Higgsinos as carriers of SUSY residual effects

G.M. Vereshkov *, V.A. Beylin, V.I. Kuksa, R.S. Pasechnik †
Research Institute of Physics,
Rostov State University, Rostov-on-Don, Russia

Abstract

New version of the MSSM scales is discussed. In this version $\mu \ll M_{SUSY} \sim M_0 \sim M_{1/2}$, where $\mu$ is the Higgsino mass, $M_0$ is the mass scale of sleptons and squarks, $M_{1/2}$ is the mass scale of gaugino. Renormalization group motivation of this MSSM version is proposed. The radiation corrections give main contribution to the splitting of neutralino and chargino masses if $M_{SUSY} > 10^7 GeV$. Calculation of the mass difference has led to the value $M_{\chi^\pm_2} - M_{\chi^0_2} \sim 360 MeV$ at $M_\chi \sim \mu \sim 3 TeV$. The mean life time of charged Higgsino in this model is $\tau_{\chi^\pm_1} = 0.4 \times 10^{-9} s$.

The analysis of the residual neutralino concentration in the cosmological plasma is developed and the value of Higgsino mass is estimated: $M_\chi \approx 3 TeV$. Formation of the residual neutralino concentration occurs in the high symmetric phase of the cosmological plasma. Problems of the relic Higgsinos searches at the underground laboratory NUSEL and Galactic neutralino annihilation radiation at the satellite detector GLAST are discussed. It is shown that the neutralino-nucleon cross section is spin-dependent. The annihilation of Galactic neutralinos occurs in $Z^0 Z^0$ and $W^+ W^-$ pairs in t- and s-channels, and also in lepton-antilepton and quark-antiquark pairs in the s-channel. The contribution to the annihilation spectrum from first two processes is calculated with using experimental data about hadron multiplicities at the mass surfaces of $Z^0$, $W^\pm$-bosons; the calculation of quark-antiquark s-channel contribution is based on the phenomenological model of hadron multiplicities at $\sqrt{s} = 2M_\chi$ with using negative binomial distribution.

1 Introduction.

As it is known, a theory doesn’t fix the MSSM scale hierarchy. Both neutralino and chargino have different properties depending on this hierarchy, therefore predictions for experiments are also different. Neutralino is nearly bino in generally accepted variant of the theory, and neutralino interactions with matter mainly occur through the scalar quarks’ exchange since their masses are close to the neutralino mass. The splitting between neutralino and chargino masses is large enough and its value has order a few GeV. It allows to register these particles through the lepton and hadron cascade decays. The standard MSSM version implies an existence of the Supergauge Desert between electroweak and GUT scales. But another variants are also possible. In particular, we are interested in in-depth study of the MSSM

*email: gveresh@ip.rsu.ru
†email: rpasech@thsun1.jinr.ru
variant, where the mass scales of squarks and sleptons and the gaugino scale were arranged far from electroweak scale in multi-TeV region (so-called the Split Supersymmetry) \[1\], \[2\]. Formally Higgsino mass remains arbitrary so it may be positioned at the EW scale. It’s so-called the light Higgsino scenario. We study in details the properties of this model, which is interesting because in the case ideas of SUSY are conserved. It should be especially actual if LHC results for the SUSY effects’ observation will be negative.

2 Objects of investigation and its properties.

The experimental testing of the supersymmetry hypothesis is one of the general purposes of Large Hadron Collider \[3\], \[4\], \[5\]. Main object of investigation is the Minimal Supersymmetric Standard Model, which represents the supersymmetric generalization of the Standard Model. Experimental program of supersymmetry searches on the LHC is based on the SUSY breaking scale estimation $M_{SUSY} \sim 1 \rightarrow 2 \text{TeV}$. There are four theoretical arguments that have lead to the estimation: 1) the MSSM is the simplest supersymmetric model compatible with well-known experimental data; 2) the mass spectrum of Higgs bosons is stable; 3) precise convergence of invariant charges at one point; 4) in the framework of MSSM we have natural interpretation of Dark Matter.

As it is known, after spontaneous breaking of the gauge symmetry supersymmetric partners of Higgs and electroweak gauge fields forms two Dirac electrically charged particles – charginos $\chi_{1,2}^\pm$, and four Majorana electrically neutral particles – neutralinos $\chi_0^\alpha$, $\alpha = 1, 2, 3, 4$. Lightest supersymmetric particle $\chi_1^0$ is main candidate to be the cold Dark Matter component \[6\], \[7\], \[8\], \[9\]. Generally $\chi_1^0$ is the superposition of $U(1)$ gaugino $\tilde{B}$ (”bino”), neutral $SU(2)$ gaugino $\tilde{W}_3$ (”wino”) and two Higgsinos $\tilde{h}_1^0, \tilde{h}_2^0$. Structure and properties of chargino and neutralino depend on relations between characteristic MSSM scales. Strong theoretical arguments in favor of one or another hierarchy of scales are absent.

In the next section will be shown that only two variant of MSSM are theoretically natural. First variant – the light gaugino scenario (bino or wino or their mixture), in which

$$|\mu| \gg M_0 \sim M_{1/2} \sim M_{SUSY} > M_{EW},$$

is well investigated early \[10\], \[11\], \[12\], \[13\].

We consider second alternative variant of MSSM, in which the Higgsino mass scale is the nearest for EW scale, but $M_{SUSY}$ is in the multi-TeV region – so-called light (separated) Higgsino scenario:

$$M_0 \sim M_{1/2} \sim M_{SUSY} \gg |\mu| > M_{EW}. \tag{2}$$

3 Renormgroup analysis.

In our model we shown precise convergence of invariant charges at the scale compatible with proton mean life. In the known MSSM scheme this convergence of invariant charges at the $M_{GUT}$ provides the MSSM building-in to the Supergravity and super string theory. In the case the scale of SUSY breaking is no so large: $M_{SUSY} \sim M_{1/2}$, so quadratic divergencies cancel near $M_H$.

We take into account all degrees of freedom in the $SU_{SUSY}(5)$ except of quark-lepton bosons. It have been found that the states, which are near $M_{GUT}$, are very important for the renormgroup analysis too.
Initial values of running constants are fixed at the \(M_Z\)-scale:
\[
\alpha^{-1}(M_Z) = 127.922 \pm 0.027, \quad \alpha_s(M_Z) = 0.1200 \pm 0.0028, \quad \sin^2 \theta_W(M_Z) = 0.23113 \pm 0.00015.
\]
To solve renormgroup equations the following initial values are used:
\[
\begin{align*}
\alpha_1^{-1}(M_Z) &= \frac{3}{5} \alpha^{-1}(M_Z)(1 - \sin^2 \theta_W(M_Z)) = 59.0132 \mp (0.0384)\sin^2 \theta_W \pm (0.0124)_\alpha, \\
\alpha_2^{-1}(M_Z) &= \alpha^{-1}(M_Z) \sin^2 \theta_W(M_Z) = 29.5666 \mp (0.0192)\sin^2 \theta_W \pm (0.0062)_\alpha \\
\alpha_3^{-1}(M_Z) &= \alpha_s^{-1}(M_Z) = 8.3333 \pm 0.1944.
\end{align*}
\]
In the one-loop approximation invariant charges at the scale \(Q_2\) are linked with its’ values at the scale \(Q_1\):
\[
\alpha_i^{-1}(Q_2) = \alpha_i^{-1}(Q_1) + \frac{b_i}{2\pi} \ln \frac{Q_2}{Q_1}, \quad b_i = \sum_j b_{ij}.
\] (4)
Here all states with masses \(M_j < Q_2/2\) at \(Q_2 > Q_1\) are summed.

