Lifting the Suppression

Electroweak Bremsstrahlung as the Dominant Dark Matter Annihilation Channel

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Outline

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Suppression of dark matter annihilations

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- Types of suppression

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Implications and further study

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- Suppression of dark matter annihilations
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  - Fierz technology
- Lifting the suppression via radiative corrections
  - Previous examples from photon bremsstrahlung
  - Electroweak bremsstrahlung
- Implications and further study
  - Leptophilic models

Varieties of Suppression

$$\chi\chi \to f\bar{f}$$

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In the non-relativistic limit, partial wave expansion gives that the L^{th} partial wave is suppressed by v^{2L}.

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Helicity Suppression

For some fermionic final state currents there arises an additional suppression of m_f/m_χ in the amplitude, leading to a suppression proportional to $(m_f/m_\chi)^2$ in the rate

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${}^3P_0(0^{++})$	Scalar	$\bar{\Psi}\Psi$
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This will introduce a helicity suppression m_f/m_χ in the amplitude[1]

[1] H. Goldberg, *Phys.Rev.Lett.* **50**, 1419, 1983

Fierz Transformations

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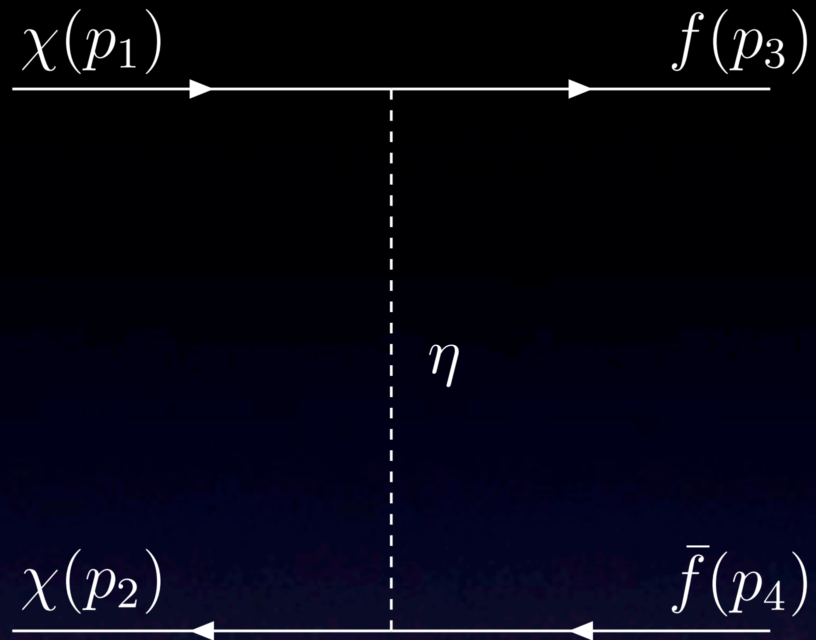

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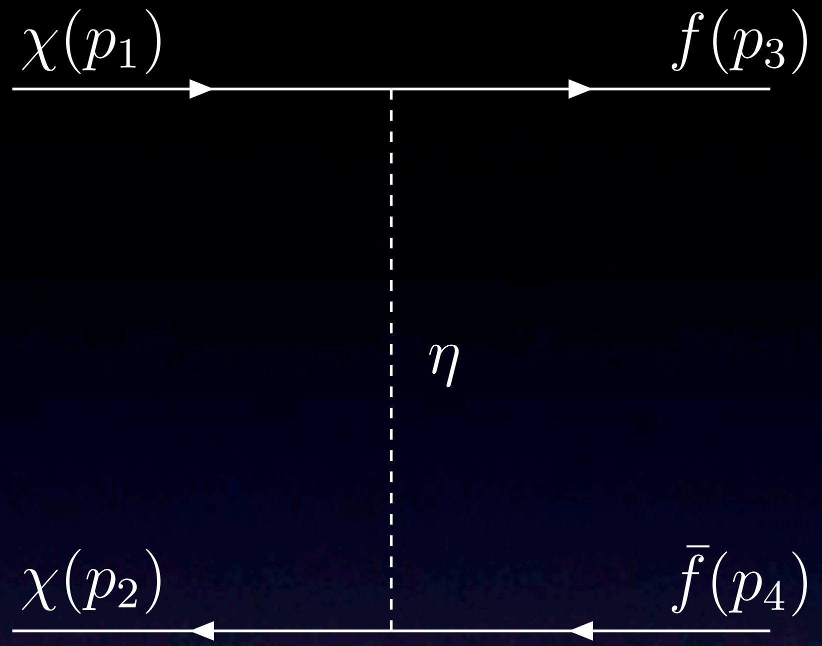

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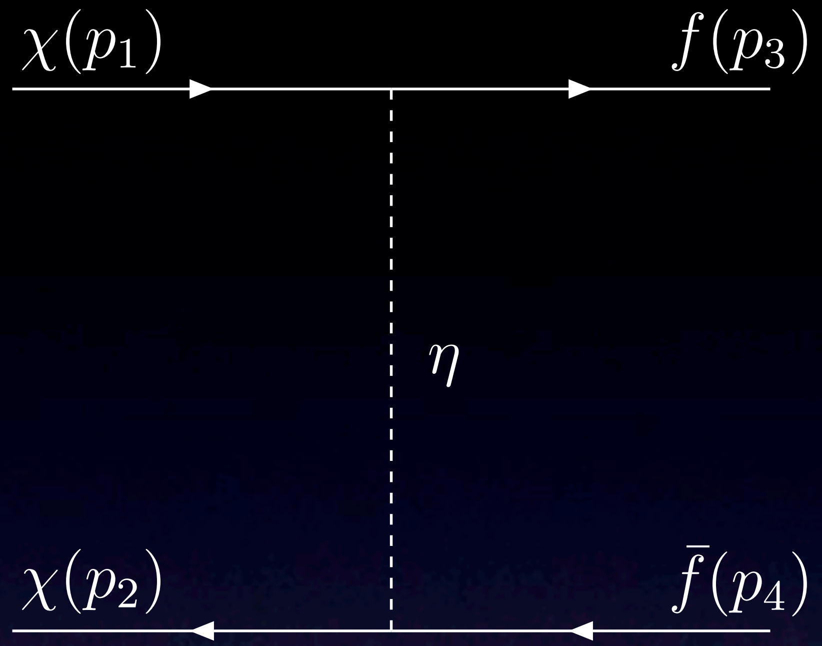

