Mirror Twin Higgs Portal Dark Matter

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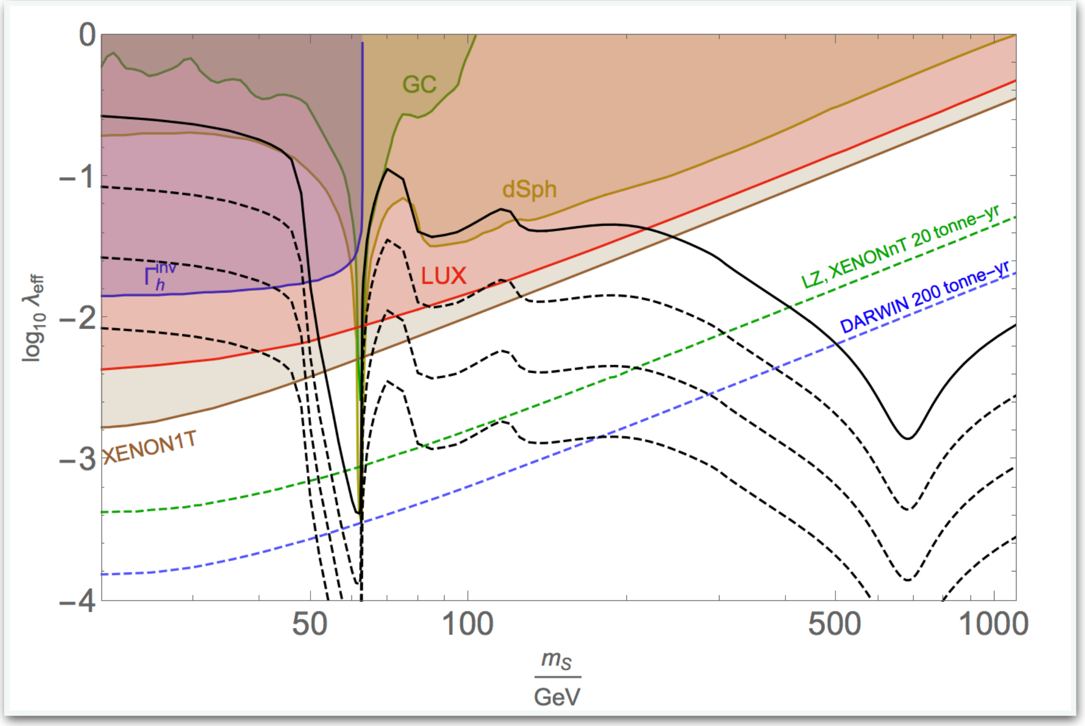

Based on ongoing work with David Curtin

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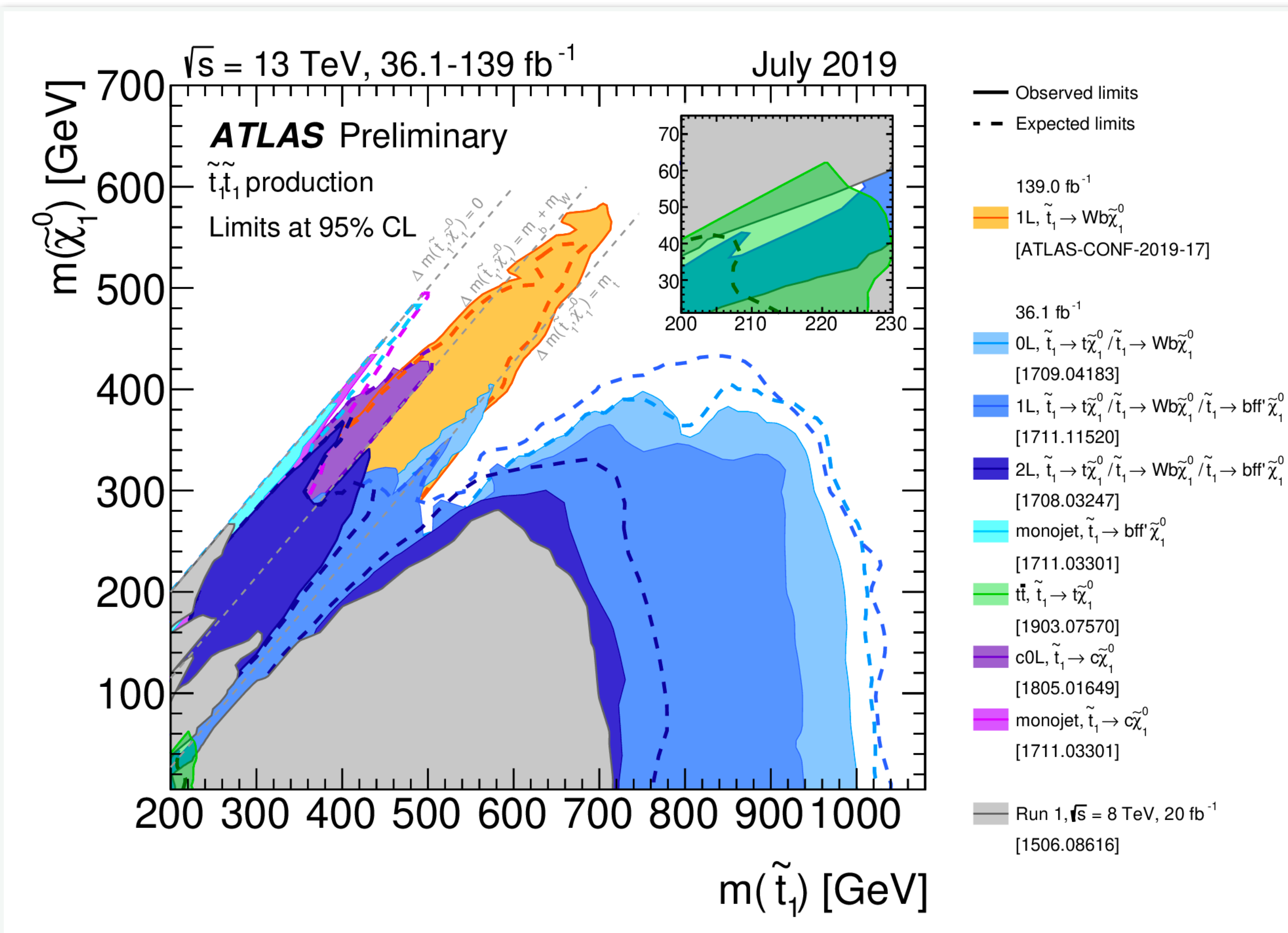
Neutral Naturalness

Motivated by hierarchy problem: where are the coloured top partners?



