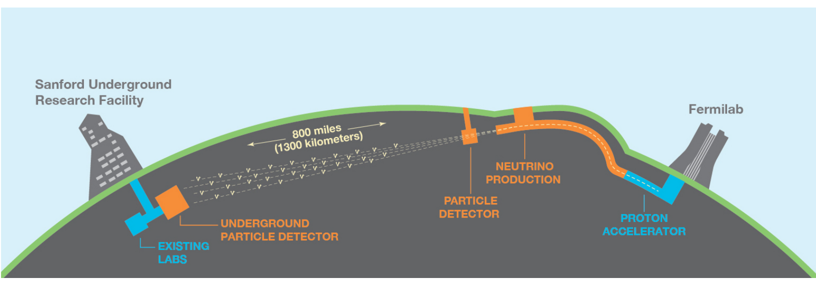

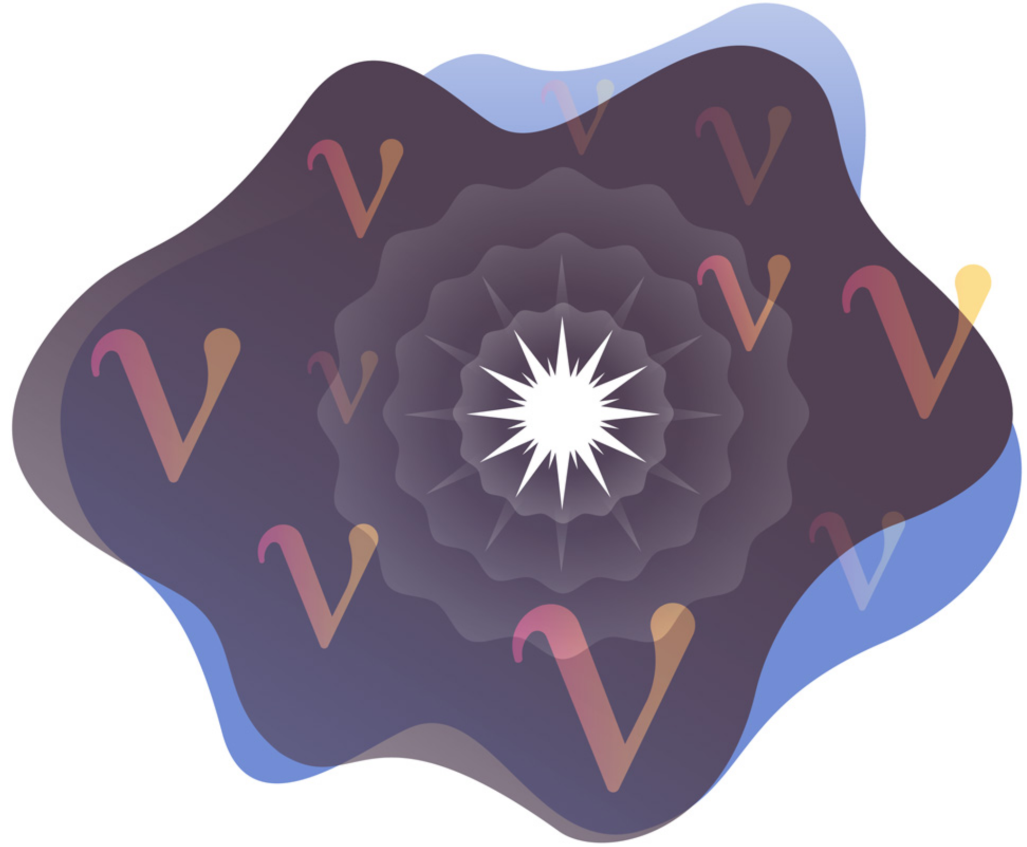

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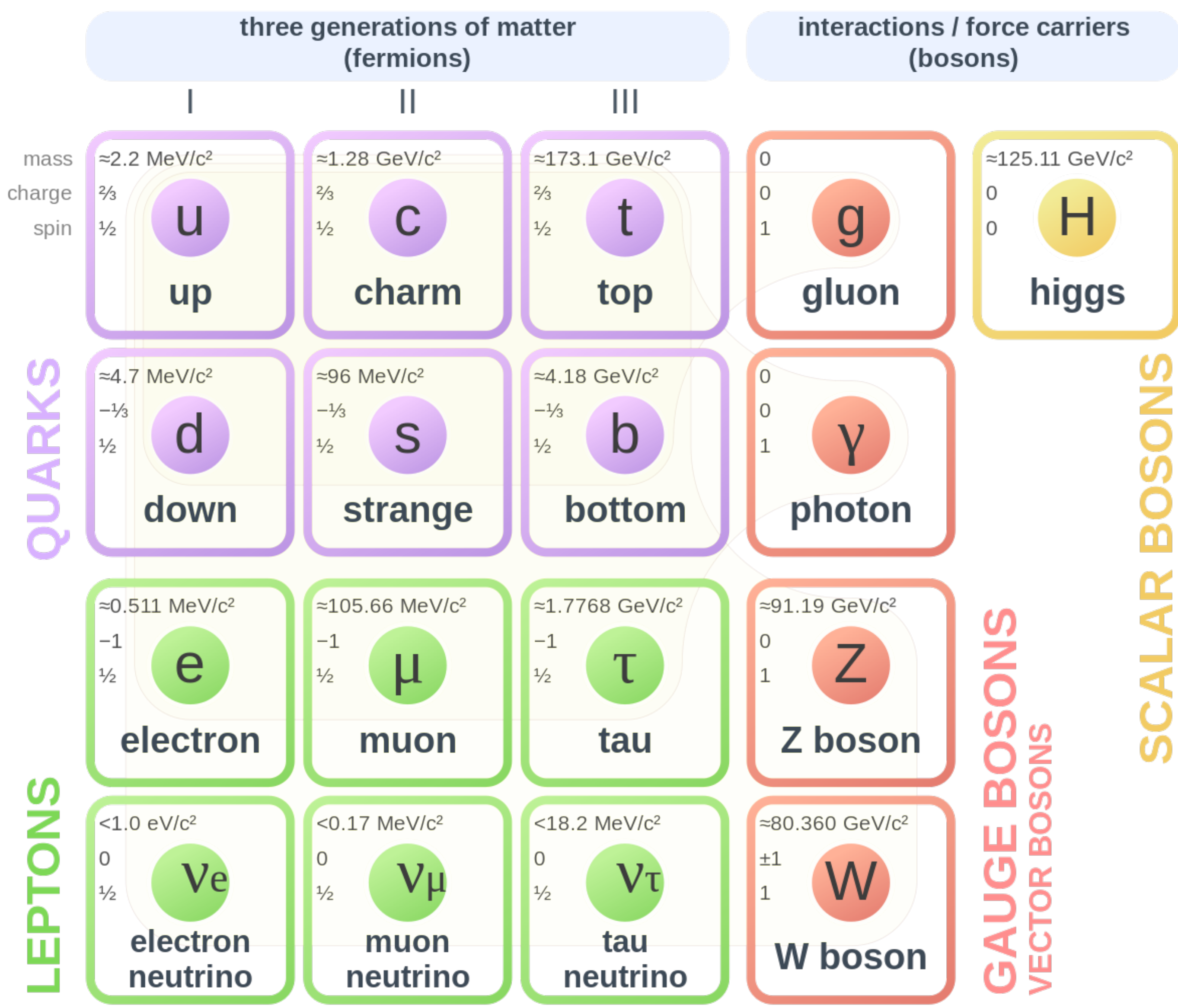
Ying-Ying Li（李英英）

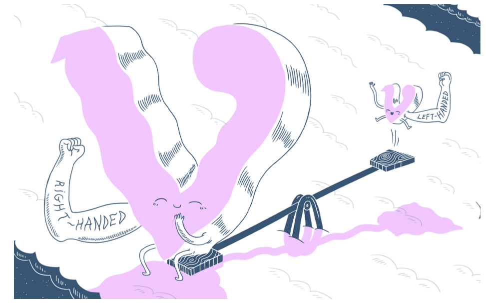
PRD 107(2023), 073005
PRL 134 (2025) , 221002
arXiv: 2406.07477, 2508.15609

New physics searches via the neutrino dipole portal

第二届中微子散射：理论、实验、唯象研讨会（*νSTEP2025*）

1897-2012:
electron, muon,
tau lepton, gluon,
W and Z boson,
top quark,
tau neutrino,
Higgs boson



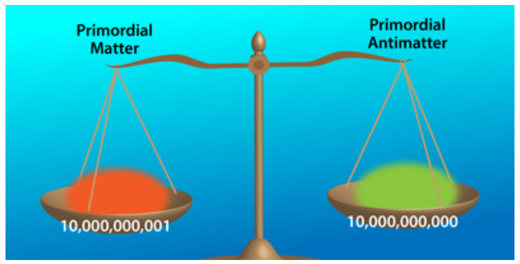


neutrino mass

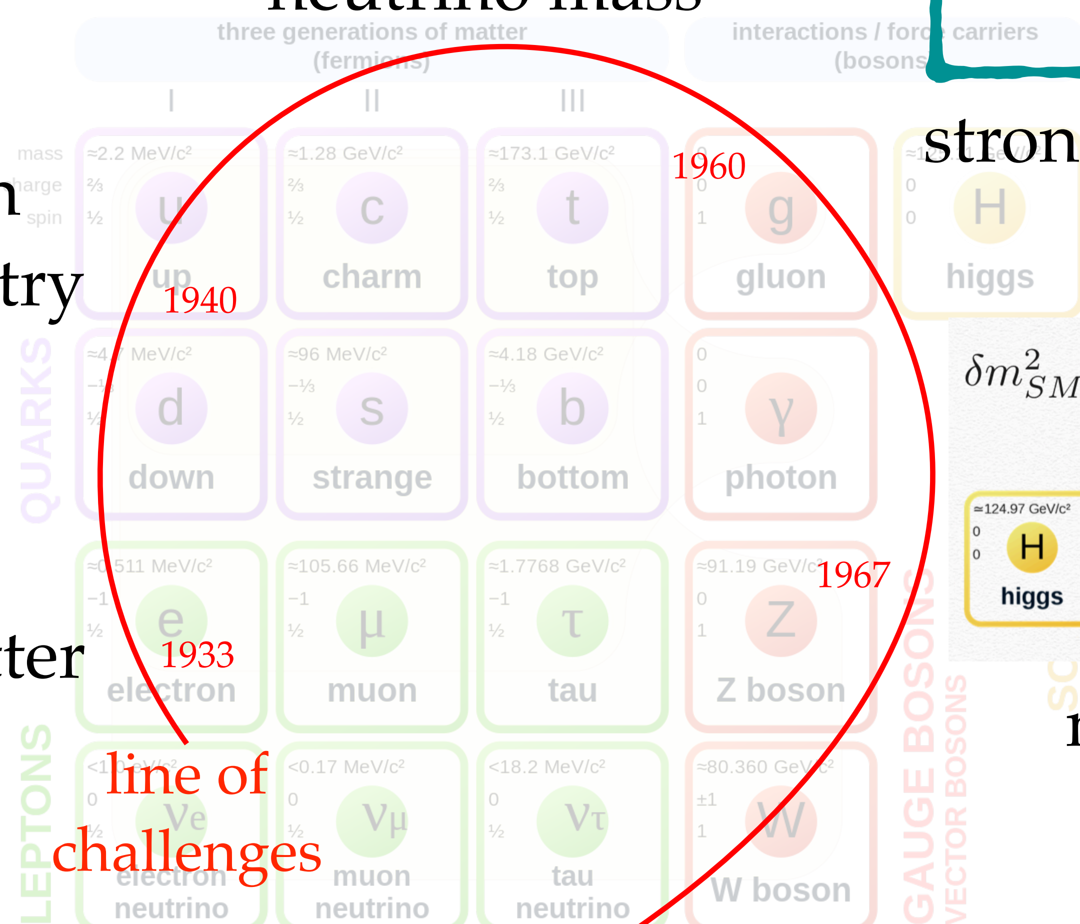
$$\mathscr{L} \supset -\frac{1}{4}G^2 + \frac{\theta g_s^2}{32\pi^2}G\tilde{G}$$

$$\bar{\theta} \lesssim 10^{-10}$$

strong CP problem

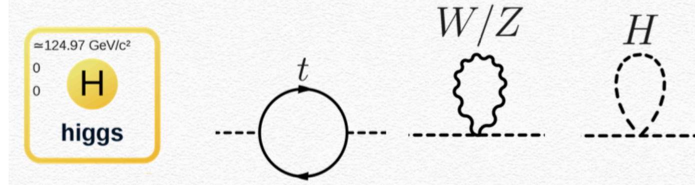


baryon asymmetry

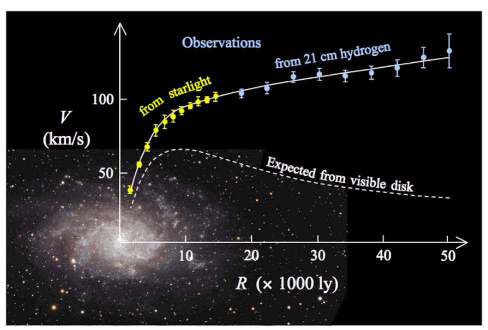


line of challenges

$$\delta m^2_{SM} \sim -\frac{3y_t^2\Lambda^2}{16\pi^2} + \frac{3g^2\Lambda^2}{16\pi^2} + \frac{3\lambda_{SM}\Lambda^2}{16\pi^2}$$

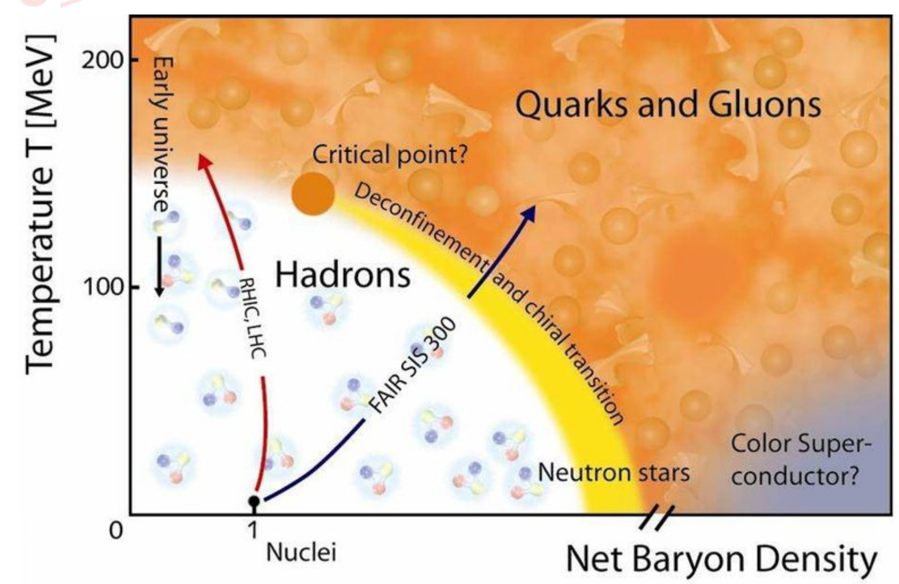


naturalness



dark matter

QCD phase diagram



now

new physics?

computational efforts?

