THE PRODUCTION OF THE HIGGS BOSON ON ELECTRON-POSITRON LINEAR COLLIDERS

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Taking into account the polarizations of the linear colliding electron-positron beams, differential, total cross-section as well as the energy-angular distribution of the fermions in the process $e^+e^- \to Hf\bar{f}$ are calculated. The characteristic features of the cross-sections and the polarization effects of the process on the linear accelerator ILC (International Linear Collider) are investigated.

Keywords: Standard Model, ILC, Higgs boson, Lepton production, e^-e^+ interactions.
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INTRODUCTION

The study of different properties of Higgs boson is the one of the most actual tasks of modern high-energy physics. The modern high-energy research at the Large Hadron Collider (LHC) at CERN, in such projects as ATLAS and CMS ones will be added by investigations on electron-positron colliders, in particular, on ILC (International Linear Collider) [1]. The pure signals and precise measurements which can be obtained with the help of linear collider of high luminosity give us the possibility for new ideas in our understanding of fundamental interactions of nature and structure of the matter, space and time. The high-energy physics on linear collider will have the new possibilities for investigations, for example, the possibility of polarized beams formation. As is known, a high degree of polarization can be realized without significant losses in luminosity. The polarized electron beam already will serve as the valuable tool for checking of Standard Model and for diagnostics of new physics. The most investigations will be carried out at energies $200 \quad GeV < \sqrt{s} < 500 \quad GeV$ and the integrated luminosity will reach the value $L_{int} = 500\ fb^{-1}$.

The polarization high degree is provided in ILC plans, for electron is on 80% and for positron on 50%. Though the beam polarization plays not the main role in definition of Higgs boson properties however this is very useful for process dividing, suppression of background processes and accuracy increase. The use of polarized beams in this context has mainly the statistic meaning. The annihilation processes are the dominating ones in e^+e^- experiments. In annihilation processes the helicities of electron and positron are correlated with virtual particle spin in direct channel. That's why the corresponding combinations of polarizations of electron and positron beams can be used for significant increase of the velocity of signal and also for effective suppression of undesirable background processes. The increase of signal/background relation in combination with high luminosity gives the additional possibilities for investigations.

1. PROCESS $e^+e^- \to Hf\bar{f}$ ON POLARIZED COLLIDING ELECTRON-POSITRON LINEAR COLLIDERS

The detail analysis of all properties of Higgs boson is the central part of ILC physics program. The two main processes $e^+e^- \to HZ$ with following decay

$$Z \to > l^+ + l^- \tag{1}$$

$$e^+e^- \to H\nu\bar{\nu} \tag{2}$$

will be considered at $\sqrt{s} = 500\ GeV$.

In the framework of the Standard Model, due to the rather strong coupling of the H- boson with W- and Z - bosons, the main sources of H- bosons will be the processes of their emission by W- and Z- bosons produced in various experiments. The particularly intense and favorable source of H- bosons could be the process $e^+e^- \to Hf\bar{f}$ occurring on linear electron-positron beams.

Note that production process of Higgs boson on polarized colliding beams $e^+e^- \to Hf\bar{f}$ had been investigated in detail earlier in [2-8]. In these works the dependences of differential cross-section distribution by invariant mass of muon pair, dependences of differential cross-section of the proses (3) on x at different energies of initial beam for the small mass of Higgs boson and as well as the dependence of total cross-section of the process (3) on energy of initial colliding beams $\sqrt{s}$ are investigated. In addition, the effects associated with polarization (both longitudinal and transverse) of colliding beams were investigated in detail in [2-8].

Due to the research of various properties of the Higgs boson planned in ILC in the near future, it becomes necessary to recalculate various characteristics of the $e^+e^- \to Hf\bar{f}$ process.

The process $e^+e^- \to Hf\bar{f}$ taking place by the one of the following scheme:

$$e^+e^- \to Z^* \to HZ^* \to Hf\bar{f}, \tag{3a}$$

$$e^+e^- \to Z \to HZ^* \to Hf\bar{f}, \tag{3b}$$

$$e^+e^- \to Z^* \to HZ \to Hf\bar{f}, \tag{3c}$$

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is investigated in detail in present work, where Z is real, Z^* is virtual neutral vector boson, f is fundamental fermion (lepton or quark). Taking into account the polarizations of the electron-positron beams, a dependence of differential cross-section on invariant mass and total cross-section of the processes (3) are calculated. The dependences of the obtained expressions on the initial energy are investigated and the characteristic features in the behavior of the cross-sections are revealed.

Within the framework of Standard Model the amplitude of the process (3) has the following form:

$$M_{fi} = 2^{3/4} G^{3/2} D_Z(q_1) D_Z(q_2) \bar{u}(-p_2)\gamma_\mu (g_V + \\ + g_A\gamma_5) u(p_1) \bar{u}(k_1)\gamma_\mu (G_V + G_A\gamma_5) u(-k_2) H(\chi), \tag{4}$$

where Γ_Z is Z-boson width, $q_1 = p_1 + p_2 = k_1 + k_2 + \chi,\ q_2 = p_1 + p_2 - \chi = k_1 + k_2;\ p_1, p_2, k_1, k_2$ and χ are the 4-impulses of electron, positron, fermion, antifermion and *H*-boson correspondingly. In (4) we neglect the terms proportional to m_e/m_Z and m_f/m_Z where m_e electron and m_f are producing fermion masses.

