# A Study of Dirac Fermionic Dark Matter


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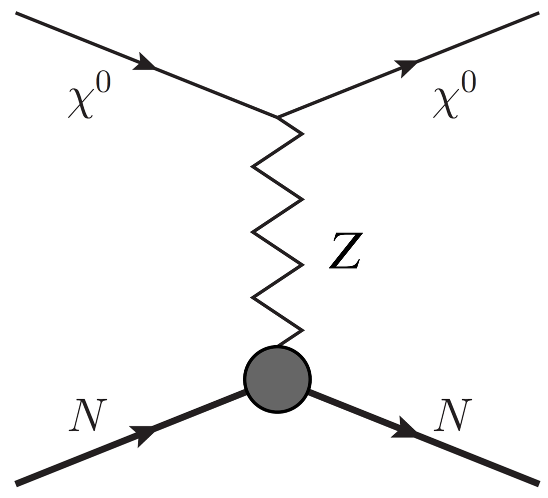
## Dirac Fermionic DM

- The existence of DM is well established.
- Its properties are poorly known.
- We study Dirac fermionic DM, which is less studied than Majorana and scalar DM.

- SI elastic cross section via Z exchange is usually larger than expt. bounds (~$10^{-45}$cm$^2$).

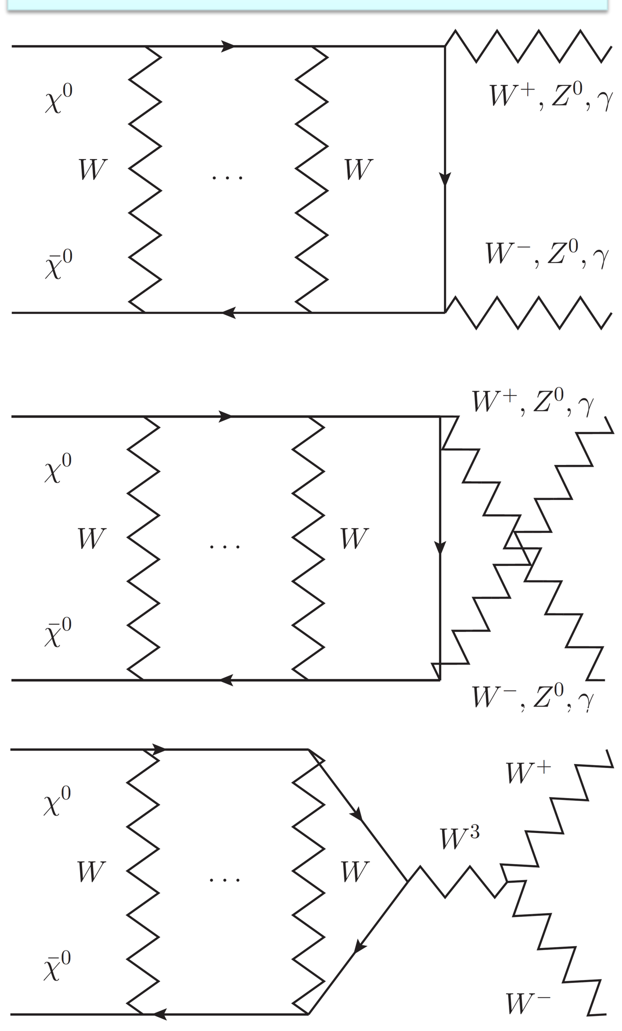
$$\sigma_N^Z \approx I_3^2 \times 10^{-40}\,\mathrm{cm}^2$$



