Differential distributions in HH production beyond LO

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HH subgroup meeting

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MAX-PLANCK-GESELLSCHAFT

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

In collaboration with:

S. Borowka, N. Greiner, G. Heinrich, S. Jones, J. Schlenk, U. Schubert, T. Zirke

Overview

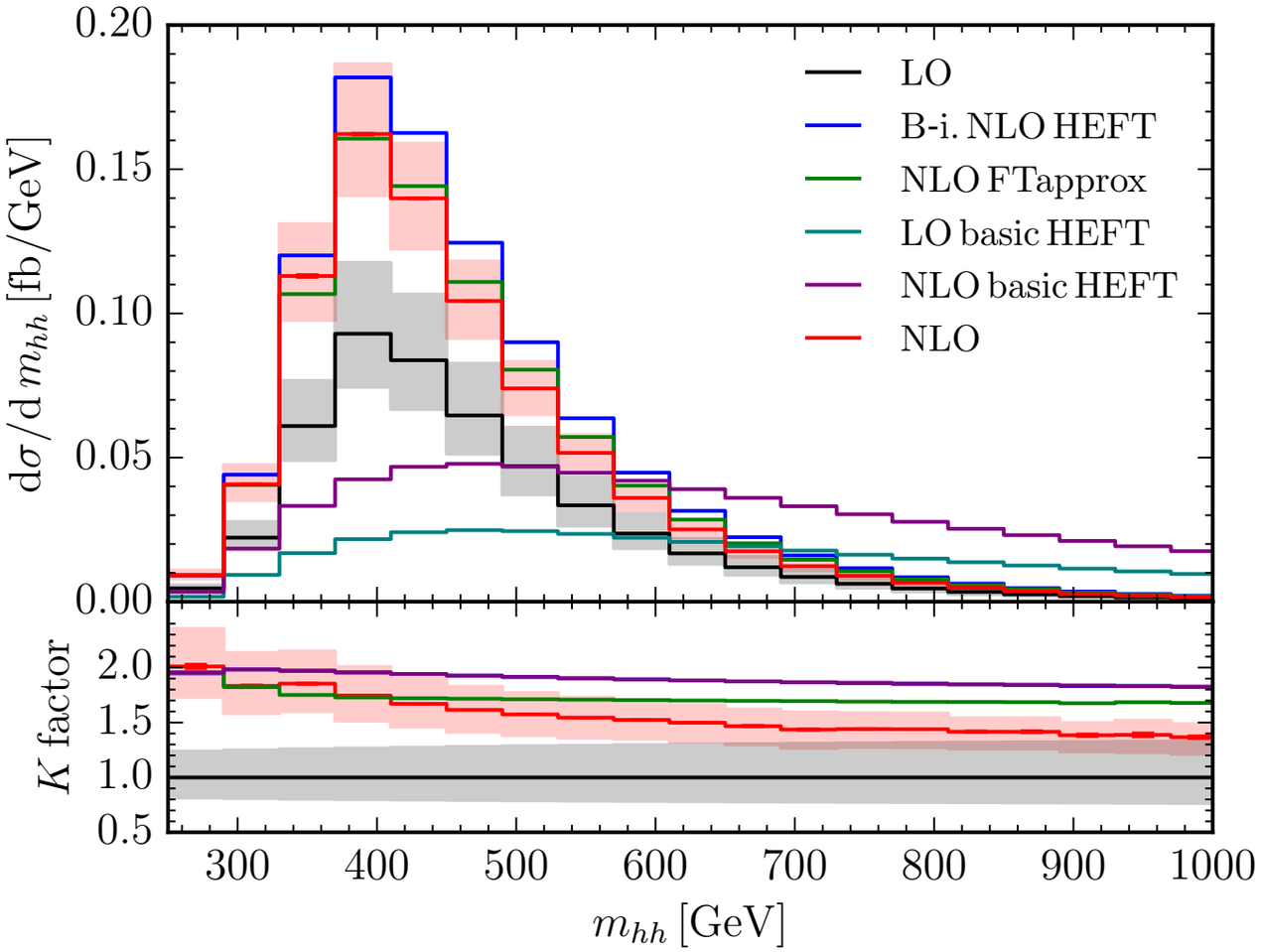
- NLO distributions
  - improved statistics
  - ➡ smaller bin sizes possible

