Constraining sleptons at the LHC in a supersymmetric low-scale seesaw scenario

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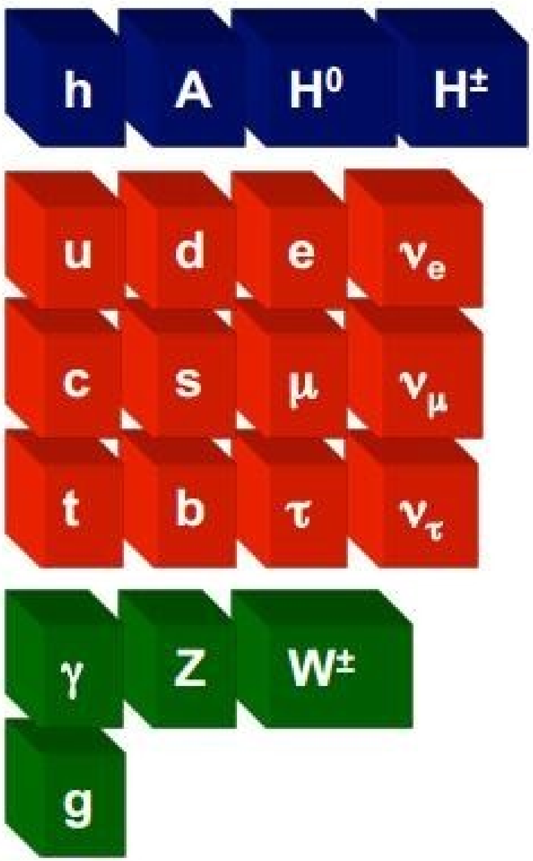
HEP - PUCP

Pontificia Universidad Católica del Perú

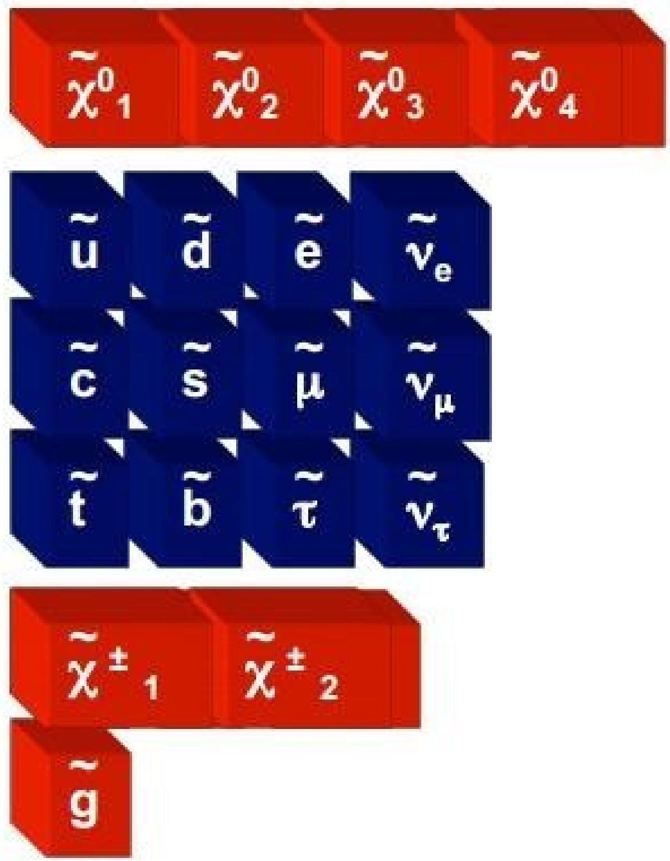
November 26, 2018

Minimal Supersymmetric Standard Model

Standard particles



Supersymmetry particles



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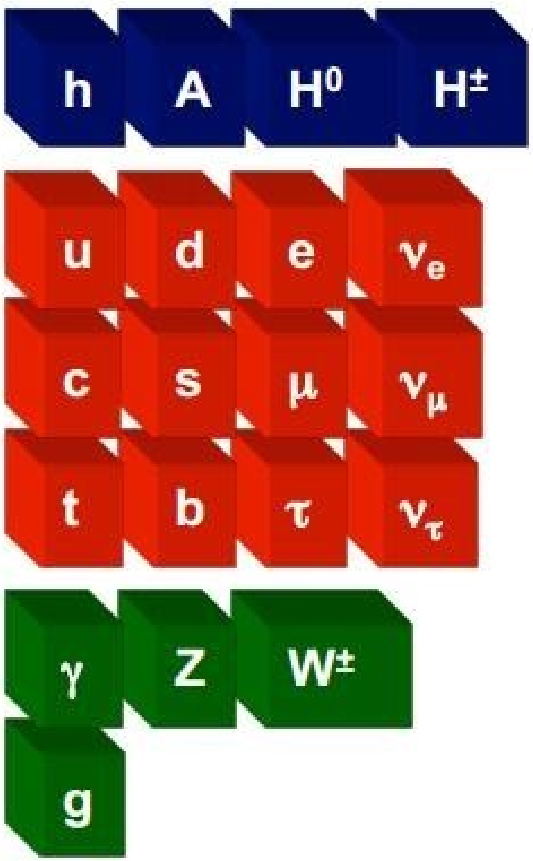

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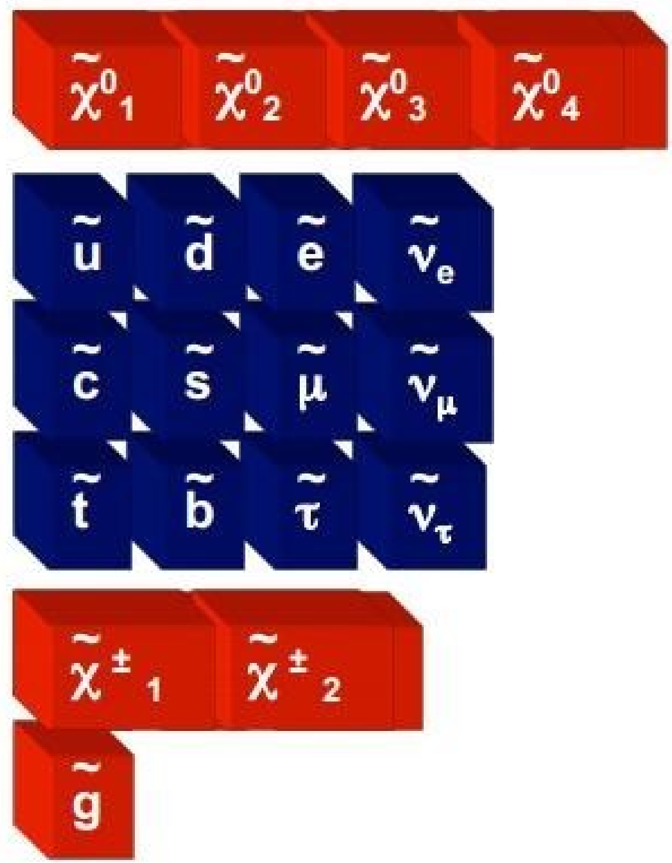

- Solves quadratic divergences
- Predicts new particles (DM canditate).

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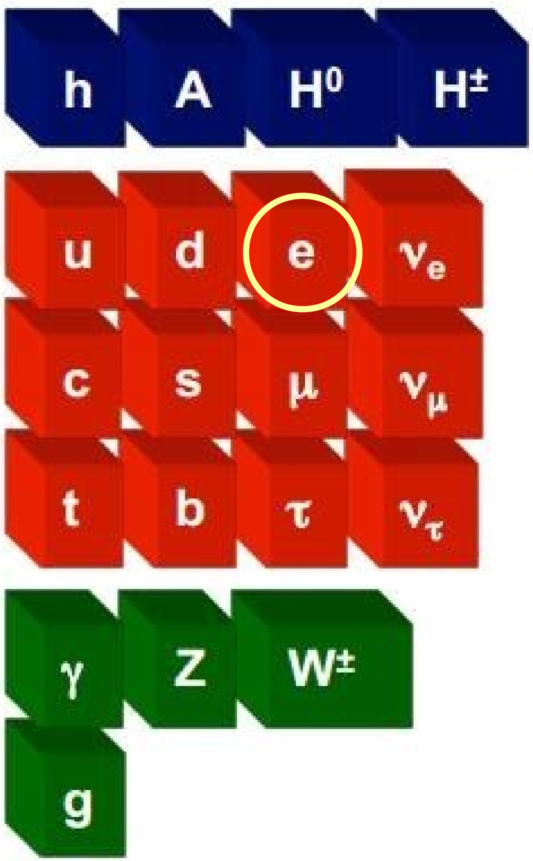

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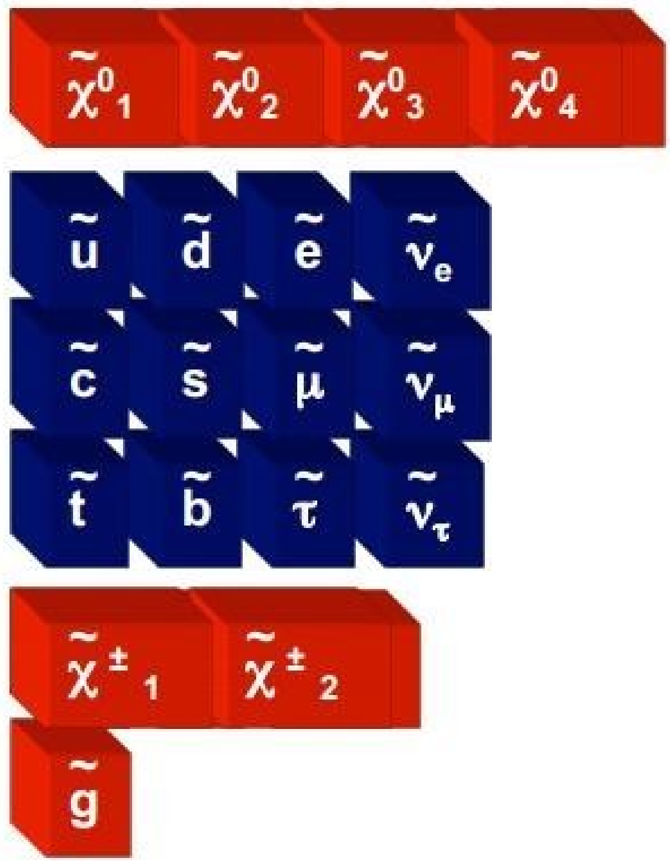

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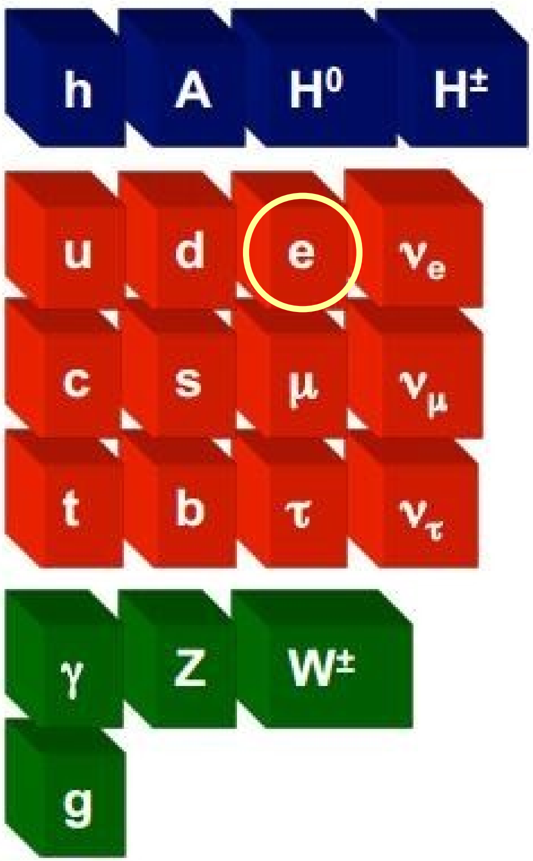

