Measurements of vector boson plus jets from ATLAS

Yoichi Ninomiya
on behalf of the ATLAS Collaboration

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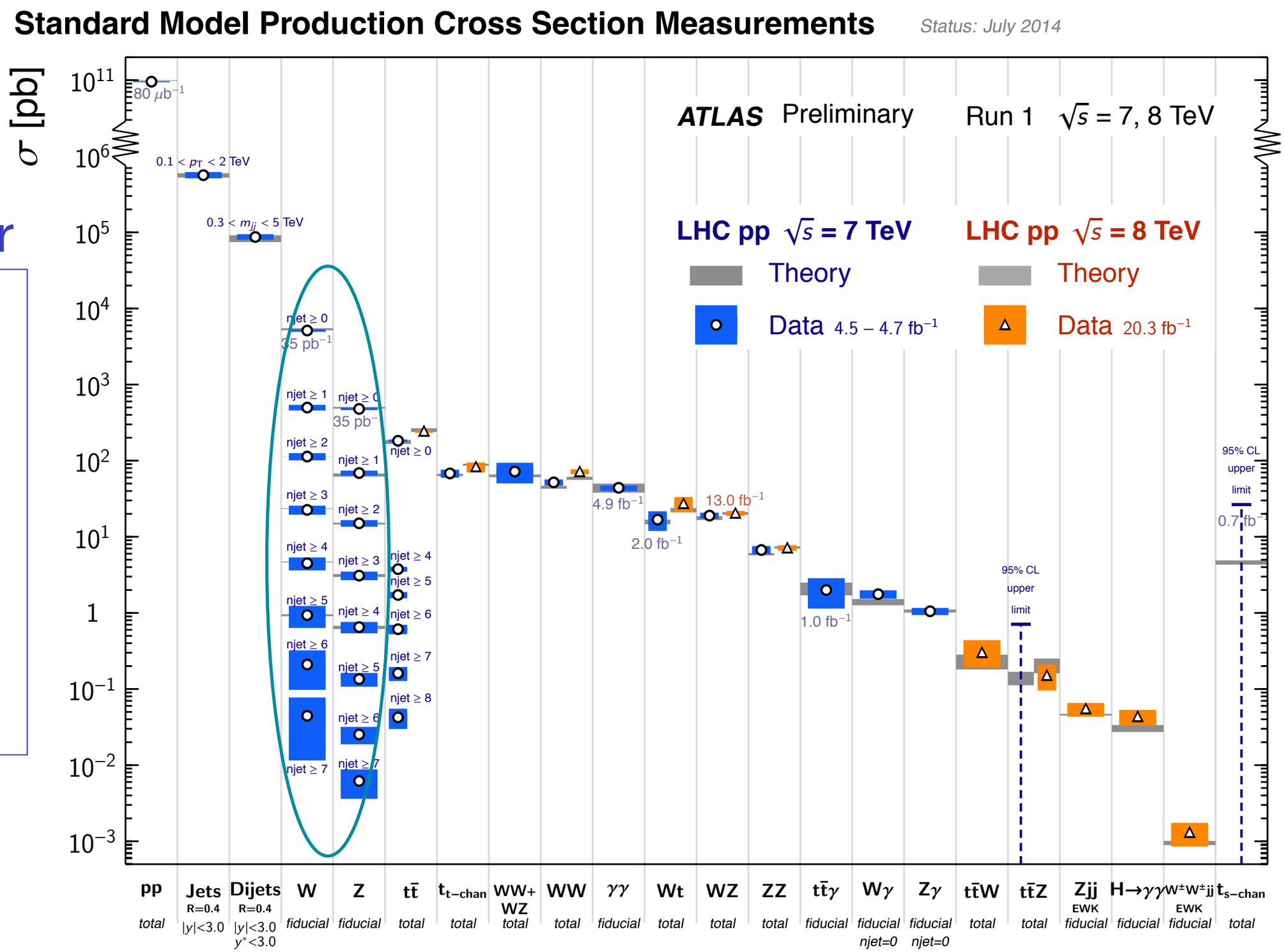
東京大学
THE UNIVERSITY OF TOKYO

Introduction

This talk cover

- W+jets
- Z+jets
- R-jets
- W+b
- Z+b(b)
- W+c/D



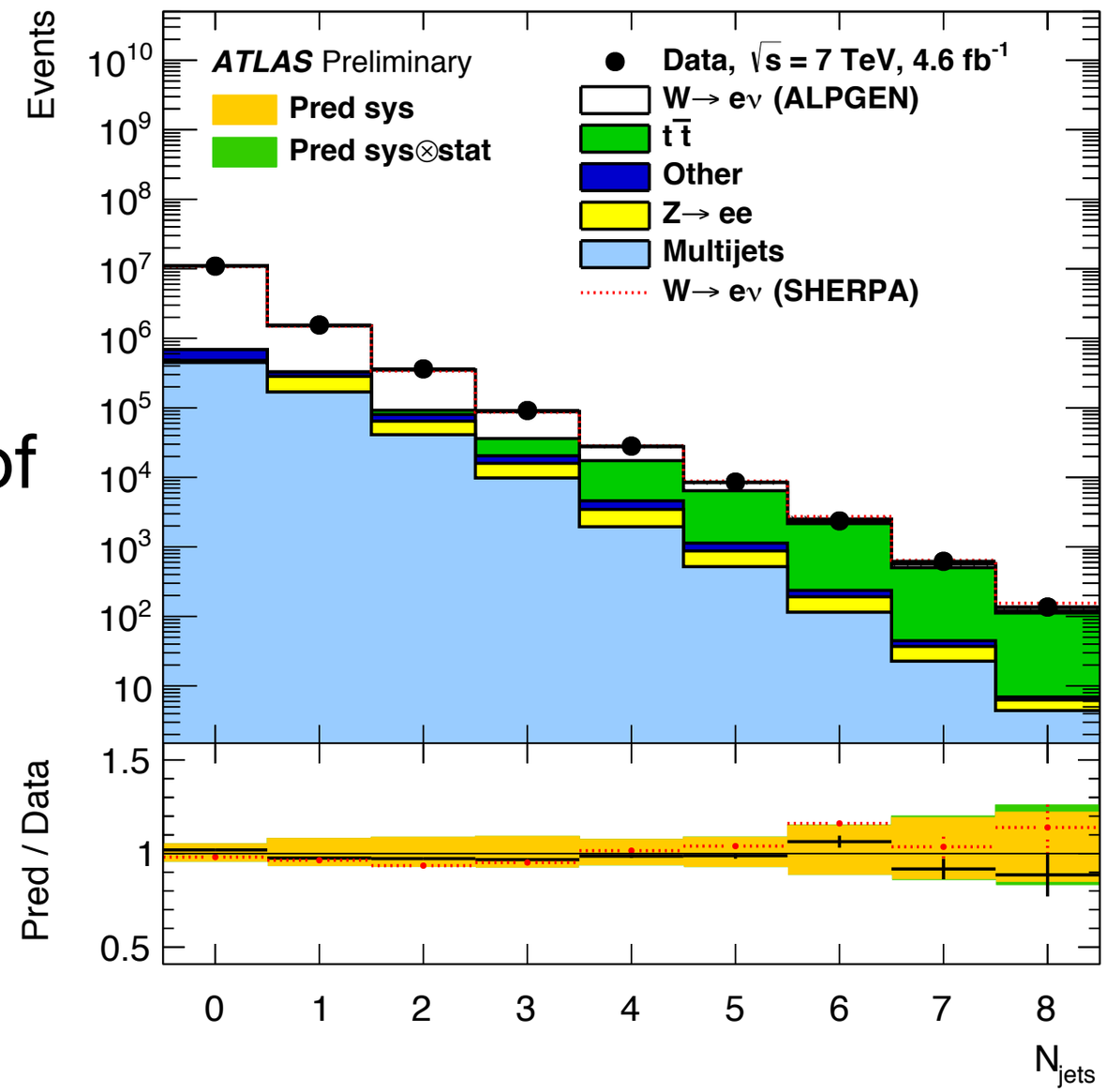
Introduction

- Motivation
  - important tests of pQCD and PDFs
  - important background for many physics
- Progress in theory
  - NLO matrix elements up to 5 jets
  - NLO pQCD samples
    - V+b 4FNS+5FNS, Multileg V+b ME+PS with 4FNS and 5FNS
  - NLO+PS merging samples
    - V+1jets, V+2jets, NLO V+bb+PS

