W + jets with ATLAS

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DESY
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HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

W production at the lHC

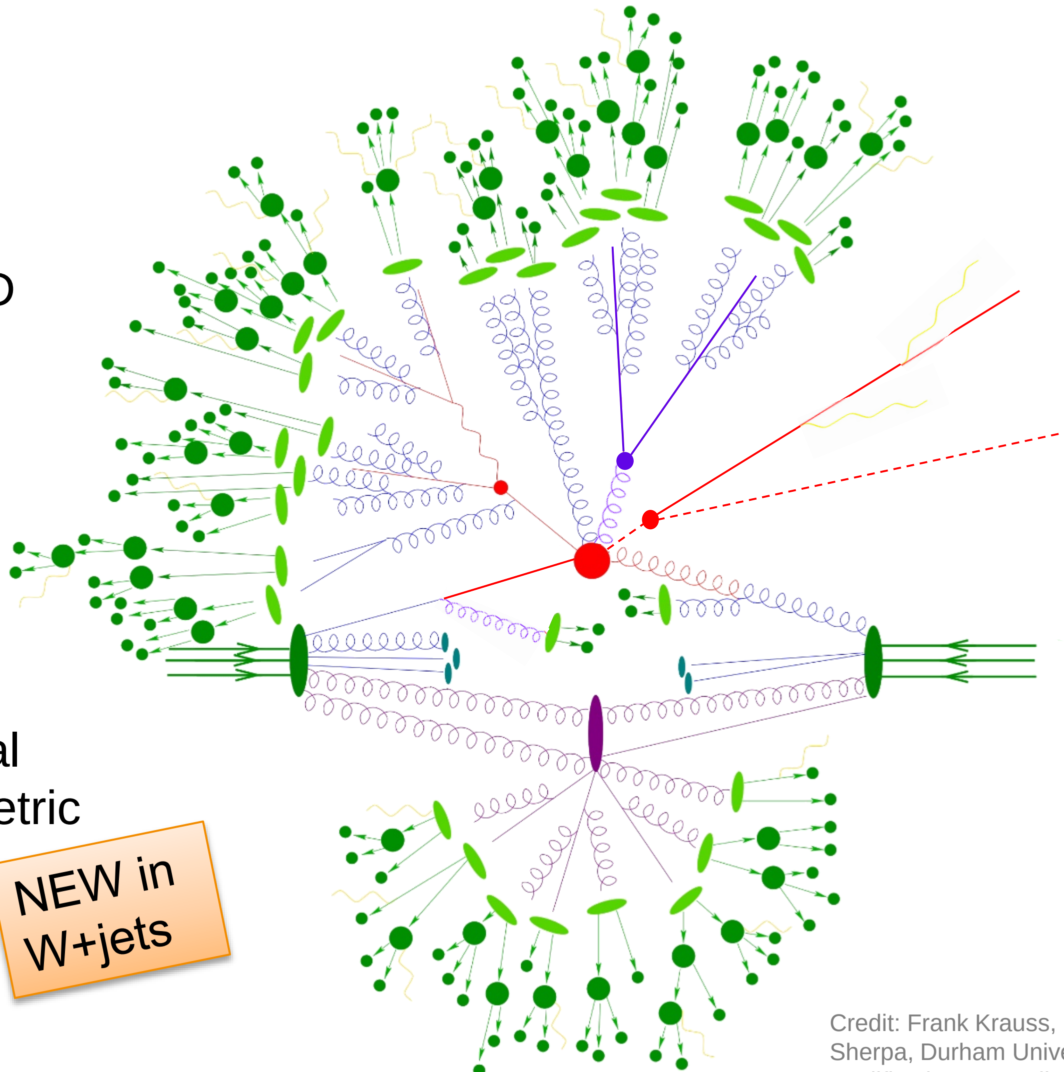
- What to study in W+jets?
  - ***High energy scales and high jet multiplicities***
    Require higher order QCD & EW, hard parton emissions, matching to partons showers

  → Test best state-of-the-art calculations

  - ***W^+ and W^- production***
    Differs at the LHC → initial state is not charge-symmetric

