

# Non-standard Higgs decays and LHC signatures from low scale ~~SUSY~~

Christoffer Petersson  
IFT - UAM/CSIC, Madrid



Warsaw, Planck 2012, May 25

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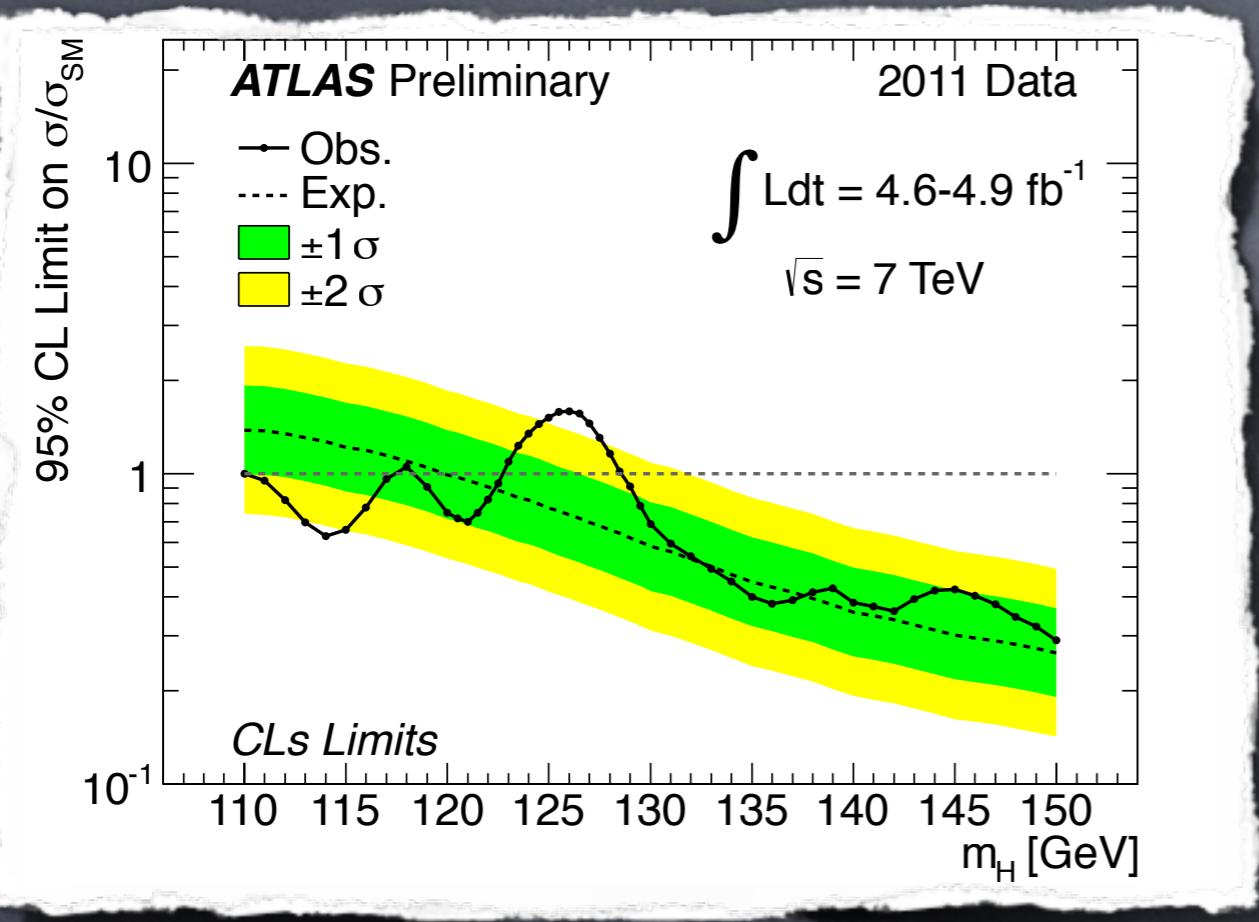
Based on:

C. P., Alberto Romagnoni and Riccardo Torre

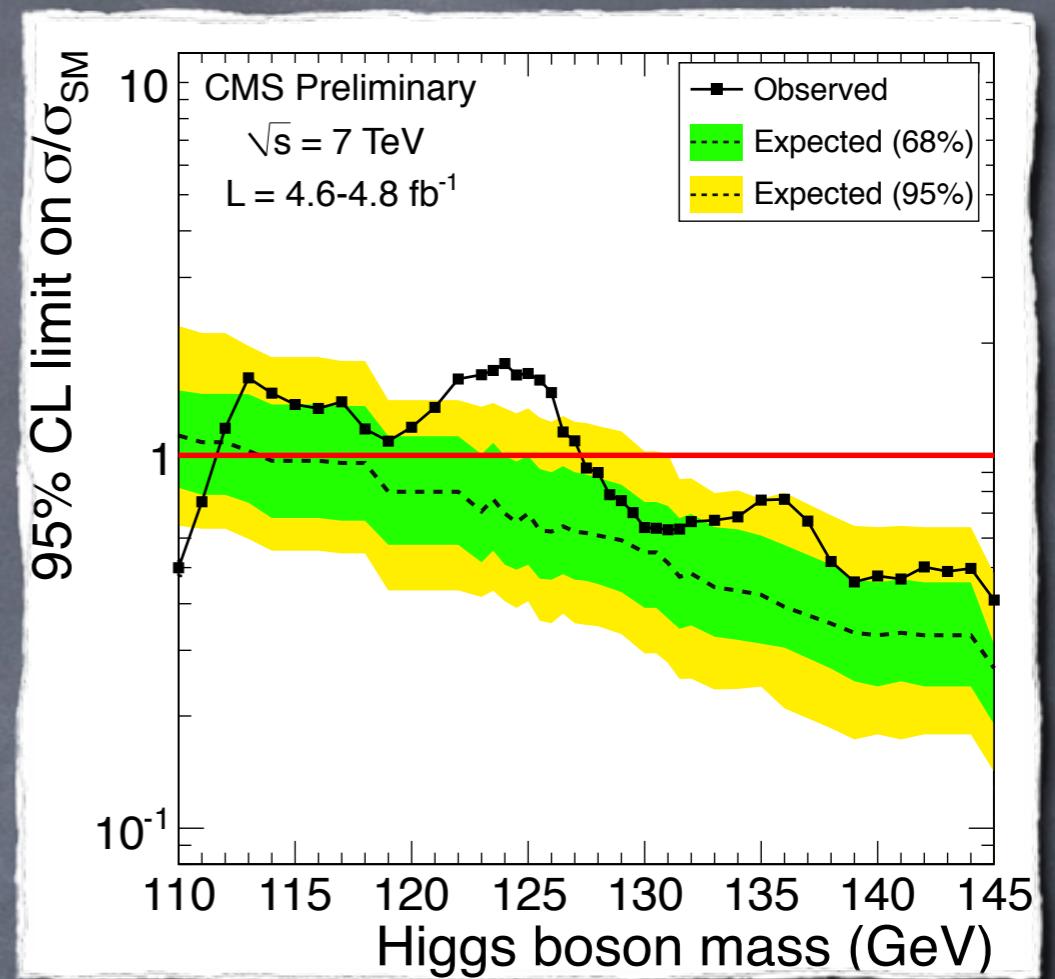
arXiv:1203.4563 [hep-ph]

C. P. and Alberto Romagnoni

JHEP 1202 142, arXiv:1111.3368 [hep-ph]