Better question:

Do the partners **have** to carry SM colour?

hep-ph/0506256

Mirror Twin Higgs

$$\mathcal{L} = \mathcal{L}_{\mathrm{SM}_A} + \mathcal{L}_{\mathrm{SM}_B}$$

Mirror copy of SM

singlet under SM charges

$$\mathbb{Z}_2 : A \leftrightarrow B$$

$$H = (H_A, H_B)^T$$

$$V = \lambda \left(H^\dagger H - \frac{f_0^2}{2} \right)^2 + \text{breaking terms}$$

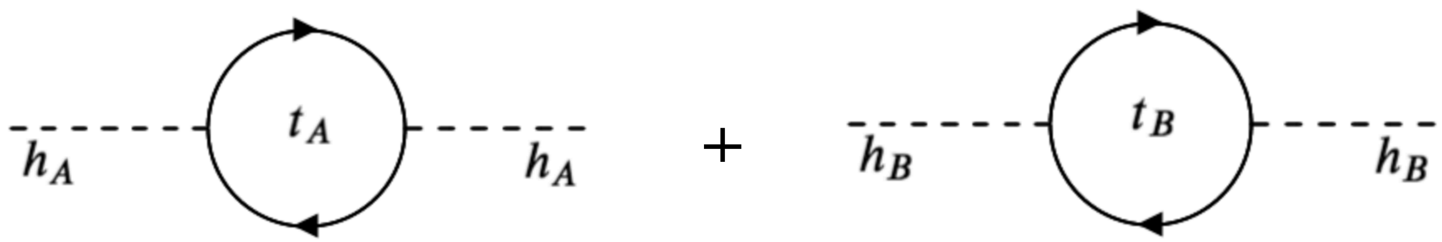
SU(4) symmetric

explicit or spontaneous, required for Higgs pheno

Mirror Twin Higgs

$$\langle H \rangle = \frac{1}{\sqrt{2}} f \quad \longrightarrow \quad SU(4) \to SU(3)$$

Measured 125 GeV Higgs identified as pNGB



$$\Delta V = \frac{3}{8\pi^2}\Lambda^2 \left(\lambda_A^2 H_A^\dagger H_A + \lambda_B^2 H_B^\dagger H_B\right) = \frac{3\lambda^2}{8\pi^2}\Lambda^2 H^\dagger H$$

SU(4) symmetric

Higgs protected at 1 loop

Problem

Twice the # of particles

↓

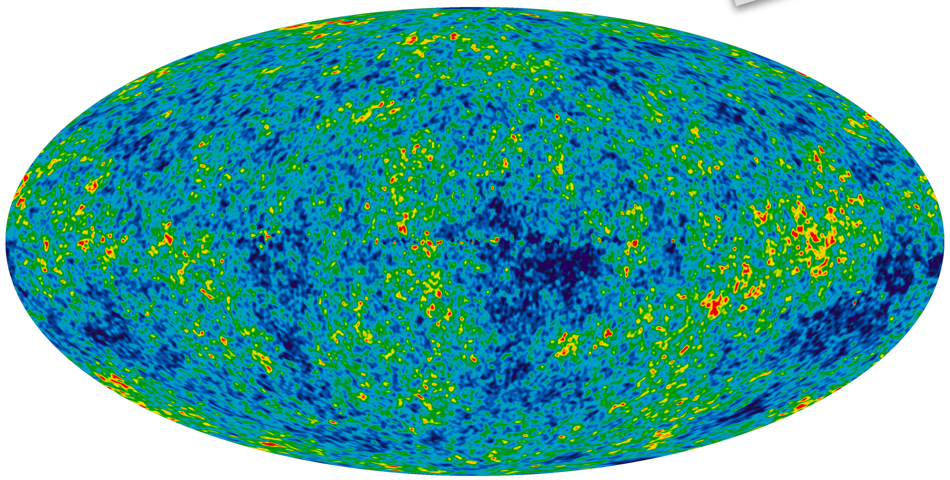
Twice the radiation present at BBN

↓

Planck 2018:

$\Delta N_{\rm eff} \lesssim 0.23$ at 2σ

highly constrained!



1611.07975
1611.07977

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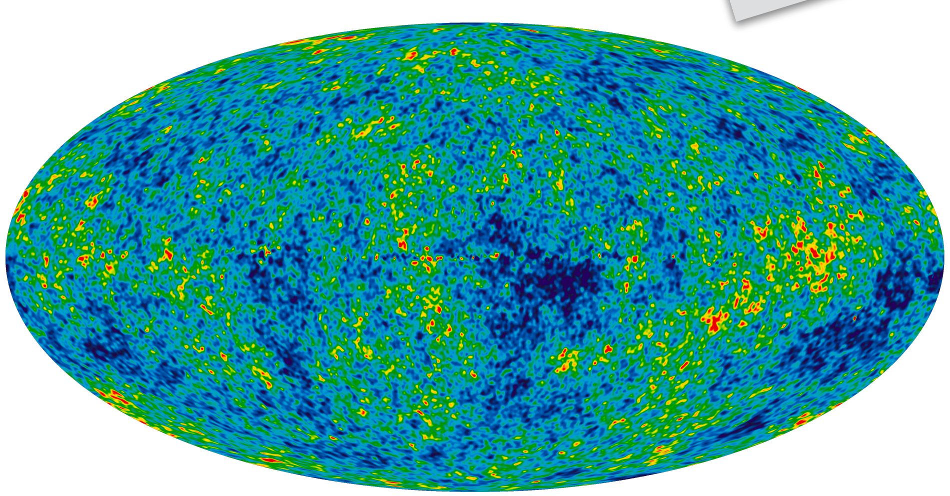


(One) solution

Asymmetric reheating

- Introduce weakly interacting, **massive**, long-lived particle with preferential decays to SM
- Freezes out relativistically, dominates cosmology at late times
- Decays at late times

