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$\gamma e^- \to he^-$ COLLISION IN RANDALL - SUNDRUM MODEL

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Abstract. *We consider the Randall - Sundrum model, which solves the Higgs hierarchy problem. In this paper, we have calculated the cross - section of the $\gamma e^- \to he^-$ process with the polarization of the electron beams. Based on the results, we show that the reaction can give observable cross - section in future accelerators at the high degree of polarization.*

Keywords: Higgs - boson sector, electron, cross - section.

I. INTRODUCTION

In the last few years, there have been many models proposed with extra dimensions to solve the hierarchy problem [1]. Randall - Sundrum model (RS) has been one of the most attractive attempts. The RS involves two three- branes bounding a slice of 5D compact anti-de Sitter [2]. Gravity is localized in the visible brane, while the Standard Model (SM) fields are supposed to be localized in the hidden brane. The fluctuations of size of the extra dimension, characterized by the scalar component of the metric otherwise known as the radion [2]. The radion may turn out to be the lightest new particle in the RS model. The phenomenological similarity and potential mixing of the radion and Higgs boson warrant detailed to distinguish between the radion and Higgs signals at colliders.

In Ref. [3], we calculated the cross - section of the production of radion in γe^- colliders. In this paper, we study the production of Higgs in γe^- colliders, our results can compare with results of [3]. This paper is organized as follows. In Sec. II, we introduce the curvature - scalar mixing and $\xi R\widehat{H}^+\widehat{H}$ (where $\widehat{H}$ is a Higgs doublet field on the visible brane), which causes the physical mass eigenstates h and ϕ to be mixtures of the original Higgs and radion fields. Sec. III is devoted to the production of Higgs in high energy γe^- colliders. Finally, we summarize our results and make conclusions in Sec. IV.

II. THE CURVATURE - SCALAR MIXING

The RS model is based on a 5D spacetime with non-factorizable geometry [1]. The single extradimension is compactified on an S^1/Z_2 orbifold of which two fixed points accommodate two three-branes (4D hyper-surfaces). Having determined the vacuum structure of the model, we discuss the possibility of mixing between gravity and the electroweak sector. The gravity - scalar mixing is described by the following action [4,5]

$$S_\xi = -\xi \int d^4x \sqrt{-g_{\text{vis}}} R(g_{\text{vis}}) \hat{H}^+ \hat{H}, \tag{1}$$

where $R(g_{vis})$ is the Ricci scalar for the metric induced on the visible brane, $g^{\mu\nu}_{vis} = \Omega^2_b(x)\,(\eta^{\mu\nu} + \varepsilon h^{\mu\nu})$. $\hat{H}$ is the Higgs field in the 5D context before rescaling to canonical normalization on the brane. The parameter ξ denotes the size of the mixing term [1,3–7]. With $\xi \neq 0$, there neither a pure Higgs boson nor pure radion mass eigenstate.

We define the mixing angle θ by

$$\tan 2\theta = 12\gamma\xi Z \frac{m^2_{h_0}}{m^2_{\phi_0} - m^2_{h_0}(Z^2 - 36\xi^2\gamma^2)}, \tag{2}$$

where

$$Z^2 \equiv 1 + 6\xi\gamma^2(1-6\xi) \equiv \beta - 36\xi^2\gamma^2. \tag{3}$$

In terms of these quantities, the new fields h and ϕ are the states that diagonalize the kinetic energy and have canonical normalization with:

$$h_0 = (cos\theta - \frac{6\xi\gamma}{Z} sin\theta)h + (sin\theta + \frac{6\xi\gamma}{Z} cos\theta)\phi \equiv dh + c\phi, \tag{4}$$

$$\phi_0 = -\frac{1}{Z} cos\theta\phi + \frac{1}{Z} sin\theta h \equiv a\phi + bh. \tag{5}$$

The corresponding mass - squared eigenvalues are [8]

$$m^2_{h,\phi} = \frac{1}{2Z^2}\left[m^2_{\phi_0} + \beta m^2_{h_0} \pm \sqrt{(m^2_{\phi_0} + \beta m^2_{h_0})^2 - 4Z^2 m^2_{\phi_0} m^2_{h_0}}\right]. \tag{6}$$

When $\xi \neq 0$, there are four independent parameters that must be specified to fix the state mixing parameters a, b, c, d of Eqs. (4) and (5) defining the mass eigenstates:

$$\Lambda_\phi,\ m_h,\ m_\phi,\ \xi, \tag{7}$$

where $\gamma = \upsilon_0/\Lambda_\phi$ with $\upsilon_0 = 246GeV$. For the reliability of the RS solution, the ratio $\frac{m_0}{M_P}$ is usually taken around $0.01 \leq \frac{m_0}{M_P} \leq 0.1$ [9] to avoid too large bulk curvature. Therefore, we consider the case of $\Lambda_\phi = 5$TeV and $\frac{m_0}{M_P} = 0.1$, which makes the radion stabilization model most natural.

