

# Higgs Theory Overview

Robert Harlander  
RWTH Aachen University

FSP CMS Annual Meeting 2024  
RWTH Aachen

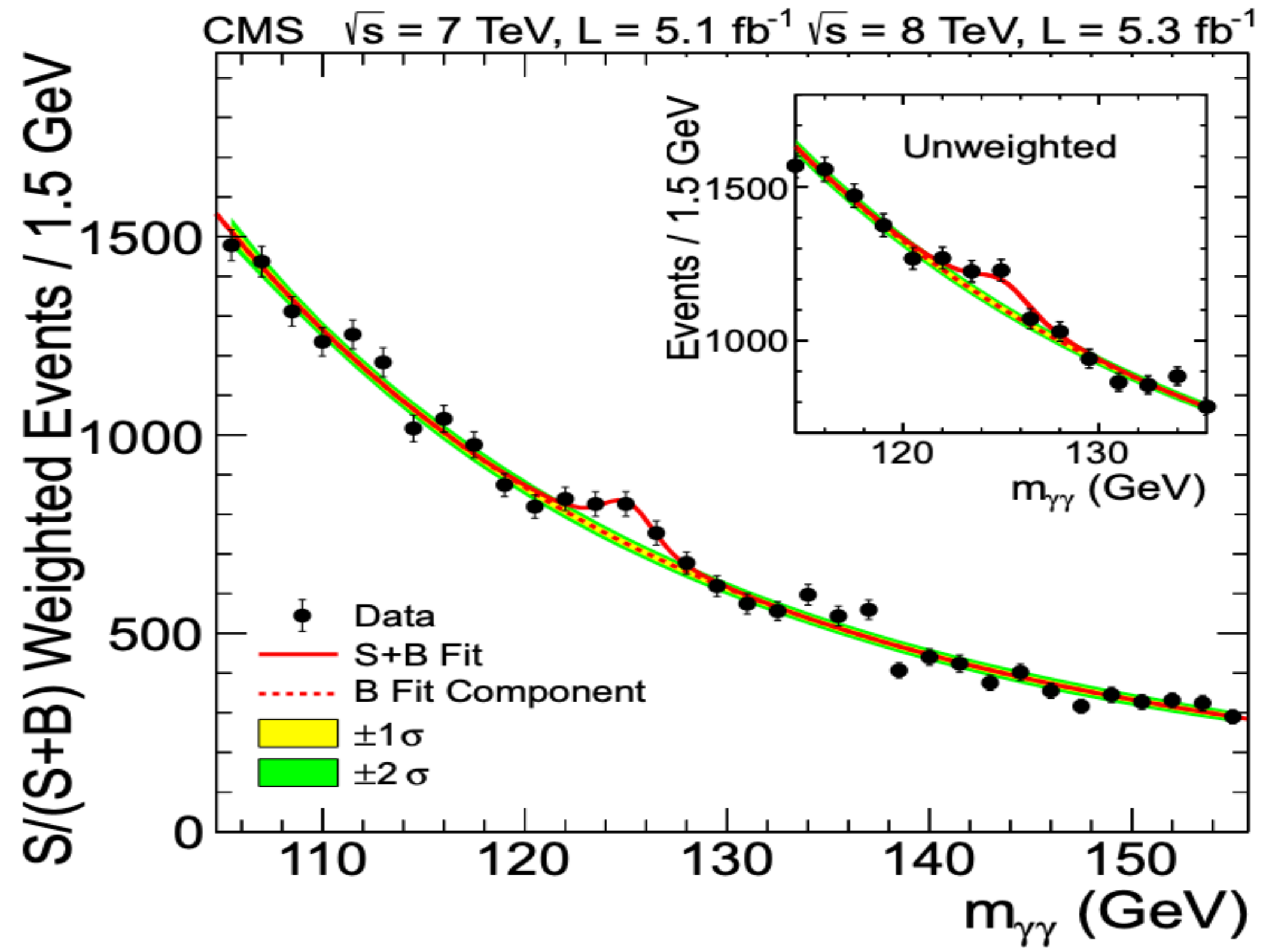
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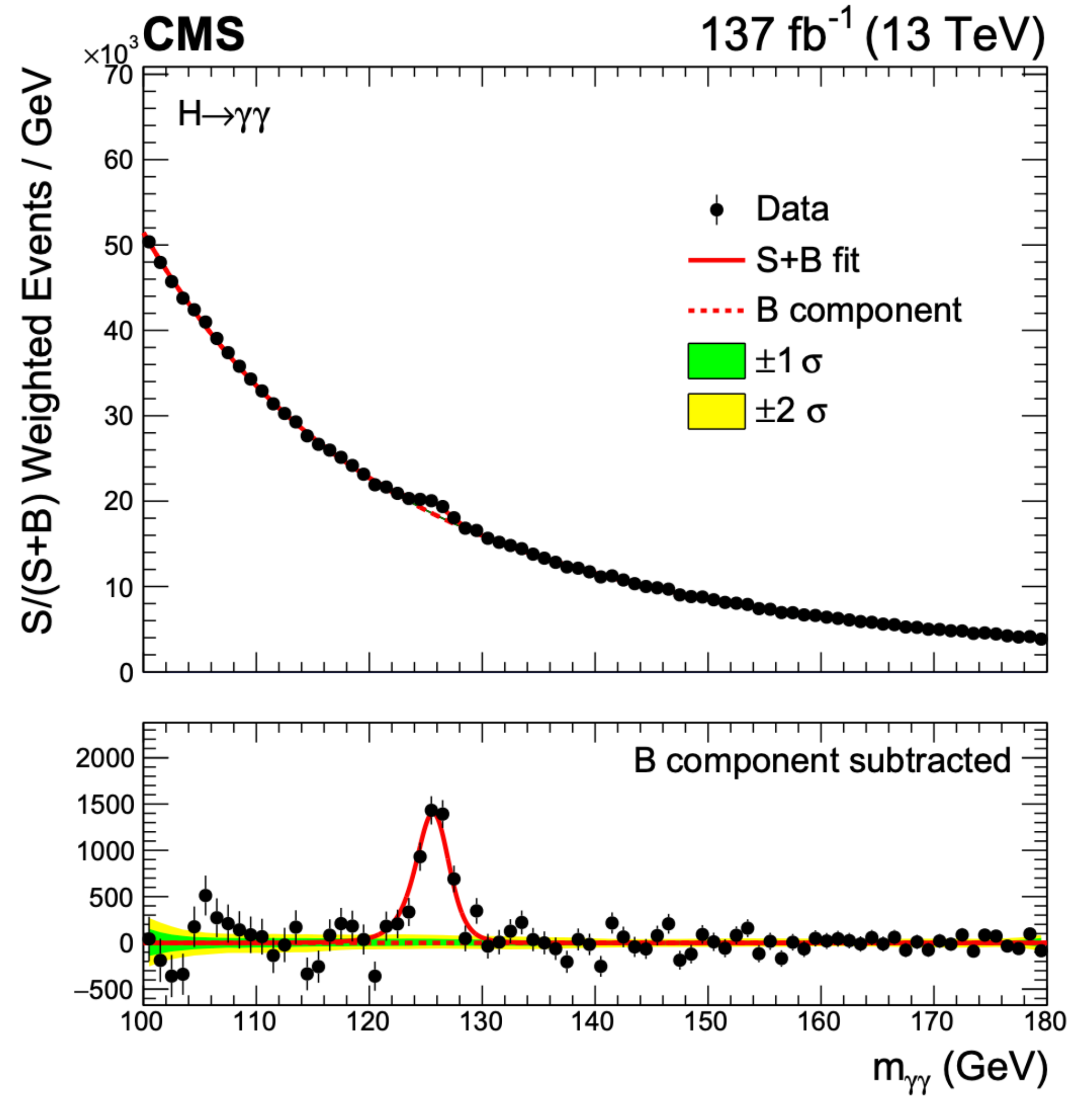
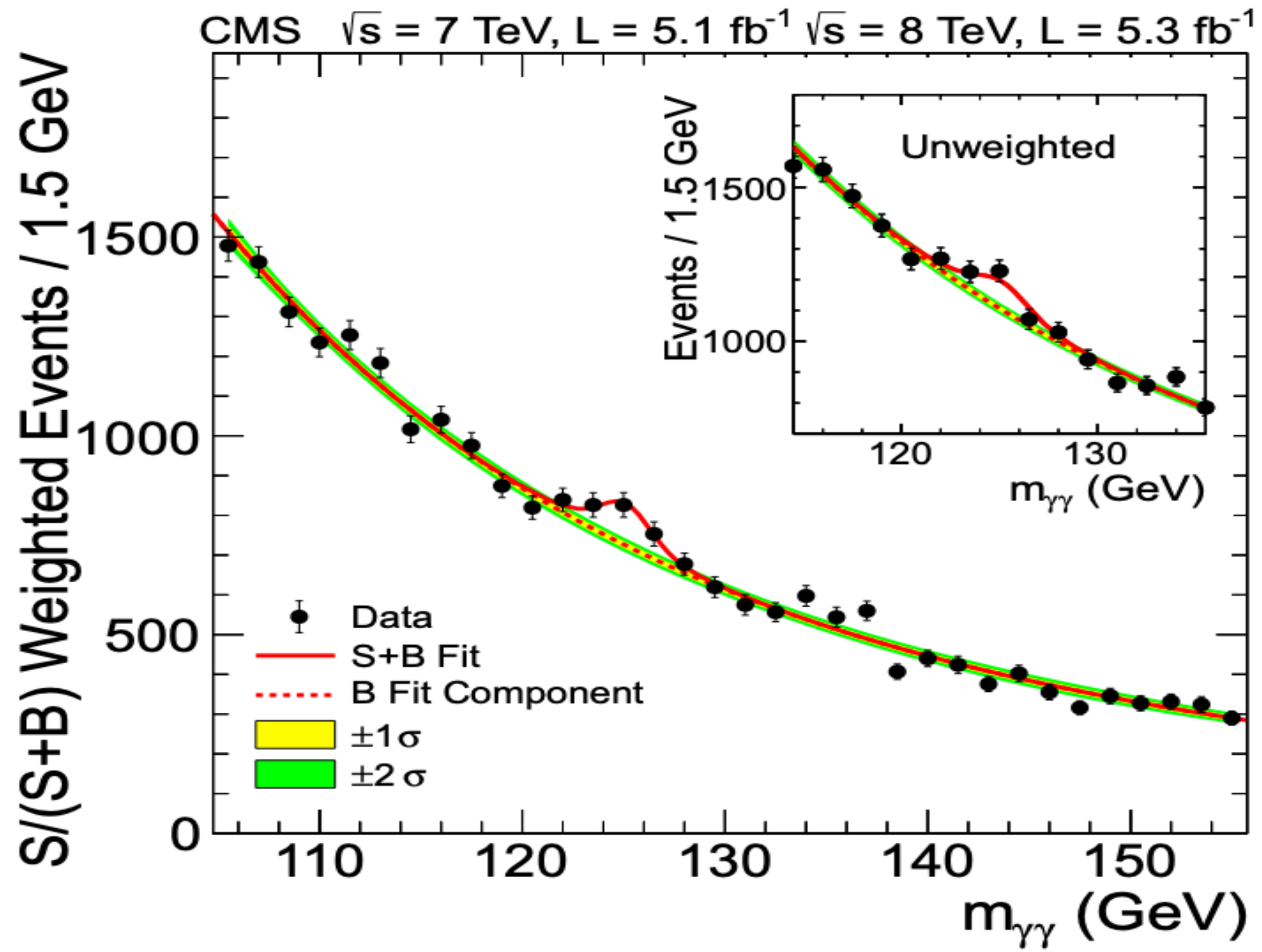
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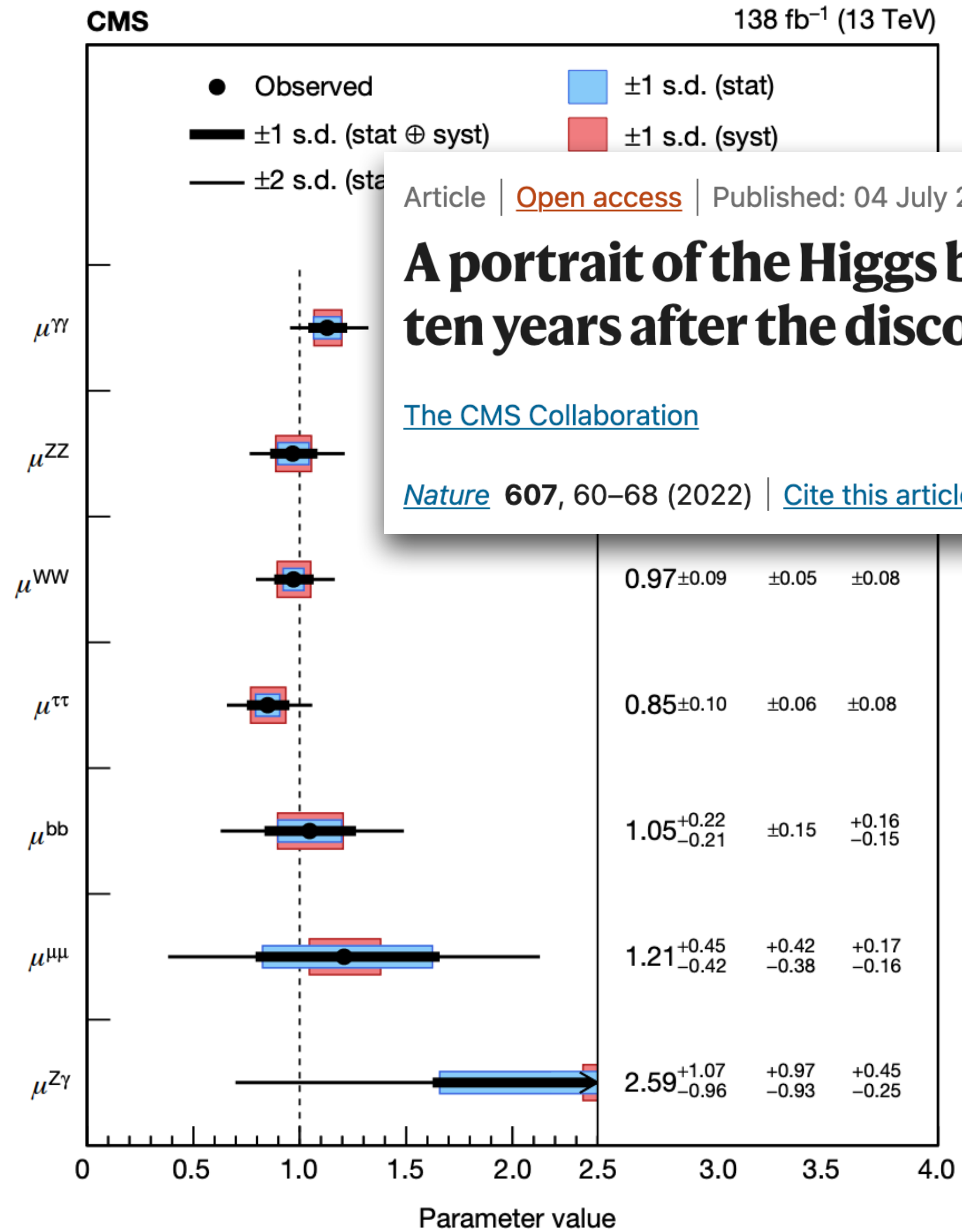
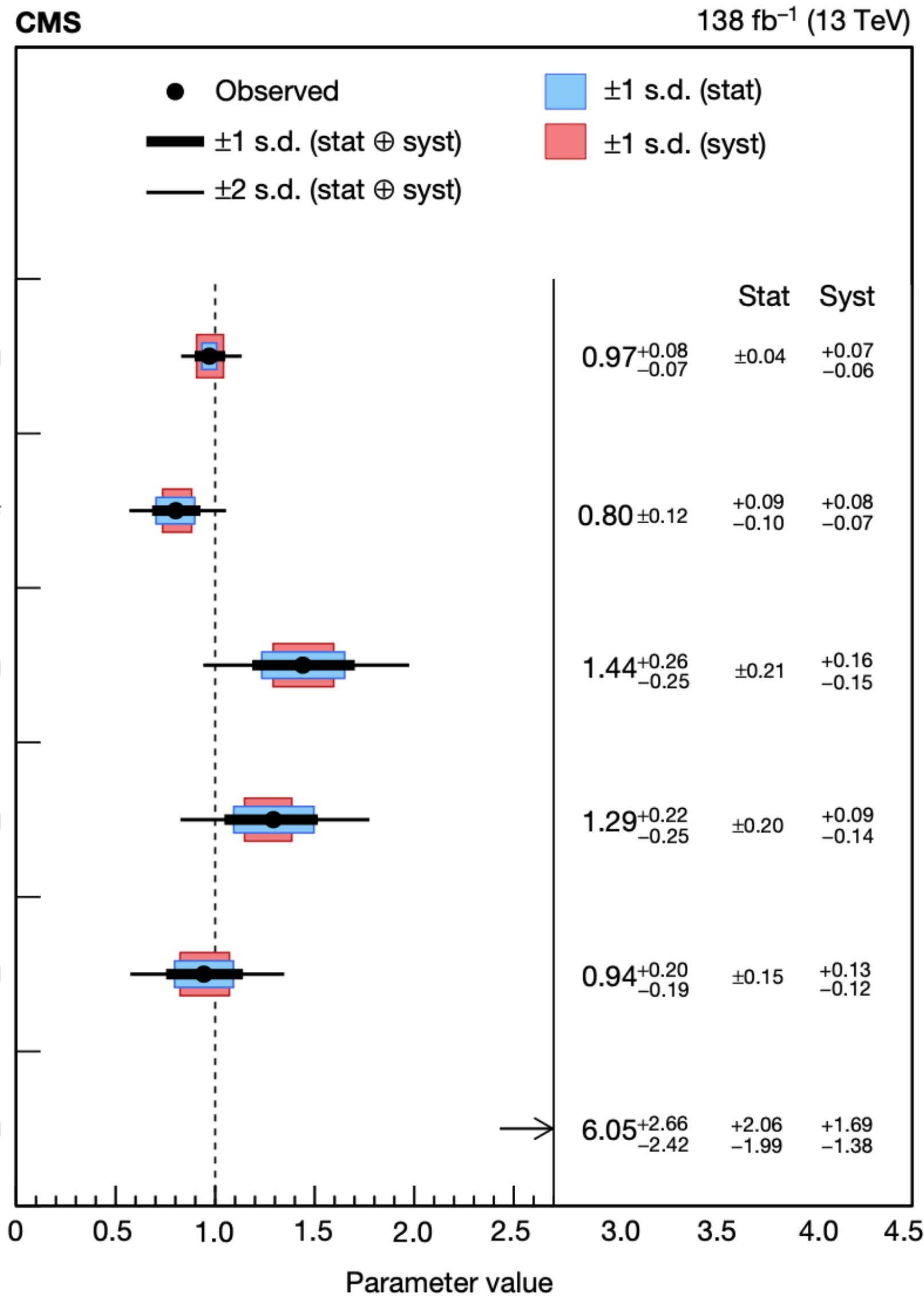
Deutsche  
Forschungsgemeinschaft  
**DFG**



Bundesministerium  
für Bildung  
und Forschung





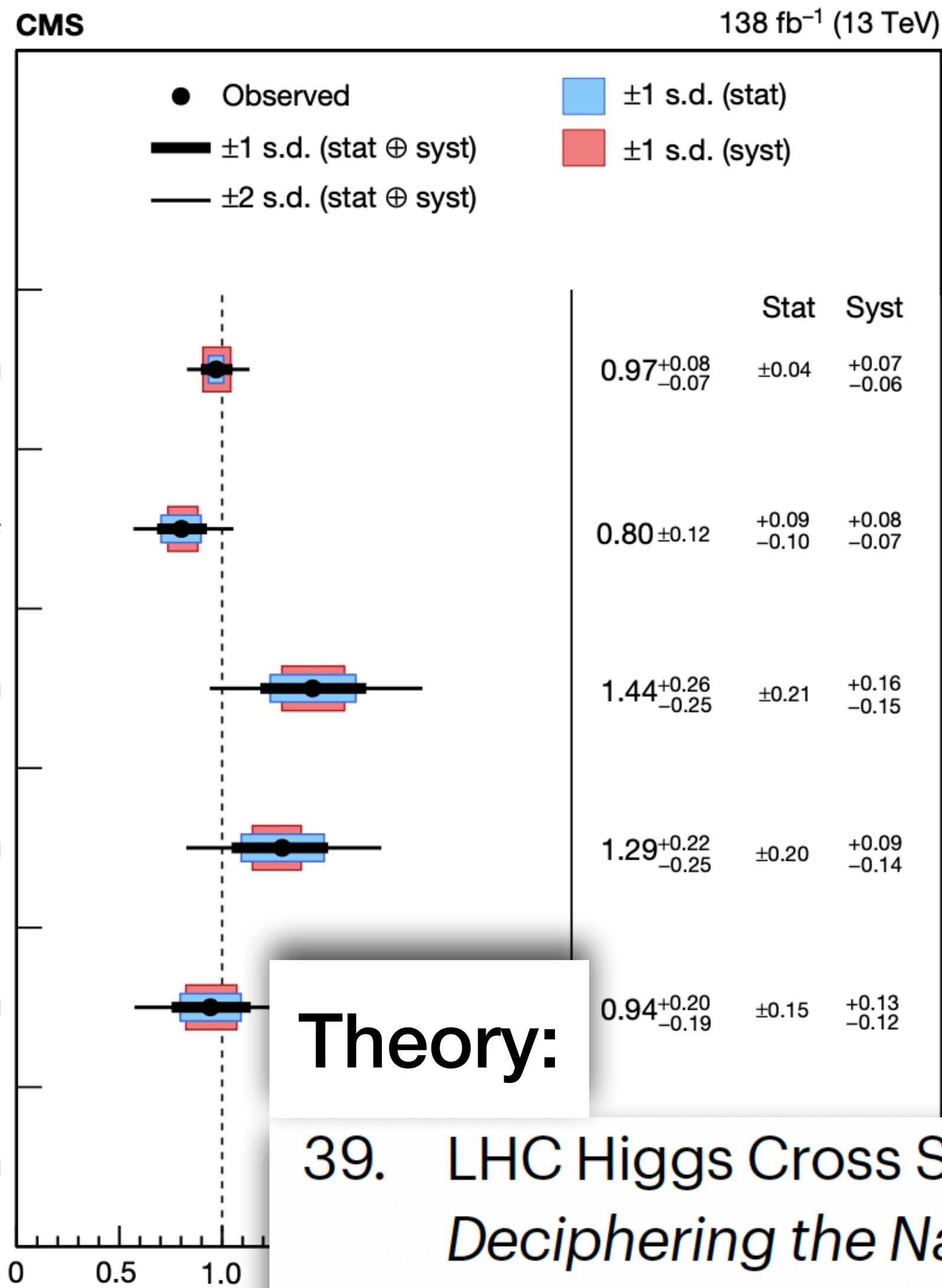


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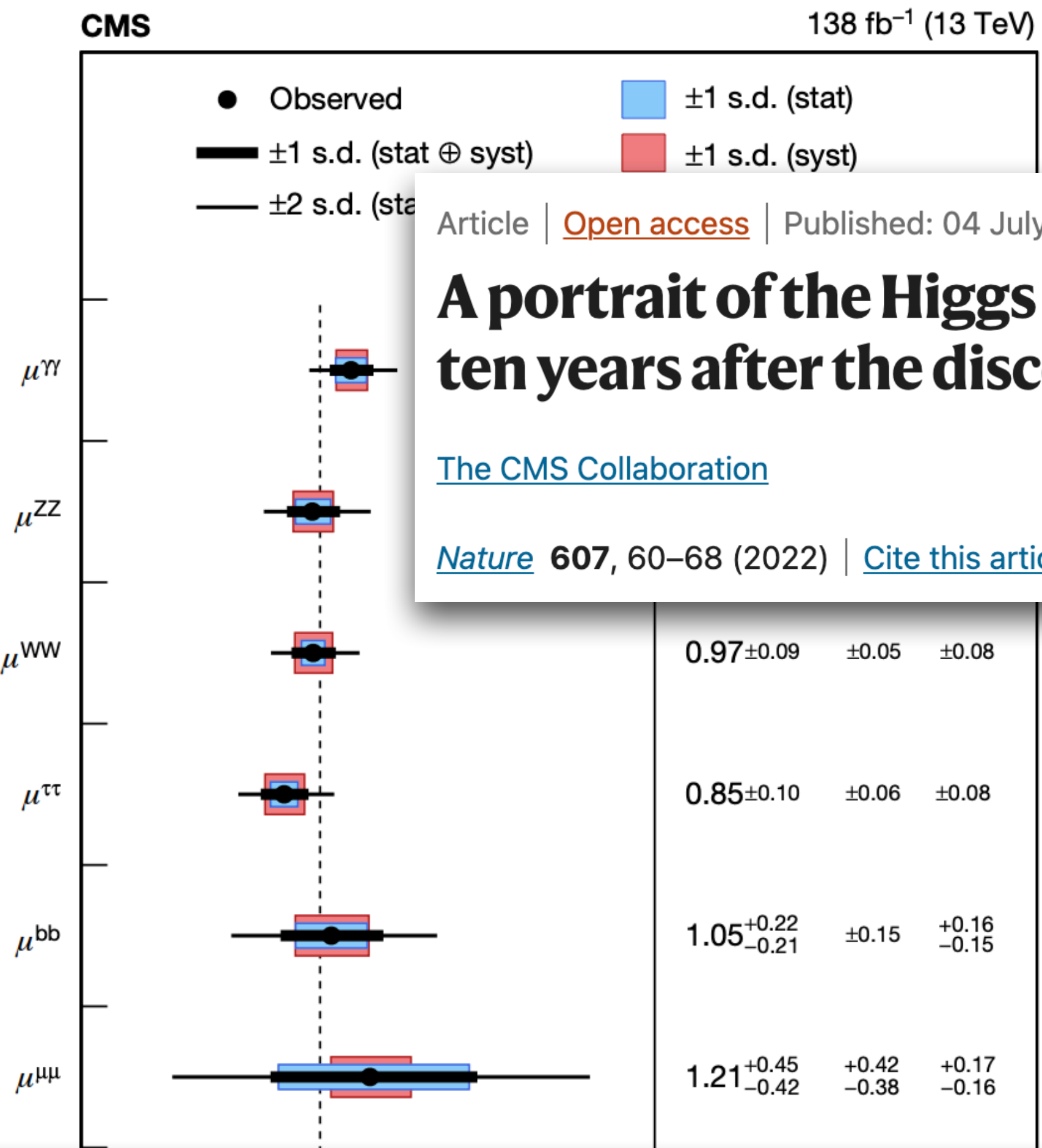
# A portrait of the Higgs boson by the CMS experiment ten years after the discovery

[The CMS Collaboration](#)

[Nature 607, 60–68 \(2022\)](#) | [Cite this article](#)



Theory:



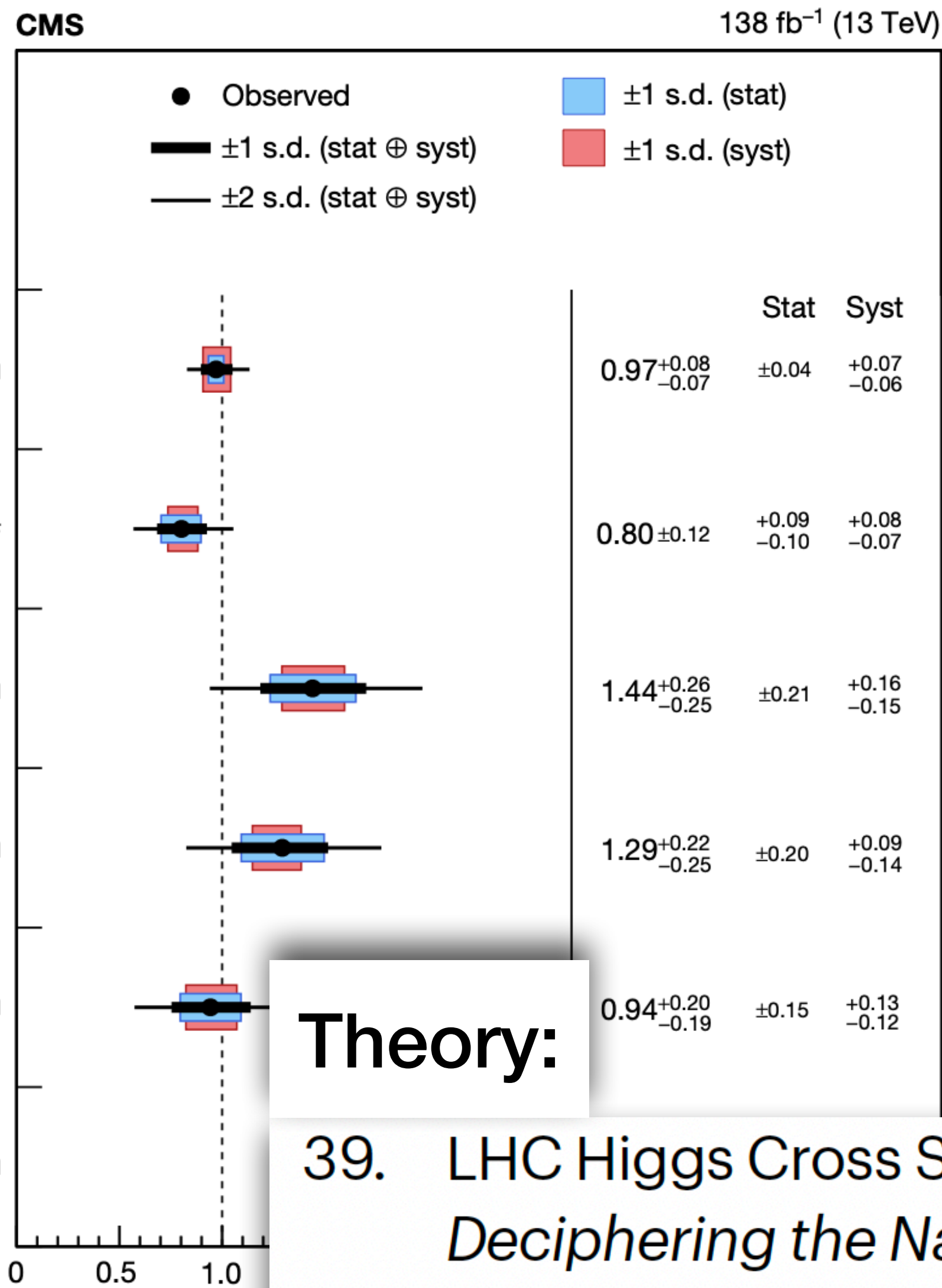
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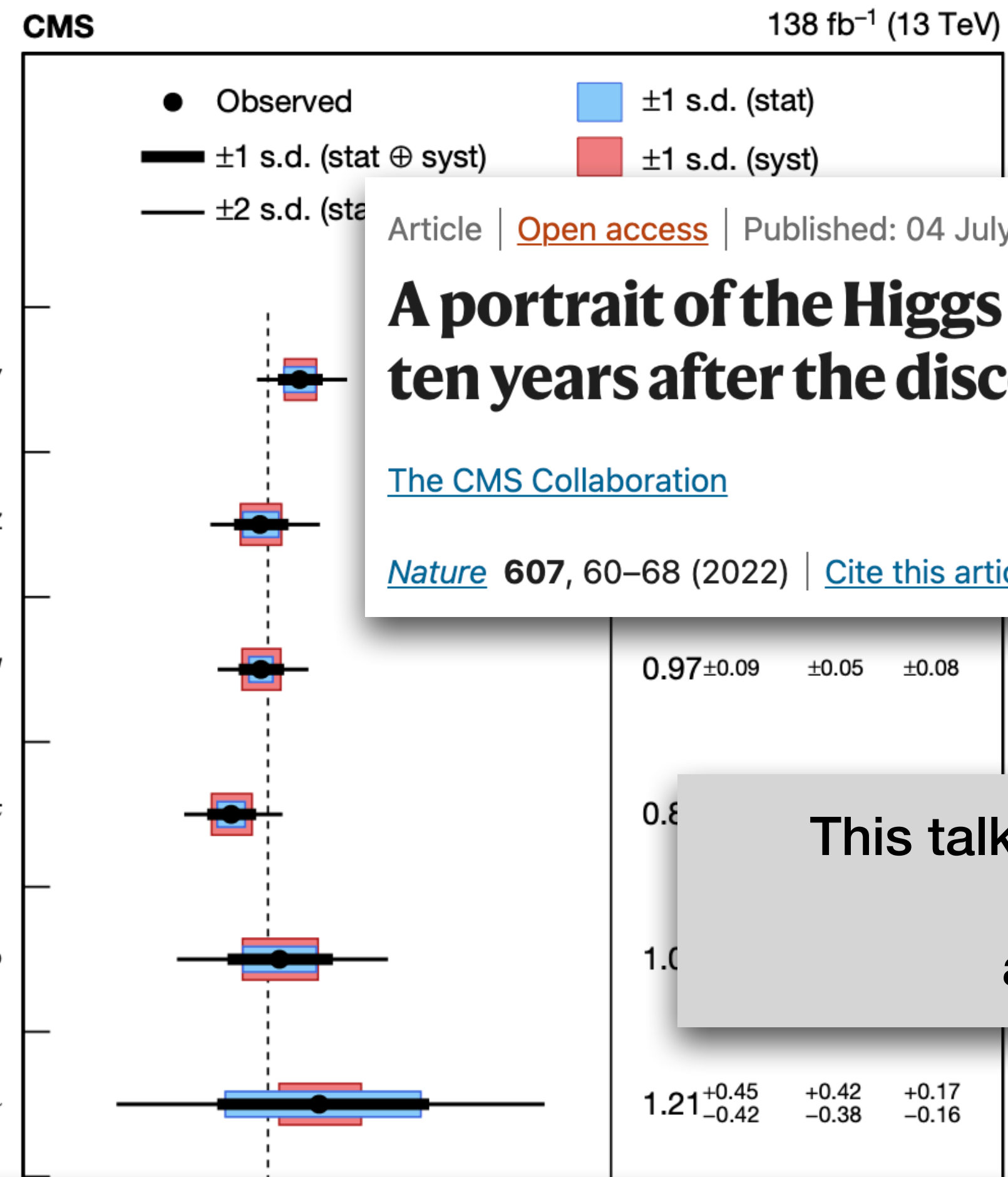
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39. LHC Higgs Cross Section Working Group *Handbook of LHC Higgs Cross Sections: 4. Deciphering the Nature of the Higgs Sector* CERN Yellow Reports: Monographs (CERN, 2017); <https://doi.org/10.23731/CYRM-2017-002>



