Collaborative Research Center TRR 257
Particle Physics Phenomenology after the Higgs Discovery

GEFÖRDERT VOM
Bundesministerium
für Bildung
und Forschung

Research Training Group
Physics of the Heaviest
Particles at the LHC

Three issues in top-quark physics

M. Czakon
RWTH Aachen University

Institute for
Theoretical
Particle Physics
and Cosmology

"Beyond Flavour Physics", 23 June 2025, Siegen

$t\bar{t}+\mathrm{jet}$

$t\bar{t}+X$

$t\bar{t}+Z$

$t\bar{t}$ + jet

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THE EUROPEAN PHYSICAL JOURNAL C

Regular Article - Theoretical Physics

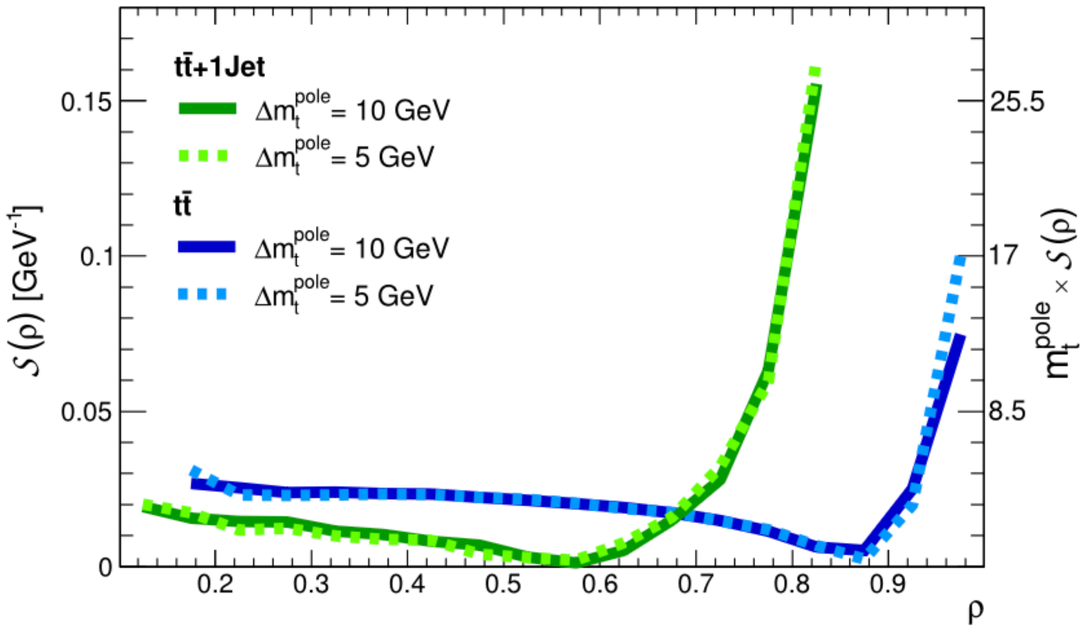
A new observable to measure the top-quark mass at hadron colliders

S. Alioli[1], P. Fernandez[2], J. Fuster[2], A. Irles[2], S. Moch[3,4], P. Uwer[5,a], M. Vos[2]

$$\mathcal{R}\left(m_t^{\text{pole}}, \rho_s\right) = \frac{1}{\sigma_{t\bar{t}+1\text{-jet}}} \frac{d\sigma_{t\bar{t}+1\text{-jet}}}{d\rho_s}\left(m_t^{\text{pole}}, \rho_s\right)$$

$$\rho_s = \frac{2m_0}{\sqrt{s_{t\bar{t}j}}}$$

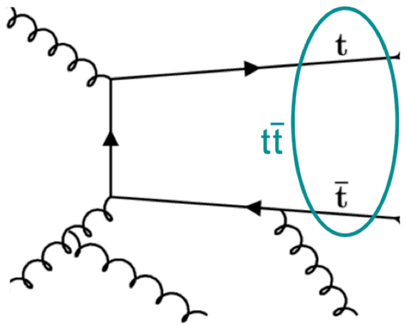
$$\left|\frac{\Delta\mathcal{R}}{\mathcal{R}}\right| \approx \left(m_t^{\text{pole}}\mathcal{S}\right) \times \left|\frac{\Delta m_t^{\text{pole}}}{m_t^{\text{pole}}}\right|$$



