Measuring DPI in ATLAS

in Wjj

Ellie Dobson

MPI@TAU

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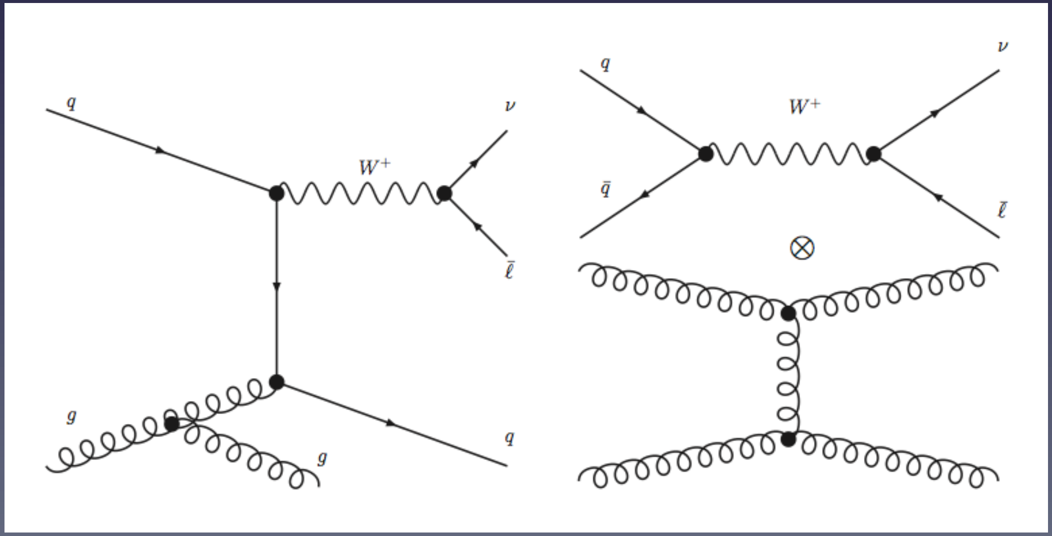
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2011-159

Motivation and method

Motivation: To quantify the probability of **hard** secondary scatter

- ? Hard DPI (double parton interactions) forms an irreducible BG to new physics searches and is not a well understood process
- ? Is DPI rate process independent?
- ? (How) does DPI rate depend on the collision energy?

Method: Exploit kinematic difference in DPI events to measure fraction of W+DPI contamination in W+2jet events, and use to extract σ_{eff}



These two will both pass W+2jet selection
- but in what fraction?