Extra degrees of freedom are taken into account in our analysis, namely: singlet quarks and their superpartners \((D_L, D_L), (D_R, \bar{D}_R)\) from superhiggs quintets of \(SU_{SUSY}(5)\); gauge superfield \((\Phi_L, \bar{\Phi}_L)\) from 24-plet in adjoint representation of \(SU(2)\) and chiral superfield \((\Psi_L, \bar{\Psi}_L)\) in the adjoint representation of \(SU(3)\). In the minimal \(SU_{SUSY}(5)\) we have \(M_5 = (M_D, M_{\bar{D}}), M_{24} = (M_{\Phi}, M_{\bar{\Phi}}, M_{\Phi}, M_{\bar{\Phi}})\) and all of them are generated by interaction with Higgs condensate at \(M_{GUT}\). Inequality \(M_5, M_{24} < M_{GUT}\), in principle, can be provided with precision in \(1 - 2\) orders.

So, one-loop invariant charges at the scale \(q^2 = (2M_{GUT})^2\) depend on all characteristic MSSM scales:
\[
\begin{align*}
\alpha_1^{-1}(2M_{GUT}) &= \alpha_1^{-1}(M_Z) - \frac{103}{60\pi} \ln 2 + \frac{1}{2\pi} \left( -7 \ln M_{GUT} + \frac{4}{15} \ln M_D + \frac{2}{15} \ln M_{\bar{D}} \\
&\quad + \frac{11}{10} \ln M_{\bar{q}} + \frac{9}{10} \ln M_{\tilde{t}} + \frac{2}{5} \ln \mu + \frac{1}{10} \ln M_H + \frac{17}{30} \ln M_t + \frac{53}{15} \ln M_Z \right), \\
\alpha_2^{-1}(2M_{GUT}) &= \frac{7}{4\pi} \ln 2 + \frac{1}{2\pi} \left( -3 \ln M_{GUT} + \frac{4}{3} \ln M_{\Phi} + \frac{2}{3} \ln M_{\bar{\Phi}} \\
&\quad + \frac{3}{2} \ln M_{\bar{q}} + \frac{1}{2} \ln M_{\tilde{t}} + \frac{4}{3} \ln M_{\tilde{w}} + \frac{2}{3} \ln \mu + \frac{1}{6} \ln M_H + \frac{1}{2} \ln M_t - \frac{11}{3} \ln M_Z \right), \\
\alpha_3^{-1}(2M_{GUT}) &= \frac{23}{6\pi} \ln 2 + \frac{1}{2\pi} \left( -\ln M_{GUT} + 2 \ln M_{\Phi} + \ln M_{\bar{\Phi}} \\
&\quad + \frac{2}{3} \ln M_D + \frac{1}{3} \ln M_{\bar{D}} + 2 \ln M_{\bar{q}} + 2 \ln M_{\tilde{t}} + \frac{2}{3} \ln M_t - \frac{23}{3} \ln M_Z \right).
\end{align*}
\] (5)
Here \(M_0 = (M_{\bar{q}}, M_{\tilde{t}})\) is the ”common” mass of scalar quarks and leptons, averaged over chiralities and generations; \(M_t\) is the \(t\)-quark mass; others mass parameters were introduced above. In compliance with internal feature of the MSSM in \(\square\) it supposes that the lightest Higgs boson mass is close to \(M_Z\), but masses of others Higgs bosons \(H, A, H^\pm\) lie at the \(M_H\) scale. Expressions \(\square\) do not depend on placing of \(M_{24}, M_5, M_0, M_{1/2}, \mu, M_H\) at the energy scale. If masses of singlet superquarks and residual Higgs superfields are equaled to \(M_{GUT}\) they are eliminated from renormgroup equations.
At every scale corresponding degrees of freedom are linked and the equaling of all charges at $M_{GUT}$ leads to equations:

$$M_{GUT} = A k_1 M_Z \left( \frac{M_Z}{M_{1/2}} \right)^{2/9}, \quad \mu = B k_2 M_Z \left( \frac{M_Z}{M_{1/2}} \right)^{1/3},$$

(6)

where

$$k_1 = K_{ql}^{-1/12} K_{GUT1}^{1/3} \equiv \left( \frac{M_t}{M_q} \right)^{1/12} \left( \frac{M_{GUT}}{M_{GUT}} \right)^{1/3},$$

$$k_2 = K_{Hl}^{-1/4} K_{ql}^{-1/4} K_{gW}^{-7/2} K_{GUT2} \equiv \left( \frac{M_t}{M_H} \right)^{1/4} \left( \frac{M_{\tilde{q}}}{M_\xi} \right)^{1/4} \left( \frac{M_{\tilde{q}}}{M_{\tilde{W}}} \right)^{7/2} \left( \frac{M_{GUT}''}{M_{GUT}} \right),$$

$$M'_{1/2} \equiv (M_{\tilde{W}} M_{\tilde{g}})^{1/2}, \quad M'_{GUT} \equiv (M_{\tilde{q}} M_{\Phi})^{1/3} (M_{\Phi} M_{\Phi})^{1/6} \leq M_{GUT},$$

$$M''_{GUT} \equiv \frac{(M_{\tilde{q}} M_{\Phi})^{7/6} (M_{\tilde{q}} M_{\Phi})^{1/2}}{(M_{\tilde{q}} M_{\Phi})^{4/3}} < M_{GUT},$$

(7)

$$A = \exp \left( \frac{\pi}{18} (5 \alpha_1^{-1}(M_Z) - 3 \alpha_2^{-1}(M_Z) - 2 \alpha_3^{-1}(M_Z)) - \frac{11}{18} \ln 2 \right) = (1.57 \times 10^{0.92}) \cdot 10^{14},$$

$$B = \exp \left( \frac{\pi}{3} (5 \alpha_1^{-1}(M_Z) - 15 \alpha_2^{-1}(M_Z) + 7 \alpha_3^{-1}(M_Z)) + \frac{157}{12} \ln 2 \right) = (2.0 \times 10^{0.15}) \cdot 10^3.$$  

(8)

The mass ratios that are labelled as $K$ are quantities, which are larger than unity. All parameters $K_{GUT1}$, $K_{GUT2}$ both in the MSSM, and in the $SU_{SUSY}(5)$ are not under the theoretical control. Due to experimental restriction $M_H > 315 GeV$ it is supposed that $1 \leq K_{GUT1} \approx K_{GUT2} \leq 10$ and $K_{Hl}$ lies in the region $2 \leq K_{Hl} \leq 10$. Parameters $K_{ql}$, $K_{gW}$ are fixed by renormgroup evolution from $M_{GUT}$ to $M_0$, $M_{1/2}$. We suppose that $1.5 \leq K_{ql} \approx K_{gW} \leq 2.5$.

