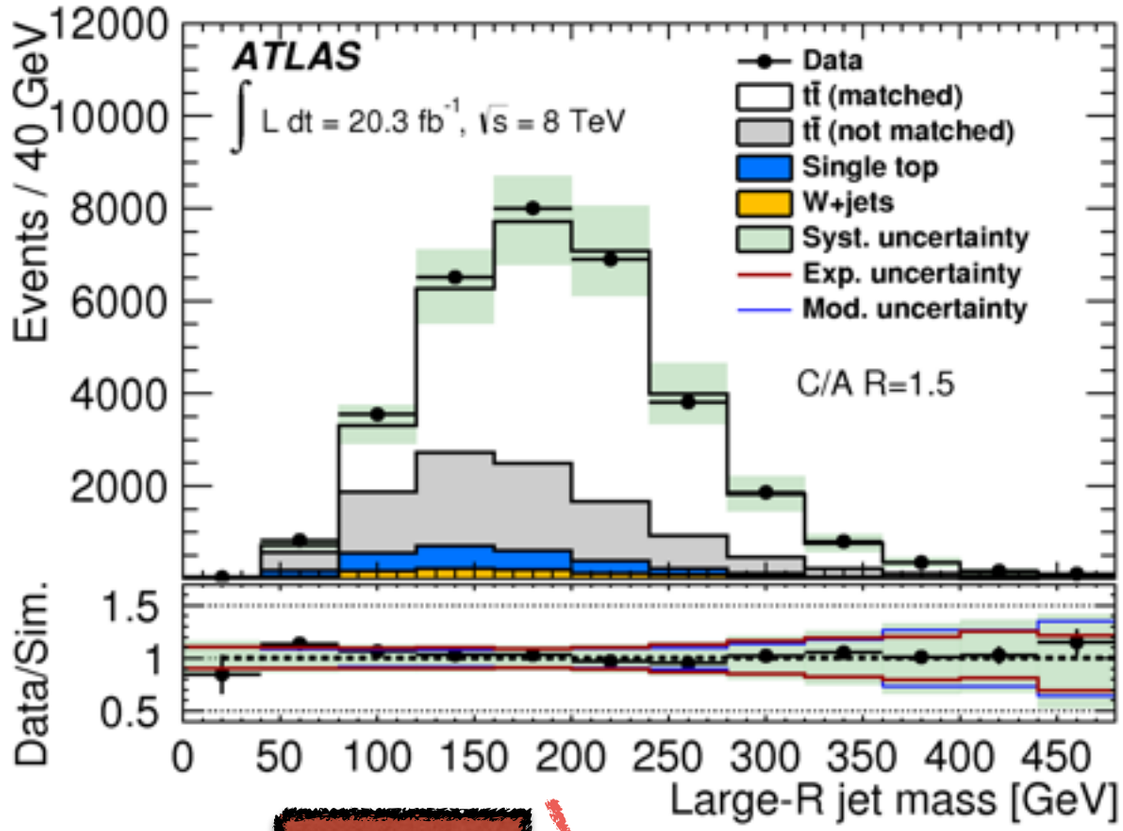
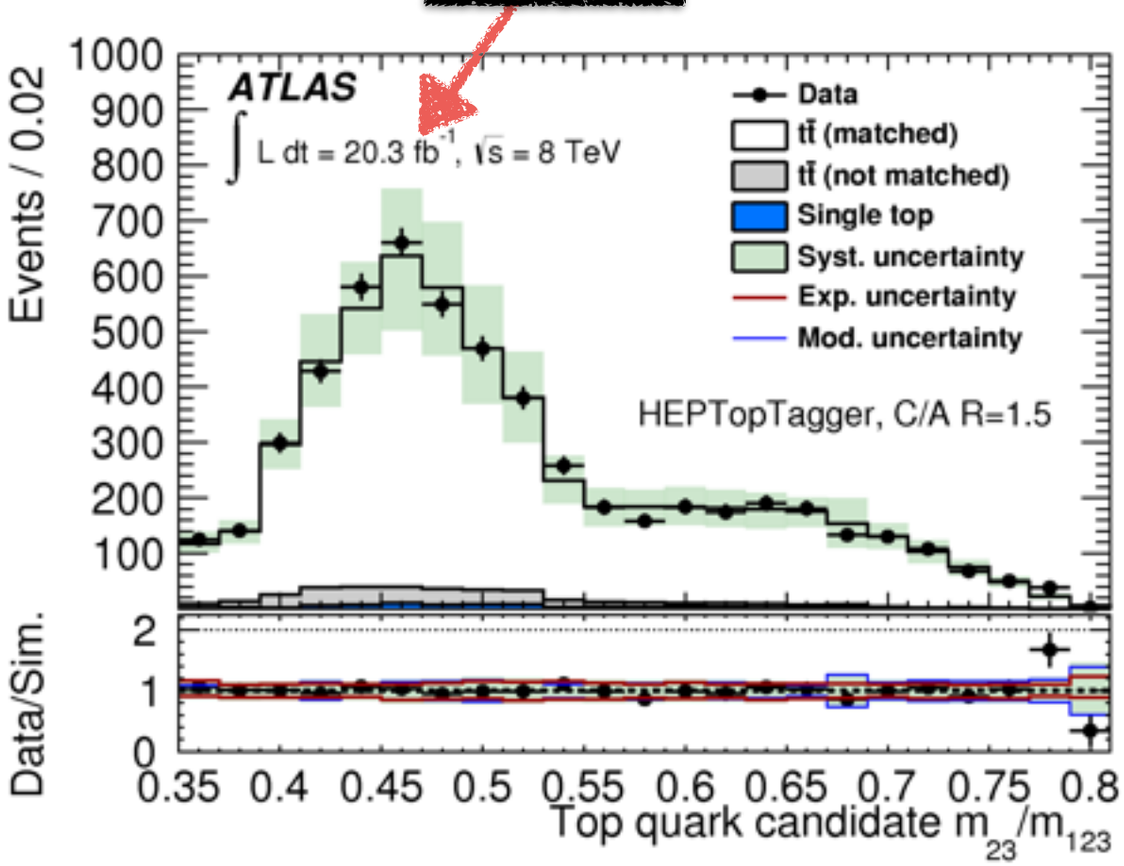


HEPTopTagger

- use C/A R=1.5 jets
- allows to go down to p_T^{top}>200GeV
- filter against pile-up
- identify top quarks via mass ratios



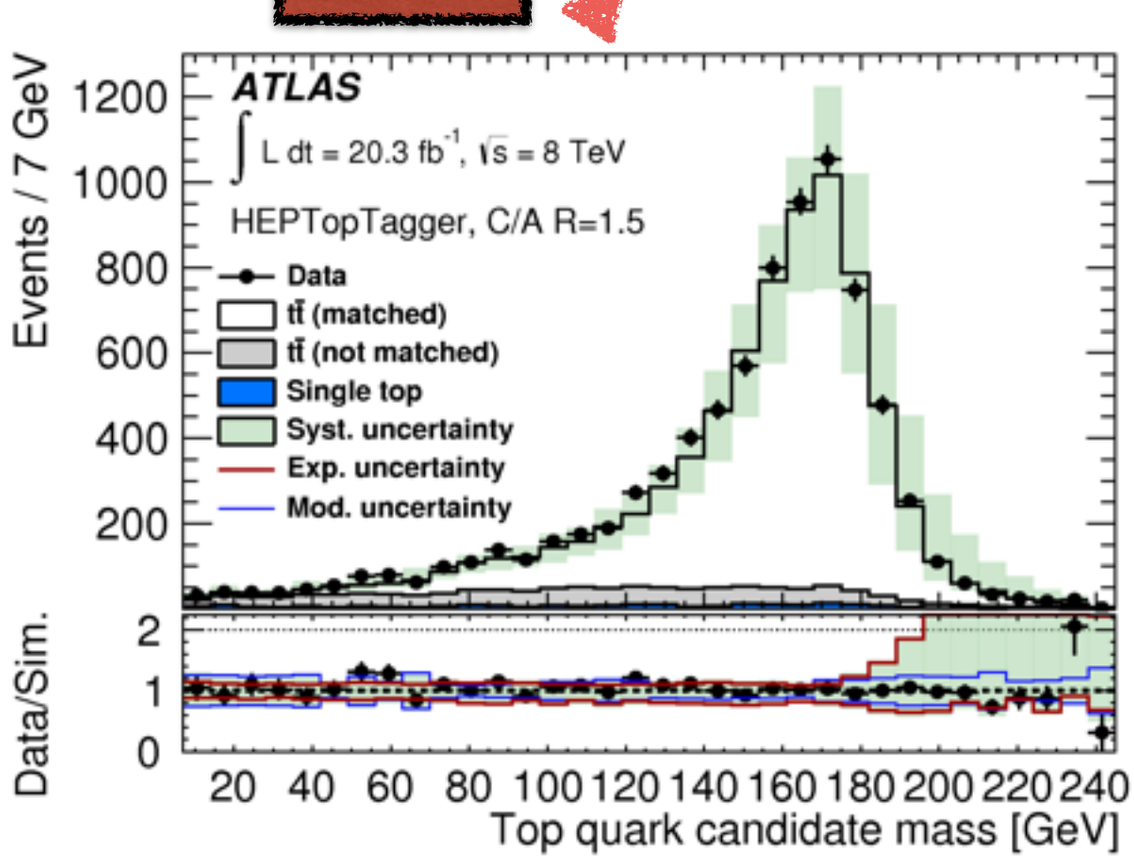
m_W/m_{top}



[HTT: Plehn et al; JHEP 1010:078,2010](#)

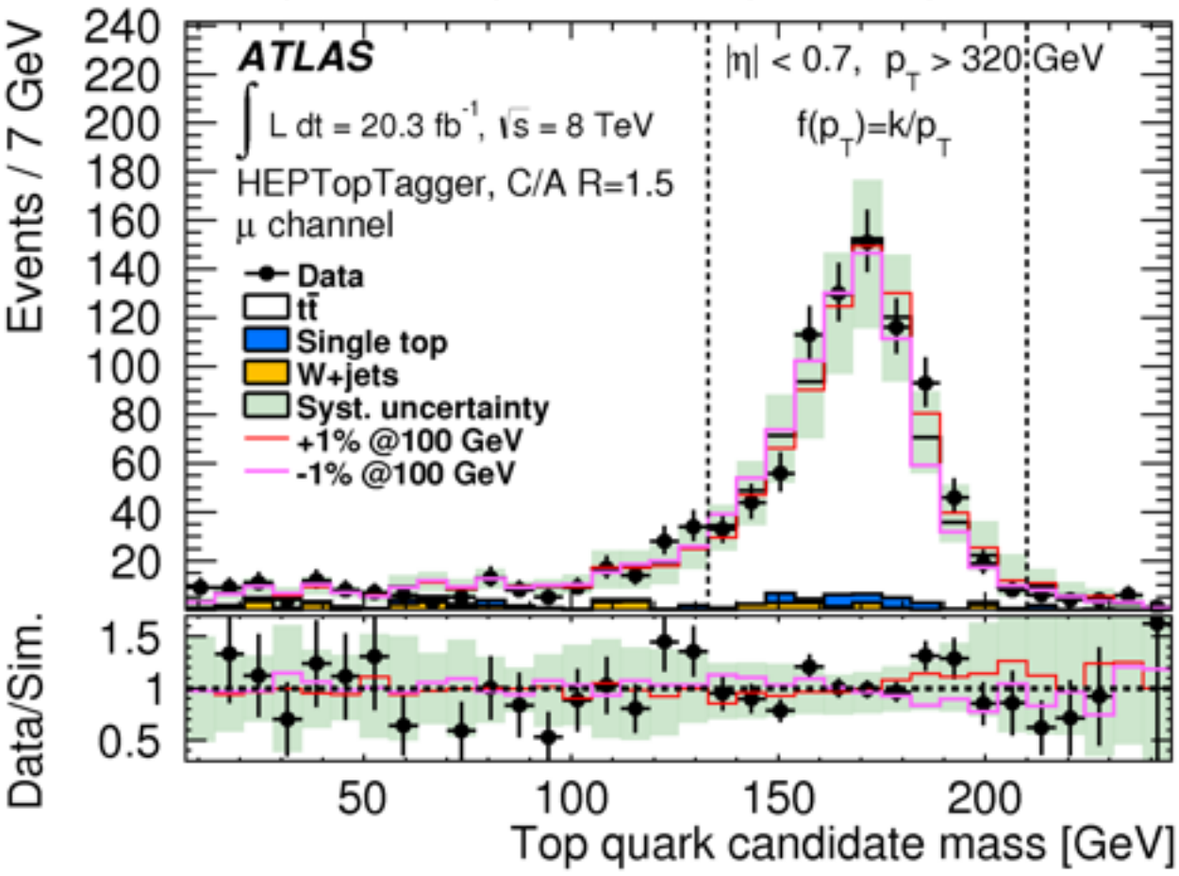
[JHEP 06 (2016) 093](#)

