Sequestered SUSY breaking and non-thermal dark matter

Luis Aparicio

ICTP

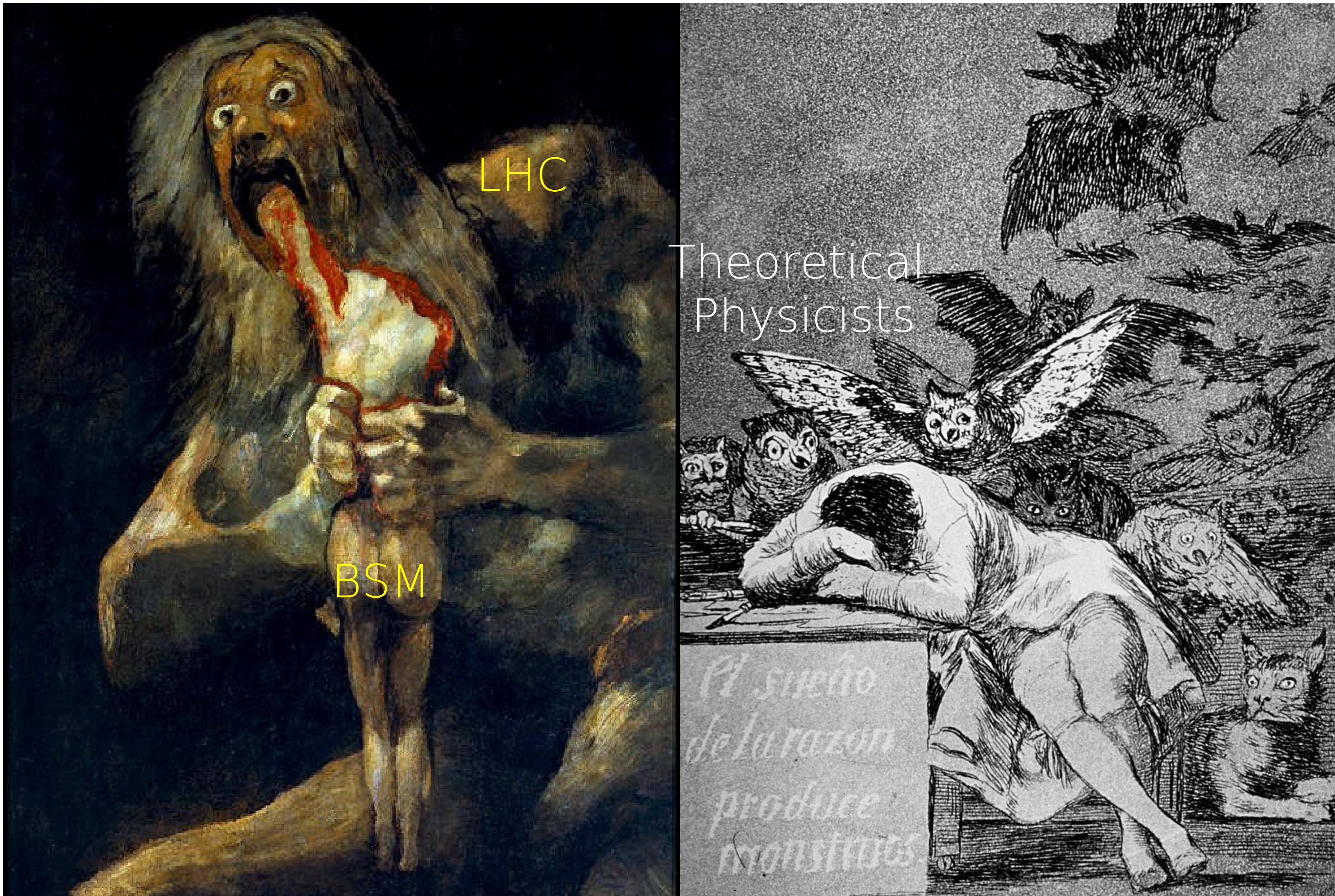
F.Quevedo, M.Cicoli, A. Maharana, S. Krippendorf , F. Muia, B.Dutta

Outline

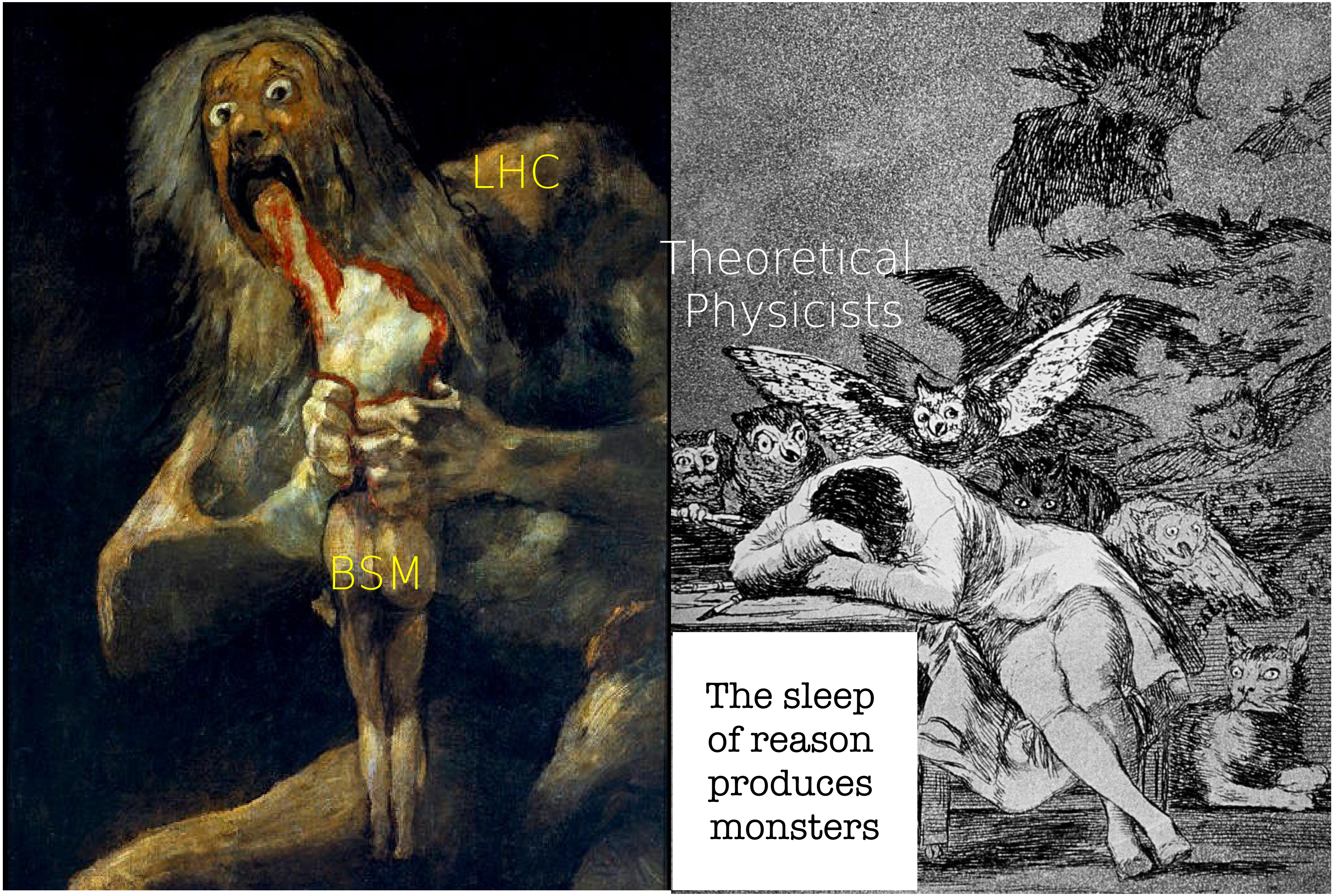
- Motivation
- SUSY breaking in LARGE Volume
- Sequestered de Sitter String Scenarios
- Non thermal dark matter in this scenarios
- Conclusions

Before the LHC...

Goya's prediction



Goya's prediction



An old question: hierarchy/naturality

Strong sector

Gravity sector

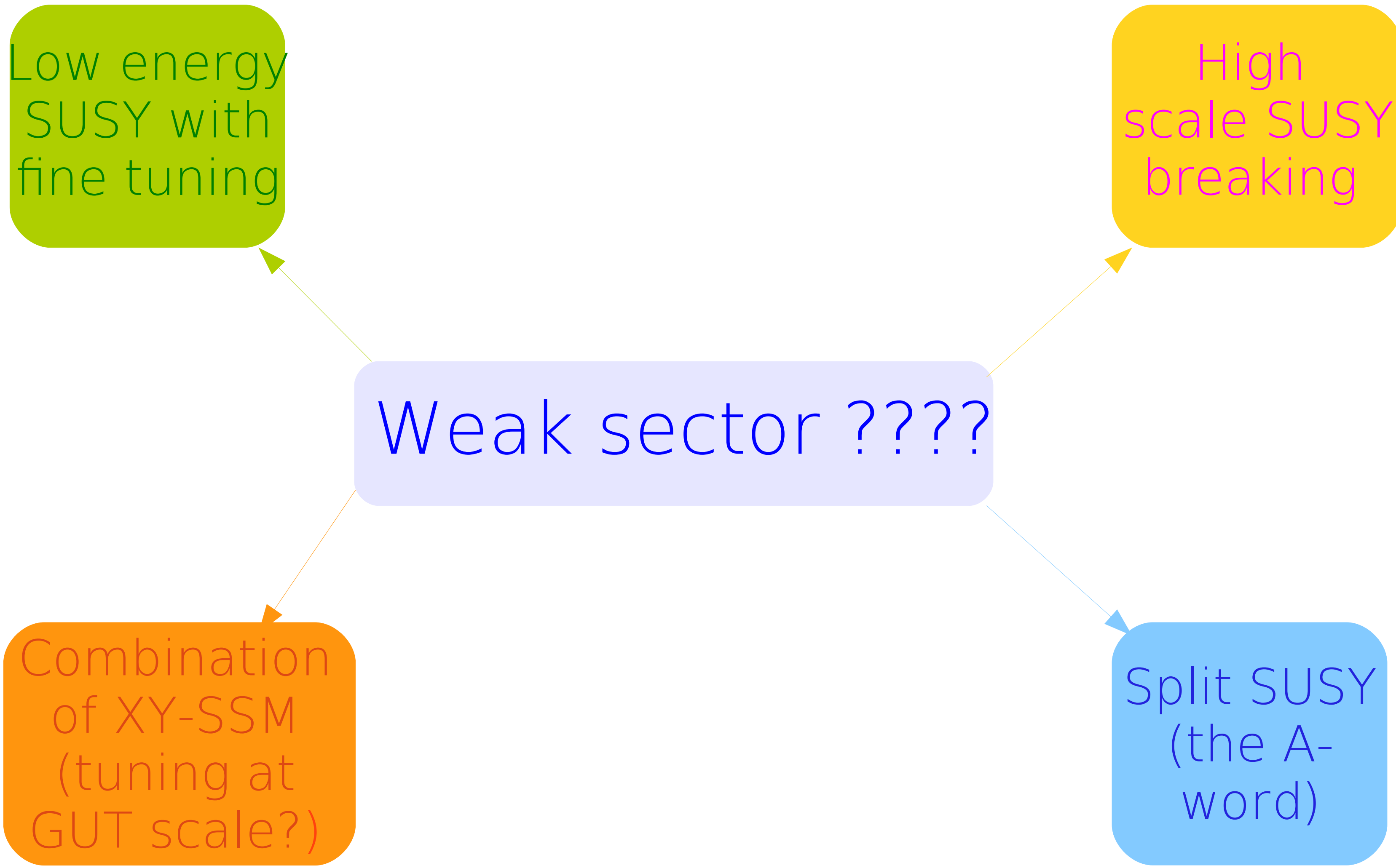
An old question: hierarchy/naturality

Weak sector ????

Strong sector

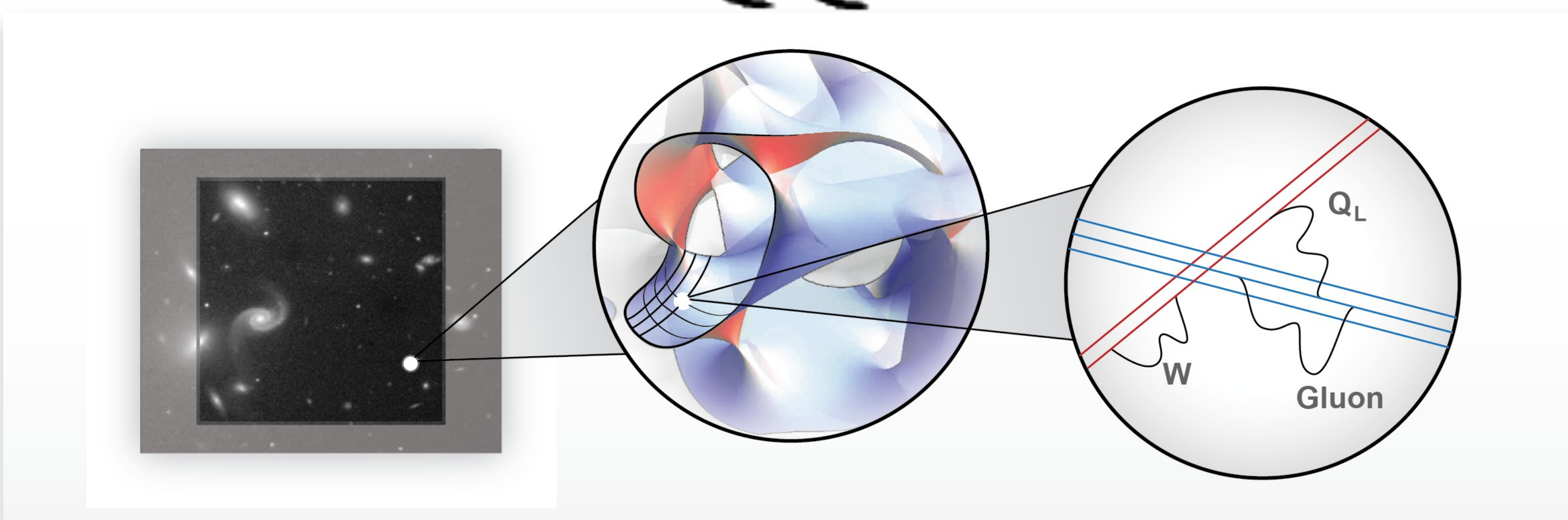
Gravity sector

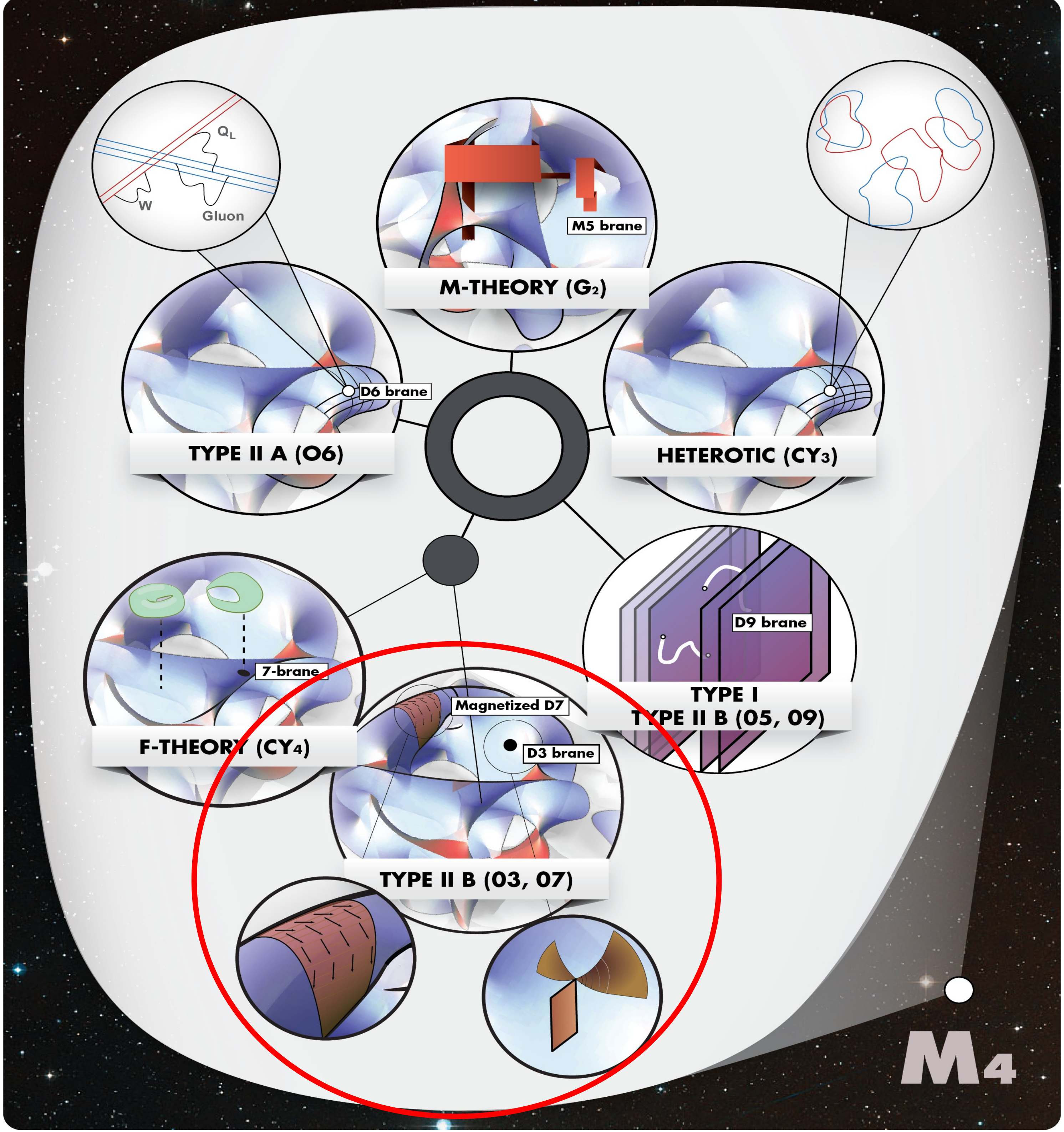
And the Higgs goes to...



Good opportunity for String Theory

STANDARD MODEL
or BSM





Q_L
W
Gluon
M5 brane
M-THEORY (G₂)
D6 brane
TYPE II A (O6)
HETEROTIC (CY₃)
D9 brane
TYPE I
TYPE II B (O5, O9)
7-brane
F-THEORY (CY₄)
Magnetized D7
D3 brane
TYPE II B (O3, O7)
M4

SUSY breaking in LARGE Volume

Fluxes

$$D_S W \equiv \partial_S W + (\partial_S \mathcal{K}) W = 0$$

$$D_a W \equiv \partial_a W + (\partial_a \mathcal{K}) W = 0$$

→ Fixes Dilaton & CS @ SUSY minimum

$W_0 = \langle \int G_3 \wedge \Omega \rangle$ ⇒ $D_T W = (\partial_T \mathcal{K}) W \propto \int G_3 \wedge \Omega$ ⇒ ~~SUSY~~

LARGE Volume

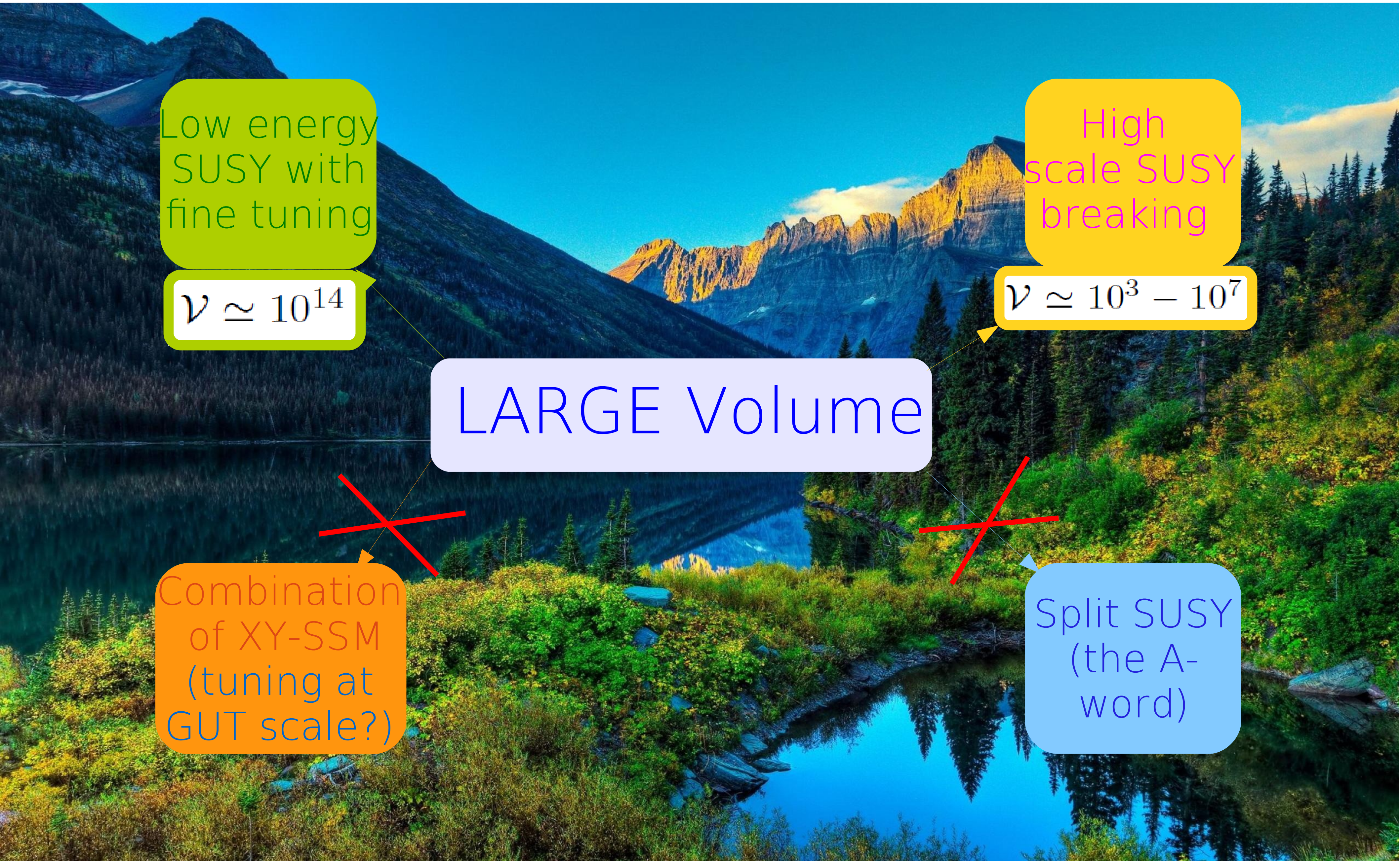
Quantum corrections & Non.Pert. effects ⇒ $\mathcal{V} \sim e^{1/g_s}$ ⇒

$$M_s = \frac{g_s^{1/4} M_P}{\sqrt{4\pi \mathcal{V}}}$$

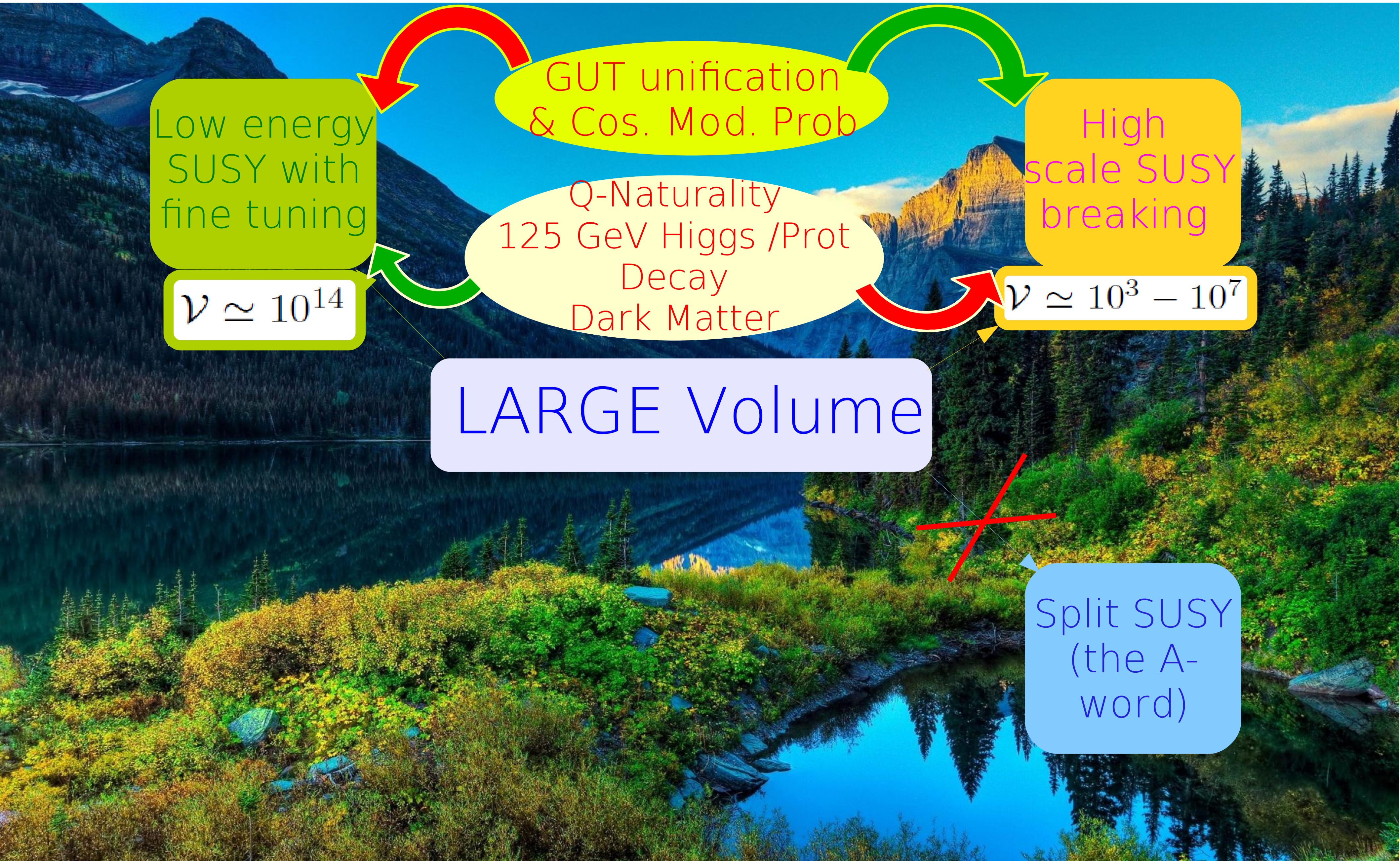
$$M_{KK} \simeq \frac{M_P}{\sqrt{4\pi} \mathcal{V}^{2/3}}$$

$$m_{3/2} = \left(\frac{g_s^2}{2\sqrt{2\pi}} \right) \frac{W_0 M_P}{\mathcal{V}}$$

