Collider signatures of goldstini in gauge mediation

Kentarou Mawatari

Vrije Universiteit Brussel

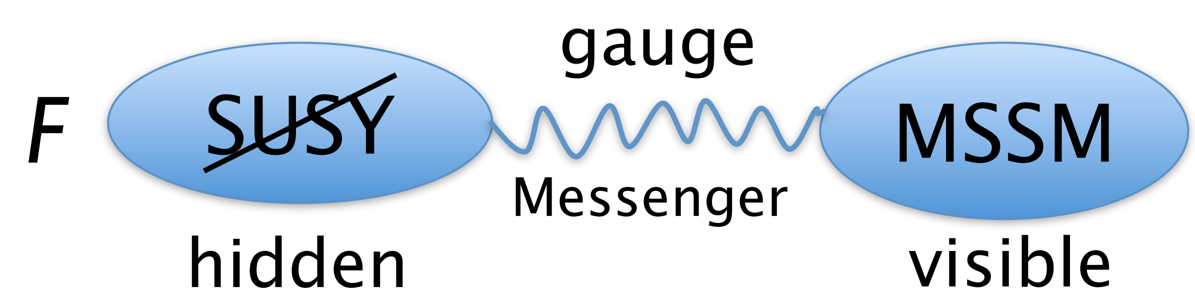
arXiv:1112.5058, in collaboration with
R. Argurio (U. Libre de Bruxelles, Belgium),
K.D.Causmaecker, A.Mariotti (Vrije U. Brussel, Belgium),
G.Ferretti (Chalmers U. of Technology, Sweden),
Y.Takaesu (KEK, Japan)

Outlines

- Gauge-mediated SUSY breaking
  - diphoton+missing energy signal for the neutralino NLSP
- Goldstini in gauge mediation
  - neutralino decay
  - collider signatures at ILC and LHC
- Summary

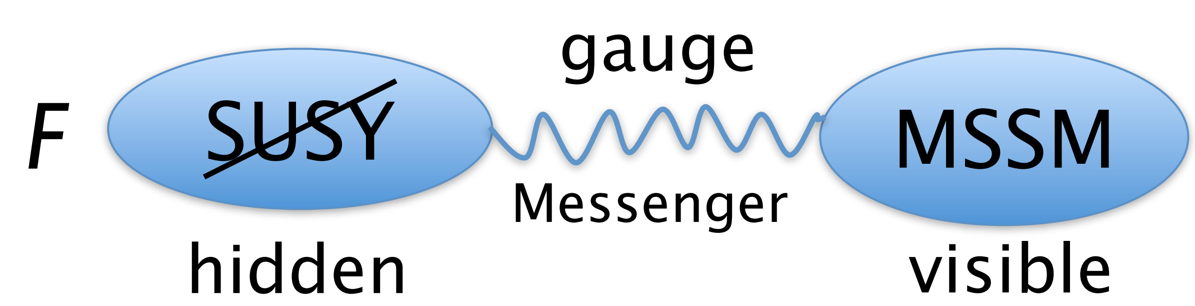
Pheno2012 @ Pittsburgh, 08/05/2012

GMSB: gauge-mediated SUSY breaking



- SUSY must be broken.
- Gauge mediation is one of the promising SUSY breaking model.
  - Gravitino is the LSP. ($m_{3/2} = m_G = F/M_{Pl} \sim O(\mathrm{eV})$)
  - The interactions of the longitudinal component of the massive gravitino, i.e. the goldstino interactions, are important at colliders.
- The collider signatures largely depend on what the NLSP (or LOSP: Lightest Observable-sector SUSY particle) is.
  - In the mGMSB model: neutralino (SPS8) or stau (SPS7)

GMSB: gauge-mediated SUSY breaking



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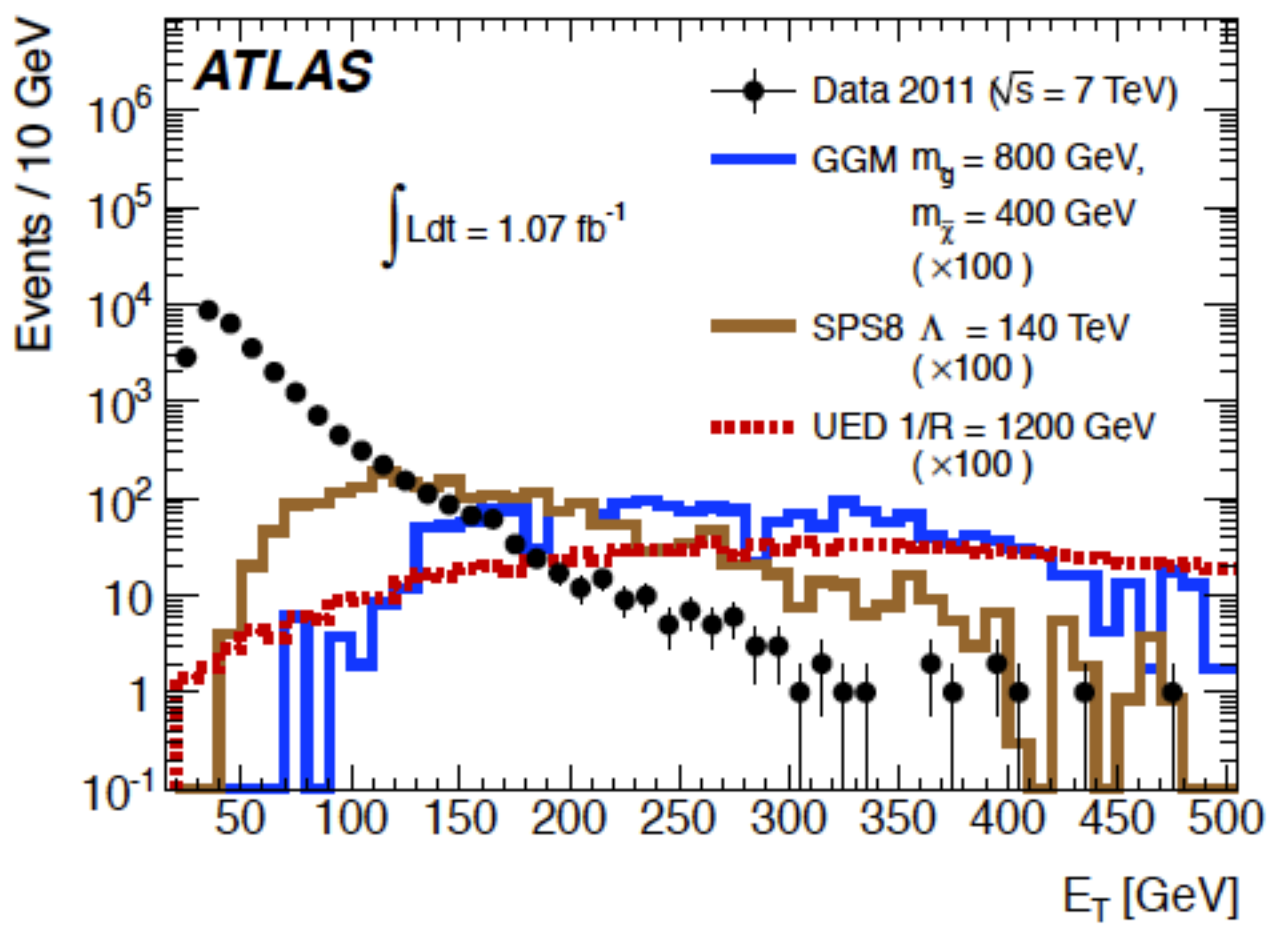
in this talk