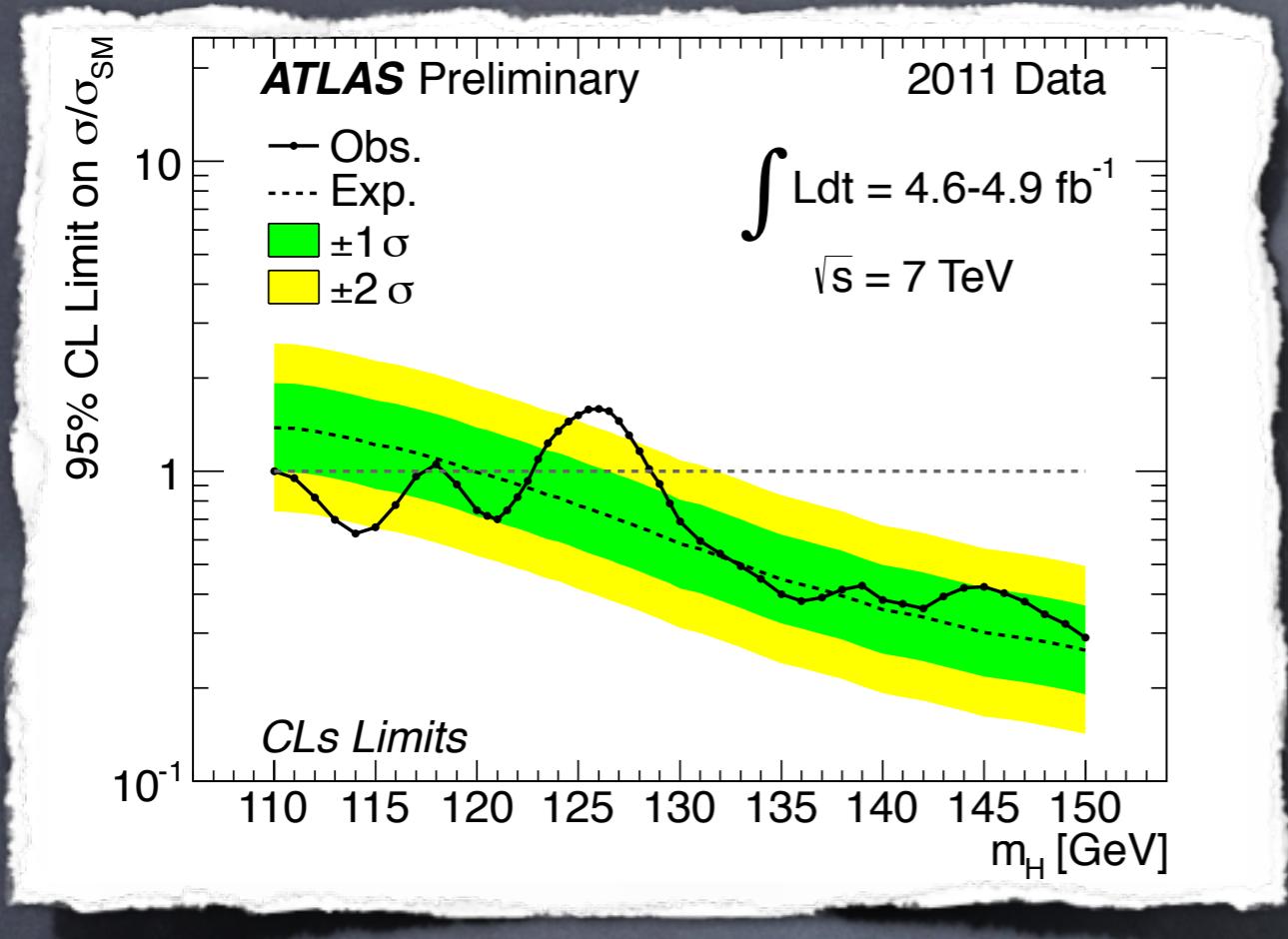


ATLAS Collaboration

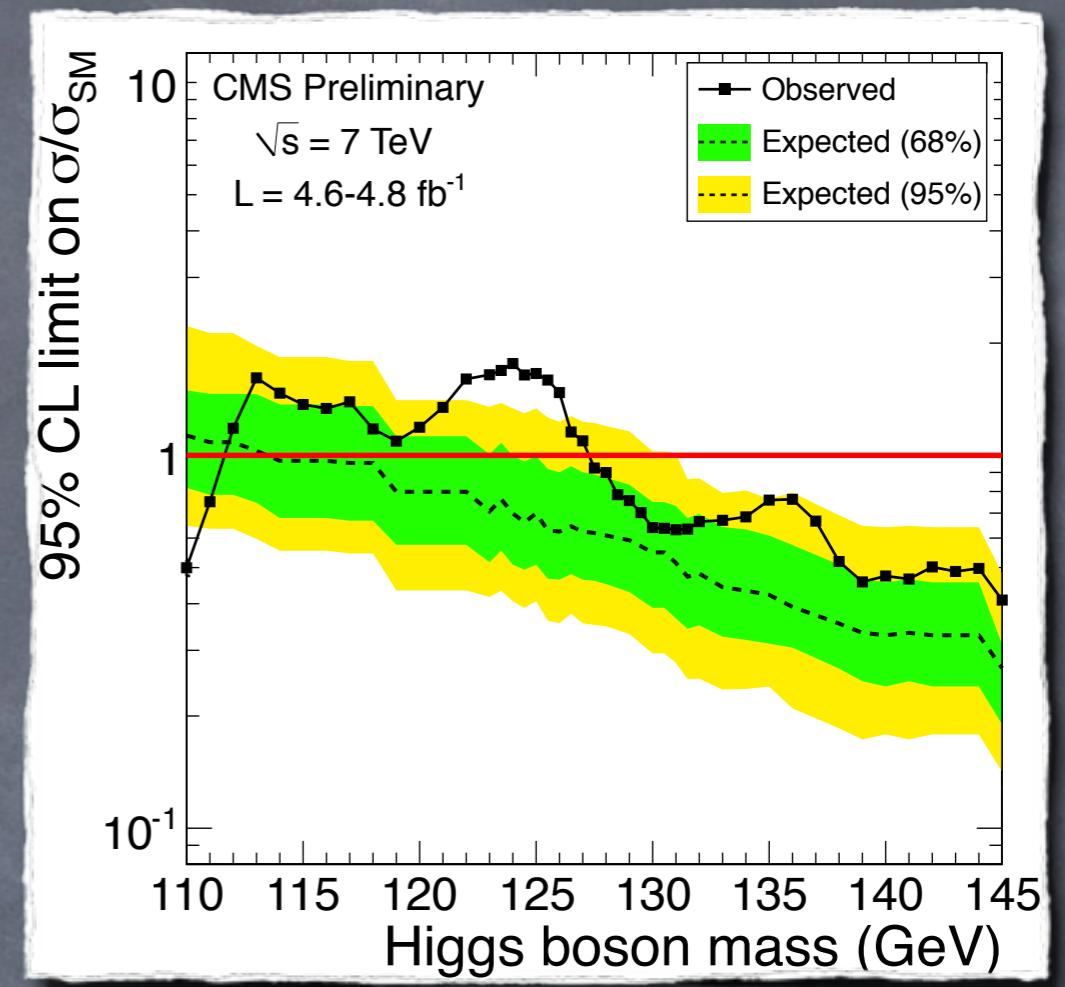


CMS Collaboration

- Hint of physics beyond the SM?
- A 125 GeV Higgs is in good agreement with SUSY.
- However, so far, no sign of SUSY.



ATLAS Collaboration



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- However, so far, no sign of SUSY.

Are we missing some class of models or final states?

This talk:  
SUSY broken spontaneously at  
around the TeV scale  
Could be discovered through a  
non-standard decay a SM-like Higgs

# Spontaneous SUSY breaking

- Spontaneous breaking of (global) SUSY implies the existence of a massless spin 1/2 Goldstone particle, the goldstino.
- In the presence of gravity, the goldstino is eaten by the spin 3/2 gravitino and the gravitino acquires a mass:

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$$m_{3/2} = \frac{f}{\sqrt{3}M_P}$$

$$m_{3/2} \approx 10^{-5} \text{ eV}$$

.  $\sqrt{f} \approx 300 \text{ GeV}$

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Exp.  
Bound

Focus of this talk :

$$m_{3/2} \approx 10^{-3} \text{ eV}$$

$$\sqrt{f} \approx \text{few TeV}$$

Gravity  
Mediation      Anomaly  
Mediation

# Goldstino Superfield

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- MSSM soft terms

$$m_{soft}^2 h_u^\dagger h_u = \frac{m_{soft}^2}{f^2} \int d^4\theta X_{\text{soft}}^\dagger X_{\text{soft}} H_u^\dagger H_u$$

$$X_{\text{soft}} = \theta^2 f$$

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- Non-linear SUSY

Komargodski, Seiberg; 0907.2441 [hep-th]

Antoniadis et al.; 1006.1662 [hep-ph]

$$X_{\text{nl}} = \frac{\psi_X \psi_X}{2F_X} + \sqrt{2}\theta \psi_X + \theta^2 F_X$$

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## • Linear SUSY

Brignole et al.; hep-ph/9709111

Casas et al.; hep-ph/0301121

C.P., Romagnoni; 1111.3368 [hep-ph]

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$$= m_{soft}^2 h_u^\dagger h_u + \frac{m_{soft}^2}{f} \bar{\psi}_X \bar{\psi}_{H_u} h_u + \dots$$

$\nearrow$

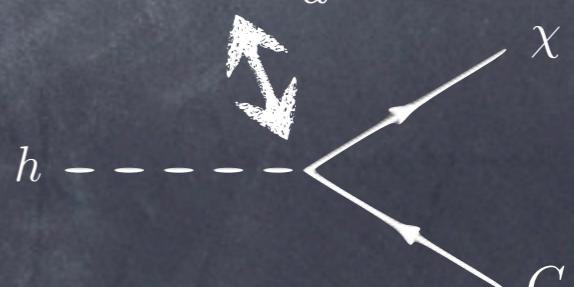
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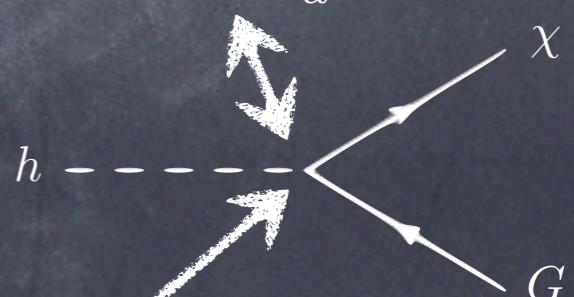
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$$\frac{B_\mu}{f} \int d^2\theta X H_d H_u = B_\mu h_d h_d + \frac{B_\mu}{f} \psi_X \psi_{H_d} h_u + \dots$$

# The Higgs mass

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- Additional quartic interactions in the Higgs potential

$$V_{\text{tree}}^{(h^4)} = \frac{g_2^2 + g_1^2}{8} \left( |h_d|^2 - |h_u|^2 \right)^2 + \frac{g_2^2}{2} |h_d^\dagger h_u|^2 + \left| \frac{m_d^2}{f} |h_d|^2 + \frac{m_u^2}{f} |h_u|^2 - \frac{B_\mu}{f} h_d \cdot h_u \right|^2$$

MSSM

Extra

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MSSM

Extra

- The mass of the lightest CP-even Higgs particle

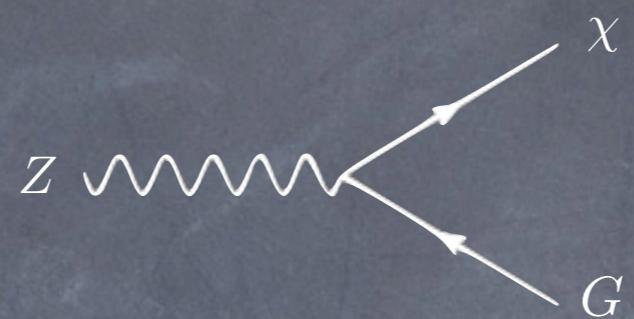
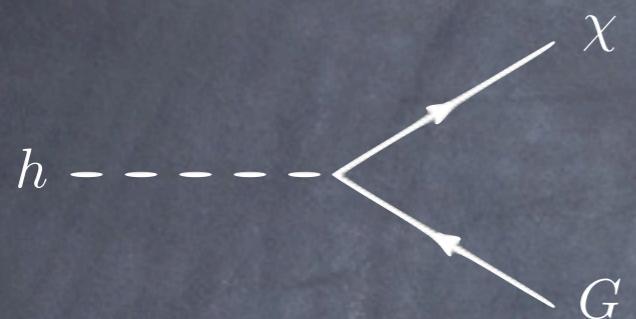
$$m_{h,\text{tree}}^2 = \left[ \frac{(g_1^2 + g_2^2)}{2} \cos^2 2\beta + \left( \frac{2\mu^2}{f} - \frac{B_\mu}{f} \sin 2\beta \right)^2 \right] v^2$$

