Scalar neutrino in U(1)xSSM and dark matter

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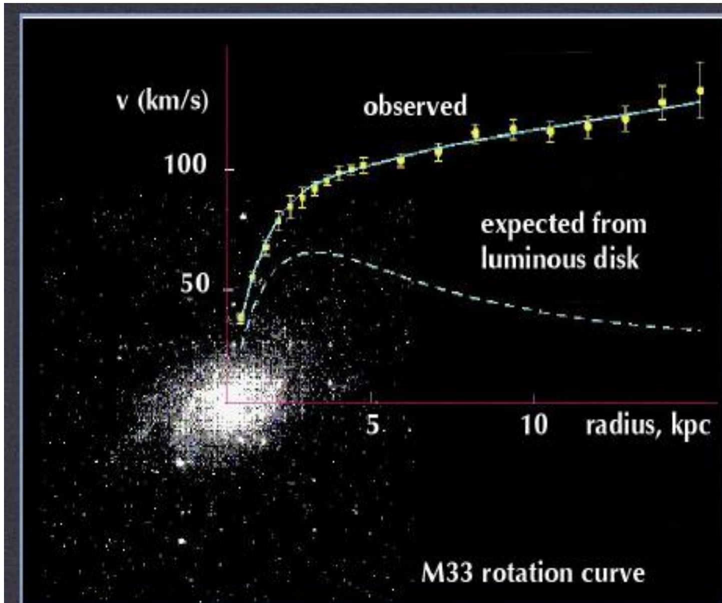
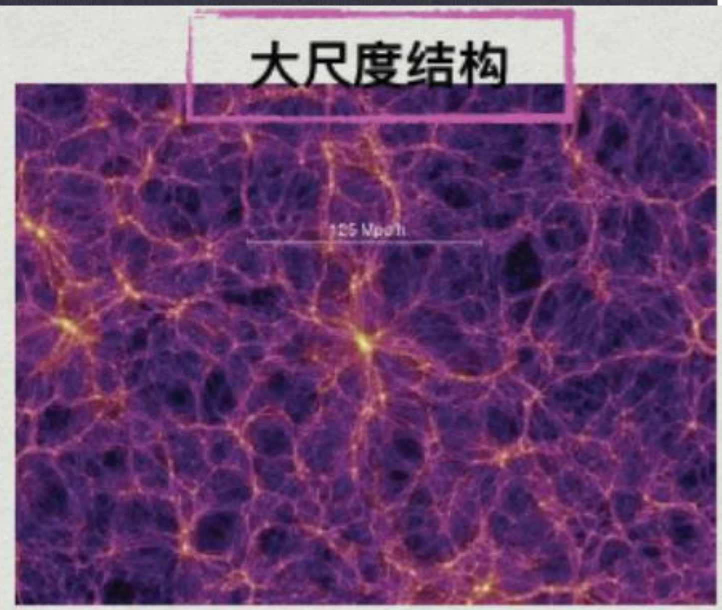
暗物质


v (km/s)
100
50
observed
expected from
luminous disk
5
10
radius, kpc
M33 rotation curve


大尺度结构

暗物质的特点与探测

（1）暗物质参与引力相互作用，有质量。

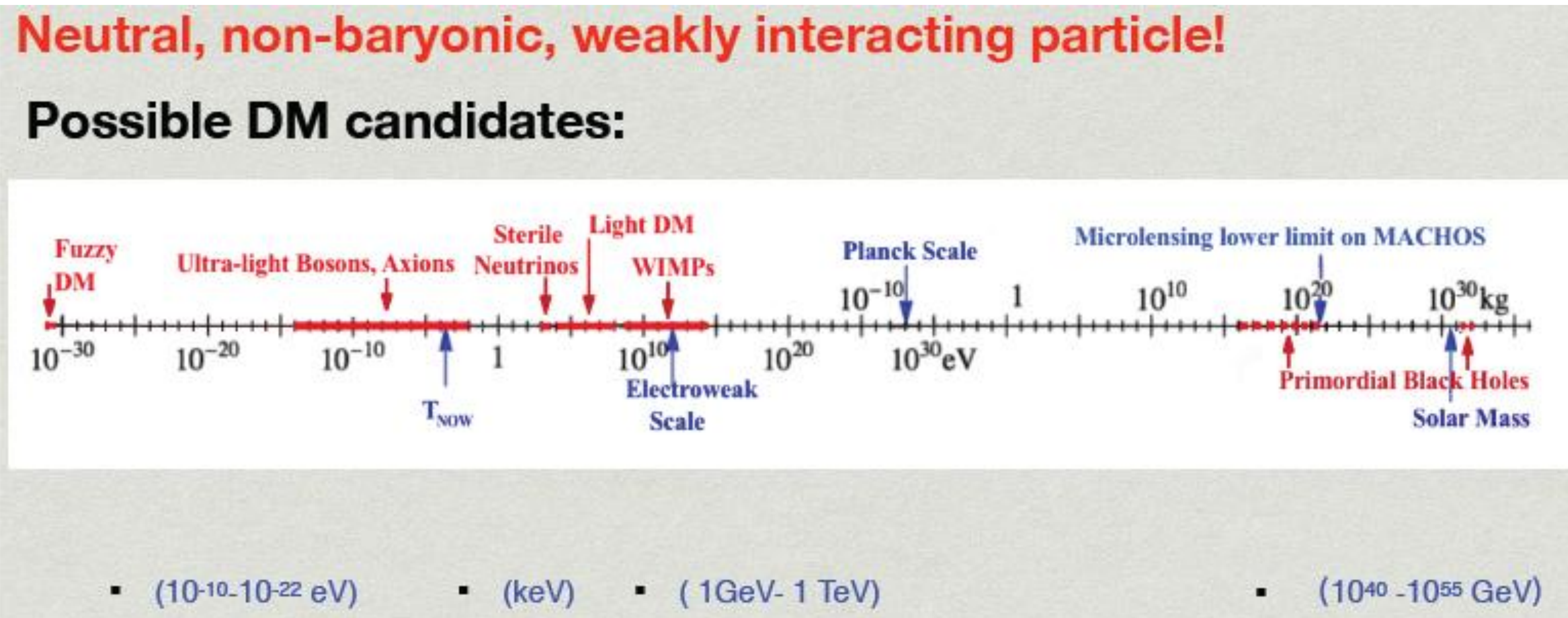
（2）暗物质应是高度稳定的。

（3）暗物质不参与电磁相互作用和强相互作用

（4）通过计算机模拟宇宙大尺度结构形成得知，大部分暗物质的运动速度应该是远低于光速，即“冷暗物质”。

直接探测，间接探测，对撞机探测

Dark matter candidates:
light neutrinos, axions,
sterile neutrinos, primordial black holes,
weakly interacting massive particles(WIMPs).



The U(1)xSSM

The local gauge group $SU(3)_C \otimes SU(2)_L \otimes U(1)_Y \otimes U(1)_X$

1. In comparison with the MSSM, our model has more superfields: $U(1)_X$ gauge field, righ-handed neutrinos, three $SU(2)_L$ singlet Higgs superfields

2. The VEV of $\overline{\eta}$ produces masses of the right-handed neutrinos.

3. The light neutrinos obtain tiny masses through the see-saw mechanism.

4. The lightest sneutrino can be a new dark matter candidate. Moreover, PAMELA claims an excess in the electron/positron flux and no excess in the proton/antiproton flux. Thus, the idea that dark matter carries lepton number is intriguing.

