Arab J. Nucl. Sci. Appl., Vol. , 56, 4 -1-8 (2023)

ISSN 1110-0451

Arab Journal of Nuclear Sciences and Applications

Web site: ajnsa.journals.ekb.eg

(E S N S A)

Formation Charginos and Dark matter from electron- positron annihilation

Zainab.A.H *, Asmaa.A. A. and M.M. Ahmed

Physics Department, Helwan University Cairo, Egypt

ARTICLE INFO

Article history:

Received: 13th Aug. 2021

Accepted: 12th Apr. 2023

Available online: 9th May 2023

Keywords:

Chargino,

Neutralino;

Dark Matter.

ABSTRACT

Two Charginos ($\tilde{\chi}^{\pm}$) and neutralino ($\tilde{\chi}^{0}$) produced in the Minimal Supersymmetric Standard Model (MSSM) via the process $e^-(p_1) + e^+(p_3) \rightarrow \tilde{\chi}_i^-(p_2) + \tilde{\chi}_j^+(p_4) + \tilde{\chi}_\ell^\circ(p_5)$ and the cross sections for this interaction calculated by Feynman rules when γ° is the propagator, and $\tilde{\chi}_\ell^0$ is a leg from (e^-) or from (e^+) where $i, j = 1, 2, and\ \ell = 1, 2, 3, 4$. There are (128) different possible situations. The cross-sections σ (pb) calculated and graphed as a function of S (GeV) (center of mass energy) based on (MSSM), The mechanisms of Feynman diagram can be detected as:

$$e^-(P_1 - P_5) + e^+(P_3) \rightarrow \gamma^0(P_2 + P_4) \rightarrow \chi_i^-(\mathrm{P}_2) + \chi_j^+(\mathrm{P}_4)$$

$$e^-(P_1) + e^+(P_3 - p_5) \rightarrow \gamma^0(P_2 + P_4) \rightarrow \chi_i^-(\mathrm{P}_2) + \chi_j^+(\mathrm{P}_4)$$

At S interval (400- 2000) GeV, the best value of σ is (1.18) Pb when $\tilde{\chi}_\ell^0$ is a leg from (e^-) and masses of Charginos are $\mathrm{m}_{\tilde{\chi}_i^-} = 700$ GeV, $\mathrm{m}_{\tilde{\chi}_j^+} = 600$GeV and $\mathrm{m}_{\tilde{\chi}_\ell^0} = 300$ GeV

1. INTRODUCTION

In the standard model (SM) the interactions between the fundamental particles at the weak scale are explained and the properties of elementary particles are described, Leptons and Quarks (fermions), and describe the mediator of the gauge field (bosons) [1]. Higgs mechanism generates both fermions and gauge bosons ($Z, W^{\pm}, g_a$) masses, while the photon leaving massless [2].

SM predicts a single neutral Higgs boson H°, which discovered in 2012 at LHC ($\mathrm{m}_{\mathrm{H}^\circ} = 125\,\mathrm{GeV}$). This discovery is a strong verification of the electroweak symmetry breaking mechanism in the SM [3, 4, and 5]. A large quantity of literature published in recent decades about a higher scale and new physics at higher scales proposed called beyond the Standard Model.

In supersymmetric standard model (SUSY), the strong and the electroweak interactions described from Planck scale to the weak scale [6]. There is a supersymmetric companion for each SM particle. The particles have half-spin differences and collective into a super field [7].

In the minimal supersemmetric standard model (MSSM), every matter fields and the gauge fields in SM have their superpartner, and it includes two Higges doublet superfields: H_1° and H_2°which give masses to the isospin $-\frac{1}{2}$ and $+\frac{1}{2}$ particles respectively [6]. This differs in SM, where the Higgs Mechanism can generate both u (up) and d (down) type masses with just one Higgs doublet [1]

The superpartner of electroweak bosons (gaugenos) associate to superpartners of Higgs bosons (Higgsinos) and form four neutralino $\tilde{\chi}_\mathrm{i}^\circ$ and two charginos $\tilde{\chi}_\mathrm{i}^{\pm}$[8].

In supersymmetric theories, winos ($\widetilde{W}^{\pm}$) and charged higgsinos ($\widetilde{H}^{\pm}$), which are the superpartner of W boson ($W^{\pm}$) and charged higgs boson ($H^{\pm}$), combined to form two charginos [9]. $\tilde{\chi}_\mathrm{i}^{\pm}$. They produced in pairs at s-channel by Z° and γ° [10, 11]

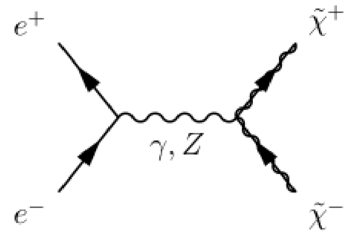


Fig. (1): Feynman diagrams for chargino pair production via s-channel

Corresponding author: zainab_adel@yahoo.com

DOI: 10.21608/ajnsa.2023.90549.1502

The lifetime of charginos between 0.1 and 10 ns and the lightest chargino mass greater than103.5 GeV [12, 13, 14].

