Precise predictions for double-Higgs production via VBF

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based on arXiv:2005.13341 and arXiv:2005.11334

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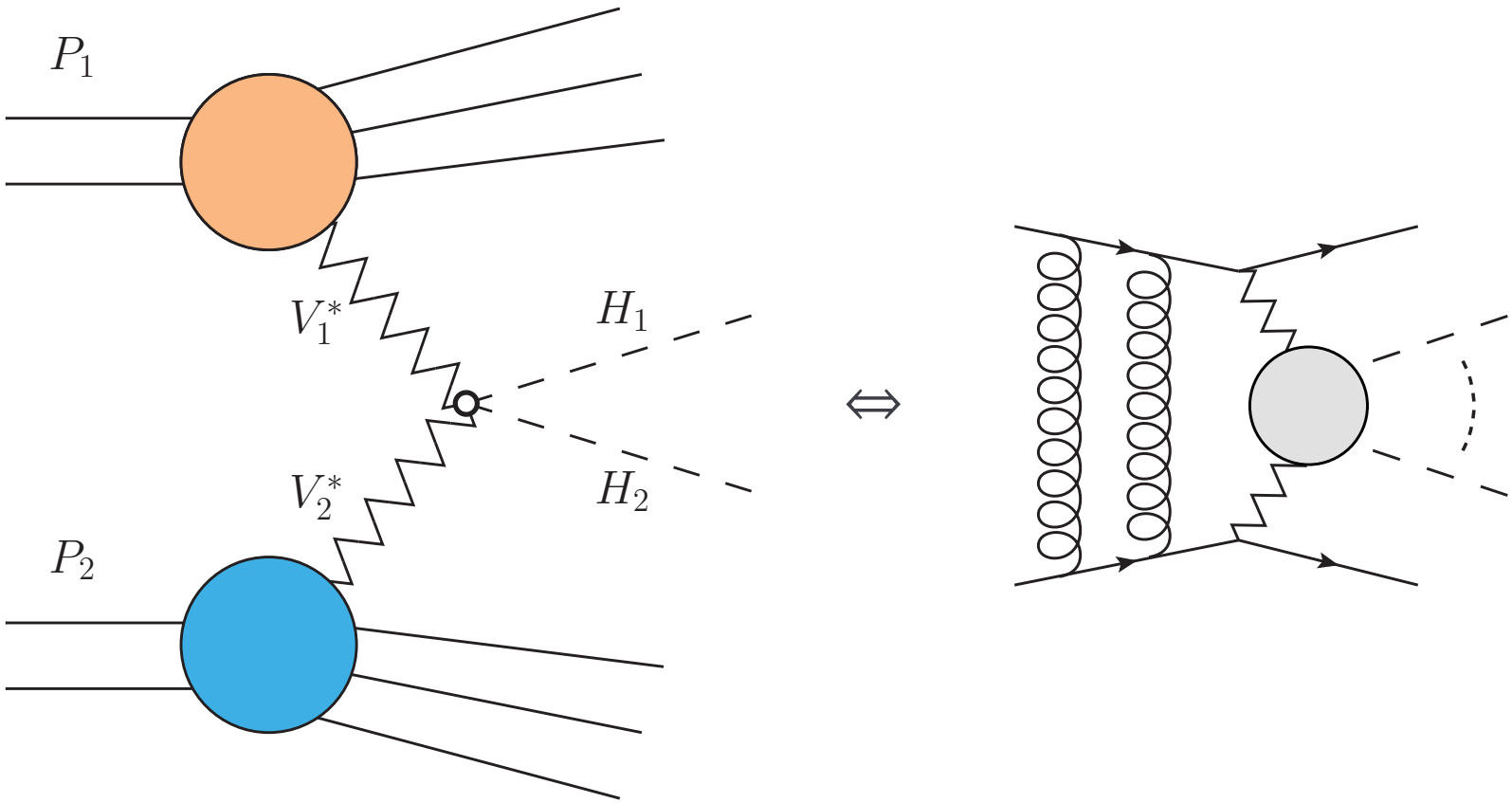
Double Higgs production in VBF

- Typically computed in structure function approximation, where interference between quark lines is neglected.
- Exact at NLO, but neglects suppressed contributions starting from NNLO.



