One Loop Corrections to Spin-Independent Blind Spot

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Outline

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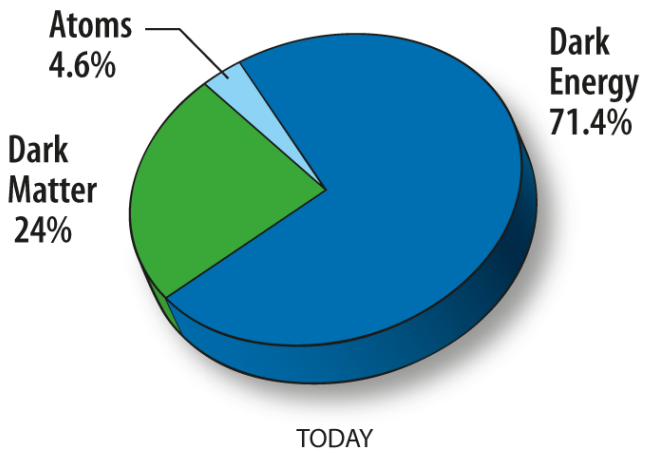
- Singlet-doublet dark matter
- SI blind spot
- One-loop corrections

Introduction

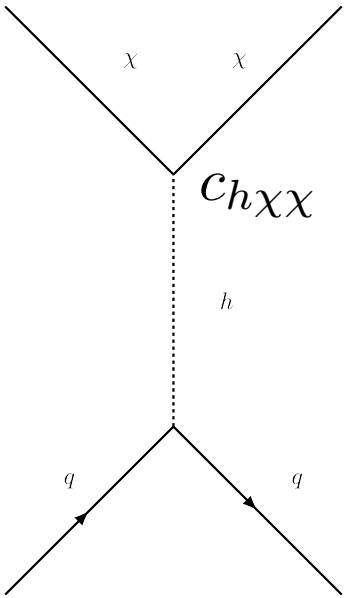


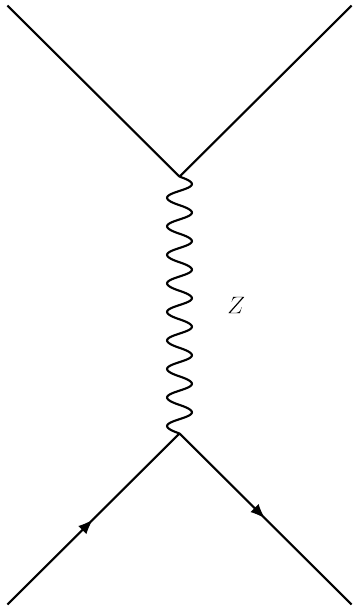
Assumptions about dark matter production

- dark matter is produced from thermal bath.

- The observed relic density is determined by the freeze-out and expansion of the Universe

Direct detection





The spin-independent cross section of nucleon is proportional to $c^2_{h\chi\chi}$

$$\sigma^N_{SI} \approx 2 \times 10^{-42} cm^2 C^2_{h\chi\chi}$$

SI blind spot when $c_{h\chi\chi}$ vanishes

Such scenarios have been studied in SUSY at tree level.

Loop corrections become dominant in such region.

arXiv: 1211.4873 C. cheung, L. Hall, D. Pinner
arXiv: 1404.0392 P. Huang, C. Wagner
arXiv: 1612.0238 T. Han, F. Kling, S. Su, Y. Wu
arXiv: 1603.0738 S. Banerjee, S. Matsumoto, K. Mukaida, Y. Tsai

Singlet-doublet model

The SM is supplemented by a Majorana fermion singlet χ_s

and two fermion doublets $\chi_{D1} = \begin{pmatrix} \chi_1^+ \\ \chi_1^0 \end{pmatrix}$ $\chi_{D2} = \begin{pmatrix} \chi_2^0 \\ \chi_2^- \end{pmatrix}$

$$L_{SD} = L_{kin} - [\frac{1}{2} M_S \chi_s \chi_s + M_D \chi_{D1} \cdot \chi_{D2} - y_1 \chi_s \chi_{D1} \cdot \tilde{H} - y_2 \chi_s \chi_{D2} \cdot H + h.c.]$$

