Vector Boson and Jets Measurements from CMS

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on behalf of CMS Collaboration

The 28th International Workshop on Weak Interactions and Neutrinos (WIN2021)

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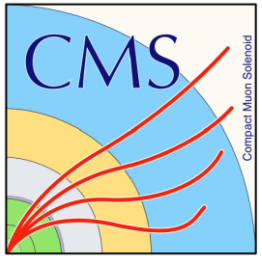

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- Z/γ + jet p_T ratio measurement (**Accepted at JHEP, arXiv:2102.02238**)
- Z boson emission collinear with jet (**arXiv:2102.02238**)
- EW production of a W boson in association with two jets (**Published at Eur. Phys. J. C 80 (2020) 43**)
- Summary

Motivation:V+jets

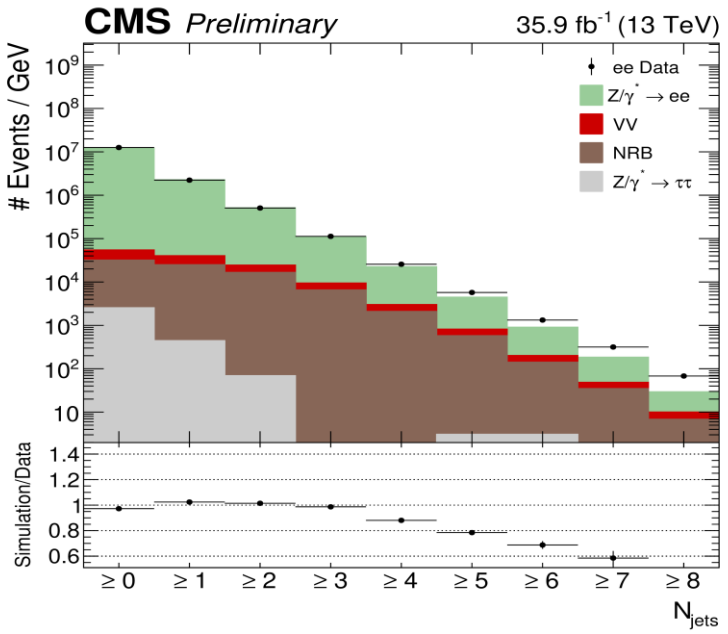
- Processes involving W and Z boson production are one of the best understood processes at hadron colliders:

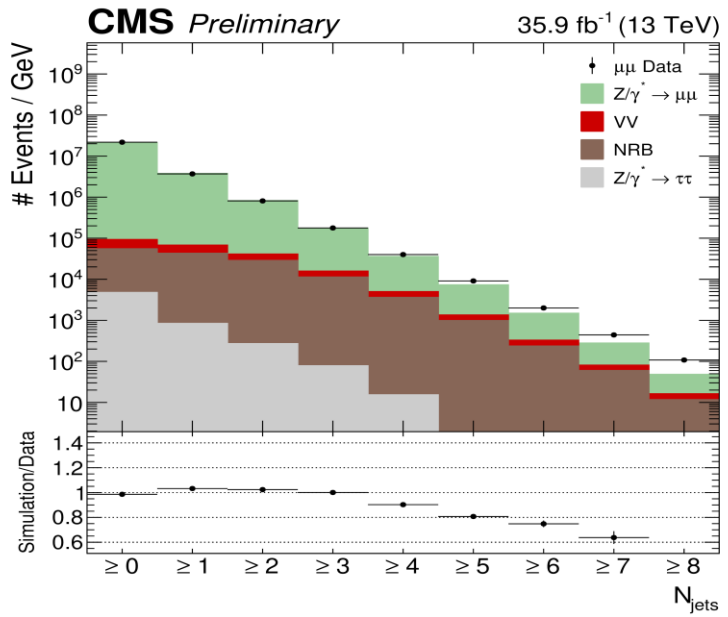
$W^{\pm} \rightarrow \ell^{\pm} \upsilon$, $Z \rightarrow \ell^{\pm}\ell^{\pm}$, (ℓ=e, μ) are among the cleanest final states experimentally:

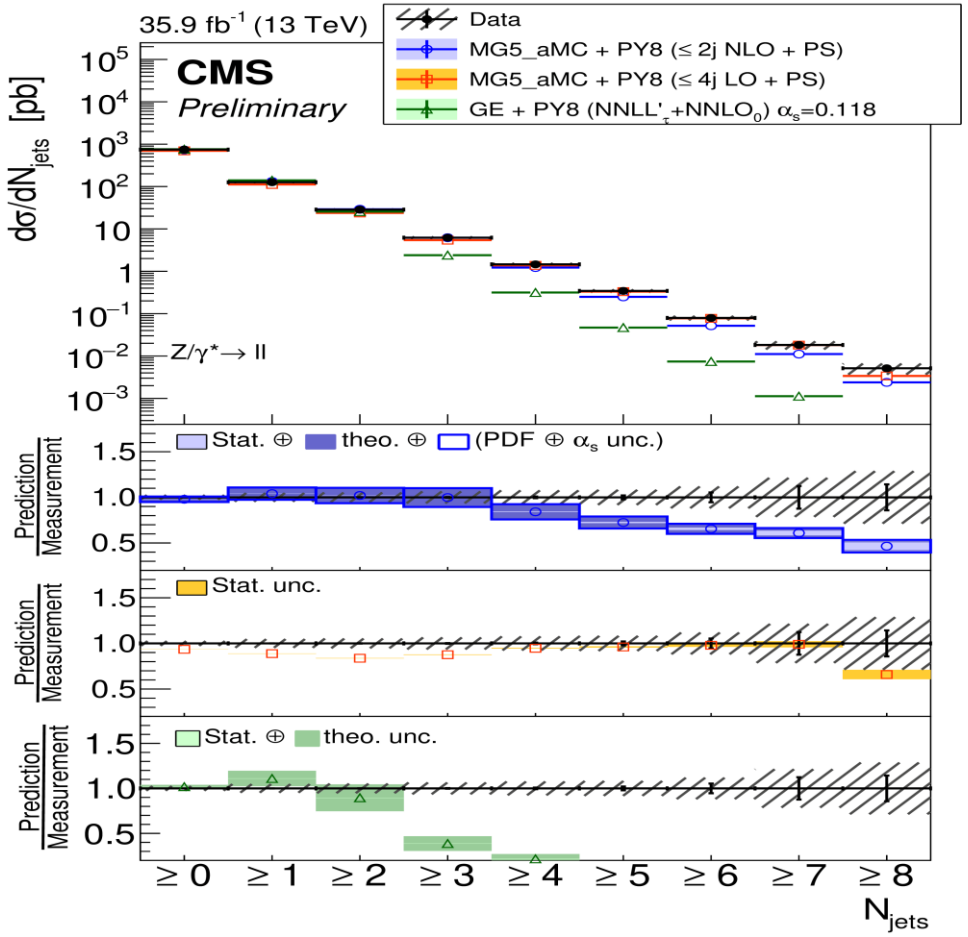
* Provide an important test of the SM.
* Test pQCD and validate our modelling of it in MC.
* Give opportunity to accurately constrain the parton distribution functions (PDFs).
* Probe/measure EW production cross sections.
* Tests of non pQCD (i.e. whether, mainly, hadronization and fragmentation play a role in V+jet yields).
* Provide backgrounds to precision measurements, Higgs physics and BSM searches.

- Various kinematic properties of jets produced with W and Z boson production are studied.
- Measurements carried out in fiducial phase space.

Z+jet x-section measurements: Jet Multiplicity





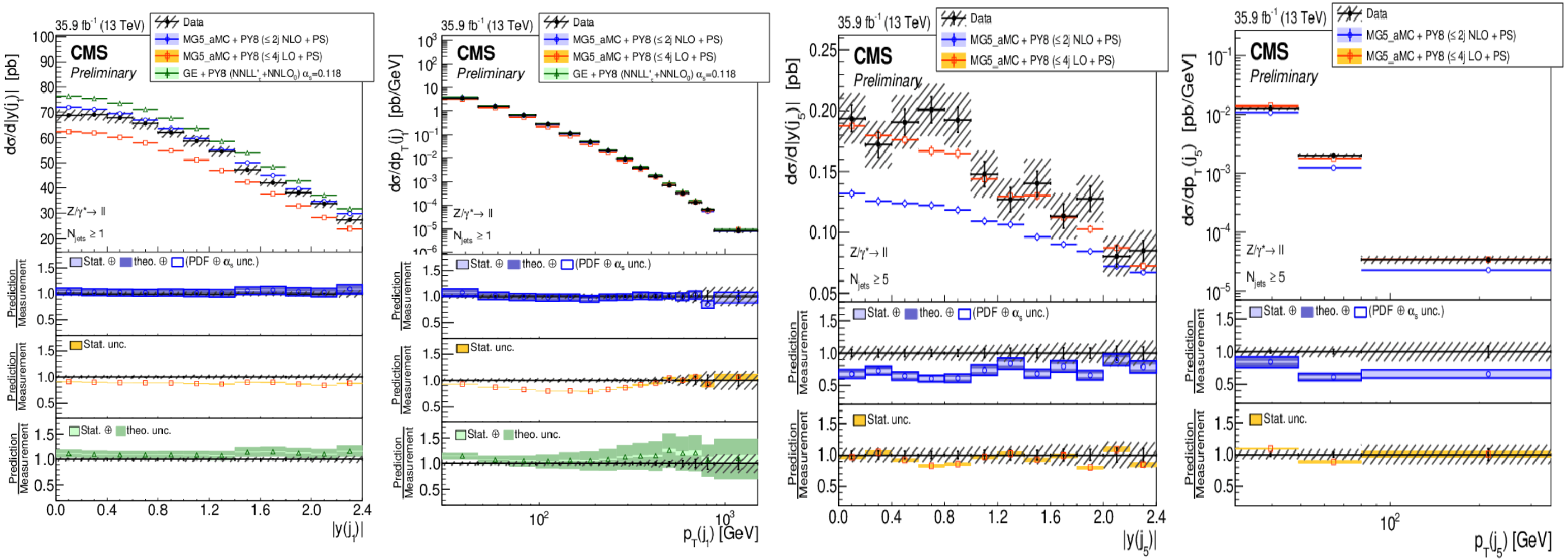


- Measured diff x- sections for Z bosons decaying to *e* or μ with $p_T > 25$ GeV and $|\eta| < 2.4$ requiring at least one jet with $p_T > 30$ GeV and $|\eta| < 2.4$.
- Unfolded to remove the detector effect.
- Measured jet multiplicities up to 8 jets.
- Compared with generators at different orders in QCD.