Non-factorisable corrections in single-Higgs VBF

- Leading non-factorisable corrections were recently computed in eikonal approximation

  [Liu, Melnikov, Penin PRL 123 (2019) 12]

- Retains contributions that not suppressed by ratio $p_{t,j}/\sqrt{s}$
- Single Higgs non-factorisable corrections can be expressed as a function of LO cross section

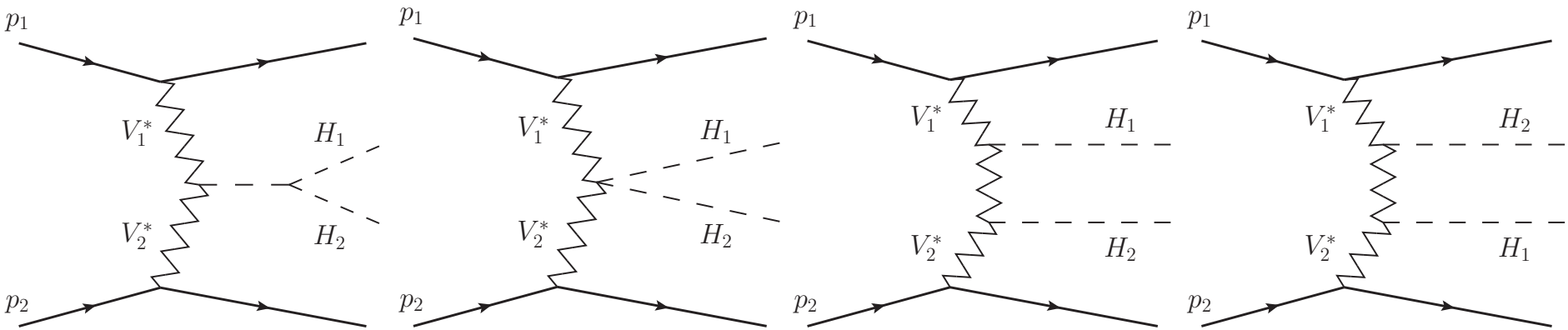
$$d\sigma^{\text{NNLO}}_{\text{non-fact}} = \left(\frac{N_c^2-1}{4N_c^2}\right)\alpha_s^2\chi_{\text{nf}}(\vec{q}_1,\vec{q}_2)d\sigma_{\text{LO}}$$

- π^2-enhancement can partially compensate colour suppression, correction to fiducial cross section $\sim 0.4\%$

Non-factorisable corrections in VBF di-Higgs production

- Calculation somewhat more involved due to the presence of box-like topologies with intermediate vector bosons
- Compute NNLO contribution to each diagram separately

$$d\sigma_{HH}^{\mathrm{LO}} = \mathrm{d}\sigma_{TT}^{\mathrm{LO}} + \mathrm{d}\sigma_{BB}^{\mathrm{LO}} + \mathrm{d}\sigma_{TB}^{\mathrm{LO}}$$



Non-factorisable corrections in VBF di-Higgs production

- LO cross section for VBF HH is result of delicate cancellation between three contributions $\mathrm{d}\sigma^{\mathrm{LO}}_{TT}$, $\mathrm{d}\sigma^{\mathrm{LO}}_{BB}$, $\mathrm{d}\sigma^{\mathrm{LO}}_{TB}$
- These are affected differently by QCD corrections, partially spoiling this cancellation

$$\mathrm{d}\sigma^{\mathrm{NNLO}}_{HH,\mathrm{nf}} \sim \left(\frac{N_c^2-1}{4N_c^2}\right)\alpha_s^2\left[\left(1-\frac{\pi^2}{3}\right)\left(\mathrm{d}\sigma^{\mathrm{LO}}_{TT}+\mathrm{d}\sigma^{\mathrm{LO}}_{TB}\right)+\left(\frac{5}{4}-\frac{\pi^2}{3}\right)\mathrm{d}\sigma^{\mathrm{LO}}_{BB}\right]$$

- Non-factorisable QCD corrections can have large impact on di-Higgs production.