$t\bar{t}$ + jet

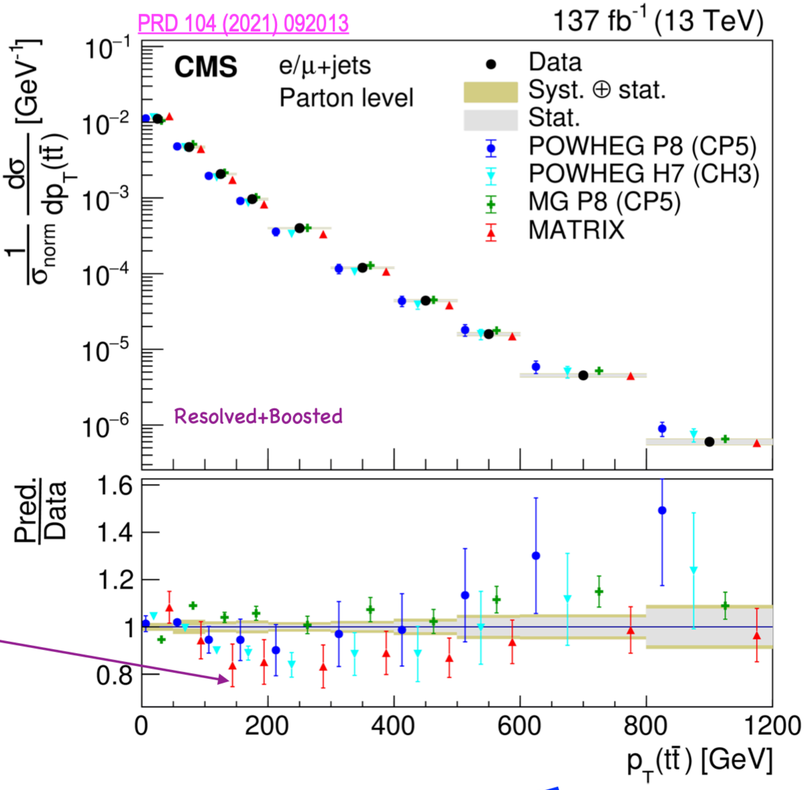
Olaf Behnke, DESY

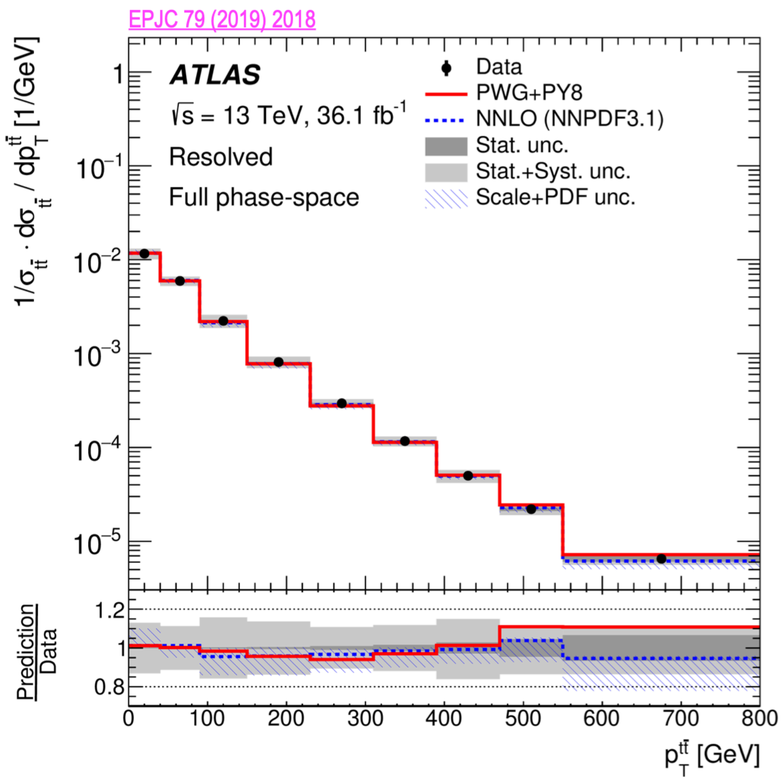
$p_T(t\bar{t})$



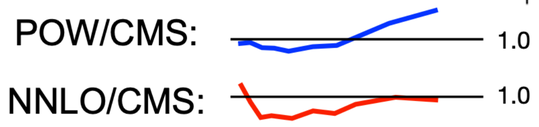
Non-zero $p_T(t\bar{t})$ directly sensitive to NLO QCD

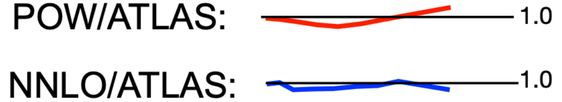
⇒ Large theory scale Uncertainties





l+jets, Parton level





$t\bar{t}$ + jet

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Numerical evaluation of two-loop QCD helicity amplitudes for $gg \to t\bar{t}g$ at leading colour

Simon Badger,[a] **Matteo Becchetti**,[b] **Colomba Brancaccio**,[a] **Heribertus Bayu Hartanto**[c,d] **and Simone Zoia**[e]

	PB_A	PB_B	PB_C	all MIs	special func. (all)	special func. (non-polylog.)
$\langle T \rangle$	43 *s*	77 *s*	66 *s*	309 *s*	297 *s*	16 *s*
σ	7 *s*	17 *s*	14 *s*	27 *s*	65 *s*	3 *s*

Table 2. Average time per segment and standard deviation for the solution of the DEs for the

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Two-loop integrals for $t\bar{t}$+jet production at hadron colliders in the leading colour approximation

Simon Badger,[a] **Matteo Becchetti**,[b] **Nicolò Giraudo**[c] **and Simone Zoia**[d]