tagging

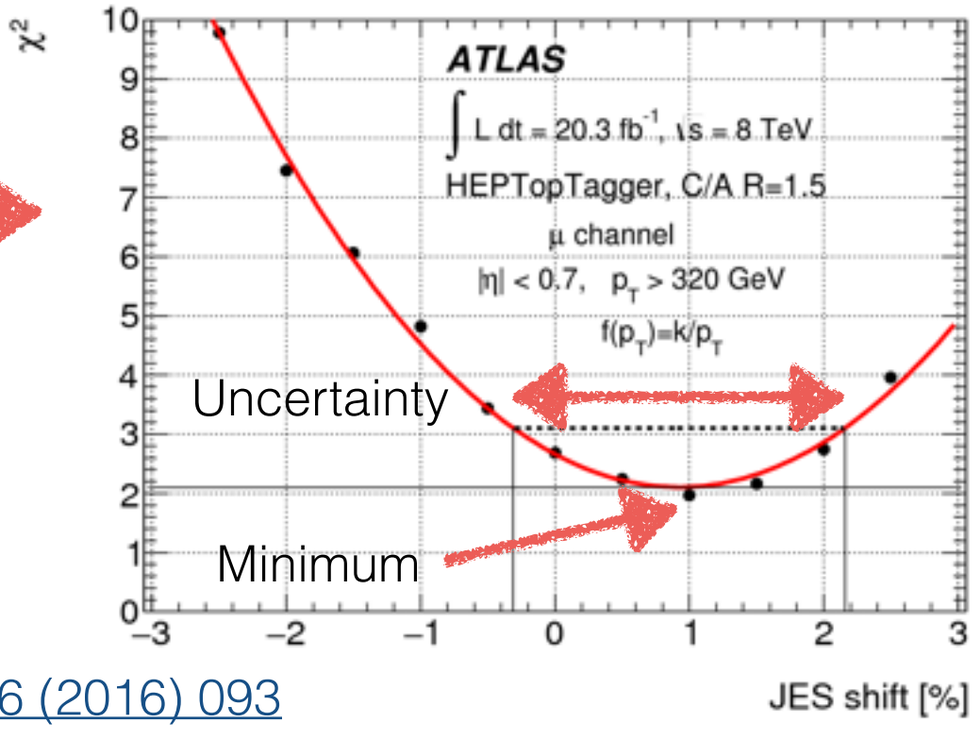


Constraining subjet JES

Use top sample, vary subjet JES



Get χ^2 distribution:



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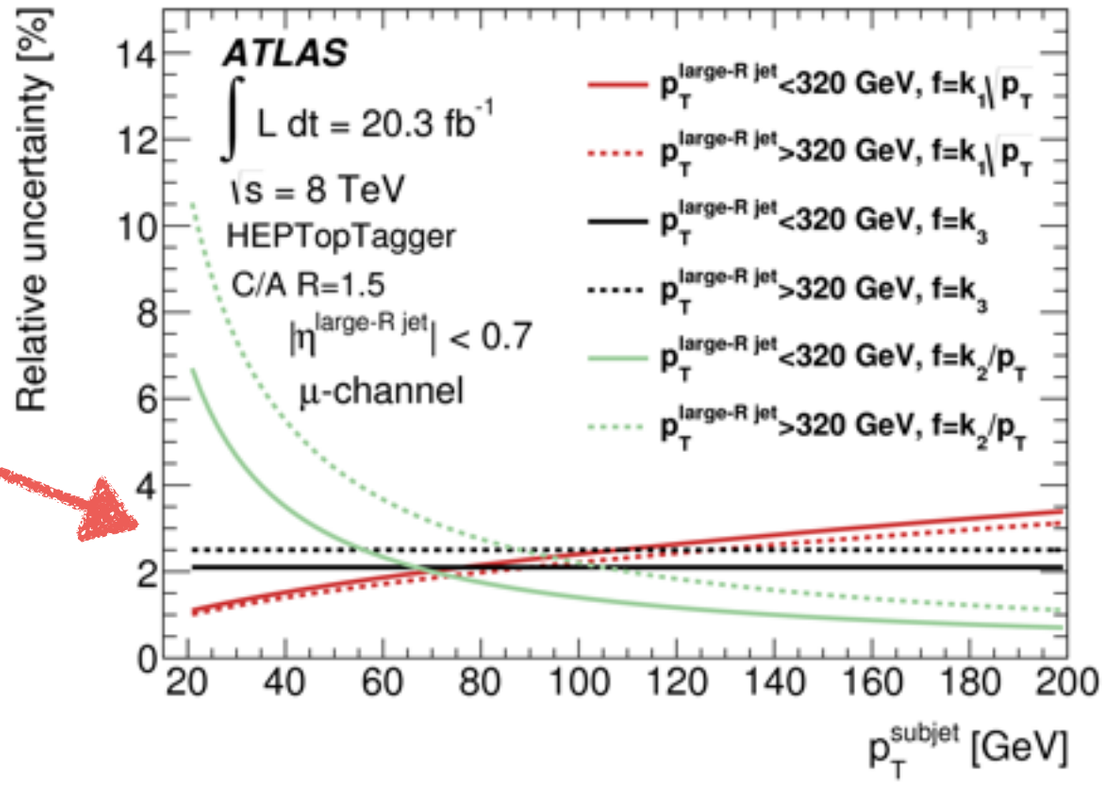

3 parametrizations of subjet p_T scale considered, emphasizing **no p_T dependence**, low p_T, or high p_T

Uncertainties can then be propagated to HTT properties (efficiency, mass…)

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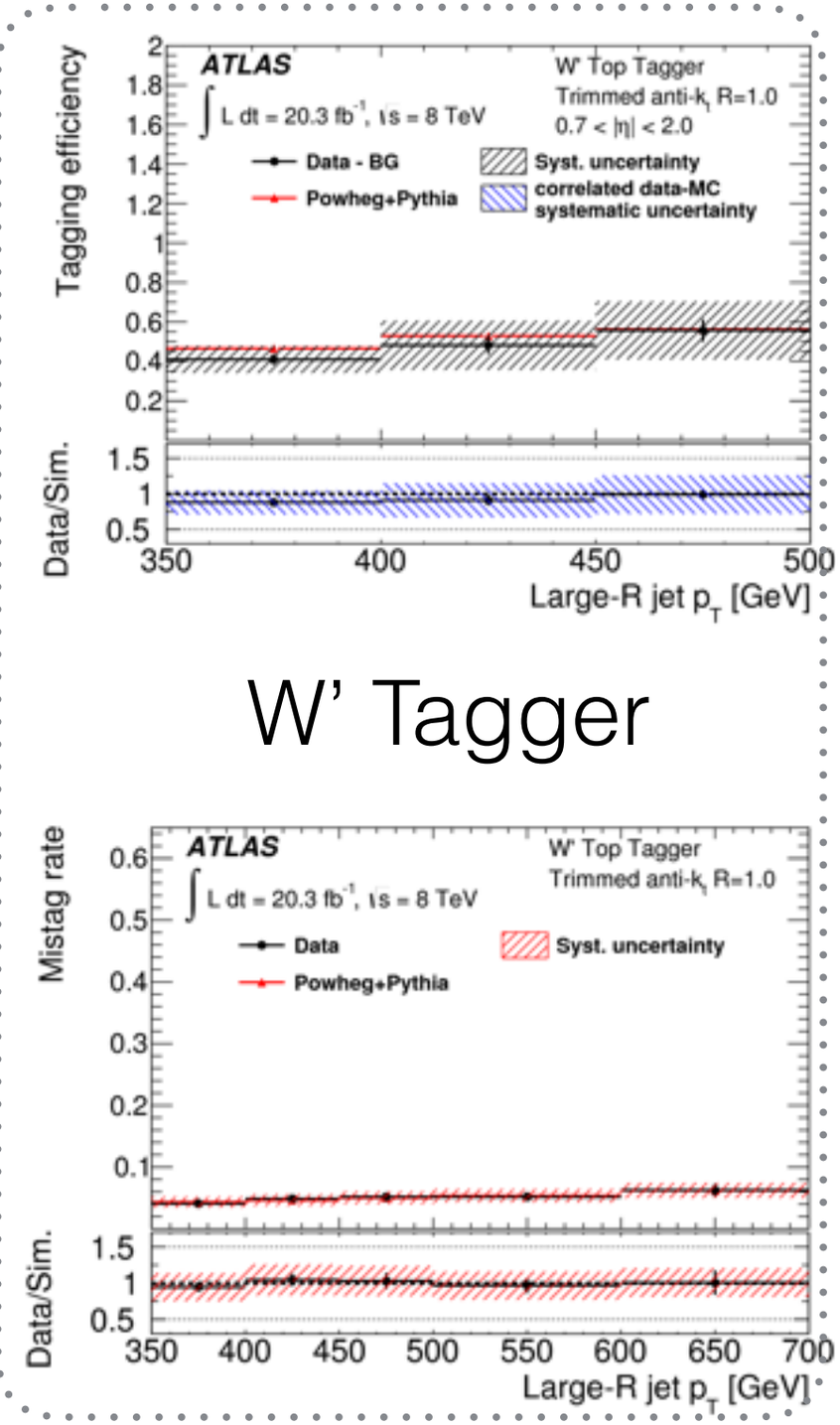
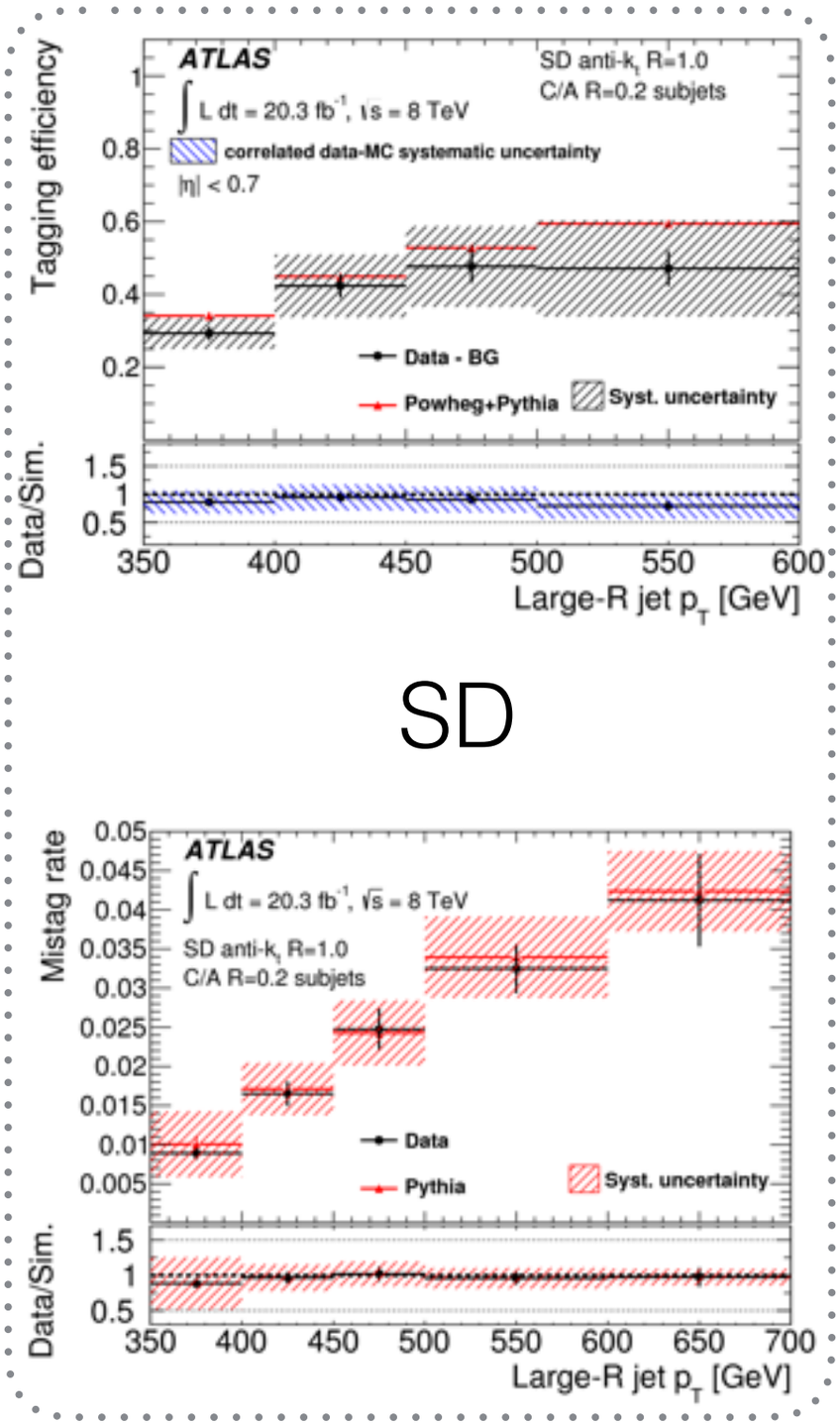
Signal and background efficiencies

