DIS2026

A Determination of the Top Mass from a Global PDF Analysis

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In collaboration with Richard D. Ball & Roy Stegeman

Based on [2603.28865]
submitted to JHEP

NNPDF

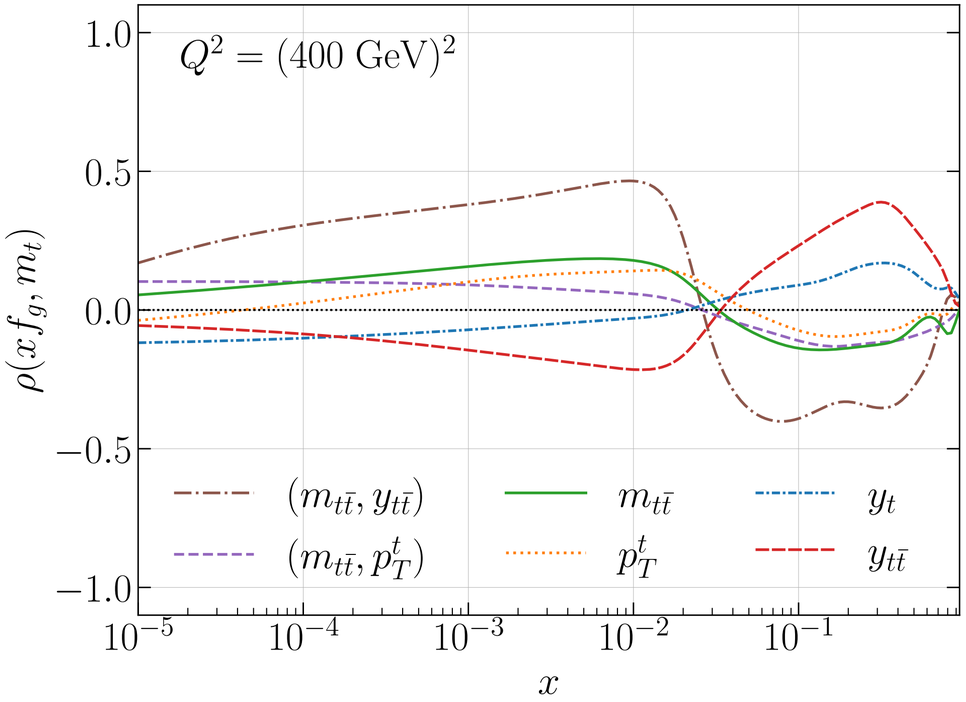
THE UNIVERSITY of EDINBURGH

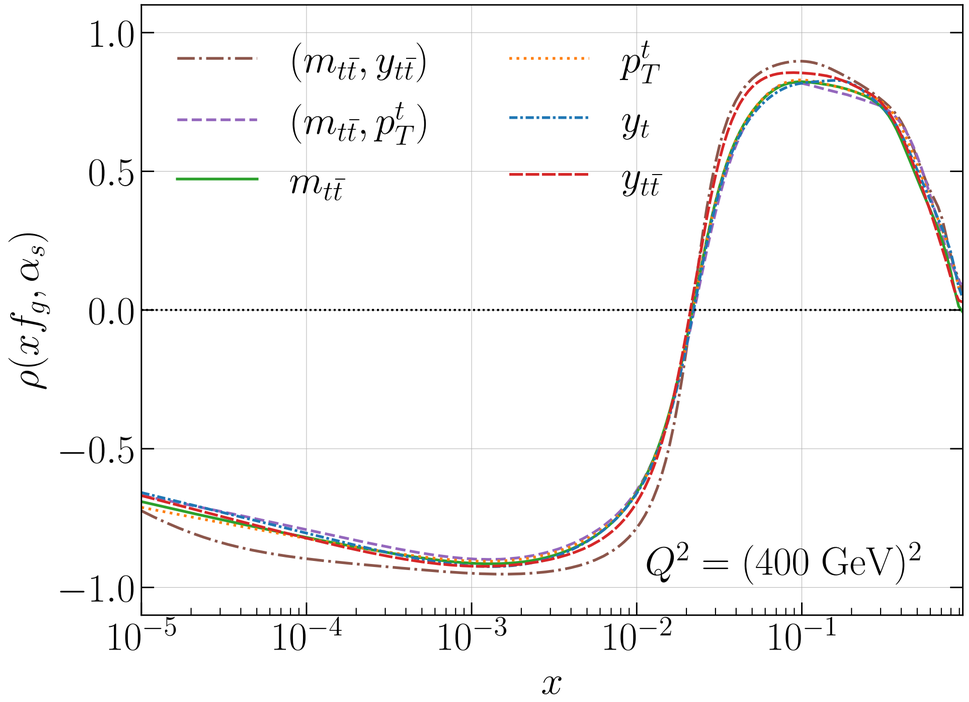
A global analysis

The top mass m_t and the strong coupling α_s are **strongly correlated** to the PDFs

making a simultaneous determination through a **global PDF fit** essential

failing to do so can lead to **biases** *[2001.04986], [2511.22561]*





Experimental data

Supplement the global **NNPDF4.0** dataset with a wide range of $t\bar{t}$ datasets from both ATLAS and CMS

Experiment and data set	**Observable**	$n_{\rm dat}$	$\mathcal{L}_{\rm int}$ [fb^{-1}]
ATLAS 13 TeV $t\bar{t}$ all hadr.	$d\sigma/dm_{t\bar{t}}$	9	36.1
	$d\sigma/d\lvert y_{t\bar{t}}\rvert$	12	
	$d^2\sigma/dm_{t\bar{t}}\, d\lvert y_{t\bar{t}}\rvert$	11	
ATLAS 13 TeV $t\bar{t}$ $\ell+j$	$d\sigma/dm_{t\bar{t}}$	9	36.0
	$d\sigma/dp_T^t$	8	
	$d\sigma/d\lvert y_t\rvert$	5	
	$d\sigma/d\lvert y_{t\bar{t}}\rvert$	7	
	$d^2\sigma/dm_{t\bar{t}}\, dp_T^t$	15	
ATLAS 8 TeV $t\bar{t}$ 2ℓ	$d\sigma/dm_{t\bar{t}}$	6	20.2
	$d\sigma/dy_{t\bar{t}}$	5	
ATLAS 8 TeV $t\bar{t}$ $\ell+j$	$d\sigma/dm_{t\bar{t}}$	7	20.3
	$d\sigma/dp_T^t$	8	
	$d\sigma/dy_t$	5	
	$d\sigma/dy_{t\bar{t}}$	5	