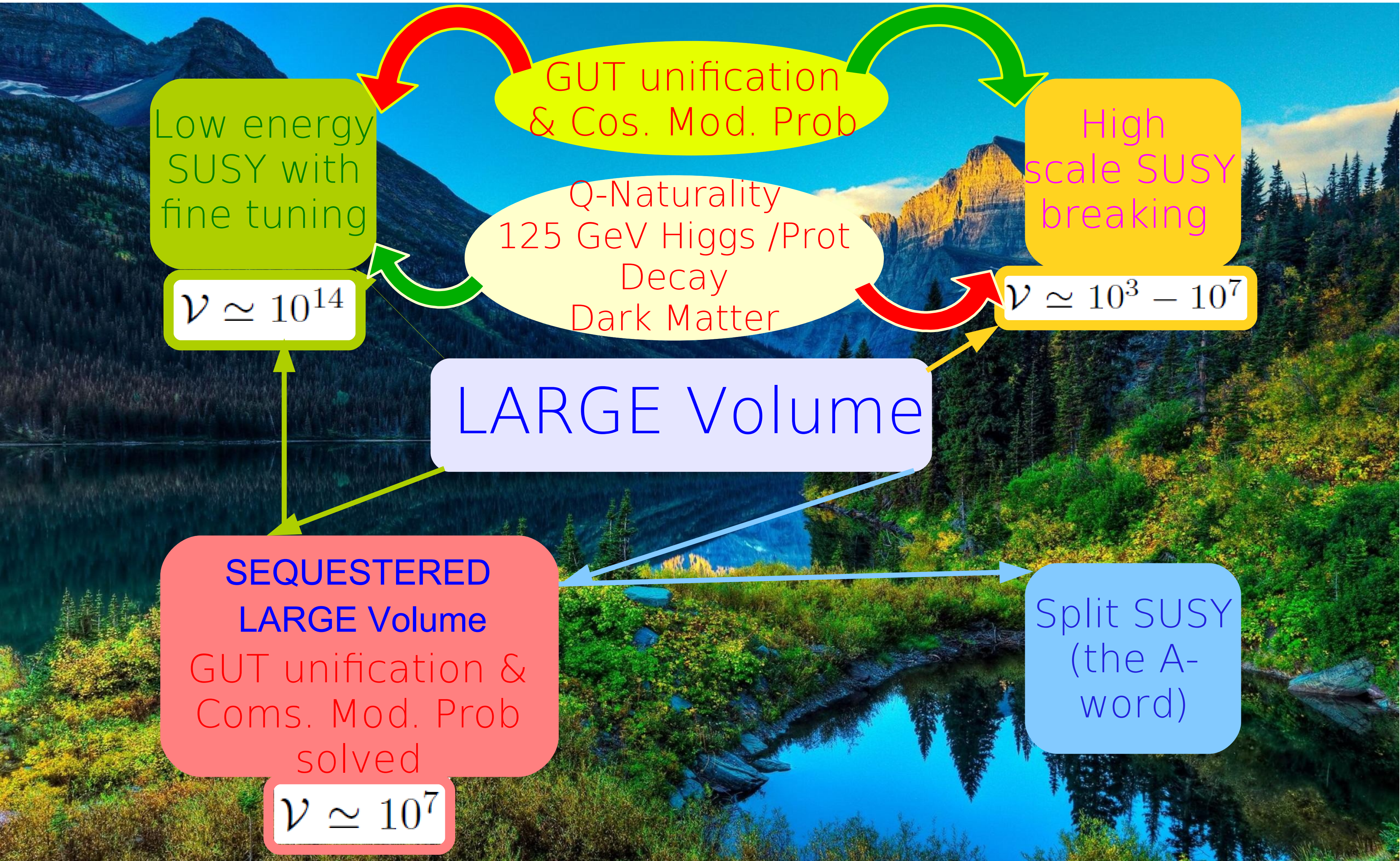
LARGE Volume Landscape



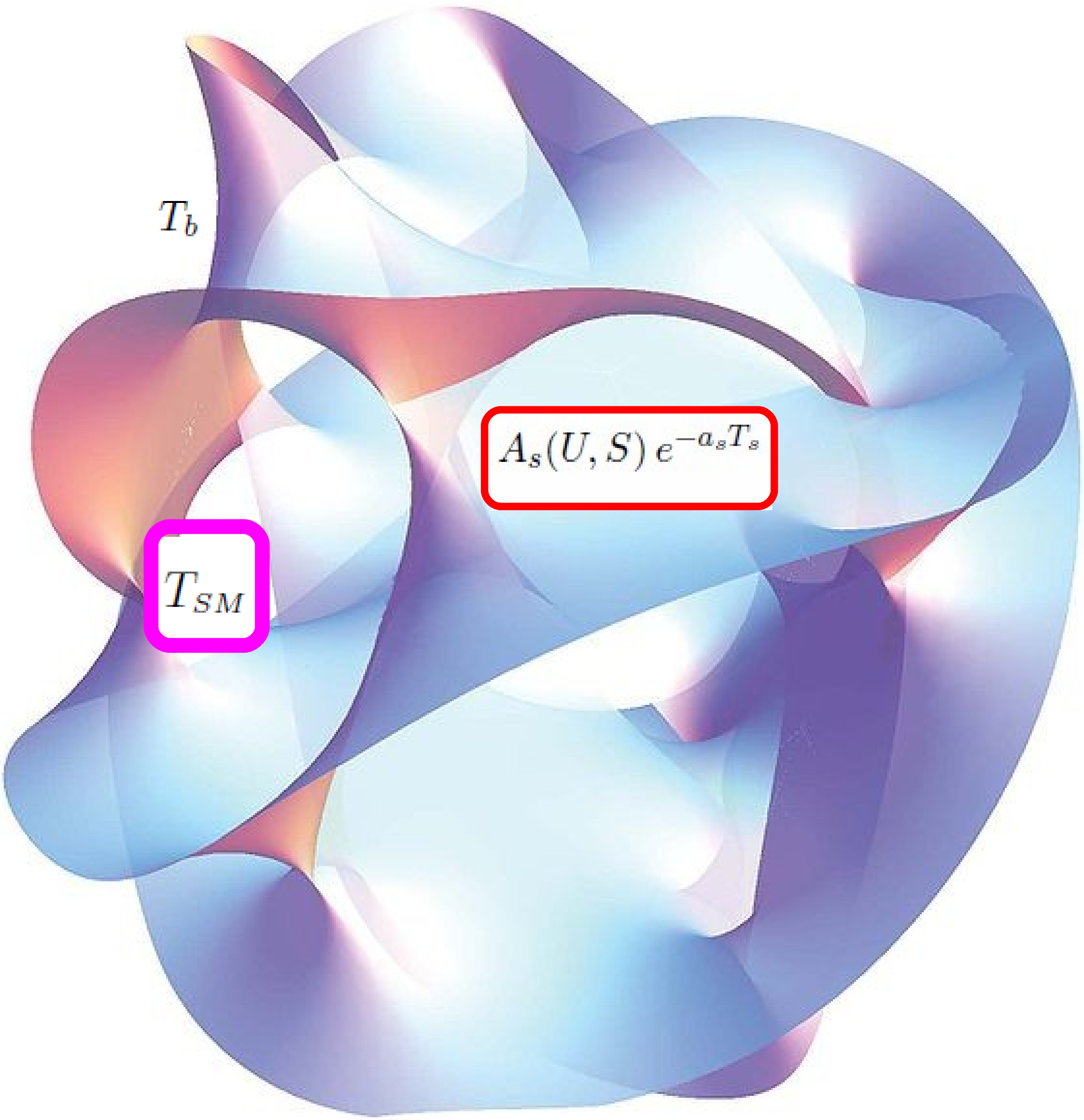
LARGE Volume Landscape



LARGE Volume Landscape



Sequestered LARGE Volume



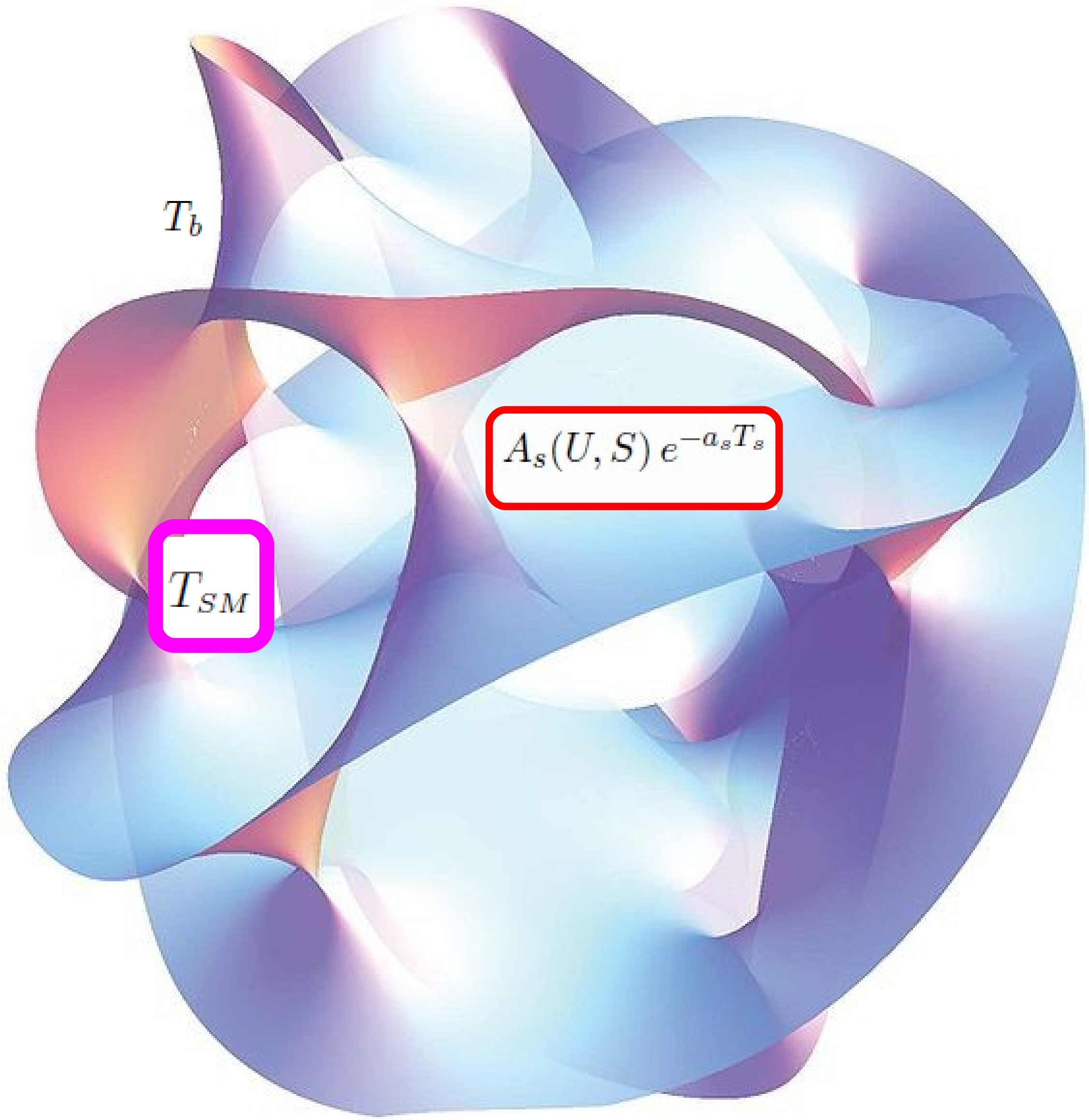
$$\mathcal{V} = \alpha_b \tau_b^{3/2} - \sum_i \alpha_i \tau_i^{3/2}$$

Sequestered LARGE Volume

Anomalous
U(1)

$$V_D = \frac{1}{2\mathrm{Re}(f_1)} \left(\sum_\alpha q_{1\alpha} \frac{\partial K}{\partial C^\alpha} C^\alpha - \xi_1 \right)^2$$

$$\xi_1 = -q_1 \frac{\partial K}{\partial T_{SM}} = -q_1 \lambda_{SM} \frac{\tau_{SM}}{\mathcal{V}}$$



$$\mathcal{V} = \alpha_b \tau_b^{3/2} - \sum_i \alpha_i \tau_i^{3/2}$$

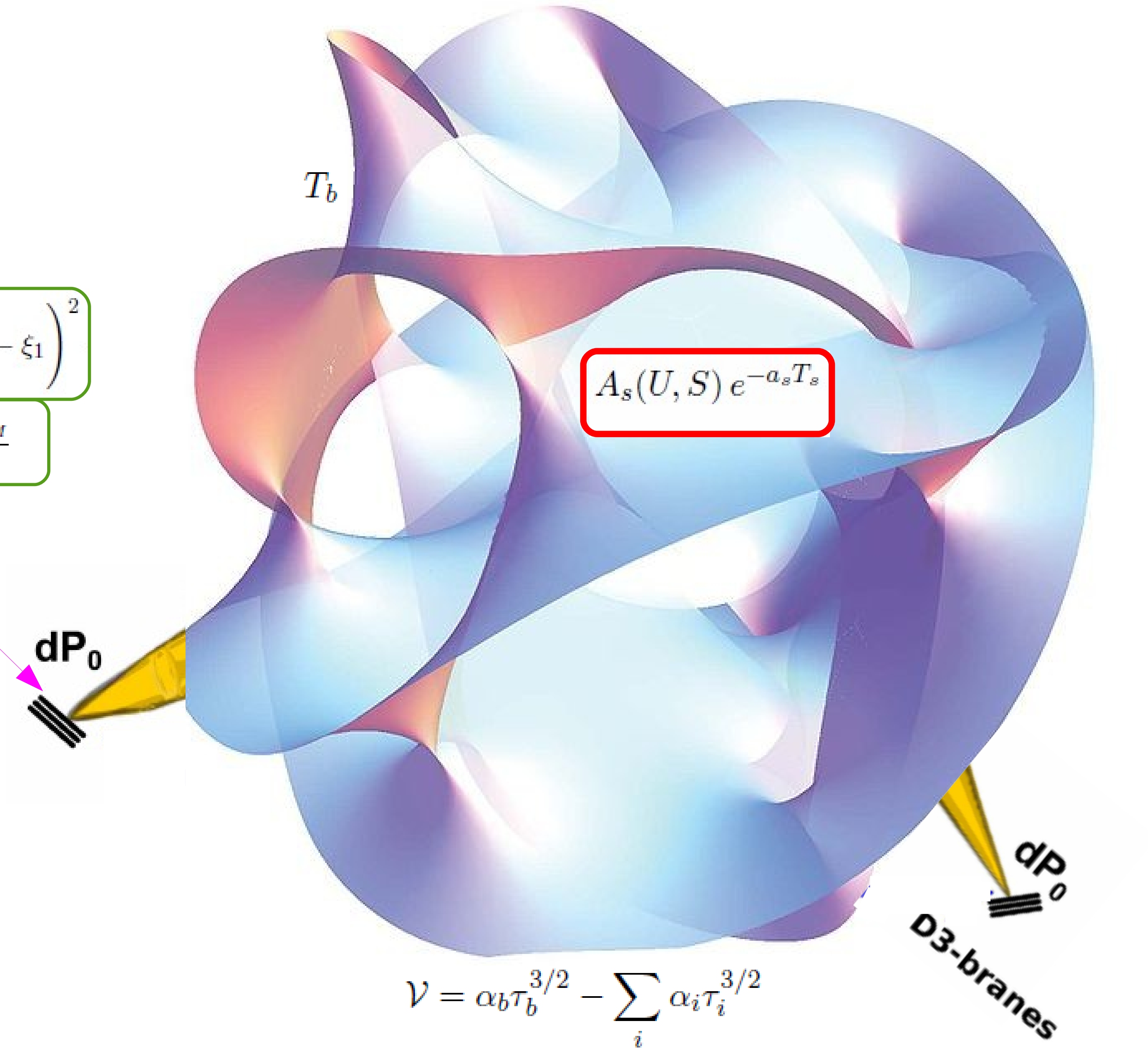
Sequestered LARGE Volume

Anomalous U(1)

$$V_D = \frac{1}{2\mathrm{Re}(f_1)}\left(\sum_\alpha q_{1\alpha}\frac{\partial K}{\partial C^\alpha}C^\alpha - \xi_1\right)^2$$

$$\xi_1 = -q_1\frac{\partial K}{\partial T_{SM}} = -q_1\lambda_{SM}\frac{\tau_{SM}}{\mathcal{V}}$$

$$\tau_{SM} = 0$$



Sequestered LARGE Volume

Anomalous U(1)

$$V_D = \frac{1}{2\mathrm{Re}(f_1)}\left(\sum_\alpha q_{1\alpha}\frac{\partial K}{\partial C^\alpha}C^\alpha - \xi_1\right)^2$$

$$\xi_1 = -q_1\frac{\partial K}{\partial T_{SM}} = -q_1\lambda_{SM}\frac{\tau_{SM}}{\mathcal{V}}$$

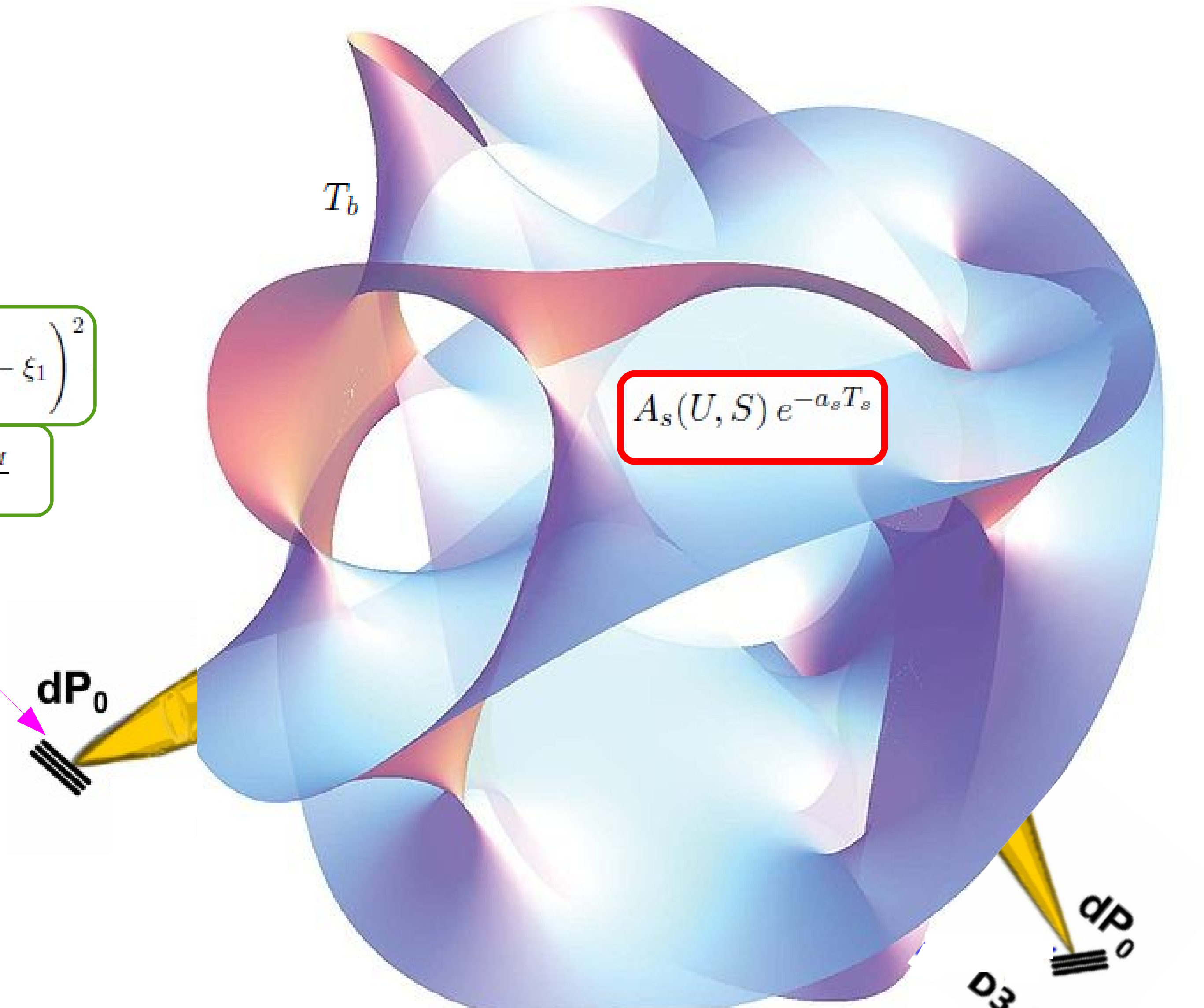
$$\tau_{SM} = 0$$

⇓

$$F^{T_{SM}} = 0$$

⇓

SUSY is sequestered



$$\mathcal{V} = \alpha_b\tau_b^{3/2} - \sum_i \alpha_i\tau_i^{3/2}$$

Sequestered LARGE Volume

Anomalous U(1)

$$V_D = \frac{1}{2\mathrm{Re}(f_1)}\left(\sum_\alpha q_{1\alpha}\frac{\partial K}{\partial C^\alpha}C^\alpha - \xi_1\right)^2$$

$$\xi_1 = -q_1\frac{\partial K}{\partial T_{SM}} = -q_1\lambda_{SM}\frac{\tau_{SM}}{\mathcal{V}}$$