Carrying out the calculations on the base of formula (4) at arbitrary polarization of initial colliding beams in the center-of- mass system we have the following expression for differential cross-section of the process (3):

$$\frac{d\sigma(\vec{s}_1, \vec{s}_2)}{dx d\Omega} = \frac{d\sigma}{dx d\Omega}\{1 + ((\vec{p}^0 \vec{s}_1) + (\vec{p}^0 \vec{s}_2))t_1 + [(\vec{s}_1 \vec{s}_2)\sin^2\theta + 2((\vec{p}^0 \vec{s}_1)(\vec{\chi}^0 \vec{s}_2) + \\ + (\vec{p}^0 \vec{s}_2)(\vec{\chi}^0 \vec{s}_1))\cos\theta - 2(\vec{\chi}^0 \vec{s}_1)(\vec{\chi}^0 \vec{s}_2)]t_2 + (\vec{p}^0 \vec{s}_1)(\vec{\chi}^0 \vec{s}_2)t_3\}, \tag{5}$$

where

$$\frac{d\sigma}{dx d\Omega} = \frac{G_F^3 m_Z^8}{6\sqrt{2}(4\pi)^3} \frac{(1 - 4r_f^2/x)^{1/2}}{(s - m_Z^2)^2 + m_Z^2\Gamma_Z^2} \cdot \frac{[(1 + r_H^2 - x)^2 - 4r_H^2]^{1/2}}{(x - m_Z^2/s)^2 + m_Z^2\Gamma_Z^2/s^2} T_0, \tag{6}$$

is cross-section of process (3) averaged and summarized by particle polarization. In (5) and (6) the following notations are accepted:

$$t_i = T_i/T_0 \qquad (i = 1,2,3)$$
$$T_0 = (g_V^2 + g_A^2)(G_V^2 + G_A^2)\{4x(1 - 4r_f^2/x) + (1 + 2r_f^2/x)[4x + ((1 + r_H^2 - x)^2 - 4r_H^2)\sin^2\theta]\} + \\ + 24r_f^2(g_V^2 + g_A^2)(G_V^2 - G_A^2),$$
$$T_1 = -2g_V g_A(G_V^2 + G_A^2)\{8x(1 - r_f^2/x) + (1 + 2r_f^2/x)[(1 + r_H^2 - x)^2 - 4r_H^2]\sin^2\theta\} - \\ - 48r_f^2 g_V g_A(G_V^2 - G_A^2)^2, \tag{7}$$
$$T_2 = (g_V^2 - g_A^2)(G_V^2 + G_A^2)(1 + 2r_f^2/x)[(1 + r_H^2 - x)^2 - 4r_H^2],$$
$$T_3 = T_0 - (1 + \cos^2\theta)T_2.$$

In expressions given above $\vec{s}_1$ and $\vec{s}_2$ are unit vectors in the directions of electron and positron polarization correspondingly; $\vec{p}^0$ and $\vec{\chi}^0$ are unit vectors in directions of impulses of electron and *H*-boson correspondingly; θ is the angle between of *H*-boson and electron impulses; $r_H = m_H/\sqrt{s}$, $r_f = m_f/\sqrt{s}$. *x* is the invariant mass of final fermion pair in *s* units (ω is Higgs boson energy) that is limited from $4r_f^2$ up to $(1 - r_H)^2$.

$$x = \frac{(k_1 + k_2)^2}{s} = 1 + r_H^2 - \frac{2\omega}{\sqrt{s}} \tag{8}$$

Let's analyze the formula (5) in different cases of initial particle polarization.

Note that, in the cases of longitudinal and transverse polarization of initial beams, the differential cross-section of the energy-angular distribution of Higgs bosons was considered in [9], were calculations carried out for the values of $G_V = g_V, G_A = g_A$ and $r_f = 0$.

2. THE CASE OF UNPOLARISED COLLIDING BEAMS

1. In the case of unpolarized colliding beams, the differential cross-section of the process is determined by formula (6). Integrating the (6) over the angles we find the following expressions for differential cross-sections of distribution of final fermion couples on invariant mass:

$$\frac{d\sigma}{dx} = \frac{G_F^3 m_Z^8}{9\sqrt{2}(4\pi)^3} \frac{(1-4r_f^2/x)^{1/2}}{(s-m_Z^2)^2 + m_Z^2\Gamma_Z^2} \cdot \frac{[(1+r_H^2-x)^2 - 4r_H^2]^{1/2}}{(x-m_Z^2/s)^2 + m_Z^2\Gamma_Z^2/s^2} A_0, \tag{9}$$

where

$$\begin{aligned} A_0 = {} & (g_V^2+g_A^2)(G_V^2+G_A^2)\{6x(1-4r_f^2/x)+(1+2r_f^2/x)[6x+ \\ & +(1+r_H^2-x)^2-4r_H^2]\}+36r_f^2(g_V^2+g_A^2)(G_V^2-G_A^2). \end{aligned} \tag{10}$$

The differential cross-section on invariant mass of $\mu^+\mu^-$ pair in (3) process without taking into consideration the particle polarizations is considered earlier in [5]. However, the formula $d\sigma(e^+e^- \to H\mu^+\mu^-)/dx$ in this work is obtained in case $G_V = g_V, G_A = g_A$ and $r_f = 0$. Moreover, this formula contains the series of inaccuracies, it is increased in 4 times and the second term of the last lines should have the form $2x(5-m_H^2/s)$ in formula (2.2) of the given work.