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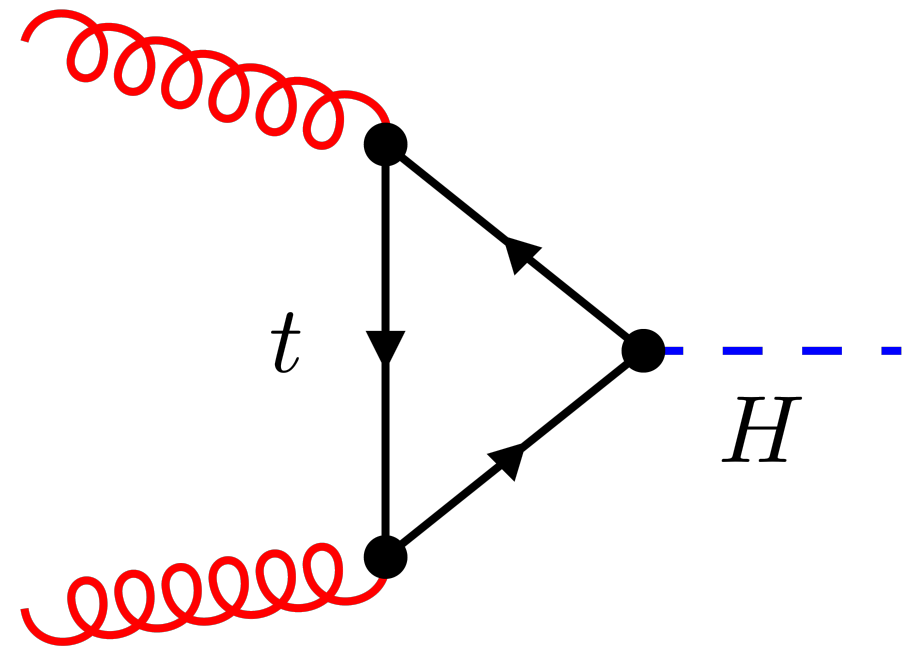
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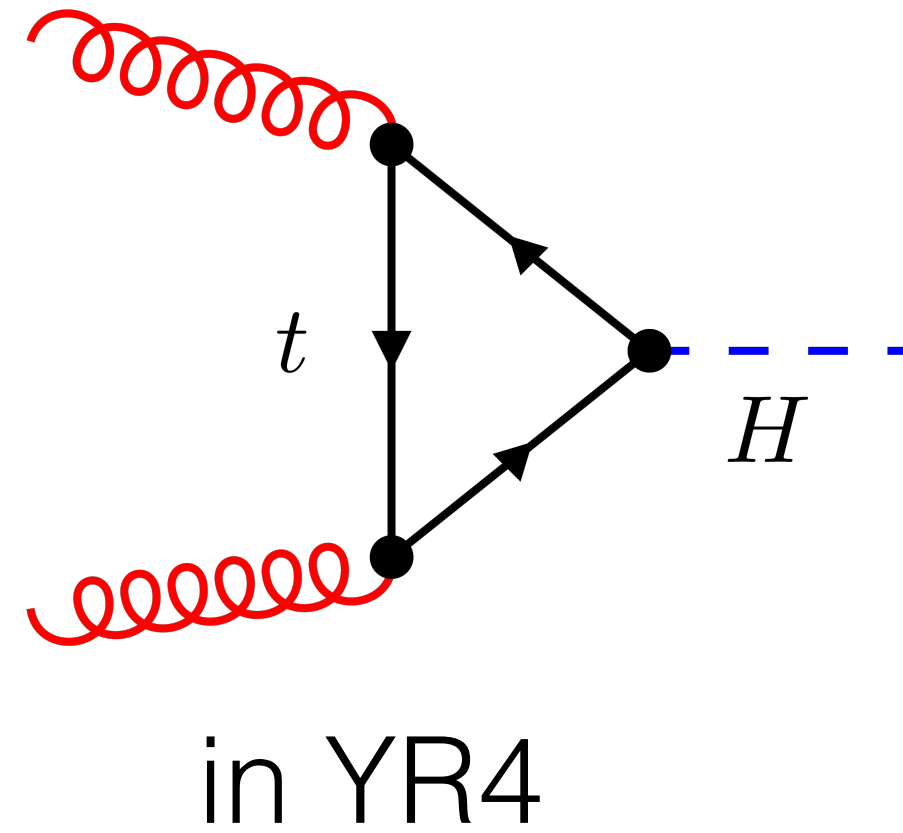
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This talk: only references to papers *after* YR4, and only highlights!



in YR4

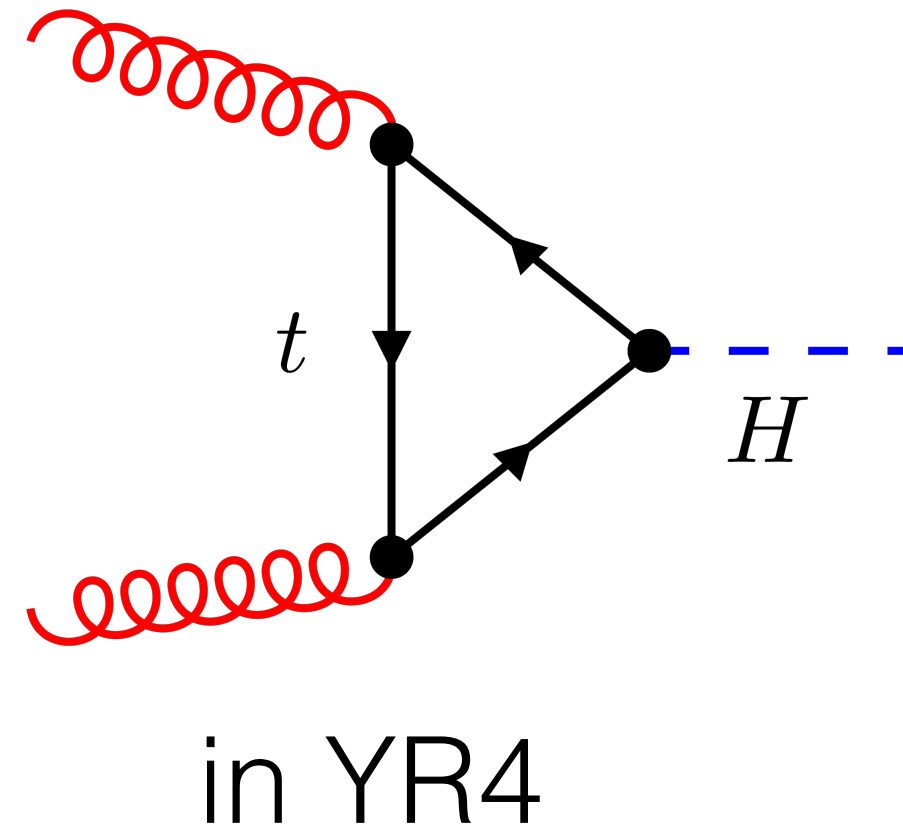
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48.58 pb =	16.00 pb	(+32.9%)	(LO, rEFT)
	+ 20.84 pb	(+42.9%)	(NLO, rEFT)
	- 2.05 pb	(-4.2%)	((t, b, c), exact NLO)
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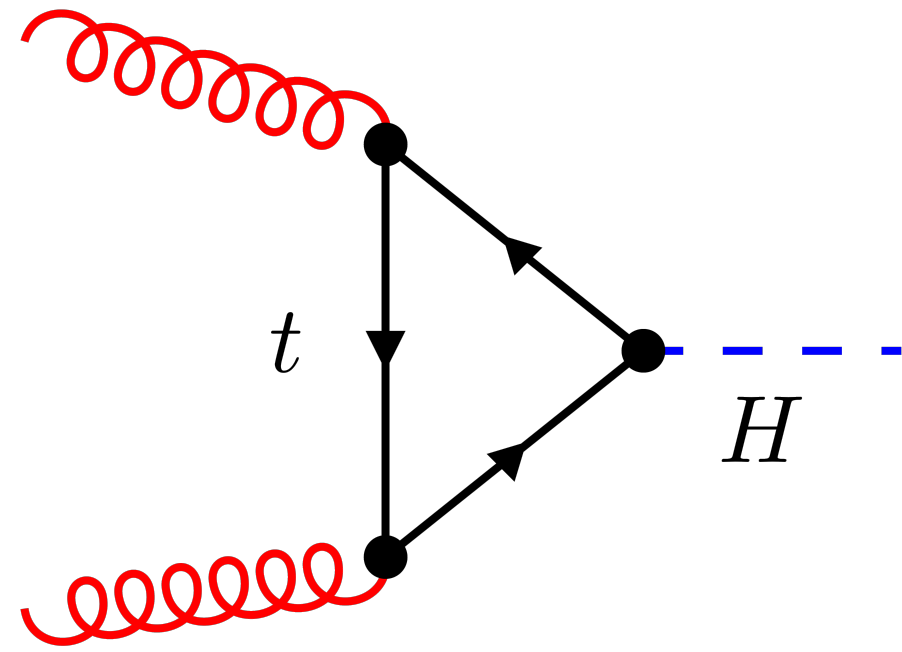
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# Uncertainty estimate:

$\delta(\text{scale})$	$\delta(\text{trunc})$	$\delta(\text{PDF-TH})$	$\delta(\text{EW})$	$\delta(t, b, c)$	$\delta(1/m_t)$
+0.10 pb -1.15 pb	$\pm 0.18$ pb	$\pm 0.56$ pb	$\pm 0.49$ pb	$\pm 0.40$ pb	$\pm 0.49$ pb
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LHCH(XS)WG YR4 '16

# Inclusive gluon fusion cross section:



in YR4

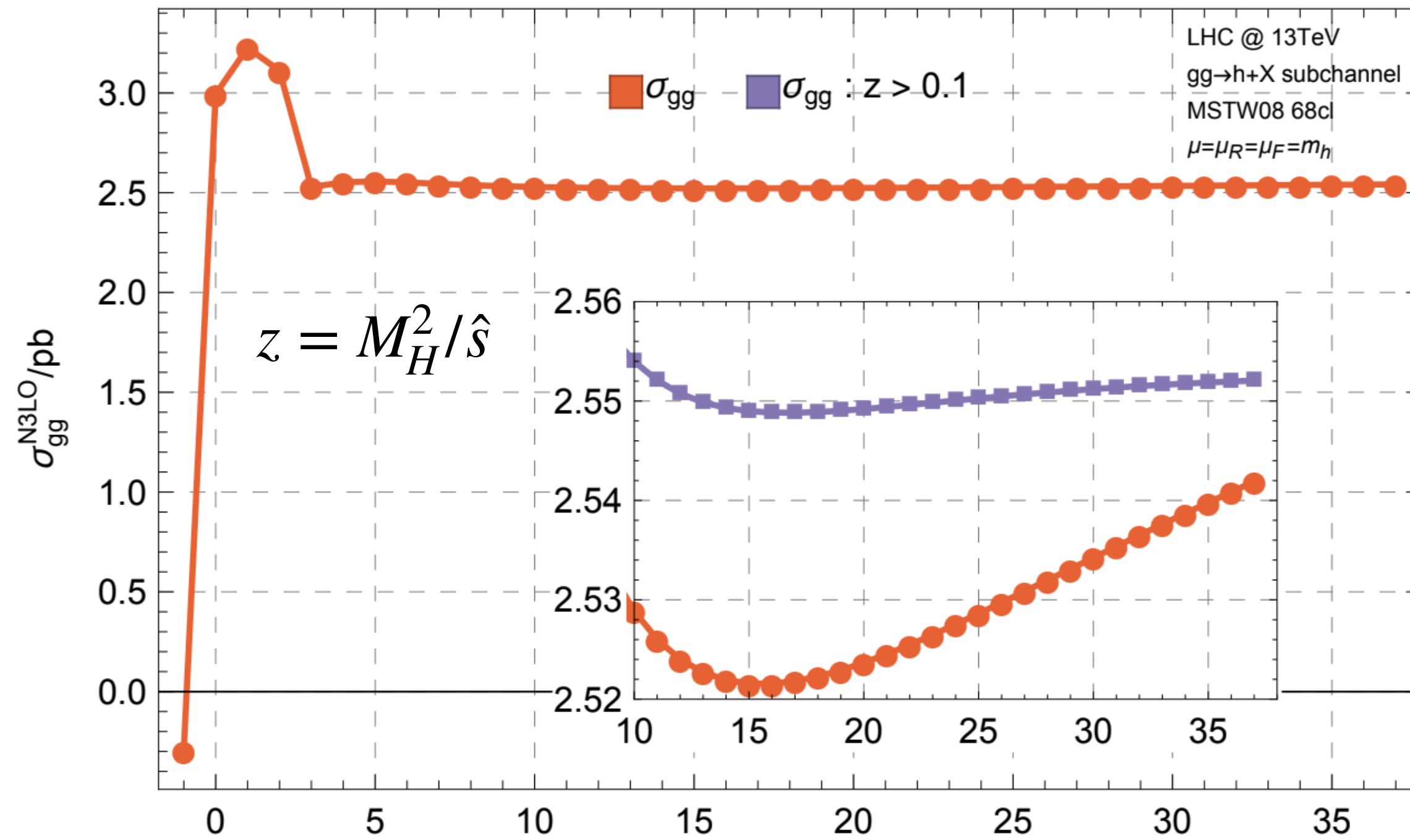
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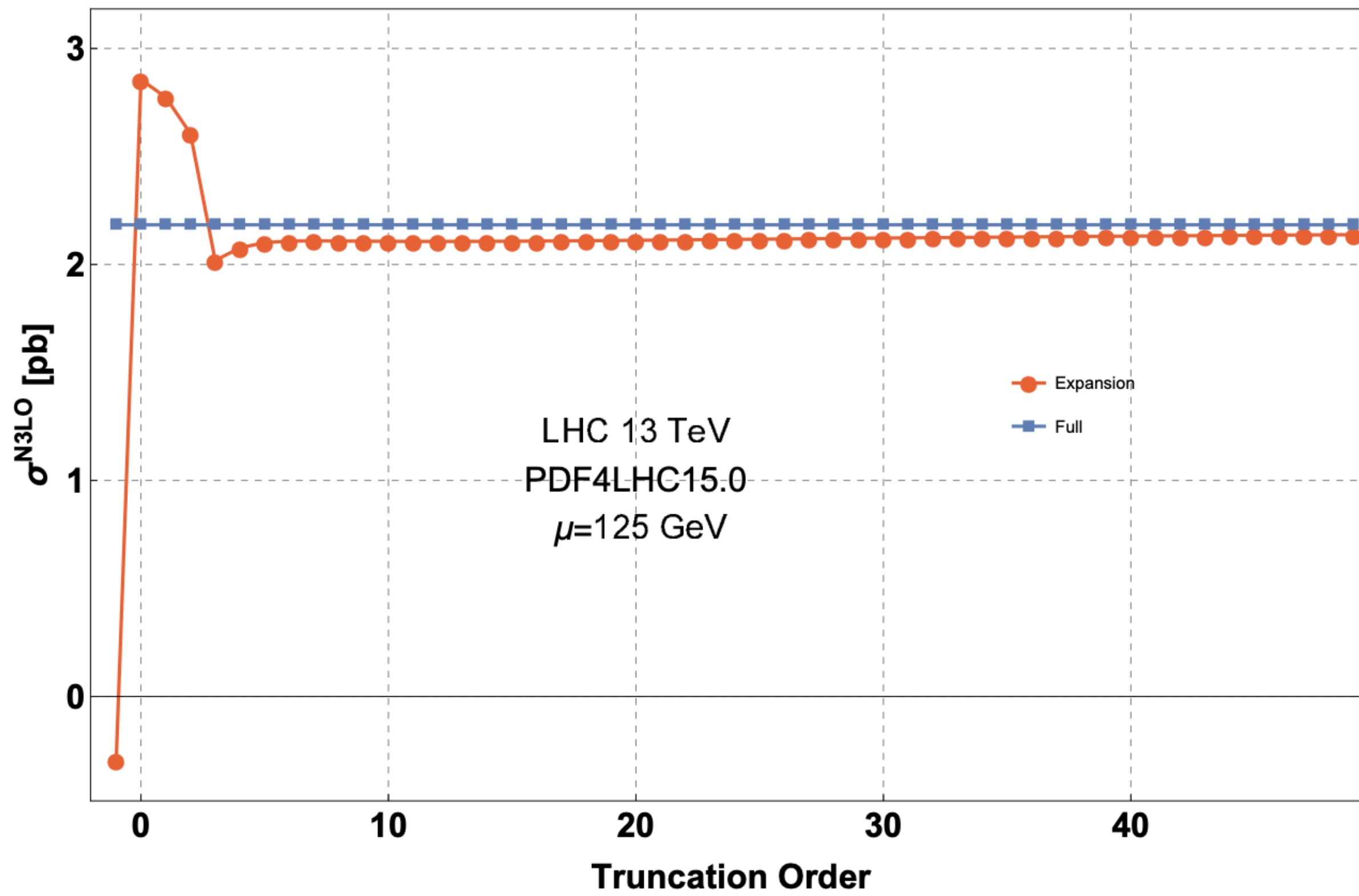
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$$\hat{\sigma}(z) = \hat{\sigma}(z \rightarrow 1) + \mathcal{O}(1-z)^{39}$$



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exact  $z$  dependence:

Higgs boson production at hadron colliders at N<sup>3</sup>LO in QCD #4

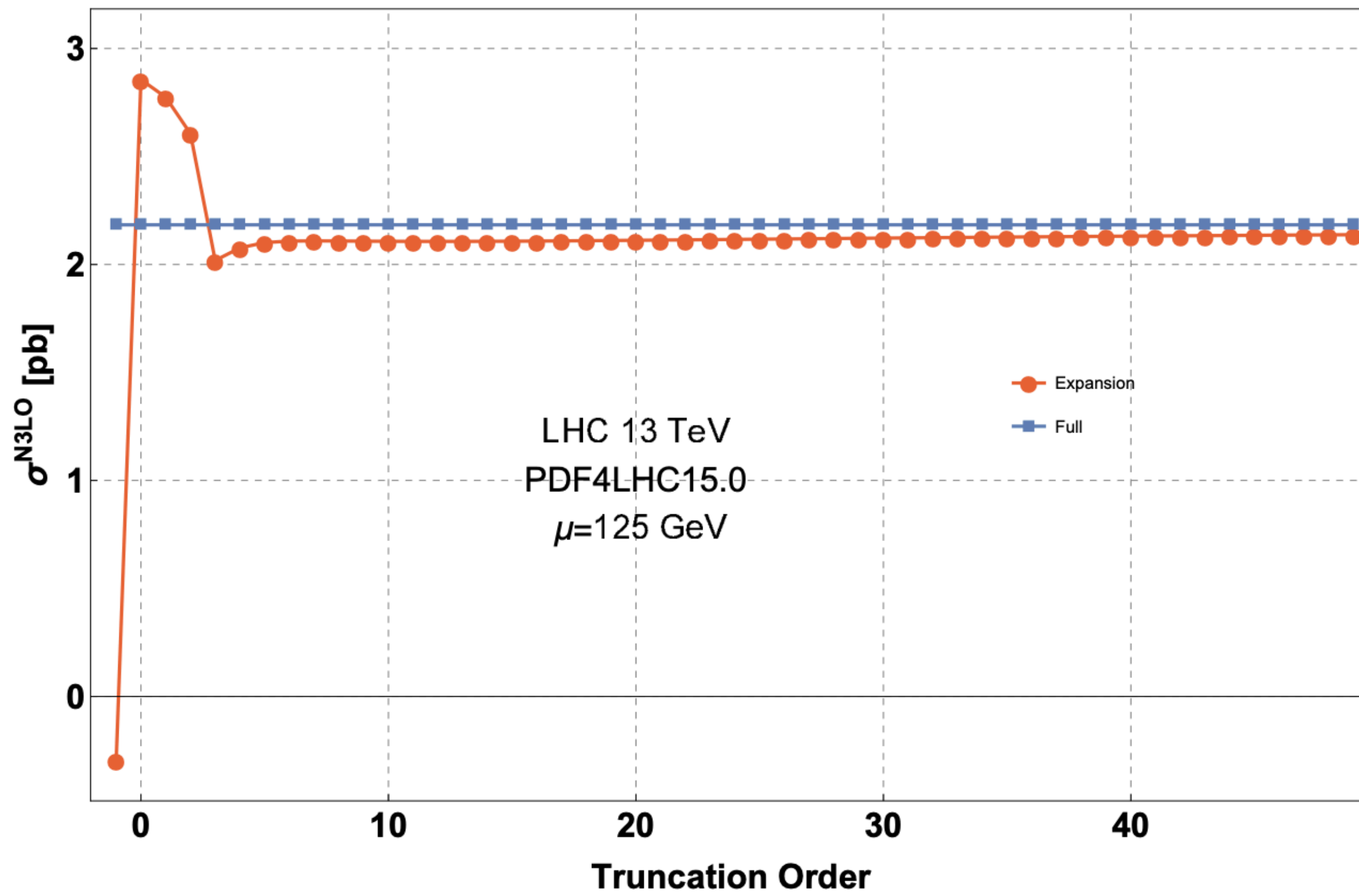
Bernhard Mistlberger (CERN) (Feb 2, 2018)

Published in: *JHEP* 05 (2018) 028 • e-Print: [1802.00833](https://arxiv.org/abs/1802.00833) [hep-ph]

pdf DOI cite claim reference search 178 citations

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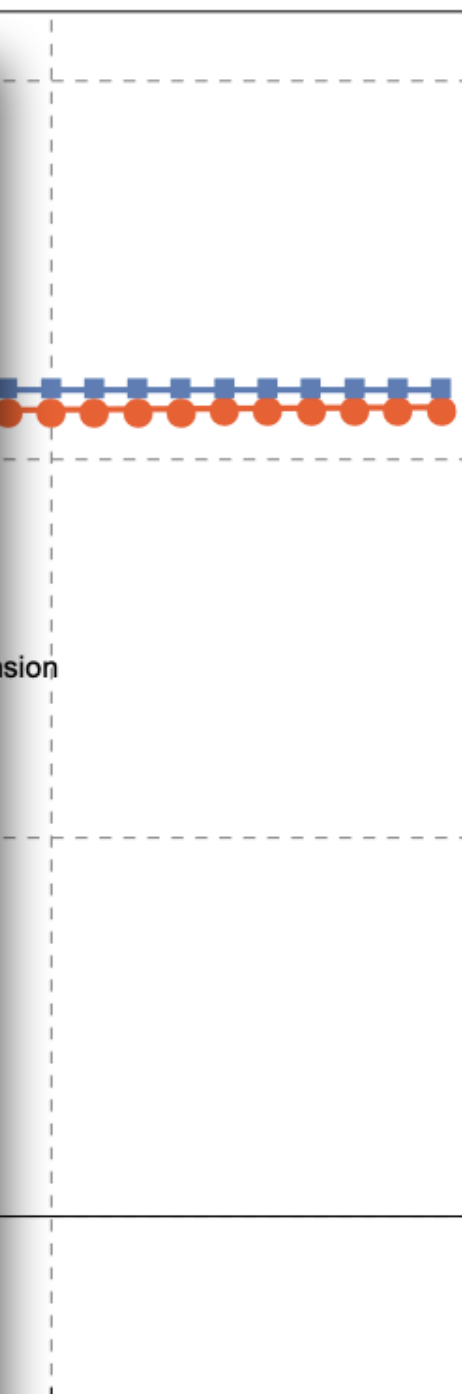
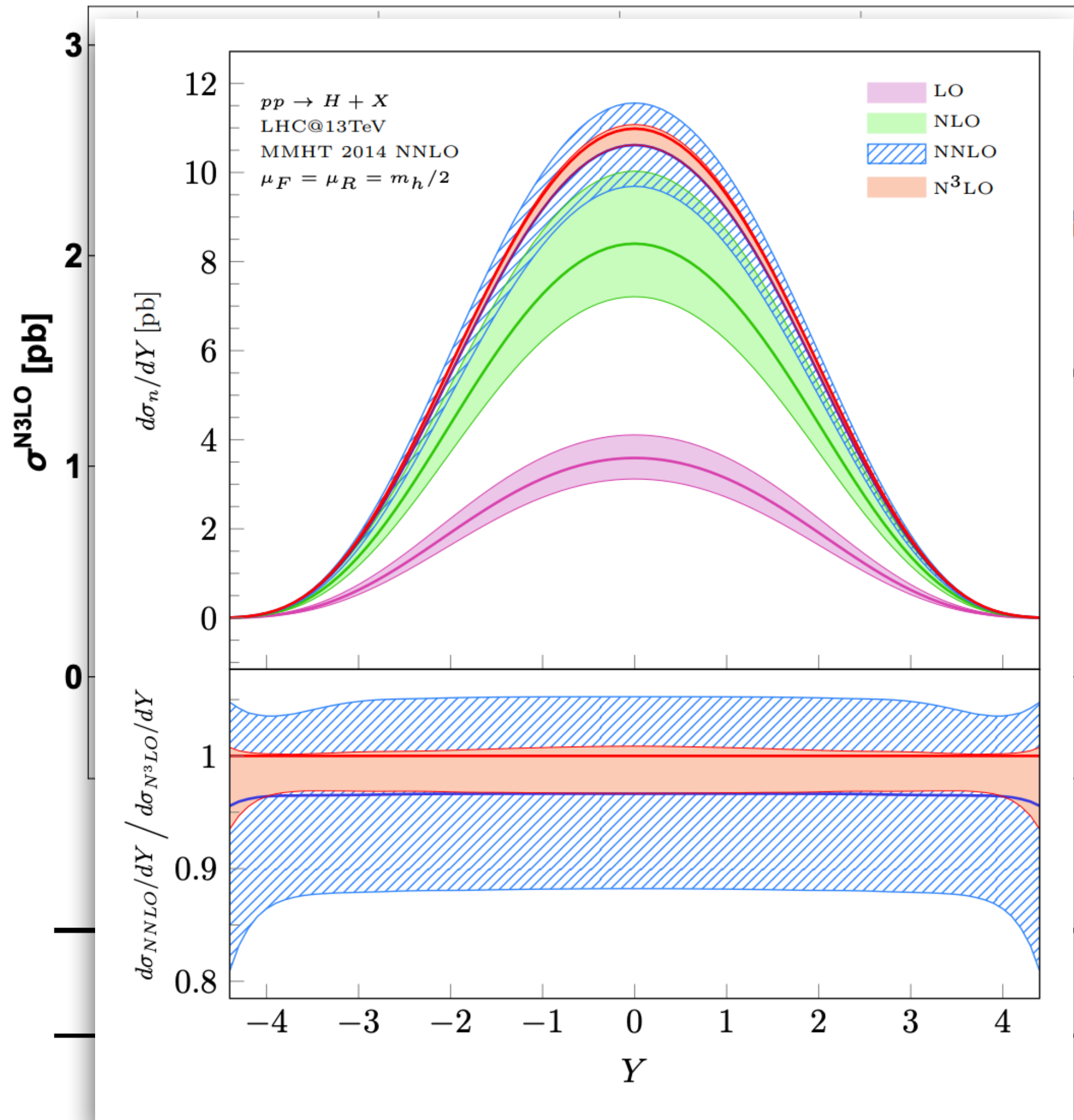


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[pdf](#) [DOI](#) [cite](#) [claim](#) [reference search](#) [178 citations](#)

**Fully Differential Higgs Boson Production to Third Order in QCD** #98  
 X. Chen (Zurich U. and KIT, Karlsruhe, TP and KIT, Karlsruhe, IAP), T. Gehrmann (Zurich U.), E.W.N. Glover (Durham U., IPPP), A. Huss (CERN), B. Mistlberger (SLAC) et al. (Feb 15, 2021)  
 Published in: *Phys.Rev.Lett.* 127 (2021) 7, 072002 • e-Print: [2102.07607](#) [hep-ph]  
[pdf](#) [DOI](#) [cite](#) [claim](#) [reference search](#) [37 citations](#)

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$\pm 0.37\%$

$\pm 1.16\%$

LHCH(XS)WG YR4 '16

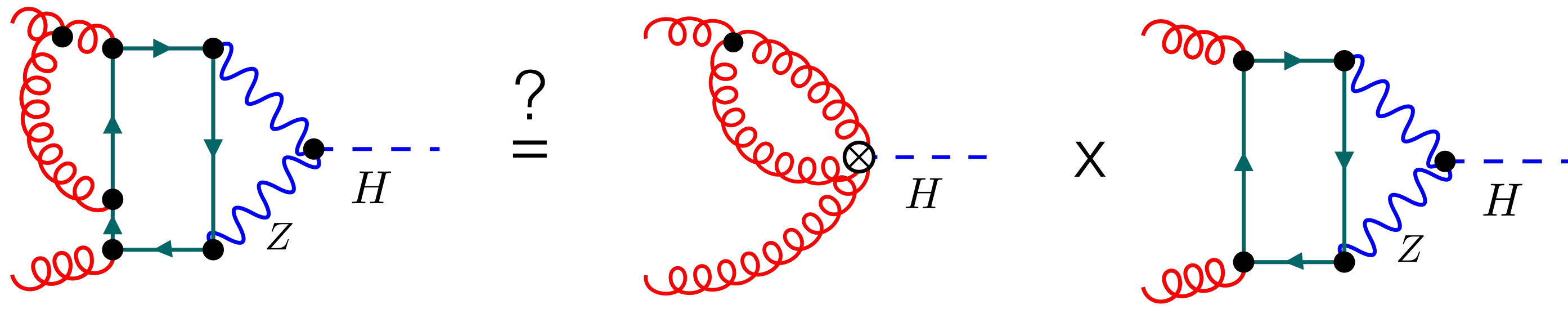
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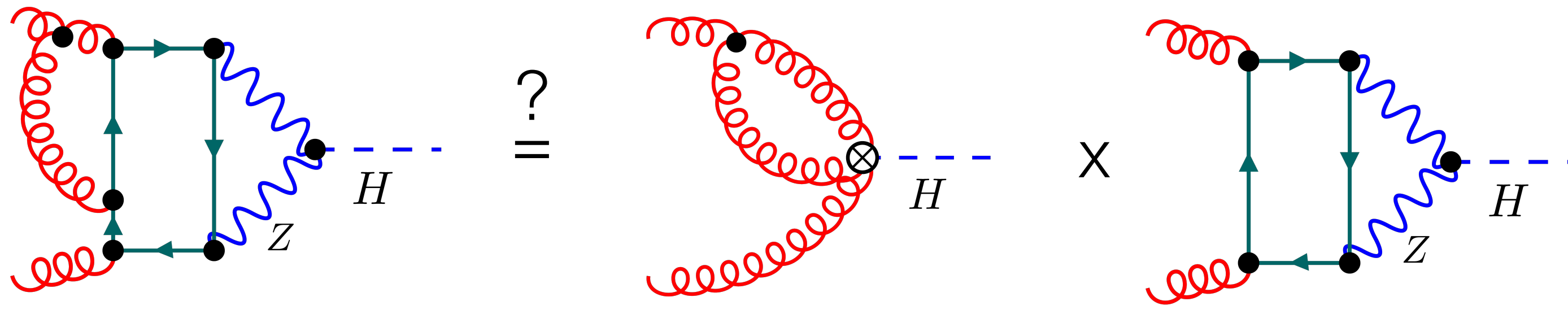
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### Higher order corrections to mixed QCD-EW contributions to Higgs boson production in gluon fusion #1

Marco Bonetti (KIT, Karlsruhe), Kirill Melnikov (KIT, Karlsruhe), Lorenzo Tancredi (CERN) (Jan 31, 2018)

Published in: *Phys.Rev.D* 97 (2018) 5, 056017, *Phys.Rev.D* 97 (2018) 9, 099906 (erratum) • e-Print: [1801.10403](https://arxiv.org/abs/1801.10403) [hep-ph]

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### Next-to-leading order corrections to light-quark mixed QCD-EW contributions to Higgs boson production #1

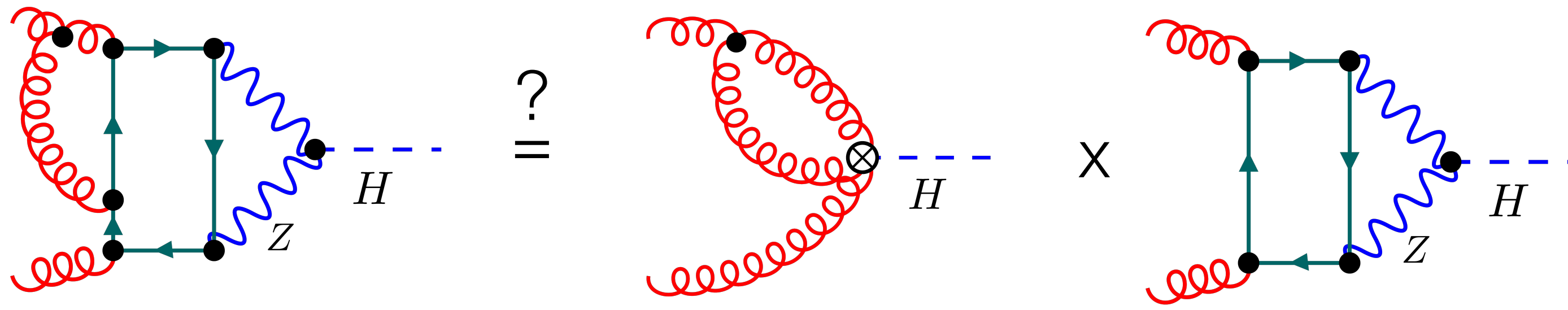
Matteo Becchetti (Turin U. and INFN, Turin), Roberto Bonciani (Rome U. and INFN, Rome), Vittorio Del Duca (Zurich, ETH and Frascati), Valentin Hirschi (Zurich, ETH), Francesco Moriello (Zurich, ETH) et al. (Oct 19, 2020)

