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Dark Matter through the Neutrino Portal

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arXiv:1910.12916 [hep-ph], arXiv:2009.01847 [hep-ph], arXiv:2102.07780 [hep-ph].

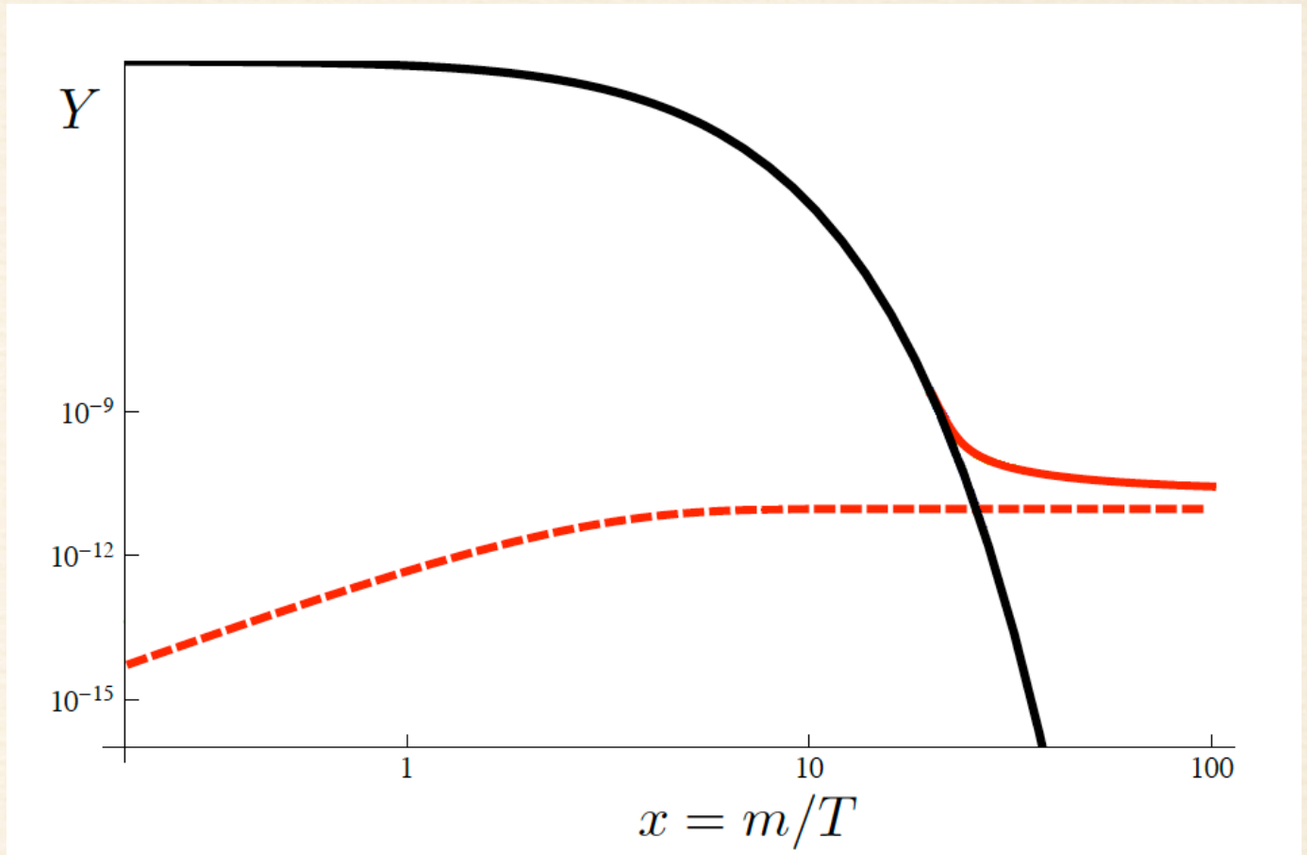
Overview

- Dark matter and neutrino portal — general discussion
- The model and constraints — Type Ib seesaw model
- Results
- Summary

Dark matter and neutrino portal

Dark Matter Production

- Freeze-out: Thermal equilibrium
- Freeze-in: Never in thermal equilibrium



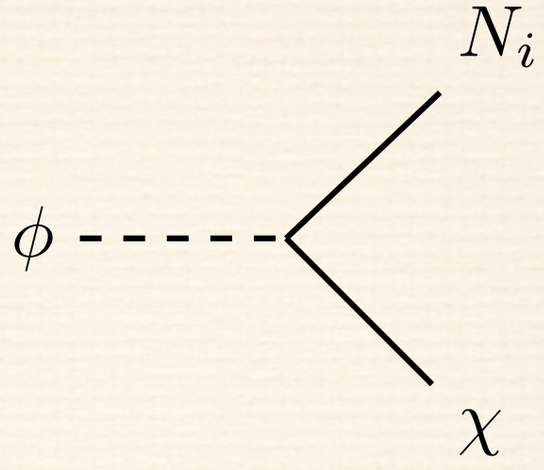
- The observed DM relic abundance gives a constraint to DM yield

$$\Omega_{\rm DM}^{\rm obs} h^2 = 0.120 \pm 0.001$$

N. Aghanim et al. (Planck), (2018), arXiv:1807.06209

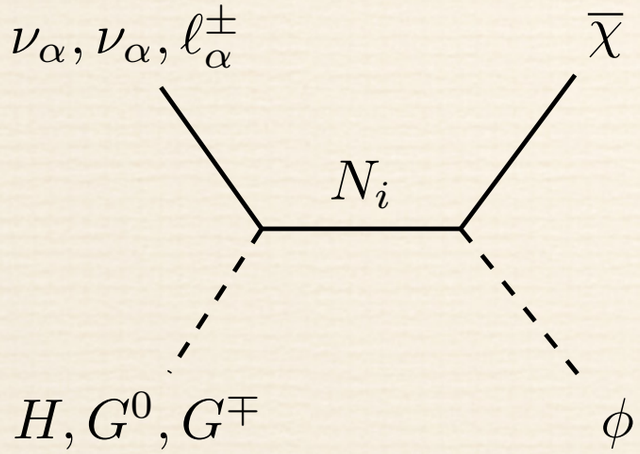
Neutrino Portal

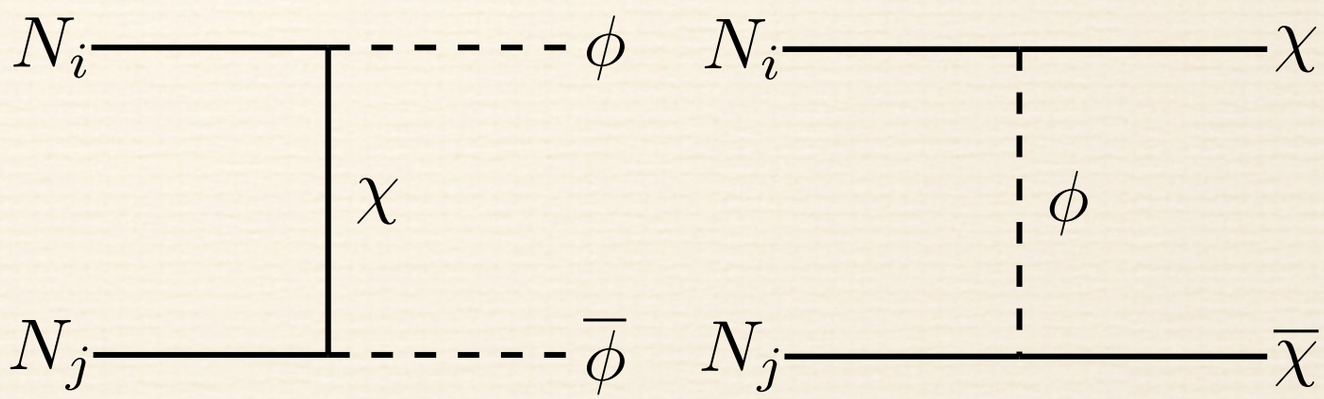
- General neutrino portal $y_i \phi \overline{\chi} N_i$