The mass of lightest chargino $\tilde{\chi}_1^{\pm}$ greater than the mass of lightest neutralino $\tilde{\chi}_1^{\circ}$ and it decay to the lightest neutralino $\tilde{\chi}_1^{\circ}$ and a pair of fermions (f) which are quarks and antiquarks or leptons and neutrinos [13]

$$\tilde{\chi}_1^{\pm} \rightarrow \tilde{\chi}_1^{\circ} + f\bar{f}` \quad \textbf{(1)}$$

The MSSM Lagrangian for the chargino masses defined as follows:

$$\mathcal{L} = -\frac{1}{2}(\psi_i^+ \psi_i^-)\begin{pmatrix} 0 & \mathcal{M}_{\tilde{\chi}^{\pm}}^T \\ \mathcal{M}_{\tilde{\chi}^{\pm}} & 0 \end{pmatrix}\begin{pmatrix} \psi_i^+ \\ \psi_i^- \end{pmatrix} \quad \textbf{(2)}$$

The Weyl states $\psi_i^+ = (i\lambda^+, \psi_{H_2}^1)$ and $\psi_i^- = (i\lambda^-, \psi_{H_1}^2)$ used to obtain the mass eigenstates in Dirac notation $\tilde{\chi}_i^{\pm}$ with the following relations:

$$\tilde{\chi}_i^{\pm} = \begin{pmatrix} \tilde{\chi}_i^{\pm} \\ \tilde{\chi}_i^{\mp} \end{pmatrix} \;, \tilde{\chi}_i^+ = V_{ij}\psi_j^+ \;, \tilde{\chi}_i^- = U_{ij}\psi_j^- \quad \textbf{(3)}$$

The charginos mass matrix given below:

$$\mathcal{M}_{\tilde{\chi}^{\pm}} = \begin{pmatrix} M_{SU(2)} & \sqrt{2}m_W \cos\beta \\ \sqrt{2}m_W \sin\beta & \mu \end{pmatrix} \quad \textbf{(4)}$$

Where:

m_W : W-boson mass

$\tan\beta = v_2/v_1$: The ratio of vacuum expectation values of two Higgs

$M_{SU(2)}$: Parameter of gaugino mass associated with SU(2) symmetry group

μ: parameter of supersymmetric Higgs mass.

With two unitary matrices U and V, the diagonalization of the charginos mass matrix $\mathcal{M}_{\tilde{\chi}^{\pm}}$ performed [6]

$$diag\,(\tilde{\chi}_1^+, \tilde{\chi}_2^+) = U^*\mathcal{M}_{\tilde{\chi}^{\pm}}V^{-1} \quad \textbf{(5)}$$

Neutralino is a hypothetical particle relating bosons to fermions There are four neutralino $\tilde{\chi}_1^{\circ}, \tilde{\chi}_2^{\circ}, \tilde{\chi}_3^{\circ}, \tilde{\chi}_4^{\circ}$ each is a mixture of neutral gauage boson ($\tilde{B}^{o}$,$\tilde{W}^{o}$) bino and neutral Wino and two neutral higgsinos $\tilde{H}_1^{o}$and $\tilde{H}_2^{o}$ [9] and there mass at the weak scale in the range (10-1000 GeV)

Through the Z boson, the heavier neutalino decays to a lighter neutralino, and through the W boson, it decays to a light chargino [15]. The lightest neutralino is the lightest supersymmetric particle (LSP) which is stable when R-parity conserved [16], and consider the basic of Weakly Interacting Massive Particles (WIMPs) which makes up the universe's cold dark matter

The universe composed of 23% dark matter, which consist of

- Baryonic dark matter: made up of baryons (i.e. protons and neutrons and combinations of these), such as black holes, neutron stars
- Non- baryonic dark matter divided into three categories of nonbaryonic dark matter (Hot Dark Matter (HDM), Warm Dark Matter (WDM), and Cold Dark Matter (CDM))

The terms hot, warm and cold refer to particles speed rather than temperature. Axions and neutralinos are examples of cold dark matter that have classical velocities motion. Gravitinos are examples of Warm dark matter that have relativistically motion and neutrinos are examples of hot dark matter that ultrarelativistically motion.

In nature, there are two ways to observe neutralino dark matter experimentally. The 1st directly by using detectors of semiconductor and through other experiments such as Cryogenic dark matter search (CDMS). The 2nd indirectly by using γ ray and neutrino telescopes [17,18]

The MSSM Lagrangian for neutralino masses defined as follows:

$$\mathcal{L}_m = -\frac{1}{2}(\psi^0)^T\,\mathcal{M}_{\tilde{\chi}^{\circ}}\,\psi^0 + h.c. \quad \textbf{(6)}$$