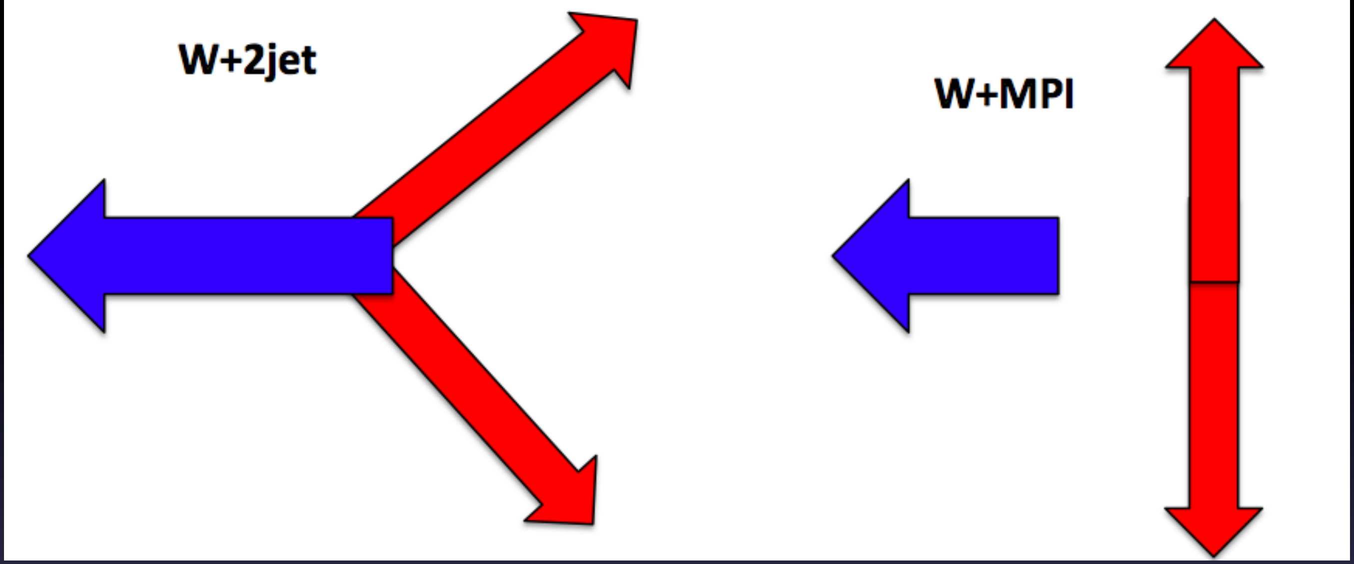
Samples and selection

Sample	Details
Pythia inclusive	v6, AMBT tune 1
Sherpa inclusive	v1.3.1, default UE, CKKW matching scale=30GeV
Alpgen+Herwig+Jimmy inclusive	MLM matching, Jimmy v4.31, AUET tune, Herwig v6.510
Sherpa MPI off	As above + MI_HANDLER=NONE
Alpgen+Herwig+Jimmy MPI off	As above + remove events **where both jets' closest outgoing parton with P_T > 3.5 GeV is not primary**
Data (W sample)	All 2010 data run
Data (jet sample)	All 2010 data run

W selection
Single lepton trigger
1 lepton (e, μ) $P_T > 20$ GeV, $\eta < 2.5$
MET > 25 GeV, $M_T > 40$ GeV
2 kt6 jets, $P_T > 20$ GeV, $y < 2.8$

Jet selection
Minimum bias trigger
Exactly 2 kt6 jets, $P_T > 20$ GeV, $y < 2.8$

Wjj topology I



W+MPI events differ from the W+2jet events in several ways:

- Total energy deposited in the event
- Transverse W momenta
- Recoil of jet system from W system
- Transverse jet momenta
- Angle between jets
- **Collinearity of jets**

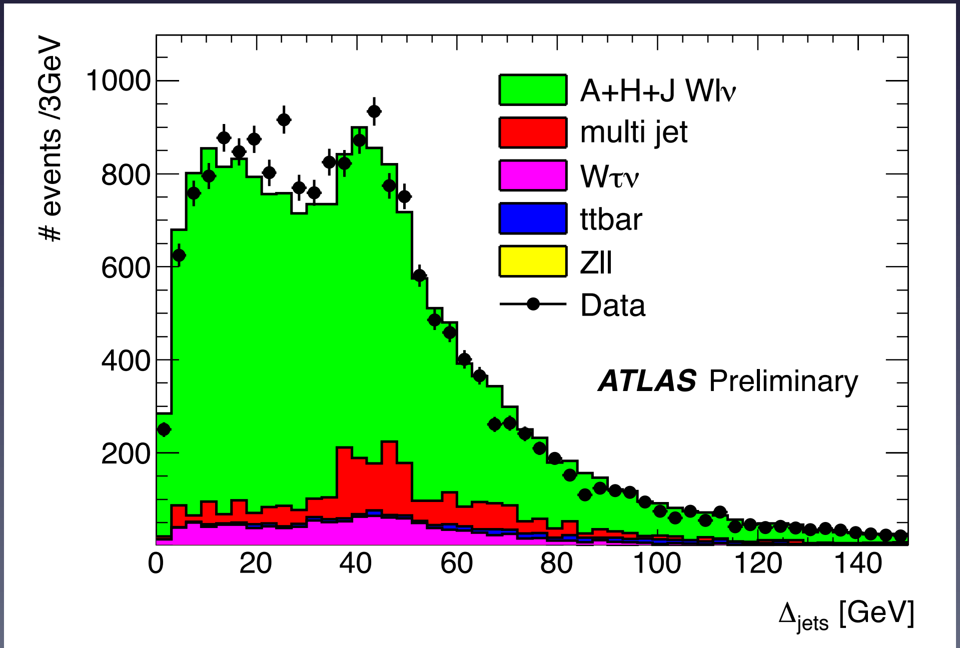
Experimentally problematic for a DPI analysis