W+jets

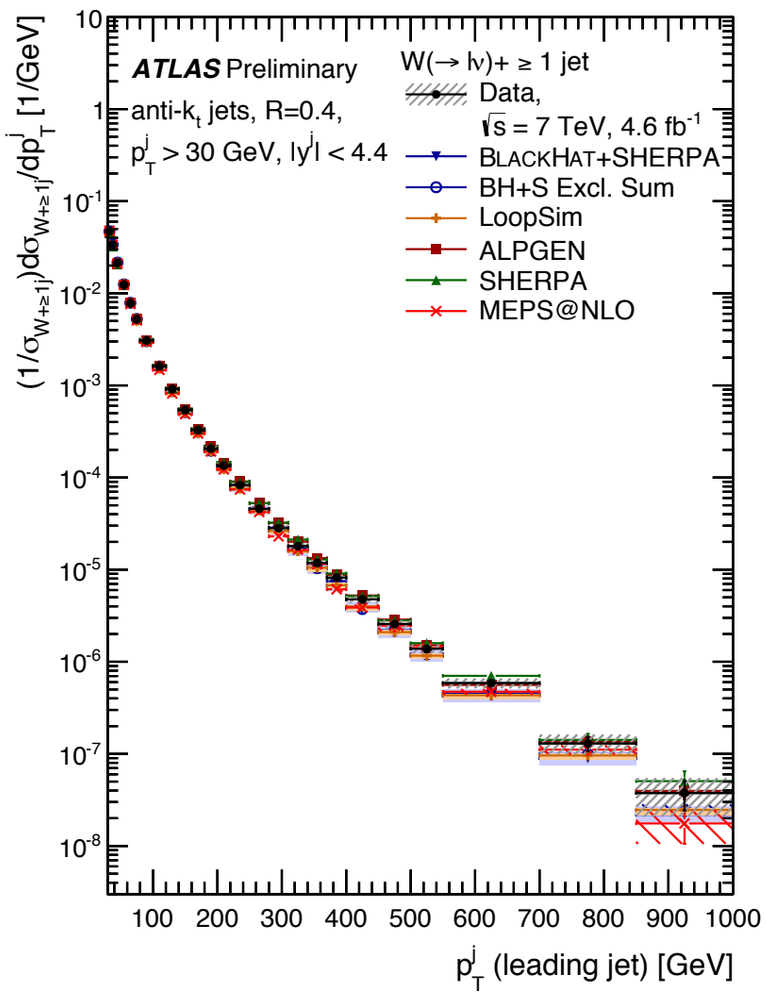
ATLAS-CONF-2014-035

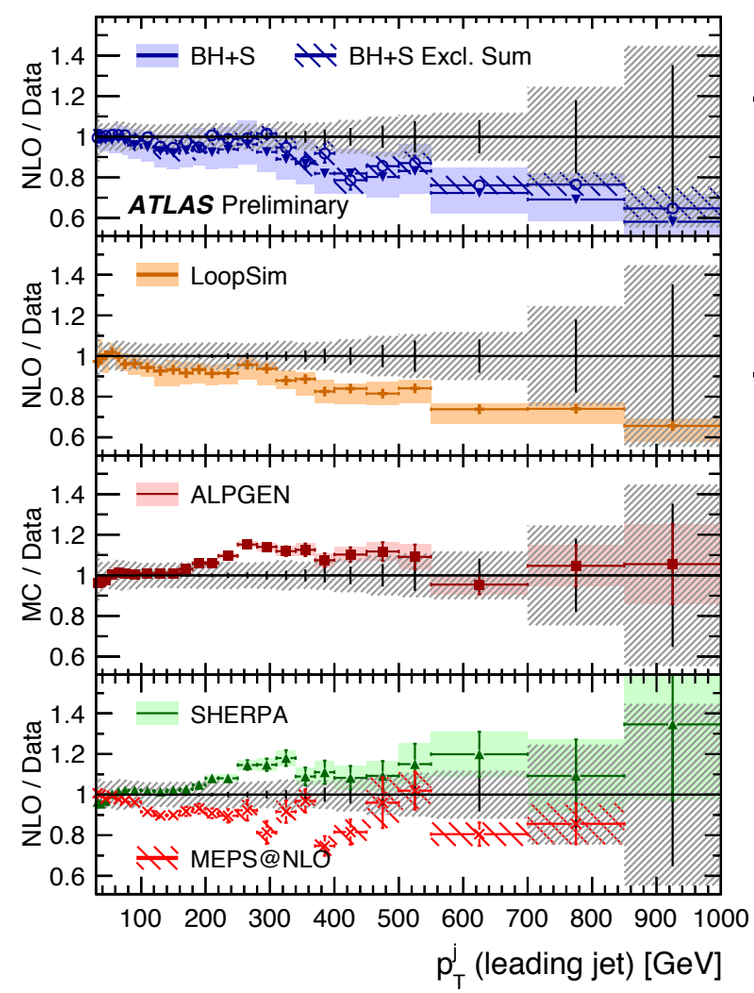
- Measure out to 1 TeV, multiplicities up to 7 jets
- Main backgrounds
  - multijets: low multiplicity
  - top: high multiplicity
- Systematics sources
  - dominated by JES, top
- Cross sections as a function of
  - jet multiplicity
  - jet p_T, rapidity
  - H_T (scalar sum p_T of all particles)
  - S_T (scalar sum p_T of all jets)
  - $\Delta\phi(j,j)$, $\Delta y(j,j)$, $\Delta R(j,j)$, $M(j,j)$



W+jets

- The leading jet p_T distribution for the case of W+≥1jet
- Comparisons from:
  - BlackHat+SHERPA (NLO), LoopSim (approximate NNLO)
  - ALPGEN, SHERPA , ME+PS@NLO (SHERPA NLO)



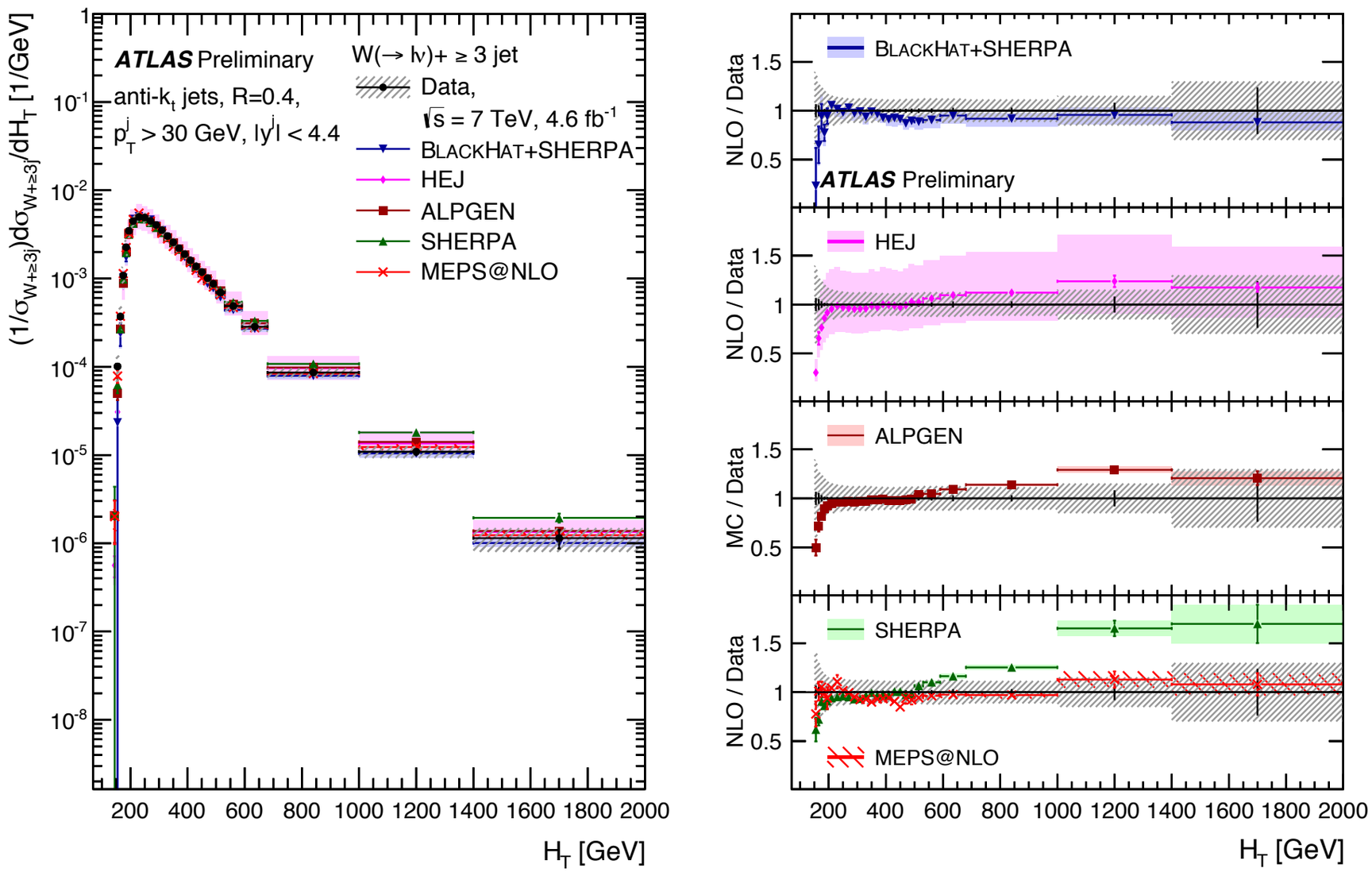


under estimate the data at large jet p_T

reasonable agreement at large jet p_T

W+jets

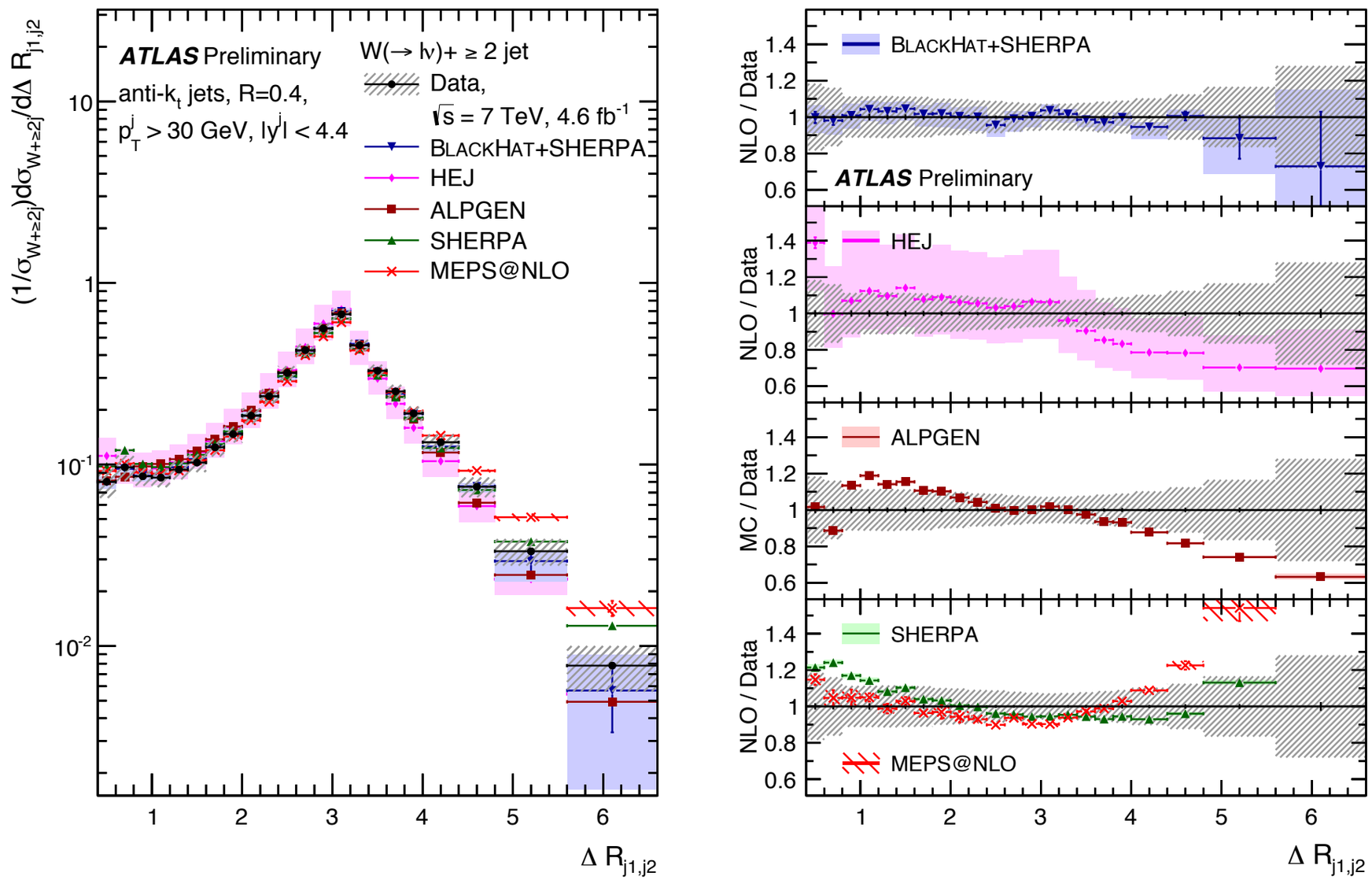
- H_T is the scalar p_T sum of the lepton and the jets
  - measure total activity in the event



