Production of Neutralinos Via H^0 Propagator From Electron – Positron Annihilation

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Abstract .The cross-sections σ, in electron (e-) positron (e+) collision, are calculated over range of center of mass energy S for the process.

$$e^+(P_1)+e^-(P_3)\to\tilde{\chi}_i^0(P_2)+\tilde{\chi}_j^0(P_4)+\tilde{\chi}_\ell^0(P_5)$$

The process will done when the products are $\tilde{\chi}_i^o$, $\tilde{\chi}_j^o$, and $\tilde{\chi}_\ell^o$, where $\tilde{\chi}_\ell^o$ is a leg from electron or positron, and H^o is a propagator. (Where i, j, ℓ = 1, 2, 3, 4).

The cross sections are calculated according to a carefully selected set of parameters. These different possible situations are graphed and tabulated. There are 512 situations in two groups, one of them when $\tilde{\chi}_\ell^0(P_5)$ is a leg from positron and the other when $\tilde{\chi}_\ell^0(P_5)$ is a leg from electron. The production mechanisms can be detected as

$$e^+(P_1-P_5)+e^-(P_3)\to H^0(P_2+P_4)\to\tilde{\chi}_i^0(P_2)+\tilde{\chi}_j^0(P_4)$$
$$e^+(P_1)+e^-(P_3-P_5)\to H^0(P_2+P_4)\to\tilde{\chi}_i^0(P_2)+\tilde{\chi}_j^0(P_4)$$

in which have the best cross-section value. At S interval (1200 - 2500) Gev, the cross-section value above 1x10^{-22} pb. with different value of neutralino mass $\tilde{\chi}_i^0$,$\tilde{\chi}_j^0$,$\tilde{\chi}_l^0$.

Keywords: neutralinos ; selectron; Neutral Higgs bosons.

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 neutralinos due to electron-positron annihilation, is calculated according to the reaction.

$$e^+(P_1)+e^-(P_3)\to\tilde{\chi}_i^0(P_2)+\tilde{\chi}_j^0(P_4)+\tilde{\chi}_\ell^0(P_5)$$

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

In the Standard Model (SM) [1] the SU (2) × U(1) group is assumed to be spontaneously broken and $W^\pm$ *and* Z^0 bosons acquire their masses through Higgs mechanism.
In the minimal version of the SM where only one Higgs doublet is present, the theory predicts one neutral scalar particle H^0 with an arbitrary mass. The existence of the Higgs boson remains the main missing ingredient for the complete consistency of the SM but it might just as well play a crucial role in the discovery of new physics.

Now, the low energy super gravity model [2] represents one of the most popular extensions of the SM super symmetry standard model is actually able to solve the problem of "naturalness" [3] for light scalar particles. In the general CP-conserving two-Higgs doublet model, three of the eight original scalar degrees of freedom become the longitudinal components of the $W^\pm$ *and* Z^0 via the Higgs mechanism. The five remaining physical degrees of freedom manifest themselves as three neutral Higgs H_1^0, H_2^0, H_3^0 and a pair of charged Higgs $H^\pm$. We assume the model to be CP-conserving, in which case H_1^0 *and* H_2^0 are CP- even while H_3^0 is CP-odd (pseudo scalar) with respect to coupling to the SM fermions.

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

The MSSM (Minimal Supersymetric Model) contains four neutralinos $\tilde{\chi}_i^0$, which are due to the mixing of photino , Zion and neutral Higgsinos. 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.
$tan\beta = {}^{v_2}/_{v_1}$

In particle physics, the neutralino [4]. is a hypothetical particle predicted by supersymmetry. There are four neutralinos that are fermions and are electrically neutral, the lightest of which is typically stable. The heaviest although sometimes $\tilde{\chi}_1^0, \cdots, \tilde{\chi}_4^0$ is also used when $\tilde{\chi}_i^{\pm}$ is used to refer to charginos. These four states are mixtures of the bino and the neutral wino (which are the neutral electroweak gauginos), and the neutral higgsinos. As the neutralinos are Majorana_fermions, each of them is identical to its antiparticle. Because these particles only interact with the weak vector bosons, they are not directly produced at hadron_colliders in copious numbers. They primarily appear as particles in cascade decays of heavier particles (decays that happen in multiple steps) usually originating from colored supersymmetric particles such as squarks or gluinos.