- heavy scalar scenario

- Dark matter producing process





ν-Yukawa process $\propto Y^2 y^2$

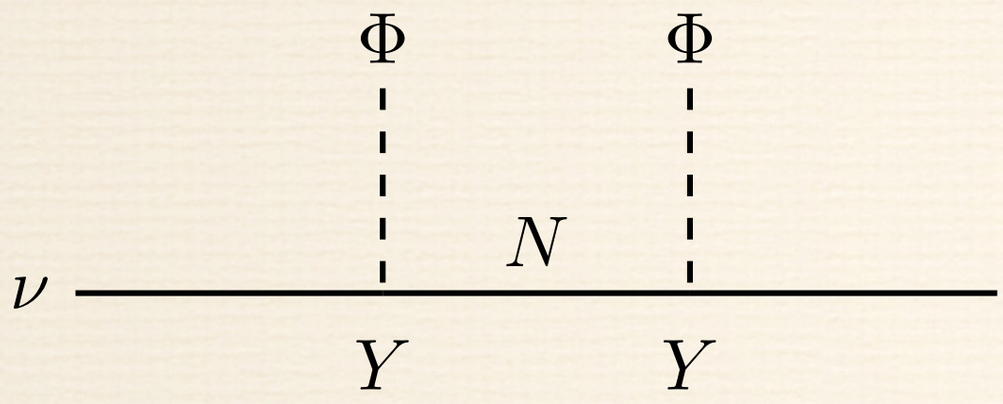
dark sector process $\propto y^4$

The model and constraints

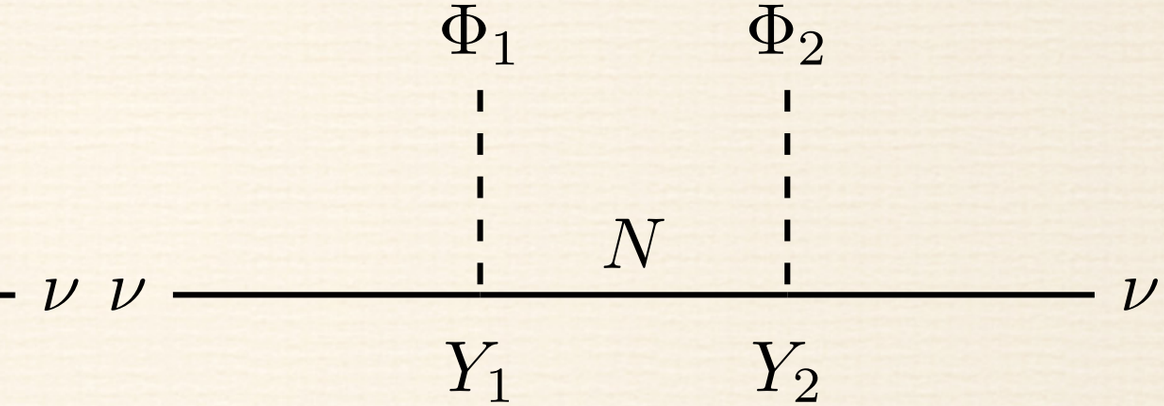
Why Type Ib?

- Large Yukawa coupling and GeV scale heavy neutrino

Type Ia $\dfrac{Y^2 v^2}{M_N}$



Type Ib $\dfrac{Y_1 Y_2 v_1 v_2}{M_N}$



- Only one heavy neutrino

$$\mathcal{L}_{\text{seesawIb}} = -Y_{1\alpha}^{*}\overline{L_{L\alpha}^{c}}\Phi_1^{*}\mathcal{N}_L - Y_{2\alpha}\overline{L_{L\alpha}}\Phi_2\mathcal{N}_R - M_N\overline{\mathcal{N}_L}\mathcal{N}_R + \text{h.c.}$$

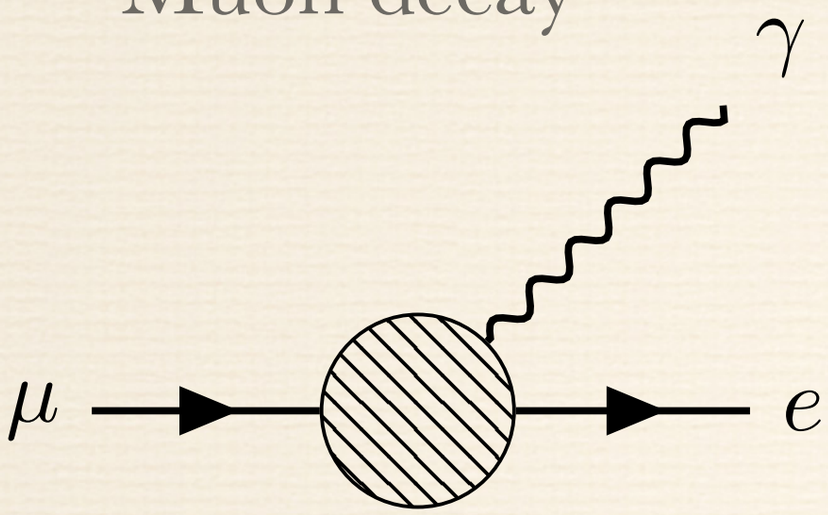
- Strongly constrained by oscillation data

$$Y_{1\alpha} \to Y_1 \qquad Y_{2\alpha} \to Y_2$$

$$\frac{Y_1 Y_2 v_1 v_2}{M_N} = 3.0 \times 10^{-11}\,\text{GeV}$$

Experimental Constraints

- Muon decay



$$|\eta_{e\mu}| = \frac{\left|Y_{1e}Y_{1\mu}^{*}v_1^2 + Y_{2e}Y_{2\mu}^{*}v_2^2\right|}{4M_N^2} \lesssim 8.4\times10^{-6}$$