Where

$$(\psi^0)^T = (i\tilde{B}, i\tilde{W}^3, \tilde{H}_1^{\circ}, \tilde{H}_2^{\circ}) \quad \textbf{(7)}$$

$$\mathcal{M}_{\tilde{\chi}^{\circ}} = \begin{pmatrix} M_1 & 0 & -M_Z\cos\beta\sin\theta_W & M_Z\sin\beta\sin\theta_W \\ 0 & M_2 & M_Z\cos\beta\cos\theta_W & -M_Z\sin\beta\cos\theta_W \\ -M_Z\cos\beta\sin\theta_W & M_Z\cos\beta\cos\theta_W & 0 & -\mu \\ M_Z\sin\beta\sin\theta_W & -M_Z\sin\beta\cos\theta_W & -\mu & 0 \end{pmatrix} \quad \textbf{(8)}$$

The neutralino mass eigenstates are $\tilde{\chi}_i^0 = N_{ij}\psi_j^0$ where N diagonalizing $\mathcal{M}_{\tilde{\chi}^\circ}$ and the neutralino masses are $m_{\tilde{\chi}_i^0}\,\eta_{N_i} = N_{im}N_{jn}(M_{\tilde{\chi}^\circ})_{mn}$

If eigenvalue was positive (negative), $\eta_{N_i} = +1(-1)$, that leaves the mass $m_{\tilde{\chi}_i^0}$ positive

There are three variables or soft terms (M_2, μ and $\tan\beta$) in chargino mass matrix and four variables or soft terms (M_1,M_2 ,μ and $\tan\beta$) in neutralino mass matrix [19].

Where:

M_1: The soft-breaking bino mass

M_2: The soft-breaking wino mass

$$m_{\tilde{\chi}_1^\pm} \simeq m_{\tilde{\chi}_2^\circ} \simeq 2m_{\tilde{\chi}_1^\circ} \quad (9)$$

$$m_{\tilde{\chi}_2^\pm} \simeq m_{\tilde{\chi}_3^\circ} \simeq m_{\tilde{\chi}_4^\circ} \simeq |\mu| \quad (10)$$

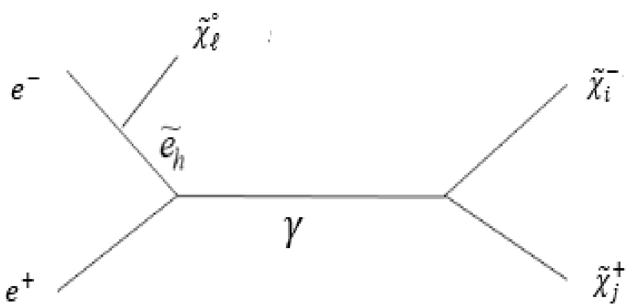
The relation in grand unification theory GUT between M_1 and M_2:

$$M_1 = \frac{5}{3}\tan\theta_w^2\, M_2 \quad (11)$$

Where $\theta_w$is the Weinberg angle and $\cos\theta_w = \frac{M_w}{M_z}$

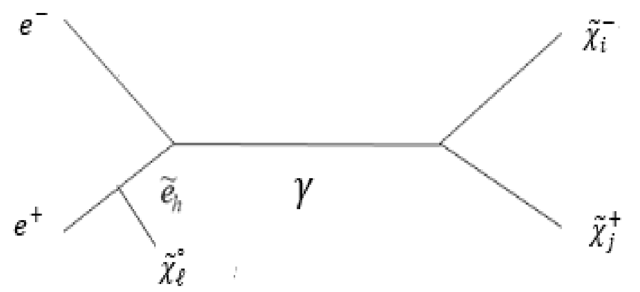
slepton is a Superpartner of a lepton that described by Supersymmetry in particle physics,. It has same flavour and electric charge alike leptons but have no spin. selectron $\tilde{e}_h$ is an example for superpartner of electron [20]

2.Feynman Diagram and M-Matrix For The process :



(a)

Fig. 2 (a): Feynman diagrams for the process $e^-(P_1) + e^+(P_3) \to \tilde{\chi}_i^-(P_2) + \tilde{\chi}_j^+(P_4) + \tilde{\chi}_\ell^0(P_5)$ via γ^0 boson propagator when $\tilde{\chi}_\ell^0$ is a leg from electron. There are (1-64) diagrams.



(b)

Fig. 2 (b): Feynman diagrams for the process $e^-(P_1) + e^+(P_3) \to \tilde{\chi}_i^-(P_2) + \tilde{\chi}_j^+(P_4) + \tilde{\chi}_\ell^0(P_5)$ via γ^0 boson propagator when $\tilde{\chi}_\ell^0$ is a leg from positron. There are (65-128) diagrams.

- **For fig. 2 (a) there are 64 situations from (1 – 64) and the Matrix element is:**

$$M_{(514-577)} = iU_{e^-}(P_1)\,(N + N^*\gamma_5)\,\overline{U}_{\tilde{\chi}^0}(P_5)\,\frac{1}{(P_1-P_5)^2-m_e^2}\,\overline{V}_{e^+}(P_3)\,e(s - P_5)\,\frac{1}{\sigma^2-m_\gamma^2}\,e\,\overline{U}_{\tilde{\chi}^-}(P_2)\,\overline{U}_{\tilde{\chi}^+}(P_4) \quad (12)$$

