AMS-02 results and decaying gravitino DM

Sho IWAMOTO（岩本　祥）
Kavli IPMU, Japan

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Reference)
M. Ibe, SI, S. Matsumoto, T. Moroi, and N. Yokozaki,
JHEP **1308** (2013) 029 [1304.1483].

Higgs!! 

➡ Hierarchy problem

⇨ SUSY !?

✓Hierarchy solved.

✓“LSP”
= DM candidate.

… M_{SUSY} = ???

Higgs!!  ----------→ $m_h = 126\,\mathrm{GeV}$

➡ Hierarchy problem

⇩

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$M_{\mathrm{SUSY}} \sim (1\text{–}1000)\,\mathrm{TeV}$

⋮

$m_{\mathrm{LSP}} \sim 1\,\mathrm{TeV}??$

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PAMELA & AMS-02
e^+ excess @ O(100) GeV

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Decaying DM scenario

(Gravitino with bilinear RPV)

Underlying model
(provides "suitably-tiny" bilinear RPV)

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- Standard Model

$$V(H) = \lambda |H|^4 - \mu^2 |H|^2 \longrightarrow \begin{cases} \langle H \rangle = \mu/\sqrt{2\lambda} \\ m_h = \sqrt{2}\mu \end{cases}$$

two adjustable parameters

m_h is a free parameter.

- MSSM
  - λ is fixed by SUSY. $\left(\lambda = \frac{m_Z^2 \cos 2\beta}{4\langle H \rangle^2} + \delta\lambda^{\rm loop}\right)$

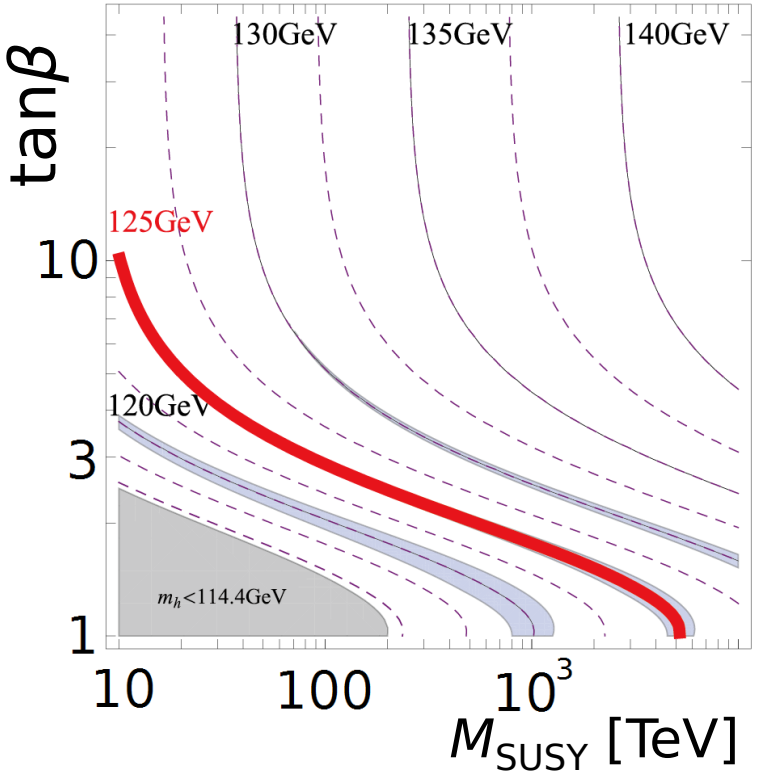
$$\Rightarrow m_h^2 \approx \underbrace{m_Z^2}_{\text{tree}} + \underbrace{\frac{1}{(4\pi)^2}\frac{12 m_t^4}{\langle H \rangle^2}\left[\ln\frac{m_{\tilde{t}}^2}{m_t^2} - \frac{(\alpha^2-6)^2}{12} + 3\right]}_{\text{one-loop level}}$$

where α is the stop mixing parameter.

  - Large loop-correction is required.
    Mass and/or mixing **of scalar-top** must be large.

If the mixing is small...

