Dark Matter, LHC, and G_2-MSSM

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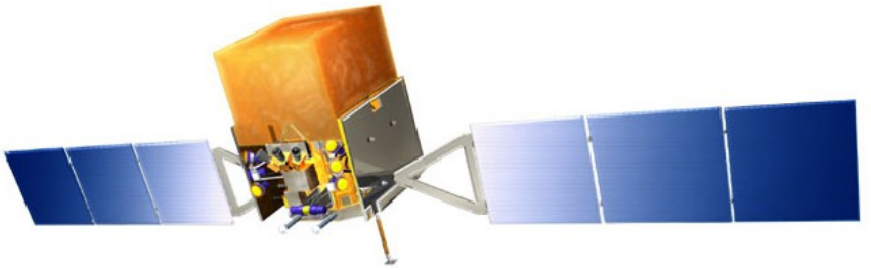
Pheno Symposium

2010-5-11

Dark Matter Experiments

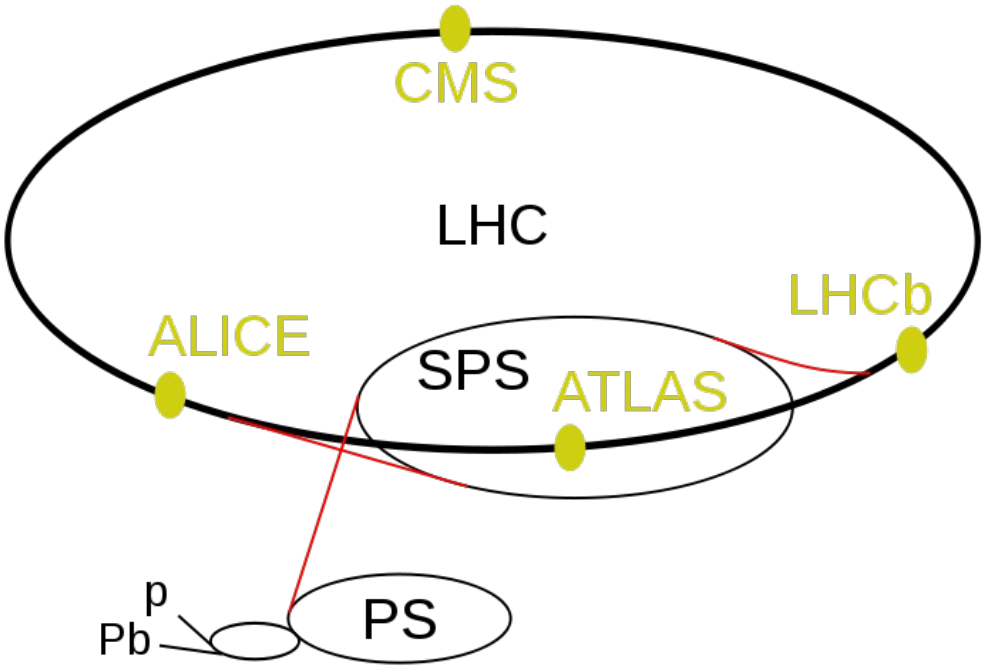
- PAMELA

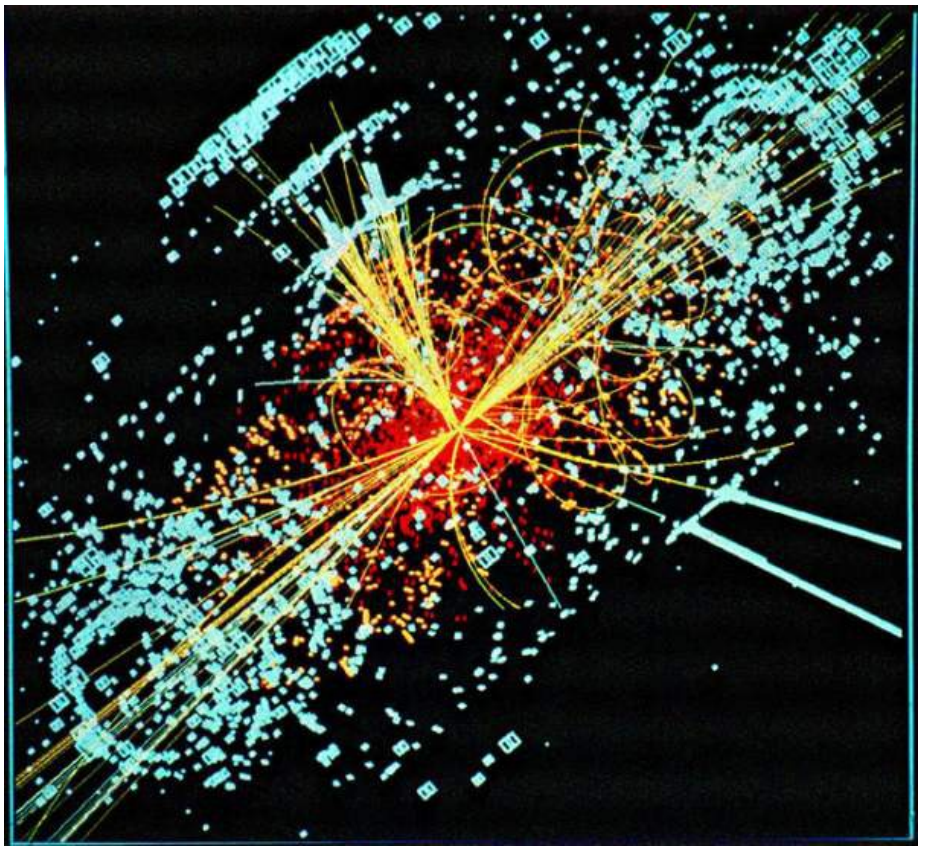
- Fermi LAT



- CDMS II, XENON 100 ...