- The SHERPA predictions tend to be above the data at high H_T

W+jets

- The angular separation tests jet production

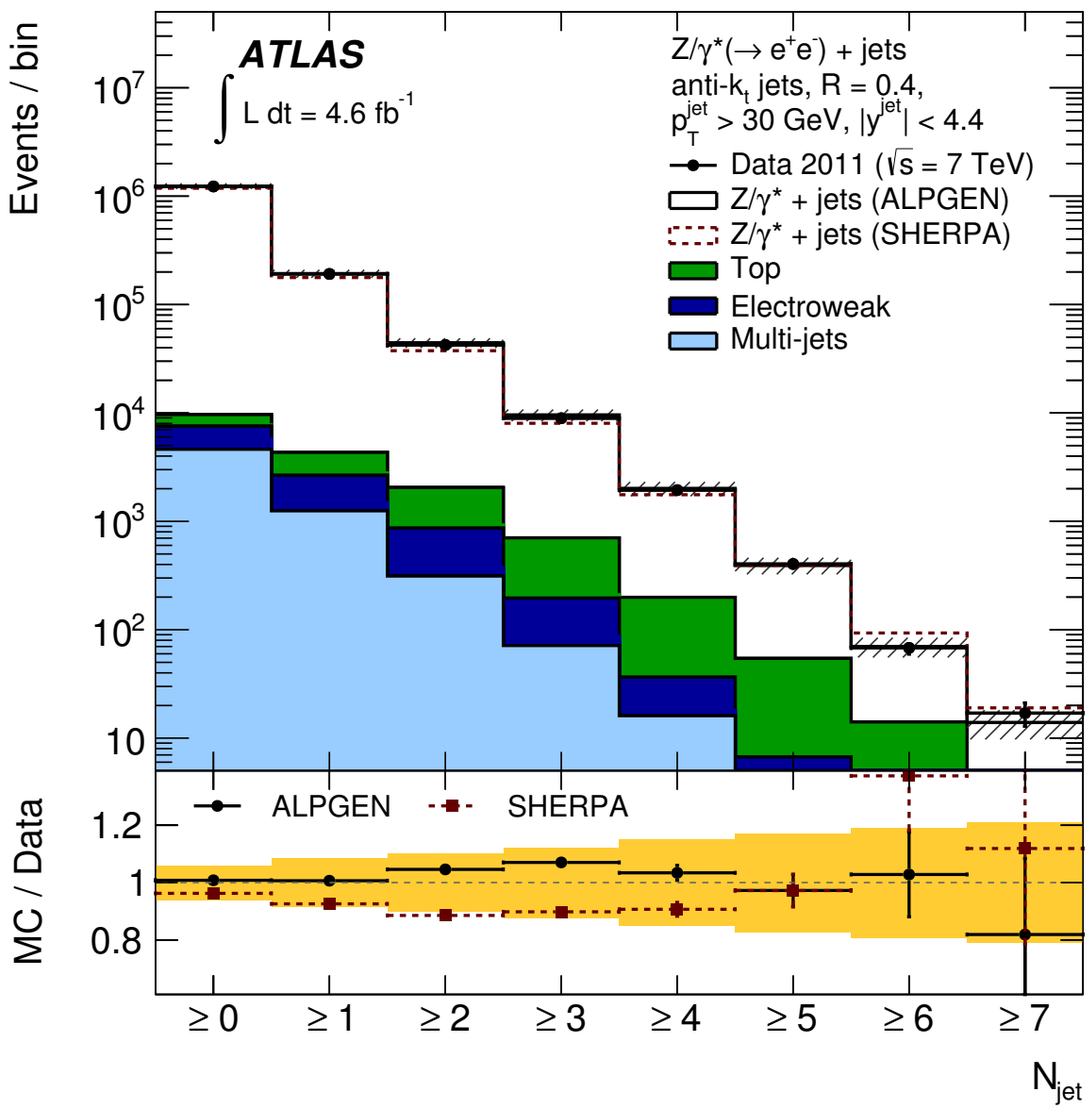


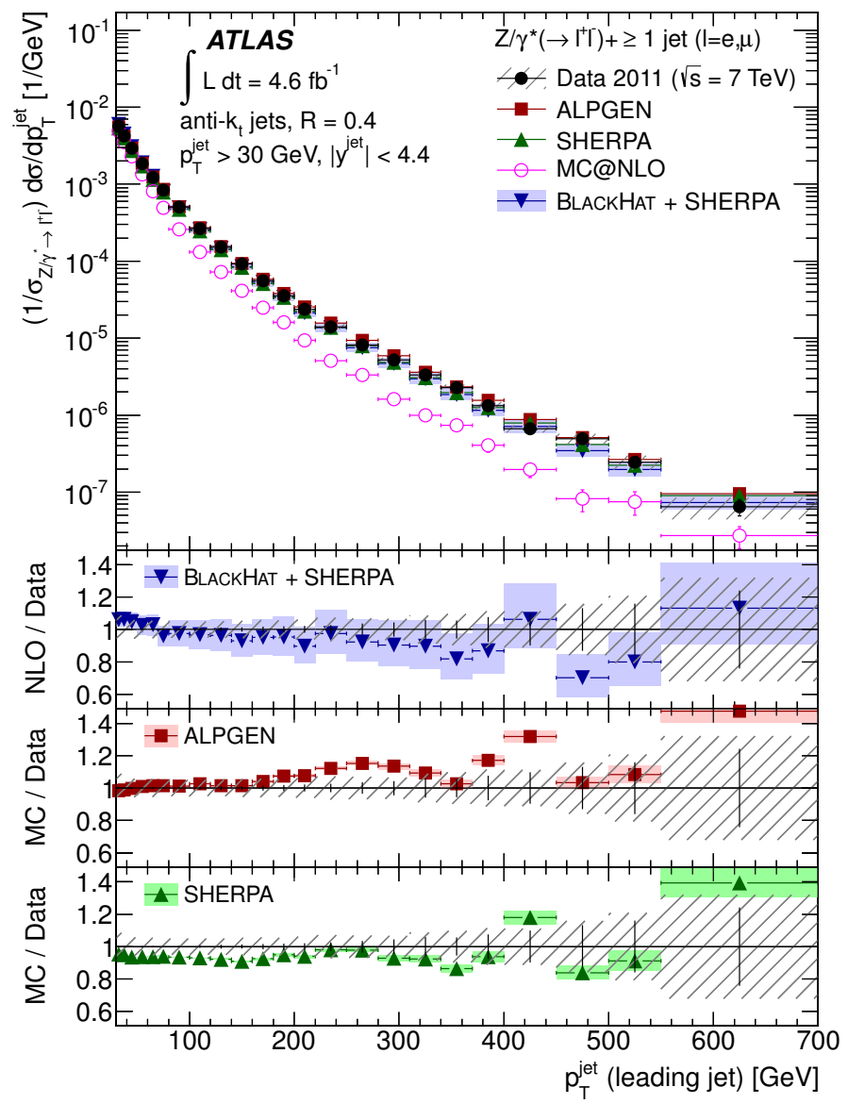
- BlackHat+SHERPA is in good agreement with data