$\Longrightarrow M_{\rm SUSY} = \mathrm{O}(1\text{–}1000)\,\mathrm{TeV}$



Ibe, Yanagida [1112.2462]

$$\longrightarrow \begin{cases} \langle H \rangle = \mu/\sqrt{2\lambda} \\ m_h = \sqrt{2}\mu \end{cases}$$

m_h is a free parameter.

$$\frac{2\beta}{2} + \delta\lambda^{\rm loop}\Big)$$

$$\frac{m_t^4}{\langle\rangle^2}\left[\ln\frac{m_{\tilde{t}}^2}{m_t^2} - \frac{(\alpha^2-6)^2}{12} + 3\right]$$

one-loop level

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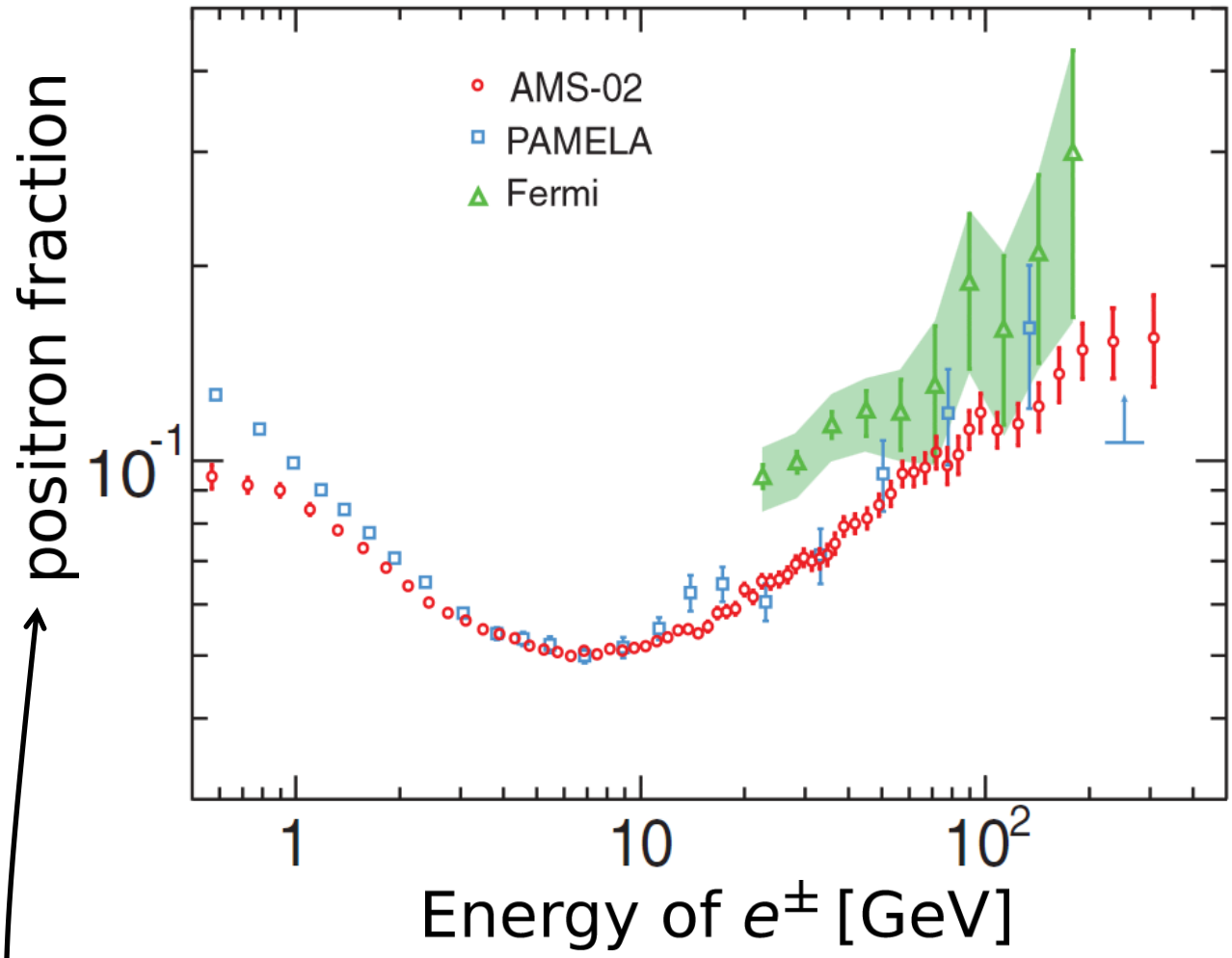
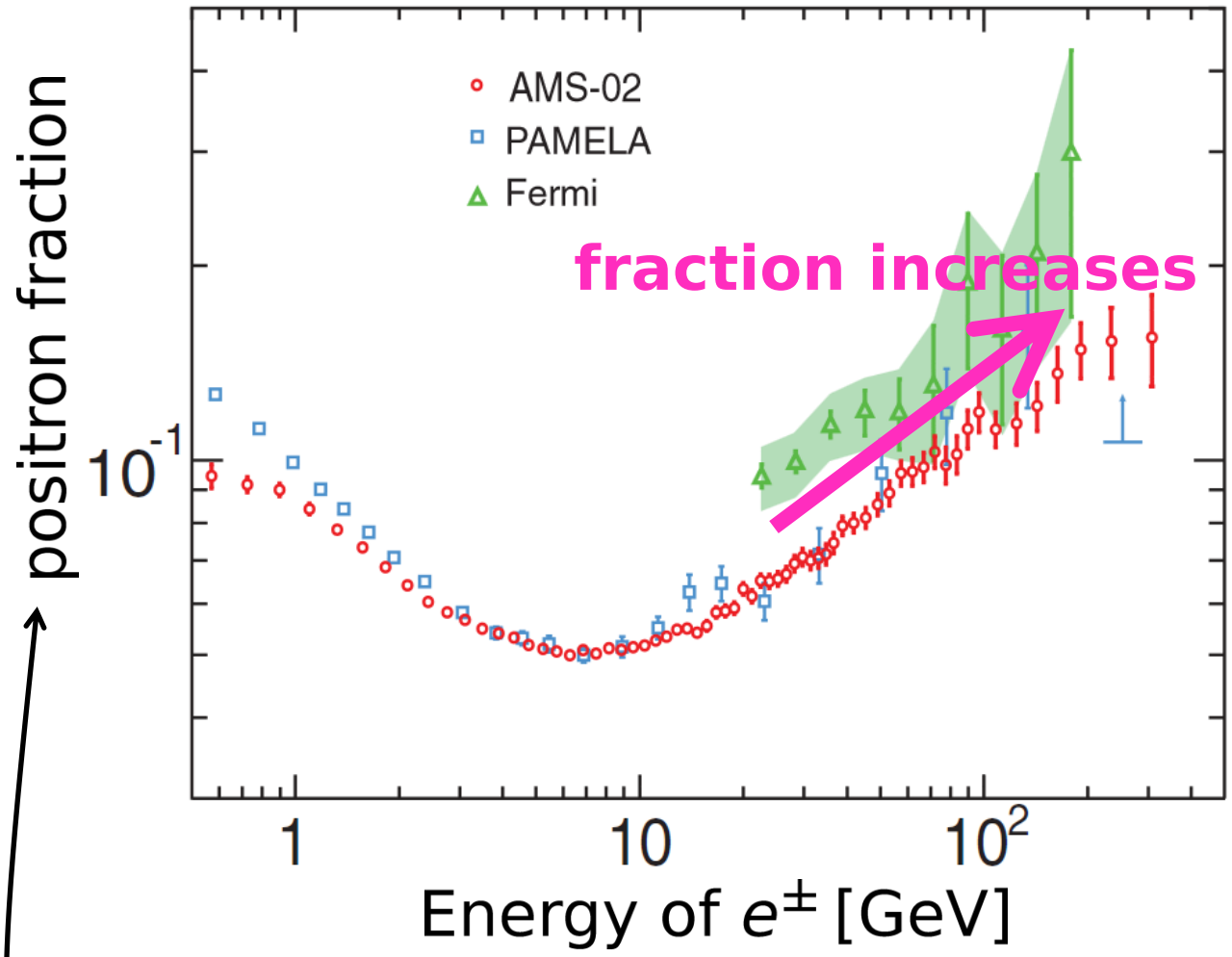
PAMELA & AMS-02 coll. (Figure from PRL **110** (2013) 141102)



