An investigation of the dark photon as mediator between dark matter and the standard model

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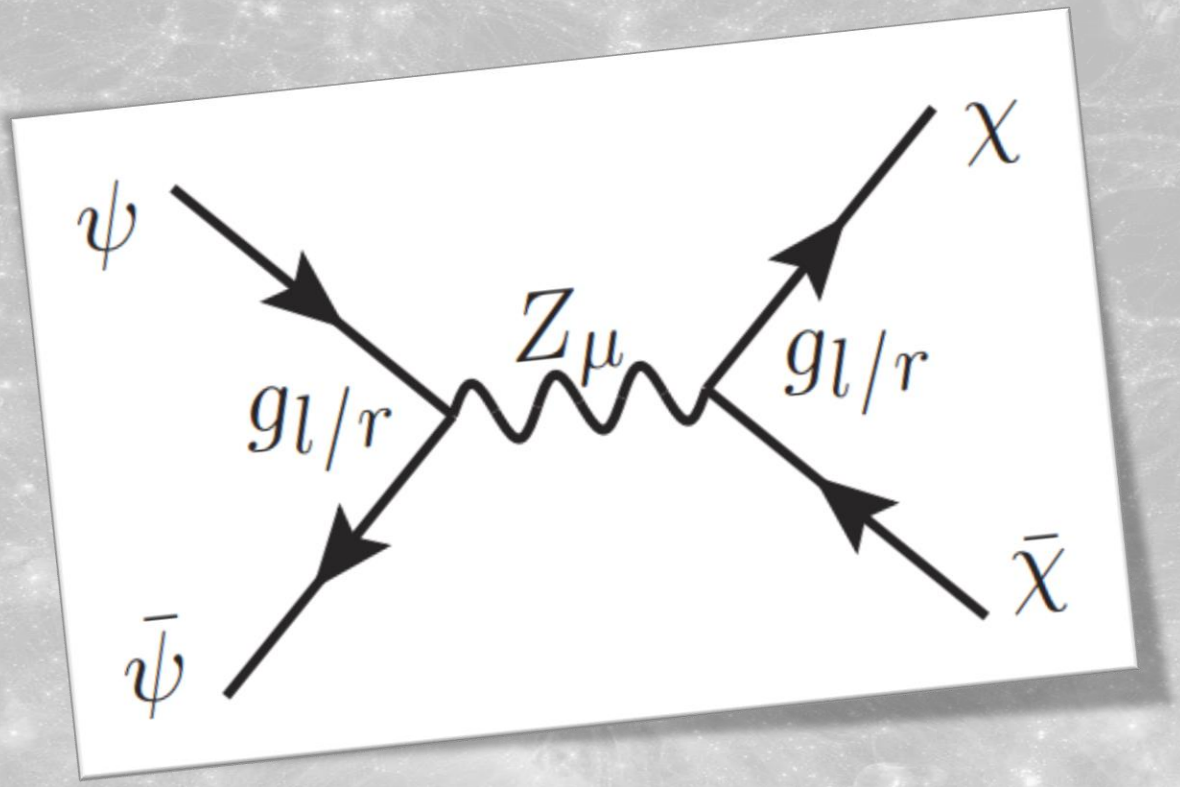
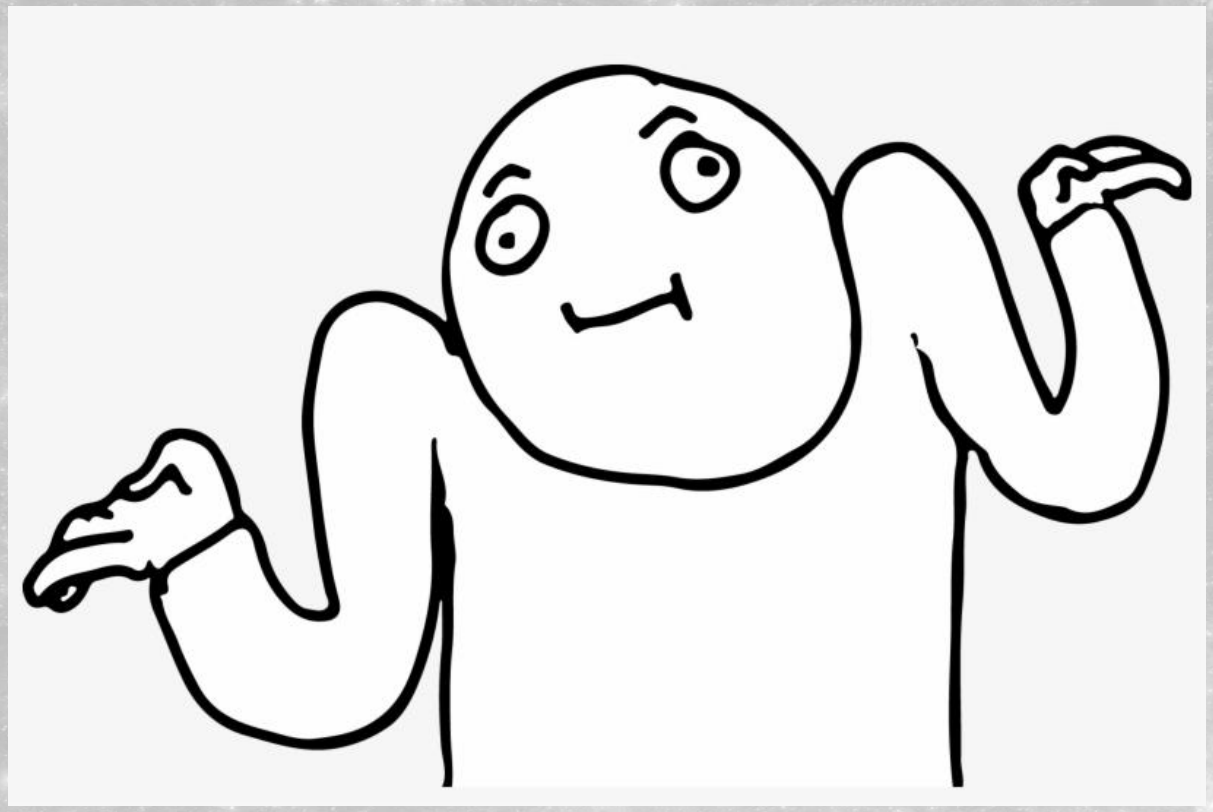
The model