The studying of $M'_{1/2}$, $\mu$ as functions of $M_{GUT}$ is the aim of analysis:

$$M'_{1/2}(M_{GUT}) = (A k_1)^{9/2} M_{Z}^{11/2} \times \left( \frac{1}{M_{GUT}^9} \right)^{1/2}, \quad \mu(M_{GUT}) = \frac{B k_2}{(A k_1)^{3/2} M_{Z}^{3/2}} \times M_{GUT}^{3/2}.$$  

(9)

We used known restrictions for the proton mean life and for $M_{SUSY}$: $(\tau_p \geq 10^{32} \text{ years at } M_{GUT} \geq 10^{15} \text{ GeV})$; $(M_{SUSY} \approx M'_{1/2} > 100 \text{ GeV at } M_{GUT} < 3 \cdot 10^{16} \text{ GeV})$.

From the analysis two variants of parameters (9) were found. In the first case $\mu \ll M'_{1/2}$, in the second one $\mu \gg M'_{1/2}$ that is shown at Fig. [4].

4 Analysis of mass spectrum.

Formally the $M_H$ scale may be arbitrary. In this scenario light particles $\chi_{1,2}^0$ and $\chi_1^\pm$ have a structure of Higgsino with masses

$$M_{\chi_1^0} \approx |\mu| - \frac{M_Z^2}{2} \left( 1 + \text{sgn}(\mu) \sin 2\beta \right) \left( \frac{\cos^2 \theta}{M_W} + \frac{\sin^2 \theta}{M_B} \right) \approx |\mu| - \frac{M_Z^2}{2 M_{SUSY}},$$

$$|M_{\chi_2^0}| \approx |\mu| + \frac{M_Z^2}{2} \left( 1 - \text{sgn}(\mu) \sin 2\beta \right) \left( \frac{\cos^2 \theta}{M_W} + \frac{\sin^2 \theta}{M_B} \right) \approx |\mu| + \frac{M_Z^2}{2 M_{SUSY}},$$

$$M_{\chi_1^\pm} \approx |\mu| - \frac{M_Z^2}{M_W} \left( \frac{|\mu|}{M_W} + \text{sgn}(\mu) \sin 2\beta \right) \approx |\mu|.$$  

(10)
Heavy particles $\chi^0_{3,4}$ and $\chi^\pm_2$ have a structure of gaugino, their masses lies at $M_{SUSY}$ scale:

$$M_{\chi^0_3} \approx M_{\tilde{B}}, \quad M_{\chi^0_4} \approx M_{\tilde{W}}, \quad M_{\chi^\pm_2} \approx M_{\tilde{W}}.$$  

(11)

Interactions through virtual gaugino, squarks and sleptons and heavy Higgs are suppressed by large masses in denominators. Basic physical effects describing by the Lagrangian of light Higgsino $\chi^0_{1,2}, \chi^\pm_1$ interactions with photons and vector bosons:

$$\Delta L = \left( e A_\mu - \frac{g_2}{2 \cos \theta} (1 - 2 \sin^2 \theta) Z_\mu \right) \bar{\chi}_1^\pm \gamma^\mu \chi_1^- + \frac{g_2}{2 \cos \theta} Z_\mu (\bar{\chi}_1^0 \gamma^\mu \chi_2^0 + \bar{\chi}_2^0 \gamma^\mu \chi_1^0) +
\frac{g_2}{\sqrt{2}} W_\mu^+ (\bar{\chi}_1^0 + \bar{\chi}_2^0) \gamma^\mu \chi_1^- + \frac{g_2}{\sqrt{2}} W_\mu^- \bar{\chi}_1^- \gamma^\mu (\chi_1^0 + \chi_2^0).$$  

(12)

Tree constraint on the mass splitting between chargino and neutralino $M_{\chi^\pm_1} - M_{\chi^0_1} \lesssim m_e$ with (11) gives some constraint on supersymmetry breaking scale: $M_{SUSY} < 10^7 \text{GeV}$. But if $M_{SUSY} > 10^7 \text{GeV}$ the radiative corrections dominate in formation of the neutralino-chargino mass spectrum. Combination of all mass operators in the one-loop approximation may lead to the finite integral on the mass surface:

$$\Delta M_\chi = -\frac{ie^2 M_Z^2}{8\pi^4} \int \frac{(q - M_\chi)dq}{q^2(q^2 - M_Z^2)[(q + p)^2 - M_\chi^2]} ,$$

For $M_\chi \gg M_Z$ we have

$$\Delta M_\chi \simeq \frac{\alpha(M_\chi) M_Z}{2}$$

(13)
To obtain the value $\alpha$ at $M_\chi$ scale by renormgroup methods we use estimation $M_H \sim M_t \sim 200 GeV$ \cite{14}, \cite{15} and $M_\chi \sim 3 TeV$ that will be obtained below. We found $\Delta M_\chi \simeq 360 MeV$. The calculation of chargino mean life time gives

$$\tau_{\chi^\pm} = \frac{15\pi^3}{G_F^2} (\Delta M_\chi)^{-5} = 0.4 \times 10^{-9} s.$$ \hspace{1cm} (14)

If we refuse from Supergauge Desert we haven’t theoretical considerations on the separated Higgsino mass. Nevertheless we can attempt to make an important step to solve this problem when we use the hypothesis that neutralino is a carrier of Dark Matter in the Universe.

5 Cosmological estimation of the separated neutralino mass.

In discussing versus of the theory physics of neutral and charged Higgsinos fixes by the Lagrangian \cite{12} and the mass spectrum \cite{10} with the radiation splitting \cite{13}. Therefore any quantitative predictions of the theory depend two parameters $\mu$, $M_H$ only. Concrete value $M_H$ isn’t essential. The basic parameter of the model with separated Higgsino is $\mu$. Let imply that neutralino is a carrier of Dark Matter in the Universe. Irreversible neutralino annihilation starts in the cosmological plasma at the moment $t_0$ and the temperature $T_0$, when mean energy of relativistic quarks and leptons compares with neutralino mass: $\bar{\epsilon}_f \simeq 3 T_0 = M_\chi$. Residual density of neutralino at $t \gg t_0$ describes by the asymptotic solution of evolutional equations: \cite{6}, \cite{7}, \cite{16}:

$$\frac{dn_\chi}{dt} + 3Hn_\chi = -\frac{1}{2}n_\chi^2 (\sigma v)_{ann},$$

$$3H^2 = 8\pi G w T^4, \quad H = \frac{1}{a} \frac{da}{dt}, \quad w T^4 = \text{const} \frac{a^4}{a^4}.$$ \hspace{1cm} (15)

Here $(\sigma v)_{ann}$ – kinetic cross section of the annihilation, which approximate to the constant in our model; $G$ – gravitational constant; $w = w(T)$ – statistical weight of plasma at the annihilation epoch. With all degrees of freedom in the two-doublet Standard Model we have $w = 443\pi^2/120$. This value was used us for analysis of annihilation at the temperature exceeding the characteristic scale of Standard Model.