Neutrino Mixing Portal

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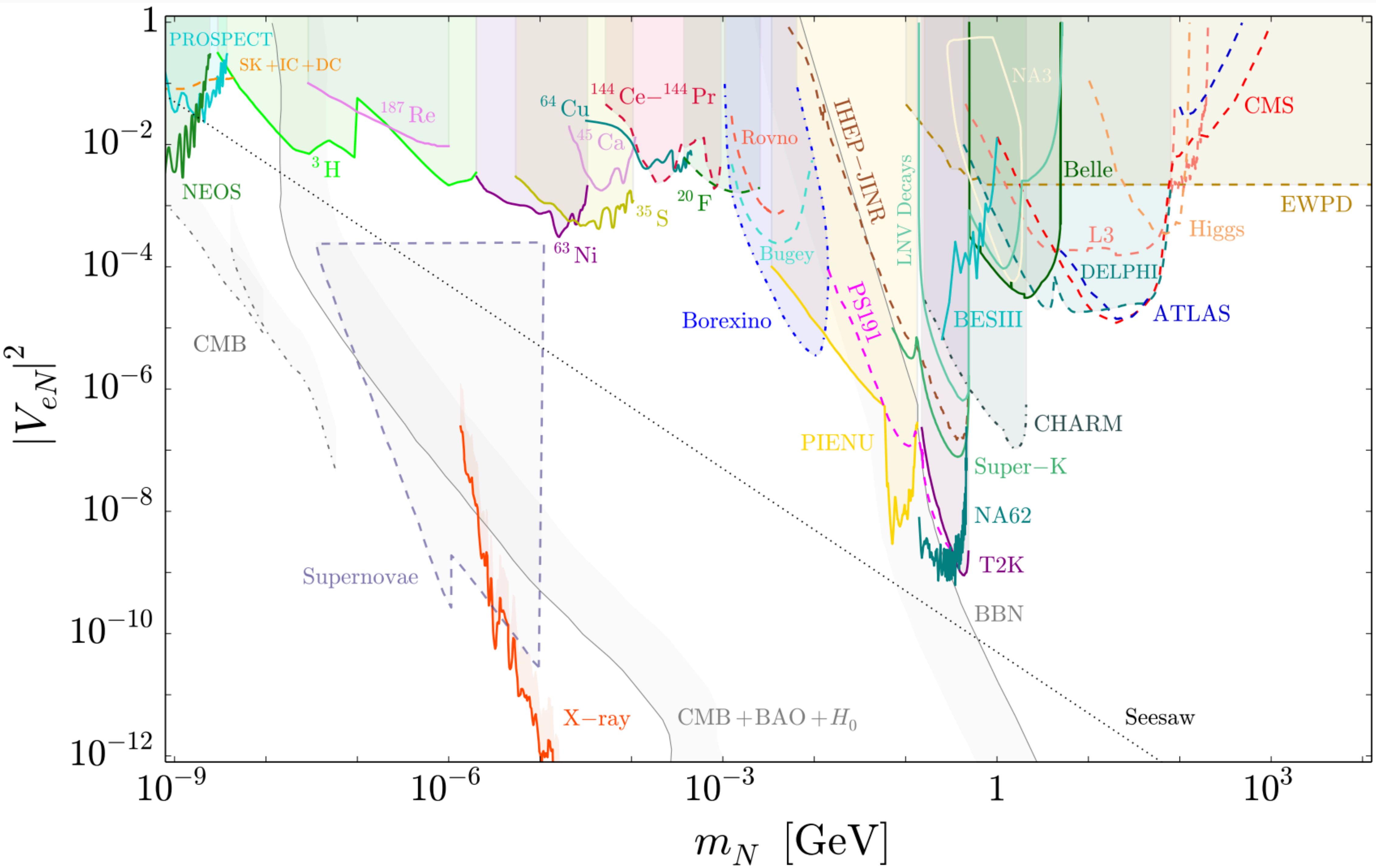
$$\Gamma_{\nu_s \to \nu_a \gamma} = 1.38 \cdot 10^{-29}\ \mathrm{sec}^{-1} \left(\frac{\sin^2 2\theta}{10^{-7}}\right)\left(\frac{m_s}{1\ \mathrm{keV}}\right)^5 .$$

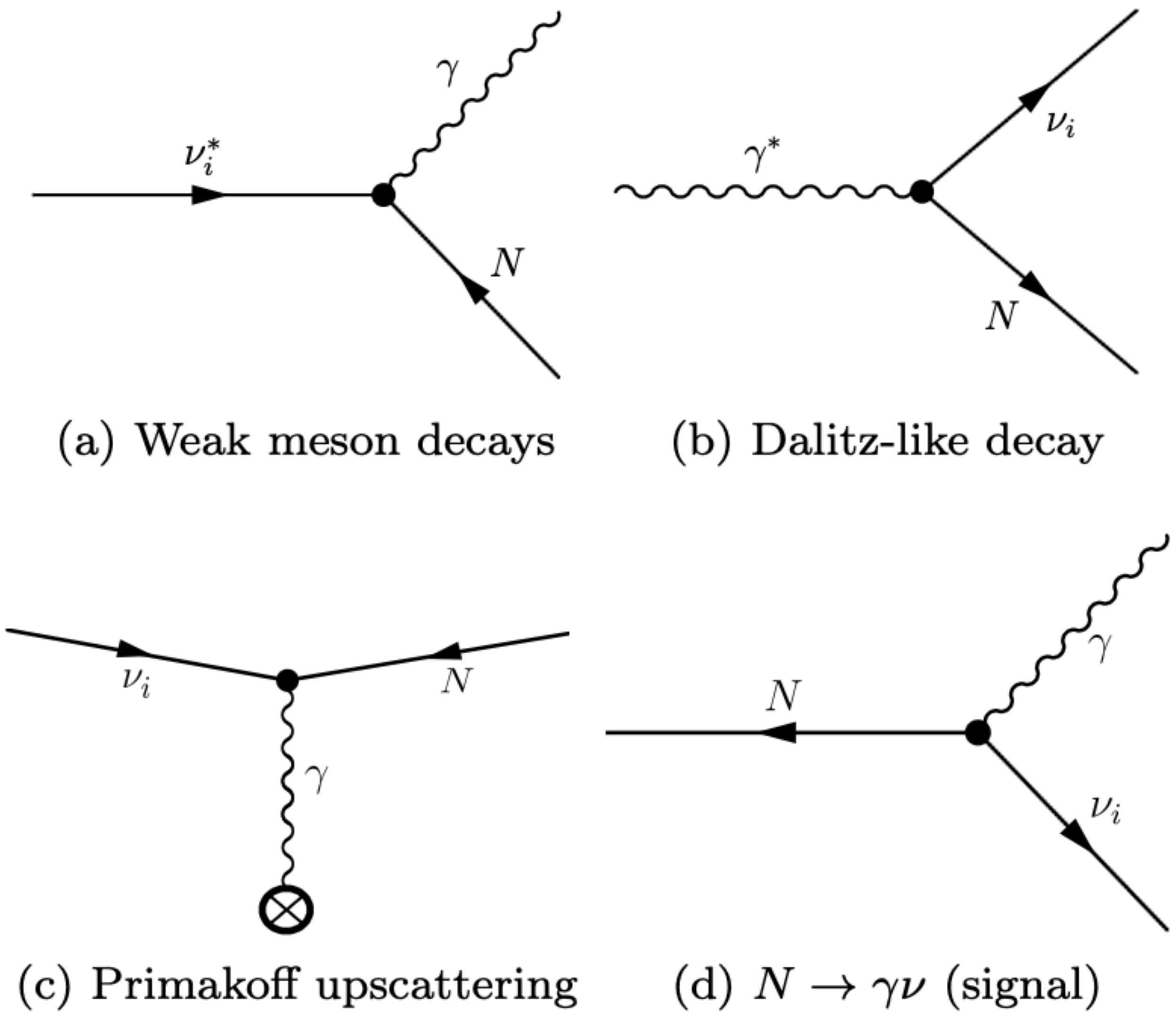


[P. D. Bolton, F. F. Deppisch, P. S. B. Dev, arXiv: 1912.03058]

Neutrino Dipole Portal

$$\mathcal{L} \supset \frac{1}{2}\mu_\nu \bar{\nu}_L^\alpha \sigma^{\mu\nu} N F_{\mu\nu}$$

$$\pi^\pm, K^\pm \to \mu^\pm \left(\overset{(-)}{\nu}_\mu{}^* \to \gamma \overset{(-)}{N}\right) \quad \pi^0, \eta \to \gamma(\gamma^* \to \nu_a N)$$



$$\mathrm{Br}(M \to N) \propto \mu_\nu^2 m_M^2$$

$$\Gamma_N = \frac{6}{4\pi}\mu_\nu^2 M_N^3$$

(flavor universal)

Current Probes: terrestrial experiments

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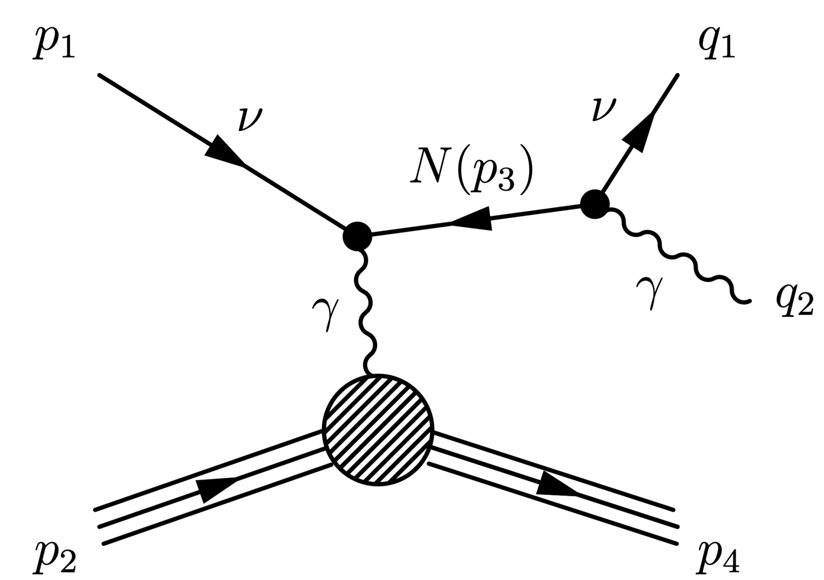
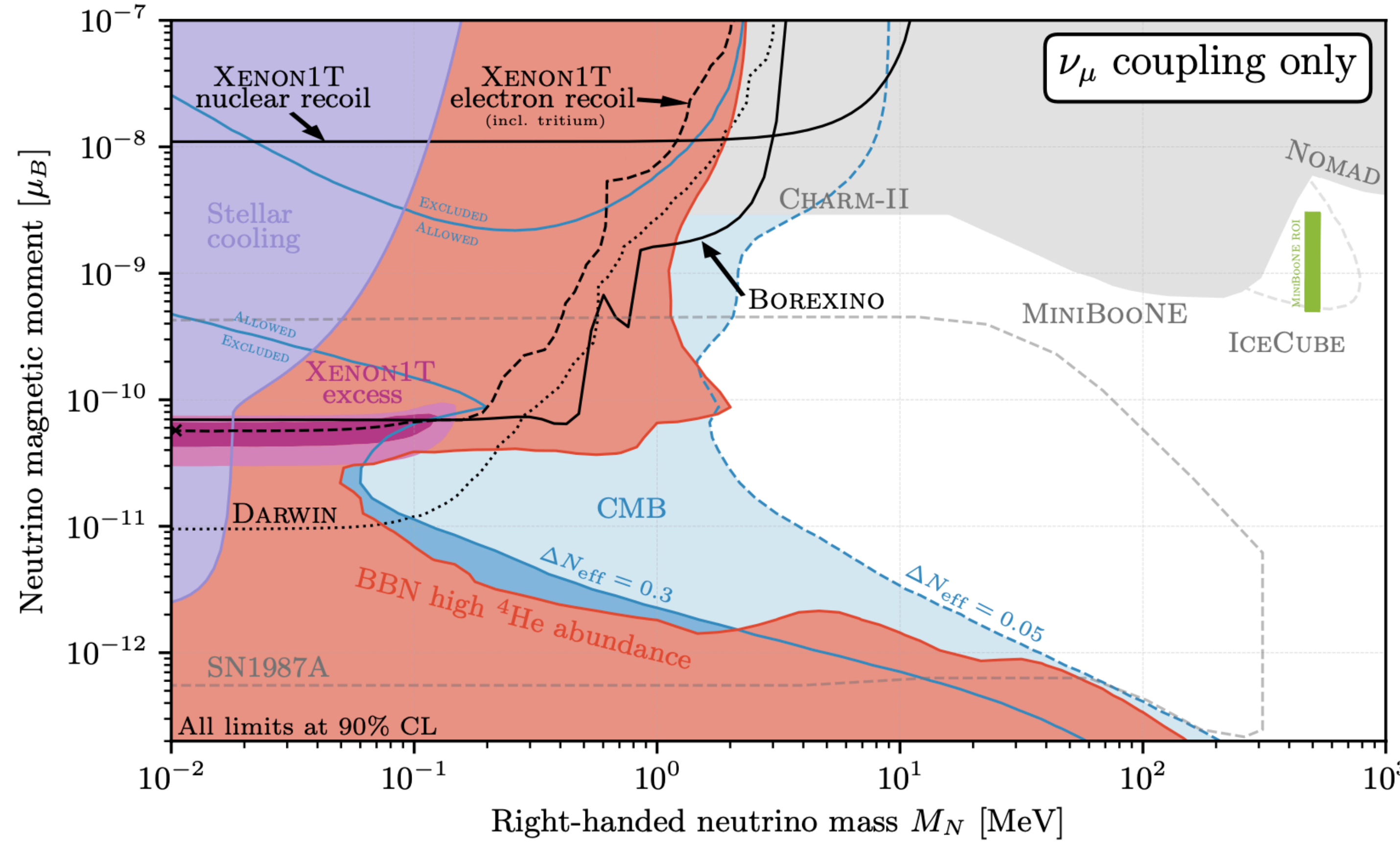
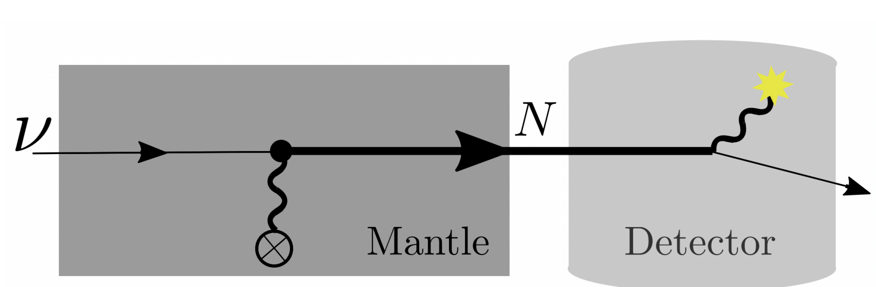
- Beam dump experiments
  MiniBoone, NONAD, CHARM