LHC Data is Coming





New Physics Beyond SM

- Clues for underlying theory: Dark Matter, LHC...
- Astrophysics Signals
  - Dark Matter Annihilation
- LHC
  - Early Discovery
- Theoretical implications

G_2-MSSM: MSSM from M Theory

- Gravitino Mass: $m_{3/2} = m_p \frac{e^{\phi_0^2/2}}{8\sqrt{\pi}\, V_7^{3/2}} C_2 \left| P \phi_0^{\frac{-2}{P}} - Q \right| e^{\frac{-P_{eff}}{Q-P}}$

  - String Scale Parameters

$$Q, P, C_2, \delta$$
$$V_7, P_{eff}, V_{\hat{Q}_{vis}}$$

B. S. Acharya, K. Bobkov, G. L. Kane, J. Shao and P. Kumar, Phys. Rev. D **78**, 065038 (2008)

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- Scalar Masses

  $m^2_{\bar{\alpha}\beta} \approx m^2_{3/2}\delta_{\bar{\alpha}\beta}$

- Trilinear Couplings

  $A_{\alpha\beta\gamma} \approx 1.48\, m_{3/2}$

- String Scale Parameters

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Soft Breaking Terms

- Gaugino Masses
  - Tree-level masses

$$M_a^{tree}(M_{unif}) \approx -\frac{\eta}{P_{eff}}\left(1+\frac{2}{\phi_0^2(Q-P)}\right)m_{3/2}$$

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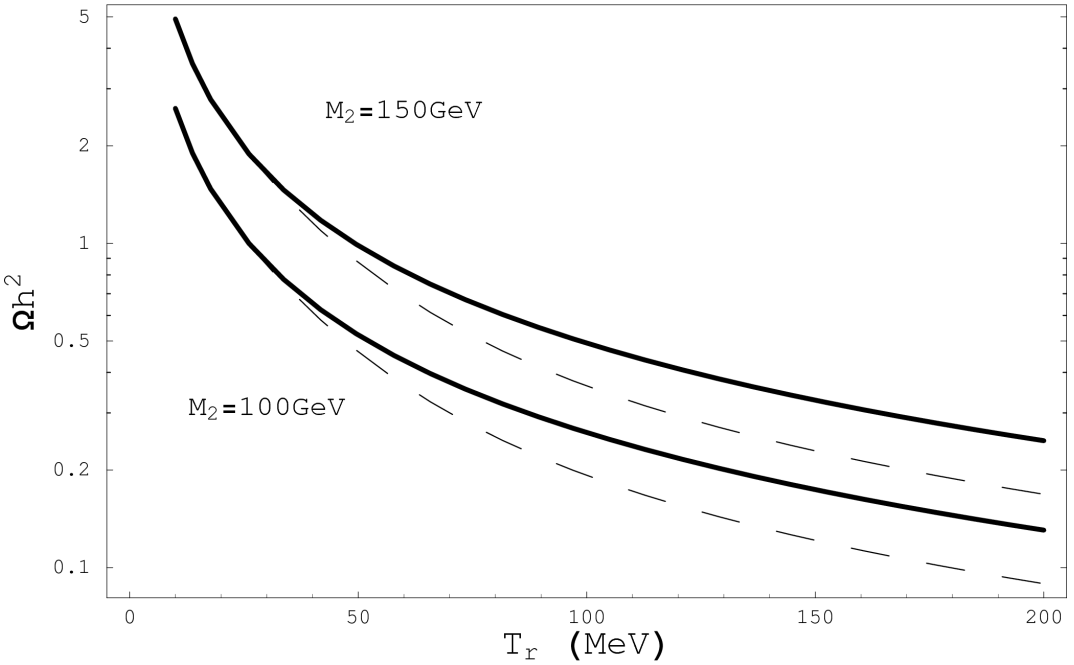
  - Anomaly contribution interference
    - ➔ Wino LSP

B. S. Acharya, K. Bobkov, G. L. Kane, J. Shao and P. Kumar, Phys. Rev. D **78**, 065038 (2008)

Moduli and Non-thermal History



- Late decay scalars

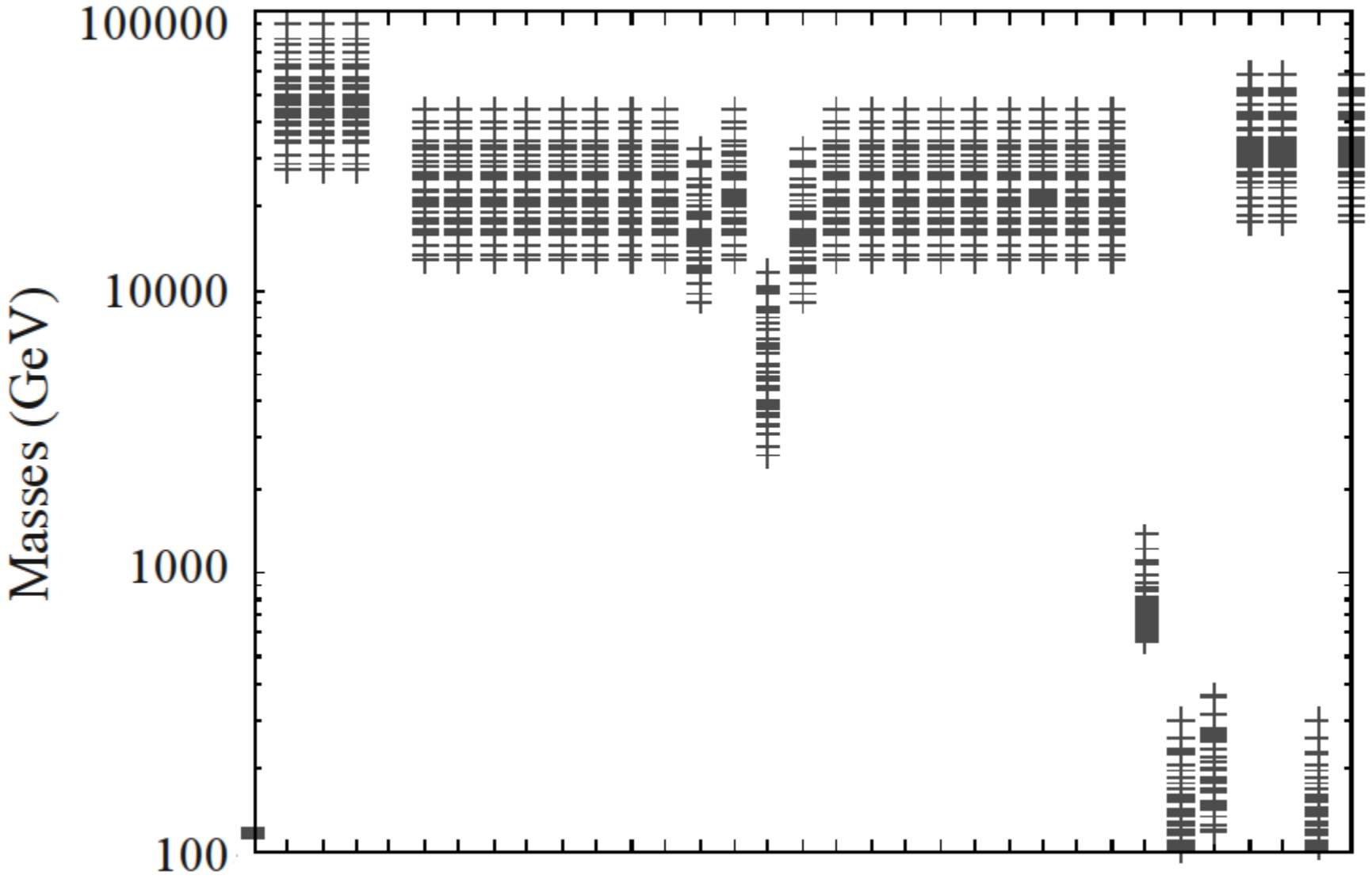
$$\Gamma_X = D_X \frac{m_X^3}{\Lambda^2}$$

