SFB 1258 | Neutrinos Dark Matter Messengers

Beyond the Standard Model physics searches with double-beta decays

Elisabetta Bossio
Technical University of Munich (elisabetta.bossio@tum.de)

Light Dark World 2023 - Karlsruhe Institute of Technology, 21 September 2023

Introduction

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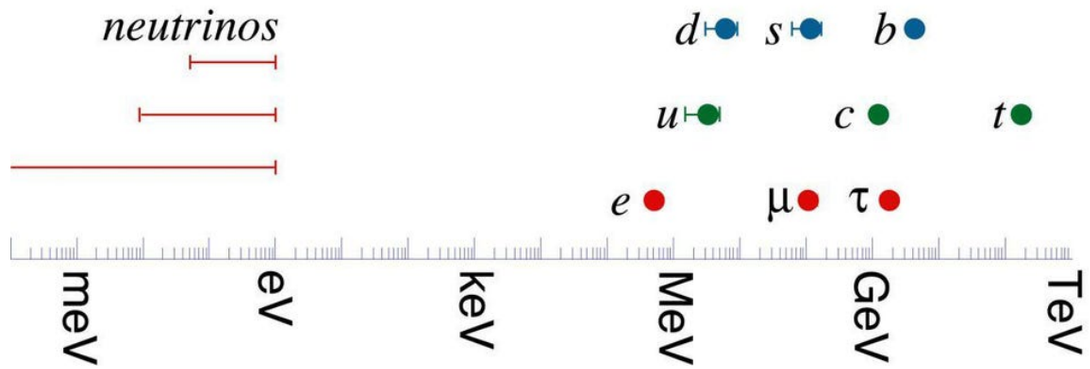

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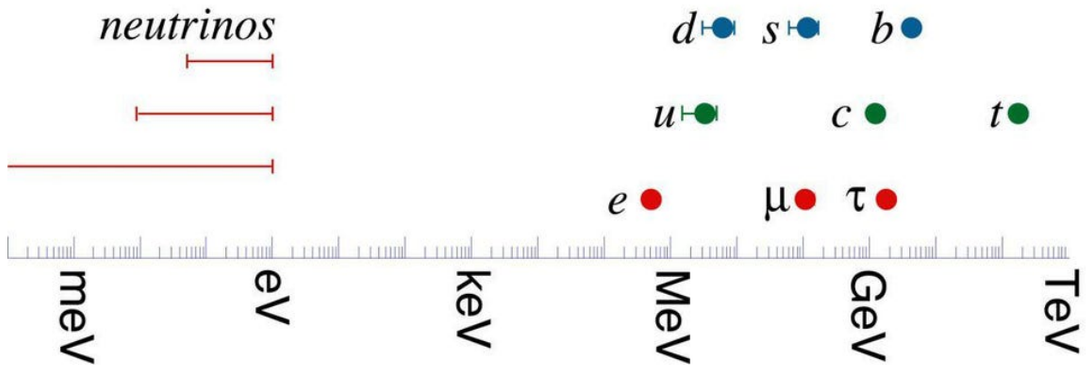
- ν could be a ***Majorana particle***:

$$\nu = \bar{\nu}$$

- Lepton number non-conserved

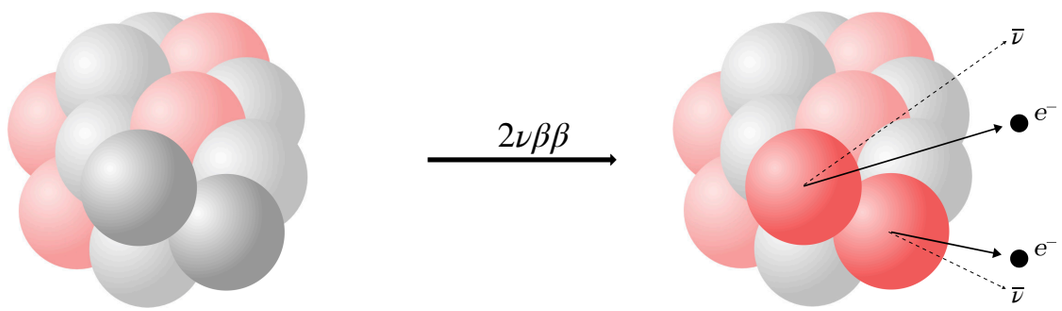


Double-beta decays

- ***Two-neutrino double-beta decay:***

$$2\nu\beta\beta: \ (A,Z) \rightarrow (A,Z+2) + 2e^- + 2\bar{\nu}$$

  - SM allowed, observed in 11 isotopes (half-life $T_{1/2} \sim 10^{18} - 10^{24}$ yr)



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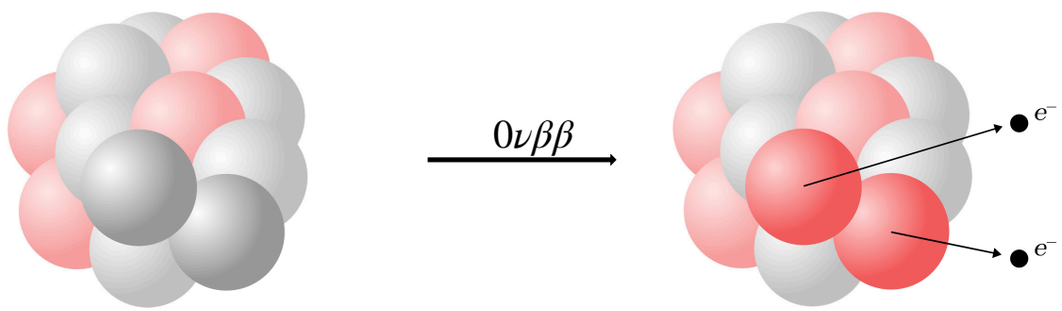

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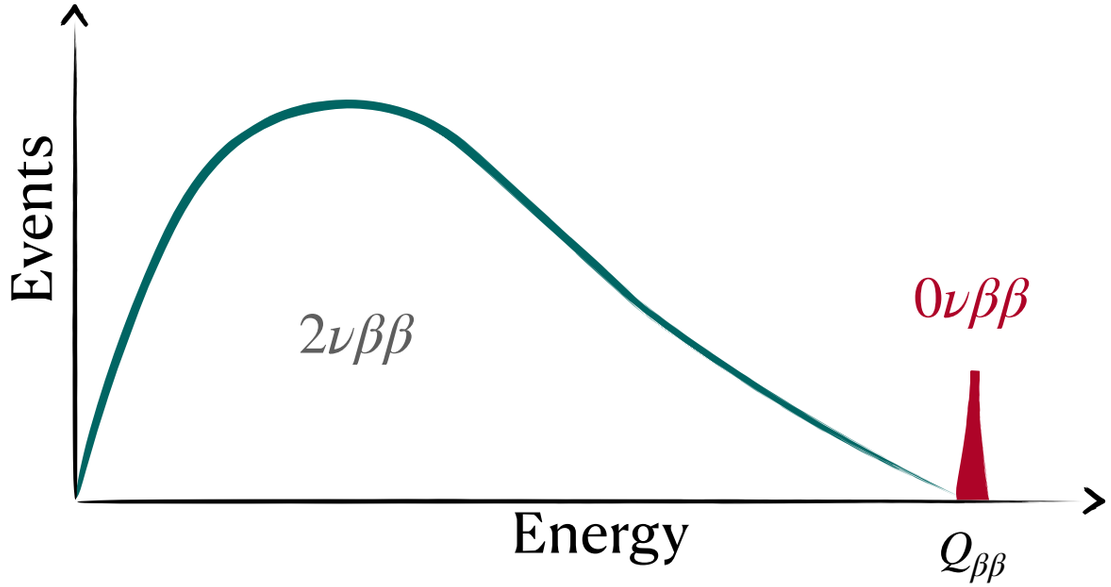

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- Simplest mechanism: *exchange of light Majorana neutrinos*

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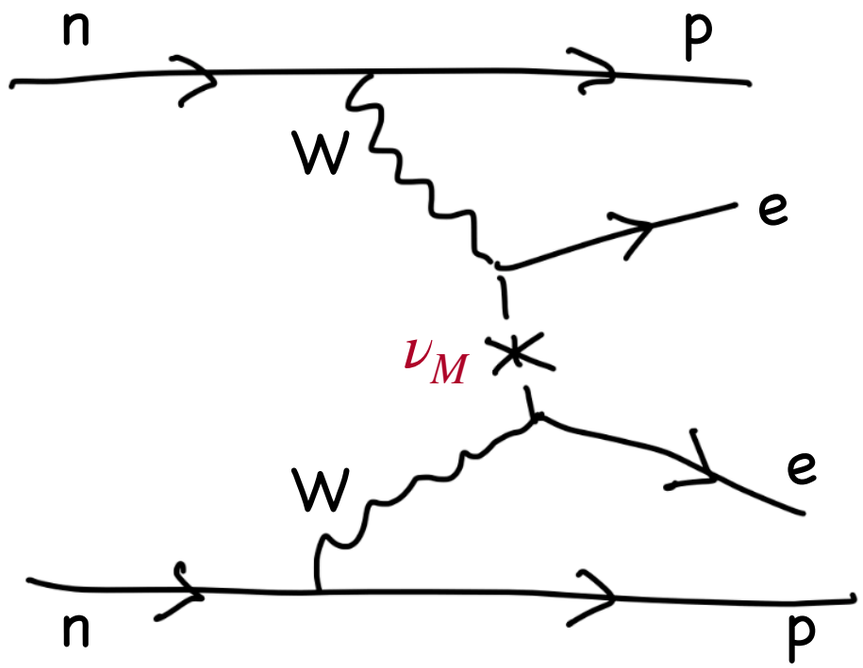

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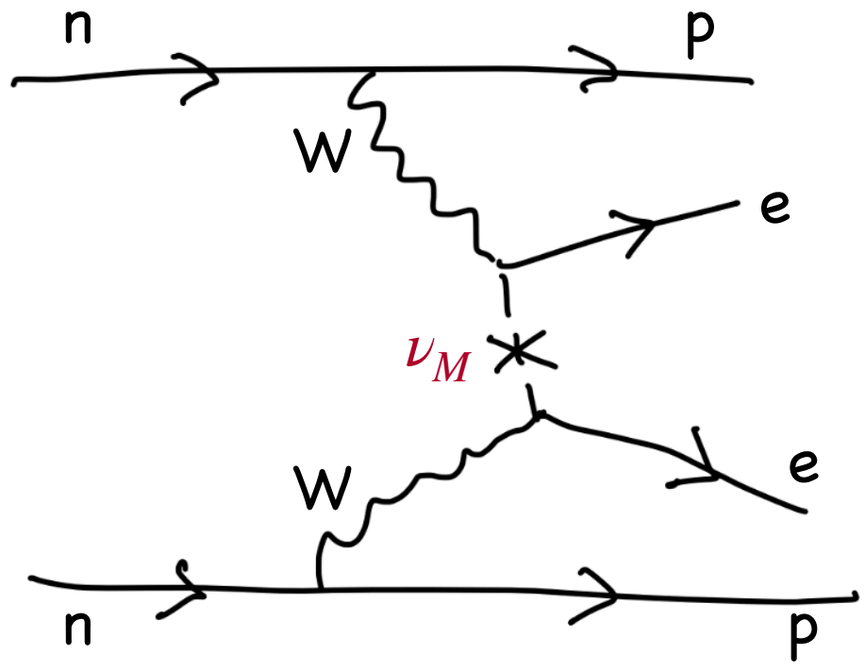

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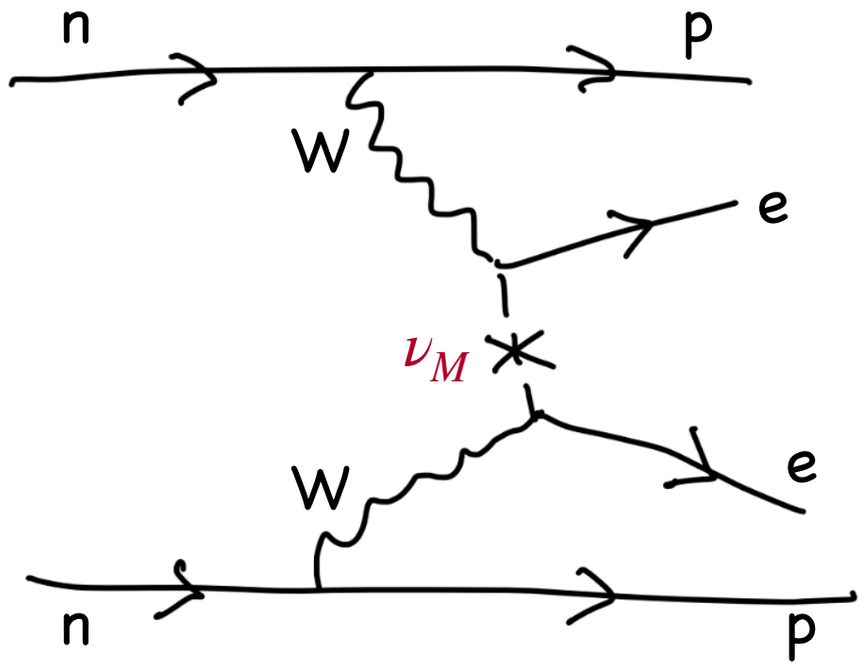

