BSM Phenomenologies inspired by Singlet-Doublet fermion dark matter

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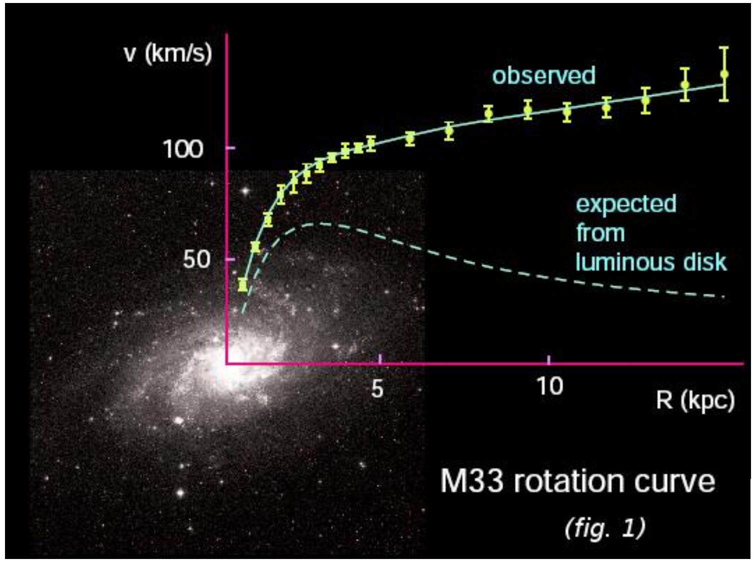
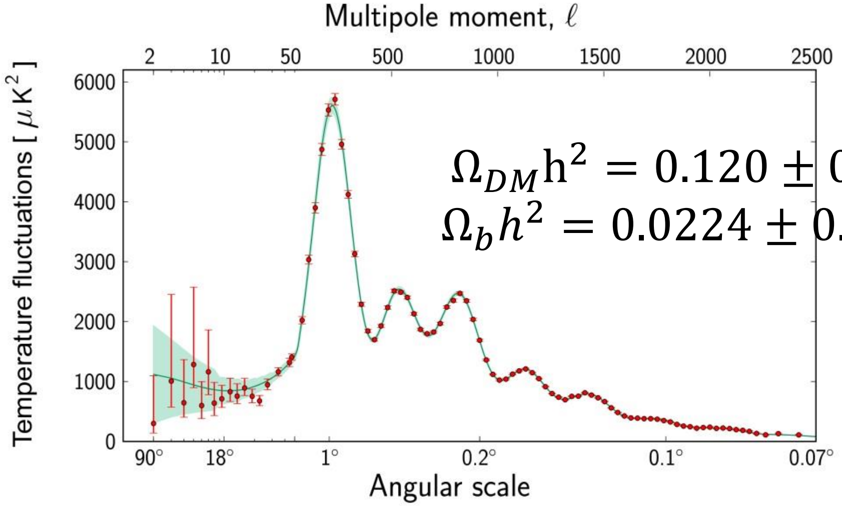
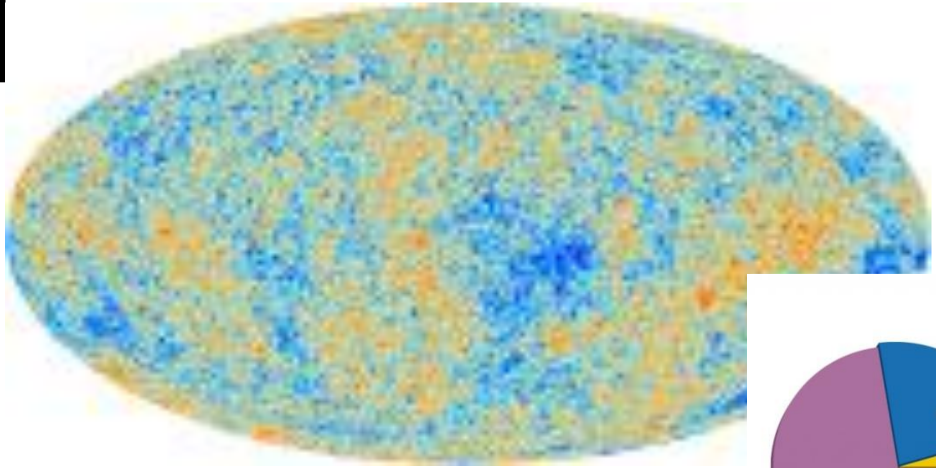
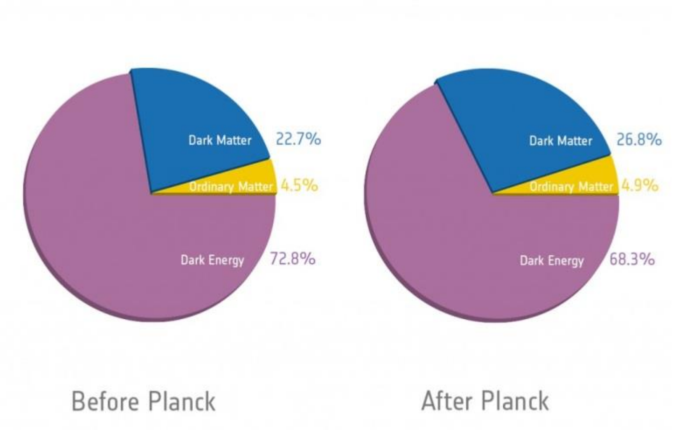
Indirect Evidences of DM



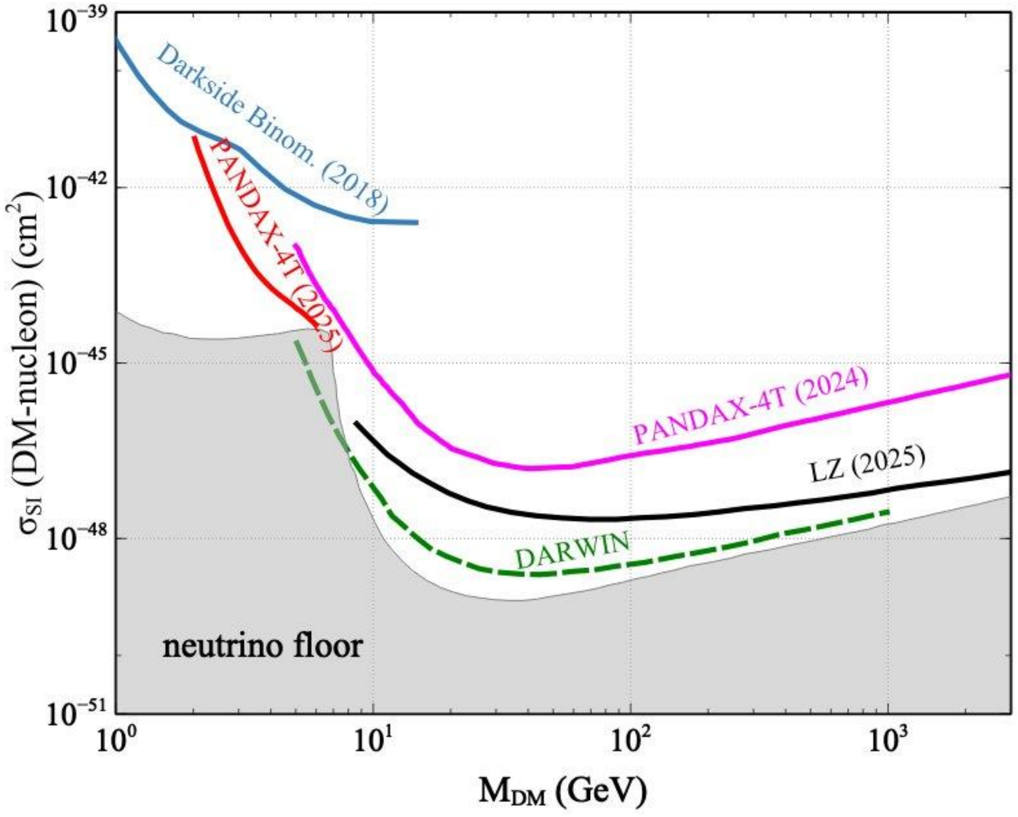


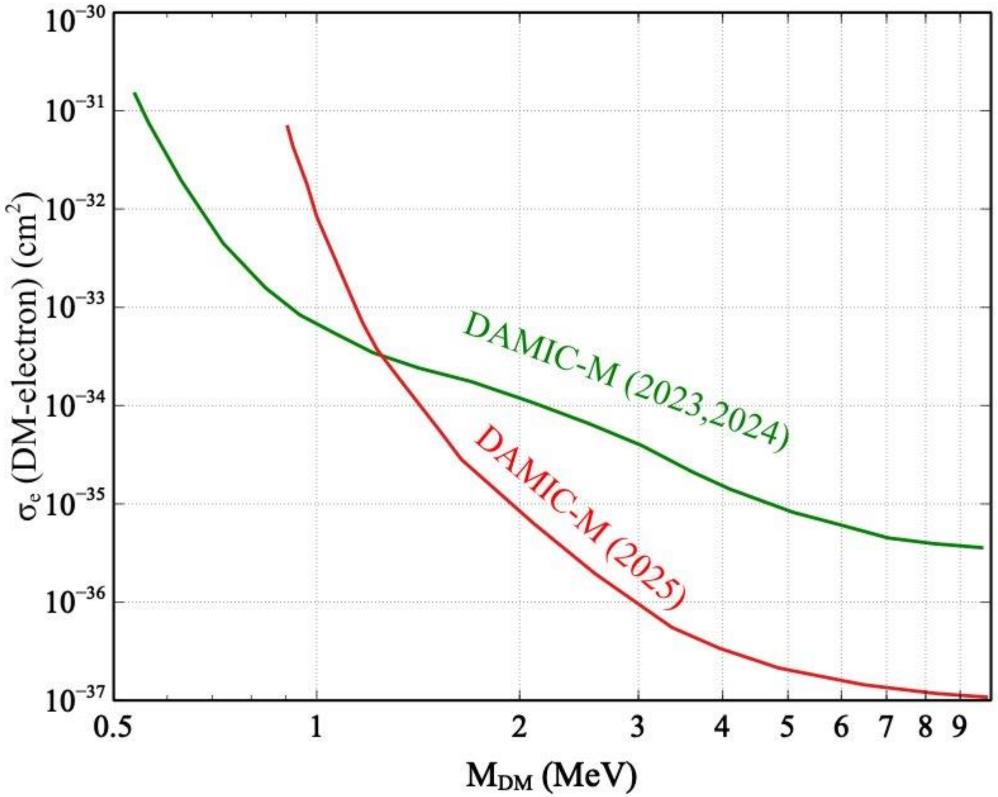
$$\Omega_{DM}\mathrm{h}^2 = 0.120 \pm 0.001$$
$$\Omega_b h^2 = 0.0224 \pm 0.0001$$



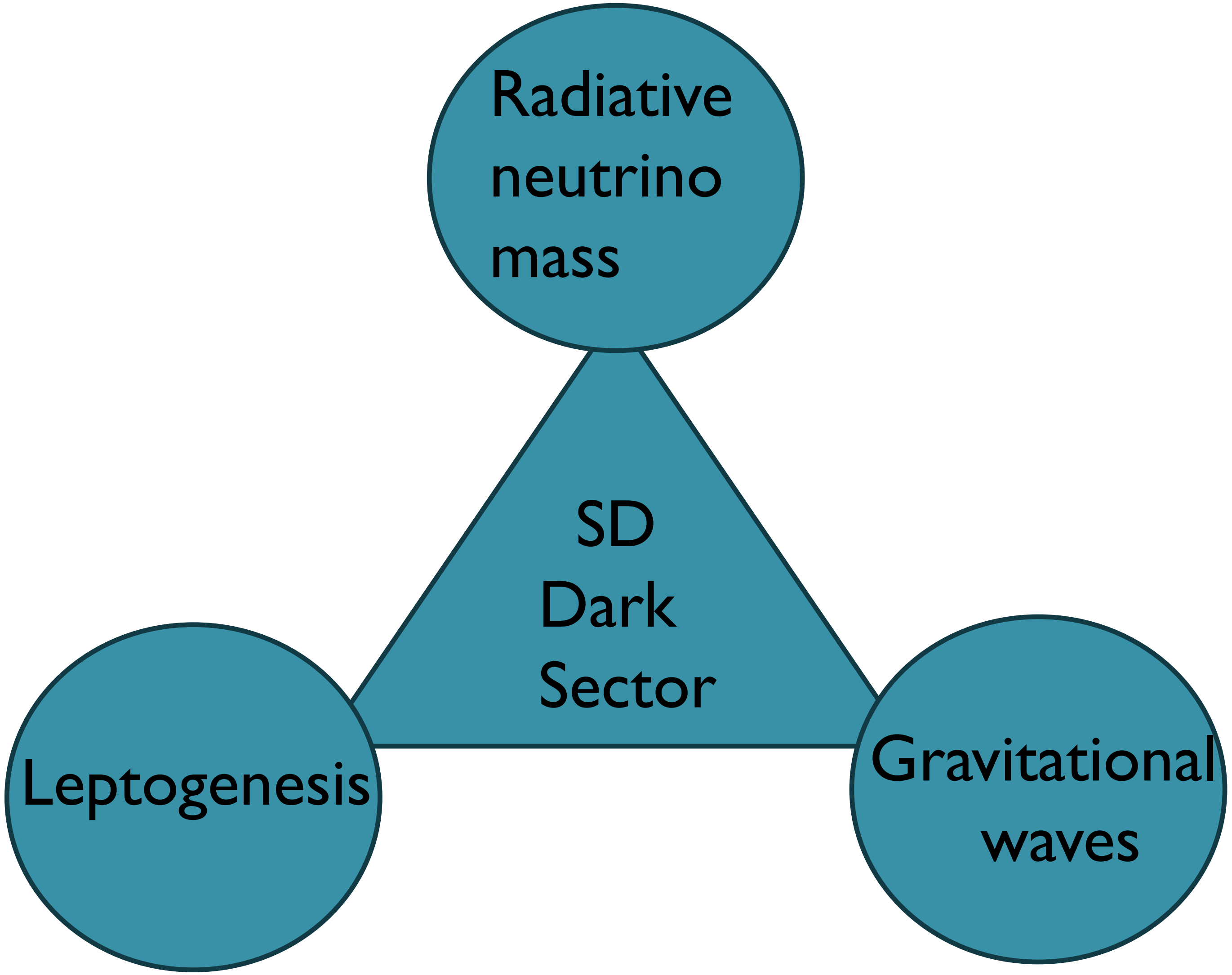


Direct detection constraints on DM





Null detection of DM implies a rich dark sector?



Singlet-Doublet mixed Dirac Fermion Dark Matter

χ^0 →A vector-like singlet Fermion

N- A vector-like doublet fermion

$\Big\}$ Odd under a Z_2 symmetry

$$\mathcal{L}_{DM} = M_N \overline{N}N + M_\chi \overline{\chi^0}\chi^0 + [Y\overline{N}\tilde{H}\chi^0 + h.c.]$$
$$+\overline{N}i\gamma^\mu D_\mu N + \overline{\chi^0}i\gamma^\mu\partial_\mu\chi^0$$

S. Bhattacharya, Nirakar Sahoo and **N. Sahu**, PRD93, 2016 [1510.02760]; PRD96, 2017 [1704.03417]

where $N = \begin{pmatrix} N^0 \\ N^- \end{pmatrix} \equiv (1,2,-1), H = \begin{pmatrix} H^+ \\ H^0 \end{pmatrix} \equiv (1,2,1), \chi^0 \equiv (1,1,0)$

The DM emerges as a mixture of singlet fermion χ^0 and the neutral component of the vector like doublet fermion N.

Singlet-Doublet mixed Dirac Fermion DM

After EW phase transition the mass matrix for neutral vector-like fermions is given by

$$\begin{pmatrix} \overline{N^0} & \overline{\chi^0} \end{pmatrix} \begin{pmatrix} M_N & m_D \\ m_D & M_\chi \end{pmatrix} \begin{pmatrix} N^0 \\ \chi^0 \end{pmatrix}$$

Where $m_D = Y < H >$

After diagonalising one gets:

$$M_1 = M_\chi - \frac{m_D^2}{M_N - M_\chi}; N_1 = \cos\theta \chi^0 + \sin\theta N^0$$

$$M_2 = M_N + \frac{m_D^2}{M_N - M_\chi}; N_2 = \cos\theta N^0 - \sin\theta \chi^0$$

$$M^\pm = M_1 \sin^2\theta + M_2 \cos^2\theta = M_N; N^\pm$$

Where $$\tan 2\theta = \frac{m_D}{M_N - M_\chi}$$

The model contains three independent parameters: $\{M_1, M_2, \sin\theta\}$ or $\{Y, M_1, M_2\}$

where, Y and $\sin\theta$ are related by

$$Y = \frac{\Delta M sin2\theta}{2v},$$

Where $\Delta M = M_2 - M_1$

DOUBLET CHERRY

SINGLET CAKE

The lightest particle is the N_1, which is candidate of dark matter with appropriate mixing angle θ

Relic density of SD-Dirac Fermion DM

The relic density can be obtained by solving the relevant Boltzmann equation:

$$\frac{dn}{dt} + 3\mathcal{H}n = -\langle\sigma v\rangle_{\text{eff}}(n^2 - (n^{\text{eq}})^2) \qquad \text{where } n = \textstyle\sum_i n_i$$

