GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

Physics of jet production in association with Z/γ* and W bosons in pp collisions at √s=7 TeV with the ATLAS detector

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on behalf of the ATLAS Collaboration

April 15, 2013

PHYSICS AT THE TERA SCALE
Helmholtz Alliance

FSP 101 ATLAS

Bundesministerium für Bildung und Forschung

Introduction

- Analysis:
  - Measurement of the inclusive and differential Z/γ* + jets cross section on hadron level
- Motivation:
  - Test of recent NLO pQCD predictions for large jet multiplicities (not accessible before)
  - Test of limitations of ME+PS generators and fixed order pQCD in regions where large logarithmic corrections and EW NLO corrections become important
  - Background for studies of the Higgs Boson and searches of new physics

- Analysis:
  - Measurement of hard double-parton interactions in W + 2 jets events
- Motivation:
  - Extract fraction of DPI events

Introduction

- Public results:
  - Phys. Rev. D85 (2012) (36 pb^{-1})
  - Preliminary results with 4.6 fb^{-1}
- Extensions with respect to 2010 paper:
  - Expand to higher jet multiplicities and higher p_T
  - Acess to forward region
  - Kinematics of 3rd and 4th jet
  - New variables: jet pT ratio, HT, ST, Z p_T
  - Exclusive multiplicity ratios
  - Observables after VBF preselection, veto efficiencies
  - Exclusive sums for NLO predictions (HT, Z p_T)

- Public results:
  - New J. Phys. 15 (2013) (36 pb^{-1})
- First measurement of its kind at the LHC

Z/γ*+jets

Z+jets cross section measurement

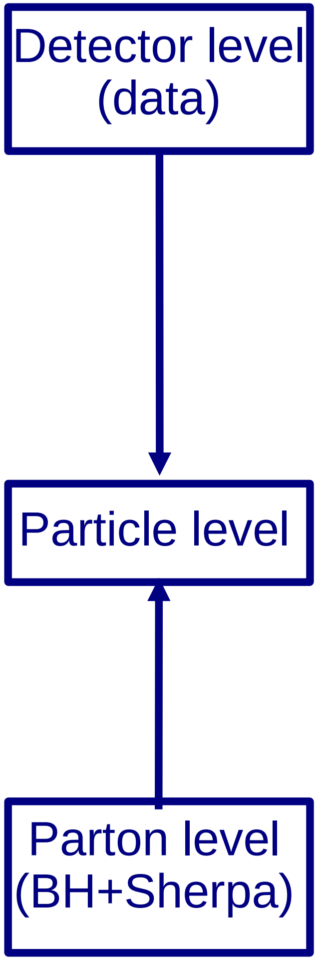
Uncertainties

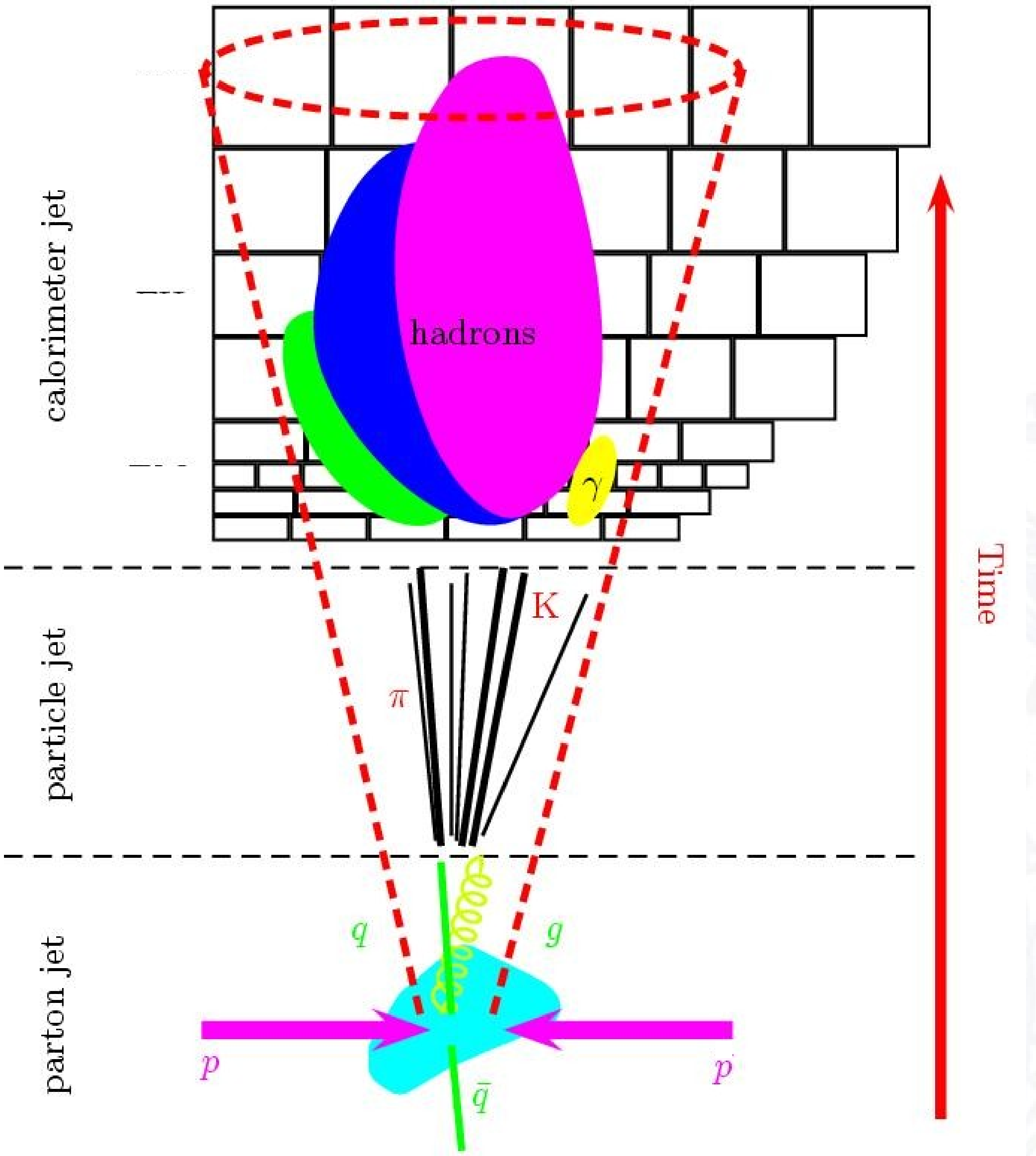
Statistics

JES, JER,
lepton reco & ID + triger

Non-perturbative effects
(UE, fragmentation)

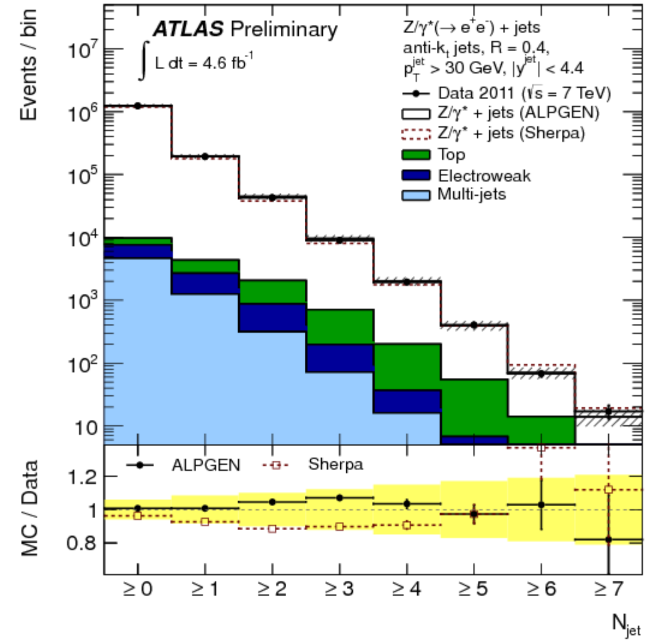
PDF, α_s

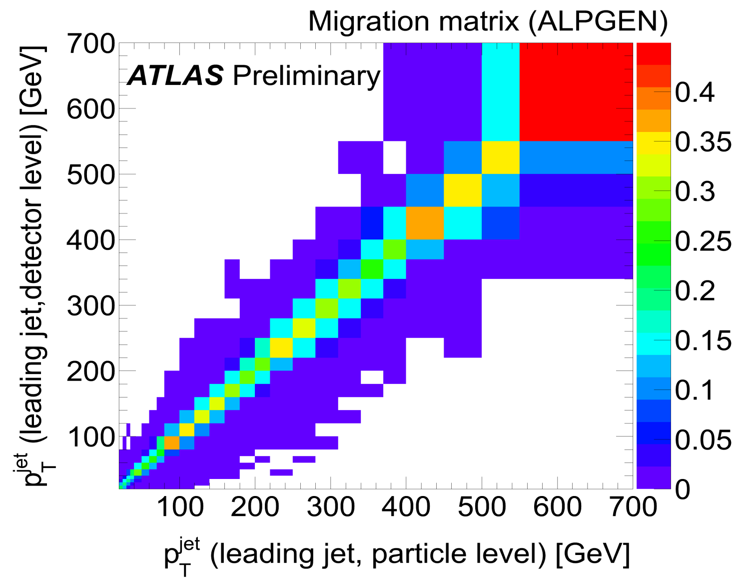




Extraction of cross section

- Event selection
- Signal MC:
  - ALPGEN+HERWIG+JIMMY, CTEQ6L1, AUET2
  - Sherpa 1.4, MENloPS, CT10
  - MC@NLO+HERWIG+JIMMY, CT10, AUET2
- Subtraction of backgrounds
  - Main backgrounds:
    - Multi-jets from data (0.4%-1.5%)
    - Ttbar from data (0.2%-26%)
    - Diboson (0.2%-1.2%)
- Unfolding method: iterative (Bayes) method (Nucl. Instrum. Meth. A 362 (1995) 487
  - Trainings sample: ALPGEN+HERWIG
- Differential measurements on dressed level and extrapolated to common phase space region





Leptons: pT> 20 GeV, |eta| < 2.5, add photons in ΔR<0.1
Z -Boson : Opposite sign leptons, 66 < m(ll) < 116 GeV
Jets: antikt, R=0.4, pT > 30 GeV, |y| < 4.4, ΔR(j,l) < 0.5

Systematic uncertainties

$Z(\rightarrow ee)$	≥ 1 jet	≥ 2 jets	≥ 3 jets	≥ 4 jets	p_T^{jet} $(30-500$ GeV)
Electron reconstruction	2.8%	2.8%	2.8%	2.8%	2.6-2.9%
Jet energy scale, resolution	7.4%	10.1%	13%	17%	4.3-9.0%
Backgrounds	0.26%	0.34%	0.44%	0.50%	0.21-3.2%
Unfolding	0.22%	0.94%	1.2%	1.9%	1.4-6.8%
Total	7.9%	10.5%	13%	17%	5.5-12.0%

$Z(\rightarrow \mu\mu)$	≥ 1 jet	≥ 2 jets	≥ 3 jets	≥ 4 jets	p_T^{jet} $(30-500$ GeV)
Muon reconstruction	0.86 %	0.87 %	0.87 %	0.88 %	$0.8-1.0$%
Jet energy scale, resolution	7.5 %	9.9 %	13%	16%	$3.2-8.7$%
Backgrounds	0.093 %	0.20 %	0.41 %	0.66 %	$0.1-1.9$%
Unfolding	0.30 %	0.68 %	0.52 %	1.3 %	$0.5-6.2$%
Total	7.6 %	10.0 %	13 %	16 %	4.4-10.2%

JES dominant component to total uncertainty

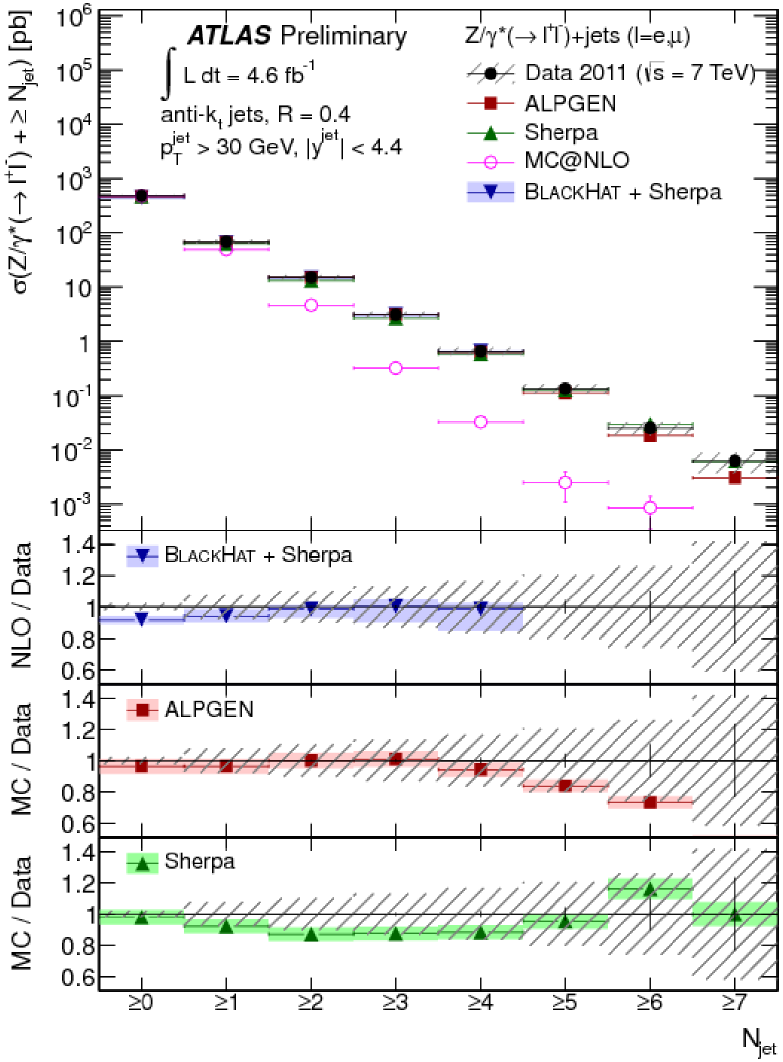
in particular in forward region: JES uncertainty 20%-30%

JES uncertainty reduced in cross section ratios for successive multiplicities: 3-4%

NLO pQCD Predictions

- BlackHat+Sherpa fixed order NLO. Five complete sets: Z+0,1,2,3,4 jets
  (C.F. Berger et al, Phys.Rev. D82 (2010) 074002, H. Ita et al, Phys. Rev. D 85 (2012) 031501)
- Scale:
  - Nominal hadronization and factorization scale: $H_T/2$
  - Systematics: varying both scales simultaniously by factor of 2
    → 4% - 13% for $N_{jet} \geq$ 1-4, dominant uncertainty
  - Exclusive distributions: I.W.Stewart, F.J. Tackmann, Phys.Rev. D 85 (2012) 034011
- PDF:
  - CT10
  - Systematics: complete PDF CTEQ10 error set, 68%CL (1% - 3% for $N_{jet} \geq$ 1-4)
- α_s uncertainty:
  - varying the input α_s at the Z scale by +/- 0.0012 (1% - 3% for $N_{jet} \geq$ 1-4)
- Theoretical prediction are corrected for
  - QED radiation effects:
    - Nominal correction: ALPGEN+HERWIG+PHOTOS (~2%)
    - Systematics: Sherpa 1.4 +YFS
  - non-perturbative contributions (UE, fragmentation):
    - Nominal correction: ALPGEN+HERWIG AUET2 tune (~3%-4%)
    - Systematics: ALPGEN+Pythia6 Perugia2011 tune

Theory/Data Comparison

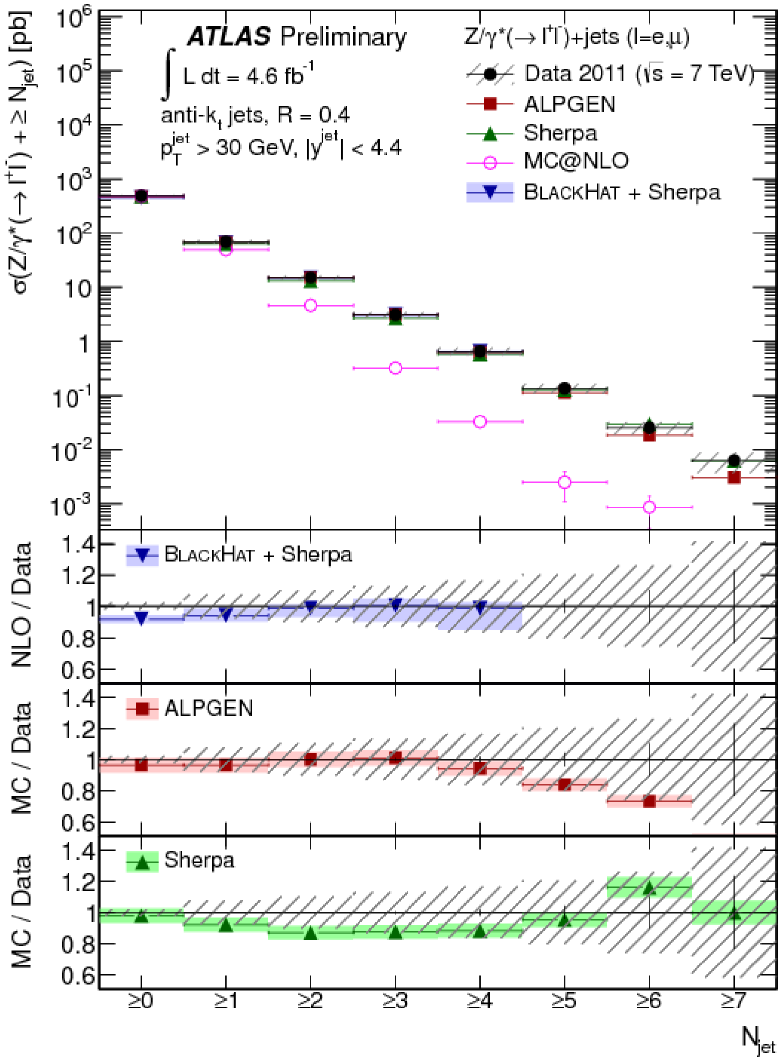


- Unfolded data compared to:
  - BlackHat+Sherpa fixed-order NLO pQCD
    C.F.Berger et al, Phys.Rev. D82 (2010) 074002
    H. Ita et al, Phys.Rev. D85 (2012) 031501
  - ALPGEN+HERWIG+JIMMY (Z+0-5p), AUET2 tune, CTEQ6L PDF
  - Sherpa 1.4 MENloPS (Z+0-5p) CT10 PDF
  - MC@NLO (Drell-Yan) +HERWIG AUET2 tune, CT10 PDF

