QCD@LHC 22/8/11

W/Z + jet production at CMS

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On behalf of the CMS Collaboration

Outline

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- Object reconstruction in CMS.

- 3 CMS analyses using 2010 dataset ~ 36 pb^{-1} at 7 TeV.
  - Analysis methods and results.

Rates of jets produced in association with W and Z bosons
- CMS-PAS-EWK-10-012

Observation of Z+b, Z → ee, μμ
- CMS-PAS-EWK-10-015

Measurement of associated charm production in W final states
- CMS-PAS-EWK-11-013

Introduction

- W/Z+jets production provides an important and stringent test of perturbative QCD.
  - Copious production at the LHC with clean experimental signatures.
  - Can be used to constrain PDFs.
  - Flavour specific final states allow probing of different PDFs.

- Selection criteria similar to well established inclusive W/Z→leptons cross section measurements.

- Measure ratios of cross sections to minimise systematic uncertainty.

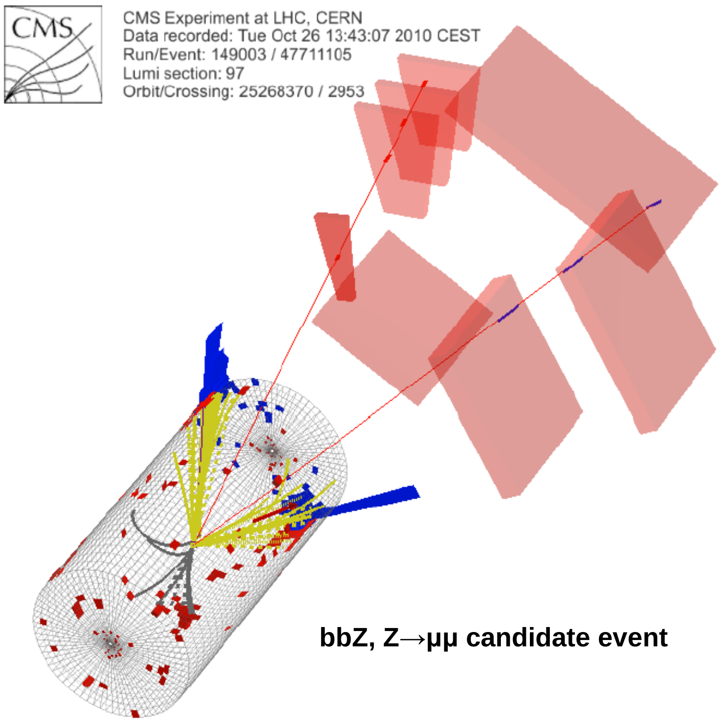
- Quote results within acceptance of analyses cuts for easier comparison with theory.

- Compare results to theoretical predictions using ME generator interfaced to Pythia parton shower.
  - MadGraph samples normalised to NNLO (inclusive W/Z+jets) or NLO (flavour specific anlayses) cross sections.

- Data driven techniques used where possible.

Object Reconstruction in CMS

- The analyses require use of all the CMS subdetectors.
  - Silicon tracker and pixel detector.
  - $PbWO_4$ crystal EM calorimeter.
  - Brass + scintilator hadron calorimeter.
  - Gas-ionisation muon chambers in return yoke of the magnet.



bbZ, Z→μμ candidate event

- Isolated leptons (e, μ) with kinematic cuts varying between analyses.

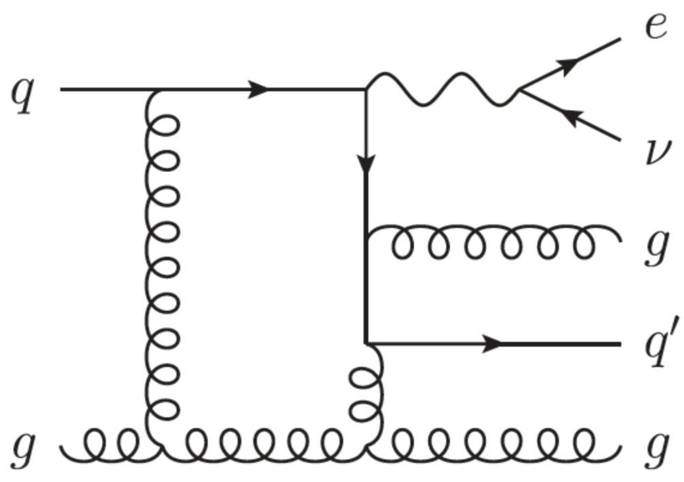
- Jets clustered by the **anti-k_t** algorithm (size parameter = 0.5).
  - Particle Flow technique used to reconstruct the jet constituents from optimum combination of all subdetector measurements.
  - Jet energies corrected for detector response and pile up effects.
  - Loose ID applied to reject signals due to calorimeter noise.

- b- and c-jets tagged with two algorithms:
  - **Track Counting (TC)**
    - Uses the impact parameter significance of tracks in the jet.
  - **Simple Secondary Vertex (SSV)**
    - Reconstructs the decay vertex and uses its decay length significance.

- Particle Flow also used to reconstruct ME_T.

W/Z+jets production

- W + 4 jets and Z + 3 jets calculations performed to NLO in QCD.
  - Phys. Rev. Lett. **106** (Mar, 2011) 092001 (W + 4 jet)
  - Phys. Rev. D **82** (Oct, 2010) 074002 (Z + 3 jet)
  - Precision varies from 10% to 30% due to uncertainties in PDFs and choice of renormalisation and factorisation scales.
  - Constrain with measurements.



- Measure the cross section ratios (jet multiplicities n are inclusive):

  σ(V + n jets) / σ(V)

  σ(V + n jets) / σ(V + (n-1) jets)

  σ(W + jets) / σ(Z + jets)

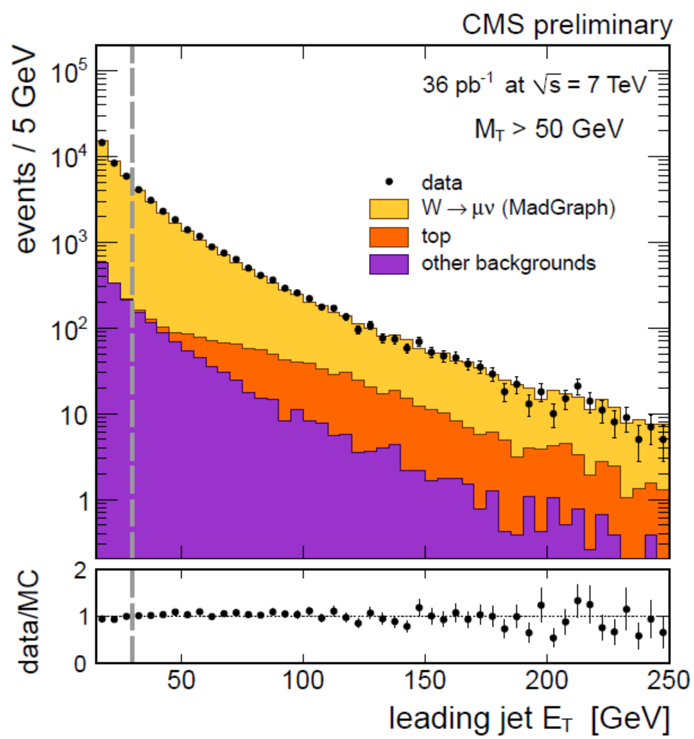
- Measure also the W charge asymmetry as a function of jet multiplicity.

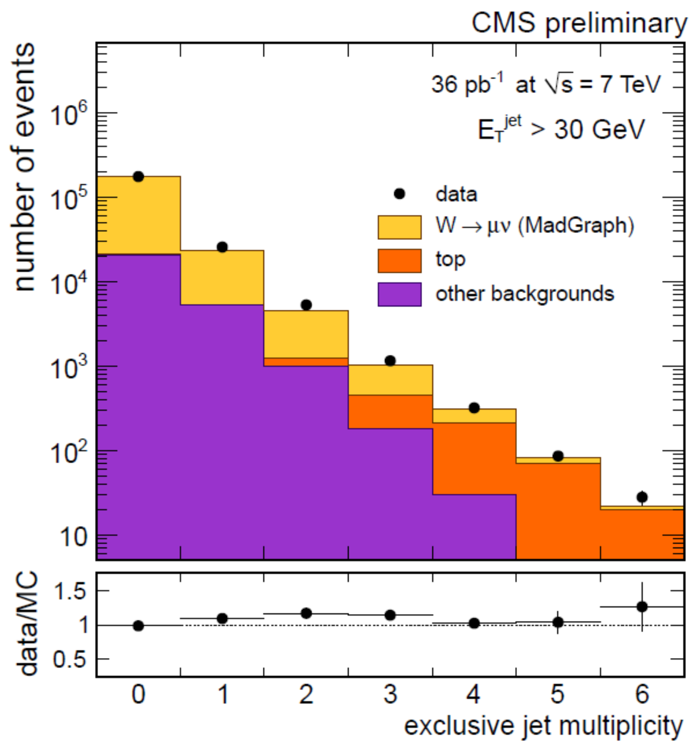
  $$A_W = [\sigma(W^+) - \sigma(W^-)] / [\sigma(W^+) + \sigma(W^-)]$$

W/Z+jets selections

- Select events with one or more good lepton (e, μ) candidates.
  - Leading lepton (e, μ) p_T > 20 GeV/c, η < 2.5 (e), η < 2.1 (μ), excluding electrons in ECAL barrel-endcap crack
  - Second lepton p_T > 10 GeV/c, η < 2.5, looser ID.
  - Events with 60 < m(ll) < 120 GeV/c^2 comprise the Z+jets sample, events failing this requirement comprise the W+jets sample such that there is no overlap between the two samples.
  - Require m_T > 50 GeV/c^2 in the W+jets sample.