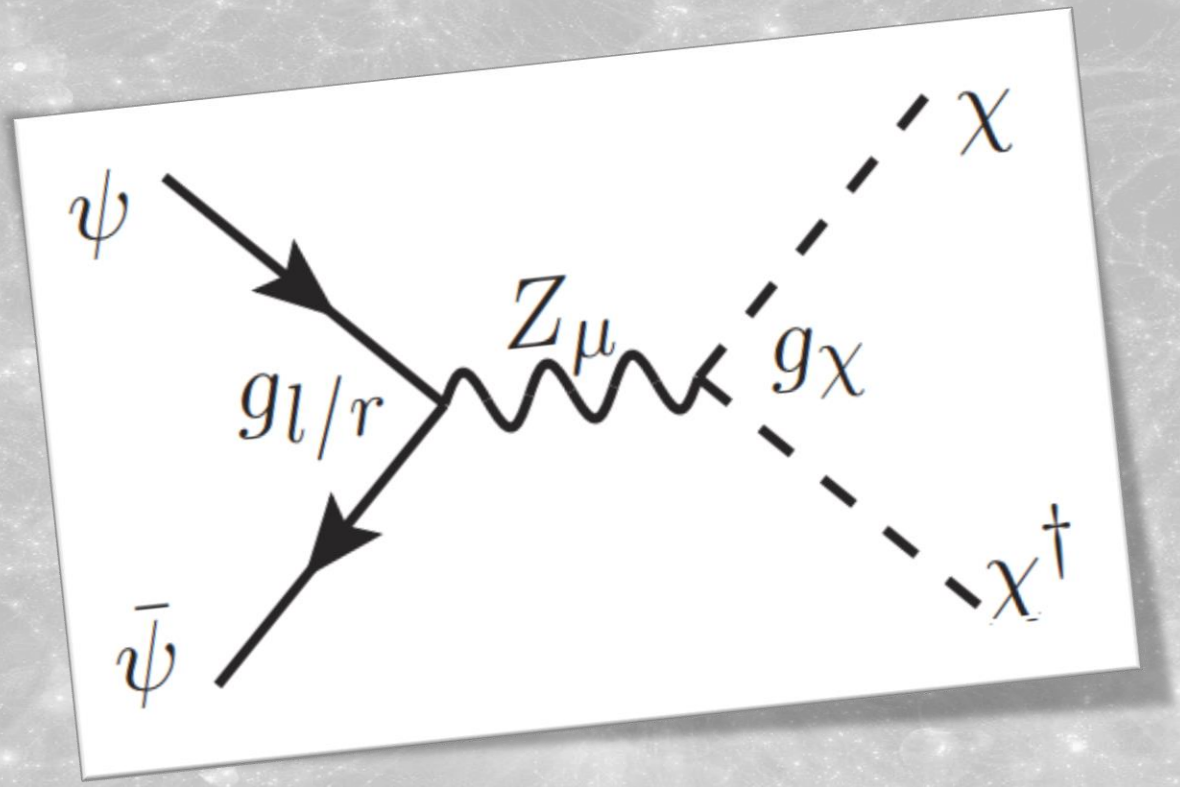
dark photon –> fermion DM



$$\mathscr{L}^{s}_{\text{int}} = -\frac{1}{4}F^{\mu\nu}F_{\mu\nu} + \frac{1}{2}M^2_{\Omega}Z^{\mu}Z_{\mu} + \left[\bar{\psi}\gamma^{\mu}\left(g_l P_L + g_r P_R\right)\psi + \bar{\chi}\gamma^{\mu}\left(g_l P_L + g_r P_R\right)\chi\right] Z_{\mu}$$