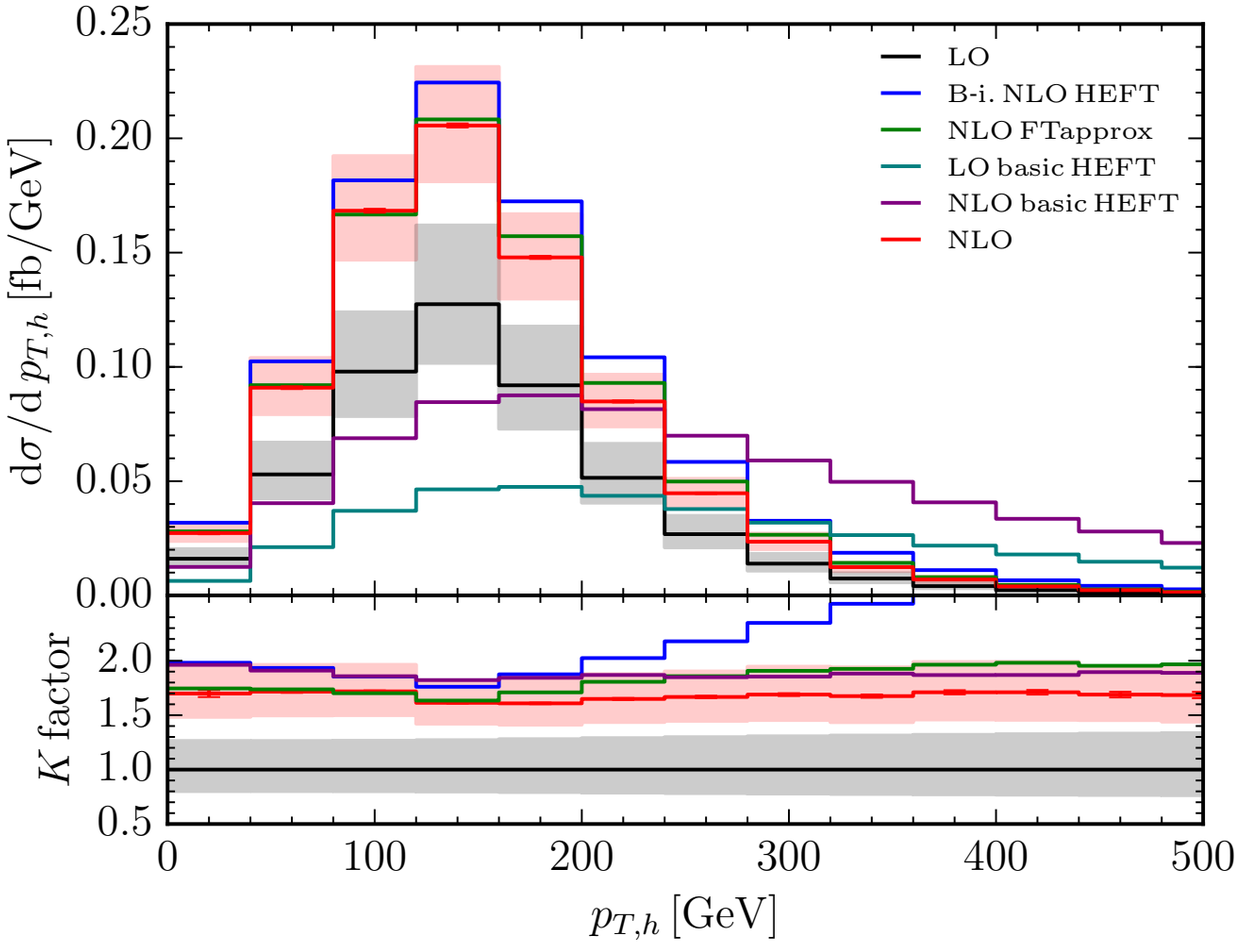
- improving approximated results

- combining full NLO with NNLO HEFT and parton shower

NLO — differential distributions

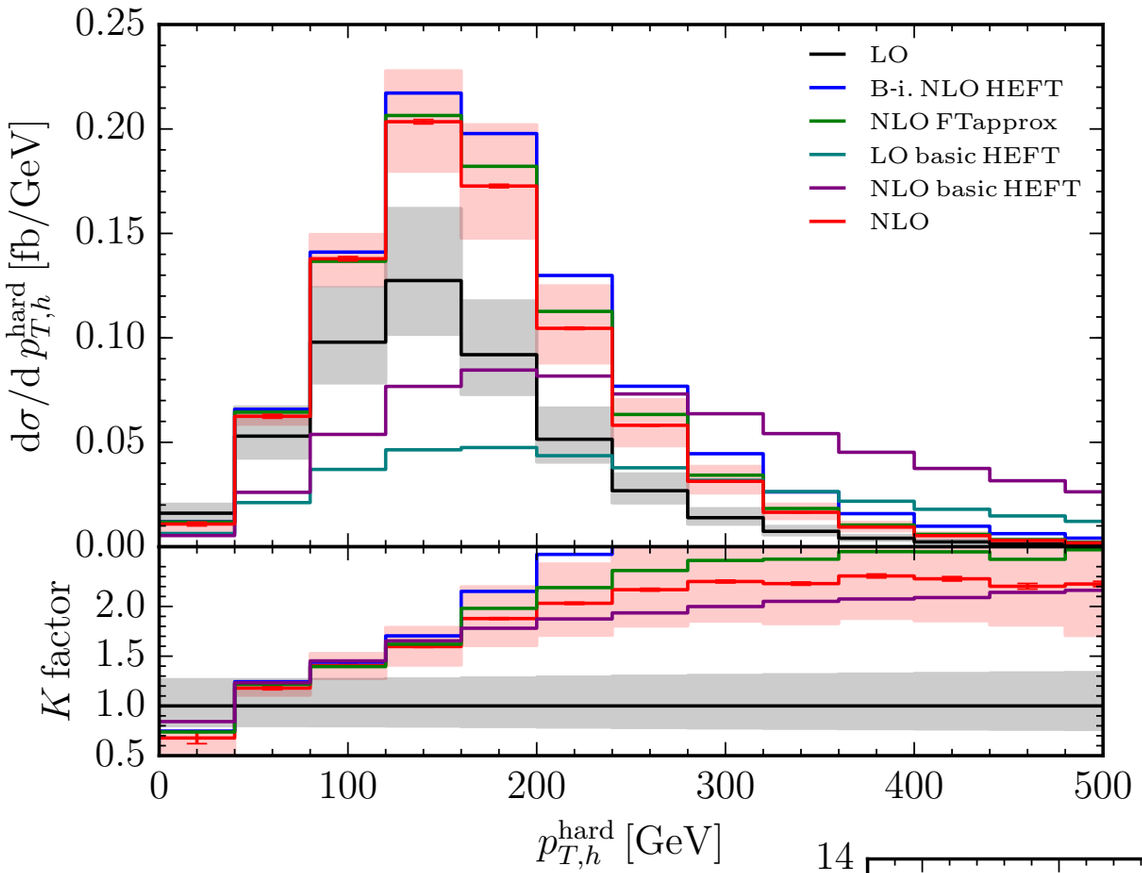
LHC@14TeV

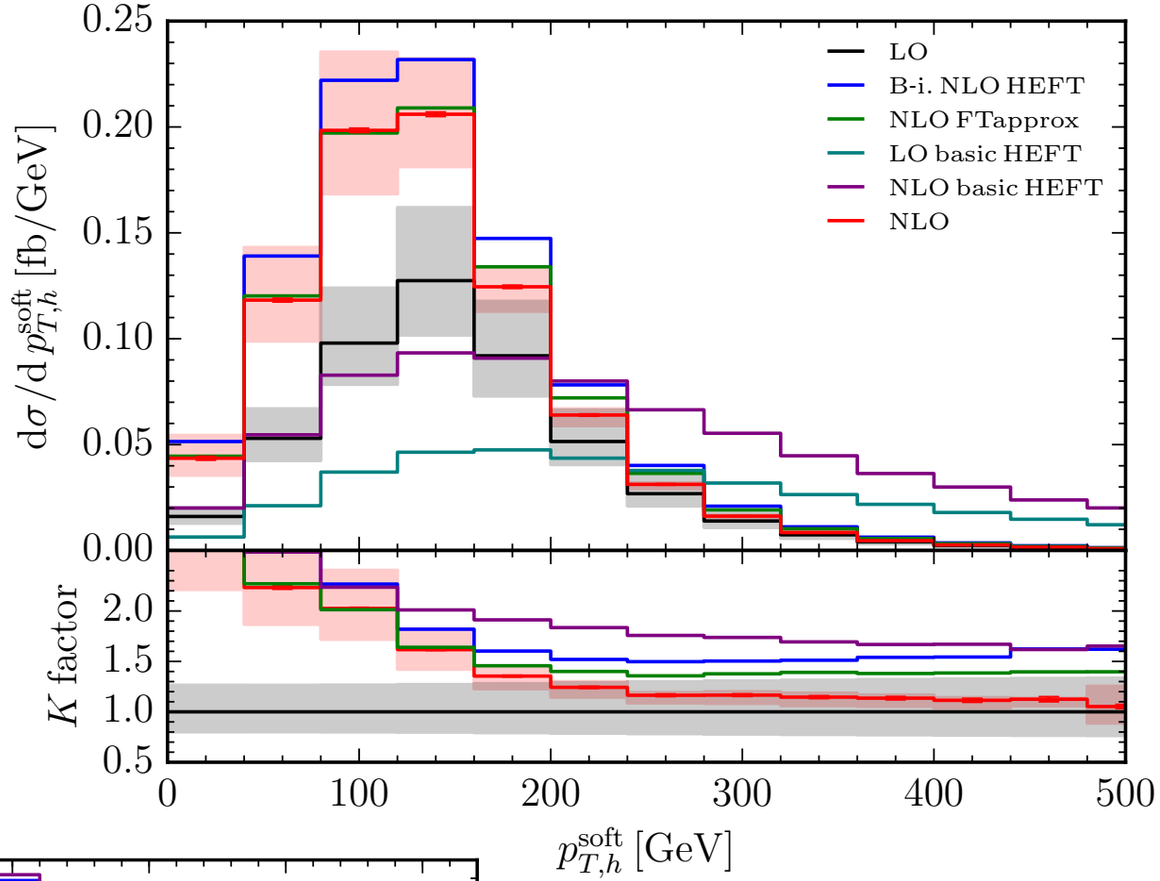


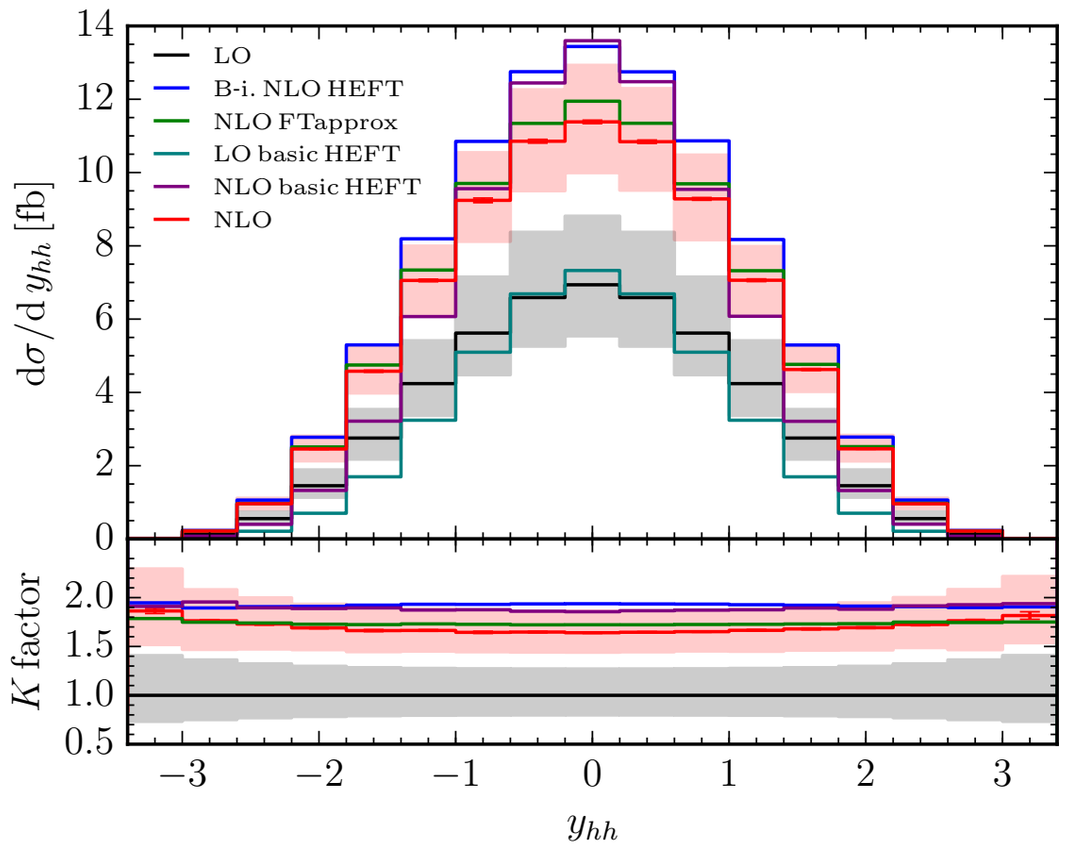


NLO — differential distributions

LHC@14TeV

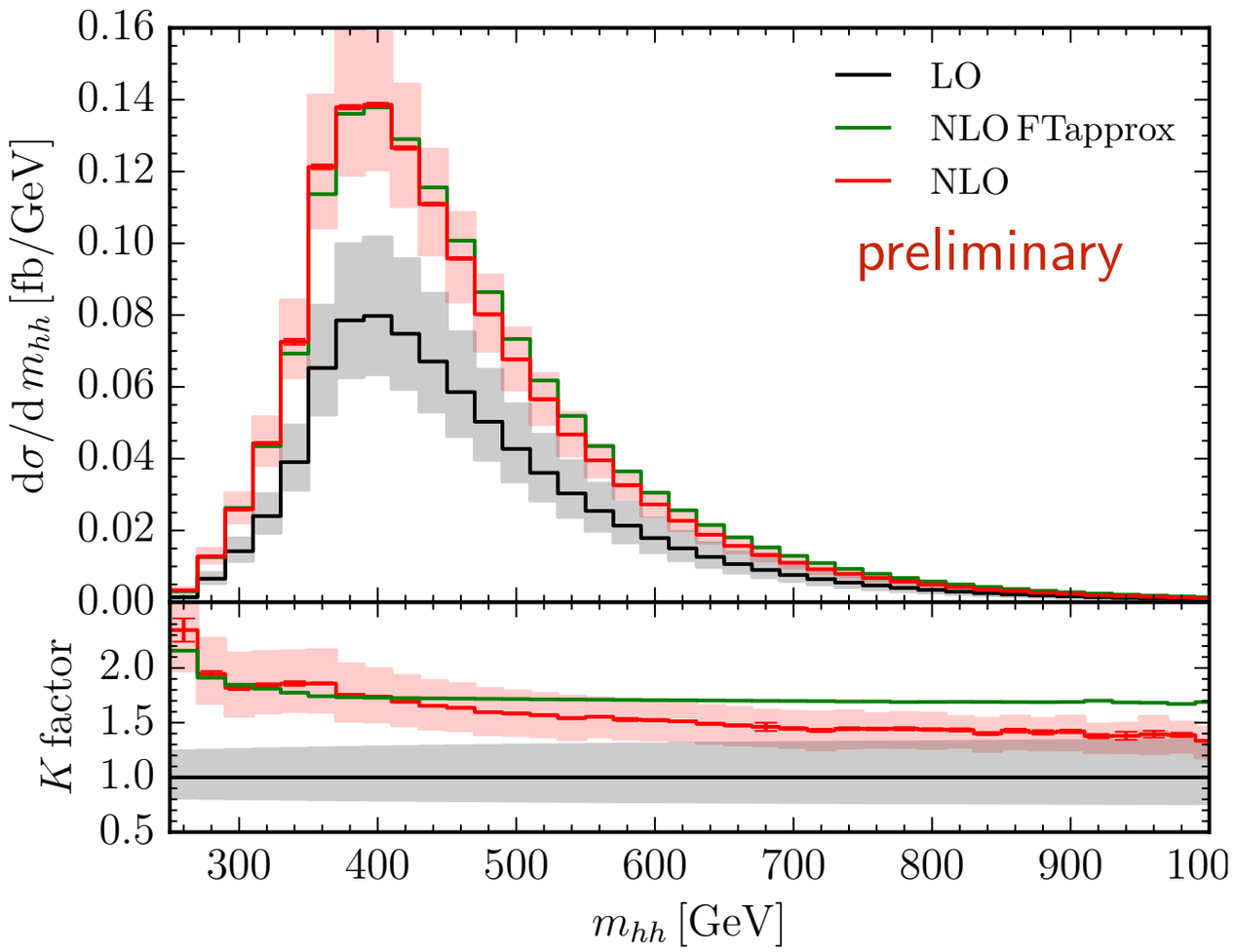


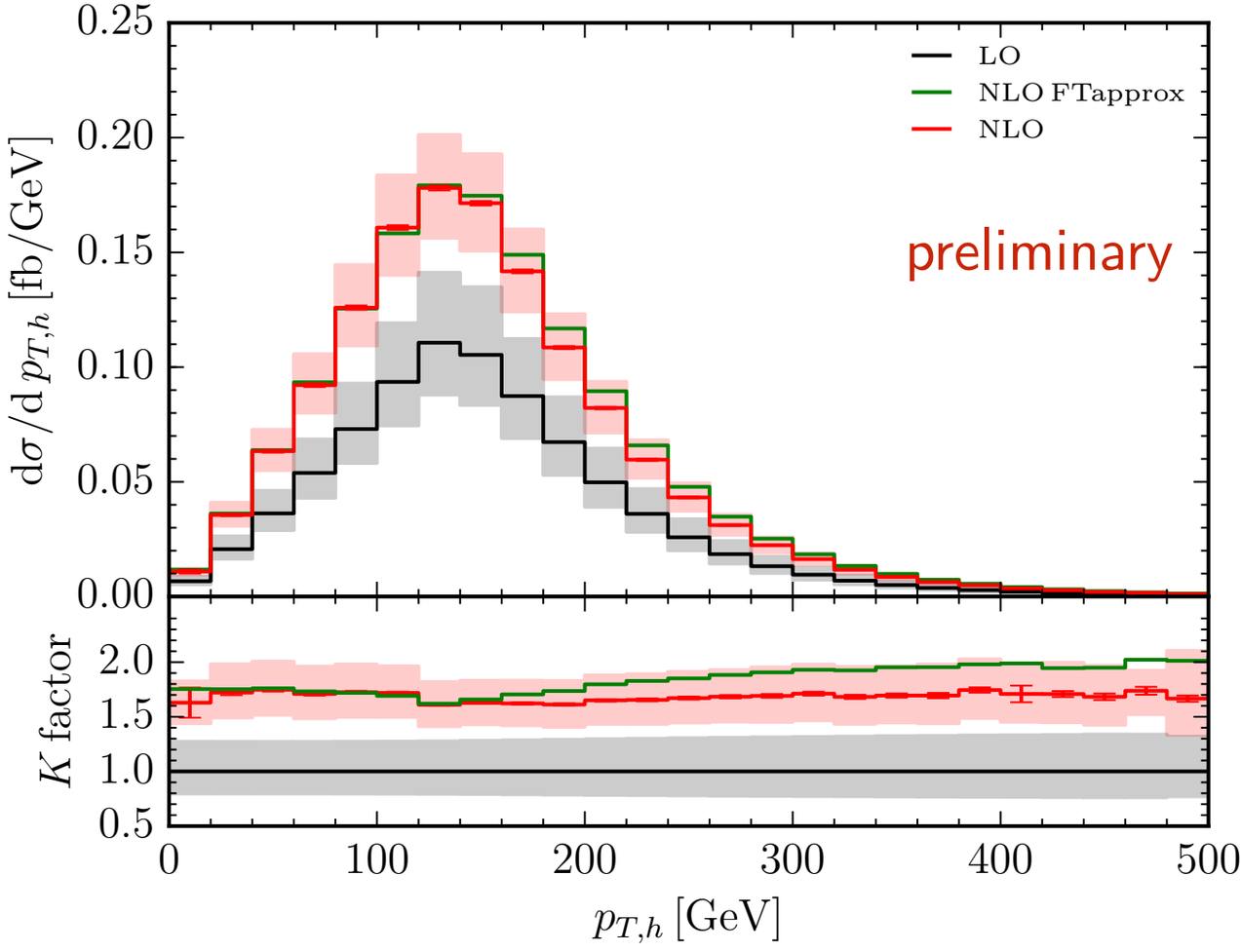




NLO — differential distributions

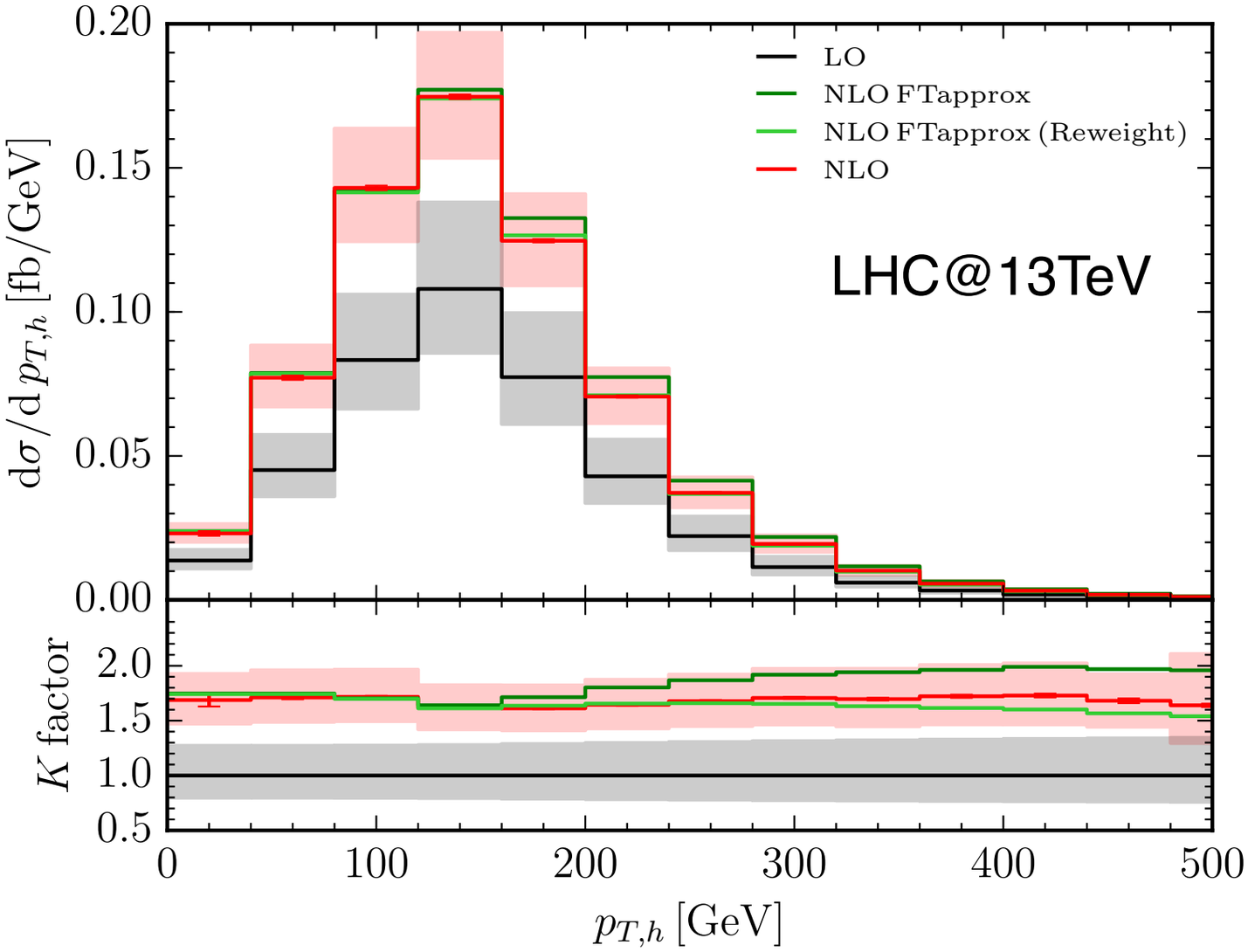
LHC@13TeV





statistics increased by factor of ~2 since October meeting

Reweighting FTapprox



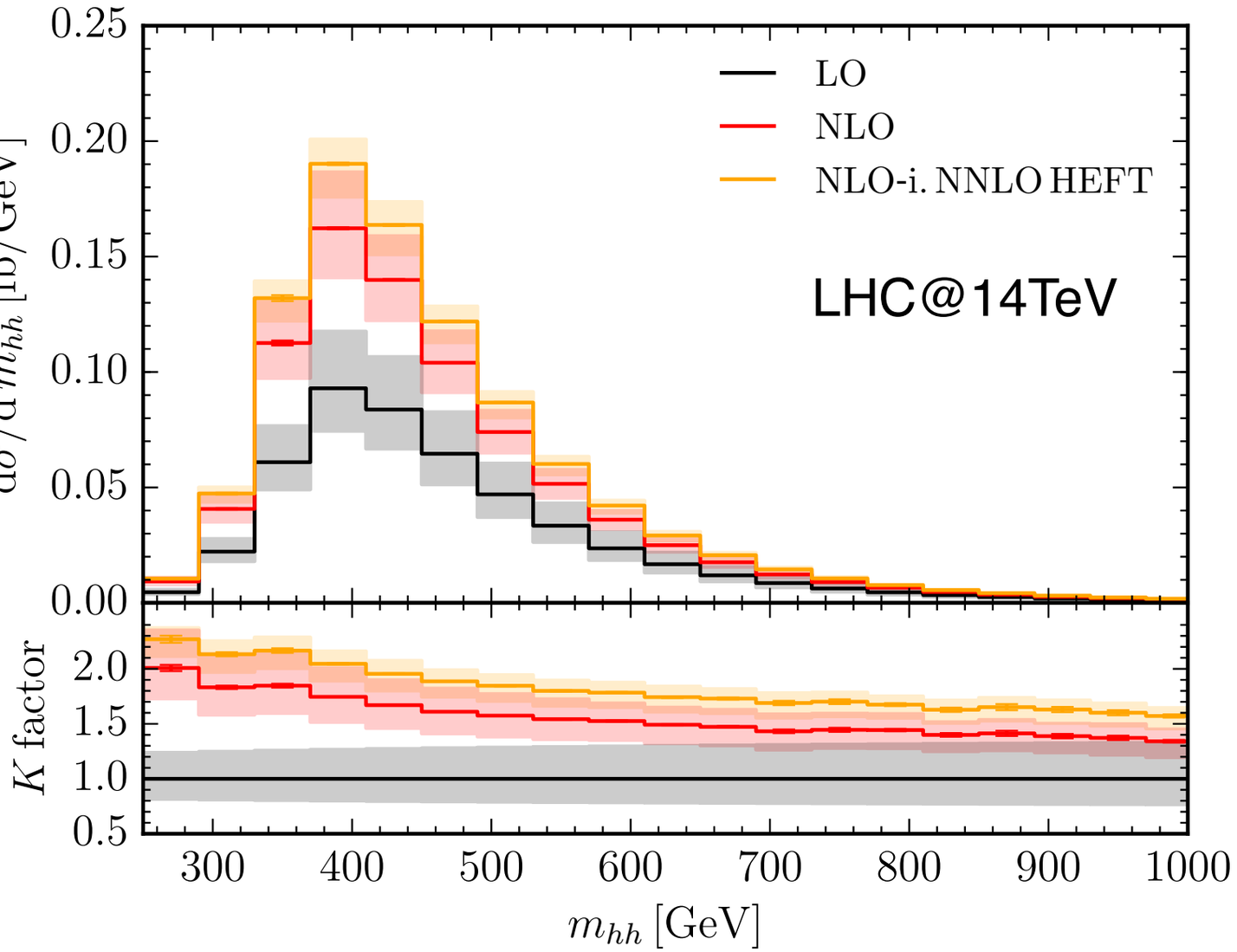