MSSM

Extra

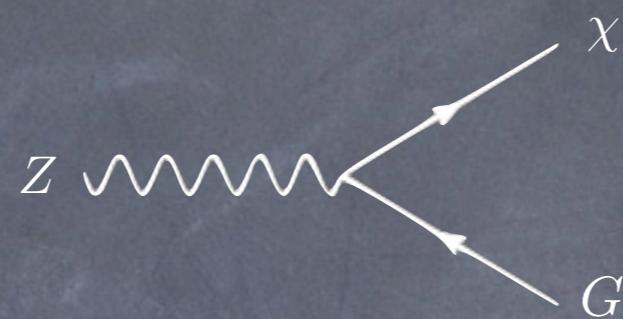
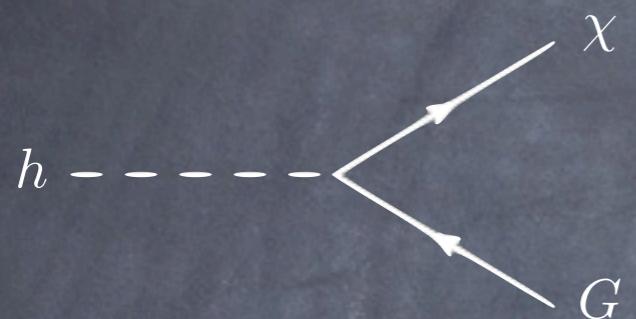
We will focus on the case where the lightest neutralino:

- is the NLSP
- is lighter than the Higgs particle

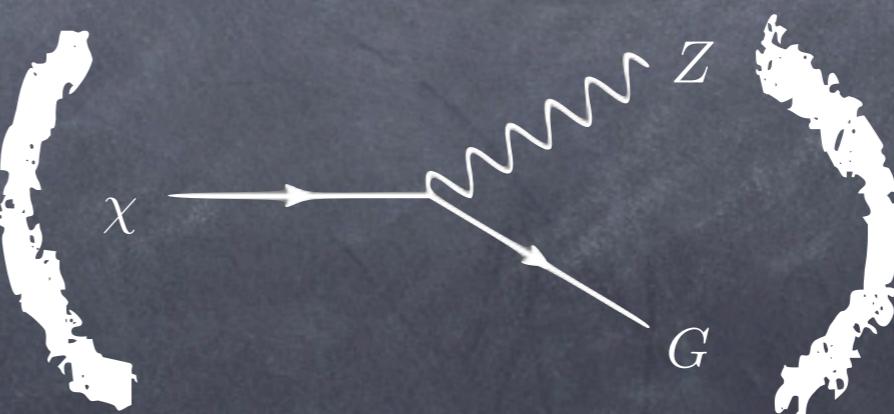
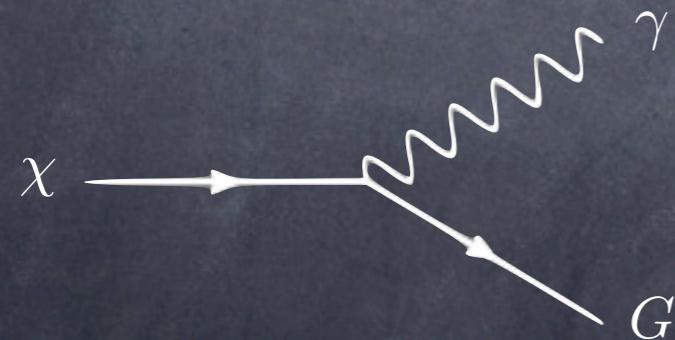


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In this case, the neutralino decays only into a goldstino and a photon (or a  $Z'$ )



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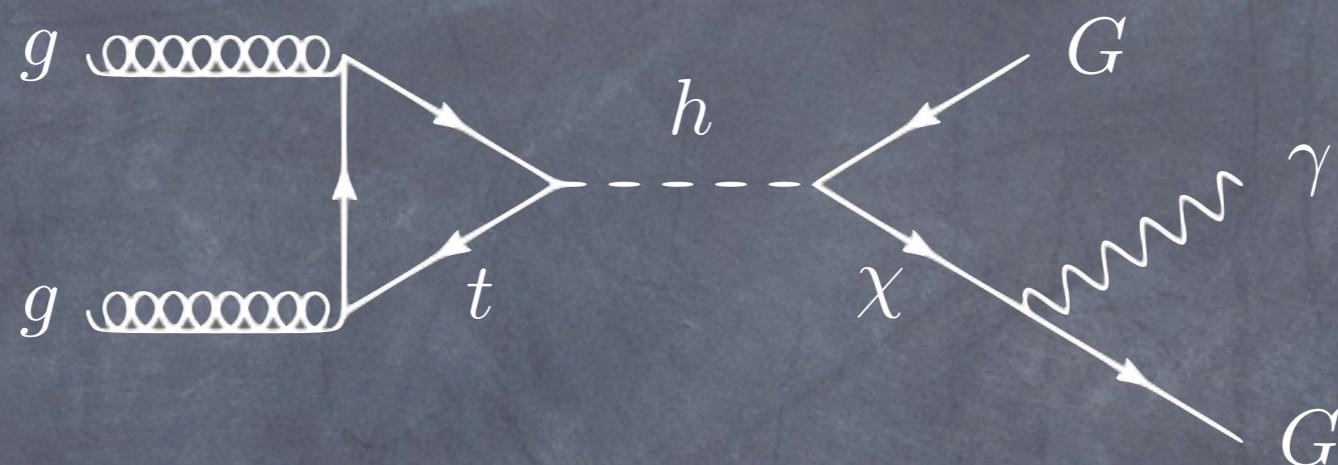
→ Final state: Mono-photon + MET

# The signal: $\gamma + \text{MET}$

The model gives rise to this signal through the following diagrams:

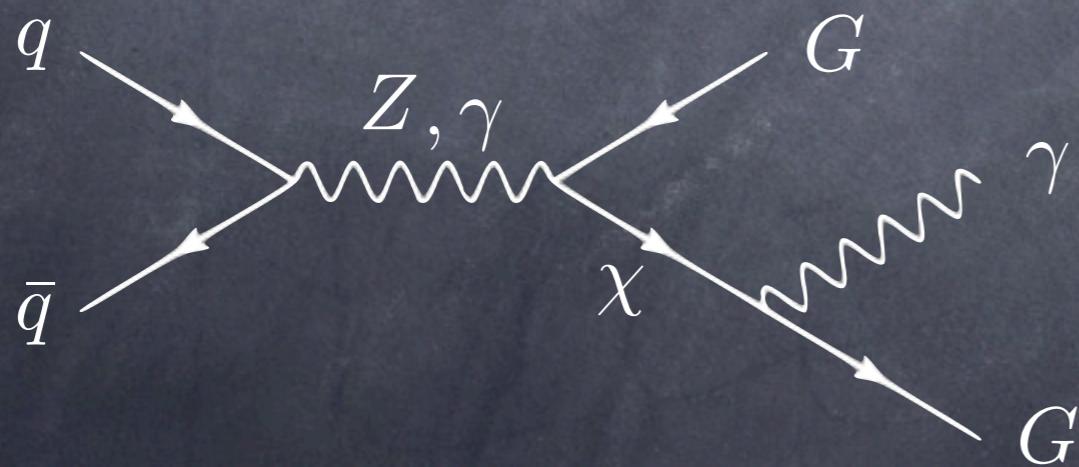
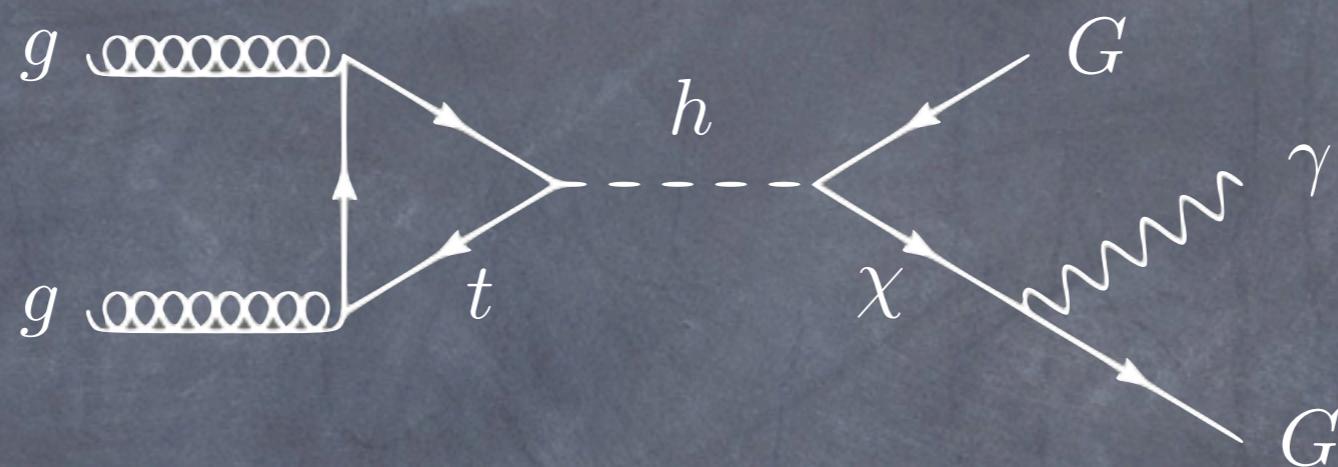
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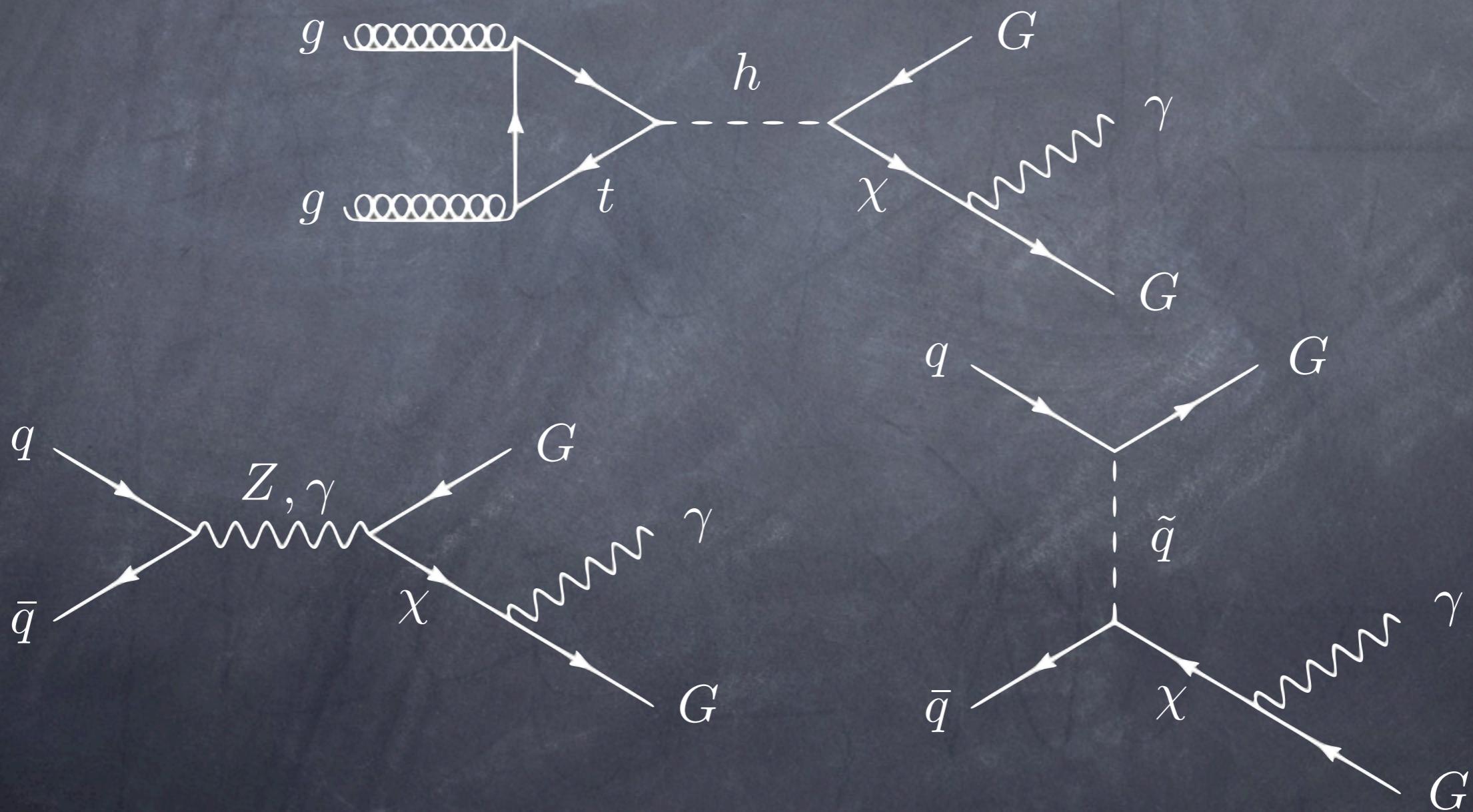
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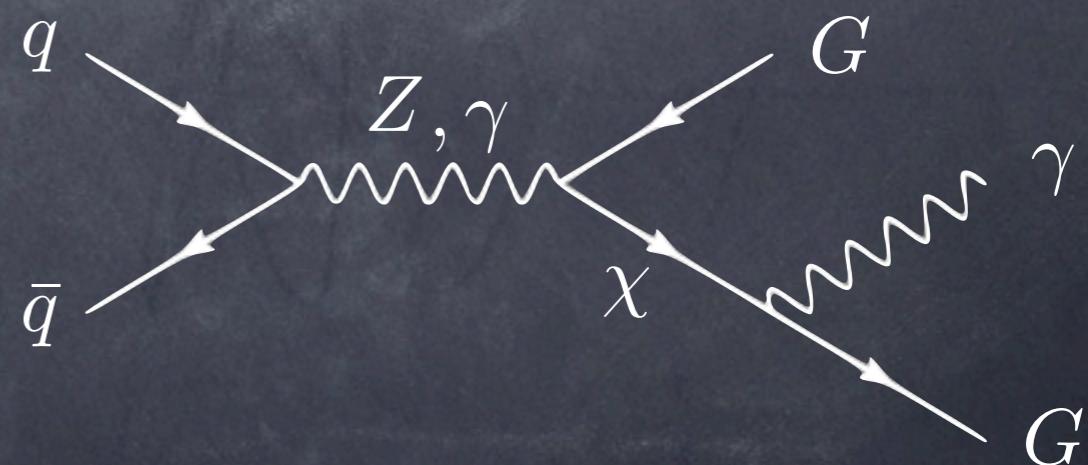
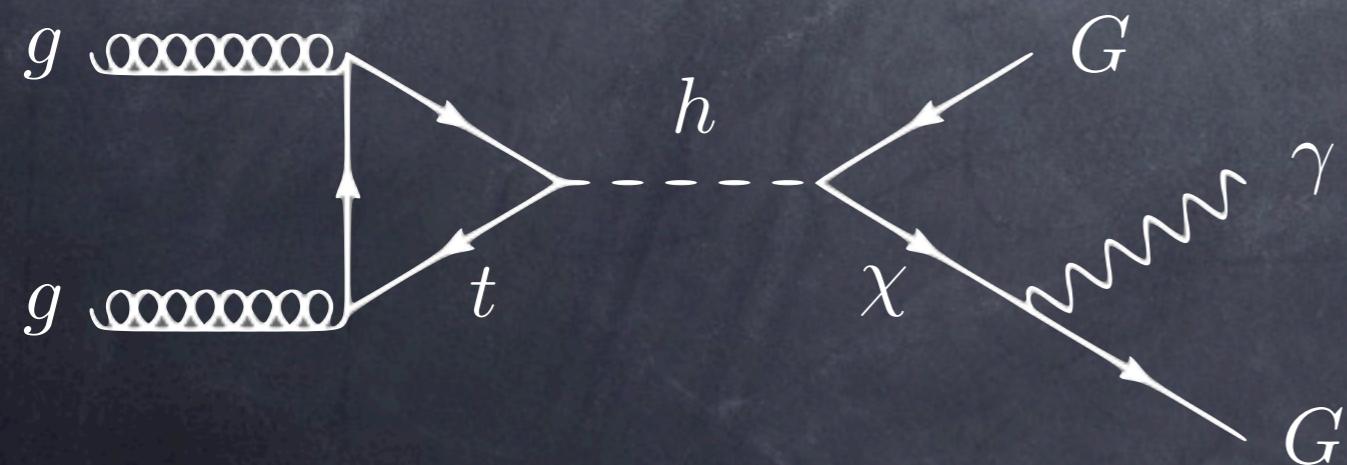
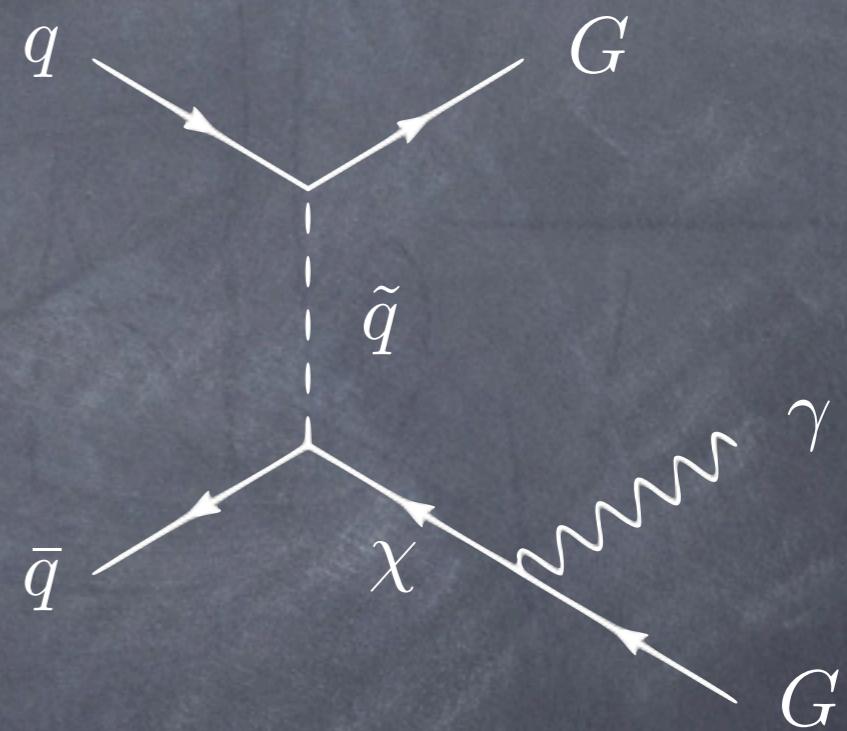
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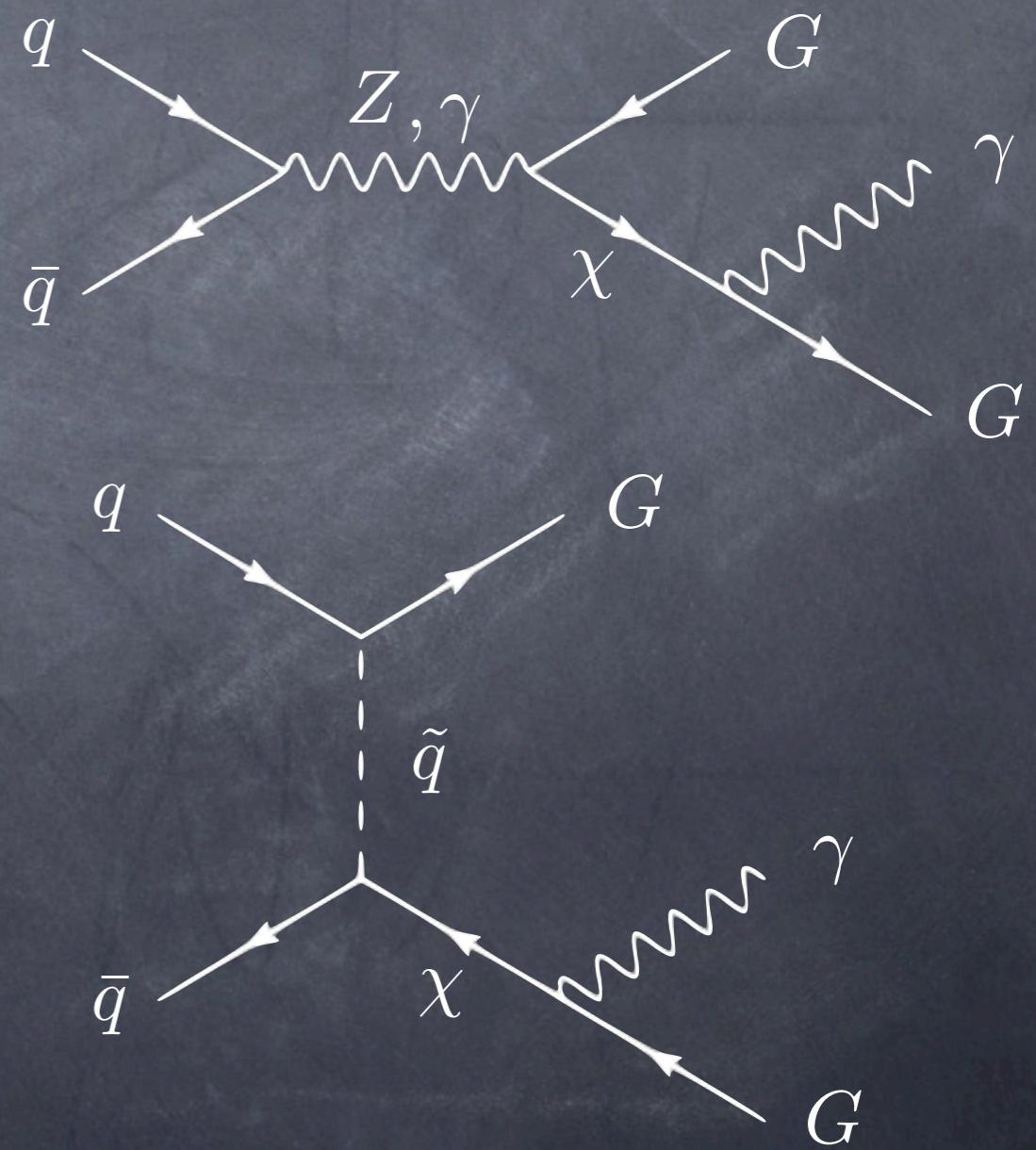
