WIMP and FIMP Dark Matter in Singlet-Triplet Fermionic Model

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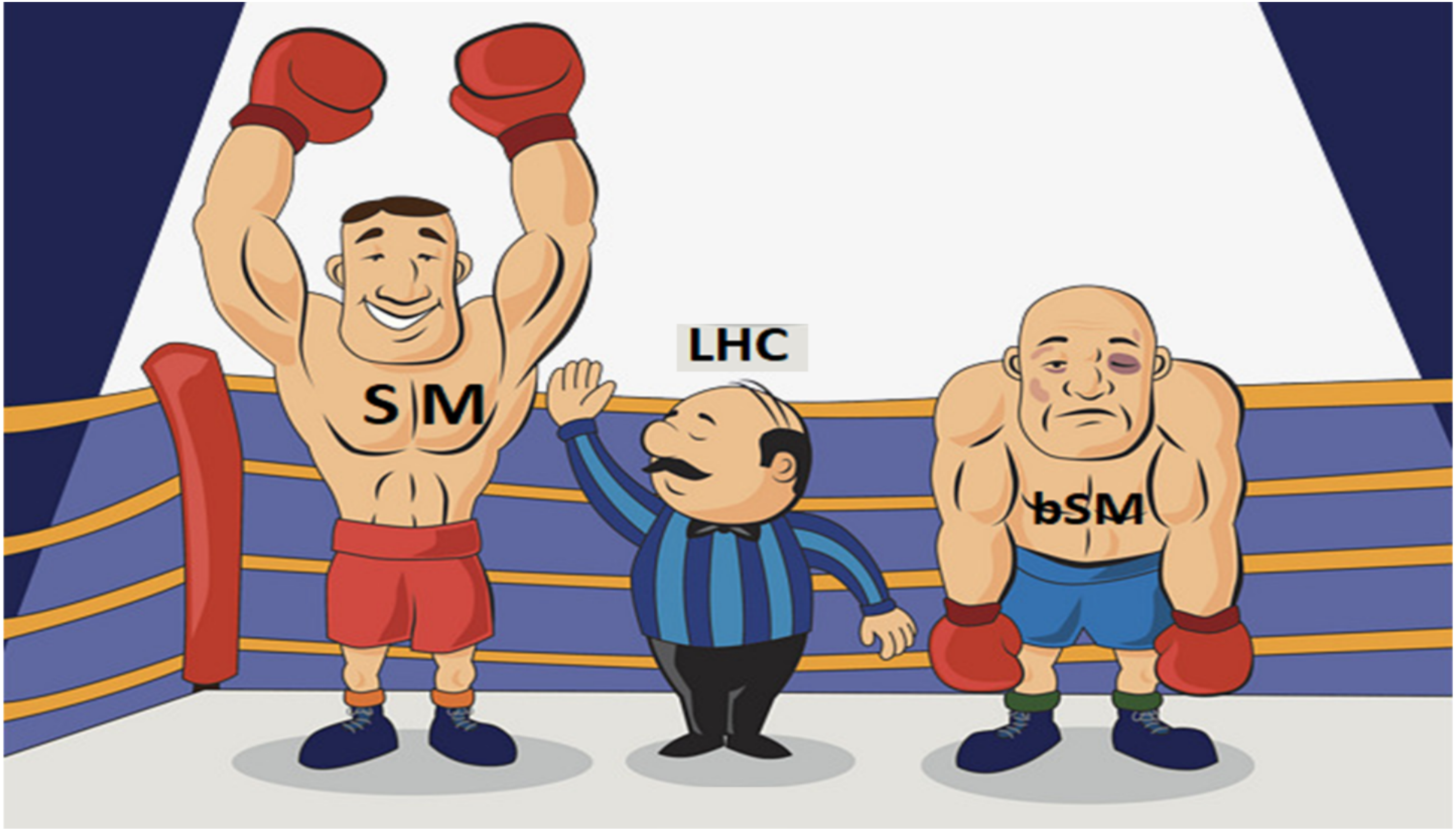
Talk Plan

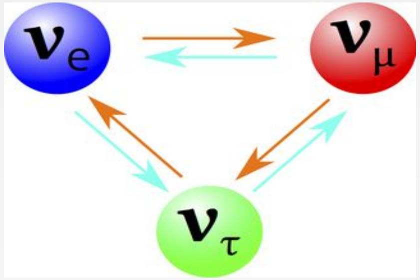
- Introduction
- Model
- Results based on SFTM
- Conclusion



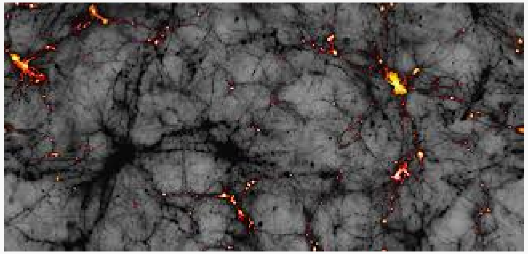
LHC results able to confirm the validity of the SM, with no signatures of new physics.

Problems in the SM

- SM fails to explain neutrino mass and mixings.



- SM doesn't have DM candidate.



- SM fails to explain observed baryon asymmetry.

Who can be a DM ?

- Should be massive
- Should be electrically neutral
- Should be present in early universe
- Should be stable or at least with half life greater than the age of the universe

