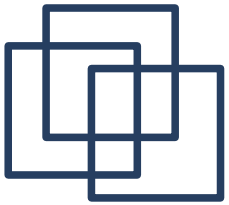

QCD-EW Correction and a New Prediction for gg → H in SM

Radja Boughezal

ITP, University of Zurich

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In collaboration with:

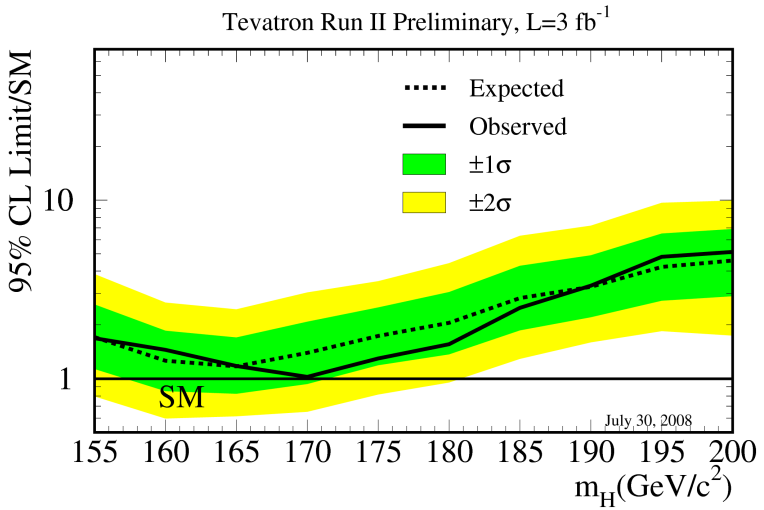
C. Anastasiou & F. Petriello

The excluded SM Higgs of M_H =170GeV at Tevatron (2008)

Combined CDF-D0 results (2008)

The Tevatron observed 95% CL upper limit on the xsection vs the predicted SM xsection

$M_H = 170\,GeV$ is excluded !



What went into the predicted xsection:

- the complete factorization assumption was used
- b-quark contributions with the same QCD enhancement as top Catani et al (2003)

$120\text{GeV} \le M_H \le 180\text{GeV} : 1.2 \le K_{tb}^{NLO}, K_{bb}^{NLO} \le 1.5$ Whereas $K_t^{NNLO} \sim 2.1$

- old PDFs (MRST2002)

$$\sigma_{QCD}^{NNLO} = \sigma^{(0)} G_{ij}(z;\alpha_s) + \sigma_b^{(0)} G_{ij}^{(0)}(z) K_{bb} + \sigma_{t,b}^{(0)} G_{ij}^{(0)}(z) K_{tb} \quad ,$$

$$\sigma_{EW}^{LO} = \sigma_{t,lf}^{(0)} G_{ij}^{(0)}(z) \quad ,$$

$$\sigma_{EW}^{NLO} = \sigma_{t,lf}^{(0)} \left\{ G_{ij}^{(0)}(z) \left[1 + a_s(C_{1w} - C_{1q})\right] + a_s G_{ij}^{(1)}(z) \right\} \quad ,$$

$$a_s = \frac{\alpha_s}{\pi}$$

$$\sigma_{EW}^{NNLO} = \sigma_{t,lf}^{(0)} \left\{ G_{ij}^{(0)}(z) \left[1 + a_s(C_{1w} - C_{1q}) + a_s^2 (C_{2w} - C_{2q} + C_{1q}(C_{1q} - C_{1w})\right] + a_s G_{ij}^{(1)}(z) \left[1 + a_s(C_{1w} - C_{1q})\right] + a_s^2 G_{ij}^{(2)} \right\} \quad ,$$

$$\sigma_{EW}^{NNLO\,CF} = \sigma_{t,lf}^{(0)} G_{ij}(z;\alpha_s) \quad ,$$

$$\sigma^{best} = \sigma_{QCD}^{NNLO} + \sigma_{EW}^{NNLO} \quad .$$

$$\sigma_b^{(0)} = \frac{G_F \alpha_s^2}{512\sqrt{2}\pi} |\mathcal{G}_b|^2,$$

$$\sigma_{t,b}^{(0)} = \frac{G_F \alpha_s^2}{512\sqrt{2}\pi} \left[2\,\mathrm{Re}\left(\mathcal{G}_t \mathcal{G}_b^*\right)\right],$$