  → Depends on the proton content → PDFs

NEW in W+jets

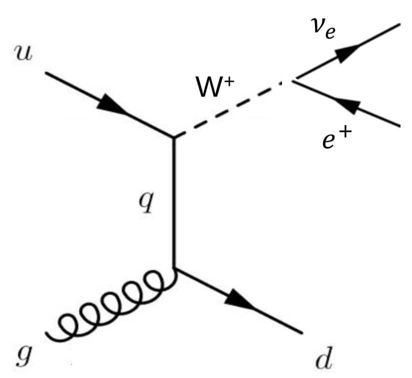


Credit: Frank Krauss, Sherpa, Durham University
Modifications: Own liability

- W+jets in 2012 data
  - Submitted this month: arXiv 1711.03296

W^+ and W^- production

> Main production for W+jet

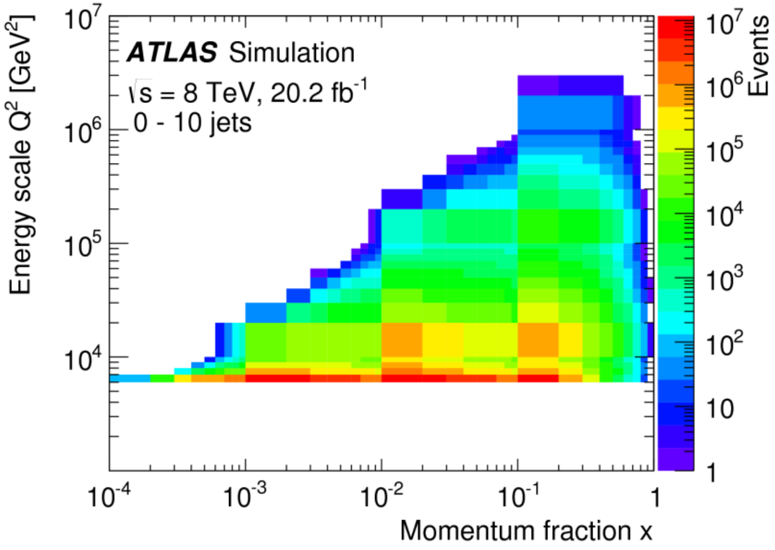


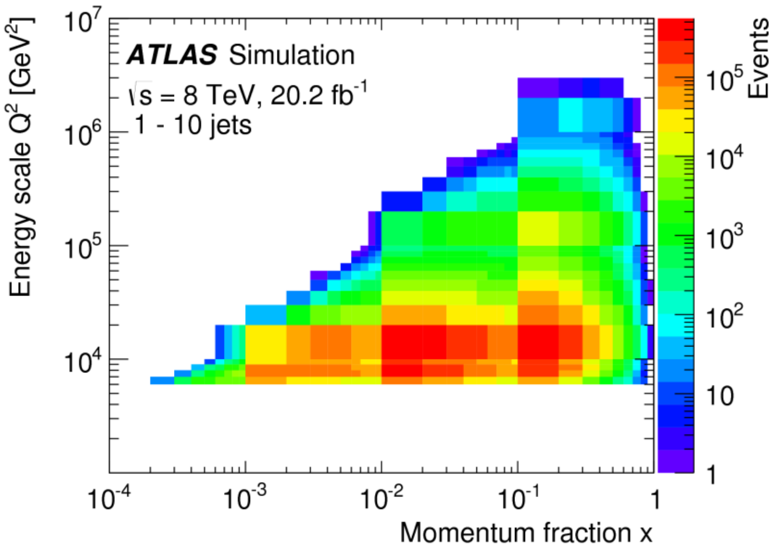
- Initial state for W^+ (W^-): ug (dg)

  → W^+/W^- depends on u/d

> Why in association with jets?

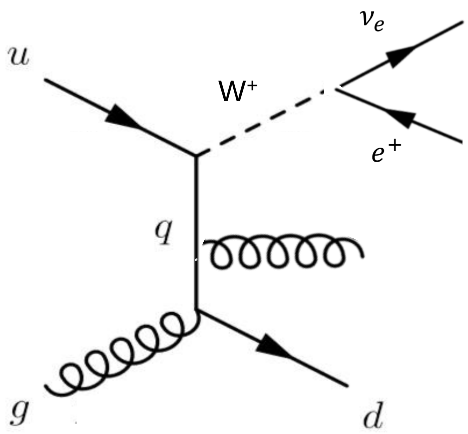
- Shift of sensitive x-Q^2 upwards
- Test similar range as Tevatron or d inelastic scattering experiments





Selection & strategy

- $W \rightarrow e\nu$ decay channel
  - Selection in a nut-shell → Measure kinematic distributions



Neutrino → E_T^{miss} >25GeV

Exactly 1 electron w/ p_T > 25GeV

Transverse mass m_T
compatible with W, i.e > 40GeV

→ No b-tagged jets w/ p_T > 20GeV, $|\eta|$<2.5 to suppress $t\bar{t}$

→ Count signal jets w/ p_T > 30GeV, $|y|$<4.4

With x being:

- N_{jets}
- H_T, p_T^W, p_T^{j1}, $|y^{j1}|$
- p_T^{j2}, $|y^{j2}|$, $m_{j1,j2}$, $\Delta R_{j1,j2}$
- $|\eta^{el}|$

Strategy
→ Select events → estimate backgrounds
→ Subtract backgrounds → unfold
→ Compare cross sections to theory

Backgrounds

- Methods

Back-ground	Estimation source	Estimation method
Multi-jet (MJ)	Data-driven	Fit of E_T^{miss}
$t\bar{t}$	MC-based	MC prediction, normalized to and validated in data
Z, $W \to \tau\nu$, single top, dibosons	MC-based	MC prediction

Backgrounds - MJ

Methods

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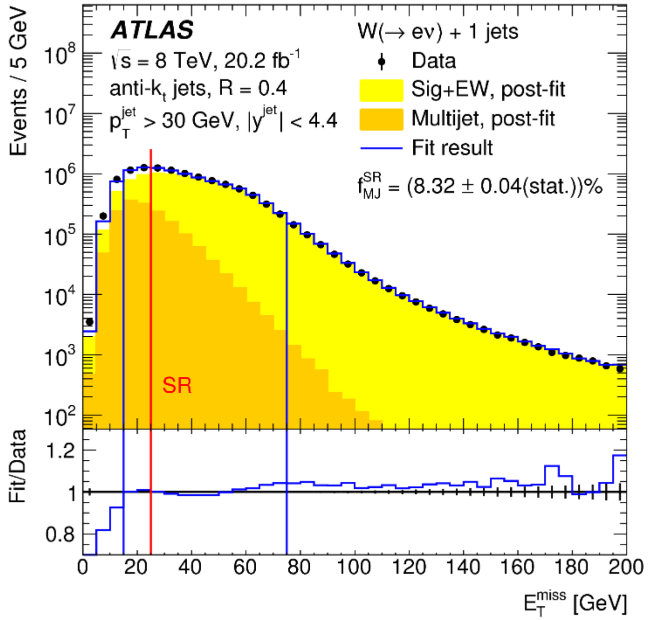
Result