The asymptotic solution of equations (15) at times, exceeding the moment when annihilation terminates, is

$$n_\chi(t) = \left( \frac{a(t_0)}{a(t)} \right)^3 \left( \frac{2\pi G w}{3} \right)^{1/2} \frac{4T_0^2}{(\sigma v)_{ann}}$$ \hspace{1cm} (16)

where $T_0 \simeq M_\chi/3$ is the temperature at the moment of annihilation beginning. Annihilation epoch begins at the moment

$$t_0 \simeq \frac{1}{4T_0^2} \left( \frac{3}{2\pi G w} \right)^{1/2}$$ \hspace{1cm} (17)

and ends when $T_1 \simeq M_\chi/20$. To obtain the value of mass density of the neutralino gas in the present-day Universe $\rho_\chi = M_\chi n_\chi$ we use the standard data for cosmological neutrino.
Evolution of the neutrino component in the cosmological plasma may be considered as adiabatic since the energy isolation occurs mainly in non-neutrino channels of the hadronization and annihilation processes at \( t > t_0 \). Therefore the ratio of scale factors in (16) we can replace by ratio of neutrino gas temperatures:

\[
\frac{a(t_0)}{a(t_U)} = \frac{T_\nu}{T_0}, \quad T_\nu \simeq \left( \frac{4}{11} \right)^{1/3} T_\gamma = 1.676 \times 10^{-13} \text{GeV},
\]

Here \( t_U \) is the age of the Universe; \( T_\nu \equiv T_\nu(t_U) \), \( T_\gamma \) is the temperature of the relic gamma radiation.

Finally for density of stable neutralinos in the epoch, characterizing by the temperature of relic neutrino \( T_\nu \), we obtain:

\[
\rho_{\chi}(T_\nu) = \frac{M_\chi}{T_0} \frac{\left( \frac{2\pi G w}{3} \right)^{1/2}}{\frac{4T_\nu^3}{(\sigma v)_{ann}}}, \quad (18)
\]

From the recent WMAP data [17], [18] the mass density of Dark Matter in the present-day Universe is equal:

\[
\rho_{DM}(t_U) \simeq (0.23 \pm 0.04)\rho_c \simeq (0.94 \pm 0.34) \times 10^{-47} \text{GeV}^4. \quad (19)
\]

Here \( \rho_c = (4.1 \pm 0.8) \times 10^{-47} \text{GeV}^4 \) is the critical density of the Universe. An assumption about the Dark Matter in the Universe is the neutralino gas provides in

\[
\rho_{\chi}(t_U) = \rho_{DM}(t_U). \quad (20)
\]

To estimate the value of neutralino mass \( M_\chi \) from (20) we should obtain the expression for kinetic cross section of neutralino annihilation in the cosmological plasma \( (\sigma v)_{ann} \) as a function of \( M_\chi \). The problem is that we don’t know in which phase of the cosmological plasma neutralino annihilation occurs. We analyze two scenario consistently.

1. **Annihilation in the low symmetric phase.** Formation of the residual neutralino concentration occurs in the low symmetric phase (LS-phase) of the cosmological plasma that is after the electroweak transition if neutralino mass \( M_\chi < 3T_{eW} \sim 300 \text{ GeV} \). In standard scenarios of the cosmological evolution of neutralino as gaugino (1) in analysis of the Majorana neutralino annihilation to massless fermions for execution of the Pauli’s principle we must take into account of thermal corrections as a result the full annihilation cross section is a function of the temperature. Formally we have two variants: the annihilation of short-living particles \( (\tau_\chi < t_0) \) and the coannihilation of long-living particles \( (\tau_\chi \gg t_0) \) [12]. The carried out analysis shown that for existing of the separated Higgsino scenario we must forbid the s-channel annihilation into quarks and leptons that is to make second Majorana neutralino \( \chi_2^0 \) unstable with mean life time is smaller than \( 10^{-10} \text{ s} \). It is possible if \( M_{SUSY} \) scale doesn’t exceed \( 10^5 \text{ GeV} \). But this scenario assumes the fine tuning of the neutralino mass to W-boson mass. Therefore

\[
M_{\chi_1^--} \sim M_{\chi_1^0} \sim M_W,
\]

that is contrary to well known experimental constraints [19]. Formally equations for annihilation in the LS-phase contain the second solution corresponding to neutralino mass in order a few TeV. But such scale is incompatible with the assumption about neutralino annihilation in the LS-phase of the cosmological plasma. So this assumption doesn’t reduce to self-consistent result.
2. Annihilation in the high symmetric phase. As it is known, at temperatures, exceeding the temperature of electroweak transition $T > T_{eW} \sim 100 \text{ GeV}$, plasma is in the high symmetric phase (HS-phase), in which Higgs condensate is absent. The characteristic feature of the HS-phase is the massless of all particles (more precisely, their masses is $m \ll T$) except Higgsino. Physical states here is quants of gauge fields $B, W_a$ ($a = 1, 2, 3$) and chiral fermions. The mass splitting disappear in the Higgsino family. As a result neutralino and chargino degrees of freedom incorporate to the fundamental representation of the $SU(2)$ group that is the unified Dirac field $\chi$, in which internal states classify over quantum numbers of the restored $SU(2)$ symmetry and they are dynamic equivalent. At the HS-phase instead of (12) we should use the Lagrangian

$$\Delta L_\chi = \frac{1}{2}g_1B_\mu \bar{\chi} \gamma^\mu \chi + \frac{1}{2}g_2W_\mu^a \bar{\chi} \gamma^\mu \tau_a \chi,$$

(21)

which adds to the Standard Model Lagrangian written in terms of gauge and chiral fields:

$$L_{SM} = -\frac{1}{2}g_1B_\mu \bar{l}_L \gamma^\mu l_L - g_1B_\mu \bar{e}_R \gamma^\mu e_R + \frac{1}{6}g_1B_\mu \bar{q}_L \gamma^\mu q_L + \frac{2}{3}g_1B_\mu \bar{u}_R \gamma^\mu u_R - \frac{1}{3}g_1B_\mu \bar{d}_R \gamma^\mu d_R$$

$$+ \frac{1}{2}g_2W_\mu^a \bar{l}_L \gamma^\mu \tau_a l_L + \frac{1}{2}g_2W_\mu^a \bar{q}_L \gamma^\mu \tau_a q_L.$$

(22)

Irreversible Higgsino annihilation occurs in the HS-phase and governed by the Lagrangians (21) and (22) if Higgsino mass is $|\mu| \gg T_{eW}$. We calculated all cross sections of the t- and s-channel Higgsino annihilation into gauge bosons and massless fermions. The technology of these calculations is analogous to calculations in the QCD. The difference is we must take into account the annihilation channels, in which initial and final states are arbitrary over the two-dimensional color, corresponding to broken $SU(2)$. Full list of all annihilation channels is

$$\chi\chi \rightarrow BB, \quad \chi\chi \rightarrow W_a W_a;$$

$$\chi\chi \rightarrow B^* \rightarrow l_L l_L, e_R e_R, q_L q_L, u_R u_R, d_R d_R; \quad \chi\chi \rightarrow W^*_a \rightarrow l_L l_L, q_L q_L,$$

(23)

where $l_L$, $q_L$, $e_R$, $u_R$, $d_R$ is chiral fermions and quarks of three generations. The calculation of the total kinetic cross section over all channels (23) gives:

$$(\sigma v)_{ann} = \frac{21g_1^4 + 6g_1^2g_2^2 + 39g_2^4}{512\pi M_\chi^2}.$$  

(24)

Here $g_1 = g_1(2M_\chi)$, $g_2 = g_2(2M_\chi)$ - gauge coupling constants at the scale $\sqrt{s} = 2M_\chi$. Their may be calculated by methods of renormalization group analysis.