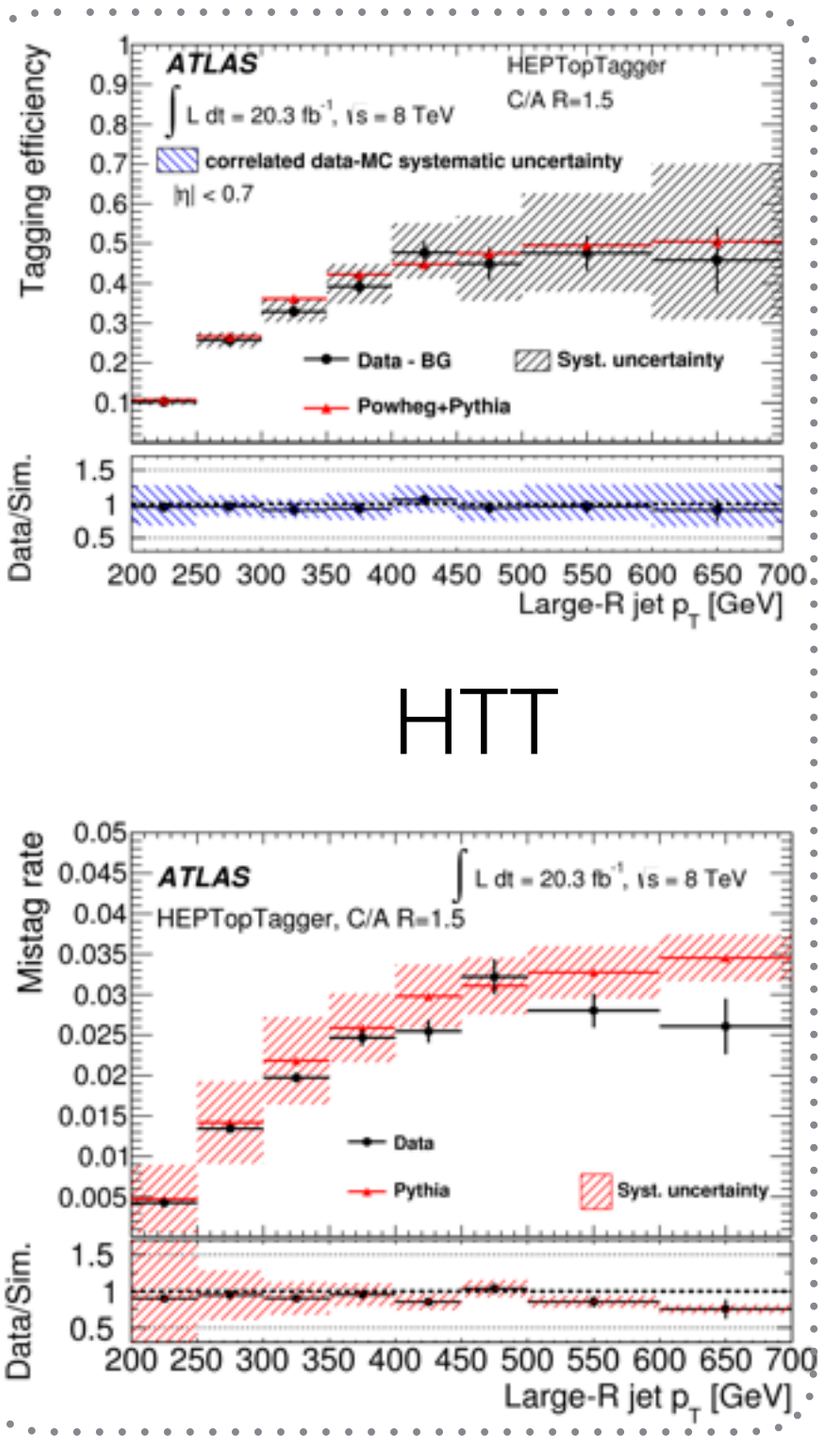
from $t\bar{t}$ lepton + jet events



W' Tagger



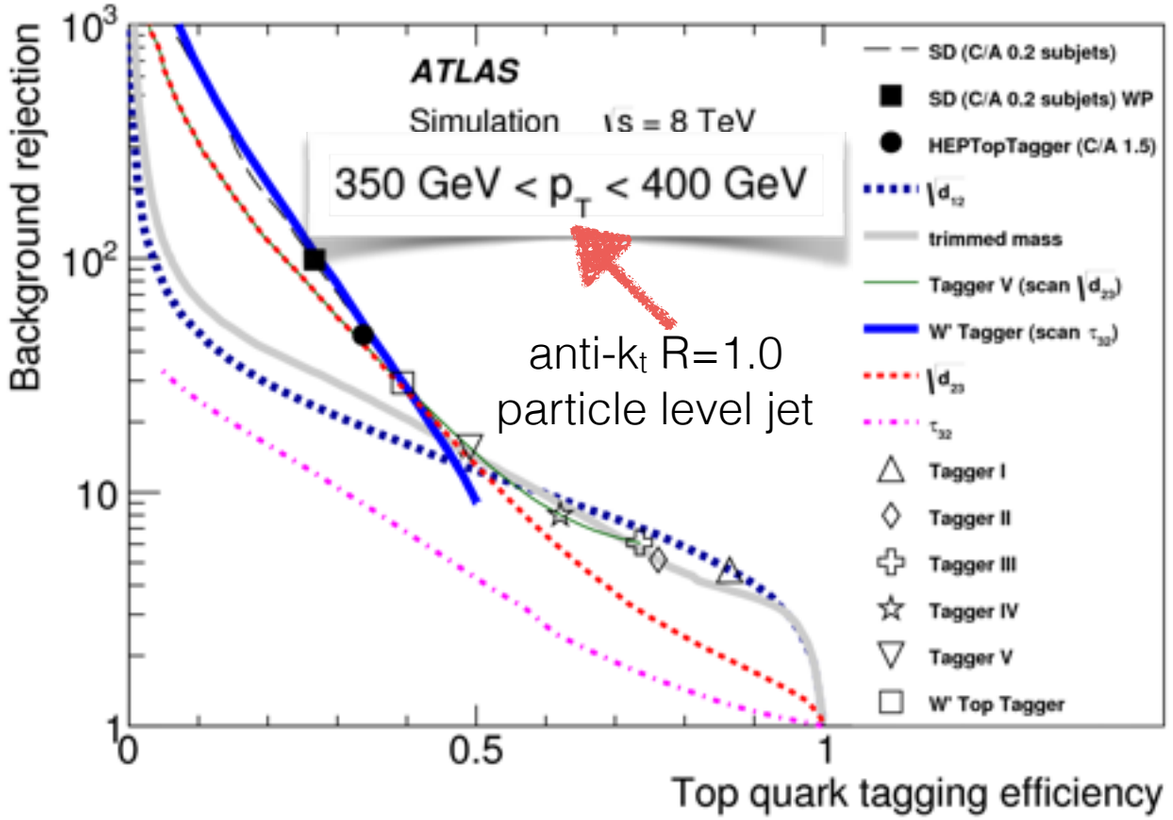
SD

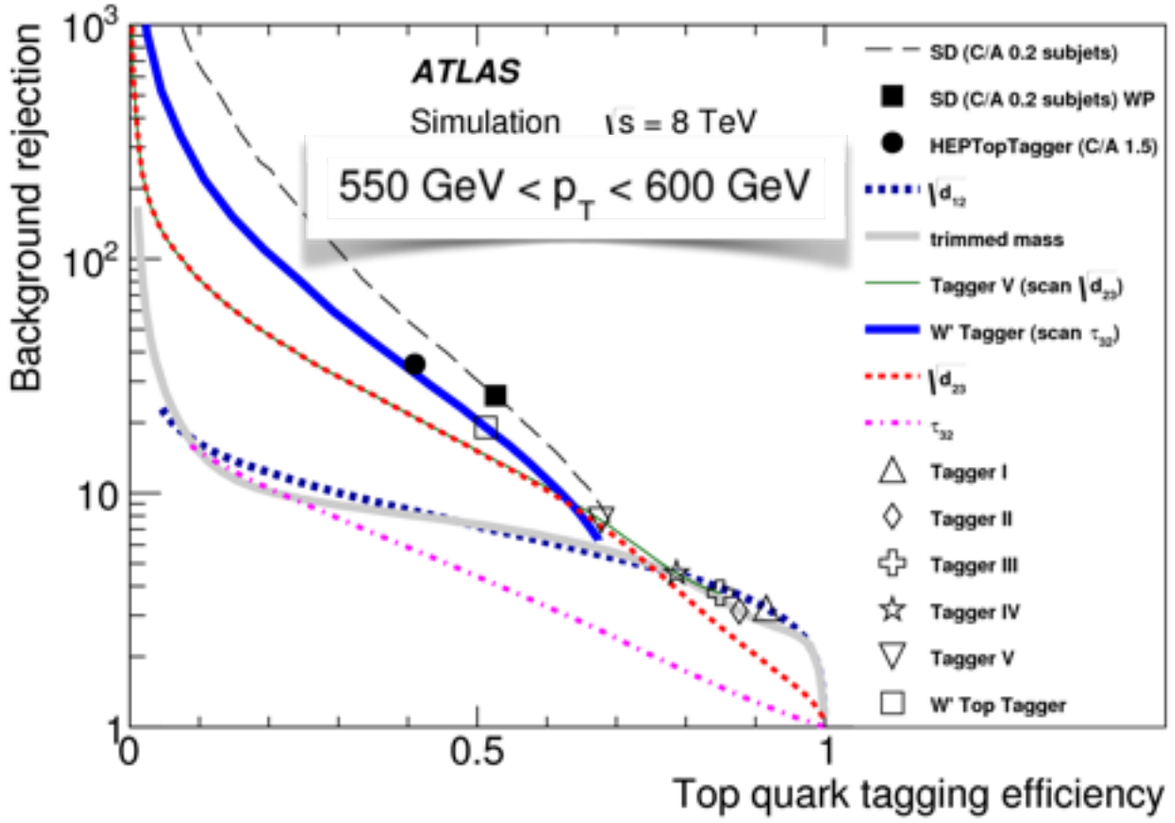


HTT

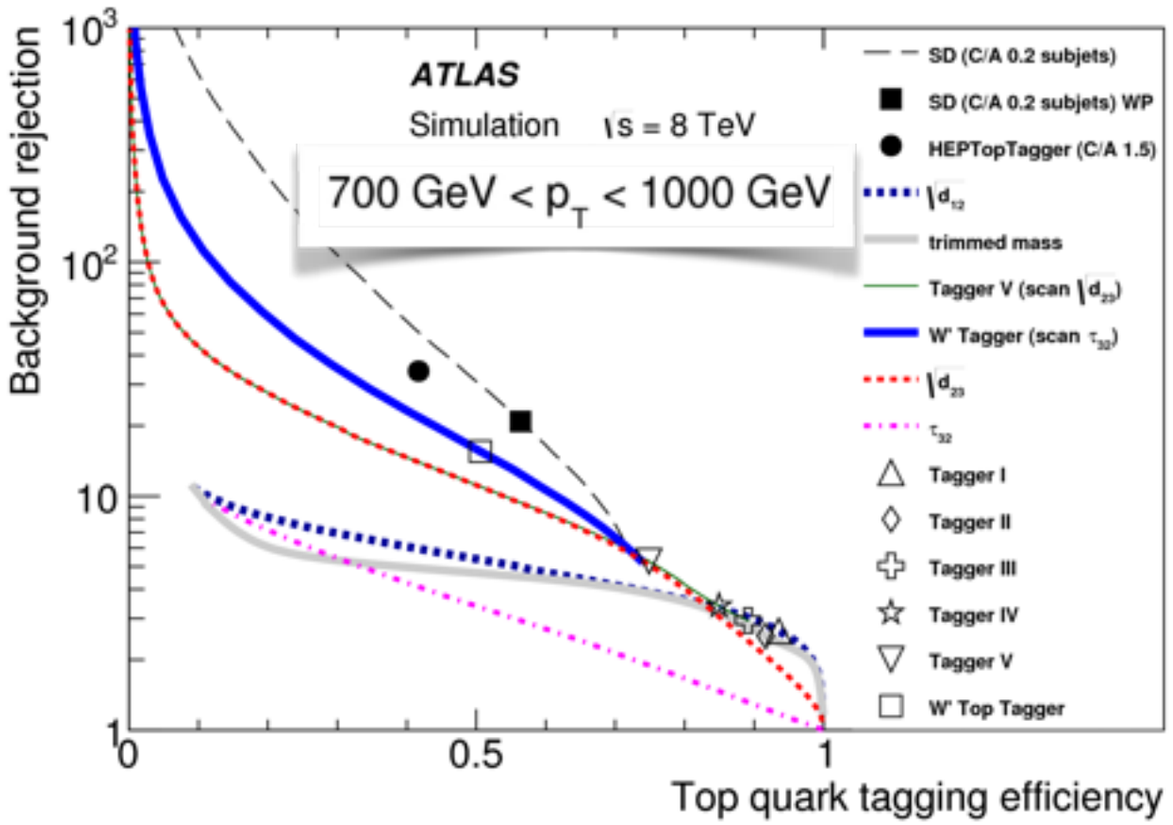
from di-jet events

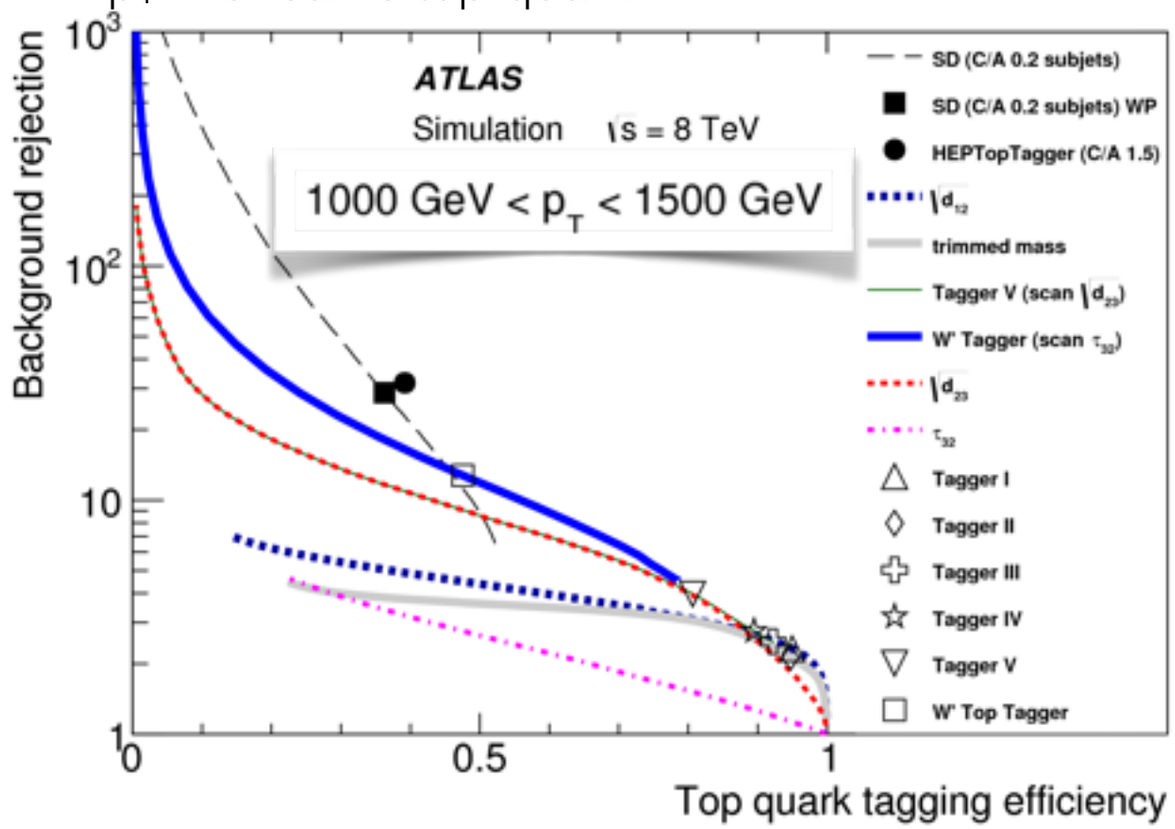
ROC curves





Caveats:
SD using R=0.2 subjets (0.1 better)
HTT not the 2.0 version, larger R = higher p_T^{jet} for same top quark





Run 1 top tagging summary

- many methods explored (out of which only a few have been used in searches/measurements)

