Cosmic Ray Constraints on Decaying Gravitino Dark Matter

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Outline

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Why Supersymmetry?

- Most general extension of the Lorentz group.
- String theory needs it.
- Many possibilities $\Rightarrow$ lots of work for us!

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B and L Violating Couplings.

$$\lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k + \lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k + \mu_i H L_i$$

L_i, Q_i, H – lepton, quark, Higgs doublets
E_i, D_i, U_i – lepton, down, up quark singlets

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Bilinear Lepton number violating couplings; induces neutrino–neutralino mixing. Not our primary focus

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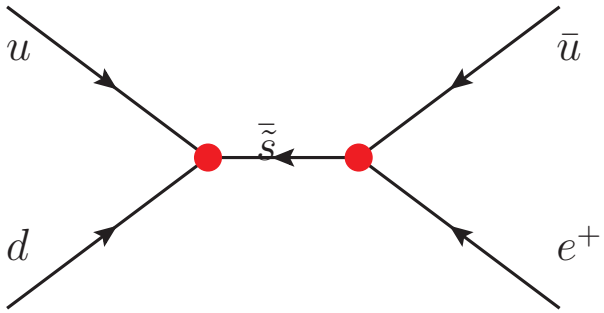
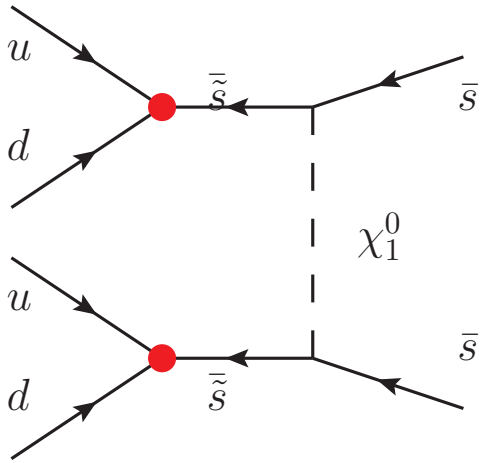
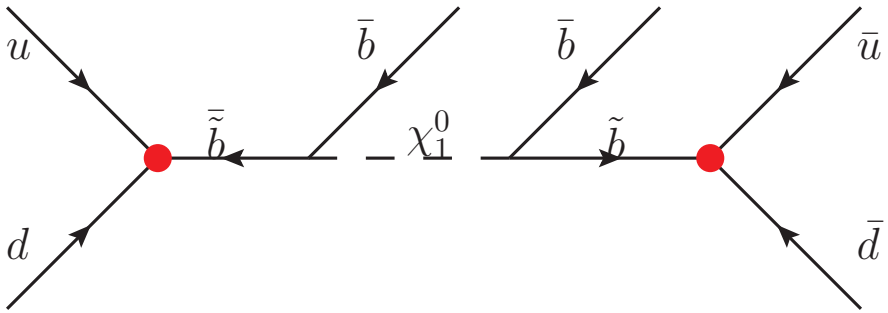
Trilinear Lepton number violating couplings

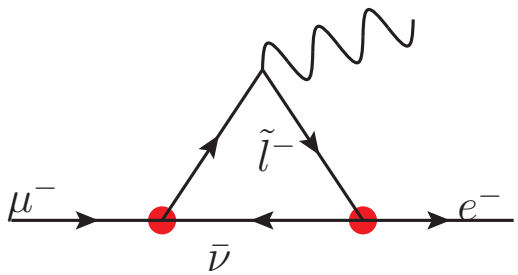
Trilinear Baryon number violating couplings

Constraints on B, L Violating Couplings









R-Parity

"Standard" solution: remove them all, i.e. R-Parity

- Discovered particles different from non-discovered ones?
- Discrete symmetries are often broken: C, P, CP, lepton flavour number, B(?), L(?)
- χ_1^0 Dark Matter requires $\lambda \lesssim 10^{-23}$.

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R-Parity Violation

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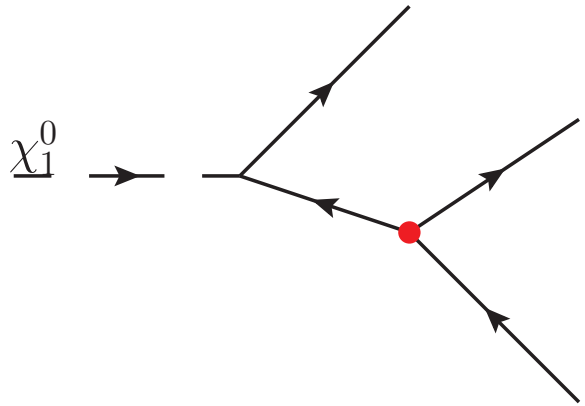
$\Rightarrow$ all sparticles decay,



Gravitino! All interactions suppressed by M_{planck}^{-1}

Dark Matter detection:

- Direct detection: nuclear recoils
- Indirect detection: annihilation products

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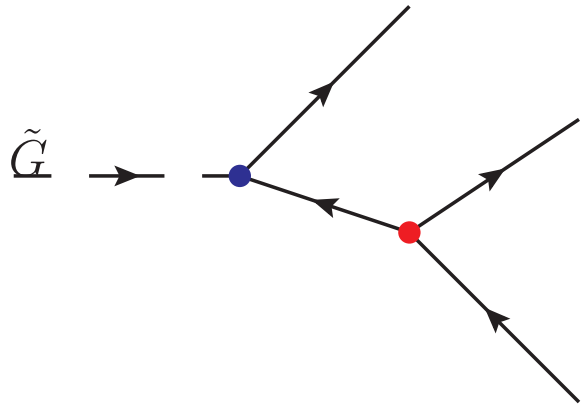

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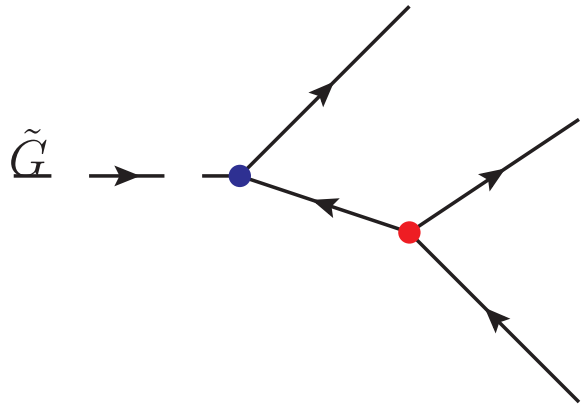