CMS-PAS-SMP-19-009

N_{jets}	$\frac{d\sigma}{dN_{jets}}$ [pb]	Tot[%]	stat [%]	JES [%]	JER [%]	Eff [%]	Lumi [%]	XSec [%]	PU [%]	LES+LER [%]	Unf sys [%]
≥ 0	744.	2.6	0.026	0.0083	0.019	0.022	2.5	0.020	0.023	0.013	0.31
≥ 1	126.	4.7	0.075	3.9	0.30	0.087	2.6	0.026	0.35	0.021	0.36
≥ 2	28.5	5.3	0.17	4.5	0.21	0.088	2.6	0.035	0.44	0.031	0.53
≥ 3	6.21	6.5	0.41	5.8	0.29	0.14	2.6	0.040	0.69	0.062	0.55
≥ 4	1.46	7.6	0.95	6.9	0.28	0.045	2.6	0.055	0.85	0.060	1.0
≥ 5	0.344	8.0	2.2	7.1	0.72	0.23	2.6	0.060	0.78	0.21	0.85
≥ 6	0.0792	11.	5.8	8.5	0.35	0.69	2.7	0.089	1.8	0.49	2.9
≥ 7	0.0183	20.	17.	10.	1.2	0.60	2.4	0.035	2.9	0.84	2.8
≥ 8	0.00514	29.	25.	12.	3.1	0.78	2.5	0.015	2.0	4.4	3.3

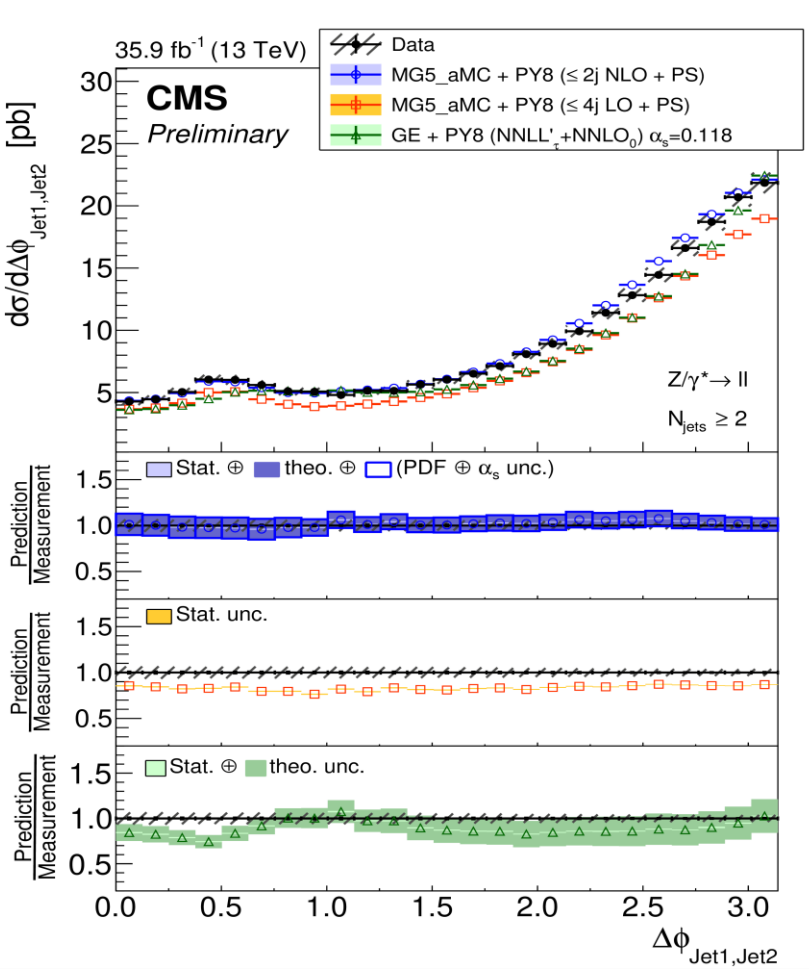
Z+jet x-section measurements: Jet y & p_T

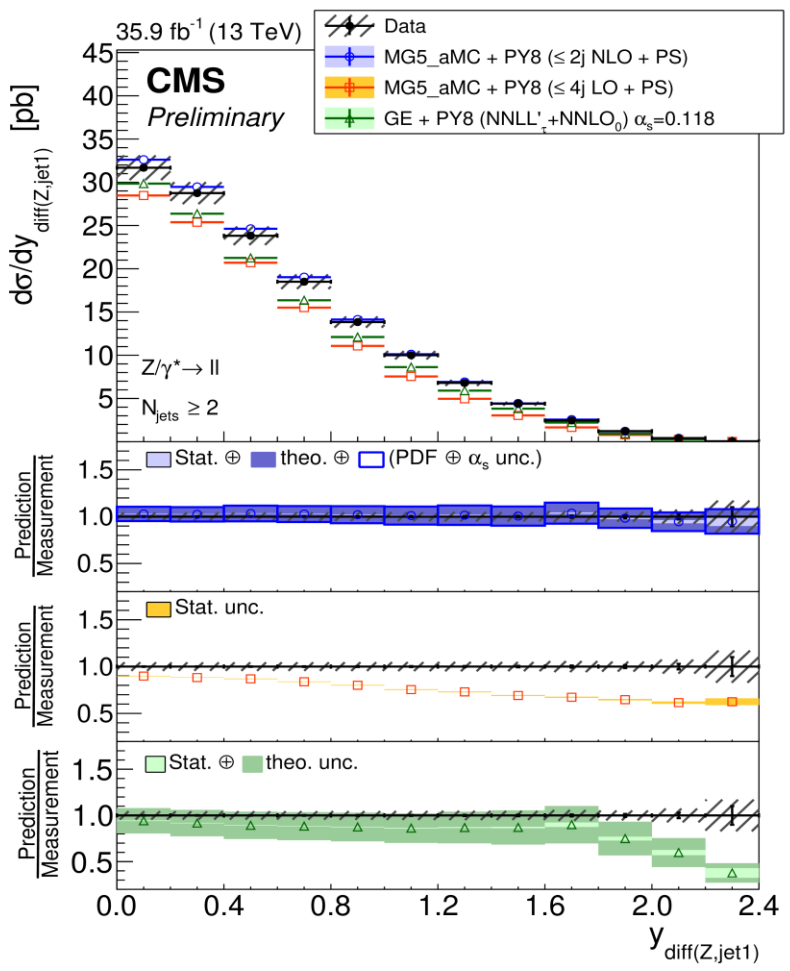


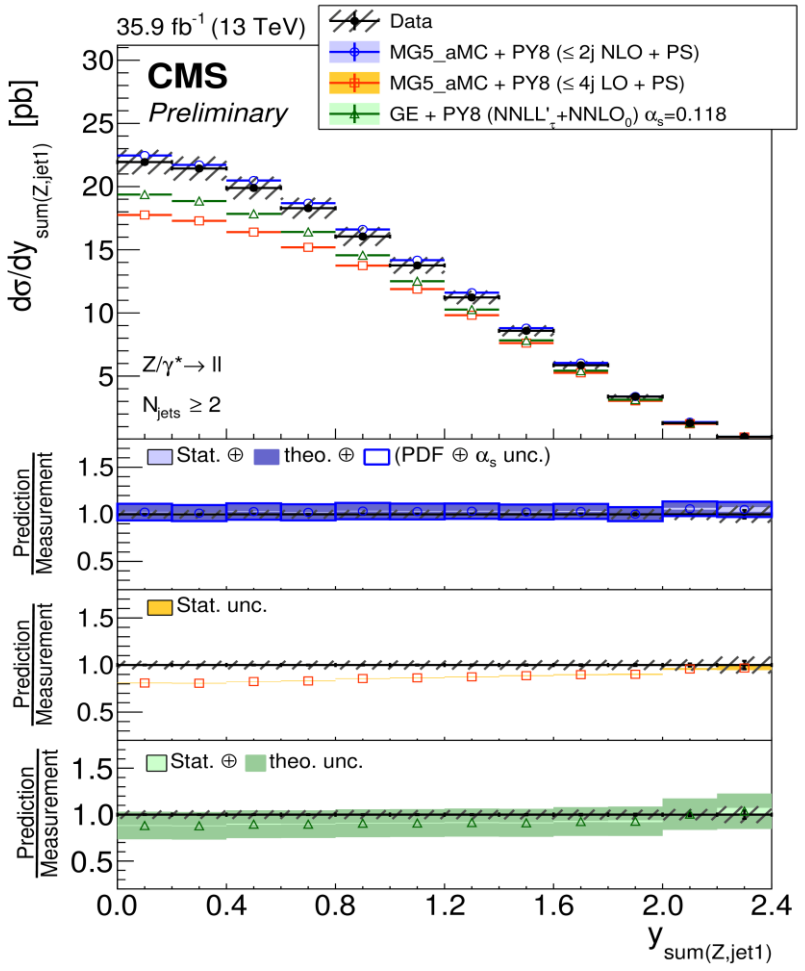
- Measured differential kinematics (y and p_T) up to 5 jets.
- Good description with MG5_aMC@NLO (NLO ≤ 2) and GE+PY8.