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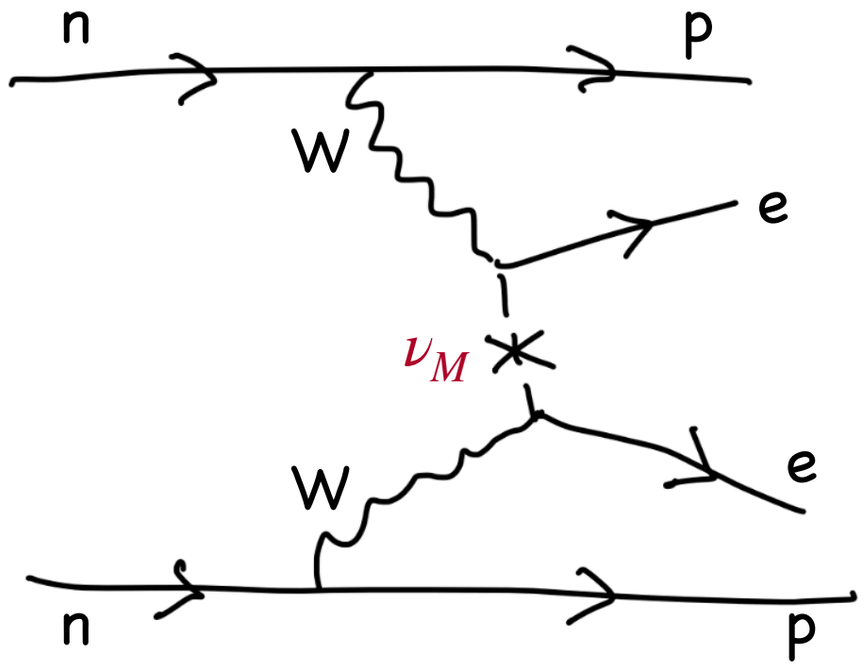

- *Effective Majorana neutrino mass:* related to neutrino parameters

$$m_{\beta\beta} = \sum_i m_i \, U^2_{ei}$$

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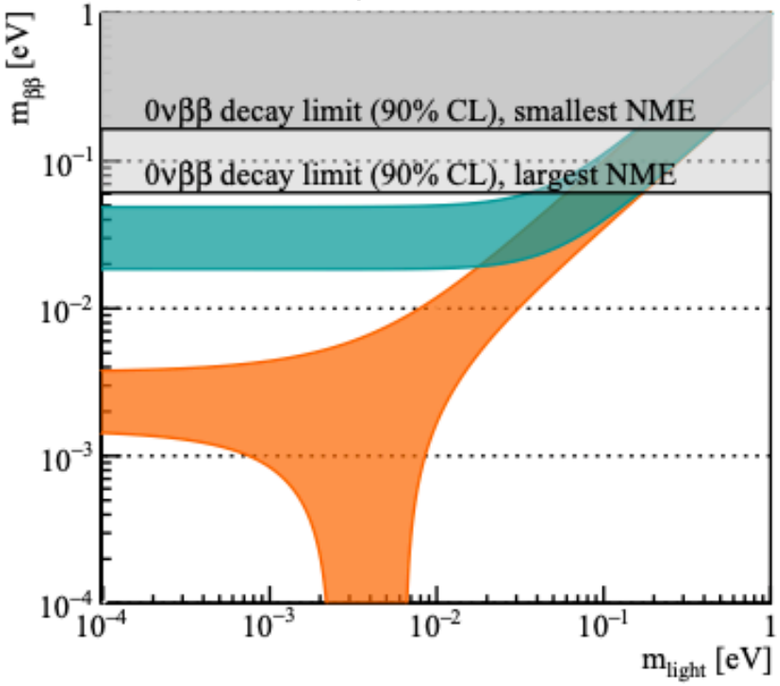
Rev. Mod. Phys. 95, 025002, arXiv:2202.01787



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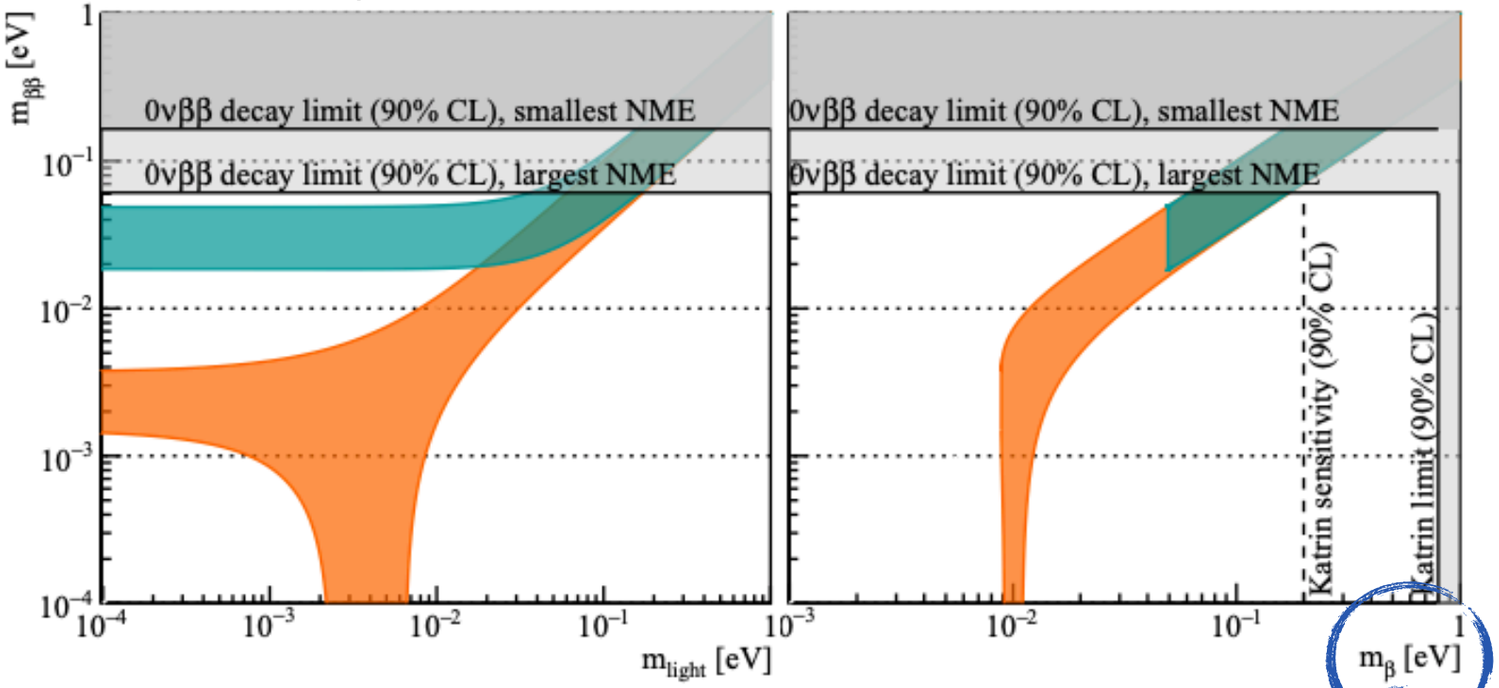

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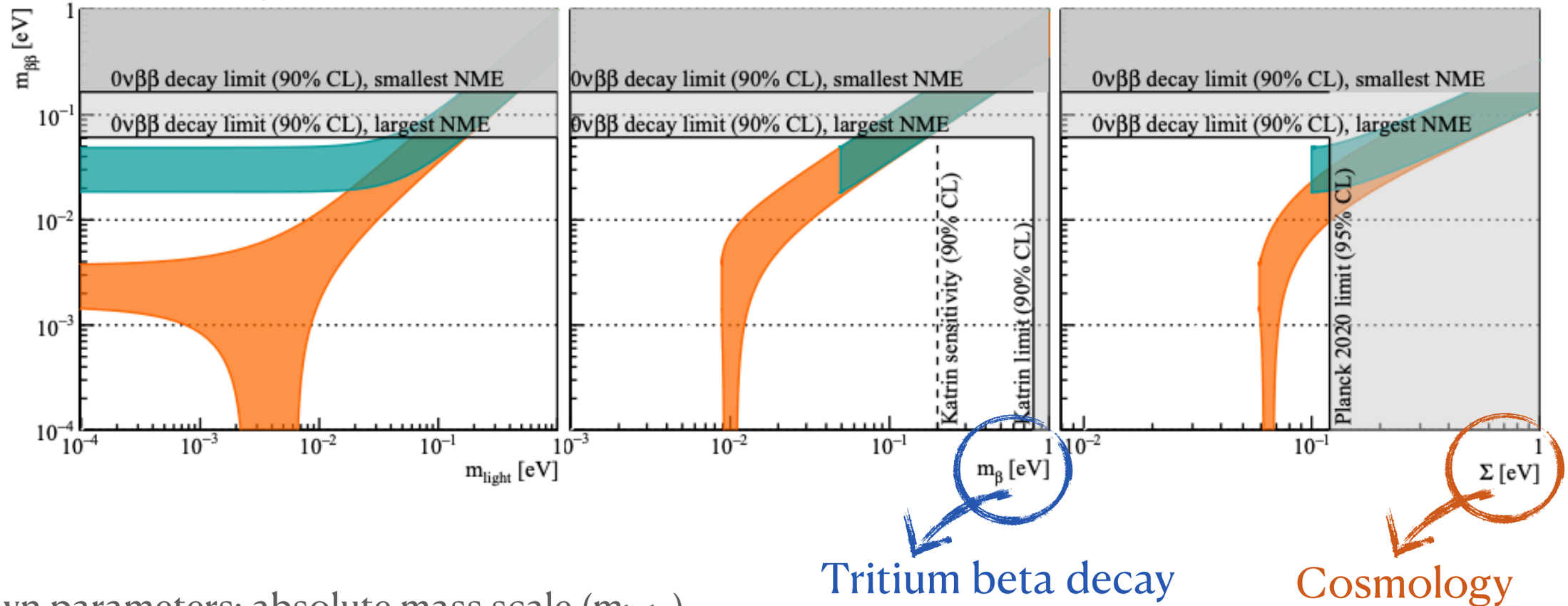

Tritium beta decay

Cosmology

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- *New physics in double-beta decay*? E.g. New particles, RH currents, Neutrino self-interaction, Lorentz violation...

Phys. Rev. Lett. 125, 171801, arXiv:2003.11836
Phys. Rev. D 103, 055019 (2021), arXiv:2011.13387
Phys. Rev. D 102, 051701 (2020), arXiv:2004.11919
M.Agostini, EB, A. Ibarra, X. Marcano, Phys. Lett. B 815 (2021) 136127
Review: EB and M.Agostini, arXiv:2304.07198

BSM physics in double-beta decays

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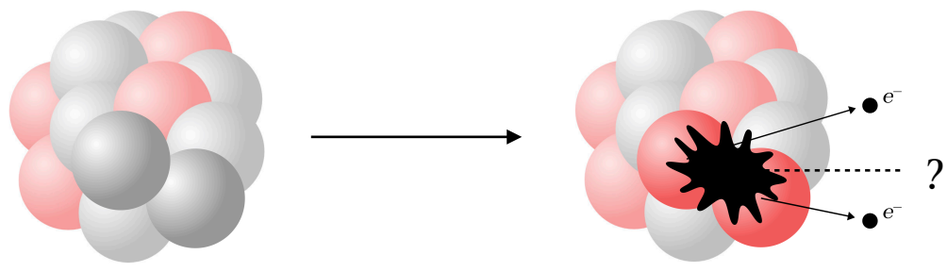

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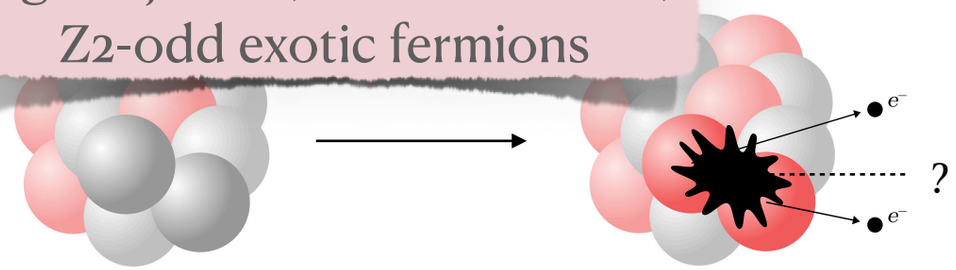

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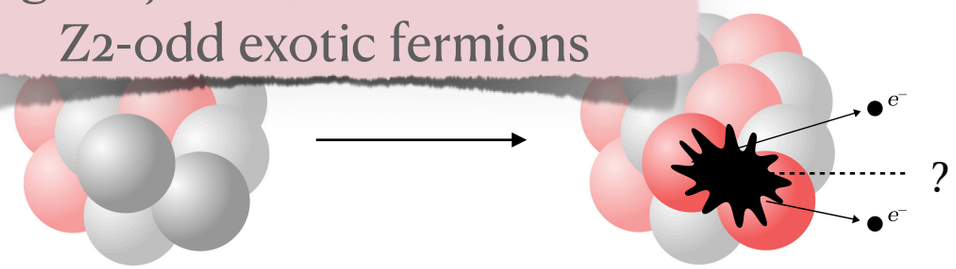

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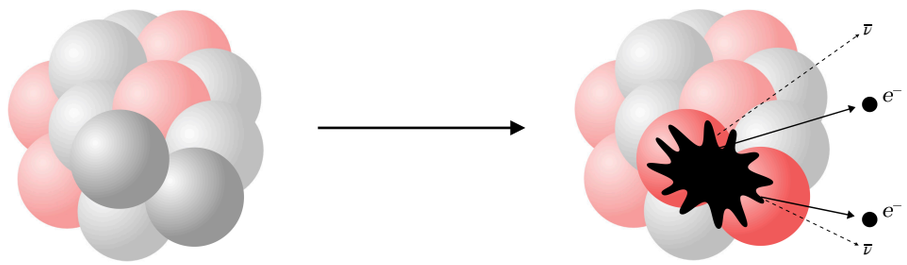

