Mixed QCD-EW Higgs production
&
Higgs precision studies

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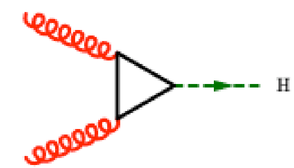
Flowing into the future: Particle Jets in Quantum Field Theory and Phenomenology

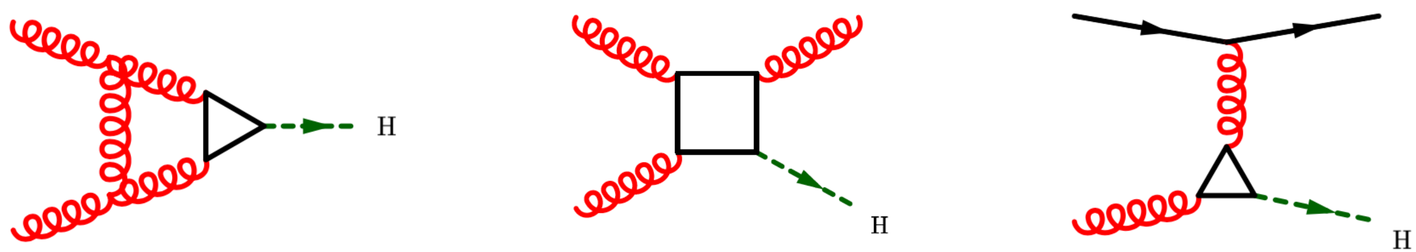
Higgs production at LHC

- In proton collisions, the Higgs boson is produced mostly via gluon fusion
  The gluons do not couple directly to the Higgs boson
  For matter, the coupling is mediated by a heavy quark loop
  The largest contribution comes from the top loop
  The production mode is (roughly) proportional to the top Yukawa coupling y_t



- QCD NLO corrections (for any heavy quark mass)

Djouadi Graudenz Spira Zerwas 1991-1995



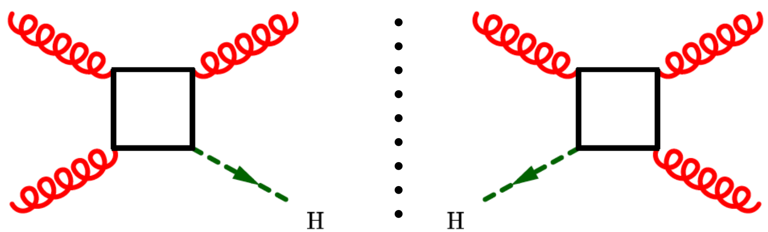
  - QCD NLO corrections are about 100% larger than leading order

- QCD NNLO corrections are known for the top-quark loop only

Czakon Harlander Klappert Niggetiedt 2021

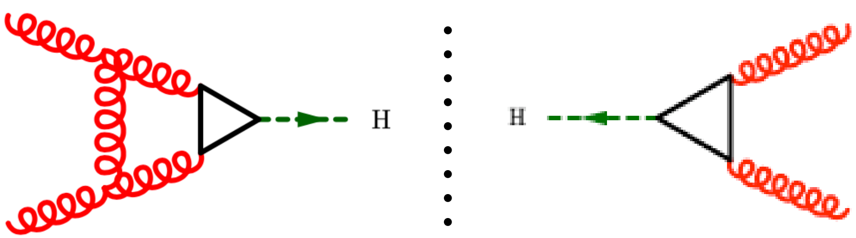
QCD NLO corrections

real radiation



K. Ellis Hinchliffe Soldate van der Bij 1988

virtual corrections



Djouadi Graudenz Spira Zerwas 1993
Anastasiou Beerli Bucherer Daleo Kunszt 2006
Aglietti Bonciani Degrassi Vicini 2006
Anastasiou Deutschmann Schweitzer 2020

} in terms of Harmonic Polylogarithms (HPL)

Polylogarithms

- classical polylogarithms $$\mathrm{Li}_m(z) = \int_0^z dt \frac{\mathrm{Li}_{m-1}(t)}{t} = \sum_{n=1}^{\infty} \frac{z^n}{n^m} \qquad \mathrm{Li}_1(z) = \sum_{n=1}^{\infty} \frac{z^n}{n} = -\ln(1-z)$$

Euler 1768
Spence 1809

- harmonic polylogarithms (HPLs)

$$H(a,\vec{w};z) = \int_0^z \mathrm{d}t\, f(a;t)\, H(\vec{w};t) \qquad f(-1;t) = \frac{1}{1+t}, \quad f(0;t) = \frac{1}{t}, \quad f(1;t) = \frac{1}{1-t}$$

with $\{a,\vec{w}\} \in \{-1,0,1\}$

Remiddi Vermaseren 1999

- classical polylogarithms are multiple polylogarithms with specific roots (0 and constant *a*)

$$G(\vec{0}_n;x) = \frac{1}{n!}\ln^n x \qquad G(\vec{a}_n;x) = \frac{1}{n!}\ln^n\left(1-\frac{x}{a}\right) \qquad G(\vec{0}_{n-1},a;x) = -\mathrm{Li}_n\left(\frac{x}{a}\right)$$

- when the root equals +1,-1,0 multiple polylogarithms become HPLs

Multiple polylogarithms

$$G(a,\vec{w};z) = \int_0^z \frac{\mathrm{d}t}{t-a} G(\vec{w};t)\,, \qquad G(a;z) = \ln\left(1-\frac{z}{a}\right)$$

$a, \vec{w} \in \mathbb{C}$

Goncharov 1998-2001

For *a* constant
Poincaré Kummer
Lappo-Danilevsky 1935

- multiple polylogarithms (MPL) form a shuffle algebra

$$G_{\omega_1}(z) G_{\omega_2}(z) = \sum_{\omega} G_{\omega}(z)$$

with ω the shuffle of ω_1 and ω_2

example

$$\begin{aligned} G(a;z)\,G(b;z) &= \int_0^z \frac{dt_1}{t_1-a} \int_0^z \frac{dt_2}{t_2-b} \\ &= \int_0^z \frac{dt_1}{t_1-a} \int_0^{t_1} \frac{dt_2}{t_2-b} + \int_0^z \frac{dt_2}{t_2-a} \int_0^{t_2} \frac{dt_1}{t_1-b} \\ &= G(a,b;z) + G(b,a;z) \end{aligned}$$

- $\lim_{z\to 0} G(a_1,\ldots,a_n;z) = 0$ unless $\vec{a} = \vec{0}$

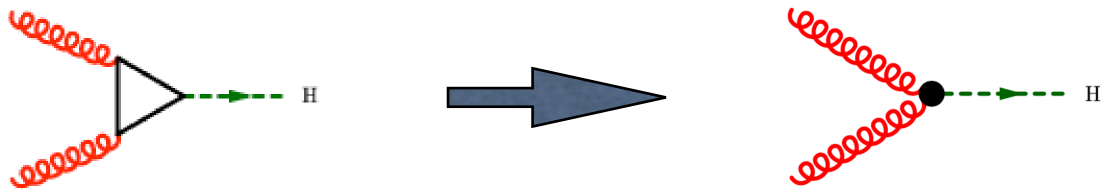
- $\frac{\partial}{\partial z} G(a_1,\ldots,a_k;z) = \frac{1}{z-a_1} G(a_2,\ldots,a_k;z)$