$\lambda = M_V$	σ_{TT}	σ_{BB}	σ_{TB}	Σ
Born	10.393 fb	14.172 fb	−23.904 fb	0.662 fb
1-loop NF	0.339%	0.518%	0.399%	2.03%
2-loop NF	−0.667%	−0.658%	−0.666%	−0.50%
Full NF	−0.327%	−0.139%	−0.267%	1.52%

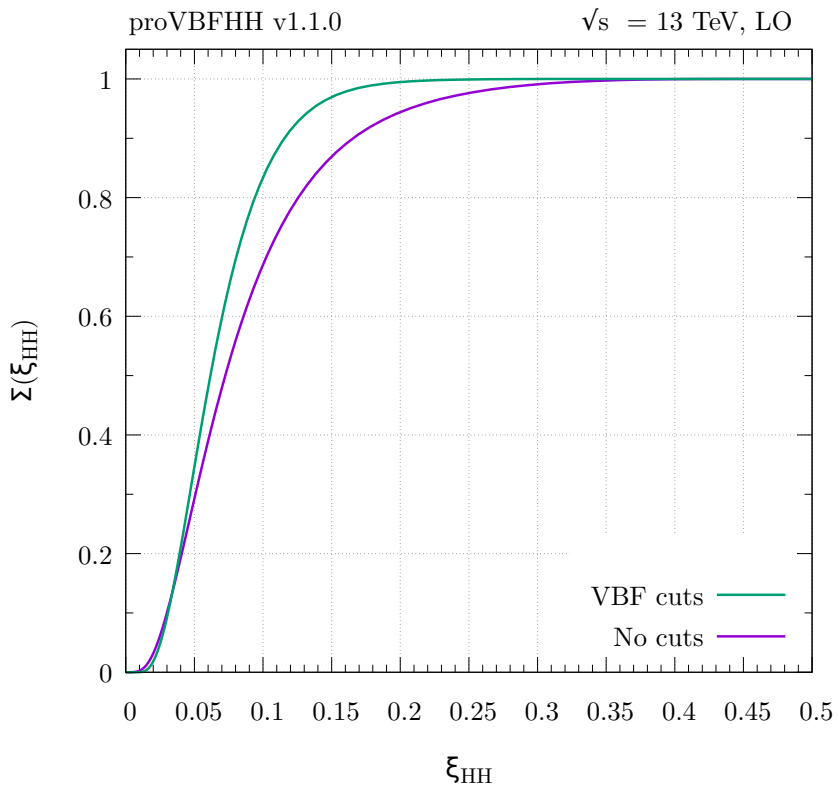
Validity of eikonal approximation

- Eikonal approximation expected to be valid when all transverse scales are small compared to c.o.m. energy.