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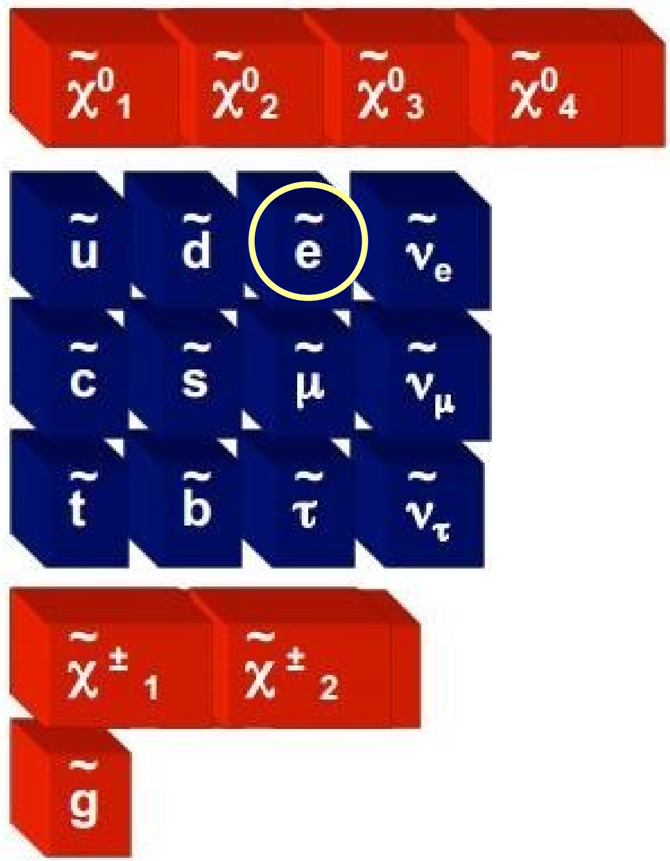

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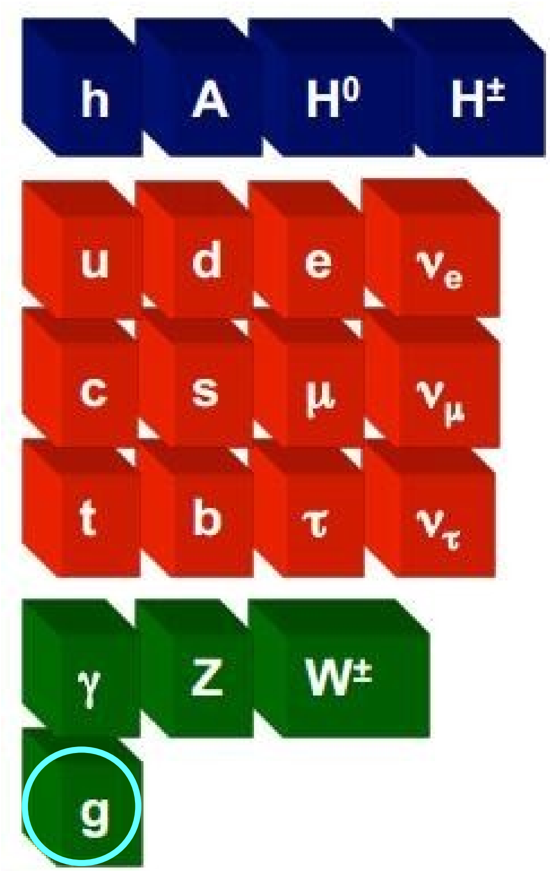

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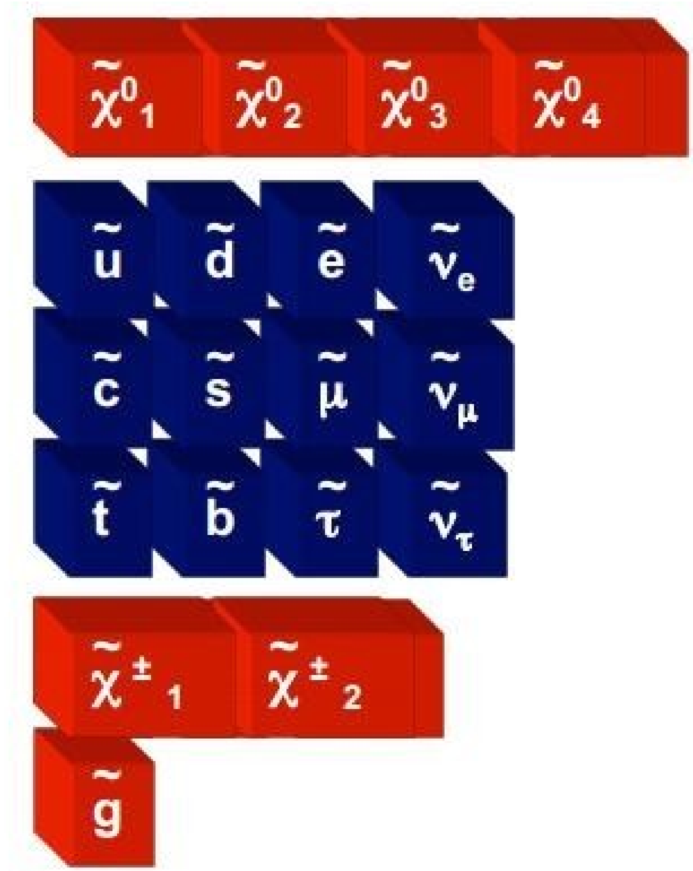

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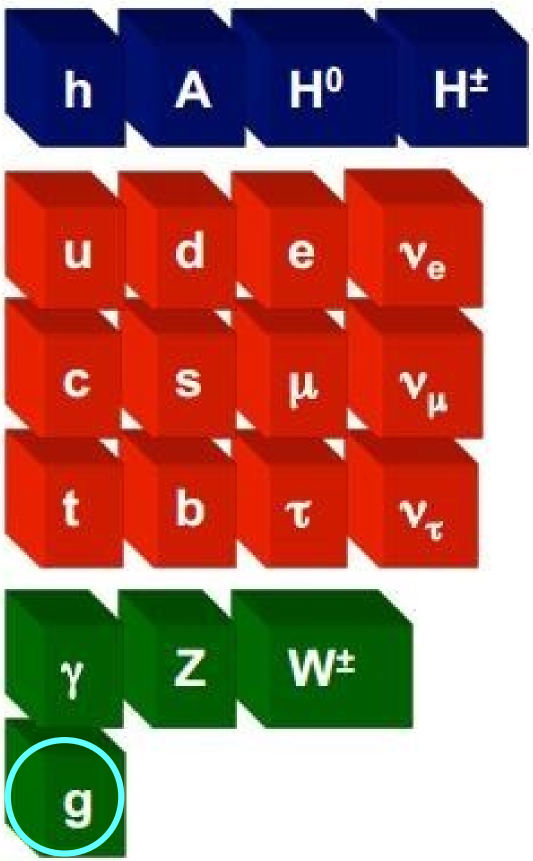

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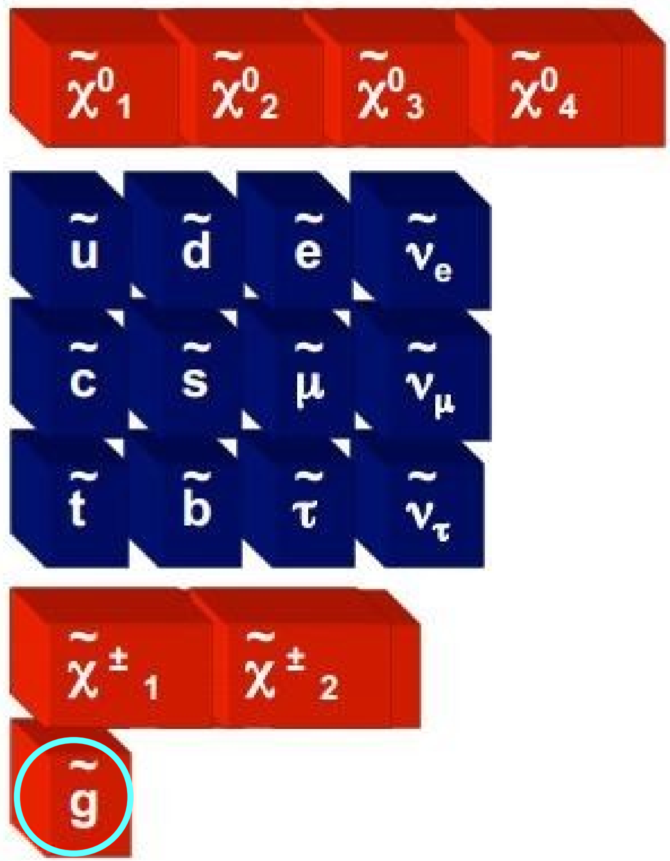

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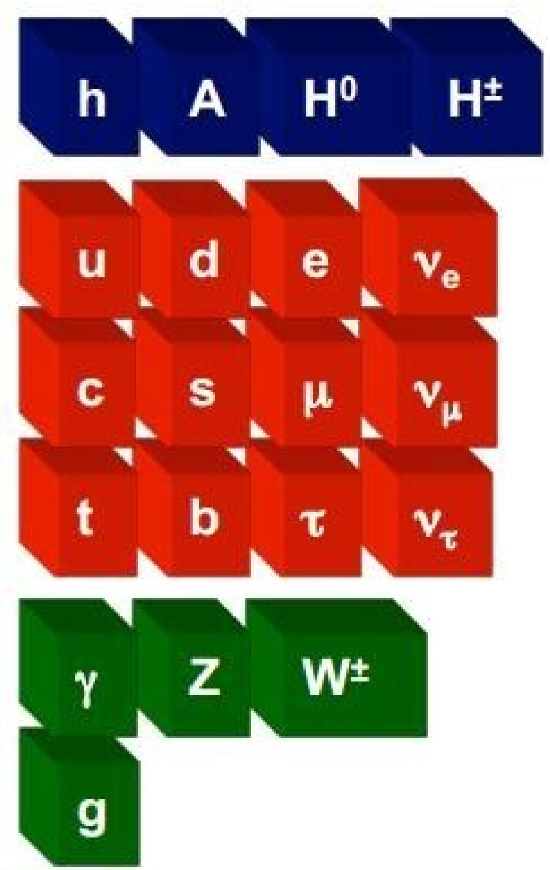

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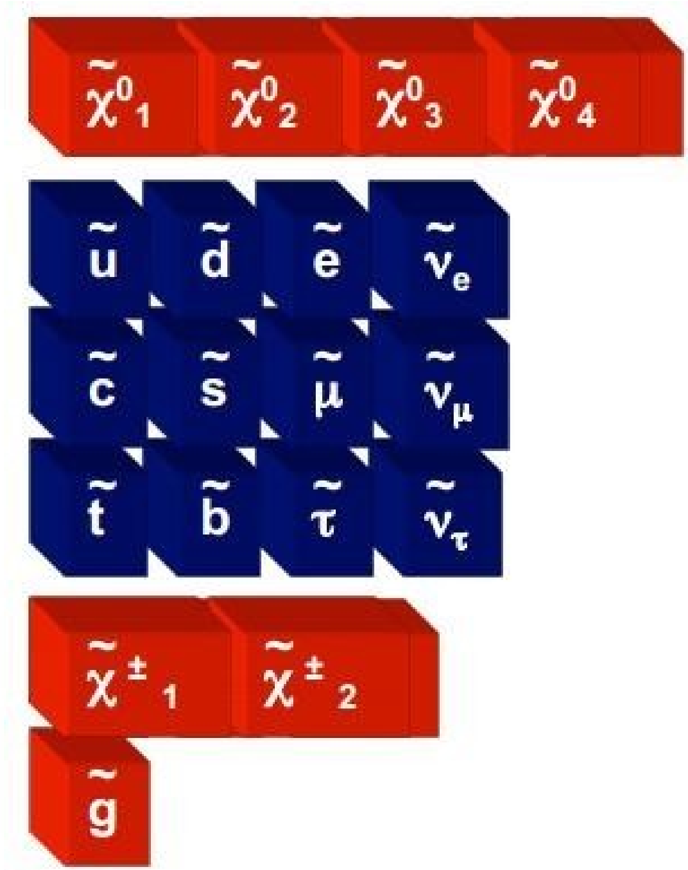

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The model predicts:

