Electroweak and QCD aspects in V+jets

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Introduction

Motivation

- Vector boson event yield at the LHC allows for sensitive evaluation of perturbative QCD
- Compare to new MC predictions to steer future calculations
- Improvements in V+jets MC performance will propagate to BSM searches

Talk Outline:

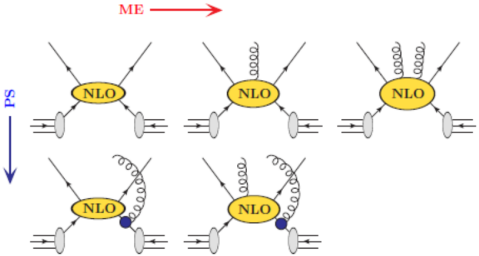
- Z + Jets* differential cross section measurements at 13TeV (arXiv:1804.05252)
- Measurement of pure EWK Z + 2 jets at 13TeV (arXiv:1712.09814)

* W+Jets differential cross section measurements at 13TeV (arXiv:1707.05979)

MC Z + Jets Signal Predictions

Madgraph5_amc@nlo (MG5_aMC) + Pythia 8

- LO matrix elements in Madgraph
  - Up to 4 outgoing partons
  - Parton showering in Pythia (CUETP8M1 tune)
  - k_T-MLM jet merging scheme
- NLO matrix elements in Madgraph
  - Up to 2 partons at NLO, 4 at LO
  - Parton showering in Pythia (CUETP8M1 tune)
  - FxFx jet merging scheme



MC Calculations and Samples

- GENEVA 1.0-RC2 (GE)
  - NNLO matrix elements + NNLL resummation
  - Parton showering in Pythia 8 (CUETP8M1 tune)
  - FxFx jet merging scheme
- NNLO Z + 1 Jet Calculation
  - N-jettiness subtraction scheme
  - Multi-parton interaction and hadronization estimated in MG5_aMC and Pythia 8

MC Sample	0j	1j	2j	3j	4j	>4j
LO MG5_aMC	LO	LO	LO	LO	LO	PS
NLO MG5_aMC	NLO	NLO	NLO	LO	LO	PS
GE	NNLO	NLO	LO	PS	PS	PS
NNLO fixed order	-	NNLO	-	-	-	-

Z+Jets Phase Space

Data Sample $= 2.19 fb^{-1}$ at 13TeV

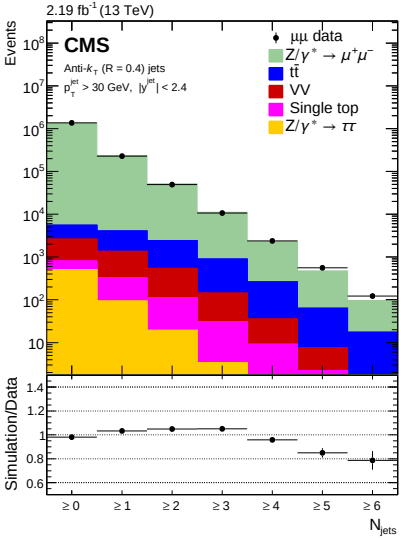
Leptons (e and μ)