defined as $\dfrac{\text{flux of } [e^+]}{\text{flux of } [e^+ + e^-]} \left(= \dfrac{\Phi(e^+)}{\Phi(e^+) + \Phi(e^-)} \right)$



reincrease
@O(100) GeV

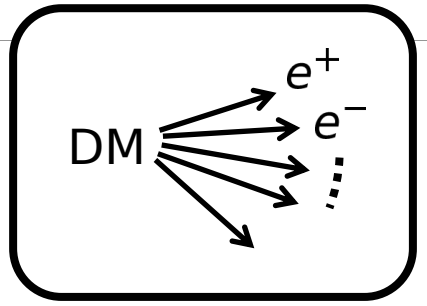
⇩

extra e^+ source
@O(100) GeV?

(or $e^+ + e^-$ source)

defined as $\dfrac{\text{flux of } [e^+]}{\text{flux of } [e^+ + e^-]} \left(= \dfrac{\Phi(e^+)}{\Phi(e^+) + \Phi(e^-)} \right)$

A decaying DM scenario



"SUSY with gravitino LSP

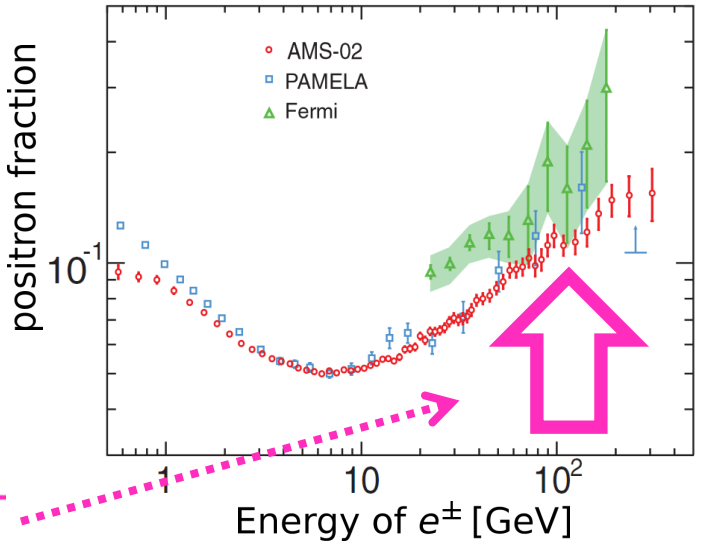
with bilinear R-parity violation"

$$\left(W_{\mathrm{RpV}} = \mu'_i L_i H_{\mathrm{u}}\right)$$

$$\text{gravitino} \xrightarrow{L_i H_{\mathrm{u}}} \begin{cases} \nu_i + h \\ \nu_i + Z \\ l_i + W \end{cases}$$

(LSP, i.e., DM)

