Chapter 1

Higgs Production Through Gluon Fusion

Gluon fusion is one of the most promising discovery channel for Higgs bosons at LHC and therefore the calculation of production cross section for this process have been in great interest. As discussed in chapter 1, in the standard model gluon fusion is the most important channel to produce a pair of Higgs bosons through a quark loop of triangle and box. Even beyond the Standard model, in MSSM gluon fusion is the major source of neutral Higgs bosons at LHC for $tan\beta \leq 5$.

Higgs production via gluon fusion at hadron colliders have been studied by several groups in the past [glover][plehn et al][discus and kao]. A similar study has been published in [] recently after Higgs discovery. However this chapter gives a complete study of the production of neutral Higgs bosons with a gluon pair via top and bottom quark loop, followed by Higgs decay in to two pairs of bottom quarks ($gg \to \phi^0\phi^0 \to 2(b\bar{b})$) and one Higgs decay into a b pair and the other Higgs decay into leptons($gg \to (\phi^0 \to (b\bar{b})(\phi^0 \to (\tau\overline{\tau}))$. Higgs signal both in Standard Model and MSSM are calculated along with the dominant Standard Model(SM) backgrounds and several distributions are presented.

1.1 Two Higgs production in Standard Model

As can be seen from fig[], Gluon fusion has contributions from virtual box diagram and virtual triangle diagram. In triangle diagram an off shell Higgs particle is produced

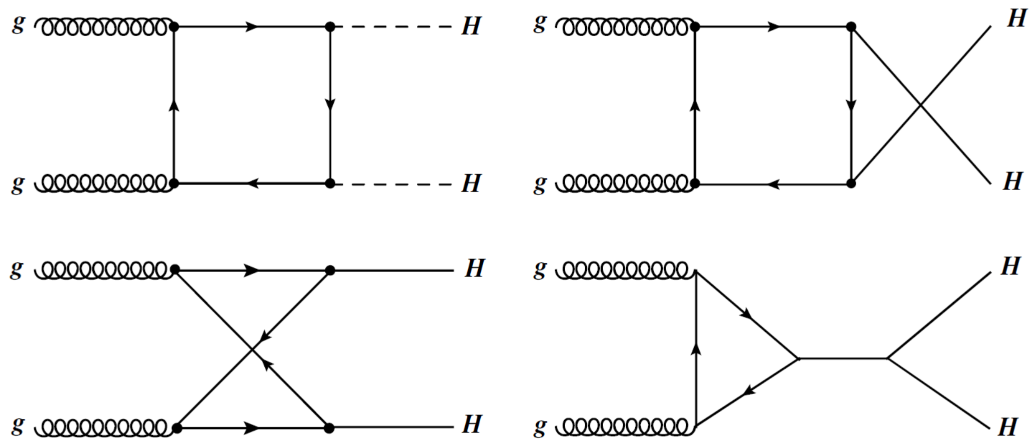

Figure 1.1: feynmann diagrams contributing for two higgs production via gluon fusion

which decays in to two real Higgs particles via three Higgs self couplings.

triangle and box amplitude calculation via tensor reduction (Pasarino Veltmann)

1.1.1 Calculation tools for the signal

The cross section of two Higgs production at LHC via gluon fusion was evaluated with $\sqrt{s} = 14\, TeV$. This process includes three box and one triangle loops given by figure[] at the order of α_s^3. Along the box and triangle loops the intermediate fermions are massive third generation quarks.The masses of these quarks for the Yukawa couplings[Appendix] are chosen to be the Next to the leading order(NLO) running masses which are calculated at the pole masses of $m_t = 173.1 GeV$ and $m_b = 4.7 GeV$. The renormalization scale is set to be $\mu_R = \sqrt{\hat{s}}$ for the calculation of strong coupling. The signal cross sections are computed using CTEQ6L1[] parton distribution functions(pdfs) with the factorization scale of $\mu_F = \sqrt{\hat{s}}$. The transition amplitudes for loops were calculated using tensor reduction procedure explained by Passarino and Veltmann[], all tensors are reduced to scalar integrals in terms of D_0, C_0, B_0 and A_0 using FORM[]. The cross section is calculated for three higgs masses around the actual Higgs mass and the contributions from triangle diagram and box diagrams are presented in table[] along with total cross section for each mass. The results also were compared to the cross sections presented in xxxxxxx et. al [] using pdfs from MSTW2008 and they were withing uncertainty.

