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Higgs Production in pp Collisions: QCD Corrections*

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ABSTRACT

Gluon fusion is the main production mechanism of Higgs bosons at the LHC and SSC for Higgs masses below ~ 700 GeV. The coupling of the Higgs to two gluons is built-up by quark-loops with heavy quarks giving the dominant contribution. The [two loop] QCD corrections to this process will be presented for arbitrary Higgs and top masses. This study includes the production of the Standard Model Higgs boson as well as of the neutral $\mathcal{CP}$-even and -odd $\mathcal{SUSY}$-Higgs particles. We find large corrections which cannot be neglected in experimental analyses of this production mechanism.

1. Higgs Production in the $\mathcal{SM}$

Within the Standard Model [$\mathcal{SM}$] the coupling of the Higgs boson to two gluons is mediated by a quark triangle. The lowest order cross section for gluon fusion can be found in.[1,2] Heavy quarks yield the dominant contribution to this cross section so that only the top quark will be considered in the $\mathcal{SM}$ case. Gluon fusion is the leading production mechanism of Higgs bosons at the LHC and SSC for Higgs masses below ~ 700 GeV with a cross section ranging between 0.1 and 100 *pb*.

QCD corrections to gluon fusion have been calculated for arbitrary Higgs and quark masses. The [two loop] virtual corrections require the calculation of five dimensional Feynman integrals which have been reduced analytically to one dimensional ones extracting ultraviolett, infrared and collinear singularities in n dimensions. The strong coupling constant α_s is renormalized in the $\overline{MS}$-scheme and the quark mass on shell.

To get an infrared finite cross section one has to add the [one loop] real corrections consisting of three incoherent processes: $gg \to Hg$, $gq \to Hq$ and $q\bar{q} \to Hg$.

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Performing phase space integration in n dimensions one picks up the infrared and collinear poles cancelling the corresponding ones from the virtual corrections. Finally collinear poles are left which have to be absorbed into the renormalized NLO structure functions, defined in the $\overline{MS}$ factorization scheme.

The final result yields a finite cross section for the gluon fusion process.[2] The very heavy quark limit agrees with former calculations[3] and can also be computed from a low energy theorem deduced from the trace anomaly of the energy momentum tensor Θ^μ_μ.[4] The QCD corrections, shown in Fig.1, are large and positive ranging from 50 to 80%. The dependence on the renormalization and factorization scales is reduced by about a factor 2 compared to the lowest order cross section so that the prediction stabilizes theoretically. The effect of different parametrizations of parton densities is rather strong amounting about 30%, but will be reduced by the HERA experiments.

2. Higgs Production in the $\mathcal{MSSM}$

The minimal supersymmetric extension of the Standard Model [$\mathcal{MSSM}$] contains five scalar Higgs particles, two neutral scalars h, H [$\mathcal{CP}$-even], one neutral pseudoscalar A [$\mathcal{CP}$-odd] and two charged ones $H^\pm$. The lowest order cross section of the pseudoscalar Higgs production by gluon fusion has been computed in,[6,9] whereas the scalar case is changed only by the inclusion of $\mathcal{SUSY}$-couplings compared to the $\mathcal{SM}$. Heavy quarks produce the leading contribution to these processes. However, depending on the $\mathcal{SUSY}$ parameter tanβ bottom quarks could provide for larger contributions to the cross sections than top quarks. The cross sections range between 0.1 and $10^5 pb$ at the LHC and SSC.

The calculation of the QCD corrections to the pseudoscalar case is performed analogous to the scalar process. The axial coupling γ_5 is defined in the 't Hooft–Veltman scheme[7] requiring the subtraction of spurious anomalies which destroy the Ward identities resulting in the introduction of a new counter term at the $A\bar{q}q$ vertex.[8] The final result for pseudoscalar production looks formally identical to the scalar case.[9] In the heavy quark limit the only difference to the scalar production appears in the virtual corrections. This limit can also be derived from a low energy theorem based on the non-renormalization of the Adler–Bell–Jackiw anomaly.[10]

The virtual corrections to the pseudoscalar process contain a Coulombic singularity at the threshold $m_A = 2m_Q$ originating from the equality of the quantum numbers of the pseudoscalar A and the 0^{-+} ground state of the $(\overline{q}q)$ quarkonium. Therefore one expects resonance formation at the threshold resulting in the appearance of a Coulombic singularity in perturbation theory. Within a few GeV around the threshold this perturbative calculation cannot be applied anymore.

