Decaying SUSY Dark Matter and 130 GeV Fermi Gamma-ray Line

Seng Pei Liew (U. of Tokyo)

(based on...) **Phys. Lett. B 721 (2013) , pp. 111; [1301.7536]**

with M. Endo, K. Hamaguchi, K. Mukaida, K. Nakayama

(and...) **Phys. Lett. B 724 (2013), pp. 88; [1304.1992]**

Corfu 2013

Summary

- 130 GeV Gamma-ray line from FERMI
- Decaying Axino and Gravitino (with trilinear RPV) are capable of explaining the signal

130 GeV γ-line

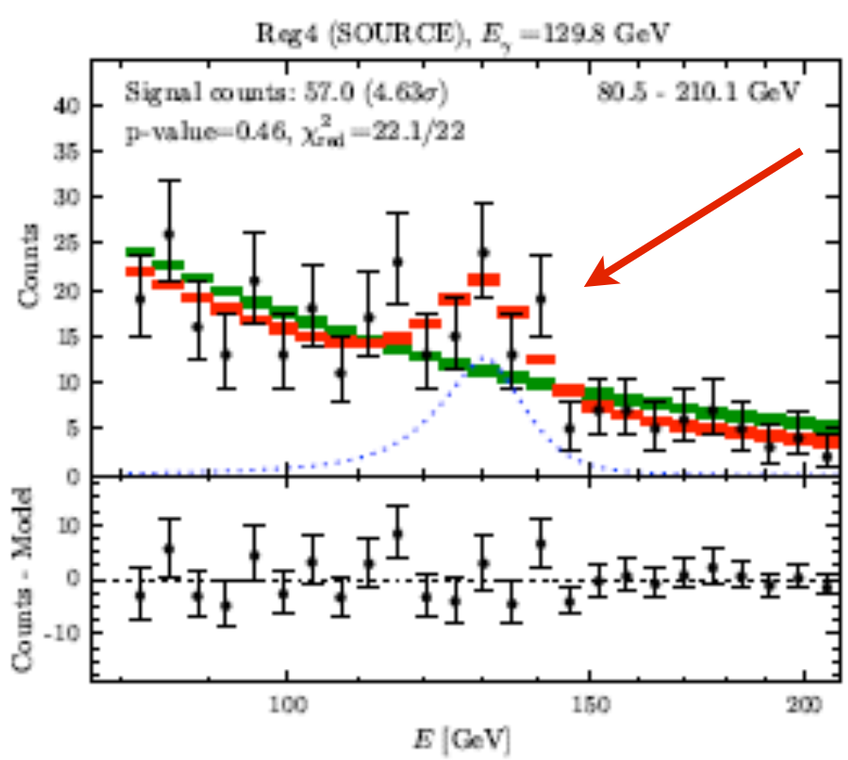
Studies on γ-rays from the Fermi data

T. Bringmann, X. Huang, A. Ibarra, S. Vogl, C. Weniger [arXiv:1203.1312]
C. Weniger [arXiv:1204.2797]
E. Tempel, A. Hektor and M. Raidal [arXiv:1205.1045]

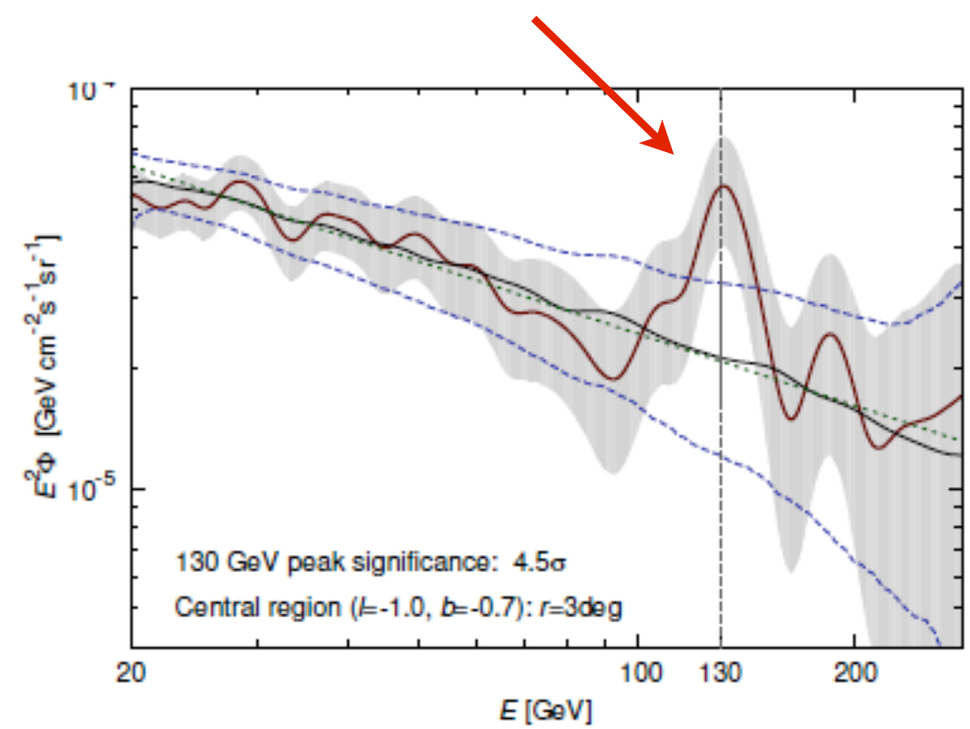
and many more...

See T. Bringmann, C. Weniger [arXiv:1208.5481] **for a review**

From the Galactic Center, they found

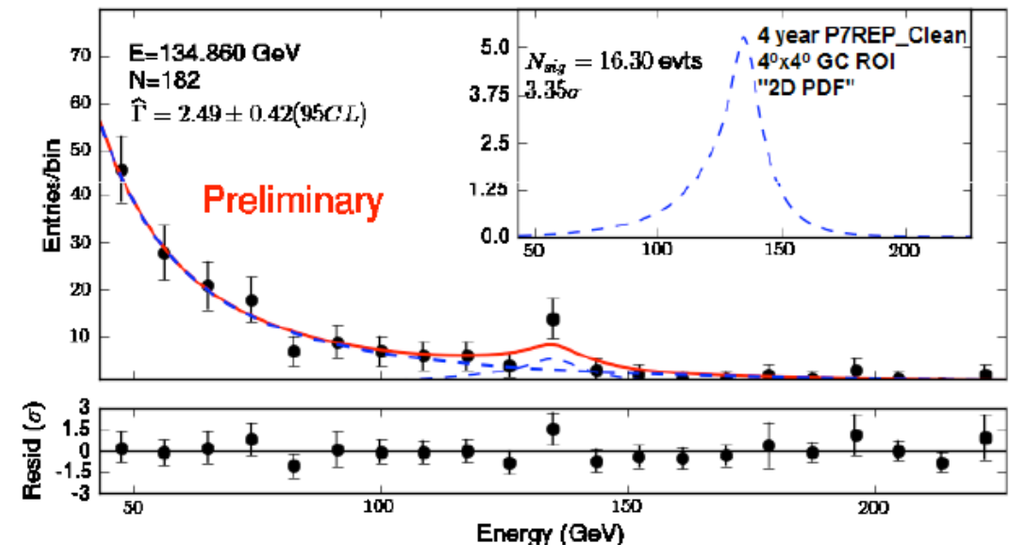


C. Weniger [arXiv:1204.2797]



E. Tempel, A. Hektor and M. Raidal [arXiv:1205.1045]

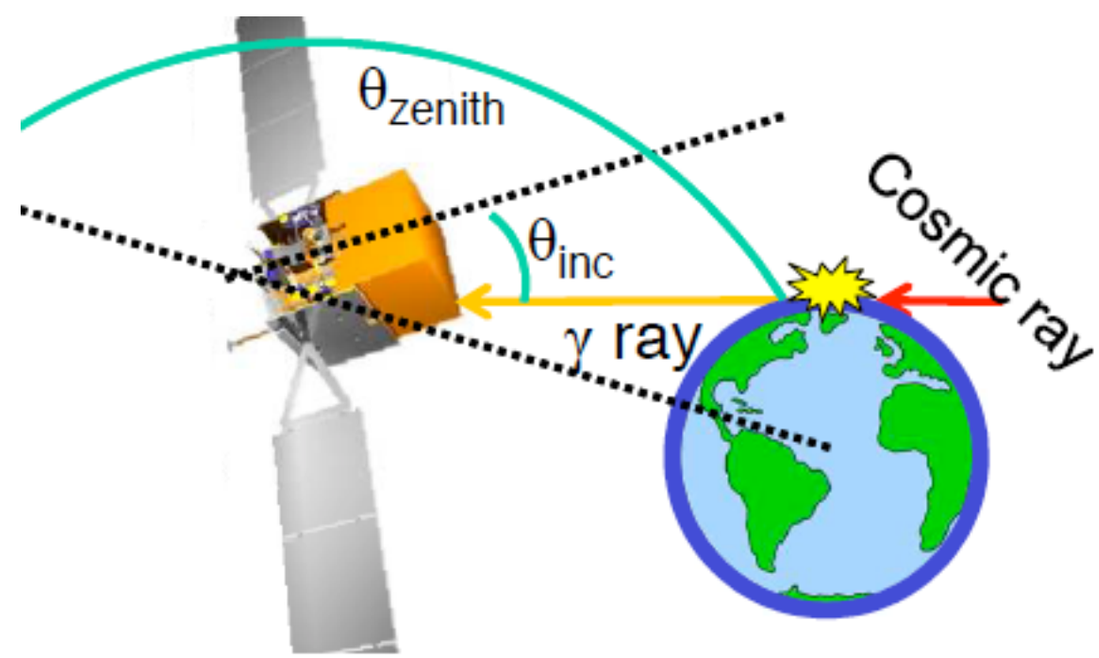
A DM signal?