- **For fig. 2 (b) there are 64 situations from (65 – 128) and the Matrix element is:**

$$M_{(578-641)} = -i\overline{V}_{e^+}(P_3)\,(N + N^*\gamma_5)\,\overline{U}_{\tilde{\chi}^0}(P_5)\,\frac{1}{(P_3-P_5)^2-m_e^2}\,U_{e^-}(P_1)\,e(s - P_5)\,\frac{1}{\sigma^2-m_\gamma^2}\,e\,\overline{U}_{\tilde{\chi}^-}(P_2)\,\overline{U}_{\tilde{\chi}^+}(P_4) \quad (13)$$

2.1. Calculations of Cross sections in (pb):

Two charginos $(\tilde{\chi}_i^-, \tilde{\chi}_j^+)$ and neutralino $\tilde{\chi}_\ell^\circ$ with momenta p_2, p_4, p_5 produced and their masses m_2, m_4, m_5 and the initial states have momenta $p_1, p_3$and their masses m_1, m_3 .

$$p_1 + p_3 = p_2 + p_4 + p_5 \quad (14)$$

$$s = \sigma + p_5 \quad (15)$$

The cross section (σ) for the reaction $e^-(p_1) + e^+(p_3) \to \tilde{\chi}_i^-(p_2) + \tilde{\chi}_j^+(p_4) + \tilde{\chi}_\ell^\circ(p_5)$ calculated from this equation:

$$\sigma = \int \pi^2 |M|^2 \frac{dx\,dy\,d\sigma^2}{\Lambda(S, m_1, m_3)\Lambda(S, \sigma, m_5)} \quad (16)$$

Where M is the matrix element, by applying Feynman rules we can write the M-matrix for the Feynman diagram and the trace theorem used to calculate the square matrix ($|M|^2$) and the function Λ defined as [21,22] :

$$\Lambda(x,y,z) = [x^4 + y^4 + z^4 - 2x^2y^2 - 2x^2z^2 - 2y^2z^2]^{1/2} \quad \mathbf{(17)}$$

Then, by using Mathematica program the integration simplifying and the limit of integration are

$$x_{\pm} = \frac{1}{4S^2}[(S^2 + m_1^2 - m_3^2)(S^2 - \sigma^2 + m_5^2) \pm \Lambda(S, m_1, m_3)\Lambda(S, \sigma, m_5)] \quad \mathbf{(18)}$$

$$y_{\pm} = \frac{1}{4\sigma^2}[(\sigma^2 + m_2^2 - m_4^2)(S^2 - \sigma^2 + m_5^2) \pm \Lambda(\sigma, m_2, m_4)\Lambda(S, \sigma, m_5)] \quad \mathbf{(19)}$$

$$(m_2 + m_4)^2 \leq \sigma^2 \leq (S^2 - m_5^2)^2 \quad \mathbf{(20)}$$

The cross sections calculated and the results graphed and tabled

The values of charginos and neutralinos in our counting assumed to be:

$m_{\tilde{\chi}^-_{(i)}} = (600\,,700)$ GeV , $m_{\tilde{\chi}^+_{(j)}} = (600\,,700)$ GeV (*i, j=1, 2*)

$m_{\tilde{\chi}^0_1} = 300$ GeV, $m_{\tilde{\chi}^0_2} = 600$ GeV, $m_{\tilde{\chi}^0_3} = 700$ GeV, $m_{\tilde{\chi}^0_4} = 800$ GeV

By applying Feynman rules and using equation (16) and Mathematica program, the cross sections for the Feynman diagram of fig. 2 (a) calculated and the results given in figs.3 (a-d) by interchanging the mass of charginos ($m_{\tilde{\chi}^-_i}, m_{\tilde{\chi}^+_j}$) at different mass of Neutralino $m_{\tilde{\chi}^\circ_\ell}$ for the interaction $e^-(p_1) + e^+(p_3) \rightarrow \tilde{\chi}^-_i(p_2) + \tilde{\chi}^+_j(p_4) + \tilde{\chi}^\circ_\ell(p_5)$

$m_{(\tilde{\chi}^-_i\,,\,\tilde{\chi}^+_j)} \rightarrow m_{(600\,,\,600)} \rightarrow m_{11}$ (blue)

$m_{(\tilde{\chi}^-_i\,,\,\tilde{\chi}^+_j)} \rightarrow m_{(700\,,700)} \rightarrow m_{22}$(red)

$m_{(\tilde{\chi}^-_i\,,\,\tilde{\chi}^+_j)} \rightarrow m_{(600\,,700)} \rightarrow m_{12}$(green)

$m_{(\tilde{\chi}^-_i\,,\,\tilde{\chi}^+_j)} \rightarrow m_{(700\,,600)} \rightarrow m_{21}$(pink)