- Dominates the energy density of the universe
- Reheat Temperature

$$T_r \sim 40\,\mathrm{MeV} > 5\,\mathrm{MeV}$$

B. S. Acharya, P. Kumar, K. Bobkov, G. Kane, J. Shao and S. Watson, JHEP 0806:064,2008

Mass Spectrum



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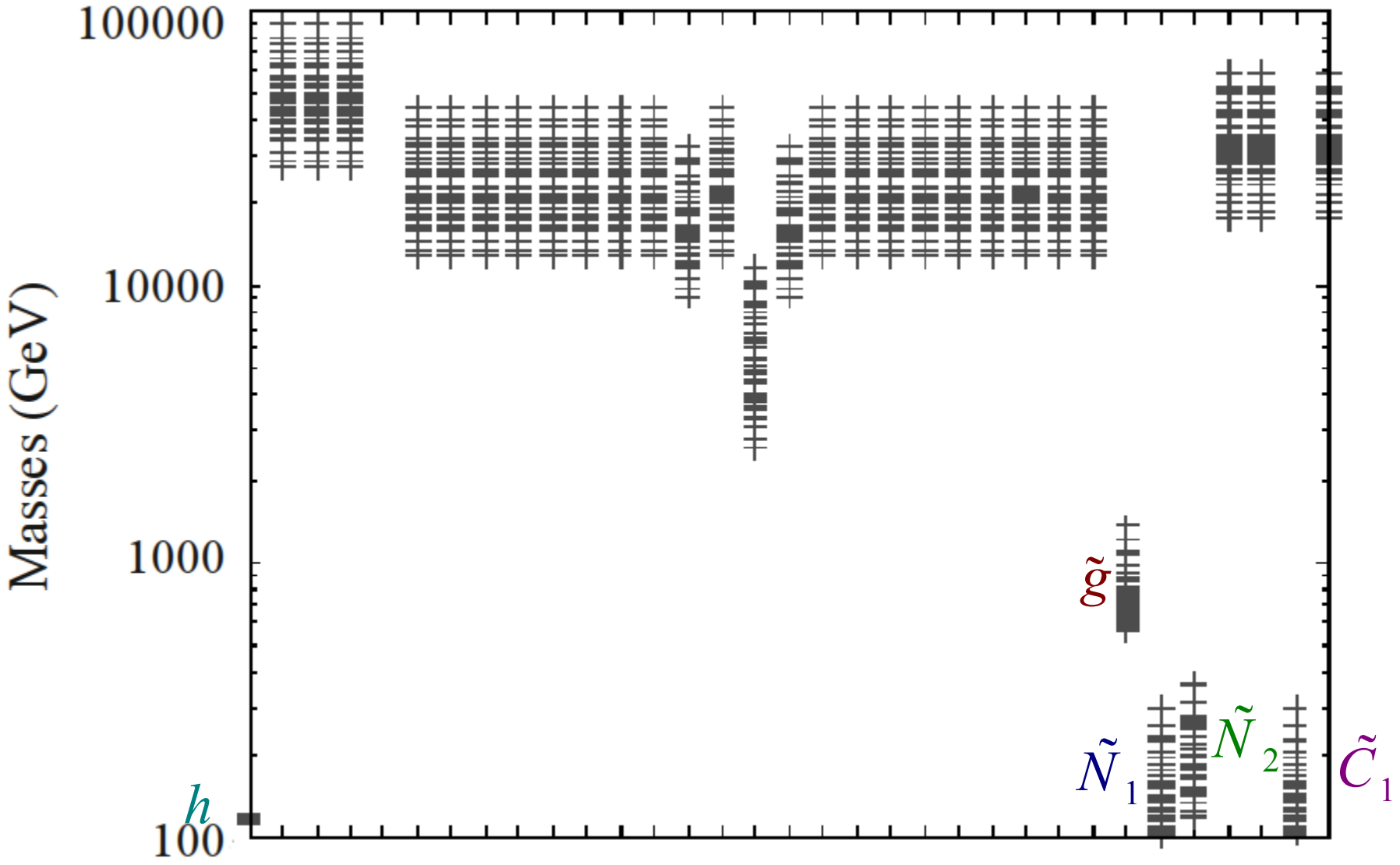

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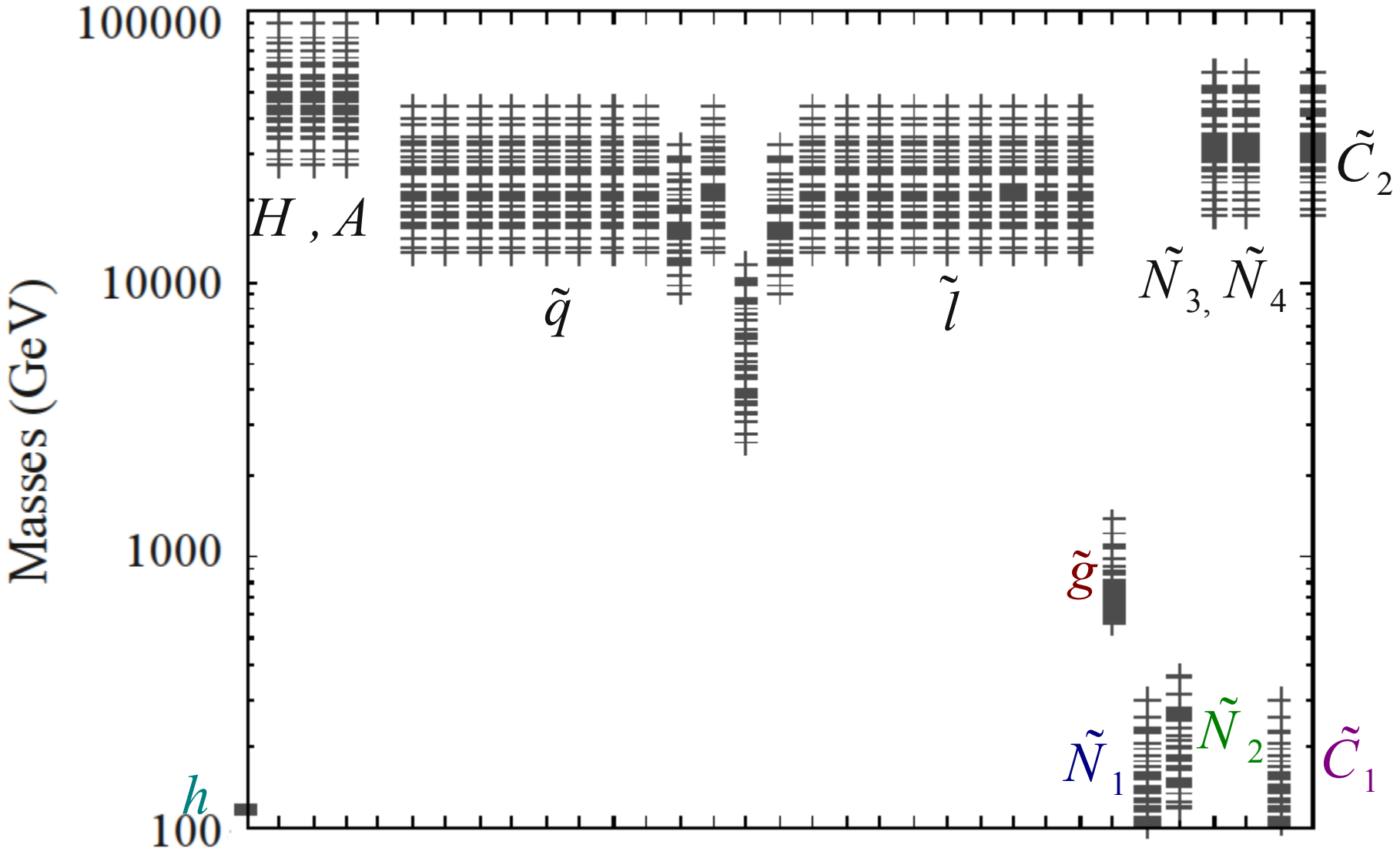