- MPLs can be represented as nested harmonic sums

$$\sum_{n_1=1}^{\infty} \frac{u_1^{n_1}}{n_1^{m_1}} \sum_{n_2=1}^{n_1-1} \cdots \sum_{n_k=1}^{n_{k-1}-1} \frac{u_k^{n_k}}{n_k^{m_k}} = (-1)^k\, G\Bigg(\underbrace{0,\ldots,0}_{m_1-1}, \frac{1}{u_1}, \ldots, \underbrace{0,\ldots,0}_{m_k-1}, \frac{1}{u_1\ldots u_k}; 1\Bigg)$$

Higgs production in HEFT

- $m_H << 2m_t$



all amplitudes are reduced by one loop

- … but, beware of quark mass effects

σ_{EFT}^{LO}	15.05 pb	σ_{EFT}^{NLO}	34.66 pb
$R_{LO}\,\sigma_{EFT}^{LO}$	16.00 pb	$R_{LO}\,\sigma_{EFT}^{NLO}$	36.84 pb
$\sigma_{ex;t}^{LO}$	16.00 pb	$\sigma_{ex;t}^{NLO}$	36.60 pb
$\sigma_{ex;t+b}^{LO}$	14.94 pb	$\sigma_{ex;t+b}^{NLO}$	34.96 pb
$\sigma_{ex;t+b+c}^{LO}$	14.83 pb	$\sigma_{ex;t+b+c}^{NLO}$	34.77 pb

Anastasiou Duhr Dulat Furlan Gehrmann Herzog Lazopoulos Mistlberger 2016

- $R_{LO} = \frac{\sigma_{ex:t}^{LO}}{\sigma_{EFT}^{LO}} = 1.063$

rescaled EFT (rEFT) does a good job (< 1%) in approximating the exact (only top) NLO σ but misses the *t-b* interference

Higgs production

- QCD corrections have been computed at N^{3}LO in HEFT

Anastasiou Duhr Dulat Herzog Mistlberger 2015
Mistlberger 2018
(in terms of MPLs and elliptic integrals)

- including quark-mass effects and QCD-EW interference the cross section is

$$\sigma = 48.58\,\mathrm{pb}^{+2.22\,\mathrm{pb}\,(+4.56\%)}_{-3.27\,\mathrm{pb}\,(-6.72\%)}\ (\text{theory}) \pm 1.56\,\mathrm{pb}\,(3.20\%)\ (\text{PDF}+\alpha_s)$$

- The breakdown of the cross section

$$\begin{aligned}
48.58\,\mathrm{pb} = \quad & 16.00\,\mathrm{pb} && (+32.9\%) && (\text{LO, rEFT}) \\
& + 20.84\,\mathrm{pb} && (+42.9\%) && (\text{NLO, rEFT}) \\
& - \ \ 2.05\,\mathrm{pb} && (-4.2\%) && ((t,b,c),\ \text{exact NLO}) \\
& + \ \ 9.56\,\mathrm{pb} && (+19.7\%) && (\text{NNLO, rEFT}) \\
& + \ \ 0.34\,\mathrm{pb} && (+0.2\%) && (\text{NNLO},\ 1/m_t) \\
& + \ \ 2.40\,\mathrm{pb} && (+4.9\%) && (\text{EW, QCD-EW}) \\
& + \ \ 1.49\,\mathrm{pb} && (+3.1\%) && (\text{N}^3\text{LO, rEFT})
\end{aligned}$$

Anastasiou Duhr Dulat Furlan Gehrmann Herzog Lazopoulos Mistlberger 2016
Handbook 4 of LHC Higgs Cross Sections 2016

Higgs production

Handbook 4 of LHC Higgs Cross Sections 2016

- 6 sources of uncertainties due to:
  higher orders
  truncation of the threshold expansion
  PDFs
  NLO corrections to QCD-EW interference
  quark mass effects (2: top mass and top-b interference) at NNLO

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

δ(trunc) = 0.11 pb   Mistlberger 2018

$\delta(1/m_t)$ = - 0.26%   Czakon Harlander Klappert Niggetiedt 2021

QCD NNLO corrections

- Top-quark mass corrections are known at NNLO

Czakon Harlander Klappert Niggetiedt 2021

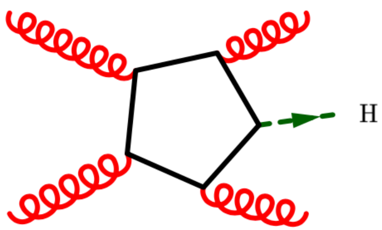
channel	$\sigma^{\rm NNLO}_{\rm HEFT}$ [pb] $\mathcal{O}(\alpha_s^2)+\mathcal{O}(\alpha_s^3)+\mathcal{O}(\alpha_s^4)$	$(\sigma^{\rm NNLO}_{\rm exact}-\sigma^{\rm NNLO}_{\rm HEFT})$ [pb] $\mathcal{O}(\alpha_s^3)$	$\mathcal{O}(\alpha_s^4)$	$(\sigma^{\rm NNLO}_{\rm exact}/\sigma^{\rm NNLO}_{\rm HEFT}-1)$ [%]
		$\sqrt{s}=8\,$TeV		
gg	$7.39+8.58+3.88$	$+0.0353$	$+0.0879\pm0.0005$	$+0.62$
qg	$0.55+0.26$	-0.1397	-0.0021 ± 0.0005	-18
qq	$0.01+0.04$	$+0.0171$	-0.0191 ± 0.0002	-4
total	$7.39+9.15+4.18$	-0.0873	$+0.0667\pm0.0007$	-0.10
		$\sqrt{s}=13\,$TeV		
gg	$16.30+19.64+8.76$	$+0.0345$	$+0.2431\pm0.0020$	$+0.62$
qg	$1.49+0.84$	-0.3696	-0.0115 ± 0.0010	-16
qq	$0.02+0.10$	$+0.0322$	-0.0501 ± 0.0006	-15
total	$16.30+21.15+9.79$	-0.3029	$+0.1815\pm0.0023$	-0.26

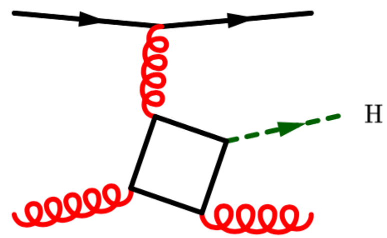
- HEFT not so good for *qg* and *qq* channels
- for top-quark mass only the on-shell scheme

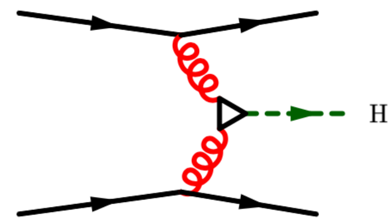
QCD NNLO corrections

- Higgs + 4-parton amplitudes at one loop

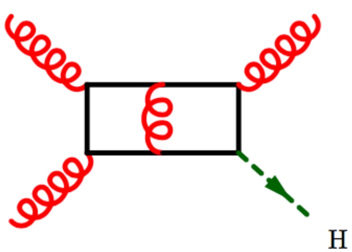
VDD Kilgore Oleari Schmidt Zeppenfeld 2001
Budge Campbell De Laurentis K. Ellis Seth 2020