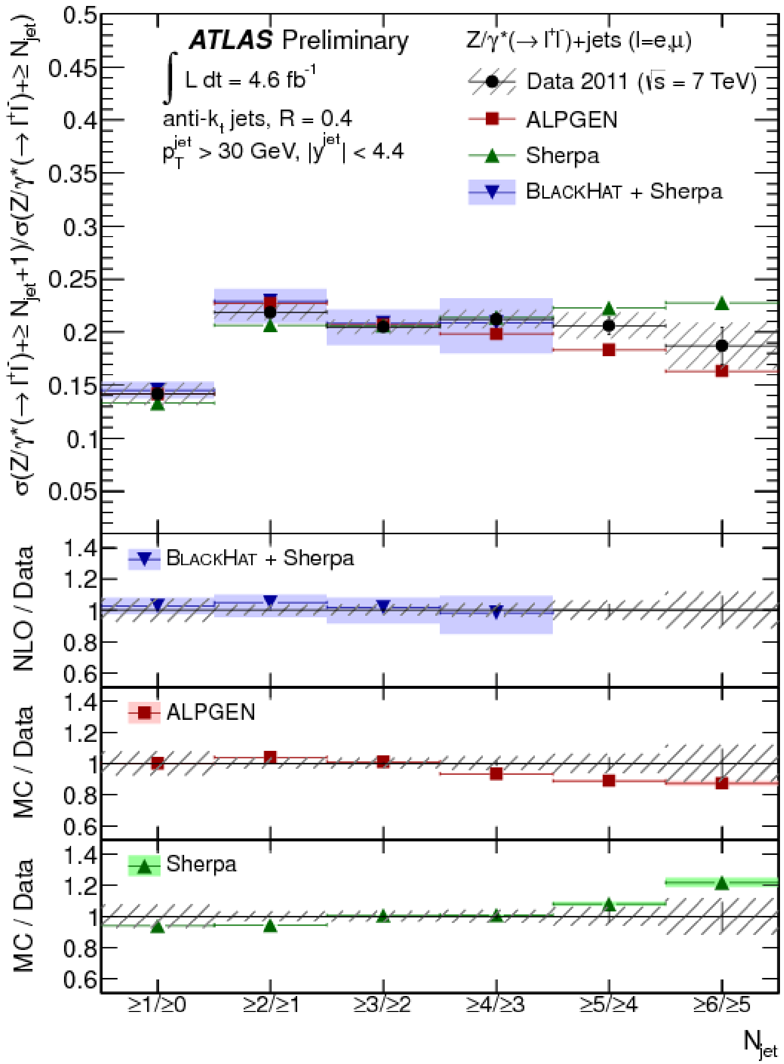
Differential cross sections normalized to inclusive cross section:
→ Cancel uncertainties on lepton reconstruction and integtrated luminosity

Results – inclusive jet multiplicity

inclusive jet multiplicity

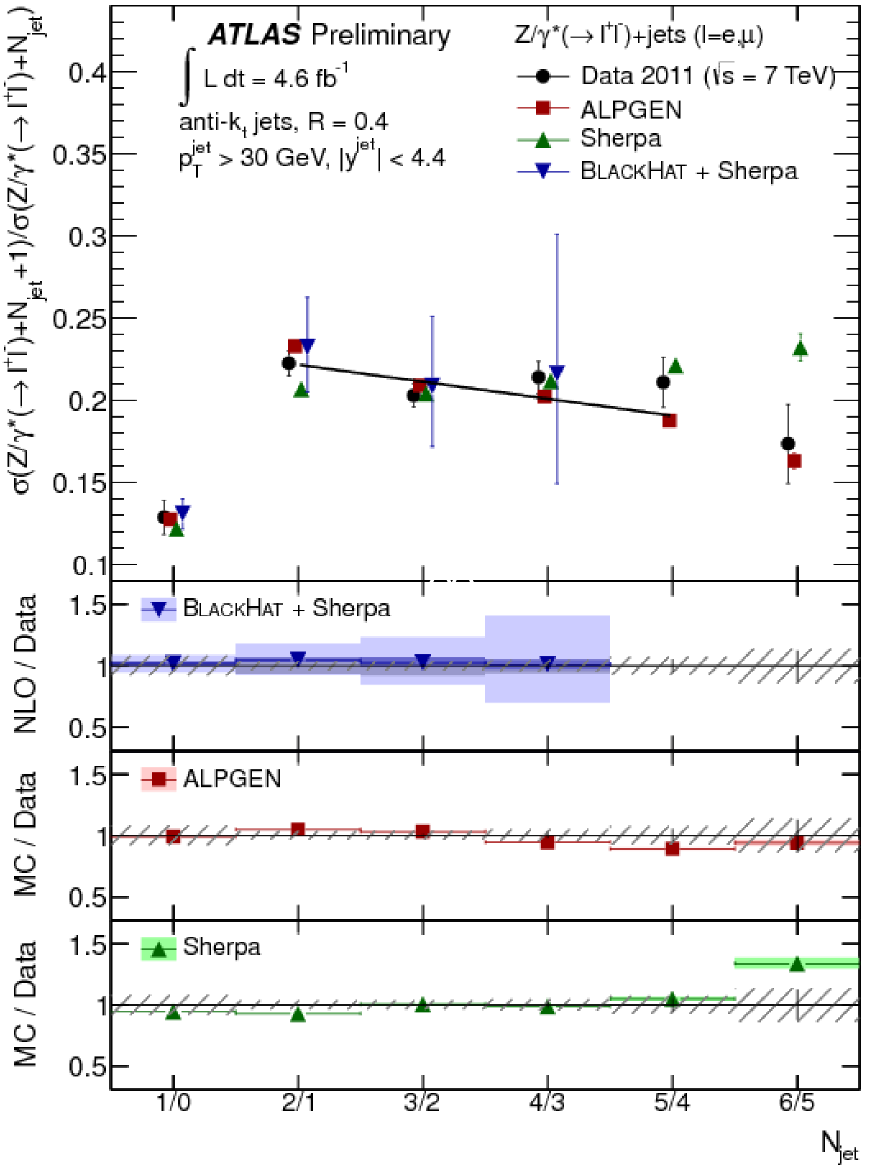


inclusive jet multiplicity ratio



- NLO pQCD, ME+PS: consistent with data
- MC@NLO: HERWIG PS fails to model jet multiplicities

Results – exclusive multiplicity ratios



Scale uncertainties calculated using inclusive scale variations, scale uncertainties assumed to be uncorrelated wrt multiplicity

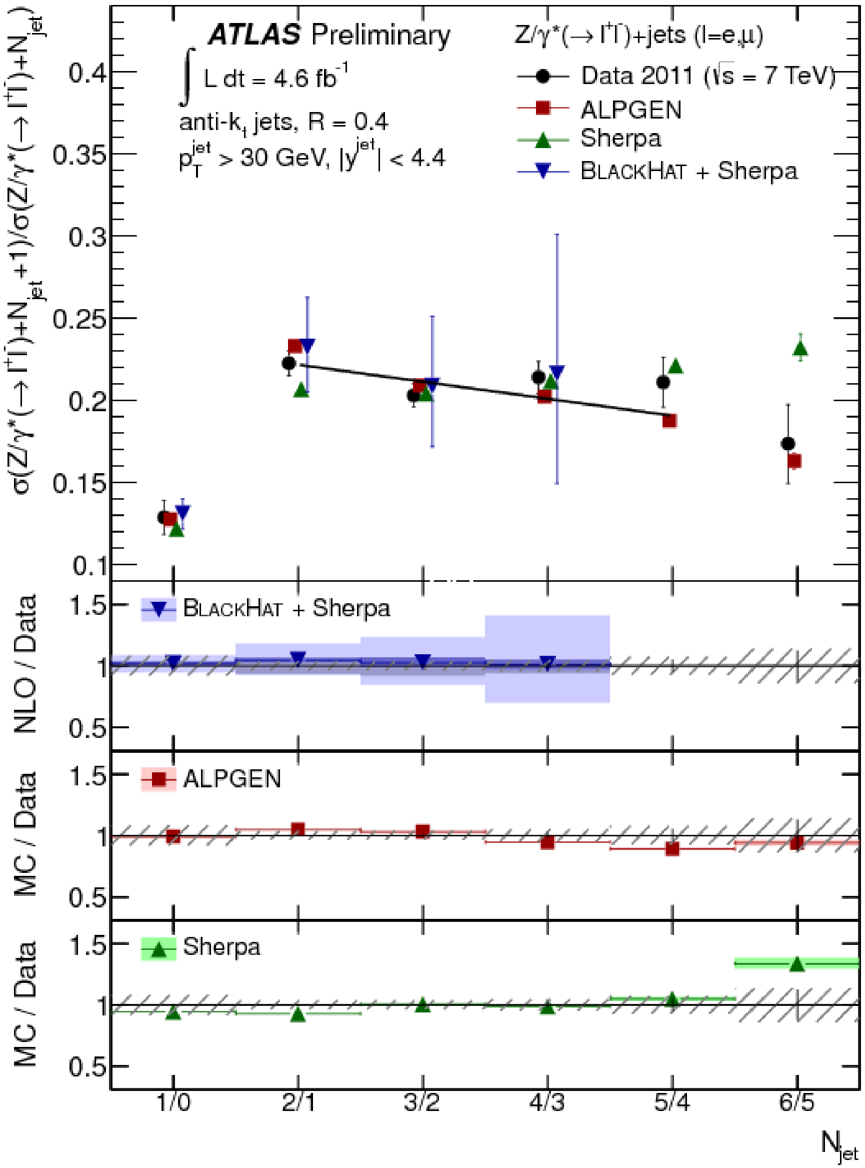
I.W.Stewart, F.J. Tackmann
Phys. Rev. D 85 (2012) 034011

Naive scale variation, correlated uncertainties

no scale variation

- Cross section for exclusive Z+1-4 jets well modelled by fixed-order NLO pQCD

Results – exclusive multiplicity ratios



Scale uncertainties calculated using inclusive scale variations, scale uncertainties assumed to be uncorrelated wrt multiplicity

I.W.Stewart, F.J. Tackmann
Phys. Rev. D 85 (2012) 034011

Naive scale variation, correlated uncertainties

no scale variation

Large uncertainties, increasing with pT(j1)/pT(j2)
Good agreement nominal NLO pQCD ↔ data

→ assumption of uncorrelated scale uncertainties too conservative?

→ need alternative methods to estimate higher-order effects

- Cross section for exclusive Z+1-4 jets well modelled by fixed-order NLO pQCD

Results – exclusive multiplicity ratios

- QED: Abelian type FSR → Poisson scaling $R_{(n+1)/n} = \frac{\bar{n}}{n}$
- QCD: Non-abelian FSR → $R_{(n+1)/n} \sim const$ for high multiplicities

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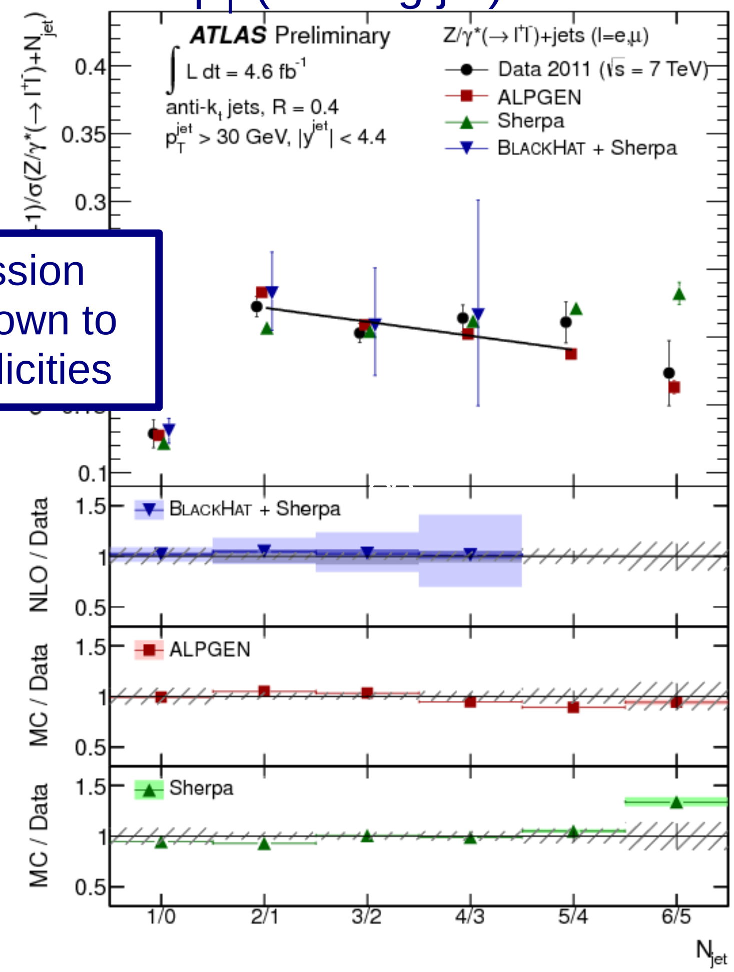
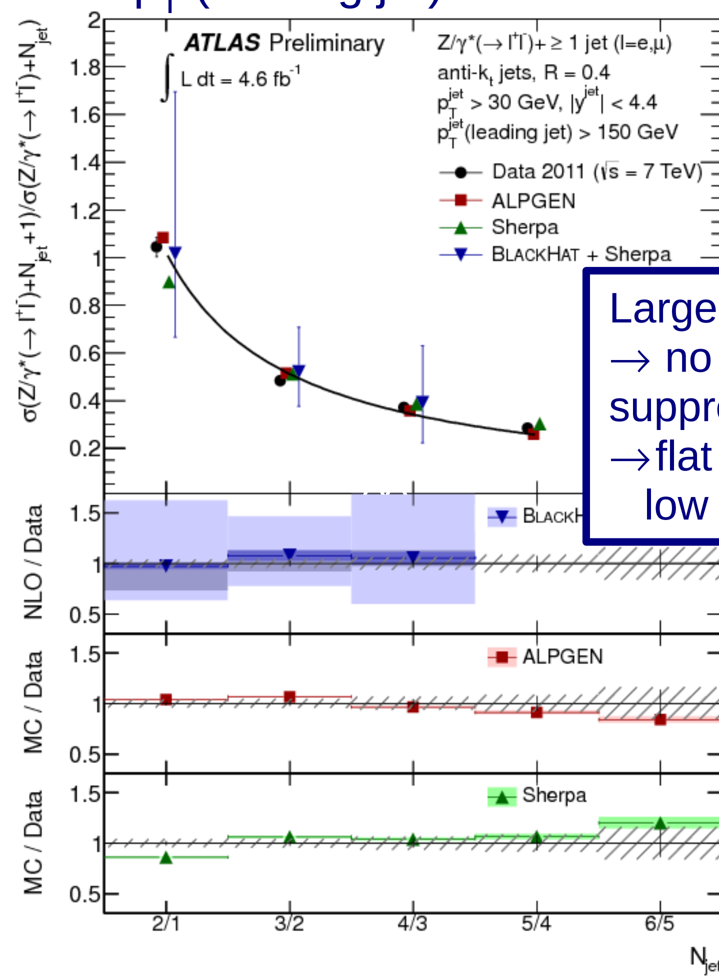
p_T (leading jet) > 30 GeV



PDF suppression
→flat ratio down to
low multiplicities

p_T (leading jet) > 150 GeV

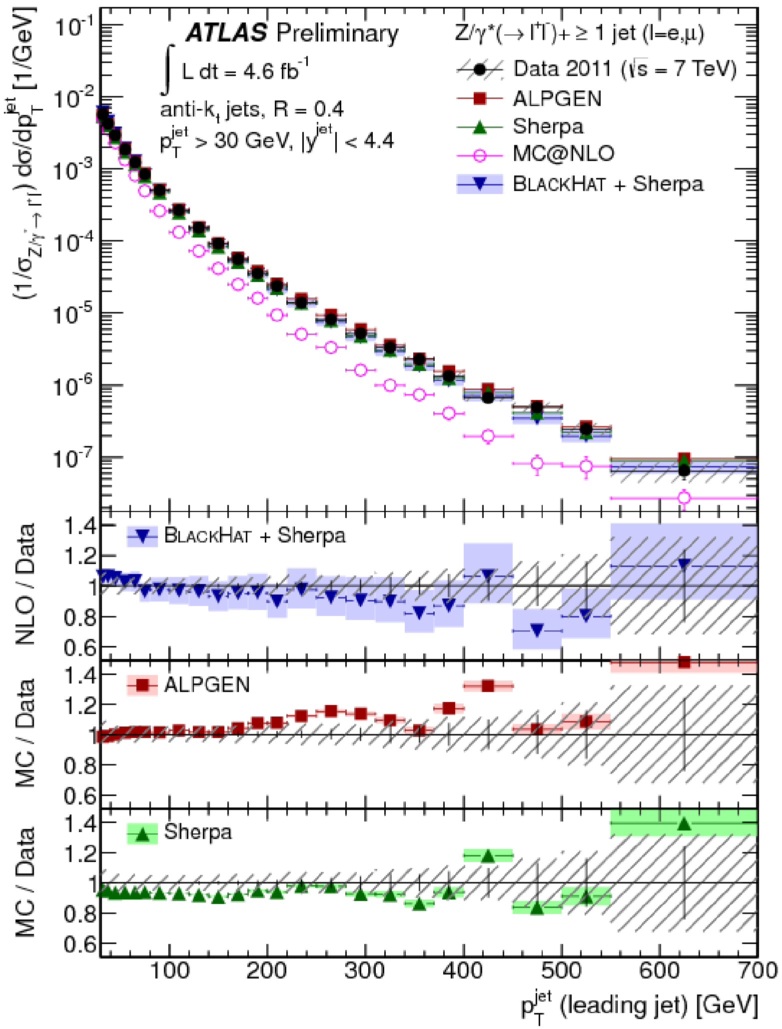


Large scale difference
→ no PDF suppression
→flat ratio down to
low multiplicities

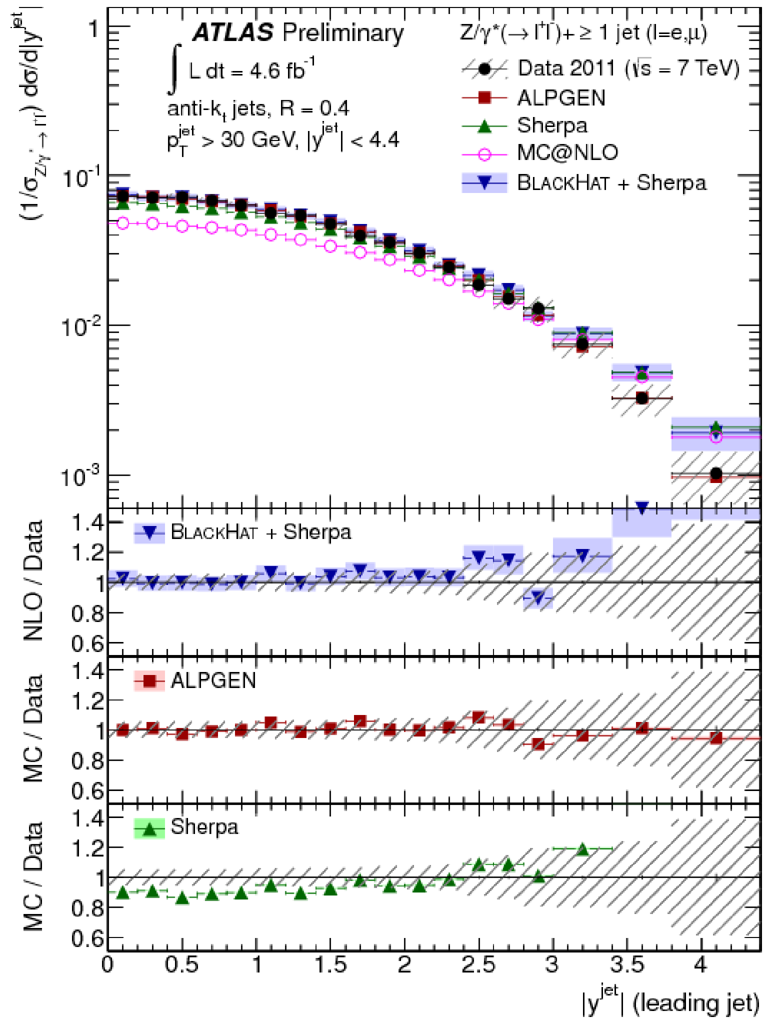
- Change of scaling pattern in general well modeled by nominal pQCD and ME+PS