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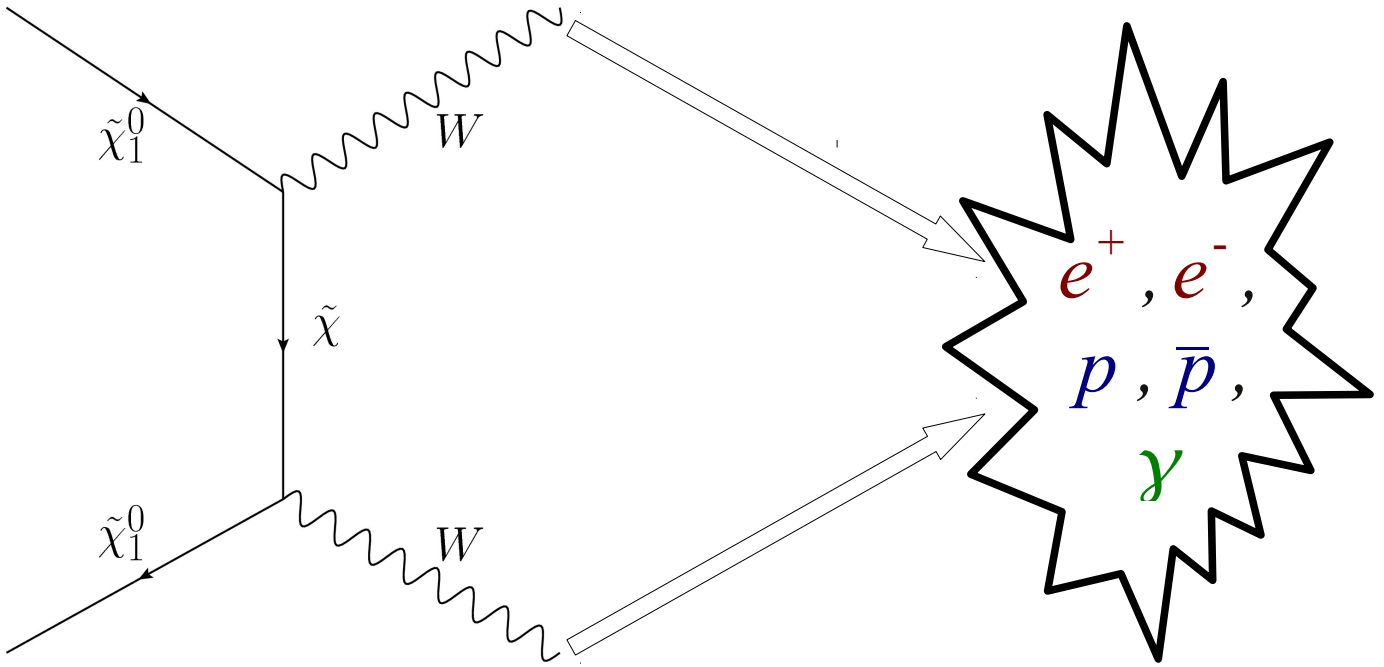
Wino-like LSP

- Wino-like LSP
  - Well motivated, bino-like LSP is not the only possibility.
  - Large annihilation cross section (PAMELA)
  - Non-thermal history (Correct relic density)