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Using the Fierz transformation

$$(\bar{v}\Gamma_1 v)(\bar{u}\Gamma_2 u) = \frac{1}{4}\Sigma_A \Delta_A (\bar{v}\gamma_A u)(\bar{u}\Gamma_1\gamma_A\Gamma_2 v)$$

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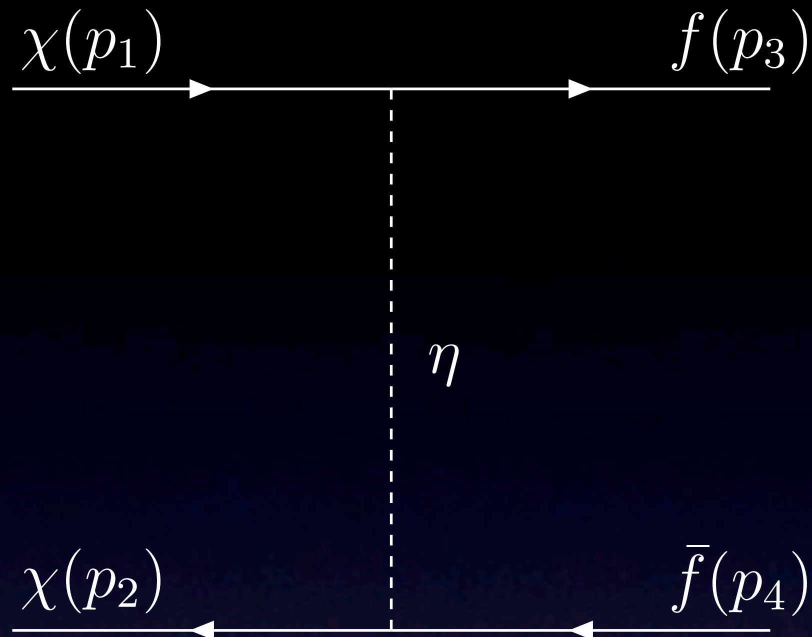

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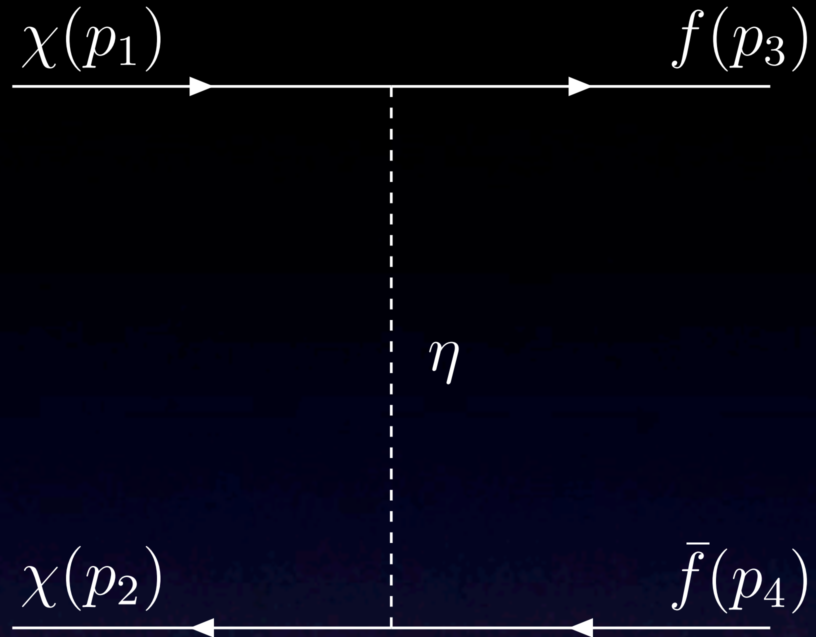

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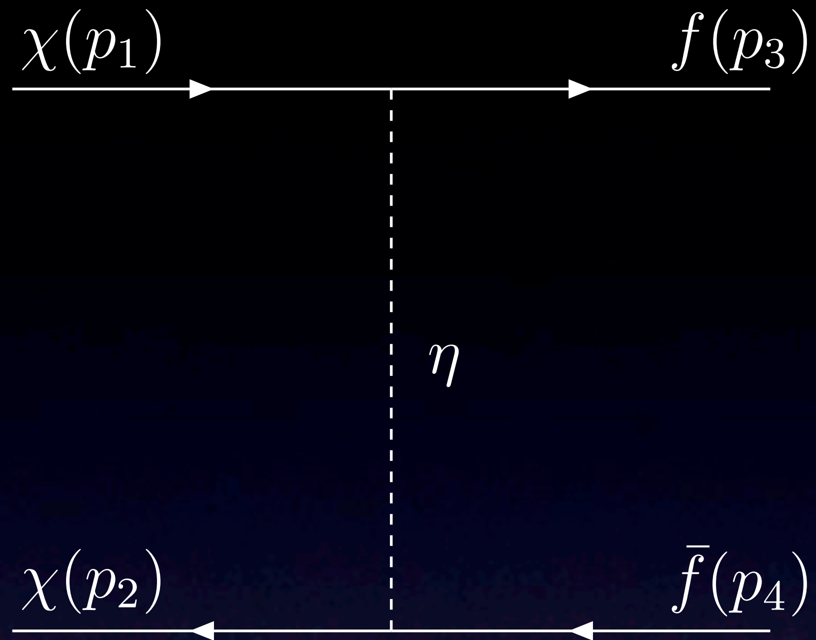