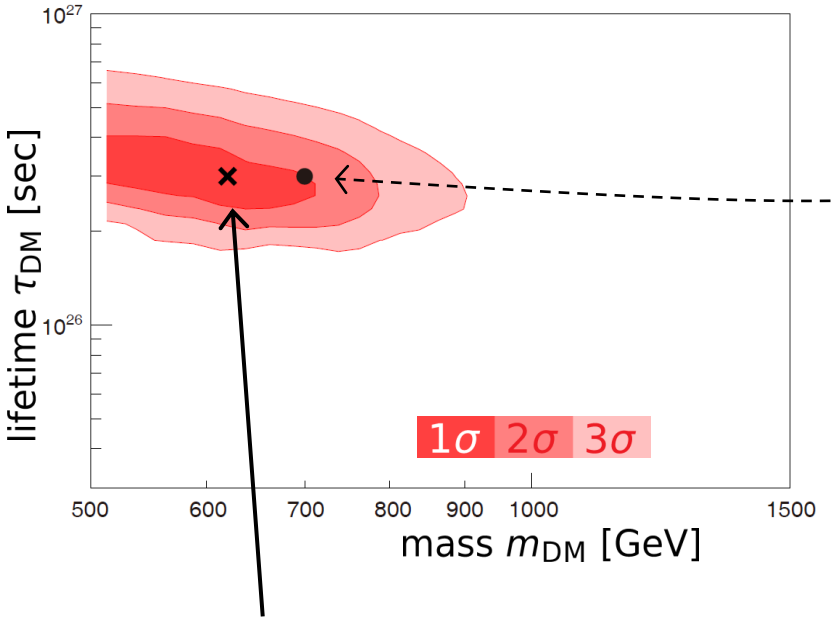
$$\longrightarrow e^+ + e^-$$



($m_{\mathrm{DM}} \sim 1\,\mathrm{TeV}$)

($E \sim \mathrm{O}(100)\,\mathrm{GeV}$)

$$W_{\mathrm{RpV}} = \mu' L_{\mathbf{2}} H_{\mathrm{u}}$$



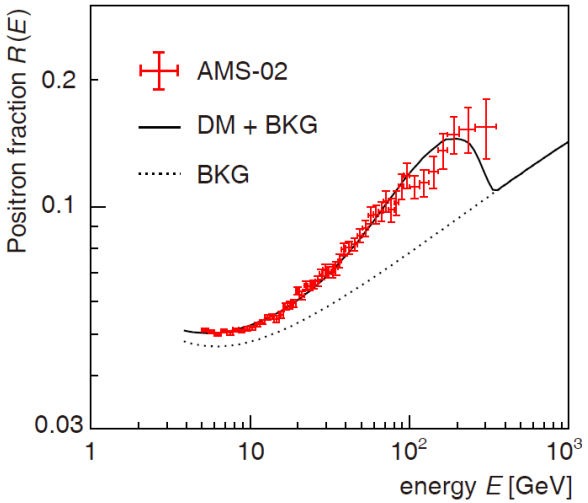
Best fit: $\chi^2/\mathrm{dof} = 77.0/67$

$(m_{\mathrm{DM}}, \tau_{\mathrm{DM}}) \sim (620\,\mathrm{GeV}, 3.0 \times 10^{26}\,\mathrm{s})$

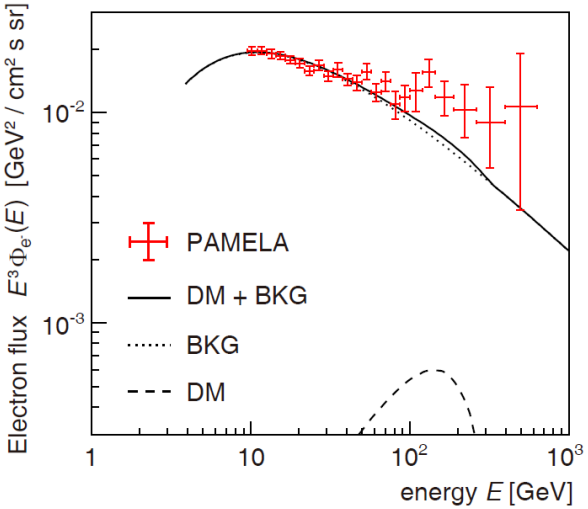
➢Sample point

$(m_{\mathrm{DM}}, \tau_{\mathrm{DM}}) = (700\,\mathrm{GeV}, 3 \times 10^{26}\,\mathrm{sec})$

