Gravitino Dark Matter and Neutrinos in Partial Split Supersymmetry

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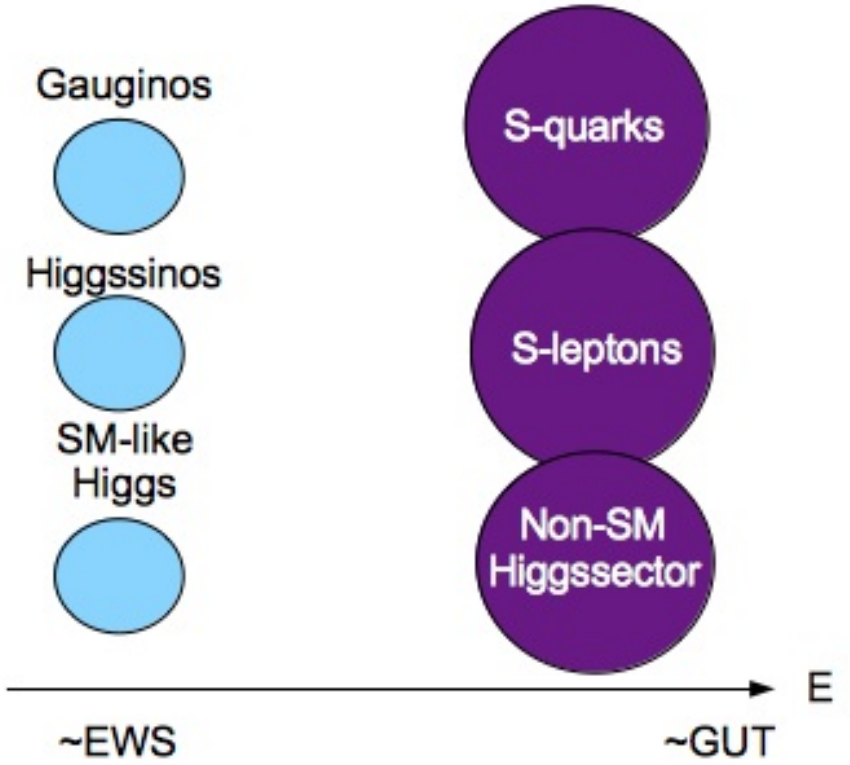
Outline

- Partial Split Supersymmetry (PSS)
- Neutrinos in PSS $\rightarrow$ constraints
- Gravitino dark matter
- Gravitino decay modes $\rightarrow$ constraints
- Combined constrains
- Conclusions

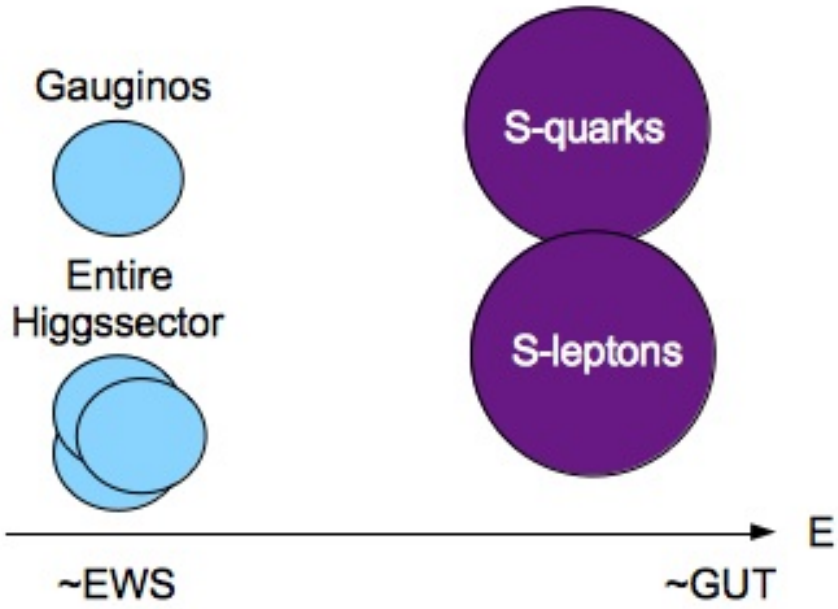
Split Supersymmetry



N. Arkani-Hamed and S. Dimopoulos, JHEP **0506**, 073 (2005); G. F. Giudice and A. Romanino, Nucl. Phys. B **706**, 65 (2005).