- Less significant feature from the Fermi Collaboration
- γ-lines from the Earth limb?
- Instrumental?

Still inclonclusive...

Summary & Updates:
C. Weniger [arXiv:1303.1798]



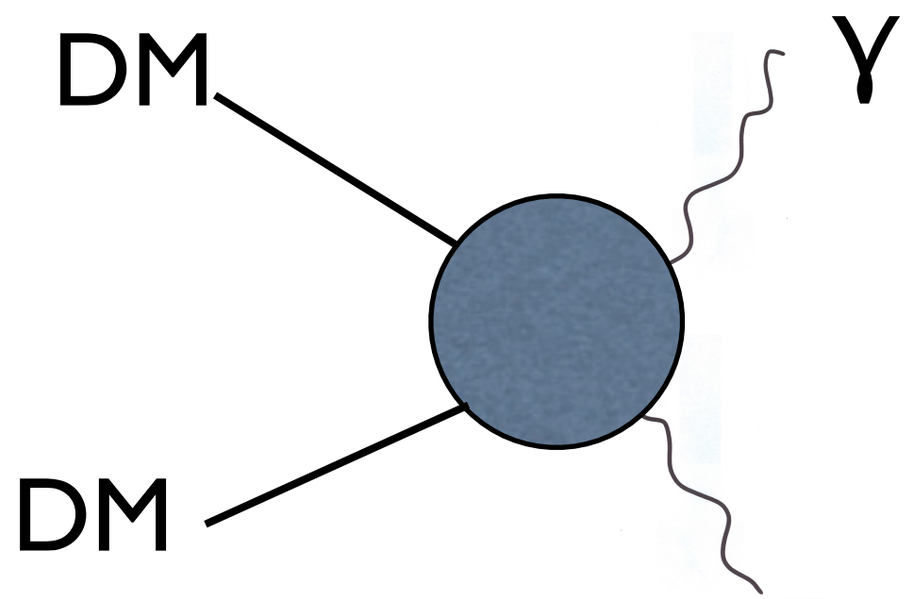
From A. Albert's talk, the Fermi Symposium Nov. 2012


NOT SURE IF IT'S DARK MATTER
OR AN EXPERIMENTAL FLUKE
memegenerator.net

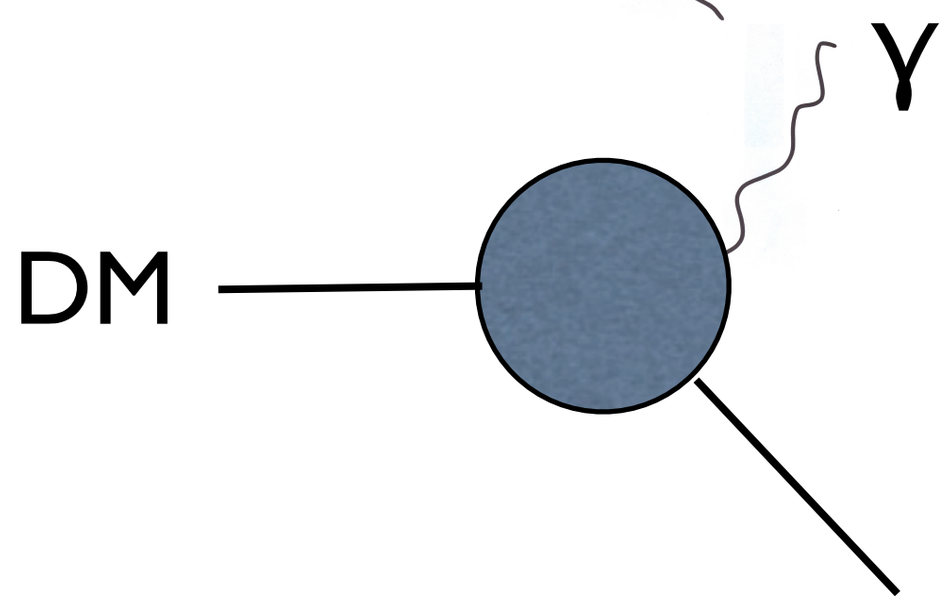
What if it is a DM Signal?

Two possibilities!

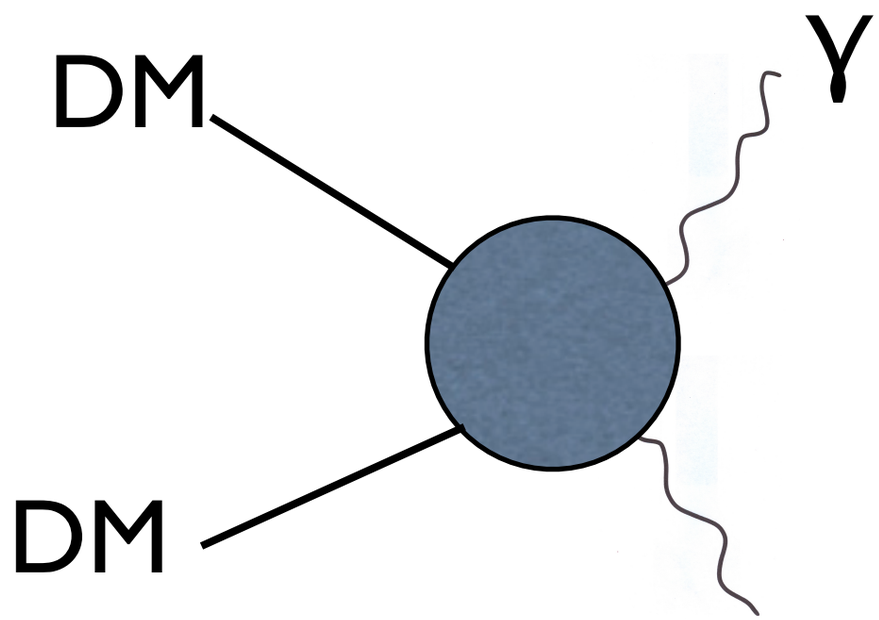
Annihilating DM



Decaying DM



- Annihilating DM (such as neutralino in SUSY)



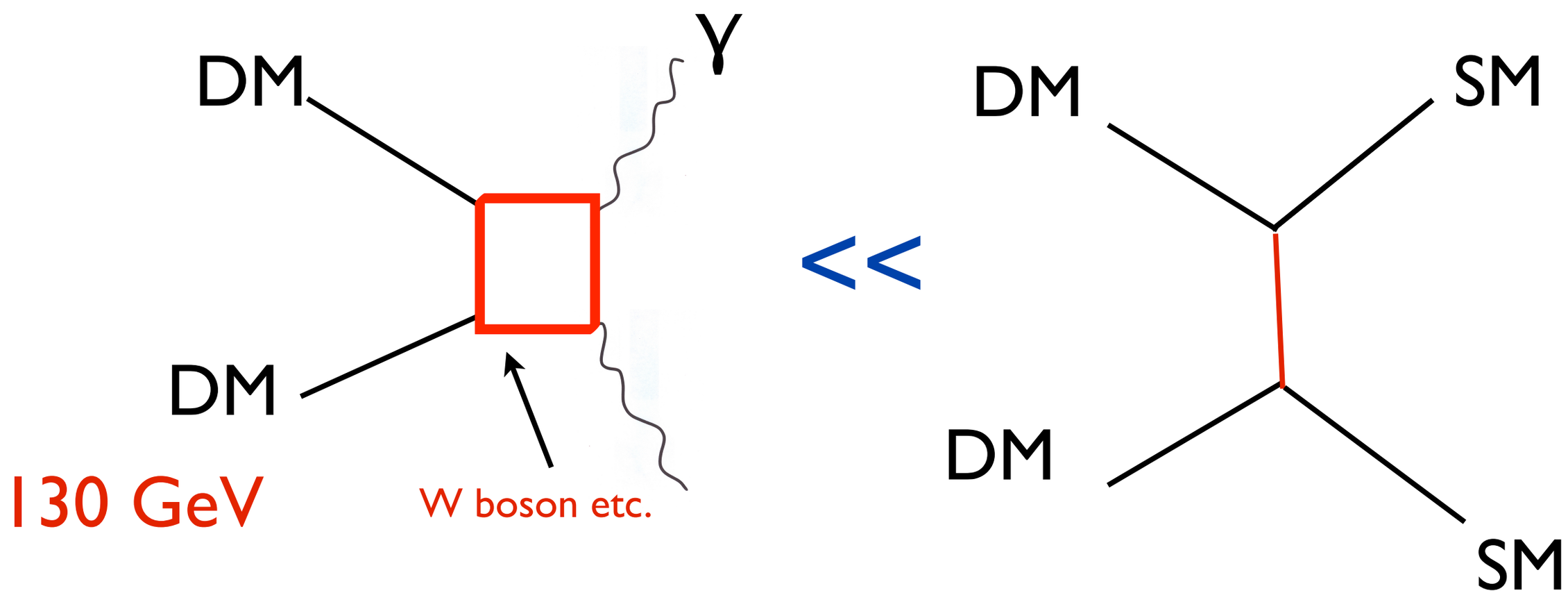
$$\langle \sigma v \rangle_{\chi\chi\to\gamma\gamma} \simeq 10^{-27}\mathrm{cm}^3\mathrm{s}^{-1}$$