$$\tau_{SM} = 0$$

⇩

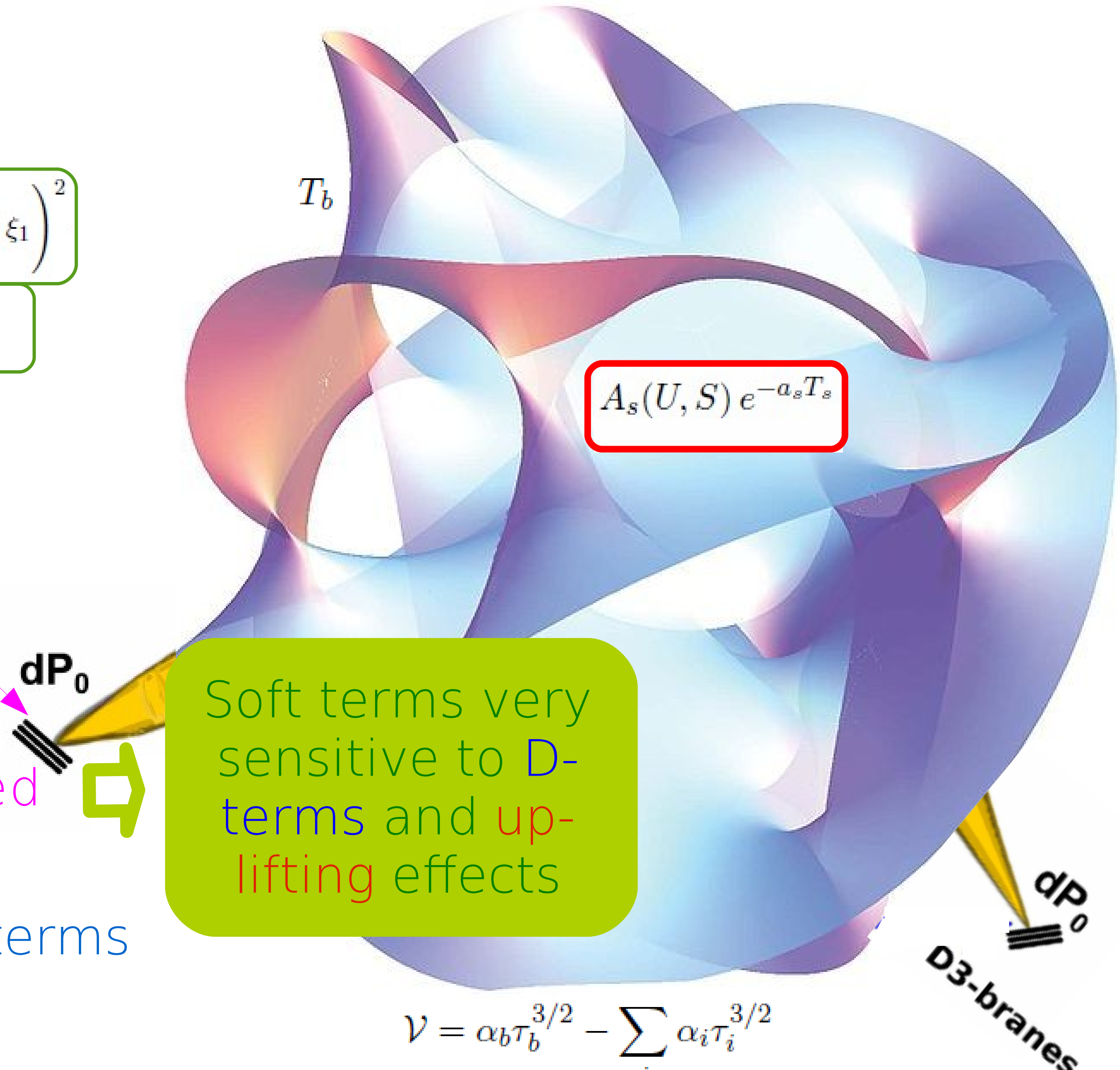
$$F^{T_{SM}} = 0$$

⇩

SUSY is sequestered

⇩

Gravitino >> soft-terms



⇨ Soft terms very sensitive to D-terms and up-lifting effects

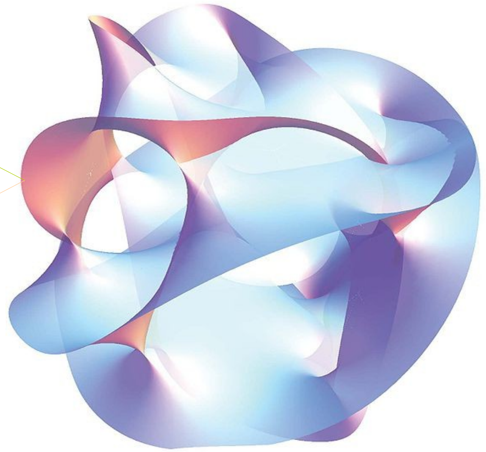
$$\mathcal{V} = \alpha_b \tau_b^{3/2} - \sum_i \alpha_i \tau_i^{3/2}$$

Scenarios for de Sitter vacua

Superpotential

$$W = W_{\text{flux}}(U,S) + A_s(U,S)\, e^{-a_s T_s} + W_{dS} + W_{\text{matter}}$$

$$W_{\text{matter}} = \mu(M) H_u H_d + \frac{1}{6} Y_{\alpha\beta\gamma}(M) C^\alpha C^\beta C^\gamma + \cdots$$



Kahler potential

$$K = -2\ln\left(\mathcal{V} + \frac{\hat{\xi}}{2}\right) - \ln(2s) + \lambda_{SM}\frac{\tau_{SM}^2}{\mathcal{V}} + \lambda_b \frac{b^2}{\mathcal{V}} + K_{dS} + K_{\text{cs}}(U) + K_{\text{matter}}$$

$$K_{\text{matter}} = \tilde{K}_\alpha(M,\overline{M})\overline{C}^{\overline{\alpha}} C^\alpha + [Z(M,\overline{M}) H_u H_d + \text{h.c.}]$$

F-terms and soft terms

$$\frac{F^{T_b}}{\tau_b} \simeq -2m_{3/2}\left(1+\frac{\hat{\xi}\epsilon_s x_{dS}}{\mathcal{V}}\right)$$

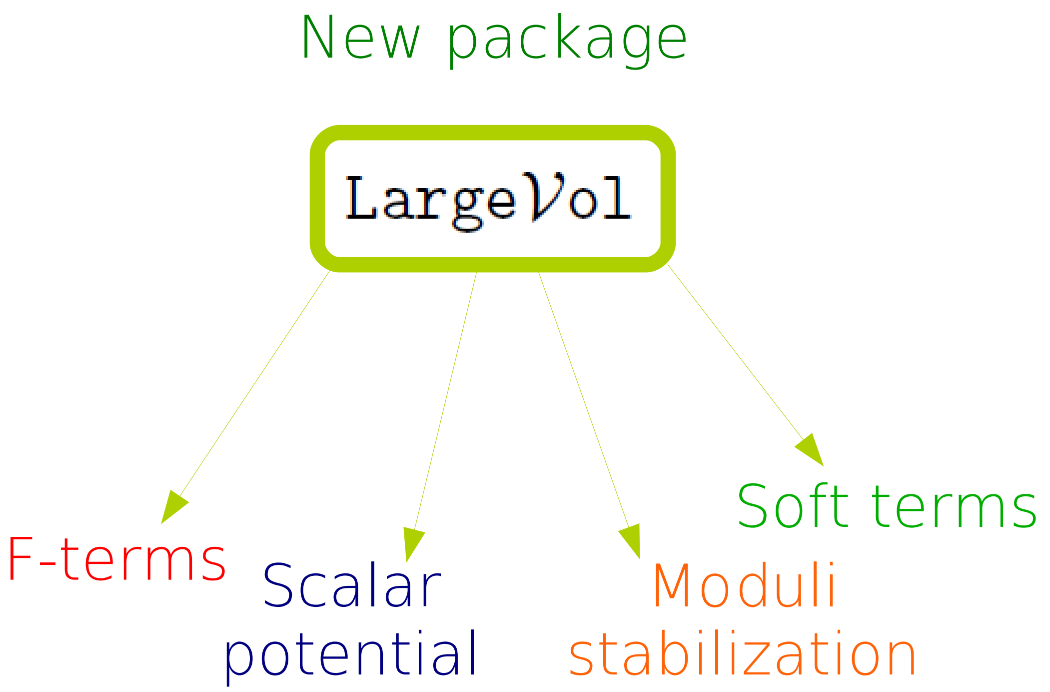
$$\frac{F^{T_s}}{\tau_s} \simeq -6m_{3/2}\epsilon_s$$

$$\frac{F^S}{s} \simeq \frac{3\omega'_S(U,S)\hat{\xi}}{2}\frac{m_{3/2}}{\mathcal{V}}$$

$$F^{U_i} = -\frac{K^{U_i\overline{U}_{\overline{j}}}}{2s^2}\frac{\omega_{\overline{U}_{\overline{j}}}(U,S)}{\omega'_S(U,S)}F^S \equiv \beta^{U_i}(U,S)F^S$$

$$\frac{F^{\phi_{dS}}}{\phi_{dS}} \simeq m_{3/2}$$

$$F^{T_{dS}} \simeq \frac{3m_{3/2}}{2}\sqrt{\frac{\hat{\xi}\epsilon_s}{2}}$$



Three possible scenarios

Local

$$m_0^2 = c_0\, m_{3/2} M_{1/2}\,, \quad A_{\alpha\beta\gamma} = (c_A)_{\alpha\beta\gamma}\, M_{1/2}\,, \quad \hat{\mu} = c_\mu\, M_{1/2}\,, \quad B\hat{\mu} = c_B m_0^2$$

Ultra Local: dS-matter field

$$m_0^2 = c_0\, \frac{m_{3/2} M_{1/2}}{\ln\left(M_P/m_{3/2}\right)}\,, \quad A_{\alpha\beta\gamma} = (c_A)_{\alpha\beta\gamma}\, M_{1/2}\,, \quad \hat{\mu} = c_\mu\, M_{1/2}\,, \quad B\hat{\mu} = c_B m_0^2$$

Ultra Local: dS-dilaton NP

$$m_\alpha = (c_0)_\alpha\, M_{1/2}\,, \quad A_{\alpha\beta\gamma} = (c_A)_{\alpha\beta\gamma}\, M_{1/2}\,, \quad \hat{\mu} = c_\mu\, M_{1/2}\,, \quad B\hat{\mu} = c_B M_{1/2}^2$$

F-terms and soft terms

Scalar masses

$$m_0^2|_F \simeq m_{3/2}^2 - \left(\frac{F^{T_b}}{2}\right)^2 \partial_{\tau_b}^2 \ln \tilde{K} \simeq \frac{5}{3\omega'_S}(3c_s - 1)\, m_{3/2} M_{1/2} \sim \mathcal{O}\left(m_{3/2}^2 \epsilon\right)$$

Local

$$m_\alpha^2|_F = -M_{1/2}^2 s^2 \left(\partial_s^2 + \beta^{U_i}\partial_{u_i}\partial_s + \beta^{U_i}\beta^{\overline{U}_j}\partial_{u_i}\partial_{u_j}\right) \ln h_\alpha(U,S) \sim \mathcal{O}\left(m_{3/2}^2 \epsilon^2\right)$$

Ultralocal

$$m_\alpha^2|_D = \frac{q_b}{2 f_\alpha(U,S)} D_{dS_1} \partial_{\tau_b} \tilde{K}_\alpha = \frac{1}{3s} m_{3/2}^2 |\phi_{dS}|^2 = \frac{3\epsilon_s}{2\omega'_S} m_{3/2} M_{1/2}$$

dS: matter field

$$m_\alpha^2|_D = \frac{q_{dS}\mathcal{V}^{2/3}}{2s f_\alpha(U,S)} D_{dS_2} \partial_{\tau_{dS}} \tilde{K}_\alpha - V_{D,0} = \frac{c_{dS}}{s} D_{dS_2} q_{dS} \frac{\tau_{dS}}{\mathcal{V}} - V_{D,0} = (2c_{dS} - 1)\, V_{D,0}$$

dS: dilaton NP

F-terms and soft terms

Trilinears

$$A_{\alpha\beta\gamma} = -\left[1 - s\beta^{U_i}\partial_{u_i}K_{cs} - \frac{2}{\omega'_S}(3c_s - 1) - s\partial_{s,u}\ln\left(\frac{Y_{\alpha\beta\gamma}}{f_\alpha f_\beta f_\gamma}\right)\right] M_{1/2}$$

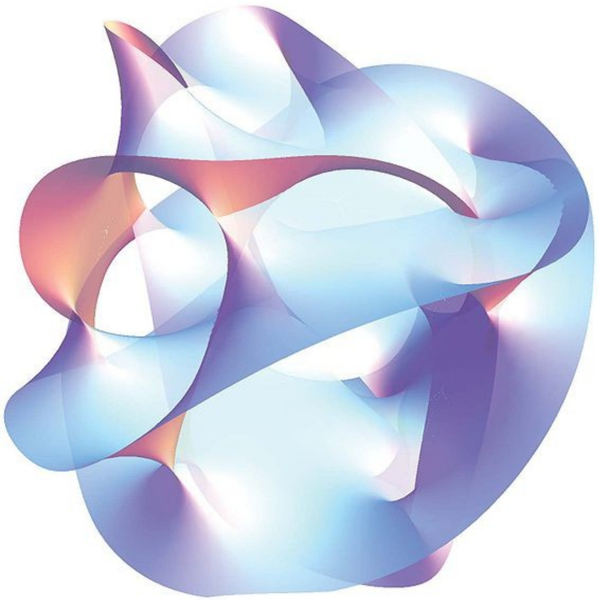
Local

$$A_{\alpha\beta\gamma} = s\partial_{s,u}\ln\left(\frac{Y_{\alpha\beta\gamma}(U,S)}{h_\alpha h_\beta h_\gamma}\right) M_{1/2} \sim \mathcal{O}\left(m_{3/2}\epsilon\right)$$

Ultralocal

Sequestered LVS Cosmology

$$\mathcal{V} = \alpha_b \tau_b^{3/2} - \sum \alpha_i \tau_i^{3/2}$$



$$m_{\rm mod} \gtrsim 30 \text{ TeV}$$

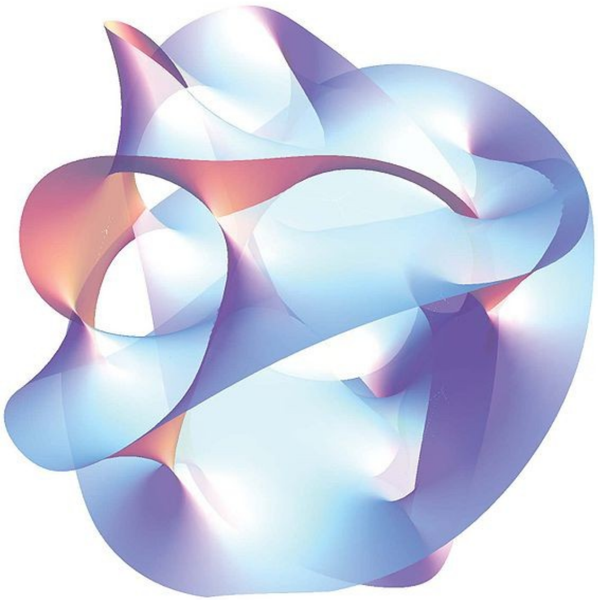
$$\mathcal{V} \sim 3 \times 10^7 \, l_s^6$$

Planck scale:	$M_P = 2.4 \times 10^{18}\text{GeV}$
String scale:	$M_S \sim \frac{M_P}{\sqrt{\mathcal{V}}} \sim 10^{15}\text{GeV}$
KK scale	$M_{KK} \sim \frac{M_P}{\mathcal{V}^{2/3}} \sim 10^{14}\text{GeV}$
Gravitino mass	$m_{3/2} \sim \frac{M_P}{\mathcal{V}} \sim 10^{11}\text{GeV}$
Small modulus	$m_{\tau_s} \sim m_{3/2} \ln\left(\frac{M_P}{m_{3/2}}\right) \sim 10^{12}\text{GeV}$
Complex structure moduli	$m_U \sim m_{3/2} \sim 10^{11}\text{GeV}$
Volume modulus	$m_{\tau_b} \sim \frac{M_P}{\mathcal{V}^{3/2}} \sim 4 \times 10^{6}\text{GeV}$
Soft terms	$M_{soft} \sim \frac{M_P}{\mathcal{V}^2} \sim 10^{3}\text{GeV}$

- Cosmological Moduli Problem solved ✓
- Gravitino problem solved ✓

Sequestered LVS Cosmology

$\mathcal{V} = \alpha_b \tau_b^{3/2} - \sum \alpha_i \tau_i^{3/2}$



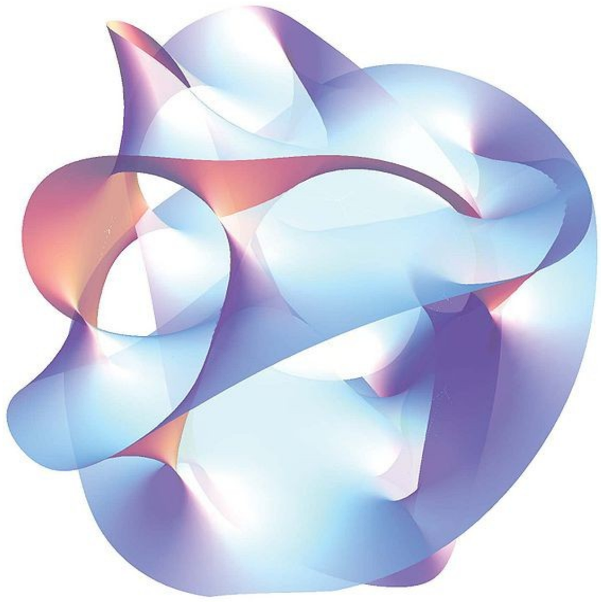
$\mathcal{V} \sim 3 \times 10^7 \, l_s^6$

Planck scale:	$M_P = 2.4 \times 10^{18}\,\mathrm{GeV}$
String scale:	$M_S \sim \frac{M_P}{\sqrt{\mathcal{V}}} \sim 10^{15}\,\mathrm{GeV}$
KK scale	$M_{KK} \sim \frac{M_P}{\mathcal{V}^{2/3}} \sim 10^{14}\,\mathrm{GeV}$
Gravitino mass	$m_{3/2} \sim \frac{M_P}{\mathcal{V}} \sim 10^{11}\,\mathrm{GeV}$
Small modulus	$m_{\tau_s} \sim m_{3/2} \ln\left(\frac{M_P}{m_{3/2}}\right) \sim 10^{12}\,\mathrm{GeV}$
Complex structure moduli	$m_U \sim m_{3/2} \sim 10^{11}\,\mathrm{GeV}$
Volume modulus	$m_{\tau_b} \sim \frac{M_P}{\mathcal{V}^{3/2}} \sim 4 \times 10^6\,\mathrm{GeV}$
Soft terms	$M_{soft} \sim \frac{M_P}{\mathcal{V}^2} \sim 10^3\,\mathrm{GeV}$

- Gravitationally coupled
- Decay very late ⇒ $H \sim \Gamma \sim m_{\mathrm{mod}}^3 / M_P^2$

Sequestered LVS Cosmology

$$\mathcal{V} = \alpha_b \tau_b^{3/2} - \sum \alpha_i \tau_i^{3/2}$$



$$\mathcal{V} \sim 3 \times 10^7\, l_s^6$$

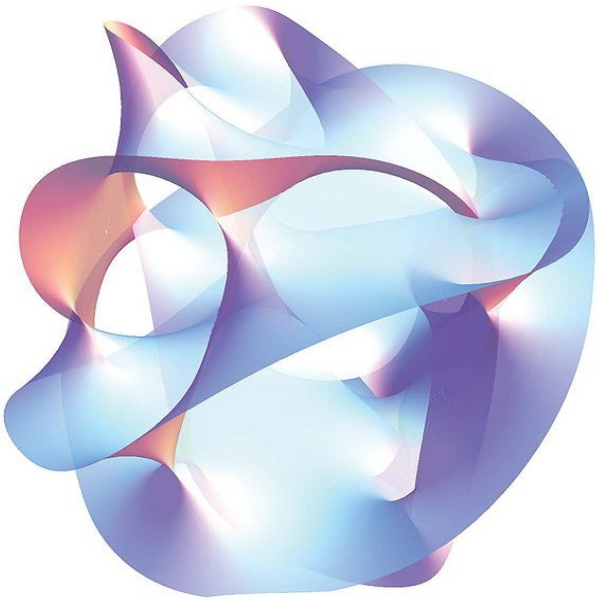
Planck scale:	$M_P = 2.4 \times 10^{18}\text{GeV}$
String scale:	$M_S \sim \frac{M_P}{\sqrt{\mathcal{V}}} \sim 10^{15}\text{GeV}$
KK scale	$M_{KK} \sim \frac{M_P}{\mathcal{V}^{2/3}} \sim 10^{14}\text{GeV}$
Gravitino mass	$m_{3/2} \sim \frac{M_P}{\mathcal{V}} \sim 10^{11}\text{GeV}$
Small modulus	$m_{\tau_s} \sim m_{3/2} \ln\left(\frac{M_P}{m_{3/2}}\right) \sim 10^{12}\text{GeV}$
Complex structure moduli	$m_U \sim m_{3/2} \sim 10^{11}\text{GeV}$
Volume modulus	$m_{\tau_b} \sim \frac{M_P}{\mathcal{V}^{3/2}} \sim 4 \times 10^6\text{GeV}$
Soft terms	$M_{soft} \sim \frac{M_P}{\mathcal{V}^2} \sim 10^3\text{GeV}$

- Gravitationally coupled
- Decay very late ⇨ $H \sim \Gamma \sim m_{\text{mod}}^3 / M_P^2$

- Last decaying modulus
- Reheats SM and Hot Big Bang is recovered

Sequestered LVS Cosmology

$$\mathcal{V} = \alpha_b \tau_b^{3/2} - \sum \alpha_i \tau_i^{3/2}$$



$$\mathcal{V} \sim 3 \times 10^7 \, l_s^6$$

Planck scale:	$M_P = 2.4 \times 10^{18}\text{GeV}$
String scale:	$M_S \sim \frac{M_P}{\sqrt{\mathcal{V}}} \sim 10^{15}\text{GeV}$
KK scale	$M_{KK} \sim \frac{M_P}{\mathcal{V}^{2/3}} \sim 10^{14}\text{GeV}$
Gravitino mass	$m_{3/2} \sim \frac{M_P}{\mathcal{V}} \sim 10^{11}\text{GeV}$
Small modulus	$m_{\tau_s} \sim m_{3/2} \ln\left(\frac{M_P}{m_{3/2}}\right) \sim 10^{12}\text{GeV}$
Complex structure moduli	$m_U \sim m_{3/2} \sim 10^{11}\text{GeV}$
Volume modulus	$m_{\tau_b} \sim \frac{M_P}{\mathcal{V}^{3/2}} \sim 4 \times 10^6\text{GeV}$
Soft terms	$M_{soft} \sim \frac{M_P}{\mathcal{V}^2} \sim 10^3\text{GeV}$

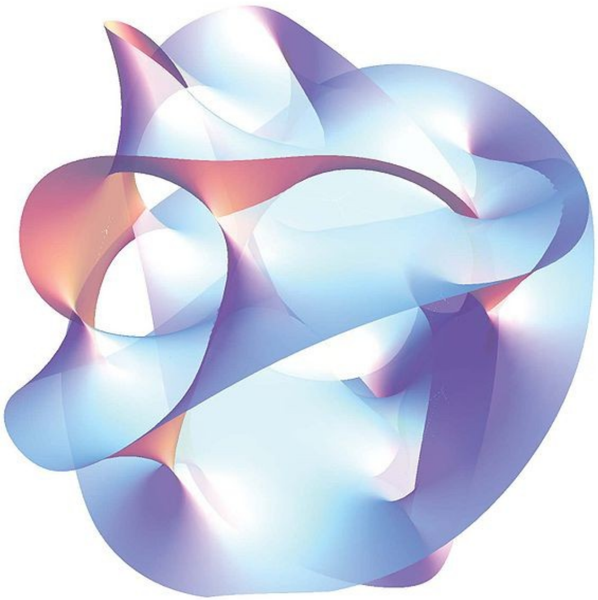
- Gravitationally coupled
- Decay very late

$$H \sim \Gamma \sim m_{\rm mod}^3 / M_P^2$$

$$T_R \sim \sqrt{\Gamma M_P} \sim m_{\rm mod} \sqrt{\frac{m_{\rm mod}}{M_P}}$$

Sequestered LVS Cosmology

$$\mathcal{V} = \alpha_b \tau_b^{3/2} - \sum \alpha_i \tau_i^{3/2}$$



$$\mathcal{V} \sim 3 \times 10^7 \, l_s^6$$

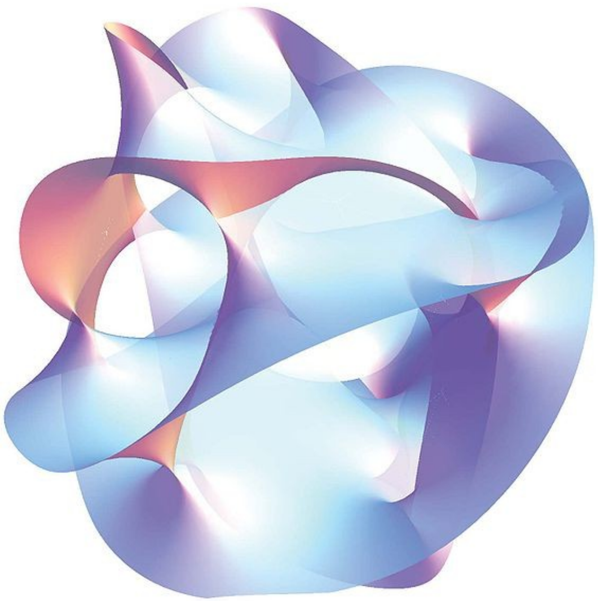
Planck scale:	$M_P = 2.4 \times 10^{18}\,\text{GeV}$
String scale:	$M_S \sim \frac{M_P}{\sqrt{\mathcal{V}}} \sim 10^{15}\,\text{GeV}$
KK scale	$M_{KK} \sim \frac{M_P}{\mathcal{V}^{2/3}} \sim 10^{14}\,\text{GeV}$
Gravitino mass	$m_{3/2} \sim \frac{M_P}{\mathcal{V}} \sim 10^{11}\,\text{GeV}$
Small modulus	$m_{\tau_s} \sim m_{3/2} \ln\left(\frac{M_P}{m_{3/2}}\right) \sim 10^{12}\,\text{GeV}$
Complex structure moduli	$m_U \sim m_{3/2} \sim 10^{11}\,\text{GeV}$
Volume modulus	$m_{\tau_b} \sim \frac{M_P}{\mathcal{V}^{3/2}} \sim 4 \times 10^{6}\,\text{GeV}$
Soft terms	$M_{soft} \sim \frac{M_P}{\mathcal{V}^2} \sim 10^{3}\,\text{GeV}$

$$T_R \sim \sqrt{\Gamma M_P} \sim m_{\rm mod}\sqrt{\frac{m_{\rm mod}}{M_P}} \quad \Rightarrow \quad T_R \sim \frac{M_{\rm soft}}{\kappa^{3/2}}\sqrt{\frac{M_{\rm soft}}{M_P}} \sim \kappa^{-3/2}\,\mathcal{O}(10^{-2})\ \text{MeV}$$

$$M_{\rm soft} = \kappa m_{\rm mod} \quad \Rightarrow \quad \kappa \sim \mathcal{O}(10^{-3} - 10^{-4})$$