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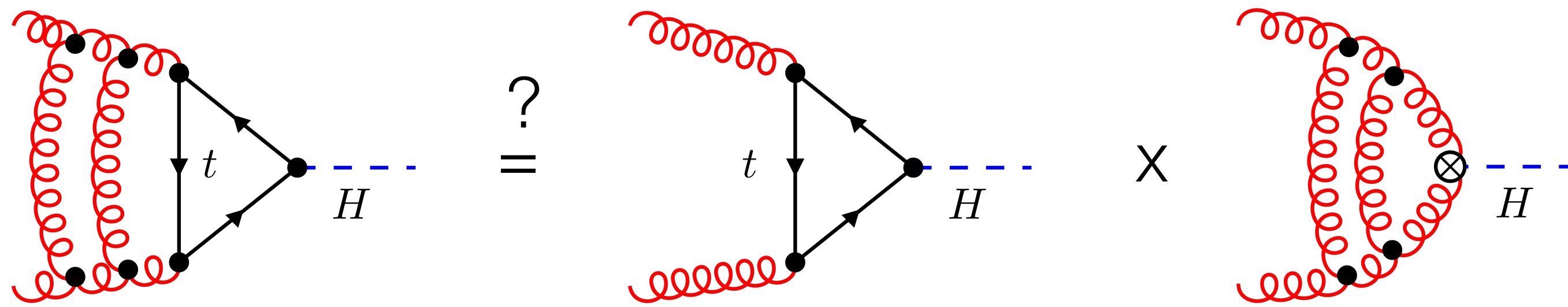
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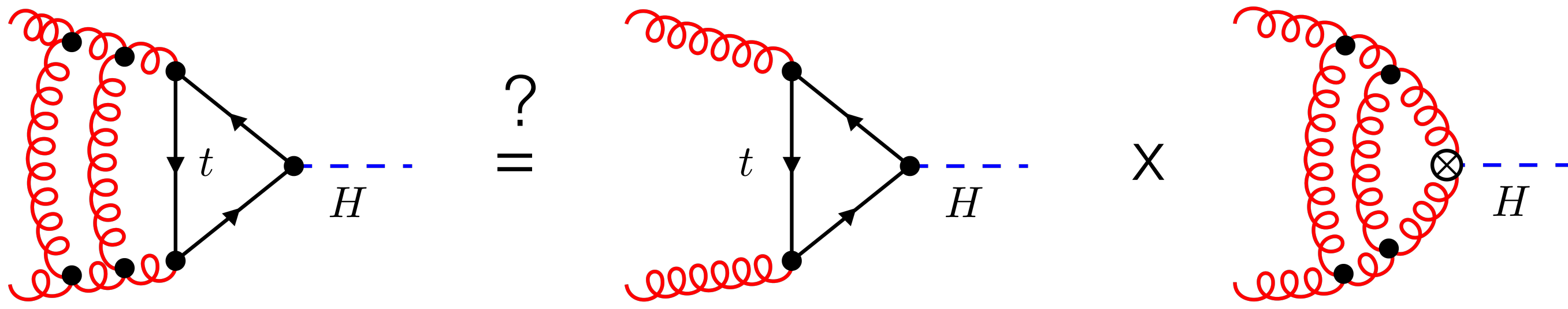


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LHCH(XS)WG YR4 '16



channel	$(\sigma_{\text{exact}}^{\text{NNLO}} / \sigma_{\text{HEFT}}^{\text{NNLO}} - 1)$ [%]
$gg$	+0.62
$qg$	-19
$qq$	-4
total	-0.16

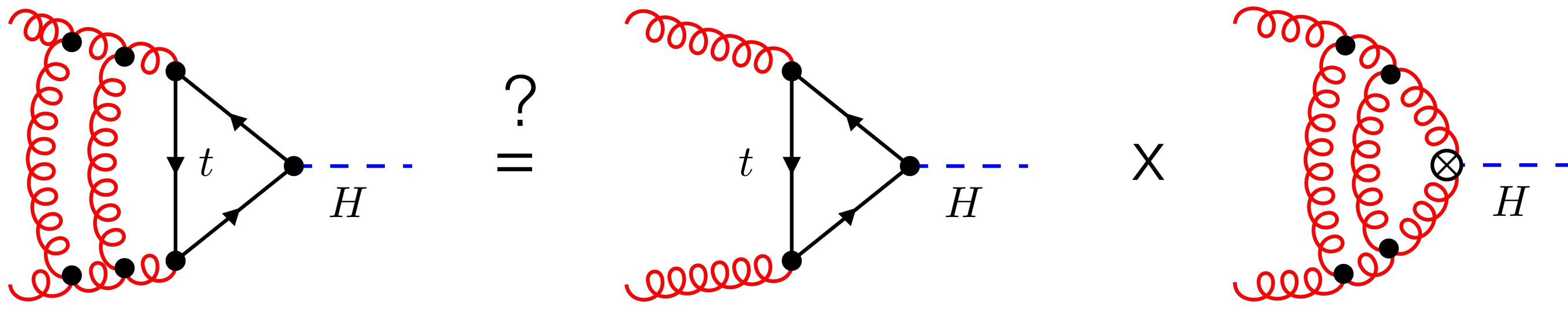
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**Exact Top-Quark Mass Dependence in Hadronic Higgs Production** #1  
 M. Czakon (Aachen, Tech. Hochsch.), R.V. Harlander (Aachen, Tech. Hochsch.), J. Klappert (Aachen, Tech. Hochsch.), M. Niggetiedt (Aachen, Tech. Hochsch.) (May 10, 2021)  
 Published in: *Phys.Rev.Lett.* 127 (2021) 16, 162002 • e-Print: [2105.04436](https://arxiv.org/abs/2105.04436) [hep-ph]  
[pdf](#) [DOI](#) [cite](#) [claim](#) [reference search](#) [15 citations](#)

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**Exact Top-Quark Mass Dependence in Hadronic Higgs Production** #1

M. Czakon (Aachen, Tech. Hochsch.), R.V. Harlander (Aachen, Tech. Hochsch.), J. Klappert (Aachen, Tech. Hochsch.), M. Niggetiedt (Aachen, Tech. Hochsch.) (May 10, 2021)

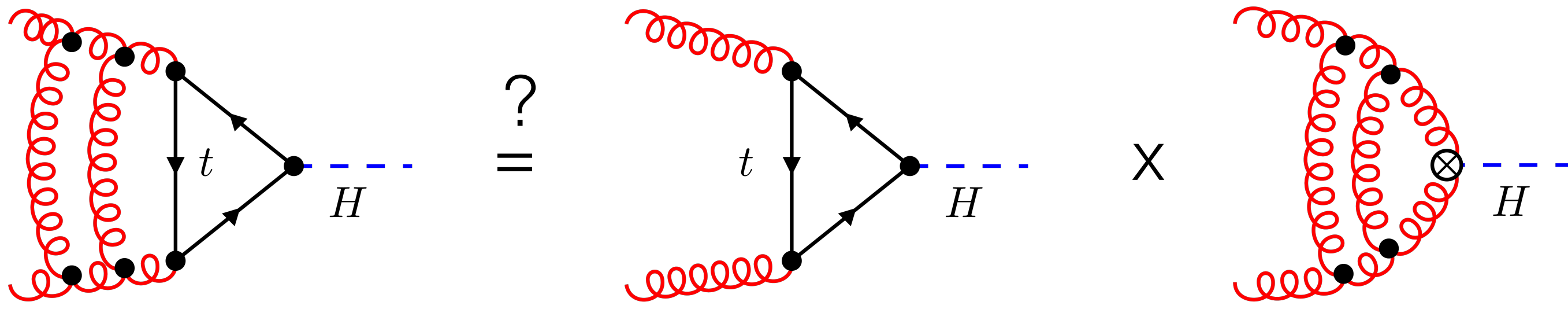
Published in: *Phys.Rev.Lett.* 127 (2021) 16, 162002 • e-Print: [2105.04436](https://arxiv.org/abs/2105.04436) [hep-ph]

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+0.10 pb -1.15 pb	<del><math>\pm 0.18</math> pb</del>	$\pm 0.56$ pb	<del><math>\pm 0.49</math> pb</del>	$\pm 0.40$ pb	$\pm 0.49$ pb
+0.21% -2.37%	<del><math>\pm 0.37\%</math></del>	$\pm 1.16\%$	<del><math>\pm 1\%</math></del>	$\pm 0.83\%$	$\pm 1\%$

LHCH(XS)WG YR4 '16





channel	$(\sigma_{\text{exact}}^{\text{NNLO}} / \sigma_{\text{HEFT}}^{\text{NNLO}} - 1) [\%]$
<i>gg</i>	+0.62
<i>qg</i>	-19
<i>qq</i>	-4
total	-0.16

Inclusive gluon fusion cross section:

48.58 pb =

16.00 pb	(+32.9%)	(LO, rEFT)
+ 20.84 pb	(+42.9%)	(NLO, rEFT)
- 2.05 pb	(-4.2%)	(( <i>t, b, c</i> ), exact NLO)
+ 9.56 pb	(+19.7%)	(NNLO, rEFT)
+ 0.34 pb	(+0.7%)	(NNLO, $1/m_t$ )
+ 2.40 pb	(+4.9%)	(EW, QCD-EW)
+ 1.49 pb	(+3.1%)	( $N^3$ LO, rEFT)

<i>gg</i>	+0.62
<i>qg</i>	-18
<i>qq</i>	-15
total	-0.32

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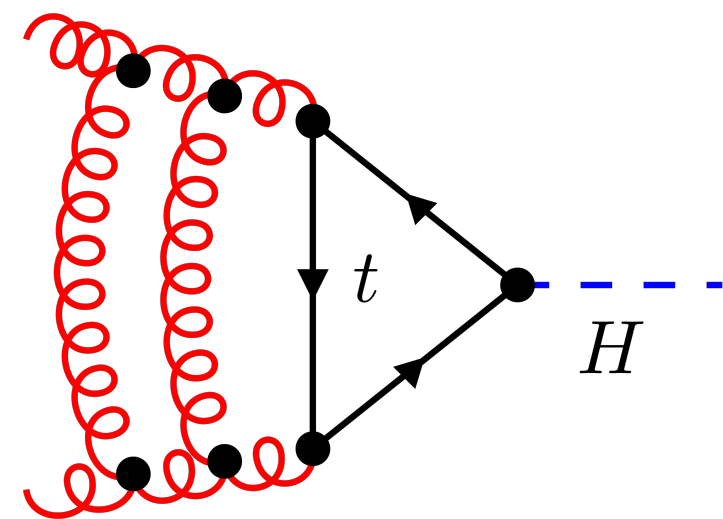
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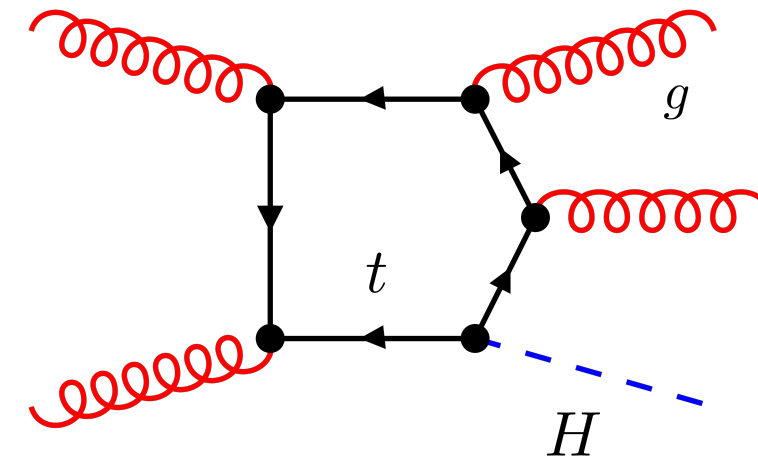
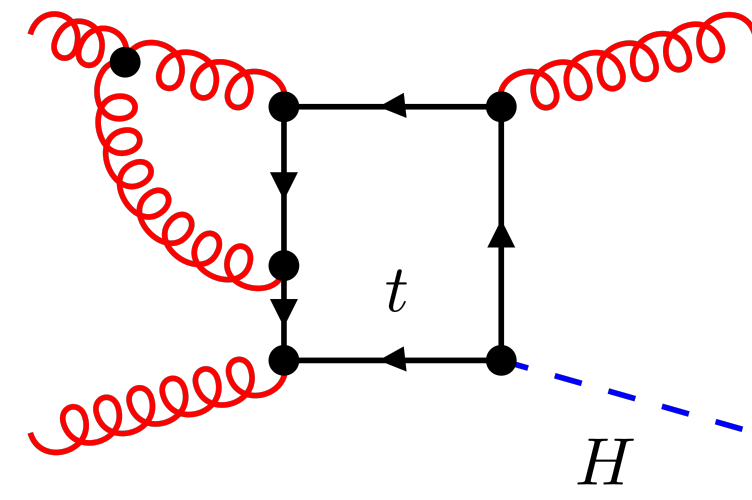
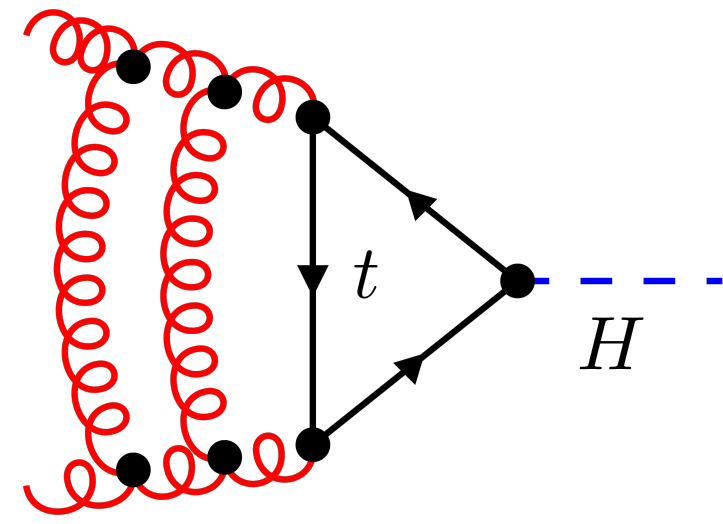
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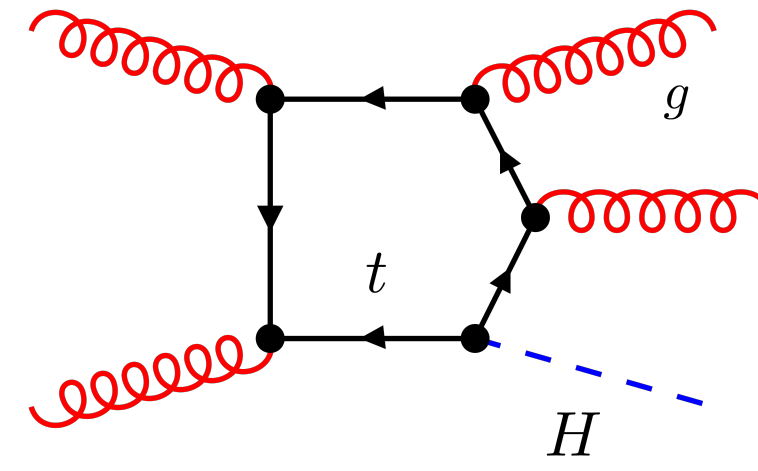
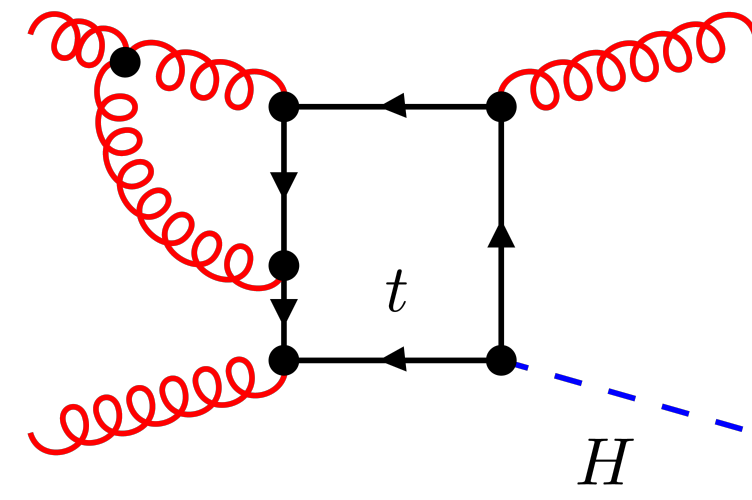
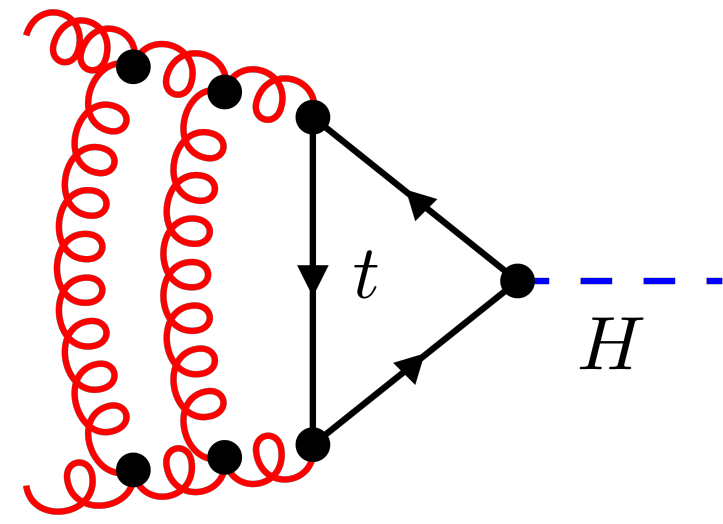
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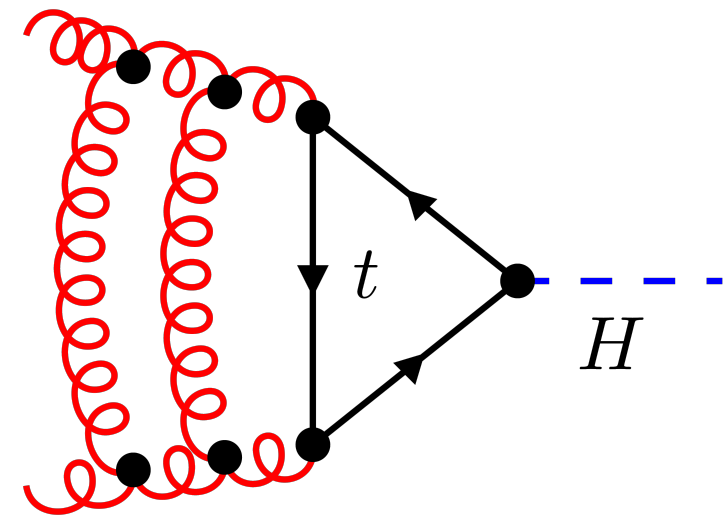
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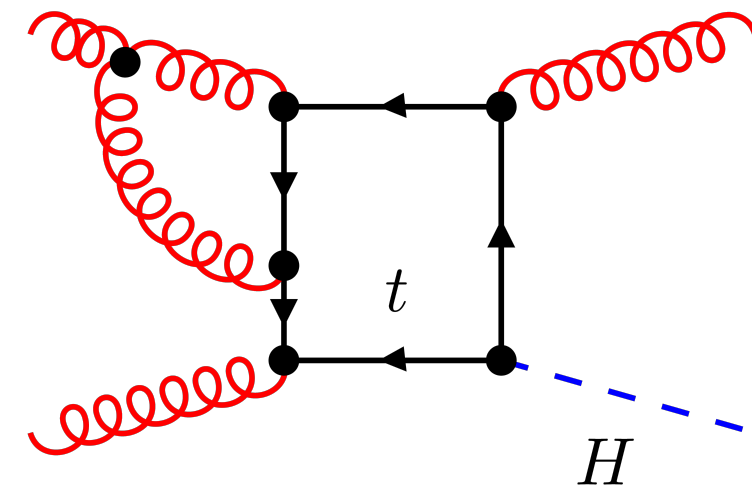




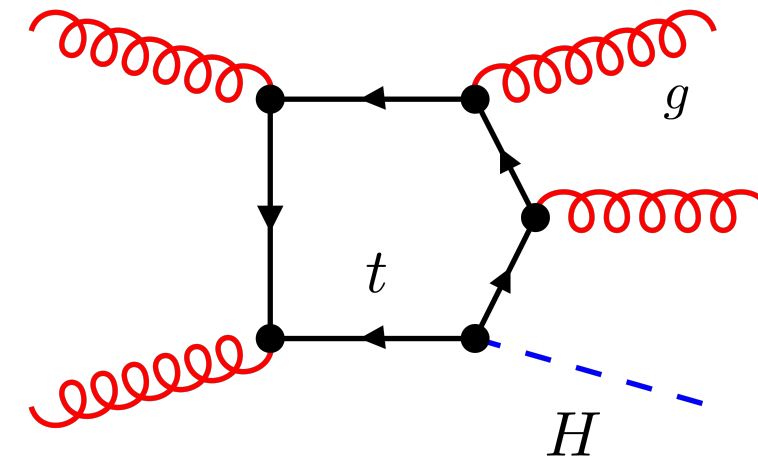
$$p_{T,H} \equiv 0$$

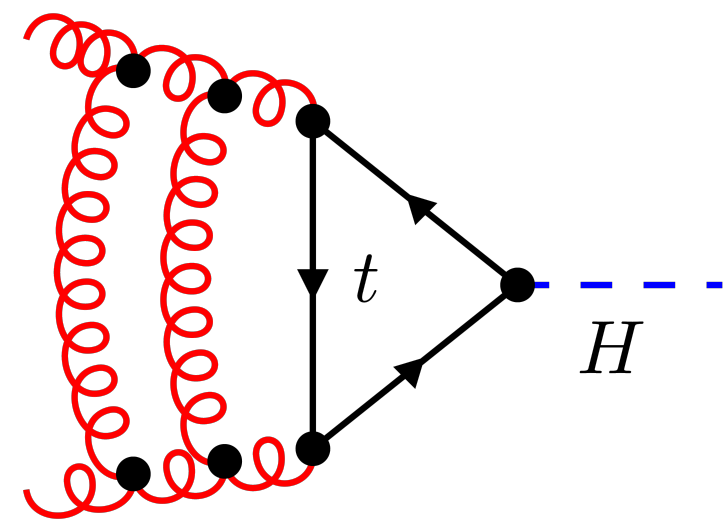


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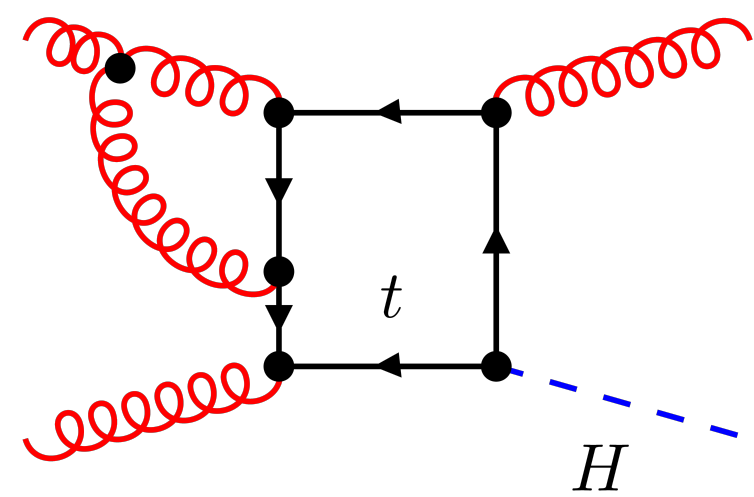


$$p_{T,H} > 0$$

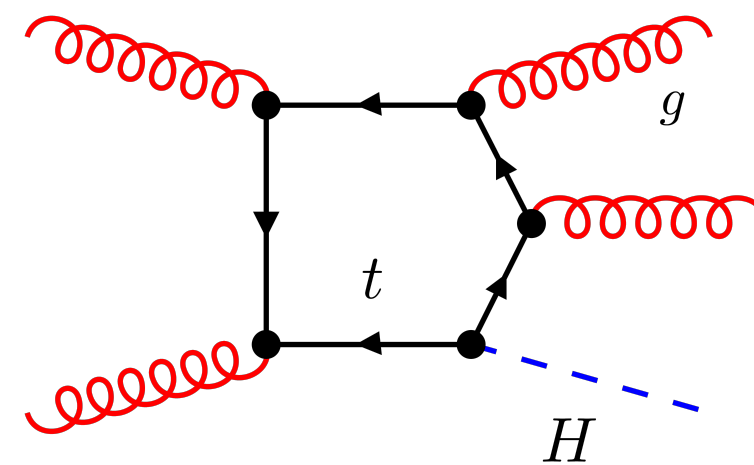




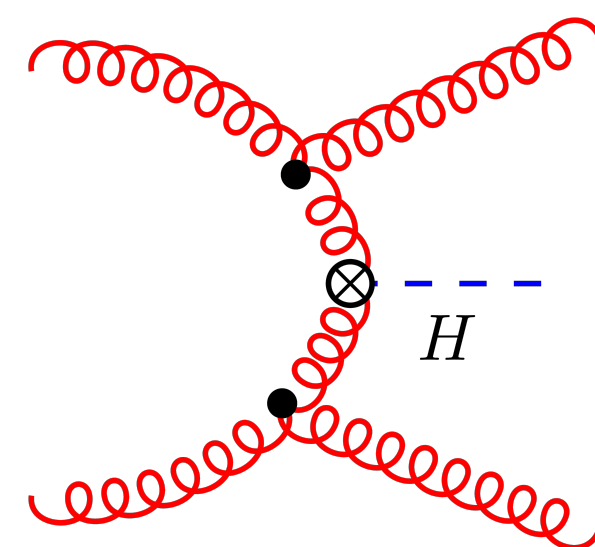
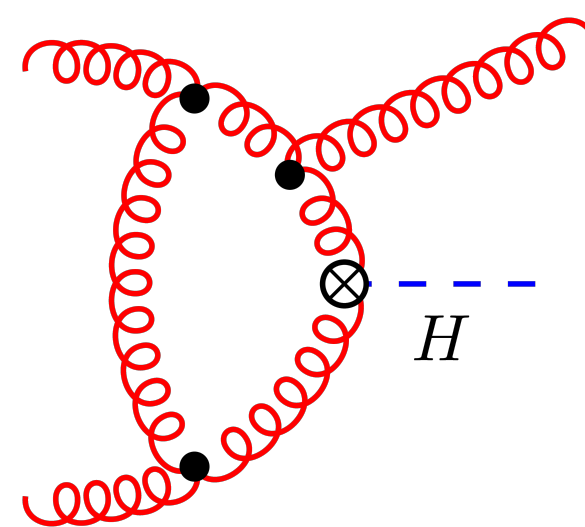
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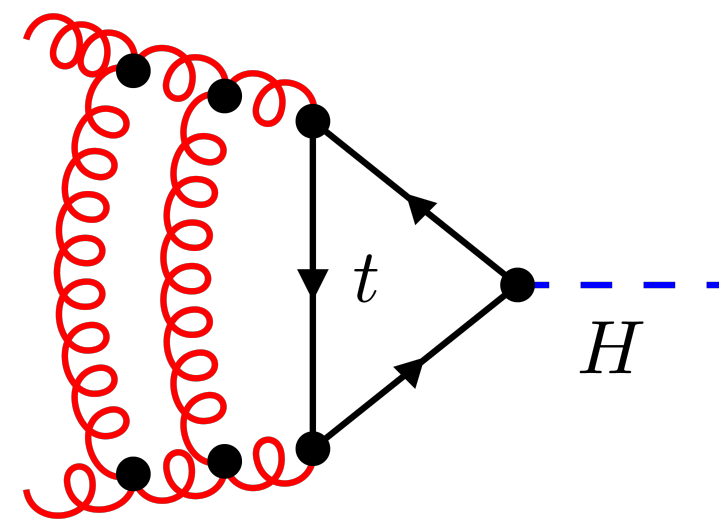


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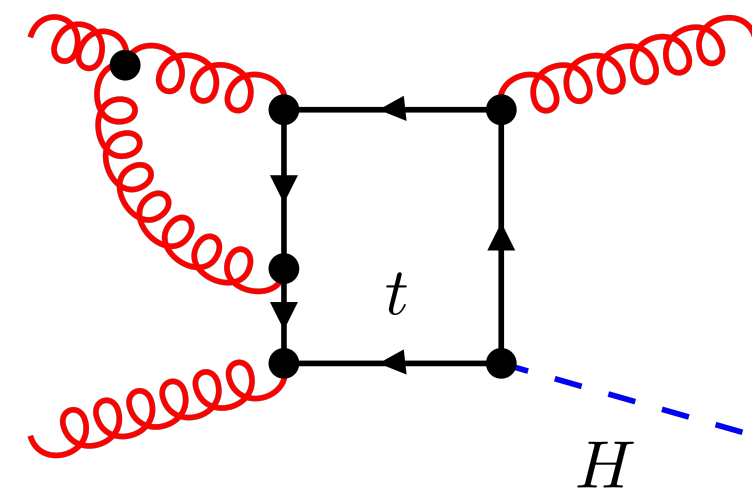


VS.