•Positron fraction $\Phi(e^+)/(\Phi(e^+)+\Phi(e^-))$



•Electron total flux $(\Phi(e^+)+\Phi(e^-)) \times E^3$



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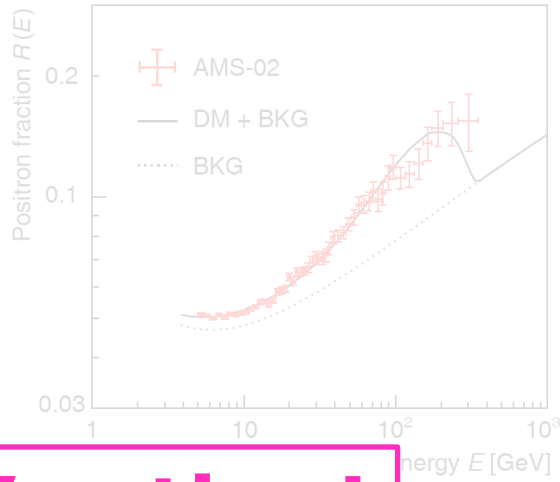
$$W_{\rm RpV} = \mu' L_2 H_{\rm u}$$

•Positron fraction



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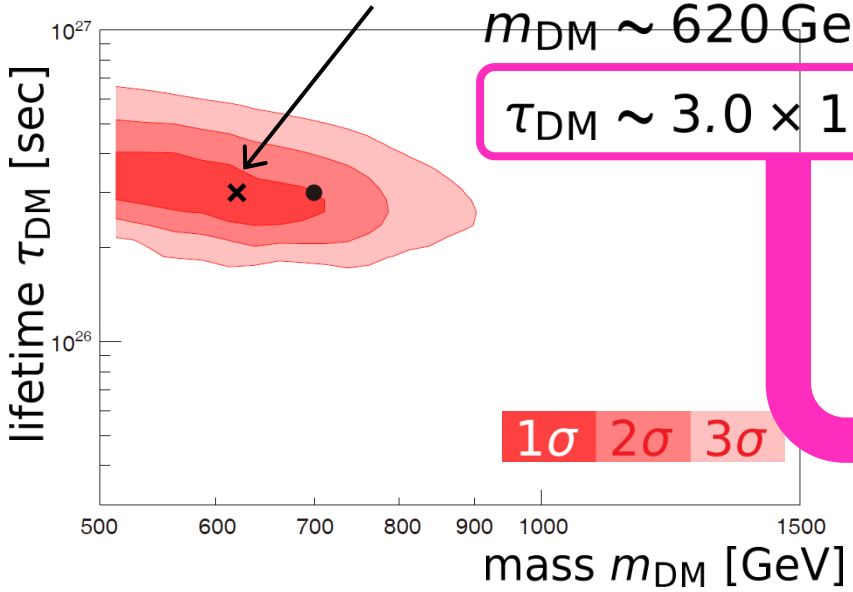
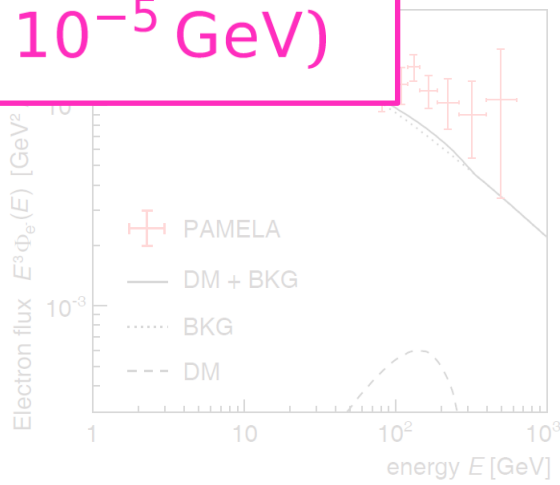


RPV = tiny!

$(\mu' \sim 10^{-5}\,{\rm GeV})$



MSSM + $\bar{N}$ + two singlets (ϕ, X) w. discrete R-sym. $\mathbb{Z}_{5R}$

extra singlets

	$H_{\rm u}$	$H_{\rm d}$	$\mathbf{10}$	$\bar{\mathbf{5}}$	$\bar{N}$	ϕ	X
$\mathbb{Z}_{5R}$	1	1	3	3	3	1	0

$$W = y_u H_{\rm u} \mathbf{10}\,\mathbf{10} + y_d H_{\rm d} \mathbf{10}\,\bar{\mathbf{5}} + y_\nu H_{\rm u} \bar{\mathbf{5}}\,\bar{N} + \mu H_{\rm u} H_{\rm d}$$

$$+ y_m \phi \bar{N}\bar{N} - \frac{c_4}{M_{\rm pl}^2}\phi^4 \bar{N} + \frac{c_7}{M_{\rm pl}^4}\phi^7$$

$$+ y_X X \left(\phi^2 + c_H \frac{\mu}{M_{\rm pl}} H_{\rm u} H_{\rm d} - c_W \frac{\langle \mathbf{W_0} \rangle}{M_{\rm pl}} \right)$$