From comparison of the theoretical expression for density (18) in the assumption, that formation of the residual neutralino concentration occurs in the HS-phase, with well known experimental constraints (19) follows that separated neutralino can constitute the Dark Matter in the Universe if its mass

$$M_\chi = 2900 \pm 500 \text{ GeV}.$$  

(25)

With such mass value the irreversible annihilation starts at the temperature $T_0 \sim M_\chi/3 \sim 1000 \text{ GeV}$, and finishes at the temperature $T_1 \sim M_\chi/20 \sim 100 \text{ GeV}$. Hence the whole process of the annihilation occurs in the HS-phase that demonstrates the internal consistency of the neutralino mass evaluation.
Of course, we should treat carefully to the value (25) since nobody knows what the Dark Matter is in reality. Besides this value supposes the execution of $M_X \ll M_{SUSY}$. However, we should emphasize that the discussing variant of the theory no less motivated phenomenologically than well known scenarios with $M_{SUSY} \sim 1 - 2 \, TeV$.

6 Problem of separated neutralino searches.

Above variant with separated Higgsinos can’t be tested at LHC because their mass splitting is drastically small. So we cannot see any lepton decays of chargino and neutralino. A check-up of our model is possible now only in astrophysics.

6.1 Direct detection.

6.1.1 Elastic scattering of separated neutralino on nucleons and nuclei.

There are approximately twenty experimental program for relic WIMPs direct detection [20], [21], [22], [23]. But we haven’t any clear evidence of their existence now.

All operating detectors use the registration of nuclear recoils. They are generated in the processes of the elastic WIMP scattering by nuclei [24]. As usual, the main problem is to discriminate signal and background. Now there is a project to use cryogenic apparatus with mass near 1 ton in the NUSEL [25], [26], [27], where the muon background is negligibly small. These experiments are planned in the same period that the LHC.

The most perspective technology is using the liquid xenon as scintillator which react to passing nuclear recoils. To study the possibility of neutralino detection in such experiments we consider neutralino-nucleon elastic scattering. It is known that spin independent part of the total cross section induced by neutralino-quark interaction through scalar quark exchange [24]. In our model this part of cross section is strongly damped by large scalar quark masses. As a result in the cross section we have only spin dependent part in the form:

$$\sigma_{\chi n} = \frac{g_2^4 m_n^2}{64\pi m_W^4}, \quad \sigma_{\chi p} = \frac{g_2^4 (1 - 4 \sin^2 \theta_W)^2 m_p^2}{64\pi m_W^4}. \quad (26)$$

As it is known the local DM density is 0.3 GeV/sm$^3$, the velocity of neutralino at the Sun position is near 200 km/s. Using these data we estimated the separated neutralino flux in detector $j_\chi \simeq 2 \cdot 10^3 \, sm^{-2} \, s^{-1}$. As example we considered one of the most perspective detectors XENON which is in the development stage. The detector threshold is $\lesssim 10 \, KeV$ for nuclear recoil energy. The typical recoil energy from interaction with galactic separated neutralino is $\sim 100 \, KeV$. Detector contains $\sim 0.34 \, m^3$ of liquid xenon $A = 131.3$. We calculated the elastic cross section of nonrelativistic neutralino on nuclei of xenon $\sim 10^{-35} \, sm^2$. The estimation of number of events gives the value that close to the planned background for considered detector $4.5 \cdot 10^{-5} \, s^{-1}$ or $\sim 1$ event per hour that can’t provide the reliable signal for existing of Dark Matter in the form of separated neutralino. The question about direct detection possibility of separated neutralino remains open.

6.1.2 Recharging of separated neutralino on nucleons.

New and exotic processes could be possible when relic neutralino penetrate through the matter. Corresponding channels are:

$$\chi^0 + p \rightarrow \chi^+ + n, \quad \chi^0 + n \rightarrow \chi^- + p.$$
Cross sections have the form:

\[
\sigma^*_{\chi p} = \frac{g_2^4 m_p^2}{16\pi m_W^4} \sqrt{\frac{E_N - \Delta m_N - \Delta M_{\chi}}{E_N}},
\]

\[
\sigma^*_{\chi n} = \frac{g_2^4 m_p^2}{16\pi m_W^4} \sqrt{\frac{E_N + \Delta m_N - \Delta M_{\chi}}{E_N}}.
\]

Here \( \Delta m_N = m_n - m_p \simeq 1\,\text{MeV} \) – proton-neutron mass difference; \( \Delta M_{\chi} = M_{\chi^+} - M_{\chi^0} \simeq 360\,\text{MeV} \) – chargino-neutralino mass difference that can be calculated from \( M_{\chi^0} \); \( E_N = \frac{1}{2}m_N v_{\text{rel}}^2 \). An average kinetic energy of neutralino in the locality of the Sun is about \( \sim 1\,\text{MeV} \), but recharging reaction is possible only if there are high energy neutralinos with \( E_{\text{kin}} > 1\,\text{TeV} \) in cosmic rays.

6.2 Indirect detection.

6.2.1 Diffuse gamma ray spectrum.

Except of direct relic neutralino detection experiments there are many projects use satellite experiments for the neutralino annihilation products observation [20], [23], [28]. It can be possible to establish some qualitative and quantitative WIMP’s characteristics from these data, mainly from the data on the neutralino annihilation spectrum from the Galactic halo. We consider this process and calculate characteristic energies in the diffuse gamma spectrum. Dirac neutralinos in the halo annihilate into \( W \)- and \( Z \)-bosons

\[
\chi \chi \rightarrow W^+W^-, \quad \chi \chi \rightarrow ZZ,
\]

and into fermions

\[
\chi \chi \rightarrow q\bar{q}, \ell\bar{\ell}.
\]

Corresponding total kinetic cross section given in the form:

\[
(\sigma v)_{\text{ann}} = \frac{g_2^4 (21 - 40 \cos^2 \theta_W + 34 \cos^4 \theta_W)}{256 \pi M_{\chi}^2 \cos^4 \theta_W}
\]

It is known that total multiplicity of secondary hadrons nearly twice larger than charged hadrons multiplicity [19], [29], [30]. Average multiplicity of charged secondary hadrons \( \langle n_{ch} \rangle(\sqrt{s}) \) was studied in \( e^+e^- \), \( pp \) and \( pp \) reactions, \( e^\pm p \) interactions [31]. It was established that charged multiplicity is an universal function of energy

\[
\tilde{n}_{ch}(\sqrt{s}) = A + B \ln \sqrt{s} + C \ln^2 \sqrt{s}, \quad \tilde{n}_{ch} \equiv \langle n_{ch} \rangle(\sqrt{s}/q_0) - n_0
\]

with fixed parameters

\[
A = 3.11 \pm 0.08, \quad B = -0.49 \pm 0.09, \quad C = 0.98 \pm 0.02.
\]

To choose a specific channel it is need to fix parameters \( q_0, n_0 \). For neutralino annihilation \( q_{0(\chi\chi)} = 1 \), \( n_{0(\chi\chi)} = 0 \).