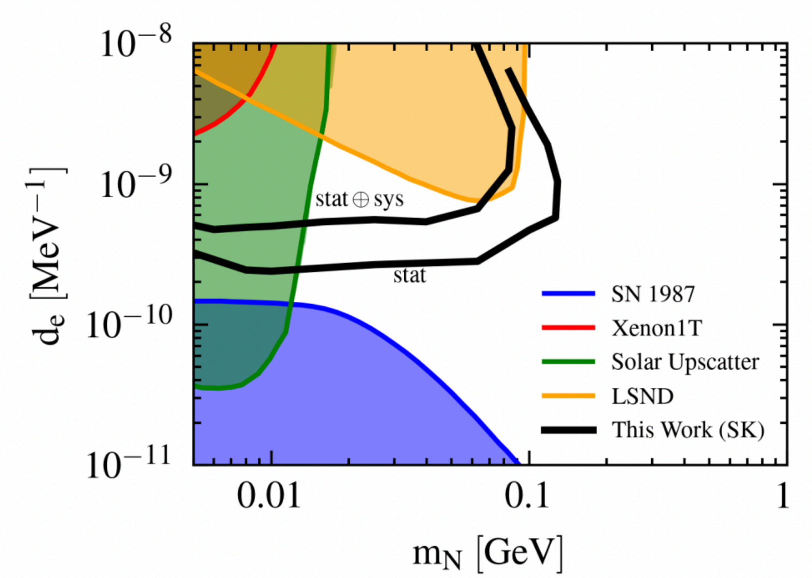
[Brdar, Greljo, Kopp, Opferkuch, arXiv:2007.15563]



- Solar/atomspheric neutrino up-scattering and decays
  Borexino, SuperK/DUNE, Super-K



[R. A., Gustafson, arXiv:2205.02234]



Current Probes: terrestrial experiments

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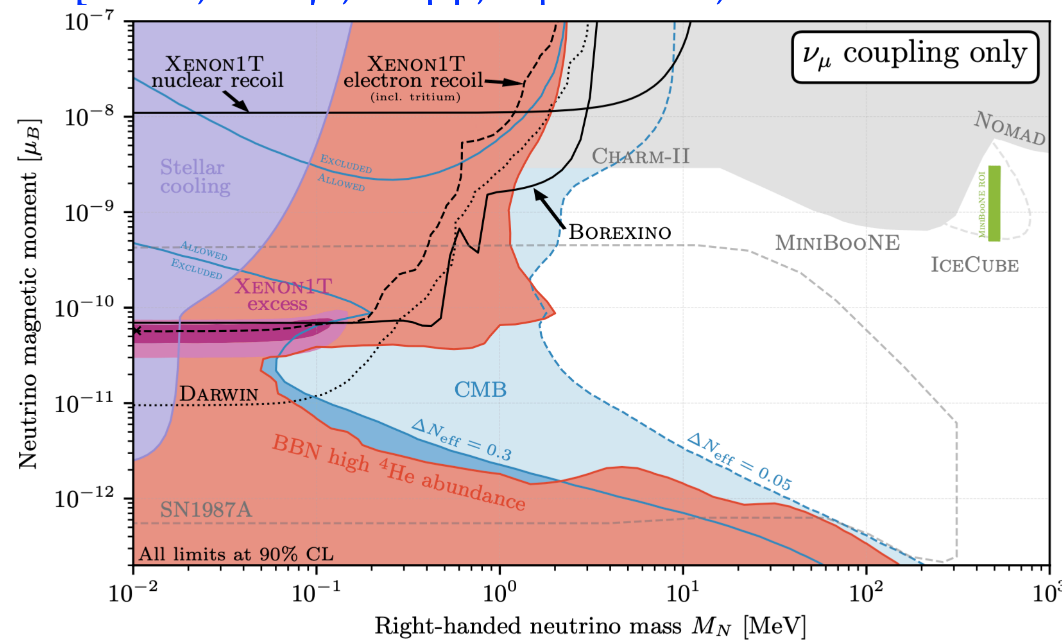
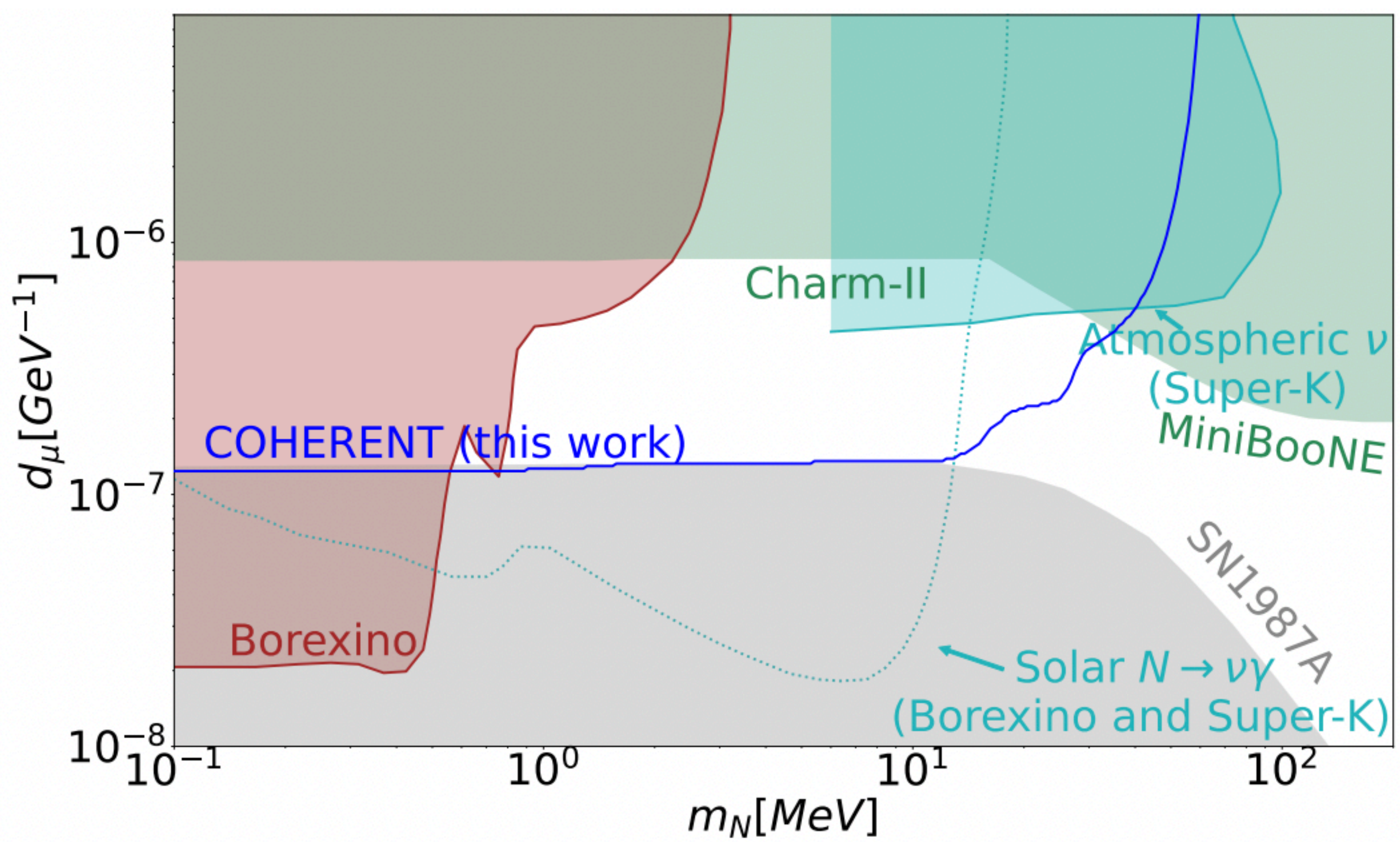
- Neutrino spectrum distortion
  Solar neutrino: *Xenon1T, Borexino*

[Brdar, Greljo, Kopp, Opferkuch, arXiv:2007.15563]



- *Neutrino spectrum distortion and timing*



Flavor specific

$$\mathcal{L} \supset \frac{1}{2}\mu_\nu \bar{\nu}_L^\alpha \sigma^{\mu\nu} N F_{\mu\nu}$$

[**YYL**, Yu-Feng Li, Shuo-Yu Xia, arXiv:2406.07477]

Multimessenger Signals – Supernova

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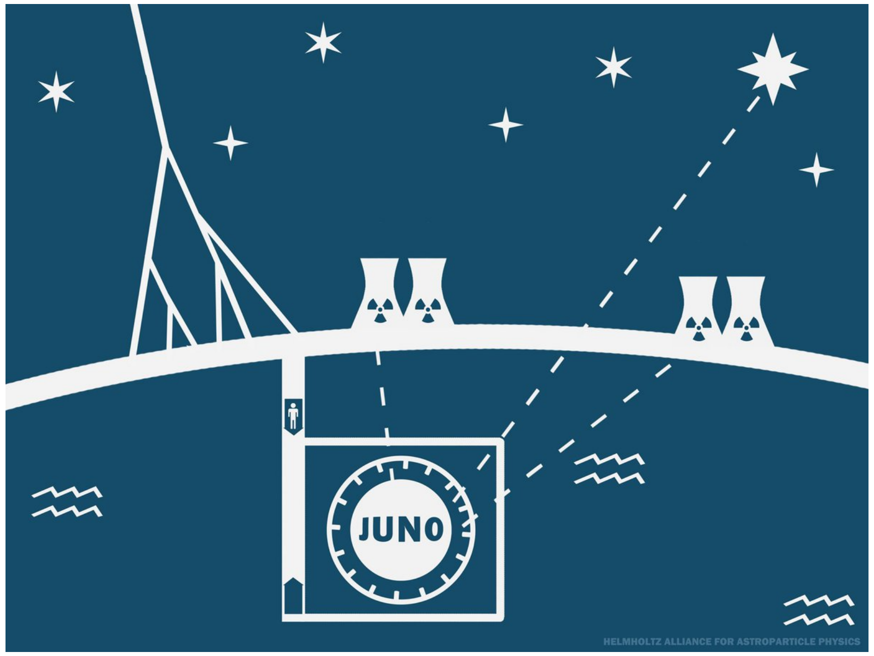
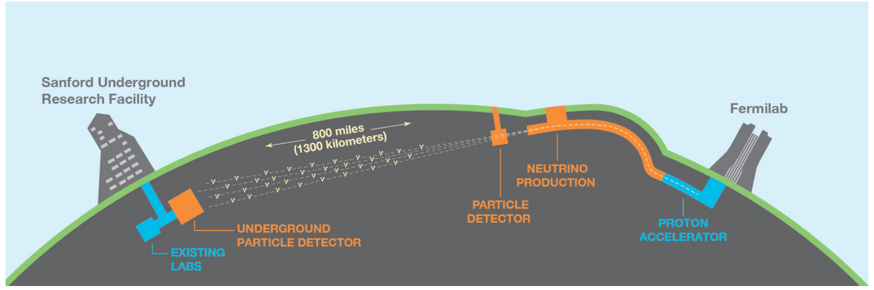
$$\nu + e^{\pm} \to N + e^{\pm}$$
$$\nu + p \to N + p$$
$$e^{+} + e^{-} \to \bar{\nu} + N$$
$$\gamma + \nu \to N$$