Neutralino LOSP(=NLSP) ($\chi \rightarrow \gamma G$): diphoton + missing energy signal

arXiv:1111.4116



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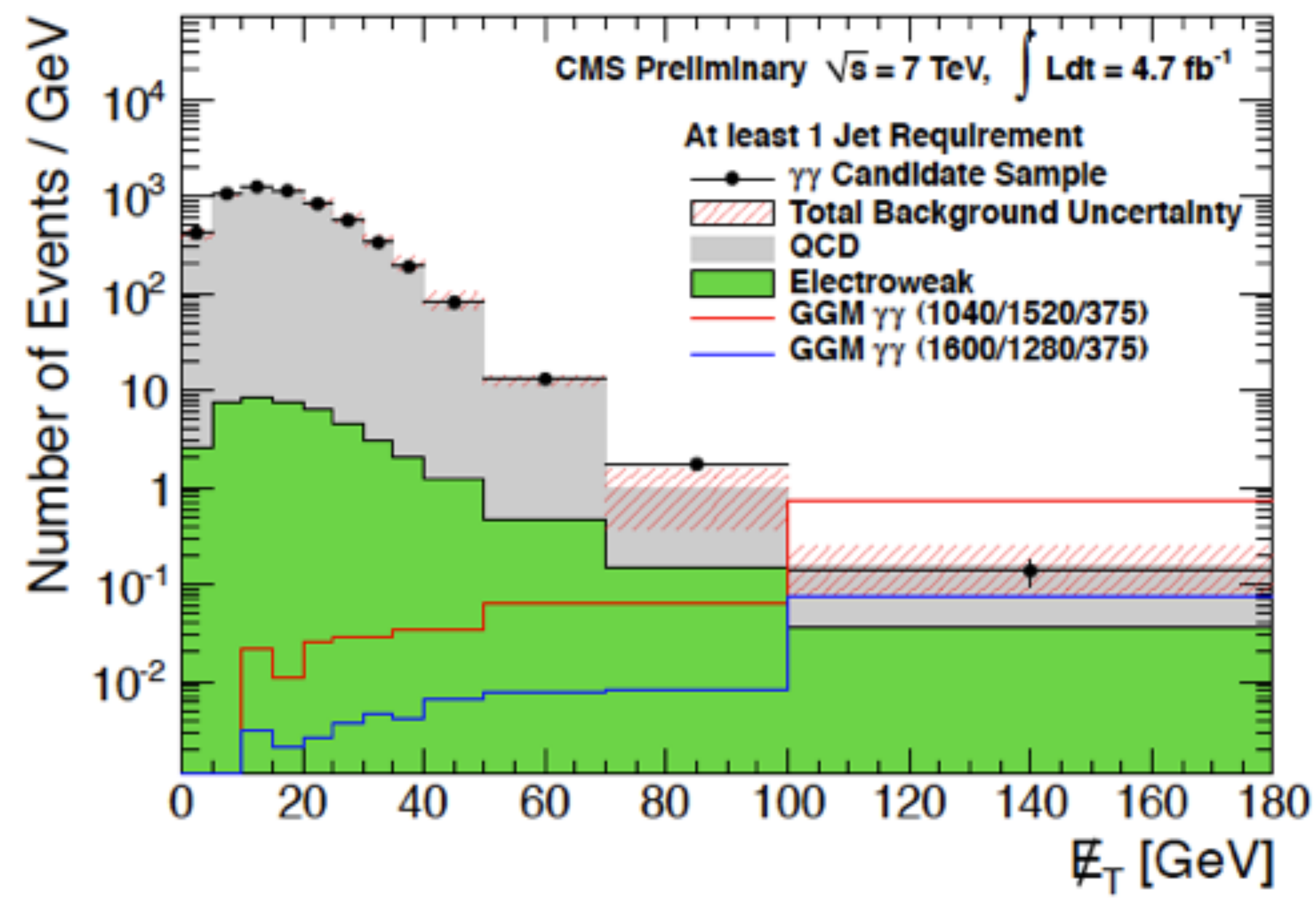

- In mGMSB, hard photons and large missing energy are expected.

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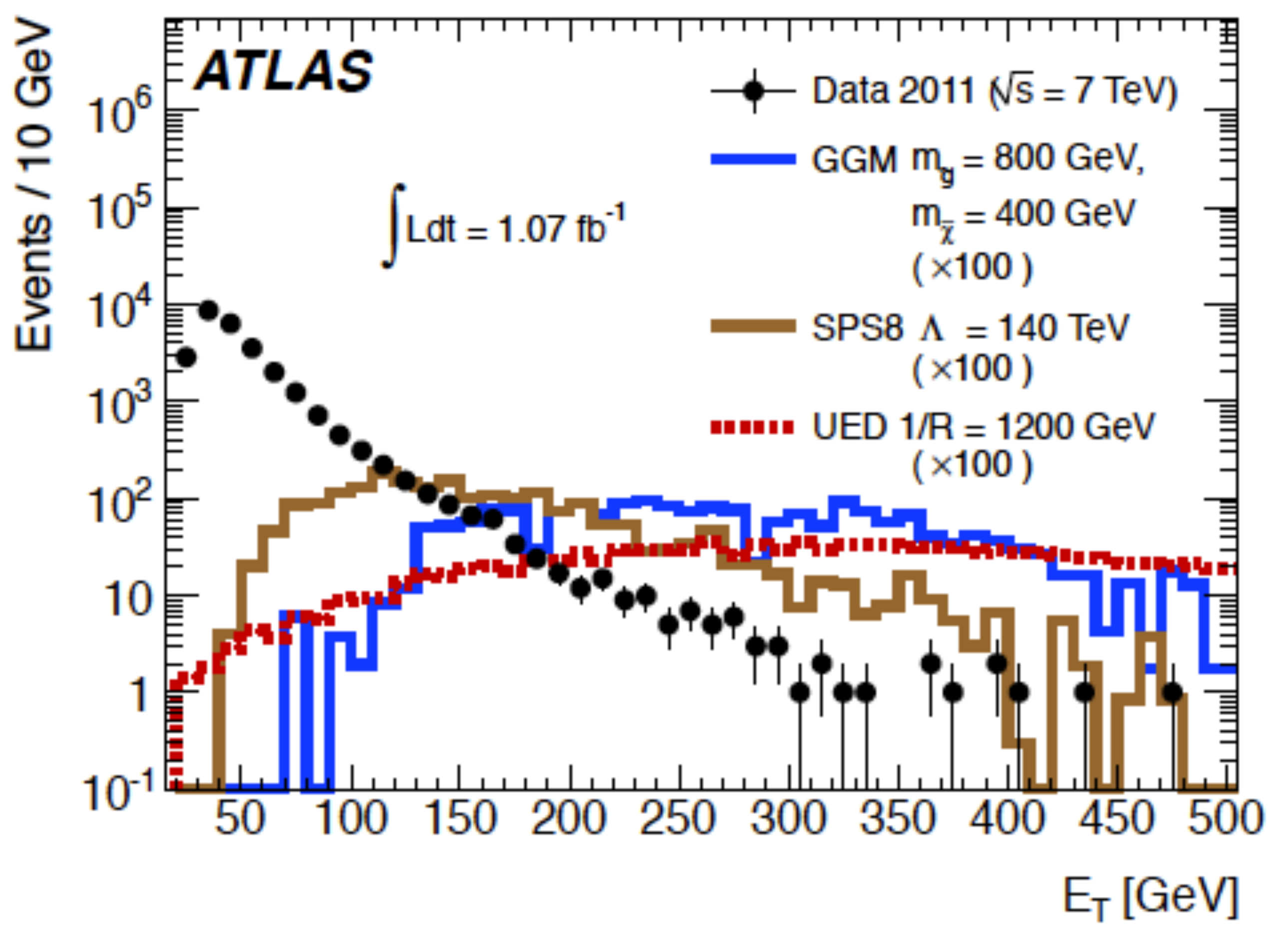

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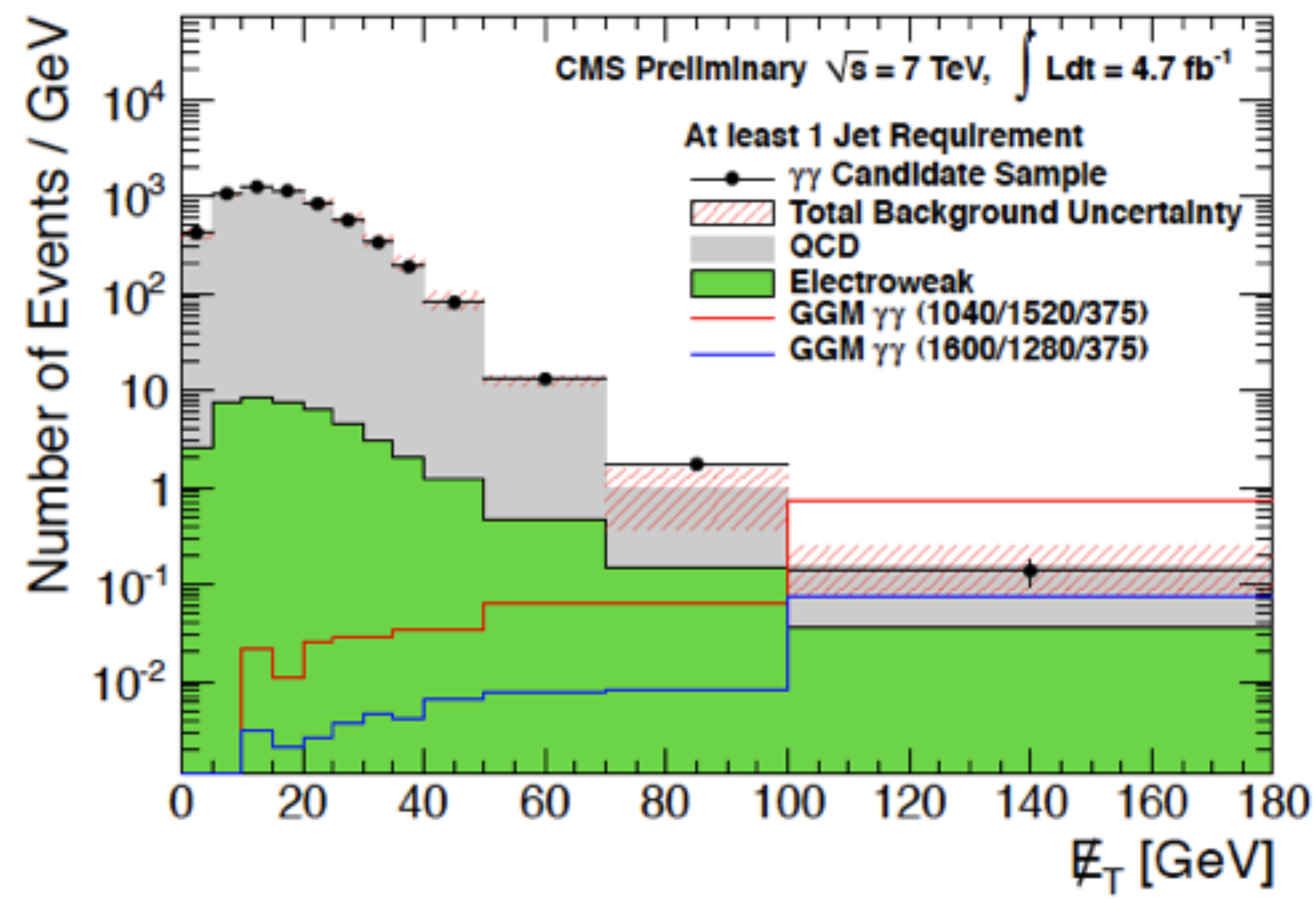