Large!

130 GeV

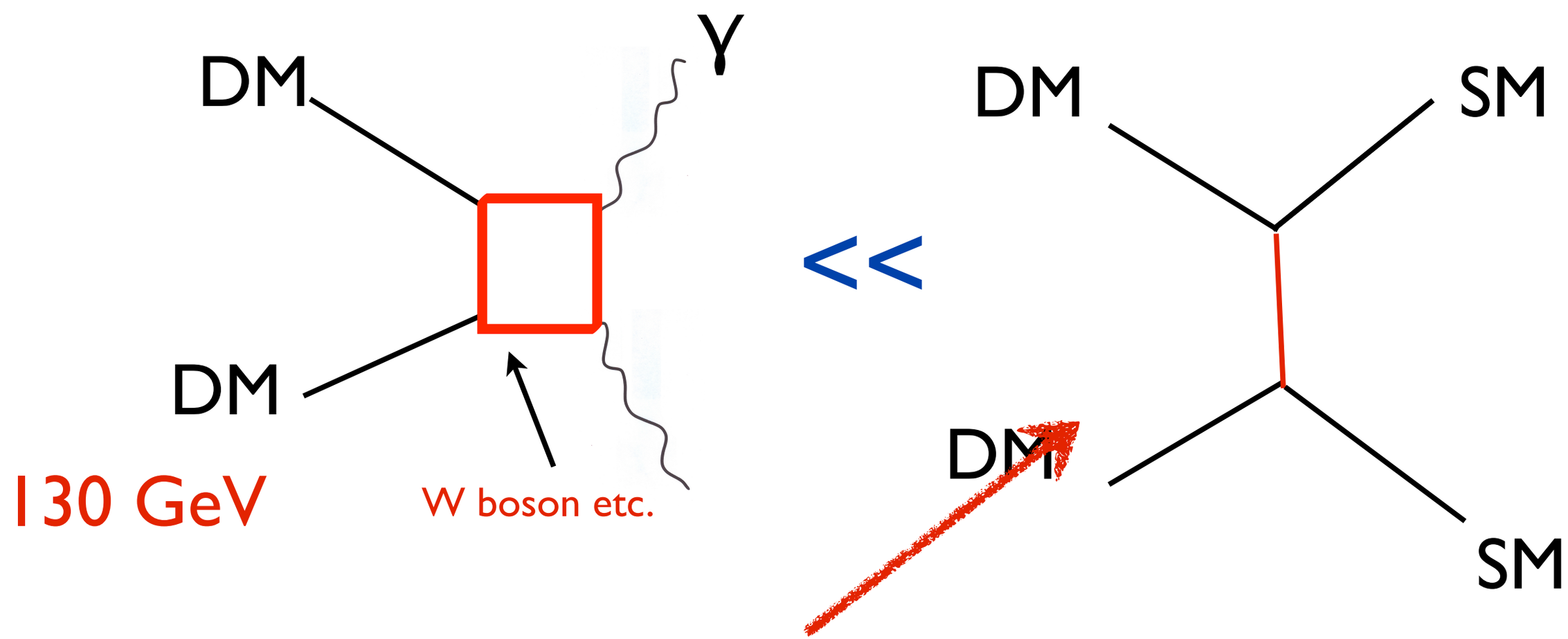
- γ from loop effects

Typically...



- γ from loop effects

Typically...



Too much continuum γ & antiprotons!

Decaying DM in SUSY

Gravitino

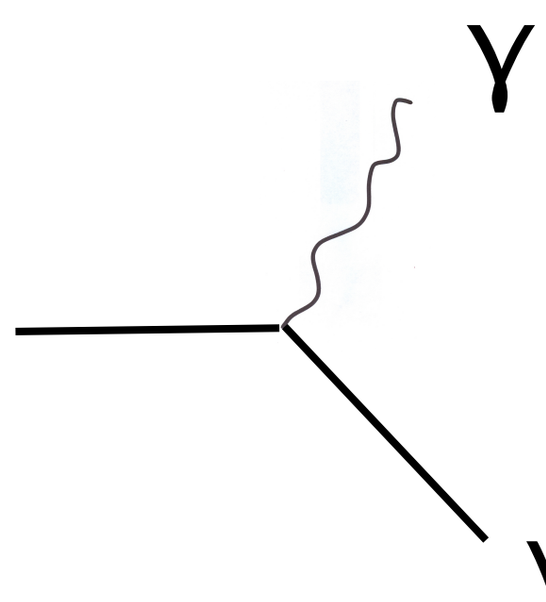
F. Takayama, M. Yamaguchi [hep-ph/0005214]

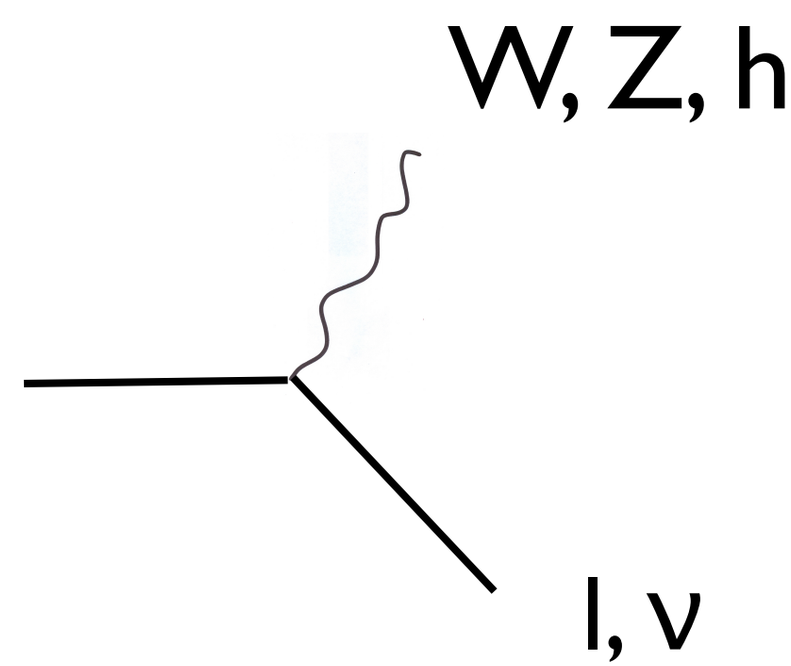
- Small bilinear R-parity violation (RPV)
- Looong lifetime

$$\mathcal{L}_{int} = -\frac{i}{\sqrt{2}\,M_{\rm Pl}}\left[\left(D^*_\mu\phi^{i*}\right)\bar{\psi}_\nu\gamma^\mu\gamma^\nu P_L\chi^i - \left(D_\mu\phi^i\right)\bar{\chi}^i P_R\gamma^\nu\gamma^\mu\psi_\nu\right]$$
$$-\frac{i}{8M_{\rm Pl}}\bar{\psi}_\mu\left[\gamma^\nu,\,\gamma^\rho\right]\gamma^\mu\lambda^{(\alpha)\,a}F^{(\alpha)\,a}_{\nu\rho} + \mathcal{O}(M_{\rm Pl}^{-2})\,.$$