Wjj topology II

$$\Delta_{jets} = \left| \vec{P}_T^{J1} + \vec{P}_T^{J2} \right|$$

Component of jets back to back

Component of jets recoiling from W

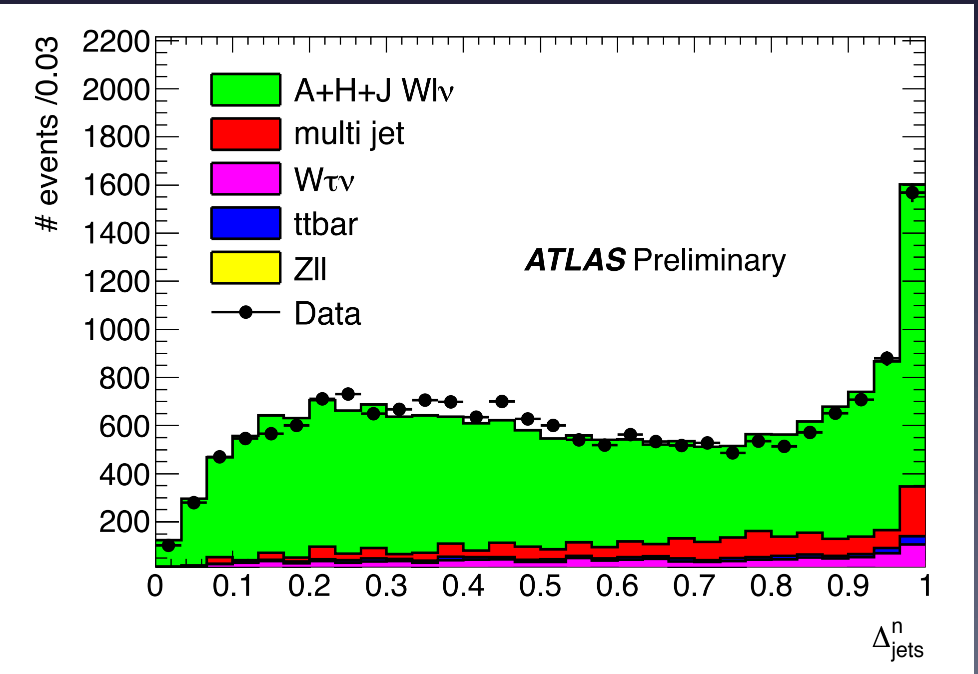


Wjj topology III

$$\Delta^{n}_{jets} = \frac{\left|\vec{P}_T^{J1} + \vec{P}_T^{J2}\right|}{\left|\vec{P}_T^{J1}\right| + \left|\vec{P}_T^{J2}\right|}$$

Component of jets back to back ↓

Component of jets recoiling from W ↓



Extracting DPI rate f_{DP}^{R}

$$f_{DP}^{R} = \frac{N_{W_0+2j_{MPI}}}{N_{W+2j}}$$

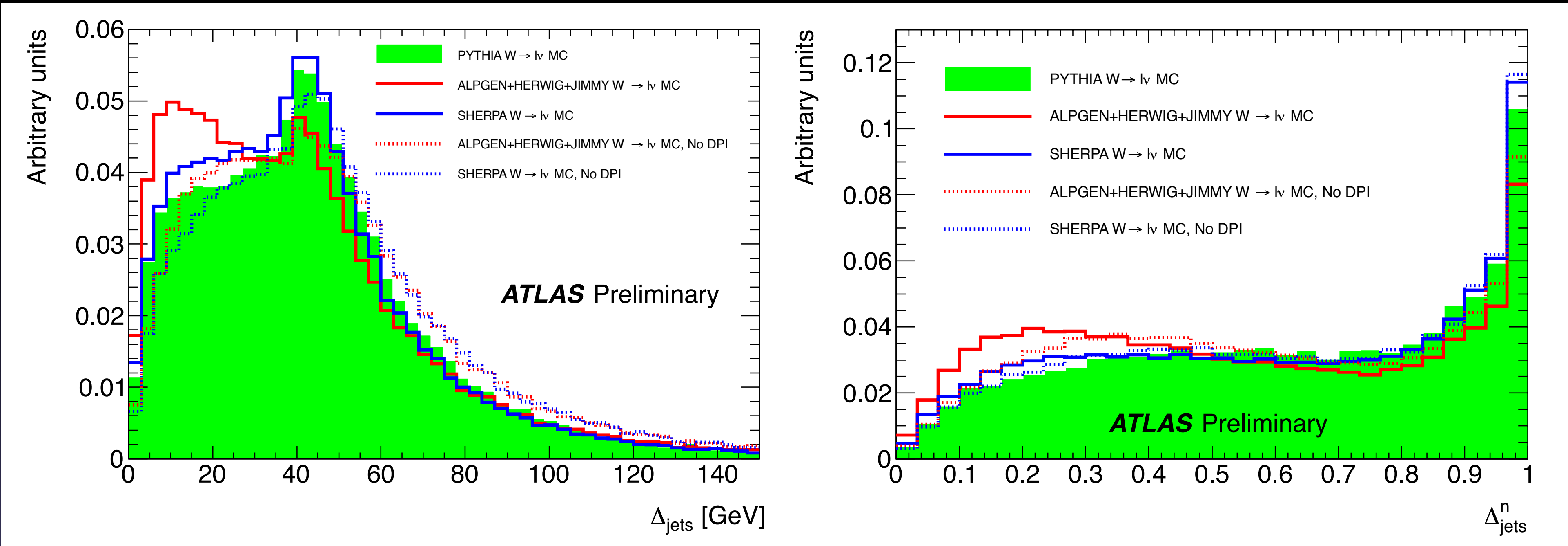
← Numbers of events seen in the detector **passing selection cuts**

