Matter-antimatter asymmetry and dark matter stability from baryon number conservation

Mar Císcar-Monsalvatje

In collaboration with **Alejandro Ibarra** and **Jérôme Vandecasteele**

Physik-Department, Technische Universität München, James-Franck-Straße, 85748 Garching, Germany

based on [2307.02592]

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Motivation

Matter-antimatter asymmetry

- We observe an asymmetry between the number of Standard Model particles and antiparticles, measured as

$$Y_B = \frac{n_B - n_{\bar{B}}}{s} = (8.75 \pm 0.23) \times 10^{-11}$$

- Sakharov conditions (1967)
  - Baryon number (B) violation
  - C and CP violation
  - Departure from thermal equilibrium

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Dark matter

- There is robust evidence for the existence of dark matter
- The relic density is measured: $\Omega_{\rm DM} = 0.265 \pm 0.007$
- The abundance of dark matter is comparable to the abundance of Standard model matter: $\Omega_{\rm DM} \simeq 5\Omega_{\rm SM}$
- We still don't know its nature, it may even carry baryon number

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Relation between them

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- The measured dark matter and baryon energy densities today are of the same order of magnitude, which hints of a common origin for both

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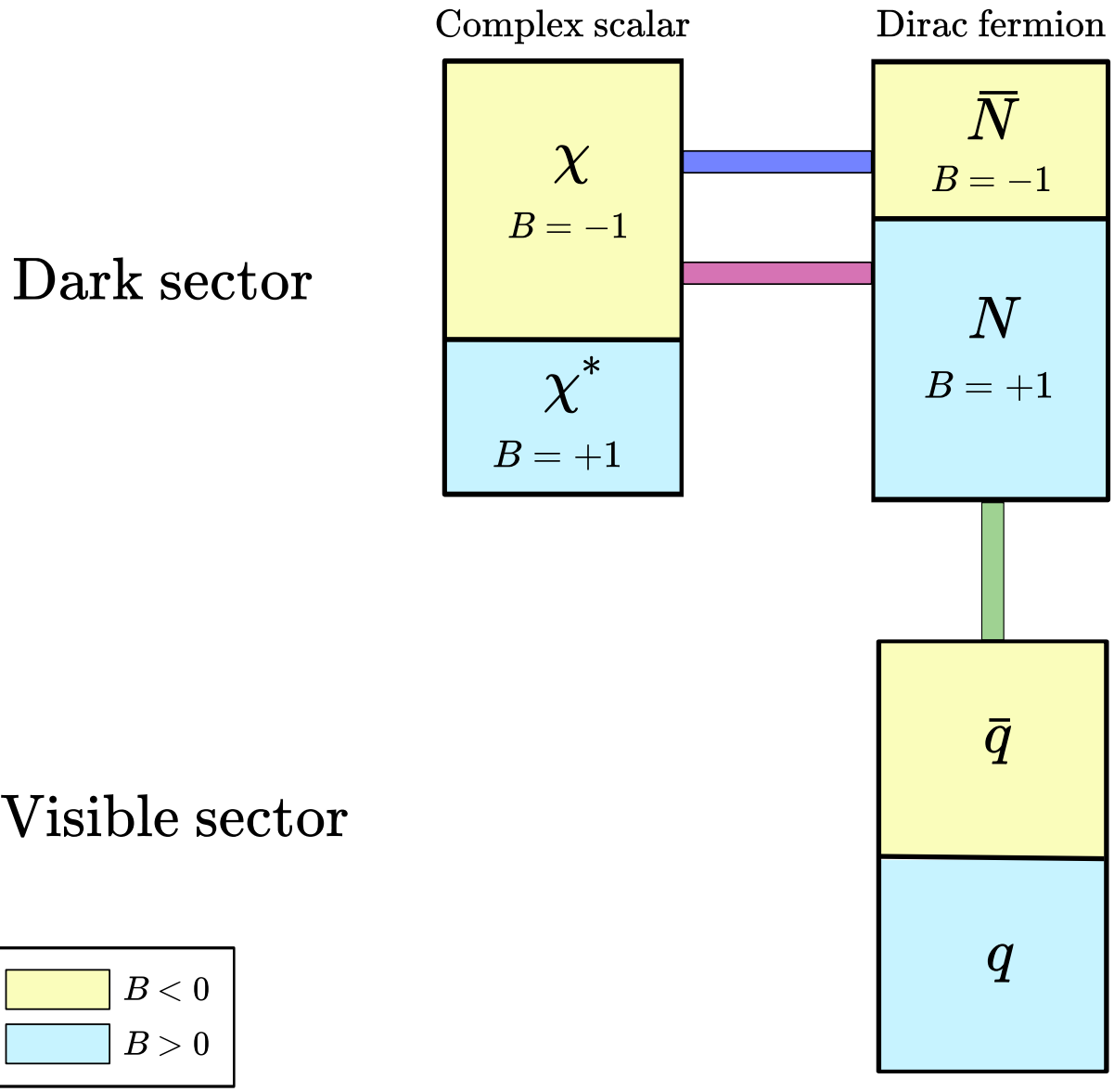
Our scenario

- We question the first Sakharov condition about B violation
- Maybe the Universe is baryon-symmetric even if the visible sector is not
- Result: we don't need B violation to do Baryogenesis
- Conditions we need:
  - C violation in the dark sector
  - Departure from thermal equilibrium
  - A portal between the dark sector and the quarks

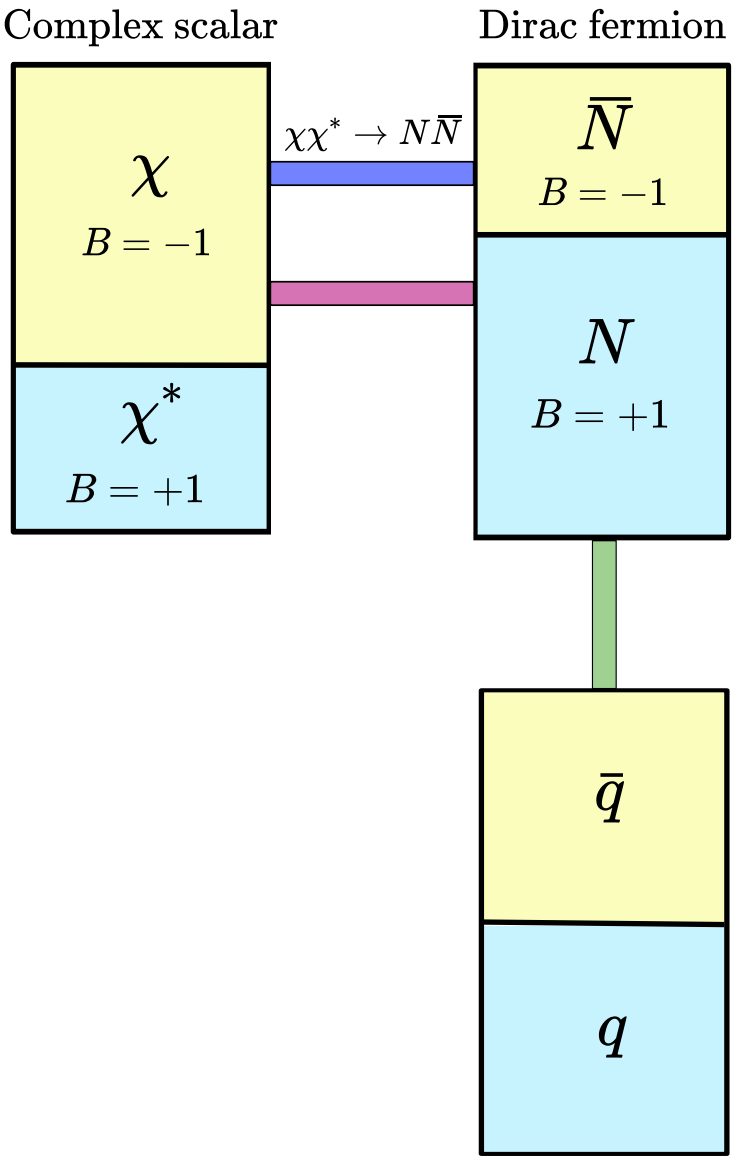
Our scenario

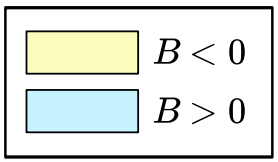


Our scenario

Dark sector

Visible sector





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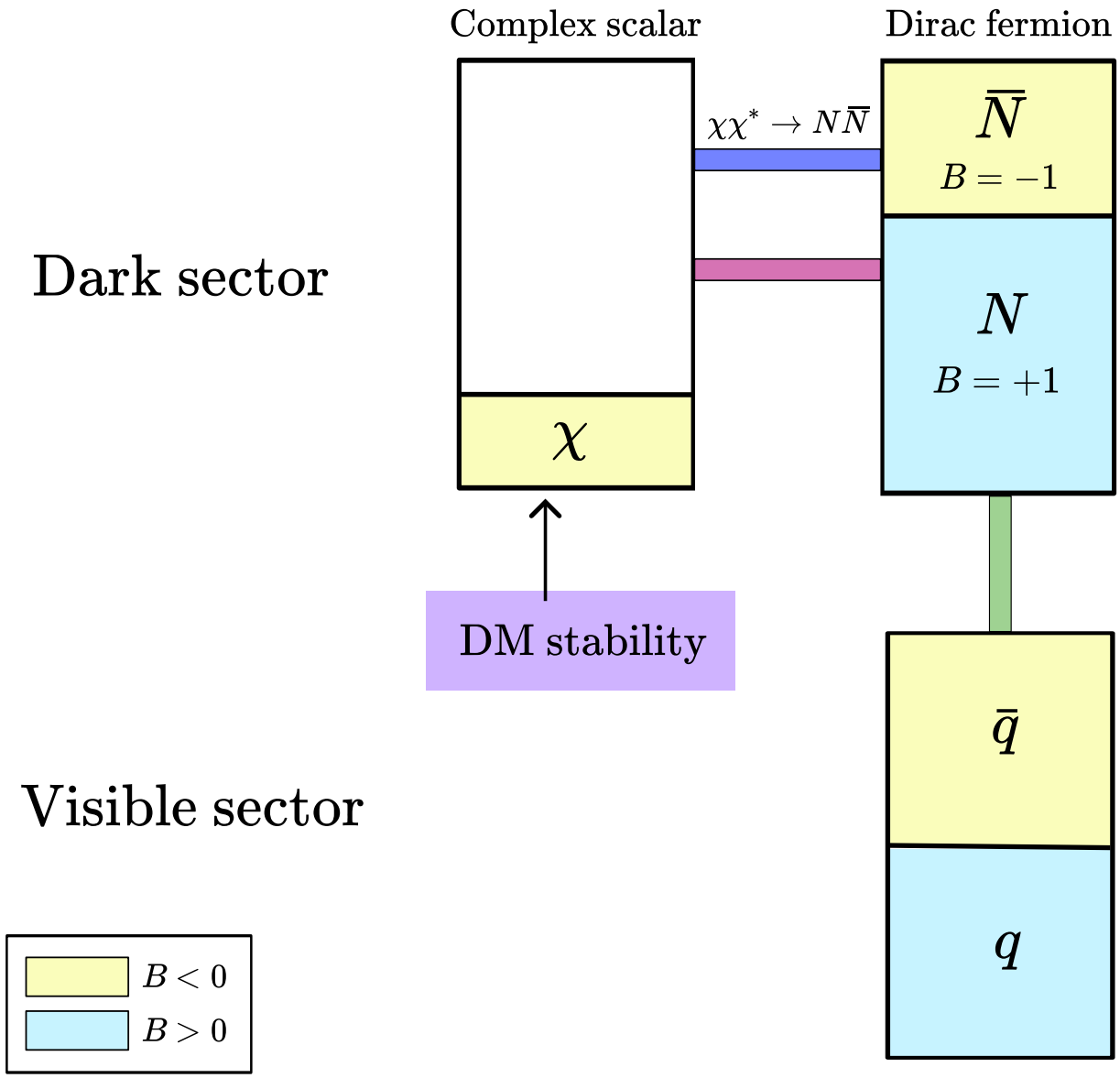