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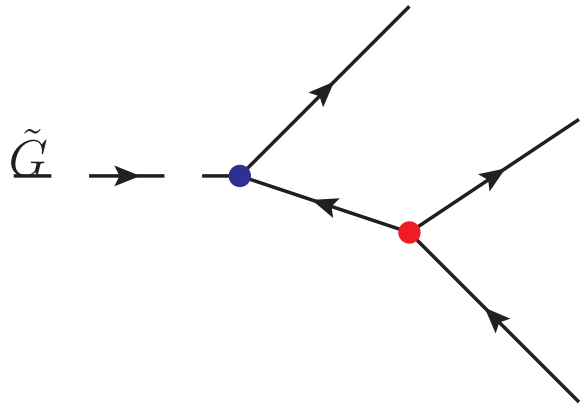

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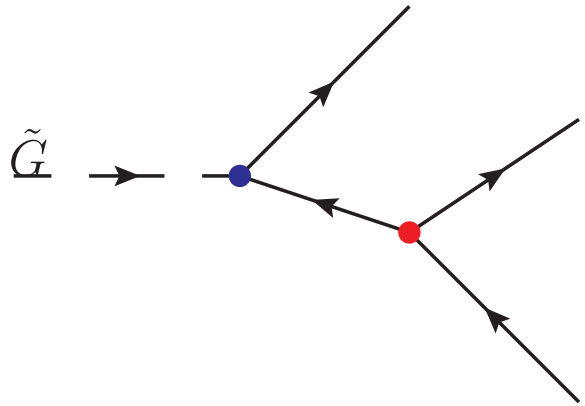


Gravitino! All interactions suppressed by M_{planck}^{-1}

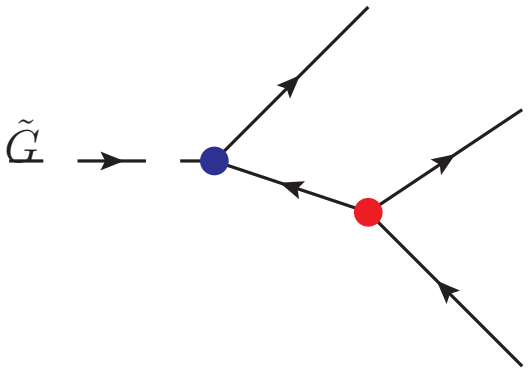
Dark Matter detection:

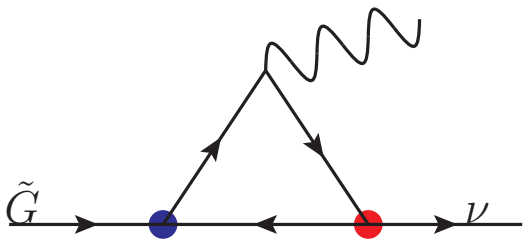
- Direct detection: nuclear recoils — forget it! (M_{planck}^{-1})
- Indirect detection: annihilation products — maybe

Gravitinos do not annihilate (again M_{planck}^{-1}) but decay

Outline

Gravitino Decay Products





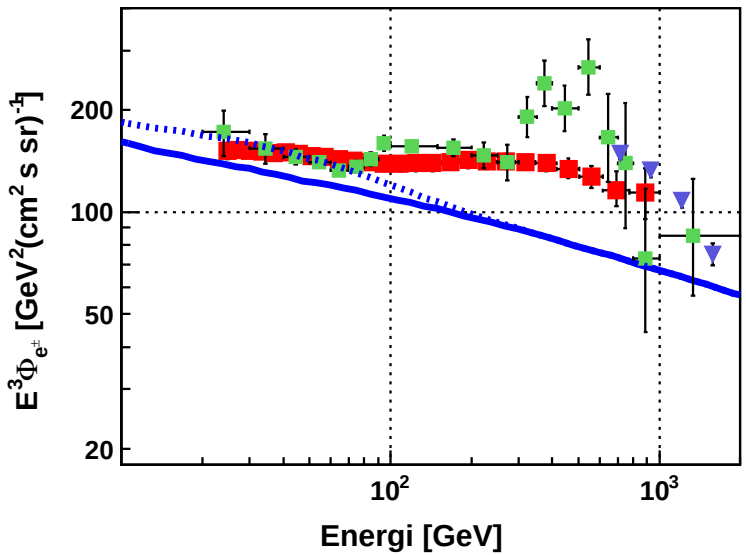
- $L_i L_j \bar{E}_k$
  - $e,\ \mu,\ \tau \Rightarrow e^{\pm},\ \nu,\ \gamma,\ \pi$
  - ν
  - $i, j = k \Rightarrow \tilde{G} \rightarrow \gamma + \nu$
- $L_i Q_j \bar{D}_k$
  - $l,\ \nu$
  - Quarks $\Rightarrow \bar{p},\ \pi(e^{\pm},\ \nu,\ \gamma)$
  - $j = k \Rightarrow \tilde{G} \rightarrow \gamma + \nu$
- $\bar{U}_i \bar{D}_j \bar{D}_k$
  - Quarks $\Rightarrow \bar{p},\ \pi(e^{\pm},\ \nu,\ \gamma)$

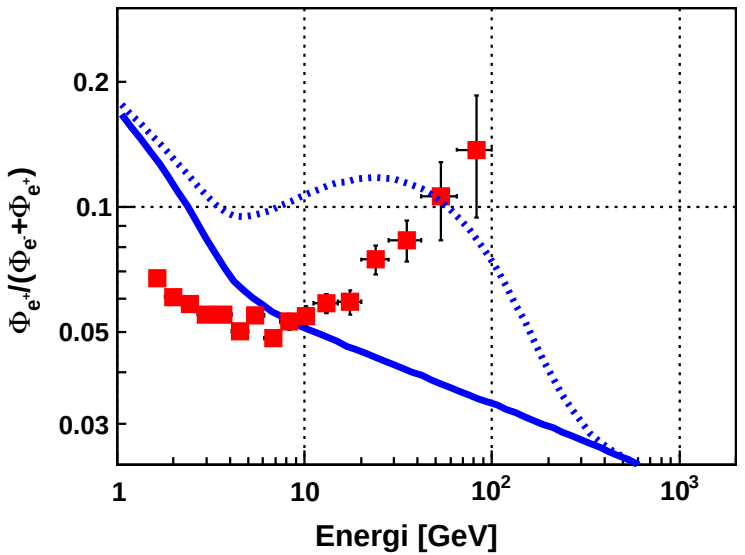
Outline

The PAMELA and Fermi LAT Anomalies

$$\lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k + \lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k$$