The dependences of $d\sigma(e^+e^- \to H\mu^+\mu^-)/dx$ on x at $m_H = 125$ GeV for different values of $\sqrt{s}$ initial beam (here and below, the curves are constructed within the framework of the Weinberg-Salam model where $G_V = g_V = -1/2 + 2\sin^2\theta_W, G_A = g_A = -1/2$, at the value of $\sin^2\theta_W = 0{,}22$) are presented in figures 1, 2 and 3.

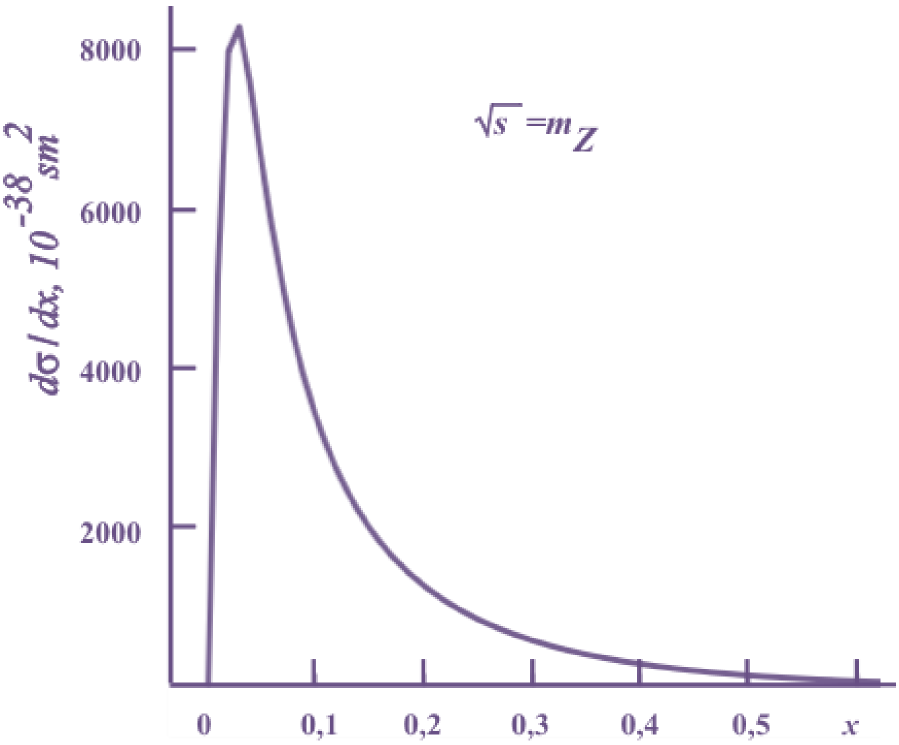

Fig.1. The dependence of differential cross-section of the (3) process on *x*.

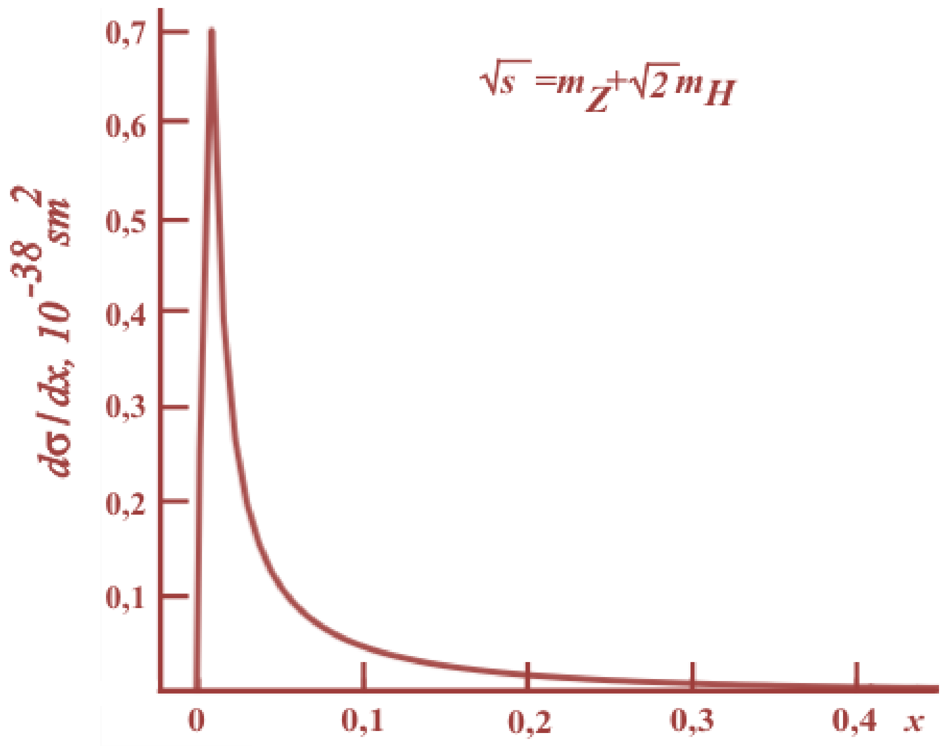

Fig.2. The dependence of the differential cross-section of the process (3) on *x*.