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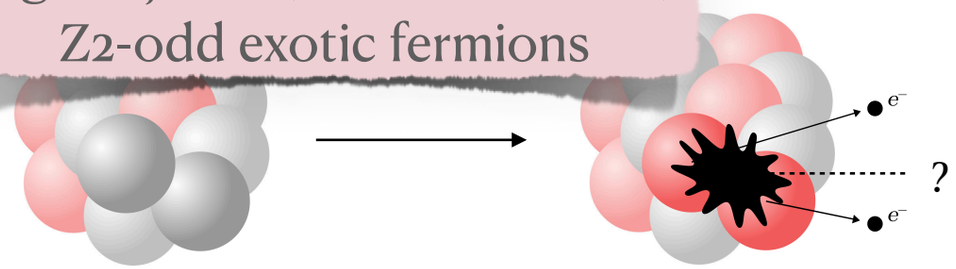

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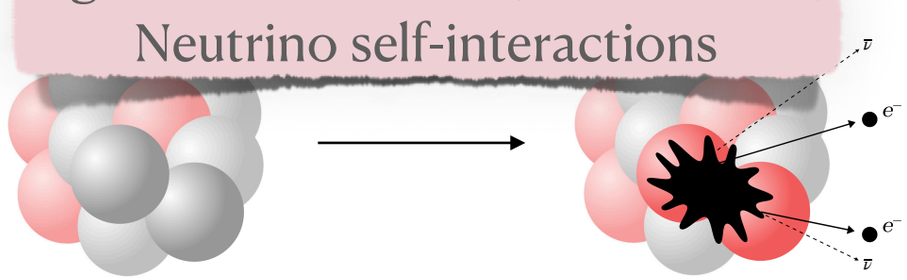

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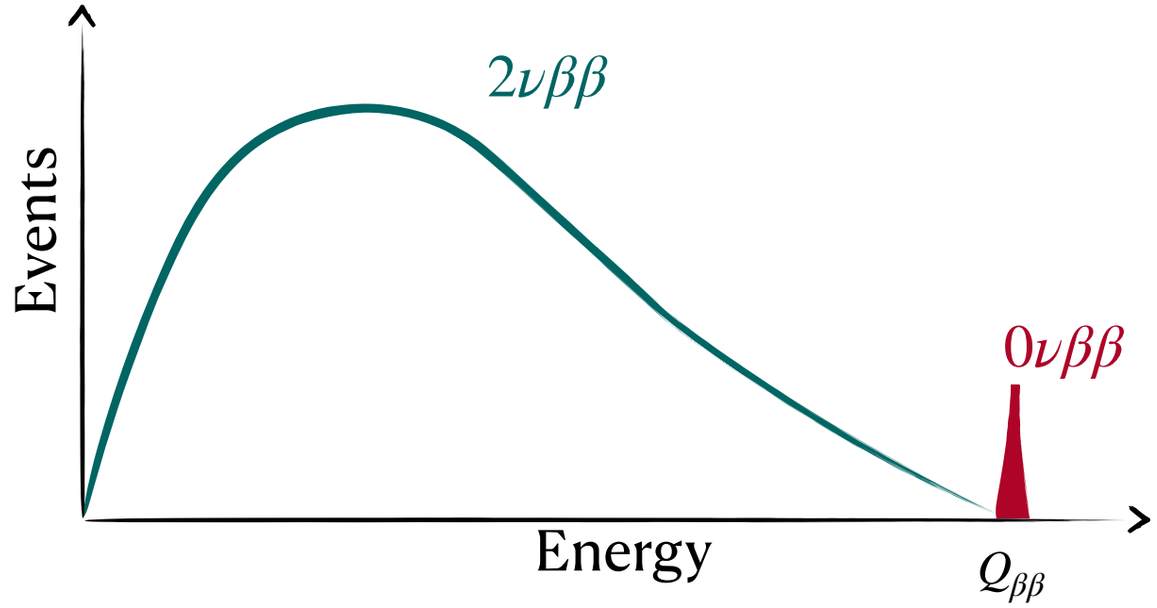

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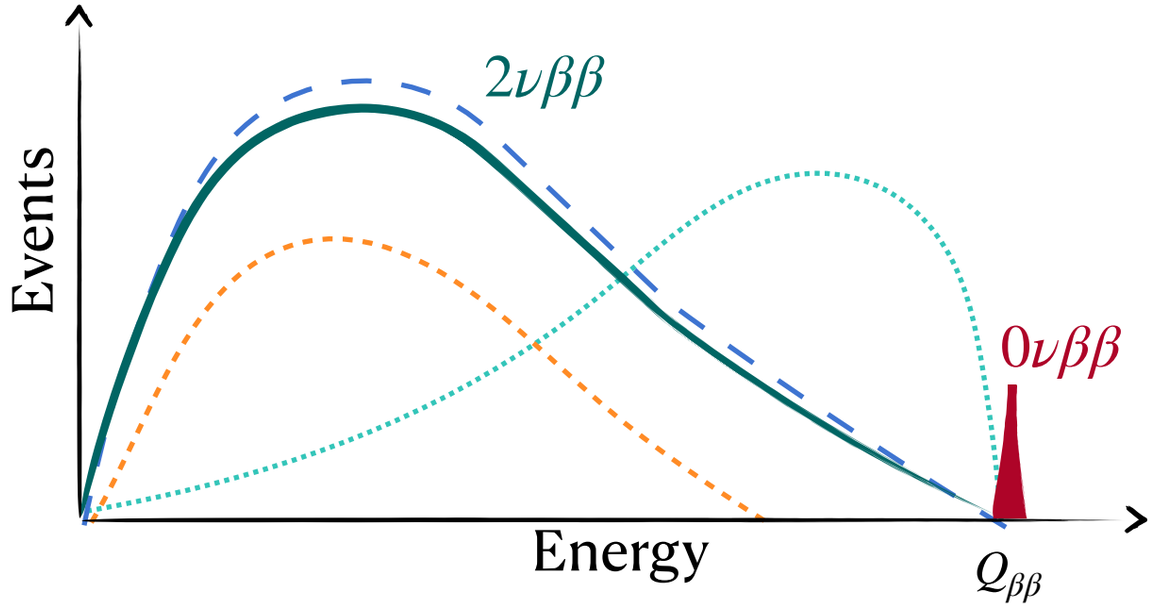

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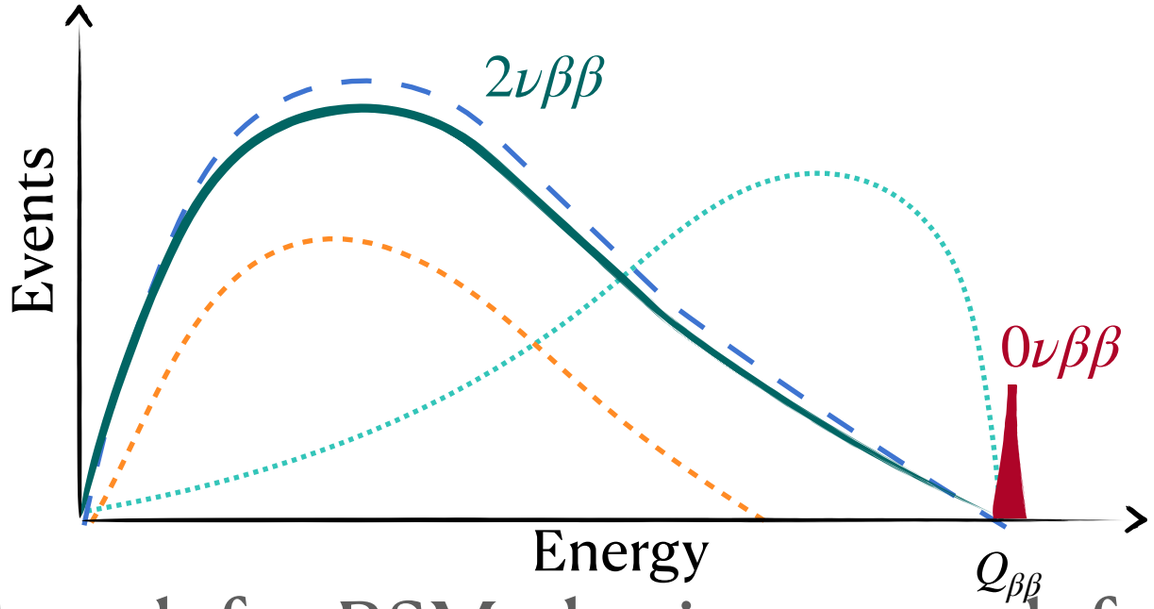

- Search for BSM physics = search for distortion of the continuous electron energy spectrum

Light exotic fermions in double-beta decay

M.Agostini, EB, A. Ibarra, X. Marcano, Phys. Lett. B 815 (2021)

See also Phys. Rev. D 103, 055019 (2021)

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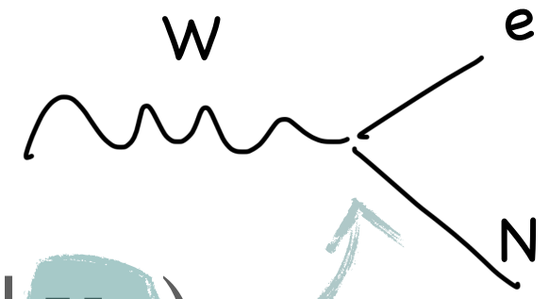

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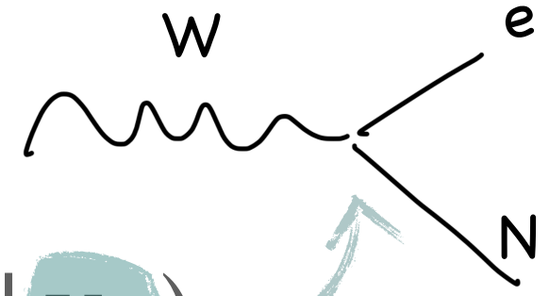

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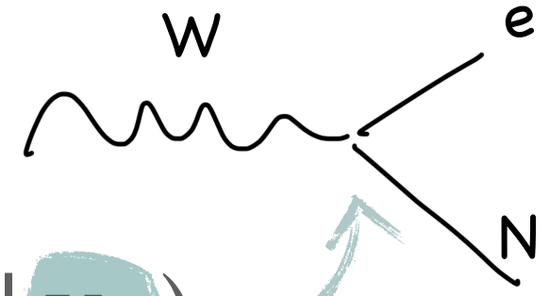

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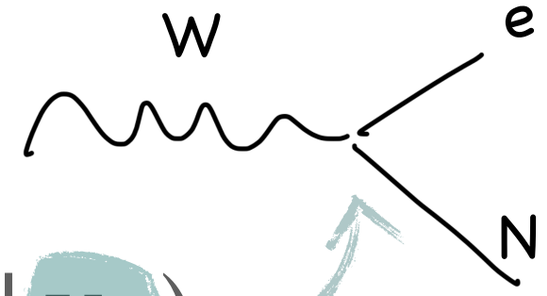

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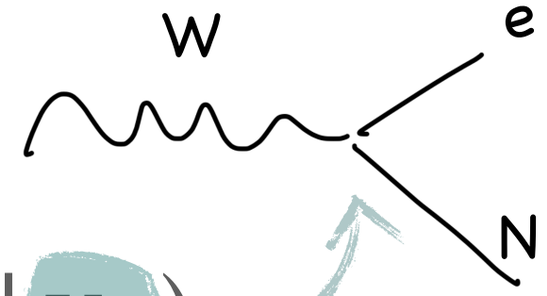

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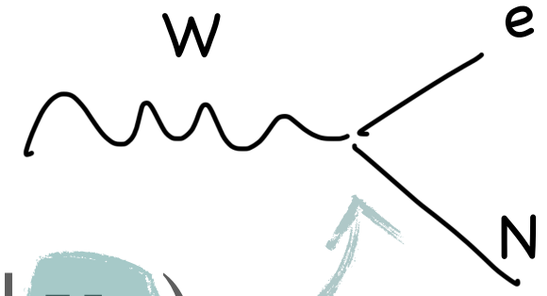