Griest and Secklel: PRD 1991

$$\begin{aligned}
\langle\sigma v\rangle_{eff} &= \frac{g_1^2}{g_{eff}^2}\langle\sigma v\rangle_{\overline{N_1}N_1} + \frac{2g_1g_2}{g_{eff}^2}\langle\sigma v\rangle_{\overline{N_1}N_2}\left(1+\frac{\Delta m}{m_{N_1}}\right)^{\frac{3}{2}} e^{-x\frac{\Delta m}{m_{N_1}}} \\
&+ \frac{2g_1g_3}{g_{eff}^2}\langle\sigma v\rangle_{\overline{N_1}N^-}\left(1+\frac{\Delta m}{m_{N_1}}\right)^{\frac{3}{2}} e^{-x\frac{\Delta m}{m_{N_1}}} \\
&+ \frac{2g_2g_3}{g_{eff}^2}\langle\sigma v\rangle_{\overline{N_2}N^-}\left(1+\frac{\Delta m}{m_{N_1}}\right)^{3} e^{-2x\frac{\Delta m}{m_{N_1}}} \\
&+ \frac{g_2^2}{g_{eff}^2}\langle\sigma v\rangle_{\overline{N_2}N_2}\left(1+\frac{\Delta m}{m_{N_1}}\right)^{3} e^{-2x\frac{\Delta m}{m_{N_1}}} \\
&+ \frac{g_3^2}{g_{eff}^2}\langle\sigma v\rangle_{N^+N^-}\left(1+\frac{\Delta m}{m_{N_1}}\right)^{3} e^{-2x\frac{\Delta m}{m_{N_1}}} .
\end{aligned}$$

annihilation

S. Bhattacharya, Purusottam Ghosh, Nirakar Sahoo and **N. Sahu**, [1812.06505]

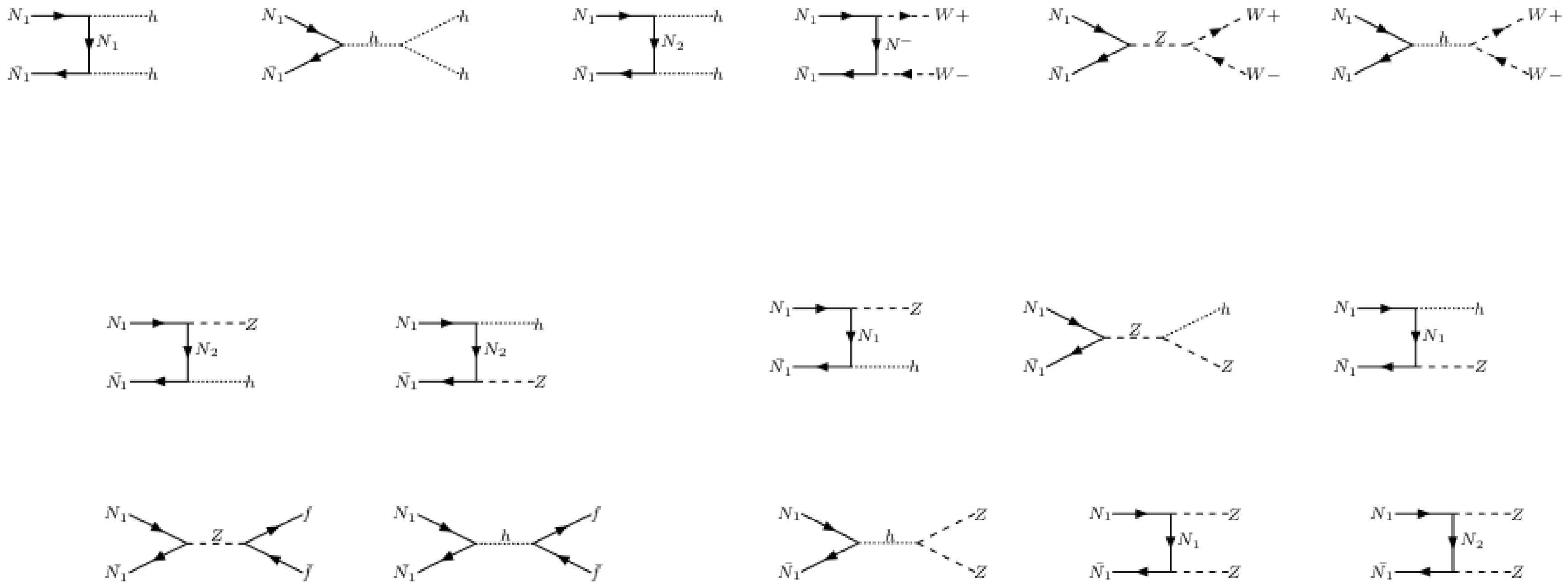
Independent of singlet-doublet mixing,

Where $g_{eff} = g_1 + g_2(1+\Delta)^{3/2}exp(-x\Delta) + g_3(1+\Delta)^{3/2}exp(-x\Delta)$.

With $\Delta = \frac{M_i - M_1}{M_1}$ $\qquad x = \frac{M_1}{T}$

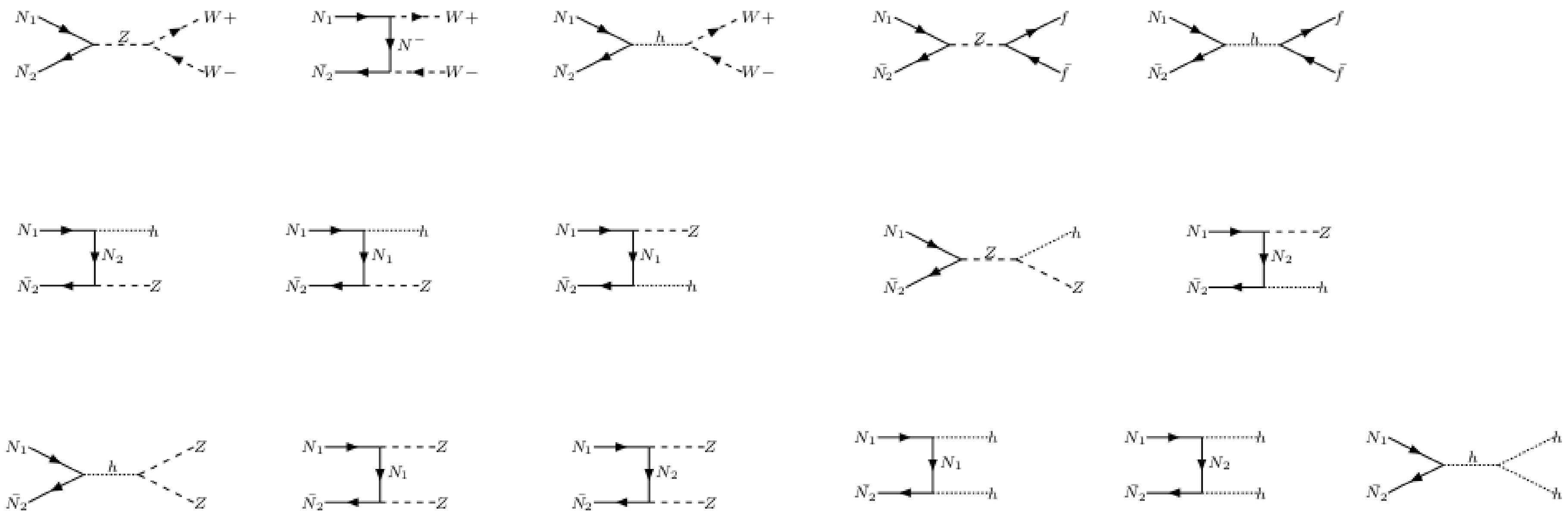
Annihilation processes

$$N_1 \overline{N_1} \rightarrow SM$$



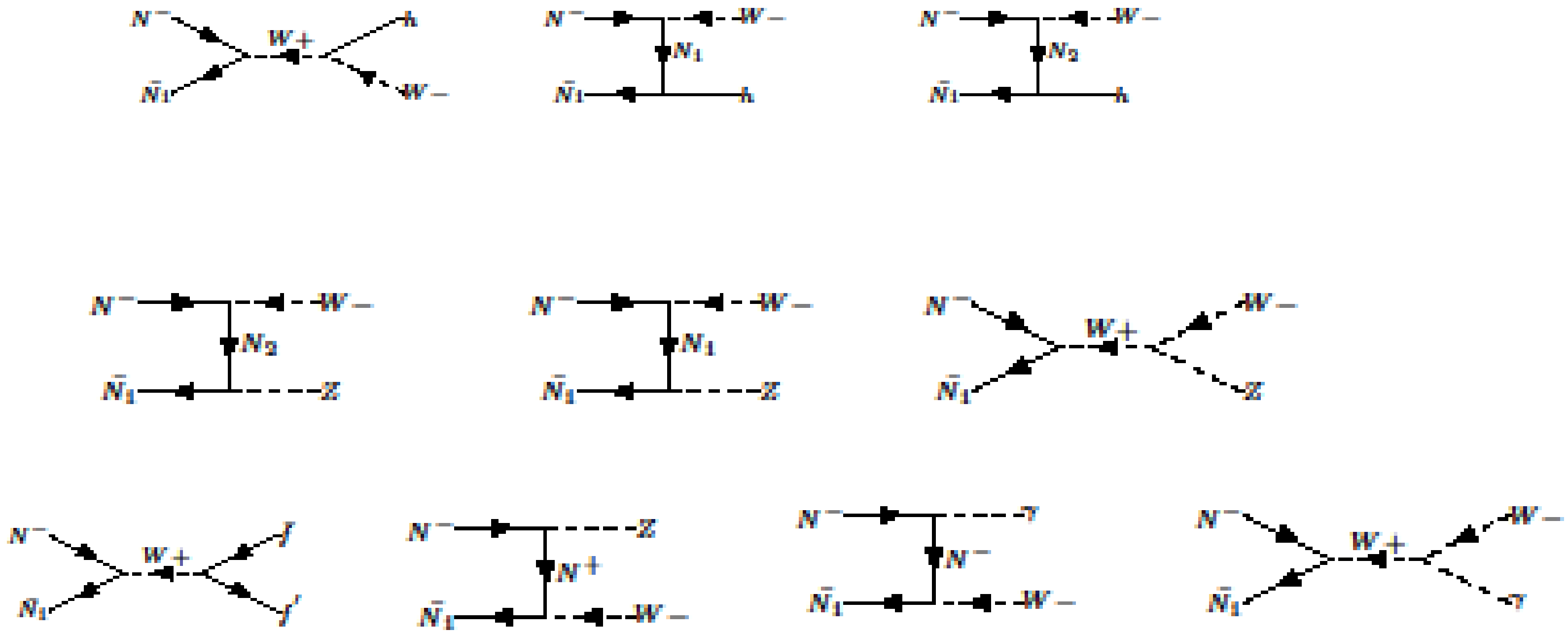
Co-annihilation processes

$$N_1 N_2 \to SM$$



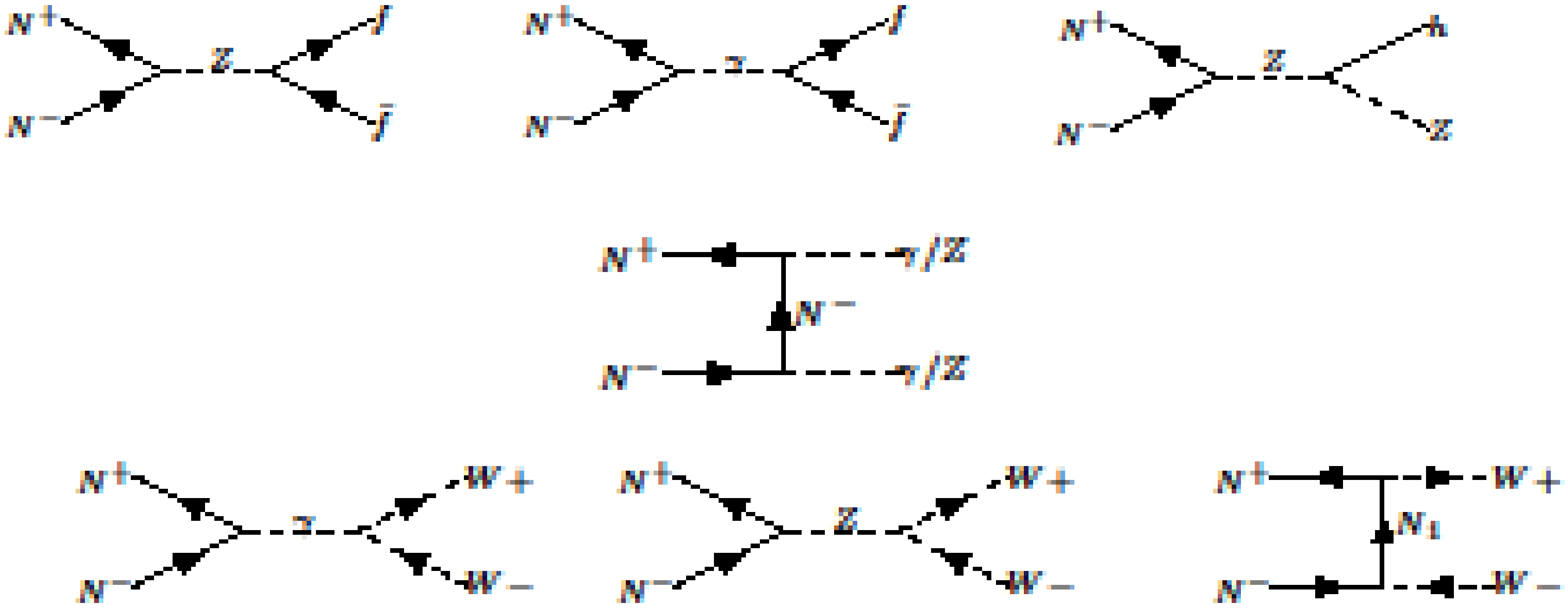
Co-annihilation processes

$$N_1 N^- \rightarrow SM$$



Co-annihilation processes

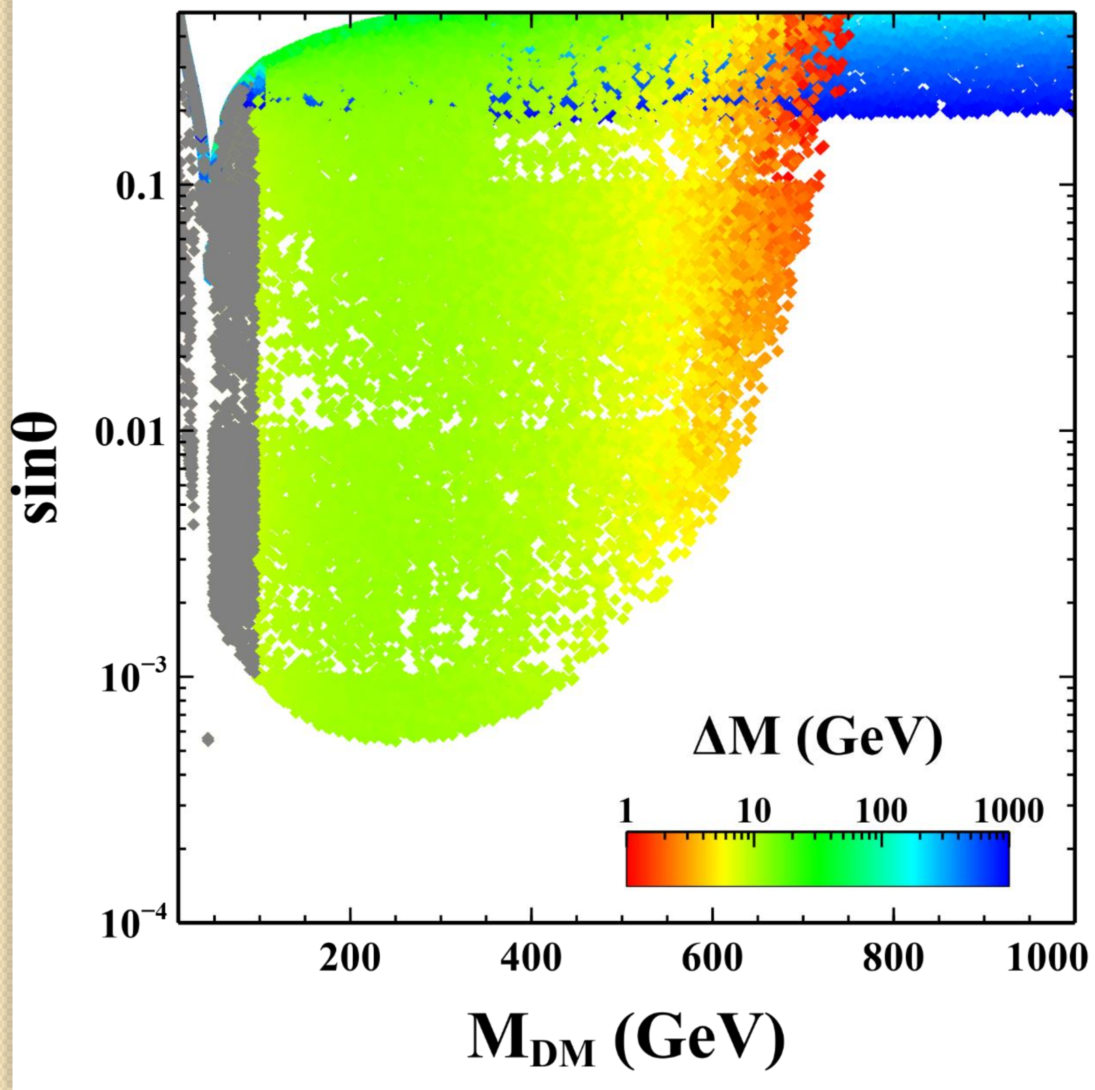
$$N^+N^- \to SM$$

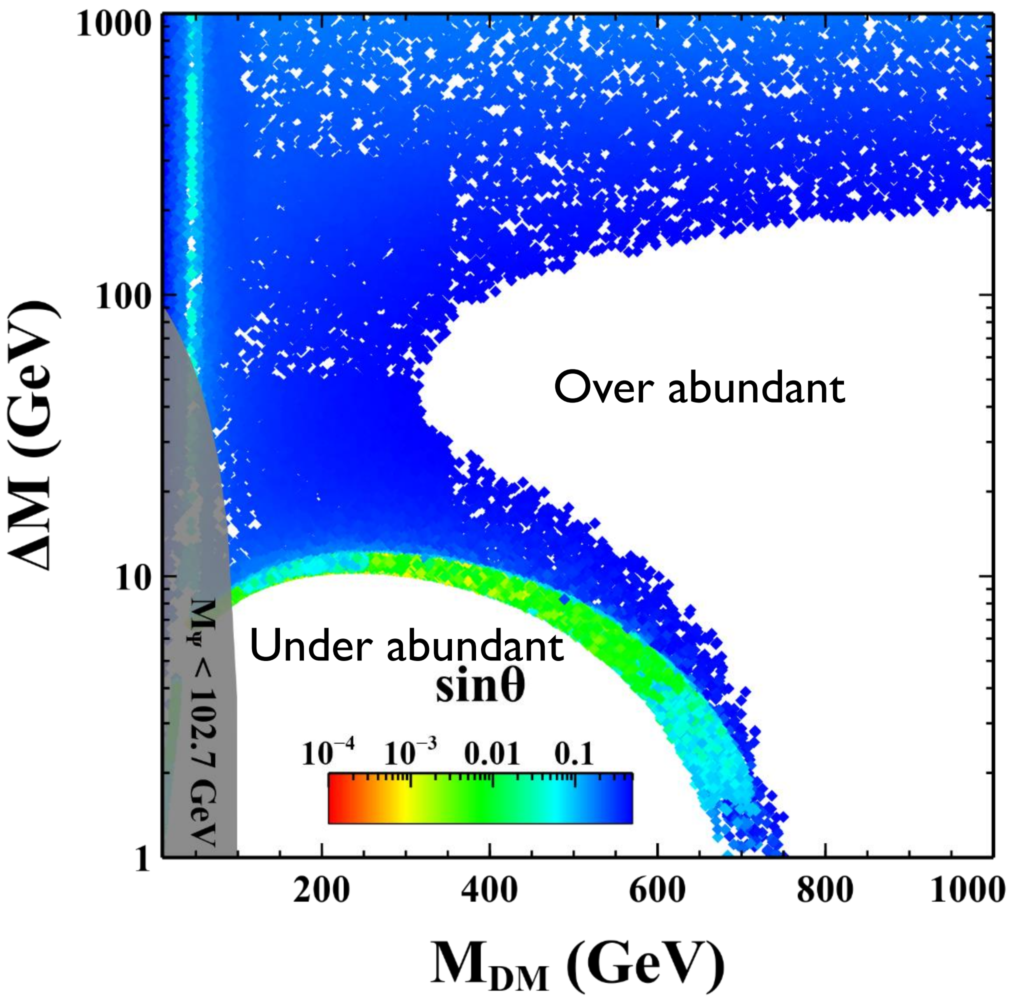


We look for the observed relic abundance in the parameter space spanned by $M_1, M_2 \approx M^{\pm}, \sin\theta$

We assume both singlet and doublet components decouple at the same epoch. This is true only for relatively large singlet-doublet mixing as shown by the following diagram:

$M_1 = M_{DM}$





Q1. What will happen if SD-mixing is further reduced ?

