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CROSS-SECTIONS CALCULATION FOR THE PROCESS $e^-(P_1)+ e^+(P_2)\text{->} H^-_i(P_2)+ H^-_j(P_{14})+ X^0_i(P_5)$

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Abstract

The cross-sections (σ), in electron (e^-) positron (e^+) collision, is calculated over range of center of mass energy(s) for the process: $e^-(P_1)+e^+(P_2)\rightarrow H_i^0(P_2)+H_i^0(P_4)+\tilde{\chi}_\ell^0(P_5)$. Feynman diagrams are taken into consideration depending on the type of the propagator as: Production of H_i^0, H_i^0 and $\tilde{\chi}_\ell^0$, when Z^0 and H^0 are the propagators exchange Where ($i, j = 1,2,3, and \ell = 1,2,3,4$). The cross section for this process is calculated according to a carefully selected set of parameters. These different possible (288) situations are graphed and tabulated in two groups, one of them when Z^0 and H^0 are the propagators and the other when H^0 and Z^0 are the propagators. The production mechanisms can be detected as $e^-(P_1)+e^+(P_2)\rightarrow H^0(P_2+P_4)\rightarrow H_i^0(P_2)+H_i^0(P_4)$ in which have the best cross-section value. At S interval (1800 - 2800) GeV, the cross-section value is ($\sigma = 6.4\times10^{-2}$ Pb). With different value of masses of H_i^0, H_i^0 and $\tilde{\chi}_\ell^0$,

Keywords: Higgs bosons; neutralinos.

1. Introduction:

One of the main open problems of particle physics is the understanding of the mechanism responsible for breakdown of the electroweak symmetry. The cross-sections for the production of two neutral Higgs boson with neutralinos due to electron-positron annihilation, is calculated according to the reaction.

$$e^-(P_1)+e^+(P_3)\rightarrow H_i^0(P_2)+H_j^0(P_4)+\tilde{\chi}_\ell^0(P_5)$$

(Where i , j =1, 2, 3, and ℓ = 1, 2, 3, 4)

The standard model (SM) is described by a renormalizable, SU(2) × U(1) gauge field theory. The renormalizability of the theory requires the Spontaneous Symmetry Breaking (SSB) and $W^\pm$ and Z^0 bosons acquire their masses through Higgs mechanism. In the SM only the couplings of Higgs with matter and gauge particles are predicted, but nothing much is known theoretically about its mass [1]. The standard model predicts a single neutral higgs boson H^0 .Although the mass of H^0 is a free parameter, self -consistency of the theory require that mass to be less than about 1 TeV.[2]

Supersymmetry (SUSY) is a symmetry which relates particles of differing spin, The particles are combined into a superfield, which contains fields differing by one-half unit of spin.[3]. In Supersymmetric theories. the scalar sector is much richer in these theories and there are five scalars: three neutrals out of which two are CP even states: the lighter (heavier) one being denoted by $H_2^0(H_1^0)$ and one CP odd state denoted by H_3^0 and a pair of charged Higgs bosons $H^\pm$. The masses of all the scalars are not independent. They are given in terms of two parameters, which can be chosen either to be $m_{H_3^0}$,tan β or $m_{H\pm,}$ tan β. Here tan β is the ratio of the vacuum expectation values of the neutral members of the two Higgs doublets that exist in the MSSM. As a result of the supersymmetry these masses satisfy certain sum rules and hence inequalities at tree level [4]:

$$m_{H_2^0}\leq m_z,\ m_{H_1^0}>m_z\ ,m_{H^\pm}>m_w,m_{H_2^0}<m_{H_1^0},\ m_{H^\pm}$$

In the minimal supersemmetric standard model (MSSM) two Higgs doublets H_d (H_1) and H_u(H_2) are needed to give masses to down- and up-type fermions. This is in contrast to the SM where with just one Higgs doublet both u and d type masses can be generated via the Higgs Mechanism [5]. In particle physics, the neutralino is a hypothetical particle predicted by supersymmetry.[6] The MSSM contains four neutralinos χ_ℓ^0 (ℓ = 1, 2, 3, 4), which are due to the mixing of photino, Zion and neutral Higgsinos.

Neutralinos tends to have

1) It mixing of the two neutral gauginos $\tilde{B}^0$ (Bino),$\tilde{W}^0$ (neutral Wino), and the two neutral Higgsinos, $\tilde{H}_1^0$and $\tilde{H}_2^0$ Note that $\tilde{\gamma}$ andZ^0 are linear combinations of the $\tilde{B}^0$ and $\tilde{W}^0$.