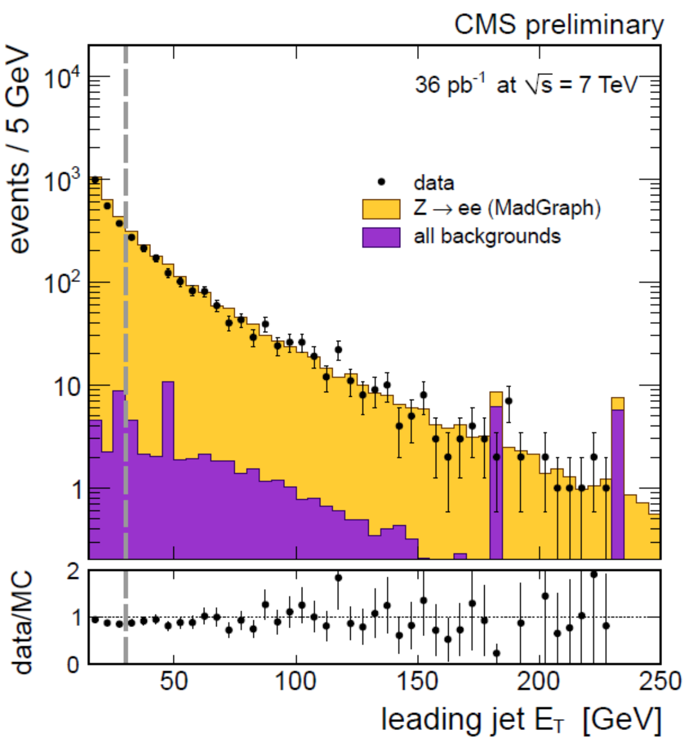
- Count jets with p_T > 30 GeV/c, η < 2.4.

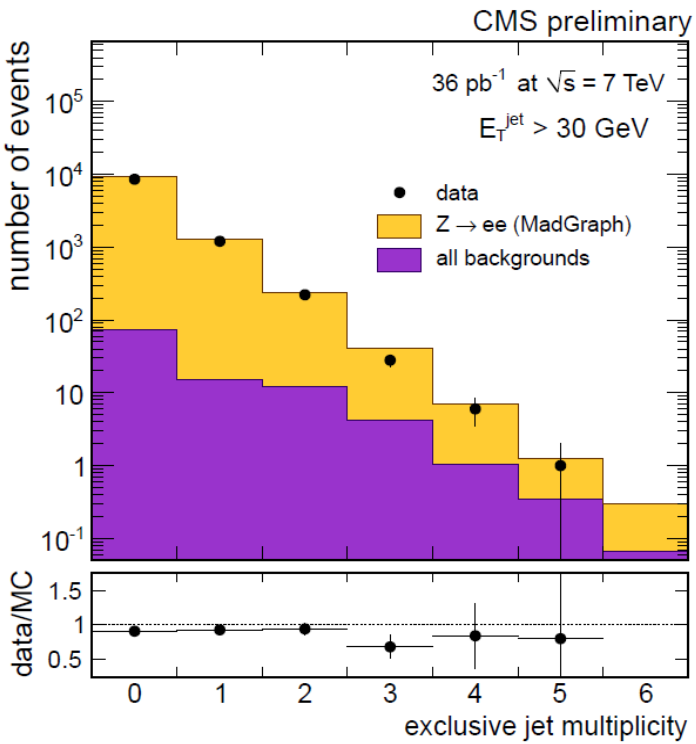




- Jet energies and multiplicities: good agreement between data and MC.

Z+jets control plots

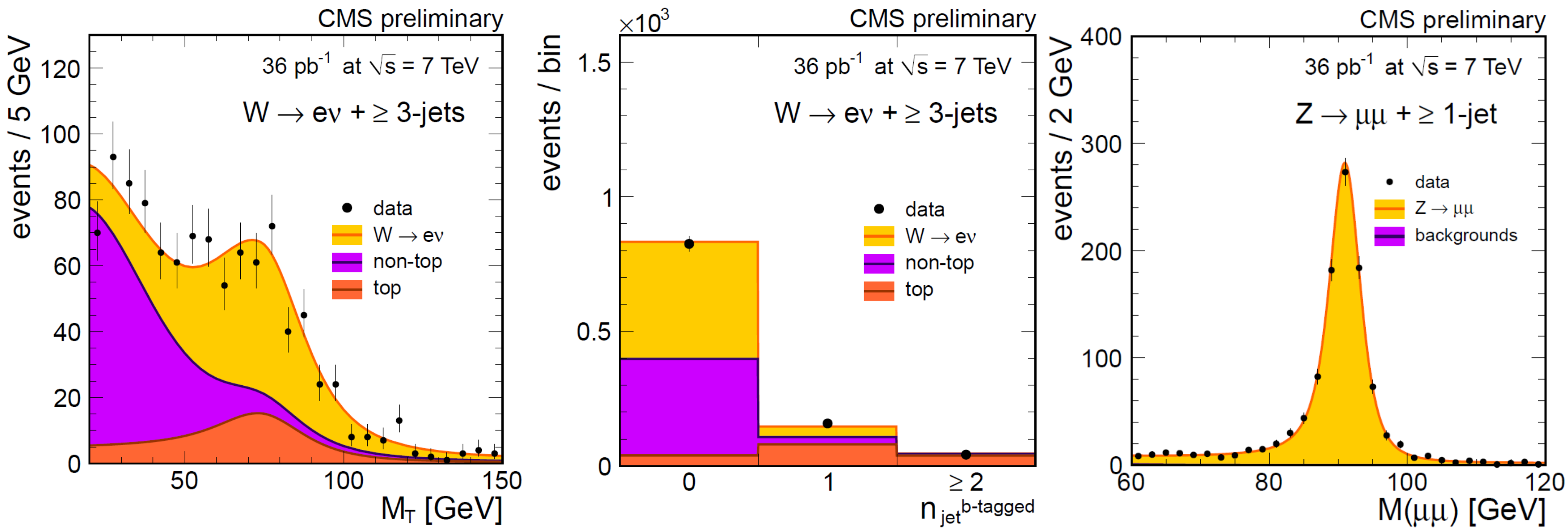




- Jet energies and multiplicities show good agreement with MC.

W/Z+jets signal extraction

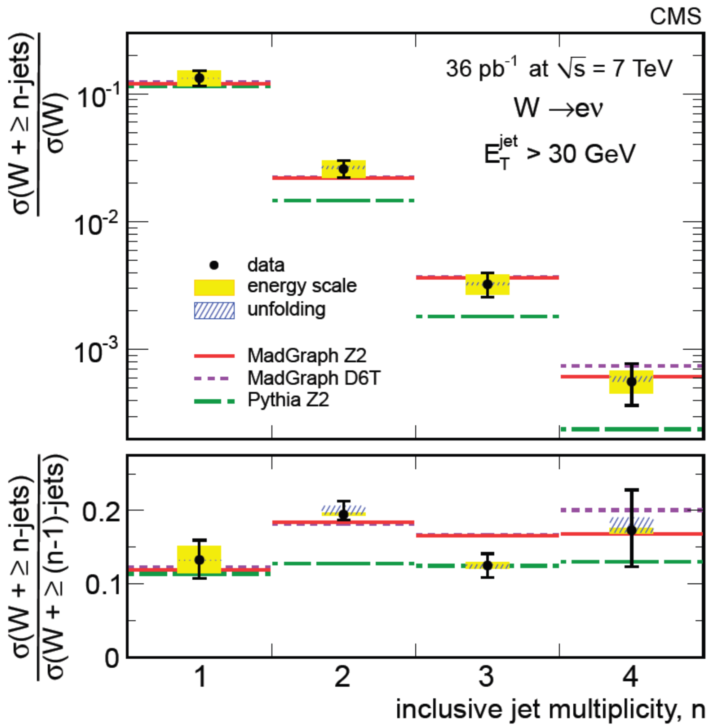
- Fit for W/Z yield in exclusive jet multiplicty bins for $N_{jet} \leq 3$ and inclusive bins for $N_{jet} \geq 4$.
  W+jets: 2D fit to m_T and $N_{b\text{-tag}}$
  - $N_{b\text{-tag}}$ provides a data driven control of the tt yield (TC b-tagging algorithm).
  Z+jets: Fit to m(ll)
  - Negligible backgrounds.

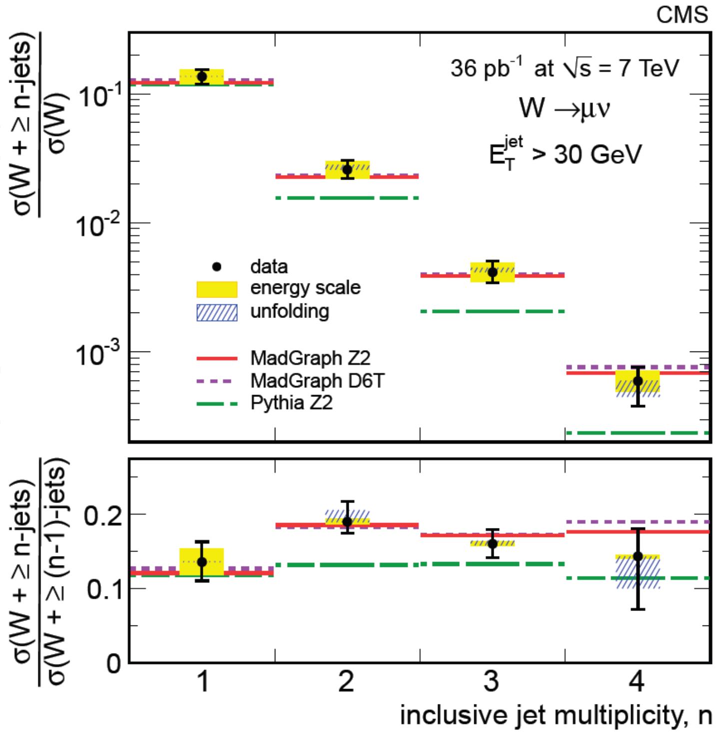


- Unfolding procedure applied to correct for migration between N_{jet} bins due to imperfect jet energy resolution and reconstruction efficiency.
  - Singular value decomposition with migration matrix derived from MadGraph W/Z+jets

W+jets results

- Measured ratios **σ(W + n jets) / σ(W)** and **σ(W + n jets) / σ(W + (n-1) jets)** :





- Good agreement with MadGraph, poor agreement with Pythia at high jet multiplicity as expected.

