Perspectives for Vector Bosons +Jets physics at LHC Run 2

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Simon de Visscher (F.N.R.S-UCL-CP3)
on behalf of CMS & ATLAS

Motivation for studying V(+jets)

- Direct: large background for many searches (Higgs, SUSY, Exotic,..) and measurements (top, diboson,...)
  - Need to control them when data driven method is not possible.

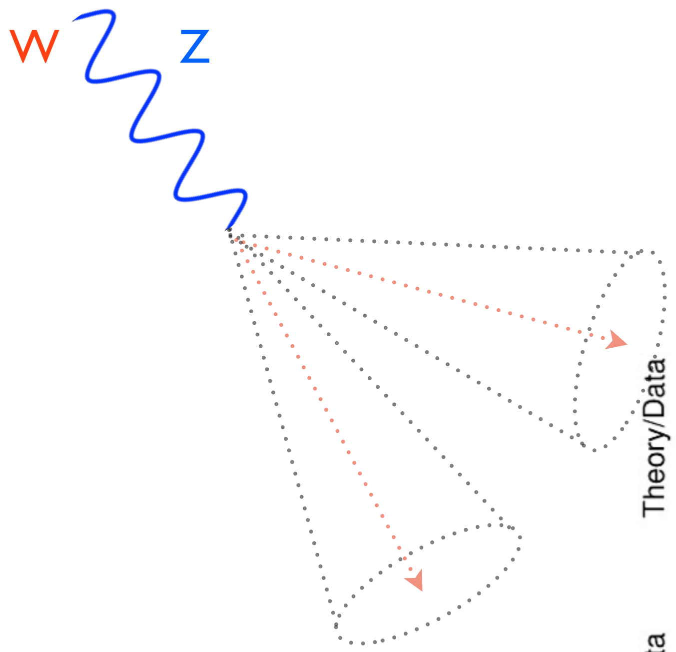
- Indirect: provides stringent test of p(QCD) and EWK sectors: lever for signals and (other) background prediction
  - PDF
  - ME+PS description (FNS, merging, scale)
  - higher order QCD and EWK corrections, e.g. at high Pt/Ht

V+jets studies and MC landscape for Run II

- V+jets SM studies: testing/validating predictions from theory
  - Most up-to-date version of ME+PS generators used for full simulation (searches, measurements)
    - Madgraph_aMC@NLO+P8/HWG (FxFx, UNLOPS, KtMLM, ShowerKt, UMEPS), ALPGEN+P8/HWG (MLM), Sherpa (CKKW-L), POWHEG+P8 (MinLO),...
  - Most recent parton-level solution (PDF, α_s)
    - LoopSIM, BlackHat+Sherpa, MEPS@NLO, DYNNLO,...
  - Validation based on
    - 7,8 TeV Rivet analyses
    - 13 TeV data (coming analyses + Rivet analyses)
- Find 'comfort' zone(s) for each generator: **which** solution is used for **which** process (background for searches, measurement), and **where**, i.e. in which phase-space region it applies.

V(+jets)

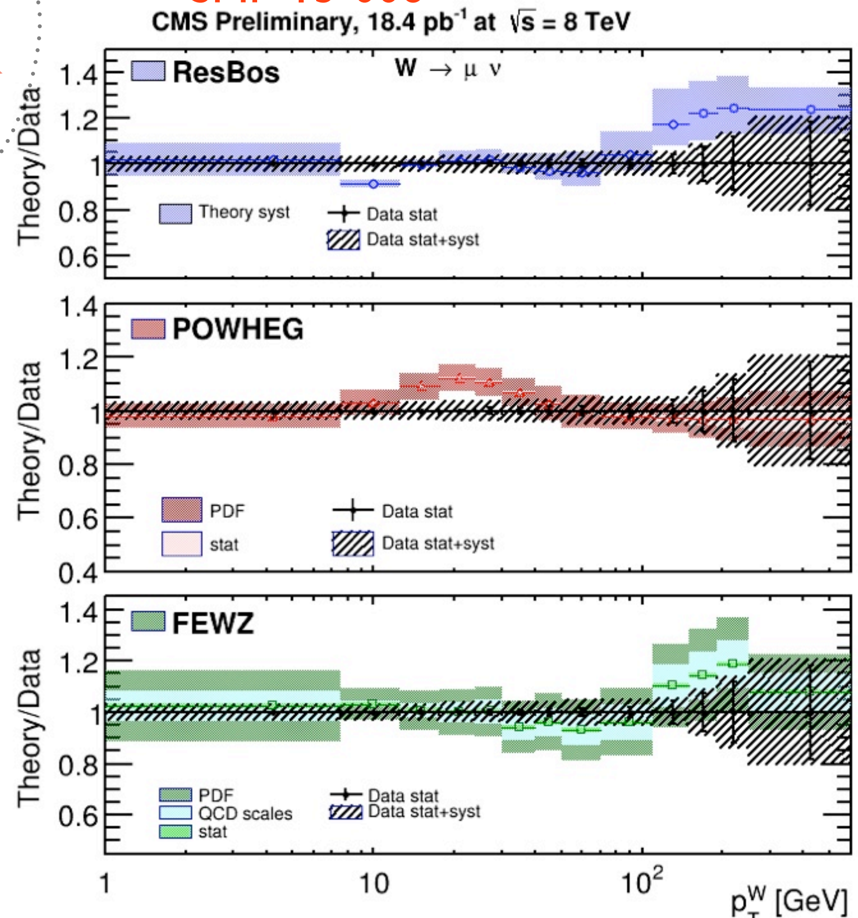
Vector boson kinematics



No explicit mention to jets, only look at V

W Pt (8 TeV)

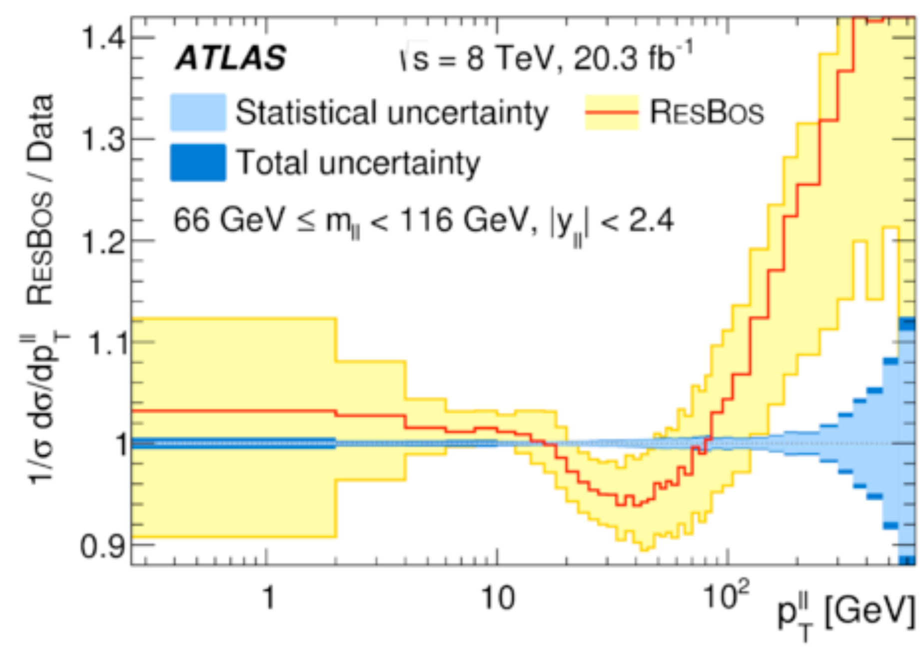
SMP-13-006



Pt(e)>25 GeV |eta(e)|<2.5
Pt(m)>20 GeV |eta(m)|<2.1
pre-FSR

Z Pt (8 TeV)

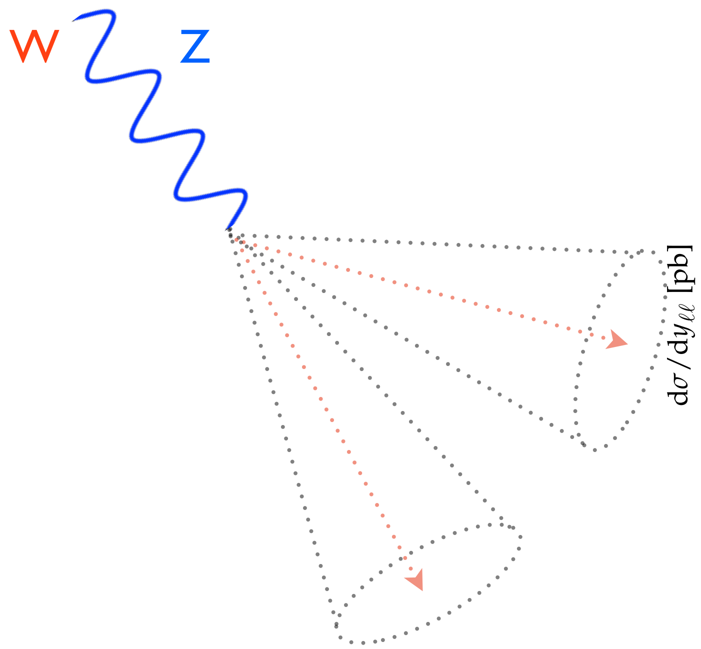
arXiv:1512.02192



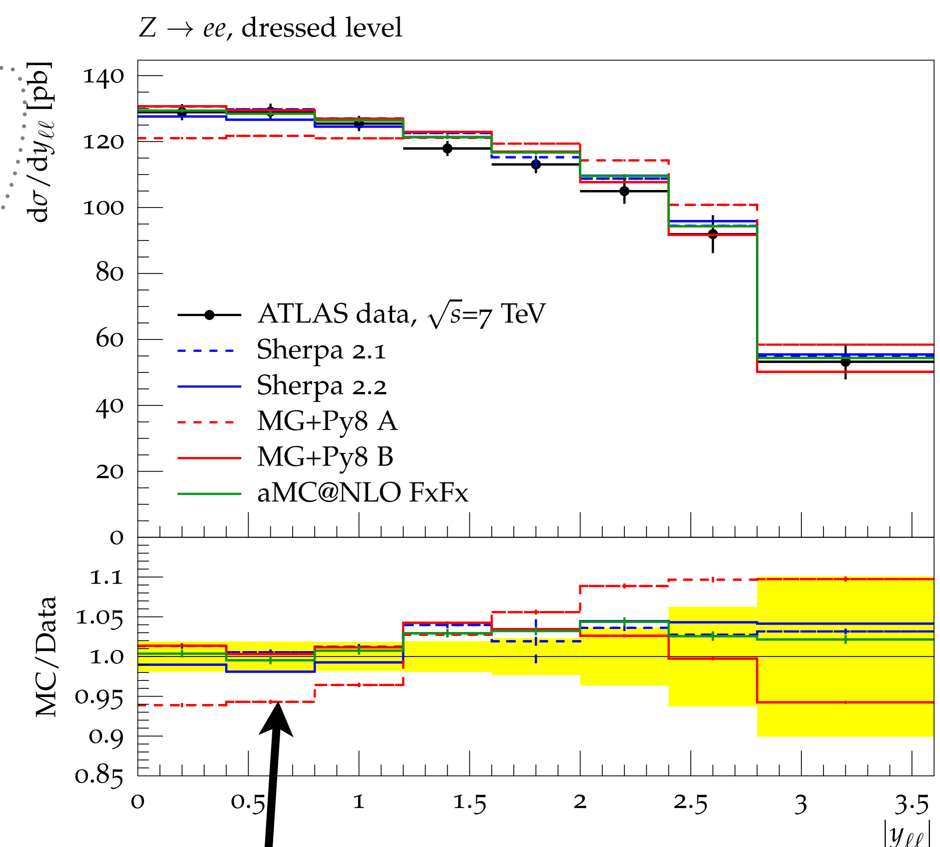
Pt(lep)>20 GeV |eta(lep)|<2.4
y(dilep)<2.4, dR(dilep)>0.15
pre-FSR

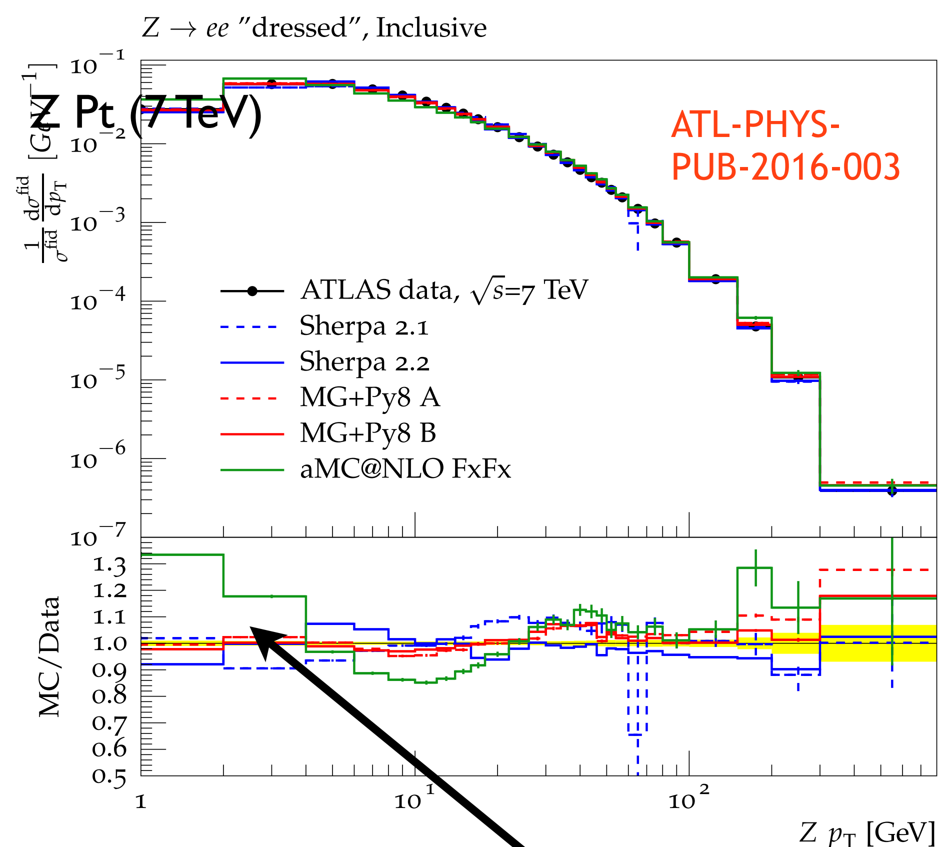
NNLO prediction follow the same trend: MC deficit below ~100, excess above 100
Powheg+pythia 6.4, excess in [10-30]

Vector boson kinematics



No explicit mention to jets, only look at V





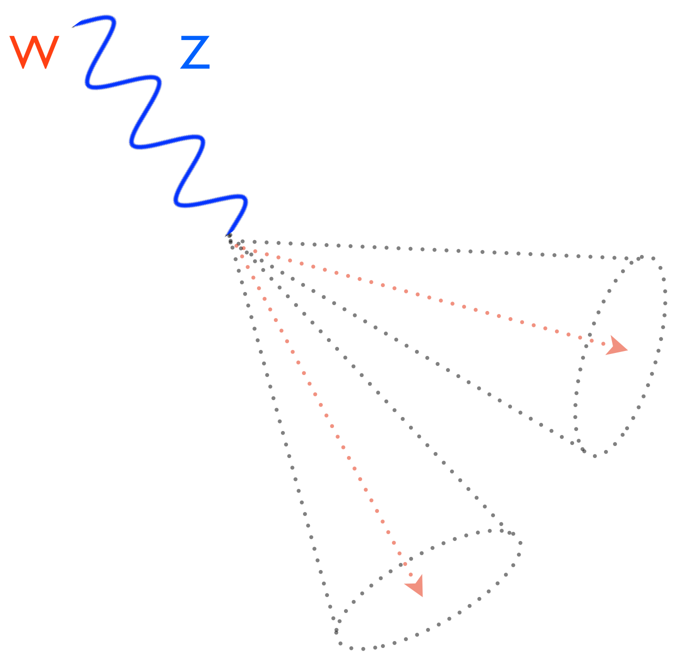
New tests with tree-level and NLO prediction (no k-factor)

MGaMC+P8 off?

MGa**MC** off?

Generator	ME	PS/Tune	ME+PS	PDF
MGaMC +P8 A	V+0..4p v5.2.2.2	v8.186 A14	Kt-MLM @20 GeV	NNPDF NLO v3.0
MGaMC +P8 B	V+0..4p v5.2.2.3	v8.210 A14	Kt-MLM @30 GeV	NNPDF NLO v2.0
Sherpa 2.1	V+0..2 NLO V+3..4 LO v2.1.1	v2.1.1	CKKW-L @20 GeV	NLO CT10
Sherpa 2.2	V+0..2 NLO V+3..4 LO v2.2.0	v.2.2	CKKW-L @20 GeV	NNLO NNPDF 3.0
MGaMC +FxFx	V+0..2 NLO v2.3.2	v8.210 Monash	FxFx @15 GeV	NNPDF 2.3

Vector boson kinematics

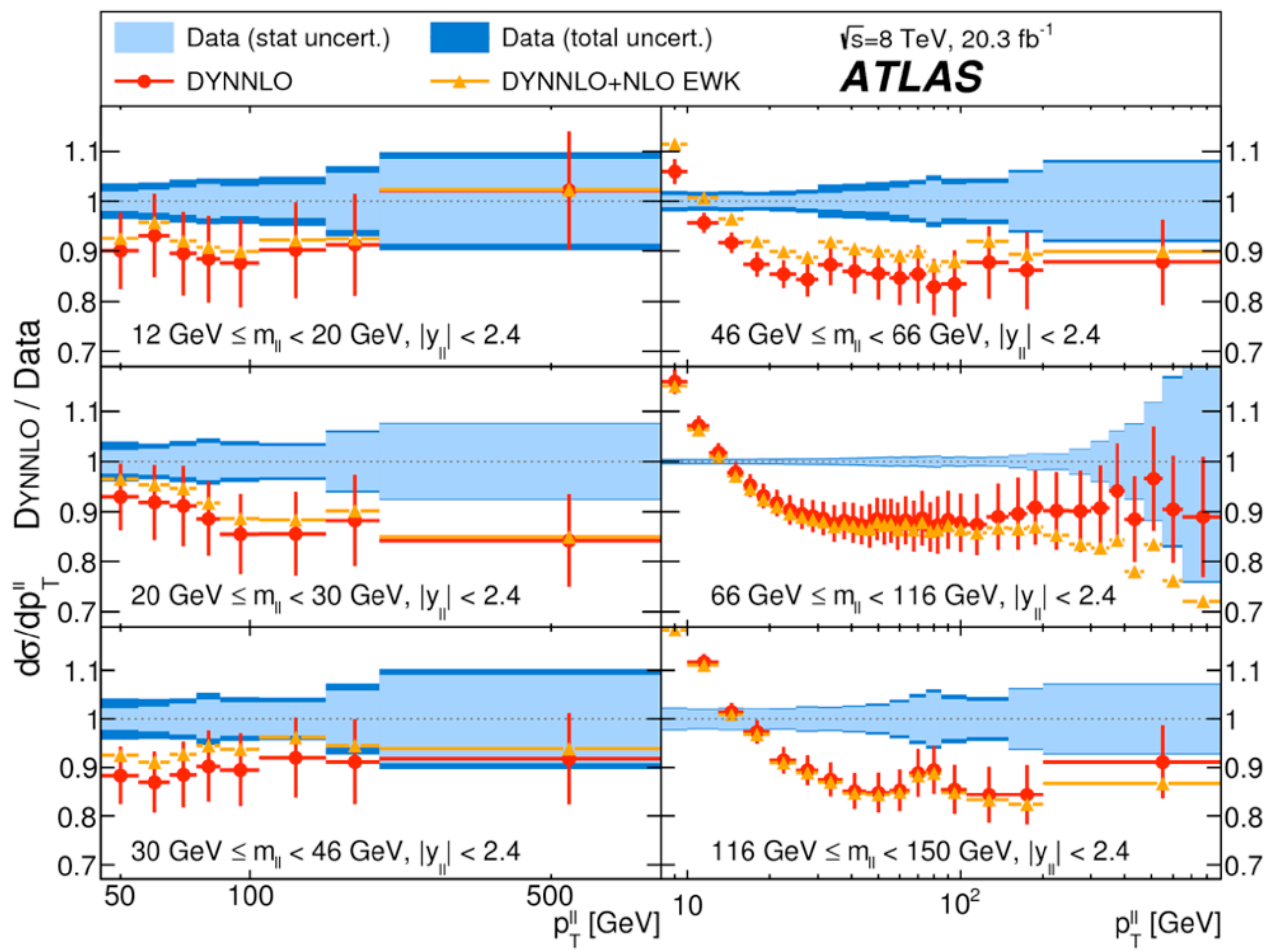


No explicit mention to jets, only look at V

Pt(lep)>20 GeV |eta(lep)|<2.4
y(dilep)<2.4, dR(dilep)>0.15
pre-FSR

Z Pt (8 TeV)

arXiv:1512.02192



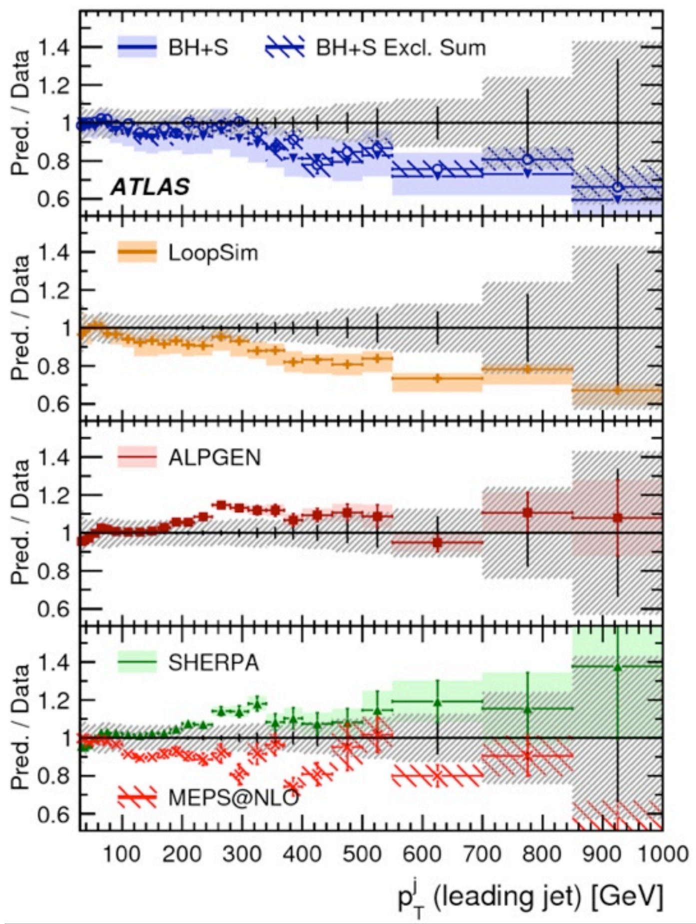
The Run I statistics does not allow sensitivity to EWK correction (max ~5%)
Need to consider this at the Run II.

V + jets

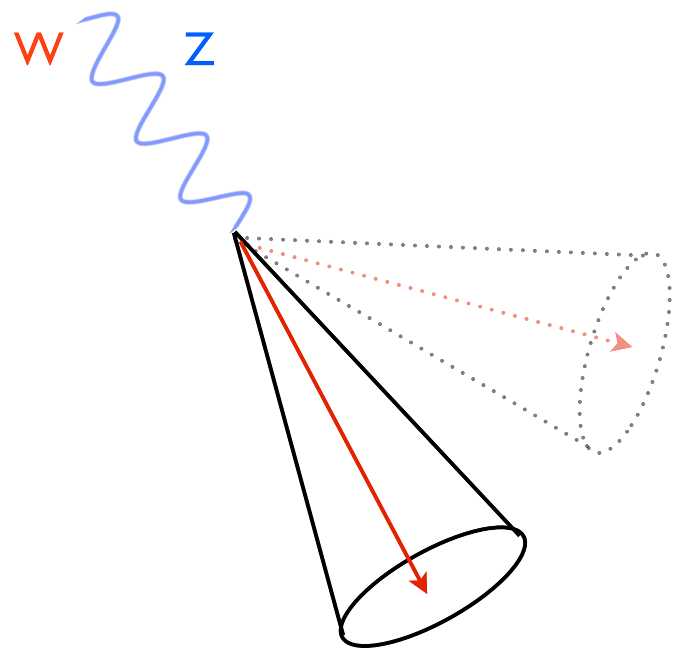
Leading jet kinematics

Eur. Phys. J. C (2015) 75:82

W+jets (7 TeV)



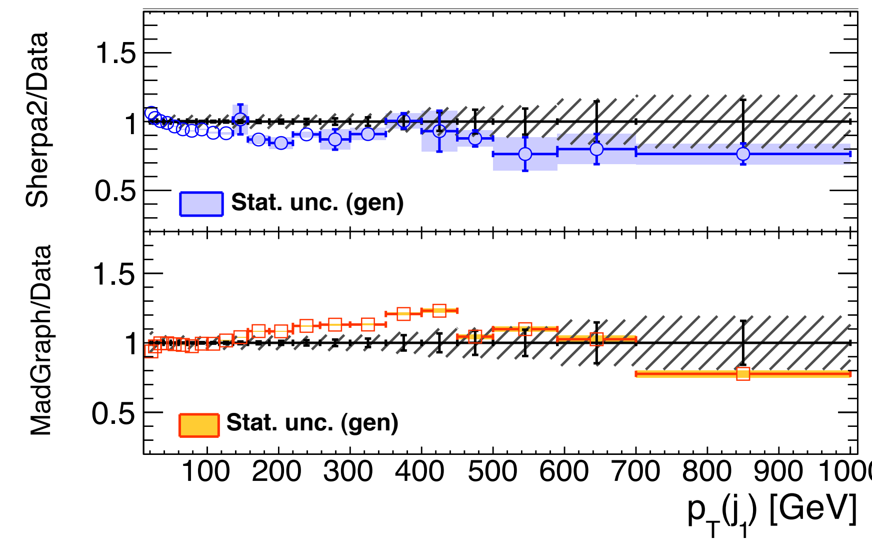
Generator	ME	PS	ME+PS	PDF
BH+Sherpa	V+0..4p	/	/	CT10
Loopsim	NNLO: 1p max NLO:2p max LO:3p max	/	/	CT10
ALPGEN	V+0..5	HG++	MLM	CTEQ6L1
Sherpa	V+0..4	v.2.2	CKKW	CT10
MEPS@NLO	virt.: BH (1j,2j) corr from LO	Sherpa	Sherpa	CT10



Agreement to 1σ for most of prediction (tree-l. or NLO)

CMS-SMP-13-007

Z+jets (8 TeV)



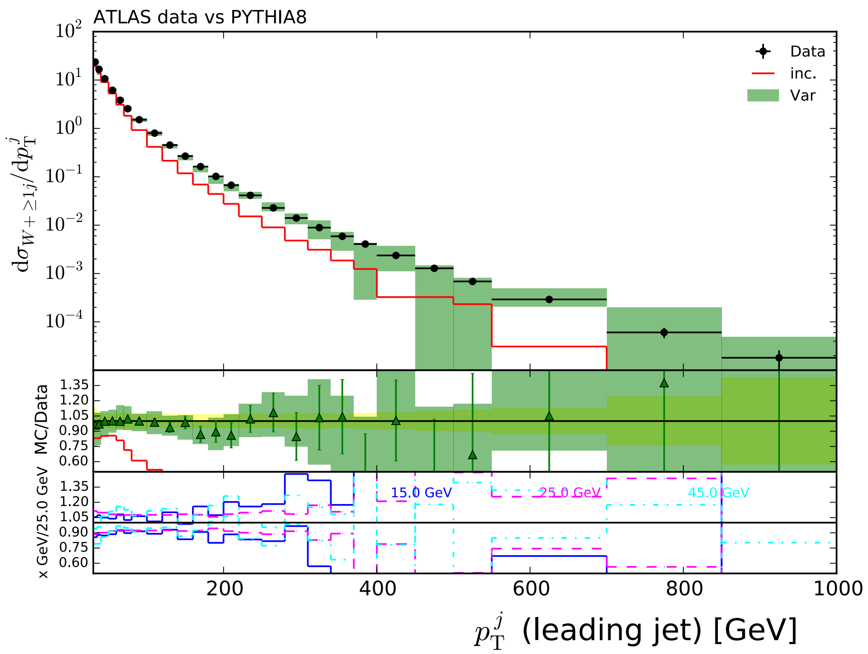
Generator	ME	PS	ME+PS	PDF
Sherpa2	V+0..2p@NLO V+3..4@LO	Sherpa	à la MEPS@ NLO	CT10
Madgraph	V+0..4@LO	P6.4	KtMLM @20 GeV	CT10

Leading jet kinematics

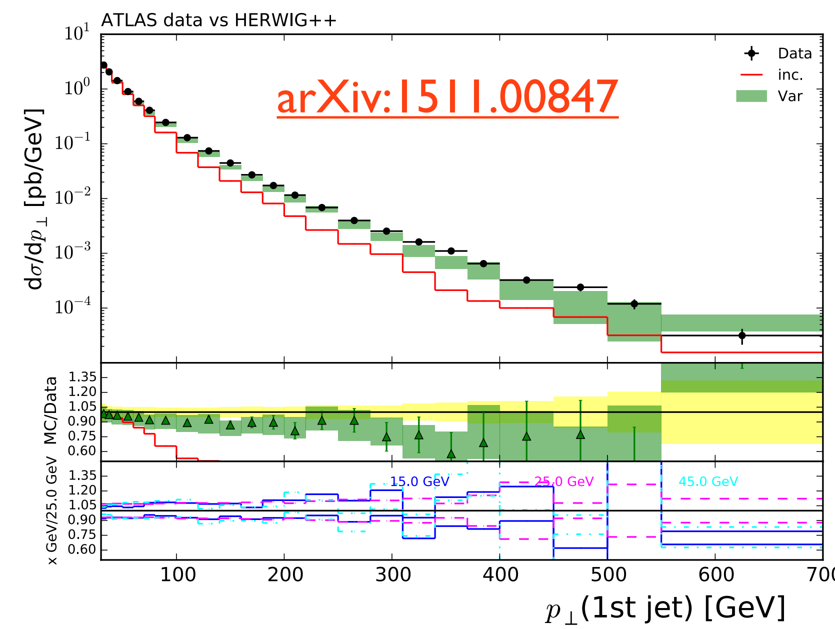
Eur. Phys. J. C (2015) 75:82

New data/MC comparisons. Agreement to ~1σ for most of prediction (tree-l. or NLO)