Results – $d\sigma/dp_T$ and $d\sigma/d|y|$

leading jet p_T



leading jet rapidity

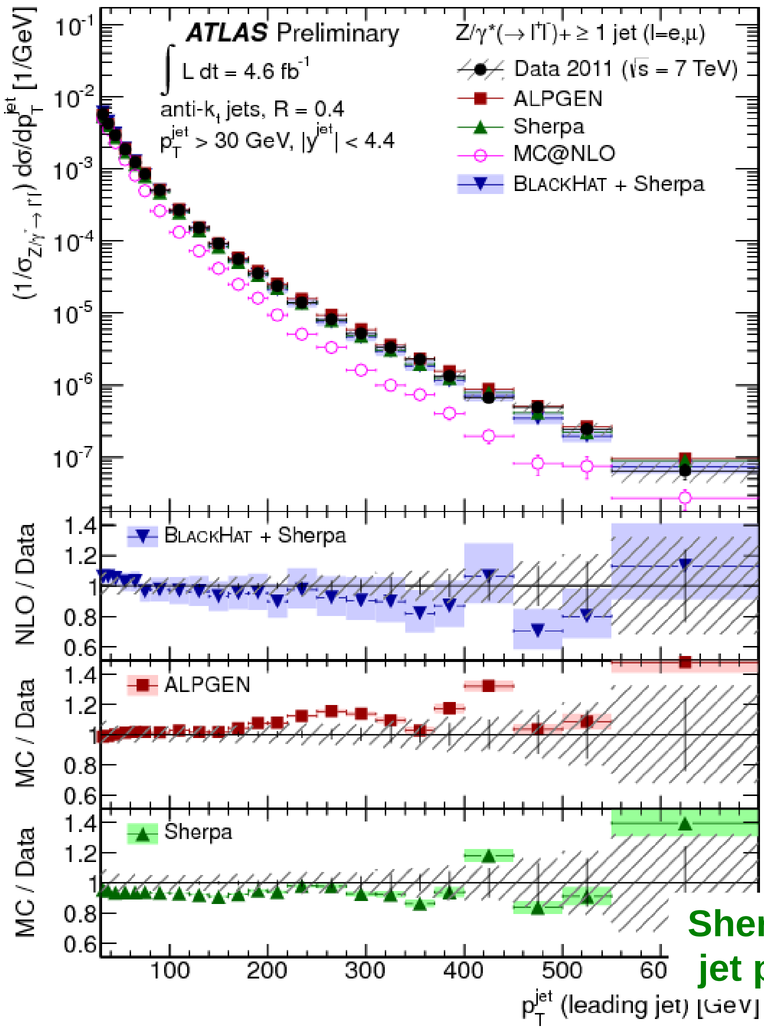


- ALPGEN: overestimates cross section for large p_T
- ➔ missing NLO EW or NLO QCD corrections
- MC@NLO: underestimates cross section

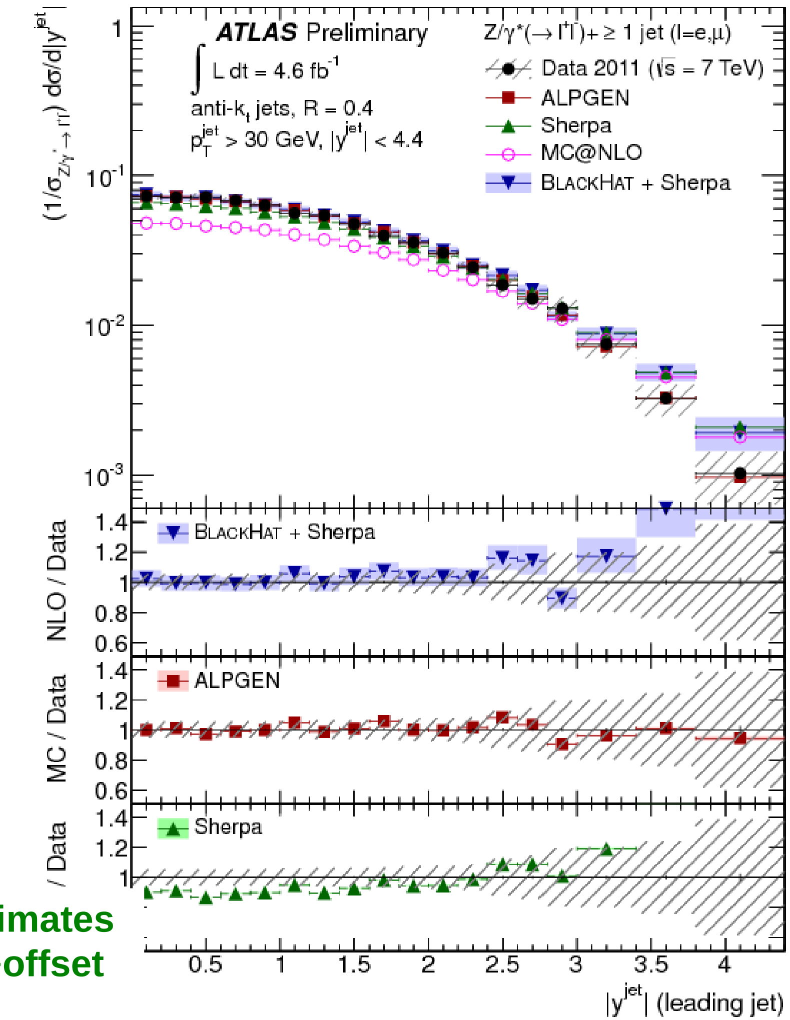
- Sherpa overestimates cross section in forward region
- ➔ systematics (mainly JES) too large for a clear statement

Results – $d\sigma/dp_T$ and $d\sigma/d|y|$

leading jet p_T



leading jet rapidity



Sherpa underestimates jet production →offset

- ALPGEN: overestimates cross section for large p_T
- ➔ missing NLO EW or NLO QCD corrections
- MC@NLO: underestimates cross section

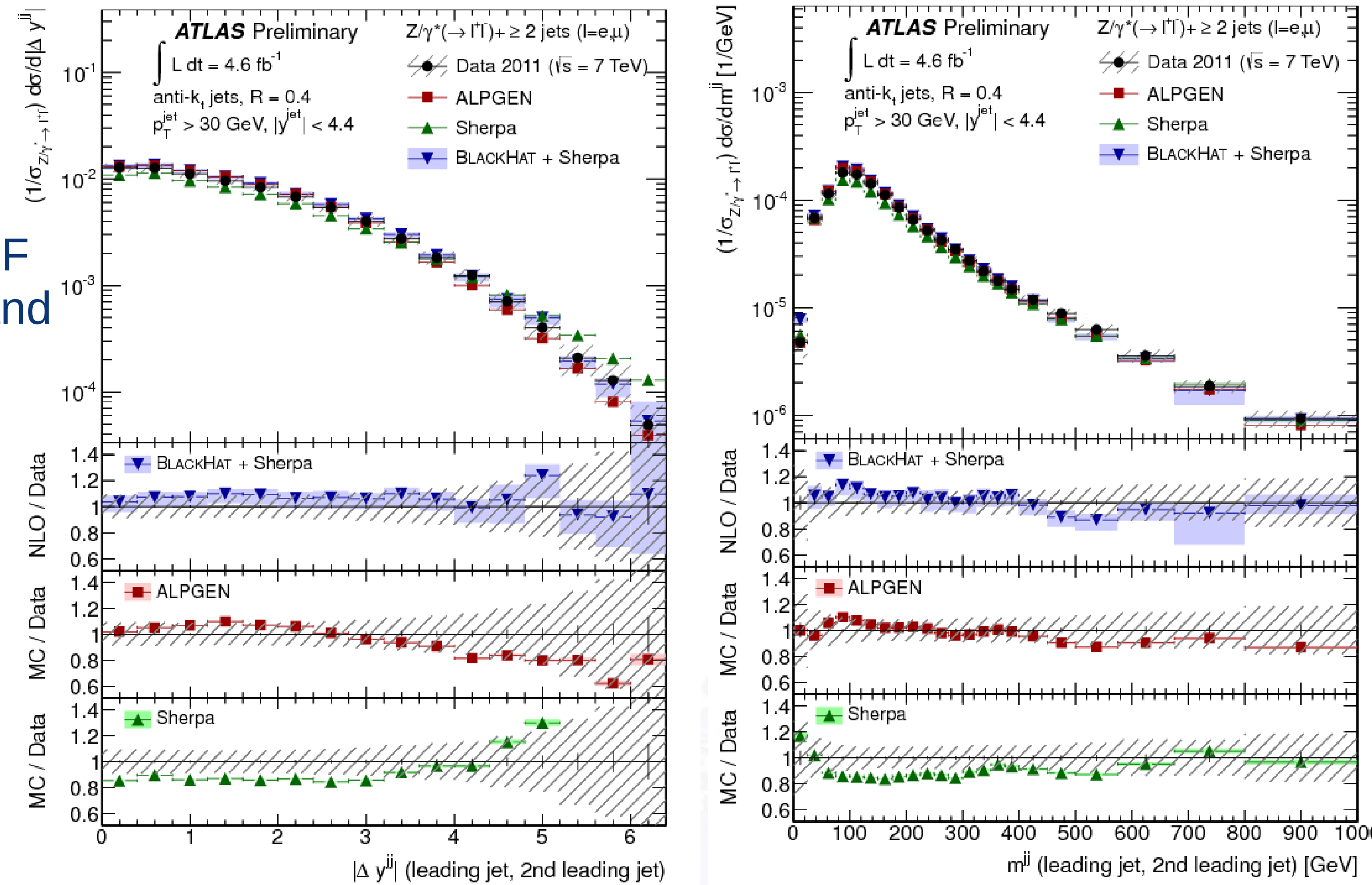
- Sherpa overestimates cross section in forward region
- ➔ systematics (mainly JES) too large for a clear statement

Results – $d\sigma/d|\Delta y^{jj}|$ and $d\sigma/dm^{jj}$

rapidity difference

dijetmass

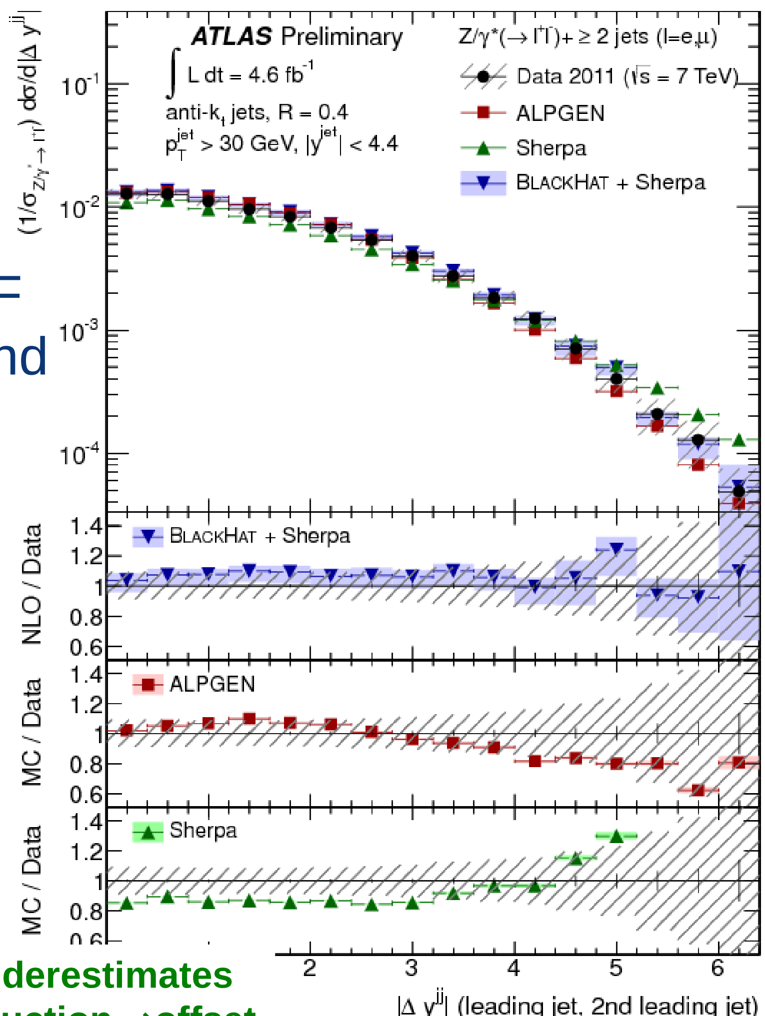
Important for VBF Higgs searches and other searches



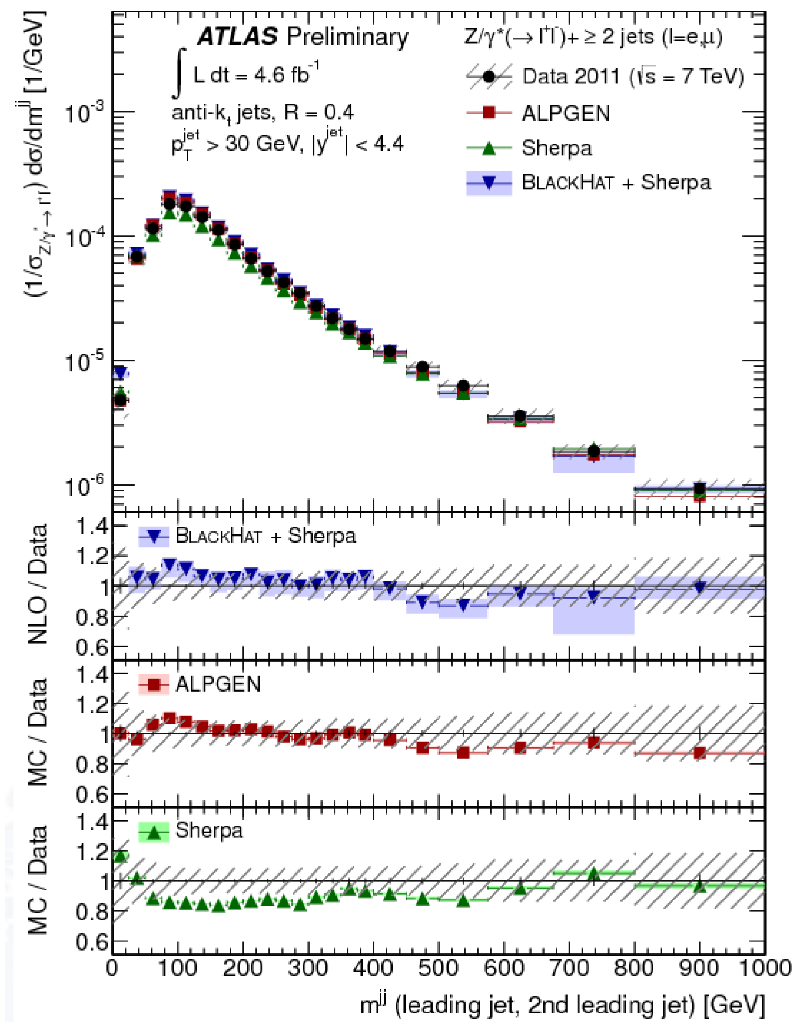
- Tendencies observed in y distribustions are reflected in dijet distributions
- BH+Sherpa/data: good agreement

Results – $d\sigma/d|\Delta y^{jj}|$ and $d\sigma/dm^{jj}$

rapidity difference



dijetmass



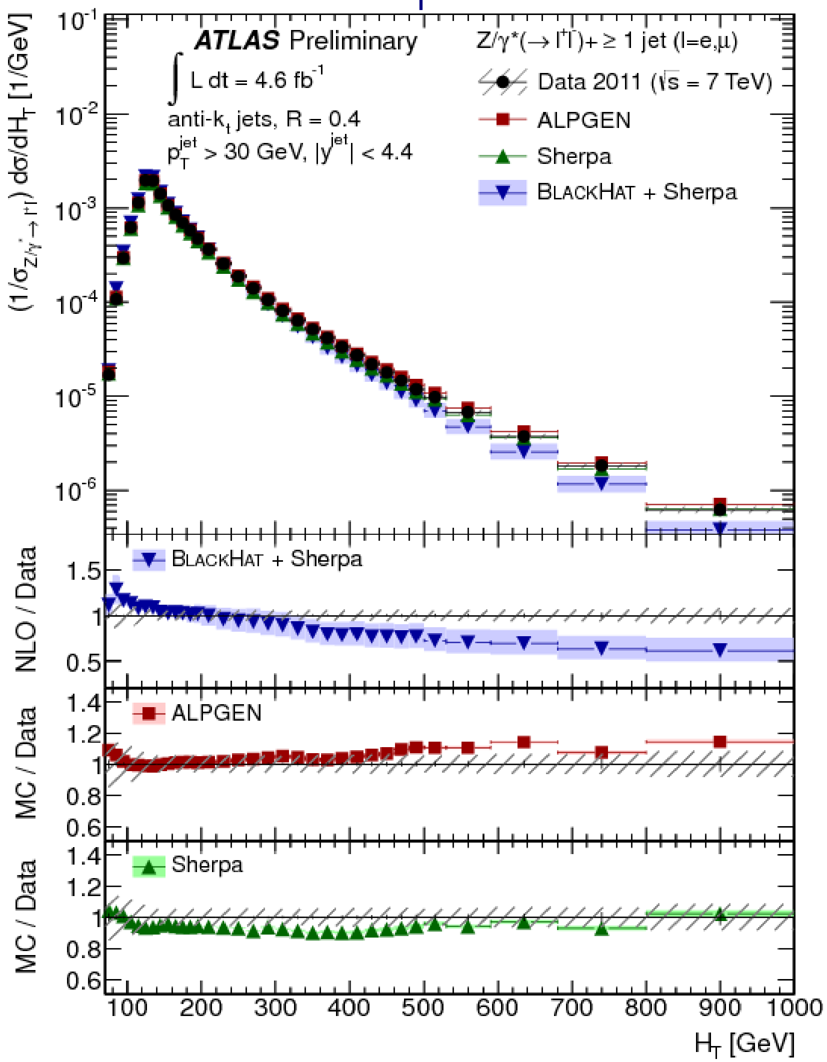
Important for VBF Higgs searches and other searches