Need a symmetry

Singlet Scalar

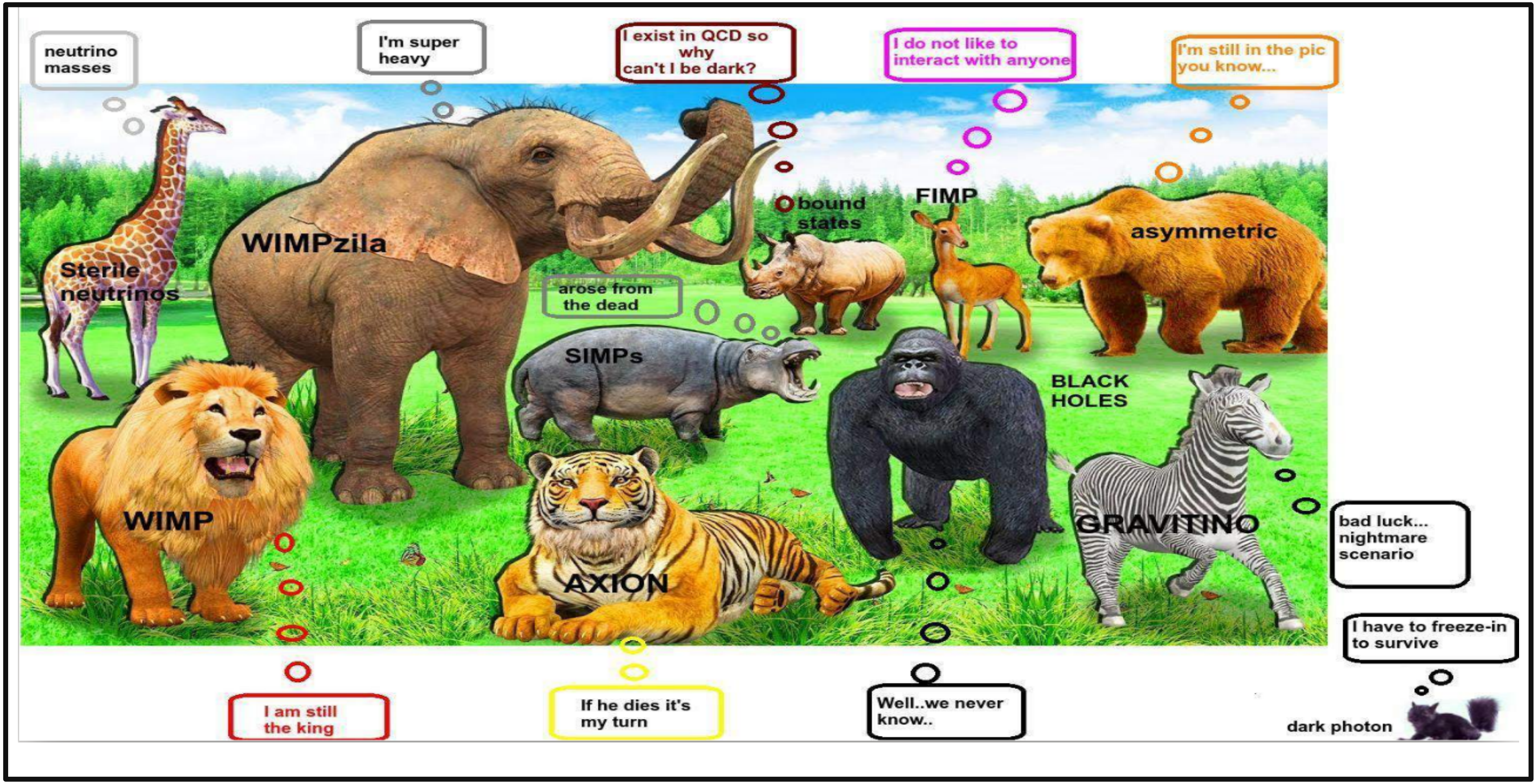
Singlet Fermion

Scalar in triplet repn

Fermion in triplet repn

...and many more

Zoo of Dark Matter Candidates

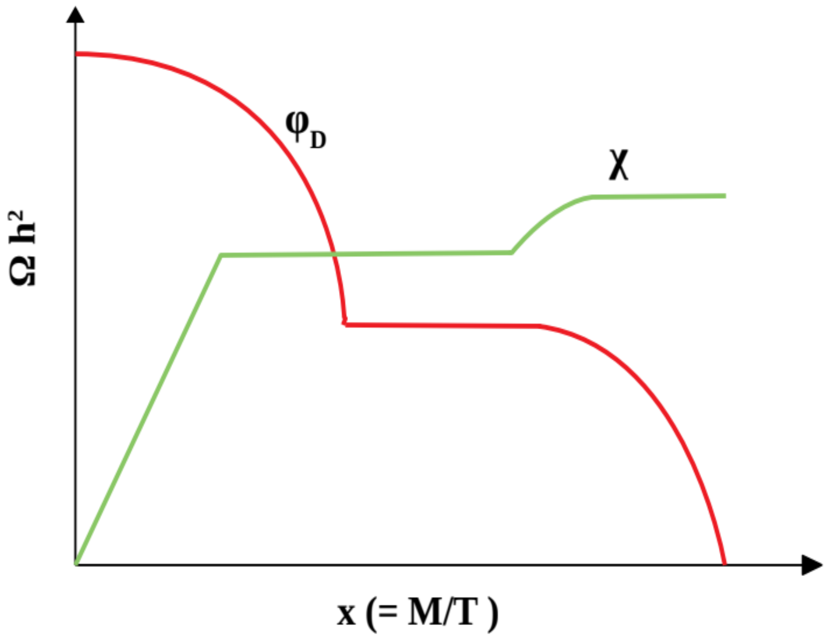


“SUPER” WIMP Dark Matter is like,

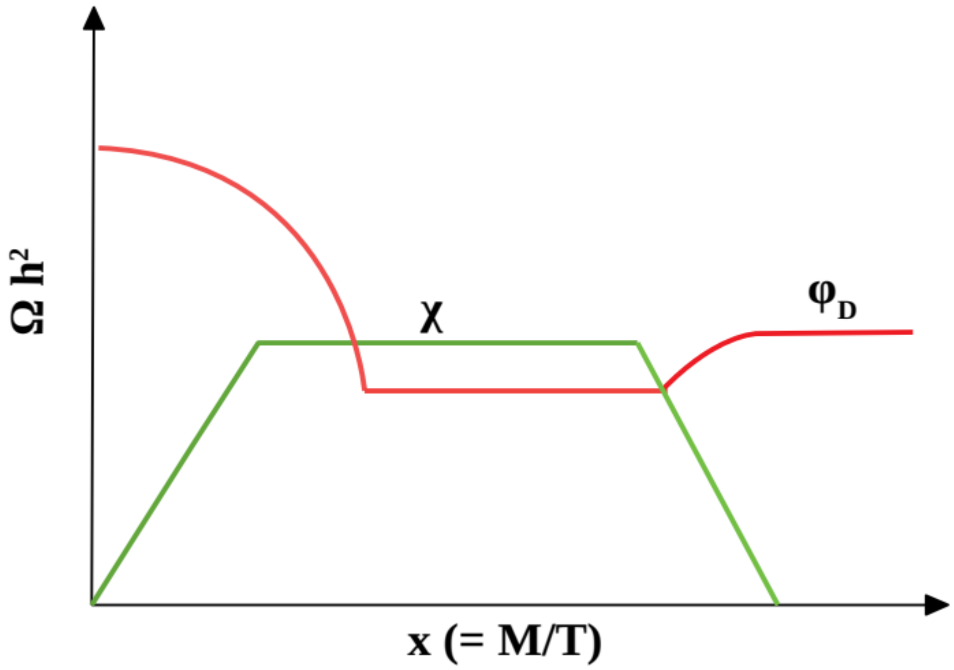
Conductor —Going “SUPER”→ **SUPER Conductor**

What is "SUPER" in SUPER WIMP DM ?