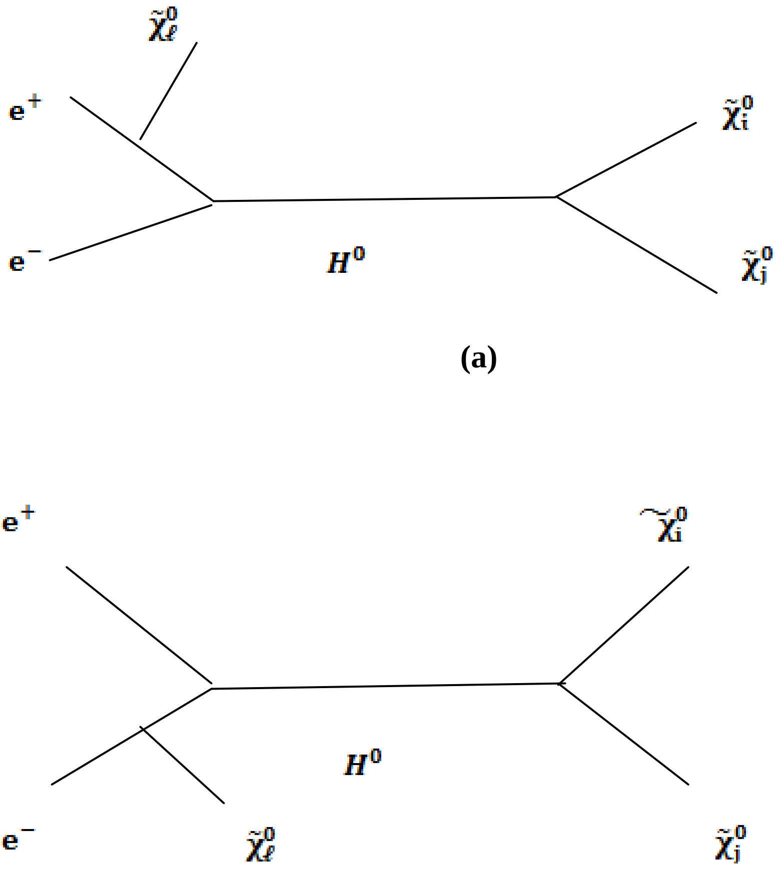
In R-parity conserving models, the lightest neutralino is stable and all supersymmetric cascade-decays end up decaying into this particle which leaves the detector unseen and its existence can only be inferred by looking for unbalanced momentum in a detector.

The heavier neutralinos typically decay through a neutral Z boson to a lighter neutralino or through a charged W boson to a light chargino[5] In supersymmetry models, all Standard Model particles have partner particles with the same quantum numbers except for the quantum number spin, which differs by 1/2 from its partner particle. Since the superpartners of the Z boson (zino), the photon (photino) and the neutral higgs (higgsino) have the same quantum numbers, they can mix to form four eigenstates of the mass operator called "neutralinos". In many models the lightest of the four neutralinos turns out to be the lightest supersymmetric particle (LSP), though other particles may also take on this role.

The MSSM model has two Higgs doublets and additional constraints [6,7].
$$m_3^2 + M_Z^2 = m_1^2 + m_2^2,$$
$$m_{\pm}^2 = m_3^2 + M_W^2,$$
$$0 \leq m_2 \leq M_Z \leq m_1.$$
From these constraints, it also follows that
$$m_2 \leq m_3 \leq m_1,$$
$$m_{1,2}^2 = 1/2\left\{m_3^2 + m_z^2 \pm \left[(m_3^2 + m_z^2)^2 - 4m_z^2 m_3^2 \cos^2 2\beta\right]^{1/2}\right\}$$
$m_1, m_2, m_3, m_{\pm}$ are the masses 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.
The two angles $\beta\ and\ \alpha$ and are fixed in terms of the Higgs boson masses [8].
$$\cos 2\alpha = -\cos 2\beta[(m_3^2 - M_z^2)/(m_1^2 - M_z^2)]$$
$$\sin 2\alpha = -\sin 2\beta[(m_1^2 + m_2^2)/(m_1^2 - m_2^2)]$$
$$\tan 2\alpha = \tan 2\beta[(m_3^2 - M_z^2)/(m_3^2 - M_z^2)]$$
The angel α can be taken to lie in the interval $-{}^{\pi}/_{2} \leq \alpha \leq 0$. And the angel β lie in the interval $0 \leq \beta \leq {}^{\pi}/_{2}$

2. Production via Neutral Higgs boson H^o propagator

2.1 Feynman Diagrams



(a)

(b)

Figure.1 Feynman diagrams for the process $e^+(P_1) + e^-(P_3) \to \tilde{\chi}_i^0(P_2) + \tilde{\chi}_j^0(P_4) + \tilde{\chi}_\ell^0(P_5)$ via Neutral Higgs boson H^0. There are (1-512) diagrams.