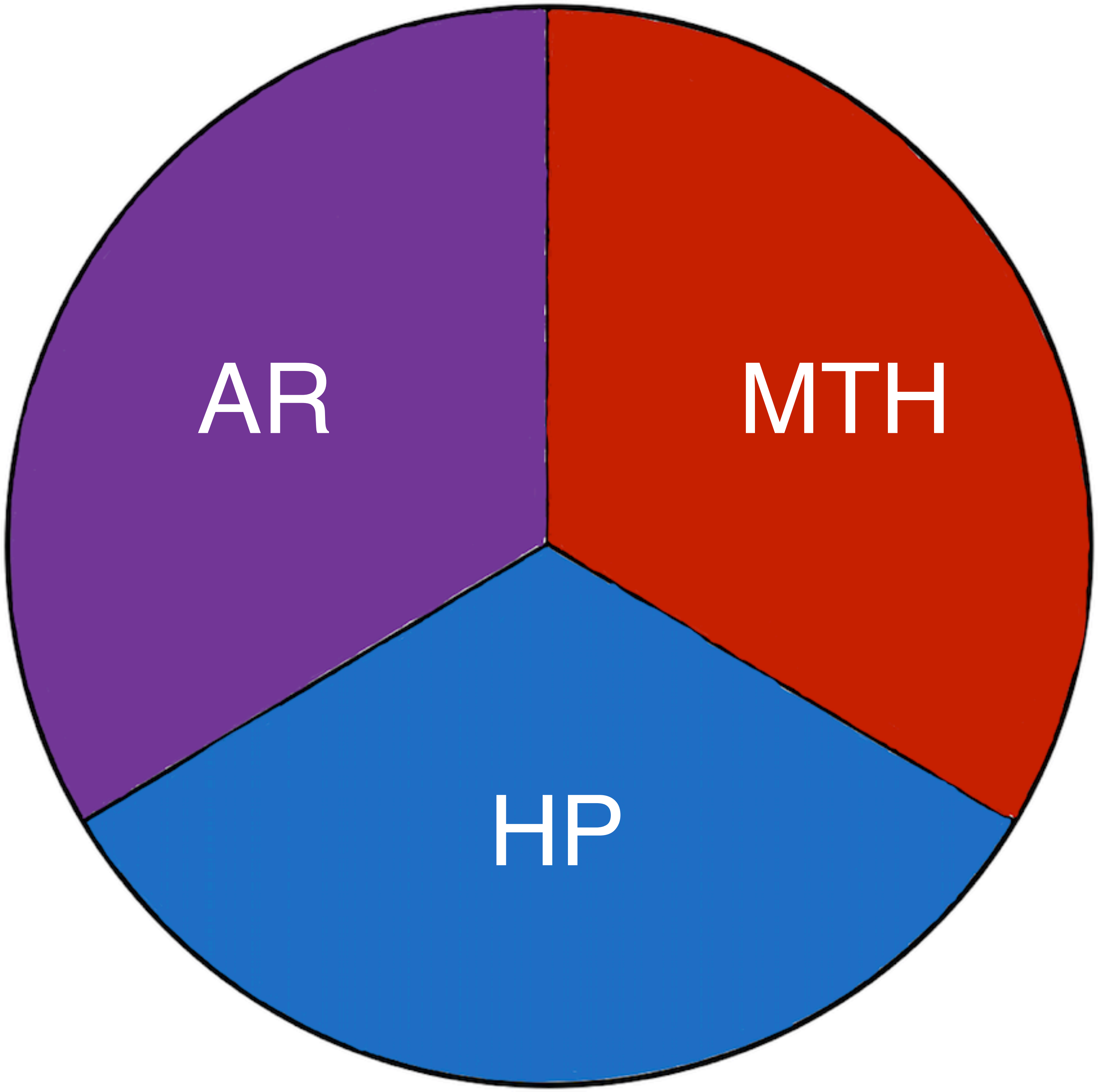
Dilutes mirror sector radiation contribution to ΔN_{eff}

What else can an asymmetrically reheated MTH do?

Introducing:

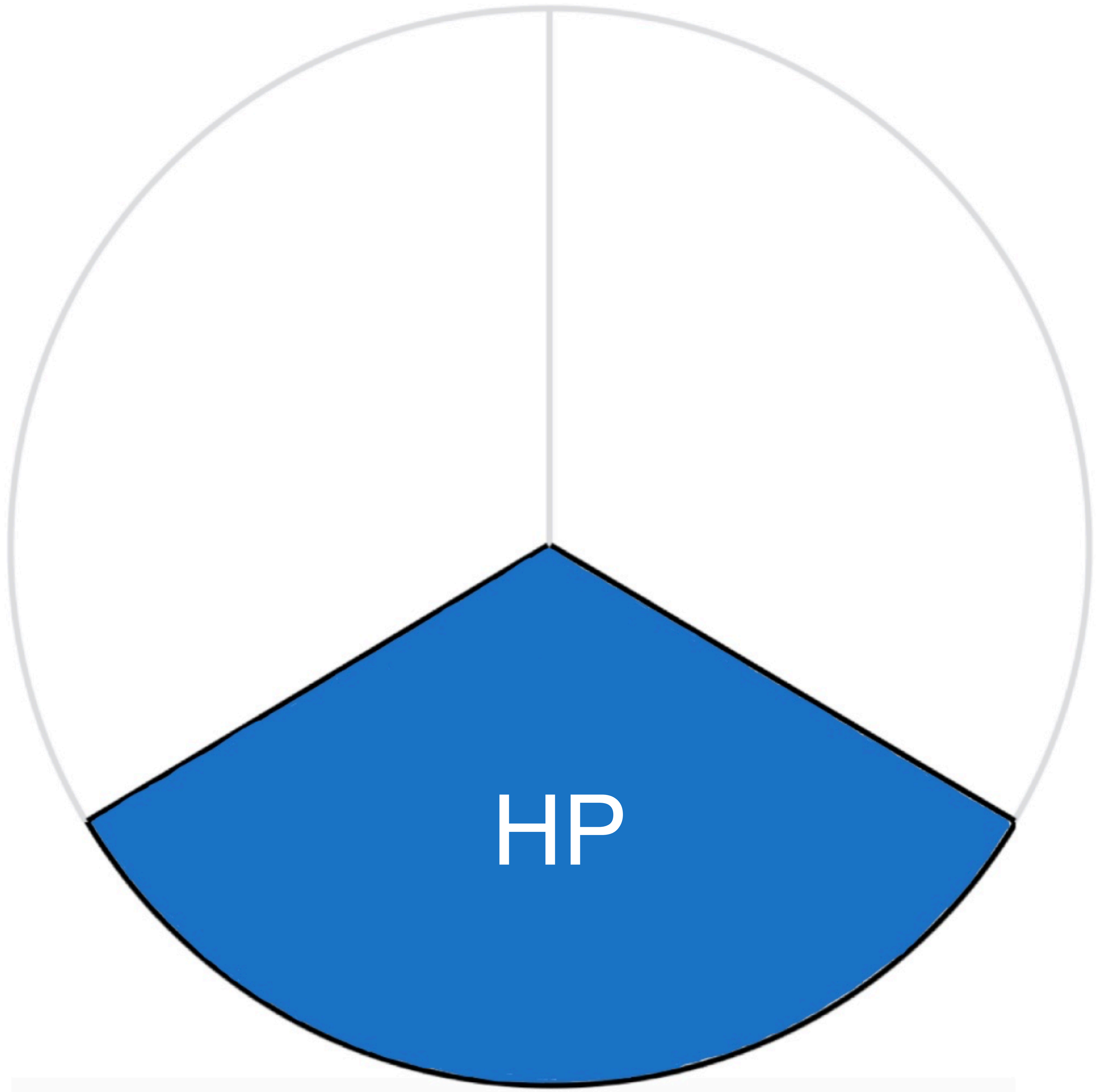
Asymmetrically Reheated Mirror Twin Higgs Portal Dark Matter