χ is a DM candidate



ϕ_D is a DM candidate



SFTM to explain DM and neutrino mass

New Particles

Symmetry Group	Baryon Fields			Fermion Fields						Scalar Fields	
	Q_L^i	u_R^i	d_R^i	L_L^i	e_R^i	N'	ρ_1	ρ_2	ρ_3	ϕ_h	Δ
$SU(3)_c$	3	3	3	1	1	1	1	1	1	1	1
$SU(2)_L$	2	1	1	2	1	1	3	3	3	2	3
$U(1)_Y$	1/6	2/3	−1/3	−1/2	−1	0	0	0	0	1/2	0
$\mathbb{Z}_2$	+	+	+	+	+	−	+	+	−	+	+

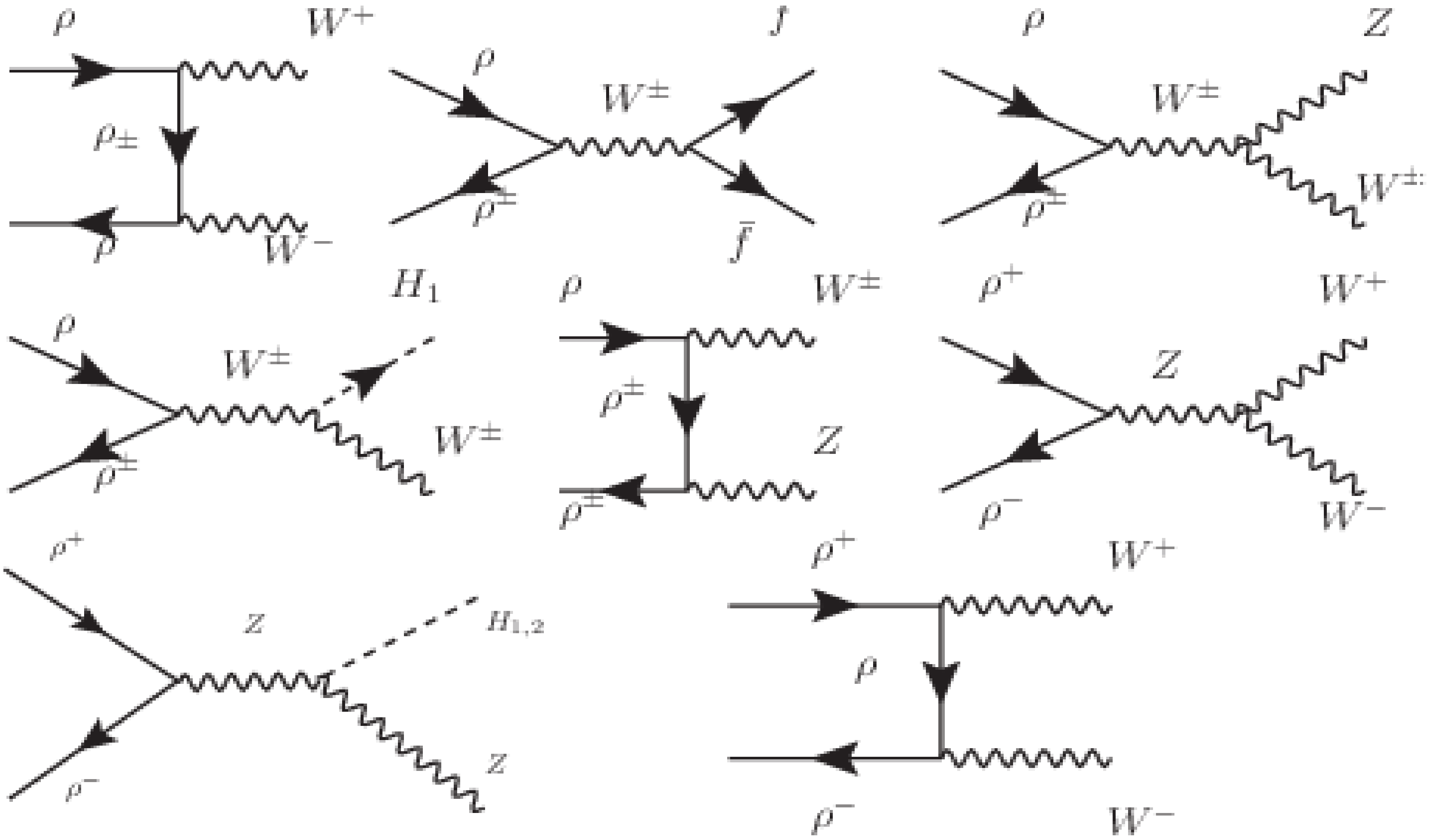
Table 1: Particle content and their corresponding charges under various symmetry groups.

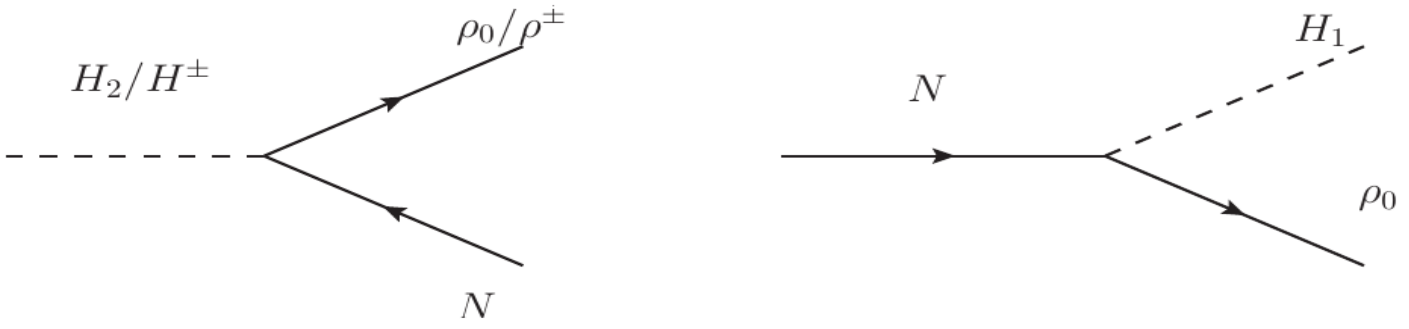
The complete Lagrangian for the model:-

$$\mathcal{L} = \mathcal{L}_{SM} + \sum_{i=1}^{3} Tr\left[\bar{\rho}_i\, i\, \gamma^\mu D_\mu \rho_i\right] + \bar{N'}\, i\, \gamma^\mu D_\mu N' + Tr[(D_\mu \Delta)^\dagger (D^\mu \Delta)] - V(\phi_h, \Delta)$$
$$- \sum_{(i,j)=(1,1)}^{(3,2)} \lambda_{ij} \bar{L}_i \phi_h \rho_j^c - Y_{\rho\Delta}\left(Tr[\bar{\rho}_3\, \Delta]\, N' + h.c.\right) - \sum_{i=1}^{3} M_{\rho_i}\, Tr[\bar{\rho_i^c} \rho_i] - M_{N'}\, \bar{N'^c} N'$$

$$V(\phi_h, \Delta) = -\mu_h^2 \phi_h^\dagger \phi_h + \frac{\lambda_h}{4} (\phi_h^\dagger \phi_h)^2 + \mu_\Delta^2 Tr[\Delta^\dagger \Delta] + \lambda_\Delta (\Delta^\dagger \Delta)^2 + \lambda_1 (\phi_h^\dagger \phi_h)\, \mathrm{Tr}\, [\Delta^\dagger \Delta]$$
$$+ \lambda_2 \left(Tr[\Delta^\dagger \Delta]\right)^2 + \lambda_3\, Tr[(\Delta^\dagger \Delta)^2] + \lambda_4\, \phi_h^\dagger \Delta \Delta^\dagger \phi_h + (\mu \phi_h^\dagger \Delta \phi_h + h.c.)$$

Scenario I → $M_N > M_\rho$ → ρ is DM candidate.