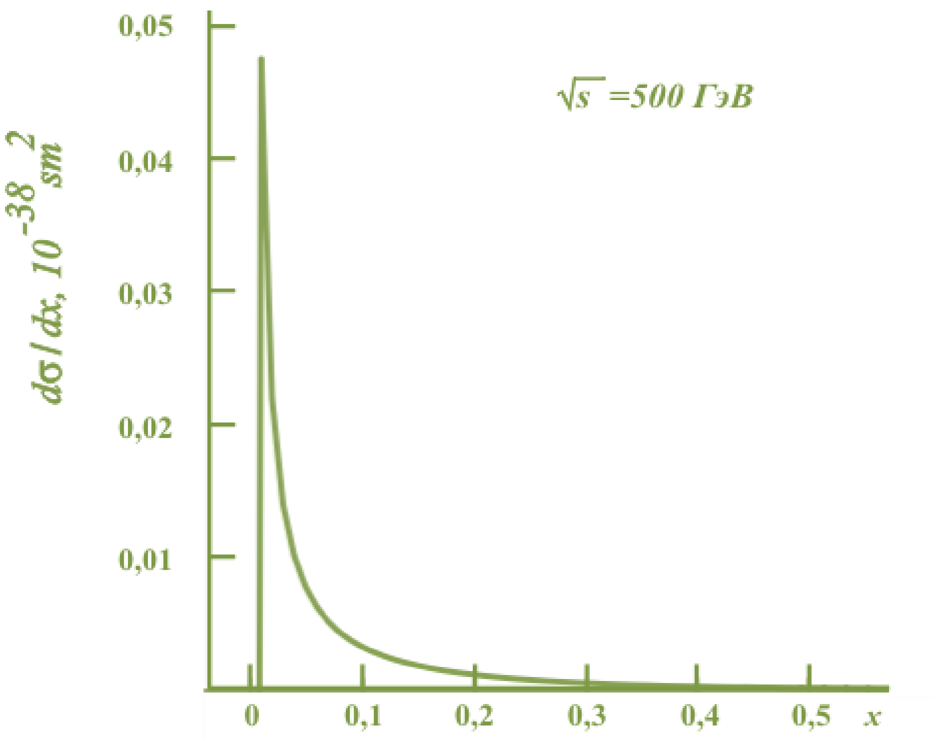

Fig.3. The dependence of the differential cross-section of the process (3) on *x*.

As one can be seen, from the figures in the differential cross-section (in $\sqrt{s}$ units) there is a maximum, and with increasing initial energy up to energy $\sqrt{s} = m_Z + m_H$ the place of the maximum shifts to the side of large values of x and at energies $\sqrt{s} = m_Z + m_H$ it is determined by the value $x = m_Z^2 / s$.

As it was shown in [5], the detection of the Higgs bosons in the process under consideration is most favorable in the region $x > 0{,}5$, since in this case most of the background events are excluded. This specific behavior of the cross-section gives us to conclude that for the detection of the Higgs boson in the process under consideration with respect to the maximum of the differential cross-section, it is not necessary to increase the energy of the initial beams above the threshold of the main reaction $e^+e^- \to HZ$.

3. TOTAL PROCESS CROSS-SECTION

Let's consider the total cross-section of the process. Carrying out the rather complicated integration over the x in (9), for the total cross-section of process (3) we obtain:

$$\sigma = \frac{G_F^3 m_Z^8}{9\sqrt{2}(4\pi)^3}\frac{(g_V^2+g_A^2)(G_V^2+G_A^2)}{(s-m_Z^2)^2+m_Z^2\Gamma_Z^2}[(1-r_H^2)^2 J_0 + 2(5-r_H^2)J_1 + J_2]. \tag{11}$$

The expressions of the quantities J_0, J_1 and J_2 appearing in (11) are the integrals of the form:

$$J_i = \int_0^{a_2} \frac{x^i\sqrt{(x-a_1)(x-a_2)}}{[(x-a)^2+b^2]}dx \qquad (i=0,1,2), \tag{12}$$

Where

$$a_1 = (1+r_H)^2, \quad a_2 = (1-r_H)^2, \quad a = m_Z^2/s, \quad b = m_Z\Gamma_Z/s.$$

