SM (EW and QCD) measurements in ATLAS and CMS

ATLAS EXPERIMENT

CMS

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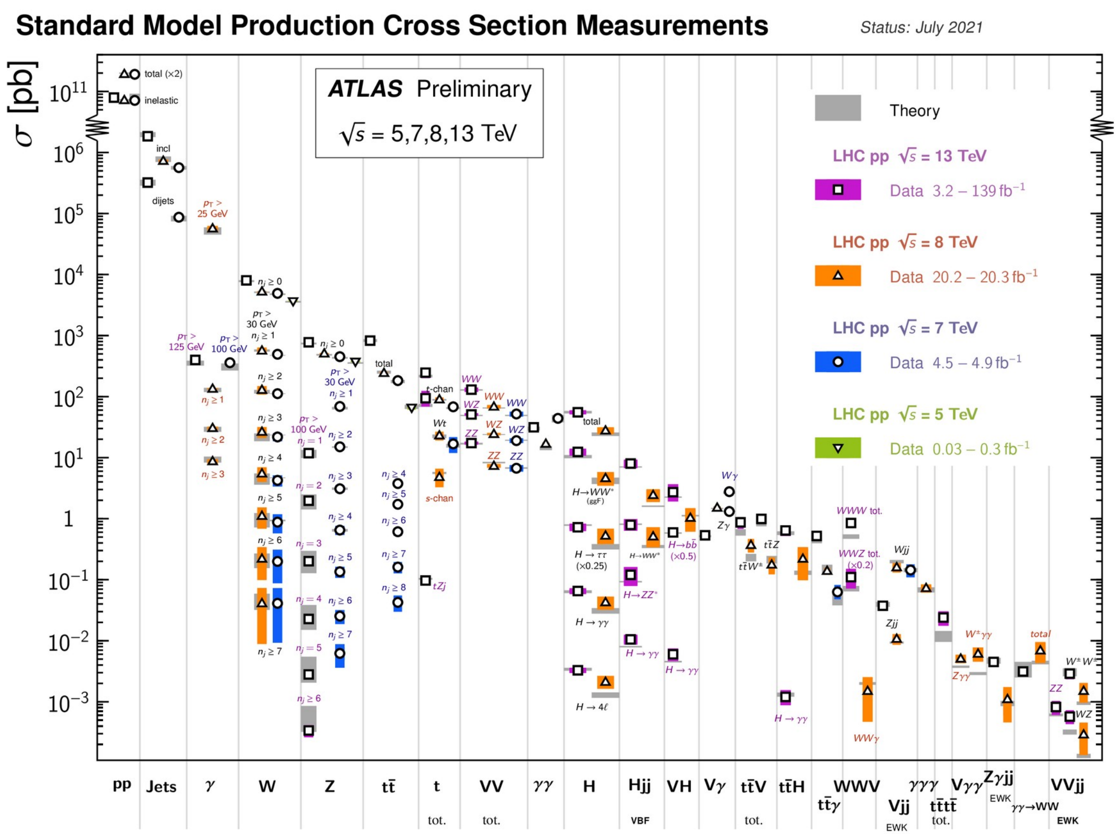
Aug. 31, 2021

on behalf of ATLAS & CMS

Outline

- Exploring processes spanning a production rate of 9 orders of magnitude: from inclusive jet production to EW production of multibosons



- Precision measurements test higher order QCD & EW calculations and constrain PDFs
- Search for effects of new physics, using the EFT formalism
- Here, will show recent results (most new from this summer).

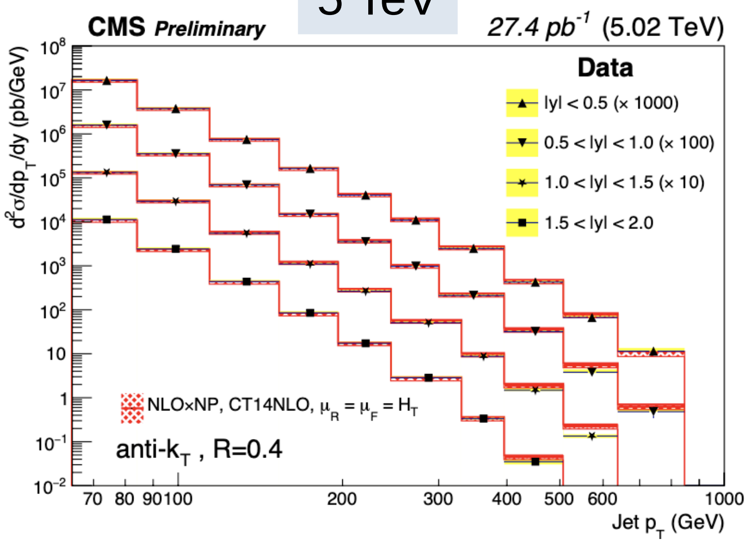
QCD

Inclusive & multi-jet production NEW

CMS-PAS-SMP-21-009 , CMS-PAS-SMP-20-011

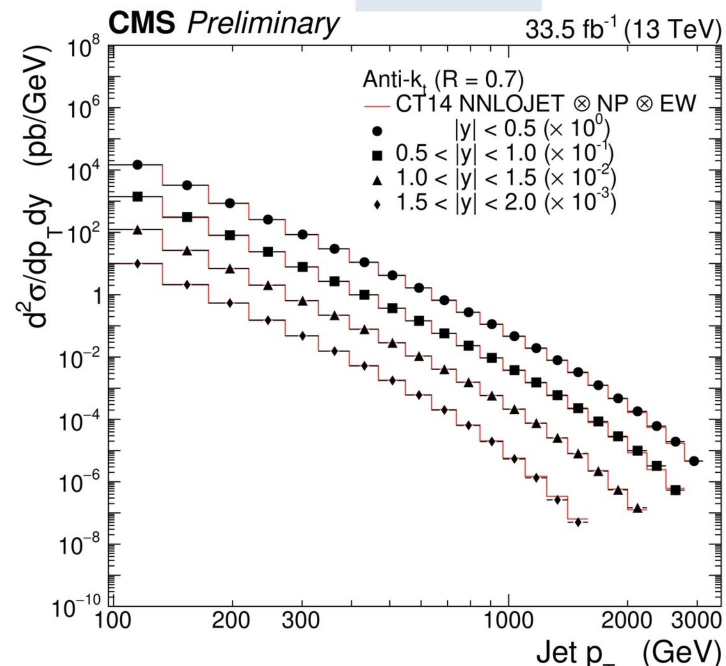
pp @ 5 TeV data (27.4 pb^{-1}) and @ 13 TeV (33.5 fb^{-1})
anti-k_T jets (R=0.4 @ 5TeV, R=0.7 @ 13TeV)

5 TeV



Inclusive jet production
Differential cross-section unfolded to particle-level jets with |y|<2

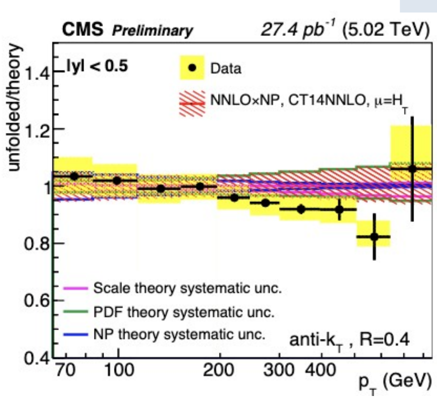
13 TeV

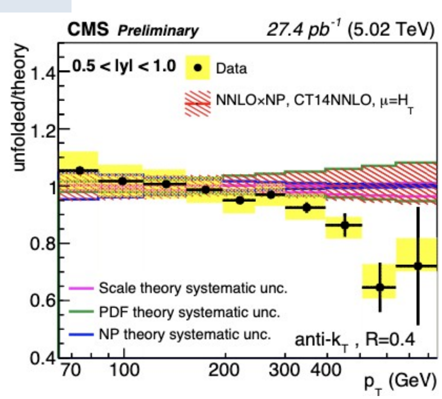


Results compared to NLO & NNLO QCD predictions μ = H_T

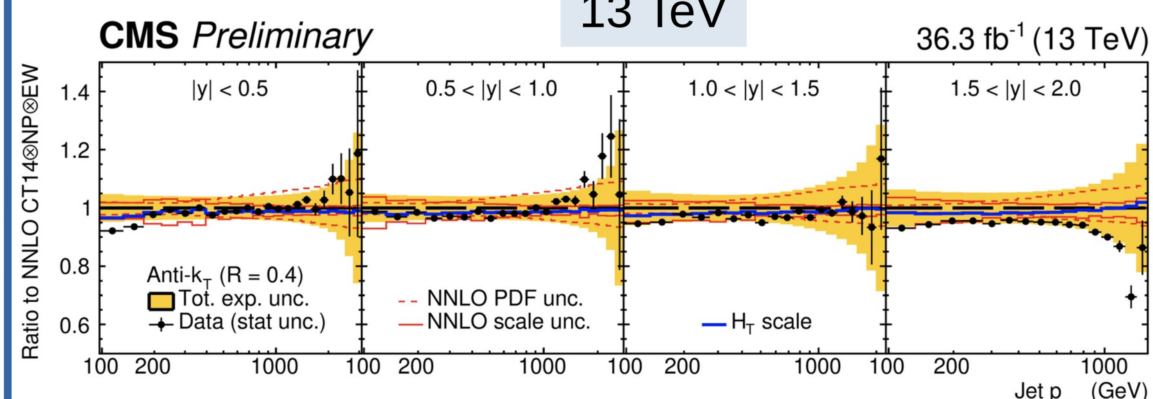
$$H_T = \sum_{\ell,jets} |p_T|$$

5 TeV





13 TeV



Inclusive & multi-jet production

NEW

CMS-PAS-SMP-21-006

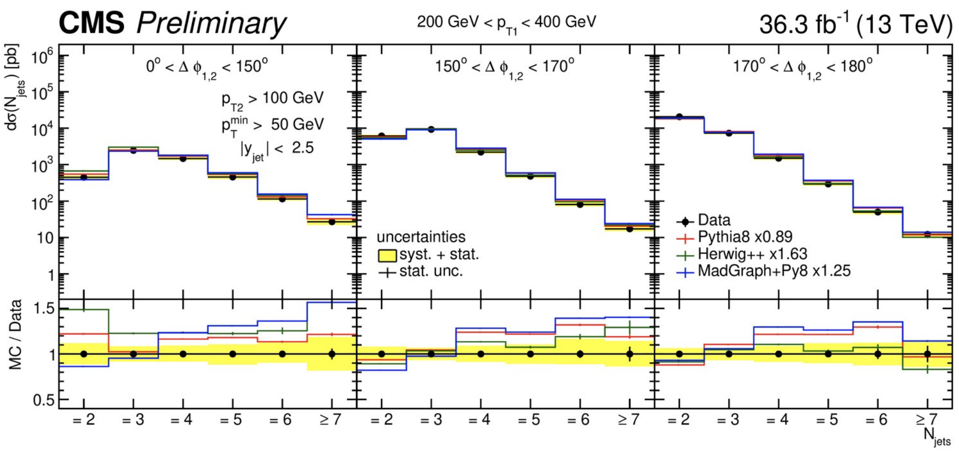
pp @ 13 TeV data (36.3 fb^{-1})

13 TeV

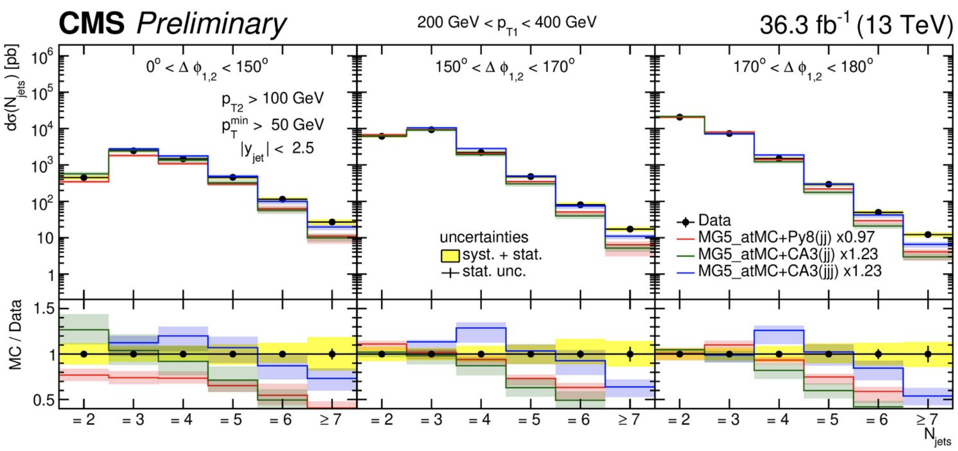
Multi-jet events (up to 7 jets)

Jet p_T > 200 , 100, 50 GeV for the rest & |y|<2.5

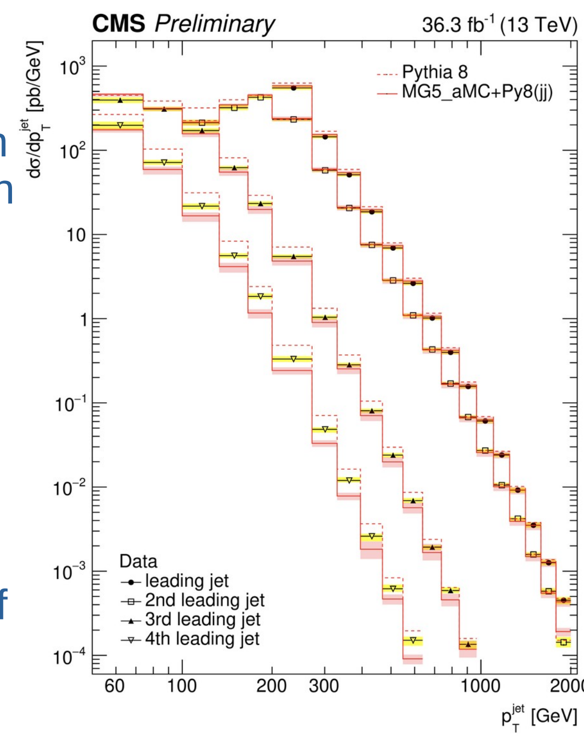
Differential distributions: N_{jets}, p_{T1}, $\Delta\varphi_{1,2}$



Data compared to LO predictions normalized to measured inclusive dijet cross section using scaling factors shown



Data compared to NLO dijet predictions of MG5_aMC+Py8 (jj) & MG5_aMC+CA3 (jj), and NLO three-jet prediction of MG5_aMC+CA3 (jjj), normalized to measured inclusive dijet cross section using scaling factors shown



In either case for the Parton Shower description (Py8 or CA3), lower jet multiplicities are OK, but prediction for high jet multiplicities are low.