- Collider data on neutrino mixing

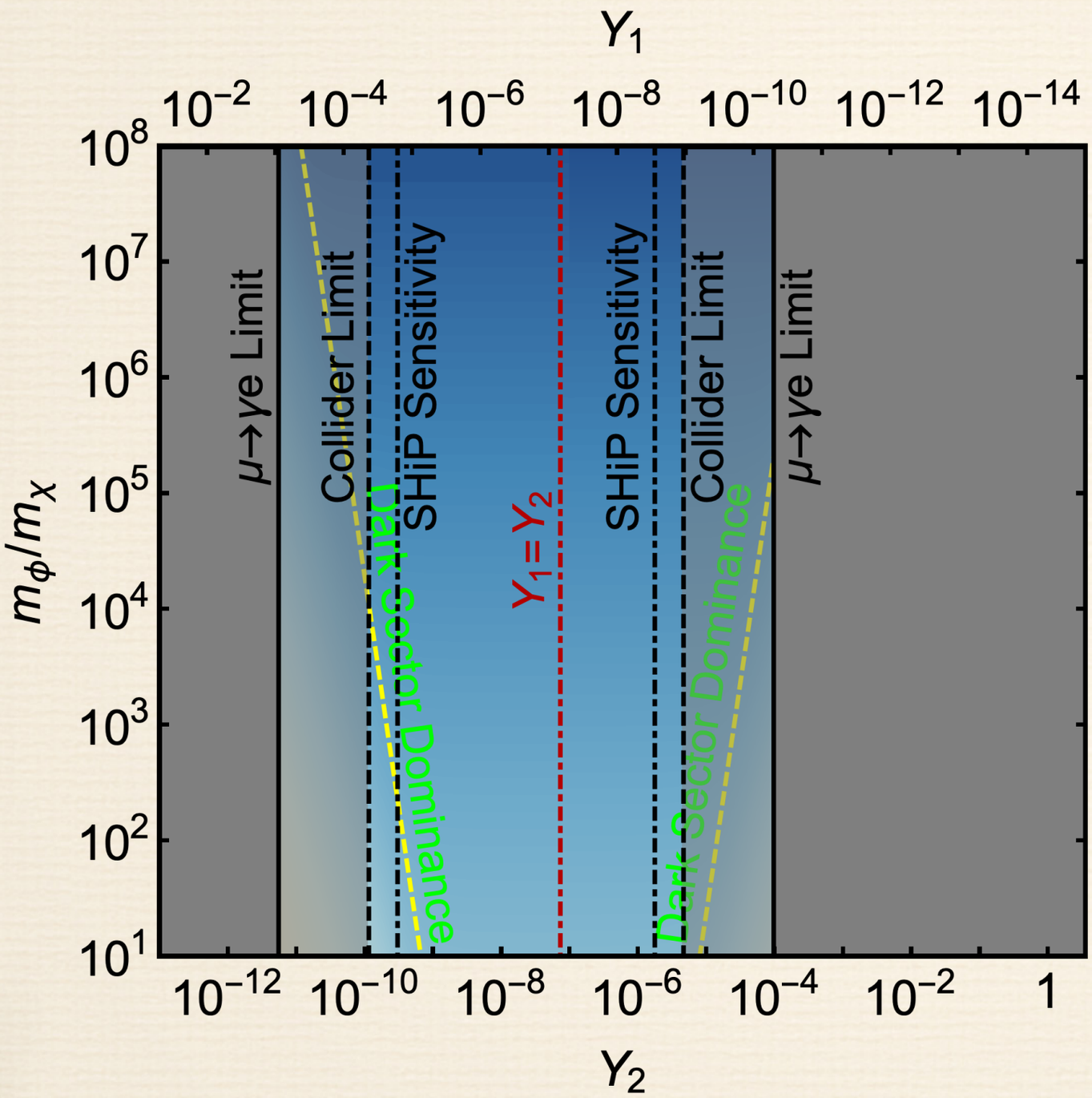
$$U_\alpha^2 = \sum_{i=L,R} |U_{\alpha i}|^2 \qquad\qquad U^T M^\nu U$$

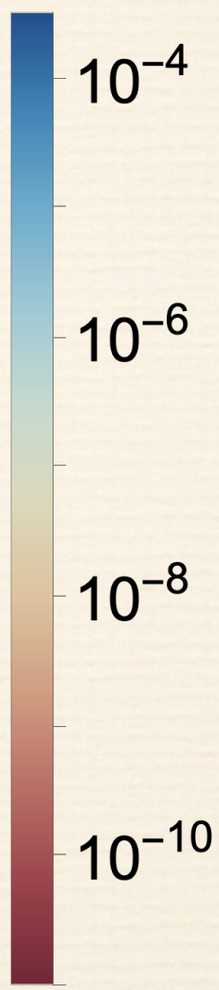
$$U_\alpha^2 = (a_\alpha + b_\alpha \cos\delta_M)\frac{v_1^2 Y_1^2}{M_N^2} + (a_\alpha - b_\alpha \cos\delta_M)\frac{v_2^2 Y_2^2}{M_N^2}$$

$$U_\alpha^2 \geq \sqrt{a'_\alpha - b'_\alpha \cos\delta_M}\,\frac{1\,\mathrm{GeV}}{M_N}$$