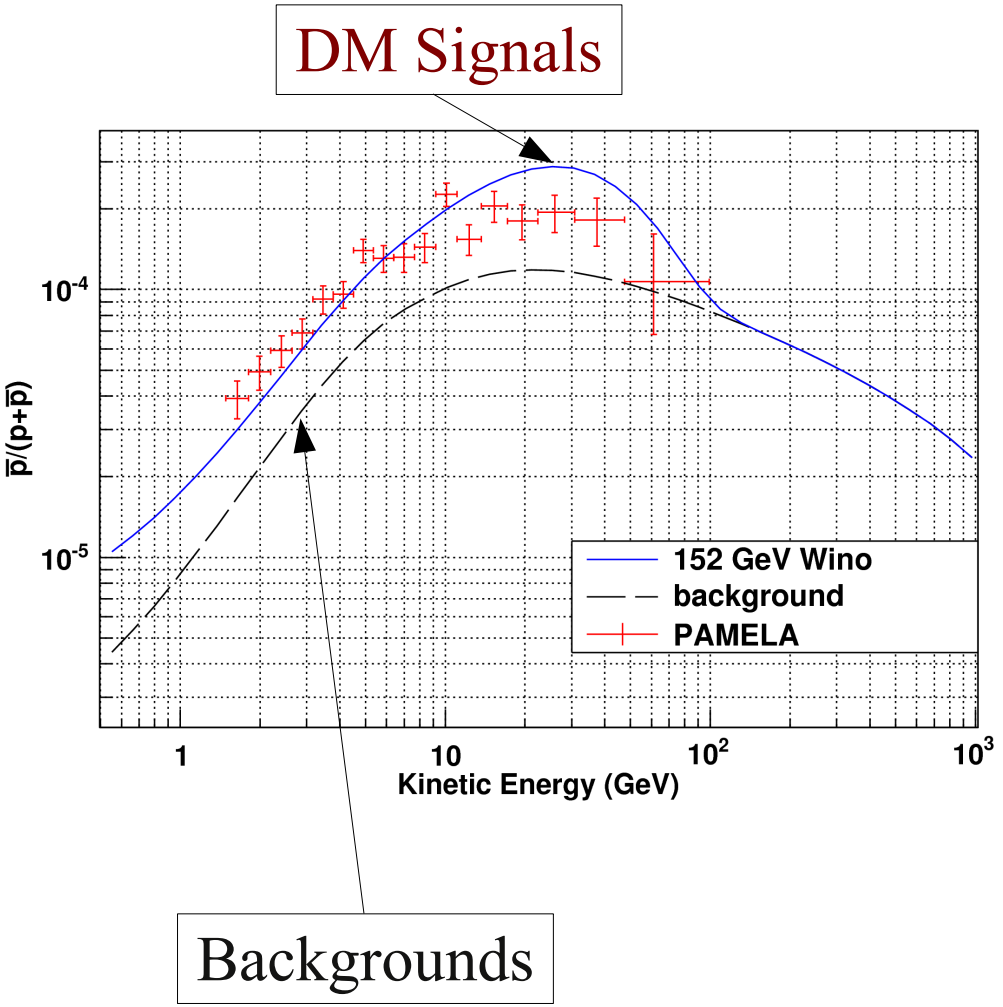


Simulation for Astrophysics Signals

- DarkSUSY
- GALPROP

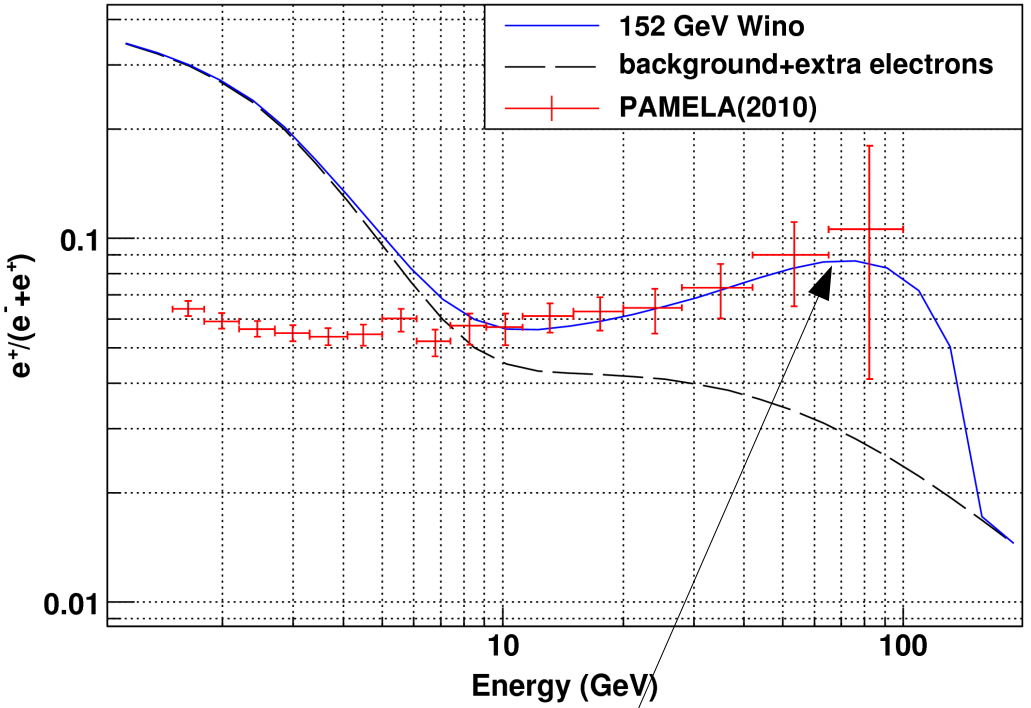
New Physics Spectrum → Simulate the Propagation → Observed Signals

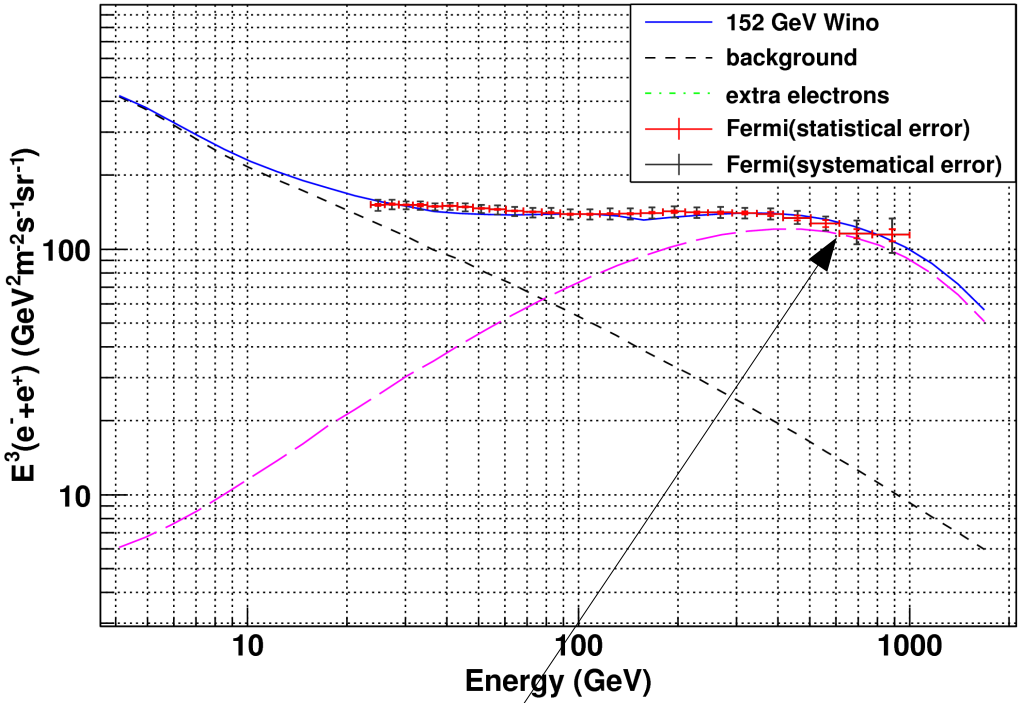
Antiproton Ratio



- Wino LSP is OK
- Different parameters from GALPROP examples
- Good B/C
- Backgrounds → Signals