CMS-PAS-SMP-19-009

Z+jet x-section measurements: Angular variables



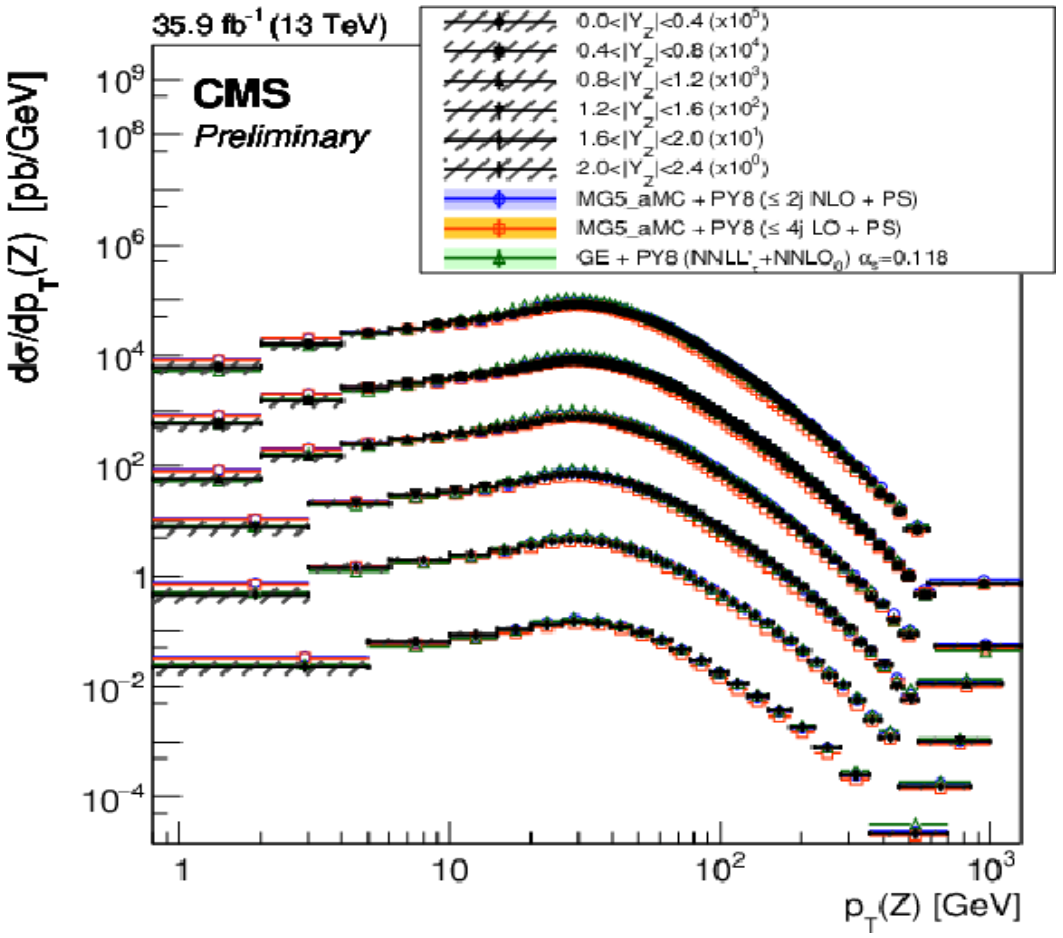


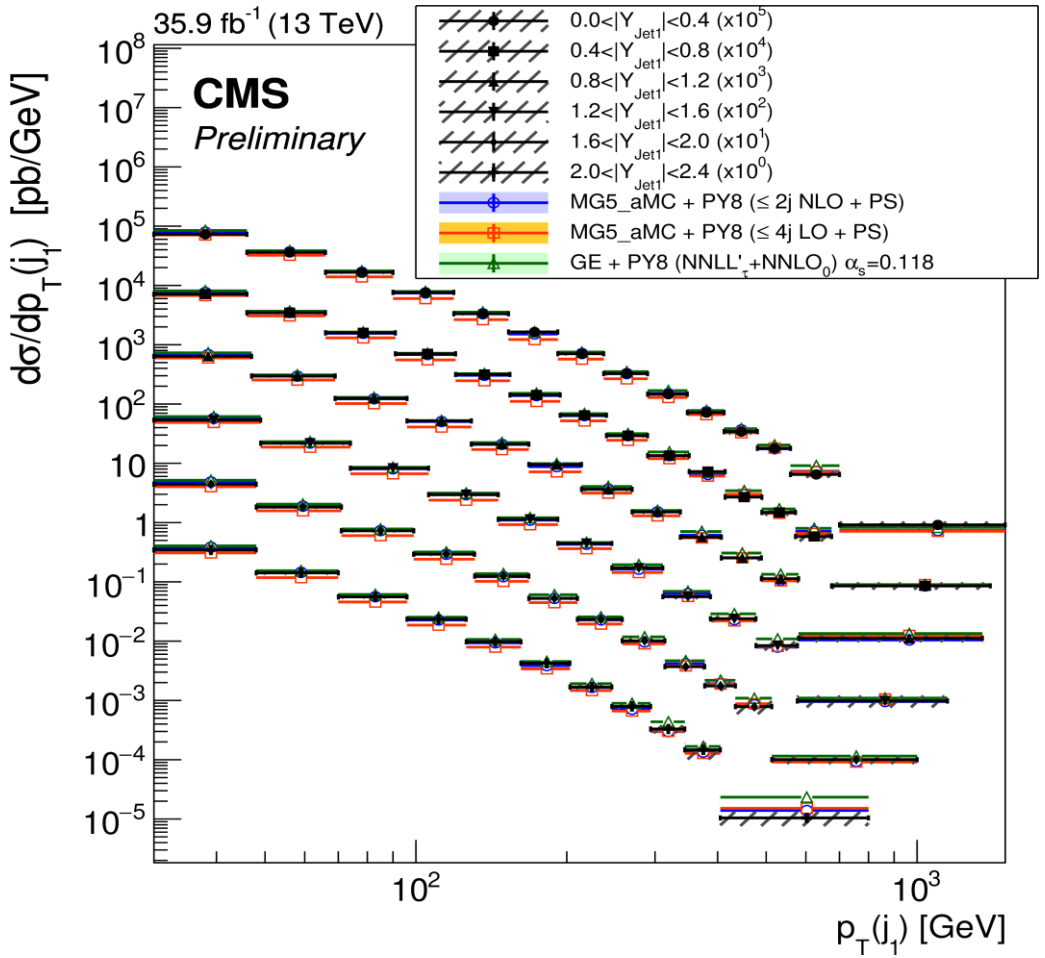


- Measured $\Delta\phi$ and y_{diff} between jets and also Z.
- Differences wrt GENEVA predictions at high y_{diff}.

CMS-PAS-SMP-19-009

Z+jet double-diff. x-section measurements: Z p_T, jet p_T





- Measured double-differential cross sections wrt Z p_T and jet p_T .

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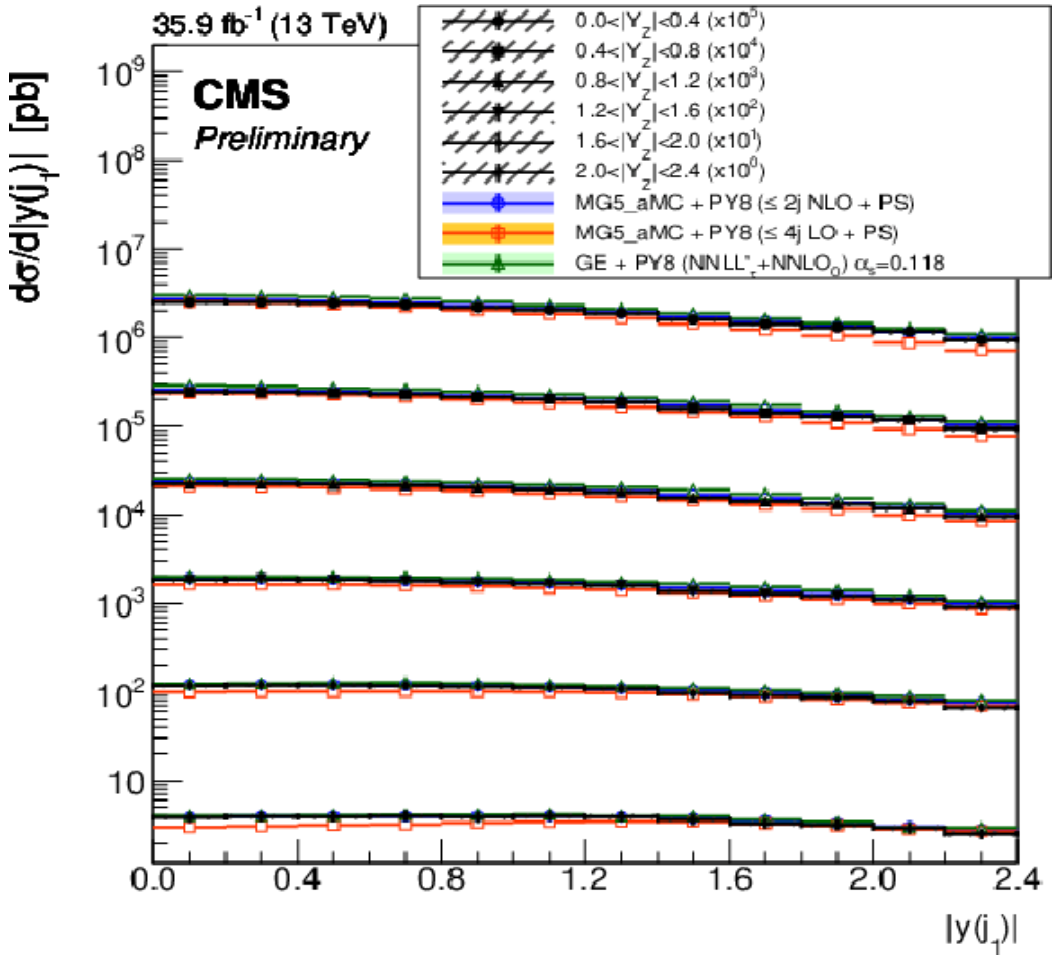
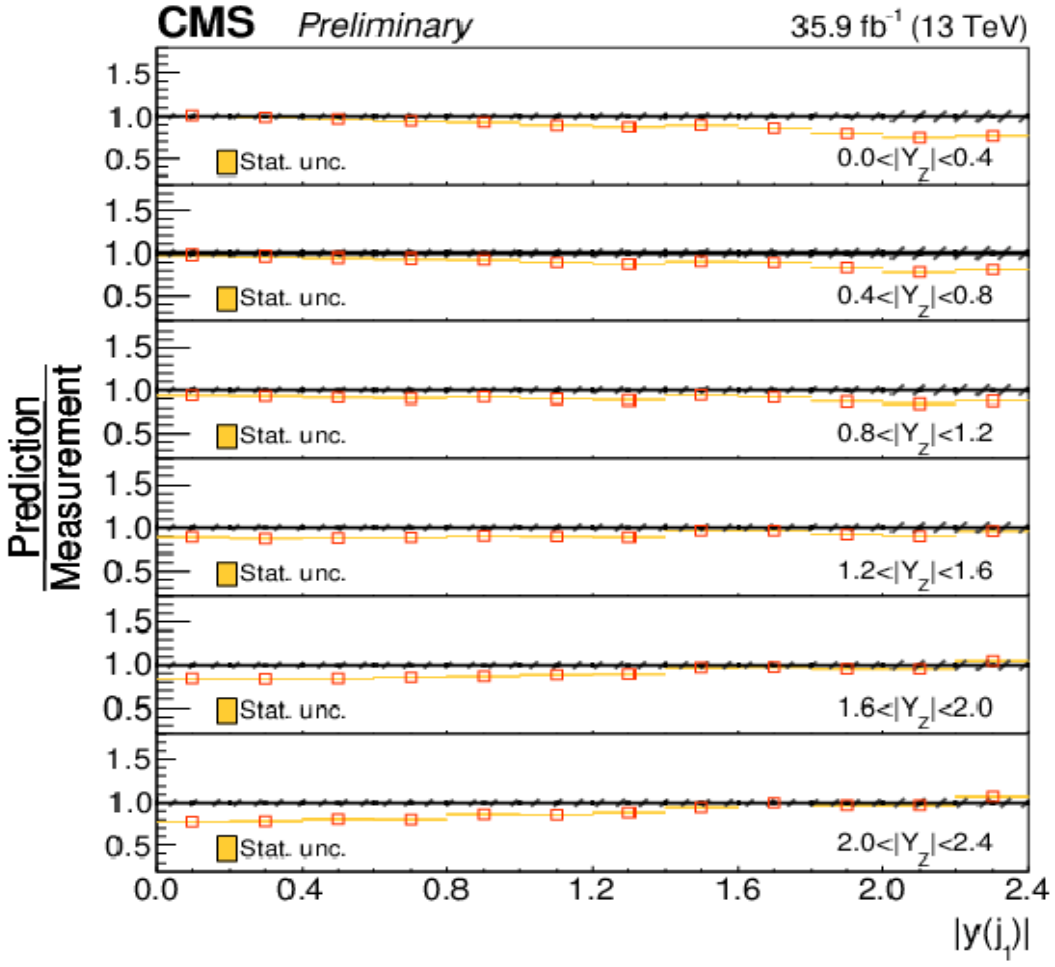
Z+jet double-diff. x-section measurements: jet y

