$gg \to WW$ at higher orders in the high-mass region for signal-background interference

M. Bonvini, FC, K. Melnikov, S. Forte, G. Ridolfi

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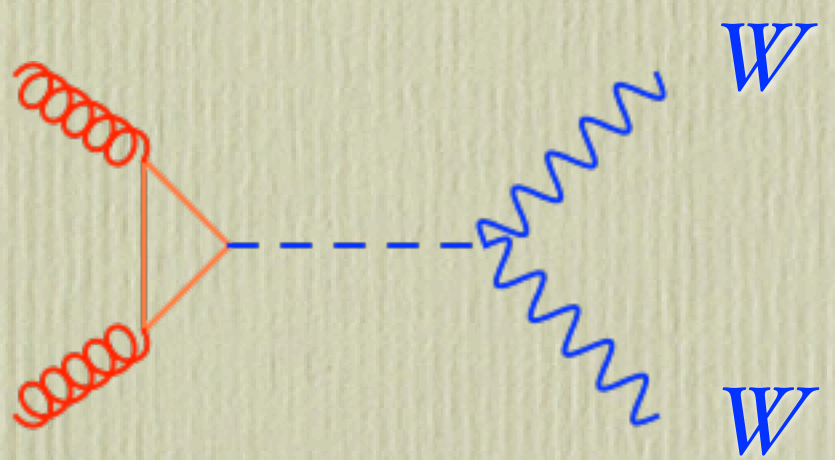
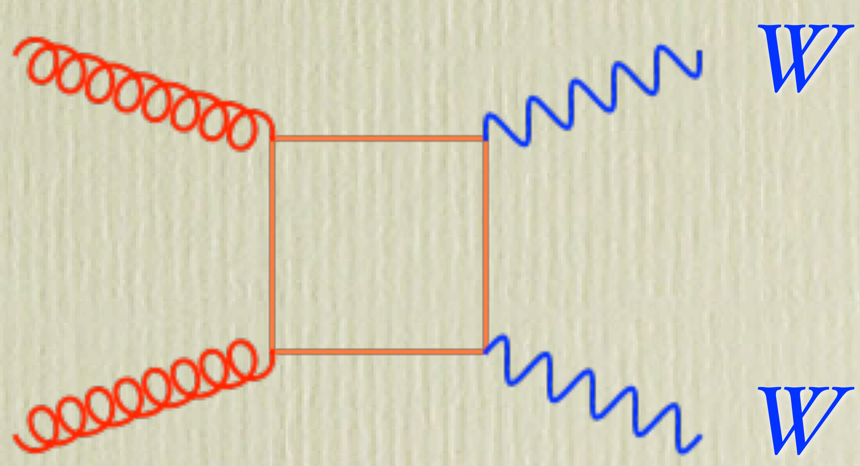
Interference in perturbative QCD