- Dominant systematic uncertainties:

  JES

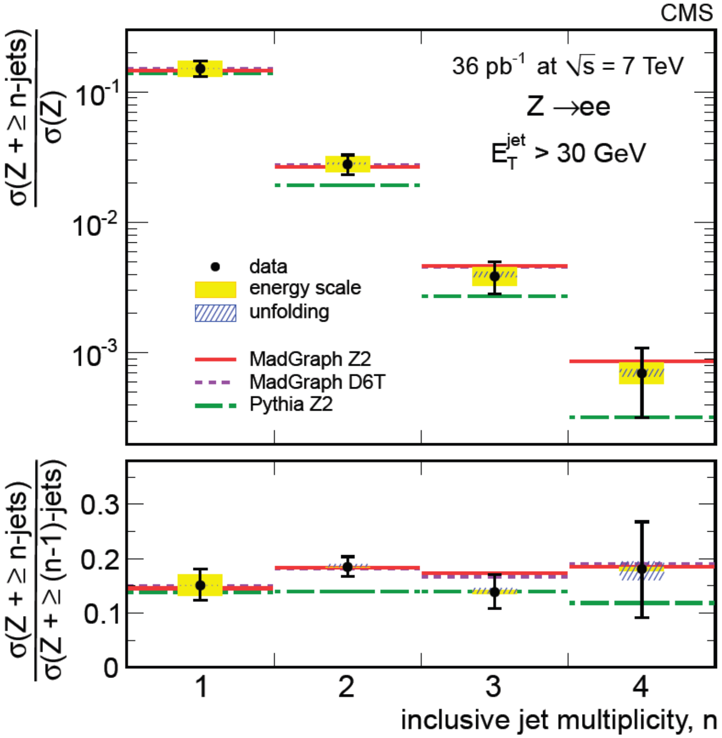
  - Difference in flavour content between W+jets and the sample used to extract the JEC is accounted for.

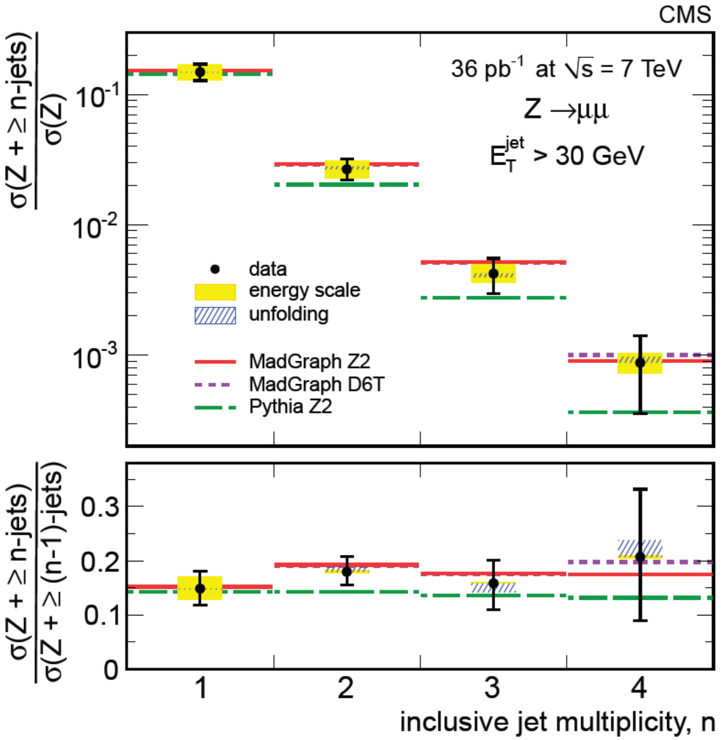
  Unfolding

  - Studied effect of different simulations (MadGraph and Pythia) and tunes (Z2 and D6T) on the migration matrix.

Z+jets results

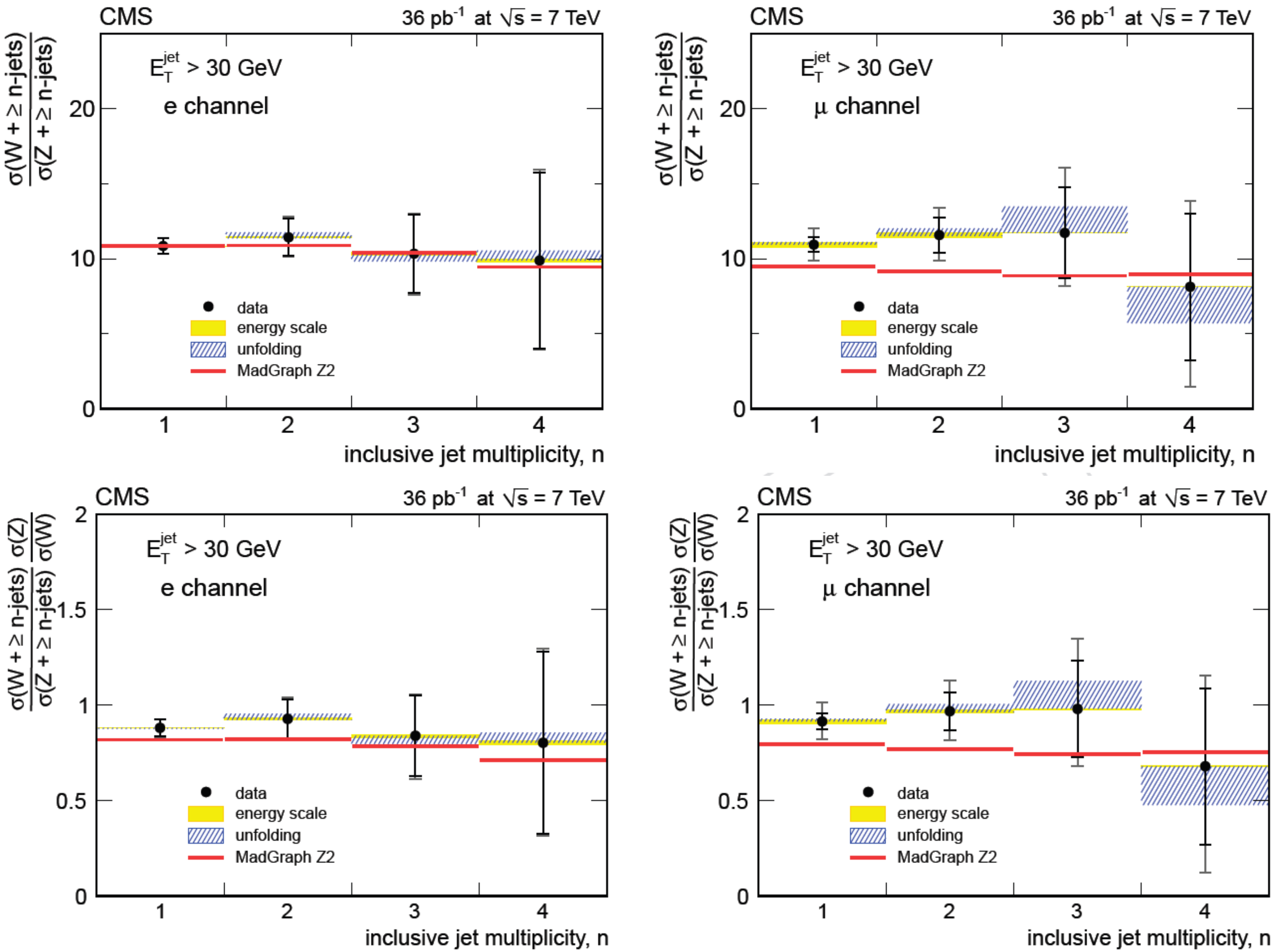
- Measured ratios **σ(Z + n jets) / σ(Z)** and **σ(Z + n jets) / σ(Z + (n-1) jets)** :





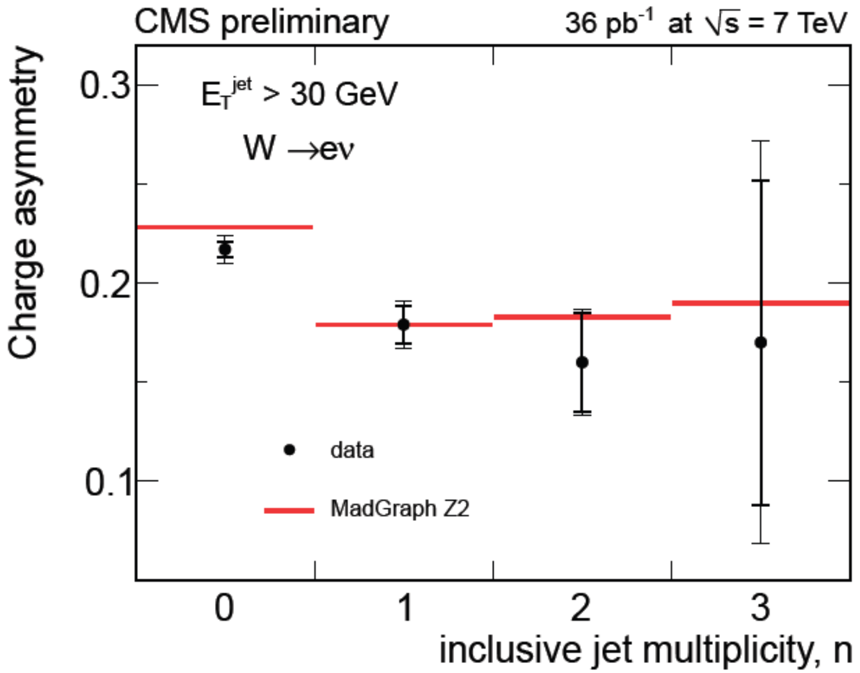
- Good agreement with MadGraph.
- Larger statistical uncertainty at high jet multiplicity than in W+jets.