Theoretically calculated integrals have the following form:

$$\begin{aligned}
&J_0/2 = -\rho_1 + C\tau_0 - A\tau_2,\\
&J_1/2 = -(2a-a_2)(\rho_1 + A\tau_2) + (a_1-a_2)\rho_2 + (2a-a_1)C\tau_0,\\
&J_2/2 = (b^2-3a^2+2aa_2)(\rho_1+A\tau_2) + (a_1-a_2)(2a-a_1-a_2)\rho_2 -\\
&\qquad -(a_1-a_2)^2\rho_3 - (b^2-3a^2+2aa_1)C\tau_0.
\end{aligned} \tag{13}$$

The following notations are accepted in (13):

$$\begin{aligned}
&\rho_1 = \frac{1}{2}Ln[(\sqrt{a_1}-\sqrt{a_2})/(\sqrt{a_1}+\sqrt{a_2}), \rho_2 = \frac{1}{2}[\rho_1 - \sqrt{a_1a_2}/(a_1-a_2)],\\
&\rho_3 = \frac{3}{4}\rho_2 - \frac{1}{4}\frac{a_1\sqrt{a_1a_2}}{(a_1-a_2)^2}, \tau_0 = (T+L)/4F_1\sqrt{C}, \tau_2 = (T-L)/4F_1\sqrt{A},\\
&T = -\frac{F_1}{F_2}[arctg\,\frac{\sqrt{Aa_2/a_1}-F_1}{F_2} + arctg\,\frac{\sqrt{Aa_2/a_1}+F_1}{F_2}],\\
&L = \frac{1}{2}Ln\frac{a_1\sqrt{C}-2\sqrt{a_1a_2}F_1+a_2\sqrt{A}}{a_1\sqrt{C}+2\sqrt{a_1a_2}F_1+a_2\sqrt{A}}, F_{1,2} = \frac{1}{\sqrt{2}}(\sqrt{AC}\pm B)^{1/2},\\
&A = (a-a_1)^2+b^2, B = (a-a_1)(a-a_2)+b^2, C = (a-a_2)^2+b^2.
\end{aligned} \tag{14}$$

In (11) we neglect the contribution of fermion mass.

The dependence of total cross-section of process (11) from $\sqrt{s}$ at $m_H = 125$ GeV is presented in fig.4.

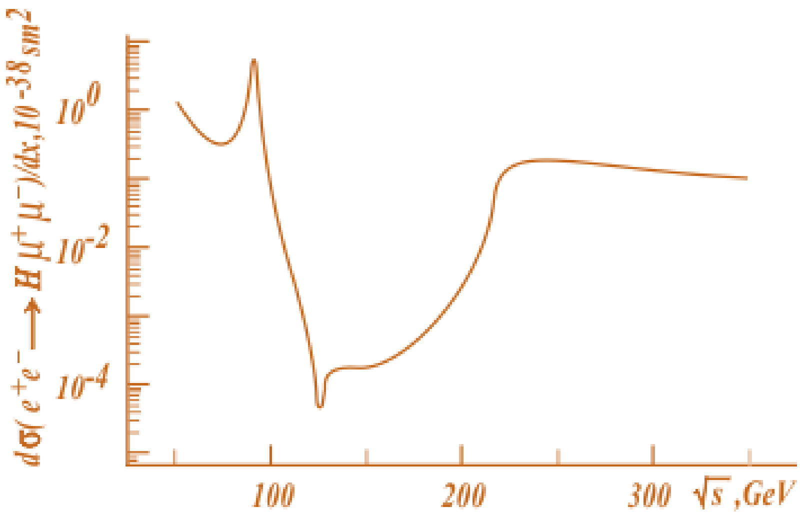

Fig. 4. The dependence of total cross-section of process $e^+e^- \to H\mu^+\mu^-$ on $\sqrt{s}$

As it is seen from the figure there are two maximums and two minimums in total cross-section of process (3). The first maximum is related to energy $\sqrt{s} = m_Z$ which corresponds to annihilation of e^+e^- - pair by $e^+e^- \to Z \to HZ^* \to H\mu^+\mu^-$ scheme. The second maximum is related to energy of initial beams $\sqrt{s} = m_Z + \sqrt{2}m_H$ which corresponds to production of *HZ* - pair by scheme $e^+e^- \to Z^* \to HZ \to H\mu^+\mu^-$ and further decay of *Z*-boson.

The carried out analysis shows that second minimum corresponds to $\sqrt{s} = 125\ GeV$ of initial beam energy and in this case for the total cross-section we have $\sigma_{tot}^{2min} \approx 3{,}9 \cdot 10^{-42} cm^2$. The second maximum corresponds to energy of initial beams $\sqrt{s} = 245\, GeV$ at which for the total cross-section we have $\sigma_{tot}^{2max} \approx 2 \cdot 10^{-39} cm^2$.

The number of events of *HZ* - pair production by $e^+e^- \to Z^* \to HZ \to H\mu^+\mu^-$ scheme is given in Table 1.

Table 1

ILC energy	*ILC luminosity, L_{int}*	*Number of events*
$\sqrt{s} = 245\ GeV$	*250 fb^{-1}*	*M=Lσ=500 events*
$\sqrt{s} = 245\ GeV$	*500 fb^{-1}*	*M=Lσ=1000 events*
$\sqrt{s} = 245\ GeV$	*1000 fb^{-1}*	*M=Lσ=2000 events*

From the Table 1 it is seen that number of events of Higgs boson production in the process $e^+e^- \to H\mu^+\mu^-$ on electron-positron collider ILC allows us to investigate Higgs boson various properties in detail.