Q2. Can we be able to produce required dark matter relic ?

Partha Kumar Paul, Sujit Kumar Sahoo and **N. Sahu**, [arXiv: 2412. 02607 (JCAP2025)]
[arXiv: 2511.14571 (PRD 2026)]

The effective cross-section approach fails

Two Boltzmann equations for the dark sector

As the singlet-Doublet mixing is reduced further, the singlet and doublet components decouple at different epochs. The singlet decouple early with a larger abundance, while the doublet components decouple at late epochs with a smaller abundance. Therefore, one needs two Boltzmann equations for the dark sector particles: $N_1, N_2, N^\pm$. One equation is not sufficient as $N^+N^- \to SM$ is independent of singlet-doublet mixing.

Sector-1: N_1 (Dominantly singlet with a little admixture of doublet)

Sector-2: N_2 (Dominantly doublet with a little admixture of singlet), $N^\pm$

Sector-0: SM particles

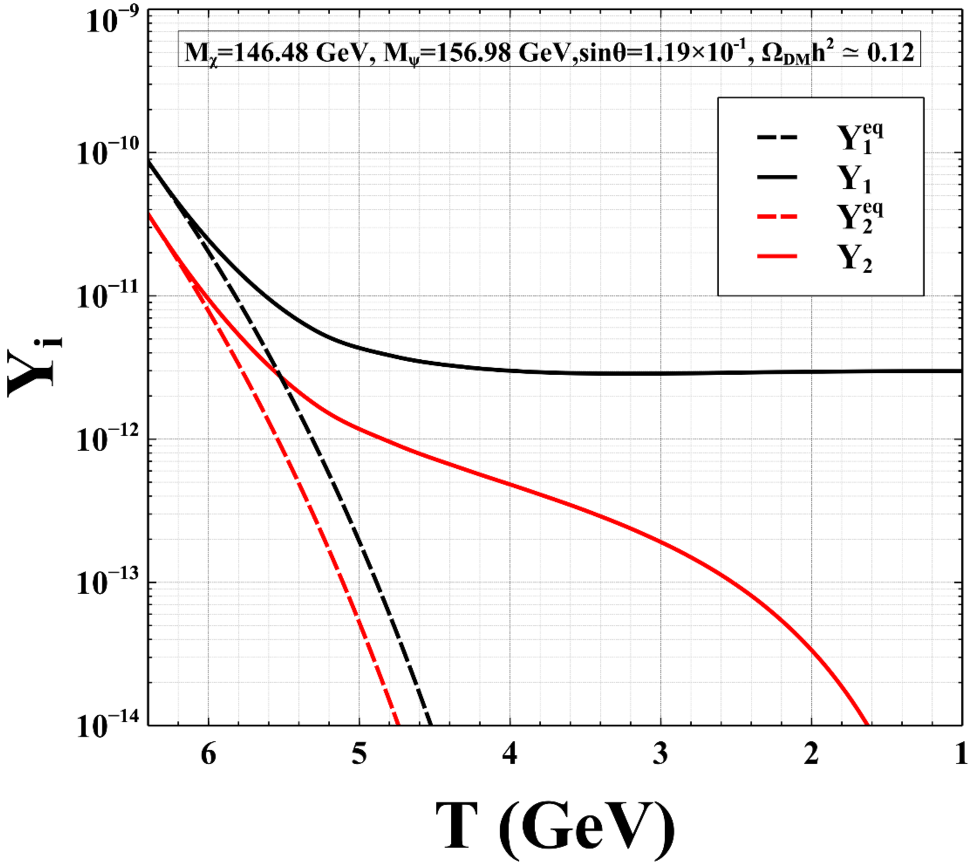
$$\frac{dY_1}{dT} = \frac{1}{3\mathcal{H}}\frac{ds}{dT}\Bigg[\langle\sigma_{1100}v\rangle(Y_1^2 - Y_1^{eq2}) + \langle\sigma_{1122}v\rangle\left(Y_1^2 - Y_2^2\frac{Y_1^{eq2}}{Y_2^{eq2}}\right) + \langle\sigma_{1200}v\rangle(Y_1Y_2 - Y_1^{eq}Y_2^{eq})$$
$$+ \langle\sigma_{1222}v\rangle\left(Y_1Y_2 - Y_2^2\frac{Y_1^{eq}}{Y_2^{eq}}\right) - \langle\sigma_{1211}v\rangle\left(Y_1Y_2 - Y_1^2\frac{Y_2^{eq}}{Y_1^{eq}}\right) - \frac{\Gamma_{2\to1}}{s}\left(Y_2 - Y_1\frac{Y_2^{eq}}{Y_1^{eq}}\right)\Bigg],$$

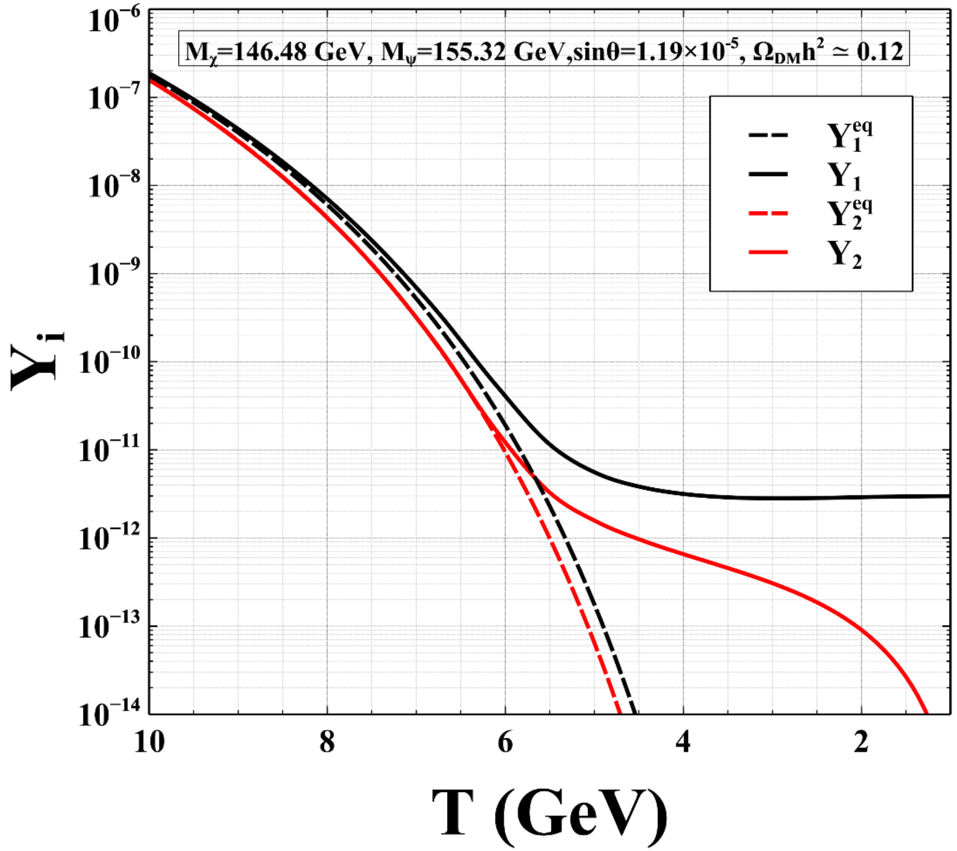
$$
\begin{aligned}
\frac{dY_2}{dT} = \; & \frac{1}{3\mathcal{H}}\frac{ds}{dT}\Bigg[\langle\sigma_{2200}v\rangle(Y_2^2 - Y_2^{eq2}) - \langle\sigma_{1122}v\rangle\left(Y_1^2 - Y_2^2\frac{Y_1^{eq2}}{Y_2^{eq2}}\right) + \langle\sigma_{1200}v\rangle(Y_1Y_2 - Y_1^{eq}Y_2^{eq}) \\
& - \langle\sigma_{1222}v\rangle\left(Y_1Y_2 - Y_2^2\frac{Y_1^{eq}}{Y_2^{eq}}\right) + \langle\sigma_{1211}v\rangle\left(Y_1Y_2 - Y_1^2\frac{Y_2^{eq}}{Y_1^{eq}}\right) + \frac{\Gamma_{2\to1}}{s}\left(Y_2 - Y_1\frac{Y_2^{eq}}{Y_1^{eq}}\right)\Bigg],
\end{aligned}
$$

Decay + coscattering

Y_1 = Comoving number density of sector-1 particle

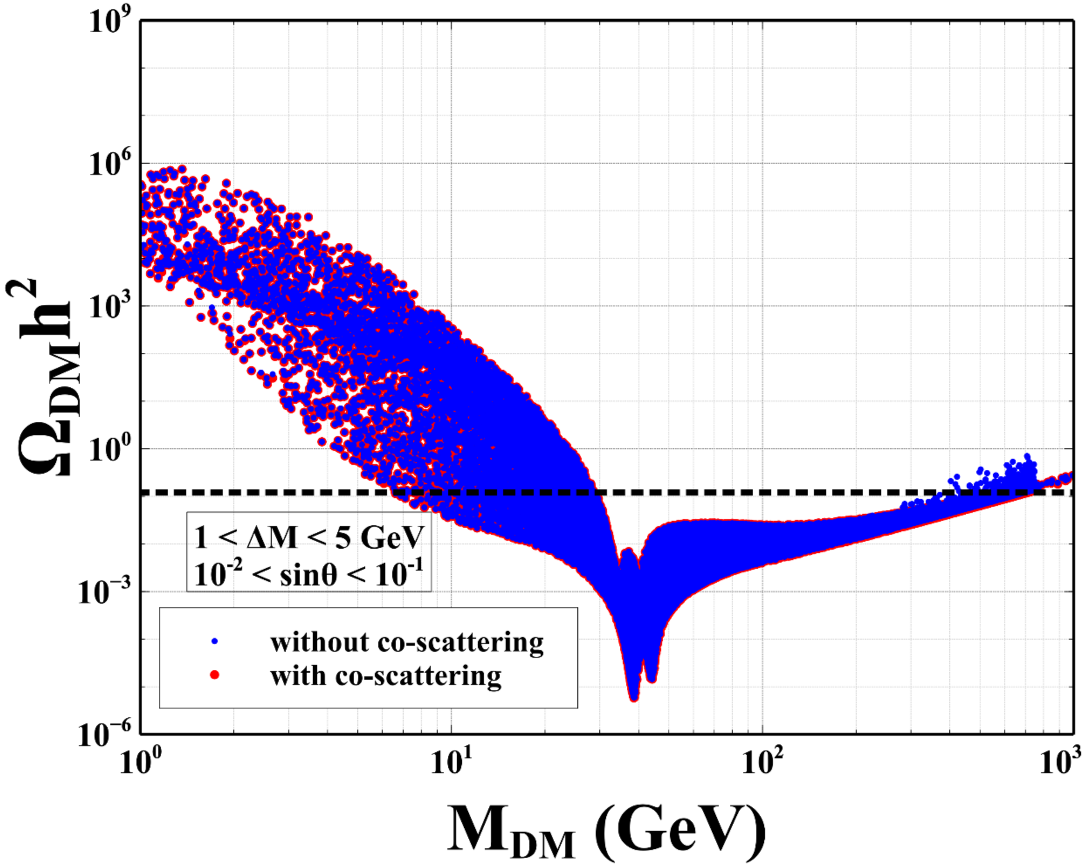
Y_2 = Comoving number density of sector-2 particles

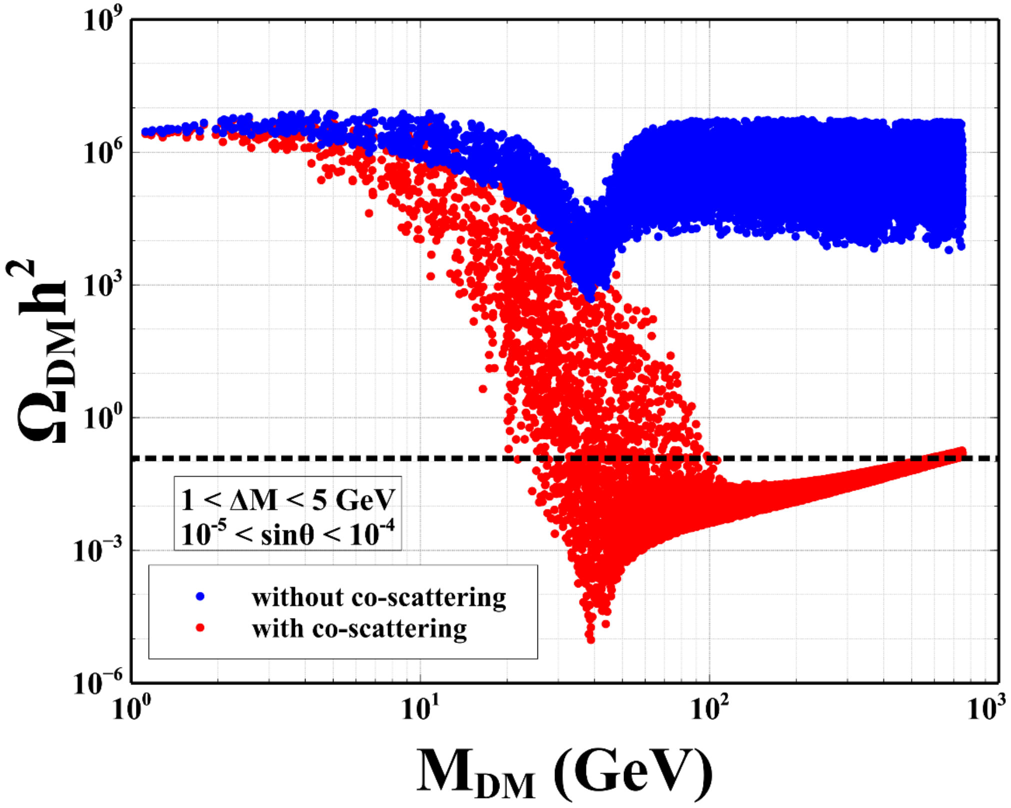




Effect of coscattering and decay on relic density

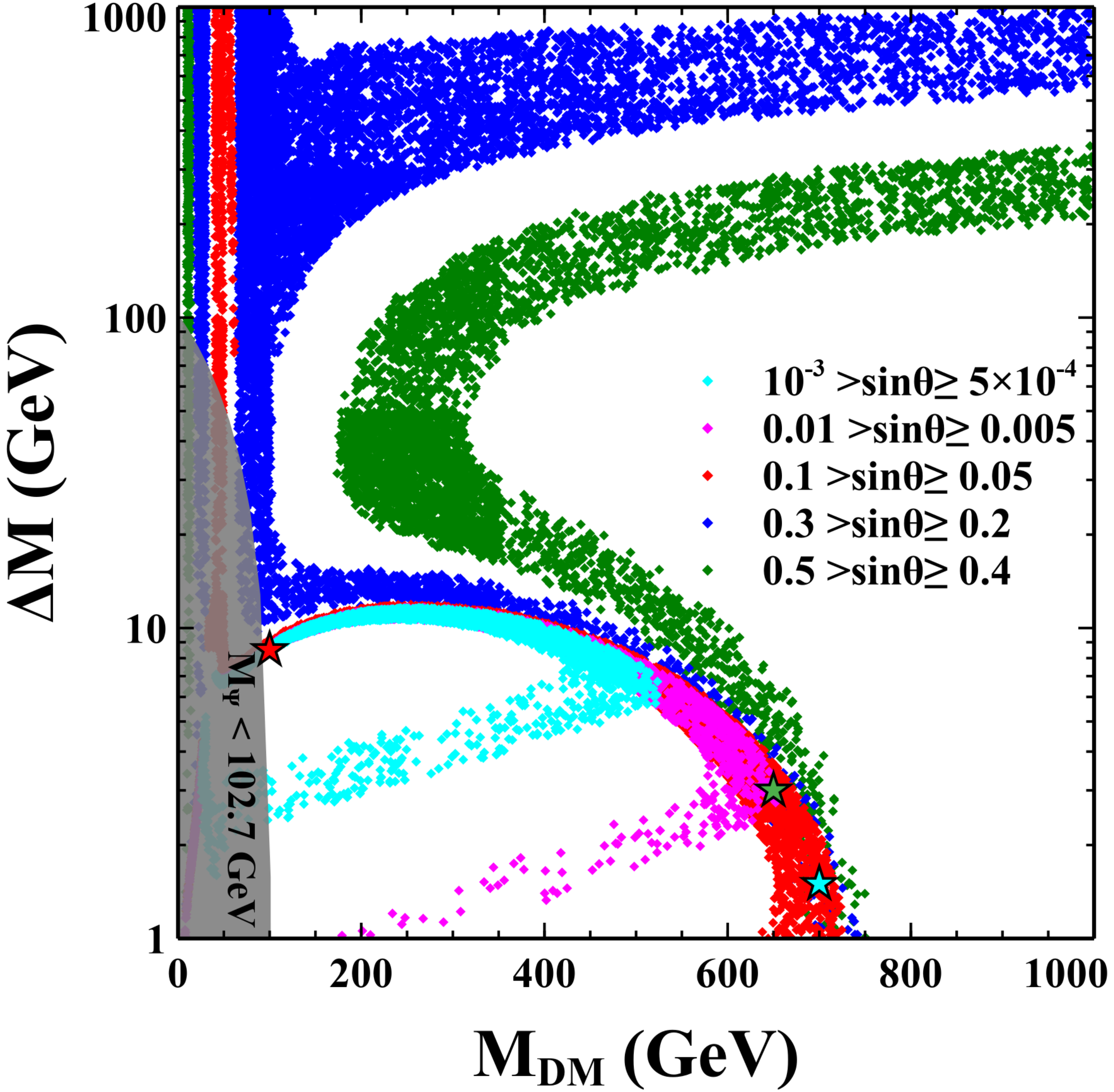
10→ 20 processes followed by 22→ 00 process