Z+jets

JHEP 07 (2013) 032

- Background smaller than W+jets
  - but less reach due to lower cross section



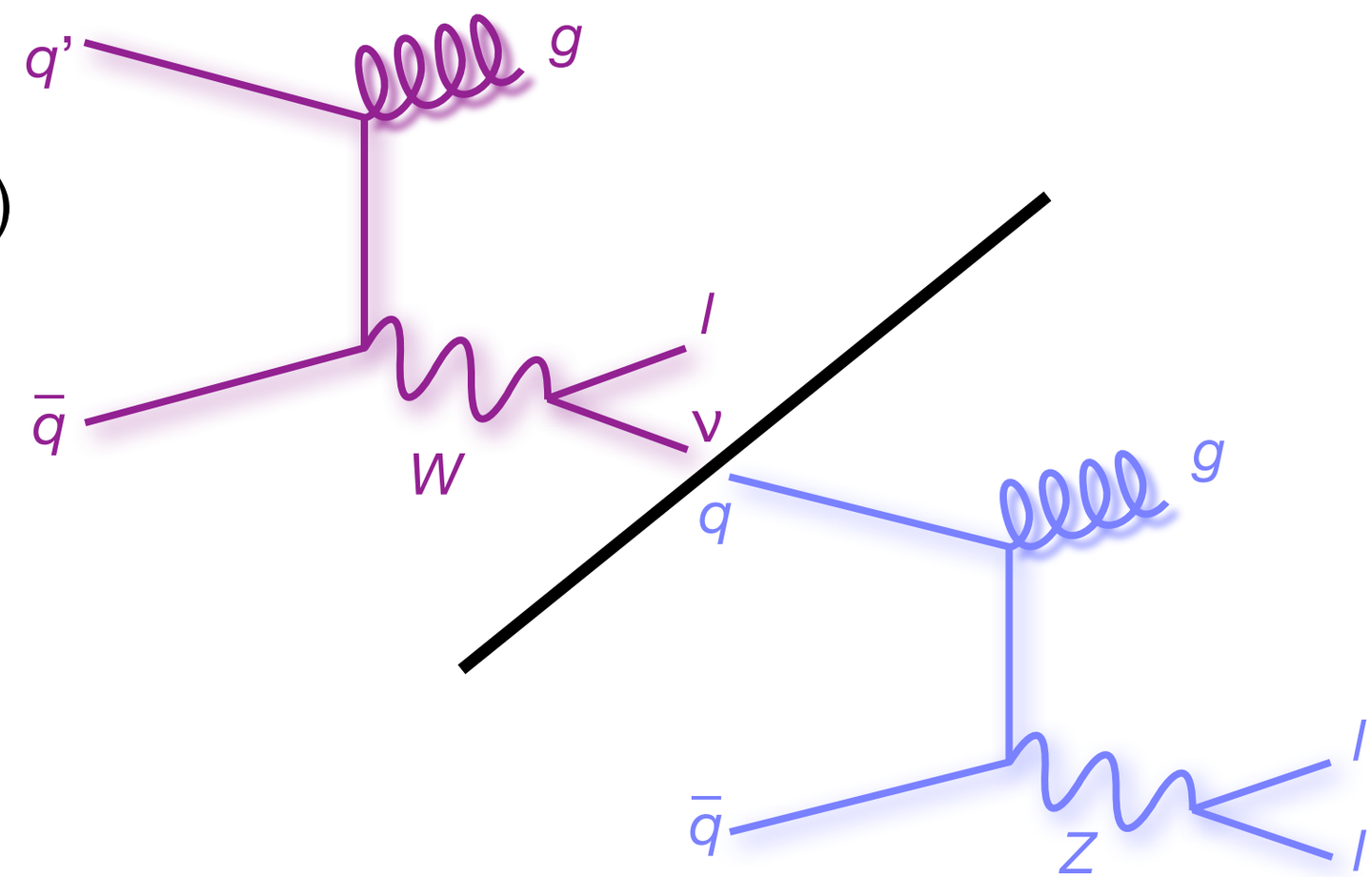


- NLO prediction is consistent with data

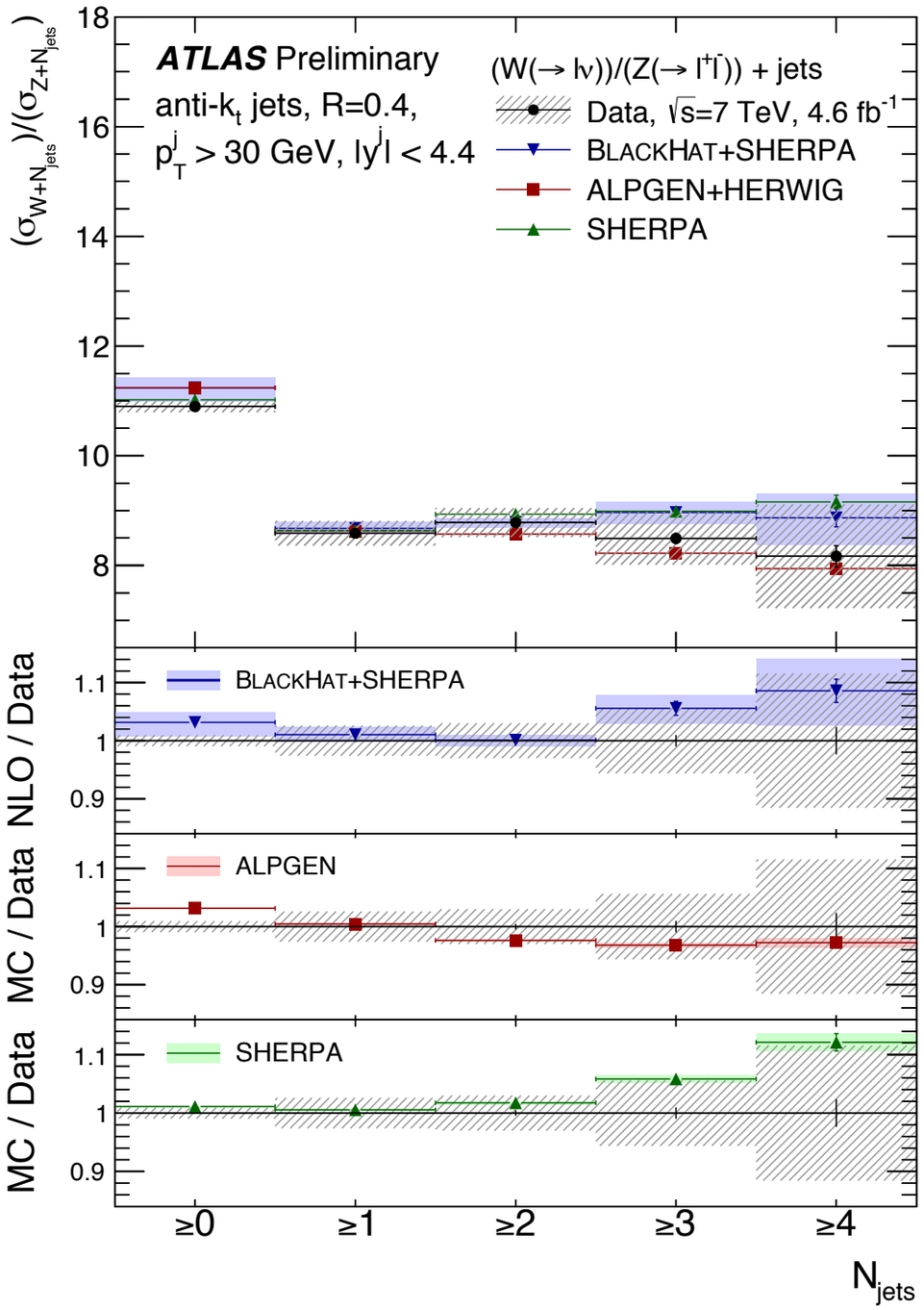
R-jets

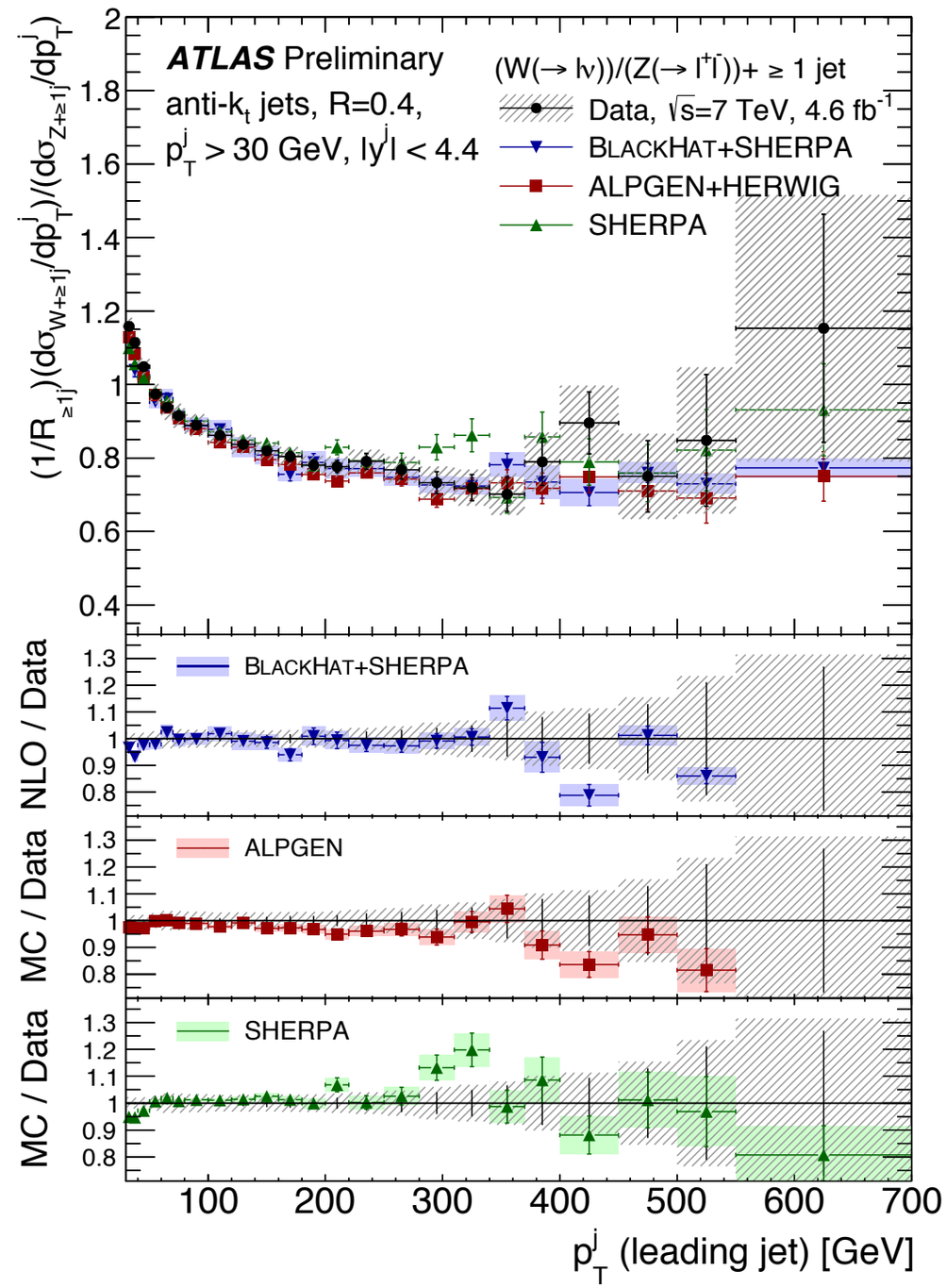
ATLAS-CONF-2014-034

- The cross section ratio of W+jets to Z+jets production
- Complementary test of pQCD compared to Z+jets or W+jets
  - cancel systematics and effects from non-perturbative processes
- Measured as a function of many variables
  - N_{jets} (up to 4 jets)
  - jet p_T, rapidity
  - S_T (scalar sum of jet p_T)
  - $\Delta R(j,j)$, $\Delta\phi(j,j)$, $M(j,j)$



R-jets





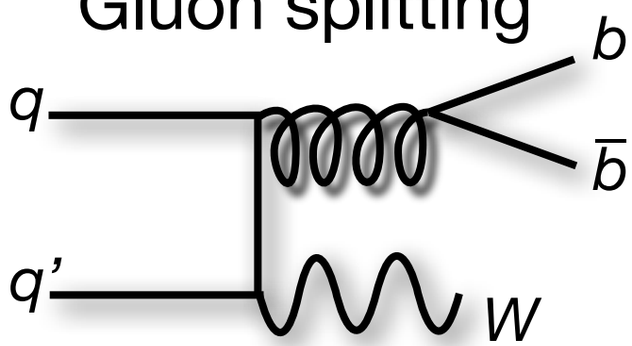
- The theoretical predictions describe the data fairly well

W+b

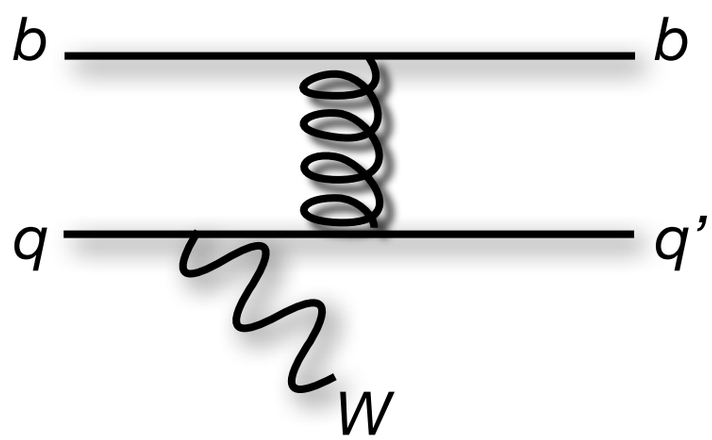
JHEP 06 (2013) 084

- Irreducible background for *WH* with $H \rightarrow b\bar{b}$
- Several processes contribute to W+b production