- Number of multijet events in signal region (SR)
- Shape of multijet distribution

Fit for each jet multiplicity



Templates

- Sig+EW → MC
- Multijet (MJ) → MJ-enhanced data sample

Fit

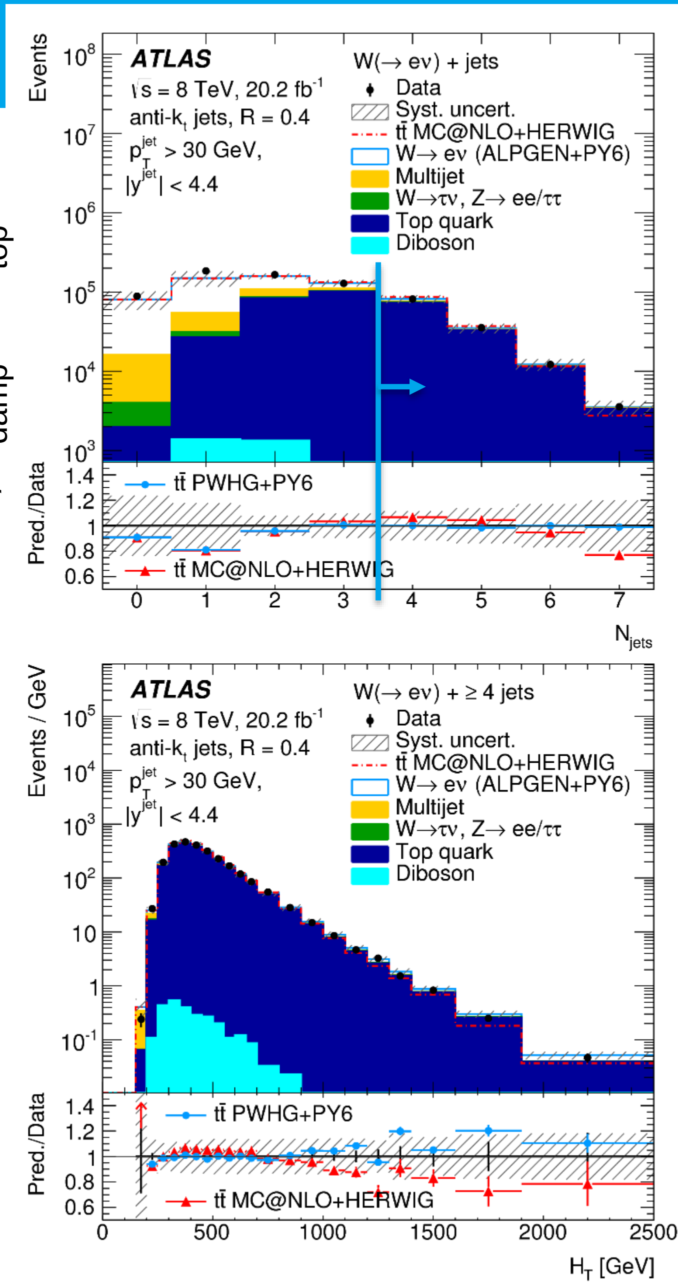
- Range: 15-75 GeV
- Separate fits for W, W^+ and W^-

Backgrounds - $t\bar{t}$

> Methods

Back-ground	Estimation source	Estimation method
Multi-jet (MJ)	Data-driven	Fit of E_T^{miss}
$t\bar{t}$	**MC-based**	**MC prediction, normalized to and validated in data**
Z, $W \to \tau\nu$, single top, dibosons	MC-based	MC prediction

$t\bar{t}$: Powheg+Pythia 6 MC, $h_{damp} = m_{top}$



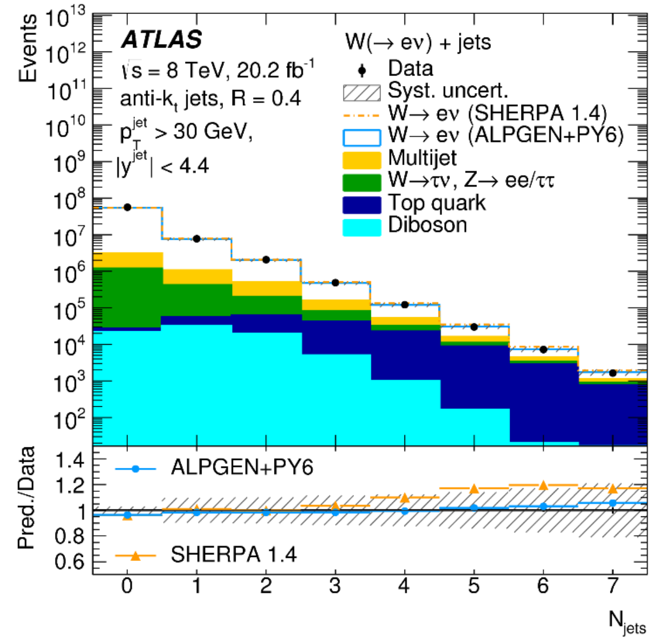
Result
- Differential distributions for $t\bar{t}$ from MC
- Normalization scaled by factor 1.086 for agreement with data