Sherpa underestimates 2-jet production →offset

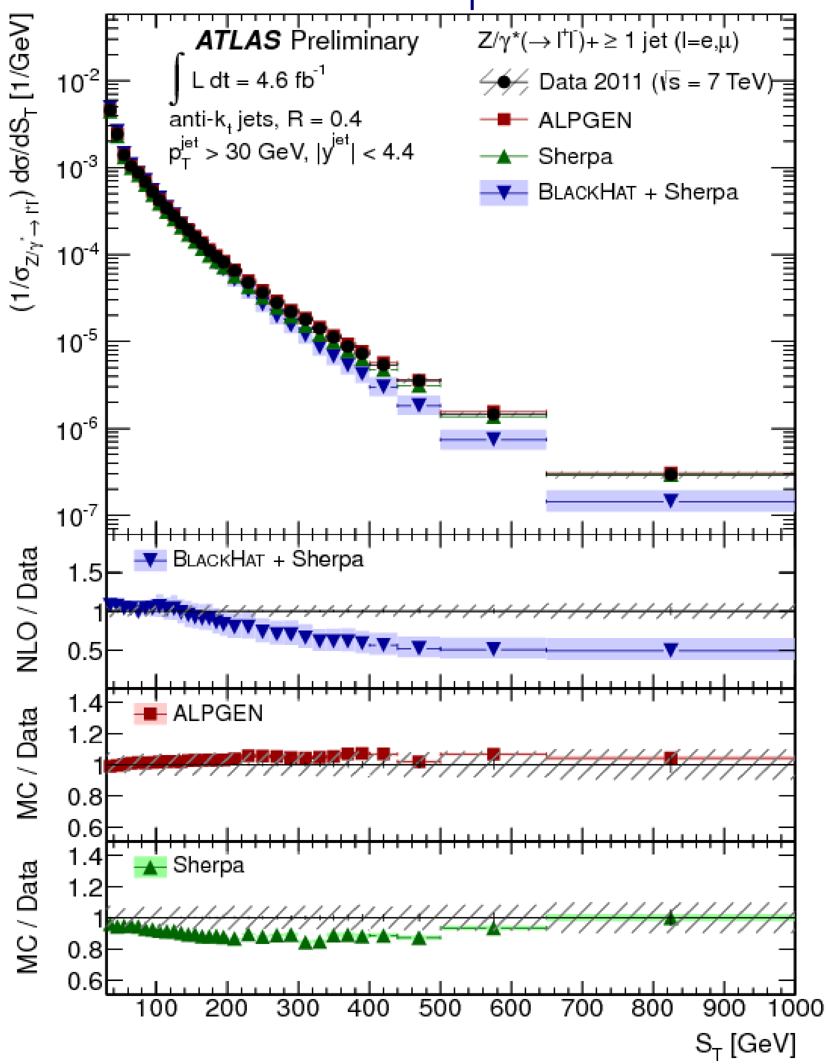
- Tendencies observed in y distribustions are reflected in dijet distributions
- BH+Sherpa/data: good agreement

Resultate - $d\sigma/dH_T$ and $d\sigma/dS_T$

H_T



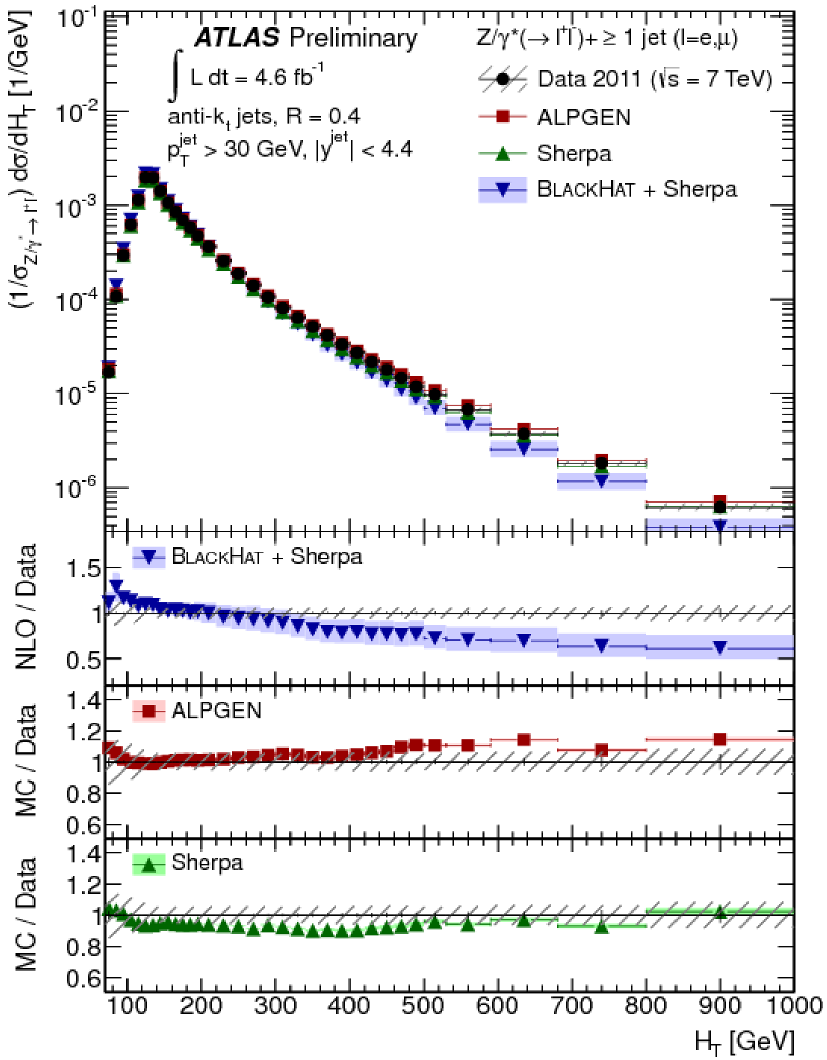
S_T



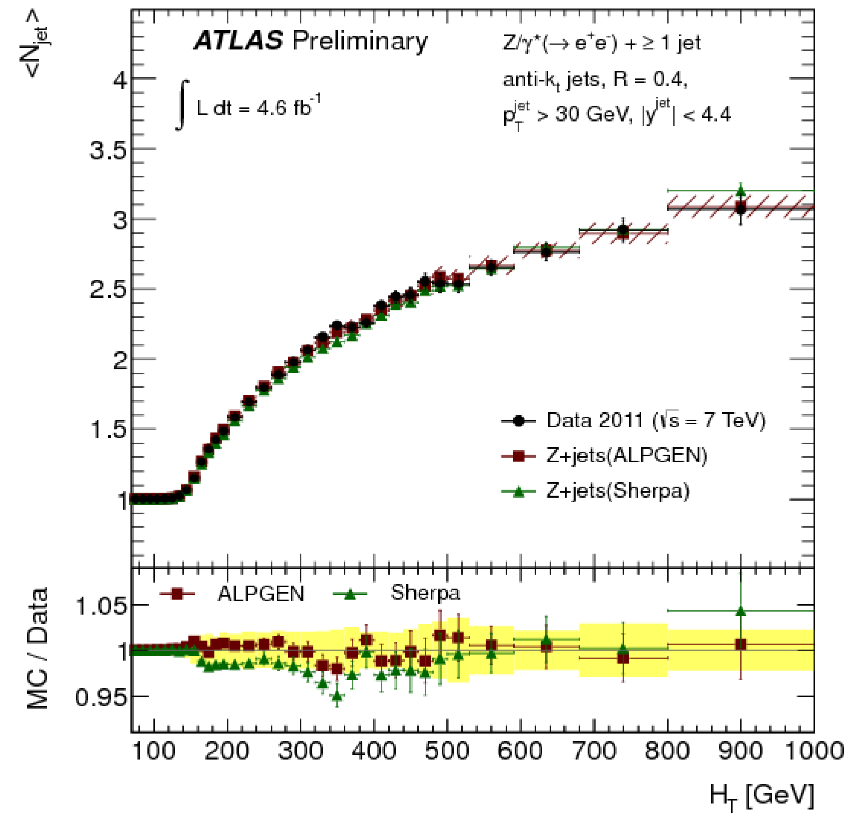
- NLO fixed order Z+≥1 jet underestimates large H_T, S_T
- ALPGEN consistent with data
- Possible explanation: missing higher order in QCD

Resultate - $d\sigma / dH_T$

BH+Sherpa Z+> 1 Jet



Average N_{jet} vs H_T

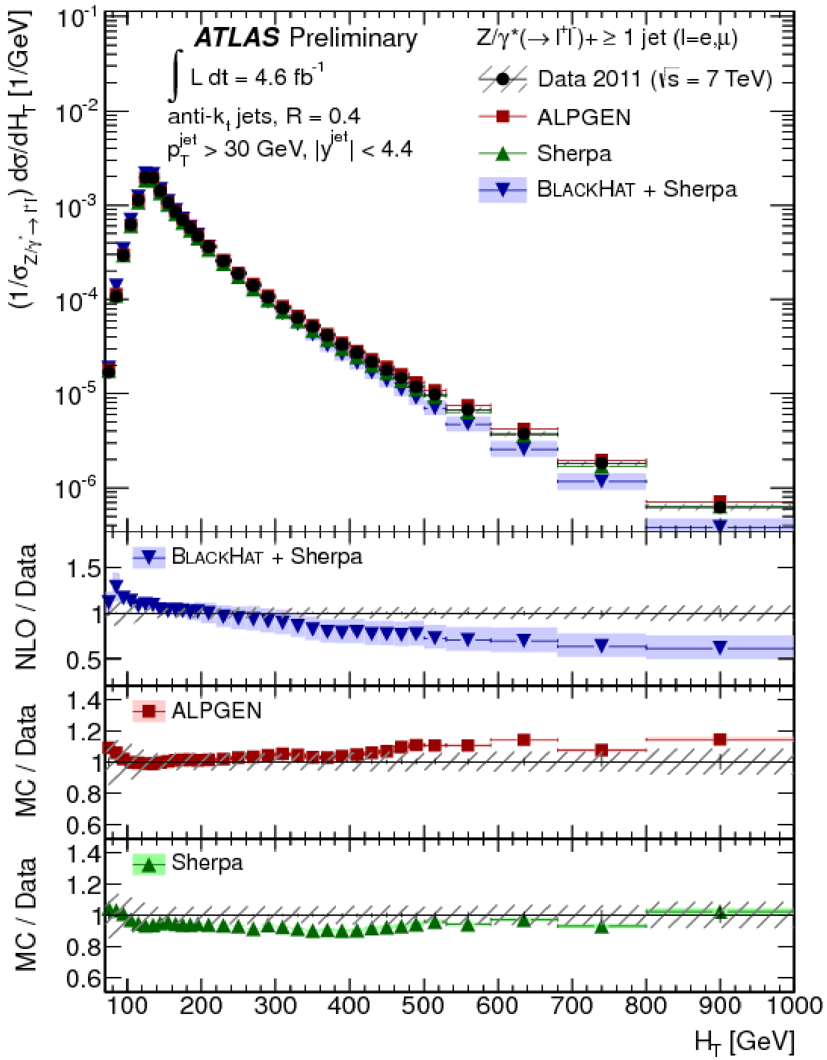


- <Njets> 2 for HT > 300 GeV
- → test exclusive sum

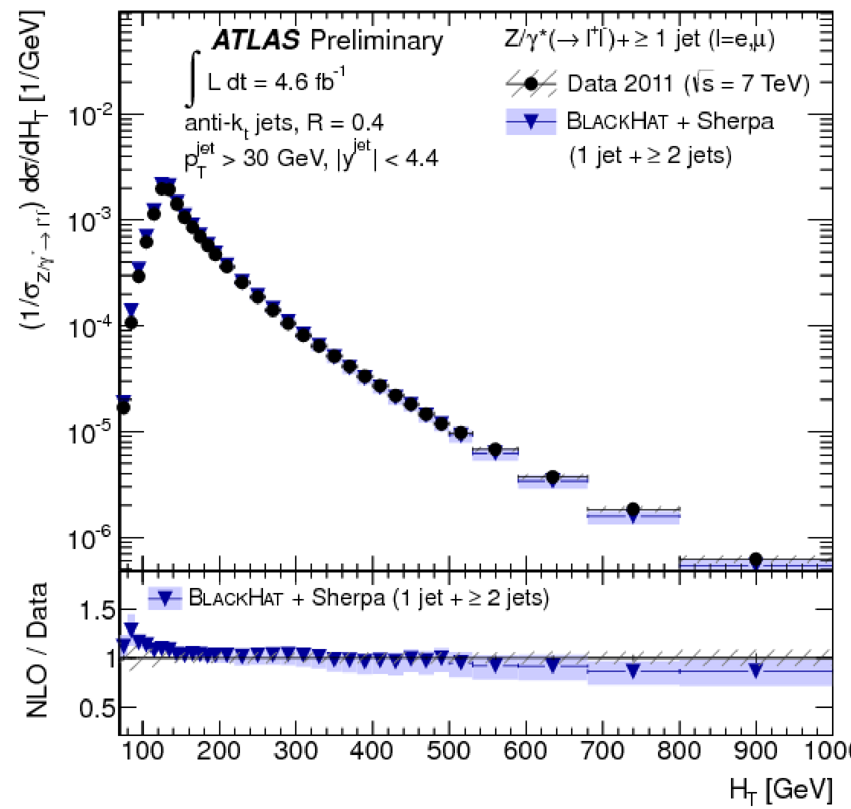
- NLO fixed order Z+≥1 jet underestimates large H_T
- ALPGEN consistent with data
- Possible explanation: missing higher order in QCD

Resultate - $d\sigma / dH_T$

BH+Sherpa Z+≥ 1 Jet



BH 1 Jet + ≥ 2 Jets

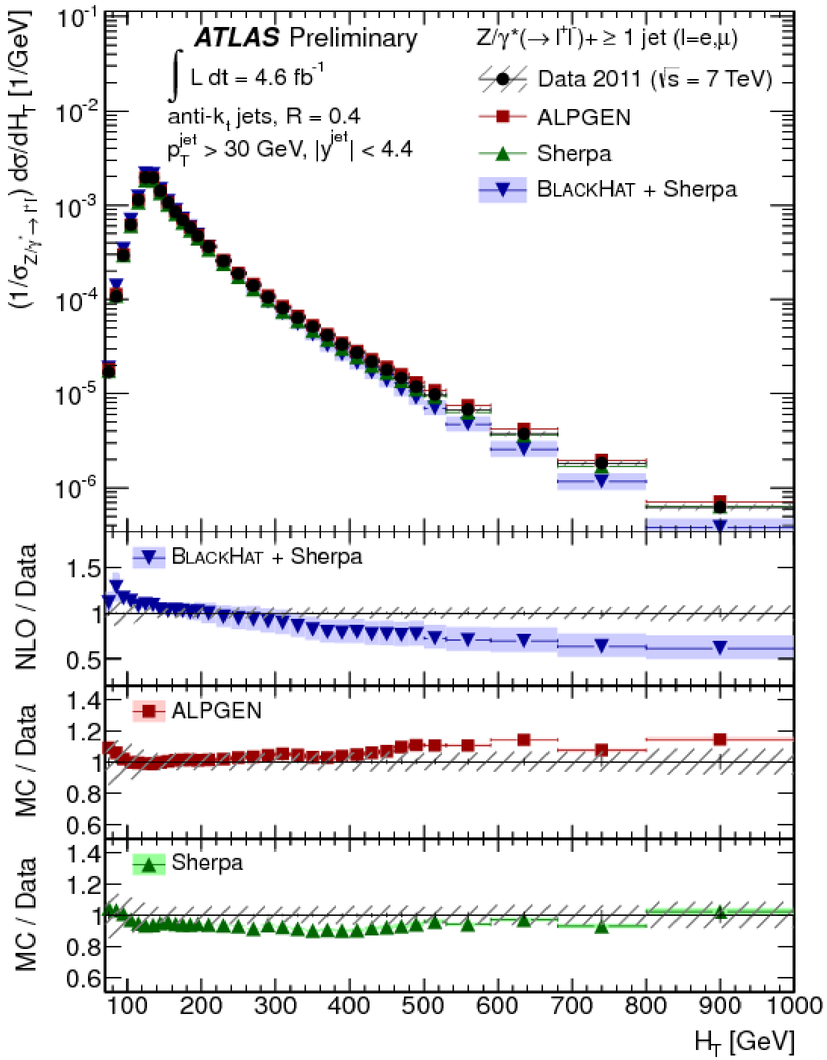


Exclusive sums perform better

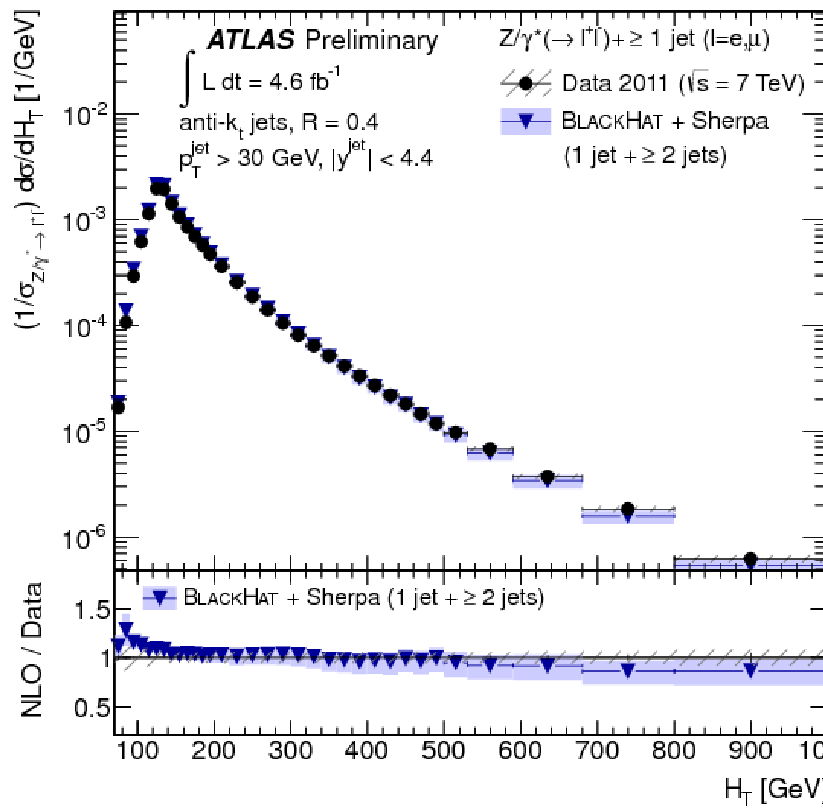
- NLO fixed order Z+≥1 jet underestimates large H_T
- ALPGEN consistent with data
- Possible explanation: missing higher order in QCD

Resultate - $d\sigma/dH_T$

BH+Sherpa Z+≥ 1 Jet



BH 1 Jet + ≥ 2 Jets



Exclusive sums perform better

- NLO fixed order Z+≥1 jet underestimates large H_T
- ALPGEN consistent with data
- Possible explanation: missing higher order in QCD

→ Incorporate higher orders into pQCD calculations for inclusive observables that cover range of jet multiplicities

