HIGGS BOSON PRODUCTION IN ELECTRON-POSITRON SCATTERING

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The discovery of the mechanism for electroweak symmetry breaking is one of the goals of the physics programme at the Large Hadron Collider (LHC). In the standard model (SM) this symmetry breaking is achieved by introducing a complex scalar doublet, leading to the prediction of the Higgs boson. There are four main mechanisms for Higgs boson production in pp collisions. The gluon-gluon fusion mechanism has the largest cross section, followed in turn by vector boson fusion, associated *WH* and *ZH* production, and production in association with top quarks, $t\bar{t}H$.

In this work the Higgs boson production is studied during electron-positron scattering:

$$e^- + e^+ \Rightarrow H + e^- + e^+ . \qquad (1)$$

The Feynman diagrams for the process (1) are shown in Fig.1.

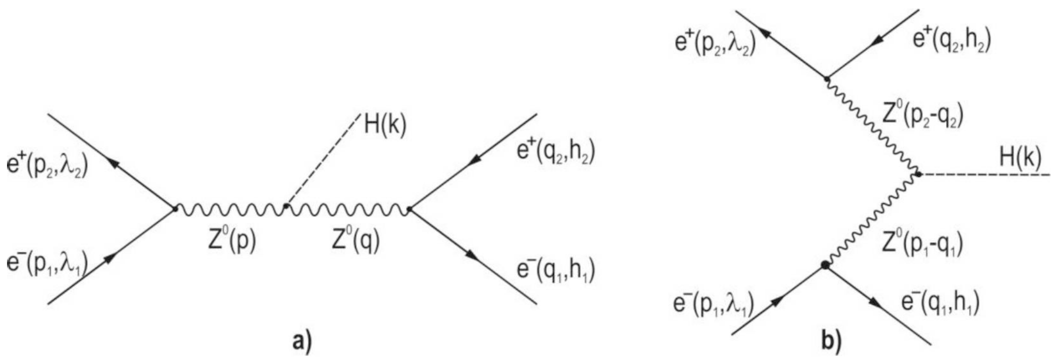

Fig. 1

The annihilation (s-channel) diagram a) correspond to four independent helicity amplitudes, which describe the process $e_L^- + e_R^+ \Rightarrow H + e_L^- + e_R^+$, $e_L^- + e_R^+ \Rightarrow H + e_R^- + e_L^+$, $e_R^- + e_L^+ \Rightarrow H + e_L^- + e_R^+$, $e_R^- + e_L^+ \Rightarrow H + e_R^- + e_L^+$, where $e_L^-(e_R^-)-$is an electron with helicity -1(+1).

The squared transition amplitudes of this processes are given by:

$$\begin{aligned}
&|M_a(e_L^- e_R^+ \Rightarrow H e_L^- e_R^+)|^2 \sim |F_{LL}^{(s)}|^2 \cdot (p_1 \cdot q_2)(p_2 \cdot q_1),\\
&|M_a(e_L^- e_R^+ \Rightarrow H e_R^- e_L^+)|^2 \sim |F_{LR}^{(s)}|^2 \cdot (p_1 \cdot q_1)(p_2 \cdot q_2),\\
&|M_a(e_R^- e_L^+ \Rightarrow H e_L^- e_R^+)|^2 \sim |F_{RL}^{(s)}|^2 \cdot (p_1 \cdot q_1)(p_2 \cdot q_2),\\
&|M_a(e_R^- e_L^+ \Rightarrow H e_R^- e_L^+)|^2 \sim |F_{RR}^{(s)}|^2 \cdot (p_1 \cdot q_2)(p_2 \cdot q_1),
\end{aligned} \qquad (2)$$

Here

$$\begin{aligned}
F_{LL}^{(s)} &= D_Z(s) D_Z(xs) g_L^2,\\
F_{LR}^{(s)} &= F_{RL}^{(s)} = D_Z(s) D_Z(xs) g_L g_R,\\
F_{RR}^{(s)} &= D_Z(s) D_Z(xs) g_R^2
\end{aligned} \qquad (3)$$

are the s-channel helicity amplitudes; $D_Z(s)$ is the propagator of the Z-boson and

$$D_Z(s) = (s - M_Z^2 + iM_Z\Gamma_Z)^{-1}, \quad x = 1 - \frac{2\omega}{\sqrt{s}} + \frac{M_H^2}{s},$$

M_H and ω the mass and energy of the Higgs boson.