Electron and Positron



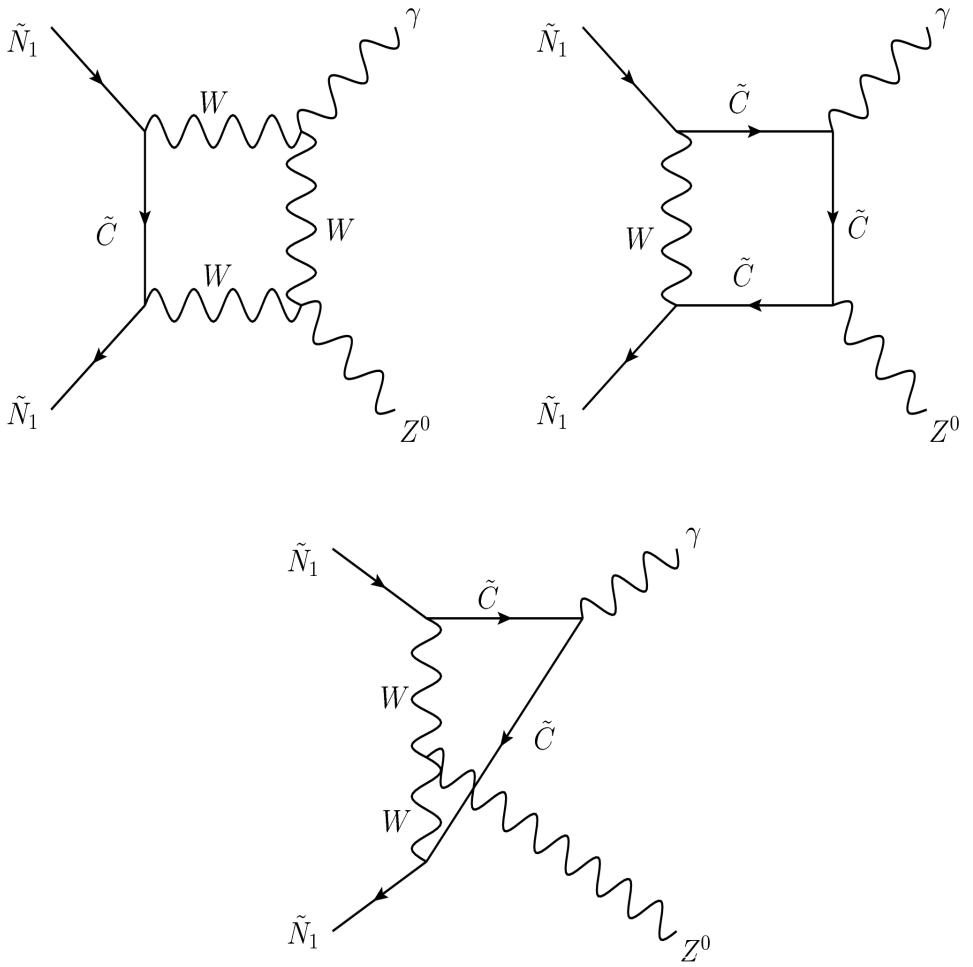


Wino contribution

Extra electrons from astrophysics (needed)