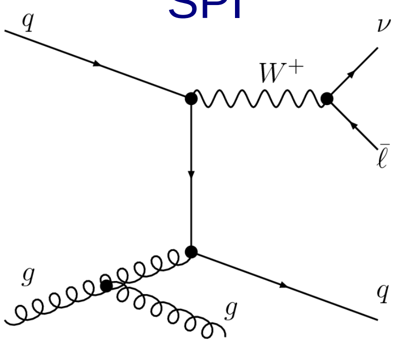
Summary & Conclusion

- Z + jets cross section measurement with full 2011 dataset
  - In general, good agreement between predictions and data
  - Multiplicity ratios: transition between Staircase to Poisson scaling pattern for large scales confirmed
  - Discrepancies for ME+PS generators and data for some phase space regions
    - Jet multiplicity up to 7 jets: well described by ME+PS generators (up to 5 jets) and BH+Sherpa, PS fails
    - Large jet p_T and Z p_T: ME+PS generators overestimate cross section, consistent with predictions for EW corrections
    - Jet rapidity: Sherpa overestimates cross section in forward region
  - Inclusive quantities (e.g. H_T, S_T and Z p_T): limitations of fixed order pQCD predictions, exclusive sums perform better

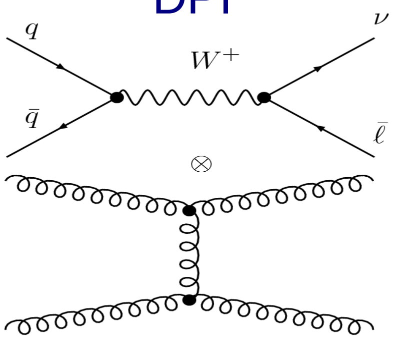
DPI in W + 2 jets

W+2jets production via

SPI



DPI



(Y)

(Z)

DPI cross section: $\hat{\sigma}^{(\mathrm{DPI})}_{Y+Z} = \frac{\hat{\sigma}_Y \cdot \hat{\sigma}_Z}{\sigma_{\mathrm{eff}}}$

σ_{eff}: parameter related to the proton size :
- Naive estimate: 50-70mb
- Tevatron: 5-15mb

$$\hat{\sigma}^{(\mathrm{tot})}_{Y+Z}(s) = \hat{\sigma}^{(\mathrm{SPI})}_{Y+Z}(s) + \hat{\sigma}^{(\mathrm{DPI})}_{Y+Z}(s) = \hat{\sigma}^{(\mathrm{SPI})}_{Y+Z}(s) + \frac{\hat{\sigma}_Y(s) \cdot \hat{\sigma}_Z(s)}{\sigma_{\mathrm{eff}}(s)}$$

$$\rightarrow \quad \sigma_{\mathrm{eff}}(s) = \frac{\hat{\sigma}_Y(s) \cdot \hat{\sigma}_Z(s)}{\hat{\sigma}^{(\mathrm{tot})}_{Y+Z}(s) - \hat{\sigma}^{(\mathrm{SPI})}_{Y+Z}(s)} = \frac{\hat{\sigma}_Y(s) \cdot \hat{\sigma}_Z(s)}{f^{(\mathrm{D})}_{\mathrm{DP}} \cdot \hat{\sigma}^{(\mathrm{tot})}_{Y+Z}(s)}$$

$$\sigma = \frac{N}{\mathcal{A}\, C\, \varepsilon\, \mathscr{L}}$$

- Acceptance A: cancel
- Unfolding corrections C: cancel
- Trigger: $\varepsilon_W = \varepsilon_{W+2j}$

  $\varepsilon_{2J} \approx 1$

In W+jets: $\sigma_{\mathrm{eff}} = \frac{\sigma_{W_{0j}} \cdot \sigma_{2j}}{\sigma_{W_{0j}+2j_{\mathrm{DPI}}}} = \frac{\sigma_{W_{0j}} \cdot \sigma_{2j}}{f^{(\mathrm{D})}_{\mathrm{DP}}\ \sigma_{W+2j}} = \frac{1}{f^{(\mathrm{D})}_{\mathrm{DP}}} \cdot \frac{N_{W_{0j}}}{N_{W+2j}} \cdot \frac{N_{2j}}{\mathcal{L}_{2j}}$

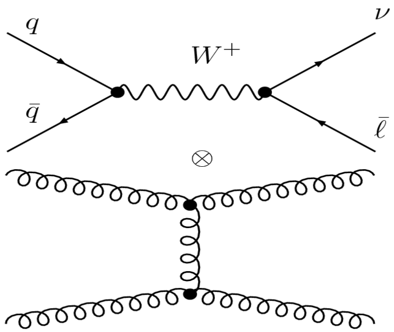
$f^{(\mathrm{D})}_{\mathrm{DP}}$: Fraction of DPI-produced W+2j events at detector level

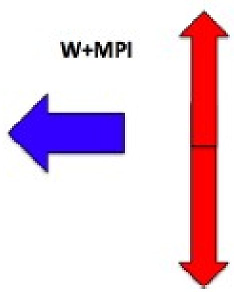
Measurement strategy

Normalized transverse momentum balance: $\Delta^{\mathrm{n}}_{\mathrm{jets}} = \frac{|\vec{p}_{\mathrm{T}}^{\,J_1} + \vec{p}_{\mathrm{T}}^{\,J_2}|}{|\vec{p}_{\mathrm{T}}^{\,J_1}| + |\vec{p}_{\mathrm{T}}^{\,J_2}|}$

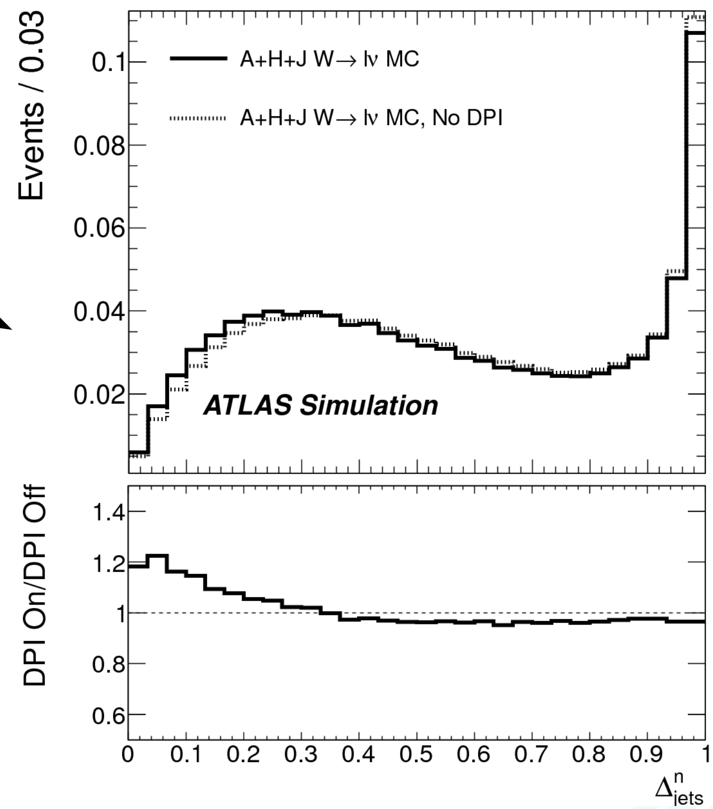
➔ extract fraction of DPI-produced events f_{DP}
using a fit with two templates: $(1 - f_{\mathrm{DP}}^{(\mathrm{D})}) \cdot A + f_{\mathrm{DP}}^{(\mathrm{D})} \cdot B$

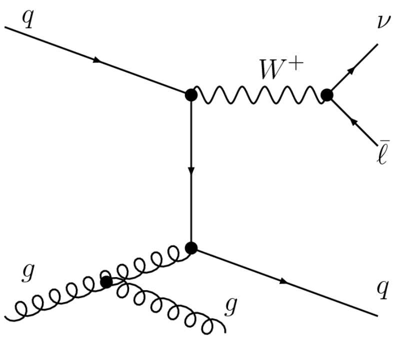
- A: DPI off: Alpgen+Herwig+Jimmy W+2jets
  hard MPI removed: p_T^{max} = 15GeV
- B: DPI: Dijets from data (2010, 184μb^{-1})

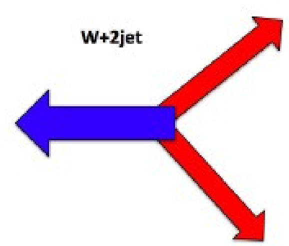




$\Delta^{\mathrm{n}}_{\mathrm{jets}}$ small

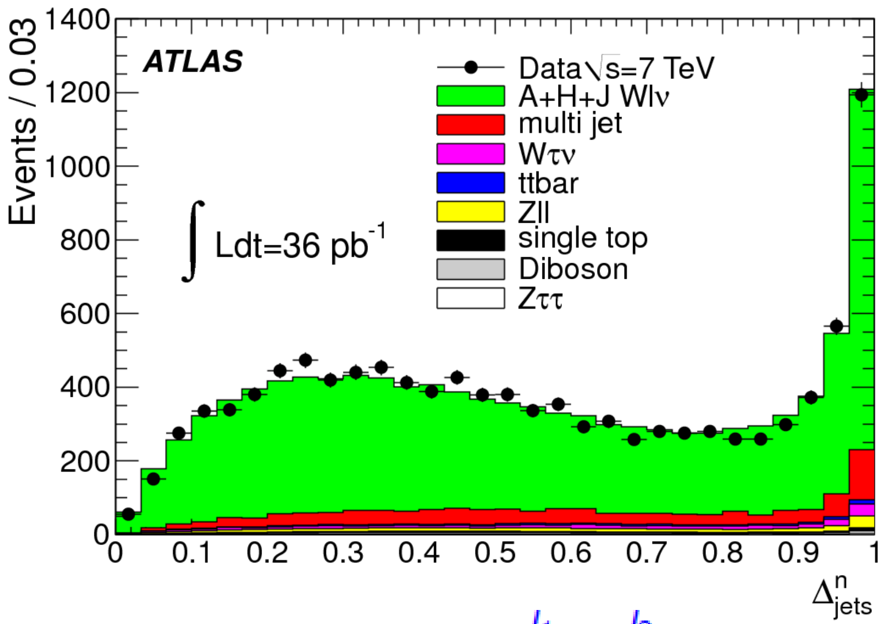




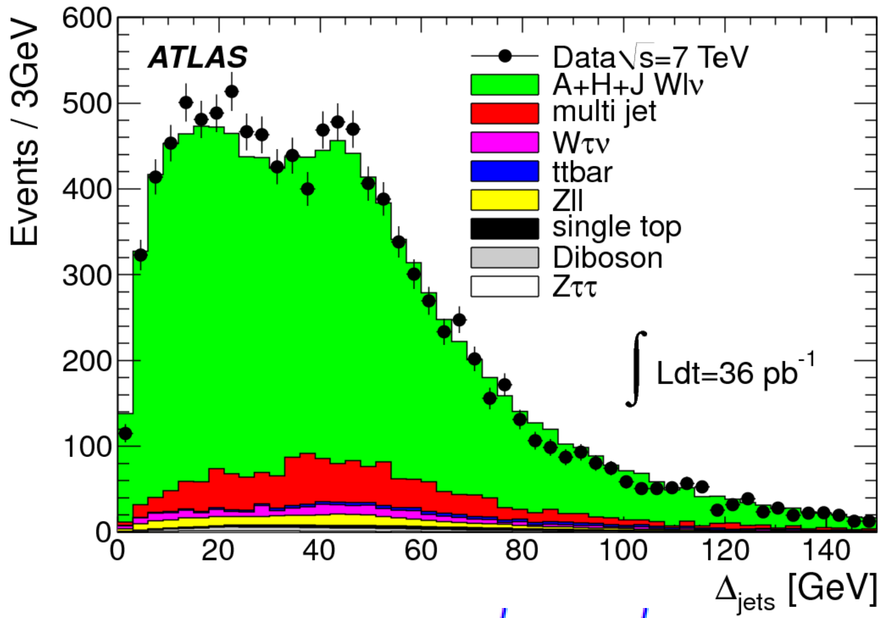


$\Delta^{\mathrm{n}}_{\mathrm{jets}}$ large

Distribution of observables



$$\Delta^{n}_{jets} = \frac{|\vec{p}_T^{J_1} + \vec{p}_T^{J_2}|}{|\vec{p}_T^{J_1}| + |\vec{p}_T^{J_2}|}$$



$$\Delta_{jets} = |\vec{p}_T^{J_1} + \vec{p}_T^{J_2}|$$

W, W+2jets: using 2010 data (36 pb^{-1})

Selection:

Leptons: p_T^l>20 GeV and |η|<2.4 (|η|<2.47, exclude cracks)

Etmiss, mT: E_t^{miss}>25 GeV and m_T > 40 GeV

Jets: p_T> 20 GeV, |y|<2.8 and $\Delta R(jl) > 0.5$

Backgrounds:

- multi-jet: 6-14%, data driven
- EW, top: 5-8%, MonteCarlo

Signal MC:

- Alpgen+Herwig+Jimmy, AUET tune
- Sherpa 1.31

Extraction of results: Uncertainties

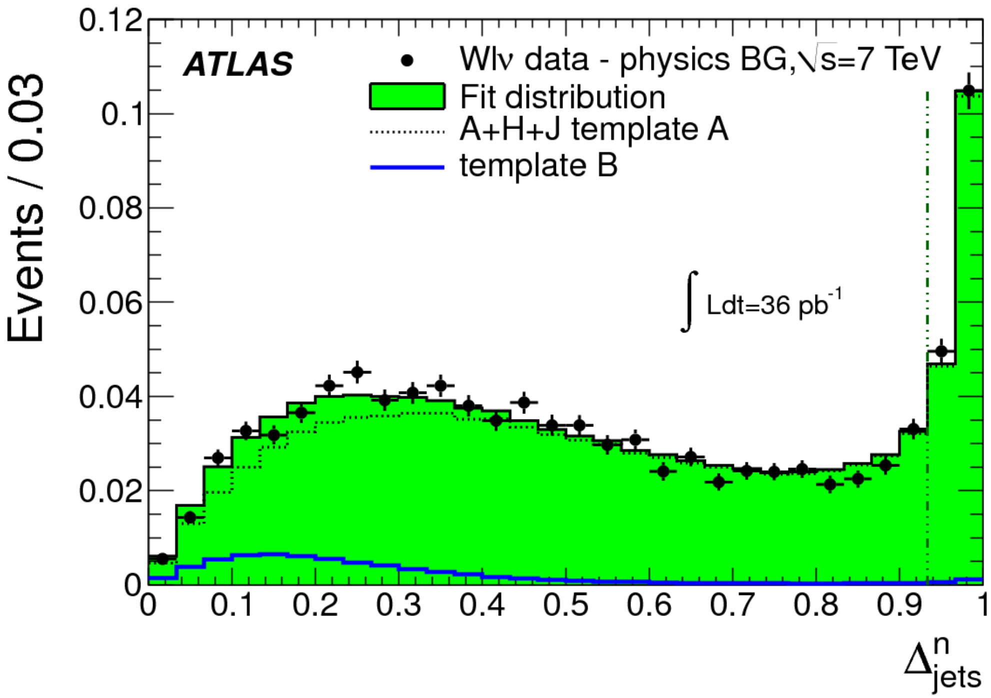


Table 1. Summary of the fractional uncertainties on $f_{\mathrm{DP}}^{(\mathrm{D})}$

Systematic source	Uncertainty (%)
Theory	10
Pile-up	13
Jet energy scale	12
Jet energy resolution	8
Background modelling and lepton response	11
Total systematic	24
Total statistical	17

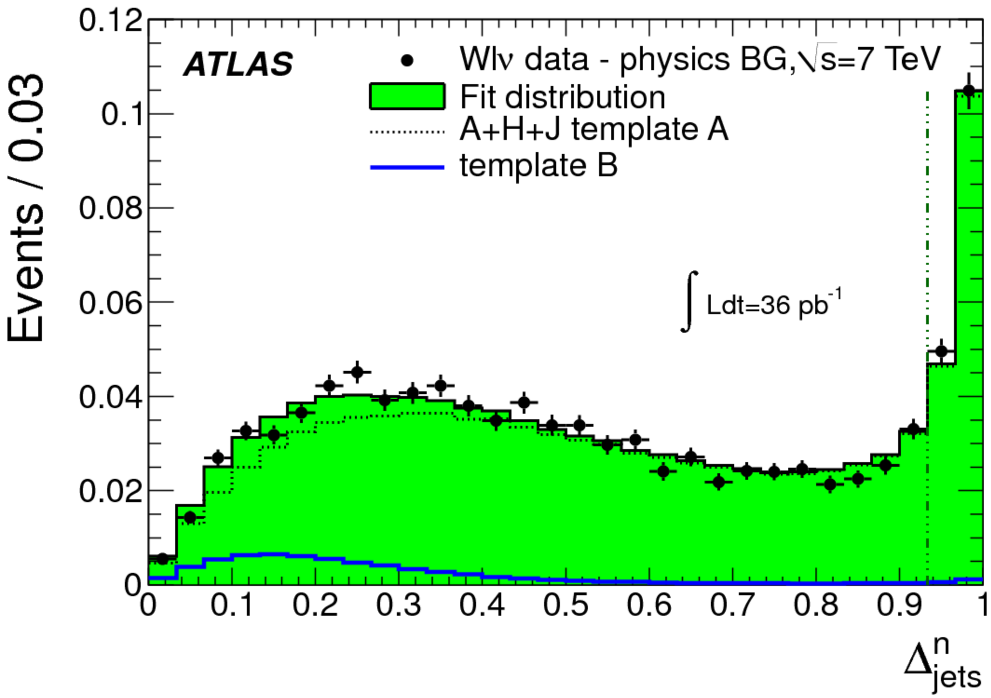
→

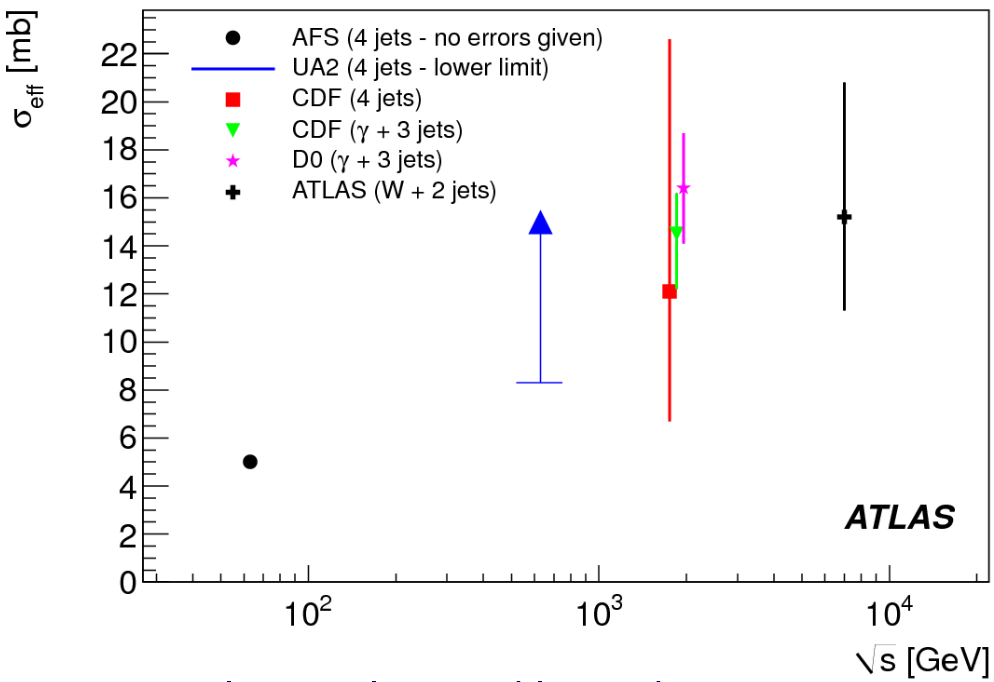
Fractional uncertainties on

$$\sigma_{\mathrm{eff}} = 1/f_{\mathrm{DP}}^{(\mathrm{D})} \cdot N_{W_{0j}} / N_{W+2j} \cdot N_{2j} / \mathcal{L}_{2j}$$