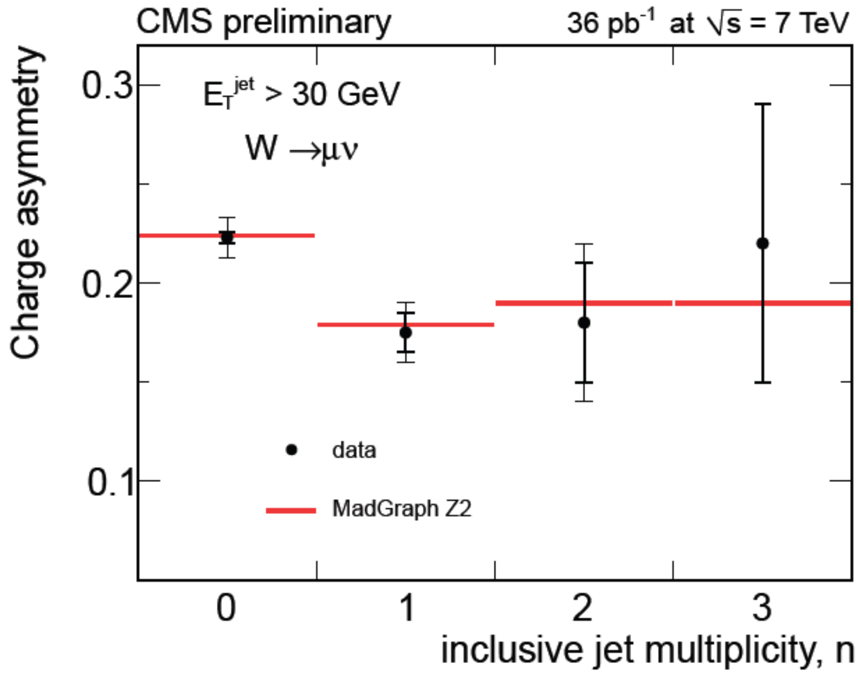
W+jets/Z+jets ratios



- Reasonable agreement with MadGraph.

W charge asymmetry





- W charge asymmetry as a function of a jet multiplicity in good agreement with MadGraph.
- Asymmetry is smaller in W+jets events as expected.
- Charge misidentification uncertainity and positive vs. negative lepton efficiency uncertainties are small and accounted for.

Z+b production

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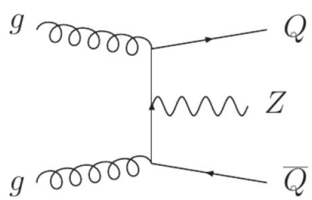
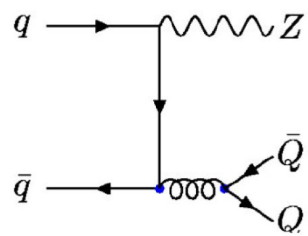
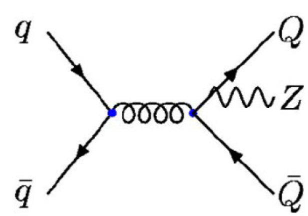
- Benchmark for searches for Higgs boson production in association with b quarks.
  - Large uncertainties in H+b cross section at NLO.
  - 30% difference between fixed and variable flavour schemes at large m_H.
  - Study of Z+b production should help to clarify which scheme is favoured by data.

- Fixed flavour scheme: u, d, s, c quarks only in the hard scattering process.
  - b quarks produced explicitly in gluon splitting.
  - Recent NLO calculation with massive b quarks: arXiv:1106.6019.



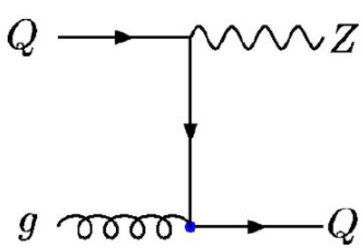




Fixed flavour:
$q\bar{q}/gg \rightarrow Z + Q\bar{Q}$,
q = u, d, s, c
Q = b, c

gg channel dominant at LHC!

- Variable flavour scheme: b quarks participate directly in hard scattering (gluon splitting integrated into PDF).
  - NLO calculations with massless b quarks: Phys. Rev. **D69** (2004) 074021, Phys. Rev. **D72** (2005) 074024, Phys. Rev. **D73** (2006) 054007.



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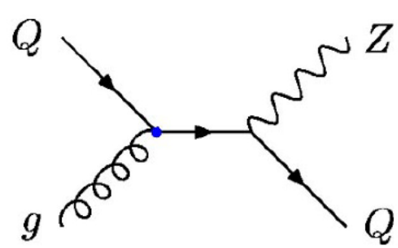


Variable flavour:
$g + Q \rightarrow Z + Q$,
Q = b, c

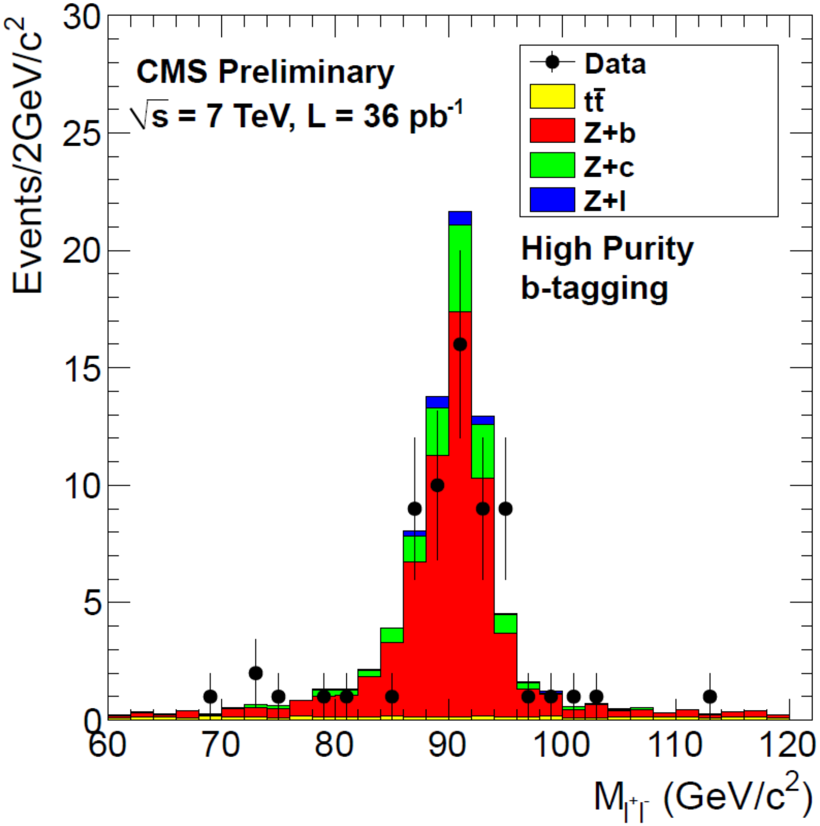
Z+b analysis

- Measure **σ(Z + b) / σ(Z + j)** and compare to fixed and variable flavour schemes implemented in MadGraph.
  - Variable flavour inclusive Z+jets sample normalised to NNLO cross section.
  - Fixed flavour Z+b, Z+c samples normalised to NLO cross section (MCFM calculation in variable flavour scheme).

- Dominant backgrounds: Z+c, Z+l (l = light jet), tt production

- Dominant uncertainties: b-tagging efficiency, b-jet purity.

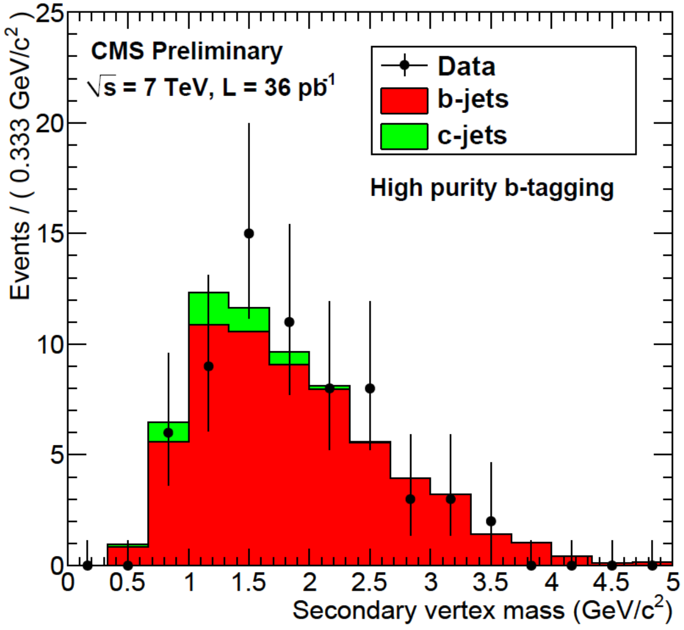
- Study electron and muon channels.
  - e p_T > 25 GeV/c, η < 2.5, excluding electrons in ECAL barrel-endcap crack
  - μ p_T > 20 GeV/c, η < 2.1
  - Jet p_T > 25 GeV/c, η < 2.1
  - b-jets tagged with SSV algorithm with High Efficiency (HE) and High Purity (HP) versions, working points corresponding to 1% and 0.1% mistag rates.
  - Select events with 60 < m(ll) < 120 GeV/c^2 and ME_T < 40 GeV (ME_T cut to suppress tt).



Z+b results

$$\mathcal{R} = \frac{N^{data}_{Z+b}\mathcal{P} - N^{MC}_{t\bar{t}}}{N^{data}_{Z+j}\varepsilon_{MC}}$$

- Need estimates of b-jet purity, tt background and b-tagging efficiency to measure **R = σ(Z + b) / σ(Z + j)**
  - Fit to secondary vertex mass with MC templates to extract b-jet purity = 88 ± 11%.
  - N_{tt} from MC.
  - b-tagging efficiency estimated in data containing jets associated with muons (20% uncertainty).