The t-channel diagram b) also has four independent helicity amplitudes, which describe the process

$$e_L^- + e_R^+ \Rightarrow H + e_L^- + e_R^+,$$
$$e_R^- + e_L^+ \Rightarrow H + e_R^- + e_L^+,$$
$$e_L^- + e_L^+ \Rightarrow H + e_L^- + e_L^+,$$
$$e_R^- + e_R^+ \Rightarrow H + e_R^- + e_R^+,$$

These processes correspond to the squared transition amplitudes:

$$\begin{aligned}
|M_b(e_L^- e_R^+ \Rightarrow He_L^- e_R^+)|^2 &\sim (F_{LL}^{(t)})^2.(p_1.q_2)(p_2.q_1),\\
|M_b(e_R^- e_L^+ \Rightarrow He_R^- e_L^+)|^2 &\sim (F_{RL}^{(t)})^2.(p_1.q_2)(p_2.q_1),\\
|M_b(e_L^- e_L^+ \Rightarrow He_L^- e_L^+)|^2 &\sim (F_{LR}^{(t)})^2.(p_1.p_2)(q_1.q_2),\\
|M_b(e_R^- e_R^+ \Rightarrow He_R^- e_R^+)|^2 &\sim |F_{RR}^{(t)}|^2.(p_1.p_2)(q_1.q_2).
\end{aligned} \tag{4}$$

Where

$$\begin{aligned}
F_{LR}^{(t)} &= D_1 D_2 g_L^2,\\
F_{RL}^{(t)} &= D_1 D_2 g_R^2,\\
F_{LL}^{(t)} &= F_{RR}^{(t)} = D_1 D_2 g_L g_R
\end{aligned} \tag{5}$$

are the t-channel helicity amplitudes, and

$$\begin{aligned}
D_1 &= [(p_1 - q_1)^2 - M_Z^2]^{-1},\\
D_2 &= [(p_2 - q_2)^2 - M_Z^2]^{-1}.
\end{aligned}$$

Among the four s-channel and four t-channel helicity amplitudes there is interference between only two amplitudes describing the process:

$$\begin{gathered}
e_L^- + e_R^+ \Rightarrow H + e_L^- + e_R^+, \quad e_R^- + e_L^+ \Rightarrow H + e_R^- + e_L^+ :\\
|M_{\text{int}}(e_L^- e_R^+ \Rightarrow He_L^- e_R^+)|^2 \sim 2\,\text{Re}[F_{LL}^{*(s)} F_{LR}^{(t)}].(p_1.q_2)(p_2.q_1),\\
|M_{\text{int}}(e_R^- e_L^+ \Rightarrow He_R^- e_L^+)|^2 \sim 2\,\text{Re}[F_{RR}^{*(s)} F_{RL}^{(t)}].(p_1.q_2)(p_2.q_1).
\end{gathered} \tag{6}$$

$e^- + e^+ \Rightarrow H + e^- + e^+$ is characterized by just six independent helicity amplitudes, which describe the processes $e_L^- + e_R^+ \Rightarrow H + e_L^- + e_R^+$, $e_R^- + e_L^+ \Rightarrow H + e_R^- + e_L^+$, $e_L^- + e_L^+ \Rightarrow H + e_L^- + e_L^+$, $e_R^- + e_R^+ \Rightarrow H + e_R^- + e_R^+$, $e_L^- + e_R^+ \Rightarrow H + e_R^- + e_L^+$, $e_R^- + e_L^+ \Rightarrow H + e_L^- + e_R^+$. The squared transition amplitudes of these processes are given by:

$$\begin{aligned}
\left|M(e_L^- e_R^+ \Rightarrow He_L^- e_R^+)\right|^2 &\sim \left|F_{LL}^{(s)} + F_{LL}^{(t)}\right|^2 (p_1 \cdot q_2)(p_2 \cdot q_1),\\
\left|M(e_R^- e_L^+ \Rightarrow He_R^- e_L^+)\right|^2 &\sim \left|F_{RR}^{(s)} + F_{RR}^{(t)}\right|^2 (p_1 \cdot q_2)(p_2 \cdot q_1),\\
\left|M(e_L^- e_L^+ \Rightarrow He_L^- e_L^+)\right|^2 &\sim (F_{LL}^{(t)})^2 (p_1 \cdot p_2)(q_1 \cdot q_2),\\
\left|M(e_R^- e_R^+ \Rightarrow He_R^- e_R^+)\right|^2 &\sim (F_{RR}^{(t)})^2 (p_1 \cdot p_2)(q_1 \cdot q_2),\\
\left|M(e_L^- e_R^+ \Rightarrow He_R^- e_L^+)\right|^2 &\sim (F_{LR}^{(s)})^2 (p_1 \cdot q_1)(p_2 \cdot q_2),\\
\left|M(e_R^- e_L^+ \Rightarrow He_L^- e_R^+)\right|^2 &\sim (F_{RL}^{(s)})^2 (p_1 \cdot q_1)(p_2 \cdot q_2).
\end{aligned} \tag{7}$$