Sequestered LVS Cosmology

$$\mathcal{V} = \alpha_b \tau_b^{3/2} - \sum \alpha_i \tau_i^{3/2}$$



$$\mathcal{V} \sim 3 \times 10^7\, l_s^6$$

Planck scale:	$M_P = 2.4 \times 10^{18}\text{GeV}$
String scale:	$M_S \sim \frac{M_P}{\sqrt{\mathcal{V}}} \sim 10^{15}\text{GeV}$
KK scale	$M_{KK} \sim \frac{M_P}{\mathcal{V}^{2/3}} \sim 10^{14}\text{GeV}$
Gravitino mass	$m_{3/2} \sim \frac{M_P}{\mathcal{V}} \sim 10^{11}\text{GeV}$
Small modulus	$m_{\tau_s} \sim m_{3/2} \ln\left(\frac{M_P}{m_{3/2}}\right) \sim 10^{12}\text{GeV}$
Complex structure moduli	$m_U \sim m_{3/2} \sim 10^{11}\text{GeV}$
Volume modulus	$m_{\tau_b} \sim \frac{M_P}{\mathcal{V}^{3/2}} \sim 4 \times 10^6\text{GeV}$
Soft terms	$M_{\text{soft}} \sim \frac{M_P}{\mathcal{V}^2} \sim 10^3\text{GeV}$

$$T_R \sim \frac{M_{\text{soft}}}{\kappa^{3/2}} \sqrt{\frac{M_{\text{soft}}}{M_P}} \sim \kappa^{-3/2}\, \mathcal{O}(10^{-2})\ \text{MeV}$$

Non-thermal LSP between

$\mathcal{O}(100)$ GeV and $\mathcal{O}(1)$ TeV

$\mathcal{O}(10)$ MeV and $\mathcal{O}(10)$ GeV

Non-thermal dark matter

Annihilation

$$\langle \sigma_{\rm ann} v \rangle_f \geq \langle \sigma_{\rm ann} v \rangle_f^{\rm Th} \sqrt{\frac{g_*(T_f)}{g_*(T_R)}} \left(\frac{T_f}{T_R} \right)$$

$$\Omega_\chi^{\rm NT} h^2 = 0.142 \sqrt{\frac{10.75}{g_*(T_R)}} \left(\frac{m_\chi}{T_R} \right) \Omega_\chi^{\rm Th} h^2$$

Branching

$$T_R \lesssim 10^{-9} m_{\rm mod} = 10^{-9} \kappa^{-1} M_{\rm soft}$$

Dark radiation overproduced

Non-thermal CMSSM/mSUGRA

Ultra Local: dS-dilaton

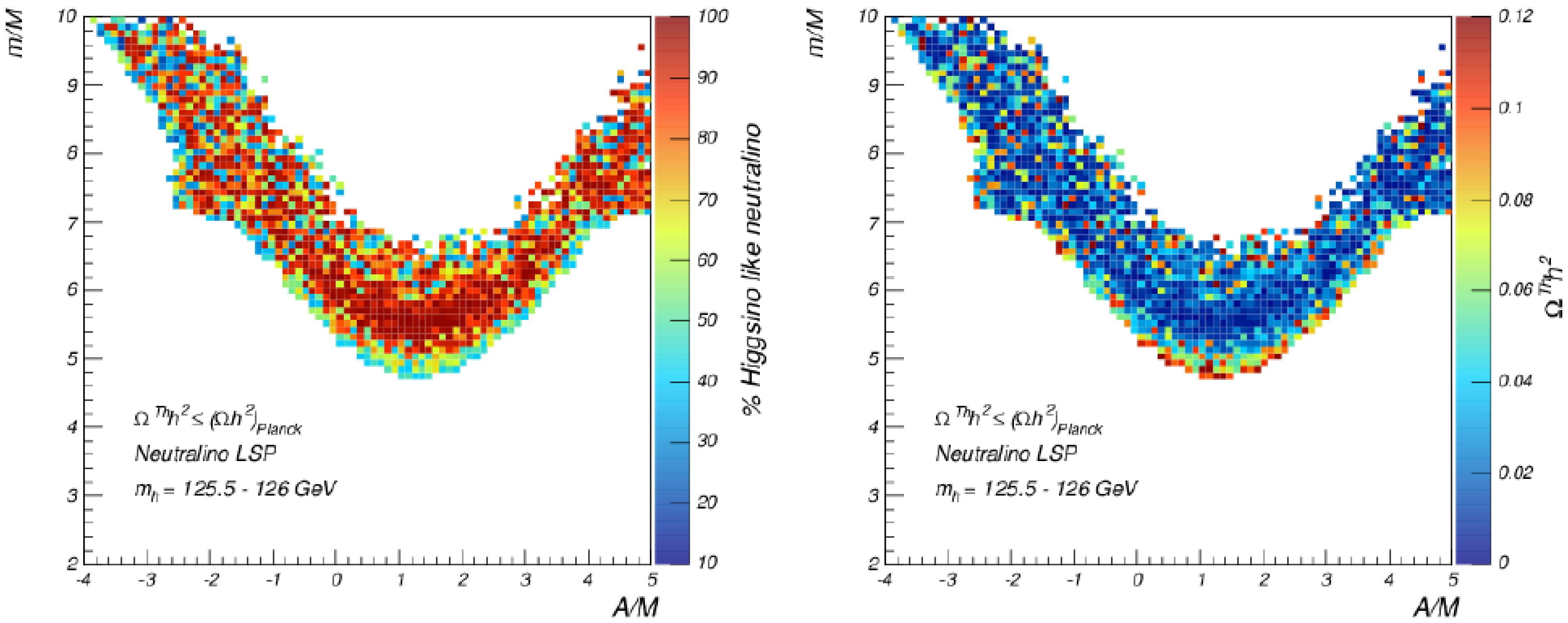
$$m_\alpha = (c_0)_\alpha M_{1/2}\,, \quad A_{\alpha\beta\gamma} = (c_A)_{\alpha\beta\gamma} M_{1/2}\,, \quad \hat{\mu} = c_\mu M_{1/2}\,, \quad B\hat{\mu} = c_B M_{1/2}^2$$

REWSB ⇩

$$m = a\,|M|\,, \quad A = b\,M\,, \quad \tan\beta \equiv \frac{\langle H_u^0\rangle}{\langle H_d^0\rangle}\,, \quad \mathrm{sign}(\mu)$$

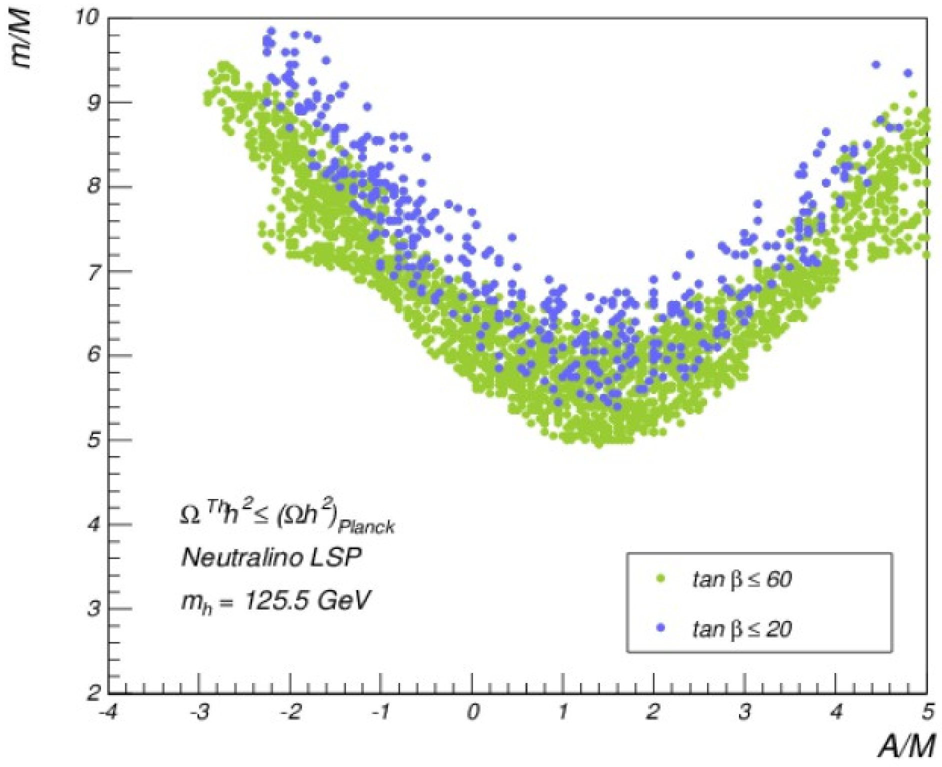
$$\Omega_\chi^{\mathrm{NT}} h^2 = 0.142\sqrt{\frac{10.75}{g_*(T_R)}}\left(\frac{m_\chi}{T_R}\right)\Omega_\chi^{\mathrm{Th}} h^2$$

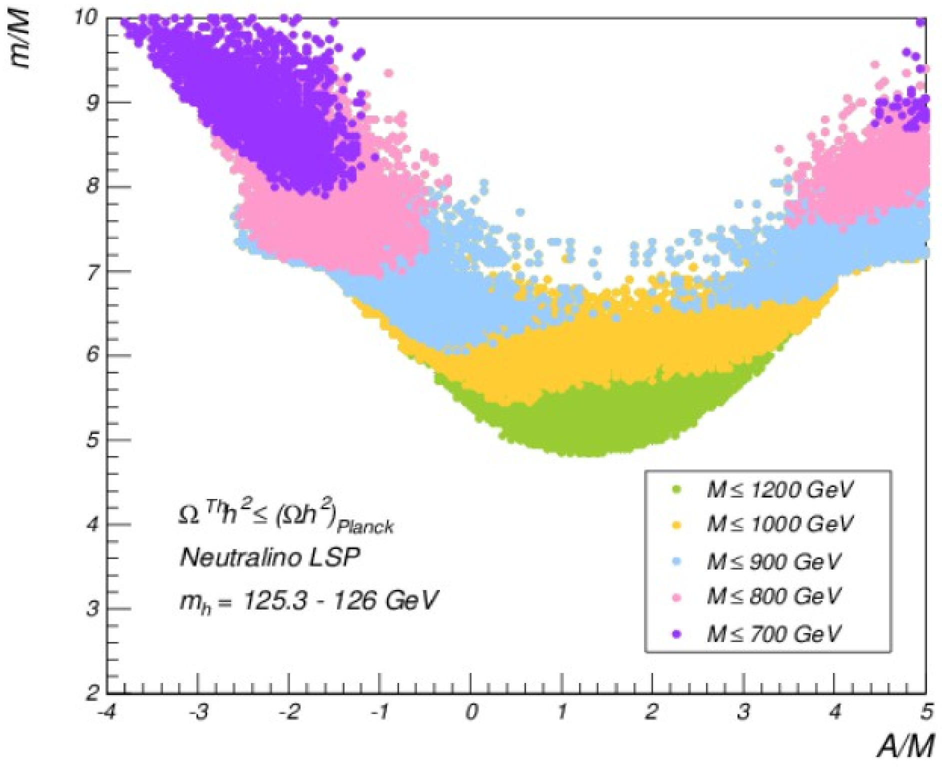
Collider and CMB constraints



$$M^2(f(Q) + g(Q)A/M + h(Q)(A/M)^2 + e(Q)(m/M)^2)$$

Collider and CMB constraints

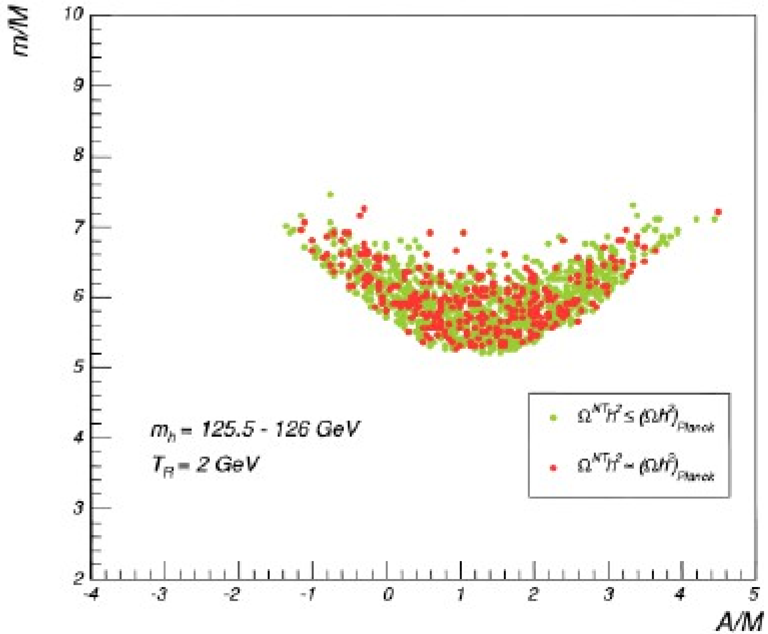


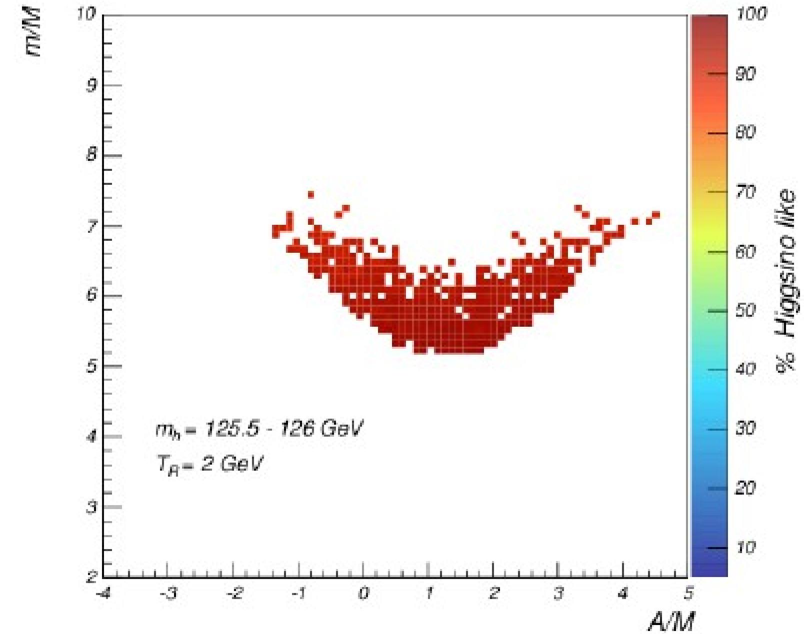


$$M^2(f(Q) + g(Q)A/M + h(Q)(A/M)^2 + e(Q)(m/M)^2)$$

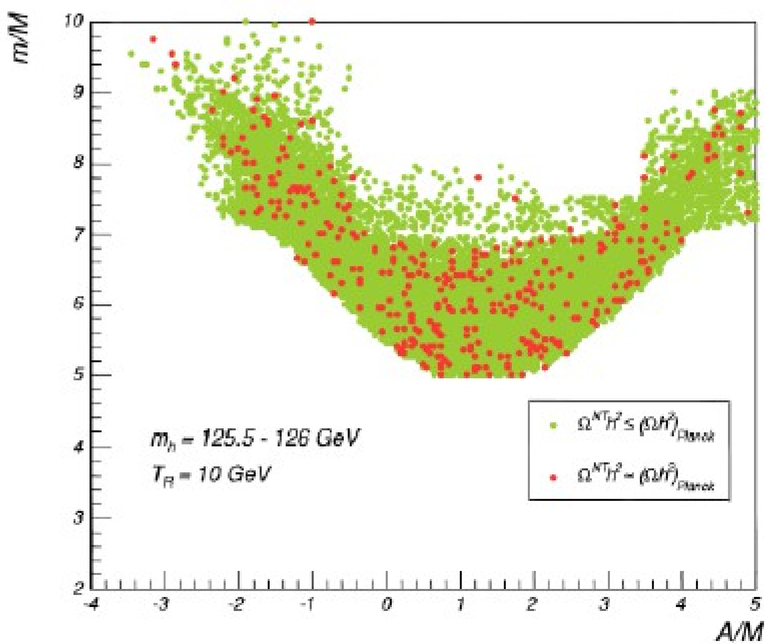
Direct and indirect constraints

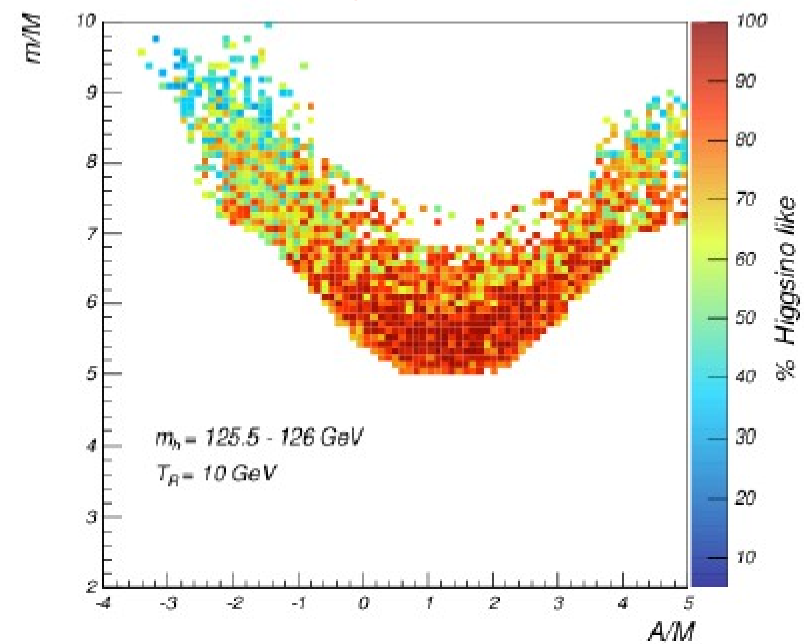
Sign mu > 0





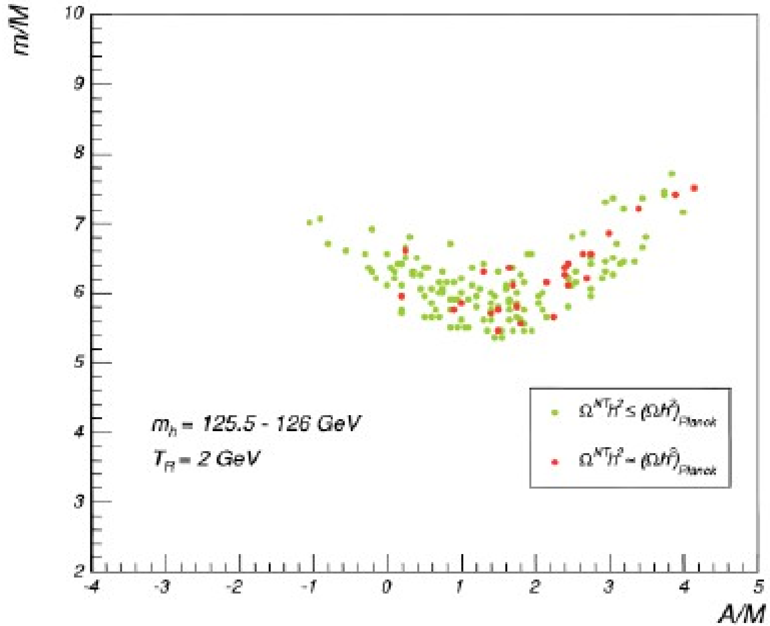
LEP, LHC, Planck and Fermi-LAT (pass 8)

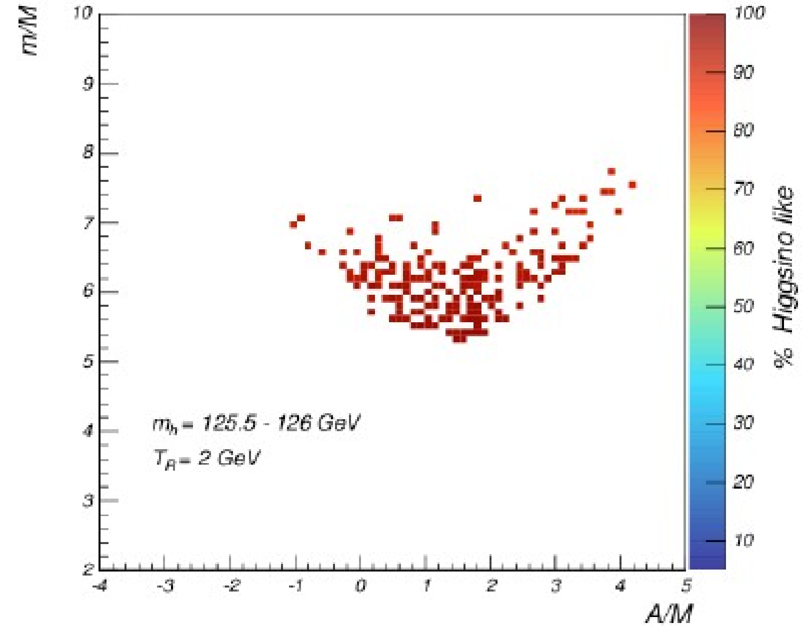




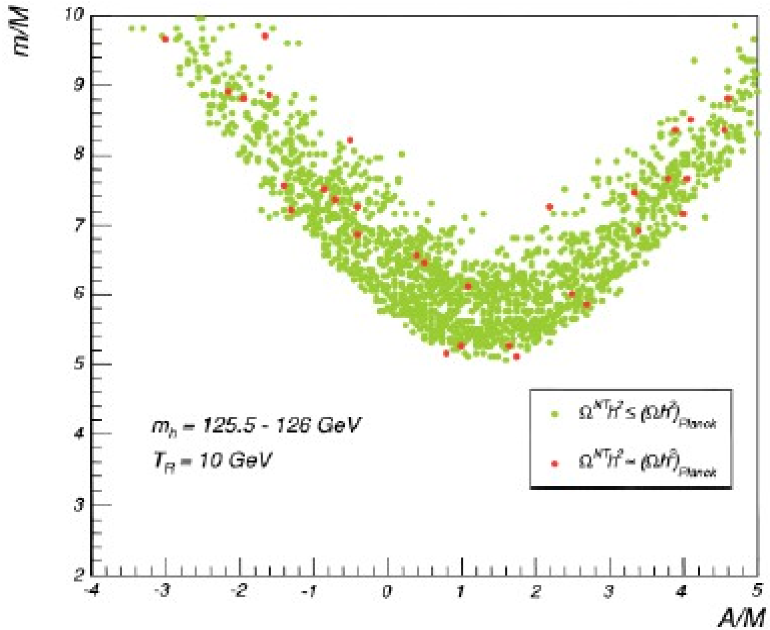
Direct and indirect constraints

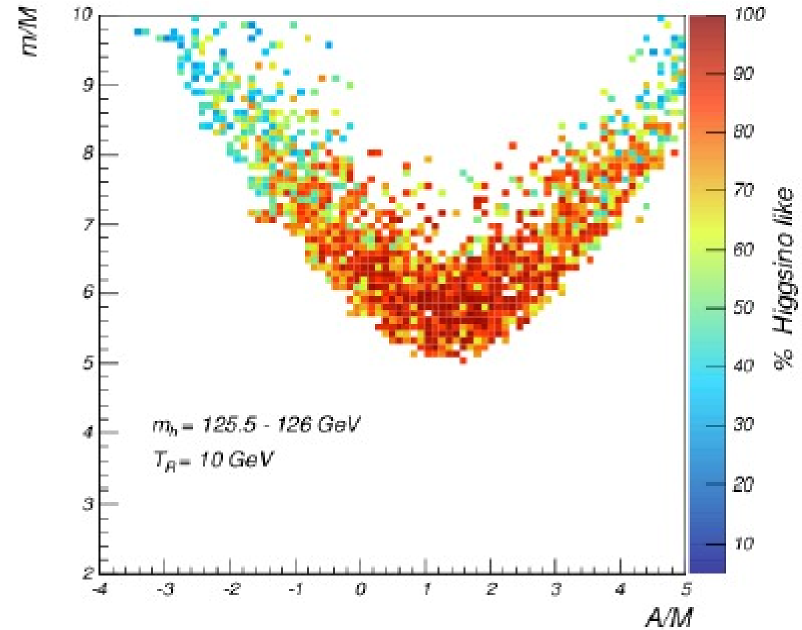
Sign mu < 0





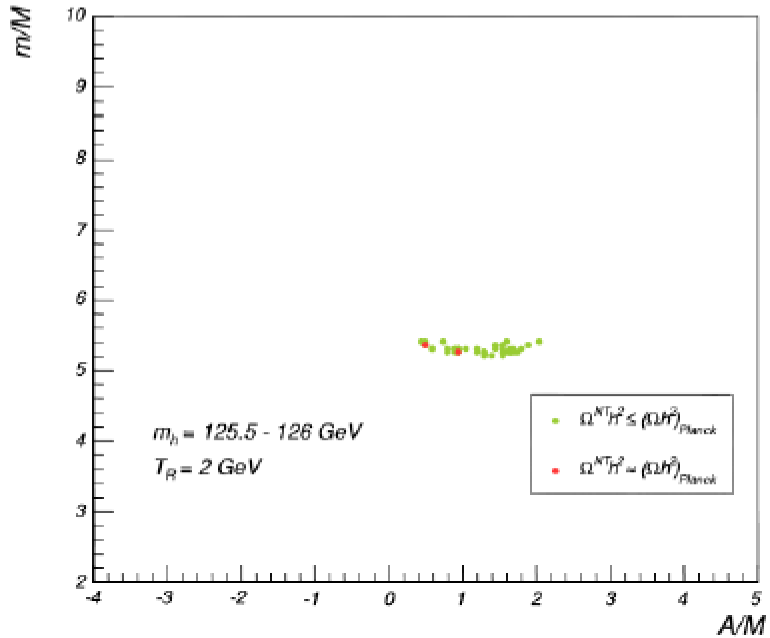
LEP, LHC, Planck and Fermi-LAT (pass 8)