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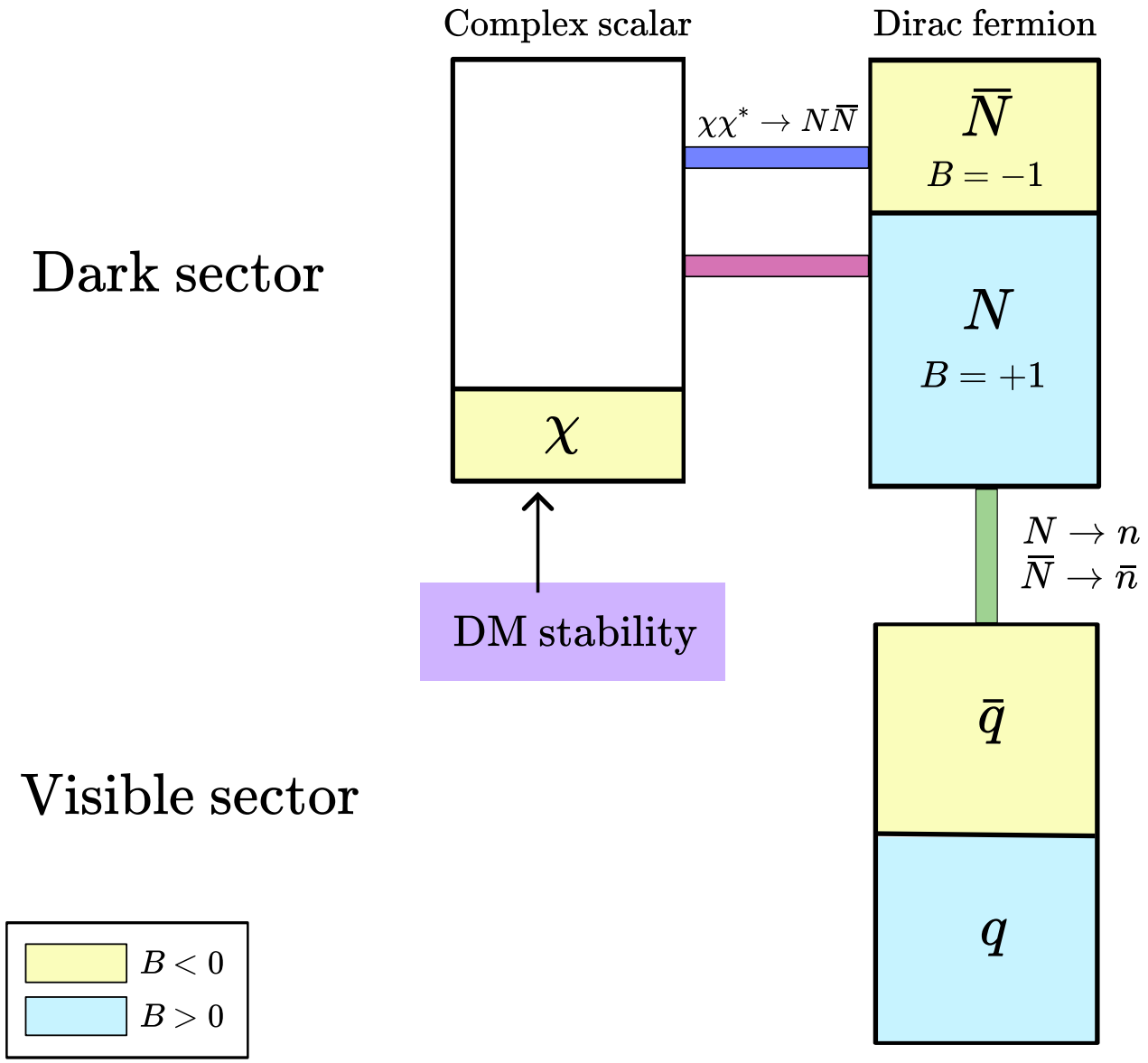

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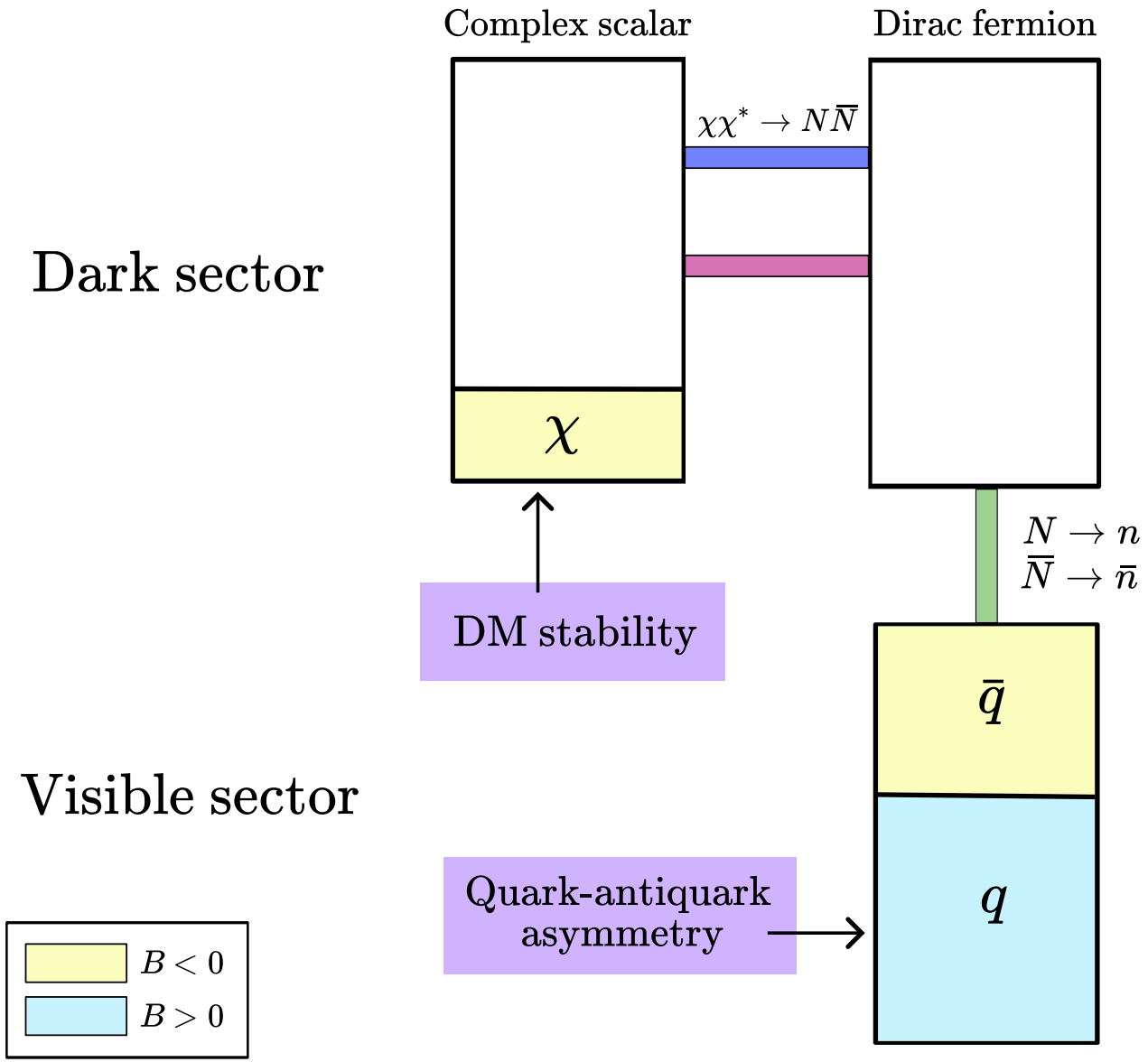

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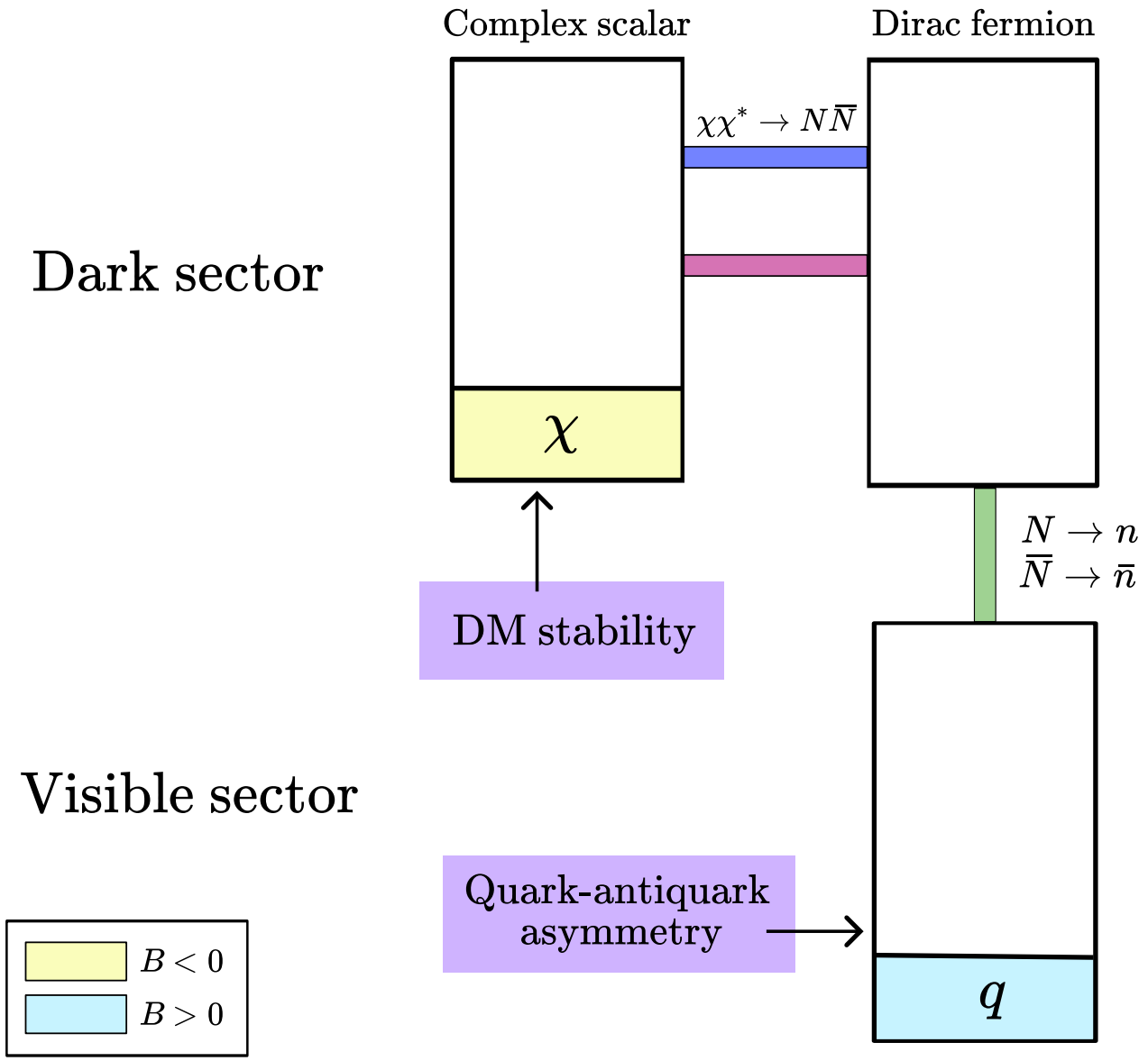

