PRODUCTION OF NEUTRAL HIGGS + JET AT THE LHC IN THE SM AND THE MSSM*

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The cross section prediction for the production of the lightest neutral Higgs boson in association with a high-p_T hadronic jet is presented in the framework of the minimal supersymmetric standard model (MSSM) and compared to the SM case. Prospects for the CERN Large Hadron Collider (LHC) are discussed.

1. Higgs + Jet in the Standard Model

The production of SM Higgs bosons in hadron collisions at the LHC will proceed mainly via gluon fusion ($gg \to H$). The detection of a SM Higgs boson with a mass below 140 GeV at the LHC is rather difficult because the predominant decay into a $b\bar{b}$-pair is swamped by the large QCD two-jet background [1]. Therefore, only through observation of the rare decay into two photons, is the inclusive single Higgs boson production considered the best search channel in this mass range at the LHC.

Alternatively, and in order to fully explore the Higgs-detection capabilities of the LHC detectors, one can investigate more exclusive channels like e.g. Higgs production in association with a high-p_T hadronic jet. The main advantage of this channel is the richer kinematical structure of the events which allows for refined cuts increasing the signal-to-background ratio. Recently, a detailed simulation[2] of the SM reaction $pp \to H + \text{jet} + X, H \to \gamma\gamma$ using the basic cuts $p_{T,\text{jet}} \geq 30\,\text{GeV}$, $|\eta_{\text{jet}}| \leq 4.5$ showed that this process

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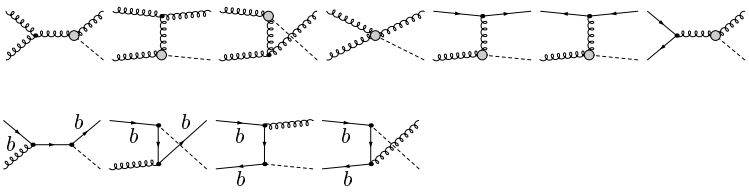

Figure 1. Partonic processes contributing to $pp \to H + \text{jet} + X$ in the SM. Hatched circles represent loops of heavy quarks. The depicted tree-level b-quark processes are much more important in the MSSM case.

is a promising alternative or supplement to the inclusive Higgs-boson production for $m_H < 140\,\text{GeV}$.

The partonic processes, calculated at present to leading order[3], contributing to the hadronic reaction $pp \to H + \text{jet} + X$ (see Fig. 1) are gluon fusion ($gg \to gH$, 50–70 % of total rate), quark–gluon scattering ($q(\bar{q})g \to q(\bar{q})H$, 30–50 % of total rate) and quark–antiquark annihilation ($q\bar{q} \to gH$, rate small). The hadronic cross section is dominated by loop-induced processes, involving effective ggH– and $ggHZ$–couplings. If the b-quark is treated as a parton present in the proton, there are additional tree-level processes for quark-gluon scattering and quark-antiquark annihilation to consider. Yet, in the SM their contribution to the hadronic cross section is small.

2. Higgs + Jet in the MSSM

Motivated by the promising SM simulation[2] we investigated[4] the MSSM process $pp \to h^0 + \text{jet} + X$, involving the lightest MSSM Higgs boson. Especially, as the process is essentially loop-induced, there are potentially large effects from virtual superpartners to be expected.

In the MSSM, the contributing partonic processes are basically the same as in the SM, *i.e.* $gg \to gh^0, q(\bar{q}) \to q(\bar{q})h^0, q\bar{q} \to gh^0$, but there are differences resulting from various sources: (i) different Yukawa couplings in the MSSM involving the mixing angles α and β of the MSSM Higgs sector. Especially, the b-quark processes are enhanced for small values of the CP-odd Higgs boson mass m_A ($< 150\,\text{GeV}$) and large $\tan\beta$ in the MSSM. (ii) Additional superpartner contributions to the amplitudes, squark-loop insertions for all SM-like topologies displayed in Fig. 1 and new Feynman graph topologies containing at least one gluino line (Fig. 2). The calculation of the partonic processes was done with the help of FeynArts/FormCalc[5].

Figure 2. Additional topologies for the loop-induced process $qg \to qh^0$ and $q\bar{q} \to gh^0$ in the MSSM. The hatched circles represent loops containing at least one gluino line.

3. Results

The partonic cross sections $\hat{\sigma}_{nm}(\hat{s})$ determine the hadronic cross section for $pp \to h^0 + \text{jet} + X$ via the convolution

$$\sigma = \int_{\tau_0}^{1} d\tau \left(\frac{dL_{gg}^{pp}}{d\tau}\, \hat{\sigma}_{gh^0}(\tau S) + \sum_q \frac{dL_{qg}^{pp}}{d\tau}\, \hat{\sigma}_{qh^0}(\tau S) + \sum_q \frac{dL_{q\bar{q}}^{pp}}{d\tau}\, \hat{\sigma}_{gh^0}(\tau S) \right) ,$$

with parton luminosities $dL_{nm}^{AB}/d\tau$, and $\sqrt{S} = 14\,\text{TeV}$ for the LHC. The cuts $p_{T,\text{jet}} \geq 30\,\text{GeV}$ and $|\eta_{\text{jet}}| \leq 4.5$ specify τ_0 and the angular-integration limits; they are chosen as in the SM analysis[2].