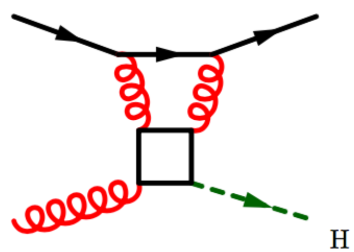






- Higgs + 3-parton amplitudes at two loops





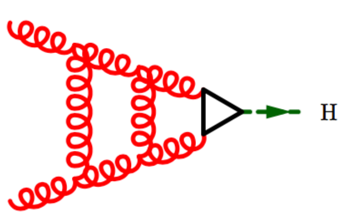
top loop: Jones Kerner Luisoni 2018
Czakon Harlander Klappert Niggetiedt 2021

arbitrary heavy quark masses (only Master Int):

Bonciani VDD Frellesvig Henn Moriello V. Smirnov 2016
all above + Hidding Maestri Salvatori 2019

multi-scale problem with complicated analytic structure
elliptic iterated integrals appear

- gg→Higgs amplitudes at three loops



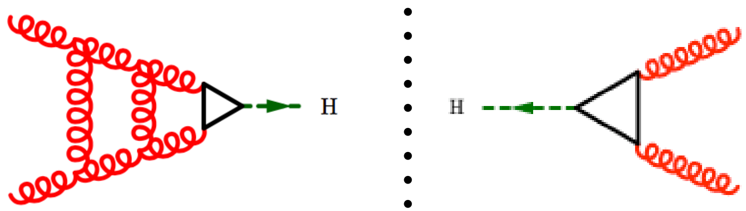
one scale: one & two top loops
one top loop + light-quark loop

Czakon Niggetiedt 2020
Harlander Prausa Usovitsch 2019

two scales: one top loop + *b*-quark loop

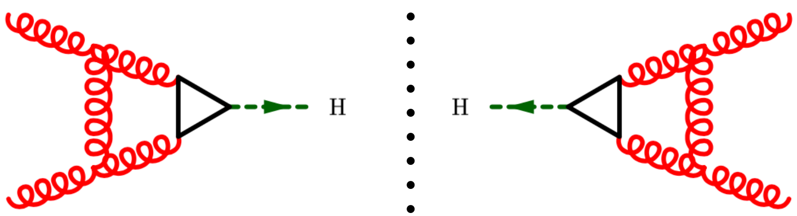
QCD NNLO corrections

virtual corrections



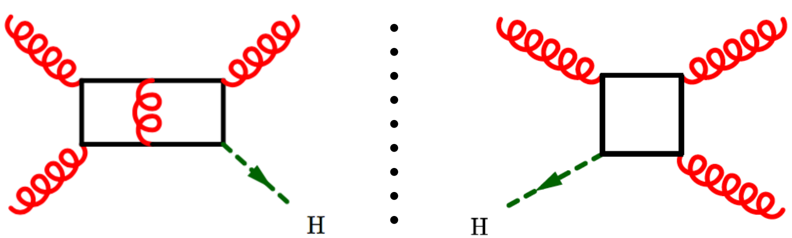
Harlander Prausa Usovitsch 2019 (one top & one light quark, in terms of HPLs)

Czakon Niggetiedt 2020 (one & two top)



Anastasiou Deutschmann Schweitzer 2020

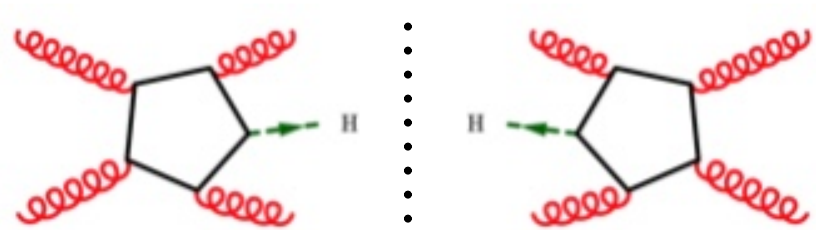
real-virtual corrections



Jones Kerner Luisoni 2018
Czakon Harlander Klappert Niggetiedt 2021 (top)

Bonciani VDD Frellesvig Henn Moriello V. Smirnov 2016
all above + Hidding Maestri Salvatori 2019 (arbitrary m_Q)