- no one tagger serves all purposes

- top tagging works!

- over a wide p_T range data is well described by simulation in signal- and background- like topologies

- top mass peak can be used for calibration

ATL-PHYS-PUB-2015-053

Run 2 smooth top tagger

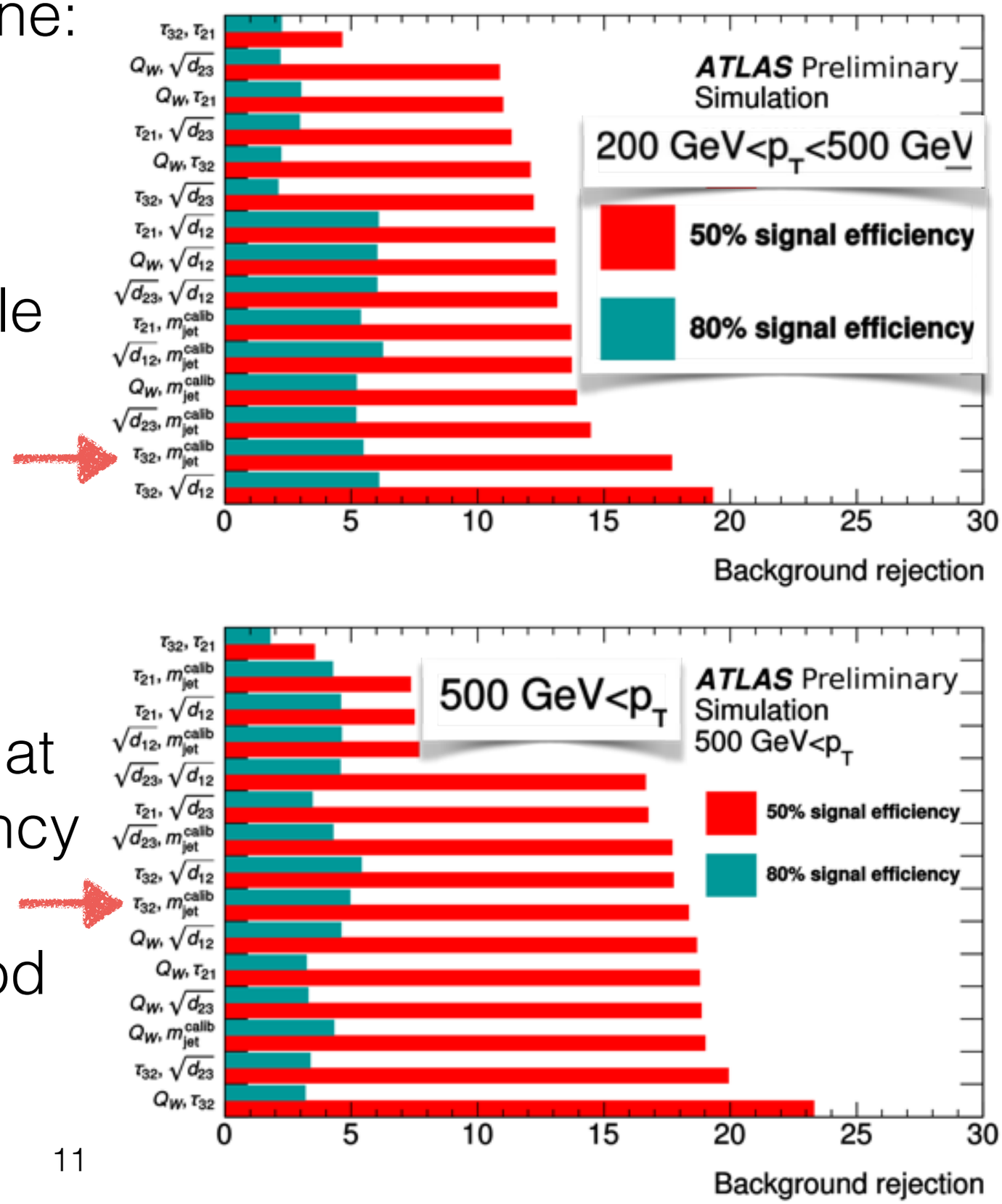
- Run 2 ATLAS large-R baseline: anti-kt R=1.0 trimmed (R_{sub}=0.2, f_{cut}=0.05)

- simple & quick use 2 variable tagger

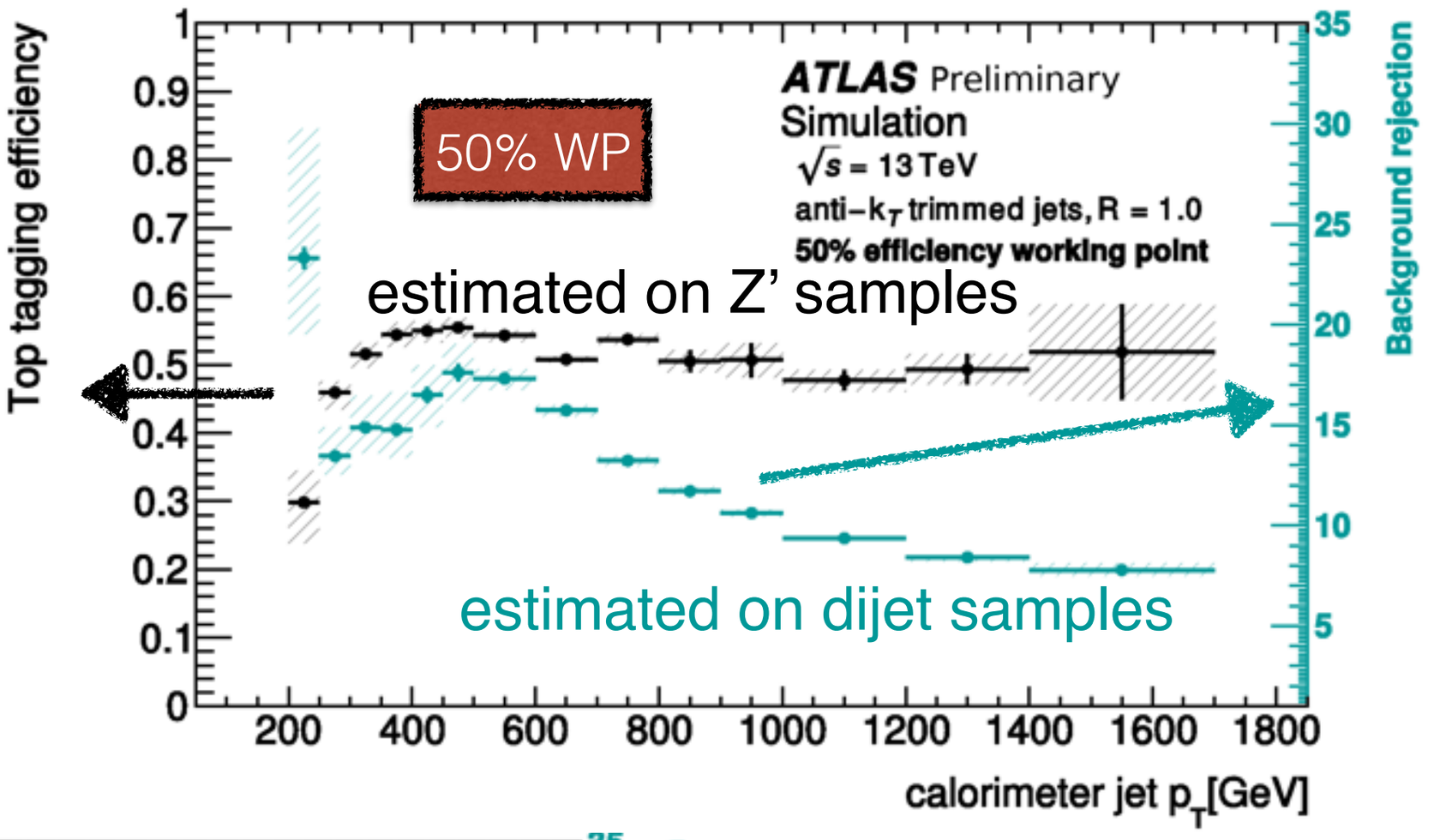
- check correlation of most discriminating variables