Lifetime ~ 10^{28} sec

Gravitino
260 GeV





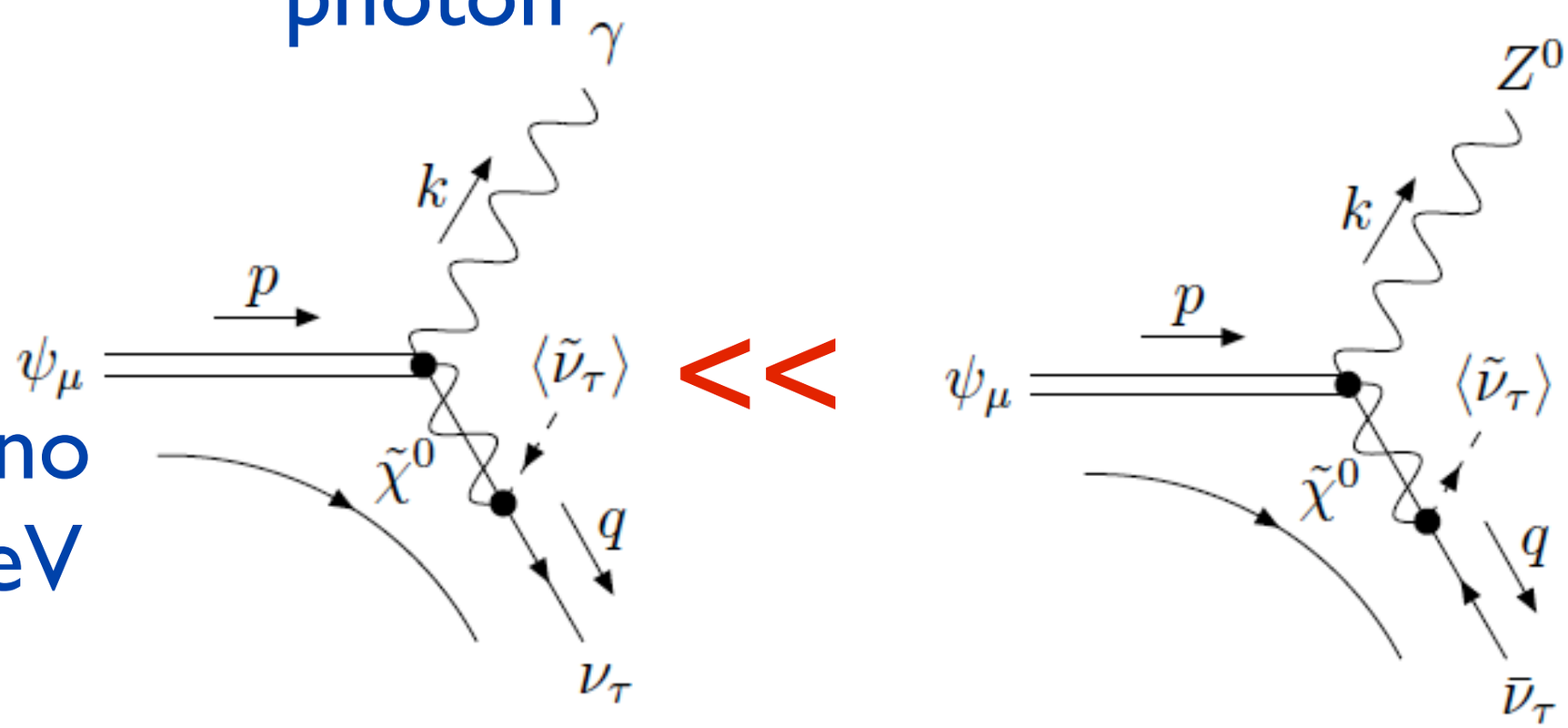
Decaying DM

Gravitino

F. Takayama, M. Yamaguchi [hep-ph/0005214]

photon

W, Z, h



Gravitino
260 GeV

from Grefe's thesis

neutrino

l, ν

W. Buchmuller, M. Garny [arXiv:1206.7056]

Too much continuum γ & antiprotons!

Theorists' reaction

Branching ratio of annihilation/decay into photon should be LARGE

Any other DM candidates?

↓

Axino
Gravitino with trilinear RPV

Axion as a solution of the Strong CP problem

$$L = \theta \frac{1}{16\pi^2} F^a_{\mu\nu} \tilde{F}^{a\mu\nu}$$ from non-perturbative effects

but $\theta \ll 10^{-9}$ from experiments (fine-tuning problem)

↓

Introduce a new field a such that $$L = \frac{a}{16\pi^2 f_a} F^a_{\mu\nu} \tilde{F}^{a\mu\nu}$$

at the minimum of the potential, $\langle a \rangle = -f_a \theta$

$$L = \frac{a}{16\pi^2 f_a} F^a_{\mu\nu} \tilde{F}^{a\mu\nu}$$

for U(1) and SU(2) gauge couplings

supersymmetrize

$$\mathcal{L}_{\tilde{a}\lambda A} = i\frac{\alpha_Y \boxed{C_Y}}{16\pi f_a}\bar{\tilde{a}}\gamma_5[\gamma^\mu,\gamma^\nu]\tilde{B}B_{\mu\nu} + i\frac{\alpha_W \boxed{C_W}}{16\pi f_a}\bar{\tilde{a}}\gamma_5[\gamma^\mu,\gamma^\nu]\tilde{W}^a W^a_{\mu\nu}$$

Axino

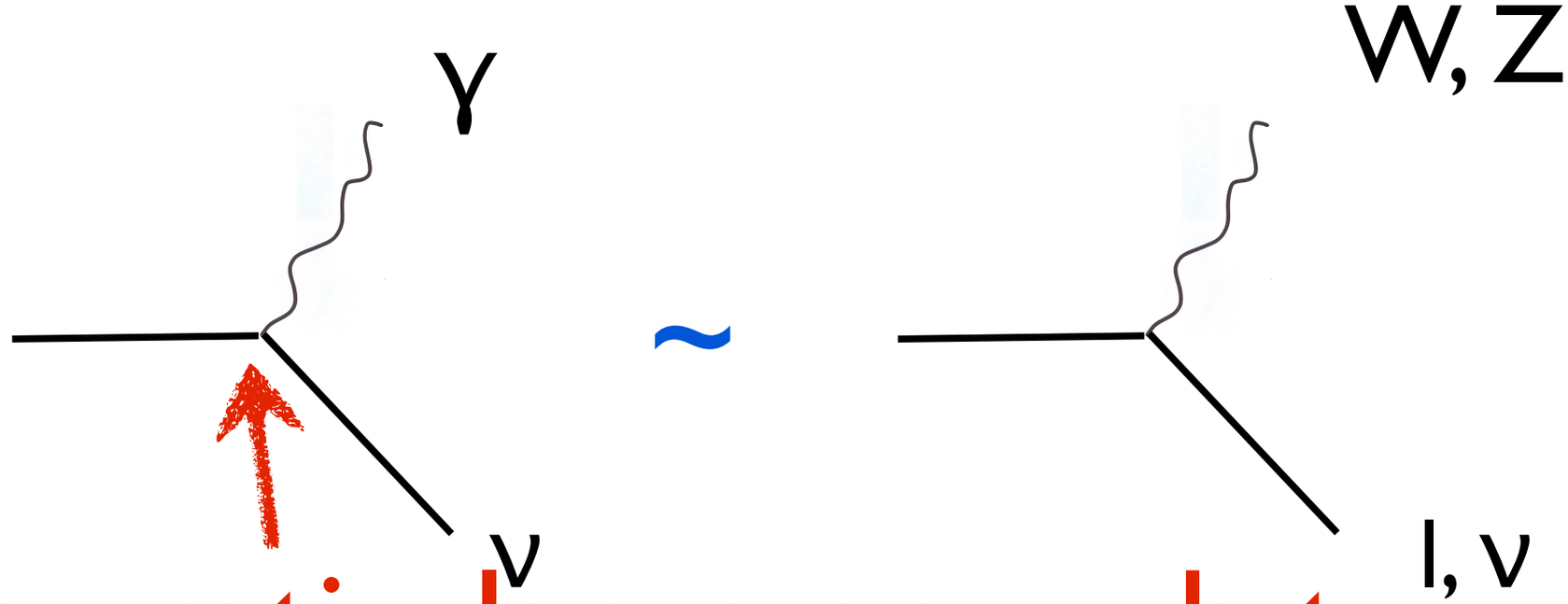
See K.Y. Choi, J.E. Kim, L. Roszkowski [1307.3330] for a review

- Small bilinear R-parity violation (RPV)
- Loooong lifetime

$\longrightarrow$ Decaying DM

$$\mathcal{L} = i\frac{\alpha_Y C_Y}{16\pi f_a}\bar{\tilde{a}}\gamma_5[\gamma^\mu,\gamma^\nu]\tilde{B}B_{\mu\nu} + i\frac{\alpha_W C_W}{16\pi f_a}\bar{\tilde{a}}\gamma_5[\gamma^\mu,\gamma^\nu]\tilde{W}^a W^a_{\mu\nu}$$

