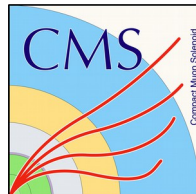


# Vector Boson (plus jets) in pp collisions at the LHC

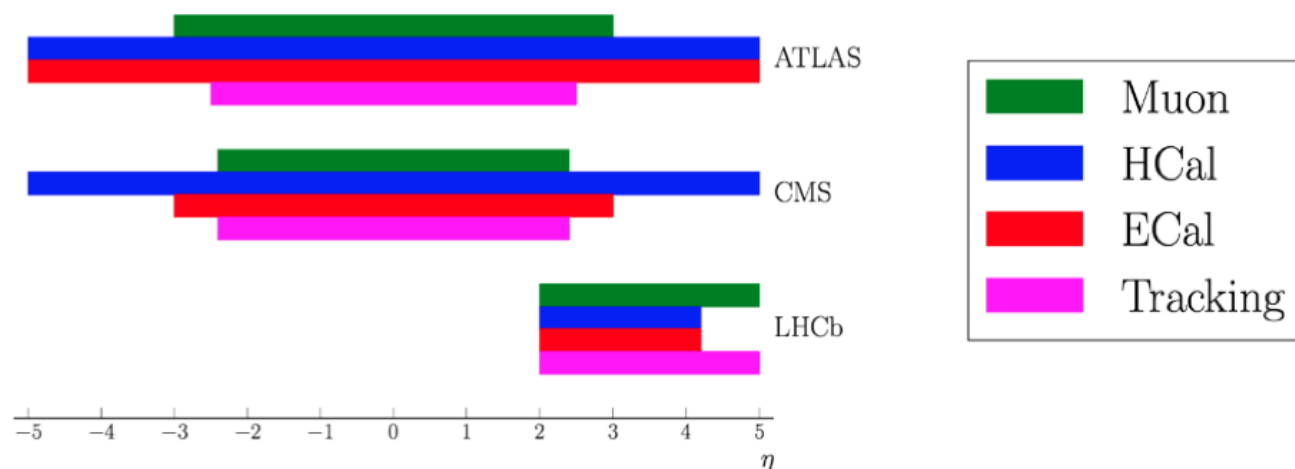
Murilo Rangel  
on behalf of the ATLAS, CMS, and LHCb Collaborations



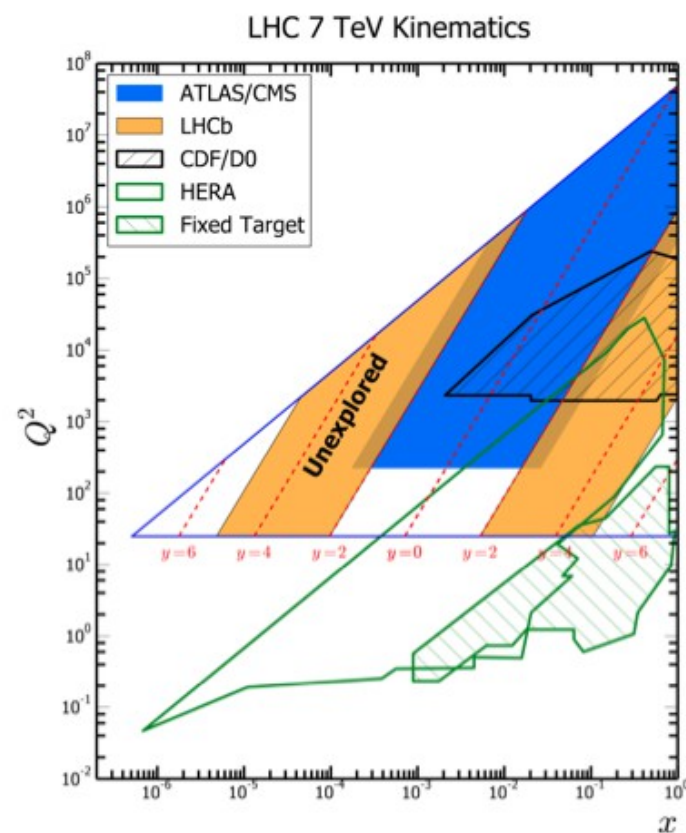
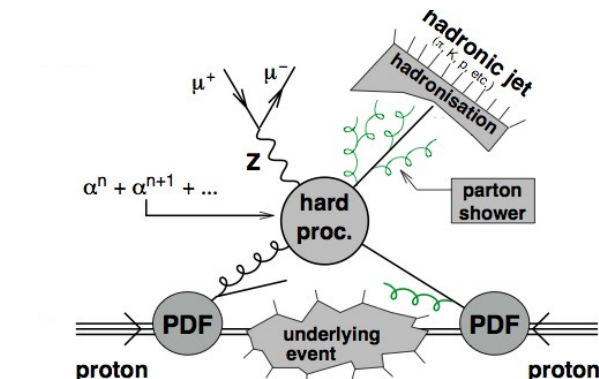
## Recent Results on Vector boson (plus jets) at LHC

### – 7/8/13 p-p collisions results

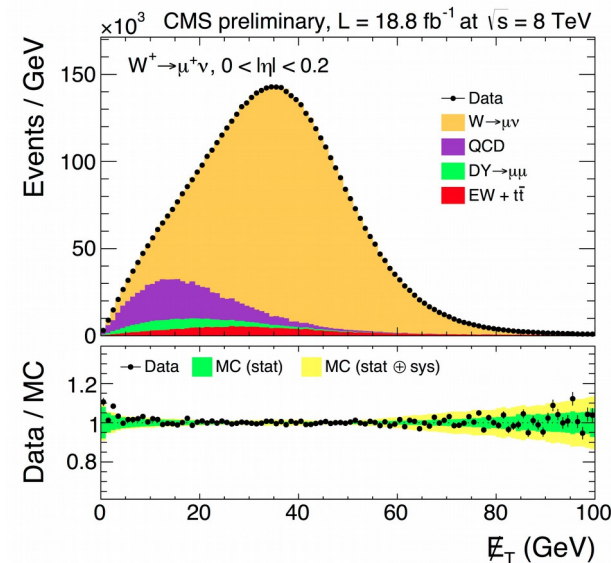
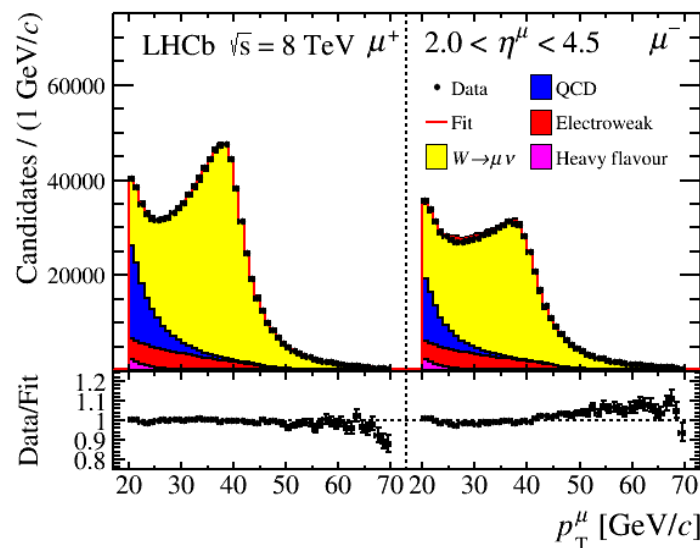
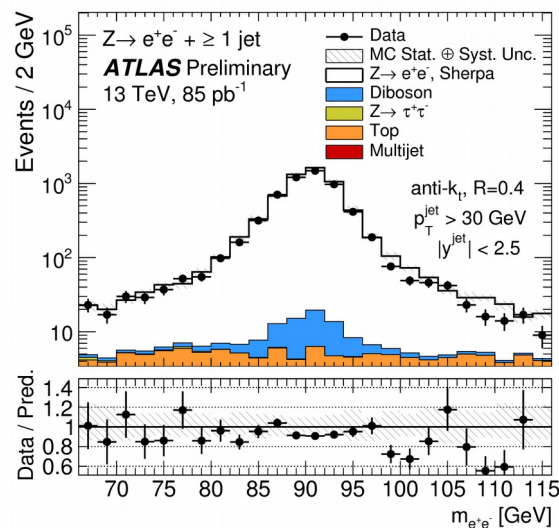
- Important tests of pQCD
- Improve constraints to PDFs / non-pQCD
- Understanding of backgrounds in search analyses