Spín ½ ↔ Spín 0

Spín 1 or 0 ↔ Spín ½

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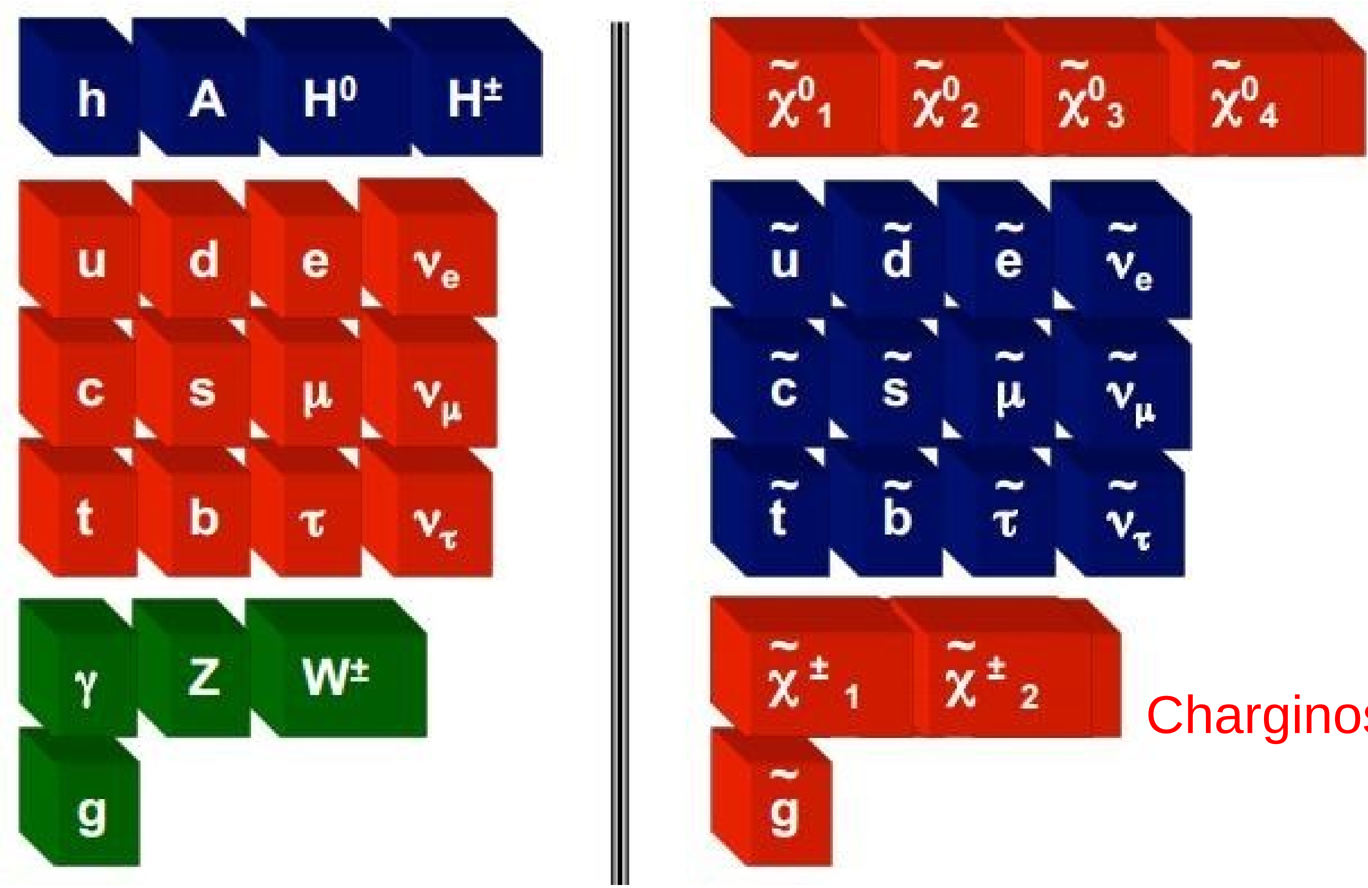

Neutralinos

Charginos

- Solves quadratic divergences
- Predicts new particles (DM canditate).

The model predicts:

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Spín 1 or 0 ↔ Spín ½

Seesaw mechanism.

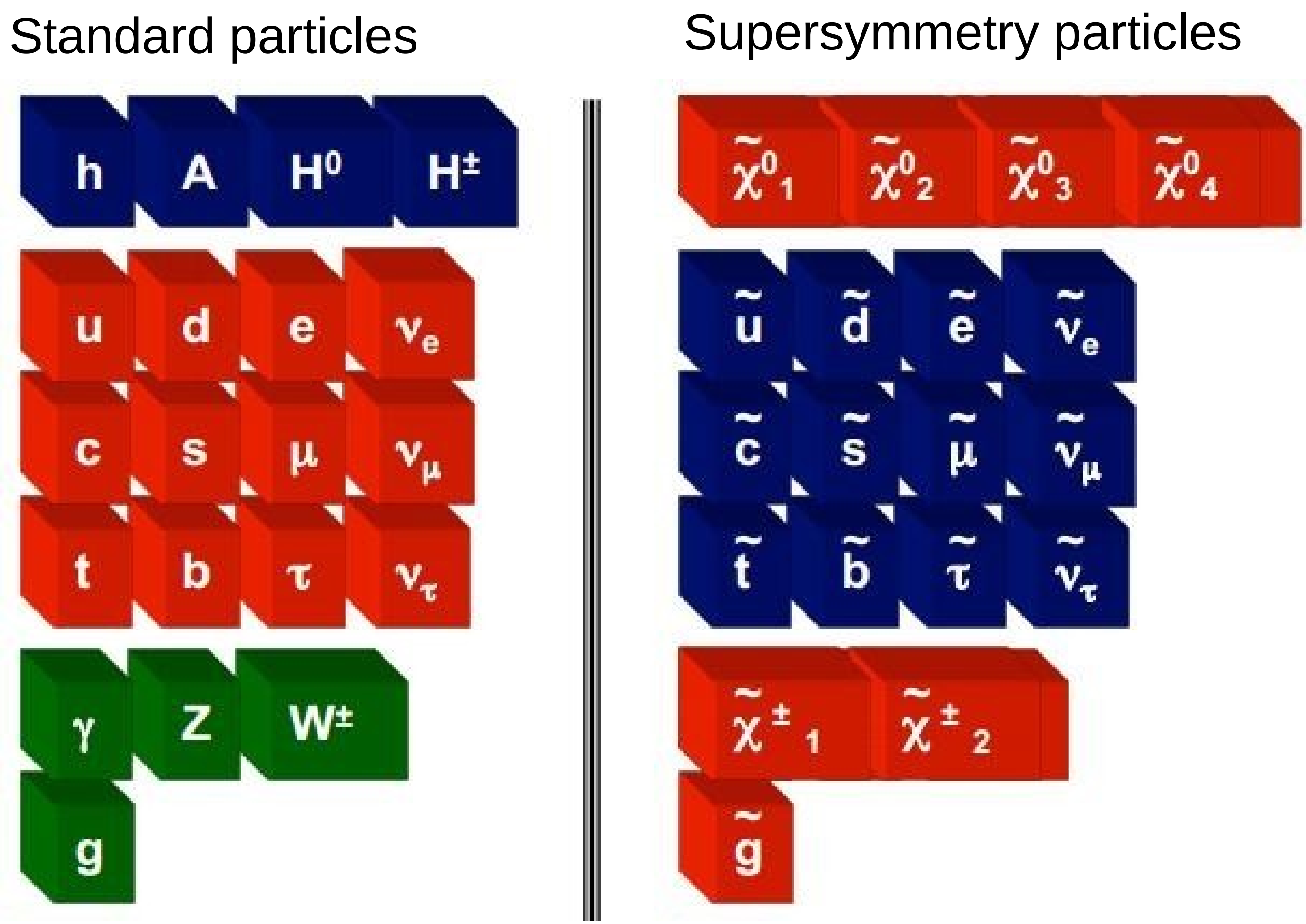
This mechanism allows us to give mass to the neutrinos of the standard model, from the addition of new neutrinos (right handed neutrinos).

The addition of this mechanism to the MSSM implies:

$$\upsilon_R \quad \Leftrightarrow \quad \tilde{\upsilon}_R$$

R-Neutrino R-sneutrino

MSSM + SeeSaw



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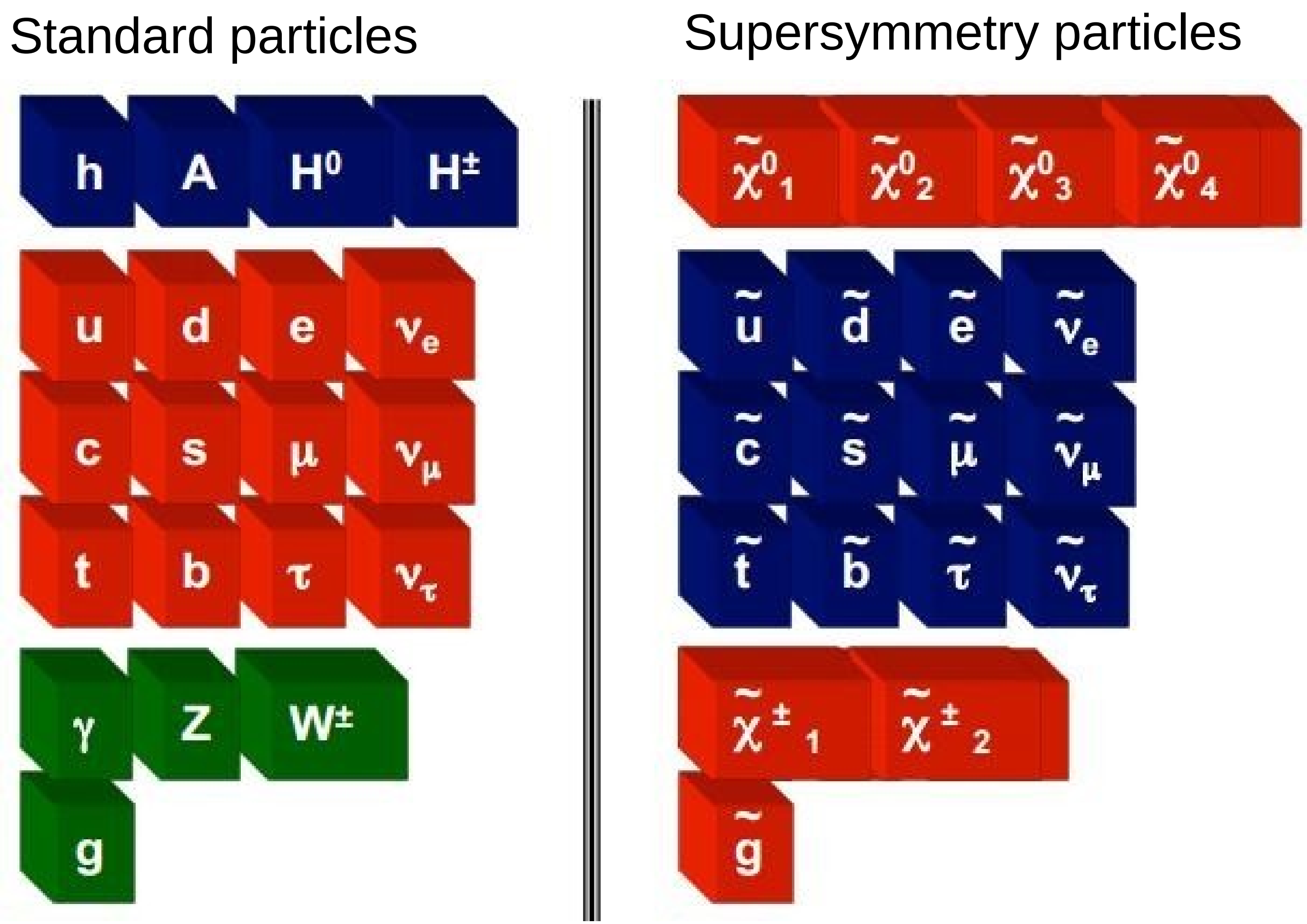
*The work is concentrated in the sleptons sector