$$\sigma_{Hi} \equiv \sigma_{tot} - \sigma_{bg}$$

LO



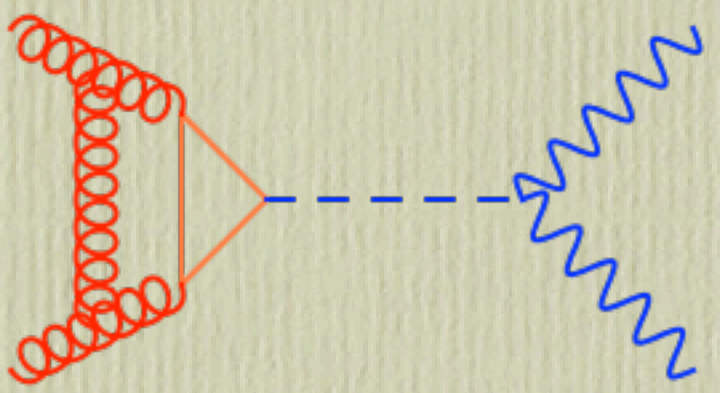


For a 600 GeV Higgs: $\sigma_{Hi}/\sigma_H \sim 1.1 - 1.3$

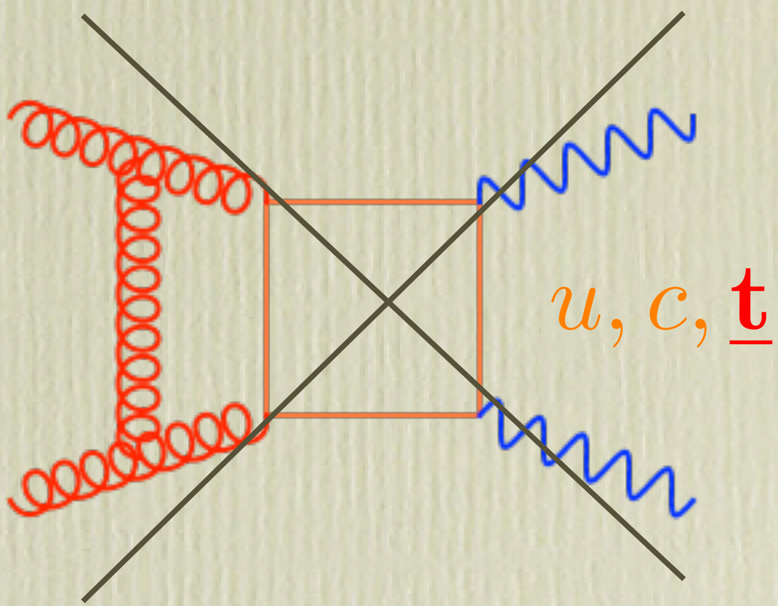
(After Higgs-selection cuts: effect reduced, but still there)

Interference in perturbative QCD

NLO



$\sigma_H^{\mathrm{NLO}} / \sigma_H^{\mathrm{LO}} \sim 2$

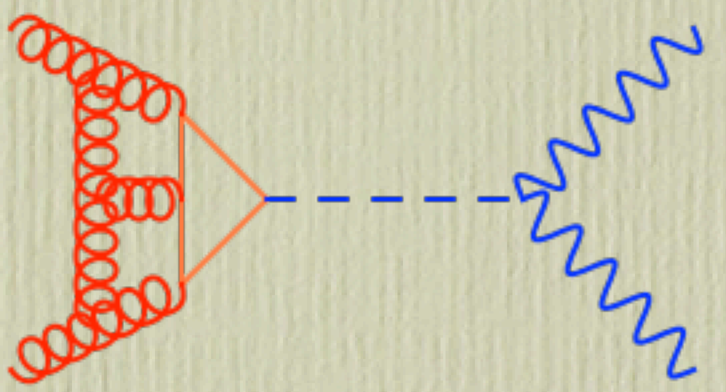


Unknown!

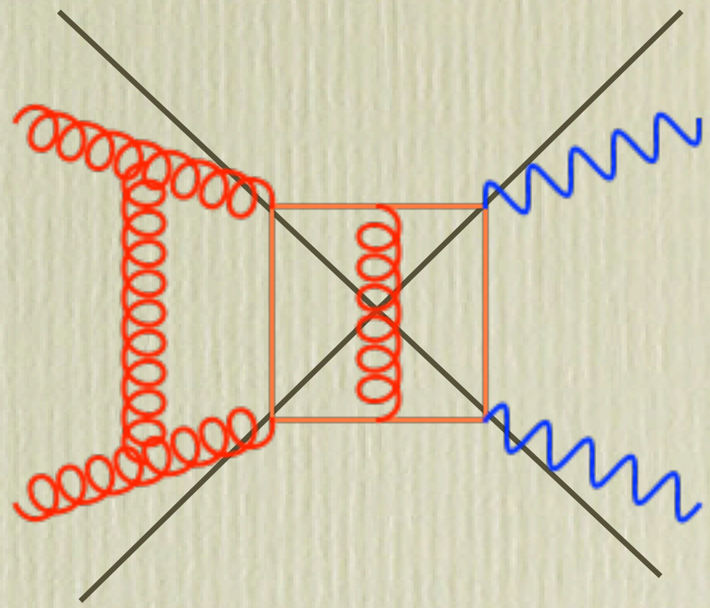
For the background,
already NLO is (far) beyond our technical reach