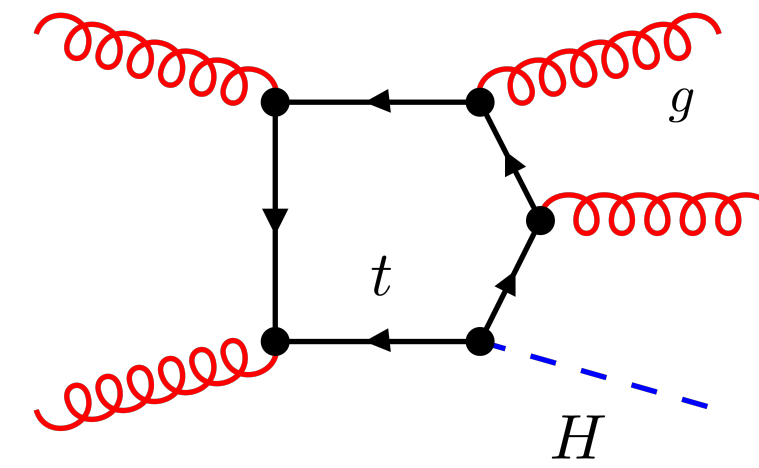




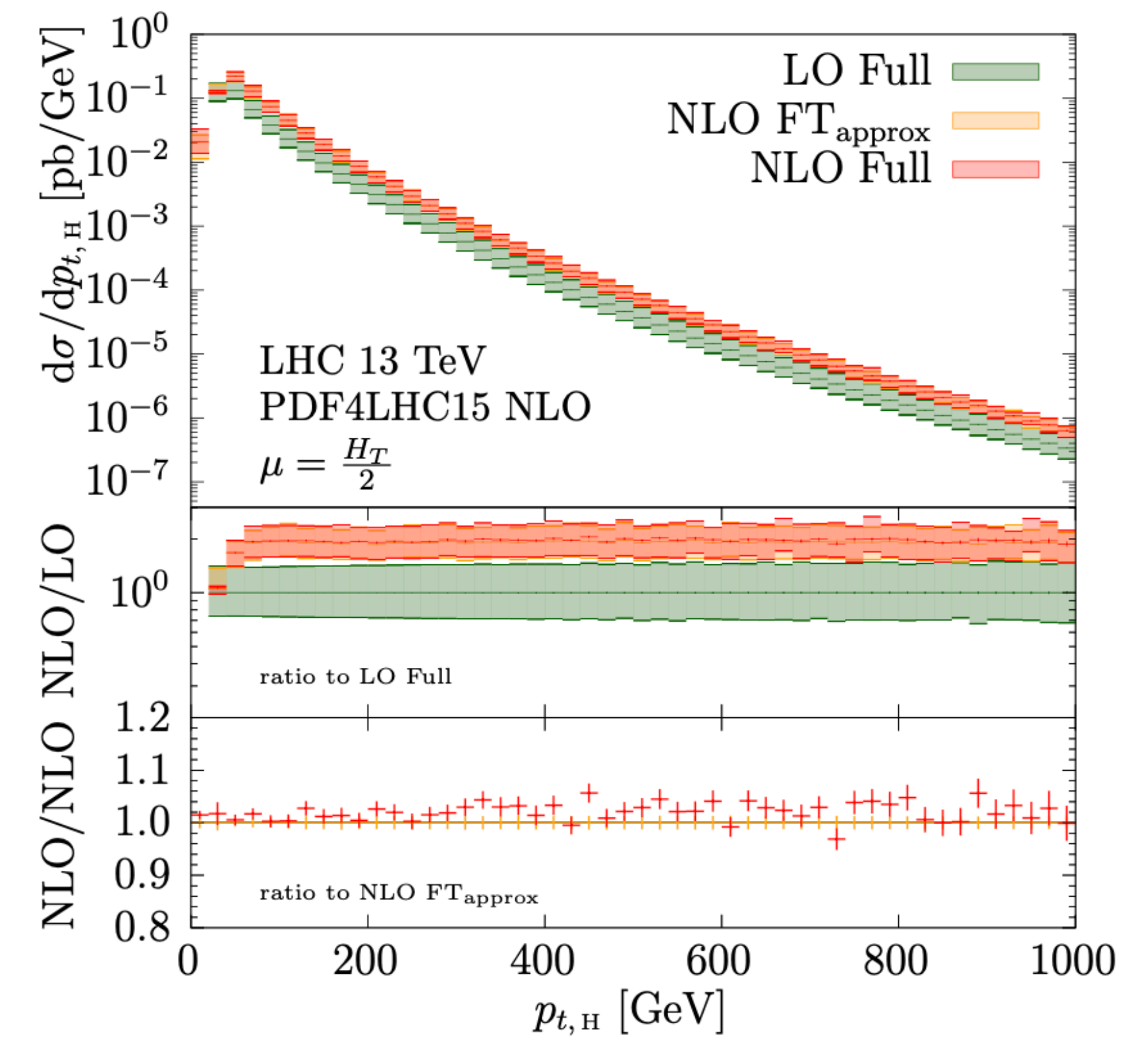
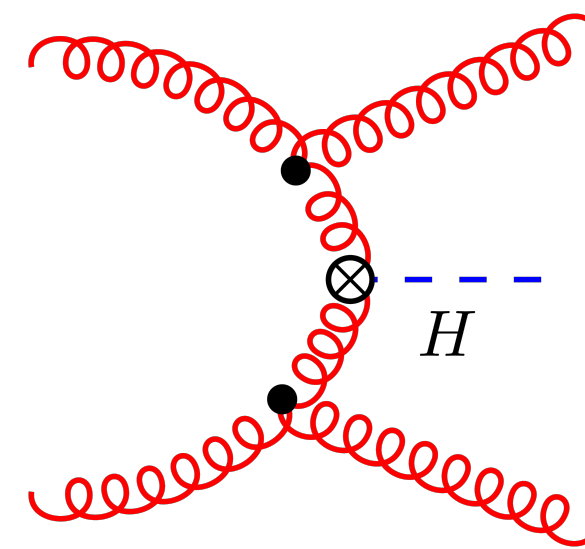
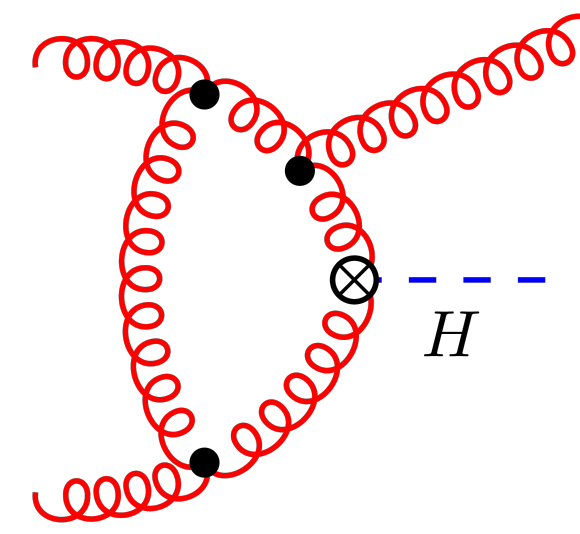
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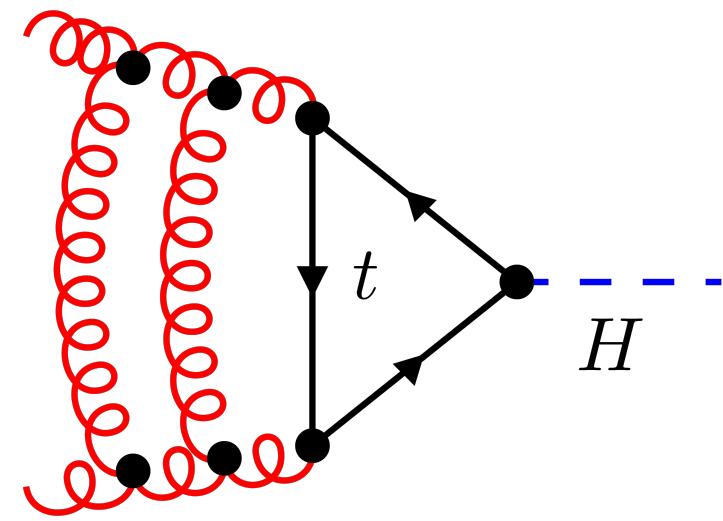


**Next-to-Leading-Order QCD Corrections to Higgs Boson Plus Jet Production with Full Top-Quark Mass Dependence** #1

S.P. Jones (Munich, Max Planck Inst.), M. Kerner (Munich, Max Planck Inst.), G. Luisoni (Munich, Max Planck Inst.) (Feb 1, 2018)

Published in: *Phys.Rev.Lett.* 120 (2018) 16, 162001, *Phys.Rev.Lett.* 128 (2022) 5, 059901 (erratum) • e-Print: [1802.00349](https://arxiv.org/abs/1802.00349) [hep-ph]

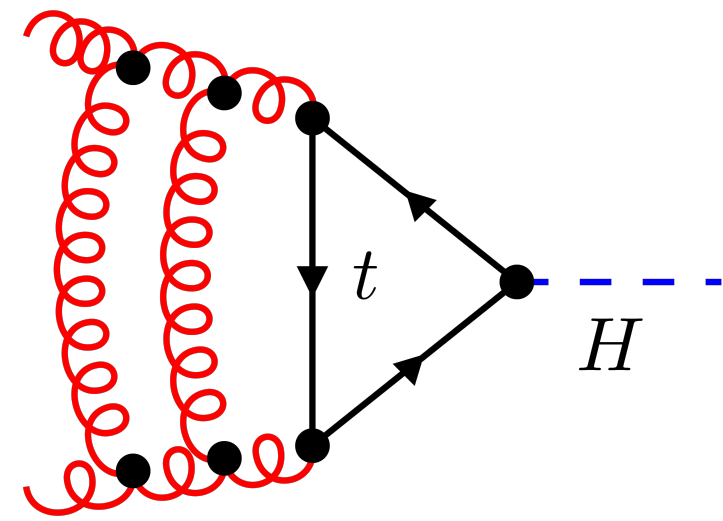
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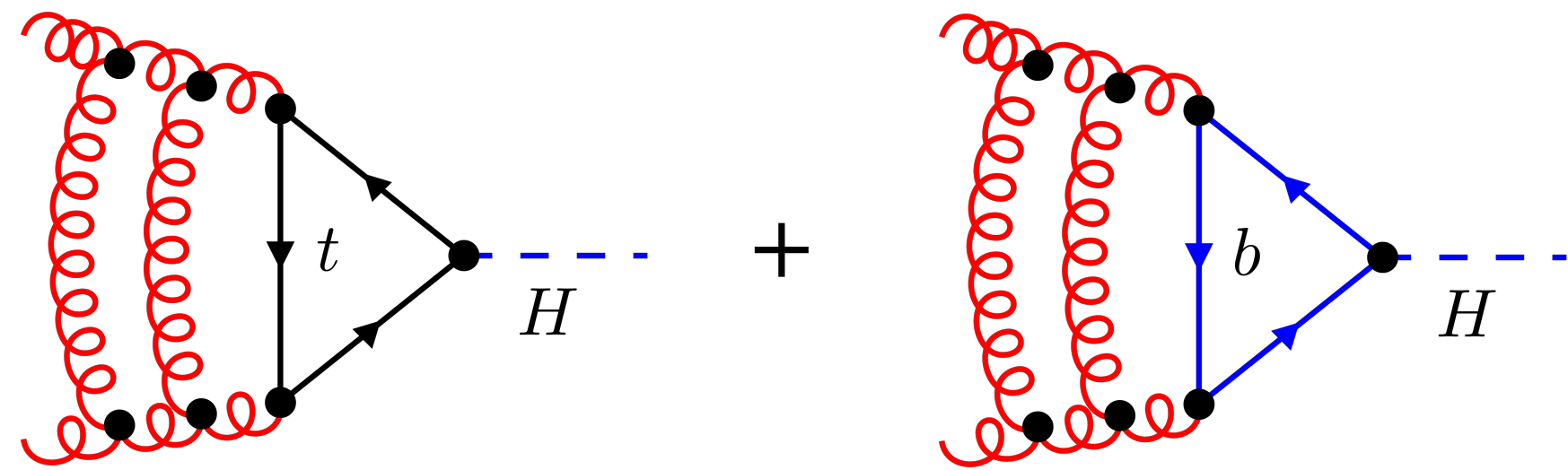
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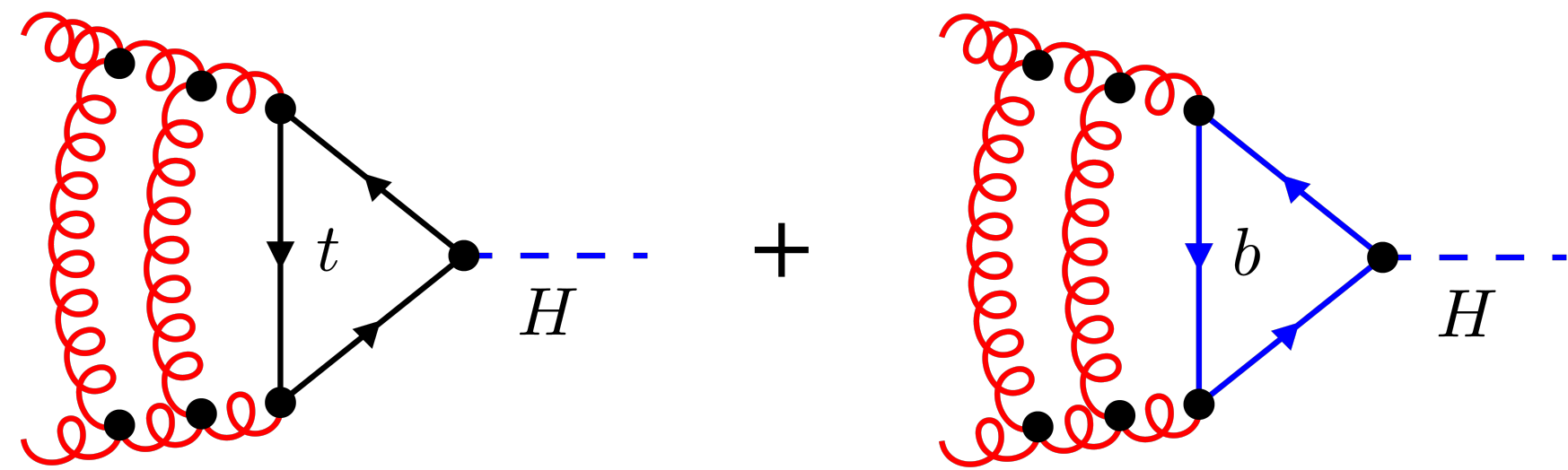
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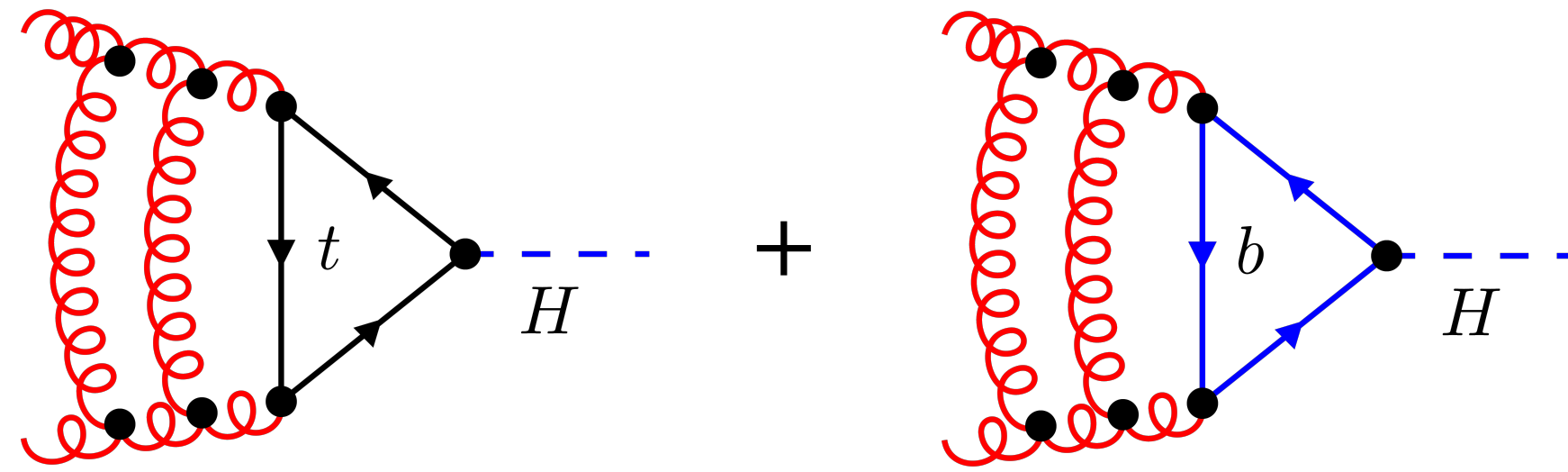
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$$\frac{\alpha_s}{\pi} \ln^2 \frac{m_b^2}{M_H^2} \approx 1.6$$

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LHCH(XS)WG YR4 '16



$$\frac{\alpha_s}{\pi} \ln^2 \frac{m_b^2}{M_H^2} \approx 1.6$$

### Top-Bottom Interference Contribution to Fully Inclusive Higgs Production #2

Michał Czakon (RWTH Aachen U.), Felix Eschment (RWTH Aachen U.), Marco Niggetiedt (Garching, Max Planck Inst.), Rene Poncelet (Cracow, INP), Tom Schellenberger (RWTH Aachen U.) (Dec 15, 2023)

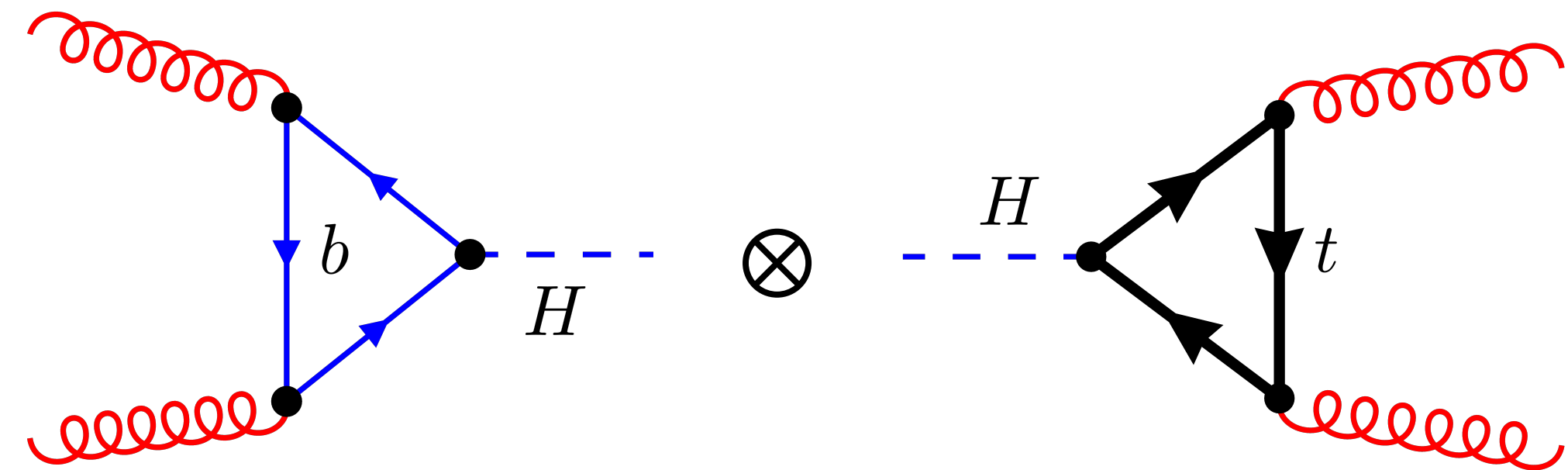
Published in: *Phys.Rev.Lett.* 132 (2024) 21, 211902 • e-Print: [2312.09896](https://arxiv.org/abs/2312.09896) [hep-ph]

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[5 citations](#)

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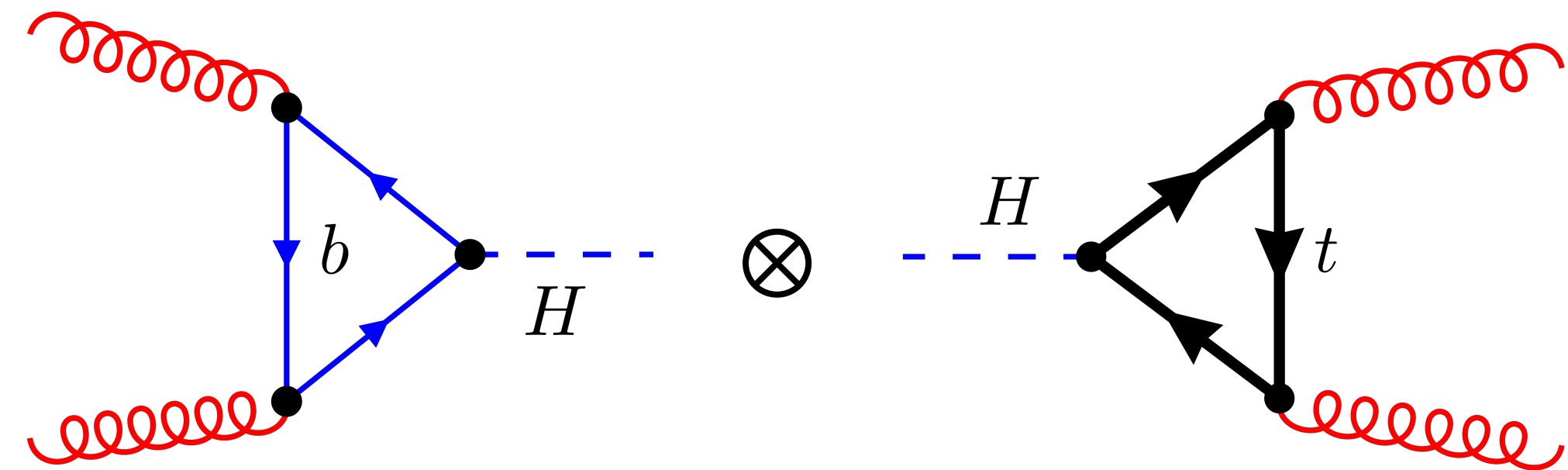
Order	$\sigma_{\text{HEFT}}$ [pb]	$(\sigma_t - \sigma_{\text{HEFT}})$ [pb]	$\sigma_{t \times b}$ [pb]	$\sigma_{t \times b} (Y_{b, \overline{\text{MS}}})$ [pb]	$\sigma_{t \times b} / \sigma_{\text{HEFT}}$ [%]
$\sqrt{s} = 13.6 \text{ TeV}$					
$\mathcal{O}(\alpha_s^2)$	+17.47	–	–2.117	–1.311	
LO	$17.47^{+4.67}_{-3.32}$	–	$-2.12^{+0.40}_{-0.57}$	$-1.31^{+0.31}_{-0.47}$	–12
$\mathcal{O}(\alpha_s^3)$	+22.76	–0.338	–0.464(1)	–0.659(1)	
NLO	$40.23^{+9.07}_{-6.77}$	$-0.338^{+0.11}_{-0.18}$	$-2.58^{+0.20}_{-0.12}$	$-1.97^{+0.28}_{-0.28}$	$-6.4^{+0.9}_{-0.8}$
$\mathcal{O}(\alpha_s^4)$	+10.47	+0.162(1)	+0.464(9)	+0.022(6)	
NNLO	$50.70^{+4.53}_{-5.14}$	$-0.176(1)^{+0.14}_{-0.03}$	$-2.12(1)^{+0.33}_{-0.16}$	$-1.95(1)^{+0.09}_{-0.03}$	$-4.2^{+0.9}_{-0.8}$



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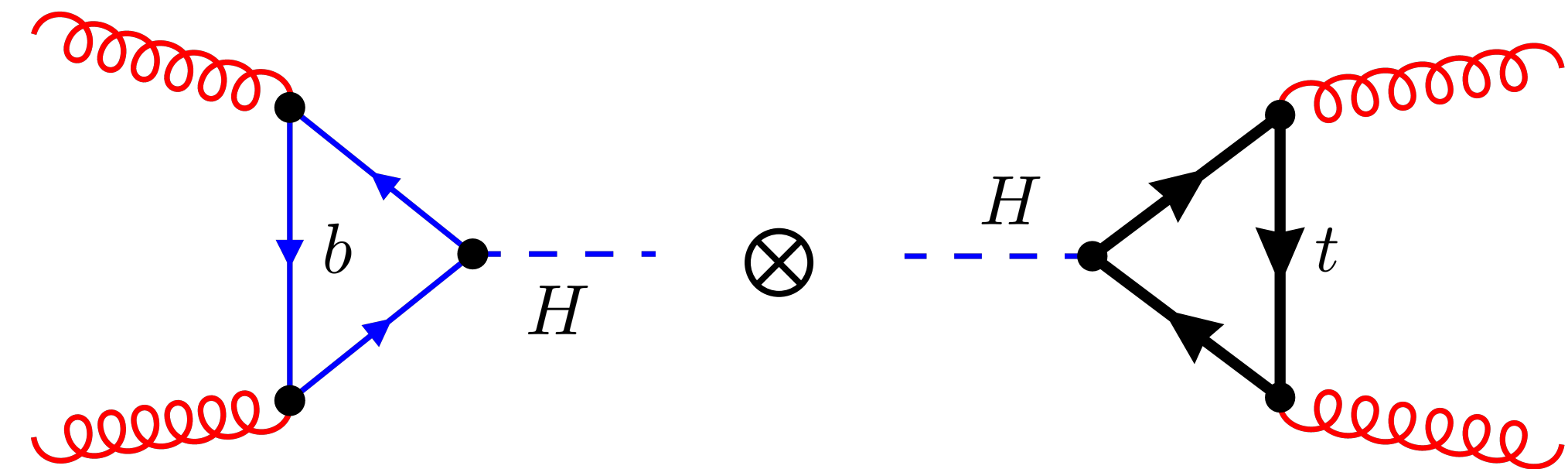
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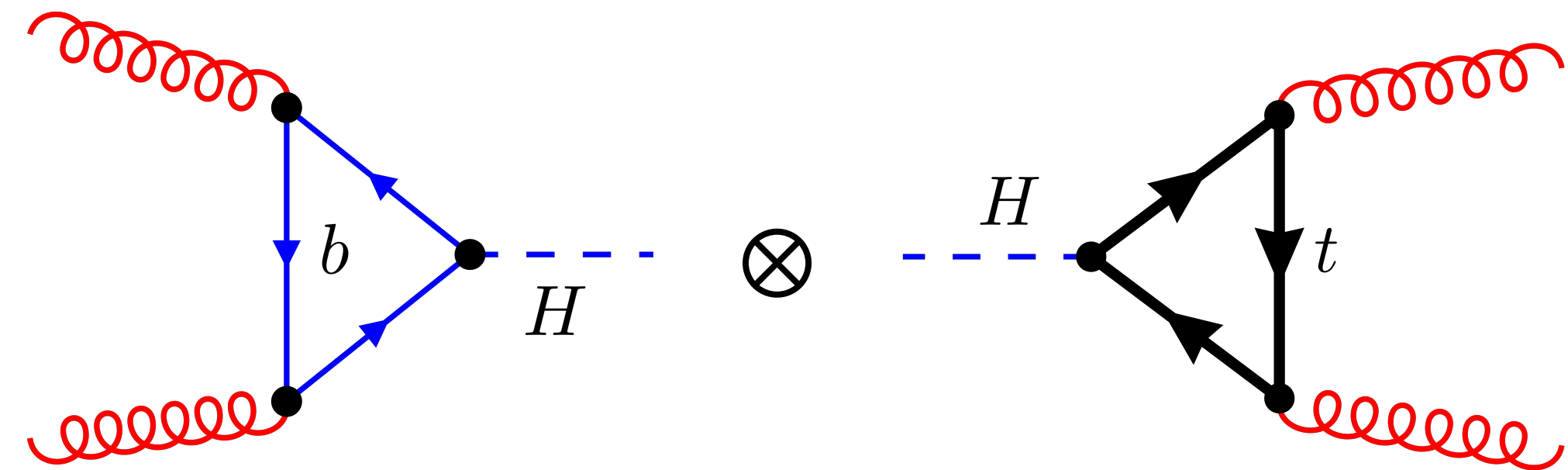
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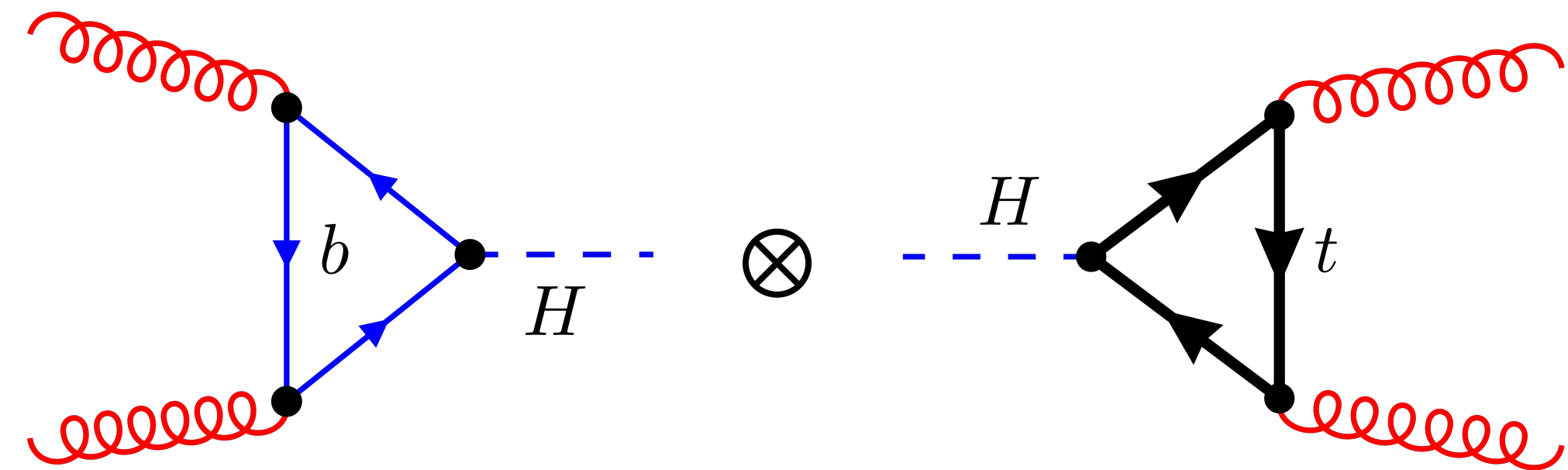




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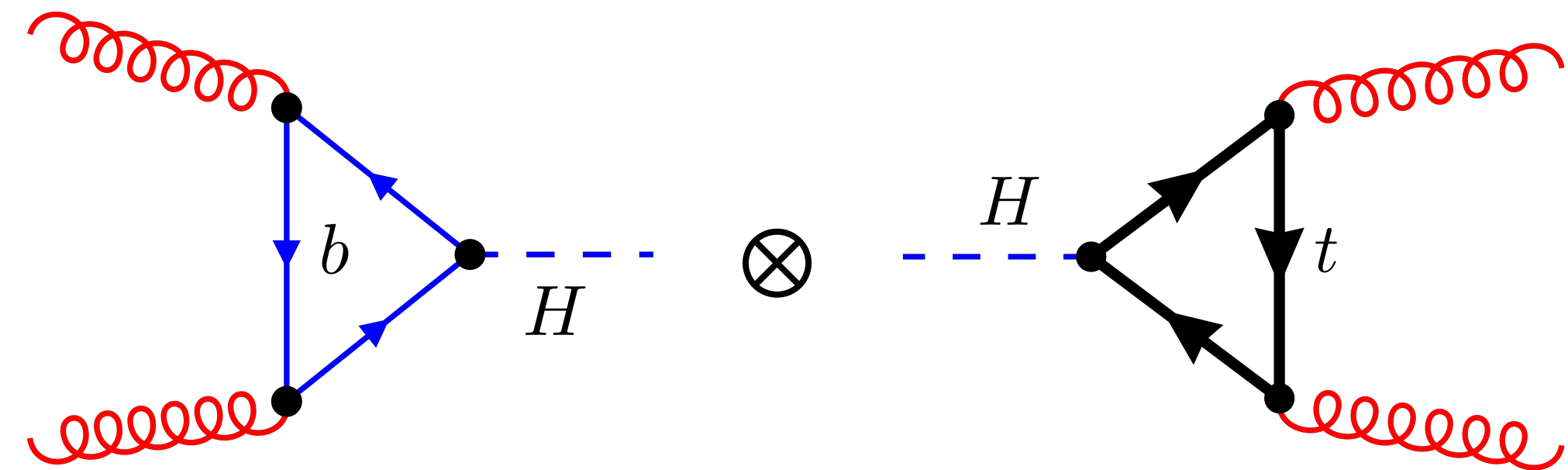
Order	$\sigma_{\text{HEFT}}$ [pb]	$(\sigma_t - \sigma_{\text{HEFT}})$ [pb]	$\sigma_{t \times b}$ [pb]	$\sigma_{t \times b} (Y_{b, \overline{\text{MS}}})$ [pb]	$\sigma_{t \times b} / \sigma_{\text{HEFT}}$ [%]
$\sqrt{s} = 13.6 \text{ TeV}$					
$\mathcal{O}(\alpha_s^2)$	+17.47	–	–2.117	–1.311	
LO	$17.47^{+4.67}_{-3.32}$	–	$-2.12^{+0.40}_{-0.57}$	$-1.31^{+0.31}_{-0.47}$	–12
$\mathcal{O}(\alpha_s^3)$	+22.76	–0.338	–0.464(1)	–0.659(1)	
NLO	$40.23^{+9.07}_{-6.77}$	$-0.338^{+0.11}_{-0.18}$	$-2.58^{+0.20}_{-0.12}$	$-1.97^{+0.28}_{-0.28}$	$-6.4^{+0.9}_{-0.8}$
$\mathcal{O}(\alpha_s^4)$	+10.47	+0.162(1)	+0.464(9)	+0.022(8)	
NNLO	$50.70^{+4.53}_{-5.14}$	$-0.176(1)^{+0.14}_{-0.03}$	$-2.12(1)^{+0.33}_{-0.16}$	$-1.95(1)^{+0.09}_{-0.03}$	$-4.2^{+0.9}_{-0.8}$

$$Y_{b, \text{pole}} \sim m_b^{\text{pole}} \approx 4.7 \text{ GeV}$$

$$Y_{b, \overline{\text{MS}}} \sim m_b^{\overline{\text{MS}}}(M_H/2) \approx 3.0 \text{ GeV}$$

Inclusive gluon fusion cross section:

48.58 pb =	16.00 pb	(+32.9%)	(LO, rEFT)
	+ 20.84 pb	(+42.9%)	(NLO, rEFT)
	– 2.05 pb	(–4.2%)	((t, b, c), exact NLO)
	+ 9.56 pb	(+19.7%)	(NNLO, rEFT)
	+ 0.34 pb	(+0.7%)	(NNLO, $1/m_t$ )
	+ 2.40 pb	(+4.9%)	(EW, QCD-EW)
	+ 1.49 pb	(+3.1%)	(N <sup>3</sup> LO, rEFT)



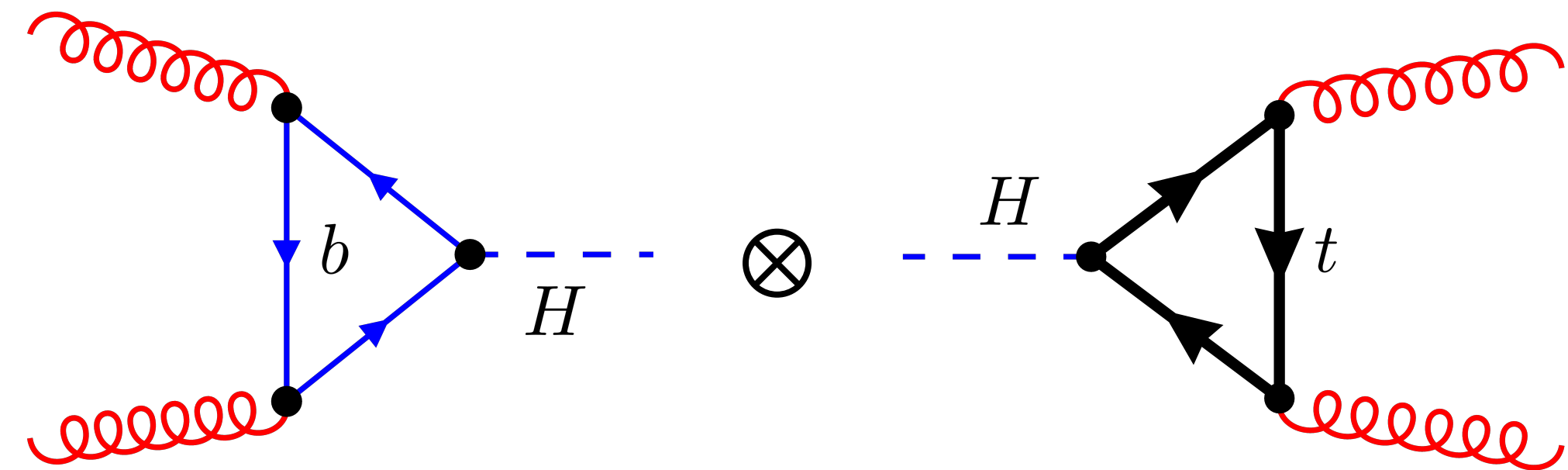
Order	$\sigma_{\text{HEFT}}$ [pb]	$(\sigma_t - \sigma_{\text{HEFT}})$ [pb]	$\sigma_{t \times b}$ [pb]	$\sigma_{t \times b} (Y_{b, \overline{\text{MS}}})$ [pb]	$\sigma_{t \times b} / \sigma_{\text{HEFT}}$ [%]
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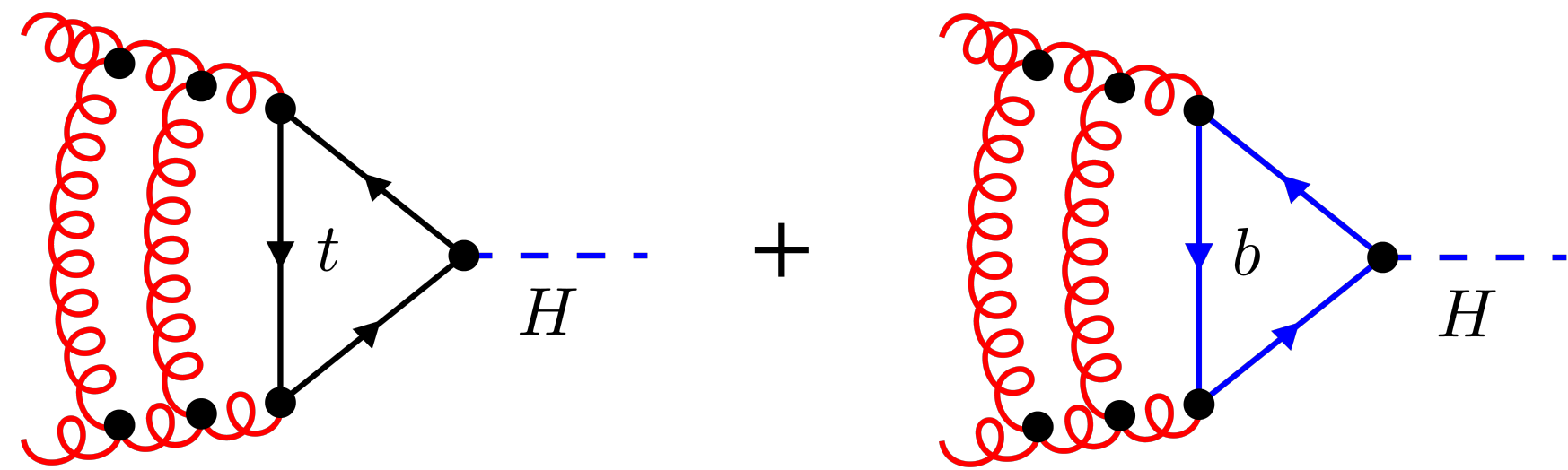
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$$\frac{\alpha_s}{\pi} \ln^2 \frac{m_b^2}{M_H^2} \approx 1.3$$