III. HIGGS PRODUCTION IN γE^- COLLISION

In this section, we consider the collision in which the initial state contains a photon and an electron, the final state contains a pair of Higgs and electron,

$$e^-(p_1) + \gamma(p_2) \to e^-(k_1) + h(k_2). \tag{8}$$

Here p_i, k_i $(i = 1,2)$ stand for the momentum. There are three Feynman diagrams contributing to reaction (8), representing the s,u,t channels exchange depicted in Fig. 1.

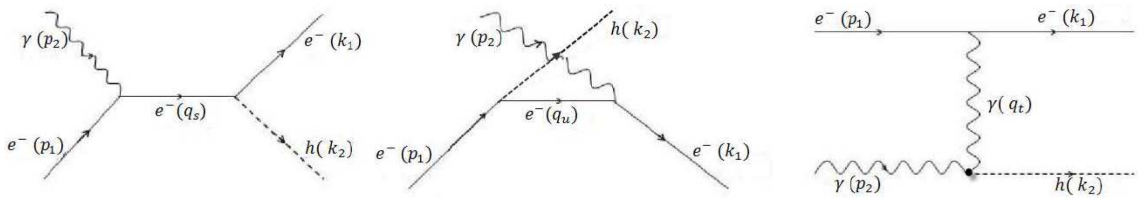

Fig. 1. Feynman diagrams for $\gamma e^- \to he^-$ collision

III.1. Higgs production in γe^- collision with unpolarized e^- beams

The amplitude squared of this process collision can be written as

$$|M|^2 = |M_s|^2 + |M_u|^2 + |M_t|^2 + 2Re(M_s^+ M_u + M_s^+ M_t + M_u^+ M_t), \tag{9}$$

where

$$\begin{aligned}|M_s|^2 =& -\frac{e^2\overline{g}^2_{ffh}}{(q_s^2 - m_e^2)^2}\{-8[2(k_1q_s)(p_1q_s) - (k_1p_1)q_s^2]+\\ &+ m_e^2[32(k_1q_s) - 16(p_1q_s) - 8(k_1p_1) + 16m_e^2 + 16q_s^2]\},\end{aligned} \tag{10}$$

$$\begin{aligned}|M_u|^2 =& -\frac{e^2\overline{g}^2_{ffh}}{(q_u^2 - m_e^2)^2}\{-8[2(k_1q_u)(p_1q_u) - (k_1p_1)q_u^2]+\\ &+ m_e^2[-16(k_1q_u) + 32(p_1q_u) - 8(k_1p_1) + 16m_e^2 + 16q_u^2]\},\end{aligned} \tag{11}$$

$$|M_t|^2 = \frac{64e^2}{q_t^4\Lambda_\gamma^2}\{2(k_1p_1)(p_2q_t)^2 + 2(k_1p_2)(p_1p_2)q_t^2 + [m_e^2 - (k_1p_1)](4(p_2q_t) + p_2^2q_t^2)\}, \tag{12}$$

$$\begin{aligned}M_s^+M_u =& -\frac{e^2\overline{g}^2_{ffh}}{(q_s^2 - m_e^2)(q_u^2 - m_e^2)}\{-16(k_1q_s)(p_1q_u) + m_e^2[-16(k_1q_s) - 8(k_1q_u)+\\ &-8(p_1q_s) + 16(p_1q_u) - 8(k_1p_1) + 16m_e^2 - 8(q_sq_u)]\},\end{aligned} \tag{13}$$

$$\begin{aligned}M_s^+M_t =& -\frac{4e^2\overline{g}_{ffh}}{(q_s^2 - m_e^2)q_t^2\Lambda_\gamma}\{3m_e^2(p_2q_t) + m_e[-(k_1q_u)(p_2q_t) + 3(p_1q_u)(p_2q_t)+\\ &-(k_1q_t)(p_1p_2) - (p_1q_t)(p_2k_1) - (k_1p_1)(p_2q_t) - (k_1q_t)(p_2q_u)+\\ &+(p_1q_t)(p_2q_u) - (k_1p_2)(q_uq_t) - (p_1p_2)(q_uq_t)]\},\end{aligned} \tag{14}$$