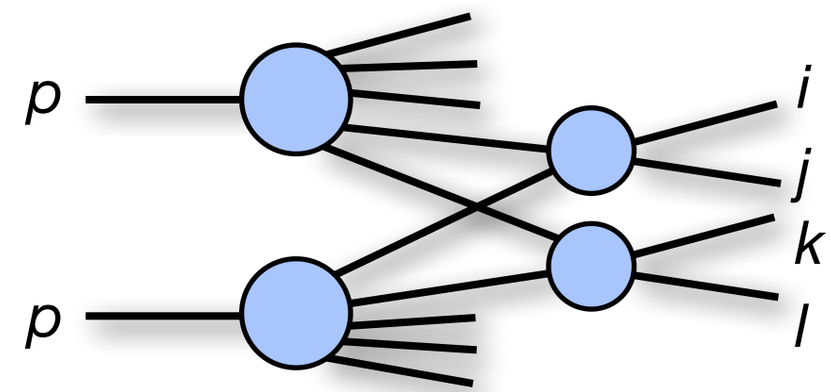
Gluon splitting



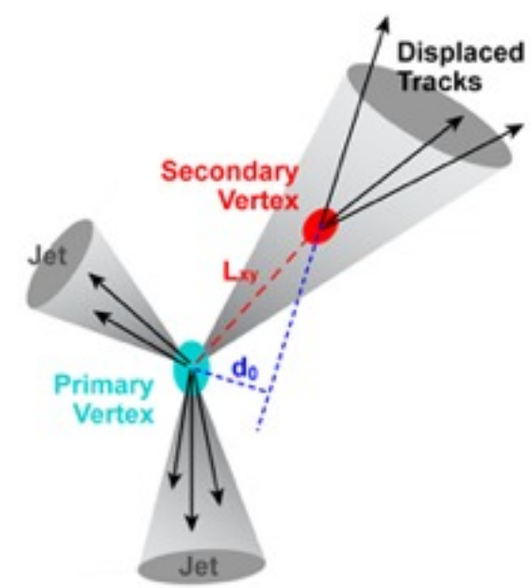
b-quark in initial state



Double Parton Interaction (DPI)

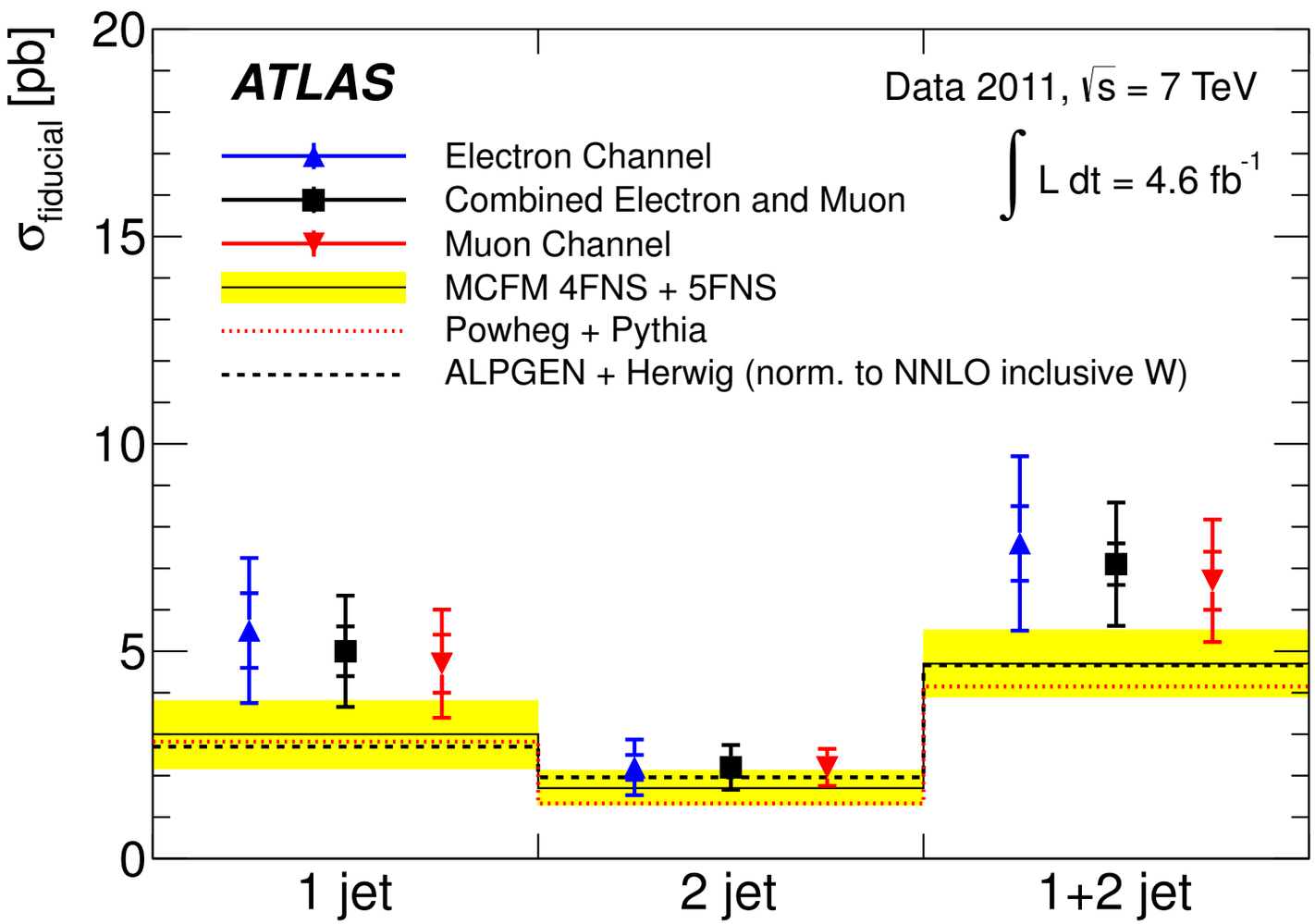


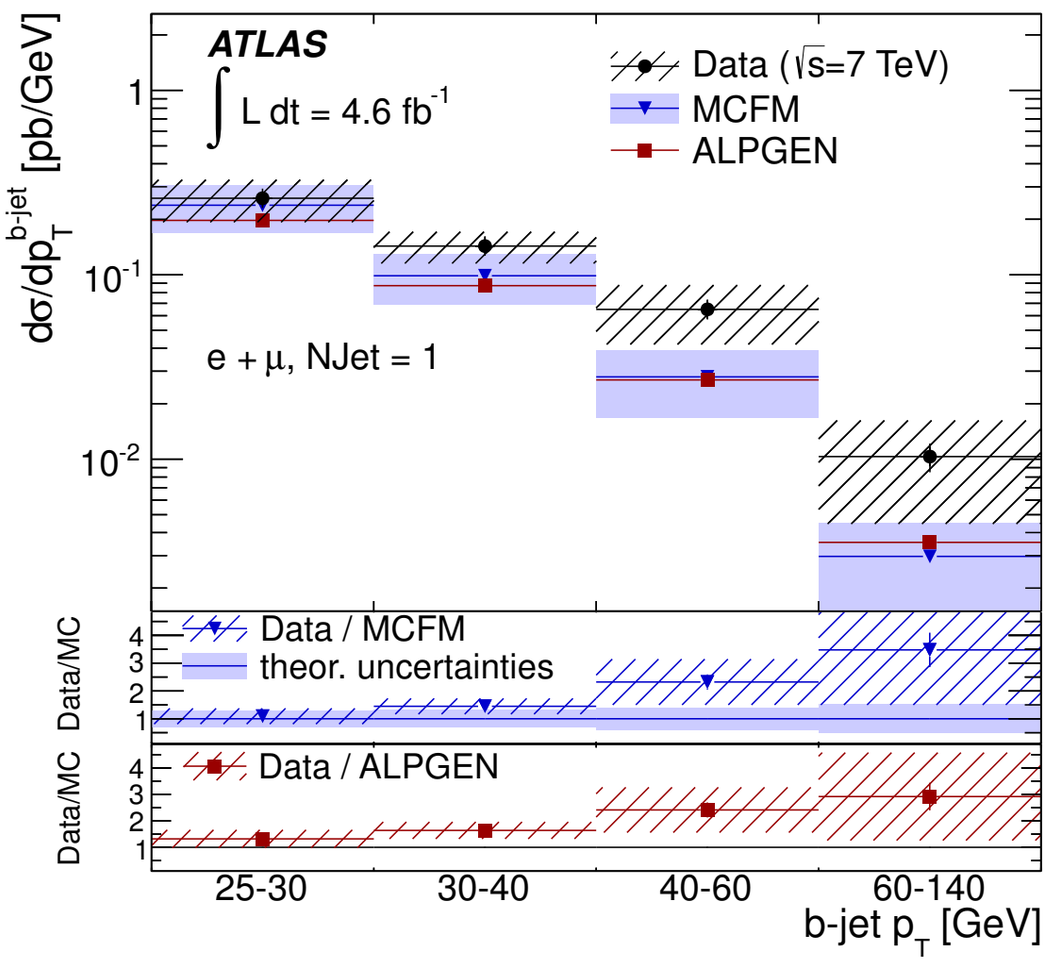
- Required exactly 1 b-tagged jet
  - W+b ("1 jet")
  - W+b+jet ("2 jet")
- Flavour tagging based on tracks
  - impact parameter, secondary vertex



W+b

- MCFM & Powheg applied correction factor for
  - non-perturbative effects: 4%(1 jet) and 8%(2 jet)
  - DPI: 1 pb(1 jet) and 0.3 pb(2 jet) → ~25% of total cross section