Results

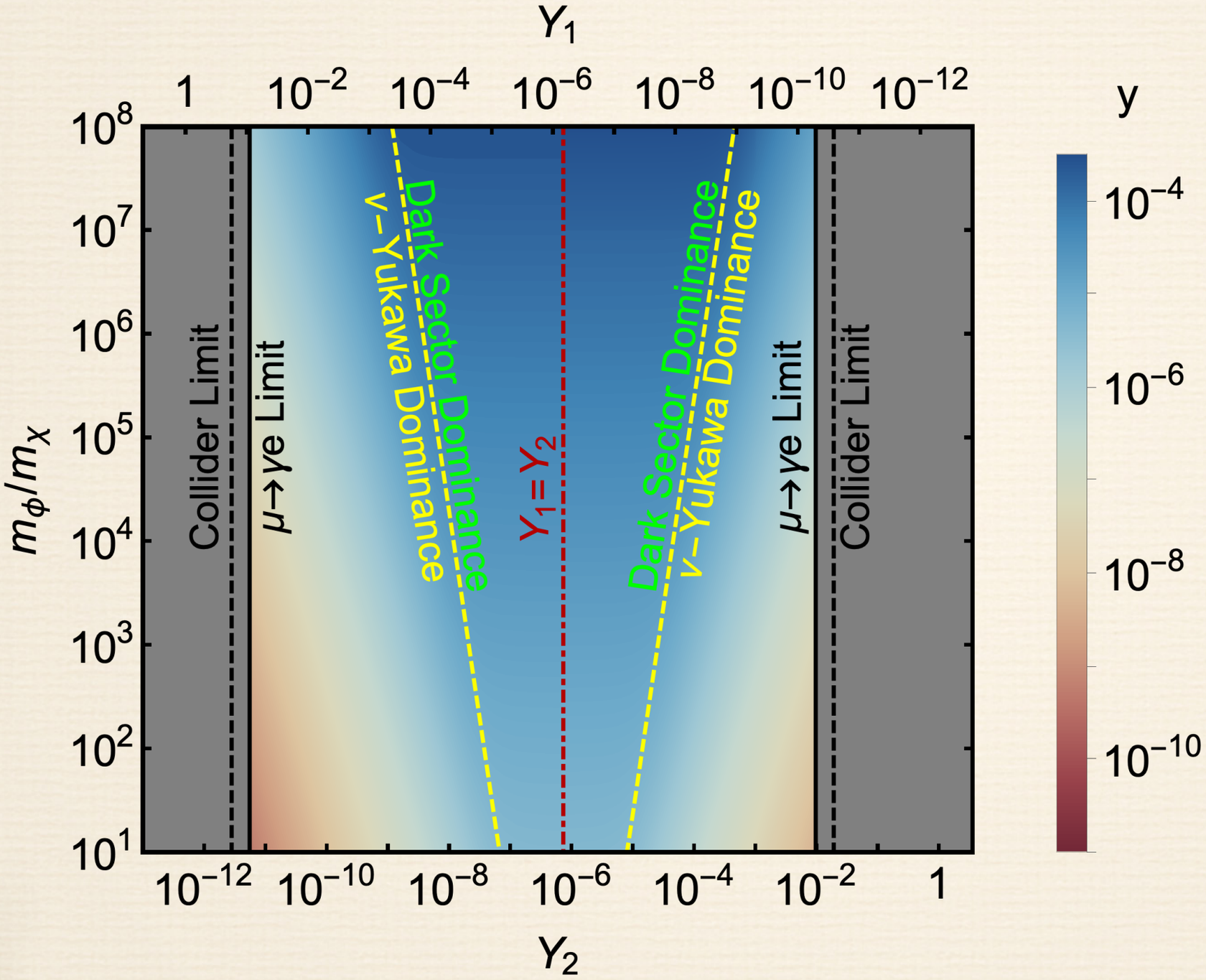
Required Portal Coupling





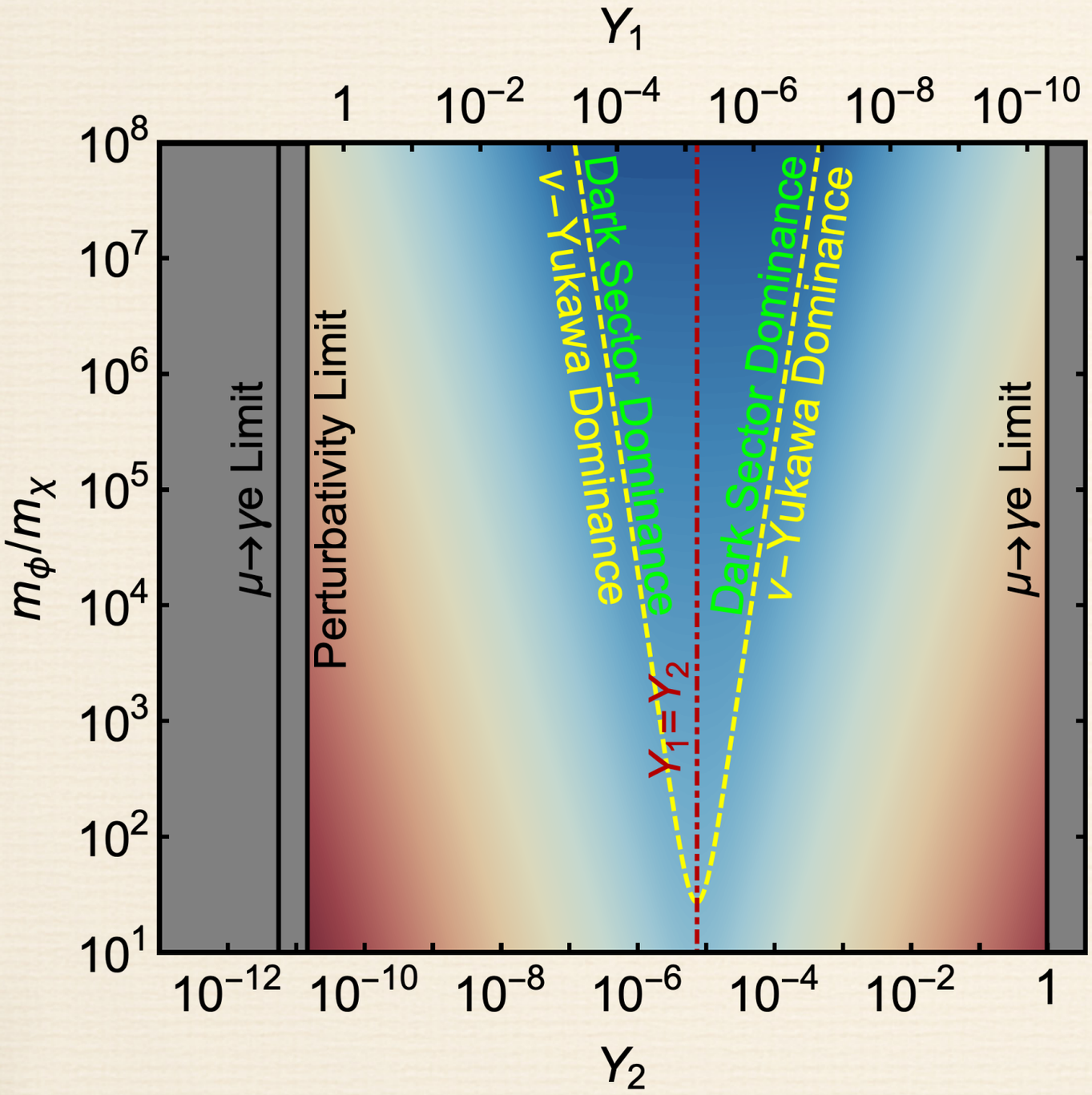
- $\tan\beta = v_2/v_1 = 10$
- $M_N = \mathbf{1}$ GeV
- ν-Yukawa dominance is only allowed in a small region when $Y_1 >> Y_2$

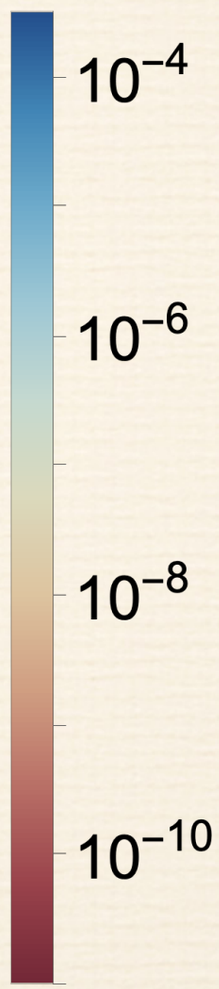
Required Portal Coupling



- $\tan\beta=v_2/v_1=10$
- $M_N=\mathbf{10^2}$ GeV
- ν-Yukawa dominance is allowed on both side