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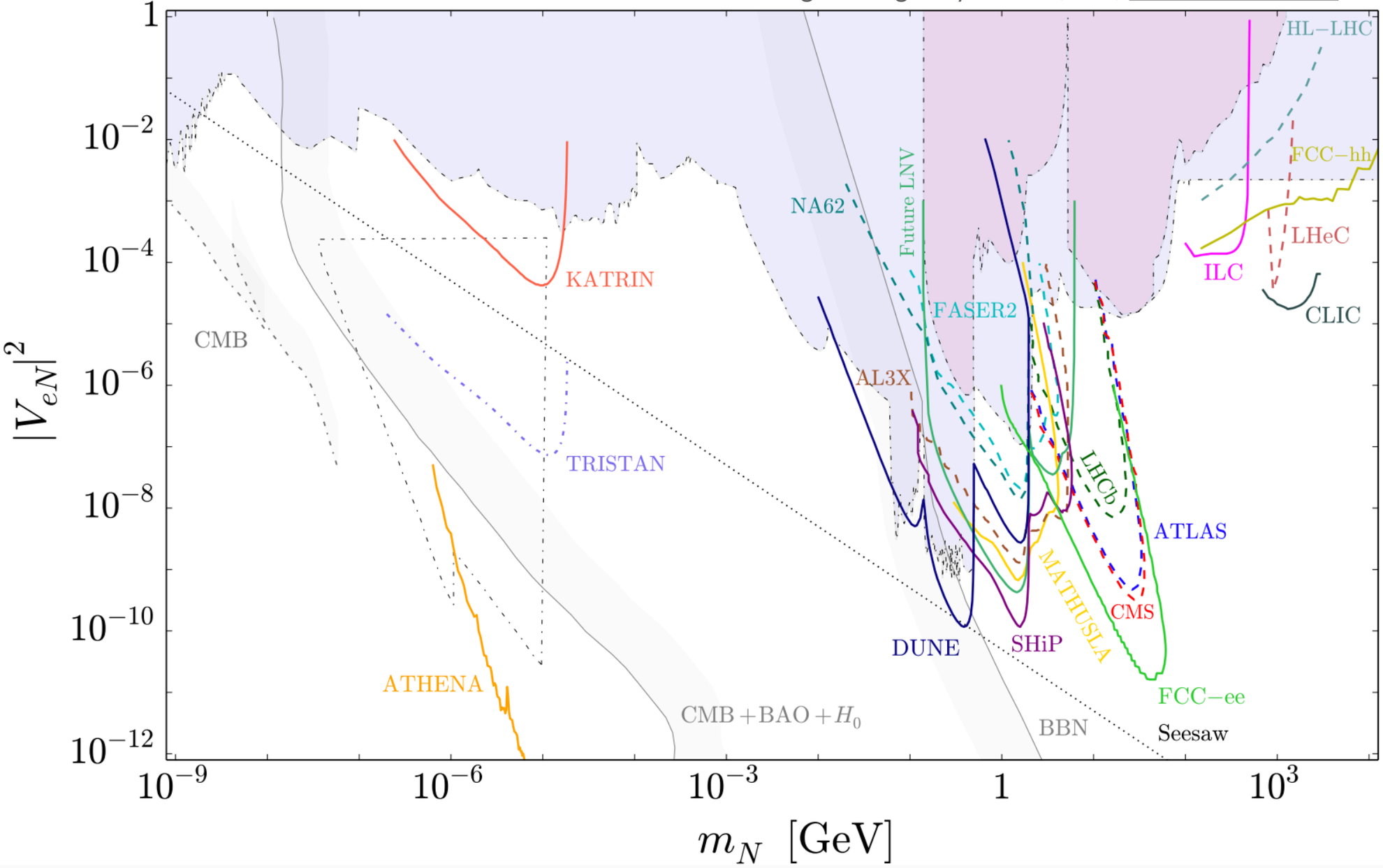
Weak bounds at 100 keV - 1 MeV

J. High Energ. Phys. 2020, 170, arXiv:1912.03058



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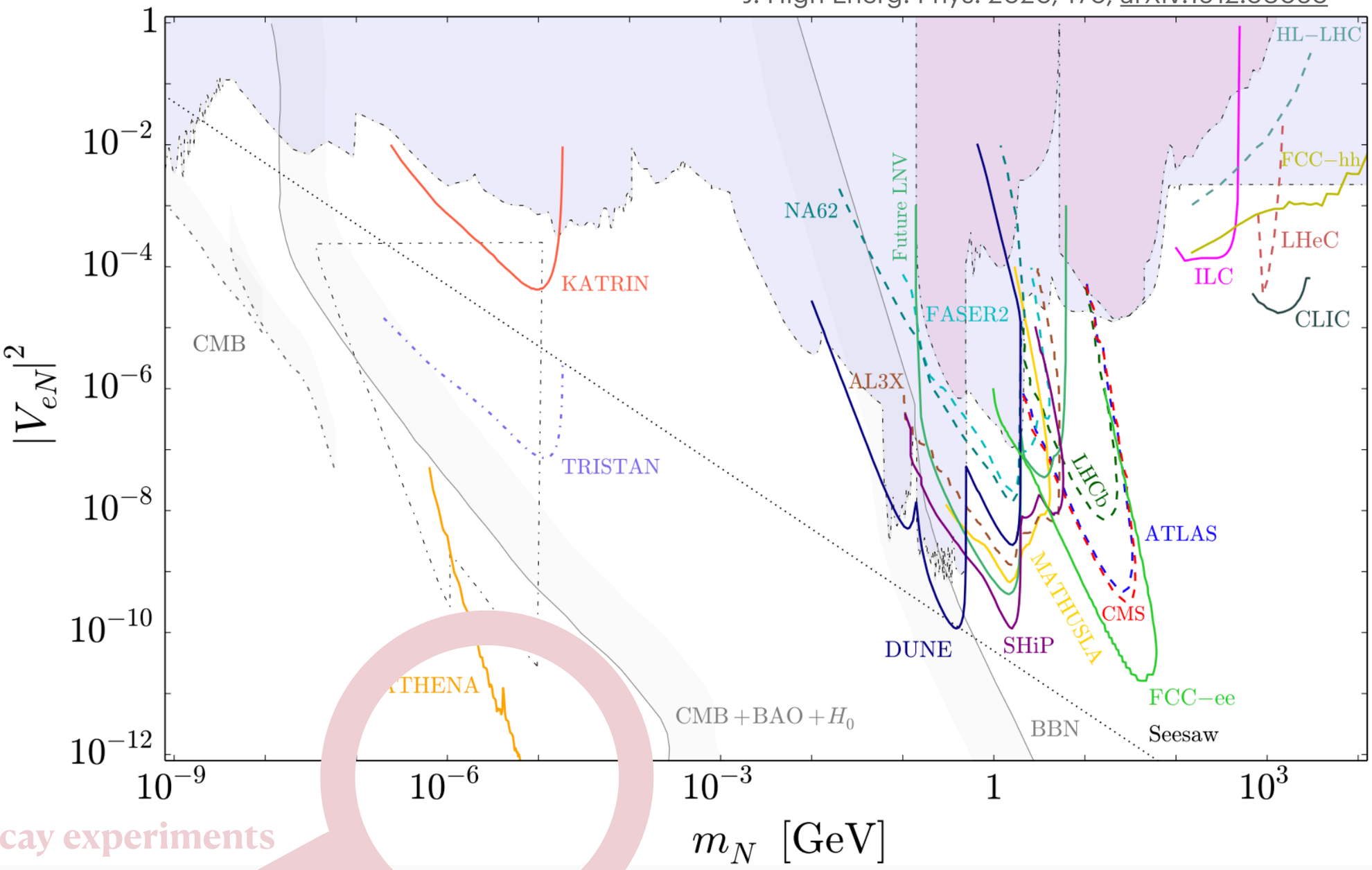

Beta decay experiments

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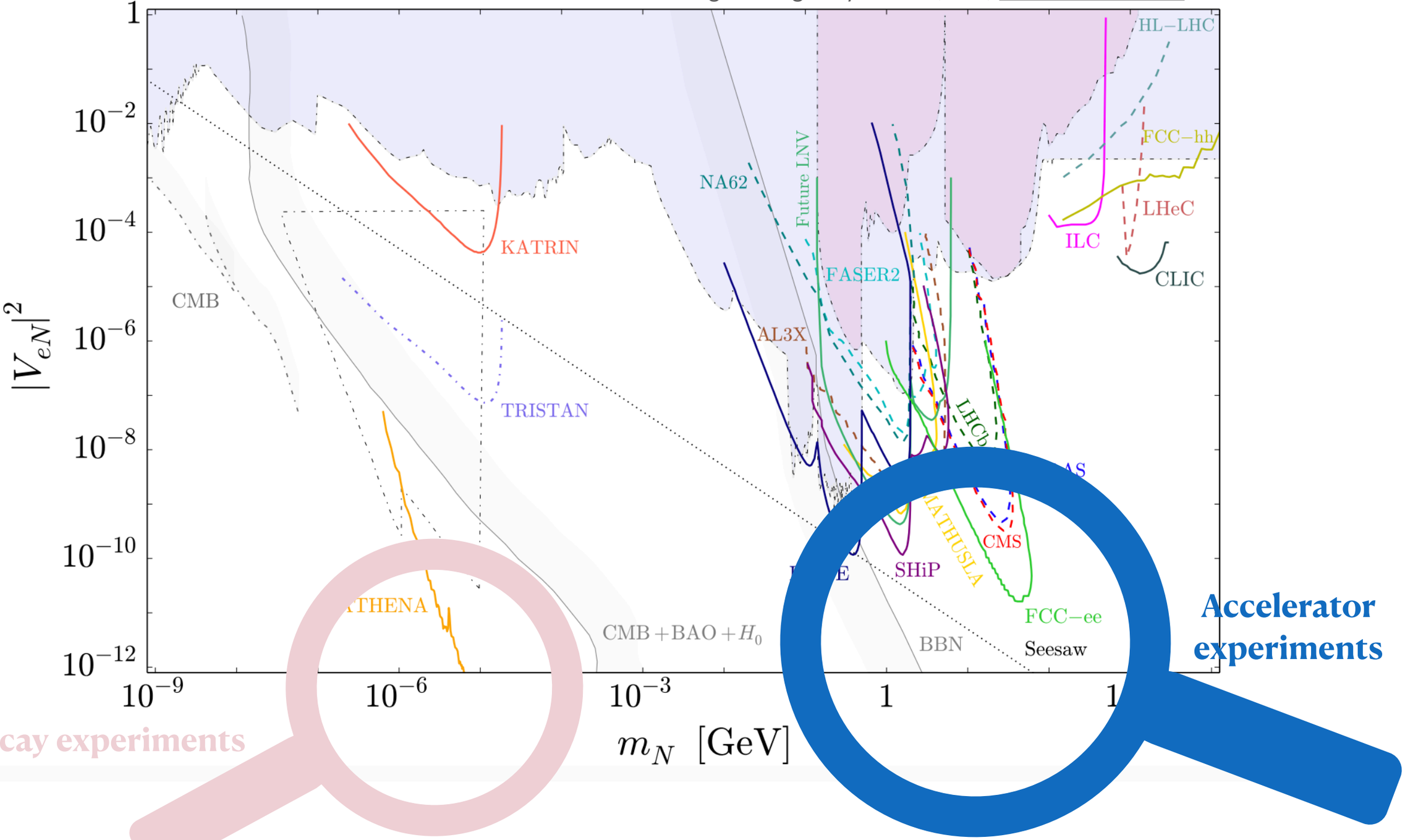

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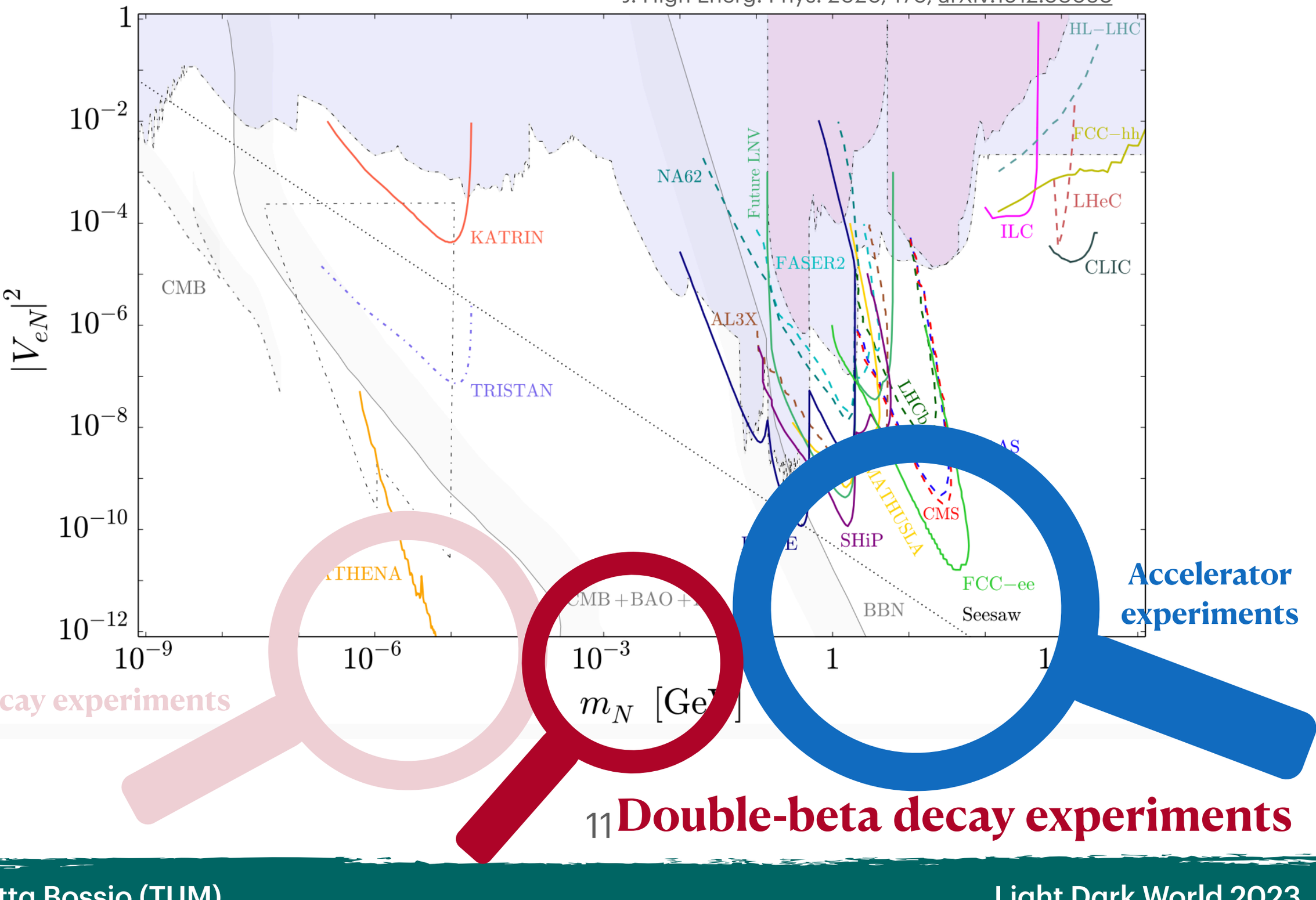