**CA3 : Parton Branching (PB) transverse momentum dependent (TMD) parton densities and PB-TMD initial state parton shower*

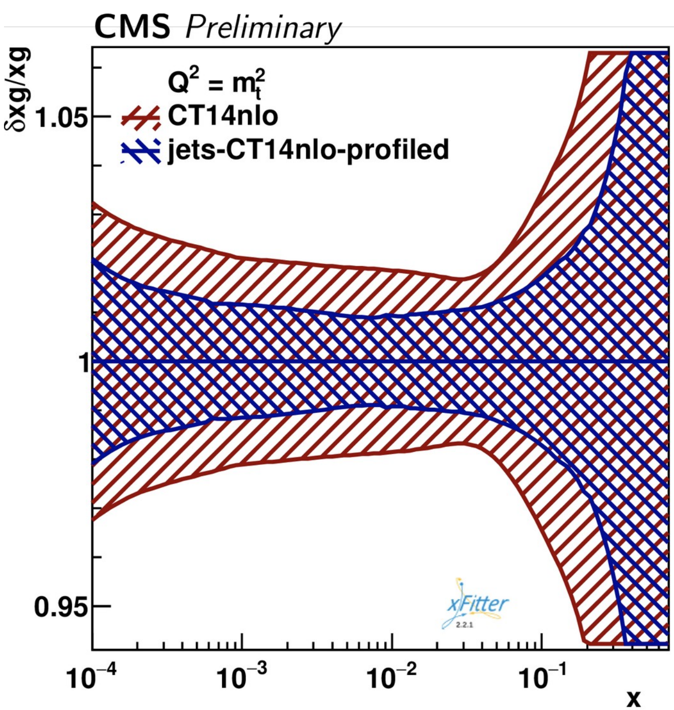
Inclusive & multi-jet production NEW

CMS-PAS-SMP-20-011

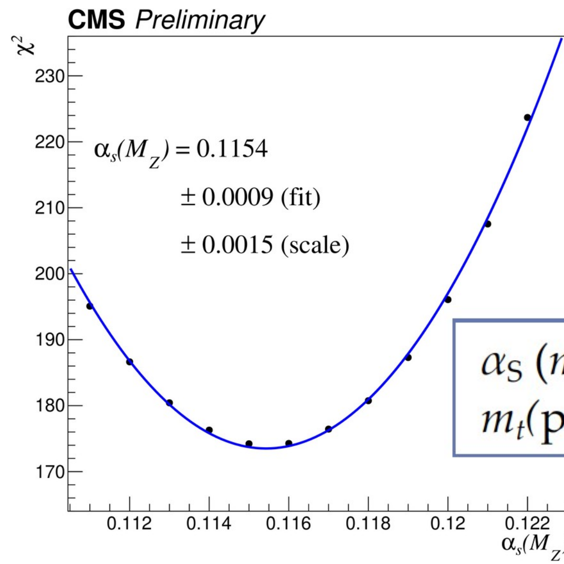
pp @ 13 TeV (33.5 fb^{-1})

CMS jet and top cross sections + HERA DIS measurements →

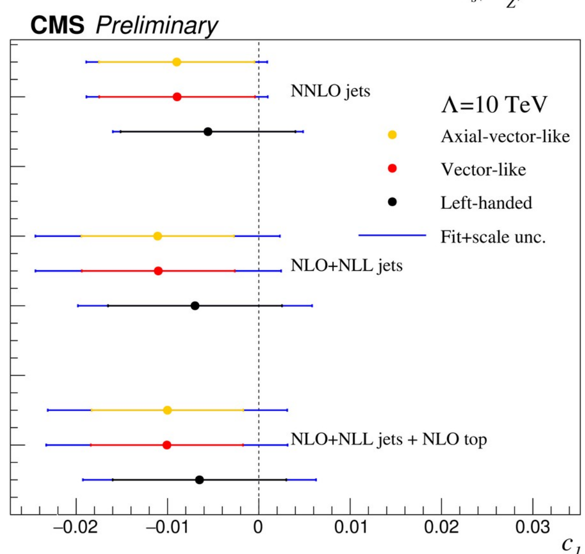
Determine: PDFs, a_s, m_{top}, limits on Wilson coefficients for quark Contact Interactions (CI)



Substantial improvement on knowledge of gluon PDFs



$\alpha_S(m_Z) = 0.1177 \pm 0.0014\text{(fit)} \pm 0.0022\text{(mod/par)}$
$m_t\text{(pole)} = 170.2 \pm 0.6\text{(fit)} \pm 0.1\text{(mod/par)}$ GeV.

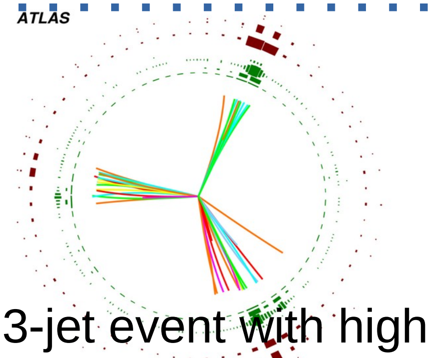


➔Derived 68%CL on EFT CI models WC consistent with zero

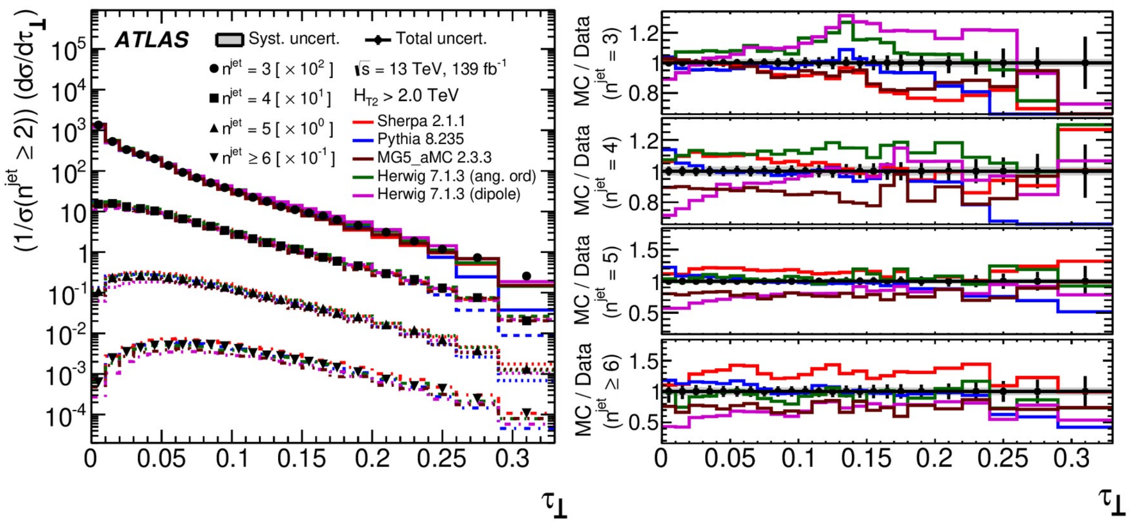
Event shapes JHEP 01 (2021) 188

pp @ 13 TeV data 139 fb^{-1}

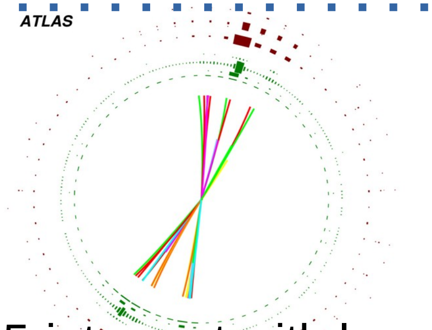
Measurements in various event-shape variables,
(i.e., transverse thrust, $\tau_\perp$, Sphericity, S, and Aplanarity, A)
in bins of jet multiplicity (n^{jet}) & in different ranges of H_{T2} (= Σ |pT| of 2 leading jets)



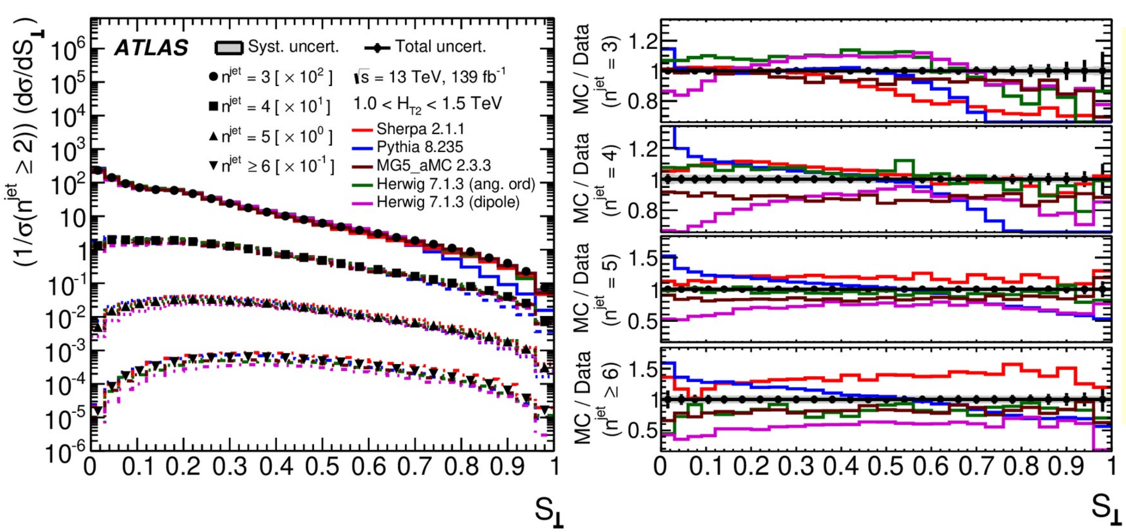
3-jet event with high Thrust & Sphericity



Measurements compared to MCs with LO & NLO ME matched to PS at LL accuracy



5-jet event with low Thrust & Sphericity



At low n^{jet}:
shape discrepancies

At high n^{jet}:
Better shapes, but discrepancies in normalisation.

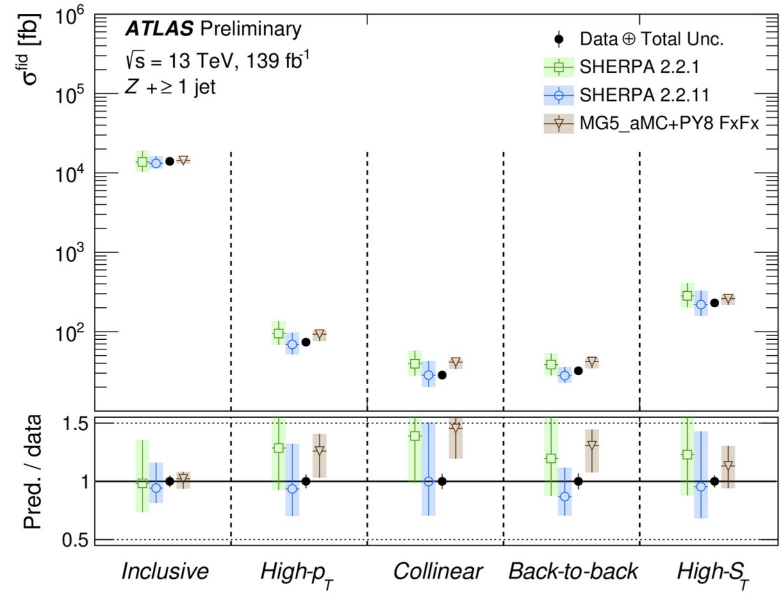
Z + high p_T jets

ATLAS-CONF-2021-033

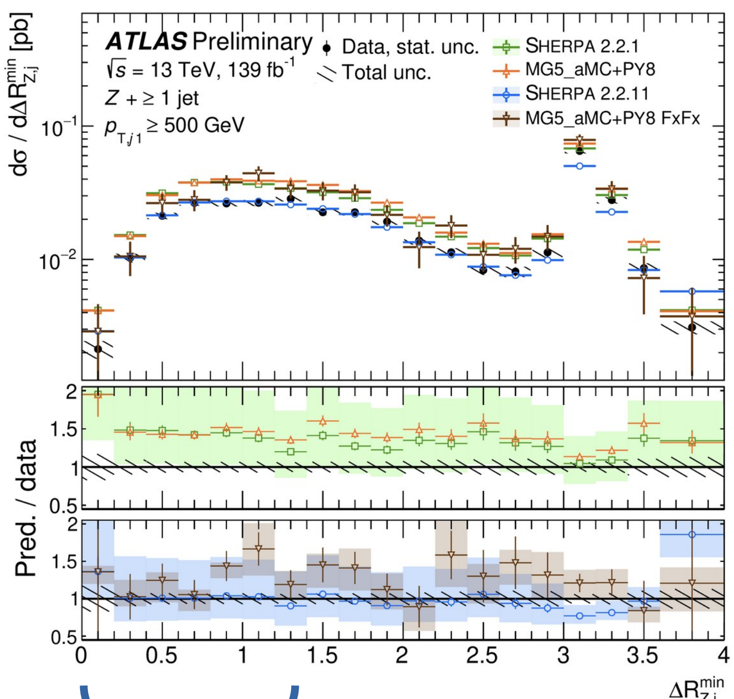
NEW

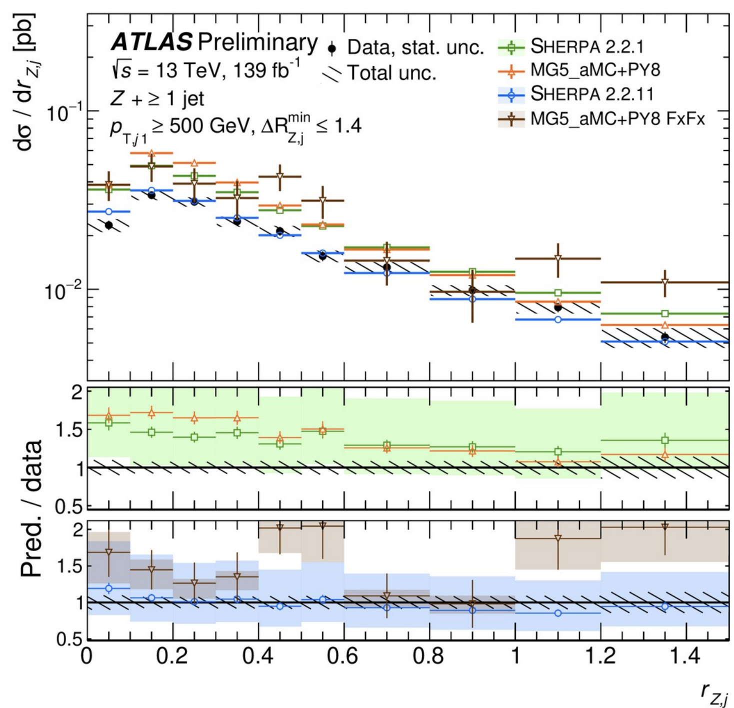
13 TeV data (139 fb^{-1}). Combined ee & μμ channels

Inclusive :	Jet p_T > 100 GeV & |y|<2.5
High p_T ("Collinear" & "back-to-back"):	Jet p_T > 500 GeV
High-S_T :	S_T > 600 GeV

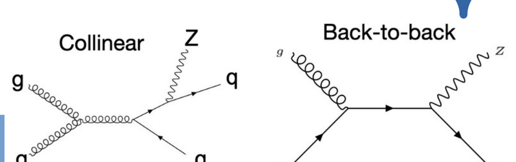


Differential cross section measurements in all regions: several variables





$r_{Z,j} \rightarrow \frac{p_T(Z)}{p_T(\text{jet})}$



Best agreement with Sherpa 2.2.11 ((NLO up to 2p and LO up to 5p, NLO EW corr, improved matching)