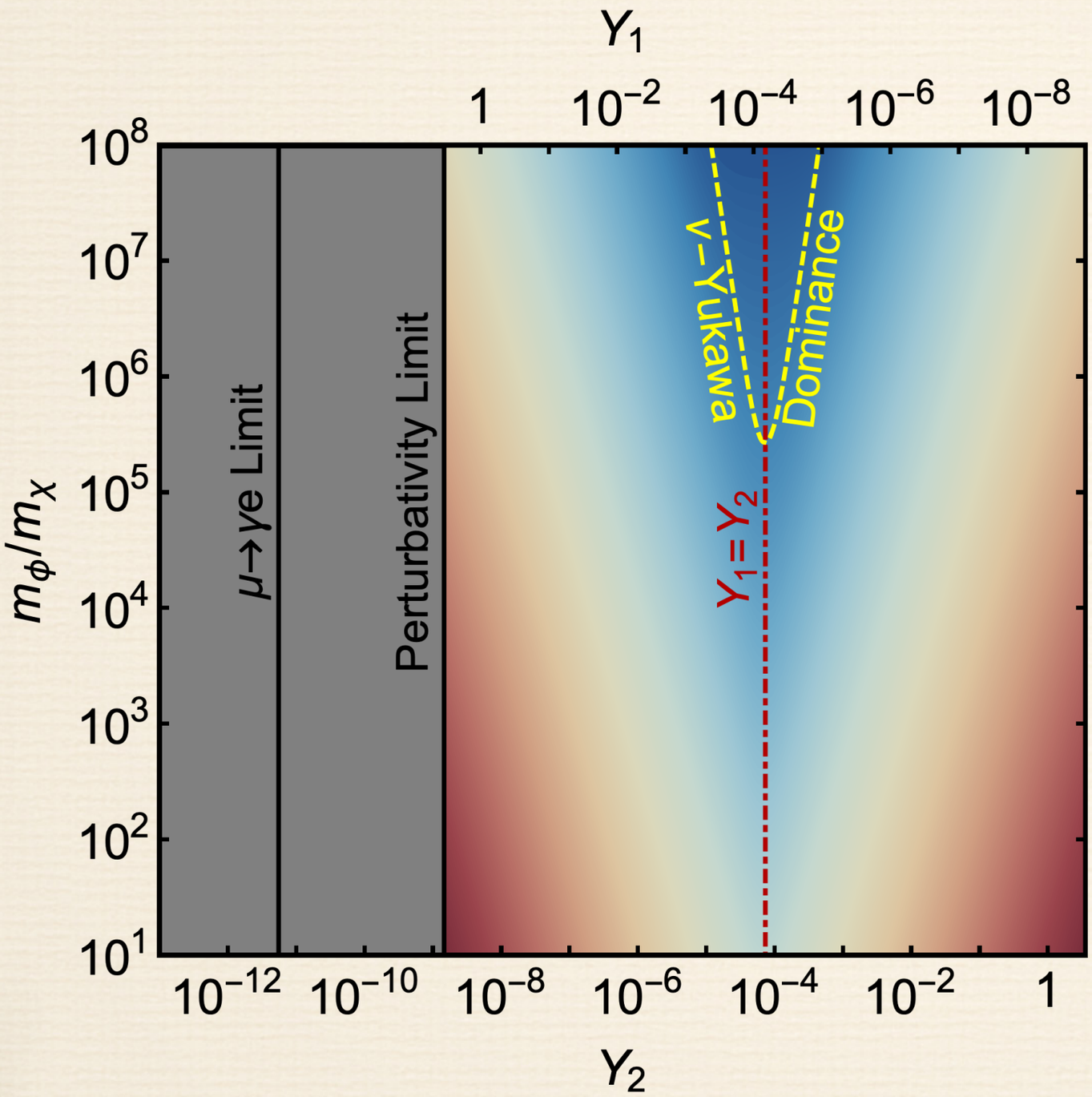
Required Portal Coupling

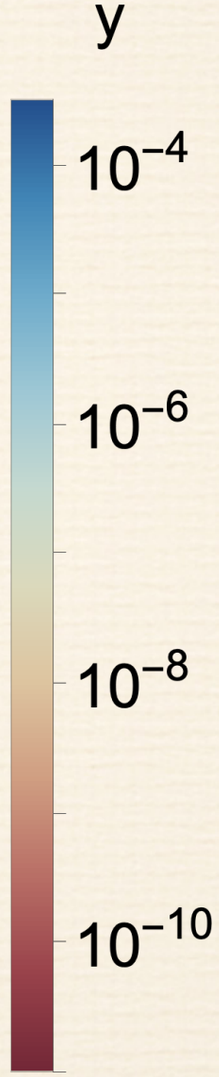




- $\tan\beta = v_2/v_1 = 10$
- $M_N = \mathbf{10^4}$ GeV
- Minimum m_ϕ/m_χ for DS dominance