5. The little hierarchy problem in MSSM is relieved in $U(1)_X$ SSM by the right-handed neutrinos, sneutrinos and additional Higgs singlets.

6. $U(1)_X$SSM includes both terms $\mu \hat{H}_u \hat{H}_d$ and $\lambda_H \hat{S} \hat{H}_u \hat{H}_d$.
When $\hat{S}$ develops a VEV $(v_S/\sqrt{2})$,
an effective μ_{eff} can be obtained as $\mu_{eff} = \mu + \lambda_H v_S/\sqrt{2}$.
This can relieve the μ problem and even solve it.

7. The interaction between three extra singlet Higgs superfields and two Higgs doublets is favorable to increase the mass of the lightest CP-even Higgs at the tree level. The $U(1)_X$ D-term gives another contribution. Considering both effects, large loop-induced contribution from stop sector is not necessary.

8. The mass of the next light CP-even Higgs can reachthe order of TeV.

The superfields in U(1)XSSM

Superfields	$SU(3)_C$	$SU(2)_L$	$U(1)_Y$	$U(1)_X$
$\hat{Q}_i$	3	2	1/6	0
$\hat{u}_i^c$	$\bar{3}$	1	-2/3	-1/2
$\hat{d}_i^c$	$\bar{3}$	1	1/3	1/2
$\hat{L}_i$	1	2	-1/2	0
$\hat{e}_i^c$	1	1	1	1/2
$\hat{\nu}_i$	1	1	0	-1/2
$\hat{H}_u$	1	2	1/2	1/2
$\hat{H}_d$	1	2	-1/2	-1/2
$\hat{\eta}$	1	1	0	-1
$\hat{\bar{\eta}}$	1	1	0	1
$\hat{S}$	1	1	0	0

The superpotential

$$W = l_W\hat{S} + \mu\hat{H}_u\hat{H}_d + M_S\hat{S}\hat{S} - Y_d\hat{d}\hat{q}\hat{H}_d - Y_e\hat{e}\hat{l}\hat{H}_d + \lambda_H\hat{S}\hat{H}_u\hat{H}_d$$
$$+\lambda_C\hat{S}\hat{\eta}\hat{\bar{\eta}} + \frac{\kappa}{3}\hat{S}\hat{S}\hat{S} + Y_u\hat{u}\hat{q}\hat{H}_u + Y_X\hat{\nu}\hat{\bar{\eta}}\hat{\nu} + Y_\nu\hat{\nu}\hat{l}\hat{H}_u.$$

The Higgs superfields

$$H_u = \begin{pmatrix} H_u^+ \\ \frac{1}{\sqrt{2}}\Big(v_u + H_u^0 + iP_u^0\Big) \end{pmatrix}, \qquad H_d = \begin{pmatrix} \frac{1}{\sqrt{2}}\Big(v_d + H_d^0 + iP_d^0\Big) \\ H_d^- \end{pmatrix},$$
$$\eta = \frac{1}{\sqrt{2}}\Big(v_\eta + \phi_\eta^0 + iP_\eta^0\Big), \qquad \bar{\eta} = \frac{1}{\sqrt{2}}\Big(v_{\bar{\eta}} + \phi_{\bar{\eta}}^0 + iP_{\bar{\eta}}^0\Big),$$
$$S = \frac{1}{\sqrt{2}}\Big(v_S + \phi_S^0 + iP_S^0\Big).$$

Scalar neutrino superfields

$$\tilde{\nu}_L = \frac{1}{\sqrt{2}}\phi_l + \frac{i}{\sqrt{2}}\sigma_l, \qquad \tilde{\nu}_R = \frac{1}{\sqrt{2}}\phi_R + \frac{i}{\sqrt{2}}\sigma_R.$$

The soft breaking terms are

$$\mathcal{L}_{soft} = \mathcal{L}_{soft}^{MSSM} - B_S S^2 - L_S S - \frac{T_\kappa}{3} S^3 - T_{\lambda_C} S\eta\bar{\eta} + \epsilon_{ij} T_{\lambda_H} S H_d^i H_u^j$$
$$- T_X^{IJ} \bar{\eta} \tilde{\nu}_R^{*I} \tilde{\nu}_R^{*J} + \epsilon_{ij} T_\nu^{IJ} H_u^i \tilde{\nu}_R^{I*} \tilde{l}_j^J - m_\eta^2 |\eta|^2 - m_{\bar{\eta}}^2 |\bar{\eta}|^2$$
$$- m_S^2 S^2 - (m_{\tilde{\nu}_R}^2)^{IJ} \tilde{\nu}_R^{I*} \tilde{\nu}_R^J - \frac{1}{2}\Big(M_X \lambda_{\tilde{X}}^2 + 2 M_{BB'} \lambda_{\tilde{B}} \lambda_{\tilde{X}}\Big) + h.c \quad .$$

The covariant derivatives of this model is shown in the general form

$$D_\mu = \partial_\mu - i\begin{pmatrix} Y, & X \end{pmatrix}\begin{pmatrix} g_Y, & g'_{YX} \\ g'_{XY}, & g'_X \end{pmatrix}\begin{pmatrix} A'^{Y}_\mu \\ A'^{X}_\mu \end{pmatrix},$$

$$\begin{pmatrix} g_Y, & g'_{YX} \\ g'_{XY}, & g'_X \end{pmatrix} R^T = \begin{pmatrix} g_1, & g_{YX} \\ 0, & g_X \end{pmatrix},$$

$$\begin{pmatrix} \gamma \\ Z \\ Z' \end{pmatrix} = \begin{pmatrix} \cos\theta_W & \sin\theta_W & 0 \\ -\sin\theta_W\cos\theta'_W & \cos\theta_W\cos\theta'_W & \sin\theta'_W \\ \sin\theta_W\sin\theta'_W & -\cos\theta'_W\sin\theta'_W & \cos\theta'_W \end{pmatrix}\begin{pmatrix} A^Y \\ V^3 \\ A^X \end{pmatrix}.$$

$$\sin^2\theta'_W = \frac{1}{2} - \frac{(g_{YX}^2 - g_1^2 - g_2^2)v^2 + 4g_X^2\xi^2}{2\sqrt{(g_{YX}^2 + g_1^2 + g_2^2)^2 v^4 + 8g_X^2(g_{YX}^2 - g_1^2 - g_2^2)v^2\xi^2 + 16g_X^4\xi^4}},$$

with $v^2 = v_u^2 + v_d^2$ and $\xi^2 = v_\eta^2 + v_{\bar{\eta}}^2$.