$$\sigma_{t,lf}^{(0)} = \frac{G_F \alpha_s^2}{512\sqrt{2}\pi} \left[2\,\mathrm{Re}\left(\mathcal{G}_t \mathcal{G}_{lf}^*\right)\right]$$

$$G_{ij}(z;\alpha_s) = \sum_{n=0}^{\infty} \left(\frac{\alpha_s}{\pi}\right)^n G_{ij}^{(n)}(z)$$

$$G_{ij}^{(0)}(z) = \delta_{ig}\delta_{jg}\delta(1-z)$$

QCD corrections to top for large M_t

Note: tb-contribution is negative

Our Goals (Anastasiou, RB, Petriello (2008)):

- Check the validity of complete factorization assumption
- Provide most up-to-date QCD prediction of $\sigma(g\,g \to H)$ with best current estimates of K-factors and newest PDFs

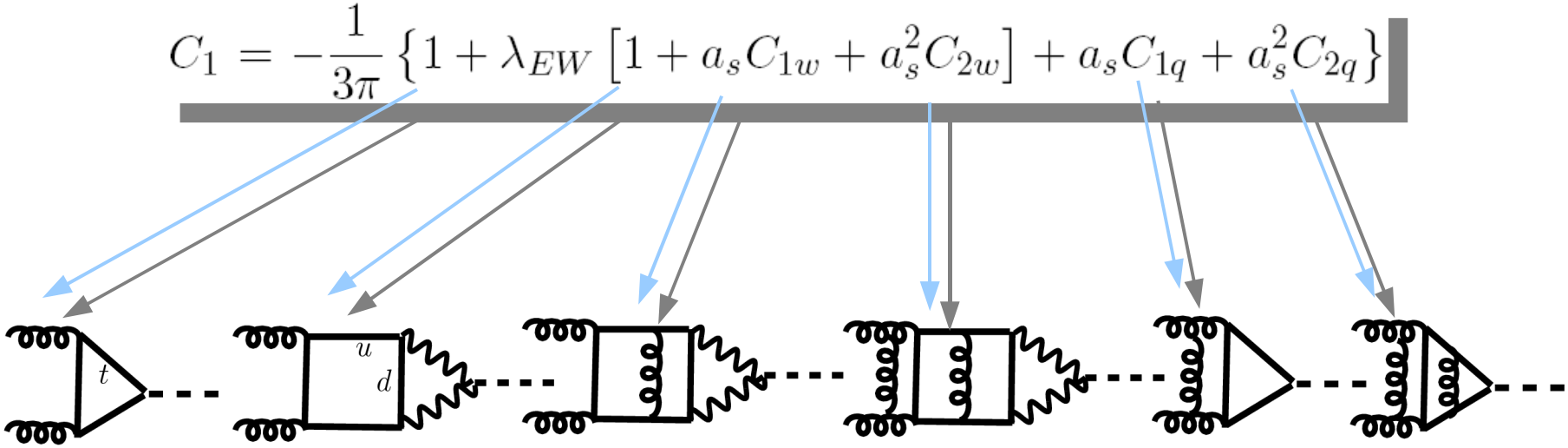
An effective theory with $M_H < M_W$

Checking Complete Factorization assumption requires $O(\alpha\alpha_s)$ and $O(\alpha\alpha_s^2)$

- Integrate the W out and calculate leading term of $O(\alpha\alpha_s)$
- Estimate the effect of $O(\alpha\alpha_s^2)$

$$L_{eff} = -\alpha_s \frac{C_1}{4v} H G^a_{\mu\nu} G^{a\mu\nu}$$

$$C_1 = -\frac{1}{3\pi}\left\{1 + \lambda_{EW}\left[1 + a_s C_{1w} + a_s^2 C_{2w}\right] + a_s C_{1q} + a_s^2 C_{2q}\right\}$$