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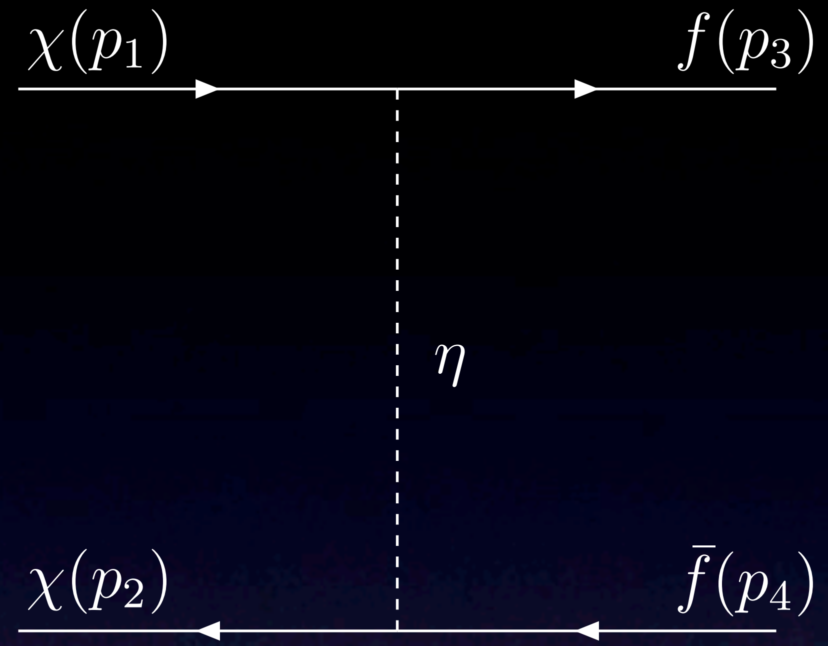

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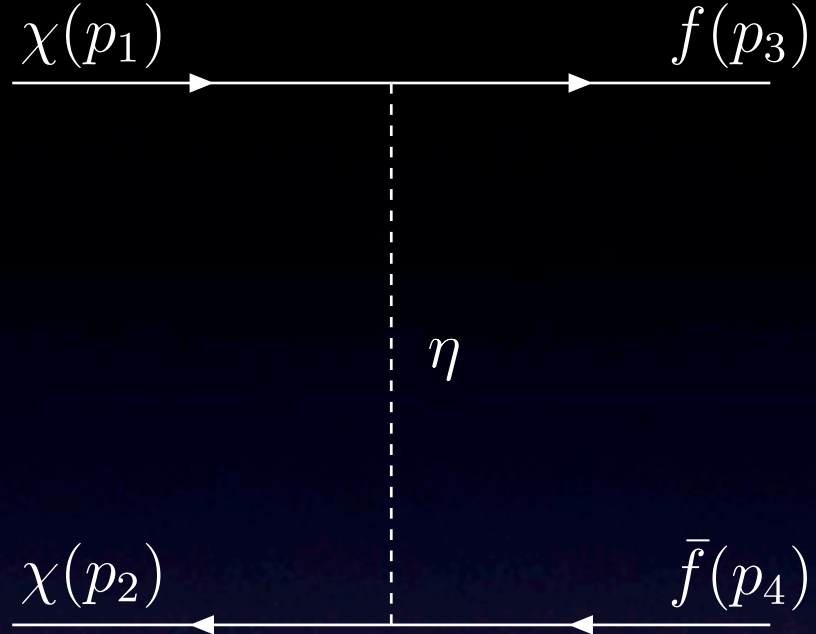

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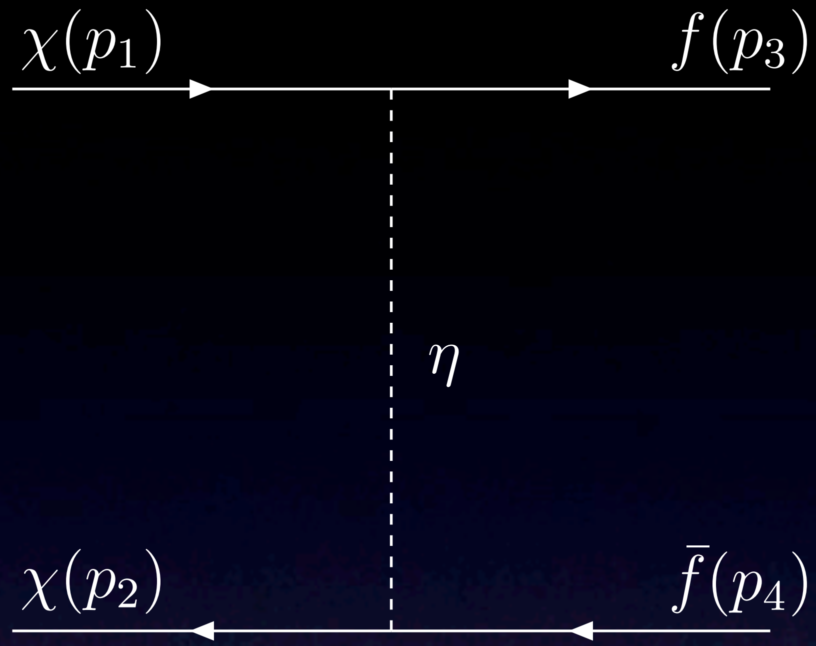

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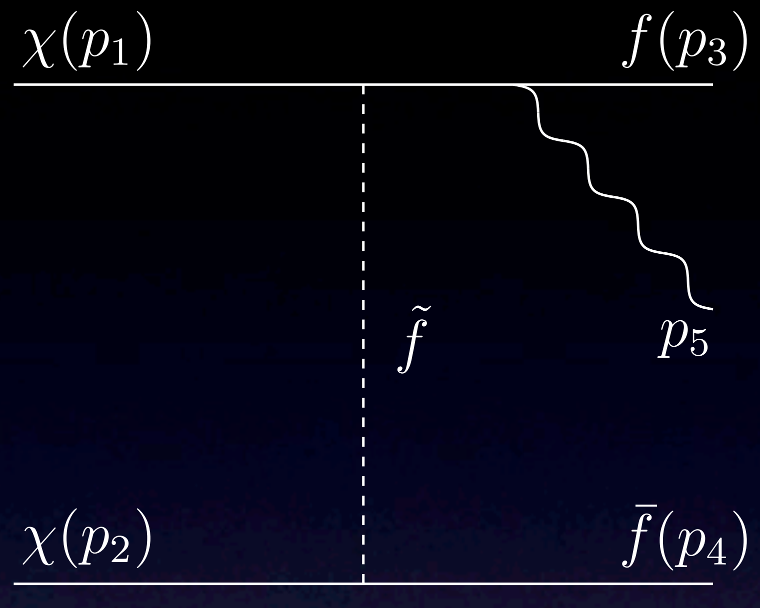