The Higgs potential is deduced here

$$\begin{aligned}
V = &\frac{1}{2}g_X(g_X + g_{YX})(|H_d^0|^2 - |H_u^0|^2)(|\eta|^2 - |\bar{\eta}|^2) + |\lambda_H|^2|H_u^0 H_d^0|^2 + m_S^2|S|^2 \\
&+\frac{1}{8}\Big(g_1^2 + g_2^2 + (g_X + g_{YX})^2\Big)(|H_d^0|^2 - |H_u^0|^2)^2 + \frac{1}{2}g_X^2(|\eta|^2 - |\bar{\eta}|^2)^2 + \lambda_C^2|\eta\bar{\eta}|^2 \\
&+(|\mu|^2 + |\lambda_H|^2|S|^2 + 2\mathrm{Re}[\mu^*\lambda_H S])(|H_d^0|^2 + |H_u^0|^2) + |\lambda_C|^2|S|^2(|\eta|^2 + |\bar{\eta}|^2) \\
&+2\mathrm{Re}[l_W^*(2M_S S + \lambda_C\eta\bar{\eta} - \lambda_H H_u^0 H_d^0 + \kappa S^2)] + 4|M_S|^2|S|^2 + 2\mathrm{Re}[\lambda_C^*\kappa\eta^*\bar{\eta}^* S^2] \\
&+|\kappa|^2|S|^4 + 4\mathrm{Re}[M_S^* S^*(\lambda_C\eta\bar{\eta} - \lambda_H H_u^0 H_d^0 + \kappa S^2)] - 2\mathrm{Re}[\lambda_C^*\lambda_H\eta^*\bar{\eta}^* H_u^0 H_d^0] + |l_W|^2 \\
&-2\mathrm{Re}[B_\mu H_d^0 H_u^0] + 2\mathrm{Re}[L_S S] + \frac{2}{3}\mathrm{Re}[T_k S^3] + 2\mathrm{Re}[T_{\lambda_C}\eta\bar{\eta}S] - 2\mathrm{Re}[T_{\lambda_H} H_d^0 H_u^0 S] \\
&-2\mathrm{Re}[\lambda_H\kappa^* H_u^0 H_d^0 (S^2)^*] + m_\eta^2|\eta|^2 + m_{\bar{\eta}}^2|\bar{\eta}|^2 + m_{H_u^0}^2|H_u^0|^2 + m_{H_d^0}^2|H_d^0|^2 + 2\mathrm{Re}[B_S S^2]. \quad (12)
\end{aligned}$$

The neutrino mass matrix is deduced in the base $(\nu_L, \bar{\nu}_R)$

$$M_\nu = \begin{pmatrix} 0 & \frac{v_u}{\sqrt{2}}(Y_\nu^T)^{IJ} \\ \frac{v_u}{\sqrt{2}}(Y_\nu)^{IJ} & \sqrt{2}v_{\bar{\eta}}(Y_X)^{IJ} \end{pmatrix},$$

The mass matrix for CP-even sneutrino (ϕ_l, ϕ_r) reads as

$$M^2_{\tilde{\nu}R} = \begin{pmatrix} m_{\phi_l\phi_l} & m^T_{\phi_r\phi_l} \\ m_{\phi_l\phi_r} & m_{\phi_r\phi_r} \end{pmatrix},$$

$$m_{\phi_l\phi_l} = \frac{1}{8}\Big((g_1^2 + g_{YX}^2 + g_2^2 + g_{YX}g_X)(v_d^2 - v_u^2) + g_{YX}g_X(2v_\eta^2 - 2v_{\bar{\eta}}^2)\Big)$$
$$+\frac{1}{2}v_u^2 Y_\nu^T Y_\nu + m_{\tilde{L}}^2,$$
$$m_{\phi_l\phi_r} = \frac{1}{\sqrt{2}}v_u T_\nu + v_u v_{\bar{\eta}} Y_X Y_\nu - \frac{1}{2}v_d(\lambda_H v_S + \sqrt{2}\mu)Y_\nu,$$
$$m_{\phi_r\phi_r} = \frac{1}{8}\Big((g_{YX}g_X + g_X^2)(v_d^2 - v_u^2) + 2g_X^2(v_\eta^2 - v_{\bar{\eta}}^2)\Big) + v_\eta v_S Y_X \lambda_C$$
$$+m_{\tilde{\nu}}^2 + \frac{1}{2}v_u^2|Y_\nu|^2 + v_{\bar{\eta}}(2v_{\bar{\eta}}Y_X Y_X + \sqrt{2}T_X).$$

The CP even Higgs $\phi_d, \phi_u, \phi_\eta, \phi_{\bar{\eta}}$ and ϕ_S mix together

in the basis: $(\phi_d, \phi_u, \phi_\eta, \phi_{\bar{\eta}}, \phi_s)$

$$m_h^2 = \begin{pmatrix} m_{\phi_d\phi_d} & m_{\phi_u\phi_d} & m_{\phi_\eta\phi_d} & m_{\phi_{\bar{\eta}}\phi_d} & m_{\phi_s\phi_d} \\ m_{\phi_d\phi_u} & m_{\phi_u\phi_u} & m_{\phi_\eta\phi_u} & m_{\phi_{\bar{\eta}}\phi_u} & m_{\phi_s\phi_u} \\ m_{\phi_d\phi_\eta} & m_{\phi_u\phi_\eta} & m_{\phi_\eta\phi_\eta} & m_{\phi_{\bar{\eta}}\phi_\eta} & m_{\phi_s\phi_\eta} \\ m_{\phi_d\phi_{\bar{\eta}}} & m_{\phi_u\phi_{\bar{\eta}}} & m_{\phi_\eta\phi_{\bar{\eta}}} & m_{\phi_{\bar{\eta}}\phi_{\bar{\eta}}} & m_{\phi_s\phi_{\bar{\eta}}} \\ m_{\phi_d\phi_s} & m_{\phi_u\phi_s} & m_{\phi_\eta\phi_s} & m_{\phi_{\bar{\eta}}\phi_s} & m_{\phi_s\phi_s} \end{pmatrix},$$

矩阵元的具体表达式不列出了，比较占地方

The mass matrix for neutralinos in the basis: $(\lambda_{\tilde{B}}, \tilde{W}^0, \tilde{H}_d^0, \tilde{H}_u^0, \lambda_{\tilde{X}}, \tilde{\eta}, \tilde{\bar{\eta}}, \tilde{s})$

$$m_{\tilde{\chi}^0} = \begin{pmatrix} M_1 & 0 & -\frac{g_1}{2}v_d & \frac{g_1}{2}v_u & M_{BB'} & 0 & 0 & 0 \\ 0 & M_2 & \frac{1}{2}g_2 v_d & -\frac{1}{2}g_2 v_u & 0 & 0 & 0 & 0 \\ -\frac{g_1}{2}v_d & \frac{1}{2}g_2 v_d & 0 & m_{\tilde{H}_u^0\tilde{H}_d^0} & m_{\lambda_{\tilde{X}}\tilde{H}_d^0} & 0 & 0 & -\frac{\lambda_H v_u}{\sqrt{2}} \\ \frac{g_1}{2}v_u & -\frac{1}{2}g_2 v_u & m_{\tilde{H}_d^0\tilde{H}_u^0} & 0 & m_{\lambda_{\tilde{X}}\tilde{H}_u^0} & 0 & 0 & -\frac{\lambda_H v_d}{\sqrt{2}} \\ M_{BB'} & 0 & m_{\tilde{H}_d^0\lambda_{\tilde{X}}} & m_{\tilde{H}_u^0\lambda_{\tilde{X}}} & M_{BL} & -g_X v_\eta & g_X v_{\bar{\eta}} & 0 \\ 0 & 0 & 0 & 0 & -g_X v_\eta & 0 & \frac{1}{\sqrt{2}}\lambda_C v_S & \frac{1}{\sqrt{2}}\lambda_C v_{\bar{\eta}} \\ 0 & 0 & 0 & 0 & g_X v_{\bar{\eta}} & \frac{1}{\sqrt{2}}\lambda_C v_S & 0 & \frac{1}{\sqrt{2}}\lambda_C v_\eta \\ 0 & 0 & -\frac{\lambda_H v_u}{\sqrt{2}} & -\frac{\lambda_H v_d}{\sqrt{2}} & 0 & \frac{1}{\sqrt{2}}\lambda_C v_{\bar{\eta}} & \frac{1}{\sqrt{2}}\lambda_C v_\eta & m_{\tilde{s}\tilde{s}} \end{pmatrix},$$

$$m_{\tilde{H}_d^0\tilde{H}_u^0} = -\frac{1}{\sqrt{2}}\lambda_H v_S - \mu, \qquad m_{\tilde{H}_d^0\lambda_{\tilde{X}}} = -\frac{1}{2}\Big(g_{YX} + g_X\Big)v_d,$$

$$m_{\tilde{H}_u^0\lambda_{\tilde{X}}} = \frac{1}{2}\Big(g_{YX} + g_X\Big)v_u, \qquad m_{\tilde{s}\tilde{s}} = 2M_S + \sqrt{2}\kappa v_S.$$