2.2_The Matrix Elements

2.2.1 First group for a (1-256) are

$$M_{a(1-256)} = \frac{g^2 M_W}{4\sin\beta} \ \bar{V}_{e^+}(P_1)\,(N + N^* \gamma_5)_\mu\,(P_1 - P_5)^{-1}\ U_{e^-}(P_3)\ \left((s - P_5)^2 - m_{H^0}^2\right)^{-1}{}_{\nu}\ [A + B(1-\gamma_5) + C(1+\gamma_5)]_\kappa\ \bar{U}_{\tilde{\chi}^0}(P_5)\,\bar{U}_{\tilde{\chi}^0}(P_2)\,\bar{U}_{\tilde{\chi}^0}(P_4)$$

2.2.2 Second group for b (257-512) are

$$M_{b(257-512)} = \frac{g^2 M_W}{4\sin\beta} \ U_{e^-}(P_3)\ (N + N^* \gamma_5)_\mu\,(P_3 - P_5)^{-1}\ \bar{V}_{e^+}(P_1)\ \left((s - P_5)^2 - m_{H^0}^2\right)^{-1}{}_{\nu}\ [A + B(1-\gamma_5) + C(1+\gamma_5)]_\kappa\ \bar{U}_{\tilde{\chi}^0}(P_5)\,\bar{U}_{\tilde{\chi}^0}(P_2)\,\bar{U}_{\tilde{\chi}^0}(P_4)$$

Where: N are the (4×4) matrices diagonalizing of the neutralino mass matrix[9].

and m_e is the electron mass,

$B = Q^*_{ii} \sin(\beta - \alpha) - \mathcal{R}^*_{ii} \sin\alpha$

$C = Q_{ij} \sin(\beta - \alpha) - \mathcal{R}_{ij} \sin\alpha$

$A = \frac{M_i\, \delta_{ij} \sin\alpha}{M_W}$

$\beta = 56.3 \;, \alpha = -34.48$

The Feynman rules for $e^+(P_1) + e^-(P_3) \to \tilde{\chi}^0_i(P_2) + \tilde{\chi}^0_i(P_4) + \tilde{\chi}^0_\ell(P_5)$ vertices [13,14,15]

$P_1 + P_3 = P_2 + P_4 + P_5$

$S = \sigma + P_5$

The results are interpreted as upper limits in the parameter space of the minimal supersymmetric standard model in a benchmark scenario favoring this decay mode (Search for neutral Higgs bosons in events with multiple bottom quarks at the Tevatron)[10]

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, thecross section for the process $e^+(P_1) + e^-(P_3) \to \tilde{\chi}^0_i(P_2) + \tilde{\chi}^0_j(P_4) + \tilde{\chi}^0_\ell(P_5)$ can be written in the form

$$\sigma = \int \pi^2 |M|^2 \frac{dx\, dy\, d\sigma^2}{\Lambda(S, m_1, m_3)\, \Lambda(S, \sigma, m_5)}$$

where M is the matrix element previously mentioned, the integration is performed using a simple approximation obtained by an improved Weizsacker-Williamson procedure [11,12]. Where

$$\Lambda(x, y, z) = [x^4 + y^4 + z^4 - 2x^2y^2 - 2x^2z^2 - 2y^2z^2]^{1/2}$$

The limit of integration is given as follows:

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

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

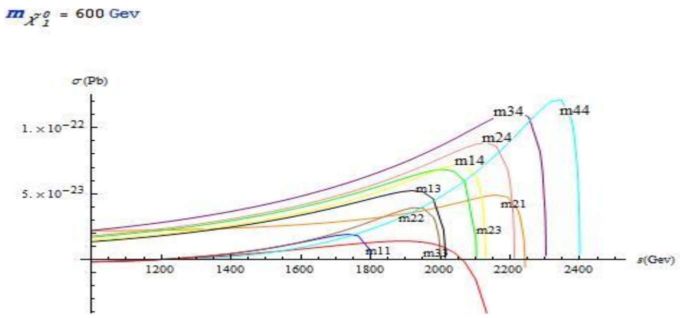
$$(m_2 + m_4)^2 \leq \sigma^2 \leq (S^2 - m_5^2)^2$$