Figs. 3(a),(b) show results for the MSSM $m_h^{\max}$ benchmark scenario[6] with a common squark-mass scale $M_{\text{SUSY}} = 400\,\text{GeV}$. For small values of the CP-odd Higgs boson mass m_A ($< 150\,\text{GeV}$) and especially for large $\tan\beta$, the b-quark Yukawa coupling is strongly enhanced compared to the top-Higgs coupling. Thus, in this parameter range, the b-quark processes dominate the hadronic cross section, and also the loop-induced processes are dominated by the b-quark loops. At large m_A ($> 200\,\text{GeV}$), the coupling of the b–Higgs coupling is much smaller than the top–Higgs coupling and therefore the loop-induced processes dominate. For $m_A = 400\,\text{GeV}$, and almost independently of $\tan\beta$, the full result is reduced by 24% compared to the result with quark loops only. Fig. 3(c) shows the M_{SUSY}–dependence of the hadronic cross section with and without superpartner contributions for the three benchmark scenarios[6]. (The large-μ scenario had to be modified[4] in order to obey the exclusion limit for the Higgs mass set by LEP data.) For moderate, but allowed, squark masses the contribution of superpartners is significant. In Fig. 3(d) we display the relative difference between the MSSM $m_h^{\max}$ scenario and the SM prediction of the hadronic cross section plotted versus m_A and $\tan\beta$. The MSSM prediction is more than 20% below the SM result (using the MSSM value of m_{h^0} for the SM Higgs mass) in the whole area of the m_A–$\tan\beta$ plane displayed.

In summary, Higgs + jet production is promising and deserves a closer look in LHC physics simulations. To that end we provide the FORTRAN

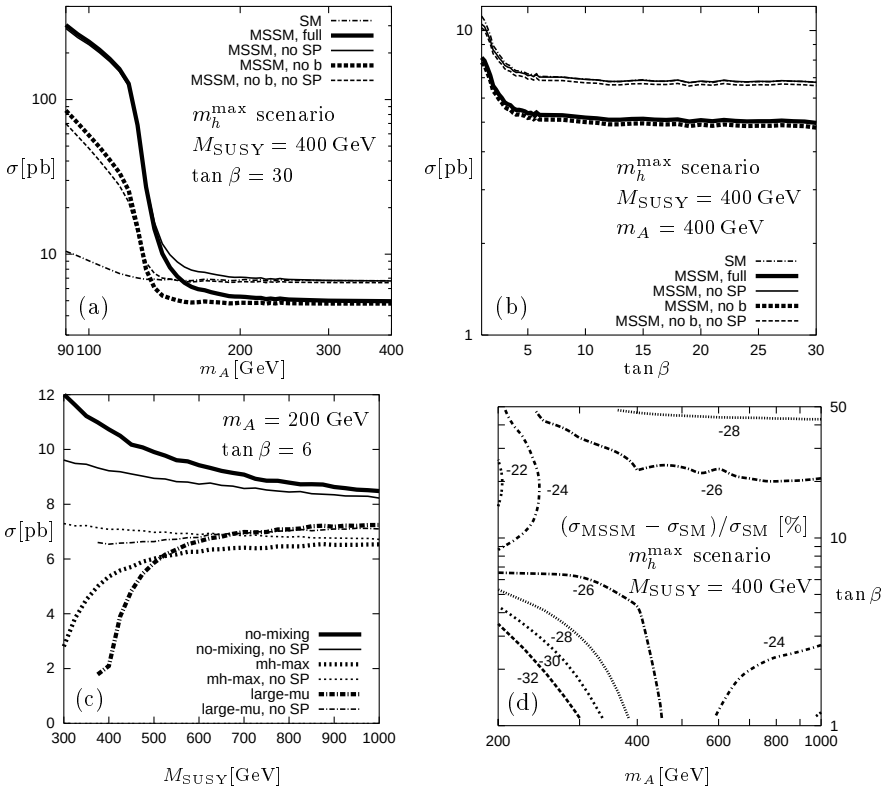

Figure 3. Hadronic cross sections in picobarn (a) as a function of m_A, (b) as a function of $\tan\beta$, both in the $m_h^{\max}$ scenario, (c) as function of $M_{\rm SUSY}$ for the three benchmark scenarios. (d) Relative difference of MSSM and SM prediction in the $m_h^{\max}$ scenario.

code for SM and MSSM predictions for general use.

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