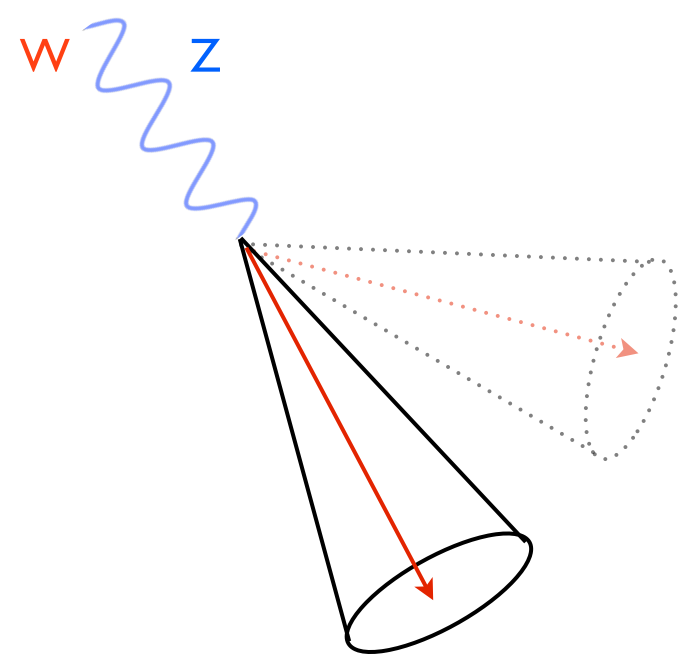
W+jets (7 TeV)

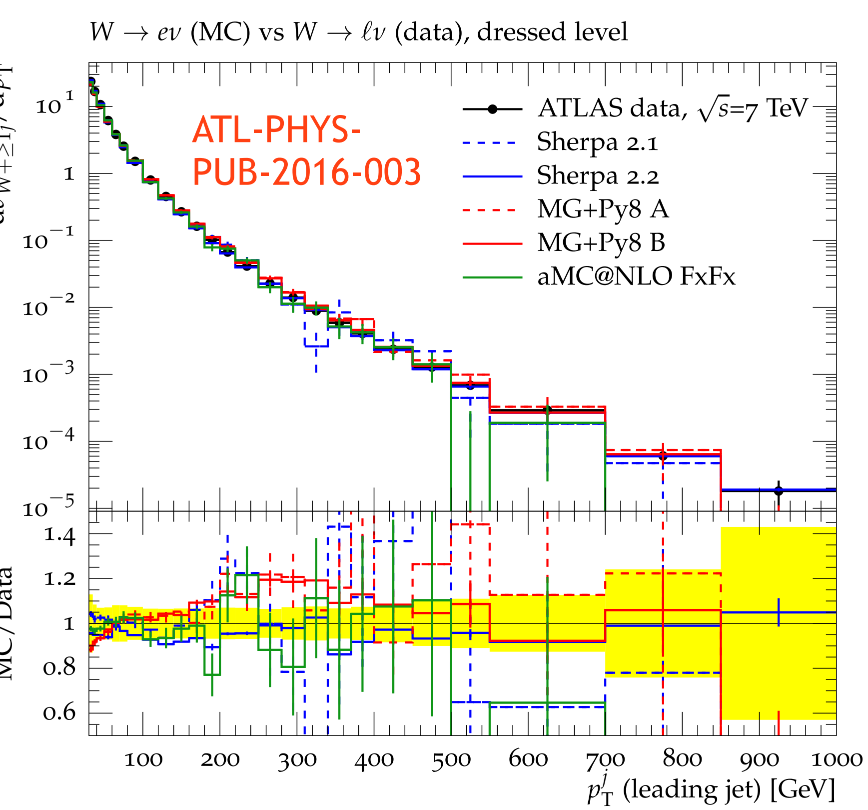


Z+jets (7 TeV)



MGaMC v2.2.1
V+0,1,2 @ NLO
Pythia 8.210 or HWG++2.7.1
FxFx merging @ 15, **25**, 45
NNPDF2.3 NLO





Generator	ME	PS/Tune	ME+PS	PDF
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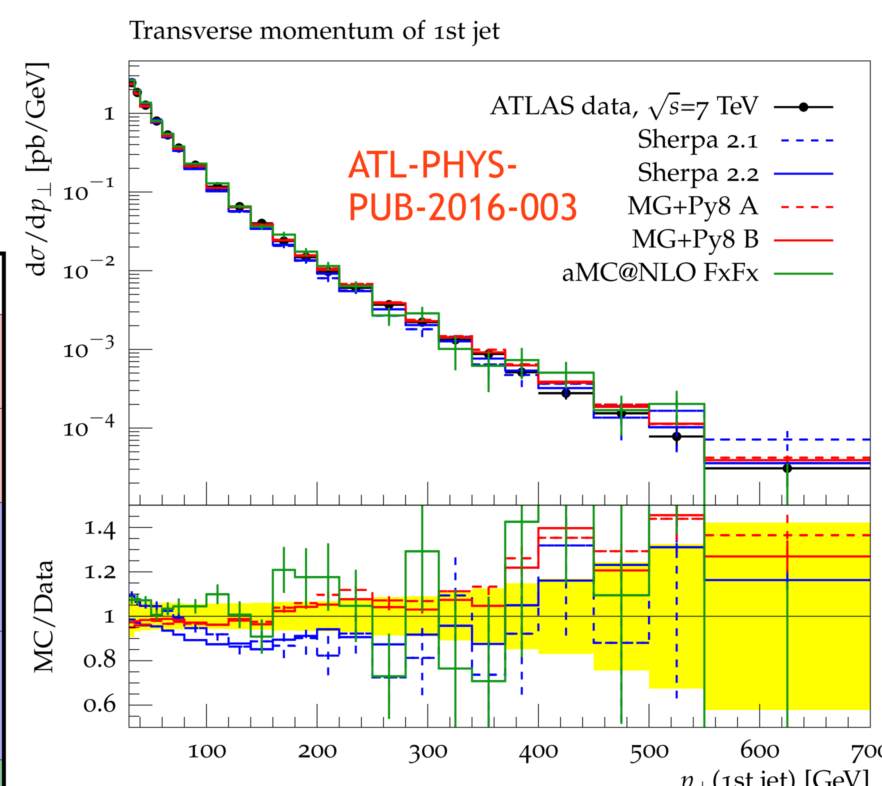
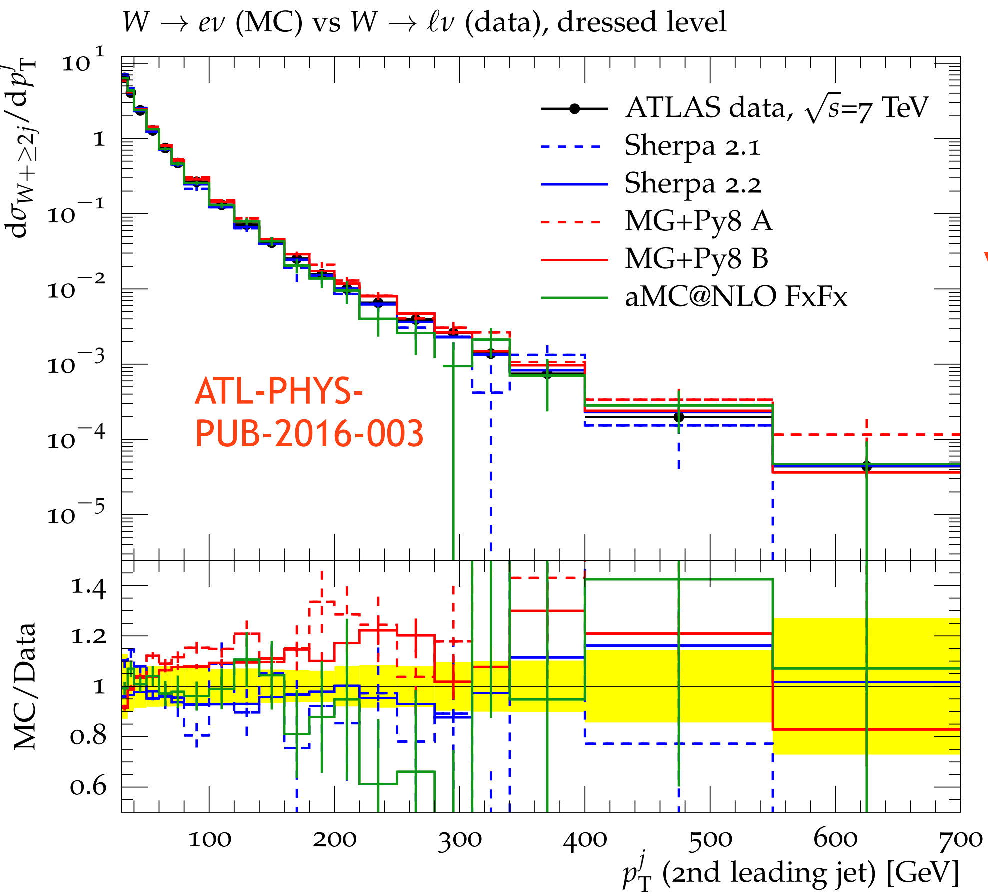


subleading jets kinematics

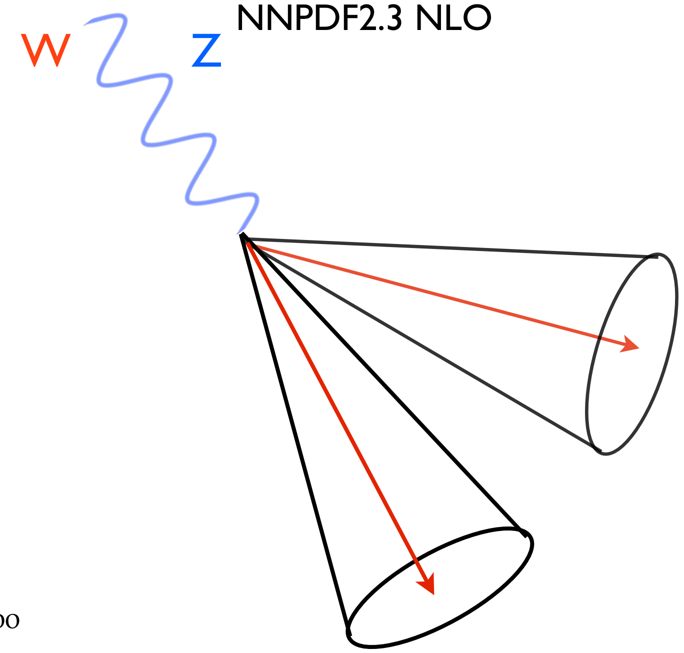
Eur. Phys. J. C (2015) 75:82

New data/MC comparisons. Agreement to ~1σ for most of prediction (tree-l. or NLO).

2nd jet in W+jets (7 TeV)

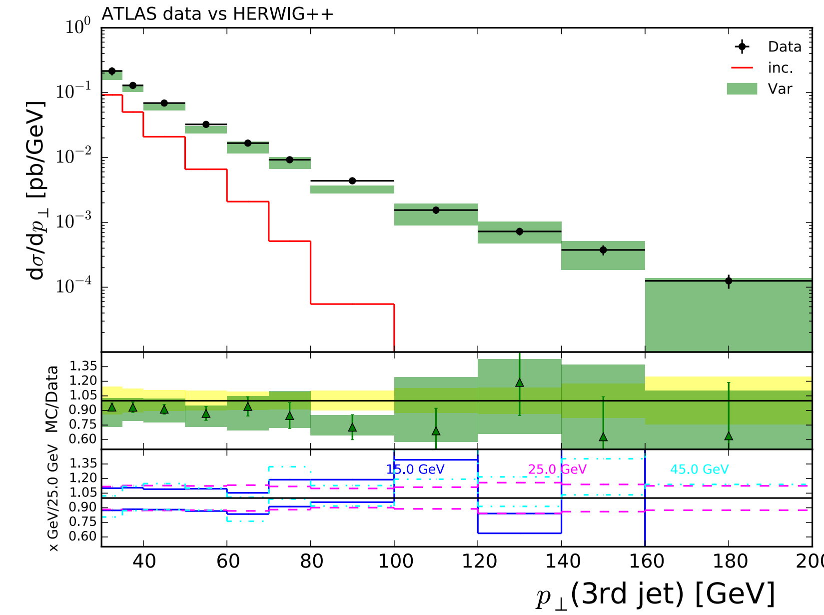


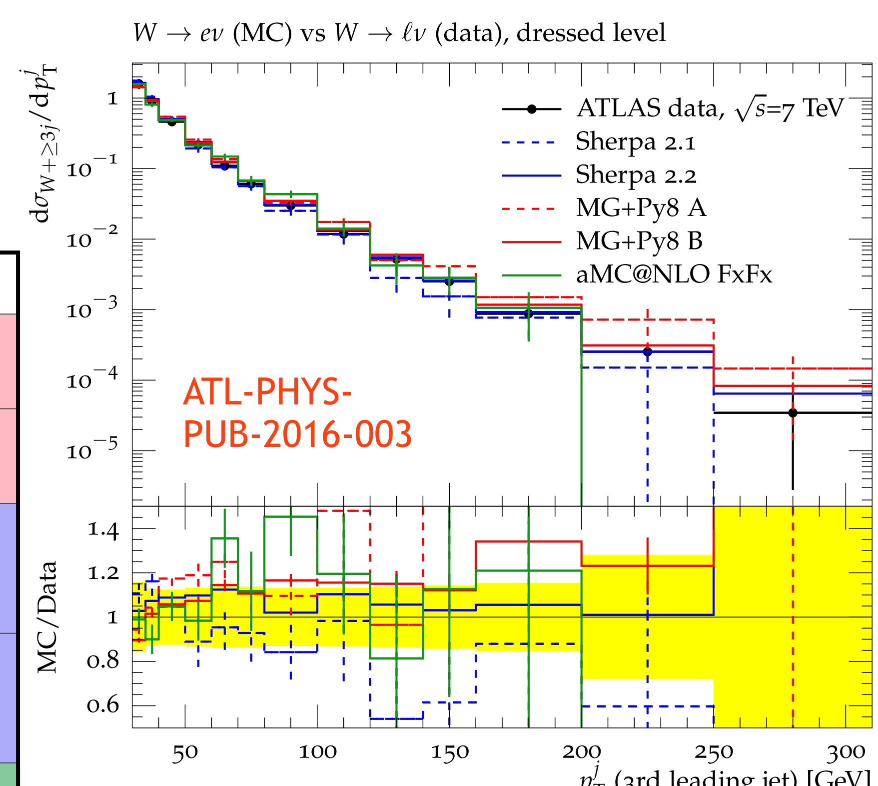
MGaMC v2.2.1
V+0,1,2 @ NLO
Pythia 8.210 or HWG++2.7.1
FxFx merging @ 15, **25**, 45
NNPDF2.3 NLO



3rd jet in Z+jets (7 TeV)

arXiv:1511.00847





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MGaMC +P8 B	V+0..4p v5.2.2.3	v8.210 A14	Kt-MLM @30 GeV	NNPDF NLO v2.0
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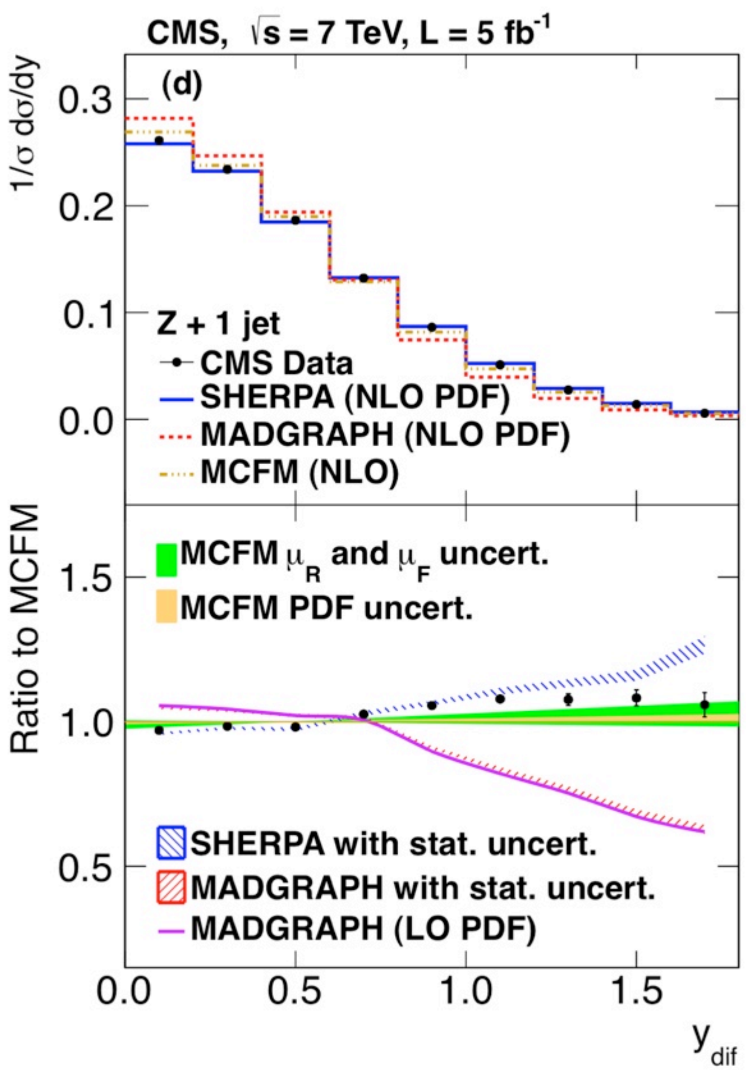
MG**a**MC +FxFx	V+0..2 NLO v2.3.2	v8.210 Monash	FxFx @15 GeV	NNPDF 2.3

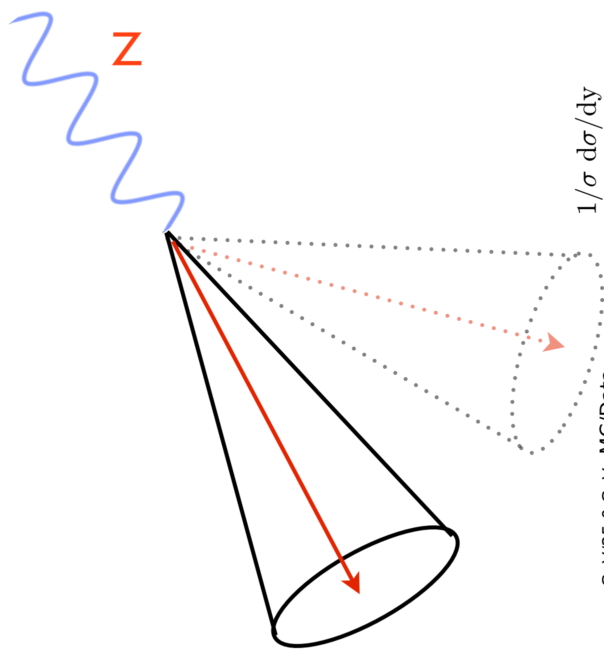
Data/MC@Run I: Z+jets «y_{diff}»

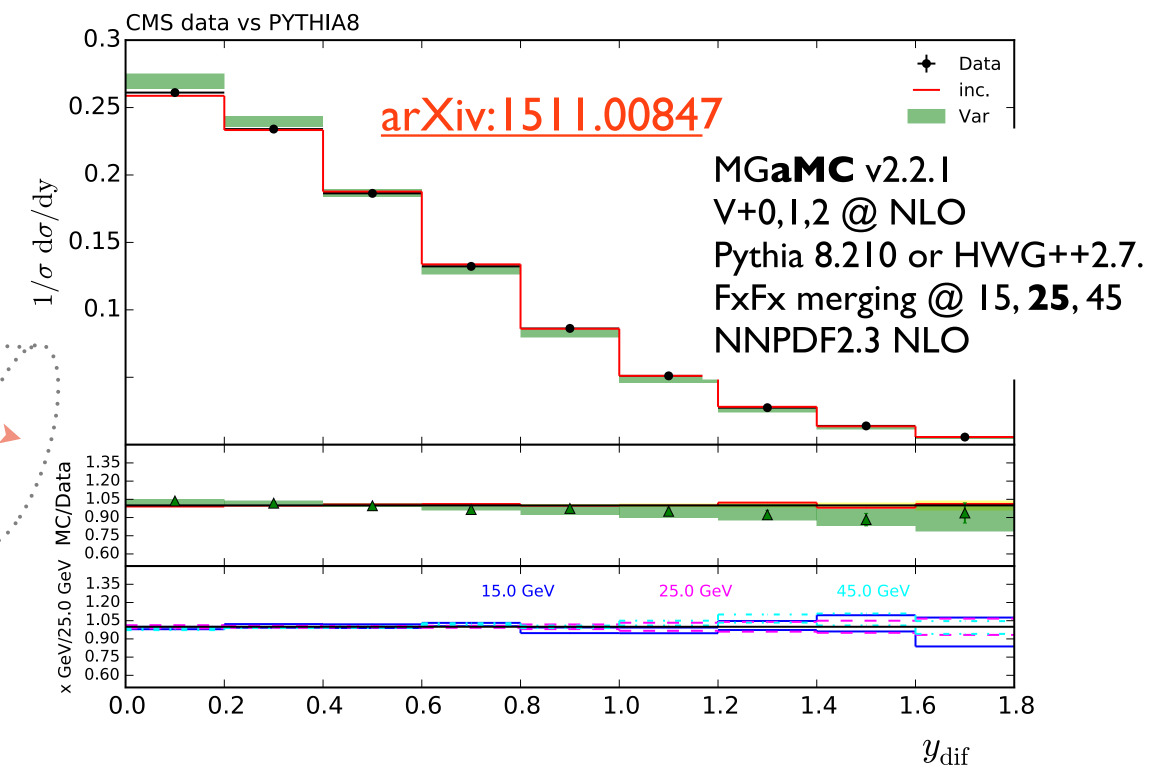
- y_{diff} : rapidity difference between Z and leading jet

Phys. Rev. D 88 (2013) 112009



Madgraph, Sherpa, MCFM severely deviating from data, uncovered by systematic uncertainties



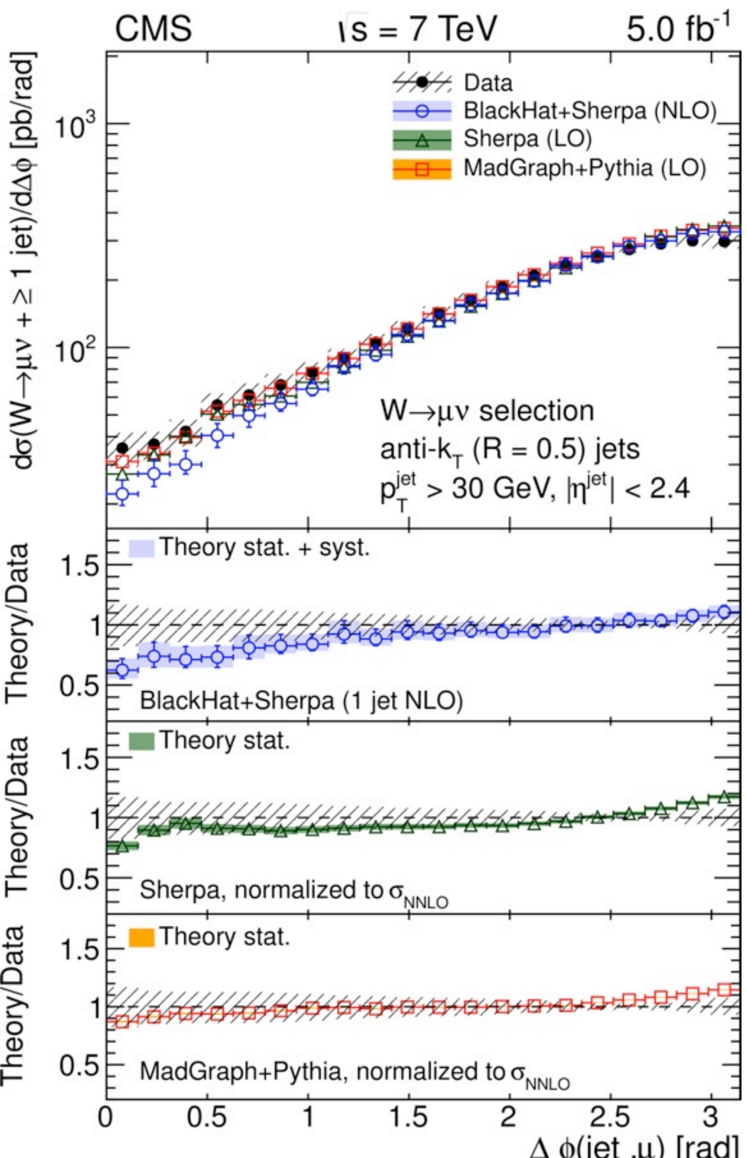


MG**aMC**+Pythia8 (FxFx): recovers the issue (same with Herwig)

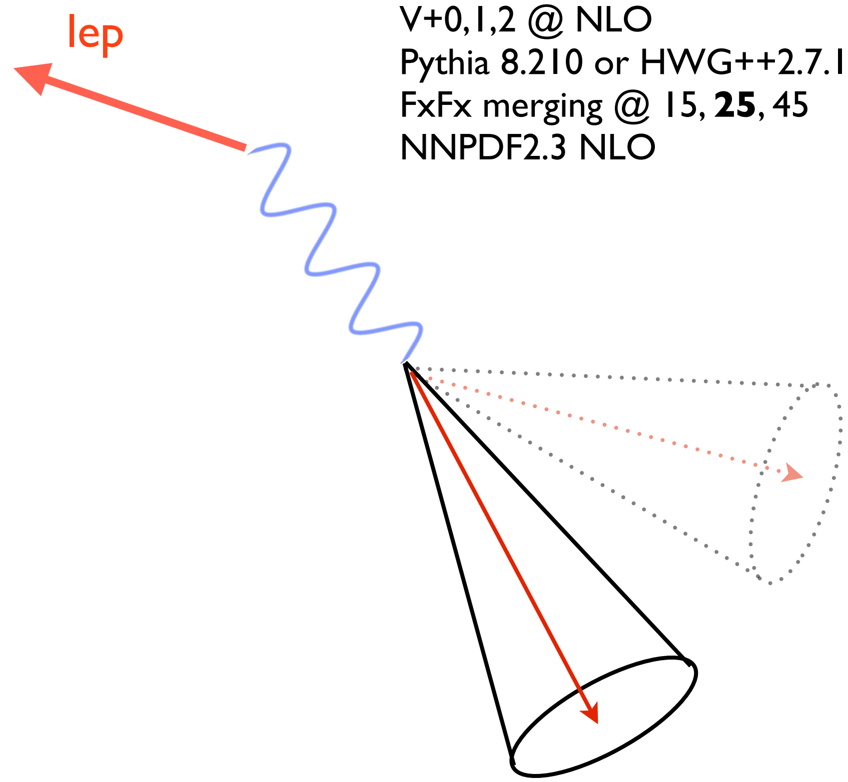
Data/MC@Run I: W+jets angular correlation

Phys. Lett. B 741 (2015) 12

W+jets (7 TeV)

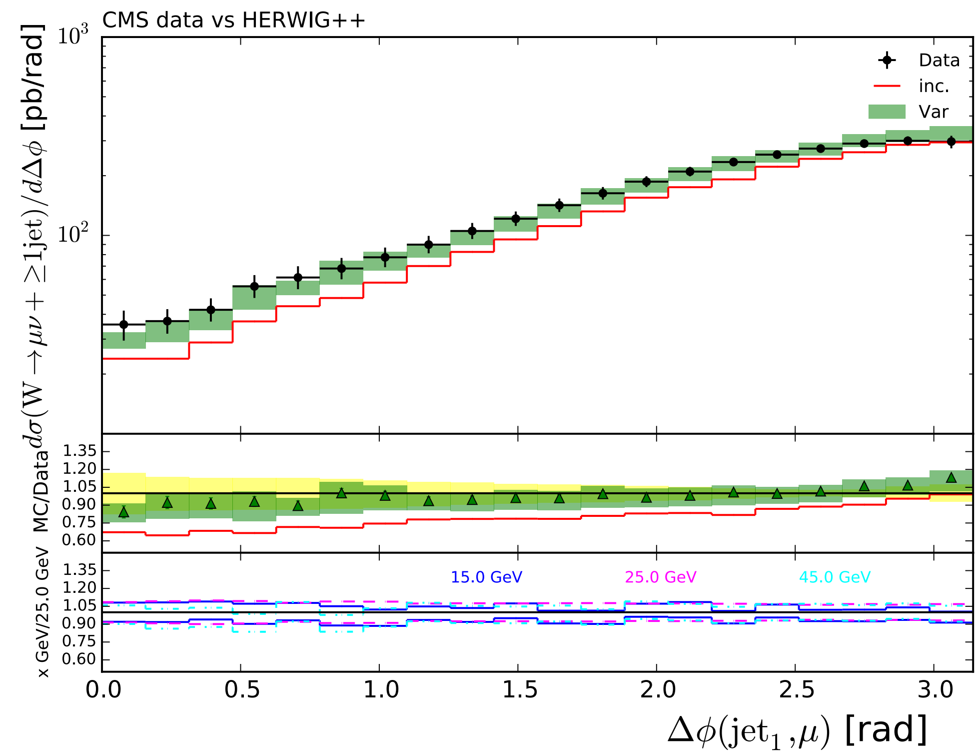


Generator	ME	PS	ME+PS	PDF
BH+Sherpa	V+0..4p	/	/	CT10
Sherpa	V+0..4 v1.4	v.2.2	CKKW	CT10
MG	V+0..4	P6.4 (Z2)	Kt-MLM @ 20 GeV	CTEQ6L1



MGa**MC** v2.2.1
V+0,1,2 @ NLO
Pythia 8.210 or HWG++2.7.1
FxFx merging @ 15, **25**, 45
NNPDF2.3 NLO

