Light mass window of lepton portal dark matter

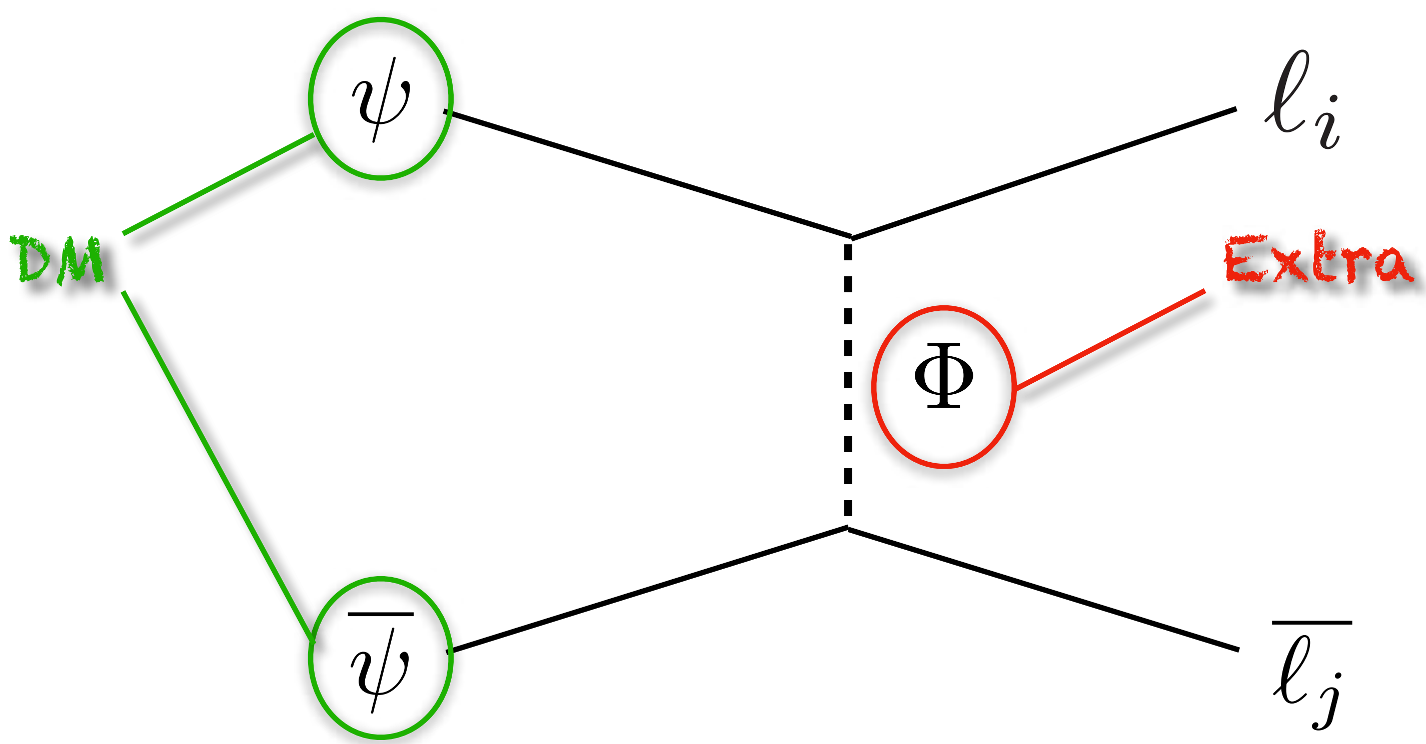
Yuji Omura (Kindai Univ.)

based on the collaboration with
J. Kawamura and S. Okawa
(arXiv: 2011.04788, 2002.12534)

Introduction

I am studying phenomenology in lepton portal DM models

with J. Kawamura and S. Okawa
(arXiv: 2002.12534)



- DM couples to only leptons.
- There are many types:

DM is scalar or fermion.