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- How will the signal distributions change in the goldstini model? (What happens if there is more than one SUSY breaking sectors?)

Cheung, Nomura, Thaler, 1002.1967
Argurio, Komargodski, Mariotti, 1102.2386

Goldstini: multiple goldstinos

$$\mathcal{L} = \mathcal{L}_{G_1} + \mathcal{L}_{G_2} = \frac{m_{\chi_1}}{2\sqrt{2}F_1}\chi\sigma^\mu\bar{\sigma}^\nu G_1 F_{\mu\nu} + \frac{m_{\chi_2}}{2\sqrt{2}F_2}\chi\sigma^\mu\bar{\sigma}^\nu G_2 F_{\mu\nu}$$

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mass eigenstate

$$G = \frac{1}{F}(F_1 G_1 + F_2 G_2)$$ true-goldstino

$$G' = \frac{1}{F}(-F_2 G_1 + F_1 G_2)$$ pseudo-goldstino

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$$\mathcal{L} = \mathcal{L}_{G} + \mathcal{L}_{G'} = \frac{m_{\chi}}{2\sqrt{2}F}\chi\sigma^\mu\bar{\sigma}^\nu G F_{\mu\nu} + K_\gamma\frac{m_{\chi}}{2\sqrt{2}F}\chi\sigma^\mu\bar{\sigma}^\nu G' F_{\mu\nu}$$

$$\left(F = \sqrt{F_1^2 + F_2^2},\ m_\chi = m_{\chi_1} + m_{\chi_2},\ K_\gamma = -\frac{m_{\chi_1}}{m_\chi}\frac{F_2}{F_1} + \frac{m_{\chi_2}}{m_\chi}\frac{F_1}{F_2}\right)$$

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- $m_G \sim$ O(eV), while $m_{G'} \sim$ O(1--100 GeV).

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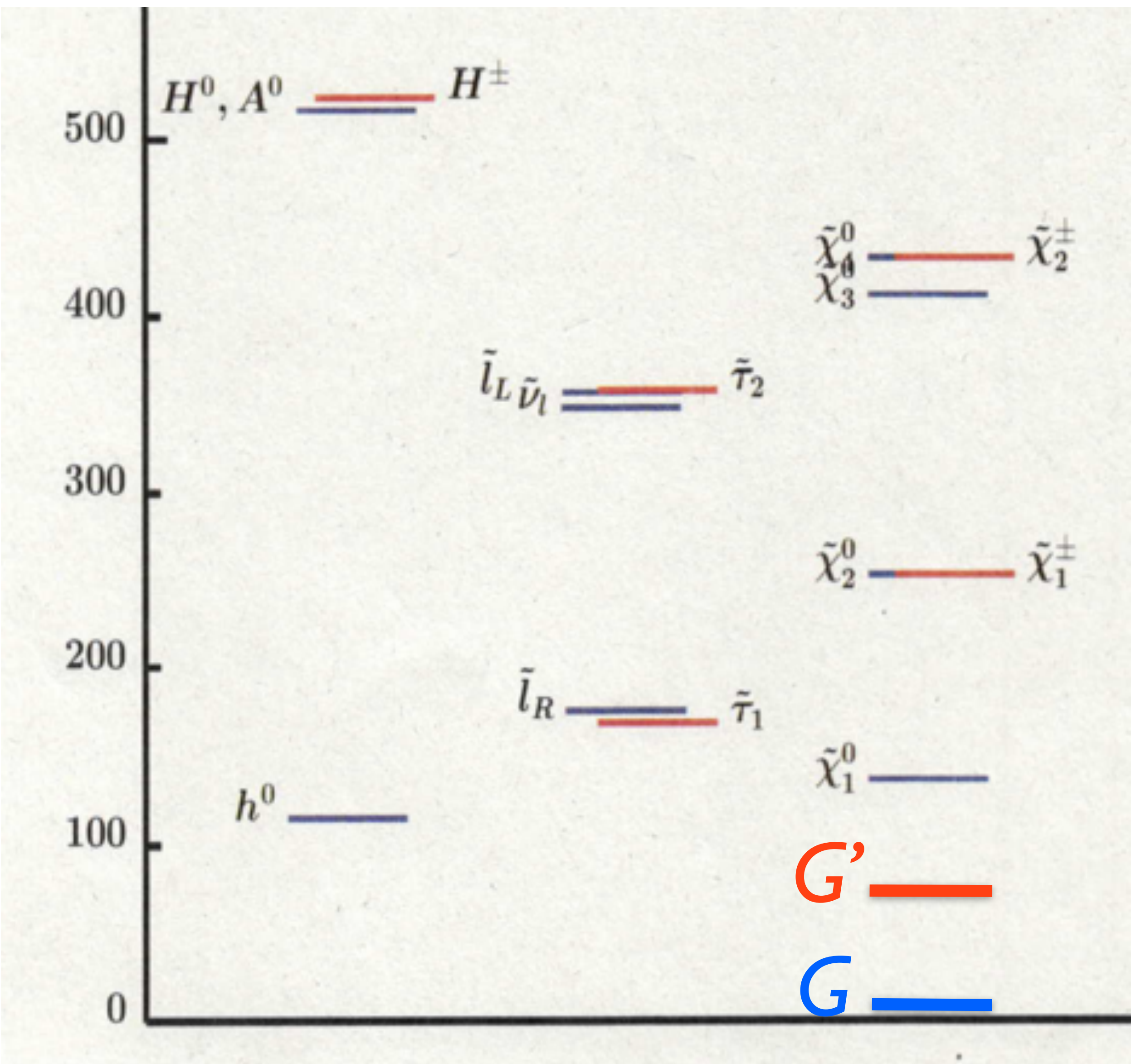
- $m_G \sim$ O(eV), while $m_{G'} \sim$ O(1--100 GeV).
  Argurio, Komargodski, Mariotti, arXiv:1102.2386
- The coupling of the pseudo-goldstino can be enhanced by K_γ.