$$\xi_{HH} = \max\{p_{t,j_1}, t, u\}/\sqrt{s}.$$

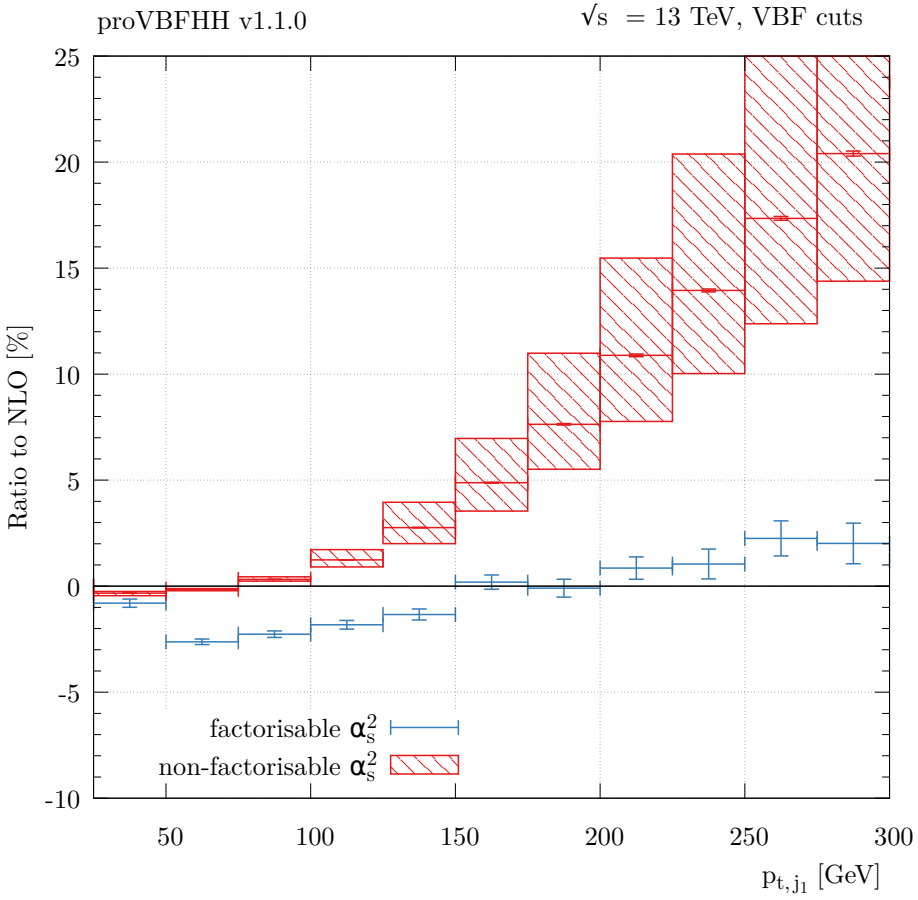
- Without cuts, normalized cross section integrated in ξ contained to $\xi_{HH} \lesssim 0.25$
- Approximation remains valid up to high transverse momentum values of the Higgs pair

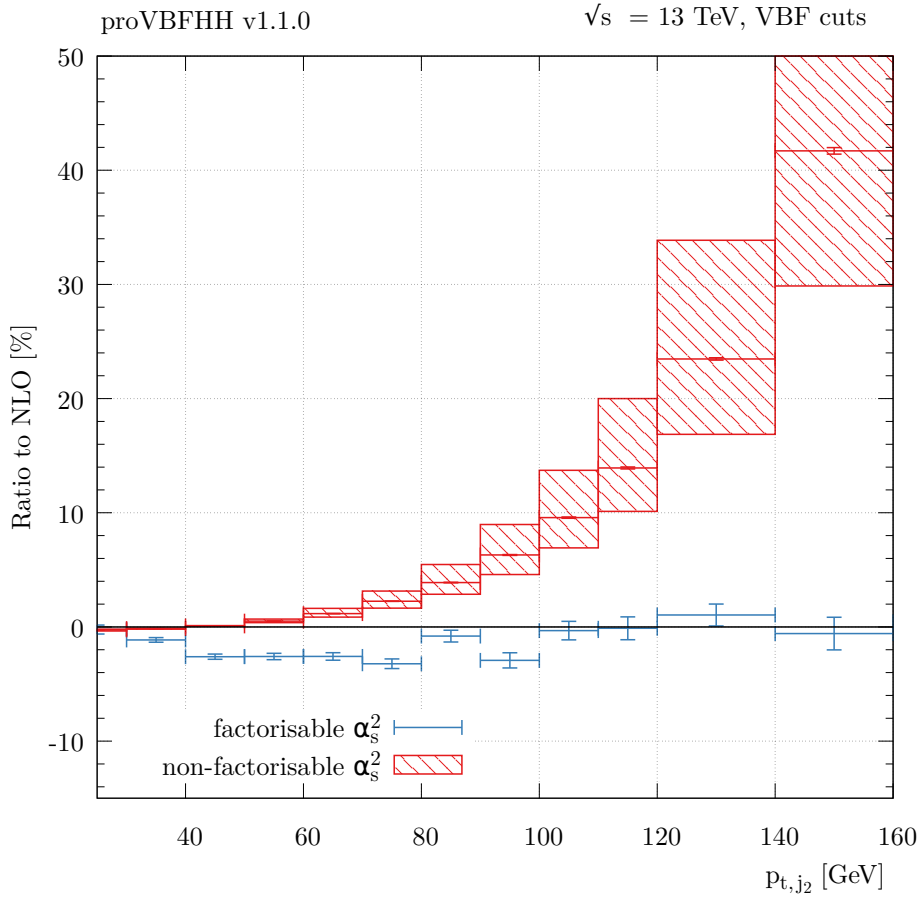
$$\Sigma(\xi) = \frac{1}{\sigma}\int_0^{\xi} \frac{d\sigma}{d\xi'} d\xi'$$