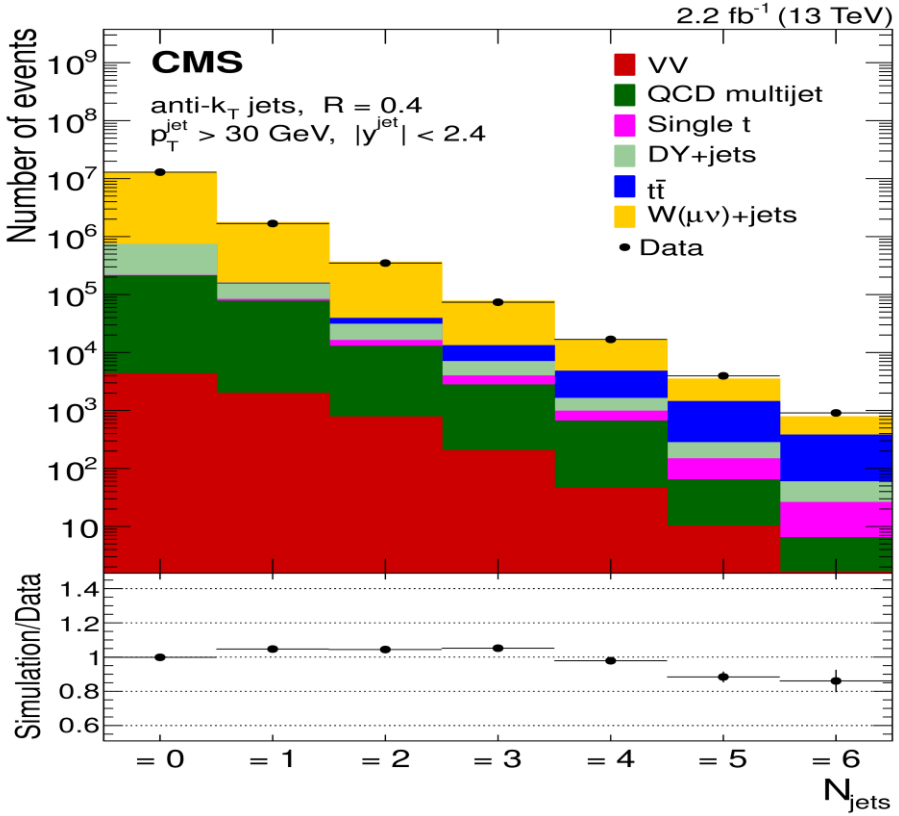




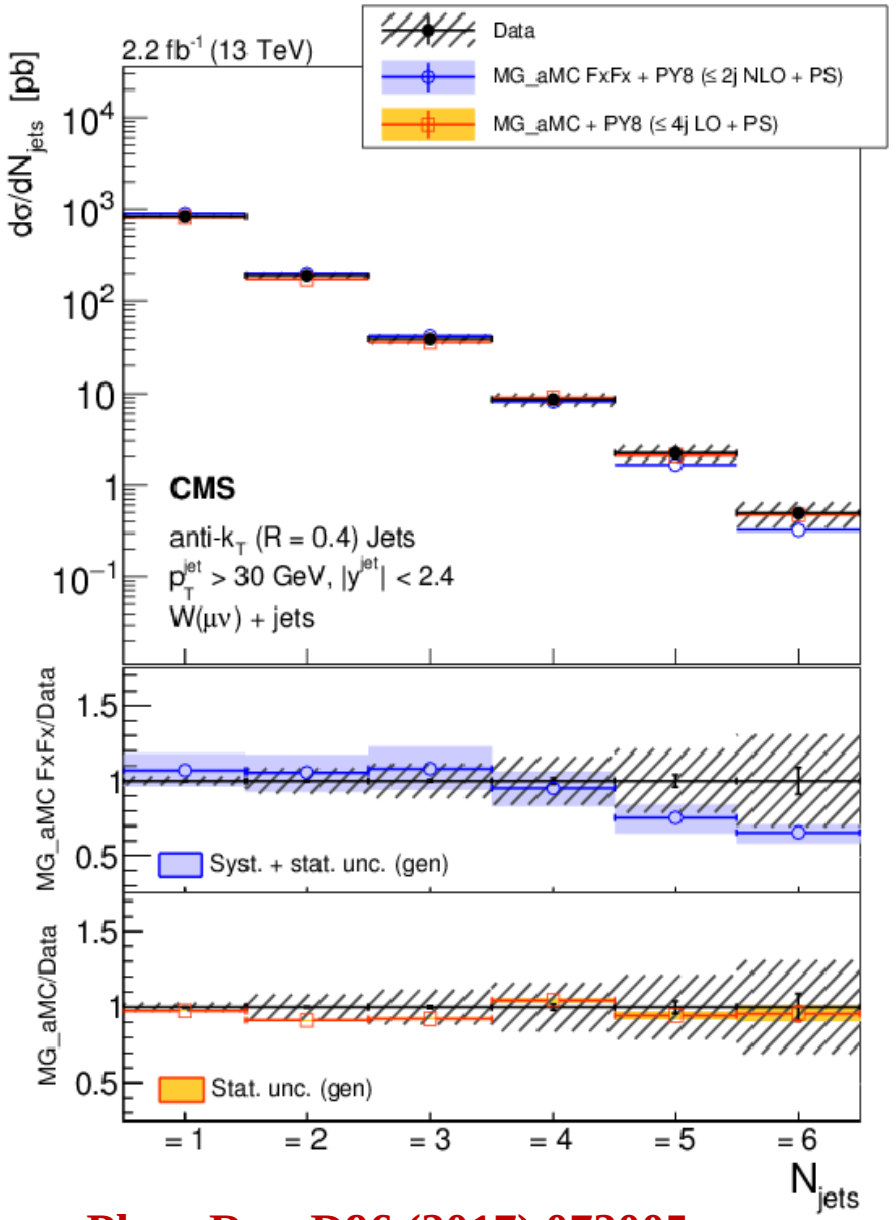
CMS-PAS-SMP-19-009

- LO MG5_aMC@NLO + PY8 fails at high y(Z) low y(j).

W+jets x-section: Jet multiplicity



- Muon $p_T > 25$ GeV and $|\eta| < 2.4$.
- Corrected for detector effects via unfolding.
- b-tag veto to suppress tt contribution.
- Data-driven estimate of QCD background.
- Measured jet multiplicity up to 6 jet.



- Measured diff. x-section for the exclusive jet multiplicity.
- Compared to the predictions of MG5_aMC@NLO with FxFx merging scheme and and MG5_aMC@NLO in LO mode.
- Measured cross sections and the predictions are in good agreement within uncertainties.

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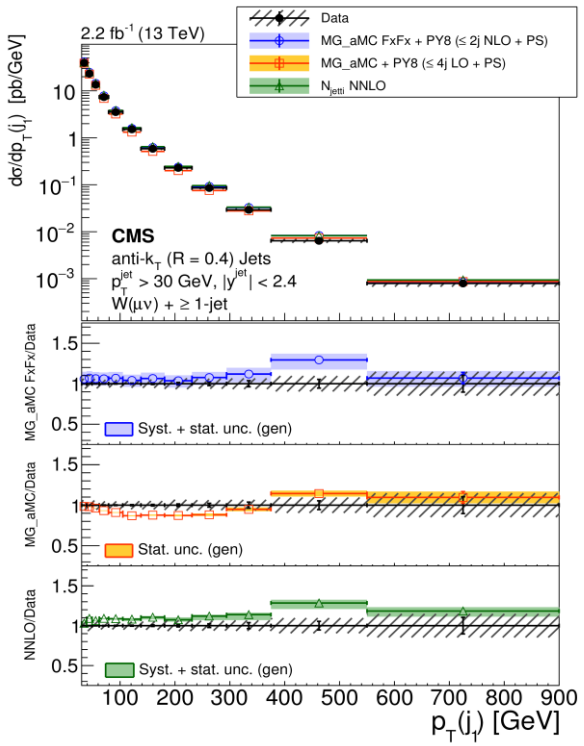
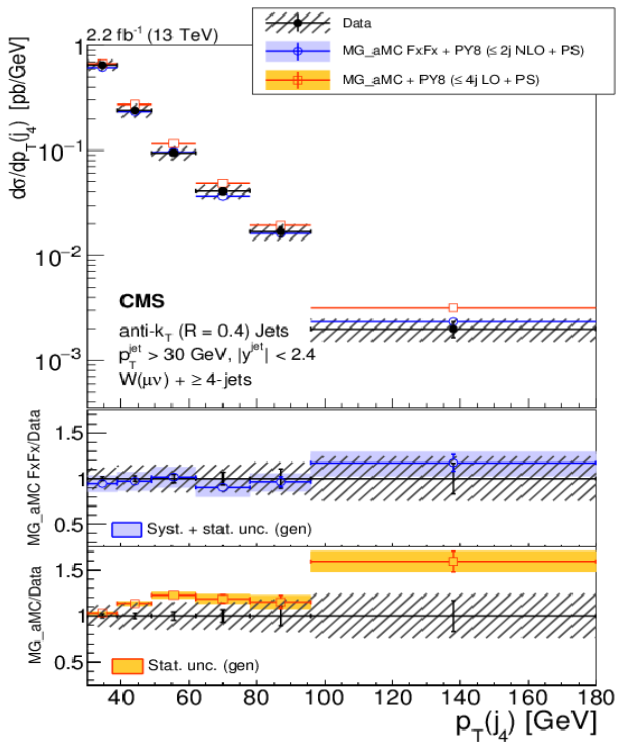
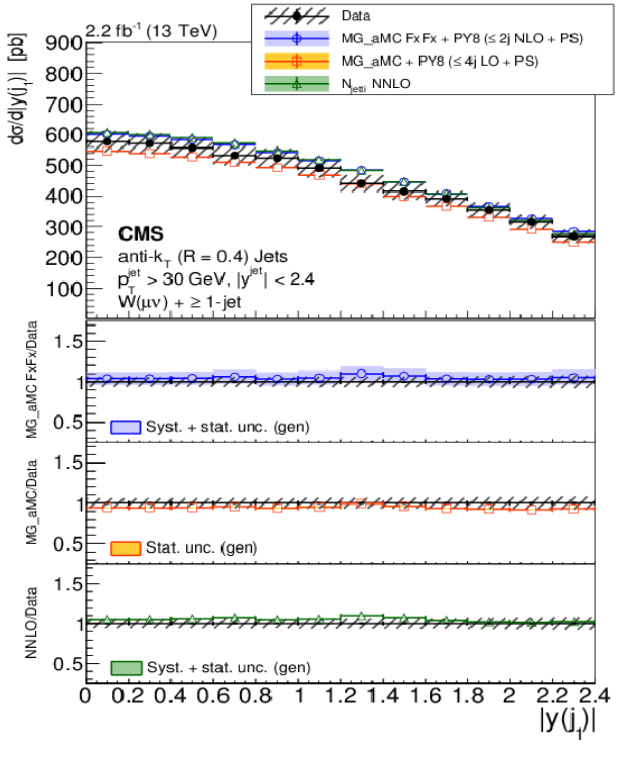
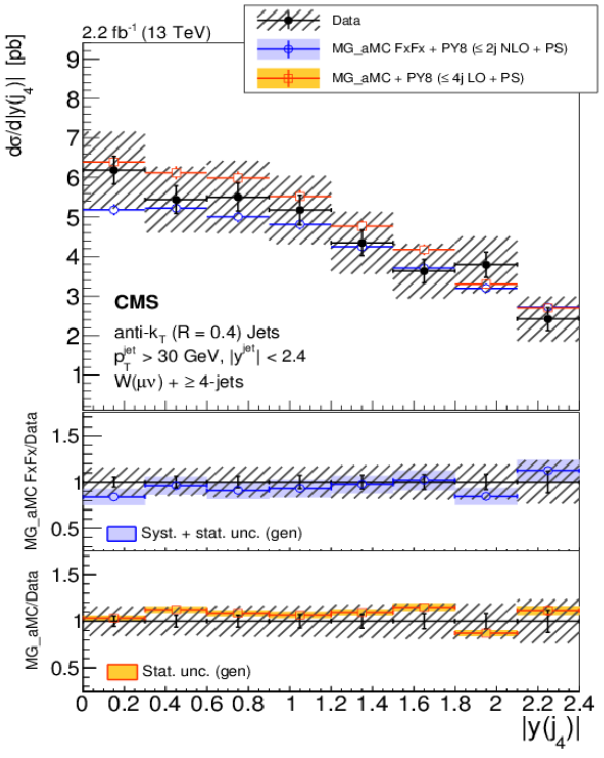
W+jets x-section: Jet p_T & y







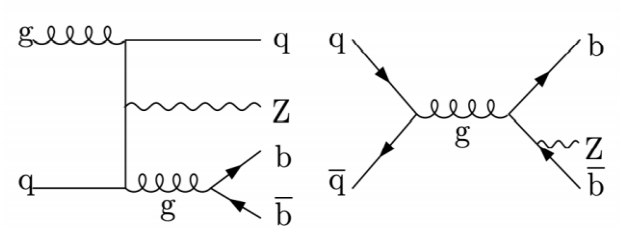


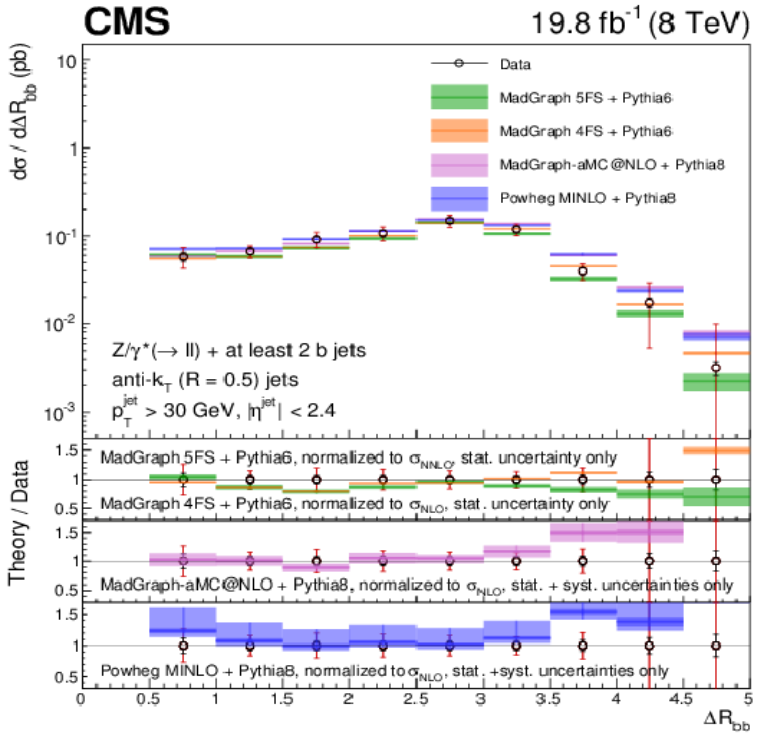
- Measured diff. x-sections for the transverse momenta of the four leading jets.
- Compared with the predictions of NLO MG_aMC with FxFx merging scheme and LO MG_aMC. The NNLO prediction for W + 1-jet is included in the first leading jet p_T.
- Better described by the NLO MG_aMC FxFx merging scheme prediction for all inclusive jet multiplicities and by the NNLO calculation for at least one jet.