Goldstini in MadGraph

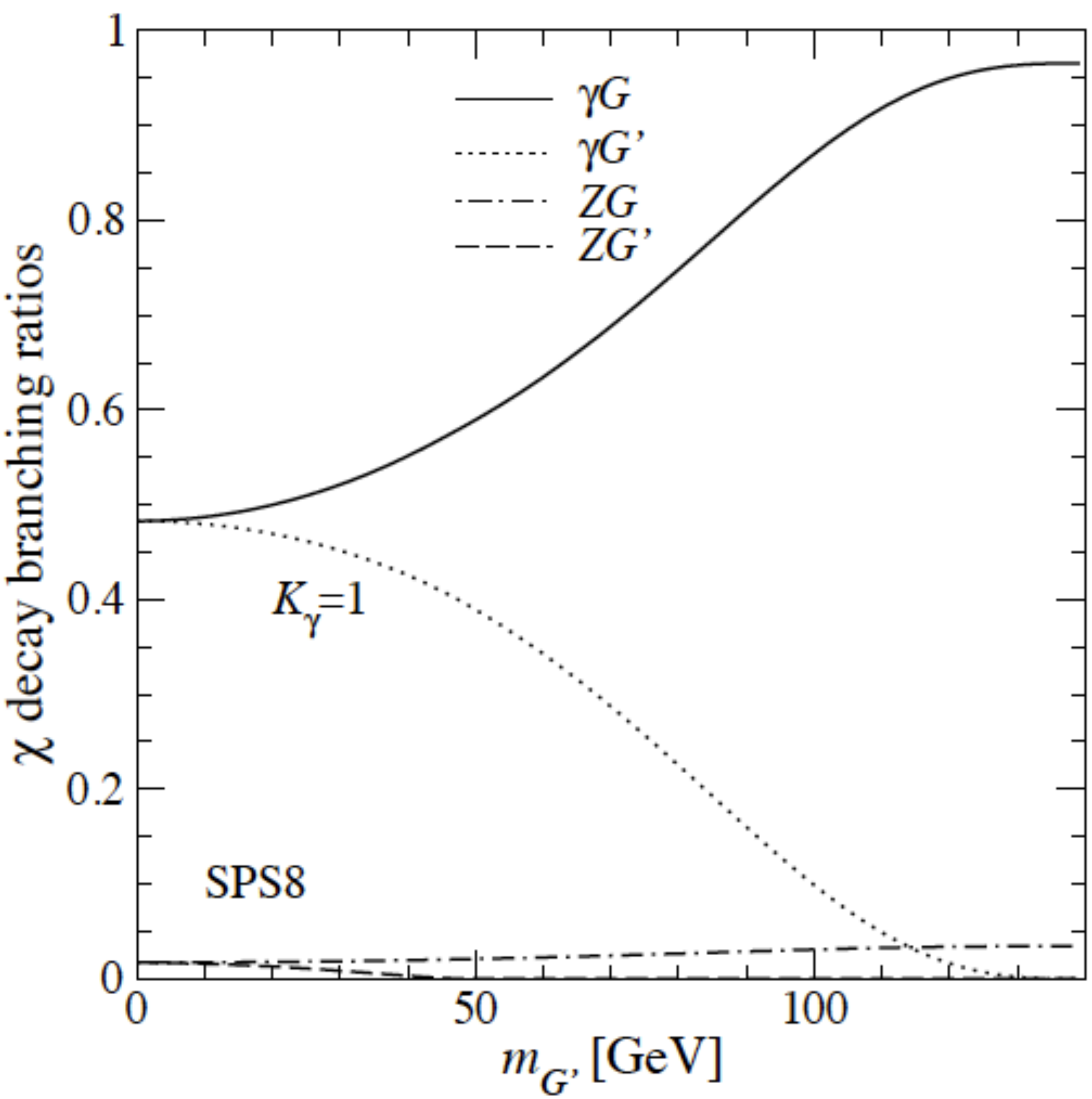
- In 2011, the implementation of the gravitino/ goldstino into the MadGraph/MadEvent v4 was accomplished:
  - "HELAS and MadGraph with spin-3/2 particles (gravitinos)"
    K. Hagiwara (KEK), KM, Y. Takaesu (KEK); EPJC71(2011) [arXiv:1010.4255]
  - "HELAS and MadGraph with goldstinos"
    KM, Y. Takaesu (KEK); EPJC71(2011) [arXiv:1101.1289]
- We extended the single goldstino model to the goldstini in MG/MEv4.
- In addition, we implemented the goldstini in MG5 with the help of FeynRules.

Mass spectrum



- As a benchmark point, we take the SPS8 point + pseudo-goldstino.
  - LOSP: lightest neutralino m_χ =140 GeV
  - NLSP: pseudo-goldstino O(eV) < $m_{G'}$ < 140 GeV
  - LSP: gravitino (true-goldstino) $m_G \sim$ O(eV)

Neutralino LOSP decay



- At SPS8, the bino component in the lightest neutralino is dominant.

  ➡ χ→γG or γG' is dominant.

- The partial decay width:

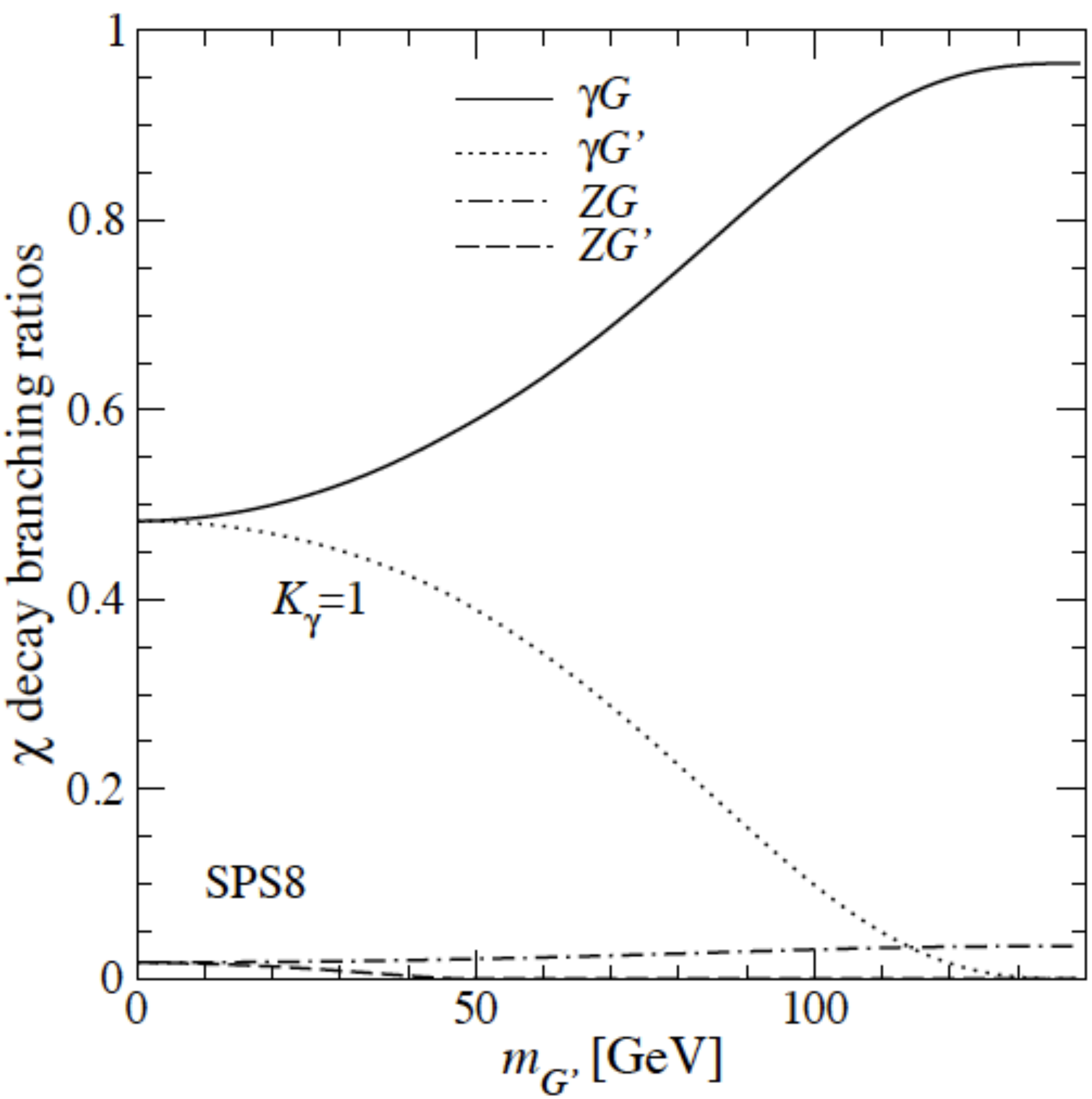
$$\Gamma(\chi \to \gamma G) = \frac{a_\gamma^2 m_\chi^5}{16\pi F^2},$$

$$\Gamma(\chi \to \gamma G') = \frac{K_\gamma^2 a_\gamma^2 m_\chi^5}{16\pi F^2}\left(1 - \frac{m_{G'}^2}{m_\chi^2}\right)^3.$$

$$a_\gamma = N_{11}^* \cos\theta_W + N_{12}^* \sin\theta_W$$

  - $B_{G'}$ is suppressed for large $m_{G'}$.
  - $B_{G'}$ is enhanced by K_γ.