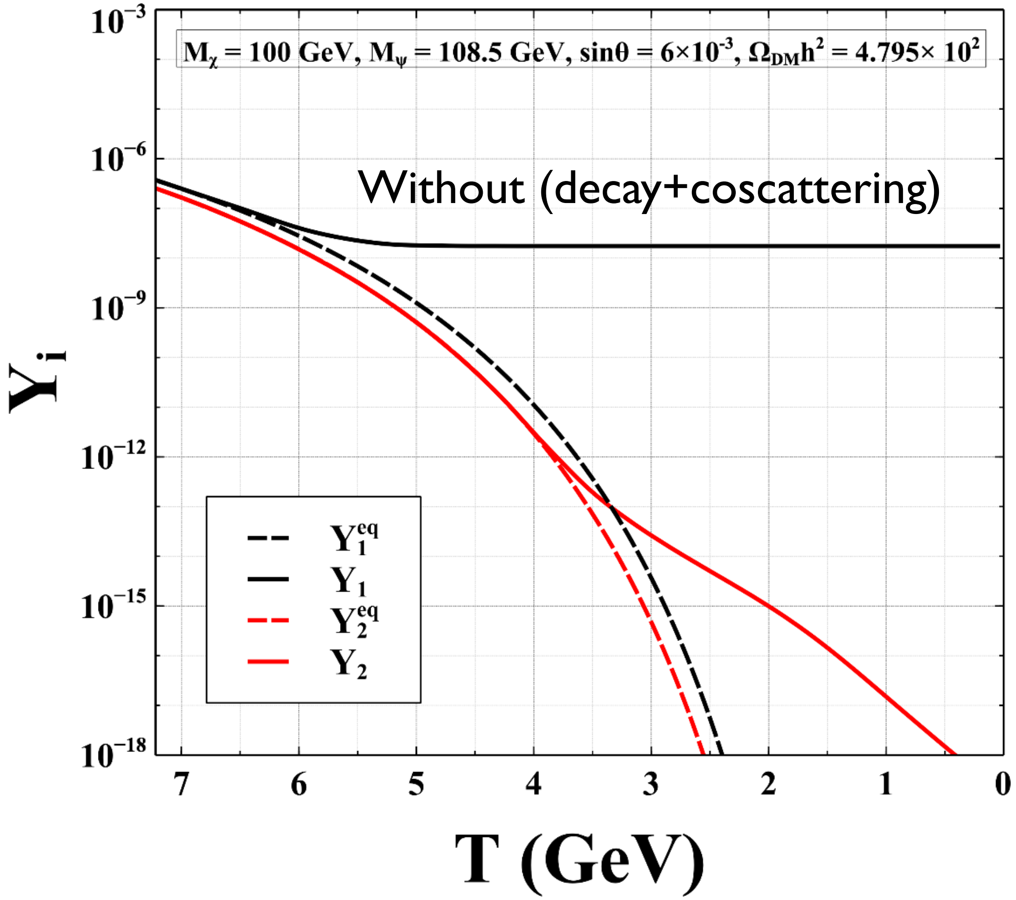
Partha Kumar Paul, Sujit Kumar Sahoo and **N. Sahu**, [arXiv: 2412. 02607 (JCAP2025)]
[arXiv: 2511.14571 (PRD 2026)]

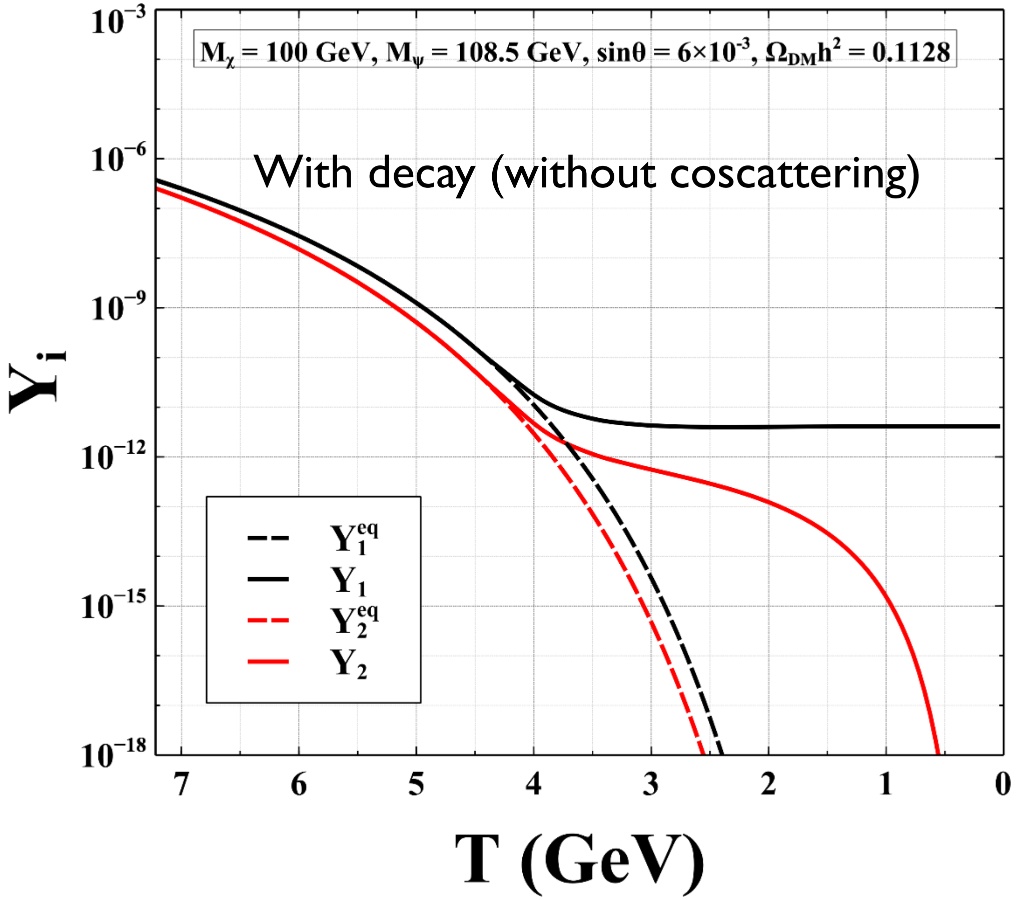
Without including coscattering effect, but decay included



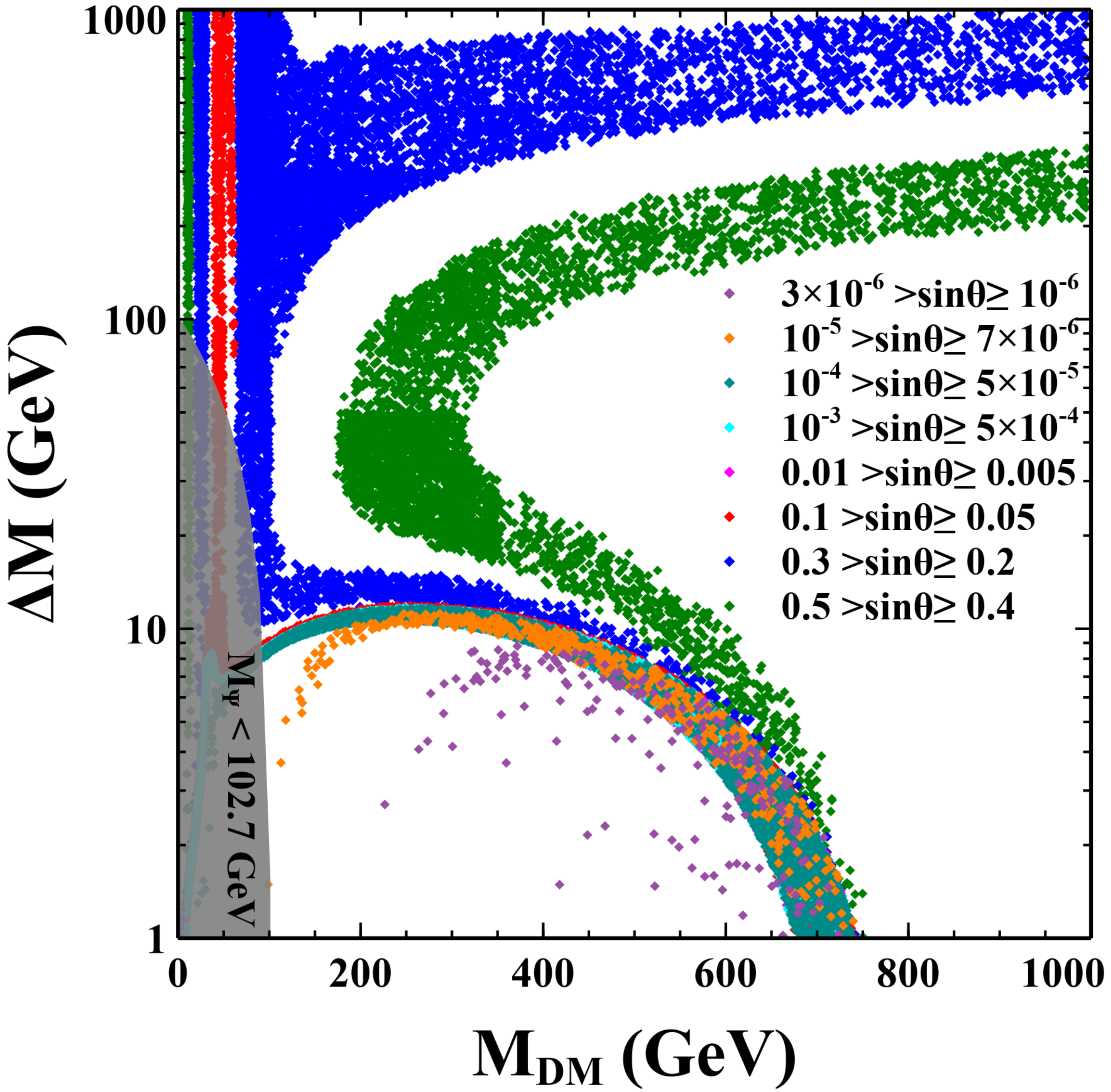
Partha Kumar Paul, Sujit Kumar Sahoo and **N. Sahu**, [arXiv: 2412. 02607 (JCAP2025)]

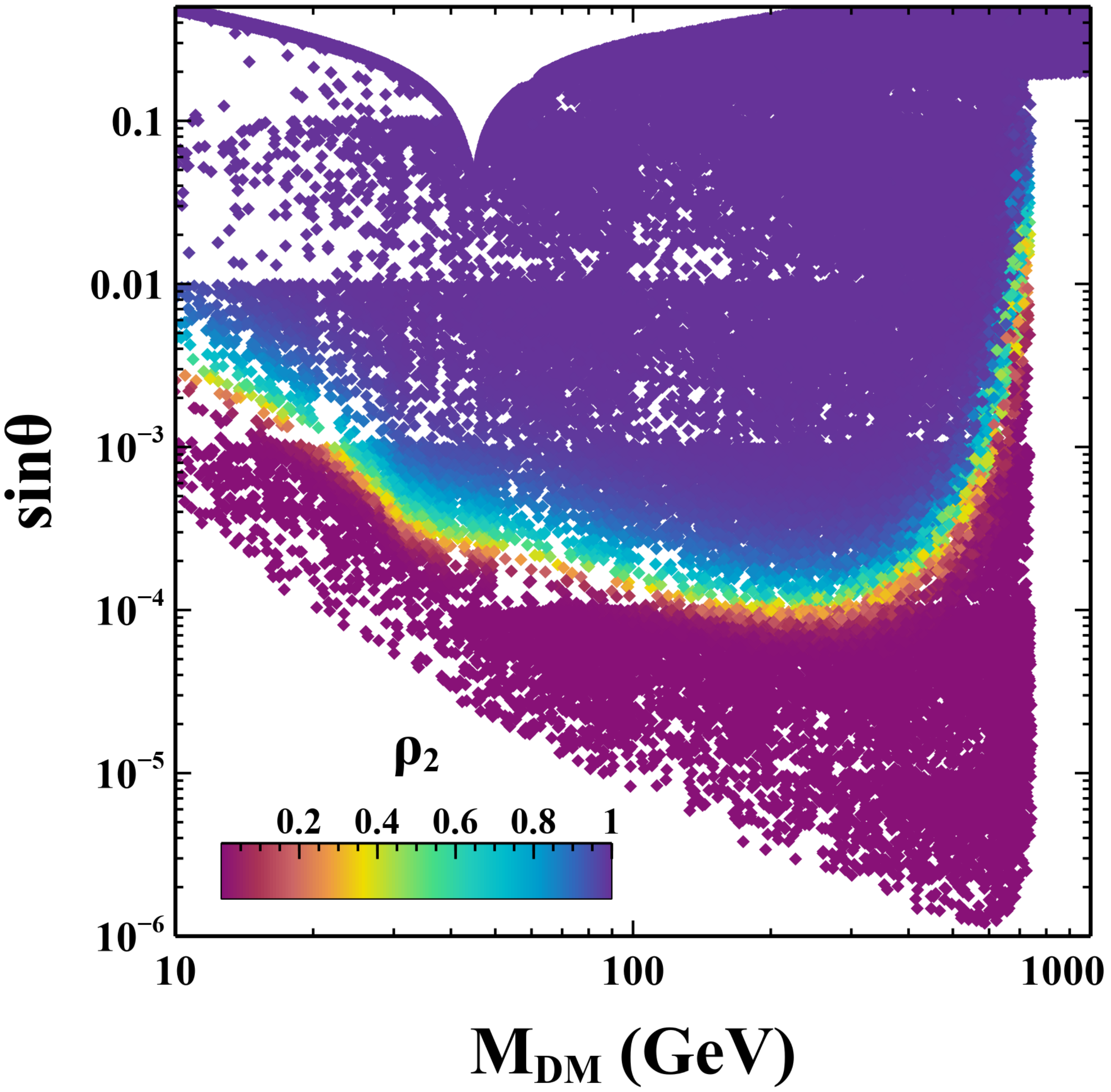
Point	$M_{\rm DM}$ (GeV)	ΔM (GeV)	$\sin\theta$	$\Omega_{2s}h^2$(no co-scattering)	$\Omega_{2s}h^2$(no co-scattering) without decay
A (⋆)	100	8.5	6×10^{-3}	0.1128	4.795×10^{2}
B (⋆)	650	3	9.5×10^{-3}	0.1269	2.503×10^{1}
C (⋆)	700	1.5	9.5×10^{-3}	0.3445	2.114×10^{1}
C (⋆)	700	1.5	9.9×10^{-2}	0.1234	0.1434





Including coscattering and decay effect





$$\rho_2 = \frac{\Omega_{2s} h^2}{\Omega_{2s} h^2(\text{no coscattering})};$$

Partha Kumar Paul, Sujit Kumar Sahoo and **N. Sahu**, [arXiv: 2412. 02607 (JCAP2025)]

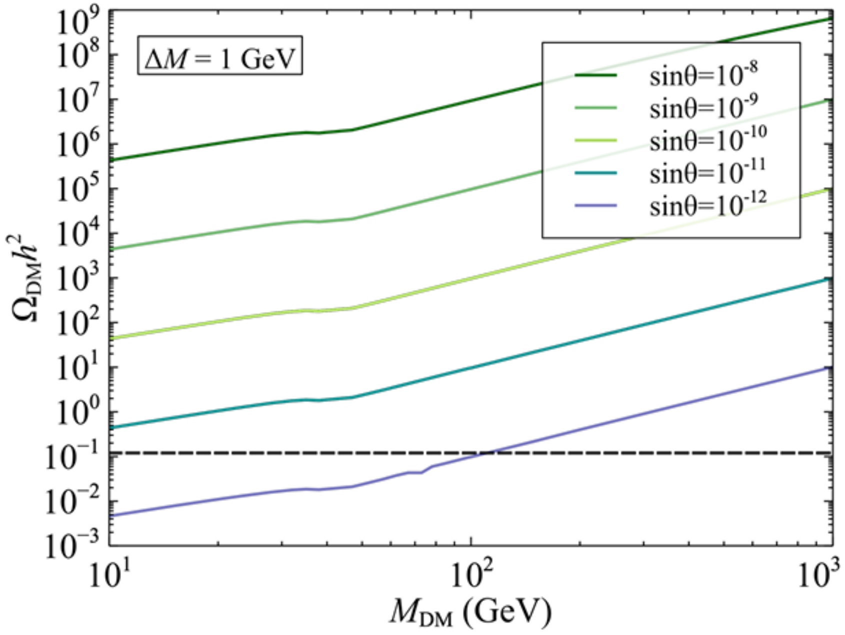
Q1. What will happen if SD-mixing is further reduced ?

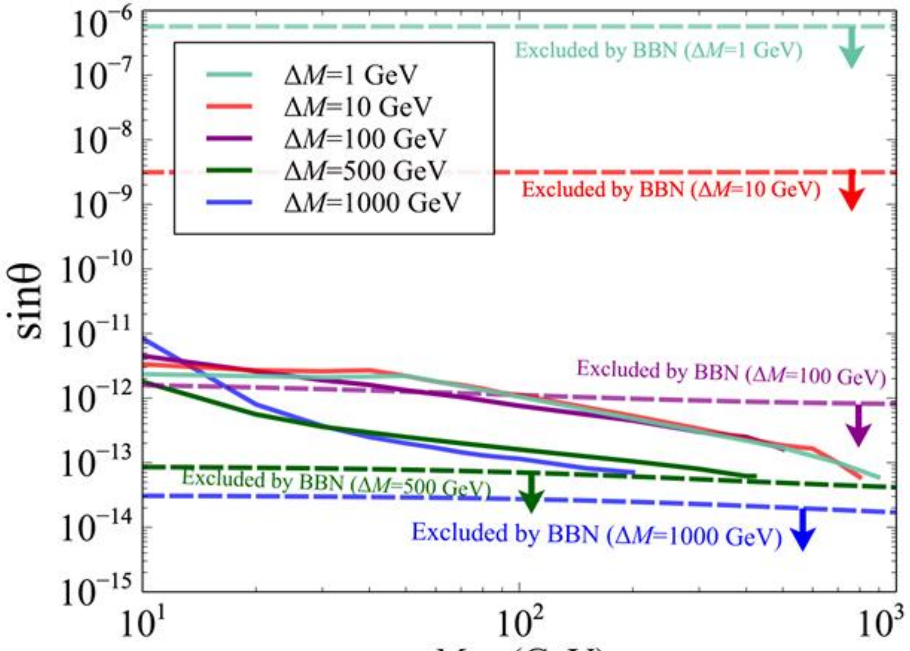
Q2. Can we be able to produce observed dark matter relic ?