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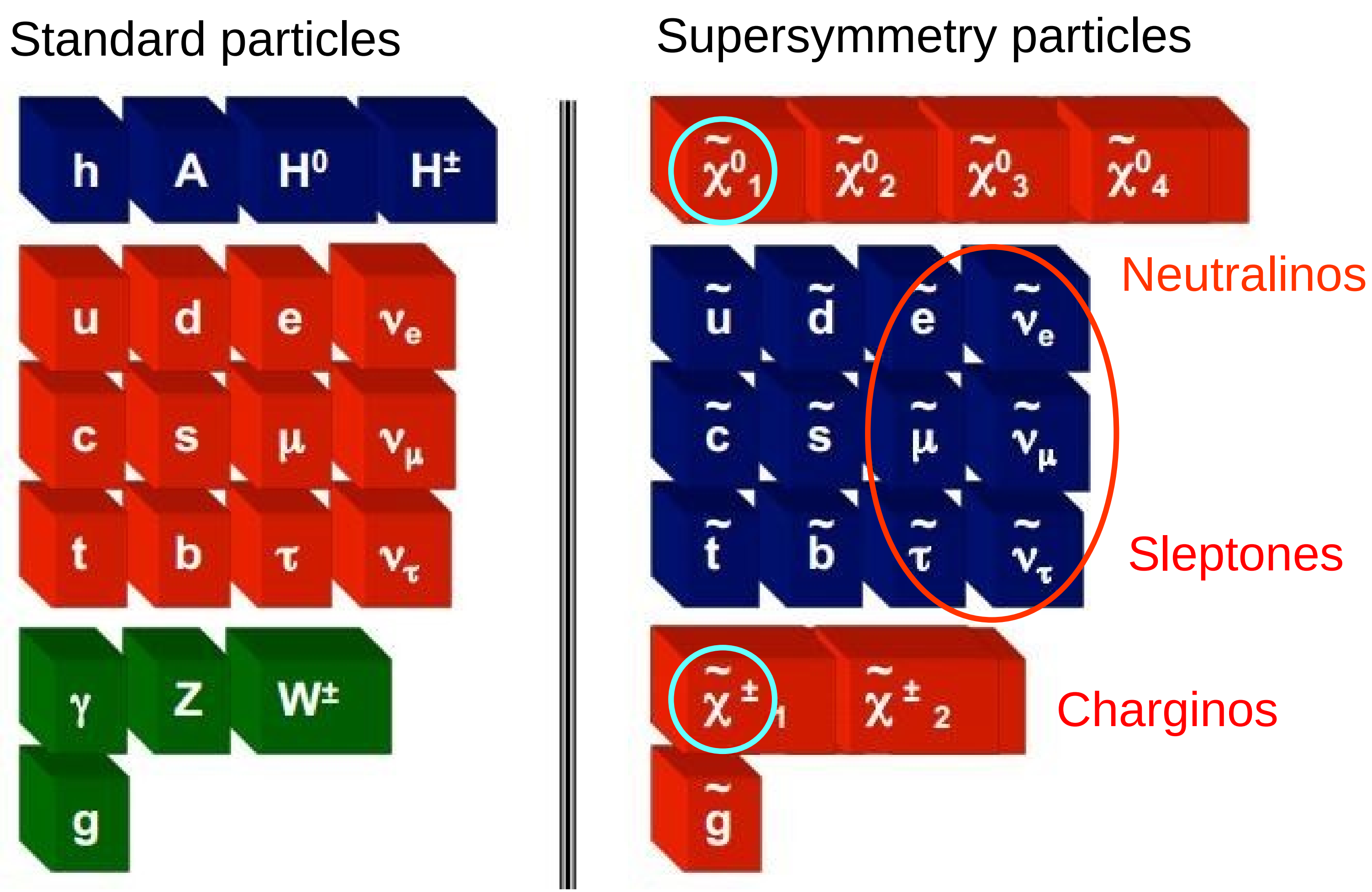

$\upsilon_R \Leftrightarrow \tilde{\upsilon}_R$

Spín ½ — Spín 0

R-Sneutrinos

Naturalness

By naturalness arguments, the μ term was kept relatively small, such that the lightest neutralinos were higgsino-like $(\tilde{\chi})$.

This means:

$$\mu \ll M_{1,2} \Rightarrow m_{\tilde{\chi}} \approx m_{\tilde{\chi}^0_{1,2}} \approx m_{\tilde{\chi}_1{}^{\pm}}$$

In our work, we choose:

$$\mu \leq 400\ GeV$$

MSSM + SeeSaw

Usually in the mssm, the lightest particle is the neutralino,

$$\tilde{\chi}^0$$

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$$\tilde{\upsilon}_R$$

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$$\tilde{\upsilon}_R$$

R-Sneutrino like LSP (Lightest and more stable particle)

In our model we consider the following cases:

$$m_{\tilde{\upsilon}_R} < m_{\tilde{\chi}} < m_{\tilde{l}}$$

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phenomenology with higgsino NLSP

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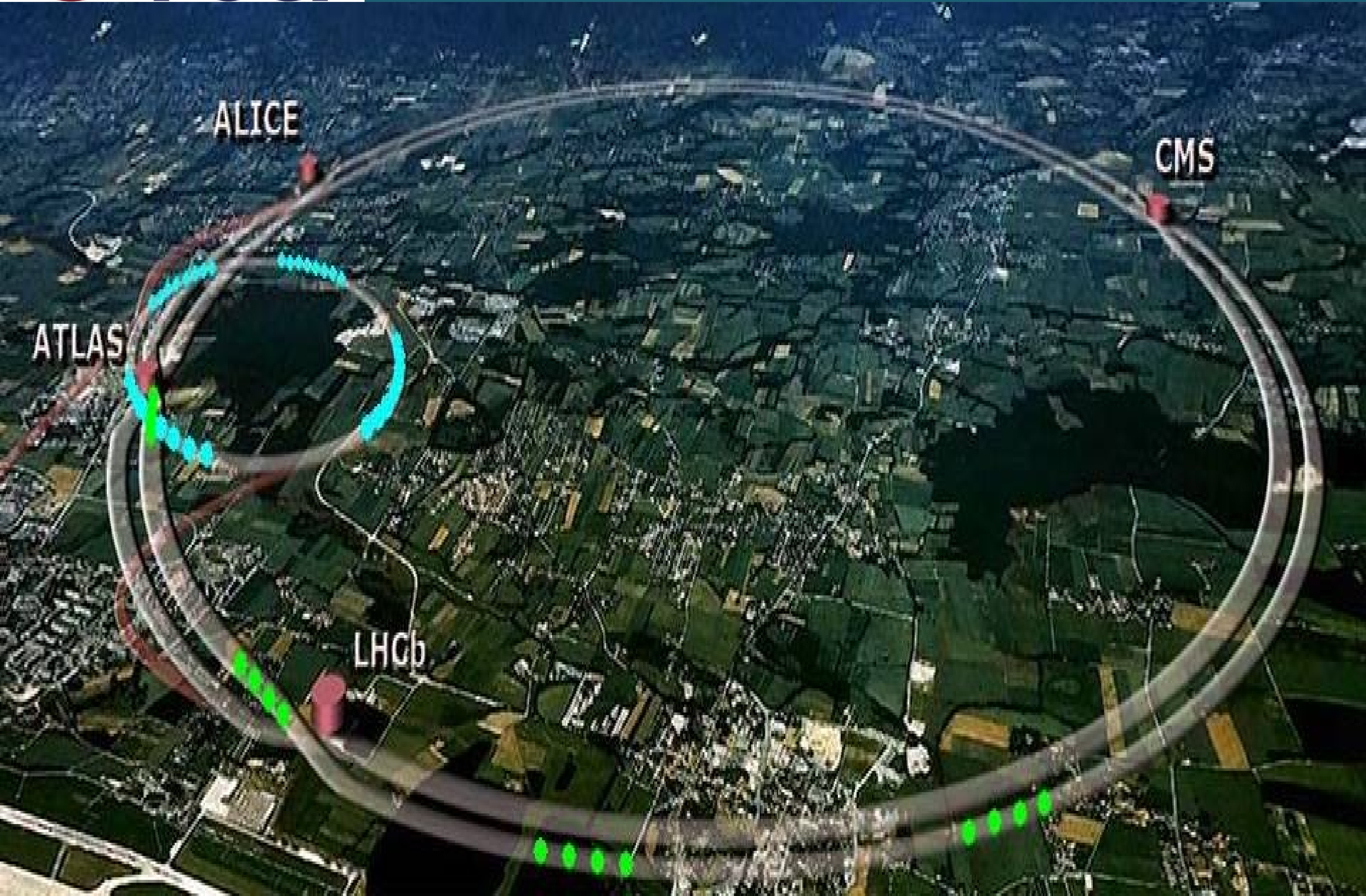
$m_{\tilde{\upsilon}_R} < m_{\tilde{\chi}} < m_{\tilde{l}}$ phenomenology with higgsino NLSP

$m_{\tilde{\upsilon}_R} < m_{\tilde{l}} < m_{\tilde{\chi}}$ phenomenology with slepton NLSP

Production of supersymmetric particles



Production of supersymmetric particles

The best way to study the properties of R-sneutrinos $\tilde{\upsilon}_R$, it is through decay in cascade of heavy particles, like as L-sleptons and higgsinos (neutralinos y charginos).

For that, we have to understand how these particles are produced.

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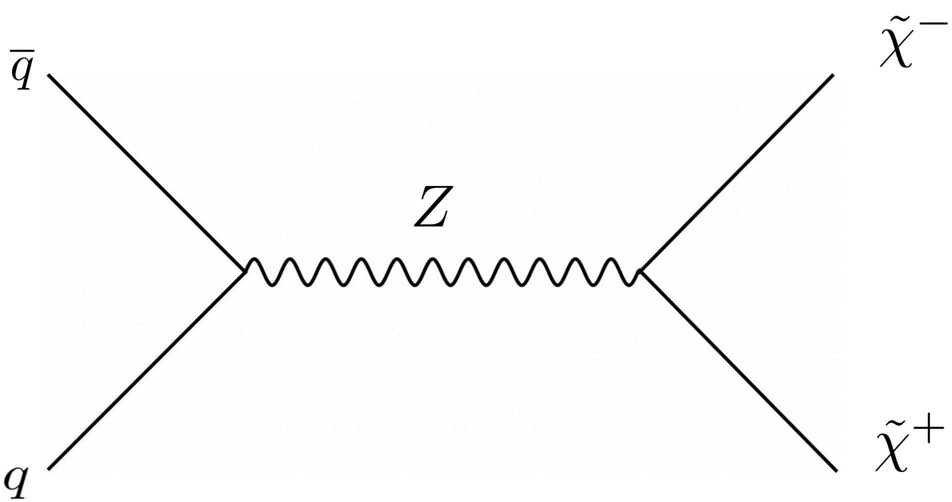
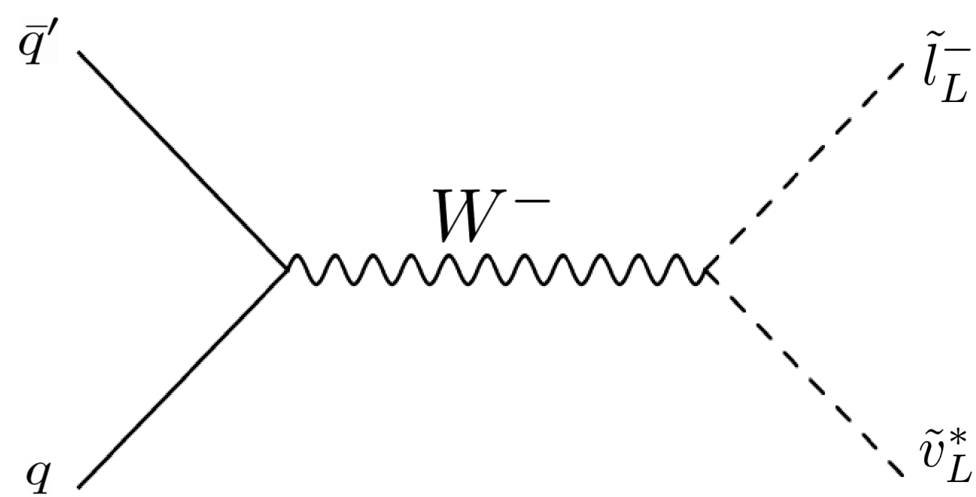


