Studies of Monte Carlo Modelling of Jets at ATLAS

Deepak Kar
On behalf of ATLAS collaboration

MPI@LHC, Shimla, December 11-15, 2017

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New Colour Reconnections Models in Pythia8

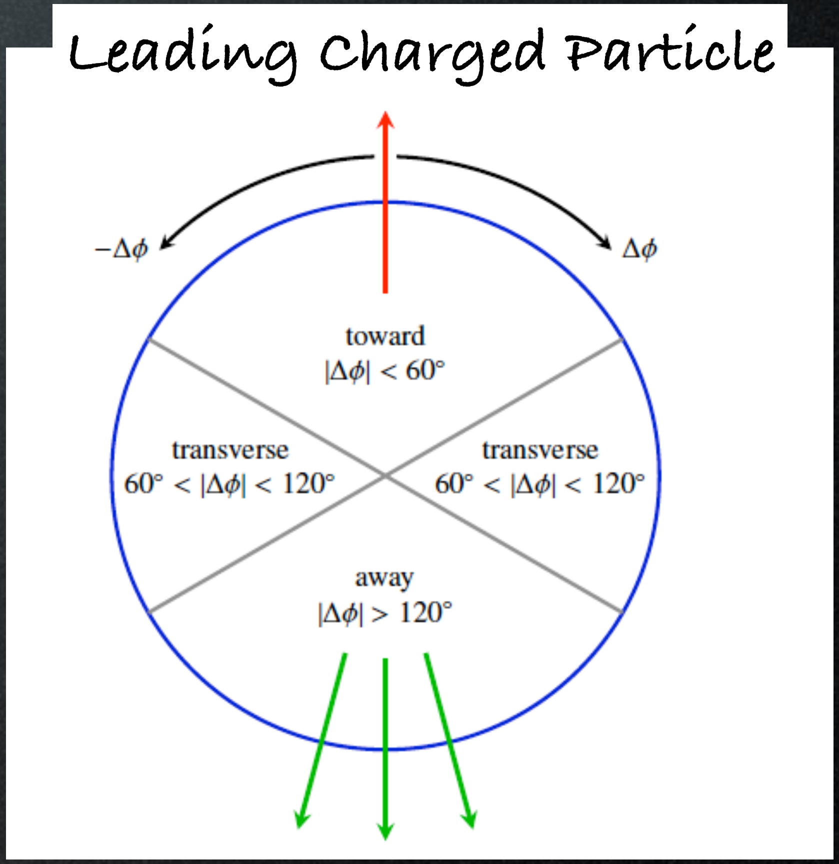
- CR0: Currently used MPI-based model.
- CR1: New QCD-based model, with more complete treatment of QCD multiplet structure, resulting in enhancement of baryon production.
- CR2: New gluon-move model, where only gluons are considered for reconnection.

Question:

- Can the newer models describe our data reasonably well?

Underlying Event Observables

- Measured at 900 GeV, 7 TeV and 13 TeV (new!) using leading charged particle.
- Tunes are derived for each CR model, and compared to A14 predictions (which uses CR0 model), and then with A14 with CR1 and CR2.



Only 13 TeV results shown: the trend is similar at lower collision energies, but somewhat worse agreement at 900 GeV

UE Activity: CR0

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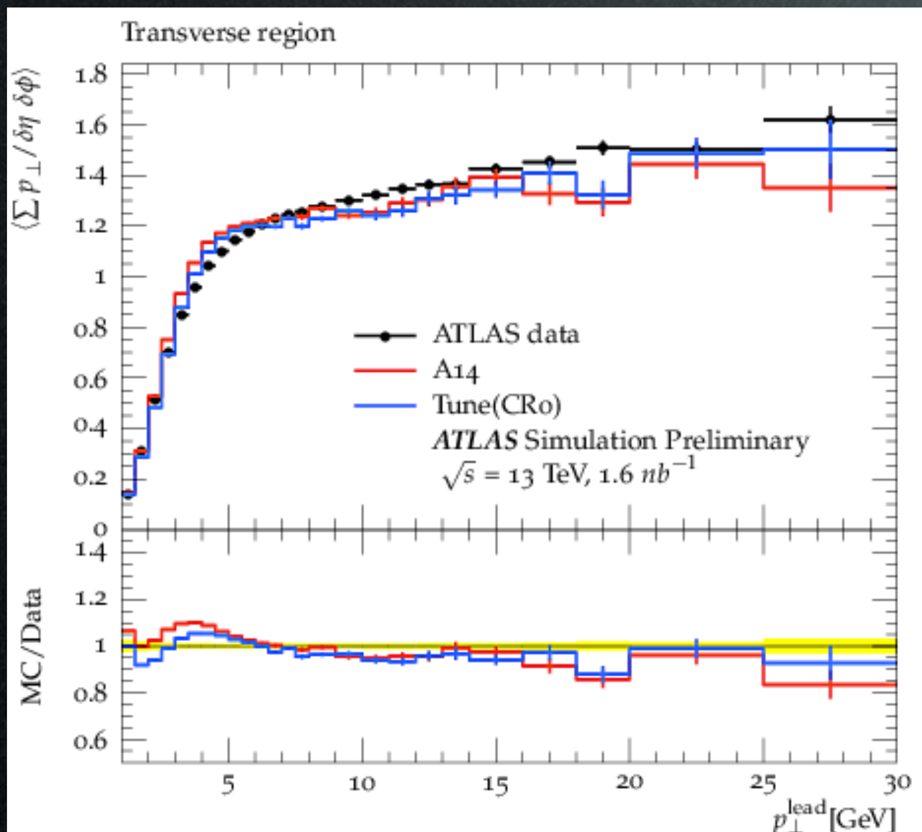

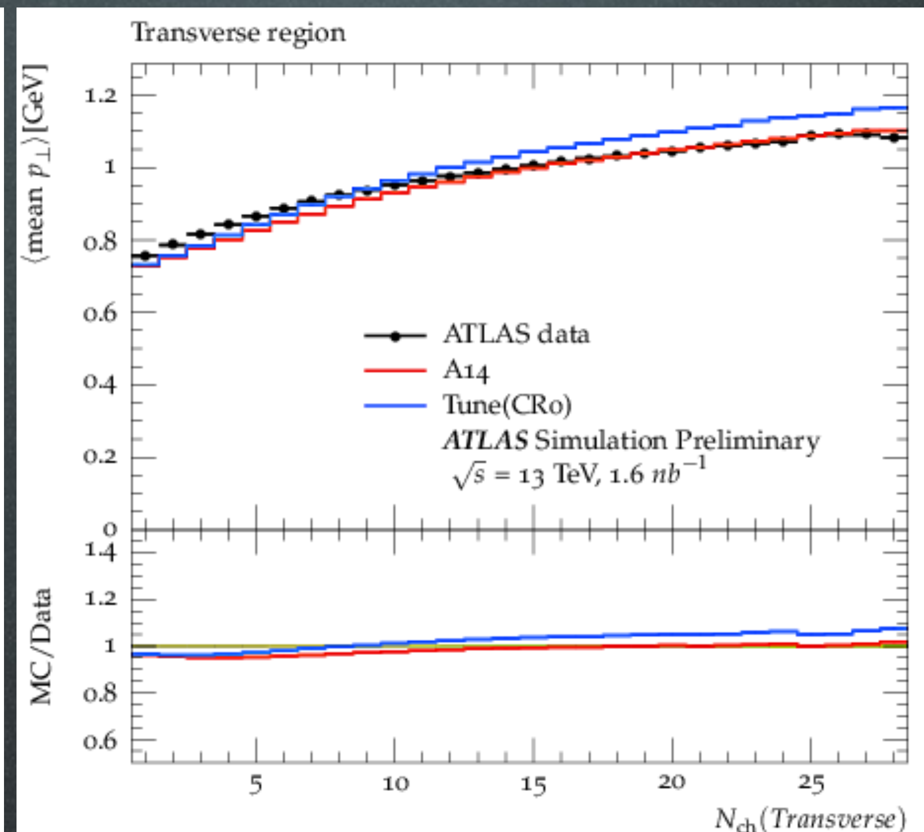

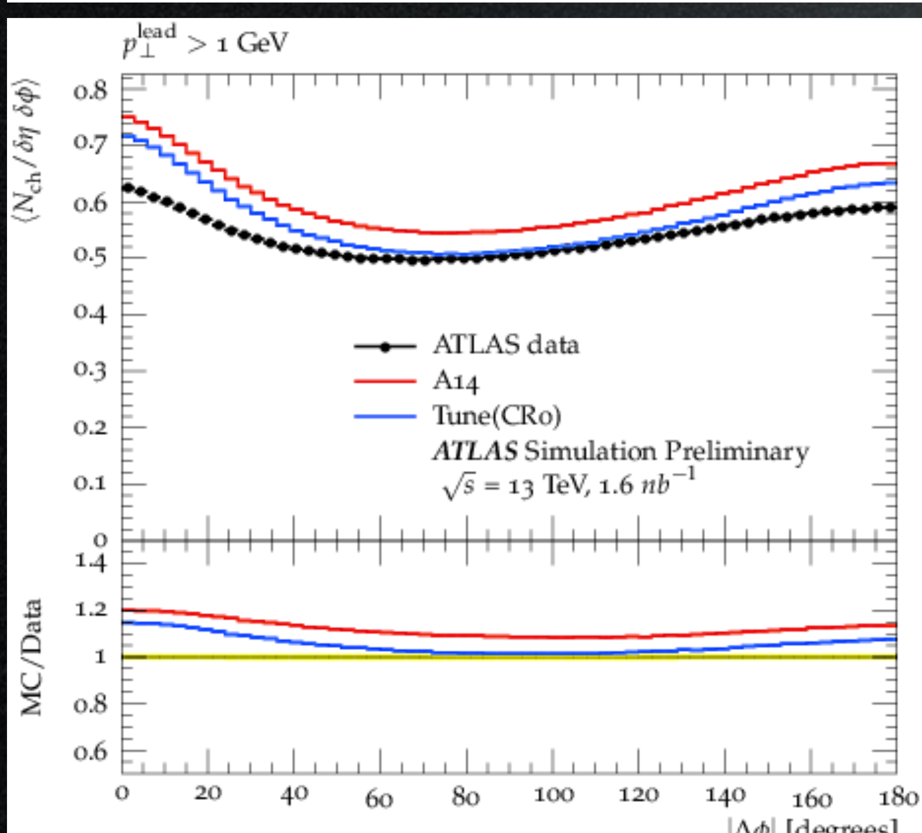

Similar level of agreement.