Partha Kumar Paul, Sujit Kumar Sahoo and **N. Sahu**, [arXiv: 2412. 02607]

SD-Dark matter relic by Freeze-in ($\sin\theta < 10^{-6}$)

In this case the singlet does not equilibrate with the doublet. However, the relic can be produced via freeze-in mechanism by including all the scattering processes along with the decay and inverse decay. We can solve the same Boltzmann equations with the initial conditions: $Y_2 = Y_2^{eq}$ and $Y_1 = 0$.



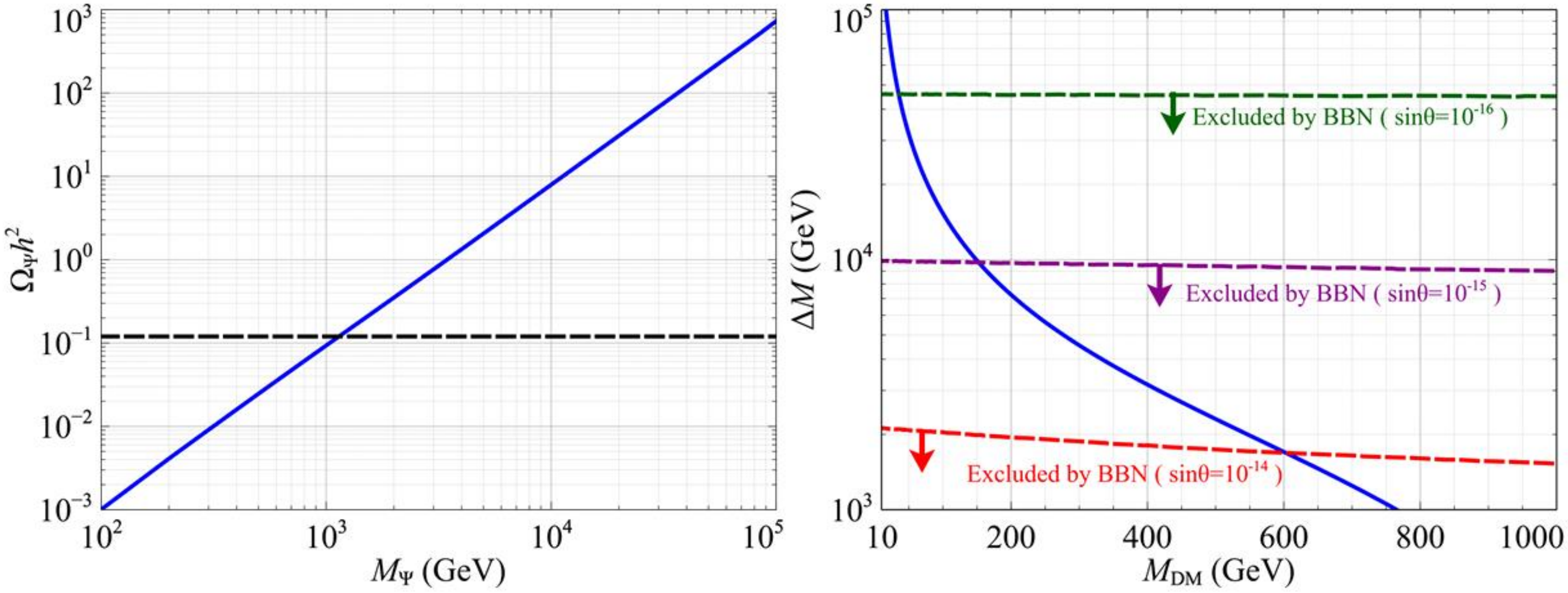


For $10^{-7} > \sin\theta > 10^{-11}$, the DM is over produced. Correct relic density is achieved for the SD-mixing angle in the range: $\{10^{-13} - 10^{-11}\}$

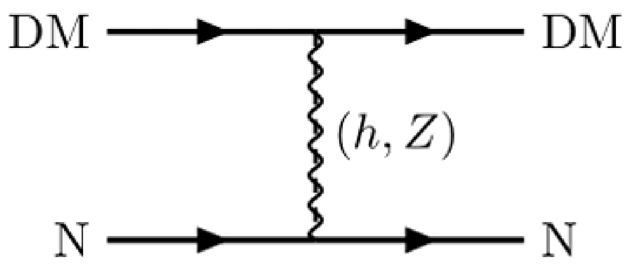
SD-Dark matter relic by super-WIMP mechanism

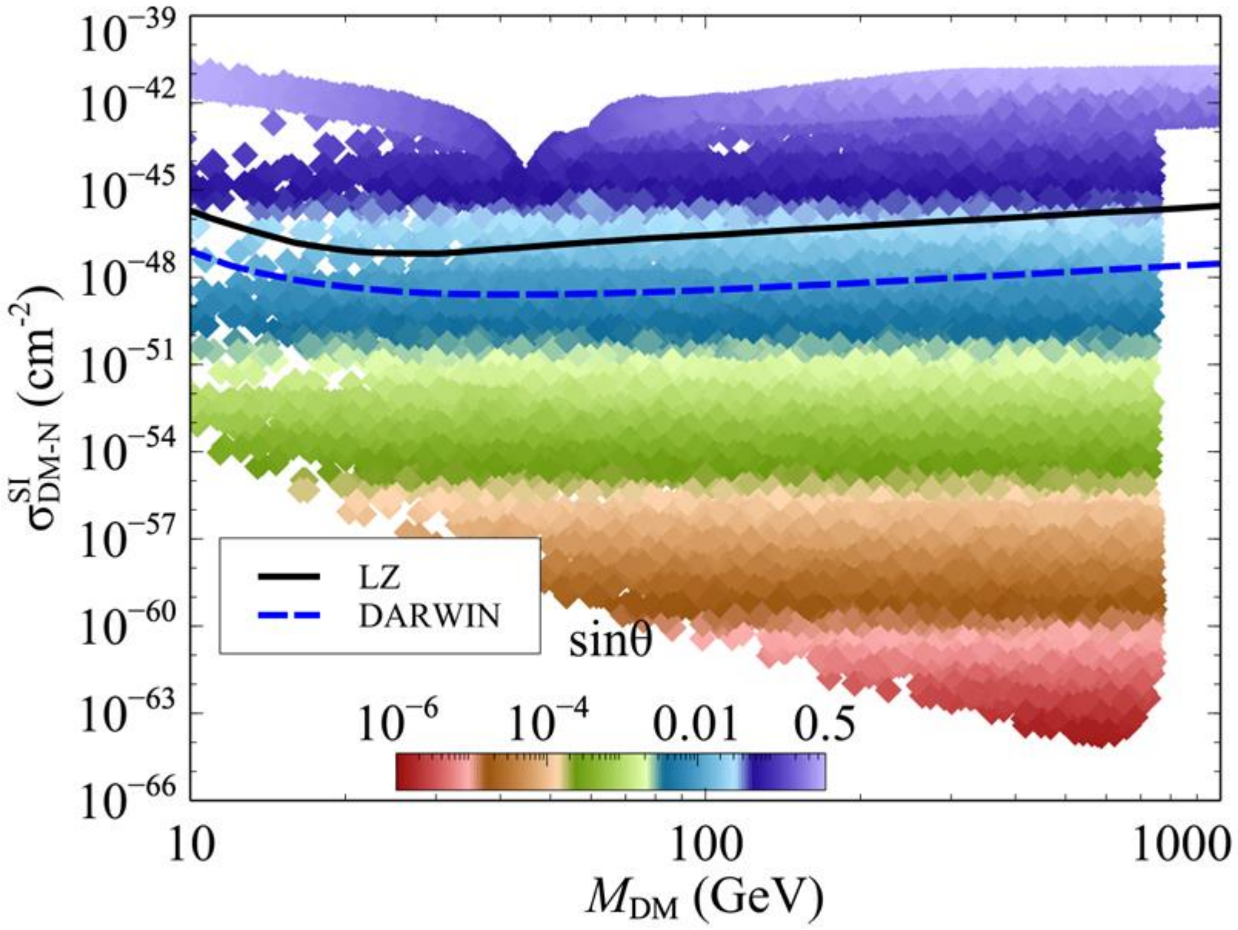
If the SD-mixing angle is reduced further, then the productions from scattering processes are negligible. However, the DM relic can be established from the decay of doublet as:

$$\Omega_{\rm DM}h^2 = \left(\frac{M_{\rm DM}}{M_\Psi}\right)\Omega_\Psi h^2$$

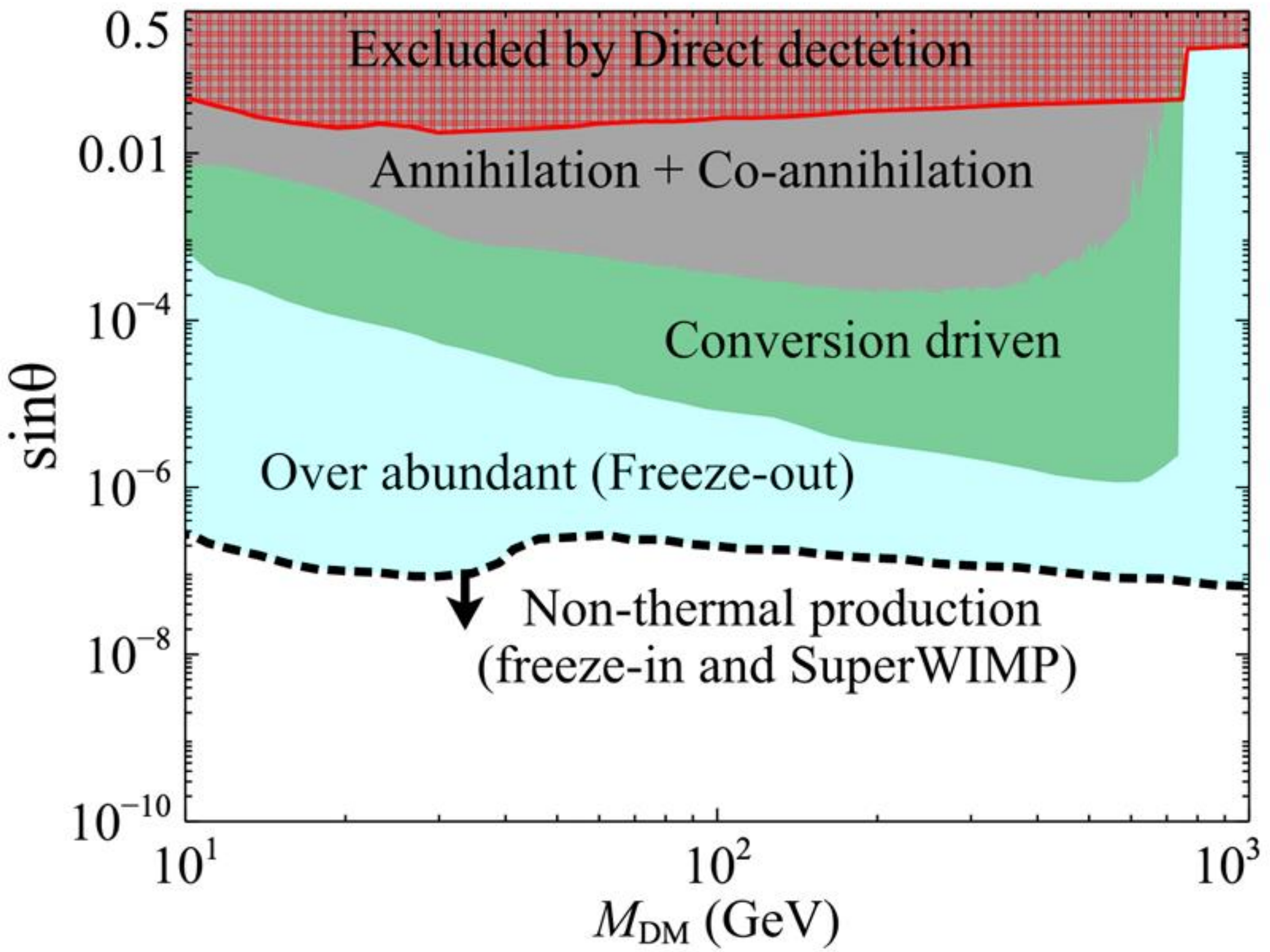


DD constraints on model parameters



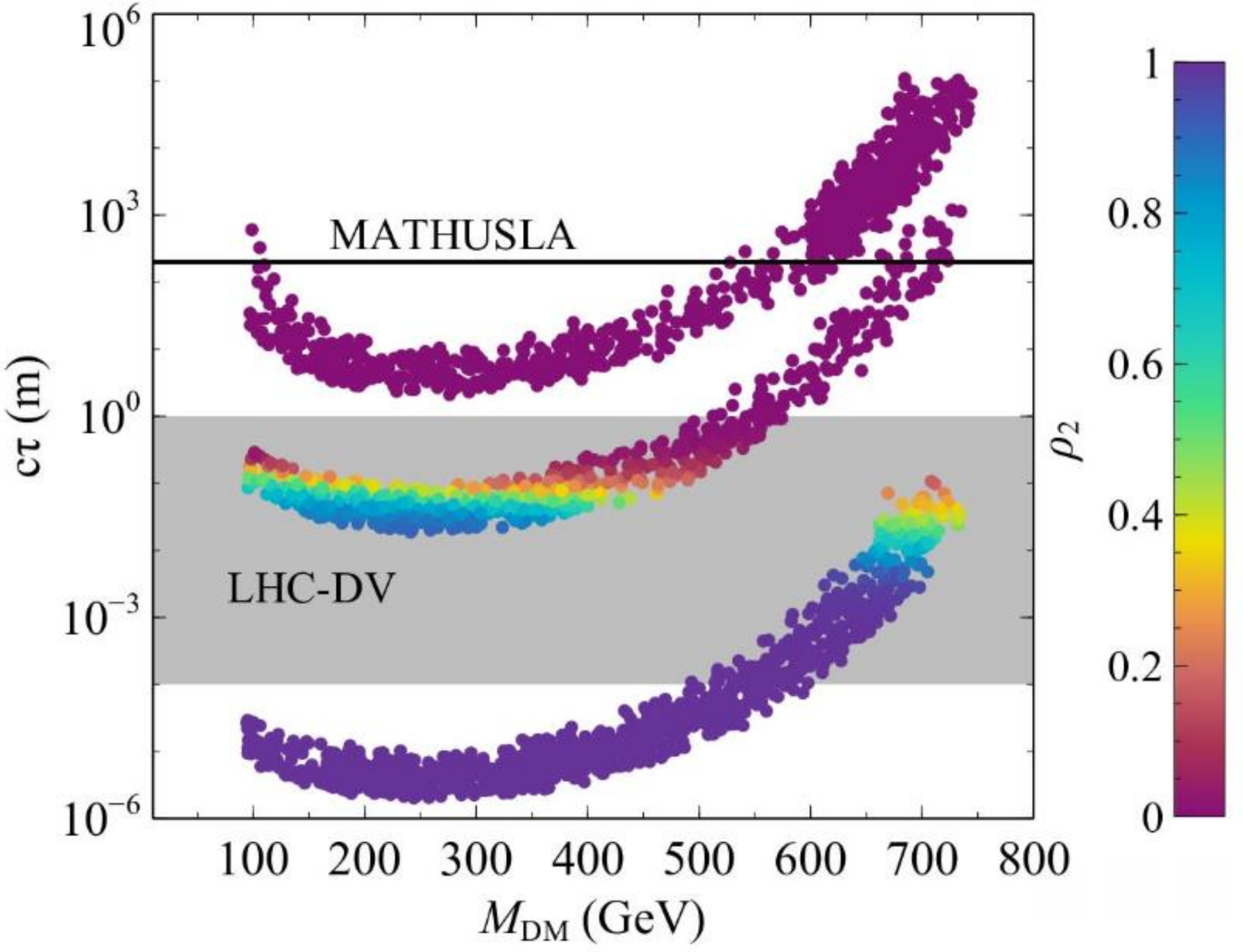


Summary plot SD-dark matter



Small singlet-doublet mixing

Testing the Hypothesis at collider via displaced vertex signature…



MATHUSLA
LHC-DV
cτ (m)
M_{DM} (GeV)
ρ_2

Singlet-Doublet DM in BSM phenomenologies

Journal of Cosmology and Astroparticle Physics

PAPER

Singlet-doublet Majorana dark matter and neutrino mass in a minimal type-I seesaw scenario

Manoranjan Dutta, Subhaditya Bhattacharya, Purusottam Ghosh and Narendra Sahu

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See also earlier work:
Hep-ph/0510064, 0705.4493,
1109.2604,1505.03867,
1311.5896, 1603.07387
1602.04788, 1504.07892
1702.07236

Fields		$SU(3)_C$	$\otimes SU(2)_L$	$\otimes U(1)_Y$	$\otimes \mathcal{Z}_2$
VLFd	$\Psi = \begin{pmatrix} \psi^0 \\ \psi^- \end{pmatrix}$	1	2	-1	-
RHNs	N_{R_1}	1	1	0	-
	N_{R_2}	1	1	0	+
	N_{R_3}	1	1	0	+
Higgs doublet	$H = \begin{pmatrix} w^+ \\ \frac{h+v+iz}{\sqrt{2}} \end{pmatrix}$	1	2	1	+

$$- \mathcal{L}_{mass} = M\overline{\psi_L^0}\psi_R^0 + \frac{1}{2}M_{R_1}\overline{N}_{R_1}(N_{R_1})^c + \frac{m_D}{\sqrt{2}}(\overline{\psi_L^0}N_{R_1} + \overline{\psi_R^0}(N_{R_1})^c) + h.c.$$

In the basis $((\psi_R^0)^c, \psi_L^0, (N_{R_1})^c)^T$ the mass matrix $\mathcal{M} = \begin{pmatrix} 0 & M & \frac{m_D}{\sqrt{2}} \\ M & 0 & \frac{m_D}{\sqrt{2}} \\ \frac{m_D}{\sqrt{2}} & \frac{m_D}{\sqrt{2}} & M_{R_1} \end{pmatrix}$.

$$\begin{aligned}
\chi_{1L} &= \frac{\cos\theta}{\sqrt{2}}(\psi_L^0 + (\psi_R^0)^c) + \sin\theta(N_{R_1})^c, \\
\chi_{2L} &= \frac{i}{\sqrt{2}}(\psi_L^0 - (\psi_R^0)^c), \\
\chi_{3L} &= -\frac{\sin\theta}{\sqrt{2}}(\psi_L^0 + (\psi_R^0)^c) + \cos\theta(N_{R_1})^c.
\end{aligned}$$

$$\begin{aligned}
m_{\chi_1} &= M\cos^2\theta + M_{R_1}\sin^2\theta + m_D\sin 2\theta, \\
m_{\chi_2} &= M, \\
m_{\chi_3} &= M_{R_1}\cos^2\theta + M\sin^2\theta - m_D\sin 2\theta.
\end{aligned}$$

$$\text{Dark Parameters :} \quad \{ \; m_{\chi_3}, \Delta M = (m_{\chi_1} - m_{\chi_3}) \approx (m_{\chi_2} - m_{\chi_3}), \; \sin\theta \; \}$$

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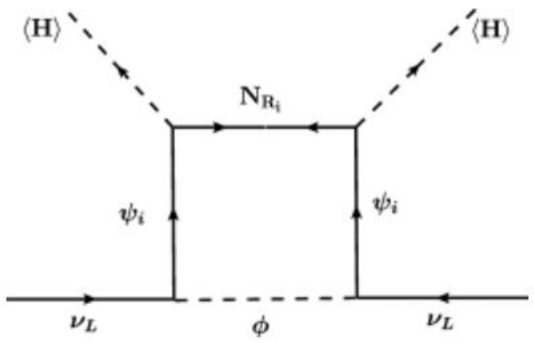
Singlet-doublet fermion origin of dark matter, neutrino mass and W-mass anomaly

Debasish Borah [a], Satyabrata Mahapatra [b], Narendra Sahu [b]



Three generations of scalar fields: ϕ required to realise Majorana masses of neutrinos

See also
arXiv: 2007.15608
arXiv: 2001.11325
arXiv: 1504.07892

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Singlet-doublet fermion Dark Matter with Dirac neutrino mass, $(g-2)_\mu$ and $\Delta N_{\rm eff}$

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ABSTRACT: We study the possibility of generating light Dirac neutrino mass via scotogenic mechanism where singlet-doublet fermion Dark Matter (DM) plays non-trivial role in generating one-loop neutrino mass, anomalous magnetic moment of muon: $(g-2)_\mu$ as well as additional relativistic degrees of freedom $\Delta N_{\rm eff}$ within reach of cosmic microwave background (CMB) experiments. We show that the Dirac nature of neutrinos can bring interesting correlations within the parameter space satisfying the $(g-2)_\mu$, DM relic density and the effective relativistic degrees of freedom $\Delta N_{\rm eff}$. While we stick to thermal singlet-doublet DM with promising detection prospects, both thermal and non-thermal origin of $\Delta N_{\rm eff}$ have been explored. In addition to detection prospects of the model at DM, $(g-2)_\mu$ and other particle physics experiments, it remains verifiable at future CMB experiments like CMB-S4 and SPT-3G.

