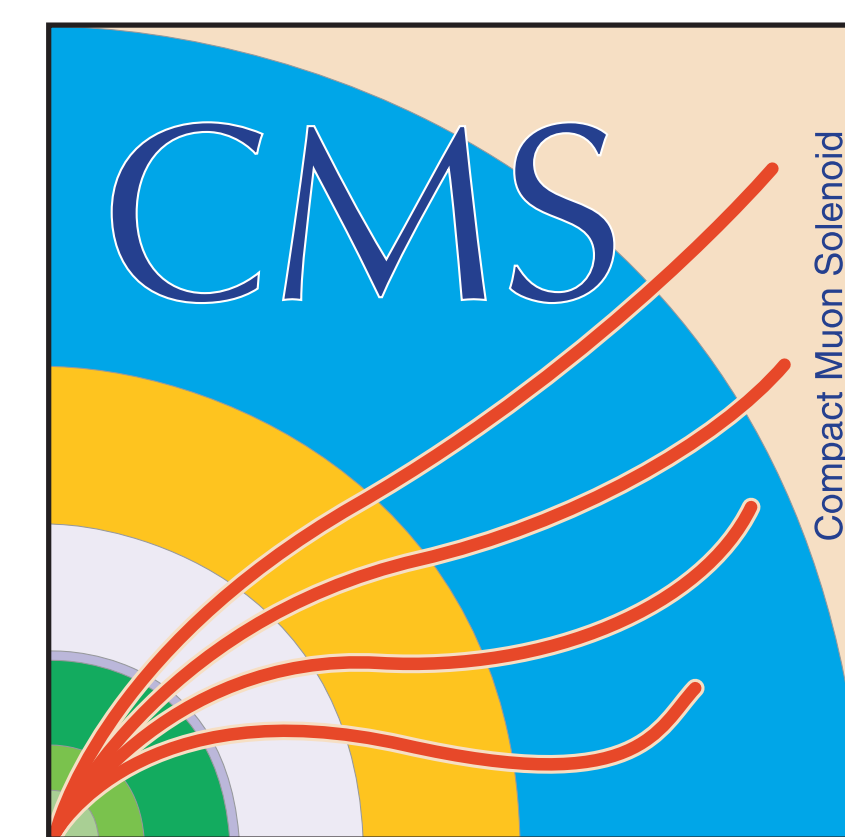


Measurement of the W boson production cross section in association with two b jets in pp collisions at $\sqrt{s} = 8$ TeV