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

$M_W = 81 Gev \;, M_Z = 100 Gev \;, M_{H^0} = 600 Gev$

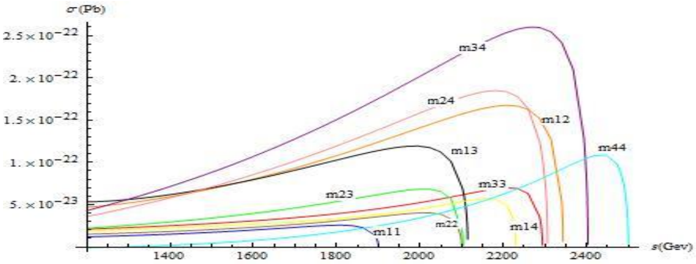
$, \; m_{\tilde{\chi}^0_4} = 900 GeV m_{\tilde{\chi}^0_1} = 600 GeV, \; m_{\tilde{\chi}^0_2} = 700 GeV, \; m_{\tilde{\chi}^0_3} = 800 GeV$

The Cross sections are calculated as a function of center of mass energy for the Feynman diagrams of figure(1.a) by using above equations and Mathematica program and the result are given in figs.(2-a) by interchanging the indices i & j and the mass of Neutralino $\tilde{\chi}^0_\ell(P_5)$ is constant with indices ℓ= 1, 2.3.



m11	Blue	m23	Green
m22	Brown	m14	Yellow
m33	Red	m24	Pink
m21	Orange	m34	Purple
m13	Black	m44	Cyan

$m_{\tilde{\chi}_2^0}(P_5) = 700 GeV$



$m_{\tilde{\chi}_3^0}(P_5) = 800 GeV$

$m_{\tilde{\chi}_3^0}$ = 800 Gev

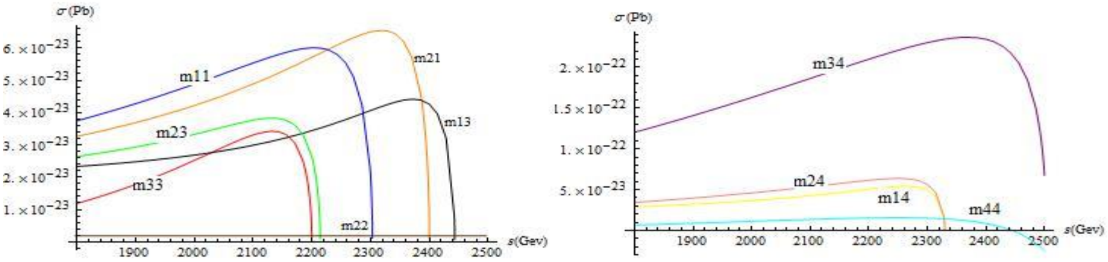
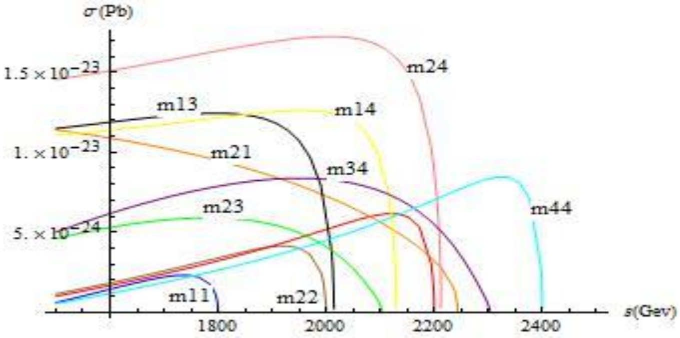


Figure (2-a). The cross section for figure (1-a) to situations (1-256). For the process

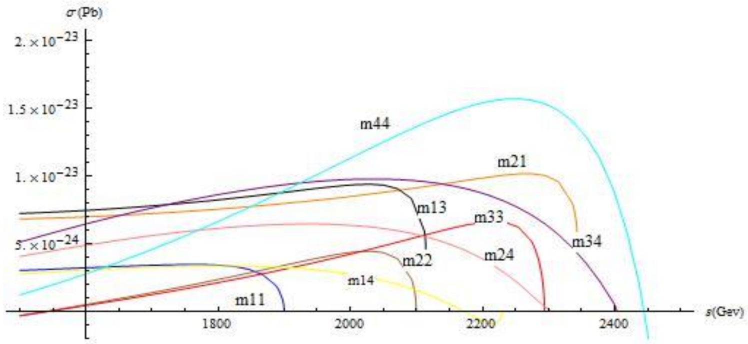
$$e^+(P_1 - P_5) + e^-(P_3) \to H^0(P_2 + P_4) \to \tilde{\chi}_i^u(P_2) + \tilde{\chi}_j^u(P_4) .$$

The Cross sections are calculated as a function of center of mass energy for the Feynman diagrams of figure(1.b) by using above equations and Mathematica program and the result are given in figs.(2-b) by interchanging the indices i & j and the mass of Neutralino $\tilde{\chi}_\ell^0(P_5)$is constant with indices ℓ = 1, 2.3.