CP-even Higgs couples with CP-even sneutrinos

$$\mathcal{L}_{H\tilde{\nu}^R\tilde{\nu}^R} = H_i\tilde{\nu}_j^R\frac{i}{4}\Big\{\sum_{a,b=1}^{3}\Big[-2\sqrt{2}Z_{kb}^{R*}Z_{j3+a}^{R*}(T_\nu)_{ab}Z_{i2}^H - 2\lambda_C v_S Z_{k3+b}^{R*}Z_{j3+a}^{R*}(Y_X^*)_{ab}Z_{i3}^H$$

$$-2\sqrt{2}Z_{k3+b}^{R*}Z_{j3+a}^{R*}(T_X)_{ab}Z_{i4}^H - 2\lambda_C v_\eta Z_{k3+b}^{R*}Z_{j3+a}^{R*}(Y_X)_{ab}Z_{i5}^H\Big] + \Big[j \leftrightarrow k\Big]$$

$$-16v_{\bar{\eta}}\sum_{a,b,c=1}^{3} Z_{k3+c}^{R*}Z_{j3+b}^{R*}(Y_X)_{ac}(Y_X)_{ab}Z_{i4}^H + \sum_{a=1}^{3} Z_{ka}^{R*}Z_{ja}^{R*}\Big[(g_{YX}g_X + g_1^2$$

$$+g_{YX}^2 + g_2^2)(-v_d Z_{i1}^H + v_u Z_{i2}^H) - 2g_{YX}g_X(-v_{\bar{\eta}}Z_{i4}^H + v_\eta Z_{i3}^H)\Big]$$

$$+\sum_{a=1}^{3} Z_{k3+a}^{R*}Z_{j3+a}^{R*}\Big[(g_{YX}g_X + g_X^2)(v_u Z_{i2}^H - v_d Z_{i1}^H) - 2g_X^2(v_\eta Z_{i3}^H - v_{\bar{\eta}}Z_{i4}^H)\Big]\Big\}\tilde{\nu}_k^{*R}.$$

We also deduce the vertexes of $\tilde{\nu}_k^R - \bar{e}_i - \chi_j^-$ and $\tilde{\nu}_k^R - \nu_i - \bar{\chi}_i^0$.

$$\mathcal{L}_{A\tilde{\nu}^I\tilde{\nu}^R} = A_i\tilde{\nu}_j^I\frac{i}{4}\sum_{a,b=1}^{3}\Big\{\Big[2v_S\lambda_C Z_{k3+b}^{R*}Z_{j3+a}^{I*}(Y_X)_{ab}Z_{i3}^A - 2\sqrt{2}Z_{kb}^{R*}Z_{j3+a}^{I*}(T_\nu)_{ab}Z_{i2}^A$$

$$-2\sqrt{2}Z_{k3+b}^{R*}Z_{j3+a}^{I*}(T_X)_{ab}Z_{i4}^A + 2v_\eta\lambda_C Z_{k3+b}^{R*}Z_{j3+a}^{I*}(Y_X)_{ab}Z_{i5}^A\Big] + \Big[R \leftrightarrow I, j \leftrightarrow k\Big]\Big\}\tilde{\nu}_k^{*R}.$$

Relic density and cross section

$n_{\tilde{\nu}_1^R}$ is governed by the Boltzmann equation

$$\frac{dn_{\tilde{\nu}_1^R}}{dt} = -3Hn_{\tilde{\nu}_1^R} - \langle\sigma v\rangle_{SA}(n^2_{\tilde{\nu}_1^R} - n^2_{\tilde{\nu}_1^R eq}) - \langle\sigma v\rangle_{CA}(n_{\tilde{\nu}_1^R}n_\phi - n_{\tilde{\nu}_1^R eq}n_{\phi eq}).$$

$\tilde{\nu}_1^R$ can both self-annihilate and co-annihilate with another species ϕ.

The species freeze out at the temperature T_F.

$$\langle\sigma v\rangle_{SA}n_{\tilde{\nu}_1^R} + \langle\sigma v\rangle_{CA}n_\phi \sim H(T_F).$$

With the supposition $M_\phi > M_{\tilde{\nu}_1^R}$

$$n_\phi = \Big(\frac{M_\phi}{M_{\tilde{\nu}_1^R}}\Big)^{3/2}\mathrm{Exp}[(M_{\tilde{\nu}_1^R} - M_\phi)/T]n_{\tilde{\nu}_1^R}.$$

Then it becomes

$$\Big[\langle\sigma v\rangle_{SA}+\langle\sigma v\rangle_{CA}\Big(\frac{M_\phi}{M_{\tilde{\nu}^R}}\Big)^{3/2}\mathtt{Exp}[(M_{\tilde{\nu}_1^R}-M_\phi)/T]\Big]n_{\tilde{\nu}_1^R}\sim H(T_F).$$

The freeze-out temperature(T_F)

$$x_F=\frac{m_D}{T_F}\simeq \ln[\frac{0.038 M_{Pl} m_D(a+6b/x_F)}{\sqrt{g_* x_F}}].$$

$$\Omega_D h^2\simeq\frac{1.07\times10^9 x_F}{\sqrt{g_*}M_{PL}(a+3b/x_F)\mathtt{GeV}}\ .$$

its value should be $\Omega_D h^2=0.1186\pm0.0020$

Particle Data Group collaboration, Phys. Rev. D **98**, 030001 (2018).

从夸克算符转换成核子算符

The operators $\tilde{\nu}^{R*}\tilde{\nu}^{R}\bar{q}q$ and $\tilde{\nu}^{R*}\partial_{\mu}\tilde{\nu}^{R}\bar{q}\gamma^{\mu}q$ at the quark level

$$a_q m_q \bar{q}q \to f_N m_N \bar{N}N, \qquad f_N = \sum_{q=u,d,s} f_{Tq}^{(N)} a_q + \frac{2}{27} f_{TG}^{(N)} \sum_{q=c,b,t} a_q,$$

$$\langle N|m_q\bar{q}q|N\rangle = m_N f_{Tq}^{(N)}, \qquad f_{TG}^{(N)} = 1 - \sum_{q=u,d,s} f_{Tq}^{(N)}.$$

convert the operator $b_q\tilde{\nu}^{R*}\partial_{\mu}\tilde{\nu}^{R}\bar{q}\gamma^{\mu}q$ to $b_N\tilde{\nu}^{R*}\partial_{\mu}\tilde{\nu}^{R}\bar{N}\gamma^{\mu}N$