The QCD corrections to Higgs production in the $\mathcal{MSSM}$ are large ranging up to factors of about 2. They are collected in Table 1 for a top mass of 140 GeV and some representative values of tanβ and the Higgs masses.

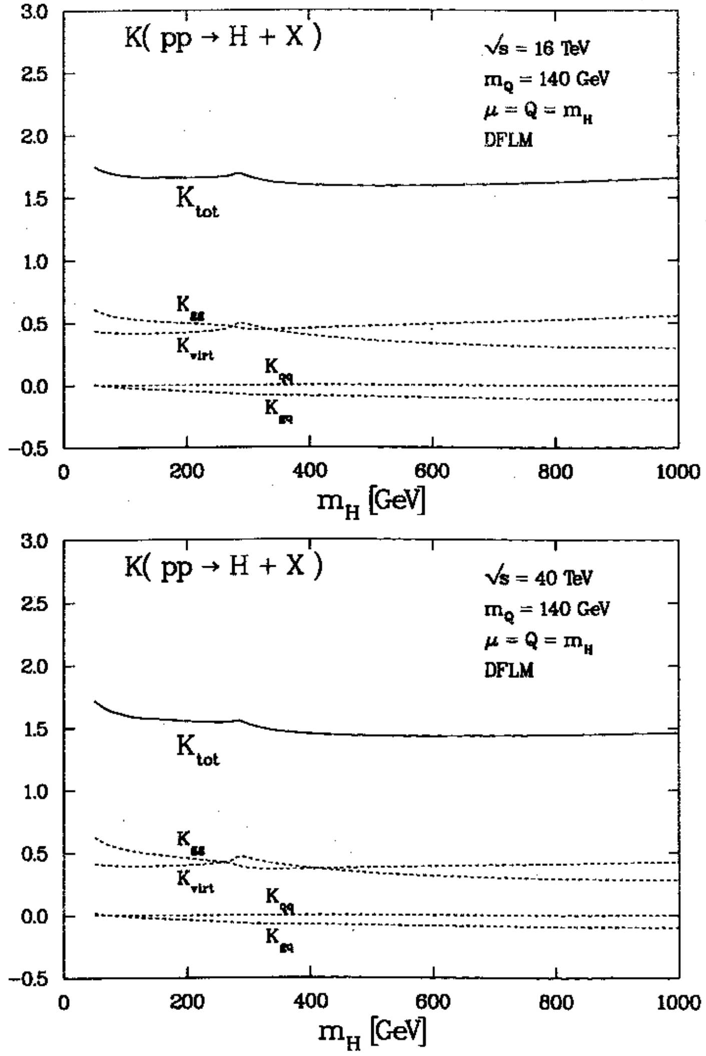

Fig.1: K factors of the QCD corrected cross sections $\sigma(pp \to H + X)$ for the LHC [$\sqrt{s} = 16$ TeV] and the SSC [$\sqrt{s} = 40$ TeV] using the DFLM parametrization of the parton densities.[5] Also shown are the individual contributions of the [infrared regularized] virtual corrections K_{virt} and the real ones K_{ij} [$i, j = g, q$].

Table 1: K factors for gluon fusion at the LHC [$\sqrt{s} = 14$ TeV] and the SSC [$\sqrt{s} = 40$ TeV] using the GRV parametrizations of the parton densities.[11]

tanβ = 1.5

Φ	m_Φ [GeV]	K [LHC]	K [SSC]
h	40	1.16	0.99
	60	1.55	1.38
	70	1.56	1.37
H	120	1.44	1.23
	300	1.63	1.37
	500	1.61	1.37
	1000	1.68	1.46
A	100	1.64	1.45
	310	1.64	1.39
	490	1.60	1.36
	1000	1.65	1.44

tanβ = 30

Φ	m_Φ [GeV]	K [LHC]	K [SSC]
h	40	0.96	0.79
	70	1.03	0.85
	110	1.57	1.38
H	110	1.40	1.20
	310	1.26	1.01
	490	1.30	1.04
	1000	1.42	1.15
A	100	1.06	0.86
	310	1.32	1.08
	490	1.42	1.16
	1000	1.53	1.29

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