Overall distribution = $(1-f^{R}_{DP})$•Template A + f^{R}_{DP}•Template B

↑ W+2jet (direct)

↑ W+2jet (MPI)

Template A: W+2jets



Sherpa mismodelling now understood to be due to placement of CKKW matching cut at 30GeV

Template B: W+DPI

Dijet selection in data

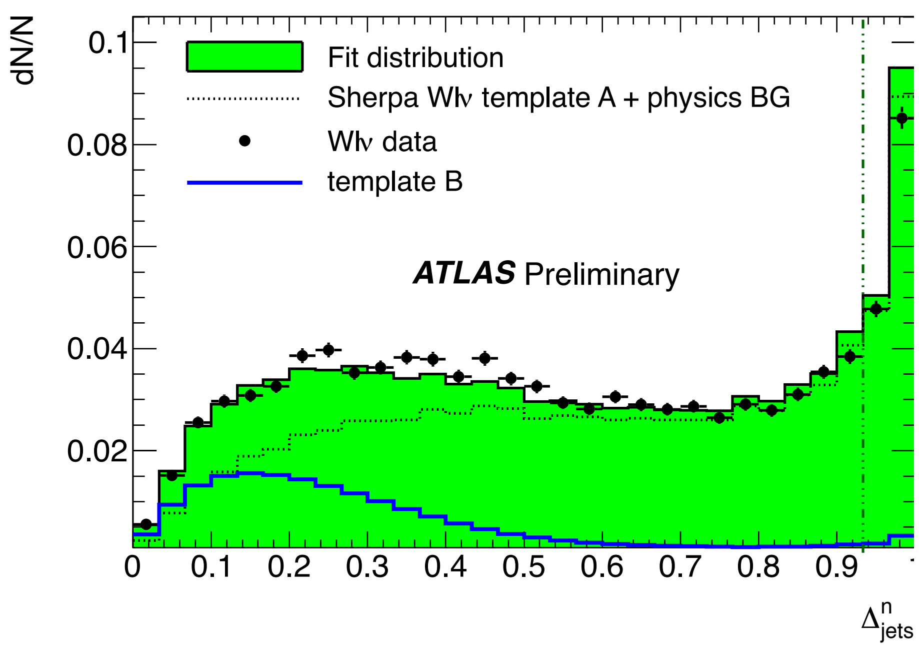
Extraction of f^R_{DP}

Overall distribution = $(1-f^R_{DP})$•Template A + f^R_{DP}•Template B

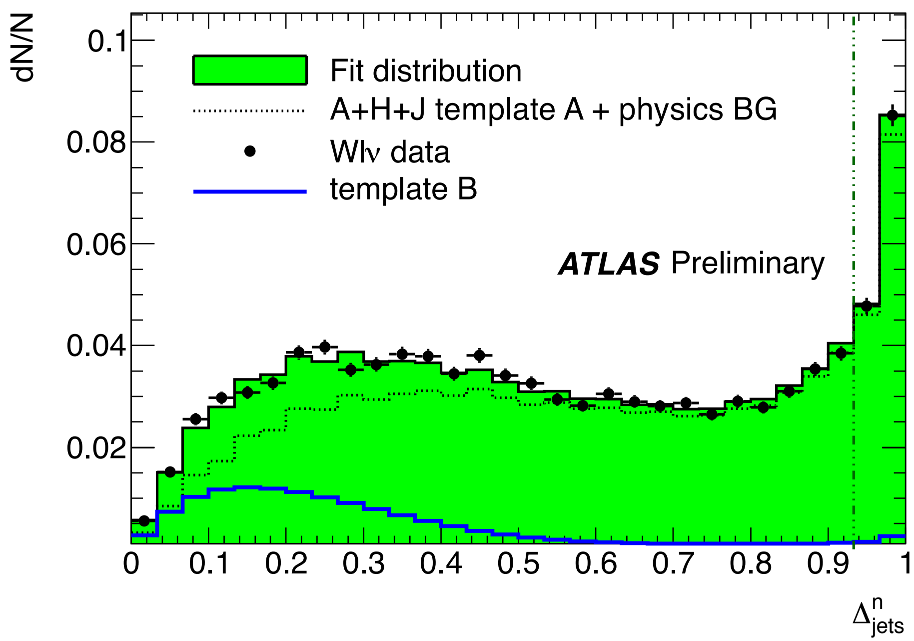
↑

X^2 minimisation