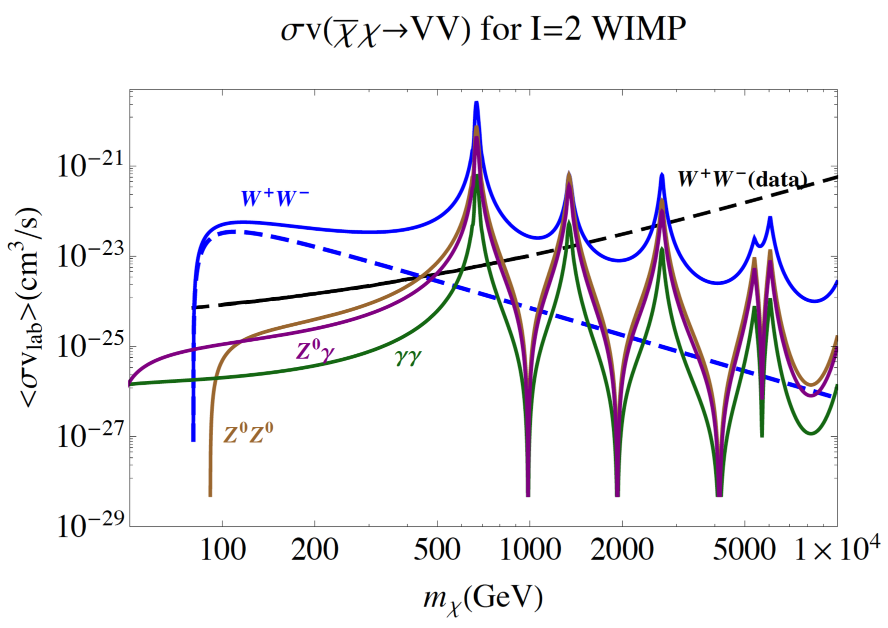

- To satisfy the direct search bound, need to have $I_3$=$Y$=0.
- There are only two possible cases:
  - (a) $I$≠0, $I_3$=$Y$=0,
  - (b) $I$=$Y$=0.