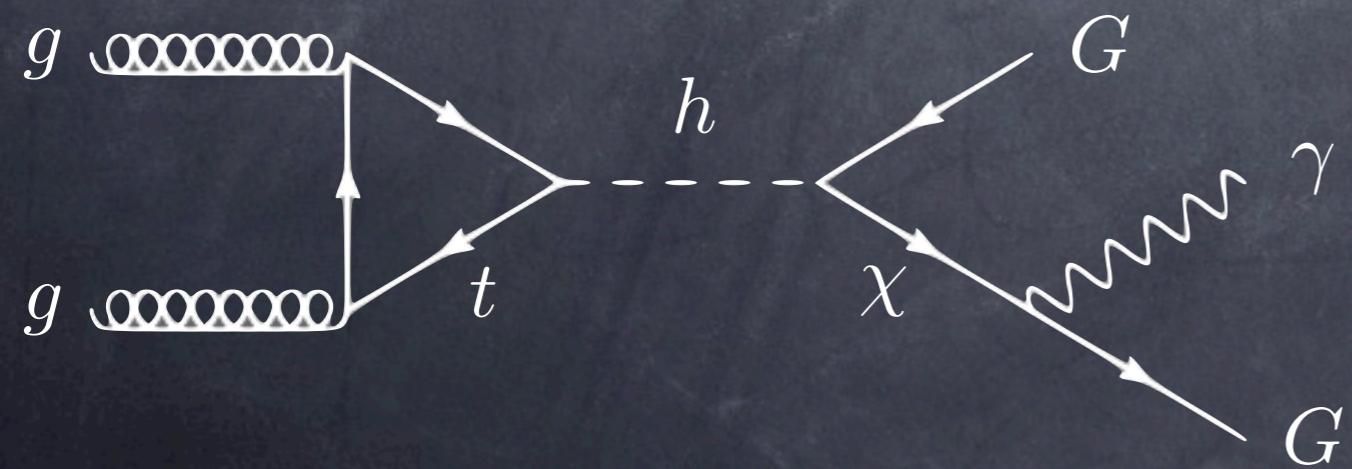
- The non-resonant production was studied in the literature with an effective approach based on integrating out everything but the Goldstino  
Brignole et al.; hep-ph/9711516 and hep-ph/9801329
- It gives a subleading contribution in the low  $p_T^\gamma$  region while it is relevant for high  $p_T^\gamma$  studies