Feynmann diag. for the dominant production of N as well its late decay to DM.

Boltzmann Equation for NLOP ‘N’:

$$\hat{L} f_N = \sum_{i=1,2} \mathcal{C}^{H_i \to N\rho} + \mathcal{C}^{AB \to N\rho} + \mathcal{C}^{N \to \, all},$$

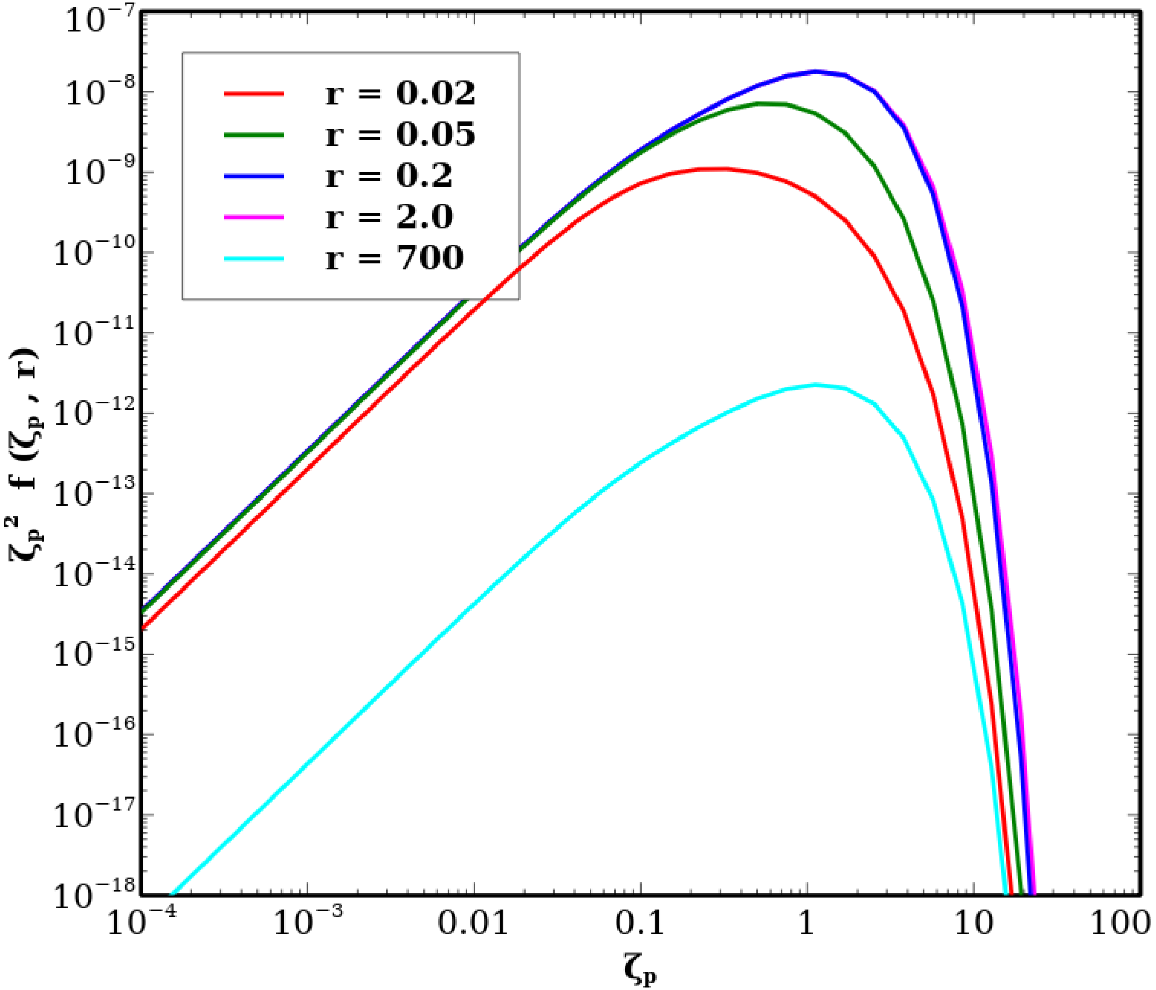
→ B.eqn to determine the distribution function of ‘N’

where,

$$\hat{L} = r\, H \left(1 + \frac{T g_s'}{3 g_s}\right)^{-1} \frac{\partial}{\partial\, r}$$

$$r = \frac{M_{sc}}{T}, \quad \xi_p = \left(\frac{g_s(T_0)}{g_s(T)}\right)^{1/3} \frac{p}{T}$$

Evolution of distribution function for ‘N’



$$n_N(r) = \frac{g\,T^3}{2\pi^2}\,\mathcal{B}(r)^3 \int d\xi_p\,\xi_p^2\,f_N(\xi_p,\,r)$$

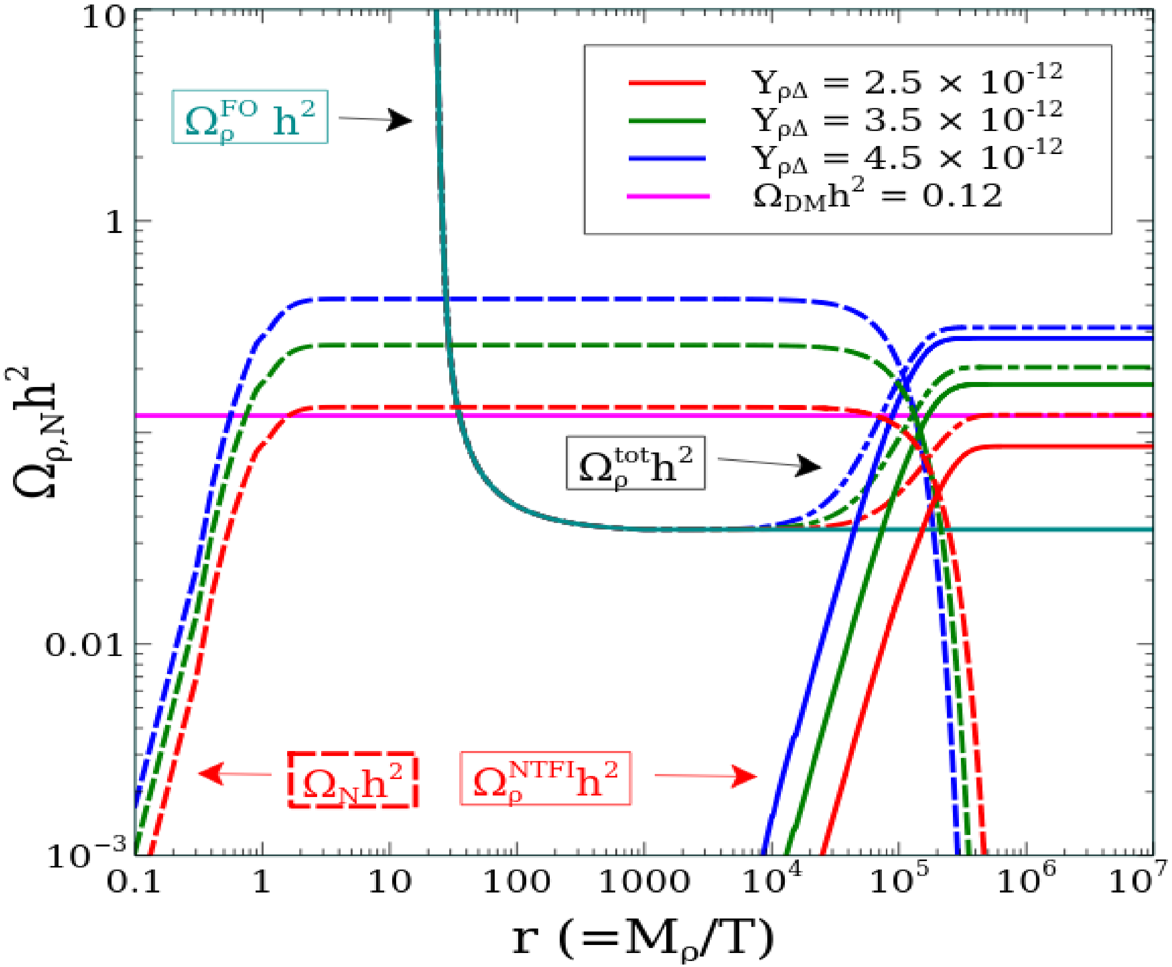
This gives number density of ‘N’ at values of r.