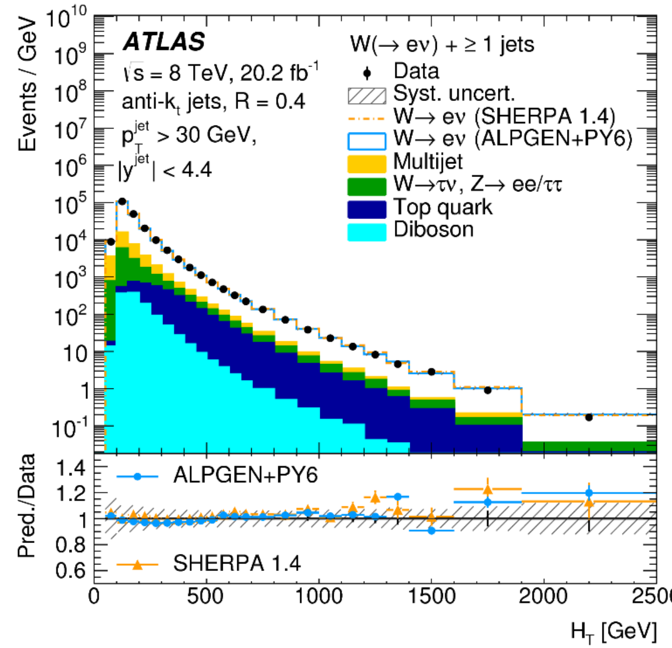
At detector level

> Composition

N_{jets}	0	1	2
$W \to e\nu$	94 %	86 %	75 %
Multijet	3 %	8 %	15 %
$t\bar{t}$	<1 %	<1 %	1 %
Single t	<1 %	<1 %	1 %
$W \to \tau\nu$	2 %	2 %	2 %
Diboson	<1 %	<1 %	1 %
$Z \to ee$	<1 %	3 %	5 %
$Z \to \tau\tau$	<1 %	<1 %	<1 %
Total predicted	54 310 000 ±22 000	7 611 700 ±4000	2 038 000 ±1700
Data observed	56 342 232	7 735 501	2 070 776

Main W+jets generator:
Alpgen+Pythia6
→ Good agreement with data



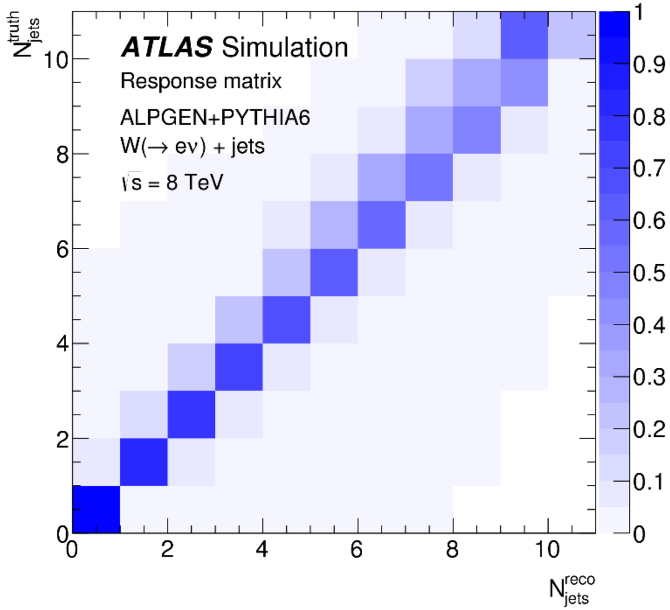


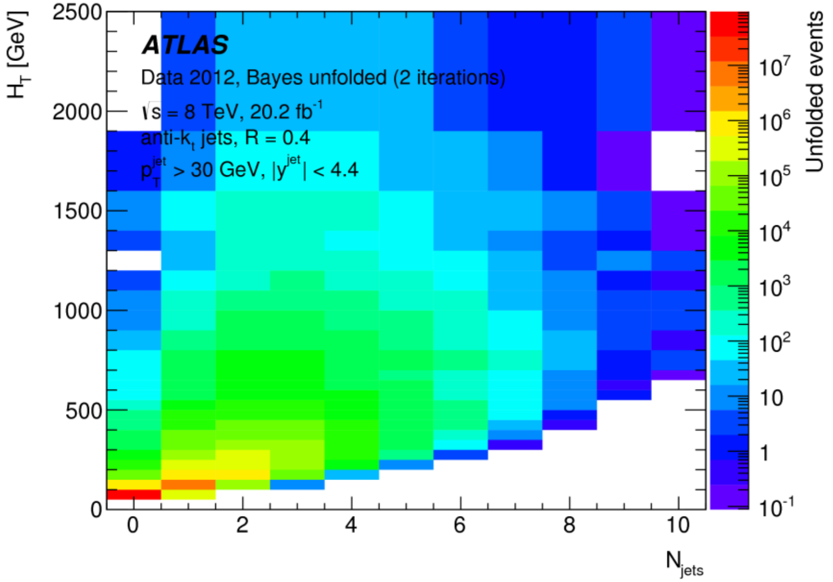
Correction for detector effects

> Want to correct for the effect of the detector on the data → Unfold

- Measure N_{jets}-dependent and differential cross sections
- Fiducial phase space similar to measured region in data
  → avoid uncertainties from MC-based extrapolation
- Unfold to particle level → Correct for selection efficiencies & resolution effects