$$\begin{aligned}M_u^+M_t =& -\frac{4e^2\overline{g}_{ffh}}{(q_s^2 - m_e^2)q_t^2\Lambda_\gamma}\{12m_e^3(p_2q_t) + 4m_e[-(k_1q_t)(p_1p_2) - (p_1q_t)(p_2k_1)+\\ &-(k_1p_1)(p_2q_t) + (k_1q_t)(p_2q_s) + 3(k_1q_s)(p_2q_t) - (k_1p_2)(q_sq_t)+\\ &-(p_1q_t)(p_2q_s) - (p_1q_s)(p_2q_t) - (p_1p_2)(q_sq_t)]\}.\end{aligned} \tag{15}$$

III.2. Higgs production in $\gamma e^- \to he^-$ process with the polarized e^- beams

This section is devoted to the cross - sections in the γe^- collision when the initial and final e^- beams are polarized. Let us consider the following cases:

a) In s - channel, we give the following results:

$$|M_{sLR}|^2 = |M_{sRL}|^2 = \frac{8e^2\overline{g}^2_{ffh}}{(q_s^2 - m_e^2)^2}[2(k_1q_s)(p_1q_s) - (k_1p_1)q_s^2], \tag{16}$$

$$|M_{sLL}|^2 = |M_{sRR}|^2 = \frac{8e^2\overline{g}^2_{ffh}}{(q_s^2 - m_e^2)^2}m_e^2(k_1p_1), \tag{17}$$

$$M^+_{sLR}M_{sLL} = M^+_{sRL}M_{sRR} = -\frac{16e^2\overline{g}^2_{ffh}}{(q_s^2 - m_e^2)^2}m_e^2(k_1q_s), \tag{18}$$

$$M^+_{sLR}M_{sRR} = M^+_{sRL}M_{sLL} = \frac{8e^2\overline{g}^2_{ffh}}{(q_s^2 - m_e^2)^2}m_e^2(p_1q_s), \tag{19}$$

$$M^+_{sLR}M_{sRL} = M^+_{sRL}M_{sLR} = -\frac{16e^2\overline{g}^2_{ffh}}{(q_s^2 - m_e^2)^2}m_e^2q_s^2, \tag{20}$$

$$M^+_{sLL}M_{sLR} = M^+_{sRR}M_{sRL} = -\frac{16e^2\overline{g}^2_{ffh}}{(q_s^2 - m_e^2)^2}m_e^2(k_1q_s), \tag{21}$$

$$M^+_{sLL}M_{sRL} = M^+_{sRR}M_{sLR} = \frac{8e^2\overline{g}^2_{ffh}}{(q_s^2 - m_e^2)^2}m_e^2(p_1q_s), \tag{22}$$

$$M^+_{sLL}M_{sRR} = M^+_{sRR}M_{sLL} = -\frac{16e^2\overline{g}^2_{ffh}}{(q_s^2 - m_e^2)^2}m_e^4. \tag{23}$$

Here, the second and the third subscripts of M are corresponding to the polarization of the initial and final e^- beams, respectively.

b) In a similar way, we consider the process in u - channel. The transition amplitude for this process can be written as

$$|M_{uLR}|^2 = |M_{uRL}|^2 = \frac{8e^2\overline{g}^2_{ffh}}{(q_u^2 - m_e^2)^2}[2(k_1q_u)(p_1q_u) - (k_1p_1)q_u^2], \tag{24}$$

$$|M_{uLL}|^2 = |M_{uRR}|^2 = \frac{8e^2\overline{g}^2_{ffh}}{(q_u^2 - m_e^2)^2}m_e^2(k_1p_1), \tag{25}$$

$$M^+_{uLR}M_{uLL} = M^+_{uRL}M_{uRR} = \frac{8e^2\overline{g}^2_{ffh}}{(q_u^2 - m_e^2)^2}m_e^2(k_1q_u), \tag{26}$$

$$M^+_{uLR}M_{uRR} = M^+_{uRL}M_{uLL} = -\frac{16e^2\overline{g}^2_{ffh}}{(q_u^2 - m_e^2)^2}m_e^2(p_1q_u), \tag{27}$$