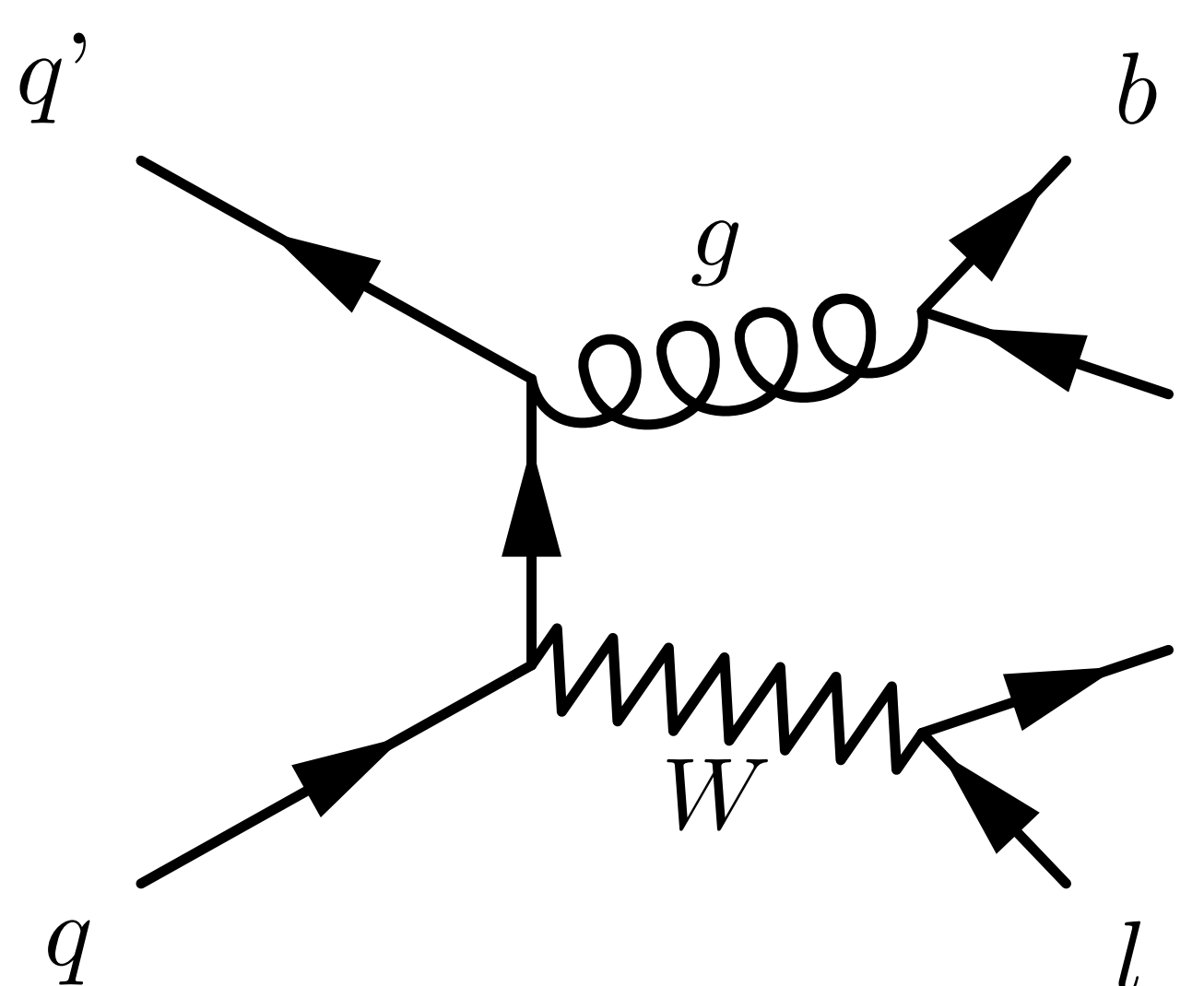
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The production cross section of the W boson in association with two b jets is measured using a sample of proton-proton collisions collected by the CMS experiment at the LHC at $\sqrt{s} = 8$ TeV. The data sample corresponds to an integrated luminosity of 19.8 fb^{-1} . The W bosons are reconstructed via their leptonic decays to muons ($W \rightarrow \mu\nu$) and electrons ($W \rightarrow e\nu$). The $W+b\bar{b}$ production cross section, $\sigma(pp \rightarrow W(\ell\nu) + b\bar{b}) = 0.69 \pm 0.02(\text{stat}) \pm 0.11(\text{syst}) \pm 0.07(\text{theo}) \pm 0.02(\text{lumi}) \text{ pb}$, measured in a fiducial region, $p_T^{\ell} > 30 \text{ GeV}$, $|\eta^{\ell}| < 2.1$, with exactly two b-tagged jets having $p_T > 25 \text{ GeV}$ and $|\eta| < 2.4$, agrees with standard model predictions.

W+b \bar{b} Signal Region Selections



Exactly two b-tagged jets:

- $p_T^{\text{jet}} > 25 \text{ GeV}$, $|\eta| < 2.4$
- b-tagged with CSV Tight
- Reject events with $p_T^{\text{jet}3} > 25 \text{ GeV}$, $|\eta| < 5.0$