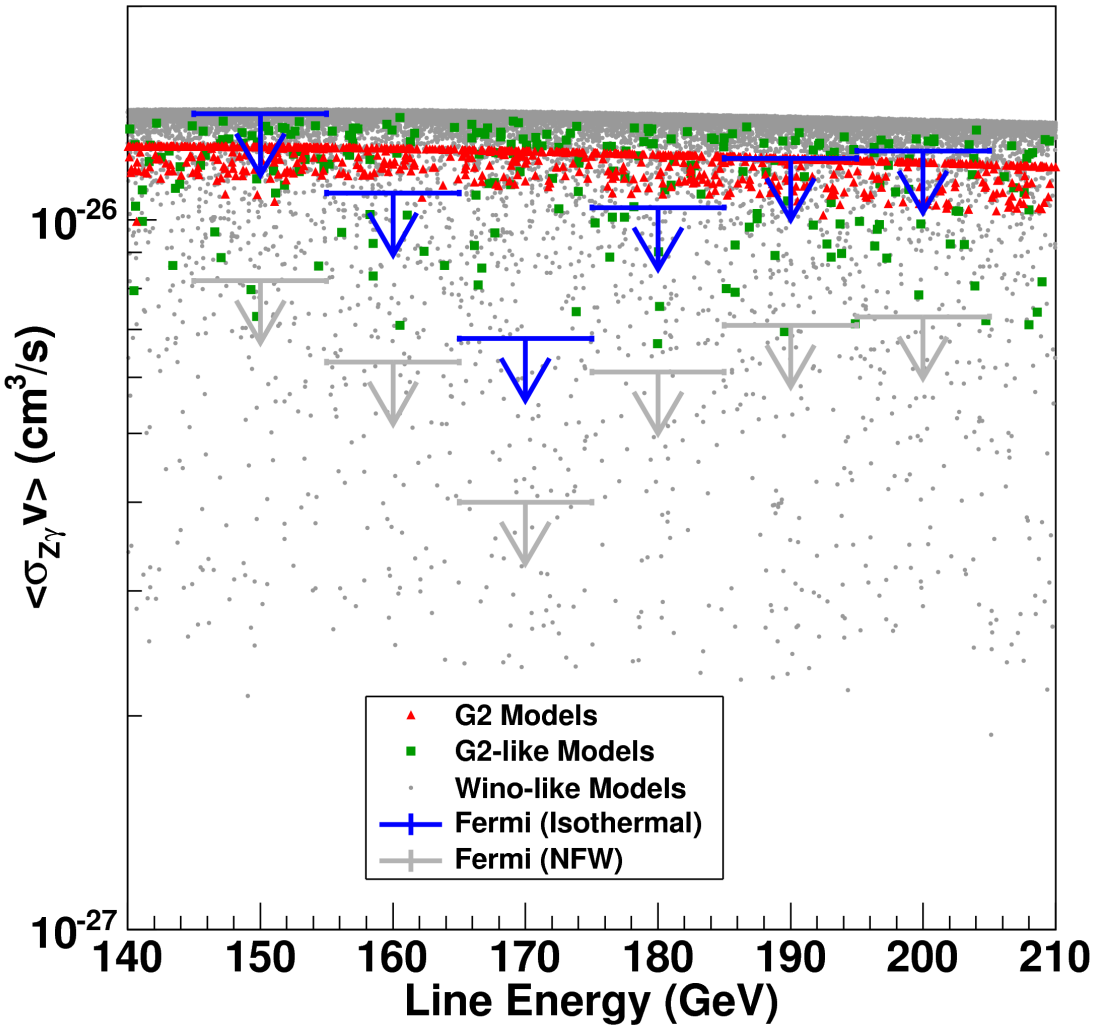
Photon Line Spectrum

- Zγ Line
  - $E_\gamma = m_{LSP}\left(1 - \frac{m_Z^2}{4 m_{LSP}^2}\right)$



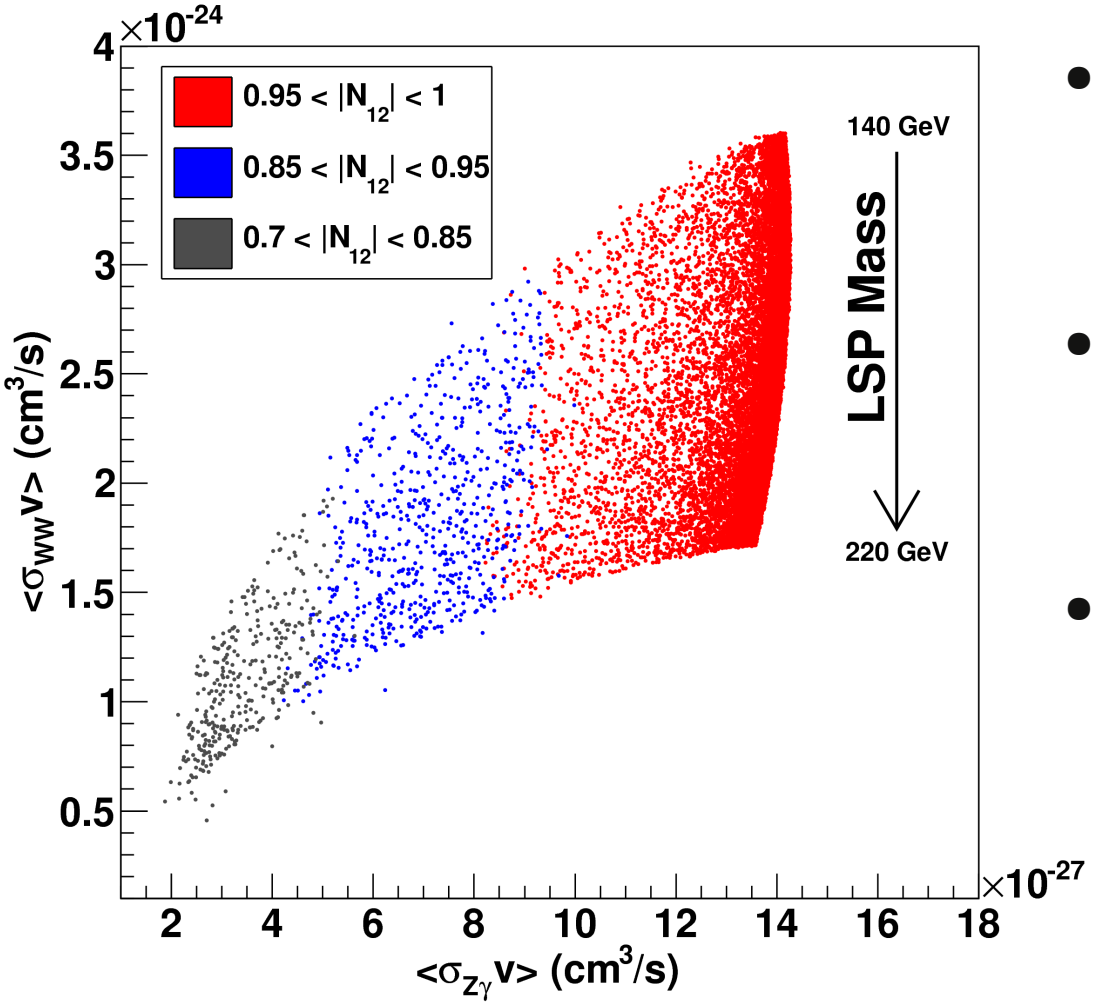
Photon Line Spectrum

- Zγ Line
  - $E_\gamma = m_{LSP}\left(1 - \frac{m_Z^2}{4 m_{LSP}^2}\right)$
- Constrain the mass of the LSP
- Isothermal profile



D. Feldman, G. Kane, R. Lu and B. D. Nelson, Phys. Lett. B **687**, 363 (2010)

Wino or Wino-like

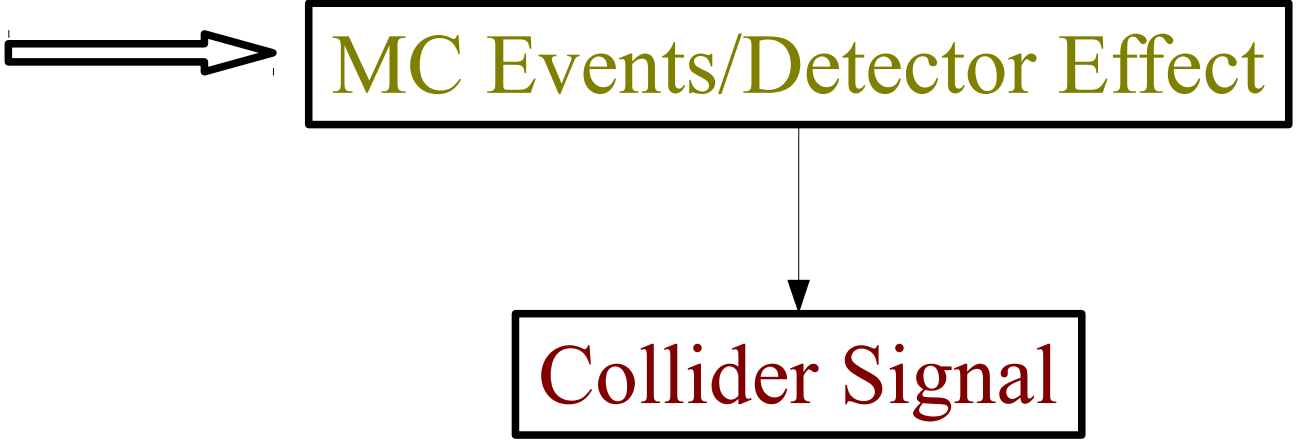


- Similar positron spectrum
- Smaller Zγ cross section
- Direct detection
  - Pure wino $\approx 10^{-47} cm^2$
  - Wino like $\approx 10^{-44} cm^2$