- $71.0 GeV < m_{ll} < 111.0 GeV$
- $p_T > 20 GeV$
- $|\eta| < 2.4$

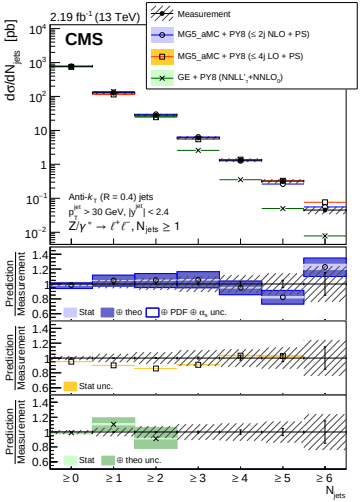
Jets

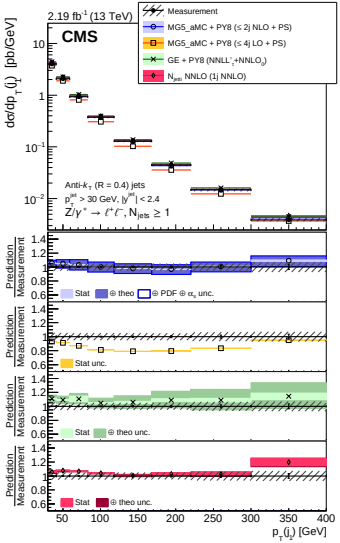
- $Anti - k_T$ clustering algorithm with R=0.4
- $p_T > 30 GeV$
- $|y| < 2.4$
- $\Delta R(\ell, jets) < 0.4$

Unfolding done to account for detector resolution



Jet Multiplicity + Leading Jet p_T





Jet Multiplicity

- Discrepencies at high multiplicities where jets in acceptance are from PS
- GE fails to describe data in PS region

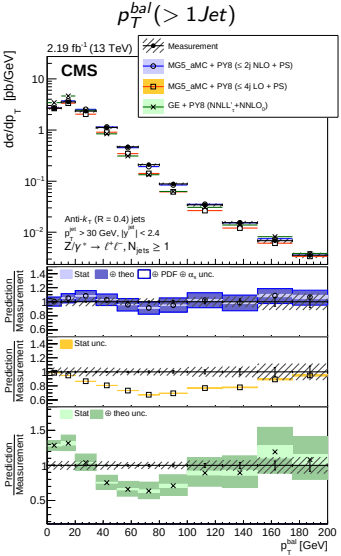
Jet p_T

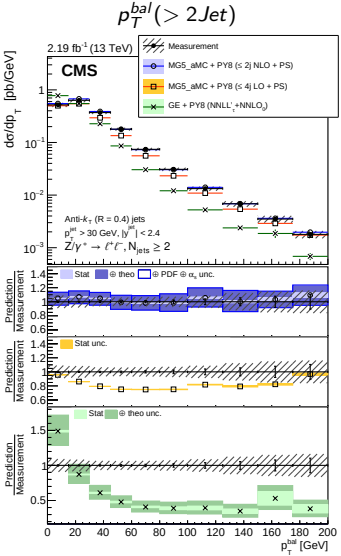
- Higher order improve shape and normalization compared to LO MG5_aMC
- Reduced systematic error for fixed order NNLO calculation

Pt Balance

$$p_T^{bal}(njets) = |\vec{p_T}(Z) + \sum^n \vec{p_T}(j_i)|$$

- Greater than zero due to missed hadronic activity
- Sensitive to modeling of soft gluon radiation
- GE discrepency in ≥ 2 jets caused by PS jets out of acceptance





EWK Z + 2 Jets at 13TeV

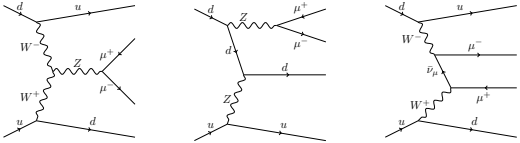
Measurement of EWK production of Z + 2 jets with $35.9 fb^{-1}$ (a)

- Distinct signature of large m_{jj} and $\Delta\eta_{jj}$
- Boosted decision tree used for signal extraction

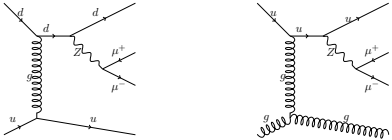
MC Predictions

- EWK Signal: LO MG5_aMC
- α_s^2 background: LO/NLO MG5_aMC given in (b)
- Pythia 8 with CUETP8M1 tune

arXiv:1712.09814



(a) Production modes: vector boson fusion, bremsstrahlung-like, and multiperipheral.



(b) Strong production modes.