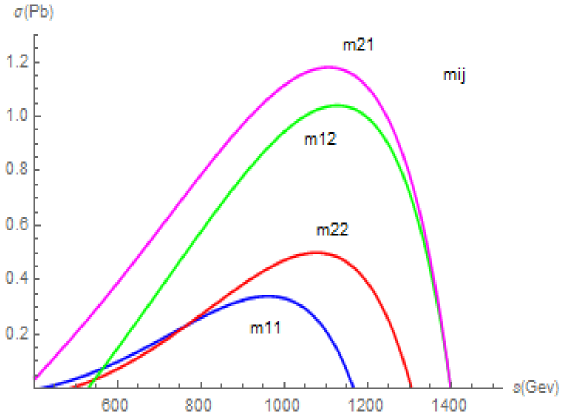


Fig. 3 (a) $m_{\tilde{\chi}^0_1} = 300$ GeV

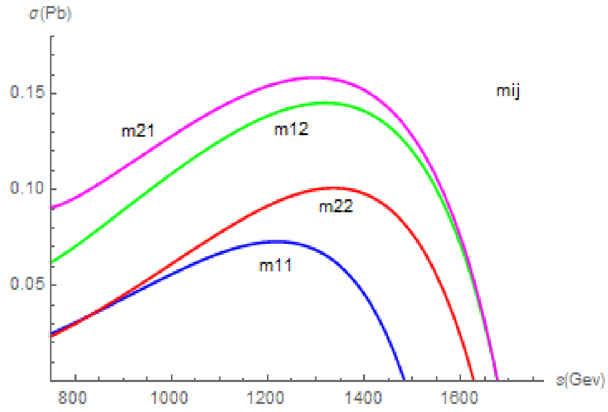


Fig. 3 (b) $m_{\tilde{\chi}^0_2} = 600$ GeV

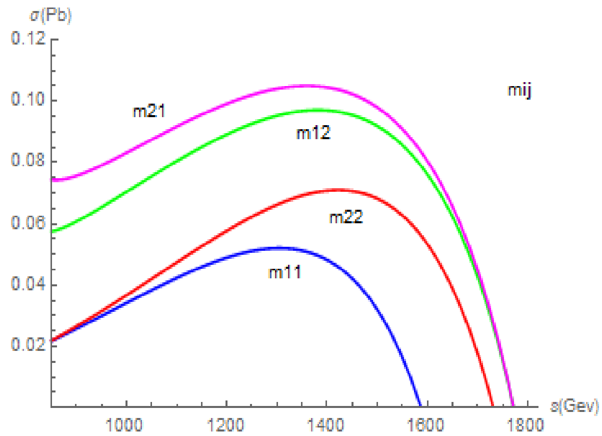


Fig. 3 (c) $m_{\tilde{\chi}^0_3} = 700$ GeV

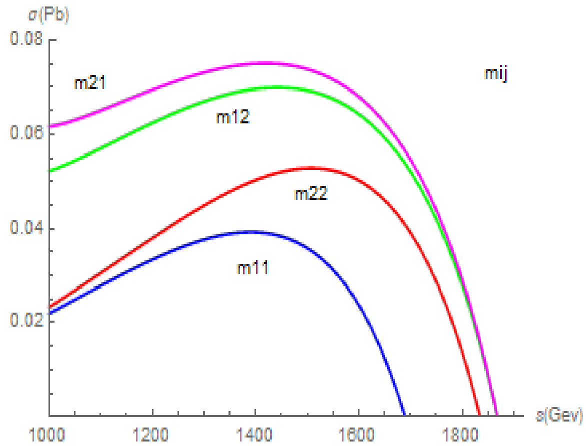


Fig. 3 (d) $m_{\tilde{\chi}^0_4} = 800$ GeV

Fig. 3(a-d): The cross sections for the process $e^-(p_1) + e^+(p_3) \rightarrow \tilde{\chi}^-_i(p_2) + \tilde{\chi}^+_j(p_4) + \tilde{\chi}^\circ_\ell(p_5)$ as a function of (s) via γ^o propagator and $\tilde{\chi}^0_\ell$ is a leg from electron by interchanging the mass of charginos ($m_{\tilde{\chi}^-_i}, m_{\tilde{\chi}^+_j}$) at different mass of Neutralino $m_{\tilde{\chi}^\circ_\ell}$

Table (1): cross section for the process $e^-(P_1 - P_5) + e^+(P_3) \rightarrow \gamma^o(P_2 + P_4) \rightarrow \chi_i^-(P_2) + \chi_j^+(P_4)$ via γ^o propagator and $\tilde{\chi}_\ell^0$ is a leg from electron by interchanging the mass of charginos $(m_{\tilde{\chi}_i^-}, m_{\tilde{\chi}_j^+})$ at different mass of Neutralino $m_{\tilde{\chi}_\ell^\circ}$

$e^-(P_1 - P_5) + e^+(P_3) \rightarrow \gamma^o(P_2 + P_4) \rightarrow \chi_i^-(P_2) + \chi_j^+(P_4)$								
$m_{\tilde{\chi}_i^-} m_{\tilde{\chi}_j^+}$	$\tilde{\chi}_1^0$=300		$\tilde{\chi}_2^0$=600		$\tilde{\chi}_3^0$=700		$\tilde{\chi}_4^0$=800	
	Fig. 3 (a)		Fig. 3 (b)		Fig. 3 (c)		Fig. 3 (d)	
	S(Gev)	σ(Pb)	S(Gev)	σ(Pb)	S(Gev)	σ(Pb)	S(Gev)	σ(Pb)
600,600	960	0.3	1218	0.07	1304	0.05	1390	0.03
700,700	1076	0.5	1336	0.10	1421	0.07	1507	0.05
600,700	1126	1.04	1319	0.14	1381	0.09	1442	0.06
700,600	1105	1.18	1298	0.15	1359	0.10	1418	0.07