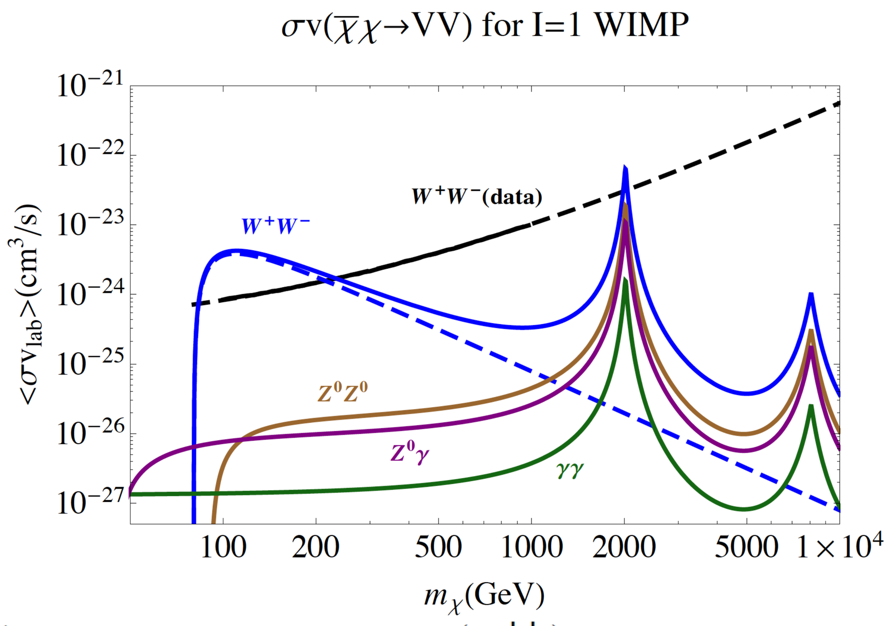
## (a) $I$≠0, $I_3$=$Y$=0 case

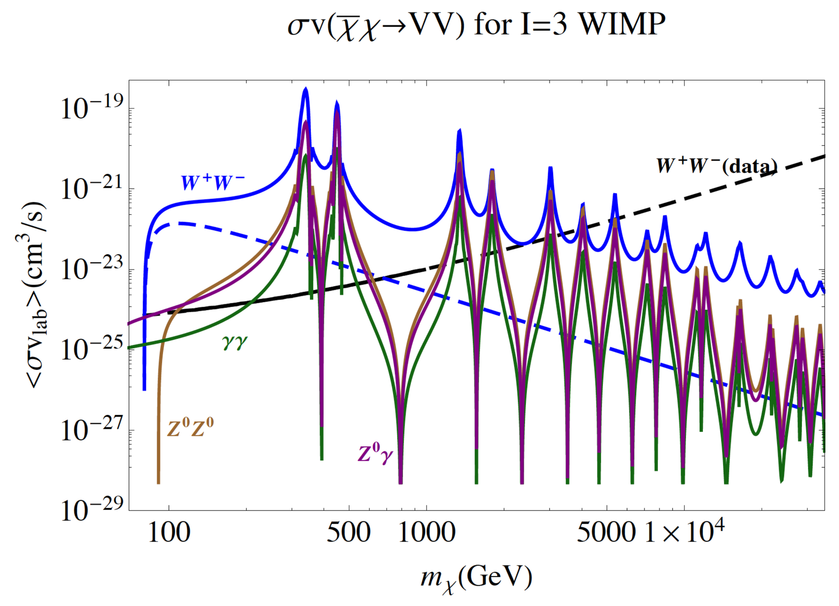
DM DM annihilate into V V



Sommerfeld enhancement



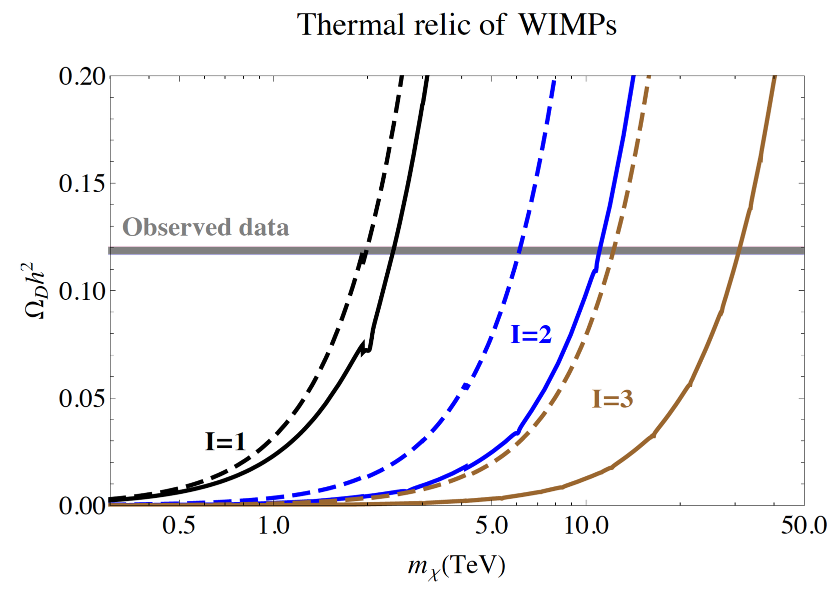



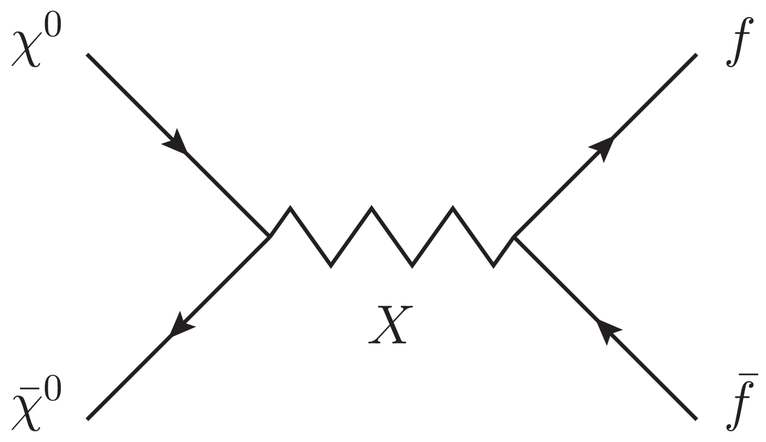

TABLE I: $m_\chi$ lower limits ($m_\chi^{\rm LL}$) obtained from Fermi-Lat constraints on $\chi\bar\chi \to W^+W^-$ rates, $m_\chi$ required to give correct thermal relic and the Galactic $\langle\sigma v\rangle$ at the corresponding dark matter masses are shown. Dark matter masses are shown in TeV, while $\langle\sigma v\rangle$ in cm$^3$/s. Values in parenthesis are obtained without using the Sommerfeld enhancement factors.