Overestimates from MG5_aMC Sherpa 2.2.1

Z + jets

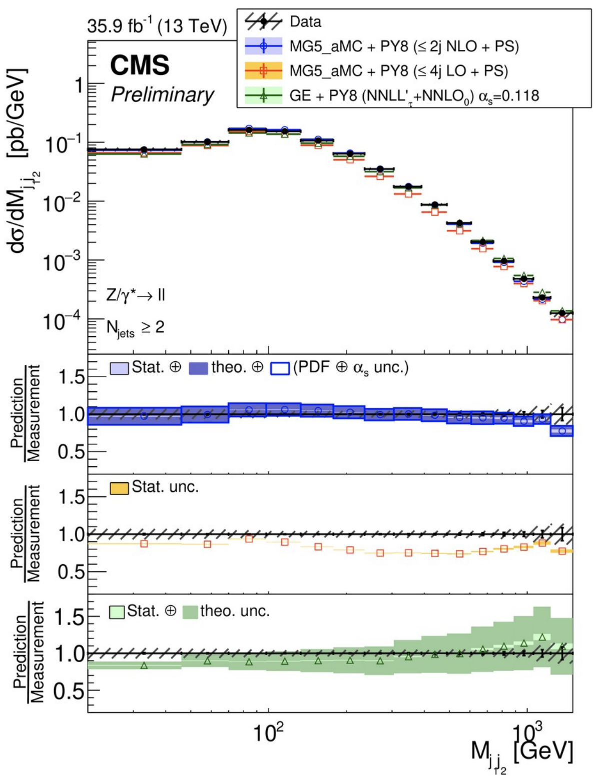
NEW

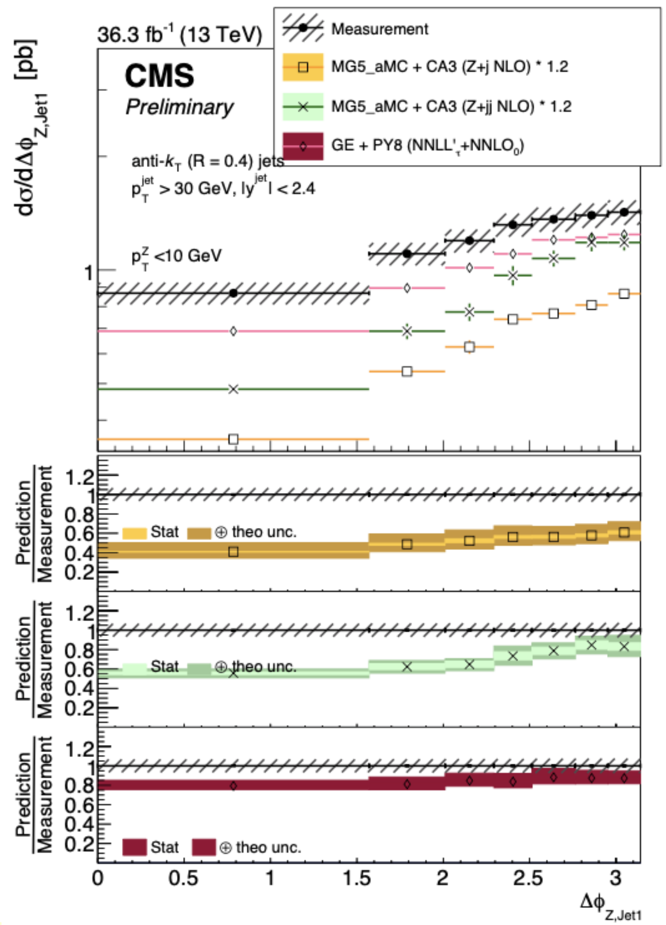
CMS-PAS-SMP-19-009 , CMS-PAS-SMP-21-003

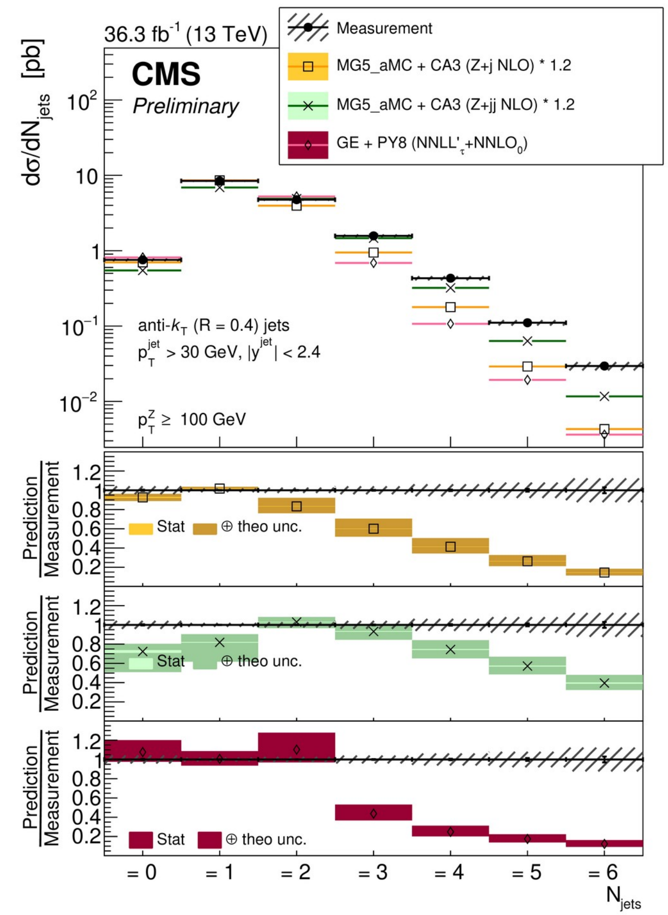
pp @ 13 TeV data (35.9 fb^{-1})
($Z \rightarrow ee/\mu\mu$ combined, leptons from SMP-17-010)
Results unfolded to particle-level jet p_T > 30 GeV & |y|<2.5

Differential distributions N_{jets}, $\Delta\varphi_{(Z,1;1,2)}$
for $p_T(Z)$ {< 10, 30-50, >100 GeV}

Compared to:
* LO & NLO + PS (MG5_aMC) [no MPI]
* NNLO with NNLL'$_\tau$ resummation (GENEVA) [with MPI]







In most regions, best descriptions is from Geneva NNLO using matrix elements at NNLO for Z production, supplemented with resummation, parton shower and MPI from PYTHIA 8
Problems for Njets >=3 *[TB-TDM (CA3) also tried, scaled by 1.2]*

V (=W,Z) + jets

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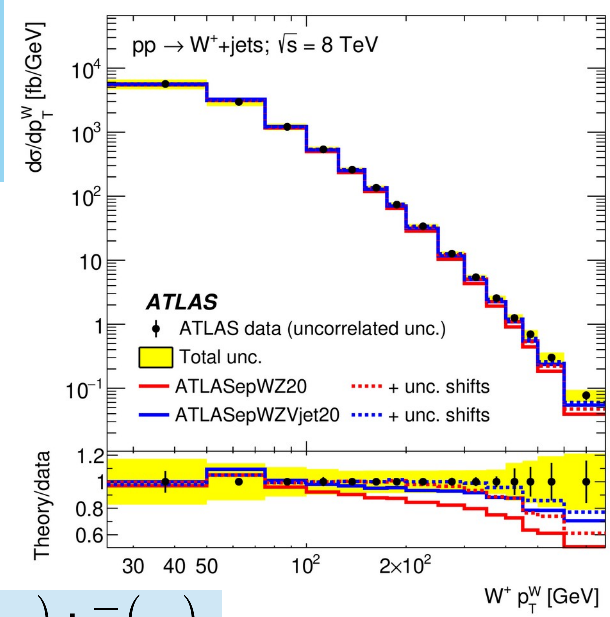
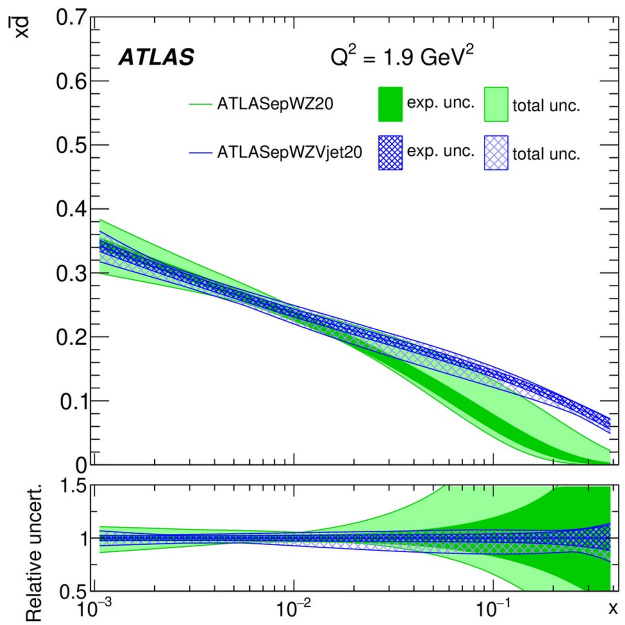


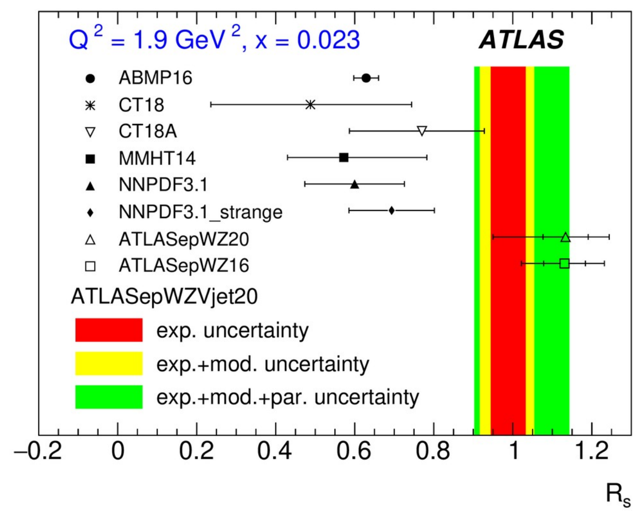
pp @ 7 & 8 TeV data (4.6 fb^{-1} & ~20 fb^{-1}).

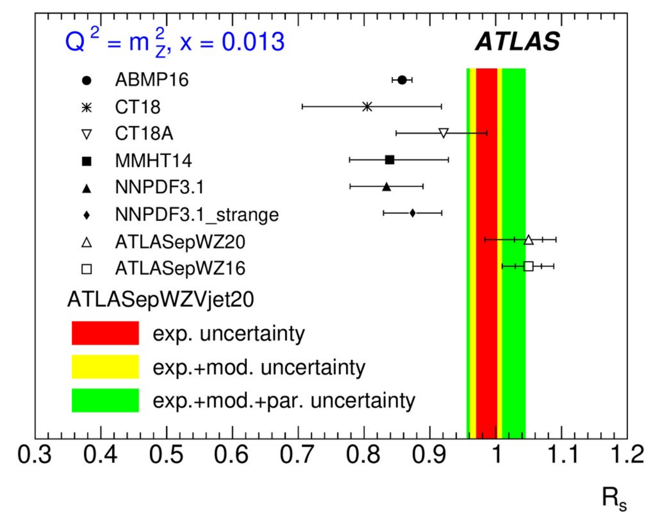
New set of PDFs produced: ATLASepWZVjet20 (included ATLAS V+jets@8TeV together with ATLAS inclusive W & Z data @ 7 TeV and HERA DIS data)
Analysis at NNLO in pQCD.

[ATLASepWZ20 same as ATLASepWZVjet20, but without the V+jets data]

$$R_s(x) = \frac{s(x)+\bar{s}(x)}{\bar{u}(x)+\bar{d}(x)}$$





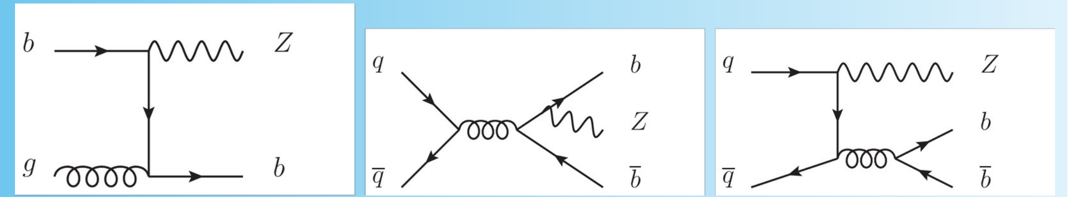


Improved determination of the sea-quark densities at high Bjorken x.

Confirms a strange-quark density similar in size to the up- and down-sea-quark densities in the range x≲0.02 (as found by previous ATLAS analyses which have produced the PDFs ATLASepWZ16).

Z + b jets NEW

CMS-PAS-SMP-20-015



pp @ 13 TeV data, 137 fb^{-1} ($Z \rightarrow$ ee/μμ combined)

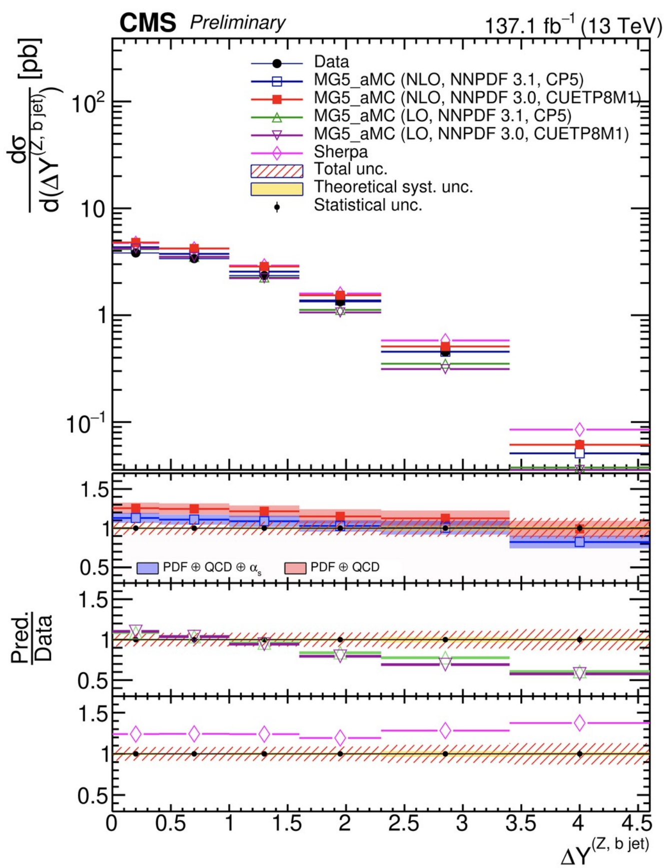
Results unfolded to particle-level b-jet p_T > 30 GeV & |η|<2.4

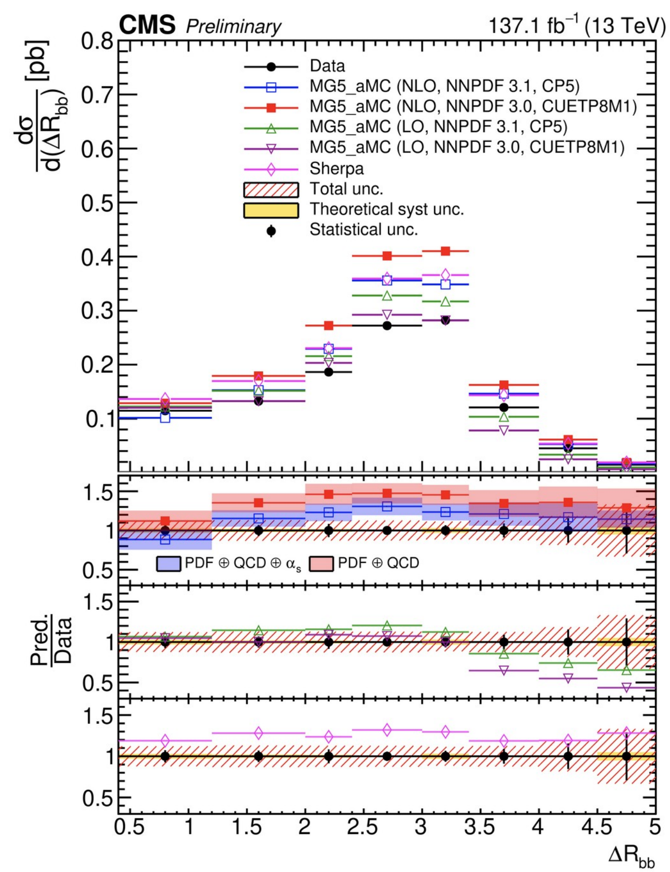
$$\sigma(pp \rightarrow Z + \geqslant 1b) = 6.52 \pm 0.04(stat) \pm 0.40(syst) \pm 0.14(theo)\ pb$$

$$\sigma(pp \rightarrow Z + \geqslant 2b) = 0.65 \pm 0.03(stat) \pm 0.07(syst) \pm 0.02(theo)\ pb$$

$$Ratio(\geqslant 2b / \geqslant 1b) = 0.100 \pm 0.005(stat) \pm 0.007(syst) \pm 0.003(theo)$$

Compared to:
* LO & NLO + PS (MG5_aMC)
* Sherpa v.2.2





* Integrated x-section better described by the LO MG5 aMC but overestimated by NLO MG5 aMC and SHERPA predictions

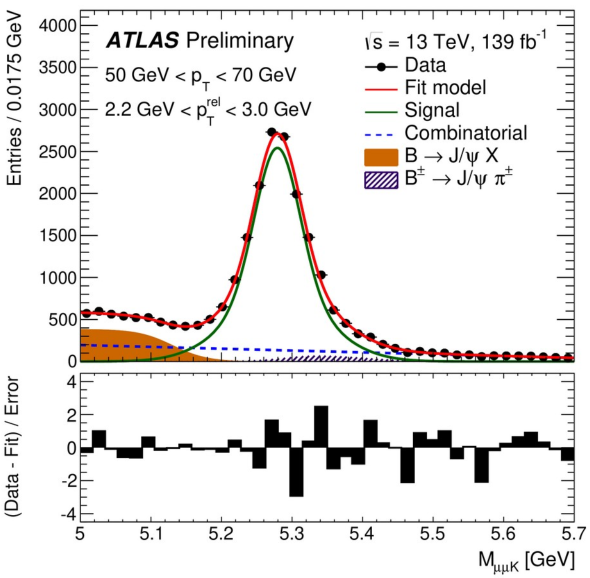
* LO MG5_aMC better in shape than the NLO