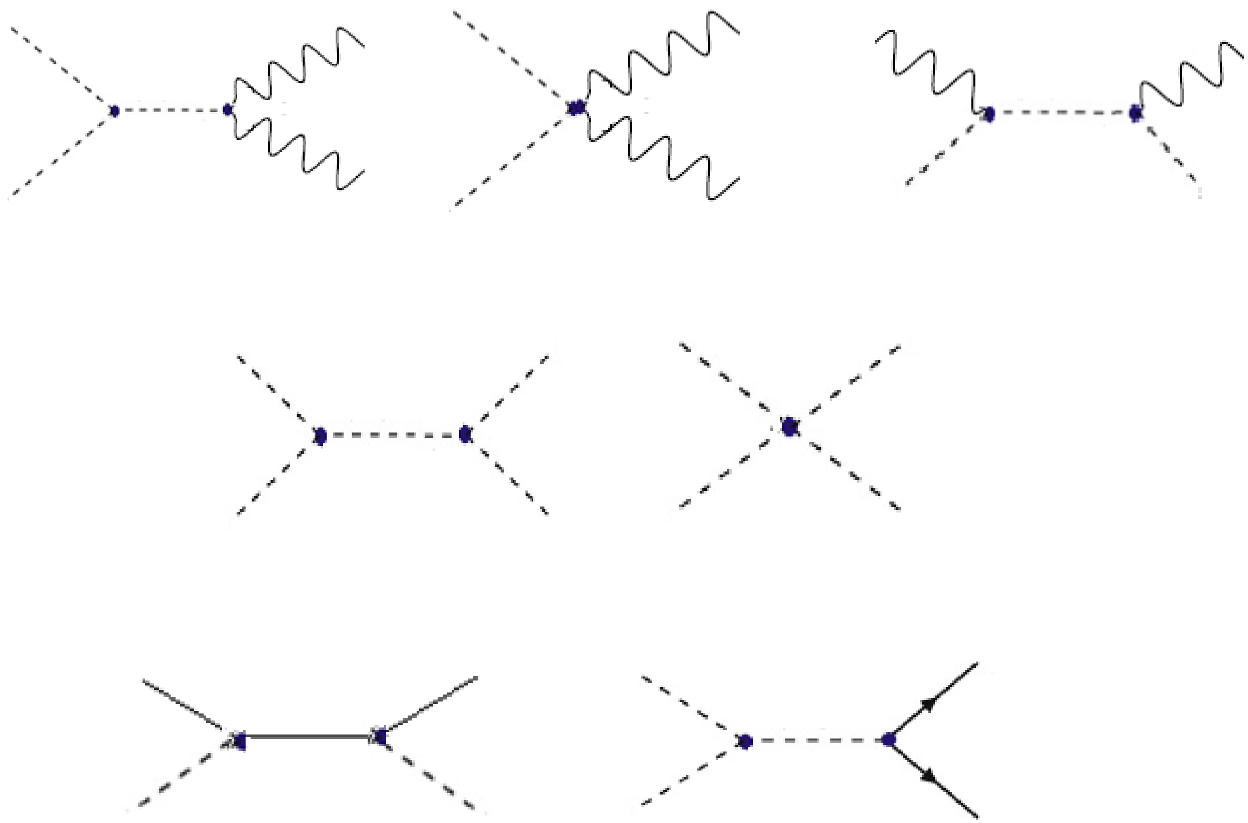
$$b_p = 2b_u + b_d, \quad b_n = 2b_d + b_u.$$

With the obtained f_N, one gets the nucleon cross section

$$\sigma = \frac{1}{\pi}\mu^2[Zf_p + (A-Z)f_n]^2.$$

self-annihilation

$$\tilde{\nu}_1^R + \tilde{\nu}_1^R \rightarrow \{(W+W),\ (Z+Z),\ (h^0 + h^0),$$
$$(\bar{u}_i + u_i),\ (\bar{d}_i + d_i),\ (\bar{l}_i + l_i),\ \ (\bar{\nu}_i + \nu_i)\}$$



co-annihilation

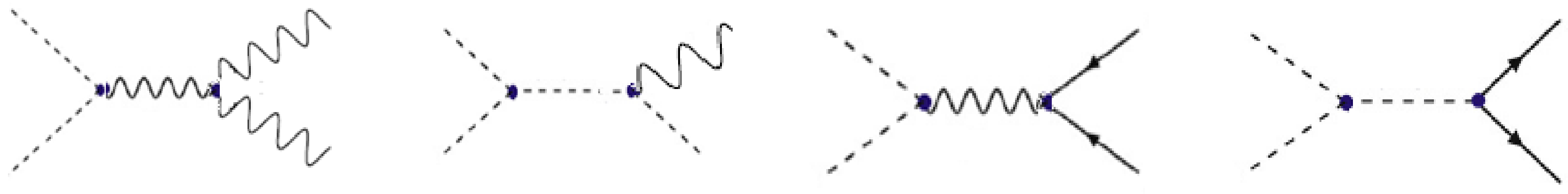
a. $\tilde{\nu}_1^R + \tilde{\nu}_k^R \to \{(W+W),\ (Z+Z),\ (h+h),\ (\bar{u}_i+u_i),\ (\bar{d}_i+d_i),$

$(\bar{l}_i+l_i),\ (\bar{\nu}_i+\nu_i)\}$ with $k=2\ldots6,\ i=1,\ 2,\ 3.$

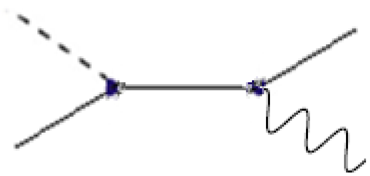
Similar as self-annihilation

b. $\tilde{\nu}_1^R + \tilde{\nu}_j^I \to \{(W+W),\ (Z+h),\ (\bar{u}_i+u_i),\ (\bar{d}_i+d_i),$

$(\bar{l}_i+l_i),\ (\bar{\nu}_i+\nu_i)\}$ and $j=1\ldots6,\ i=1\ldots3.$

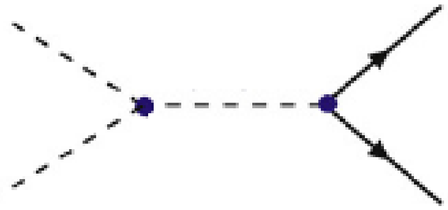


c. $\tilde{\nu}_1^R + \chi_n^0 \to \{(Z + \nu_i),\ (W^+ + l_i^-),\ (W^- + l_i^+)\}$
$n = 1 \dots 8,\ i = 1 \dots 3.$



scattering off nucleon

The main scattering processes of CP-even sneutrinos off nucleons are $\tilde{\nu}^R + q \to \tilde{\nu}^R + q$ and $\tilde{\nu}^R + q \to \tilde{\nu}^I + q$.



Numerical results

The used parameters

$$M_S = 0.8 \text{ TeV},\ T_\kappa = 1.6 \text{ TeV},\ M_1 = M_2 = M_{BL} = 1 \text{ TeV},\ \tan\beta = 11,\ g_{YX} = 0.2,$$

$$\upsilon_\eta = 15.5 \times \cos\beta_\eta \text{ TeV},\ \upsilon_{\bar\eta} = 15.5 \times \sin\beta_\eta \text{ TeV},\ Y_{X11} = Y_{X22} = 0.5,\ Y_{X33} = 0.4,$$

$$g_X = \kappa = \lambda_H = 0.3,\ \lambda_C = -0.3,\ M_Q^2 = 2.5 \text{ TeV}^2,\ M_{BB'} = 0.4 \text{ TeV},\ T_{\lambda_H} = 1.8 \text{ TeV},$$