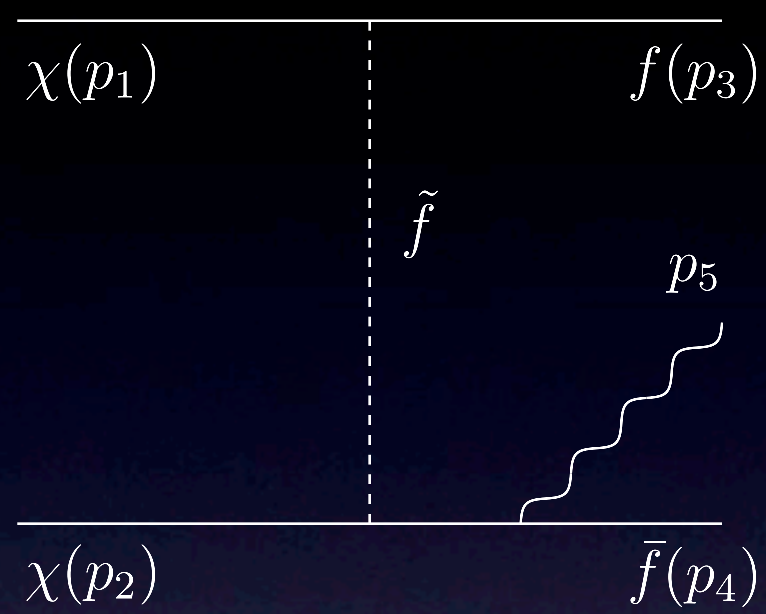

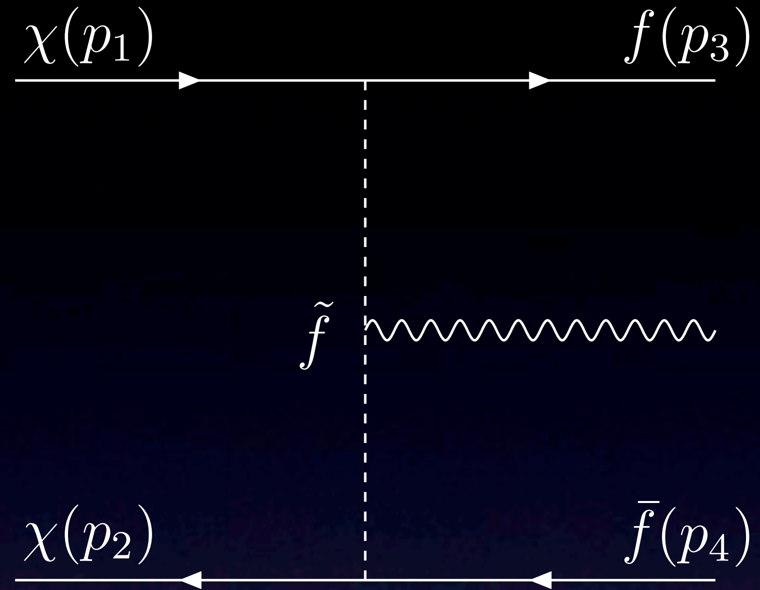

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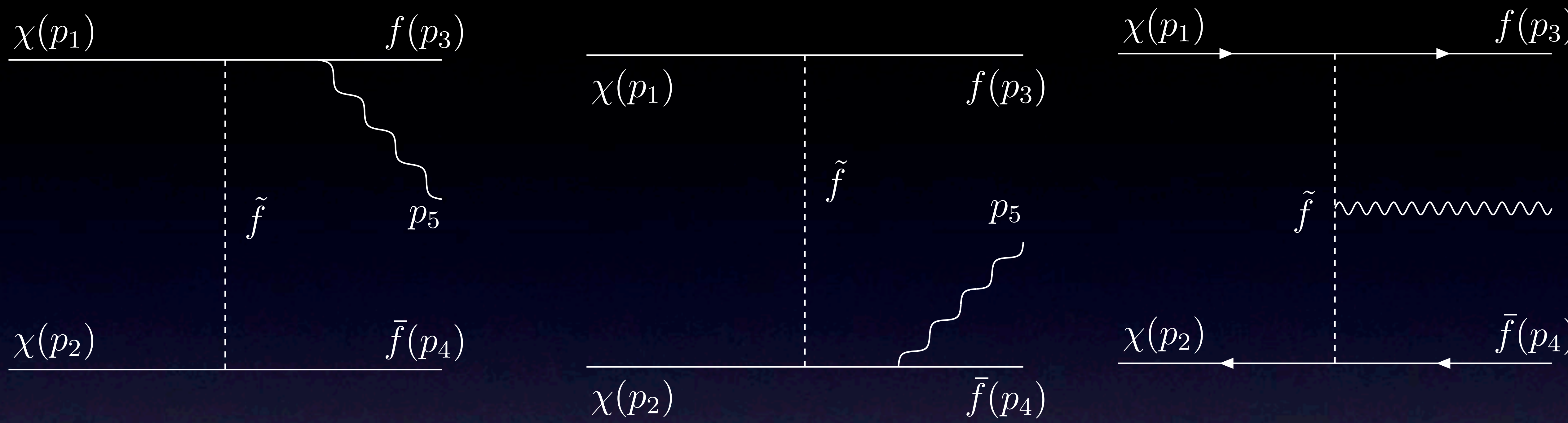

It has been known for some time that radiative corrections to the dark matter annihilation process can be enormous when compared to the lowest order rate[1,2,3,4].

[1] L. Bergstrom, Phys.Lett. B **225**, 372 (1989)

[2] R. Flores, K.A. Olive, and S. Rudaz, Phys.Lett. B **232**, 377 (1989)

[3] T.Bringmann, L. Bergstrom, and J. Edsjo, JHEP **0801** 049 (2008)

[4] V. Barger, Y.Gao, W.-Y.Keung, and D. Marfatia, Phys.Rev.D **80**, 063537 (2009)

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It has been shown that electroweak bremsstrahlung can have a significant effect on processes which dominantly produce final state leptons[1,2].