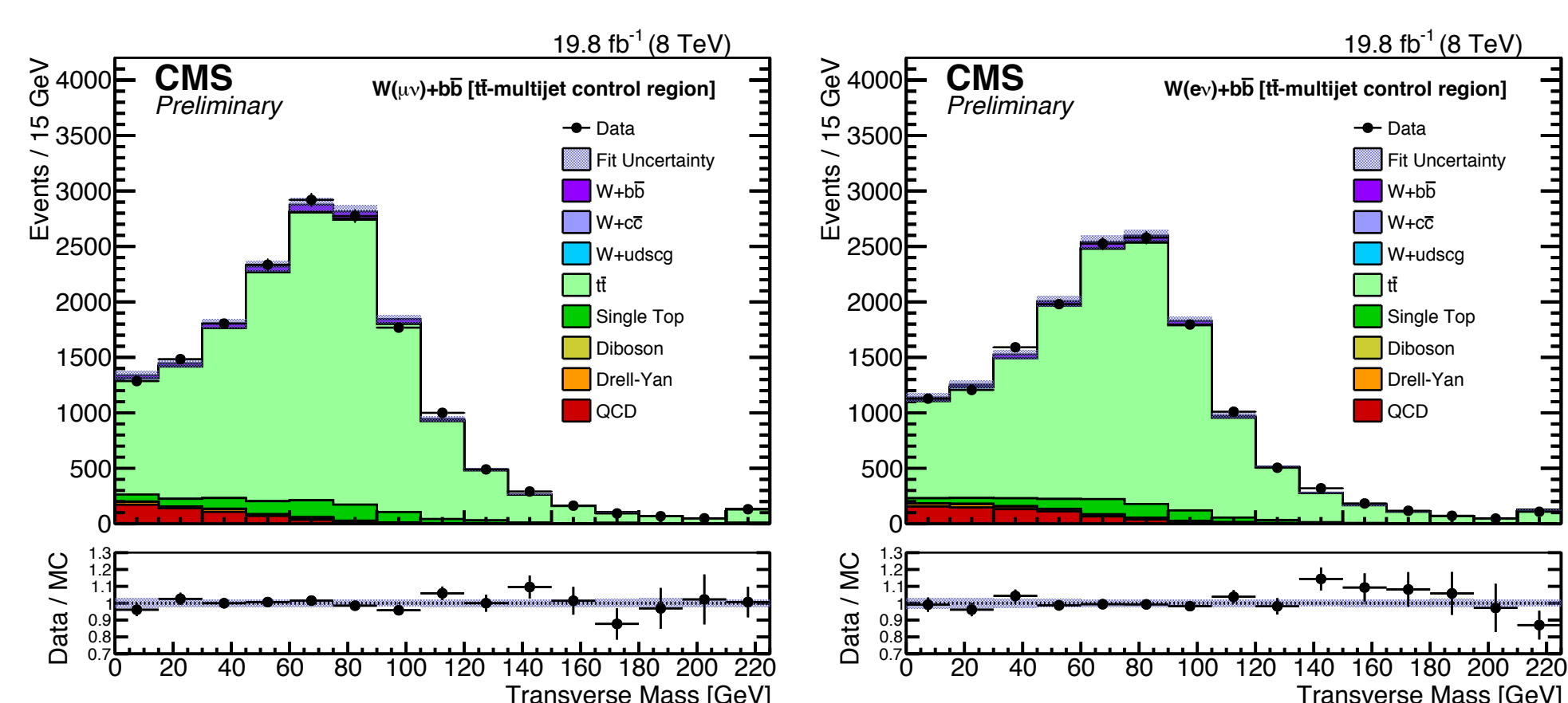
Exactly one lepton

- (muon or electron):
- $p_T^{\text{lep}} > 30 \text{ GeV}$, $|\eta| < 2.1$
 - pileup corrected tight isolation
 - Reject events with $p_T^{\text{lep}2} > 10 \text{ GeV}$, $|\eta| < 2.4$

Triggers:

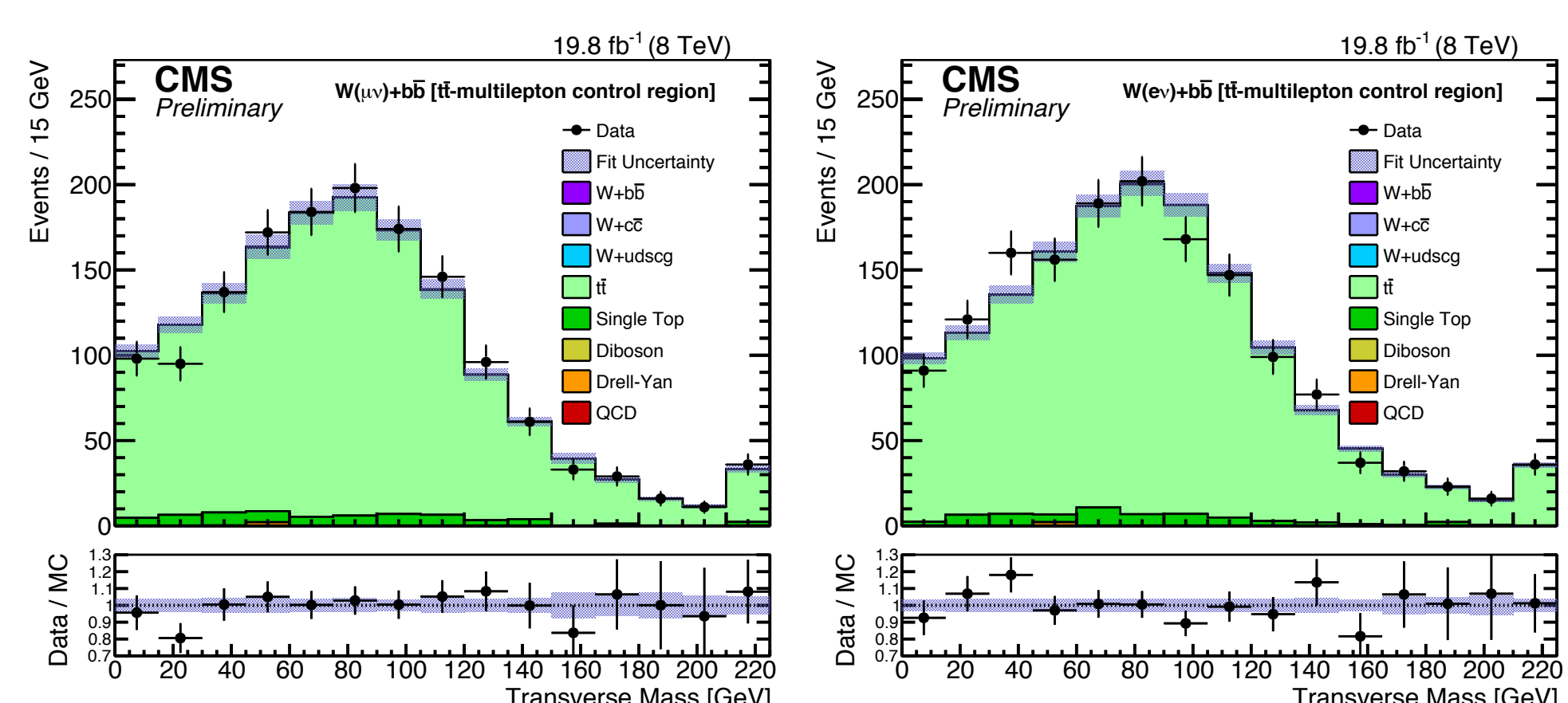
- Single Isolated Muon $p_T > 24 \text{ GeV}$
- Single Isolated Electron $p_T > 27 \text{ GeV}$

Three-step Fitting Procedure



Step 1: Fit in $t\bar{t}$ -multiplet control region

- inverted jet veto (less sensitive to JES)
- fit for b-tagging efficiency scale factors



Step 2: Fit in $t\bar{t}$ -multiplepton control region

- inverted lepton veto (sensitive to JES and b-tagging efficiency)
- fit for jet energy scale (JES)

Step 3: Fit in the $W+b\bar{b}$ signal region, using both the separate and combined lepton channels