Since in linear colliders ILC electrons and positrons will be longitudinally polarized, in this paper we will not consider the transverse polarizations of $e^+ e^-$ beams.

Note that the detail analysis of transversally polarized beams in process (3) is investigated in [7-8].

4. THE CASE OF LONGITUDINAL POLARIZATION OF COLLIDING e^+e^- -BEAMS

In this case for the differential cross-section of the process (3) we have:

$$\frac{d\sigma(h_1,h_2)}{d\Phi} = \frac{d\sigma}{d\Phi}[1 + (h_1 - h_2)A_s - h_1h_2], \tag{15}$$

where h_1 and h_2 are longitudinal polarizations of electron and positron correspondingly. The formula (15) is applicable both to the differential cross-section in the variable $dxd\Phi$, and in variables $d\Phi$ and dx variables separately.

Moreover in the case of $dxd\Phi = d\Omega$ we have $F = t_1$ (expression for the t_1 one can find in (7)) and in the case of $d\Phi = d\Omega$ we have.

$$A_s = -\frac{2g_V g_A}{(g_V^2 + g_A^2)}. \tag{16}$$

In the case $d\Phi = dx$ we have

$$A_s = A_1 / A_0, \tag{17}$$

where

$$A_1 = -2g_V g_A(G_V^2 + G_A^2)\{12x(1 - r_f^2/x) + [(1 + r_H^2 - x)^2](1 + 2r_f^2/x)\} - \\ -72 r_f^2 g_V g_A(G_V^2 - G_A^2), \tag{18}$$

and A_0 is determined according to (10). The quantity A_s determines the spin asymmetry due to the difference $(h_1 - h_2)$.

The effect of the electron beam polarization, determined according to:

$$N(h_1) = \frac{d\sigma(0,0)/d\Phi - d\sigma(h_1,0)/d\Phi}{d\sigma(0,0)/d\Phi + d\sigma(h_1,0)/d\Phi} \tag{19}$$

and found on the basis of formula (15), has the form

$$N(h_1) = -h_1 A_s/(2 + h_1 A_s) \tag{20}$$

The effect of positron beam polarization can be found from (20) by the substitution $h_1 \to h_2$.

It is easy to see that in case $r_f = 0$ the spin asymmetries A_s in distributions on variables dx and $d\Phi$ coincide, moreover $A_s = -23{,}7$ % at Weinberg angle $sin^2\eta = 0{,}22$. The effect of the beams polarization also has the same property, which at the value $sin^2\eta = 0{,}22$ is equal to: $N(h_1 = 1) = N(h_2 = -1) = 1\ \ 3$ %, $N(h_1 = -1) = N(h_2 = 1) = -10{,}6$ %.

Note that on ILC at $h_1 = 0{,}8$ the effect of electron beam polarization is equal $N(h_1 = 0{,}8) = 10{,}4$ % and at $h_2 = 0{,}5$ the effect of positron beam polarization is equal $N(h_2 = 0{,}5) = 0{,}56$ %.

Integrating the expression (9) over the all variables we have the following expression of the total cross-section of the process (3) in the case of longitudinal-polarized initial beams:

$$\sigma(h_1, h_2) = \sigma\left[1 - \frac{2g_V g_A}{(g_V^2 + g_A^2)}(h_1 - h_2) - h_1 h_2\right]. \tag{21}$$

5. ENERGY-ANGULAR DISTRIBUTION OF FERMIONS IN $e^+e^- \to Hf\bar{f}$.

Carrying out the calculations on the base of (4), for the arbitrary polarization of the initial colliding beams in the center-of-mass system, we have the following cross - section for the energy-angular distribution of fermions:

$$\frac{d\sigma(\vec{s}_1, \vec{s}_2)}{d\varepsilon d\Omega} = \frac{d\sigma}{d\varepsilon d\Omega}\{1 + ((\vec{p}^{\,0}\vec{s}_1) + (\vec{p}^{\,0}\vec{s}_2))f_1 + [(\vec{s}_1\vec{s}_2)sin^2\vartheta + \\ + 2((\vec{p}^{\,0}\vec{s}_1)(\vec{k}^0\vec{s}_2) + (\vec{p}^{\,0}\vec{s}_2)(\vec{k}^0\vec{s}_1))cos\vartheta - \\ - 2(\vec{k}^0\vec{s}_1)(\vec{\chi}^0\vec{s}_2)]f_2 + (\vec{p}^{\,0}\vec{s}_1)(\vec{k}^0\vec{s}_2)f_3\}, \tag{22}$$

where

$$\frac{d\sigma}{d\varepsilon d\Omega} = \frac{G_F^3}{2\sqrt{2}(4\pi)^4 \varepsilon\beta^2} \frac{m_Z^8}{(m_Z^2 - q_1^2)^2 + m_Z^2 \Gamma_Z^2} F_0, \tag{23}$$