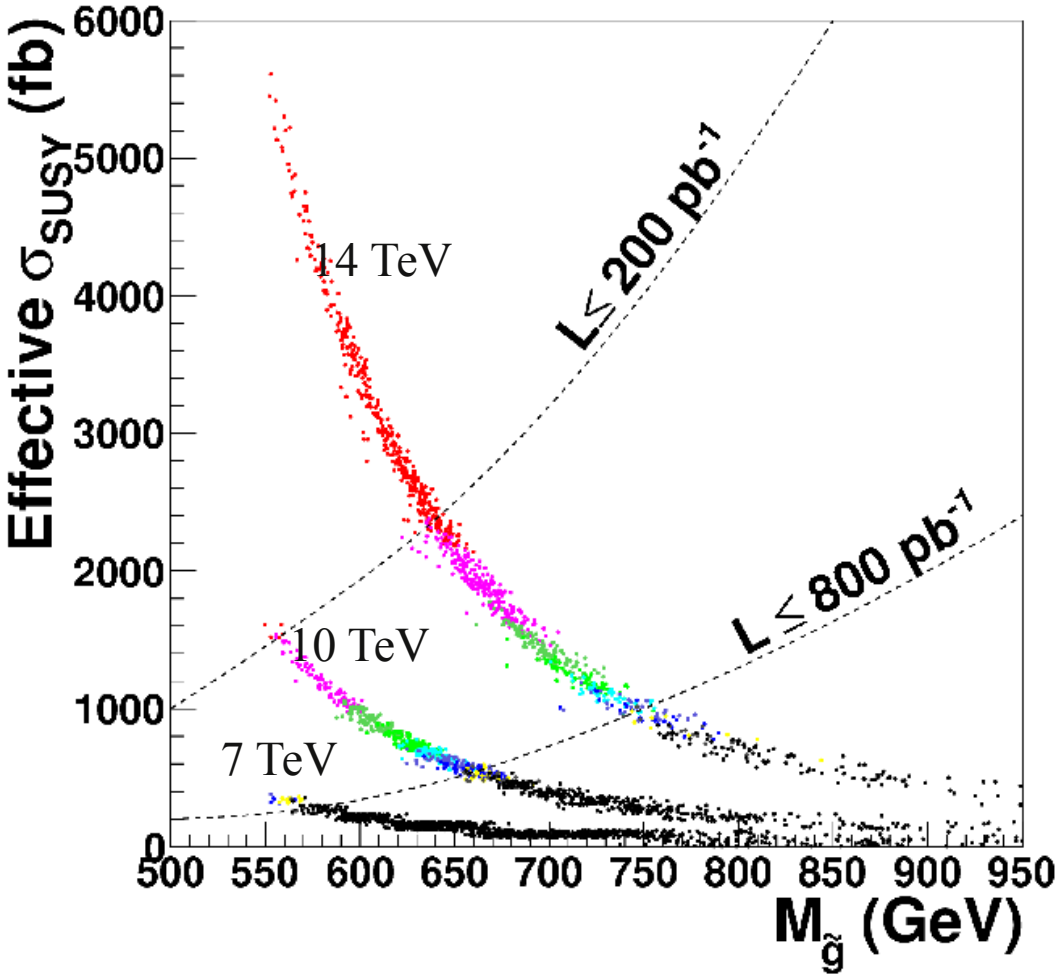
D. Feldman, G. Kane, R. Lu and B. D. Nelson, Phys. Lett. B **687**, 363 (2010)

LHC Simulation

- SoftSUSY ⟹ Mass Spectrum
- SUSY-HIT ⟹ Branching Fraction
- PYTHIA/PGS ⟹ MC Events/Detector Effect



Global Discovery Potential



- 1000 Models
- Most can be definitively tested at 14 TeV with 5 fb^{-1}
- 10 TeV and 7 TeV, Some.

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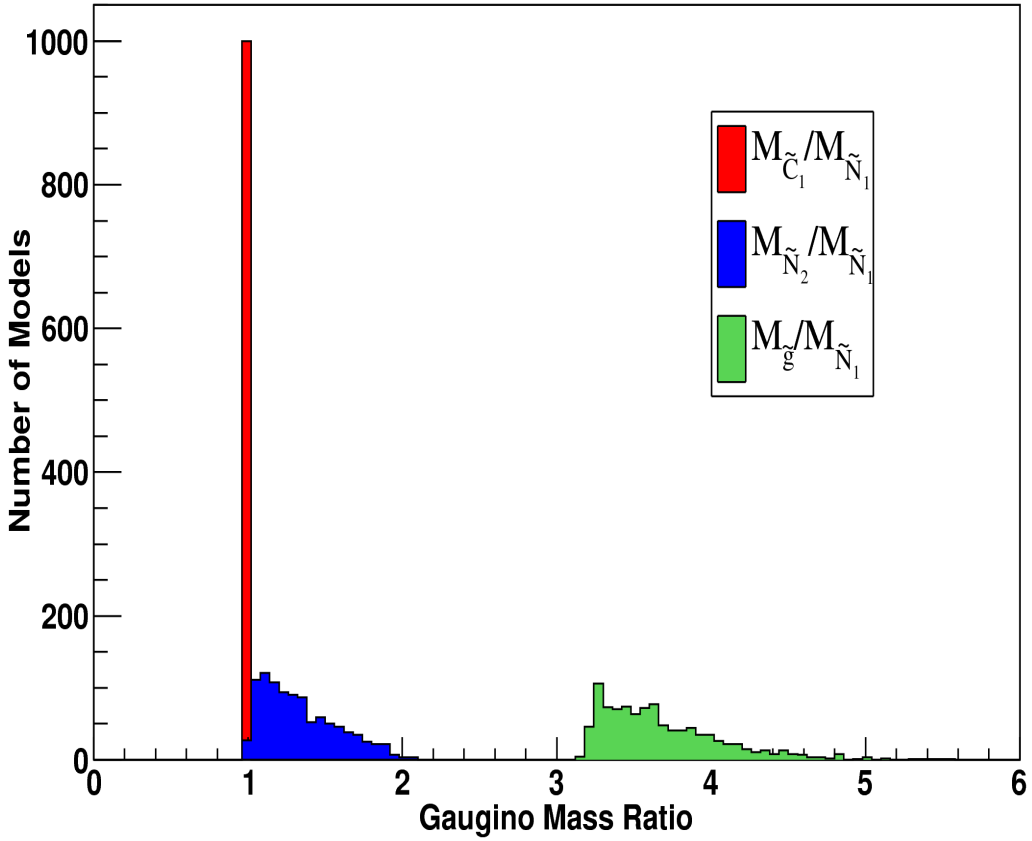
LHC Signatures

- Wino LSP
  - Degenerate $\tilde{C}_1, \tilde{N}_1$
  - Hard to study
- Gluino
  - Tagged Sample
  - $\tilde{C}_1, \tilde{N}_2$ decays in vertex layers



- See also arXiv:1004.4902 (G. F. Giudice, T. Han, K. Wang and L. T. Wang)

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Summary and Future Plan

- Describe PAMELA/Fermi signals with a wino LSP

  (With extra flux from astrophysics)

  - Direct Detection – Wino vs wino-like

- Test G_2-MSSM at the LHC

- Cosmology and string theory

  - Non-thermal history of the universe!

- Search for underlying theory