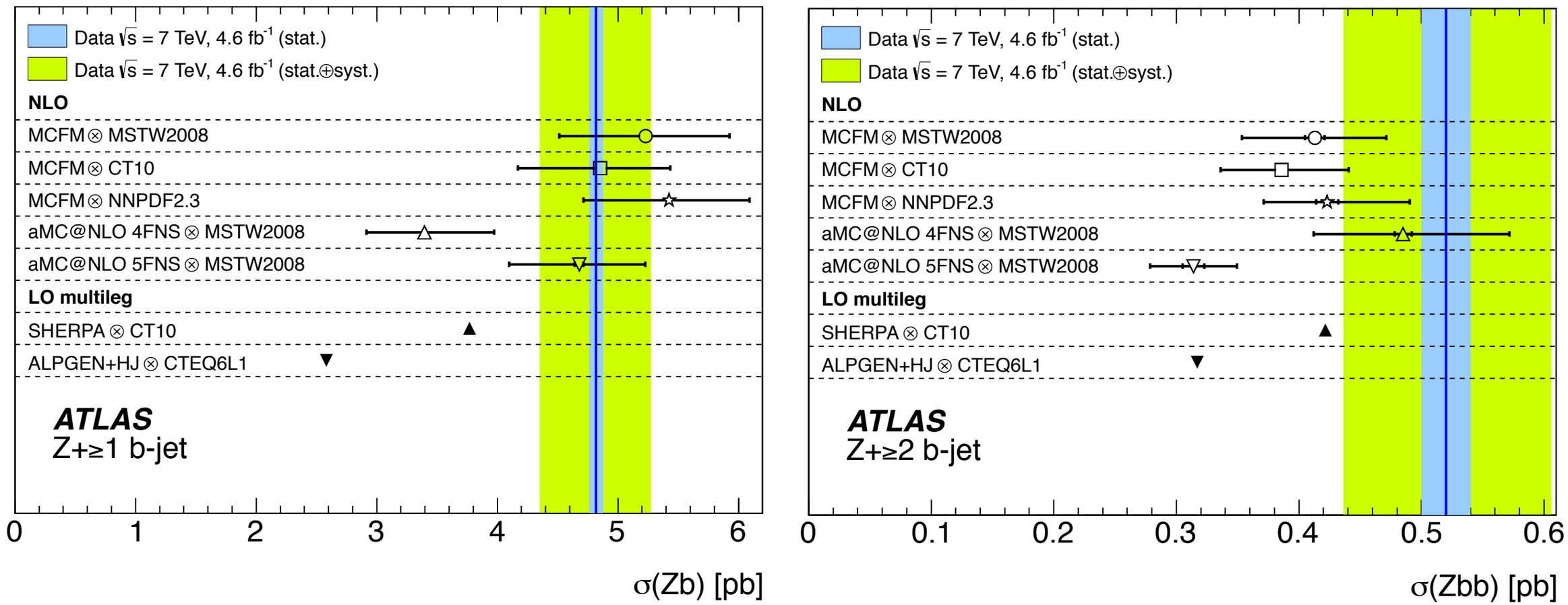


- Theory tends to underestimate the data

Z+b(b)

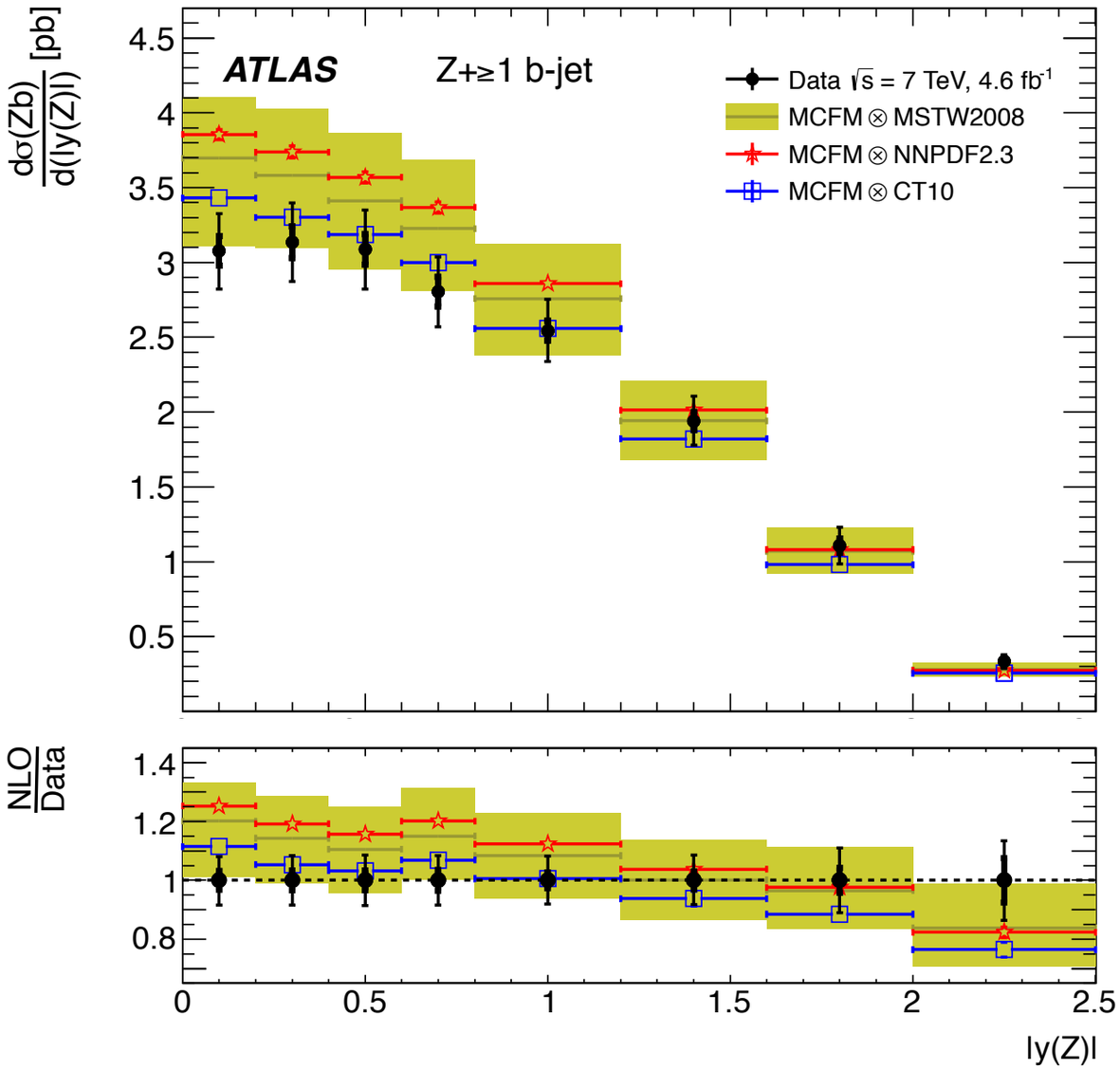
arXiv:1407.3643[hep-ex]

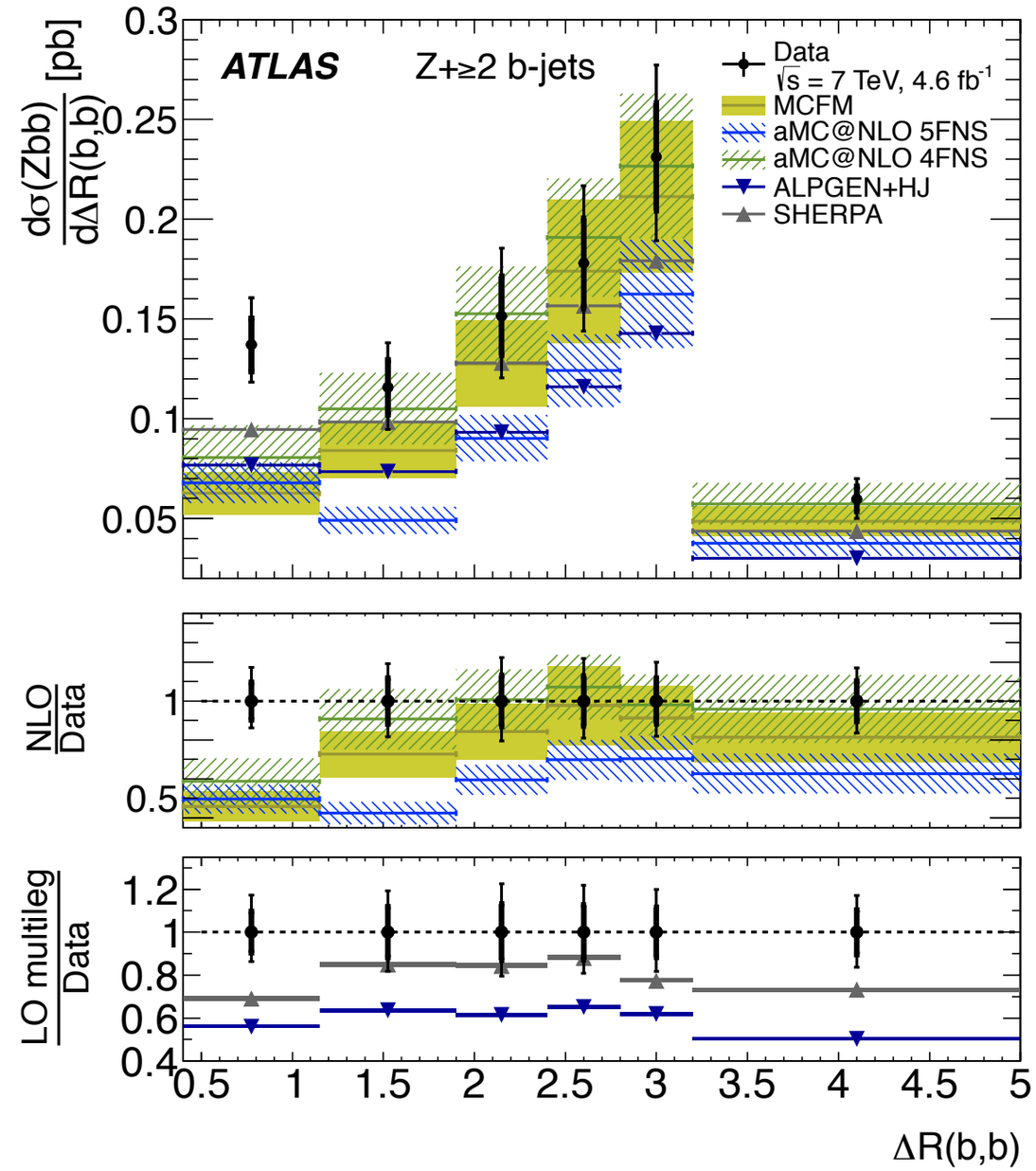
- Irreducible background for ZH with $H \to b\bar{b}$
- Use same b-tagging algorithm as W+b



- MCFM predictions agree with the data within the uncertainties
- Z+b is good in 5FNS, while Z+bb is good in 4FNS

Z+b(b)