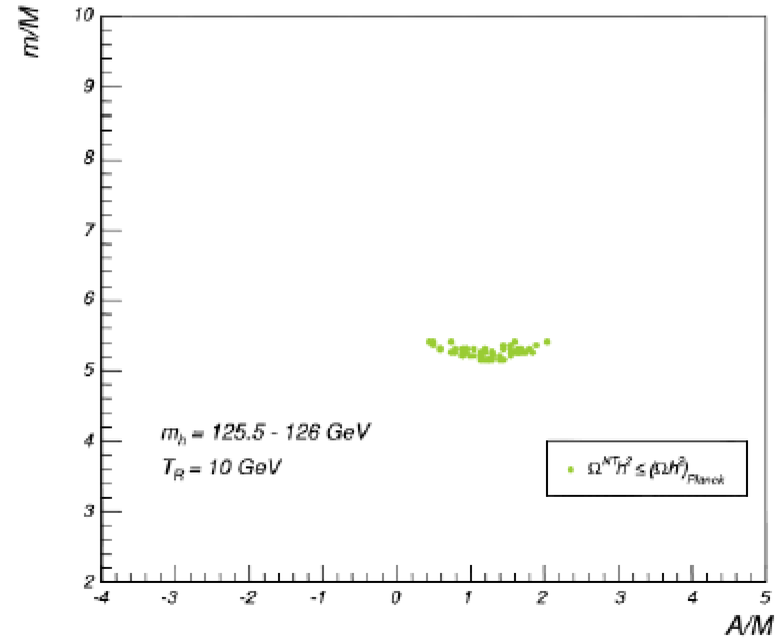




Direct and indirect constraints

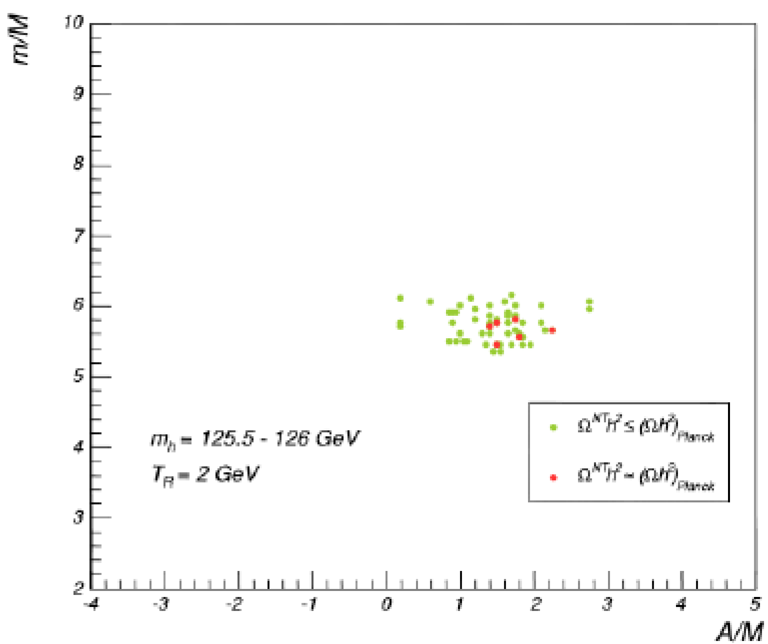
Sign mu > 0

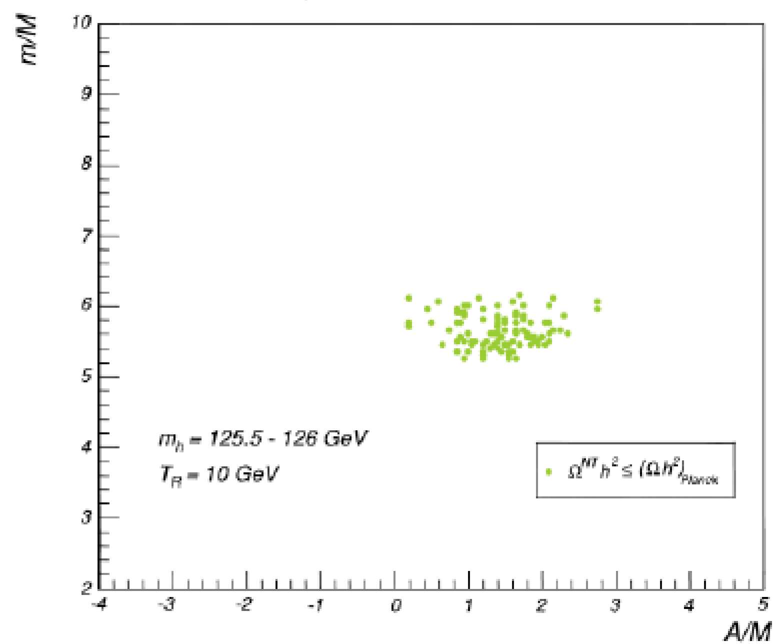




LEP, LHC, Planck and Fermi-LAT (pass 8) & LUX

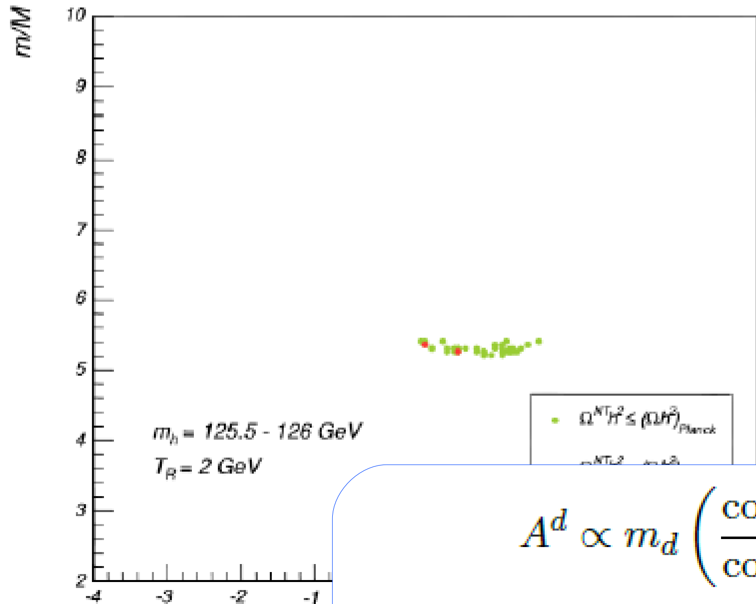
Sign mu < 0

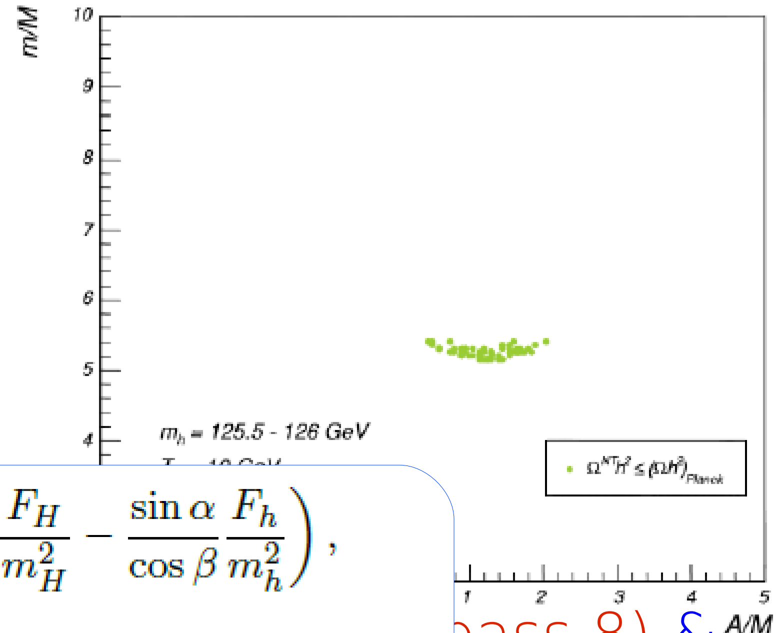




Direct and indirect constraints

Sign mu > 0





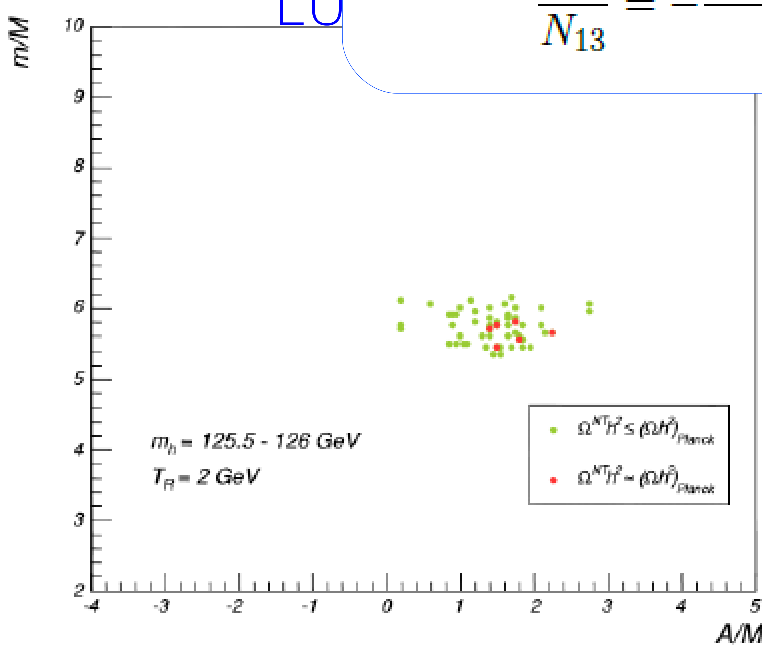
LE... ...pass 8) & ...

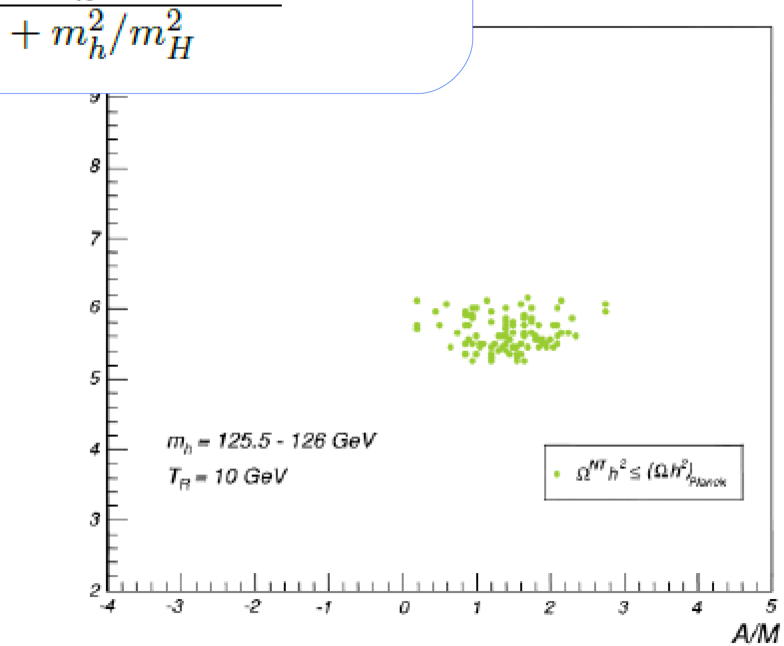
LU...

$$A^d \propto m_d \left(\frac{\cos\alpha}{\cos\beta} \frac{F_H}{m_H^2} - \frac{\sin\alpha}{\cos\beta} \frac{F_h}{m_h^2} \right),$$

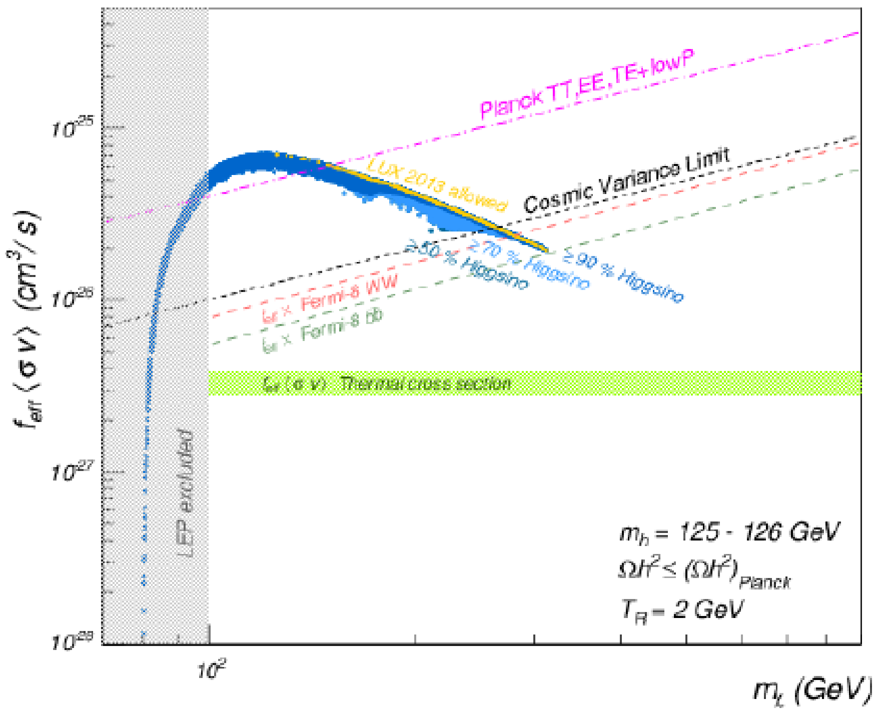
$$\frac{N_{14}}{N_{13}} = -\frac{\tan\alpha + m_h^2/m_H^2 \cot\alpha}{1 + m_h^2/m_H^2}$$

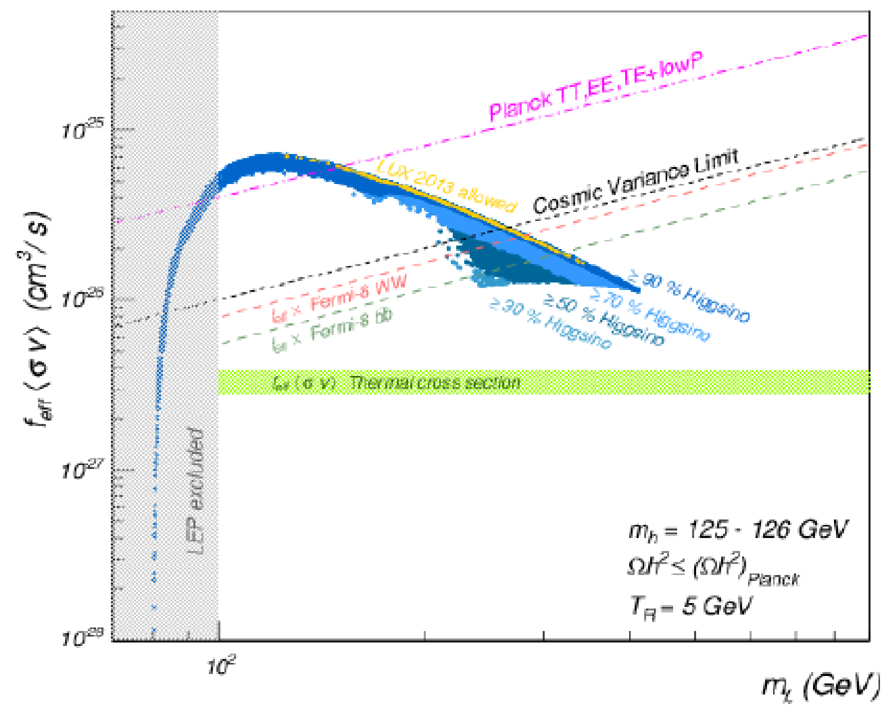
Sign mu < 0

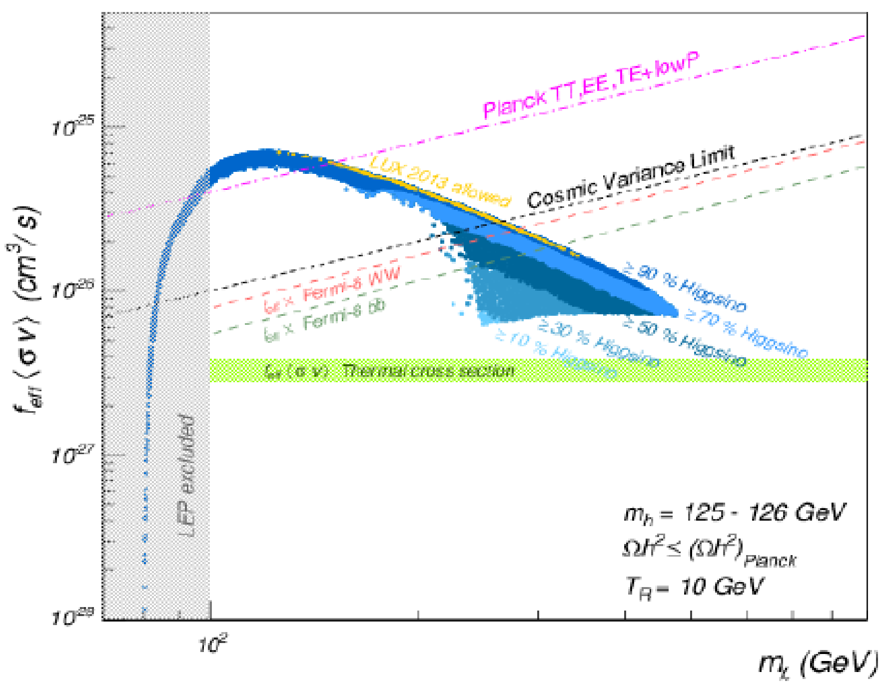




Analysis of results



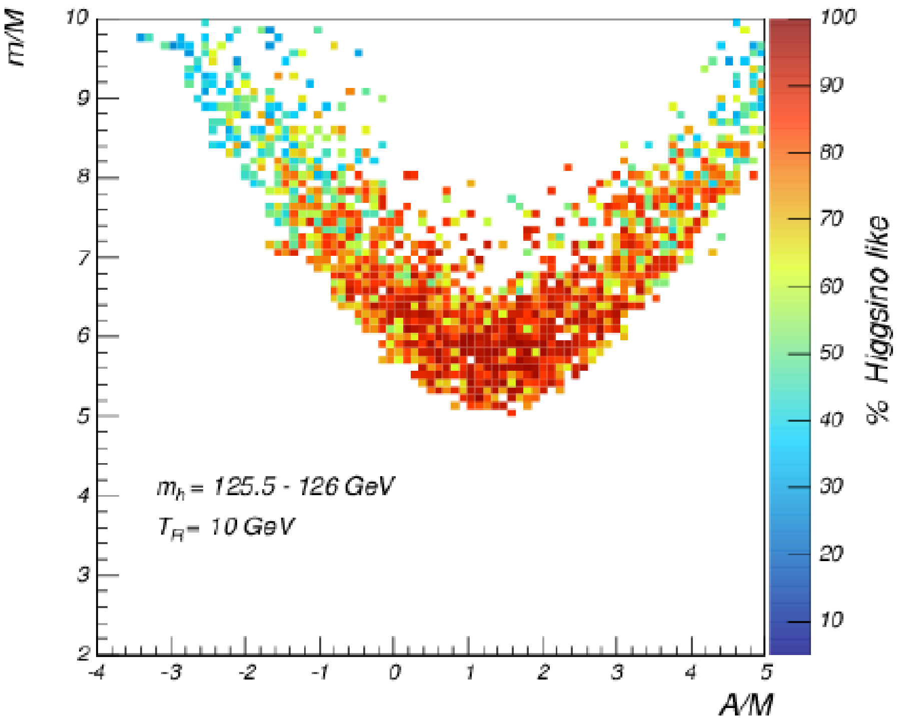


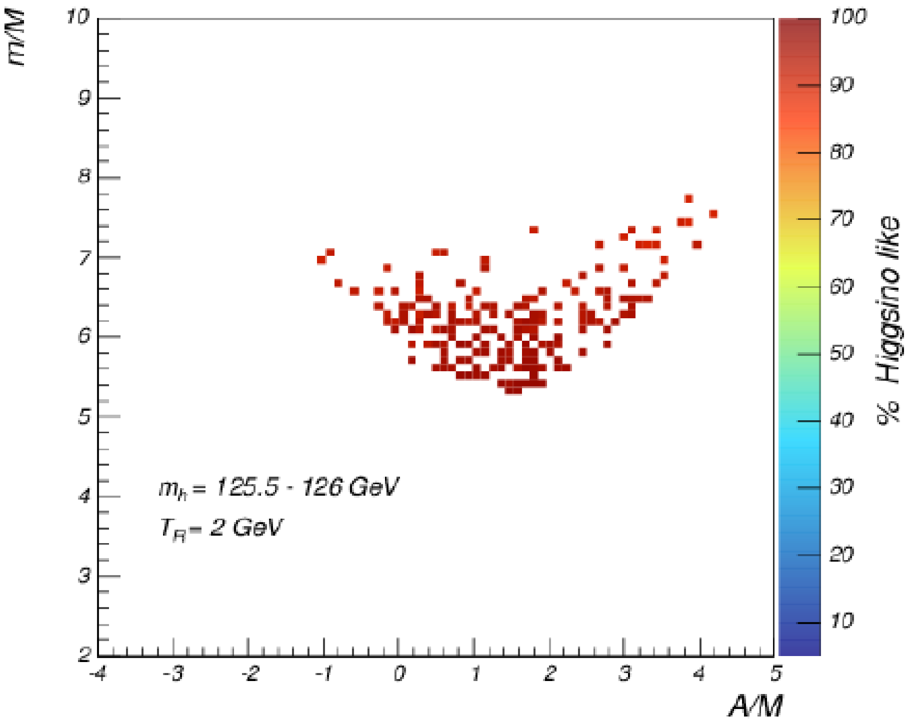


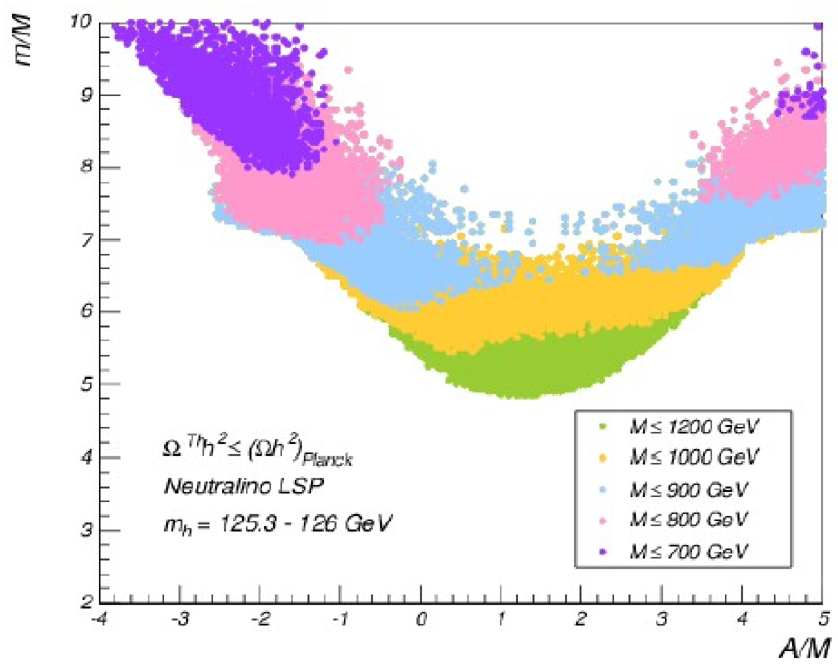
$$C_{\tilde{\chi}\tilde{\chi}h} \simeq \frac{m_Z \sin\theta_W \tan\theta_W}{M_1^2 - \mu^2}\left(M_1 + \mu \sin 2\beta\right)$$

$$C_{\tilde{\chi}\tilde{\chi}h} \simeq \frac{1}{2}\left(1 \pm \sin 2\beta\right)\left(\tan^2\theta_W \frac{m_Z \cos\theta}{M_1 - |\mu|} + \frac{m_Z \cos\theta}{M_2 - |\mu|}\right)$$