* Sherpa overestimated (~ x 1.2) the integrated, but described shapes well

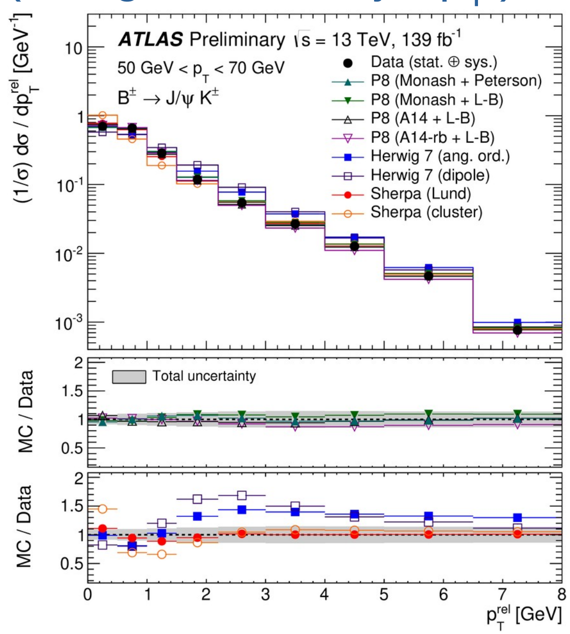
b fragmentation STDM-2018-52

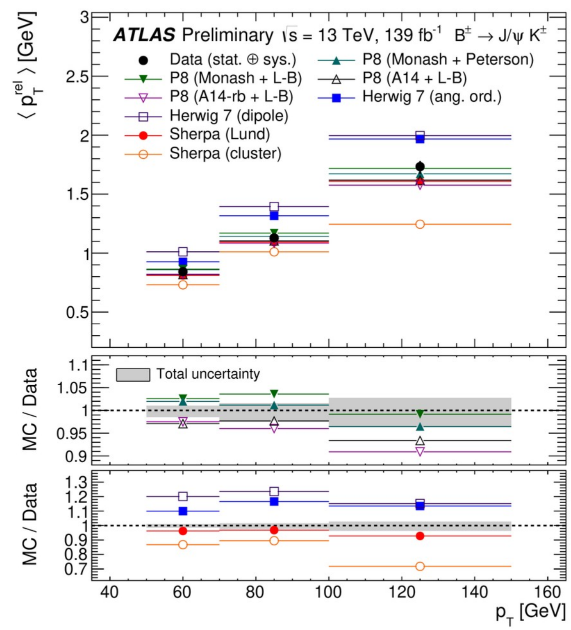
NEW

pp @ 13 TeV data (139 fb^{-1})
B → J/ψ K in jets



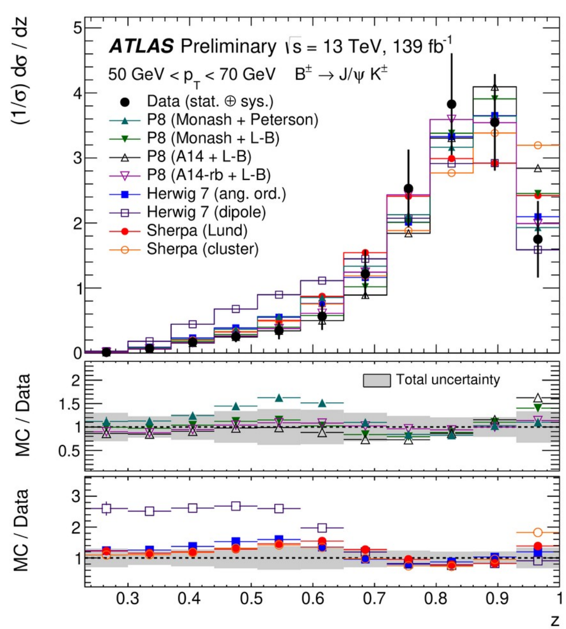
B momentum profiles relative to the jet-axis
(in regions of the jet p_T)

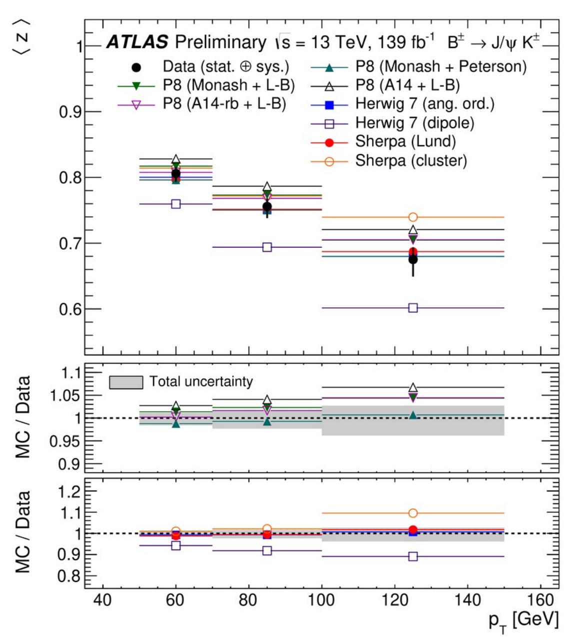




Transverse profile, p_T^{rel}

Longitudinal profile, z





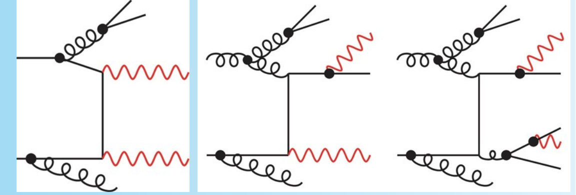
Pythia fragmentation models tend to give a decent description of the data.

HERWIG 7 (dipole PS) is visibly off in different regions.

Di-photon (γγ) production

arXiv:2107.09330

NEW



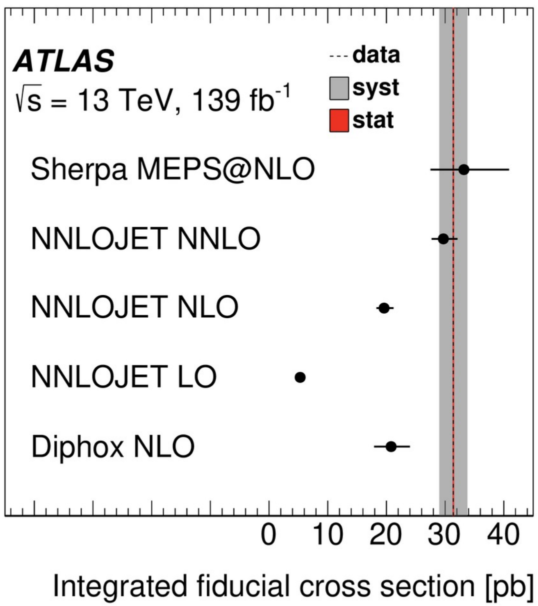
pp @ 13 TeV data (139 fb^{-1})

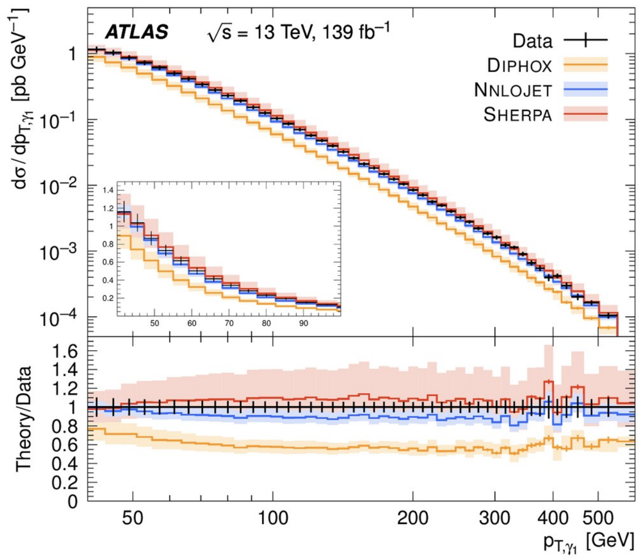
Results to particle level.

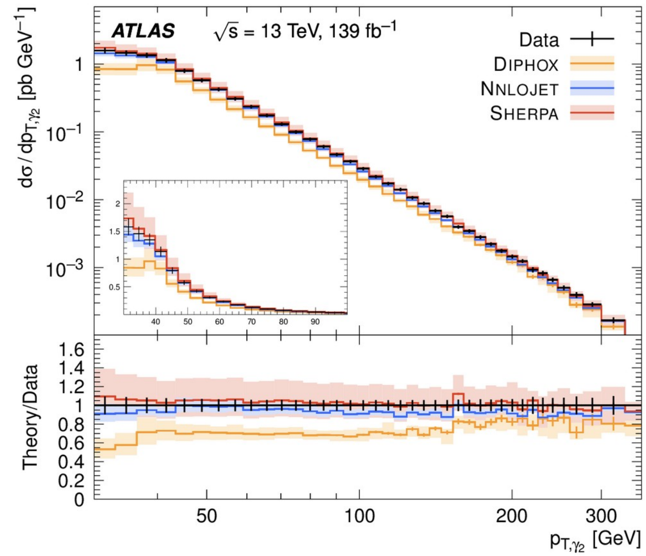
Photon p_T > 40, 30 GeV & $|\eta|$<2.37 & DR(γ,γ) > 0.4

Differential distributions in agreement with Sherpa MEPS and Fixed Order NNLO

$$\sigma_{\gamma\gamma} = 31.4 \pm 0.1\ (\text{stat.}) \pm 2.4\ (\text{syst.})\ \text{pb}$$

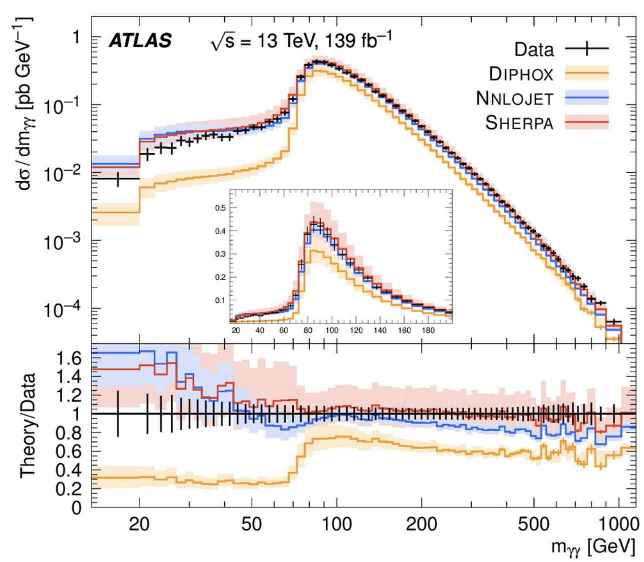


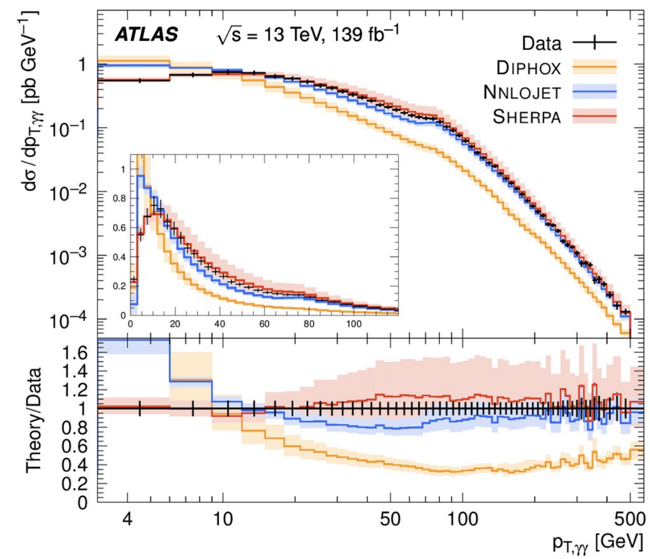




Signal purity ~ 60% (p_T dependent)

Main challenge and uncertainty from non-prompt photons; estimated with data-driven methods





Triple J/ψ production

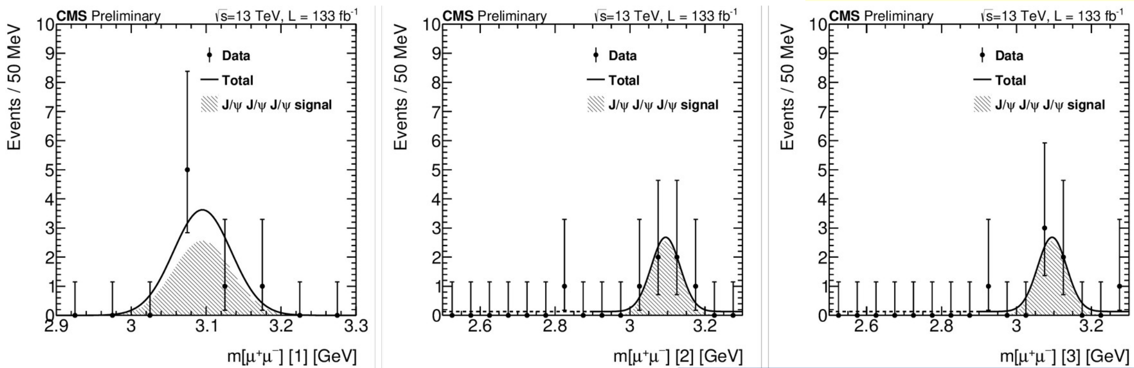
NEW

CMS-PAS-BPH-21-004

pp @ 13 TeV data (133 fb^{-1})

6μ consistent from 3 J/ψ

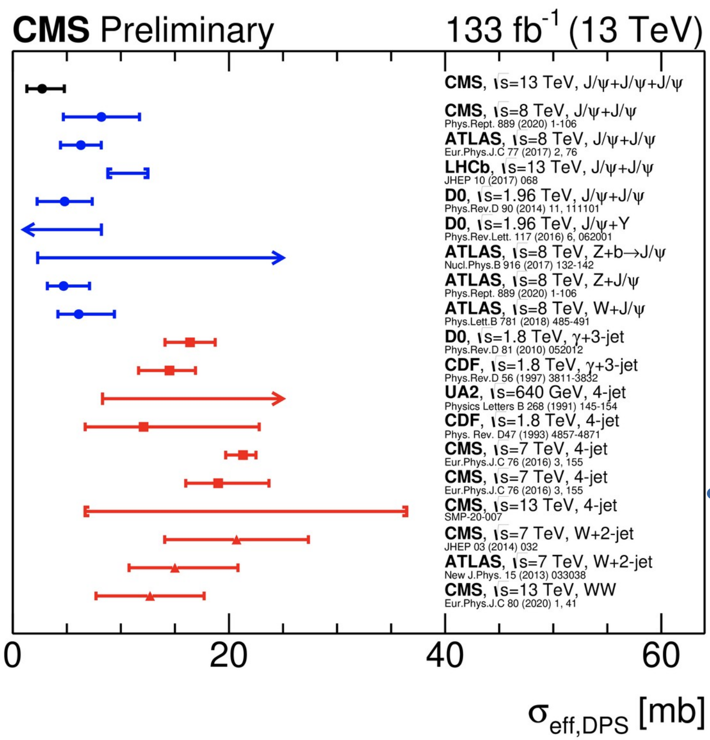
Sensitive to
Triple Parton Scattering (TPS)!



6 events in data.