Systematic source	Uncertainty (%)
$f_{\mathrm{DP}}^{(\mathrm{D})}$	24
Background and lepton response	5
Luminosity	3
Total systematic	$^{+33}_{-20}$
Total statistical	17

Extraction of results





Results consistent with previous measurements at lower energies

$$f_{DP}^{(D)} = 0.08 \pm 0.01\ (\text{stat.}) \pm 0.02\ (\text{sys.})$$

$$\rightarrow \sigma_{\text{eff}}(7\ \text{TeV}) = 15 \pm 3\ (\text{stat.})\ ^{+5}_{-3}\ (\text{sys.})\ \text{mb}$$

Direct comparison with theory: $f_{DP}^{(P)}$

→ unfold distributions to the hadron level:

$$p_T^P \geqslant 20\,\text{GeV}, \quad |y^P| \leqslant 2.8 \quad \text{and} \quad \Delta R_{P\ell} > 0.5$$

→ fit unfolded distributions

→ results within 10% of detector level results, as expected

Summary and Conclusion

- Measurement of hard double-parton interactions in W + 2 jets events
  - Fraction of DPI events in W+2jets data was extracted from a template fit to normalized transvere momentum balance
  - σ_{eff} has been calculated from f_{DP}, value consistent with earlier measurements based on lower cms energies

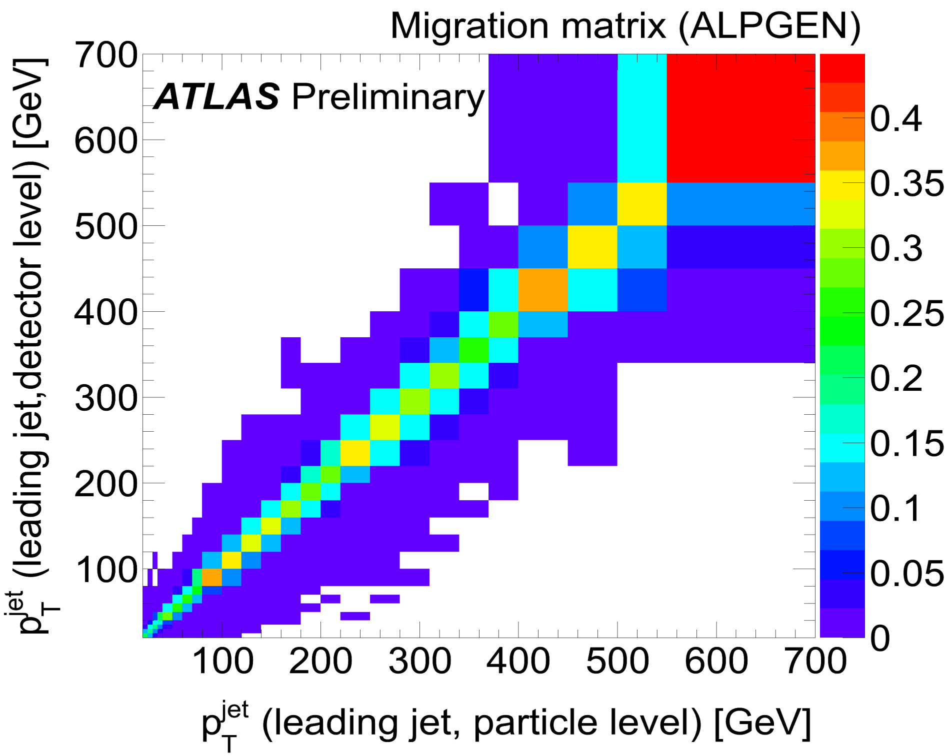
Back-Up

Unfolding for detector effects

- Differential cross sections: fiducial region for dressed leptons and particle level jets
  Dressed leptons: photons within cone of 0.1 around lepton direction
- Unfolding method: iterative (Bayes) method (Nucl. Instrum. Meth. A 362 (1995) 487)
  - Trainings sample: ALPGEN+HERWIG+JIMMY
  - Correction for mis-matched jets and different hierarchy at reco and truth level
  - Number of iterations optimized for each distribution by minimizing χ^2 between unfolded and truth Sherpa and MC@NLO pseudodata

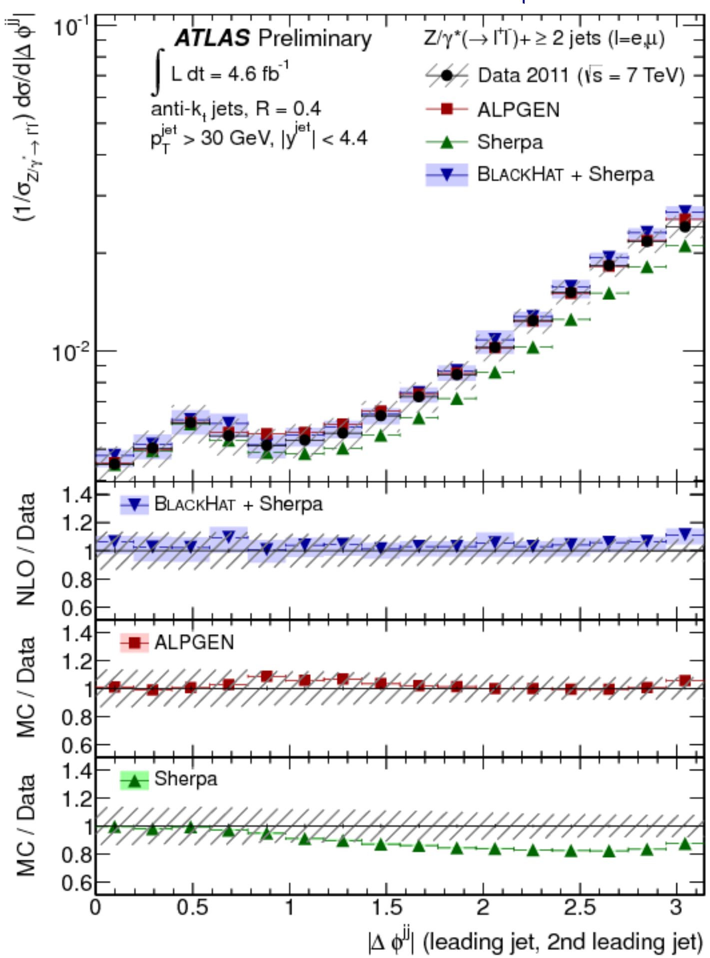
$$\chi^2 = \sum_i \frac{(U_i - T_i)^2}{(\delta T_i)^2}$$

- Dominant systematic uncertainties:
  - Comparison of unfolded cross sections using Alpgen and Sherpa as training sample
  - Limited MC statistics in migration matrix

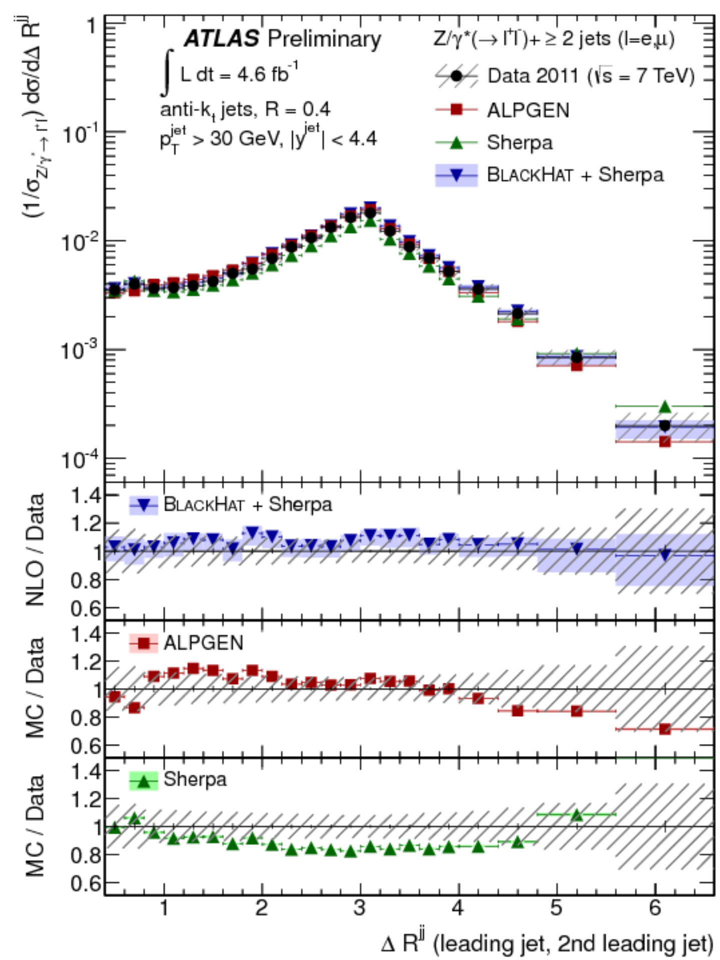


Results – $d\sigma/d|\Delta\phi^{jj}|$ and $d\sigma/dR^{jj}$

difference in ϕ



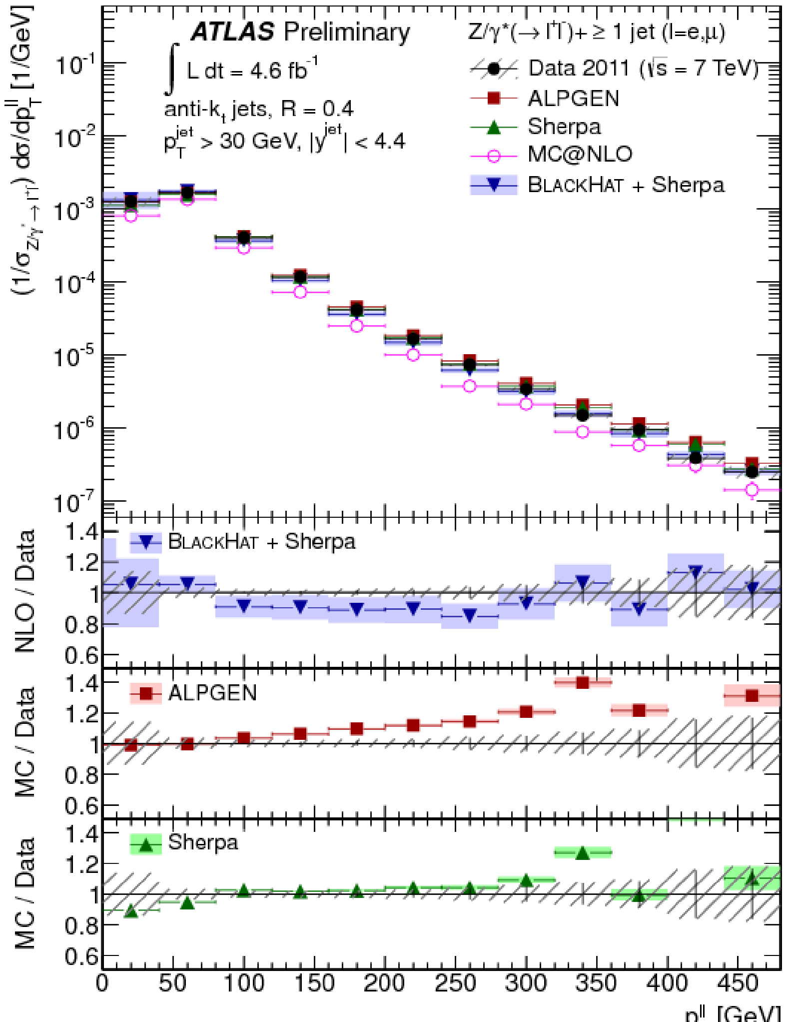
difference in R



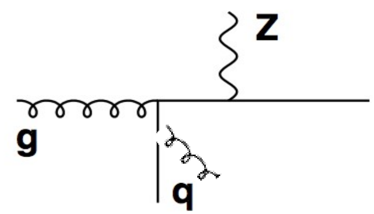
- Sherpa/data: distributions too flat
- ALPGEN/data: discrepancies for large ΔR^{jj}
- BH+Sherpa/data: good agreement

Results – dσ /dp$_T^Z$

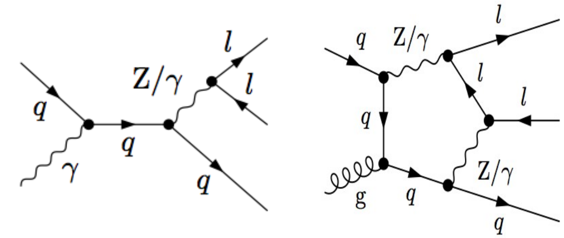
BH+Sherpa Z+ ≥ 1 Jet

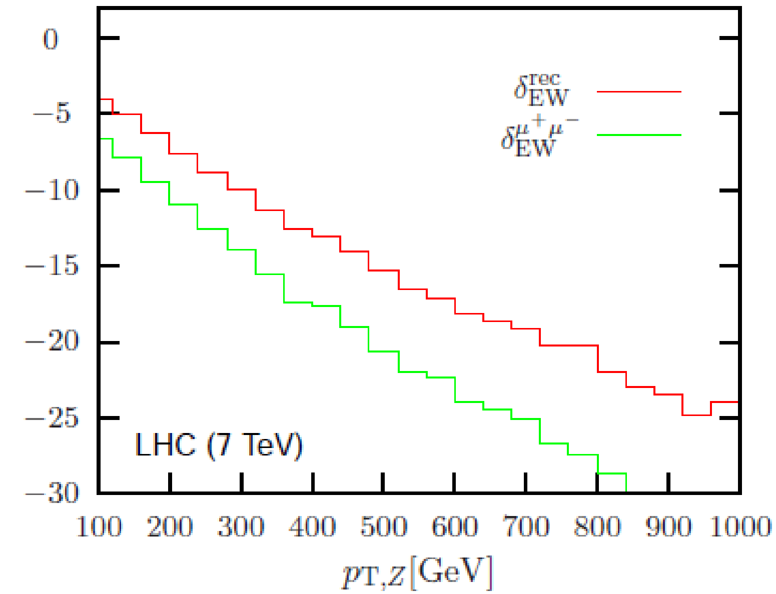


QCD higher orders



Large EW NLO effects





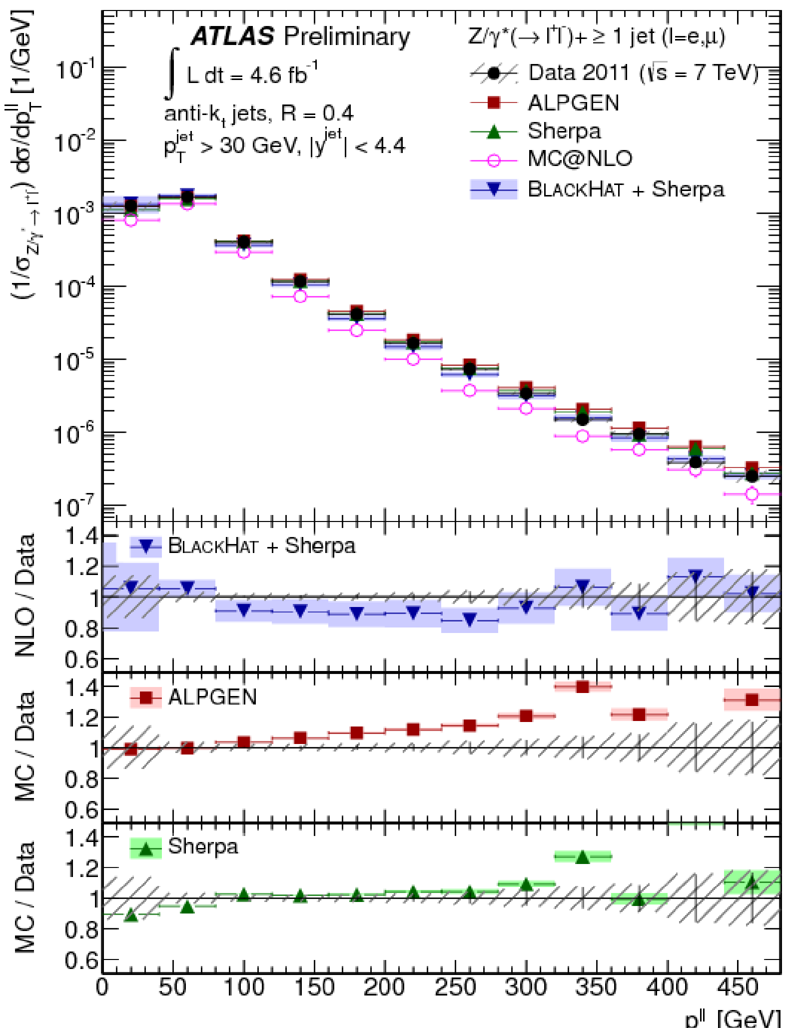
Denner et al, JHEP06 (2011) 069, 7TeV: A. Mueck

factorize for pT(Z), exclusive pT(jet)

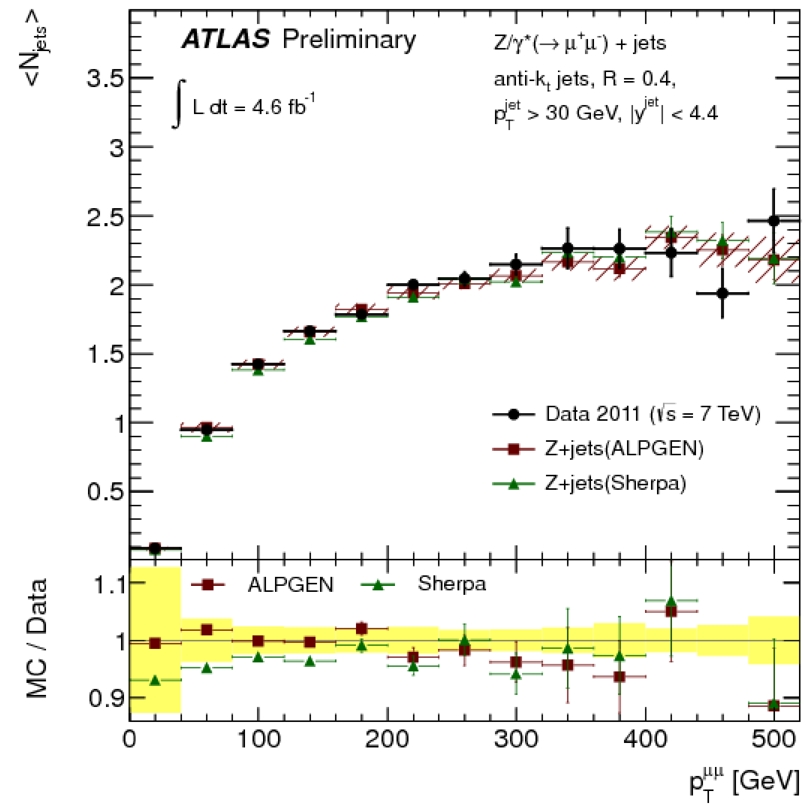
- NLO fixed order Z+≥1 jet underestimate large Z p_T
- ALPGEN: overestimates large Z p_T, consistent with NLO EW, expect HO QCD as well