Analysis of results



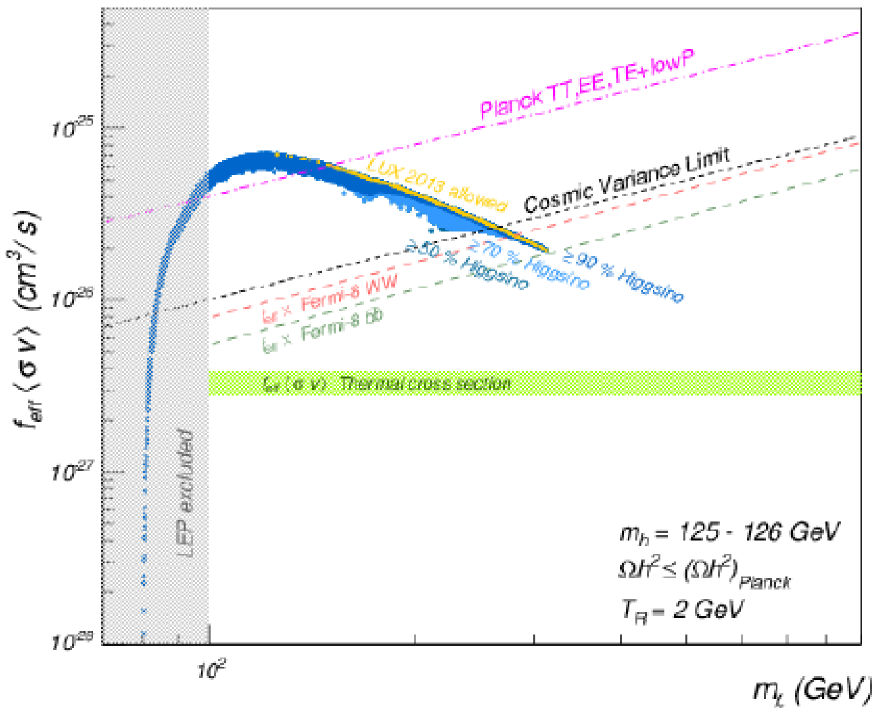


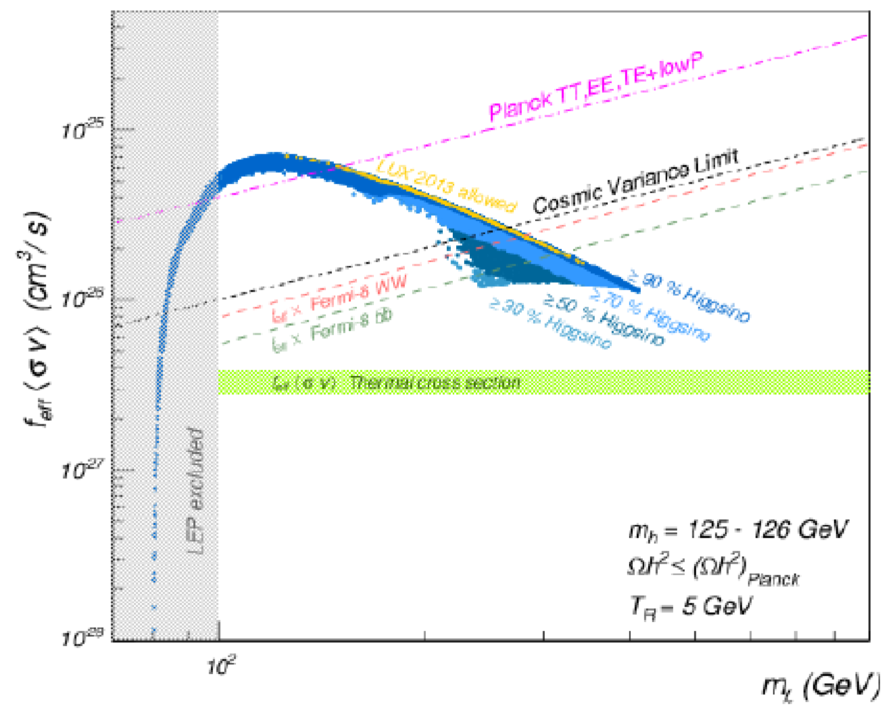


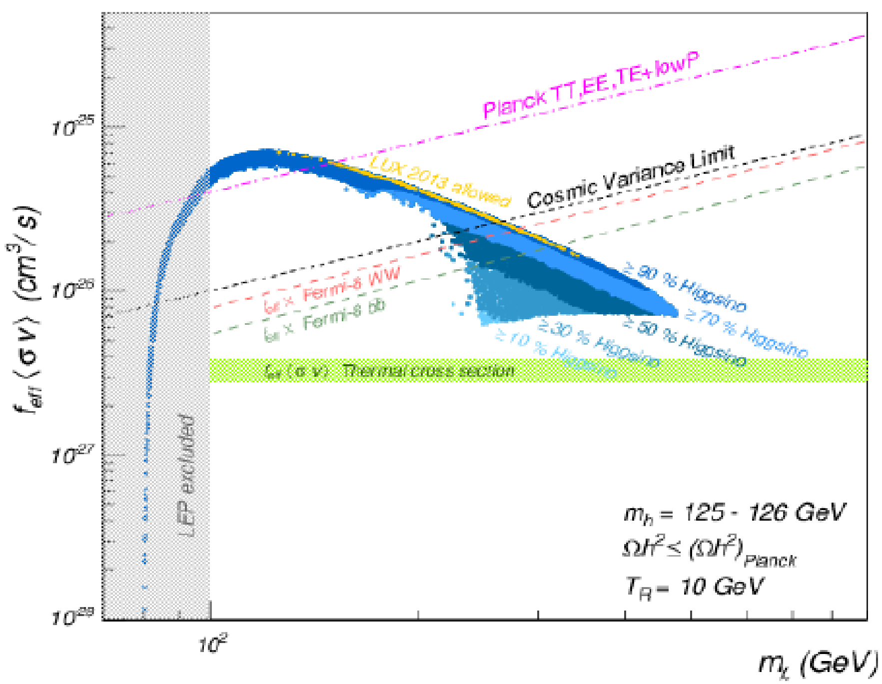
$$C_{\tilde{\chi}\tilde{\chi}h} \simeq \frac{m_Z \sin\theta_W \tan\theta_W}{M_1^2 - \mu^2}(M_1 + \mu \sin 2\beta)$$

$$C_{\tilde{\chi}\tilde{\chi}h} \simeq \frac{1}{2}(1 \pm \sin 2\beta)\left(\tan^2\theta_W \frac{m_Z \cos\theta}{M_1 - |\mu|} + \frac{m_Z \cos\theta}{M_2 - |\mu|}\right)$$

Analysis of results



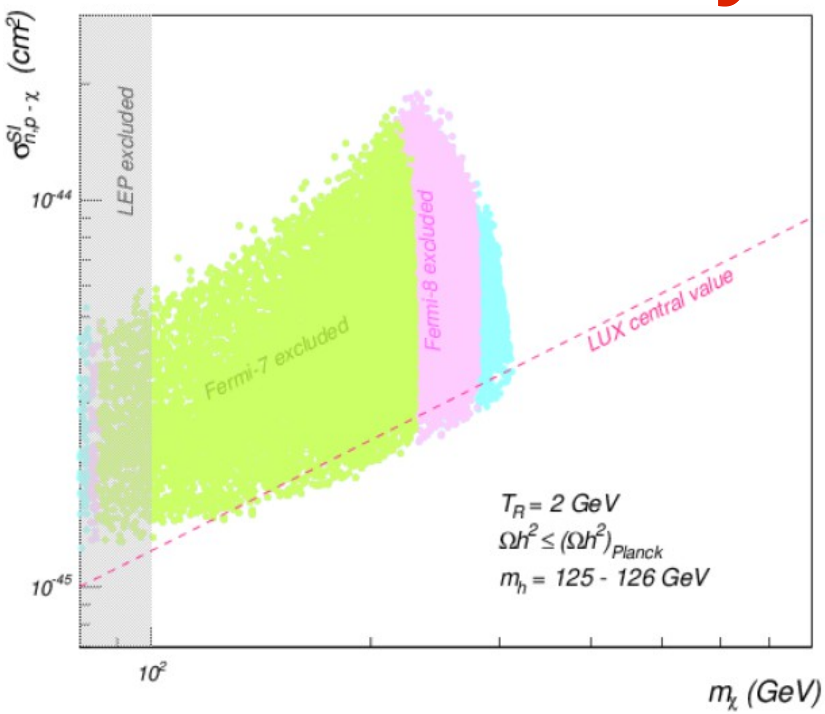


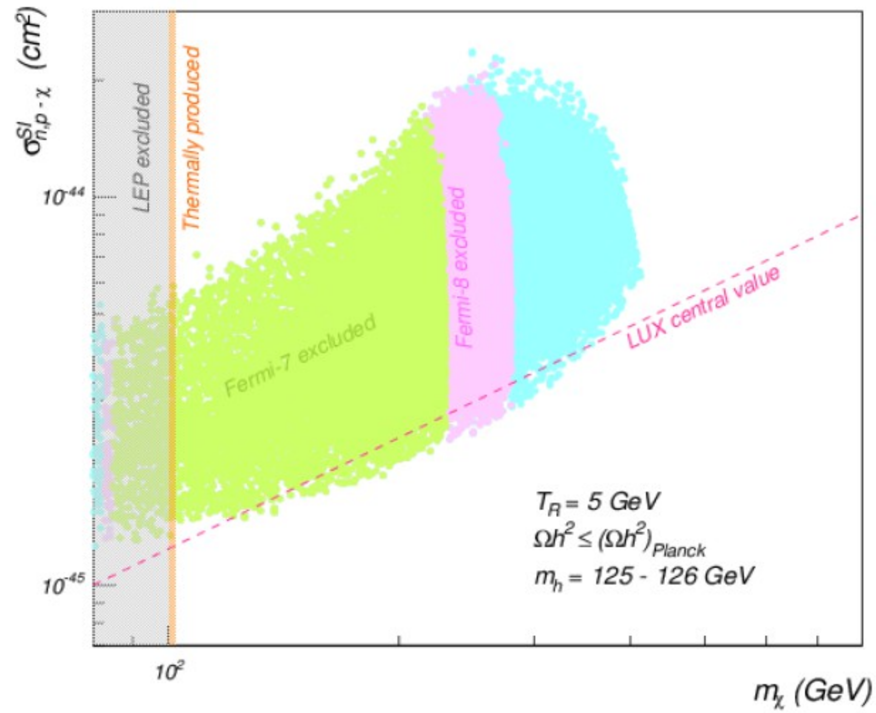


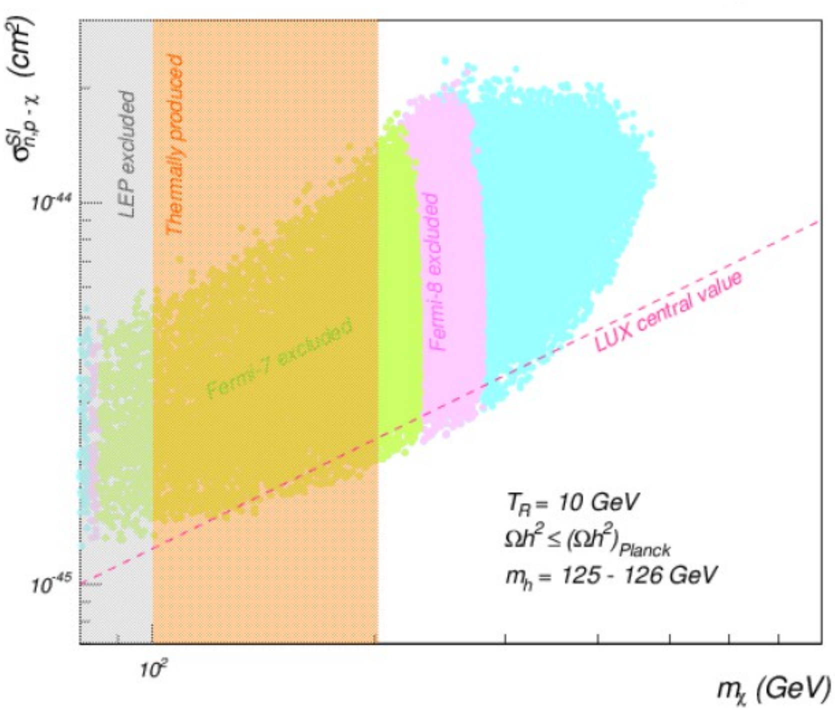
$$C_{\tilde{\chi}\tilde{\chi}h} \simeq \frac{m_Z \sin\theta_W \tan\theta_W}{M_1^2 - \mu^2} \left(M_1 + \mu \sin 2\beta\right)$$

$$C_{\tilde{\chi}\tilde{\chi}h} \simeq \frac{1}{2}\left(1 \pm \sin 2\beta\right)\left(\tan^2\theta_W \frac{m_Z \cos\theta}{M_1 - |\mu|} + \frac{m_Z \cos\theta}{M_2 - |\mu|}\right)$$

Analysis of results





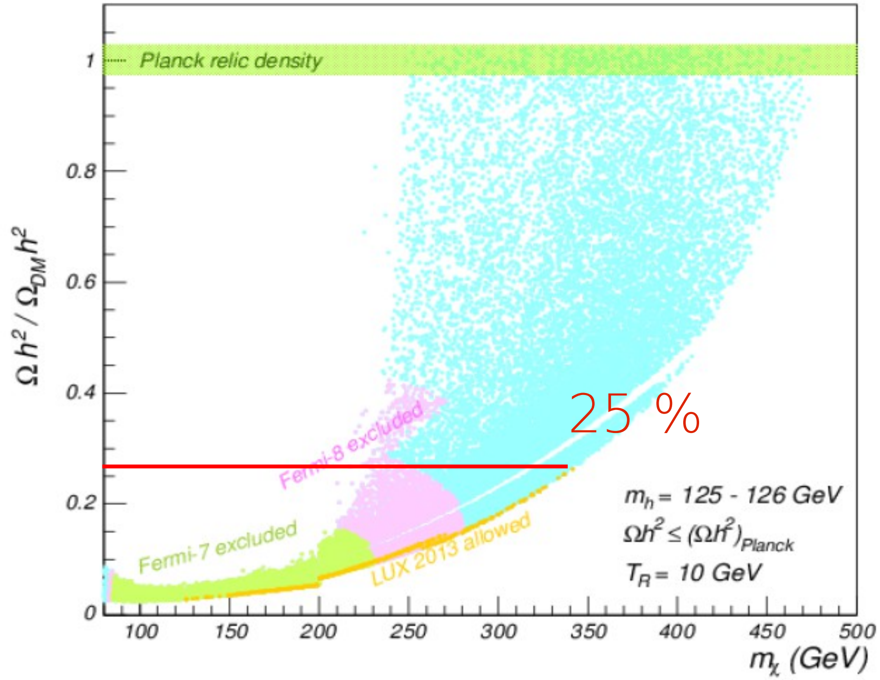


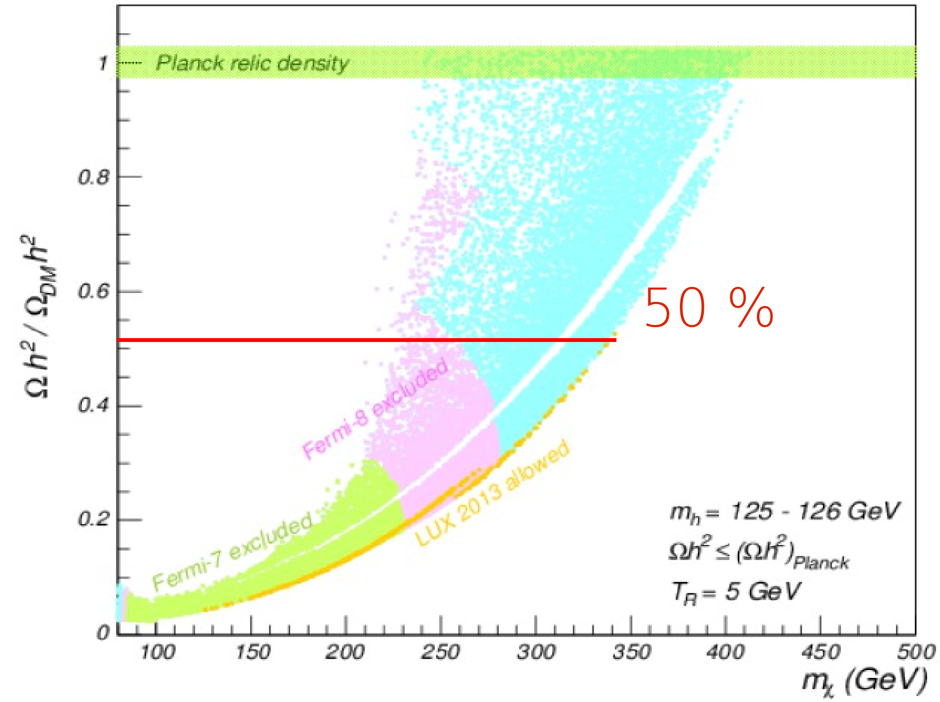
$$\langle \sigma_{\rm eff} v \rangle = \frac{g_2^4}{512\pi\mu^2}\left(21 + 3\tan^2\theta_W + 11\tan^4\theta_W\right)$$

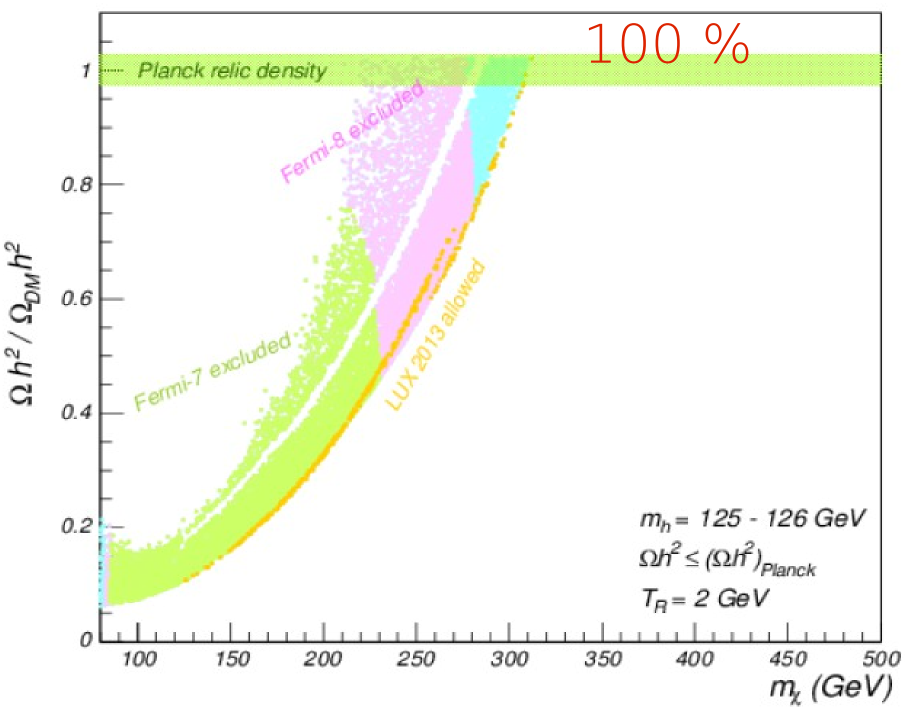
$$\langle \sigma_{\rm eff} v \rangle = \sum_f \frac{g_2^4 \tan^2\theta_W \left(T_{3_f} - Q_f\right)^4 r(1+r^2)}{2\pi m_{\tilde f}^2 (1+r)^4}$$