where,

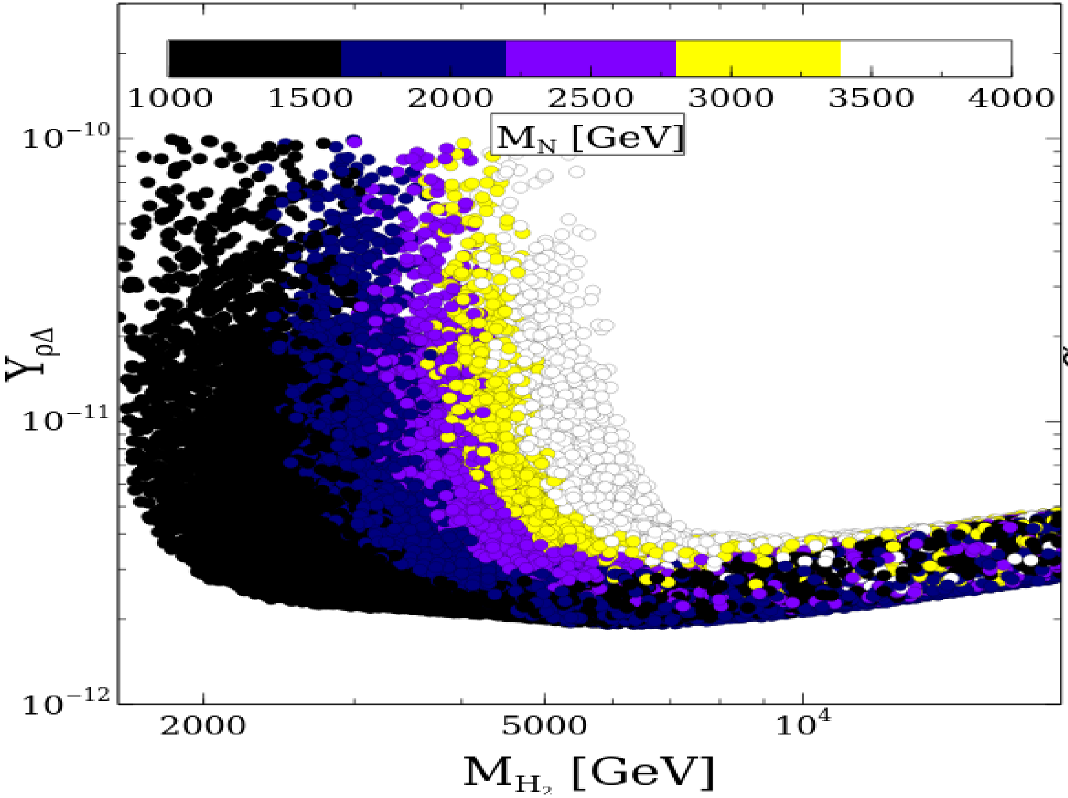
$$\mathcal{B}(r) = \left(\frac{g_s(T_0)}{g_s(T)}\right)^{1/3} = \left(\frac{g_s(M_{sc}/r)}{g_s(M_{sc}/r_0)}\right)^{1/3}.$$