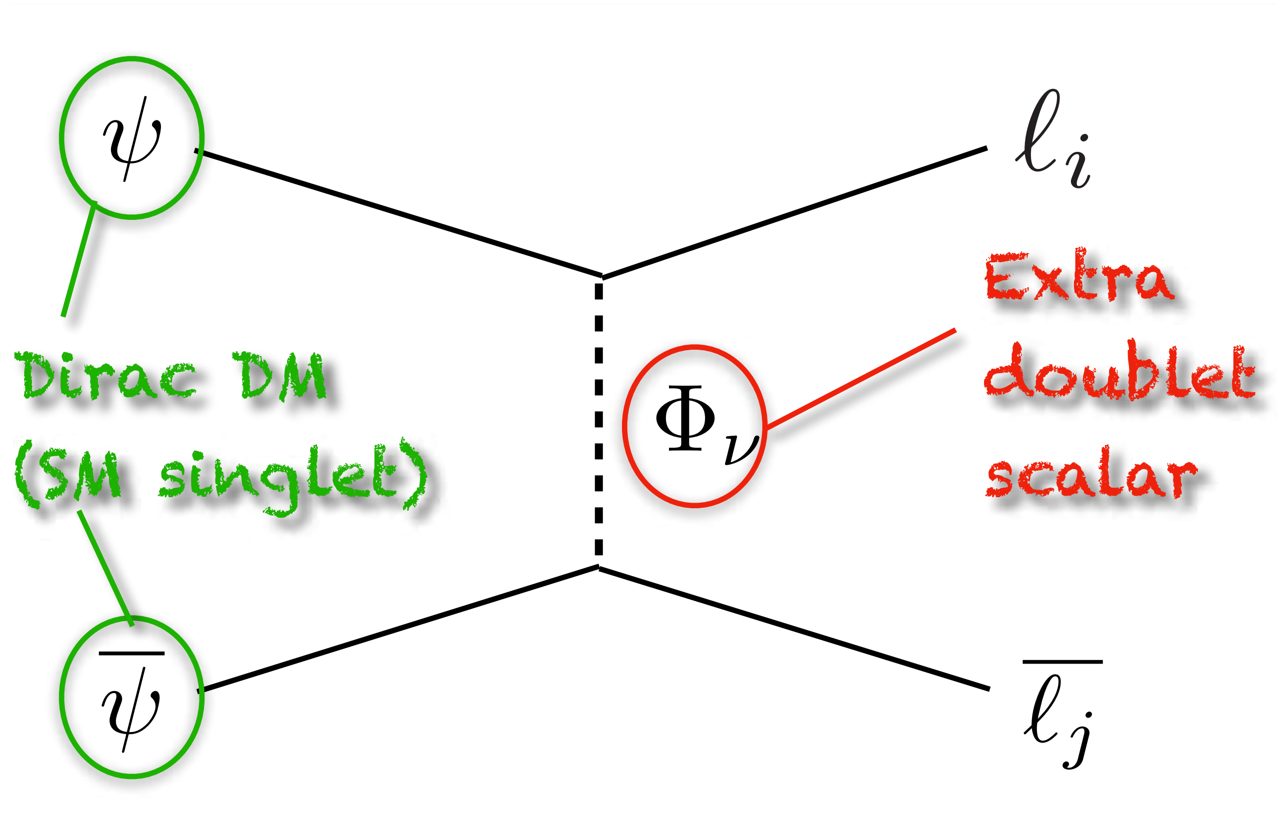
Interesting points

YO, J. Kawamura and S. Okawa
(arXiv: 2002.12534)

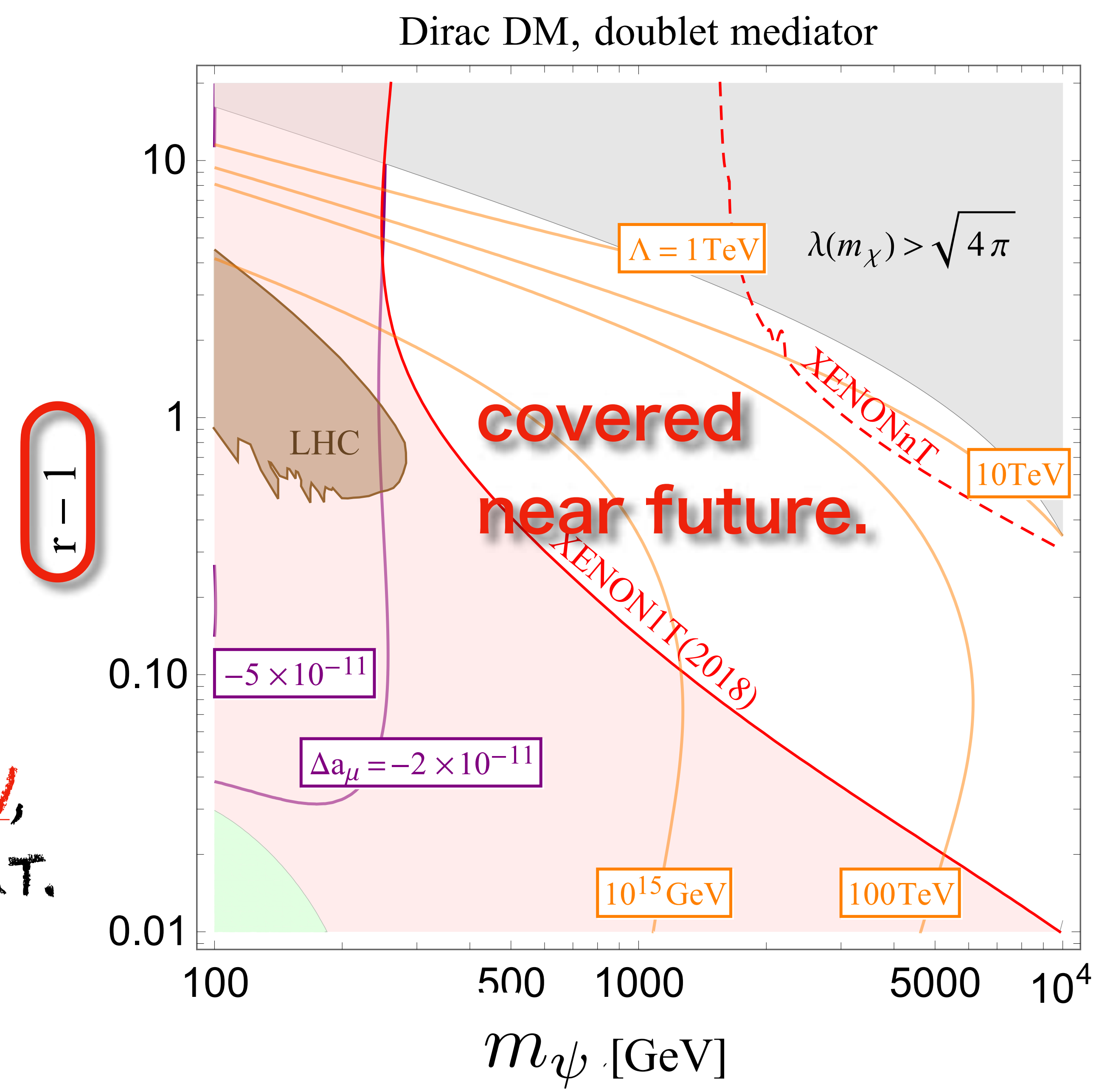
- Setup is very simple, and could be interrupted as so effective models of many extended SMs.
- Strong bound from DM direct detection can be evaded at the tree level, but one-loop is enough large to test these models.
- muon g-2 is enhanced in some setups.
- DM indirect search can test real DM model.
- The mediator predicts the characteristic signals that can be discovered at the LHC.

ex) current status of Dirac Fermion DM model

2002.12534 with Kawamura, Okawa



$$r = \frac{m_{\Phi_\nu}}{m_\psi}$$



Assuming DM is heavier than 100 GeV, all regions will be covered by XENONnT.