$$r = M_1^2/m_{\tilde f}^2$$

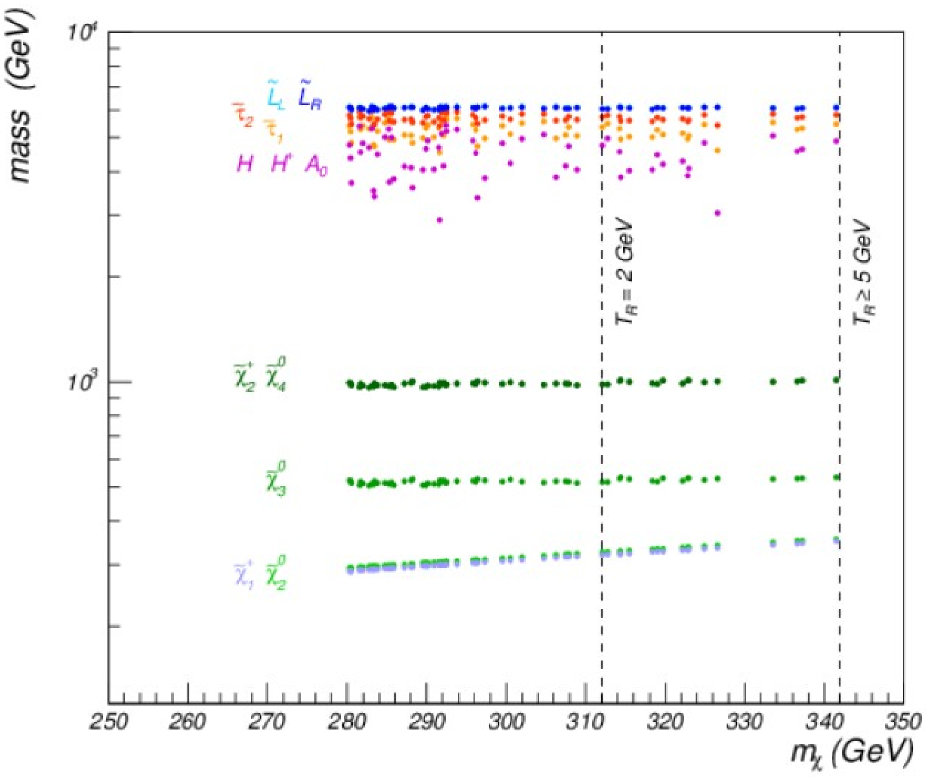
Analysis of results

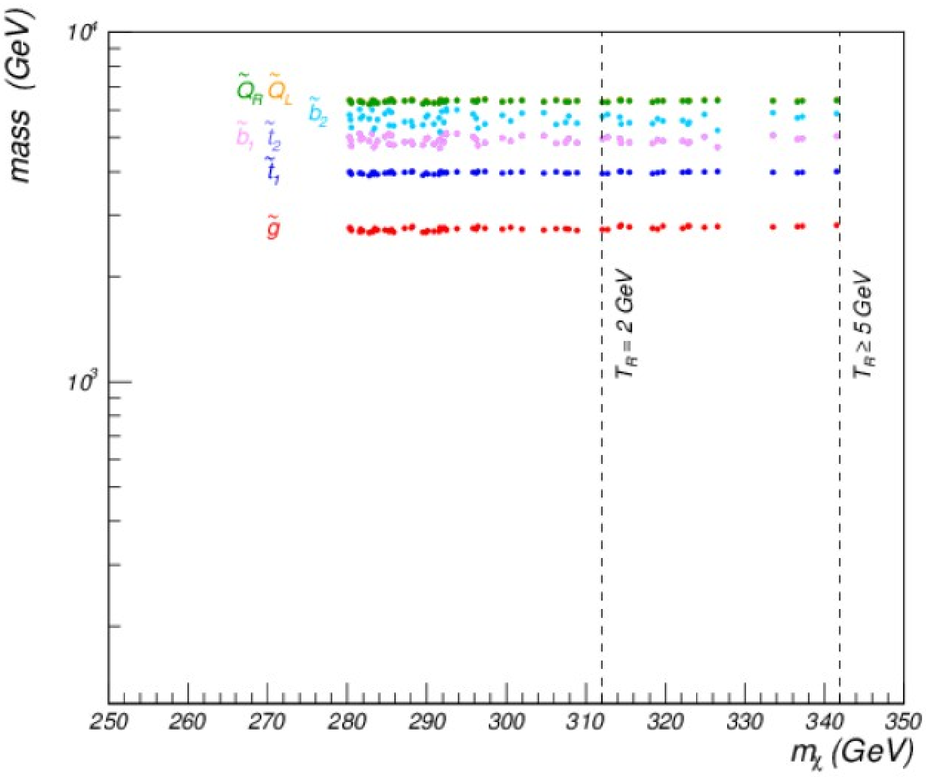




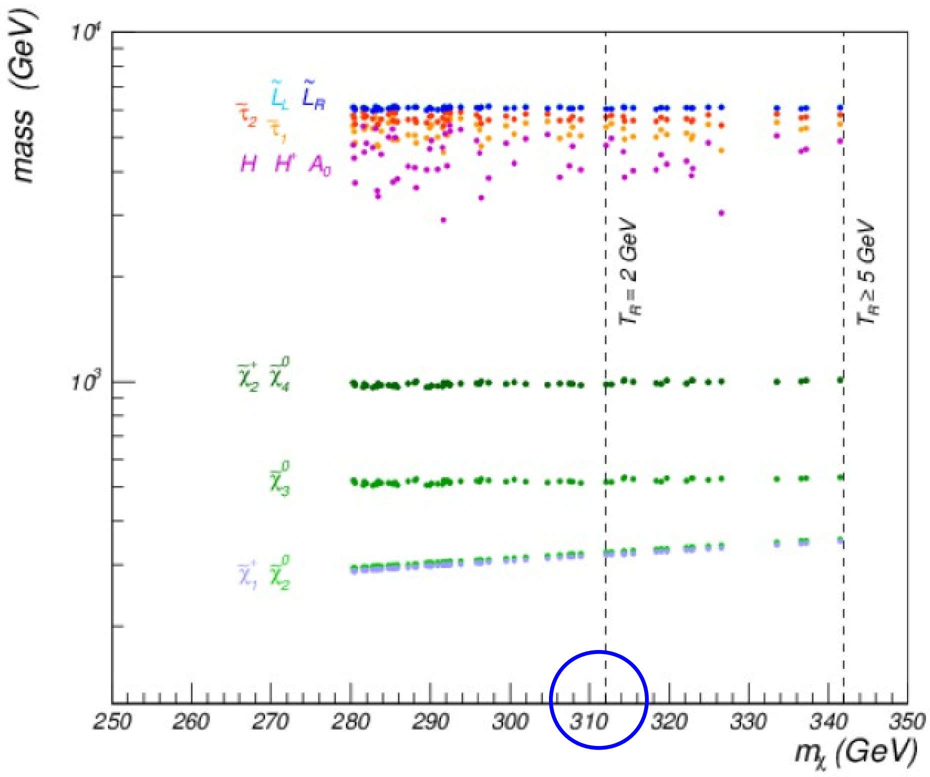


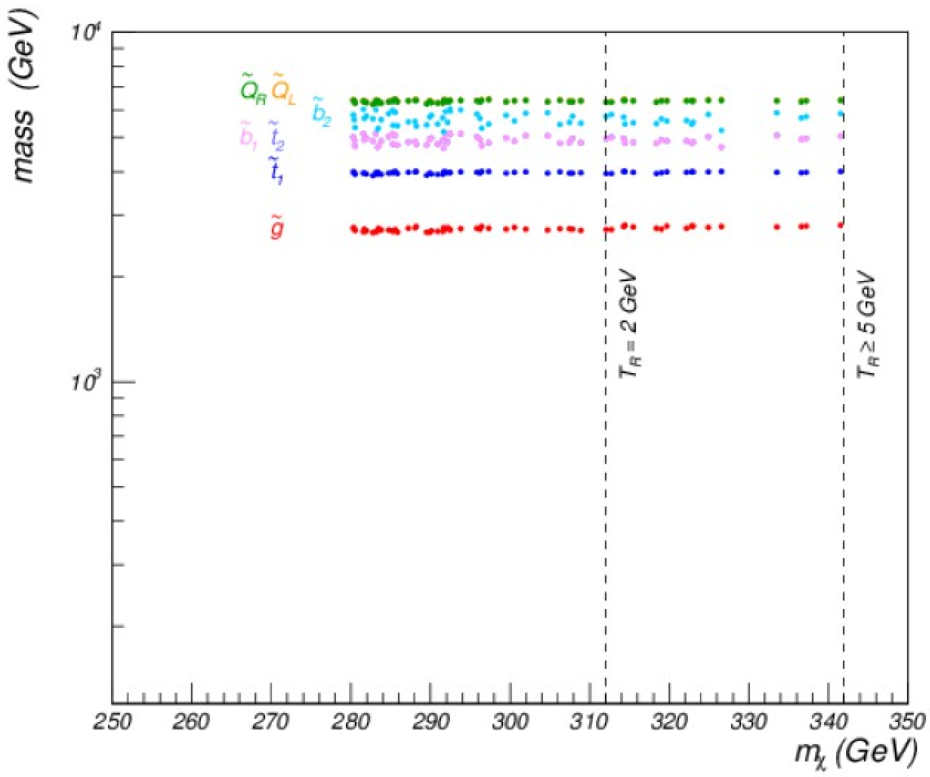
Spectrum and LHC prospects





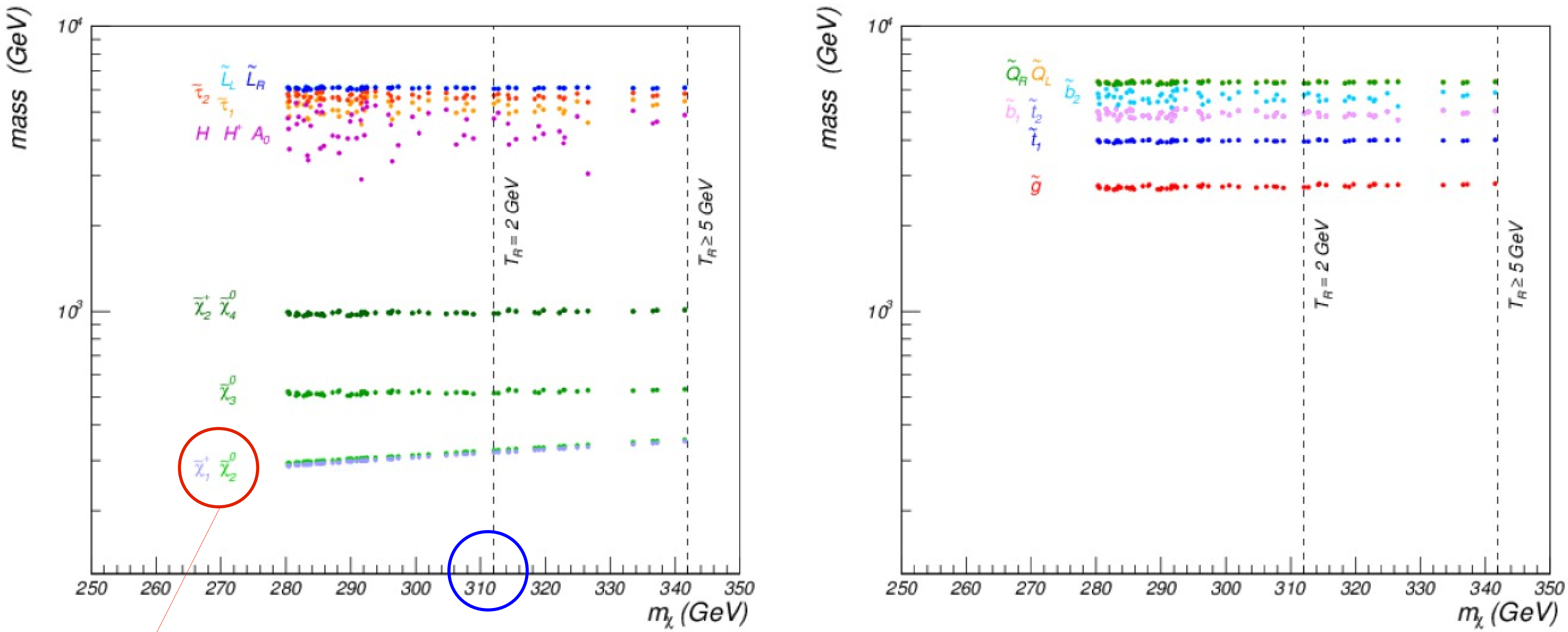
Spectrum and LHC prospects





Neutralino Higgsino like around 300 GeV saturates Planck for T = 2 GeV

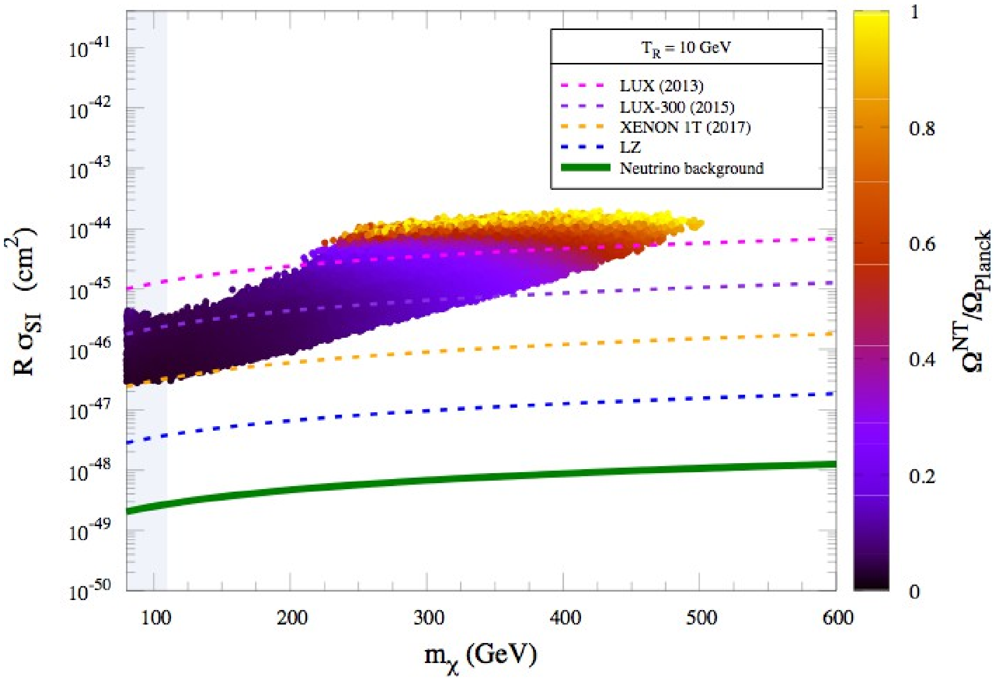
Spectrum and LHC prospects

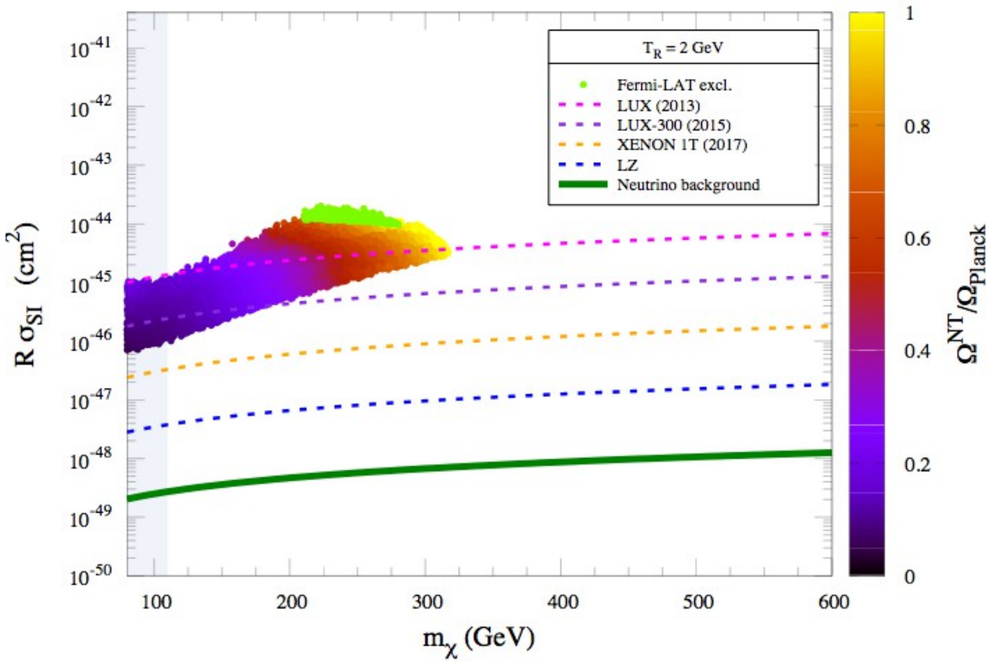


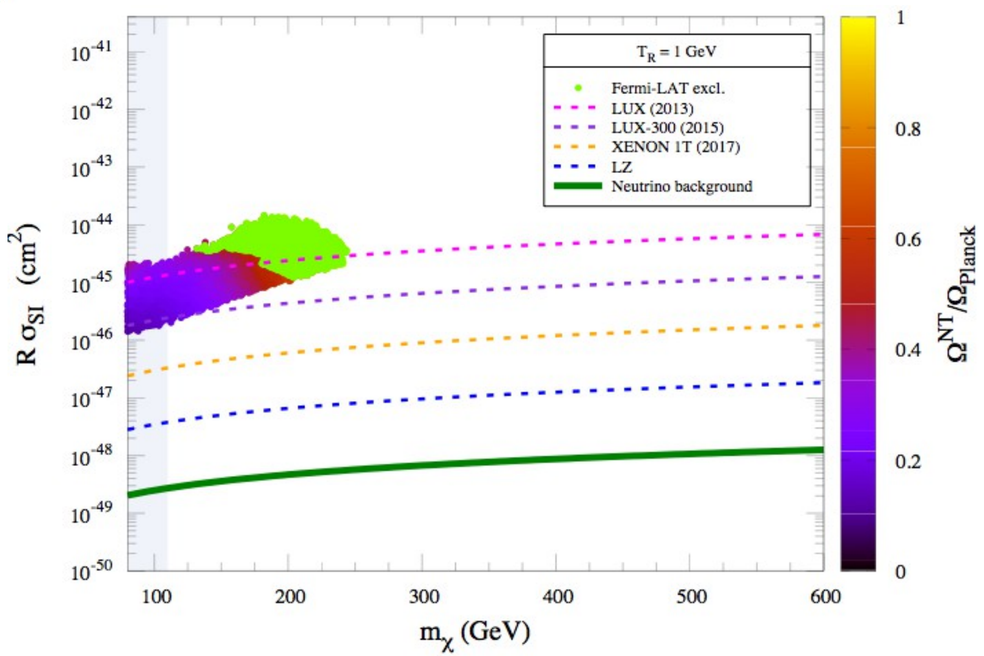
Neutralino Higgsino like around 300 GeV saturates Planck for T = 2 GeV

- Monojet + soft leptons + ME
- Monojet signal
- Vector Boson Fusion jets + large ME

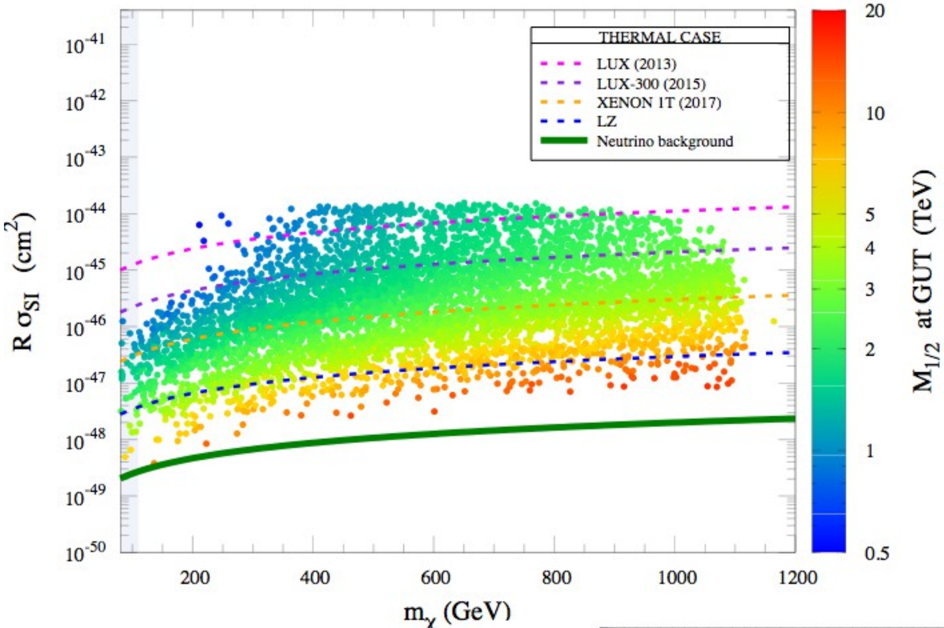
Analysis of results

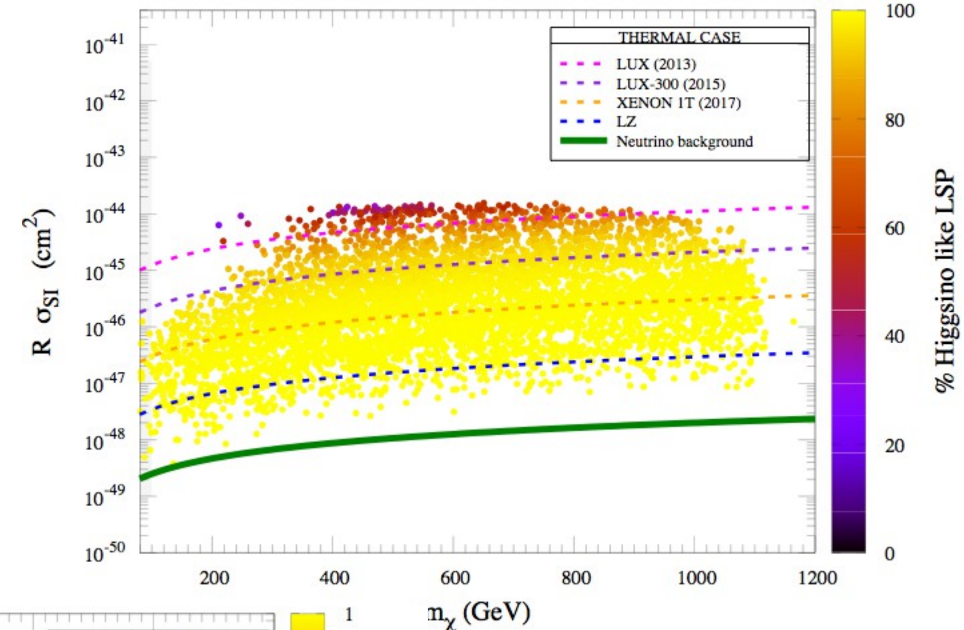


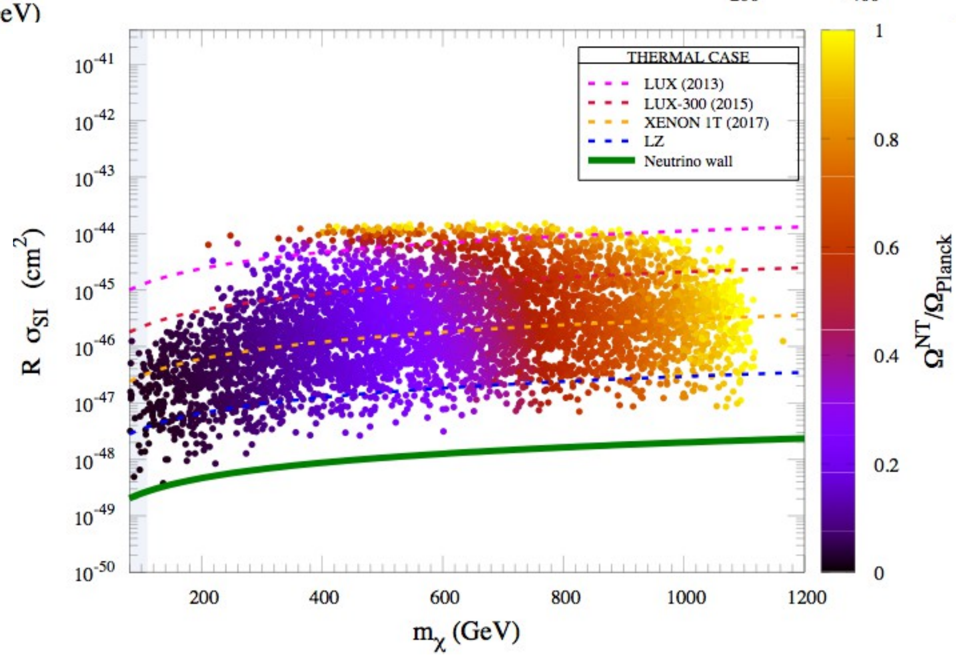




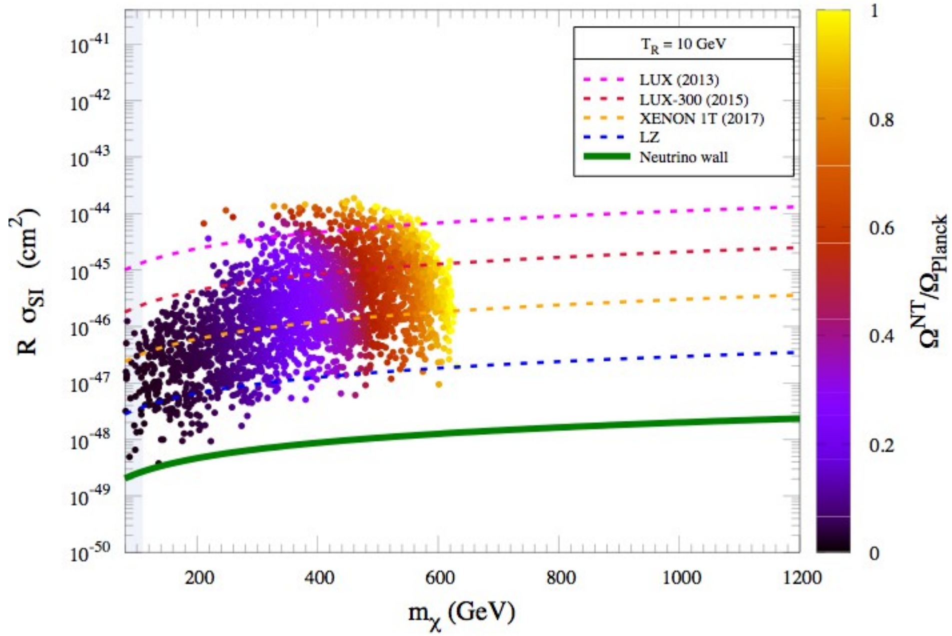
MSSM results (preliminary)