FTapprox Reweight:

$$d\sigma \approx d\sigma_{LO} + d\sigma'_{NLO}$$

$$d\sigma'_{\mathrm{NLO}}(X) = d\sigma^{\mathrm{FTap.}}_{\mathrm{NLO}}(X) \cdot \underbrace{\frac{d\sigma^{\mathrm{full}}_{\mathrm{NLO}}(m_{hh})}{d\sigma^{\mathrm{FTap.}}_{\mathrm{NLO}}(m_{hh})}}_{K_{m_t}}$$

$\rightarrow$ FTapprox results can be improved by reweighting with $K_{m_t}(m_{hh})$

NLO-improved HEFT



first attempt to combine

- Full NLO

Borowka, Greiner, Heinrich, Jones, MK, Schlenk, Zirke 16

- NNLO HEFT

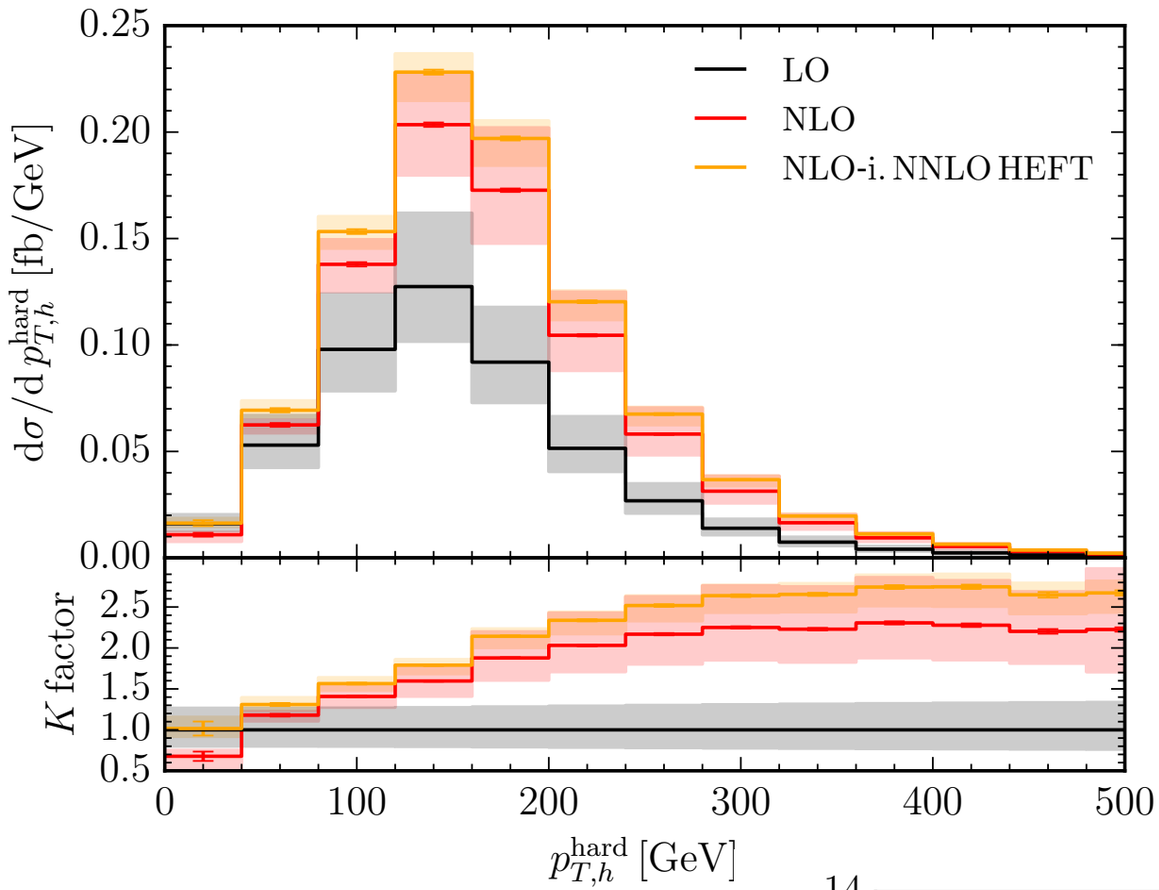
de Florian, Grazzini, Hanga, Kallweit, Lindert, Maierhöfer, Mazzitelli, Rathlev 16