Neutralino LOSP decay



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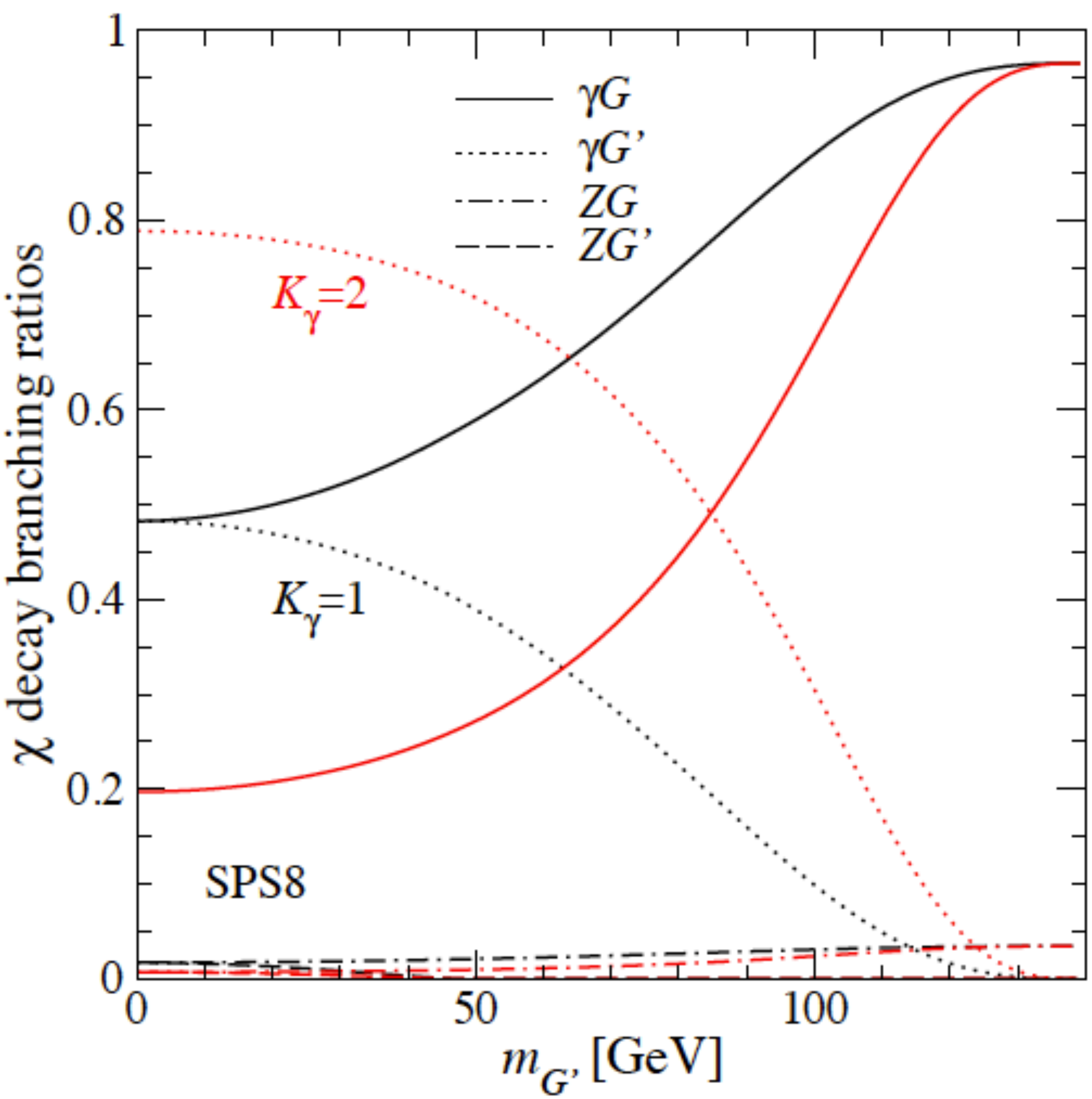

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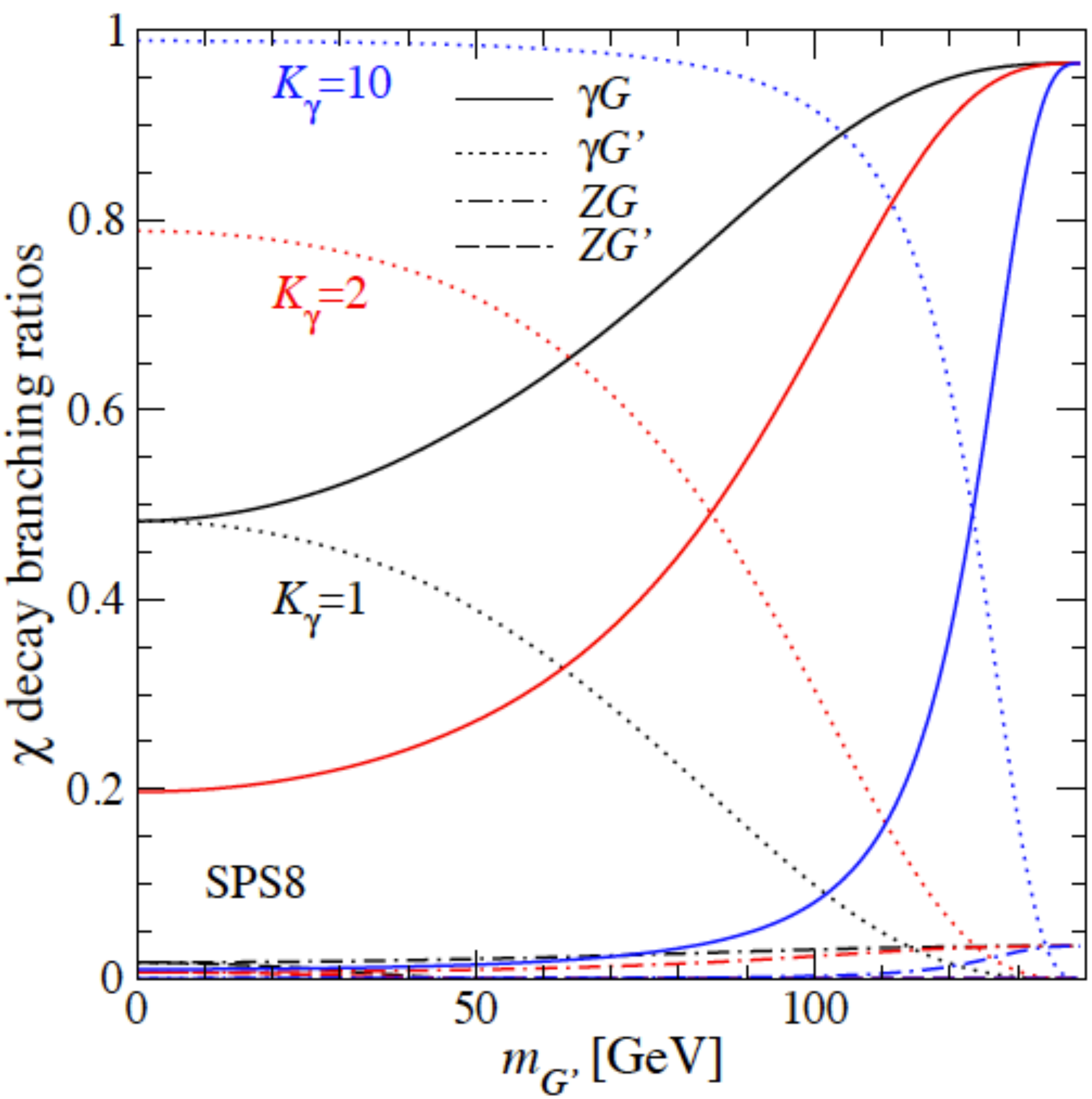