Axino
260 GeV

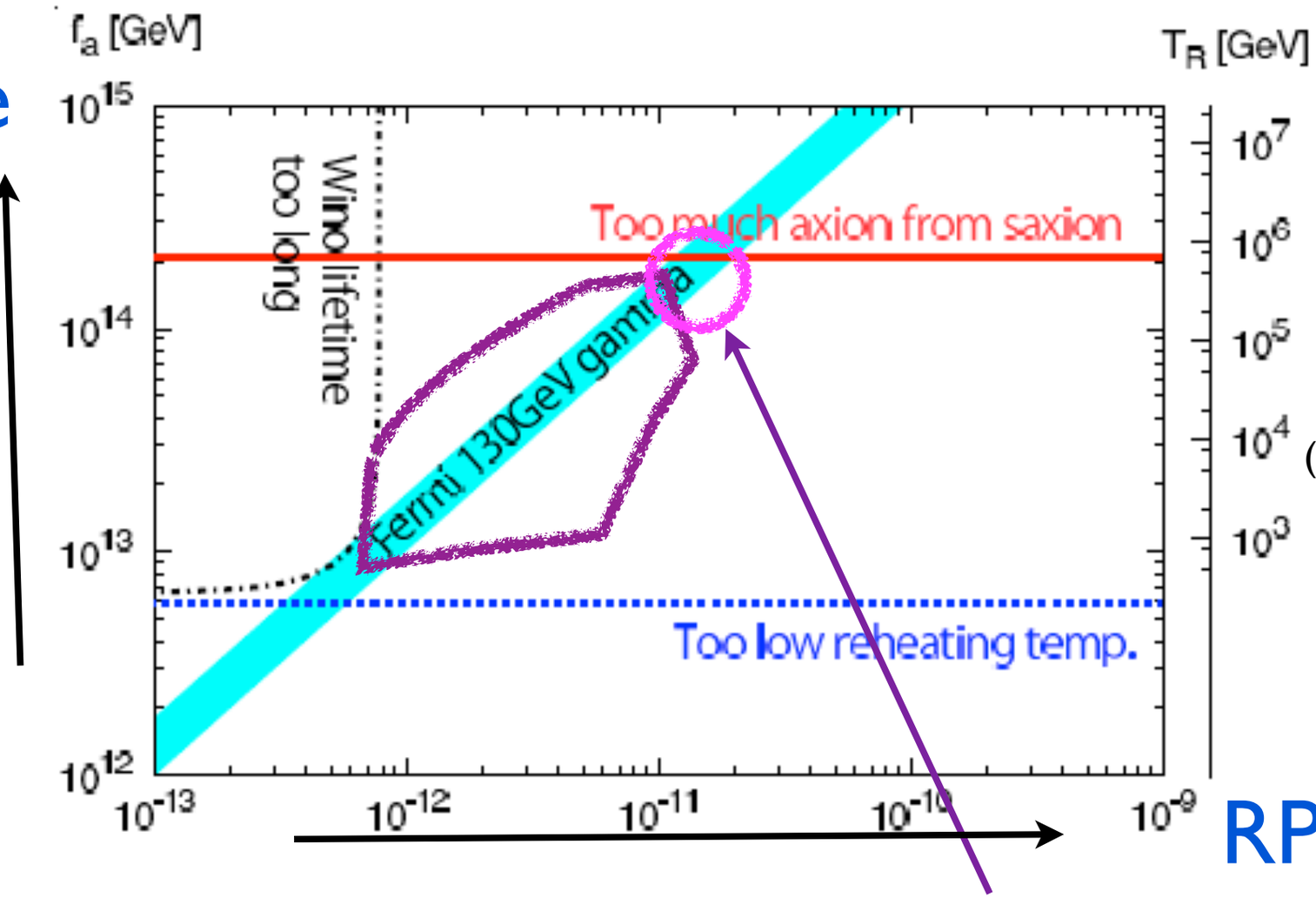


Branching ratio large enough to explain the 130-GeV γ-line!

Results

M. Endo, K. Hamaguchi, SPL, K. Mukaida, K. Nakayama [arXiv:1301.7536]

PQ Scale



(Wino NLSP, similar for Bino NLSP)

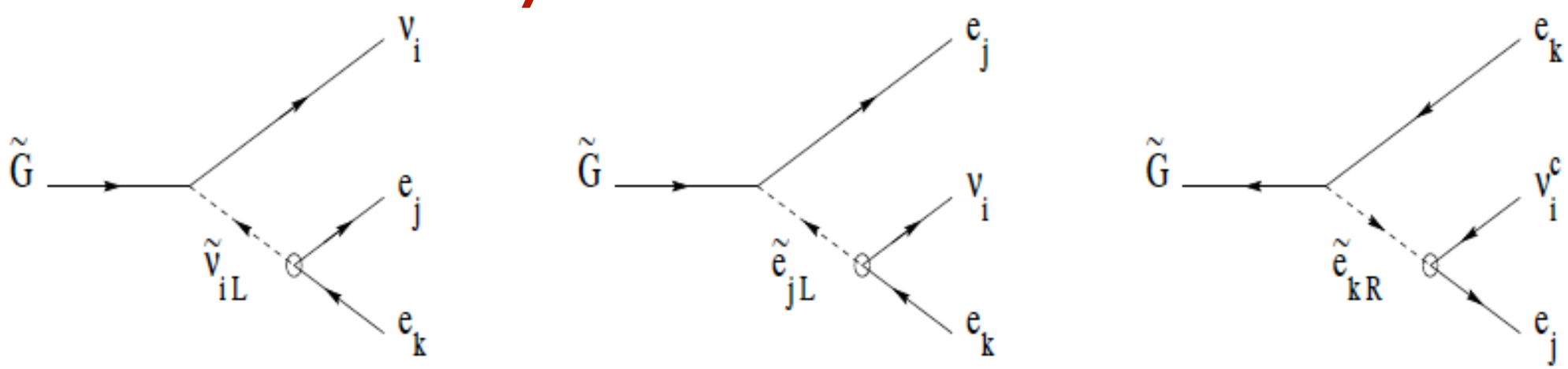
RPV parameter

(Can explain dark radiation)

Gravitino with trilinear RPV

Tree-level decay

G. Moreau, M. Chemtob [arXiv:0107286]

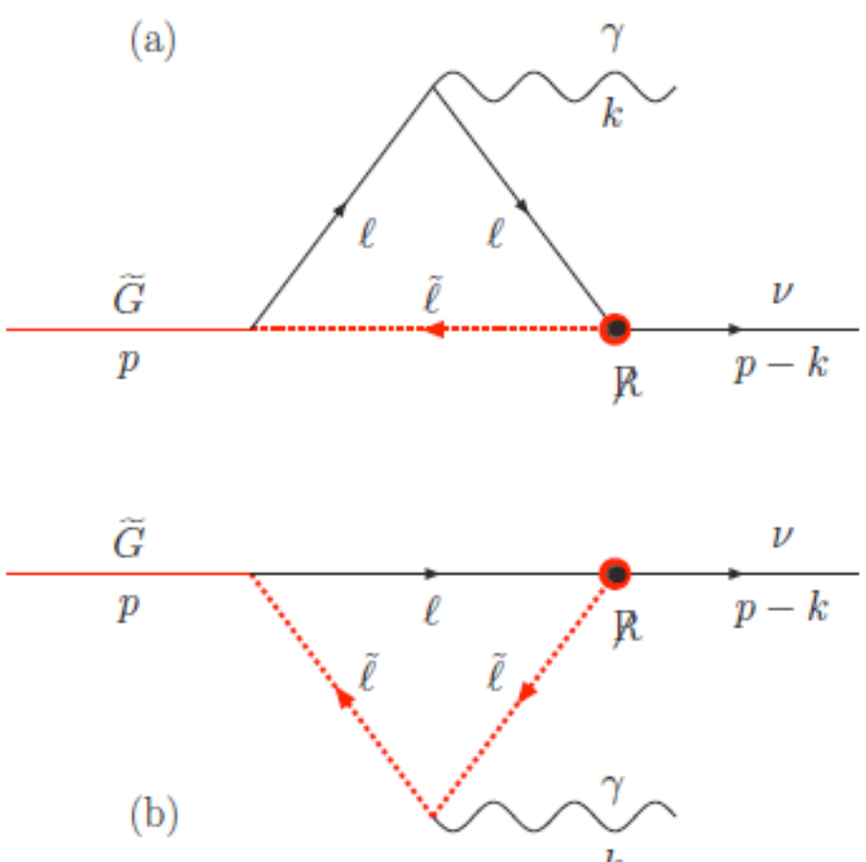


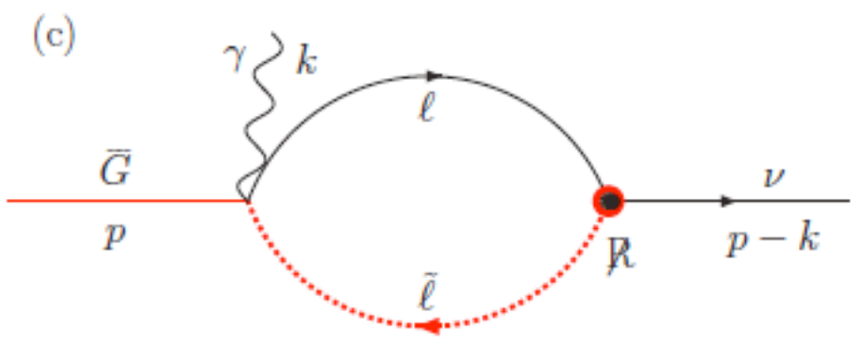
Phase space suppression

vs.