Mass matrix in the basis $\{\chi_s, \chi_1^0, -\chi_2^0\}$

$$M_N = \begin{pmatrix} M_S & \frac{y \sin\beta v}{\sqrt{2}} & \frac{y \cos\beta v}{\sqrt{2}} \\ \frac{y \sin\beta v}{\sqrt{2}} & 0 & M_D \\ \frac{y \cos\beta v}{\sqrt{2}} & M_D & 0 \end{pmatrix}$$

M_S and y are positive $\beta \in (0, \frac{\pi}{2})$ M_D can be positive or negative

Spin-independent blind spot

The mass of lightest neutral particle is M1

$$Det[M_N - M_1] = 0 \longrightarrow g^0_{h\chi_1\chi_1} = \frac{1}{2}\frac{\partial M_1(v)}{\partial v}$$

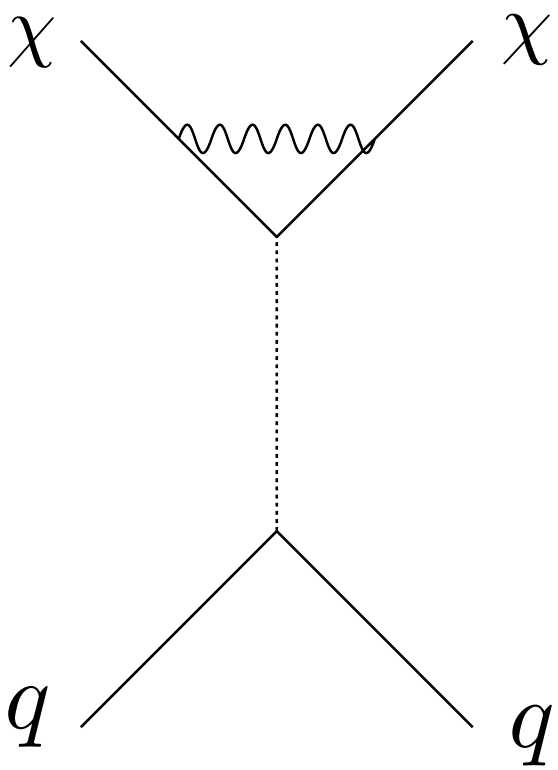
$$= \frac{y^2 v[M_D \sin(2\beta) + M_1]}{6M_1^2 - 4M_1 M_S - 2\eta^2 M_D^2 - y^2 v^2}$$

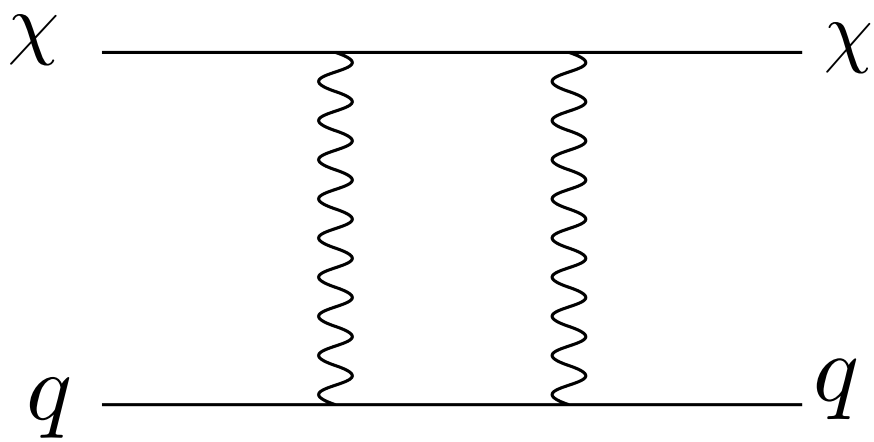
If coupling is zero, lightest particle mass cannot get contribution from electroweak symmetry breaking. The physical mass has to be either M_S or $-M_D$