double-real radiation

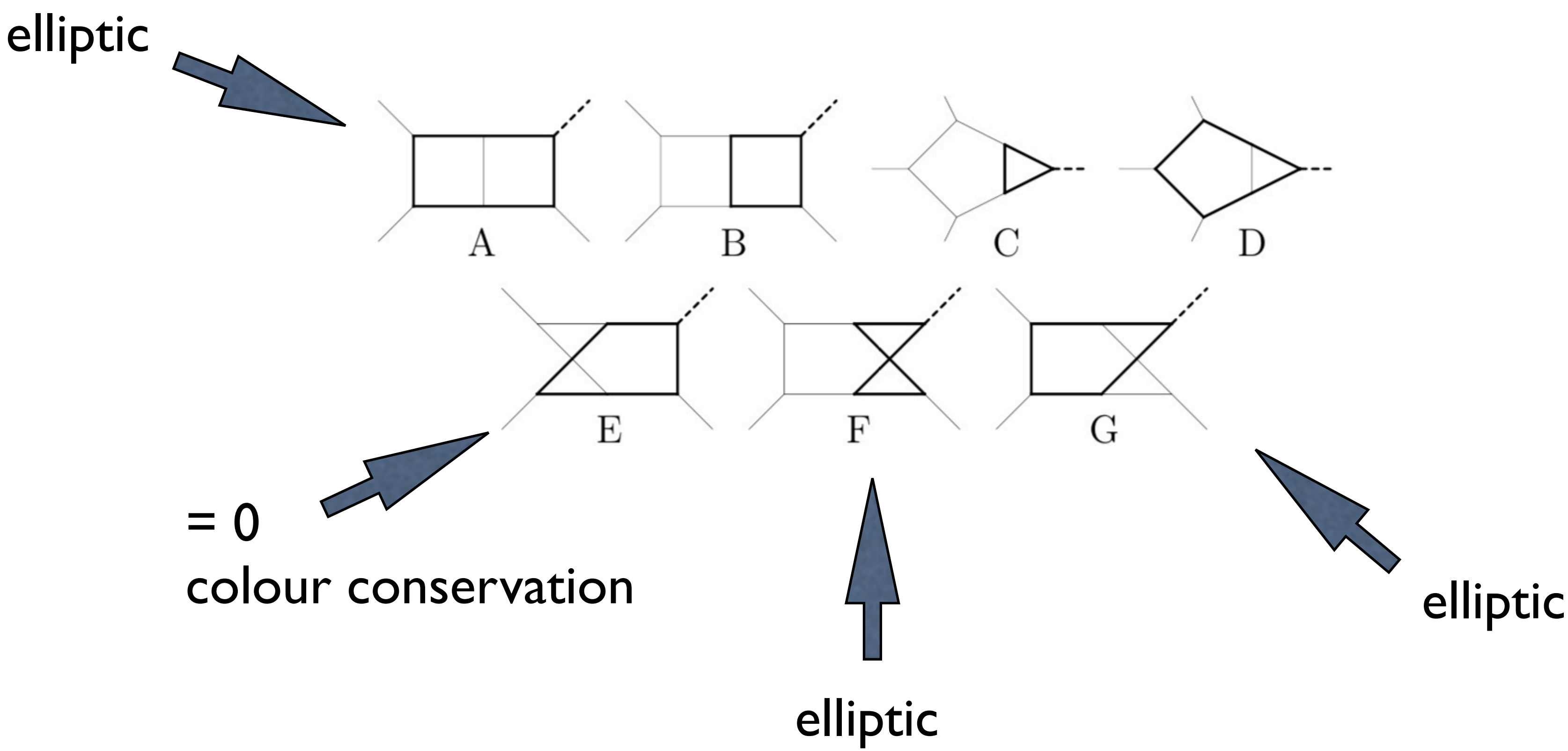


VDD Kilgore Oleari Schmidt Zeppenfeld 2001
Budge Campbell De Laurentis K. Ellis Seth 2020

Higgs+3-parton Master Integrals at two loops

4 scales, s, t, m_H, m_t → 3 external parameters
6 seven-propagator integral families

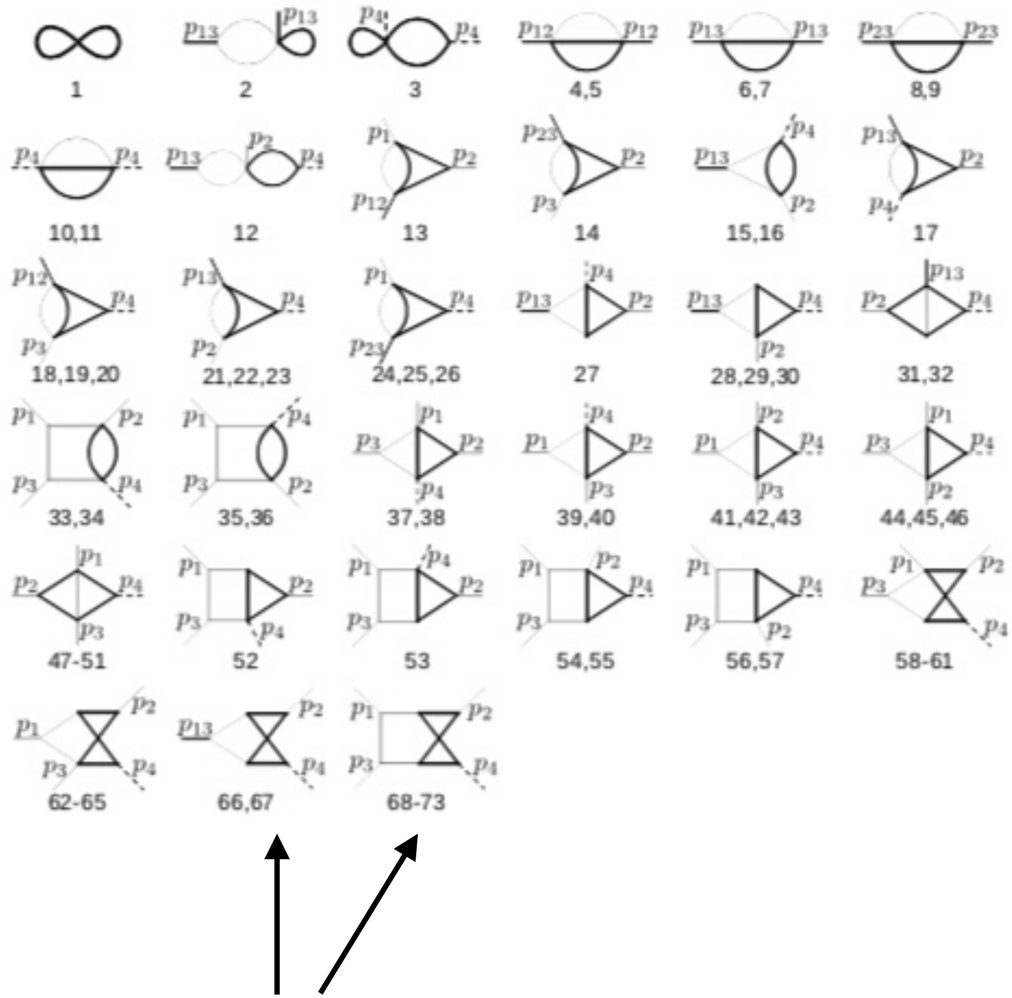
Bonciani VDD Frellesvig Henn Moriello V. Smirnov 2016 (A, B, C, D)
Bonciani VDD Frellesvig Henn Hidding Maestri Moriello Salvatori V. Smirnov 2019 (F)
Frellesvig Hidding Maestri Moriello Salvatori 2019 (G)



Family F: 73 MIs (65 in the polylogarithmic sector, 8 in the elliptic sector)
alphabet: 69 independent letters, with 12 independent square roots

solved through generalised power series expansion — Moriello 2019
of the differential equations, defining the parameter n-ples along a contour

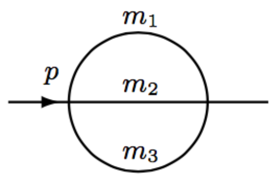
73 Master Integrals



elliptic

Elliptic iterated integrals

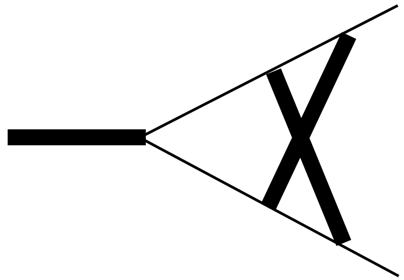
- 2-loop sunrise graph



Sabry 1962: …;Broadhurst 1989; …; Bloch Vanhove 2013; …
Brödel Duhr Dulat Penante Tancredi 2017-2019