- **For fig. 2 (b):**

The Cross section for the Feynman diagrams of fig. 2 (b) Calculated and the results are given in fig.4 (a-d) by interchanging the mass of charginos $(m_{\tilde{\chi}_i^-}, m_{\tilde{\chi}_j^+})$ at different mass of Neutralino $m_{\tilde{\chi}_\ell^\circ}$

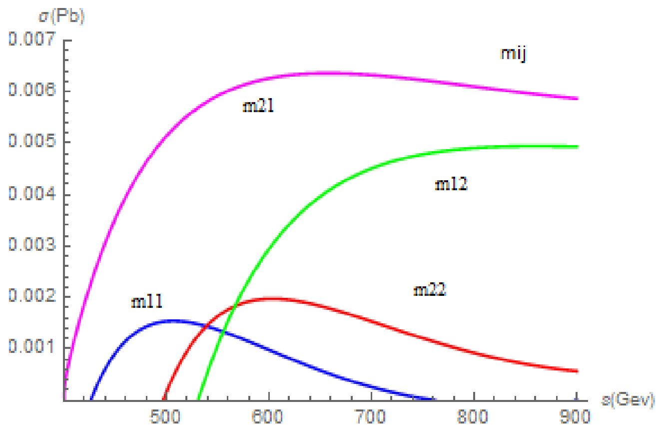


Fig. 4 (a) $m_{\tilde{\chi}_1^0}$ = 300 GeV

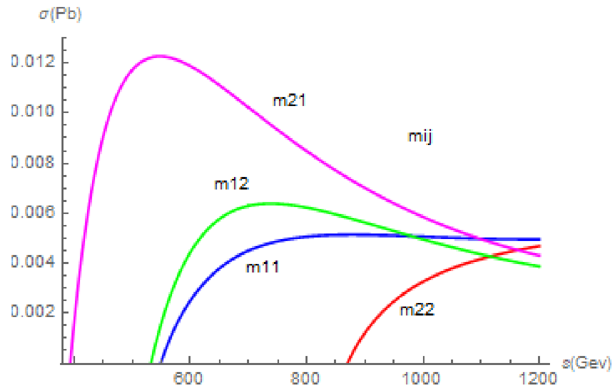


Fig. 4 (b) $m_{\tilde{\chi}_2^0}$ = 600 GeV

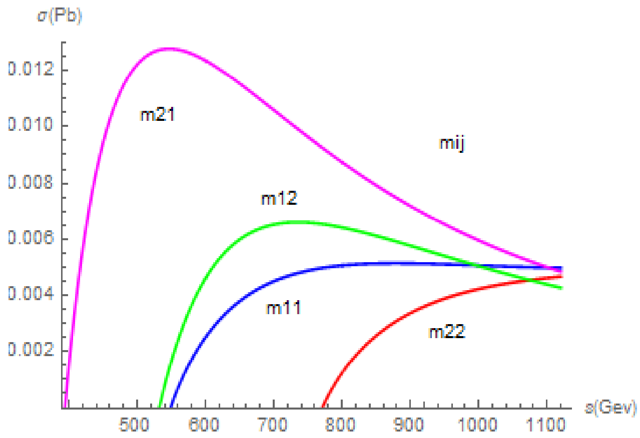


Fig. 4 (c) $m_{\tilde{\chi}_3^0}$ = 700 GeV

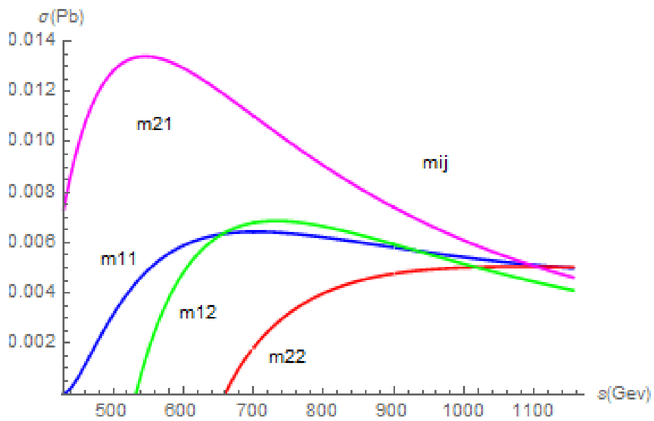


Fig. 4 (d) $m_{\tilde{\chi}_4^0}$ = 800 GeV

Fig. 4 (a-d): The cross sections for the process $e^-(p_1) + e^+(p_3) \rightarrow \tilde{\chi}_i^-(p_2) + \tilde{\chi}_j^+(p_4) + \tilde{\chi}_\ell^\circ(p_5)$ as a function of (s) via γ^opropagator and $\tilde{\chi}_\ell^0$ is a leg from positron by interchanging the mass of charginos $(m_{\tilde{\chi}_i^-}, m_{\tilde{\chi}_j^+})$ at different mass of Neutralino $m_{\tilde{\chi}_\ell^\circ}$