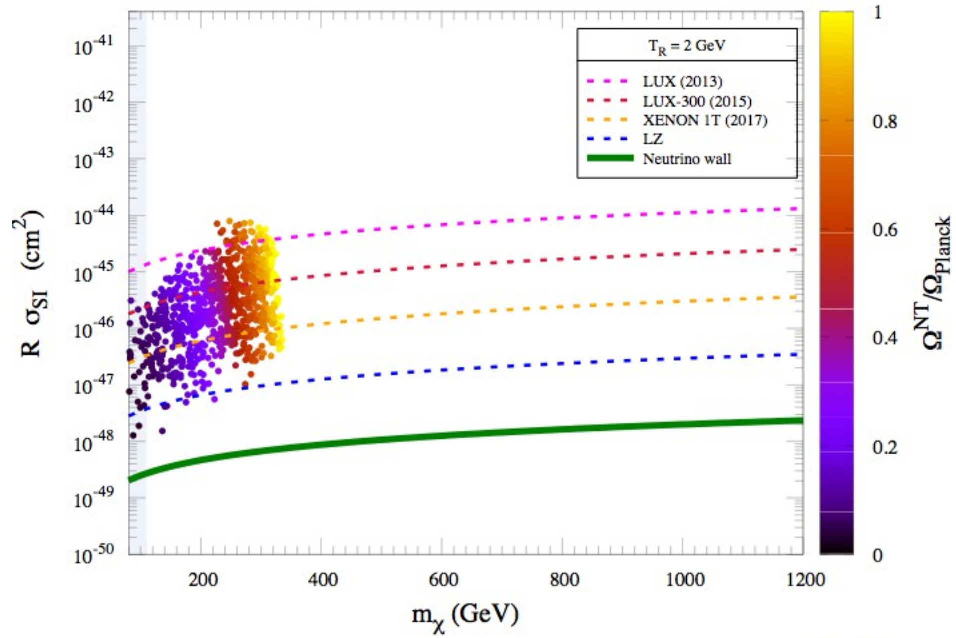


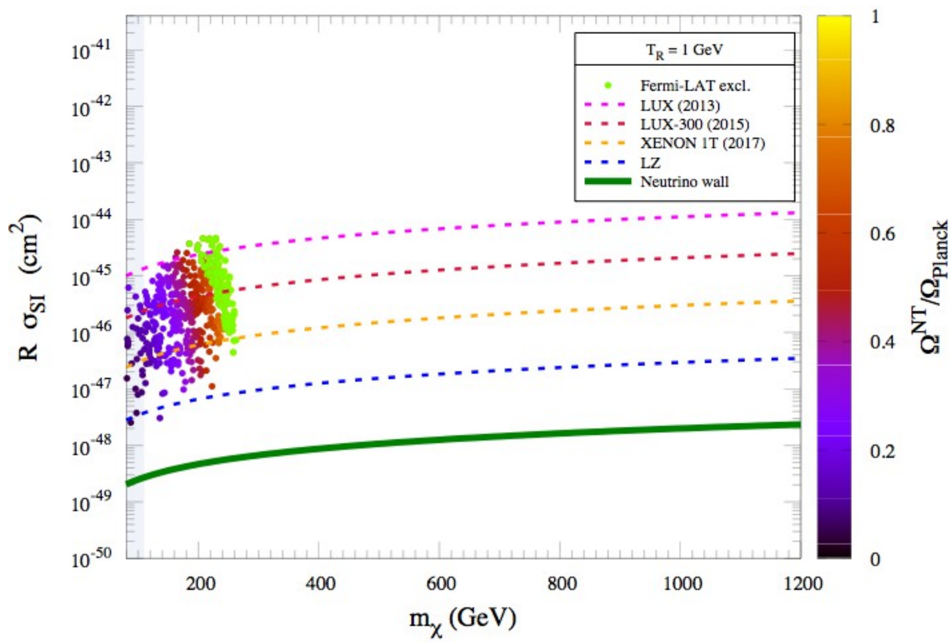


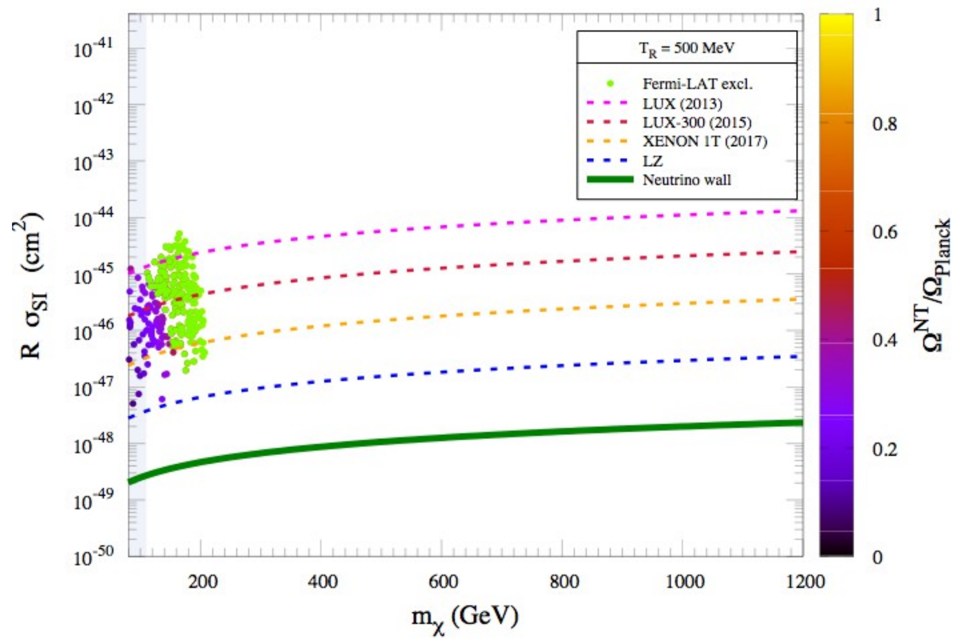


MSSM results (preliminary)

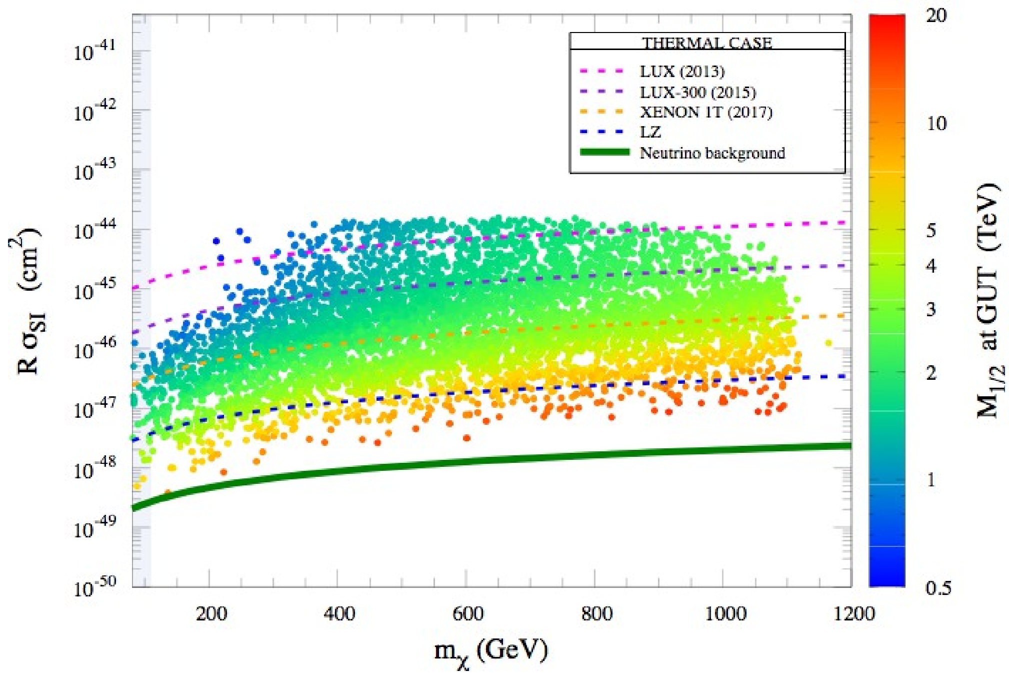


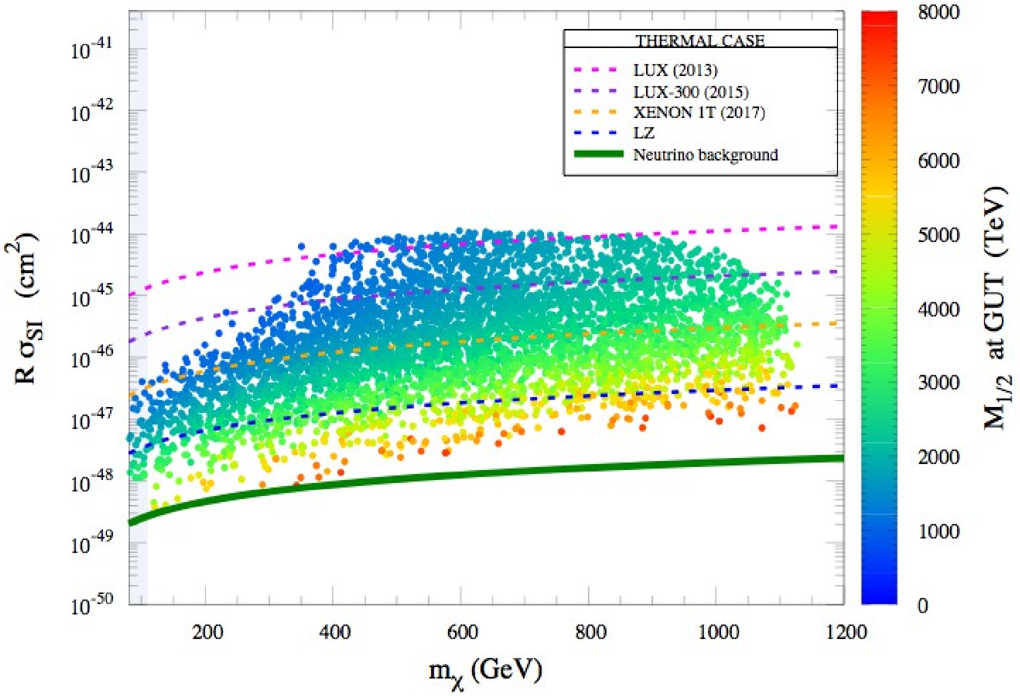




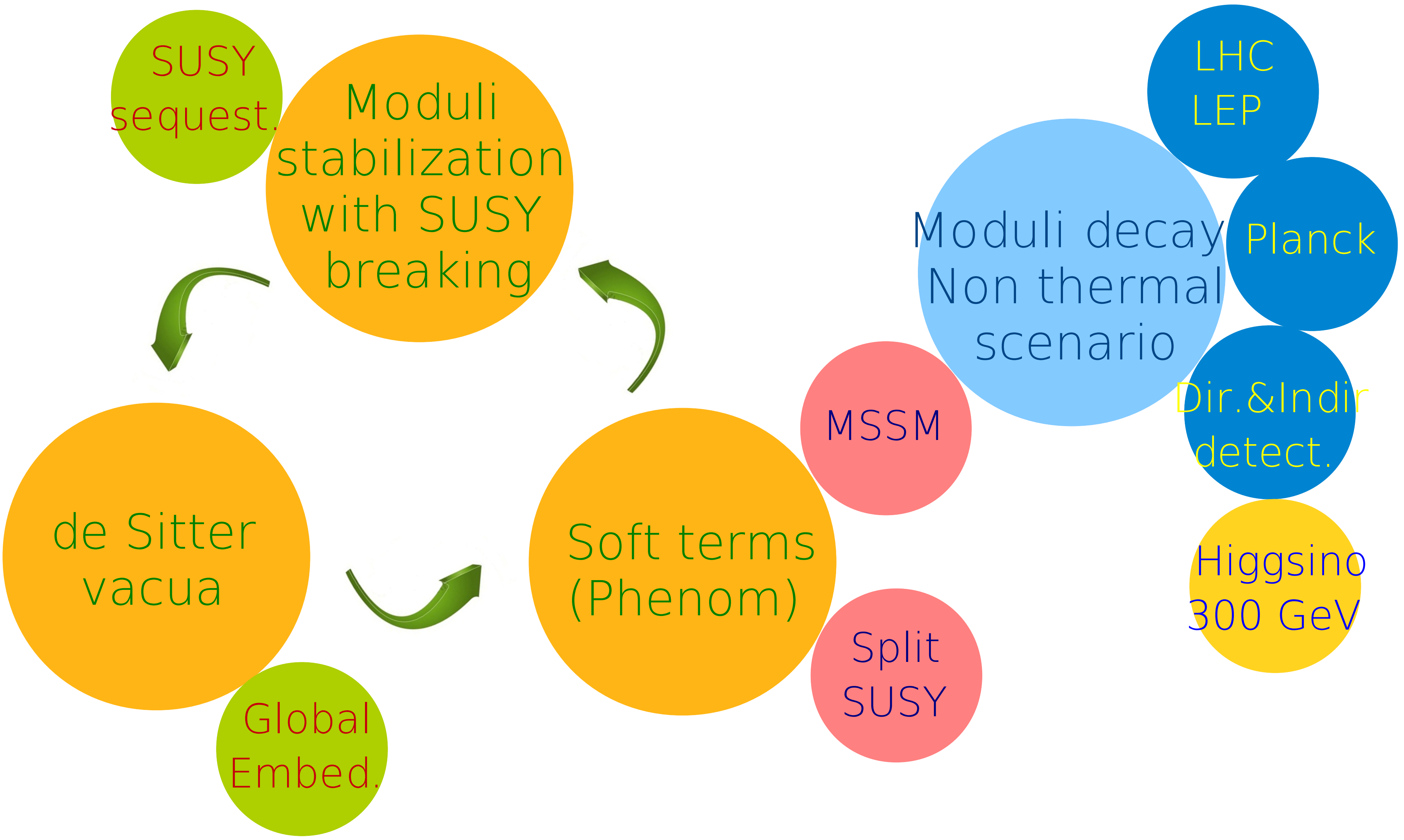


MSSM results (preliminary)





Conclusions



Conclusions

SUSY sequest.

Moduli stabilization with SUSY breaking

de Sitter vacua

Global Embed.

Soft terms (Phenom)

MSSM

Split SUSY

Moduli decay Non thermal scenario

LHC LEP

Planck

Dir.&Indir detect.

Backup slides

F-terms and soft terms

Matter metric

$$\tilde{K}_\alpha = \frac{f_\alpha(U,S)}{\mathcal{V}^{2/3}}\left(1 - c_s\frac{\hat{\xi}}{\mathcal{V}} + \tilde{K}_{dS} + c_{SM}\tau_{SM}^p + c_b b^p\right),$$

Local

$$\hat{Y}_{\alpha\beta\gamma} = e^{K/2}\frac{Y_{\alpha\beta\gamma}(U,S)}{\sqrt{\tilde{K}_\alpha\tilde{K}_\beta\tilde{K}_\gamma}}$$

⇒

$$\tilde{K}_\alpha = h_\alpha(S,U)\,e^{K/3} \simeq \frac{h_\alpha(U,S)\,e^{K_{cs}/3}}{(2s)^{1/3}\mathcal{V}^{2/3}}\left(1 - \frac{\hat{\xi}}{3\mathcal{V}} + \frac{1}{3}K_{dS}\right)$$

Ultralocal

F-terms and soft terms

Matter metric

$$\tilde{K}_\alpha = \frac{f_\alpha(U,S)}{\mathcal{V}^{2/3}}\left(1 - c_s\frac{\hat{\xi}}{\mathcal{V}} + \tilde{K}_{ds} + c_{SM}\tau_{SM}^p + c_b b^p\right),$$

Local

$$\hat{Y}_{\alpha\beta\gamma} = e^{K/2}\frac{Y_{\alpha\beta\gamma}(U,S)}{\sqrt{\tilde{K}_\alpha\tilde{K}_\beta\tilde{K}_\gamma}}$$

⇨

$$\tilde{K}_\alpha = h_\alpha(S,U)\, e^{K/3} \simeq \frac{h_\alpha(U,S)\, e^{K_{cs}/3}}{(2s)^{1/3}\mathcal{V}^{2/3}}\left(1 - \frac{\hat{\xi}}{3\mathcal{V}} + \frac{1}{3}K_{ds}\right)$$

Ultralocal

Gaugino masses

$$M_{1/2} = \frac{F^S}{2s} \simeq \frac{3\omega'_S(U,S)\hat{\xi}}{4}\frac{m_{3/2}}{\mathcal{V}} \sim \mathcal{O}\left(m_{3/2}\epsilon\right) \ll m_{3/2}$$

$$\epsilon \equiv \frac{m_{3/2}}{M_P} \ll 1$$

Non-thermal dark matter

Non thermal dark matter relic density

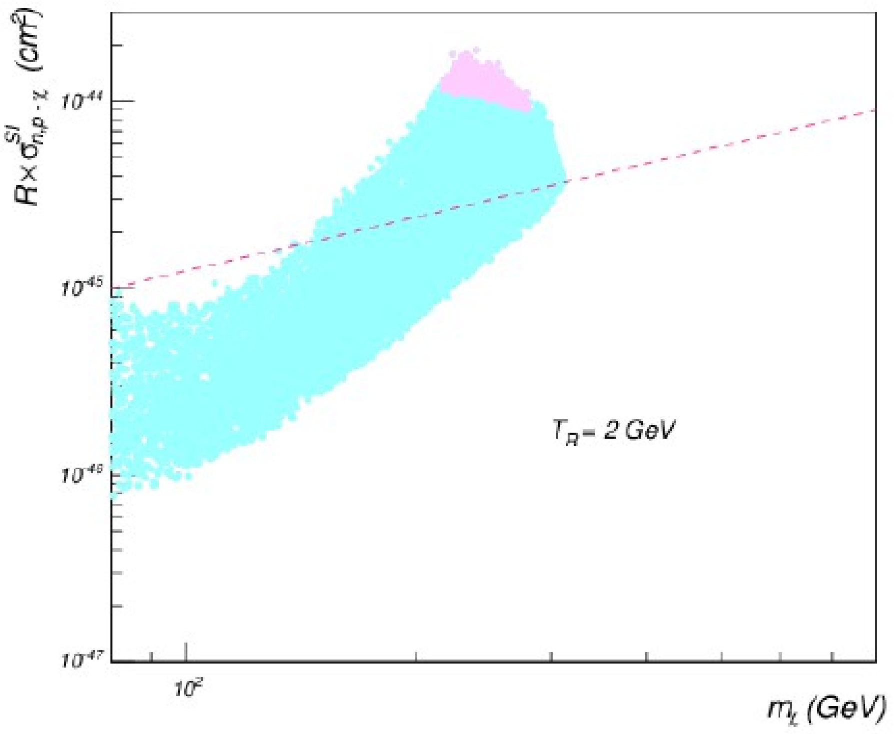
$$\left(\frac{n_\chi}{s}\right)^{\rm NT} = \min\left[\left(\frac{n_\chi}{s}\right)_{\rm obs}\frac{\langle\sigma_{\rm ann}v\rangle_f^{\rm Th}}{\langle\sigma_{\rm ann}v\rangle_f}\sqrt{\frac{g_*(T_f)}{g_*(T_R)}}\left(\frac{T_f}{T_R}\right), Y_{\rm mod}\,{\rm Br}_\chi\right]$$

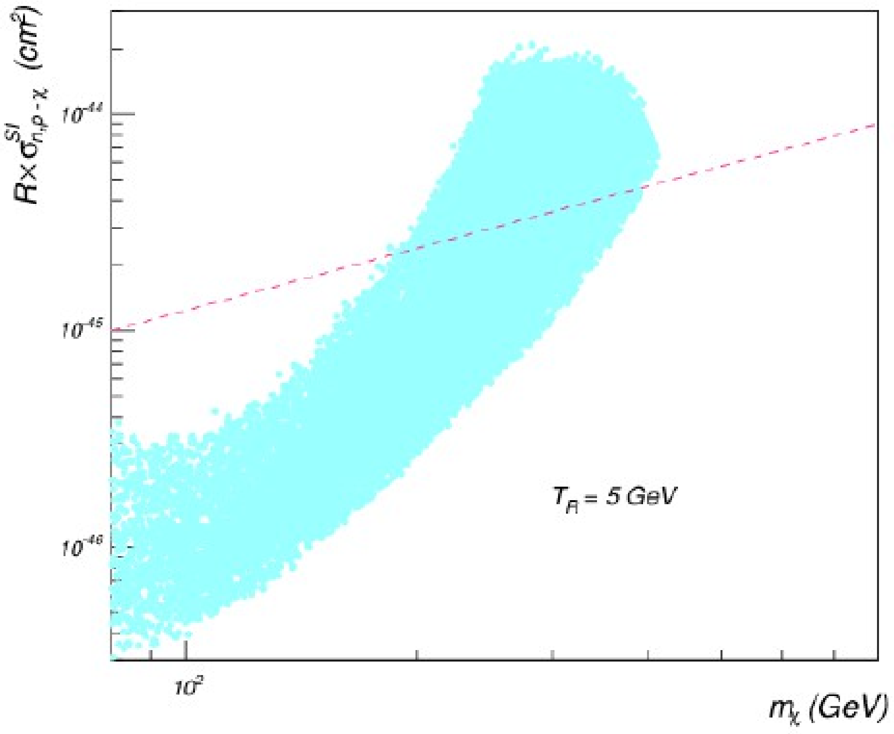
$$\langle\sigma_{\rm ann}v\rangle_f^{\rm Th} \simeq 2\times 10^{-26}{\rm cm}^3\,{\rm s}^{-1}$$

$$\left(\frac{n_\chi}{s}\right)_{\rm obs} = \left(\Omega_\chi h^2\right)_{\rm obs}\left(\frac{\rho_{\rm crit}}{m_\chi s h^2}\right) \simeq 0.12\left(\frac{\rho_{\rm crit}}{m_\chi s h^2}\right)$$

$$Y_{\rm mod} \equiv \frac{3T_R}{4m_{\rm mod}} \sim \sqrt{\frac{m_{\rm mod}}{M_P}}$$

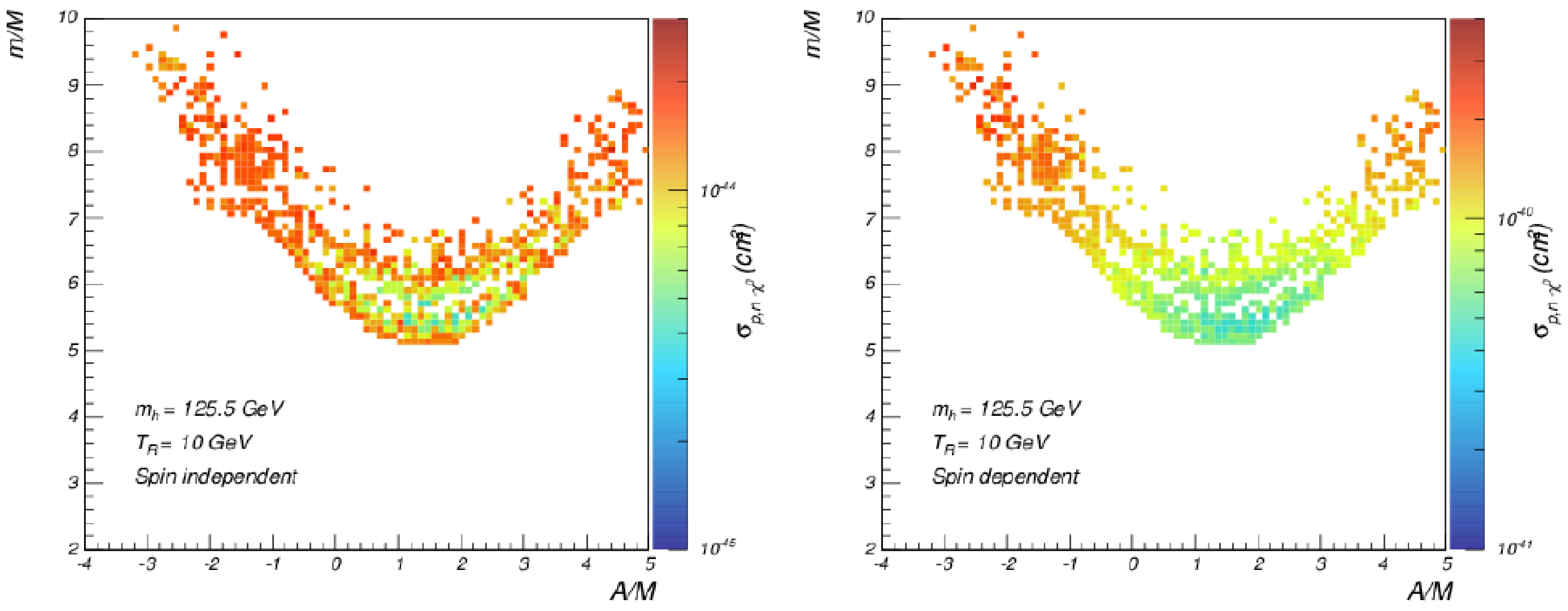
Astrophysical uncertainties





$$R = \frac{\Omega^{NT}h^2}{0.12} \simeq \frac{T_f}{T_R}\frac{\Omega^{Th}h^2}{0.12}$$

Spin independent / dependent



SUSY scale and Higgs mass