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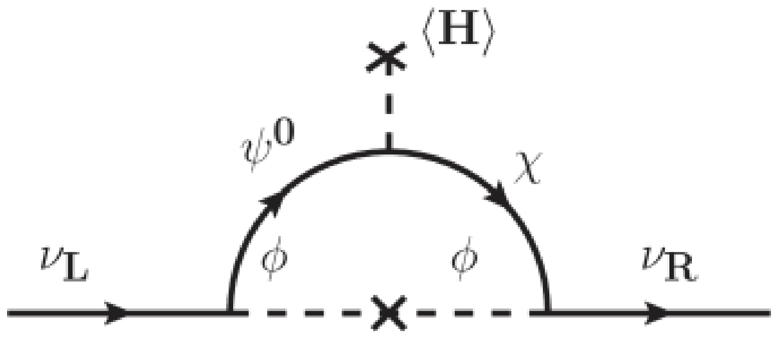


Singlet-doublet self-interacting dark matter and radiative neutrino mass

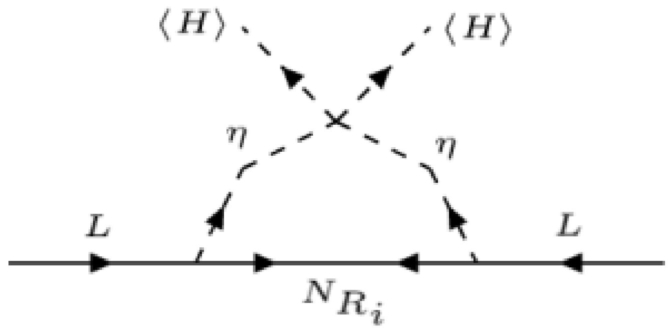
Debasish Borah[1,*], Manoranjan Dutta[2,†], Satvabrata Mahapatra[2,‡], and Narendra Sahu[2,§]

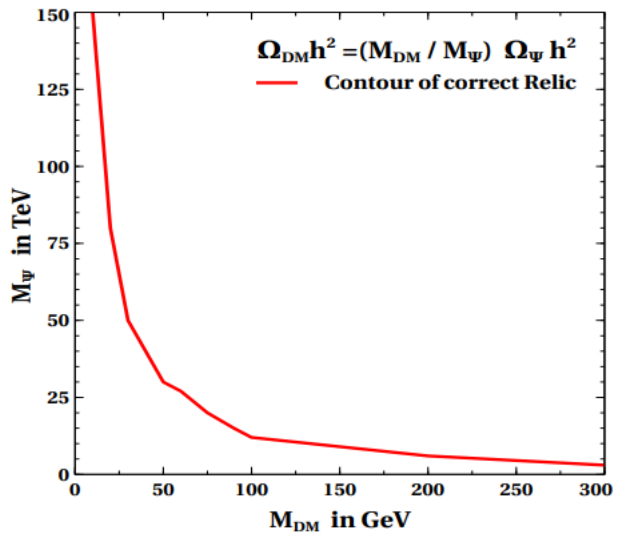
Show more

Phys. Rev. D **105**, 075019 – **Published 22 April, 2022**

DOI: https://doi.org/10.1103/PhysRevD.105.075019

Fields		$SU(3)_C$	$SU(2)_L$	$U(1)_Y$	$\otimes \mathcal{Z}_2$
Fermions	$\Psi = \begin{pmatrix} \psi^0 \\ \psi^- \end{pmatrix}$	1	2	-1	-
	$N_{R_i}\ (i=1,2,3)$	1	1	0	-
Scalars	$S = \frac{s+u+is'}{\sqrt{2}}$	1	1	0	+
	$\eta = \begin{pmatrix} \eta^+ \\ \frac{\eta^0+i\eta^I}{\sqrt{2}} \end{pmatrix}$	1	2	1	-





•Published in: *JHEP* 07 (2026) 264

Gravitational Wave Probe of Singlet-Doublet Dark Matter Induced Radiative Neutrino Mass

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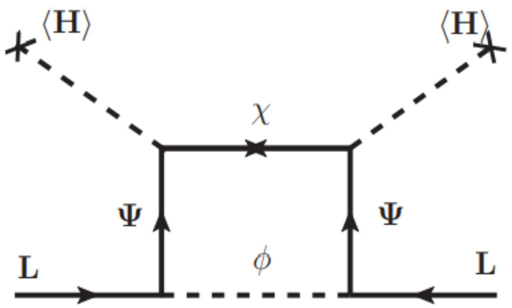
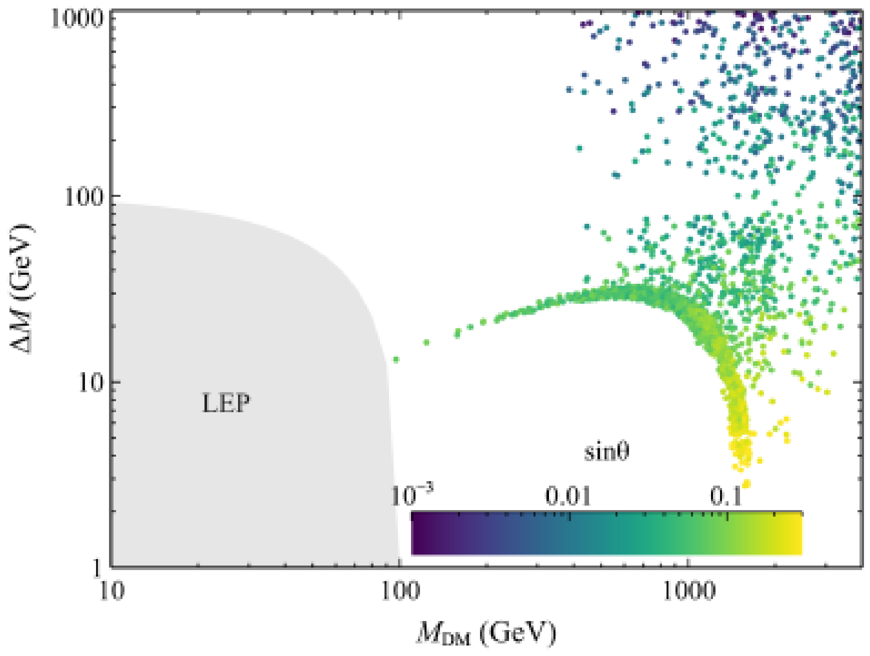
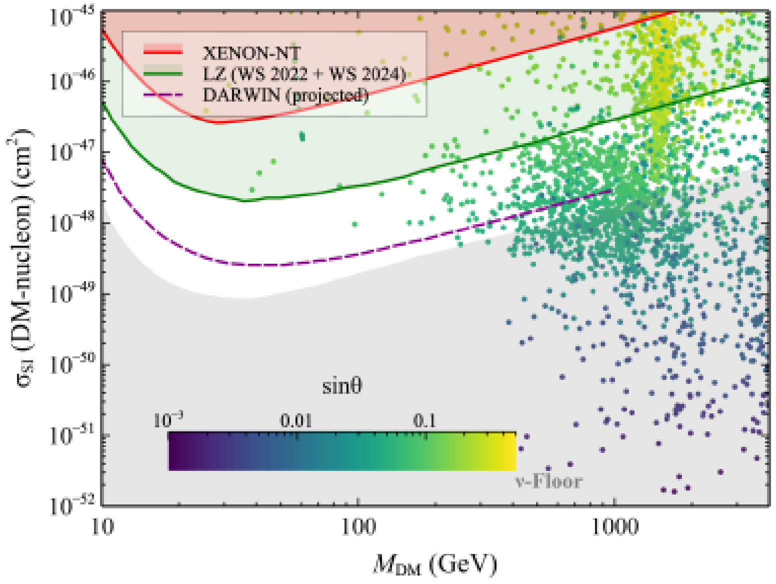
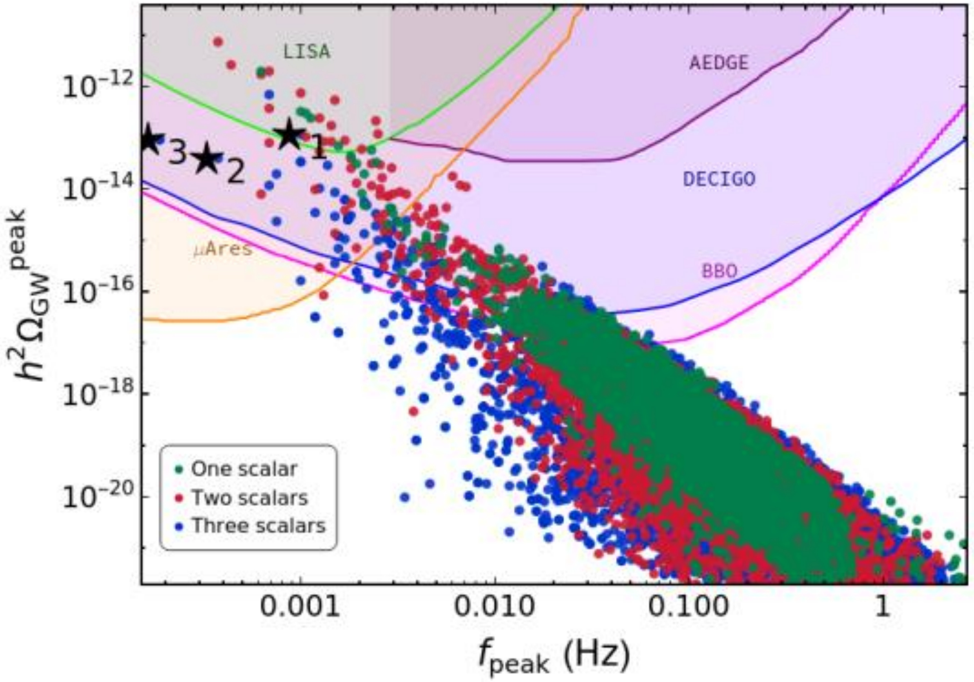
Abstract. We investigate an one loop radiative neutrino mass model, where the loop particles, notably a singlet fermion (χ), a doublet fermion (Ψ) and three generations of singlet scalars ($\phi_i, i = \{1,2,3\}$) are assumed to be odd under an additional $\mathcal{Z}_2$-symmetry. In this setup, the singlet fermion mixes with the neutral component of the doublet to give rise singlet-doublet Majorana dark matter. The addition of $\mathcal{Z}_2$ odd scalars in the model provides rich phenomenological implications. We find that the quartic interaction terms between the SM Higgs and ϕ_is play a significant role in modifying the scalar potential to have a first-order phase transition (FOPT) leading to observable gravitational waves (GWs) spectra. We also examine the non-trivial role played by the singlet-doublet fermion DM and the scalars in loop-induced neutrino mass, $(g-2)_\mu$, and lepton flavor violation. We find that the model is predictive due to the combined constraints and can be verified at different terrestrial experiments.

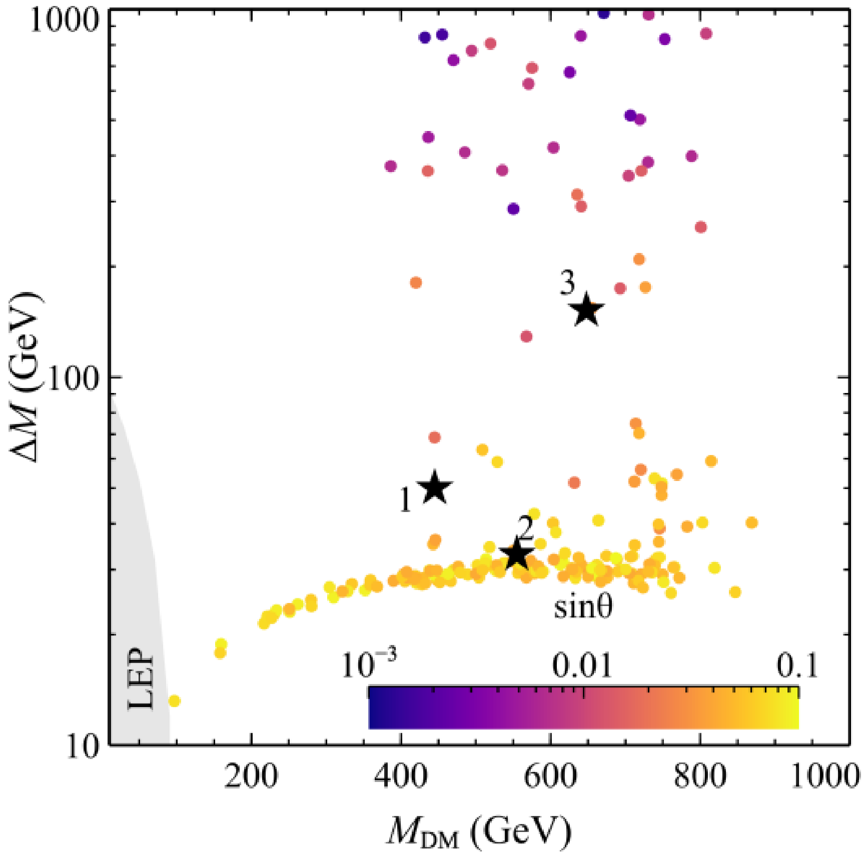








LISA
AEDGE
DECIGO
BBO
μAres
One scalar
Two scalars
Three scalars
$h^2\Omega_{GW}^{peak}$
f_{peak} (Hz)



LEP
sinθ
10^{-3}
0.01
0.1
ΔM (GeV)
M_{DM} (GeV)

Singlet-Doublet DM, neutrino mass and Leptogenesis

arXiv: 2605.04824

Singlet-doublet dark matter induced radiative neutrino mass and TeV scale leptogenesis

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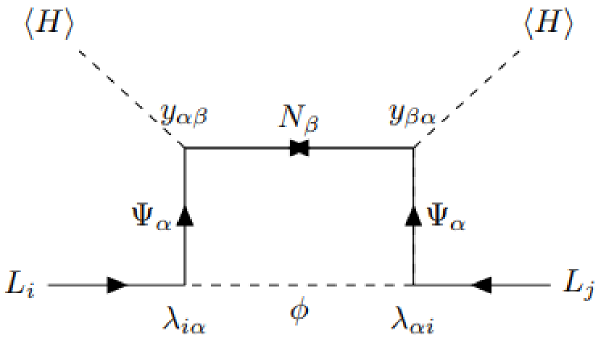
(Dated: May 7, 2026)

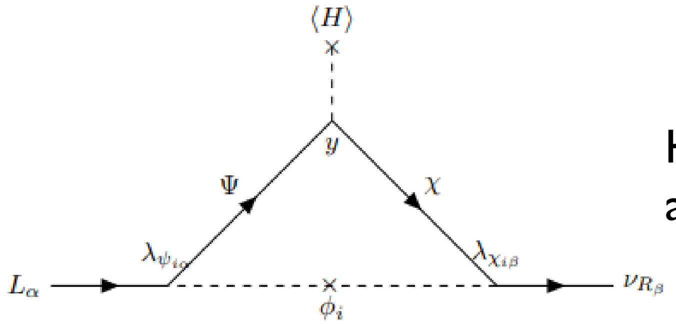
The singlet–doublet dark matter (SDDM) model is a well-motivated WIMP framework that accommodates viable dark matter over a broad range of parameter space. In this work, we explore the possibility of TeV-scale leptogenesis within two realizations of the SDDM setup: Majorana SDDM scenario and Dirac SDDM scenario. The light neutrino mass, in either case, arises radiatively at one loop level. The particles running in the loop are responsible for Dark matter relic and TeV-scale leptogenesis while satisfying other phenomenological constraints. In the Majorana setup, the Standard Model is extended by three generations of singlet fermions N_i and doublet fermions Ψ_i, and a singlet scalar ϕ. The *CP*-violating, out-of-equilibrium decays of the heavier singlets ($N_{2,3}$) generate baryon asymmetry via the leptogenesis route, while the first generation of singlet-doublet fermions give rise to the usual SD Majorana dark matter. In the Dirac setup, the standard model is extended by three generations of complex scalars (ϕ_i) and right-handed Dirac partners (ν_{R_i}) of SM neutrinos (ν_{L_i}), along with a pair of singlet–doublet fermions χ and Ψ. The *CP*-violating out-of-equilibrium decays of the scalar fields ϕ_i generate baryon asymmetry via the Dirac leptogenesis route. We show that in the Majorana setup, successful leptogenesis is possible even in the sub-TeV regime, while in the Dirac setup, the scale of leptogenesis is at a few TeV. With the particle mass at the TeV scale, the model remains promising for collider experiments, particularly through signatures such as prompt decays and displaced vertex searches. In addition, the presence of Dirac neutrinos can contribute to $\Delta N_{\rm eff}$, providing complementary cosmological signatures.