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



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



**Jets** are identified with anti- $k_T$  algorithm ( $R=0.4/0.5$ )

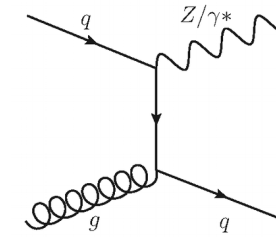
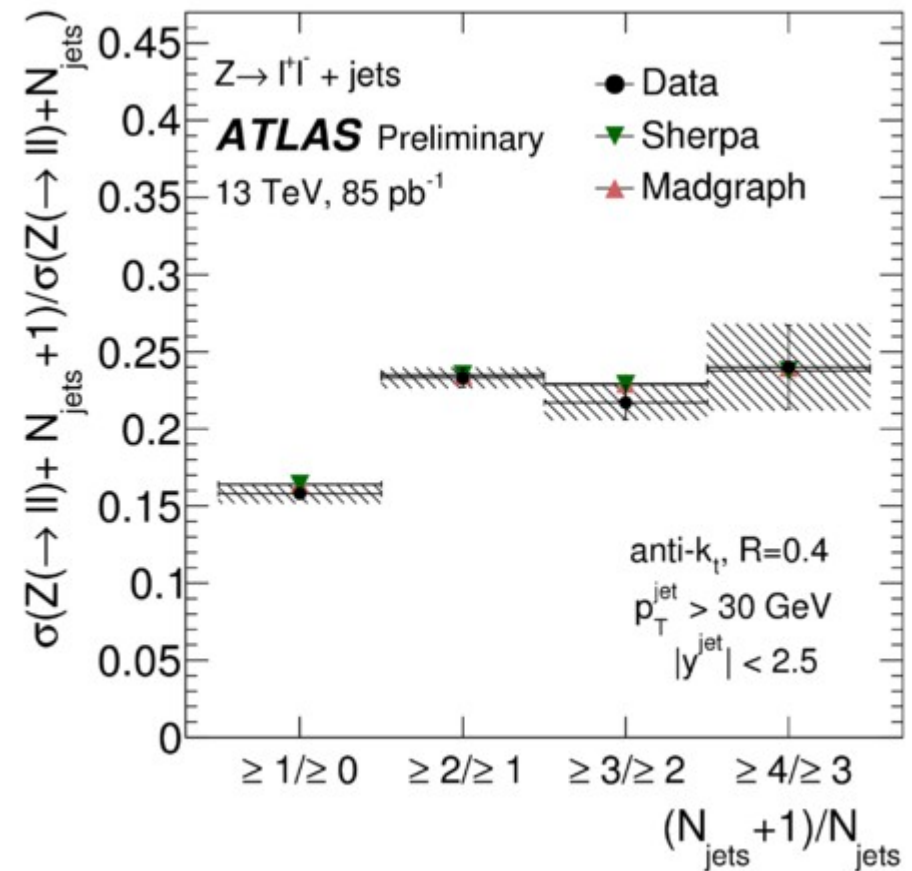
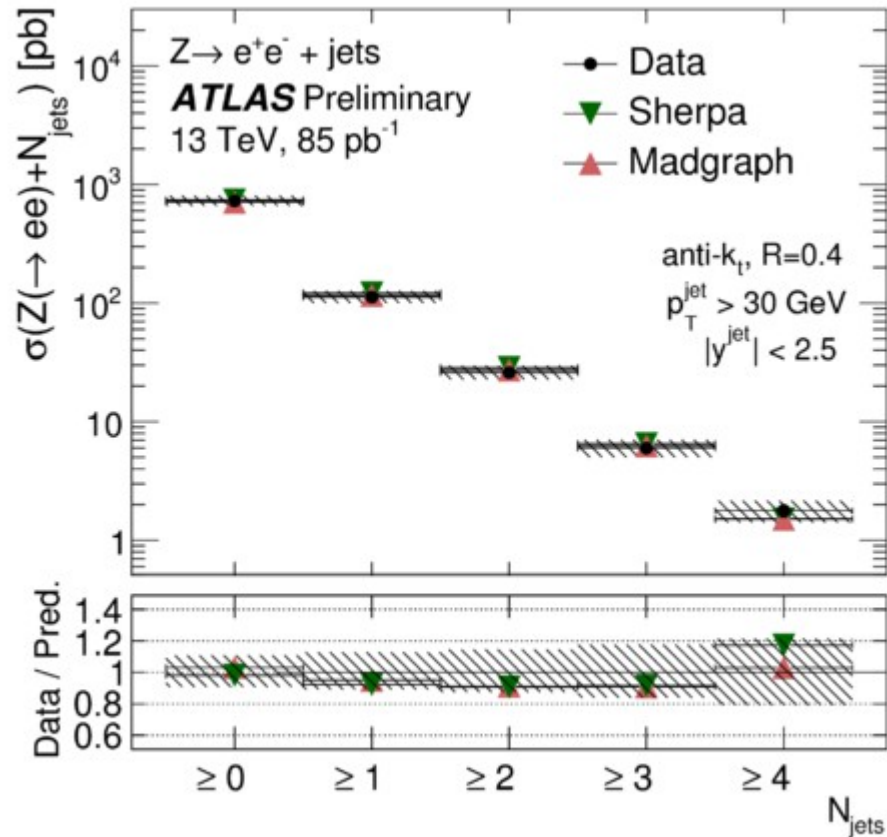
- energy **calibrated** to the particle-level using simulation
- residual corrections determined using data ( $Z/\gamma^* + \text{jets}$  or di-jets)

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

My **apologies** for the extensive use of acronyms (letter soup)

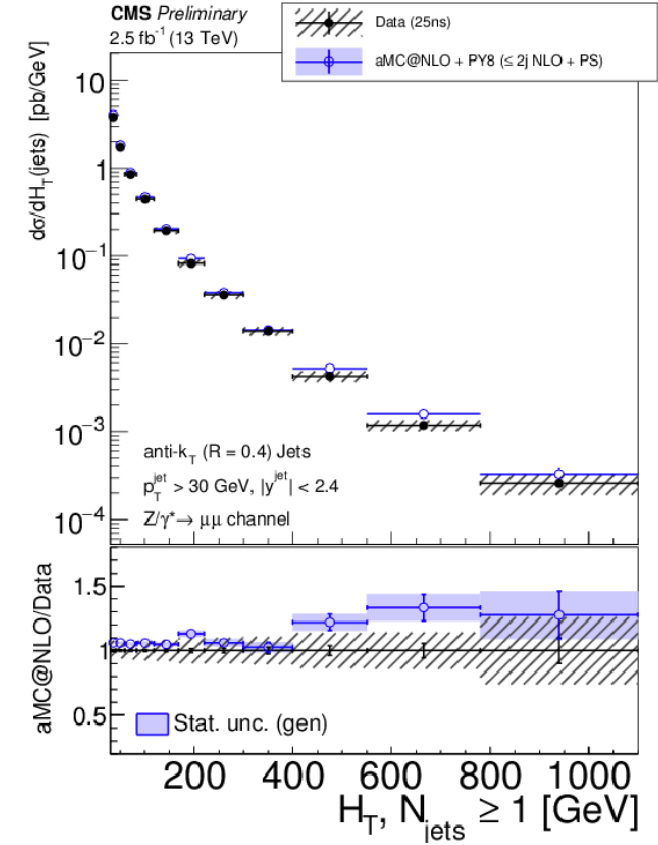
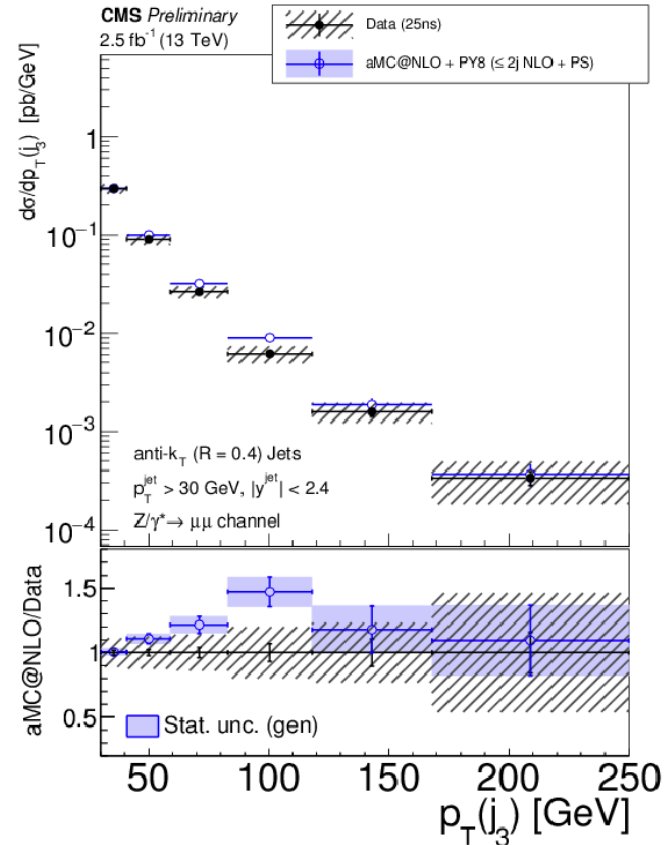
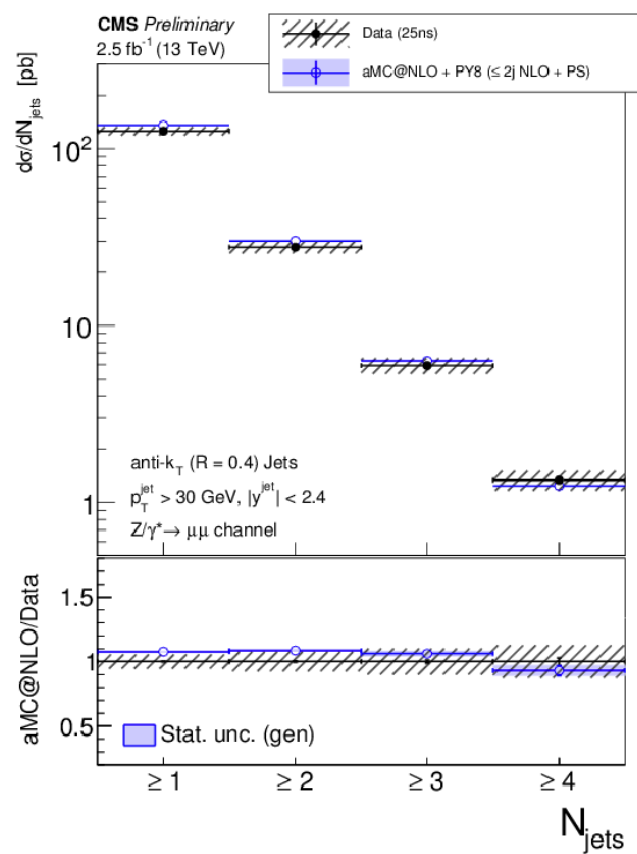
# 13 TeV cross-sections