Experiment and data set	**Observable**	$n_{\rm dat}$	$\mathcal{L}_{\rm int}$ [fb^{-1}]
CMS 13 TeV $t\bar{t}$ 2ℓ 138 fb^{-1}	$d\sigma/dm_{t\bar{t}}$	7	138.0
	$d^2\sigma/dm_{t\bar{t}}\, d\lvert y_{t\bar{t}}\rvert$	16	
	$d\sigma/dp_T^t$	7	
	$d\sigma/d\lvert y_t\rvert$	10	
CMS 13 TeV $t\bar{t}$ 2ℓ	$d\sigma/dm_{t\bar{t}}$	7	35.9
	$d\sigma/dp_T^t$	6	
	$d\sigma/d\lvert y_t\rvert$	10	
	$d\sigma/d\lvert y_{t\bar{t}}\rvert$	10	
CMS 13 TeV $t\bar{t}$ $\ell+j$	$d\sigma/dm_{t\bar{t}}$	15	137.0
	$d^2\sigma/dm_{t\bar{t}}\, d\lvert y_{t\bar{t}}\rvert$	35	
	$d\sigma/dp_T^t$	16	
	$d\sigma/dy_t$	11	
	$d\sigma/dy_{t\bar{t}}$	10	

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Challenge: sensitivity to m_t is spectra dependent while cross correlations are not always available

Solution: perform separate m_t determinations for each observable

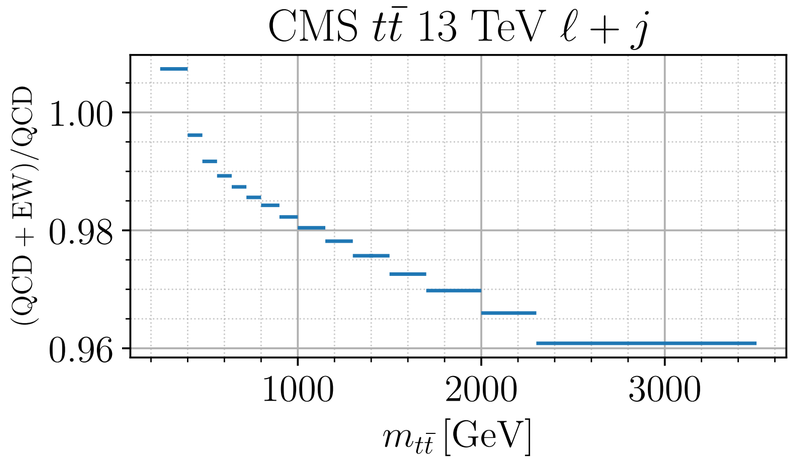
Same for CMS

Theory predictions

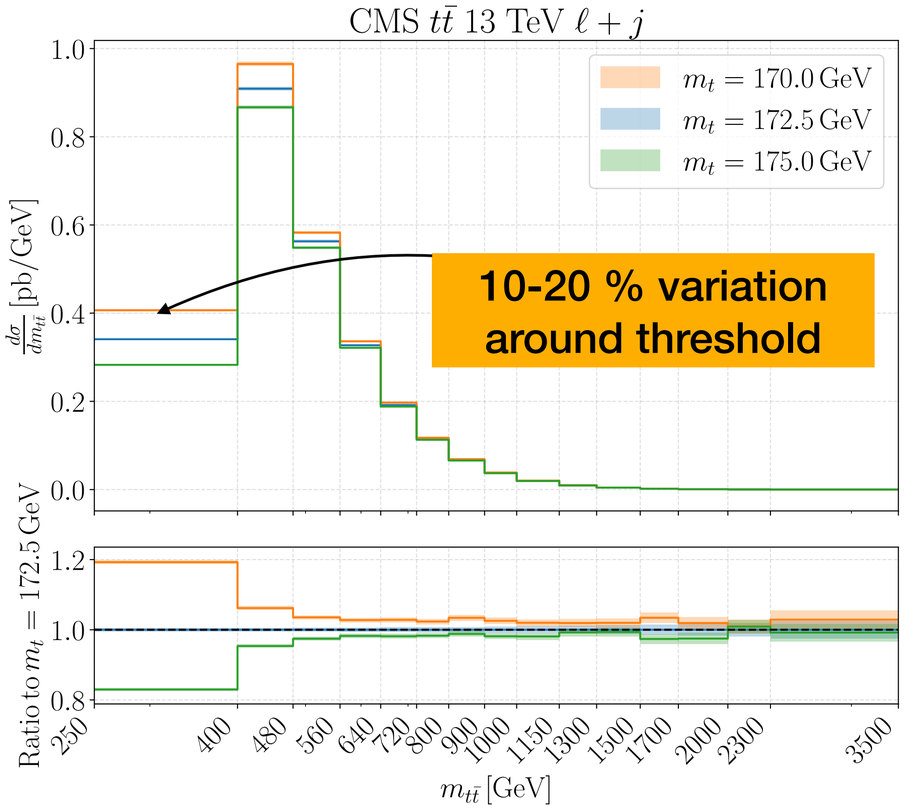
- We work with the pole-mass in the on-shell scheme
- State-of-the-art **NNLO QCD** differential $t\bar{t}$ predictions with MATRIX interfaced to PineAPPL complemented with **EW corrections** from MG5 with *[2506.14486]*

$$m_t^{\text{pole}} = 170.0, 172.5, 175.0\,\text{GeV}$$

- Include MHOUs by default



4% reduction wrt NNLO QCD



Closure testing the methodology

Ball, Pearson [2105.05114]

NNPDF collab. [2109.02653]