Resultate - $d\sigma / dp_T^Z$

BH+Sherpa Z+ ≥ 1 Jet



Average N_{jet} vs Z P_T

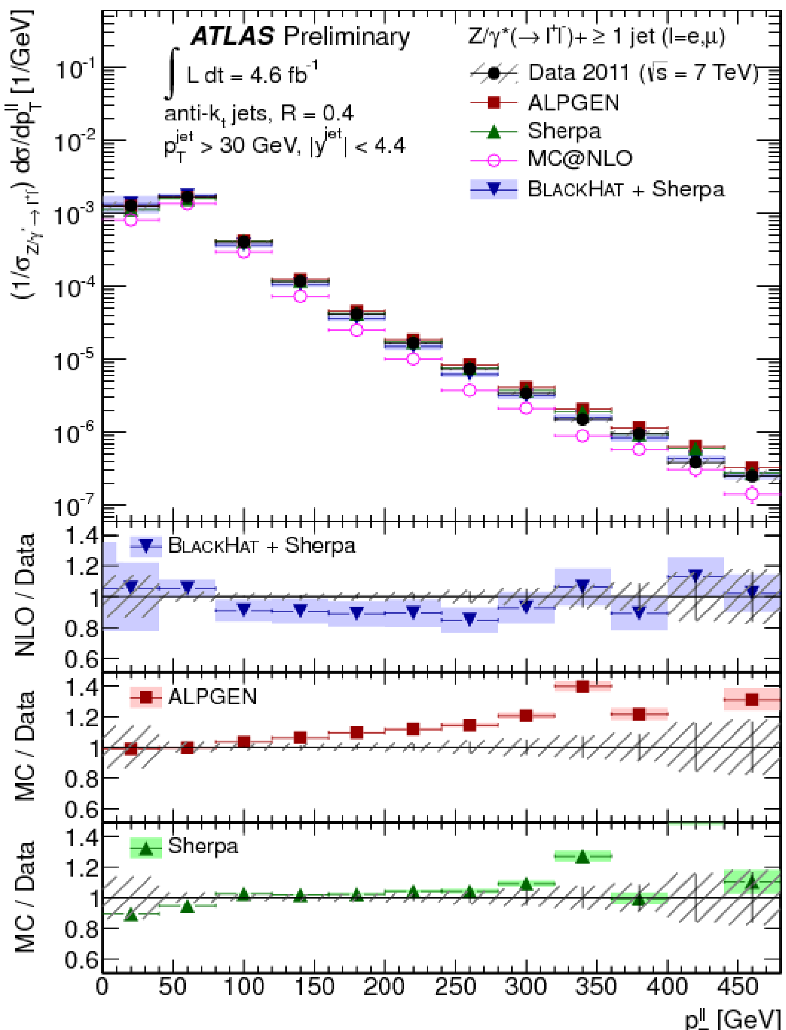


- NLO fixed order Z+≥1 jet underestimate large Z p_T
- ALPGEN: overestimates large Z p_T, consistent with NLO EW, expect HO QCD as well

- <Njets> ~2 above pT=160 GeV
- Large scale difference between the two jets seems not well modelled for NLO fixed order Z+≥1 jet

Resultate - $d\sigma / dp_T^Z$

BH+Sherpa Z+ ≥ 1 Jet



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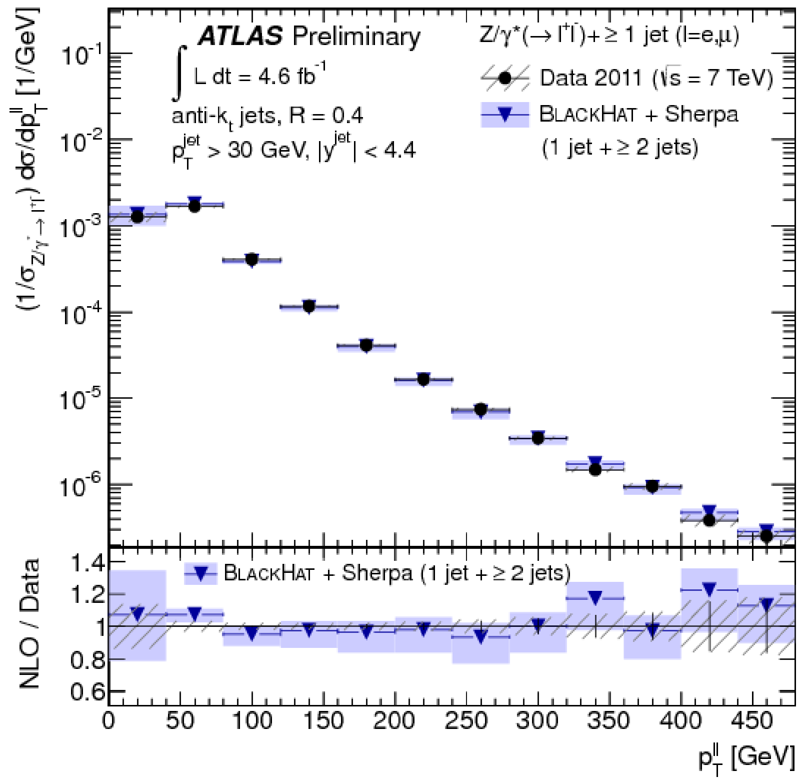
BH+Sherpa 1 Jet + ≥ 2 Jets

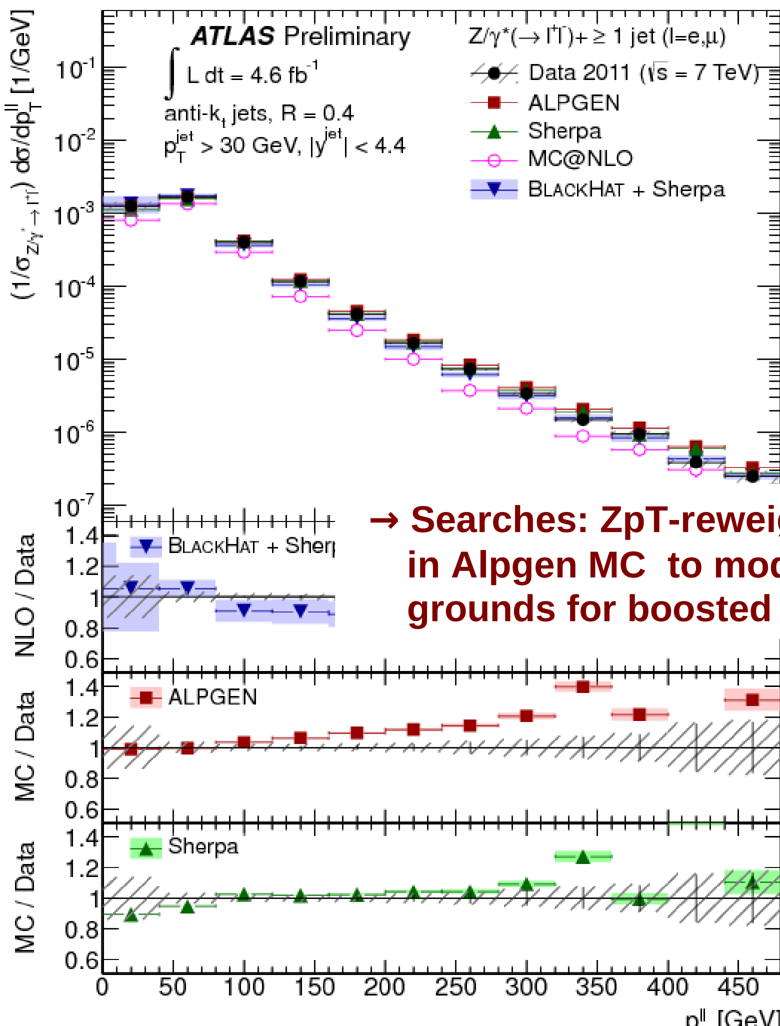
(Phys. Rev. D85 (2012) 092002)



Exclusive sums perform better

Resultate - $d\sigma / dp_T^Z$

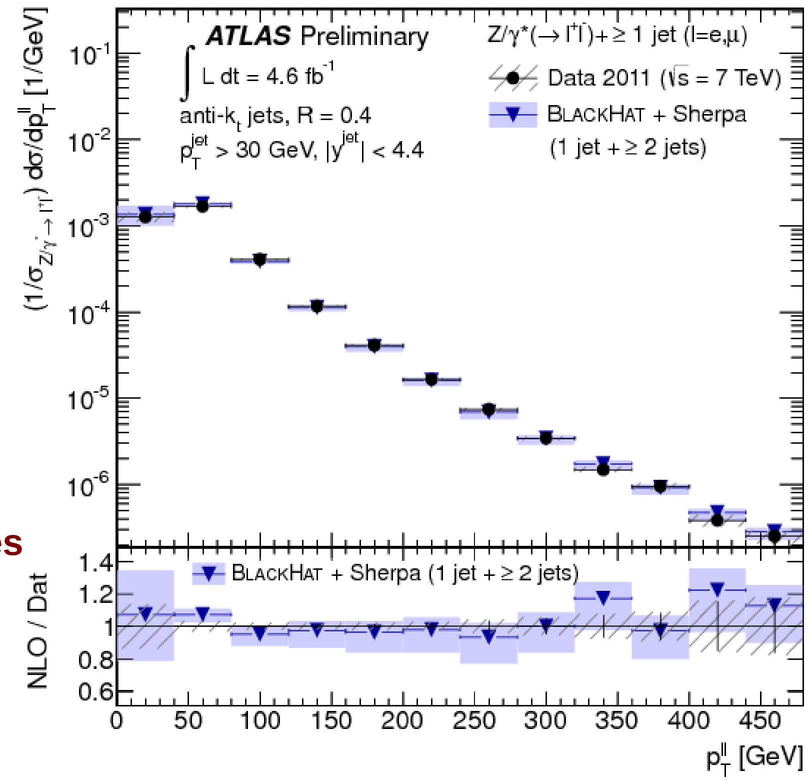
BH+Sherpa Z+ ≥ 1 Jet



→ **Searches: ZpT-reweighting in Alpgen MC to model back-grounds for boosted topologies**

BH+Sherpa 1 Jet + ≥ 2 Jets

(Phys. Rev. D85 (2012) 092002)



Exclusive sums perform better

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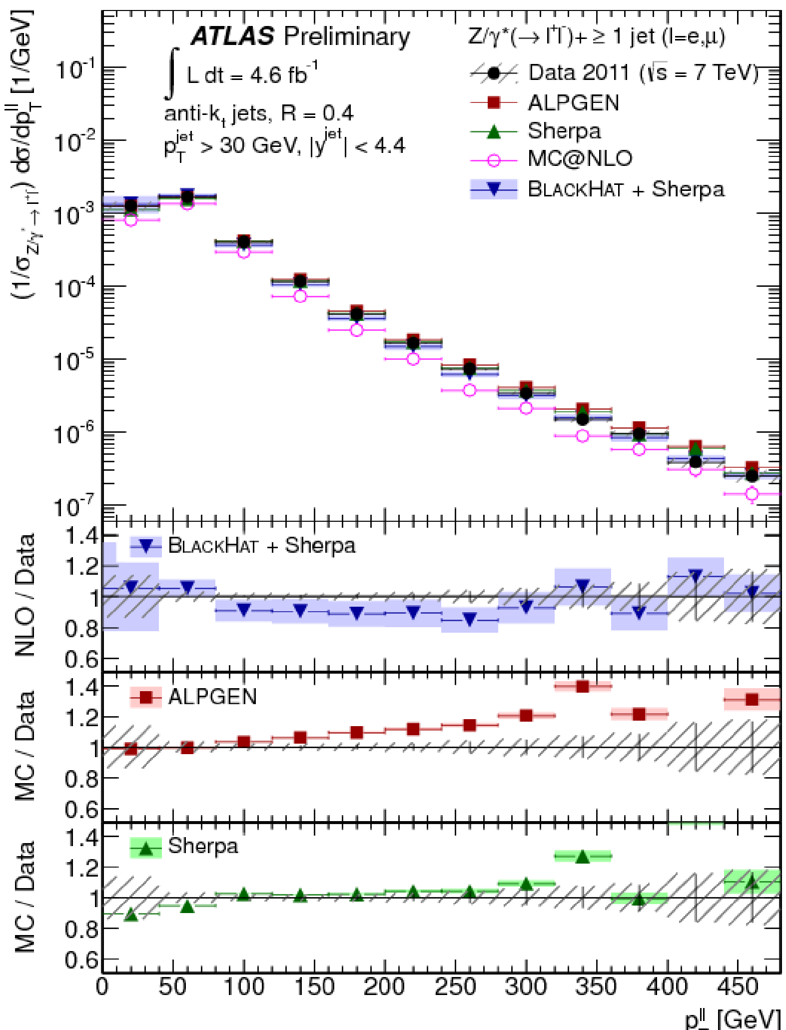
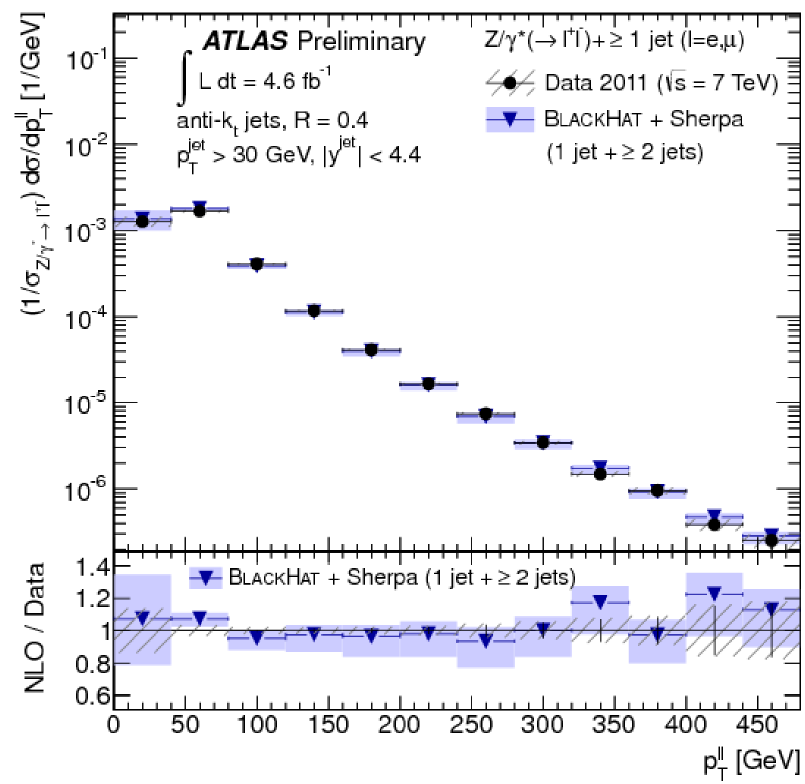
Resultate - $d\sigma / dp_T^Z$

BH+Sherpa Z+ ≥ 1 Jet



BH+Sherpa 1 Jet + ≥ 2 Jets

(Phys. Rev. D85 (2012) 092002)



Exclusive sums perform better

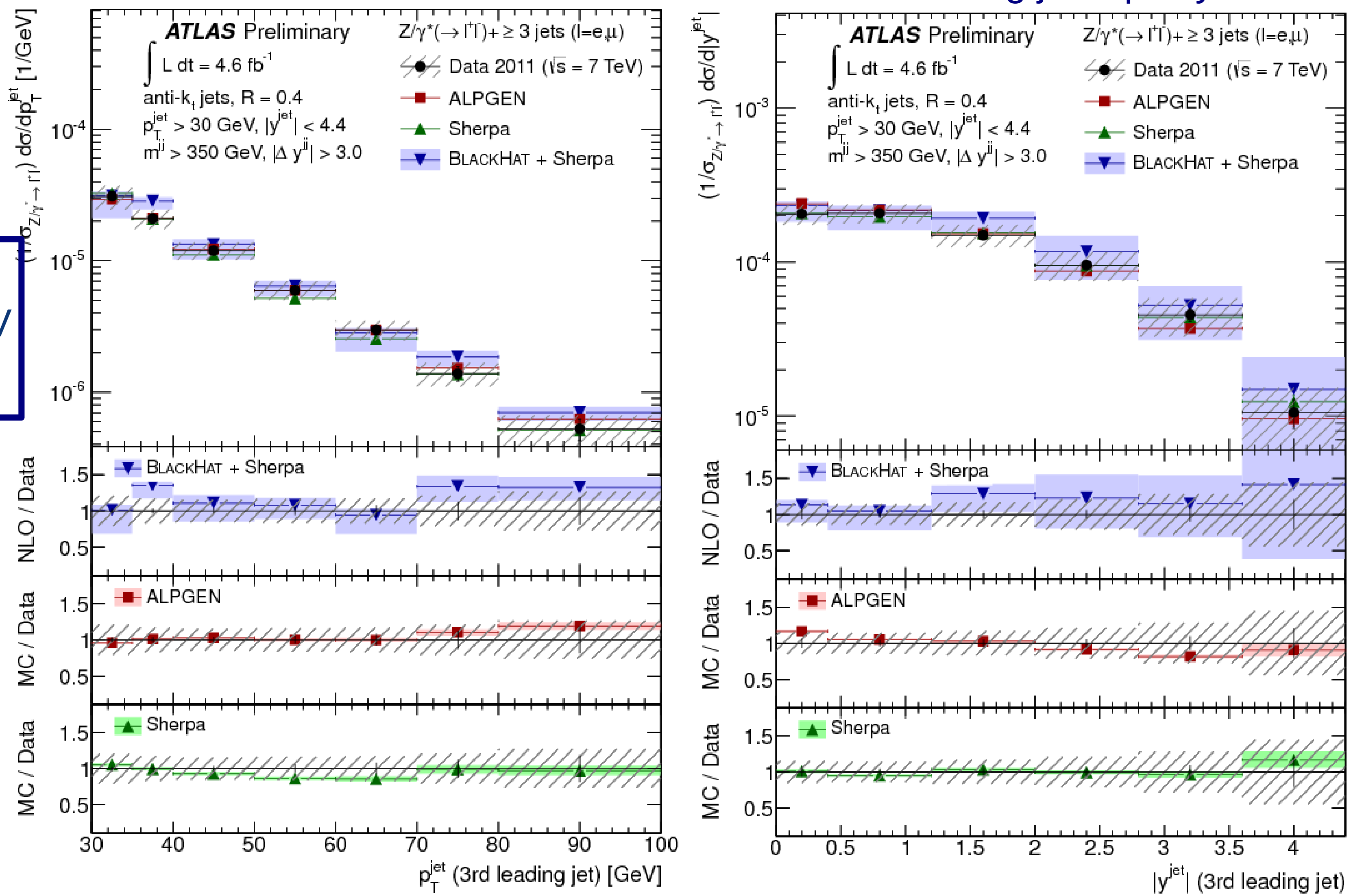
- NLO fixed order Z+≥1 jet underestimate large Z p_T
- ALPGEN: overestimates large Z p_T, consistent with NLO EW, expect HO QCD as well

→ Need more precise pQCD calculations to disentangle higher-order EW from QCD

→ New observables to better disentangle EW and QCD effects?