Asymmetrically Reheated Twin Higgs Portal Dark Matter



Asymmetrically Reheated Twin

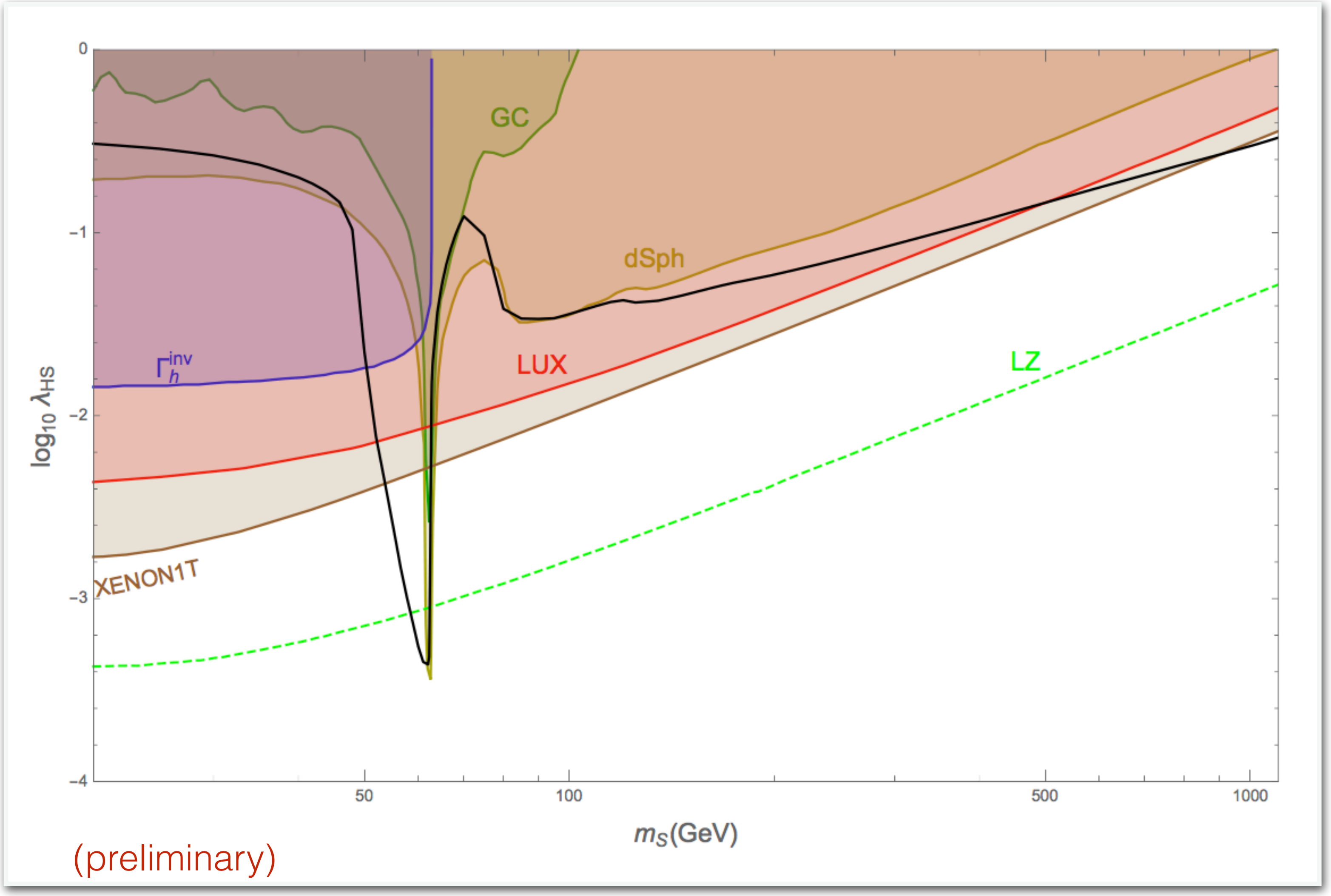
Higgs Portal Dark Matter



Singlet-scalar Higgs portal (SHP)

- Simple DM extension of SM:

$$V = \frac{1}{2}m_S^2 S^2 + \frac{1}{4!}\lambda_S S^4 + \frac{1}{2}\lambda_{HS} H^\dagger H S^2$$