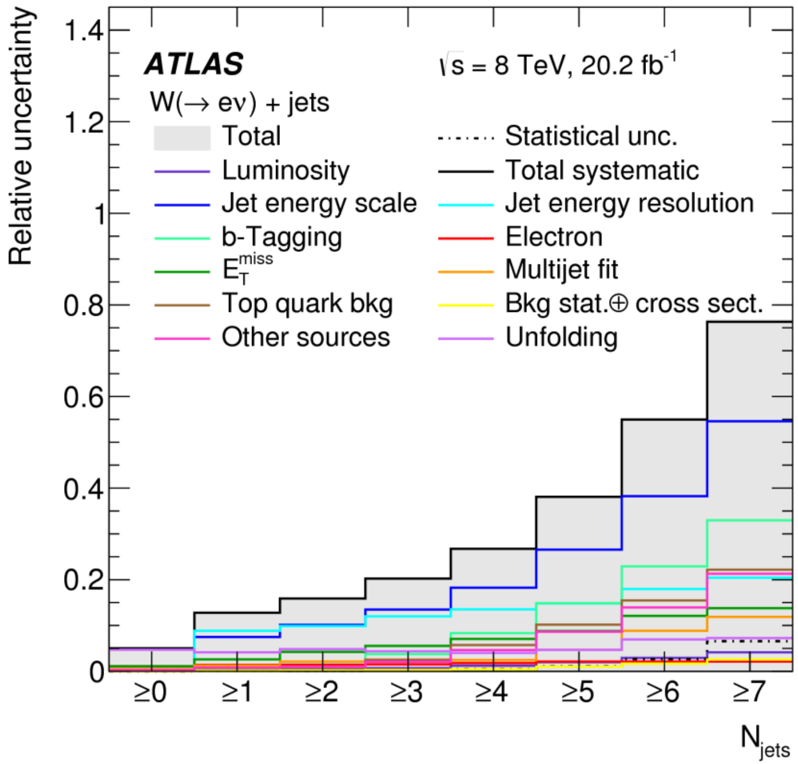
→ Differential distributions measured & unfolded in 2D