$$\mathcal{L} \supset \frac{1}{2}\mu_\nu \bar{\nu}_L^\alpha \sigma^{\mu\nu} N F_{\mu\nu}$$

$$N \to \nu + \gamma$$





Multimessenger Signals : γ – ray detection

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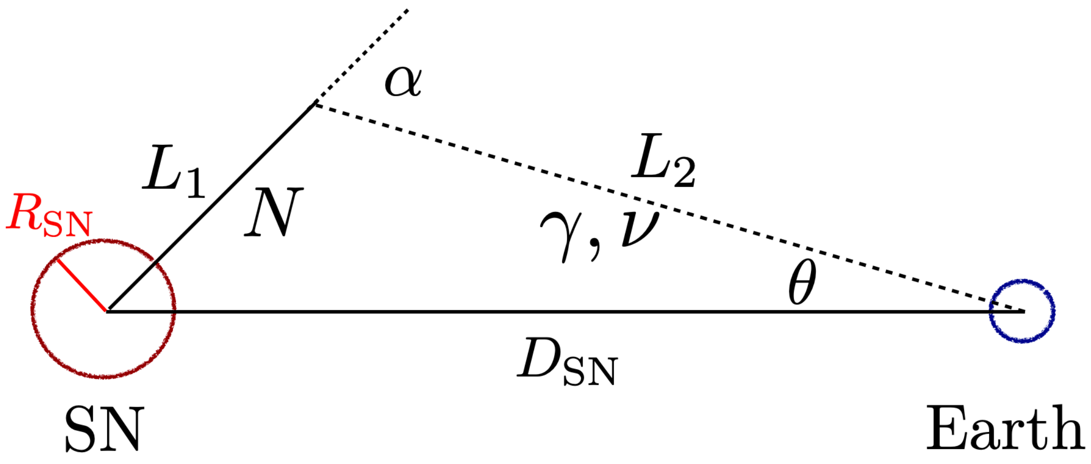
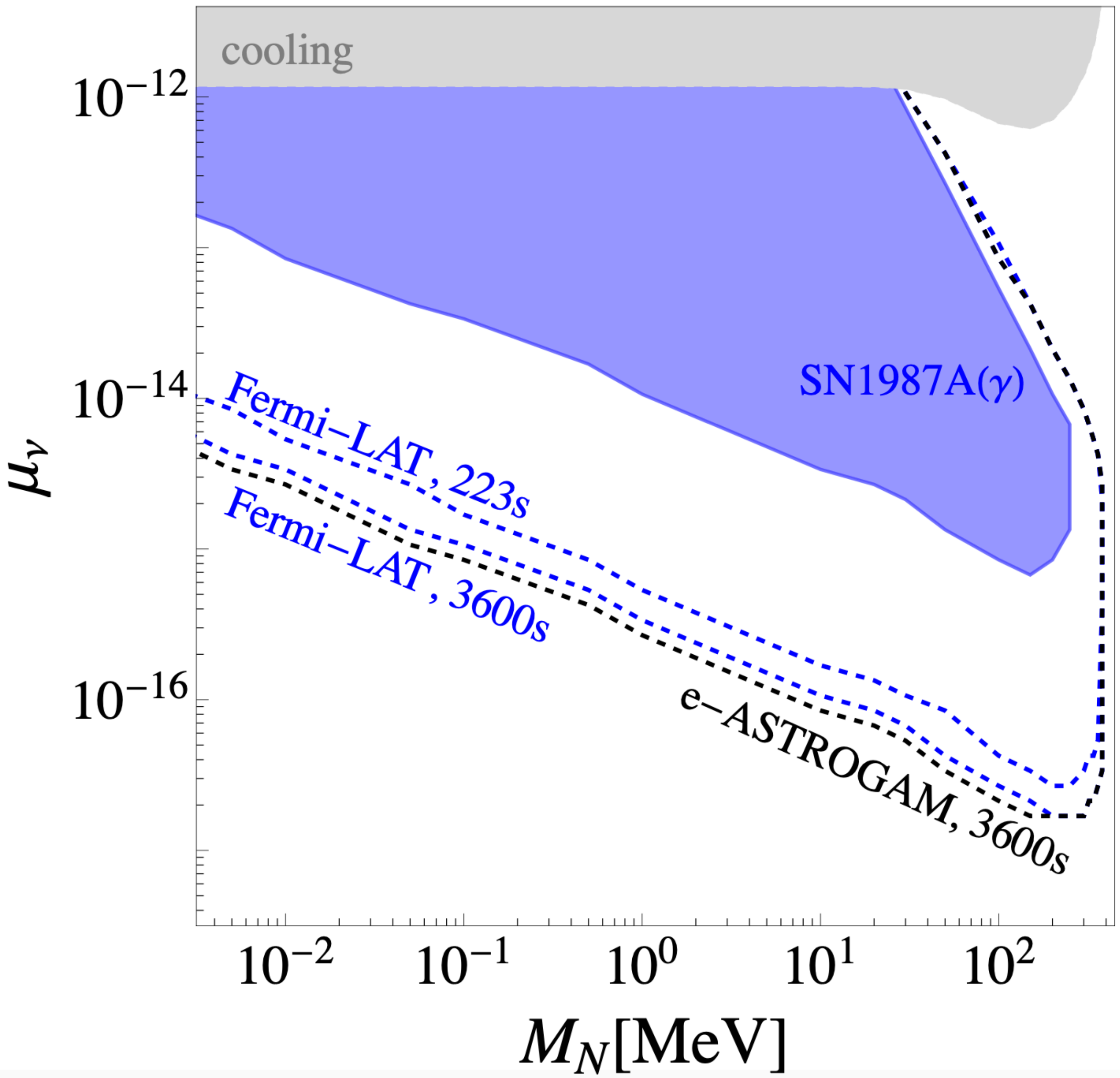


- At the time of SN1987A, the Gamma-Ray Spectrometer (GRS) observed Nobs = 1393 photons with energy 25-100 MeV at $\Delta t < 223s$

- Assuming a SN event happens in the galaxy at a distance of D_SN = 10kpc,
  Fermi-LAT: $E_\gamma > 100\text{MeV}, \theta < 5^\circ$
  e-ASTROGAM: $E_\gamma > 1\text{MeV}, \theta < 1.25^\circ$



[V. Brdar, A. D. Gouv^ea, YYL, P. A. N. Machado, PRD 107 (2023) , 073005]

Multimessenger Signals : neutrino detection

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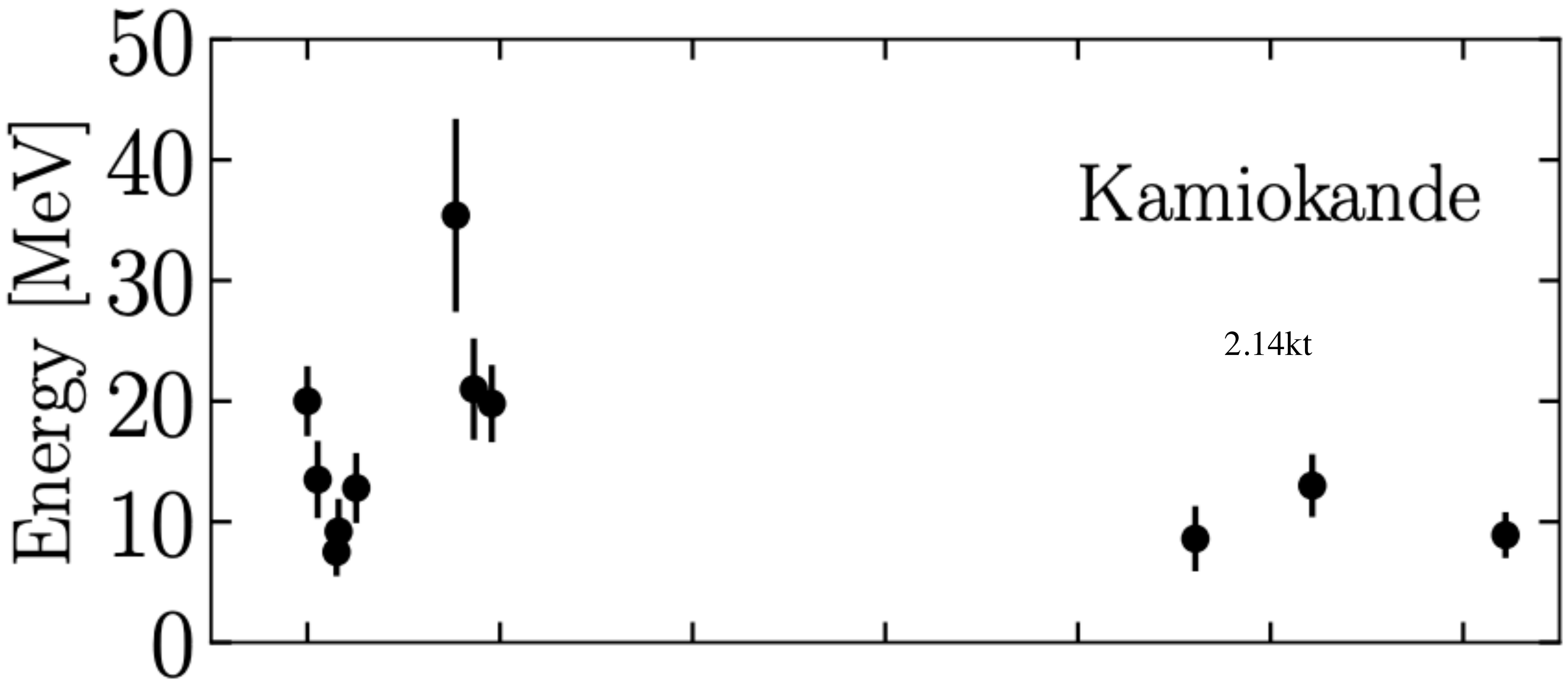
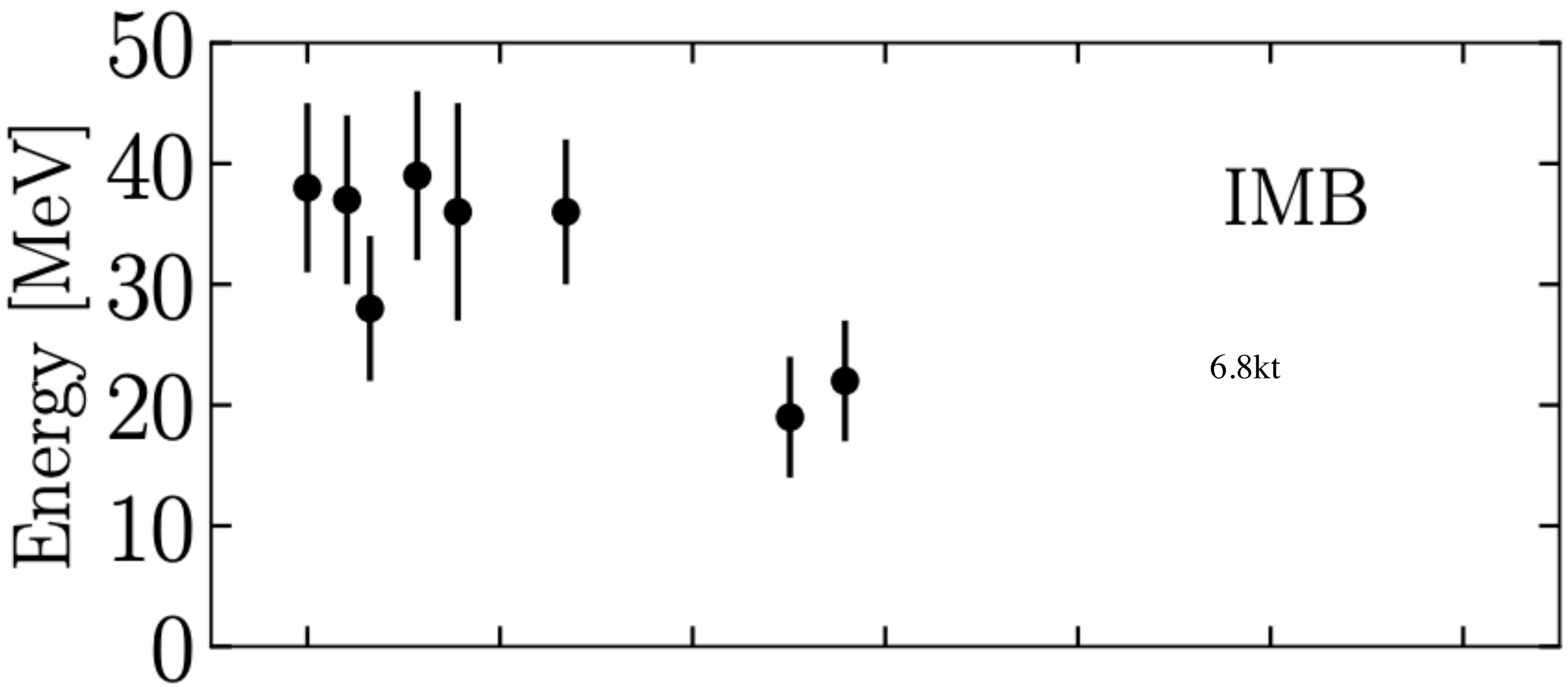