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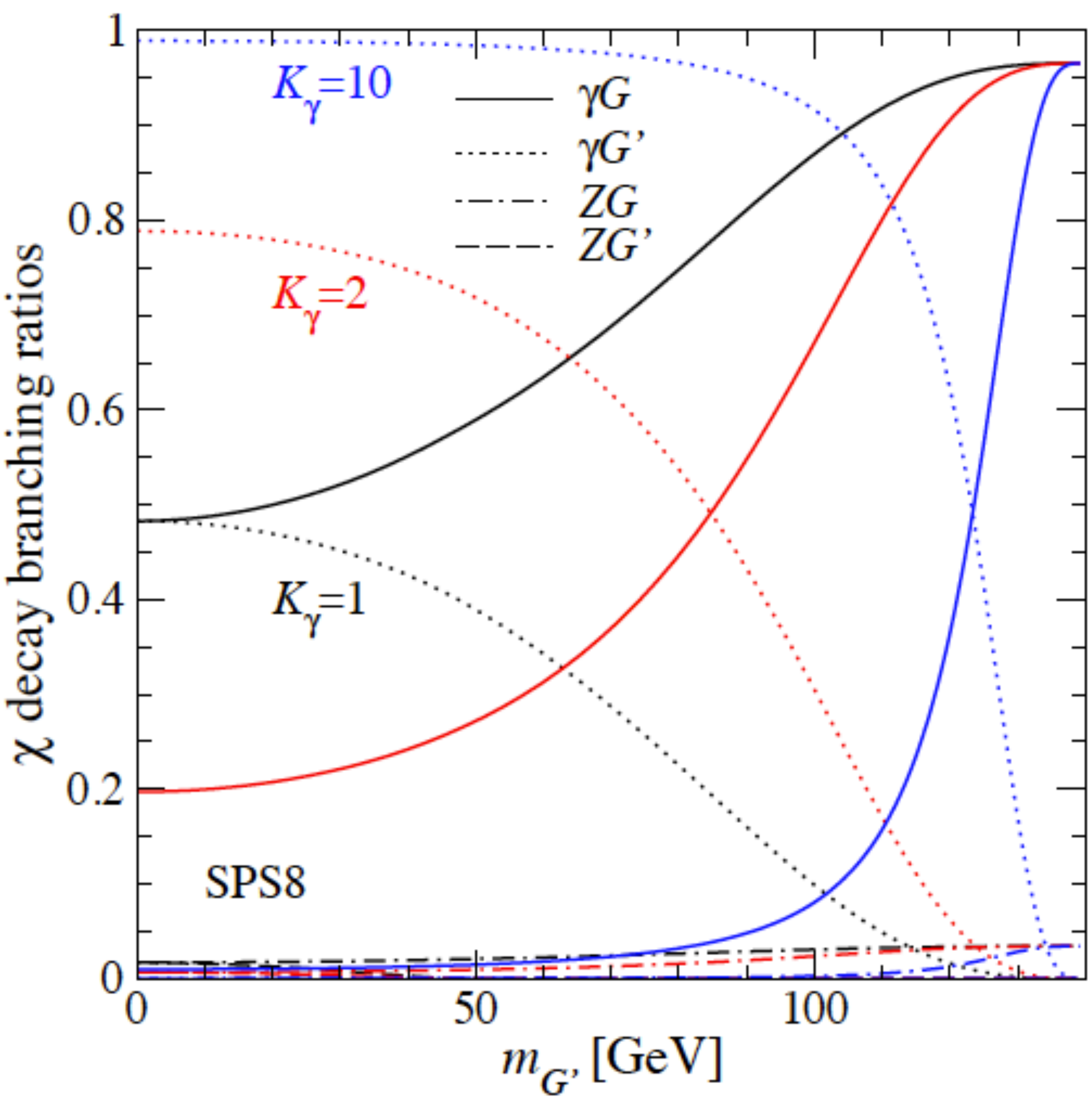

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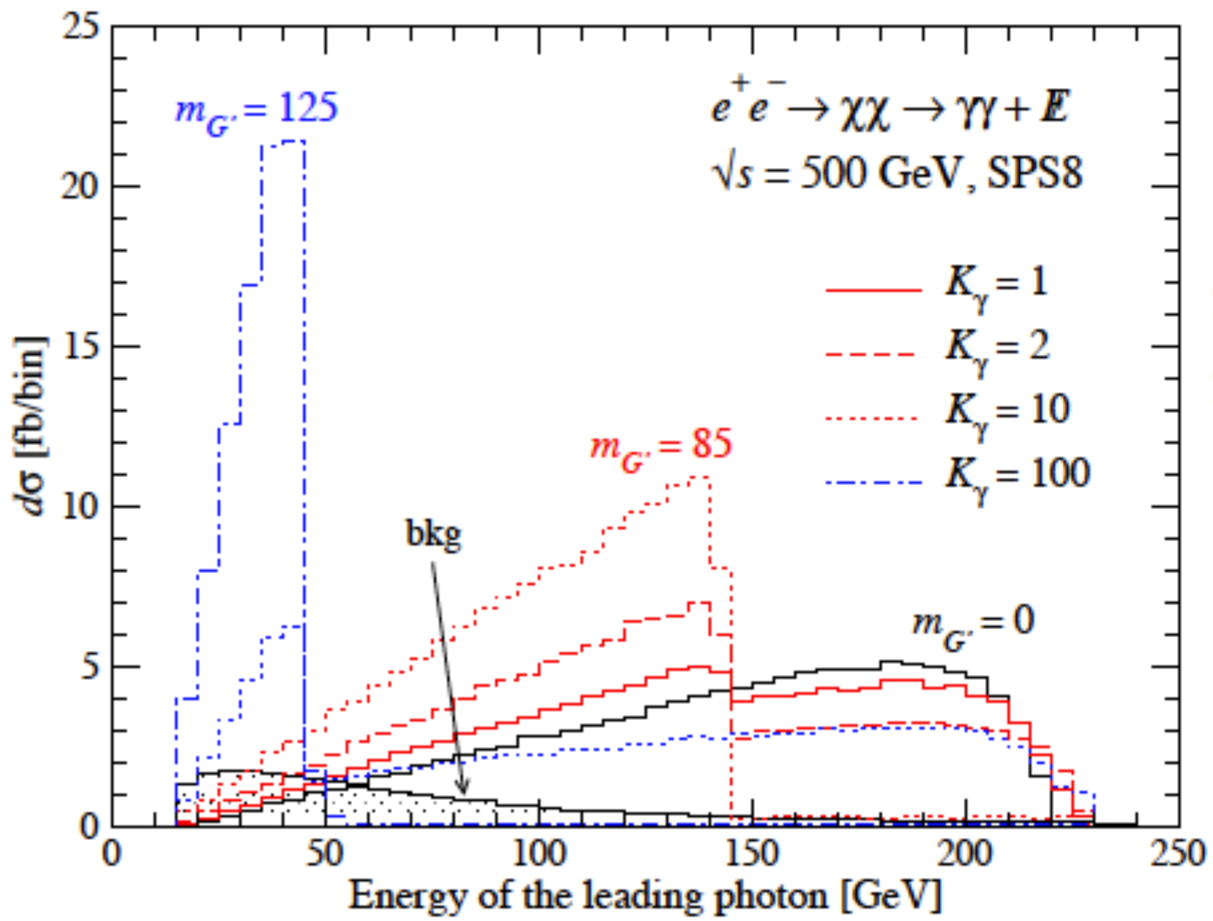
ILC: $e^+e^- \to \chi\chi \to \gamma(G \text{ or } G')\,\gamma(G \text{ or } G')$



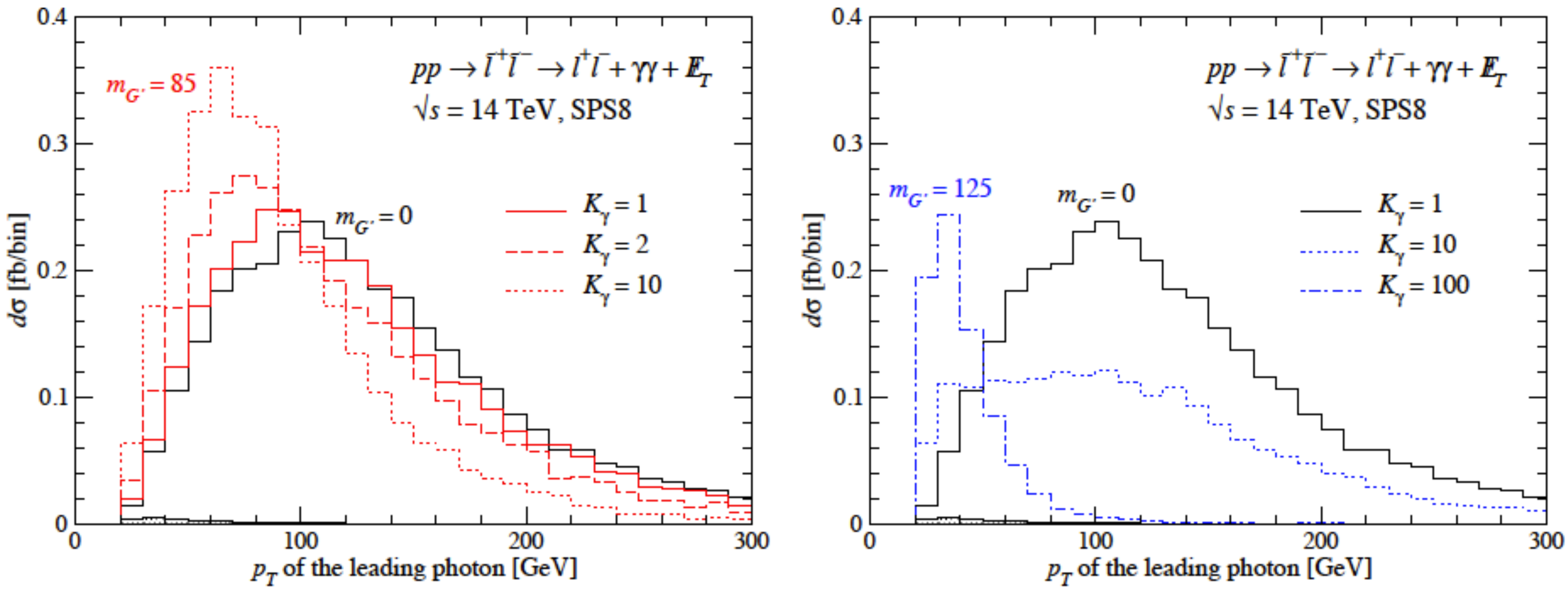
1a.	$m_{G'} = 85$ GeV	with $K_\gamma = 1$	$[B(\chi \to \gamma G') \sim 0.2]$
1b.	$m_{G'} = 85$ GeV	with $K_\gamma = 2$	$[B(\chi \to \gamma G') \sim 0.5]$
1c.	$m_{G'} = 85$ GeV	with $K_\gamma = 10$	$[B(\chi \to \gamma G') \sim 1]$
2a.	$m_{G'} = 125$ GeV	with $K_\gamma = 10$	$[B(\chi \to \gamma G') \sim 0.5]$
2b.	$m_{G'} = 125$ GeV	with $K_\gamma = 100$	$[B(\chi \to \gamma G') \sim 1]$