Interference in perturbative QCD

NNLO



$\sigma_H^{\mathrm{NNLO}}/\sigma_H^{\mathrm{NLO}} \sim 1.2$



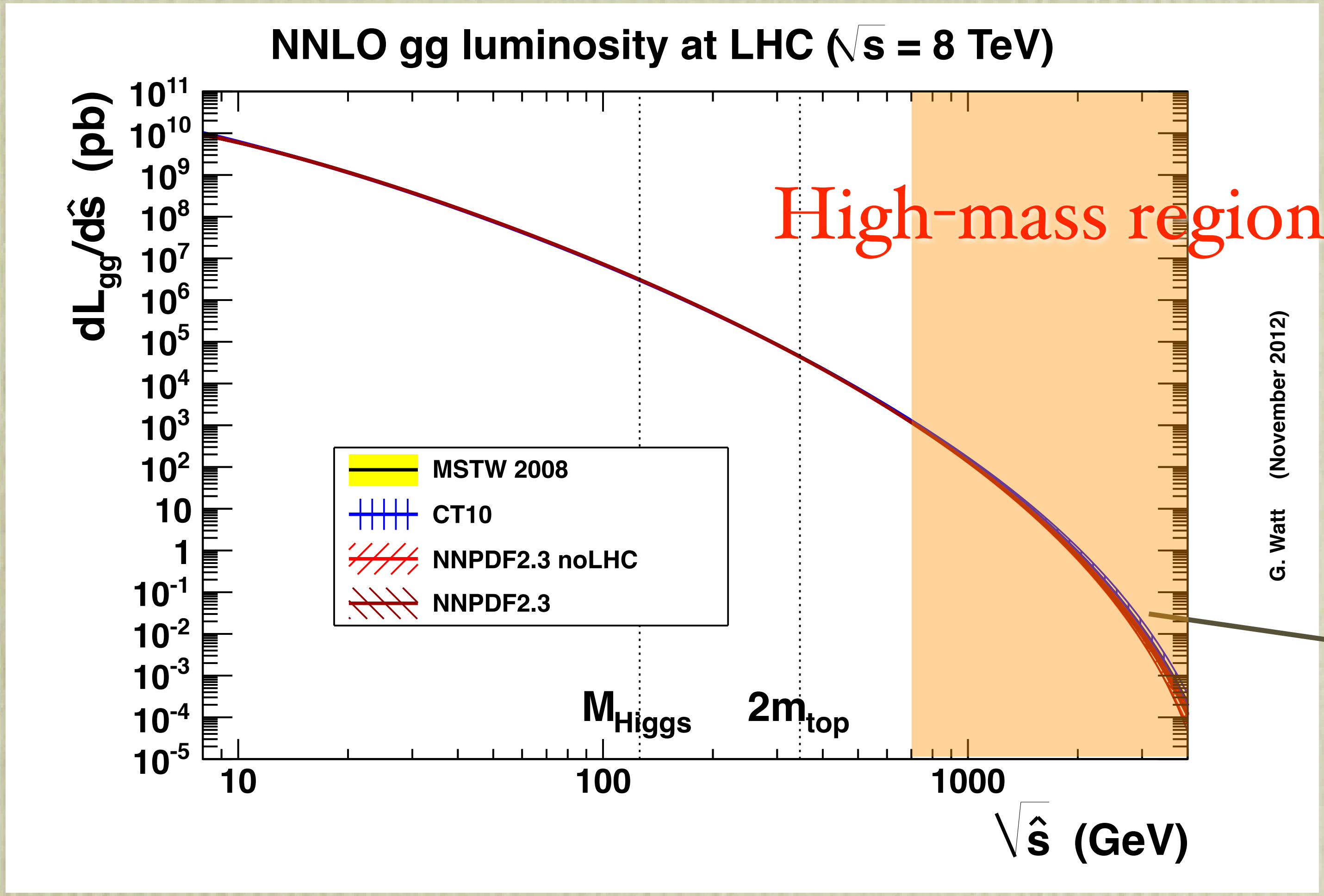
out of question

- Large signal K-factor $\longrightarrow$ LO analysis may be unreliable
- Unknown K-factor for the background

Can we estimate corrections to the background?

