Electroweak corrections to Higgs production via gluon fusion

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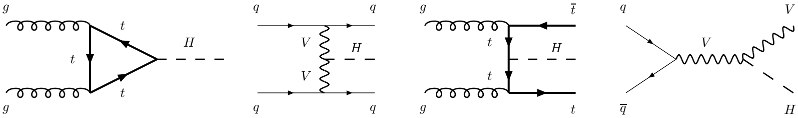
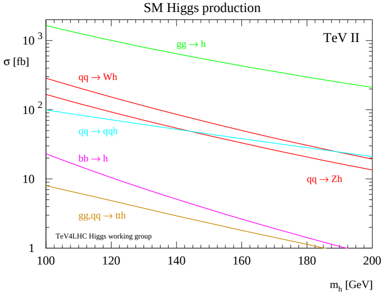
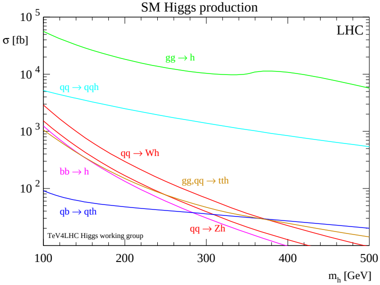
Hadronic SM Higgs production

Gluon-fusion production channel has by far the largest cross section both at the TEVATRON and the LHC







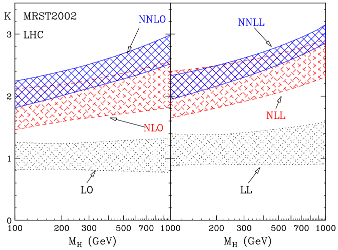
Hahn,Heinemeyer,Maltoni,Weiglein,Willenbrock [hep-ph/0607308]

QCD corrections

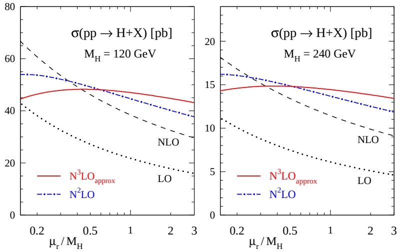
NLO and NNLO QCD corrections to the cross section extremely large

Dawson'91,Djouadi,Spira,Zerwas'91,Spira,Djouadi,Graudenz,Zerwas'95
Harlander,Kant'05,Anastasiou,Beerli,Bucherer,Daleo,Kunszt'06,
Aglietti,Bonciani,Degrassi,Vicini'06

Harlander'00,Catani,de Florian,Grazzini'01,Harlander,Kilgore'01,
Anastasiou,Melnikov'02,Ravindran,Smith,van Neerven'03



Catani,de Florian,Grazzini,Nason [hep-ph/0306211]



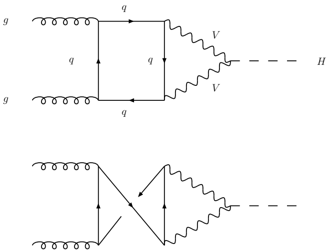
Moch,Vogt [hep-ph/0508265]

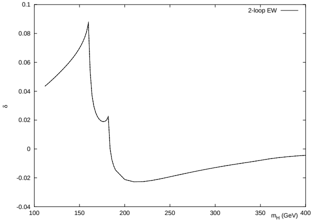
N^3LO soft limit ⇒ 5% uncertainty

also NNLO beyond the $M_t \to \infty$ approximation, talk by K. Ozeren at LoopFest

EW corrections

- Top diagrs by expansions Djouadi,Gambino’94;Degrassi,Maltoni’04
- Light-quark analytically Aglietti,Bonciani,Degrassi,Vicini’04





Aglietti,Bonciani,Degrassi,Vicini [hep-ph/0404071]

- Full NLO above *WW* threshold SA,Passarino,Sturm,Uccirati’08
- NNLO QCD/EW effective Anastasiou,Boughezal,Petriello’08

Complex poles

Problem with the crossing of both *WW* and *ZZ*: square-root divergencies

$gg \to H$ amplitude $\Rightarrow$ terms proportional to $1/\beta_V$, $\beta_V = \sqrt{1 - 4\,M_V^2/M_H^2}$

Cure problems with crossing of thresholds implementing the complex-mass scheme at 1 loop Denner, Dittmaier, Roth, Wieders'05