- All scalars heavy except of SM-like Higgs
- Abandon Higgs naturalness
- Keep unification
- Solve proton decay
- Solve FCNC
- Solve CP violation

Partial Split Supersymmetry



- S-quarks and S-leptons heavy
- Abandon Higgs naturalness
- Keep unification
- Solve . . . same . . .

M. A. Diaz, P. Fileviez Perez and C. Mora,
Phys. Rev. D **79**, 013005 (2009);
R. Sundrum, JHEP **1101**, 062 (2011).

Neutrinos in Split Susy

Need violation of R parity

$$\mathcal{L}_{PSS}^{RpV} = -i\epsilon_i \widetilde{H}_u^T \sigma_2 L_i \; - \; \frac{i}{\sqrt{2}} b_i H_u^T \sigma_2 (\tilde{g}_d \sigma \widetilde{W} - \tilde{g}'_d \widetilde{B}) L_i \; + \; h.c., \qquad (1)$$

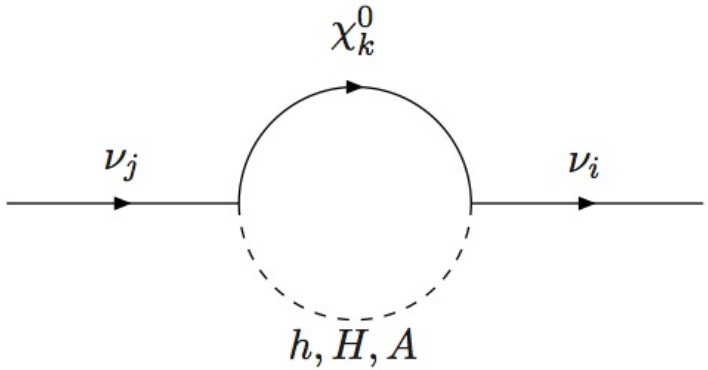
Mixing of neutralinos induces neutrino mass matrix

$$M_{SS}^{ij} = A \lambda^i \lambda^j \qquad (2)$$

Only one mass $\neq 0$
also at loop level, where $\Lambda_i = \mu b_i v_u + \epsilon_i v_d$

Neutrinos in Partial Split Susy

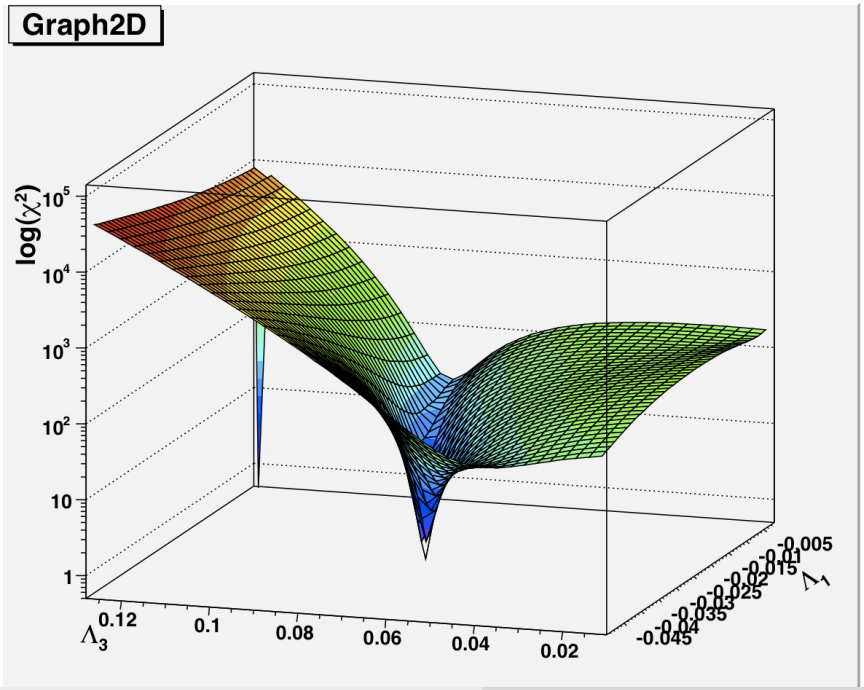
At tree level same as SS
but at one loop level:



Neutrino mass matrix:

$$M_{PSS}^{ij} = A\Lambda^i\Lambda^j + B(\epsilon^i\Lambda^j + \epsilon^j\Lambda^i) + C\epsilon^i\epsilon^j \quad (3)$$

Fits ν-masses and ν-angles:



M. A. Diaz, F. Garay and B. Koch,
Phys. Rev. D **80**, 113005 (2009)

Gravitino Dark Matter

Problem in PSS:

The usual scalar DM candidates of Susy are too heavy!