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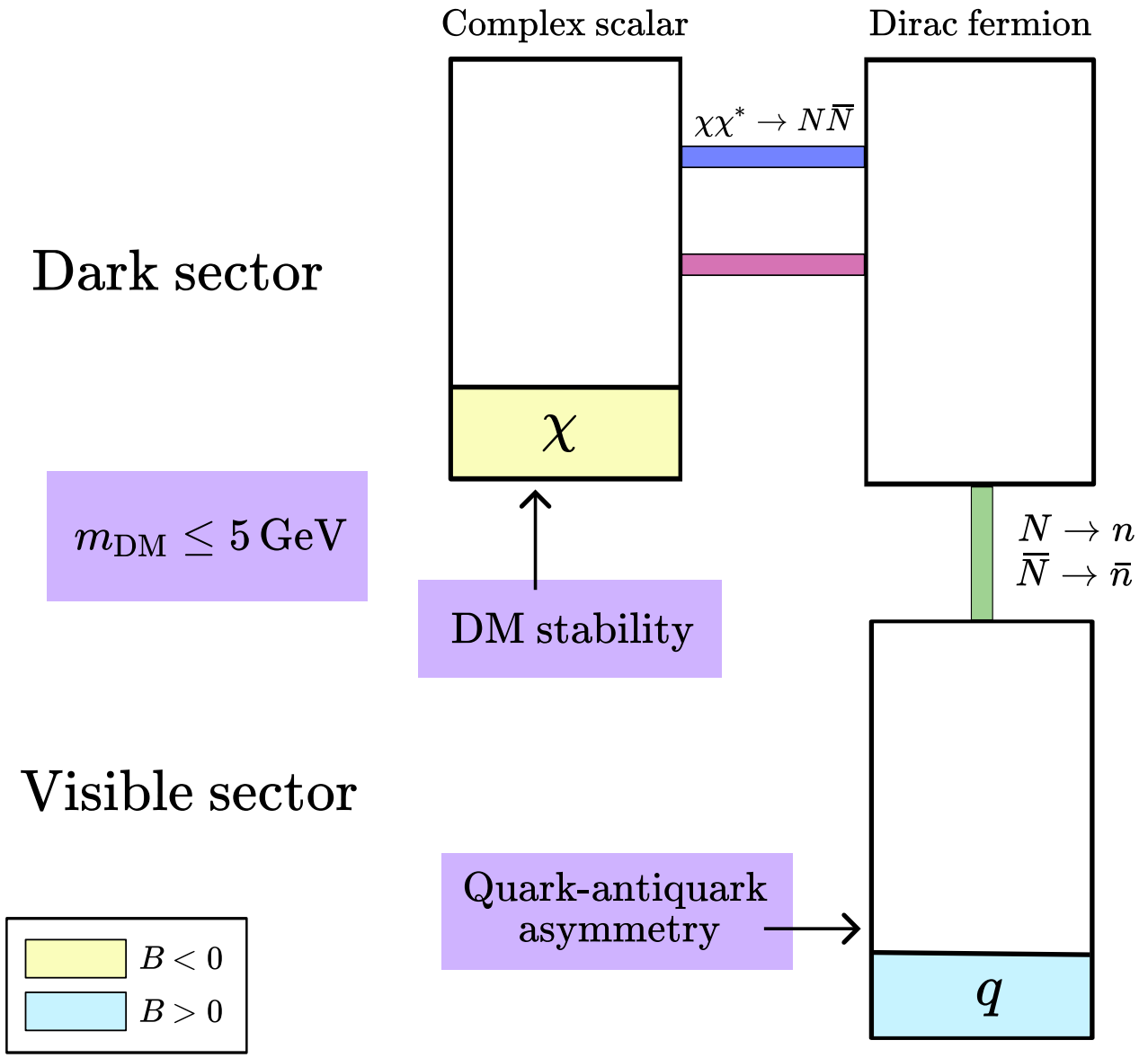

B-conserving interactions

Dark sector:

$$\mathcal{L} \supset \frac{1}{\Lambda_0}\chi\chi^*\overline{N}\,N + \frac{1}{\Lambda_2}\left(\chi\chi\overline{N}^c N + h.c.\right)$$

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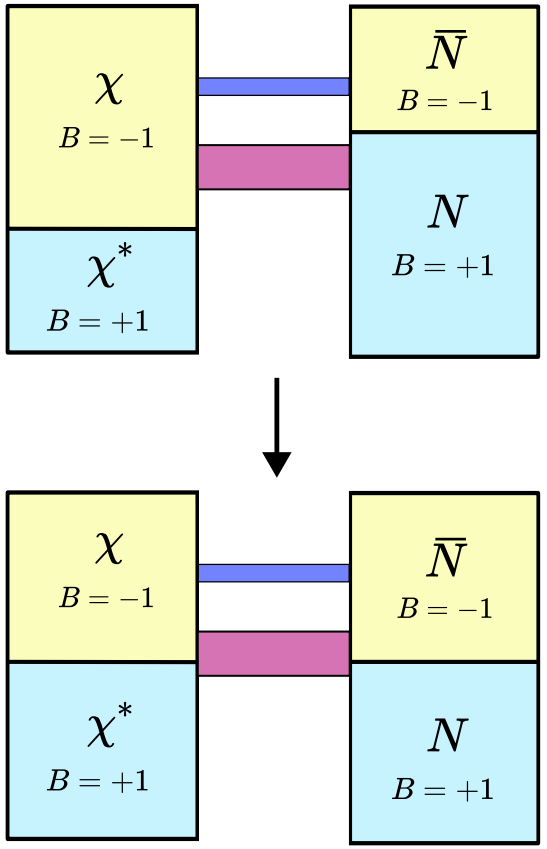

wash out

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Strong

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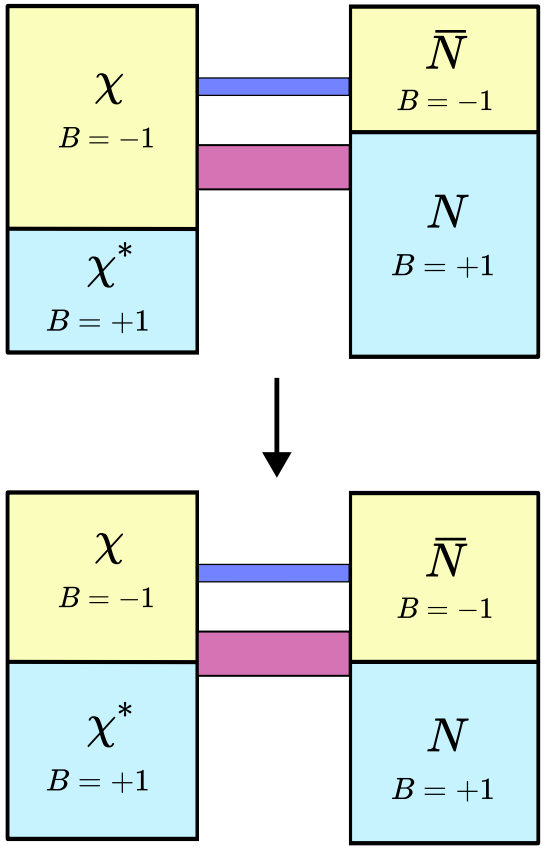
Weak



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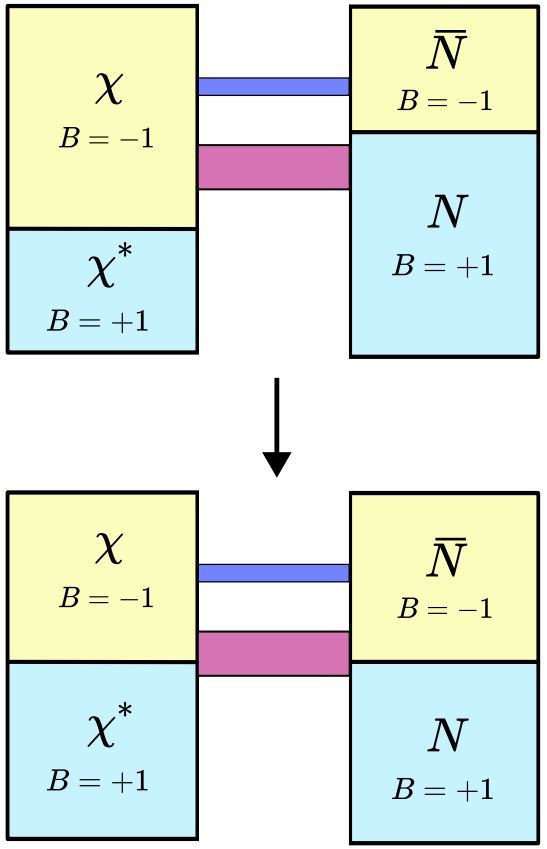
Strong **Weak**



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Neutron portal:

$$\mathcal{L} \supset \frac{1}{{\Lambda_n}^2}\left(\overline{N}d_R\overline{u_R^c}d_R + h.c\right)$$

Neutron portal $N \leftrightarrow udd$

$$\delta m = 1.4 \times 10^{-8}\left(\frac{10^3 \text{ GeV}}{\Lambda_n}\right)^2 \text{ GeV}$$

Mass mixing $\delta m \overline{N} n$

[Fornal et al. 2007.13931]

Dynamics

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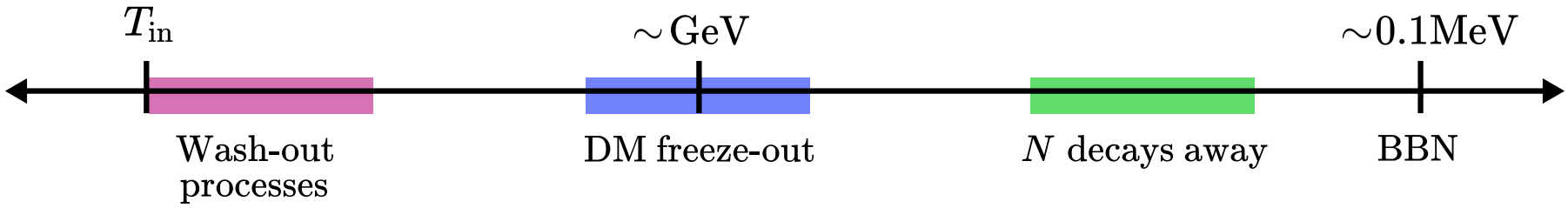