We have used experimental data on multiplicity in \( Z \rightarrow hh \) decay [32]. For estimation we suppose that charged hadrons part \( \propto \langle n_{ch} \rangle/\langle n_h \rangle \) doesn’t depend on energy and have the value \( \propto \simeq 0.49 \).
To plan an experiment it is important to know characteristic photon energies that are generated in the following decays: \( \pi^0 \rightarrow 2\gamma \), \( \eta^0 \rightarrow 3\gamma \), \( \eta^0 \rightarrow 3\pi^0 \rightarrow 6\gamma \). In the annihilation channel \( \chi \rightarrow 2\pi \), the total hadron multiplicity is described by logarithmic function well:

\[
\langle n_{hh} \rangle = \kappa^{-1}(A + B \ln 2M_\chi + C \ln^2 2M_\chi) \simeq 149, \quad M_\chi \simeq 3 \text{ TeV}.
\]

(30)

Average energy of the neutral pion in neutralino annihilation products is \( \bar{E}_{\pi^0} \simeq \bar{E}_{\eta^0} \simeq M_\chi / \langle n_{hh} \rangle \). So we have characteristic maximal photon energy in the \( \pi^0 \rightarrow 2\gamma \) decay:

\[
\bar{E}_{\gamma(\pi^0 \rightarrow 2\gamma)} \simeq \bar{E}_{\pi^0} / 2 = 20 \text{ GeV}.
\]

(31)

Analogously from decays \( \eta^0 \rightarrow 3\gamma \) and \( \eta^0 \rightarrow 3\pi^0 \rightarrow 6\gamma \) energies of photons are:

\[
\bar{E}_{\gamma(\eta^0 \rightarrow 3\gamma)} \simeq \bar{E}_{\eta^0} / 3 = 13.5 \text{ GeV}, \quad \bar{E}_{\gamma(\eta^0 \rightarrow 6\gamma)} \simeq \bar{E}_{\eta^0} / 6 = 6.7 \text{ GeV}.
\]

(32)

Then we considered second annihilation channel \( \chi \rightarrow WZ \). Total hadron multiplicity of W- and Z-bosons decays is

\[
\langle n_{WW} \rangle \simeq 42.9.
\]

(33)

Average energy of the neutral pion is \( \bar{E}_{\pi^0} \simeq \bar{E}_{\eta^0} \simeq M_\chi / \langle n_{WW} \rangle \). So we have characteristic maximal photon energies:

\[
\bar{E}_{\gamma(\pi^0 \rightarrow 2\gamma)} \simeq \bar{E}_{\pi^0} / 2 \simeq 35 \text{ GeV};
\]

\[
\bar{E}_{\gamma(\eta^0 \rightarrow 3\gamma)} \simeq \bar{E}_{\eta^0} / 3 = 23.3 \text{ GeV}, \quad \bar{E}_{\gamma(\eta^0 \rightarrow 6\gamma)} \simeq \bar{E}_{\eta^0} / 6 = 12 \text{ GeV}.
\]

(34)

Multiplicity distribution in a wide energy region is described by the negative binomial distribution (NBD) with a good precision, which depends on energy very weak (as logarithm) \( [29] \):

\[
P(n; \bar{n}, k) = \frac{k(k+1)\ldots(k+n-1)}{n!} \cdot \frac{(\bar{n}/k)^n}{[1+(\bar{n}/k)]^{n+k}};
\]

(35)

\[
k^{-1}(\sqrt{s}) = a + b \ln \sqrt{s},
\]

where \( n \equiv n_{ch}, \bar{n} \equiv \bar{n}_{ch} \). Coefficients of the function \( k^{-1}(\sqrt{s}) \) is different for various channels:

\[
a_{ee} = -0.064 \pm 0.003, \quad b_{ee} = 0.023 \pm 0.002;
\]

\[
a_{pp/\bar{p}p} = -0.104 \pm 0.004, \quad b_{pp/\bar{p}p} = 0.058 \pm 0.001.
\]

(36)

(37)

Using NBD we found approximate photon distribution over the energy. The number of
photons with the energy $E_\gamma$ in one $\chi\bar{\chi}$-annihilation act may be defined by

$$\frac{dN_\gamma}{dE_\gamma} \simeq \frac{2M_\chi}{E_\gamma^2} \left\{ \left[ Br(\pi^0/h) + Br(\eta^0/h) \cdot Br(\eta^0 \rightarrow 2\gamma) \right] \times 
\times \left[ Br(h)\langle n_{ch}^{ff} \rangle P \left( \frac{M_\chi}{2E_\gamma}; \langle n_{ch}^{ff} \rangle, k_{ff} \right) + \frac{1}{2} Br(WZ)\langle n_{ch}^{WZ} \rangle P \left( \frac{M_\chi}{4E_\gamma}; \langle n_{ch}^{WZ} \rangle, k_{WZ} \right) \right] + 
+ Br(\eta^0/h) \left[ Br(\eta^0 \rightarrow 3\pi^0) + \frac{1}{3} Br(\eta^0 \rightarrow \pi^+\pi^-\pi^0) \right] \times 
\times \left[ Br(h)\langle n_{ch}^{ff} \rangle P \left( \frac{M_\chi}{6E_\gamma}; \langle n_{ch}^{ff} \rangle, k_{ff} \right) + \frac{1}{2} Br(WZ)\langle n_{ch}^{WZ} \rangle P \left( \frac{M_\chi}{12E_\gamma}; \langle n_{ch}^{WZ} \rangle, k_{WZ} \right) \right] + 
\frac{1}{3} Br(\eta^0/h) Br(\eta^0 \rightarrow \pi^+\pi^-\gamma) \times 
\times \left[ Br(h)\langle n_{ch}^{ff} \rangle P \left( \frac{M_\chi}{3E_\gamma}; \langle n_{ch}^{ff} \rangle, k_{ff} \right) + \frac{1}{2} Br(WZ)\langle n_{ch}^{WZ} \rangle P \left( \frac{M_\chi}{6E_\gamma}; \langle n_{ch}^{WZ} \rangle, k_{WZ} \right) \right] \right\}. \quad (38)$$

Here $Br(WZ) \simeq 0.2$ is the total branching for neutralino annihilation into $W$- $Z$-bosons; charge hadron multiplicities $\langle n_{ff}^{ff} \rangle$ and $\langle n_{ff}^{WZ} \rangle$ defined in (30) and (33); values $k_{ff}^{-1} = k_{WZ}^{-1} = (2M_\chi) = 0.4$ and $k_{WZ}^{-1} = k_{WZ}^{-1}(M_\chi) = 0.12$ defined with coefficients (37) and (36) correspondingly. The spectrum is shown graphically at Fig. 2.

![Figure 2: Diffuse gamma ray annihilation spectrum.](image)

Calculated gamma-ray flux of annihilation radiation from clumped galactic halo is closes to sensitivity threshold of the satellite detector GLAST. The question about principal possibility for registration of the neutralino annihilation spectrum at GLAST remains open.
6.2.2 High energy gamma ray bursts as a result of collapse and total annihilation of neutralino clumps.

Consideration neutralino as a carrier of DM mass in the Universe generates questions about their evolution and about astrophysical phenomenons which evidence both the existence of neutralino and the reality of the evolution process with neutralino participation.