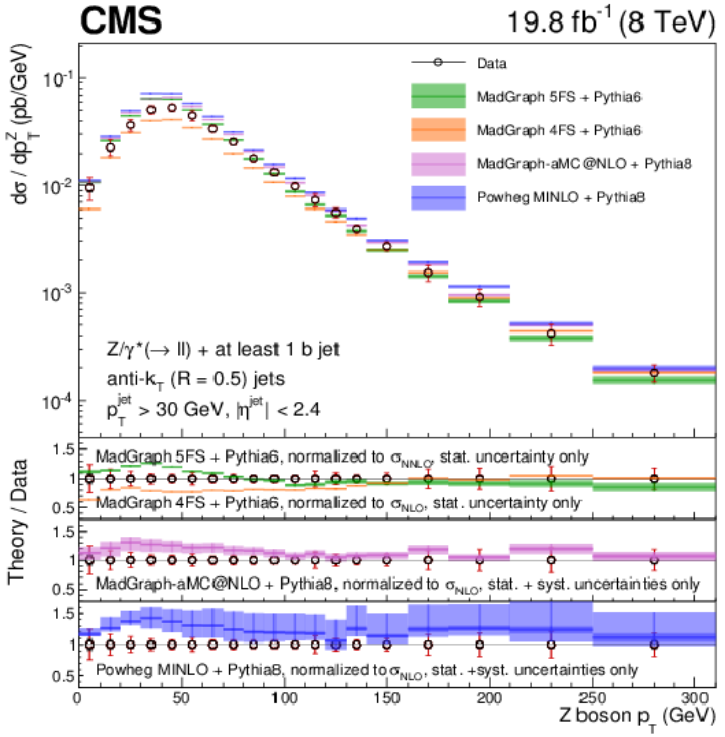
Phys. Rev. D96(2017) 072005

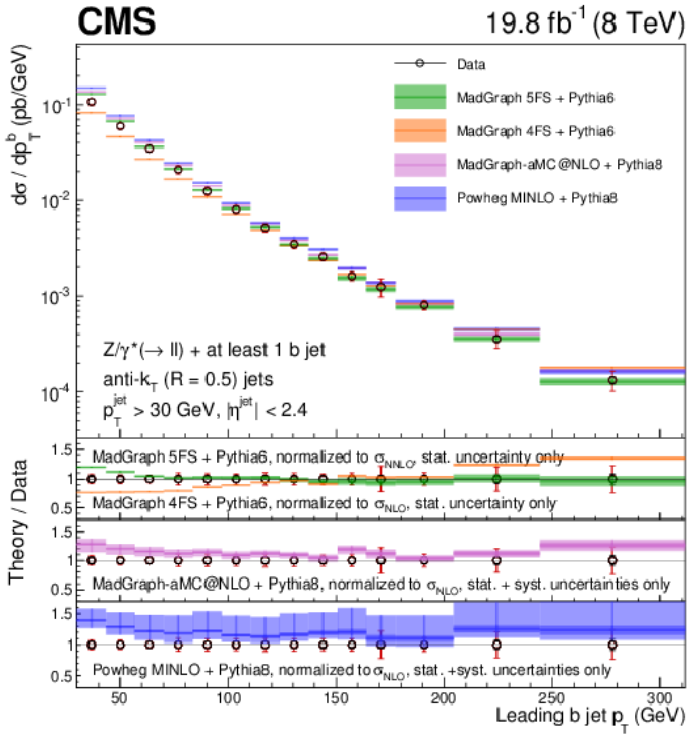
V + HF measurements

- Important to study V+ HF production at the LHC:
  * Probe HF PDFs.
  * Collinear production of b quarks (gluon splitting)









- Measured diff. x-sections for Z(1b) production as a function of the leading b jet & Z boson p_T and for Z(2b) production as a function of ΔR_{bb} .
- Compared with the MadGraph 5FS, MadGraph 4FS, MadGraph5_aMC@NLO, and Powheg MINLO theoretical predictions.

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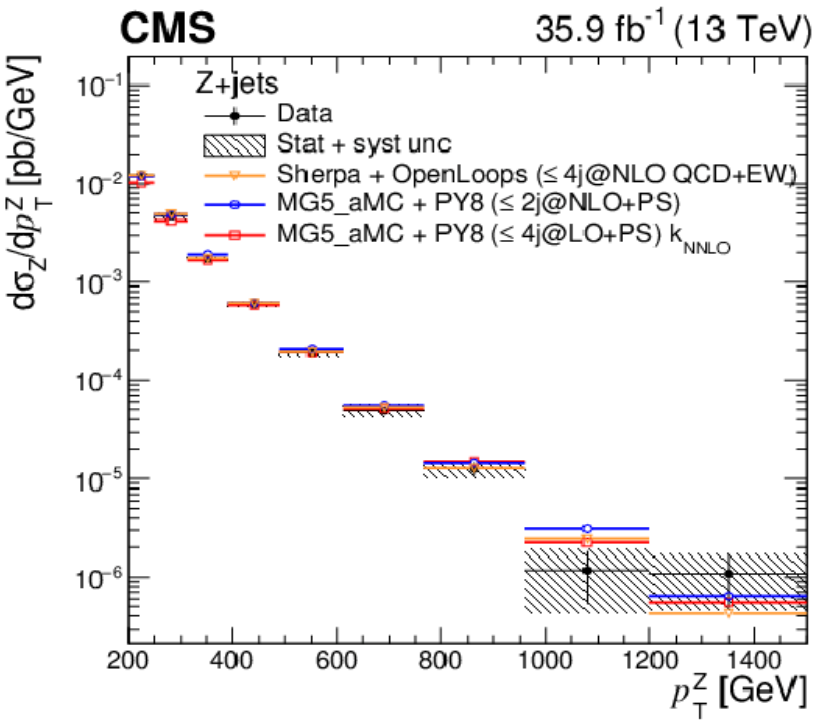
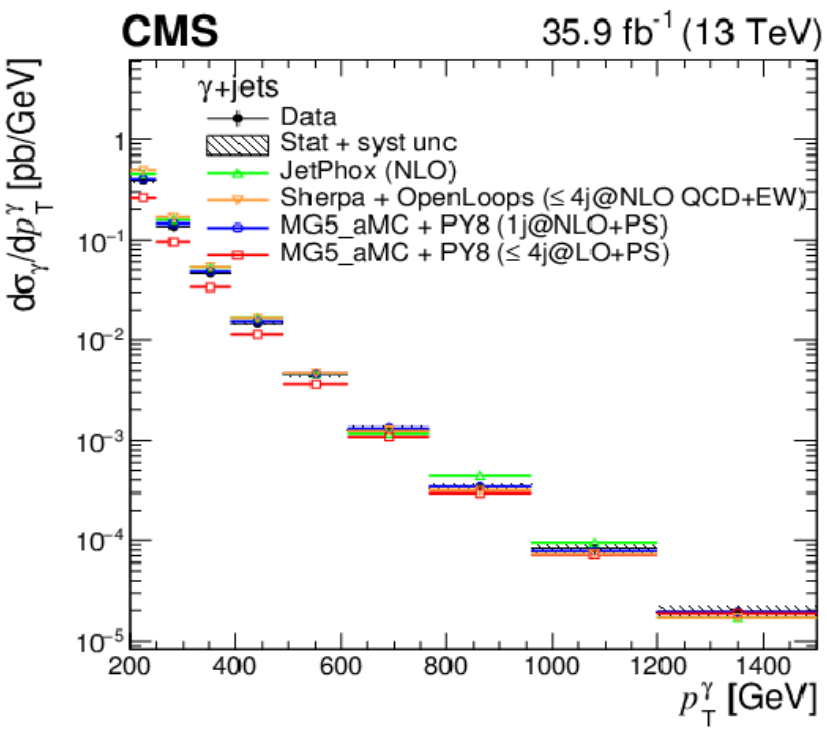
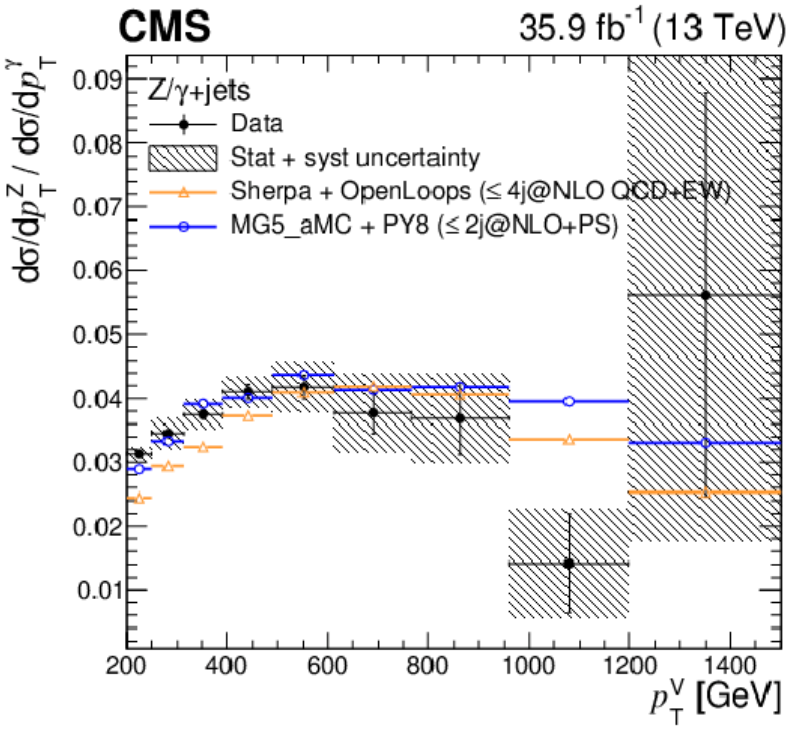
Z/γ + jet p_T ratio measurements