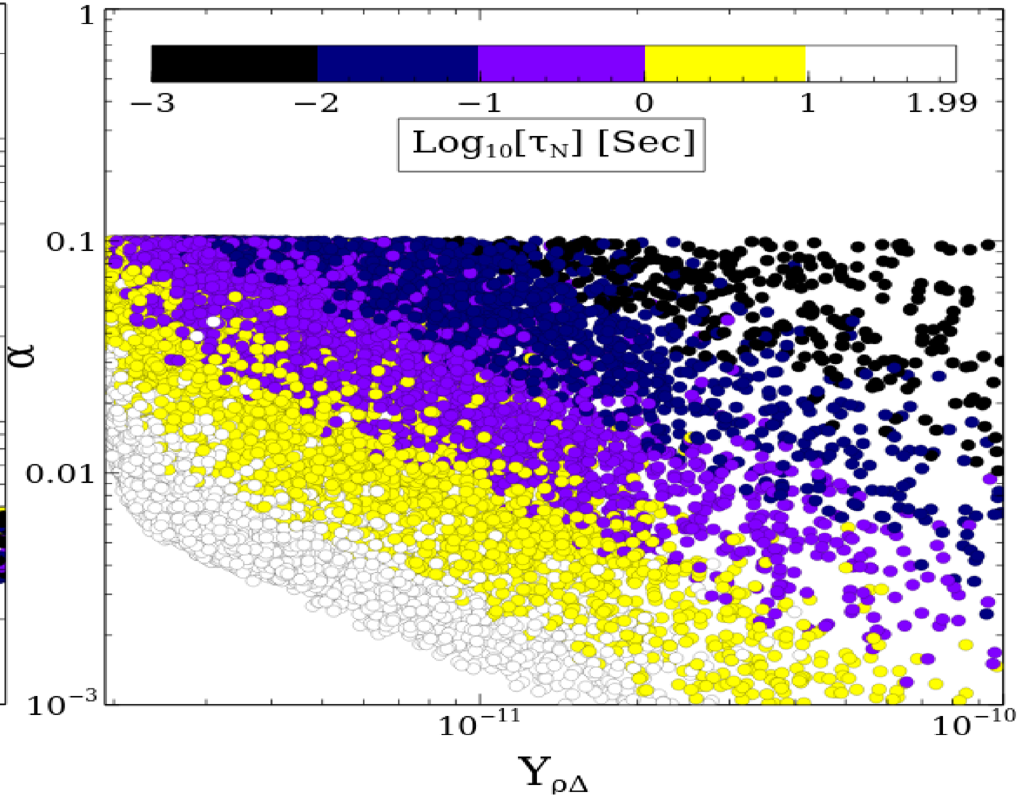
Results:-

$M_N = 2000\ \text{GeV},\ M_\rho = 1300\ \text{GeV}$



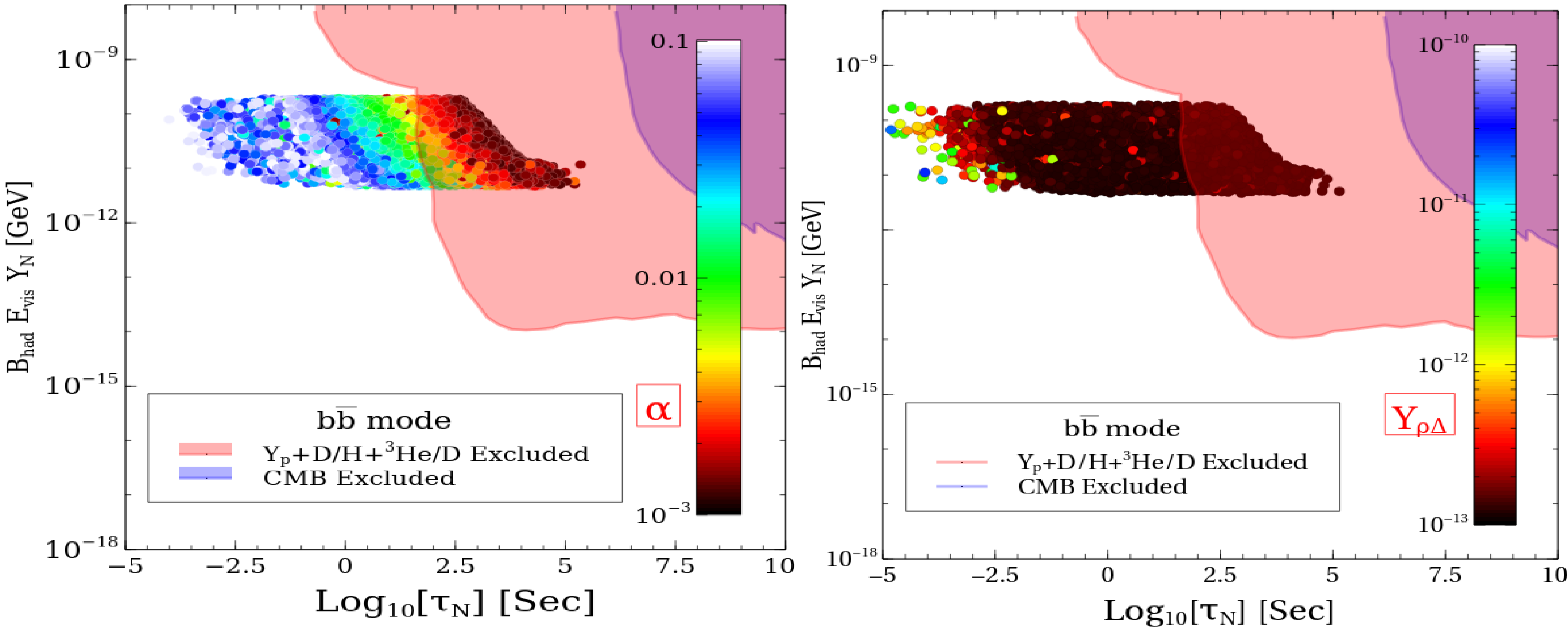
Results:-





- All the points in LP and RP satisfy relic density and BBN bound.
- In LP, M_{H2} < 7 TeV, there is effect of phase space suppression arises from the decay of $H_2 \rightarrow \rho N$ decay. To counter the suppression, the portal coupling is increased. This is in turn decreases the life time of N which is shown in RP.