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**

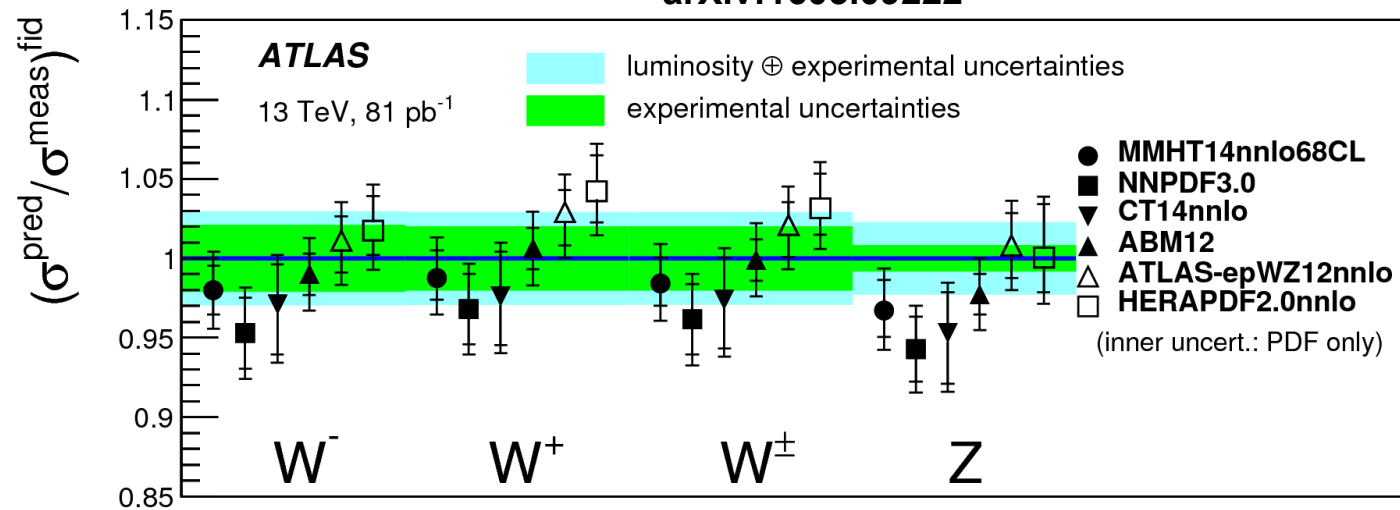
## Using $Z \rightarrow \mu\mu$ final state



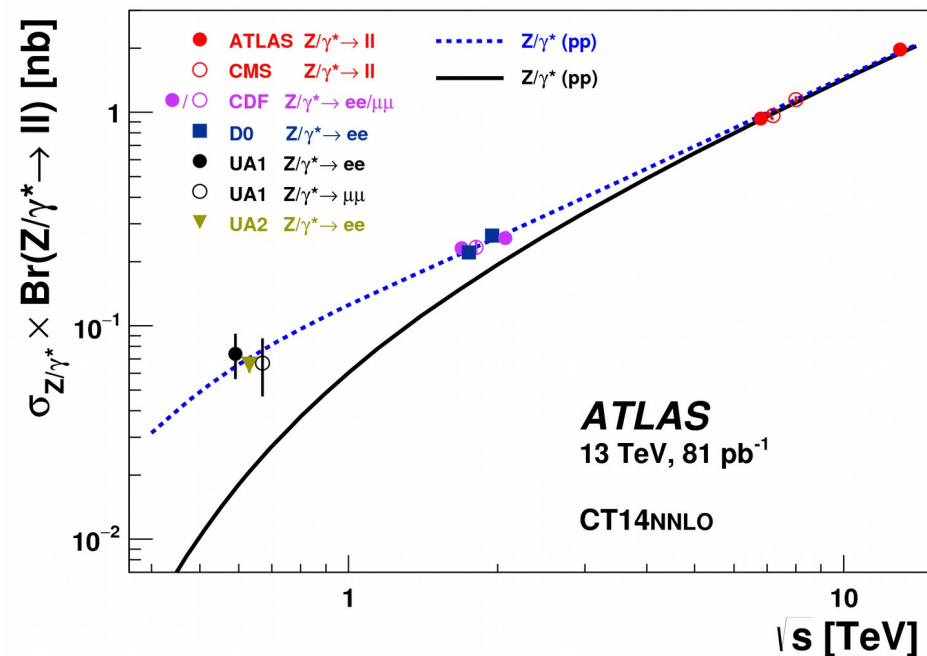
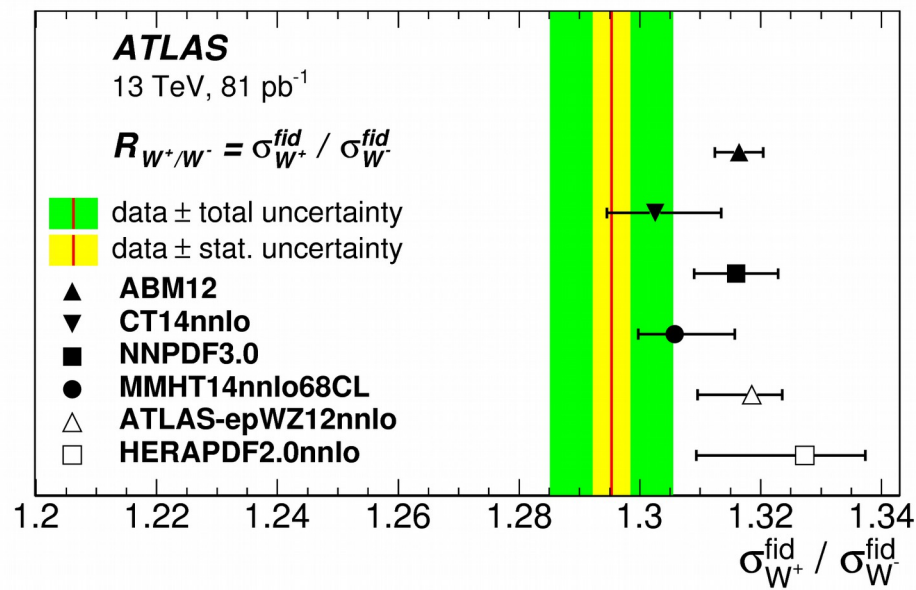
Differential measurements are compared to [MADGRAPH5\\_AMC@NLO](#)

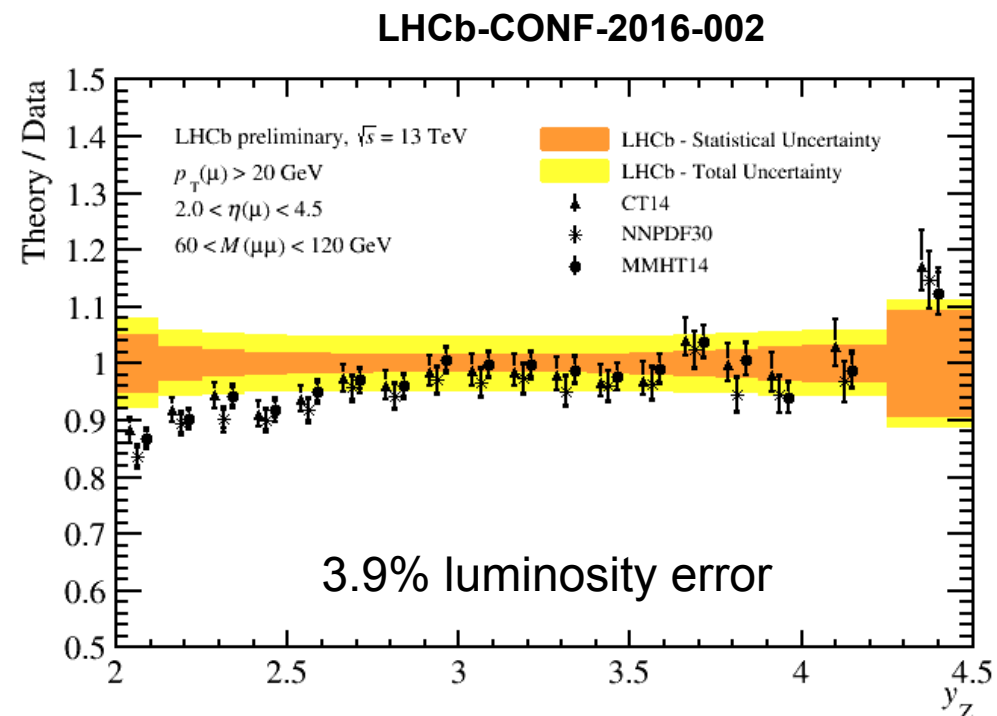
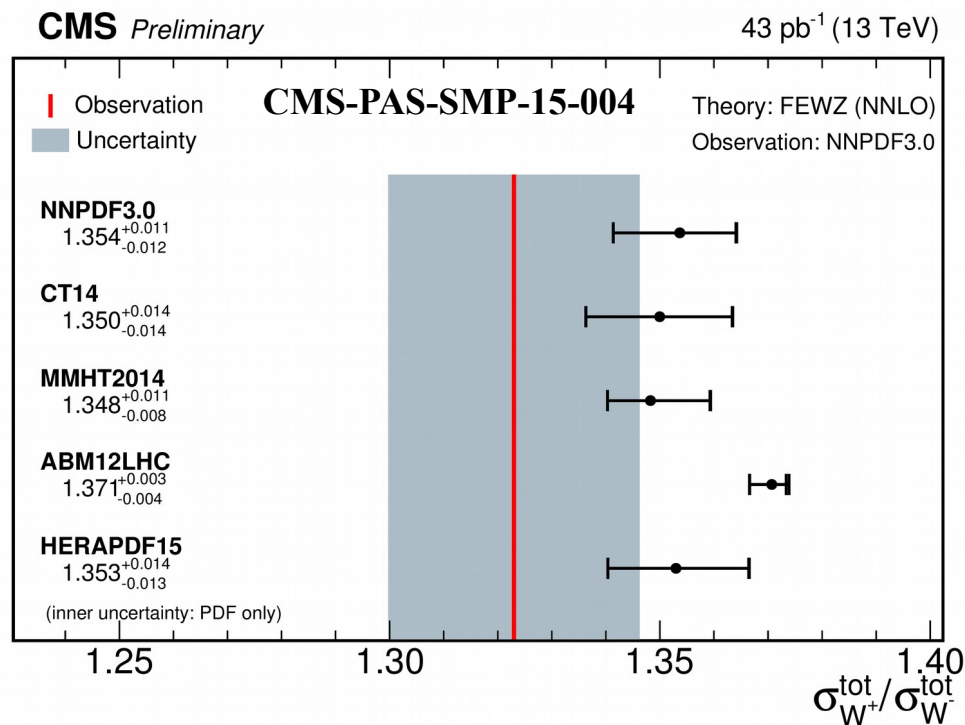