1) "Minimal" introduction of the complex-mass scheme

Decompose $A = A_{\mathrm{div}}^{1,\mathrm{W}}/\beta_W + A_{\mathrm{div}}^{1,\mathrm{Z}}/\beta_Z + A_{\mathrm{fin}}$

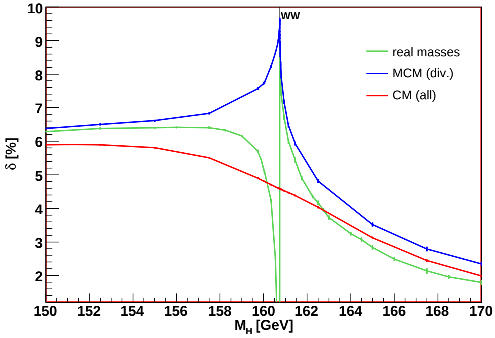
Introduce the CMS in both threshold factors β_V and coefficients $A_{\mathrm{div}}^{1,2}$

2) Complete introduction of the complex-mass scheme

Introduce the CMS in all divergent and finite terms of the amplitude

Threshold behaviour for $gg \to H$

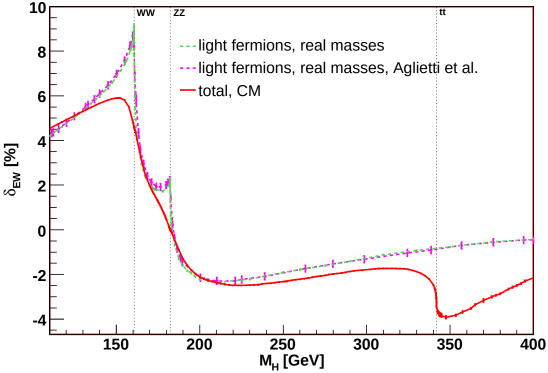
Comparison of EW corrections to $gg \to H$ around the WW threshold, obtained using different schemes for treating unstable particles



- Result obtained with real masses divergent at WW; good approx. below/above
- MCM setup gives finite result at WW; large effect 9.6 % associated with cusp
- CM setup smoothens singular behaviour; effects at threshold reduced to 4.6 %

EW corrections to $gg \to H$

Summary of EW corrections to $gg \to H$ for $100\ \text{GeV} < M_H < 400\ \text{GeV}$



- Light fermions dominate up to 300 GeV; top-quark diagrams relevant at $t\bar{t}$ threshold, with relative correction $\delta_{ew} \sim -4\%$
- CMs change the result around *WW* and *ZZ* thresholds, where cusps disappear

Inclusion of NLO EW effects

Partonic result convoluted with the PDFs:

$$\sigma(h_1 h_2 \to H) = \sum_{i,j} \int_0^1 dx_1 dx_2 f_{i,h_1}(x_1, \mu_F^2) f_{j,h_2}(x_2, \mu_F^2) \times$$

$$\times \int_0^1 dz \, \delta\left(z - \frac{M_H^2}{s x_1 x_2}\right) z \sigma^0 G_{ij}(z, \mu_R^2, \mu_F^2)$$

I) Complete factorization $G_{ij} \to (1 + \delta_{EW}) G_{ij}$

$\Rightarrow$ multiply NNLO QCD result $\times$ EW correction factor at NLO

II) No factorization $G_{ij} \to G_{ij} + \alpha_S^2 \delta_{EW} G_{ij}^{(0)}$

$\Rightarrow$ add NLO EW to NNLO QCD corrections

- effective-theory computation of mixed three-loop EW and QCD effects by Anastasiou,Boughezal,Petriello'08 supports the hypothesis of a complete factorization at the pragmatic level

Conclusions

- Performed a complete computation of the NLO EW corrections to $gg \to H$; all contributions evaluated for any value of M_H; corrections range between $+6\%$ for $M_H = 150$ GeV (light fermions) and -4% for $M_H \sim 2\,M_t$ (top-quark diagrams)

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- Full implementation of the complex-mass scheme needed to avoid large effects at two-particle thresholds; for $M_H = 2\,M_W$, corrections reduced from $+10\%$ (almost naive introduction of finite-width effects) to $+5\%$ (CMS in all terms)

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- Results included by `Anastasiou-Boughezal-Petriello '08` and `de Florian-Grazzini '09` for most updated prediction for σ_H at hadron colliders