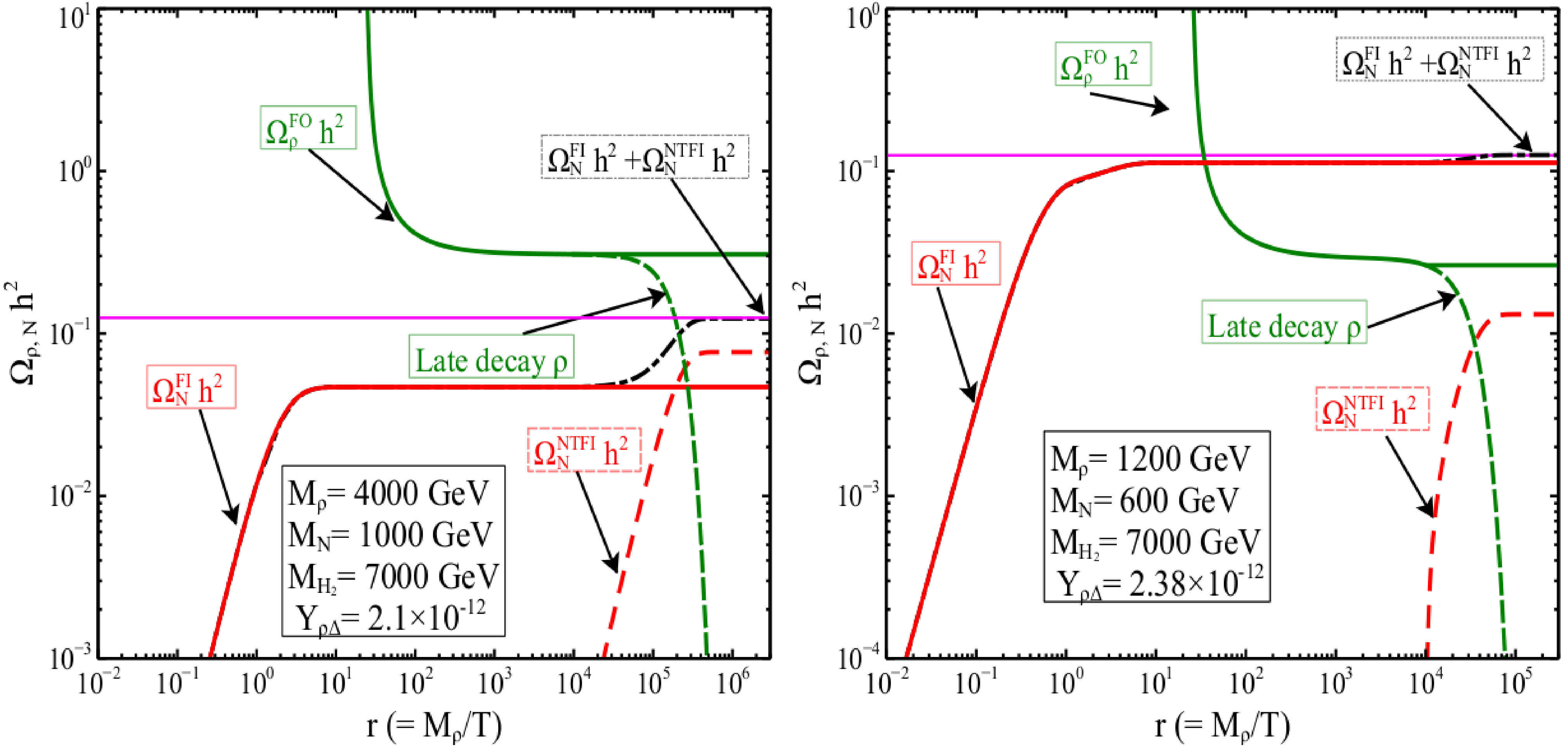
BBN Constraint



- All the points in LP and RP satisfy observed DM relix density.

- Lower value of YρΔ and sin α gets rules out from BBN due to excess hadronic injection to plasma at late times.

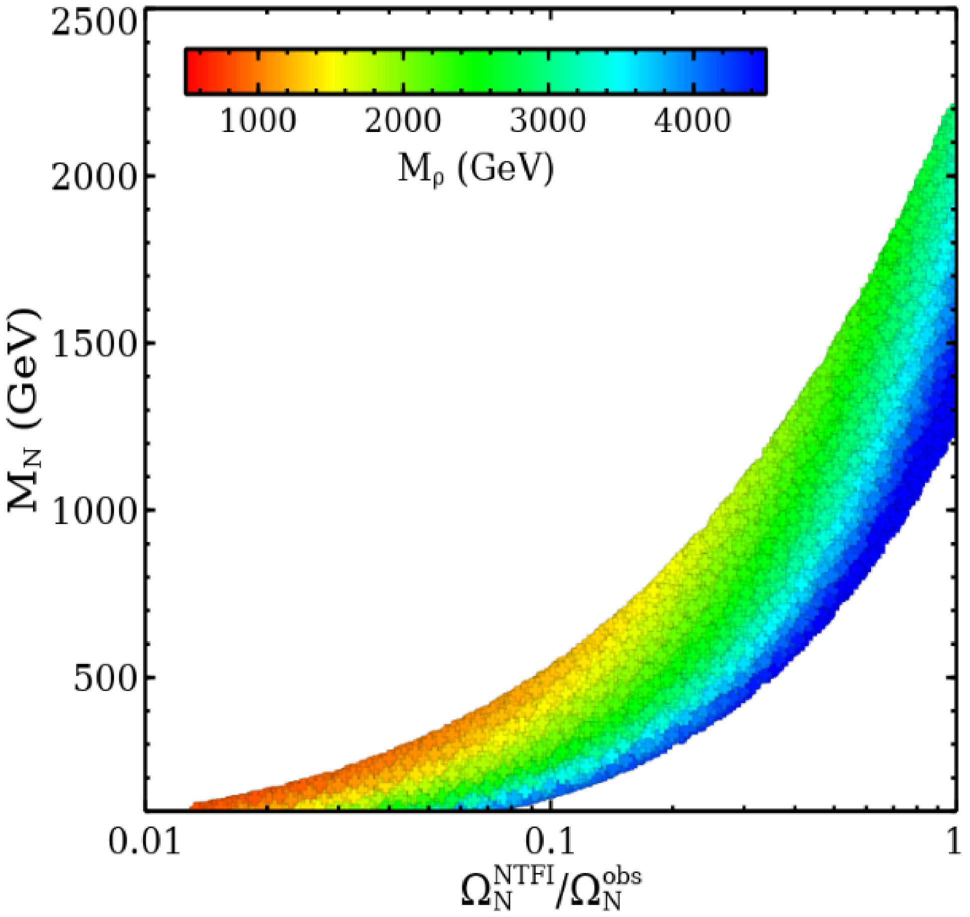
Scenario II → $M_\rho > M_N$ → 'N' is dark matter candidate.