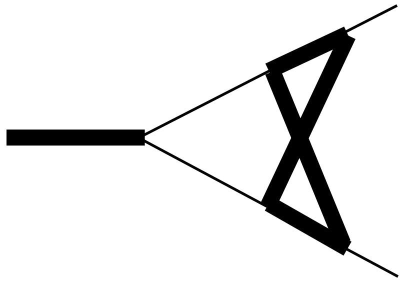
- 2-loop 3-pt functions

electroweak form factor



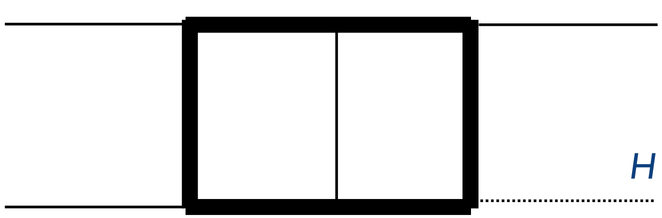
Aglietti Bonciani Grassi Remiddi 2007

t-*t*bar



von Manteuffel Tancredi 2017

- 2-loop 4-pt function for Higgs + 1 jet



Bonciani VDD Frellesvig Henn Moriello V. Smirnov 2016

- iterated integrals on $\mathscr{M}_{0,p}$ are multiple polylogarithms

Brown 2006

$\mathscr{M}_{0,p}$ = space of configurations of p points on the Riemann sphere

$$G(a,\vec{w};z) = \int_0^z \frac{\mathrm{d}t}{t-a} G(\vec{w};t)\,, \qquad G(a;z) = \ln\left(1-\frac{z}{a}\right) \qquad a,\vec{w}\in\mathbb{C}$$

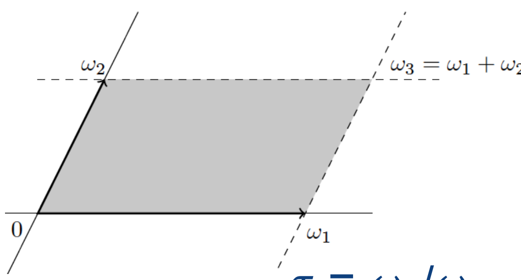
- iterated integrals on a torus …

Brown Levin 2011

$$\tilde{\Gamma}\left(\begin{smallmatrix} n_1 \dots n_k \\ z_1 \dots z_k \end{smallmatrix};z,\tau\right) = \int_0^z dt\, g^{(n_1)}(t-z_1,\tau)\,\tilde{\Gamma}\left(\begin{smallmatrix} n_2 \dots n_k \\ z_2 \dots z_k \end{smallmatrix};t,\tau\right)$$

$n_i \in \mathbb{N}, \quad z_i \in \mathbb{C}$

kernels $g^{(n)}$ have at most simple poles at $z = m + n\tau$



$\tau = \omega_2/\omega_1$

$m,n\in\mathbb{Z}$

… are elliptic multiple polylogarithms (eMPL)

$$E_3\left(\begin{smallmatrix} n_1 \dots n_k \\ z_1 \dots z_k \end{smallmatrix};z,\vec{a}\right) = \int_0^z dt\, \varphi_{n_1}(z_1,t,\vec{a})\, E_3\left(\begin{smallmatrix} n_2 \dots n_k \\ z_2 \dots z_k \end{smallmatrix};t,\vec{a}\right) \qquad n_i\in\mathbb{Z}, \quad z_i\in\mathbb{C} \quad a_i\in\mathbb{R}$$

with $\vec{a} = (a_1,a_2,a_3)$ are the zeroes of the elliptic curve $y^2 = (x-a_1)(x-a_2)(x-a_3)$

and $E_3(;z,\vec{a}) = 1$

- 2-loop sunrise can be written in terms of eMPLs

Brödel Duhr Dulat Penante Tancredi 2017

Differential Equations

- Differential Equation method to solve the MIs

  $$\partial_i f(x_n;\varepsilon) = A_i(x_n;\varepsilon) f(x_n;\varepsilon)$$

  f: N-vector of MIs, A_i: NxN matrix, i=1,…,n external parameters

  but in some cases ε-independent form

  $$\partial_i f(x_n;\varepsilon) = \varepsilon A_i(x_n) f(x_n;\varepsilon)$$ Henn 2013

  solution in terms of iterated integrals

- Take two points (a_1, …, a_n) and (b_1,…, b_n) in the *n*-dim parameter space, and parametrise the contour $\gamma(t)$ that connects the two points

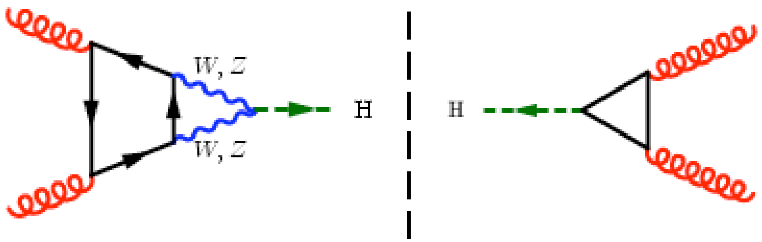
  $$\gamma(t) : t \to \{x_1(t), \ldots, x_n(t)\} \qquad \vec{x}(0) = \vec{a}\,, \qquad \vec{x}(1) = \vec{b}$$

  and write the differential equation with respect to *t*.
  Then find a solution about a point τ by series expanding the coefficient matrix *A* and then iteratively integrating it.
  The procedure works in general, for canonical or elliptic sectors

Moriello 2019

QCD-EW interference

- The Higgs boson may (indirectly) couple to gluons also via the gauge coupling i.e. through a double (electroweak boson + quark) loop



Aglietti Bonciani Degrassi Vicini 2004
(light fermion loop)
Degrassi Maltoni 2004
Actis Passarino Sturm Uccirati 2008
(heavy fermion loop)

(in terms of MPLs)

(numerically
… elliptic integrals appear)

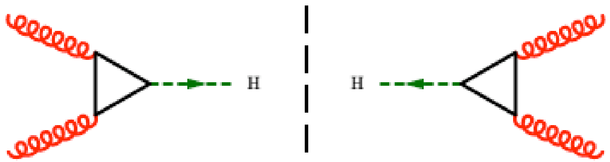
$O(\alpha_s^2\alpha^2)$

- the top loop yields a 2% correction to the 5 light fermion loops

- gg-initiated QCD NLO corrections (light fermion loop) computed in various approximations:
  — $m_{w,z} \to \infty$ limit — Anastasiou Boughezal Petriello 2009
  — soft approximation — Bonetti Melnikov Tancredi 2018
  — $m_{w,z} \to 0$ limit — Anastasiou VDD Furlan Mistlberger Moriello Schweitzer Specchia 2018

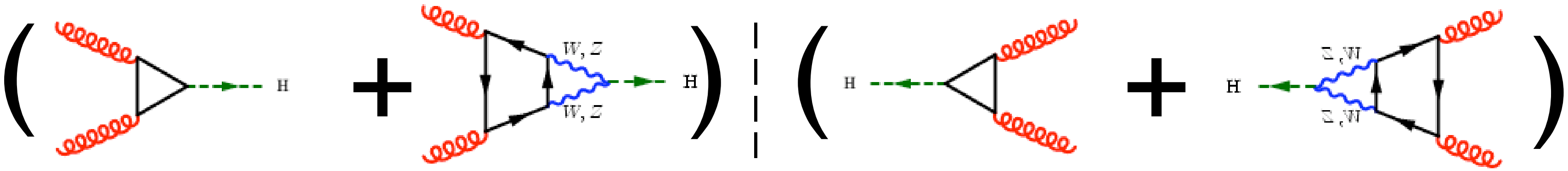
  and found to be about 5% wrt NLO (HEFT) cross section