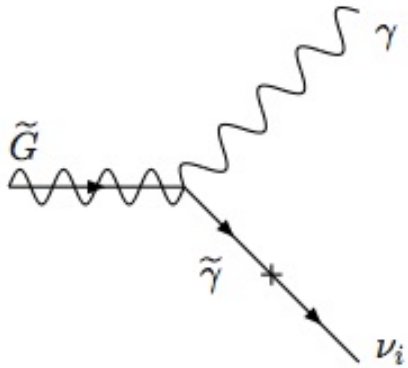
Remaining candidate, gravitino:

$$\left(\epsilon^{\mu\nu\rho\sigma}\gamma^5\gamma_\nu\partial_\rho - im\sigma^{\mu\sigma}\right)\psi_\sigma = 0 \quad (4)$$

In principle stable, but R-parity violation $\Rightarrow$ unstable!

Gravitino Decay Modes

Two body decay:



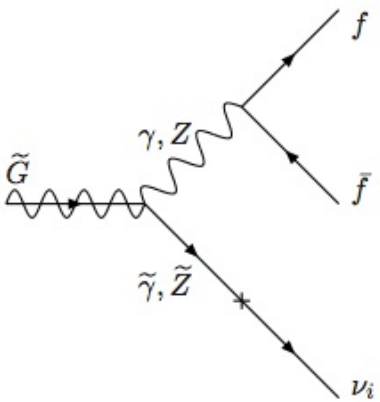
(Dominant for $m_{3/2}$ small)

$$\Gamma(\widetilde{G} \to \gamma\nu) = \frac{m_{3/2}^3}{32\pi M_P^2}|U_{\widetilde{\gamma}\nu}|^2 \qquad (5)$$

with

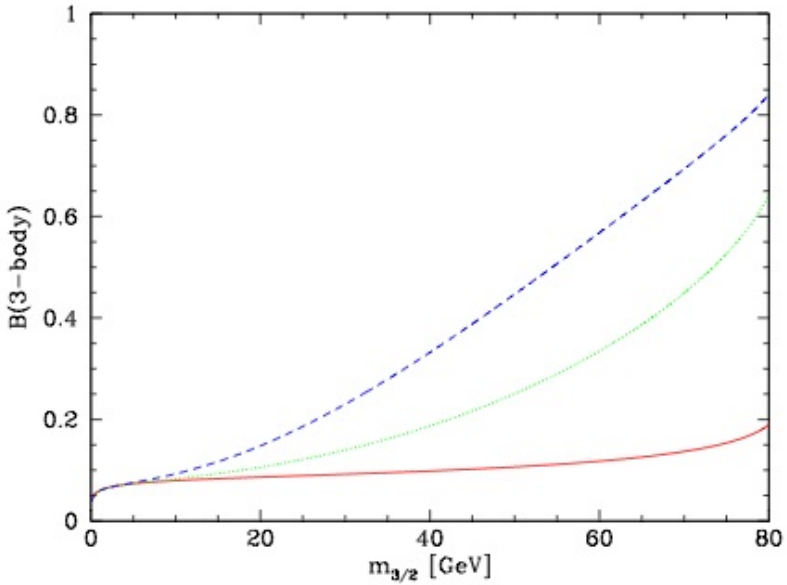
$$U_{\widetilde{\gamma}\nu_i} \simeq \frac{\mu}{2(\det M_\chi \mathbf{o})}\left(\tilde{g}_d M_1 s_W - \tilde{g}'_d M_2 c_W\right)\Lambda_i$$

Three body decay:



$+\ldots$

Branching ratio



Induced Photon flux

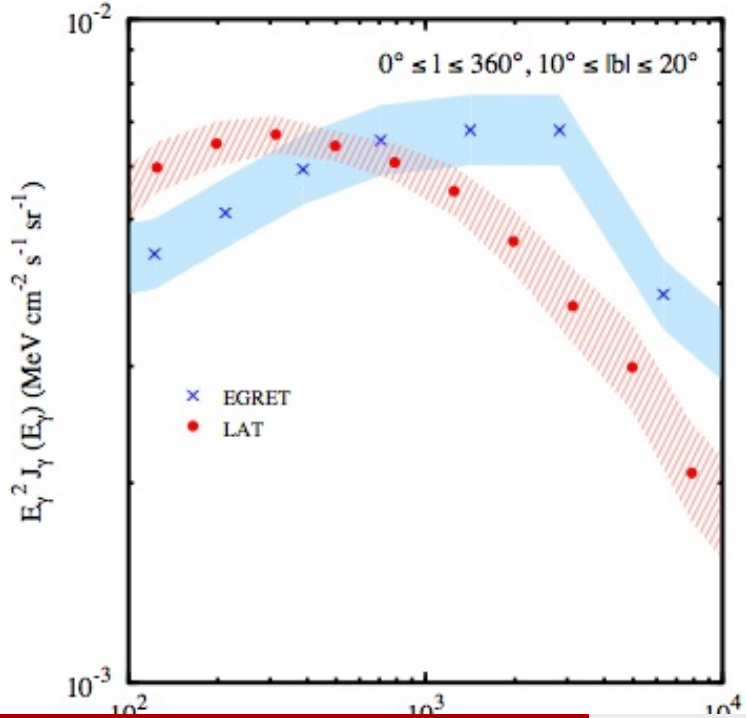
Two body decay should induce photon flux!

Flux from dark matter halo dominant:

$$E^2 \frac{dJ_{halo}}{dE} = d_\gamma \Gamma(\widetilde{G} \to \gamma\nu) \frac{m_{3/2}}{2} \delta\left(E - \frac{m_{3/2}}{2}\right) \tag{6}$$

where d_γ constant from DM profile

Compare to observed photon flux:



$\Rightarrow$Constraint on gravitino lifetime

$$\left(\frac{\tau_{3/2}}{10^{27}\ \mathrm{s}}\right) > B \frac{0{,}851}{p} \left(\frac{m_{3/2}}{1\ \mathrm{GeV}}\right)^{0{,}41}$$

B: two body branching ratio
p: detector efficiency at $E = p_{3/2}$
$\leftarrow$ FermiLAT, PRL 103,251101(2009)

Connecting Neutrino Model with Gravitino DM

Link due to neutrino photino mixing:

$$\underbrace{\Gamma(\widetilde{G} \to \gamma\nu)}_{\text{determines } \gamma\text{-flux}} \sim |U_{\tilde{\gamma}\nu_i}|^2 \simeq \underbrace{\left(\frac{\mu}{2(\det M_{\chi^0})} \left(\tilde{g}_d M_1 s_W - \tilde{g}'_d M_2 c_W \right) \Lambda_i \right)^2}_{\text{parameters of neutrino model}}$$

Numerical parameter scan, values of $U_{\tilde{\gamma}\nu_i}$

- Fixed: $Q = 951{,}7$, $M_2 = 2M_1$
- Continuous: $\tan\beta$, $|\mu|$, m_h, m_A, ϵ_i, Λ_i
- Discrete: $M_1 = 100, 300, 500$ GeV

Connecting Neutrino Model with Gravitino DM

Link due to neutrino photino mixing:

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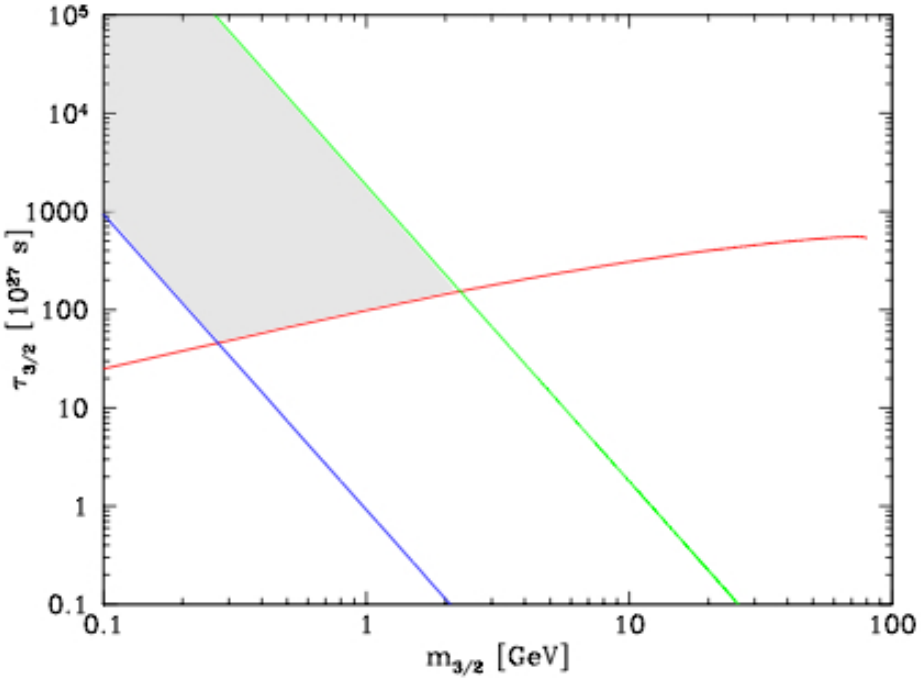
Numerical parameter scan, values of $U_{\tilde{\gamma}\nu_i}$