(N)NLO in the soft approximation

We are interested in the production of a high invariant mass system in the gluon-gluon channel



$$\sigma = \int_\tau^1 \frac{dz}{z} \mathcal{L}\left(\frac{\tau}{z}\right) \hat{\sigma}(z)$$

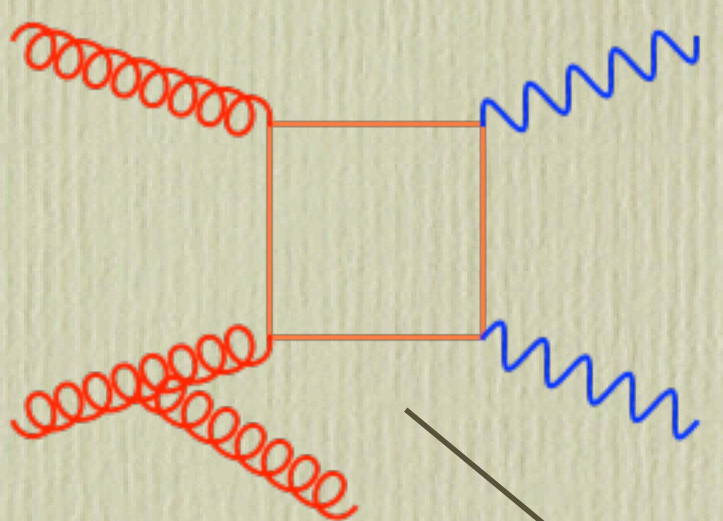
$$\tau = Q^2/s$$

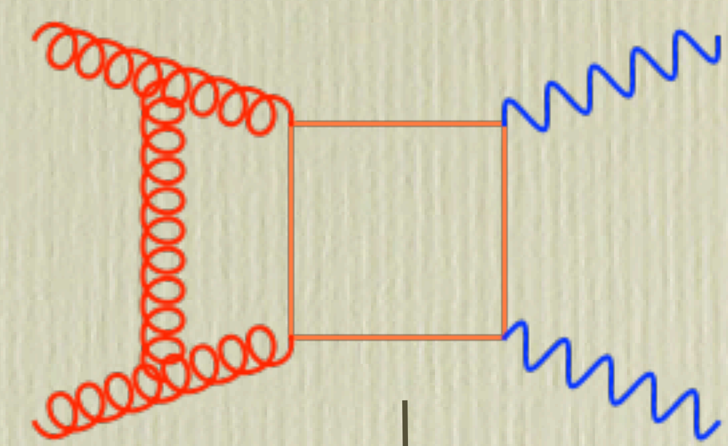
Rapidly falling gluon PDF!

The cross section is dominated by the soft $z \sim 1$ region

(N)NLO in the soft approximation

Enhanced terms: emission of soft gluons





$$\hat{\sigma} = \sigma_0 + \sigma_0 \frac{\alpha_s}{2\pi}\left(8C_A\left[\frac{\ln 1 - z}{1 - z}\right]_+ + c_1\delta(1 - z) + \text{reg}\right) + \text{h.o.}$$