Table (2): cross sections for the reaction $e^-(P_1)+e^+(P_3-p_5)\to\gamma^0(P_2+P_4)\to\chi_i^-(P_2)+\chi_j^+(P_4)$ via γ^opropagator and $\tilde{\chi}_\ell^0$ is a leg from positron by interchanging the mass of charginos ($m_{\tilde{\chi}_i^-}, m_{\tilde{\chi}_j^+}$) at various mass of Neutralino $m_{\tilde{\chi}_\ell^\circ}$

$e^-(P_1)+e^+(P_3-p_5)\to\gamma^0(P_2+P_4)\to\chi_i^-(P_2)+\chi_j^+(P_4)$								
$m_{\tilde{\chi}_i^-} m_{\tilde{\chi}_j^+}$	$\tilde{\chi}_1^0$=300		$\tilde{\chi}_2^0$=600		$\tilde{\chi}_3^0$=700		$\tilde{\chi}_4^0$=800	
	Fig. 4 (a)		Fig. 4 (b)		Fig. 4 (c)		Fig. 4 (d)	
	S(Gev)	σ(Pb)	S(Gev)	σ(Pb)	S(Gev)	σ(Pb)	S(Gev)	σ(Pb)
600,600	506	0.0015	800	0.005	900	0.005	714	0.006
700,700	603	0.0019	1200	0.004	1100	0.004	1100	0.005
600,700	860	0.005	736	0.006	735	0.007	732	0.007
700,600	659	0.006	547	0.012	546	0.012	545	0.013

Table (3): The highest values of (σ) for the reaction $e^-(P_1)+e^+(P_3)\to\tilde{\chi}_i^-(P_2)+\tilde{\chi}_j^+(P_4)+\tilde{\chi}_\ell^0(P_5)$, with several masses of Charginos ($m_{\tilde{\chi}_i^-}, m_{\tilde{\chi}_j^+}$) and Neutralino $m_{\tilde{\chi}_\ell^\circ}$.

$e^-(P_1)+e^+(P_3)\to\chi_i^-(P_2)+\chi_j^+(P_4)+\tilde{\chi}_\ell^0(P_5)$	Fig. no.	$m_{\tilde{\chi}_\ell^0}$	$m_{\tilde{\chi}_i^-} m_{\tilde{\chi}_j^+}$	S(GeV) at max σ	σ(Pb)
via γ^0 propagator and $\tilde{\chi}_\ell^0$ emitted from e^-	3 (a)	$300GeV$	700,600	1105	1.18
	3 (b)	$600GeV$	700,600	1298	0.15
	3 (c)	$700GeV$	700,600	1359	0.10
	3 (d)	$800GeV$	700,600	1418	0.07
via γ^0 propagator and $\tilde{\chi}_\ell^0$ emitted from e^+	4 (a)	$300GeV$	700,600	659	0.006
	4 (b)	$600GeV$	700,600	547	0.012
	4 (c)	$700GeV$	700,600	546	0.012
	4 (d)	$800GeV$	700,600	545	0.013

2.2 RESULTS AND DISSECTION

After studding the Feynman rules and calculate (σ) as a function of (S) for the reaction $e^-(p_1)+e^+(p_3)\to\tilde{\chi}_i^-(p_2)+\tilde{\chi}_j^+(p_4)+\tilde{\chi}_\ell^\circ(p_5)$ via γ^o propagator

- When $\tilde{\chi}_\ell^0$ is a leg from e^- .In figs.3 (a-d), the range of energy (s) from 400 to 2000 and there are various maximum values for (σ) at several values of Chargino mass ($m_{\tilde{\chi}_i^-}, m_{\tilde{\chi}_j^+}$) and several value of neutralino mass $m_{\tilde{\chi}_\ell^0}$. From table (1), the best value of σ is (1.18) Pb when masses of Charginos are $m_{\tilde{\chi}_i^-}=700$ GeV, $m_{\tilde{\chi}_j^+}=600$GeV and $m_{\tilde{\chi}_\ell^0}=300$ GeV
- When $\tilde{\chi}_\ell^0$ is a leg from e^+ .In figs.4 (a-d), the range of energy (s) from 400 to 1200, and there are various maximum values for (σ) at several values of Chargino mass ($m_{\tilde{\chi}_i^-}, m_{\tilde{\chi}_j^+}$) and several value of neutralino mass $m_{\tilde{\chi}_\ell^0}$. From table (2), the best value of σ is (0.013) Pb when masses of Charginos are $m_{\tilde{\chi}_i^-}=700$ GeV, $m_{\tilde{\chi}_j^+}=600$GeV and $m_{\tilde{\chi}_\ell^0}=800$ GeV

In figs. (3, 4) we notice the increasing of (σ) when (s) increase but at fixed value of (s) we notice decreasing of (σ), the range of (s) from 400 to 2000