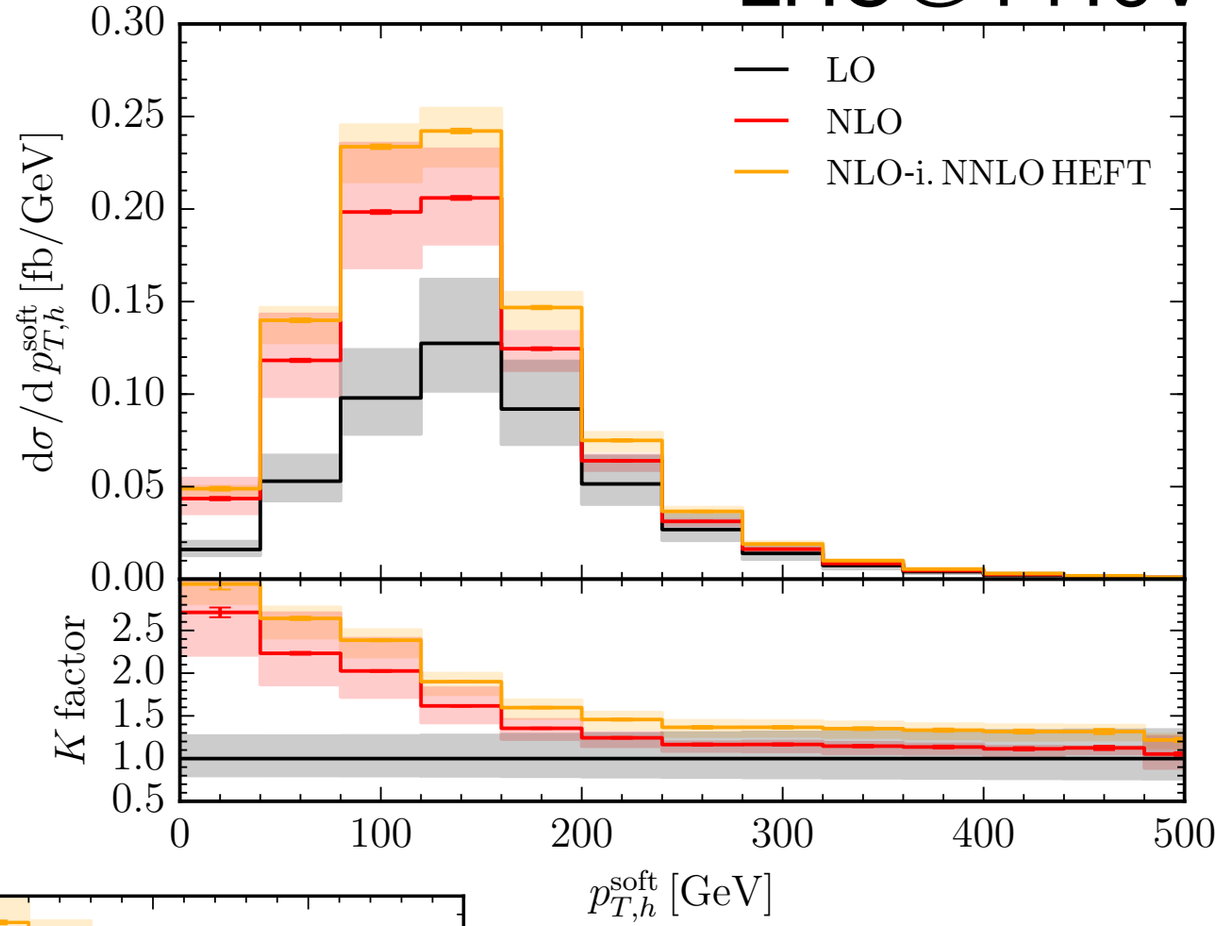
Differential rescaling of σ_{NLO} by $K^{\mathrm{HEFT}}_{\mathrm{NNLO}}$

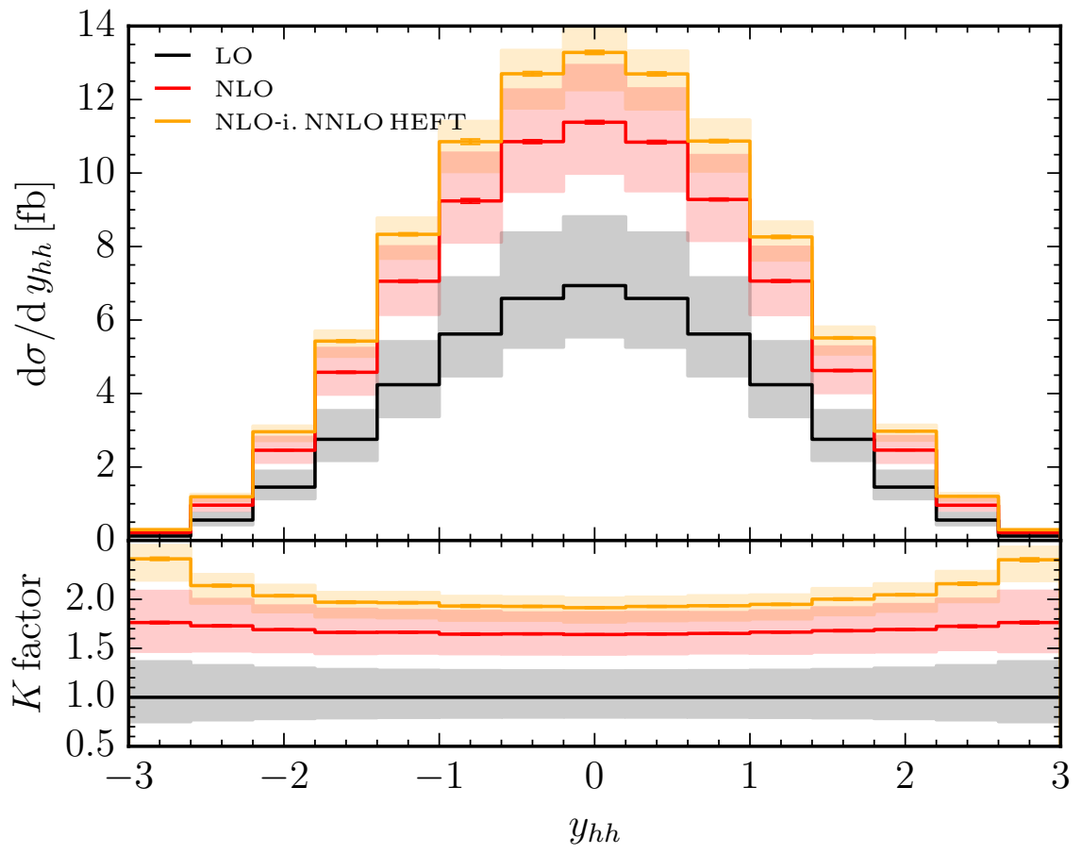
$$\frac{\mathrm{d}\sigma_{\mathrm{approx}}}{\mathrm{d}m_{hh}} = \frac{\mathrm{d}\sigma^{\mathrm{full}}_{\mathrm{NLO}}}{\mathrm{d}m_{hh}} \cdot \frac{\mathrm{d}\sigma^{\mathrm{HEFT}}_{\mathrm{NNLO}}/\mathrm{d}m_{hh}}{\mathrm{d}\sigma^{\mathrm{HEFT}}_{\mathrm{NLO}}/\mathrm{d}m_{hh}}$$

NLO-improved HEFT

LHC@14TeV







Work in Progress / Outlook

constructing grid for virtual amplitude

allows for:

status:
- work in progress
- reliable predictions for majority of phase space, but
  - large deviations
  - underestimated error estimates

  in some PS regions
- requires more testing

- improved combination of

  full NLO + NNLO HEFT

  (with Grazzini, Kallweit,

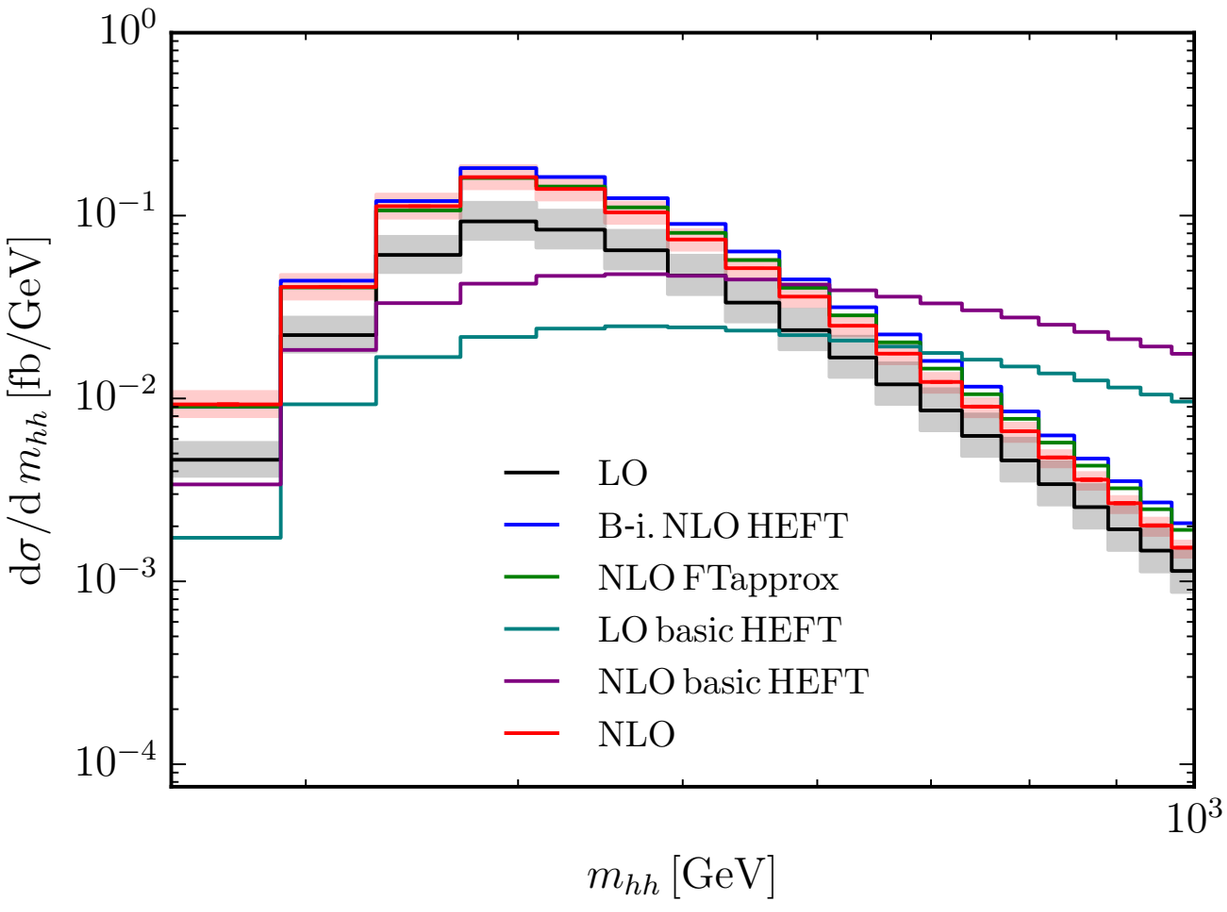
  Mazzitelli, Lindert)

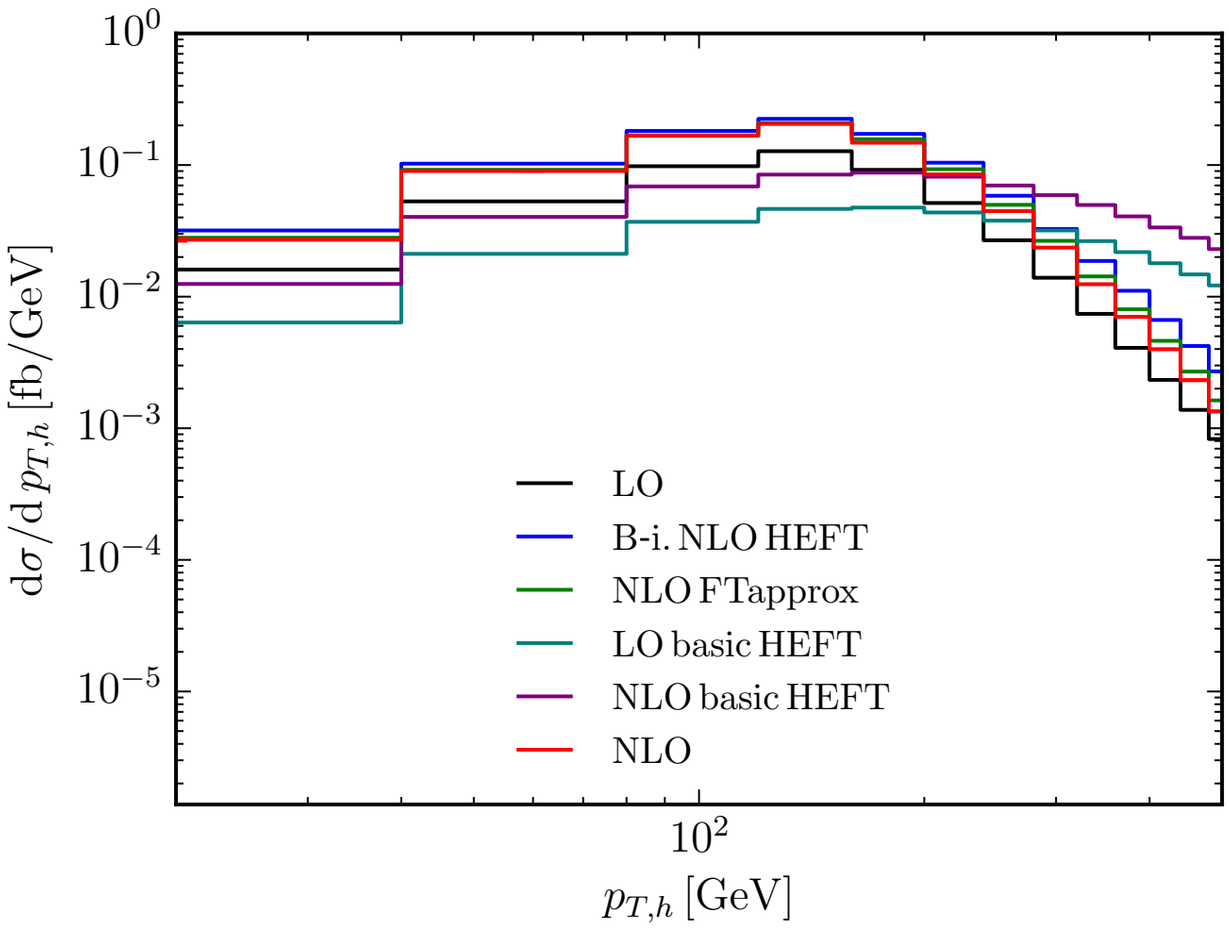
- full NLO + parton shower
  - POWHEG (with Luisoni)
  - MG5_aMC@NLO (with Vryonidou)
  - Sherpa (with Höche, Kuttimalai)
  - Herwig (with Papaefstathiou, Plätzer)

Thank you for your attention!