Systematic Uncertainties

	uncertainty	variation	effect on the measured cross section	
normalization	uncorrelated	$t\bar{t}$	7.4%	9.1%
		Single Top	5.4%	2.7%
		W + udscg	13.2%	1.6%
		W + c \bar{c}	8.1%	< 1%
		Diboson	8.1%	2.2%
		Drell-Yan	7.9%	1.6%
		QCD	50%	1-3%
norm. + shape	correlated	b tag rescale	12.9%	12.3%
		JES rescale	$1.6 \times \sigma_{\text{JES}}$	< 1%
		JES	σ_{JES}	6.0%
		UES	σ_{UES}	< 1%
		MES	σ_{MES}	1.6%
		EES	σ_{EES}	3.5%
		Id/Iso/Trg	$\sigma_{\text{Id/Iso/Trg}}$	< 1%
luminosity			2.6%	
theory (scale+PDF)			10%	

Predicted Cross Sections

MCFM (x Hadronization):

Parton + Jets (MSTW2008)
applied hadronization correction factor (0.81 ± 0.07)
corrected for double parton scattering (DPS) ($0.06 \pm 0.06 \text{ pb}$)

MG+Py6 5F: (five flavour)

MadGraph 5 (CTEQ6L LO) + Pythia 6 (Z2*)

MG+Py6 4F: (four flavor)

MadGraph 5 (NNLO PDF) + Pythia 6 (CUETP8M1)
corrected for effects of DPS ($0.06 \pm 0.06 \text{ pb}$)

MG+Py8 4F: (four flavor)

MadGraph 5 (NNLO PDF) + Pythia 8 (CUETP8M1)
corrected for effects of DPS ($0.06 \pm 0.06 \text{ pb}$)

Simulated Samples

W + jets, Z + jets: (five flavor - massless b quarks included)

MadGraph 5 (CTEQ6L LO) + Pythia 6 (Z2*), cross section from FEWZ (NNLO)
W+b \bar{b} , W+c \bar{c} , W+udscg separated using jet parton flavor

W+b \bar{b} : (four flavor)

MadGraph 5 (CTEQ6L LO) + Pythia 6 (Z2*)
normalized to W+b \bar{b} component of W + jets (five flavor)

t \bar{t} :

MadGraph 5 (CTEQ6L LO) + Pythia 6 (Z2*), cross section from CMS/ATLAS data

Single Top:

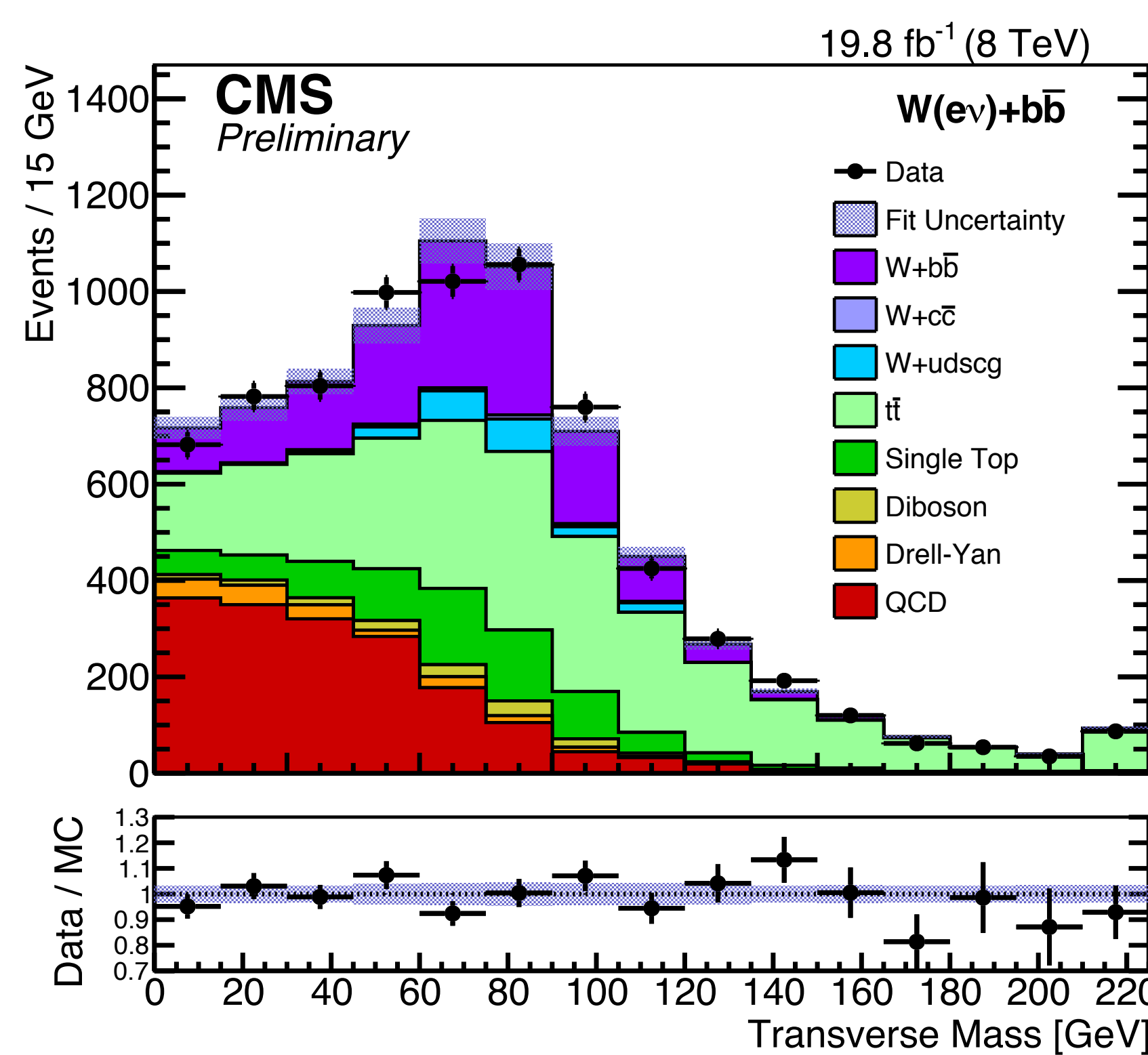
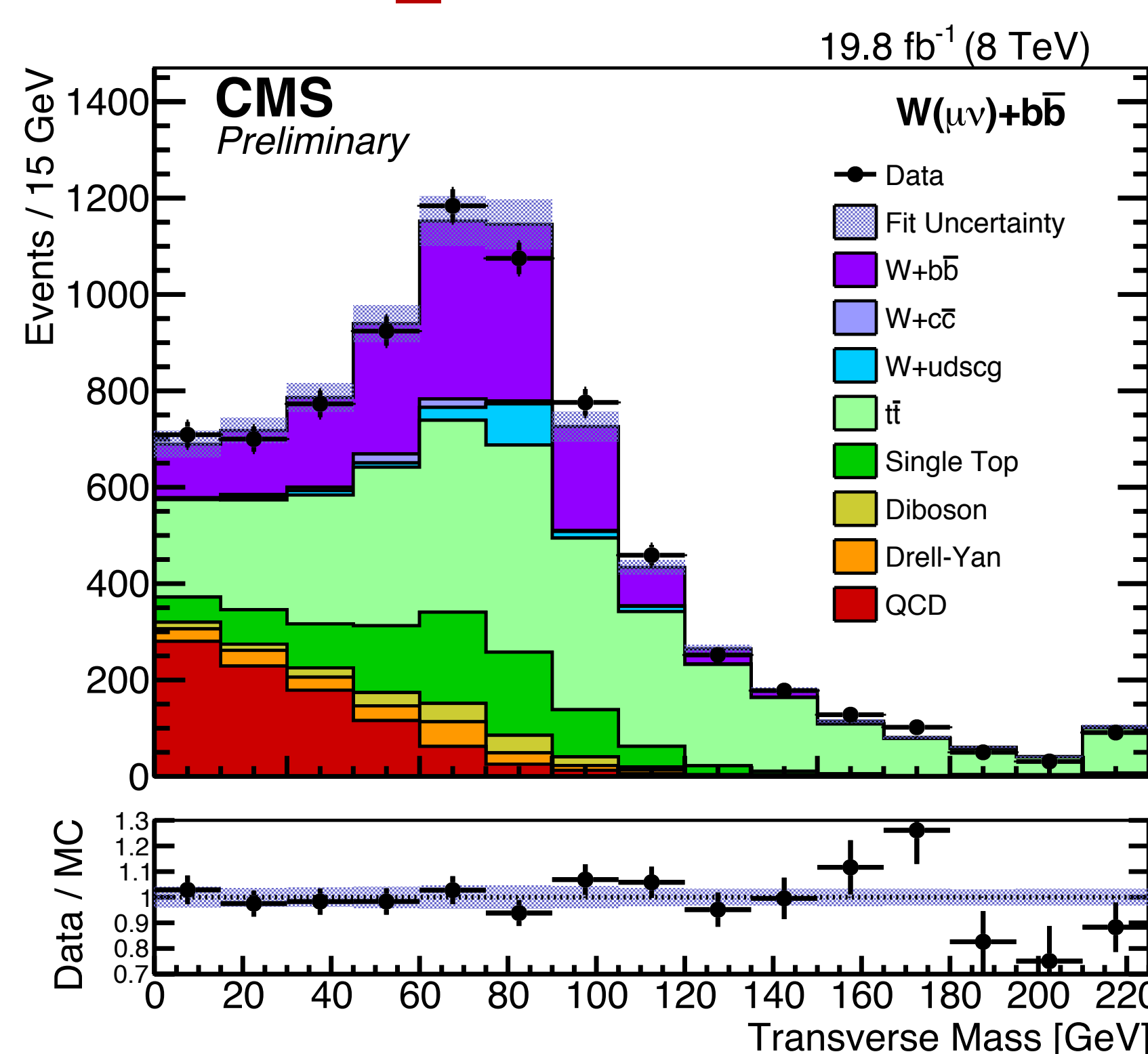
Powheg 2.0 (CTEQ6M NLO) + Pythia 6 (Z2*), cross section from MCFM (NLO)