Electrons and positrons, UDD-112, M_{SUSY} = 2 TeV, $M_{\tilde{G}}$ = 1.8 TeV





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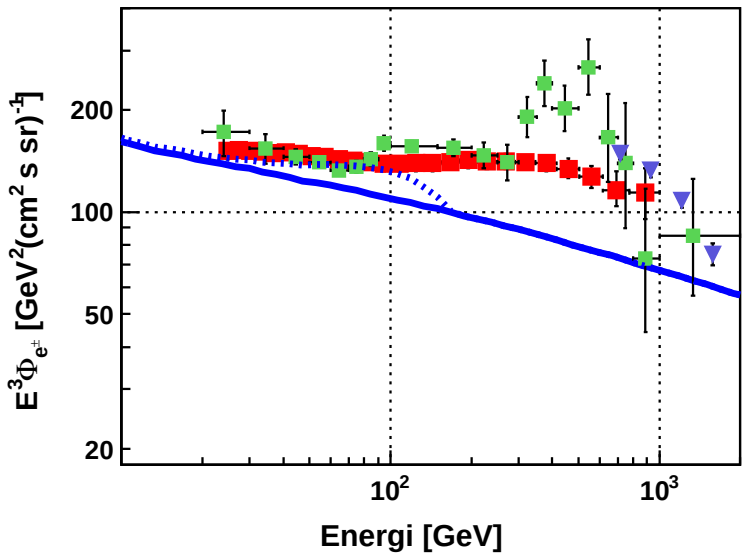
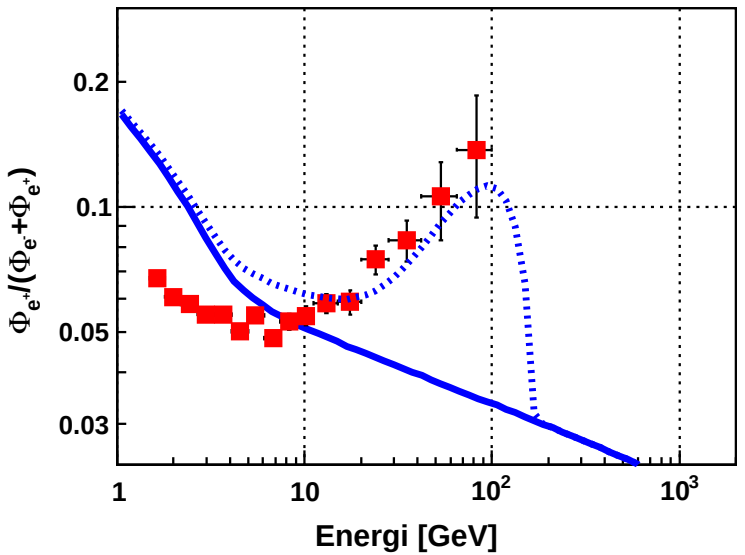
Electrons and positrons, LQD-122, M_{SUSY} = 1 TeV, M_G = 320 GeV





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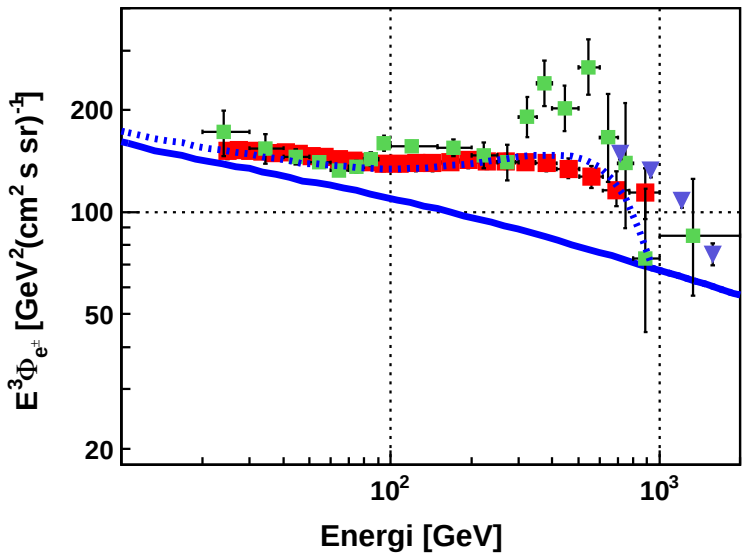
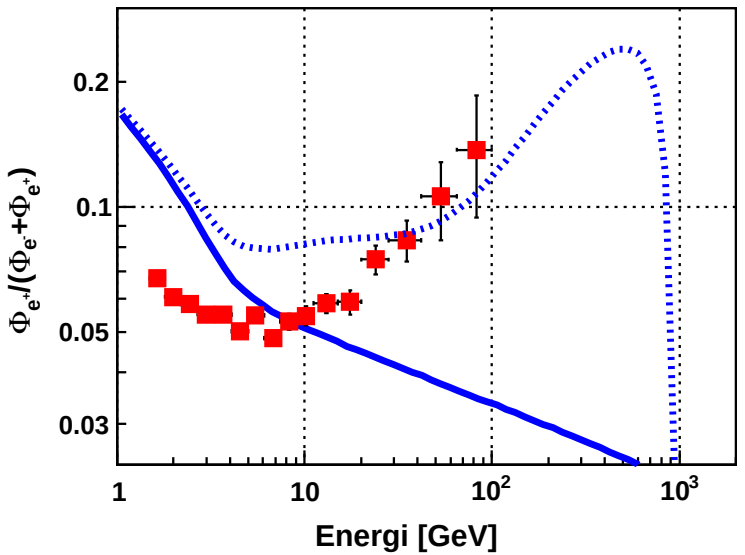
Electrons and positrons, LQD-133, M_{SUSY} = 2 TeV, $M_{\tilde{G}}$ = 1.8 TeV