This data was not used in A14.

Mean p_T vs multiplicity can be modelled well.

UE Activity: CR1

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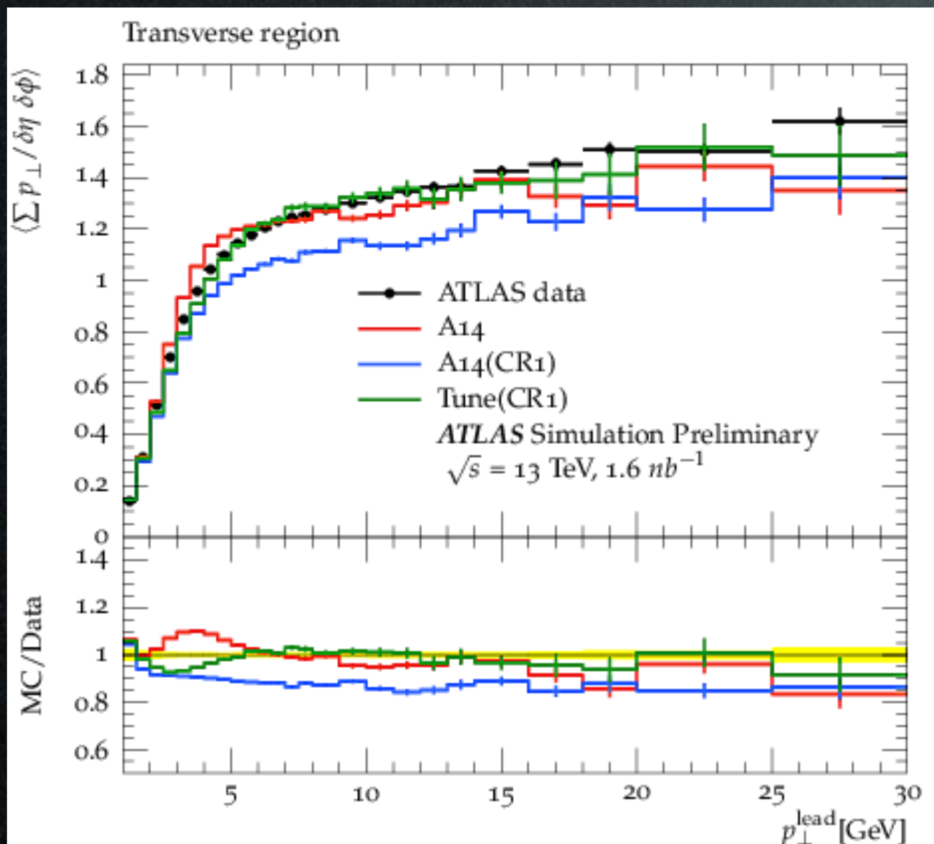

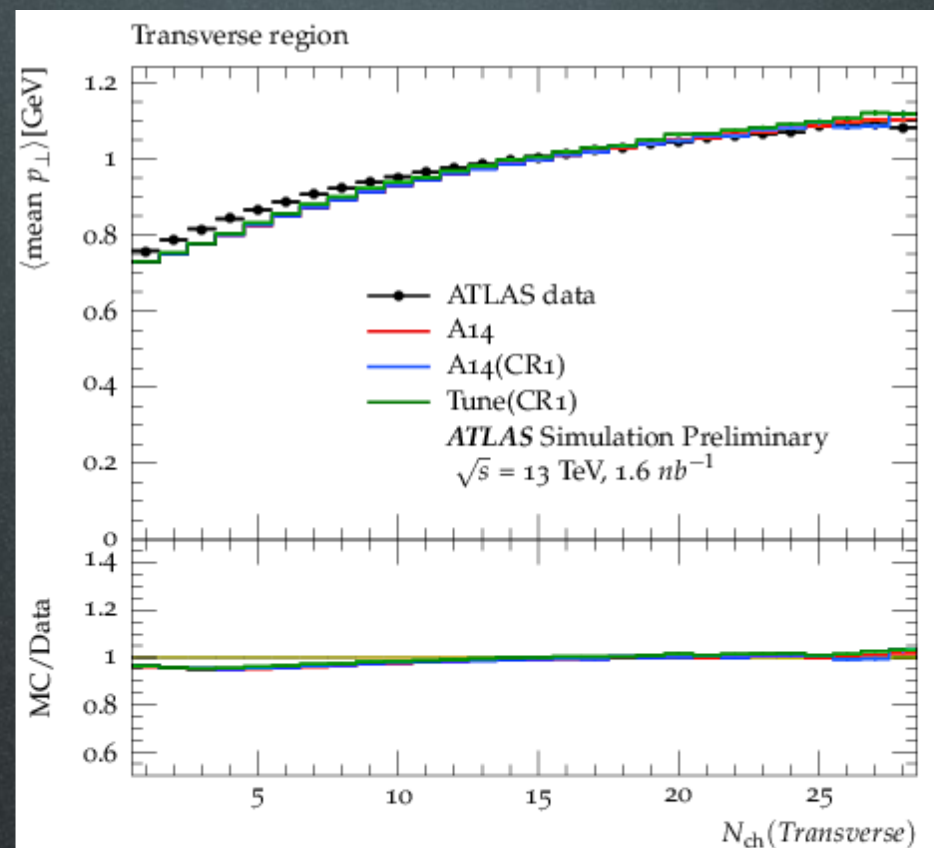

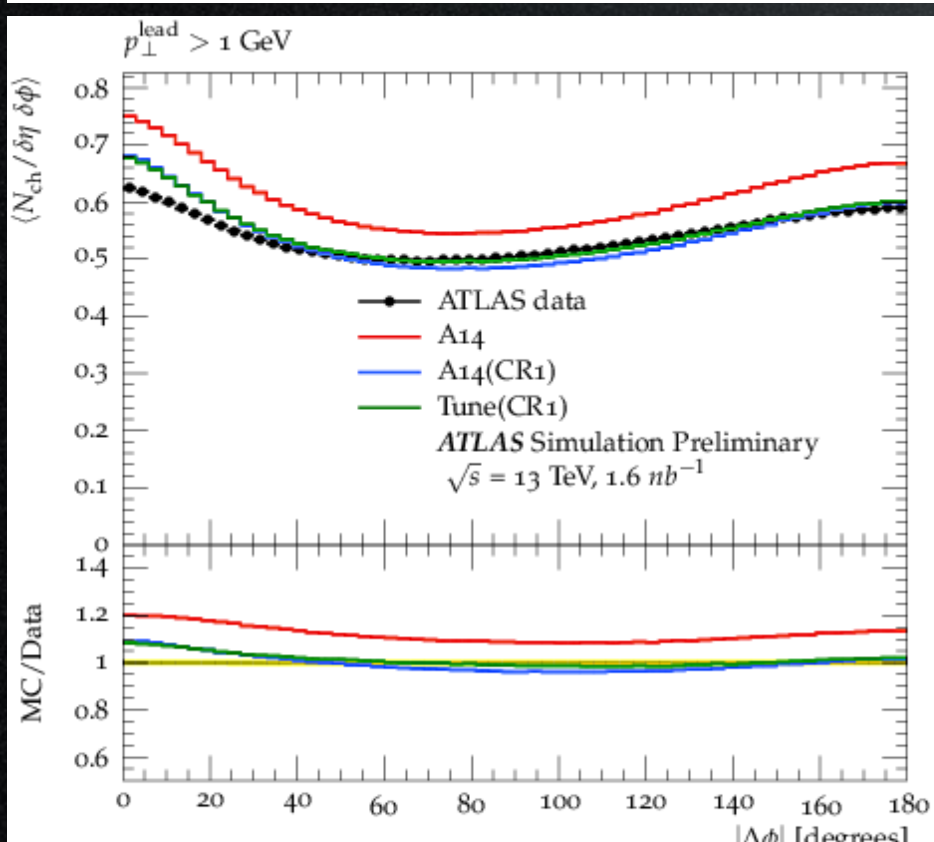

Only changing to CR1 degrades performance.

Retuning helps.