Backup

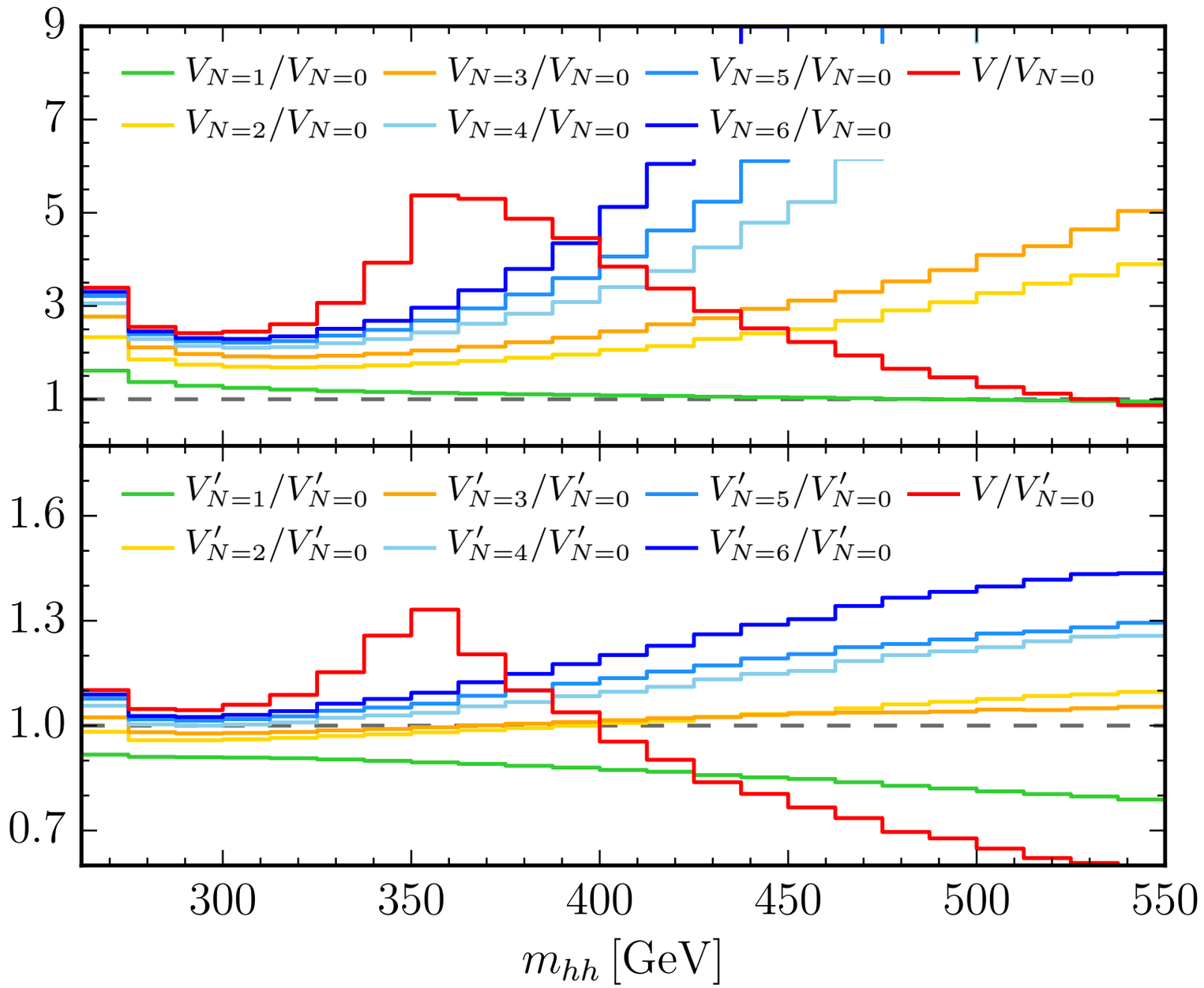
scaling behavior





Results - Amplitude

comparison to HEFT and expansion in $1/m_t$



$$V_N = \left(d\hat{\sigma}^{\text{virt}}_{\text{exp},N} + d\hat{\sigma}^{\text{LO}}_{\text{exp},N}(\epsilon) \otimes I\right) \frac{d\hat{\sigma}^{\text{LO}}(\epsilon)}{d\hat{\sigma}^{\text{LO}}_{\text{exp},N}(\epsilon)}$$

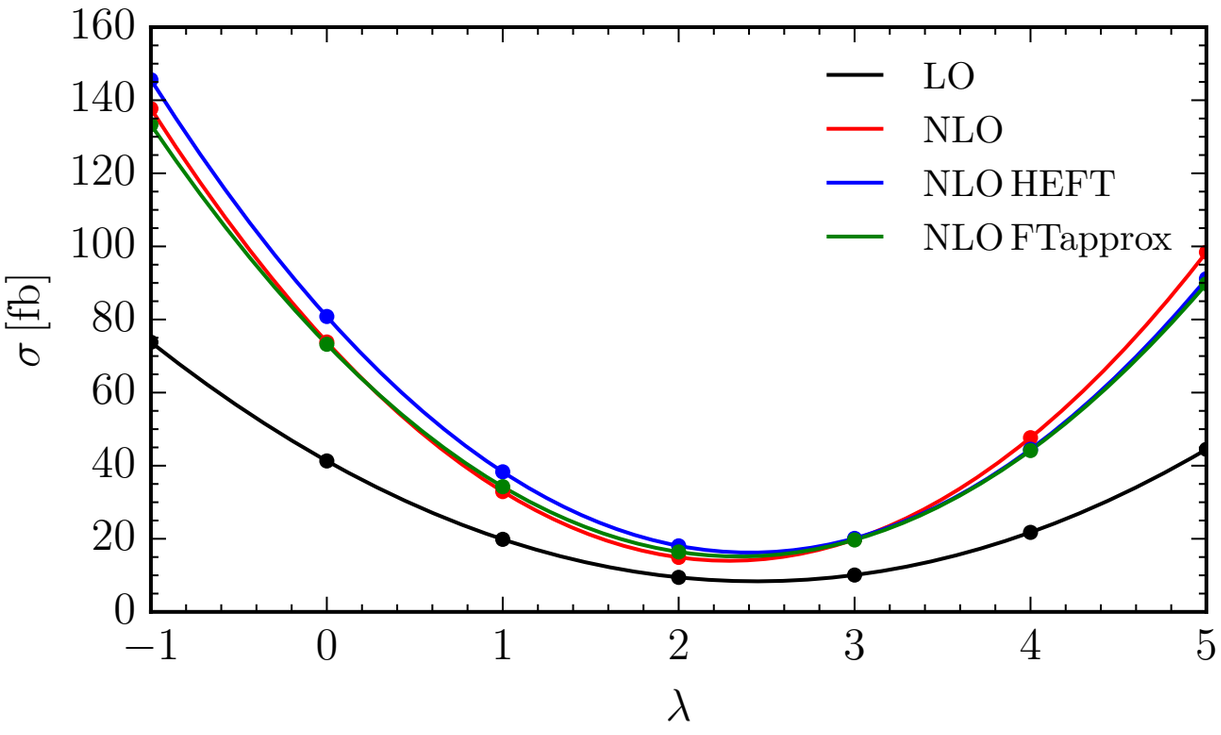
$$d\hat{\sigma}_{\text{exp},N} = \sum_{\rho=0}^{N} d\hat{\sigma}^{(\rho)} \left(\frac{\Lambda}{m_t}\right)^{2\rho}$$

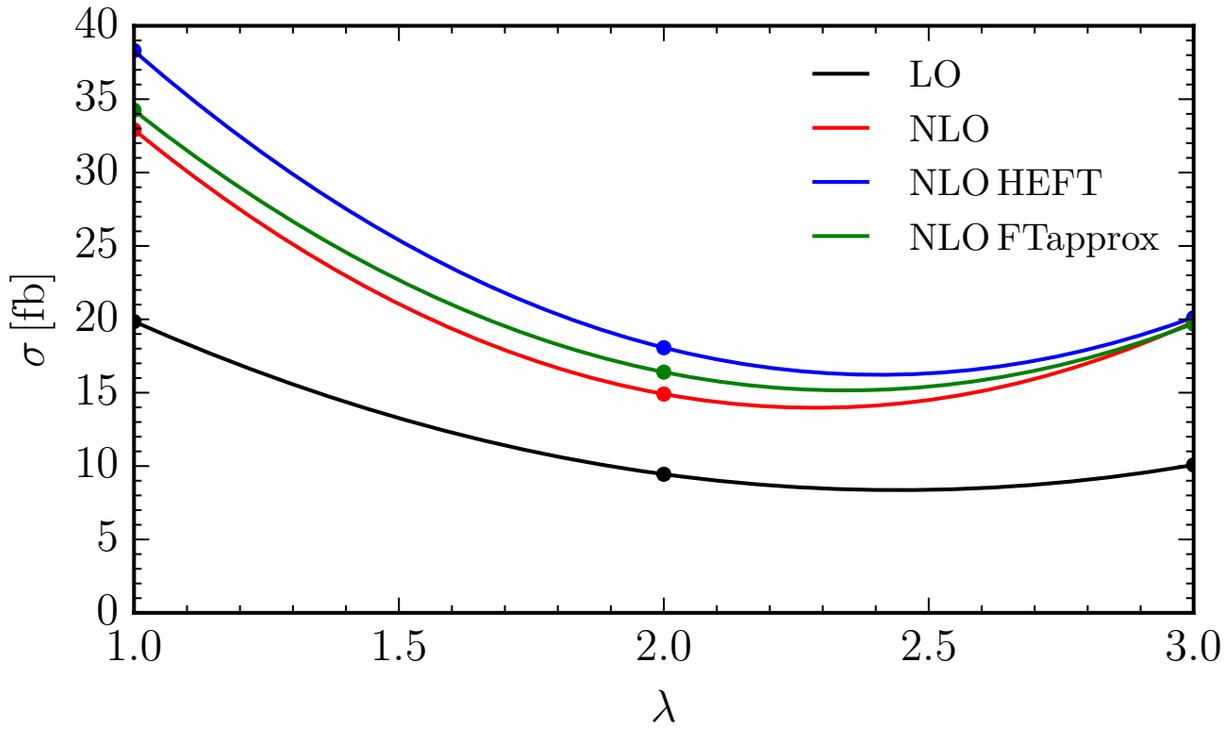
$$\Lambda \in \left\{\sqrt{\hat{s}}, \sqrt{\hat{t}}, \sqrt{\hat{u}}, m_h\right\}$$