Fit yields: $N_{events} = 5^{+2.6}_{-1.9}$

$$\sigma_{\rm TPS}^{pp\to\psi_1\,\psi_2\,\psi_3+X} = \left(\frac{m}{3!}\right)\frac{\sigma_{\rm SPS}^{pp\to\psi_1+X}\,\sigma_{\rm SPS}^{pp\to\psi_2+X}\,\sigma_{\rm SPS}^{pp\to\psi_3+X}}{\sigma^2_{\rm eff,TPS}}$$



Measured 3 J/ψ cross-section and extracted $\sigma_{\rm eff,DPS}$

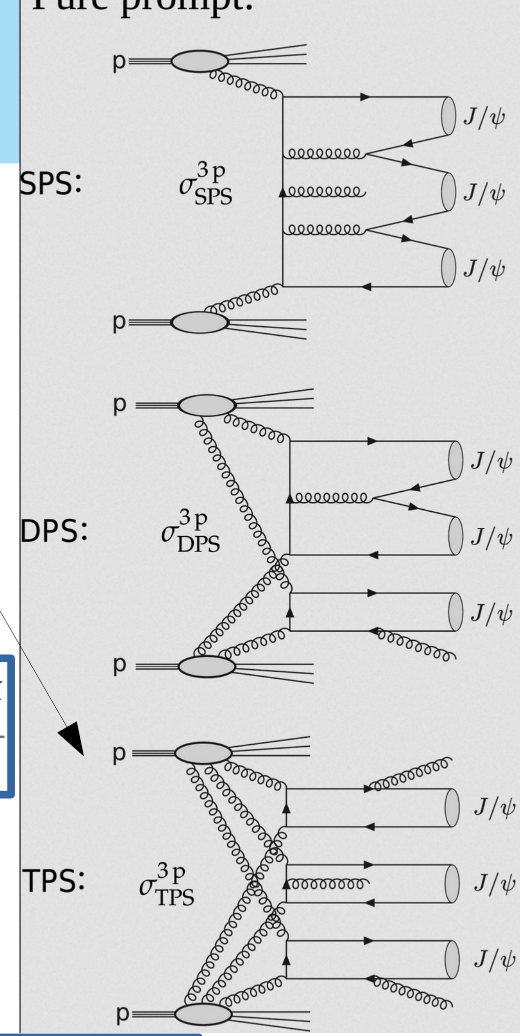
$$\sigma_{pp\to J/\psi\,J/\psi\,J/\psi} = 272^{+141}_{-104}(stat) \pm 17(syst.)\ fb$$

$$\sigma_{eff,DPS} = 2.7^{+1.4}_{-1.0}(\exp.)^{+1.5}_{-1.0}(theo.)\ mb$$

* $\sigma_{\rm eff,DPS}$

- consistent with other quarkonium measurements (3-10 mb)
- smaller than the values extracted from other final states

Pure prompt:



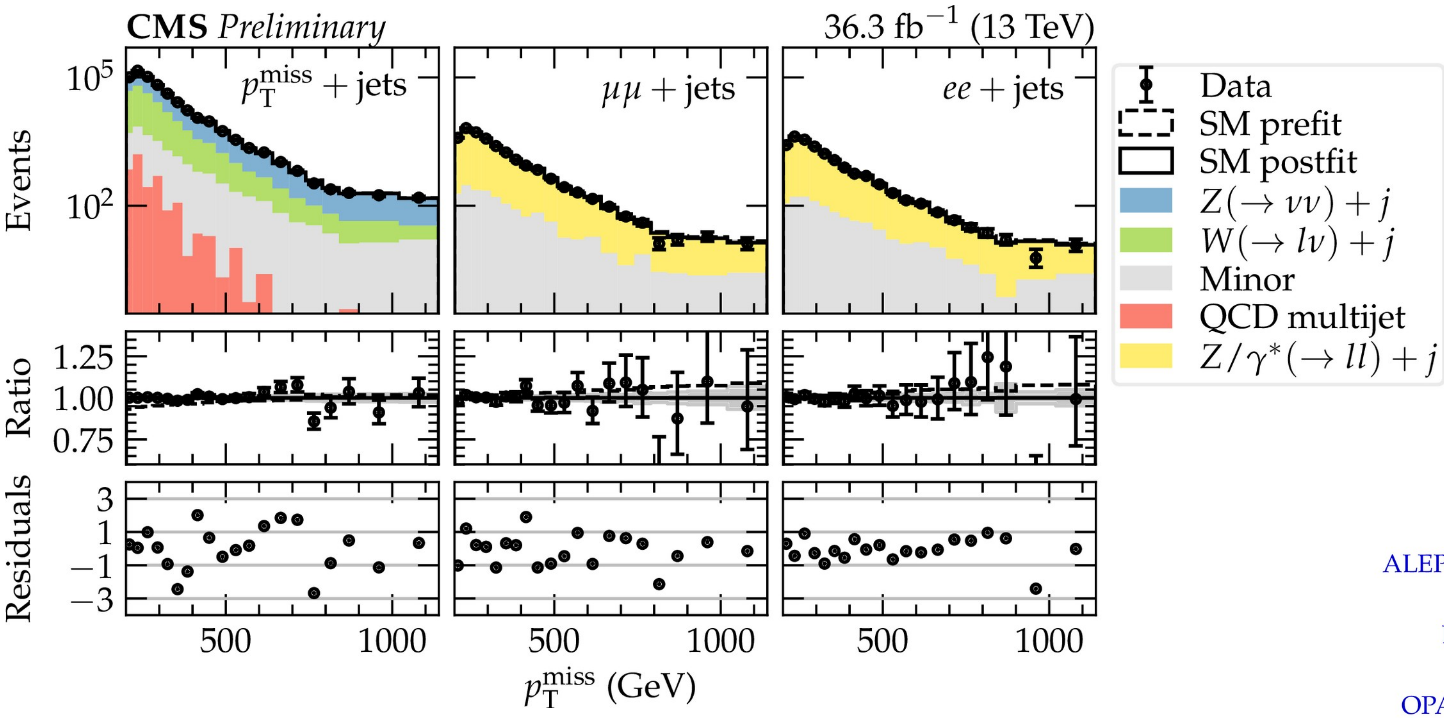
EW

Width of Z → invisible

CMS-PAS-SMP-18-014 **NEW**

pp @ 13 TeV data (36.3 fb^{-1})

Simultaneous fit for Z → invisible (Missing Energy), ee, μμ channels



Invisible:

p_T^{miss} > 200 GeV

excluding Z → ee/μμ

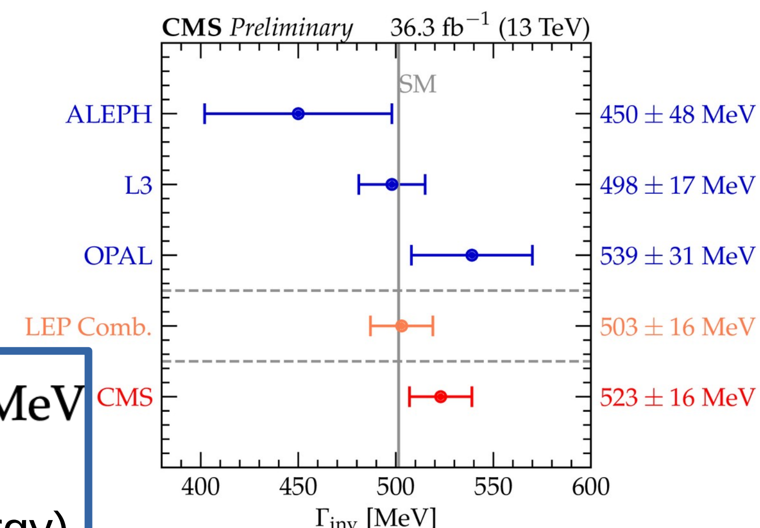
W+jets and QCD estimated in dedicated control regions

Measured:

$$\frac{\sigma(Z+jets)B(Z\to\nu\nu)}{\sigma(Z+jets)B(Z\to\ell\ell)} = \frac{\Gamma(Z\to\nu\nu)}{\Gamma(Z\to\ell\ell)}$$

Γ_{inv} =523±3(stat)±16(syst) MeV

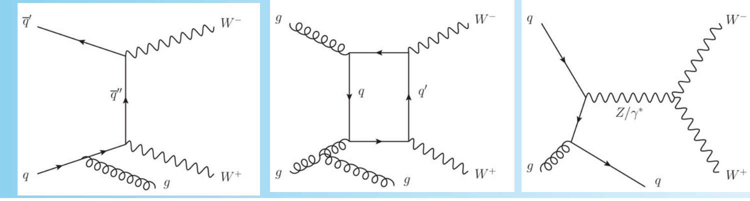
(major uncertainties from: lepton efficiency & jet energy)



The first measurement of the Z invisible width at a hadron collider; the single most precise direct measurement in the world, competitive with the combined direct measurement from LEP

WW + >=1 jet production

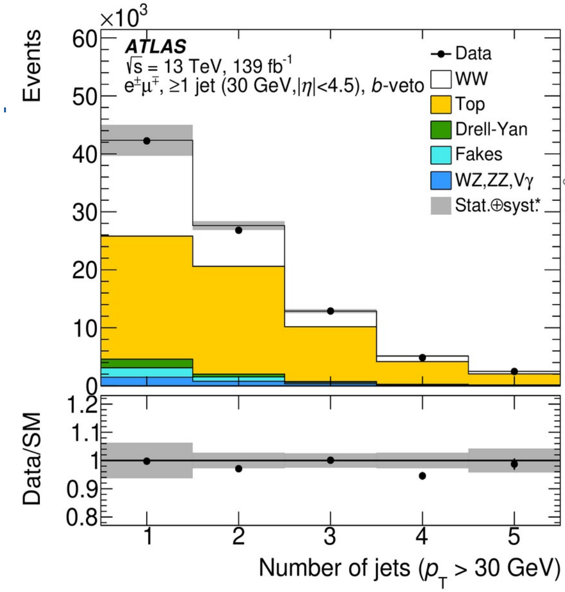
JHEP 06 (2021) 003



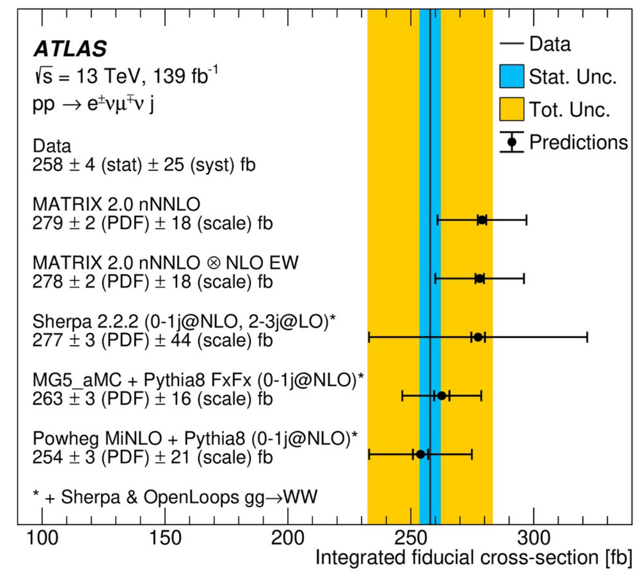
pp @ 13 TeV data (139 fb^{-1})

xsec vs.
p_T(lepton), m_T(WW), p_T(jets), N_{jets}, etc.

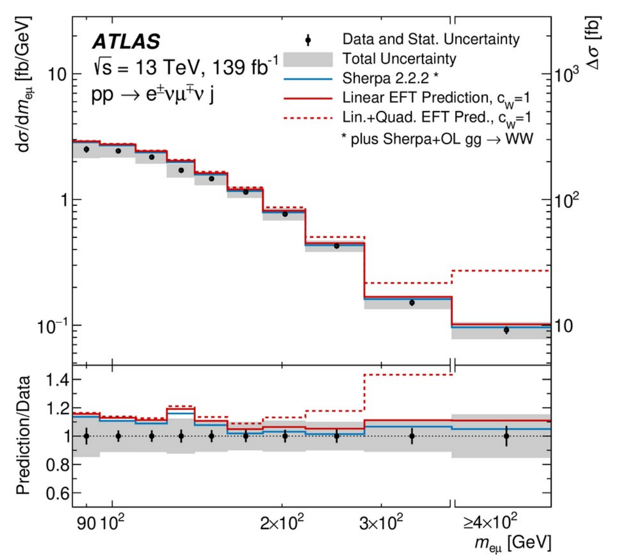
Fiducial selection requirements		
p_T^{ℓ}	>	27 GeV
$\lvert\eta^{\ell}\rvert$	<	2.5
$m_{e\mu}$	>	85 GeV
p_T^{j}	>	30 GeV
$\lvert y^{j}\rvert$	<	4.5

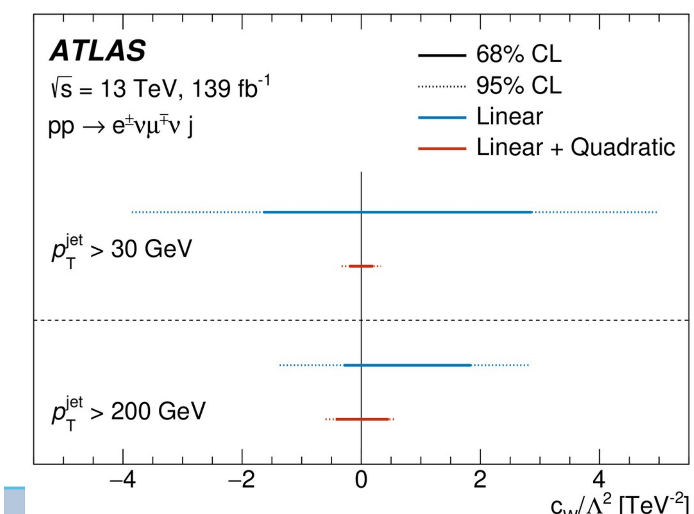


Test of pQCD and EW theory
Sensitive to EW boson self-interactions



Limits on aTGCS obtained , also in a phase space (p_T^{jet} > 200 GeV)
where linear term (interference bw SM & anomalous amplitude) is enhanced.





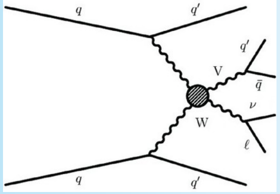
All consistent with SM

CMS has also performed WW+N(0,1,>=2)jet measurements (SMP-18-004)

WV VBS semileptonic

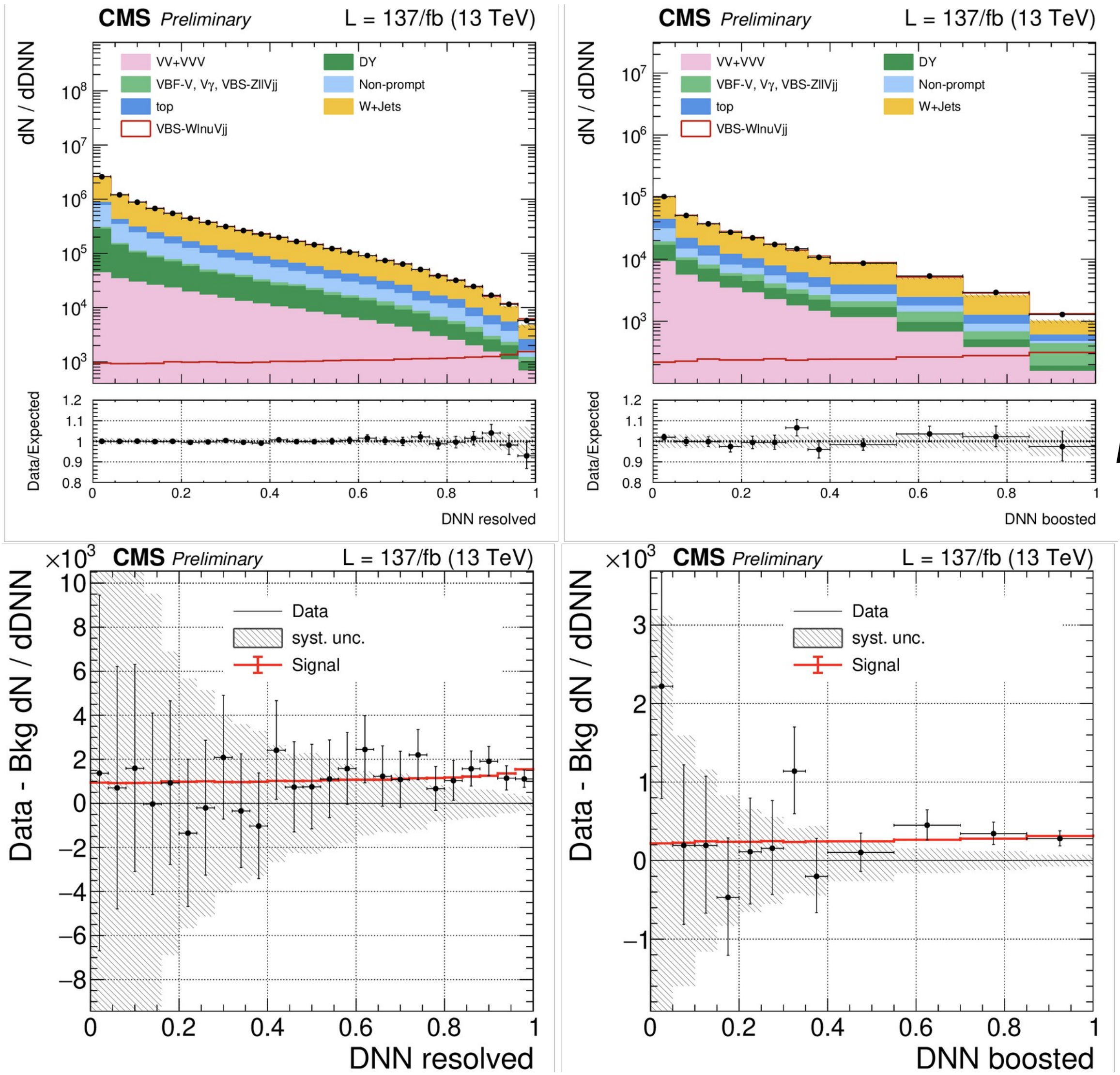
NEW

CMS-PAS-SMP-20-013



pp @ 13 TeV data (137 fb^{-1}). **W+jets : W → e/μ channels. V → jets (2 resolved jets or 1 boosted)**

Deep Neural Net used:

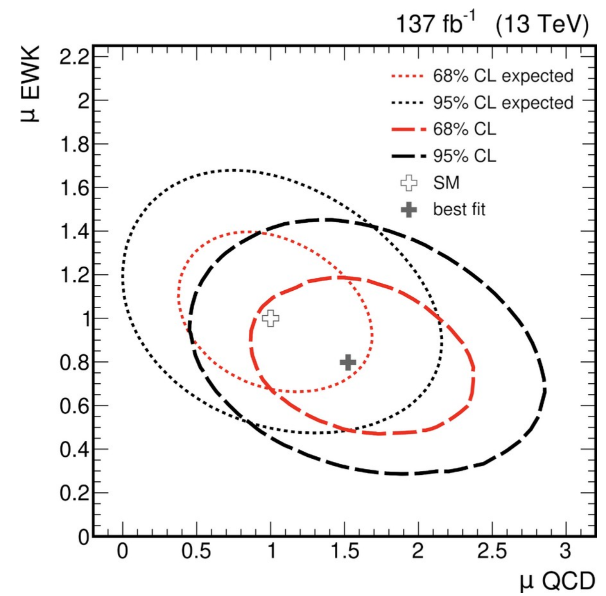


$\sigma_{EW} = 1.9 \pm 0.5$ pb

Observation significance:
4.4σ (observed)
5.1σ (expected)

First evidence of EW WV production in semileptonic channel

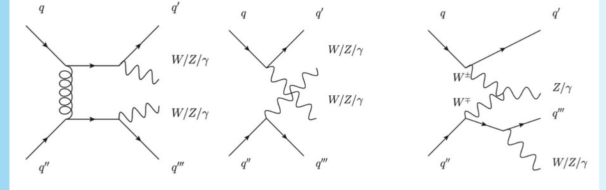
$$\mu_{EW} = \sigma/\sigma_{SM} = 0.85^{+0.24}_{-0.20} = 0.85^{+0.21}_{-0.17}(syst.) \pm 0.12(stat.)$$



Observation of EW Zγ + 2 jets

ATLAS-CONF-2021-038 , CERN-EP-2021-137

NEW

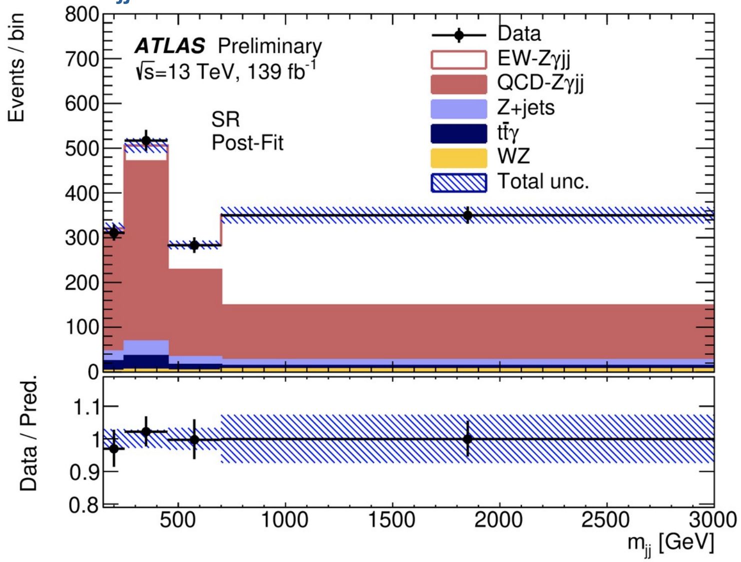


pp @ 13 TeV data (139 fb^{-1})

Z → ll

CR for main QCD Zγ + jj bkg, and Wγ + jj.
Data-driven non-prompt γ

Fit m_{jj} distribution



$$\mu_{EW} = \sigma / \sigma_{SM} = 0.95^{+0.15}_{-0.14}$$

Observation significance:
10σ (obs), 11σ (exp)

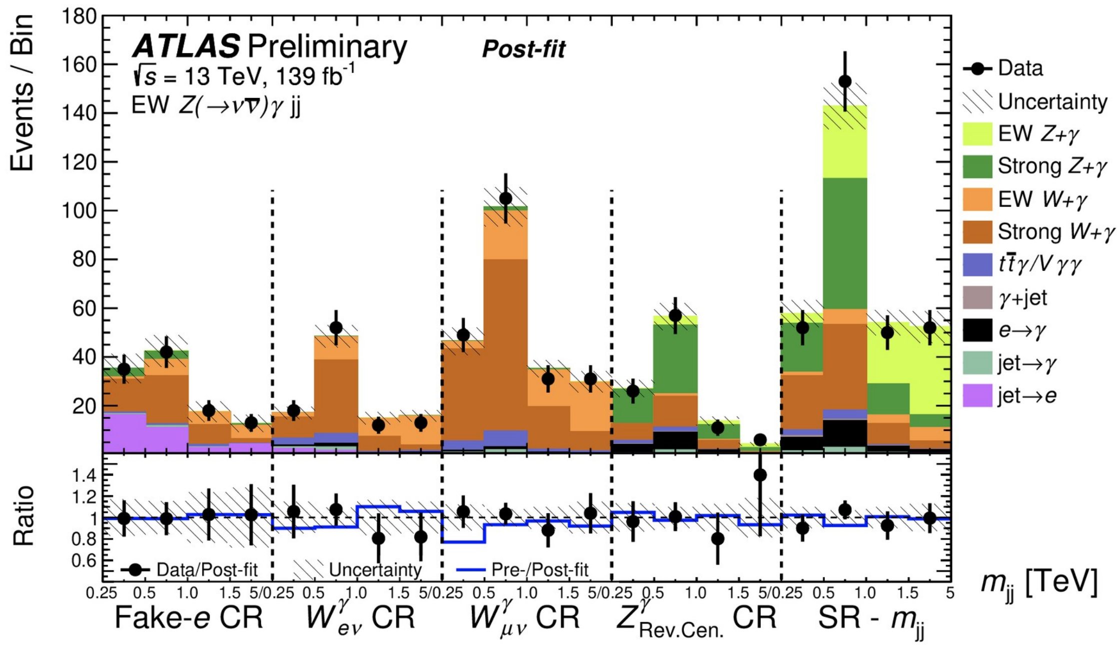
Fiducial cross-sections:

$$\sigma_{EW}(pp \rightarrow Z\gamma + 2\ jets) = 4.49 \pm 0.40(stat) \pm 0.42(syst)\ fb$$

$$\sigma_{EW+QCD}(pp \rightarrow Z\gamma + 2\ jets) = 20.6 \pm 0.6(stat) \pm 1.2(syst)\ fb$$

Z → νν

(important for BSM physics)



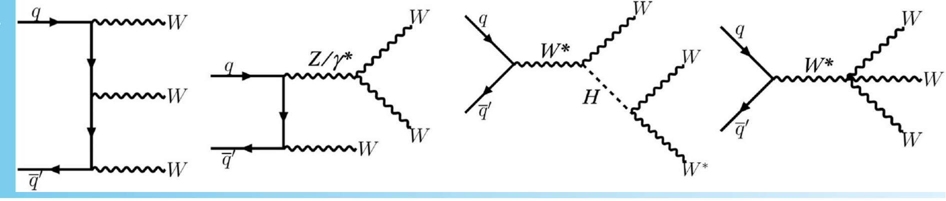
$$\mu_{EW} = 1.03 \pm 0.25$$

Observation significance:
5.2σ (obs), 5.1σ (exp)

Fiducial cross-sections:

$$\sigma_{EW}(pp \rightarrow Z\gamma + 2\ jets) = 1.31 \pm 0.20(stat) \pm 0.20(syst)\ fb$$

Observation of WWW production ATLAS-CONF-2021-039

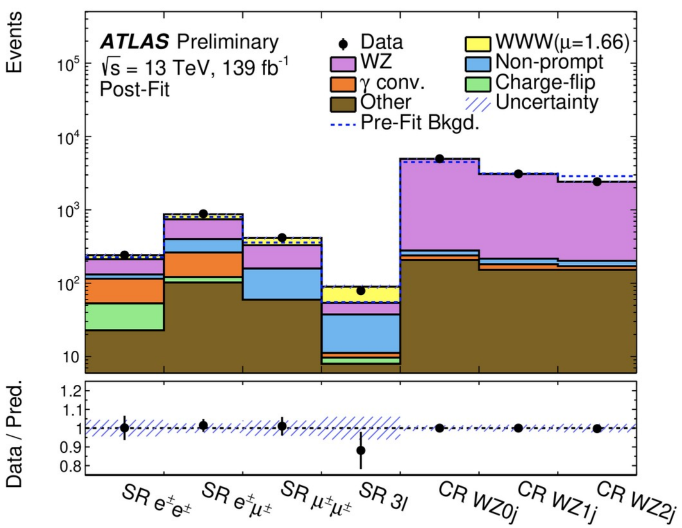


NEW

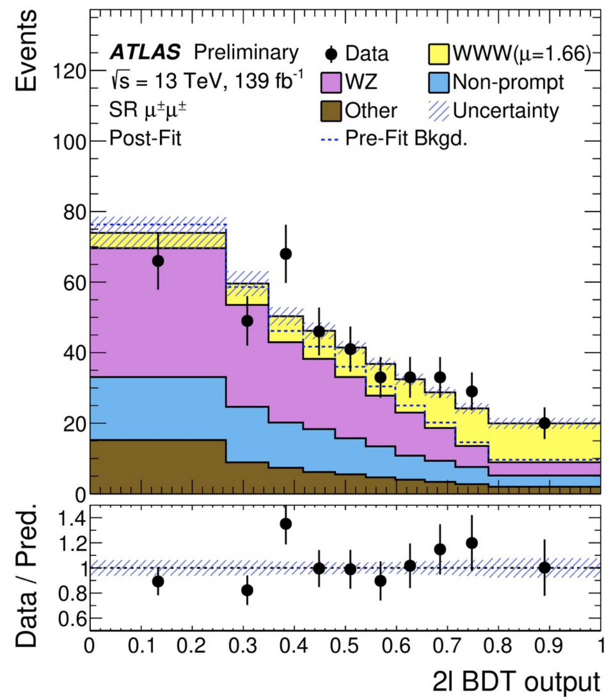
pp @ 13 TeV data (139 fb^{-1})

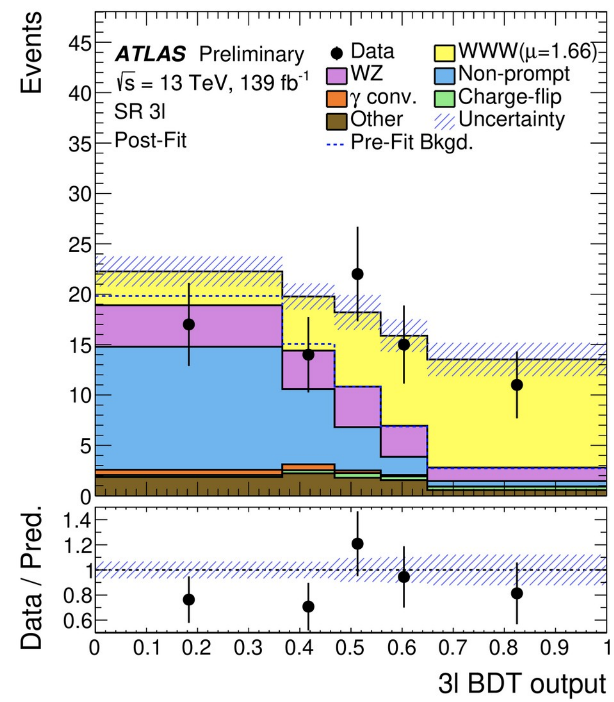
2 SameSign (SS) leptons (e/μ) + 2jets, or 3 leptons (no OS SameFlavor pairs)

Dominant Bkg: WZ → lνll estimated in 3 dedicated CRs.
Data-driven estimates:
non-prompt, γ-conversions, charge-flip



Dedicated BDTs in the **2l**epton & **3l**epton regions





σ_{WWW}= 850 ± 100 (stat.) ± 80 (syst.) fb
signal includes off shell WH(WW*)

First observation of WWW production with a significance of 8.2σ (5.4σ expected)

Fit	Observed (expected) significances [σ]	$\mu(WWW)$
$e^{\pm}e^{\pm}$	2.3 (1.4)	1.69 ± 0.79
$e^{\pm}\mu^{\pm}$	4.6 (3.1)	1.57 ± 0.40
$\mu^{\pm}\mu^{\pm}$	5.6 (2.8)	2.13 ± 0.47
2ℓ	6.9 (4.1)	1.80 ± 0.33
3ℓ	4.8 (3.7)	1.33 ± 0.39
Combined	**8.2 (5.4)**	**1.66 ± 0.28**

Combined EFT fit

NEW

ATL-PHYS-PUB-2021-022

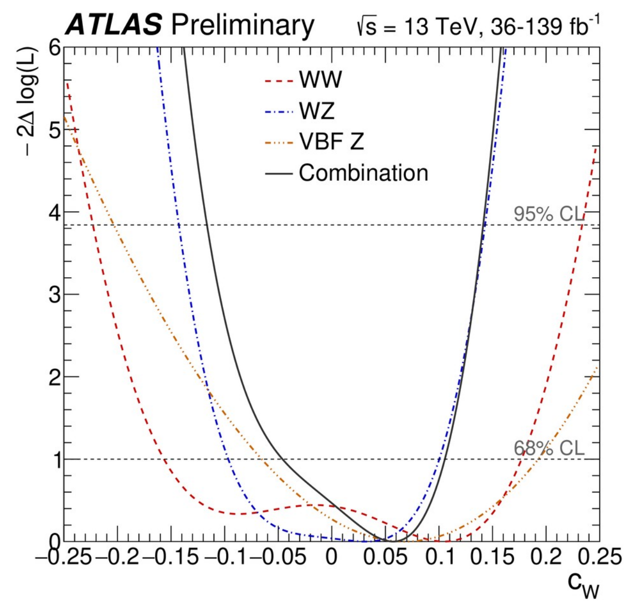
pp @ 13 TeV data (36-139 fb^{-1})

6 Differential distributions:

WW (36fb^{-1}) : leading lepton pT
WZ (36fb^{-1}) : mT(WZ)
4ℓ (139fb^{-1}) : m(Z2) in 3 m(4ℓ) regions
VBF Z (139fb^{-1}) : $\Delta\varphi$(jj)

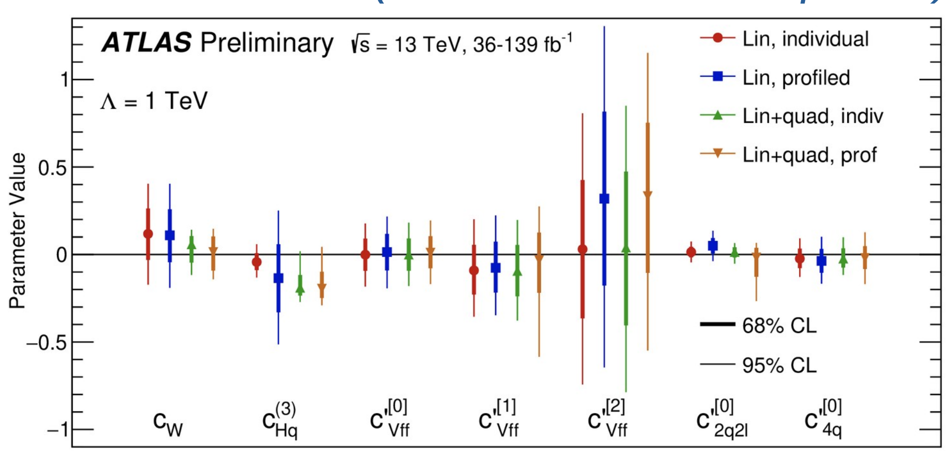
33 dimension-6 operators
(Warsaw basis
↔ SMEFT interpretation)

Considered:
Dim6 contributions from
Linear-only & including quadratic terms



Results in individual Wilson coefficients & in 15 linear combinations

Individual (i.e., with the rest kept at 0), and also with the rest profiled



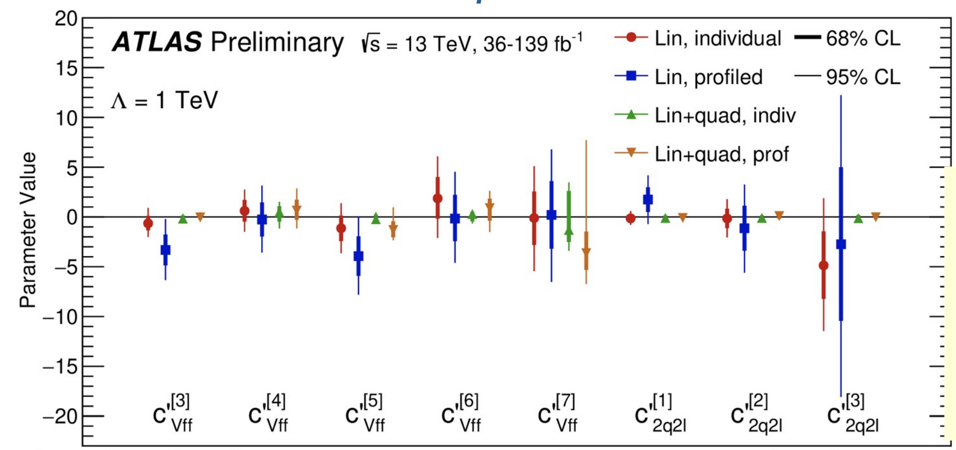
$c'^{[0]}_{Vff} \approx 0.81c_{HWB} + 0.38c_{HD} + 0.13c^{(1)}_{Hl} + 0.37c^{(3)}_{Hl} - 0.14c^{(1)}_{ll} + 0.12c^{(1)}_{Hq}$