arXiv:1603.09222



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



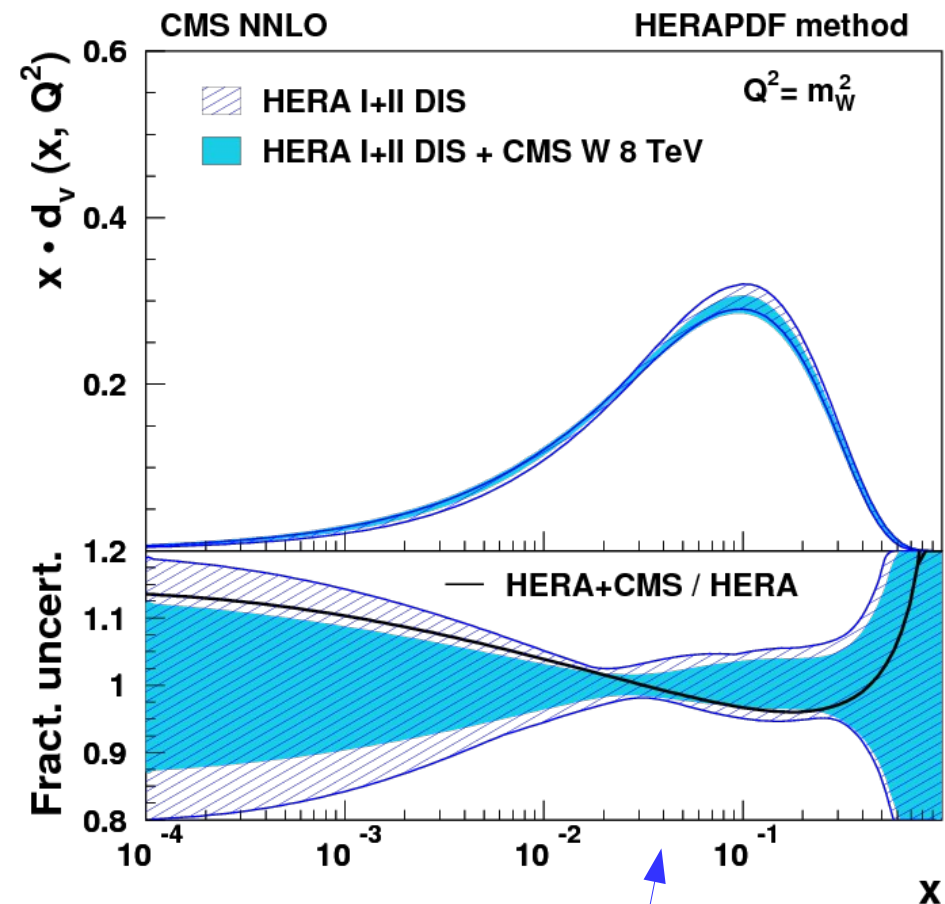
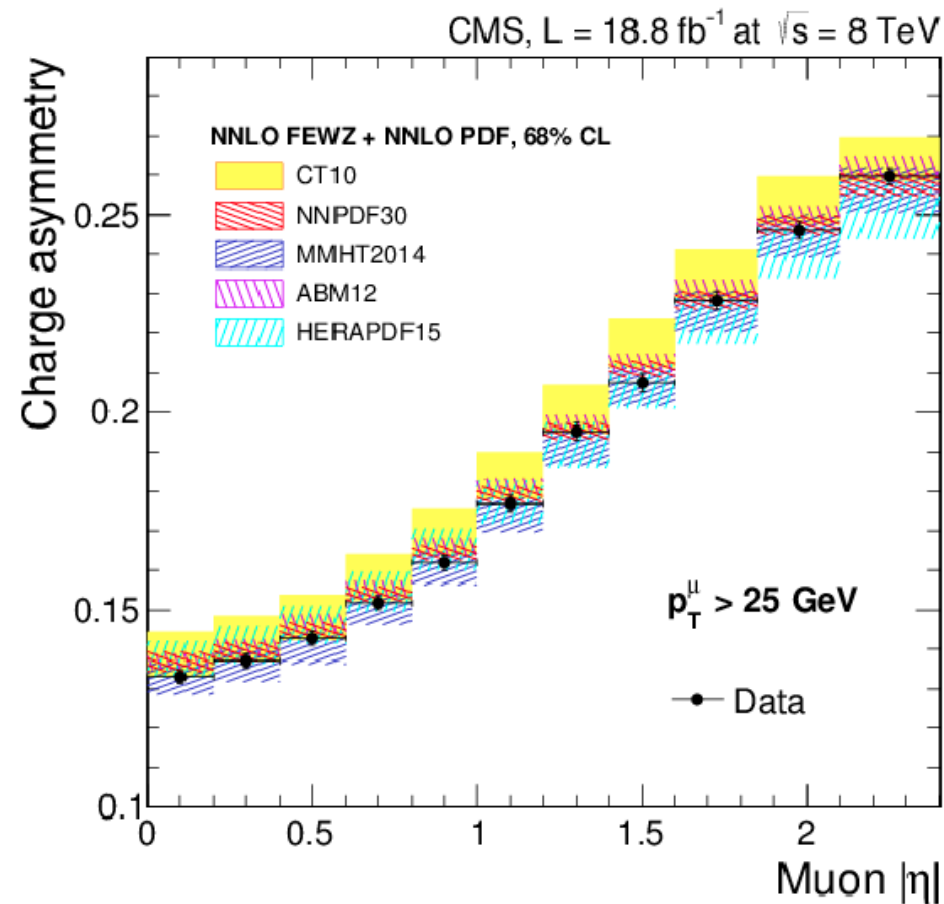


- 13 TeV inclusive W/Z cross-section
- Impressive amount of work in a timely fashion!
  - Precise measurements with first data
  - Few tensions already observed comparing with FEWZ NLO



7/8 TeV

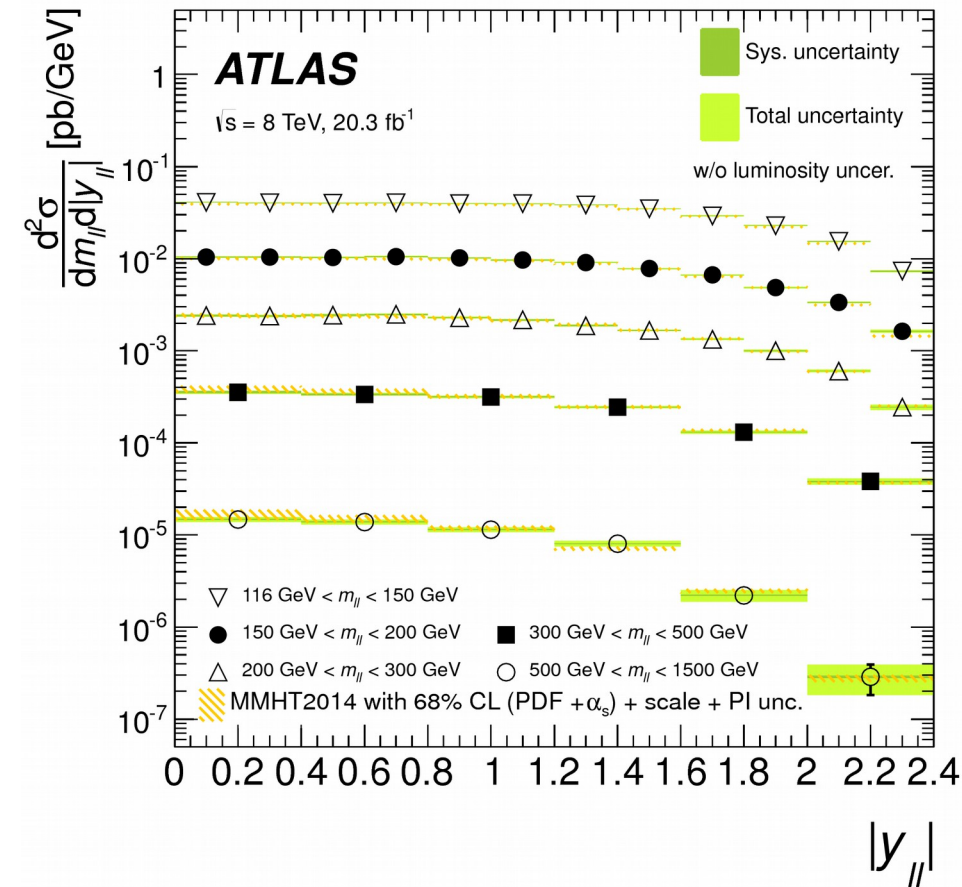
W/Z (plus jets)



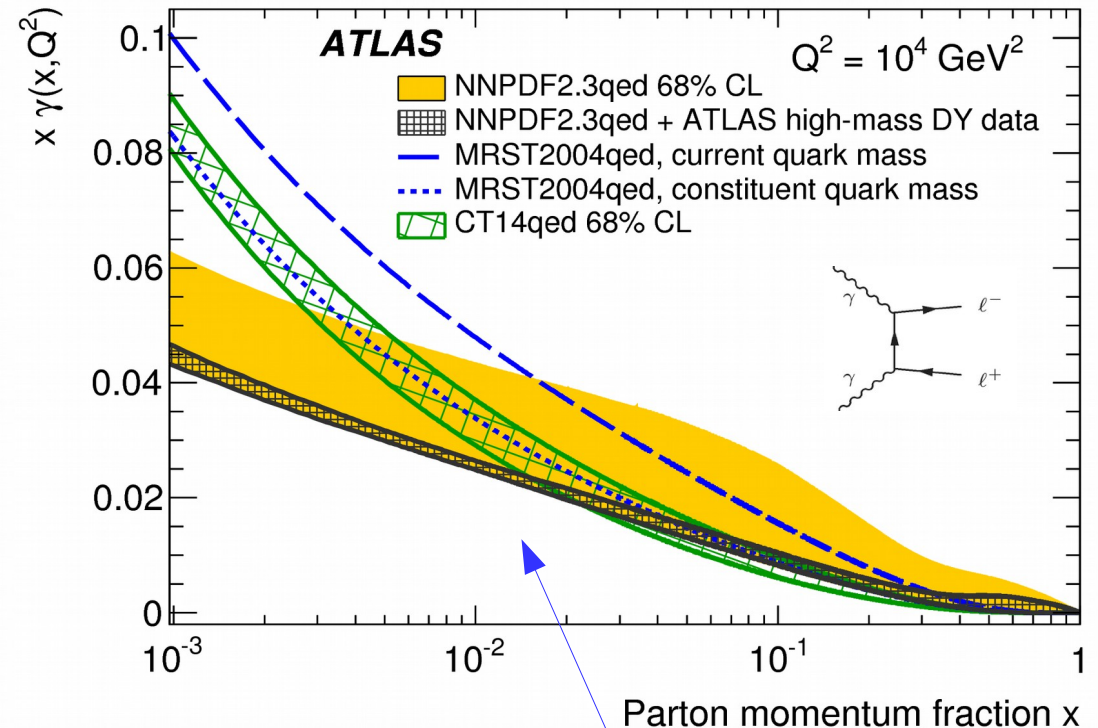
Differential measurements are compared to NNLO FEWZ predictions