$$V'_N = V_N \cdot \frac{B}{B_N}$$

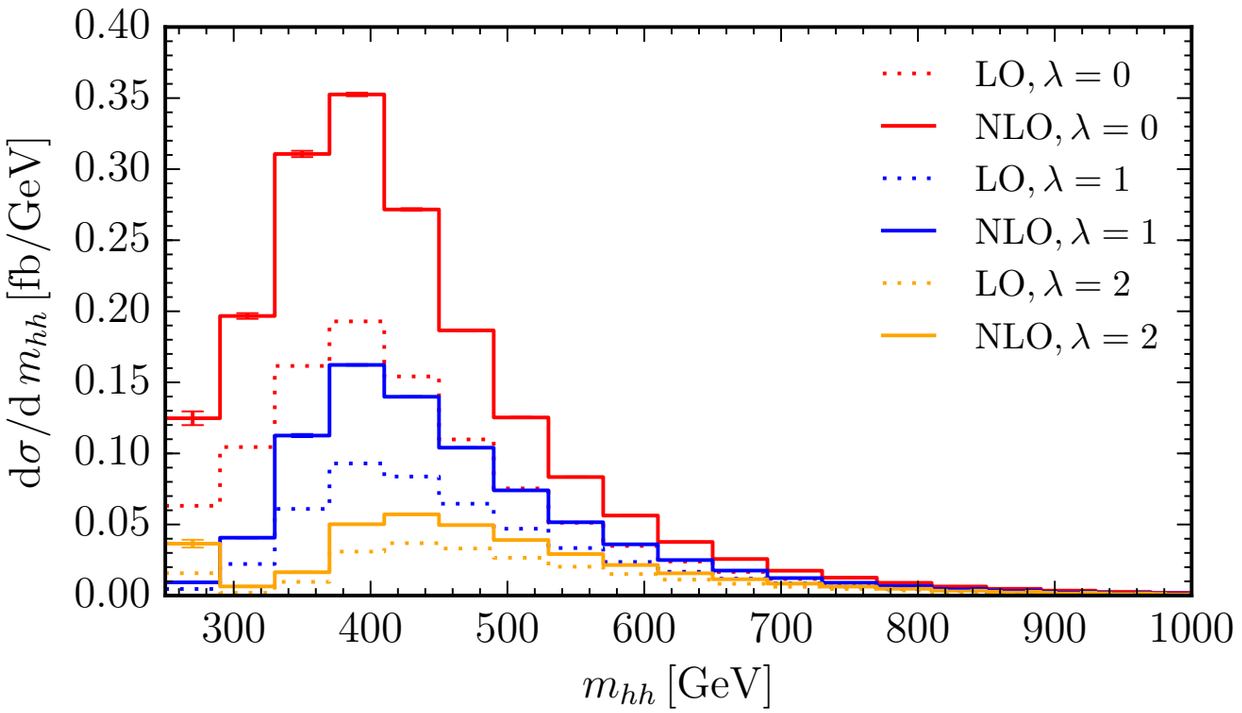
$V_{N\geq 4}$: thanks to J. Hoff

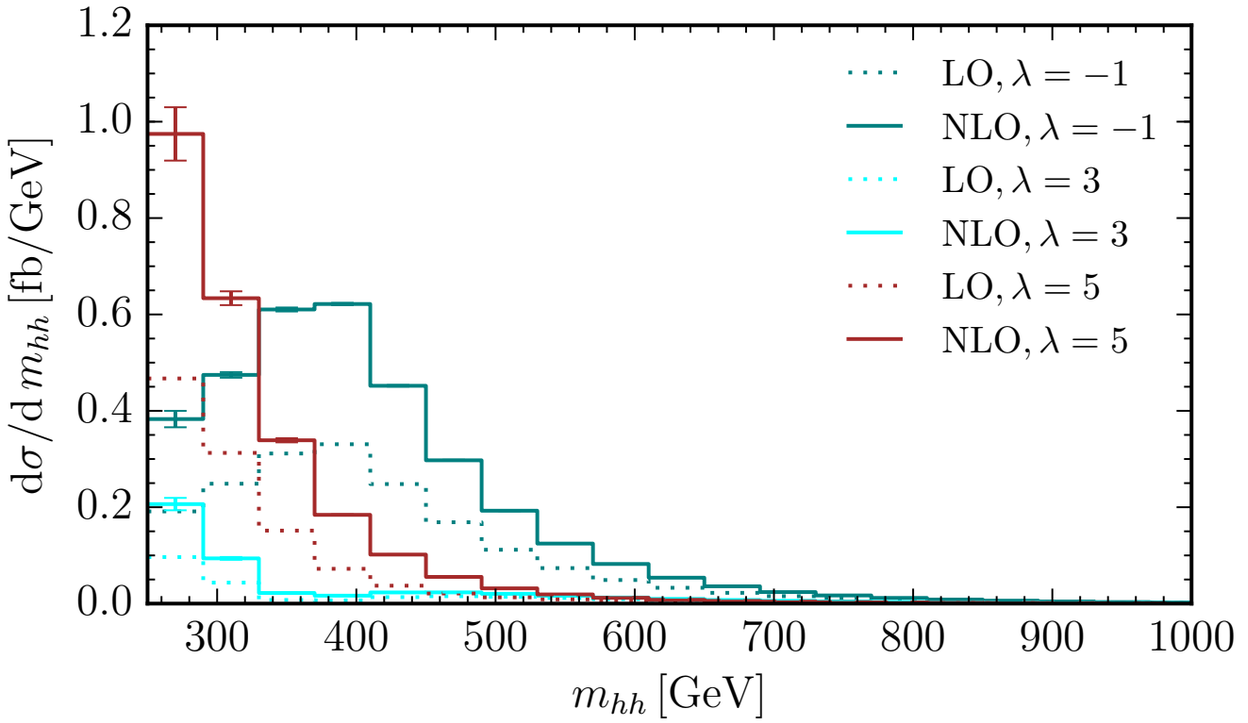
modified Higgs self-interactions



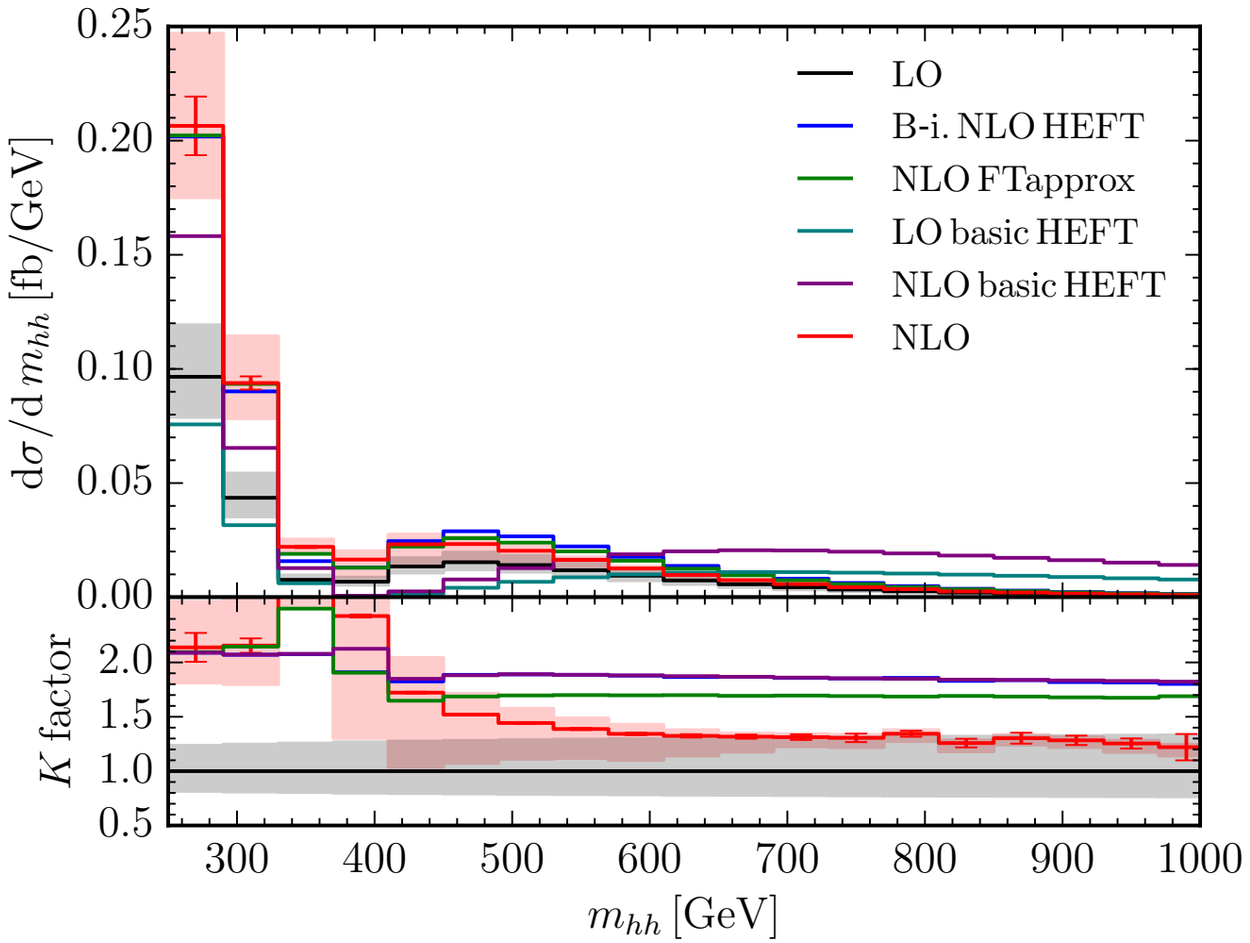


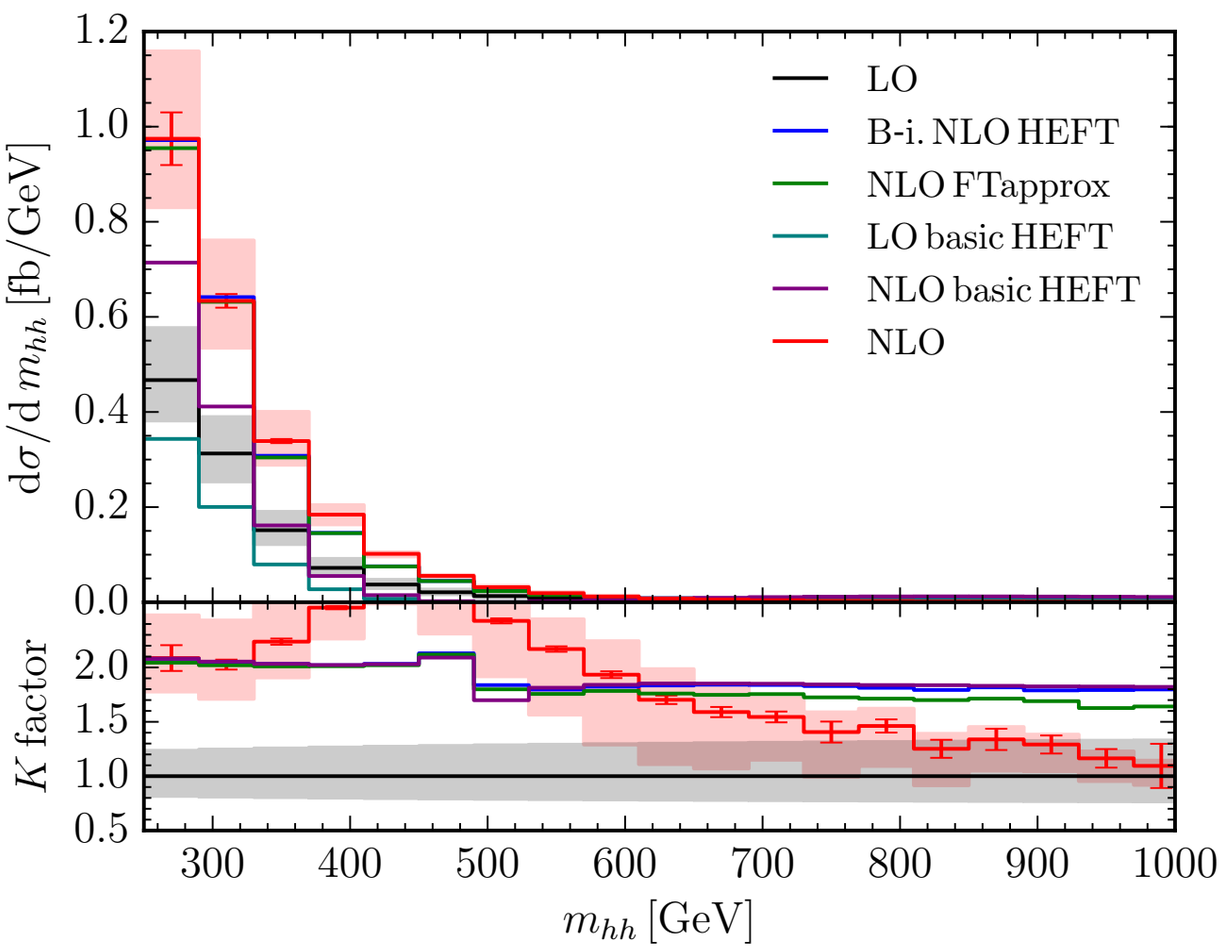
modified Higgs self-interactions

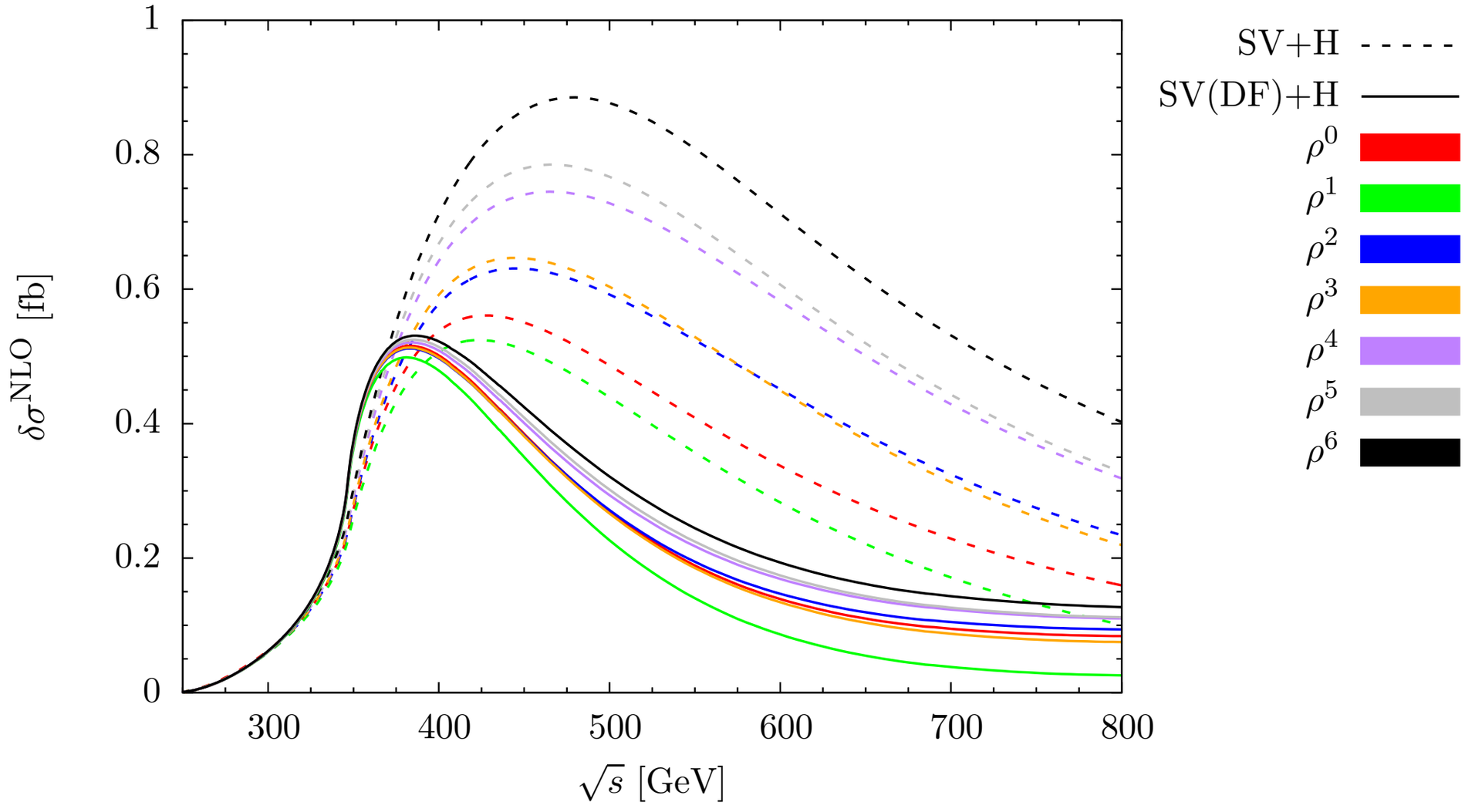




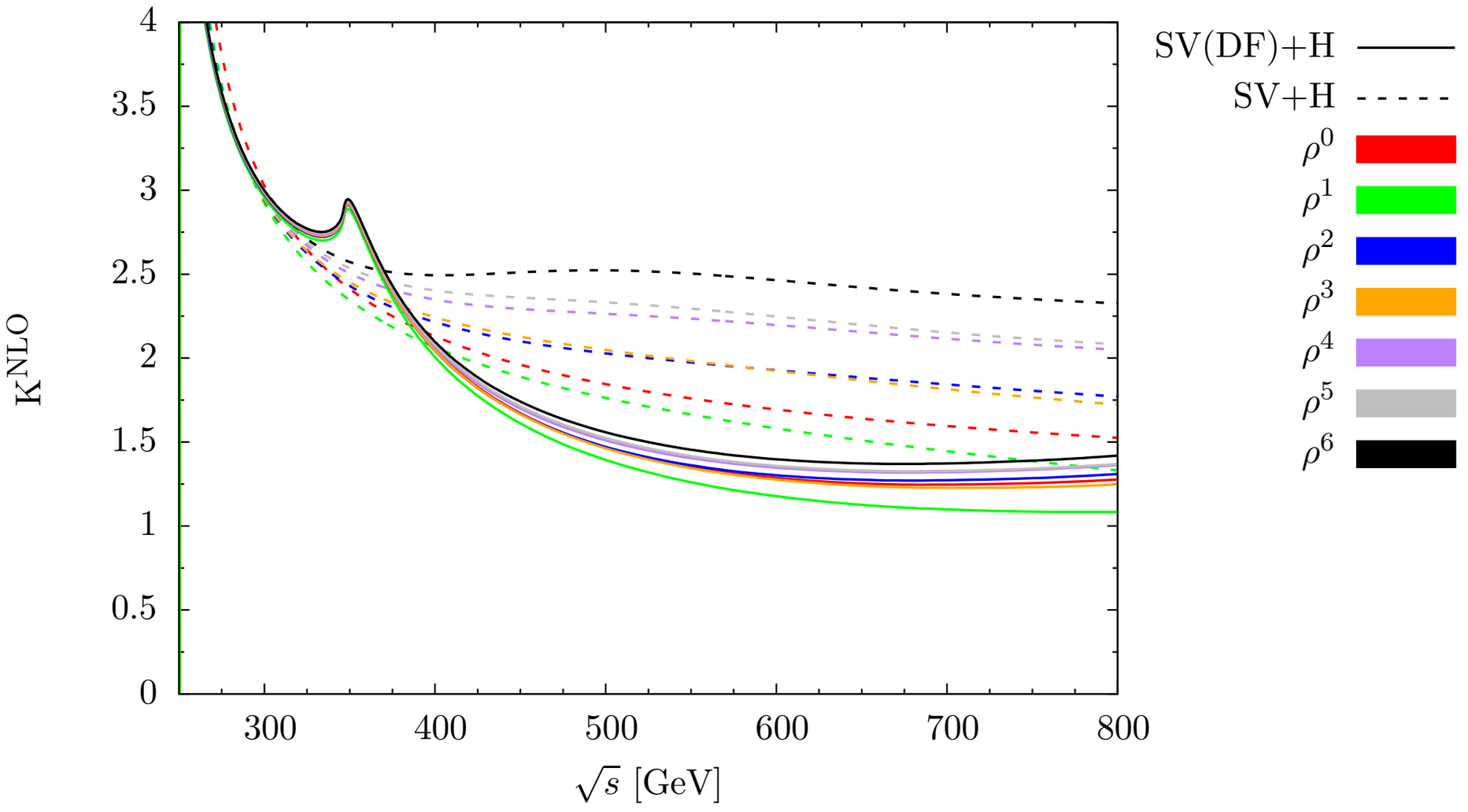
modified Higgs self-interactions





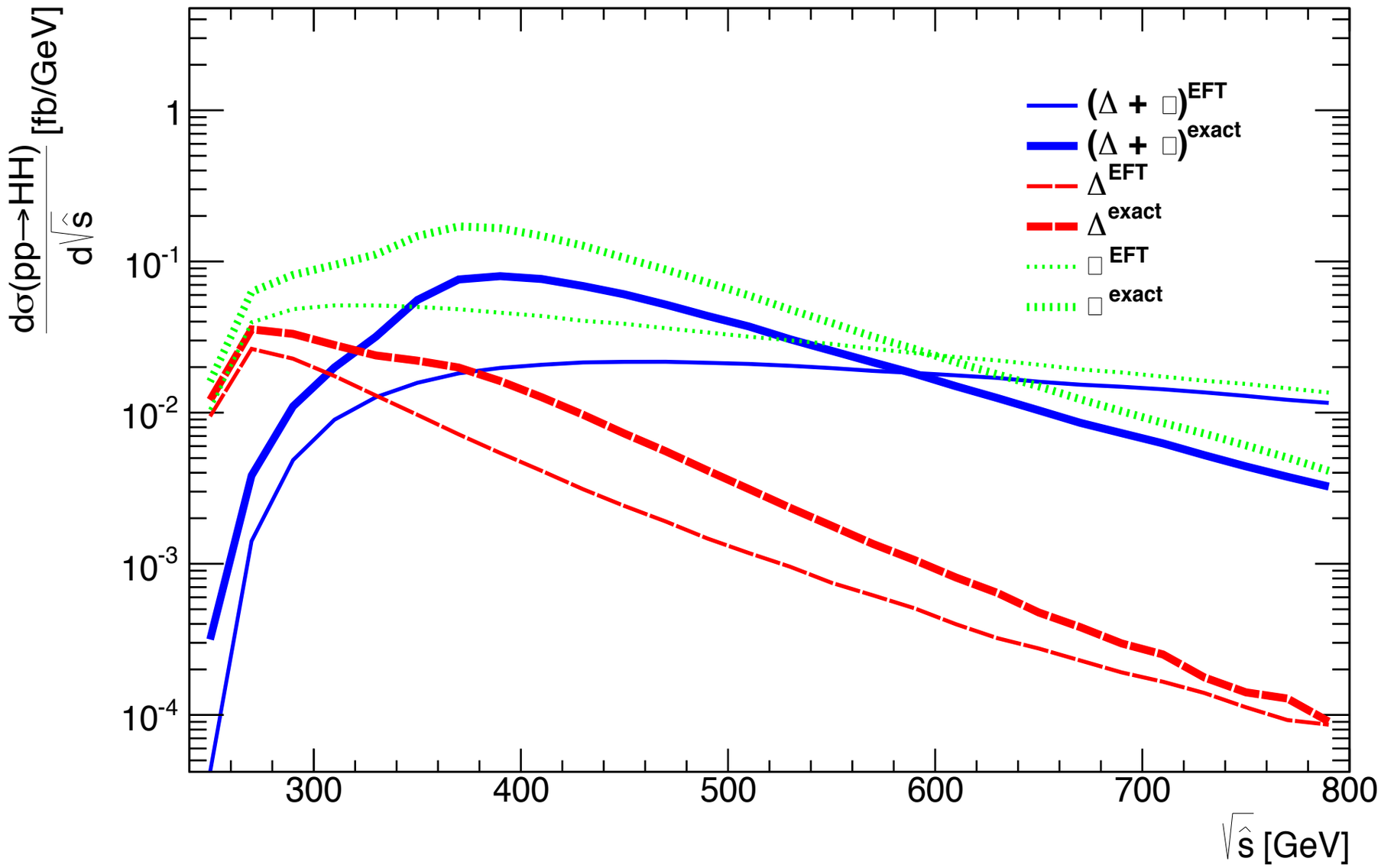


Grigo, Hoff, Steinhauser `15



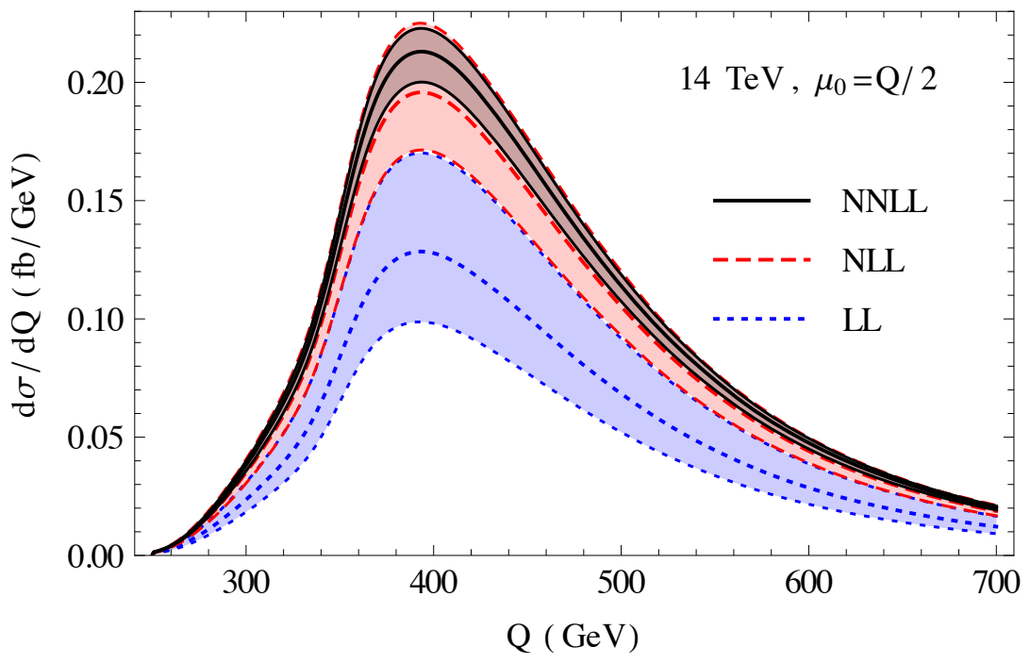
Grigo, Hoff, Steinhauser `15

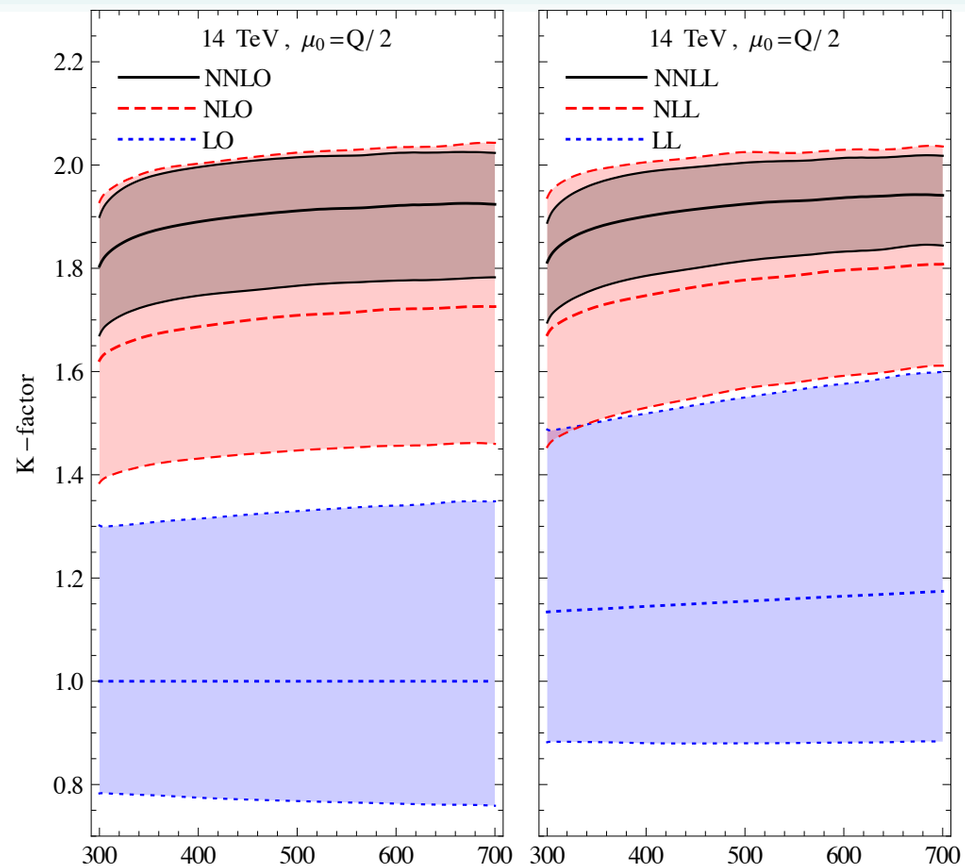