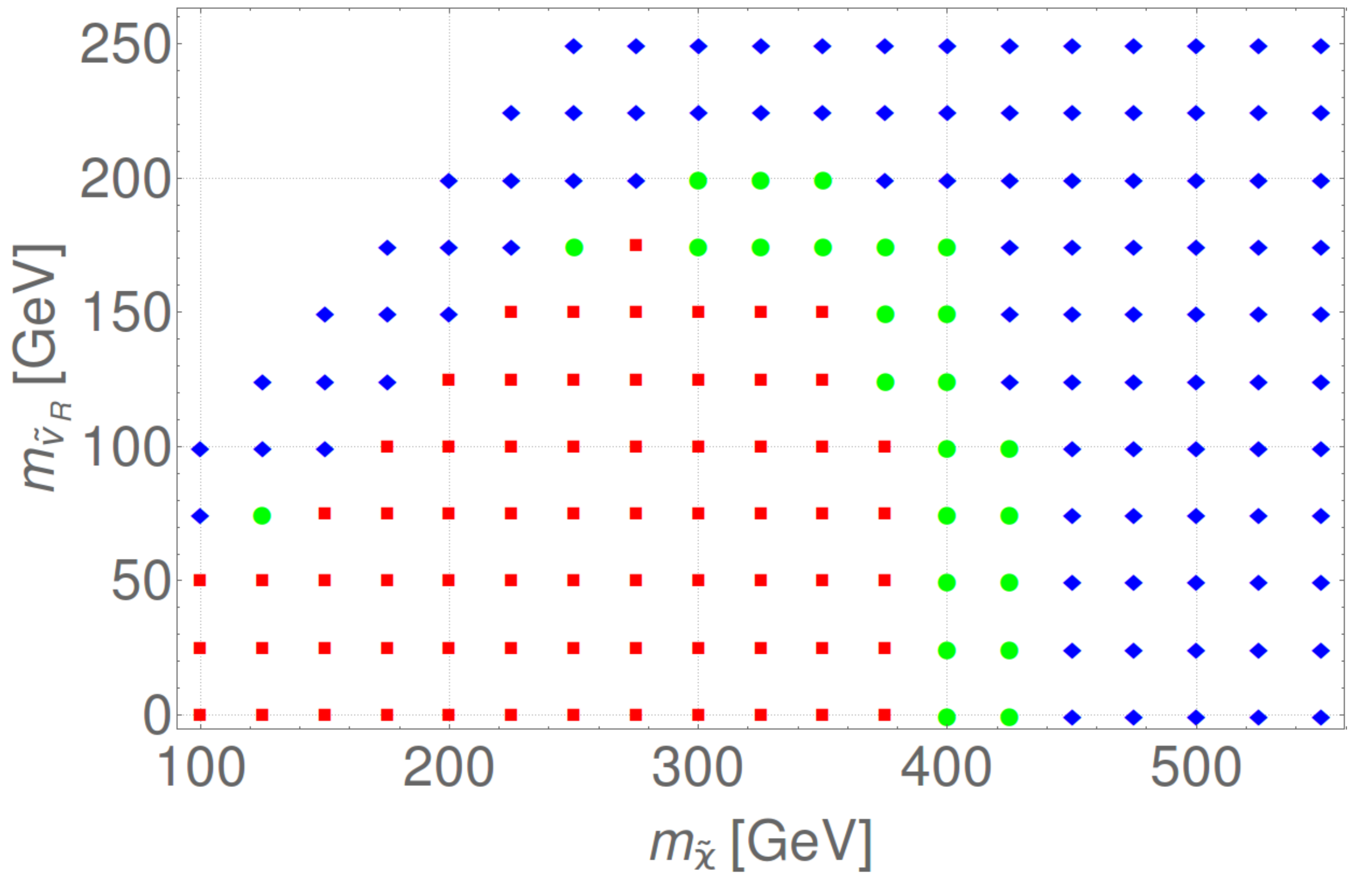


Electro-Weak Drell-Yan processes.

Charginos production

Signal: $$p\,p \to \tilde{\chi}^{+}\tilde{\chi}^{-},\, \tilde{\chi}^{\pm} \to l^{\pm}\, \tilde{v}_{R}^{(*)}$$

- Excluded
- Allowed
- Ambiguous



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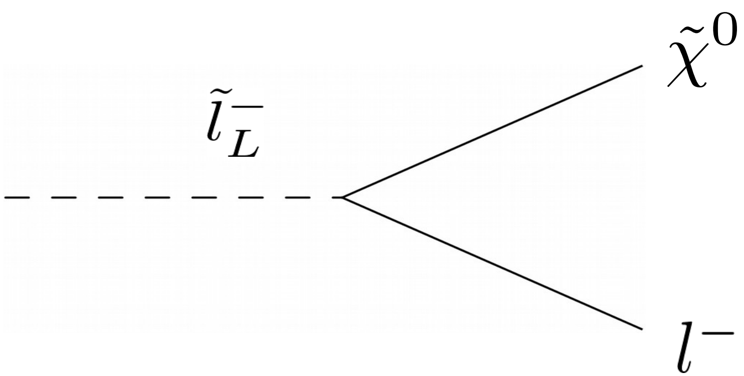
Higgsino NLSP

$$m_{\tilde{v}_R} < m_{\tilde{\chi}} < m_{\tilde{l}}$$

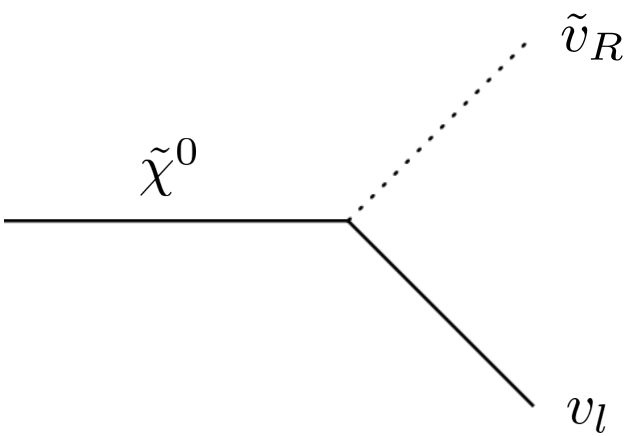
- Sleptons:

$$\tilde{l}_L^- \to \tilde{\chi}^0 l^-$$



- Neutralinos:

$$\tilde{\chi}^0 \to \tilde{v}_R v_l$$

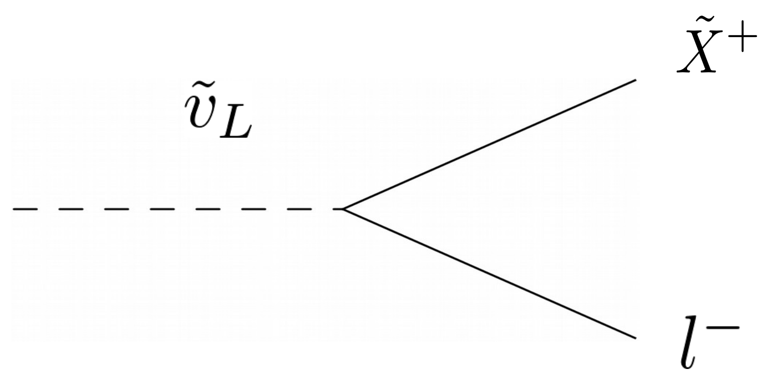


Higgsino NLSP

$$m_{\tilde{\upsilon}_R} < m_{\tilde{\chi}} < m_{\tilde{l}}$$

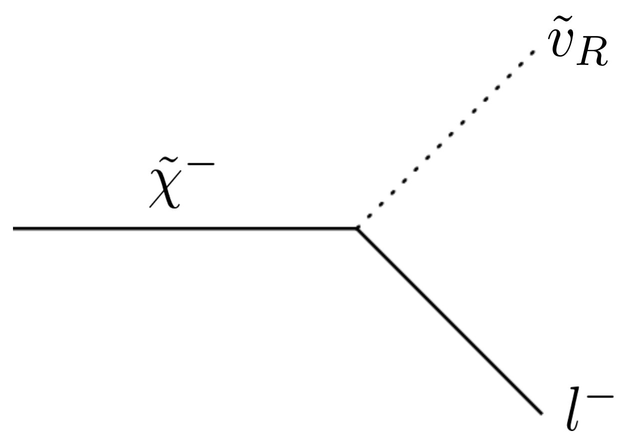
- L-Sneutrinos:

$$\tilde{\upsilon}_L \to \tilde{\chi}^+ l^-$$



- Charginos:

$$\tilde{\chi}^- \to \tilde{\upsilon}_R l^-$$



Higgsino NLSP

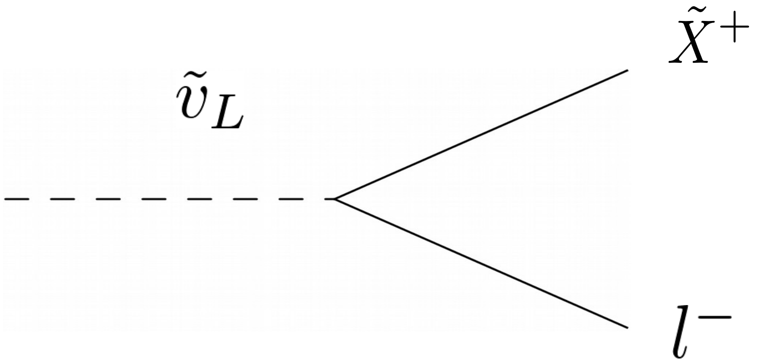
$$m_{\tilde{v}_R} < m_{\tilde{\chi}} < m_{\tilde{l}}$$

Signal

$$p\,p \rightarrow \tilde{l}_L^- \tilde{v}_L^* \rightarrow 3l + E_{Tmiss}$$

- L-Sneutrinos:

$$\tilde{v}_L \rightarrow \tilde{\chi}^+ l^-$$



- Charginos:

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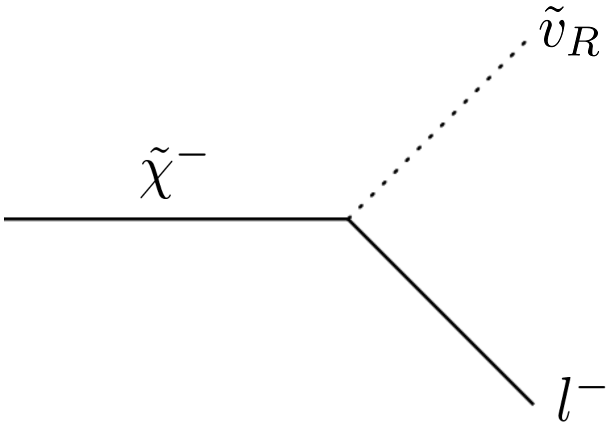
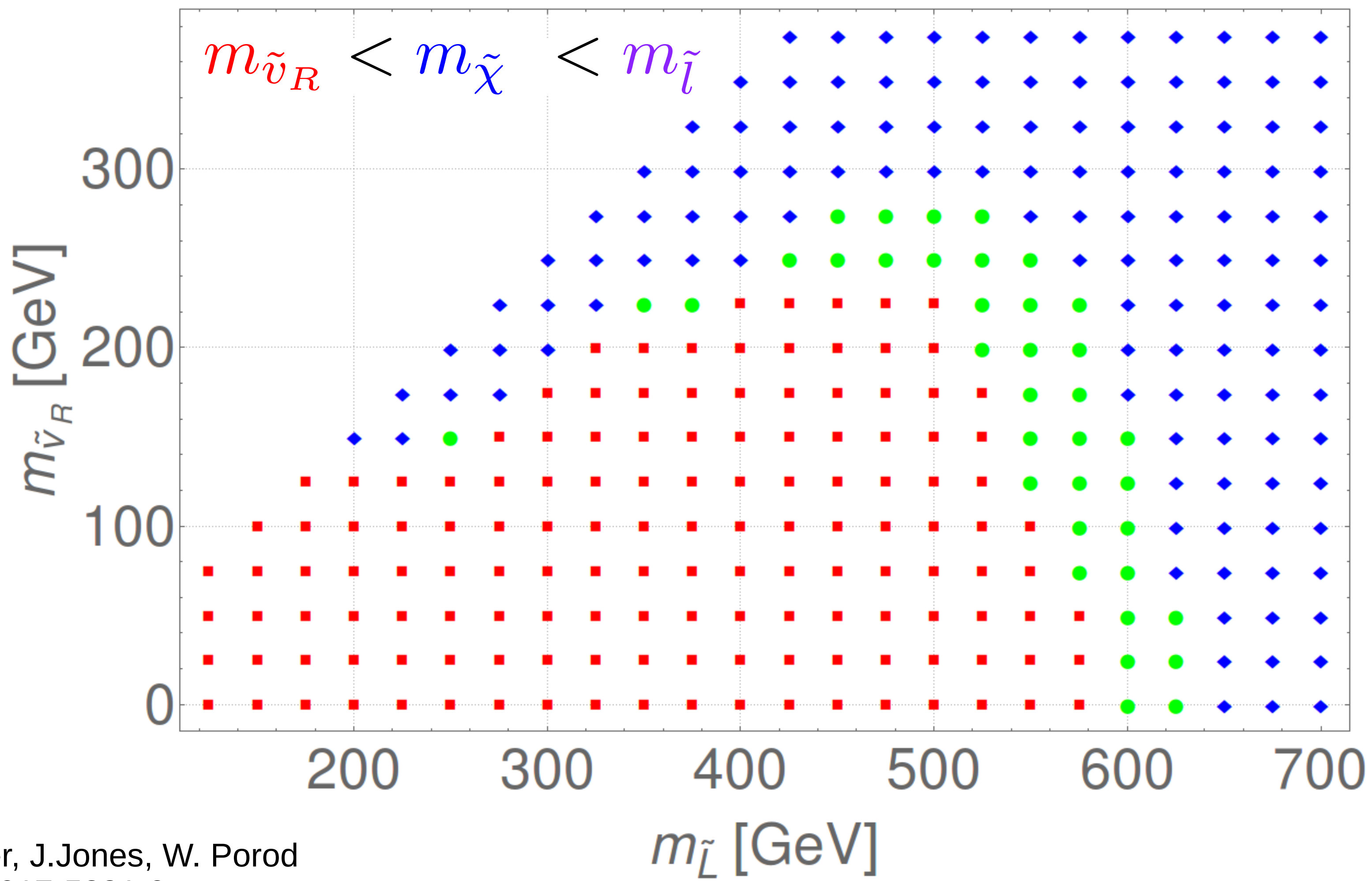