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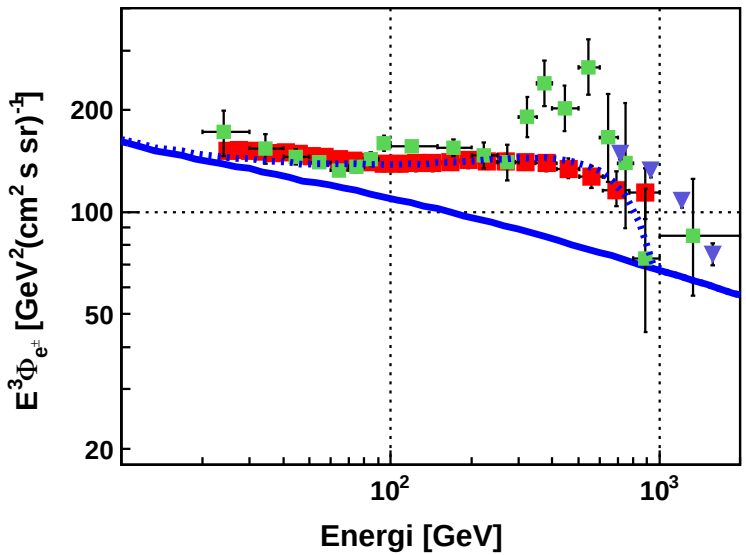
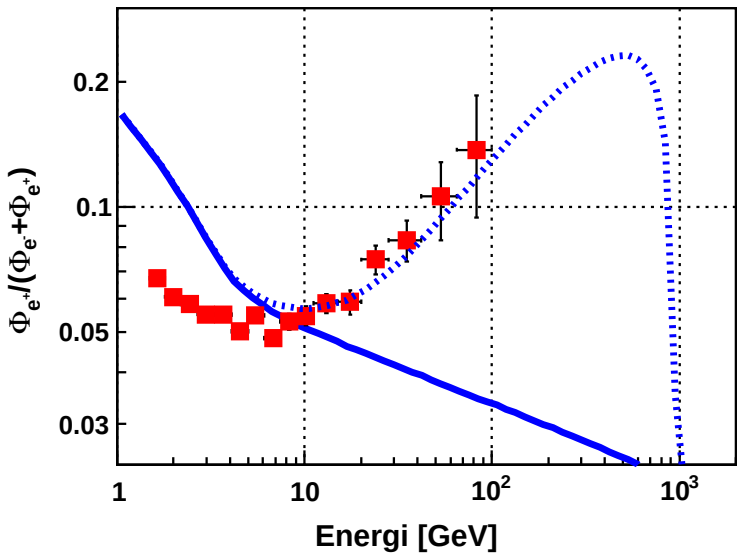
Electrons and positrons, LLE-133, M_{SUSY} = 6 TeV, $M_{\tilde{G}}$ = 1.8 TeV





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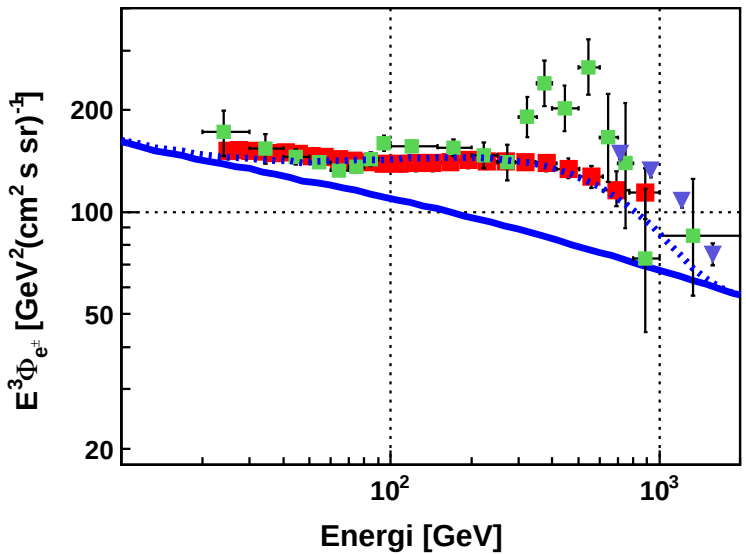
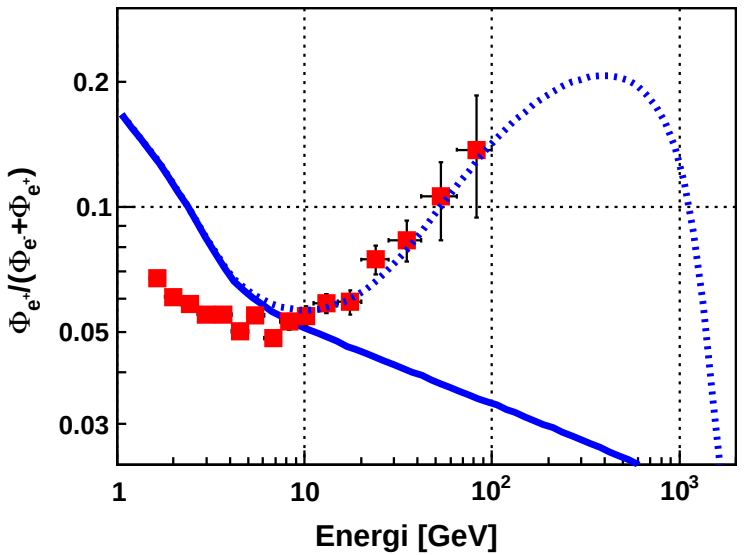
Electrons and positrons, LLE-233, M_{SUSY} = 6 TeV, $M_{\tilde{G}}$ = 3.6 TeV





The PAMELA and Fermi LAT Anomalies

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ijk	$M_{\tilde{G}} = 1.8$ TeV	$M_{\tilde{G}} = 2.5$ TeV	$M_{\tilde{G}} = 3.7$ TeV
121	excluded	excluded	–
122	bad	bad	excluded
123	good	ok	–
131	excluded	excluded	–
132	good	ok	–
133	good	ok	bad
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132	good	ok	–
133	good	ok	bad
231	excluded	excluded	–
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233	excluded	ok	good

