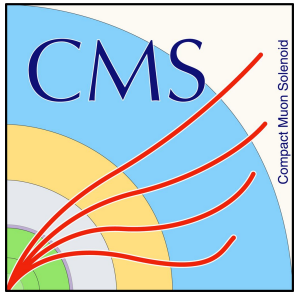
Recent experimental results with implications for PDFs

Bogdan Malaescu,
on behalf of the ATLAS and CMS collaborations



LPNHE PARIS

anr agence nationale de la recherche AU SERVICE DE LA SCIENCE

cnrs

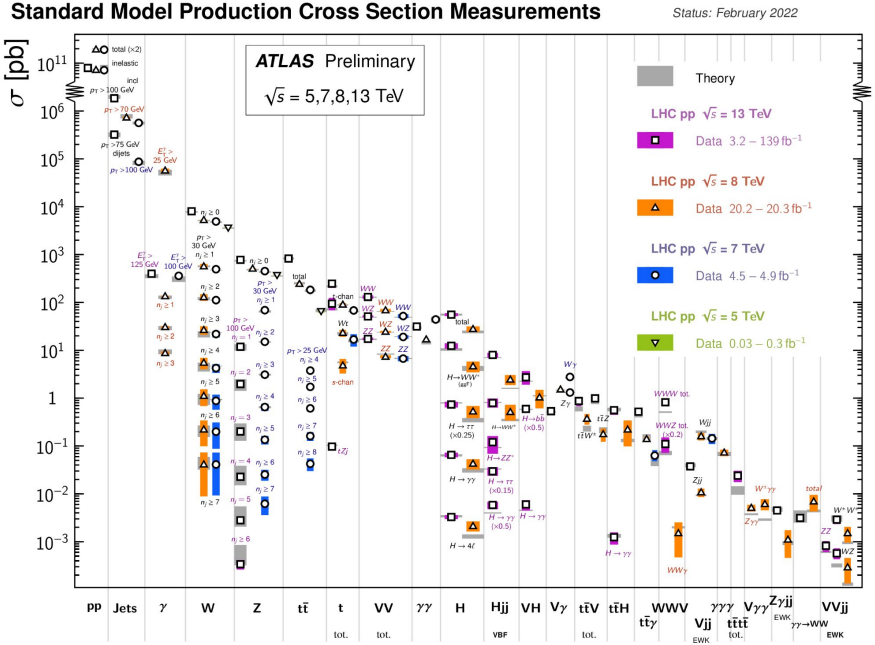
"Almost nothing on almost everything"
Jean d'ORMESSON

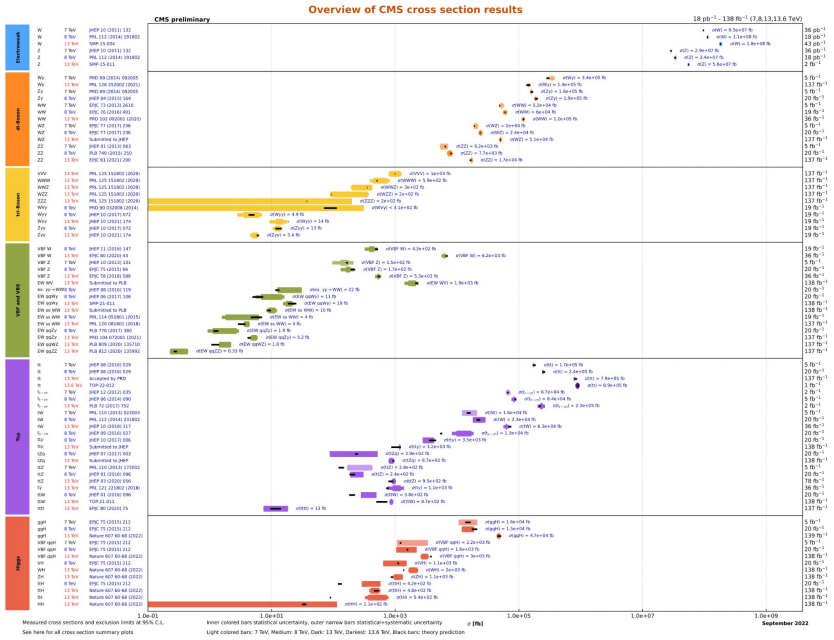
LHCP 2023 – Belgrade – 25/05/2020

Introduction

Numerous “Standard Model measurements” performed by ATLAS and CMS

Good agreement for many processes, *over 15 orders of magnitude*



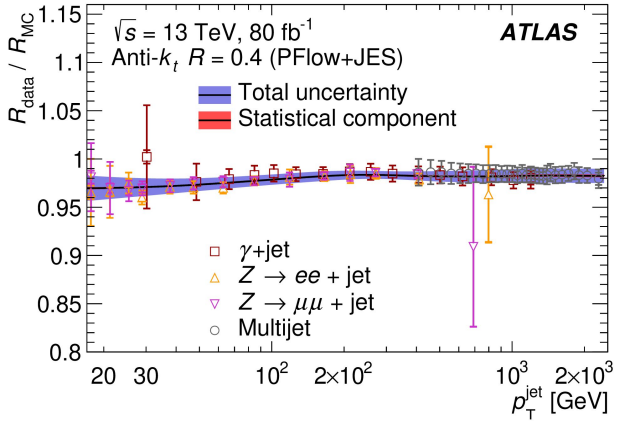


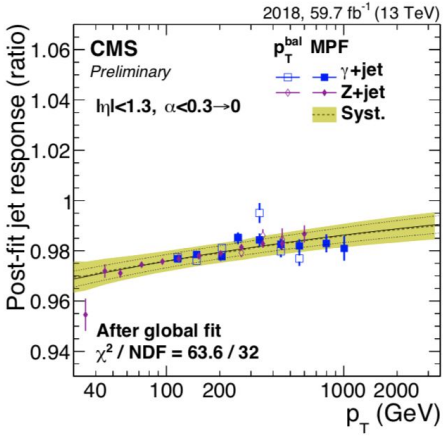
Testing the Standard Model *(with PDFs being one of the key inputs)* through rare processes and differential/precision measurements

possible due to excellent reconstruction and calibration performance results

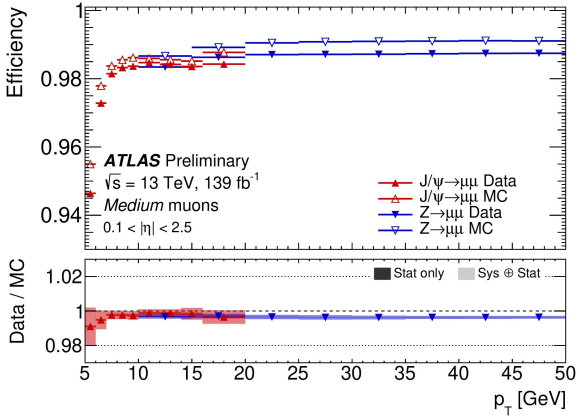
Excellent Reconstruction and Calibration Performance

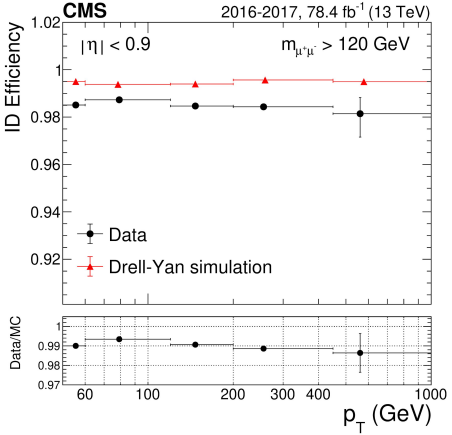
Data-driven calibration of small-R jets ~(sub-)percent precision → Jet cross-sections





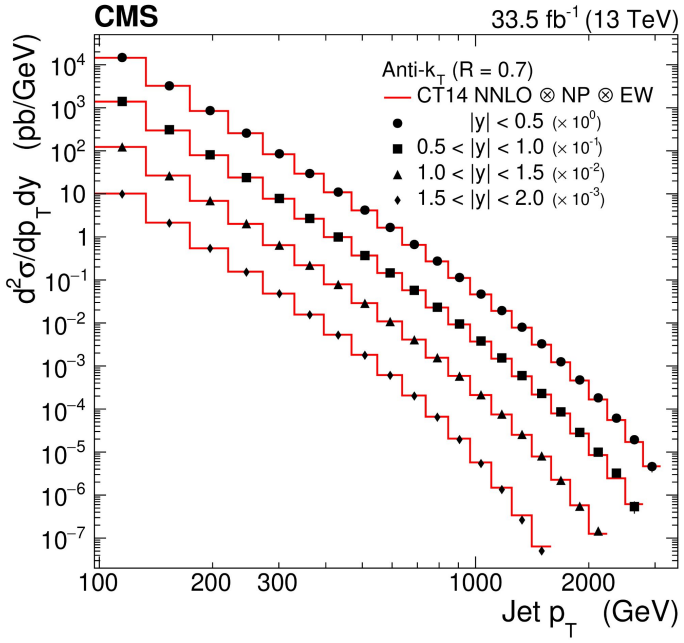
Data-driven calibration of muon efficiency ~per-mil precision → W+Charm and p_T(Z) cross-sections