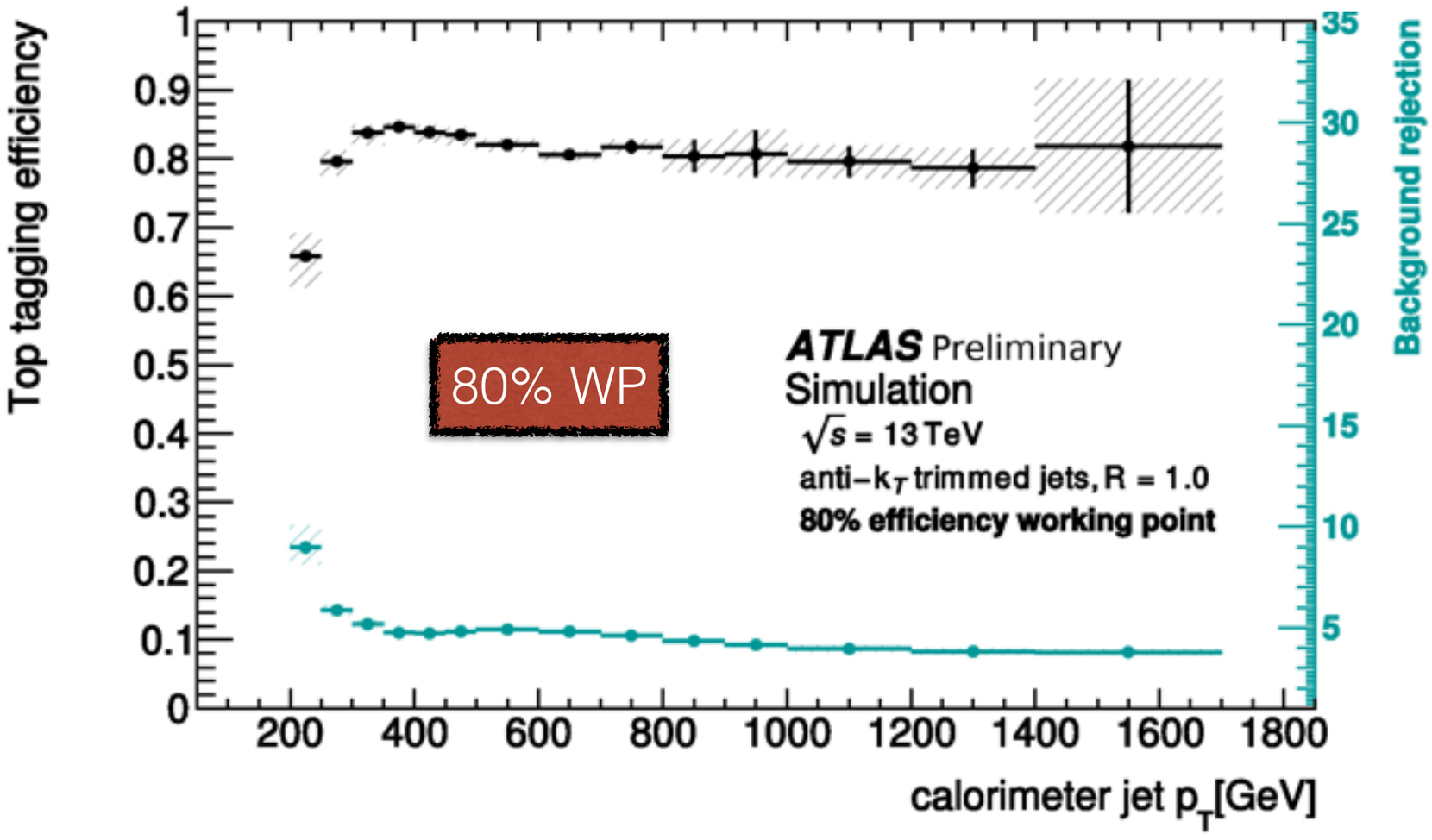
- study background rejection at 50% and 80% signal efficiency

- pick combination that is good everywhere: m_{jet} & τ_{32}^{WTA}



Efficiency and rejection





Constant signal efficiency vs p_T, by applying p_T dependent cuts on m_{jet} & τ_{32}

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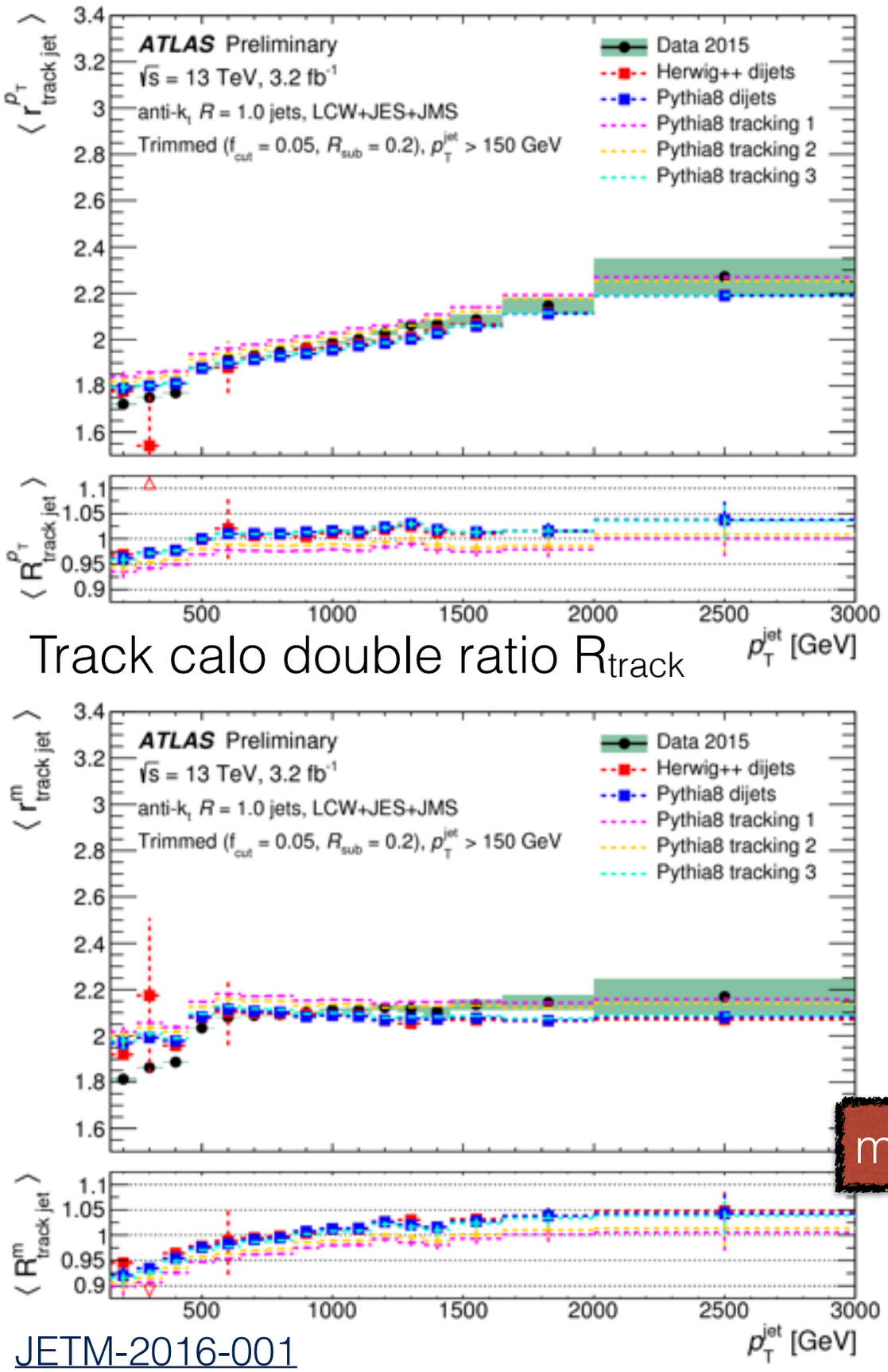
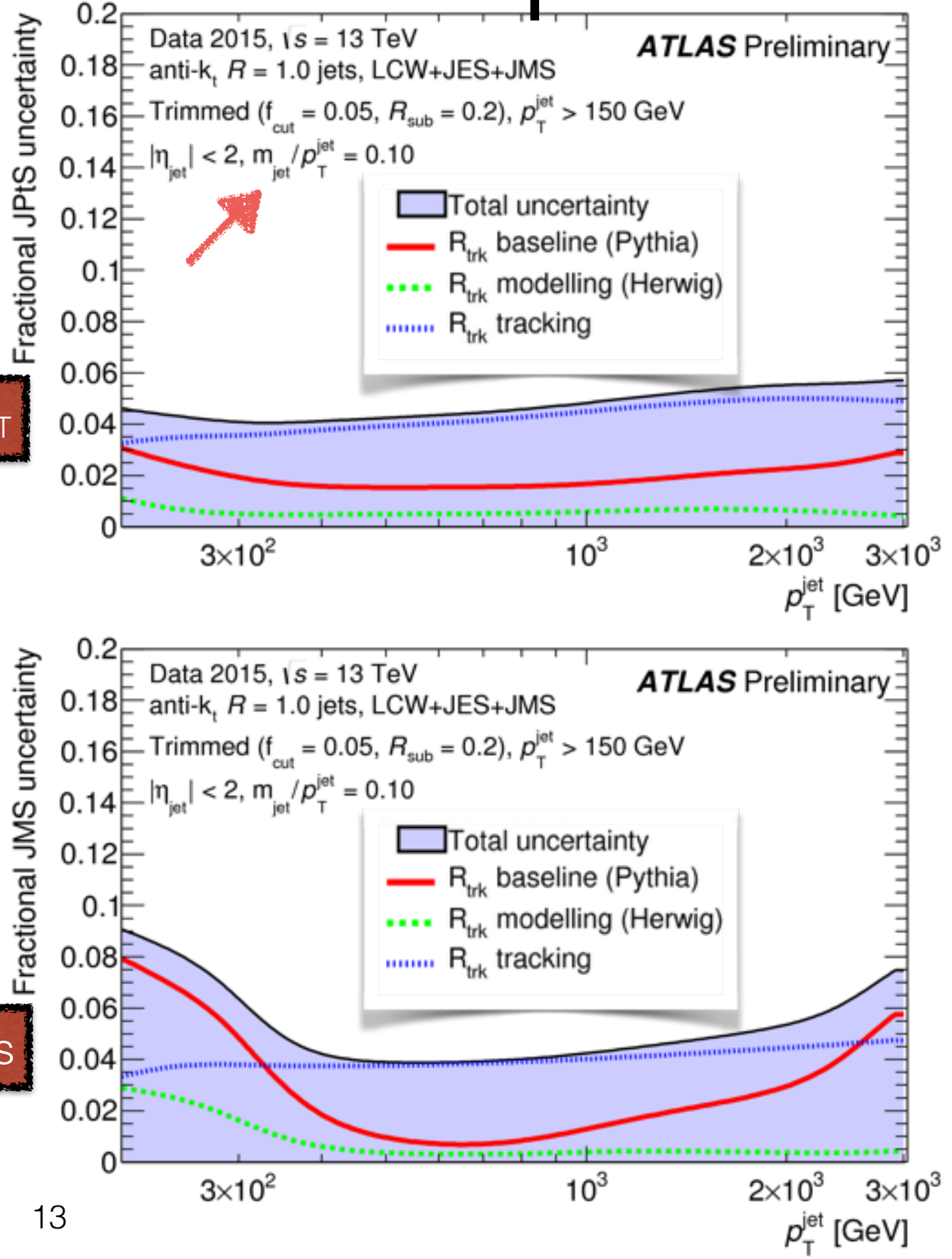
Uncertainties on inputs