Higgsino NLSP

$$p\,p \to \tilde{l}_L^- \tilde{\upsilon}_L^* \to 3l + E_{T miss}$$

$$m_{\tilde{\chi}^0} = m_{\tilde{\upsilon}_R + 25 GeV}$$

- Excluded
- Allowed
- Ambiguous



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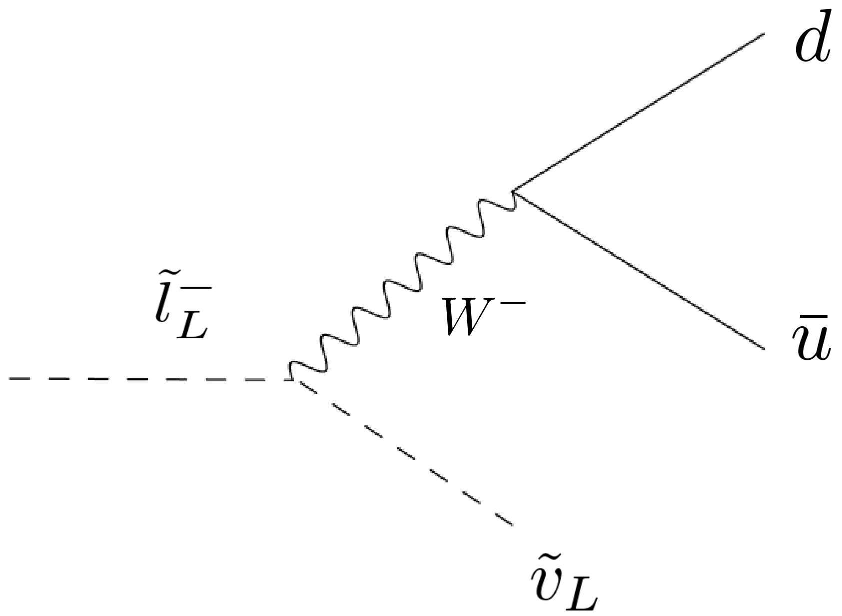
Slepton NLSP

$m_{\tilde{\upsilon}_R} < m_{\tilde{l}} < m_{\tilde{\chi}}$

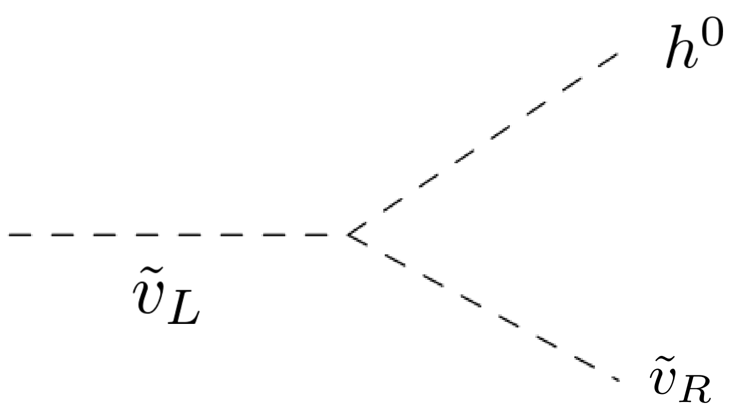
- Sleptons:

$$\tilde{l}_L^- \to 2j\tilde{\upsilon}_L$$



- L-Sneutrinos:

$$\tilde{\upsilon}_L \to \tilde{\upsilon}_R h^0$$



Slepton NLSP

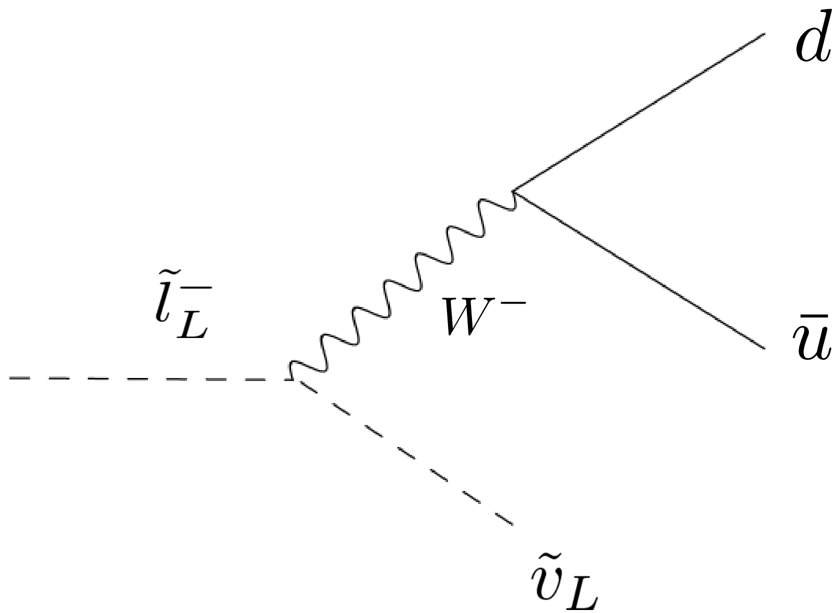
$$m_{\tilde{\nu}_R} < m_{\tilde{l}} < m_{\tilde{\chi}}$$

Signal

$$pp \to \tilde{l}_L^- \tilde{\nu}_L^* \to 2h^0 + j's + E_{Tmiss}$$

- Sleptons :

$$\tilde{l}_L^- \to 2j\tilde{\nu}_L$$



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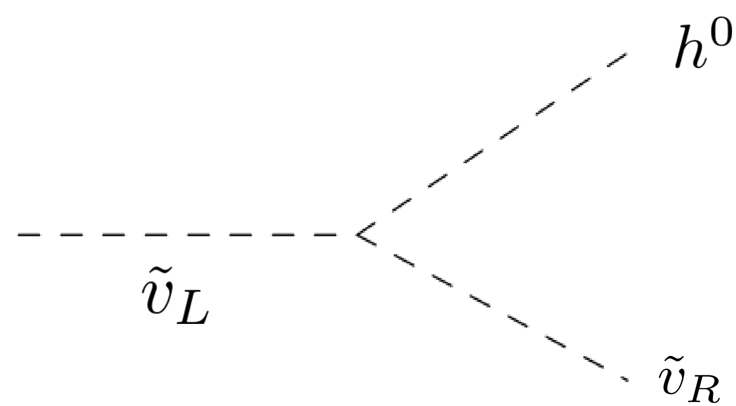
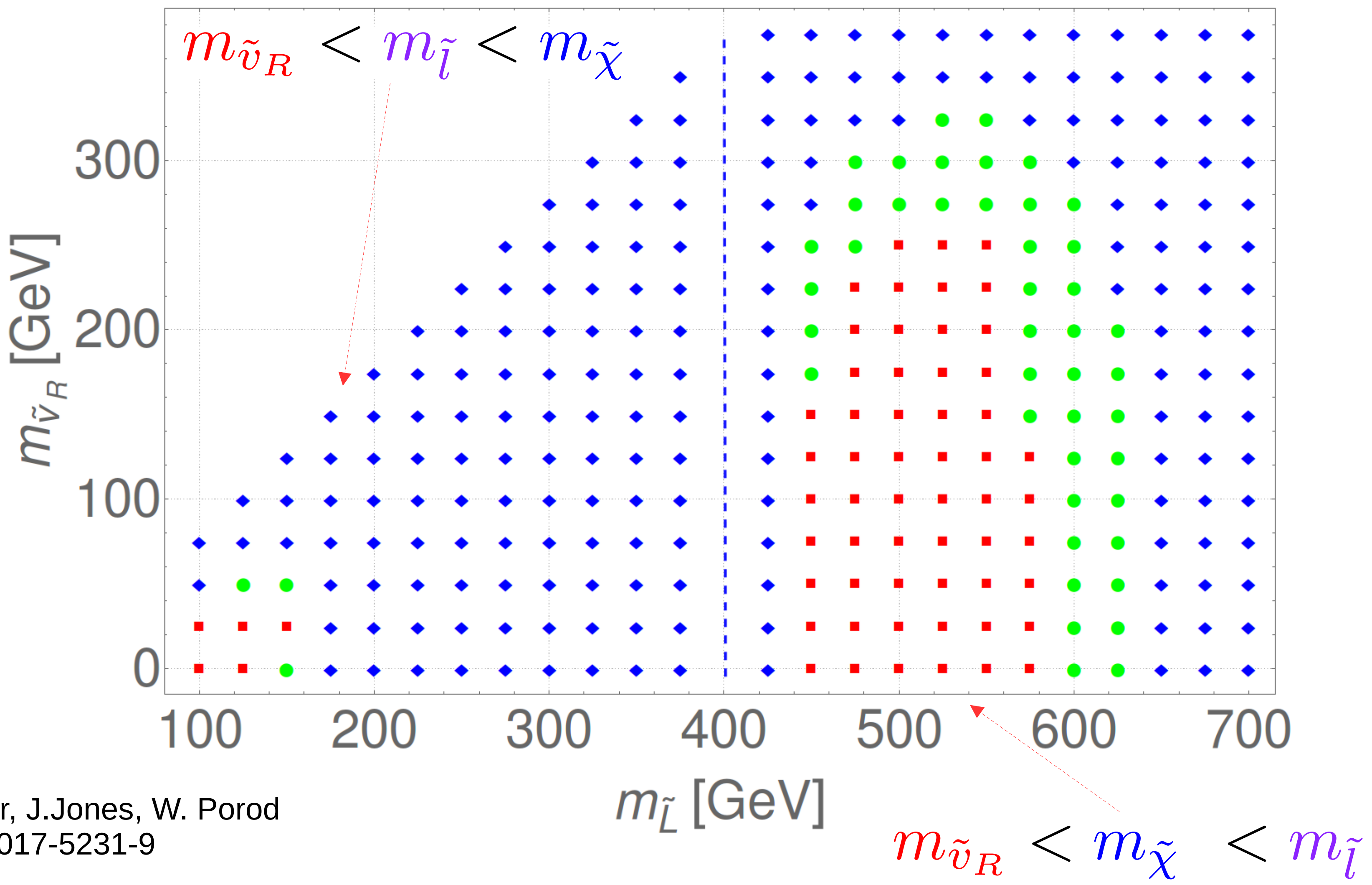


Slepton NLSP

$$p\,p \rightarrow \tilde{l}_L^- \tilde{v}_L^* \rightarrow 2h^0 + j's + E_{Tmiss}$$

$m_{\tilde{\chi}} = 400\,GeV$



- Excluded
- Allowed
- Ambiguous

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Conclusions

- We observed that phenomenology of the R-Sneutrino depends on the mass of sleptons and higgisinos.