is cross-section of the process (3) averaged and summed on particle polarizations. In (22) and (23) we introduce the following designations: $f_i = F_i/F_0$ $(i=1,2,3)$

$$\begin{aligned} F_0 &= (g_V^2 + g_A^2)(G_V^2 + G_A^2)[\varepsilon(Q+R)(1-\beta^2\cos^2\vartheta) - 2R] + \\ &+ 8(g_V^2 + g_A^2)(G_V^2 - G_A^2)\varepsilon\beta^2 r_f^2 P - 8g_V g_A G_V G_A R\beta\cos\vartheta, \\ F_1 &= 4G_V G_A(g_V^2 + g_A^2)R\beta\cos\vartheta - 2g_V g_A(G_V^2 + G_A^2)[\varepsilon(Q+R)(1- \\ &- \beta^2\cos^2\vartheta) - 2R] - 16g_V g_A(G_V^2 - G_A^2)\varepsilon\beta^2 r_f^2 P, \\ F_2 &= (g_V^2 - g_A^2)(G_V^2 + G_A^2)(Q+R)\varepsilon\beta^2, \; F_3 = F_0 - (1+\cos^2\vartheta)F_2 \end{aligned} \tag{24}$$

In the above mentioned formulae, $\vec{p}^{\,0}$ - and $\vec{k}^{\,0}$ - are the unit vectors in the directions of the electron momenta and the producing fermion correspondingly; ϑ - the angle of emission of the fermion with respect to the direction of the electron momentum, β - the velocity of the producing fermion, ε - its energy in units $\sqrt{s}/2$ which is limited from $2r_f$ up to $1 - r_H^2 - 2r_f r_H$. The expressions for *P*, *Q* and *R* quantities are given in the appendix.

Note that in [10] a complete and all-lateral analysis of the energy-angular distribution of process (3) was carried out in the case of arbitrary polarized colliding beams (for small values of the Higgs boson mass).

In the case of unpolarized colliding beams, the energy-angular distribution of the producing fermions in the process (3) is determined by the formula (23). The analysis of the cross - section and other characteristics of the process (3) will be carried out below for the production of muons in the framework of the Weinberg-Salam model.

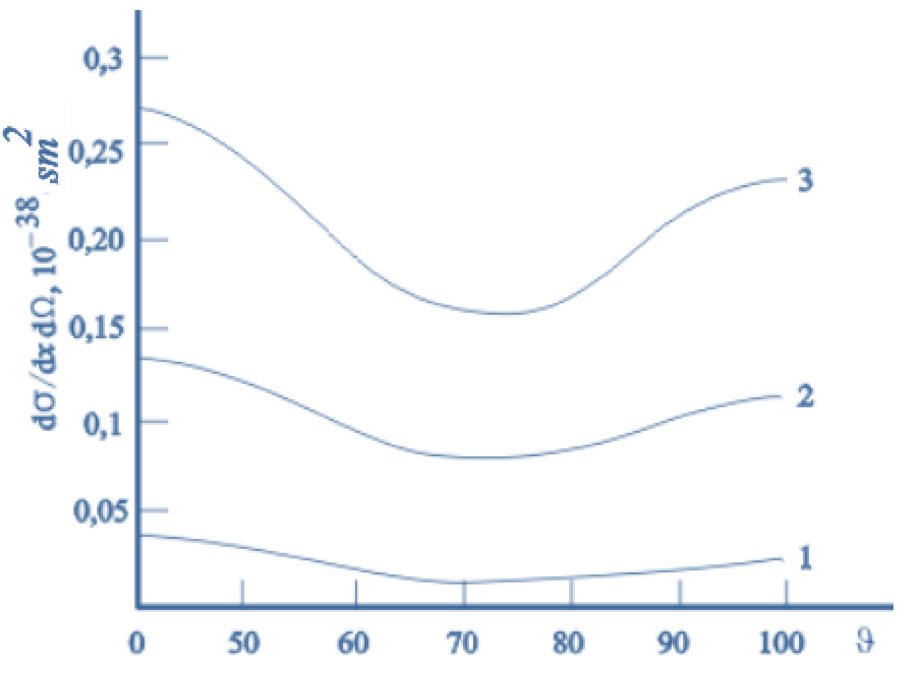

*Fig.5.*The dependence of energy-angular distribution on ϑ

At $\sqrt{s} = m_Z$ and $m_H = 175$ *GeV* the dependence of the cross-section $d\sigma(e^+e^- \to H\mu^+\mu^-)/d\varepsilon d\Omega$ on the muon emission angle ϑ for various values of ε are presented in Fig. 5. The curves 1, 2 and 3 correspond to the values $\varepsilon = 0.3$, 0.4, and 0.5. As one can be seen from Fig. 5, for a given value ε, the cross-section is larger for small angles. We note that the initial energy is highlighted by the fact that the process under consideration occurs with the production of the *Z*- resonance, thus having the largest cross-section.