Fiducial results

Setup: 13 TeV LHC, same cuts as Mathieu Pellen





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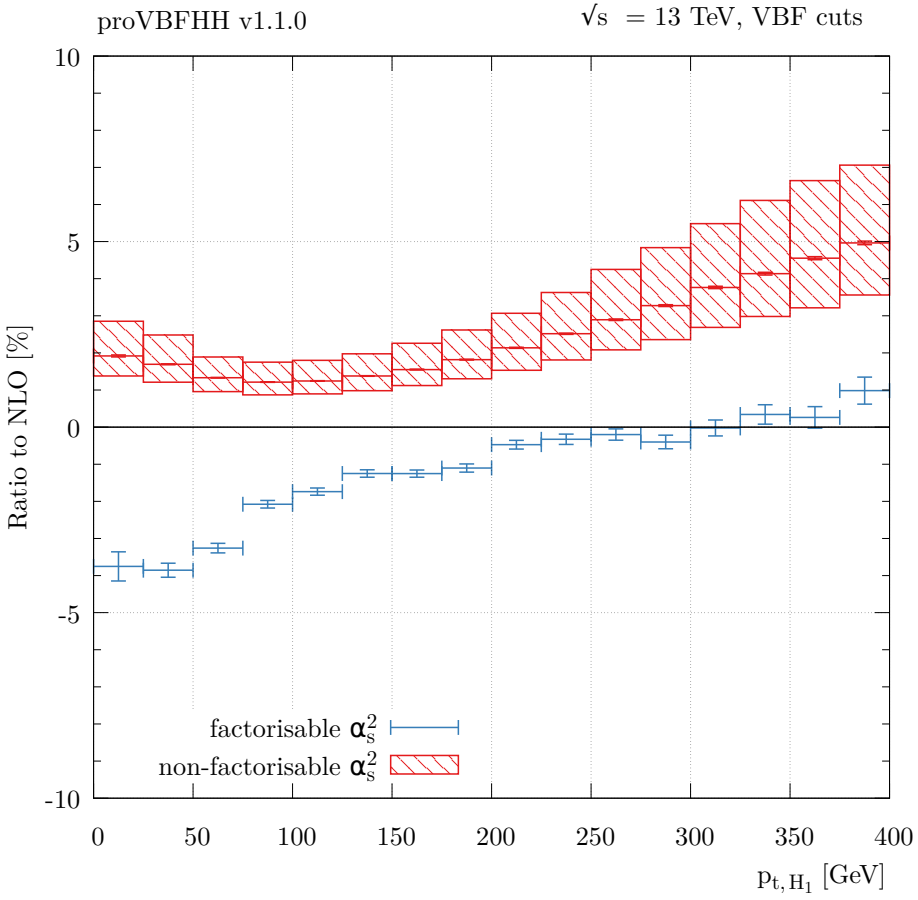