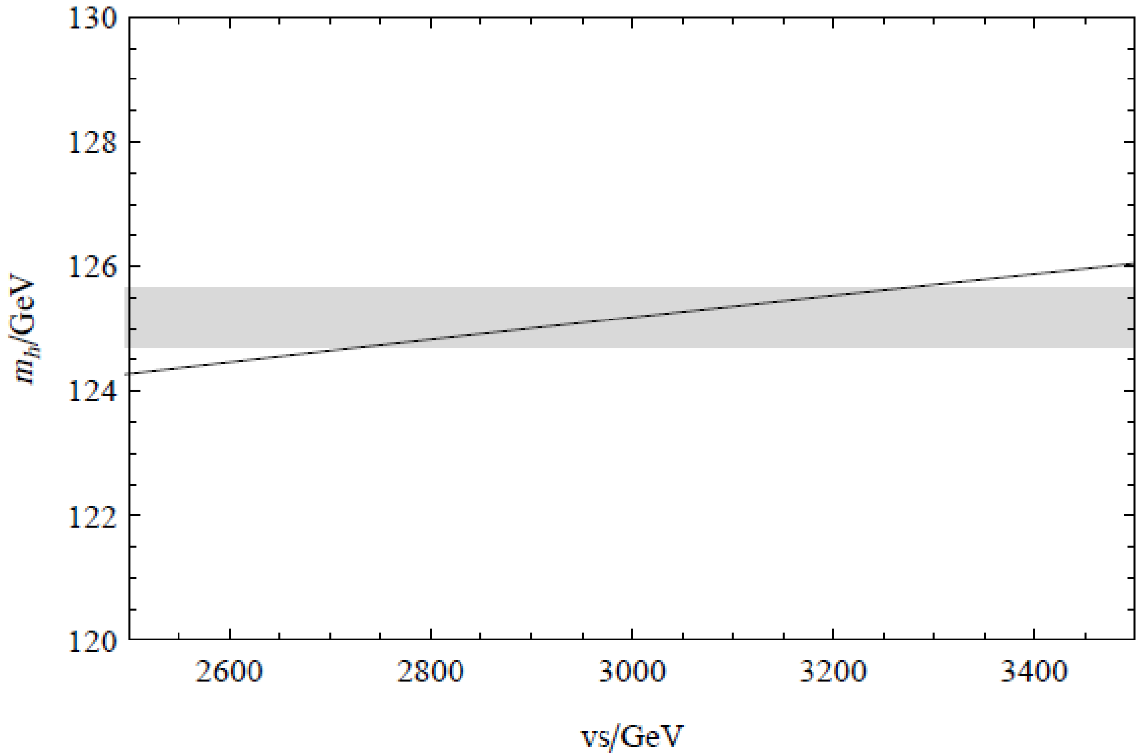
$$T_{X11} = T_{X22} = -1 \text{ TeV},\ T_{X33} = -2 \text{ TeV},\ T_{e11} = T_{e22} = -3 \text{ TeV},\ T_{e33} = -4 \text{ TeV},$$

$$T_{\lambda_C} = 0.25 \text{ TeV},\ B_\mu = B_S = M_T^2 = 1 \text{ TeV}^2,\ \tan\beta_\eta = 0.83,\ T_{\nu11} = T_{\nu22} = 0 \text{ TeV},$$

$$l_W = 4 \text{ TeV}^2,\ M_{\nu11}^2 = M_{\nu22}^2 = 0.5 \text{ TeV}^2,\ M_{L11}^2 = M_{L22}^2 = M_{E11}^2 = M_{E22}^2 = 3 \text{ TeV}^2.$$

$$f_{Tu}^{(p)} = 0.0153, \quad f_{Td}^{(p)} = 0.0191, \quad f_{Ts}^{(p)} = 0.0447,$$

$$f_{Tu}^{(n)} = 0.0110, \quad f_{Td}^{(n)} = 0.0273, \quad f_{Ts}^{(n)} = 0.0447.$$

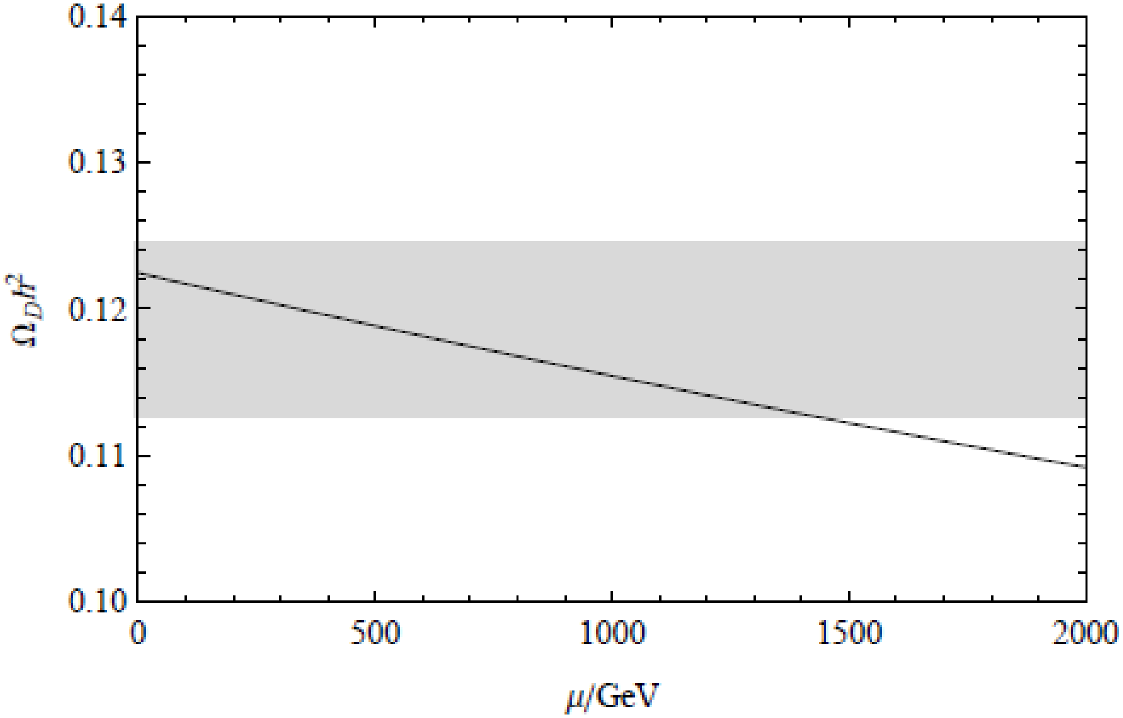


$\mu = 0.5$ TeV, $m_S^2 = 1$ TeV^2 and $A_t = 2.6$ TeV.

The loop corrections include stop contributions, that are taken into account.

the lightest CP-even Higgs mass in three σ: 125.18 ± 0.48 GeV.