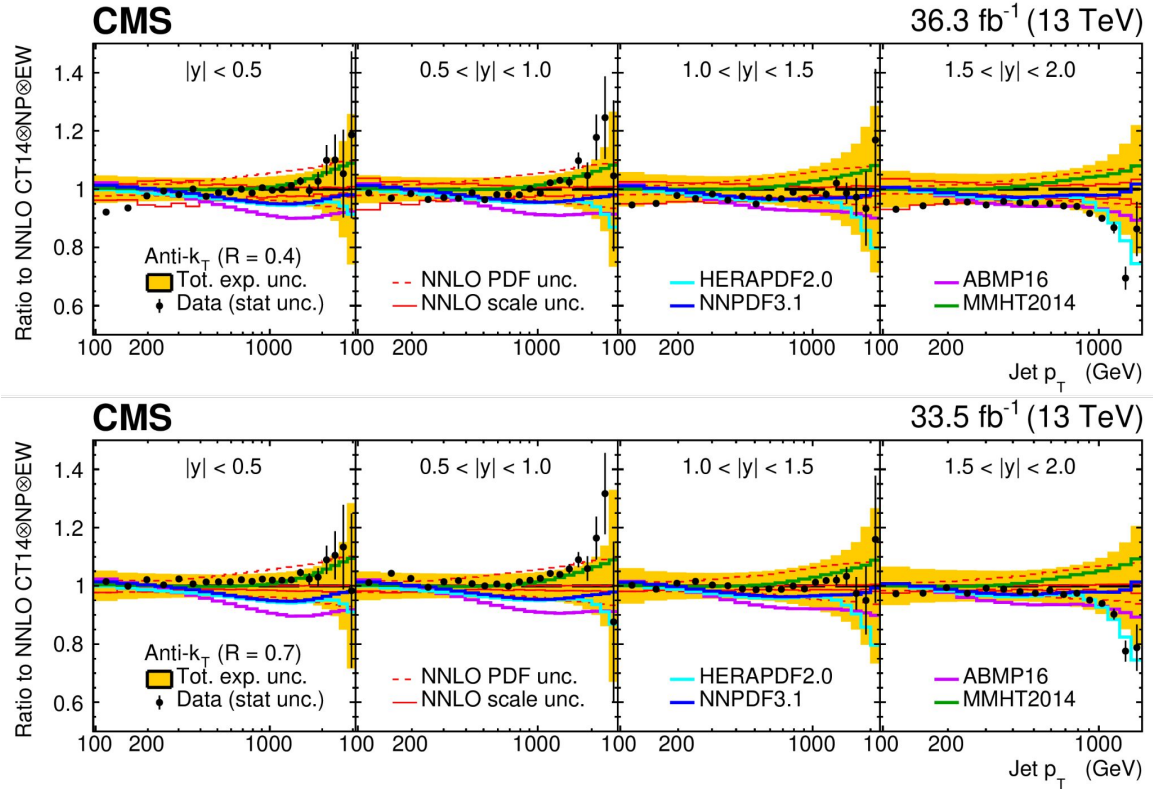




CMS Jet Cross-Sections

arXiv:2111.10431
Addendum: JHEP02(2022)142





Measured unfolded differential cross-sections of inclusive jet production:
p_T, |y|, for anti-k_T jets of radius R=0.4 and R=0.7
→ Good sensitivity to PDFs

CMS Jet Cross-Sections

arXiv:2111.10431
Addendum: JHEP02(2022)142

→ Simultaneous evaluation of α_S and PDFs

Data sets		HERA+CMS Partial χ^2/N_{dp}
HERA I+II neutral current	e^+p, $E_p = 920$ GeV	376/332
HERA I+II neutral current	e^+p, $E_p = 820$ GeV	60/63
HERA I+II neutral current	e^+p, $E_p = 575$ GeV	202/234
HERA I+II neutral current	e^+p, $E_p = 460$ GeV	209/187
HERA I+II neutral current	e^-p, $E_p = 920$ GeV	227/159
HERA I+II charged current	e^+p, $E_p = 920$ GeV	46/39
HERA I+II charged current	e^-p, $E_p = 920$ GeV	56/42
CMS inclusive jets 13 TeV	$0.0 < \|y\| < 0.5$	8.6/22
	$0.5 < \|y\| < 1.0$	23/21
	$1.0 < \|y\| < 1.5$	13/19
	$1.5 < \|y\| < 2.0$	14/16
Correlated χ^2		81
Global χ^2/N_{dof}		1302/1118

→ Good description of the data by fit result

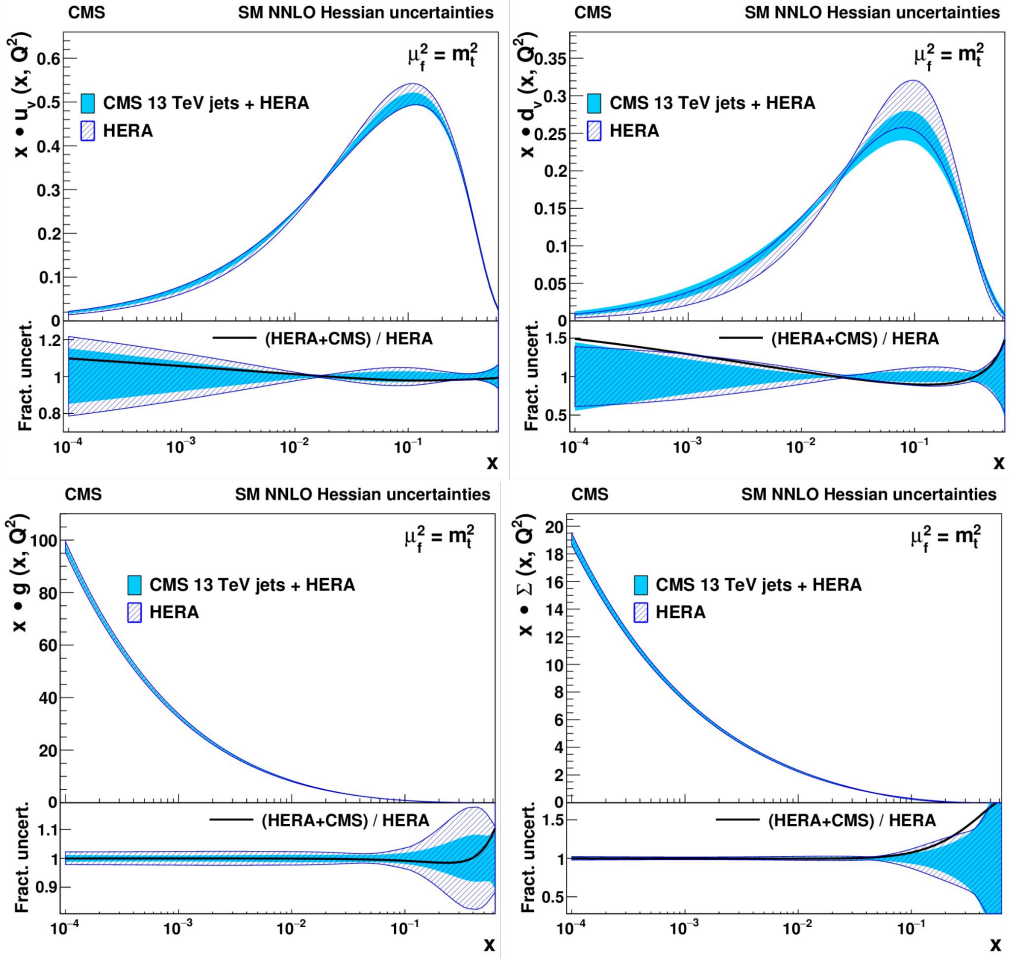
OLD (NNLO k-Factors): $\alpha_S(m_Z) = 0.1170 \pm 0.0014$ (fit) ± 0.0007 (model) ± 0.0008 (scale) ± 0.0001 (param.)

NEW (NNLO Grids): $\alpha_S(m_Z) = 0.1166 \pm 0.0014$(fit) ± 0.0007(model) ± 0.0004(scale) ± 0.0001(param.)

→ Improved precision

CMS Jet Cross-Sections

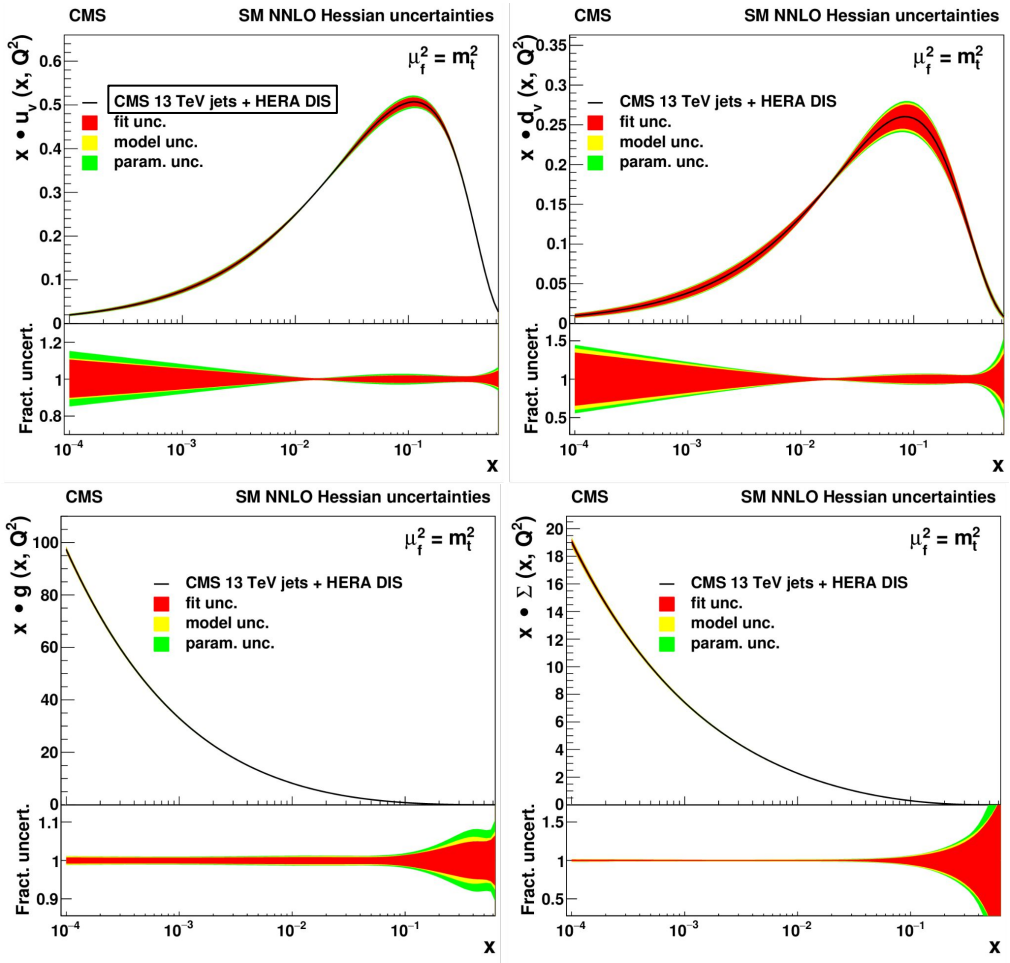
arXiv:2111.10431
Addendum: JHEP02(2022)142