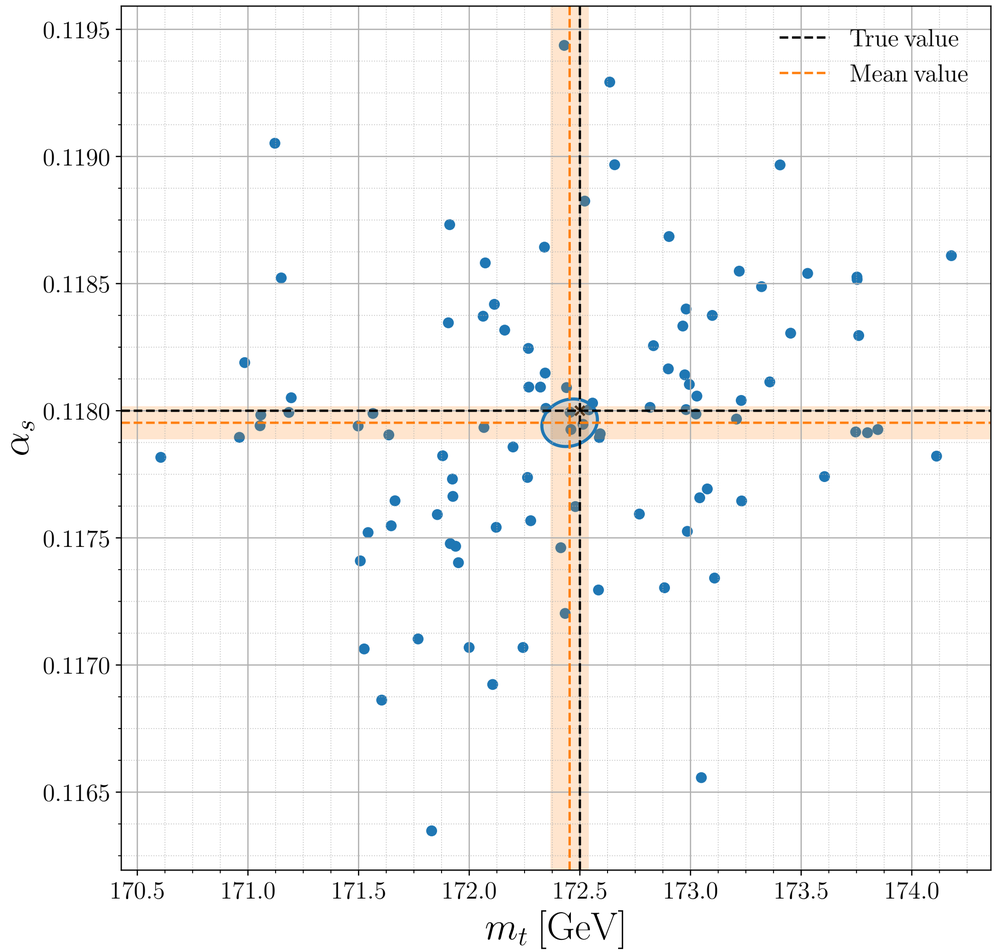
Ensure negligible bias in fitting methodology $\alpha_s^* = 0.118$ $m_t^* = 172.5$ GeV

1. $T(\alpha_s^*, m_t^*) = (f \otimes f)_{\text{true}} \otimes \hat{\sigma}_{\text{NNLO}}$

   $D = T + \eta$ ← *Noise: exp. + MHOUs*

2. Optimise $\chi^2(D, T)$ with cross-validation

3. Find α_s, m_t and repeat



The Top Mass at aN3LO with QED and EW Corrections

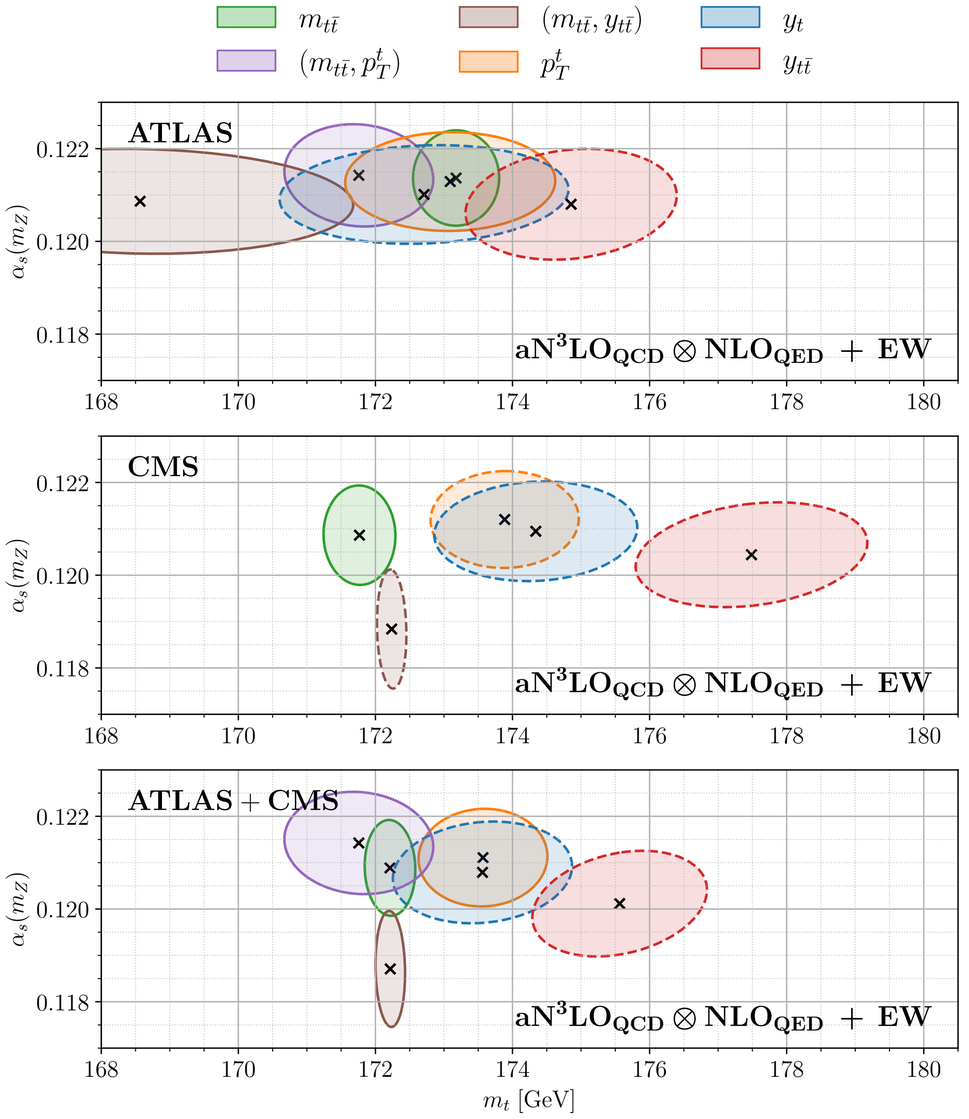
- Strong hierarchy in sensitivity to m_t across observables, $m_{t\bar{t}}$ **the most sensitive**

$$m_t = 172.21 \pm 0.24\,\text{GeV}$$

$$\chi^2 = 1.156$$

$$n_{\text{dat}} = 4587 \quad (53\ t\bar{t}\ \text{datapoints})$$

- No significant correlations except for rapidity dist.
- At this level of precision, **various small corrections become relevant**: N3LO, QED, EW, …, toponium?