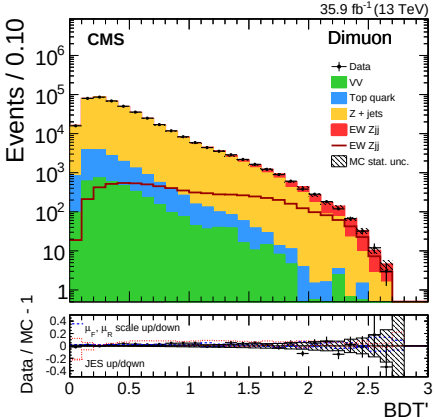
BDT Results

Sample	Initial		BDT >0.92	
	ee	$\mu\mu$	ee	$\mu\mu$
Total background	159890 $\pm$ 510	411890 $\pm$ 890	283 $\pm$ 29	505 $\pm$ 43
EW Zjj signal	2833 $\pm$ 10	6665 $\pm$ 16	194.9 $\pm$ 2.6	379.7 $\pm$ 3.9
Data	163640	422499	418	892

Signal strength determined from fit of the BDT' output

EWK Z + 2 jets fiducial cross section:

- Measurement: $\sigma(EWjj) = 552 \pm 19(stat) \pm 55(syst) fb$
- Prediction: $\sigma_{LO}(EWjj) = 543 \pm 24 fb$



Conclusion

Z + Jets differential cross section

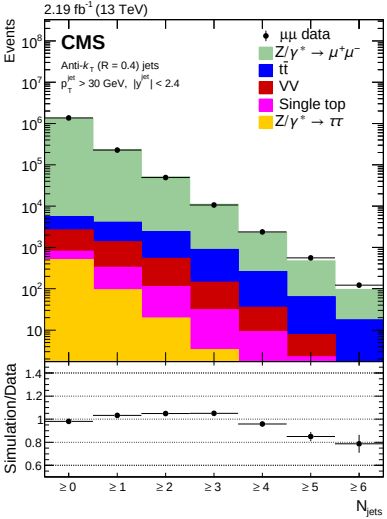
- NLO MG5_aMC best global description of data
- Extend the reach of the ME to higher multiplicities $\rightarrow$ reduce dependence on the parton shower
- Improvements in systematic uncertainties in NNLO fixed order calculation

Most precise measurement of EWK + 2 Jets production:

- $\sigma(EWjj) = 552 \pm 19(stat) \pm 55(syst) fb$

BACKUP

Jet Multiplicity + Unfolding



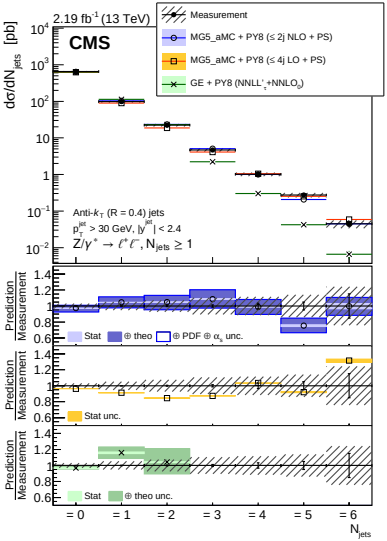
Background processes

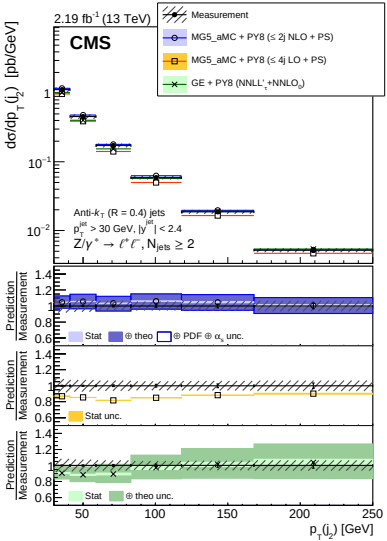
- Simulated with NLO POWHEG or MG5_aMC + Pythia 8
- $t\bar{t}$ corrected with data driven method

Data Unfolding

- Account for limited detector resolution
- Background samples subtracted from data
- NLO MG5_aMC sample used for unfolding

Jet p_T + Multiplicity exclusive





BDT Variables

- Most powerful variables: m_{jj}, $\Delta\eta_{jj}$
- Others include quark-gluon likelihood (QGL), p_{Tjj}