## Top-Bottom Interference Contribution to Fully Inclusive Higgs Production #2

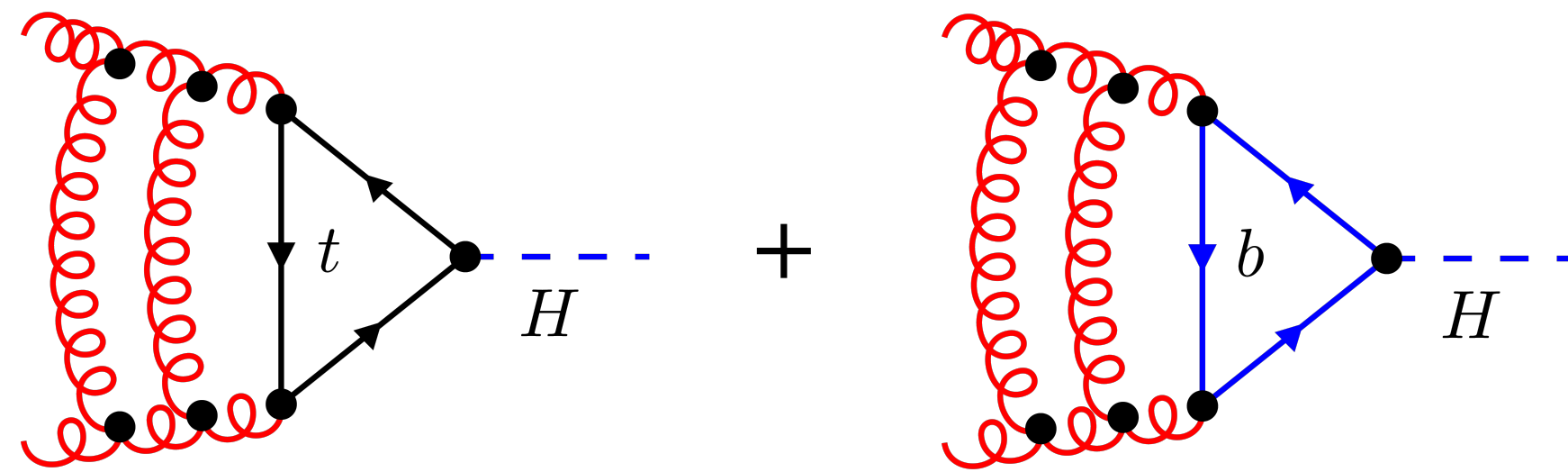
Michał Czakon (RWTH Aachen U.), Felix Eschment (RWTH Aachen U.), Marco Niggetiedt (Garching, Max Planck Inst.), Rene Poncelet (Cracow, INP), Tom Schellenberger (RWTH Aachen U.) (Dec 15, 2023)

Published in: *Phys.Rev.Lett.* 132 (2024) 21, 211902 • e-Print: [2312.09896](https://arxiv.org/abs/2312.09896) [hep-ph]

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[5 citations](#)

$\delta(\text{scale})$	<del><math>\delta(\text{trunc})</math></del>	$\delta(\text{PDF-TH})$	<del><math>\delta(\text{EW})</math></del>	$\delta(t, b, c)$	<del><math>\delta(1/m_t)</math></del>
+0.10 pb -1.15 pb	<del><math>\pm 0.18 \text{ pb}</math></del>	$\pm 0.56 \text{ pb}$	<del><math>\pm 0.49 \text{ pb}</math></del>	$\pm 0.40 \text{ pb}$	<del><math>\pm 0.49 \text{ pb}</math></del>
+0.21% -2.37%	<del><math>\pm 0.37\%</math></del>	$\pm 1.16\%$	<del><math>\pm 1\%</math></del>	$\pm 0.83\%$	<del><math>\pm 1\%</math></del>

LHCH(XS)WG YR4 '16



$$\frac{\alpha_s}{\pi} \ln^2 \frac{m_b^2}{M_H^2} \approx 1.3$$

## Top-Bottom Interference Contribution to Fully Inclusive Higgs Production #2

Michał Czakon (RWTH Aachen U.), Felix Eschment (RWTH Aachen U.), Marco Niggetiedt (Garching, Max Planck Inst.), Rene Poncelet (Cracow, INP), Tom Schellenberger (RWTH Aachen U.) (Dec 15, 2023)

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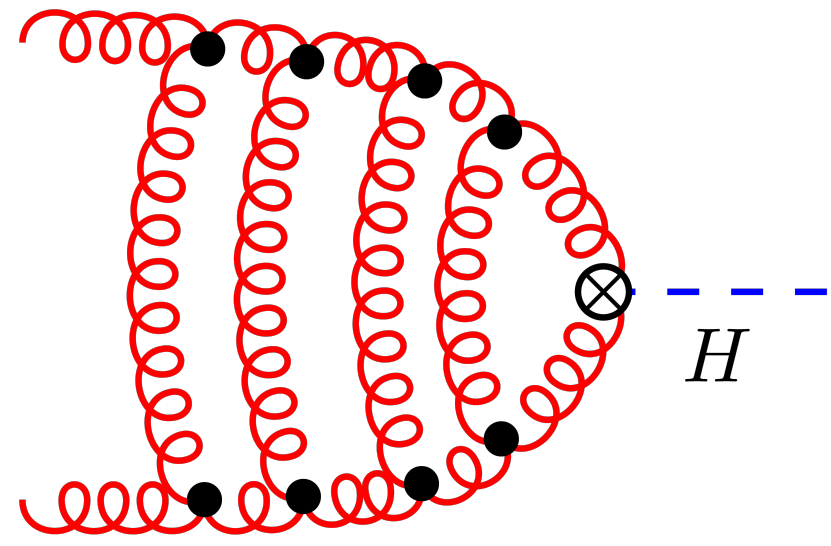
LHCH(XS)WG YR4 '16

$\delta(\text{scale})$	<del><math>\delta(\text{trunc})</math></del>	$\delta(\text{PDF-TH})$	<del><math>\delta(\text{EW})</math></del>	<del><math>\delta(t, b, c)</math></del>	<del><math>\delta(1/m_t)</math></del>
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LHCH(XS)WG YR4 '16

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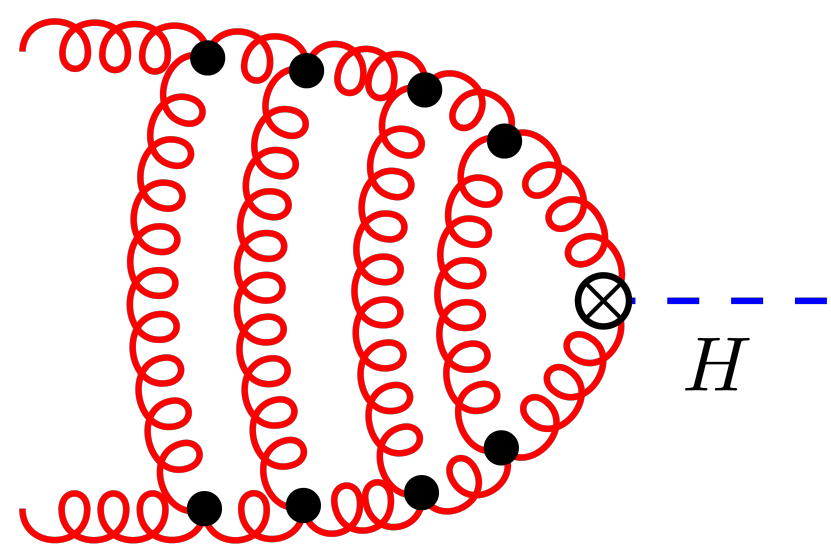
LHCH(XS)WG YR4 '16



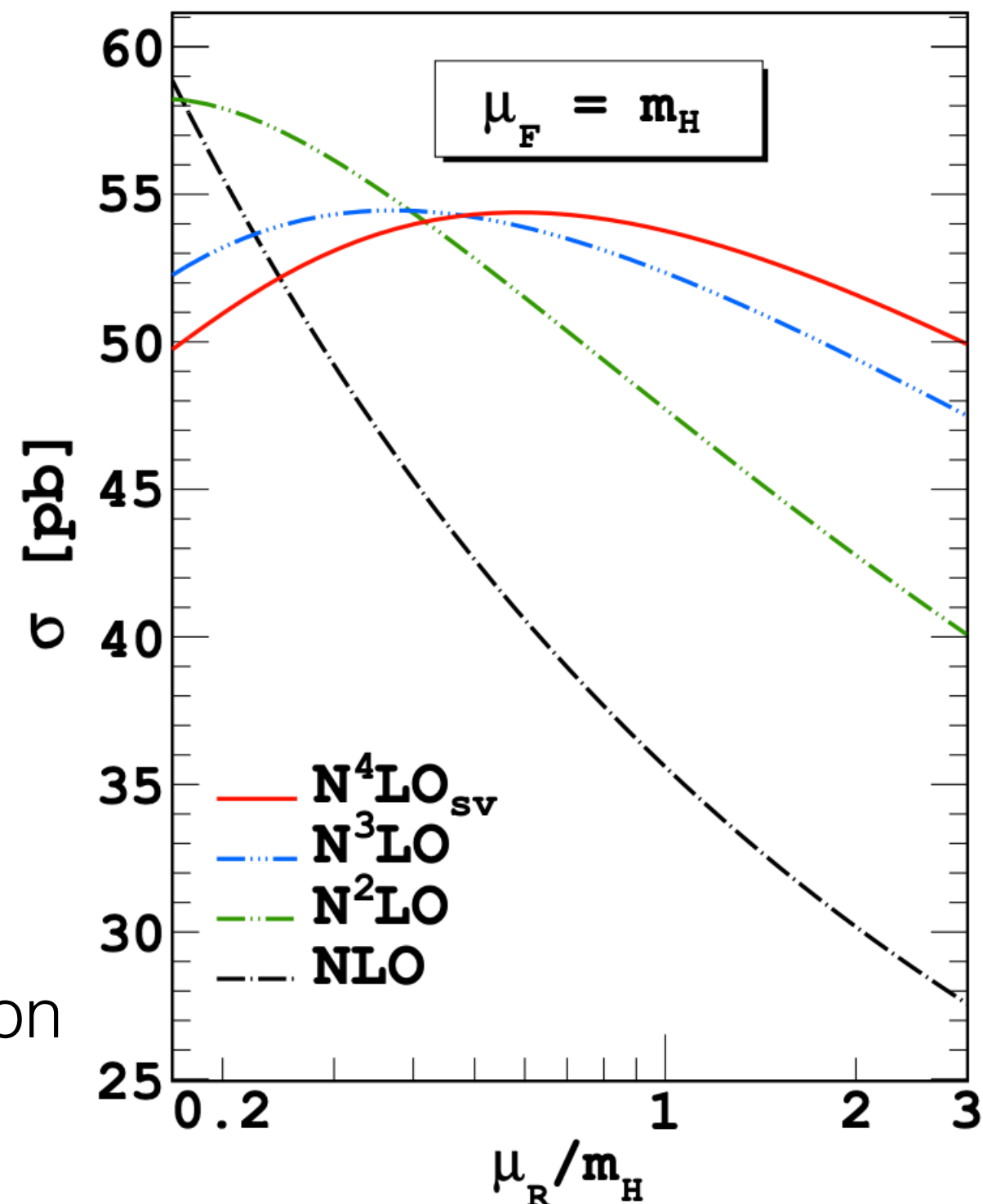
$\delta(\text{scale})$	<del><math>\delta(\text{trunc})</math></del>	$\delta(\text{PDF-TH})$	<del><math>\delta(\text{EW})</math></del>	<del><math>\delta(t, b, c)</math></del>	<del><math>\delta(1/m_t)</math></del>
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LHCH(XS)WG YR4 '16





soft-virtual approximation



**Approximate four-loop QCD corrections to the Higgs-boson production cross section** #1

G. Das (Siegen U.), S. Moch (Hamburg U., Inst. Theor. Phys. II), A. Vogt (Liverpool U., Dept. Math.) (Apr 1, 2020)

Published in: *Phys.Lett.B* 807 (2020) 135546 • e-Print: 2004.00563 [hep-ph]

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$\delta(\text{scale})$	<del><math>\delta(\text{trunc})</math></del>	$\delta(\text{PDF-TH})$	<del><math>\delta(\text{EW})</math></del>	<del><math>\delta(t, b, c)</math></del>	<del><math>\delta(1/m_t)</math></del>
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LHCH(XS)WG YR4 '16

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LHCH(XS)WG YR4 '16

## A Benchmarking of QCD Evolution at Approximate $N^3LO$

#9

A. Cooper-Sarkar (Oxford U.), T. Cridge (DESY), F. Giuli (CERN), L.A. Harland-Lang (University Coll. London), F. Hekhorn (Jyvaskyla U. and Helsinki U.) et al. (Jun 23, 2024)

e-Print: [2406.16188](#) [hep-ph]

[pdf](#) [cite](#) [claim](#) [reference search](#) [7 citations](#)

## The path to $N^3LO$ parton distributions

#8

NNPDF Collaboration • Richard D. Ball (Heriot-Watt U. (main) and Maxwell Inst. Math. Sci., Edinburgh and U. Edinburgh, Higgs Ctr. Theor. Phys.) et al. (Feb 28, 2024)

Published in: *Eur.Phys.J.C* 84 (2024) 7, 659 • e-Print: [2402.18635](#) [hep-ph]

[pdf](#) [DOI](#) [cite](#) [claim](#) [reference search](#) [24 citations](#)

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A. Cooper-Sarkar (Oxford U.), T. Cridge (DESY), F. Giuli (CERN), L.A. Harland-Lang (University Coll. London), F. Hekhorn (Jyvaskyla U. and Helsinki U.) et al. (Jun 23, 2024)

e-Print: [2406.16188](#) [hep-ph]

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## A Benchmarking of QCD Evolution at Approximate $N^3LO$

#9

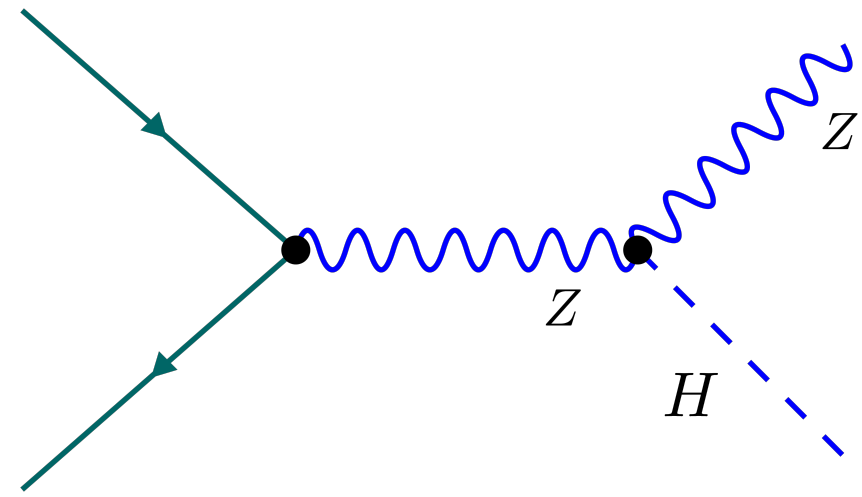
A. Cooper-Sarkar (Oxford U.), T. Cridge (DESY), F. Giuli (CERN), L.A. Harland-Lang (University Coll. London), F. Hekhorn (Jyvaskyla U. and Helsinki U.) et al. (Jun 23, 2024)

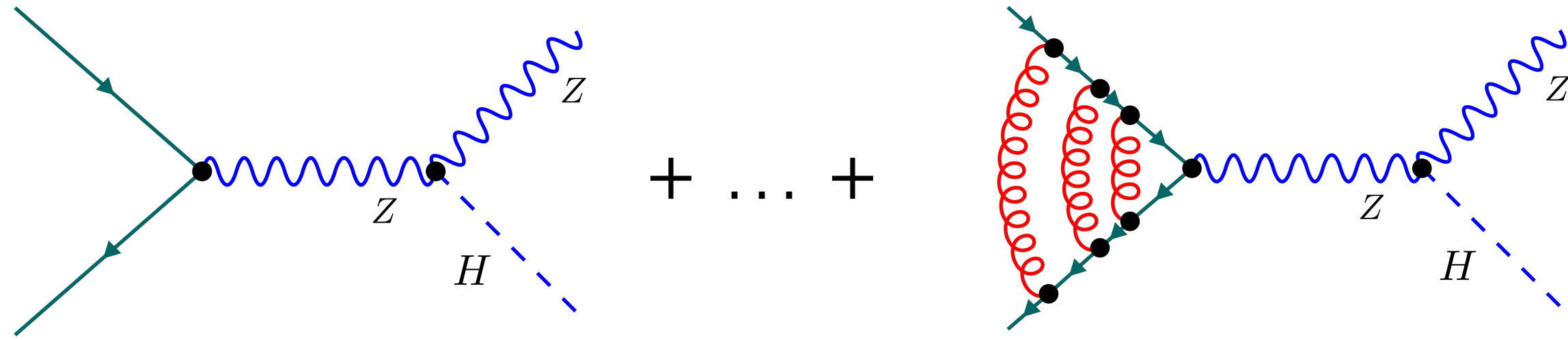
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$\delta(\text{scale})$	$\delta(\text{trunc})$	$\delta(\text{PDF-TH})$	$\delta(\text{EW})$	$\delta(t, b, c)$	$\delta(1/m_t)$
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LHCH(XS)WG YR4 '16





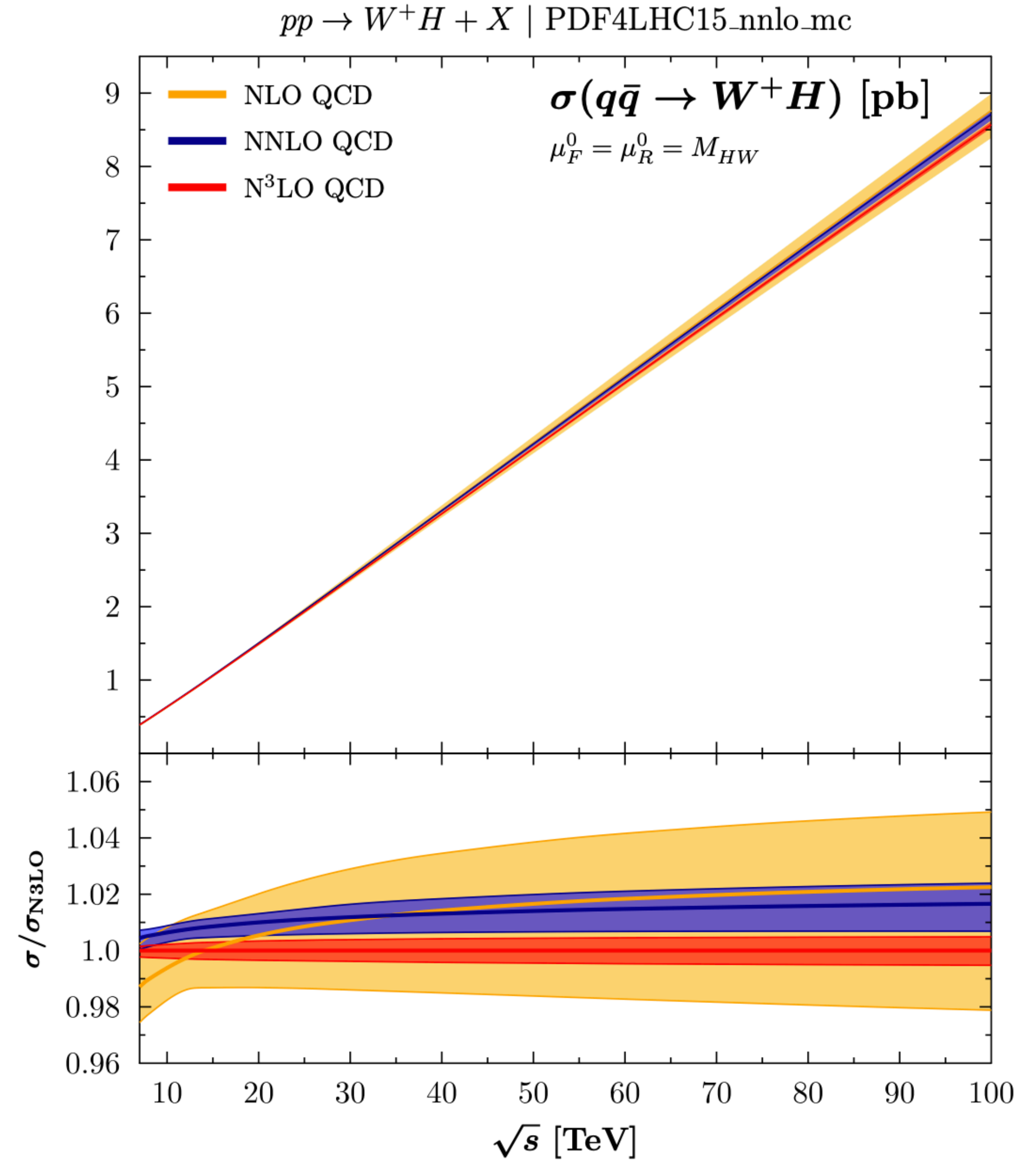
## Inclusive Production Cross Sections at N3LO #2

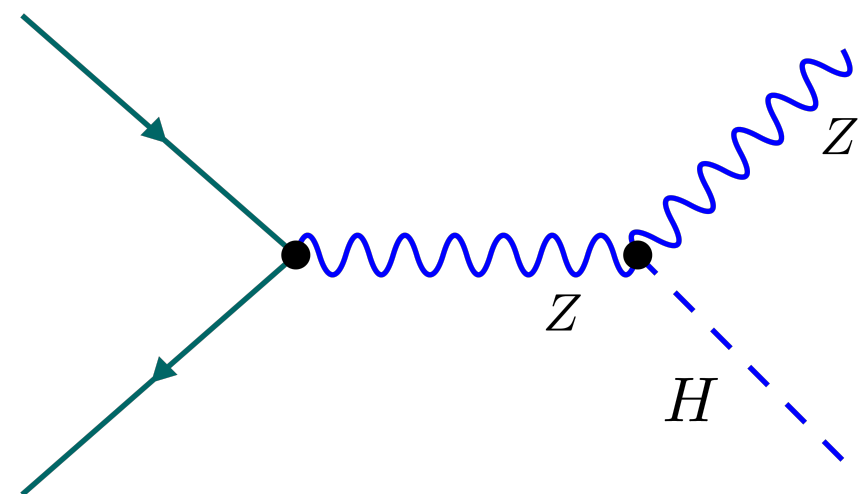
Julien Baglio (CERN), Claude Duhr (U. Bonn, Phys. Inst., BCTP), Bernhard Mistlberger (SLAC), Robert Szafron (Brookhaven) (Sep 13, 2022)

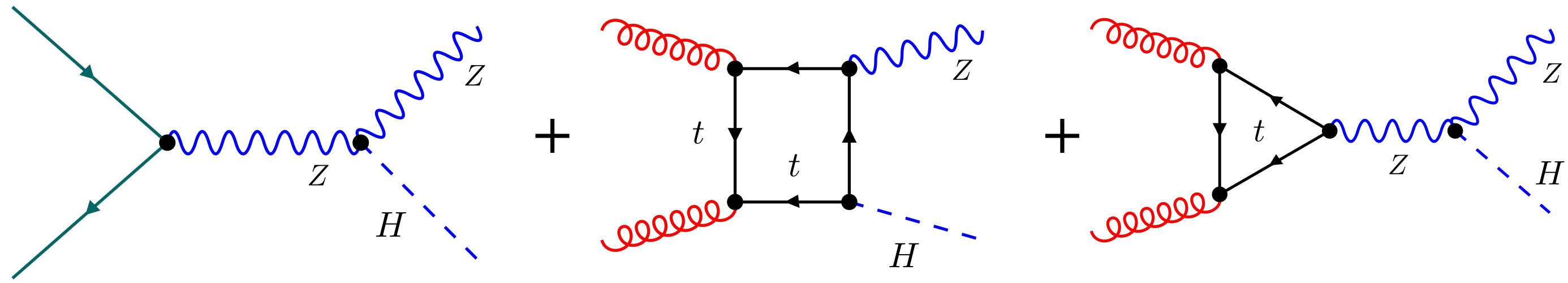
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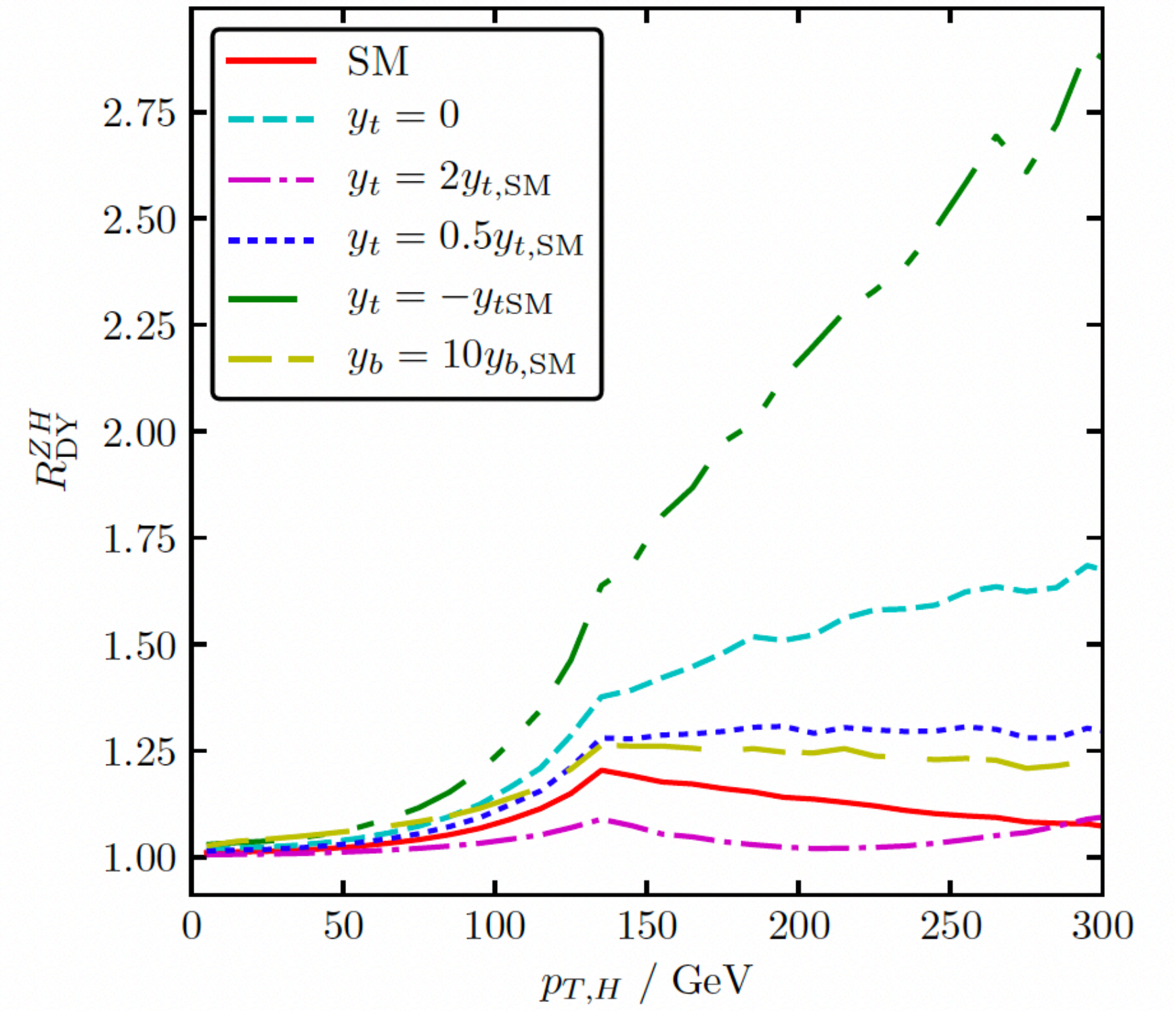
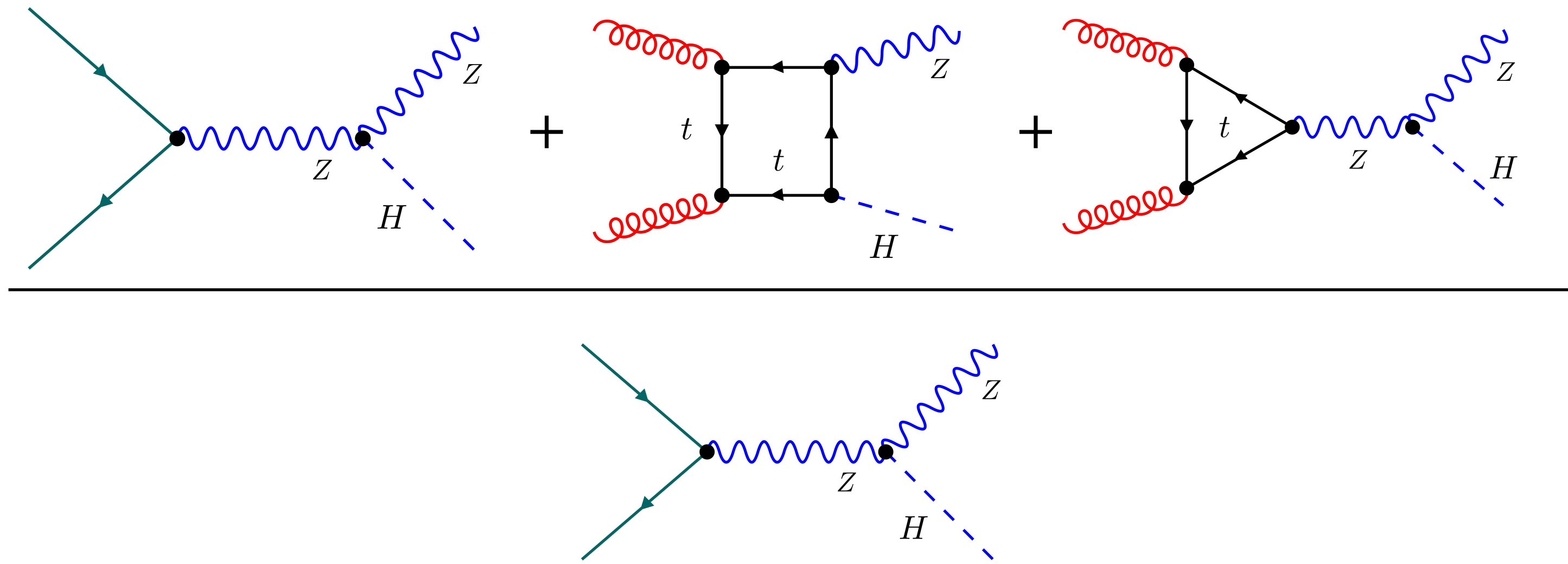
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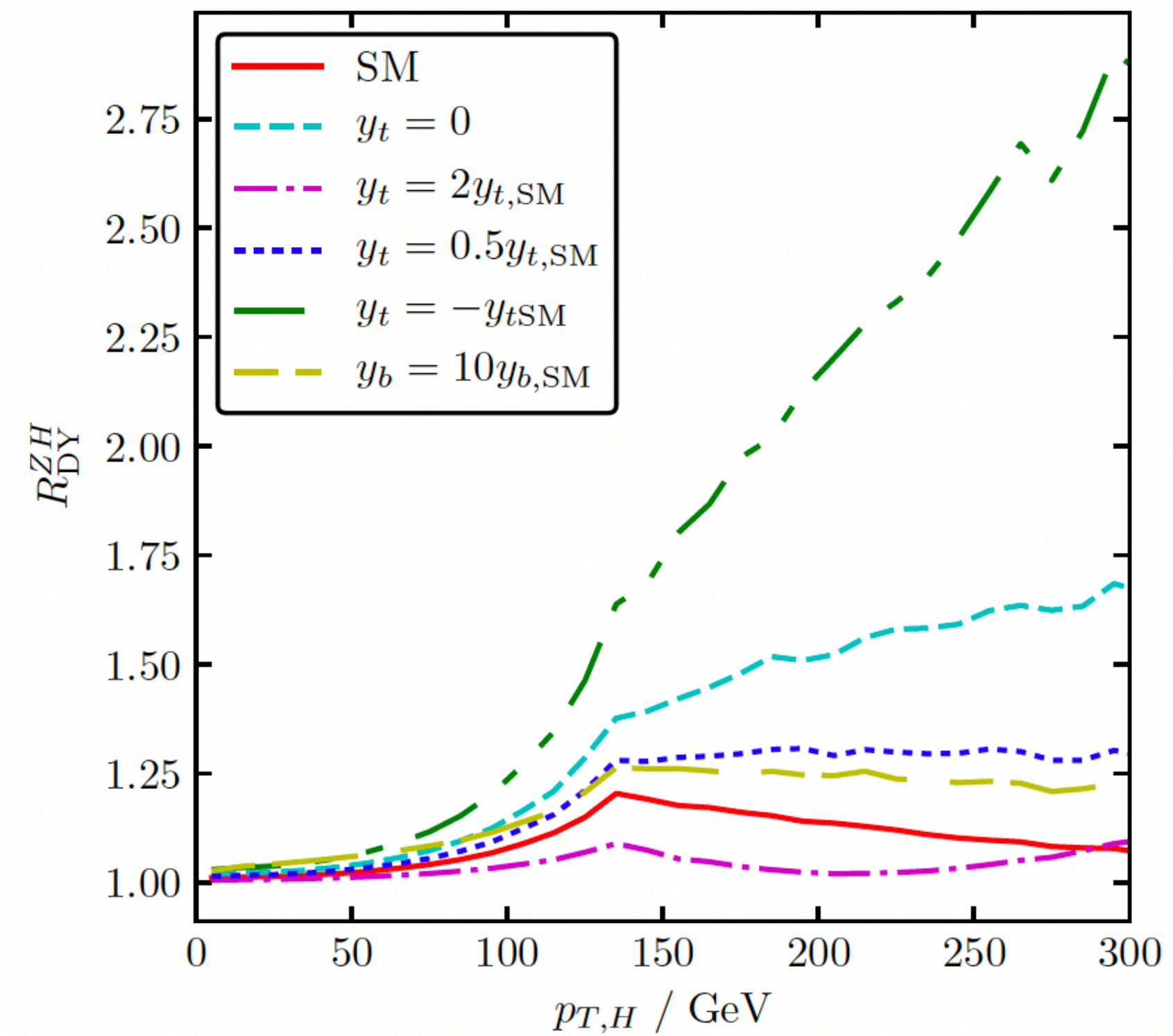
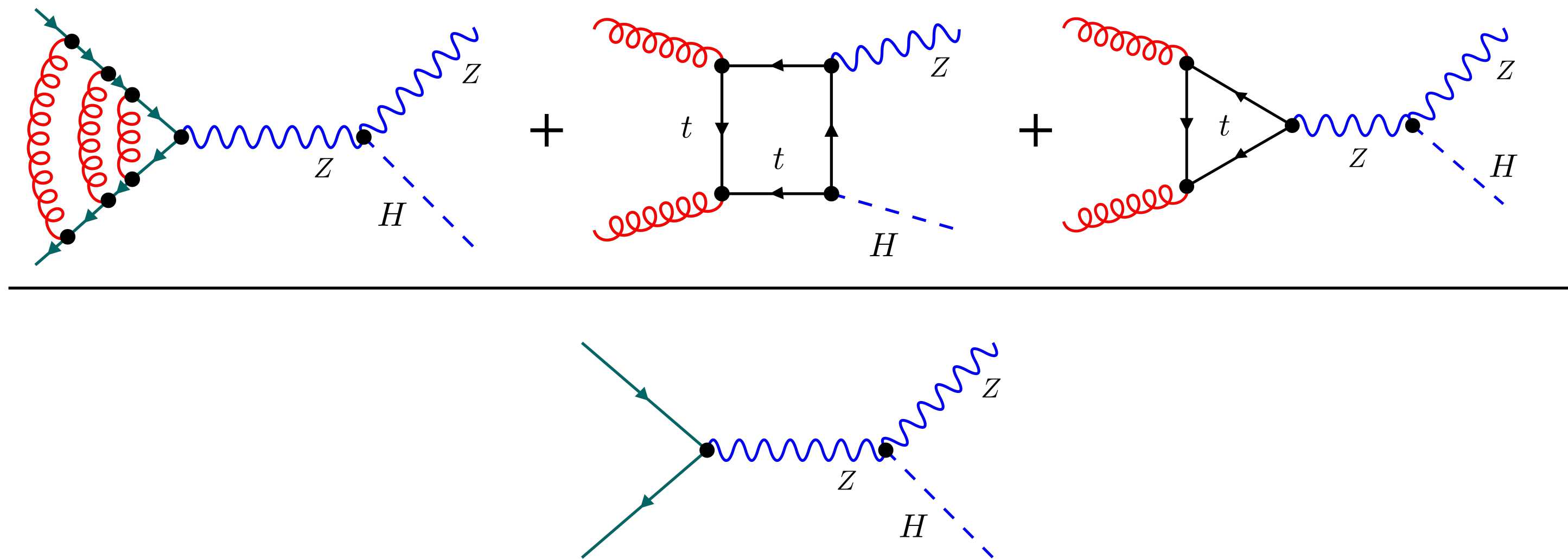