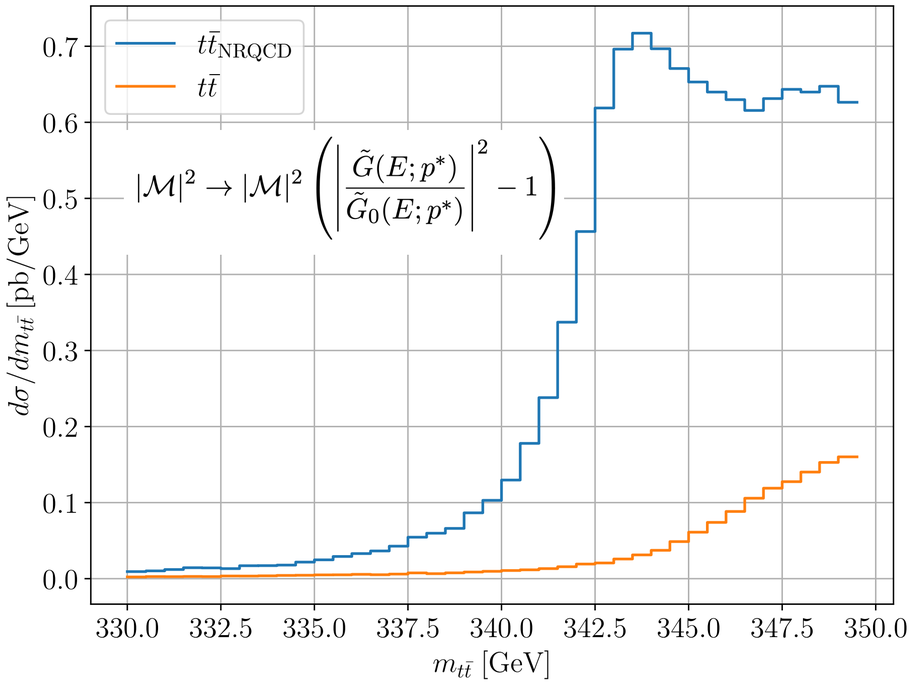
Excess at threshold, toponium?

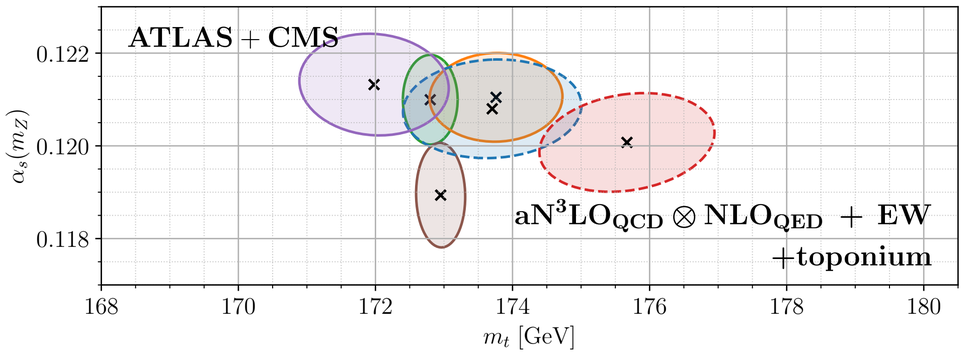
Model threshold excess with respect to the NNLO $t\bar{t}$ background using NRQCD *[2411.18962]*

- Included in the fit through a k-factor with a **50% theoretical uncertainty**
- Induces an upward shift of ~0.6 GeV in m_t

$$m_t = 172.80 \pm 0.26\,\text{GeV} \qquad \chi^2 = 1.079$$

- **Consistency** of results from wide variety of different observables - overlap within 1σ





Summary

- **Global** m_t determination within the NNPDF 4.0 framework, fully taking into account **correlations** to the PDFs and α_s
- Threshold corrections shift m_t up by 0.6 GeV in $m_{t\bar{t}}$ based extractions
- We find a very competitive uncertainty of $m_t = 172.80 \pm 0.26$ GeV with $\chi^2 = 1.079$

Thank you very much for your attention!

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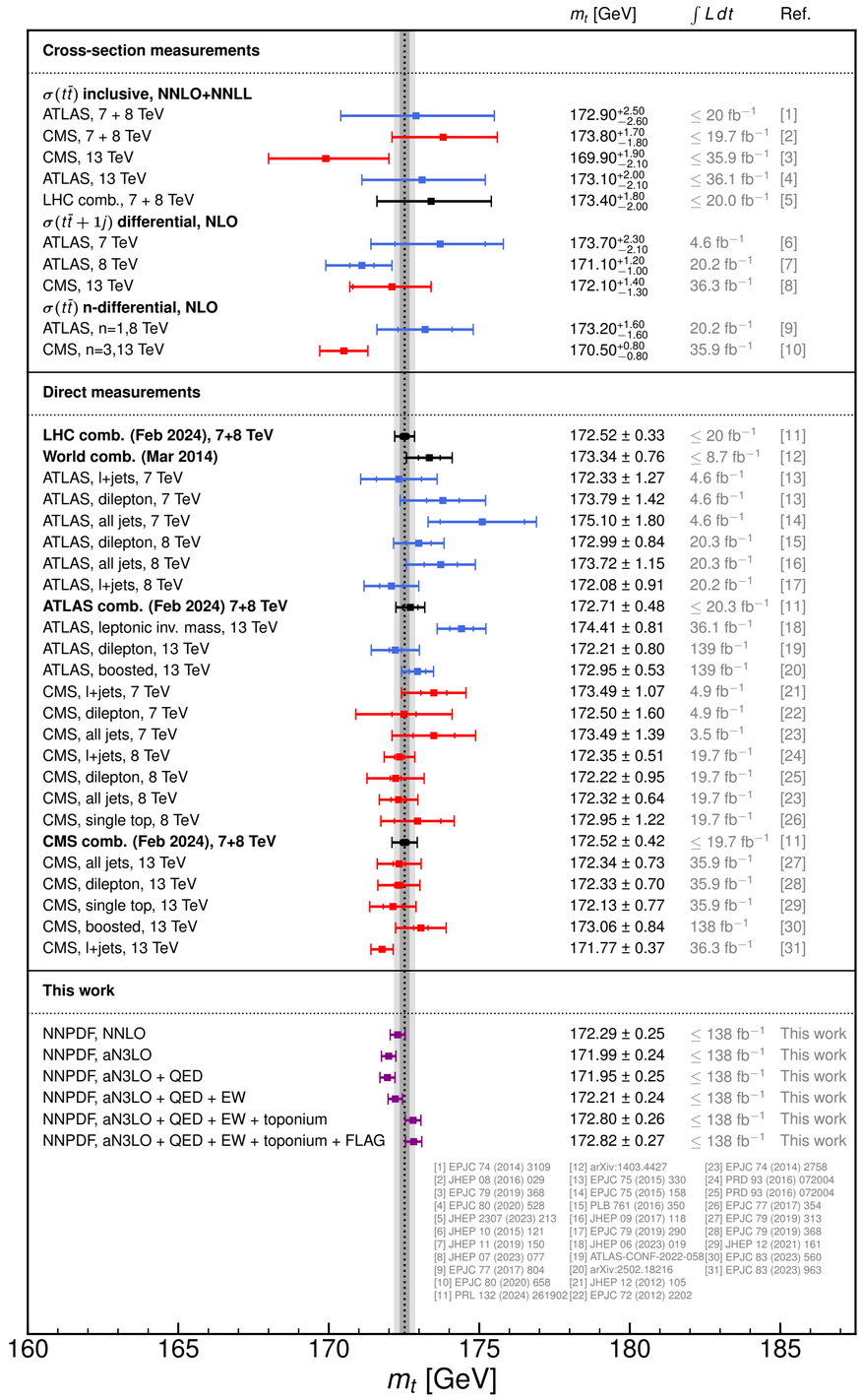