2) Masses at the weak scale (10-1000 GeV).

3) In models in which R-parity is conserved and the lightest of the four neutralinos is the lightest supersymmetric particle LSP , the lightest neutralino is stable.

4) The lightest neutralino is an excellent candidate to comprise the universe's cold dark matter, and consider as the basic Weak Interaction Massive Particle (WIMP) .

5) Neutralinos are related by the weak nuclear force to each other and to charginos and are mixtures of superpartner's fields in the MSSM that have zero lepton number.

6) Neutralino dark matter could be observed experimentally in nature either indirectly or directly

i- Indirectly using γ ray and neutrino telescopes .

ii- Direct through experiments such as Cryogenic dark matter search (CDMS) it is a series of experiments designed to directly detect particle dark matter in the form of WIMPs. Using an array of semiconductor detectors[7].

The heavier neutralinos typically decay through a neutral Z boson to a lighter neutralino or through a charged W boson to a light chargino[8]

The neutralino sector depends on four parameters: gaugino masses M and M' associated with the U(1) and SU(2) subgroups of standard model , the Higgs mass parameter μ , and the ratio of the vacuum expectation values (VEV) of the Higgs fields.

$$tan\beta = {}^{v_2}/_{v_1}$$

The MSSM model has two Higgs doublets and additional constraints [9,10].

$$m_3^2 + M_Z^2 = m_1^2 + m_2^2,$$
$$m_{\pm}^2 = m_3^2 + M_W^2,$$
$$0 \le m_2 \le M_Z \le m_1.$$

From these constraints, it also follows that

$$m_2 \le m_3 \le m_1,$$
$$m_{1,2}^2 = 1/2\left\{m_3^2 + m_Z^2 \pm \left[(m_3^2 + m_Z^2)^2 - 4m_Z^2 m_3^2 \cos^2 2\beta\right]^{1/2}\right\}$$

where the masses $m_1, m_2, m_3, m_{\pm}$ of the Higgs particles $H_1^0, H_2^0, H_3^0, H^{\pm}$ respectively. and θ_w is the standard weak mixing angle. Importantly, these SUSY relations guarantee that the neutral Higgs particle H_2^0 exists with a mass less than that of the Z.

The two angles $\beta\ and\ \alpha$ and are fixed in terms of the Higgs boson masses [11].

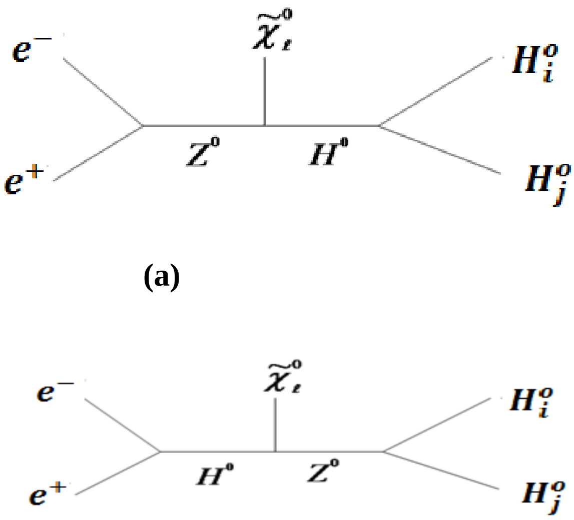
$$\cos 2\alpha = -\cos 2\beta[(m_3^2 - M_z^2)/(m_1^2 - M_z^2)]$$
$$\sin 2\alpha = -\sin 2\beta[(m_1^2 + m_2^2)/(m_1^2 - m_2^2)]$$
$$\tan 2\alpha = \tan 2\beta[(m_3^2 - M_z^2)/(m_3^2 - M_z^2)]$$

The angel α can be taken to lie in the interval $-{}^{\pi}/_2 \le \alpha \le 0$. And the angel β lie in the interval $0 \le \beta \le {}^{\pi}/_2$

In particle physics, a slepton is a sfermion which is hypothetical boson Super partner of a lepton whose existence is implied by Supersymmetry. Slepton have the same flavor and electric charge as corresponding leptons and their spin is zero. For example slectron $\tilde{e}_R$ is superpartner of electron

2. Production of H_i^0 ,H_j^0 and $\tilde{\chi}_\ell^0$, when z^0 and H^0 are the propagators exchange:

2.1. Feynman Diagram for group (a) and group (b):



(a)

(b)

Figure.1. Feynman diagrams for the process $e^-(P_1) + e^+(P_3) \to H_i^o(P_2) + H_j^o(P_4) + \tilde{\chi}_\ell^0(P_5)$ via Z and Higgs boson exchange. There are (1-288) diagrams.