Double-beta decay rate

$\sin\theta \sim U_{e4}$

- Incoherent superposition of three terms

$$\frac{d\Gamma}{dT} = \cos^4\theta \frac{d\Gamma_{\nu\nu}}{dT}\theta(T_0 - T) + 2\cos^2\theta\sin^2\theta \frac{d\Gamma_{\nu N}}{dT}\theta(T_0 - T - x_N) + \sin^4\theta \frac{d\Gamma_{NN}}{dT}\theta(T_0 - T - 2x_N)$$

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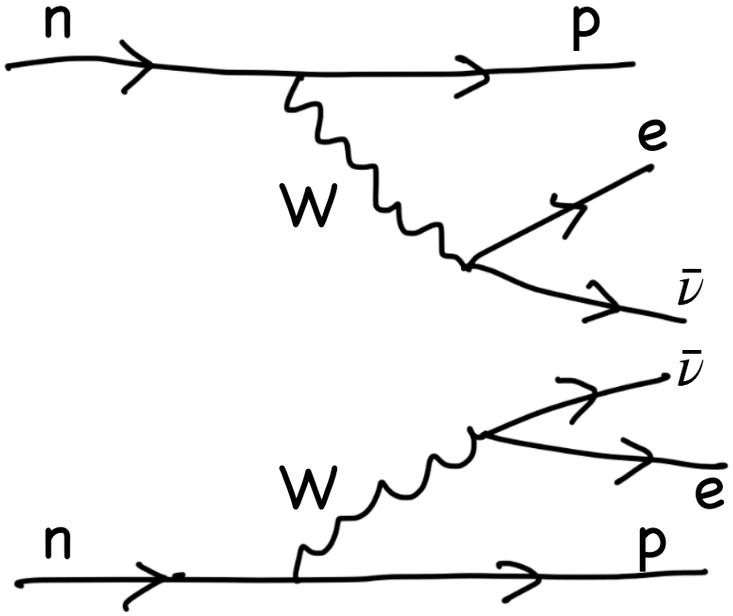

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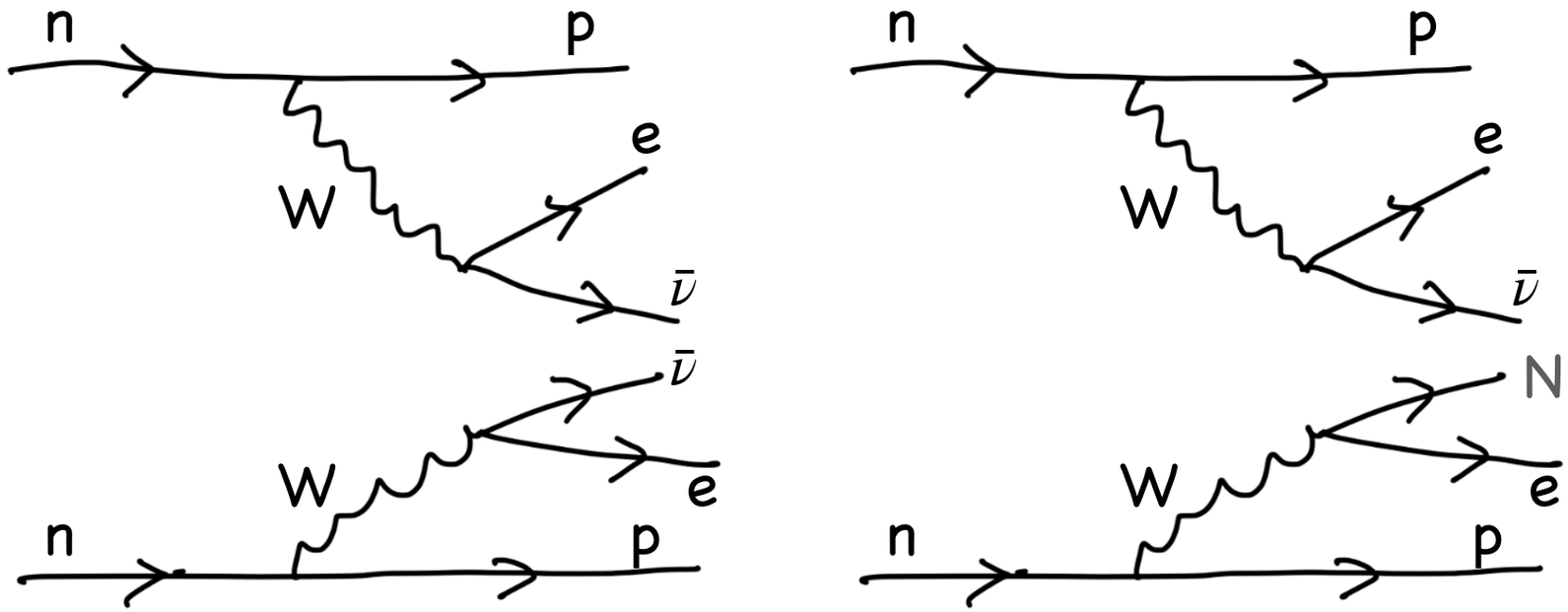

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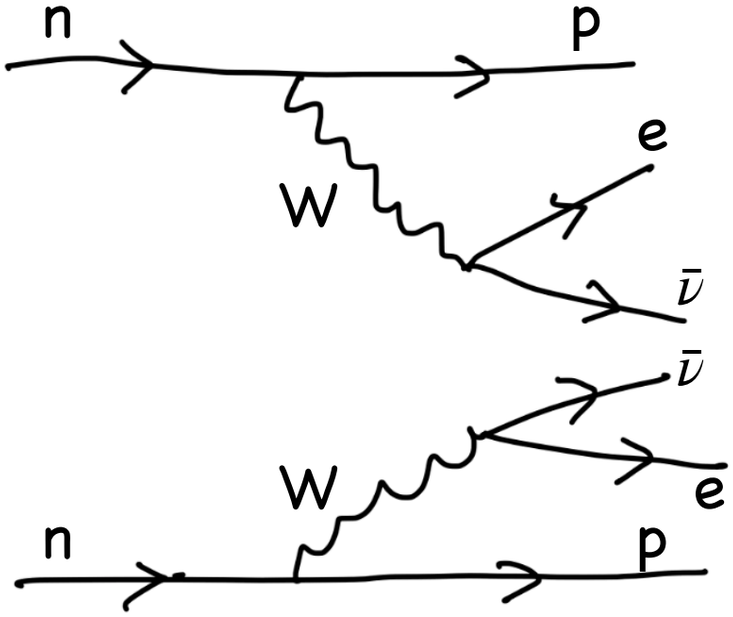

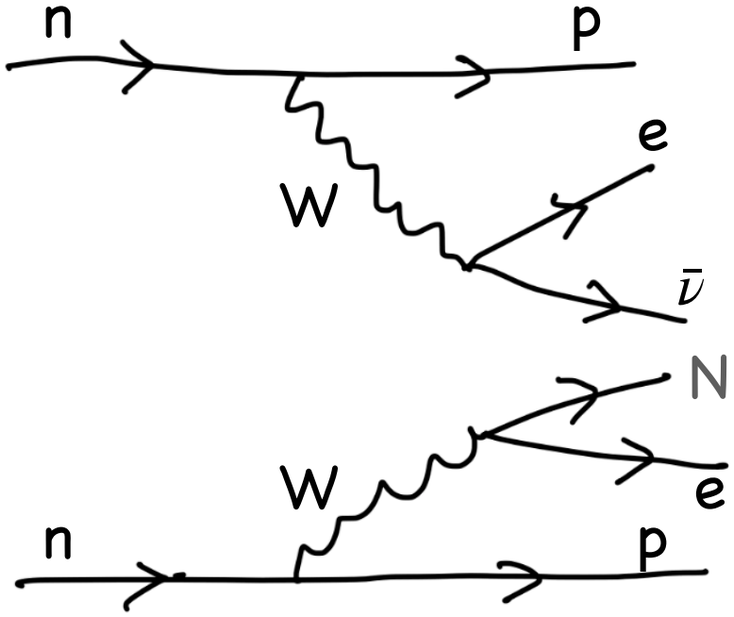

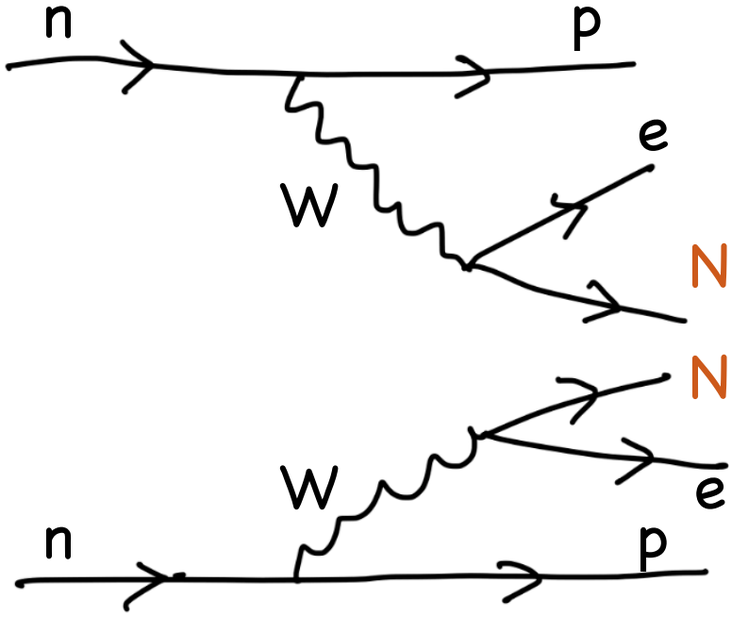

- Reduced by a factor $\cos^4\theta$

- Negligible experimentally $\propto \sin^4\theta$

Shape distortion of the energy spectrum

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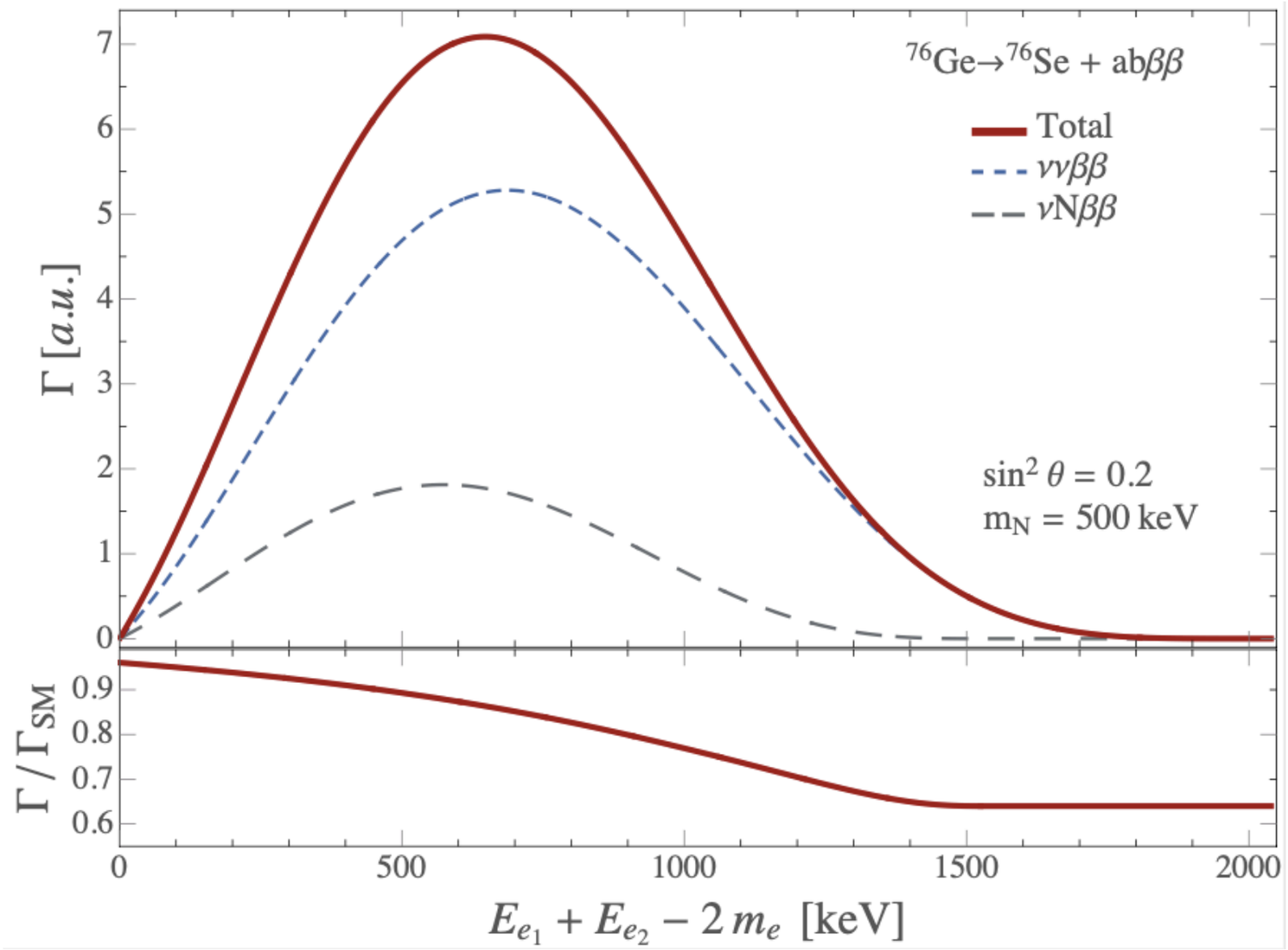