- Results in good agreement with fixed flavour MadGraph samples.

Sample	$\mathcal{R}(Z \to ee)$ (%), $p_T^e > 25$ GeV, $\lvert\eta^e\rvert < 2.5$	$\mathcal{R}(Z \to \mu\mu)$ (%), $p_T^\mu > 20$ GeV, $\lvert\eta^\mu\rvert < 2.1$
Data HE	$4.3 \pm 0.6(stat) \pm 1.1(syst)$	$5.1 \pm 0.6(stat) \pm 1.3(syst)$
Data HP	$5.4 \pm 1.0(stat) \pm 1.2(syst)$	$4.6 \pm 0.8(stat) \pm 1.1(syst)$
MADGRAPH	$5.1 \pm 0.2(stat) \pm 0.2(syst) \pm 0.6(theory)$	$5.3 \pm 0.1(stat) \pm 0.2(syst) \pm 0.6(theory)$
MCFM	$4.3 \pm 0.5(theory)$	$4.7 \pm 0.5(theory)$

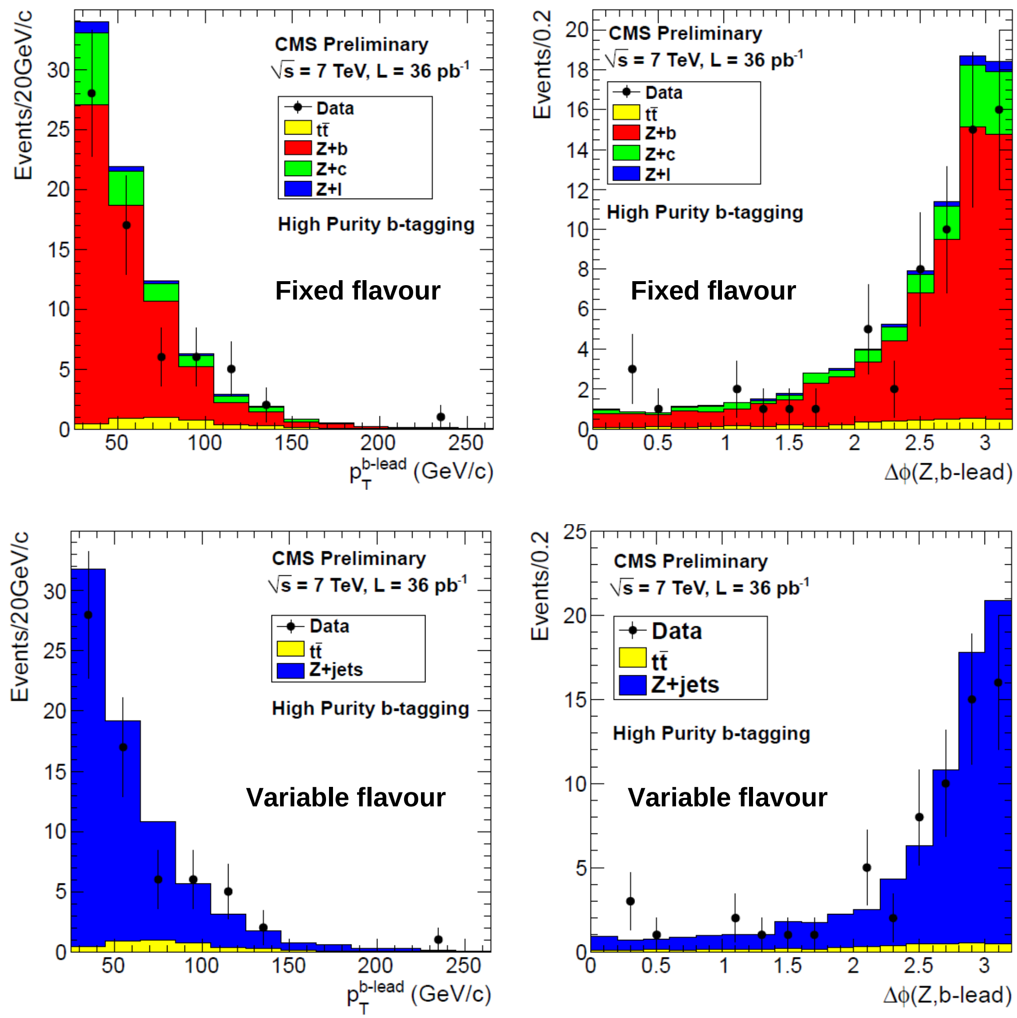
Z+b: fixed vs. variable flavour

- Yields from variable flavour inclusive Z+jets sample also in agreement with data.

Selection	Data	$\sum MC$	$t\bar{t}$	$Z+j$
HE eeb	54 ± 7	64.2 ± 1.1	2.0 ± 0.1	62.2 ± 1.1
HP eeb	29 ± 5	30.1 ± 0.8	1.60 ± 0.09	28.5 ± 0.8
HP eebb	1 ± 1	1.1 ± 0.1	0.39 ± 0.04	0.7 ± 0.1
HE $\mu\mu$b	91 ± 10	92.5 ± 1.4	3.0 ± 0.1	89.5 ± 1.4
HP $\mu\mu$b	36 ± 6	44.4 ± 0.9	2.4 ± 0.1	42.0 ± 0.9
HP $\mu\mu$bb	1 ± 1	1.6 ± 0.2	0.52 ± 0.05	1.1 ± 0.1

- Shapes of p_T(b) and $\Delta\varphi$(Z, b) in agreement with data in both fixed and variable flavour MadGraph samples.

- Scheme dependence cannot be resolved with current statistics.

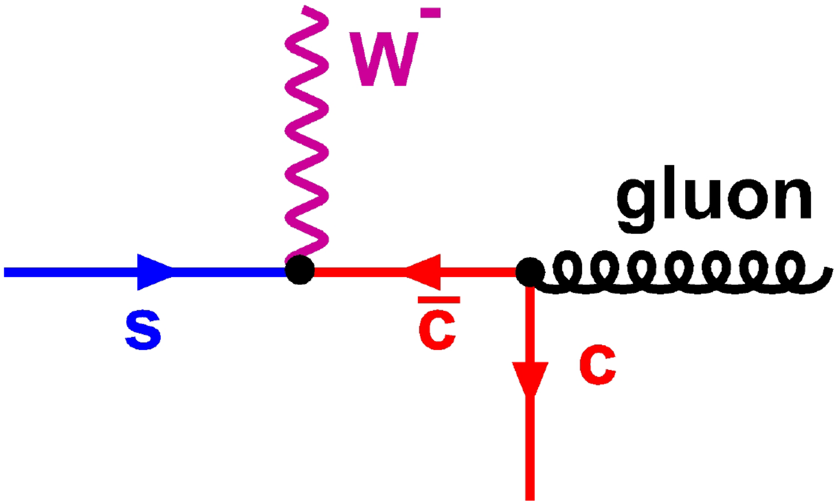


W+c production

- Rate of W+c production sensitive to s quark content of the proton.
  - Production dominated by $\bar{s}g \rightarrow W^+\bar{c}$, $sg \rightarrow W^-c$

- W+b production is highly suppressed: use b-tagging techniques to identify the c-jet.

- Measure ratios
  $R_c^{\pm} = \sigma(W^+c) / \sigma(W^-c)$
  $R_c = \sigma(W + c) / \sigma(W + j)$



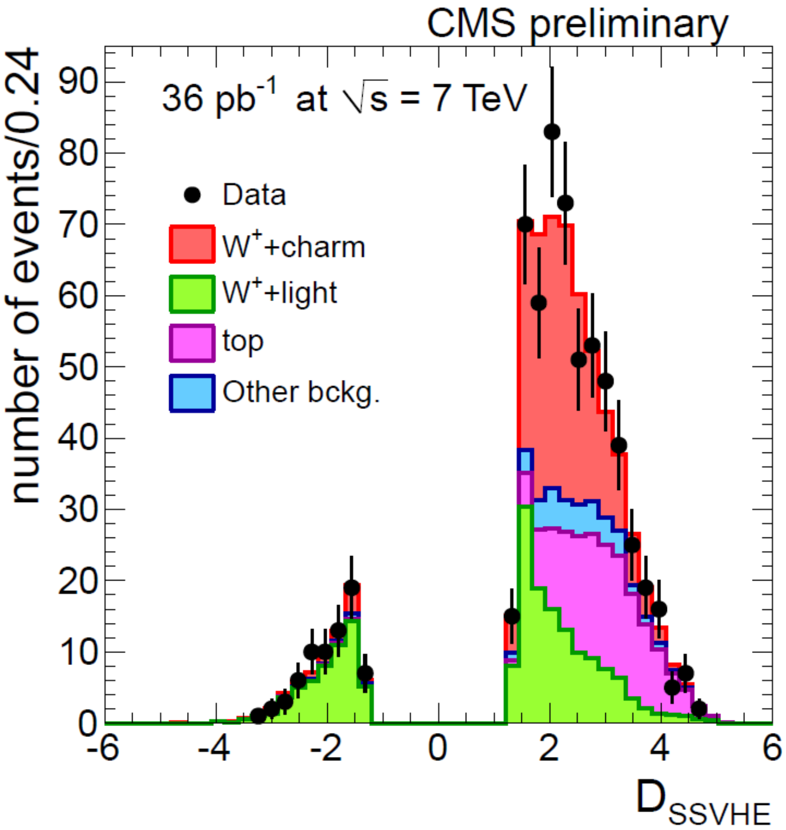
- Dominant backgrounds from top and W+l production.

- Analysis uses POWHEG NLO generator with CT10 PDF set for electroweak processes.
  - With cut on hard jet multiplicity.
  - Allows detailed comparison with NLO PDFs.
  - MadGraph used to cross check.

- Select events with muon p_T > 25 GeV/c, η < 2.1 and at least one jet p_T > 20 GeV/c, η < 2.1.
  - Require at least one jet tagged with SSVHE algorithm.
  - Veto events with dimuon or ≥ 3 hard jets (p_T > 40 GeV/c) to supress Drell-Yan and tt backgrounds.
  - Require $m_T > 50$ GeV/c^2.