UE Activity: CR2

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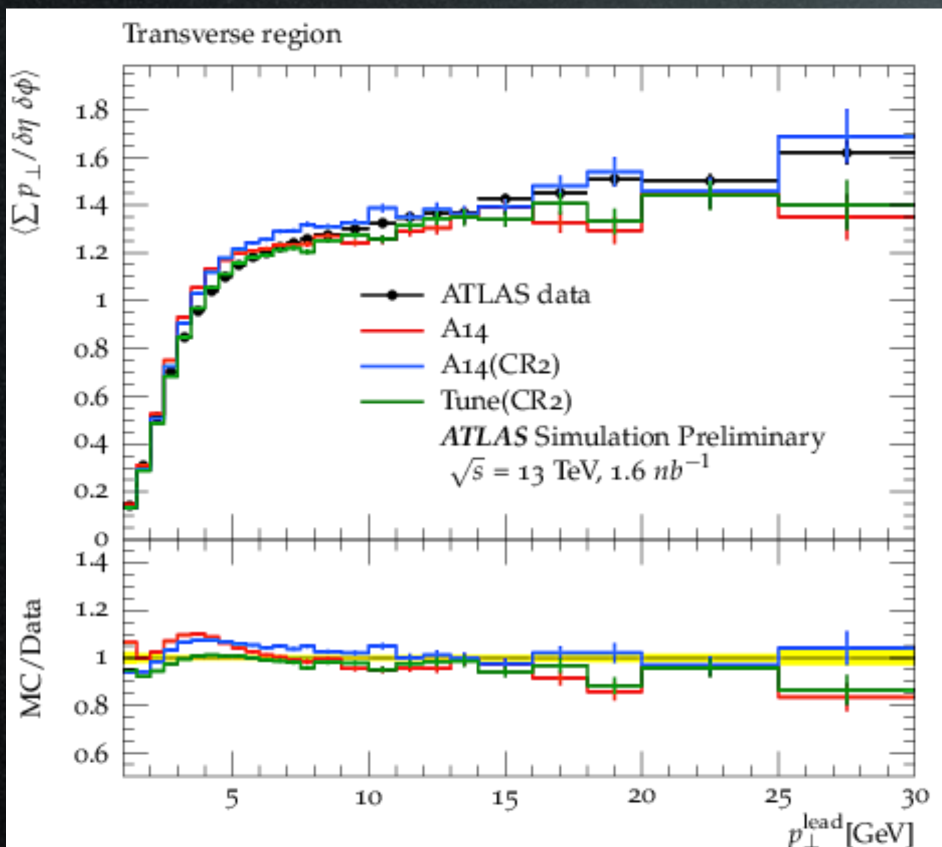
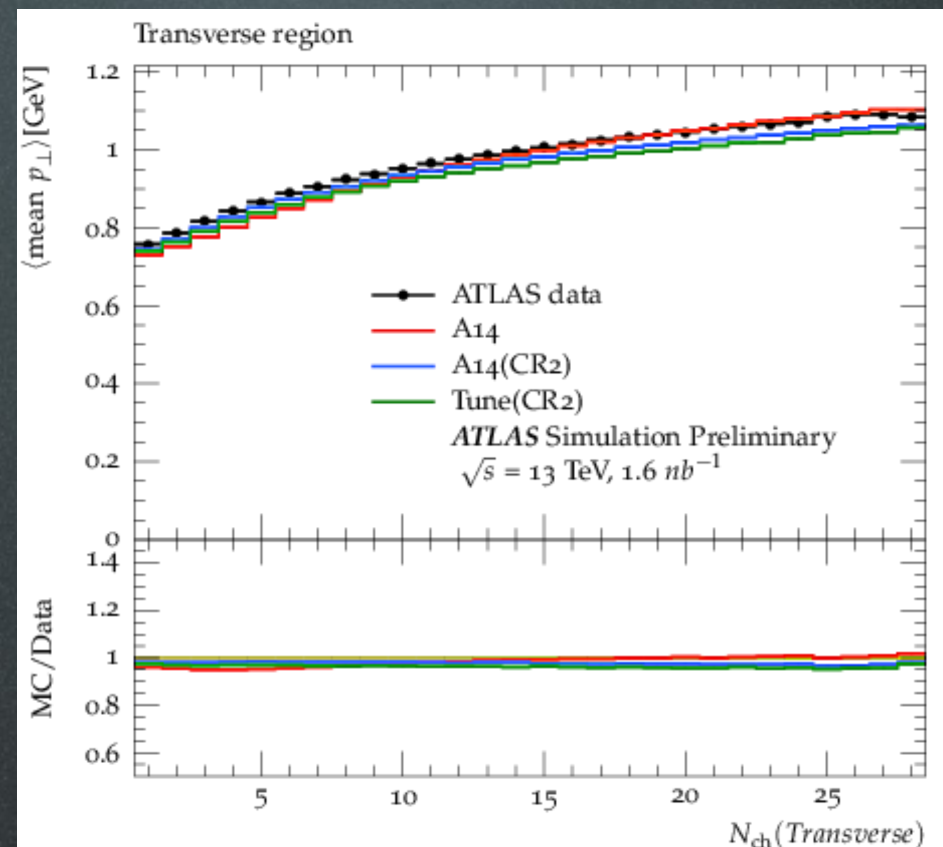
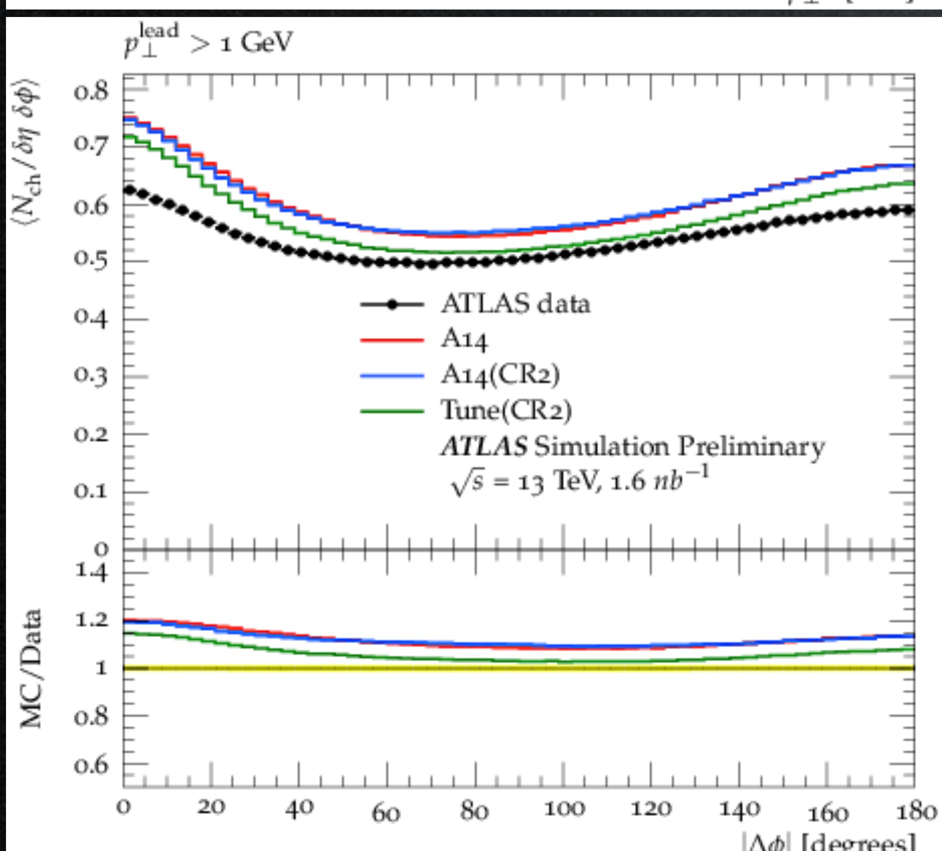






Not a significant improvement by retuning, more study needed.

Tuned Values

Parameter	A14/ Default (range)	Tune CR0	CR1	CR2
`MultipartonInteractions:pT0Ref`	2.09	2.15	1.89	2.21
`MultipartonInteractions:expPow`	1.85	1.81	2.10	1.63
`ColourReconnection:range`	1.71	2.92	–	–
`ColourReconnection:m0`	0.3 (0.1 - 5)	–	2.17	–
`ColourReconnection:junctionCorrection`	1.20 (0.01 - 10)	–	9.33	–
`ColourReconnection:m2Lambda`	1.0 (0.25-16)	–	–	6.73
`ColourReconnection:fracGluon`	1.0 (0-1)	–	–	0.93
`ColourReconnection:dLambdaCut`	0 (0-10)	–	–	*0.0*
χ^2, Ndof		17706, 2929	18597, 2928	113814, 2928
$\chi^2/Ndof$		6.1	6.4	38.9

Worst fit for CR2 tune, but overall reasonable level of agreement can be achieved with all models.