$$M^+_{uLR}M_{uRL} = M^+_{uRL}M_{uLR} = -\frac{16e^2\overline{g}^2_{ffh}}{(q_u^2 - m_e^2)^2}m_e^2q_u^2, \tag{28}$$

$$M^+_{uLL}M_{uLR} = M^+_{uRR}M_{uRL} = \frac{8e^2\overline{g}^2_{ffh}}{(q_u^2 - m_e^2)^2}m_e^2(k_1q_u), \tag{29}$$

$$M^+_{uLL}M_{uRL} = M^+_{uRR}M_{uLR} = -\frac{16e^2\overline{g}^2_{ffh}}{(q_u^2 - m_e^2)^2}m_e^2(p_1q_u), \tag{30}$$

$$M_{uLL}^{+}M_{uRR}=M_{uRR}^{+}M_{uLL}=-\frac{16e^{2}\overline{g}_{ffh}^{2}}{(q_{u}^{2}-m_{e}^{2})^{2}}m_{e}^{4}. \tag{31}$$

c) In t - channel, the initial left (or right) - handed e^{-} beams produce the photon with the momentum q_t and the final left (or right) - handed e^{-} beams. The photon in the intial state collides the photon with the momentum q_t to produce Higgs in the final state. The transition amplitude for this process is given by

$$\begin{aligned}|M_{tLL}|^{2}=|M_{tRR}|^{2}=&\frac{64e^{2}}{q_{t}^{4}\Lambda_{\gamma}^{2}}\{[2(p_{2}q_{t})^{2}(k_{1}p_{1})+2(k_{1}p_{2})(p_{1}p_{2})q_{t}^{2}]+\\&-(k_{1}p_{1})[4(p_{2}q_{t})^{2}+q_{t}^{2}p_{2}^{2}]\},\end{aligned} \tag{32}$$

$$M_{tLL}^{+}M_{tRR}=M_{tRR}^{+}M_{tLL}=\frac{64e^{2}}{q_{t}^{4}\Lambda_{\gamma}^{2}}m_{e}^{2}[4(p_{2}q_{t})^{2}+q_{t}^{2}p_{2}^{2}]. \tag{33}$$

d) Considering the s, u channel interference, the transition amplitude can be written as

$$M_{sLR}^{+}M_{uLR}=M_{sRL}^{+}M_{uRL}=\frac{16e^{2}\overline{g}_{ffh}^{2}}{(q_{s}^{2}-m_{e}^{2})(q_{u}^{2}-m_{e}^{2})}(k_{1}q_{s})(p_{1}q_{u}), \tag{34}$$

$$M_{sLR}^{+}M_{uLL}=M_{sRL}^{+}M_{uRR}=\frac{16e^{2}\overline{g}_{ffh}^{2}}{(q_{s}^{2}-m_{e}^{2})(q_{u}^{2}-m_{e}^{2})}m_{e}^{2}(k_{1}q_{s}), \tag{35}$$

$$M_{sLL}^{+}M_{uLL}=M_{sRR}^{+}M_{uRR}=\frac{8e^{2}\overline{g}_{ffh}^{2}}{(q_{s}^{2}-m_{e}^{2})(q_{u}^{2}-m_{e}^{2})}m_{e}^{2}(k_{1}p_{1}), \tag{36}$$

$$M_{sLL}^{+}M_{uLR}=M_{sRR}^{+}M_{uRL}=\frac{8e^{2}\overline{g}_{ffh}^{2}}{(q_{s}^{2}-m_{e}^{2})(q_{u}^{2}-m_{e}^{2})}m_{e}^{2}(k_{1}q_{u}), \tag{37}$$

$$M_{sLR}^{+}M_{uRR}=M_{sRL}^{+}M_{uLL}=\frac{8e^{2}\overline{g}_{ffh}^{2}}{(q_{s}^{2}-m_{e}^{2})(q_{u}^{2}-m_{e}^{2})}m_{e}^{2}(p_{1}q_{s}), \tag{38}$$

$$M_{sLR}^{+}M_{uRL}=M_{sRL}^{+}M_{uLR}=\frac{8e^{2}\overline{g}_{ffh}^{2}}{(q_{s}^{2}-m_{e}^{2})(q_{u}^{2}-m_{e}^{2})}m_{e}^{2}(q_{s}q_{u}), \tag{39}$$