Diboson (WW, WZ, ZZ):

Pythia 6 (CTEQ6L LO) + Pythia 6 (Z2*), cross section from MCFM (NLO)

QCD: (data driven)

Shape from inverted lepton isolation control region
Initial normalization to match data in $0 < M_T < 20 \text{ GeV}$

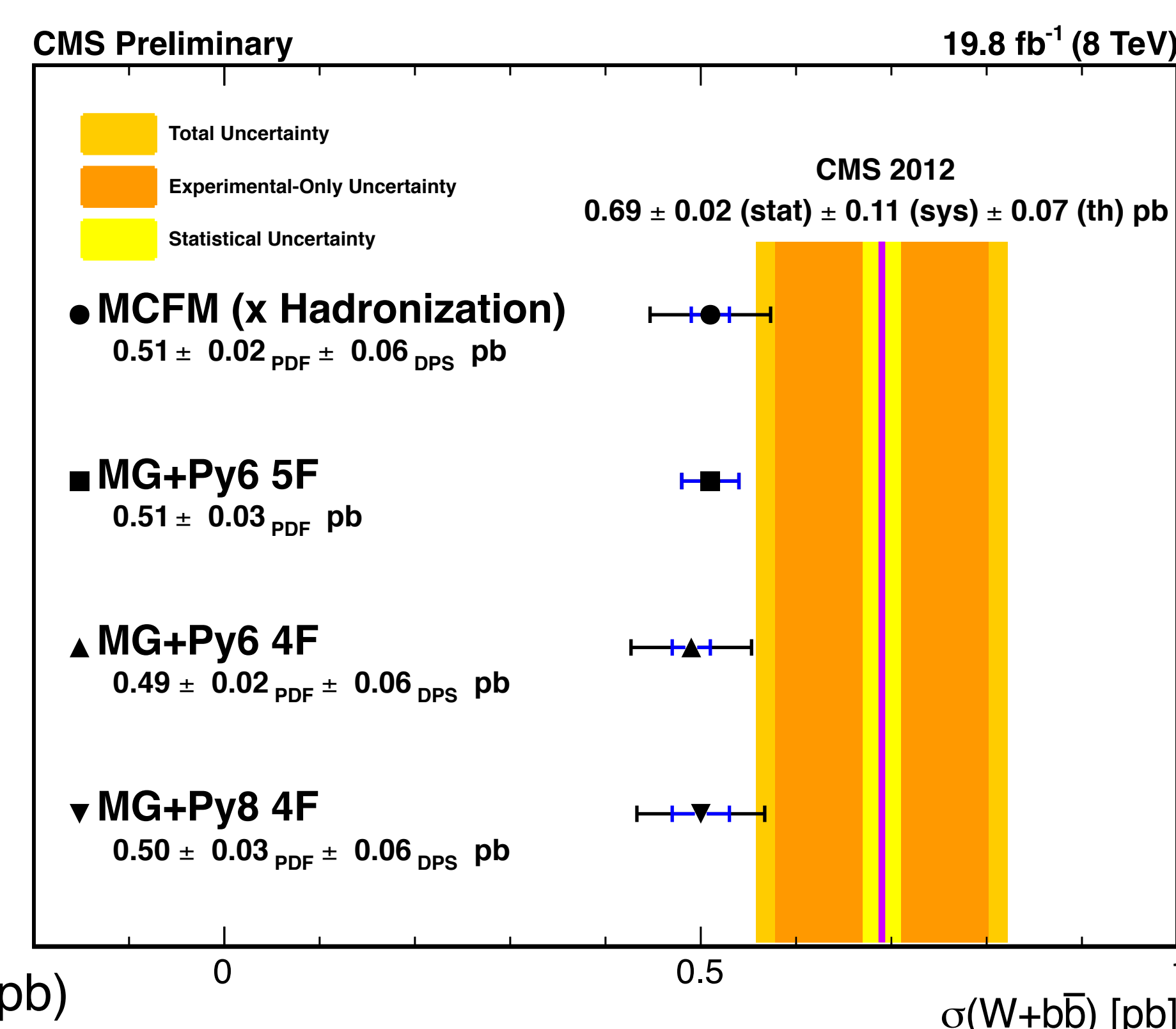


Fitted Yields

Data	muon		electron	
	Initial	Fitted	Initial	Fitted
W + bb	1318.5	1792.6	1117.0	1522.3
W + c \bar{c}	59.6	58.6	35.9	34.9
W + udscg	179.9	164.9	217.8	201.8
t \bar{t}	2997.9	3219.3	2595.8	2793.3
Single Top	886.7	901.1	763.2	777.2
Drell-Yan	209.5	210.5	176.8	177.9
Diboson	174.5	176.1	138.2	139.8
QCD	1148.6	911.8	1673.6	1708.2
Signal strength	1.27 ± 0.24		1.38 ± 0.30	
Combined	1.35 ± 0.23			

Observed Cross Sections

Channel	$\sigma(pp \rightarrow W(\ell\nu) + b\bar{b})$, pb
Muon	$0.65 \pm 0.03(\text{stat}) \pm 0.12(\text{syst}) \pm 0.07(\text{theo}) \pm 0.02(\text{lumi})$
Electron	$0.70 \pm 0.04(\text{stat}) \pm 0.15(\text{syst}) \pm 0.07(\text{theo}) \pm 0.02(\text{lumi})$
Combined	$0.69 \pm 0.02(\text{stat}) \pm 0.11(\text{syst}) \pm 0.07(\text{theo}) \pm 0.02(\text{lumi})$



References

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CMS: SMP-14-020

<https://cds.cern.ch/record/2121354>