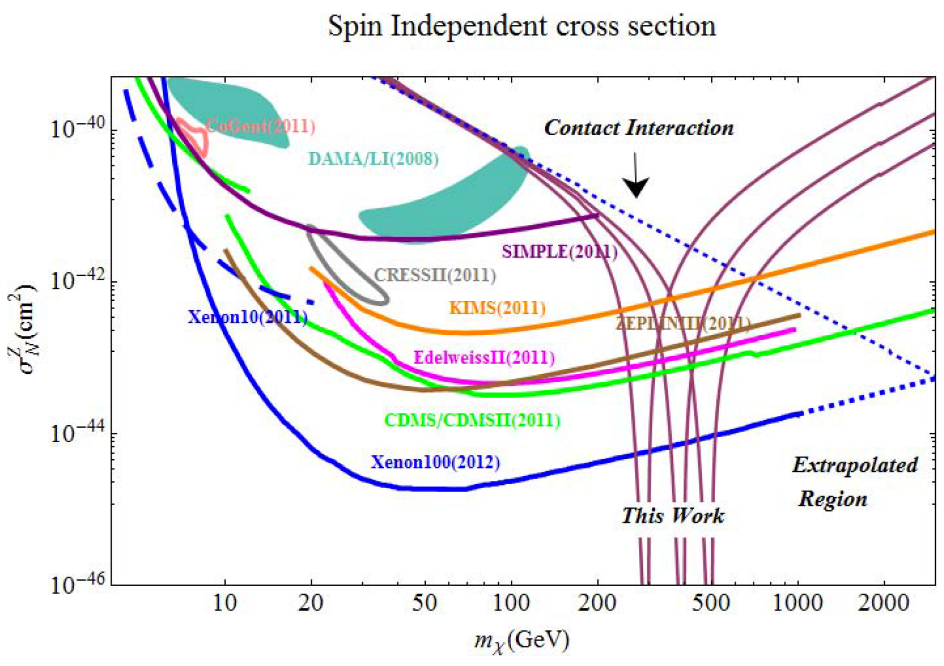
| Isospin | $m_\chi^{\rm LL}$ (Indirect) | $m_\chi$ (Relic) | $\langle\sigma v\rangle(W^+W^-)$ | $\langle\sigma v\rangle(Z^0Z^0)$ | $\langle\sigma v\rangle(Z^0\gamma)$ | $\langle\sigma v\rangle(\gamma\gamma)$ |
|---|---|---|---|---|---|---|
| $I=1$ | 0.23(0.22) | $2.42 \pm 0.02(1.98 \pm 0.01)$ | $8.1 \times 10^{-25}$ | $2.2 \times 10^{-25}$ | $1.2 \times 10^{-25}$ | $1.8 \times 10^{-26}$ |
| $I=2$ | $1.54^a$(0.45) | $11.06 \pm 0.07(6.13 \pm 0.04)$ | $6.6 \times 10^{-24}$ | $4.5 \times 10^{-25}$ | $2.6 \times 10^{-25}$ | $3.7 \times 10^{-26}$ |
| $I=3$ | $5.52^a$(0.69) | $30.92 \pm 0.22(12.26 \pm 0.09)$ | $2.2 \times 10^{-24}$ | $1.1 \times 10^{-27}$ | $6.2 \times 10^{-28}$ | $8.8 \times 10^{-29}$ |

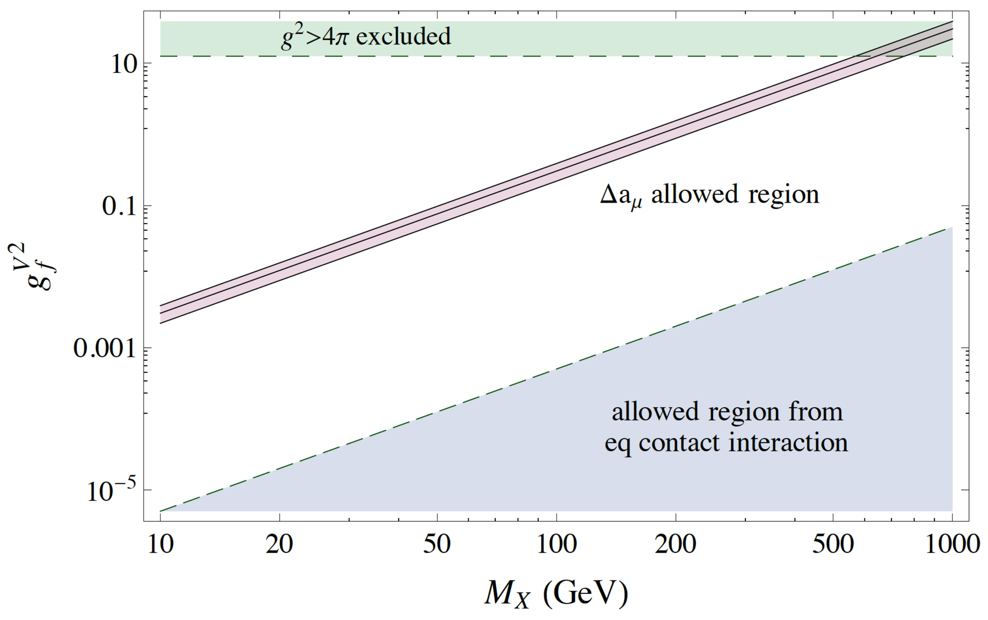
[a] Inferred by comparing to the extrapolated Femi-LAT data.