See 2002.12534 for more detail.

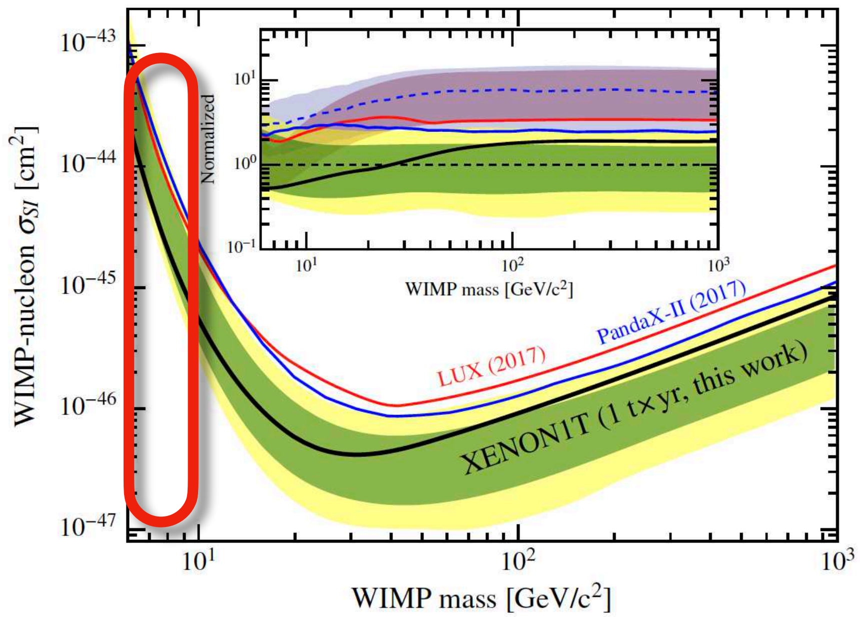
In this talk,

introduce our recent results based on arXiv:2011.04788 (collaboration with S.Okawa).

We study light DM mass region in Dirac DM model.

$$10\mathrm{MeV} \leq m_{DM} \leq 10\mathrm{GeV}$$

PRL121,111302



Motivation is

- evade the strong bound from direct detection.
- this is novel possibility that light DM is thermally produced.
- can be tested by Higgs signal and neutrino observation.

Setup

Matter content

	Fields	spin	$SU(3)$	$SU(2)_L$	$U(1)_Y$	$U(1)_L$	stabilize DM Z_2
	Q_L^i	$1/2$	$\mathbf{3}$	$\mathbf{2}$	$\frac{1}{6}$	0	$+$
	u_R^i	$1/2$	$\mathbf{3}$	$\mathbf{1}$	$\frac{2}{3}$	0	$+$
	d_R^i	$1/2$	$\mathbf{3}$	$\mathbf{1}$	$-\frac{1}{3}$	0	$+$
	ℓ_L^i	$1/2$	$\mathbf{1}$	$\mathbf{2}$	$-\frac{1}{2}$	1	$+$
	e_R^i	$1/2$	$\mathbf{1}$	$\mathbf{1}$	-1	1	$+$
DM	ψ_L	$1/2$	$\mathbf{1}$	$\mathbf{1}$	0	1	$-$
DM	ψ_R	$1/2$	$\mathbf{1}$	$\mathbf{1}$	0	1	$-$
	Φ	1	$\mathbf{1}$	$\mathbf{2}$	$\frac{1}{2}$	0	$+$
extra	Φ_ν	1	$\mathbf{1}$	$\mathbf{2}$	$\frac{1}{2}$	0	$-$

Relevant couplings

$$-\mathcal{L}_\ell = y_\nu^i \, \overline{\ell_L^i} \, \widetilde{\Phi}_\nu \, \psi_R + h.c.$$