Λ_2

$$\chi\chi \leftrightarrow \bar{N}\bar{N}$$
$$\chi^*\chi^* \leftrightarrow NN$$
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Λ_0

$$\chi\chi^* \leftrightarrow N\bar{N}$$

Λ_n

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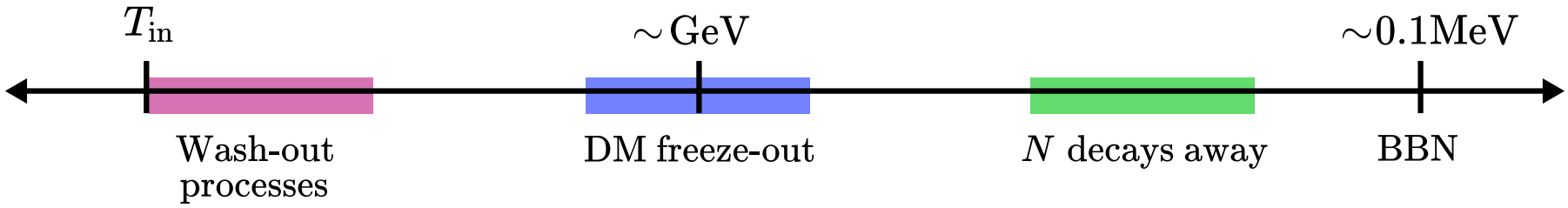

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- We find that for

$$\begin{cases} \Lambda_2 \gtrsim 10^{10}\,\text{GeV}, & \text{correct visible asymmetry}, \\ \Lambda_0 \lesssim 10^{4}\,\text{GeV}, & \text{correct DM abundance}, \\ \Lambda_n \text{ compatible with experiments}, & \text{asymmetry transmitted before BBN}. \end{cases}$$

Constraints

Dark matter

- We don't expect signals from direct or indirect detection, due to the high suppression of the involved processes. (see back-up slide)
- Possibility to detect dark matter via a Higgs portal is open.

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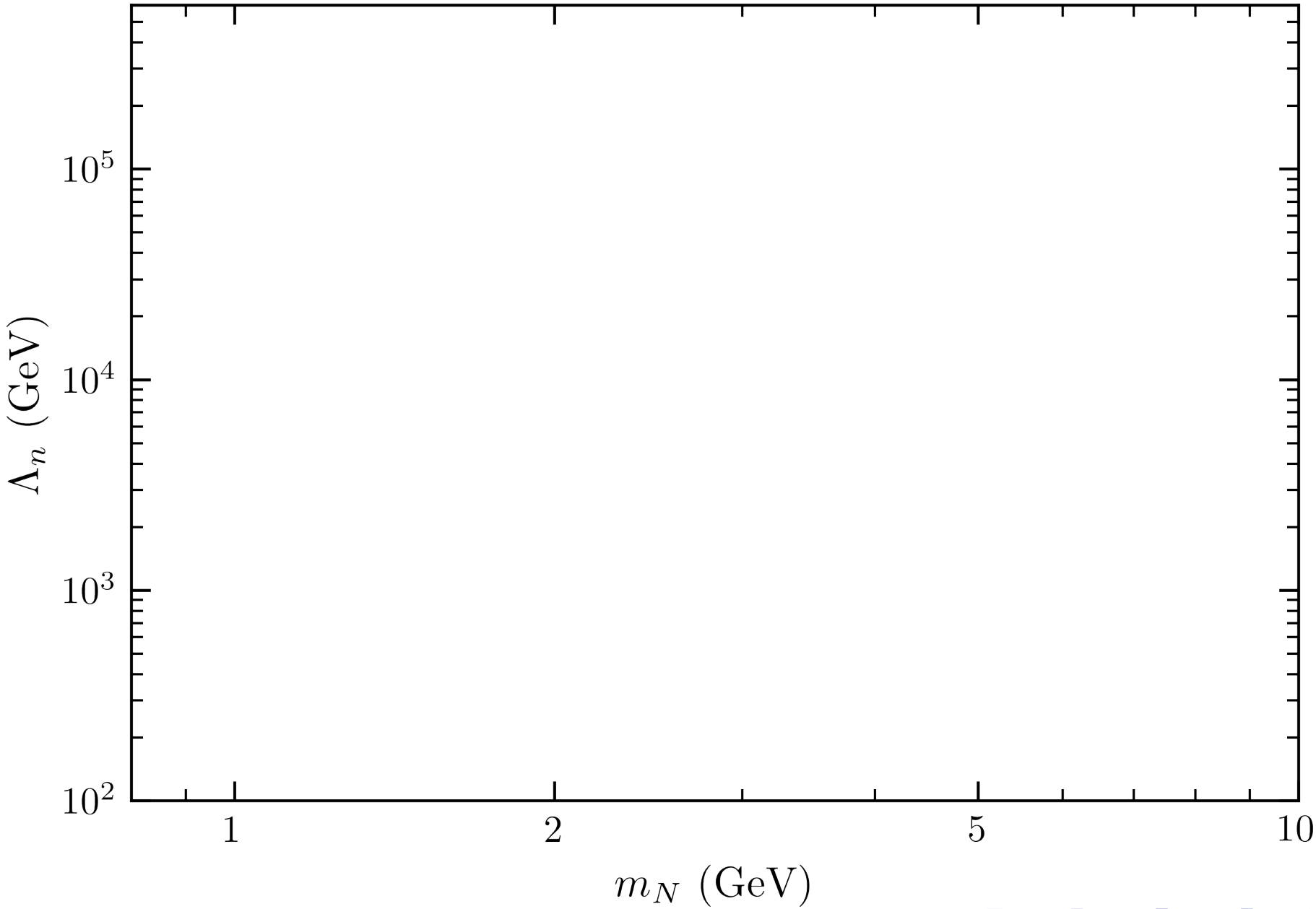
Neutron portal

Detection prospects with interesting signals!

- Impacts the cosmological history [Allahverdi et al. 2108.13136]
- Could be probed in colliders
- Well defined window in parameter space

Neutron portal constraints



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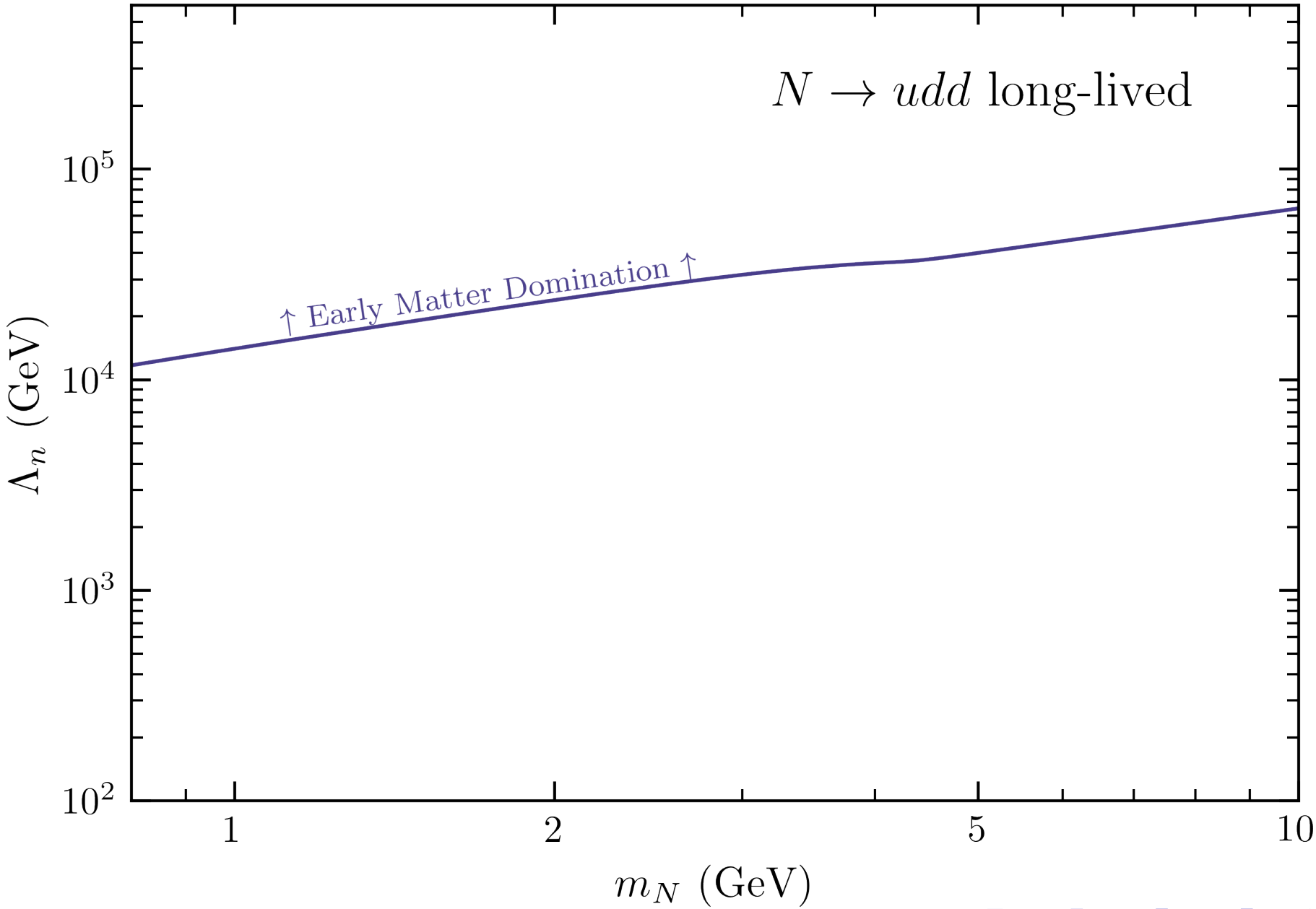