Using HERA PDF method at NNLO, fit can be significantly improved for  $10^{-1} > x > 10^{-3}$

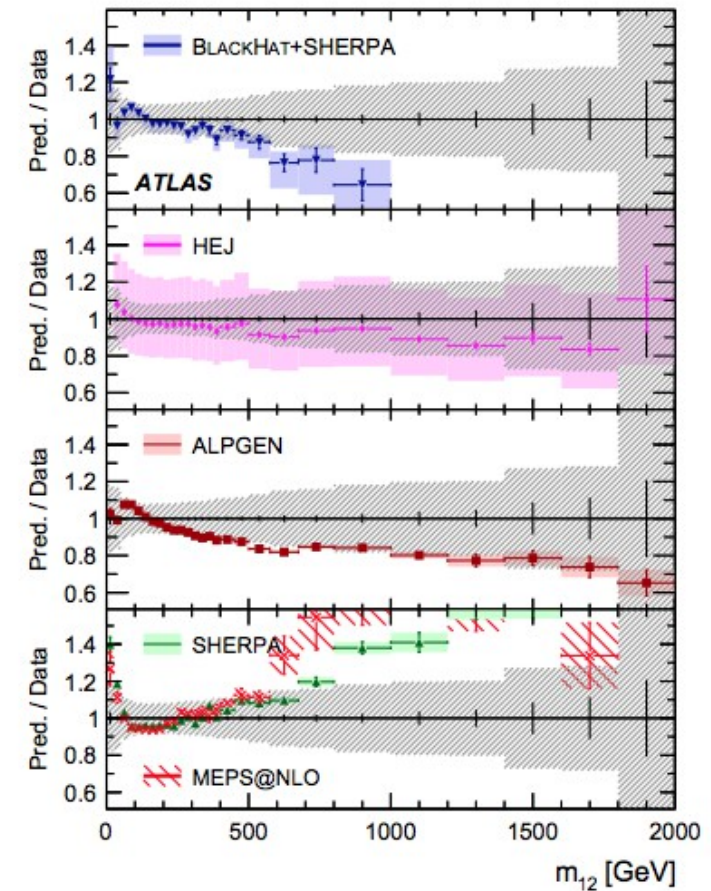
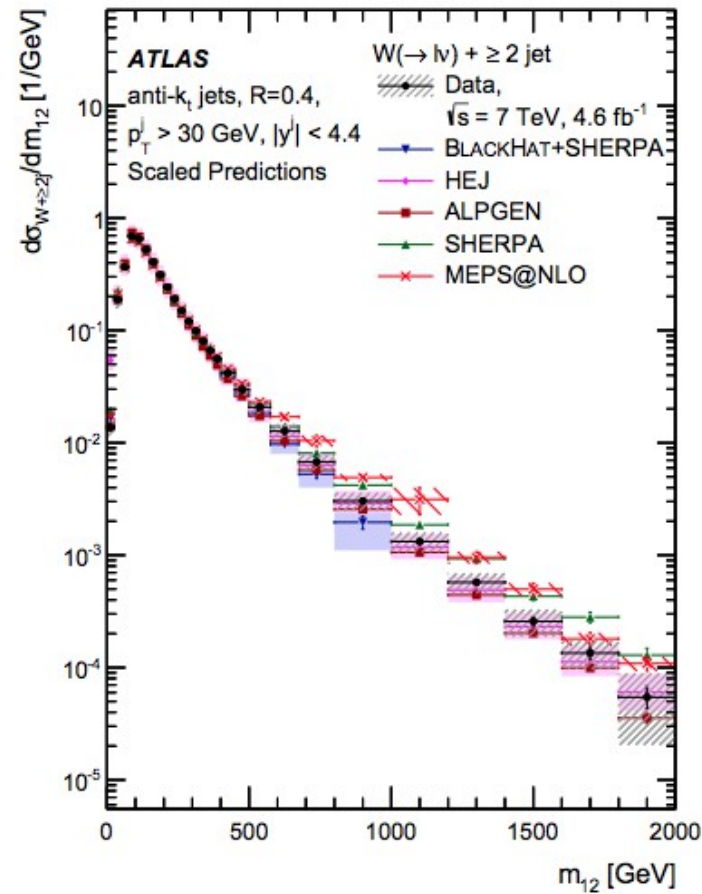
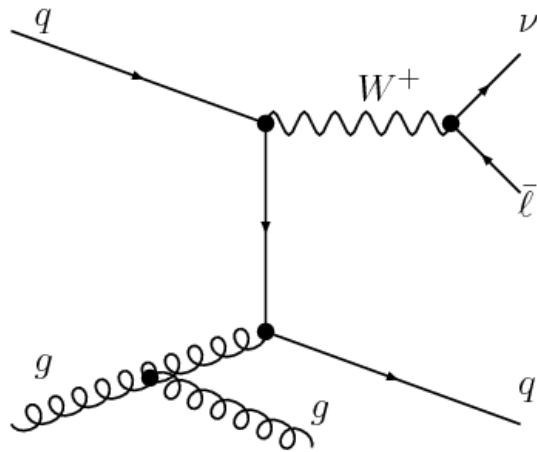
## Studies of high-mass DY and photon induced processes $116 < M_{\parallel} < 1500$ GeV



Differential measurements are compared to  
**NNLO FEWZ + IP-MRST2004qed**

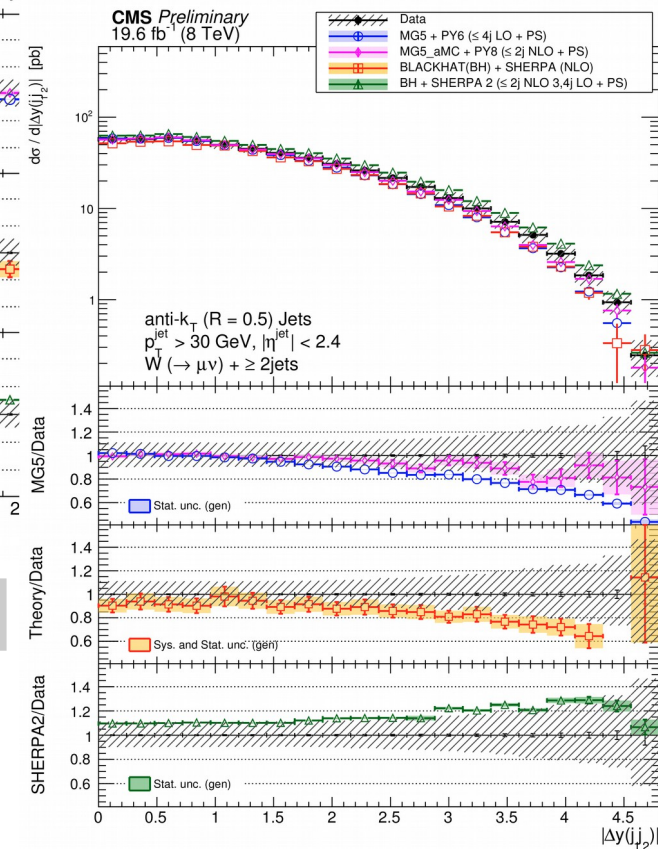
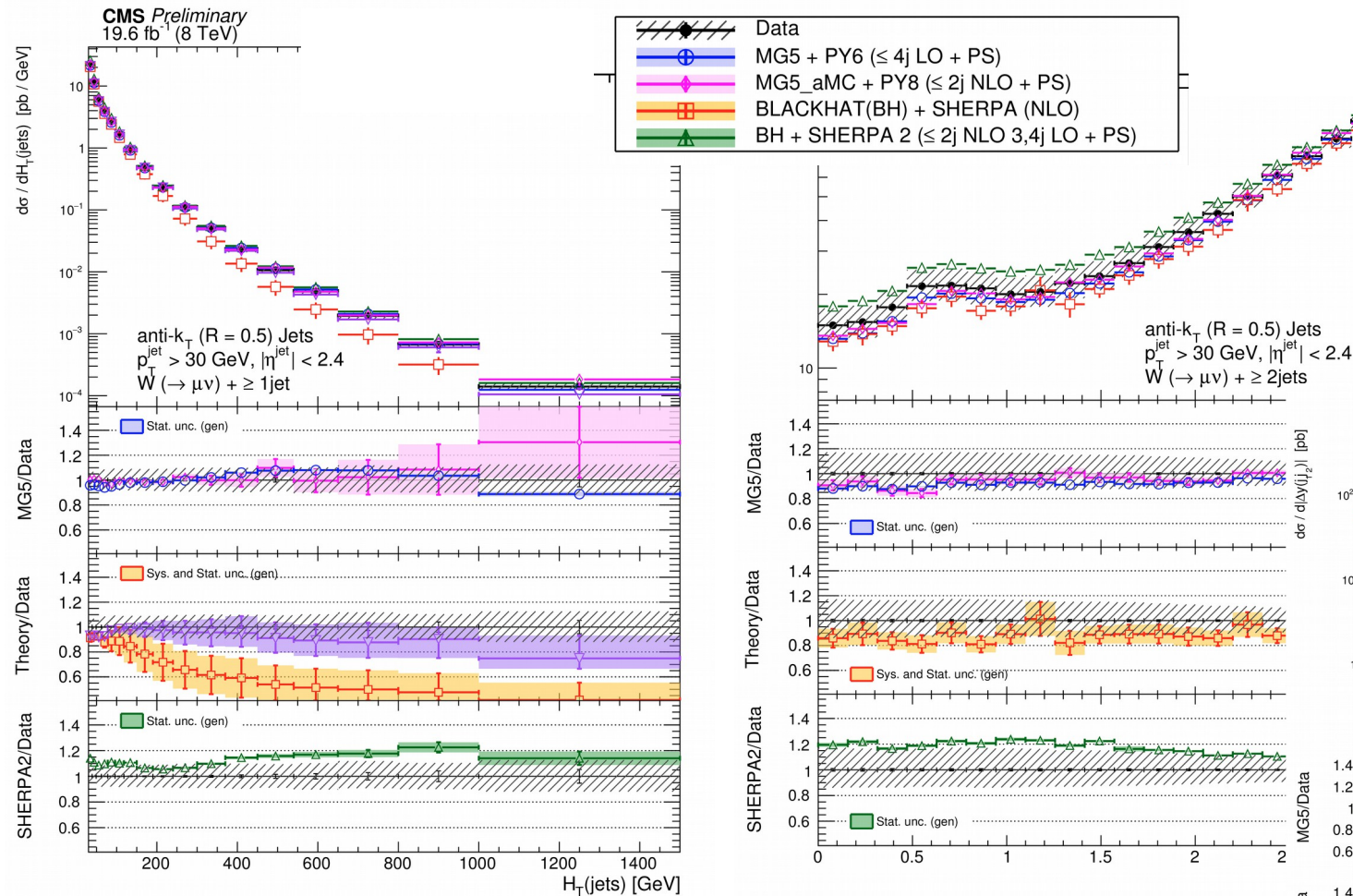