X^2/N_{dof} 1.4, $f^R_{DP} = 0.18$



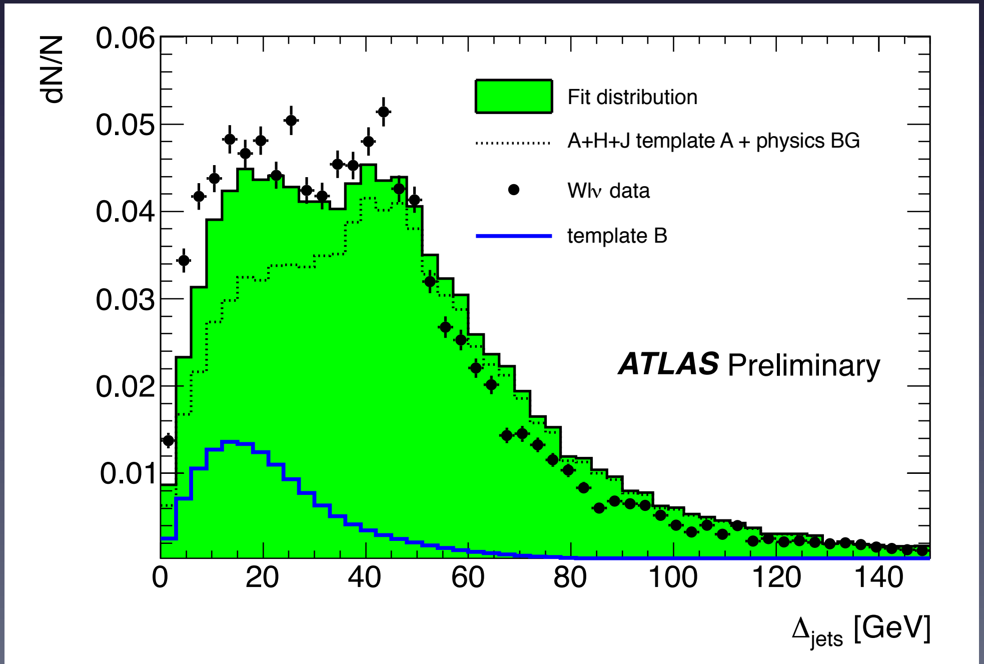
$X^2/N_{dof}=0.9$, $f^R_{DP} = 0.14$



Comparison to Δ_{jets}

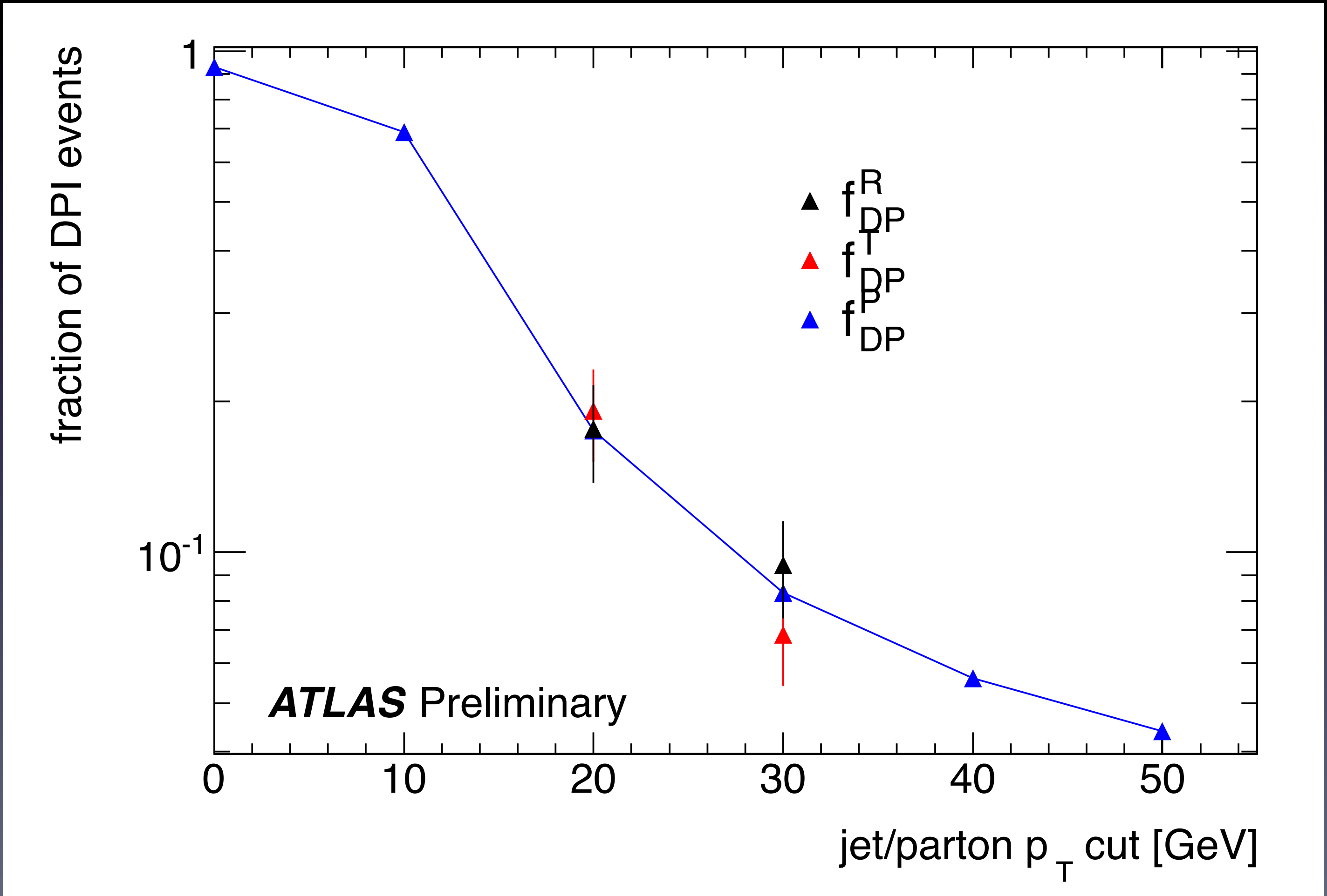
From previous fit

Overall distribution = $(1-f^R_{DP})$•Template A + f^R_{DP}•Template B



Variation of f^{R}_{DP} with phase space

Both predicted and extracted DPI rate decrease as P_T cut is raised



f^R_{DP} results

Source of uncertainty	Method of evaluation	Fractional uncertainty / %
Generator modelling	ALPGEN+HERWIG+JIMMY VS SHERPA	12
Transition to parton level	Monte Carlo studies	10
Jet reconstruction	Jet energy scale shift	10
Pileup	Varying vertex number requirement	8
Trigger bias	Comparison of data streams	5
Background modelling	Varying multi jet background normalisation	1
Total systematic	Quadratic sum of the above	21
Total statistical	$\chi^2 + 1$	7

Table 2: Summary of the uncertainties on the extraction of f^{R}_{DP}.