Loop suppression

S. Lola, P. Osland, A.R. Raklev [arXiv:0707.2510]

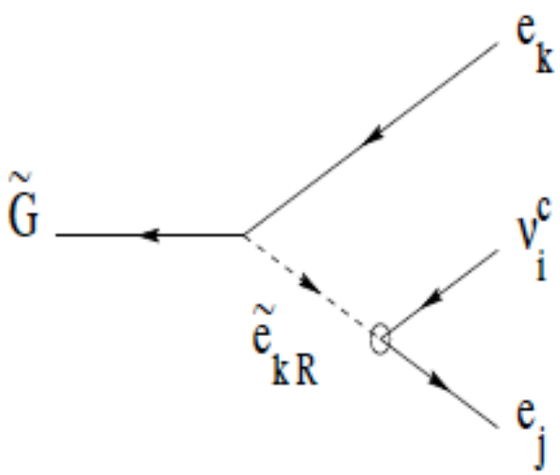




Radiative decay

Gravitino with trilinear RPV

suppressed by sfermion mass!

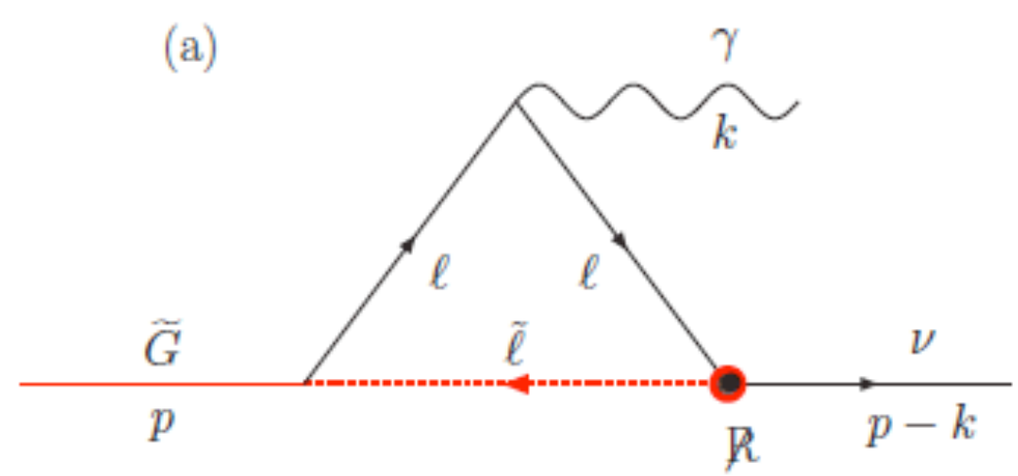


$$\Gamma(\psi_{3/2} \to \bar{\tau}\nu_i e_j) \simeq \frac{|\lambda_{ij3}|^2}{90(32)^2\pi^3} \frac{m_{3/2}^7}{M_{\rm Pl}^2 m_{\tilde{\tau}_R}^4}$$

$$\mathcal{L}_{int} = -\frac{i}{\sqrt{2}\,M_{\rm Pl}} \left[(D_\mu^* \phi^{i*})\, \bar{\psi}_\nu \gamma^\mu \gamma^\nu P_L \chi^i - (D_\mu \phi^i)\, \bar{\chi}^i P_R \gamma^\nu \gamma^\mu \psi_\nu \right]$$
$$- \frac{i}{8M_{\rm Pl}} \bar{\psi}_\mu \left[\gamma^\nu, \gamma^\rho\right] \gamma^\mu \lambda^{(\alpha)a} F_{\nu\rho}^{(\alpha)a} + \mathcal{O}(M_{\rm Pl}^{-2}) \,.$$

$$\Gamma(\psi_{3/2} \to \gamma\nu_i) \sim \frac{\alpha \lambda_{ijj}^2 m_{3/2} m_j^2}{M_{\rm Pl}^2}$$

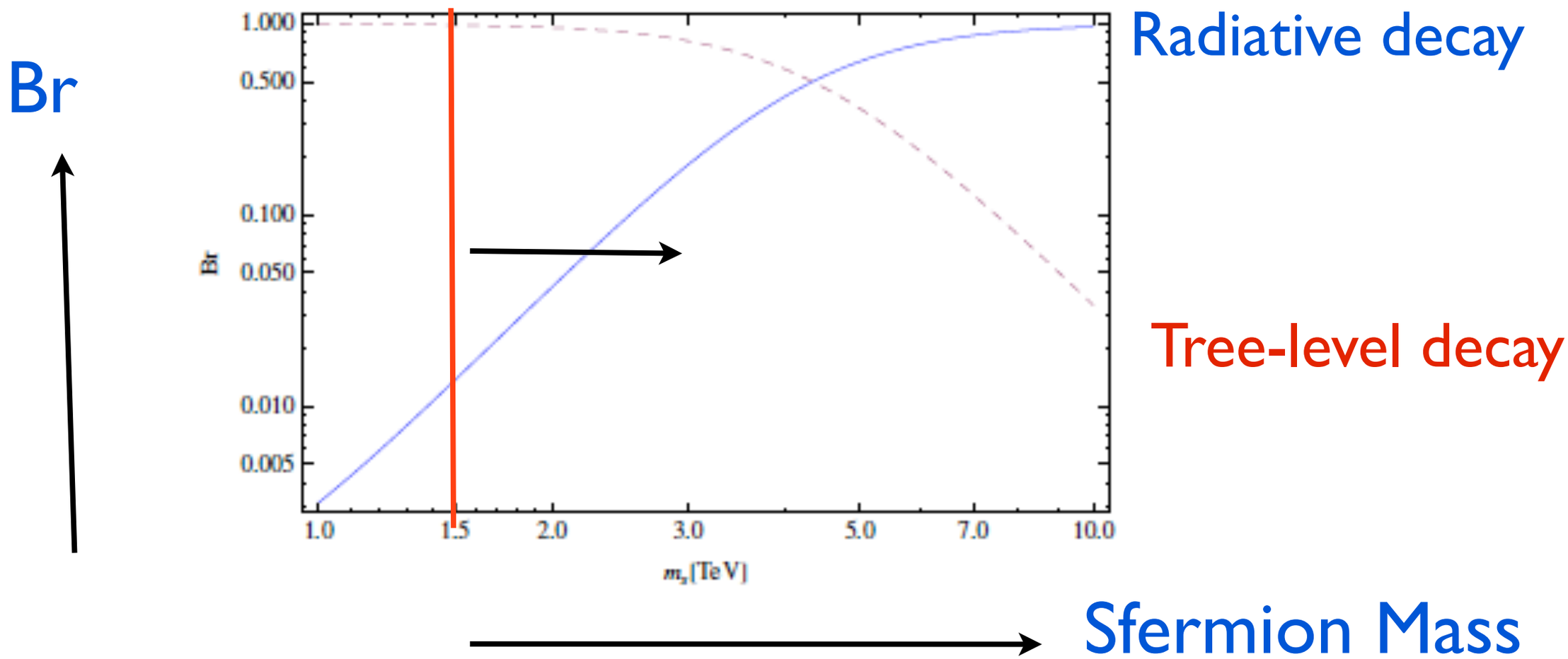
Independent of sfermion mass!



$$\mathcal{L}_{int} = -\frac{i}{\sqrt{2}\,M_{\rm Pl}}\left[\left(\boxed{D^*_\mu}\phi^{i*}\right)\bar{\psi}_\nu\gamma^\mu\gamma^\nu P_L\chi^i - \left(\boxed{D_\mu}\phi^i\right)\bar{\chi}^i P_R\gamma^\nu\gamma^\mu\psi_\nu\right]$$