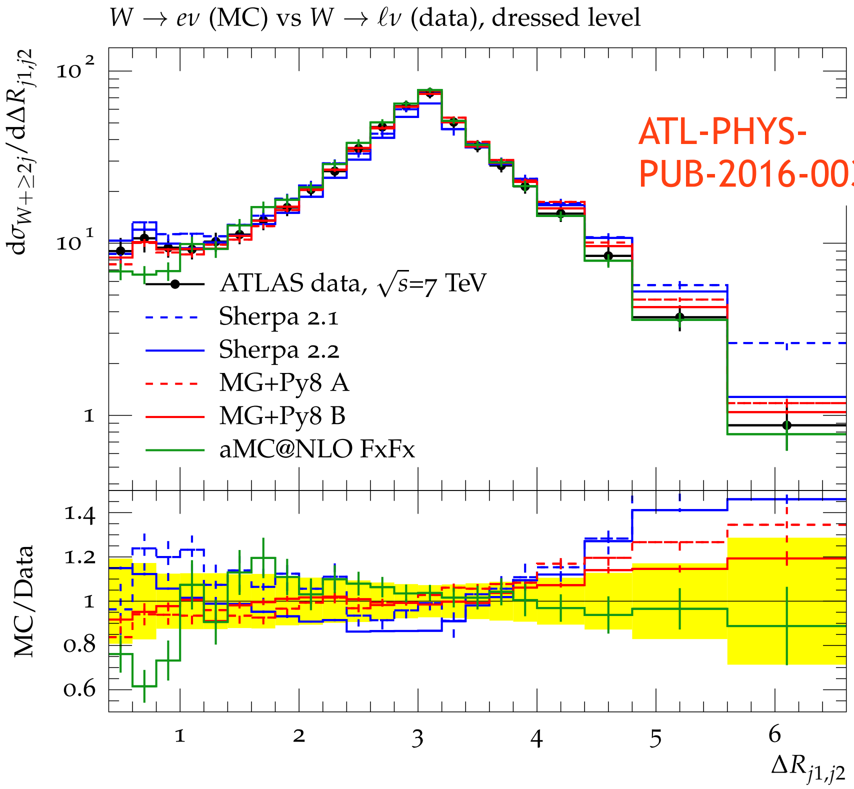
arXiv:1511.00847



Trends at NLO (BH) and LO (Sherpa, MG). Still present with aMC@NLO (FxFx)

Data/MC@Run I: W+jets angular correlation

W+jets (7 TeV)



ATL-PHYS-PUB-2016-003

Generator	ME	PS/Tune	ME+PS	PDF
MGaMC +P8 A	V+0..4p v5.2.2.2	v8.186 A14	Kt-MLM @20 GeV	NNPDF NLO v3.0
MGaMC +P8 B	V+0..4p v5.2.2.3	v8.210 A14	Kt-MLM @30 GeV	NNPDF NLO v2.0
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MGa**MC** +FxFx	V+0..2 NLO v2.3.2	v8.210 Monash	FxFx @15 GeV	NNPDF 2.3

MGa**MC** v2.2.1
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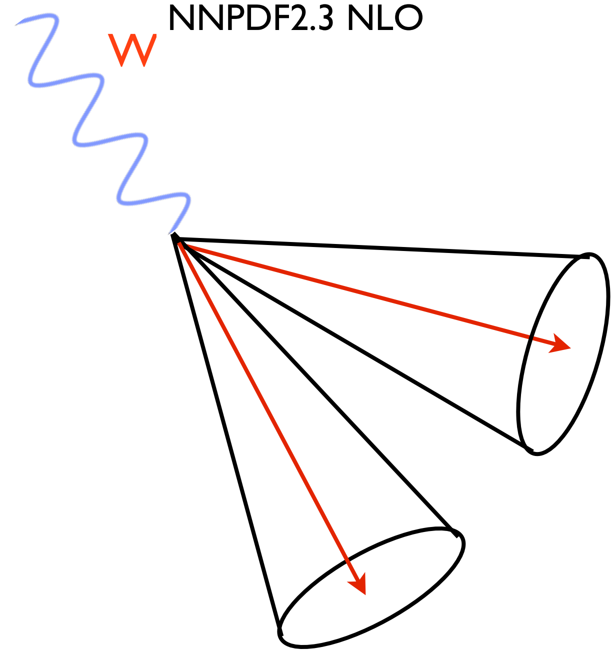
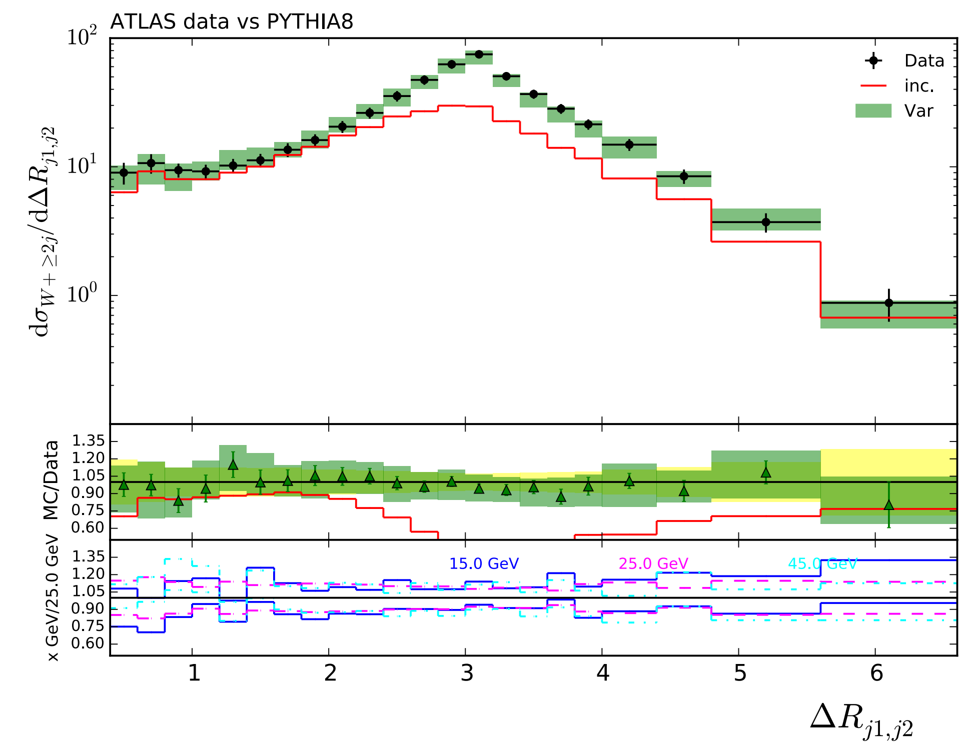


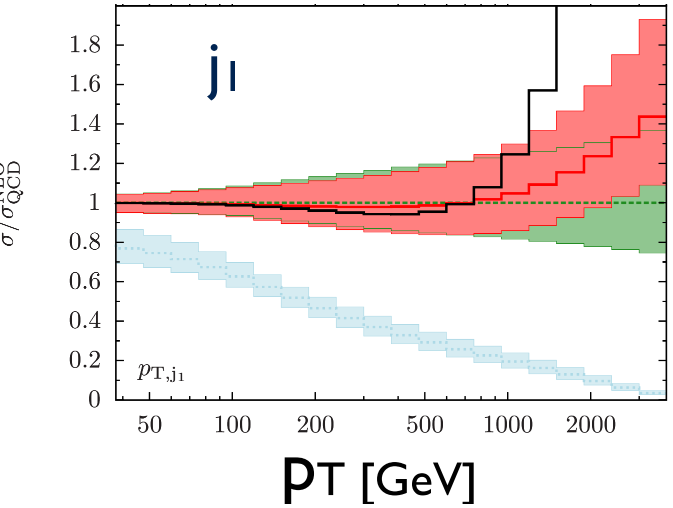
All in agreement, except
aMC@NLO (low dPhi)
Sherpa 2.1 & 2.2 (high dPhi)

arXiv:1511.00847

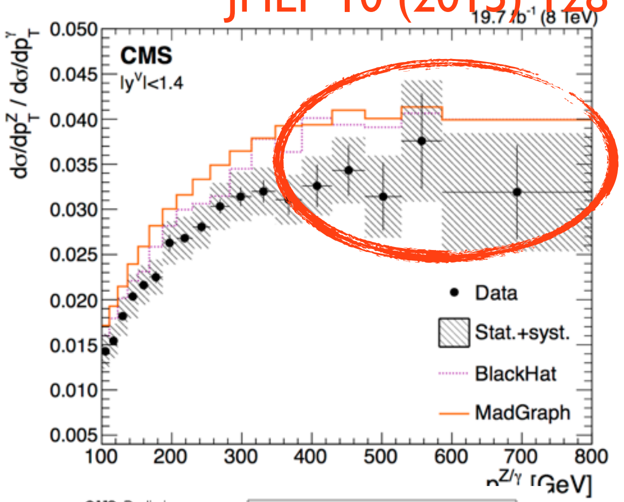


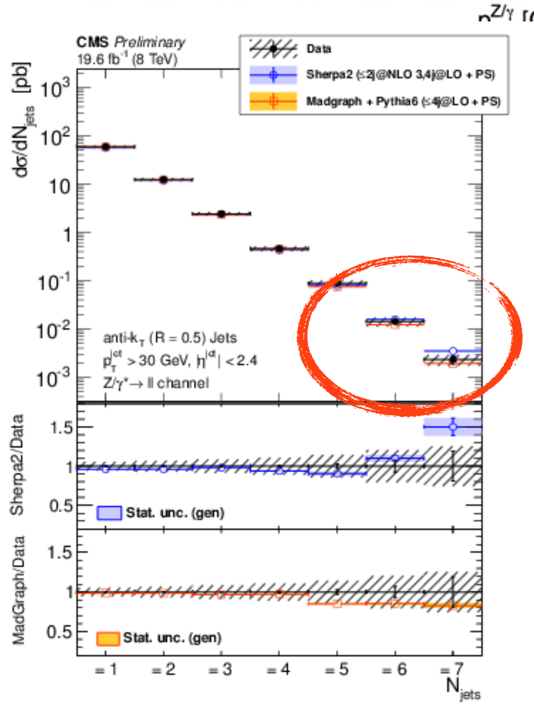
Excellent description with aMC@NLO

V+jets in Run II

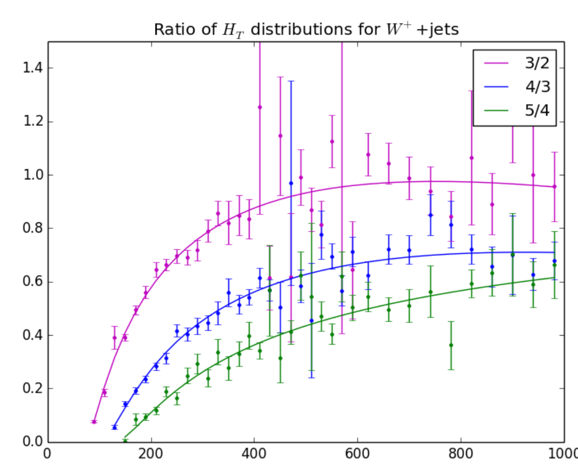


JHEP 10 (2015) 128





- Test NLO QCD + EWK
  - Use high Pt of V or leading jet to test impact of EWK correction
    - Probably no sensitivity at Run I (effect~uncertainty), reduction of stat uncertainty at Run II should help
  - Use V/V' ratio
    - Milder sensitivity to QCD and EWK correction, but also partial cancellation of uncertainties
    - Example: Z/g ratio: plateau height sensitive to EWK correction...but most probably not in Run I. What about W+jets/Z+jets?
- Test V+1 jets NNLO QCD
  - Gehrmann-De Ridder et al., arXiv:1507.02850, Boughezal et al., arXiv:1512.01291, Boughezal et al., Phys. Rev. Lett. 115, 062002 (2015)
- Large number of jets from NLO prediction
  - Knowing σ(V+n jet)/σ(V+(n-1) jet)@NLO: estimate σ(V+n+1 jet)



Bern et al.
Phys. Rev. D 92, 014008 (2015)

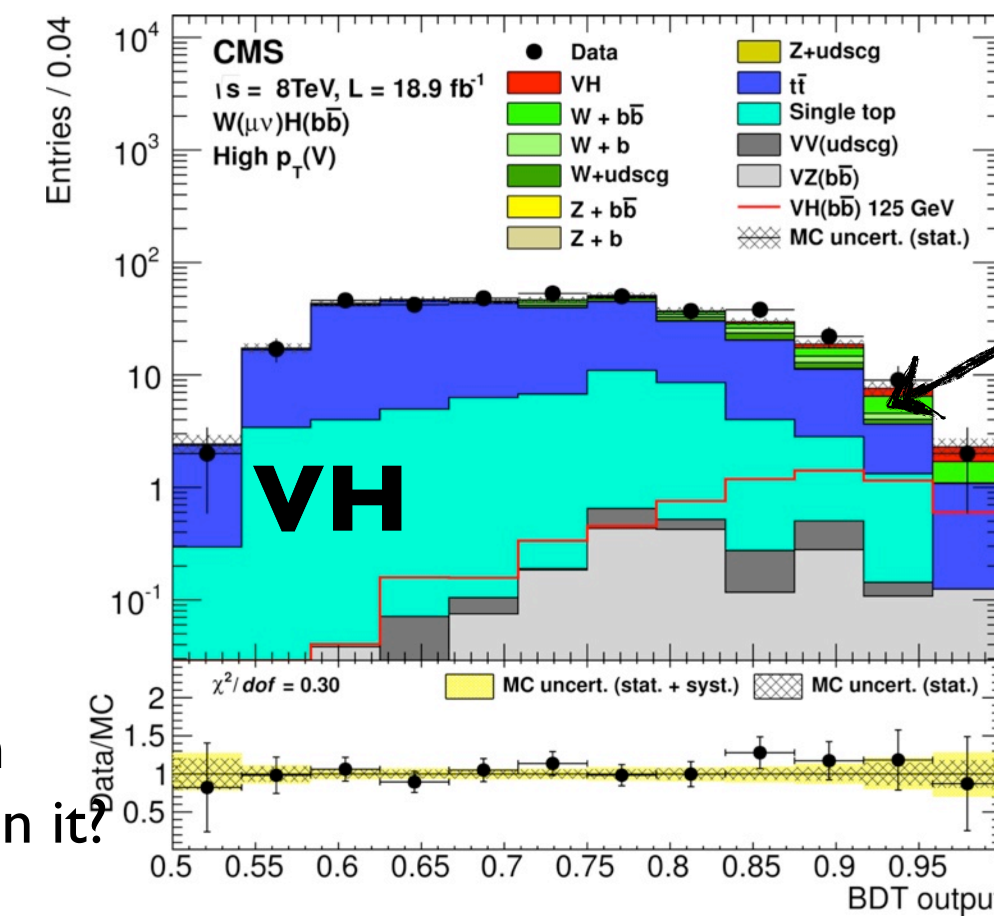
V+HF

Motivation for studying V+HF final states

[Phys.Rev. D89 (2014) 012003]

TH

Number of quark flavour in p (NQF)
ME-PS merging vs NQF
Scales
Q mass
fragmentation, decay
...



...yes

V+HF

Really worth spending time on it?

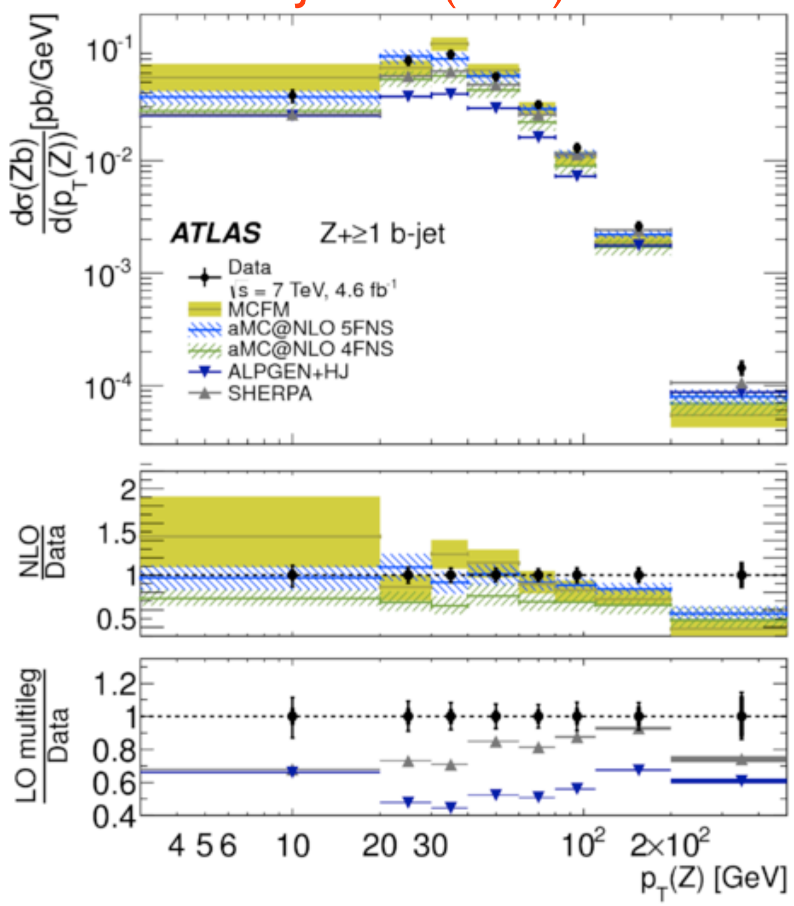
Exp.

heavy flavours tagging
much smaller statistics
potentially large background
removing DPS component
...

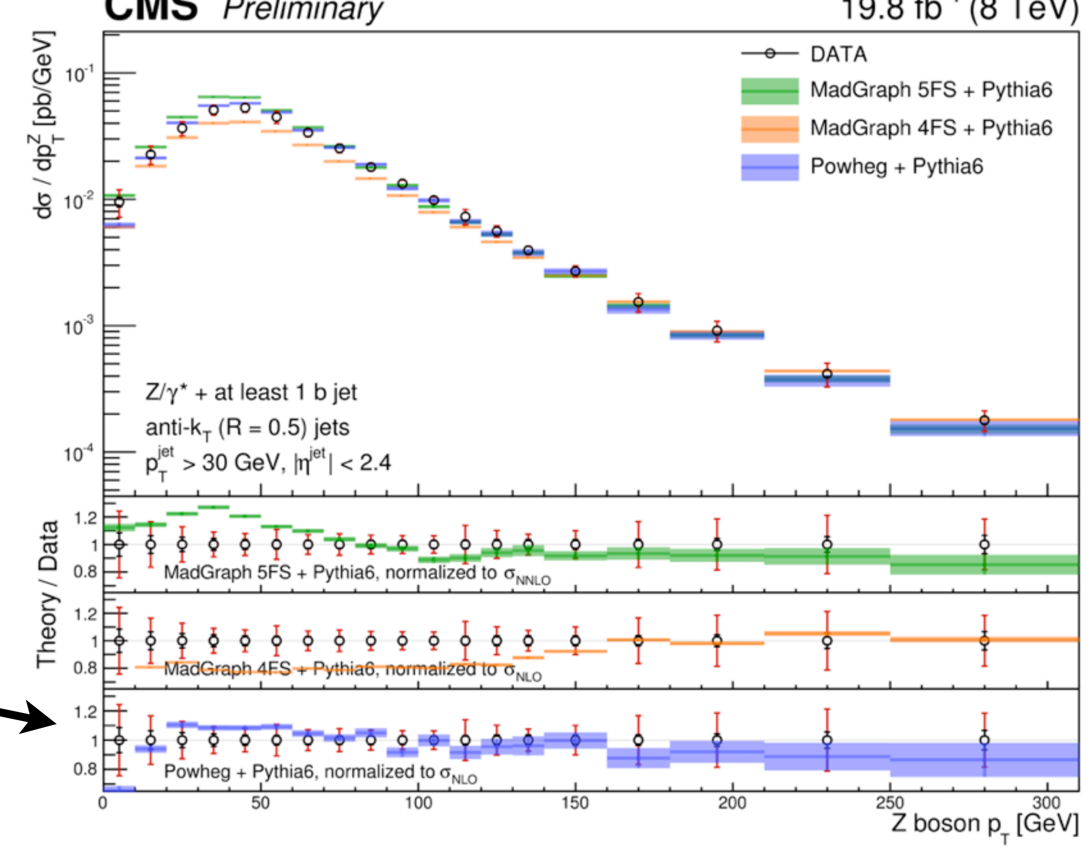
+ indirect insight on possible pp→bbX, ...
+ access to IQ proton content
+...

Data/MC@Run I: Z+>=1,2 b-jet in Run I

JHEP10(2014)141



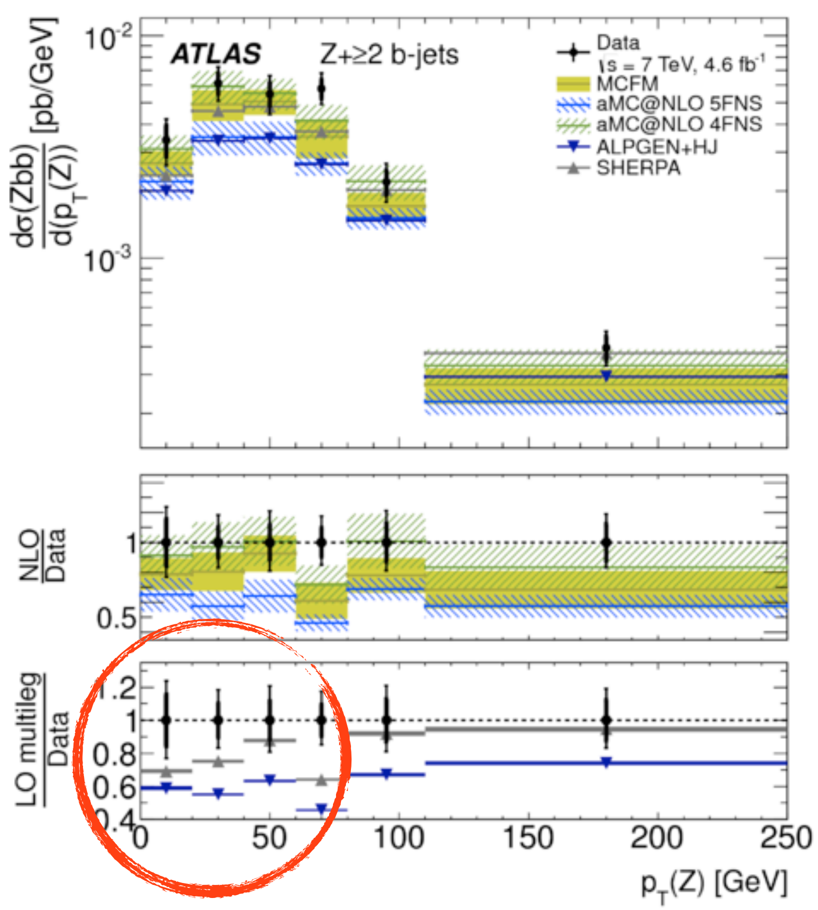
CMS-PAS-SMP-14-010

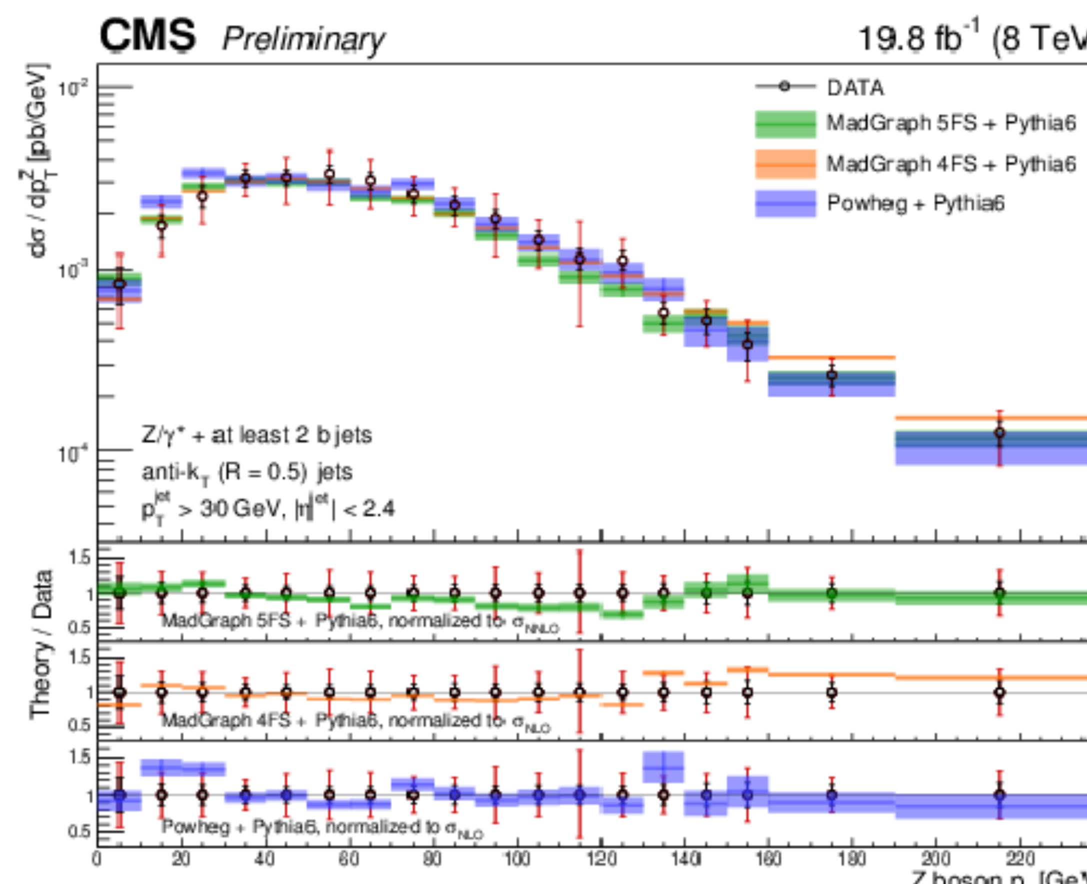


Z+>=1b jet

NLO prediction have the same behaviour. HO corr. missing?