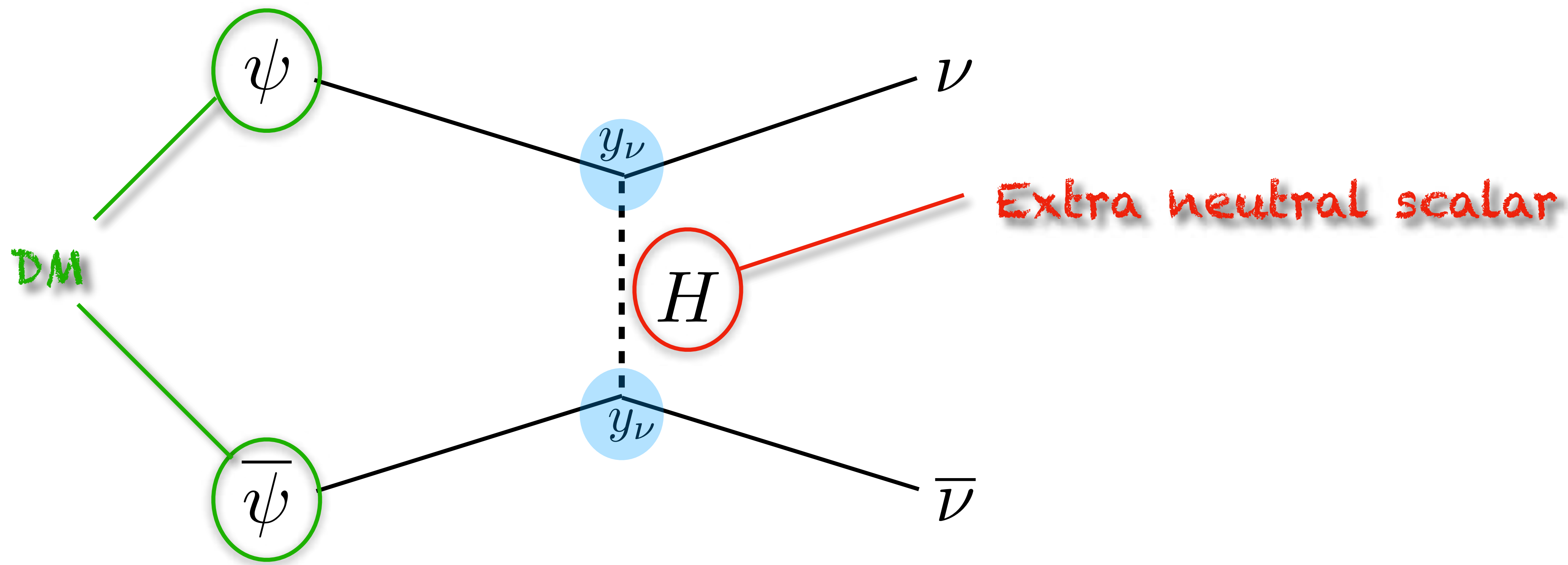
After EWSB

$$-\mathcal{L}_\ell = y_\nu^i \left[\frac{1}{\sqrt{2}} \overline{\nu_L^i} (H - iA) \psi_R - \overline{e_L^i} H^- \psi_R \right] + h.c.$$

DM annihilation

We assume DM dominantly couples to τ and ν

If DM is lighter than τ, DM annihilates to ν



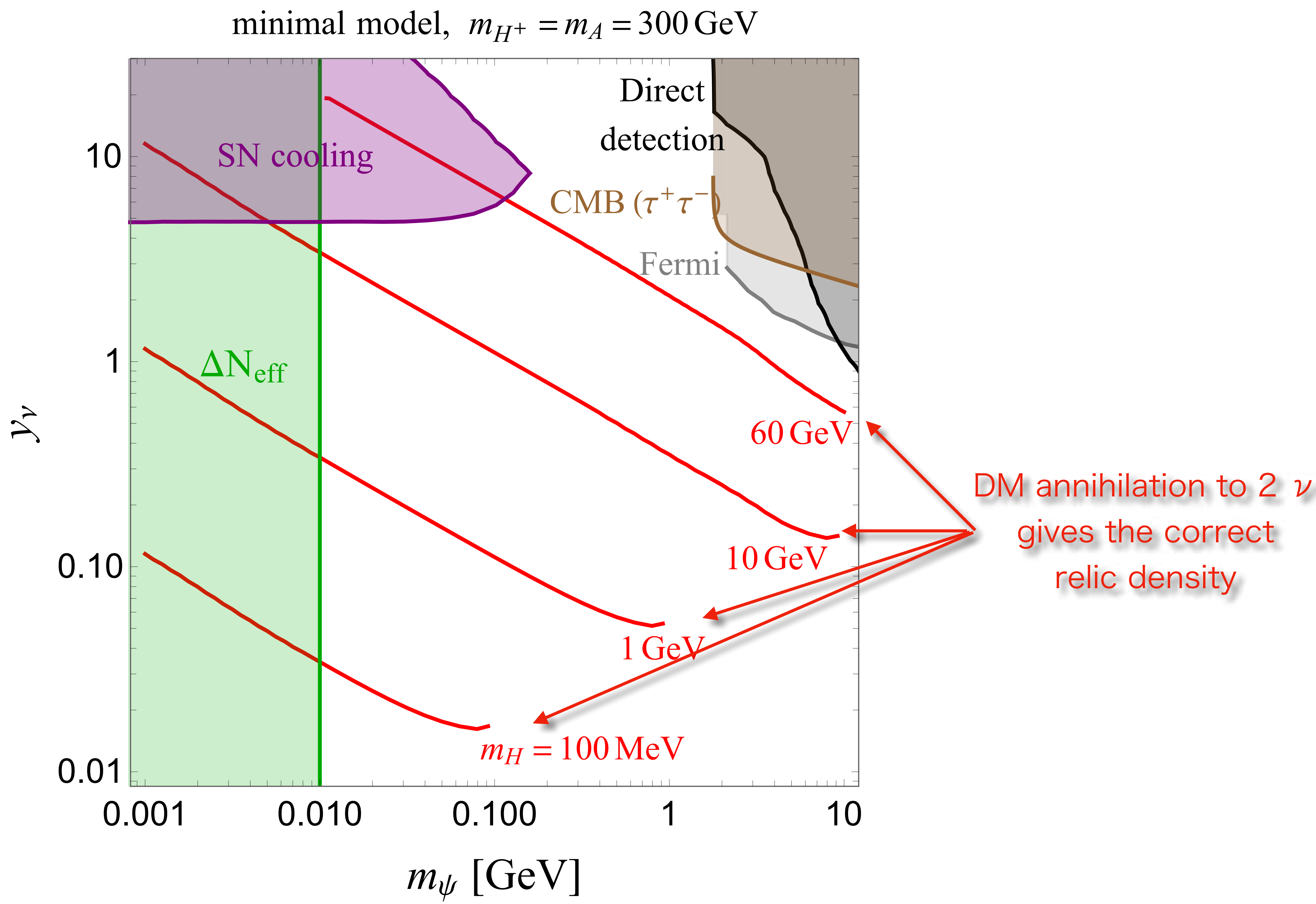
$$(\sigma v_{\rm rel})_{\psi\bar{\psi}\to\nu\bar{\nu}} \simeq \frac{y_\nu^4 m_\psi^2}{128\pi(m_\psi^2 + m_H^2 - m_\nu^2)^2}\sqrt{1-\frac{m_\nu^2}{m_\psi^2}}$$

If H is also light, cross section is enough large to thermally produce DM.