Practical implementation of the CMS

Practical implementation of the complex-mass scheme through two steps:

1. Replace on-shell masses M_V^2 with complex poles $s_V = \mu_V(\mu_V - i\gamma_V)$
2. Trade the real parts of the W and Z self-energies (mass renormalization at 1 loop) for the complete self-energies, including imaginary parts

$\Rightarrow$ Replace the conventional on-shell mass renormalization equations with the associated expressions for the complex poles of the W and Z bosons

$$m_i^2 = M_i^2 \left[1 + \frac{G_F M_W^2}{2\sqrt{2}\,\pi^2} \mathrm{Re}\Sigma_i^{(1)}(M_i^2)\right] \quad \Rightarrow \quad m_i^2 = s_i \left[1 + \frac{G_F s_W}{2\sqrt{2}\,\pi^2} \Sigma_i^{(1)}(s_i)\right]$$

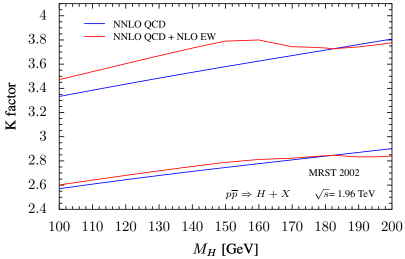
$\Rightarrow$ Insert the full self-energy for the W boson in the renormalization equation for the Fermi-coupling constant, expressed through the complex mass of the W, s_W

$$g = 2\left(\sqrt{2} G_F s_W\right)^{1/2} \left[1 - \frac{G_F s_W}{4\sqrt{2}\,\pi^2}\Delta\right], \Delta = \Sigma_W^{(1)}(0) - \Sigma_W^{(1)}(s_W) + 6 + \frac{7 - 4 s_\theta^2}{2 s_\theta^2} \ln c_\theta^2$$

CMS $\to$ replacements done also at the level of the couplings $\Rightarrow s_\theta^2 = 1 - s_W/s_Z$

NLO EW corrections at the Tevatron

Impact of NLO EW effects at Tevatron II, $\sqrt{s} = 1.96$ TeV,
100 GeV $< M_H <$ 200 GeV (using HIGGSNNLO, by M.Grazzini)

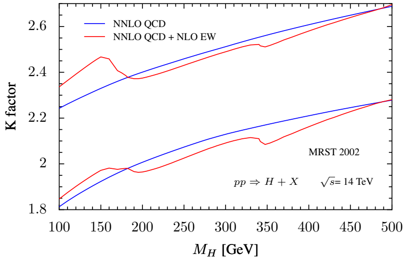


M_H [GeV]	δ_{CF} [%]	δ_{PF} [%]
120	$+4.9$	$+1.6$
140	$+5.7$	$+1.8$
160	$+4.8$	$+1.5$
180	$+0.5$	$+0.1$
200	-2.1	-0.6

- Uncertainty band shows stronger sensitivity on the Higgs mass, once NLO EW effects are included
- Impact of NLO EW corrections smaller respect to NNLL resummation `Catani,de Florian,Grazzini,Nason'03` ($+12$ % for $M_H = 120$ GeV)
- Effective-theory computation of **mixed three-loop EW and QCD effects** by `Anastasiou,Boughezal,Petriello'08` supports the hypothesis of a complete factorization at the pragmatic level

NLO EW corrections at the LHC

Impact of NLO EW effects at LHC, $\sqrt{s} = 14$ TeV,
100 GeV $< M_H <$ 500 GeV (using HIGGSNNLO, by M.Grazzini)



M_H [GeV]	δ_{CF} [%]	δ_{PF} [%]
120	$+4.9$	$+2.4$
150	$+5.9$	$+2.8$
200	-2.1	-1.0
310	-1.7	-0.9
410	-0.8	-0.8

- Uncertainty band shows stronger sensitivity on the Higgs mass, once NLO EW effects are included
- *WW* and $t\bar{t}$ thresholds visible, but smooth having introduced everywhere CMs
- Impact of NLO EW corrections comparable to that of NNLL resummation `Catani,de Florian,Grazzini,Nason'03` ($+6$ % for $M_H = 120$ GeV); for large M_H NLO EW corrections turn negative, screening effect with NNLL resummation