Large impact in the photon PDF (using Bayesian reweighting)



Predictions from different programs  
Variety of agreement and discrepancy



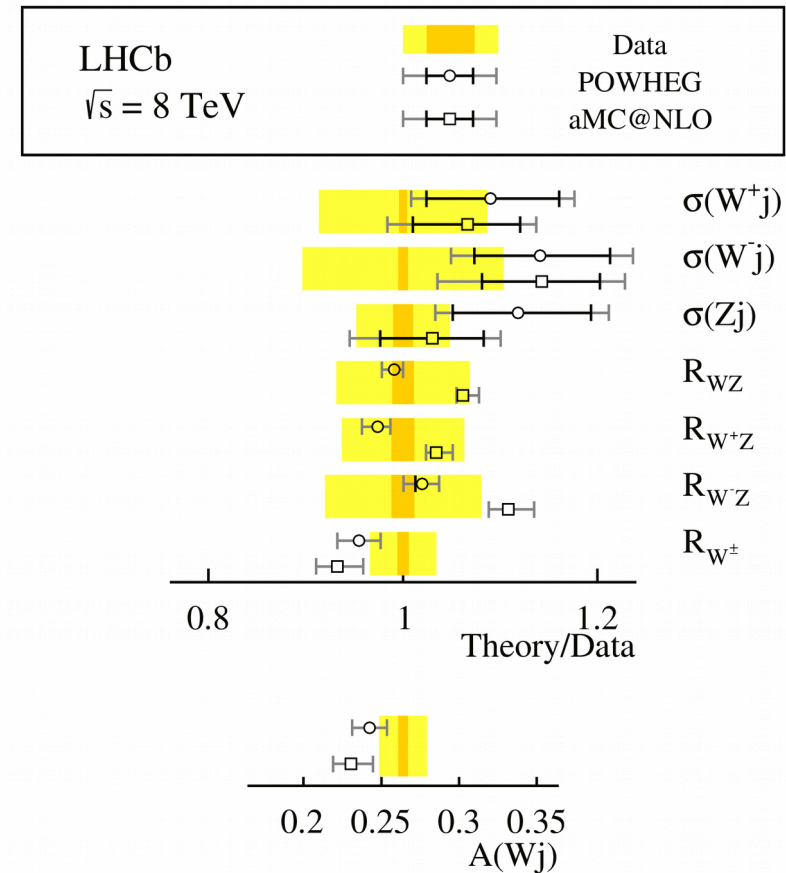
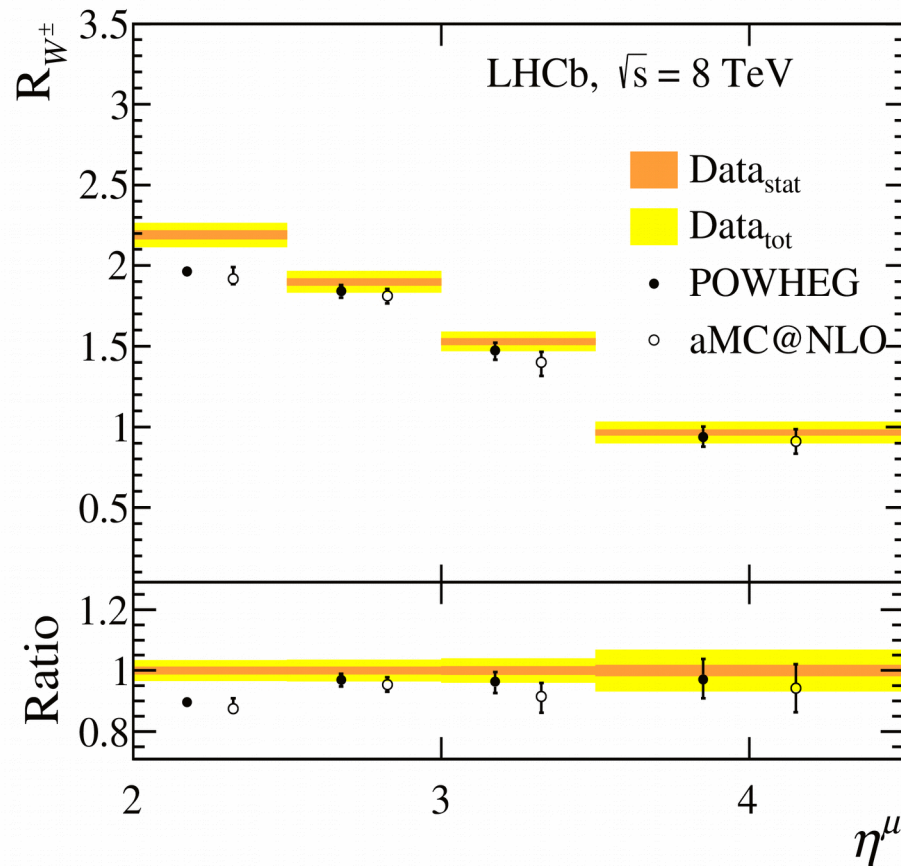


Several distributions among the jets and the muon are studied

Predictions from different programs  
**Variety** of agreement and discrepancy

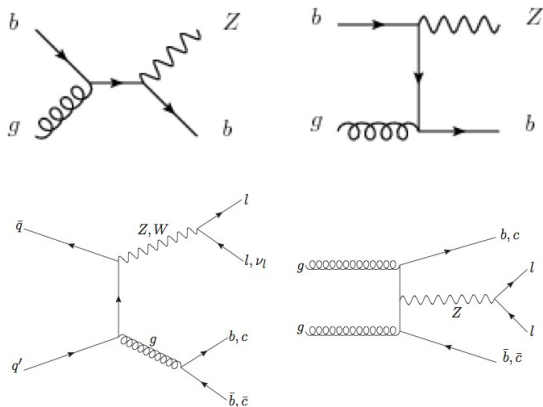
2/fb at 8 TeV

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

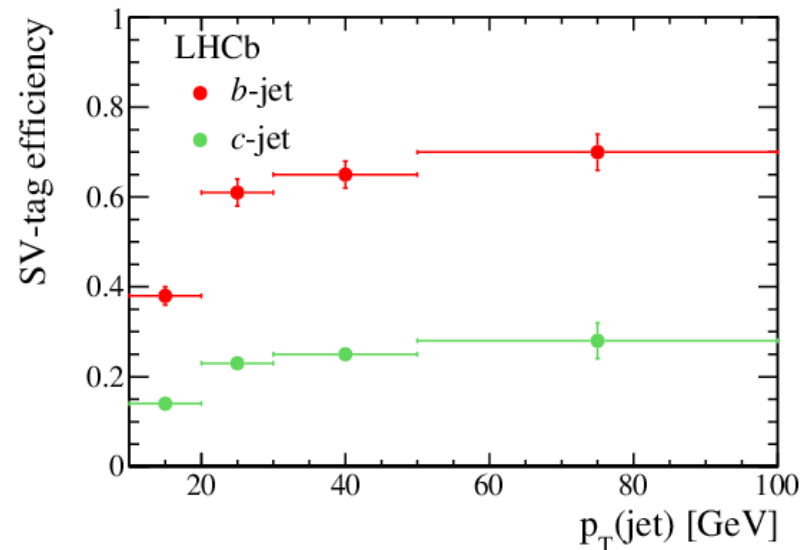
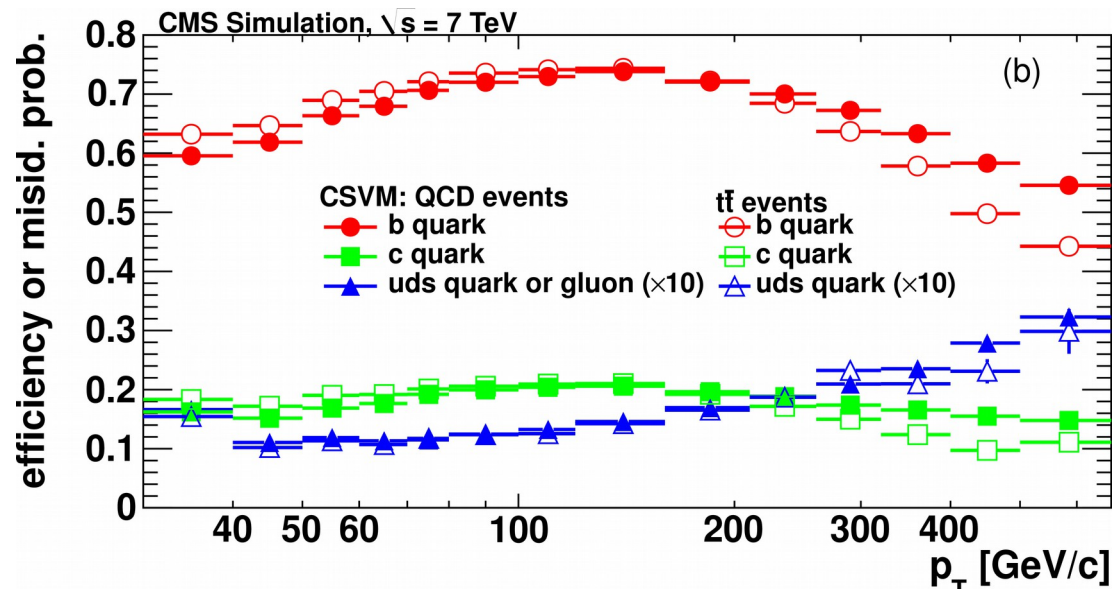