Tuned Values

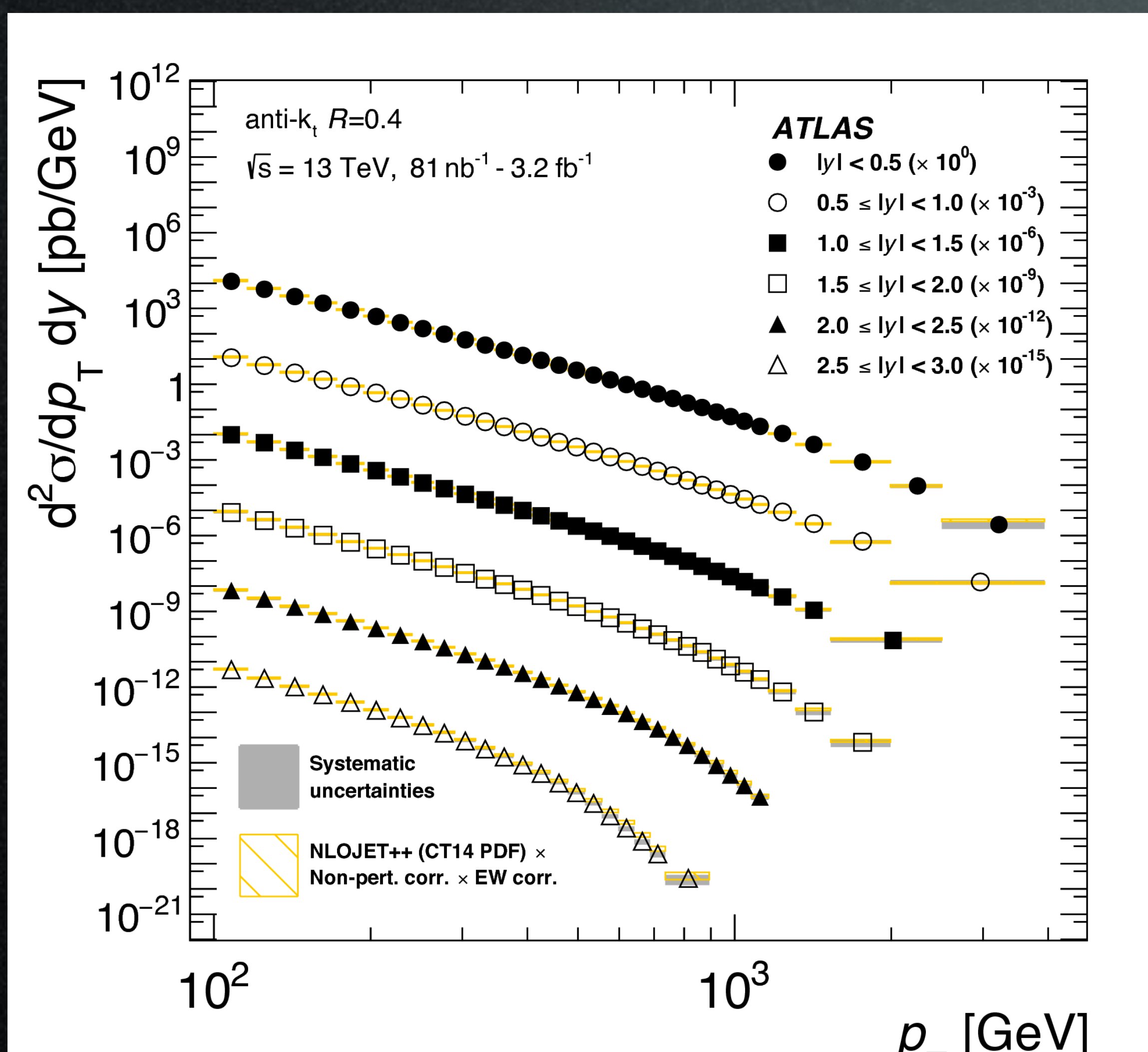
arXiv:1709.04207

These different CR models can be used to estimate CR uncertainty in a realistic way.

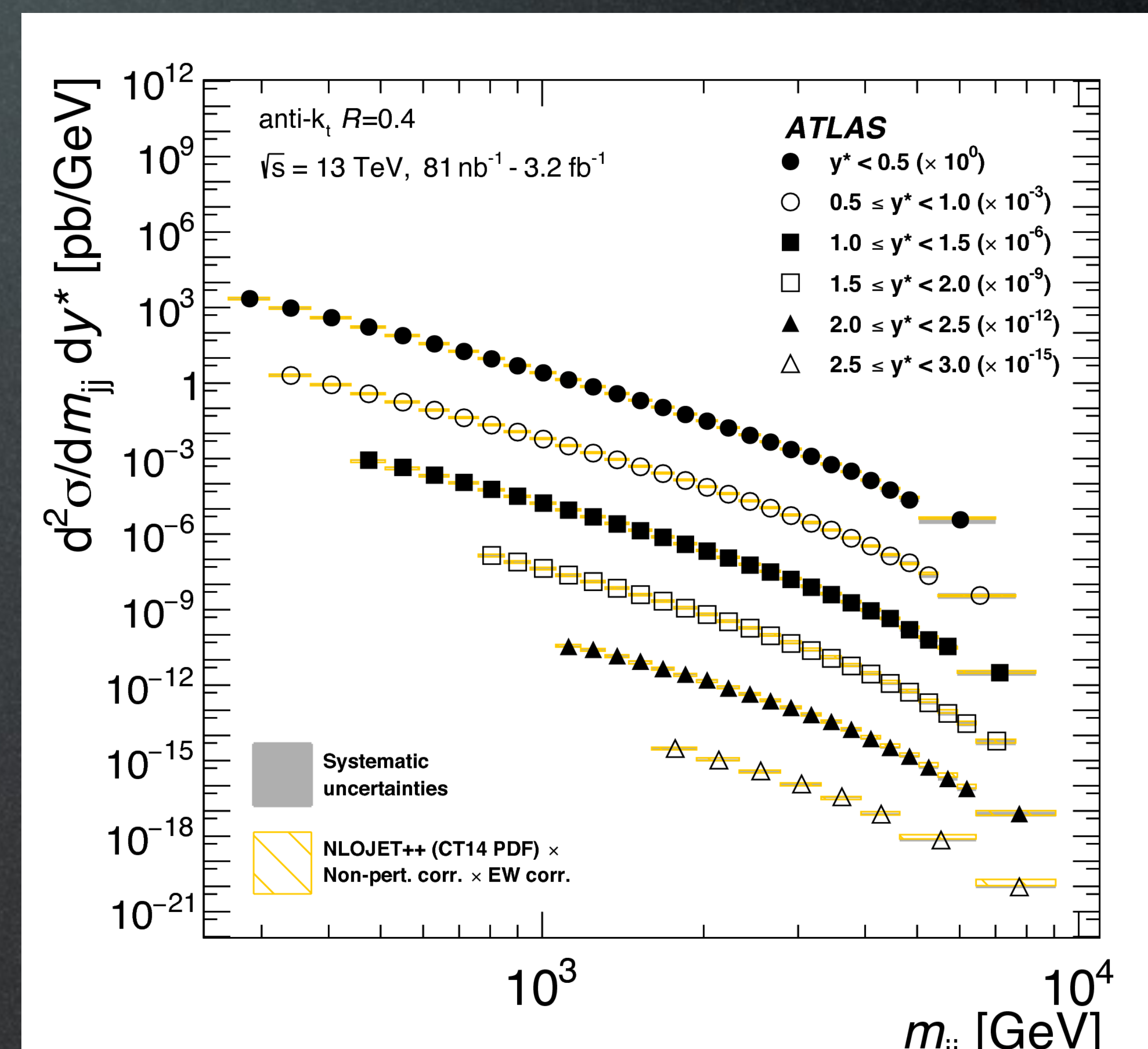
Many analyses suffer from a large CR modelling uncertainty, such as top mass.

Source	Uncertainty [GeV]
Detector model	
Electron	$^{+0.14}_{-0.07}$
Muon	$^{+0.11}_{-0.06}$
Jet energy scale	$^{+0.42}_{-0.30}$
Jet energy resolution	± 0.27
Jet vertex fraction	$^{+0.13}_{-0.03}$
Jet reconstruction efficiency	± 0.03
Missing transverse momentum	± 0.01
b-Tagging	$^{+0.32}_{-0.24}$
Signal model	
ME event generator	± 0.41
Colour reconnection	± 0.19
Underlying event	± 0.11
Radiation	± 0.07
PDF	± 0.06
PS/hadronisation	± 0.05
Background model	
Multijet	$^{+0.04}_{-0.00}$
W+jets	± 0.02
Single top	< 0.01
Template statistical uncertainty	± 0.07
Luminosity	$^{+0.03}_{-0.00}$
Total systematic uncertainty	$^{+0.79}_{-0.68}$

Jets have been measured with unprecedented reach and accuracy in Run 2:

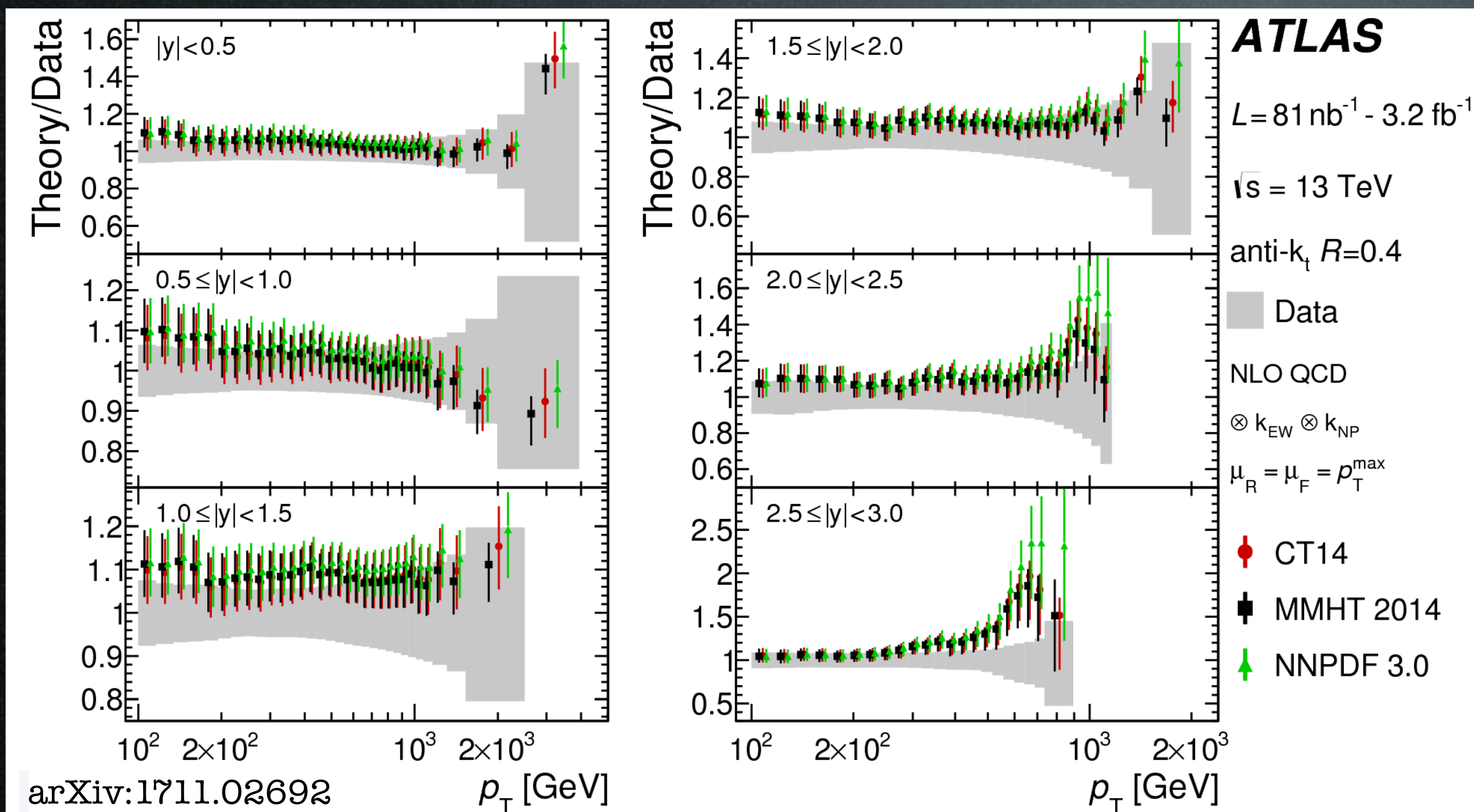


arXiv:1711.02692



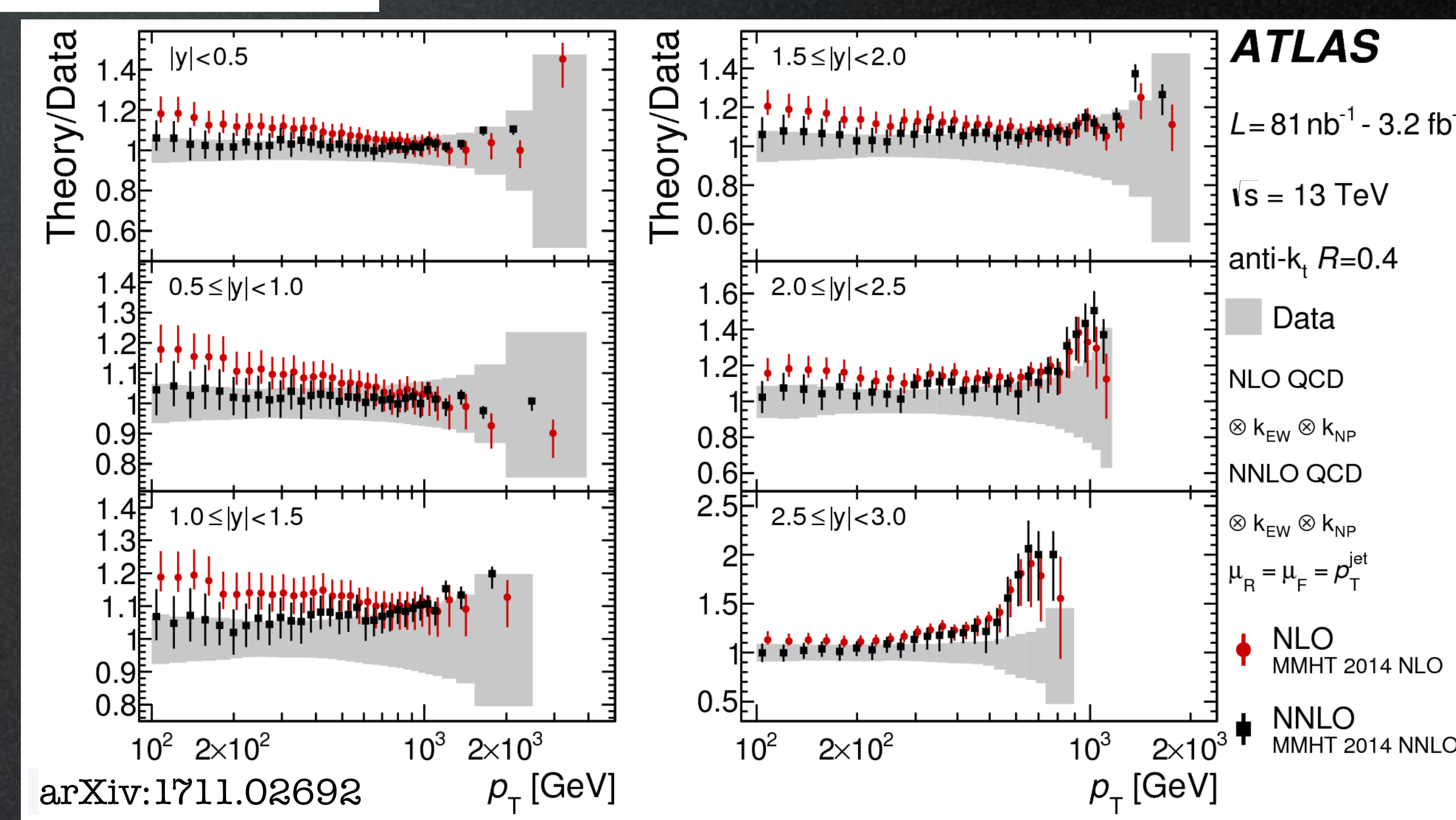
arXiv:1711.02692

Modelling



Comparison with NLO pQCD predictions calculated using NLOJET++ with three different PDF sets (CT14, MMHT 2014, NNPDF 3.0)

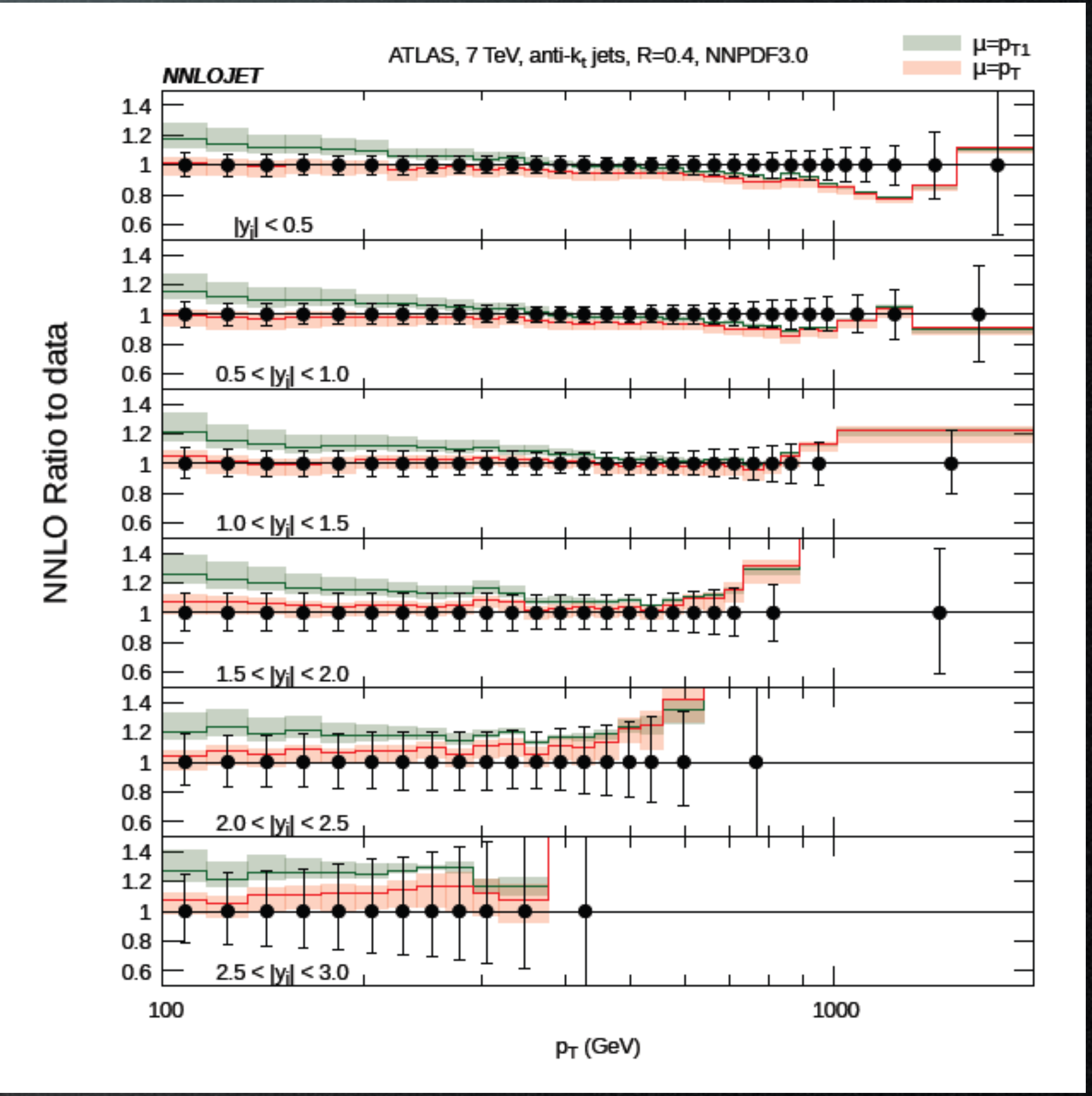
Comparison with NLO and NNLO pQCD predictions calculated using NLOJET++ and NNLOJET withMMHT 2014 PDF