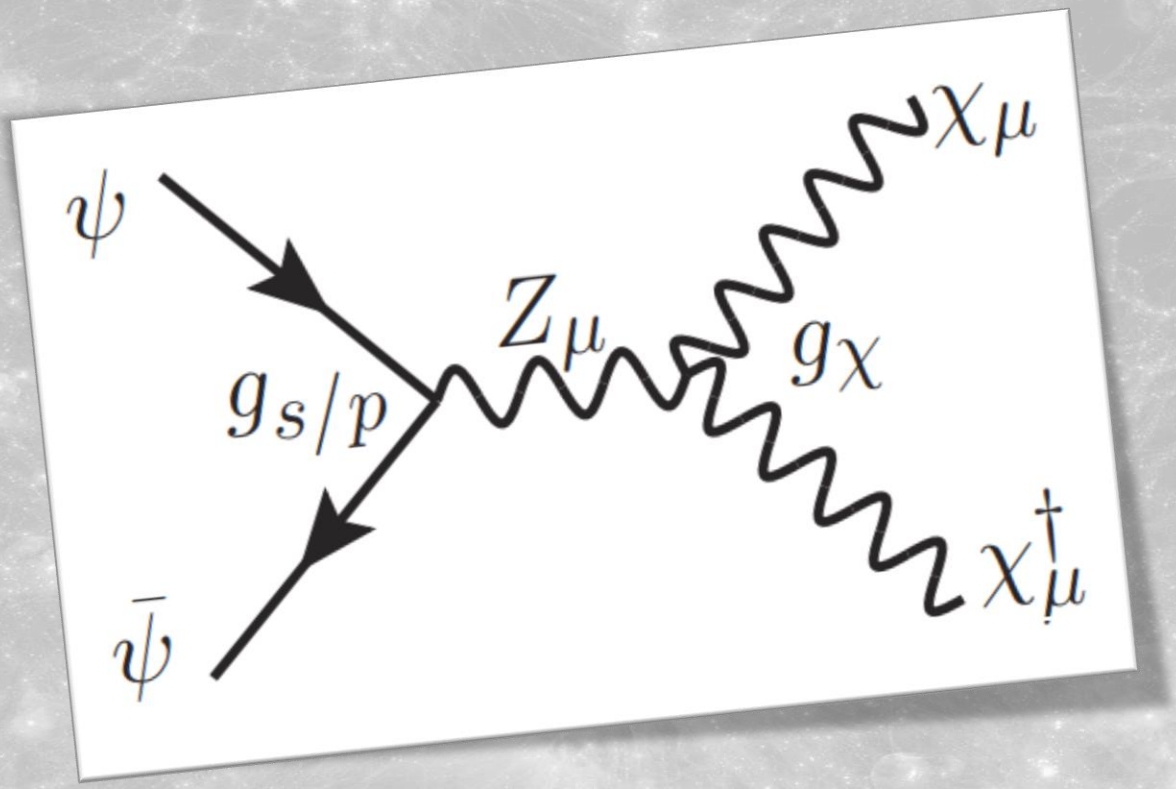


dark photon –> scalar DM



$$\mathscr{L}_{\text{int}} = -\frac{1}{4}F^{\mu\nu}F_{\mu\nu} + \frac{1}{2}M_\Omega^2 Z^\mu Z_\mu + g_\chi\left(\chi^\dagger\partial_\mu\chi - \chi\partial_\mu\chi^\dagger\right)Z^\mu + \bar{\psi}\gamma^\mu\left(g_l P_L + g_r P_R\right)\psi Z_\mu$$