- Coupling probed by direct detection also sets relic density

- Nearly excluded by experiment

$$\Omega h^2 = 0.1198 \pm .0003$$

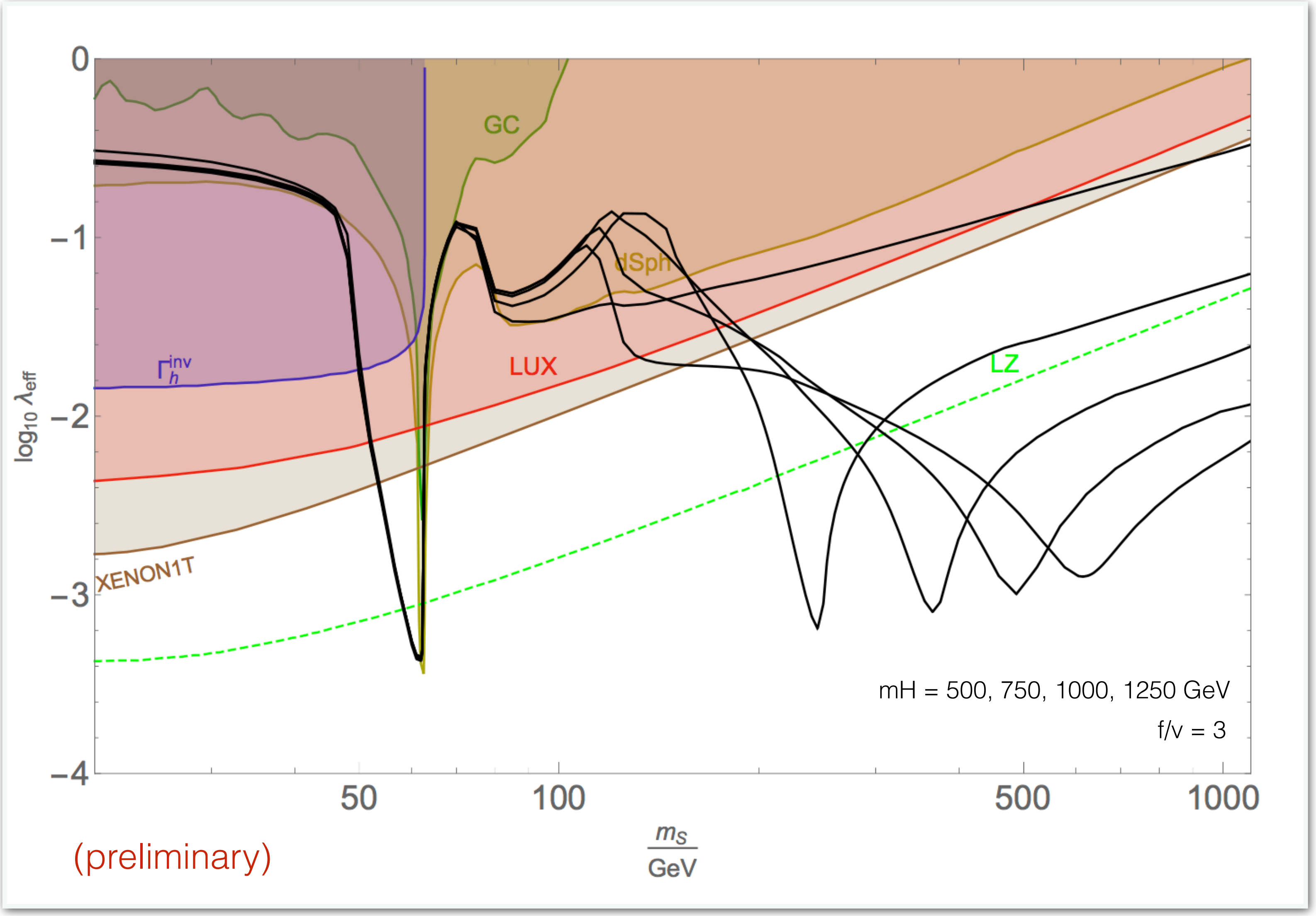
arXiv:1805.12562

arXiv:1701.08134

Mirror Twin Higgs Portal (MTHP)

- Couple singlet-scalar to the **Twin Higgs**:

$$V = \frac{1}{2}m_S^2 S^2 + \frac{1}{4!}\lambda_S S^4 + \frac{1}{2}\lambda_{HS}(H_A^\dagger H_A + H_B^\dagger H_B)S^2$$



arXiv:1805.12562

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- Extra annihilation channels, heavy Higgs resonance

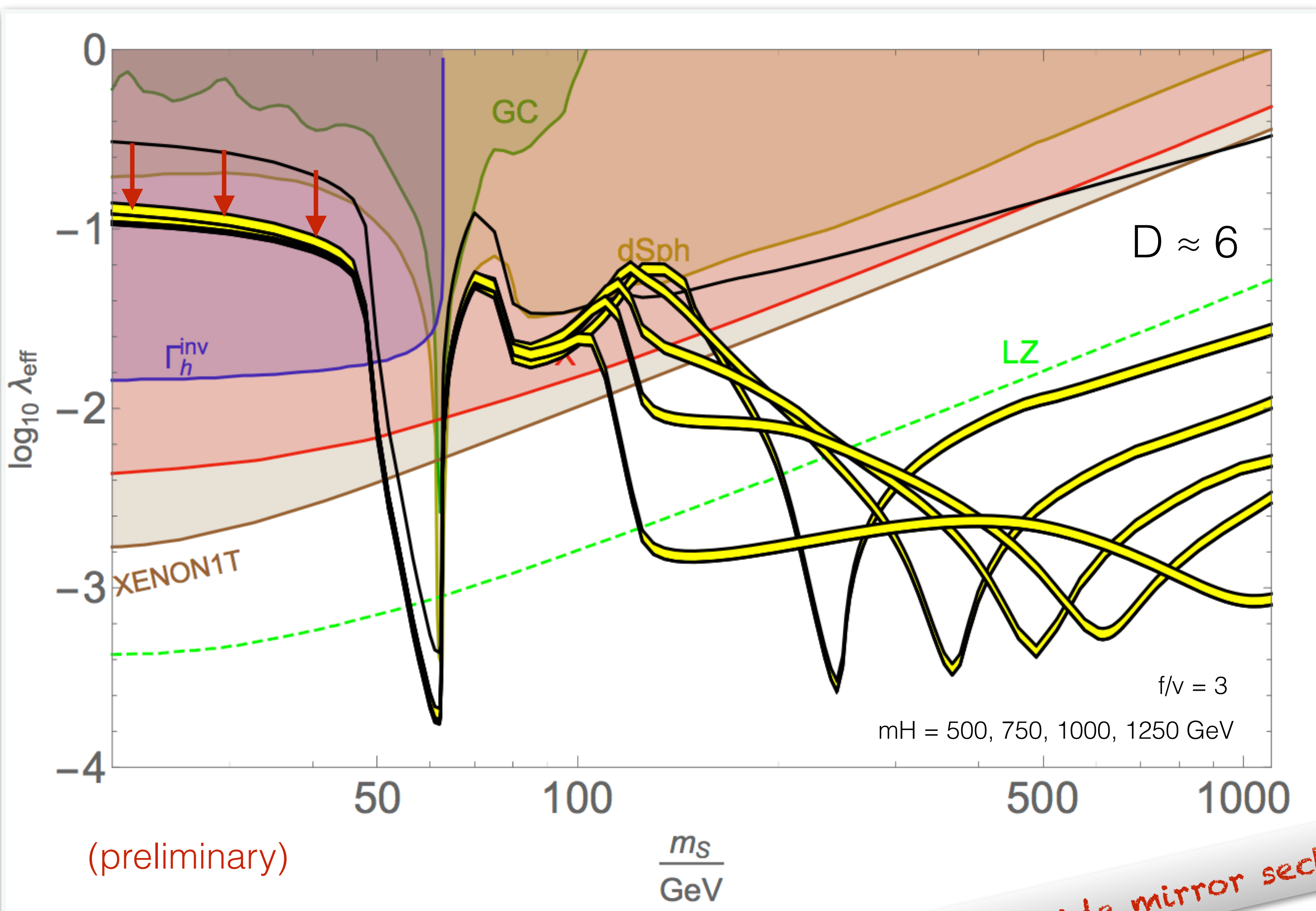
- Large regions of unexplored parameter space!