Canonical differential equations for the elliptic two-loop five-point integral family relevant to $t\bar{t}$+jet production at leading colour

Matteo Becchetti,[1] Christoph Dlapa,[2] and Simone Zoia[3]

$t\bar{t} + X$

PHYSICAL REVIEW LETTERS **123,** 082001 (2019)

Higher Order Corrections to Spin Correlations in Top Quark Pair Production at the LHC

Arnd Behring
Institut für Theoretische Teilchenphysik und Kosmologie, RWTH Aachen University, D-52056 Aachen, Germany and Institute for Theoretical Particle Physics, KIT, D-76128 Karlsruhe, Germany

Michał Czakon
Institut für Theoretische Teilchenphysik und Kosmologie, RWTH Aachen University, D-52056 Aachen, Germany

Alexander Mitov and Rene Poncelet
Cavendish Laboratory, University of Cambridge, Cambridge CB3 0HE, United Kingdom

Andrew S. Papanastasiou

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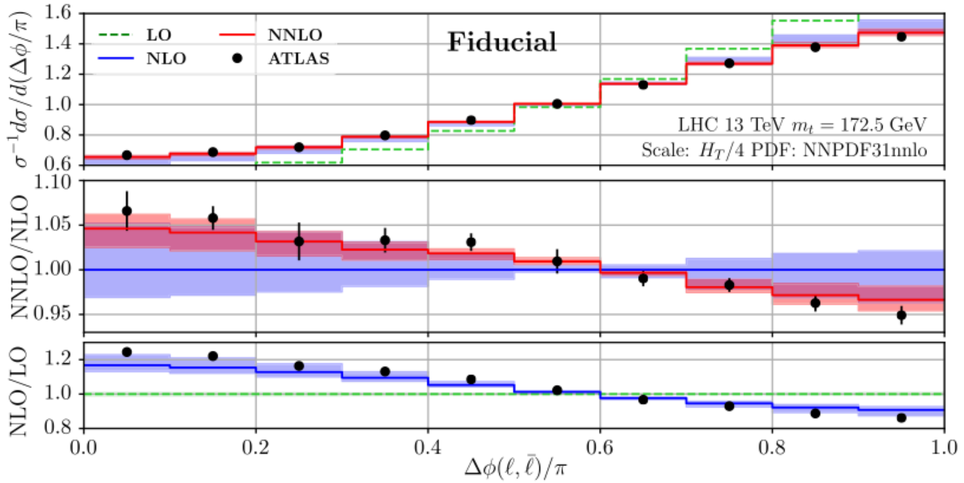
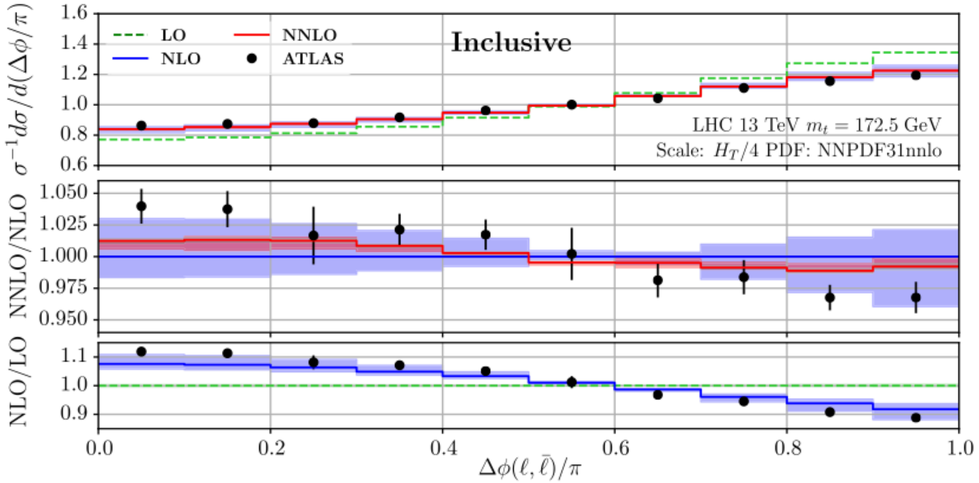
NNLO QCD corrections to leptonic observables in top-quark pair production and decay