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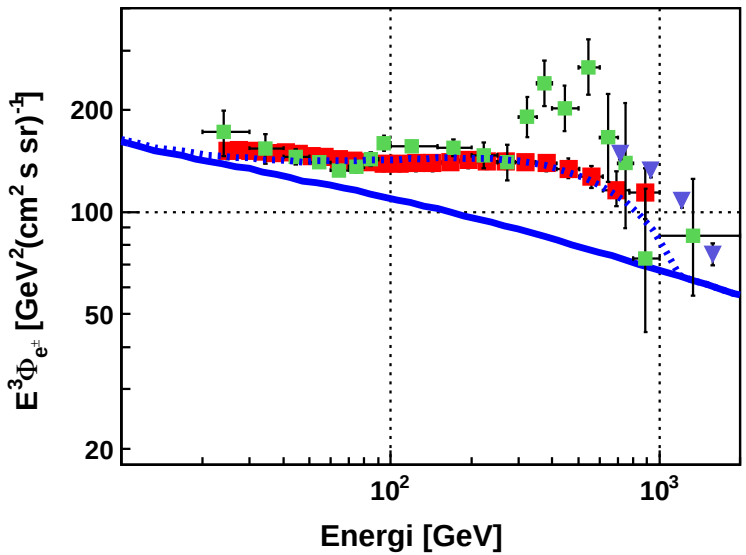
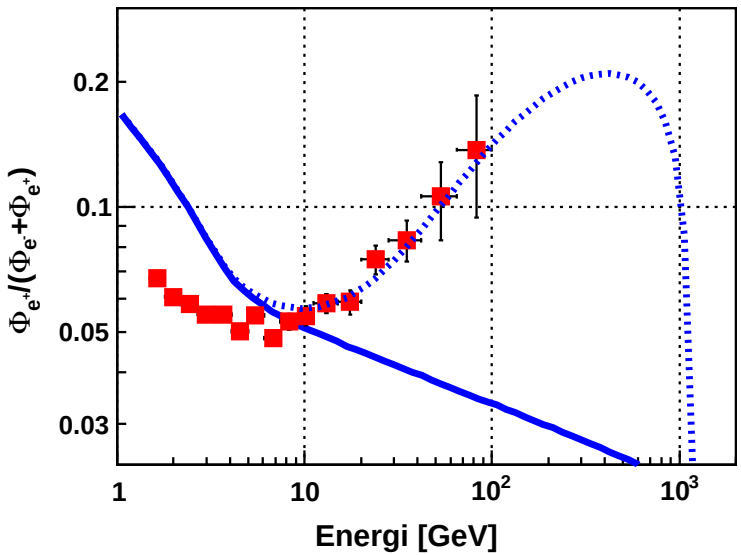
Electrons and positrons, LLE-233 LLE-121, M_{SUSY} = 6 TeV, M_G = 2.2 TeV





The PAMELA and ATIC Anomalies

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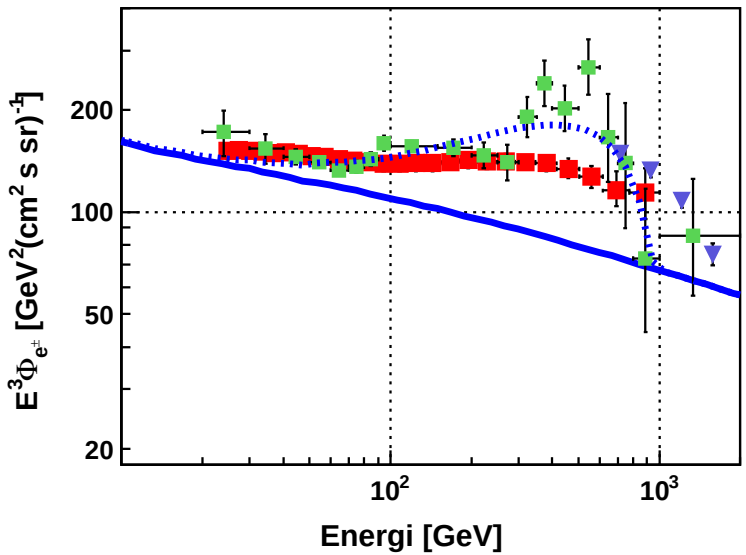
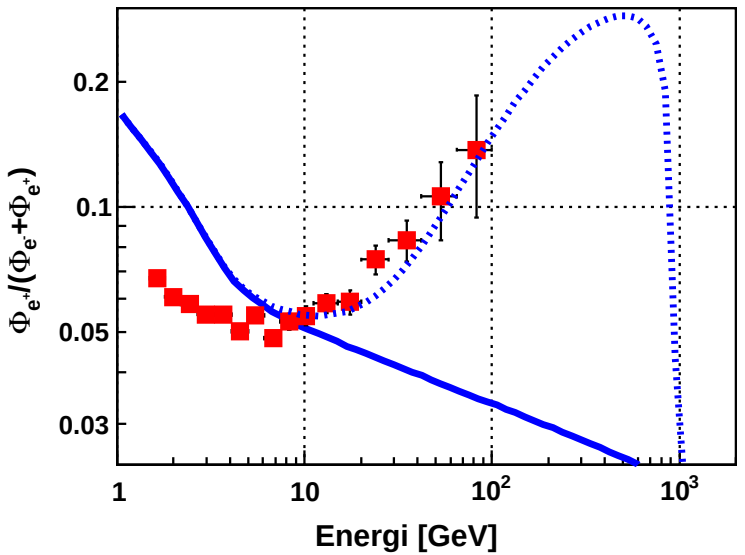
Electrons and positrons, LLE-231, M_{SUSY} = 2 TeV, $M_{\tilde{G}}$ = 1.8 TeV





Outline

Constraints from the PAMELA $\bar{p}$ data

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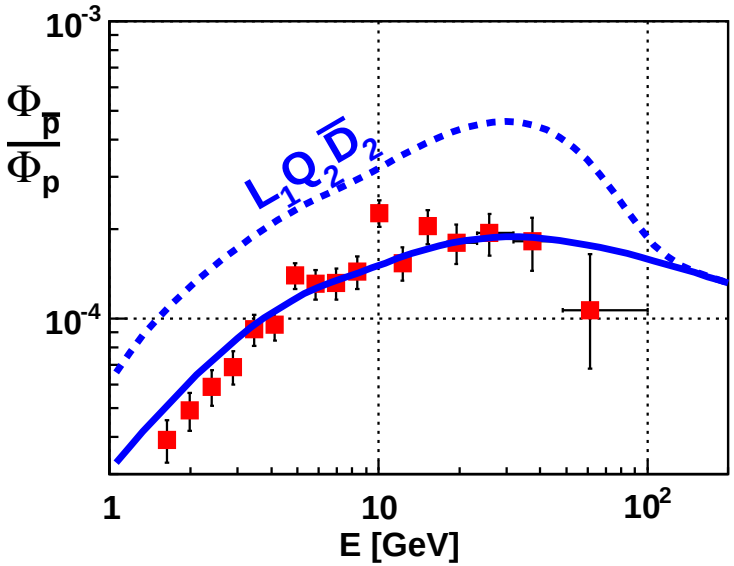