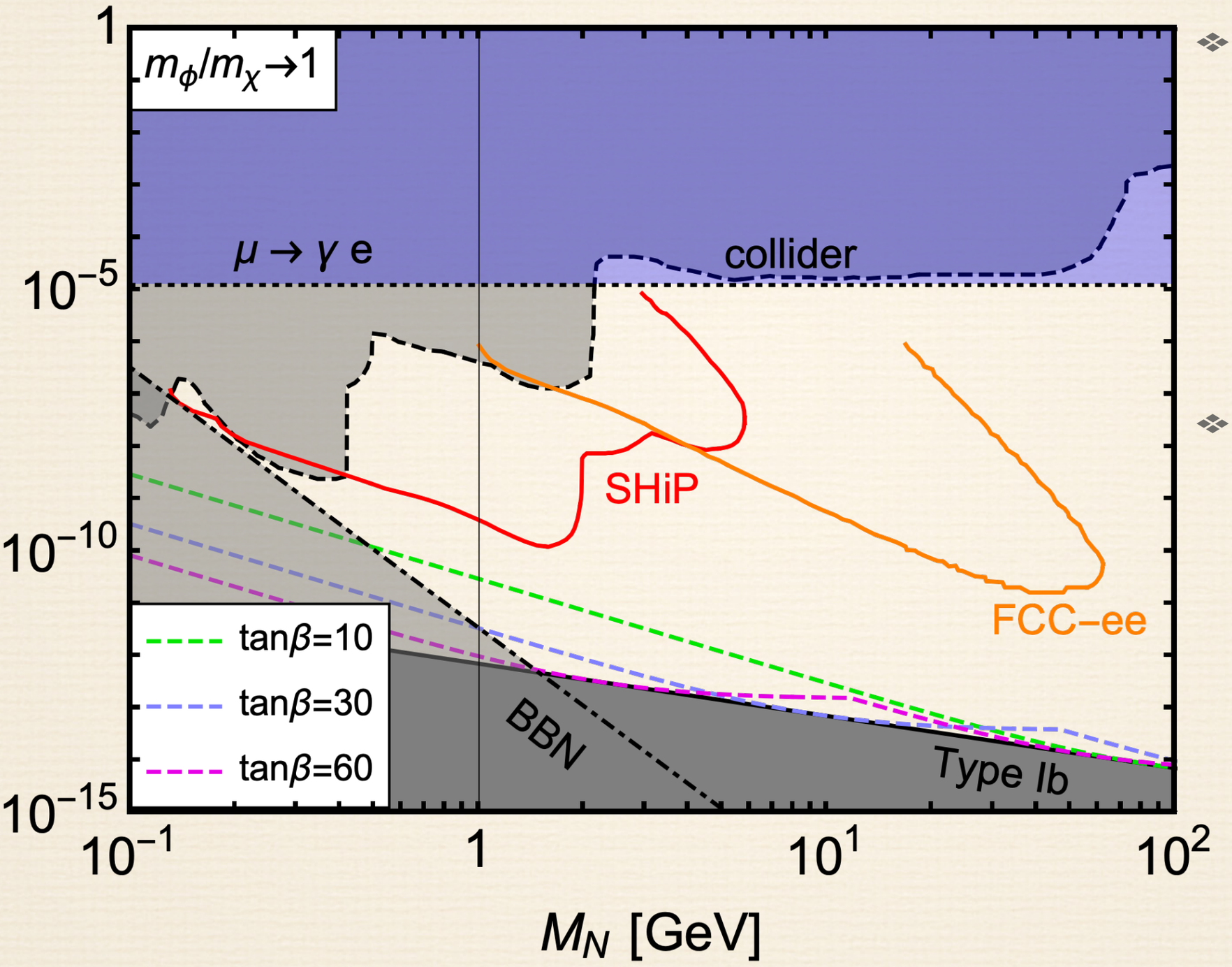
Required Portal Coupling





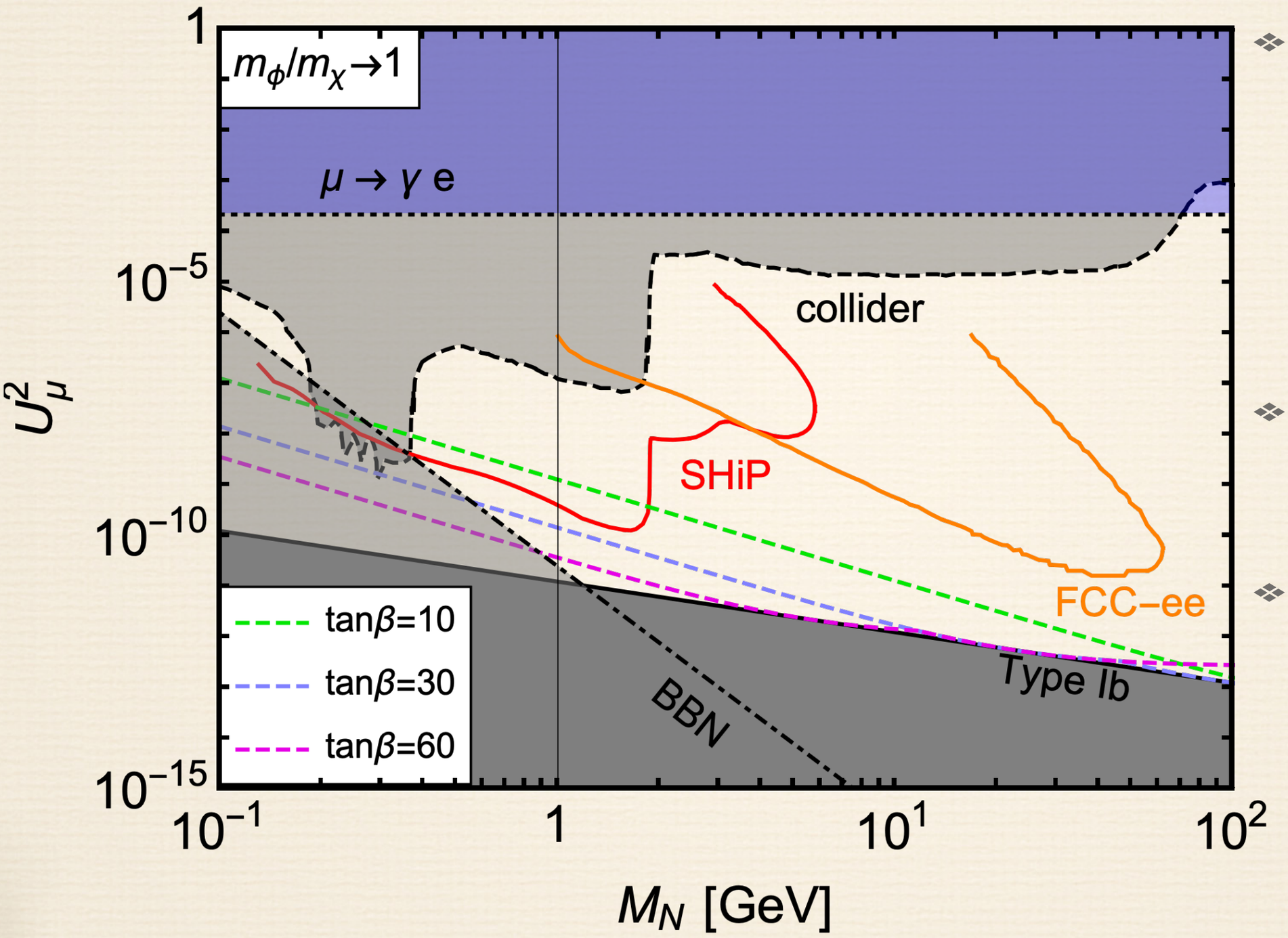
- $\tan\beta=v_2/v_1=10$
- $M_N=\mathbf{10^6}$ GeV
- ν-Yukawa dominance is favoured in most region

Relation to Experiments



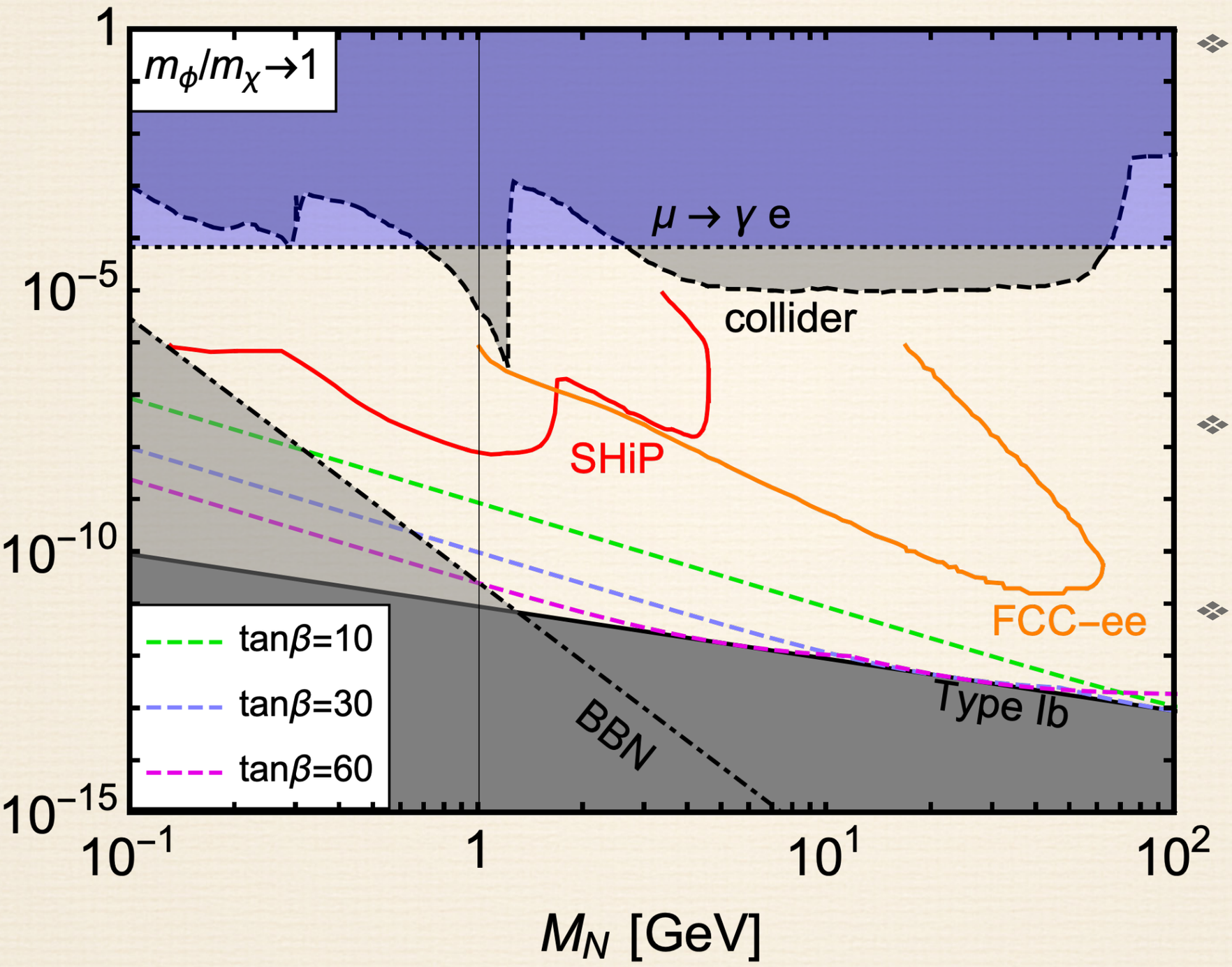
- ν-Yukawa dominance is allowed above the coloured dashed lines
- Downwards as tanβ increases