$c'^{[1]}_{Vff} \approx 0.73c^{(1)}_{Hl} - 0.28c^{(3)}_{Hl} - 0.48c_{He} + 0.38c^{(1)}_{ll} + 0.13c^{(1)}_{Hq}$

$c'^{[2]}_{Vff} \approx 0.37c_{HWB} + 0.17c_{HD} - 0.31c^{(1)}_{Hl} - 0.53c^{(3)}_{Hl} + 0.25c_{He} + 0.59c^{(1)}_{ll} - 0.21c^{(1)}_{Hq}$

$c'^{[0]}_{2q2l} \approx -0.37c^{(1)}_{lq} + 0.89c^{(3)}_{lq} - 0.11c_{lu} - 0.21c_{eu} - 0.13c_{qe}$

$c'^{[0]}_{4q} \approx 0.11c^{(11)}_{qq} + 0.22c^{(18)}_{qq} + 0.95c^{(31)}_{qq} - 0.2c^{(38)}_{qq}$



$c'^{[3]}_{Vff} \approx -0.19c^{(1)}_{Hl} - 0.14c^{(3)}_{Hl} + 0.86c^{(1)}_{Hq} + 0.41c_{Hu} - 0.17c_{Hd}$

$c'^{[4]}_{Vff} \approx -0.35c_{HWB} + 0.49c_{HD} + 0.26c^{(1)}_{Hl} + 0.35c^{(3)}_{Hl} + 0.51c_{He} + 0.38c^{(1)}_{ll} + 0.18c^{(1)}_{Hq}$

$c'^{[5]}_{Vff} \approx 0.25c_{HD} + 0.33c^{(1)}_{Hl} - 0.22c^{(3)}_{Hl} + 0.18c_{He} - 0.35c^{(1)}_{ll} - 0.3c^{(1)}_{Hq} + 0.71c_{Hu} - 0.16c_{Hd}$

$c'^{[6]}_{Vff} \approx -0.22c^{(1)}_{Hl} + 0.52c^{(3)}_{Hl} - 0.39c_{He} + 0.44c^{(1)}_{ll} - 0.22c^{(1)}_{Hq} + 0.52c_{Hu}$

$c'^{[7]}_{Vff} \approx -0.28c_{HWB} + 0.71c_{HD} - 0.31c^{(1)}_{Hl} - 0.21c^{(3)}_{Hl} - 0.5c_{He} - 0.14c^{(1)}_{ll}$

$c'^{[1]}_{2q2l} \approx 0.56c^{(1)}_{lq} + 0.44c^{(3)}_{lq} + 0.61c_{eu} - 0.1c_{ed} + 0.34c_{qe}$

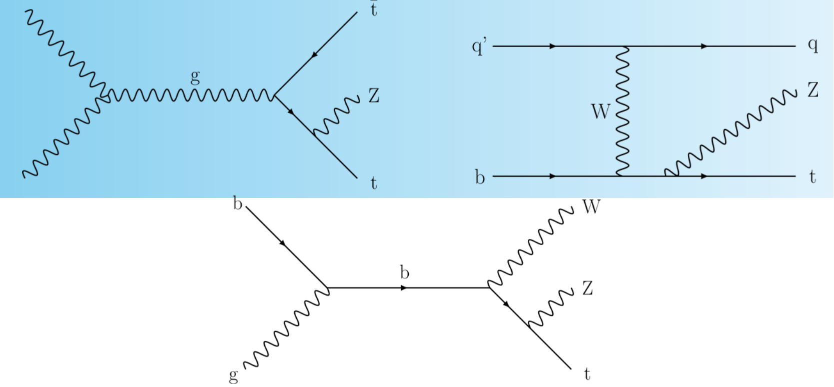
$c'^{[2]}_{2q2l} \approx 0.68c^{(1)}_{lq} + 0.15c^{(3)}_{lq} + 0.33c_{lu} - 0.51c_{eu} + 0.13c_{ed} - 0.37c_{qe}$

$c'^{[3]}_{2q2l} \approx -0.27c^{(1)}_{lq} + 0.79c_{lu} - 0.39c_{ld} + 0.26c_{eu} - 0.22c_{ed} - 0.16c_{qe}$

Towards a global ATLAS SMEFT interpre-tation

tZ & ttZ EFT limits

CMS-PAS-TOP-21-001 NEW



pp @ 13 TeV data (138 fb^{-1})

3 or 4 leptons, b-jets, p_T(miss), extra jets

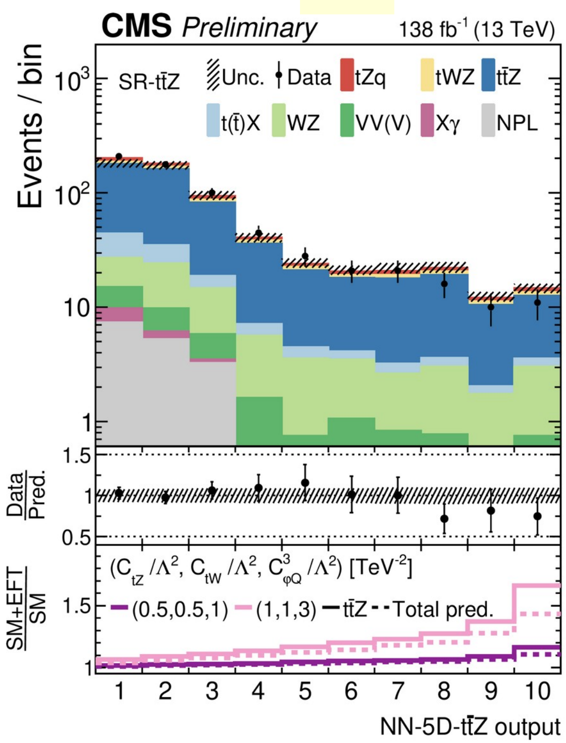
Dedicated CRs for WZ, ZZ bkgs

Data-driven estimates: non-prompt leptons

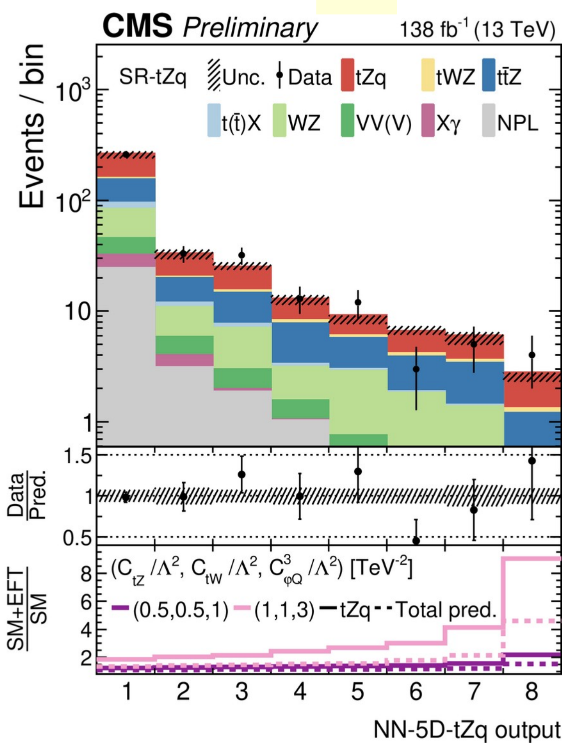
NNs used for separation of SM and BSM contributions

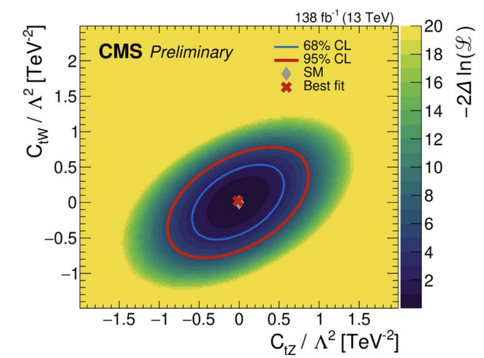
Operator	WC	Mapping to Warsaw-basis coefficients
$\mathcal{O}_{tZ}$	c_{tZ}	$\mathrm{Re}\{-s_W c_{uB}^{(33)} + c_W c_{uW}^{(33)}\}$
$\mathcal{O}_{tW}$	c_{tW}	$\mathrm{Re}\{c_{uW}^{(33)}\}$
$\mathcal{O}_{\varphi Q}^{3}$	$c_{\varphi Q}^{3}$	$c_{\varphi q}^{3(33)}$
$\mathcal{O}_{\varphi Q}^{-}$	$c_{\varphi Q}^{-}$	$c_{\varphi q}^{1(33)} - c_{\varphi q}^{3(33)}$
$\mathcal{O}_{\varphi t}$	$c_{\varphi t}$	$c_{\varphi u}^{(33)}$

ttZ

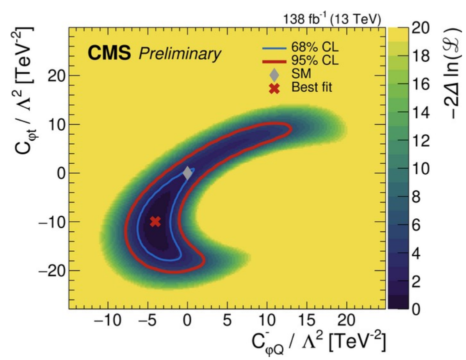


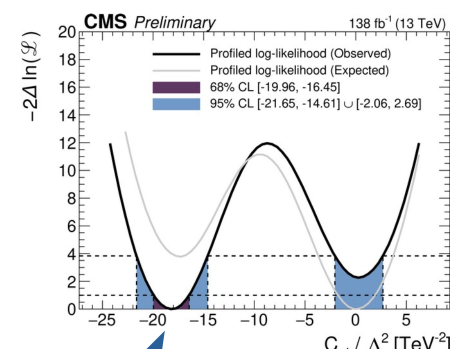
tZ





Results consistent w/ SM @95% C.L.





BSM $C_{\varphi Q}$ coefficient as deeper minimum at non-SM value, (SM minimum at 0 is still OK, within 95% C.L.)

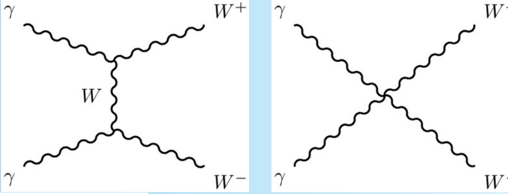
Conclusions

- Showed recent SM results from ATLAS and CMS (most are new from this summer)
  - Investigate processes spanning 9 orders of magnitude in cross-section: inclusive jets → multi-bosons → vector-boson-scattering
- Run 2 dataset (~140 fb^{-1}) has allowed precision measurements in both ATLAS and CMS
  - Test higher order QCD & EW calculations and constrain PDFs
  - Search for effects of new physics, using the EFT formalism
- Run 3 (starting soon) will double the data sample
  - Reducing systematic uncertainties (theoretical & experimental) is important
- Precision measurements can lead to (indirect) discoveries

Thank you!

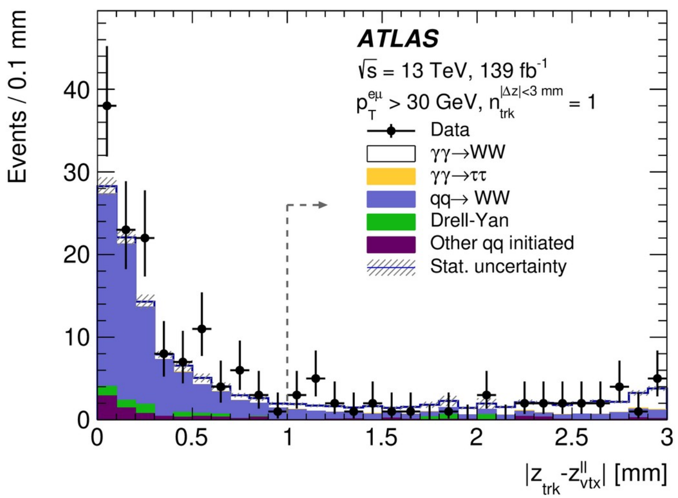
Observation of γγ → WW

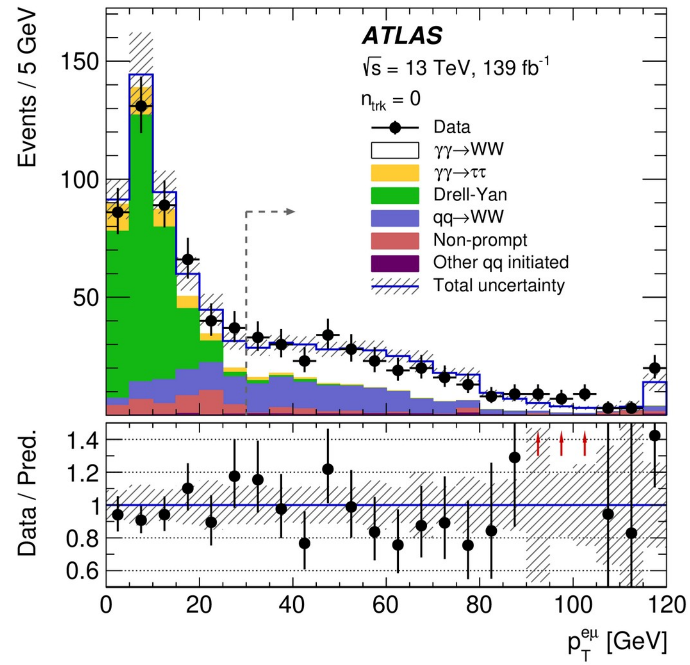
Phys. Lett. B 816 (2021) 136190

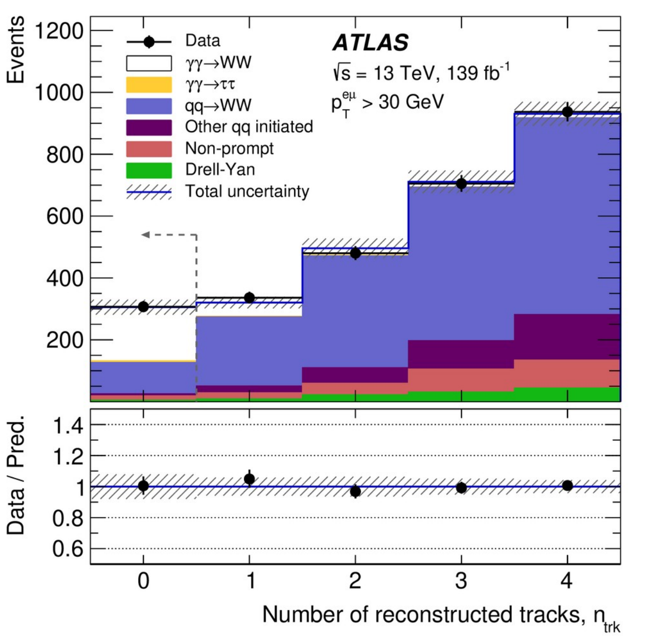


pp @ 13 TeV data (139 fb^{-1})

eμ events (no extra charged particles from the *same pp vertex*)







	Signal region		Control regions	
n_{trk}	$n_{\mathrm{trk}} = 0$		$1 \leq n_{\mathrm{trk}} \leq 4$	
$p_{\mathrm{T}}^{e\mu}$	> 30 GeV	< 30 GeV	> 30 GeV	< 30 GeV
$\gamma\gamma \to WW$	174 ± 20	45 ± 6	95 ± 19	24 ± 5
$\gamma\gamma \to \ell\ell$	5.5 ± 0.3	39.6 ± 1.9	5.6 ± 1.2	32 ± 7
Drell–Yan	4.5 ± 0.9	280 ± 40	106 ± 19	4700 ± 400
$qq \to WW$ (incl. gg and VBS)	101 ± 17	55 ± 10	1700 ± 270	970 ± 150
Non-prompt	14 ± 14	36 ± 35	220 ± 220	500 ± 400
Other backgrounds	7.1 ± 1.7	1.9 ± 0.4	311 ± 76	81 ± 15
Total	305 ± 18	459 ± 19	2460 ± 60	6320 ± 130
Data	307	449	2458	6332

cross section for the $\gamma\gamma \to WW$ process of $3.13 \pm 0.31(\mathrm{stat.}) \pm 0.28(\mathrm{syst.})$ fb