Scale Choice

arXiv:1705.08205

- Difference between choosing leading jet pT or inclusive jet pT
- What should be the right choice?
- Should it depend on the kinematics or topology of the event?
- Relevant for PDF fit



V+Jets Modelling

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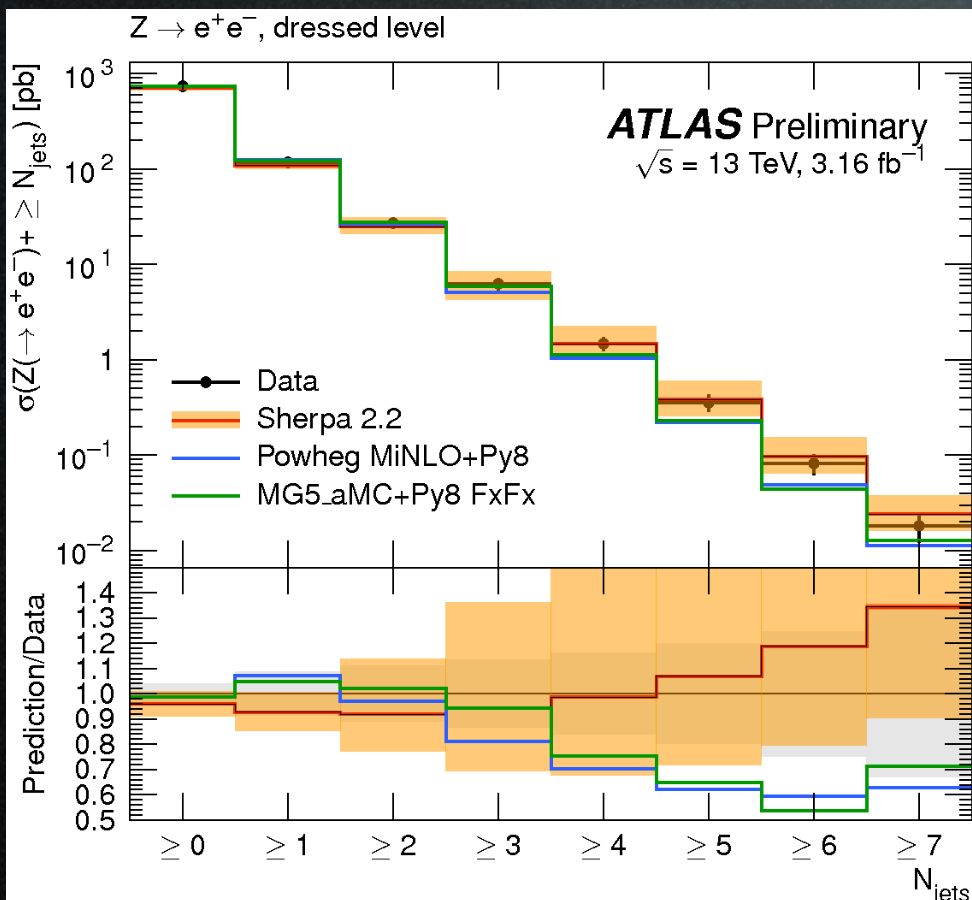

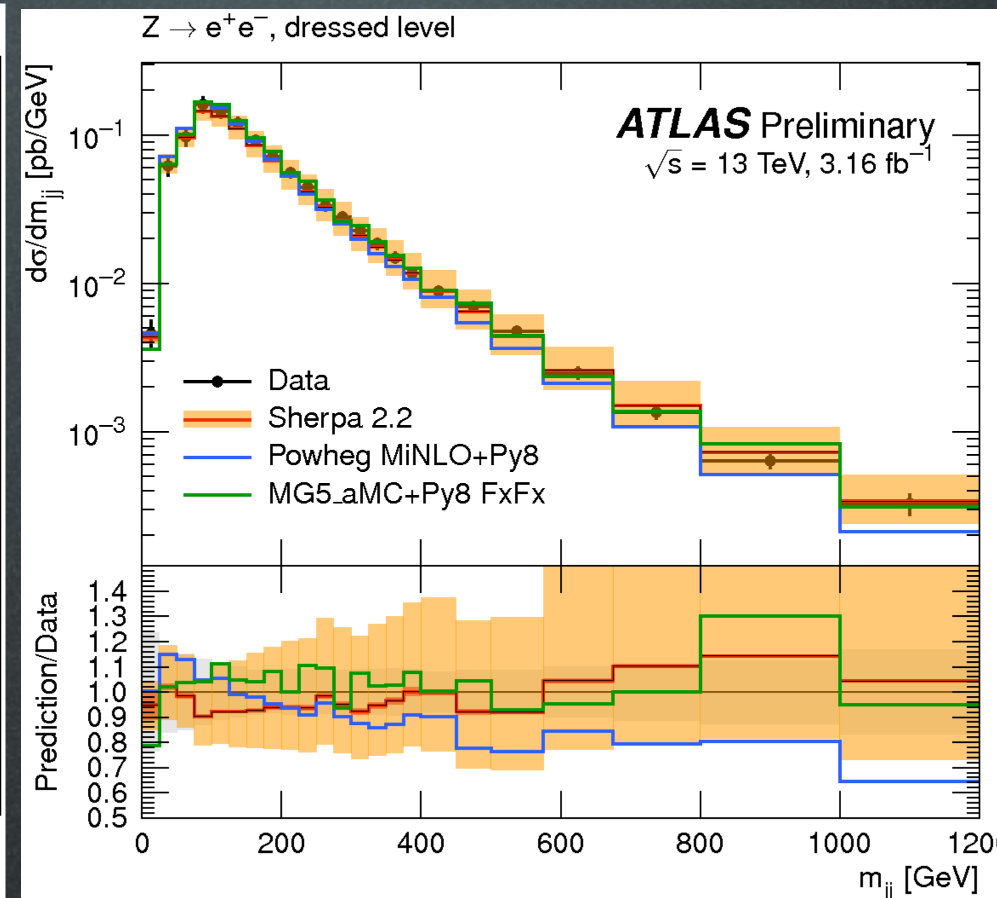

Dijet mass modelling gets worse at high masses

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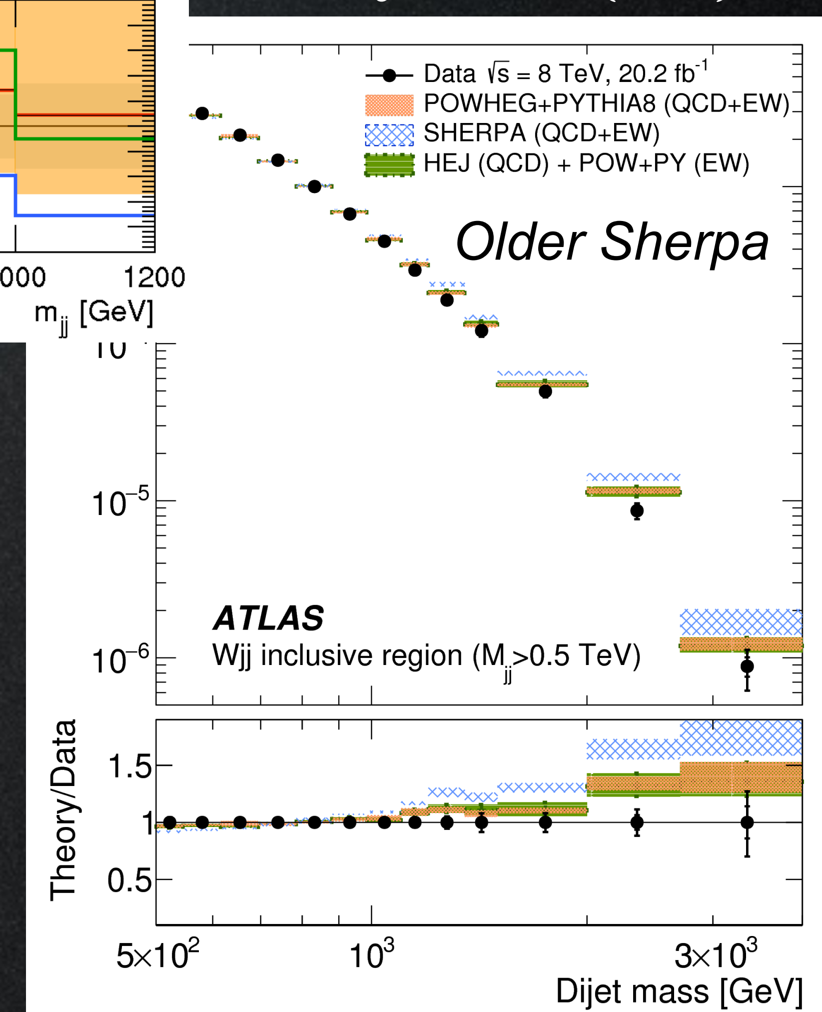

Sherpa: NLO-accurate for up to two extra emissions and LO-accurate for up to four extra emissions. Too much activity at high multiplicity.