Asymmetrically Reheated MTHP

- Extend model to include some asymmetrically decaying particle
- Dilution by factor D:

$$\lambda_{\text{eff}} \to \frac{1}{\sqrt{D}}\lambda_{\text{eff}}$$

$$D = \frac{\Omega_{\text{freeze out}}}{\Omega_{\text{observed}}}$$



DM diluted alongside mirror sector!

Enhanced signature space!

How much dilution can we expect?

$$\Omega_{\text{DM}} \propto \frac{1}{\lambda^2}$$

νMTH

- Type-1 seesaw:

$$\mathcal{L} \supset -y\left(L_A H_A N_A + L_B H_B N_B\right) - \frac{1}{2} M_N \left(N_A^2 + N_B^2\right) - M_{AB} N_A N_B + \text{h.c.}$$

- N decay **dilutes** the DM:

$$\Gamma_N \sim \left(\frac{m_\nu}{M_N}\right) M_N^5 \qquad D \sim \frac{M_N}{\Gamma_N^{1/2}}$$

more mass —> more energy injected

later decay —> greater domination

- Schematically,

$$\Delta N_{\rm eff} \sim \Gamma_{A/B} + \frac{1}{D^{4/3}}$$

generically goes as $\sim \frac{v^2}{f^2}$

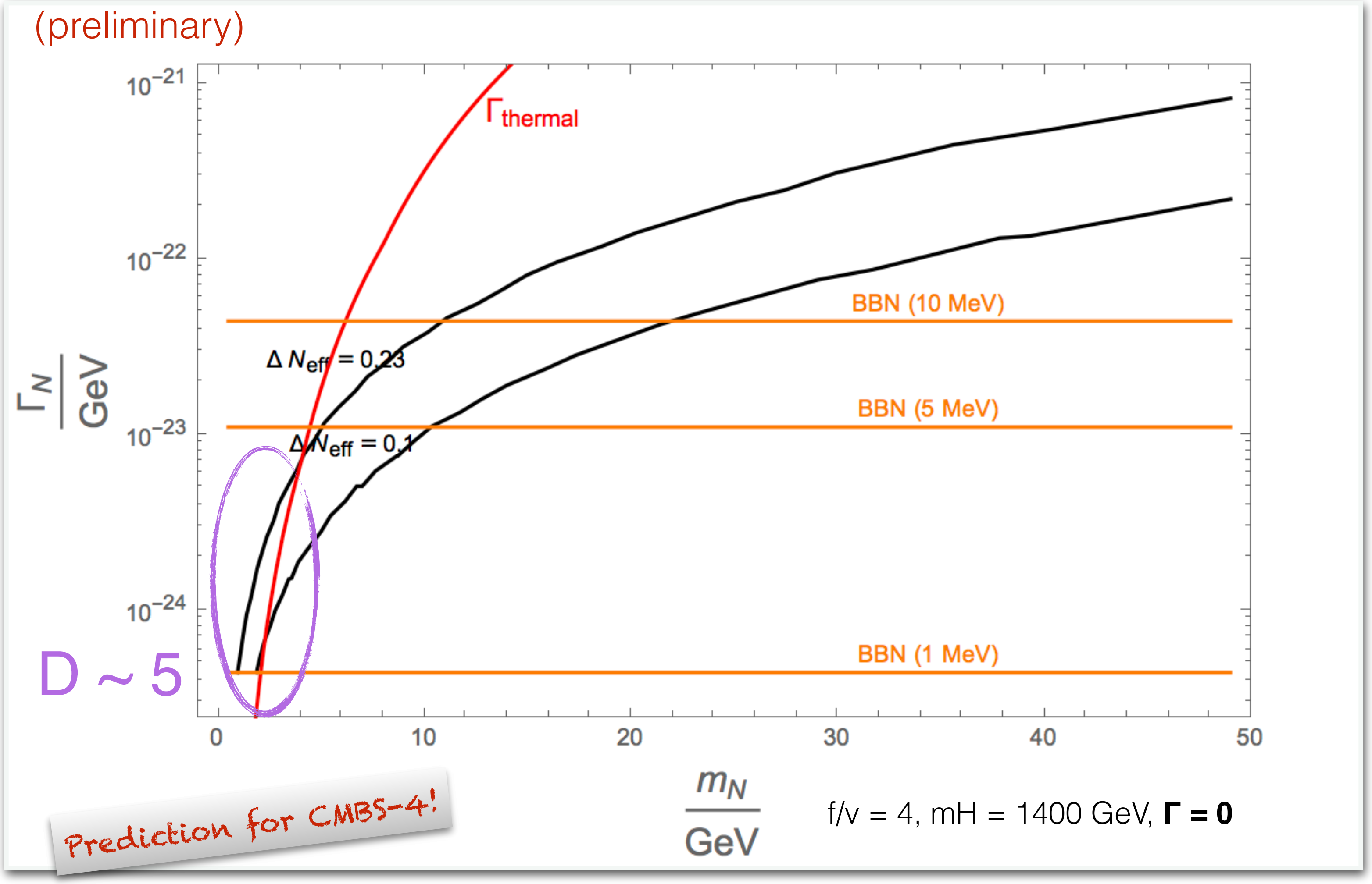
Challenge: $\Delta N_{\rm eff}$ bounds

$$\Delta N_{\rm eff} \sim \Gamma_{A/B} + \frac{1}{D^{4/3}}$$

- Hard to make $\Delta N_{\rm eff}$ small enough, even if $D \to \infty$

Challenge: thermal production

- Coupling to thermal bath $\sim \dfrac{m_\nu}{M_N}$



If the N are **only** produced thermally:

Too small —> N **never thermalize**, cannot dominate

Too big —> N **decouple non-relativistically**, cannot dominate

XMTH

- Z2 symmetric potential

$$V = \lambda_x X(X+x)(H_A^\dagger H_A + H_B^\dagger H_B) + \frac{1}{2} m_X^2 X^2$$

- Thermal production coupling **independent** of mass

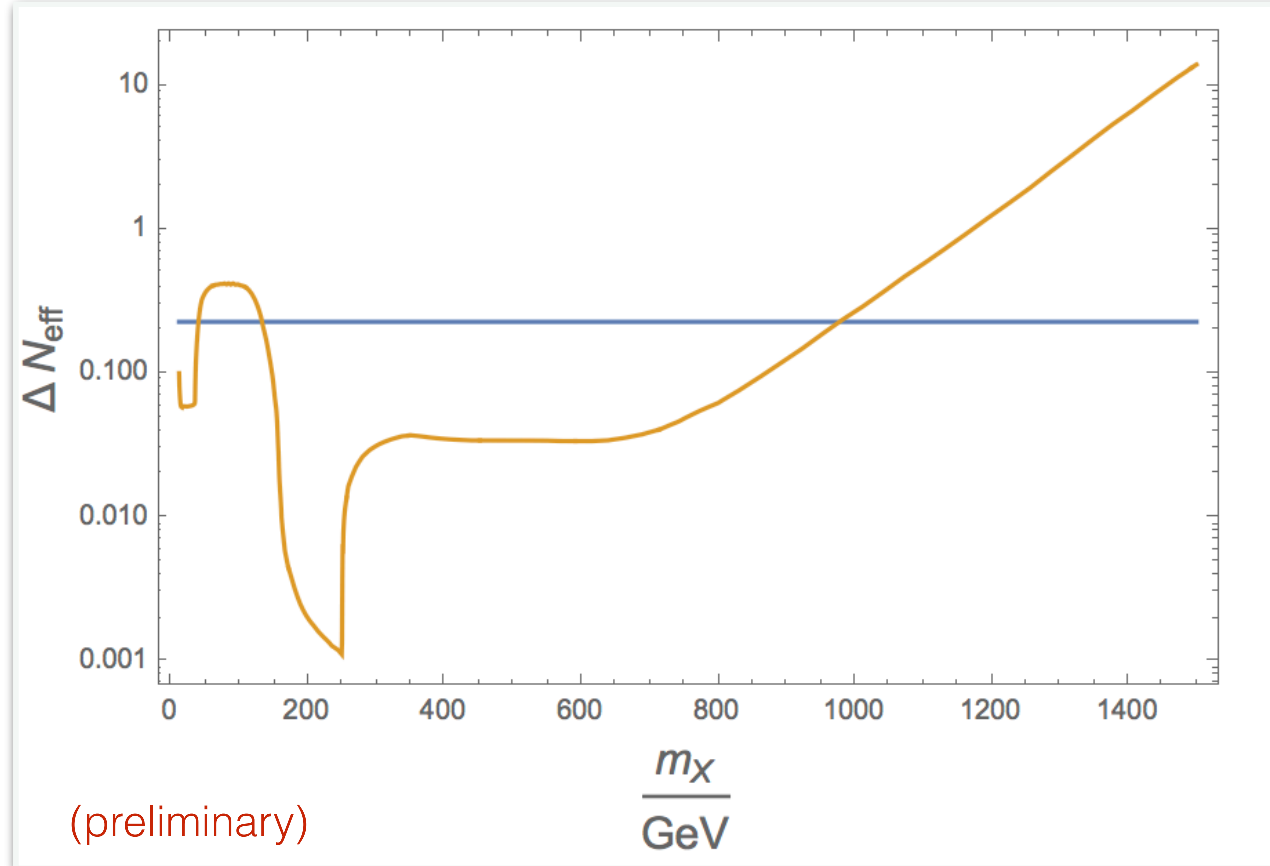
$$D \sim \frac{M_X}{\Gamma_X^{1/2}}$$

M_X ← free parameter

$\Gamma_X^{1/2}$ ← fix at minimum

- Below $\Delta N_{\rm eff}$ bounds →

—> Mass thresholds drive $\Gamma_{A/B}$ down as low as 10^-4



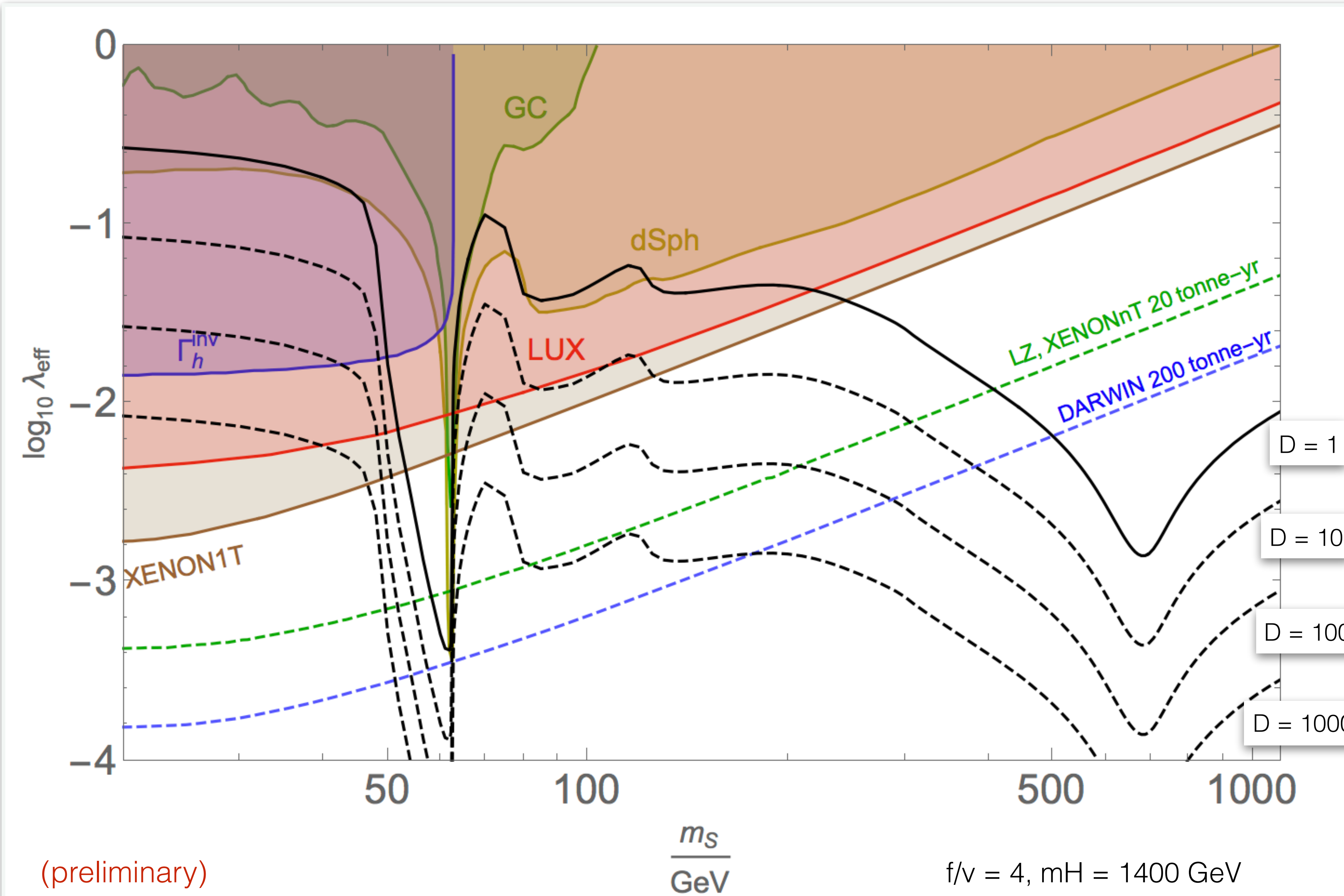
(preliminary)