Observation significane (i.e., bkg-only excluded at) 8.4σ

Event shapes JHEP 01 (2021) 188

Thrust axis ˆnT : direction w.r.t which projection of the jet momenta is maximum

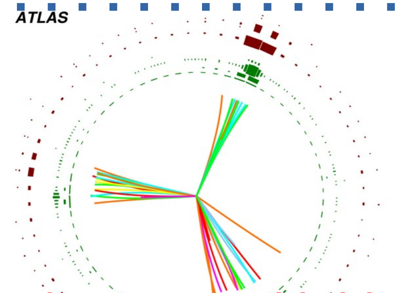
Transverse thrust: $T_{\perp} = \frac{\sum_i |\vec{p}_{\mathrm{T},i} \cdot \hat{n}_{\mathrm{T}}|}{\sum_i |\vec{p}_{\mathrm{T},i}|}$

Isotropy of event:

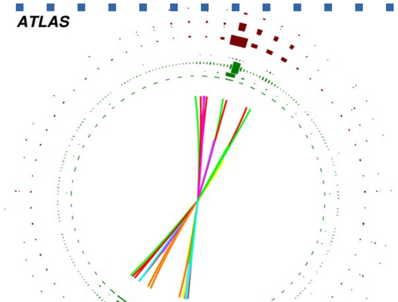
Sphericity (S) and Aplanarity (A)

S → 1 : spherical

A → 1/2 : planar



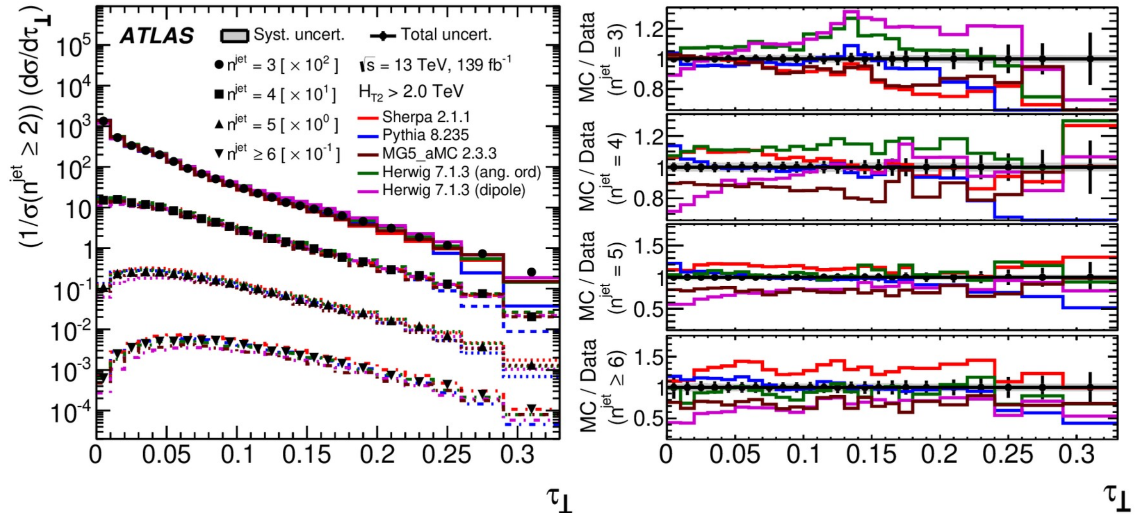
3-jet event with high Thrust & Sphericity

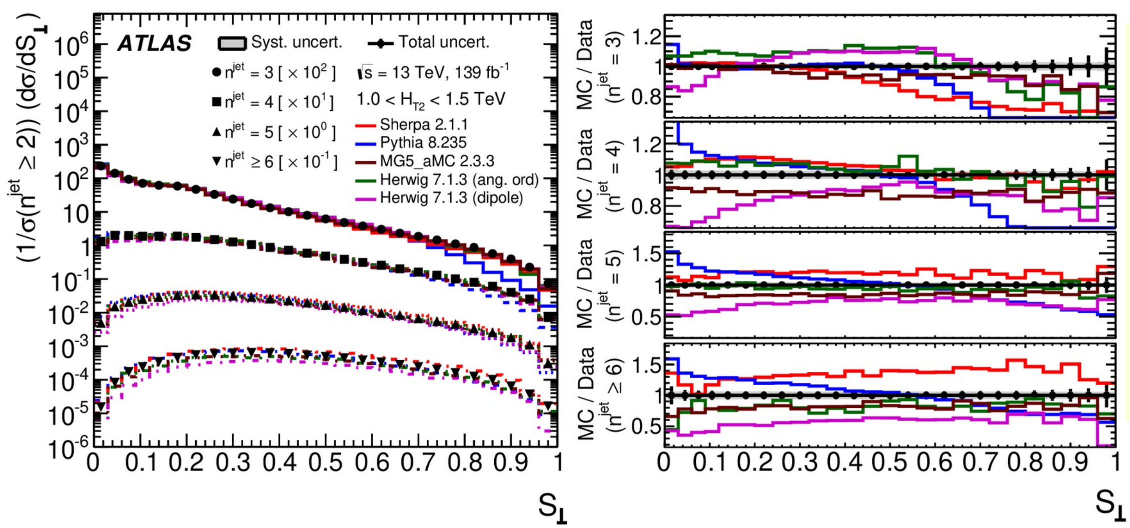


5-jet event with low Thrust & Sphericity

Measurements in various event-shape variables, in bins of jet multiplicity (n^{jet}) & in different ranges of H_{T2} (= Σ |pT| , 2 leading jets)

Measurements compared to MCs with LO & NLO ME matched to PS at LL accuracy





At low n^{jet}:
shape discrepancies

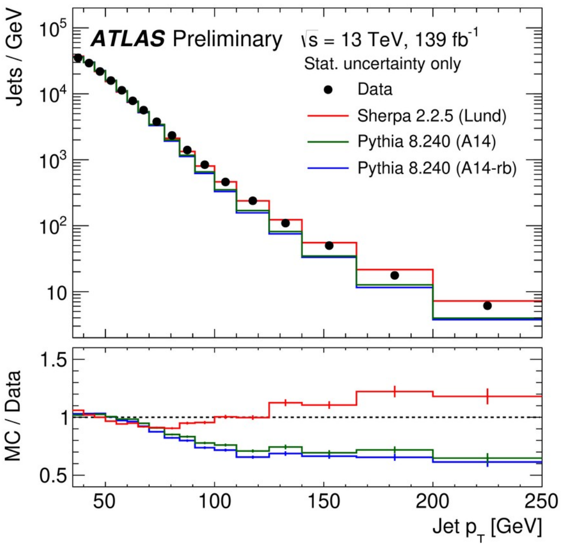
At high n^{jet}:
Better shapes but discrepancies in normalisation.

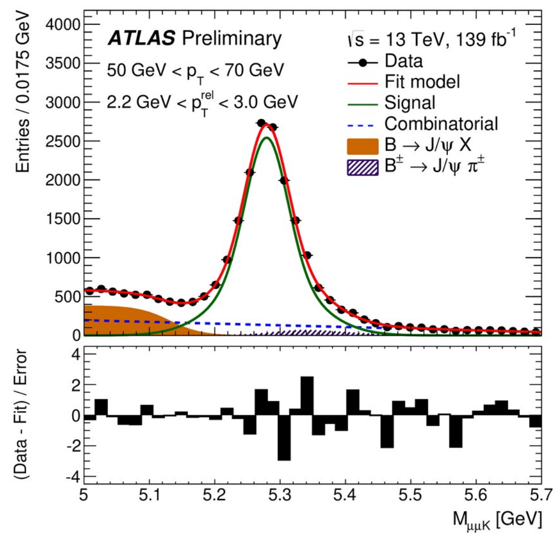
b fragmentation STDM-2018-52

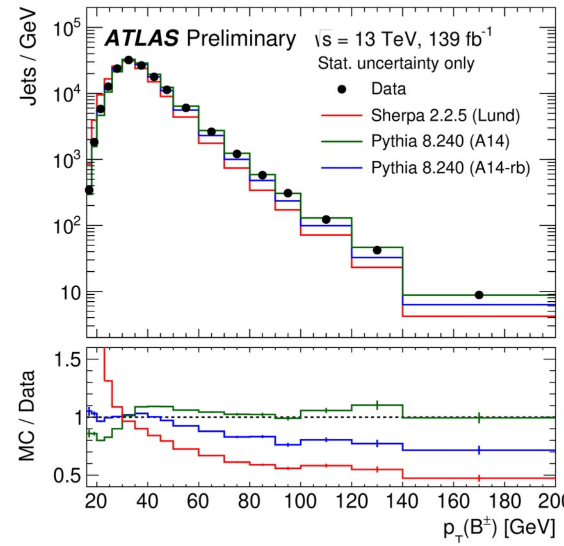
NEW

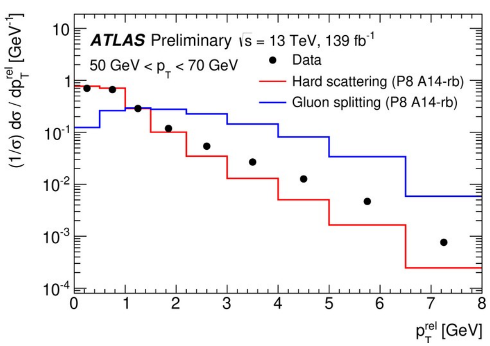
pp @ 13 TeV data (139 fb^{-1})

Measurement of b-quark fragmentation properties in jets using the decay $B^\pm \to J/\psi K^\pm$ in pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector



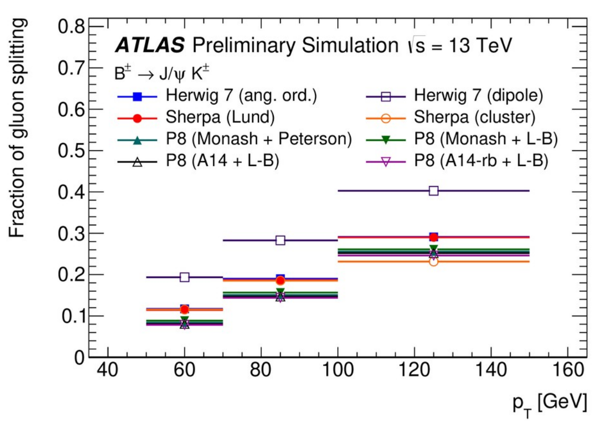






Jets classified as g → bb if 2 B decays identified in ΔR<0.4 from jet

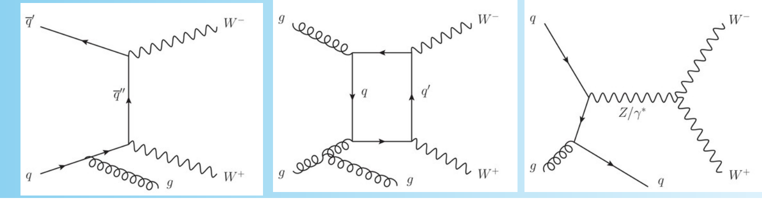
Generator	ME order	Scales μ_r, μ_f	Parton shower	PDF set	Tune	Hadronisation
Pythia 8	$2\to2$ @ LO	$(m_{T3}\cdot m_{T4})^{\frac{1}{2}}$	p_T-ordered	CTEQ6L1 NNPDF2.3	A14 A14-RB Monash	Lund–Bowler Lund–Bowler Lund–Bowler Peterson
Sherpa	$2\to2$ @ LO	$H(s,t,u)$	CSS (dipole)	CT14	–	Cluster model Lund string model
Herwig 7	$2\to2$ @ LO	$\sqrt{\frac{2stu}{s^2+t^2+u^2}}$	Angle-ordered Dipole	MMHT2014	–	Cluster model



HERWIG 7 model w/ dipole-based parton shower shows systematically larger fraction than the rest

WW + >=1 jet production

JHEP 06 (2021) 003

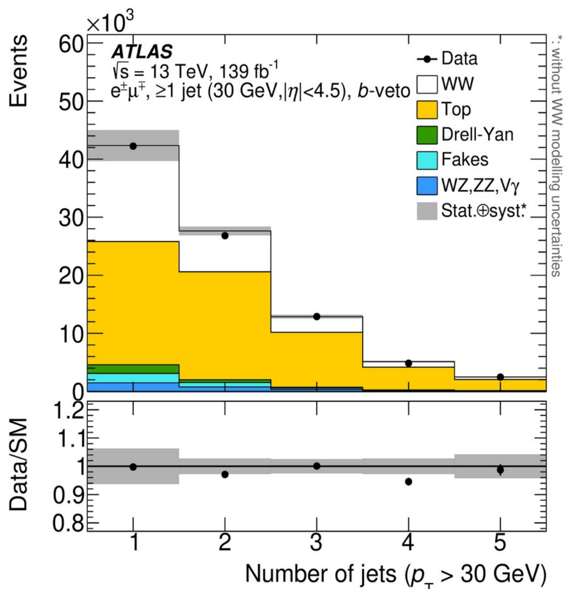


Full pp @ 13 TeV data (139 fb^{-1})

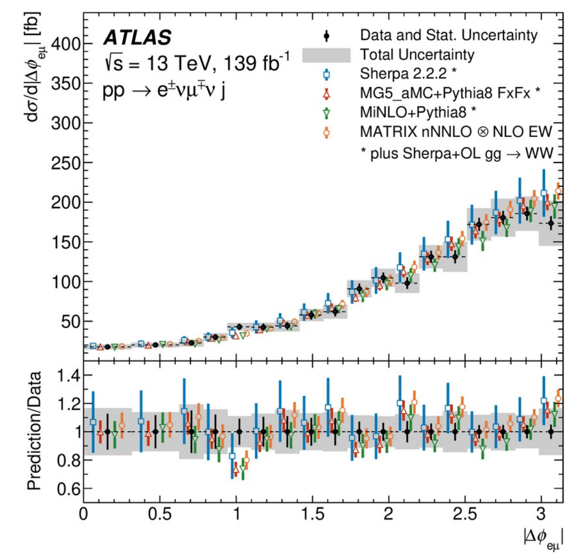
xsec vs.
p_T(lepton), m_T(WW), p_T(jets), N_{jets}, etc.

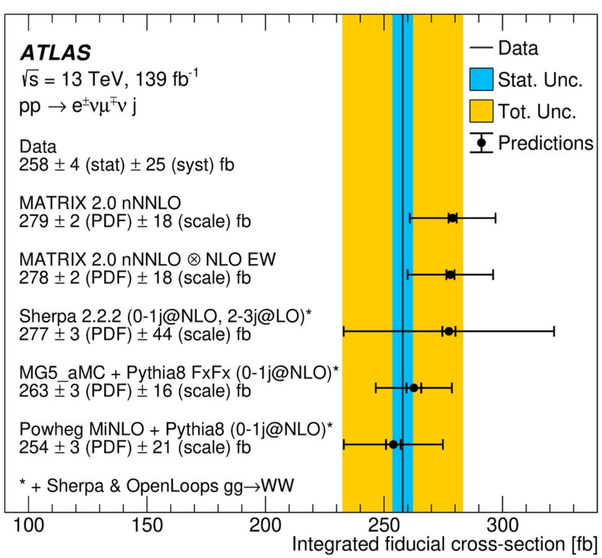
Fiducial selection requirements		
p_T^ℓ	>	27 GeV
$\lvert\eta^\ell\rvert$	<	2.5
$m_{e\mu}$	>	85 GeV
p_T^j	>	30 GeV
$\lvert y^j\rvert$	<	4.5

Test of pQCD and EW theory
Sensitive to EW boson self-interactions



	Signal region		$p_T^{\text{lead. jet}}$ > 200 GeV	
Data	89 239		5825	
Total SM	91 600 ± 2500		5980 ± 150	
WW	28 100 ± 1200	31%	2480 ± 60	42%
Total bkg.	63 500 ± 1800	69%	3500 ± 140	58%
Top	55 800 ± 1500	61%	3030 ± 110	51%
Drell–Yan	2200 ± 700	2%	66 ± 9	1%
Fake leptons	2700 ± 1100	3%	140 ± 70	2%
$WZ, ZZ, V\gamma$	2800 ± 500	3%	270 ± 70	4%





Limits on aTGCS obtained , also in a phase space (p_T^{jet} > 200 GeV)
where linear term (interference bw SM & anomalous amplitude) is enhanced.