The next table shows that the highest values of σ (Pb) for each mode and their energy S (GeV) at several values of Chargino mass ($m_{\tilde{\chi}_i^-}, m_{\tilde{\chi}_j^+}$) and several value of neutralino mass($m_{\tilde{\chi}_\ell^0}$) to conclude the best value of cross-section for the reaction $e^-(P_1)+e^+(P_3)\to\tilde{\chi}_i^-(P_2)+\tilde{\chi}_j^+(P_4)+\tilde{\chi}_\ell^0(P_5)$

3. CONCLUSION

The highest cross section (σ) for the reaction $e^{-}(P_1) + e^{+}(P_3) \rightarrow \tilde{\chi}_i^{-}(P_2) + \tilde{\chi}_j^{+}(P_4) + \tilde{\chi}_\ell^{0}(P_5)$. identified from table (3)

-The best cross section is (1.18 Pb) at (S= 1105 GeV) and masses of Charginos are $m_{\tilde{\chi}_i^-} = 700$ GeV, $m_{\tilde{\chi}_j^+} = 600$GeV and mass of Neutralino $m_{\tilde{\chi}_\ell^0} = 300$ GeV , via γ^opropagator and $\tilde{\chi}_\ell^0$ is a leg from electron in Fig. 3 (a) for the reaction $e^{-}(P_1 - P_5) + e^{+}(P_3) \rightarrow \gamma^{0}(P_2 + P_4) \rightarrow \chi_i^{-}(P_2) + \chi_j^{+}(P_4)$

REFERENCE

[1] Herrero, Maria J. "The Higgs system in and beyond the standard model." Lectures on Particle Physics, Astrophysics and Cosmology. Springer, Cham, (2015). 188-252.

[2] Nguyen, Kien. "The higgs mechanism." (2009).

[3] Barton, Adam, et al. "Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC." Physics Letters B 716.1 (2012): 1-29.

[4] Chatrchyan, Serguei, et al. "Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC." Physics Letters B 716.1 (2012): 30-61.

[5] Aad, Georges, et al. "Combined Measurement of the Higgs Boson Mass in p p Collisions at s= 7 and 8 TeV with the ATLAS and CMS Experiments." Physical review letters 114.19 (2015): 191803.

[6] Sonmez, Nasuf. "Pair production of the lightest chargino at γγ-collider." Nuclear Physics B 939 (2019): 233-252.

[7] ATLAS collaboration. "Search for chargino-neutralino pair production in final states with three leptons and missing transverse momentum in√ s= 13 TeV pp collisions with the ATLAS detector." CERN: Geneva, Switzerland (2021).

[8] The GAMBIT Collaboration, Eur. Phys. J. C (2019) [hep-ph/1809.02097v3].

[9] Aad, Georges, et al. "Search for direct production of electroweakinos in final states with missing transverse momentum and a Higgs boson decaying into photons in pp collisions at $\sqrt{s} =$ 13 TeV with the ATLAS detector." Journal of High Energy Physics 2020.10 (2020): 1-46.

[10] HEUER, R.-D., et al. TESLA technical design report part III: Physics at an e+ e-linear collider. arXiv preprint hep-ph/0106315, (2001).

[11] de Vera MT, Berggren M, List J. Chargino production at the ILC. arXiv preprint arXiv:2002.01239. (2020)

[12] AAD, Georges, et al. Search for charginos nearly mass degenerate with the lightest neutralino based on a disappearing-track signature in p p collisions at (s)= 8 TeV with the ATLAS detector. Physical Review D, (2013), 88.11: 112006.

[13] CHOI, S. Y., et al. Chargino pair production in $e^{-}e^{+}$ collisions. The European Physical Journal C-Particles and Fields, (1999), 7.1: 123-134.

[14] H.Baer, V.Barger and H.Serce (2019) [hep-ph/1907.06693v1].

[15] BERTONE, Gianfranco (ed.). Particle dark matter: observations, models and searches. Cambridge University Press, (2010).

[16] Aldufeery E, Binjonaid M. Dark matter constraints and the neutralino sector of the scNMSSM. Universe. (2021); 7(2):31

[17] MARTIN, Stephen P. A supersymmetry primer. In: Perspectives on supersymmetry. (1998). p. 1-98.

[18] M.M. Ahmed, Nous MH, Yehia S, Asmaa A.A. THE PRODUCTION CROSS-SECTIONS FOR THE PROCESS. In Modern Trends in Physics Research: Third International Conference on Modern Trends in Physics Research, (2011) (Vol. 998, p. 323). World Scientific.

[19] LI, Tianjun. Determining M_1, M_2, μ and $\tan\beta$ in MSSM from Chargino and Neutralino Masses. (1998).

[20] M. M. Ahmed, Asmaa. A. A, Zainab. A. H. Production of Neutralino and Tow Higss Bosons from electron-positron annihilation via $H^{\circ}$and Z°propagators. Journal of Modern Trends in Physics Research, (2019), 19: 17-24.

[21] S.M.Bilenky and J.Hosek, (1990) Phys.Rep.,90 ,73.

[22] WILLIAMSON JR, W. Pedestrian Covariant Phase-Space Integration. American Journal of Physics, (1965), 33.12: 987-994.