W+c results

- Extract W+c yield by fitting to the SSVHE discriminator with MC templates.
  - Fit extends to negative tags (where SV is in "wrong direction"); helps to constrain the W+l component.
  - tt component checked in control region in data with inverted jet multiplicity cut.



$$R_c^{\pm} = 0.92 \pm 0.19\,(stat.) \pm 0.04\,(syst.)$$

- Dominant uncertainties on $R_c^{\pm}$ in background templates.

$$R_c = 0.143 \pm 0.015\,(stat.) \pm 0.024\,(syst.)$$

- R_c uncertainity dominated by secondary vertex reconstruction efficiency.

- Results in agreement with MCFM predictions at NLO.

Ratio	MCFM (CT10)	MCFM (MSTW08)	MCFM (NNPDF21)
$R_c^{\pm}$	$0.915^{+0.006}_{-0.006}$	$0.881^{+0.022}_{-0.032}$	0.902 ± 0.008
R_c	$0.125^{+0.013}_{-0.007}$	$0.118^{+0.002}_{-0.002}$	0.103 ± 0.005

Summary

- Rates of jet production in association with W and Z bosons measured by CMS.
  - Rates and jet multiplicity scaling behaviour well described by ME+PS simulation.

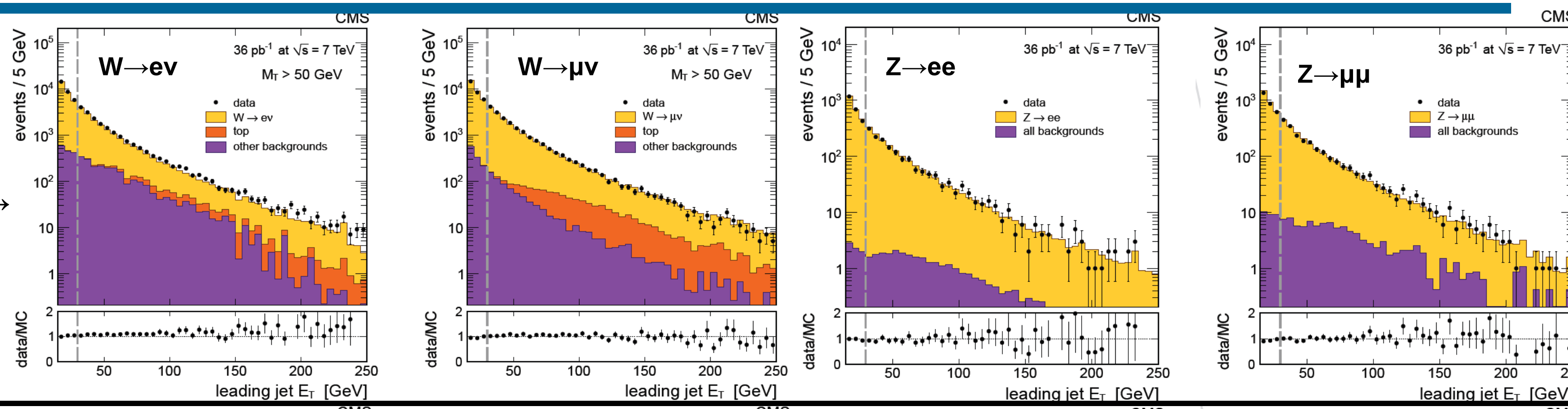
- Observations of Z+b and W+c production in agreement with theory.
  - Measurements still largely statistics limited.

- Analyses are currently being updated with 2011 data ~ 1.5 fb^{-1}: will allow more detailed study of W/Z+jets production.
  - Differential cross sections.
  - Sensitivity to Z+b flavour scheme dependency.
  - Use measurements to constrain PDFs.