$$M_{sLL}^{+}M_{uRL}=M_{sRR}^{+}M_{uLR}=-\frac{16e^{2}\overline{g}_{ffh}^{2}}{(q_{s}^{2}-m_{e}^{2})(q_{u}^{2}-m_{e}^{2})}m_{e}^{2}(p_{1}q_{u}), \tag{40}$$

$$M_{sLL}^{+}M_{uRR}=M_{sRR}^{+}M_{uLL}=-\frac{16e^{2}\overline{g}_{ffh}^{2}}{(q_{s}^{2}-m_{e}^{2})(q_{u}^{2}-m_{e}^{2})}m_{e}^{4}. \tag{41}$$

e) In the u, t channel interference, the transition amplitude can be written as

$$\begin{aligned}M_{uLR}^{+}M_{tLL}=M_{uRL}^{+}M_{tRR}=&\frac{16e^{2}\overline{g}_{ffh}}{q_{t}^{2}\Lambda_{\gamma}(q_{u}^{2}-m_{e}^{2})}\times\\&\times m_{e}[(p_{2}q_{t})(k_{1}q_{u})+(p_{2}q_{u})(k_{1}q_{t})+(k_{1}p_{2})(q_{u}q_{t})],\end{aligned} \tag{42}$$

$$\begin{aligned}M_{uLR}^{+}M_{tRR}=M_{uRL}^{+}M_{tLL}=&-\frac{16e^{2}\overline{g}_{ffh}}{q_{t}^{2}\Lambda_{\gamma}(q_{u}^{2}-m_{e}^{2})}\times\\&\times m_{e}[3(p_{2}q_{t})(p_{1}q_{u})+(p_{2}q_{u})(p_{1}q_{t})-(p_{1}p_{2})(q_{u}q_{t})],\end{aligned} \tag{43}$$

$$M^+_{uLL}M_{tLL} = M^+_{uRR}M_{tRR} = \frac{16e^2\overline{g}_{ffh}}{q_t^2\Lambda_\gamma(q_u^2-m_e^2)}\times$$
$$\times\, m_e[(p_2q_t)(k_1p_1)+(p_1p_2)(k_1q_t)+(k_1p_2)(p_1q_t)], \quad (44)$$

$$M^+_{uLL}M_{tRR} = M^+_{uRR}M_{tLL} = -\frac{48e^2\overline{g}_{ffh}}{q_t^2\Lambda_\gamma(q_u^2-m_e^2)}m_e^3(p_2q_t). \quad (45)$$

f) In the s, t channel interference, the transition amplitude can be written as

$$M^+_{sLR}M_{tLL} = M^+_{sRL}M_{tRR} = -\frac{16e^2\overline{g}_{ffh}}{q_t^2\Lambda_\gamma(q_s^2-m_e^2)}\times$$
$$\times\, m_e[3(p_2q_t)(k_1q_s)+(p_2q_s)(k_1q_t)-(k_1p_2)(q_sq_t)], \quad (46)$$

$$M^+_{sLR}M_{tRR} = M^+_{sRL}M_{tLL} = \frac{16e^2\overline{g}_{ffh}}{q_t^2\Lambda_\gamma(q_s^2-m_e^2)}\times$$
$$\times\, m_e[(p_2q_t)(p_1q_s)+(p_2q_s)(p_1q_t)+(p_1p_2)(q_sq_t)], \quad (47)$$

$$M^+_{sLL}M_{tLL} = M^+_{sRR}M_{tRR} = \frac{16e^2\overline{g}_{ffh}}{q_t^2\Lambda_\gamma(q_s^2-m_e^2)}\times$$
$$\times\, m_e[(p_2q_t)(k_1p_1)+(p_1p_2)(k_1q_t)+(k_1p_2)(p_1q_t)], \quad (48)$$

$$M^+_{sLL}M_{tRR} = M^+_{sRR}M_{tLL} = -\frac{48e^2\overline{g}_{ffh}}{q_t^2\Lambda_\gamma(q_u^2-m_e^2)}m_e^3(p_2q_t). \quad (49)$$

III.3. The cross-section of Higgs production in γe^-

From the expressions of the differential cross - section and the total cross - section:

$$\frac{d\sigma}{d(cos\theta)} = \frac{1}{64\pi s}\frac{|\overrightarrow{k}|}{|\overrightarrow{p}|}|M|^2, \quad (50)$$

where M is the the scattering amplitude, we assess the number and make the identification, evaluation of the results obtained from the dependence of the differential cross - section by $cos\theta$, the total cross-section fully follows $\sqrt{s}$ and the polarization factors of e^- beams (P_1,P_2).