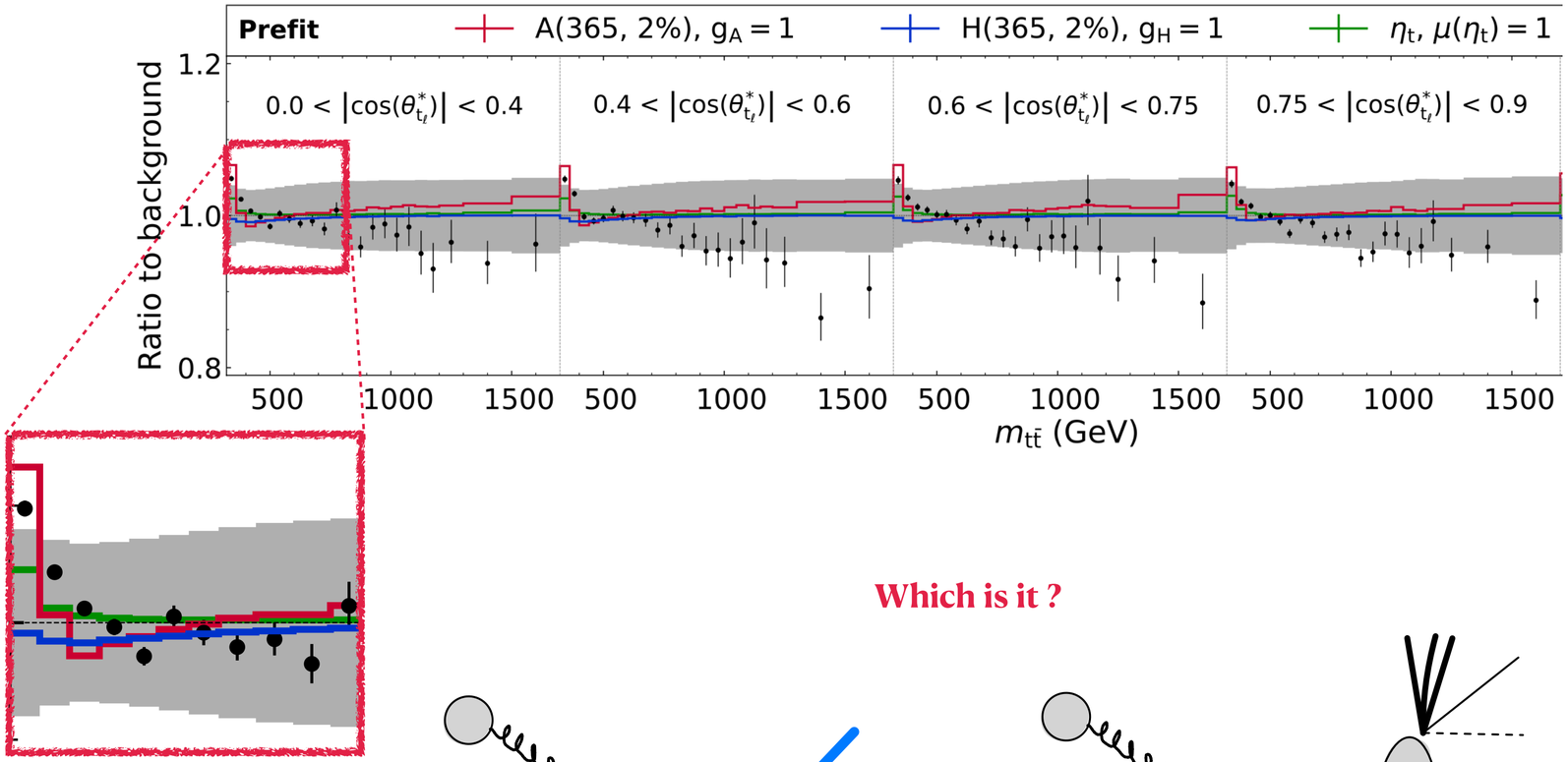
Michał Czakon,[a] Alexander Mitov[b] and Rene Poncelet[b]



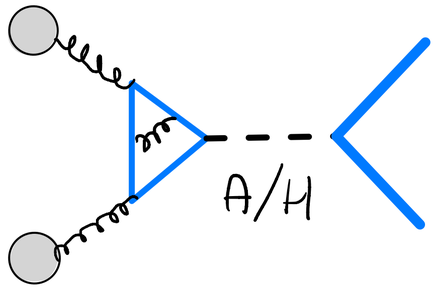


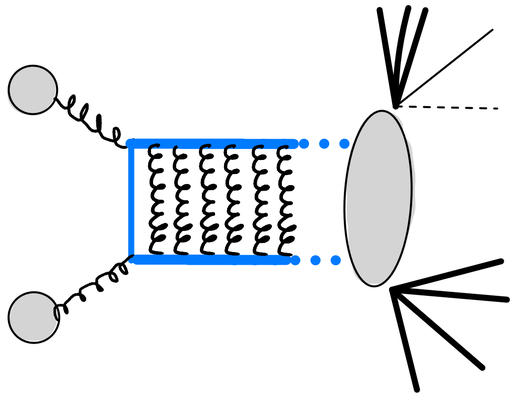
$t\bar{t} + X$

CMS PAS HIG-22-013



Which is it ?