According to high resolution cold dark matter simulations in framework of hierarchical principle of structure formation large virilized halos are formed through the constant merging of smaller halos formed at earlier times. Neutralinos at the gravitational isolation stage $z = 8 \div 10$ formed dense massive clumps of different scales [33], [34]. It likes naturally that DM clumps are in the state of dynamical equilibrium as a result of compensation of own gravitational forces by forces of tidal interactions with each other. In consequence of inner instability the clump can turn into irreversible collapse state. The growth of density provides the growth of annihilation rate. So neutralino clouds become more and more intense sources of relativistic particles. At final stage of this process there is a gamma ray burst with maximal characteristic photon energies defined above [31], [32], [34]. Specific energy and time distribution of the gamma radiation are connected with neutralino parameters and give an important information about structure of the MSSM and about its correspondence with cosmology. Therefore our main statement consist in the nature of rare powerful cosmological gamma ray bursts is a result of the total annihilation of neutralino clumps.

We analyzed the qualitative and quantitative descriptions of this process in the spherically symmetric collapse model with two assumptions. First, annihilation products leave a clump during a time substantially smaller than the time of its macroscopic evolution. And second, an annihilating clump is spatially homogeneous and isotropic since more dense regions annihilate faster than the rest and heterogeneities are vanishing.

The model, defined by equations of mass and momentum balance and the equation of nonrelativistic gravitational theory, is:

$$\frac{d}{dt} \int \rho \chi dV = - \int \rho \chi v_i dS_i - \int 2(\sigma v)_{\text{ann}} \rho^2 \chi M \chi \cdot M dV,$$

$$\frac{d}{dt} \int \rho \chi v_i dV = - \int (\rho \chi v_i v_k + P_{ik}) dS_k - \int \rho \chi \nabla \cdot \phi dV - \int \nu_{\text{dis}} \rho \chi v_i dV - \int 2(\sigma v)_{\text{ann}} \rho^2 \chi v_i dV,$$

$$\Delta \phi = 4\pi G \rho \chi,$$

(39)

where $P_{ik}$ is the pressure tensor for neutralino gas. It is absent in consequence of second assumption. Last terms in balance equations describe the momentary going away of annihilation products from the collapsing clump. Taken into account that annihilation and scattering are cross-channels. In the local form we have the simple system:

$$\frac{dM}{dt} = - \frac{3(\sigma v)_{\text{ann}} M^2}{2\pi M \chi}, \quad \left( \frac{dR}{dt} \right)^2 = \frac{2GM}{R} \left( 1 - \beta^2 \frac{R}{R_0} \right),$$

(40)

which integrates elementary. Here $R$ is a clump radius; $M = 4\pi \rho \chi R^3/3$ is a clump mass; $R_0 = \text{const}$ is an initial radius; $\beta^2 \leq 1$ is the constant which fixed by initial velocity of the
surface clump compression. The results are in the parametric form

\[ M(\zeta) = M_0 \left[ 1 + \frac{(\sigma v)_{\text{ann}}}{M_\chi} \left( \frac{3\rho_\chi(\ast)}{2\pi G} \right)^{1/2} \left( \frac{\zeta^3}{3} + \beta^2 \zeta \right) \right]^{-2}, \]

\[ R(\zeta) = R_0 (\zeta^2 + \beta^2)^{-1}, \]

\[ \left( \frac{8\pi G\rho_\chi(\ast)}{3} \right)^{1/2} t(\zeta) = \frac{1}{\beta^2} \left( \frac{\zeta}{\zeta^2 + \beta^2} - (1 - \beta^2)^{1/2} \right) + \frac{1}{\beta^3} \left( \arctan \frac{\zeta}{\beta} - \arctan \frac{(1 - \beta^2)^{1/2}}{\beta} \right) + \frac{(\sigma v)_{\text{ann}}}{3M_\chi} \left( \frac{3\rho_\chi(\ast)}{2\pi G} \right)^{1/2} \left( \ln(\zeta^2 + \beta^2) + \frac{2\beta^2(\zeta^2 + \beta^2 - 1)}{\zeta^2 + \beta^2} \right), \]

where \( M_0 \sim M_\odot = 4 \cdot 10^{33} \text{g}, \rho_\chi(\ast) \sim 10^{-4} \text{g/cm}^3 \) are initial clump mass and density. As you see \( M(t) \to 0, R(t) \to 0 \) for \( t \to \infty \).

Annihilation rate is

\[ -\frac{dM}{dt} \equiv \dot{E}_{\text{ann}} = M_0 \rho_\chi(\ast) \cdot \frac{2(\sigma v)_{\text{ann}}}{M_\chi} \cdot \frac{(\zeta^2 + \beta^2)^3}{1 + \frac{(\sigma v)_{\text{ann}}}{M_\chi} \left( \frac{3\rho_\chi(\ast)}{2\pi G} \right)^{1/2} \left( \frac{\zeta^3}{3} + \beta^2 \zeta \right)} \]

Generally behavior of this function is that a slow growth at small times changes into quick evolution around narrow peak after which there is an exponential drop to zero. This behavior explains by changing of the parameter hierarchy during the collapse. We use the convenient time scale

\[ \dot{E}_{\text{ann}} = \frac{M_0}{4} \left( 1 - \frac{(t - t_0)^2}{2\tau_0^2} \right), \quad \tau_0 = \frac{(\sigma v)_{\text{ann}}}{3\pi GM_\chi}. \]

Here \( t_0 \) is the time of maximum. As we have

\[ g = \frac{(\sigma v)_{\text{ann}}}{M_\chi} \left( \frac{3\rho_\chi(\ast)}{2\pi G} \right)^{1/2} \ll 1 \]

than the annihilation rate doesn't depend on initial conditions and expresses through fundamental constants only. Dependence of function \( \dot{E}_{\text{ann}}/M_0 \) via dimensionless time \( \eta = (t - t_0)/\tau_0 \) shown at the left Fig. Special features of this function is skewness. About 80 % of clump mass annihilates during the time

\[ t_{\text{ann}} = 6\tau_0 = \frac{2(\sigma v)_{\text{ann}}}{\pi GM_\chi} = \frac{g_2^4 (21 - 10 \cos^2 \theta_W + 34 \cos^4 \theta_W)}{128 \pi^2 M_\chi^3 G \cos^3 \theta_W} \simeq 30 \text{ s}, \quad M_\chi \simeq 3 \text{ TeV} \]

at that effectively it proceeds between \( t_A^- = 4\tau_0 \) (before maximum) and \( t_A^+ = 2\tau_0 \) (after maximum).

The mass evolution \( M_\chi \) is shown at the right Fig. Decay time of collapsing neutralino clump expresses through MSSM parameters and gravitational constant but it is absolutely independent from initial density and initial velocity of clump compressing.
Figure 3: Annihilation rate $\dot{E}_A/M_*(\epsilon)$ and relative mass $M/M_*(\epsilon)$ of neutralino clump as a function of dimensionless time $\eta$.

7 Conclusion.

Here we discuss the variant of supersymmetric extension of the SM, where Higgsino mass scale is lower than the scale of soft SUSY breaking: $\mu \ll M_{SUSY} \sim M_0 \sim M_{1/2}$. We call the model as Model with Separated Higgsinos.