Summary of results

Parameters to lead correct relic density of DM

2011.04788 with Okawa



Parameters to lead correct relic density of DM

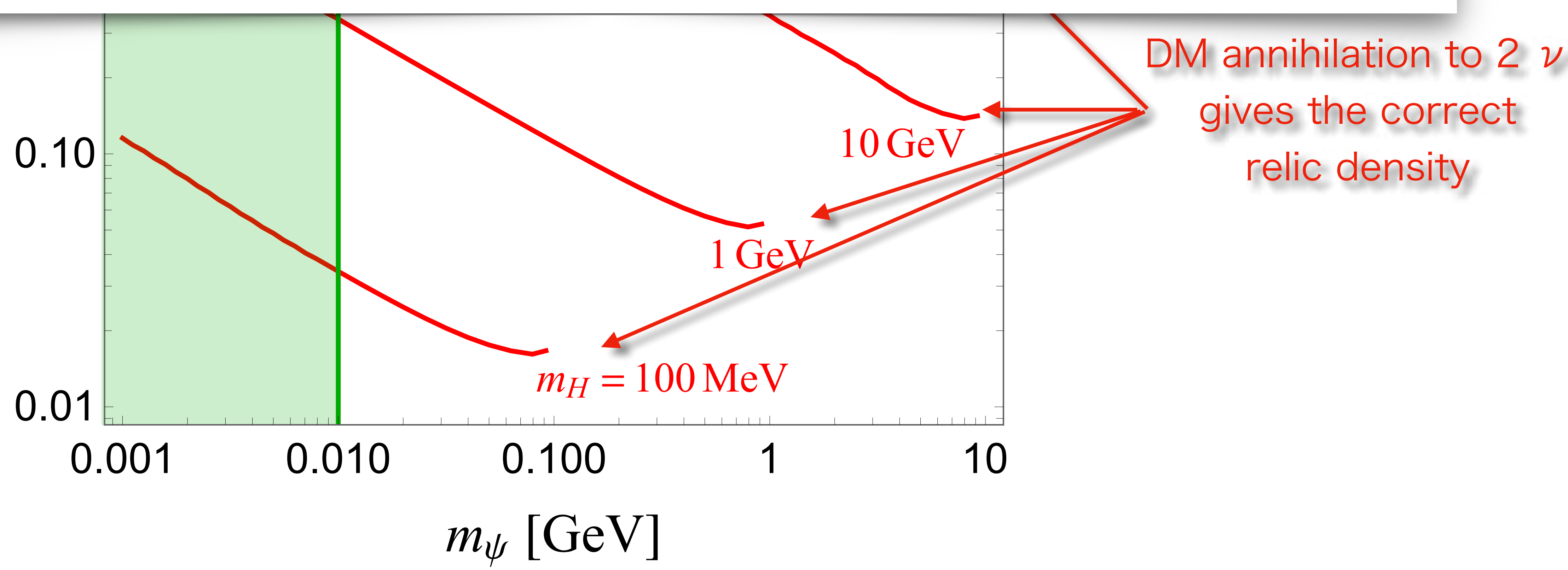
2011.04788 with Okawa

DM mass : $10\mathrm{MeV} \leq m_\psi \leq 10\mathrm{GeV}$

extra scalar mass: $m_\psi \leq m_H \leq \mathcal{O}(10)\mathrm{GeV}$