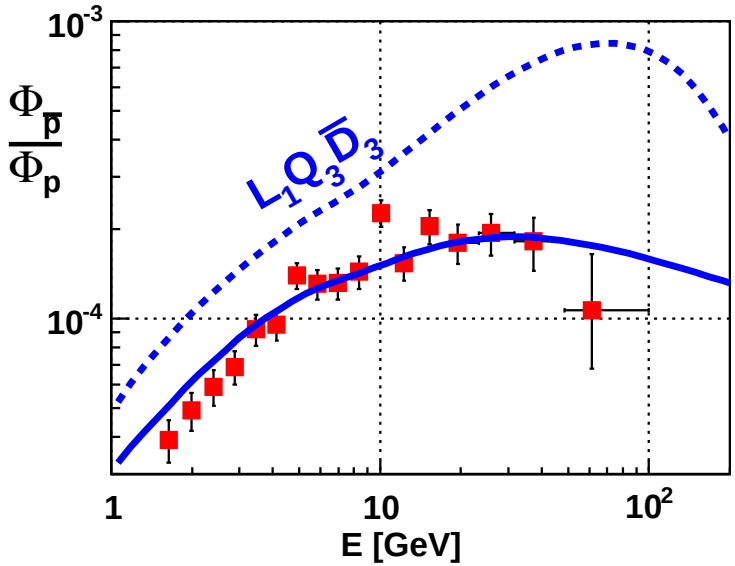

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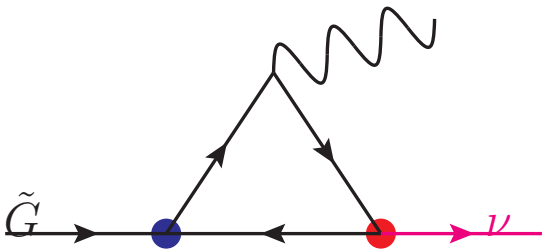
Give no $\bar{p}$ at all!

Ideal for explaining the electron positron anomalies.