Kinematical cuts: $E_\gamma > 15$ GeV and $|\eta_\gamma| < 2$
$M_{\rm inv} > 100$ GeV

$$E_\gamma^{\rm max,min} = \frac{\sqrt{s}}{4}\left(1 - \frac{m_{G'}^2}{m_\chi^2}\right)\left(1 \pm \sqrt{1 - \frac{4m_\chi^2}{s}}\right)$$

- The photon spectrum is softer than that in the single goldstino case ($m_{G'}$=0).
- The distributions largely depends on K_γ, i.e. the χ branching ratio.
- The two $E^{\rm max}$ edges can determine both m_χ and $m_{G'}$.

LHC: $pp \to \tilde{l}^+\tilde{l}^- \to (l^+\chi)(l^-\chi) \to l^+l^- + \gamma\gamma + \not{E}_T$



- The photon spectrum is softer than that in the single goldstino case ($m_{G'}$=0).
- The distributions largely depends on K_γ, i.e. the χ branching ratio.
- A hard photon cut in SUSY searches would overlook the goldstini signatures.

Summary

- We studied collider signatures of multiple SUSY breaking hidden sectors coupled with the visible sector by gauge interactions.

  ➡ pseudo-goldstino with mass O(1-100 GeV)
  massive gravitino (true-goldstino) with mass O(eV)

- Here, we considered a neutralino LOSP, which decays into a photon and a true/pseudo-goldstino.

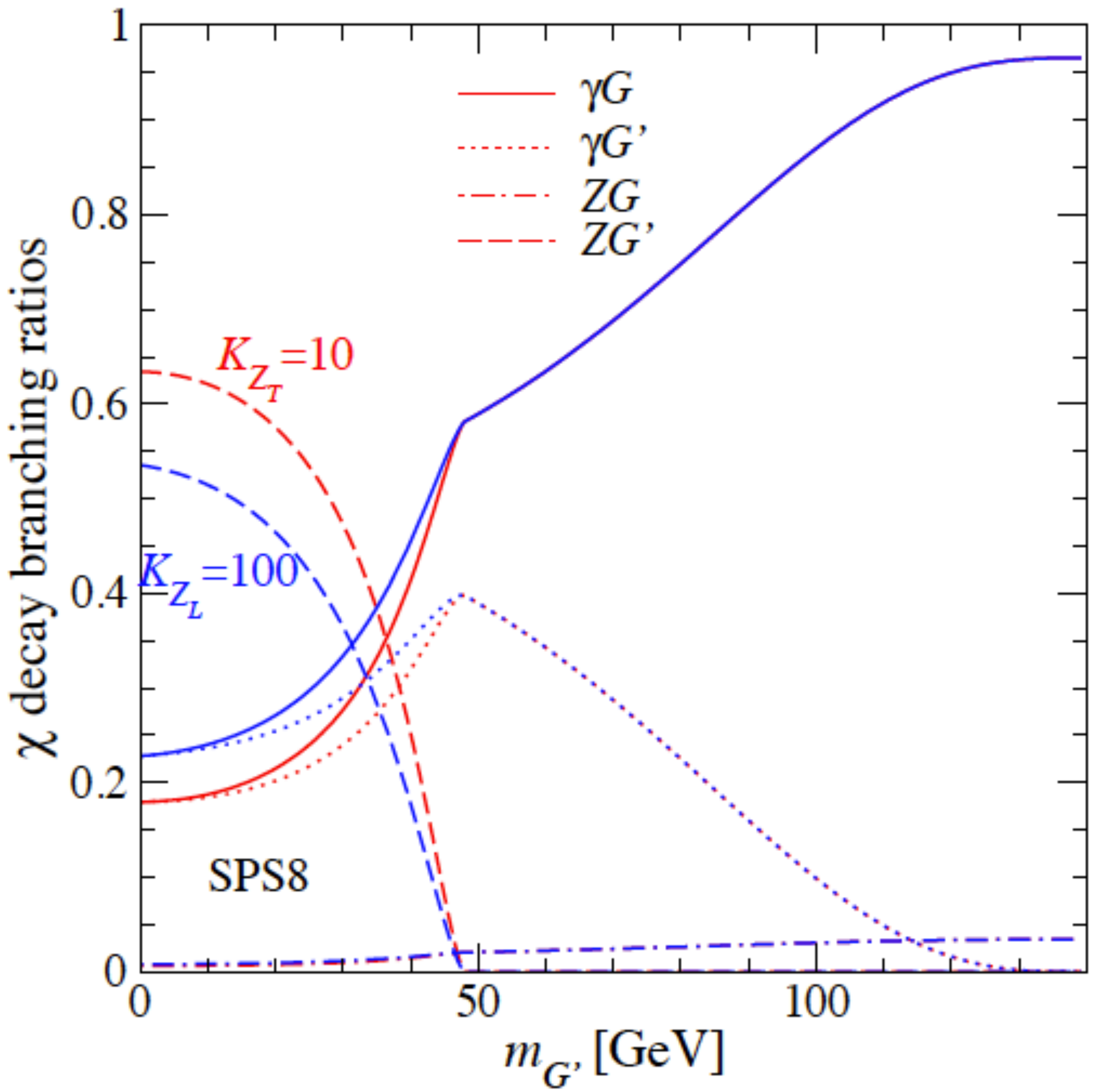
- We found that the photon spectrum is softer and more structured, compared to standard GMSB.

  ➡ The multiple-goldstino, i.e. the goldstini scenarios can ease the experimental constraints on GMSB.

- We are extending our study to other benchmark points and LOSPs, e.g., stau, stop, ...

backup

Neutralino LOSP decay



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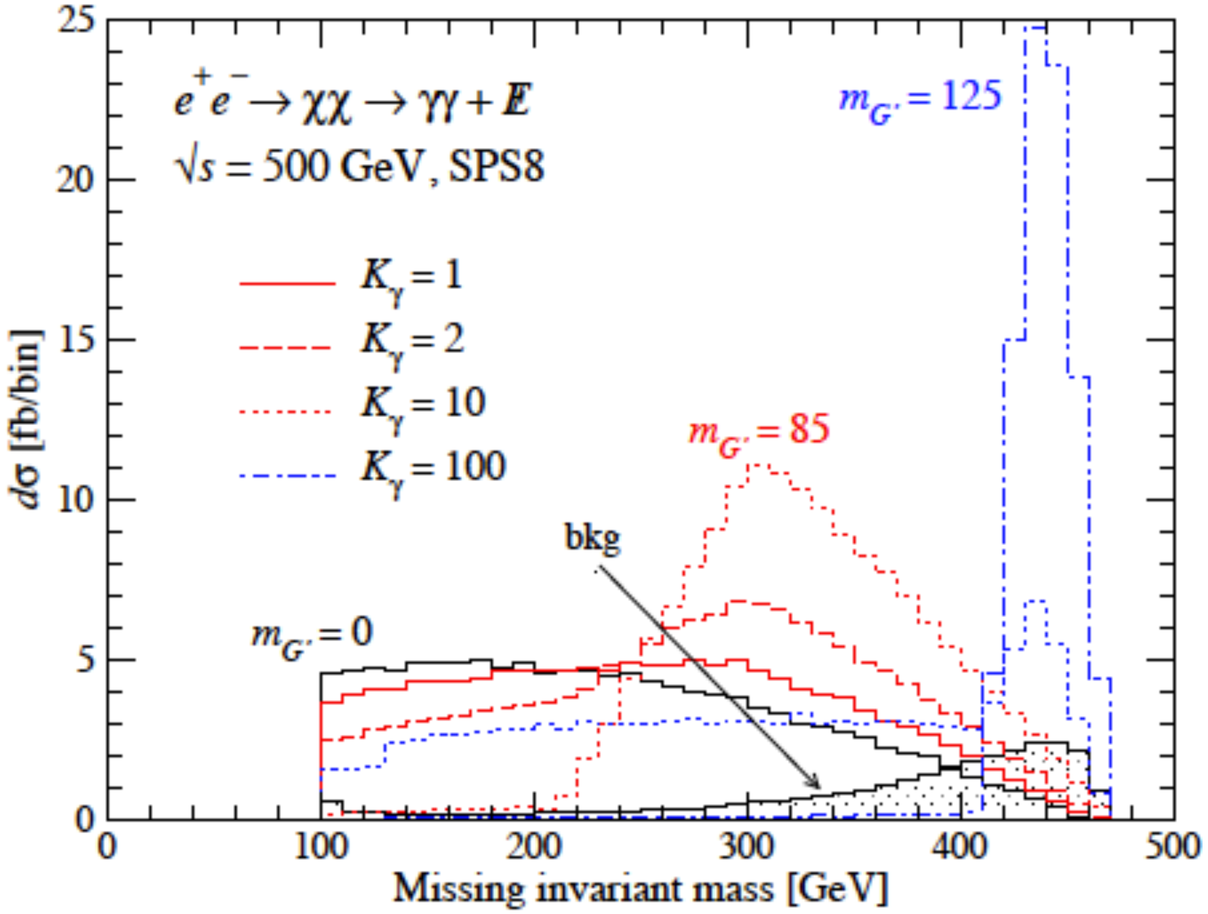