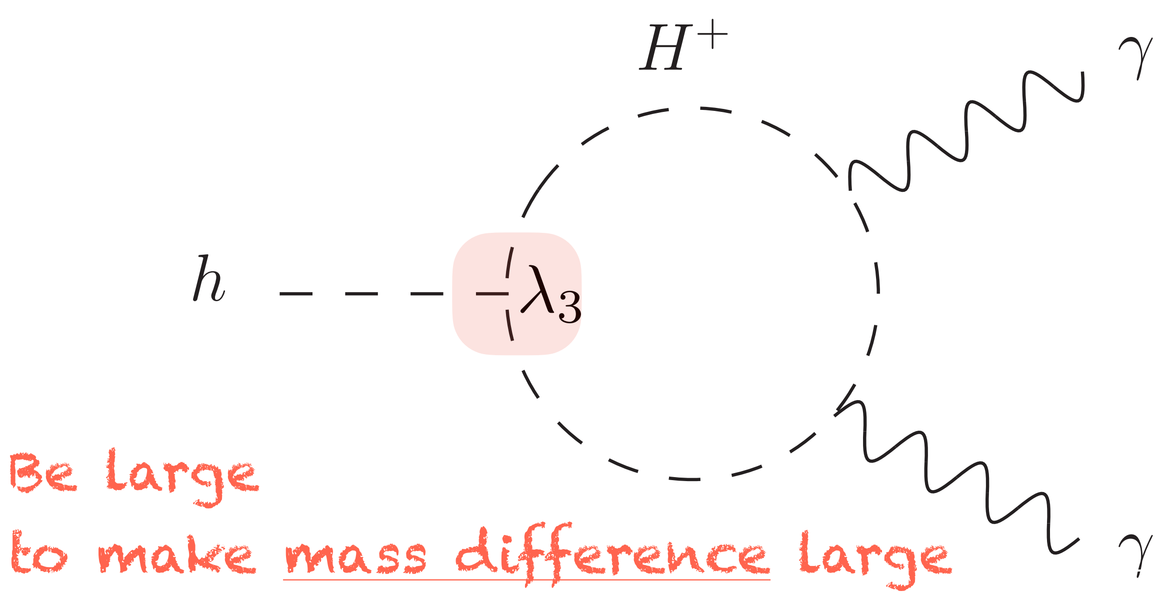
Yukawa coupling: $y_\nu \leq 1$

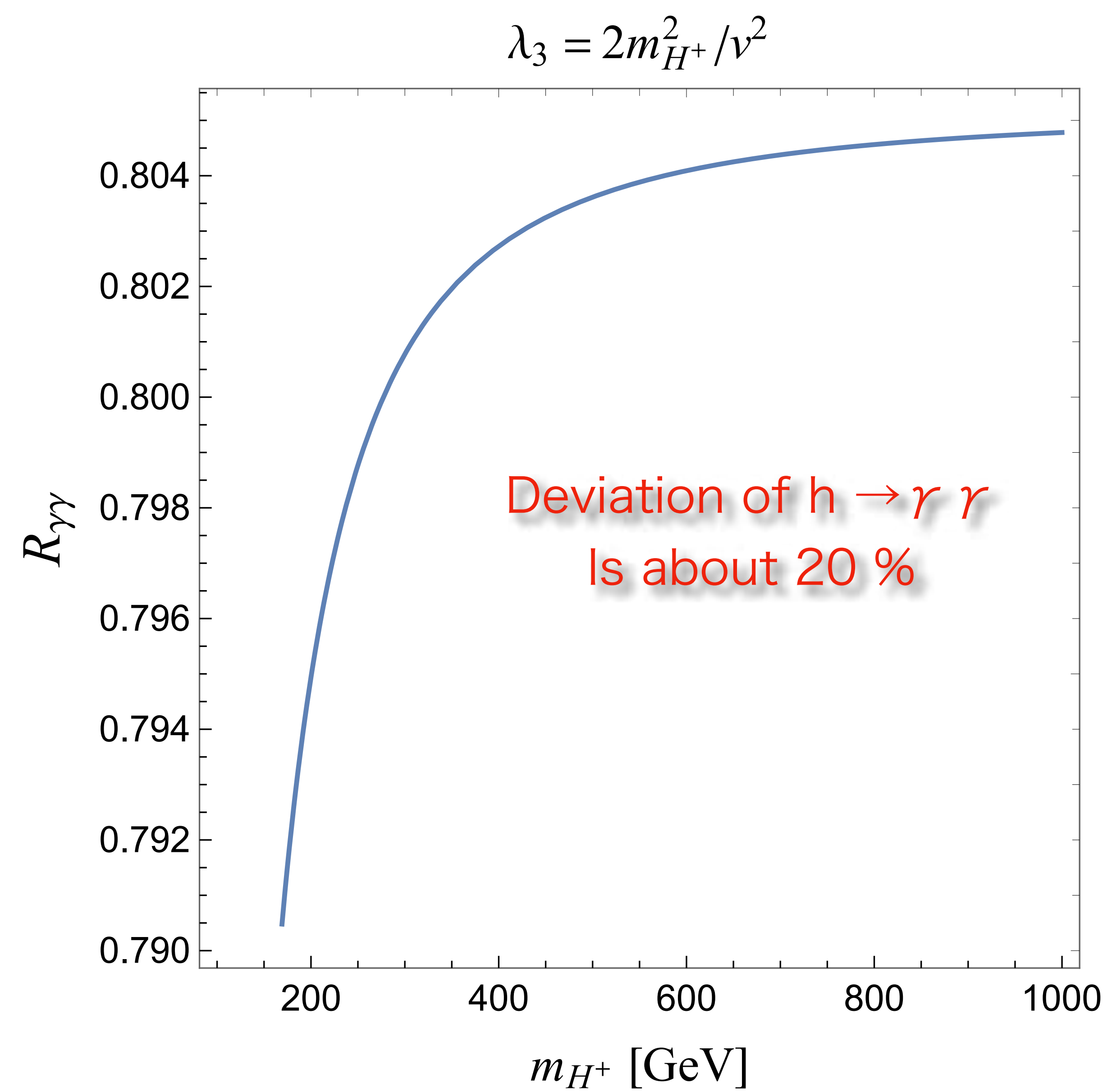
Other scalar masses: $m_{H_\pm} = m_A = 300\mathrm{GeV}$ **in our analysis**



It is difficult to test this mass region in the direct detection, but possible in the 125 GeV Higgs signal.