Bulk of the result, universal

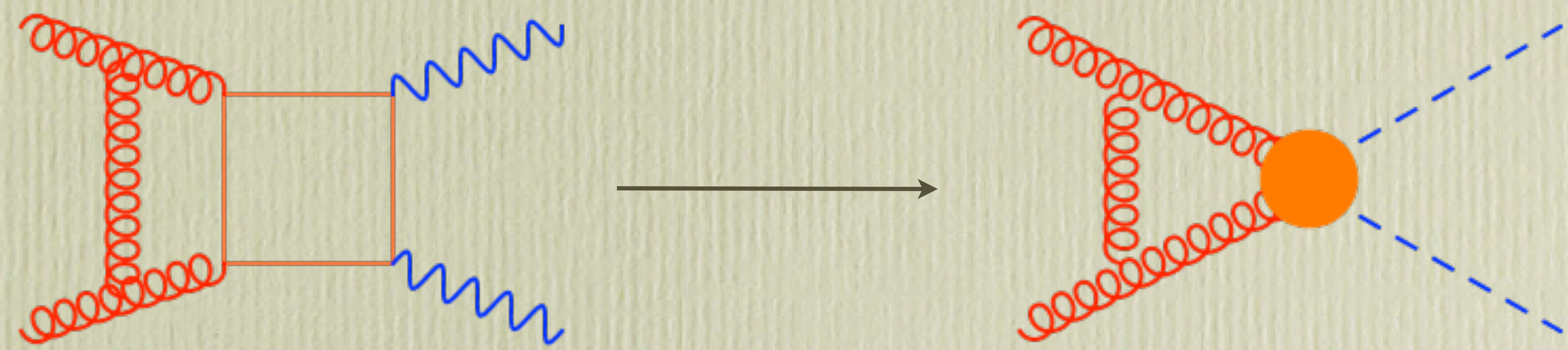
Compute as Stefano discussed this morning

Assign uncertainty to the approximation (reg. terms)

Process-dependent

Process-dependent part: rough estimate

A rough estimate: $m_W^2 \ll Q^2 \ll m_t^2 \sim m_b^2$



In this limit, the result can be obtained via the equivalence theorem and an effective Lagrangian

We take the result in this limit as reference value $\bar{c}_{1,2}$ and compute its impact by varying $-5\ \bar{c}_{1,2} < c_{1,2} < 5\ \bar{c}_{1,2}$

Results for the interference:

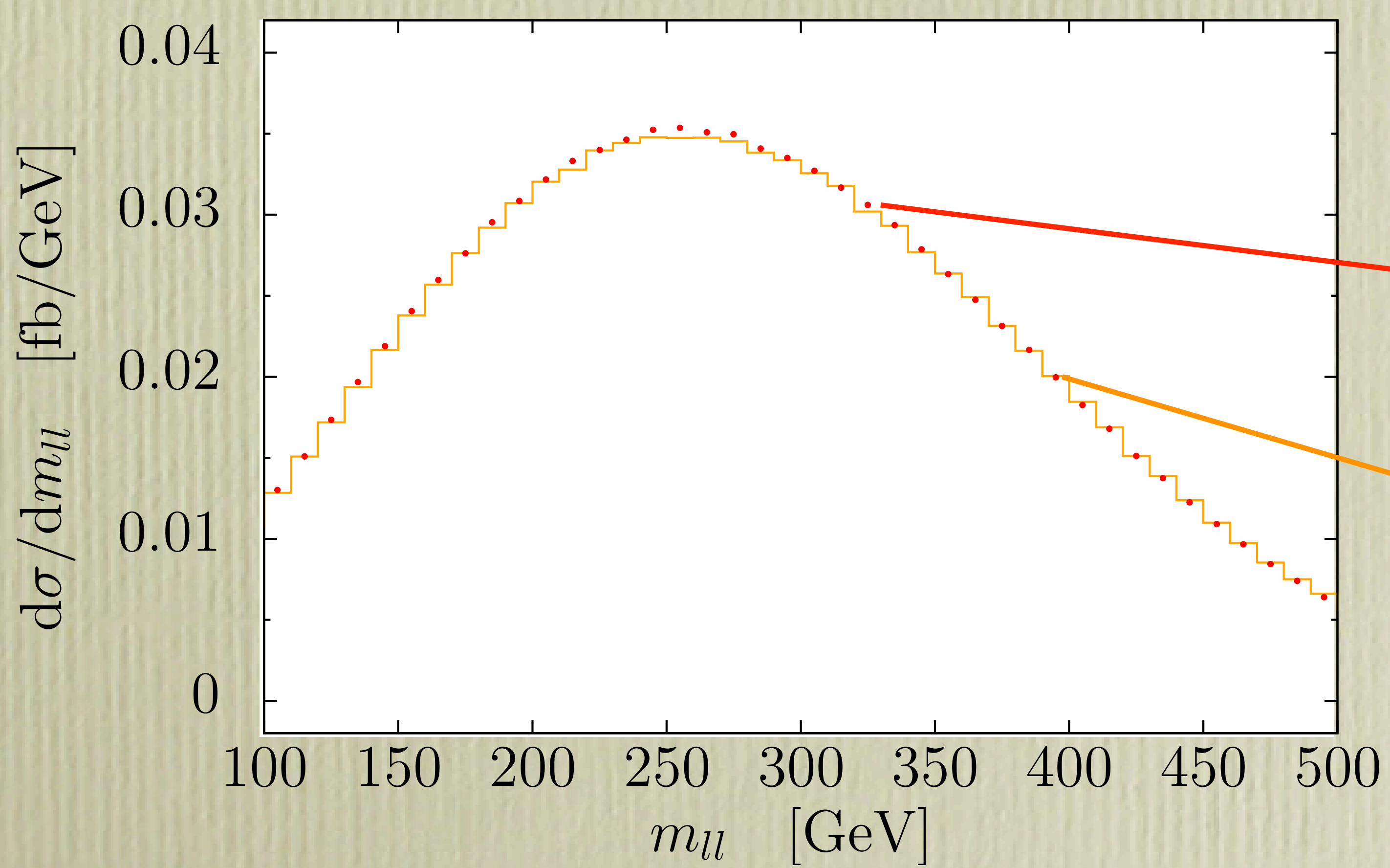
- Construct our improved soft - collinear approximation for $\sigma_{Hi} \equiv \sigma_{tot} - \sigma_{bg}$
- For the Higgs, use the known (N)NLO delta-function coefficients
- For the background, use the reference value in the limit $m_W^2 \ll Q^2 \ll m_t^2 \sim m_b^2$
- To evaluate the uncertainty of the approximation
  - subleading terms in the soft approximation
  - vary $-5\ \bar{c}_{1,2} < c_{1,2} < 5\ \bar{c}_{1,2}$ for the background
  - sum the two uncertainties in quadratures

Validation: Higgs-only signal

Inclusive K-factors

	$\sqrt{s} = 8$ TeV		$\sqrt{s} = 13$ TeV	
	NLO	NNLO	NLO	NNLO
exact	2.150	2.78	2.074	2.67
soft-collinear	2.19±5	2.82±12	2.13±6	2.73±12