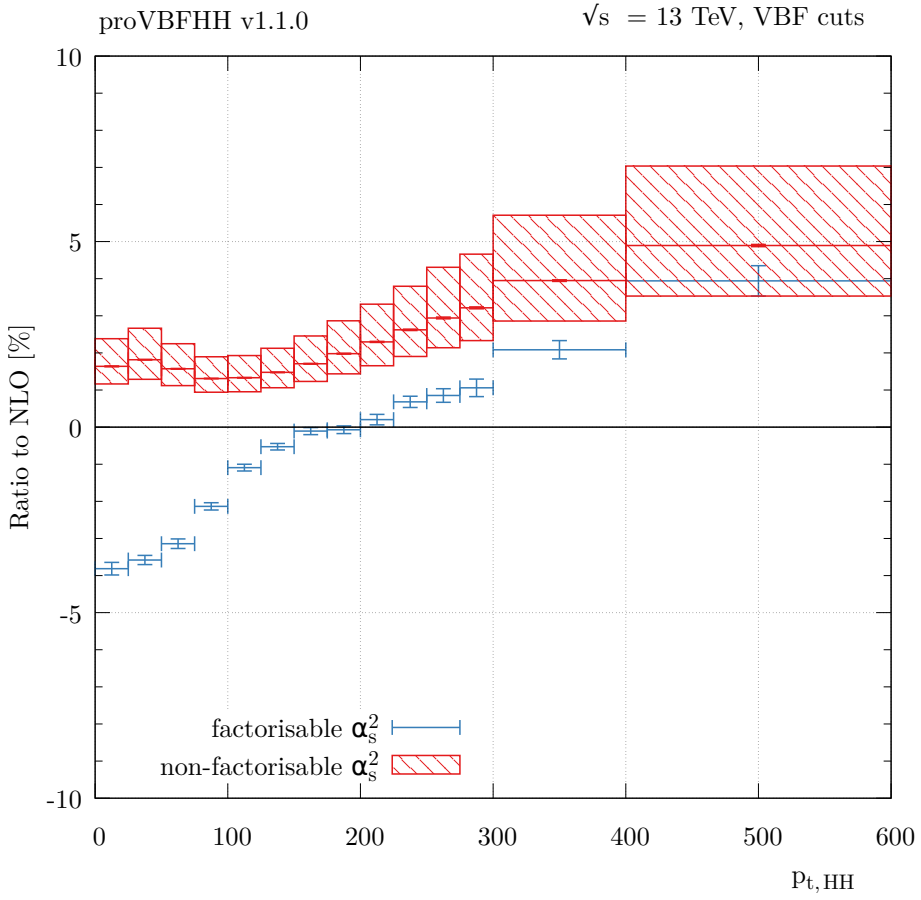

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