MG5_aMC@NLO lacks additional multilegs beyond the third emission,

Large scale uncertainties of the order of 30 to 40 %.

B-hadron Pair Production

$$B(\rightarrow J/\psi[\rightarrow \mu^+\mu^-] + X)B(\rightarrow \mu + X)$$

Tested against different Pythia8 g->bb splitting modes:

Option label	Descriptions
Opt. 1	The same splitting kernel, $(1/2)(z^2+(1-z)^2)$, for massive as massless quarks, only with an extra β phase-space factor. This was the default setting in PYTHIA8.1, and currently must also be used with the MC@NLO [36] method.
Opt. 4	A splitting kernel $z^2+(1-z)^2+8r_q z(1-z)$, normalised so that the z-integrated rate is $(\beta/3)(1+r/2)$, and with an additional suppression factor $(1-m_{qq}{}^2/m^2_{\mathrm{dipole}})^3$, which reduces the rate of high-mass $q\bar{q}$ pairs. This is the default setting in PYTHIA8.2.
Opt. 5	Same as Option 1, but reweighted to an $\alpha_{\mathrm{s}}(km^2_{qq})$ rather than the normal $\alpha_{\mathrm{s}}(p^2_{\mathrm{T}})$, with $k=1$.
Opt. 5b	Same as Option 5, but setting $k=0.25$.
Opt. 8	Same as Option 4, but reweighted to an $\alpha_{\mathrm{s}}(km^2_{qq})$ rather than the normal $\alpha_{\mathrm{s}}(p^2_{\mathrm{T}})$, with $k=1$.
Opt. 8b	Same as Option 8, but setting $k=0.25$.

Also against 4 and 5 flavour schemes in Madgraph and Sherpa

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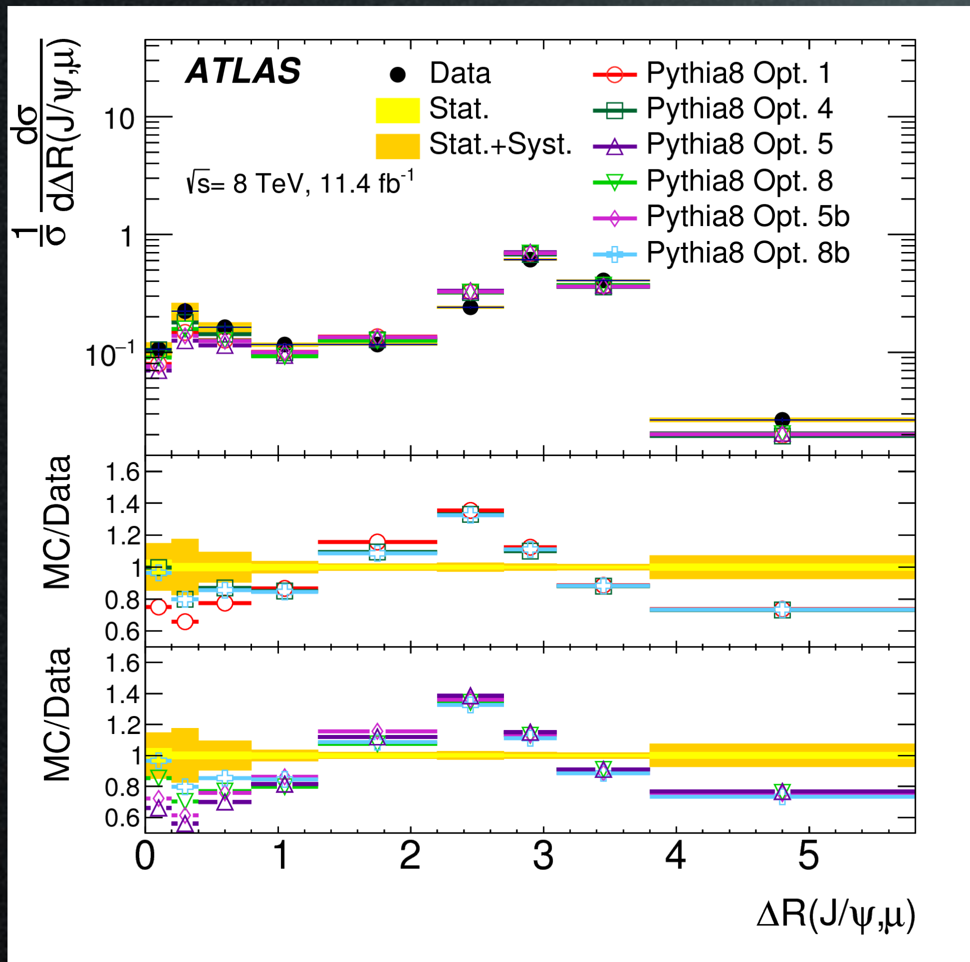