SN1987A, neutrino events

water-Cherenkov detectors



- No significant excess was observed by Kamiokande-II and IMB for

$E_\nu > 50\text{MeV}, \Delta t < 2$ days

Multimessenger Signals : neutrino detection

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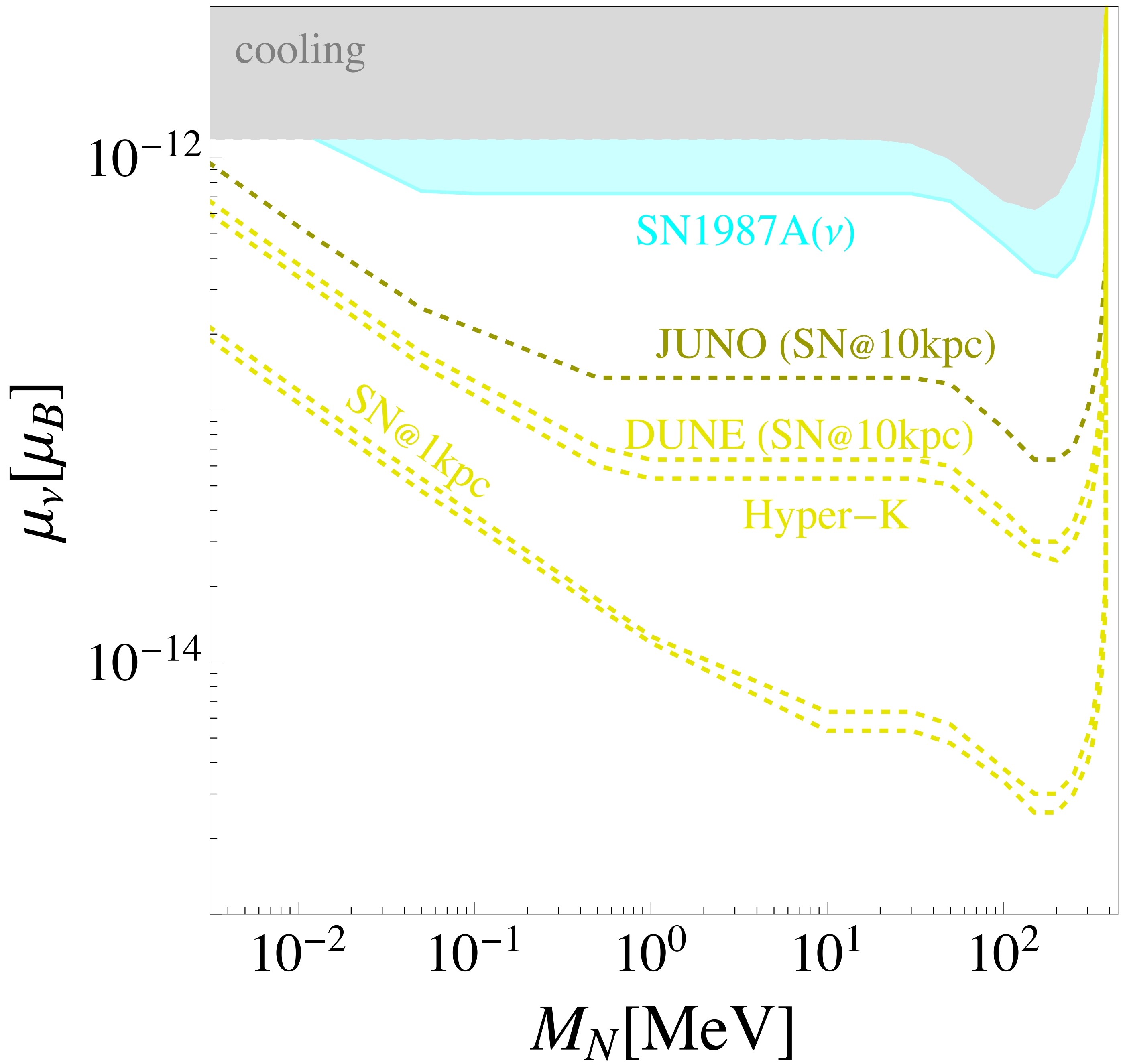
- Assuming a SN event happens in the galaxy at a distance of D_SN = 10kpc,
  JUNO: 20kt fiducial volume, liquid scintillator detector
  DUNE: 40kt, liquid argon
  Hyper-K: 188kt fiducial volume water Cherenkov

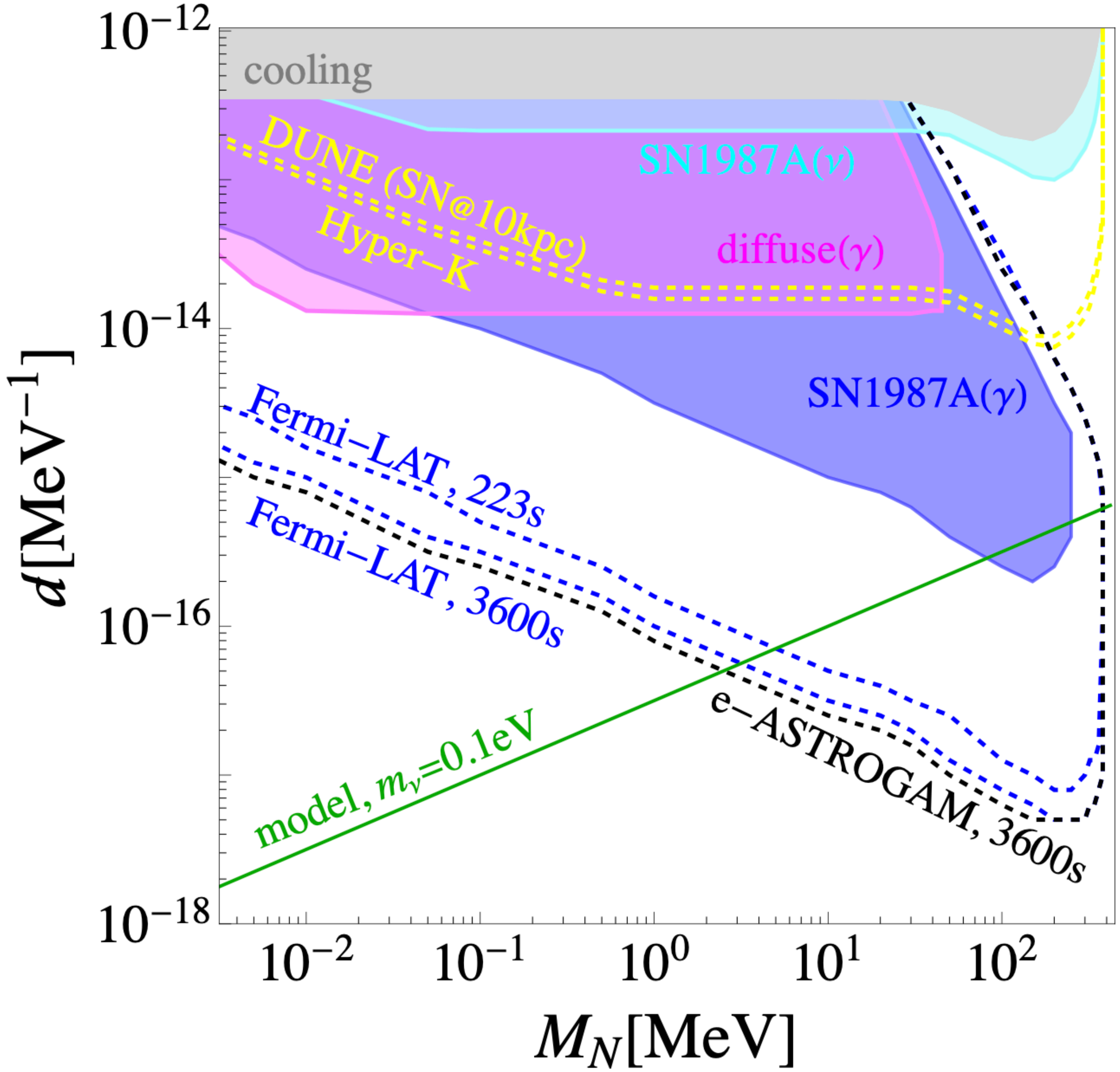


[V. Brdar, A. D. Gouv^ea, YYL, P. A. N. Machado, PRD 107 (2023) , 073005]

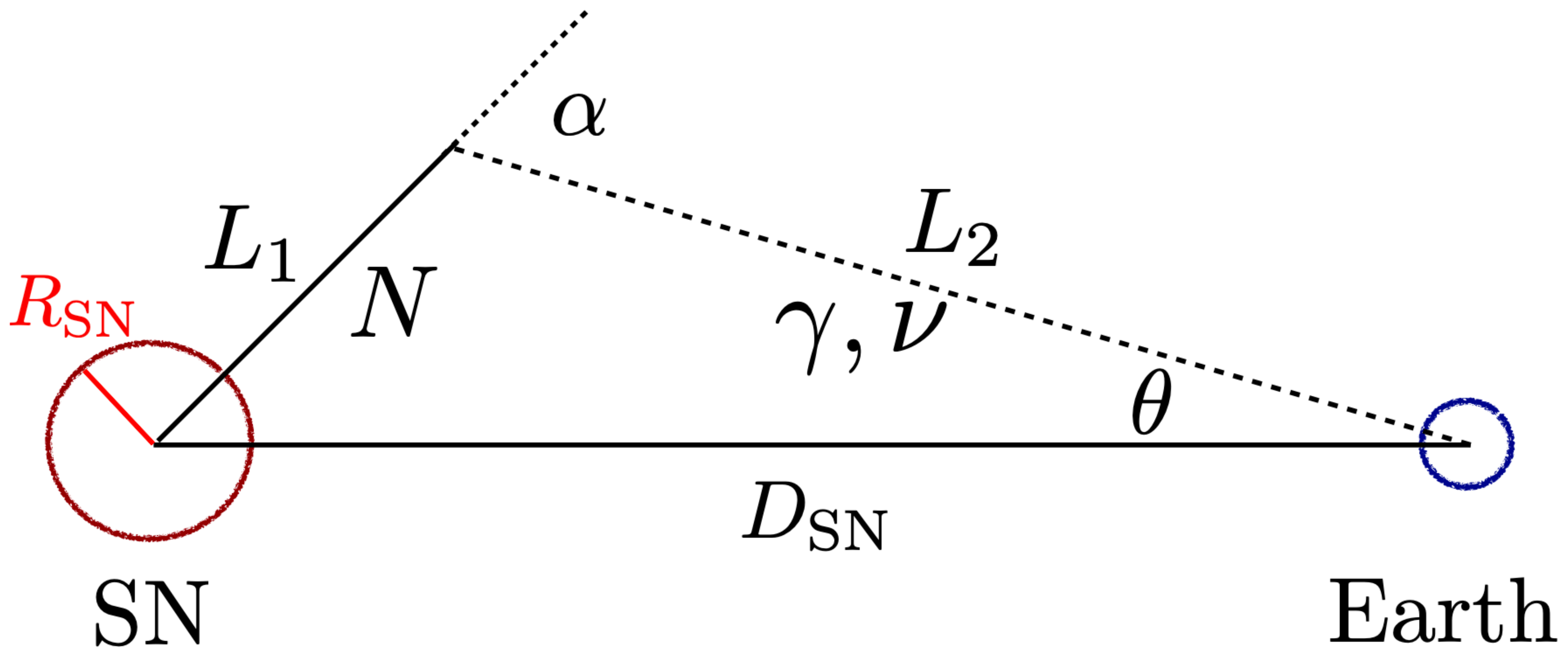
Multimessenger Signals

diffused BSM Photon and neutrino background

$$\mathcal{L} \supset \frac{1}{2}\mu_\nu \bar{\nu}_L^\alpha \sigma^{\mu\nu} N F_{\mu\nu}$$



[V. Brdar, A. D. Gouv^ea, YYL, P. A. N. Machado, PRD 107 (2023) , 073005]