Backup

Summary

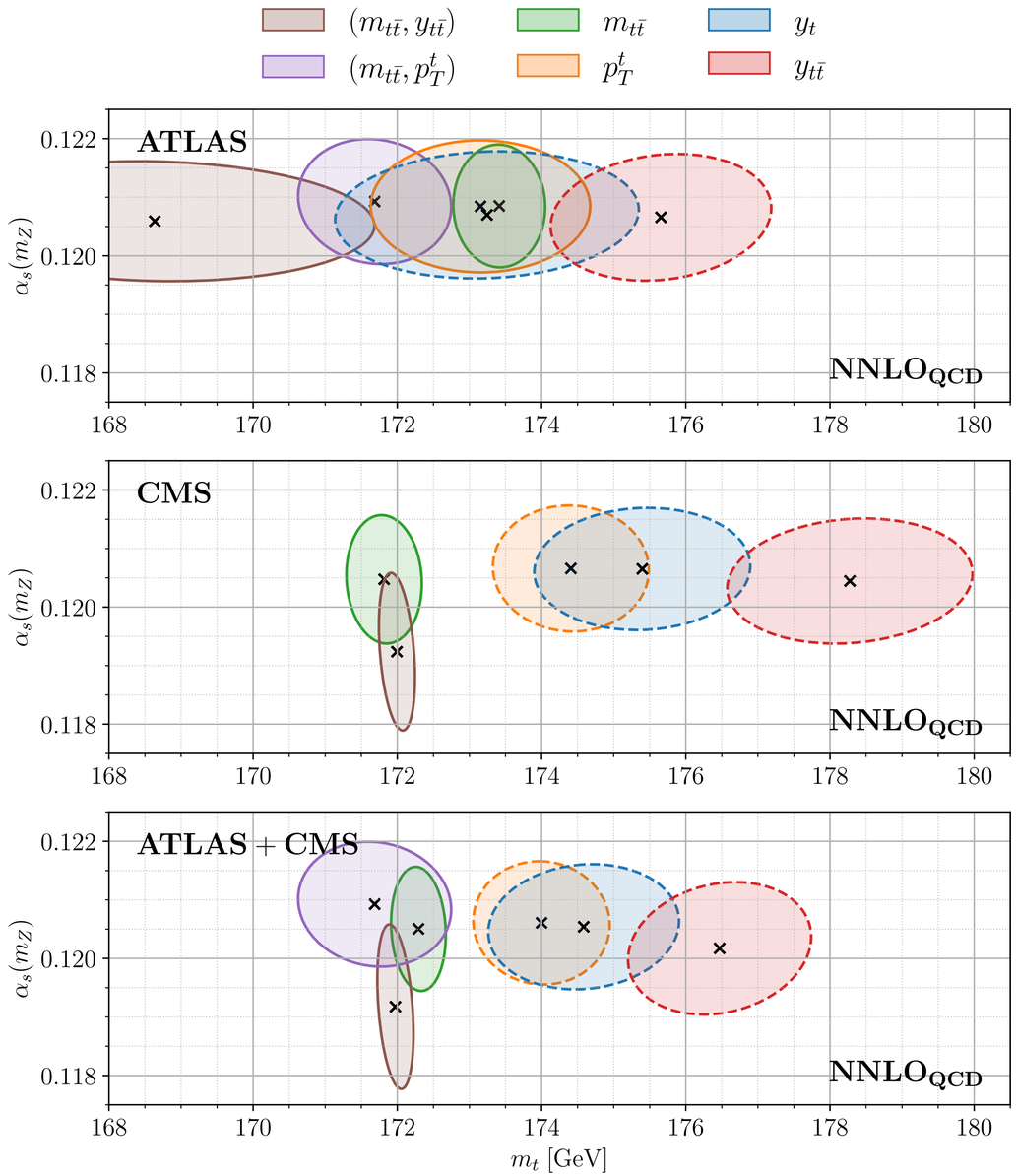
	$\mathbf{aN^3LO_{QCD} \otimes NLO_{QED}}$ $\mathbf{+ EW}$	$\mathbf{aN^3LO_{QCD} \otimes NLO_{QED}}$ $\mathbf{+ EW + topo.}$	$\mathbf{aN^3LO_{QCD} \otimes NLO_{QED}}$ $\mathbf{+ EW + topo. + FLAG}$
$m_{t\bar{t}}$	172.21 ± 0.24	172.80 ± 0.26	172.82 ± 0.27
p_T^t	173.57 ± 0.62	173.76 ± 0.64	173.77 ± 0.66
y_t	173.56 ± 0.87	173.70 ± 0.86	173.65 ± 0.88
$y_{t\bar{t}}$	175.56 ± 0.84	175.67 ± 0.85	175.71 ± 0.87
$(m_{t\bar{t}}, p_T^t)$	171.76 ± 0.72	171.98 ± 0.72	172.02 ± 0.74
$(m_{t\bar{t}}, y_{t\bar{t}})$	172.22 ± 0.14	172.95 ± 0.24	172.97 ± 0.25