→ Precision of PDFs improved, especially for the high-x gluon PDF

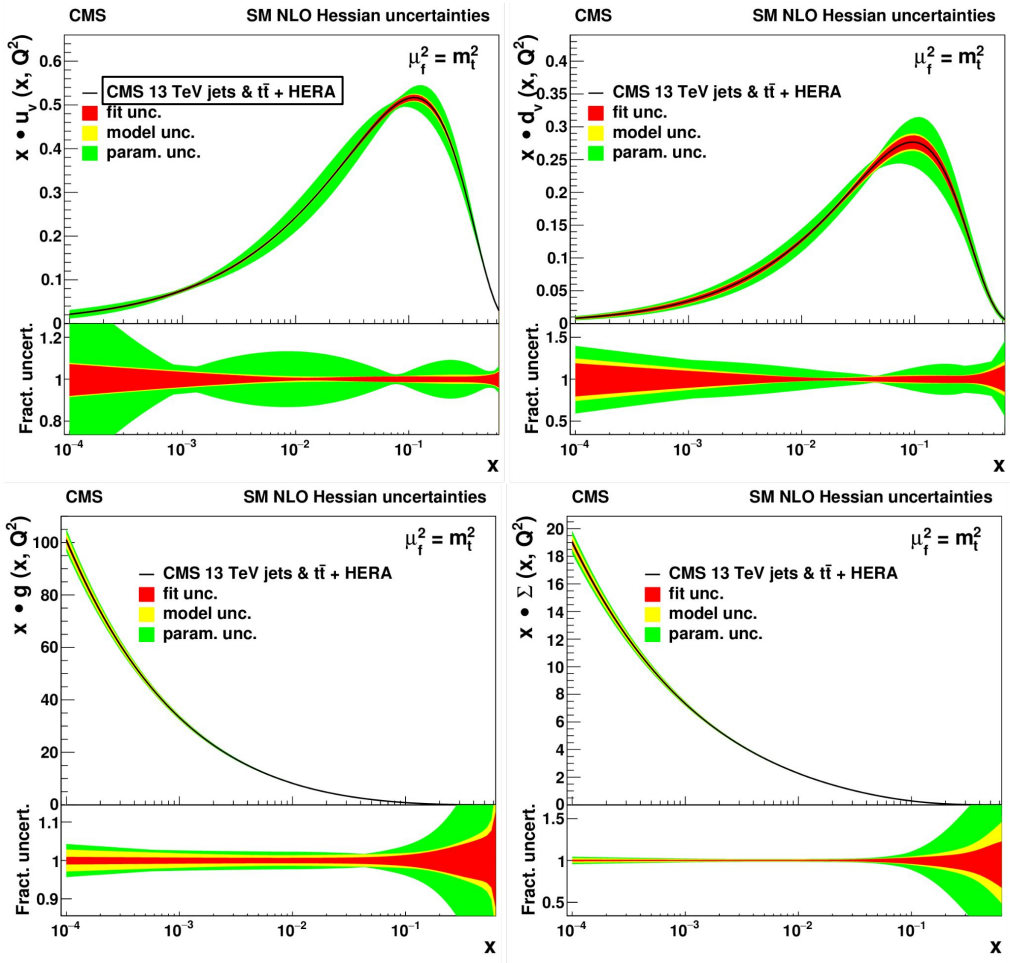
CMS Jet Cross-Sections

arXiv:2111.10431
Addendum: JHEP02(2022)142



CMS Jet Cross-Sections

arXiv:2111.10431
Addendum: JHEP02(2022)142



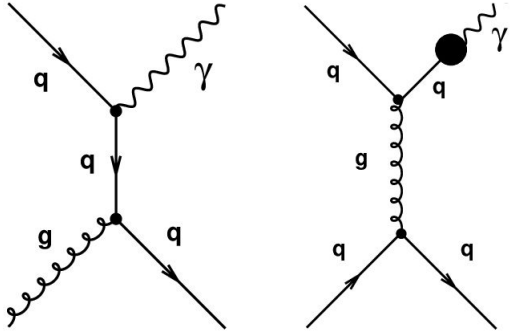
See talk by Daniel Savoiu

Inclusive Photon Production

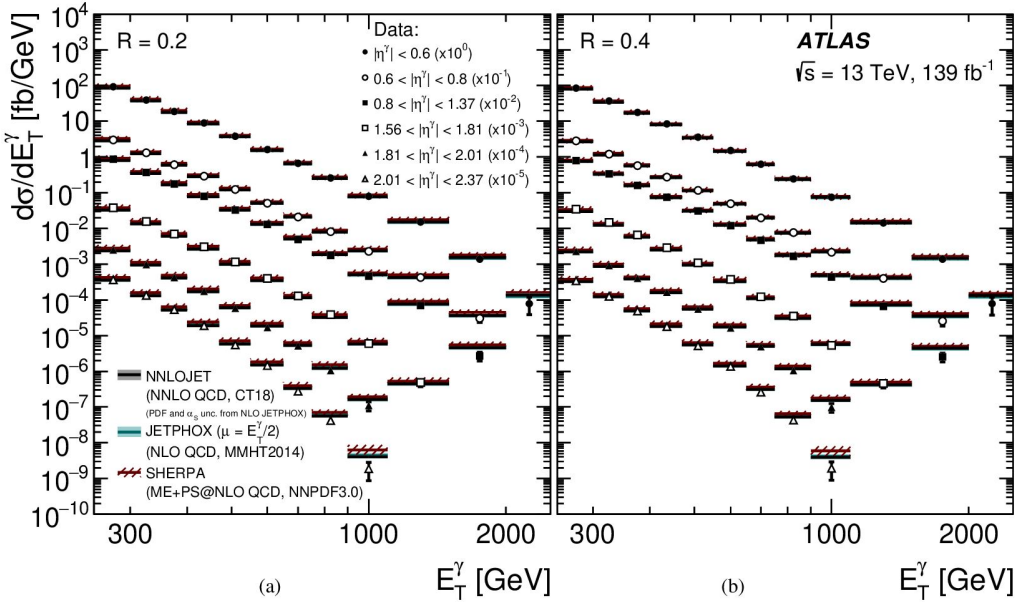
arXiv:2302.00510

Measured unfolded differential cross-sections of inclusive photon production:
E_T^γ, η^γ, isolation cone radius (R)

Requirement	Phase-space region					
E_T^γ	$E_T^\gamma > 250$ GeV					
Isolation	$E_T^{iso} < 4.2 \cdot 10^{-3} \cdot E_T^\gamma + 4.8$ GeV					
η^γ	$\lvert\eta^\gamma\rvert < 0.6$	$0.6 < \lvert\eta^\gamma\rvert < 0.8$	$0.8 < \lvert\eta^\gamma\rvert < 1.37$	$1.56 < \lvert\eta^\gamma\rvert < 1.81$	$1.81 < \lvert\eta^\gamma\rvert < 2.01$	$2.01 < \lvert\eta^\gamma\rvert < 2.37$

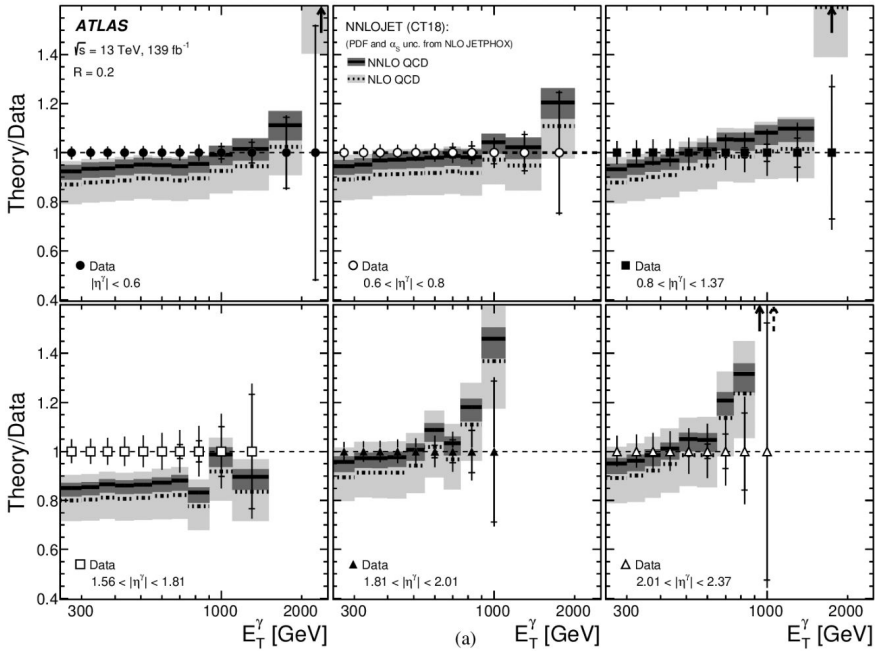


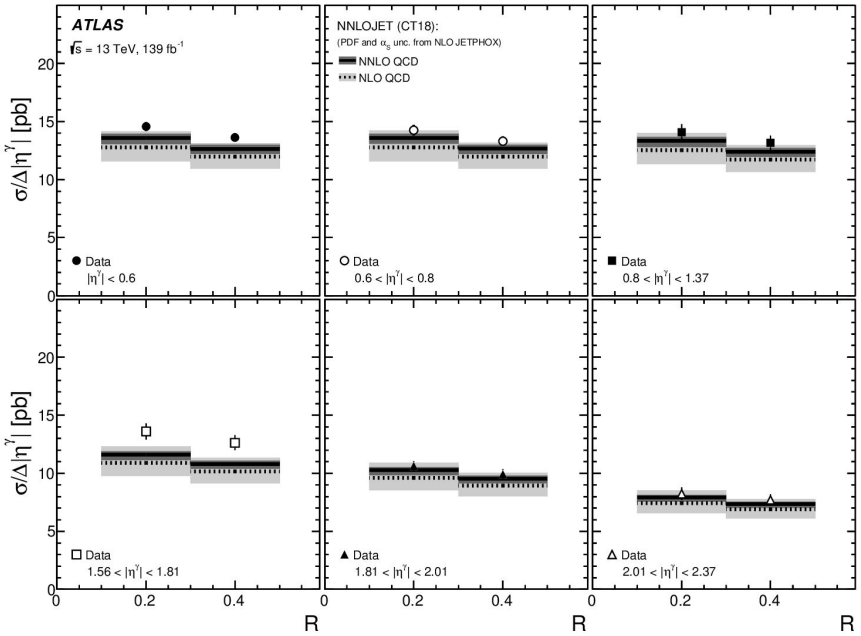
→ Data-driven estimate of QCD background