In the SI unit, we choose $m_e = 0,00051$ GeV, $\Lambda_\phi = 5$ TeV, $\frac{1}{\Lambda_\gamma} = iC_\gamma$, $C_\gamma = -\frac{\alpha}{2\pi\upsilon_0}\times[g_{fV}\sum_i e_i^2N_c^iF_i(\tau_i)-(b_2+b_Y)g_r]$ [3, 5, 11]. We give some estimates for the cross-section as follows

i) When the beams in the initial and final state are polarized, the total cross - section which depends on typical polarization coefficients P_1,P_2 is shown in Fig. 2. The total cross - section achieves the maximum value in case of $P_1 = P_2 = -1$ or $P_1 = P_2 = 1$ and the minimum value in case of $P_1 = -1, P_2 = 1$ or $P_1 = 1, P_2 = -1$.

ii) In Fig. 3, we plot the differential cross-section as a function of the $\cos\theta$. The collision energy is choosen as $\sqrt{s} = 3$ TeV. The Fig. 3a, typical polarization coefficients are choosen as $P_1 = P_2 = 1, 0.5, 0$ respectively, shows that the differential cross - sections increase when the $\cos\theta$ increases from -1 to 1. When $\cos\theta \simeq 1$, the differential cross - sections reach the maximum value. The result shows the advantage direction to collect Higgs from experiment. In Fig. 3b, the differential cross - section decreases as $-1 < \cos\theta < 1$ with $P_1 = -1$, $P_2 = 1$.

iii) In Fig. 4, we plot the total cross-section as a function of the collision energy $\sqrt{s}$ in the cases P_1, P_2 same to Fig. 3. Fig. 4a shows that the total cross - sections increase fastly in the region $1TeV < \sqrt{s} < 5TeV$, which are larger than cross - sections of radion in RS model [3]. Therefore, it is large enough to measure Higgs production at very high energies. Fig.4b shows that the total cross - section decreases when $\sqrt{s}$ increases.

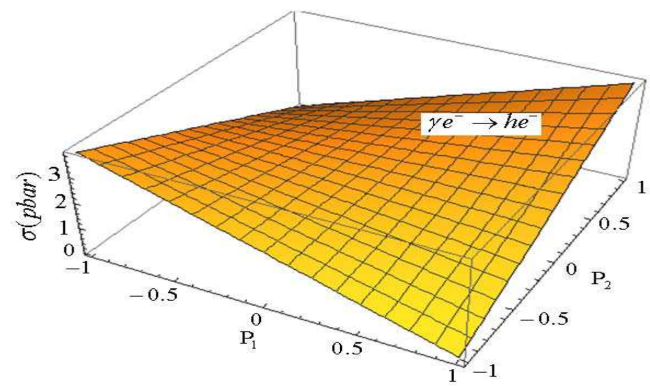

Fig. 2. The total cross-section as a function of the polarization coefficients P_1, P_2

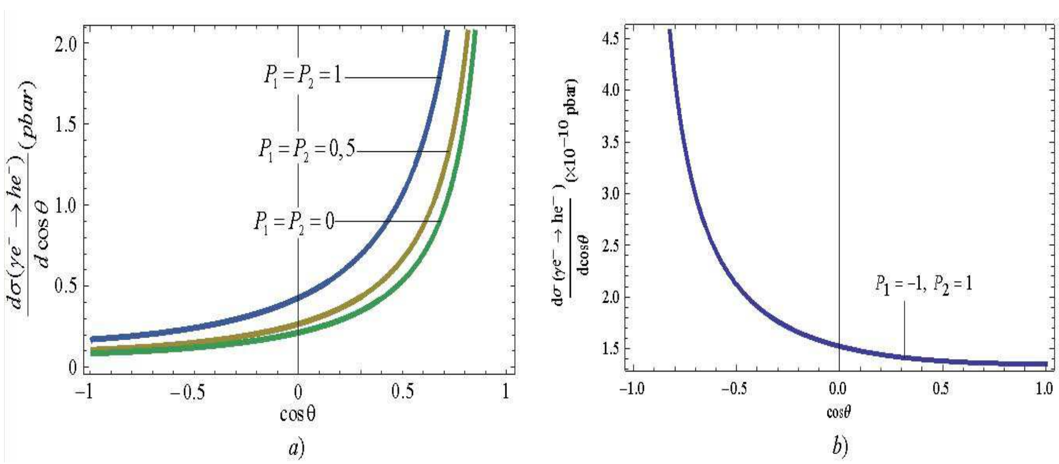

Fig. 3. The cross-section as a function of $cos\theta$. Typical polarization coefficients are chosen as $P_1 = P_2 = 1$, 0.5 and 0, respectively (a) and $P_1 = -1, P_2 = 1$ (b)