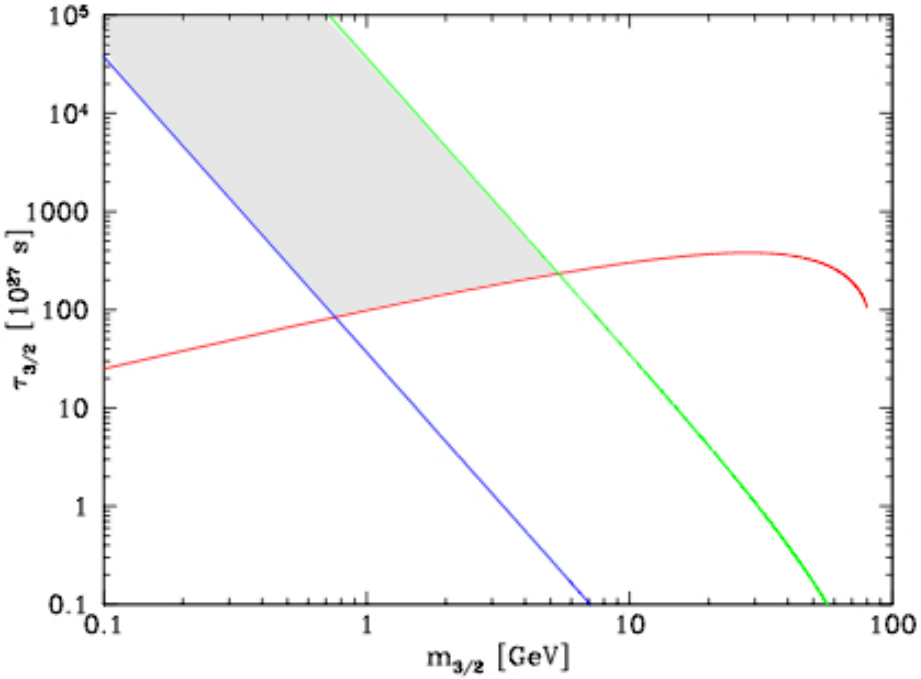
M_1	$\lvert U_{\tilde{\gamma}\nu}\rvert^2$(min)	$\lvert U_{\tilde{\gamma}\nu}\rvert^2$(max)
100 GeV	2×10^{-16}	4×10^{-13}
300 GeV	2×10^{-17}	3×10^{-14}
500 GeV	1×10^{-17}	1×10^{-14}

Combined constraints

Combined constraints from gravitino DM and neutrino mass matrix



(a) *Allowed region for* $M_1 = 100$ *GeV.*



(b) *Allowed region for* $M_1 = 500$ *GeV.*

Maximal value for $m_{3/2}$! (Low)

Conclusions

Conclusions:

- PSS valuable neutrino model
- Gravitino in PSS is a good DM candidate
- If $m_{3/2} < M_W$ then $\Rightarrow m_{3/2} < 10$ GeV
- Further studies on the way

Literature

- This work:

  Marco Aurelio Diaz, Sebastian Garcia Saenz, Benjamin Koch, arXiv:1106.0308 submitted do PRD

- Related work neutrino:

  M.Hirsch,M.A.Diaz,W.Porod,J.C.Romao andJ.W.F.Valle,Phys.Rev.D 65, 119901 (2002); M.Maltoni,T.Schwetz, M.A.Tortola and, J.W.F.Valle, NewJ.Phys.6, 122 (2004); M.A.Diaz, P.FileviezPerez and C.Mora, Phys.Rev.D79, 013005 (2009) ...

- Related work gravitino:

  M. Grefe, DESY-THESIS-2008-043; L. Covi, arXiv:1003.3819 [hep-ph];
  W. Buchmuller, AIP Conf. Proc. 1200, 155 (2010);
  K.Y. Choi, D. Restrepo, C.E. Yaguna and O. Zapata, JCAP 1010, 033 (2010)
  K.Y. Choi and C.E. Yaguna, Phys. Rev. D 82, 015008 (2010) ...

Backups