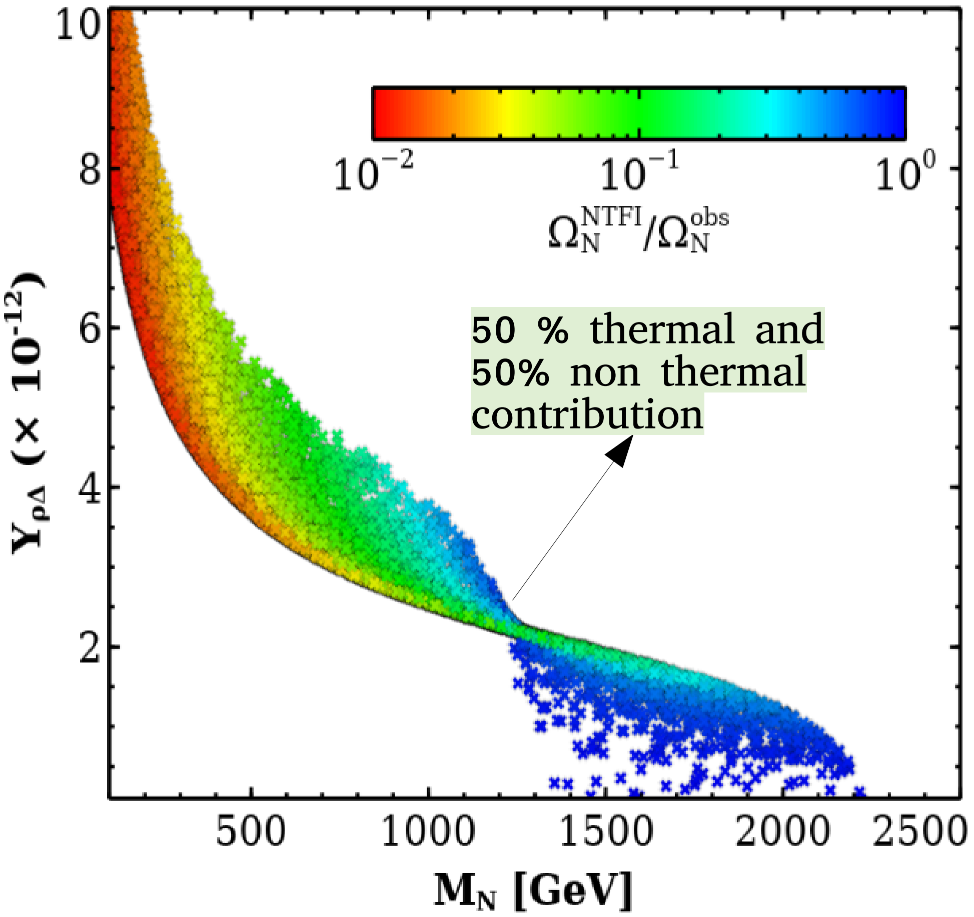


Results:-

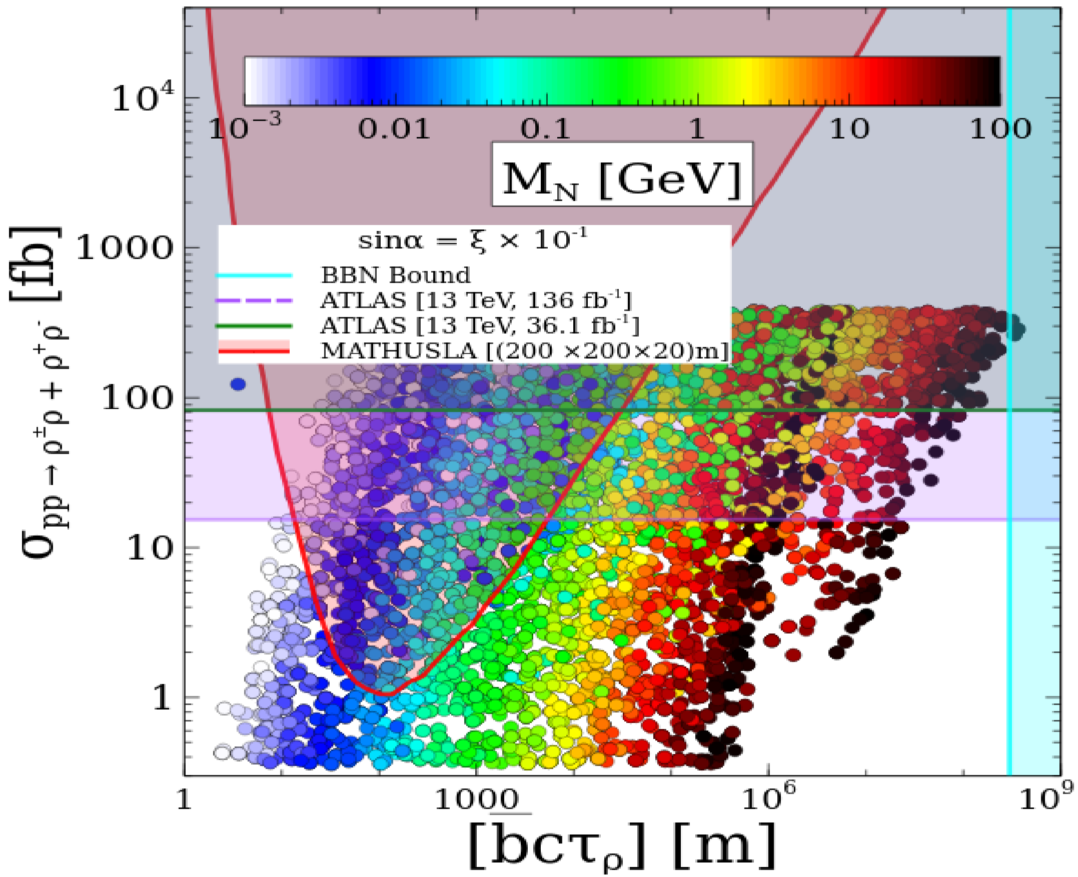
Parameters Varied

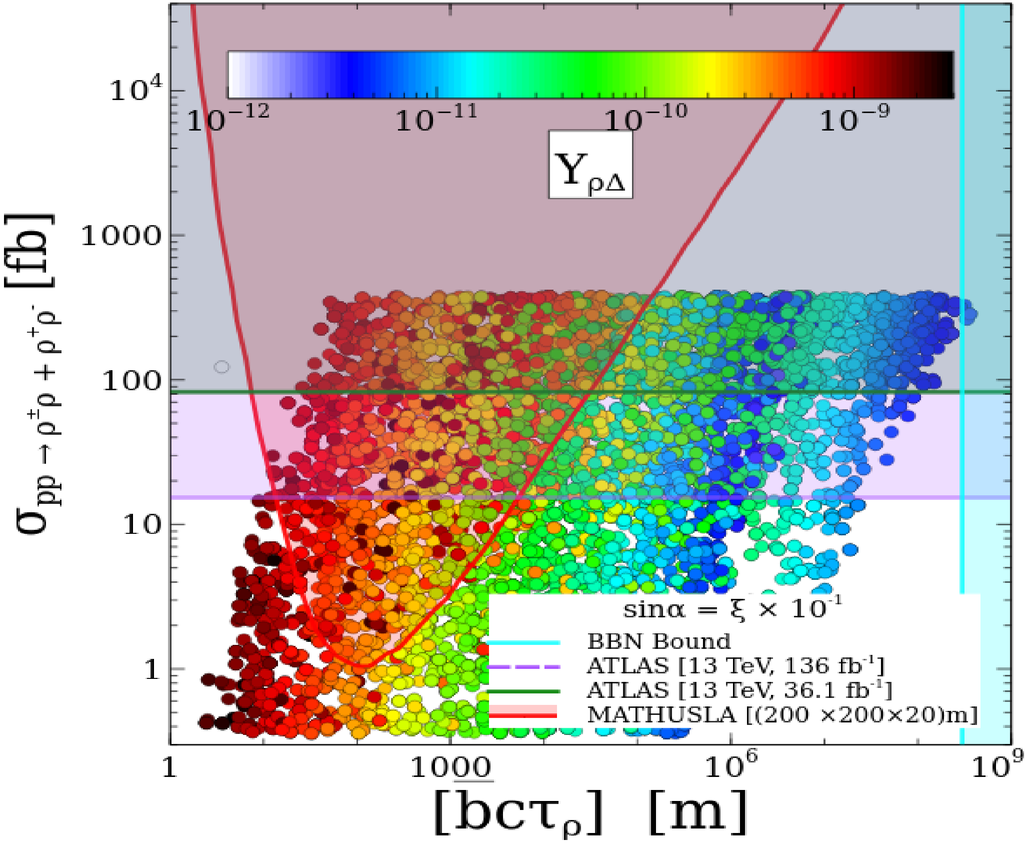
$$10^{-11} < Y_{\rho\Delta} < 10^{-15},\ 100\,\text{GeV} \leq M_N \leq 1800\ \text{GeV and } 600\,\text{GeV} \leq M_\rho \leq 4500\,\text{GeV}$$





Substantial Annhilation Contribution: $M_N < M_\rho$ and $M_{H_2} < M_\rho + M_N$





- Large portion of the region is already ruled out by the ATLAS 136 fb^{-1} data.
- MATHUSLA can detect MeV to GeV range DM mass with the large coupling strength.

Conclusion:-

- The present work can solve two well-accepted SM problems namely a dark matter candidate and the origin of the neutrino mass.
- We investigated different production mechanism for the production of DM.
- We also constrained our model paramters through BBN and found the model to viable in large areas of parameter space.
- We investigated the possible detection prospects of FIMP DM at the MATHUSLA detector

THANK YOU
for your
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