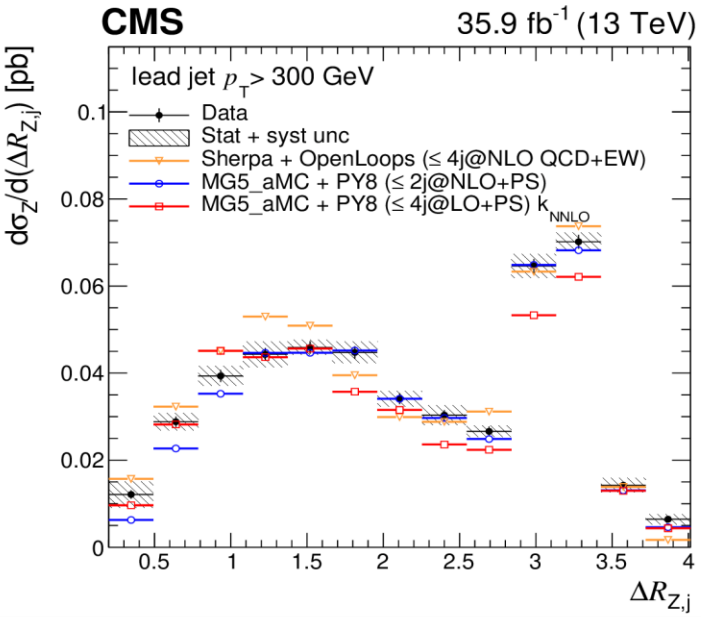


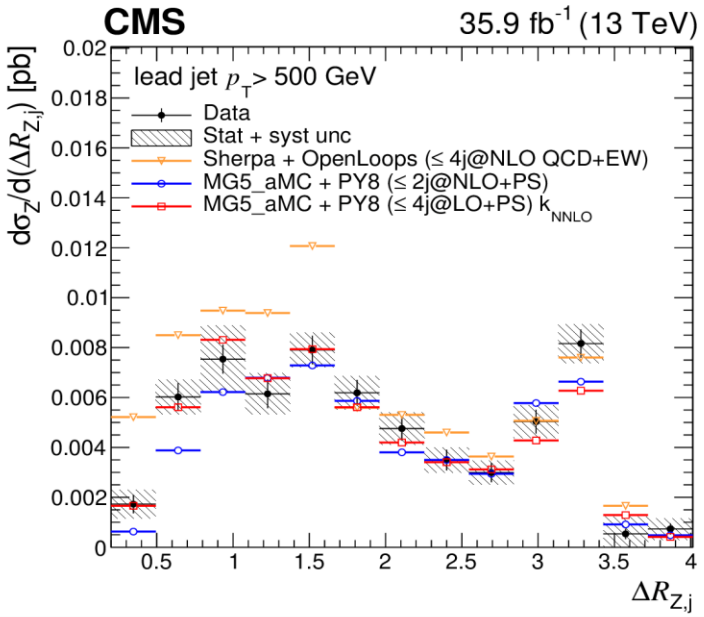


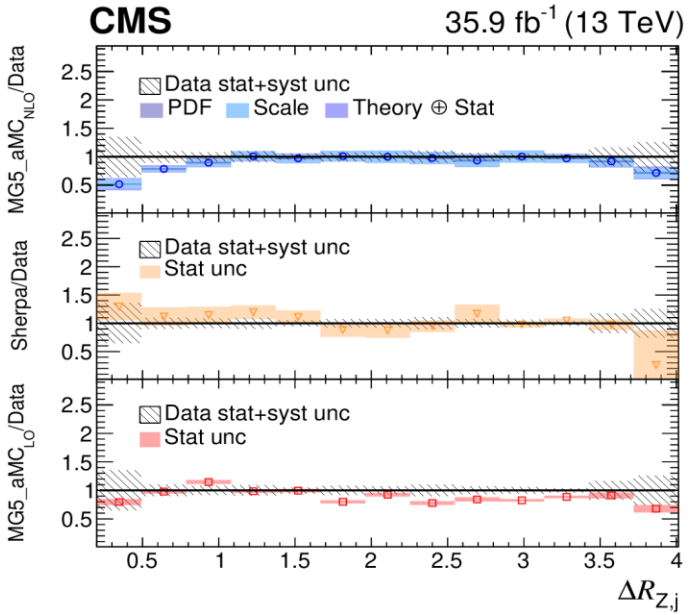


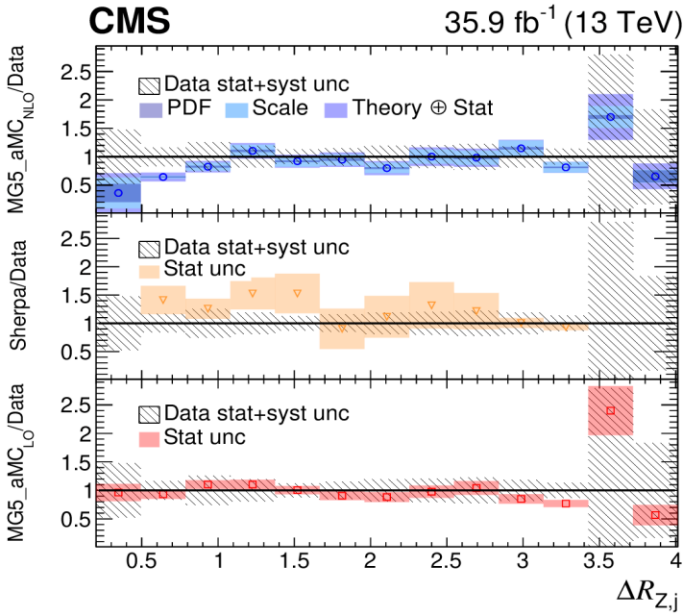
- First measurement at 13 TeV of the ratio of cross sections for Z + jets to γ + jets as a function of boson p_T. **arXiv:2102.02238**
- Selected events with:
  Photon $p_T > 200$ GeV and $|\eta| < 1.4$
  Z boson $p_T > 200$ GeV, $|y| < 1.4$
  Muon $p_T > 30$ GeV, $|\eta| < 2.4$
  Jets $p_T > 40$ GeV, $|\eta| < 2.4$
- Compared with predictions from LO and NLO calculations from MG5_aMC@NLO, and NLO (QCD+EW) prediction from Sherpa + OpenLoops, NLO JetPhox (for γ + jets measurement).

Z boson emission collinear with a jet





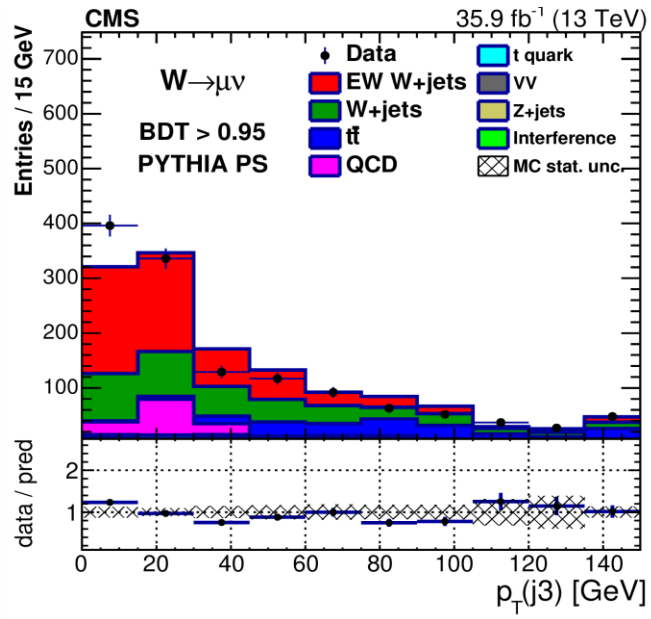


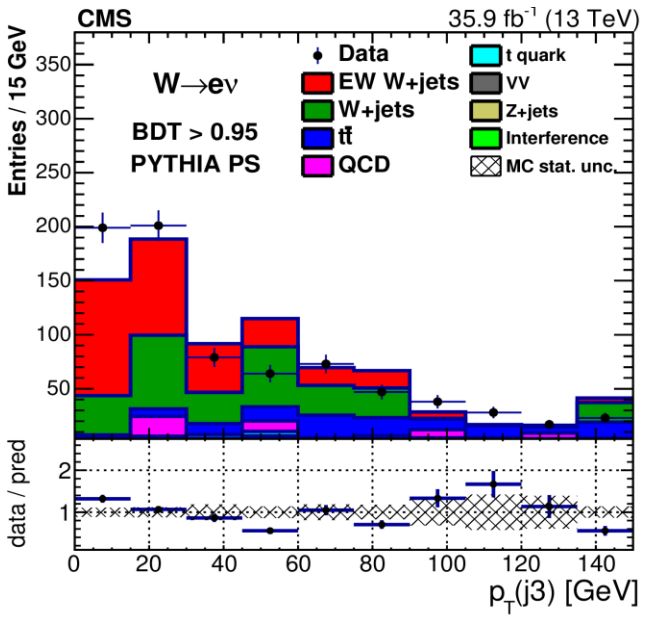


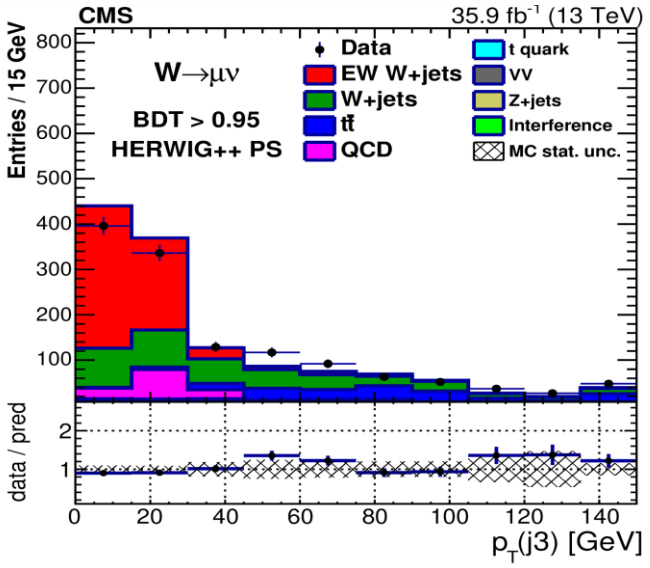
- Measured differential cross section of Z + jets as a function of the angular separation between the Z boson and the closest jet.
- The measurement of the emission of a Z boson collinear to a jet represents the first explicit study of this topology at the LHC.
- Compared with theoretical predictions from MG5_aMC@NLO and Sherpa + OpenLoops, where the leading jet p_T is above 300 and 500 GeV.

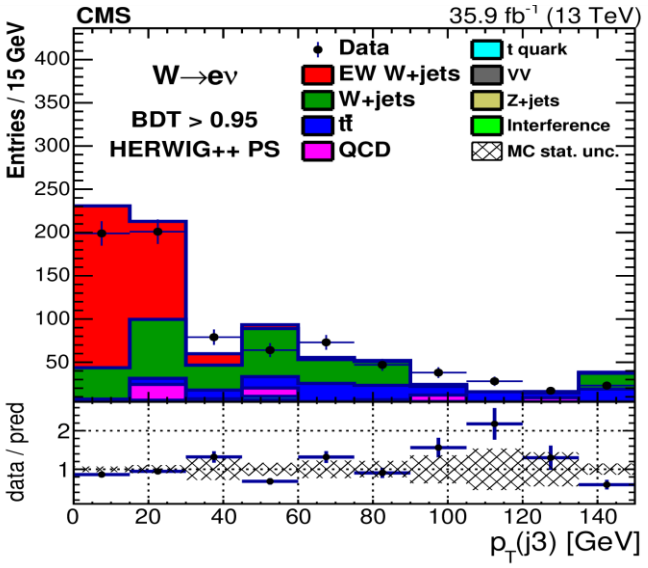
arXiv:2102.02238

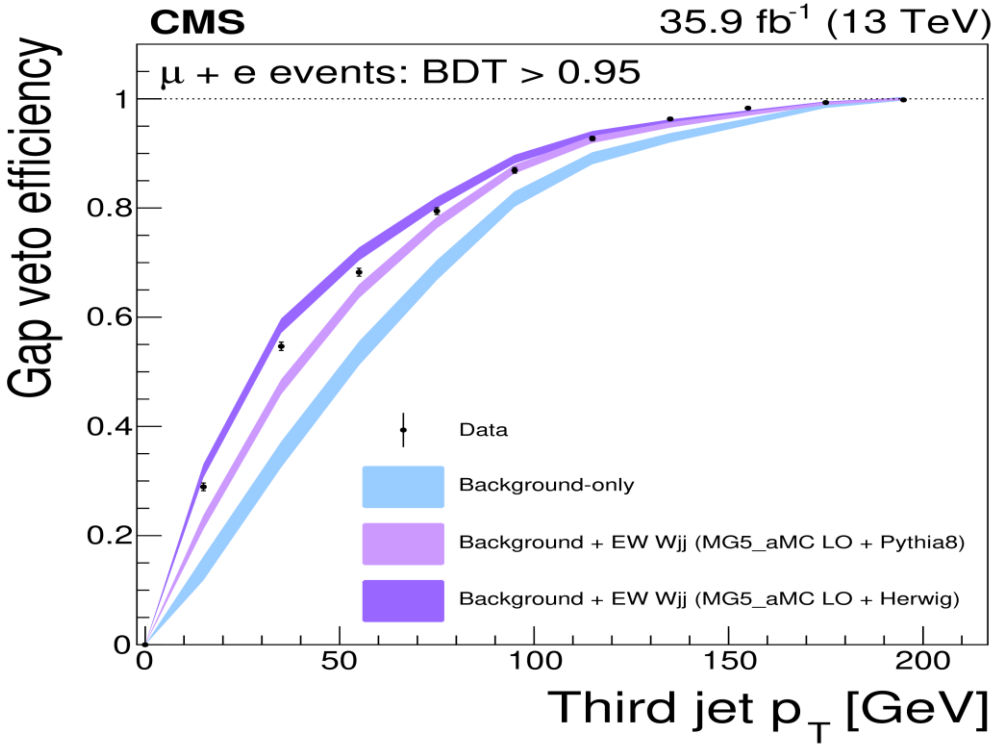
EW production of a W boson in association with two jets











- Measured p_T of the leading additional jet in W_{jj} events.
- Compared data and simulations including the signal prediction from MG5 aMC@NLO interfaced with either PYTHIA or HERWIG++ parton showering.