QCD-EW interference



$$\hat{\sigma}_{Q\,ij} = \sigma_Q^{(0)} G_{ij}^{(0)} \qquad G_{ij}^{(0)} = \delta_{ig}\delta_{jg}\delta\,(1-z) \qquad z = \frac{m_H^2}{x_1 x_2 s}$$

$$\sigma_Q^{(0)} = G_F \alpha_s^2 \left|\mathcal{G}_Q\right|^2 \qquad \mathcal{G}_Q \sim \sum MPLs$$



$$\hat{\sigma}_{Q/EW\,ij} = \sigma_{Q/EW}^{(0)} G_{ij}^{(0)} \qquad \sigma_{Q/EW}^{(0)} = G_F \alpha_s^2 \left|\mathcal{G}_Q + \mathcal{G}_{EW}\right|^2 \qquad \mathcal{G}_{EW} \sim \alpha \sum MPLs$$

neglect EW²

$$\sigma_{Q/EW}^{(0)} = \sigma_Q^{(0)} (1 + \lambda_{EW}) \qquad \lambda_{EW} = \frac{2\,\mathrm{Re}[\mathcal{G}_Q \mathcal{G}_{EW}^*]}{|\mathcal{G}_Q|^2}$$

- QCD corrections

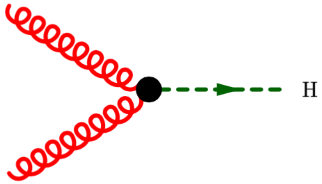
$$\hat{\sigma}_{Q/EW\,ij} = \sigma_Q^{(0)} \sum_{\ell=0}^{\infty} \alpha_s^\ell \left(G_{Q\,ij}^{(\ell)} + \lambda_{EW}\, G_{EW\,ij}^{(\ell)} \right) \qquad G_{Q\,ij}^{(0)} = G_{EW\,ij}^{(0)} = G_{ij}^{(0)}$$

- Factorization ansatz $\quad G_{EW\,ij}^{(\ell)} = G_{Q\,ij}^{(\ell)}$

Actis Passarino Sturm Uccirati 2008

QCD-EW interference

$$\frac{m_H}{m_t} \to 0$$



$$\mathcal{L}_{EFT} = \frac{\alpha_s}{4v} C\, H\, G^a_{\mu\nu} G^{a\,\mu\nu}$$

Wilson coefficients $C \sim 1 + \alpha_s C_q^{(1)} + \mathcal{O}(\alpha_s^2)$ $C_q^{(1)} = \frac{11}{4}$

$$\frac{m_H}{m_V} \to 0 \qquad C \sim 1 + \sum_{\ell=0}^{\infty} \alpha_s^\ell C_q^{(\ell)} + \lambda_{EW} \left(1 + \sum_{\ell=0}^{\infty} \alpha_s^\ell C_{ew}^{(\ell)} \right)$$

Factorization ansatz $C_{ew}^{(\ell)} = C_q^{(\ell)}$

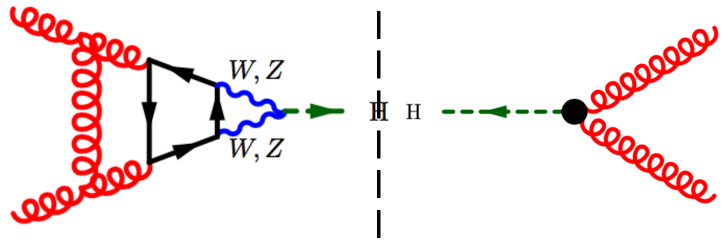
however $C_{ew}^{(1)} = \frac{7}{6}$

Anastasiou Boughezal Petriello 2009

QCD-EW interference

- gg-initiated QCD NLO corrections (light fermion loop): $O(\alpha_s^3\alpha^2)$

Becchetti Bonciani VDD Hirschi Moriello Schweitzer 2020

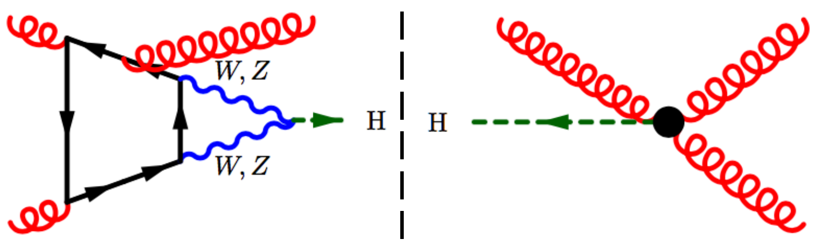


Bonetti Melnikov Tancredi 2016

IR local subtraction schemes

MadGraph MC@NLO

Frixione Kunszt Signer 1995
Frederix Frixione Maltoni Stelzer 2009



COLORFUL

VDD Somogyi Trocsanyi 2006
Somogyi 2009
VDD Deutschmann Lionetti 2019

Becchetti Bonciani Casconi VDD Moriello 2018
Bonetti Panzer V. Smirnov Tancredi 2020
Becchetti Moriello Schweitzer 2021

LO $\sigma_{gg\to H+X}^{(\alpha_s^2\alpha^2)} = 0.68739^{+23.4\%+2.0\%}_{-17.3\%-2.0\%}$ pb

NLO $\sigma_{gg\to H+X}^{(\alpha_s^2\alpha^2+\alpha_s^3\alpha^2)} = 1.467(2)^{+18.7\%+2.0\%}_{-14.6\%-2.0\%}$ pb   i.e. NLO 110% wrt LO

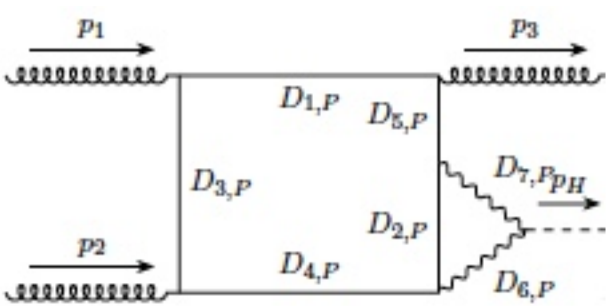
gg-initiated NLO corrections in HEFT $\sigma_{gg\to H+X}^{(\mathrm{HEFT},\alpha_s^2\alpha+\alpha_s^3\alpha)} = 30.484^{+19.8\%+1.9\%}_{-15.3\%-1.9\%}$ pb

thus our NLO result 4.8% wrt gg-initiated NLO HEFT

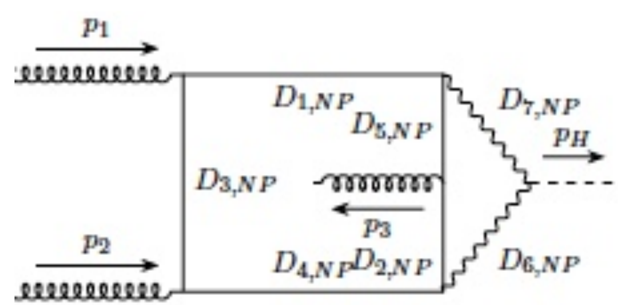
QCD-EW Higgs+3-parton master integrals at two loops

