HIGGS BOSON PRODUCTION CHANNELS

S.K. Abdullayev, M.Sh. Gojayev, F.A. Saddigh
Baku State University, Azerbaijan
s_abdullayev@mail.ru, m_qocayev@mail.ru, f_seddig@yahoo.com

The standard model(SM) of strong and electroweak interaction is a gauge theory based on the symmetry group $SU_C(3)\times SU_L(2)\times U_Y(1)$ with massless particles. The mechanism that provides mass for all the particles is called spontaneous symmetry breaking (SSB):

$$SU_C(3)\times SU_L(2)\times U_Y(1)\to SU_C(3)\times U_{QED}(1).$$

The SSB is generated by the non-zero expectation of a SU(2) doublet and is called Higgs doublet. This doublet also gives rise to a scalar particle, the Higgs boson, which couples to all massive fields in the theory. Some experiments are carried out for the discovery of Higgs boson in different experimental labs. Finally at Tevatron and CERN new information are getting achieved concerning the existence of Higgs boson with the mass of 125 GeV.

In this work we analyze one of the most important channels for Higgs boson production at the electron-positron and proton-antiproton (proton-proton) collisions:

$$e^- + e^+ \Rightarrow H + Z^0, \tag{1}$$

$$p + \bar{p}(p+p) \Rightarrow H + Z^0 + X, \tag{2}$$

$$p + \bar{p}(p+p) \Rightarrow H + W + X. \tag{3}$$

The process (1) that we shall analyze is the one corresponding to a Z^0 boson production and radiated Higgs boson.

The total cross section of this process is given by:

$$\sigma(e^-e^+ \to HZ^0) = \frac{\pi\alpha^2}{x_w{}^2(1-x_w)^2}\cdot\frac{g_L{}^2(e)+g_R{}^2(e)}{(s-M_Z^2)^2+\Gamma_Z^2M_Z^2}\cdot\frac{q_H}{\sqrt{s}}\left(M_Z^2+\frac{1}{3}q_H^2\right). \tag{4}$$

Here $x_w=\sin^2\theta_w$, $g_L(e)=-\frac{1}{2}+x_w$, $g_R(e)=x_w$, θ_w is the Weinberg angle and

$$q_H=\frac{1}{2\sqrt{s}}.(s^2+M_H^4+M_Z^4-2sM_H^2-2sM_Z^2-2M_H^2M_Z^2)^{1/2}.$$

At the energy scale $\sqrt{s}$ =500 GeV and Weinberg's parameter x_w=0.232 the cross section (4) reaches 0.05 pb for the 125 GeV Higgs mass.

The second process that we analyze is the Higgs-strahlung process $p+\bar{p}\to H+Z^0+X$. The total hadronic cross section for the HZ^0 case takes this form:

$$\sigma(p\bar{p}\to HZ^0X)=\int_{\tau_0}^{1}dx_1\int_{\tau_0/x_1}^{1}dx_2u(x_1)u(x_2)\hat{\sigma}(u\bar{u}\Rightarrow HZ^0)+\int_{\tau_0}^{1}dx_1\int_{\tau_0/x_1}^{1}dx_2d(x_1)d(x_2)\hat{\sigma}(d\bar{d}\Rightarrow HZ^0).$$

Here $\tau_0=\frac{(M_H+M_Z)^2}{s}$ and x_1 and x_2 are called momentum fractions, $u(x_1)$, $u(x_2)$, $d(x_1)$ and $d(x_2)$ are the parton distribution functions for the quarks (they represent the probability density of finding a quark with momentum $x_{1,2}$ inside a proton) and

$$\sigma(q\bar{q} \Rightarrow HZ^0) = \frac{\pi\alpha^2}{N_c x_w^{\,2}(1-x_w)^2} \cdot \frac{g_L^2(q)+g_R^2(q)}{(\hat{s}-M_Z^2)^2+\Gamma_Z^2 M_Z^2} \cdot \frac{q_H}{\sqrt{\hat{s}}}\left(M_Z^2+\frac{1}{3}q_H^2\right). \quad (6)$$

Here $N_c = 3$ is the number of colours.

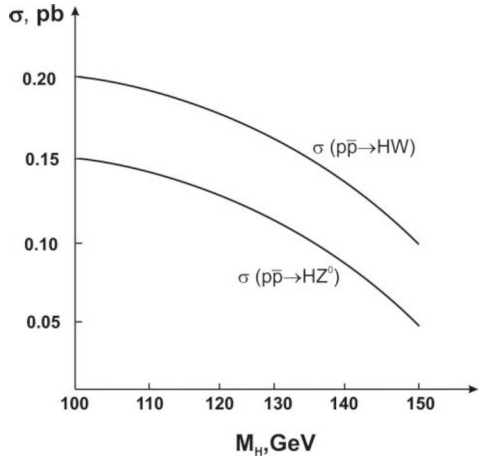
As for the HZ^0 process, we have the following:

$$\sigma(p\bar{p} \to HWX) = 2\int_{\tau_0}^{1} dx_1 \int_{\tau_0/x_1}^{1} dx_2 u(x_1) d(x_2) \hat{\sigma}(u\bar{d} \Rightarrow HW^+), \quad (7)$$

$$\hat{\sigma}(u\bar{d} \Rightarrow HW^+) = \frac{\pi\alpha^2}{N_c x_w^{\,2}} \cdot \frac{\cos^2\theta_c}{(\hat{s}-M_W^2)^2} \cdot \frac{q_H}{\sqrt{\hat{s}}}(M_H^2+\frac{1}{3}q_H^2). \quad (8)$$

The following plot shows the dependence of $\sigma(p\bar{p} \Rightarrow HZ^0X)$ and $\sigma(p\bar{p} \Rightarrow HWX)$ with the Higgs mass at the Tevatron energy $\sqrt{S} = 2TeV$.

As expected the cross section $\sigma(p\bar{p} \Rightarrow HWX)$ is the dominating one. It reaches 0,2 pb for 100 GeV Higgs mass.



Gluon fusion through a heavy-quark functions loop is the main production mechanism of the Higgs boson at hadron colliders:

$$g + g \Rightarrow H.$$

The cross section in the parton center of mass frame looked like

$$\hat{\sigma}(gg \Rightarrow H) = \frac{M_H^2}{64\eta^2} \cdot \frac{\alpha_s^2}{\pi} n^2 \,|D(n)|^2\, \delta(\hat{s}-M_H^2) \quad (9)$$

Let's express the Dirac delta function in term x_1, x_2 and $\tau_0 = M_H^2/S$:

$$\delta(\hat{s}-M_H^2) = \delta(x_1 x_2 S - M_H^2) = \frac{1}{x_1 S}\delta\left(x_2 - \frac{\tau_0}{x_1}\right).$$

The total integrated cross section is given by the expression:

$$\sigma(gg \Rightarrow H) = \int dx_1 \int dx_2 g(x_1,\mu) g(x_2,\mu) \hat{\sigma}(gg \Rightarrow H) =$$

$$= \frac{n^2}{64} \cdot \frac{\tau_0}{\eta^2} \cdot \frac{\alpha_s^2}{\pi} |D(n)|^2 \int_{\tau_0}^{1} \frac{dx_1}{x_1} g(x_1,\mu) g(\tau_0/x_1,\mu), \quad (10)$$

where $g(x_i,\mu)$ are the parton distribution function for the gluons, $n = \frac{m^2}{M_H^2}$, μ is the parton distribution functions energy scale.