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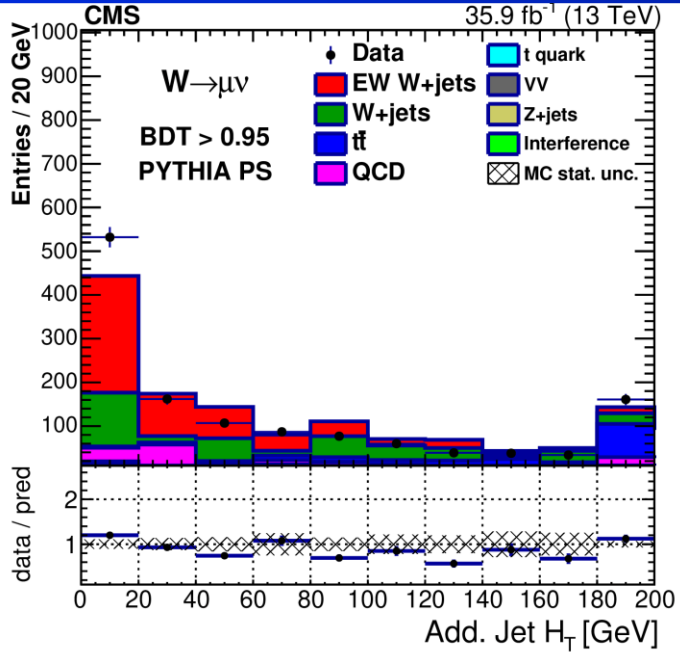
Summary

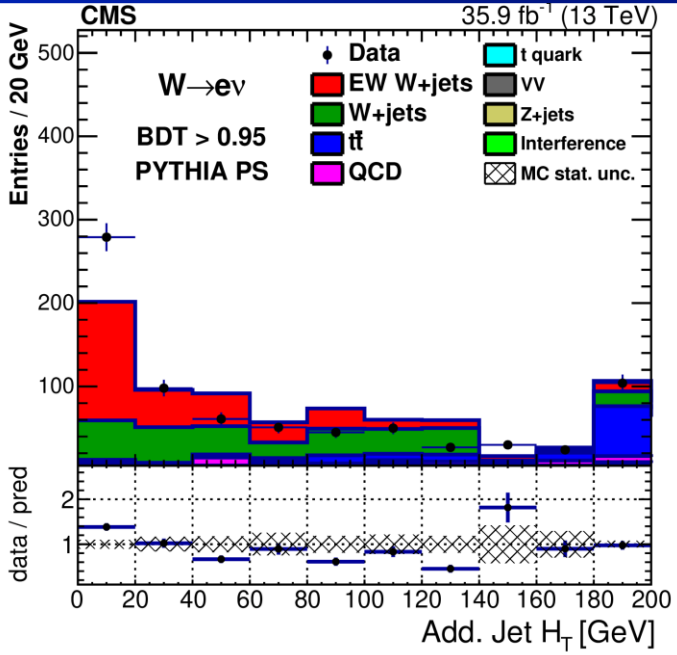
- An overview of V+jets studies from CMS is given.
- Differential distributions as functions of a broad range of kinematical observables are measured and compared to theoretical predictions.
- Comparisons are made between the unfolded data and several theory at NLO or NNLO predictions.
- Measurements provide stringent test of our understanding of the SM.
- There’s much more ongoing stay tuned for the future results.

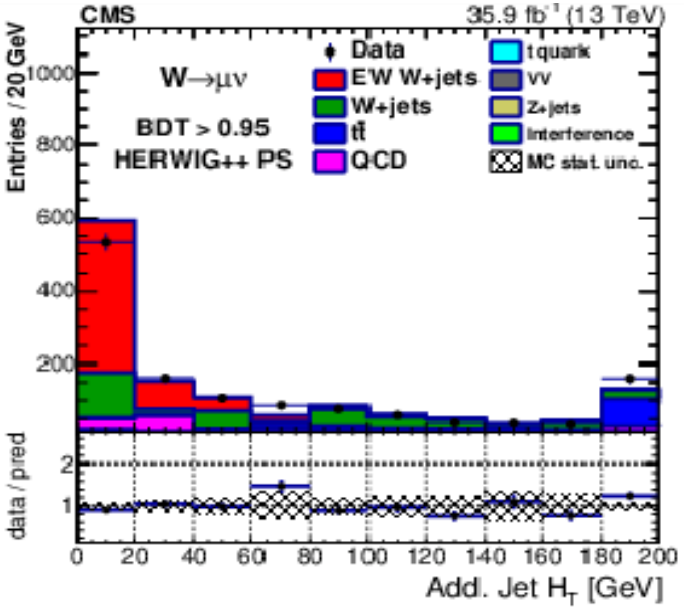
Thank you!

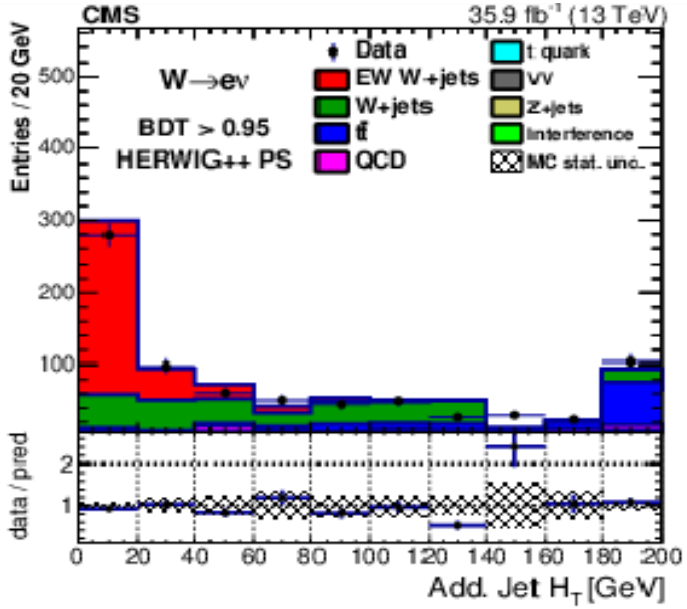
Backup Slides

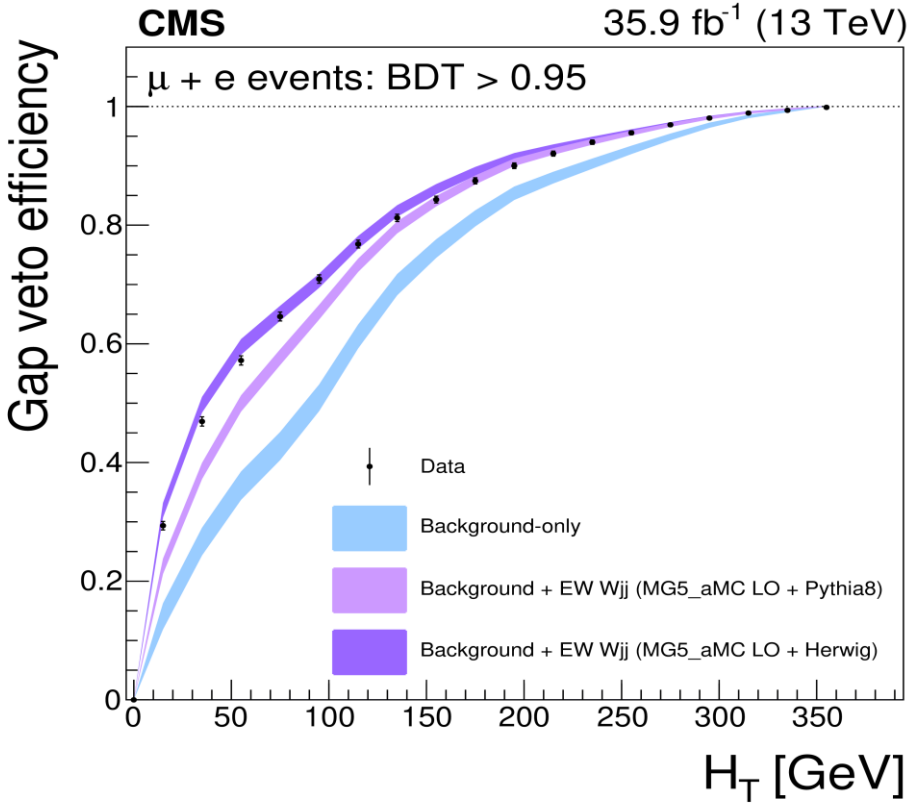
EW production of a W boson in association with two jets











- Measured H_T of all additional jets.
- Compared data and simulations including the signal prediction from MADGRAPH5 aMC@NLO interfaced with either PYTHIA or HERWIG++ parton showering.

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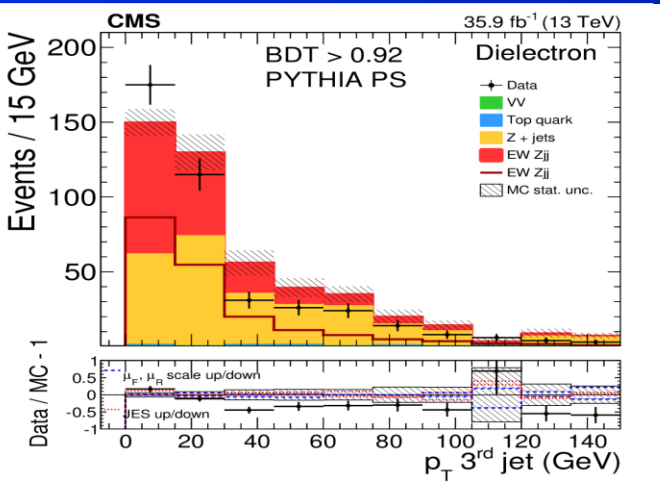
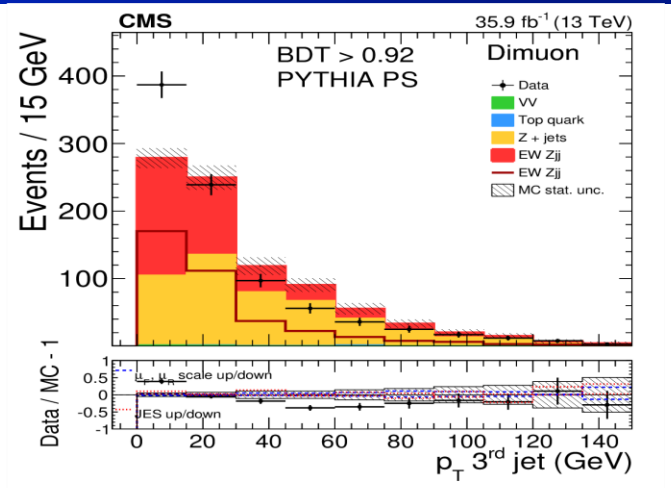
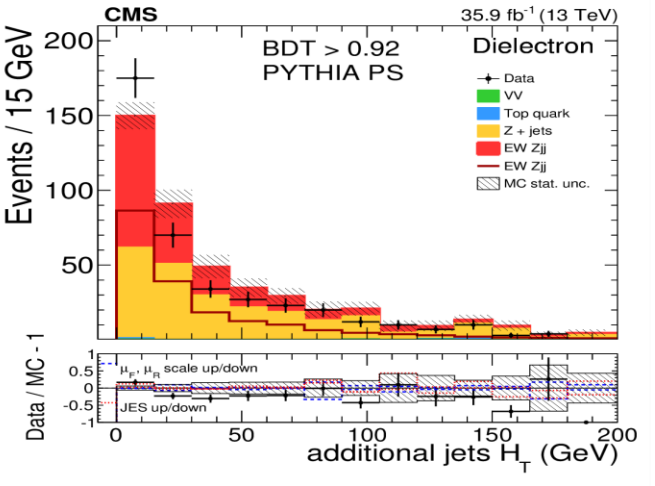
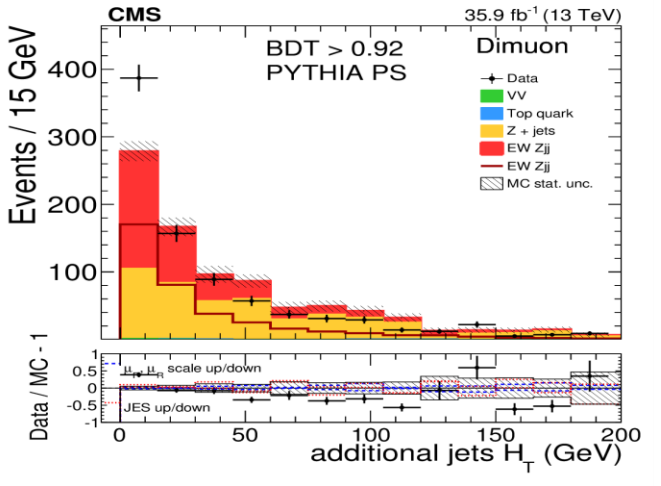
EW production of a Z boson in association with two jets