[1]N.F. Bell, JBD, T.Jacques, and T.J. Weiler, Phys.Rev. D **78** 083540 (2008)

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These studies were done assuming no helicity suppression. We will now investigate these effects in conjuction with the suppressed processes.

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For Majorana dark matter the cross-section in the massless lepton limit is

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We see that the expected velocity suppression arises

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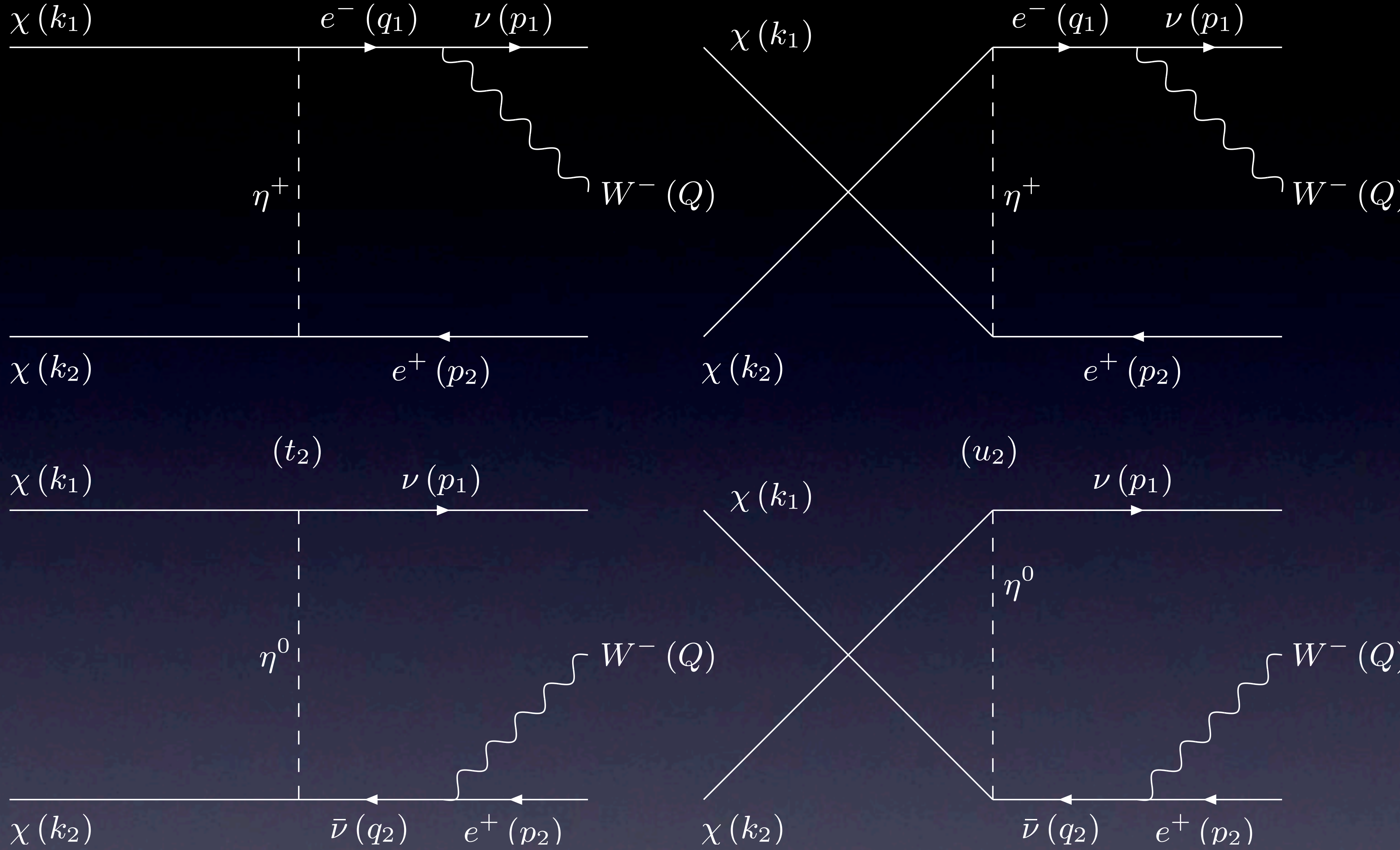
Lifting the Suppression with W or Z emission



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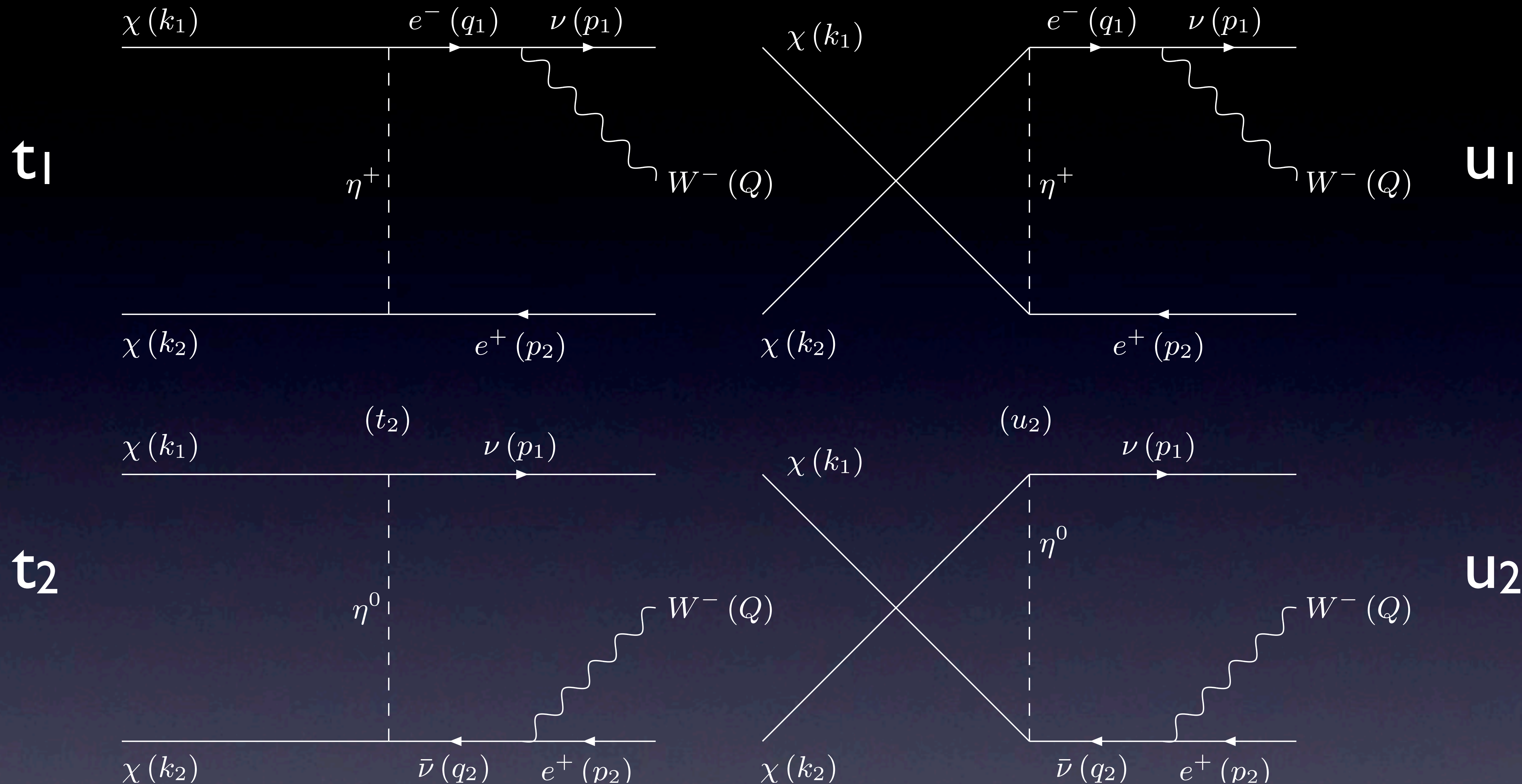