The mass of snertino dark matter is around 320 GeV



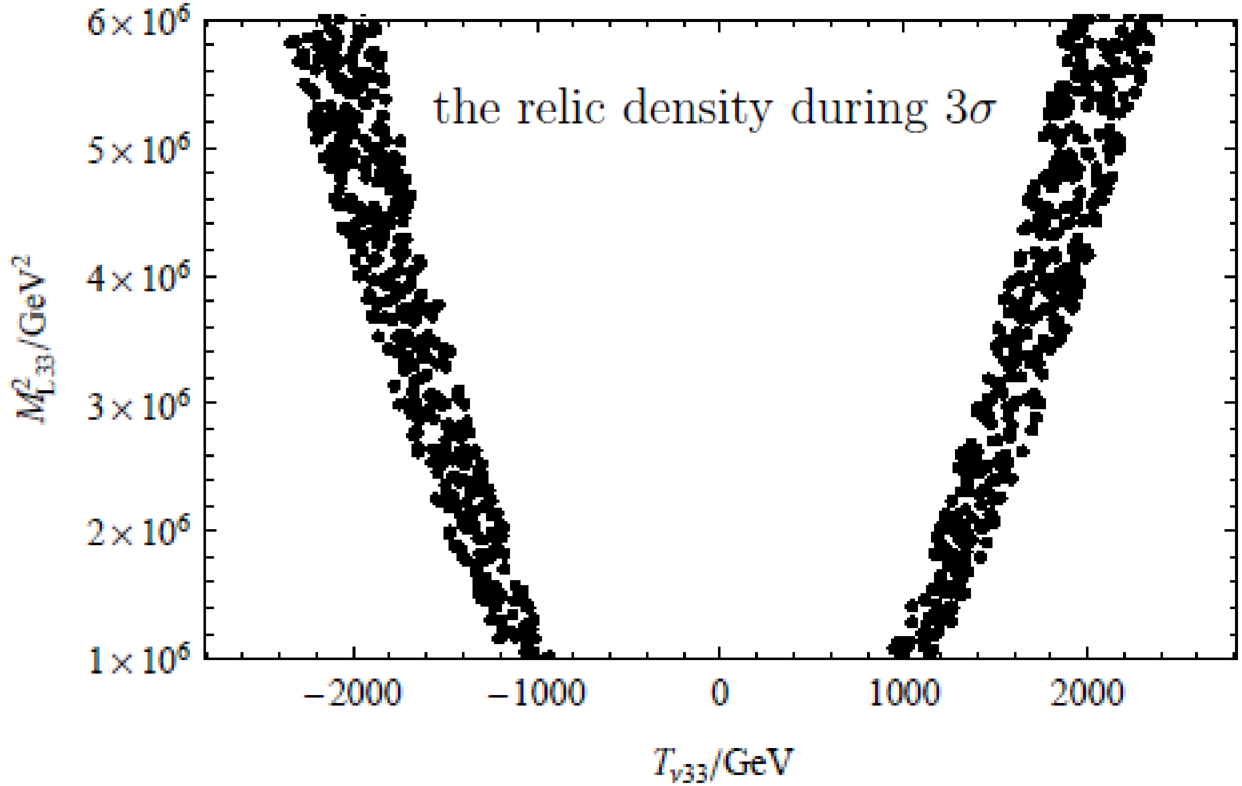
With the same parameters, the lightest neutralino in the MSSM is around 500 GeV as $\mu = 500$ GeV.

The neutralino mass matrix in the $U(1)_X$SSM is 8×8,

$m_{\tilde{H}_d^0 \tilde{H}_u^0} = -\frac{1}{\sqrt{2}}\lambda_H v_S - \mu$ corresponds to $-\mu$ in the MSSM neutralino mass matrix.

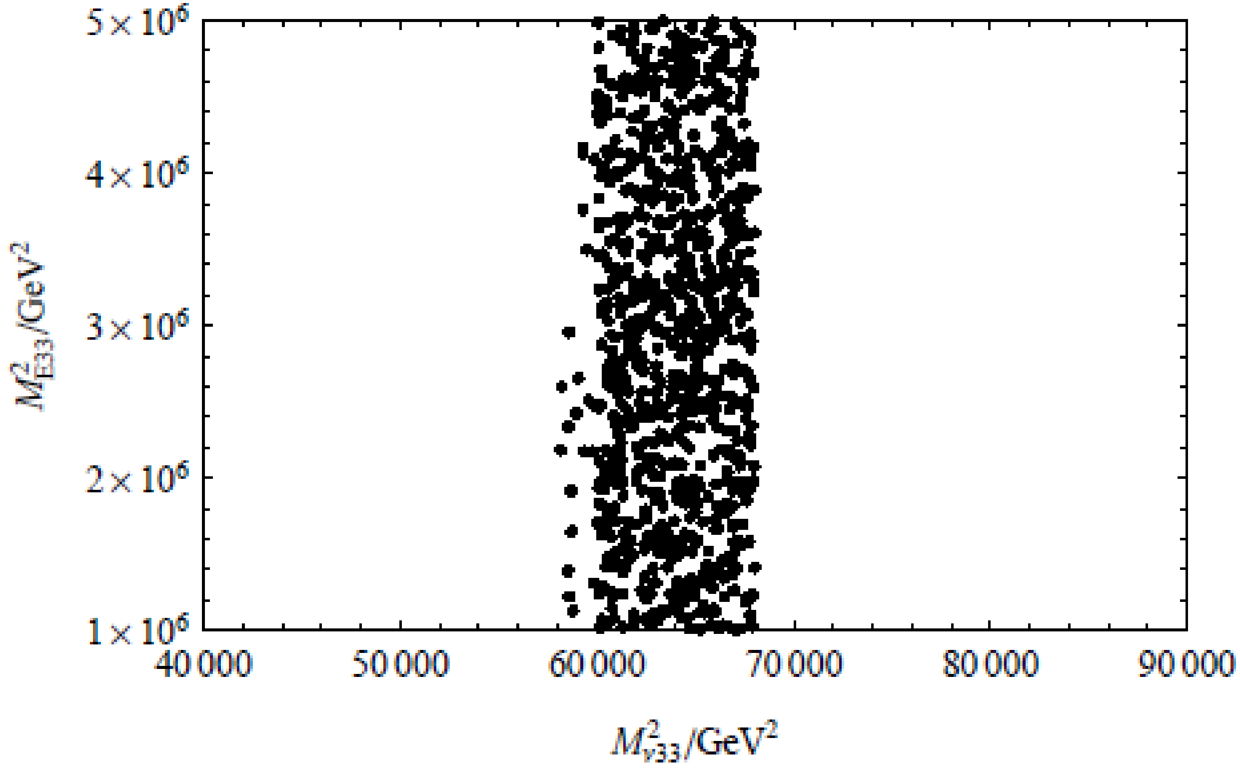
with $v_S = 3000$ GeV and $\lambda_H = 0.3$, $m_{\tilde{H}_d^0 \tilde{H}_u^0} = -\frac{1000}{\sqrt{2}} - \mu \sim -707 - \mu$.

In one σ of $\Omega_D h^2$, the lightest neutralino is around 850 GeV.