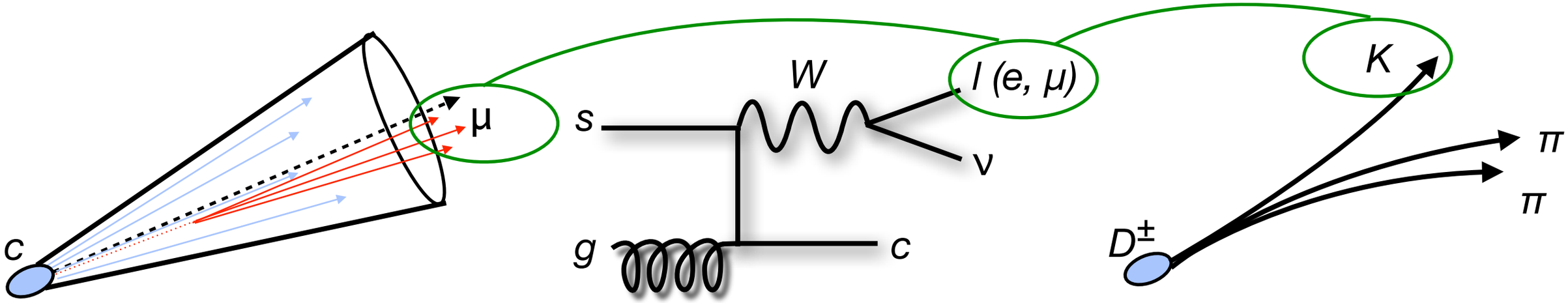


- Reasonable descriptions of the data within the uncertainties for Z rapidity
- Low ΔR(b,b) shows some disagreement, possible a sign of gluon splitting contribution

W+c/D

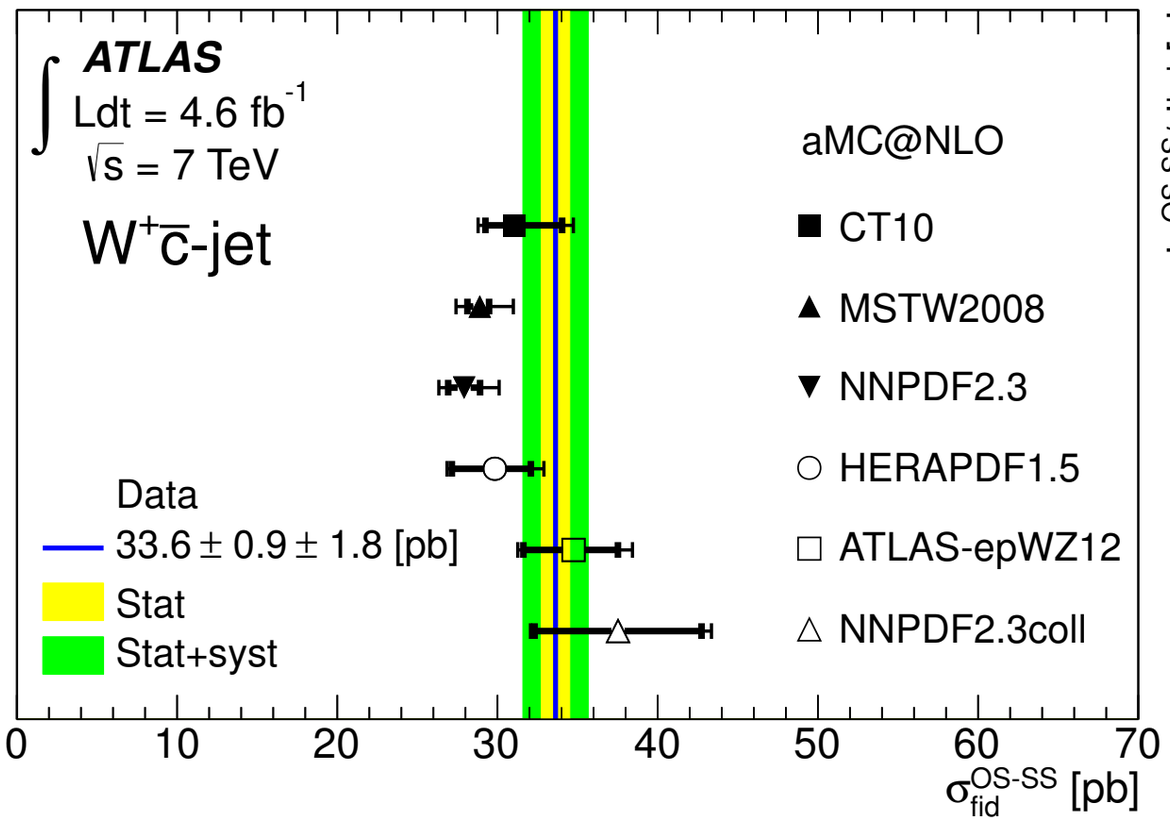
JHEP 05 (2014) 068

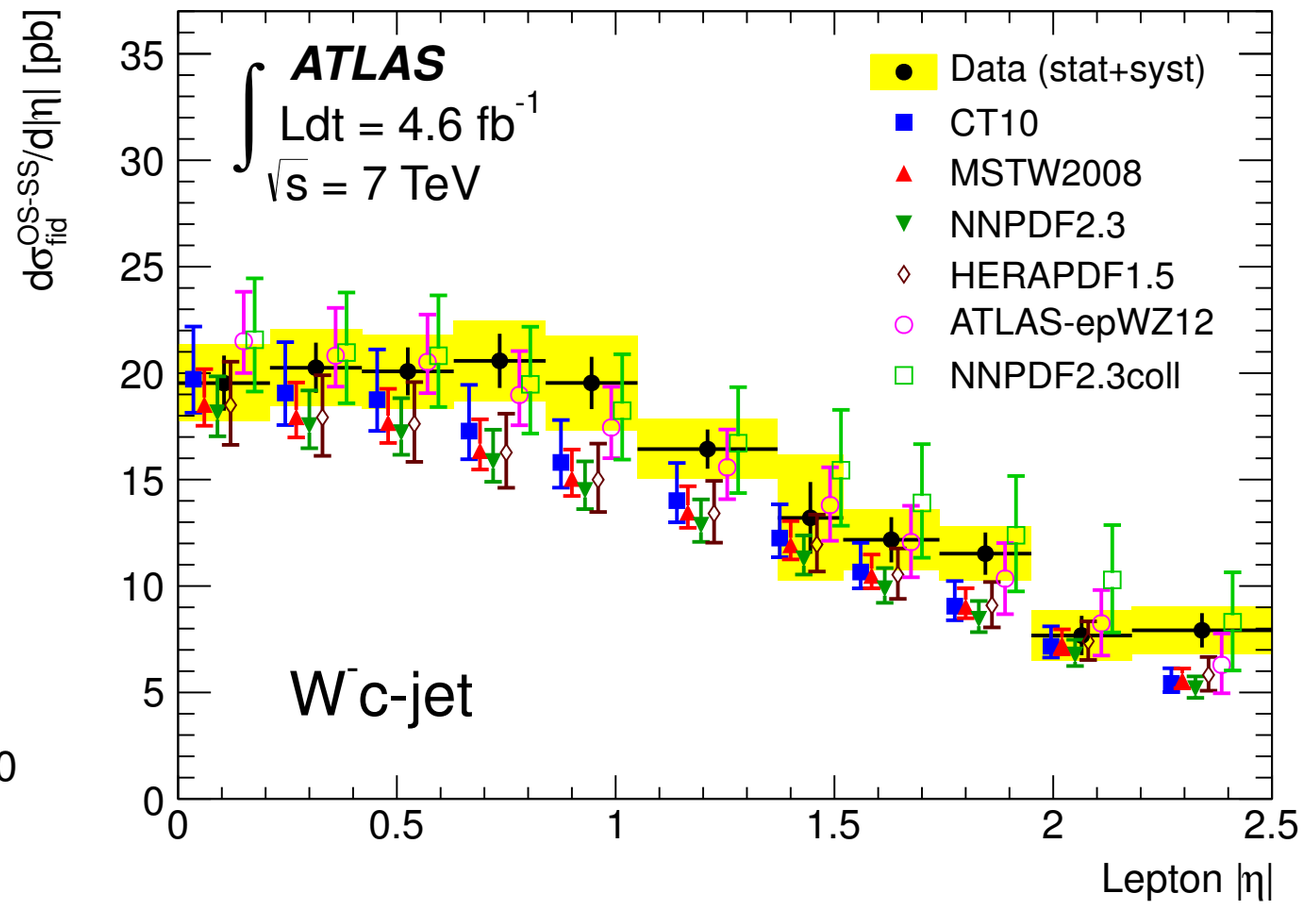
- Sensitive to strange PDF at x~0.01
- SU(3) flavour symmetry (symmetric light quark sea)
  - broken by the strange quark mass?
  - depends on x?
- c quark tagging method
  - soft muon tagging (semi-leptonic decay to muon)
  - reconstruct charmed hadron
- OS - SS subtraction
  - use charge correlation between *W* and *c* to reduce W+c$\bar{c}$ contribution