Results

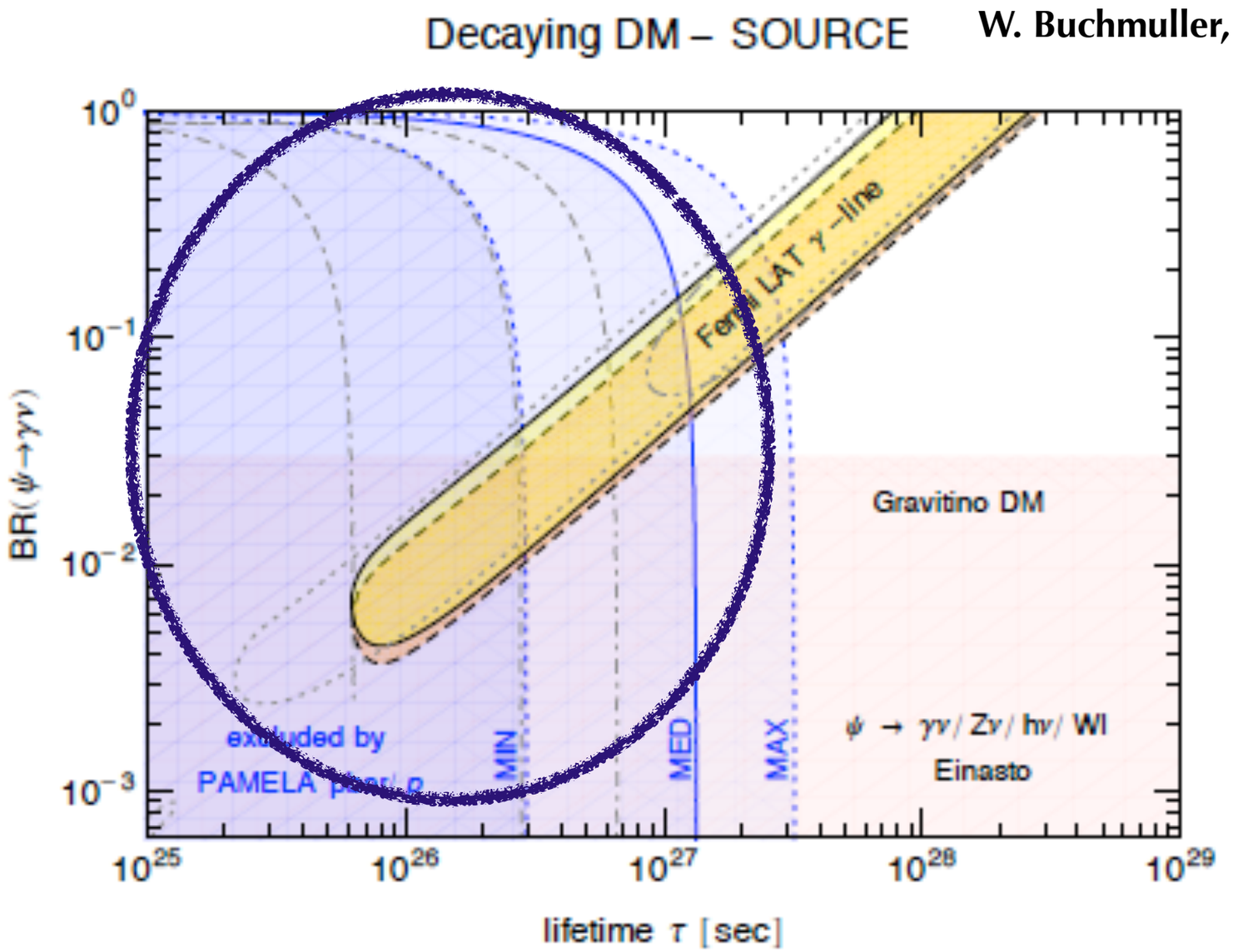
SPL [arXiv:1304.1992]



RPV coupling ~ 10^{-7}

cosmologically compatible with
BBN and Thermal Leptogenesis

Anti-proton flux constraint for gravitino with bilinear RPV



No anti-proton flux from trilinear LLE RPV operators!

Conclusion

2 SUSY DM candidates to explain 130 GeV line

Axino with bilinear RPV

- Well motivated
- (can explain dark radiation)

Gravitino with trilinear RPV

- no anti-proton (LLE)
- compatible with thermal leptogenesis

from Marco Cirelli's talk

Summary

Data hangover

More data!

[redacted] let's be more optimistic! [redacted]

The FERMI line was fun, but it's probably not DM.

FERMI gammas.

Neutrino experiments.

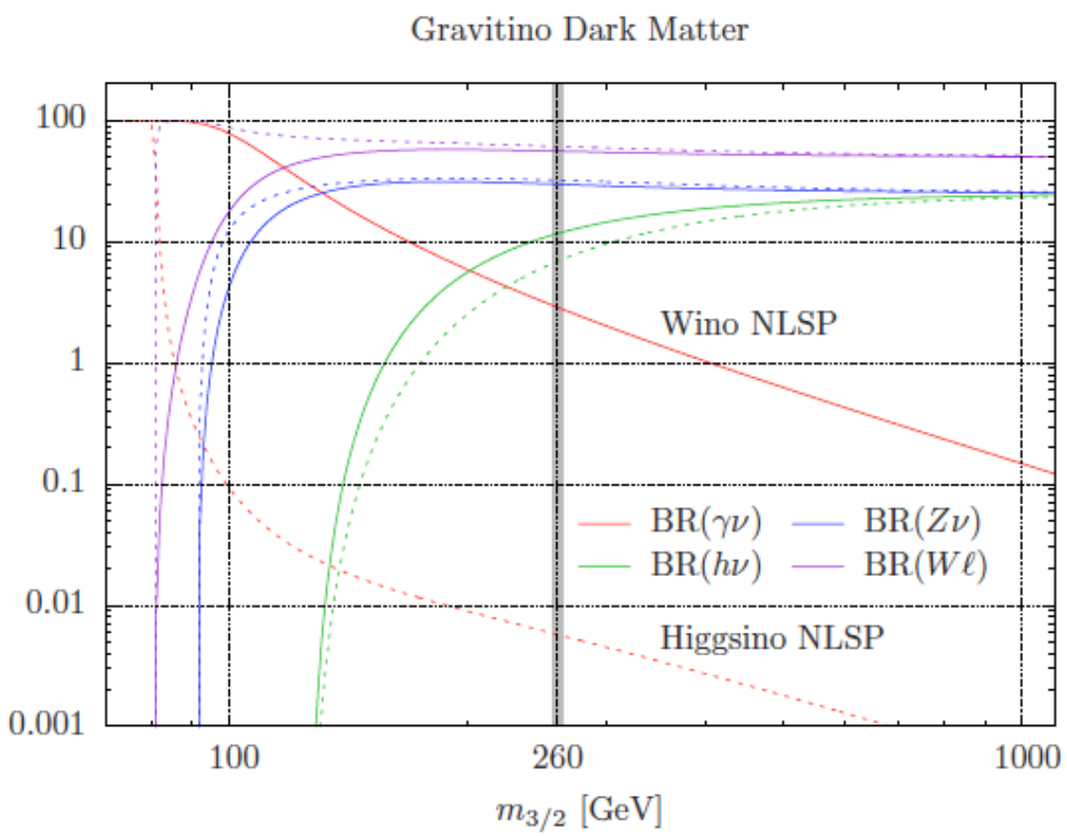
Antideuterons.

And also from HESS

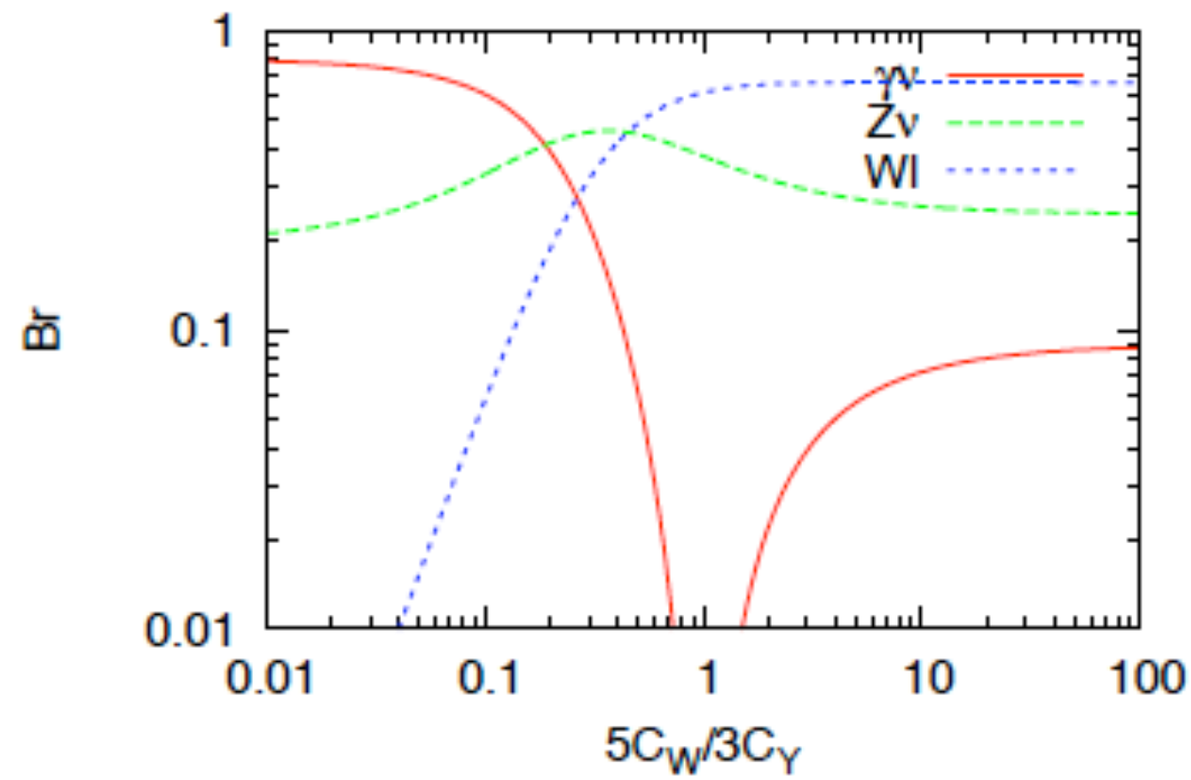
[redacted]