2.2. The Matrix Elements

2.2.1. for group a (1-144) are

$$M_{a(1-144)} = \frac{g^3 m_z}{16\cos^3\theta_w} U_{e^-}(P_1)\gamma_l C\, \bar{V}_{e^+}(P_3)(S^2 - M_Z^2)^{-1}(S - P_5)_\nu \bar{U}_{\tilde{\chi}^0}(P_5)\left(\sigma^2 - m_{H^0}^2\right)^{-1} F_{xyl}$$

Where

$$C = 4\,\mathrm{Sin}^2\theta_W + \gamma_5 - 1$$

F_{xyl} Is given as:

$F_{111} = -\cos 2\alpha \cos(\beta + \alpha)$

$F_{222} = -\cos 2\alpha \sin(\beta + \alpha)$

$F_{112} = F_{121} = F_{211} = 2\sin 2\alpha \cos(\beta + \alpha) + \sin(\beta + \alpha)\cos 2\alpha$

$F_{122} = F_{212} = F_{221} = -2\sin 2\alpha \sin(\beta + \alpha) + \cos(\beta + \alpha)\cos 2\alpha$

$F_{133} = F_{331} = F_{313} = \cos 2\beta \cos(\beta + \alpha)$

$F_{323} = F_{233} = F_{332} = -\cos 2\beta \sin(\beta + \alpha)$

The Feynman rules for $e^- e^+ H^0$ vertices are [12]

$P_1 + P_3 = P_2 + P_4 + P_5$

$S = \sigma + P_5$

2.2.2. For group b (145 - 288) are

$$M_{b(145-288)} = \frac{g^3 m_e}{8 M_w \cos^2\theta_w} U_{e^-}(P_1) B_x \bar{V}_{e^+}(P_3)\left(S^2 - m_{H^0}^2\right)^{-1}(S - P_5)_\nu(\sigma^2 - M_Z^2)^{-1} b_{\ell y}(P_2 + P_4)_K \bar{U}_{\tilde{\chi}^0}(P_5)$$

Where m_e is the electron mass, for B_x (x=1, 2, 3) are

$B_1 = \frac{\cos\beta}{\cos\alpha}$, $B_2 = \frac{\sin\beta}{\cos\alpha}$, $B_3 = \gamma_5 \tan\alpha$

For $b_{\ell y}$ we have $b_{13} = b_{31} = \sin(\alpha - \beta)$, $b_{23} = b_{32} = \cos(\alpha - \beta)$

2.3. Cross section calculations:

In this work we have 3-body final states with momentum P_2 , P_4 , P_5 and the initial states have momentum P_1 , P_3 .In general, the cross section for the process $e^-(P_1) + e^+(P_3) \rightarrow H_i^o(P_2) + H_j^o(P_4) + \tilde{\chi}_\ell^0(P_5)$ can be written in the form

$$\sigma = \int \pi^2 |\mathrm{M}|^2 \frac{\mathrm{dx\,dy\,d}\sigma^2}{\Lambda(\mathrm{S},\mathrm{m}_1,\mathrm{m}_3)\,\Lambda(\mathrm{S},\sigma,\mathrm{m}_5)}$$

Where M is the matrix element previously mentioned, the integration is performed using a simple approximation obtained by an improved Weizsacker-Williamson procedure[13,14]. Where

$\Lambda(\mathrm{X,Y,Z}) = [\mathrm{X}^4 + \mathrm{Y}^4 + \mathrm{Z}^4 - 2\mathrm{X}^2\mathrm{Y}^2 - 2\mathrm{X}^2\mathrm{Z}^2 - 2Y^2Z^2]^{1/2}$

The limit of integration is given as follows:

$$x_\pm = \frac{1}{4S^2}[(S^2 + m_1^2 - m_3^2)(S^2 - \sigma^2 + m_5^2) \pm \Lambda(S, m_1, m_3)\Lambda(S, \sigma, m_5)]$$

$$y_\pm = \frac{1}{4\sigma^2}[(\sigma^2 + m_2^2 - m_4^2)(S^2 - \sigma^2 + m_5^2) \pm \Lambda(\sigma, m_2, m_4)\Lambda(S, \sigma, m_5)]$$

$$(m_2 + m_4)^2 \le \sigma^2 \le (S^2 - m_5^2)^2$$

In all our calculations by using Mathematica program, we assume the following values for vector-boson masses [15, 16] suggested:

$M_W = 81$ GeV

$M_Z = 100$ GeV

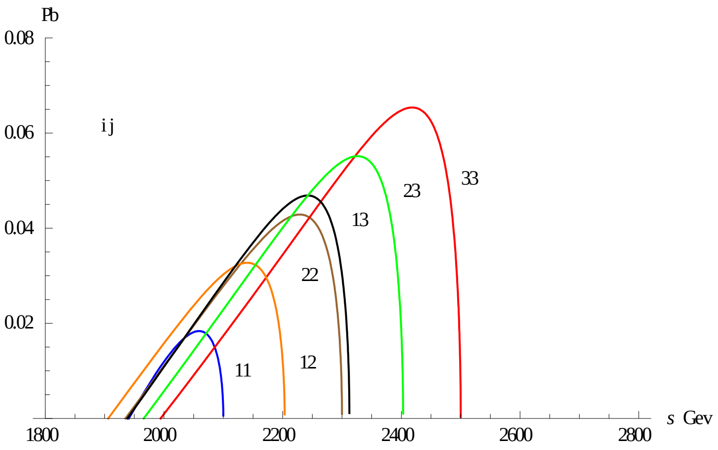
$M_{H^0} = 800$ GeV

$m_{H_1^o} = 700$ GeV, $m_{H_2^o} = 800$ Gev, $m_{\mathrm{H}_3^o} = 900$ Gev

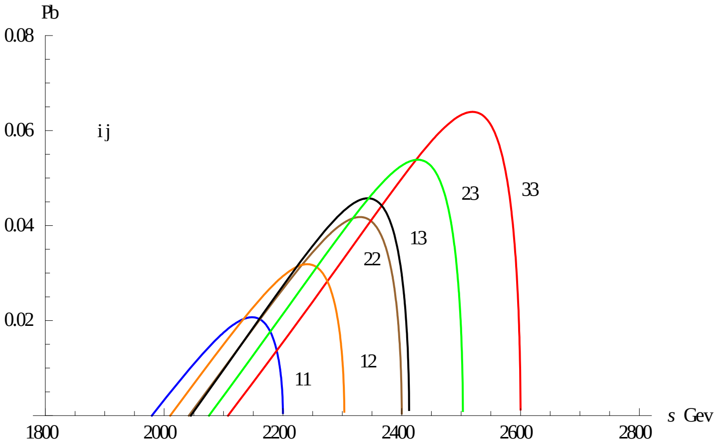
$m_{\tilde{\chi}_1^0} = 700$ GeV, $m_{\tilde{\chi}_2^0} = 800$ GeV, $m_{\tilde{\chi}_3^0} = 900$ GeV, $m_{\tilde{\chi}_4^0} = 1000$ GeV

The Cross sections are calculated as a function of center of mass energy for the Feynman diagrams of figure(1.a) and (1.b) by using above equations and Mathematica program and the result are given in figs.(2) and figs (3) by interchanging the indices i & j and the mass of Neutralino $\tilde{\chi}_\ell^0(P_5)$