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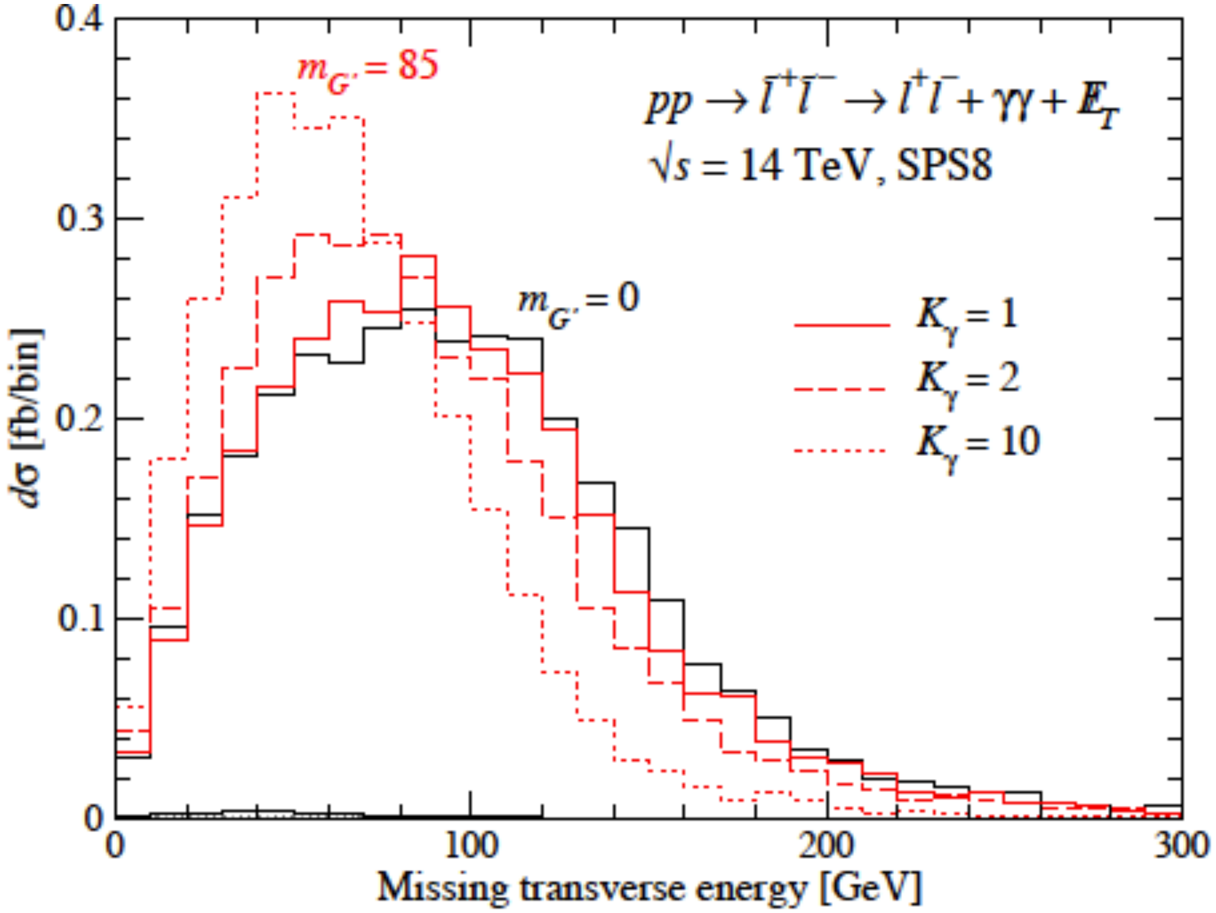
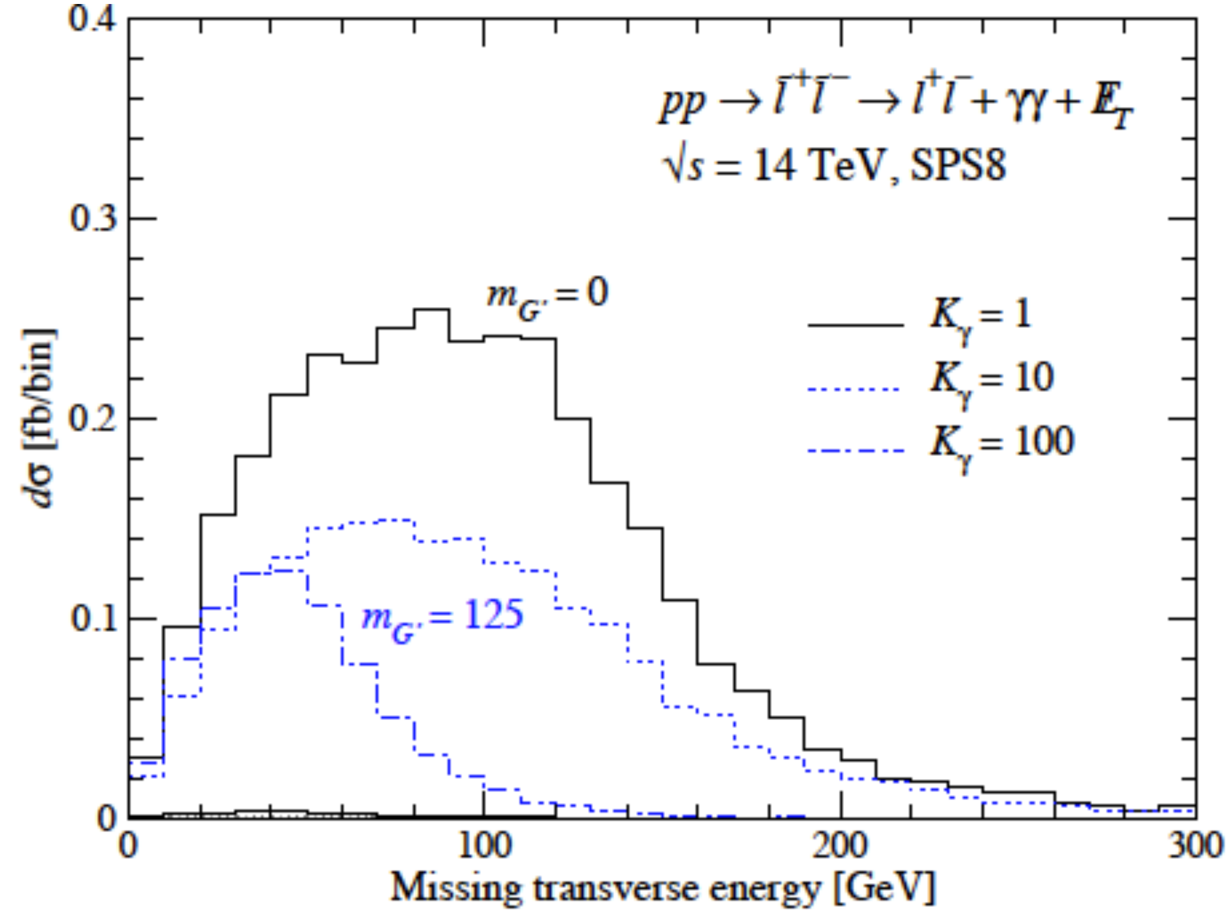
Kinematical cuts: $E_\gamma > 15$ GeV and $|\eta_\gamma| < 2$
$M_{\rm inv} > 100$ GeV

- The invisible invariant mass cut is imposed to remove the SM *Z* background.
- The distributions largely depends on $m_{G'}$ and K_γ.

LHC: $pp \to \tilde{l}^+\tilde{l}^- \to (l^+\chi)(l^-\chi) \to l^+l^- + \gamma\gamma + \not{E}_T$





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