4 scales, s, t, m_H, m_V → 3 external parameters
7 seven-propagator integral families
48 MIs (planar), 61 MIs (non-planar)
alphabet: square roots are present, but an MPL representation is possible

Becchetti Bonciani Casconi VDD Moriello 2018 (planar MIs)
Becchetti Moriello Schweitzer 2021 (non-planar MIs)



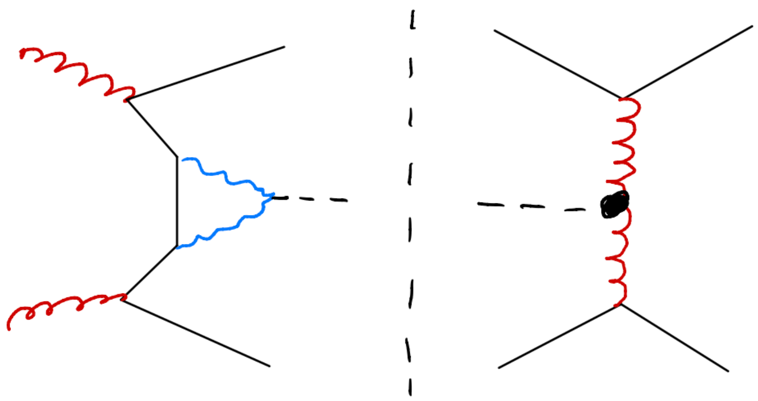
planar



non-planar

solved through generalised power series expansion Moriello 2019

- missing: *gg* —> *Hqq*: $O(\alpha_s^3\alpha^2)$

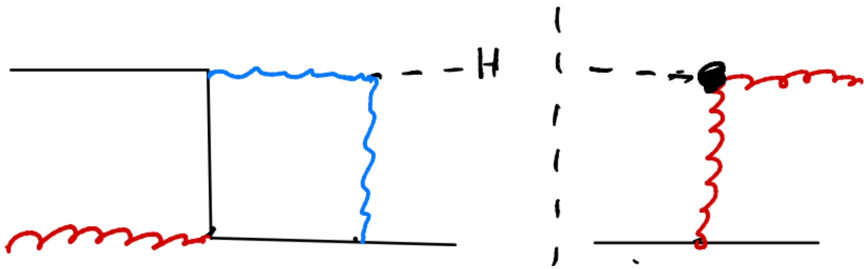


less than 2% of NLO mixed QCD-EW corrections to *gg* —> *H*

Hirschi Lionetti Schweitzer 2019

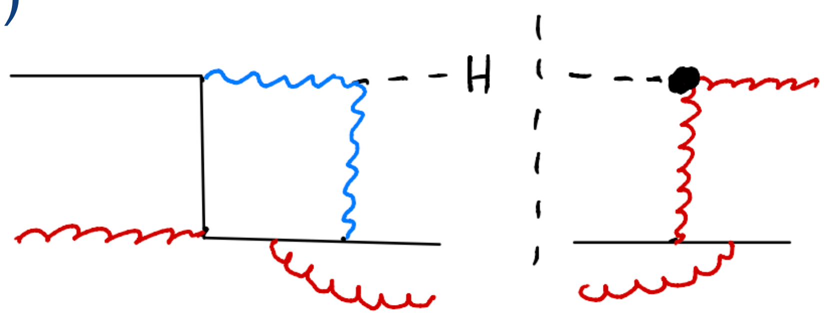
missing: *qg*-initiated QCD-EW interference

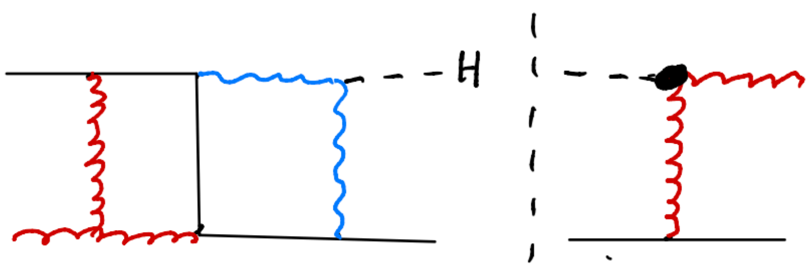
$O(\alpha_s^2\alpha^2)$

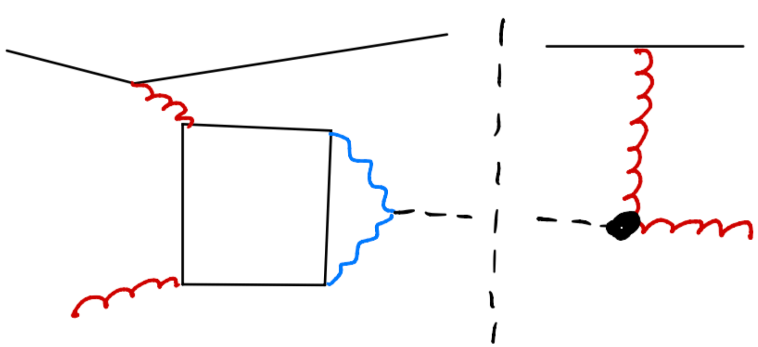


Hirschi Lionetti Schweitzer 2019

$O(\alpha_s^3\alpha^2)$



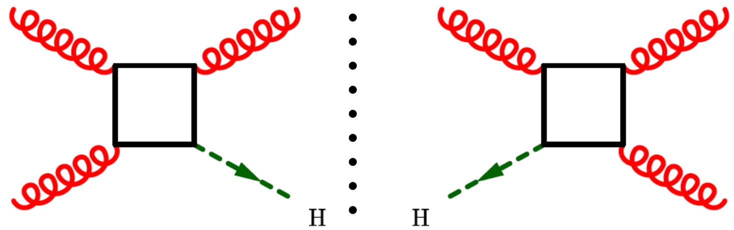




Becchetti Bonciani Casconi VDD Moriello 2018 (planar MIs)

Higgs p_T distribution at LHC

- leading order



K. Ellis Hinchliffe Soldate van der Bij 1988

- high-p_T tail of the Higgs p_T distribution is sensitive to the structure of the loop-mediated Higgs-gluon coupling
  New Physics particles circulating in the loop would modify it

- QCD NLO corrections known for the top-quark only (on-shell scheme)

Jones Kerner Luisoni 2018
Chen Huss Jones Kerner Lang Lindert Zhang 2021

- Full (=t+b) QCD NLO corrections are not known

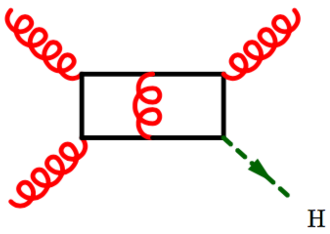
- HEFT $m_H << 2m_t$ and $p_T << m_t$

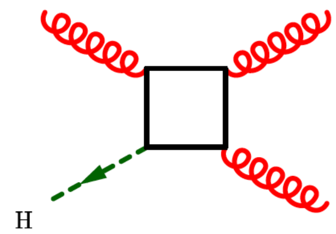
  QCD corrections are known at NNLO in HEFT, and yield a 15% increase wrt NLO