dark photon –> vector DM



$$\mathscr{L}_{\text{int}} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + \frac{1}{2}M_\Omega^2 Z_\mu Z^\mu - ig_\chi Z_\mu \chi_\nu^\dagger \left(\partial^\mu \chi^\nu - \partial^\nu \chi^\mu\right) + ig_\chi Z^\mu \chi^\nu \left(\partial_\mu \chi_\nu^\dagger - \partial_\nu \chi_\mu^\dagger\right)$$
$$- ig_\chi \left(\partial^\mu Z^\nu - \partial^\nu Z^\mu\right) \chi_\mu^\dagger \chi_\nu + \bar{\psi}\gamma^\mu \left(g_l P_L + g_r P_R\right) \psi Z_\mu$$

Methods

Methods

$$\sigma_{tot}^{fermionica} = \frac{1}{16\pi}\frac{1}{\left(s-4m_e^2\right)}\frac{m_e^2 m_x^2}{\left[s-M_\Omega^2\right]^2+M_\Omega^2\Gamma_{fermion}^2}$$

$$\times\left\{\begin{aligned}&\frac{2}{sm_e^2m_x^2}\left\{\frac{g^4}{3}\left[\left(s+t-\mu\right)^3+\left(t-\mu\right)^3\right]+2g^2g_{l/r}^2\left[s\mu-4m_e^2m_x^2+4\frac{g_{l/r}^2}{g^2}m_e^2m_x^2\right]\right\}\\&+\frac{t}{M_\Omega^4}\left\{g^4\left[s+2\mu-8\frac{m_e^2m_x^2}{s}\right]-4g^2g_{l/r}^2\left[2s-\mu\right]+4g_{l/r}^4s\right\}\\&+\frac{8t}{M_\Omega^2}\left(g^2-g_{l/r}^2\right)^2\end{aligned}\right\}$$