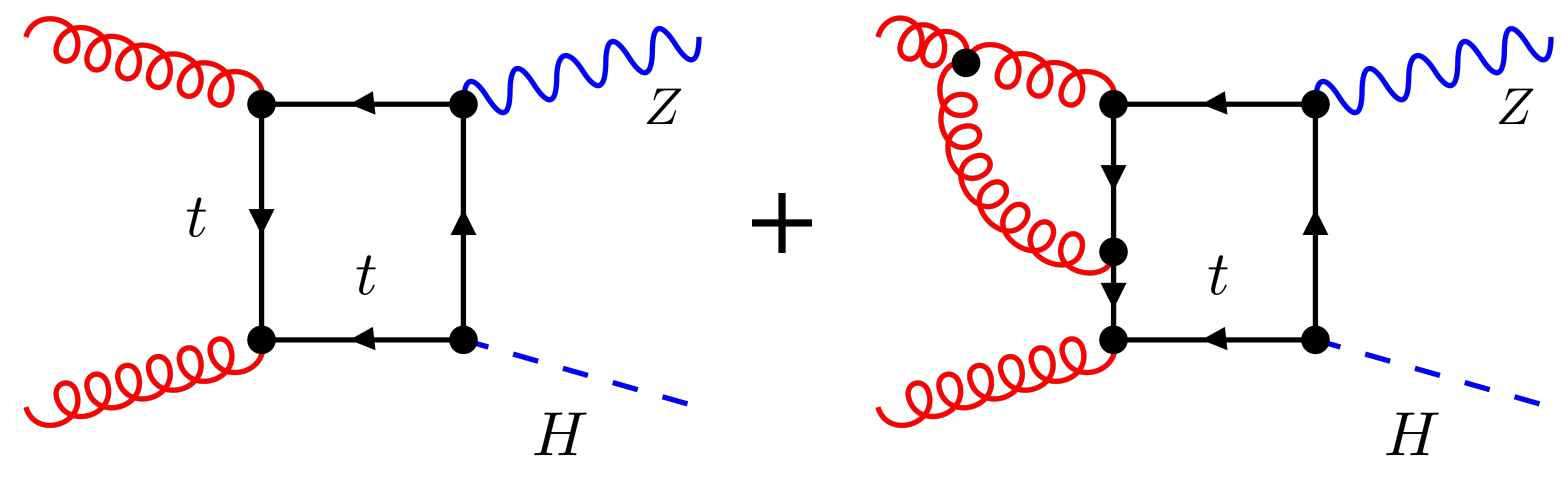


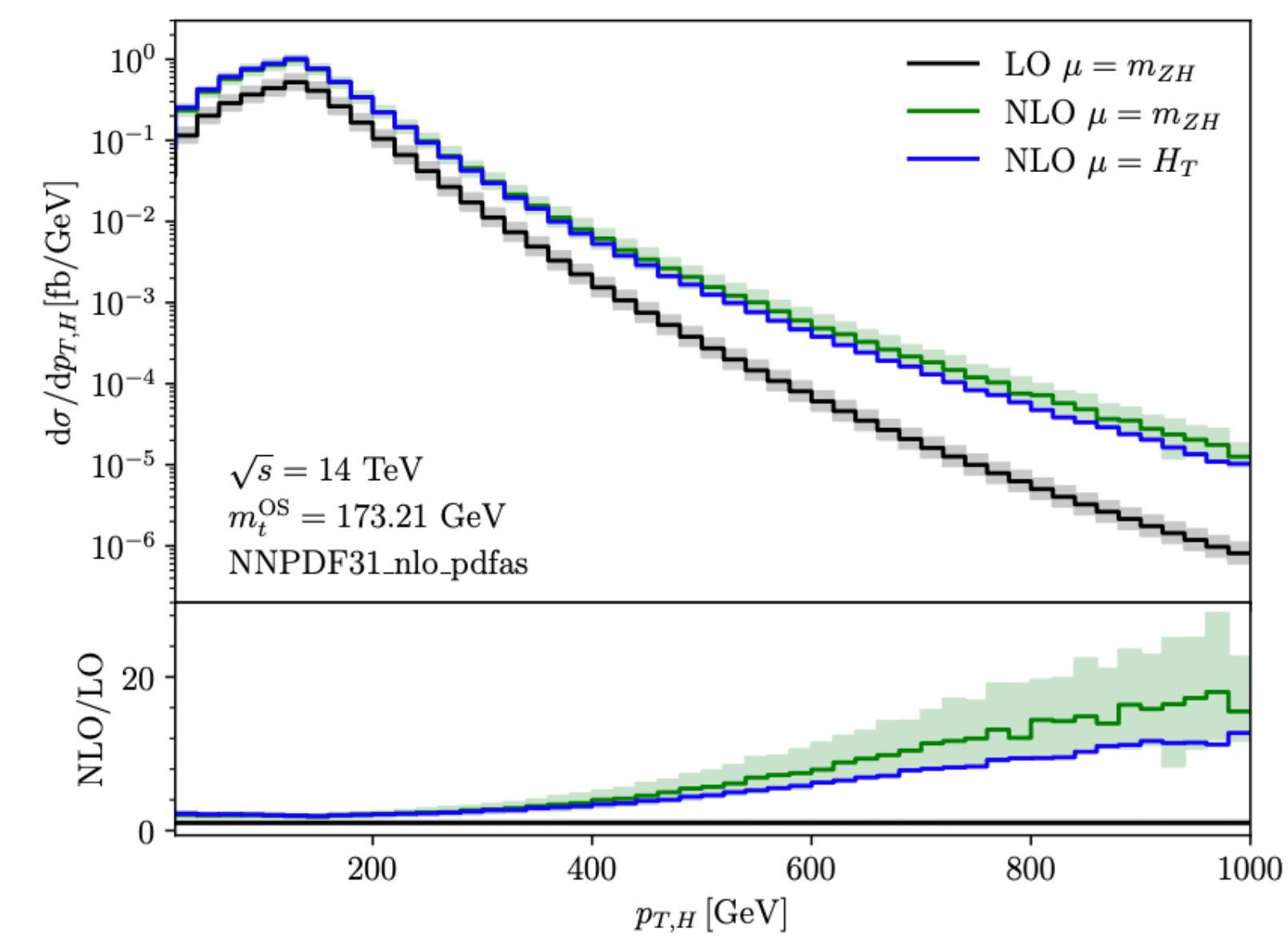
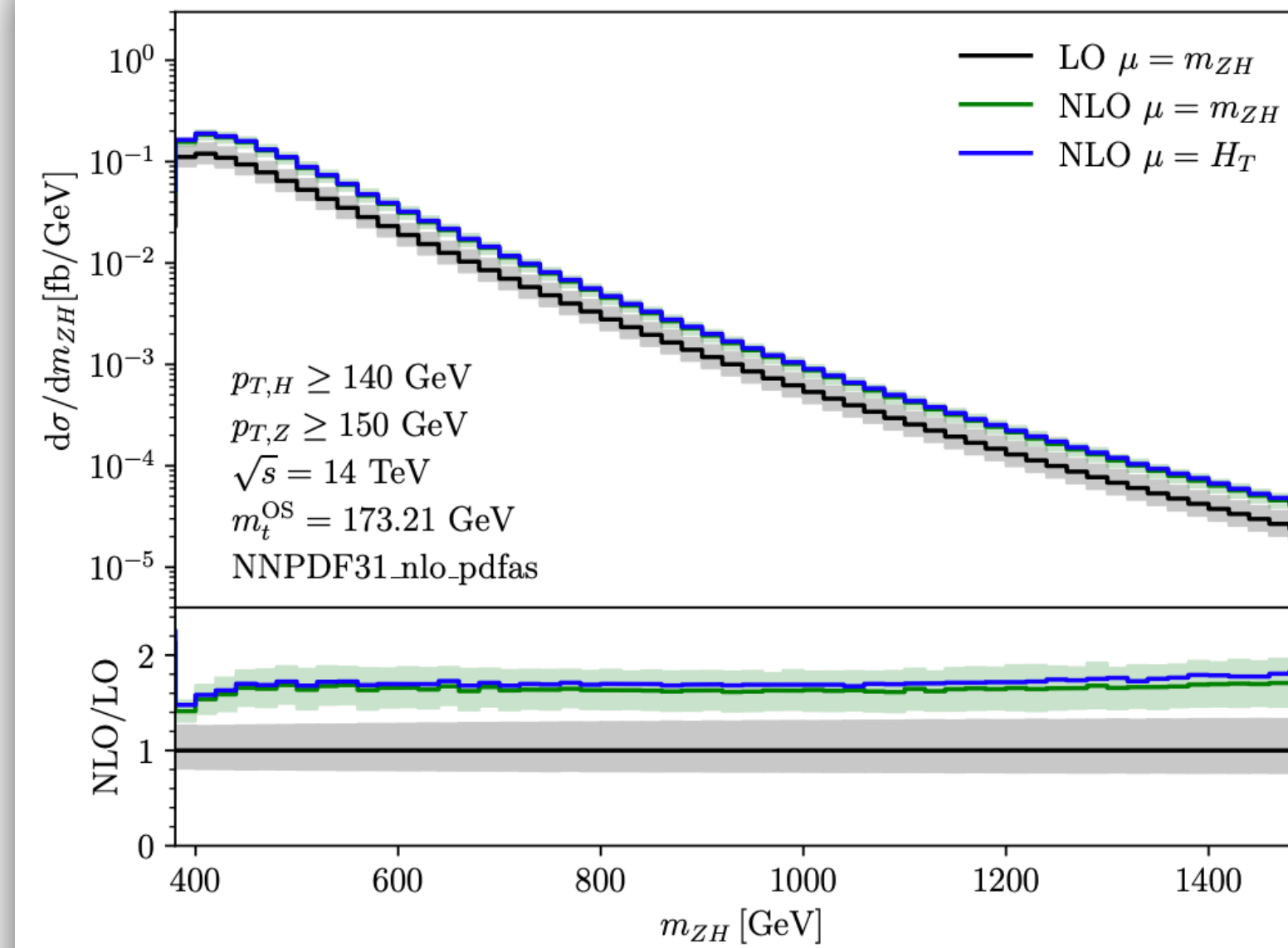
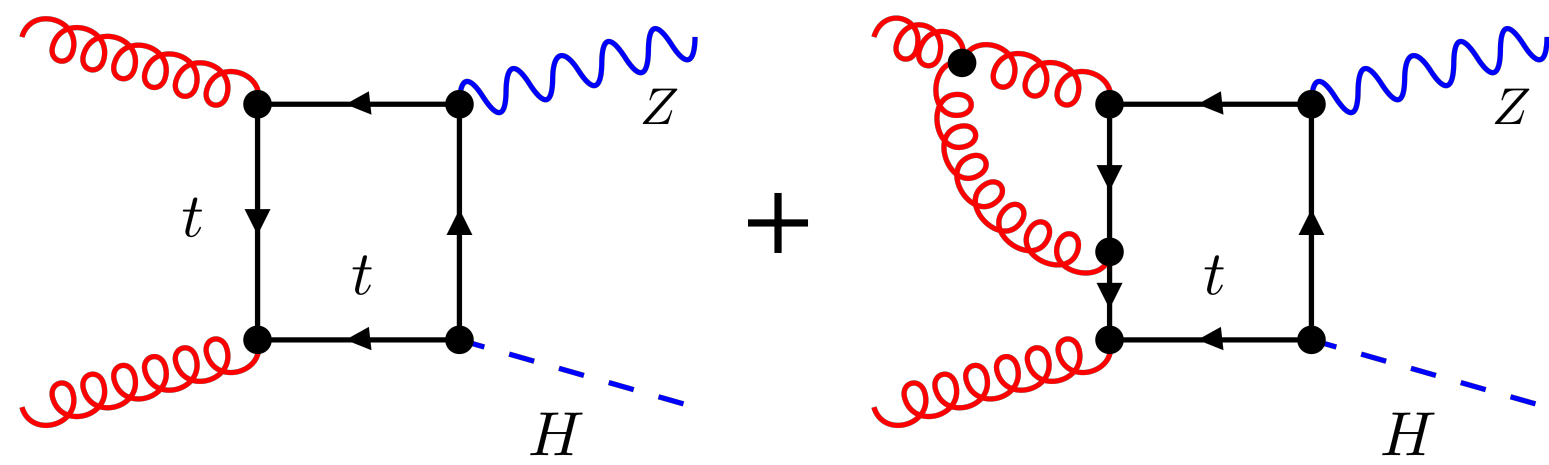












## Next-to-leading order corrections for $gg \rightarrow ZH$ with top quark mass dependence

#10

Guoxing Wang (Zhejiang U., Inst. Mod. Phys.), Xiaofeng Xu (Bern U.), Yongqi Xu (Peking U. and Peking U., SKLNPT), Li Lin Yang (Zhejiang U., Inst. Mod. Phys.) (Jul 17, 2021)

Published in: *Phys.Lett.B* 829 (2022) 137087 • e-Print: [2107.08206](#) [hep-ph]

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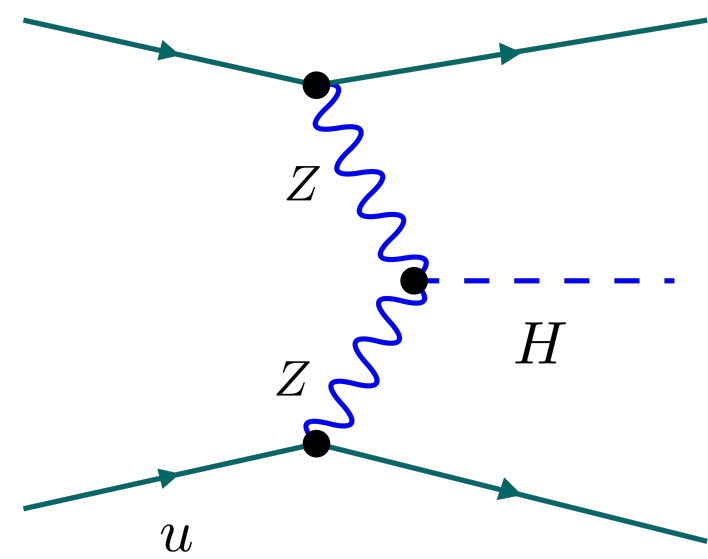
## ZH production in gluon fusion at NLO in QCD

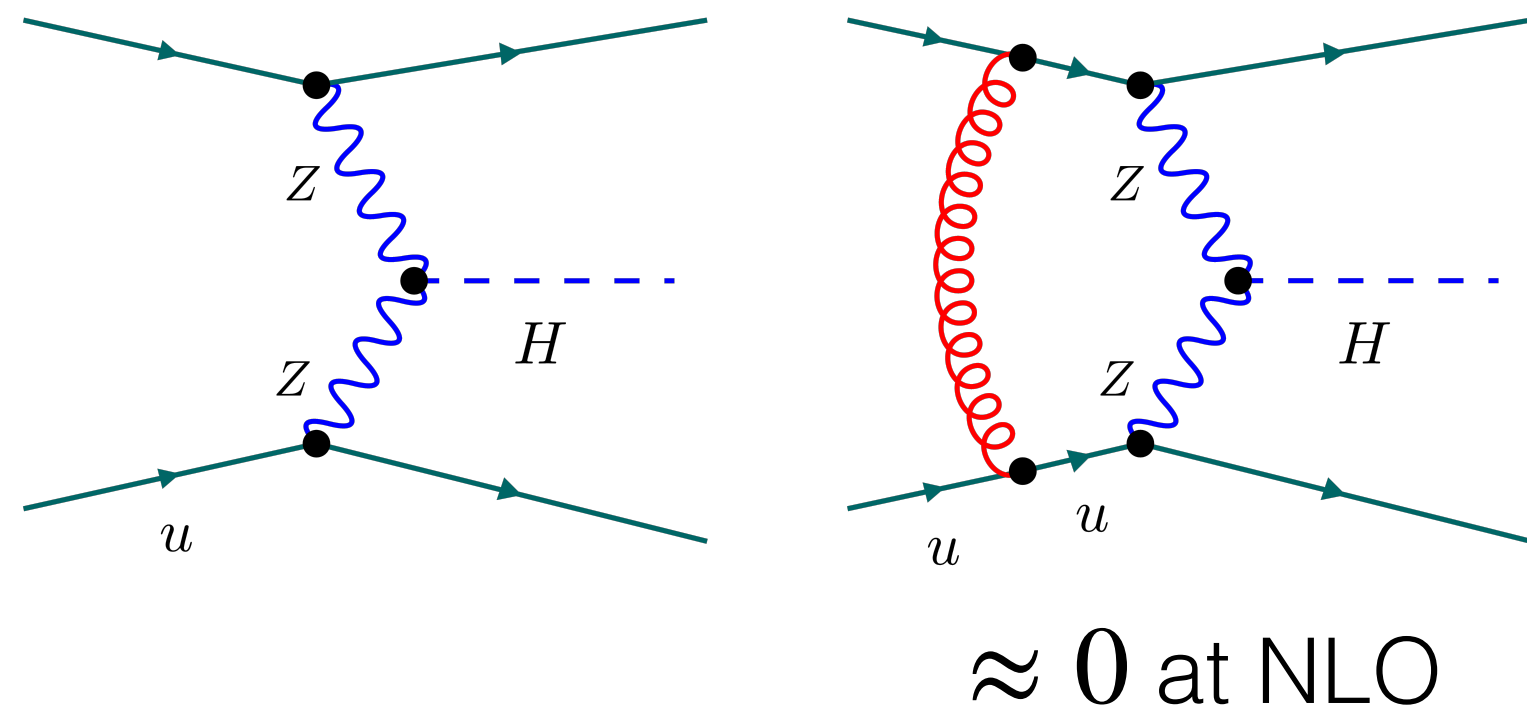
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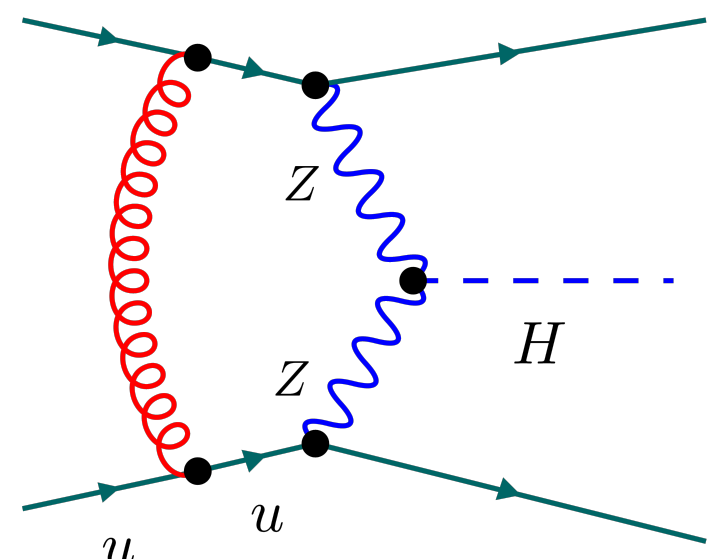
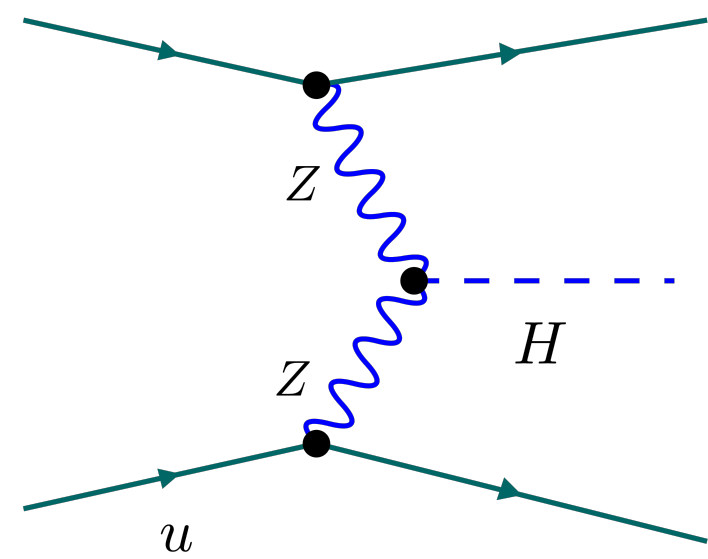
Long Chen (RWTH Aachen U. and Shandong U.), Joshua Davies (Sussex U.), Gudrun Heinrich (KIT, Karlsruhe), Stephen P. Jones (Durham U., IPPP), Matthias Kerner (KIT, Karlsruhe and KIT, Karlsruhe, IKP) et al. (Apr 11, 2022)

Published in: *JHEP* 08 (2022) 056 • e-Print: [2204.05225](#) [hep-ph]

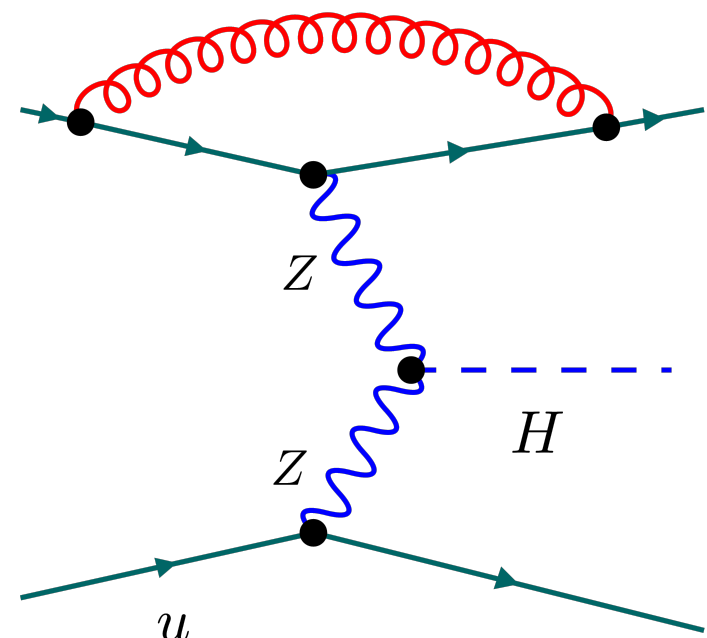
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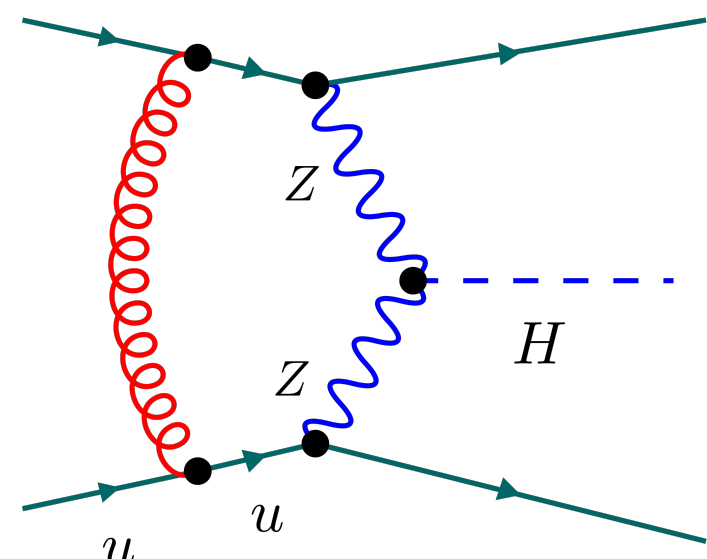
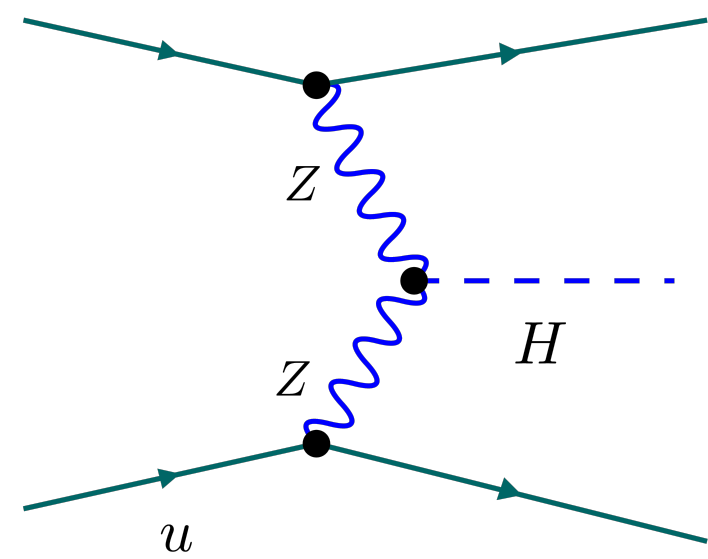




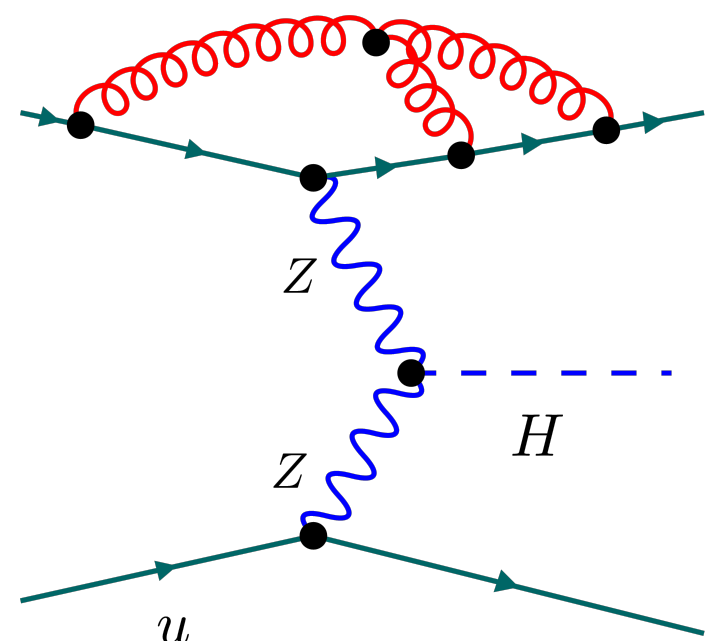
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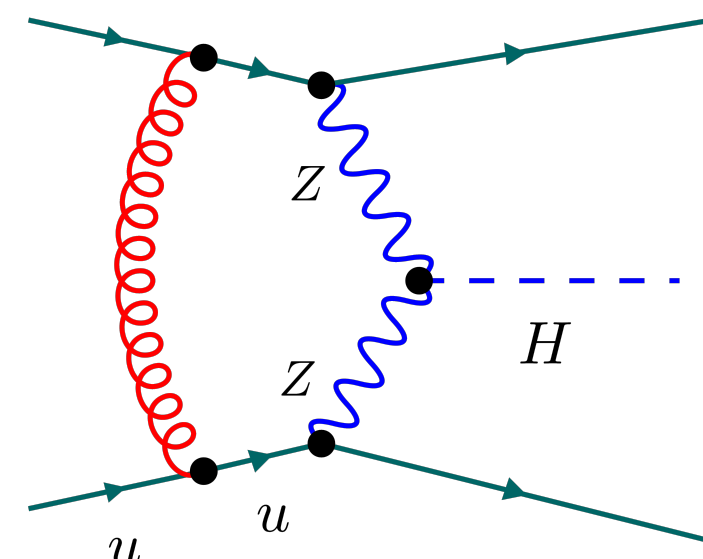
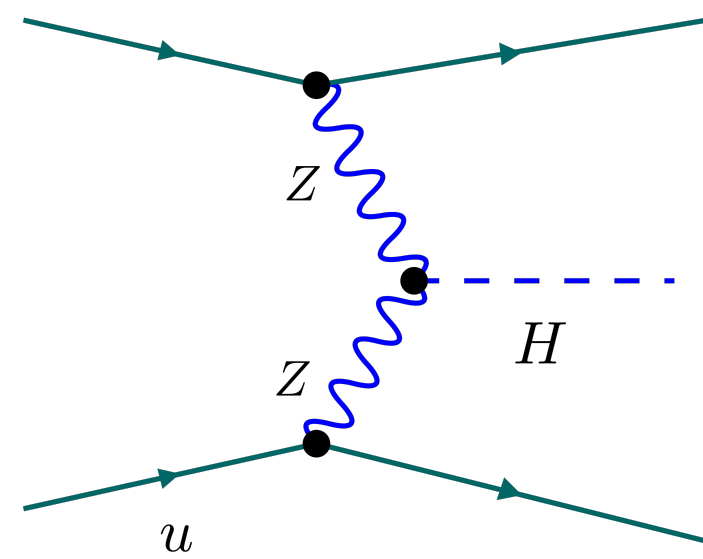
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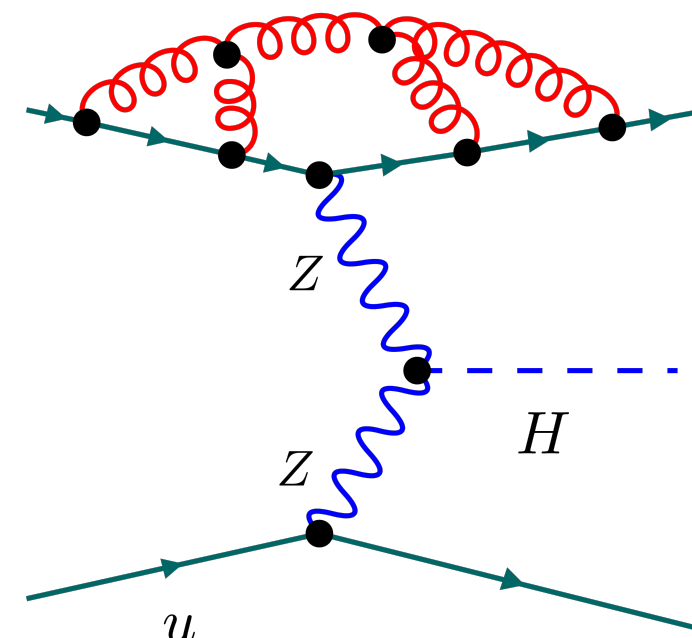
$\approx 0$  at NLO