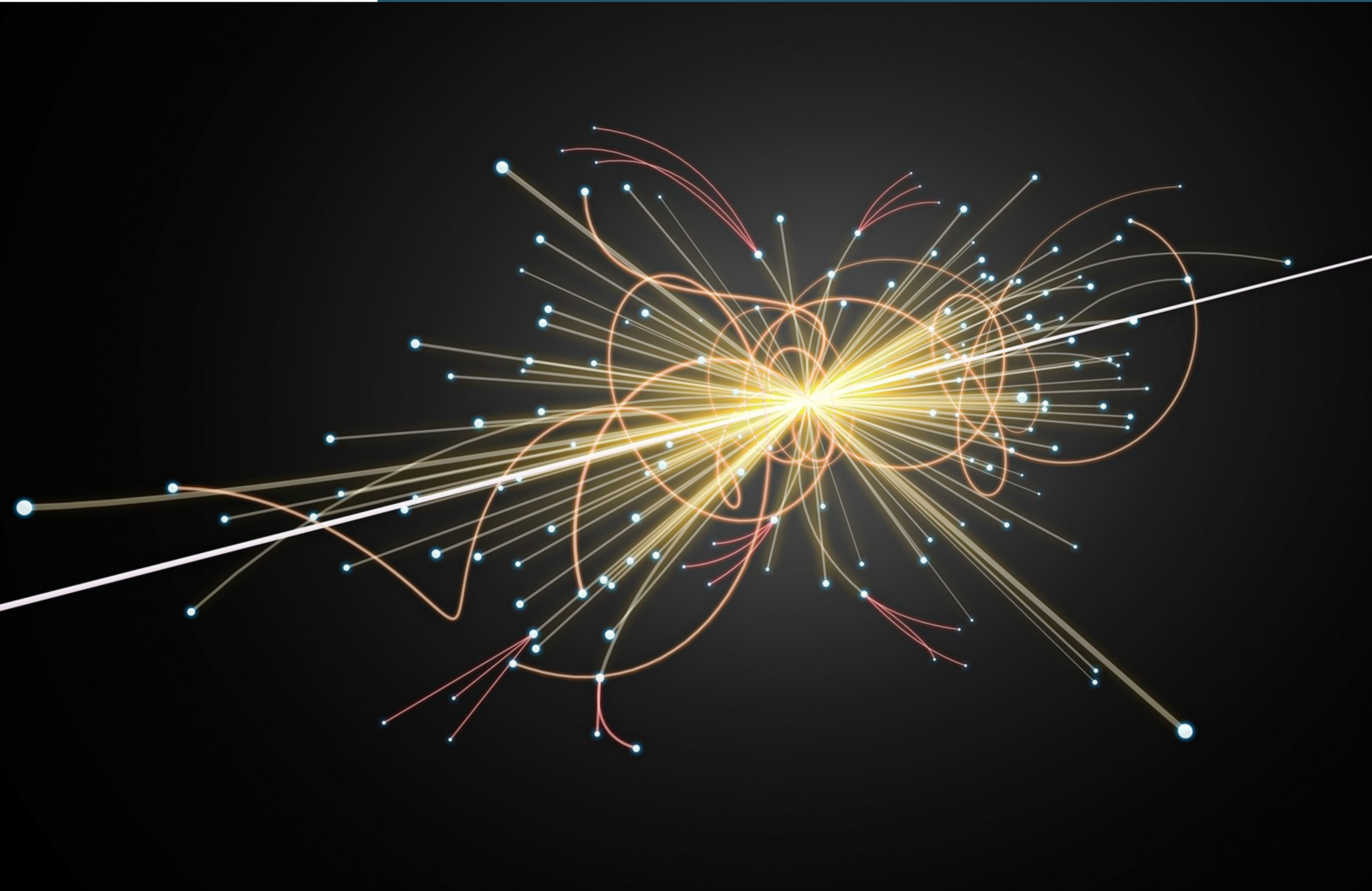
- We see that, for vanishing $m_{\tilde{\upsilon}_R}$, the bound on $m_{\tilde{\chi}}$ can be as large as 375 GeV. For relatively small values of $m_{\tilde{\chi}}$, one finds that R-sneutrino masses lighter than $m_{\tilde{\chi}}$ − 75 GeV are ruled out, with the allowed region increasing for $m_{\tilde{\chi}} \gtrsim$ 250 GeV.

- We found that, as long as $m_{\tilde{\chi}} < m_{\tilde{l}}$, we can exclude slepton masses to a maximum of 575 GeV. For lower values of slepton mass, the R-sneutrino masses can be excluded up to about 200 GeV.

- In case $m_{\tilde{l}} < m_{\tilde{\chi}}$, constraints became very weak, as final states were either too soft, or not probed by current searches.


Thanks

Backup



Seesaw mechanism

We introduce new states (right-handed field)

$$\mathcal{L}_{seesaw} = \mathcal{L}_{SM} - m_D \bar{v}_R v_L + \frac{1}{2} m_R \, \bar{v}^c_R \, v_R + h.c.$$

Eventually we will get

$$\mathcal{L}^{v}_{mass} = \frac{1}{2} \bar{N}^c_L M N_L + h.c. \qquad N_L = \begin{pmatrix} v_L \\ v^C_R \end{pmatrix}$$

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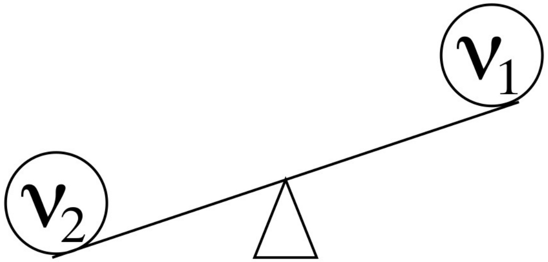
$$\mathcal{L}_{seesaw} = \mathcal{L}_{SM} - m_D \bar{\nu}_R \nu_L + \frac{1}{2} m_R \bar{\nu}_R^c \nu_R + h.c.$$

Eventually we will get

$$\mathcal{L}_{mass}^{\nu} = \frac{1}{2} \bar{N}_L^c M N_L + h.c. \qquad N_L = \begin{pmatrix} \nu_L \\ \nu_R^C \end{pmatrix}$$

$$m_1 \simeq \frac{m_{\mathrm{D}}^2}{m_R}$$

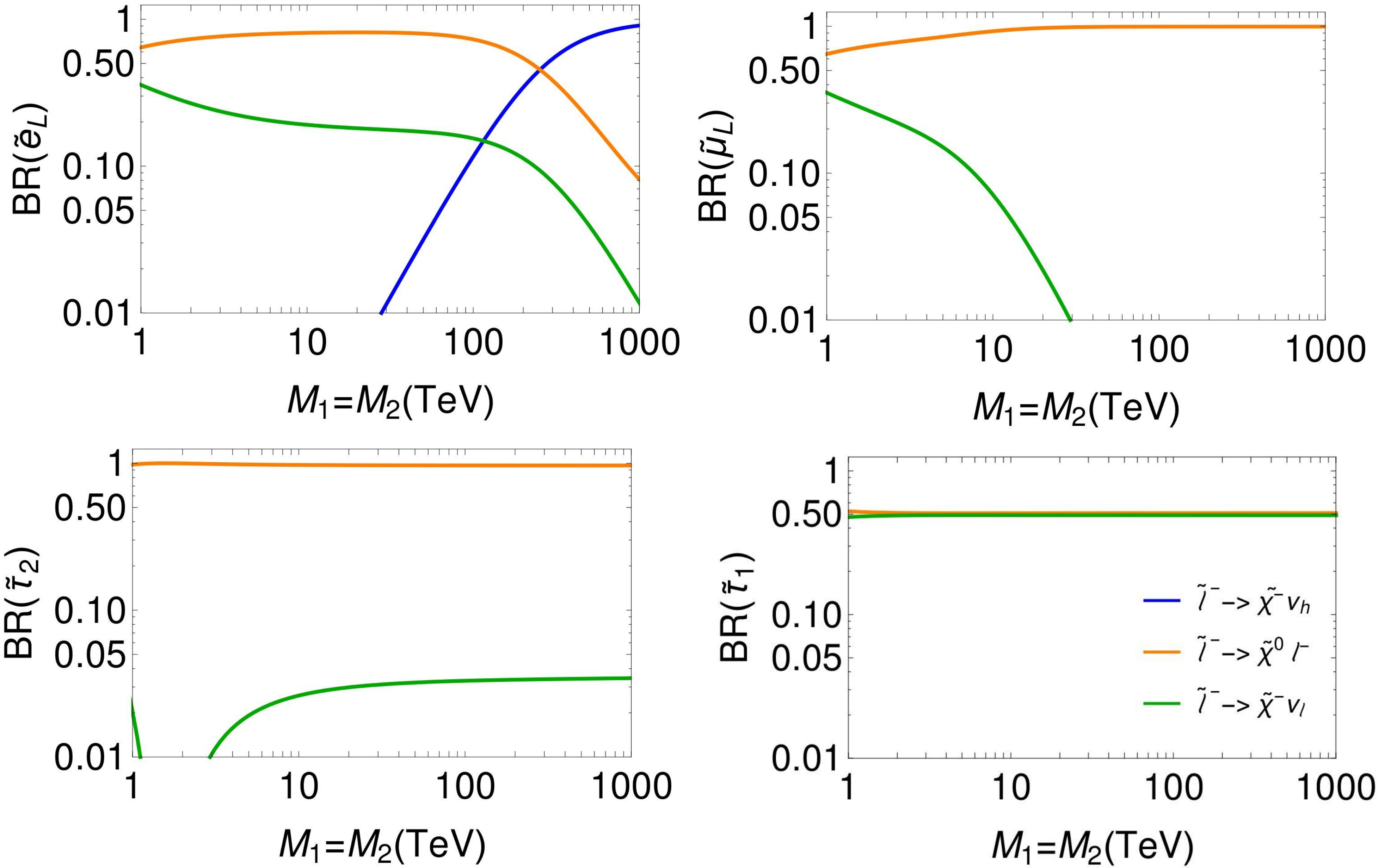
$$M = \begin{pmatrix} 0 & m_D \\ m_D & m_R \end{pmatrix}$$



$$m_2 \simeq m_R$$

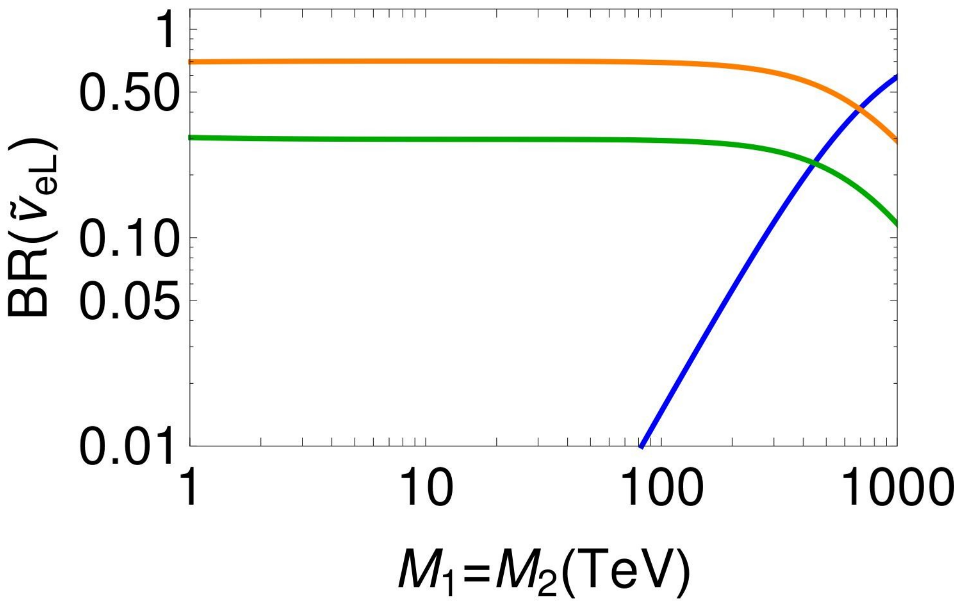
R-Sneutrino LSP y light higgsinos

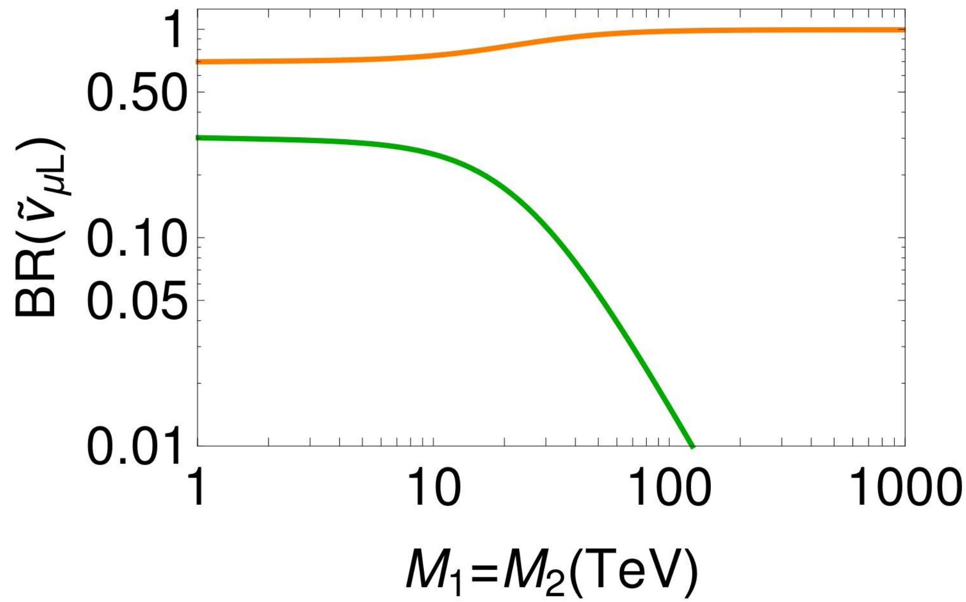
$$m_{\tilde{\nu}_R} < m_{\tilde{\chi}} < m_{\tilde{l}}$$