Double differential dist $(m_{t\bar{t}}, y_{t\bar{t}})$ most sensitive to m_t

Toponium induces a significant upward shift in m_t

Lattice constraints on α_s do not shift m_t

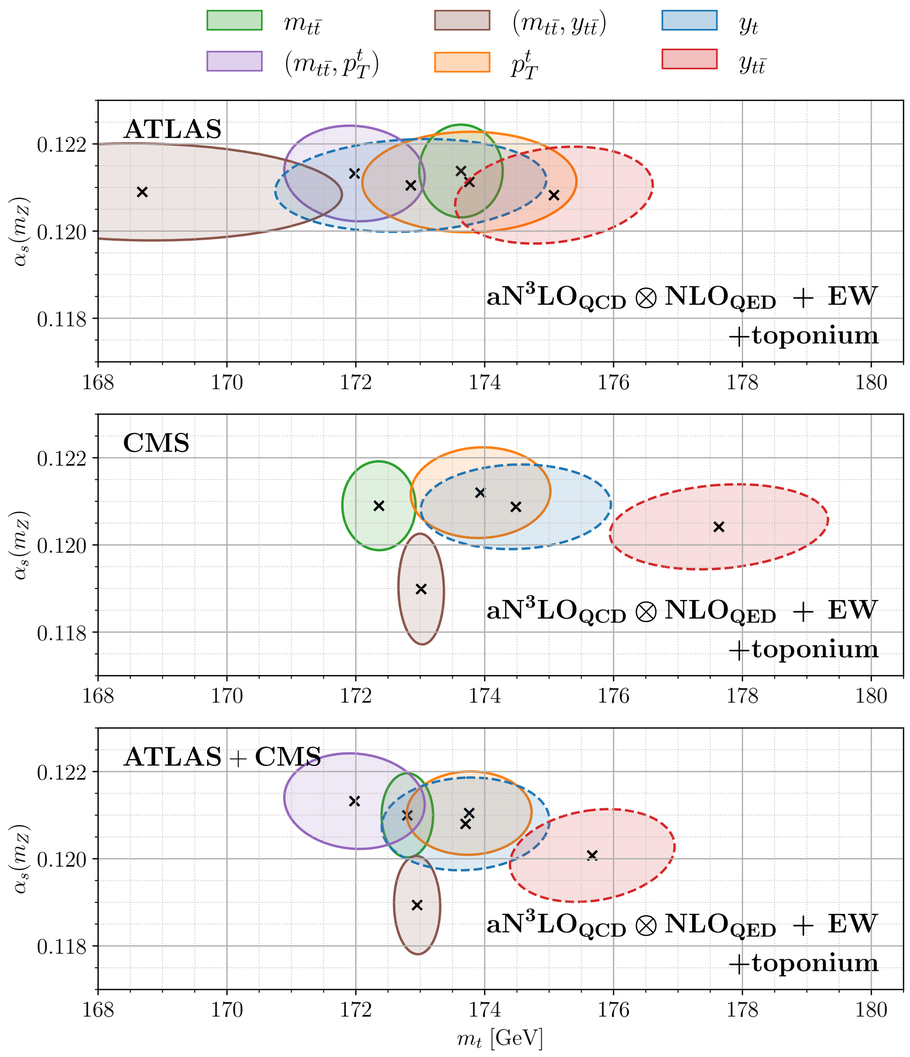
Top mass at NNLO + MHOU

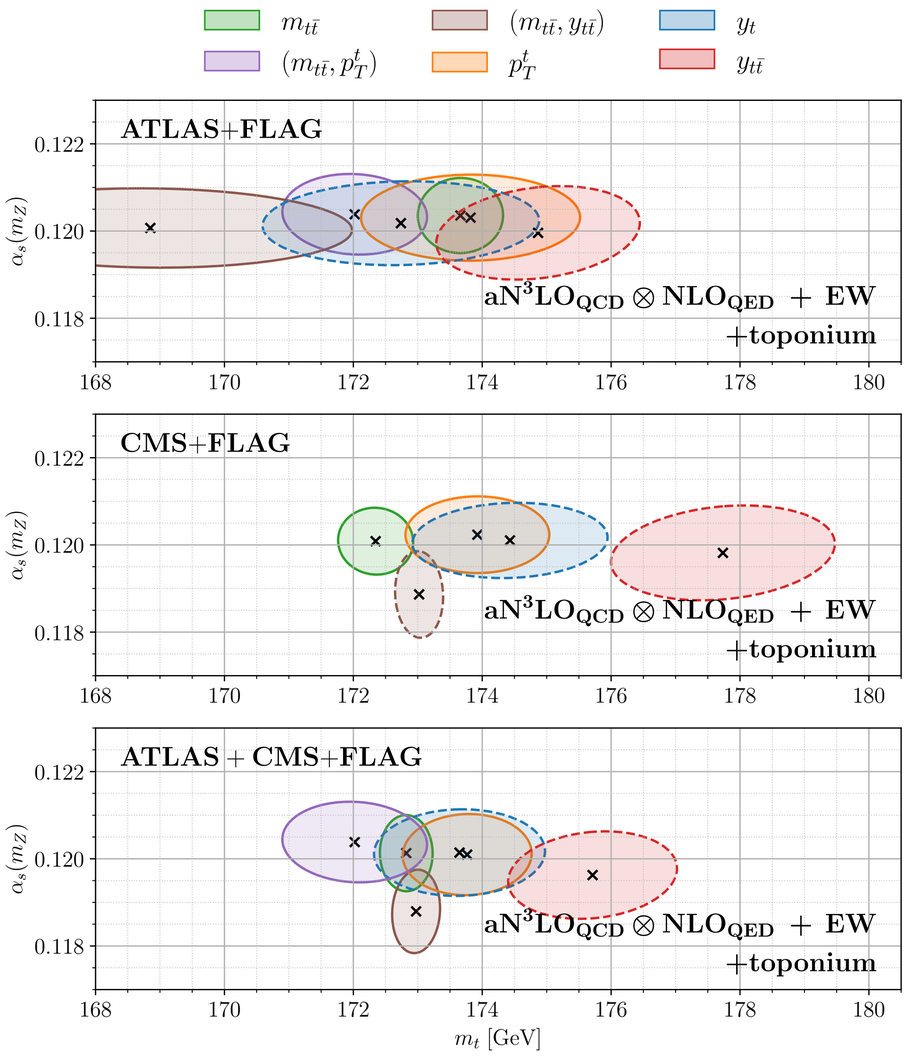


Correlations at NNLO + MHOU

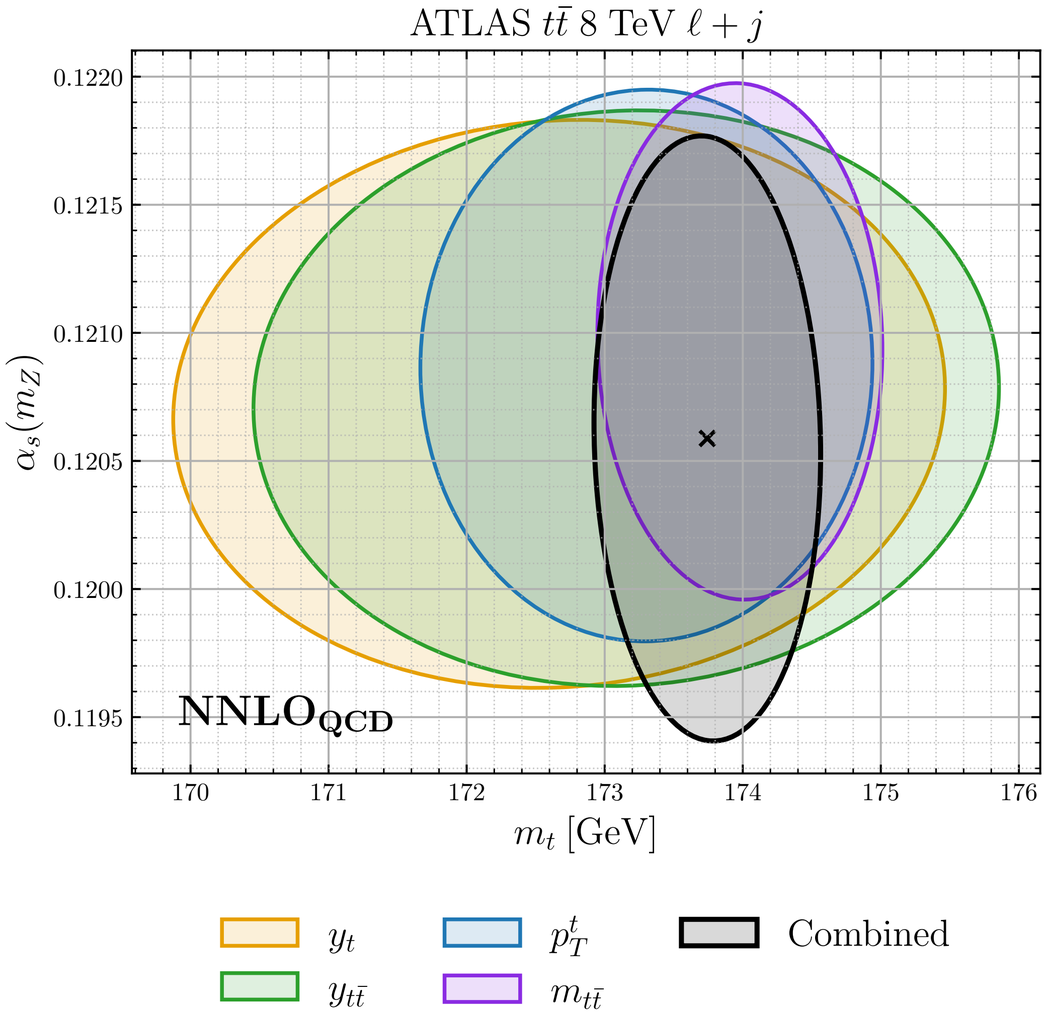
Observable	ATLAS	CMS	ATLAS + CMS
$(m_{t\bar{t}}, p_T^t)$	$m_t = 171.69 \pm 0.70$ $\alpha_s = 0.12093 \pm 0.00071$ $\rho = -0.086$		
$(m_{t\bar{t}}, y_{t\bar{t}})$	$m_t = 168.64 \pm 2.02$ $\alpha_s = 0.12059 \pm 0.00068$ $\rho = -0.073$	$m_t = 171.99 \pm 0.17$ $\alpha_s = 0.11924 \pm 0.00089$ $\rho = -0.324$	$m_t = 171.97 \pm 0.17$ $\alpha_s = 0.11918 \pm 0.00093$ $\rho = -0.329$