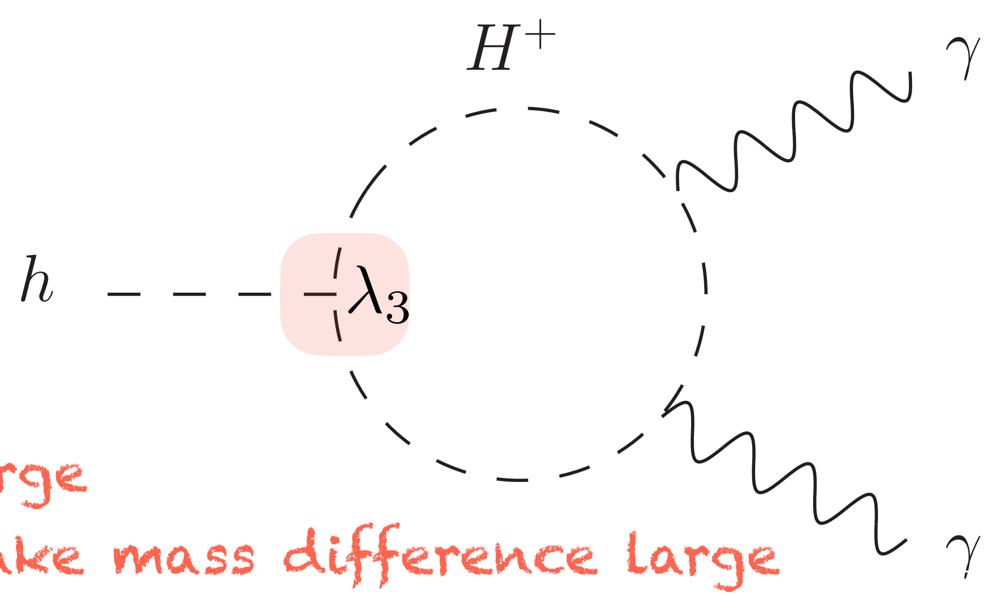
2011.04788 with Okawa





It is difficult to test this mass region in the direct detection, but possible in the 125 GeV Higgs signal.

2011.04788 with Okawa

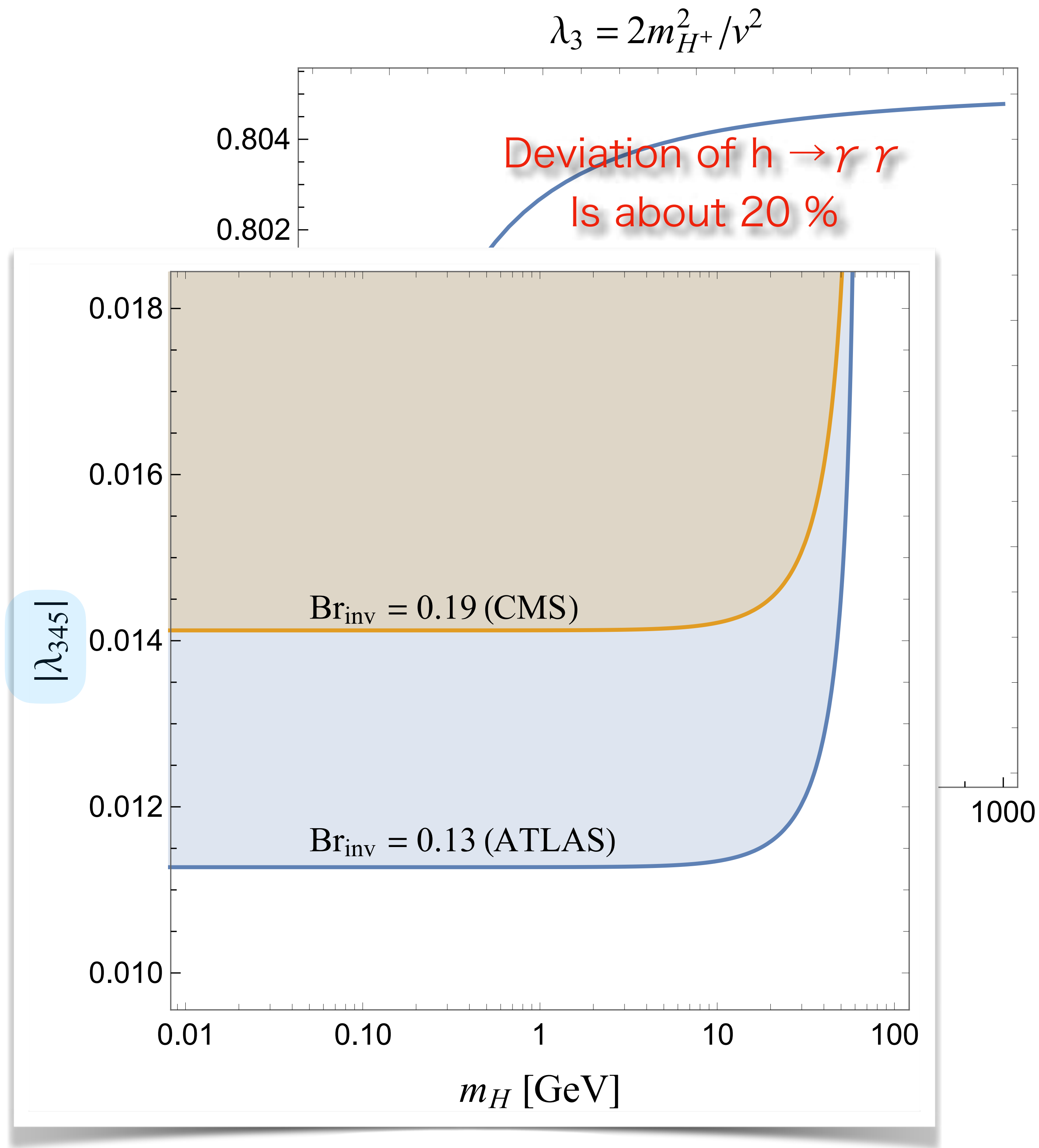


Be large
to make mass difference large

In addition, h decays to HH,
that is invisible decay of h.