Inclusive Photon Production

arXiv:2302.00510

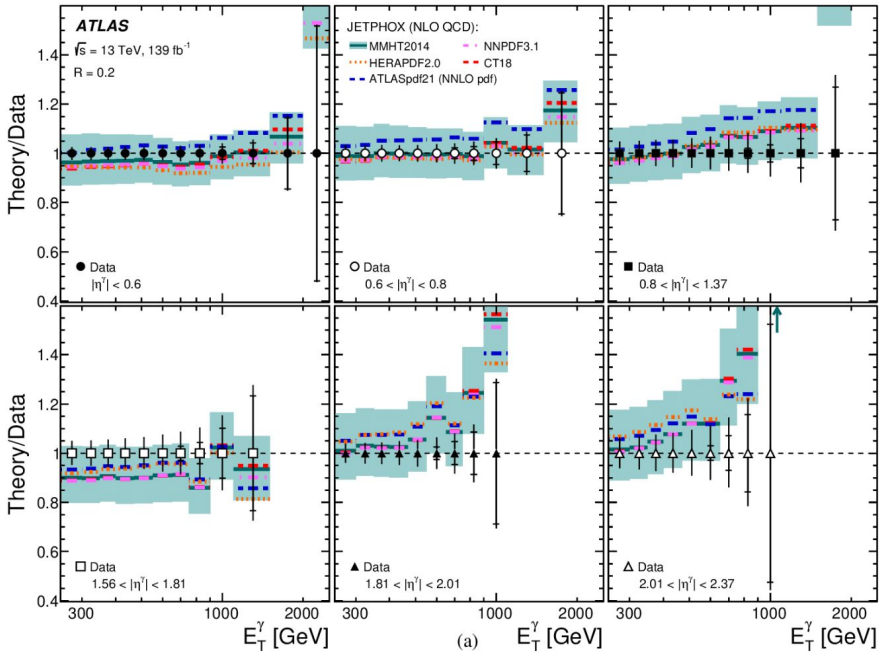


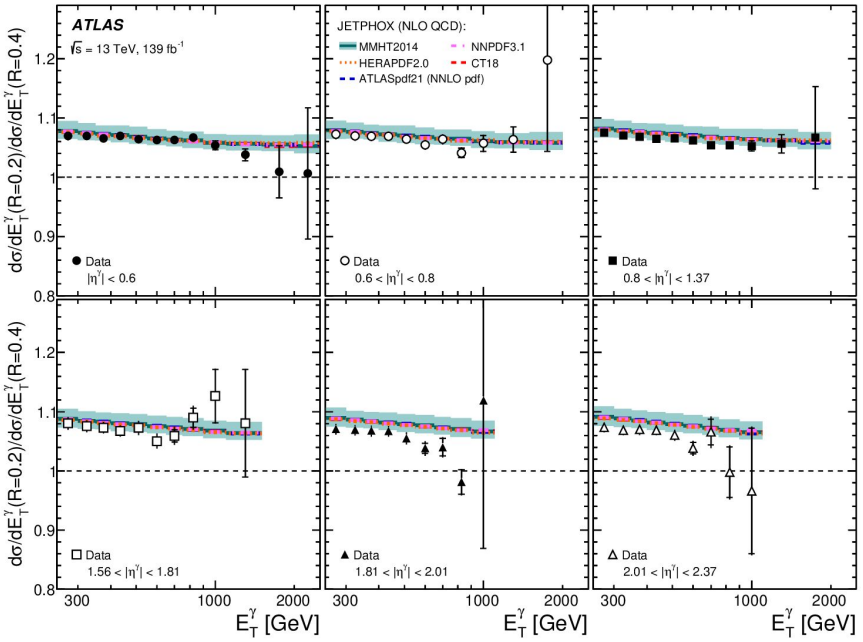


→ Measurement precise enough to distinguish between state-of-the-art predictions

Inclusive Photon Production

arXiv:2302.00510





→ Fine granularity in η^{γ} enhances sensitivity to PDFs

→ No PDF dependence for *Xsec ratio* as a function of isolation cone radius (R) ;
Reduced uncertainties provide stringent test of pQCD

W + Charm

arXiv:2302.00336

Considered decay modes (+ charge conjugates)

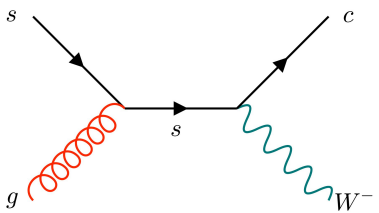
- $D^+ \to K^-\pi^+\pi^+$
- $D^{*+} \to D^0\pi^+ \to (K^-\pi^+)\pi^+$

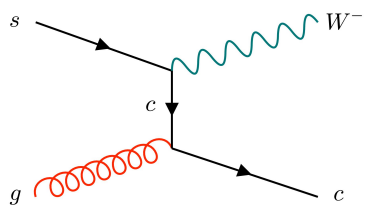
$\to W^+D^{(*)}$ signal extracted through profile likelihood fit

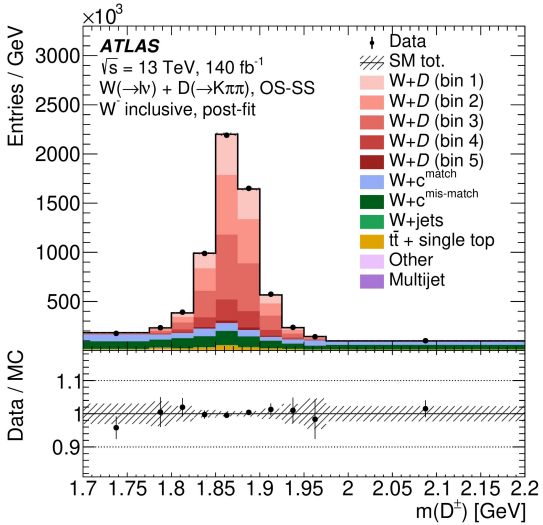
- D^+: reconstructed secondary-vertex mass distribution
- D^{*+}: mass difference $m(D^{*+}-D^0)$

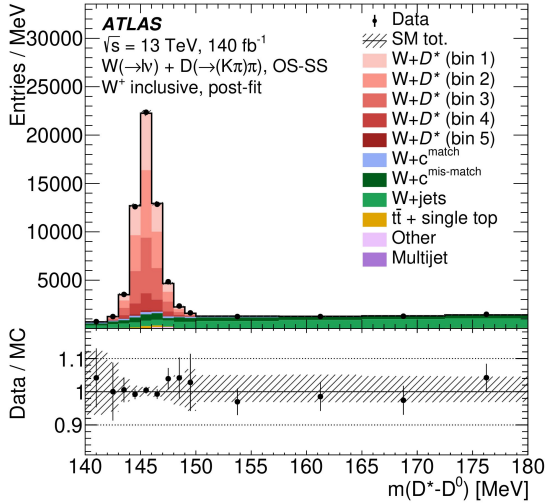
(also unfolds for detector effects)

$\to$ Main backgrounds: single-W w/o $D^{(*)}$; $t\bar{t}$; Multijet (data-driven)





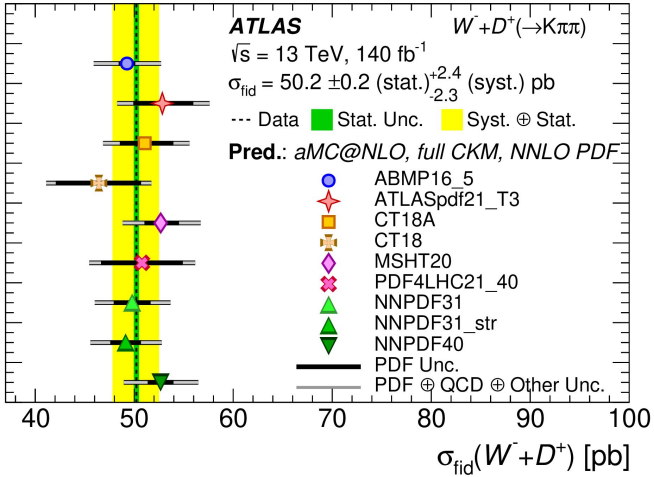


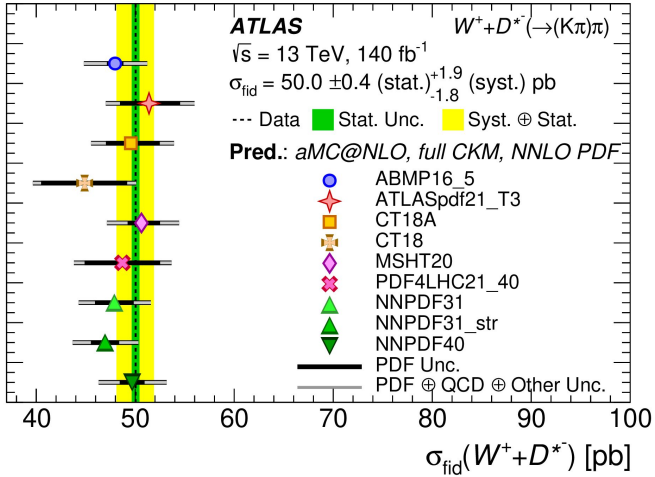


Channel	$\sigma_{\text{fid}}^{\text{OS-SS}}(W+D^{(*)}) \times B(W \to \ell\nu)$ [pb]
W^-+D^+	50.2 ± 0.2 (stat.) $^{+2.4}_{-2.3}$ (syst.)
W^++D^-	48.5 ± 0.2 (stat.) $^{+2.3}_{-2.2}$ (syst.)
W^-+D^{*+}	51.1 ± 0.4 (stat.) $^{+1.9}_{-1.8}$ (syst.)
W^++D^{*-}	50.0 ± 0.4 (stat.) $^{+1.9}_{-1.8}$ (syst.)
	$R_c^{\pm} = \sigma_{\text{fid}}^{\text{OS-SS}}(W^++D^{(*)})/\sigma_{\text{fid}}^{\text{OS-SS}}(W^-+D^{(*)})$
$R_c^{\pm}(D^+)$	0.965 ± 0.007 (stat.) ± 0.012 (syst.)
$R_c^{\pm}(D^{*+})$	0.980 ± 0.010 (stat.) ± 0.013 (syst.)
$R_c^{\pm}(D^{(*)})$	0.971 ± 0.006 (stat.) ± 0.011 (syst.)