Z+>=2b jet



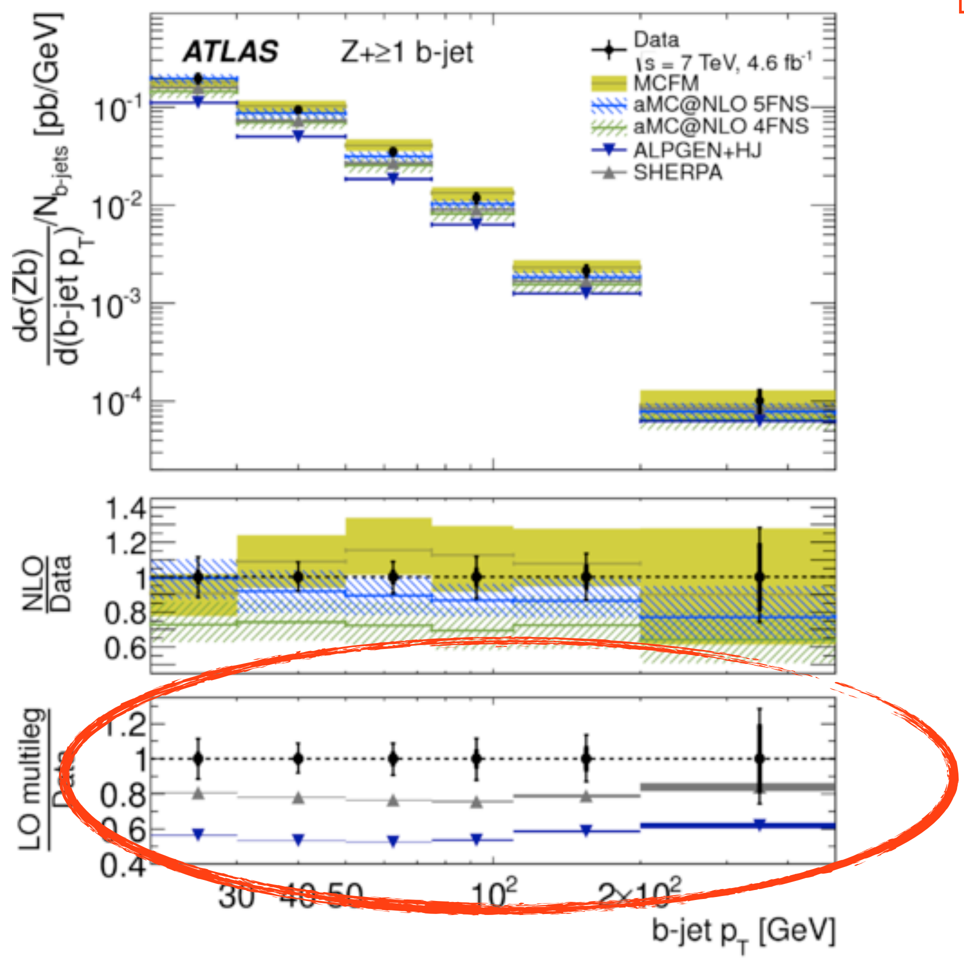


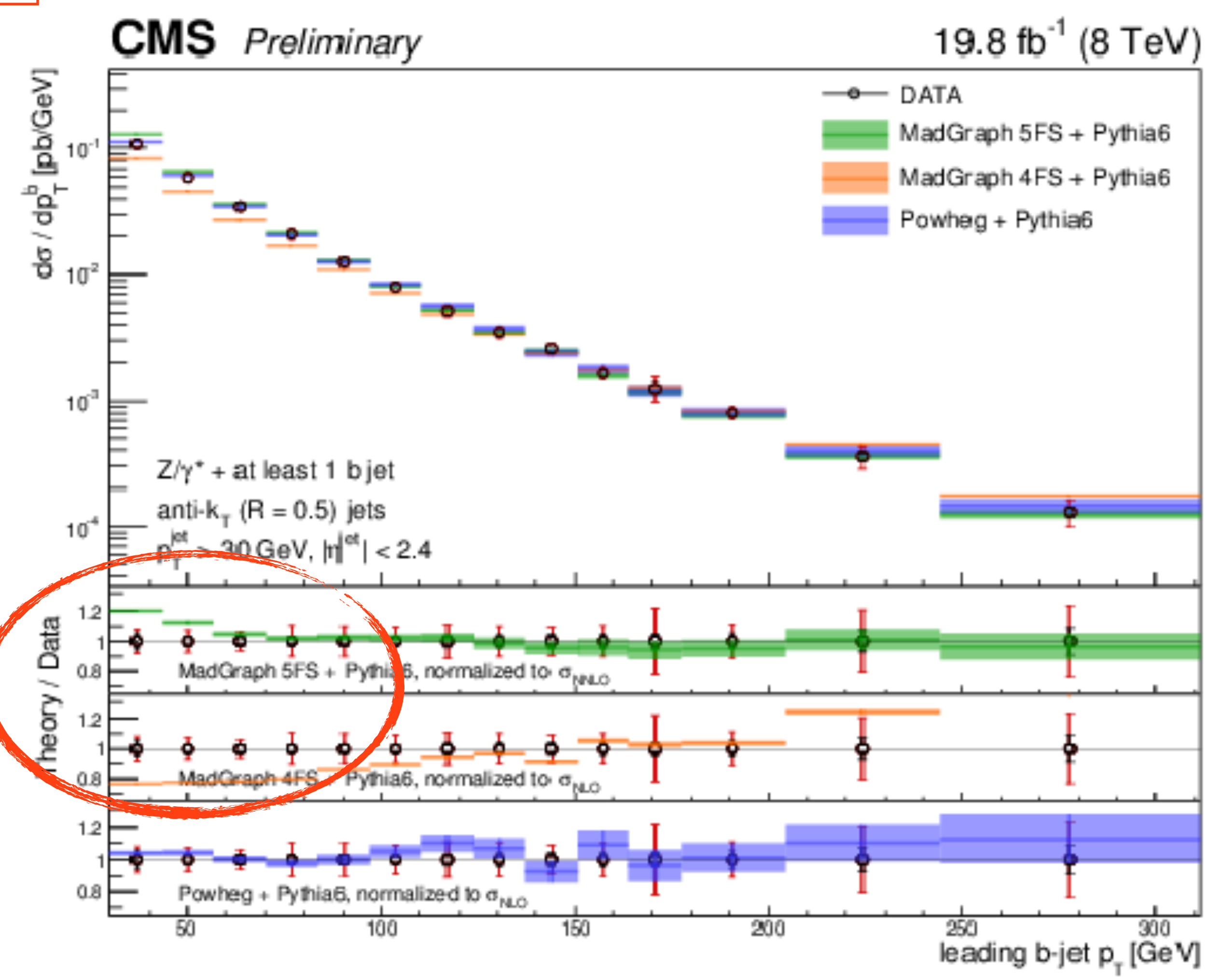
Data/MC@Run I: Z+>=1,2 b-jet in Run I

JHEP10(2014)141

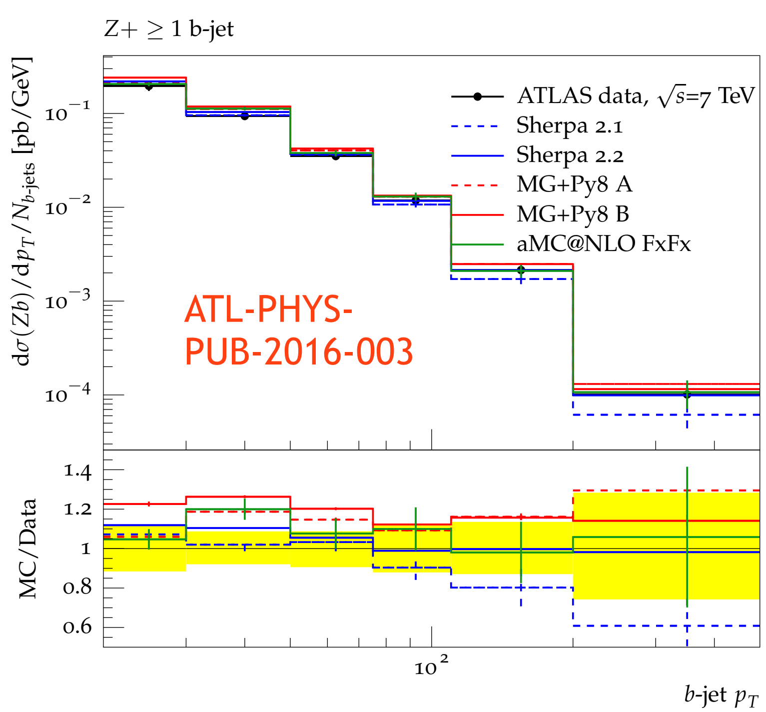
Z+>=1b jet

CMS-PAS-SMP-14-010



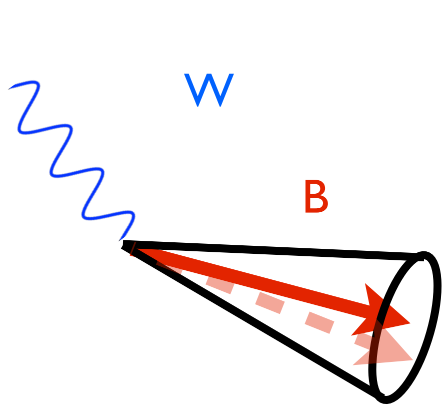


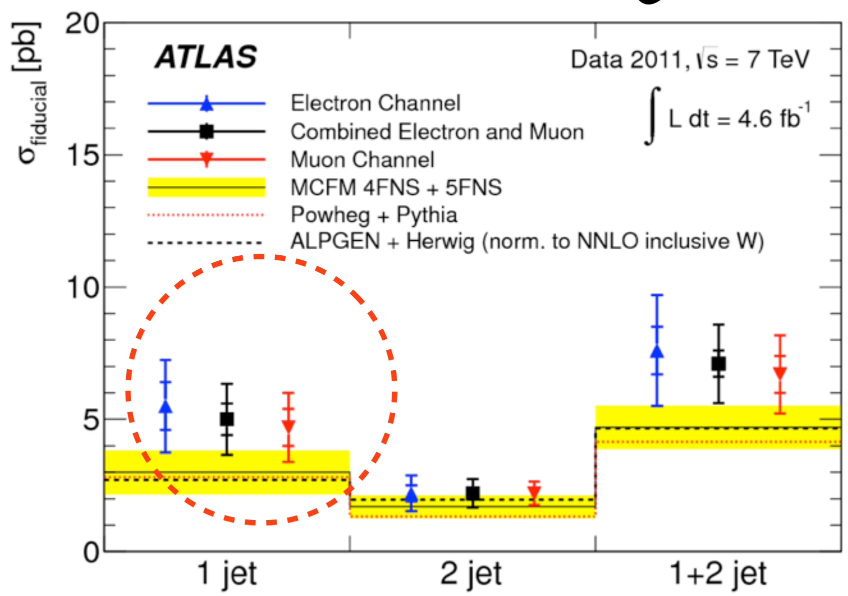
ALPGEN+H, Sherpa: shape ok, normalisation off
MG 4F/5F+P6: large disagreement in soft Pt region only



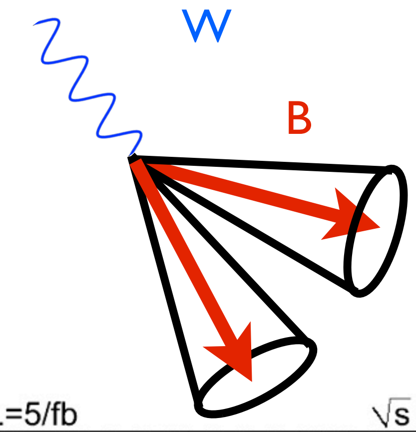
Good agreement apart
MG 5F «25ns»: soft pt
Sherpa 2.1: high pt.

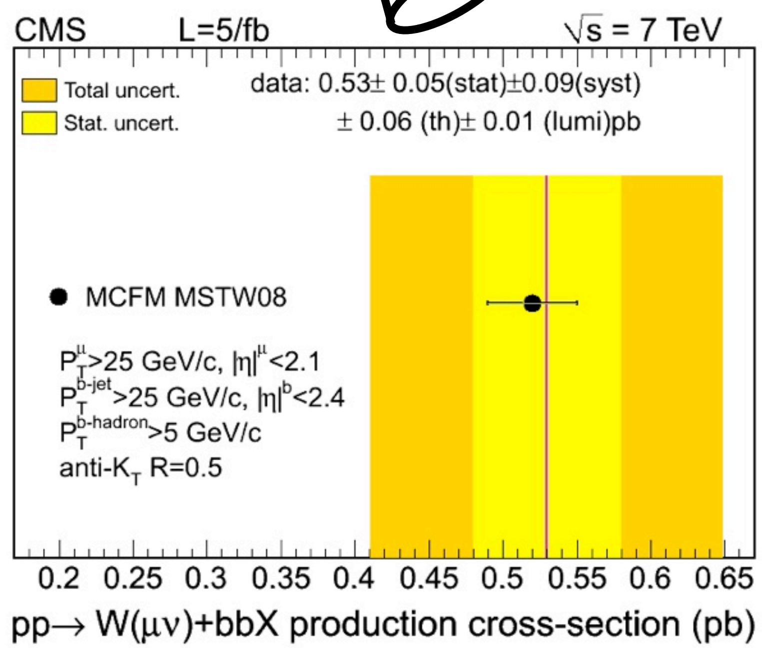
W+1b/2b, Z+2b



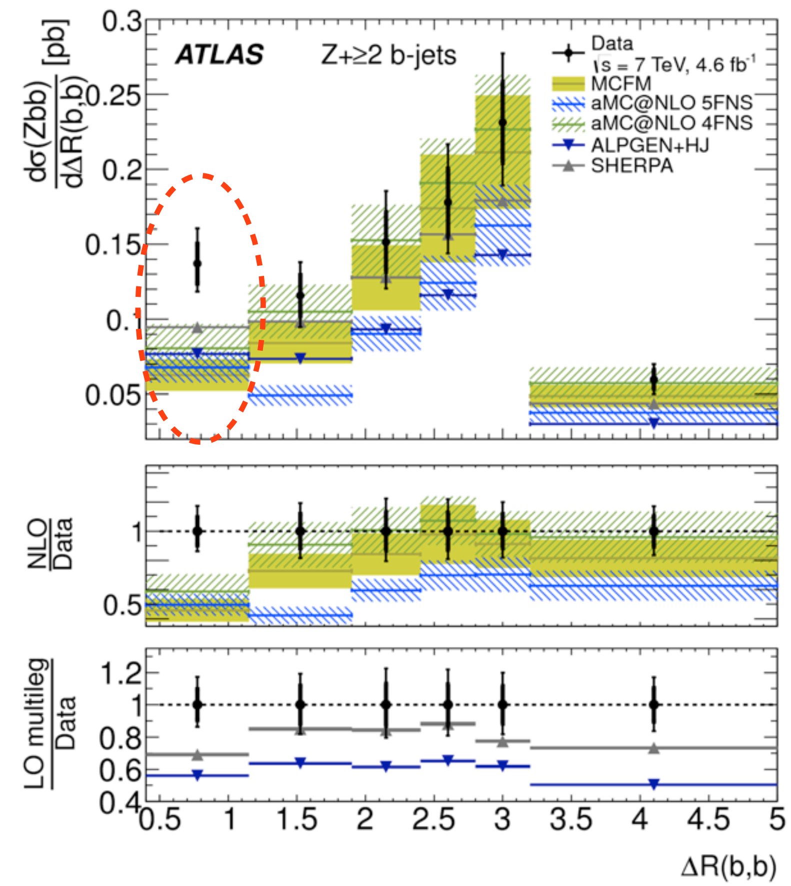


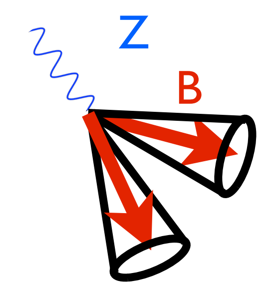
W+>=1b
1-σ excess



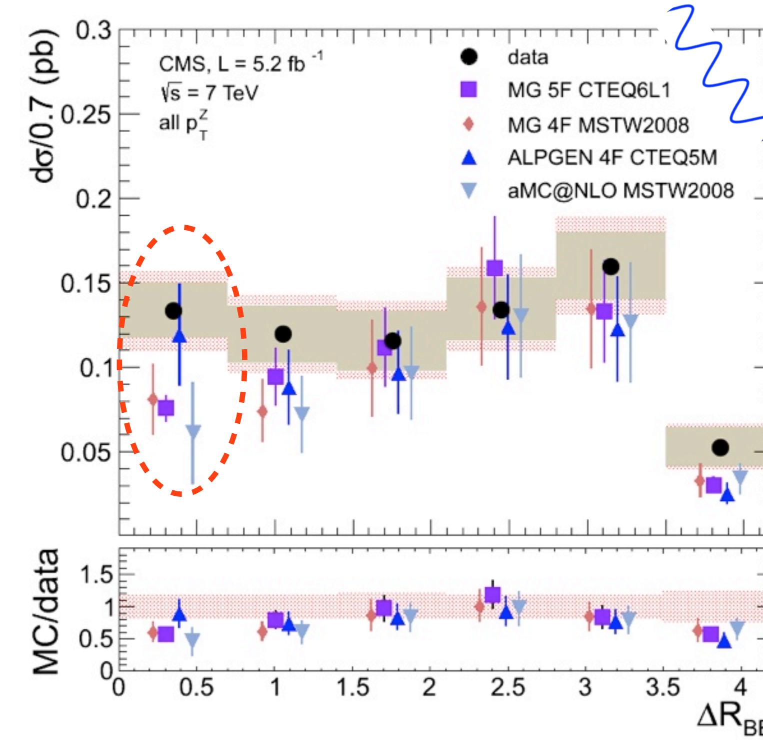


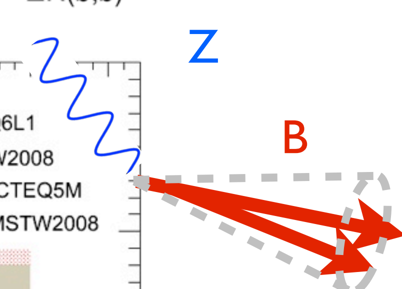
W+2b
no excess





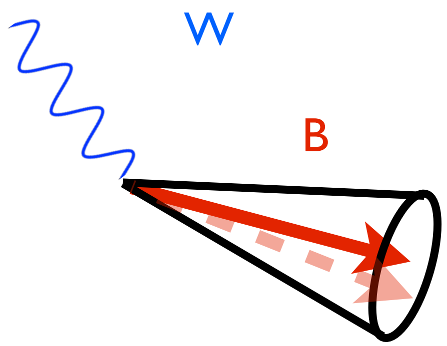
Z+2b
excess in
collinear
bb region

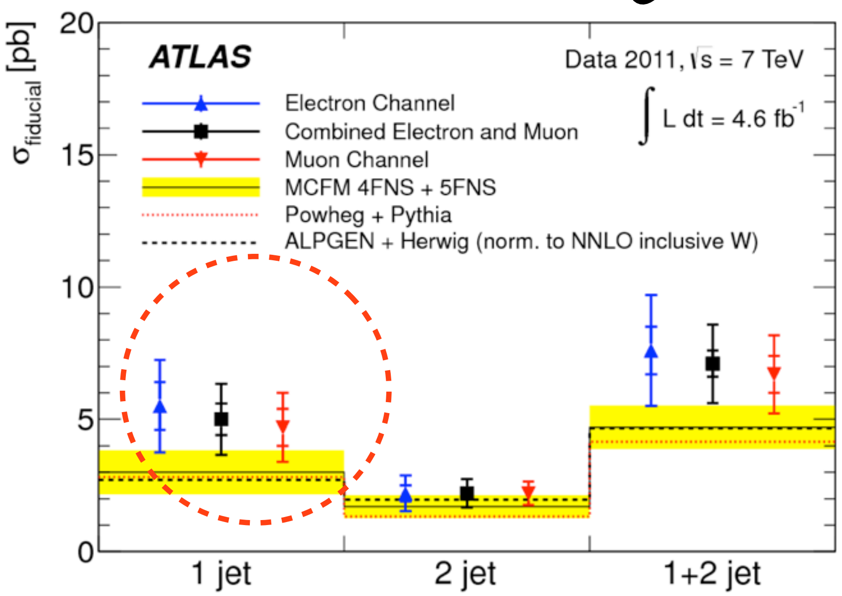




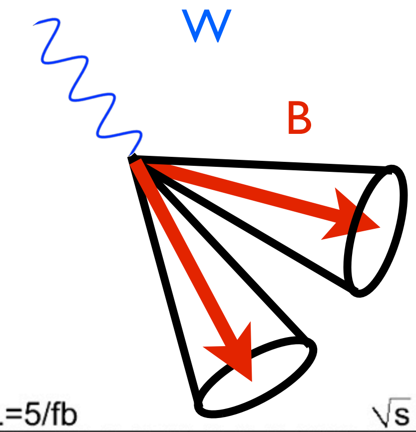
Compatible with mismodeling of b-quark collinear production

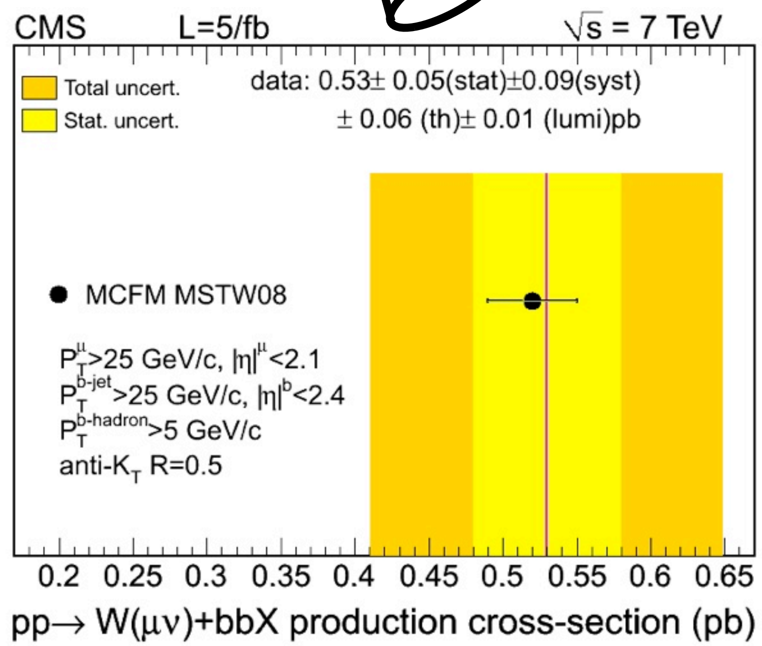
W+1b/2b, Z+2b



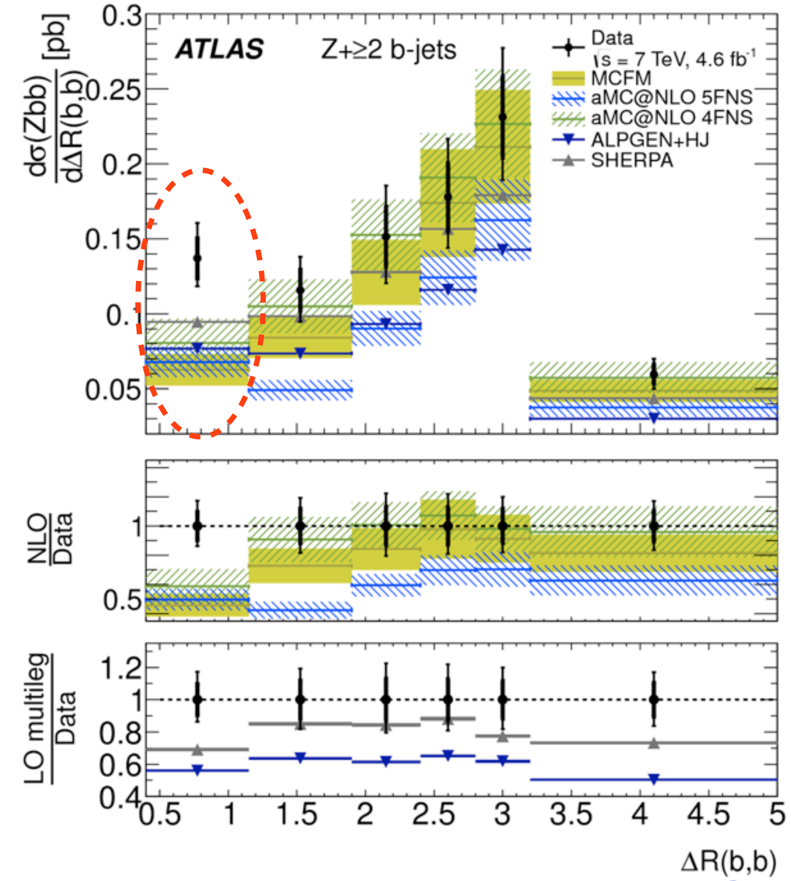


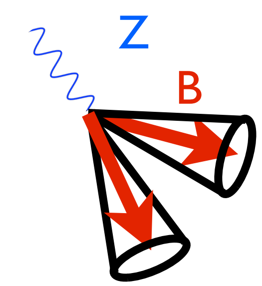
W+>=1b
1-σ excess



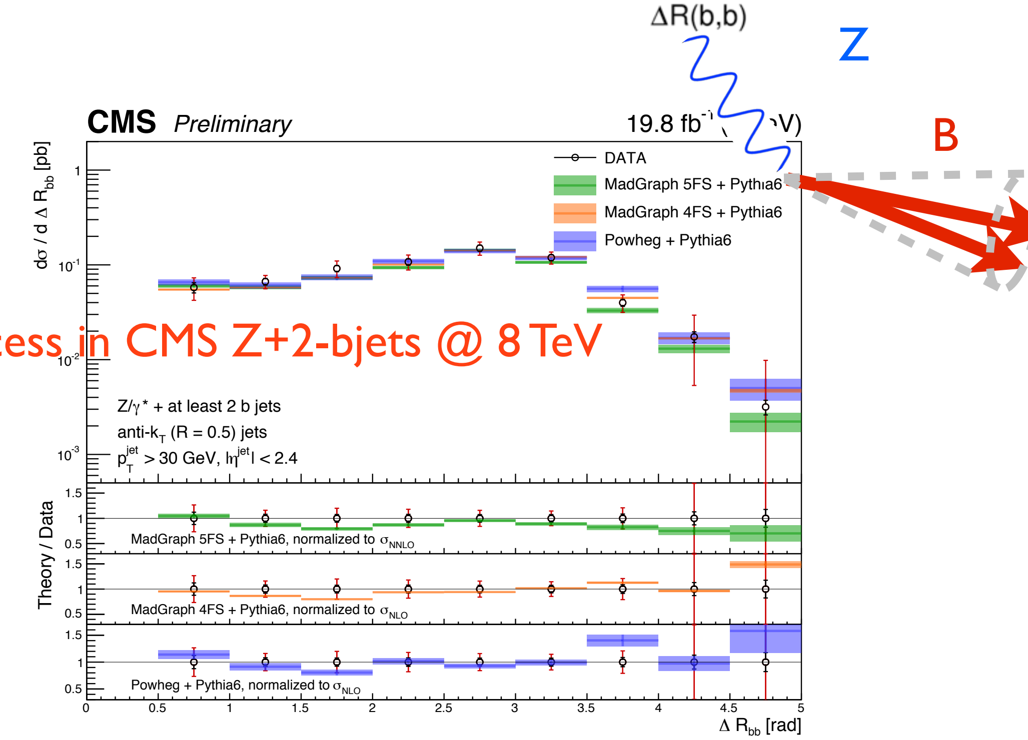


W+2b
no excess





Z+2b excess in collinear bb region



No excess in CMS Z+2-bjets @ 8 TeV

Compatible with mismodeling of b-quark collinear production

V+HF in Run II

- For Run II
  - predictions vs W+1b and Z+2B-hadrons/2b-jets
    - Add γ + HF
    - consider Vcc, with D meson exclusive decays? Full RUn II stat to be considered in this case
  - Clarify the use of 4F and 5F predictions
  - 4F prediction
    - Tree level or NLO?
    - Impact of scale choices at NLO for 4F
  - Need also a more coherent of MC treatment between ATLAS and CMS in the data/MC comparison

For Run II: Intrinsic heavy quark

- Test experimentally the hypothesis of an NP HQ (charm) contribution in the proton, using γ+c, Z+c, W+b

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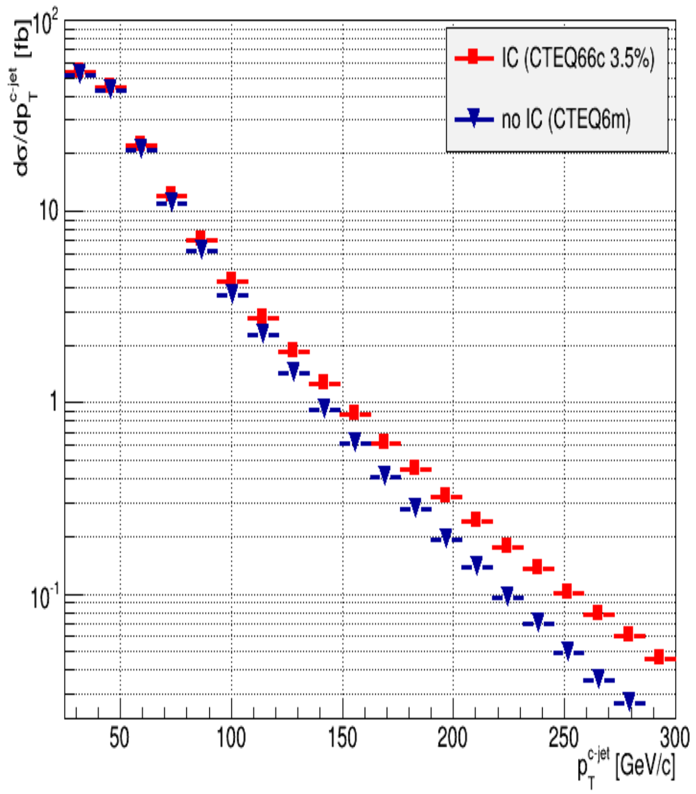
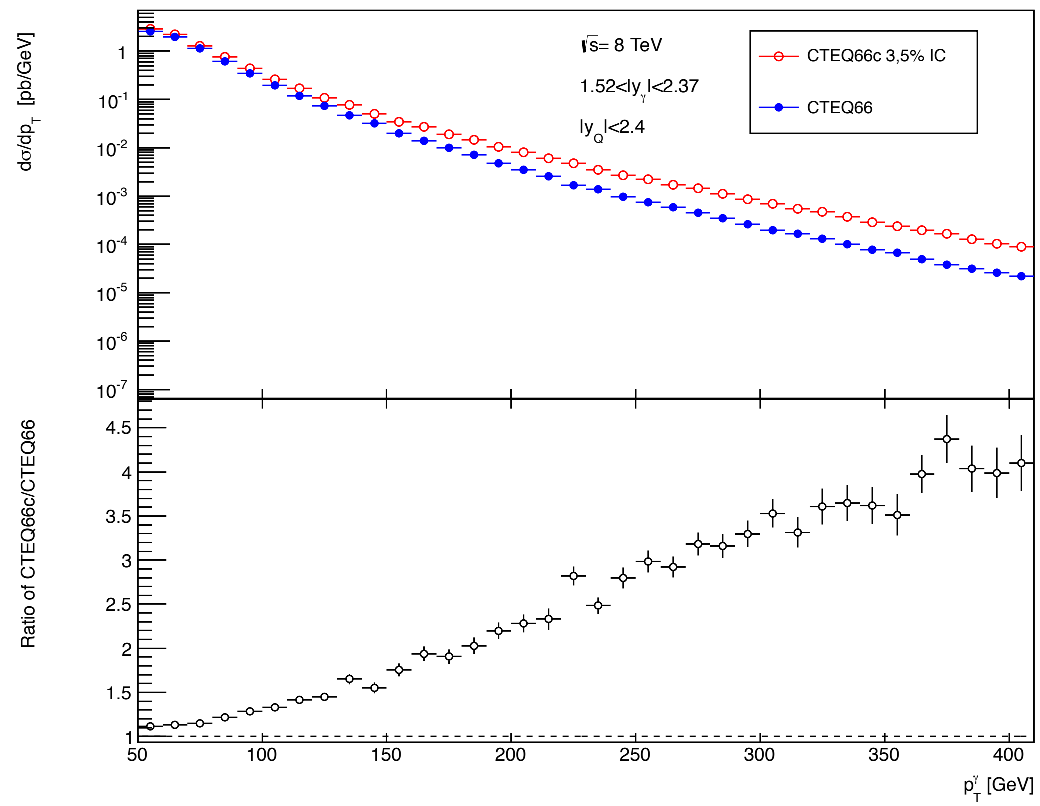


Phys.Lett. B728 (2014) 602-606

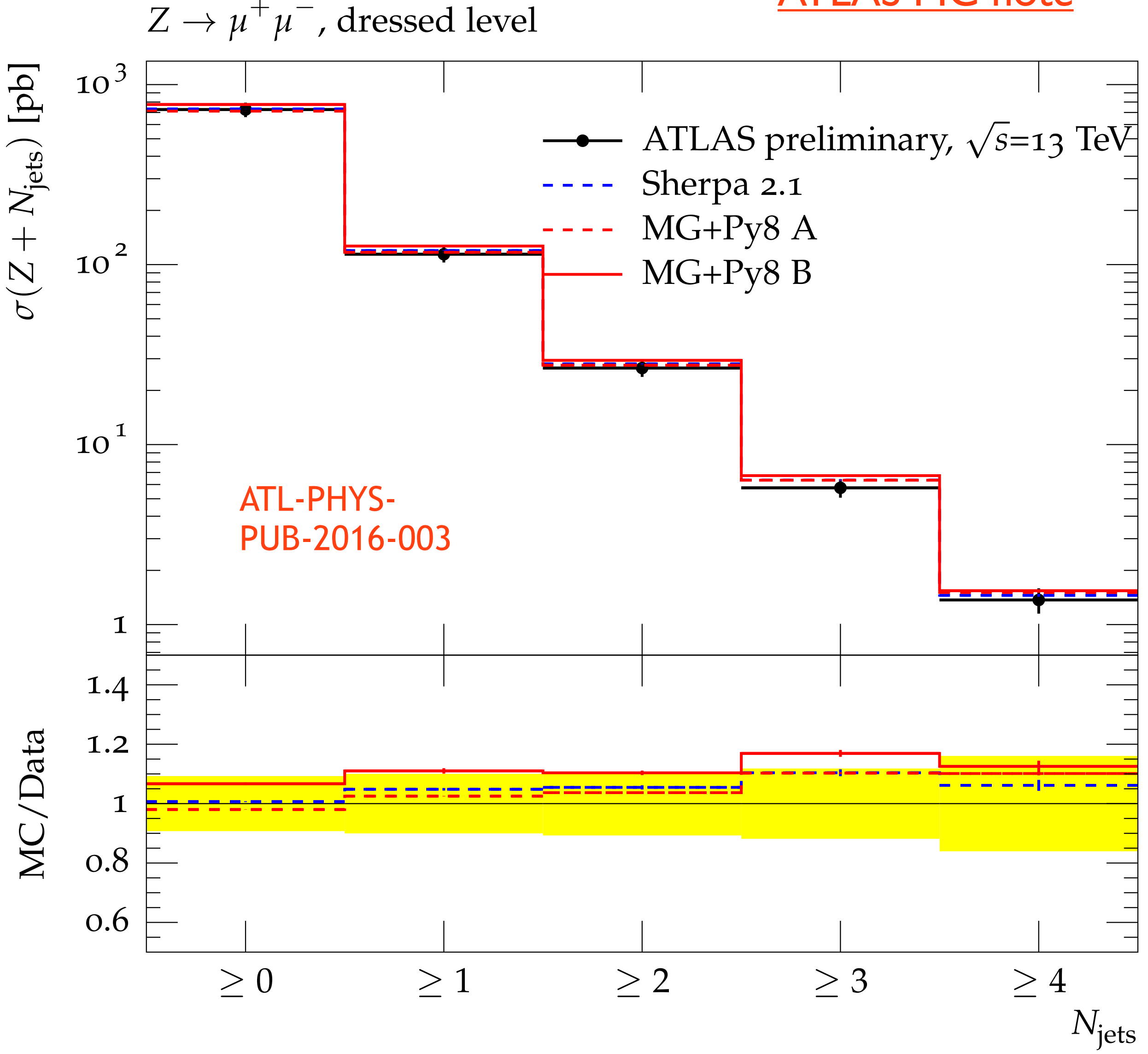


- Recent (NN)PDF developments to include IC in global fit [Ball et al. arXiv:1510.00009]
- Might be challenging depending on the ability to control the scale, PDF, merging uncertainties and dependency to FNS choice. Not clear how to attack this problem efficiently.