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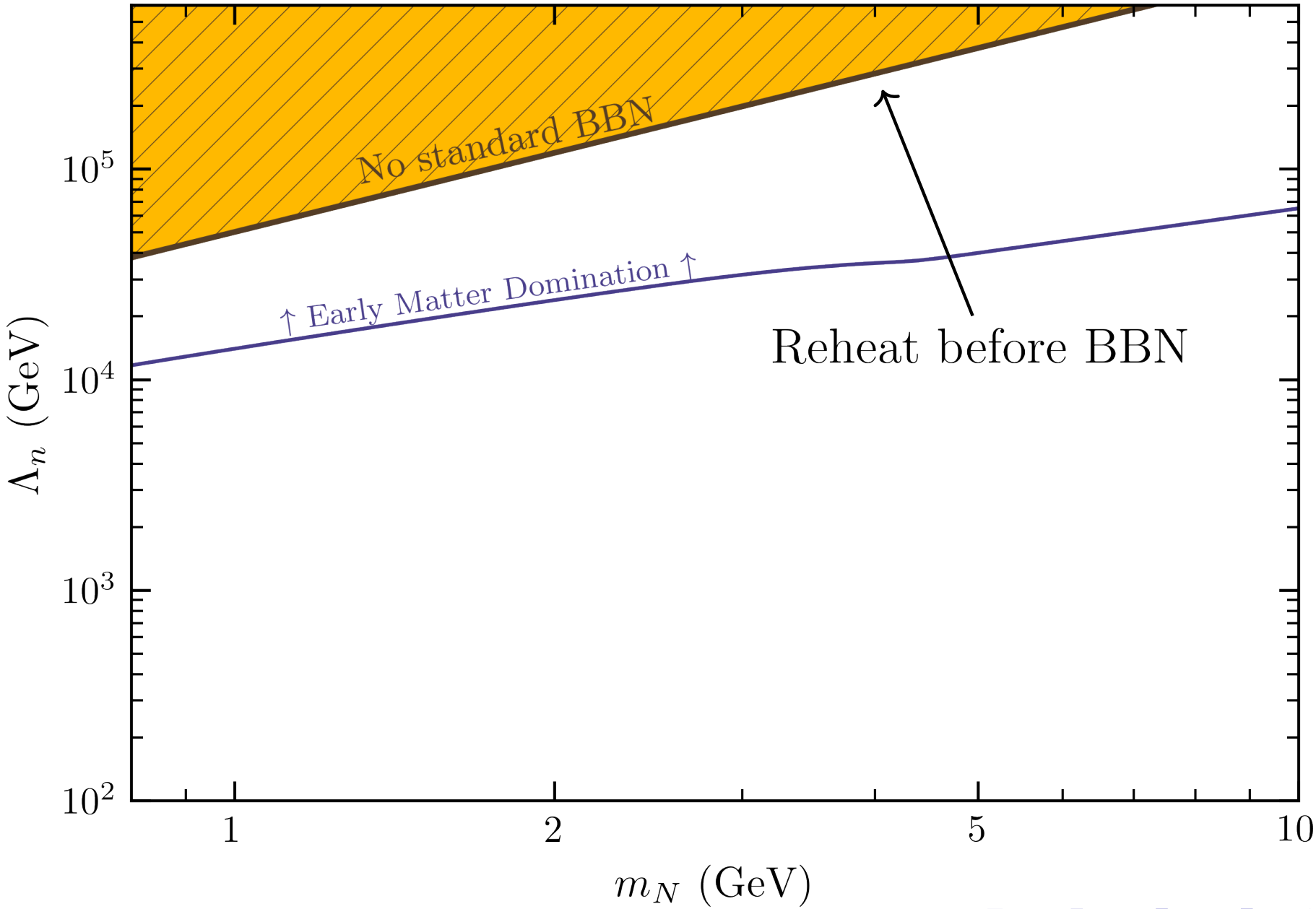

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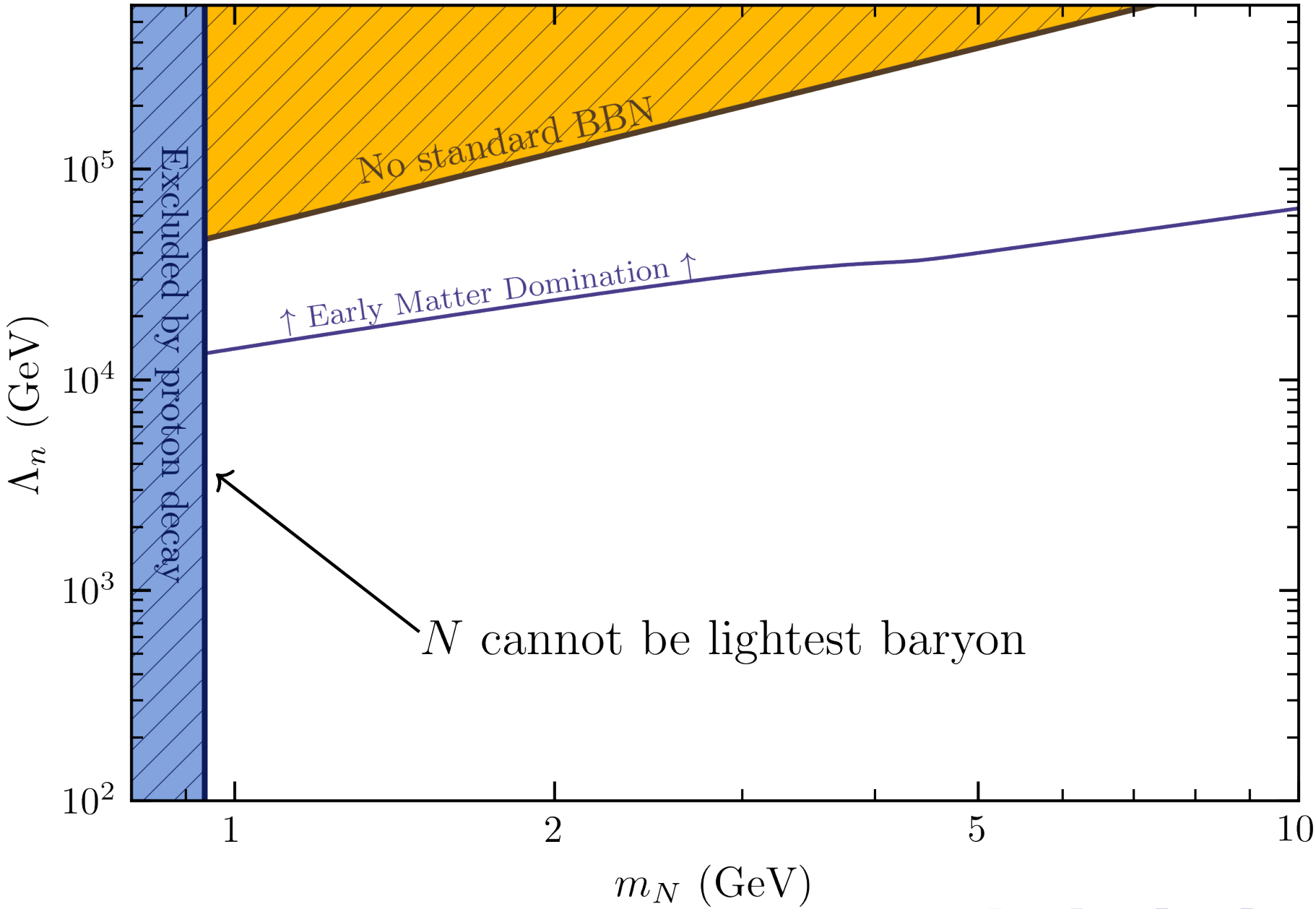

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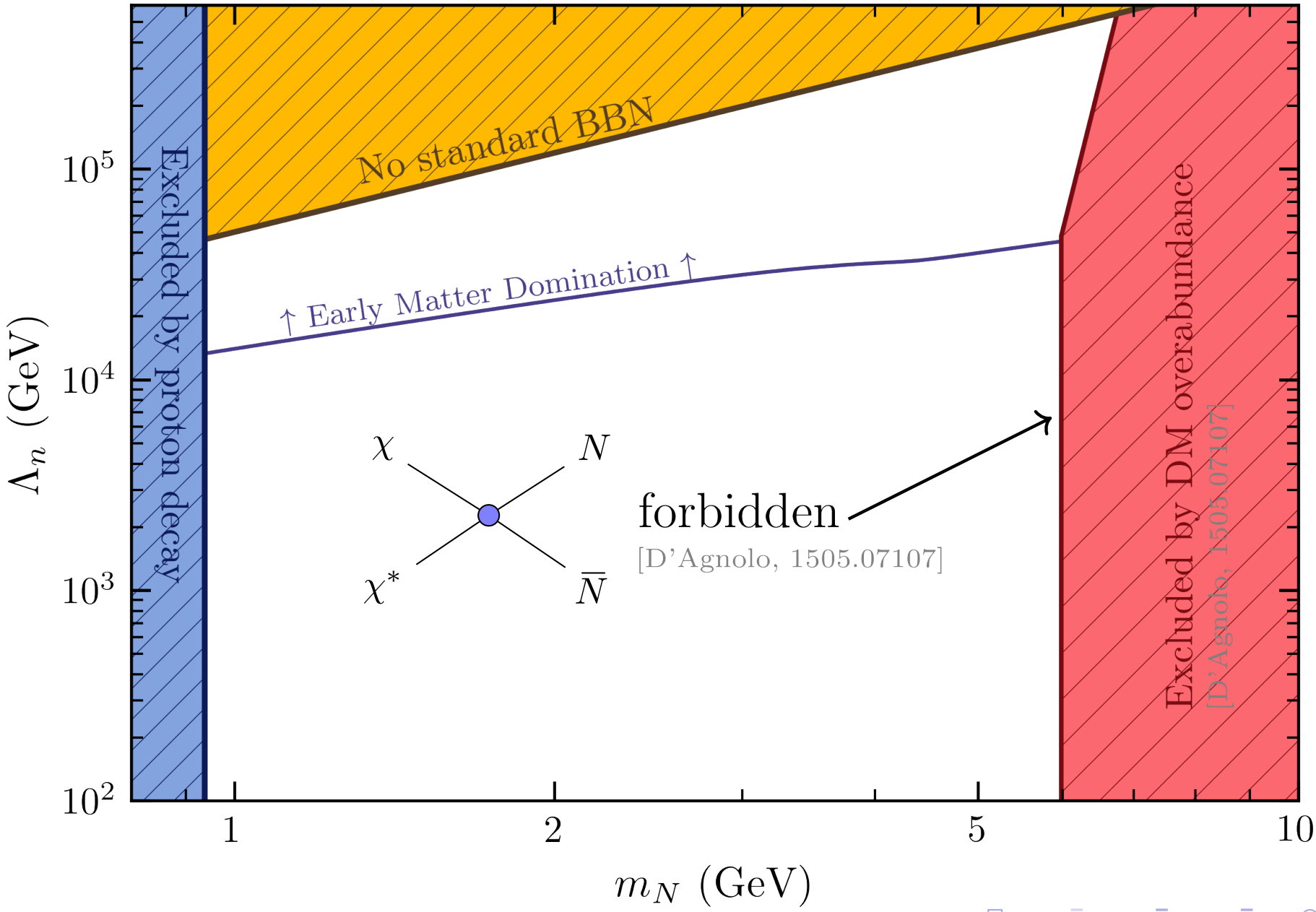