Majorana mass



N_1 plays the role of DM while N_2,3 decay can give leptogenesis.

Dirac mass



Here lepton number is conserved. Dirac leptogenesis arises via the decay of singlet scalar.

Thank you

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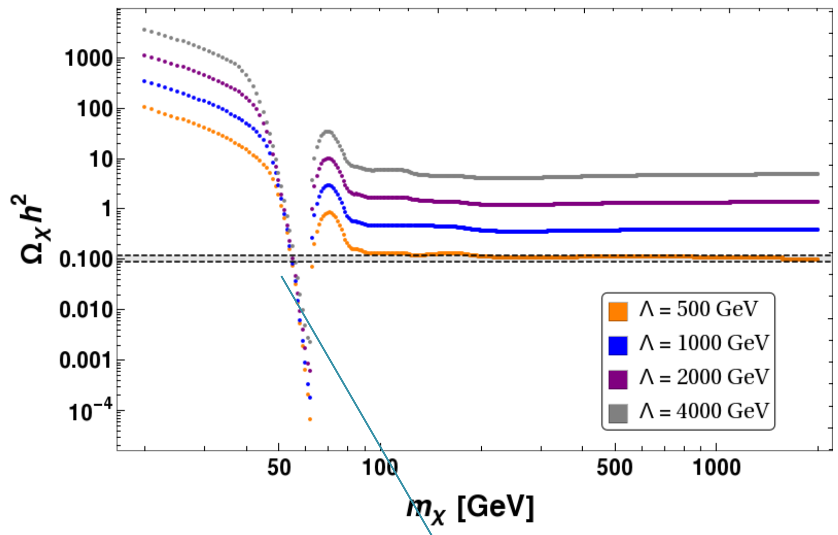
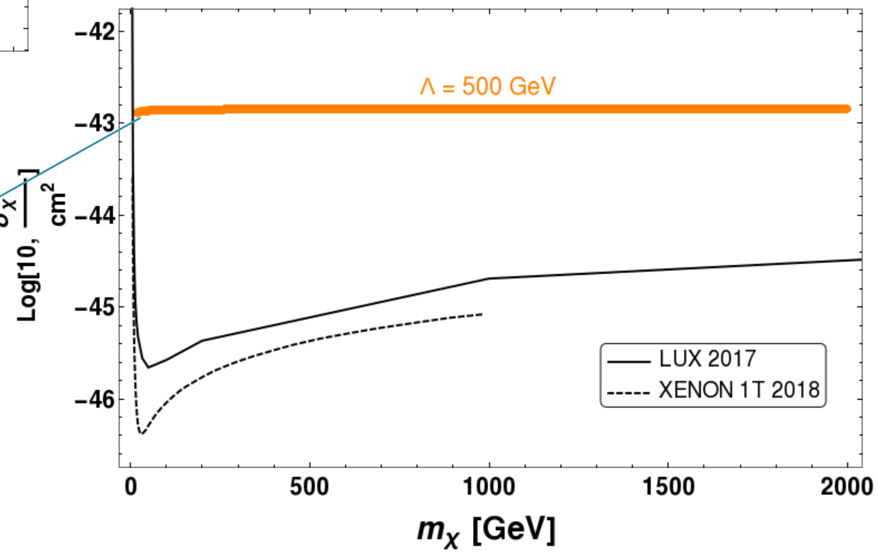
Vector-like Singlet fermion DM

$$\mathcal{L}_{DM} = \bar{\chi}(i\gamma^\mu\partial_\mu - m_\chi)\chi - \frac{1}{\Lambda}\left(H^\dagger H - \frac{v^2}{2}\right)\bar{\chi}\,\chi$$

S. Bhattacharya, Purusottam Ghosh, Nirakar Sahoo and **N. Sahu**, [1812.06505]



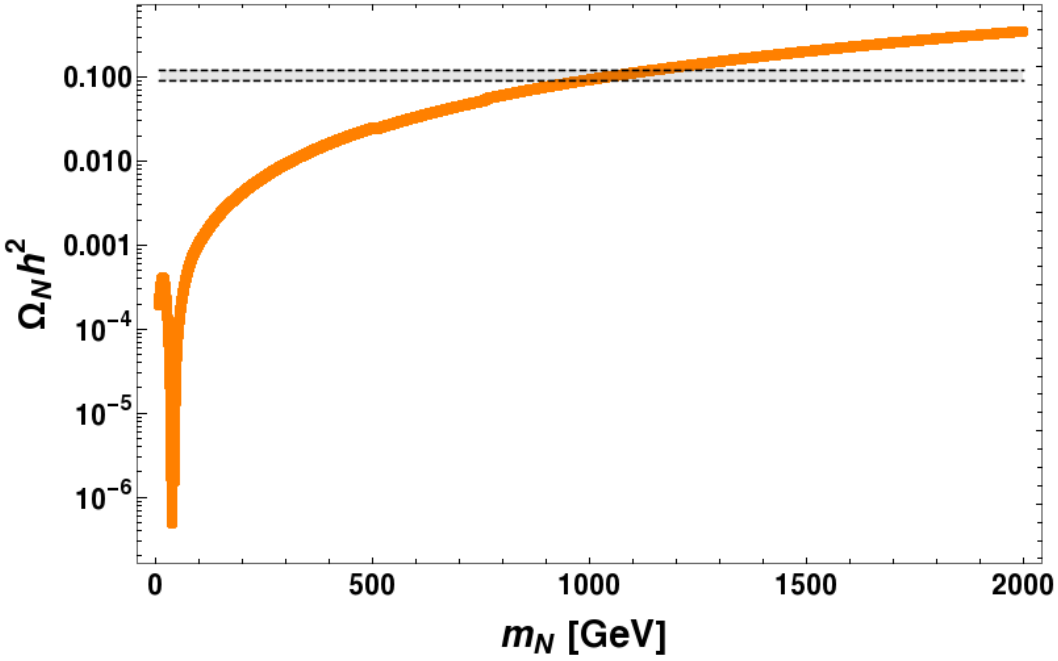


Allowed zone of valid DM

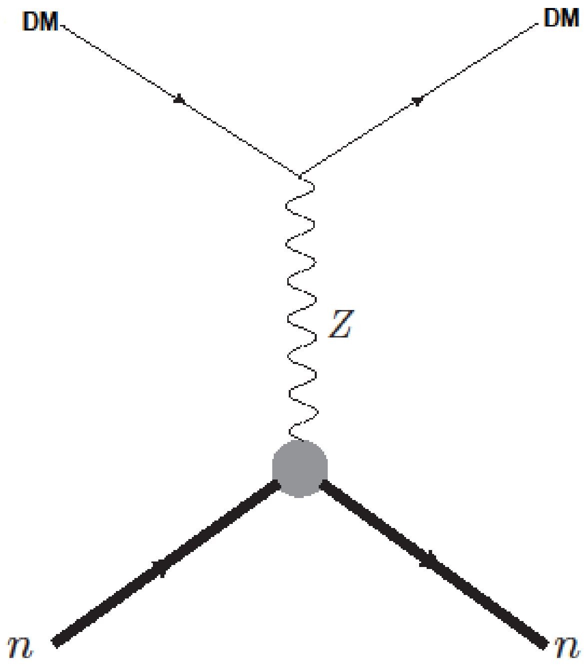
Vector-like Inert lepton doublet DM

$$\mathcal{L}_{DM} = \bar{N}(i\gamma^\mu D_\mu - m_N)\mathrm{N}$$

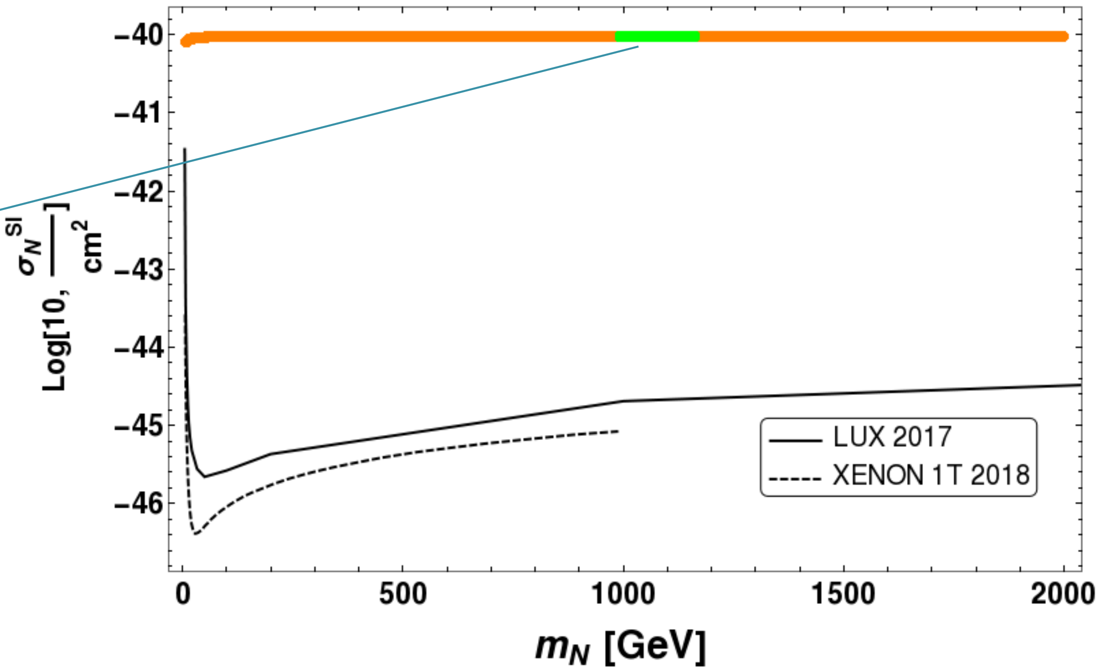
$$N = \begin{pmatrix} N^0 \\ N^- \end{pmatrix} \equiv (1,2,-1)$$