A quick look to 13 TeV data/MC comparisons

Z (+jets) from ATLAS

ATLAS MC note

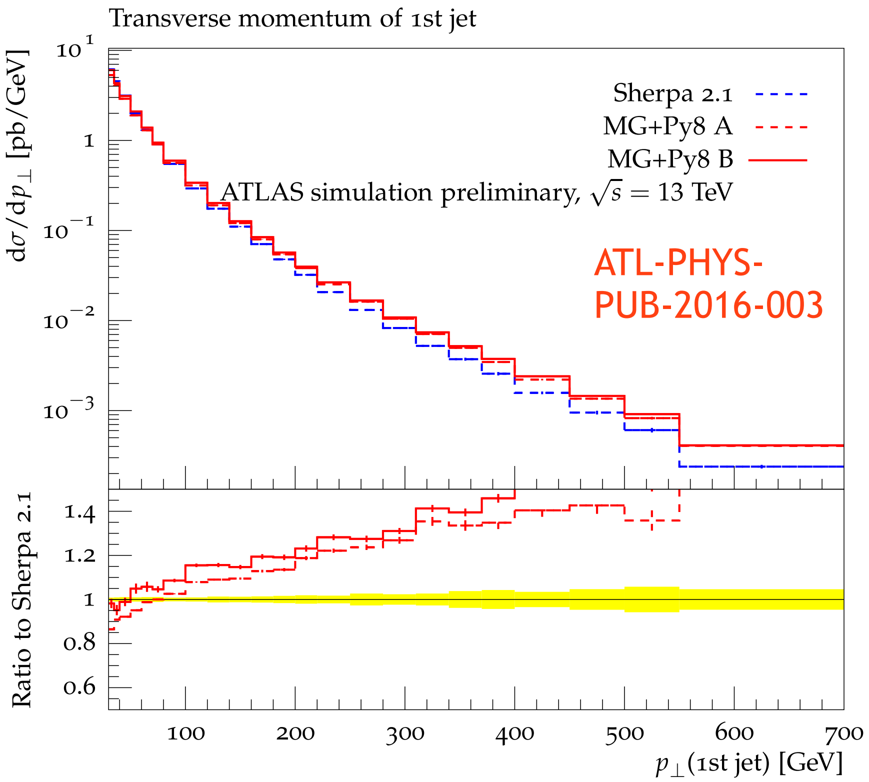


MG predictions behave similarly (apart for rapidity), but show a large difference w.r.t. Sherpa

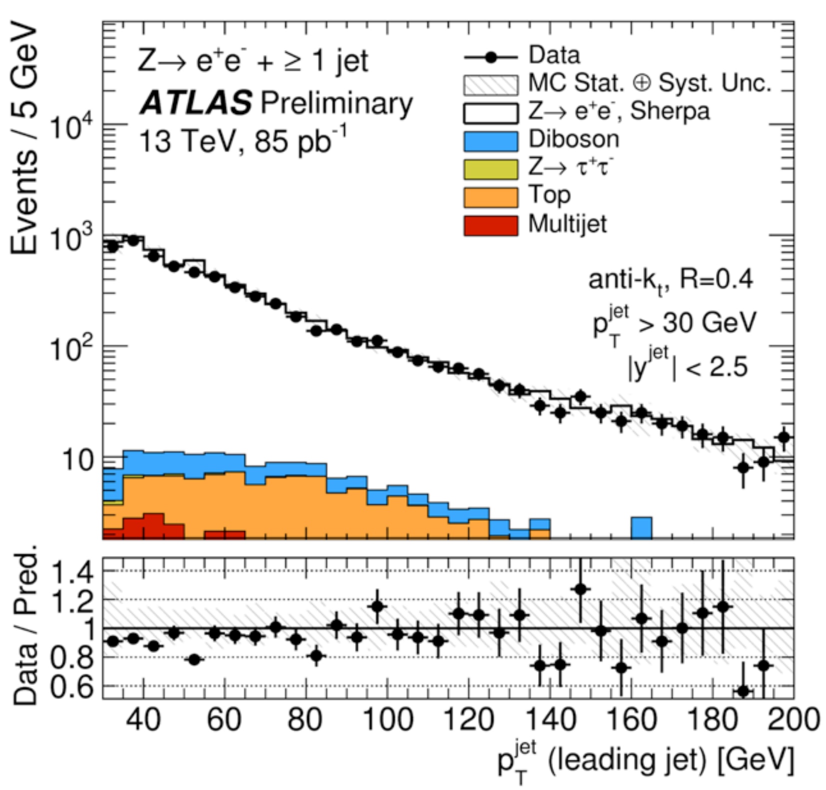
Generator	ME	PS	ME+PS	PDF
MG+P8 A	V+0..4p v5.2.2.2	v8.186	Kt-MLM @20 GeV	NNPDF NLO v3.0
MG+P8 B	V+0..4p v5.2.2.3	v8.210	Kt-MLM @30 GeV	NNPDF NLO v2.0
Sherpa 2.1	V+0..2 NLO V+3..4 LO v2.1.1	v2.1.1	CKKW-L @20 GeV	NLO CT10

Z+jets from ATLAS

ATLAS MC note



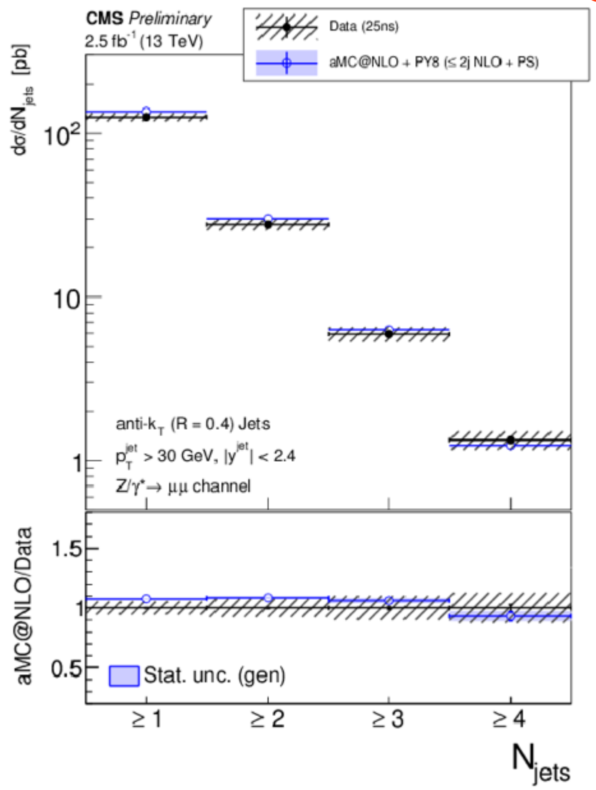
Generator	ME	PS	ME+PS	PDF
MG+P8 A	V+0..4p v5.2.2.2	v8.186	Kt-MLM @20 GeV	NNPDF NLO v3.0
MG+P8 B	V+0..4p v5.2.2.3	v8.210	Kt-MLM @30 GeV	NNPDF NLO v2.0
Sherpa 2.1	V+0..2 NLO V+3..4 LO v2.1.1	v2.1.1	CKKW-L @20 GeV	NLO CT10

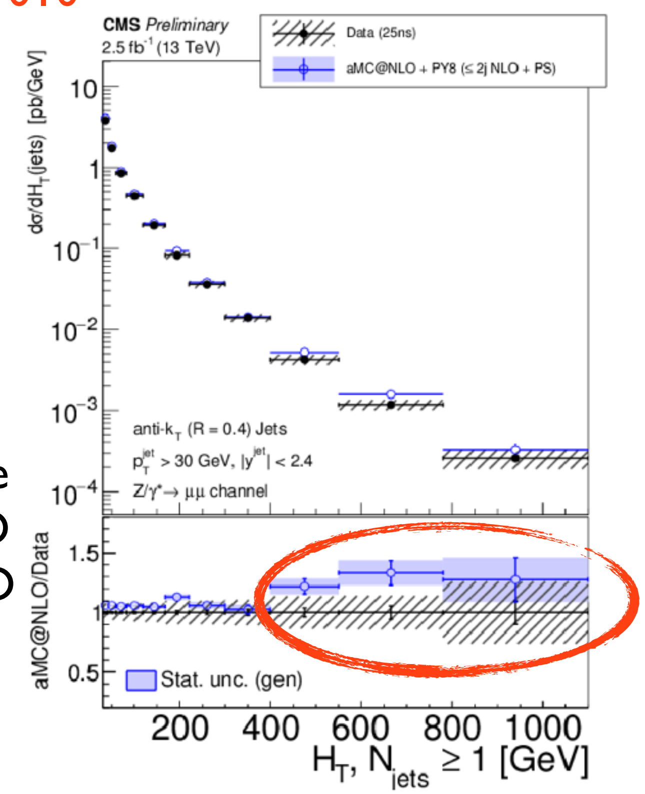


MG predictions behave similarly, but show a large difference w.r.t. Sherpa (which seems to match the data).

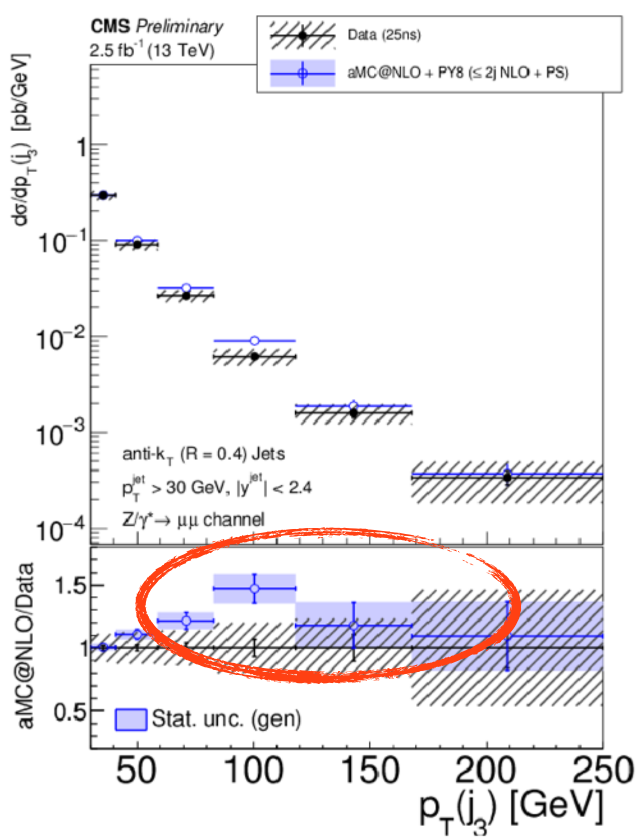
Z+jets from CMS

CMS-PAS-SMP-15-010





MGa**MC**+P8
CUETP8M1 tune
Norm. to NNLO
NNPDF 3.0 NLO



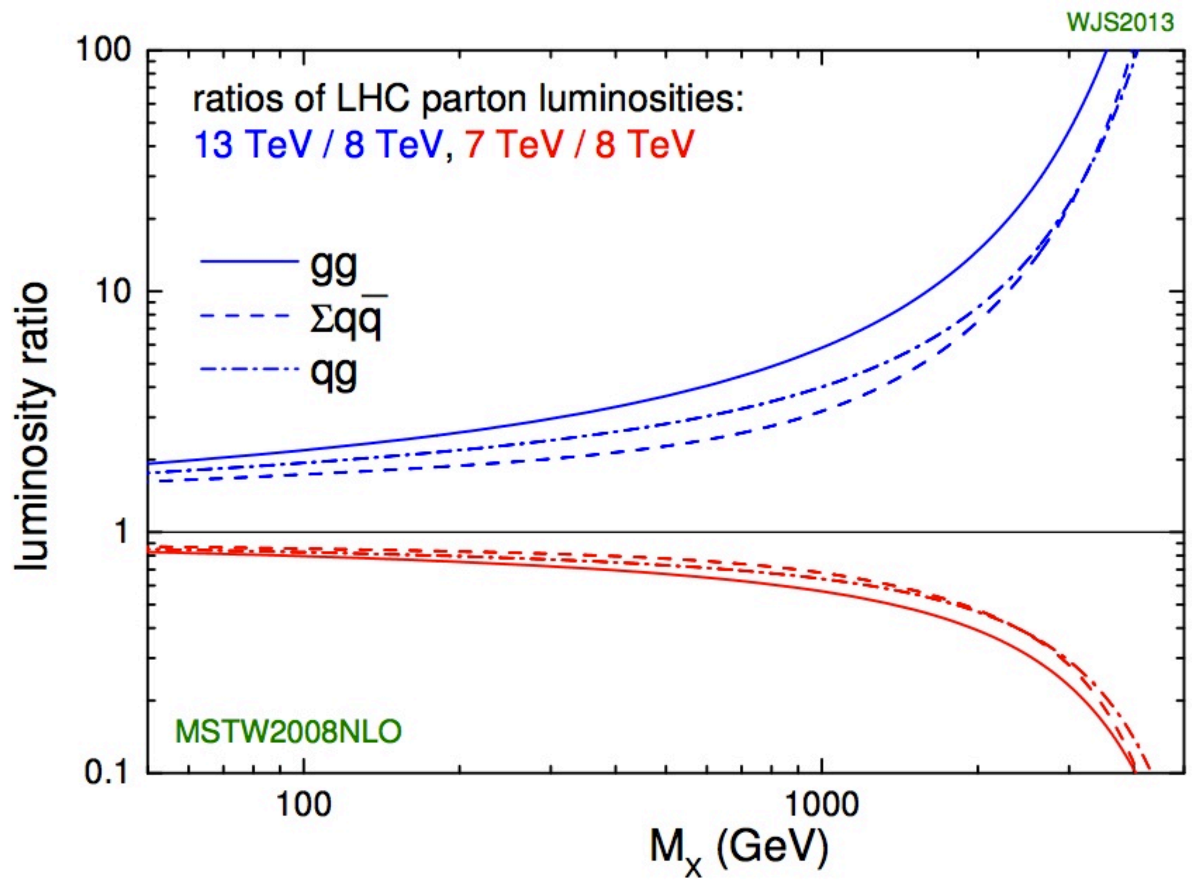
Conclusion

- CMS and ATLAS have provided many V(+jets) results during Run I
  - V+light: test predictions from theory and refine knowledge of (p)QCD and EWK higher order corrections. The understanding of the data/MC discrepancies is partial so far.
  - V+HF:
    - Run I confirmed known effects (W+b), and even seem to enforce them (Z+bb)
    - Need a coherent understanding of these processes, the direct and indirect impact on search is potentially large.
- Need to identify how the most up-to-date/recent prediction do work at 13 TeV: which solution for which process, where it makes sense
  - Coordination between ATLAS and CMS?
- Data/MC comparison with Run II started.
  - Run II statistics + new HO prediction from theory
    - More sensitivity to understand impact of EWK corrections
    - access new corners of the phase, also using 2/3/..-D slicing: better understanding of particular kinematic configurations

Backup slides

V+jets at Run I and Run II: statistics

- Let's assume L=100/fb per experiment at 13 TeV
  - Xsec increase x lumi increase w.r.t. 8 TeV ($pt_{jet,l}$>30 GeV, $|eta_{jet,l}|$<2.5)
    - ⇒ >~8 x more statistics available at the end of the Run 2 for W and Z+jets (more for gq and gg initial states)



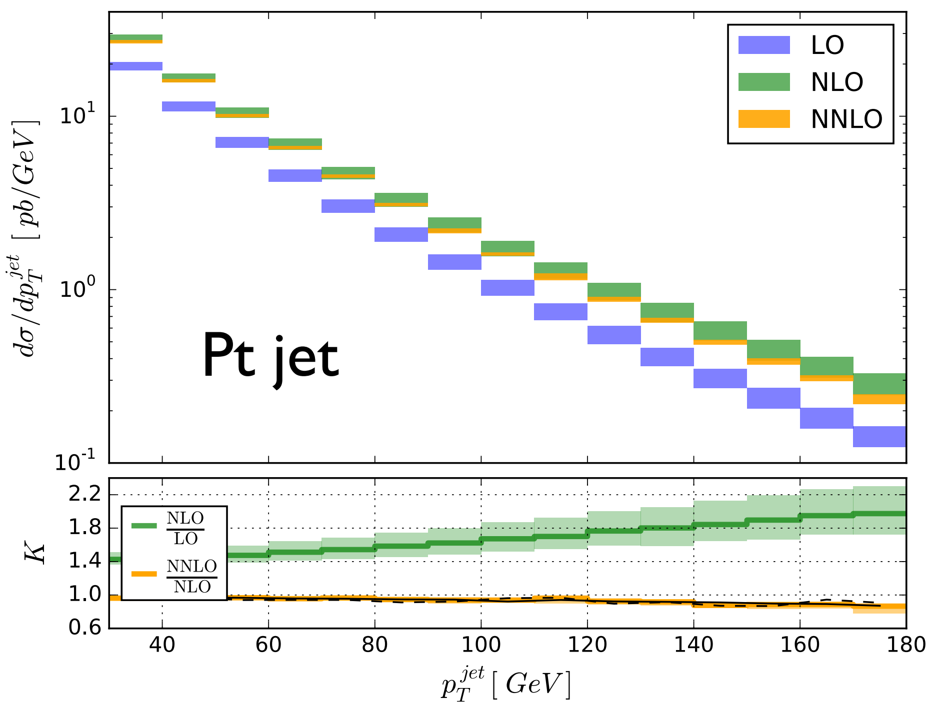
- Stattistical uncertainty reduction allows to
  - probe higher scales (Pt, Ht,...)
  - slice the phase-space (2/3/..-D measurements)

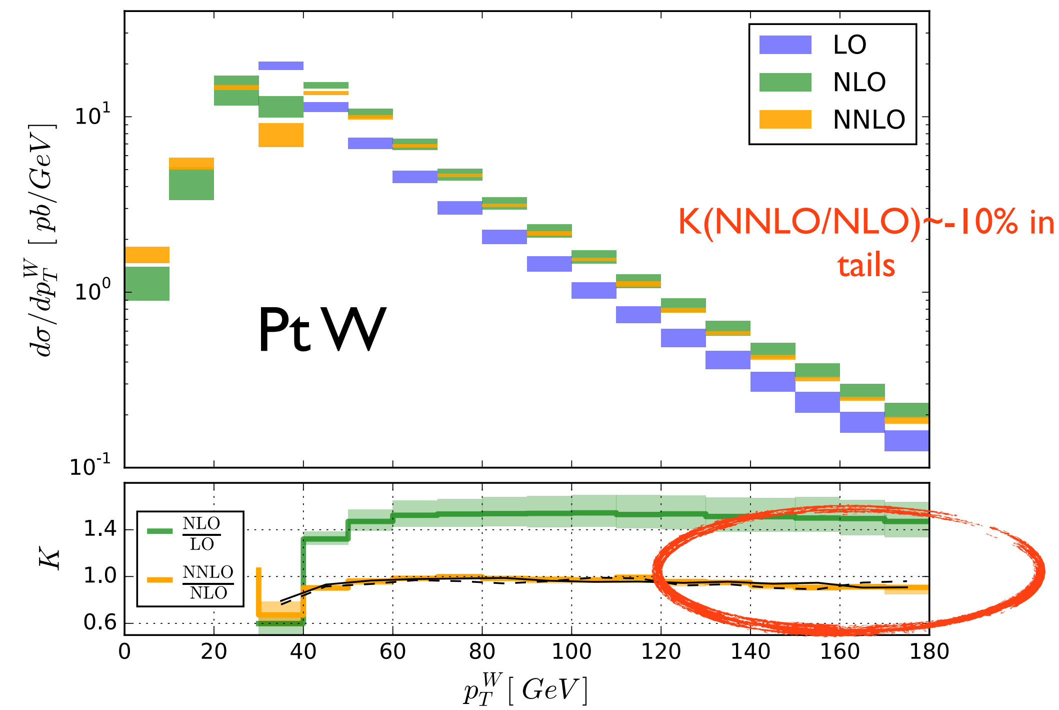
W and Z+1 jet @ NNLO: Data vs MC

Gehrmann-De Ridder et al., arXiv:1507.02850
Boughezal et al., arXiv:1512.01291
Boughezal et al., Phys. Rev. Lett. 115, 062002 (2015)

- Extraction of (g-)PDF, measurement of α_S

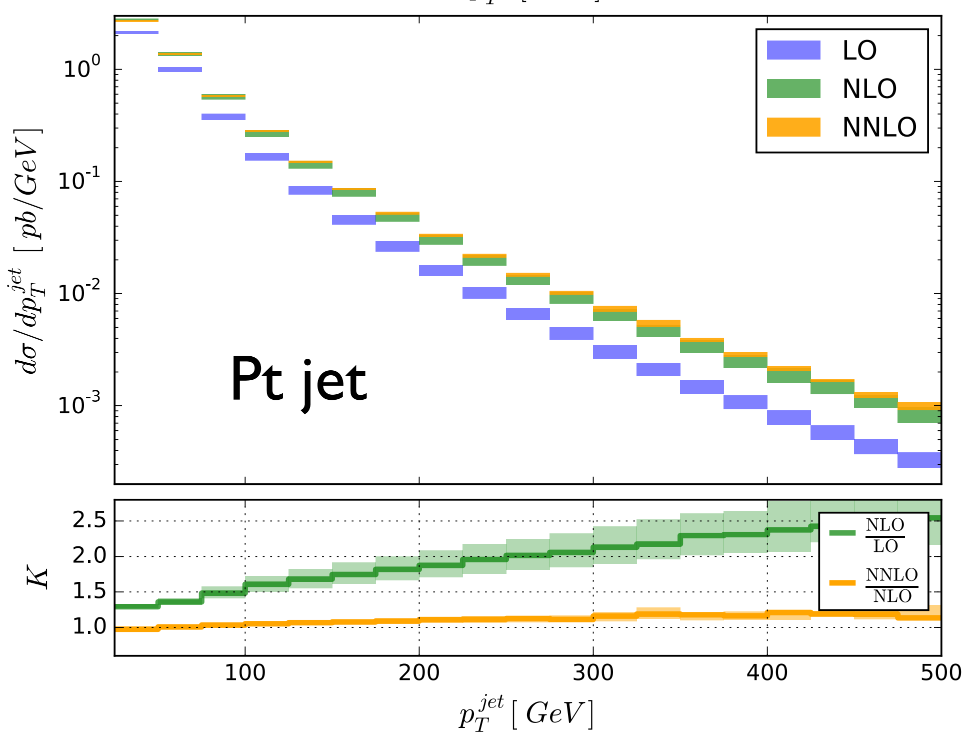
W+1 jet

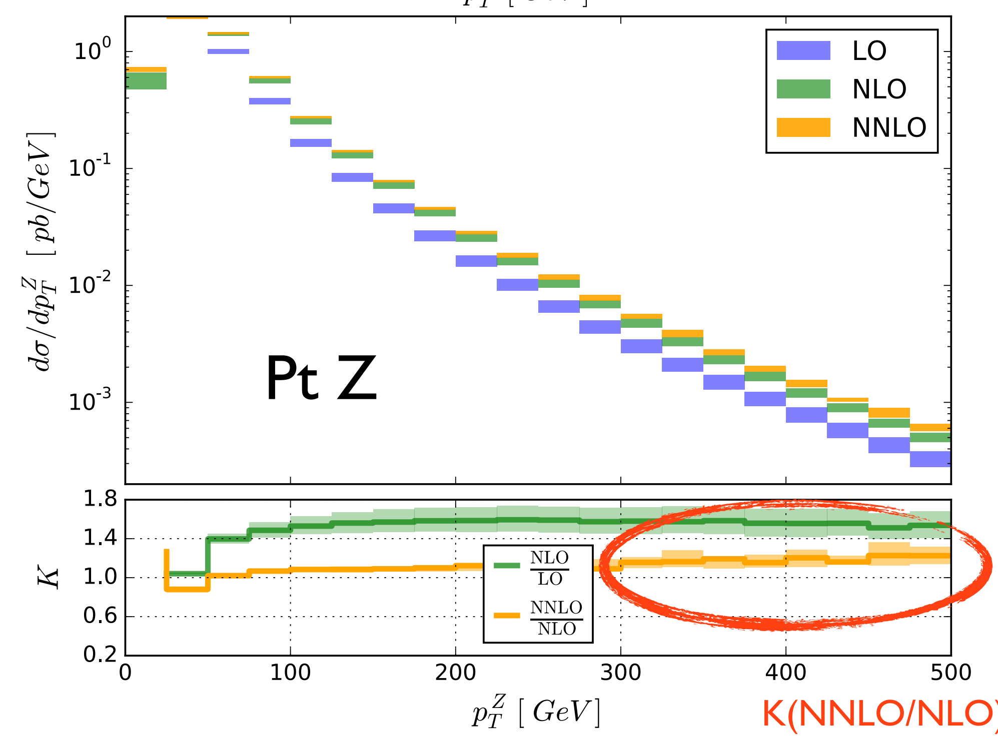




K(NNLO/NLO)~-10% in tails

Z+1 jet

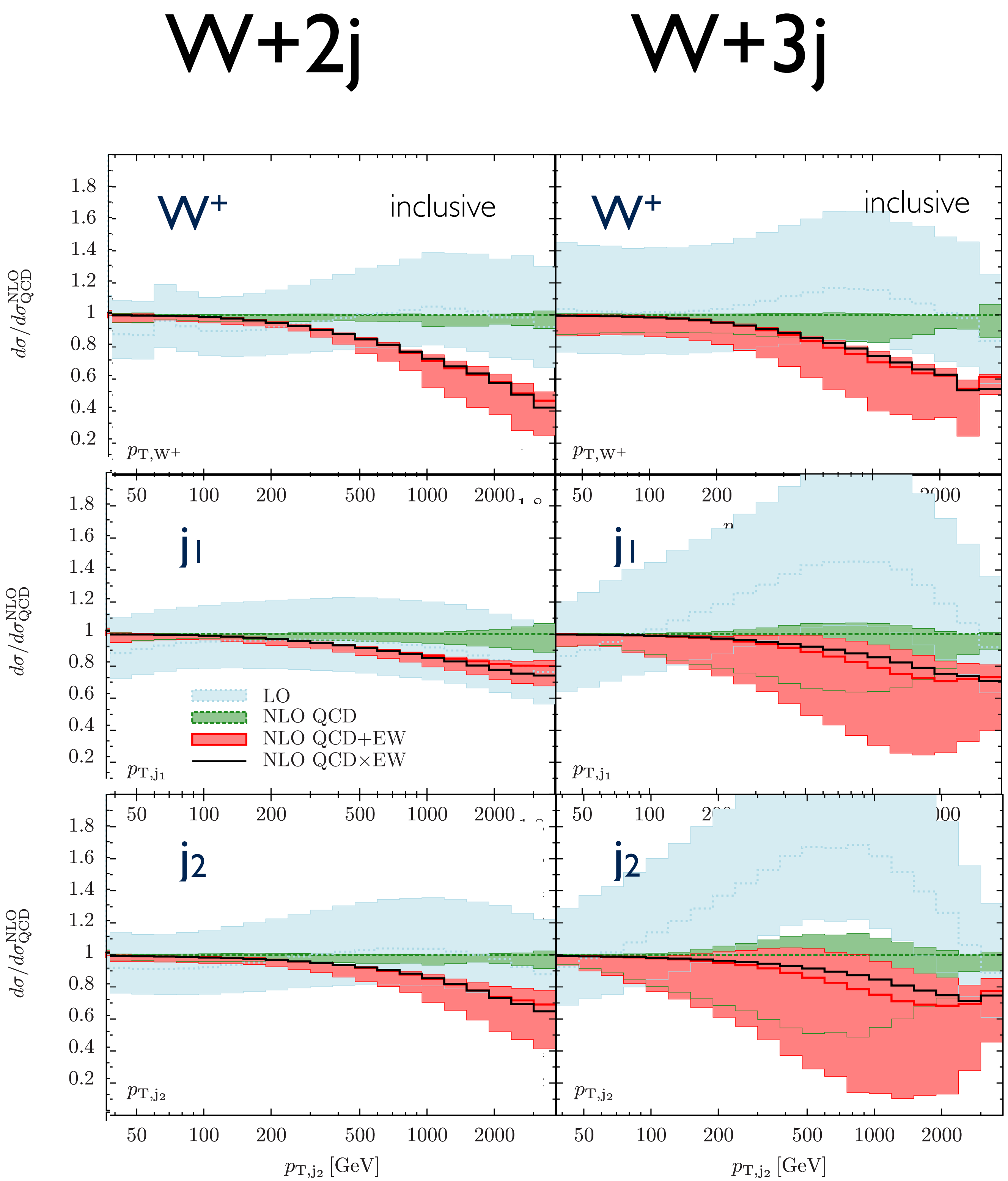




K(NNLO/NLO)~20% in tails

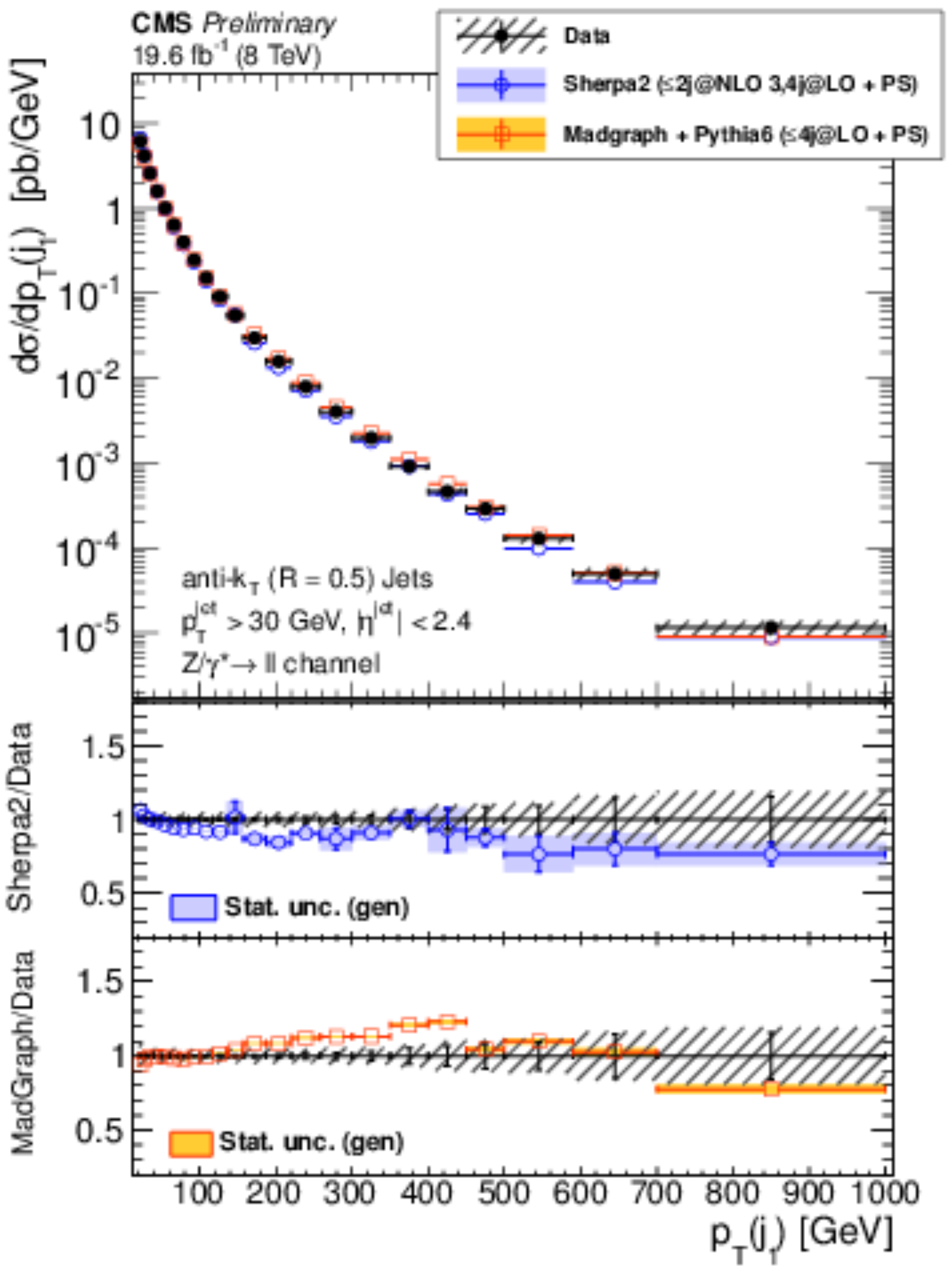
- NNLO uncertainty smaller than the experimental one
- Need to quantify the improvement with Data/MC comparison