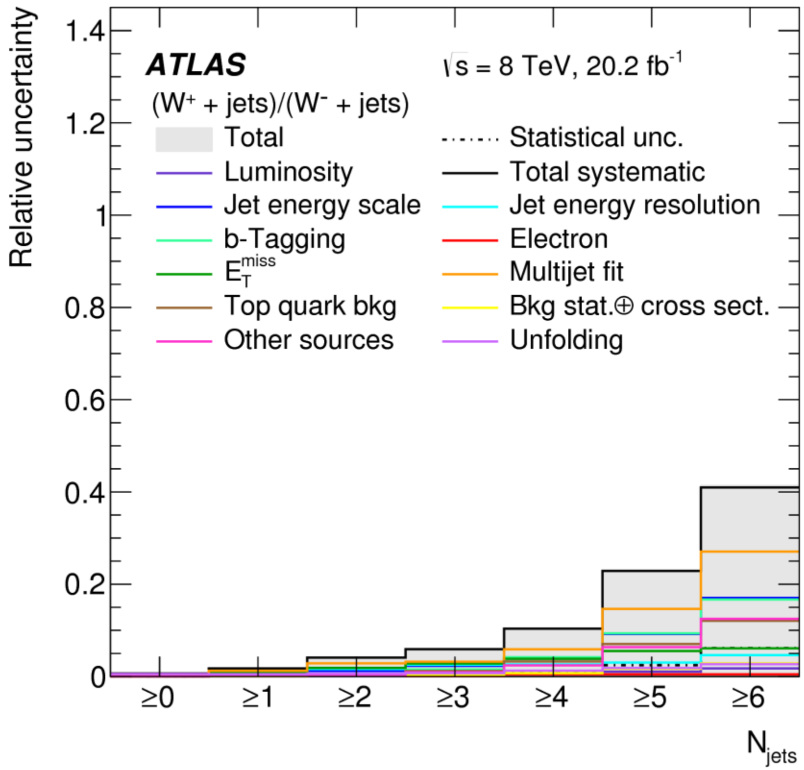




Systematic uncertainties

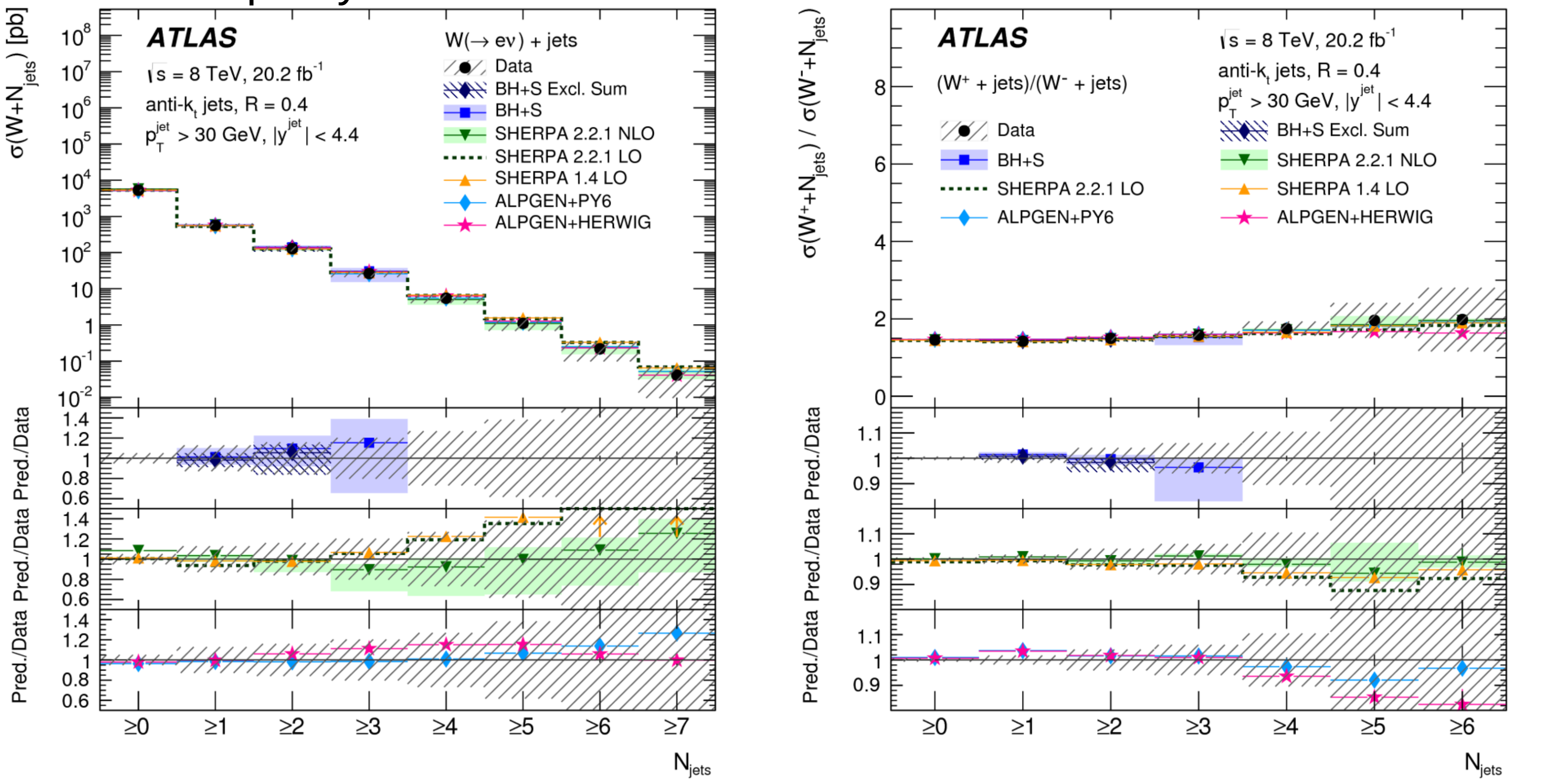
- Dominating: Jet uncertainties
  - In W cross section → In W^+/W^- cross section ratio





→ Very good cancellation of systematic uncertainties at low N_{jets} → especially interesting for jet uncertainties