Cross section	$M_H = 123GeV$	$M_H = 126$ GeV	$M_H = 129$ GeV
TRIANGLE	4.678	4.763	4.853
BOX	35.14	34.57	34.03
TOTAL	16.96	16.32	15.72

Table 1.1: Cross section in fb for standard model higgs pair production via gluon fusion

1.2 Higgs decay into $b\bar{b}$

Each Higgs produced by gluon fusion, decays in to $b\bar{b}$ was considered and cross section for $pp \to (h \to b\bar{b})(h \to b\bar{b})$ was calculated using Narrow width Approximation. Fig() shows the invariant-mass($M_{ij}, i, j = 1, 2, 3, 4$) distribution of the $b_i b_j$ pairs for the Higgs signal $pp \to b\bar{b}\, b\bar{b} + X$ via $gg \to HH$. Fig() represents the transverse-momentum distribution of the final state bottom quarks($b\; or\; \bar{b}$) and as can be seen from the figure, the bottom quarks are ordered according to their transverse momenta, $p_T(b_1) \geq p_T(b_2) \geq p_T(b_3) \geq p_T(b_4)$. We have required the cuts $p_t(b) > 20\, GeV$ and

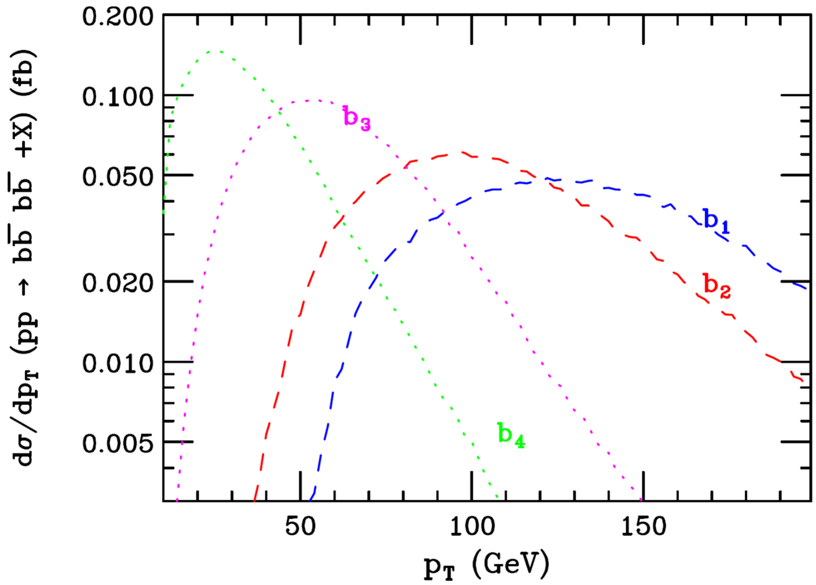

Figure 1.2: The transverse momentum distribution for the final b quarks produced generating the higgs signal from $pp \to (h \to b\bar{b})\ \ (h \to b\bar{b})$

$|\eta_b| < 2.5$ and we apply mass window of $M_\phi \pm \Delta M_{bb}$ where $\Delta M_{bb} = 0.15 M_\phi$ in this figure.