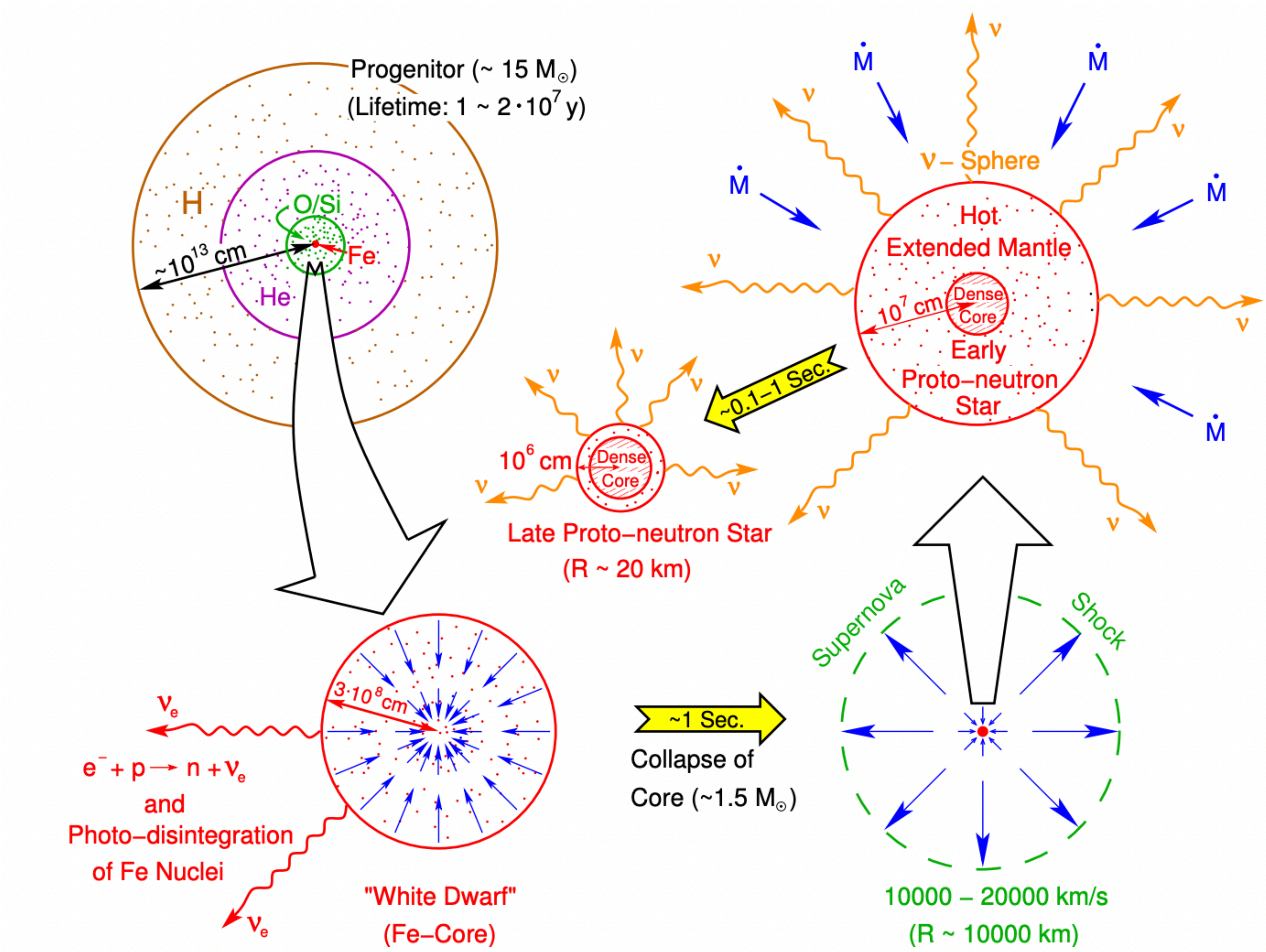


$$\delta t = \left(\frac{L_1}{\beta} - L_1\right) + (L_1 + L_2 - D_{\rm SN})$$

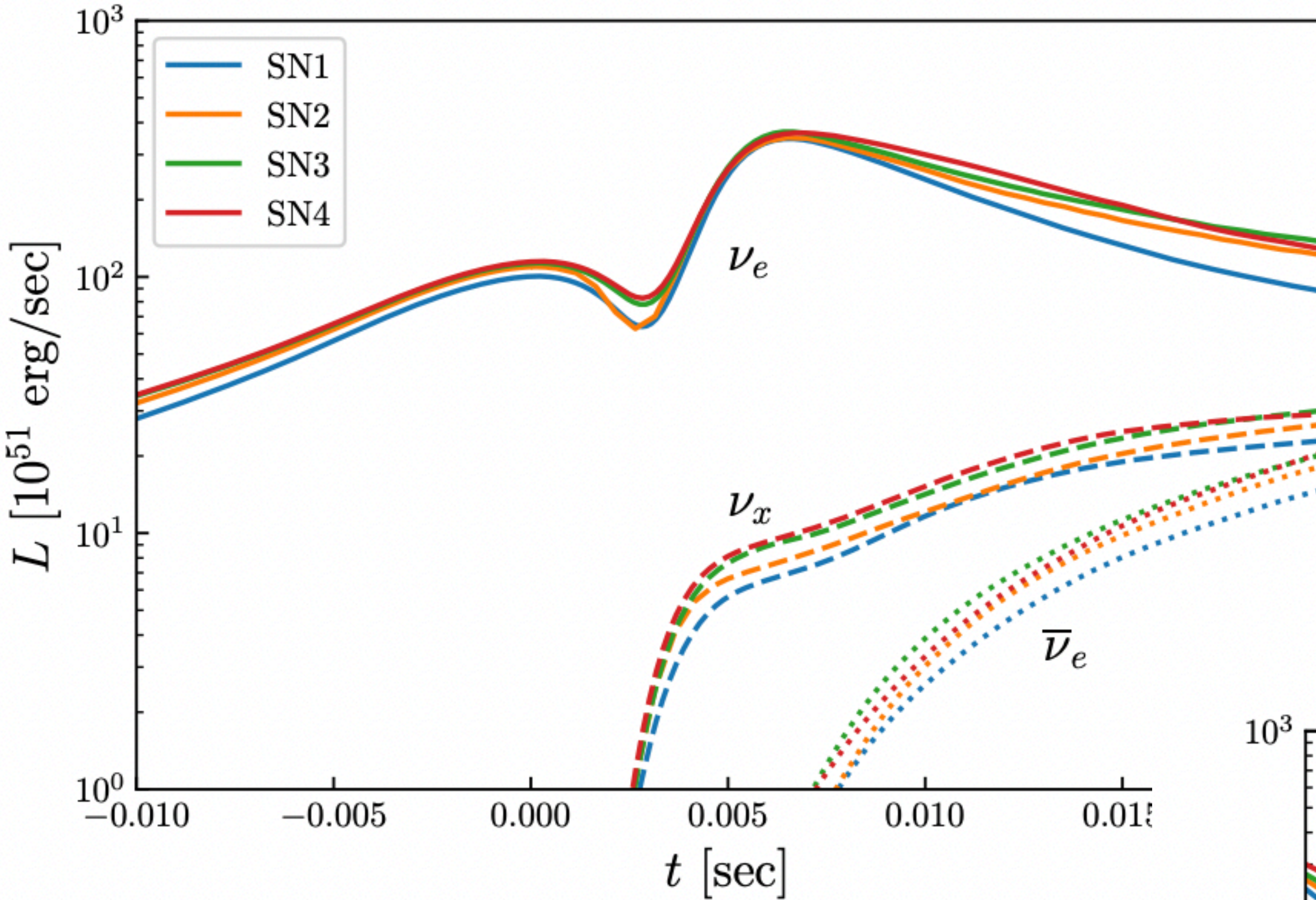
Timing of neutrinos at production?

[C. A. Argüelles, V. Brdar, J. Lazar, **YYL**, PRL 134 (2025) , 221002]

Evolution of a massive star from the onset of iron-core collapse to a neutron star



[Hans-Thomas Janka, arXiv:1702.08713]

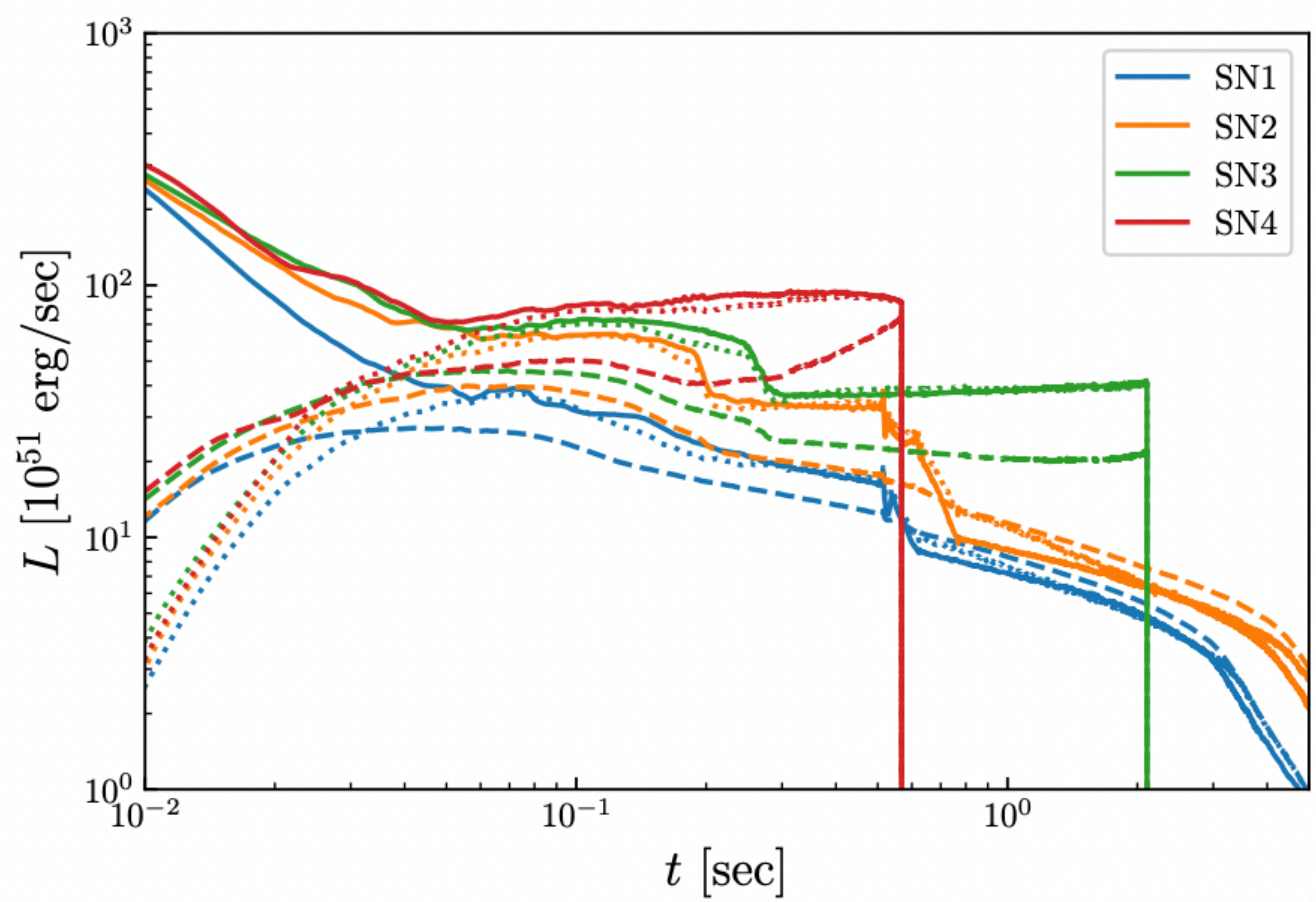


Neutrinos from SN bursts

[V. Brdar, X.-J. Xu, arXiv:2204.13135]

$$\nu e^- \to N e^-$$

$$N \to \nu(\bar{\nu})\gamma$$



$$\mathcal{L} \supset -g_{\alpha\beta}\nu_\alpha\nu_\beta\phi + \text{h.c.} - m_\phi \phi\phi^*$$

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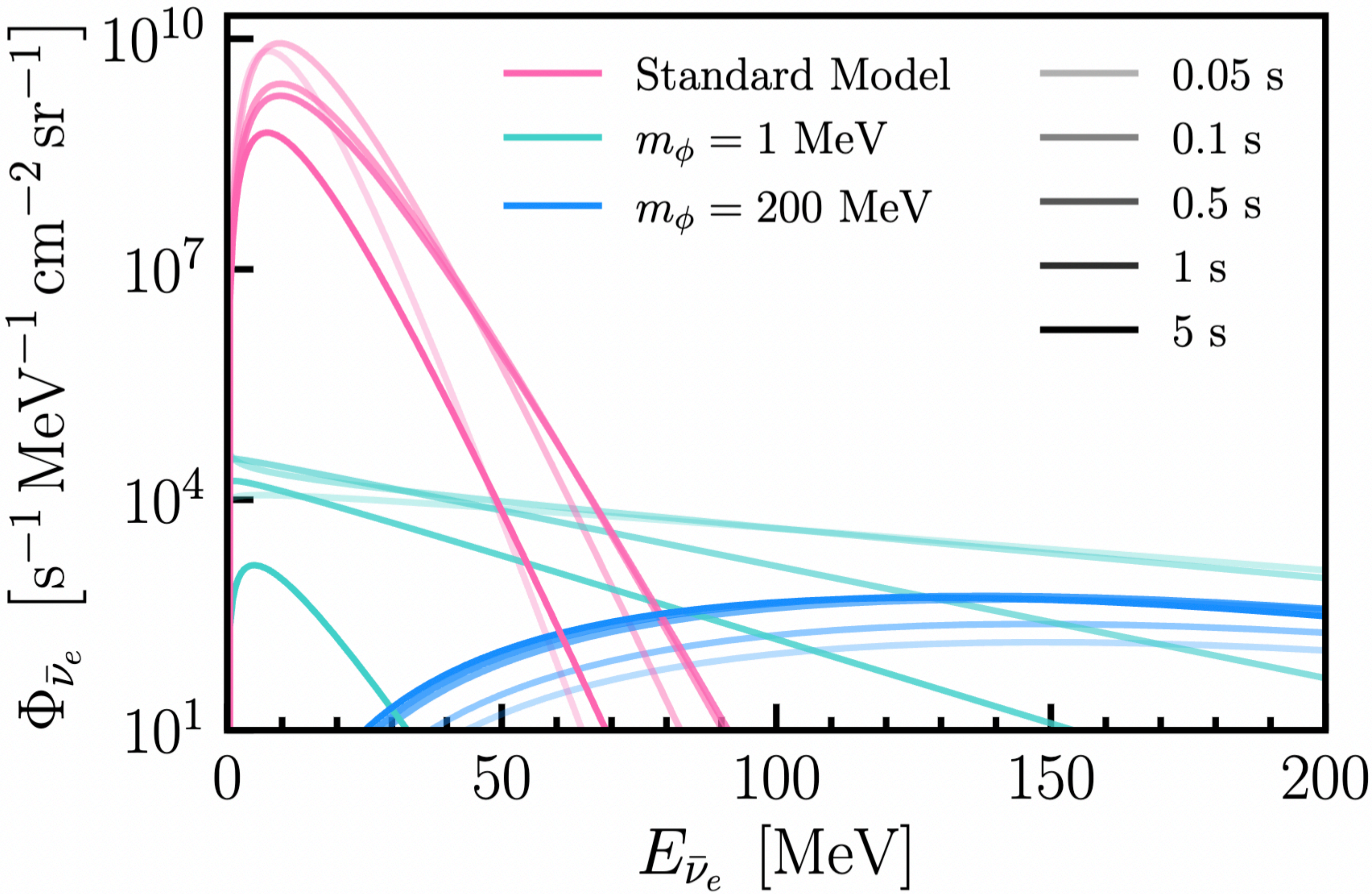
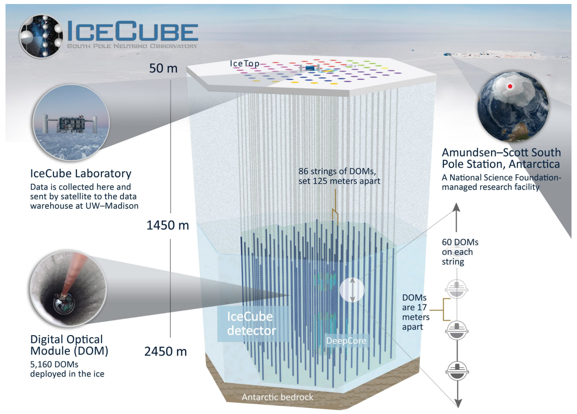