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$$\langle \mathbf{W_0} \rangle = m_{3/2} M_{\rm pl}^2$$

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(mediated by X)

with $m_{3/2} \sim 1\,\text{TeV}$ and $c, y \sim \text{O}(1)$, $\begin{cases} \langle\phi\rangle = \text{O}(10^{11})\,\text{GeV}, \\ \langle\bar{N}\rangle = \text{O}(10^{-5})\,\text{GeV}. \end{cases}$

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Bilinear RpV ~ O(10^{-5})GeV (as desired)

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$\mathbb{Z}_{5R}$-breaking (induced by ~~SUSY~~)

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$$+ y_X X \left(\phi^2 + c_H \frac{\mu}{M_{\rm pl}} H_u H_d - c_W \frac{\langle \mathbf{W_0} \rangle}{M_{\rm pl}} \right)$$

(mediated by X)

Majorana mass ~ O(10^{11})GeV

with $m_{3/2} \sim 1\,\text{TeV}$ and $c, y \sim \text{O}(1)$, $\begin{cases} \langle \phi \rangle = \text{O}(10^{11})\,\text{GeV}, \\ \langle \bar{N} \rangle = \text{O}(10^{-5})\,\text{GeV}. \end{cases}$

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1. Decaying Gravitino dark matter

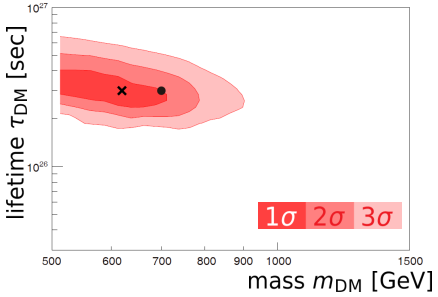
through bilinear R-parity violation

- is motivated by the Higgs mass ($m_h = 126\,\mathrm{GeV}$).
- explains the AMS-02 results with

$$W_{\not R_p V} = \mu' L_2 H_u,$$

$$(m_{\mathrm{DM}}, \tau_{\mathrm{DM}}) \sim (700\,\mathrm{GeV}, 10^{26}\,\mathrm{sec}).$$

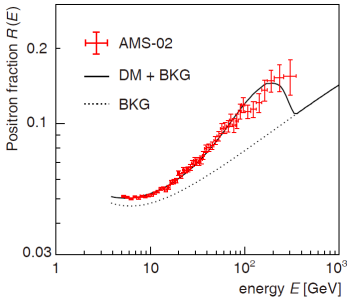
$$(\mu' \sim 10^{-5}\mathrm{GeV})$$

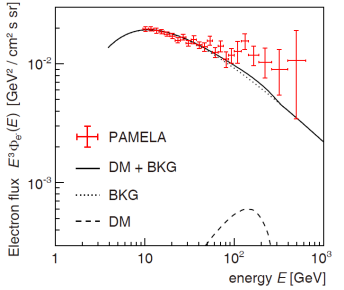


2. Model for the bilinear RpV

	H_u	H_d	$\mathbf{10}$	$\overline{\mathbf{5}}$	$\bar{N}$	ϕ	X
$\mathbb{Z}_{5R}$	1	1	3	3	3	1	0

$$m_{3/2} \sim 1\,\mathrm{TeV} \implies \begin{cases} \mu' \sim 10^{-5}\,\mathrm{GeV}, \\ M_N \sim 10^{11}\,\mathrm{GeV}. \end{cases}$$