Discovery potential of double-beta decay experiments

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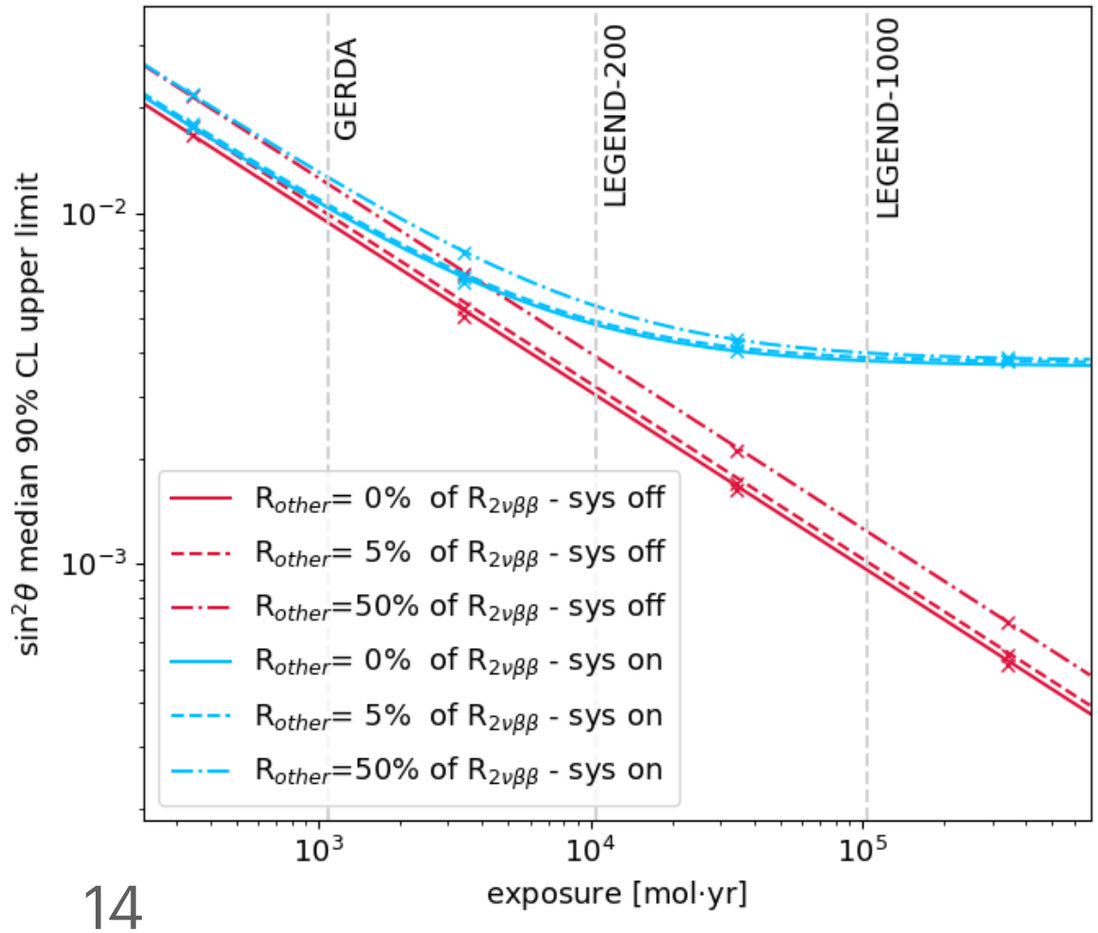

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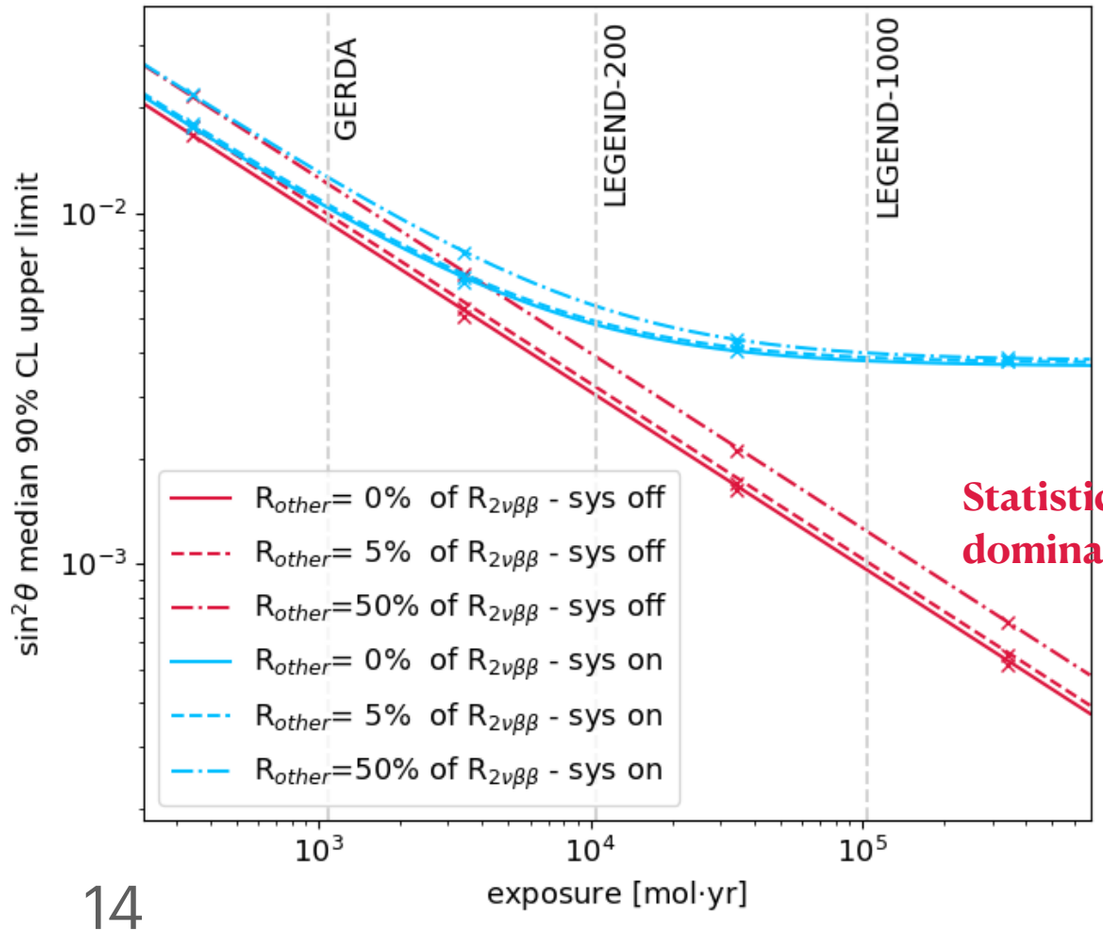

Statistical uncertainty dominant

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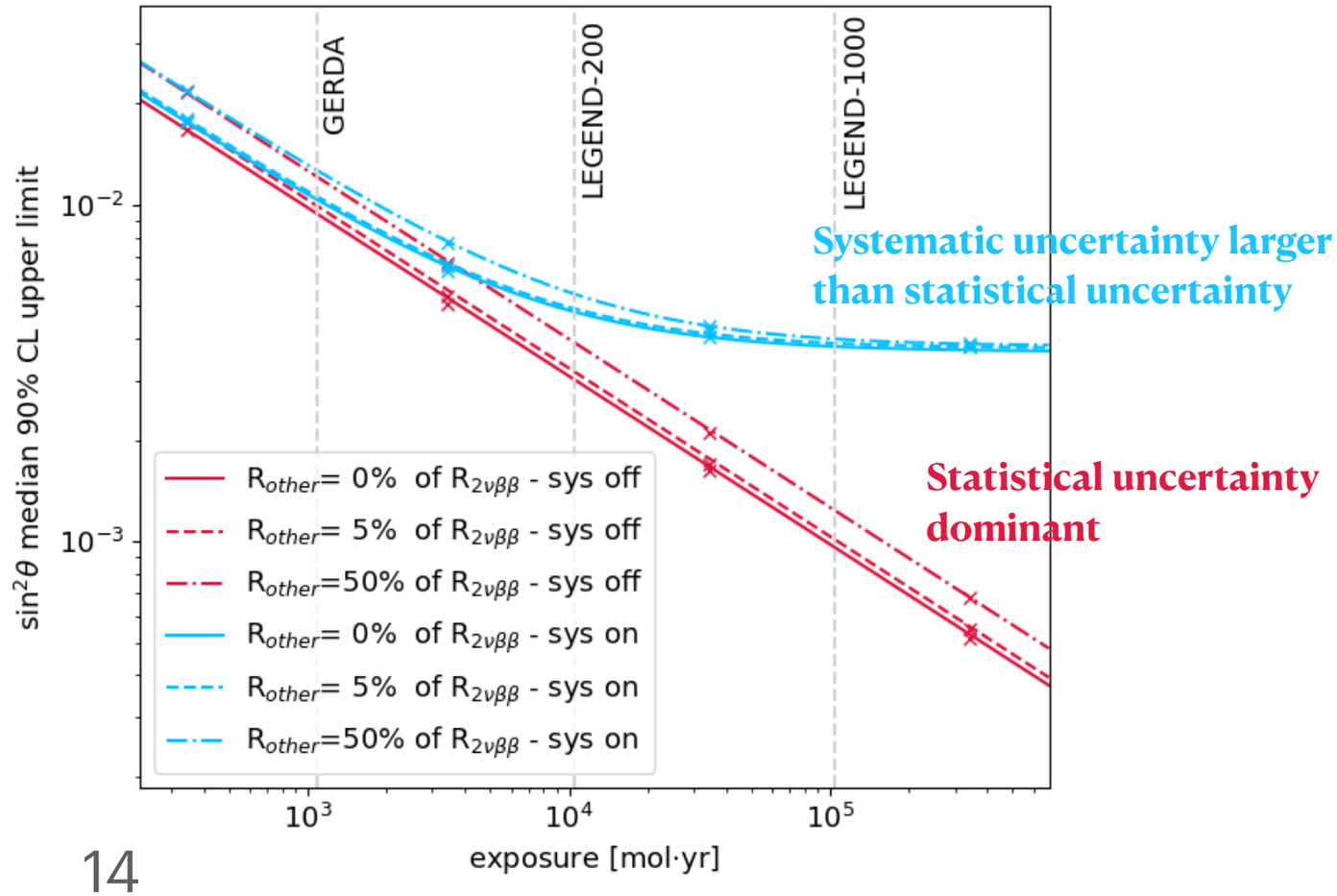
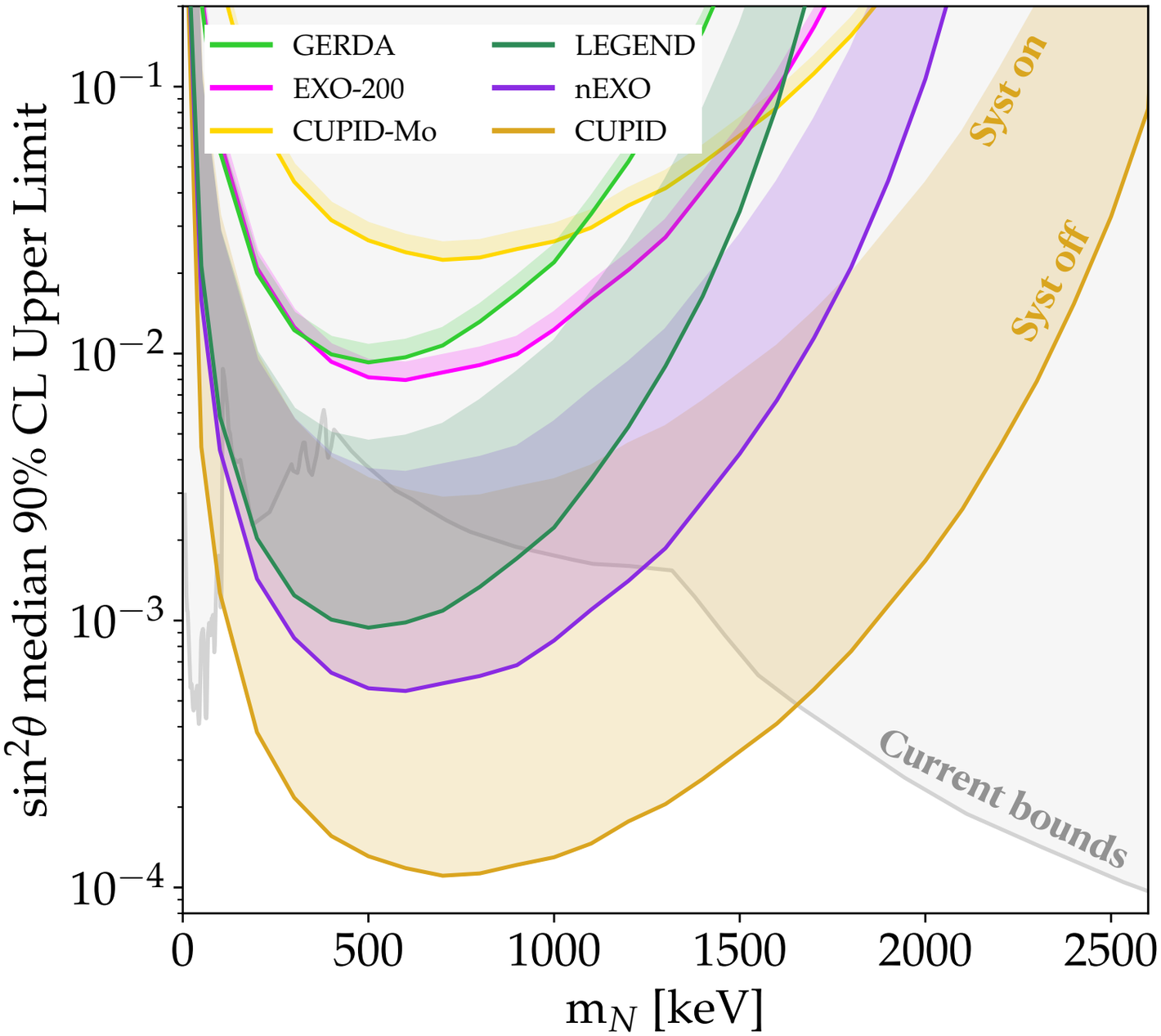