W + Charm

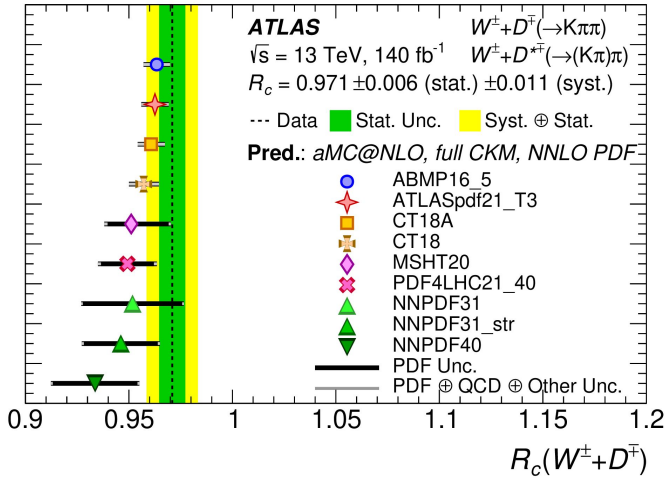
arXiv:2302.00336





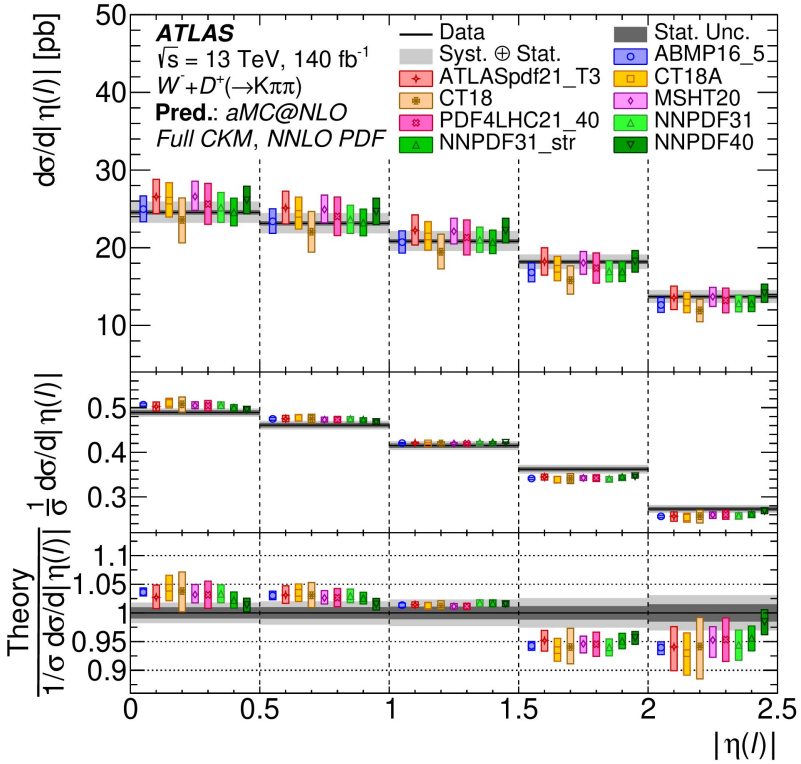
→ Fiducial cross-sections: experimental precision (syst.-dominated) comparable to the PDF uncertainties (smaller than the total NLO theory uncertainty); Data-theory agreement for all PDFs

→ $R_c^{\pm}$: comparable statistical and systematic uncertainties; PDFs imposing symmetric strange-sea ($s = \bar{s}$) have smaller uncertainties and are consistent with the measurement: s - $\bar{s}$ asymmetry small in the probed Bjorken-x region



W + Charm

arXiv:2302.00336



→ Measured differential p_T (backup) and $|\eta(l)|$ distributions;

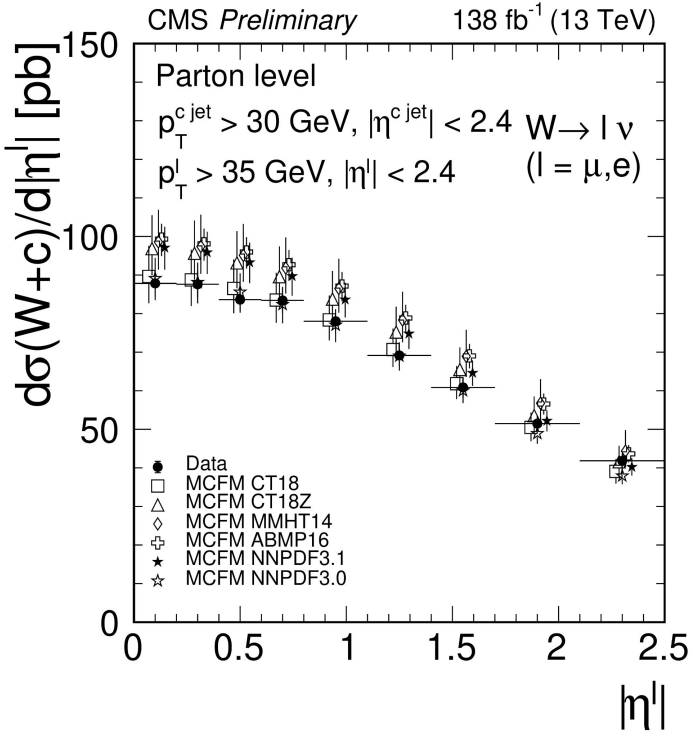
$|\eta(l)|$: good sensitivity to PDF variations (small experimental systematic uncertainties and highly correlated among bins)

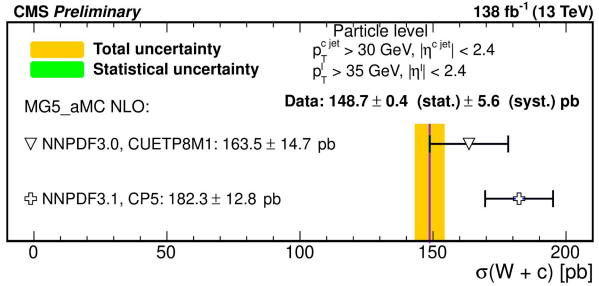
W + Charm

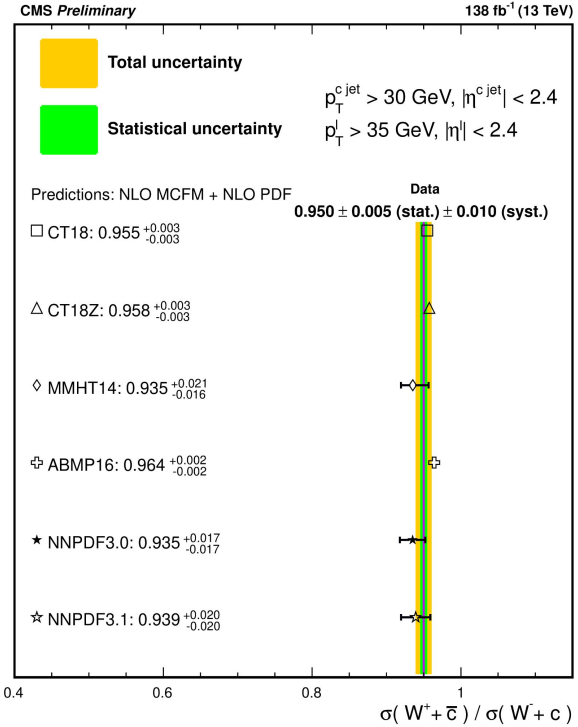
CMS-PAS-21-005

→ Charm jets tagged by the presence of a muon or a secondary vertex inside the jet

→ Measurement unfolded to particle and parton levels





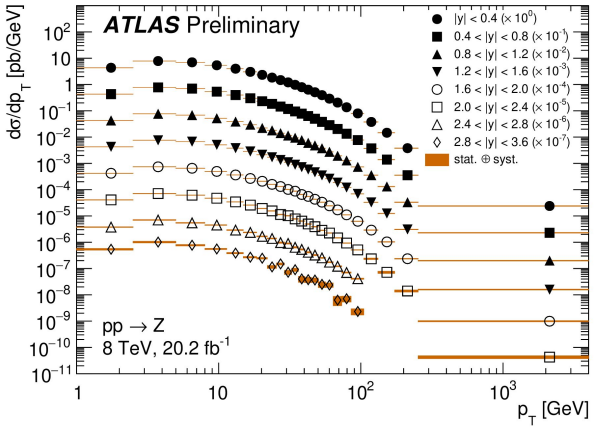


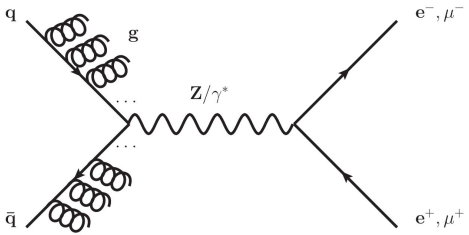
→ Good sensitivity to PDF variations

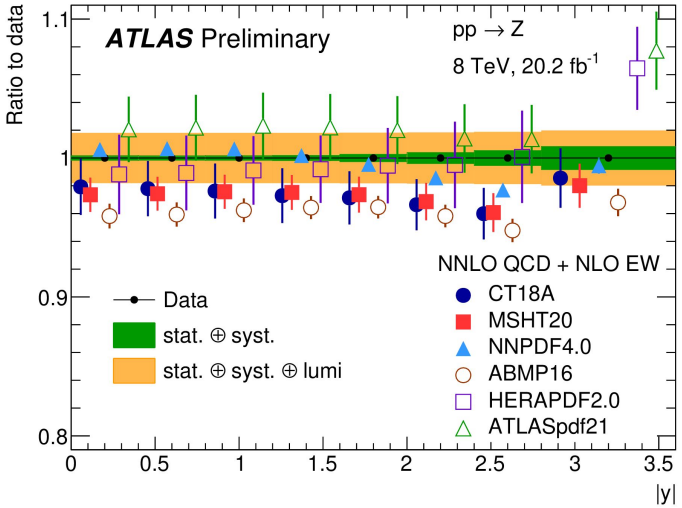
See next talk by Stefanos Leontsinis

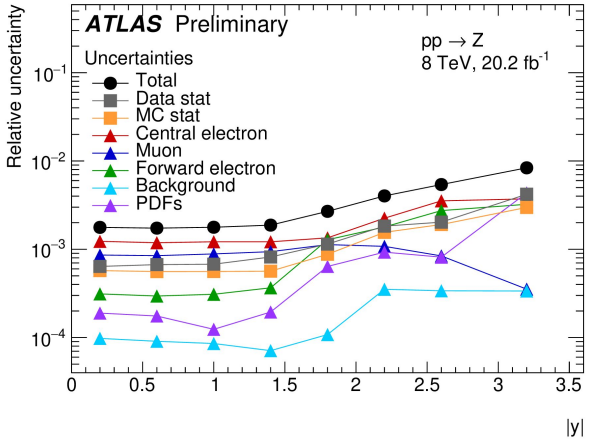
$p_T(Z)$ Cross-Section and α_S

ATLAS-CONF-2023-013
ATLAS-CONF-2023-015









→ Double-differential measurement in (p_T, $|y|$) of absolute and normalised cross-sections at the Z pole, within the full phase space of the decay leptons (based on spherical harmonics x A_i)