Track calo double ratio R_{track}

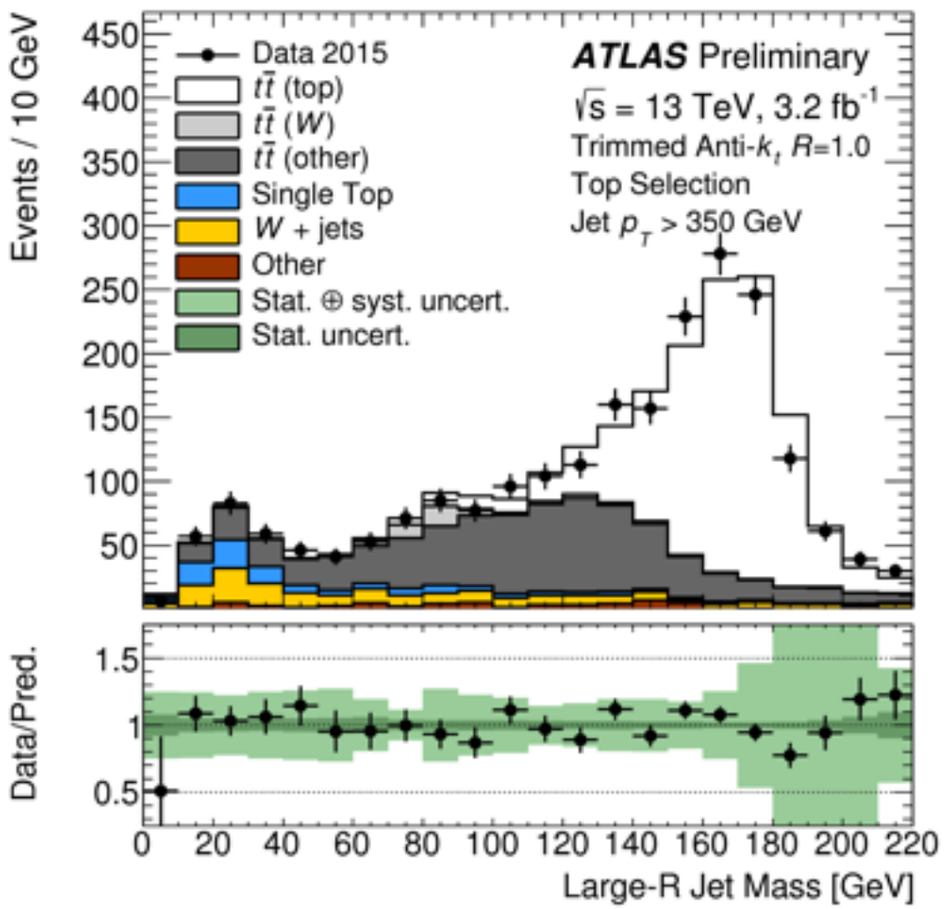
JETM-2016-001

pT

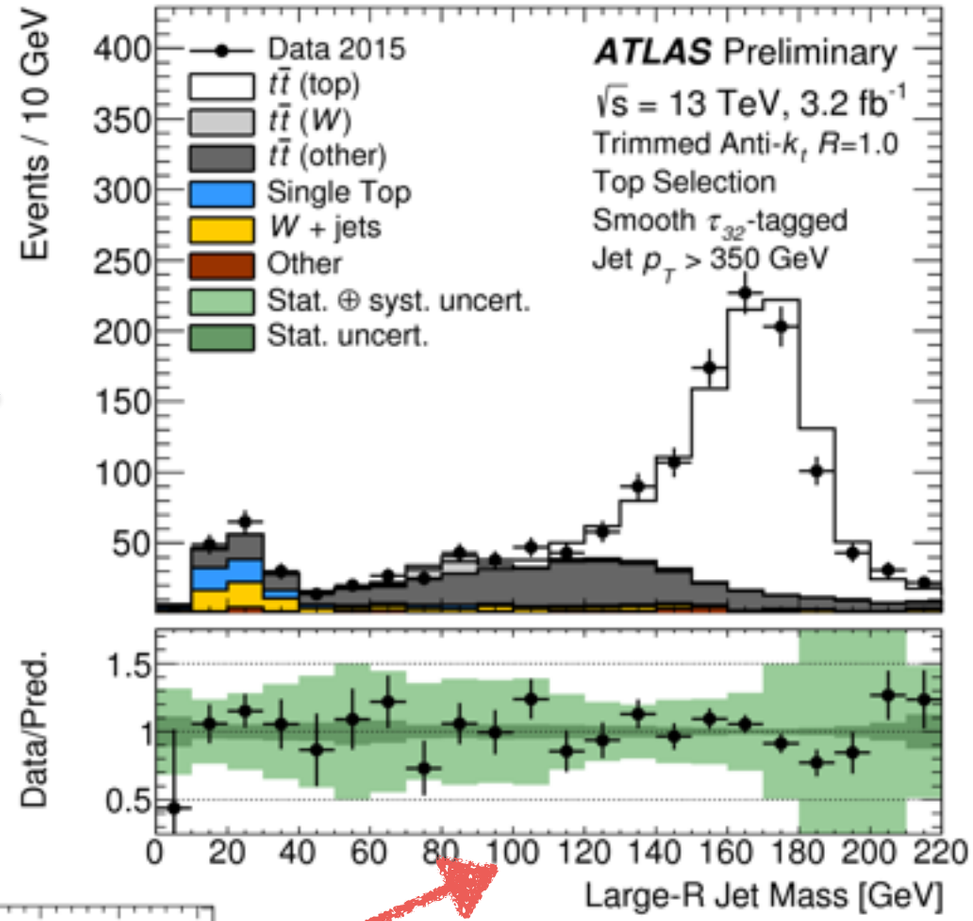


mass

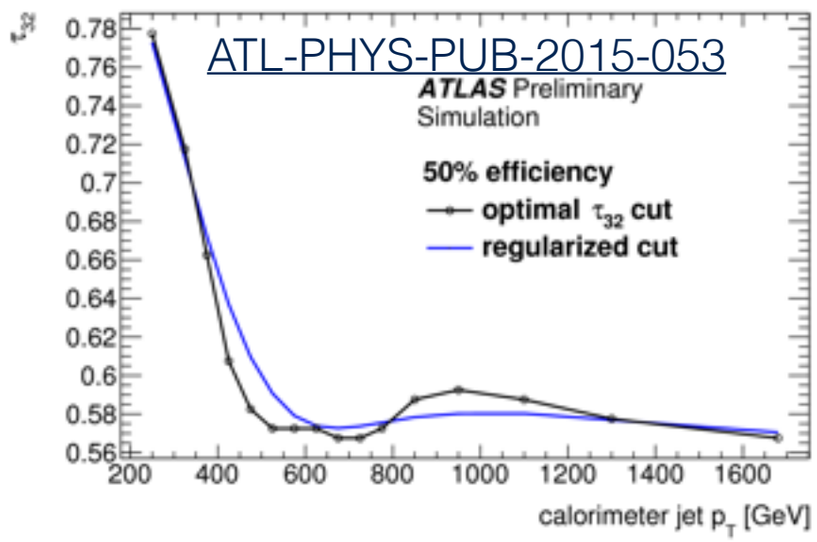
Smooth top tagger in 13 TeV tt̄ data

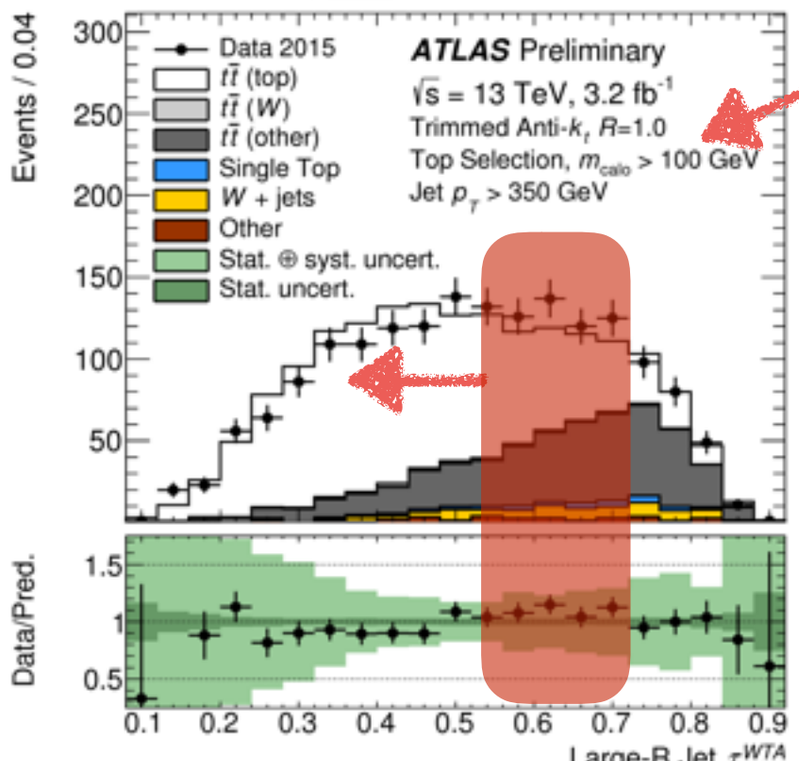


JETM-2016-005



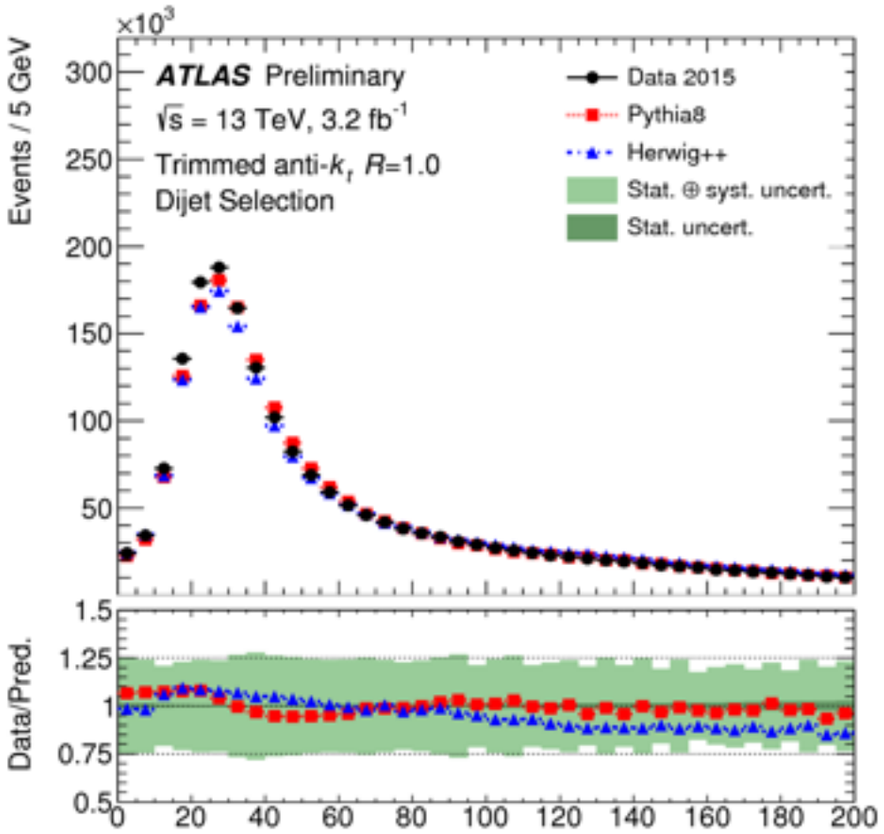
p_T dependent τ_{32} cut



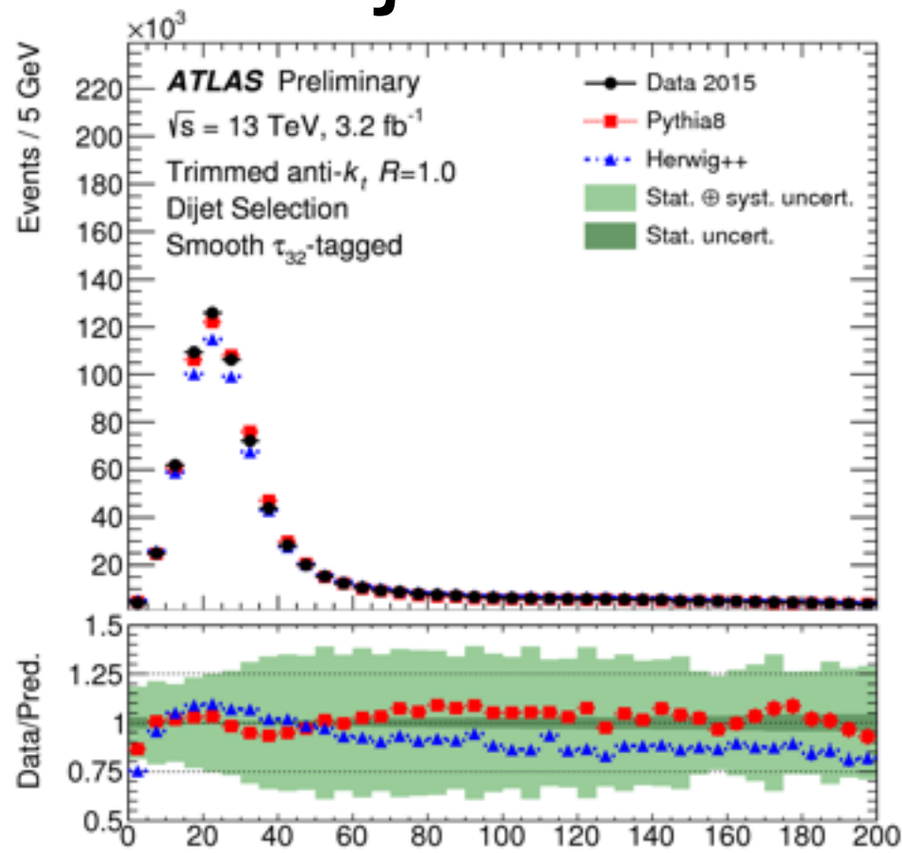


Tagger inputs in signal topology described within uncertainties

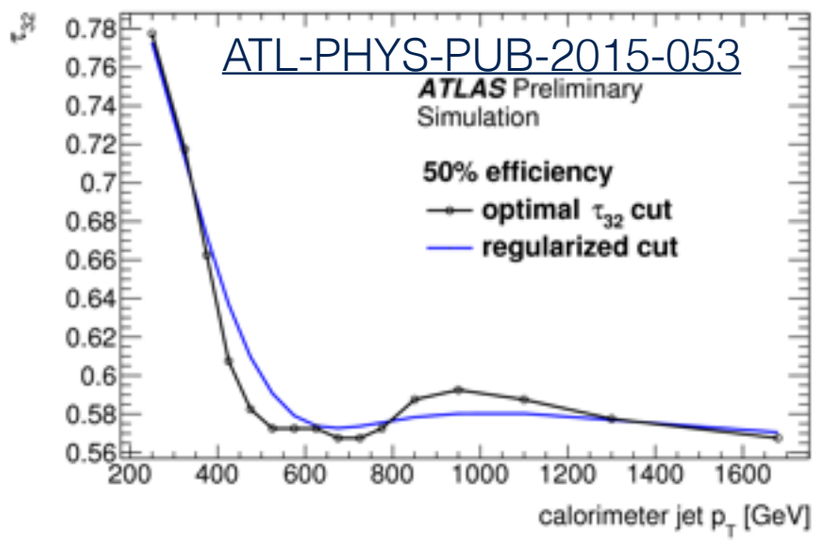
Smooth top tagger in Run 2 dijet data