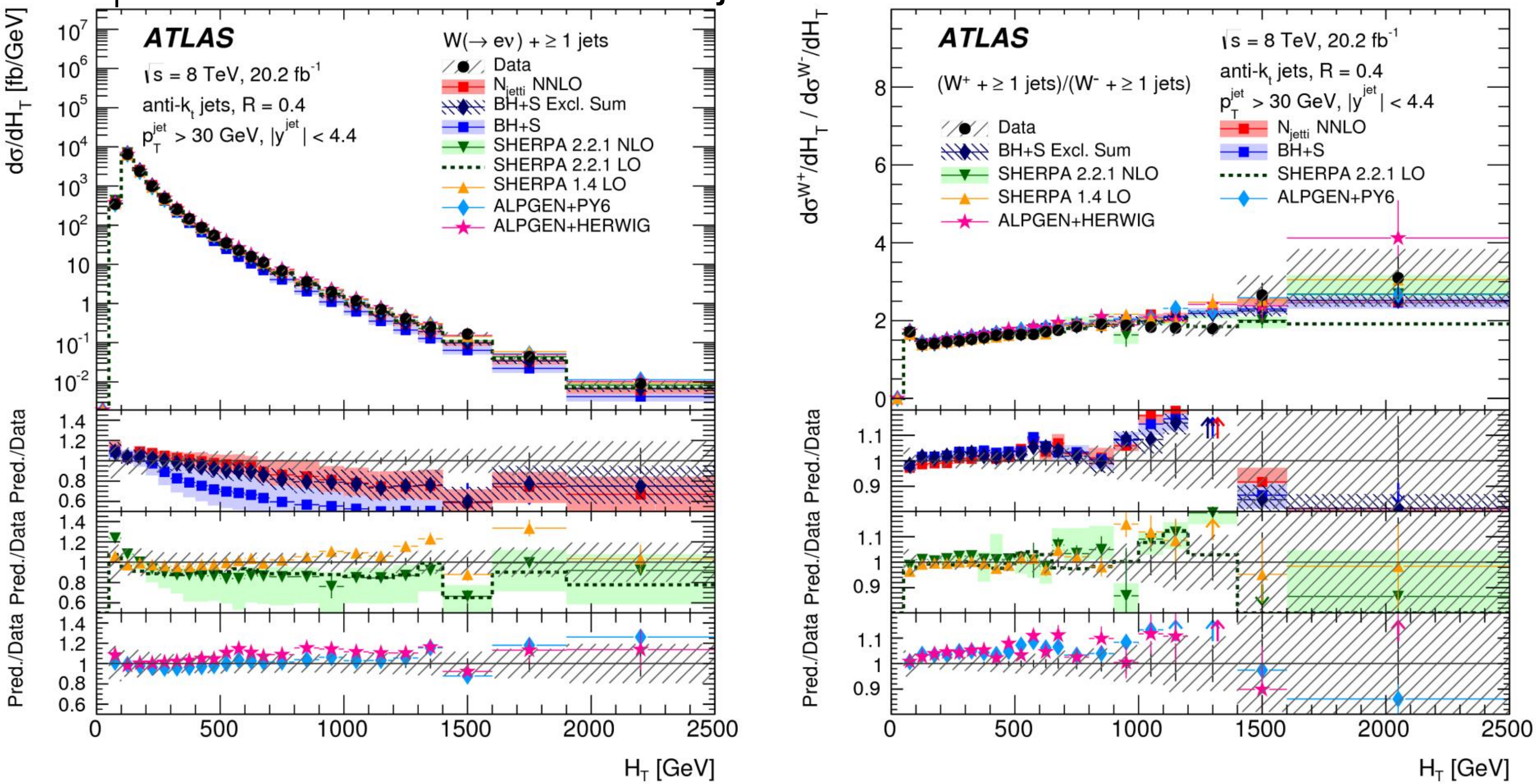
> Jet multiplicity



→ Good agreement of most predictions
→ NLO improves Sherpa 2.2.1 description at higher N_{jets}

Measured cross sections

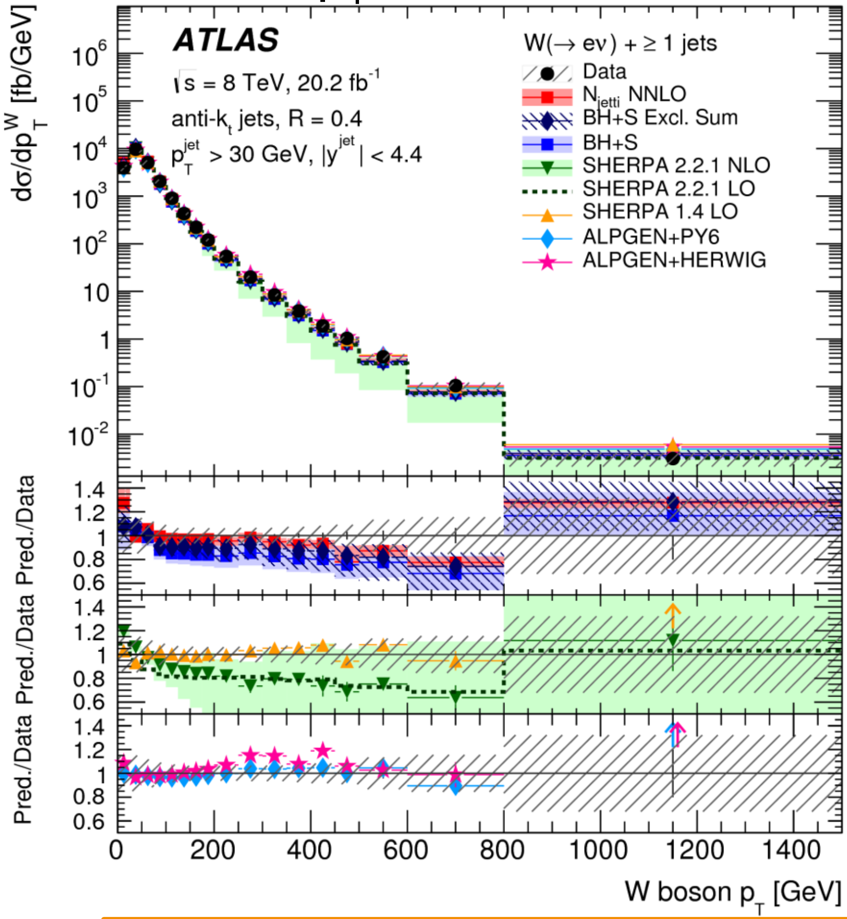
> H_T in association with at least 1 jet