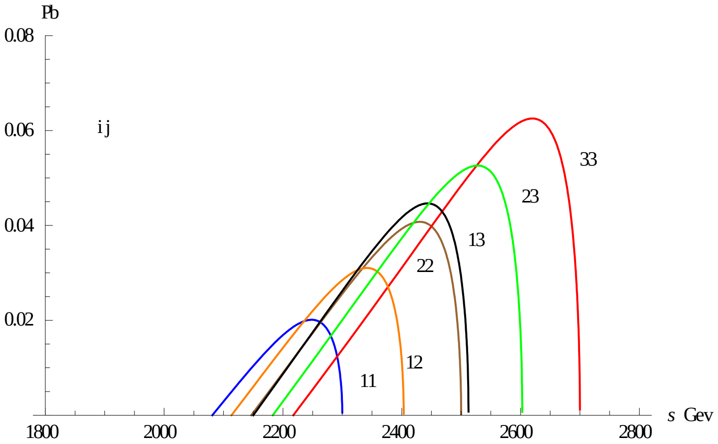
$m_{\tilde{\chi}_1^0}$=700Gev



$m_{\chi_2^0} = 800\text{Gev}$



$m_{\chi_3^0} = 900\text{Gev}$



$m_{\chi_4^0} = 1000\text{Gev}$

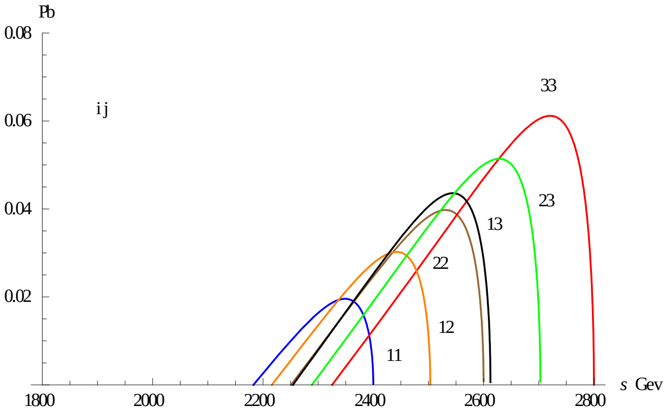
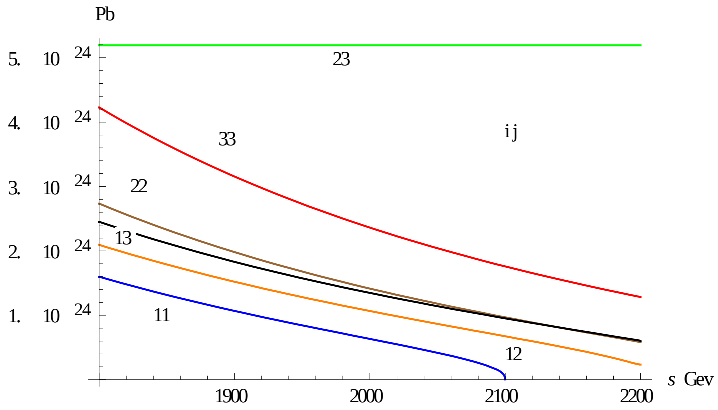
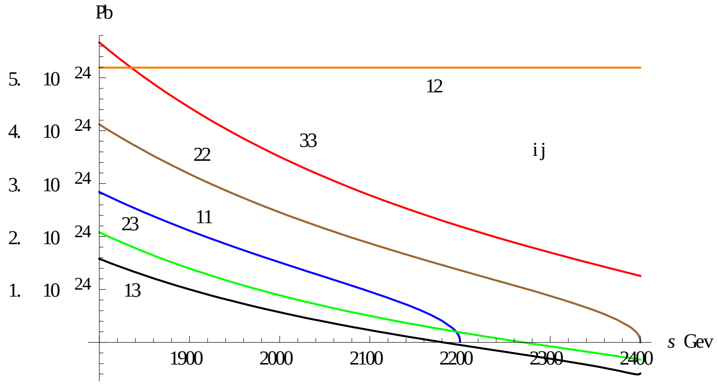


Figure2. The cross sections via Z^o and H^o propagators for group a (1-144) diagram, for the process $e^-(P_1) + e^+(P_3) \rightarrow H^o(P_2 + P_4) \rightarrow H_i^o(P_2) + H_j^o(P_4)$.