- Projected dilution:

D ~ 10 - 1000

(preliminary)

Result



0
−1
−2
−3
−4
$\log_{10}\lambda_{\text{eff}}$
GC
dSph
LUX
Γ_h^{inv}
XENON1T
LZ, XENONnT 20 tonne-yr
DARWIN 200 tonne-yr
D = 1
D = 10
D = 100
D = 1000
50
100
500
1000
$\frac{m_S}{\text{GeV}}$
(preliminary)
f/v = 4, mH = 1400 GeV

Conclusion

- MTH can solve (little) hierarchy problem without coloured tops

- Asymmetric reheating can dilute problematic radiation **and** dark matter

- Incorporating DM into asymmetrically reheated MTH leads to new predictions for DD experiments!

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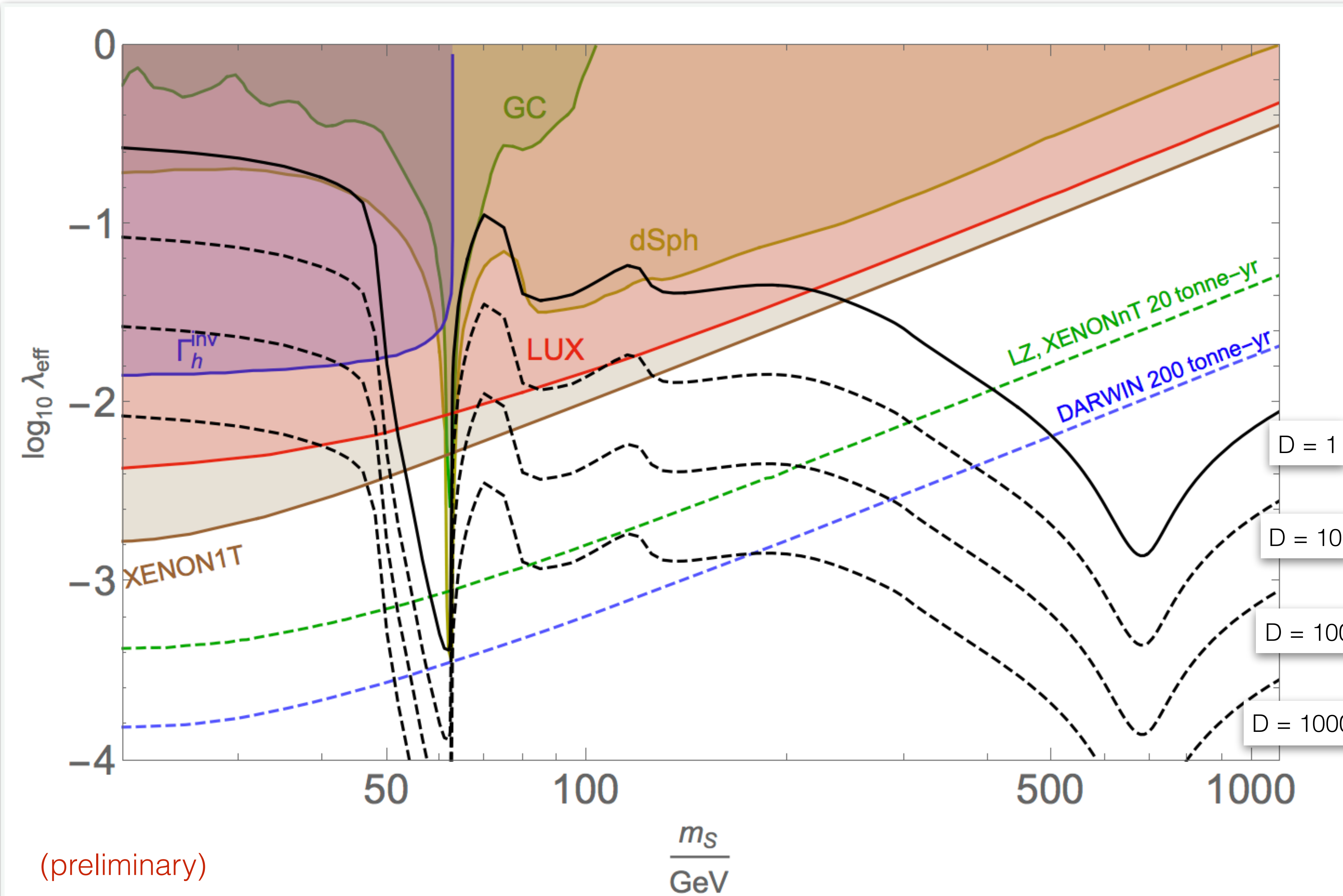
Thank you for listening!



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