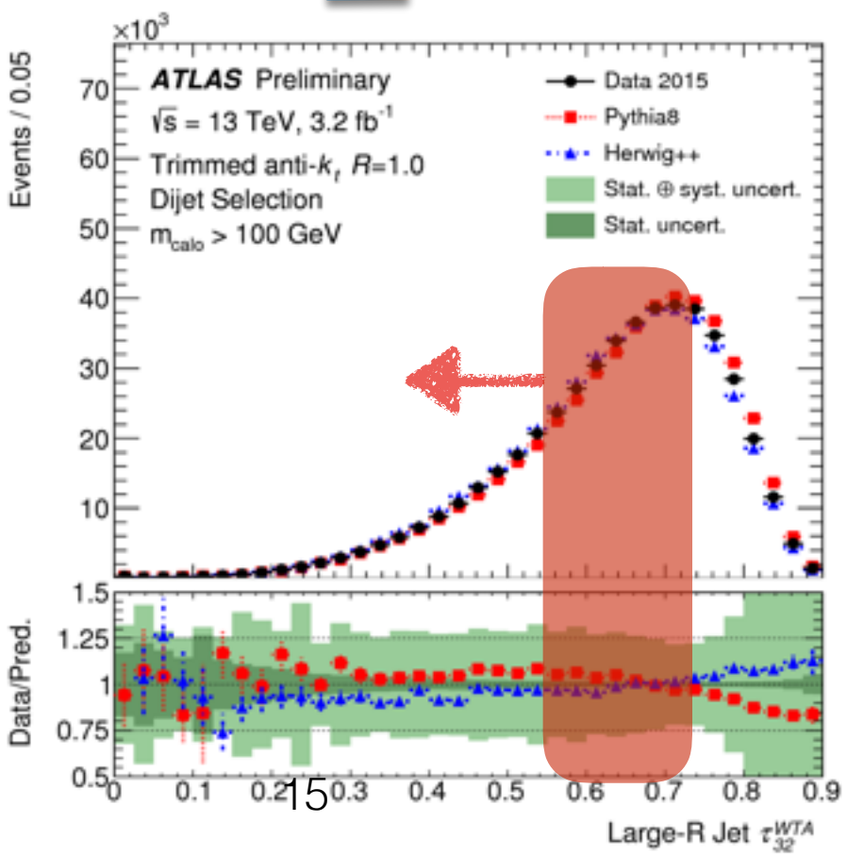


JETM-2016-005



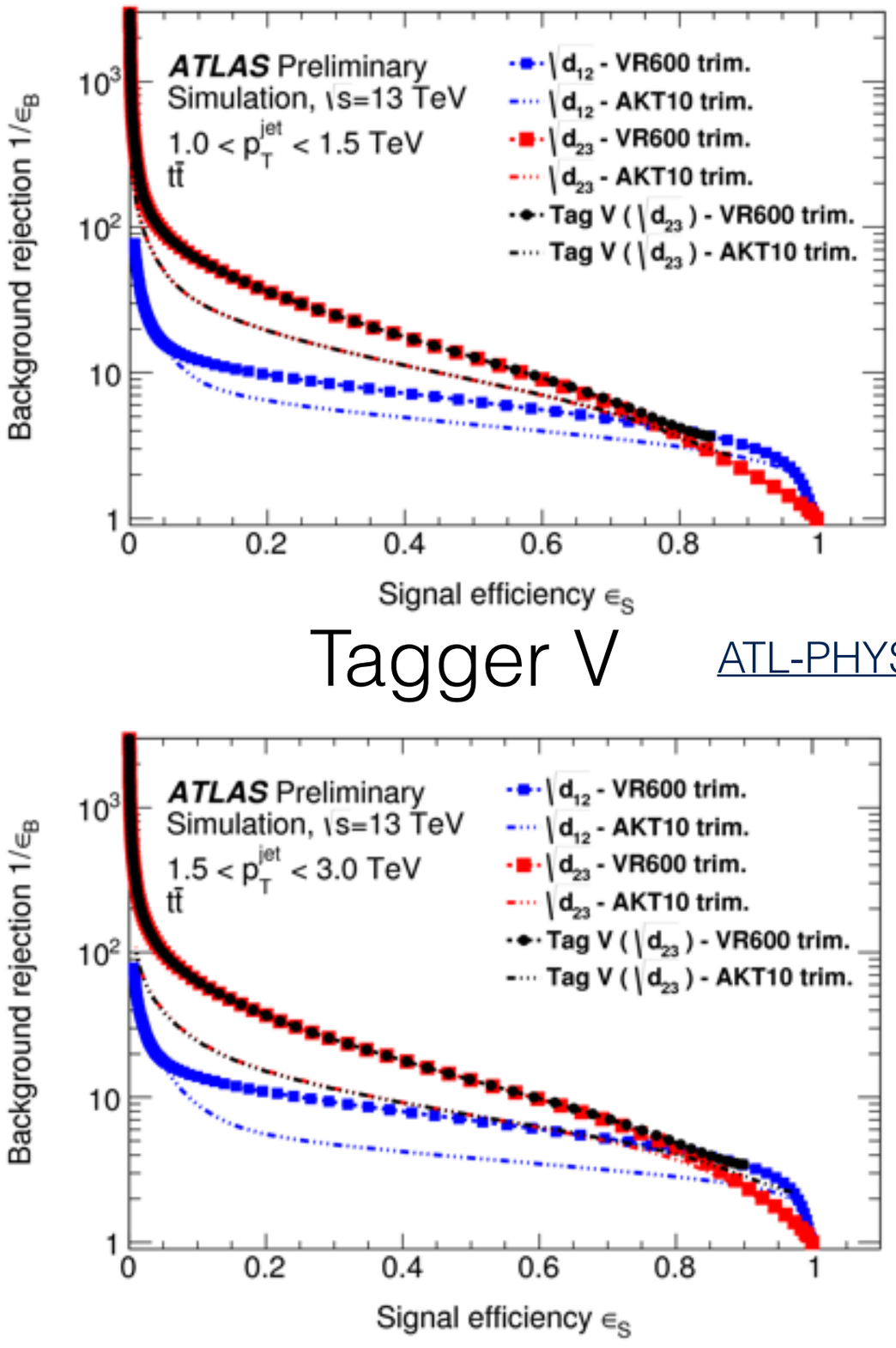
pT dependent τ_{32} cut



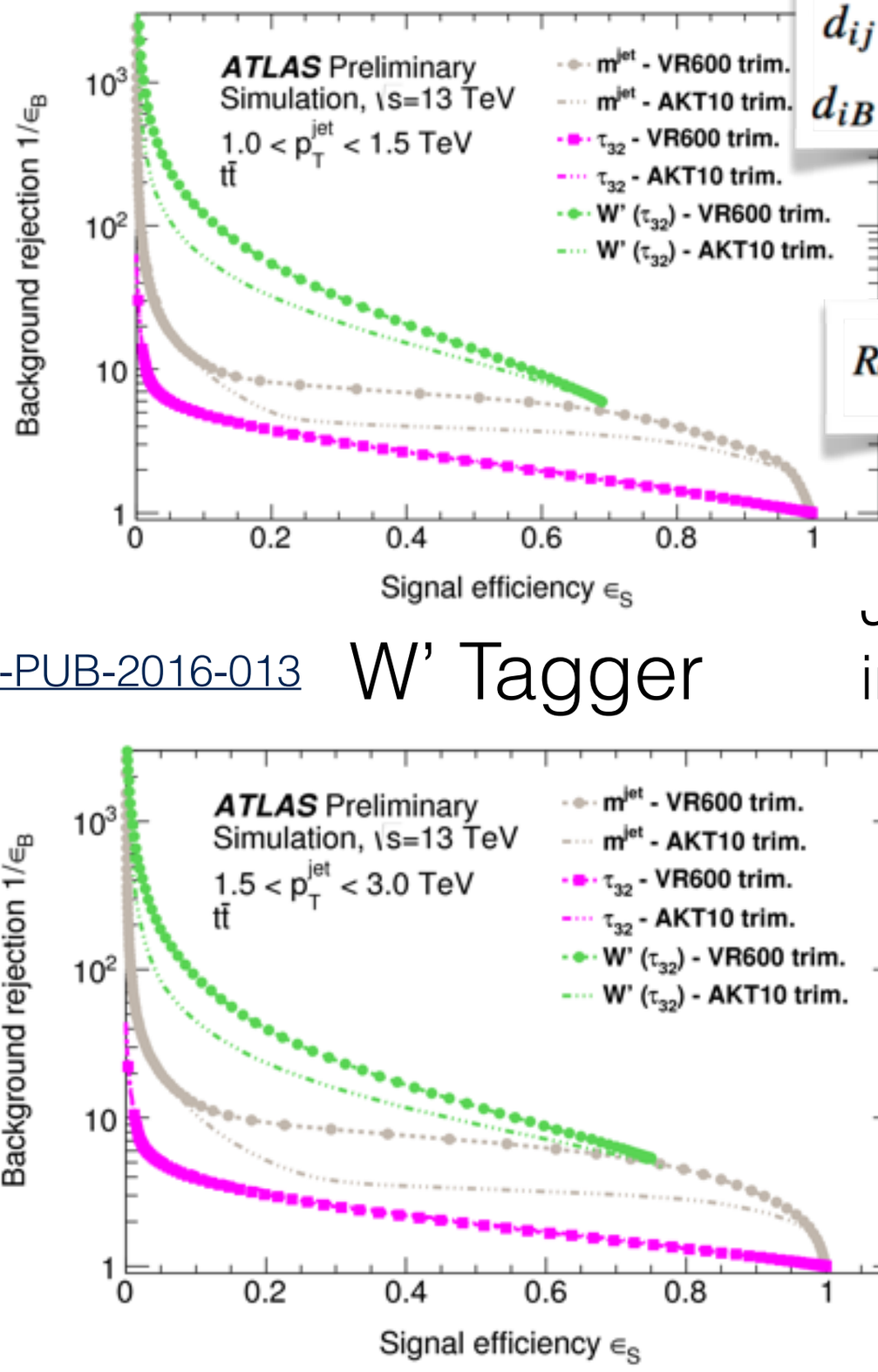


Tagger inputs in background topology described within uncertainties

Variable R jets for top tagging



Tagger V



W' Tagger

$$d_{ij} = \min(p_{Ti}^{2n}, p_{Tj}^{2n})\,\Delta R_{ij}^2$$

$$d_{iB} = p_{Ti}^{2n}\,R_0^2,$$

$$R_0 \longrightarrow R_{eff}(p_{T,i}) = \frac{\rho}{p_{T,i}}$$

Jet shrinks with increasing p_T

[ATL-PHYS-PUB-2016-013]