Differential Cross Section



Slawinska, van den Wollenberg,
van Eijk, Bentvelsen `14

NNLO and NNLL results

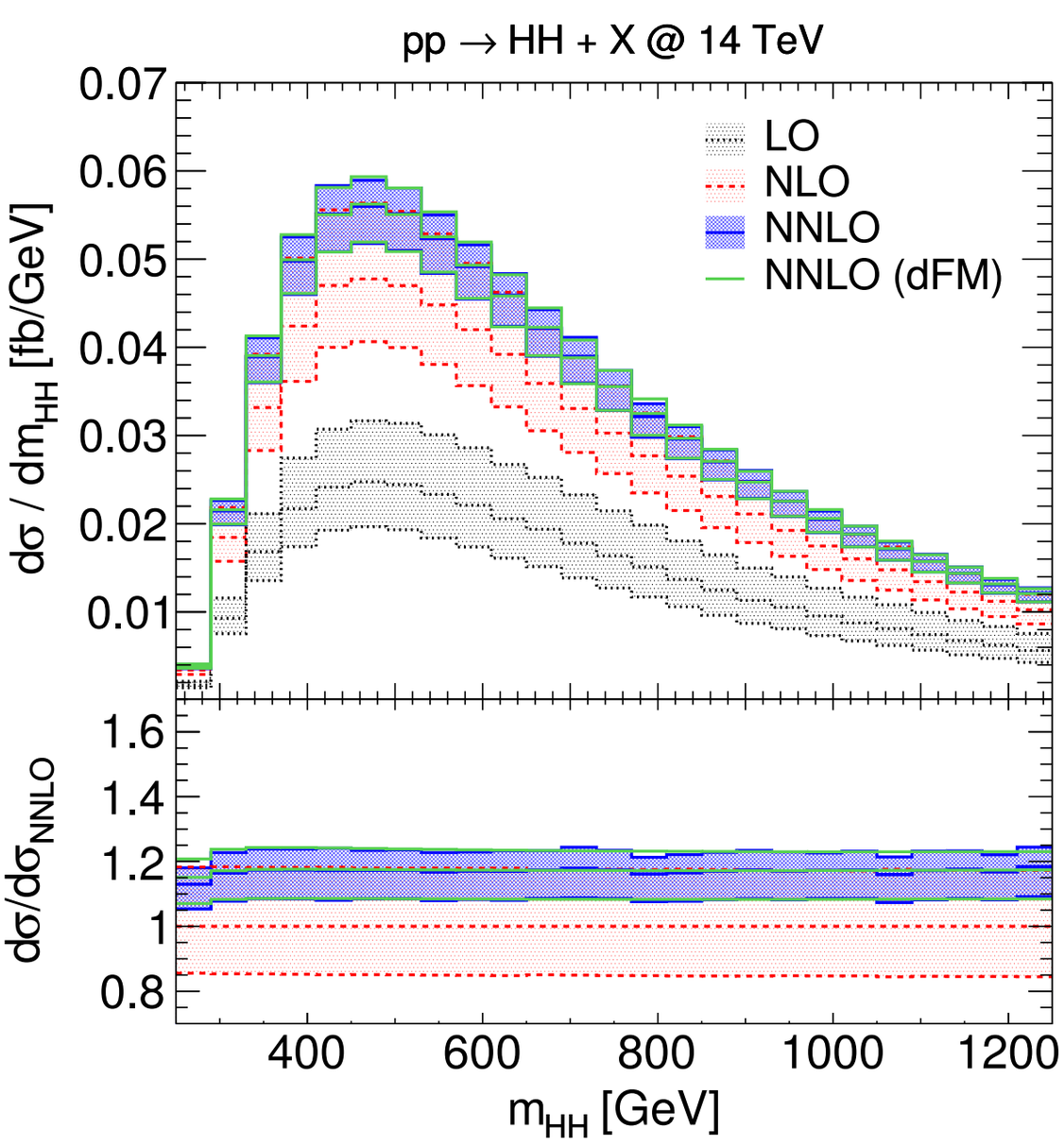


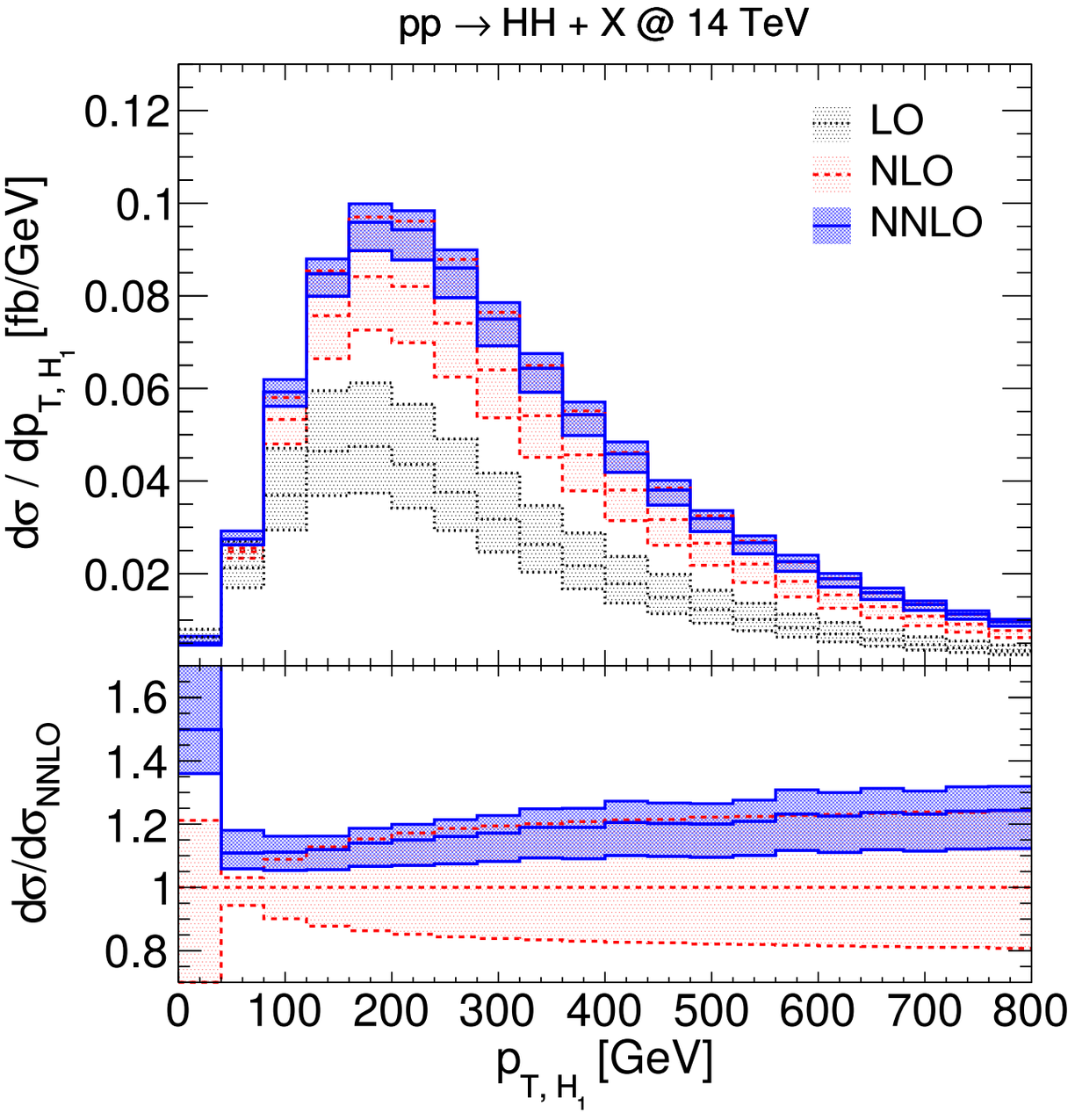


de Florian, Mazzitelli `15

$\mu_0 = Q$	NNLO (fb)	scale unc. (%)	NNLL (fb)	scale unc. (%)	PDF unc. (%)	PDF+α_S unc. (%)
8 TeV	9.92	$+9.3 - 10$	10.8	$+5.4 - 5.9$	$+5.6 - 6.0$	$+9.3 - 9.2$
13 TeV	34.3	$+8.3 - 8.9$	36.8	$+5.1 - 6.0$	$+4.0 - 4.3$	$+7.7 - 7.5$
14 TeV	40.9	$+8.2 - 8.8$	43.7	$+5.1 - 6.0$	$+3.8 - 4.0$	$+7.5 - 7.3$
33 TeV	247	$+7.1 - 7.4$	259	$+5.0 - 6.1$	$+2.2 - 2.8$	$+6.1 - 6.1$