case A $M_1 = M_S$: $-M_D > M_S$ $\sin(2\beta) = M_S/(-M_D)$

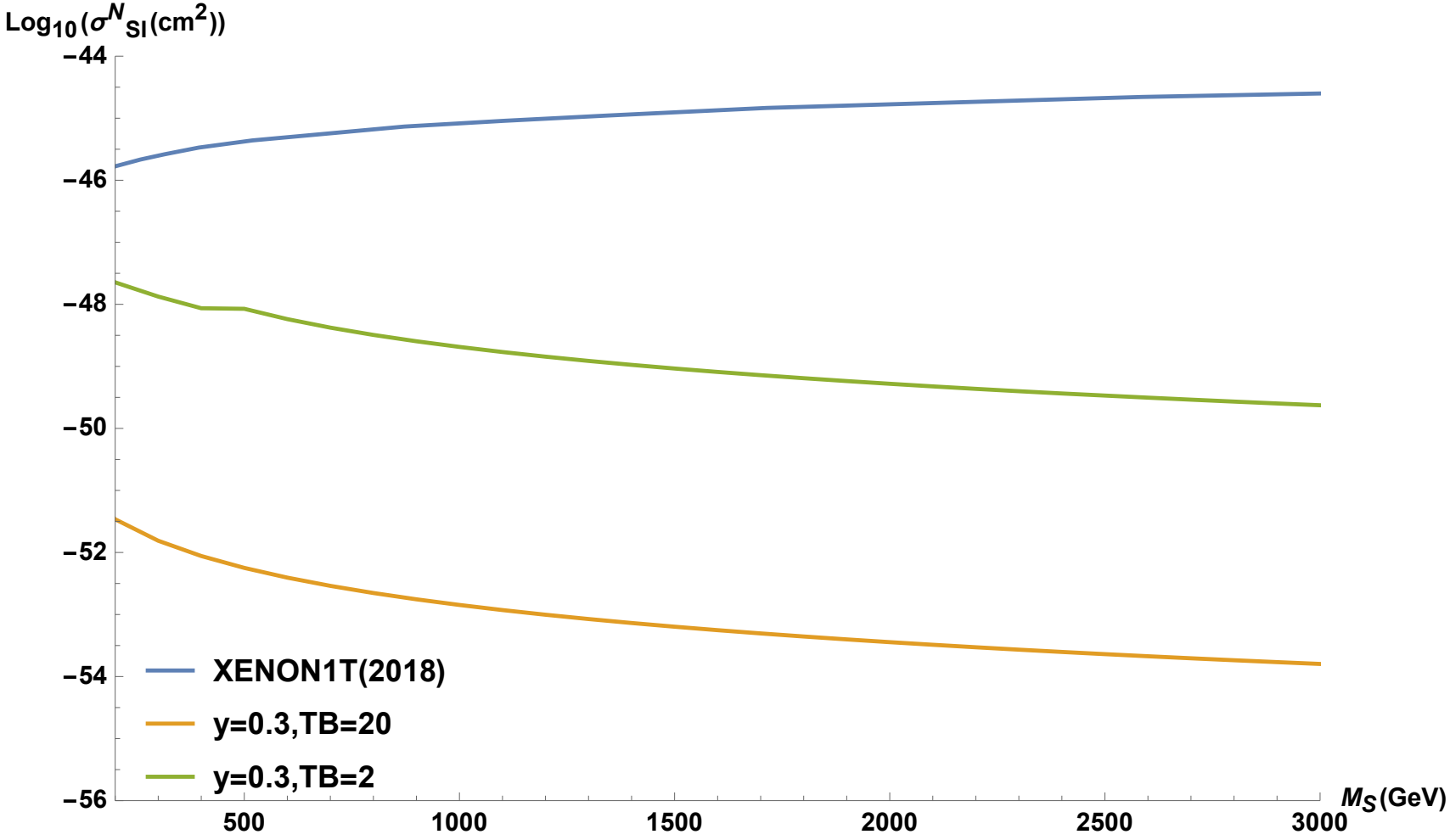
case B $M_1 = -M_D$: $-M_D < (M_S + \sqrt{M_S^2 + y^2 v^2})/2$ $\tan\beta = 1$