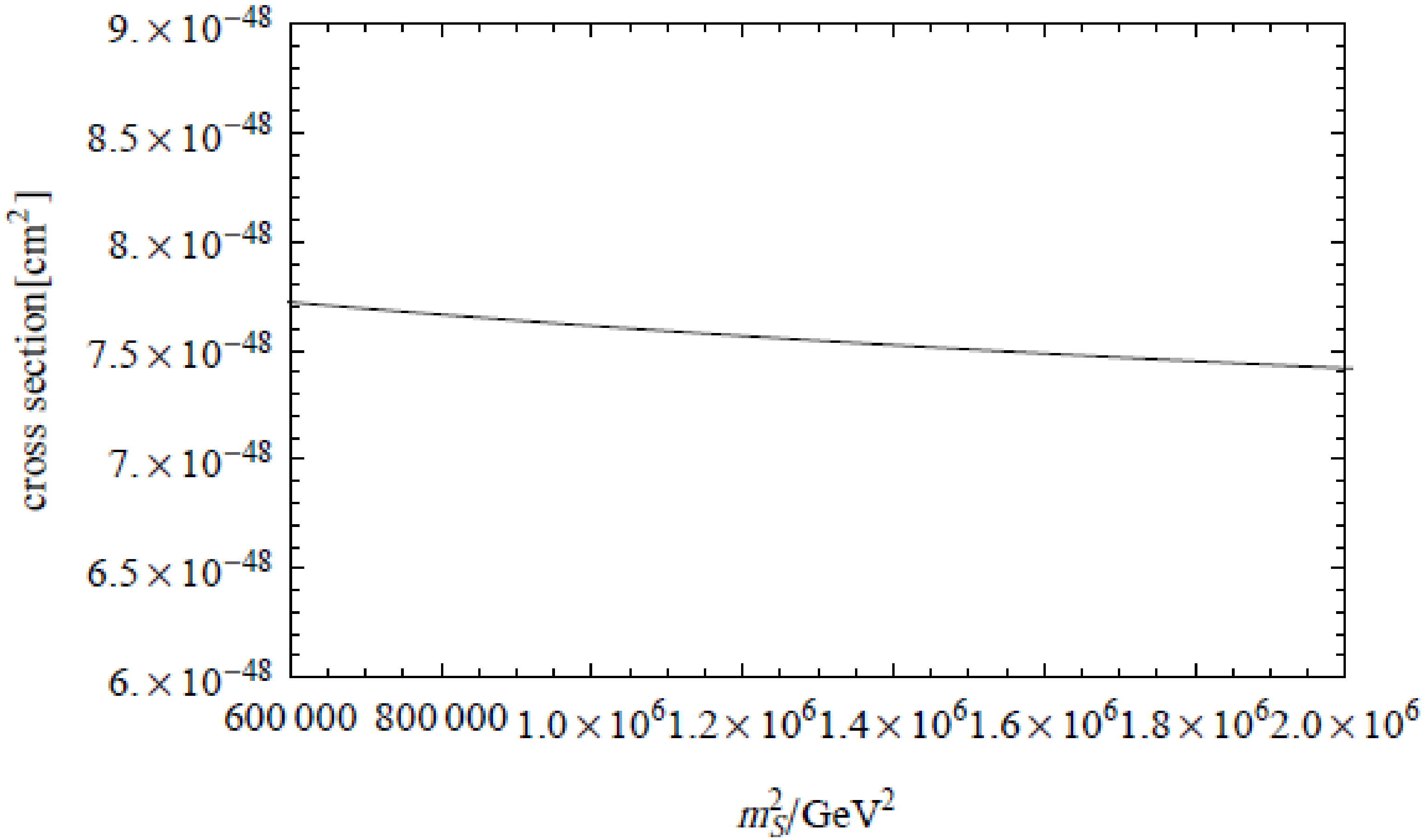
The allowed results of the relic density in the plane of M^2_{L33} and $T_{\nu 33}$

$$\mu = 500 \text{ GeV},\ m^2_{\nu 33} = 250^2 \text{ GeV}^2,\ M^2_{E33} = 3 \text{ TeV}^2.$$

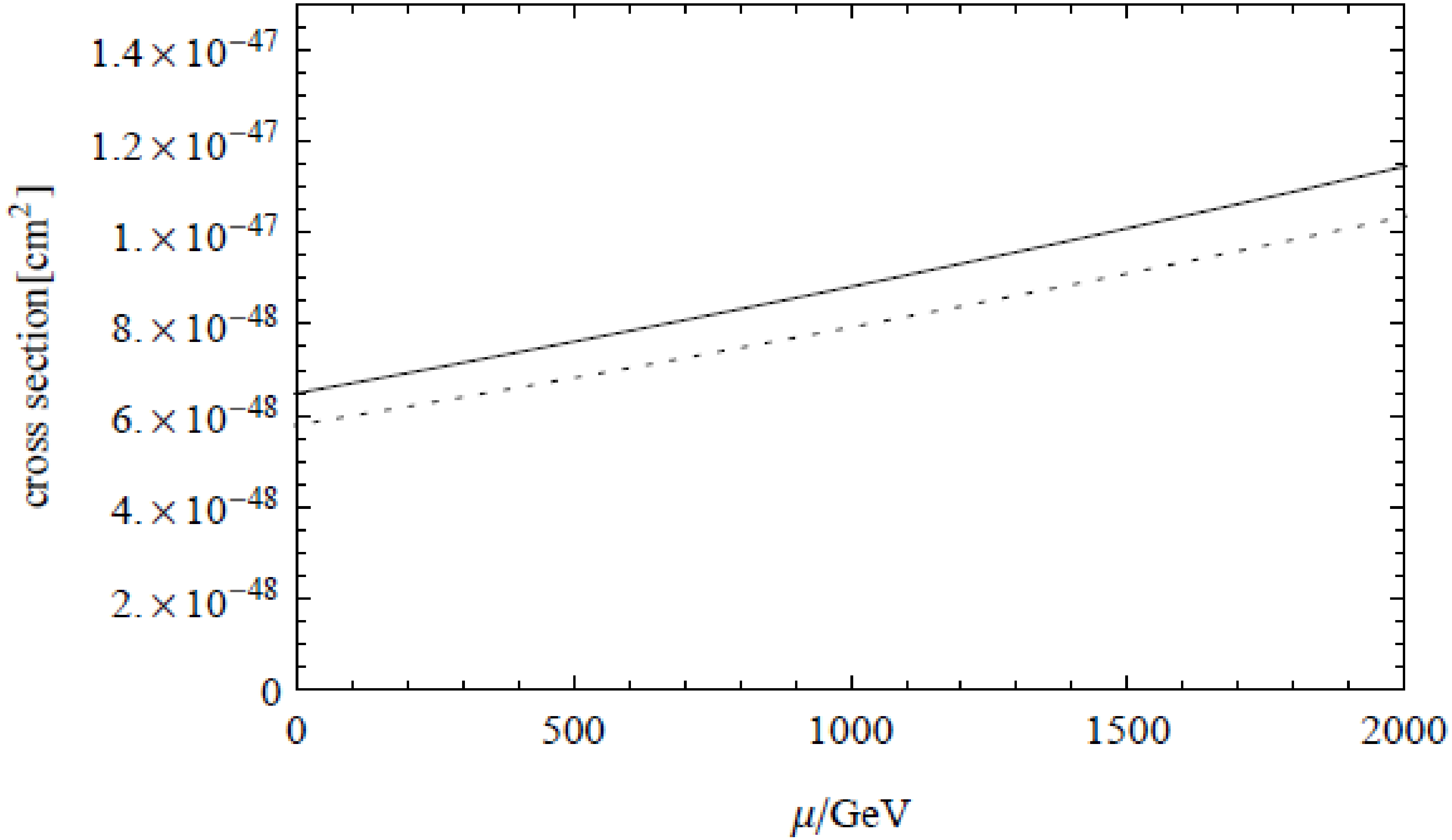


The allowed results of the relic density in the plane of M^2_{E33} and $M^2_{\nu 33}$

$\mu = 500$ GeV, $T_{\nu 33} = 1.6$ TeV and $M^2_{L33} = 3$ TeV^2.



The cross section versus m_S^2.



The cross section versus μ.

Summary

1、由于三个Higgs单态的引入，CP-even Higss的质量混合矩阵是5*5的，树图阶的最轻Higgs 质量可以比MSSM的结果大，大的圈图修正已经不是必要的了。

2、以最轻的标量中微子充当暗物质，寻找到的参数空间，既可以拟合暗物质的丰度，又可以满足直接探测与核子散射带来的关于截面的实验限制

3、数值结果发现，μ， vs以及直接影响标量中微子质量的参数，对结果影响比较明显。

4、所取得参数满足CP-even的Higgs粒子（暗物质湮灭中的S道）是主要贡献，且粒子质量不会出现共振效应。

5、U(1)xSSM较好的解决了MSSM存在的不足。

谢谢