An effective theory with $M_H < M_W$

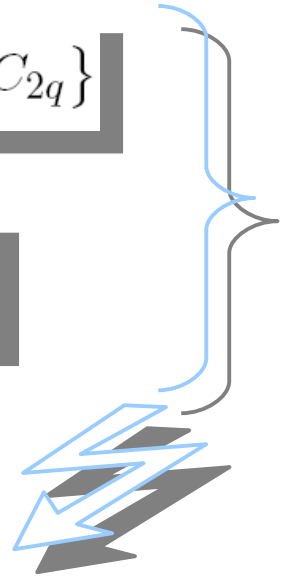
Checking Complete Factorization assumption requires $O(\alpha\alpha_s)$ and $O(\alpha\alpha_s^2)$

- Calculate leading term of $O(\alpha\alpha_s)$ for $M_H < M_W$
- Estimate the effect of $O(\alpha\alpha_s^2)$

$$L_{eff} = -\alpha_s \frac{C_1}{4v} H G^a_{\mu\nu} G^{a\mu\nu}$$

$$C_1 = -\frac{1}{3\pi}\left\{1 + \lambda_{EW}\left[1 + a_s C_{1w} + a_s^2 C_{2w}\right] + a_s C_{1q} + a_s^2 C_{2q}\right\}$$

$$C_1^{fac} = -\frac{1}{3\pi}\left(1 + \lambda_{EW}\right)\left\{1 + a_s C_{1q} + a_s^2 C_{2q}\right\}$$



Factorization holds if $C_{1w} = C_{1q}$ & $C_{2w} = C_{2q}$?

Results I

$C_{1w} = \frac{7}{6}$ to be compared with $C_{1w}^{fac} = C_{1q} = 11/4$

$$
\begin{aligned}
\sigma_{QCD}^{NNLO} &= \sigma^{(0)} G_{ij}(z;\alpha_s) + \sigma_b^{(0)} G_{ij}^{(0)}(z) K_{bb} + \sigma_{t,b}^{(0)} G_{ij}^{(0)}(z) K_{tb} \quad , \\
\sigma_{EW}^{LO} &= \sigma_{t,lf}^{(0)} G_{ij}^{(0)}(z) \quad , \\
\sigma_{EW}^{NLO} &= \sigma_{t,lf}^{(0)} \left\{ G_{ij}^{(0)}(z) \left[1 + a_s (C_{1w} - C_{1q})\right] + a_s G_{ij}^{(1)}(z) \right\} \quad , \\
\sigma_{EW}^{NNLO} &= \sigma_{t,lf}^{(0)} \left\{ G_{ij}^{(0)}(z) \left[1 + a_s (C_{1w} - C_{1q}) + a_s^2 (C_{2w} - C_{2q} + C_{1q}(C_{1q} - C_{1w})\right] \right. \\
&\quad \left. + a_s G_{ij}^{(1)}(z) \left[1 + a_s (C_{1w} - C_{1q})\right] + a_s^2 G_{ij}^{(2)} \right\} \quad , \\
\sigma_{EW}^{NNLO\,CF} &= \sigma_{t,lf}^{(0)} G_{ij}(z;\alpha_s) \quad , \\
\sigma^{best} &= \sigma_{QCD}^{NNLO} + \sigma_{EW}^{NNLO} \quad .
\end{aligned}
$$

pure QCD-contributions dominate: Suppressed by $\frac{\alpha_s}{\pi}, \left(\frac{\alpha_s}{\pi}\right)^2$