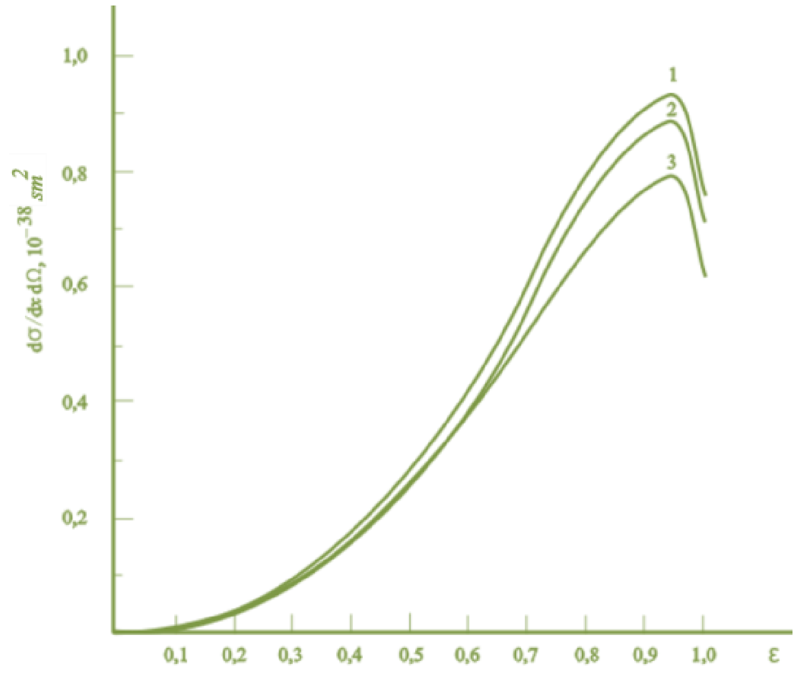

Fig. 6. Dependence of energy-angular distribution on ε

The dependence of cross-section $d\sigma(e^+e^- \to H\mu^+\mu^-)/d\varepsilon d\Omega$ on ε at different ϑ (as in fig.5 at $\sqrt{s}=m_z$ и $m_H = 175$ *GeV)* is presented in fig.6. Curves 1,2 and 3 correspond to values $\vartheta = 5^\circ, 20^\circ$ and 35°.

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APPENDIX

At calculation of energy-angular fermion distribution in process (3) there are integrals of following type:

$$I_0 = \int \frac{1}{[(p_1+p_2-\chi)^2 - m_Z^2]^2 + m_Z^2\Gamma_Z^2} \frac{d\vec{k}_2}{\omega_2}\frac{d\vec{\chi}}{\omega}\delta^4(k_2+\chi-q), \qquad (\Pi.1)$$

$$I_\alpha = \int \frac{k_{2\alpha}}{[(p_1+p_1-\chi)^2 - m_Z^2]^2 + m_Z^2\Gamma_Z^2} \frac{d\vec{k}_2}{\omega_2}\frac{d\vec{\chi}}{\omega}\delta^4(k_2+\chi-q), \qquad (\Pi.2)$$

where $q = p_1 + p_2 - k_1$.

For the calculation of the integrals (A.1) and (A.2), first of all, we give the region of admissible energy values of the Higgs boson (ω). Using the laws of conservation of energy and momentum in the process (3), we have (in the center-of-mass system of initial beams):

$$\omega_{max} = \sqrt{s}\,\frac{(1-\varepsilon+r_H^2)(2-\varepsilon)+\varepsilon\beta\sqrt{(1-\varepsilon-r_H^2)^2-4r_f^2r_H^2}}{4(1-\varepsilon+r_f^2)},$$

$$\omega_{min} = \sqrt{s}\,\frac{(1-\varepsilon+r_H^2)(2-\varepsilon)-\varepsilon\beta\sqrt{(1-\varepsilon-r_H^2)^2-4r_f^2r_H^2}}{4(1-\varepsilon+r_f^2)}.$$

Integrals (П.1) and (П.2) have the following form:

$$I_0 = \frac{2\pi}{s^2 \varepsilon\beta} P \, ,$$

$$I_\alpha = \frac{\pi}{s^2 \varepsilon^3 \beta^3} (Qk_{1\alpha} - Rq_\alpha) \, .$$

Where

$$P = \frac{1}{\Gamma} [arctg \, \frac{2\omega_{max}/\sqrt{s} - (1 - r_Z^2 + r_H^2)}{\Gamma} - arctg \, \frac{2\omega_{min}/\sqrt{s} - (1 - r_Z^2 + r_H^2)}{\Gamma} \, ,$$

$$Q = (\varepsilon - 2r_f^2) I_1 - 2(1 - \varepsilon + r_f^2) I_2 \, , R = 2r_f^2 I_1 - (\varepsilon - 2r_f^2) I_2 \, ,$$

$$I_1 = 2(1 - \varepsilon - r_H^2 + 2r_f^2) P \, , \; I_2 = 2(r_Z^2 - 2r_f^2) P - ln \frac{[2\omega_{max}/\sqrt{s} - (1 - r_Z^2 + r_H^2)]^2 + \Gamma^2}{[2\omega_{min}/\sqrt{s} - (1 - r_Z^2 + r_H^2)]^2 + \Gamma^2}$$

$$r_Z = m_Z / \sqrt{s} \; , \; \Gamma = m_Z \Gamma_Z / s \, .$$

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