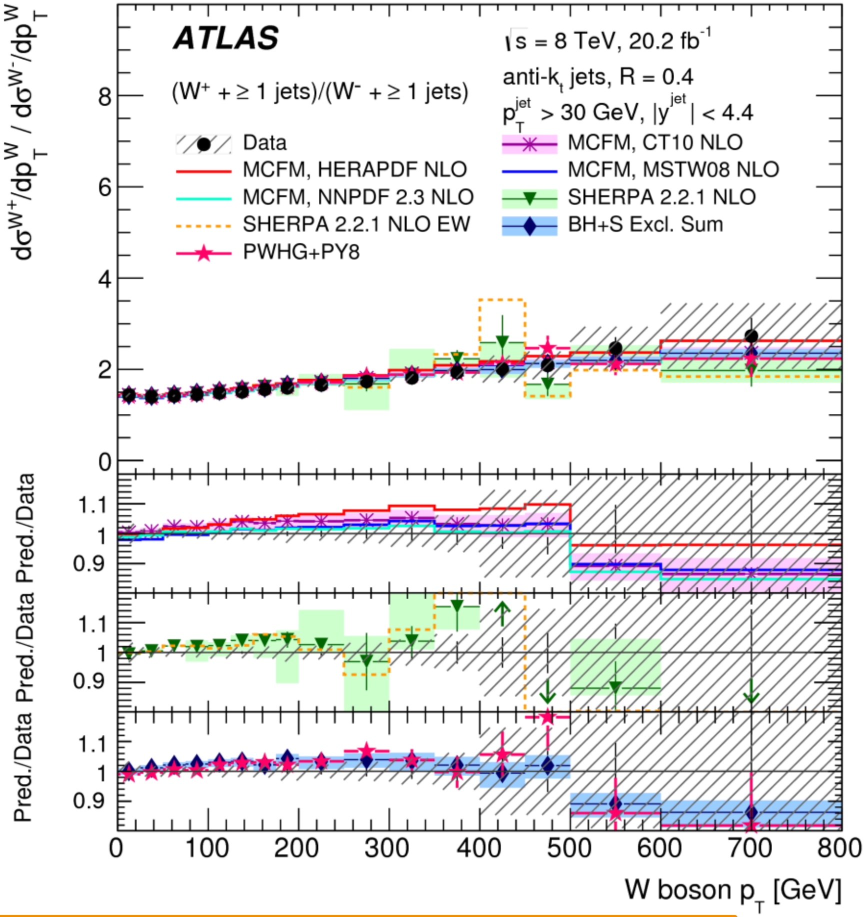


→ Sensitive to contributions from higher N_{jets}
→ NNLO improves on NLO → In W^+/W^-, higher order effects cancel

Measured cross sections

- W boson p_T in association with at least 1 jet





→ Reasonable description of data by NNLO prediction
→ PDFs impact W^+/W^- prediction by about the experimental uncertainty

Summary

- Measurement of W+jets production at $\sqrt{s}$=8TeV by ATLAS published
  - Interesting for testing recent pQCD predictions and for PDF inputs
  - Measurement performed separately for W, W^+ and W^- production
  - Dominating backgrounds: Multijets and $t\bar{t}$
    → Estimated data-driven and MC-based, but with validation in data
  - Unfolding to particle level for fiducial cross section measurement
    → 2-dimensional unfolding for differential distributions
  - Good cancellation of dominating jet-based uncertainties in W^+/W^- ratio
  - Comparison of data to 9 different predictions from multileg LO to NNLO
    → Reasonable agreement throughout → difficulties in particlar regions

→ For more on this, it's time for a closer look at the W+jets 2012 paper

Thank you for your attention

Backup

Composition in signal region

Table 1: Signal and background contributions in the signal region for different jet multiplicities as percentages of the total number of predicted events, as well as the total numbers of predicted and observed events. The uncertainty in the total predicted number of events is statistical only.

N_{jets}	0	1	2	3	4	5	6	7
$W \to e\nu$	94 %	86 %	75 %	67 %	57 %	47 %	40 %	35 %
Multijet	3 %	8 %	15 %	16 %	16 %	16 %	14 %	14 %
$t\bar{t}$	<1 %	<1 %	1 %	6 %	16 %	27 %	36 %	43 %
Single t	<1 %	<1 %	1 %	1 %	2 %	2 %	2 %	1 %
$W \to \tau\nu$	2 %	2 %	2 %	2 %	2 %	1 %	1 %	1 %
Diboson	<1 %	<1 %	1 %	1 %	1 %	1 %	<1 %	<1 %
$Z \to ee$	<1 %	3 %	5 %	6 %	6 %	6 %	5 %	5 %
$Z \to \tau\tau$	<1 %	<1 %	<1 %	<1 %	<1 %	<1 %	<1 %	<1 %
Total predicted	54 310 000 ±22 000	7 611 700 ±4000	2 038 000 ±1700	478 640 ±720	120 190 ±320	30 450 ±150	7430 ±63	1735 ±20
Data observed	56 342 232	7 735 501	2 070 776	486 158	120 943	29 901	7204	1641

Fiducial definition

Table 2: Kinematic criteria defining the fiducial phase space for the $W \to e\nu$ final state in association with jets.

	Electron criteria
Electron p_{T}	$p_{\mathrm{T}} > 25$ GeV
Electron pseudorapidity	$\lvert\eta\rvert < 2.5$
	W criteria
Electron decay	Exactly one electron
Missing transverse momentum	$E_{\mathrm{T}}^{\mathrm{miss}} > 25$ GeV
Transverse mass	$m_{\mathrm{T}} > 40$ GeV
	Jet criteria
Jet p_{T}	$p_{\mathrm{T}} > 30$ GeV
Jet rapidity	$\lvert y\rvert < 4.4$
Jet–electron distance	$\Delta R(e, \text{jet}) \geq 0.4$ (otherwise event is removed)