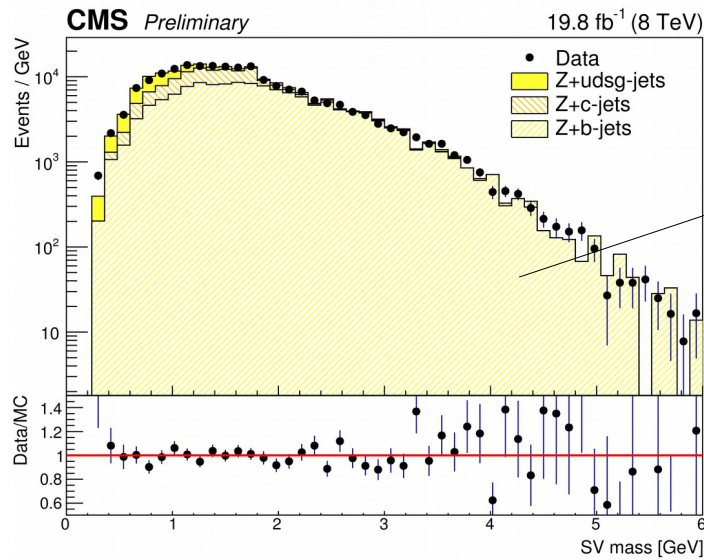


# 7/8 TeV

## V+heavy-quark

Heavy-flavor identification with secondary-vertex and MVA analysis



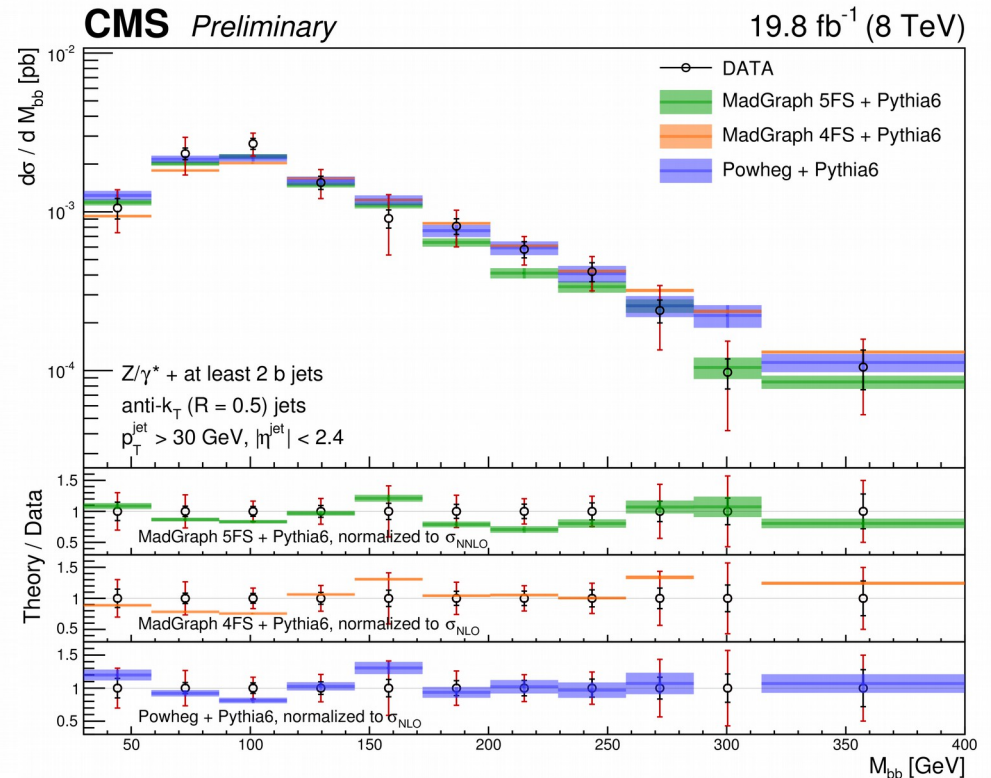
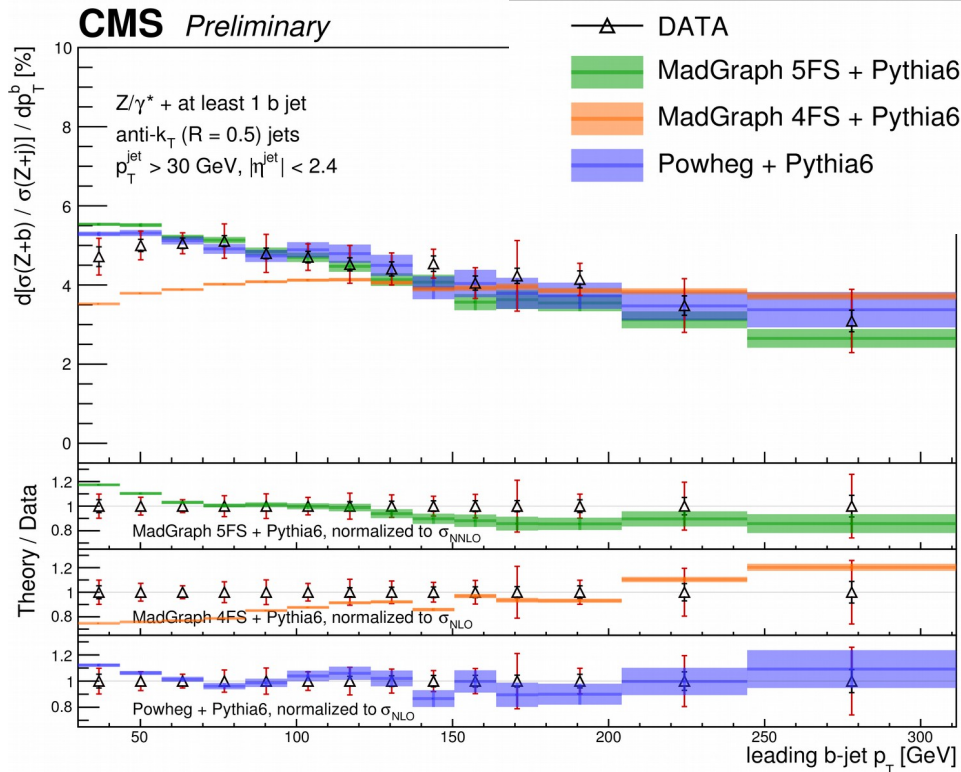


	$c_c$	$c_{uds-g}$
Z(1b) (ee)	$1.29 \pm 0.13$	$1.70 \pm 0.21$
Z(1b) ( $\mu\mu$ )	$1.51 \pm 0.12$	$1.18 \pm 0.19$

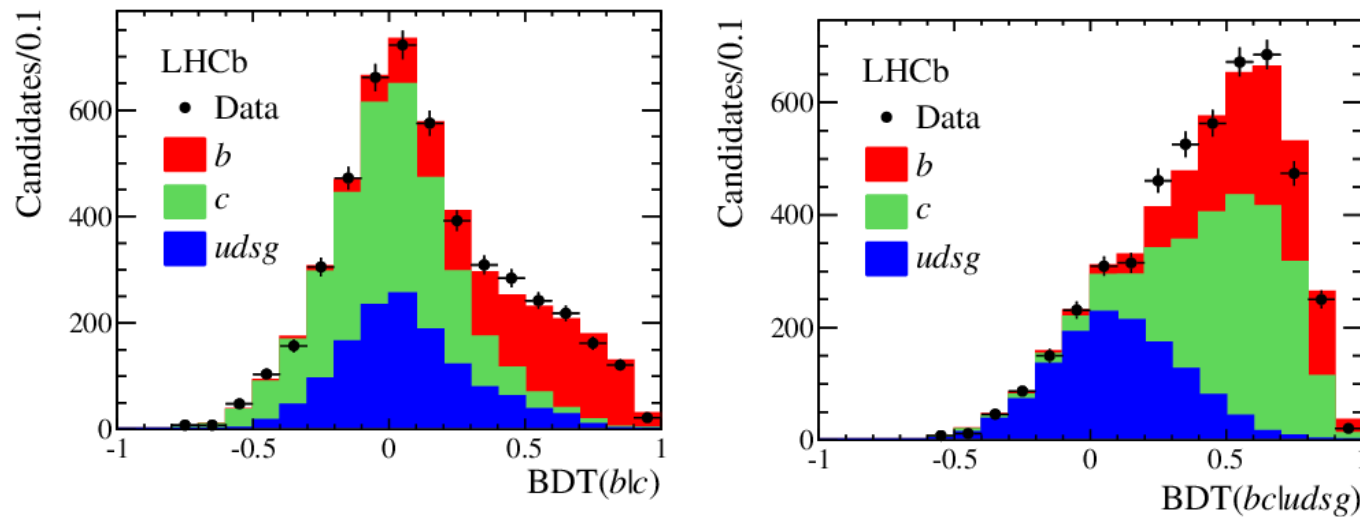
	$c_{bb}$
Z(2b) (ee)	$1.18 \pm 0.12$
Z(2b) ( $\mu\mu$ )	$1.17 \pm 0.09$

