Vector Boson (plus jets) in pp collisions at the LHC

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on behalf of the ATLAS, CMS, and LHCb Collaborations
Outline

Recent Results on Vector boson (plus jets) at LHC

– 7/8/13 p-p collisions results
  – Important tests of pQCD
  – Improve constraints to PDFs / non-pQCD
  – Understanding of backgrounds in search analyses

Many results not covered in this talk:
LHCb Results, ATLAS Results, CMS Results
See QCD and EW parallel sessions
See Matthias Schott talk
Selection overview

Events are selected with **candidates** of $Z \rightarrow ee/\mu\mu$ and $W \rightarrow e\nu/\mu\nu$

**Jets** are identified with anti-$k_T$ algorithm ($R=0.4/0.5$)
- energy **calibrated** to the particle-level using simulation
- residual corrections determined using data ($Z/\gamma^*+$jets or di-jets)

Measurements are compared to predictions (particle level) of several **MC**

**My apologies** for the extensive use of acronyms (letter soup)
13 TeV cross-sections
Using both $Z \rightarrow ee$ and $Z \rightarrow \mu\mu$ final states

Cross-sections and ratios for different jet multiplicities are compared to Madgraph5_aMC and Sherpa
Using $Z \rightarrow \mu \mu$ final state

Differential measurements are compared to MADGRAPH5_AMC@NLO
Inclusive W/Z

**Main uncertainties**
- 2.1% luminosity
- 3.4(1.4)% QCD for W
- 1.7% JES/JER for W(ev)
- <1% other
Inclusive W/Z

CMS Preliminary

CMS-PAS-SMP-15-004

Observation: NNPDF3.0

Theory: FEWZ (NNLO)

NNPDF3.0
1.354^{+0.011}_{-0.012}

CT14
1.350^{+0.014}_{-0.014}

MMHT2014
1.348^{+0.011}_{-0.008}

ABM12LHC
1.371^{+0.003}_{-0.004}

HERAPDF15
1.353^{+0.014}_{-0.013}

(inner uncertainty: PDF only)

σ_{tot} / σ_{W}

1.25 1.30 1.35 1.40

LHCb-CONF-2016-002

LHCb preliminary, \sqrt{s} = 13 TeV

p_{T}(\mu) > 20 GeV

2.0 < \eta(\mu) < 4.5

60 < M(\mu\mu) < 120 GeV

3.9\% luminosity error

13 TeV inclusive W/Z cross-section
- Impressive amount of work in a timely fashion!
- Precise measurements with first data
- Few tensions already observed comparing with FEWZ NLO
7/8 TeV
W/Z (plus jets)
Differential measurements are compared to NNLO FEWZ predictions.

Using HERA PDF method at NNLO, fit can be significantly improved for $10^{-1} > x > 10^{-3}$.
Studies of high-mass DY and photon induced processes $116 < M_{ll} < 1500$ GeV

Differential measurements are compared to NNLO FEWZ + IP-MRST2004qed

Large impact in the photon PDF (using Bayesian reweighting)
Predictions from different programs

Variety of agreement and discrepancy
Several distributions among the jets and the muon are studied.

Predictions from different programs:

**Variety** of agreement and discrepancy.
2/fb at 8 TeV
Using muon final states – $2.2 < \eta(\text{jet}) < 4.5$

Measurement of total cross-sections are in fair agreement with POWHEG and aMC@NLO
7/8 TeV

V+heavy-quark

Heavy-flavor identification with secondary-vertex and MVA analysis
Differential cross-sections and ratios $Z+b/Z+j$

Data are compared with predictions of MADGRAPH (4/5FS) and POWHEG NLO

$\begin{align*}
C_C & \quad C_{udsg} \\
Z(1b) \ (ee) & \quad 1.29 \pm 0.13 \quad 1.70 \pm 0.21 \\
Z(1b) \ (\mu\mu) & \quad 1.51 \pm 0.12 \quad 1.18 \pm 0.19 \\
C_{bb} \\
Z(2b) \ (ee) & \quad 1.18 \pm 0.12 \\
Z(2b) \ (\mu\mu) & \quad 1.17 \pm 0.09
\end{align*}$
W+b/c-jets at LHCb

Data: 1/fb+2/fb at 7 TeV and 8 TeV

Measurements are in good agreement with CT10 NLO MCFM predictions

2D Fit is used to measure bottom and charm contributions
Simultaneous fit to electron and muon final states

MCFM and MADGRAPH predictions, with DPS effects, are lower than measurements.
→ Comprehensive set of results at 7, 8 and 13 TeV

→ A wide variety of precise W/Z (plus jets) measurements probing PDFs and pQCD

→ ATLAS, CMS and LHCb experiments have an active program to study vector boson (plus jets)
  + More precise measurements coming soon

THANK YOU!