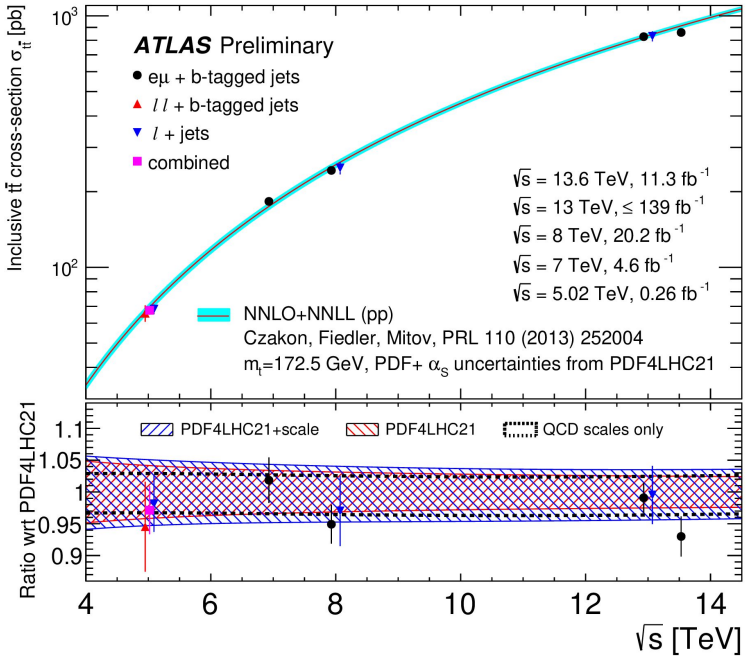
→ Negligible theoretical uncertainties

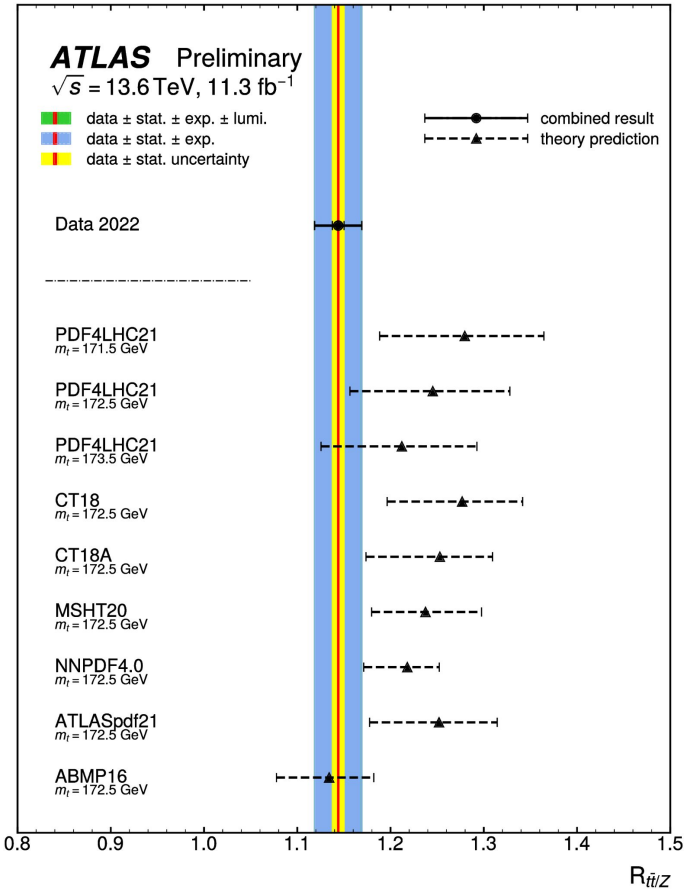
→ Sensitive to α_S (*most precise experimental determination*) and PDFs

See talks by Fabrice Balli and Xingguo Li

$t\bar{t}$ / Z Cross-Section Ratio at 13.6 TeV (Run 3)

ATLAS-CONF-2023-006





$$\sigma_{t\bar{t}} = 859 \pm 4(\text{stat.}) \pm 22(\text{syst.}) \pm 19(\text{lumi.})\text{pb},$$

$$\sigma^{\text{fid.}}_{Z\to\ell\ell} = 751 \pm 0.3(\text{stat.}) \pm 15(\text{syst.}) \pm 17(\text{lumi.})\text{pb},$$

$$R_{t\bar{t}/Z} = 1.144 \pm 0.006(\text{stat.}) \pm 0.022(\text{syst.}) \pm 0.003(\text{lumi.})$$

→ Cross-section ratio (taking into account the correlations) allows to reduce systematic uncertainties

→ Sensitive to PDFs

Summary and conclusions

The large luminosity collected by ATLAS & CMS at the LHC allows to perform precision measurements enabling the evaluation of α_S and constraining the proton PDFs
testing fundamental aspects of the Standard Model and studying its EFT-based extensions

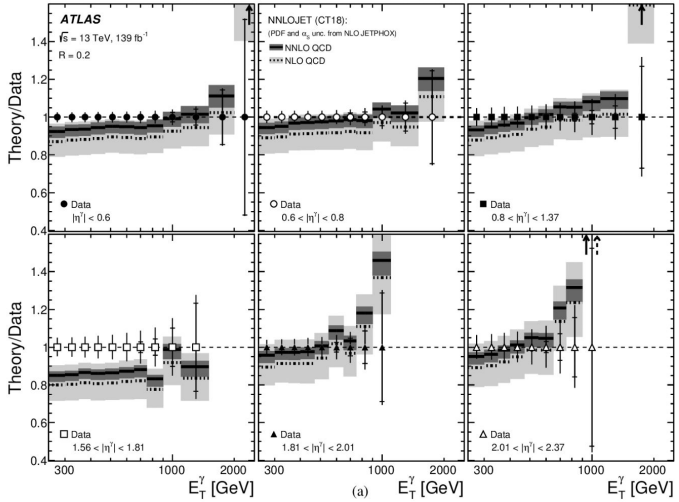
More results and further details on this amazing program in plenary / parallel session talks

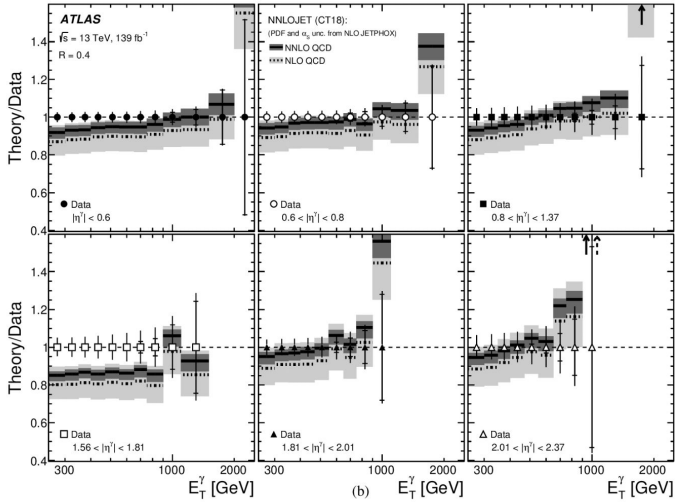
Thank you for listening !!!