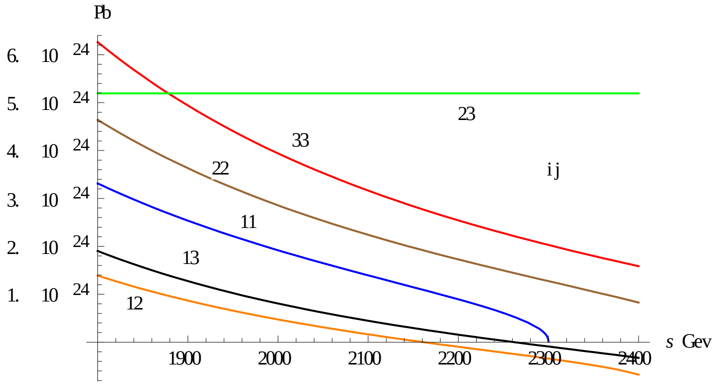
$m_{\chi_1^0}$=700Gev



$m_{\chi_2^0}$ = 800Gev



$m_{\chi_3^0}$ = 900Gev



$m_{\tilde{\chi}_4^0} = 1000\text{Gev}$

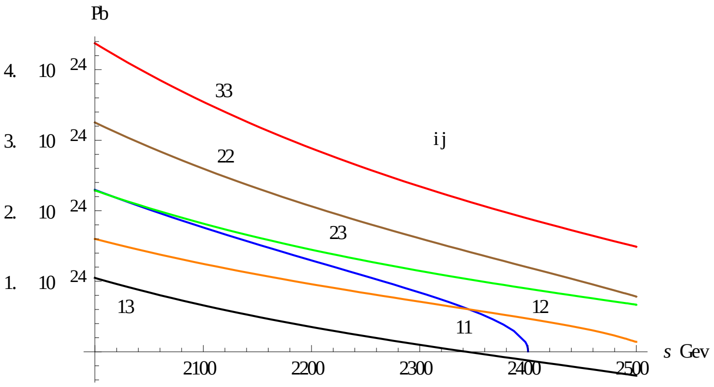


Figure 3. The cross sections via $H^o$and Z^o propagators for group b (145-288) diagram**,** for the process $e^-(P_1)+e^+(P_3)\rightarrow Z^o(P_2+P_4)\rightarrow H_i^o(P_2)+H_j^o(P_4)$

3. Conclusion:

Figs.(2) and Fig.(3), show the cross-sections for the process $e^-(P_1)+e^+(P_3)\rightarrow H_i^o(P_2)+H_j^o(P_4)+\tilde{\chi}_\ell^0(P_5)$ as a function of center of mass energy S . via Higgs boson and Z boson propagators exchange

If center of mass energy S increase the cross-sections increase, but after certain value of S the value of cross sections decrease. The following table shows the comparison between all data of cross-section to determine the best value of cross-section.

4. Table:

$e^-(P_1)+e^+(P_3)\rightarrow H_i^0(P_2)+$	**fig. no.**	$m_{\tilde{\chi}_\ell^0}$	**i j**	**S(Gev)at max σ**	**σ(Pb)**
Production via Z^0 and H^0 propagators $e^-(P_1)+e^+(P_3)\rightarrow H^o(P_2+P_4$	2	$700GeV$	33	2420	6.4×10^{-2}
		$800GeV$	33	2521	6.3×10^{-2}
		$900GeV$	33	2625	6.2×10^{-2}
		$1000GeV$	33	2723	6.1×10^{-2}
Production via H^0 and Z^0 propagators $e^-(P_1)+e^+(P_3)\rightarrow Z^o(P_2+P_4$	3	$700GeV$	23	1800	4.5×10^{-24}
		$800GeV$	33	1800	5.6×10^{-24}
		$900GeV$	33	1800	6.1×10^{-24}
		$1000GeV$	33	2000	4.3×10^{-24}

Table the peak values of the cross sections of the interaction $e^-(P_1)+e^+(P_3)\rightarrow H_i^0(P_2)+H_j^0(P_4)+\tilde{\chi}_\ell^0(P_5)$ with different i&j values of higgs boson at different values of incident energies.

5. Discution:

5.1. The Dominant situation:

From the table we have success to identify the scenario for highest cross section for the reaction for the group (a), but for the group (b) we neglect it because the value of cross sections is very small. For neutral Higgs bosons H_i^o , H_j^o as outgoing particles have mass of $M_{H_i^o} = 900\ Gev$, $M_{H_j^o} = 900\text{Gev}$ and $m_{\tilde{\chi}_i^0} = 700\ Gev$ the peak value of cross section goes up to $(6.4 \times 10^{-2}\ \text{Pb})$ at (S= 2420 Gev) When Z^0 and H^0 propagators.

5.2.The competing situation:

For$M_{H_i^o} = 900\ Gev$, $M_{H_j^o} = 900\text{Gev}$ and $m_{\tilde{\chi}_i^0} = 800\ Gev$ the peak value of cross section goes up to $(6.3 \times 10^{-2}\ \text{Pb})$ at (S= 2521 Gev) when Z^0 and H^0 propagators.

For$M_{H_i^o} = 900\ Gev$, $M_{H_j^o} = 900\text{Gev}$ and $m_{\tilde{\chi}_i^0} = 900\ Gev$ the peak value of cross section goes up to $(6.2 \times 10^{-2}\ \text{Pb})$ at (S= 2625 Gev) when Z^0 and H^0 propagators.

For$M_{H_i^o} = 900\ Gev$, $M_{H_j^o} = 900\text{Gev}$ and $m_{\tilde{\chi}_i^0} = 1000\ Gev$ the peak value of cross section goes up to $(6.1 \times 10^{-2}\ \text{Pb})$ at (S= 2723 Gev) when Z^0 and H^0 propagators.

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