$t\bar{t} + X$

Phys. Lett. B 866 (2025) 139532

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Letter

Updated predictions for toponium production at the LHC

M.V. Garzelli [a,b], G. Limatola [b,c], S.-O. Moch [b,*], M. Steinhauser [d], O. Zenaiev [b]

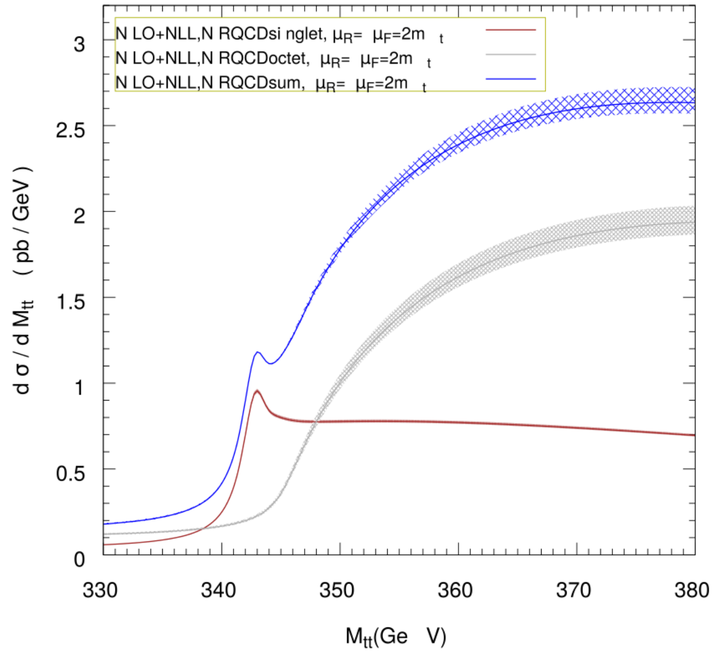
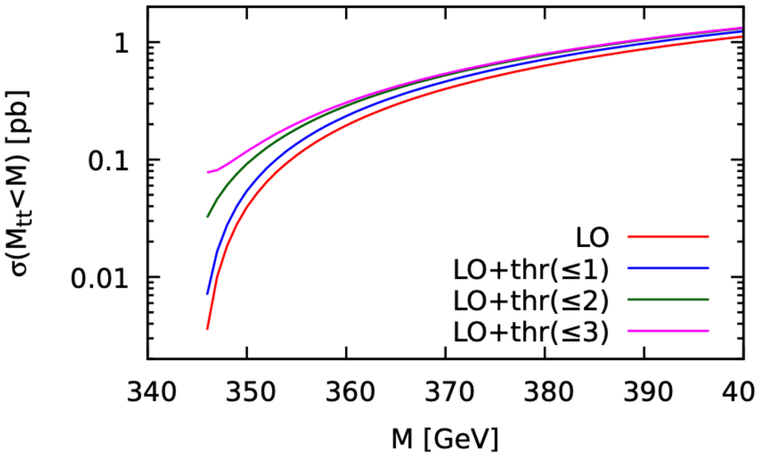
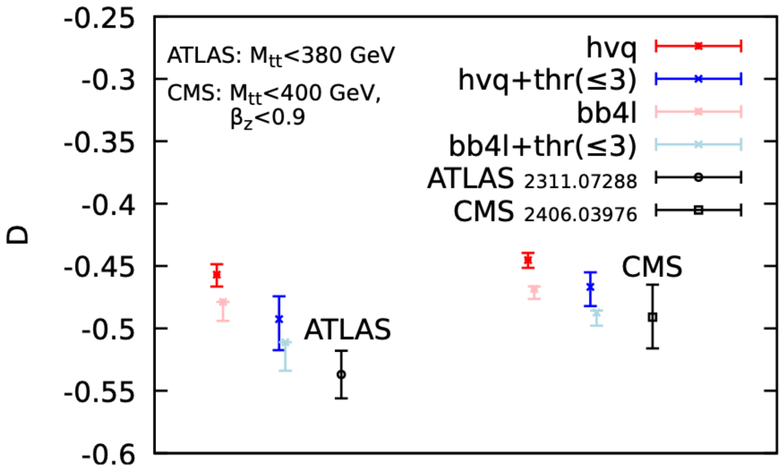


Fig. 1. Invariant mass distribution $d\sigma/dM_{t\bar{t}}$ in NRQCD with Coulomb and threshold resummation for the dominant individual production channels, also listed in Table 1: $gg \to {}^1S_0^{[1]}$ (brown), $gg \to {}^1S_0^{[8]} + q\bar{q} \to {}^3S_1^{[8]}$ (grey) and their sum (blue). The width of the band reflects the dependence on the scale choices $\mu_r = \mu_f \in \{m_t, 2m_t, 4m_t\}$ for the convolution $\mathcal{L} \otimes F$.

Spin Correlations in $t\bar{t}$ Production and Decay at the LHC in QCD Perturbation Theory.