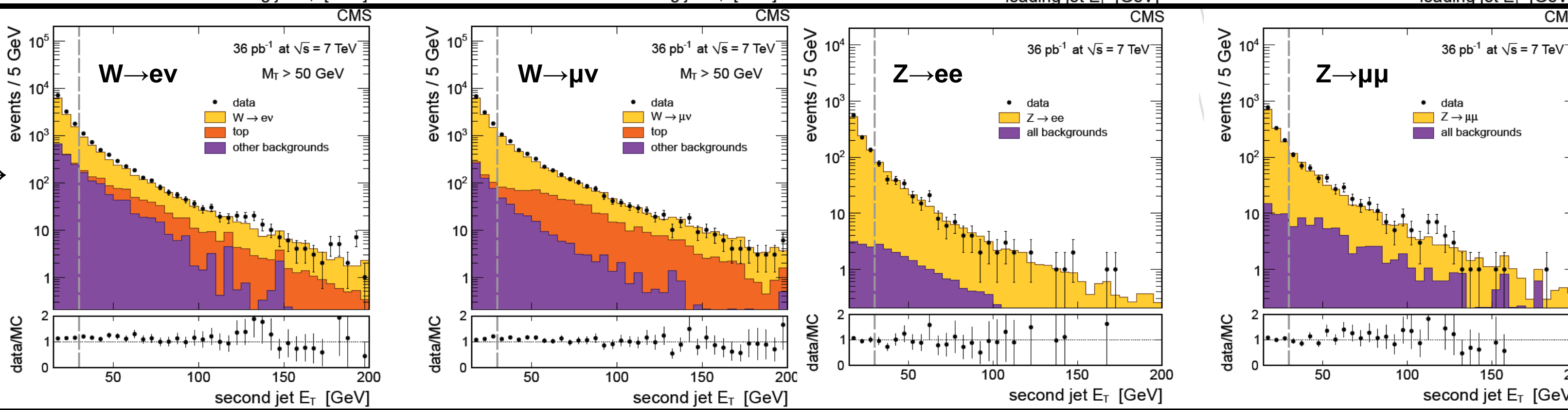
Backup

Control plots

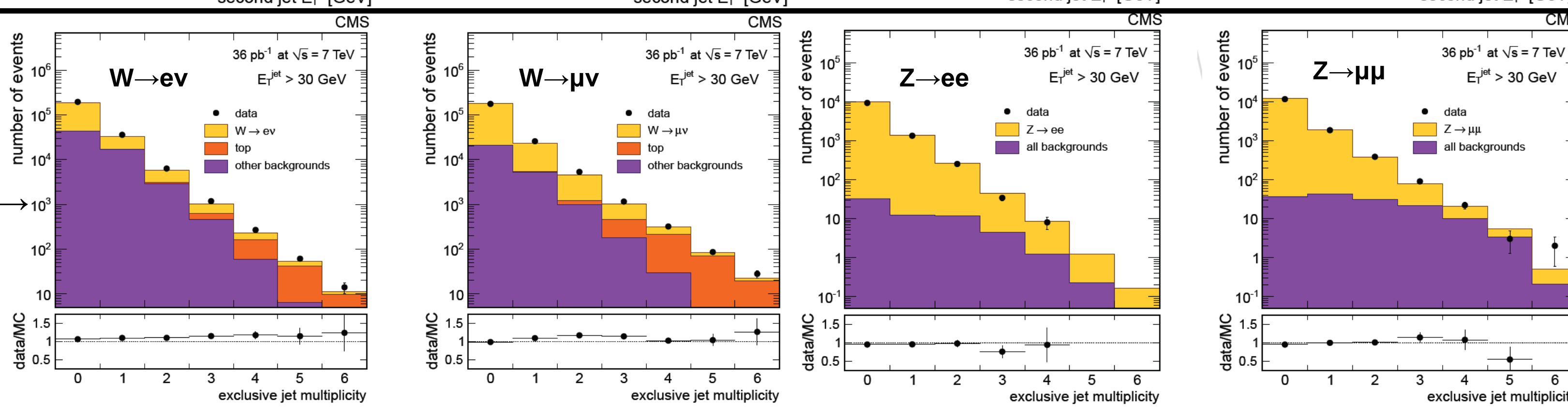
Leading jet E_T →



Second jet E_T →

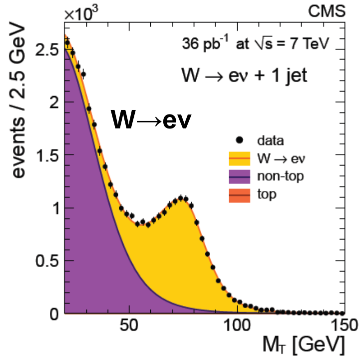


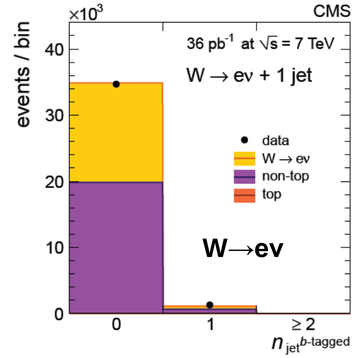
Jet multiplicity →

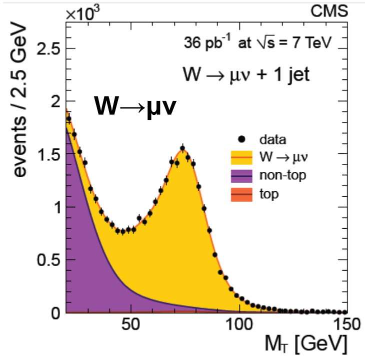


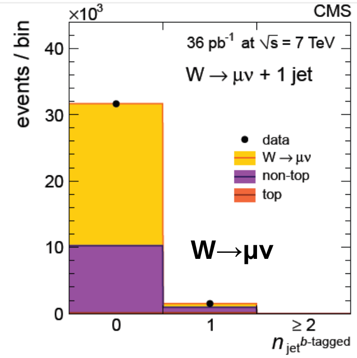
m_T, $N_{b\text{-tag}}$, m(ll) fits

W + 1 jet →

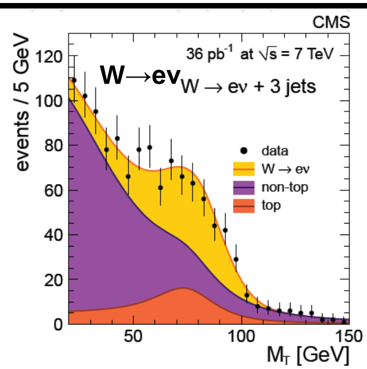


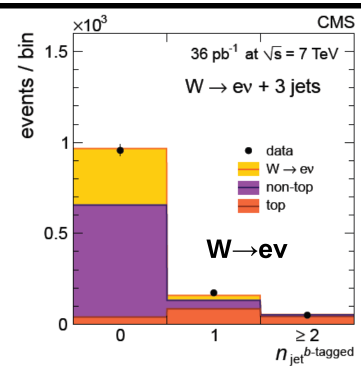


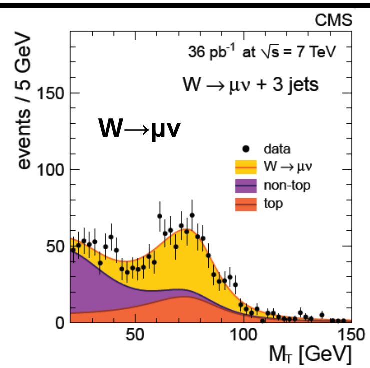


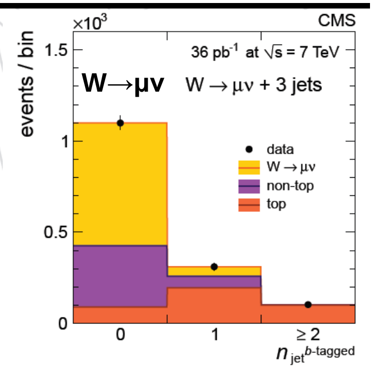


W + 3 jets →

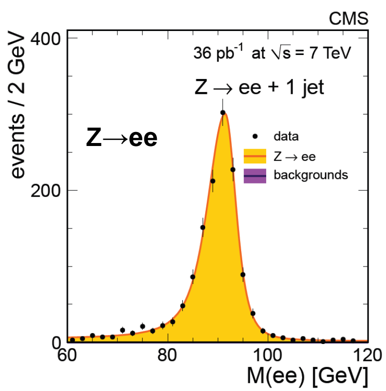


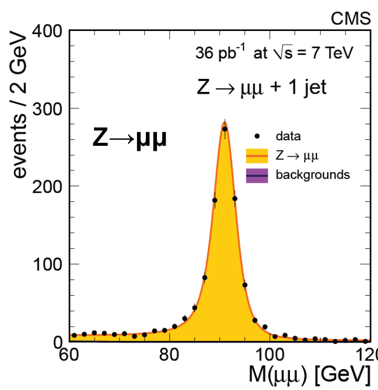






Z + 1 jet →





Uncertainties on jet rates

Uncertainties on jet rate in $W \to e\nu$ events [%]					
Jet multiplicity	0	1	2	3	≥ 4
Jet counting	∓ 5	± 8	$^{+11}_{-10}$	$^{+14}_{-12}$	$^{+16}_{-15}$
Selection efficiency	± 0.5	± 0.3	± 1.0	± 1.7	± 4
Signal extraction		± 0.1	± 0.4	± 3	± 9
Total systematics	∓ 5	± 8	$^{+11}_{-10}$	$^{+14}_{-12}$	± 17
Statistical uncertainty	± 0.3	± 1.0	± 2.4	± 10	± 28

Uncertainties on jet rate in $W \to \mu\nu$ events [%]					
Jet multiplicity	0	1	2	3	≥ 4
Jet counting	∓ 5	± 8	$^{+11}_{-10}$	$^{+14}_{-12}$	$^{+16}_{-15}$
Selection efficiency	± 3	± 6	± 4	± 10	± 17
Signal extraction		± 0.1	± 0.4	± 3	± 9
Total systematics	± 6	± 10	$^{+13}_{-12}$	$^{+19}_{-17}$	± 26
Statistical uncertainty	± 0.3	± 0.9	± 2.4	± 5.6	± 21

Uncertainties on jet rate in $Z \to e^+e^-$ events [%]					
Jet multiplicity	0	1	2	3	≥ 4
Jet counting	∓ 5	± 8	$^{+11}_{-10}$	$^{+14}_{-12}$	$^{+16}_{-15}$
Selection efficiency	± 1.1	± 1.0	± 2.2	± 2.6	± 6
Total systematics	∓ 5	± 8	$^{+11}_{-10}$	$^{+14}_{-12}$	$^{+17}_{-16}$
Statistical uncertainty	± 1.1	± 3.1	± 7	± 17	± 43

Uncertainties on jet rate in $Z \to \mu^+\mu^-$ events [%]					
Jet multiplicity	0	1	2	3	≥ 4
Jet counting	∓ 5	± 8	$^{+11}_{-10}$	$^{+14}_{-12}$	$^{+16}_{-15}$
Selection efficiency	± 3	$^{+6}_{-5}$	$^{+7}_{-6}$	± 10	$^{+24}_{-12}$
Total systematics	± 6	± 10	$^{+13}_{-12}$	$^{+18}_{-16}$	$^{+30}_{-21}$
Statistical uncertainty	± 0.9	± 2.6	± 5.2	± 18	± 41

W/Z+jets cross section ratios

Table 4: $\sigma(W+\geq n \text{ jets})/\sigma(W)$, the jet multiplicities normalized to the inclusive cross section.

n jets	σ ratio	stat	stat + fit and efficiency	jet counting	unfolding
electron channel					
$\geq 1 / \geq 0$ jets	0.133	0.001	0.002	$^{+0.019}_{-0.017}$	$^{+0.000}_{-0.001}$
$\geq 2 / \geq 0$ jets	0.026	0.000	0.001	$^{+0.004}_{-0.004}$	$^{+0.001}_{-0.000}$
$\geq 3 / \geq 0$ jets	0.0032	0.0002	0.0004	$^{+0.0006}_{-0.0005}$	$^{+0.0001}_{-0.0001}$
$\geq 4 / \geq 0$ jets	0.0006	0.0000	0.0002	$^{+0.0001}_{-0.0001}$	$^{+0.0001}_{-0.0000}$
muon channel					
$\geq 1 / \geq 0$ jets	0.136	0.001	0.007	$^{+0.019}_{-0.017}$	$^{+0.001}_{-0.000}$
$\geq 2 / \geq 0$ jets	0.026	0.000	0.002	$^{+0.004}_{-0.004}$	$^{+0.002}_{-0.000}$
$\geq 3 / \geq 0$ jets	0.0041	0.0001	0.0005	$^{+0.0008}_{-0.0006}$	$^{+0.0003}_{-0.0000}$
$\geq 4 / \geq 0$ jets	0.0006	0.0000	0.0002	$^{+0.0001}_{-0.0001}$	$^{+0.0000}_{-0.0001}$

Table 5: $\sigma(Z+\geq n \text{ jets})/\sigma(Z)$, the jet multiplicities normalized to the inclusive cross section.

n jets	σ ratio	stat	stat + fit and efficiency	jet counting	unfolding
electron channel					
$\geq 1 / \geq 0$ jets	0.151	0.003	0.006	$^{+0.021}_{-0.019}$	$^{+0.005}_{-0.000}$
$\geq 2 / \geq 0$ jets	0.028	0.001	0.003	$^{+0.004}_{-0.004}$	$^{+0.002}_{-0.000}$
$\geq 3 / \geq 0$ jets	0.0039	0.0004	0.0009	$^{+0.0007}_{-0.0006}$	$^{+0.0005}_{-0.0001}$
$\geq 4 / \geq 0$ jets	0.0007	0.0000	0.0004	$^{+0.0001}_{-0.0001}$	$^{+0.0001}_{-0.0000}$
muon channel					
$\geq 1 / \geq 0$ jets	0.149	0.003	0.011	$^{+0.022}_{-0.020}$	$^{+0.000}_{-0.001}$
$\geq 2 / \geq 0$ jets	0.027	0.001	0.004	$^{+0.004}_{-0.004}$	$^{+0.001}_{-0.000}$
$\geq 3 / \geq 0$ jets	0.0042	0.0005	0.0012	$^{+0.0008}_{-0.0006}$	$^{+0.0000}_{-0.0003}$
$\geq 4 / \geq 0$ jets	0.0009	0.0000	0.0006	$^{+0.0002}_{-0.0001}$	$^{+0.0001}_{-0.0000}$

Table 6: $\sigma(W+\geq n \text{ jets})/\sigma(W+\geq (n-1) \text{ jets})$, the ratio of jet multiplicities.

n jets	σ ratio	stat	stat + fit and efficiency	jet counting	unfolding
electron channel					
$\geq 1 / \geq 0$ jets	0.133	0.002	0.002	$^{+0.019}_{-0.017}$	$^{+0.000}_{-0.001}$
$\geq 2 / \geq 1$ jets	0.195	0.007	0.007	$^{+0.002}_{-0.001}$	$^{+0.012}_{-0.000}$
$\geq 3 / \geq 2$ jets	0.125	0.014	0.015	$^{+0.004}_{-0.004}$	$^{+0.002}_{-0.004}$
$\geq 4 / \geq 3$ jets	0.173	0.046	0.049	$^{+0.003}_{-0.004}$	$^{+0.017}_{-0.003}$
muon channel					
$\geq 1 / \geq 0$ jets	0.136	0.002	0.007	$^{+0.019}_{-0.017}$	$^{+0.001}_{-0.000}$
$\geq 2 / \geq 1$ jets	0.190	0.005	0.014	$^{+0.004}_{-0.003}$	$^{+0.016}_{-0.000}$
$\geq 3 / \geq 2$ jets	0.160	0.011	0.018	$^{+0.004}_{-0.003}$	$^{+0.004}_{-0.002}$
$\geq 4 / \geq 3$ jets	0.144	0.025	0.037	$^{+0.002}_{-0.003}$	$^{+0.000}_{-0.043}$