[C. A. Argüelles, V. Brdar, J. Lazar, **YYL**, PRL 134 (2025) , 221002]



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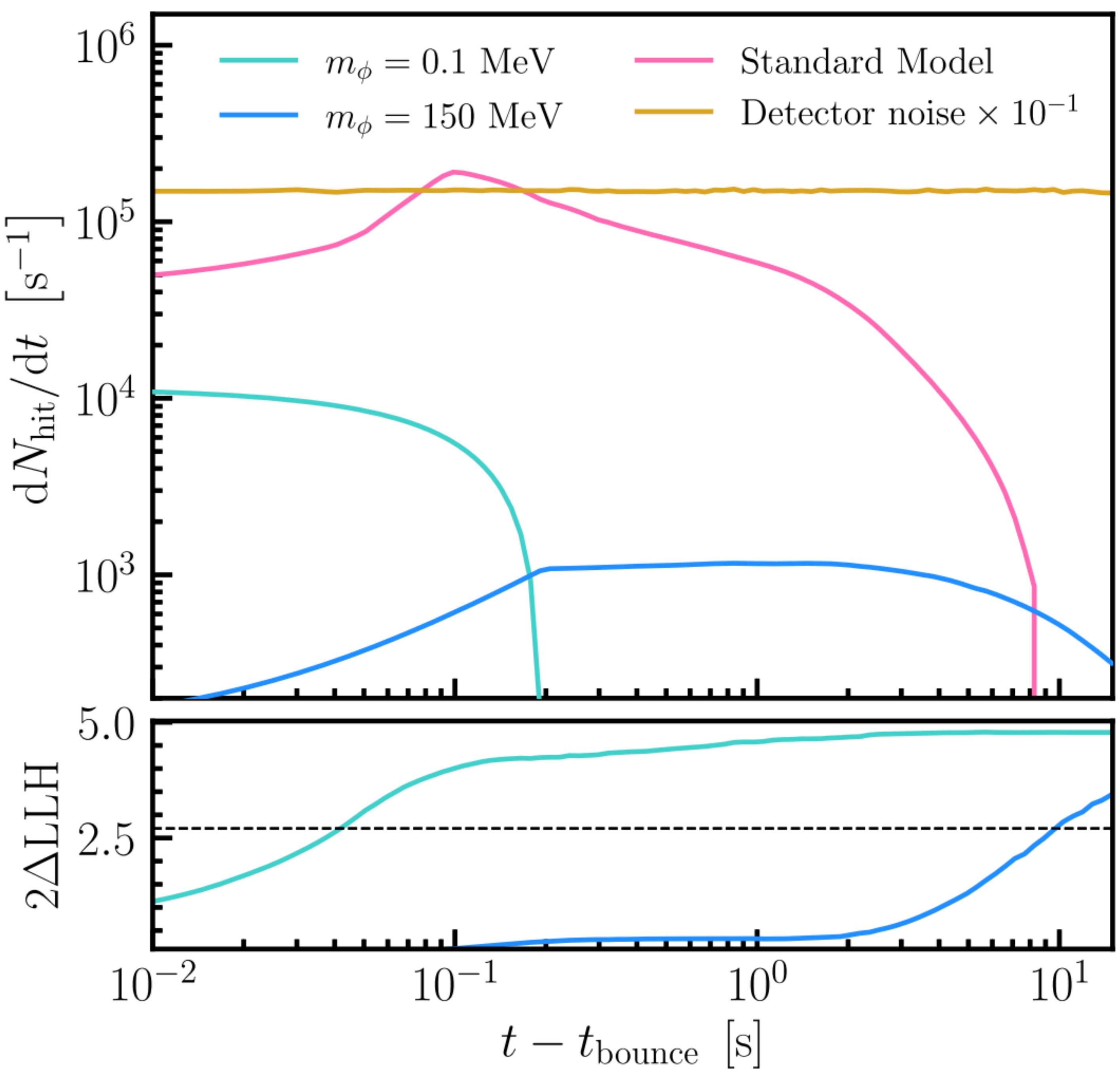
High energy (TeV): muon neutrino

Low energy (MeV): $\bar{\nu}_e + p \rightarrow e^+ + n$



[C. A. Argüelles, V. Brdar, J. Lazar, **YYL**, PRL 134 (2025) , 221002]

$$\mathcal{L} \supset \frac{1}{2}\mu_\nu \bar{\nu}_L^\alpha \sigma^{\mu\nu} N F_{\mu\nu}$$

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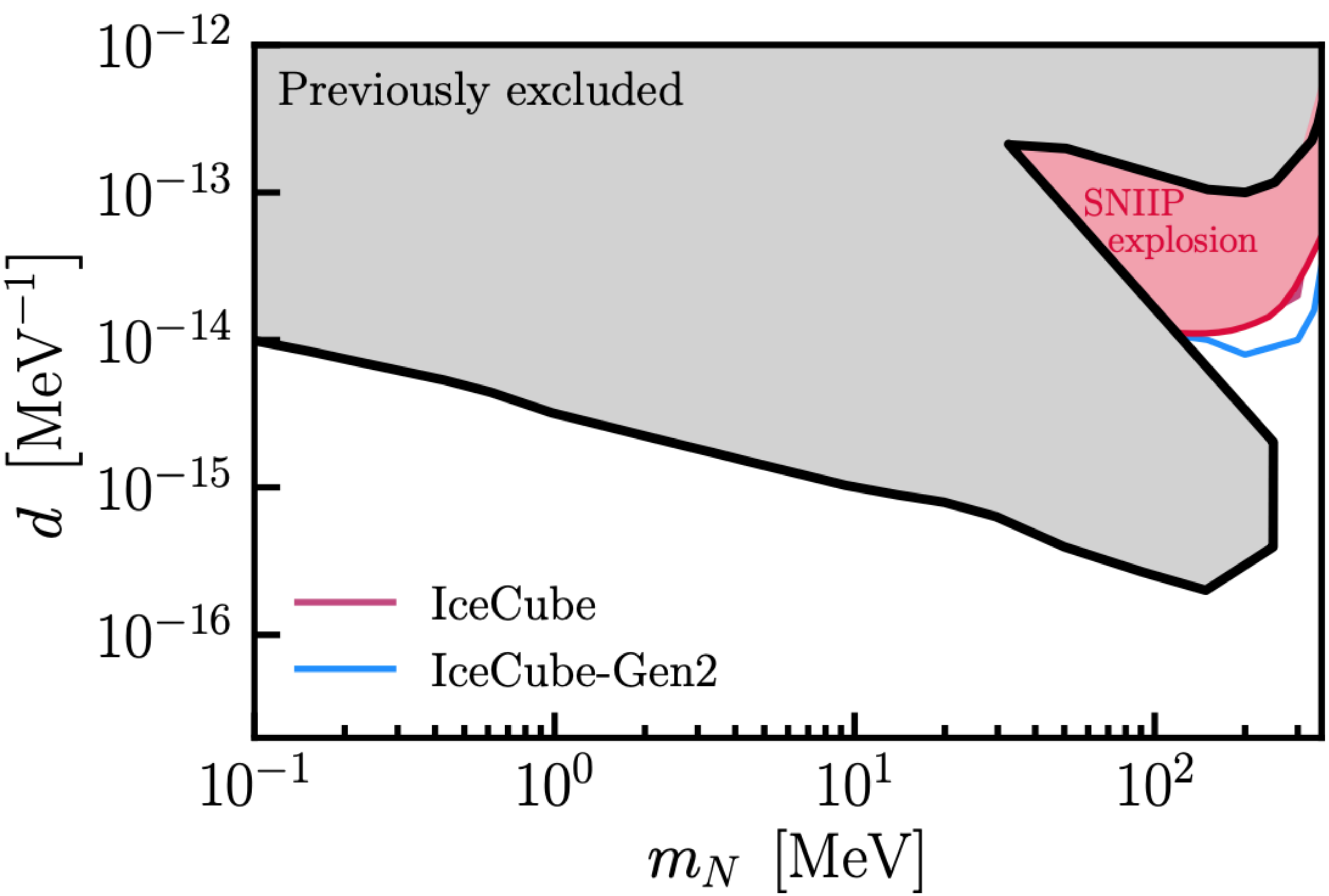

SN Type IIP light curves

$E_{\rm dep} < 10^{50}$ erg

[C. A. Argüelles, V. Brdar, J. Lazar, **YYL**, PRL 134 (2025) , 221002]

Minimal Left-Right Symmetric Model

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$$SU(2)_L \times SU(2)_R \times U(1)_{B-L}$$
$$\to SU(2)_L \times U(1)_Y \to U(1)_Q$$

$$\begin{pmatrix} W_L^\pm \\ W_R^\pm \end{pmatrix} = \begin{pmatrix} \cos\zeta & -\sin\zeta \\ \sin\zeta & \cos\zeta \end{pmatrix} \begin{pmatrix} W_1^\pm \\ W_2^\pm \end{pmatrix}$$

$$Q_L^i\left(\tfrac{1}{2},0,\tfrac{1}{3}\right): \begin{pmatrix} u_L \\ d_L \end{pmatrix}^\alpha, \quad \begin{pmatrix} c_L \\ s_L \end{pmatrix}^\alpha, \quad \begin{pmatrix} t_L \\ b_L \end{pmatrix}^\alpha$$
$$Q_R^i\left(0,\tfrac{1}{2},\tfrac{1}{3}\right): \begin{pmatrix} u_R \\ d_R \end{pmatrix}^\alpha, \quad \begin{pmatrix} c_R \\ s_R \end{pmatrix}^\alpha, \quad \begin{pmatrix} t_R \\ b_R \end{pmatrix}^\alpha$$
$$\Psi_L^a\left(\tfrac{1}{2},0,-1\right): \begin{pmatrix} \nu_{eL} \\ e_L^- \end{pmatrix}, \quad \begin{pmatrix} \nu_{\mu L} \\ \mu_L^- \end{pmatrix}, \quad \begin{pmatrix} \nu_{\tau L} \\ \tau_L^- \end{pmatrix},$$
$$\Psi_R^a\left(0,\tfrac{1}{2},-1\right): \begin{pmatrix} N_{eR} \\ e_R^- \end{pmatrix}, \quad \begin{pmatrix} N_{\mu R} \\ \mu_R^- \end{pmatrix}, \quad \begin{pmatrix} N_{\tau R} \\ \tau_R^- \end{pmatrix}$$

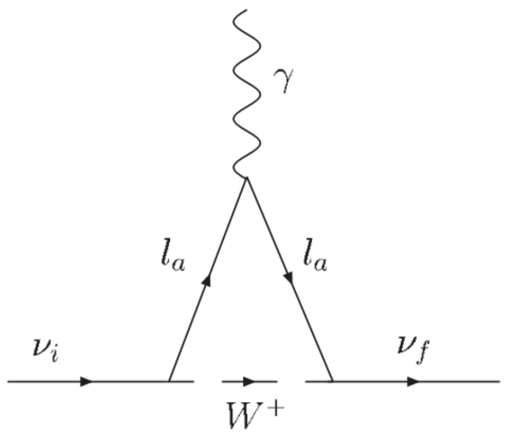
bi-doublet

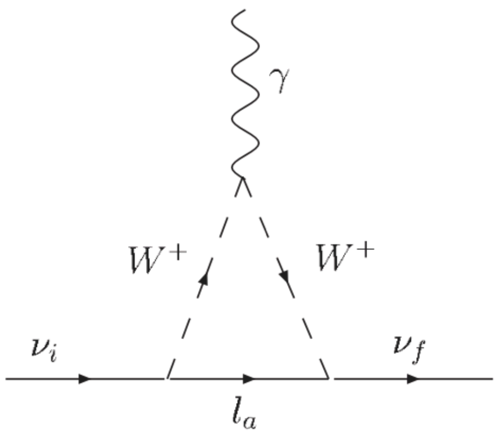
$$\mathscr{L}_{\text{Yukawa}}^L = \{\overline{L}_{Li}(h_{ij}\phi + \tilde{h}_{ij}\tilde{\phi})L_{Rj} + \text{h.c.}\}$$
$$+ \{\overline{L}_{Ri}^c(h_M)_{ij}\Sigma_L L_{Lj} + \overline{L}_{Li}^c(h_M)_{ij}\Sigma_R L_{Rj} + \text{h.c.}\}$$

triplet

without left-right mixing

$$U = \begin{pmatrix} U_L & 0_{3\times3} \\ 0_{3\times3} & U_R^* \end{pmatrix}$$





$$\mu_{ji} = \frac{eG_F}{2\sqrt{2}\pi^2}\sin 2\zeta \sum_{\alpha=1}^{3} m_{\ell\alpha}\,\text{Im}\left[(PU^*)_{\alpha j}(P_s U^*)_{\alpha i}\right]$$