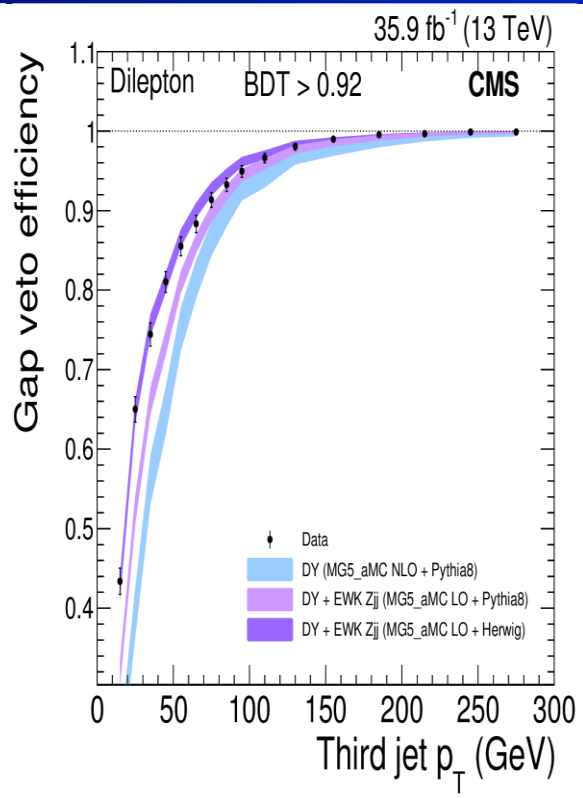


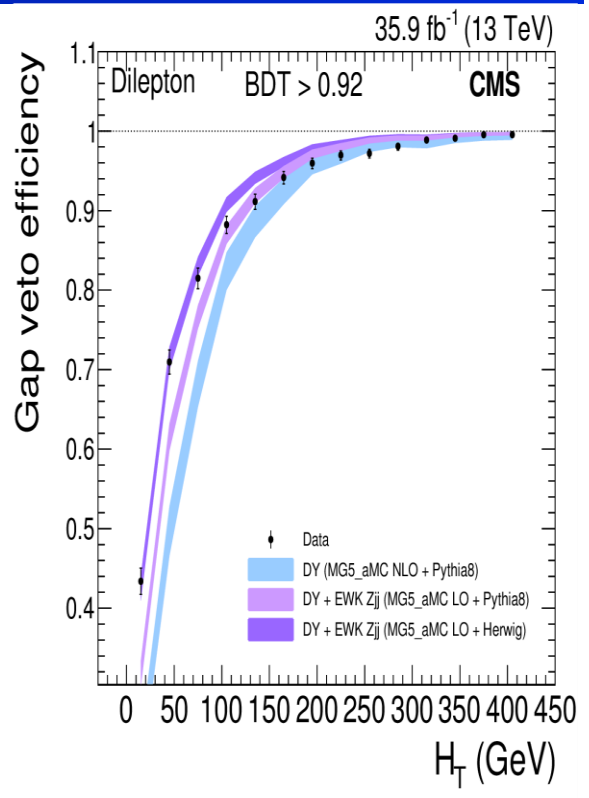






- Transverse momentum of the third highest p_T jet, and H_T of all additional jets within the pseudorapidity interval of the two tagging jets in dielectron and dimuon events with BDT > 0.92.





- Efficiency of a gap activity veto in dielectron and dimuon events with BDT > 0.92, as a function of the additional jet p_T, and of the total H_T of additional jets.

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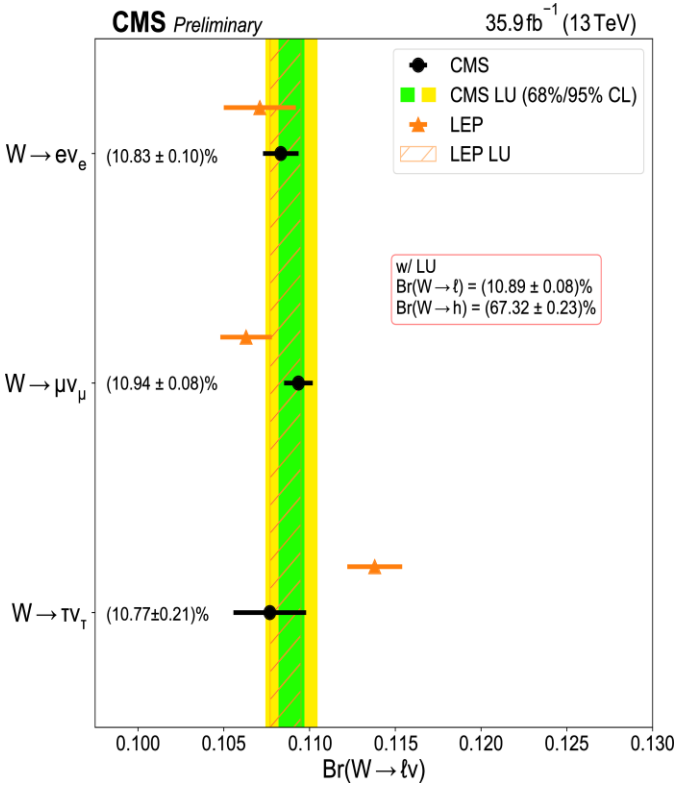
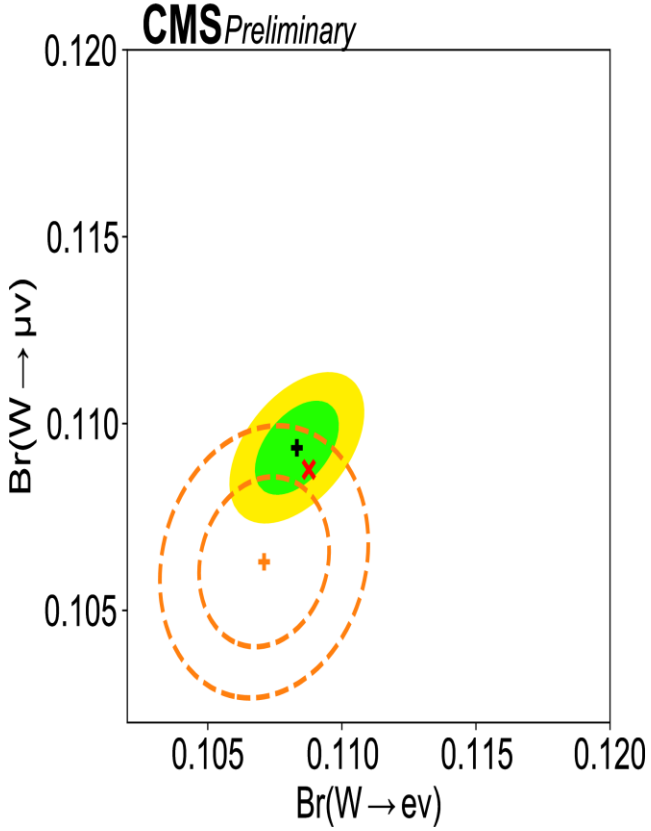
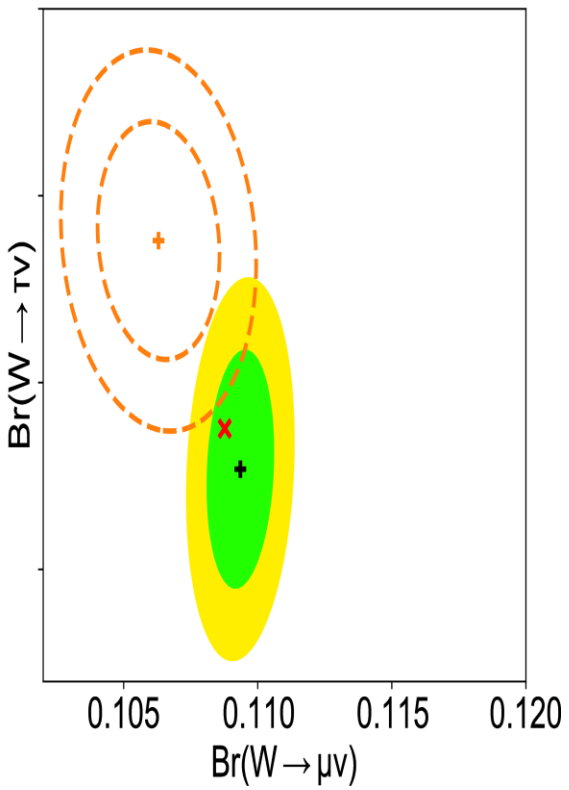
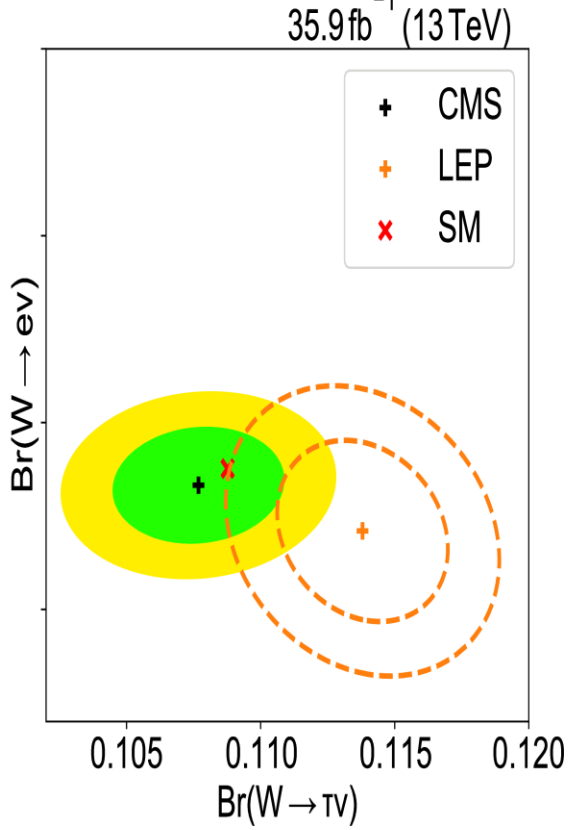
Precision measurement of the W boson decay branching fractions









	CMS	LEP
$\mathcal{B}(W \to e\overline{\nu}_e)$	$(10.83 \pm 0.01 \pm 0.10)\%$	$(10.71 \pm 0.14 \pm 0.07)\ \%$
$\mathcal{B}(W \to \mu\overline{\nu}_\mu)$	$(10.94 \pm 0.01 \pm 0.08)\%$	$(10.63 \pm 0.13 \pm 0.07)\ \%$
$\mathcal{B}(W \to \tau\overline{\nu}_\tau)$	$(10.77 \pm 0.05 \pm 0.21)\%$	$(11.38 \pm 0.17 \pm 0.11)\ \%$
$\mathcal{B}(W \to h)$	$(67.46 \pm 0.04 \pm 0.28)\%$	–
with LU		
$\mathcal{B}(W \to \ell\overline{\nu})$	$(10.89 \pm 0.01 \pm 0.08)\%$	$(10.86 \pm 0.06 \pm 0.09)\%$
$\mathcal{B}(W \to h)$	$(67.32 \pm 0.02 \pm 0.23)\%$	$(67.41 \pm 0.18 \pm 0.20)\%$

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