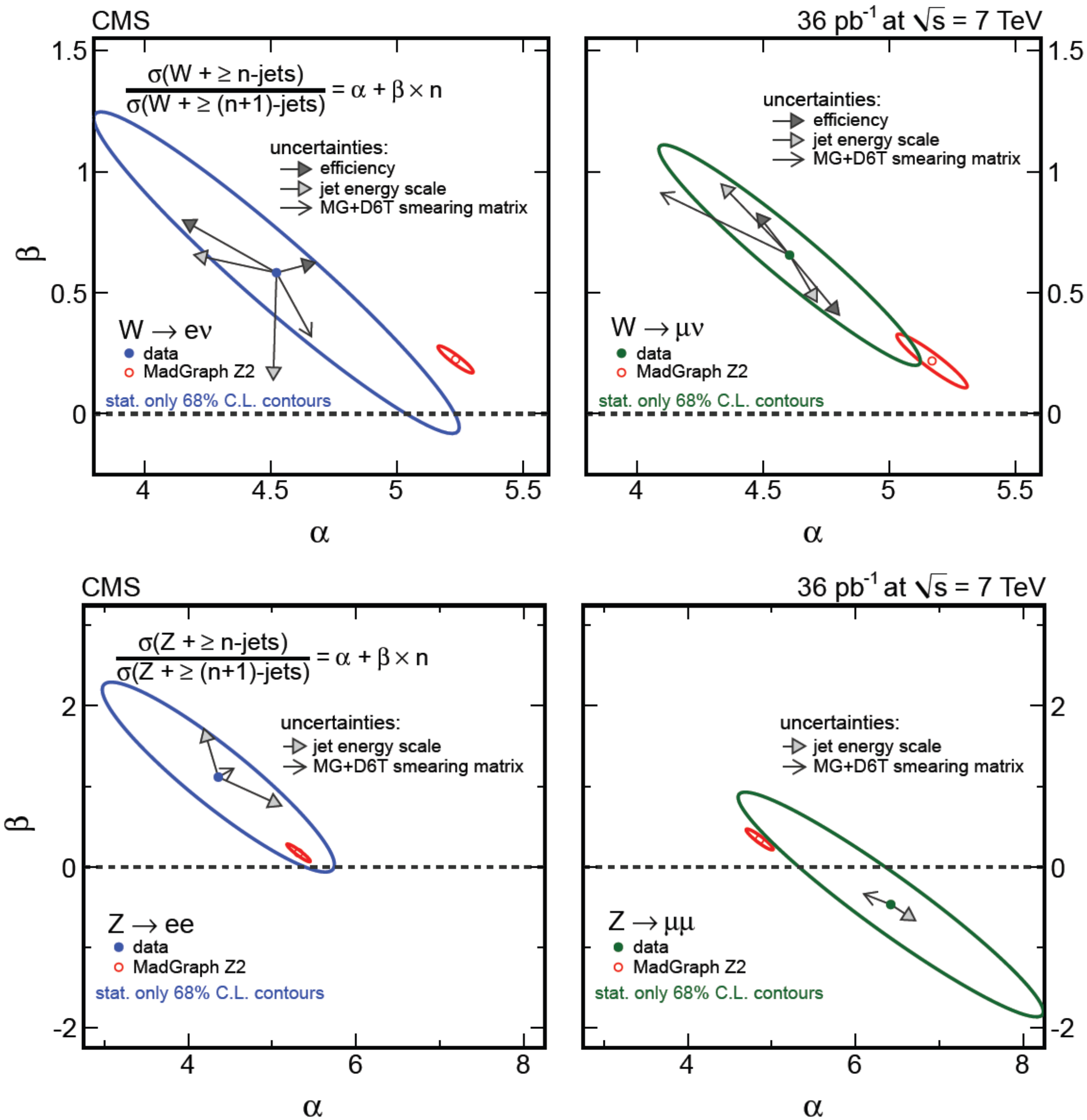
Table 7: $\sigma(Z+\geq n \text{ jets})/\sigma(Z+\geq (n-1) \text{ jets})$, the ratio of jet multiplicities.

n jets	σ ratio	stat	stat + fit and efficiency	jet counting	unfolding
electron channel					
$\geq 1 / \geq 0$ jets	0.151	0.006	0.006	$^{+0.021}_{-0.019}$	$^{+0.001}_{-0.000}$
$\geq 2 / \geq 1$ jets	0.185	0.017	0.017	$^{+0.002}_{-0.001}$	$^{+0.006}_{-0.000}$
$\geq 3 / \geq 2$ jets	0.138	0.030	0.030	$^{+0.004}_{-0.004}$	$^{+0.008}_{-0.003}$
$\geq 4 / \geq 3$ jets	0.181	0.085	0.085	$^{+0.003}_{-0.004}$	$^{+0.014}_{-0.021}$
muon channel					
$\geq 1 / \geq 0$ jets	0.149	0.005	0.011	$^{+0.022}_{-0.020}$	$^{+0.000}_{-0.001}$
$\geq 2 / \geq 1$ jets	0.180	0.016	0.023	$^{+0.003}_{-0.003}$	$^{+0.011}_{-0.000}$
$\geq 3 / \geq 2$ jets	0.158	0.036	0.043	$^{+0.002}_{-0.001}$	$^{+0.000}_{-0.017}$
$\geq 4 / \geq 3$ jets	0.207	0.104	0.117	$^{+0.002}_{-0.003}$	$^{+0.031}_{-0.000}$

Test of Berends-Giele scaling

Imperial College London

- Test scaling behaviour
  $C_n = \sigma(V + n \text{ jets}) / \sigma(V + (n+1) \text{ jets})$
- $C_n = \alpha + \beta n$ to allow for deviations from LO.
  - Use measurements of cross section ratios to fit for α and β.
- 68% CL countours on the plots for statistical uncertainty only. Systematic uncertainties shown as arrows.
- MadGraph shows reasonable agreement with data.
- W and Z measurements agree.



Z+b: fixed vs. variable flavour

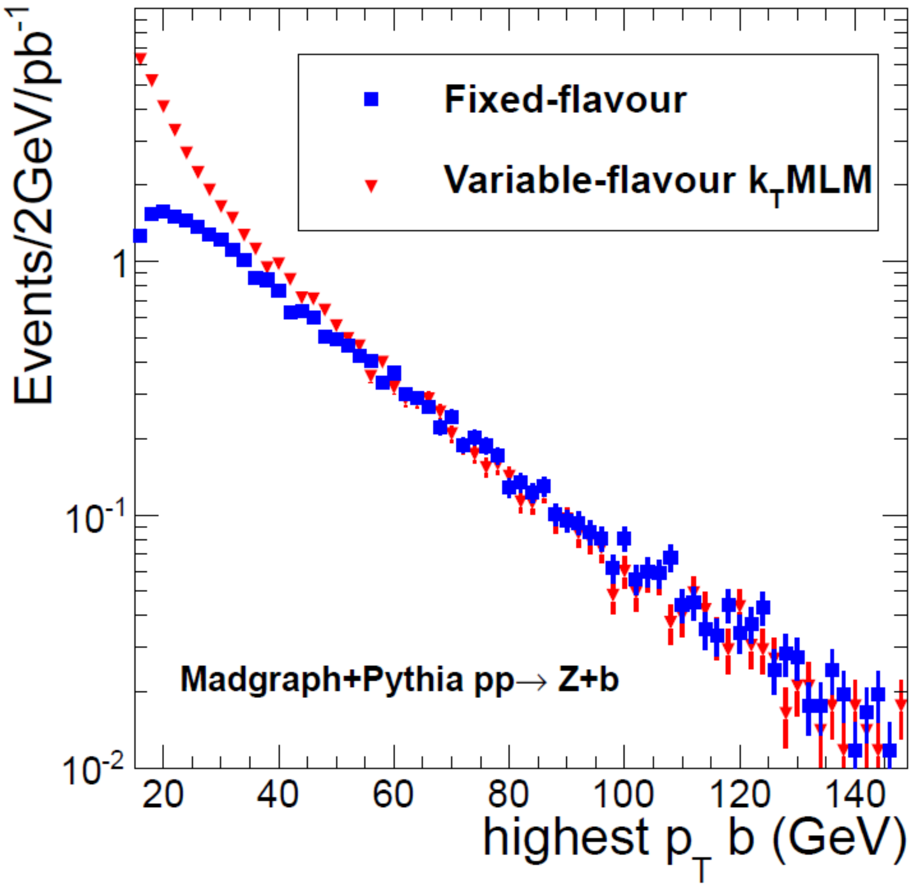


Figure 3: p_T of the highest p_T b-quark in the MADGRAPH Z+b fixed-flavour sample (blue squares) and in the MADGRAPH Z+j variable-flavour sample (red triangles).

W+c systematic uncertainties

Table 3: Relative systematic uncertainties (%) in the measurement of $R_c^{\pm}$.

Source	Relative uncertainty (%)
Charge asymmetry in efficiency	1.0
Muon resolution	<0.1
Pile-up effects	1.8
Jet energy scale/resolution	1.1
Jet multiplicity	0.7
Vertex reconstruction	0.3
Top templates	1.7
Light-quark contribution	1.1
W+b background	0.2
Other Monte Carlo backgrounds	1.4
PDF uncertainties	2.2
Charm fragmentation function	<0.1
Charm fragmentation BRs	0.1
TOTAL	4.1

Table 4: Relative systematic uncertainties (%) in the measurement of R_c.

Source	Relative uncertainty (%)
Charge asymmetry in efficiency	-
Muon resolution	0.7
Pile-up effects	2.5
Jet energy scale/resolution	2.3
Jet multiplicity	2.5
Vertex reconstruction	14.1
Top templates	6.2
Light-quark contribution	3.3
W+b background	2.4
Other Monte Carlo backgrounds	0.2
PDF uncertainties	0.2
Charm fragmentation function	0.2
Charm fragmentation BRs	0.2
TOTAL	16.5