$m_{t\bar{t}}$	$m_t = 173.41 \pm 0.42$ $\alpha_s = 0.12085 \pm 0.00069$ $\rho = -0.017$	$m_t = 171.82 \pm 0.35$ $\alpha_s = 0.12047 \pm 0.00073$ $\rho = -0.068$	$m_t = 172.29 \pm 0.25$ $\alpha_s = 0.12050 \pm 0.00070$ $\rho = -0.100$
p_T^t	$m_t = 173.15 \pm 1.01$ $\alpha_s = 0.12084 \pm 0.00075$ $\rho = -0.000$	$m_t = 174.41 \pm 0.72$ $\alpha_s = 0.12066 \pm 0.00071$ $\rho = -0.026$	$m_t = 174.00 \pm 0.63$ $\alpha_s = 0.12061 \pm 0.00070$ $\rho = -0.032$
y_t	$m_t = 173.24 \pm 1.39$ $\alpha_s = 0.12070 \pm 0.00072$ $\rho = 0.080$	$m_t = 175.40 \pm 0.99$ $\alpha_s = 0.12065 \pm 0.00069$ $\rho = 0.050$	$m_t = 174.58 \pm 0.88$ $\alpha_s = 0.12054 \pm 0.00071$ $\rho = 0.089$
$y_{t\bar{t}}$	$m_t = 175.66 \pm 1.01$ $\alpha_s = 0.12066 \pm 0.00072$ $\rho = 0.146$	$m_t = 178.28 \pm 1.13$ $\alpha_s = 0.12045 \pm 0.00071$ $\rho = 0.119$	$m_t = 176.47 \pm 0.84$ $\alpha_s = 0.12017 \pm 0.00075$ $\rho = 0.173$