Paolo Nason,[b] Emanuele Re,[a,b,1] Luca Rottoli[a,b]





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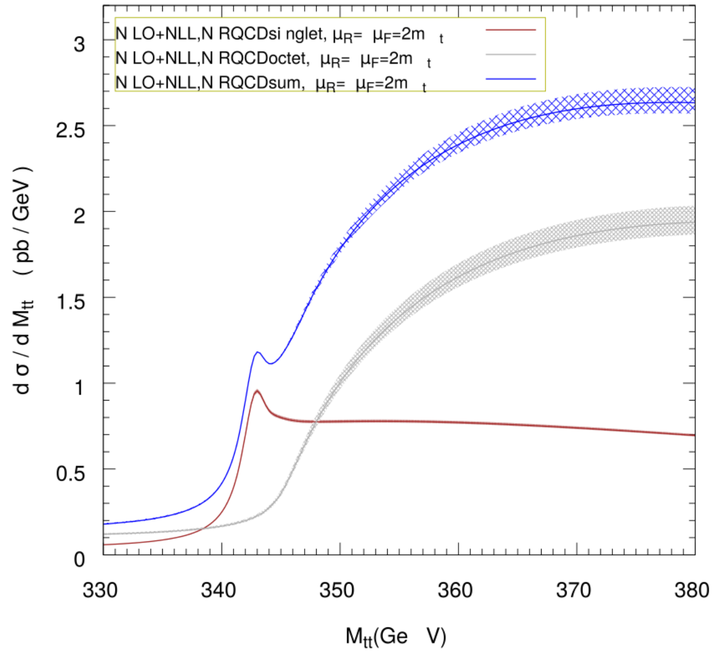

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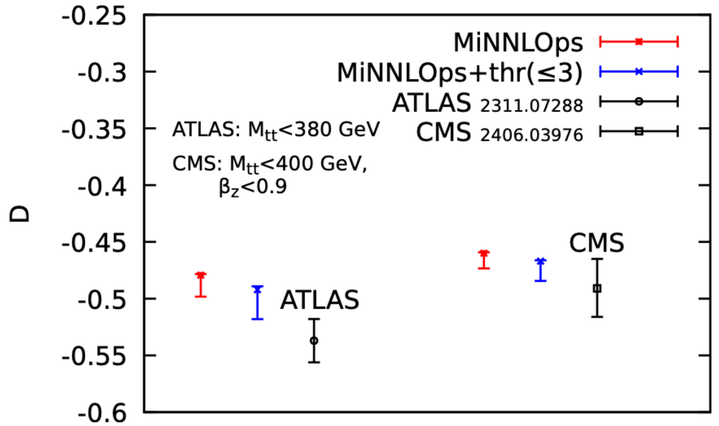
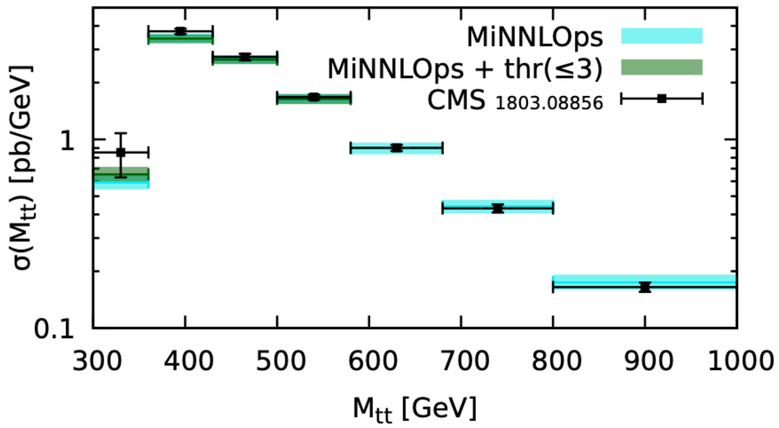
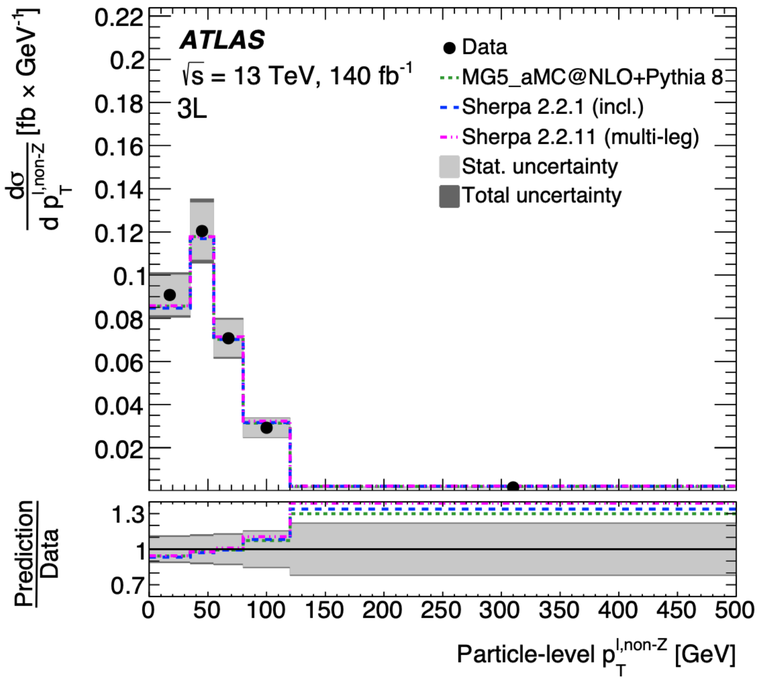