Sensitivity projections



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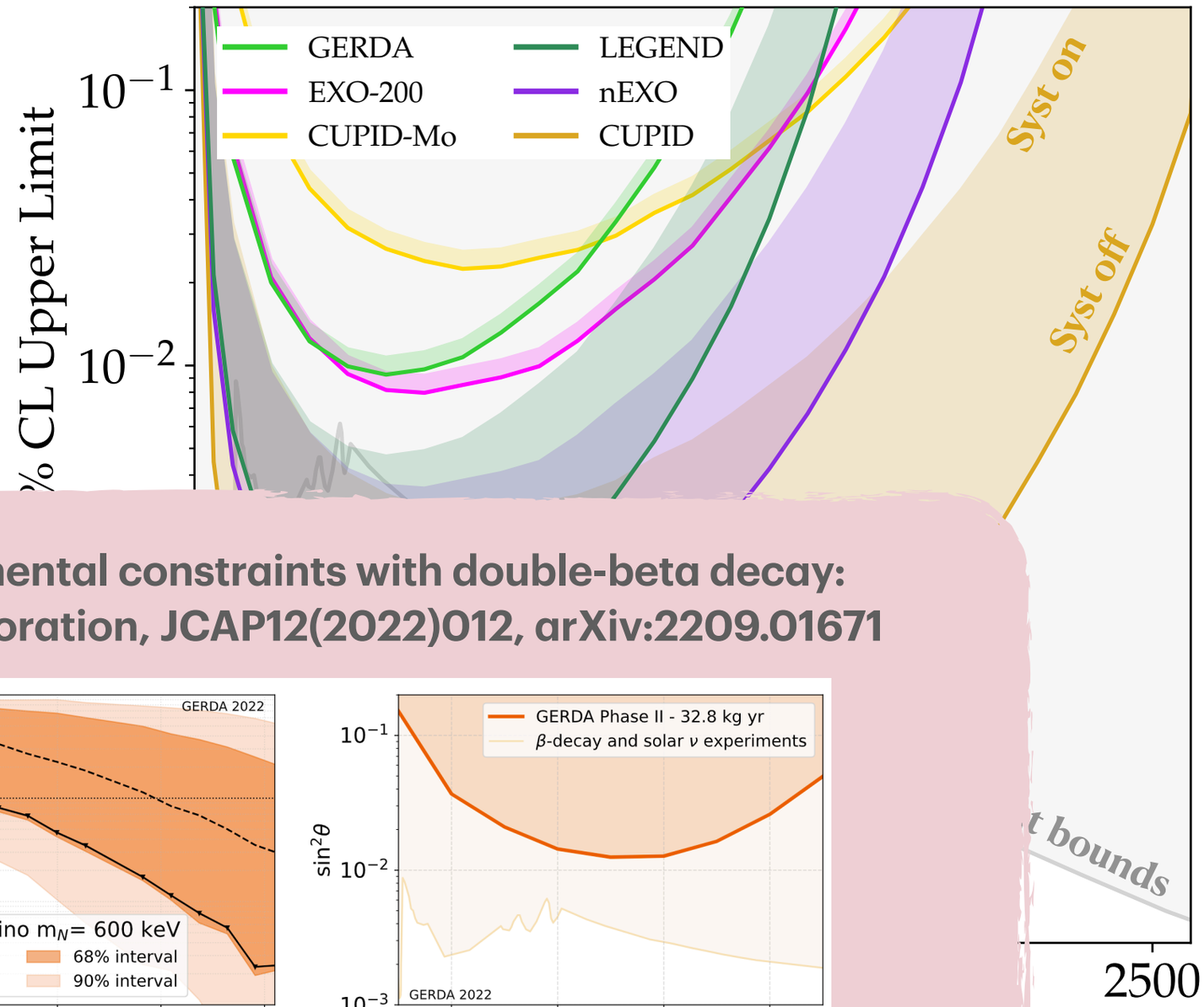
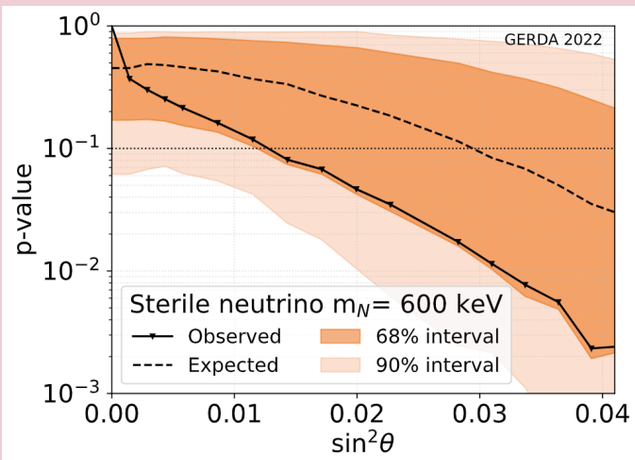
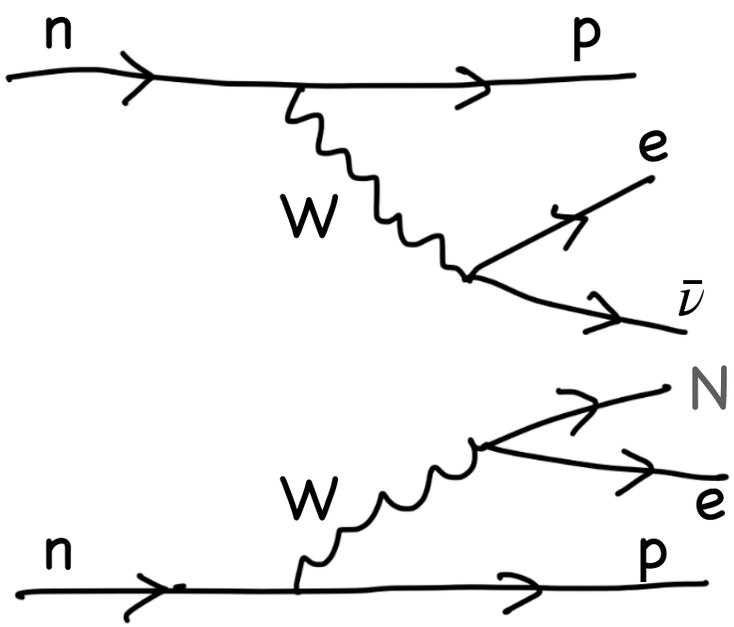


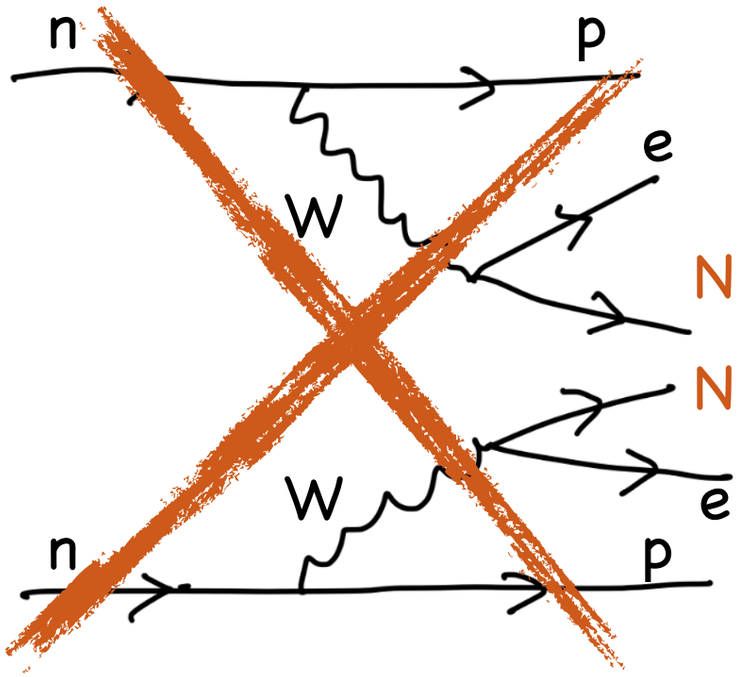
First experimental constraints with double-beta decay:
GERDA Collaboration, JCAP12(2022)012, arXiv:2209.01671



Exotic pair production

- If single production is allowed, pair production is subdominant





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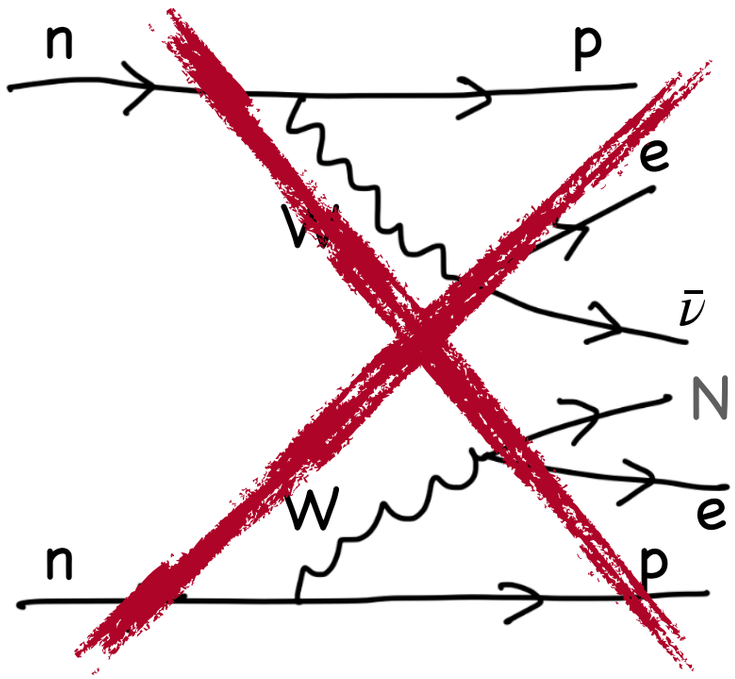

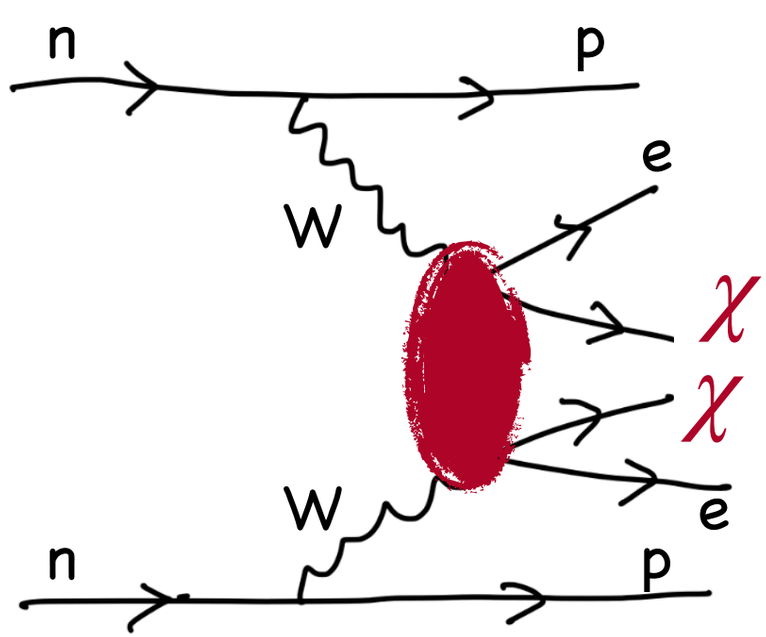

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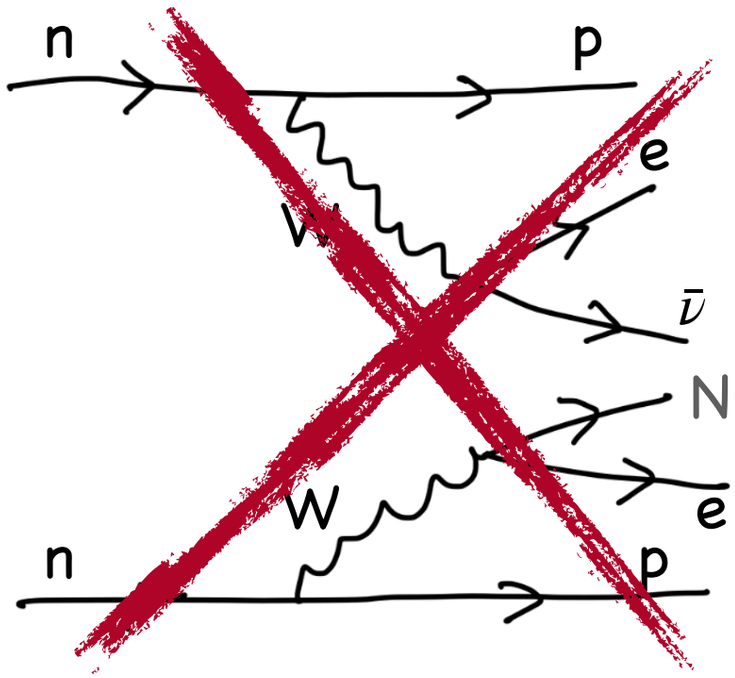