$$f^{R}_{DP} = 0.16 \pm 0.01\ (\text{stat.}) \pm 0.03\ (\text{sys.}).$$

Introducing σ_{eff}

$$\sigma_{eff} := \frac{\sigma_A \cdot \sigma_B}{\sigma_{AB}}$$

Can think of σ_{eff} as the effective area of the proton

-> Larger σ_{eff} : smaller DPI rate

Collab	E_{COM}	PT cuts /GeV	σ_{eff} /mb
AFS	63GeV	4	~5
UA2	630GeV	15	>8.3
CDF (jjjj)	1.8TeV	25	$12.1^{+10.5}_{-5.4}$
CDF (ϒjjj)	1.8TeV	15 on ϒ, 5-7 on j	$14.5^{+1.7}_{-2.3}$
D0 (ϒjjj)	1.96TeV	60->80 on ϒ	$16.4^{0.3}_{-2.3}$
ATLAS (Wjj) ?	7TeV	20 on l/ν, 20 on j	??

σ_{eff} is postulated to be process independent – its measurement in W+2jets allows calculation of DPI background **to any physics analysis**

Converting to σ_{eff}

Taking input definitions

$$f_{\text{DP}}^{\text{R}} = \frac{N_{W_0+2\text{j}_{\text{DPI}}}}{N_{W+2j}}, \qquad \sigma_{\text{eff}} = \frac{\sigma_{W_0} \cdot \sigma_{2\text{j}}}{\sigma_{W_0+2\text{j}_{\text{DPI}}}},$$

writing i.t.o cross sections

$$\sigma_{\text{eff}} = \frac{1}{f_{\text{DP}}^{\text{R}}} \cdot \frac{N_{W_0}\, N_{2j}}{N_{W+2j}} \cdot \frac{A_{W_0+2\text{j}_{\text{DPI}}}}{A_{W_0}\, A_{2j}} \cdot \frac{\epsilon_{W_0+2\text{j}_{\text{DPI}}}}{\epsilon_{W_0}\, \epsilon_{2j}} \cdot \frac{\mathcal{L}_{W_0+2\text{j}_{\text{DPI}}}}{\mathcal{L}_{W_0}\, \mathcal{L}_{2j}}.$$

and using input assumptions of analysis*

$$A_{W_0+2\text{j}_{\text{DPI}}} = A_{W_0} \cdot A_{2j_{DPI}},$$
$$A_{2j_{DPI}} = A_{2j_D}.$$

Yields**

$$\boxed{\sigma_{\text{eff}} = \frac{1}{f_{\text{DP}}^{\text{R}}} \cdot \frac{N_{W_0}\, N_{2j_D}}{N_{W+2j}} \cdot \frac{1}{\epsilon_{2j_D}} \cdot \frac{1}{\mathcal{L}_{2j_D}}.}$$

* need small correction for overlap removal
** include additional systematic for trigger bias