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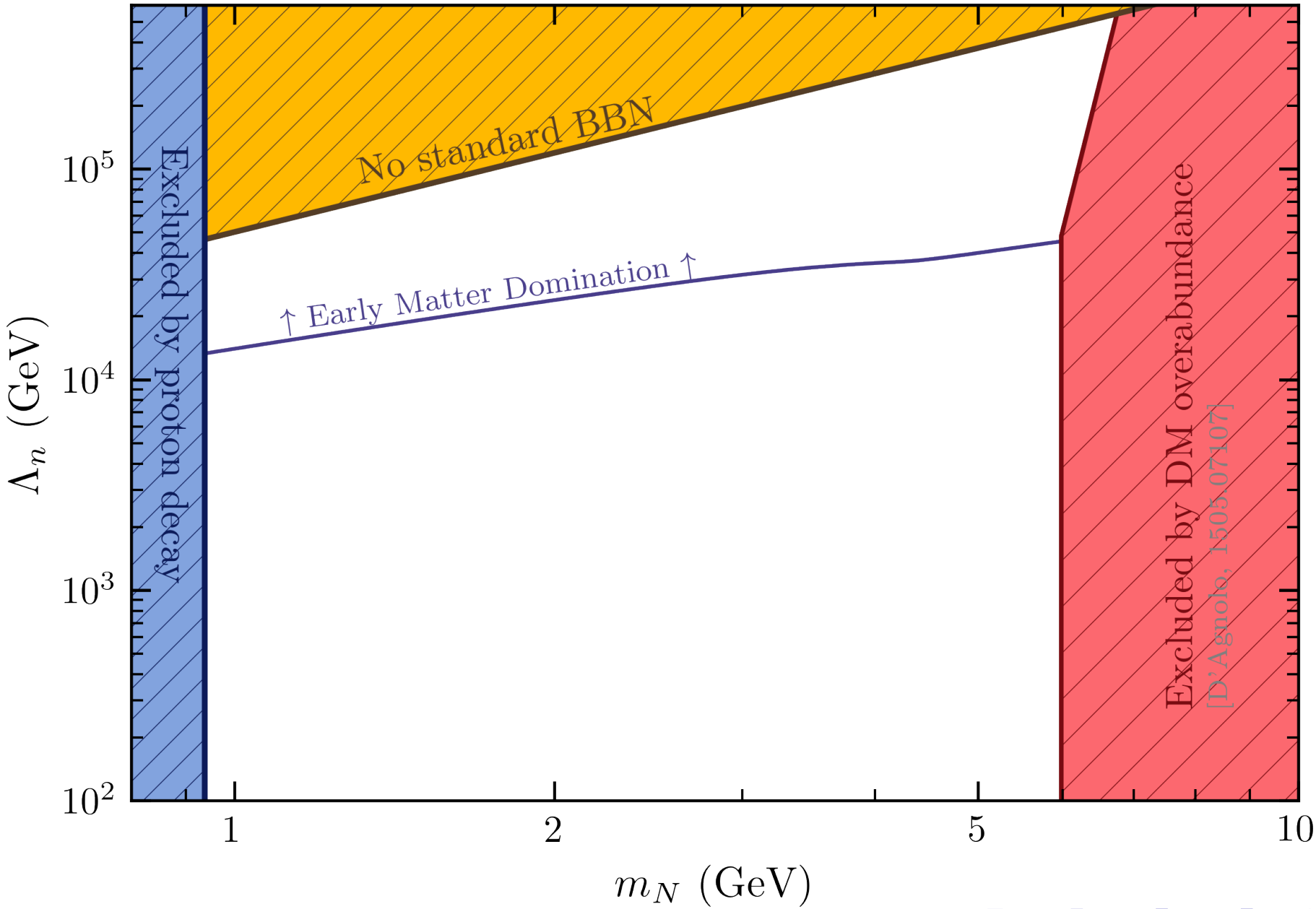

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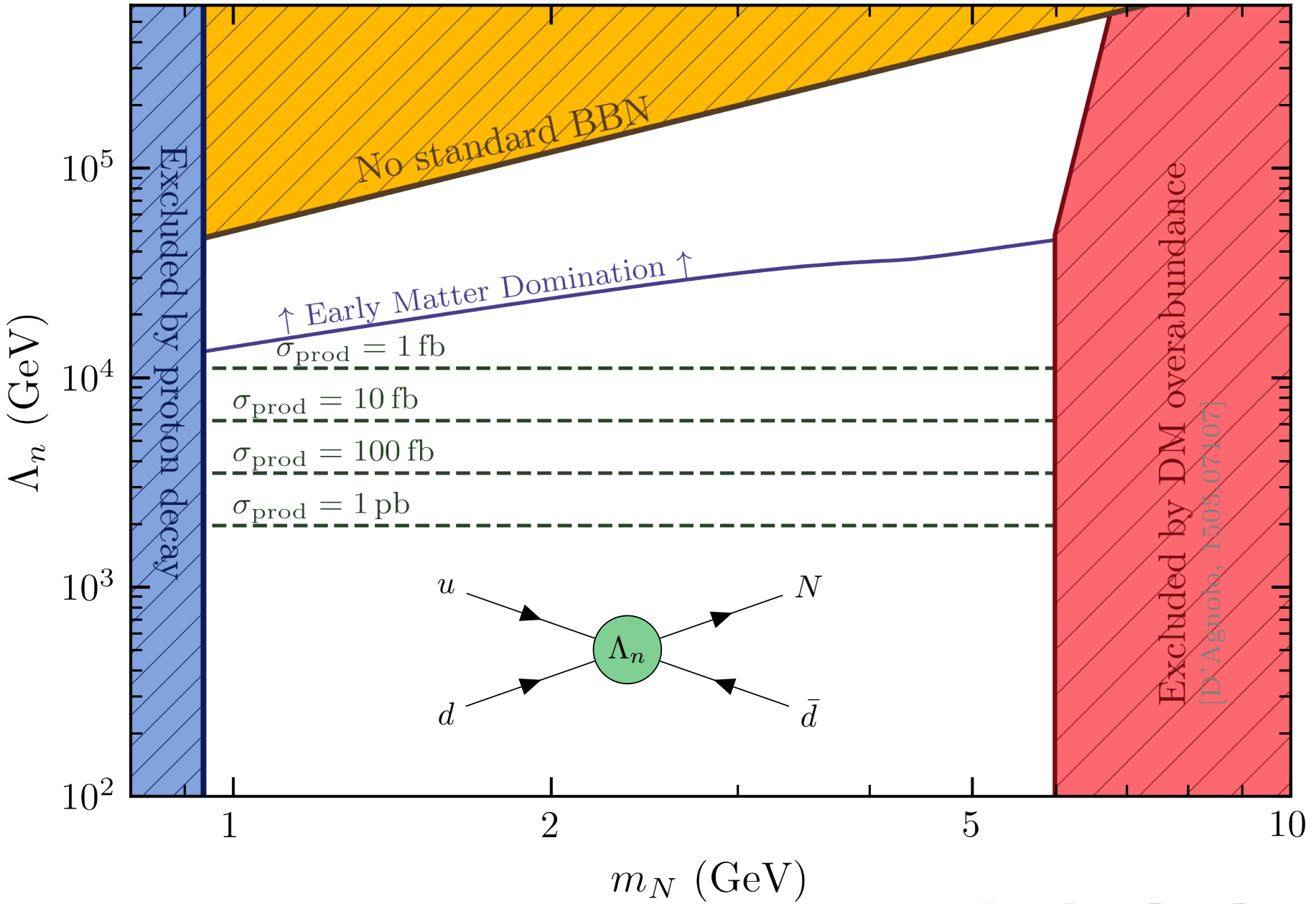

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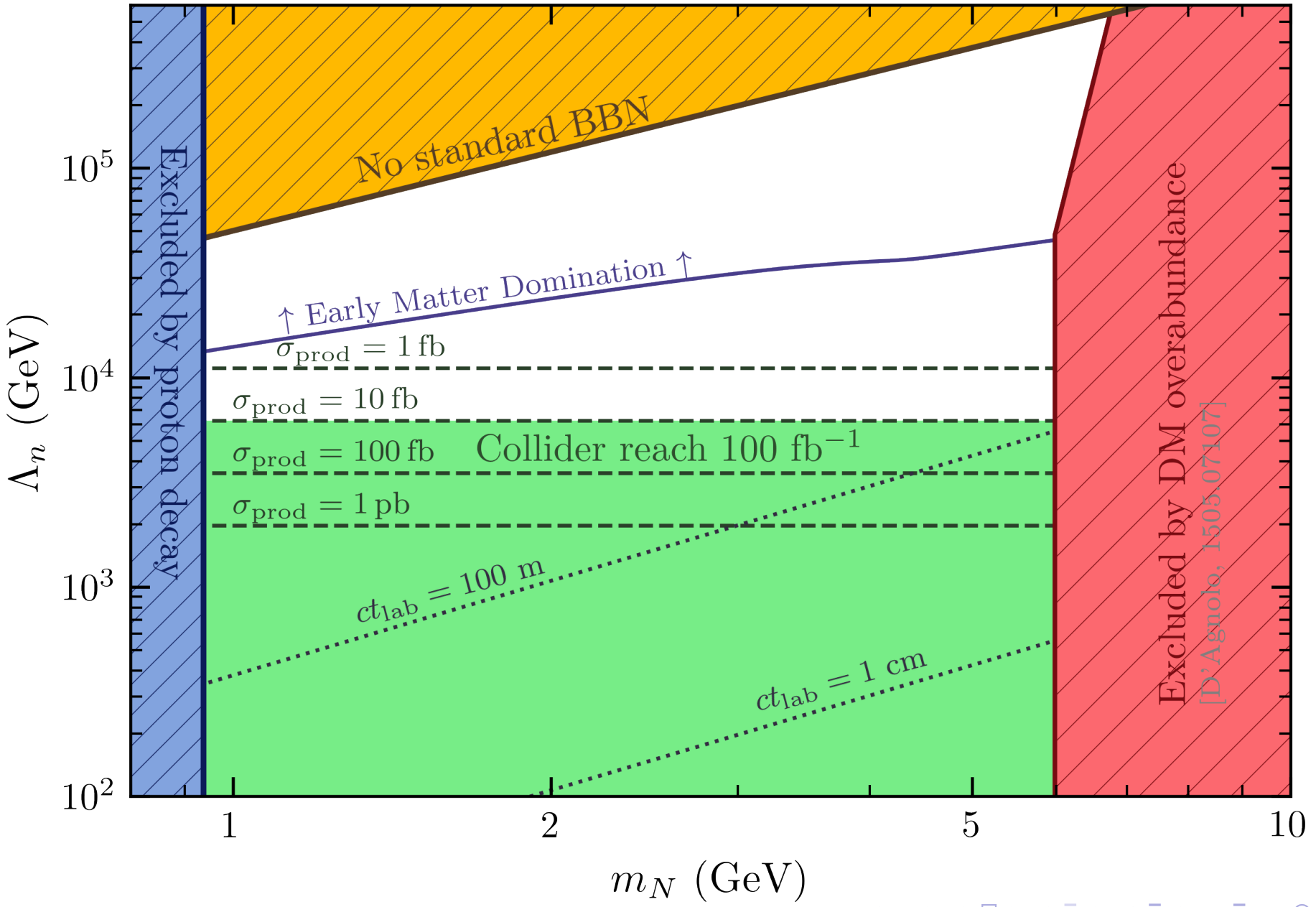


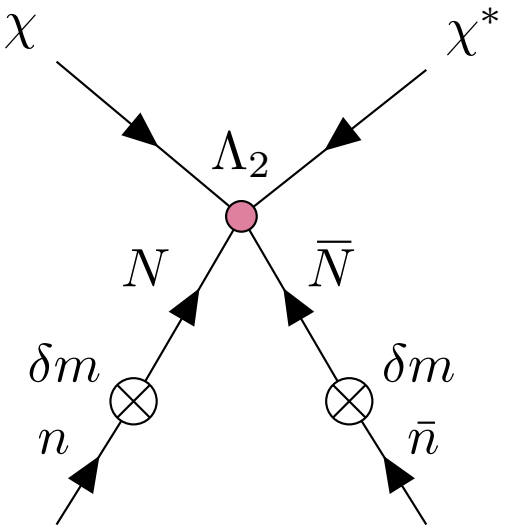
Conclusions

- We proposed a novel scenario where we solve both the DM and quark-antiquark asymmetry questions without baryon number violation.
- We predict a thermal, light DM candidate with highest mass possible of 5 GeV, the stability of which follows naturally and is linked to the quark-antiquark asymmetry.
- We have viable prospects for probing the particles in the Neutron Portal. The parameter space has a defined and constrained window.
- Next: we are working on providing an explicit realization for this scenario in a UV complete model, for which the asymmetry within the dark sector is generated by a leptogenesis-inspired mechanism.