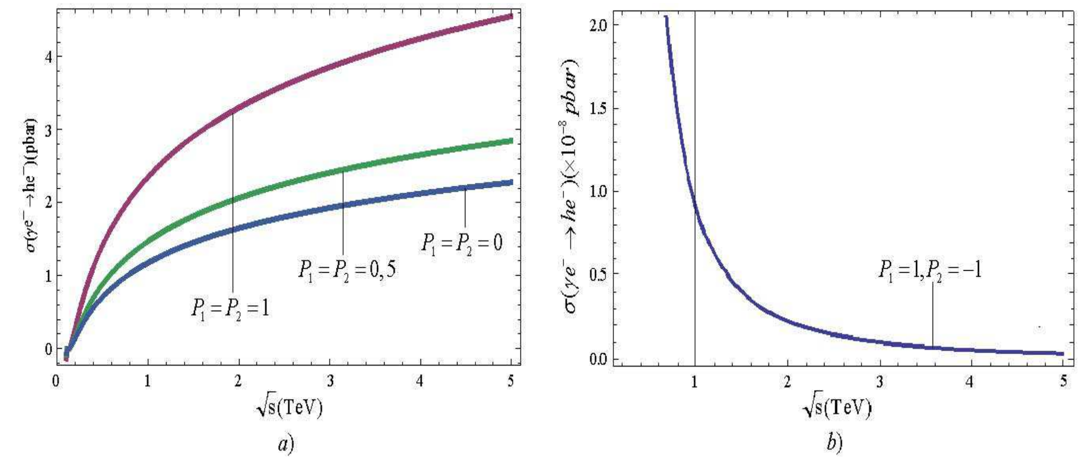

Fig. 4. The total cross-section as a function of the collision energy $\sqrt{s}$. Typical polarization coefficients are chosen as $P_1 = P_2 = 0.0$, 0.5 and 1, respectively (a) and $P_1 = -1, P_2 = 1$ (b)

IV. CONCLUSION

In this paper, we have evaluated the Higgs production in γe^- collision. The result shows that the production cross-section of Higgs depends on the polarization of e^- beams and the collision energy. In the high energy region, the production cross - section of Higgs is much larger than that of radion in the same conditions.

REFERENCES

[1] L. Randall and R. Sundrum, *Phys. Rev. Lett.* **83** (1999) 3370, arxiv:hep-ph/9905221.
[2] W. D. Goldberger and M. B. Wise, *Phys. Rev. Lett.* **83** (1999) 4922, arXiv:hep-ph/9907447.
[3] D. V. Soa, D. T. L. Thuy, N. H. Thao and T. D. Tham, *Mod. Phys. Lett. A* **27**(2) (2012) 1250126.
[4] J. J. van der Bij, *Acta Phys. Polon.* B **25** (1994) 827; R. Raczka, M. Pawlowski, *Found. Phys.* **24** (1994) 1305, hep-th/9407137.
[5] G. F. Giudice, R. Rattazzi and J. D. Wells, *Nucl. Phys. B* **595** (2001) 250.
[6] M. Chaichain, A. Datta, K. Huitu and Z. Yu, *Phys. Lett. B* **524** (2002) 161.
[7] K. Cheung, C. S. Kim and J-H. Song, *Phys. Rev. D* **67** (2003) 075017.
[8] T. Han, G. D. Kribs and B. McElrath, *Phys. Rev. D* **64** (2001) 076003.
[9] H. Davoudiasl, J. L. Hewett and T. G. Rizzo, *Phys. Rev. D* **63** (2001) 075004.
[10] C. S. Kim, J. D. Kim and Jeong-hyeon Song, *Phys. Rev. D* **67** (2003) 015001.
[11] T. Han, G. D. Kribs and B. McElrath, *Phys. Rev. D* **64** (2001) 076003, arXiv:hep-ph/0104074.