see Aparajita's and Qi's talks for W and H

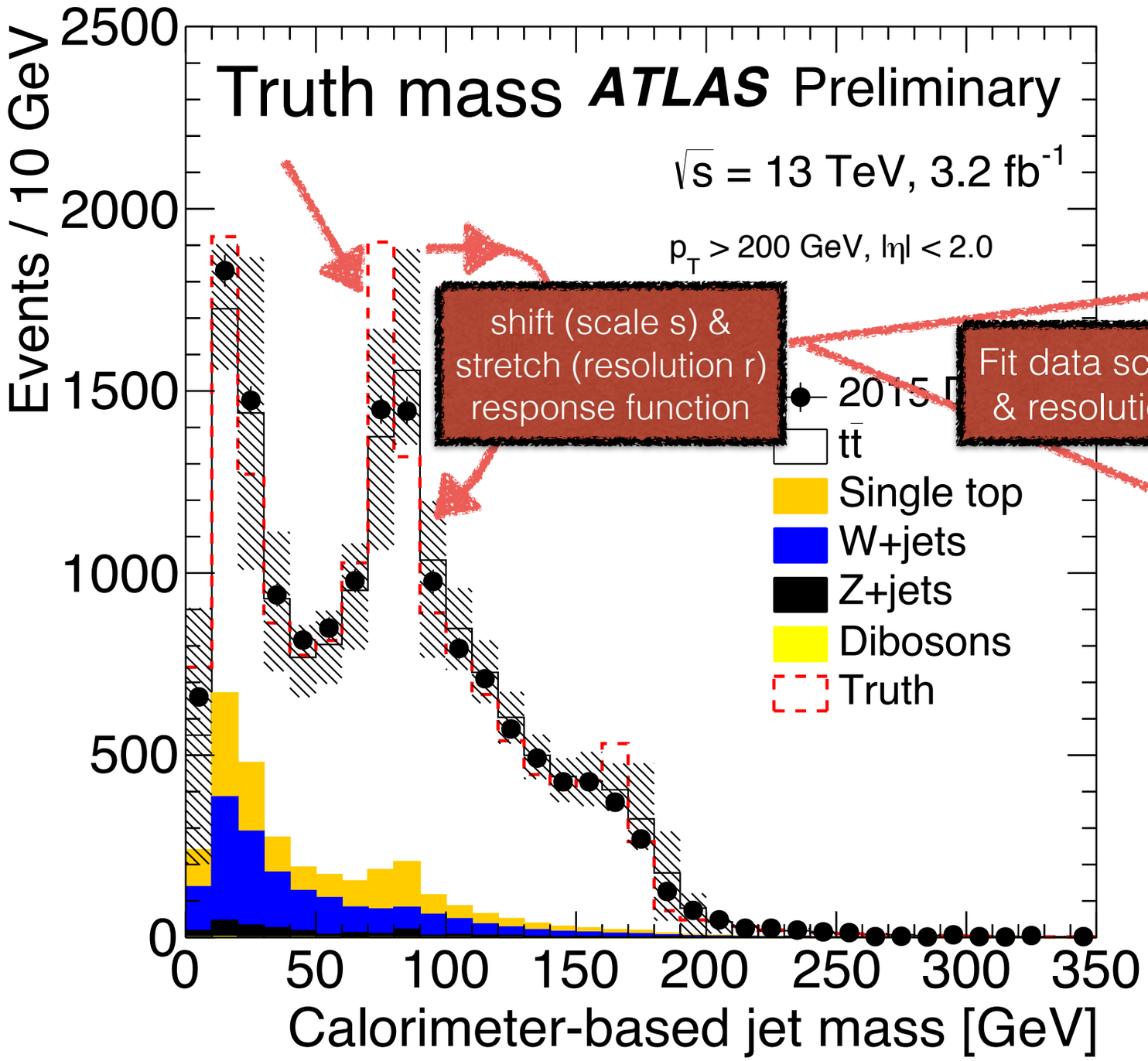
D. Krohn, J. Thaler and L.-T. Wang, Jets with Variable R, JHEP 06 (2009) 059

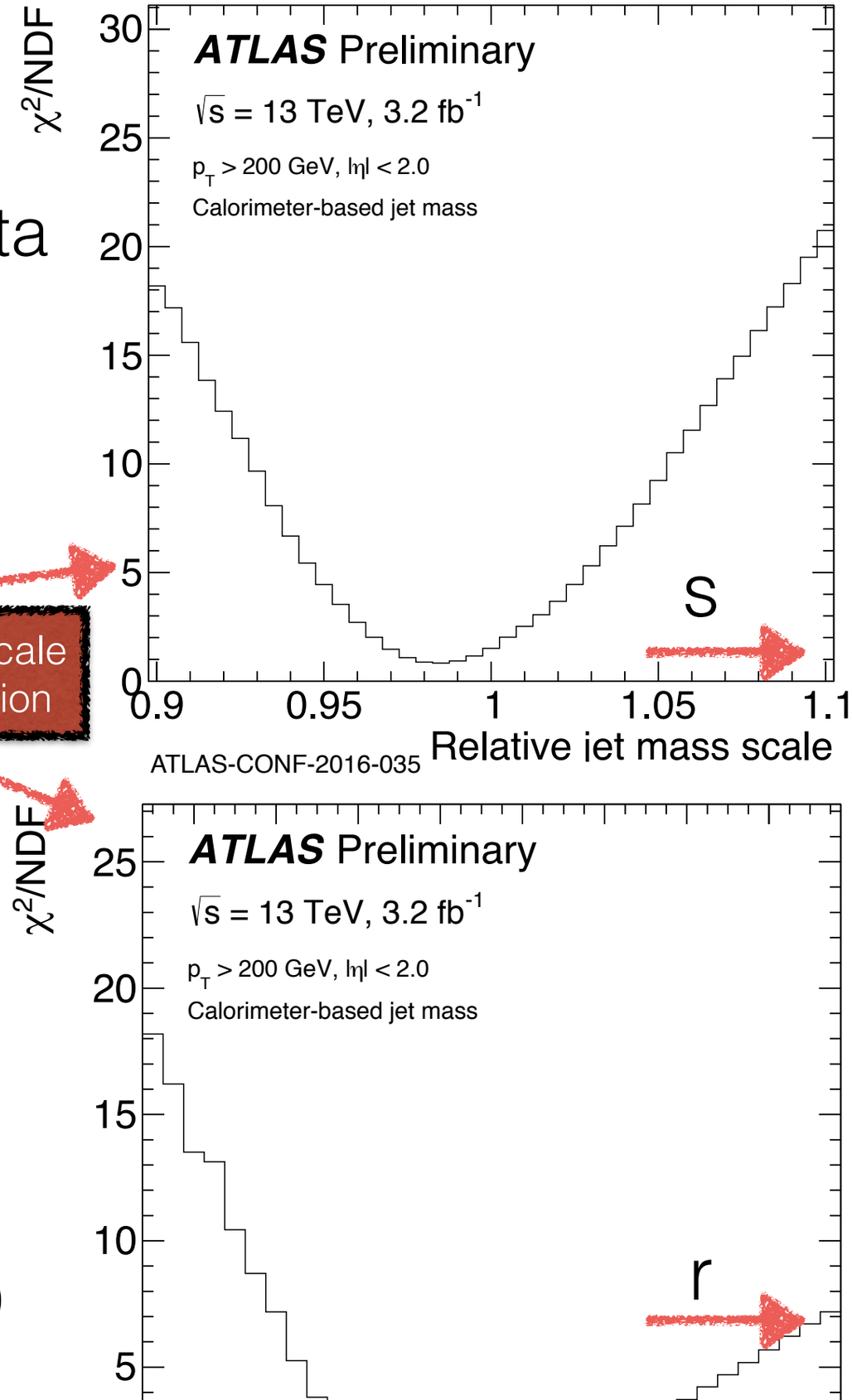
Run 2 top tagging summary

- it still works!
- simple substructure variable based tagger improved to have constant signal efficiency
- smooth top tagger fully commissioned and has been used successfully in $t\bar{t}$ resonance search, see Aine's talk
- top tagging may benefit from mass reconstruction/track assisting in the future, see Roland's talk
- top tagging will benefit from improved uncertainties estimated in-situ in 13TeV data

Forward folding

aka mass scale & resolution from $t\bar{t}$ data

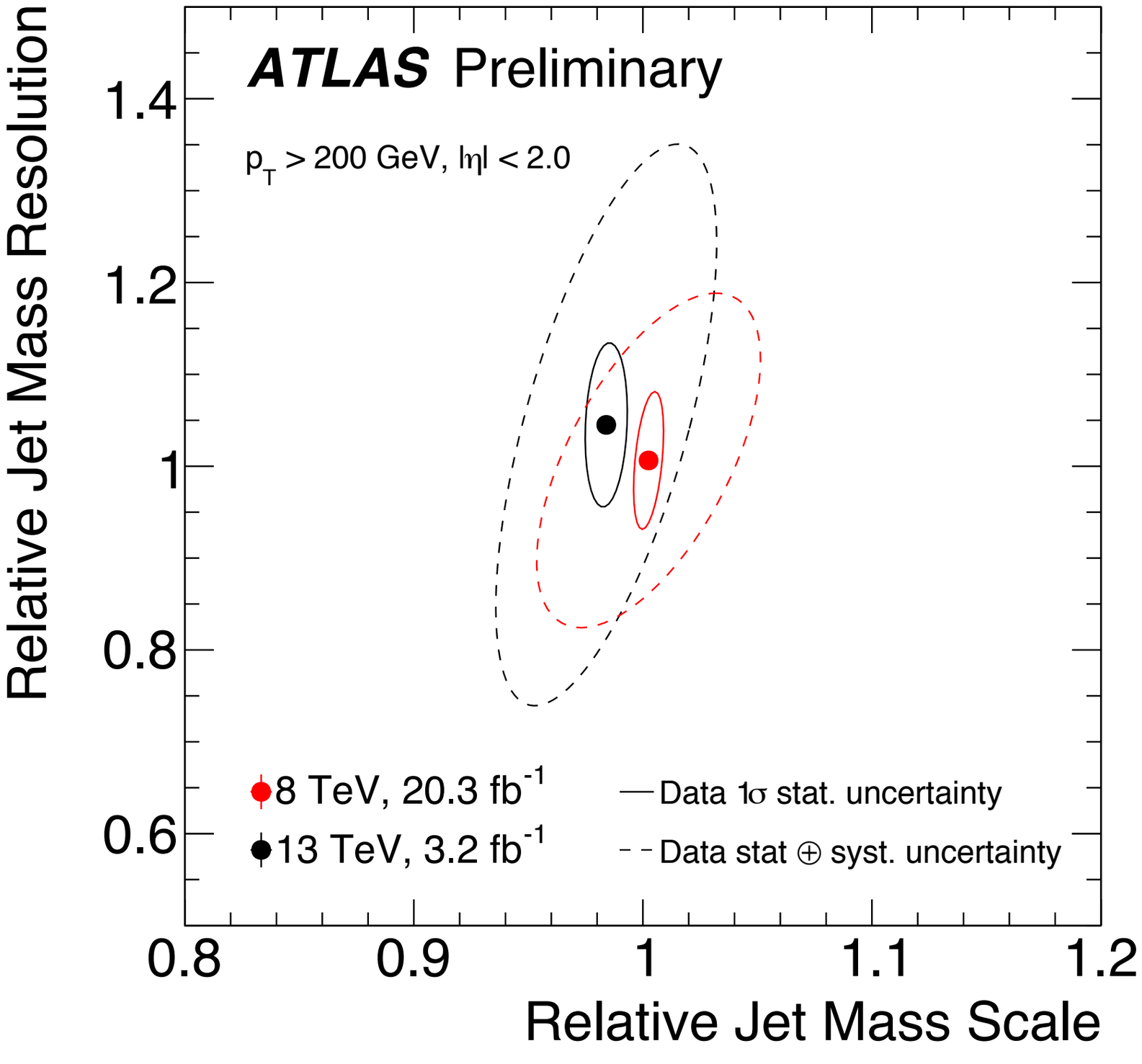




New 13 TeV plots, for details see Run 1 note:

ATLAS-CONF-2016-008

Forward folding results



ATLAS-CONF-2016-035

scale uncertainty roughly 8%

resolution uncertainty roughly 20%

will improve with more data

in Run 2 method extended to p_T

limited to p_T range we have tops in

Final summary

- top tagging works
- in-situ measurements will help understand calibrations & uncertainties much better
- more in-situs being added to the arsenal
- top tagging will benefit!

large R multi-jet balance