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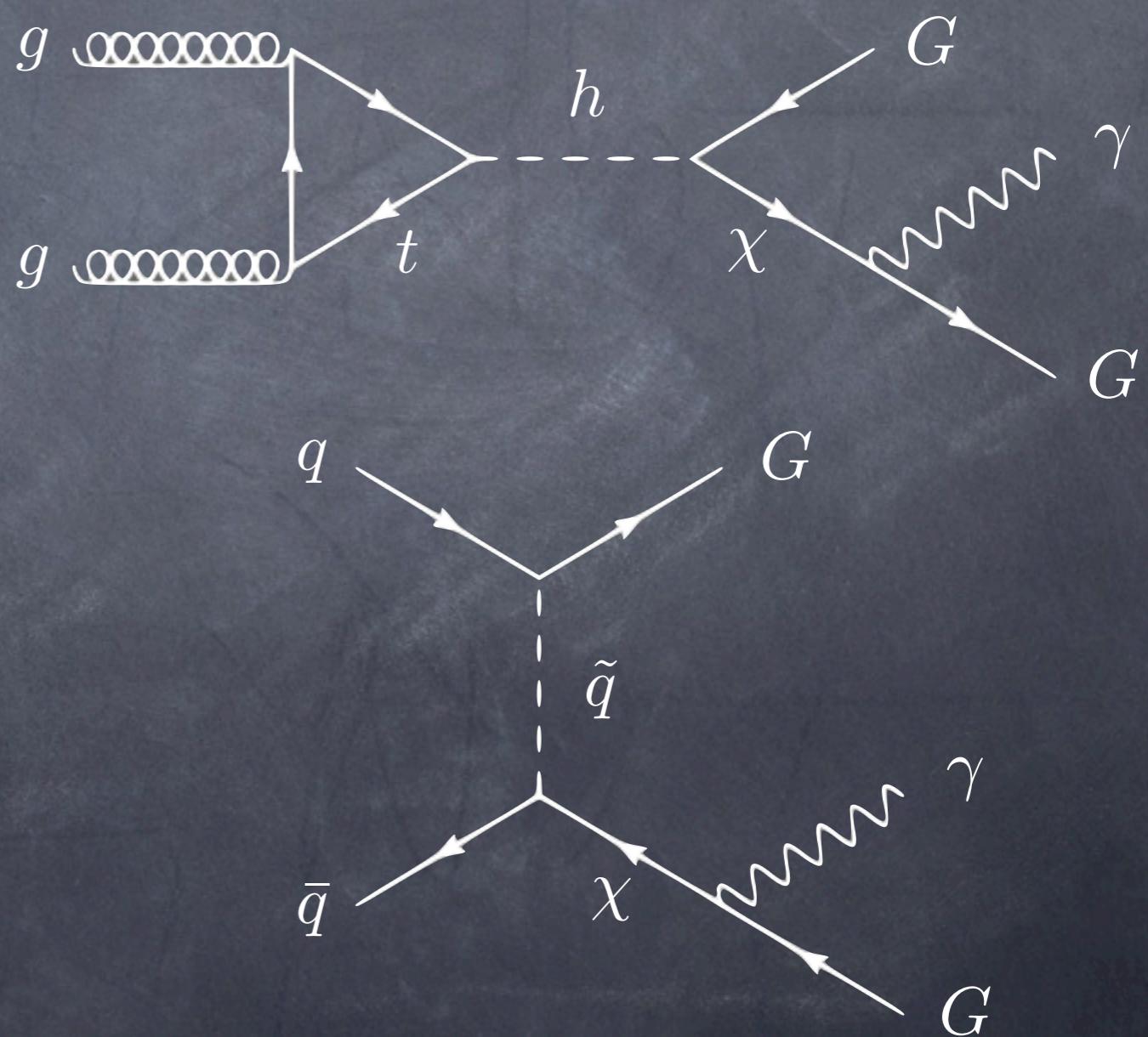
- The photon s-channel contribution is completely negligible while the Z one is relevant only for  $m_\chi \lesssim m_Z$
- It contributes only in the  $p_T^\gamma \lesssim m_Z/2$  region