Backup

Inclusive Photon Production

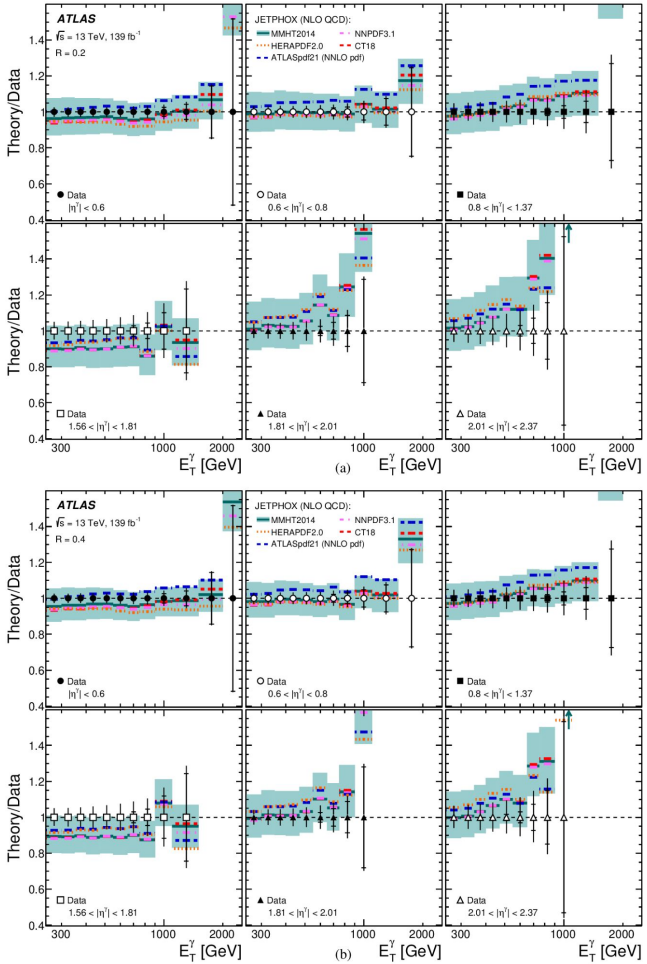
arXiv:2302.00510

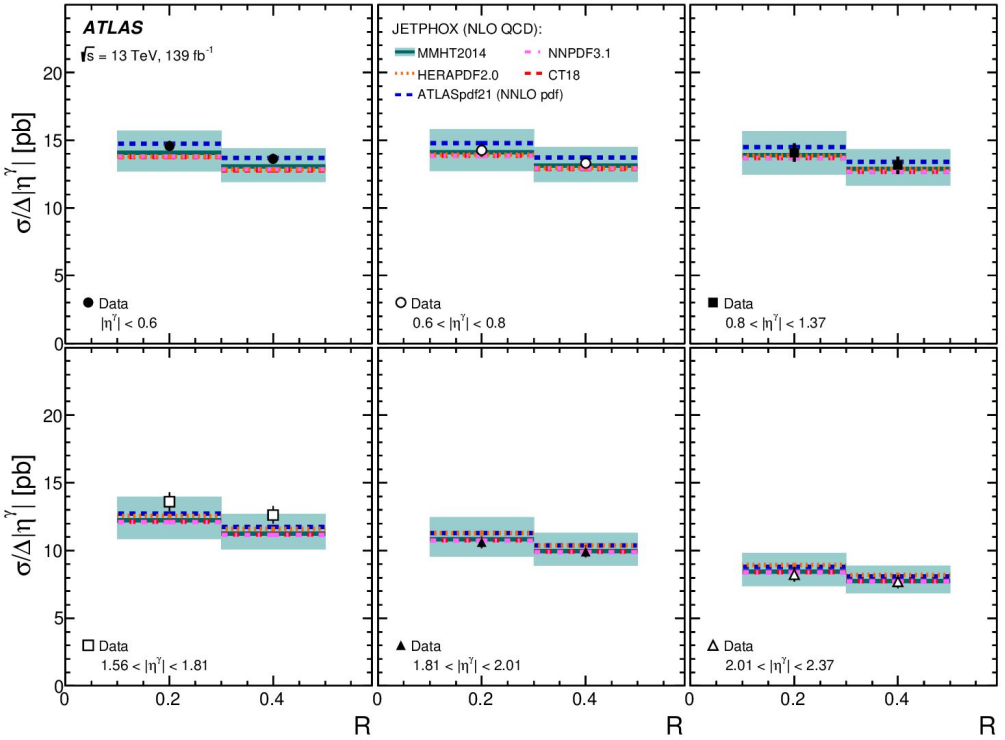




Inclusive Photon Production

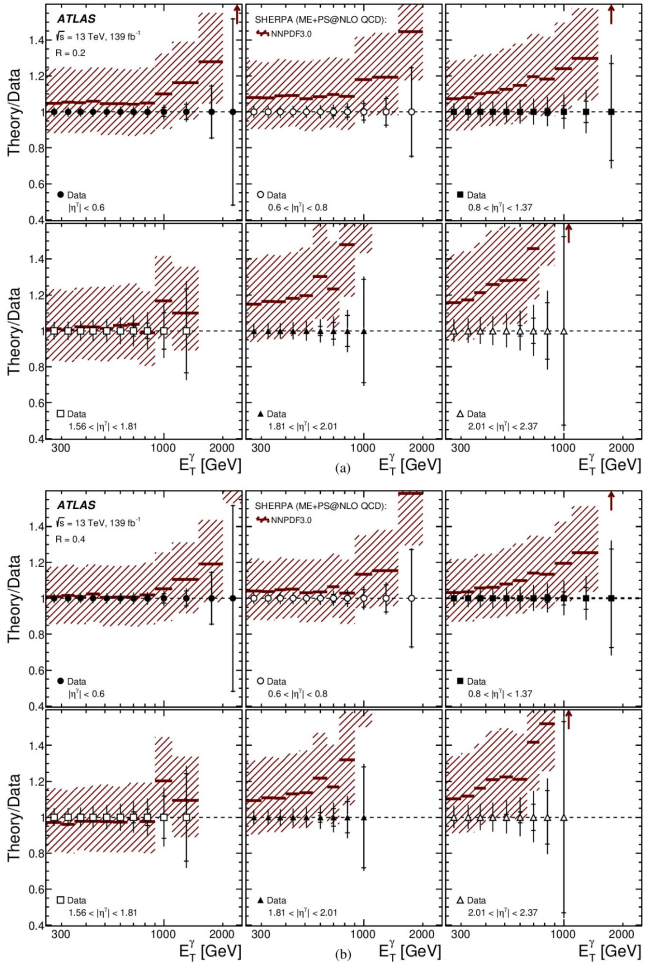
arXiv:2302.00510

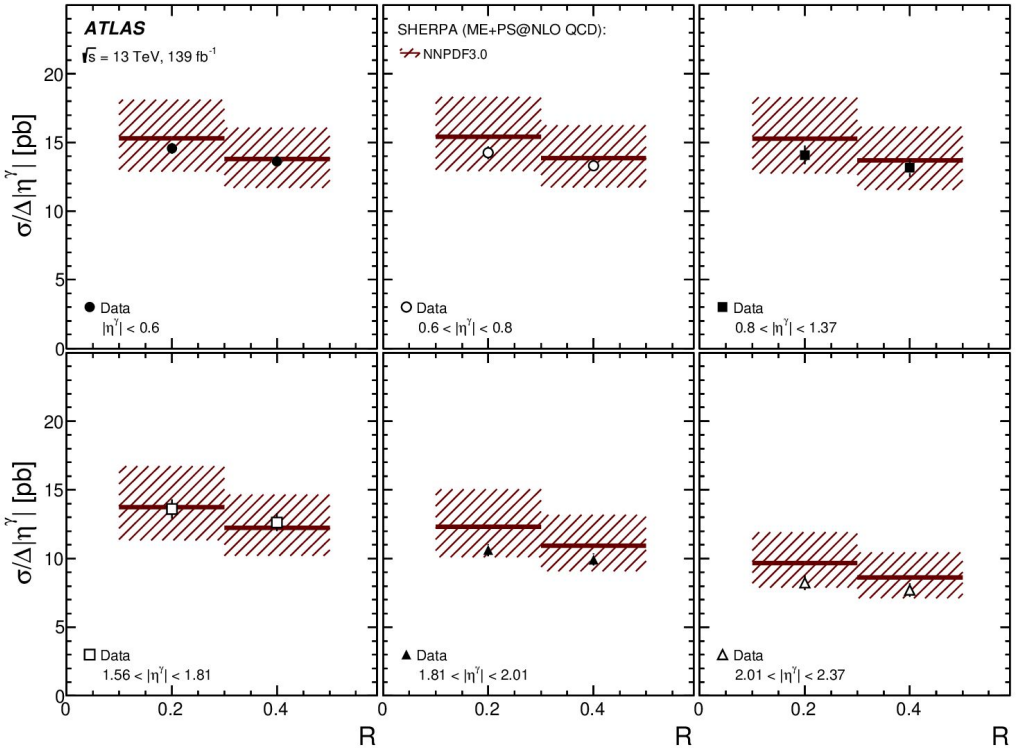




Inclusive Photon Production

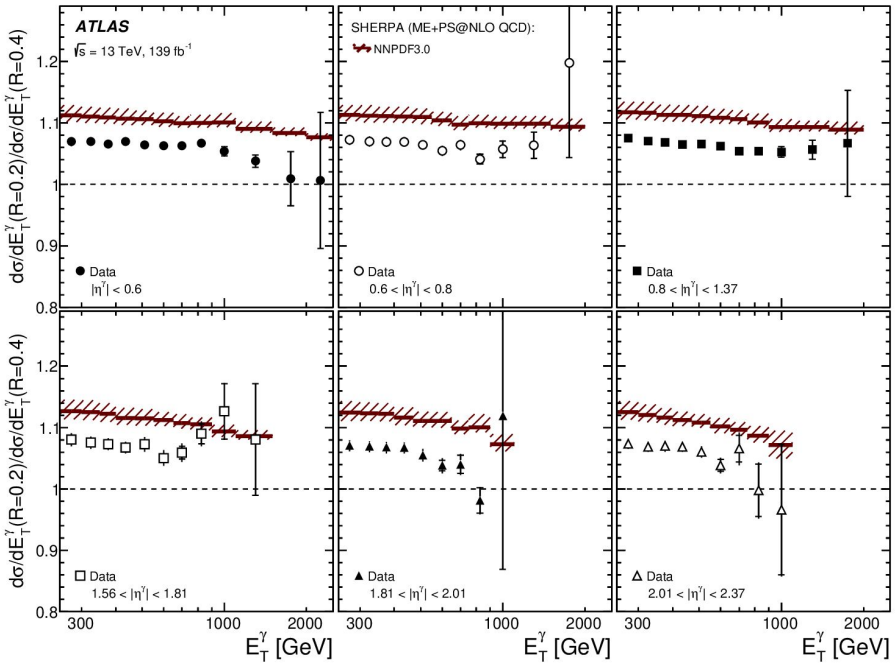
arXiv:2302.00510

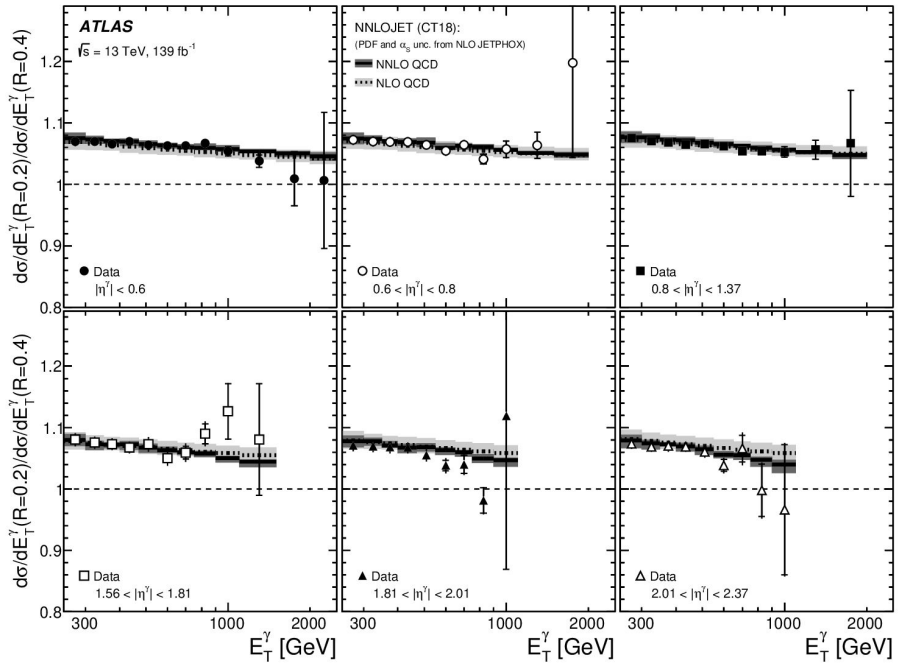




Inclusive Photon Production

arXiv:2302.00510



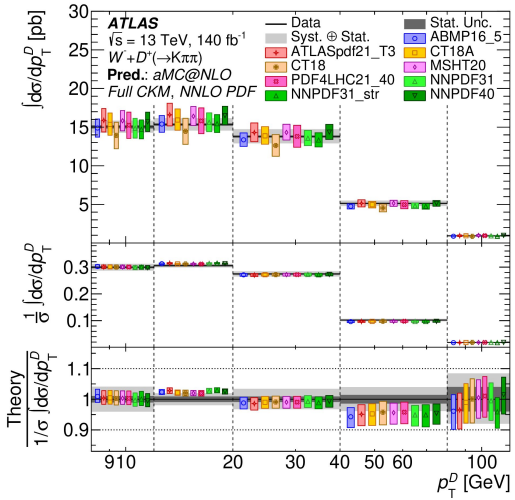


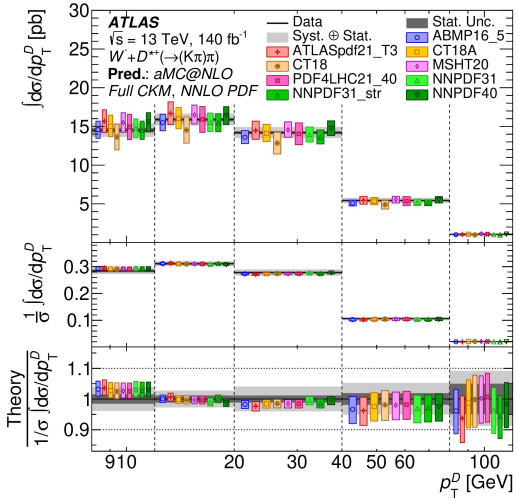
→ Sherpa systematically above measured for Xsec ratio as a function of isolation cone radius (R)