Backup

Gravitino vs Axino

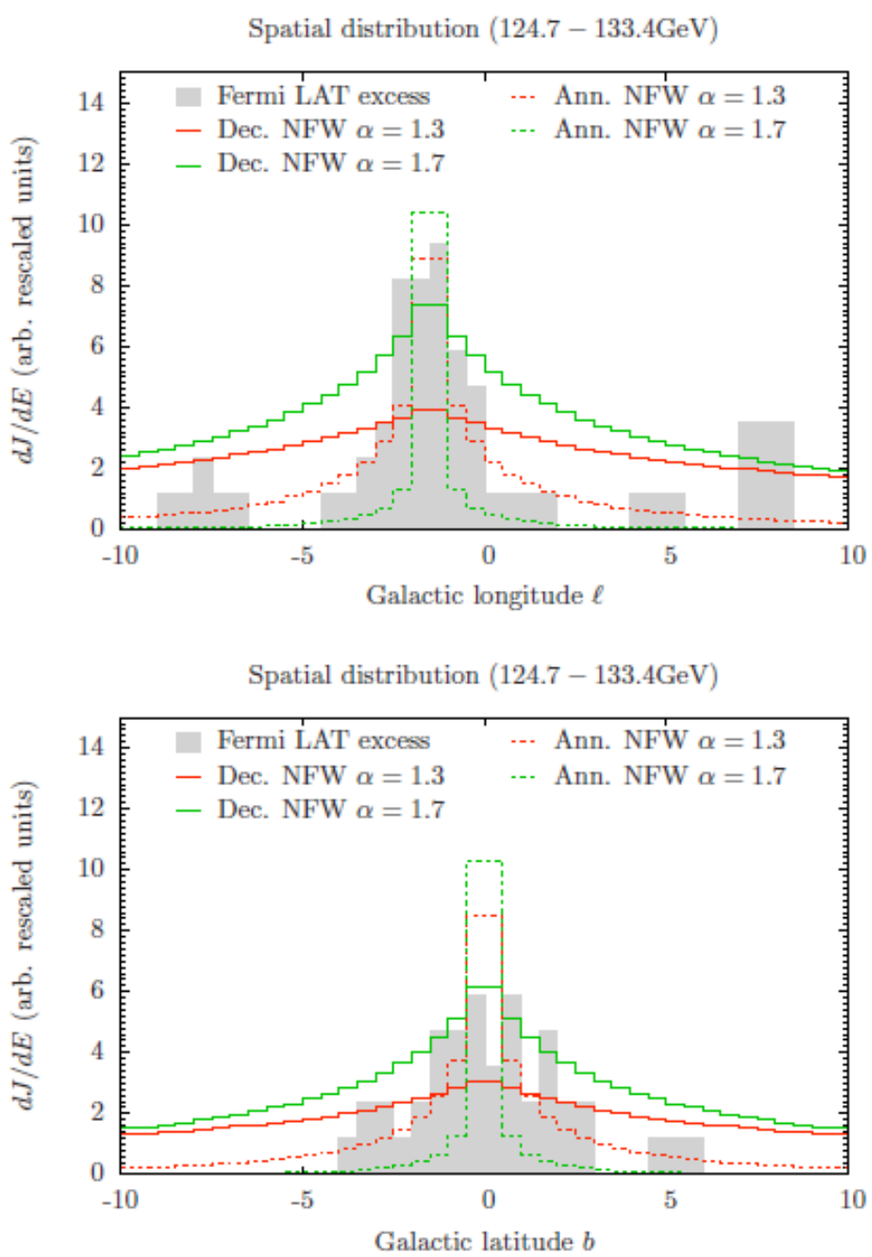


W. Buchmuller, M. Garny [arXiv:1206.7056]

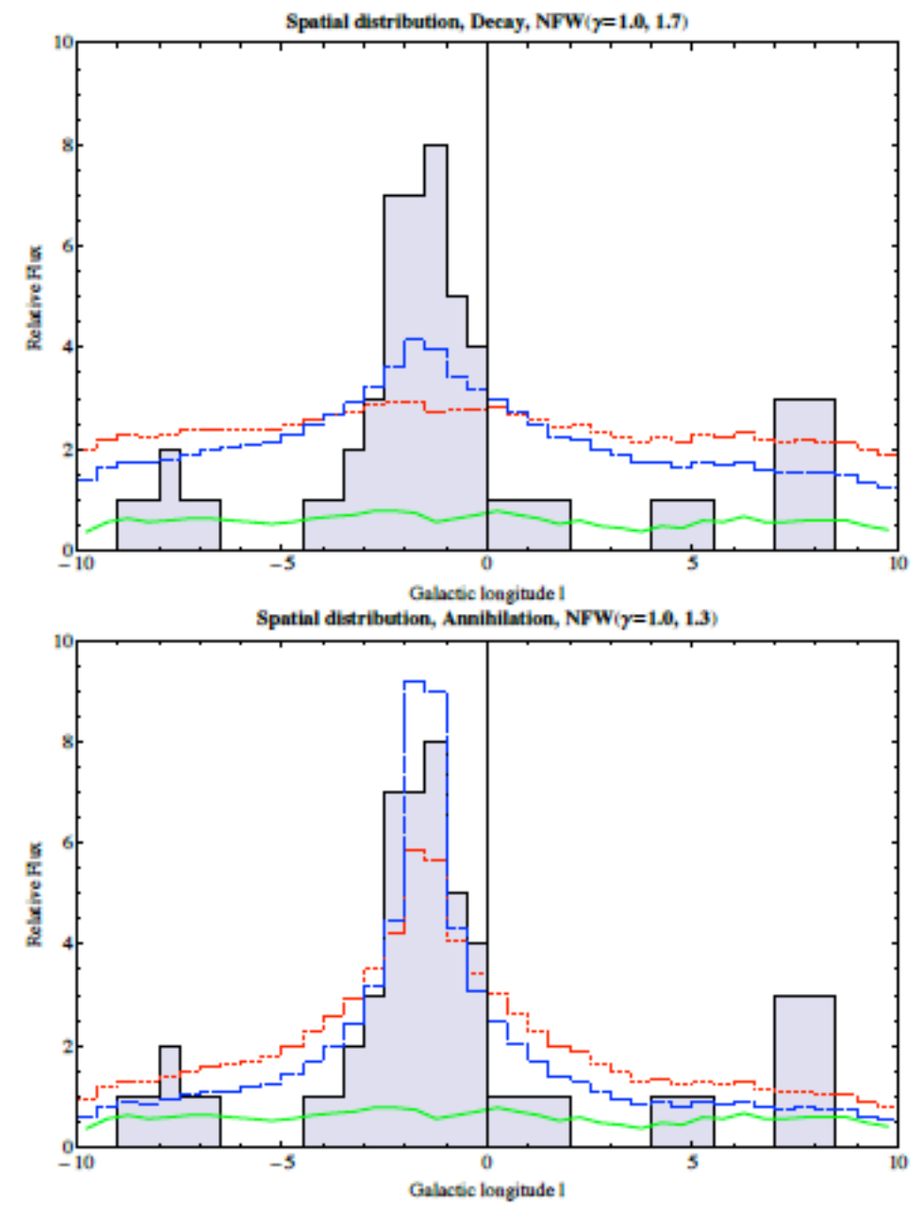


M. Endo, K. Hamaguchi, SPL, K. Mukaida, K. Nakayama [arXiv:1301.7536]

Annihilating DM vs. Decaying DM



W. Buchmuller, M. Garny [arXiv:1206.7056]



J.C. Park, S.C. Park [arXiv:1207.4981]