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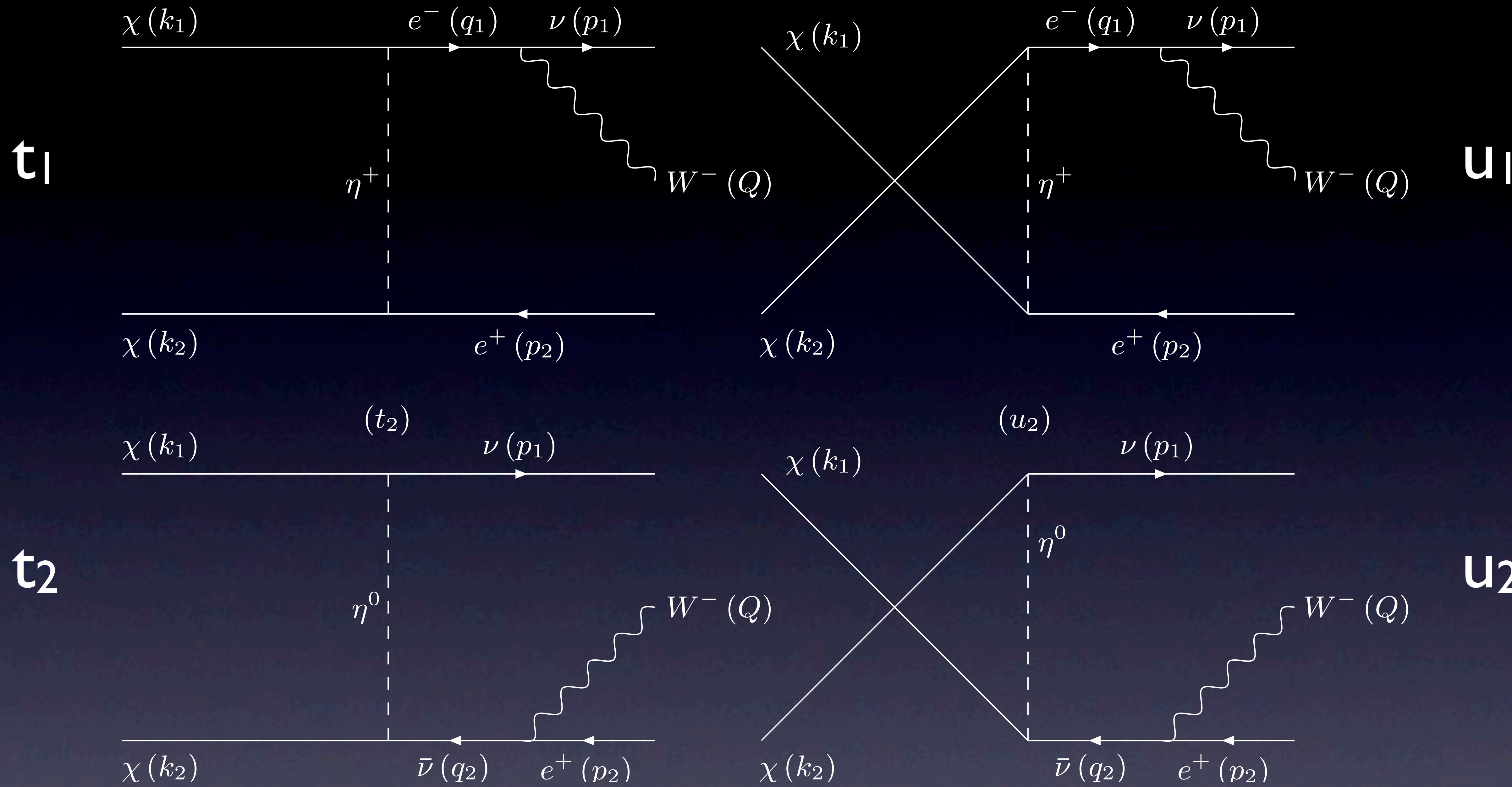

Contributions to $\chi\chi \to e^+\nu W^-$

Applying the Fierz Relations

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$$\mathcal{M}_{t_1} = \frac{igf^2}{\sqrt{2}q_1^2}\frac{1}{t_1-m_\eta^2}\Big(\bar{v}(k_2)P_L v(p_2)\Big)\Big(\bar{u}(p_1)\gamma^\mu P_L \not{q}_1 u(k_1)\Big)\epsilon_\mu^Q$$