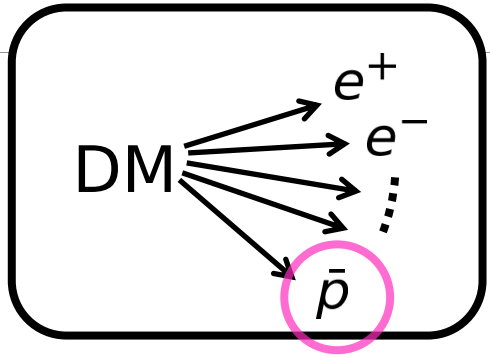


Backup

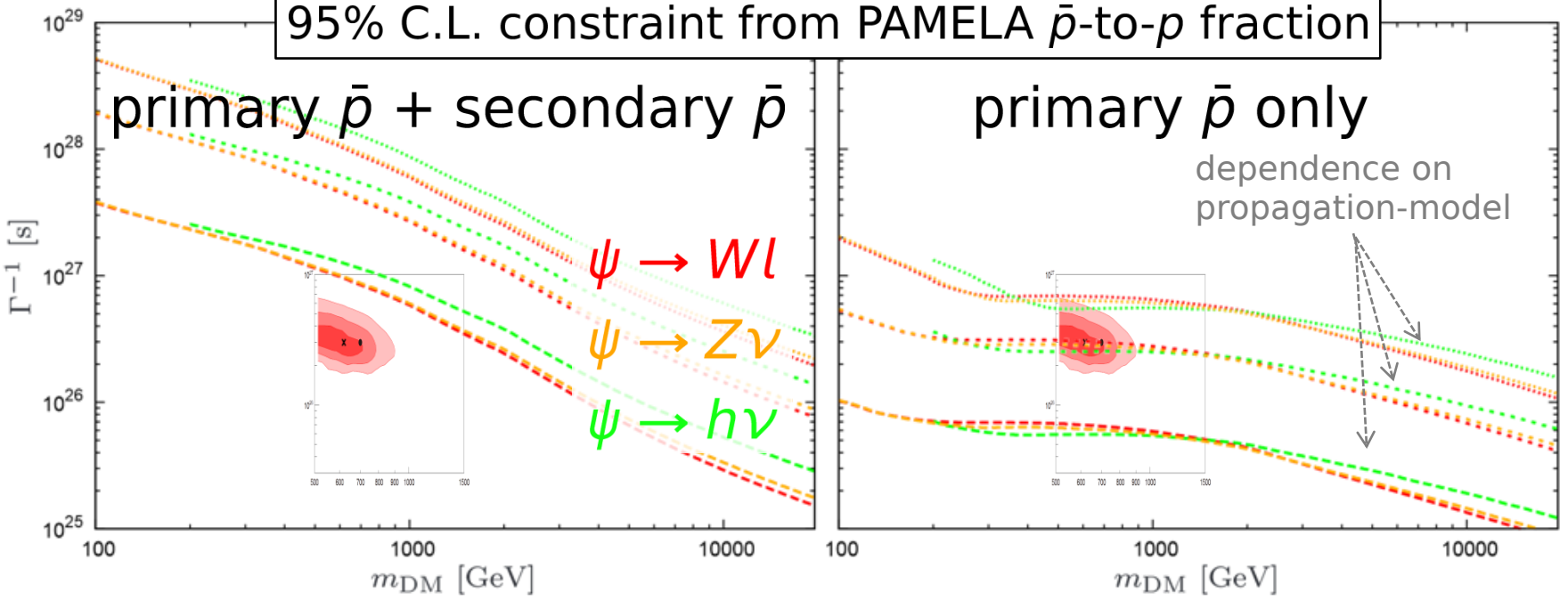
$(m_{\rm DM}, \tau_{\rm DM}) \sim (700\,{\rm GeV}, 10^{26}\,{\rm sec})$

is on the edge of anti-proton constraint.

$\left({\rm DM} \to \{W, Z, h\} \to q\bar{q} \to p\bar{p}\right)$



95% C.L. constraint from PAMELA $\bar{p}$-to-p fraction



Garny, Ibarra, Tran [1205.6783]
See also: Delahaye and Grefe [1305.7183]

primary = from DM decay
secondary = spallation on interstellar gas