Boughezal Caola Melnikov Petriello Schulze 2015
Boughezal Focke Giele Liu Petriello 2015
Chen Cruz-Martinez Gehrmann Glover Jaquier 2016

Higgs p_T distribution at NLO

virtual corrections

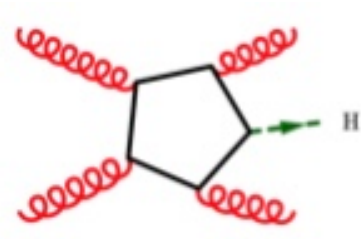


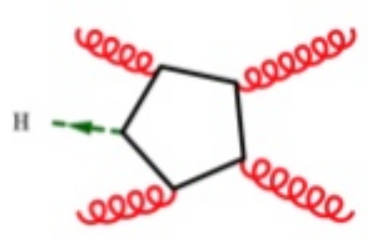


Jones Kerner Luisoni 2018 (top)
Czakon Harlander Klappert Niggetiedt 2021

Bonciani VDD Frellesvig Henn Moriello V. Smirnov 2016
all above + Hidding Maestri Salvatori 2019 (arbitrary m_Q)

real corrections

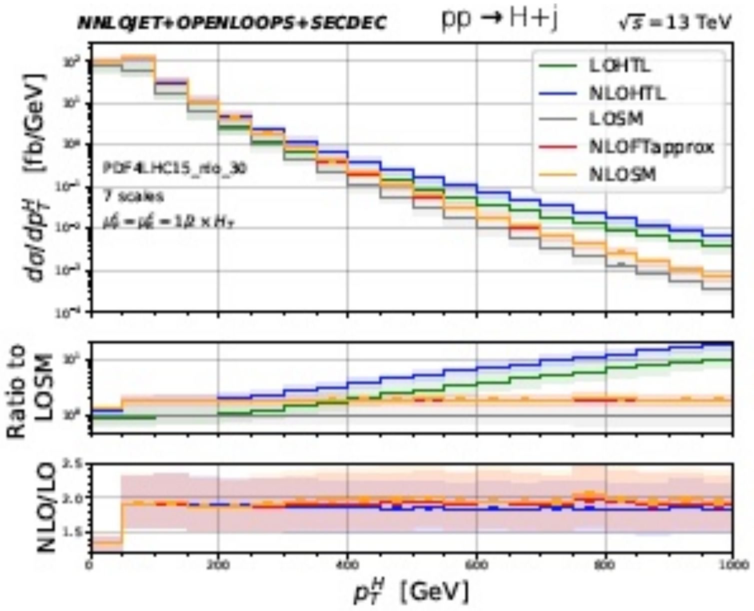




VDD Kilgore Oleari Schmidt Zeppenfeld 2001
Budge Campbell De Laurentis K. Ellis Seth 2020

Higgs p_T distribution at LHC

- QCD (top) NLO corrections have been computed numerically

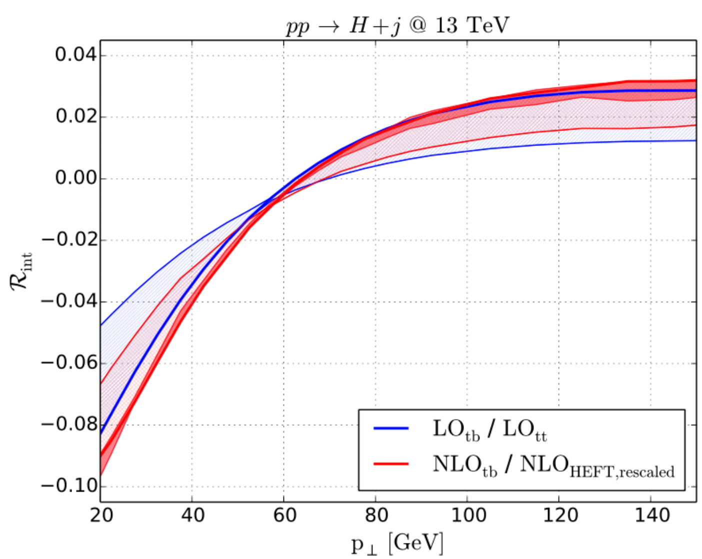


Jones Kerner Luisoni 2018
Chen Huss Jones Kerner Lang Lindert Zhang 2021

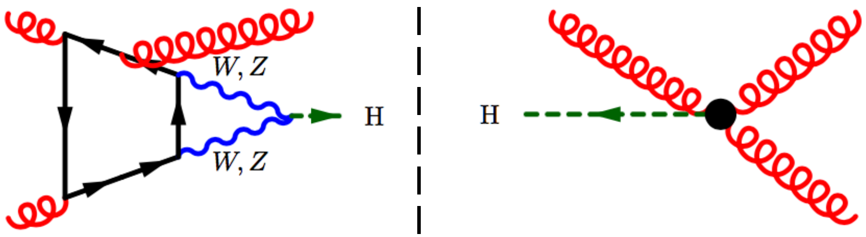
No *t*-*b* interference
On-shell mass renormalisation

- QCD NLO corrections to *t*-*b* interference, using top loop in HEFT and *b*-quark loop in small m_b limit

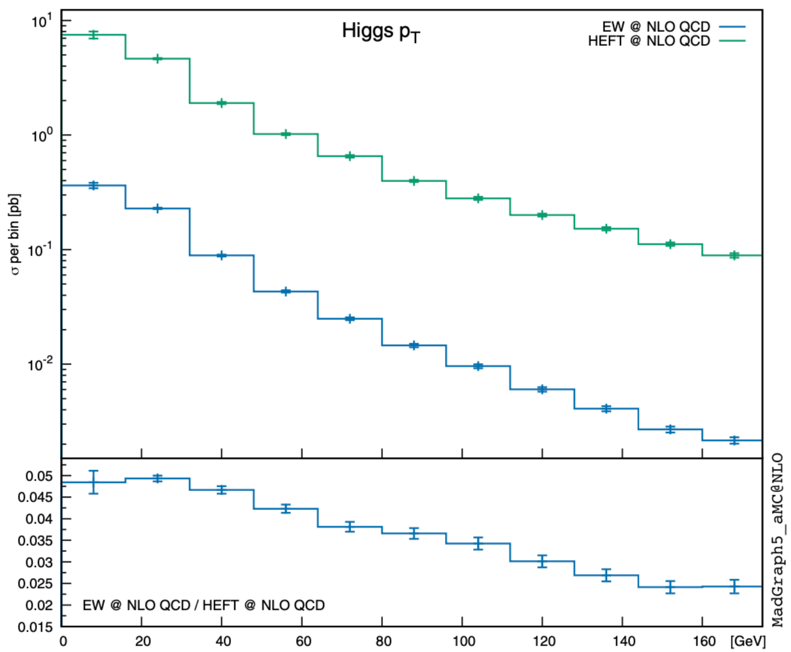
Lindert Melnikov Tancredi Wever 2017



Higgs p_T distribution due to QCD-EW interference



Becchetti Bonciani VDD Hirschi Moriello Schweitzer 2020



gg-initiated QCD-EW p_T spectrum harder than HEFT