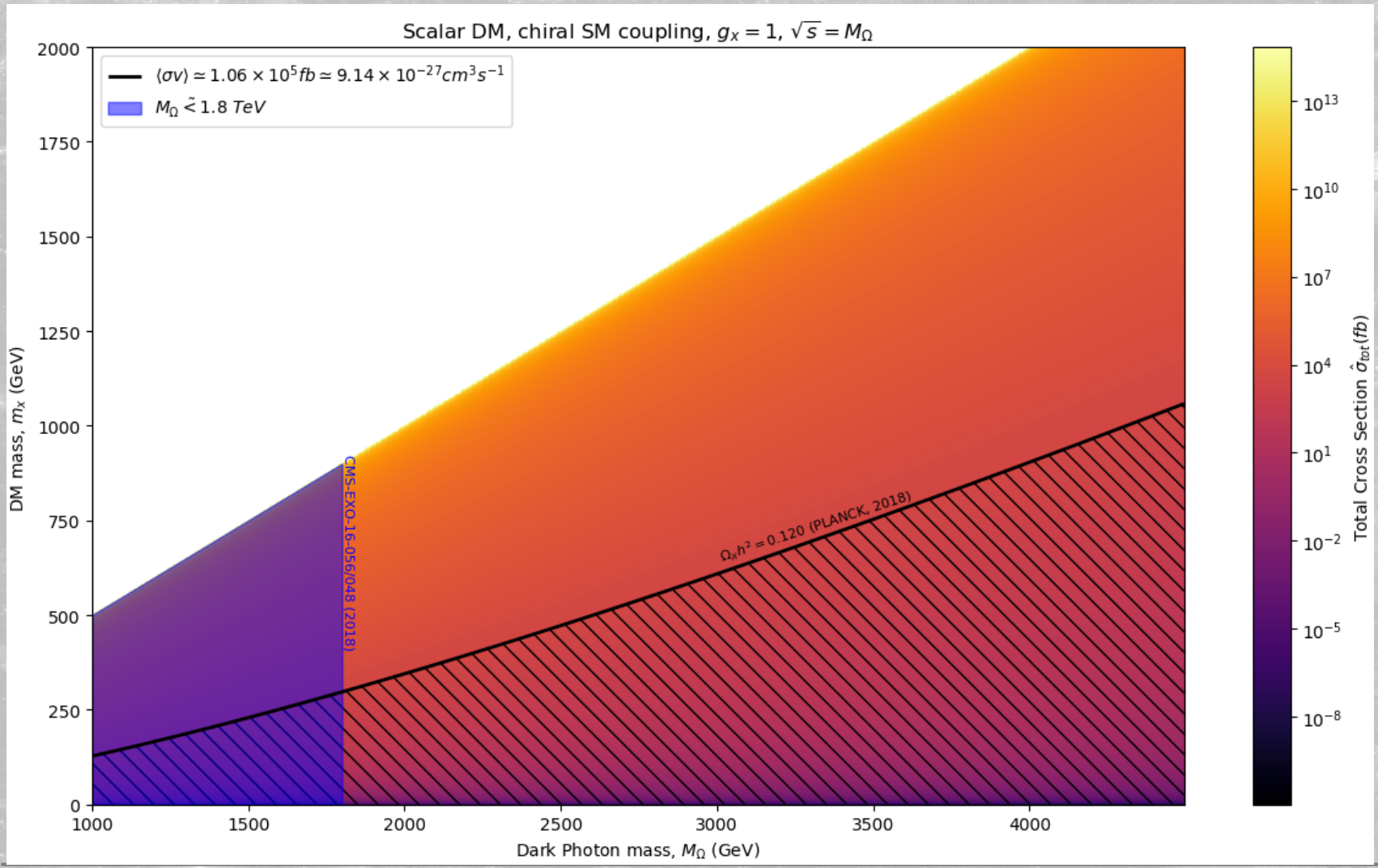
python™

```
#Mdf = (90)**2       #massa ao quadrado do fóton escuro
#mx = (0.10565)**2       # massa ao quadrado da matéria escura
me = (0.000511)**2     #massa ao quadrado do elétron
g = (gl**2) + (gr**2)   # definição de g
glr = 2*gl*gr           # definição de glr
brn = 0.3894*10**12  ## conversão para barn

############ SESSÃO DE CHOQUE \sigma^ ############

def sigma_fermion(Mdf2,mx2):  ## sessão de choque e integração de "-t" a "+t"

    Mdf = Mdf2**2
    s = Mdf
    mx = mx2**2
    u = me + mx # definição de u (não a variavel de mandelstan)

    GM_F = (((s-4*mx)**(1/2))/((48*np.pi)*Mdf))* (2*g*(s-2*mx) + 3*glr*mx*  + (g*s)/2)  ## largura de decaim
    t = -0.5*( ((s-4*me)**0.5) * ((s-4*mx)**0.5) + 2*u-s )
    csa = ((1/(16*np.pi)) * (1/(s-4*me))) * (me*mx/(((s-Mdf)**2) + (Mdf*GM_F**2)) ) * ( (2/(s*me*mx))* (((g*
    t = 0.5*( ((s-4*me)**0.5) * ((s-4*mx)**0.5) + 2*u-s )
    csb = ((1/(16*np.pi)) * (1/(s-4*me))) * (me*mx/(((s-Mdf)**2) + (Mdf*GM_F**2)) ) * ( (2/(s*me*mx))* (((g*
    return csa - csb




Mdf1 = np.arange(0, 4500, 5) # valor da massa para o fóton escuro
mx1 = np.arange(0, 2000, 1) # massa da matéria escura, minimo
```