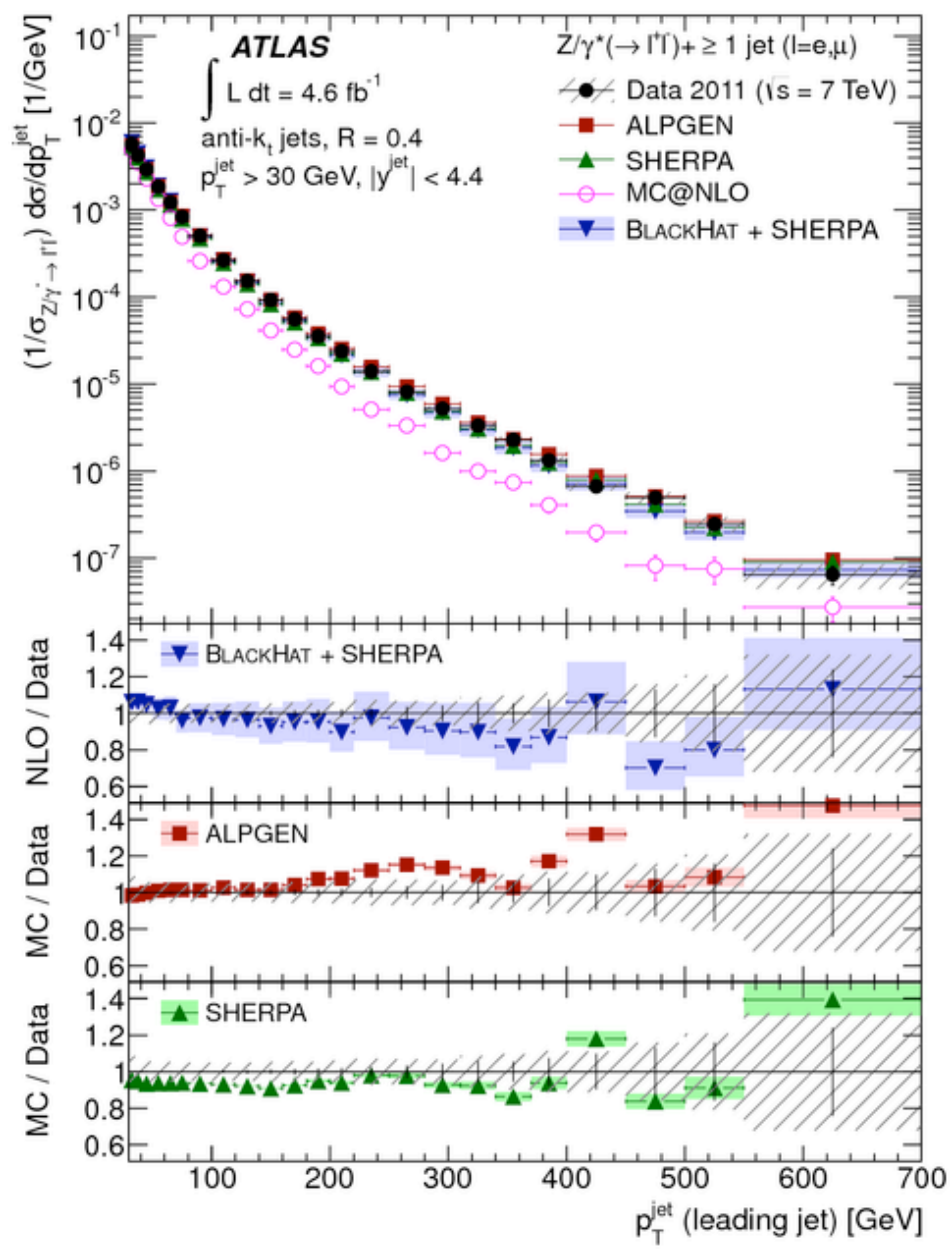
Kallweit et al., arXiv:1511.08692



- W/Z/γ et jet production at higher scale: larger effect of QCD and EW correction
  - W pt:
    - LO→NLO (**QCD**): ~1 (but very large uncertainties on the LO)
    - Adding **EW**:
      - -10% at ~600 GeV (8 TeV data)
      - -50% at 2 TeV
  - Jet pt:
    - LO→NLO (**QCD**): same as for W pt
    - Adding **EW**:
      - W+1j remains the best probe (smaller uncertainties)

V+jets main 'features': Z+jets

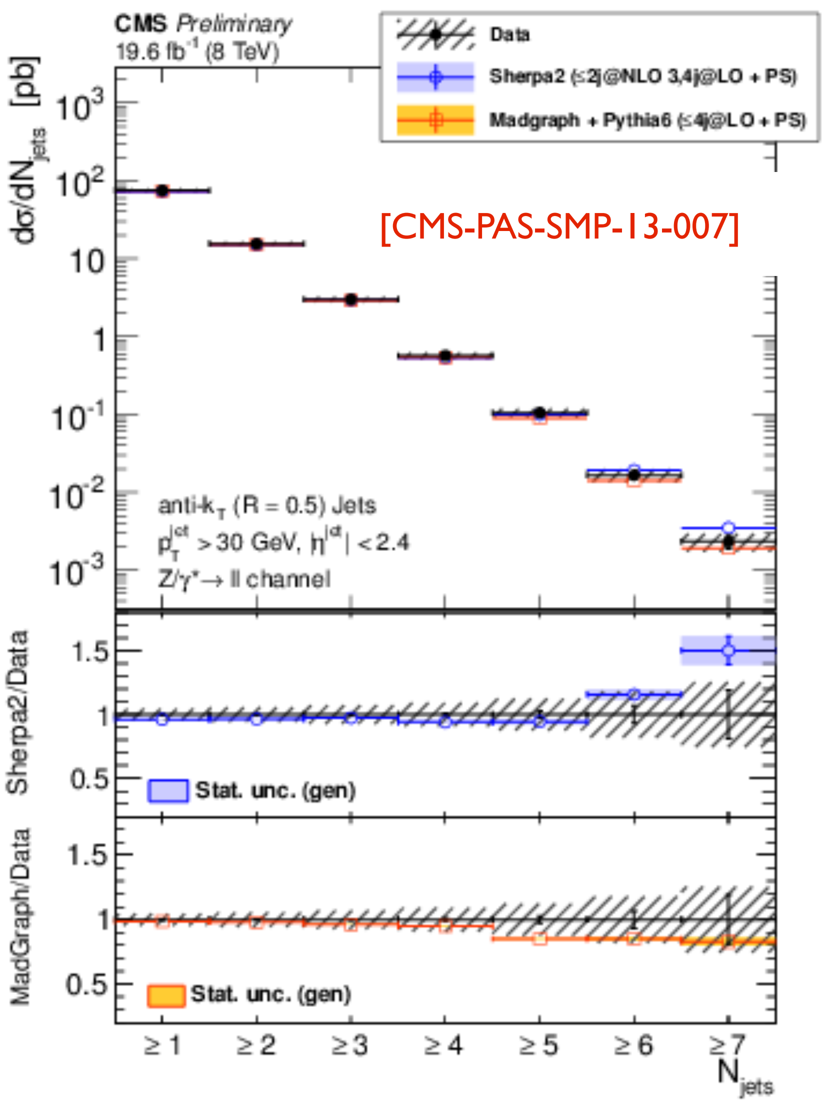




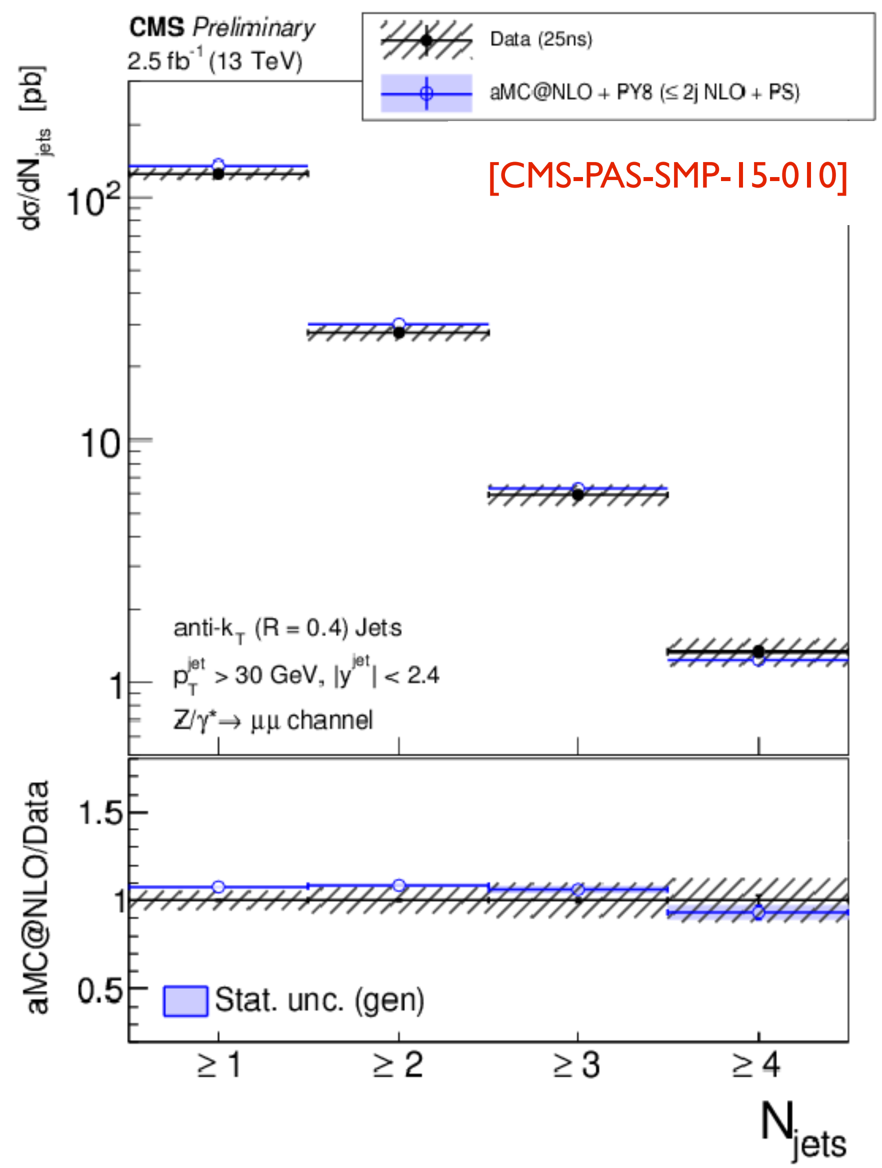
Leading jet pt: issue less pronounced for Z+jets than for W+jets

Z+jets

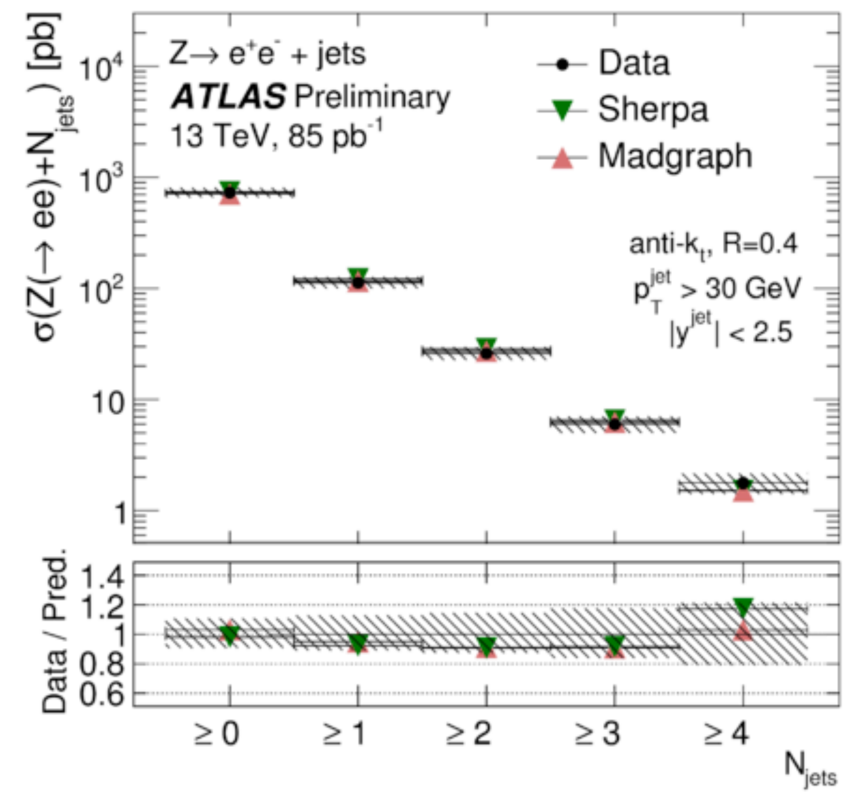
CMS@8 TeV



CMS@13 TeV



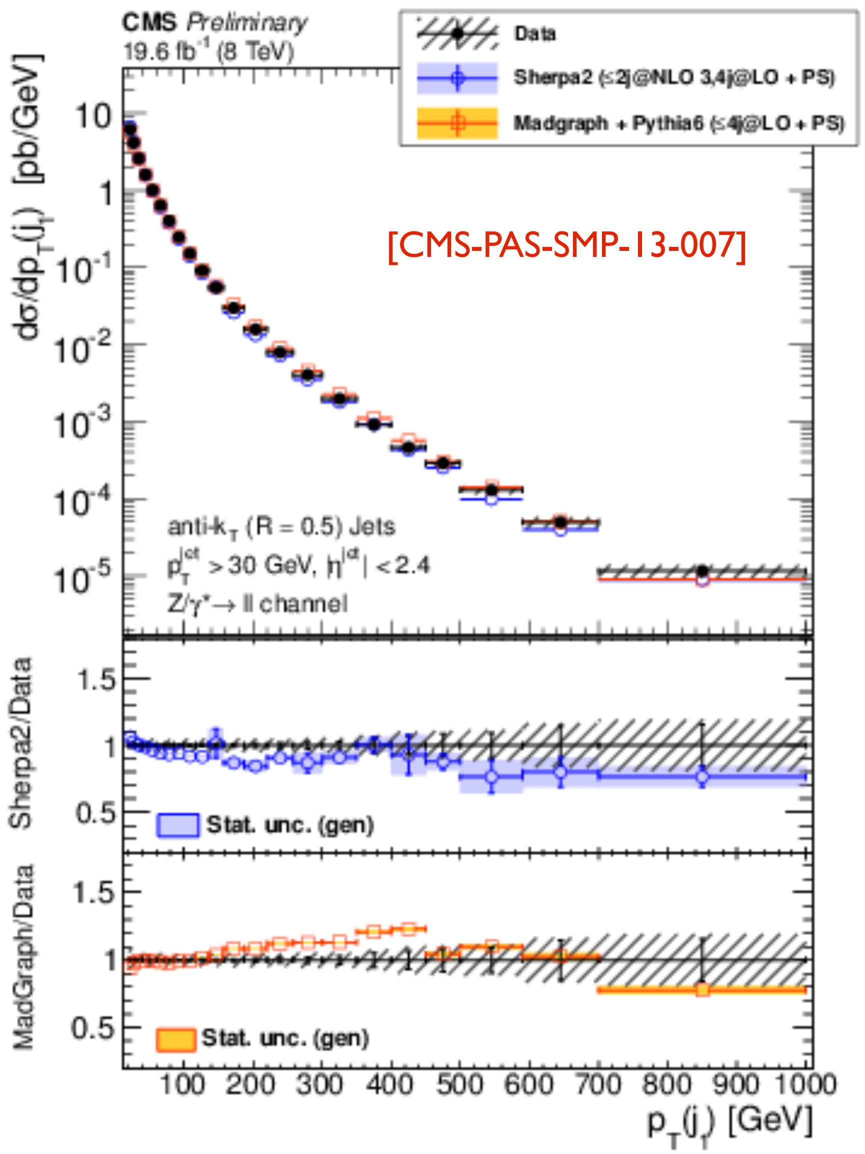
ATLAS@13 TeV



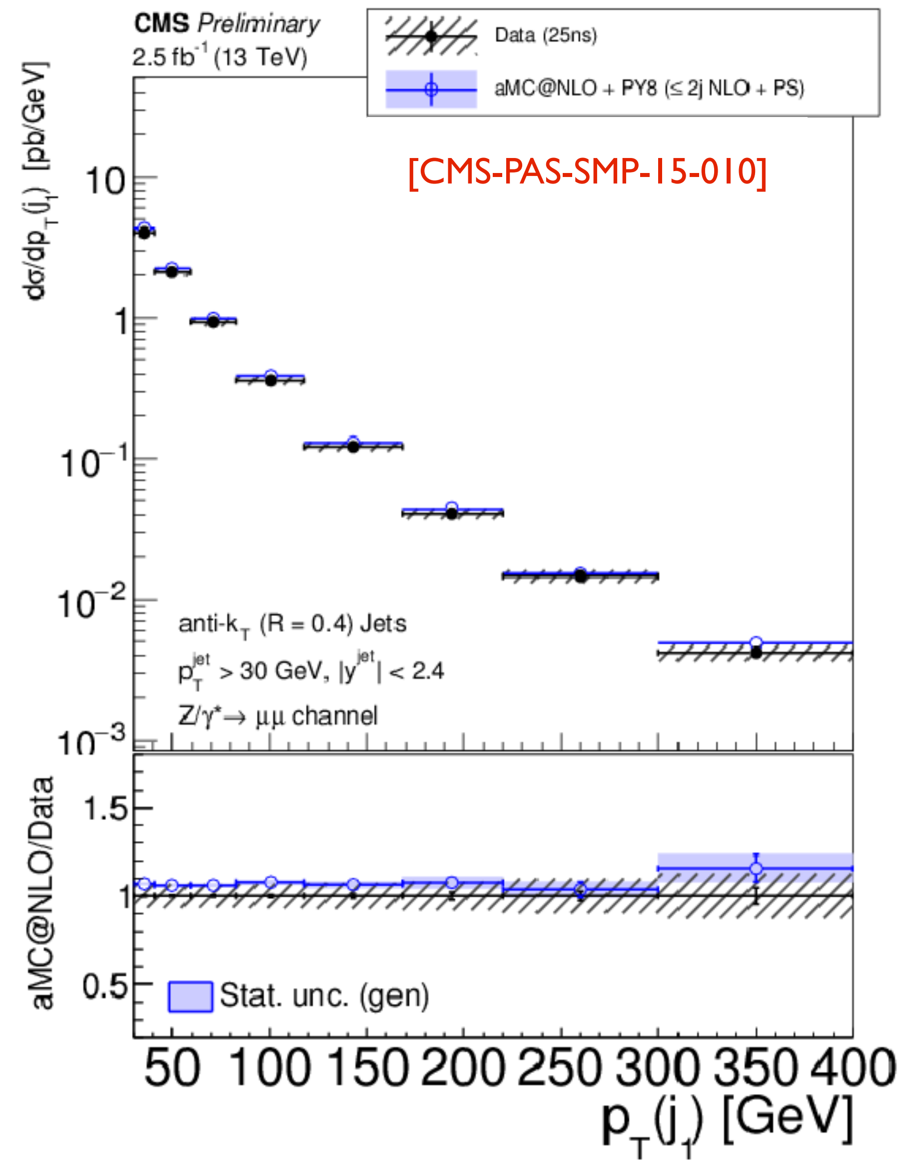
Different trends observed. Generally very reasonable agreement, even with tree-level predictions

Z+jets

CMS@8 TeV



CMS@13 TeV

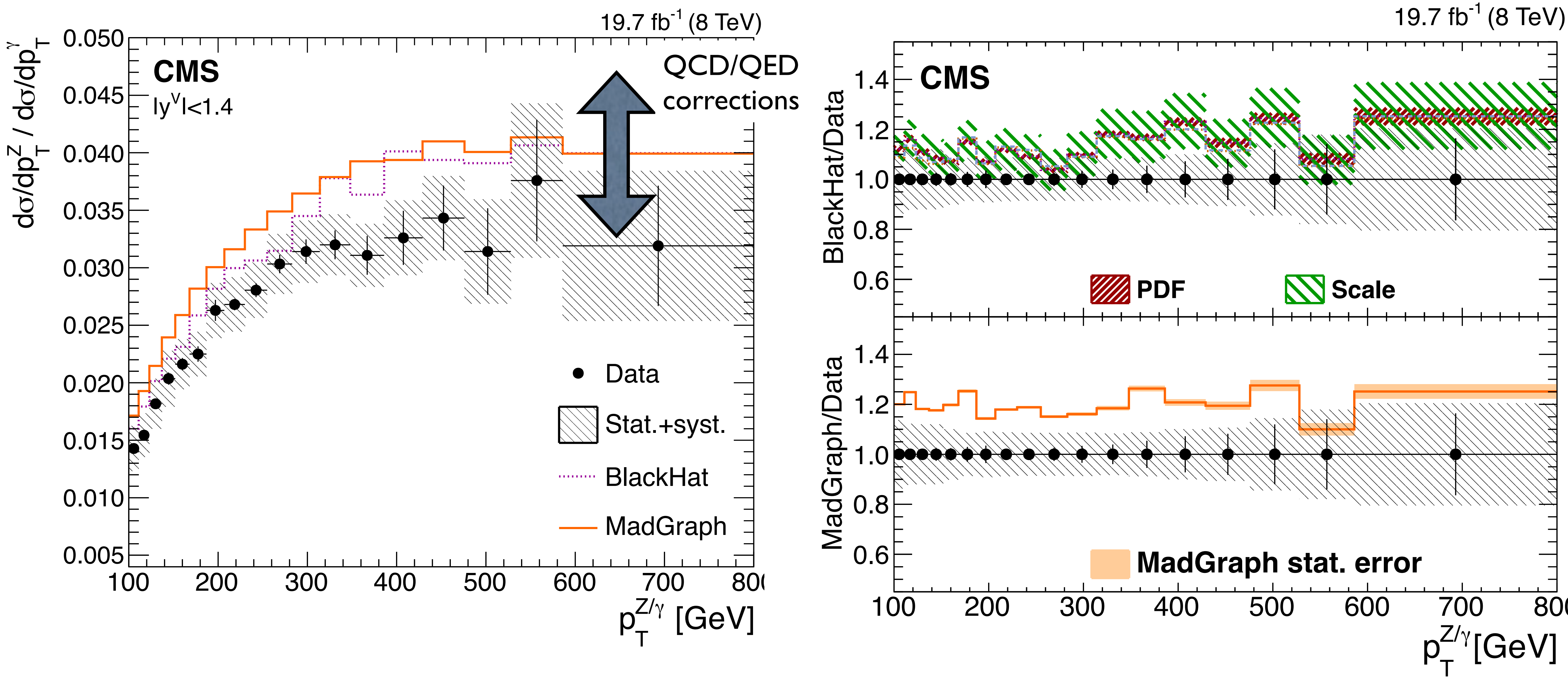


Different trends observed. Generally very reasonable agreement, even with tree-level predictions

V+jets ratio: Z+jets/γ+jets @ 8 TeV

1) Precision measurement (partial cancellation of systematics)
2) Data-driven prediction of Z+jets through γ+jets

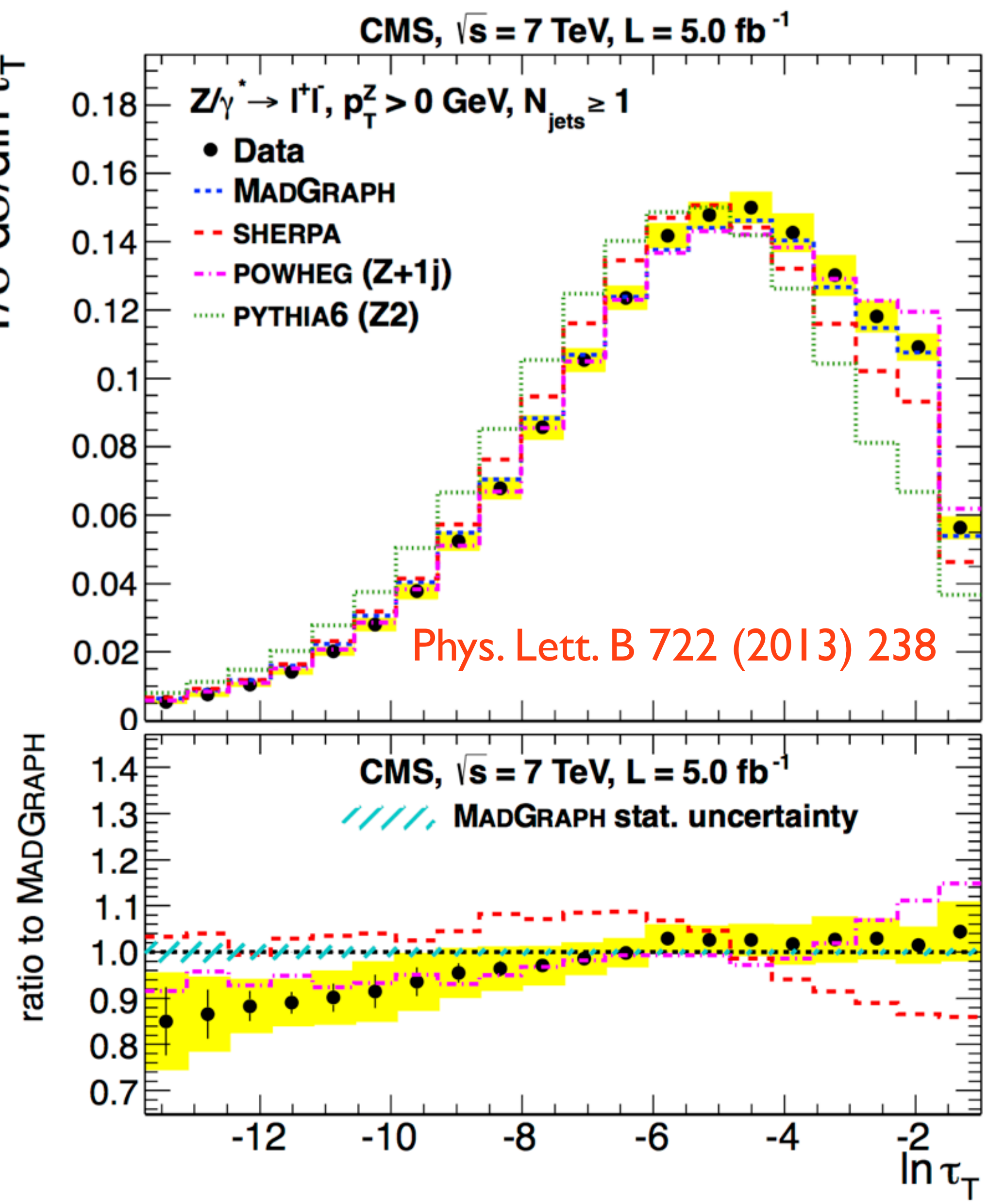
[arxiv.1505.06250]