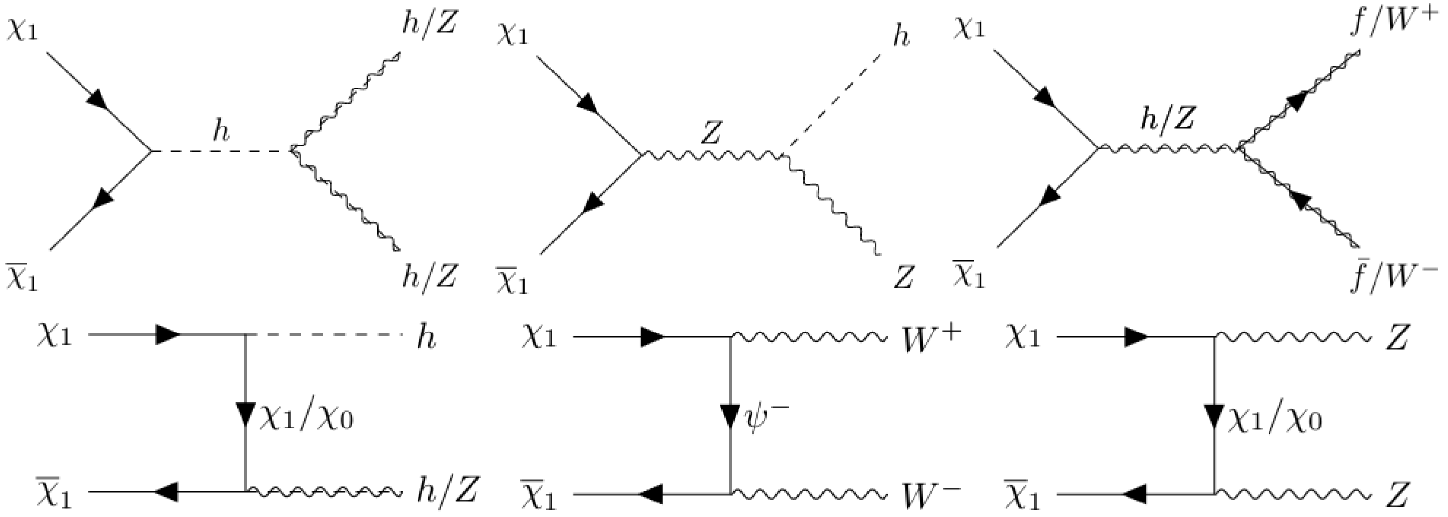


S. Bhattacharya, Purusottam Ghosh, Nirakar Sahoo and **N. Sahu**, [1812.06505]

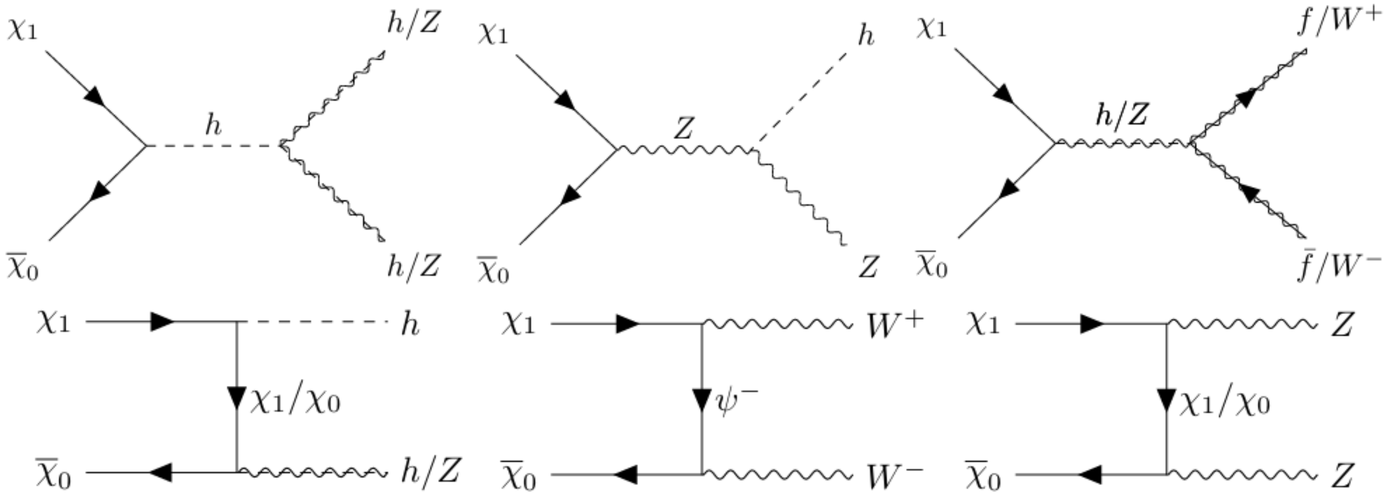


Inert lepton doublet DM alone is ruled out by direct search

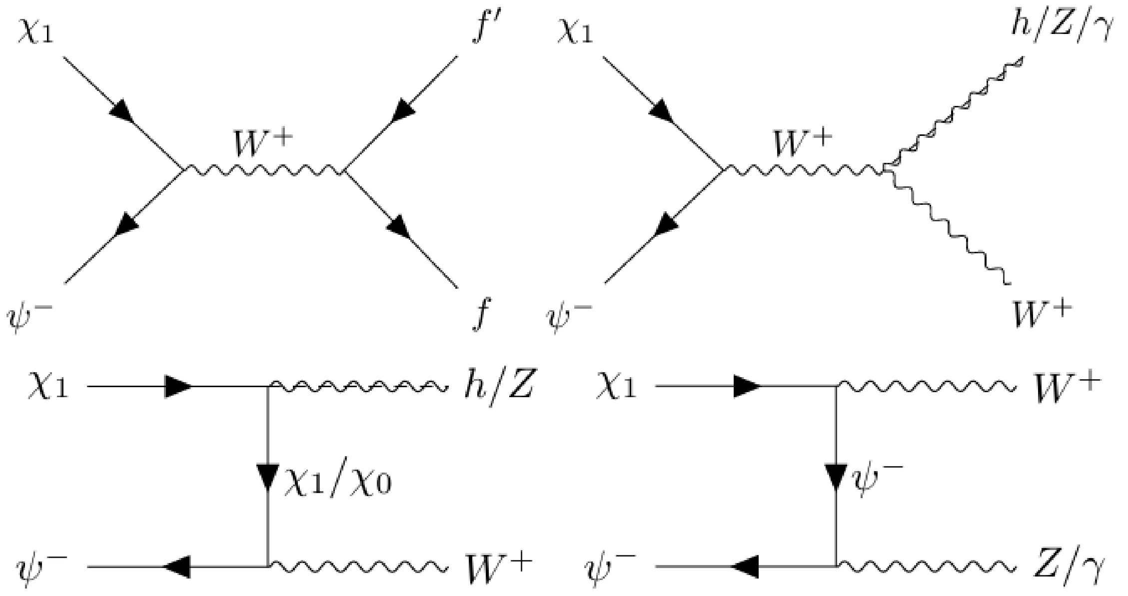




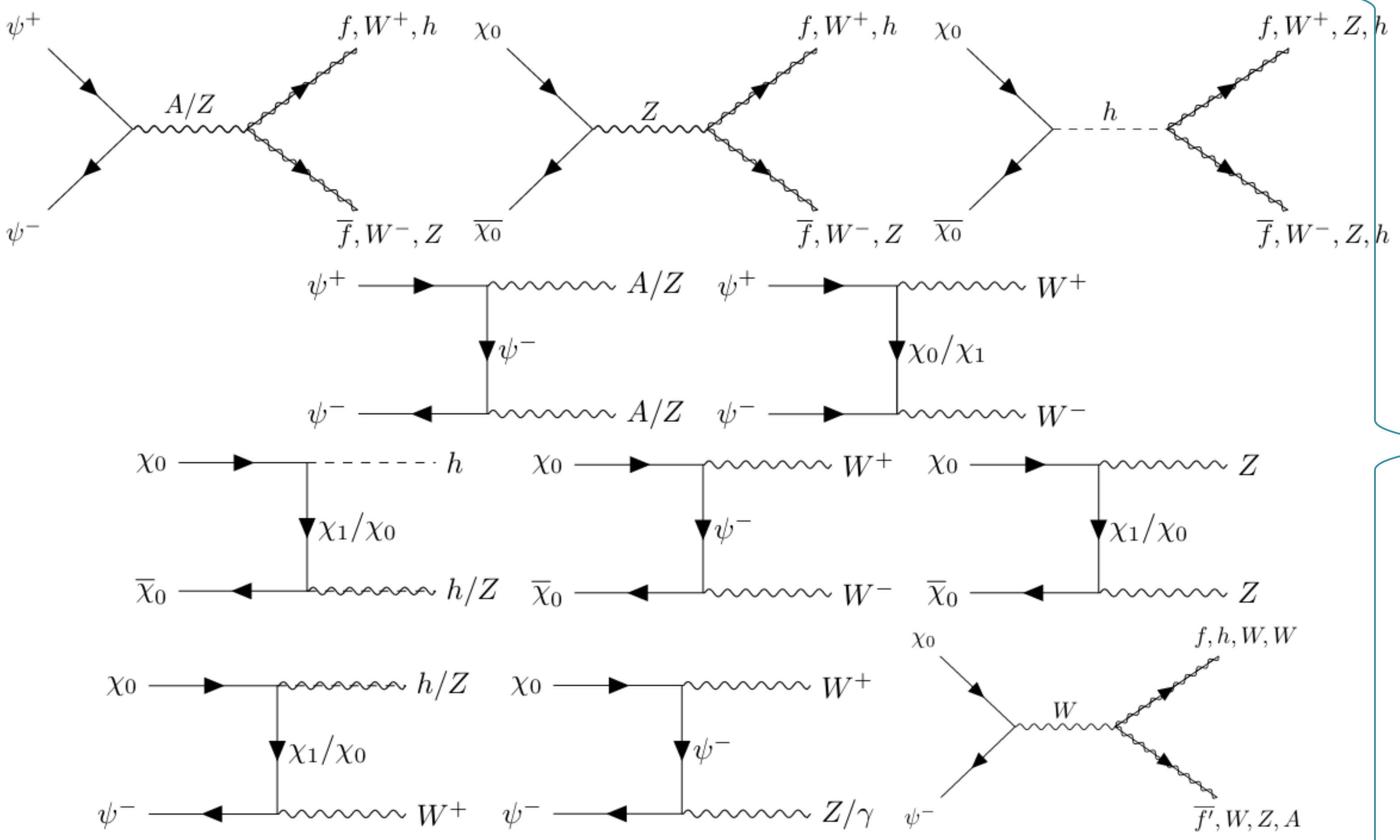
1100 processes



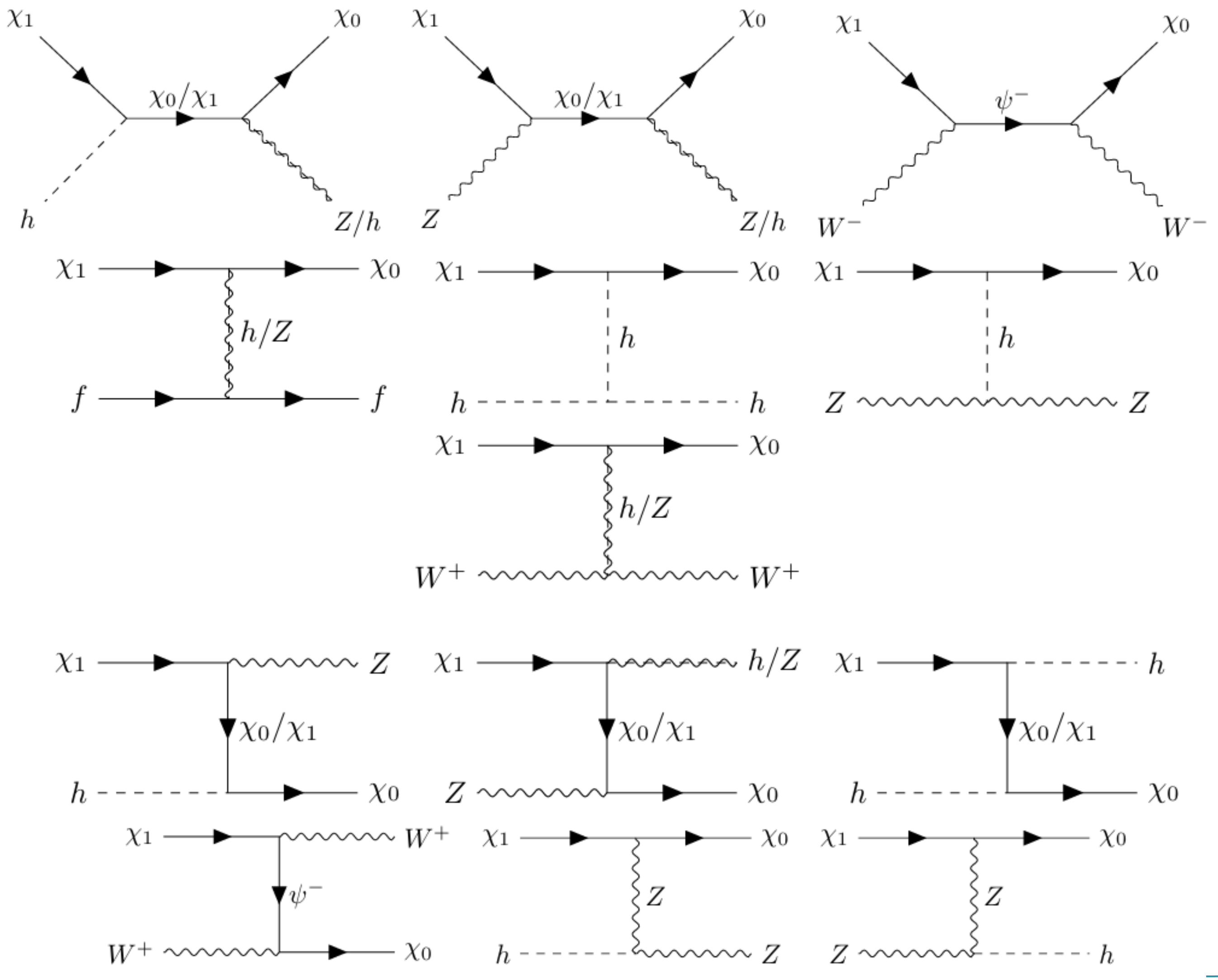
1200 processes



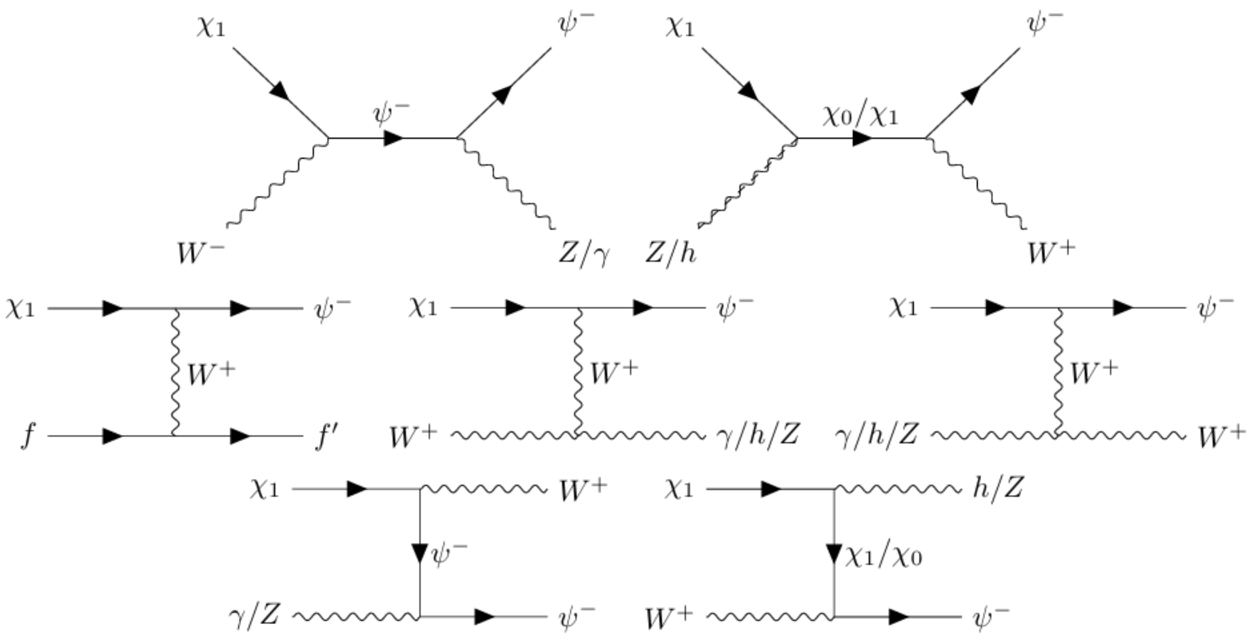
1200 processes



2200 processes



1020 processes



1020 processes

$$\Gamma_{2\to 1} = \Gamma_{\Psi\to\chi,\mathrm{SM}}\frac{K_1(M_\Psi/T)}{K_2(M_\Psi/T)} + \langle\sigma_{2010}v\rangle n^{\mathrm{eq}}_{\mathrm{SM}}$$

Decay term

Singlet-Doublet dark matter parameter space in details along with neutrino mass and other BSM phenomenologies:

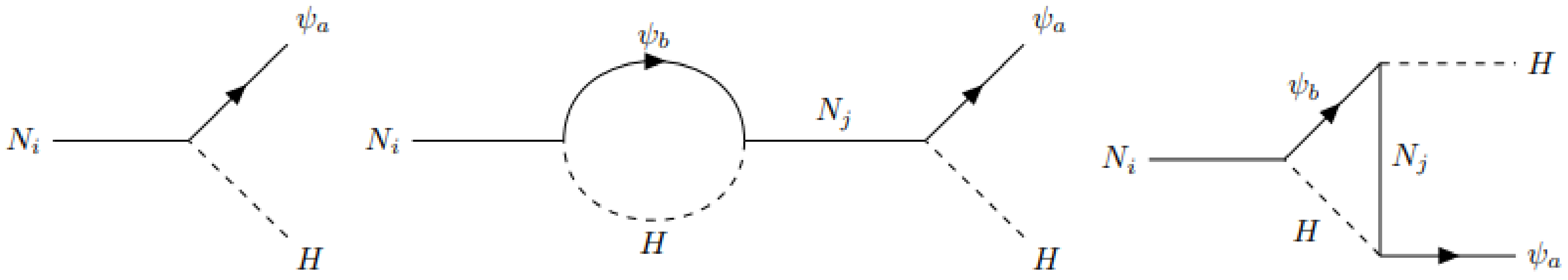
S. Bhattacharya, Nirakar Sahoo and **N. Sahu**, PRD93, 2016 [1510.02760]
S. Bhattacharya, S Patra, Nirakar Sahoo, **N.Sahu**, JCAP 1606, 2016 [1601.01569]
S. Bhattacharya, Nirakar Sahoo and **N. Sahu**, PRD96, 2017 [1704.03417]
S. Bhattacharya, Purusottam Ghosh, Nirakar Sahoo and **N. Sahu**, [1812.06505] (Mini review)
M. Dutta, S. Bhattacharya, P. Ghosh and **N. Sahu** [2009.00885]
D. Borah, M. Dutta, S. Mahapatra & **N. Sahu**., [2109.02699]
D. Borah, S. Mahapatra & **N. Sahu**, [2204. 09671]
D. Borah, S. Mahapatra, D. Nanda, S.K. Sahoo & **N. Sahu** [2310.03721]
Partha Kumar Paul, Sujit Kumar Sahoo and **N. Sahu**, [arXiv: 2412. 02607]
Partha Kumar Paul, Sujit Kumar Sahoo and **N. Sahu** **[arXiv: 2511.14571]**
UJJal Kumar Dey, Santu Kumar Manna, Partha Kumar Paul, Sujit Kumar Sahoo and **N.Sahu** **[arXiv: 2511.19386]**

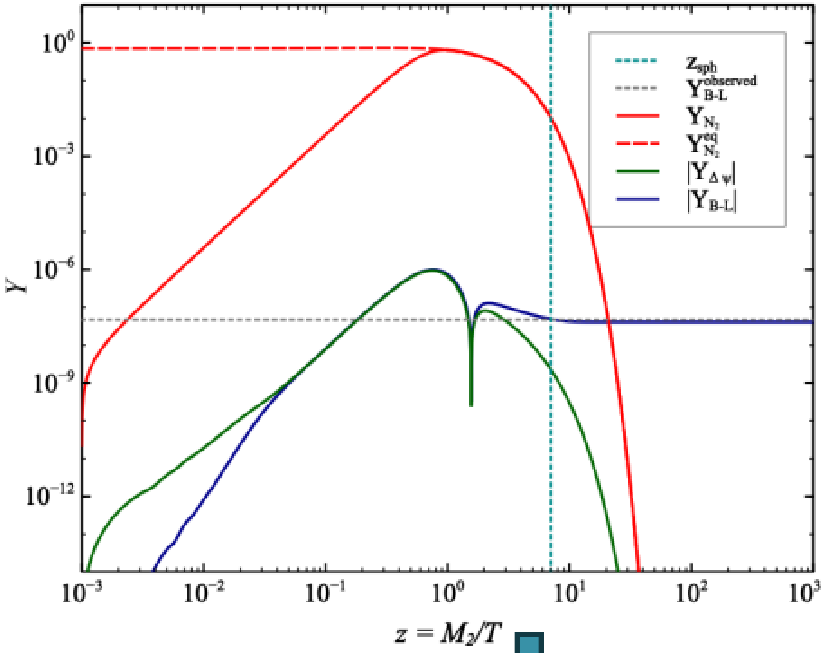
See also earlier works: [hep-th/0501082] , [hep-ph/0510064] , [hep-ph/0705.4493] [arXiv: 0706.0918], [arXiv: 1109.2604], [arXiv: 1311.5896]. [arXiv: 1411.1335], [arXiv: 1504.07892], [arXiv: 1505.03867], [arXiv: 1506.04149], [arXiv: 1509.05323]

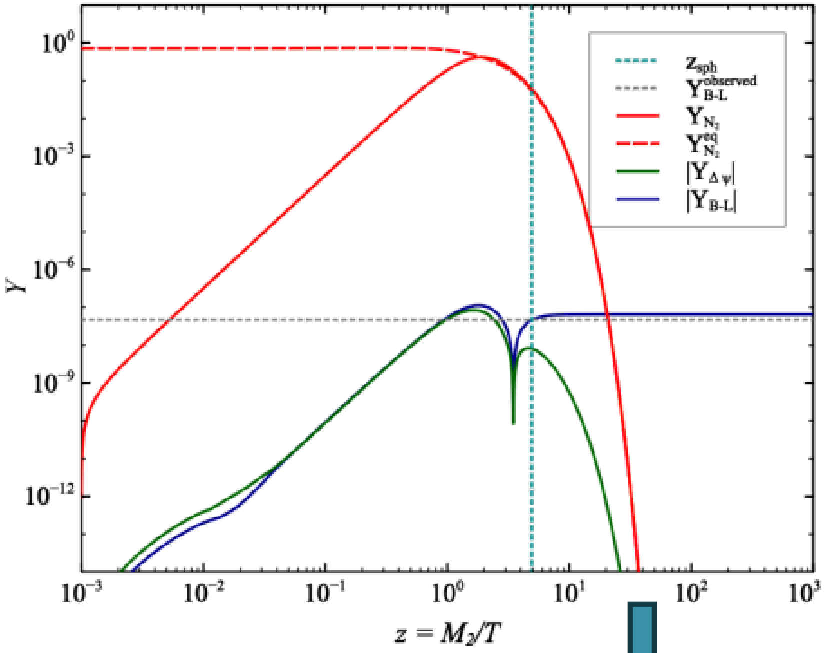
Leptogenesis from $N_{2,3}$ decay

In the early universe, the CP-violating out-of-equilibrium decays of heavier generations of singlet fermions (N_2, N_3) can generate asymmetries in the Ψ_2, Ψ_3 through the decay channel $N \to \Psi H$. This asymmetry is subsequently transferred to the SM leptons through the decay processes $\Psi_{2,3} \to L\phi$. The first-generation singlet–doublet fermions, being the lightest, do not participate in leptogenesis. The resulting lepton asymmetry is partially converted into the baryon asymmetry via sphaleron processes.

CP-violation processes







$$y = \begin{pmatrix} 1.04 \times 10^{-3} & 0 & 0 \\ 0 & -5.36 \times 10^{-7} + 6.59 \times 10^{-7} i & -7.5 \times 10^{-2} - 2.37 i \\ 0 & 1.828 \times 10^{-7} - 1.854 \times 10^{-8} i & -5.41 \times 10^{-3} + 2.498 i \end{pmatrix}$$

$$y = \begin{pmatrix} 1.04 \times 10^{-3} & 0 & 0 \\ 0 & 1.584 \times 10^{-7} + 1.185 \times 10^{-7} i & 9.639 \times 10^{-1} - 1.070 i \\ 0 & 1.739 \times 10^{-8} + 4.69 \times 10^{-8} i & -1.598 \times 10^{-1} + 1.054 i \end{pmatrix}.$$

Singlet-Doublet Fermionic Dark Matter in Gauge Theory of Baryons

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•
e-Print: 2408.12424 [hep-ph]

Taramati[a] **, Rameswar Sahu**[b,c] **, Utkarsh Patel**[a] **, Kirtiman Ghosh**[b,c] **, Sudhanwa Patra**[a]

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$$G \equiv SU(3)_C \otimes SU(2)_L \otimes U(1)_Y \otimes U(1)_B$$

SM Fermions	$SU(3)_C$	$SU(2)_L$	$U(1)_Y$	$U(1)_B$
$Q_L = \begin{pmatrix} u_L \\ d_L \end{pmatrix}$	$\mathbf{3}$	$\mathbf{2}$	$1/6$	$1/3$
u_R	$\mathbf{3}$	$\mathbf{1}$	$2/3$	$1/3$
d_R	$\mathbf{3}$	$\mathbf{1}$	$-1/3$	$1/3$
$\ell_L = \begin{pmatrix} \nu_L \\ e_L \end{pmatrix}$	$\mathbf{1}$	$\mathbf{2}$	$-1/2$	0
e_R	$\mathbf{1}$	$\mathbf{1}$	-1	0

Gauge fields	$SU(2)_L$ $\vec{W}_\mu$	$U(1)_Y$ B_μ	$U(1)_B$ Z'_μ
Fermions (Other than SM)			
$\Psi_L = \begin{pmatrix} \Psi_L^+ \\ \Psi_L^0 \end{pmatrix}$	$\mathbf{2}$	$1/2$	B_1
$\Psi_R = \begin{pmatrix} \Psi_R^+ \\ \Psi_R^0 \end{pmatrix}$	$\mathbf{2}$	$1/2$	B_2
ξ_L	$\mathbf{1}$	1	B_2
ξ_R	$\mathbf{1}$	1	B_1
χ_L	$\mathbf{1}$	0	B_2
χ_R	$\mathbf{1}$	0	B_1
Scalar fields			
H	$\mathbf{2}$	$1/2$	0
S	$\mathbf{1}$	0	$B_1 - B_2$