Lattice constraints on α_s do not shift m_t

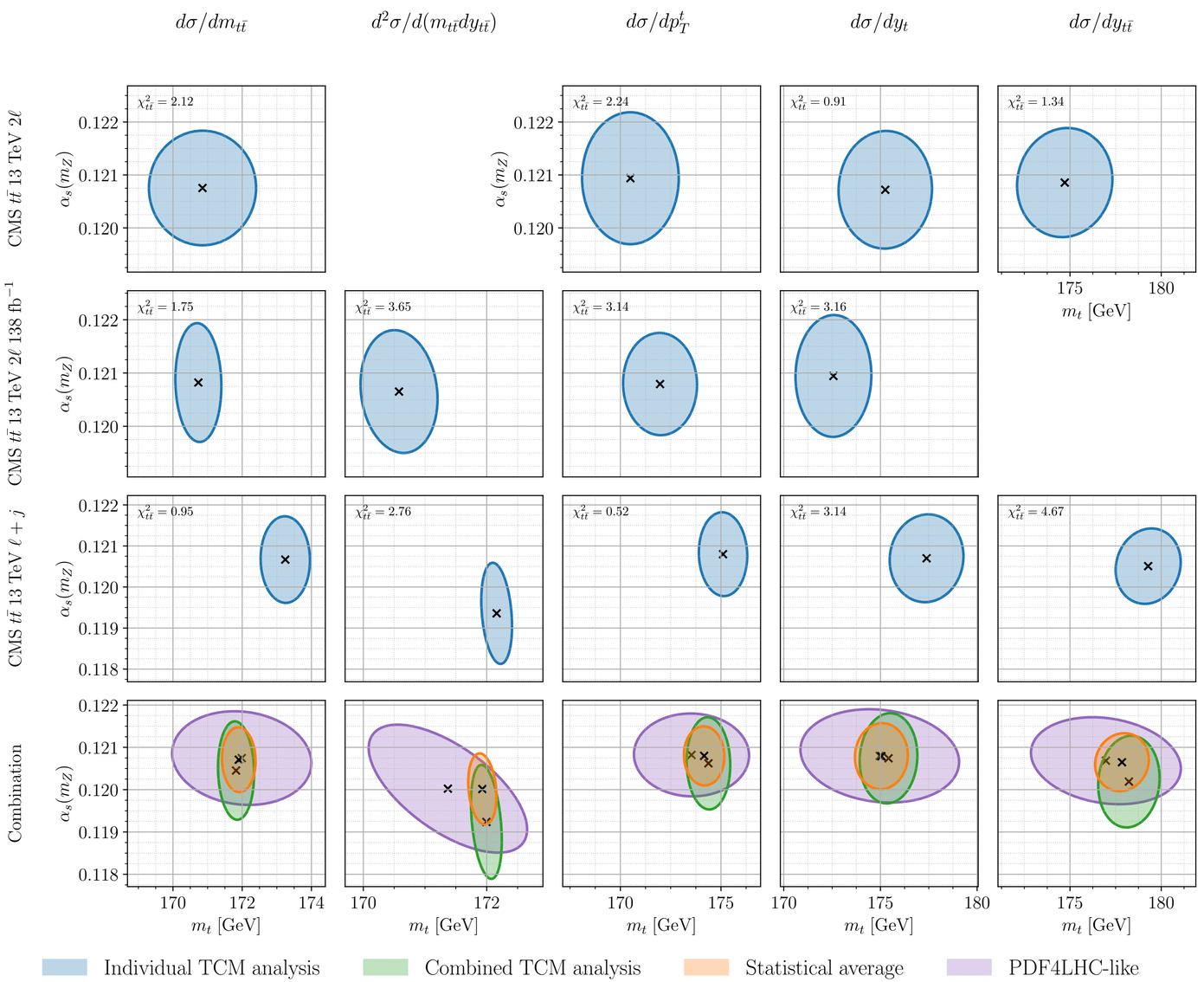




Interspectra correlations



Statistical combination - CMS

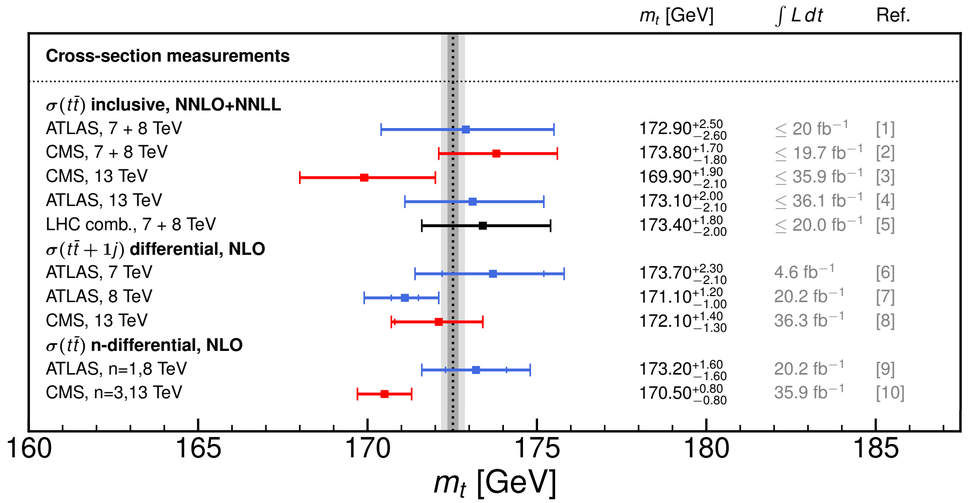


Determining the top mass

Cross-section based measurements

- Compare measured cross-sections to state-of-the-art theoretical predictions
- Pole mass (or $\overline{\mathrm{MS}}$ mass)

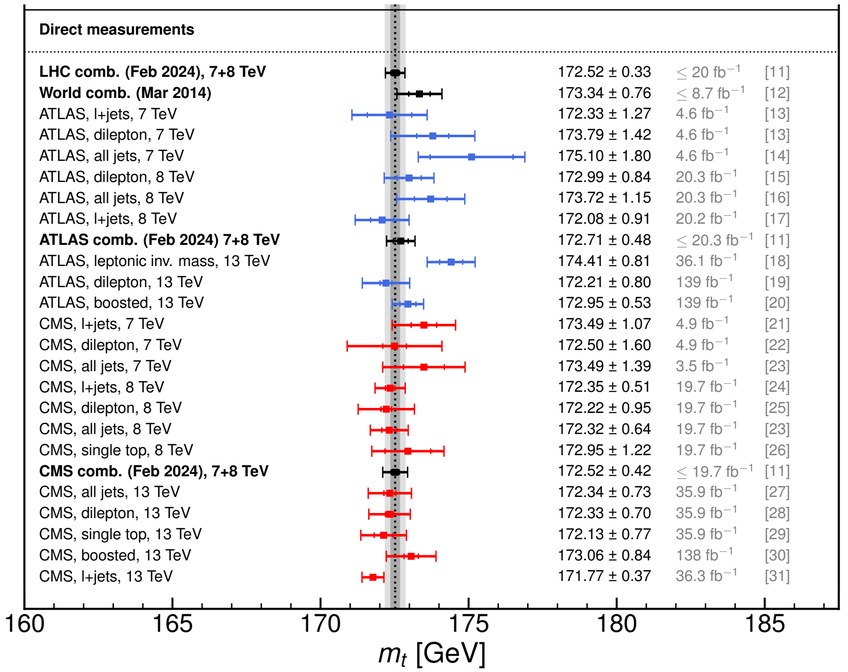
This talk



[1701.05838], [2009.07763], [2010.04171], [2306.14885], [2311.05509], [2311.02157], [2407.00545]

Direct measurements

- Reconstruct m_t from top-quark decays
- Monte Carlo mass



Adopted from the EFT top WG summary plots