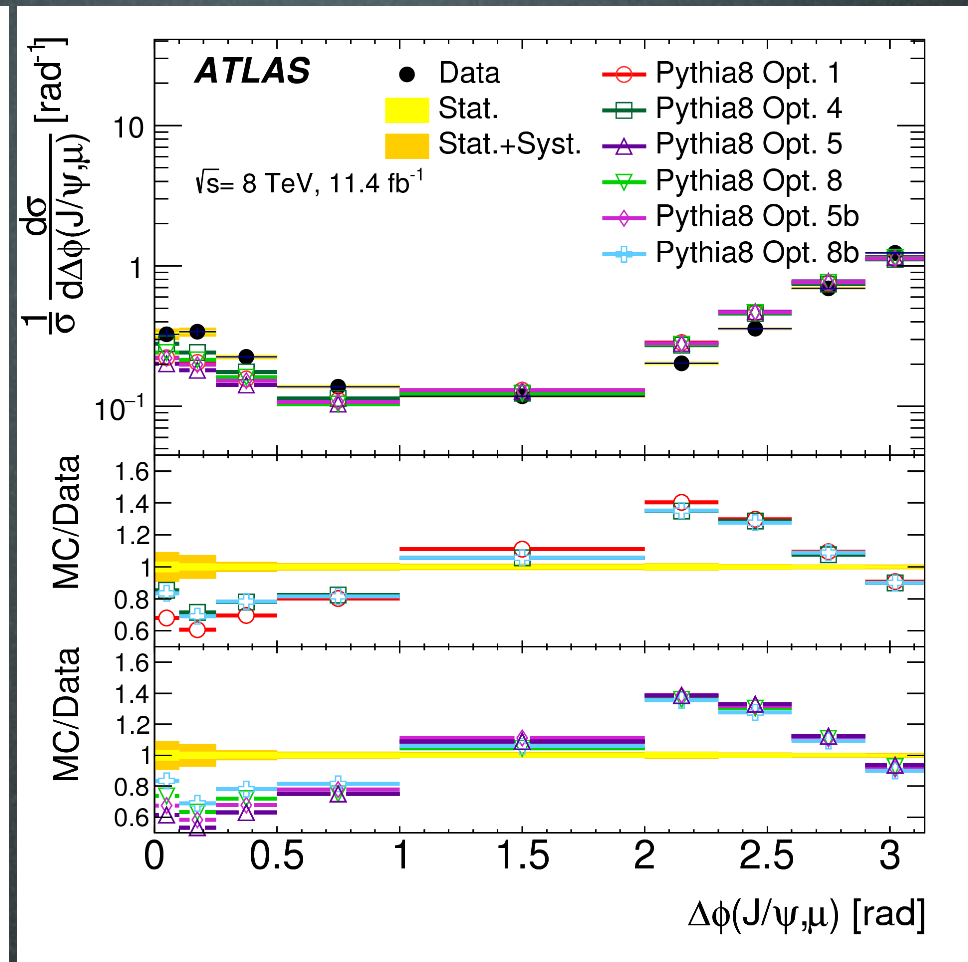

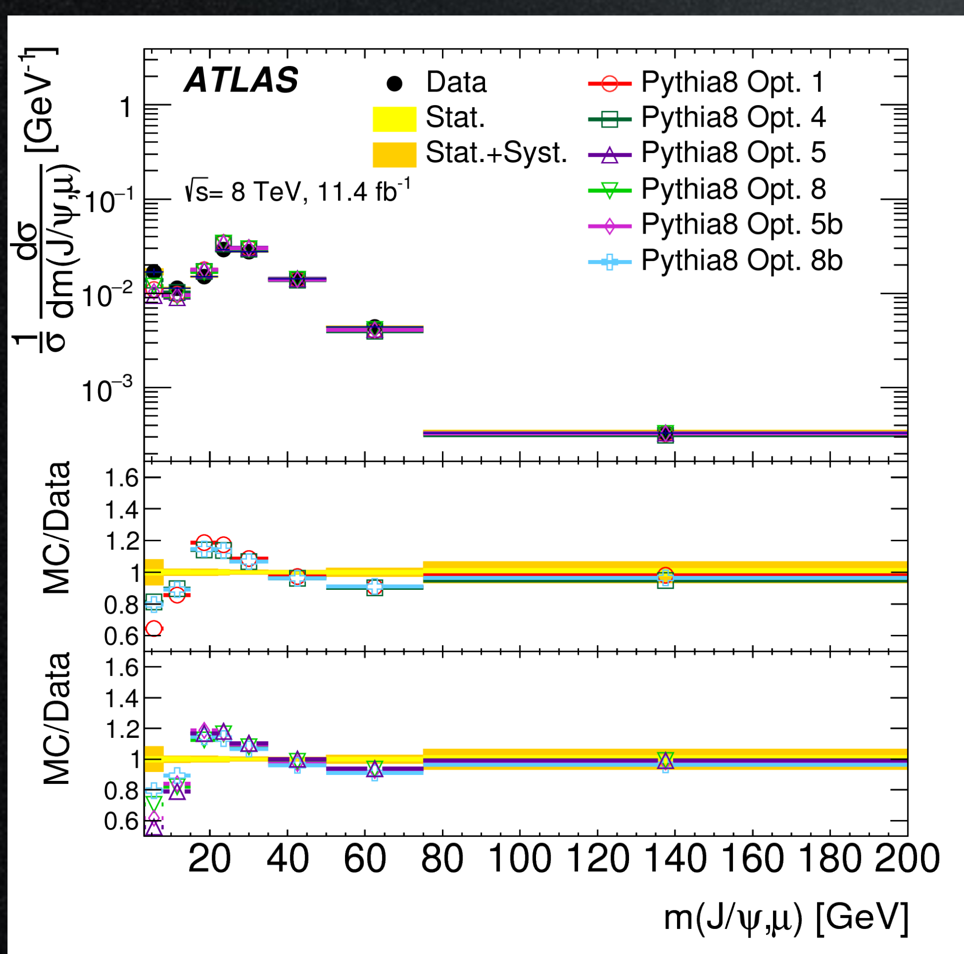

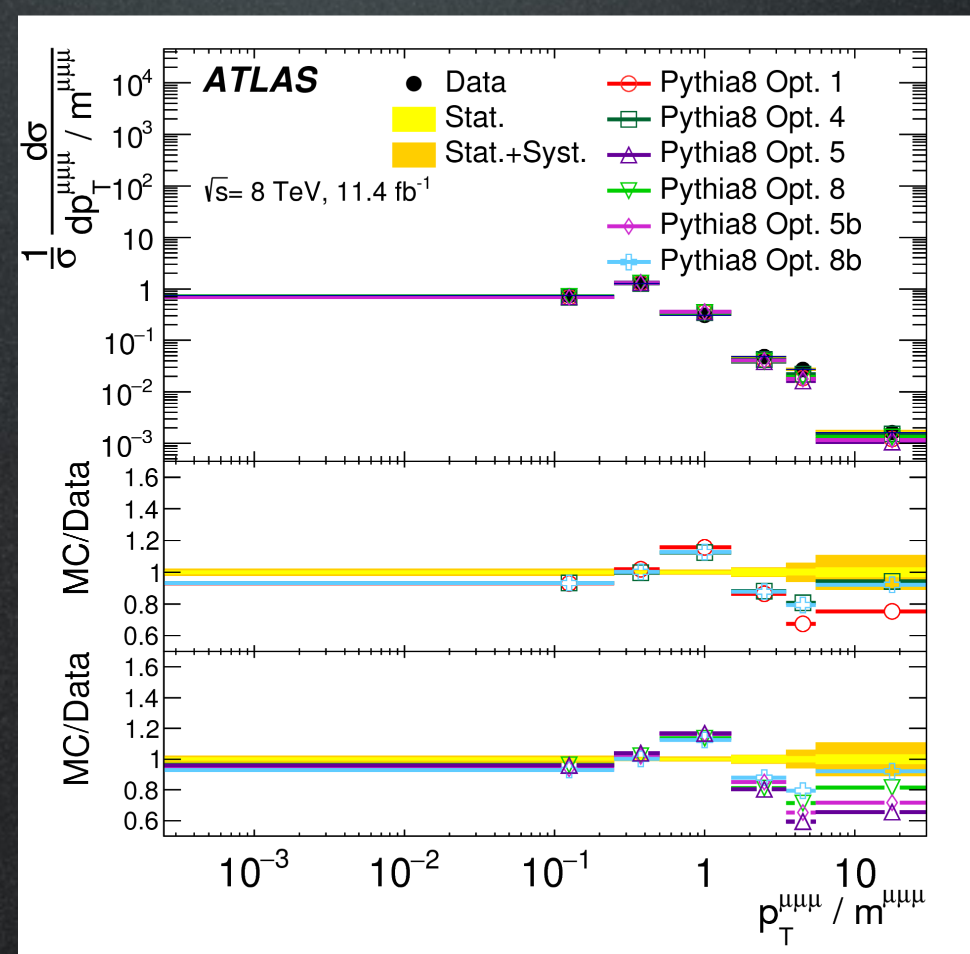

The p_T-based scale splitting kernels (Opt. 1 and 4) generally give a better descriptions with the kernel of Opt. 4 performing the best.

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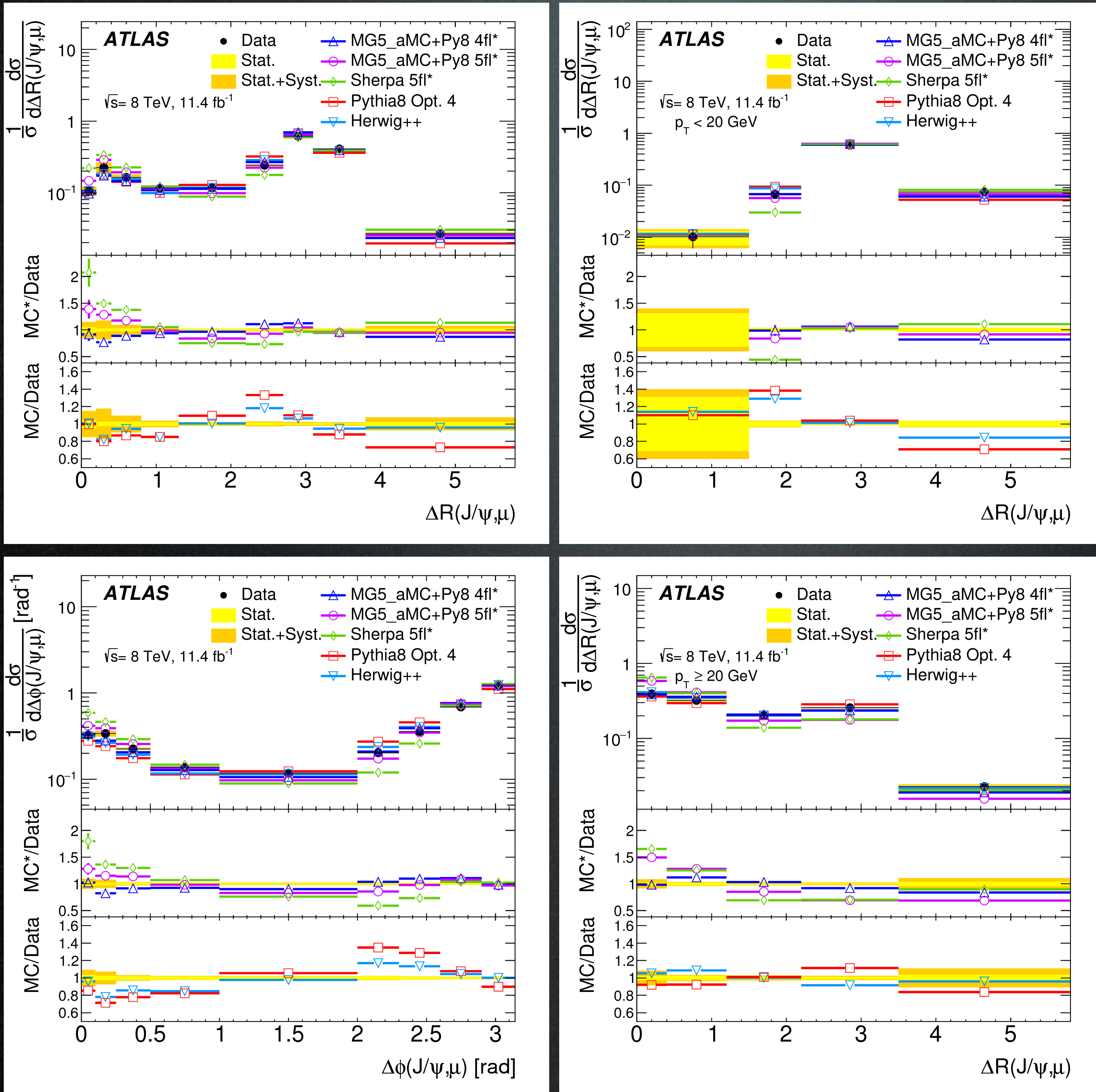

Herwig++ slightly better than Pythia8.

The 4- and 5-flavour MadGraph5_aMC@NLO+Pythia8 predictions bracket the data, with the 4-flavour closer in shape.

The 5-flavour schemes have similar shape in Sherpa.

Summary

- Underlying event distributions at three c.m energies can be described reasonably well by newer CR models
- Jet distributions are described reasonably well by state-of-the-art predictions
- Improvements possible in V+jets modelling, specifically in dijet mass or jet multiplicity
- B-hadron pair production modelling is compared against data