$m_{\tilde{\chi}_1^0} = 600 GeV$



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



$m_{\tilde{\chi}_1^0} = 800GeV$

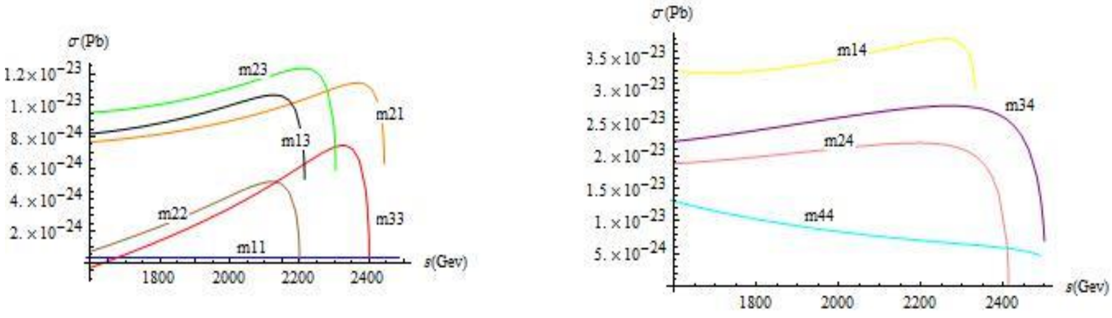


Figure (2-b). The cross section for figure(1-a) to situations (257 - 256). For the process $e^+(P_1) + e^-(P_3 - P_5) \to H^0(P_2 + P_4) \to \tilde{\chi}_i^0(P_2) + \tilde{\chi}_j^0(P_4)$.

3. Results:

Figs.(2-a) and Fig.(2-b), show the cross-sections for the process $e^+(P_1) + e^-(P_3) \to \tilde{\chi}_i^0(P_2) + \tilde{\chi}_j^0(P_4) + \tilde{\chi}_\ell^0(P_5)$ as a function of center of mass energy S . (Neutralino is emitted from positron or electron as legs through Neutral Higgs boson H^0 propagator).

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.

No expected significant different in value of $\tilde{\chi}_4^0 = 900\ Gev$ mass consider.

4. Table

$e^+(P_1)+e^-(P_3)\rightarrow\tilde{\chi}_i^0(P_2)+\tilde{\chi}_j^0(P_4)+\tilde{\chi}_\ell^0(P_5)$	fig. no.	$m_{\tilde{\chi}_\ell^0}$	i j	S(Gev)at max σ	Max σ(Pb)
Group – 1 Situations (1-256). For the process $e^+(P_1-P_5)+e^-(P_3)\rightarrow H^0(P_2+P_4)\rightarrow\tilde{\chi}_i^0(P_2)+\tilde{\chi}_j^0(P_4)$.	2-a	$600GeV$	44	2350	$1.2x10^{-22}$
		$700GeV$	34	2300	2.6×10^{-22}
		$800GeV$	34	2400	2.3×10^{-22}
Group – 2 Situations (257 - 256). For the process $e^+(P_1)+e^-(P_3-P_5)\rightarrow H^0(P_2+P_4)\rightarrow\tilde{\chi}_i^0(P_2)+\tilde{\chi}_j^0(P_4)$.	2-b	$600GeV$	24	2050	1.7×10^{-23}
		$700GeV$	44	2300	1.5×10^{-23}
		$800GeV$	14	2280	3.8×10^{-23}

5. conclusion

From table , it could be concluded that the reaction has highest cross section for the reaction For $\tilde{\chi}_i^0=800\ \mathrm{Gev}$, $\tilde{\chi}_j^0=900\mathrm{Gev}$ and $m_{\tilde{\chi}_\ell^0}=700\ \mathrm{Gev}$ the cross section goes up to $(2.6\times10^{-22}\mathrm{Pb})$ at (S= 2300 Gev) when Neutralino is emitted from positron as a leg via Neutral Higgs boson propagator.

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7. References

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