Relation to Experiments



- ν-Yukawa dominance is allowed above the coloured dashed lines
- Downwards as tanβ increases
- Strongest constraint given by ν_μ mixing

Relation to Experiments



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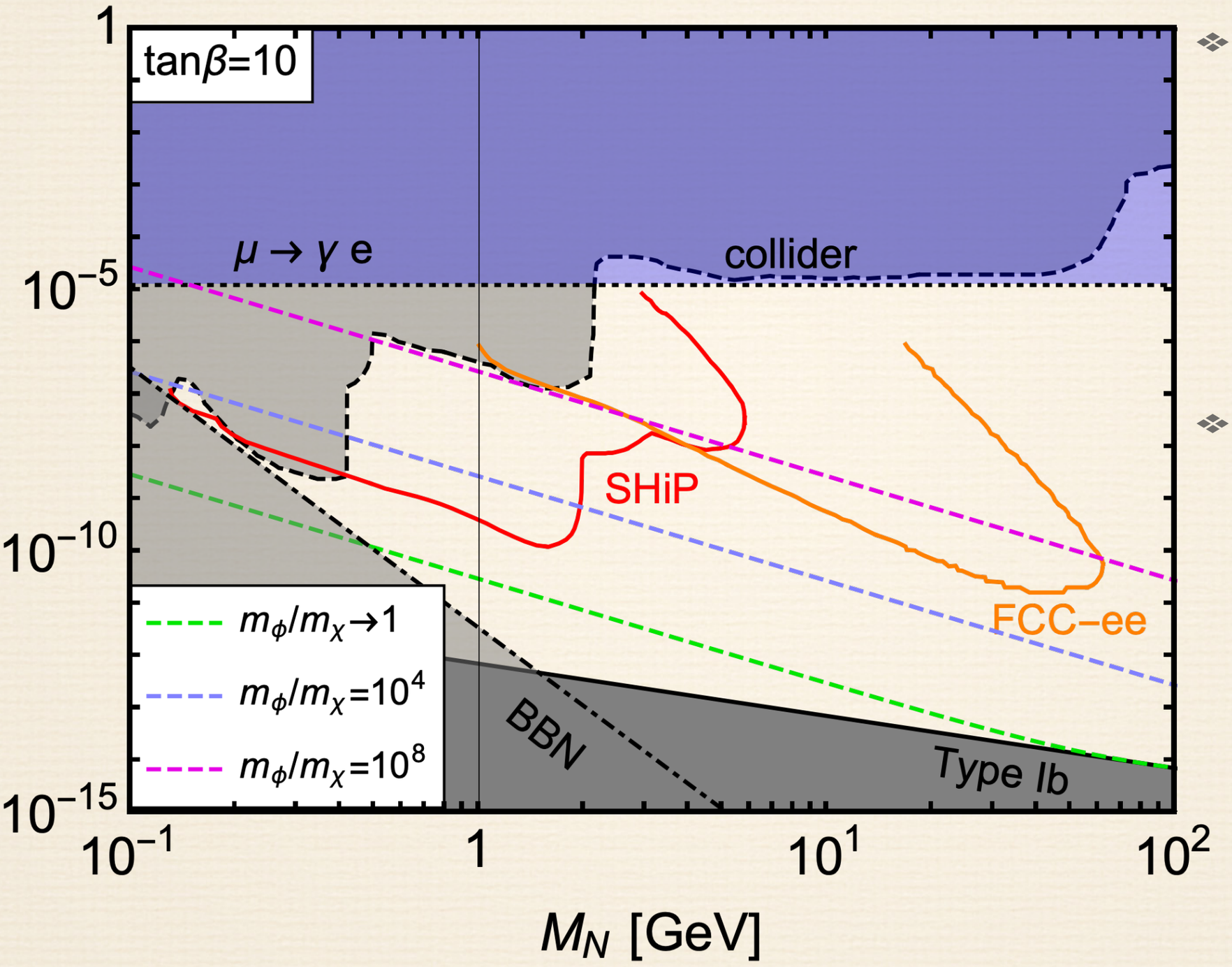
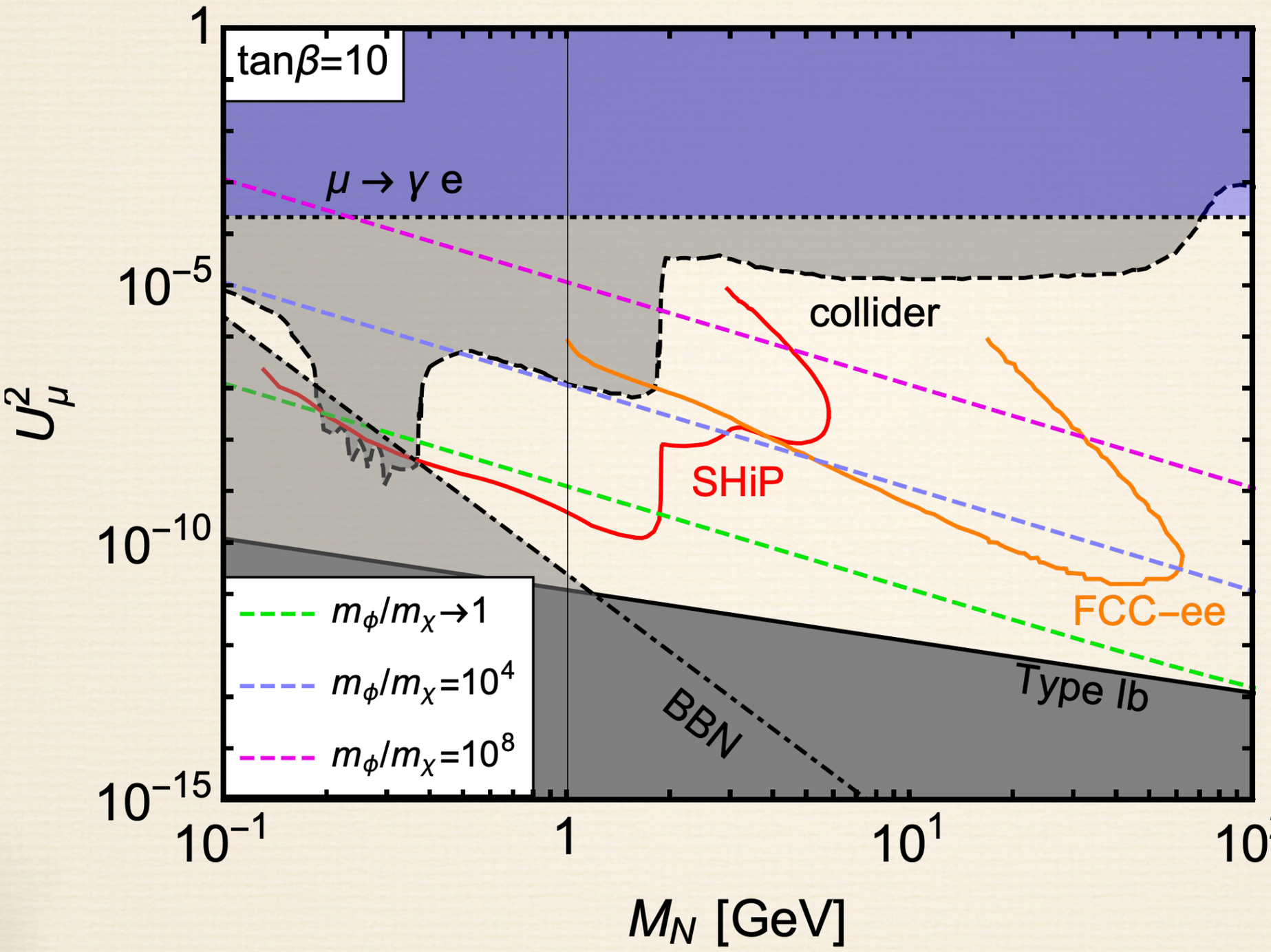