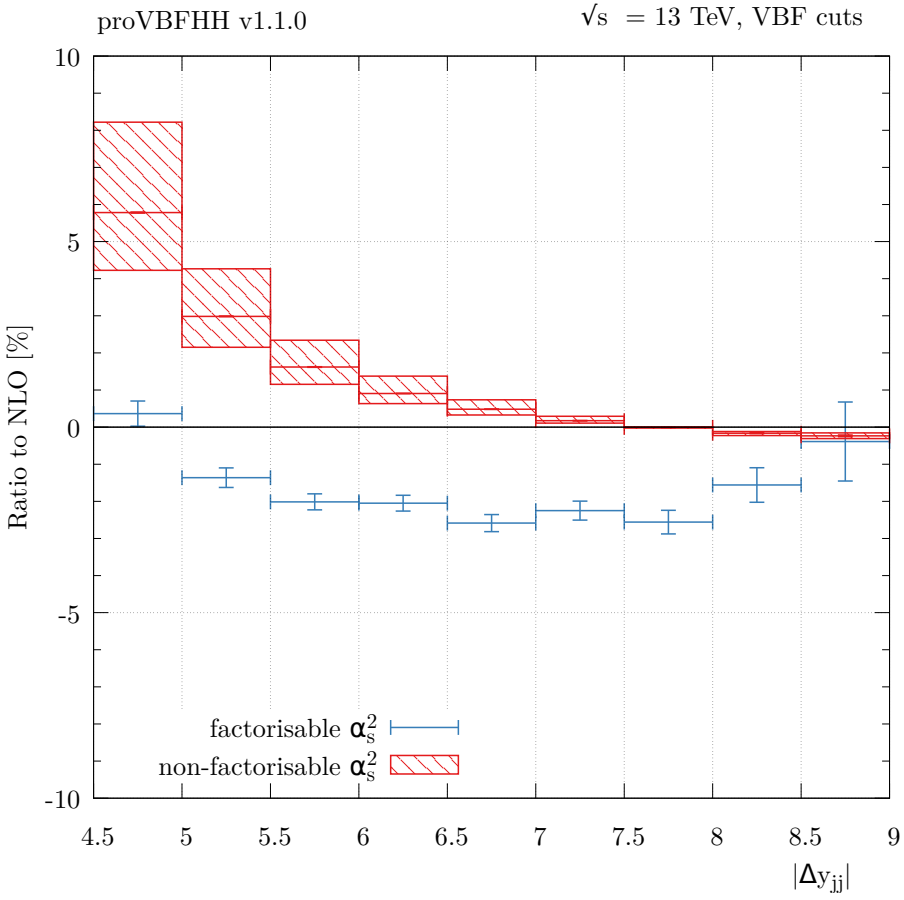
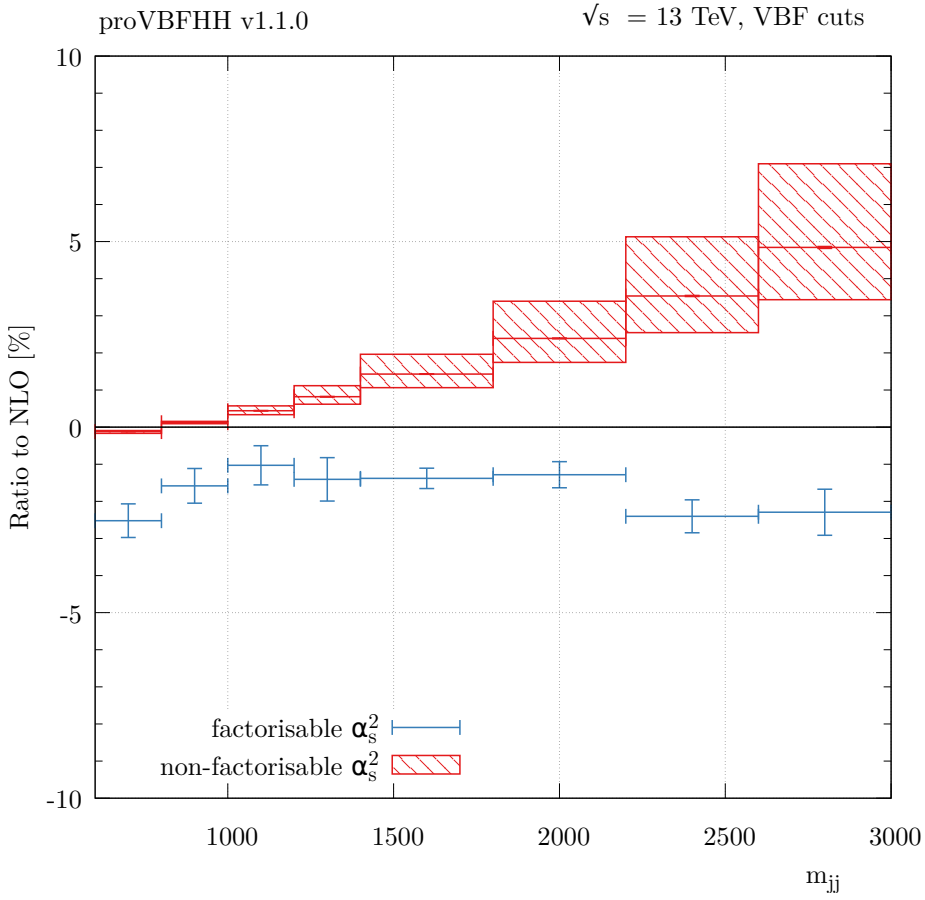
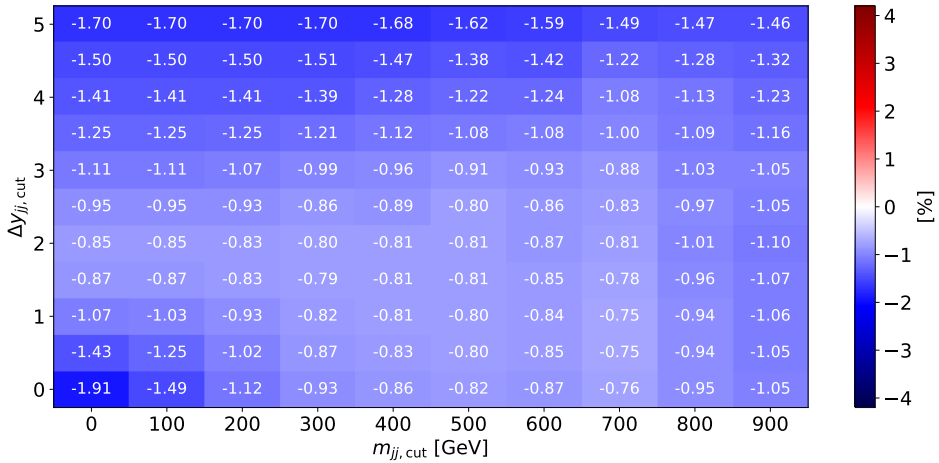