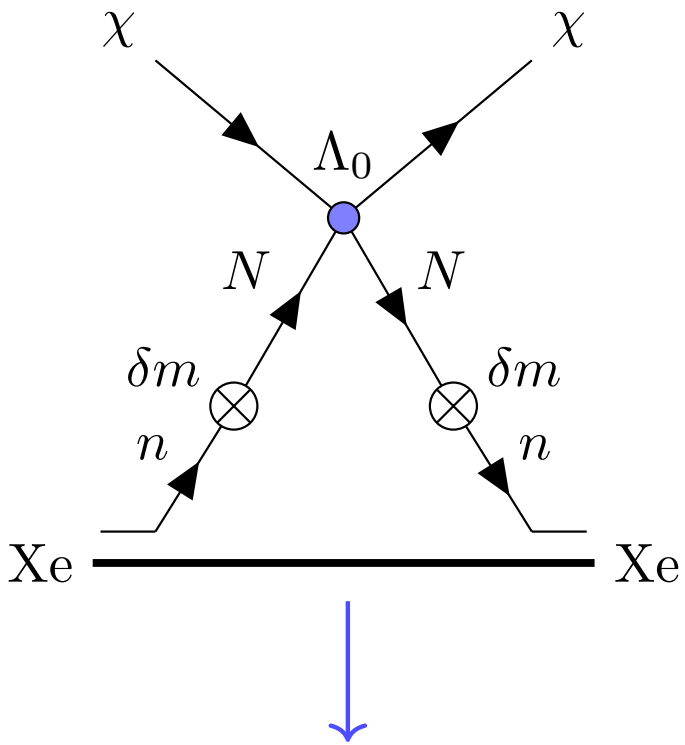
Thank you for your attention!

Direct detection of DM

Very suppressed due to small mixing δm

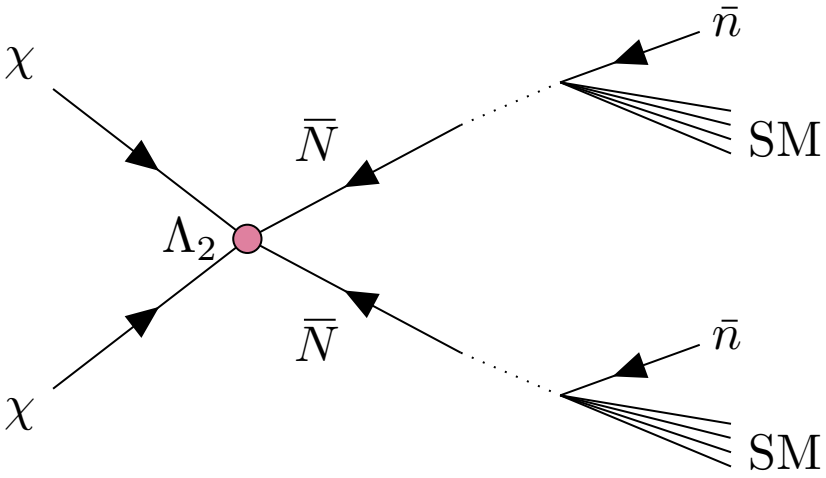


Transmutes a neutron into an antineutron

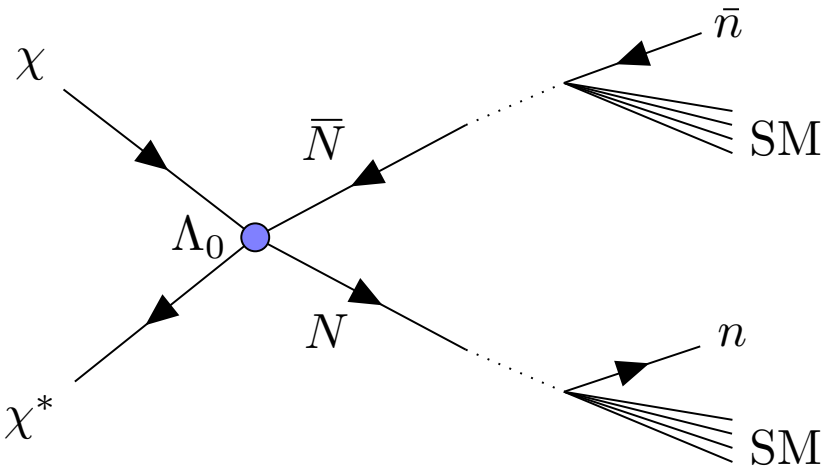


Neutron stars don't help...