100 TeV	1660	$+6.8 - 7.1$	1723	$+5.2 - 6.1$	$+2.1 - 3.0$	$+5.7 - 5.8$
$\mu_0 = Q/2$	NNLO (fb)	scale unc. (%)	NNLL (fb)	scale unc. (%)	PDF unc. (%)	PDF+α_S unc. (%)
8 TeV	10.8	$+5.7 - 8.5$	11.0	$+4.0 - 5.6$	$+5.8 - 6.1$	$+9.6 - 9.3$
13 TeV	37.2	$+5.5 - 7.6$	37.4	$+4.2 - 5.8$	$+4.1 - 4.3$	$+7.8 - 7.6$
14 TeV	44.2	$+5.5 - 7.6$	44.5	$+4.2 - 5.9$	$+3.9 - 4.1$	$+7.6 - 7.4$
33 TeV	264	$+5.3 - 6.6$	265	$+4.6 - 6.1$	$+2.4 - 2.7$	$+6.3 - 6.1$
100 TeV	1760	$+5.3 - 6.7$	1762	$+4.9 - 6.4$	$+2.2 - 3.1$	$+6.2 - 7.0$

NNLO HEFT





de Florian, Grazzini, Hanga, Kallweit,
Lindert, Maierhöfer, Mazzitelli, Rathlev 16