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$$= \frac{igf^2}{\sqrt{2}q_1^2}\frac{1}{t_1 - m_\eta^2}\epsilon_\mu^Q \frac{1}{4}\Big[\Big(\bar{v}(k_2)u(k_1)\Big)\Big(\bar{u}(p_1)P_L\gamma^\mu P_L \not{q}_1 v(p_2)\Big)$$ S $\longrightarrow 0$

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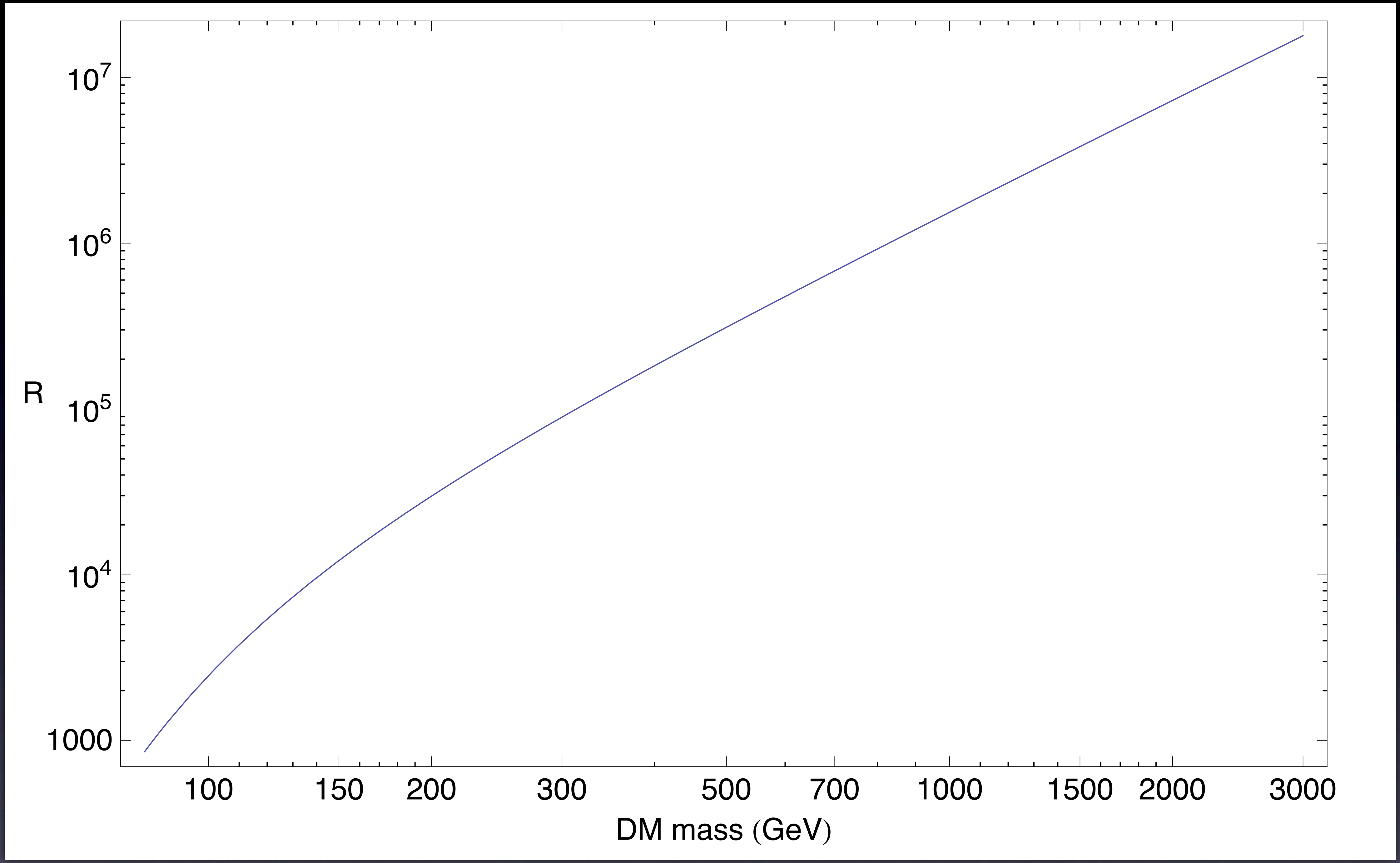
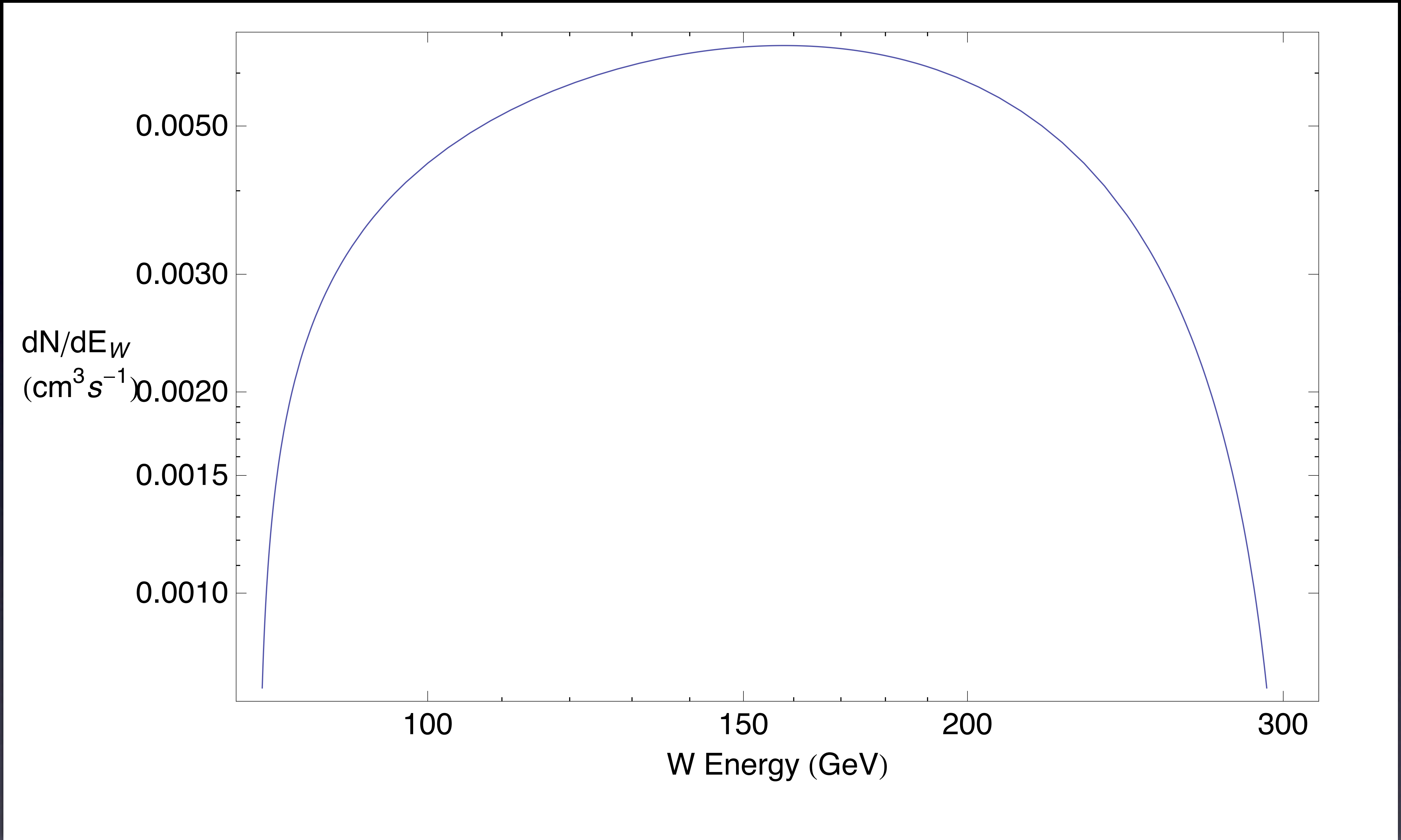
Results