Loop Corrections

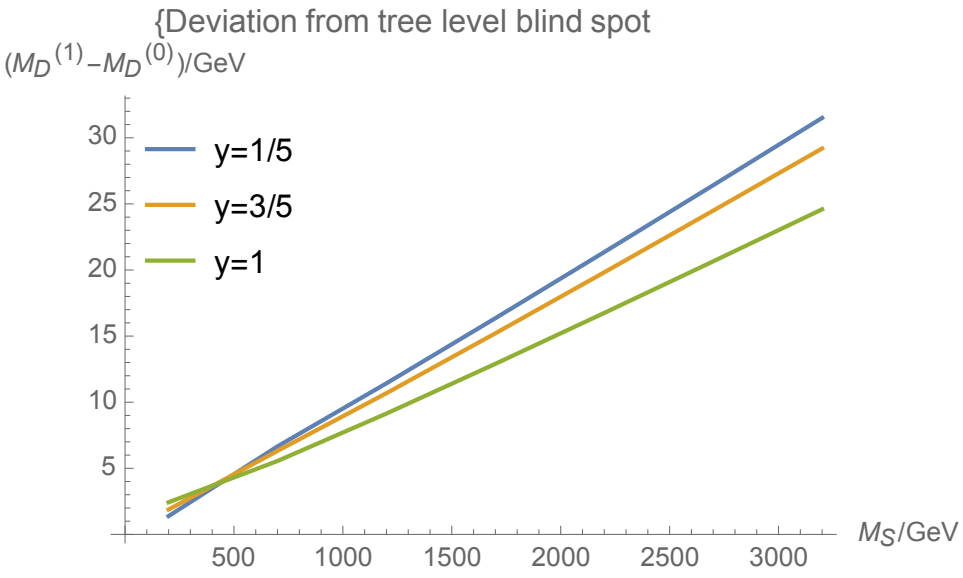




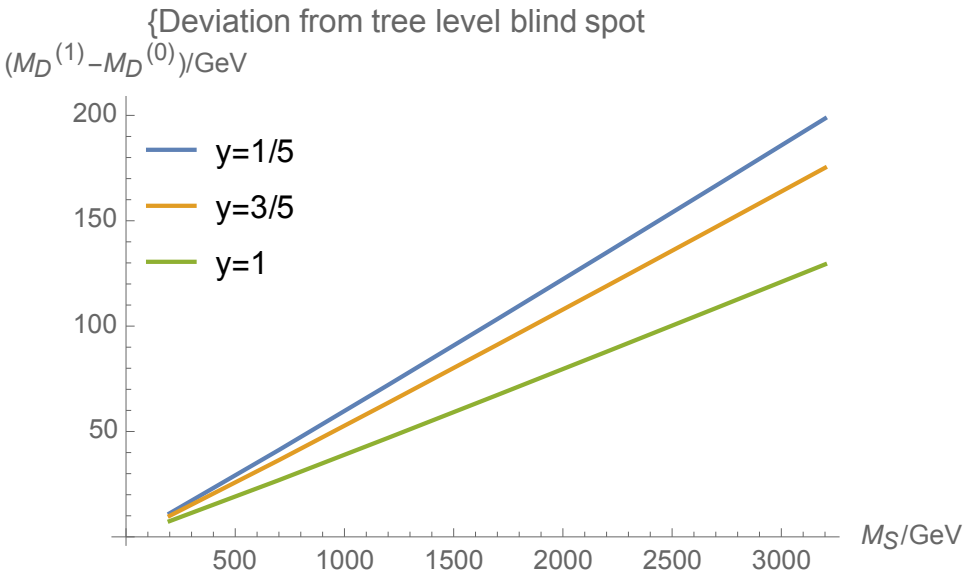
Numerical Results



Numerical Results



$\tan\beta = 2$



$\tan\beta = 10$

$$g \propto yv^2(M_D \sin(2\beta) + M_1)$$

$$\delta g \propto yv^2 \frac{2tb}{1+tb^2}\delta M_D$$

Conclusion

- The singlet-doublet model is generic model.
- Tree level coupling vanishes at the blind spot.
- Loop corrections becomes important
- At large $\tan\beta$,singlet-doublet mixing is small, tree level blind spot will get small corrections from one loop diagrams
- The one loop corrections will shifted after inducing one loop diagram.