DIS



$\approx 0$  at NLO



DIS

## Vector-Boson Fusion Higgs Production at Three Loops in QCD

#8

Frédéric A. Dreyer (UPMC, Paris (main) and Paris, LPTHE and CERN), Alexander Karlberg (Oxford U., Theor. Phys.) (Jun 2, 2016)

Published in: *Phys.Rev.Lett.* 117 (2016) 7, 072001 • e-Print: [1606.00840](https://arxiv.org/abs/1606.00840) [hep-ph]

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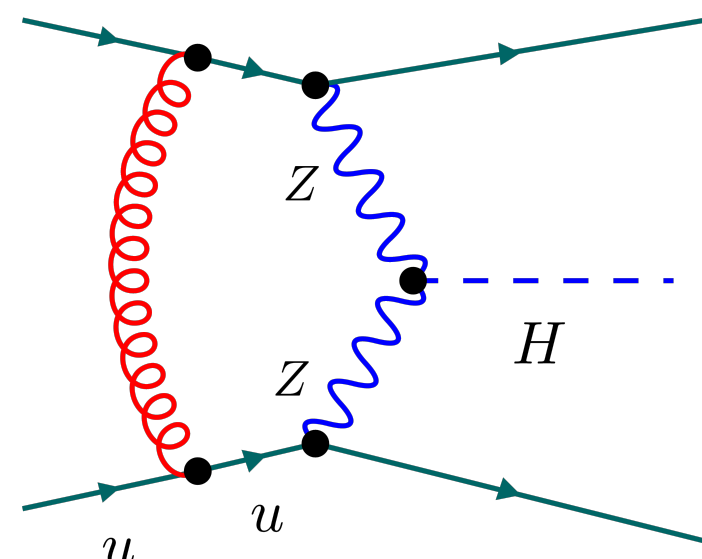
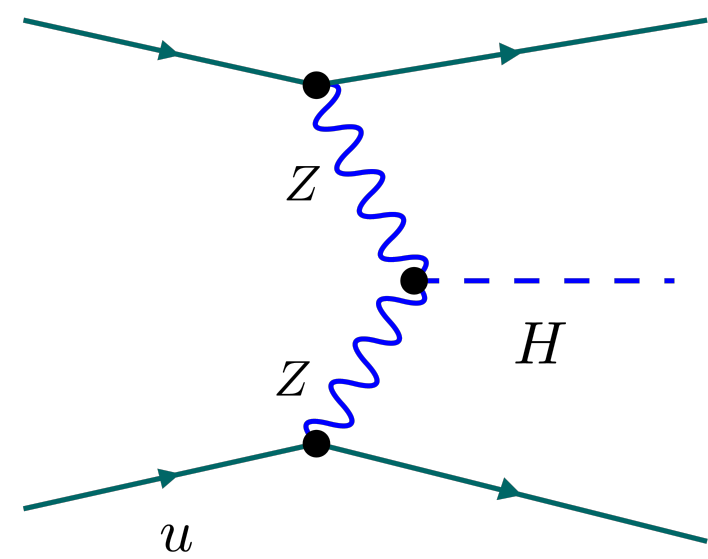
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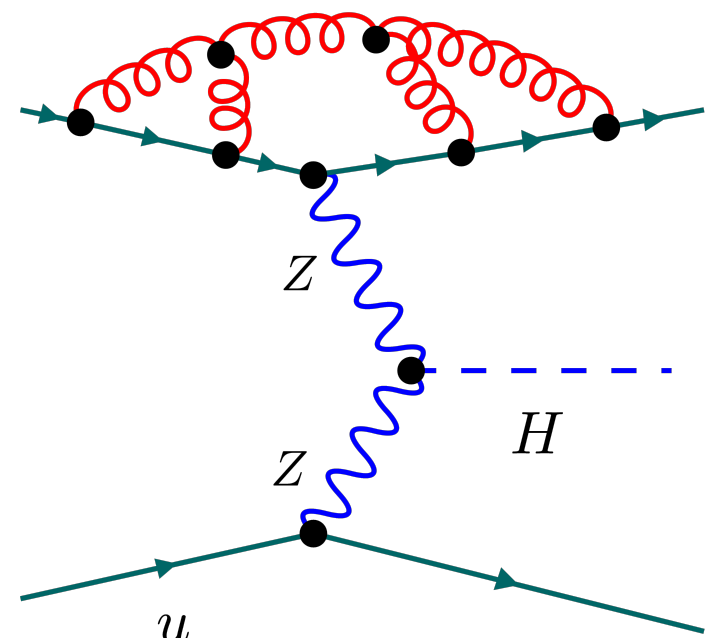
reference search

141 citations





$\approx 0$  at NLO



DIS

## Vector-Boson Fusion Higgs Production at Three Loops in QCD

#8

Frédéric A. Dreyer (UPMC, Paris (main) and Paris, LPTHE and CERN), Alexander Karlberg (Oxford U., Theor. Phys.) (Jun 2, 2016)

Published in: *Phys.Rev.Lett.* 117 (2016) 7, 072001 • e-Print: 1606.00840 [hep-ph]

pdf

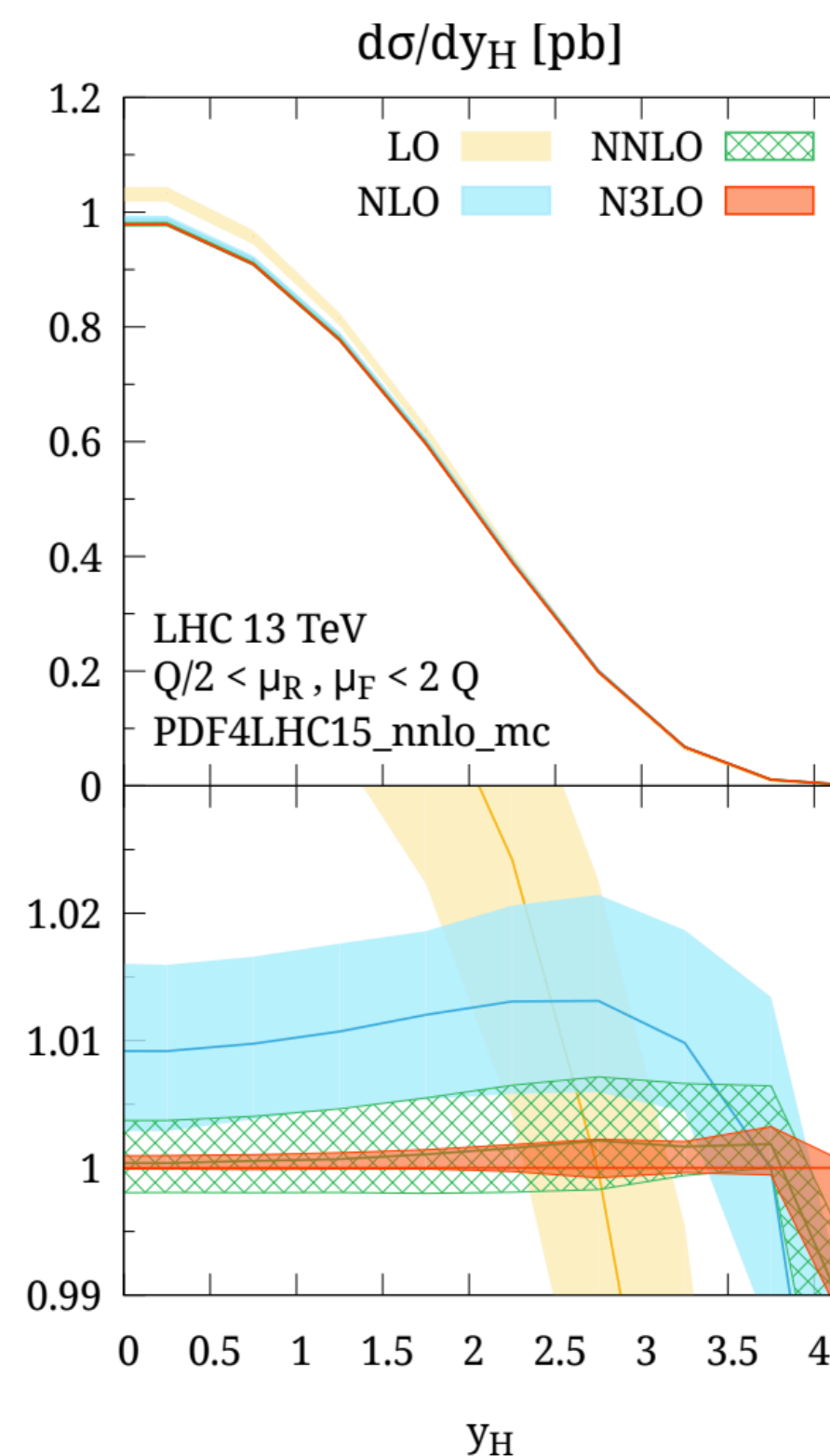
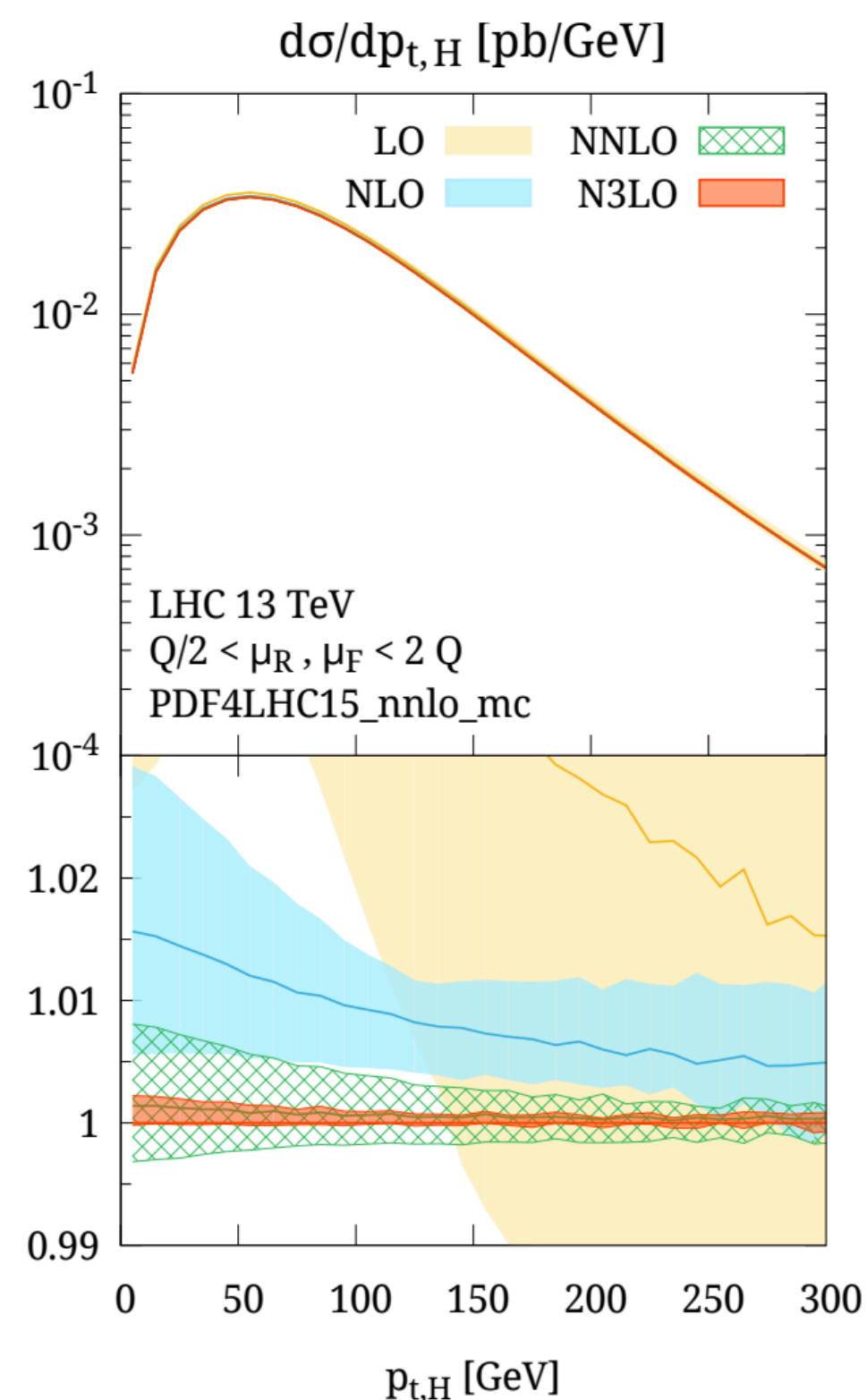
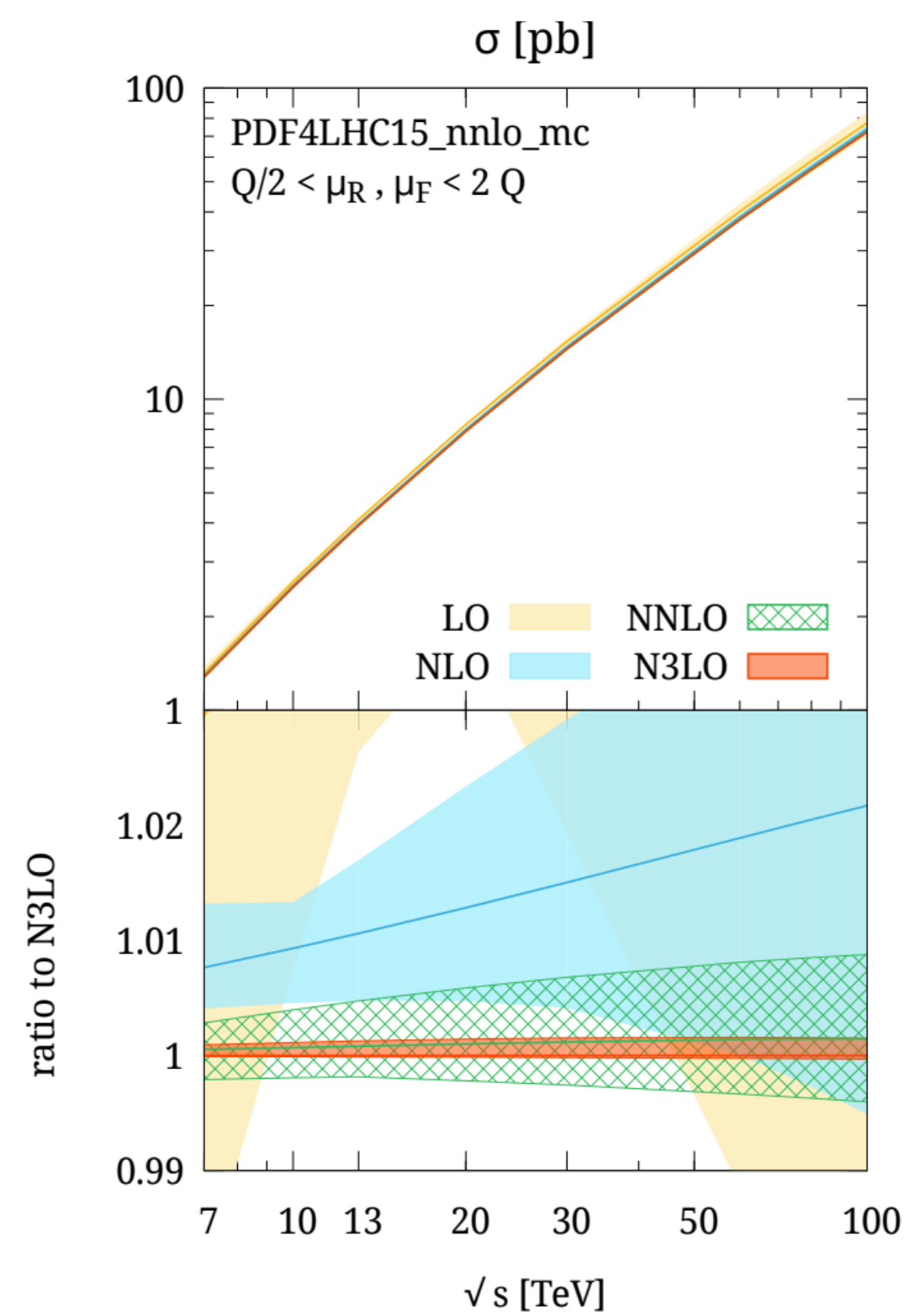
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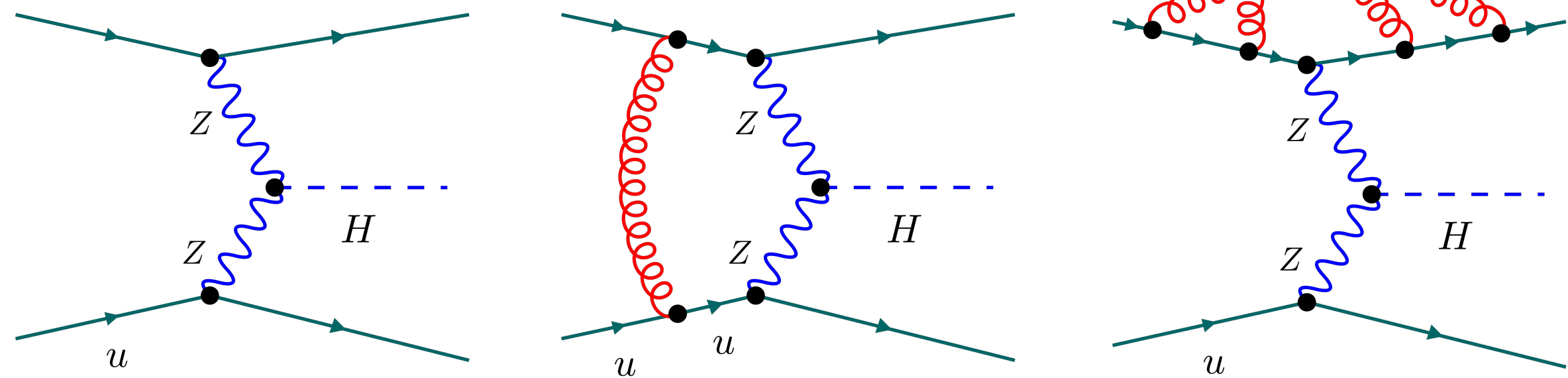
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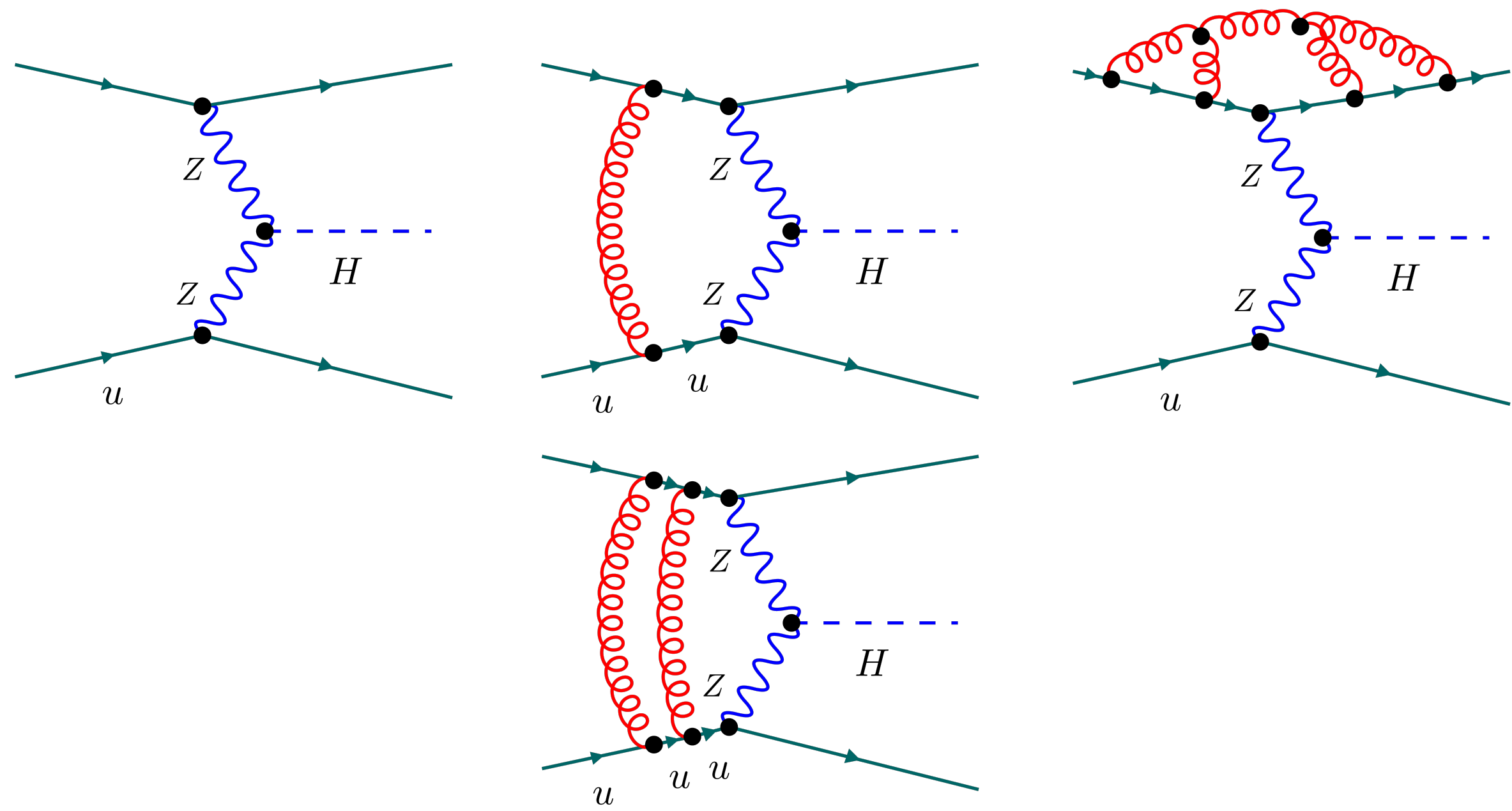
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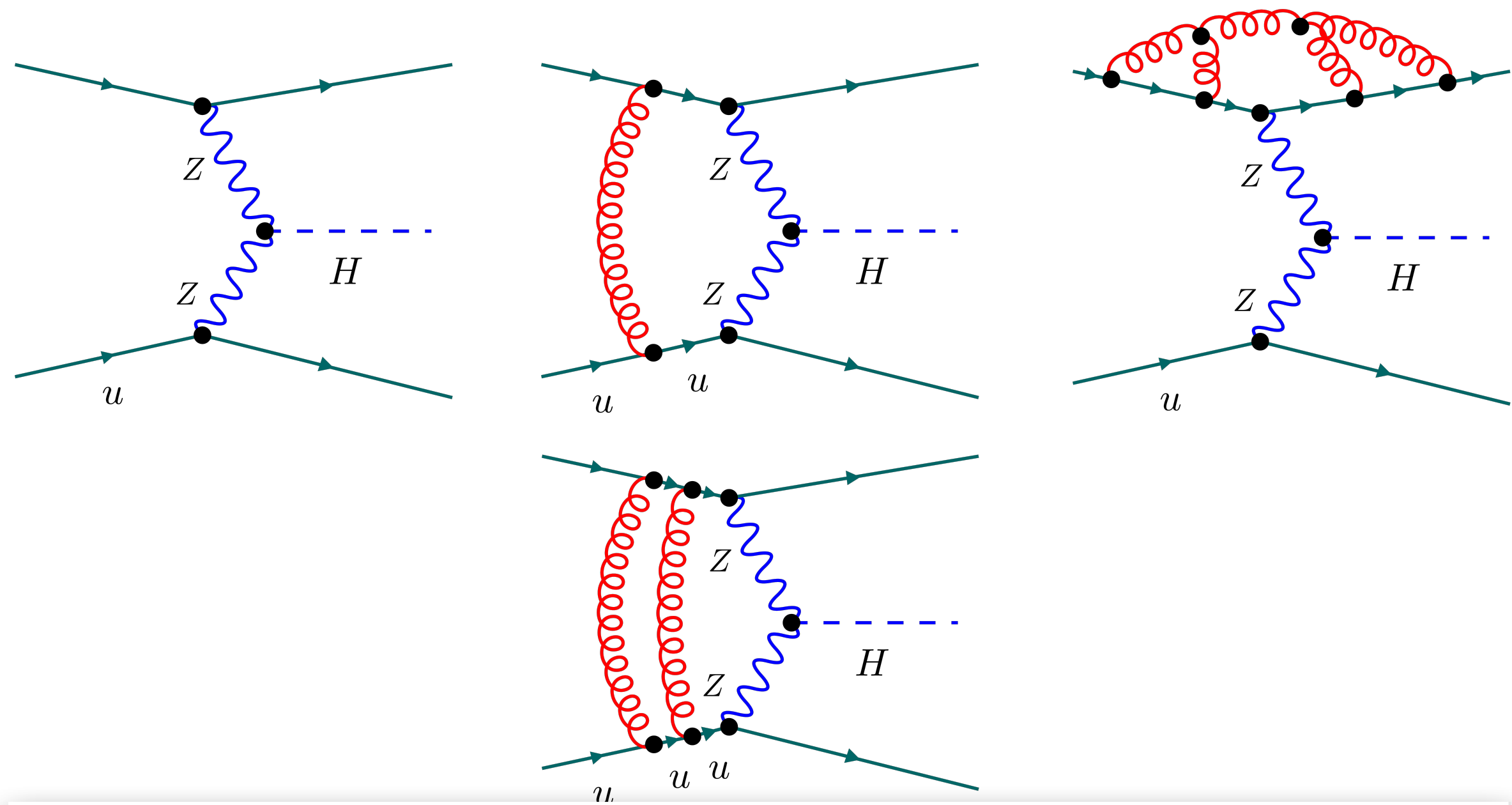
reference search

141 citations









## Nonfactorizable QCD Effects in Higgs Boson Production via Vector Boson Fusion #1

Tao Liu (Alberta U.), Kirill Melnikov (KIT, Karlsruhe, TTP), Alexander A. Penin (Alberta U. and KIT, Karlsruhe, TTP and Zurich, ETH) (Jun 26, 2019)

Published in: *Phys.Rev.Lett.* 123 (2019) 12, 122002 • e-Print: [1906.10899](https://arxiv.org/abs/1906.10899) [hep-ph]

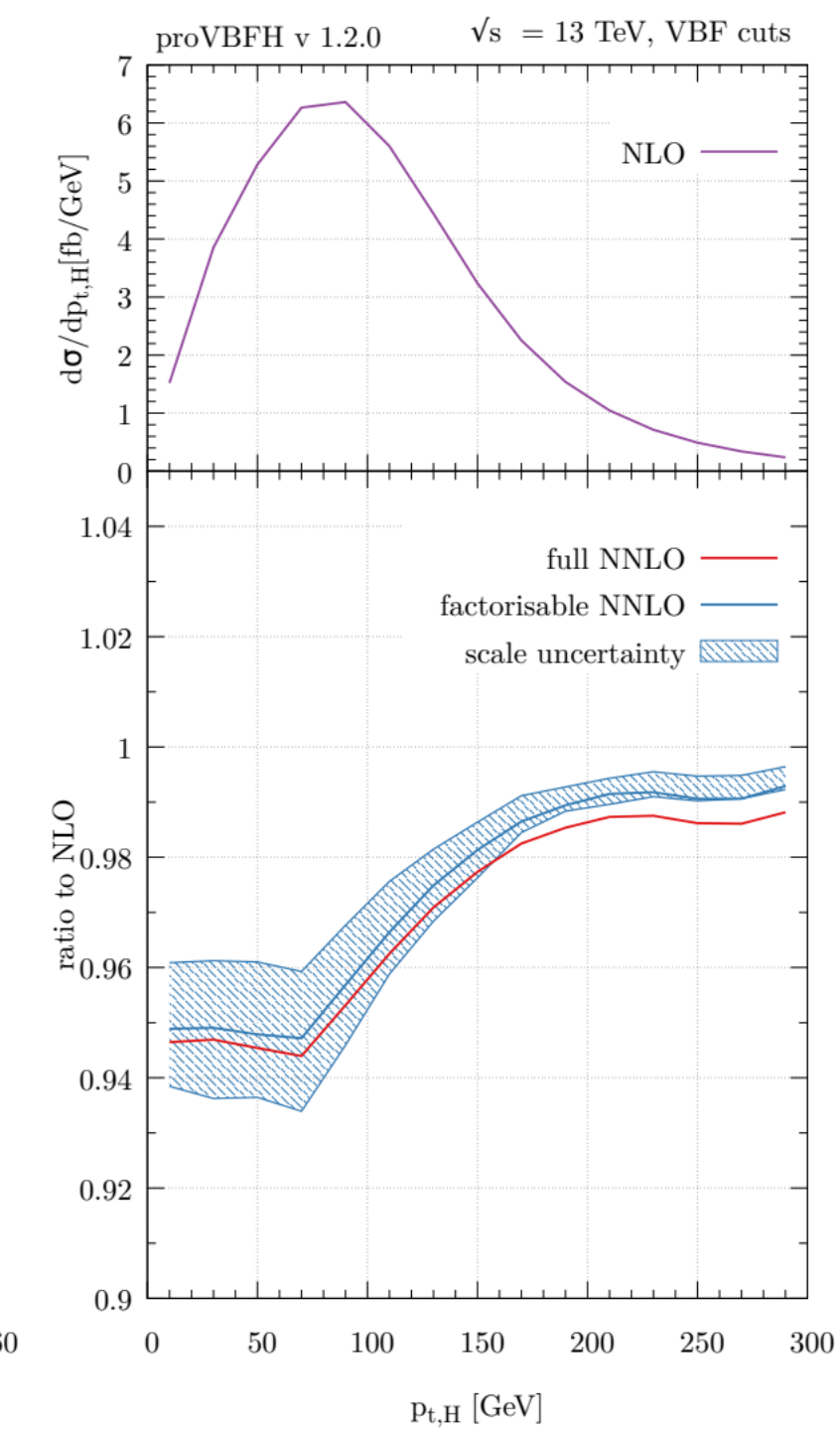
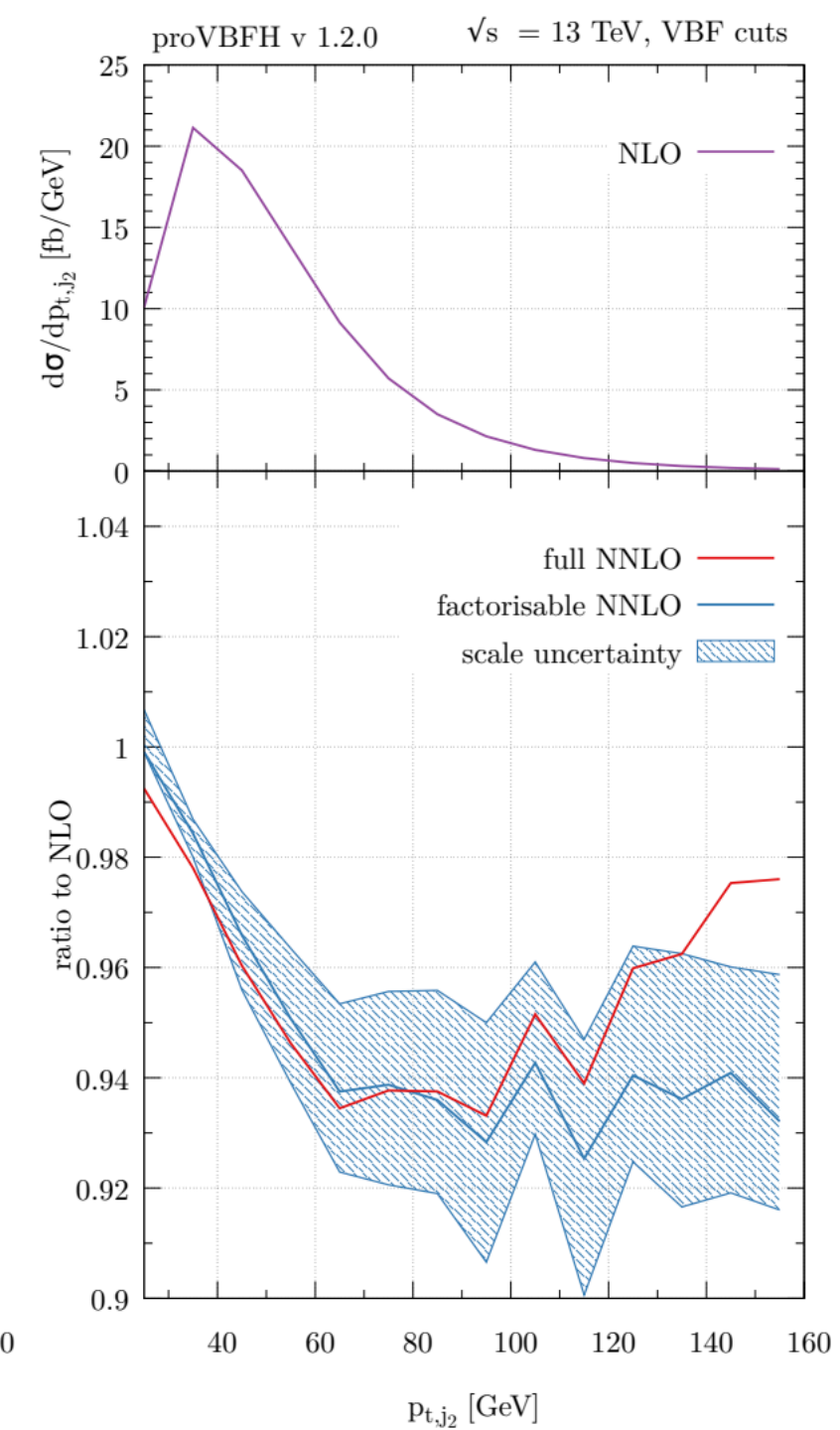
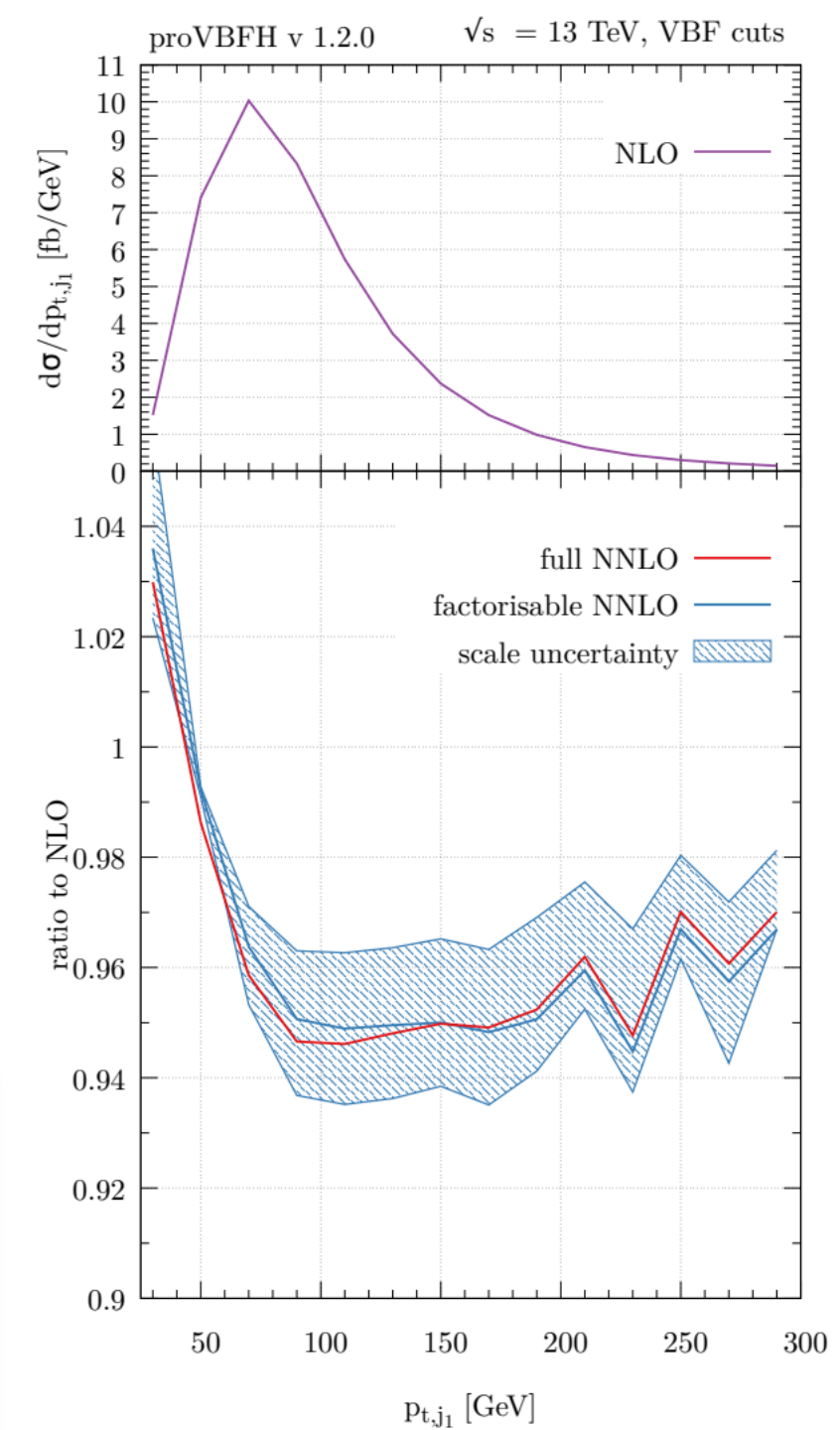
pdf DOI cite claim reference search 31 citations