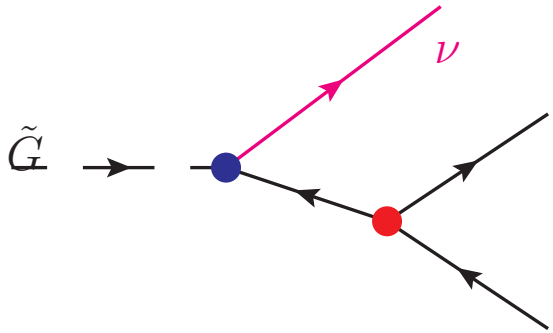
Outline

Neutrinos from Decaying Gravitinos

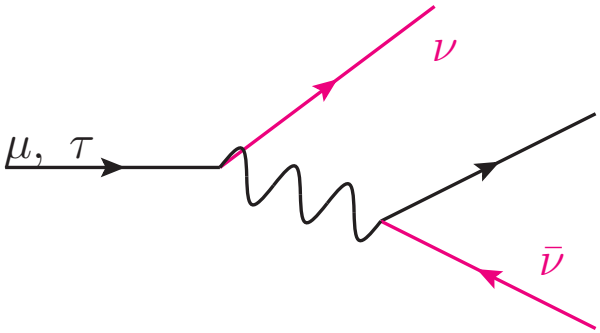
Monochromatic line



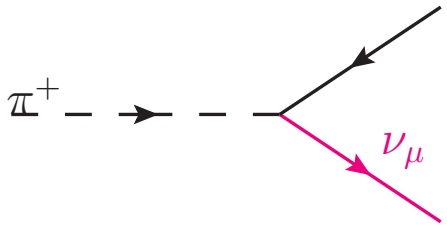
Three body decay



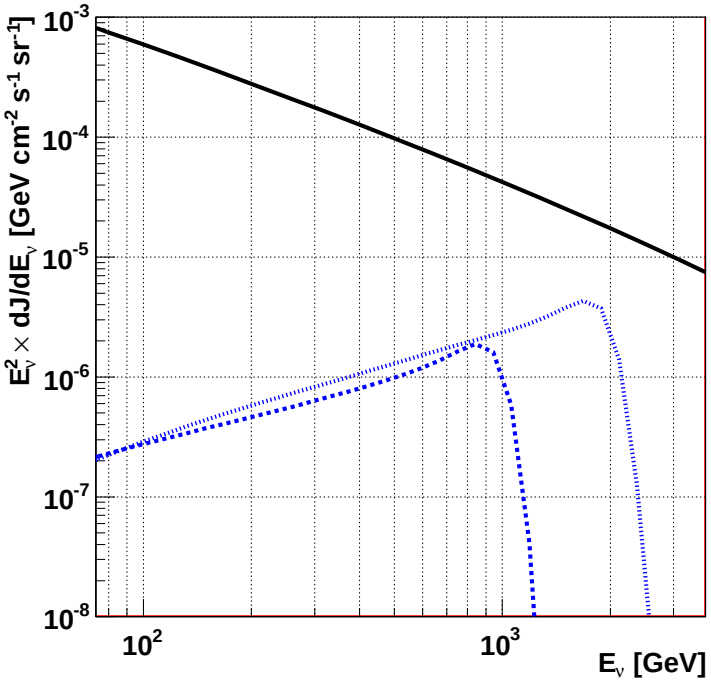
$\mu,\ \tau$ *decay*

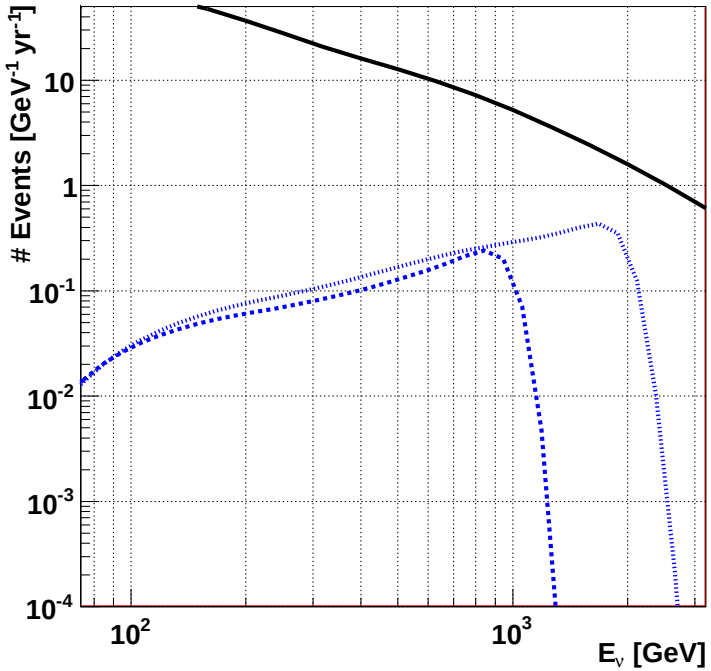


Pion decay



Neutrinos from Decaying Gravitinos

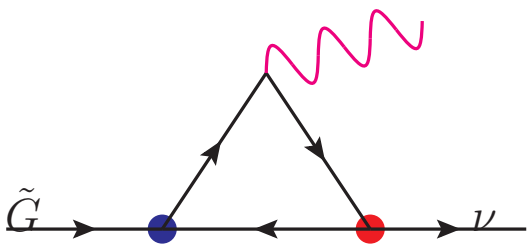




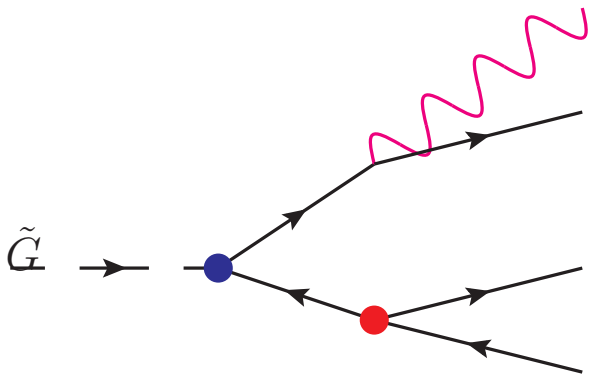
Outline

Gamma Rays from Decaying Gravitinos

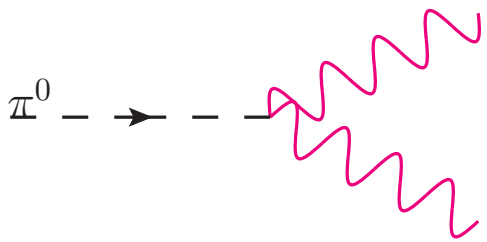
Monochromatic line



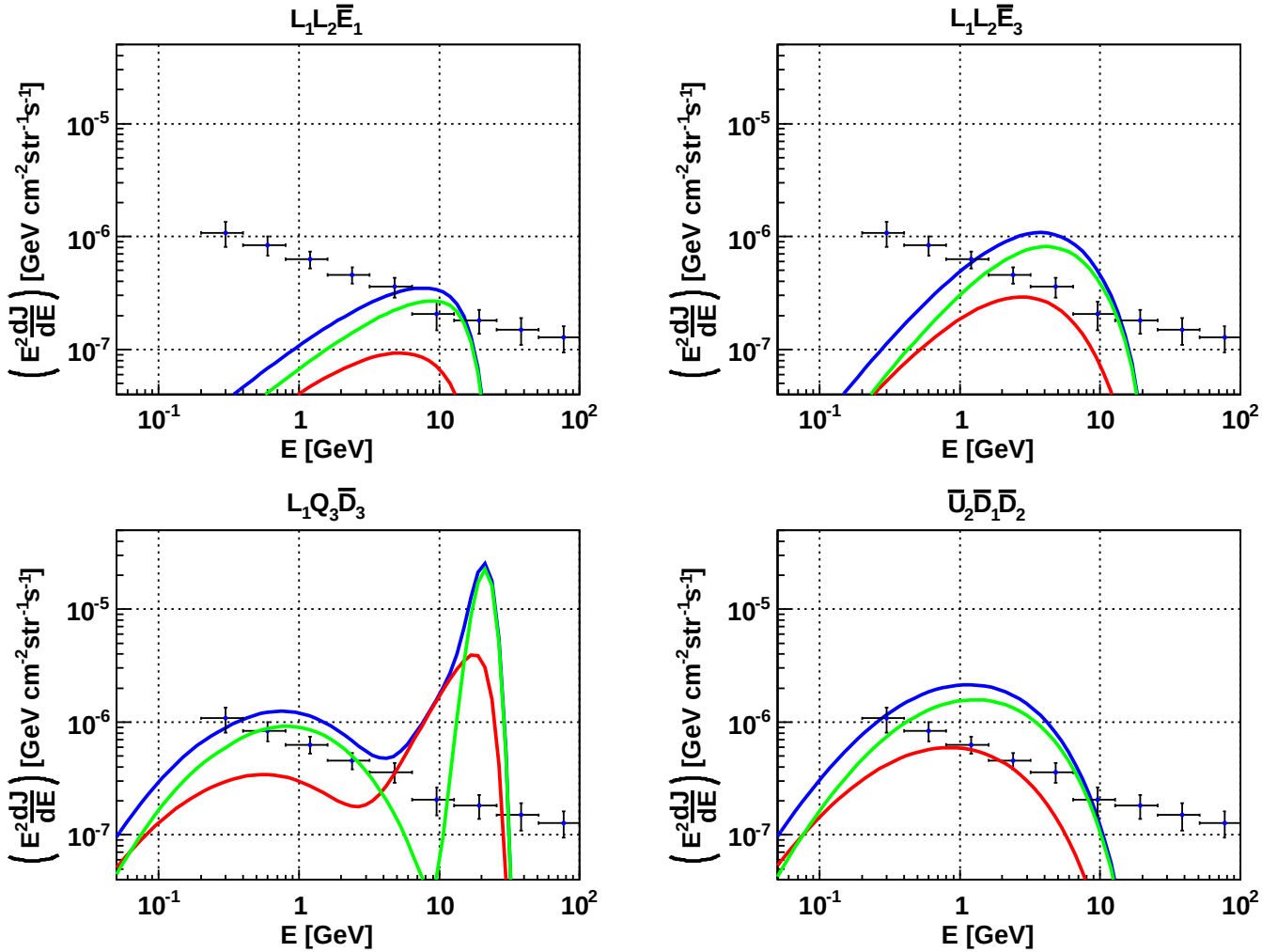
Final state radiation



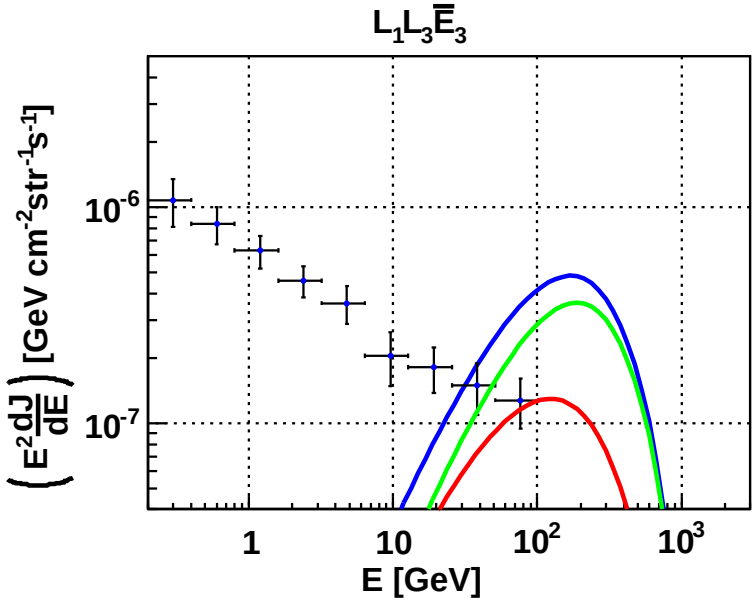
Pion decay