- ν-Yukawa dominance is allowed above the coloured dashed lines
- Upwards as m_ϕ/m_χ increases

Relation to Experiments



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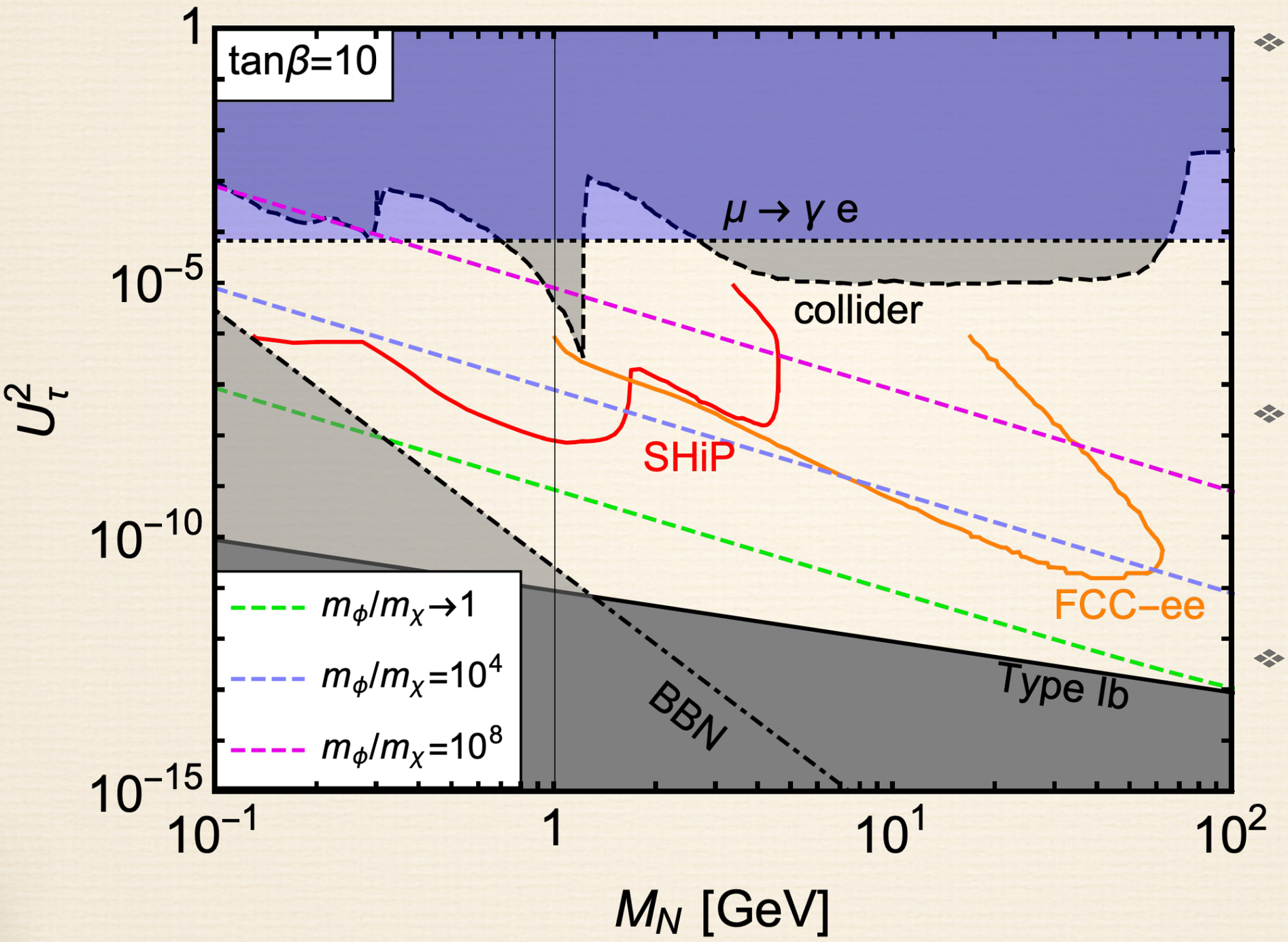

- ν-Yukawa dominance is allowed above the coloured dashed lines
- Upwards as m_ϕ/m_χ increases
- Strongest constraint given by ν_μ mixing

Summary

- We discussed dark matter production in a minimal extension of type Ib seesaw model
- The DM-ν relation is strongly constrained by experimental results when the heavy neutrino is GeV scale
- The results can be further constrained by future experiments

Thanks!