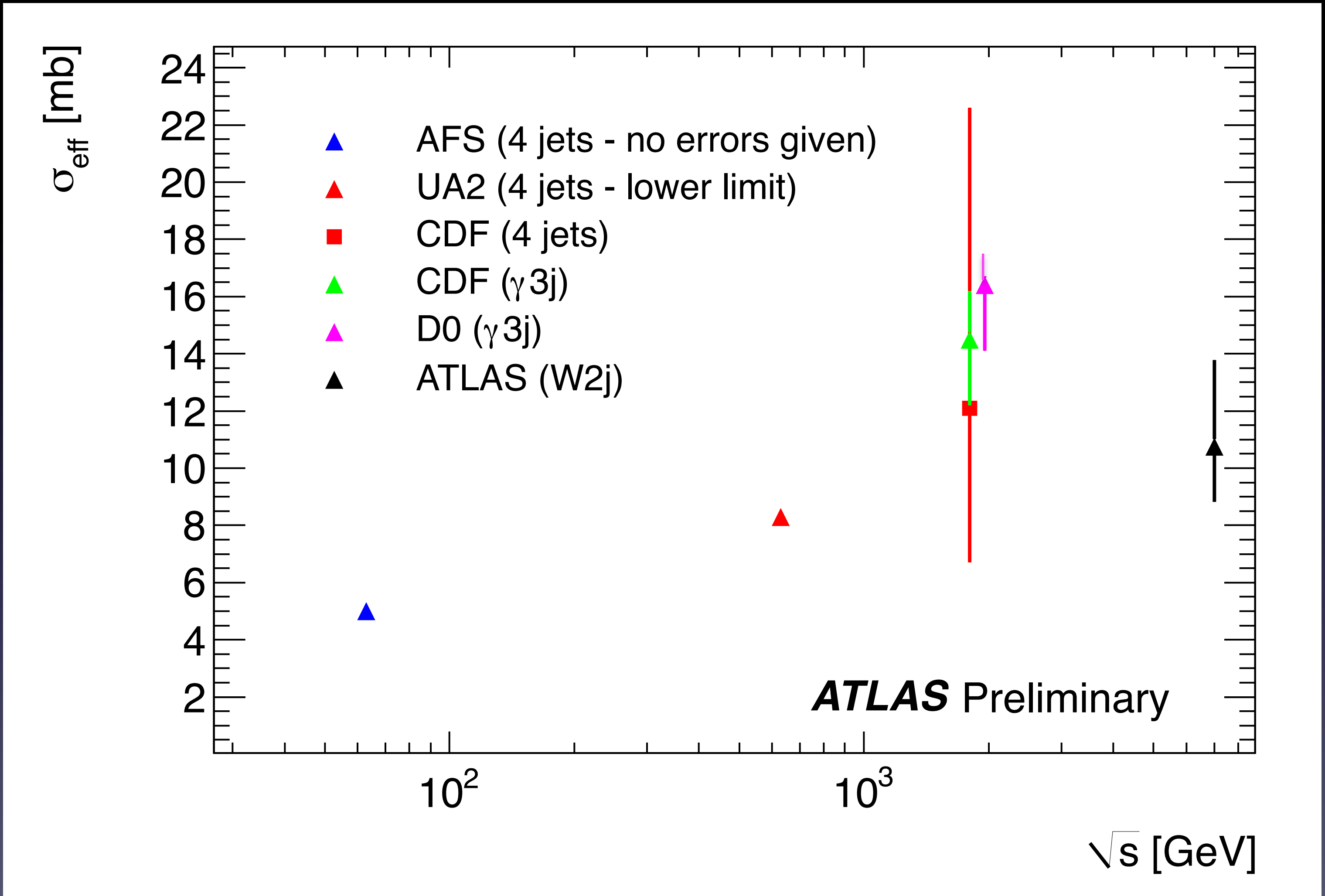
σ_{eff} results

Quantity	Systematic source	Method of evaluation	Fractional uncertainty /%
$N_{W0}/N_{W2} \cdot N_{jj}$	Acceptance cancellation	Section 6.1	< 3
N_{W0}/N_{W2}	Background modelling	Reference [53]	5
$\mathscr{L}_{jj}$	Luminosity	Beam parameters [52]	3.4
f_{DP}	Total	As in Table 2	21

Table 3: Summary of the systematic uncertainties on σ_{eff}.

$$\sigma_{eff}(7\,\text{TeV}) = 11 \pm 1\,(\text{stat.})\,^{+3}_{-2}\,(\text{sys.})\,\text{mb.}$$

Putting the result into context….



Results consistent with other measurements

Conclusions

The relative DPI rate is extracted for W+2jet events in the ATLAS detector:

$$f_{\mathrm{DP}}^{\mathrm{R}} = 0.16 \pm 0.01\ (\mathrm{stat.}) \pm 0.03\ (\mathrm{sys.}).$$

From this, the effective cross section is measured in 7 TeV pp collisions

$$\sigma_{\mathrm{eff}}(7\ \mathrm{TeV}) = 11 \pm 1\ (\mathrm{stat.})\ ^{+3}_{-2}\ (\mathrm{sys.})\ \mathrm{mb}.$$

which is consistent with results obtained in different channels at the Tevatron.

Coming up in the paper…

- New Sherpa samples with lower matching cut (increased σ_{eff})
- Better understanding of how f_{DP} translates from parton to reconstruction level
- Truth-level distributions

backup

f^R_{DP}=parton level f^P_{DP}?

Fit

ALPGEN+HERWIG+JIMMY=

$(1-f^T_{DP})$ A (Sherpa) + f^T_{DP} B

- vary f^P_{DP} in **ALPGEN+HERWIG+JIMMY**

Parton level MPI rate