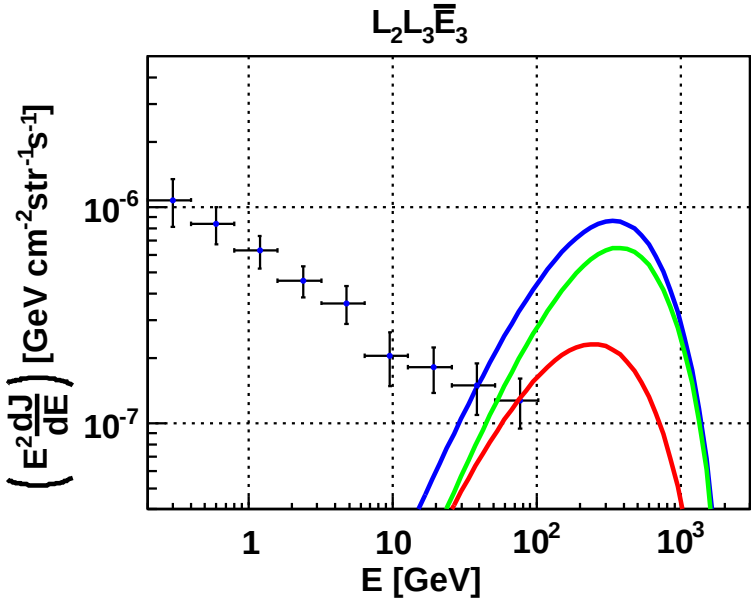


Gamma Rays from Decaying Gravitinos



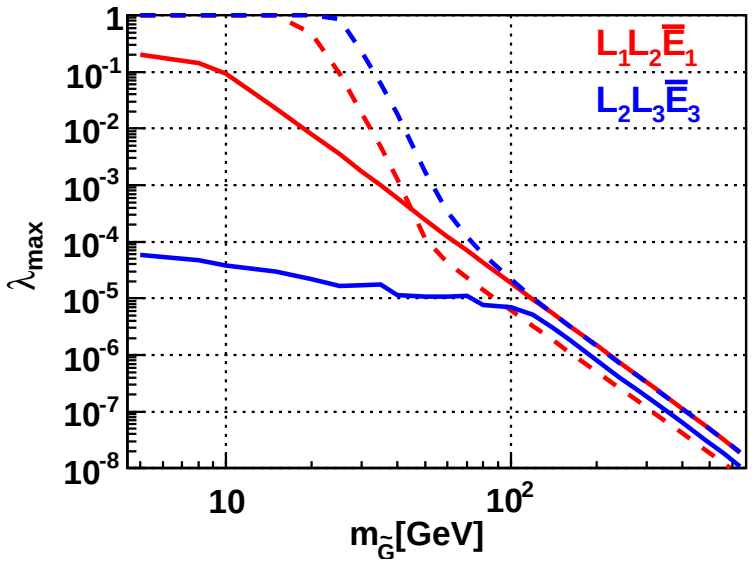
Gamma Ray Signals compared to Fermi LAT data

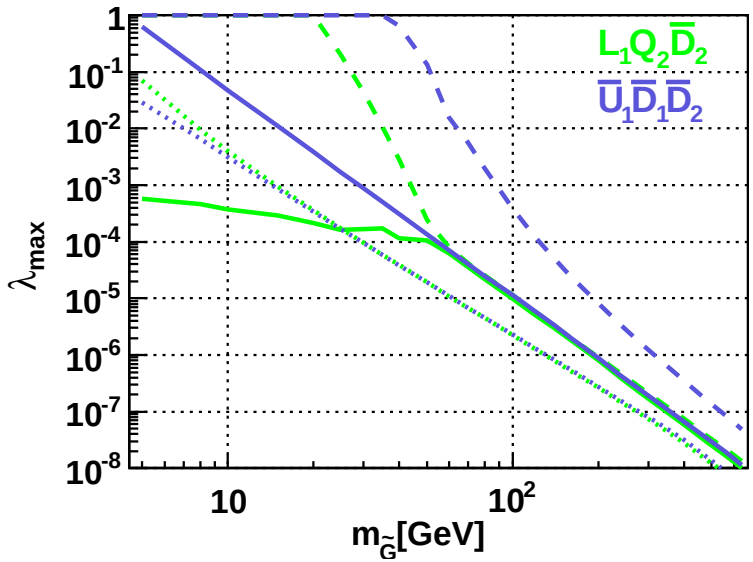




Outline

Constraints on R-Parity Violating Couplings





Summary

- Gravitino Dark Matter in R-Parity Violating Supersymmetric models can well explain the recent anomalies in cosmic ray electrons and positrons, seen by PAMELA, Fermi LAT and ATIC.
- Fermi LAT isotropic diffuse gamma ray data make such interpretation unlikely.
- A light gravitino ($m_{\tilde{G}} \lesssim 100$ GeV) might allow R-Parity Violating decays at the LHC.

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