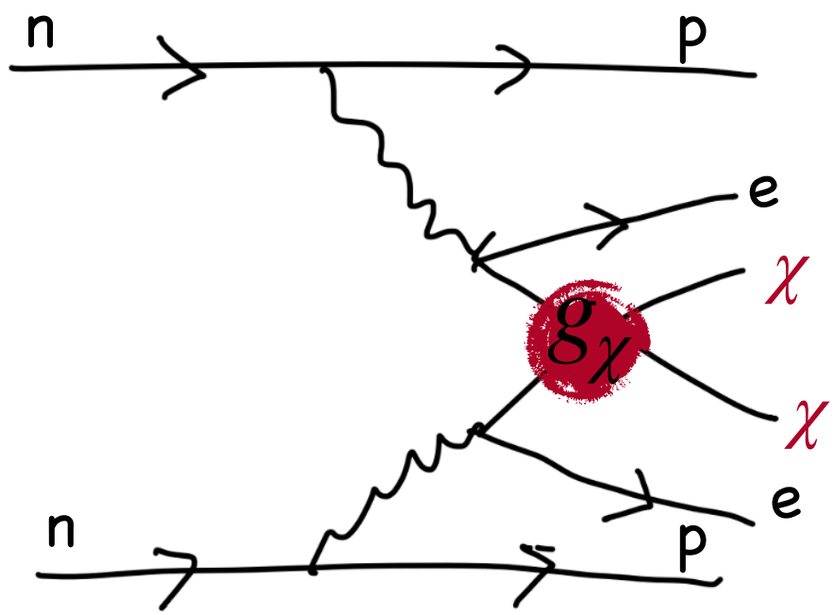

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- Effective interaction:

$$\mathscr{L}_{eff} = g_\chi \nu\nu\chi\chi$$

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- Sum of two terms:

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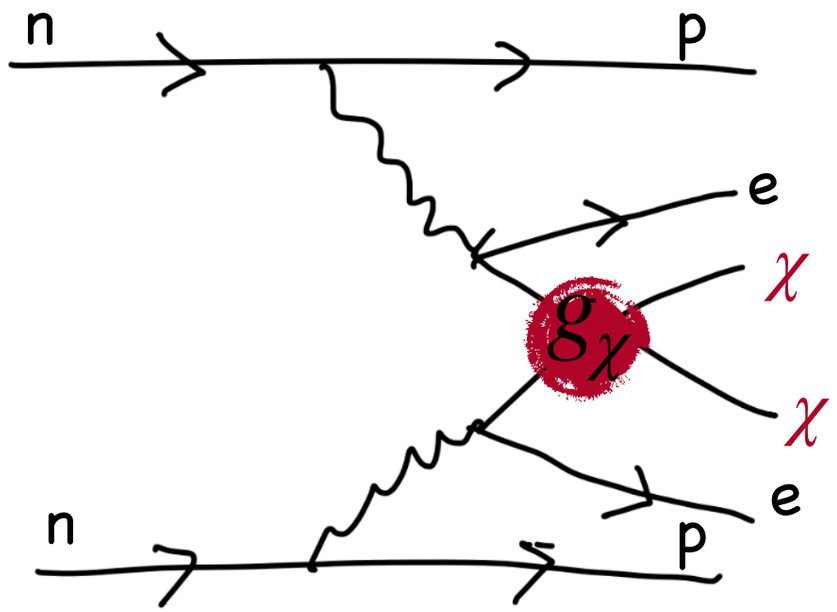

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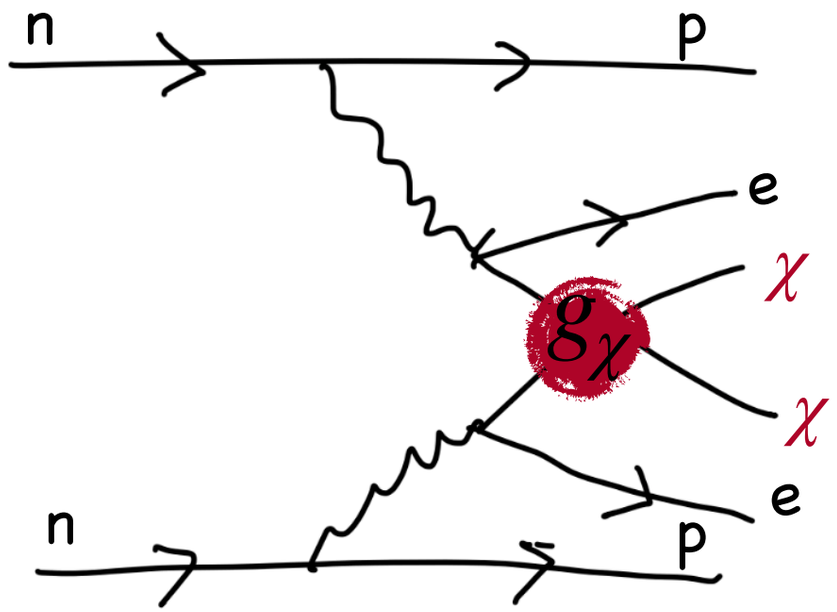
Additional uncertainty



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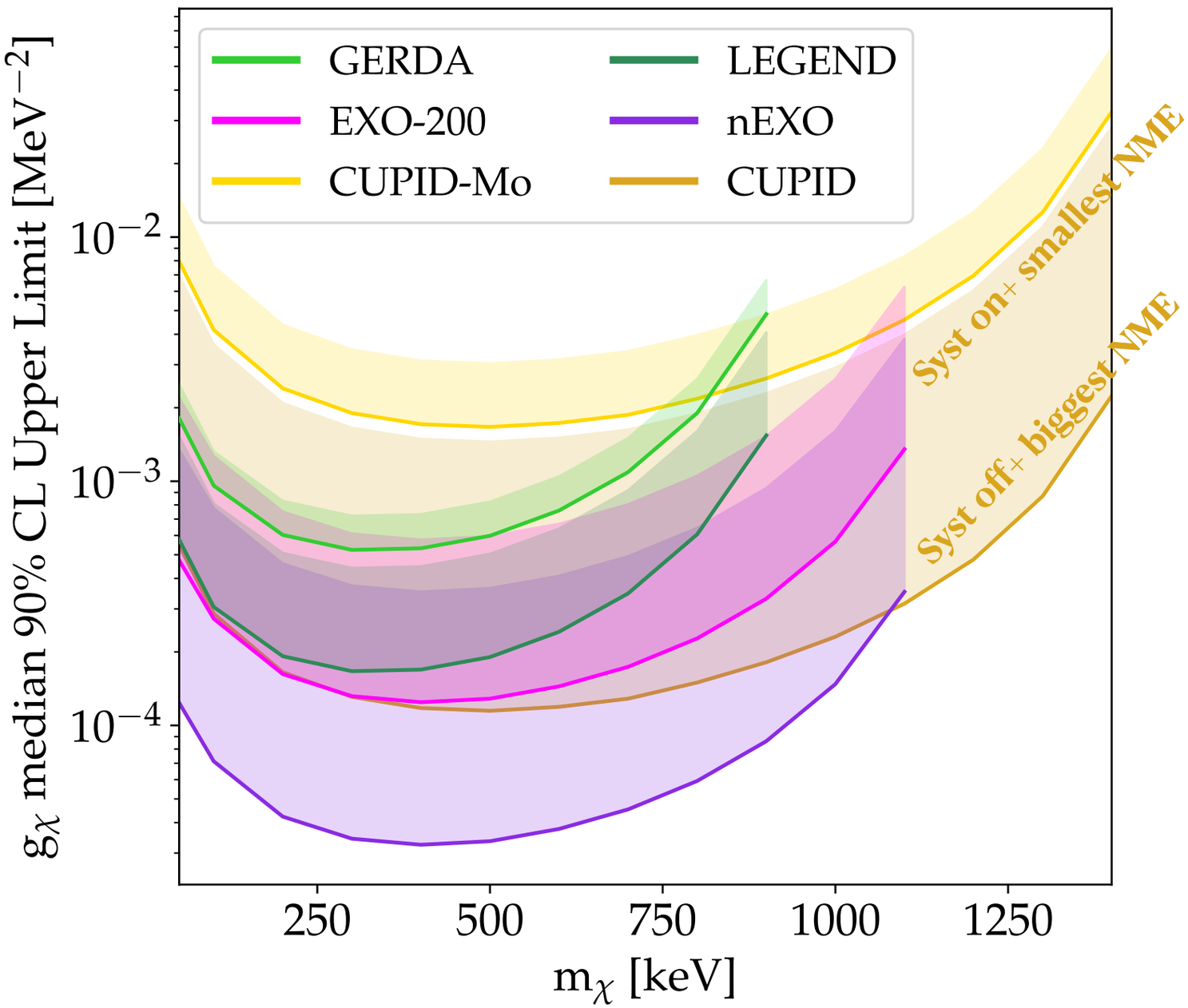

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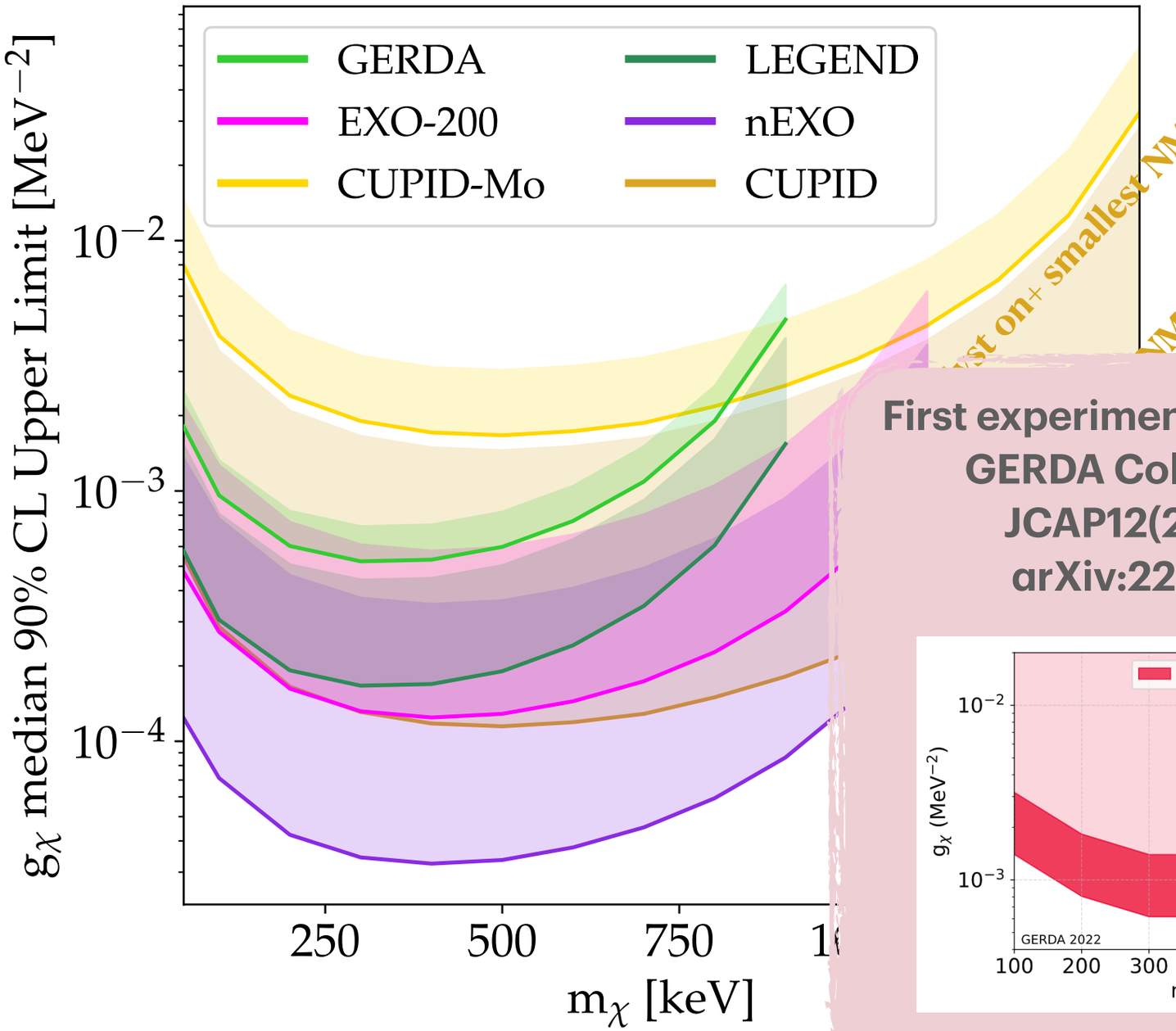

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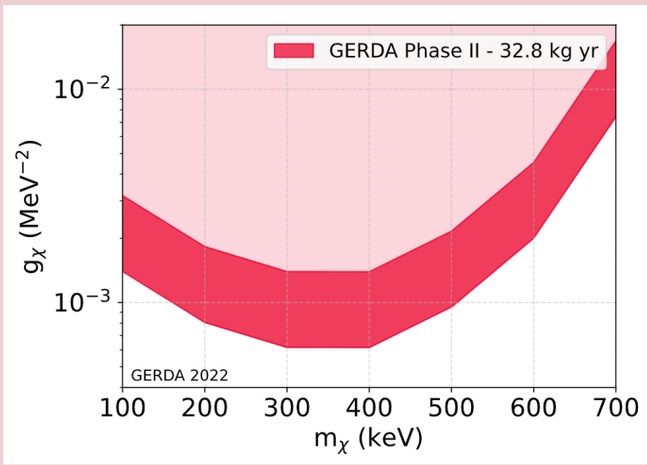

Conclusions

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