Results

$$
\begin{aligned}
\sigma_{QCD}^{NNLO} &= \sigma^{(0)} G_{ij}\left(z;\alpha_s\right) + \sigma_b^{(0)} G_{ij}^{(0)}\left(z\right) K_{bb} + \sigma_{t,b}^{(0)} G_{ij}^{(0)}\left(z\right) K_{tb} \quad , \\
\sigma_{EW}^{LO} &= \sigma_{t,lf}^{(0)} G_{ij}^{(0)}\left(z\right) \quad , \\
\sigma_{EW}^{NLO} &= \sigma_{t,lf}^{(0)} \left\{ G_{ij}^{(0)}\left(z\right)\left[1 + a_s(C_{1w} - C_{1q})\right] + a_s G_{ij}^{(1)}\left(z\right) \right\} \quad , \\
\sigma_{EW}^{NNLO} &= \sigma_{t,lf}^{(0)} \left\{ G_{ij}^{(0)}\left(z\right)\left[1 + a_s(C_{1w} - C_{1q}) + a_s^2\left(C_{2w} - C_{2q} + C_{1q}(C_{1q} - C_{1w})\right]\right. \right. \\
&\quad \left. \left. + a_s G_{ij}^{(1)}\left(z\right)\left[1 + a_s(C_{1w} - C_{1q})\right] + a_s^2 G_{ij}^{(2)} \right\} \quad , \\
\sigma_{EW}^{NNLO\,CF} &= \sigma_{t,lf}^{(0)} G_{ij}\left(z;\alpha_s\right) \quad , \\
\sigma^{best} &= \sigma_{QCD}^{NNLO} + \sigma_{EW}^{NNLO} \quad .
\end{aligned}
$$

used MRST 2008 PDFs

Included are:

- NNLO K-factor computed in large M_t and normalized to exact LO top-result
- $O(\alpha)$ (exact results by Actis et al (2008)) & new $O(\alpha\,\alpha_s)$ light-quark results
- b-quark results with excat NLO K_{tb}, K_{bb}

Results 2

An example : MH=170GeV (σ in pb)

original	MSTW 2008 PDFs	K_{tb}, K_{bb}	EW effects
0.3542	0.3212	0.3377	0.3444

A decrease of 6% in xsection !

Results 2: New Prediction

Tevatron

m_H[GeV]	σ^{best}[pb]	m_H[GeV]	σ^{best}[pb]
110	1.417 ($\pm$7% pdf)	160	0.4344 ($\pm$9% pdf)
115	1.243 ($\pm$7% pdf)	165	0.3854 ($\pm$9% pdf)
120	1.094 ($\pm$7% pdf)	170	0.3444 ($\pm$10% pdf)
125	0.9669 ($\pm$7% pdf)	175	0.3097 ($\pm$10% pdf)
130	0.8570 ($\pm$8% pdf)	180	0.2788 ($\pm$10% pdf)
135	0.7620 ($\pm$8% pdf)	185	0.2510 ($\pm$10% pdf)
140	0.6794 ($\pm$8% pdf)	190	0.2266 ($\pm$11% pdf)
145	0.6073 ($\pm$8% pdf)	195	0.2057 ($\pm$11% pdf)
150	0.5439 ($\pm$9% pdf)	200	0.1874 ($\pm$11% pdf)
155	0.4876 ($\pm$9% pdf)	–	–

- Values for xsection are 4-6% lower than used in 2008 exclusion by Tevatron for MH = 150-170 GeV
- Theoretical uncertainty from scale dependence obtained by varying $\mu \in [\frac{M_H}{4}, M_H]$ → [-11%, +7%]
- PDF errors estimated using error eigenvectors provided with MRST2008 fit

New results accounted for in new Tevatron analysis: extended exclusion range to 160-170GeV

Summary

1) Checked the validity of factorization of QCD & EW corrections by calculating leading term of 3-loop $O(\alpha\alpha_s)$ in $gg \to H$ due to diagrams with light quarks

It is violated

However effect on cross section is screened due to the structure of QCD corrections

2) Provided an updated theoretical prediction for inclusive $\sigma(g\,g \to H)$ with best current estimates of K-factors and newest PDFs (MRST2008)

Updated prediction is 5% lower than what was previously used by Tevatron in 2008 exclusion

New results accounted for in new Tevatron analysis:
extended exclusion range to 160-170GeV arXiv:0903.4001 [hep-exp]