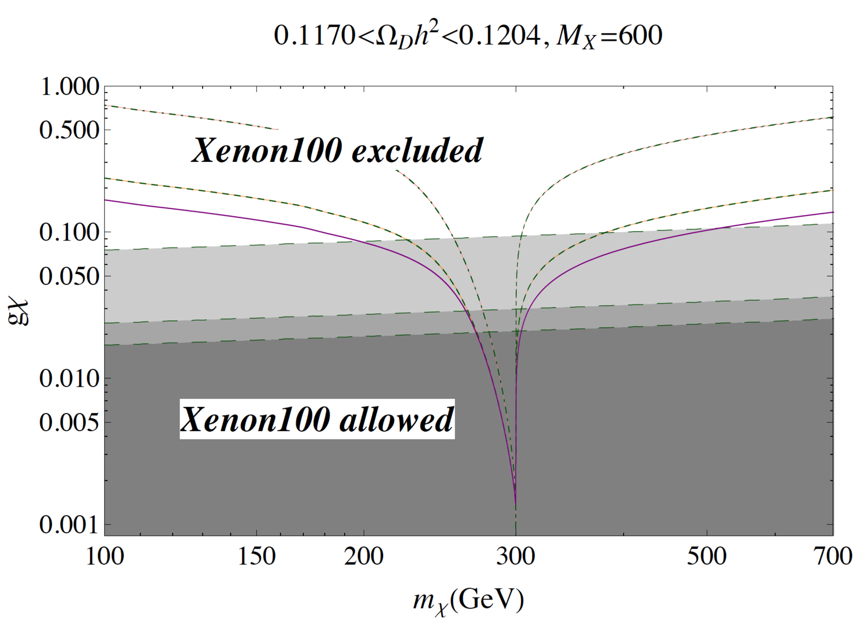
## (b) $I$=$Y$=0 case

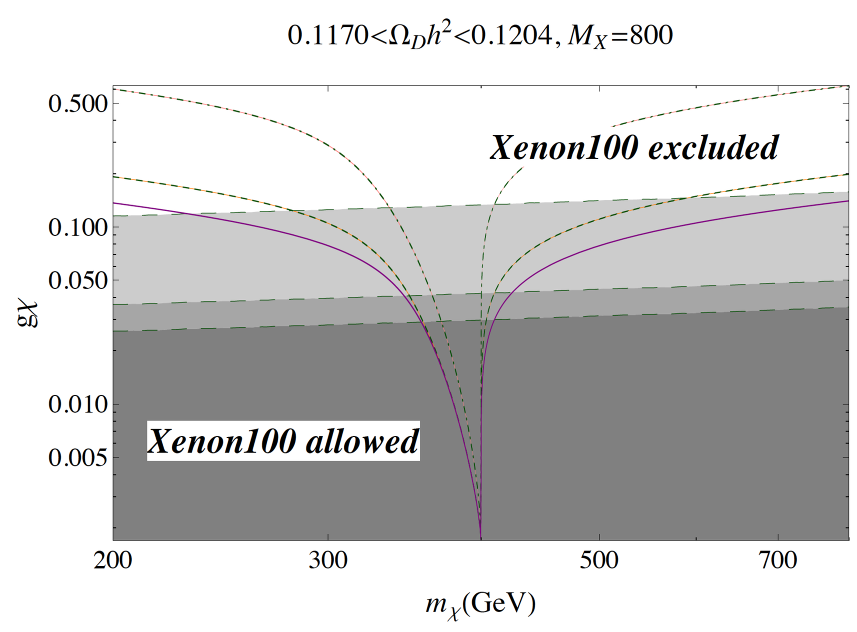
From renormalizability and gauge symmetry, we need a gauge singlet vector to mediate interaction to SM particles.