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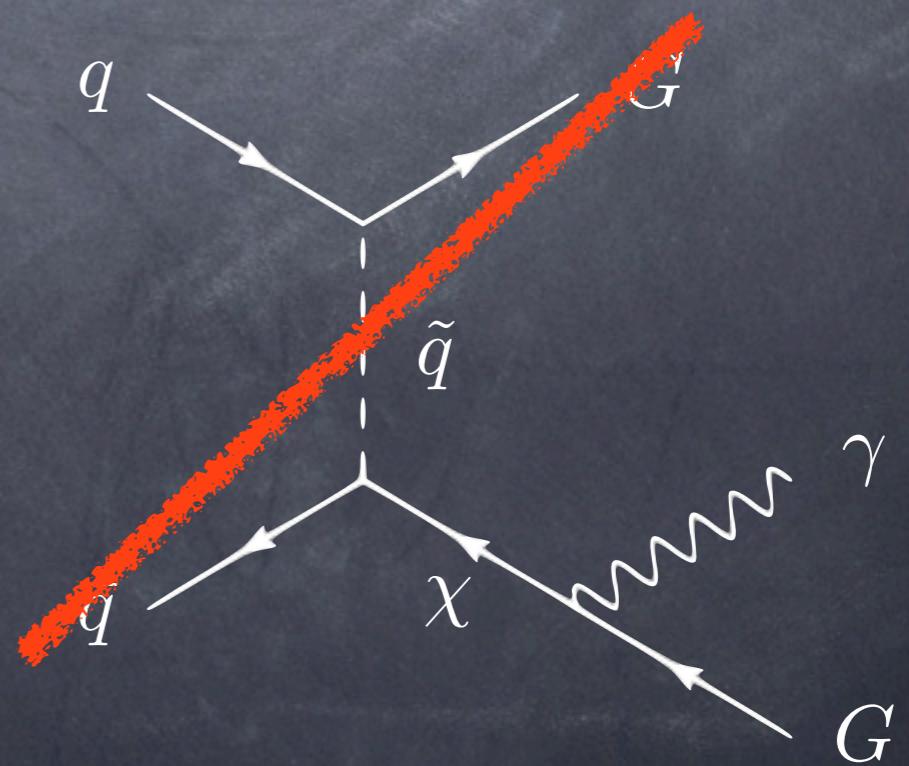
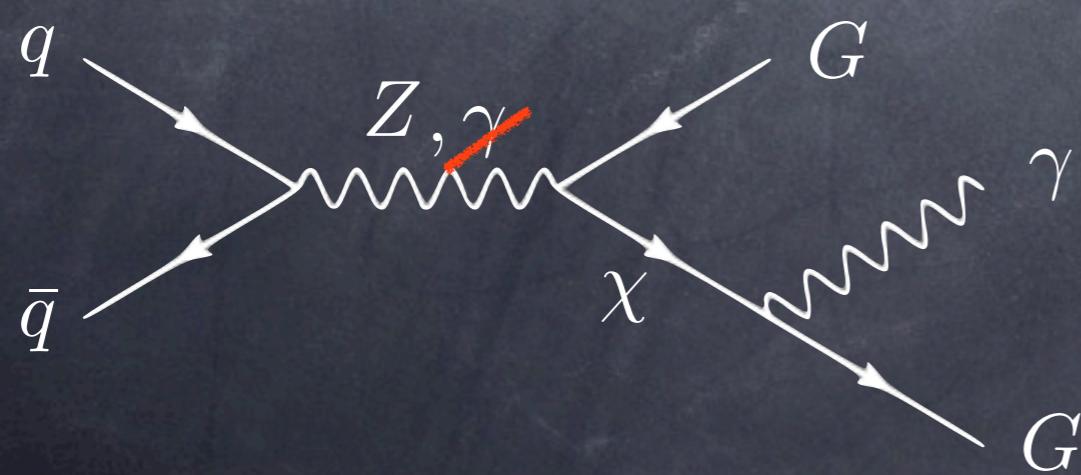
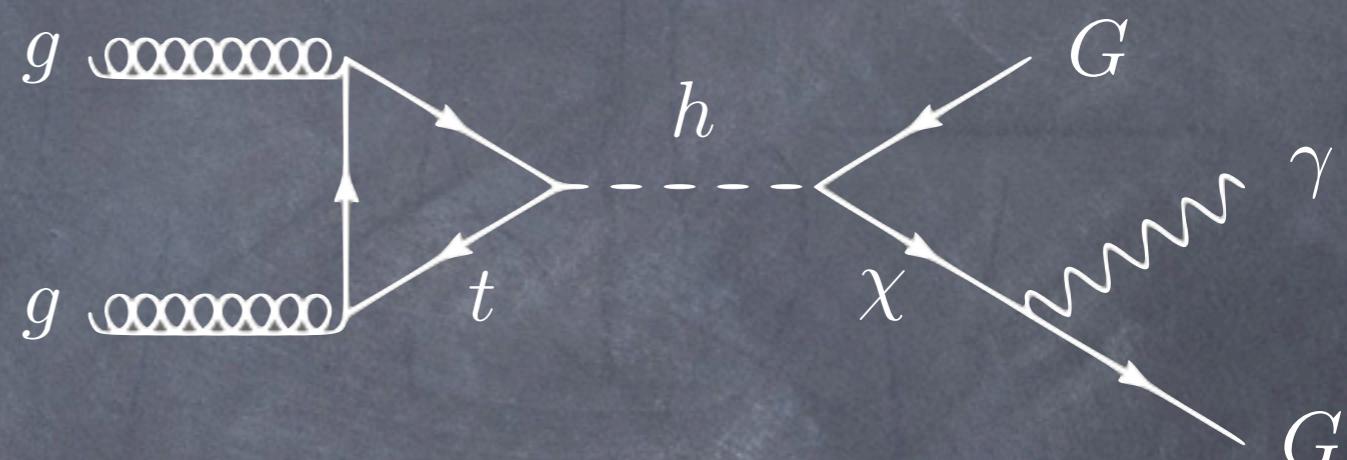
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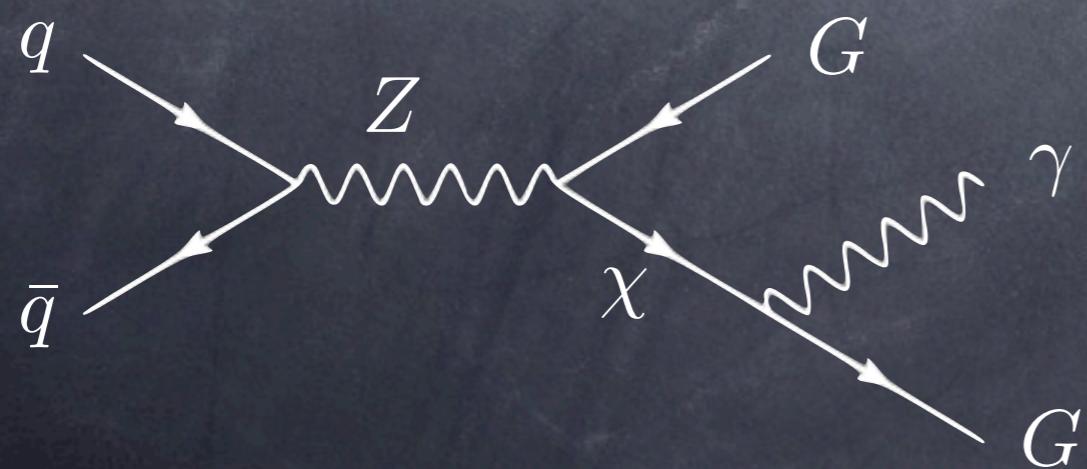
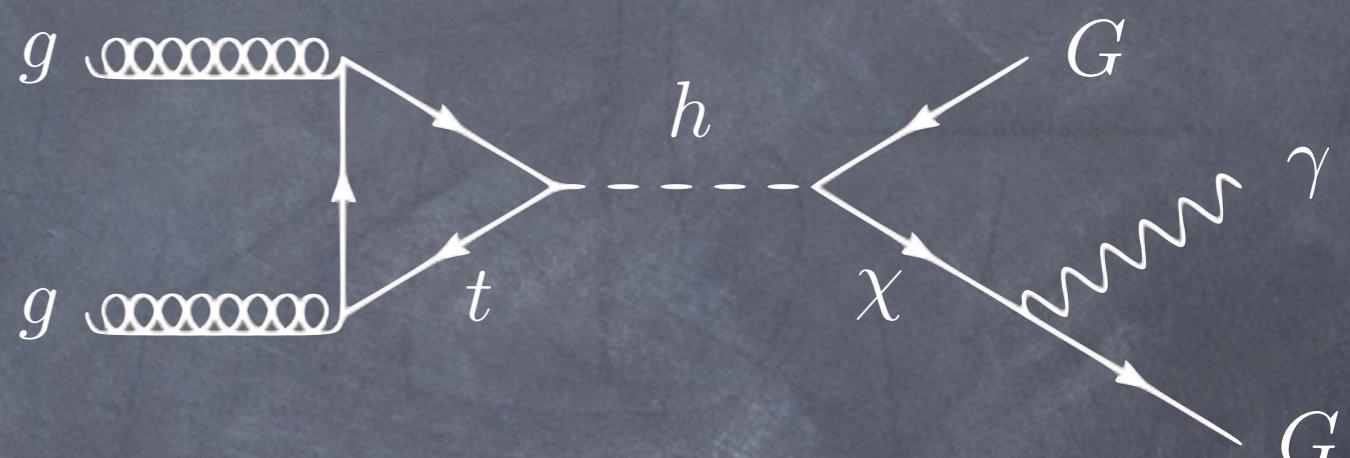
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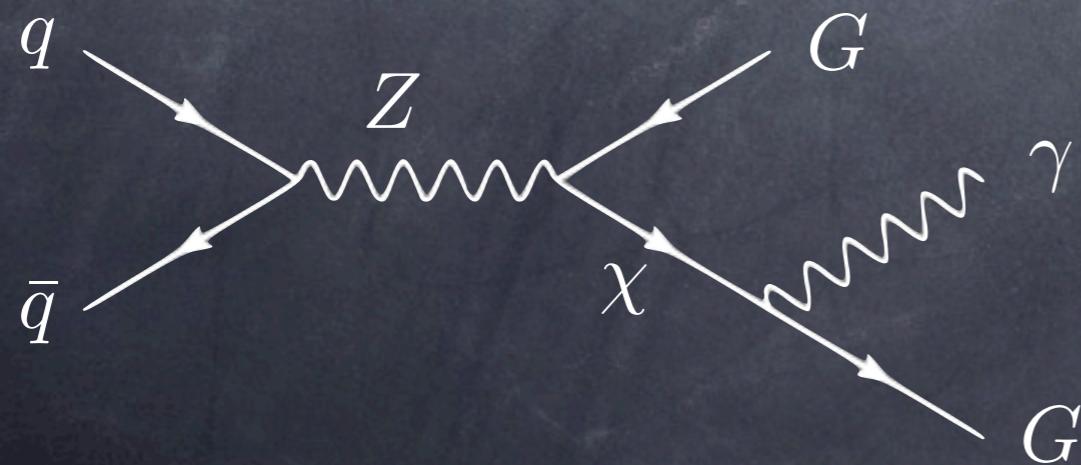
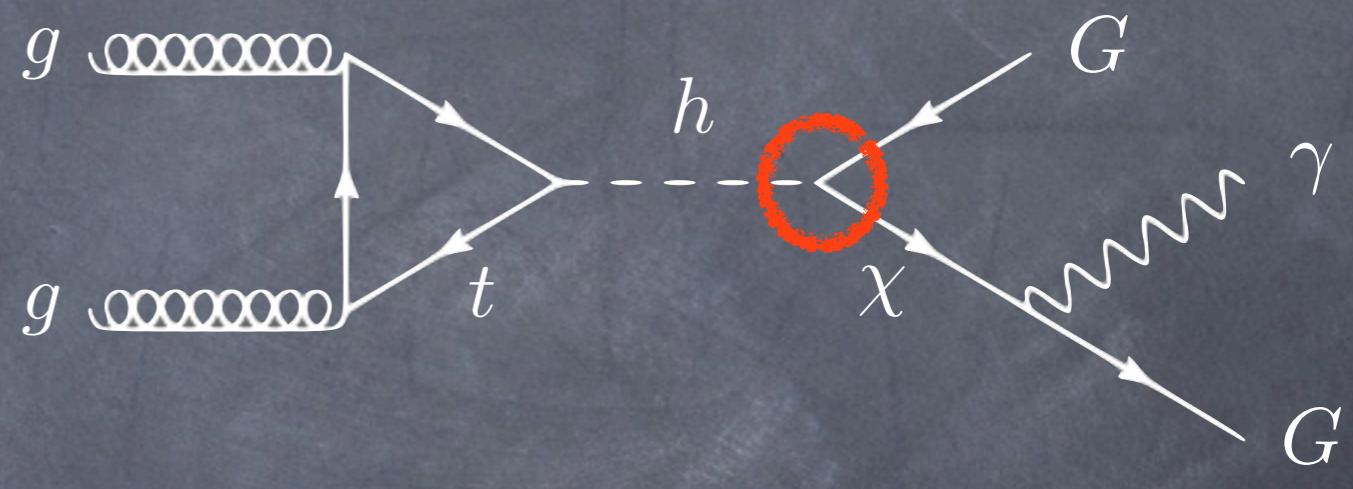
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- Need only the new vertices:  
 $h\chi G$ ,  $\chi\gamma G$ ,  $\chi ZG$