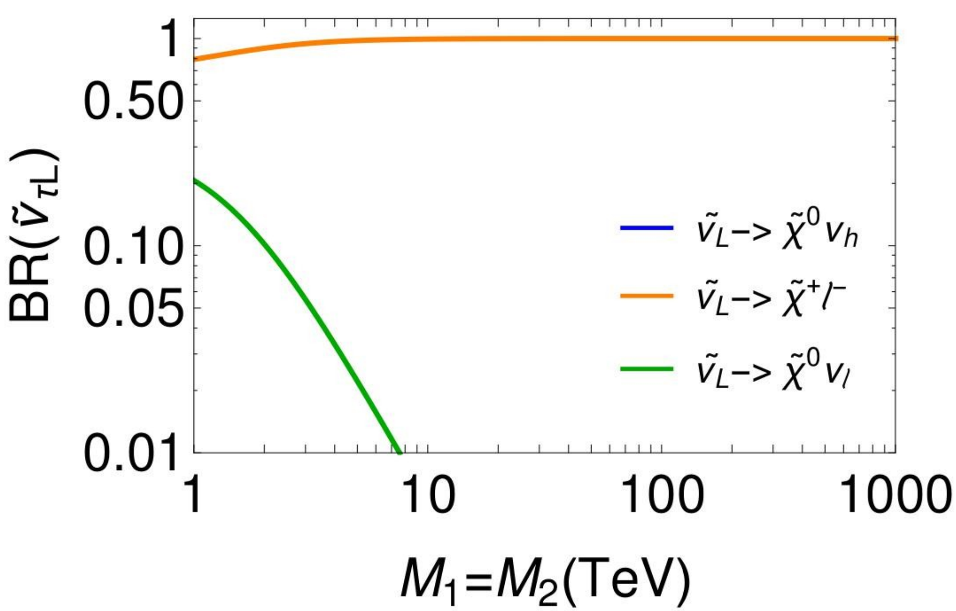


R-Sneutrino LSP and light higgsinos

$$m_{\tilde{v}_R} < m_{\tilde{\chi}} < m_{\tilde{l}}$$







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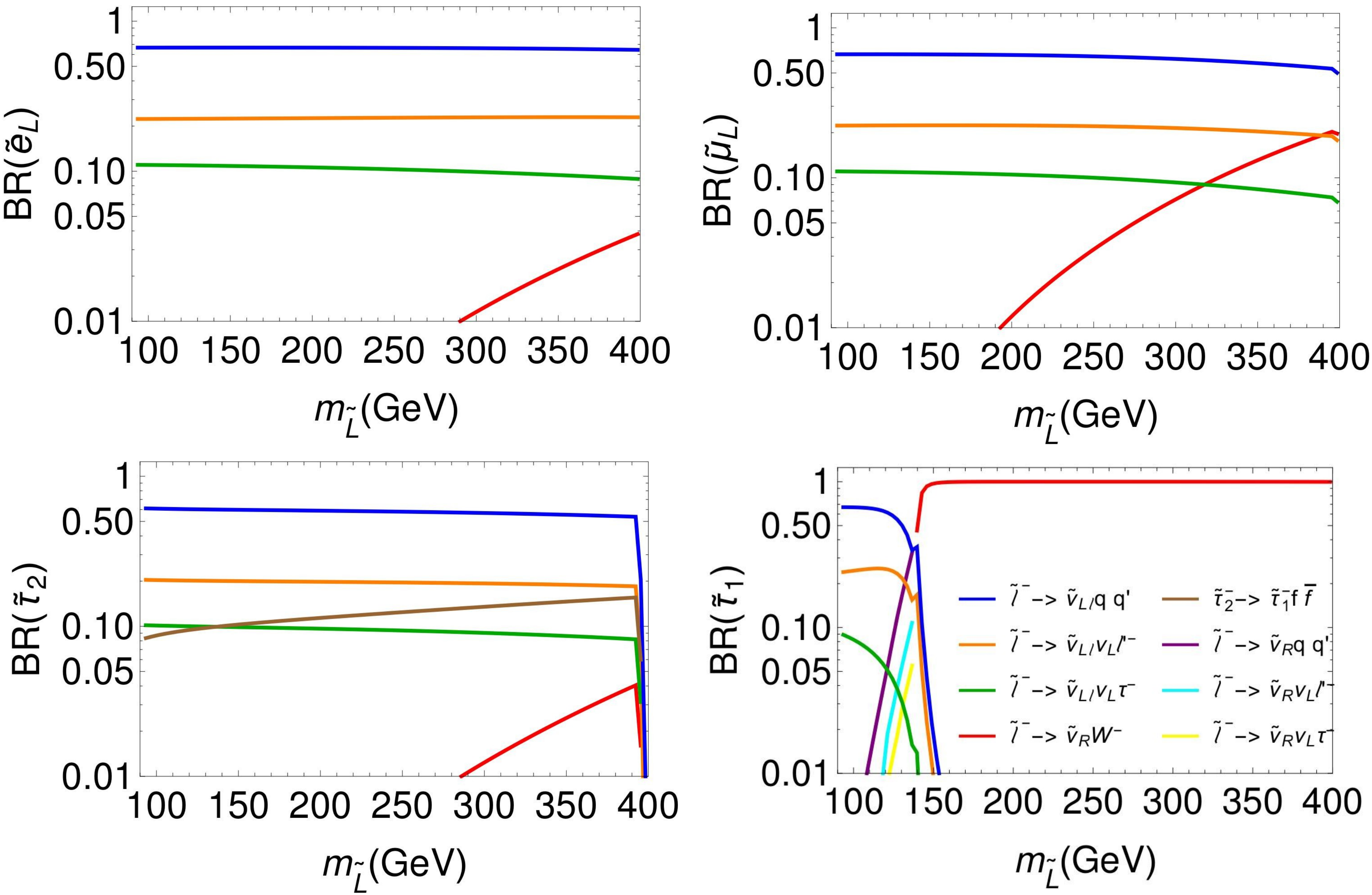

R-Sneutrino LSP and heavy Higgsinos

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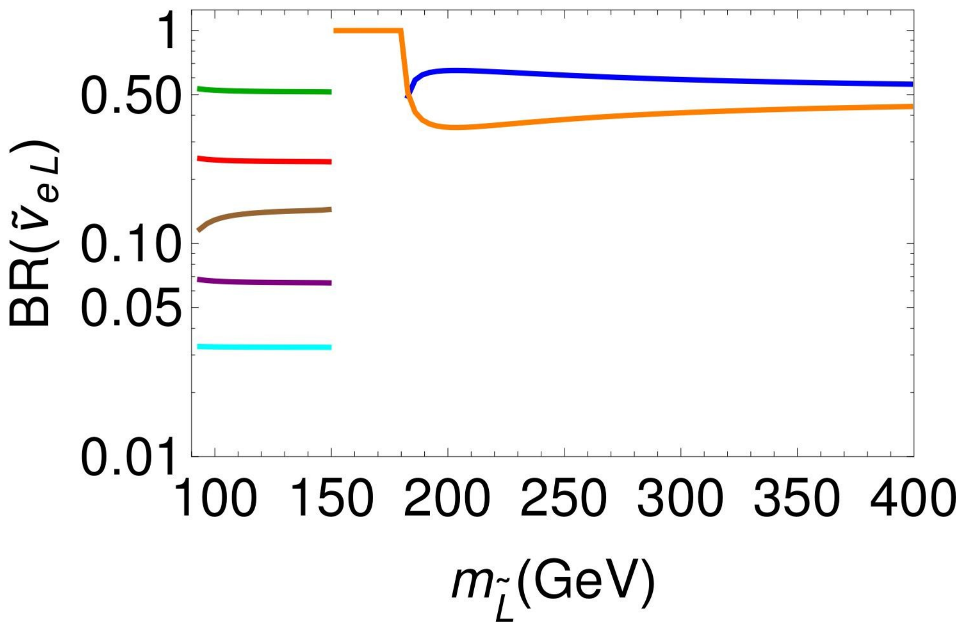

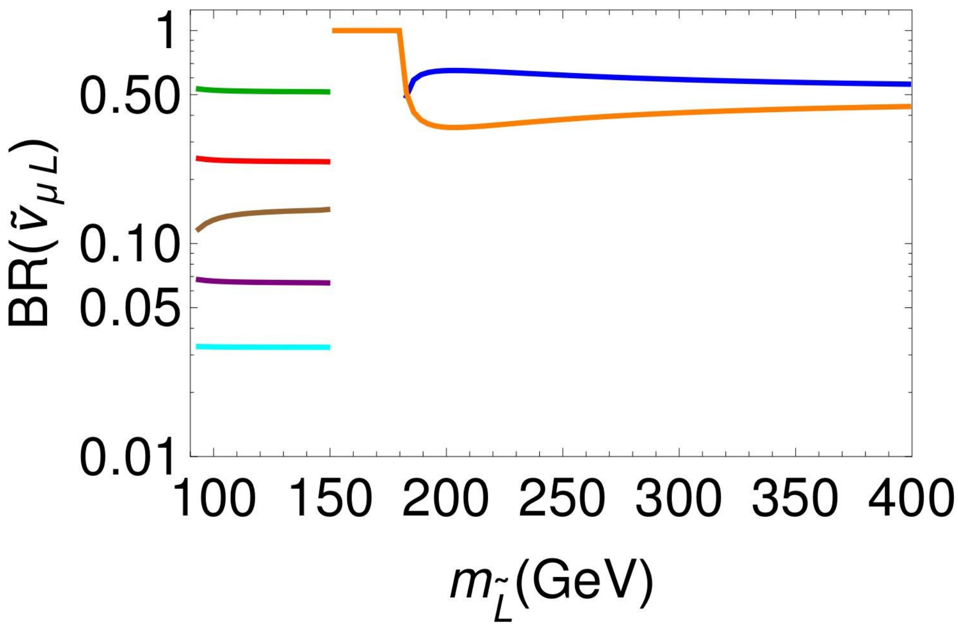

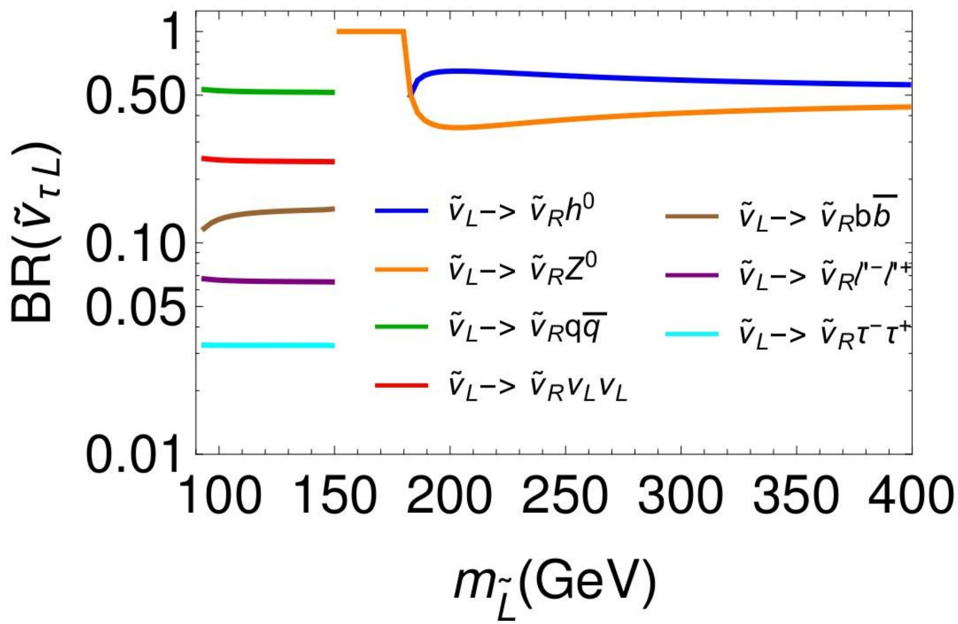

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