Results

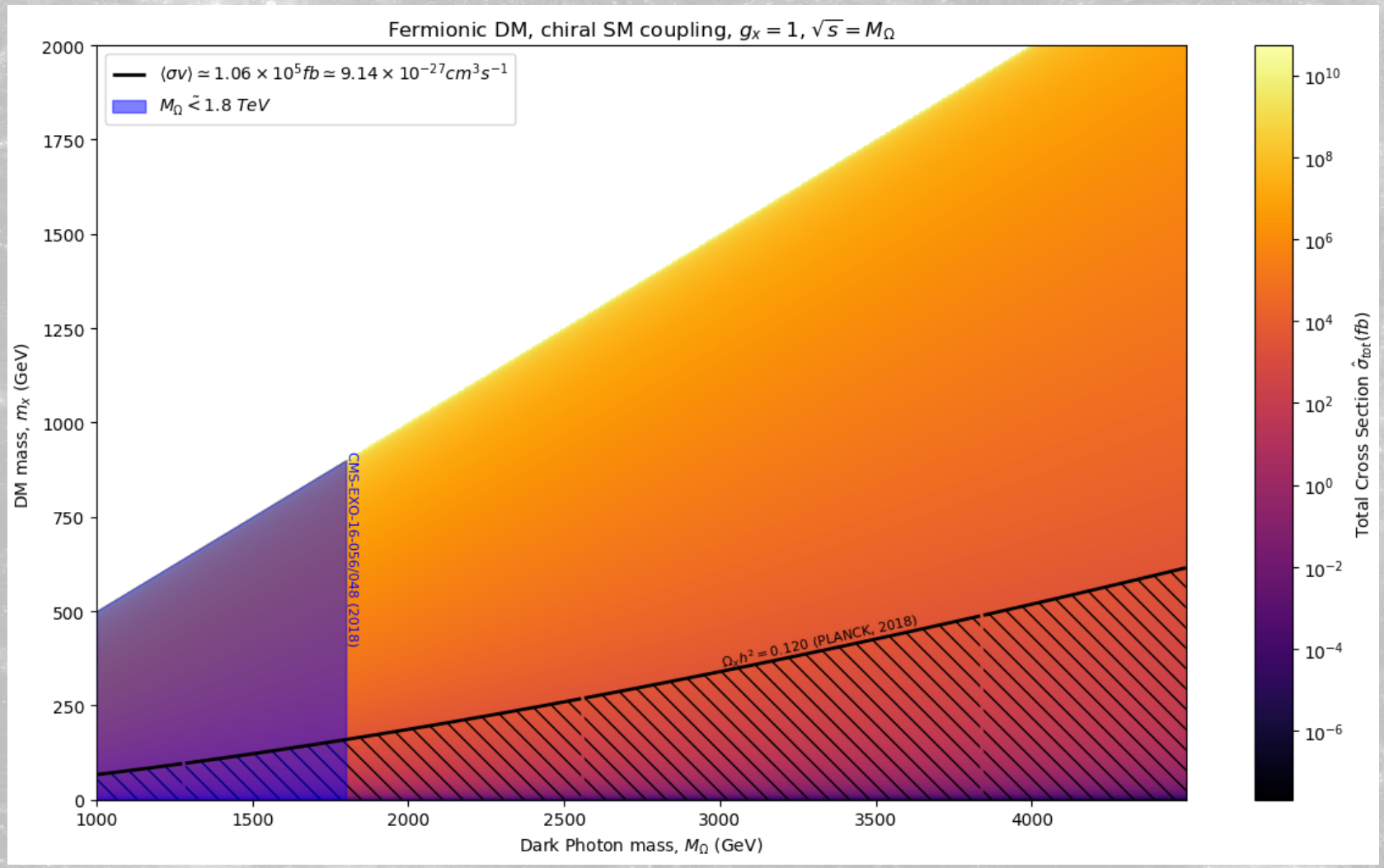
Results

Variation of the annihilation cross section in function of the masses of the mediator and the **scalar DM**