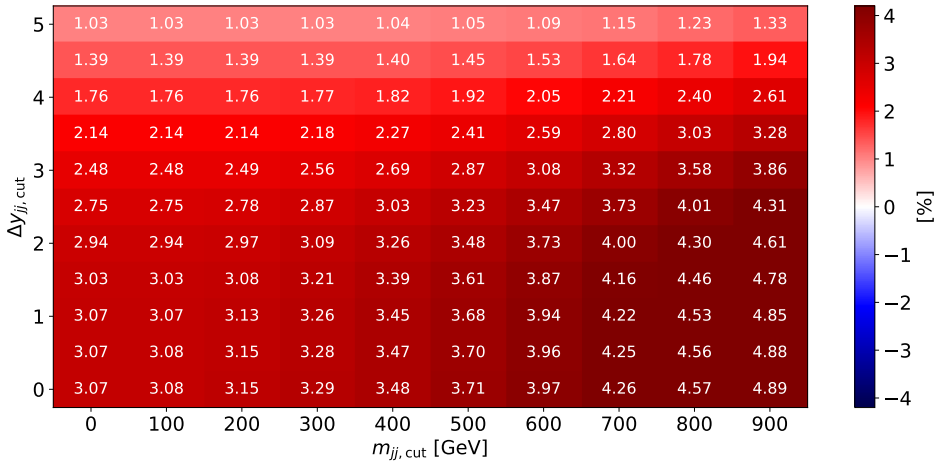


Impact of selection cuts

Ratio of the factorisable and non-factorisable NNLO corrections relative to LO as a function of the m_{jj} and Δy_{jj} selection cut.



(a) Factorisable corrections



(b) Non-factorisable corrections

Conclusions

- Calculation of NNLO non-factorisable QCD corrections in the eikonal approximation extended to double Higgs production.
- Non-factorisable corrections enhanced in di-Higgs case due to delicate cancellation of the various Born diagrams, which is spoiled by the radiative corrections.
- NF corrections are of same order of magnitude or even dominant compared to the NNLO factorisable ones.
- These effects have been implemented in `proVBFH` 1.2.0 and `proVBFHH` 1.1.0.

code available at: *provbfh.hepforge.org*