Cross section in fb	$MH = 123GeV$	$MH = 126$ GeV	$MH = 129$ GeV
$\sigma(gg- > hh- > 4b)$	7.02	5.89	4.79
BFBB	0.663	0.617	0.567

Table 1.2: Cross section in fb for $gg \to hh \to b\bar{b}b\bar{b} + X$ for standard model using pdfs from CTEQ6L1 BFBB is the branching ratio for each mass of Higgs

The calculated cross sections for the complete $\sigma(gg- > hh- > bbbb)$ with both

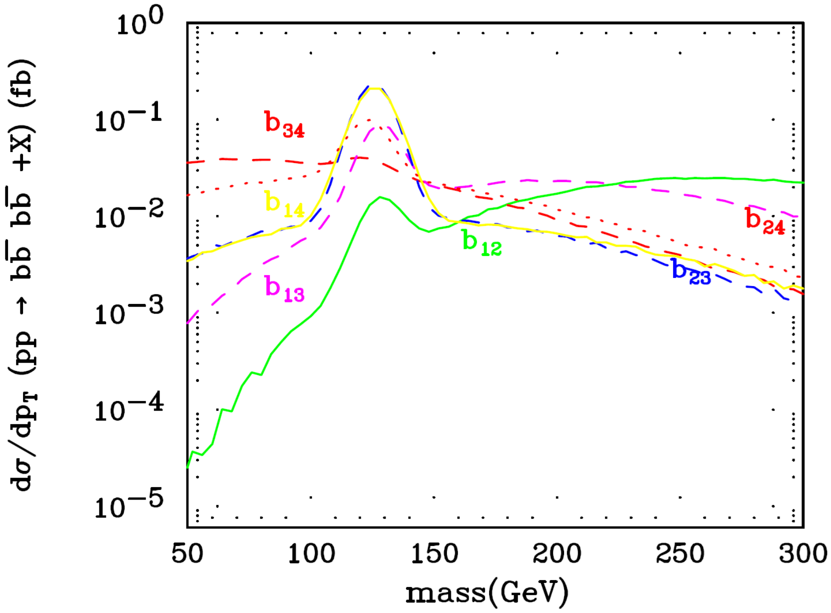

Figure 1.3: The invariant mass distribution for the Higgs signal from $gg- > hh \to b\bar{b}\, b\bar{b}$ with $M_h = 126\ GeV$

scales μ_F and μ_R of $sqrts$, with the choice pt and eta cuts for b quarks $P_T(b) \geq 10GeV$ and $|\eta_b| \leq 2.5$ are given in table[]. sectionHiggs decay into bb tautau Calculation

Cuts

Distributions

Cross sections

1.3 Two Higgs production in MSSM

Production of two neutral higgs through gluon fusion in MSSM is discussed here and fig[] shows the possible combinations of Feynmann diagrams for $pp \longrightarrow gg \longrightarrow \Phi_i\Phi_j$ where $\Phi_i = h, H, A$.

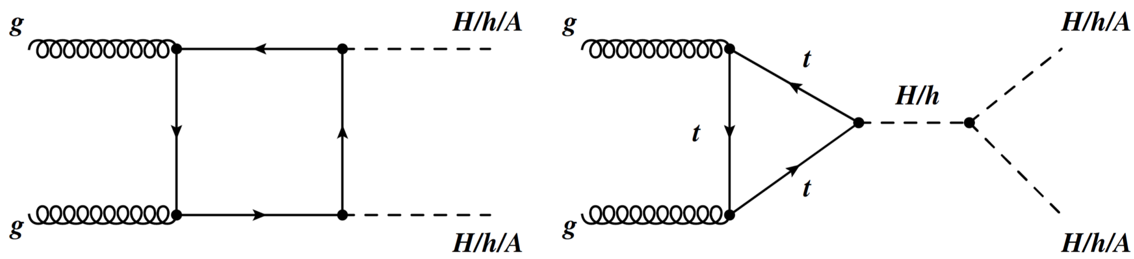

Figure 1.4: xxx

1.4 calculation tools

Feynman diagrams

Tanb values,couplings

Calculation/ scales/pdfs

1.5 mssm cross section gg-¿hh-¿4b

Cuts Distributions Cross sections for A/h/H

1.6 mssm cross section gg-¿hh-¿bbtata

Cuts Distributions Cross sections for A/h/H

1.7 possible backgrounds /contours

1.7.1 pp-¿4b

1.7.2 pp-¿bbtata

1.8 comparison

References