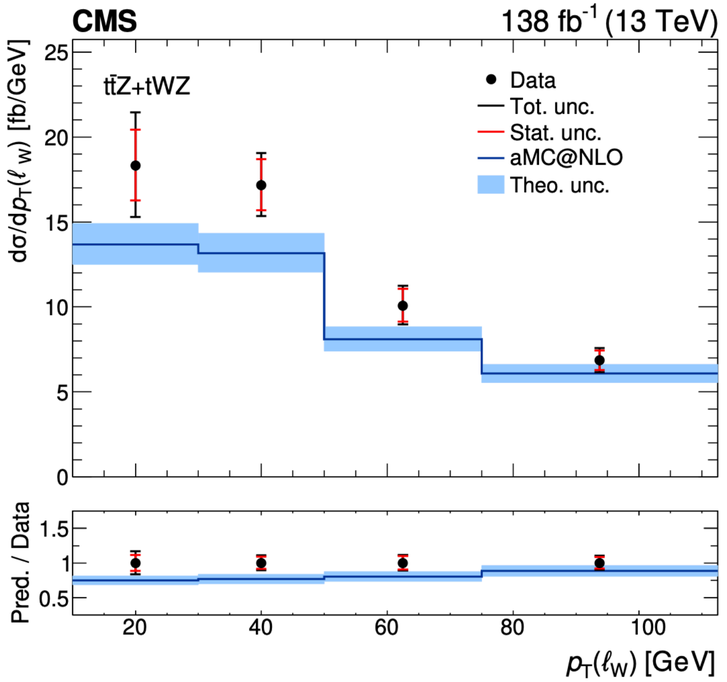


$t\bar{t} + Z$

ATLAS collaboration, *Inclusive and differential cross-section measurements of $t\bar{t}Z$ production in pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector, including EFT and spin-correlation interpretations*, *JHEP* **07** (2024) 163 [2312.04450].

CMS collaboration, *Measurements of inclusive and differential cross sections for top quark production in association with a Z boson in proton-proton collisions at $\sqrt{s}$ = 13 TeV*, *JHEP* **02** (2025) 177 [2410.23475].





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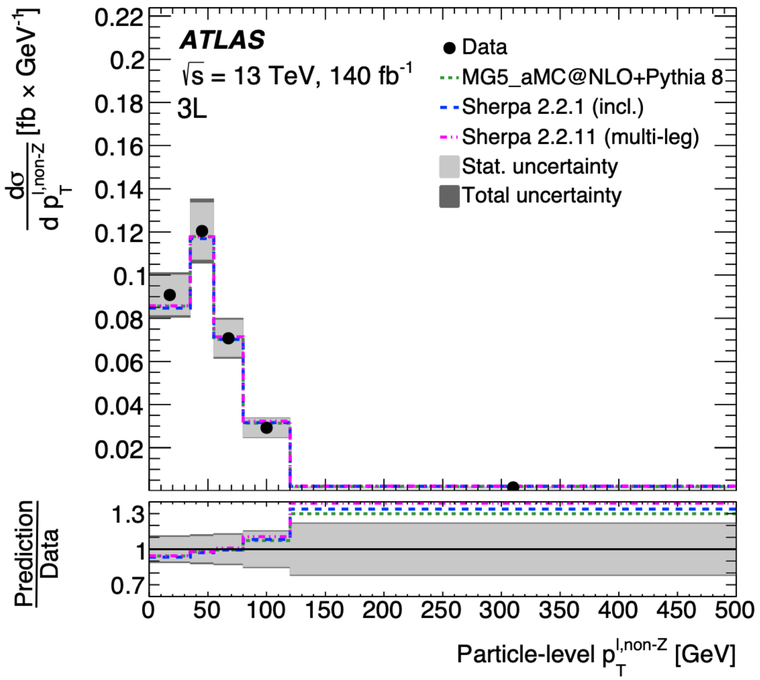
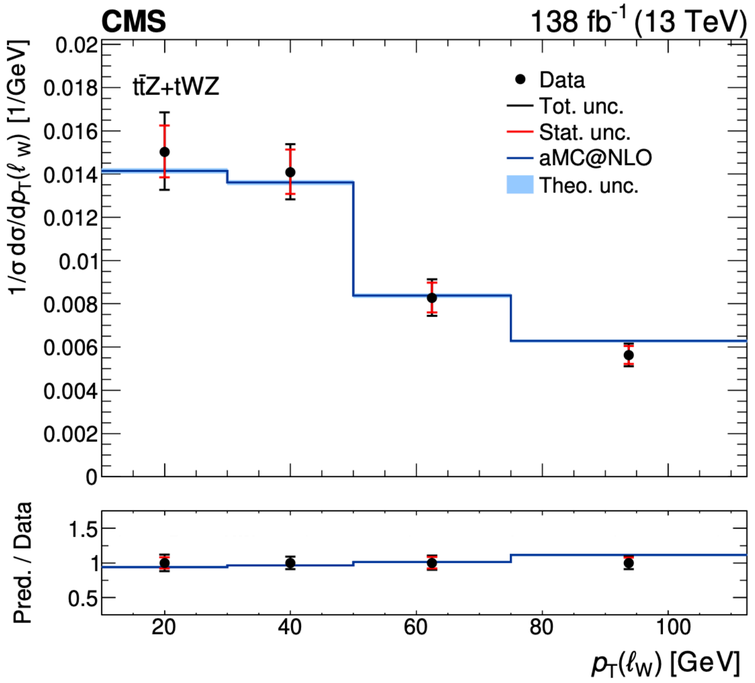