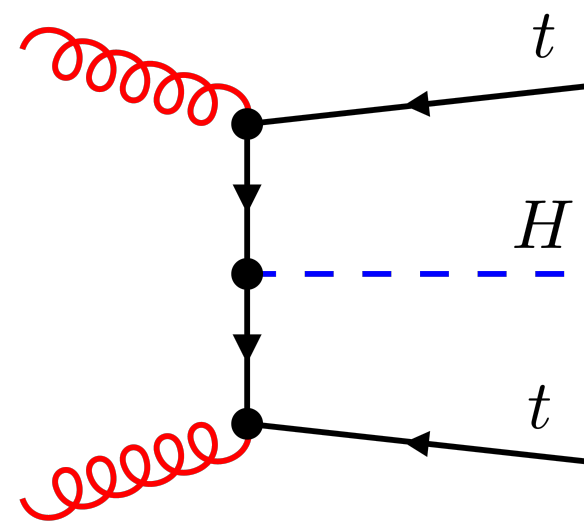
## On the impact of non-factorisable corrections in VBF single and double Higgs production #3

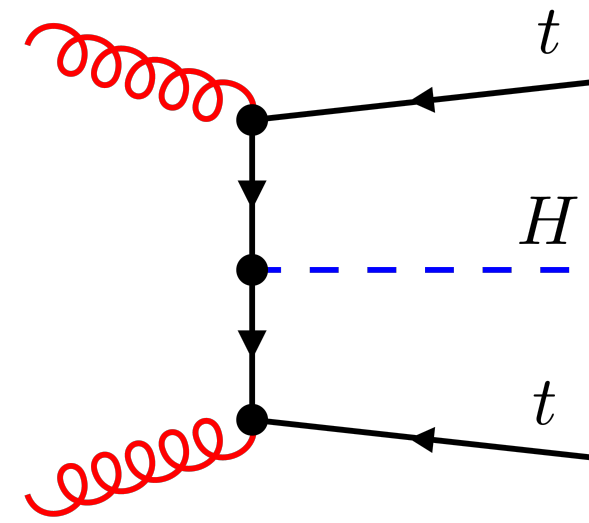
Frédéric A. Dreyer (Oxford U., Theor. Phys.), Alexander Karlberg (Oxford U., Theor. Phys.), Lorenzo Tancredi (Oxford U., Theor. Phys.) (May 22, 2020)

Published in: *JHEP* 10 (2020) 131 • e-Print: [2005.11334](https://arxiv.org/abs/2005.11334) [hep-ph]

pdf DOI cite claim reference search 16 citations







## The simplest of them all: $t\bar{t}W^\pm$ at NLO accuracy in QCD

#29

Giuseppe Bevilacqua (MTA-DE, Debrecen), Huan-Yu Bi (RWTH Aachen U.), Heribertus Bayu Hartanto (Durham U., IPPP), Manfred Kraus (Florida State U.), Malgorzata Worek (RWTH Aachen U.) (May 19, 2020)

Published in: *JHEP* 08 (2020) 043 • e-Print: [2005.09427](https://arxiv.org/abs/2005.09427) [hep-ph]

pdf

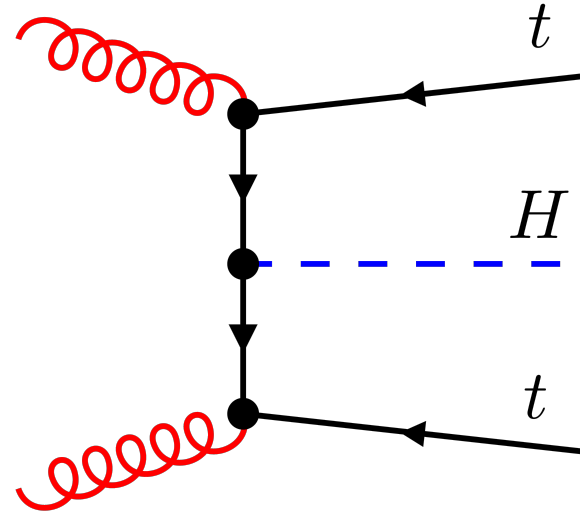
DOI

cite

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38 citations



The simplest of them all:  $t\bar{t}W^\pm$  at NLO accuracy in QCD #29

Giuseppe Bevilacqua (MTA-DE, Debrecen), Huan-Yu Bi (RWTH Aachen U.), Heribertus Bayu Hartanto (Durham U., IPPP), Manfred Kraus (Florida State U.), Malgorzata Worek (RWTH Aachen U.) (May 19, 2020)

Published in: *JHEP* 08 (2020) 043 • e-Print: [2005.09427](#) [hep-ph]

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NLO QCD corrections to full off-shell production of  $t\bar{t}Z$  including leptonic decays #4

Giuseppe Bevilacqua (MTA-DE, Debrecen and Debrecen U.), Heribertus Bayu Hartanto (Cambridge U.), Manfred Kraus (Florida State U.), Jasmina Nasufi (RWTH Aachen U.), Malgorzata Worek (RWTH Aachen U.) (Mar 29, 2022)

Published in: *JHEP* 08 (2022) 060 • e-Print: [2203.15688](#) [hep-ph]

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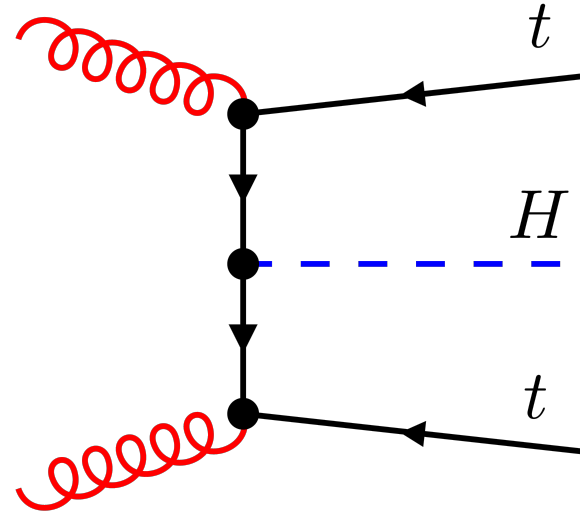
DOI

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reference search

7 citations



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Giuseppe Bevilacqua (MTA-DE, Debrecen), Huan-Yu Bi (RWTH Aachen U.), Heribertus Bayu Hartanto (Durham U., IPPP), Manfred Kraus (Florida State U.), Malgorzata Worek (RWTH Aachen U.) (May 19, 2020)

Published in: *JHEP* 08 (2020) 043 • e-Print: [2005.09427](#) [hep-ph]

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Published in: *JHEP* 08 (2022) 060 • e-Print: [2203.15688](#) [hep-ph]

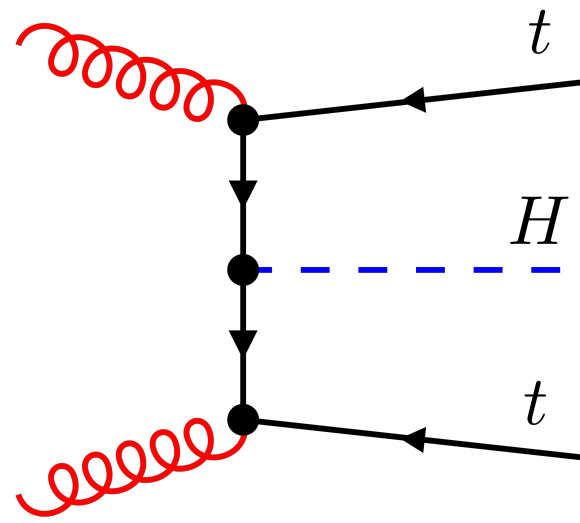
### Higgs production in association with off-shell top-antitop pairs at NLO EW and QCD at the LHC #18

Ansgar Denner (Wurzburg U.), Jean-Nicolas Lang (Wurzburg U.), Mathieu Pellen (Wurzburg U.), Sandro Uccirati (INFN, Turin and Turin U.) (Dec 21, 2016)

Published in: *JHEP* 02 (2017) 053 • e-Print: [1612.07138](#) [hep-ph]

pdf DOI cite claim reference search 52 citations





### The simplest of them all: $t\bar{t}W^\pm$ at NLO accuracy in QCD #29

Giuseppe Bevilacqua (MTA-DE, Debrecen), Huan-Yu Bi (RWTH Aachen U.), Heribertus Bayu Hartanto (Durham U., IPPP), Manfred Kraus (Florida State U.), Malgorzata Worek (RWTH Aachen U.) (May 19, 2020)

Published in: *JHEP* 08 (2020) 043 • e-Print: [2005.09427](#) [hep-ph]



### NLO QCD corrections to full off-shell production of $t\bar{t}Z$ including leptonic decays #4

Giuseppe Bevilacqua (MTA-DE, Debrecen and Debrecen U.), Heribertus Bayu Hartanto (Cambridge U.), Manfred Kraus (Florida State U.), Jasmina Nasufi (RWTH Aachen U.), Malgorzata Worek (RWTH Aachen U.) (Mar 29, 2022)

Published in: *JHEP* 08 (2022) 060 • e-Print: [2203.15688](#) [hep-ph]



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Ansgar Denner (Wurzburg U.), Jean-Nicolas Lang (Wurzburg U.), Mathieu Pellen (Wurzburg U.), Sandro Uccirati (INFN, Turin and Turin U.) (Dec 21, 2016)

Published in: *JHEP* 12 (2016) 175 • e-Print: [1612.07501](#) [hep-ph]



### $t\bar{t}b\bar{b}$ at the LHC: On the size of off-shell effects and prompt $b$ -jet identification #5

Giuseppe Bevilacqua (MTA-DE, Debrecen and Debrecen U.), Huan-Yu Bi (RWTH Aachen U.), Heribertus Bayu Hartanto (Cambridge U.), Manfred Kraus (Florida State U.), Michele Lupattelli (RWTH Aachen U.) et al. (Feb 22, 2022)

e-Print: [2202.11186](#) [hep-ph]



cite



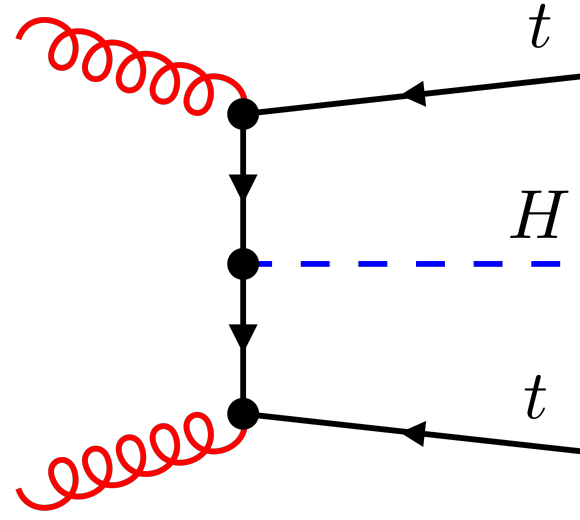
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reference search



5 citations



**The simplest of them all:  $t\bar{t}W^\pm$  at NLO accuracy in QCD** #29

Giuseppe Bevilacqua (MTA-DE, Debrecen), Huan-Yu Bi (RWTH Aachen U.), Heribertus Bayu Hartanto (Durham U., IPPP), Manfred Kraus (Florida State U.), Malgorzata Worek (RWTH Aachen U.) (May 19, 2020)

Published in: *JHEP* 08 (2020) 043 • e-Print: [2005.09427](#) [hep-ph]



**NLO QCD corrections to full off-shell production of  $t\bar{t}Z$  including leptonic decays** #4

Giuseppe Bevilacqua (MTA-DE, Debrecen and Debrecen U.), Heribertus Bayu Hartanto (Cambridge U.), Manfred Kraus (Florida State U.), Jasmina Nasufi (RWTH Aachen U.), Malgorzata Worek (RWTH Aachen U.) (Mar 29, 2022)

Published in: *JHEP* 08 (2022) 060 • e-Print: [2203.15688](#) [hep-ph]



**Higgs production in association with off-shell top-antitop pairs at NLO EW and QCD at the LHC** #18

Ansgar Denner (Wurzburg U.), Jean-Nicolas Lang (Wurzburg U.), Mathieu Pellen (Wurzburg U.), Sandro Uccirati (INFN, Turin and Turin U.) (Dec 21, 2016)

Published in: *JHEP* 12 (2016) 107 • e-Print: [1612.08802](#) [hep-ph]



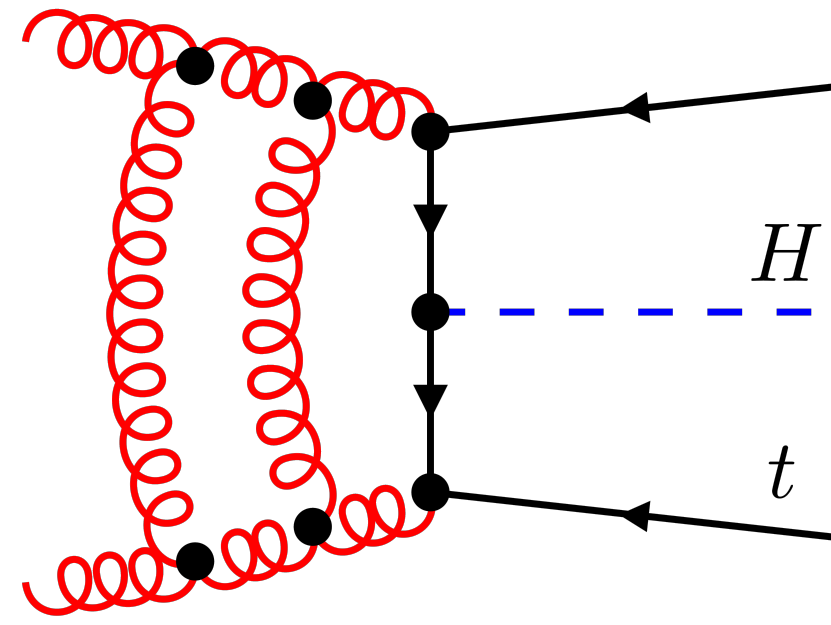
**$t\bar{t}b\bar{b}$  at the LHC: On the size of off-shell effects and prompt  $b$ -jet identification** #5

Giuseppe Bevilacqua (MTA-DE, Debrecen and Debrecen U.), Huan-Yu Bi (RWTH Aachen U.), Heribertus Bayu Hartanto (Cambridge U.), Manfred Kraus (Florida State U.), Michele Lupattelli (RWTH Aachen U.) et al. (Feb 22, 2022)

e-Print: [2202.11186](#) [hep-ph]



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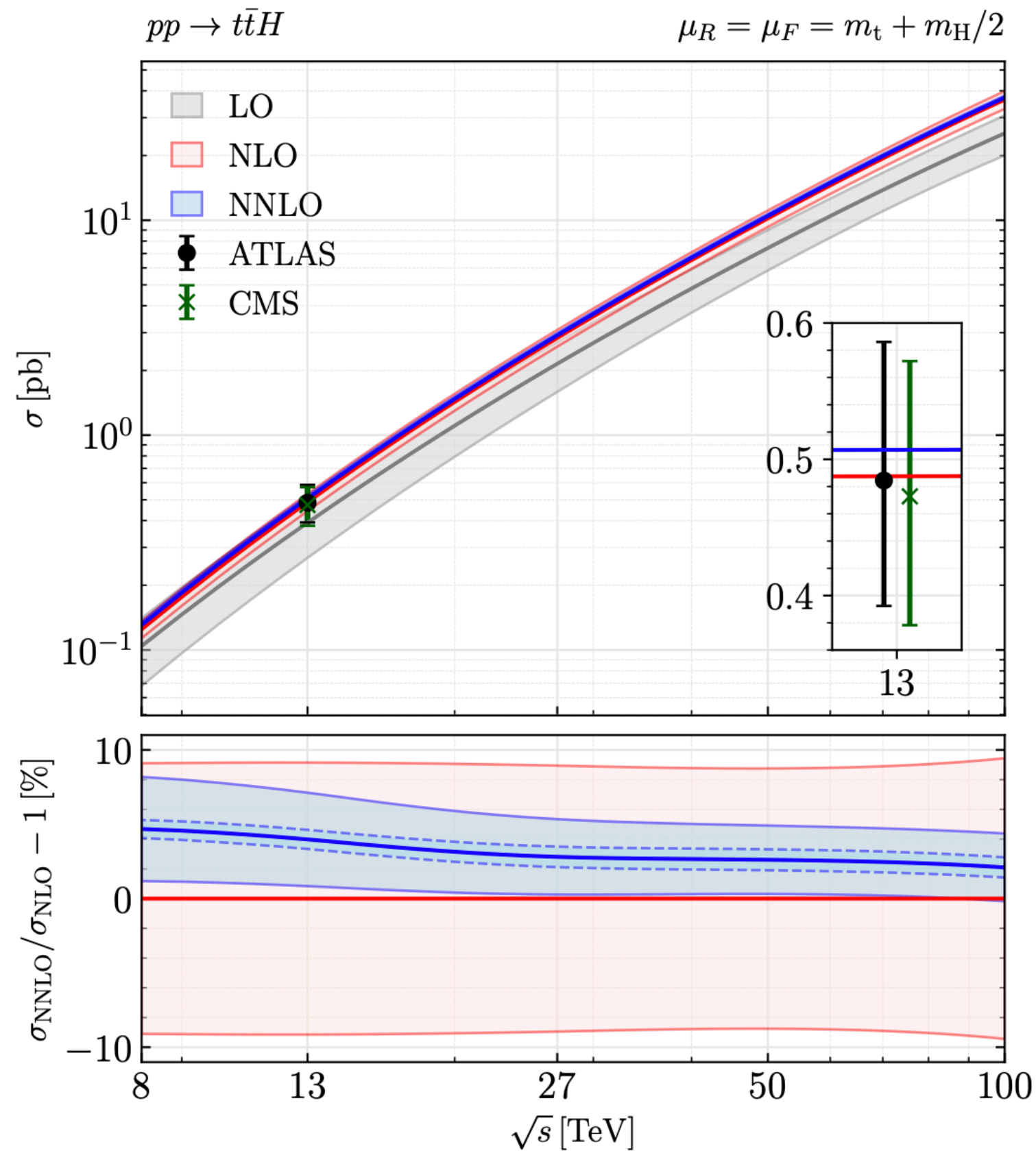


## $t\bar{t}H$ production in NNLO QCD

#1

Stefano Catani (INFN, Florence and Florence U.), Simone Devoto (INFN, Milan and Milan U.), Massimiliano Grazzini (Zurich U.), Stefan Kallweit (INFN, Milan Bicocca and Milan Bicocca U.), Javier Mazzitelli (Munich, Max Planck Inst. and PSI, Villigen) et al. (Oct 14, 2022)

e-Print: [2210.07846](https://arxiv.org/abs/2210.07846) [hep-ph]



## Two-loop QCD amplitudes for $t\bar{t}H$ production from boosted limit

#1

Guoxing Wang (Zhejiang U. and Paris, LPTHE), Tianya Xia (Zhejiang U.), Li Lin Yang (Zhejiang U.), Xiaoping Ye (Peking U.) (Feb 1, 2024)

Published in: *JHEP* 07 (2024) 121 • e-Print: [2402.00431](https://arxiv.org/abs/2402.00431) [hep-ph]

[pdf](#) [DOI](#) [cite](#) [claim](#) [reference search](#) [5 citations](#)

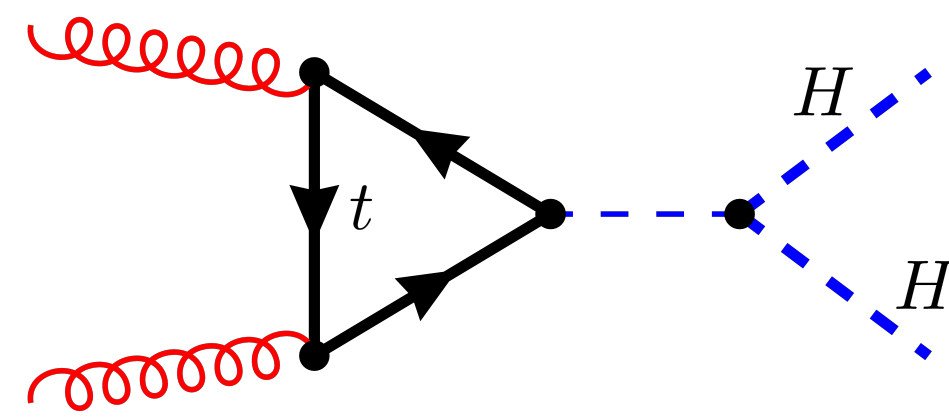
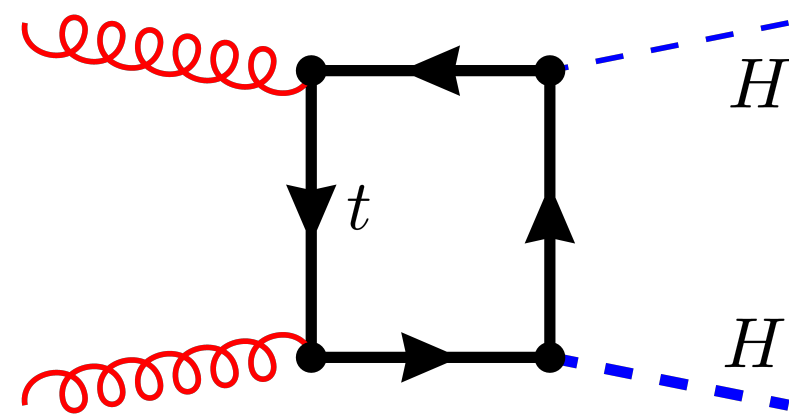
## Two-loop amplitudes for $t\bar{t}H$ production: the quark-initiated $N_f$ -part

#4

Bakul Agarwal (KIT, Karlsruhe, TP), Gudrun Heinrich (KIT, Karlsruhe, TP), Stephen P. Jones (Durham U.), Matthias Kerner (KIT, Karlsruhe, TP), Sven Yannick Klein (RWTH Aachen U.) et al. (Feb 5, 2024)

Published in: *JHEP* 05 (2024) 013, *JHEP* 06 (2024) 142 (erratum) • e-Print: [2402.03301](https://arxiv.org/abs/2402.03301) [hep-ph]

[pdf](#) [DOI](#) [cite](#) [claim](#) [reference search](#) [9 citations](#)



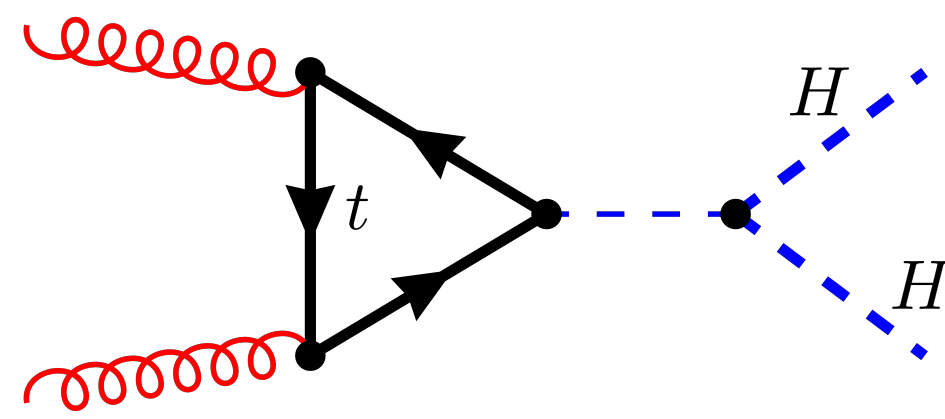
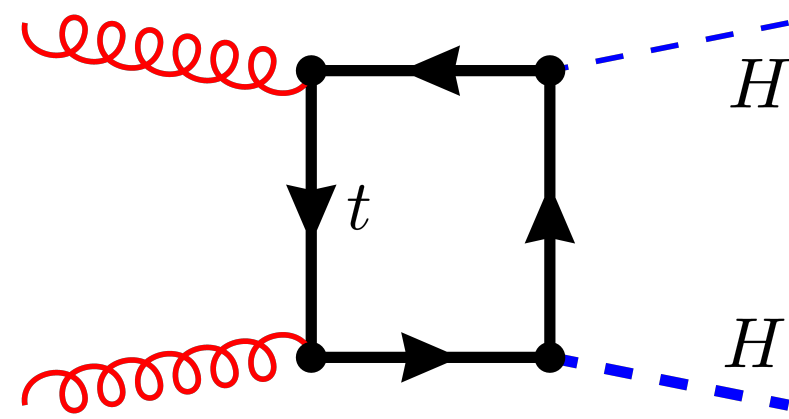
NLO

electro-weak

**Higgs Boson Pair Production in Gluon Fusion at Next-to-Leading Order with Full Top-Quark Mass Dependence** #2  
 S. Borowka (Santa Barbara, KITP and Zurich U.), N. Greiner (Zurich U.), G. Heinrich (Munich, Max Planck Inst.), S.P. Jones (Munich, Max Planck Inst.), M. Kerner (Munich, Max Planck Inst.) et al. (Apr 21, 2016)  
 Published in: *Phys.Rev.Lett.* 117 (2016) 1, 012001, *Phys.Rev.Lett.* 117 (2016) 7, 079901 (erratum) • e-Print: [1604.06447](#) [hep-ph]  
 pdf DOI cite claim reference search 343 citations

**Gluon fusion into Higgs pairs at NLO QCD and the top mass scheme** #13  
 Julien Baglio (Tubingen U.), Francisco Campanario (Valencia U., IFIC and KIT, Karlsruhe, TP), Seraina Glaus (KIT, Karlsruhe, TP and PSI, Villigen and Zurich U.), Margarete Mühlleitner (KIT, Karlsruhe, TP), Michael Spira (PSI, Villigen) et al. (Nov 14, 2018)  
 Published in: *Eur.Phys.J.C* 79 (2019) 6, 459 • e-Print: [1811.05692](#) [hep-ph]  
 pdf DOI cite claim reference search 179 citations

**Electroweak corrections to Higgs boson pair production: The top-Yukawa and self-coupling contributions** #10  
 Gudrun Heinrich (KIT, Karlsruhe, TP), Stephen Jones (Durham U., IPPP), Matthias Kerner (KIT, Karlsruhe, TP), Thomas Stone (Durham U., IPPP), Augustin Vestner (KIT, Karlsruhe, TP) (Jul 5, 2024)  
 e-Print: [2407.04653](#) [hep-ph]  
 pdf cite claim reference search 6 citations



NLO

electro-weak

### Higgs Boson Pair Production in Gluon Fusion at Next-to-Leading Order with Full Top-Quark Mass Dependence #2

S. Borowka (Santa Barbara, KITP and Zurich U.), N. Greiner (Zurich U.), G. Heinrich (Munich, Max Planck Inst.), S.P. Jones (Munich, Max Planck Inst.), M. Kerner (Munich, Max Planck Inst.) et al. (Apr 21, 2016)

Published in: *Phys.Rev.Lett.* 117 (2016) 1, 012001, *Phys.Rev.Lett.* 117 (2016) 7, 079901 (erratum) • e-Print: [1604.06447](#) [hep-ph]

pdf DOI cite claim reference search 343 citations

### Gluon fusion into Higgs pairs at NLO QCD and the top mass scheme #13

Julien Baglio (Tubingen U.), Francisco Campanario (Valencia U., IFIC and KIT, Karlsruhe, TP), Seraina Glau (KIT, Karlsruhe, TP and PSI, Villigen and Zurich U.), Margarete Mühlleitner (KIT, Karlsruhe, TP), Michael Spira (PSI, Villigen) et al. (Nov 14, 2018)

Published in: *Eur.Phys.J.C* 79 (2019) 6, 459 • e-Print: [1811.05692](#) [hep-ph]

pdf DOI cite claim reference search 179 citations

### Electroweak corrections to Higgs boson pair production: The top-Yukawa and self-coupling contributions #10

Gudrun Heinrich (KIT, Karlsruhe, TP), Stephen Jones (Durham U., IPPP), Matthias Kerner (KIT, Karlsruhe, TP), Thomas Stone (Durham U., IPPP), Augustin Vestner (KIT, Karlsruhe, TP) (Jul 5, 2024)

e-Print: [2407.04653](#) [hep-ph]

pdf cite claim reference search 6 citations

## Towards NNLO:

### Higgs boson pair production at NNLO with top quark mass effects #1

Massimiliano Grazzini (Zurich U.), Gudrun Heinrich (Munich, Max Planck Inst.), Stephen Jones (Munich, Max Planck Inst.), Stefan Kallweit (CERN), Matthias Kerner (Munich, Max Planck Inst.) et al. (Mar 6, 2018)

Published in: *JHEP* 05 (2018) 059 • e-Print: [1803.02463](#) [hep-ph]

pdf DOI cite claim reference search 252 citations

### Three-loop corrections to Higgs boson pair production: reducible contribution #1

Joshua Davies (Liverpool U., Dept. Math.), Kay Schönwald (Zurich U.), Matthias Steinhauser (KIT, Karlsruhe, TTP), Marco Vitti (KIT, Karlsruhe, TTP and KIT, Karlsruhe, IAP) (May 30, 2024)

Published in: *JHEP* 08 (2024) 096 • e-Print: [2405.20372](#) [hep-ph]

pdf DOI cite claim reference search 7 citations

### Towards $gg \rightarrow HH$ at next-to-next-to-leading order: Light-fermionic three-loop corrections #2

Joshua Davies (Sussex U.), Kay Schönwald (Zurich U.), Matthias Steinhauser (KIT, Karlsruhe, TTP) (Jul 10, 2023)

Published in: *Phys.Lett.B* 845 (2023) 138146 • e-Print: [2307.04796](#) [hep-ph]

pdf DOI cite claim reference search 11 citations

### Real-virtual corrections to Higgs boson pair production at NNLO: three closed top quark loops #3

Joshua Davies (KIT, Karlsruhe, TTP), Florian Herren (KIT, Karlsruhe, TTP), Go Mishima (KIT, Karlsruhe, TTP and KIT, Karlsruhe, IKP), Matthias Steinhauser (KIT, Karlsruhe, TTP) (Apr 26, 2019)

Published in: *JHEP* 05 (2019) 157 • e-Print: [1904.11998](#) [hep-ph]

pdf DOI cite claim reference search 23 citations

## What I could not talk about...

- off-shell Higgs production
- Higgs decays
- resummation
- EFT
- BSM
- ...

# Conclusions

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- needs to be taken into account in analyses