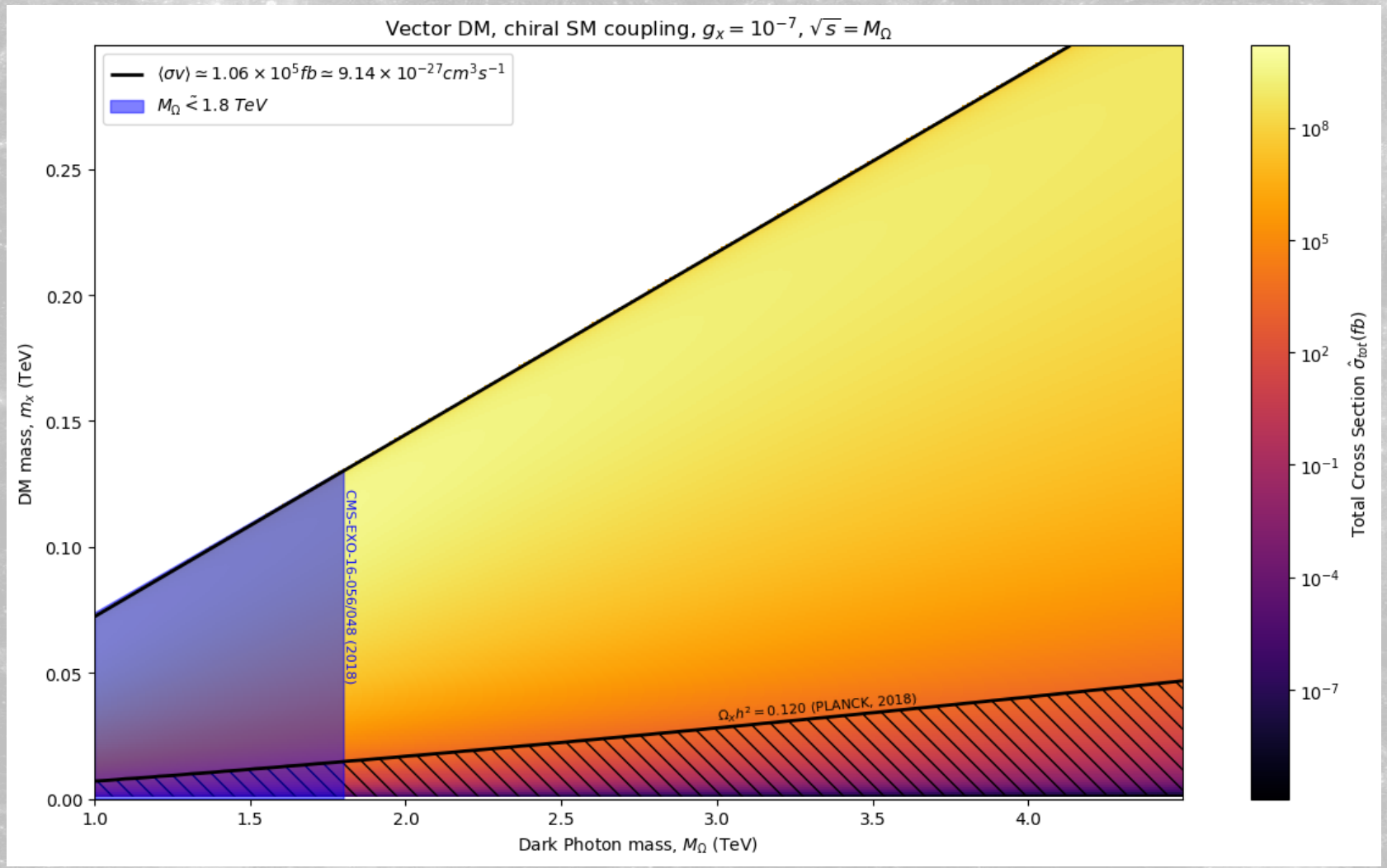
Results

Variation of the annihilation cross section in function of the masses of the mediator and the **fermion DM**



Results

Variation of the annihilation cross section in function of the masses of the mediator and the **vector DM**



Parameters

Parameter	Value
SM fermion mass	$m_e = 511\ keV$
SM coupling (left)	$g_l = 0.25$
SM coupling (right)	$g_r = 0$
DM coupling (scalar and fermion DM)	$g_x = 1$
DM coupling (vector DM)	$g_x = 10^{-7}$
Dimensionless Hubble parameter	$h = 0.678$
Present day CMB temperature	$T_0 = 2.7255$
$\langle \sigma v \rangle = \sigma v + \vartheta(v^2)$	where $v = c/3$
$\mathrm{X} \equiv m_x / T_{f.o.}$	$X = 30$

References

[1] H. Dreiner *et al*, *Physical Review D* **87** 075015 (2012). arXiv:1308.4409v1 [hep-ph]

[2] S. Profumo, *TASI 2012 Lectures on Astrophysical Probes of Dark Matter* (2013). arXiv:1301.0952v1 [hep-ph];

[3] Planck Collaboration, *Planck 2018 results. VI. Cosmological parameters* (2018). arXiv:1807.06209v1 [astro-ph.CO]

[4] CMS Collaboration, *Physical Review D* **97** 092005 (2018). arXiv:1712.02345 [hep-ex]