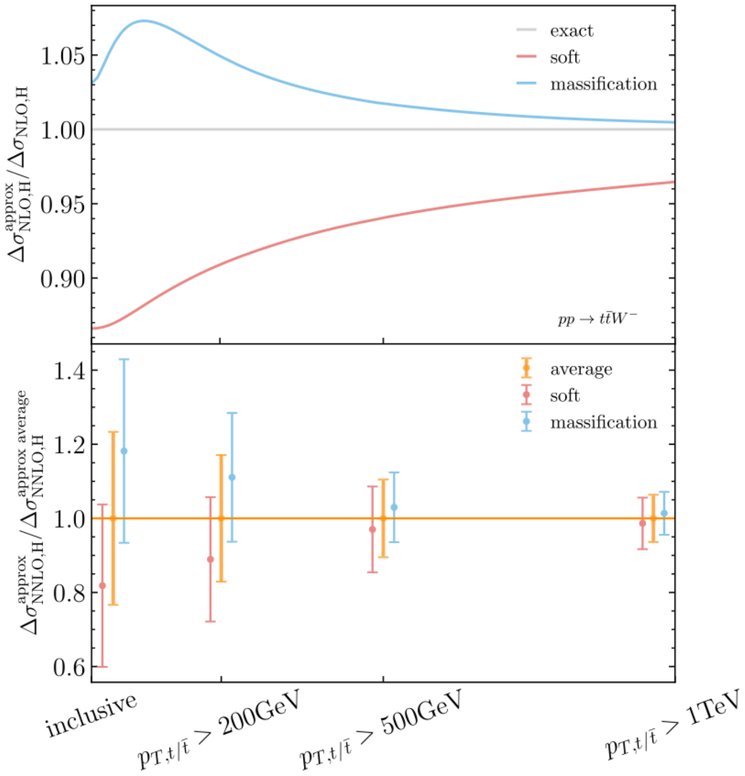
$t\bar{t} + Z$

PHYSICAL REVIEW LETTERS **131,** 231901 (2023)

Editors' Suggestion

Precise Predictions for the Associated Production of a *W* Boson with a Top-Antitop Quark Pair at the LHC

Luca Buonocore,[1] Simone Devoto,[2] Massimiliano Grazzini,[1] Stefan Kallweit,[3] Javier Mazzitelli,[4] Luca Rottoli,[1] and Chiara Savoini[1]



	$\sigma_{t\bar{t}W^+}$ [fb]	$\sigma_{t\bar{t}W^-}$ [fb]	$\sigma_{t\bar{t}W}$ [fb]	$\sigma_{t\bar{t}W^+}/\sigma_{t\bar{t}W^-}$
LO_{QCD}	$283.4^{+25.3\%}_{-18.8\%}$	$136.8^{+25.2\%}_{-18.8\%}$	$420.2^{+25.3\%}_{-18.8\%}$	$2.071^{+3.2\%}_{-3.2\%}$
NLO_{QCD}	$416.9^{+12.5\%}_{-11.4\%}$	$205.1^{+13.2\%}_{-11.7\%}$	$622.0^{+12.7\%}_{-11.5\%}$	$2.033^{+3.0\%}_{-3.4\%}$
NNLO_{QCD}	$475.2^{+4.8\%}_{-6.4\%} \pm 1.9\%$	$235.5^{+5.1\%}_{-6.6\%} \pm 1.9\%$	$710.7^{+4.9\%}_{-6.5\%} \pm 1.9\%$	$2.018^{+1.6\%}_{-1.2\%}$
$\text{NNLO}_{\text{QCD}} + \text{NLO}_{\text{EW}}$	$497.5^{+6.6\%}_{-6.6\%} \pm 1.8\%$	$247.9^{+7.0\%}_{-7.0\%} \pm 1.8\%$	$745.3^{+6.7\%}_{-6.7\%} \pm 1.8\%$	$2.007^{+2.1\%}_{-2.1\%}$
ATLAS [11]	$585^{+6.0\%\ +8.0\%}_{-5.8\%\ -7.5\%}$	$301^{+9.3\%\ +11.6\%}_{-9.0\%\ -10.3\%}$	$890^{+5.6\%\ +7.9\%}_{-5.6\%\ -7.9\%}$	$1.95^{+10.8\%\ +8.2\%}_{-9.2\%\ -6.7\%}$
CMS [10]	$553^{+5.4\%\ +5.4\%}_{-5.4\%\ -5.4\%}$	$343^{+7.6\%\ +7.3\%}_{-7.6\%\ -7.3\%}$	$868^{+4.6\%\ +5.9\%}_{-4.6\%\ -5.9\%}$	$1.61^{+9.3\%\ +4.3\%}_{-9.3\%\ -3.1\%}$