$\sigma v(\chi\chi \to e^+ \nu W^-)/\sigma v(\chi\chi \to e^+ e^-)$ vs. m_χ (GeV) $m_\eta = 10^{10}$ GeV

Spectra



$M_\chi = 300 \text{ GeV}, \; M_\eta = 10^{10} \text{ GeV}$

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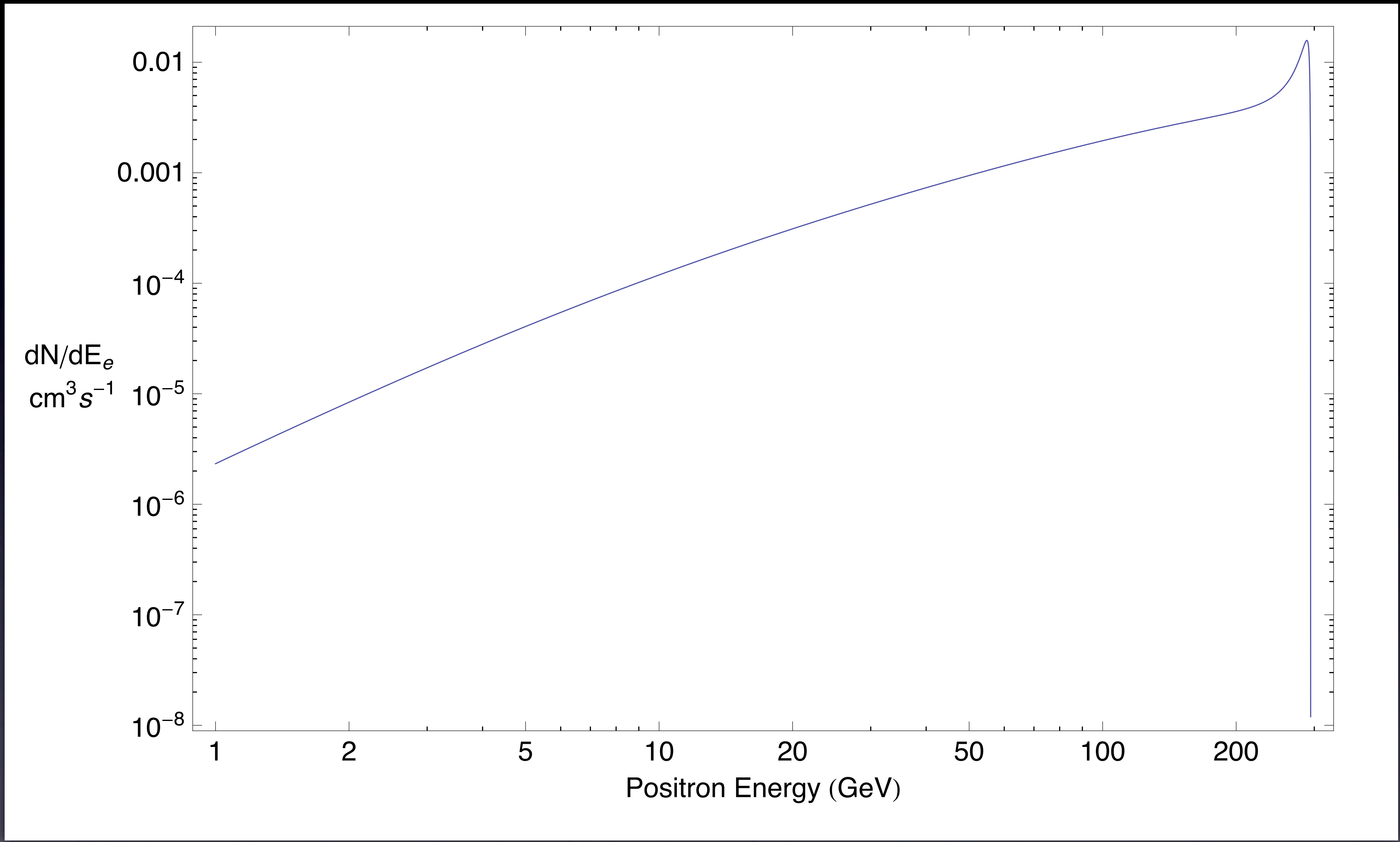

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We have recapitulated under what circumstances these suppressions may arise and how they may be circumvented

We have demonstrated in an example model that electroweak bremsstrahlung may have dramatic effects on suppressed processes leading to possibly strong constraints on various models