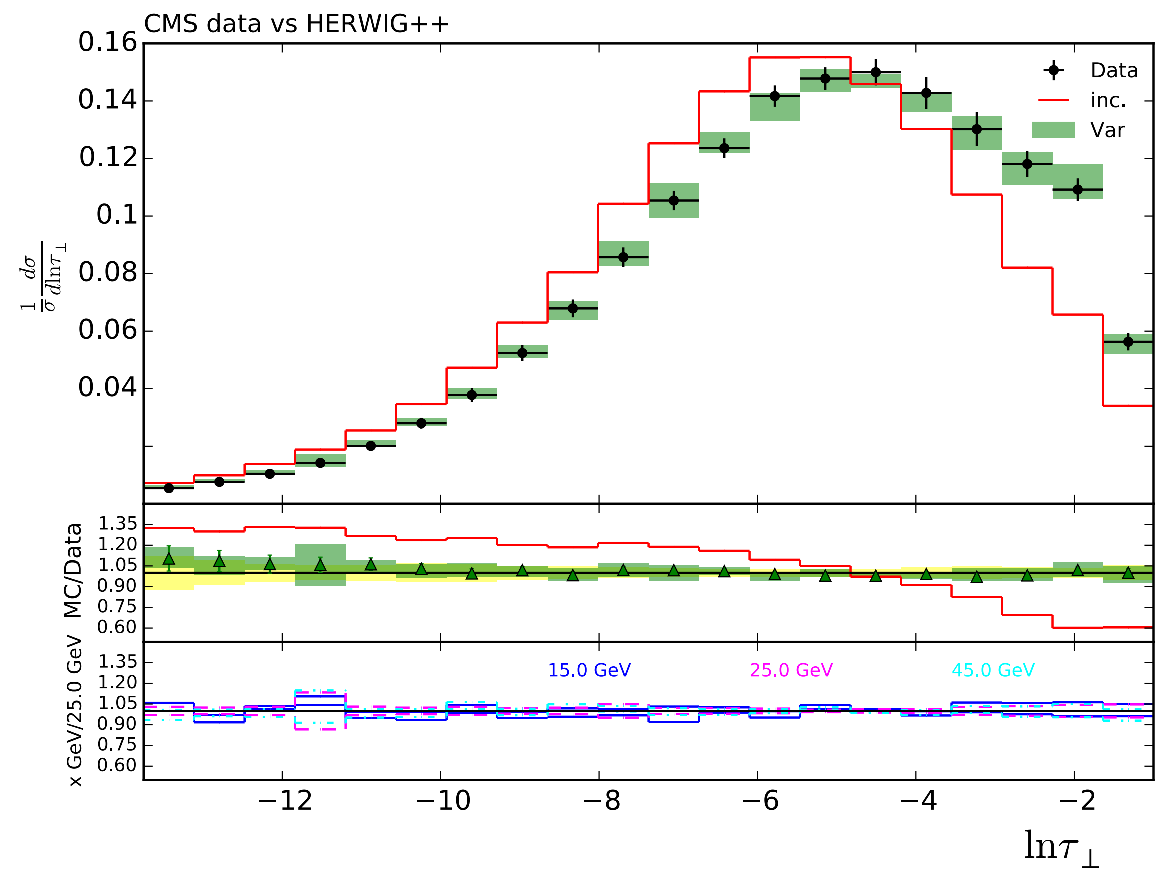
Data and MC agree within uncertainties.
tree-level and NLO behave similary

- Event shapes

$$\tau_{\mathrm{T}} \equiv 1 - \max_{\vec{n}_\tau} \frac{\sum_i |\vec{p}_{\mathrm{T},i} \cdot \vec{n}_\tau|}{\sum_i p_{\mathrm{T},i}},$$



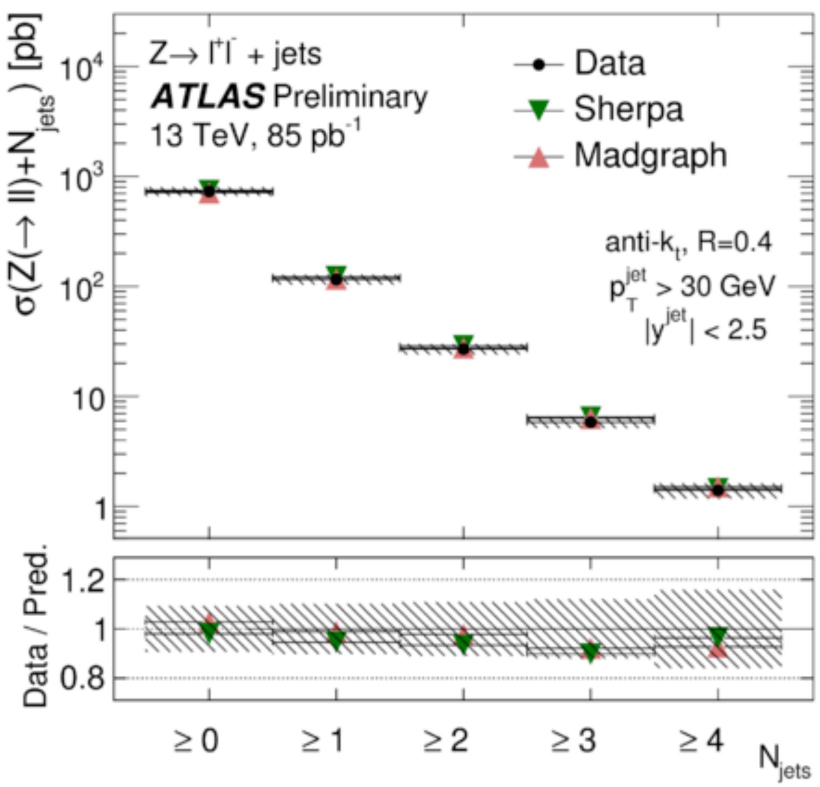
Pythia, MG and Sherpa deviate strongly, Powheg does a good job



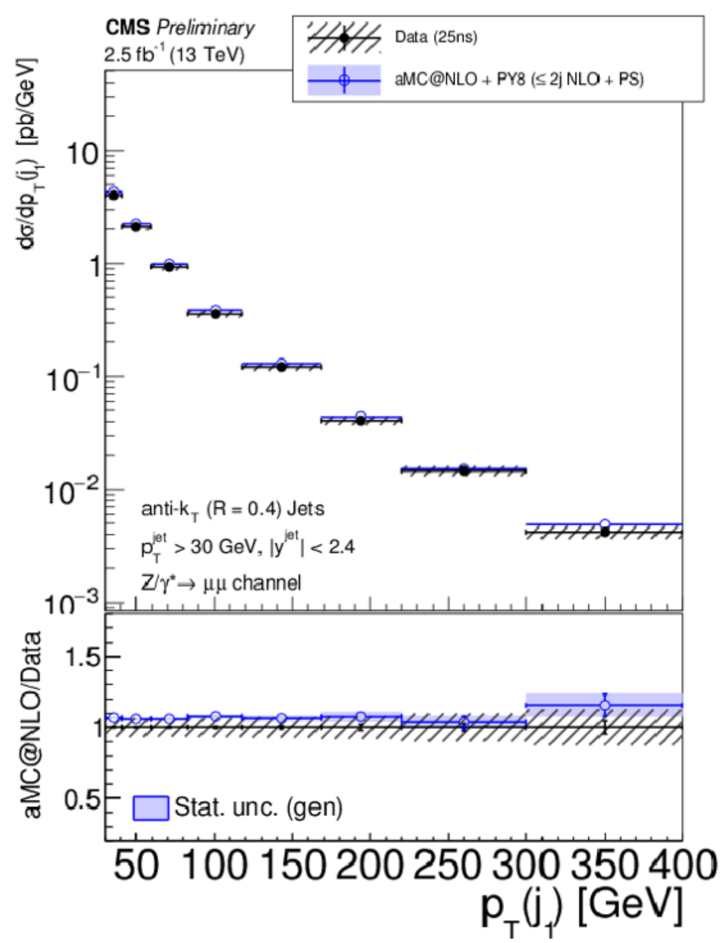
aMC@NLO +Pythia8 (FxFx): in agreement (same with Herwig)

Preliminary public V+jets results

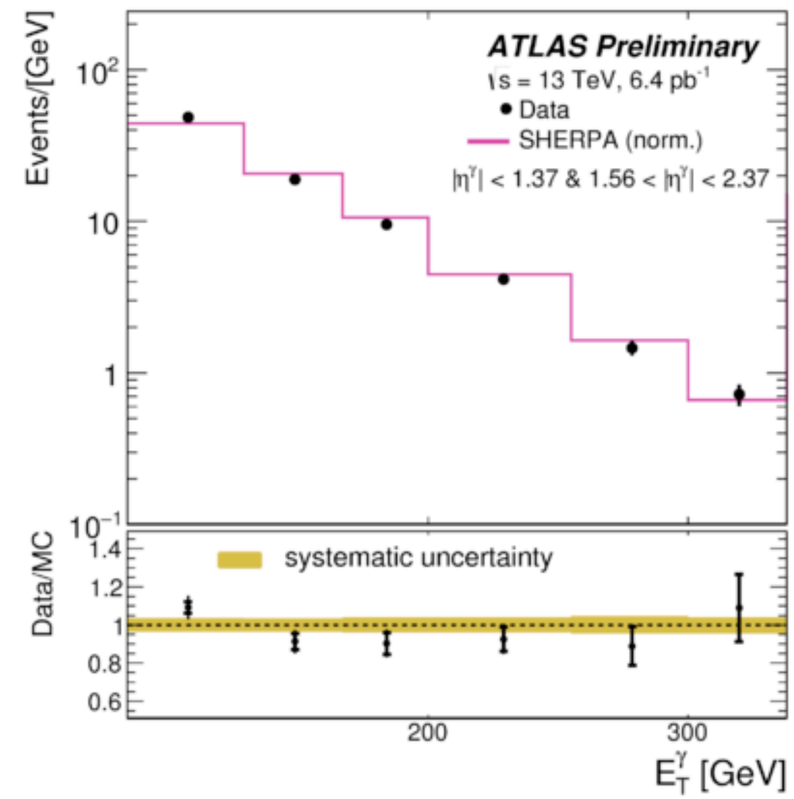
Z+jets (ATLAS)



Z+jets (CMS)



γ+jets (ATLAS)

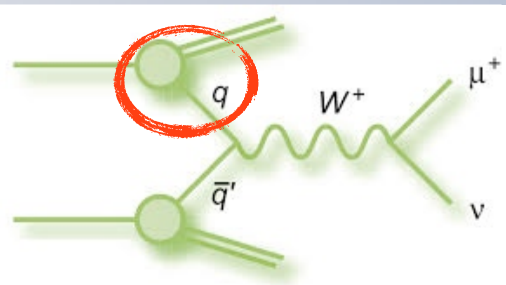


No superseeding of physics message from Run I yet, but new results will come fast

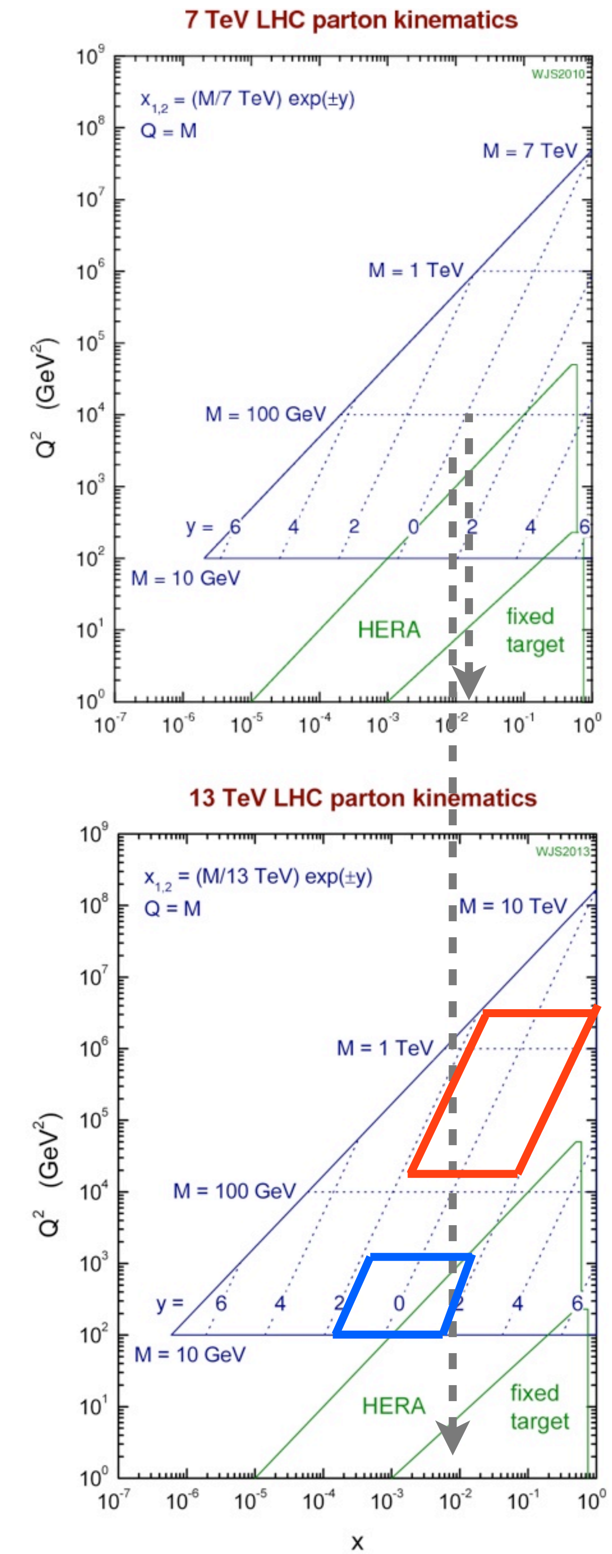
For Run II: other V+(light) jets points

- PDF from photon+jets
  - Current LHC only allow mild reduction of g-PDF uncertainty. A reduction of systematic uncertainties is the key.
    - One promising solution: use ratio between 13 and 8 TeV photon spectra for a partial cancellation of uncertainties (both experimental and theoretical)
    - Consider different photon isolation isolation?
- N-jetiness: test of jet resummation
  - Experimentally: problematic of using vetos on soft radiation in searches (lower background, etc...)
  - Measure 0-, 1-, 2-jetiness first using jets, then using charged particles
- W+c: extract strange PDF
  - Increase of statistics will allow more precise PDF fit: shed light on s-PDF tension between CMS and ATLAS.

- Light q-PDF in low/high x



- Moving from 7/8 TeV to 13 TeV: access different x regions
- Exploit inclusive xsec (W, Z)
  - W Pt, Z Pt, W charge asymmetry,...
  - e.g. high DY mass or low DY mass ranges to target specific x ranges
    - high mass range:
      - Run II can make a big difference in stat.
      - Access to photon PDF
- Inclusive xsec ratio
  - less sensitivity to αs and PDF, but (partial) cancellation of exp. systematics and scale uncertainties.
    - Double ratio: using ratio of processes at 2 different energies?



ATLAS MC note: Z+jets

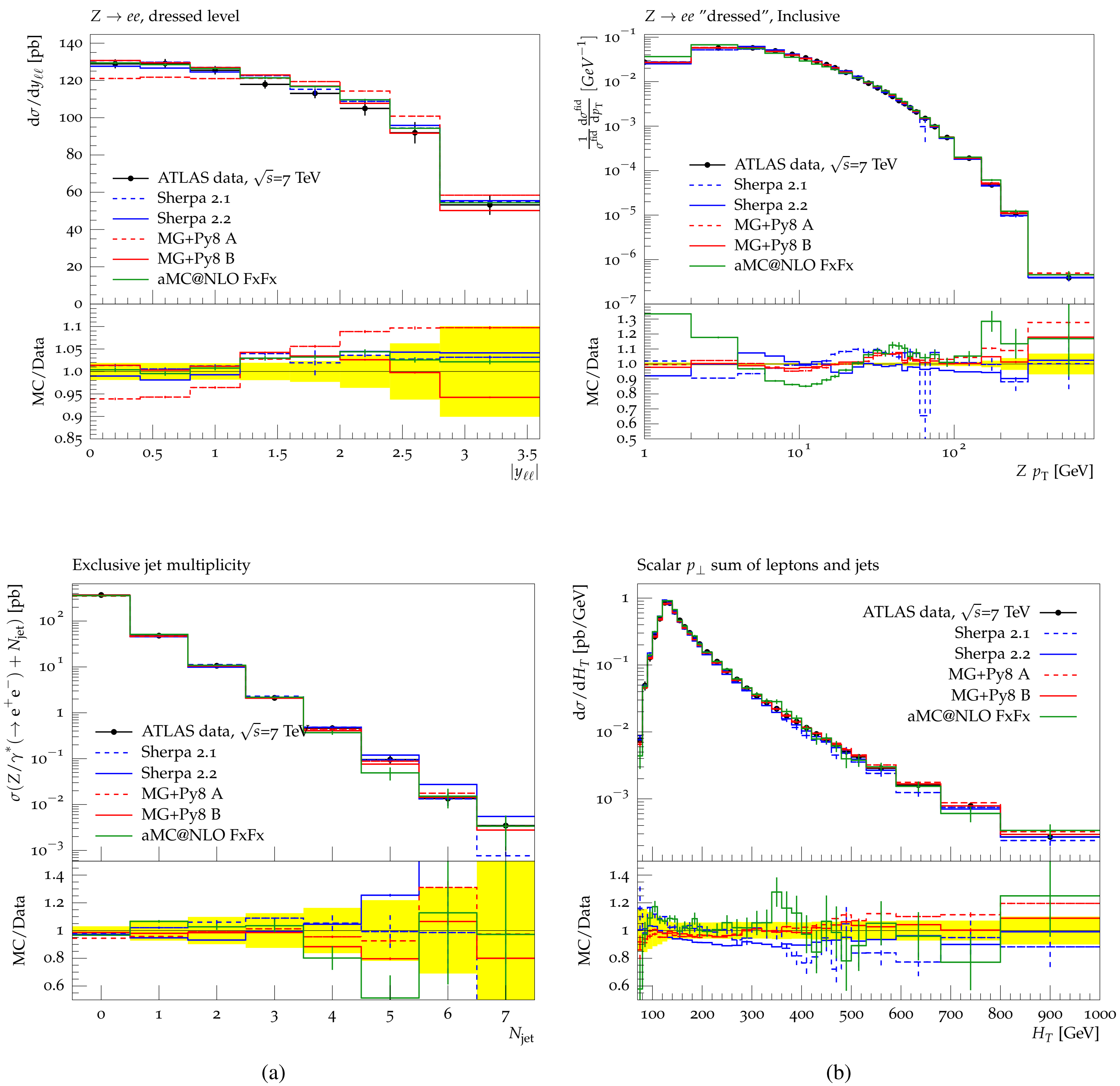


Figure 2: (a) Exclusive jet multiplicity and (b) H_T (the scalar sum of lepton and jet transverse momenta) in the 7 TeV Z+jets analysis. No k-factor is applied to the aMC@NLO sample.

ATLAS MC note: Z+jets

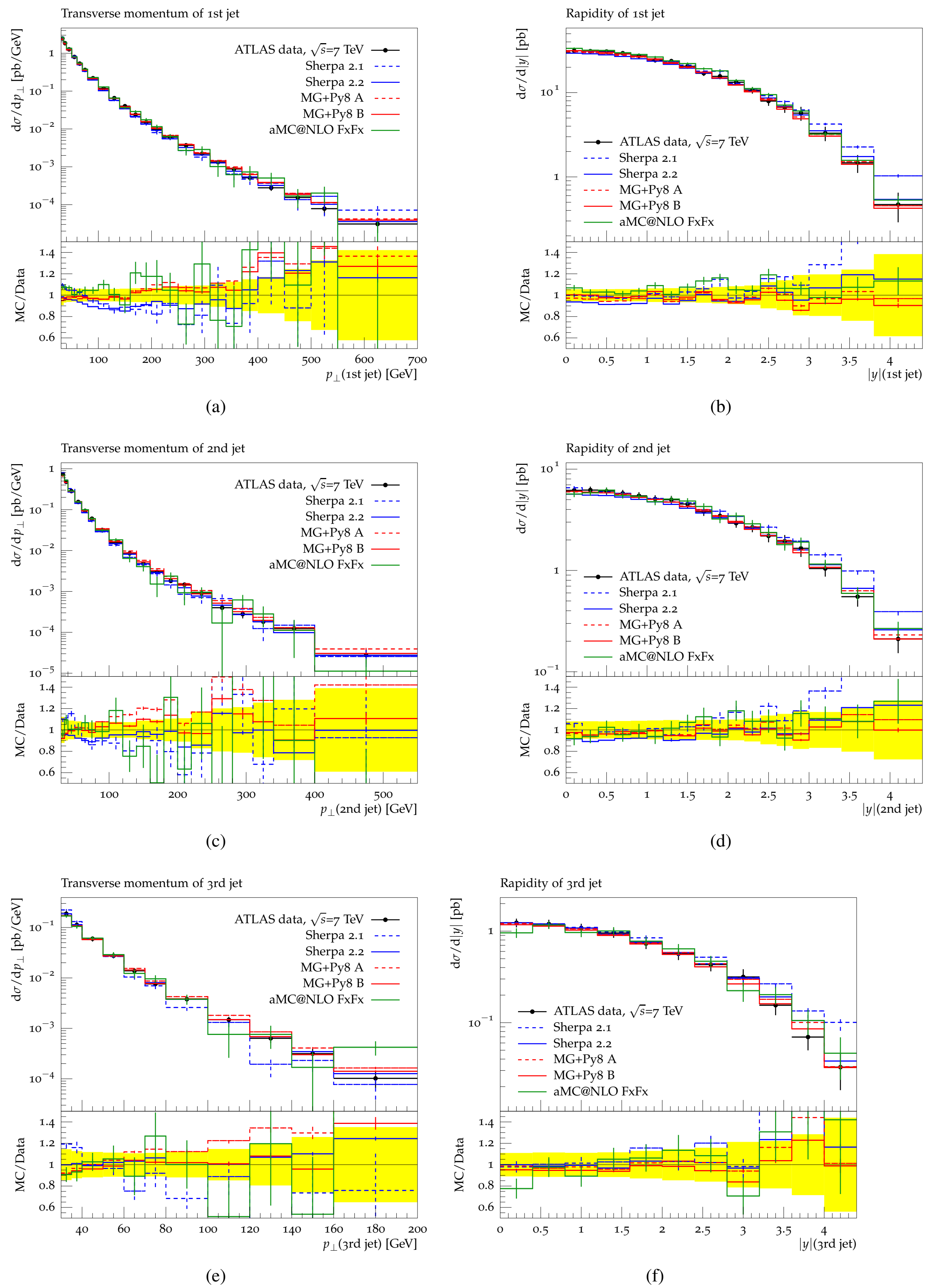


Figure 3: Transverse momentum and rapidity of the leading (a,b), second (c,d) and third (e,f) jets, in the 7 TeV Z+jets analysis. No k-factor is applied to the aMC@NLO sample.

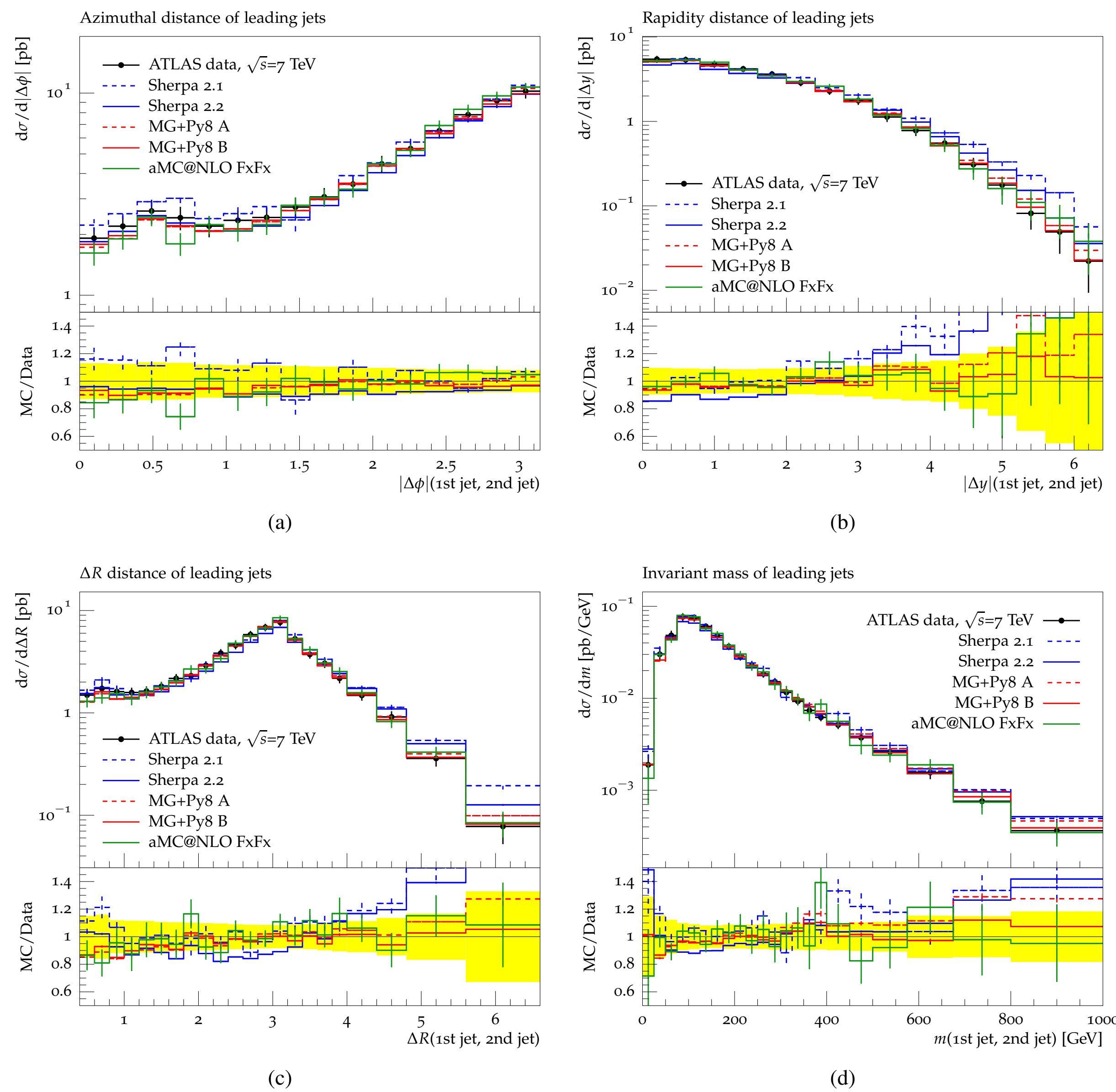


Figure 4: The (a) $\Delta\phi$, (b) Δy, (c) ΔR and (d) invariant mass of the leading and second jets in the 7 TeV Z+jets analysis. No k-factor is applied to the aMC@NLO sample.

ATLAS MC note: Z+jets

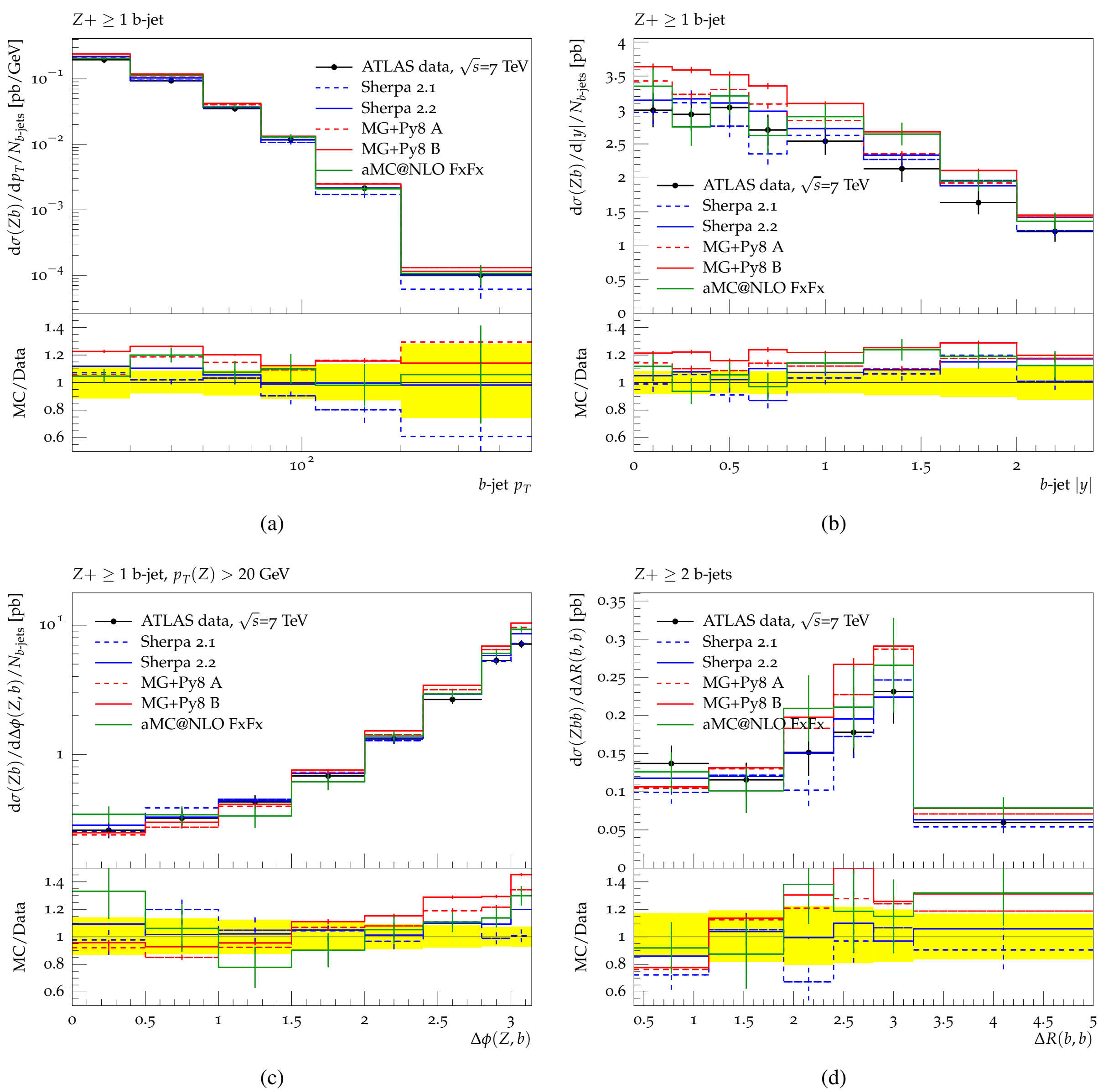


Figure 5: Transverse momentum (a) and rapidity (b) of *b*-jets in *Z* events, and (c) $\Delta\phi$ between the *Z* and *b*-jet for the *Z*+*b*-jets analysis at 7 TeV. For *Z* events with at least two *b*-jets, (d) ΔR between the two leading *b*-jets. No k-factor is applied to the aMC@NLO sample.