Differential distributions



NLO(MCFM) x K-factor

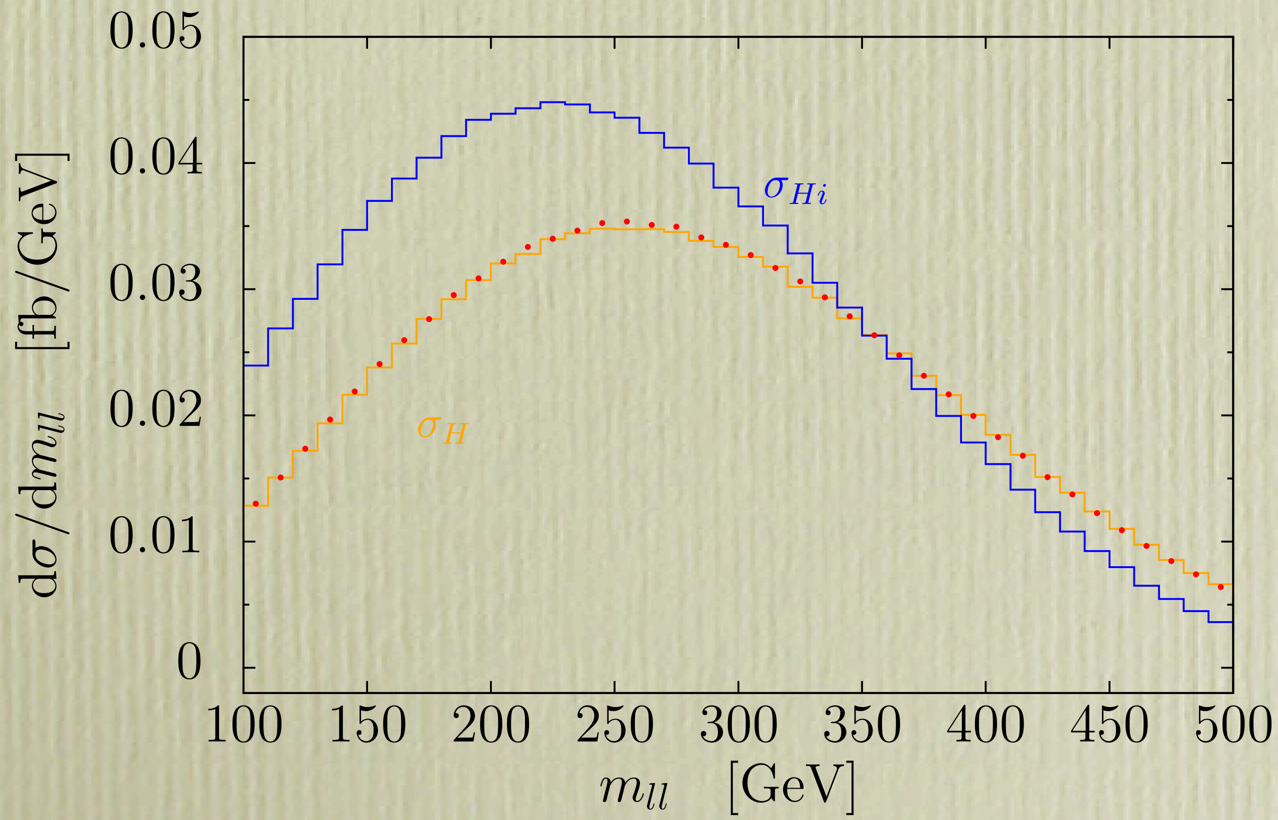
Approximate NNLO

Results for the interference

Inclusive K-factors: no cuts

	$\sqrt{s} = 8$ TeV			$\sqrt{s} = 13$ TeV		
	LO	NLO	NNLO	LO	NLO	NNLO
σ_H	0.909	1.99(5)	2.6(1)	3.77	8.1(2)	10.3(5)
σ_{Hi}	1.188	2.6(1)	3.4(3)	4.56	9.7(4)	12.5(9)
$\sigma_H/\sigma_H^{\mathrm{LO}}$	—	2.19(5)	2.8(1)	—	2.14(5)	2.7(1)
$\sigma_{Hi}/\sigma_{Hi}^{\mathrm{LO}}$	—	2.2(1)	2.9(2)	—	2.13(9)	2.8(2)

Differential distributions



We believe that the interference K-factor can be estimated to $\mathcal{O}(10\%)$ accuracy