Results – distributions after VBF cuts

3rd leading jet p_T | 3rd leading jet rapidity



VBF preselection:

- $m_{jj} >$ 350 GeV
- $\Delta y >$ 3.0

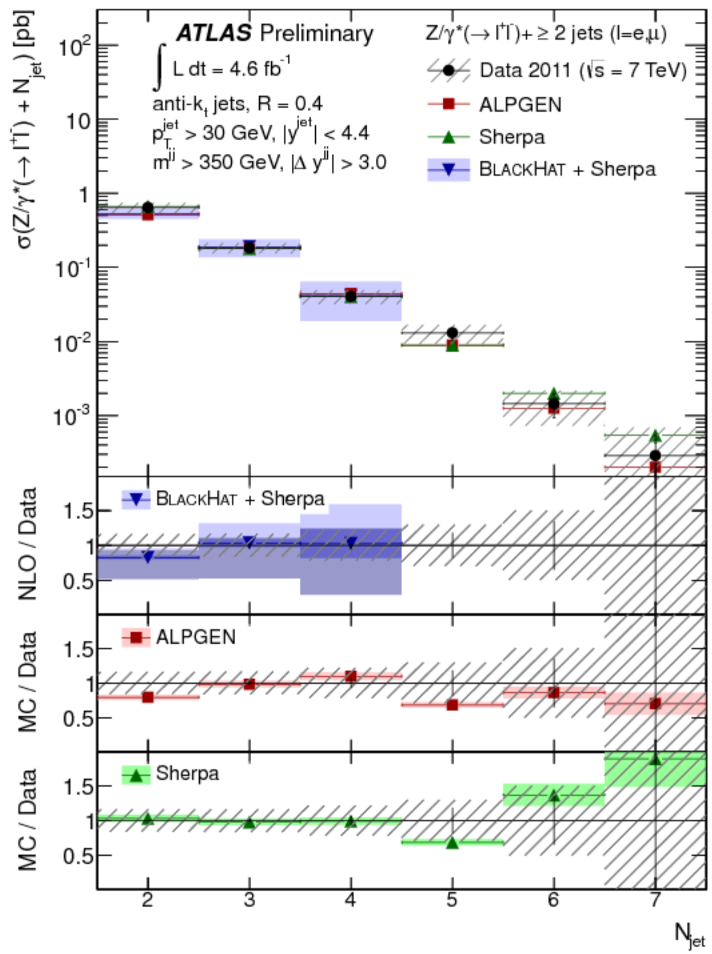
In general, good agreement between predictions and data

Results – distributions after VBF cuts

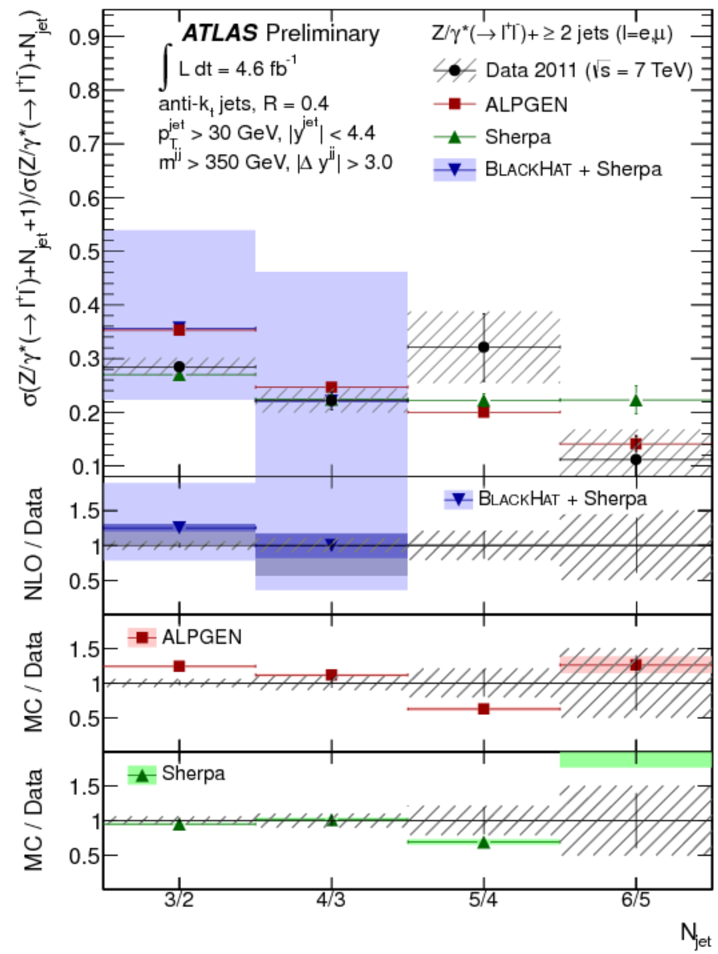
VBF preselection:

- $m_{jj} > 350$ GeV
- $\Delta y > 3.0$

exclusive jet multiplicity



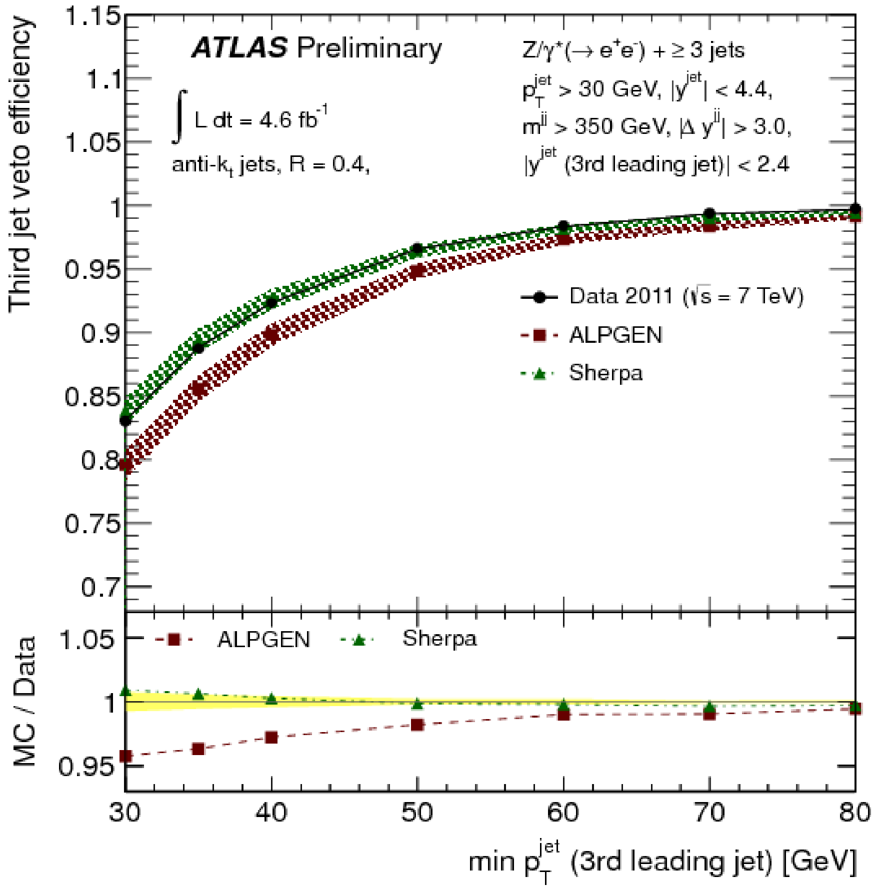
exclusive jet multiplicity ratio

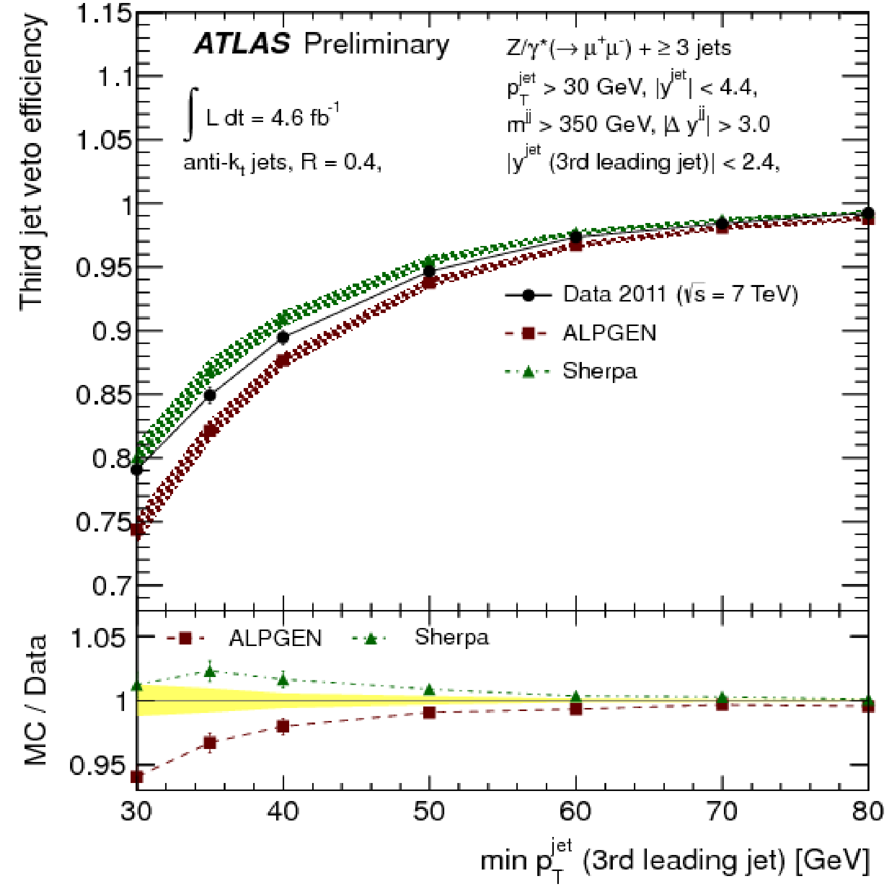


In general, good agreement between predictions and data

Results – distributions after VBF cuts

Survival efficiency of 3rd jet in the central region after VBF preselection



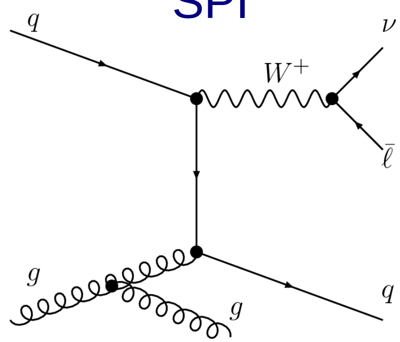


- Sherpa/data: good agreement
- ALPGEN predicts too small efficiency

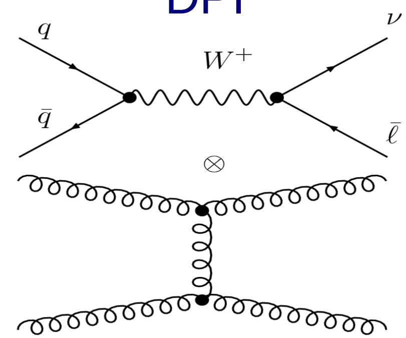
Introduction

W+2jets production via

SPI



DPI



DPI cross section: $$d\hat{\sigma}^{(\mathrm{DPI})}_{Y+Z}(s) = \frac{m}{2\sigma_{\mathrm{eff}}(s)} \int dx_{i_1}\, dx_{j_1}\, dx_{i_2}\, dx_{j_2}\, [f_{i_1 j_1}(x_{i1}, x_{j_1}, \mu_F) \times f_{i_2 j_2}(x_{i_2}, x_{j_2}, \mu_F)\, d\hat{\sigma}_{i_1 i_2 \to Y}(x_{i_1}, x_{i_2}, s)\, d\hat{\sigma}_{j_1 j_2 \to Z}(x_{j_1}, x_{j_2}, s)]$$

DPDF factorize ➔ $$\hat{\sigma}^{(\mathrm{DPI})}_{Y+Z} = \frac{\hat{\sigma}_Y \cdot \hat{\sigma}_Z}{\sigma_{\mathrm{eff}}}$$

σ_{eff}: parameter related to the proton size : Naive estimate: 50-70mb

Tevatron: 5-15mb

$$\hat{\sigma}^{(\mathrm{tot})}_{Y+Z}(s) = \hat{\sigma}^{(\mathrm{SPI})}_{Y+Z}(s) + \hat{\sigma}^{(\mathrm{DPI})}_{Y+Z}(s) = \hat{\sigma}^{(\mathrm{SPI})}_{Y+Z}(s) + \frac{\hat{\sigma}_Y(s)\cdot\hat{\sigma}_Z(s)}{\sigma_{\mathrm{eff}}(s)}$$

$$\longrightarrow \quad \sigma_{\mathrm{eff}}(s) = \frac{\hat{\sigma}_Y(s)\cdot\hat{\sigma}_Z(s)}{\hat{\sigma}^{(\mathrm{tot})}_{Y+Z}(s) - \hat{\sigma}^{(\mathrm{SPI})}_{Y+Z}(s)} = \frac{\hat{\sigma}_Y(s)\cdot\hat{\sigma}_Z(s)}{f^{(\mathrm{D})}_{\mathrm{DP}}\cdot\hat{\sigma}^{(\mathrm{tot})}_{Y+Z}(s)}$$

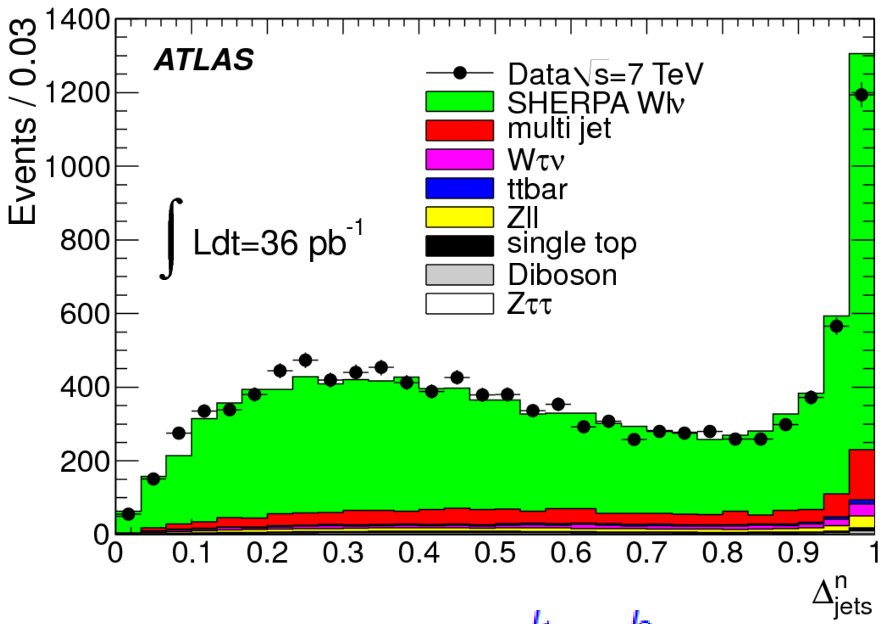
$$\sigma = \frac{N}{\mathcal{A}\, C\, \varepsilon\, \mathcal{L}}$$

- Acceptance A: cancel
- Unfolding corrections C: cancel
- Trigger: $\varepsilon_W = \varepsilon_{W+2j}$
  $\varepsilon_{2J} \approx 1$

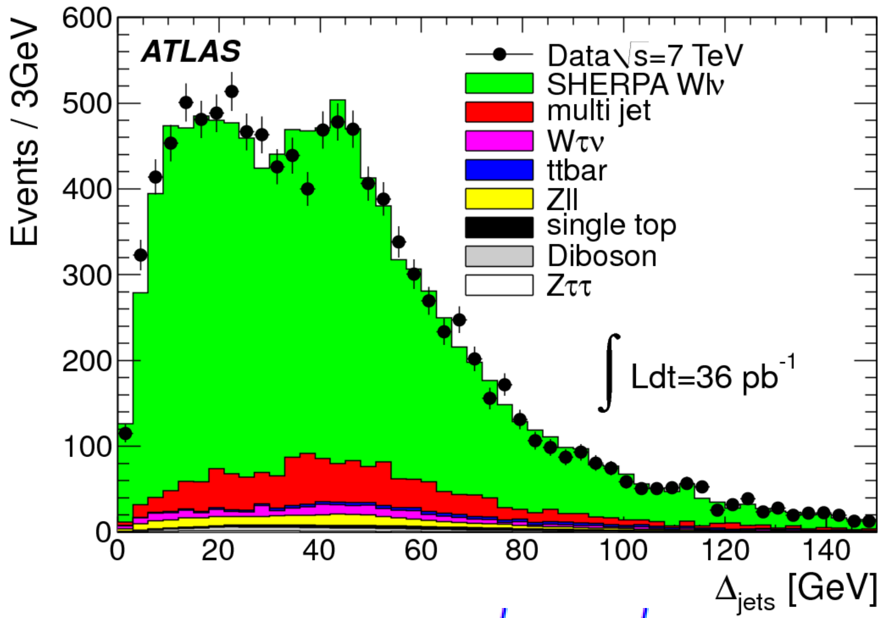
In W+jets: $$\sigma_{\mathrm{eff}} = \frac{\sigma_{W_{0j}}\cdot\sigma_{2j}}{\sigma_{W_{0j}+2j\,\mathrm{DPI}}} = \frac{\sigma_{W_{0j}}\cdot\sigma_{2j}}{f^{(\mathrm{D})}_{\mathrm{DP}}\ \sigma_{W+2j}} = \frac{1}{f^{(\mathrm{D})}_{\mathrm{DP}}}\cdot\frac{N_{W_{0j}}}{N_{W+2j}}\cdot\frac{N_{2j}}{\mathcal{L}_{2j}}$$

$f^{(\mathrm{D})}_{\mathrm{DP}}$: Fraction of DPI-produced W+2j events at detector level

Distribution of observables



$$\Delta^{\rm n}_{\rm jets} = \frac{|\vec{p}_{\rm T}^{J_1} + \vec{p}_{\rm T}^{J_2}|}{|\vec{p}_{\rm T}^{J_1}| + |\vec{p}_{\rm T}^{J_2}|}$$



$$\Delta_{\rm jets} = |\vec{p}_{\rm T}^{J_1} + \vec{p}_{\rm T}^{J_2}|$$

W, W+2jets: using 2010 data (36 pb^{-1})

Selection:

Leptons: p_T^l>20 GeV and |η|<2.4 (|η|<2.47, exclude cracks)

Etmiss, mT: E_t^{miss}>25 GeV and m_T > 40 GeV

Jets: p_T> 20 GeV, |y|<2.8 and $\Delta R(jl) > 0.5$

Backgrounds:

- multi-jet: 6-14%, data driven
- EW, top: 5-8%, MonteCarlo

Signal MC:

- Alpgen+Herwig+Jimmy, AUET tune
- Sherpa 1.31