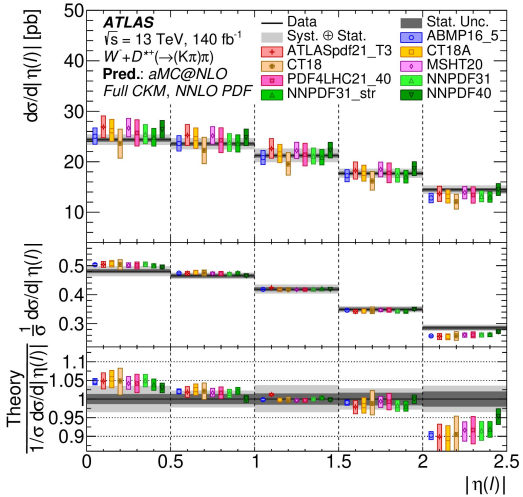
→ Good description by (N)NLO pQCD

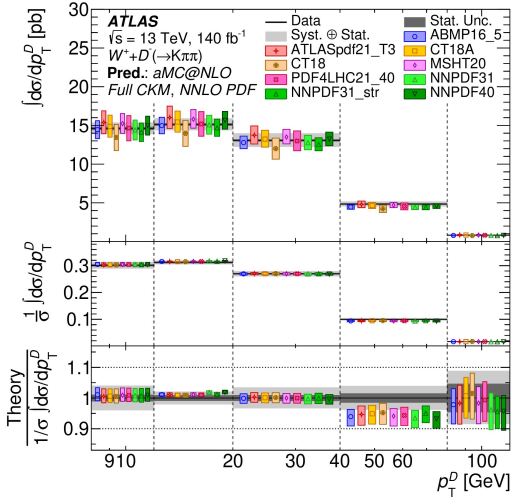
W + Charm

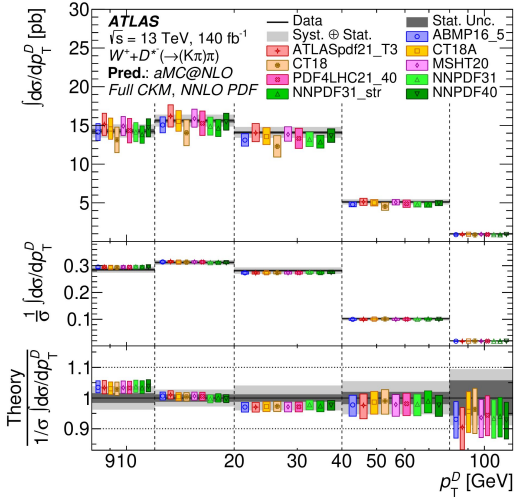
arXiv:2302.00336

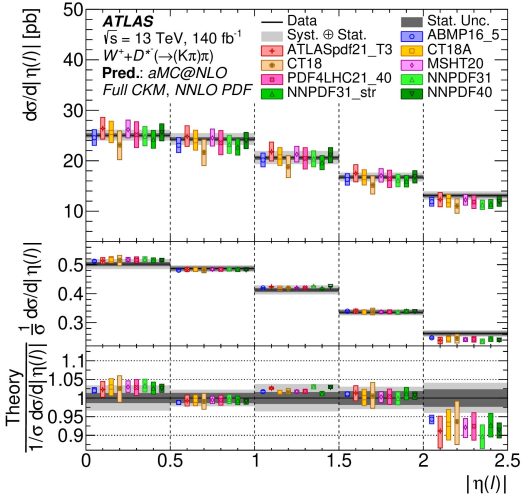






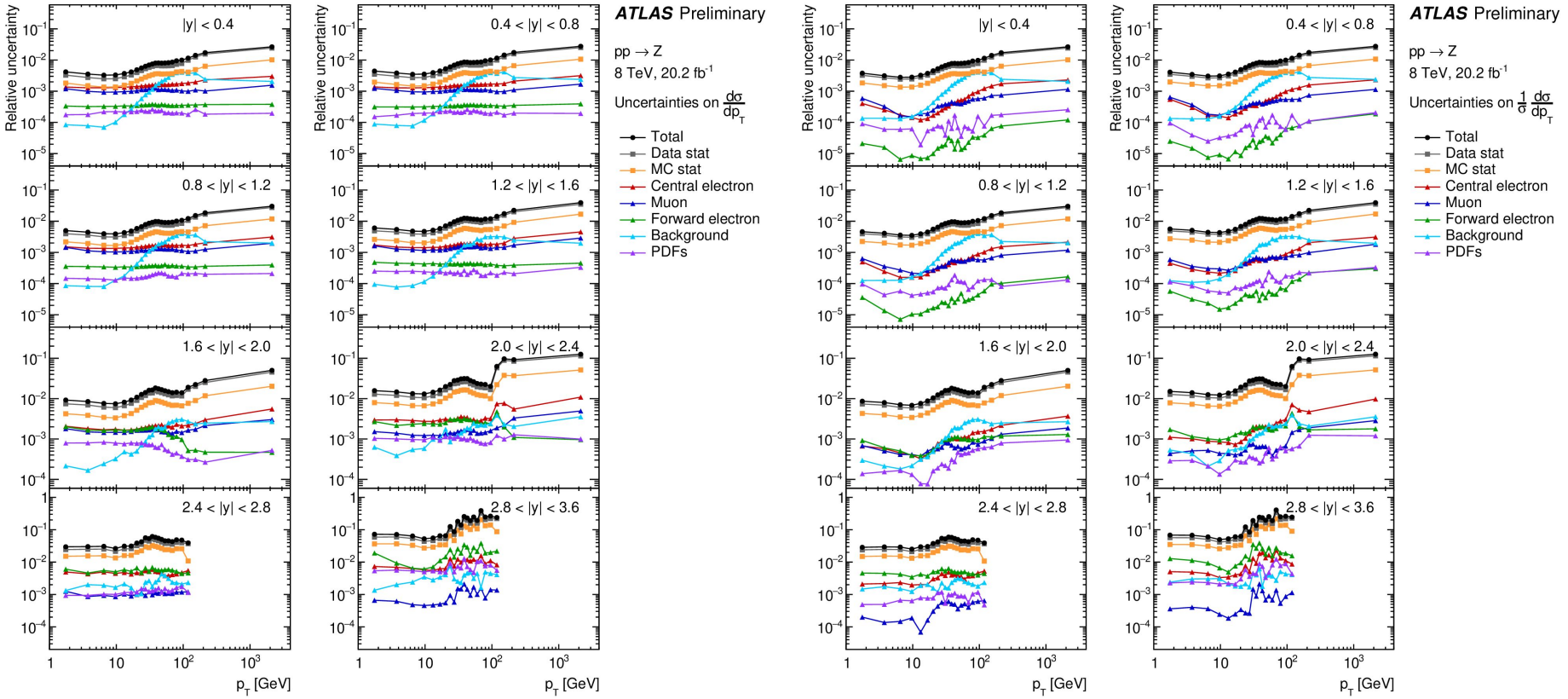






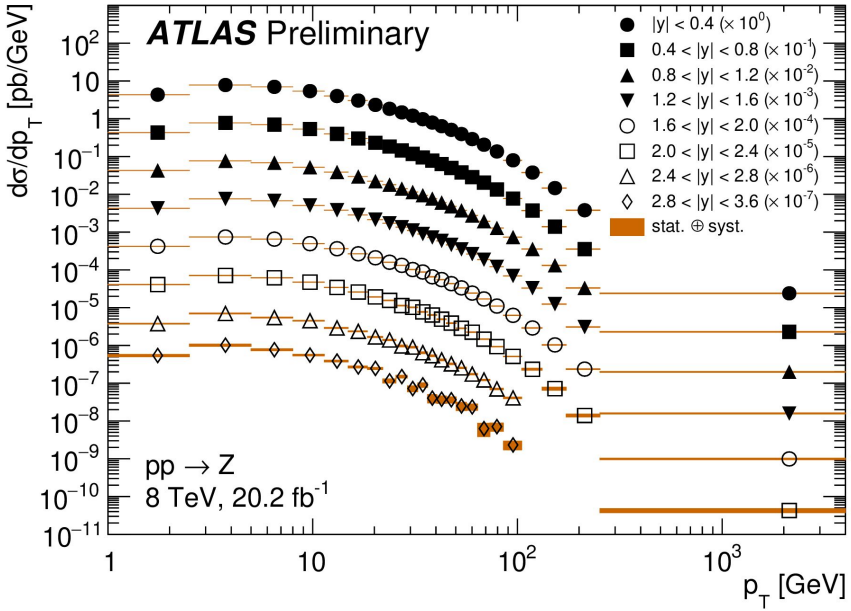
$p_T(Z)$ Cross-Section and α_S

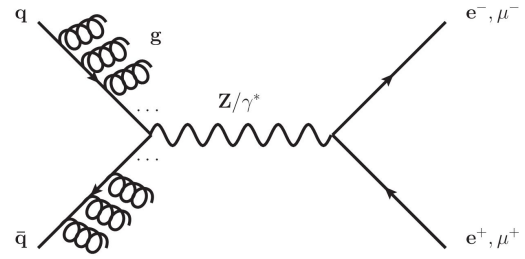
ATLAS-CONF-2023-013
ATLAS-CONF-2023-015

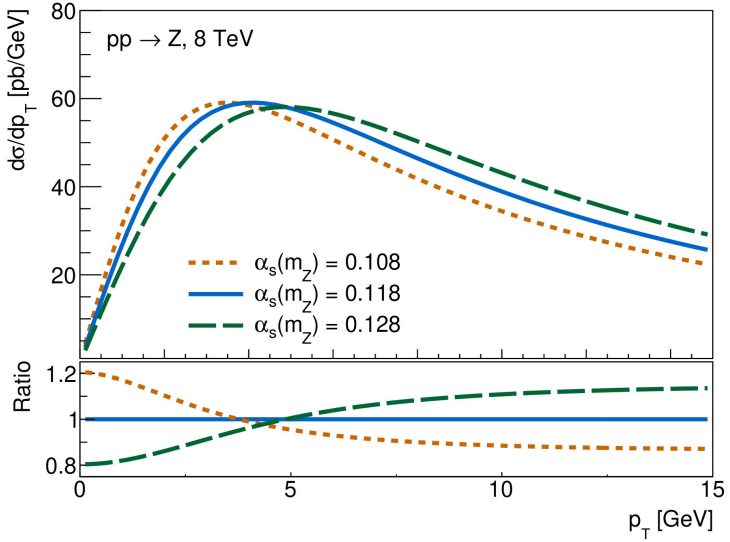


$p_T(Z)$ Cross-Section and α_S

ATLAS-CONF-2023-013
ATLAS-CONF-2023-015







→ Double-differential measurement sensitive to α_S (*most precise experimental determination*)