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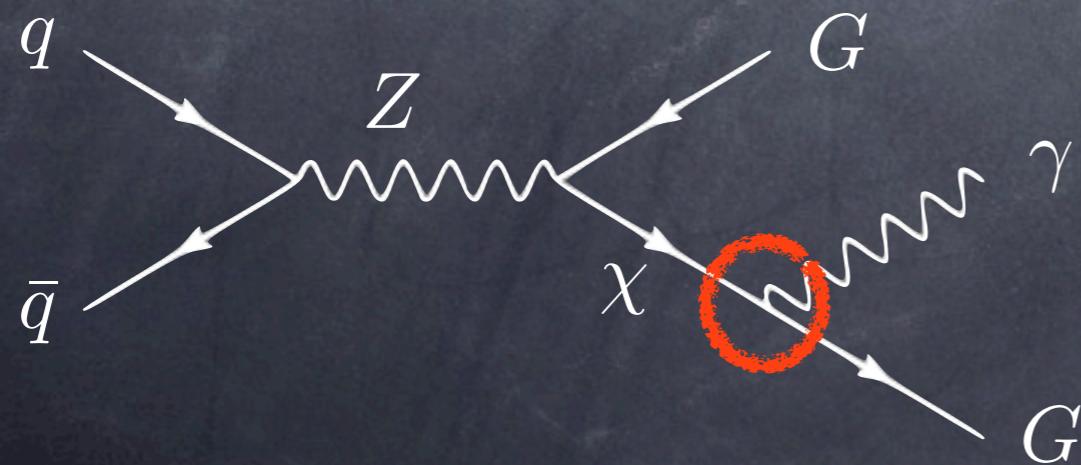
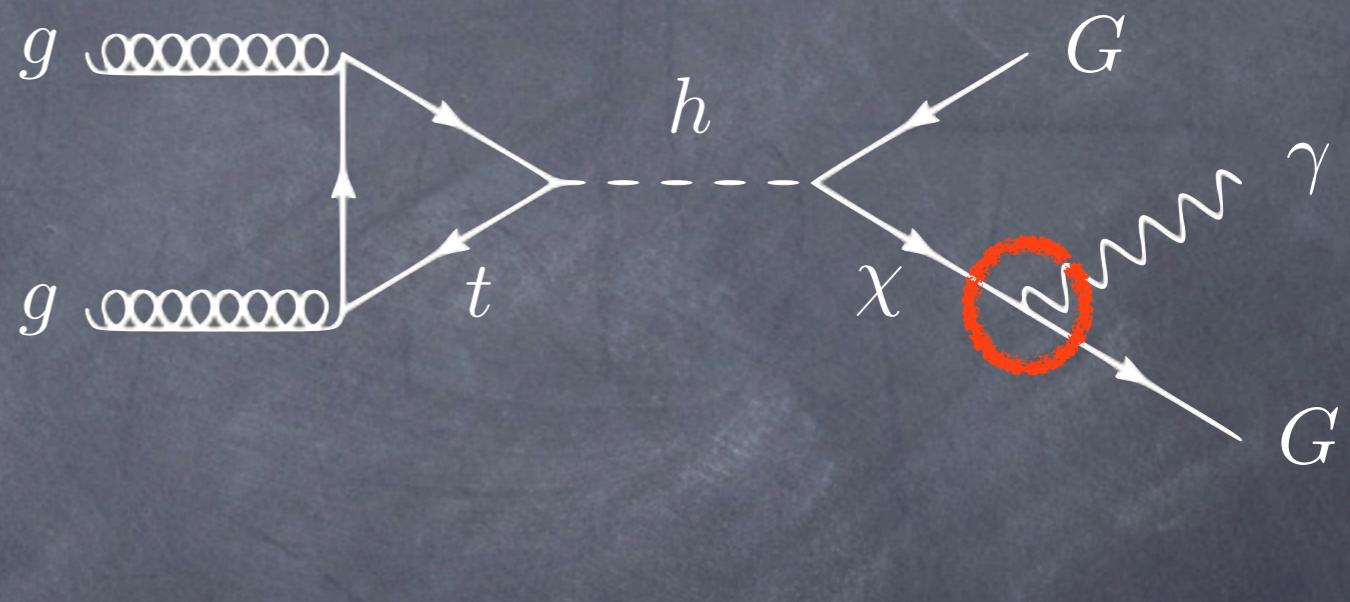
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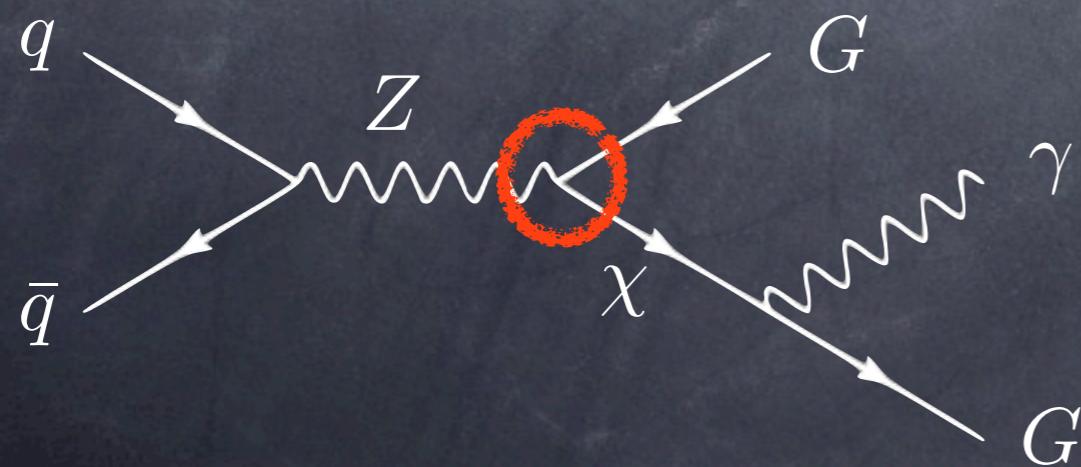
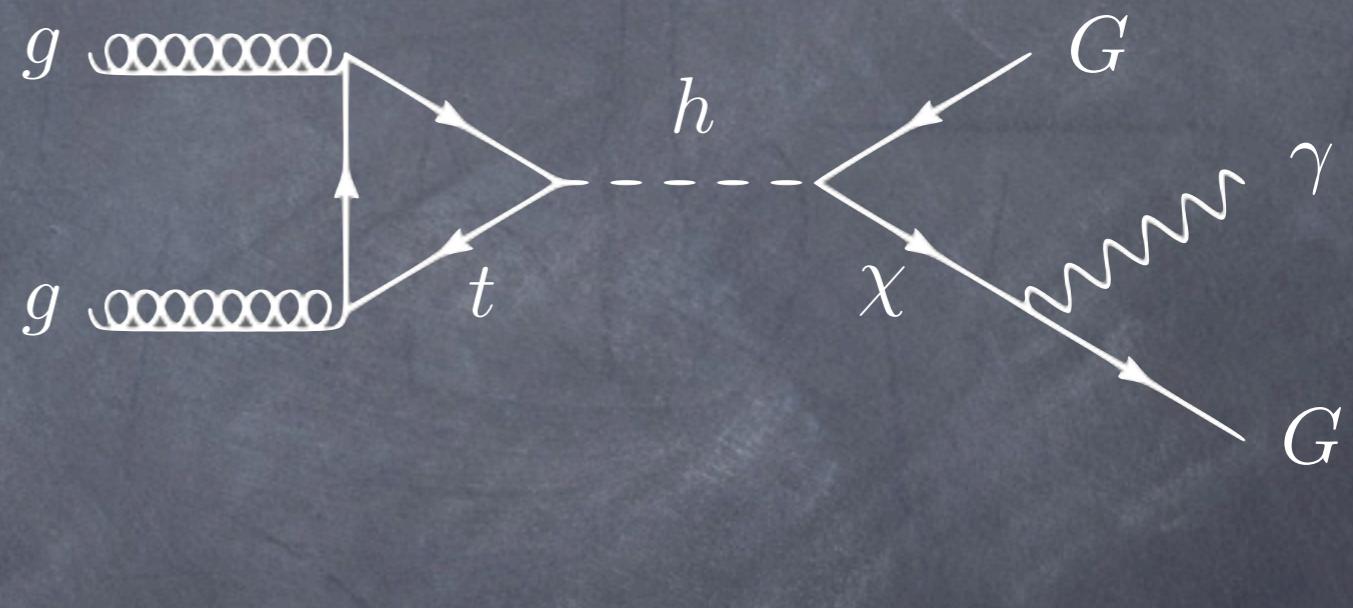
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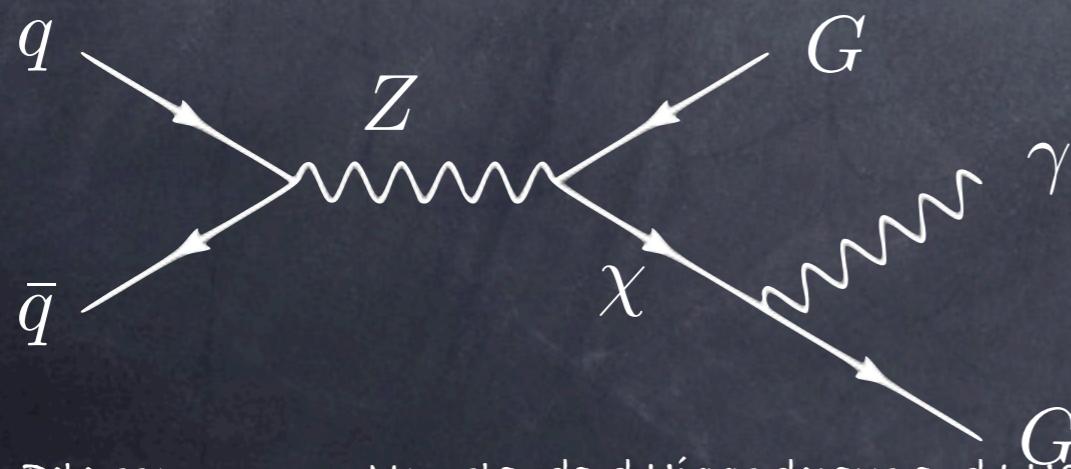
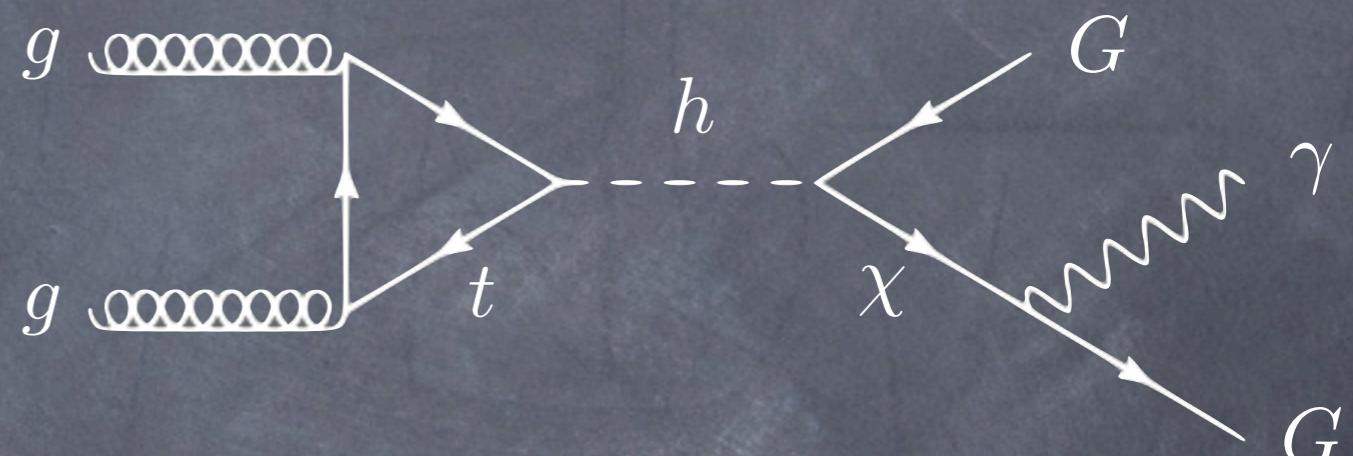
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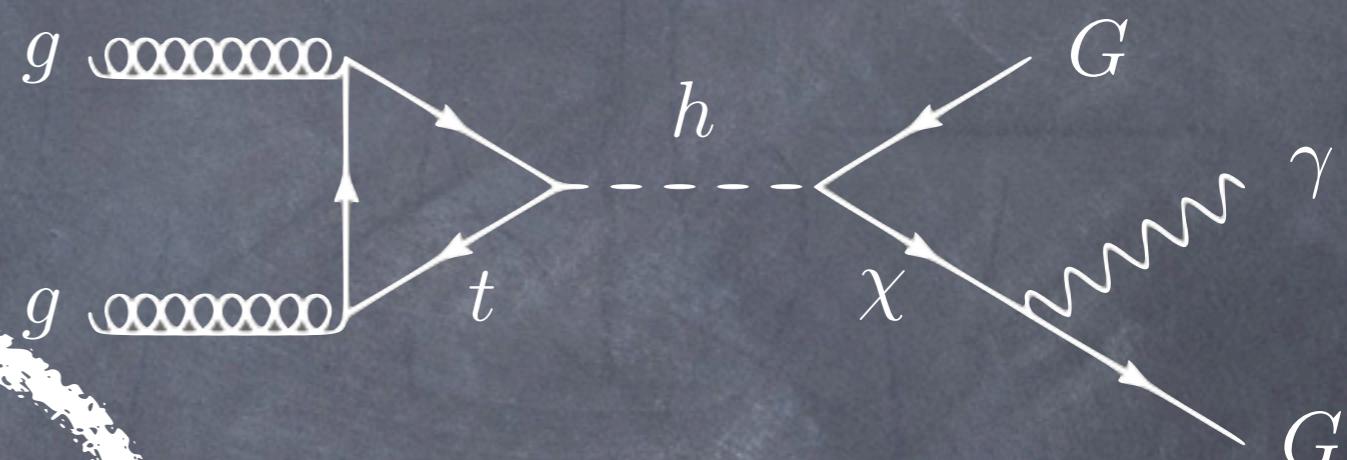
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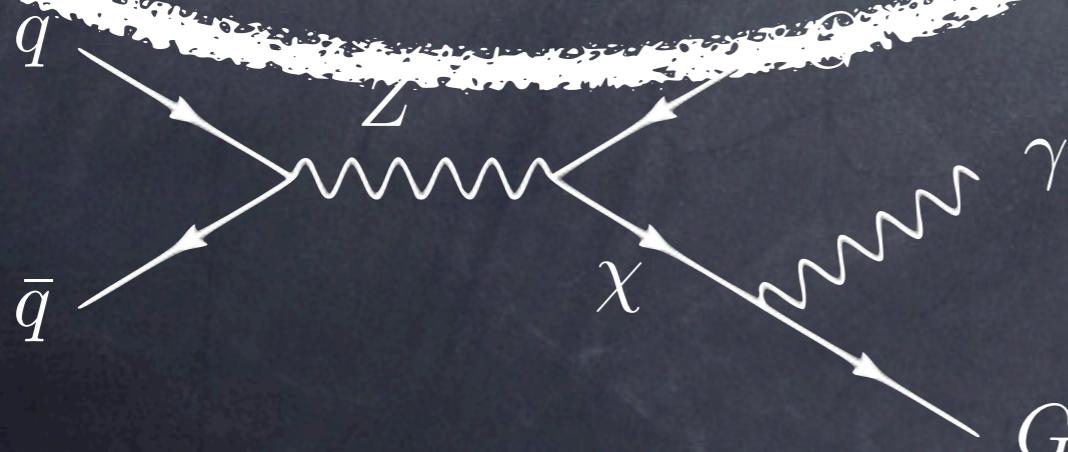
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Simplified model  
for  $\gamma + \text{MET}$



To be continued in the  
following talk...

# Conclusions

- The lack of superpartner observations and the hint for a Higgs boson with a mass around 125 GeV motivate studies beyond the MSSM.
- We discussed a scenario in which SUSY is broken spontaneously at the TeV scale and the MSSM soft terms are promoted to supersymmetric operators.
- This scenario takes into account the dynamics and interactions of the goldstino (and sgoldstino) and modifies the usual MSSM phenomenology.
- For example, a SM-like 125 GeV Higgs can be accommodated without requiring large quantum corrections.
- Characteristic signature: Non-standard Higgs decay with the final state  $\gamma + \text{MET}$ , for  $p_T^\gamma < m_h/2$ .

# Future directions

- Other characteristic decays involving the goldstino or sgoldstino
- UV completion

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Thanks for your attention!