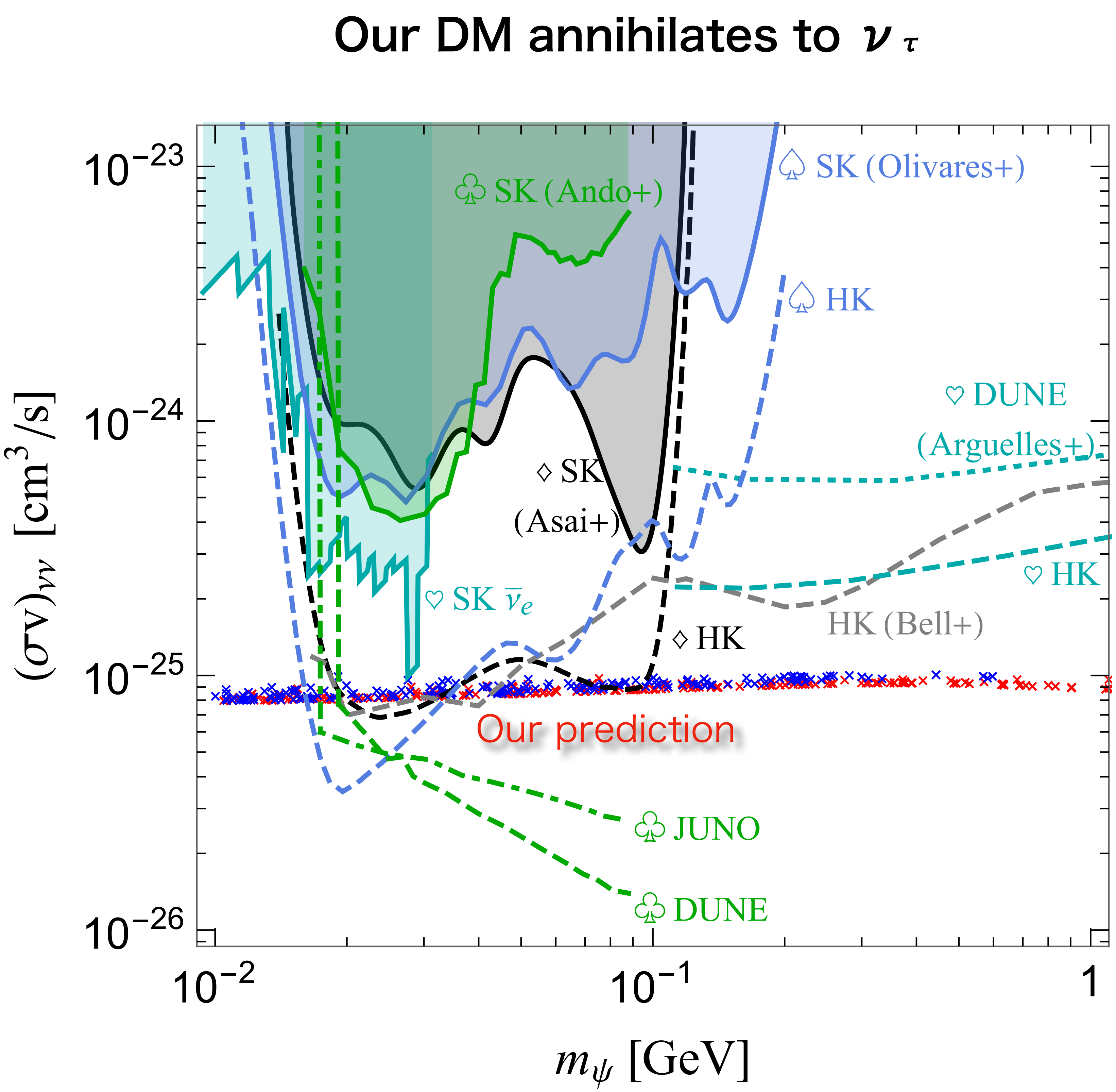
$$\frac{\lambda_{345}}{4}(2vh+h^2)H^2$$

should be small.



It is possible to test in the indirect detection.

2011.04788 with Okawa



Summary and comments

- In lepton portal DM models, direct detection is given by the loop diagrams, but Dirac DM model is almost ruled out if $m_{DM} \geq 100\,\mathrm{GeV}.$
- DM lighter than 10 GeV can evade the strong bound. Mediator should be also light.
- Making mass difference among scalars is a big issue: large couplings required in the scalar potential. $\rightarrow$ A solution is to add one more scalar (See our paper, arXiv: 2011.04788, S.Okawa and YO).
- In Higgs physics, h $\rightarrow \gamma\,\gamma$ is largely deviated (about 20 %) and invisible decay is also large, because of the large couplings.
- We can test our model, in the neutrino observation.

END

Backup

Extended model with a scalar

2011.04788 with Okawa

	Fields	spin	$SU(3)$	$SU(2)_L$	$U(1)_Y$	$U(1)_L$	Z_2
	Q_L^i	$1/2$	$\mathbf{3}$	$\mathbf{2}$	$\frac{1}{6}$	0	$+$
	u_R^i	$1/2$	$\mathbf{3}$	$\mathbf{1}$	$\frac{2}{3}$	0	$+$
	d_R^i	$1/2$	$\mathbf{3}$	$\mathbf{1}$	$-\frac{2}{3}$	0	$+$
	ℓ_L^i	$1/2$	$\mathbf{1}$	$\mathbf{2}$	$-\frac{1}{2}$	1	$+$
	e_R^i	$1/2$	$\mathbf{1}$	$\mathbf{1}$	-1	1	$+$
	ψ_L	$1/2$	$\mathbf{1}$	$\mathbf{1}$	0	1	$-$
	ψ_R	$1/2$	$\mathbf{1}$	$\mathbf{1}$	0	1	$-$
	Φ	1	$\mathbf{1}$	$\mathbf{2}$	$\frac{1}{2}$	0	$+$
	Φ_ν	1	$\mathbf{1}$	$\mathbf{2}$	$\frac{1}{2}$	0	$-$
extra	S	1	$\mathbf{1}$	$\mathbf{1}$	0	0	$-$

Additional coupling involving S

$$-\Delta\mathcal{L} = A_S\,\Phi^\dagger\Phi_\nu S + h.c.$$

Result in extended model with a scalar

2011.04788 with Okawa