ATLAS MC note: W+jets

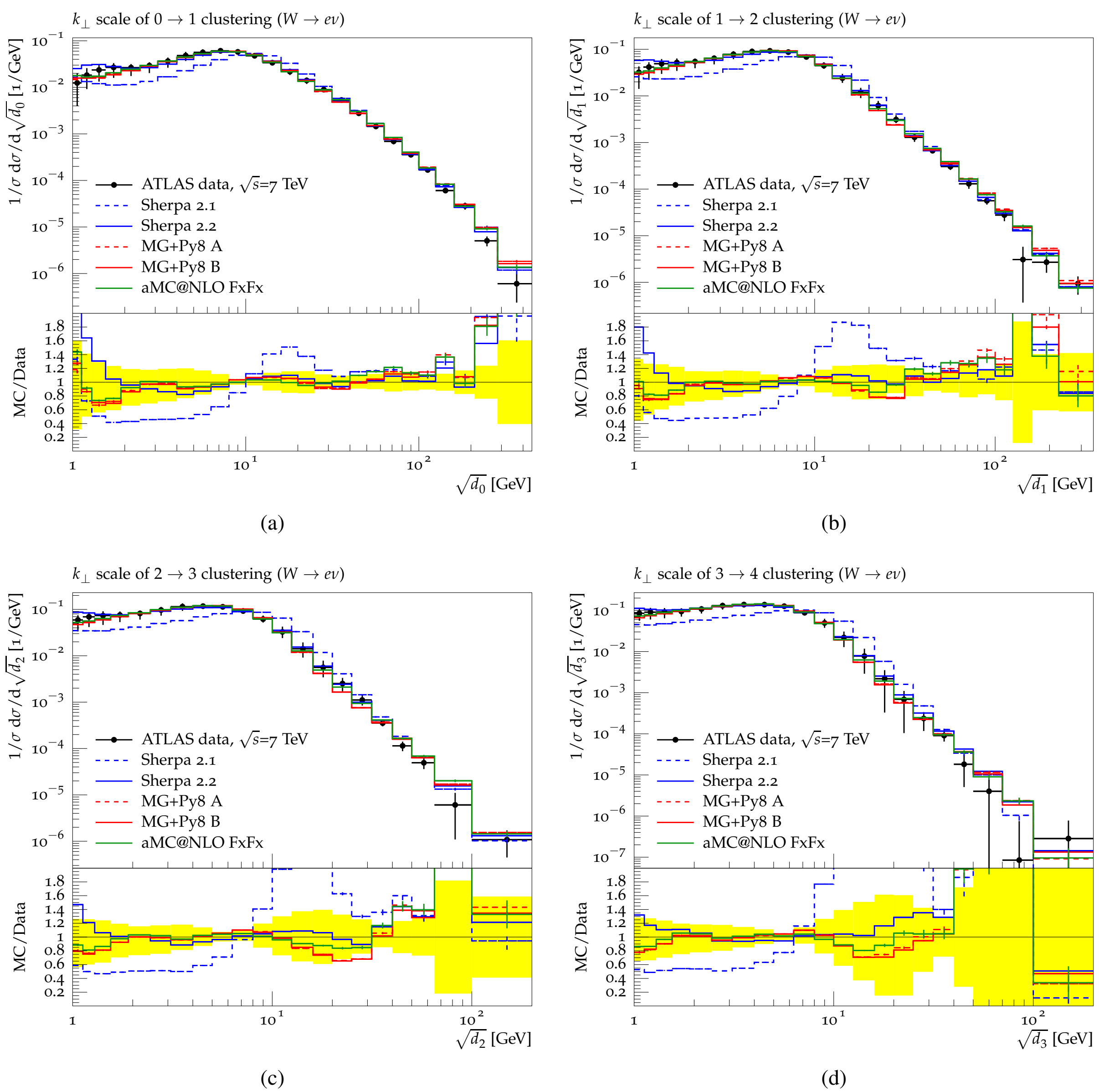


Figure 6: k_t scale of the (a) 0 → 1, (b) 1 → 2, (a) 2 → 3, and (a) 3 → 4 clusterings in the W+jets analysis at 7 TeV. No k-factor is applied to the aMC@NLO sample.

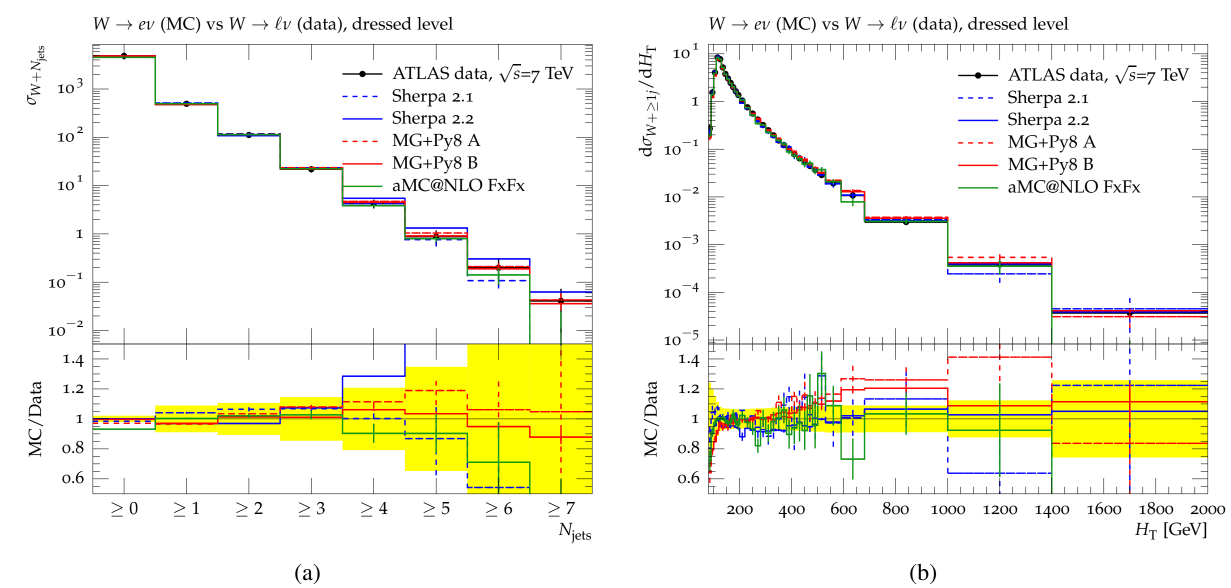


Figure 7: The (a) inclusive jet multiplicity and (b) H_T in the 7 TeV W+jets analysis. No k-factor is applied to the aMC@NLO sample.

ATLAS MC note: W+jets

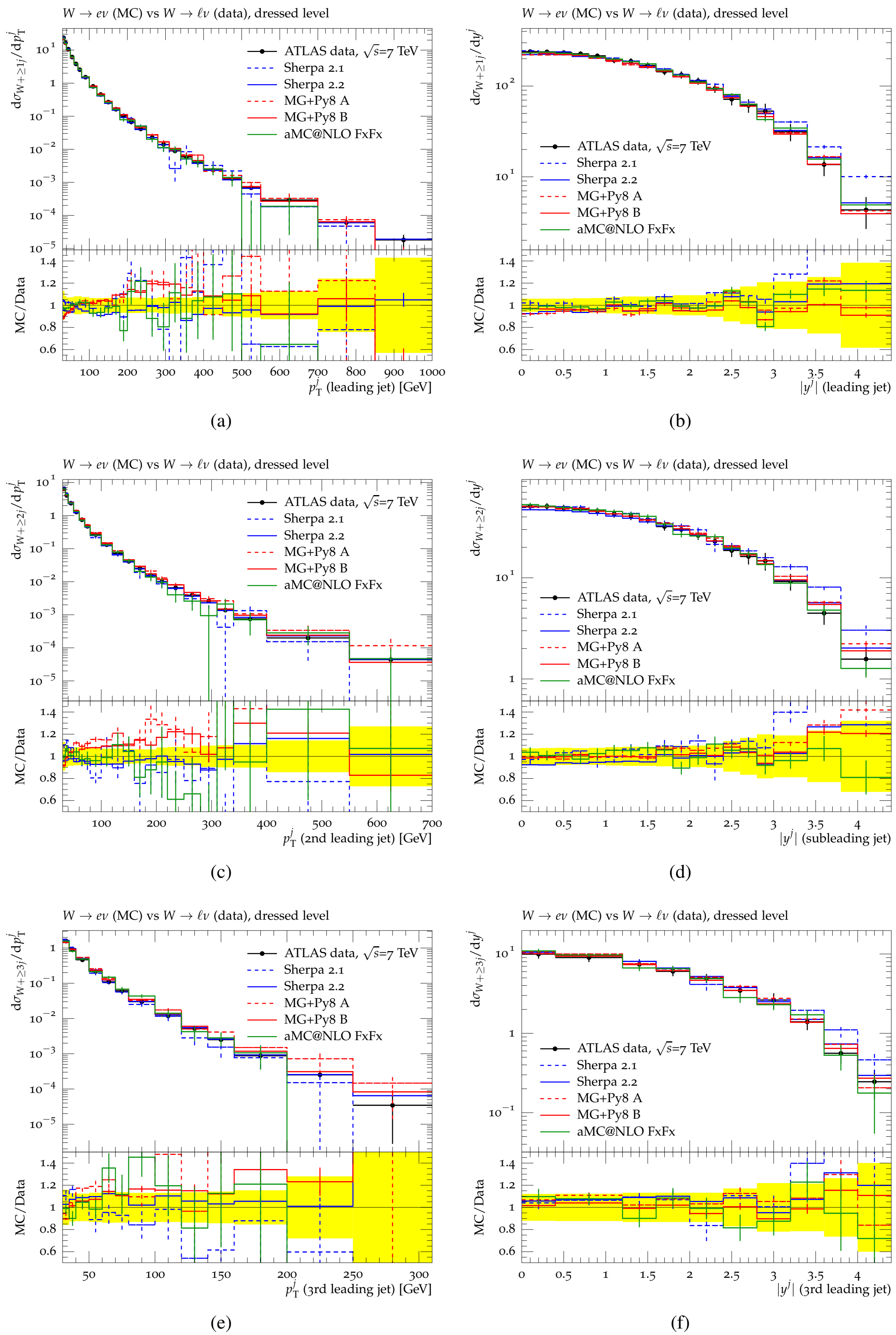


Figure 8: The p_T and rapidity of the (a,b) leading, (c, d) subleading (e,f) third jets in the 7 TeV W+jets analysis. No k-factor is applied to the aMC@NLO sample.

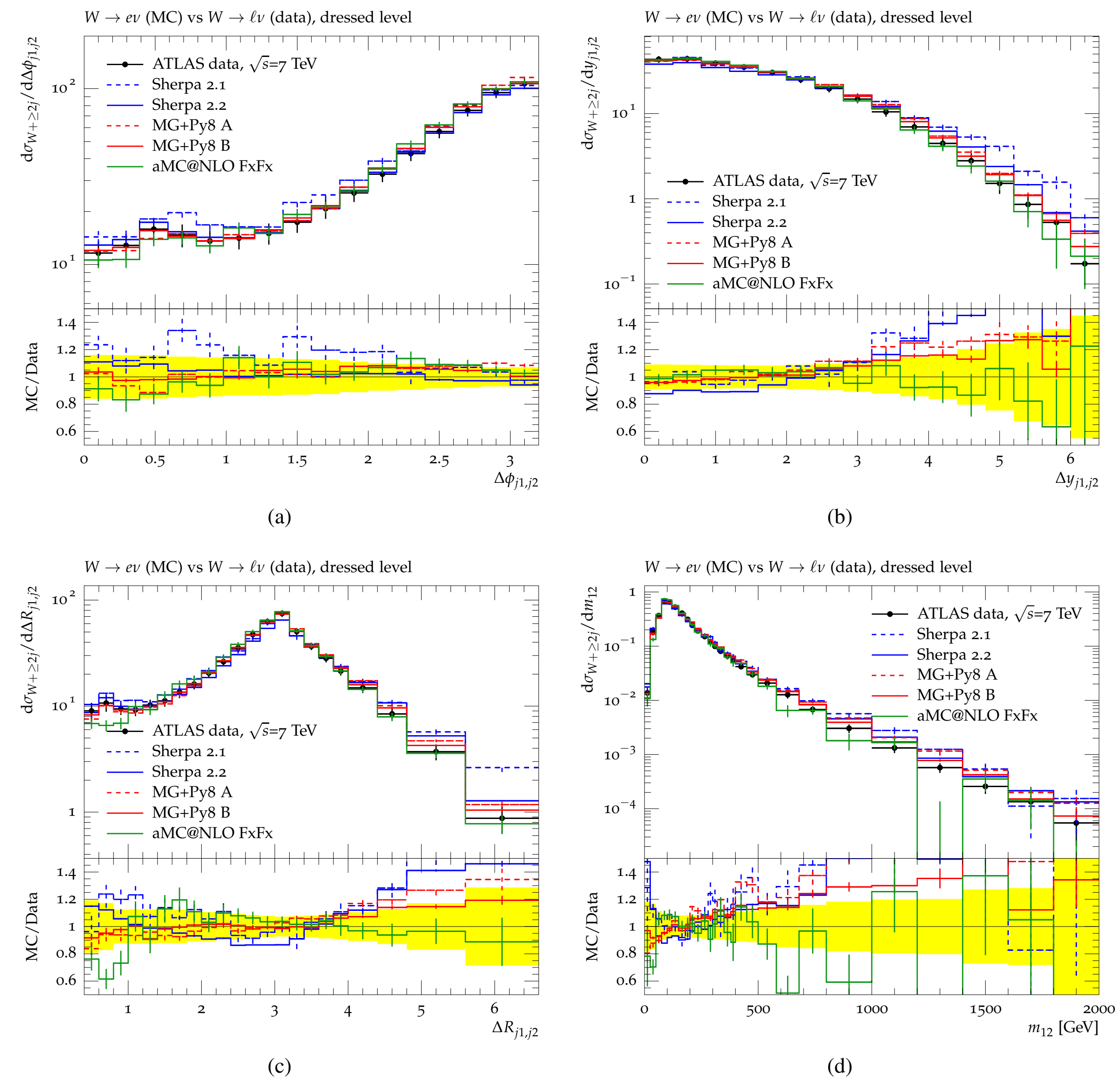


Figure 9: The (a) $\Delta\phi$, (b) Δy, (c) ΔR and (d) invariant mass of the leading and second jets in the 7 TeV W+jets analysis. No k-factor is applied to the aMC@NLO sample.

For Run II: Testing QCD and EW at NLO with Z+j and γ+jets

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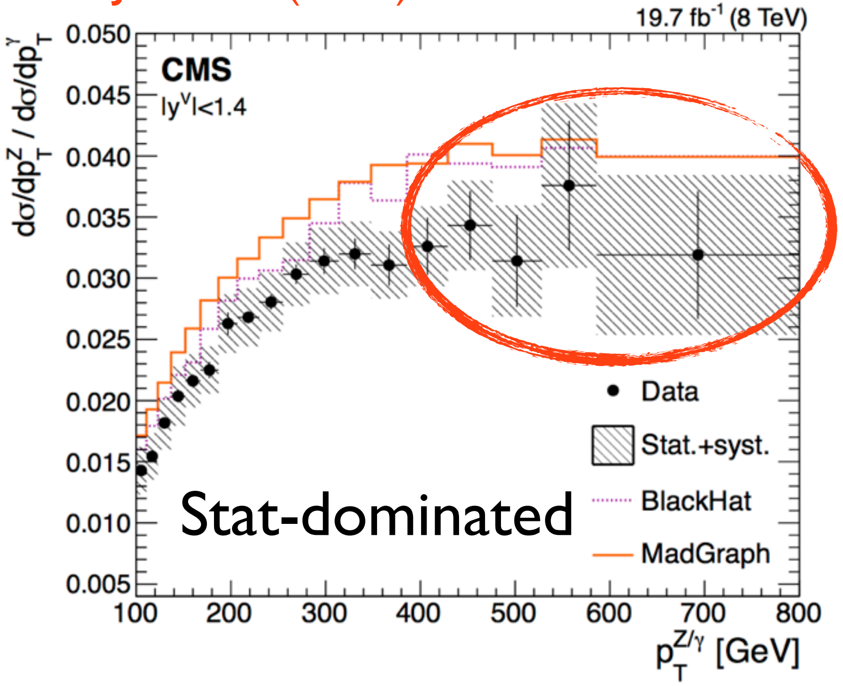
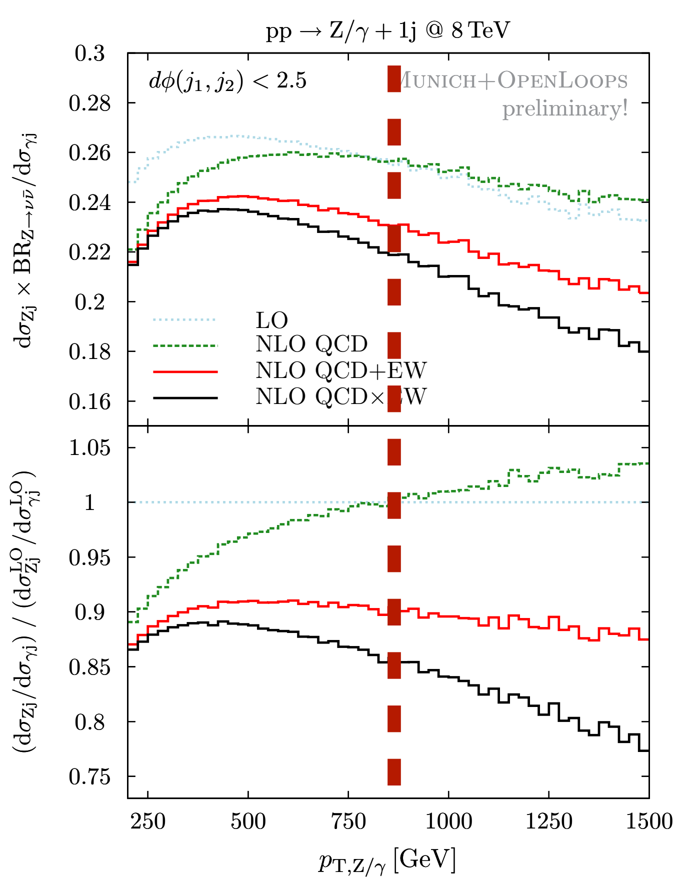


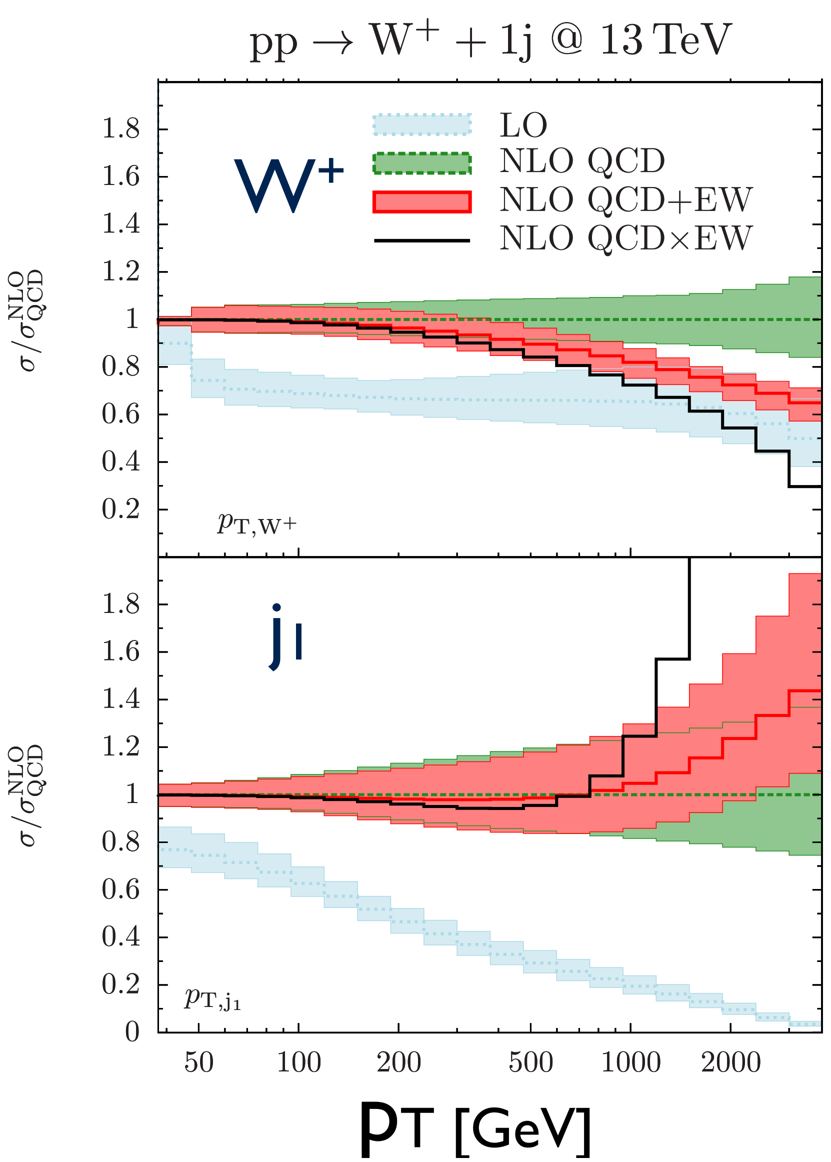


Kallweit et al., arXiv:1511.08692

- Z+j/γ+j ratio of pt spectra:
  - partial cancellation of uncertainties (jets,...), hence gets to more precision
  - Useful for SUSY search (control Z via γ)
- Run I: up to 800 GeV
  - LO→NLO (**QCD**): effect on ratio is very small
  - Adding **EWK**: effect on ratio:
    - -15% at 600 GeV (Run I), but large exp. uncertainty
    - -20% at 1.5 TeV
- At 13 TeV, expect sensitivity to **EWK** corrections at 500-600 GeV?
  - Below, exp. systematics might still dominate
- What effect for W/Z ratio (better exp. cancellation)?

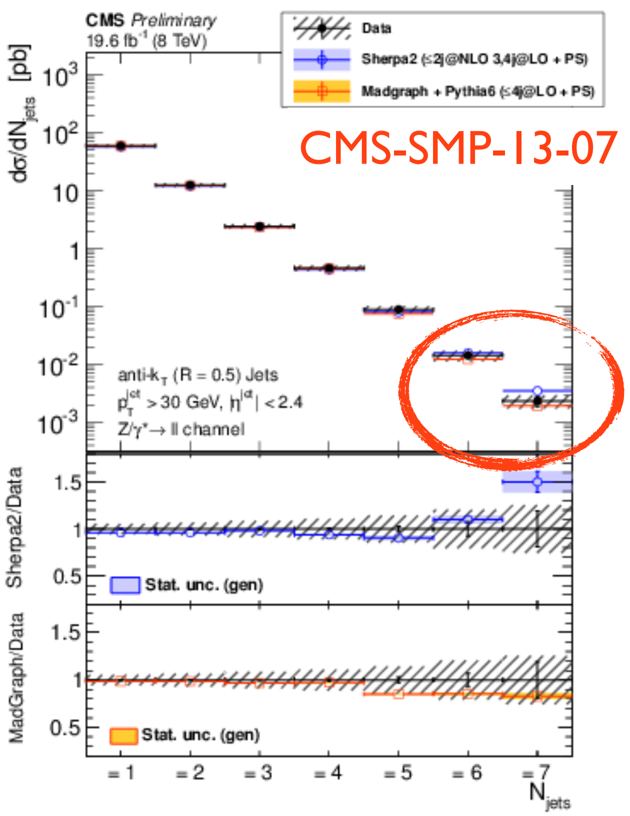
For Run II: Testing higher order corrections

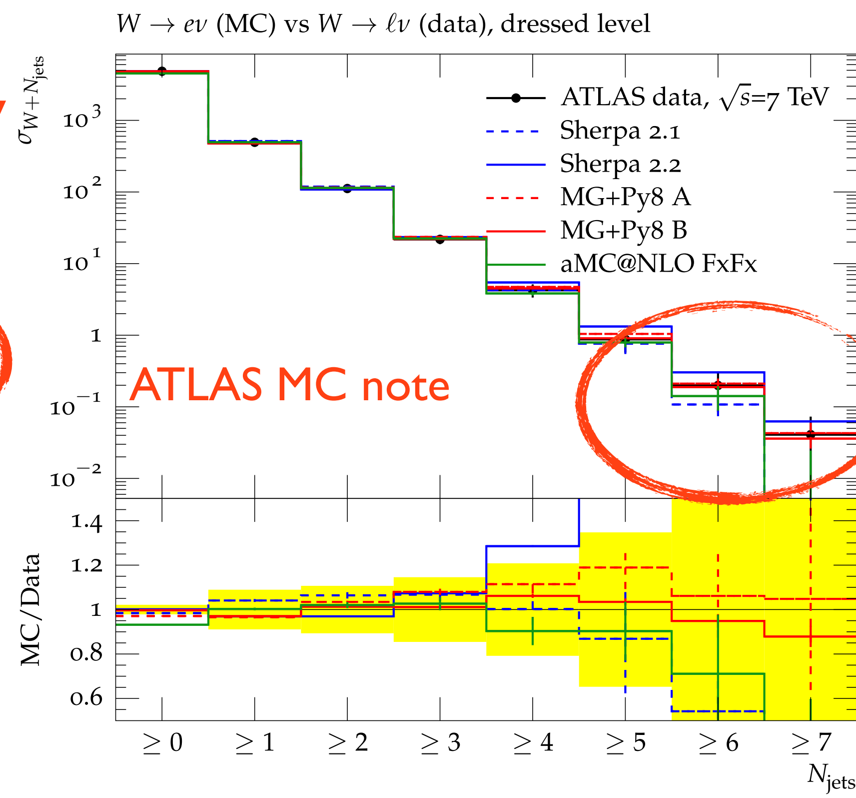
Kallweit et al., arXiv:1511.08692



- Test NLO QCD+EWK correction:
  - W Pt
    - LO→NLO (**QCD**): +100% above ~200 GeV
    - Adding **EW**:
      - -10% at ~600 GeV (8 TeV data)
      - -40% at 2 TeV
  - Jet pt:
    - LO→NLO (**QCD**): +1000% in tail
    - Adding **EW**:
      - probably no sensitivity for Run I (~1 TeV)
      - +10% at 1.5 TeV (Run II)
- Test NNLO QCD:
  - Gehrmann-De Ridder et al., arXiv:1507.02850, Boughezal et al., arXiv:1512.01291, Boughezal et al., Phys. Rev. Lett. 115, 062002 (2015)
- Run II will be a nice playground for all of this

For Run II: V+n jets/V+jets: predict higher jet multiplicities

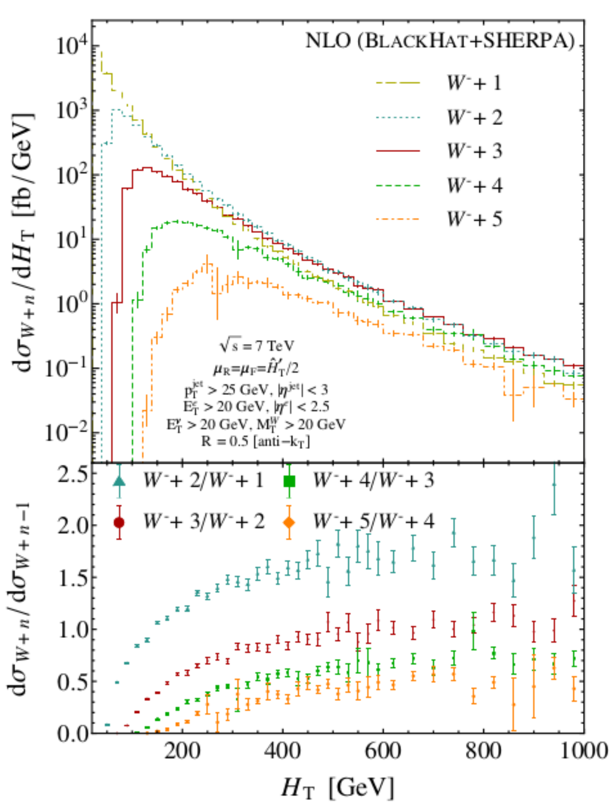




- Predict large number of jets at NLO is complex. One possibility:
  - Use NLO pred. for σ(V+n jet)/σ(V+(n-1) jet) to estimate σ(V+n+1 jet).
  - Ratio: partial cancellation of experimental (jet,..) and theoretical (scale, PDF,..) uncertainties
  - Fit to derive the evolution of a given distribution when passing from n-1 to n jets
  - Propagate to n+1, including uncertainties
- W+n+1 jet xsec
- Differential? Example with Ht in W+jets

Bern et al. Phys. Rev. D 92, 014008 (2015)

fit with: $$\frac{d\sigma_{V+n}}{d H_T} = \left(\frac{N_C \alpha_s}{2\pi}\right)^n f(H_T)\mathcal{N}_n \ln^{\tau_n}\rho_{H,n}\left(1-H_T/H_T^{\max}\right)^{\gamma_n}$$



fit and get
the parameters
dependency to n jets