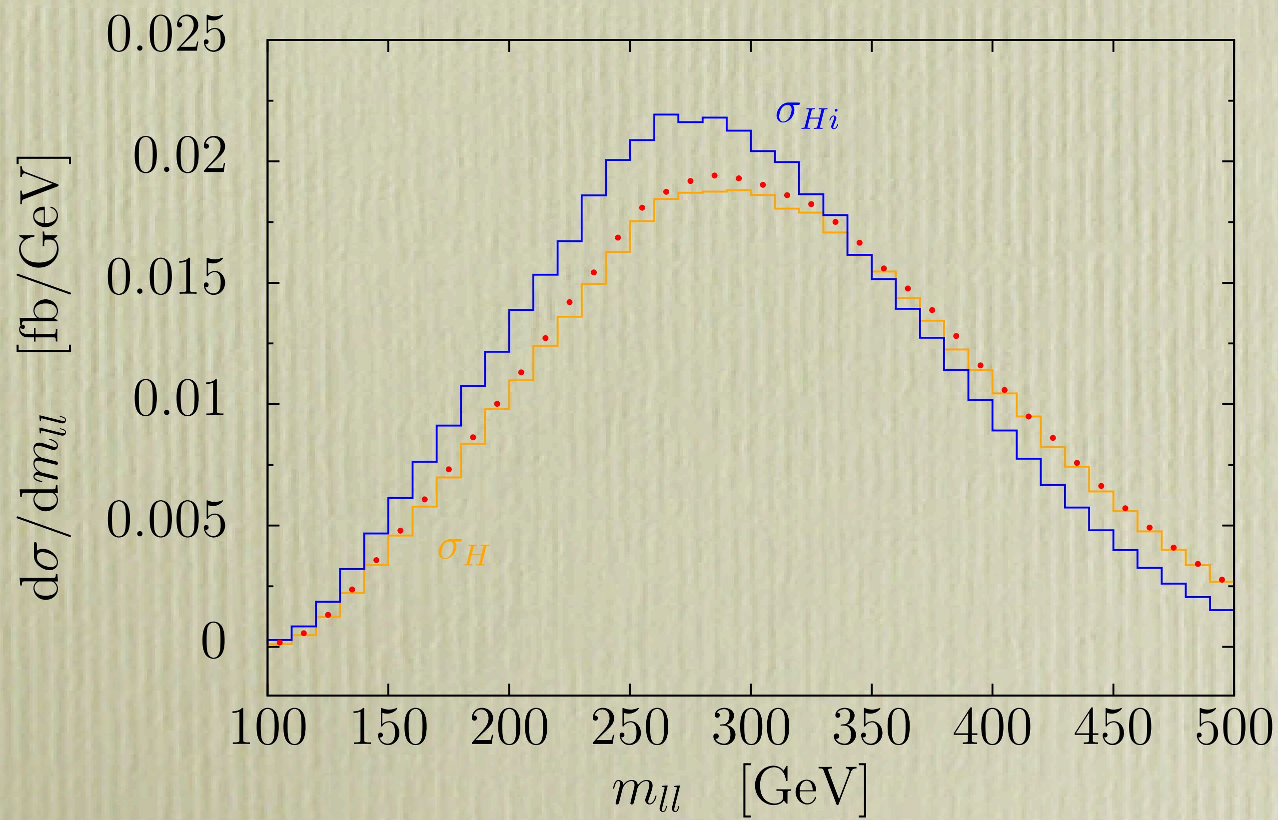
The interference K-factor is very similar to the (gg) Higgs K-factor

Results for the interference

Inclusive K-factors: Higgs-based cuts

	$\sqrt{s} = 8$ TeV			$\sqrt{s} = 13$ TeV		
	LO	NLO	NNLO	LO	NLO	NNLO
σ_H	0.379	0.83(2)	1.07(5)	1.55	3.29(8)	4.2(2)
σ_{Hi}	0.427	0.93(3)	1.20(7)	1.66	3.5(1)	4.5(2)
$\sigma_H/\sigma_H^{\mathrm{LO}}$	—	2.19(5)	2.8(1)	—	2.13(5)	2.7(1)
$\sigma_{Hi}/\sigma_{Hi}^{\mathrm{LO}}$	—	2.19(7)	2.8(2)	—	2.12(6)	2.7(1)

Differential distributions



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Conclusions

We believe we can estimate corrections to the interference to better than 10%

To this accuracy, the interference K-factors are very similar to the signal-only $gg \to H \to WW$ K-factors, both for inclusive cross sections and with Higgs-based selection cuts

(gg-multiplicative hypothesis)

The soft-collinear approximation only depends on the color flow → similar results expected for the ZZ channel