W+c

- Comparison with aMC@NLO with various PDF sets

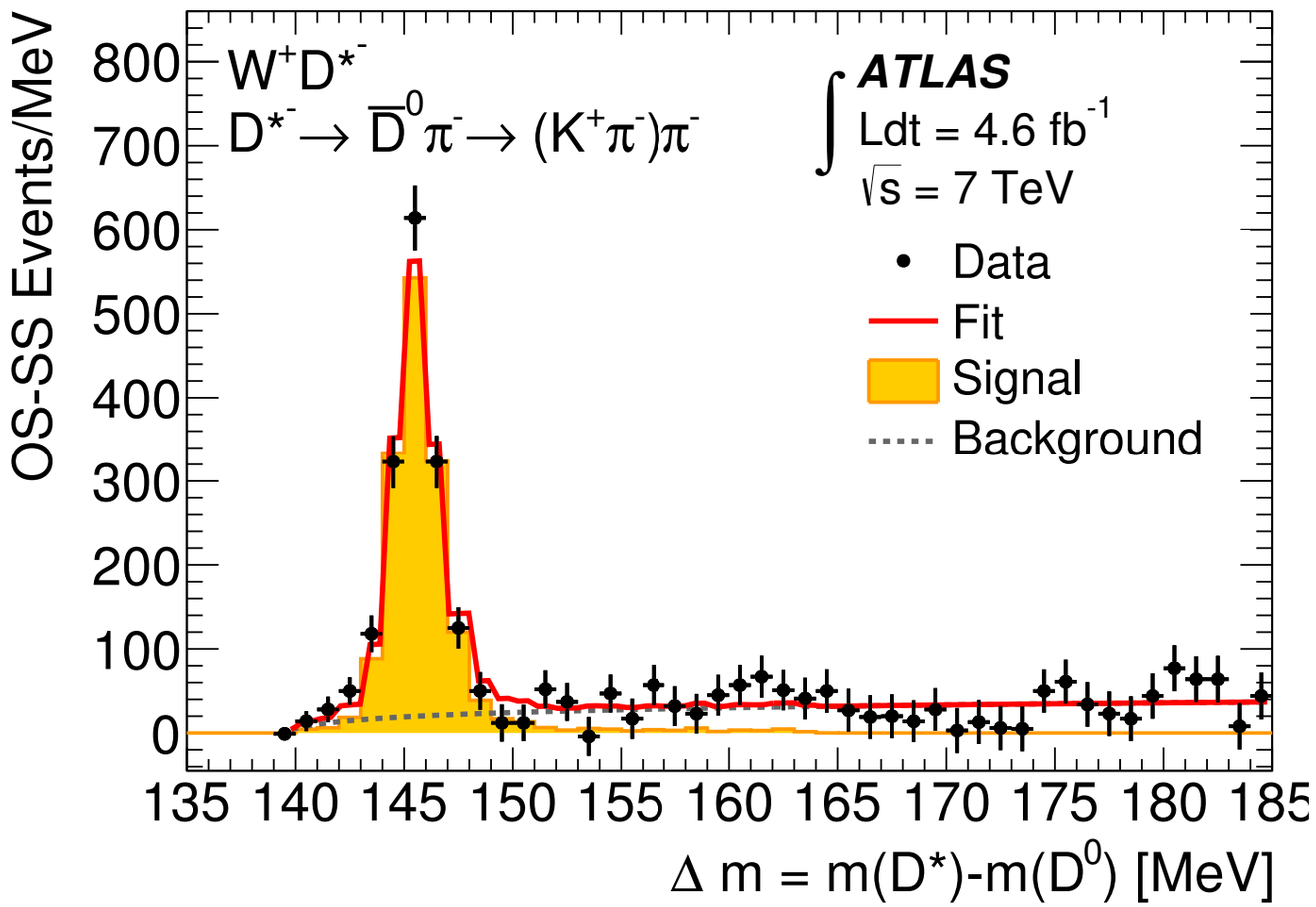


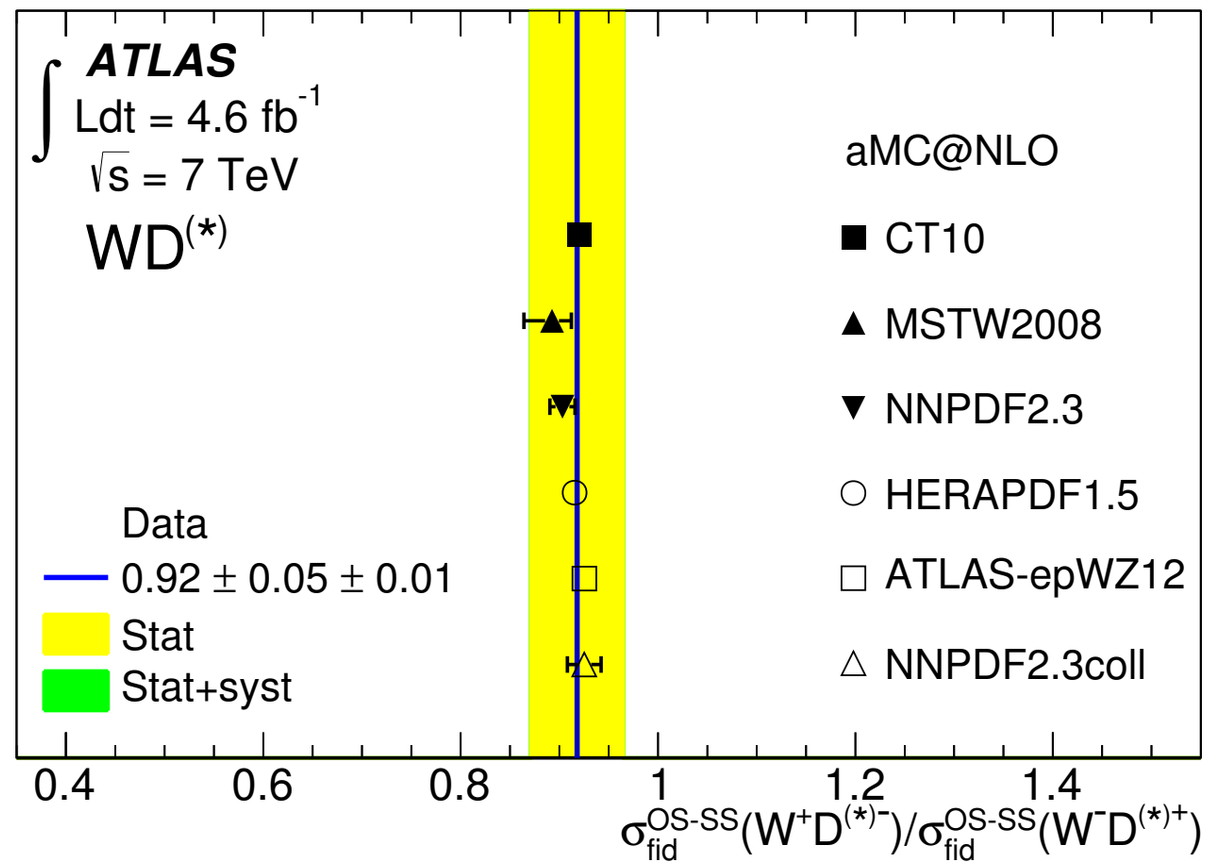


- The shapes are in good agreement

W+D

- Decay channels for D meson
  - $D^+ \to K\pi\pi$, $D^* \to D^0\pi$ with $D^0 \to K\pi$, $D^0 \to K\pi\pi^0$, $D^0 \to K\pi\pi\pi$

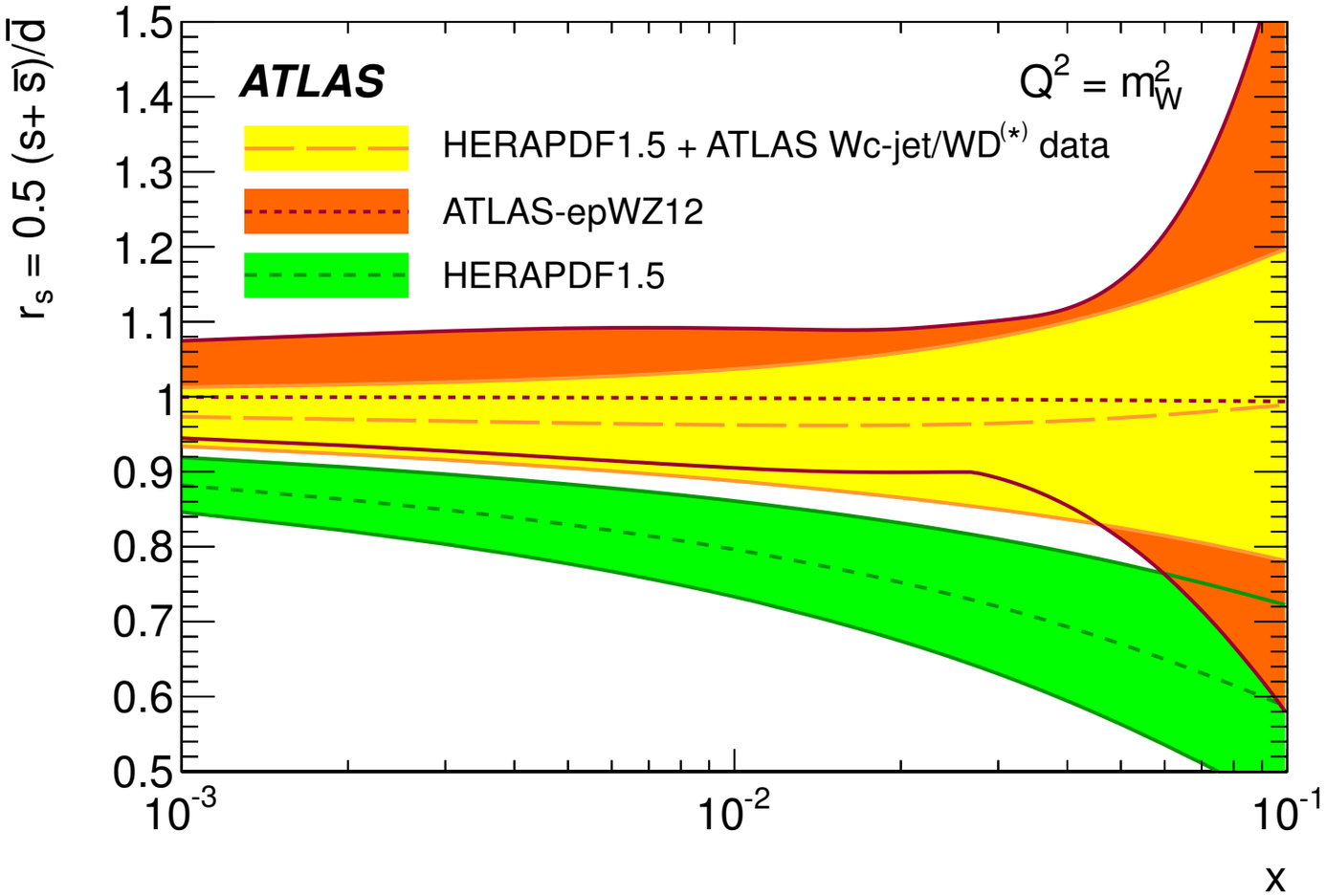




- $\sigma(W^+D^{(*)-})/\sigma(W^-D^{(*)+})$ can probe $s/\bar{s}$ symmetry, currently compatible with all PDFs
  - ratio < 1 because of contribution by d-valence

W+c/D

- Determine strange suppression r_s using HERAPDF1.5 set, best fit value:
  - $r_s \equiv 0.5(s + \bar{s})/\bar{d} = f_s/(1 - f_s) = 0.96^{+0.16+0.21}_{-0.18-0.24}$



- ATLAS Wc-jet/WD(*) data favor a symmetric light-quark sea in agreement with inclusive W, Z fit (ATLAS-epWZ12)

Conclusion

- W/Z + jets processes constitute important tests of pQCD with light and heavy flavour quark
- These processes are also important background for many physics
- Theoretical predictions are advancing greatly
  - in general good agreement with the data
  - heavy flavour matching and modeling is a hot topic
  - ATLAS W+c data supports symmetric light-quark sea