Indirect detection of DM

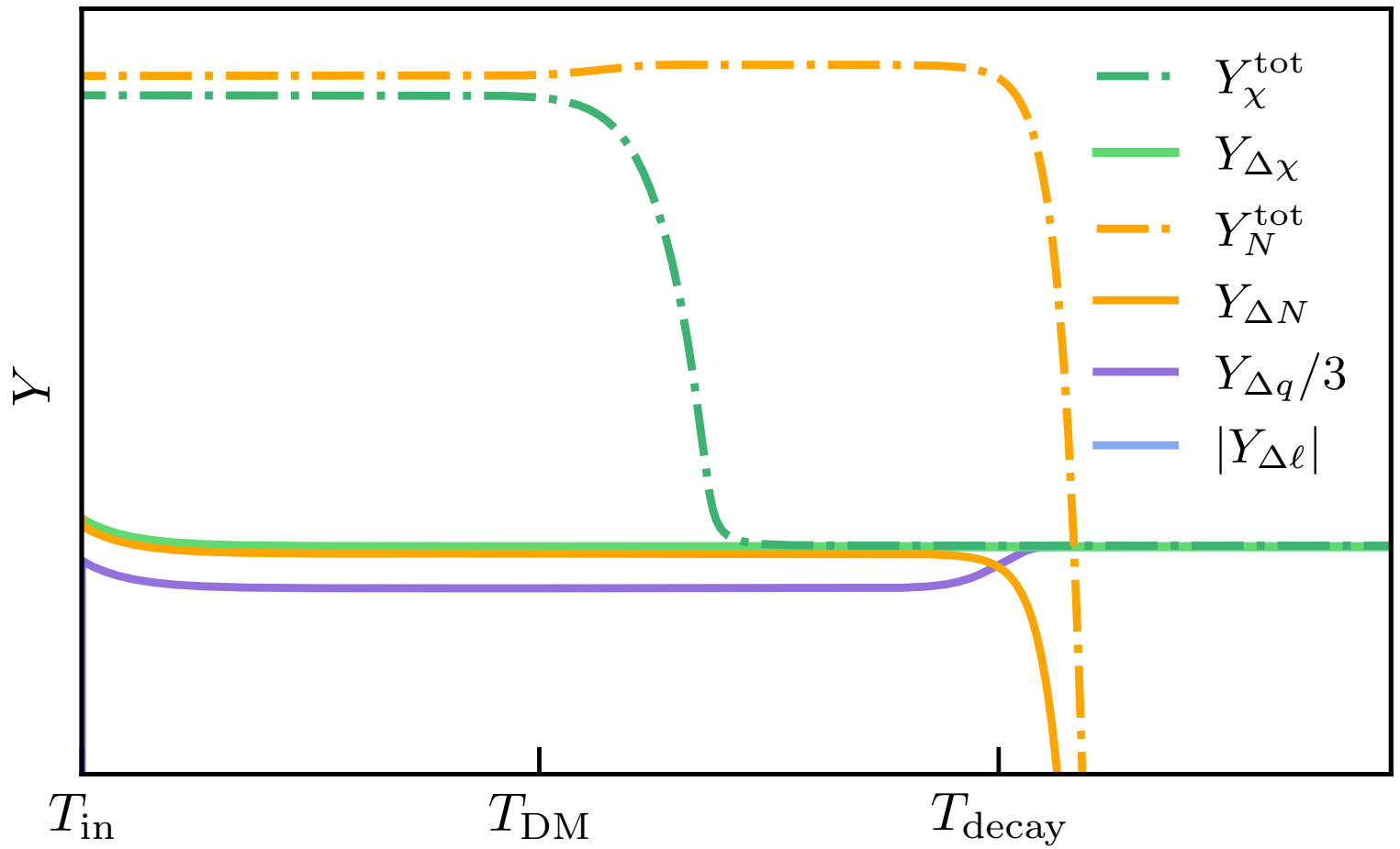


Happens even for asymmetric dark matter



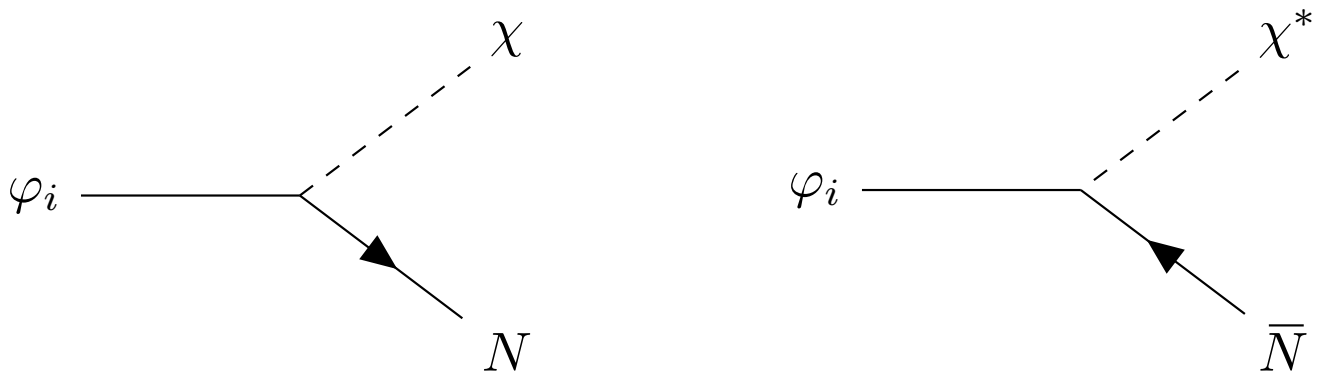
Stronger signal but very soft spectrum

Full Boltzmann equations solutions



Generation of the initial condition

Introducing φ_1 and φ_2, Majorana fermions with $B = 0$



If sphalerons are efficient at $T_{\rm in}$

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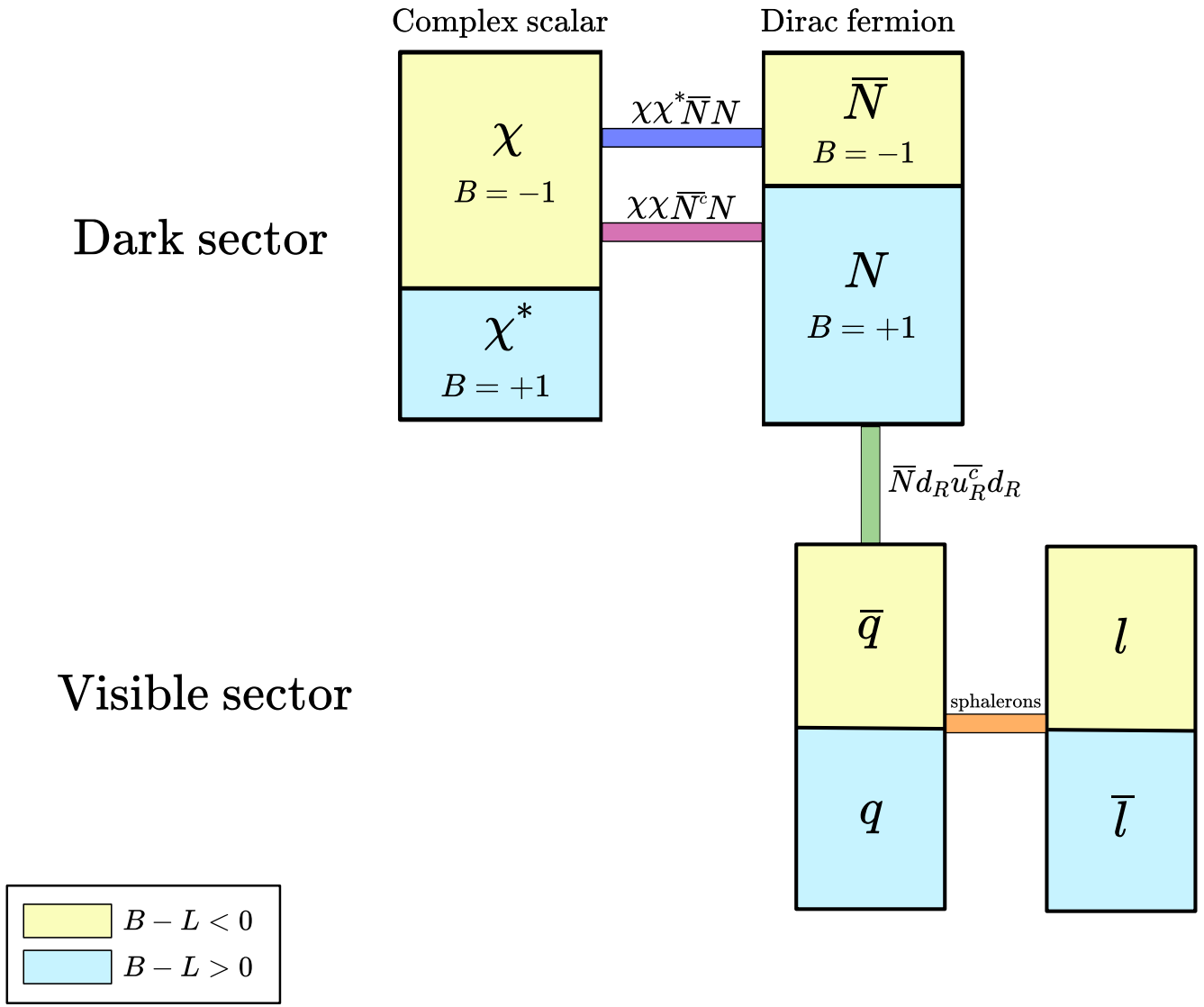

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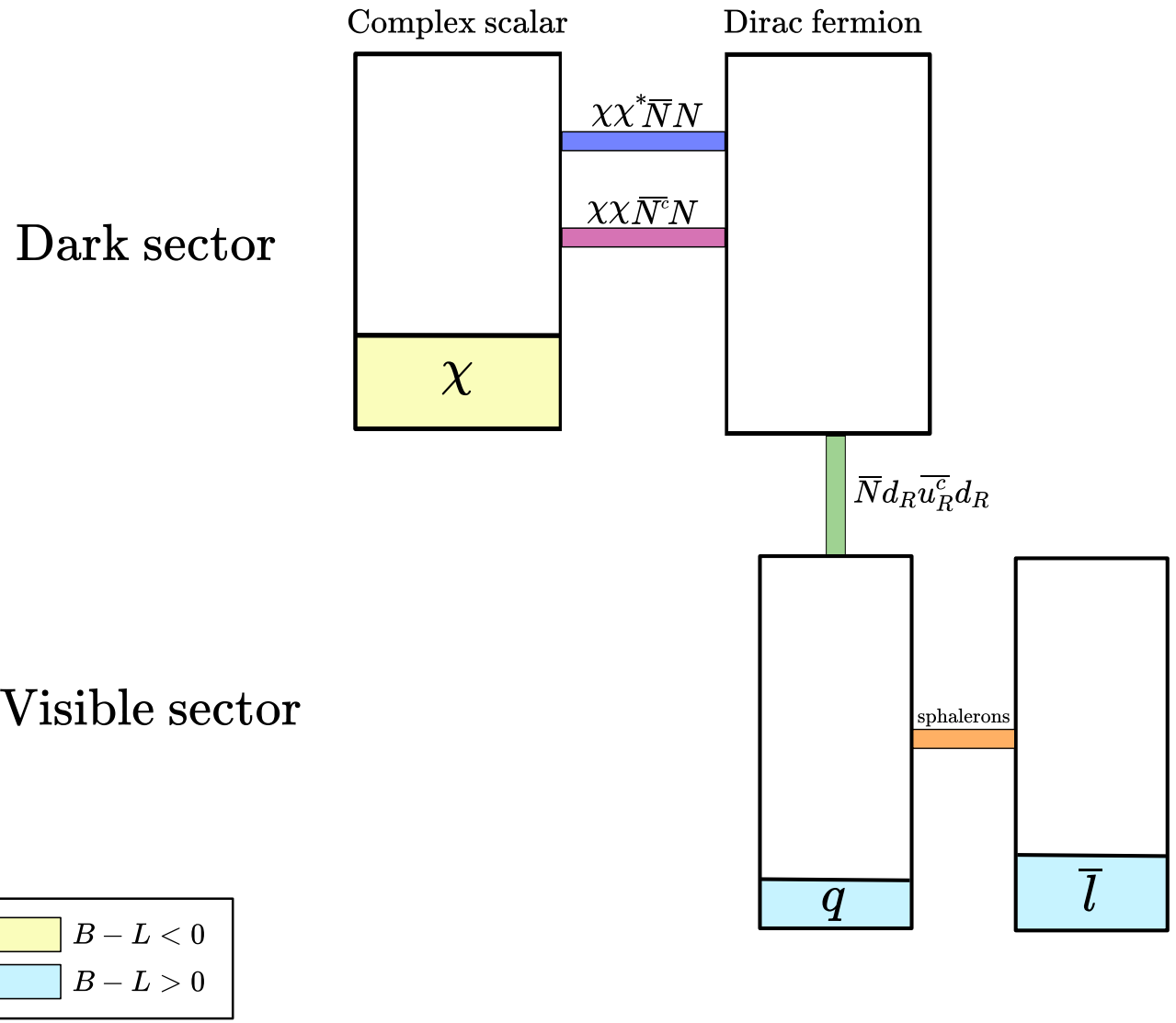
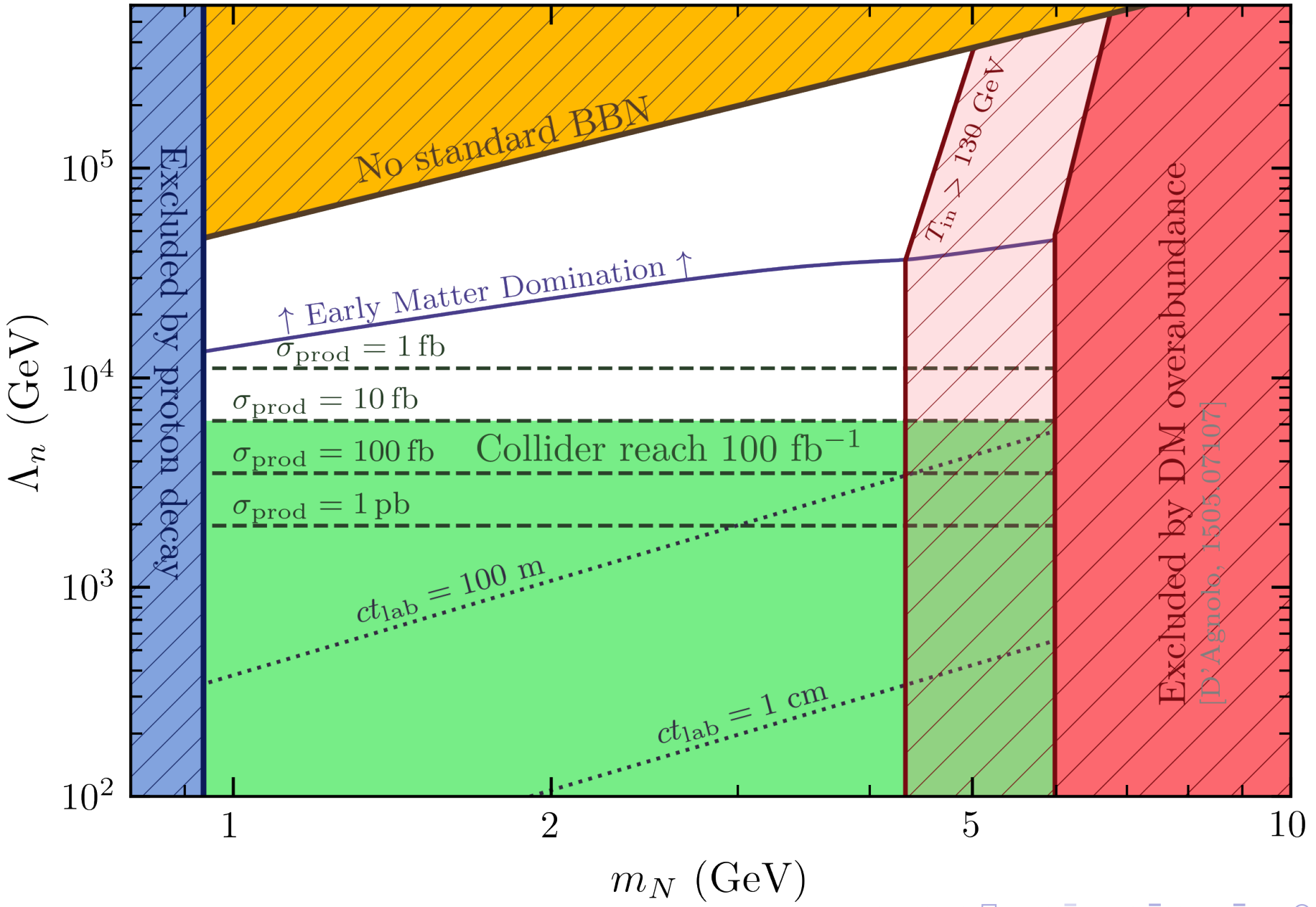


Asymmetry redistribution

	Assymetry is generated	**Spalerons and neutron portal active**	N **decay away (Sphalerons off)**
χ	$Y_{\Delta\chi}$	$Y_{\Delta\chi}$	$Y_{\Delta\chi}$
N	$Y_{\Delta\chi}$	$\frac{42}{79}Y_{\Delta\chi}$	0
$B_{\rm SM}$	0	$\frac{12}{79}Y_{\Delta\chi}$	$\frac{54}{79}Y_{\Delta\chi}$
$L_{\rm SM}$	0	$-\frac{25}{79}Y_{\Delta\chi}$	$-\frac{25}{79}Y_{\Delta\chi}$

$$m_{\rm DM} \simeq 3.4\,\text{GeV}$$

Neutron portal constraints (with sphalerons)



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