In the model, as in the commonly used MSSM, the precise convergence of invariant charges takes place at the scale that does not contradict to proton mean life time constraint. When $M_{SUSY} > 10^7$ GeV radiation corrections dominate in the neutralino-chargino mass splitting. From the calculation of splitting and the renormgroup evolution we get $M_{\chi^\pm} - M_{\chi^0} \simeq 360$ MeV at $M_{\chi} \approx \mu \approx 3$ TeV. This value have got from the analysis of the neutralino relic in cosmological plasma. We supposed that neutralino is a DM carrier. In the model formation of the neutralino relic occurs in high symmetric phase of the plasma. Charged Higgsino mean life time is $\tau_{\chi^\pm_{\chi_1}} \approx 0.4 \times 10^{-9}$ s. Problems of relic separated neutralino search in underground (NUSEL) and satellite (GLAST) experiments are discussed. It have been shown that spin dependent component dominates in neutralino-nucleon cross section. Possibility of the separated neutralino registration at perspective detector XENON is analyzed. In this case the signal is closed to the planned background. Process of high energy neutralino recharging on nuclei have been considered for the case when neutralinos with large kinetic energies (more than 1 TeV) are in cosmic rays. The spectrum of diffuse annihilation radiation have been calculated and analyzed for the galactic DM. Annihilation cross sections for galactic neutralino have been calculated. Contribution to the gamma ray spectrum from t- and s-channel neutralino annihilation into $Z^0Z^0$ and $W^+W^-$ pairs has been calculated using experimental data about hadron multiplicities at mass surfaces of $Z^0$, $W^\pm$-bosons; quark-antiquark s-channel contribution has been estimated using the phenomenological model of hadron multiplicities at $\sqrt{s} = 2M_\chi$. In the Galaxy a collapse and total annihilation of neutralino clumps should take place if neutralinos are main carriers of its mass. Time and energy distribution of the gamma ray radiation are calculated. It is shown that nearly 80 percents of the clump mass annihilate in 30 seconds.
References

[1] N. Arkani-Hamed (Harvard U., Phys. Dept.), S. Dimopoulos (Stanford U., Phys. Dept.),
G.F. Giudice, A. Romanino (CERN) "Aspects of Split Supersymmetry", CERN-PH-
TH/2004-183, hep-th/0409232.

[2] N. Arkani-Hamed, S. Dimopoulos, "Supersymmetric Unification Without Low Energy
Supersymmetry and Signatures for Fine-Tuning at the LHC", hep-th/0405159.

[3] S. Abdullin et al. "Discovery potential for supersymmetry in CMS", CMS-NOTE
1998/006

[4] I. Iashvili, A. Kharchilava, K. Mazumdar "Study of $\chi^\pm_1\chi^0_2$ Pair Production with the
CMS Detector at LHC", CMS-NOTE 1997/007

[5] V.A. Mitsou "Search for new physics with ATLAS at the LHC", ATL-CONF-2000-002
(2000)

[6] J. Primack "The nature of Dark Matter", astro-ph/0112255

[7] J. Primack "Dark Matter and Structure Formation", astro-ph/9707285

[8] J. Ellis, J. Hadelin, D. Nanopoulos, K. Olive, M. Sredniki, Nucl. Phys. B238, 453
(1984)

[9] G. Jungman, M. Kamionkowski, K. Griest, Phys. Rep. 267, 195 (1996)

[10] D. Pierce, A. Padopoulos "Radiative Corrections to Neutralino and Chargino Masses in
the Minimal Supersymmetric Model", Phys. Rev., D50 (1994) 565-570, hep-ph/9312248

[11] P. Gondolo, K. Freese "CP-Violating Effects in Neutralino Scattering and Annihilation",
JHEP 0207, (2002) 052, hep-ph/9908390

[12] J. Edsjo, P. Gondolo "Neutralino Relic Density including Coannihilation", Phys. Rev.,
D56 (1997) 1879-1894, hep-ph/9704361

[13] R. Aloisio "Multiwavelength observation of WIMP annihilation", astro-ph/0405110

[14] M.S. Chanowitz "Higgs boson mass constraints from precision data and direct
searches", hep-ph/9807452

[15] A. Belyaev, D. Garcia, J. Guasch "Prospects for heavy supersymmetric charged Higgs
boson searches at hadron colliders", JHEP 0206 (2002) 059, hep-ph/0203031

[16] P. Gondolo, "Non-Baryonic Dark Matter" astro-ph/0403064

[17] L. Verde, et al. "The 2dF Galaxy Redshift Survey: the bias of galaxies and the density
of the Universe", MNRAS 335, 432 (2002)

[18] D.N. Spergel, et al. "First-Year Wilkinson Microwave Anisotropy Probe (WMAP)
Observations: Determination of Cosmological Parameters", Astrophys. J. Suppl., 148,
175 (2003)
[19] K. Hagiwara, et al (Particle Data Group) “Review of Particle Physics”, Phys. Rev. D66, (2002)

[20] R. Bernabei et al. "Dark Matter search", Riv. N. Cim. 26 n.1 (2003) 1-73

[21] P.F. Smith "Direct detection of weakly intracting massive particles using non-cryogenic techniques”, Phil. Trans. R. Soc. Lond. A (2003) 361, 2591-2606

[22] Nigel J.T. Smith "Dark Matter detectors and the use of interaction location information for background suppression”, Nuclear Instruments and Methods in Physics Research, A 513 (2003) 215-221

[23] T.J. Sumner "Experimental Searches for Dark Matter", www.livingreviews.org/Articles/Volume5/2002-4sumner

[24] A. Kurylov, M. Kamionkowski "Generalized Analysis of Weakly-Interacting Massive Particle Searches”, hep-ph/0307185

[25] J.F. Wilkerson "National Underground Science Laboratory at Homestake”, University of Washington, Dark Matter 2002, Feb. 22, 2002

[26] J.F. Wilkerson "Science Intersections at a National Underground Science and Engineering Laboratory”, University of Washington, CIPANP, May 24, 2003

[27] J.F. Wilkerson "Discovery Opportunities at a National Underground Science and Engineering Laboratory”, University of Washington, NIST Physics Colloquium, Jan. 30, 2003

[28] A. Tasitsiomi, J. Gaskins, A. Olinto "Neutralino annihilation γ-rays from clumps and the LMC", astro-ph/0306561

[29] The L3 Collaboration, "Measurement of charged-particle multiplicity distributions and their $H_q$ moments in hadronic Z decays at LEP”, Phys. Lett. B577, 109–119 (2003), hep-ex/0110072

[30] I.M. Dremin, J.W. Gary "Hadron multiplicities”, Phys. Rept., 349 (2001) 301-393 hep-ph/0004215

[31] S. Aid et al. "Charged Particle Multiplicities in Deep Inelastic Scattering at Hera”, hep-ex/9608011

[32] C. Caso et al. (Particle Data Group) "Review of Particle Physics”, European Phys. Jour. C3, 1, 2000 (URL: http://pdg.lbl.gov)

[33] S. Hofmann, D. J. Schwarz, H. Stocker "Formation of small-scale structure in SUSY CDM”, astro-ph/0211325

[34] J.R. Primack "Status of Cold Dark Matter Cosmology”, astro-ph/0205391