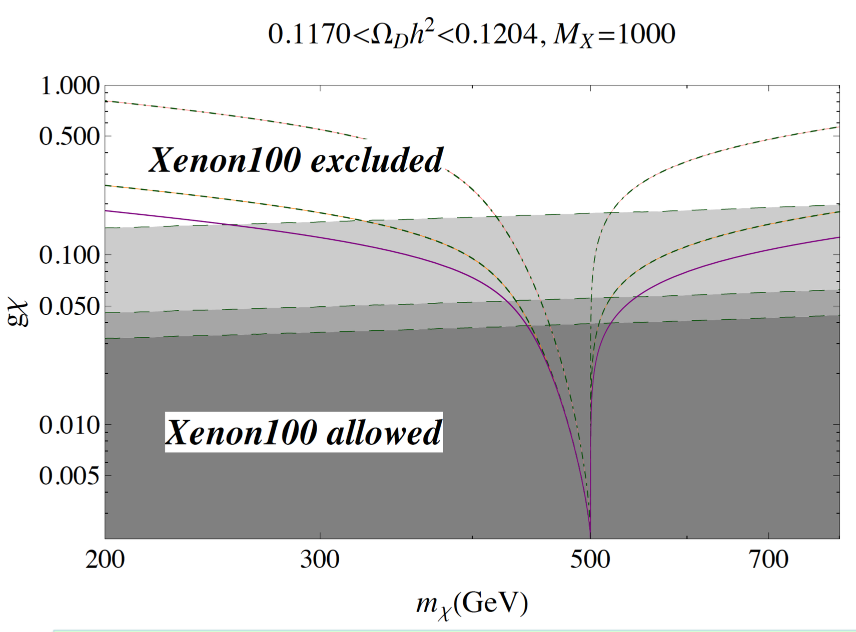


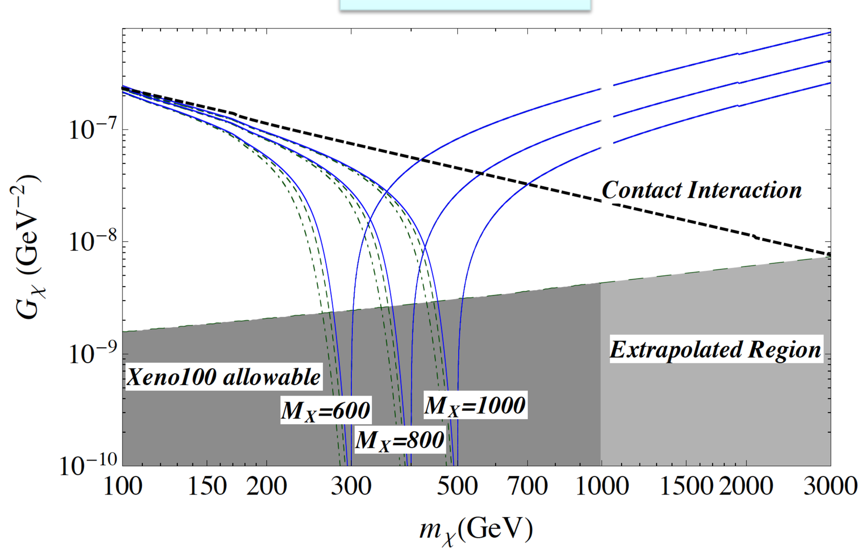




Combined




$g_f/g_\chi$=(0.1,1,2) from top to bottom

$G_\chi = g_\chi g_f / M_X^2$

## Conclusion

- To satisfy the direct search bound, the quantum number of Dirac fermionic DM is determined to be $I_3 = Y = 0$. There are only two possibilities: $I$≠0, $I_3$=$Y$=0 or $I$=$Y$=0.
- In the $I$≠0 case, the Sommerfeld enhancement is sizable for large $I$, producing large $\chi^0\bar\chi^0 \to VV$ rates. The DM Relic density can be reproduced with O(1-10) TeV $m_\chi$, without violating the Fermi-LAT bound.
- In the $I$=0 case, a SM-singlet vector mediator $X$ is required from renormalizability and the SM gauge quantum numbers. To satisfy the latest bounds of direct searches and to reproduce the DM relic density at the same time, resonant enhancement in the DM annihilation diagram is needed. Masses are correlated.


See arXiv:1305.7008 for more details