Differential cross-sections and ratios Z+b/Z+j

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

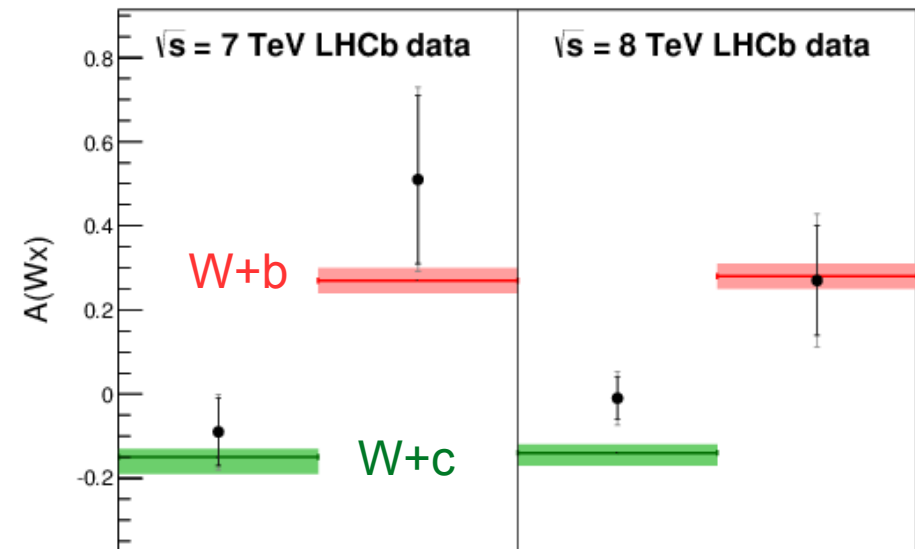
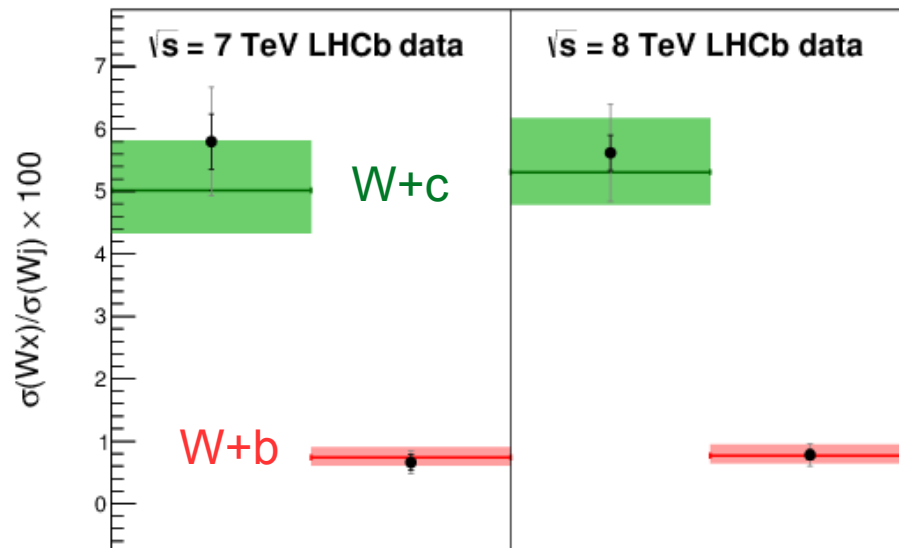


Data: 1/fb+2/fb at 7 TeV and 8 TeV

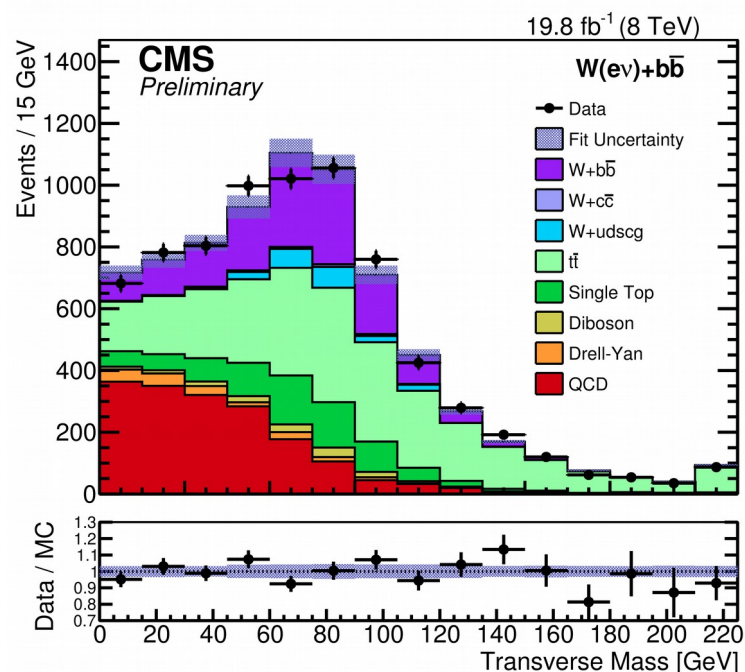
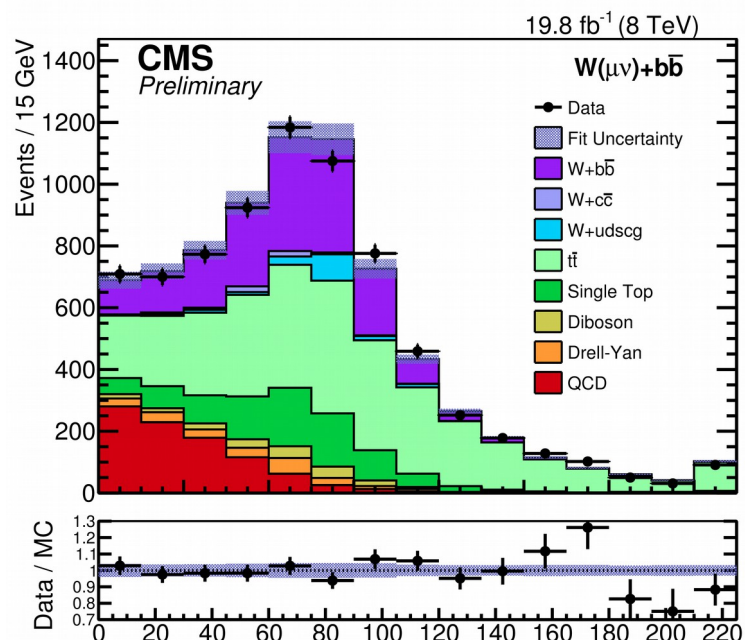


2D Fit is used to measure bottom and charm contributions

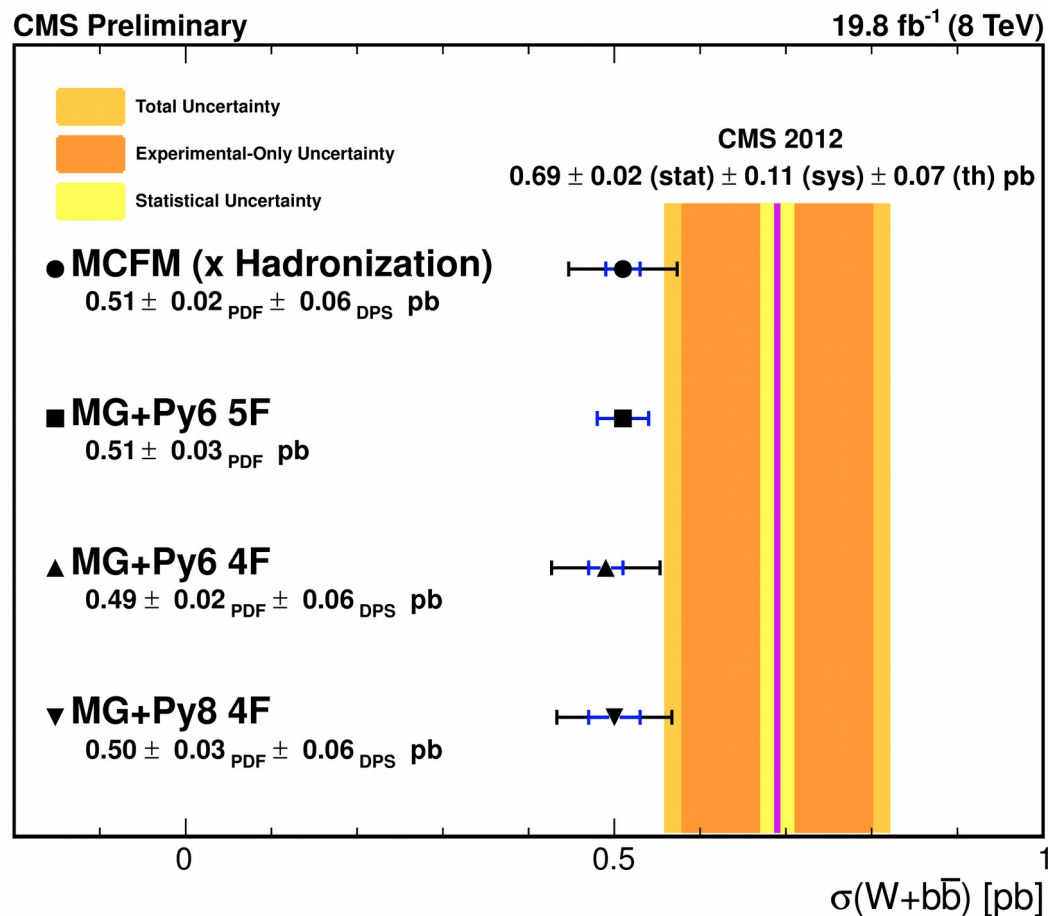
$$\mathcal{A}(Wq) \equiv \frac{\sigma(W^+q) - \sigma(W^-q)}{\sigma(W^+q) + \sigma(W^-q)}$$



Measurements are in good agreement with CT10 NLO MCFM predictions



## 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!