Minimal Left-Right Symmetric Model

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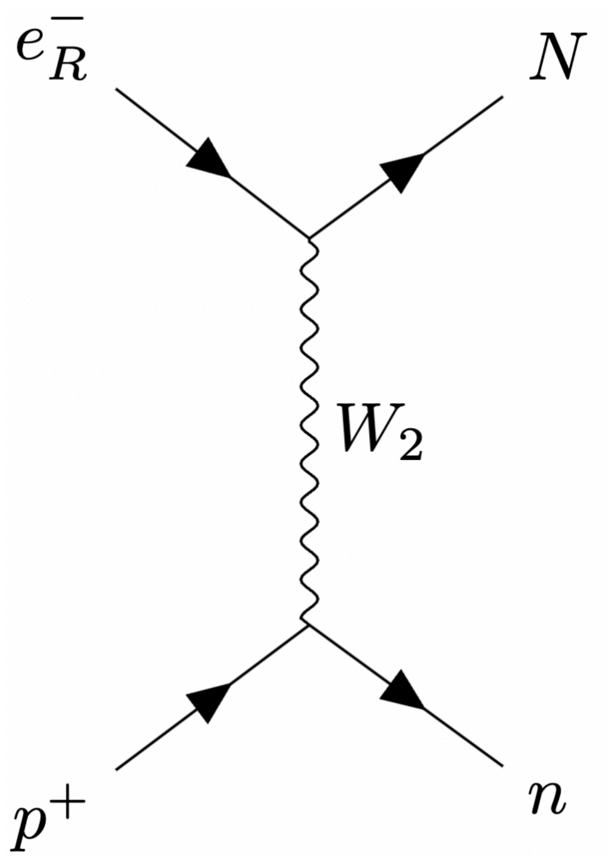
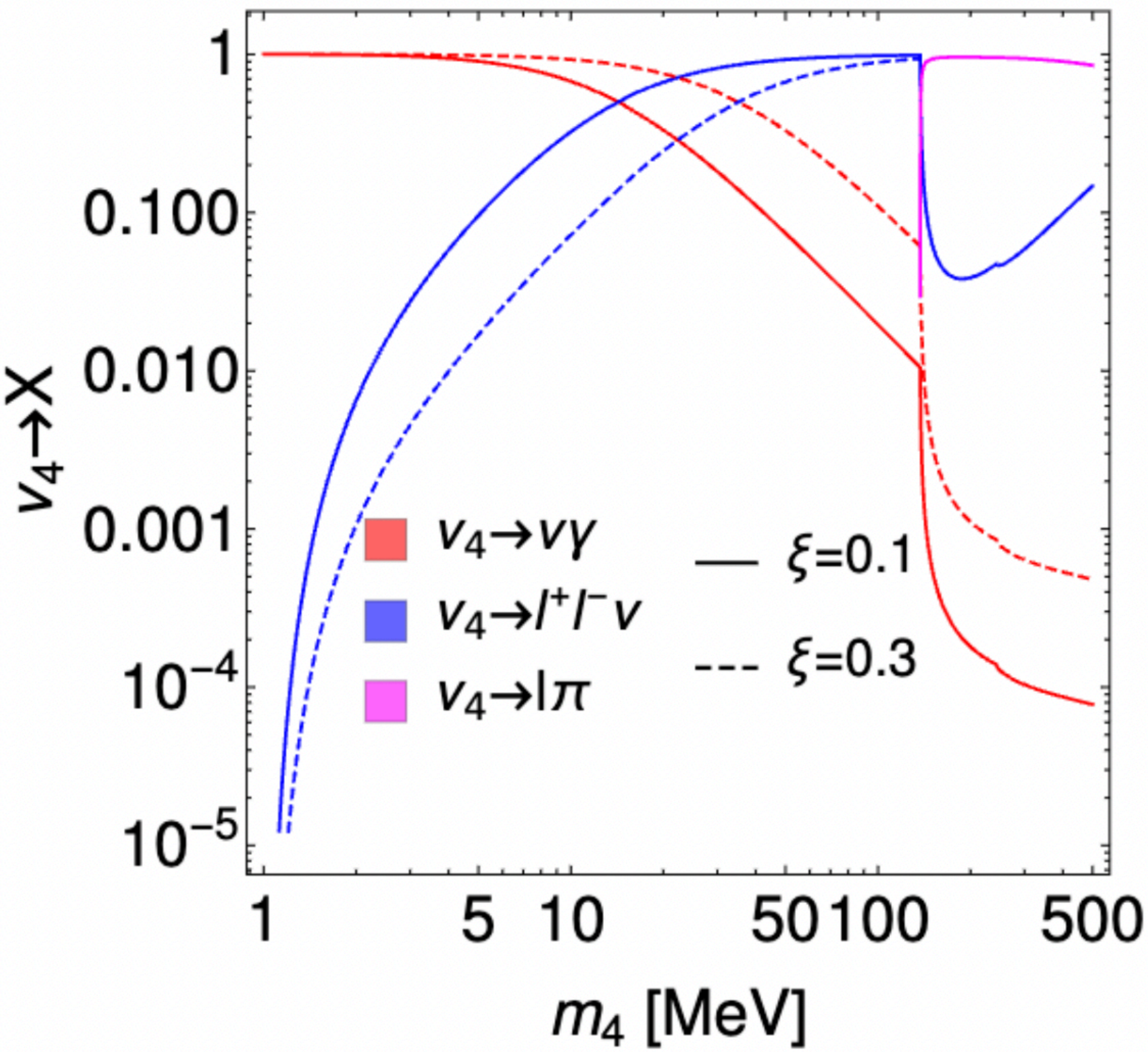
Tree level production in SN



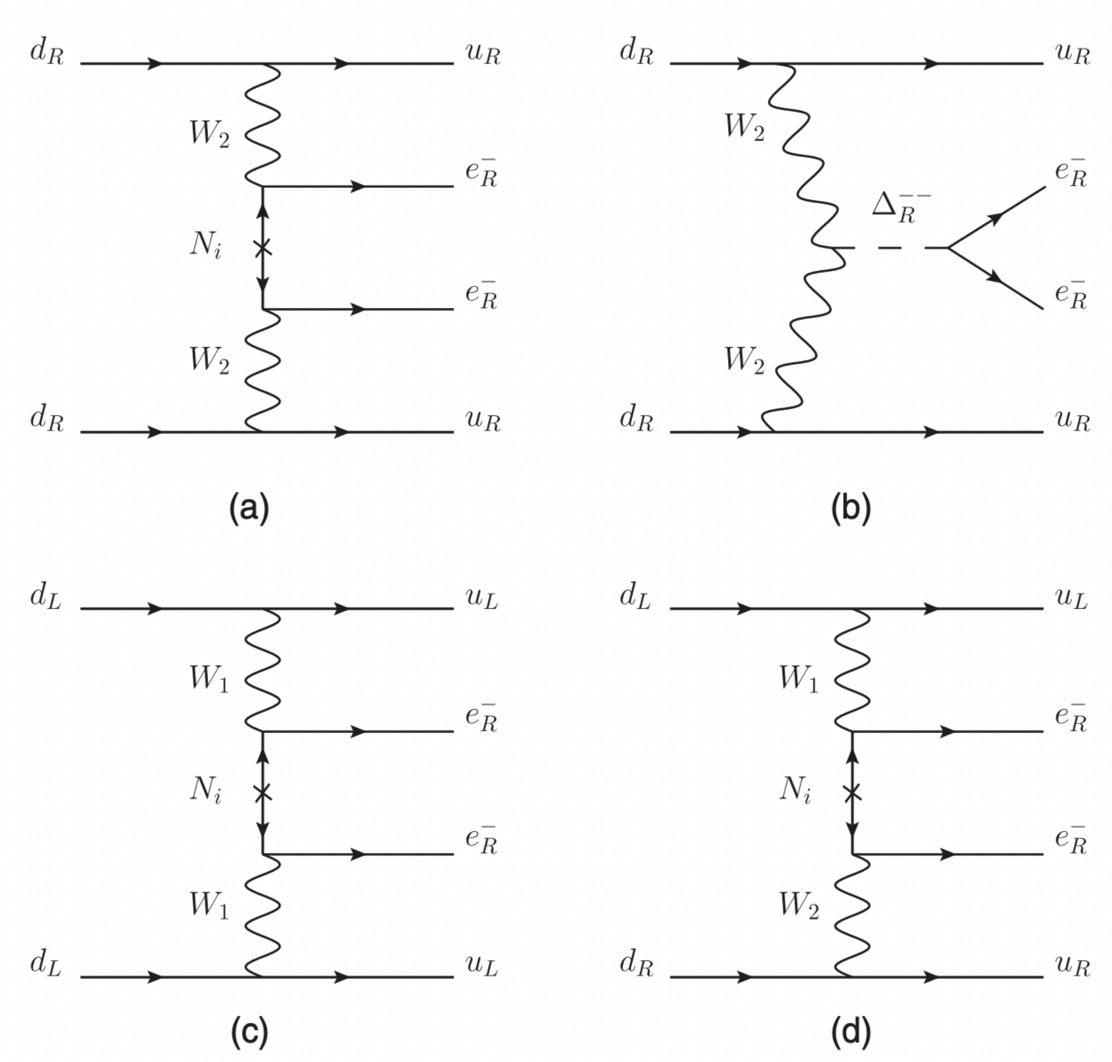
including three-body decay channel



[Gang Li, YYL, Sida Lu, Ye-Ling Zhou, arXiv:2508.15609]

Minimal Left-Right Symmetric Model

Majorana Case



next generation of 0νββ decay
searches with ton-scale detectors

[G. Li et al., arXiv:2009.01257]

Minimal Left-Right Symmetric Model

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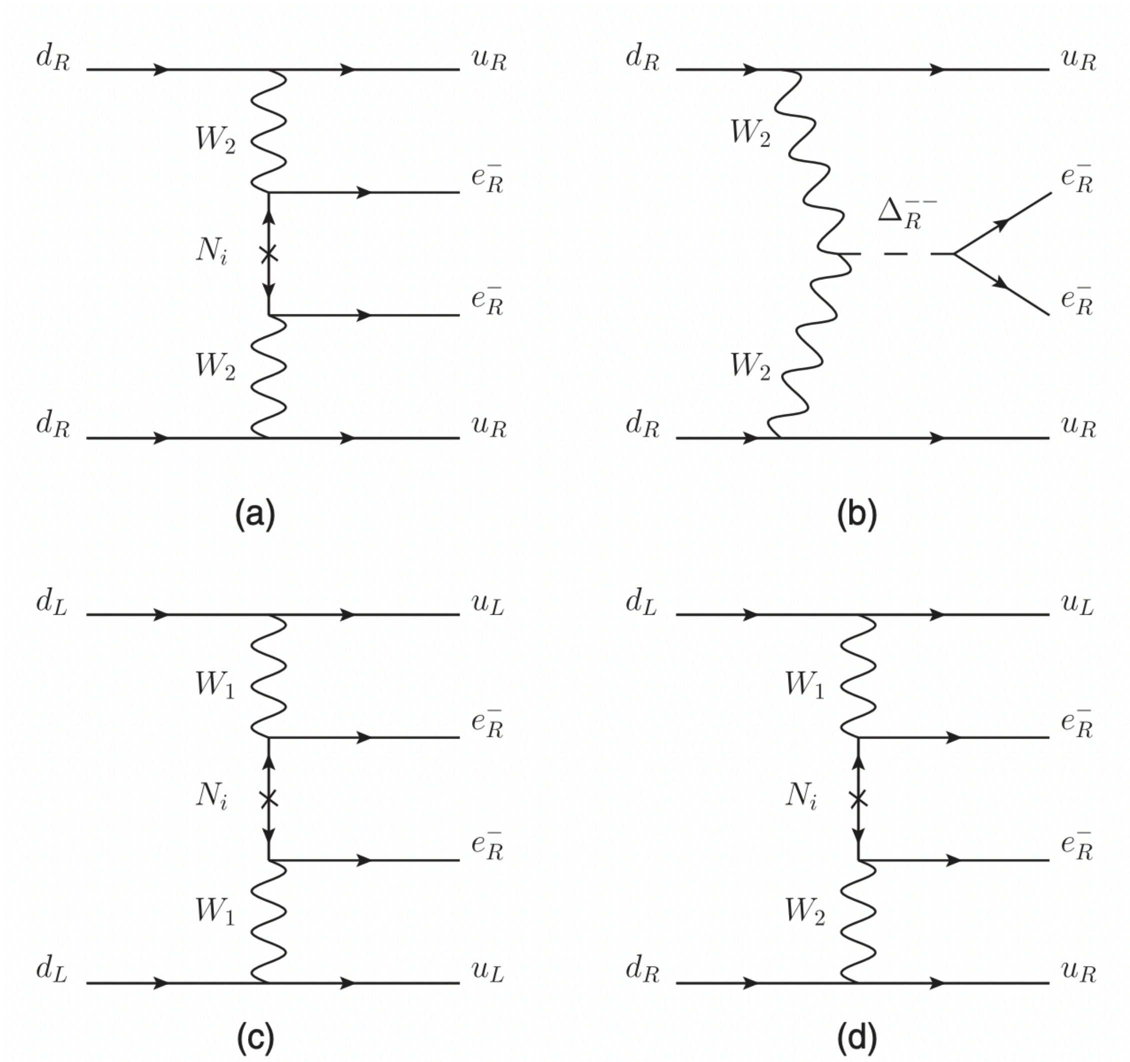
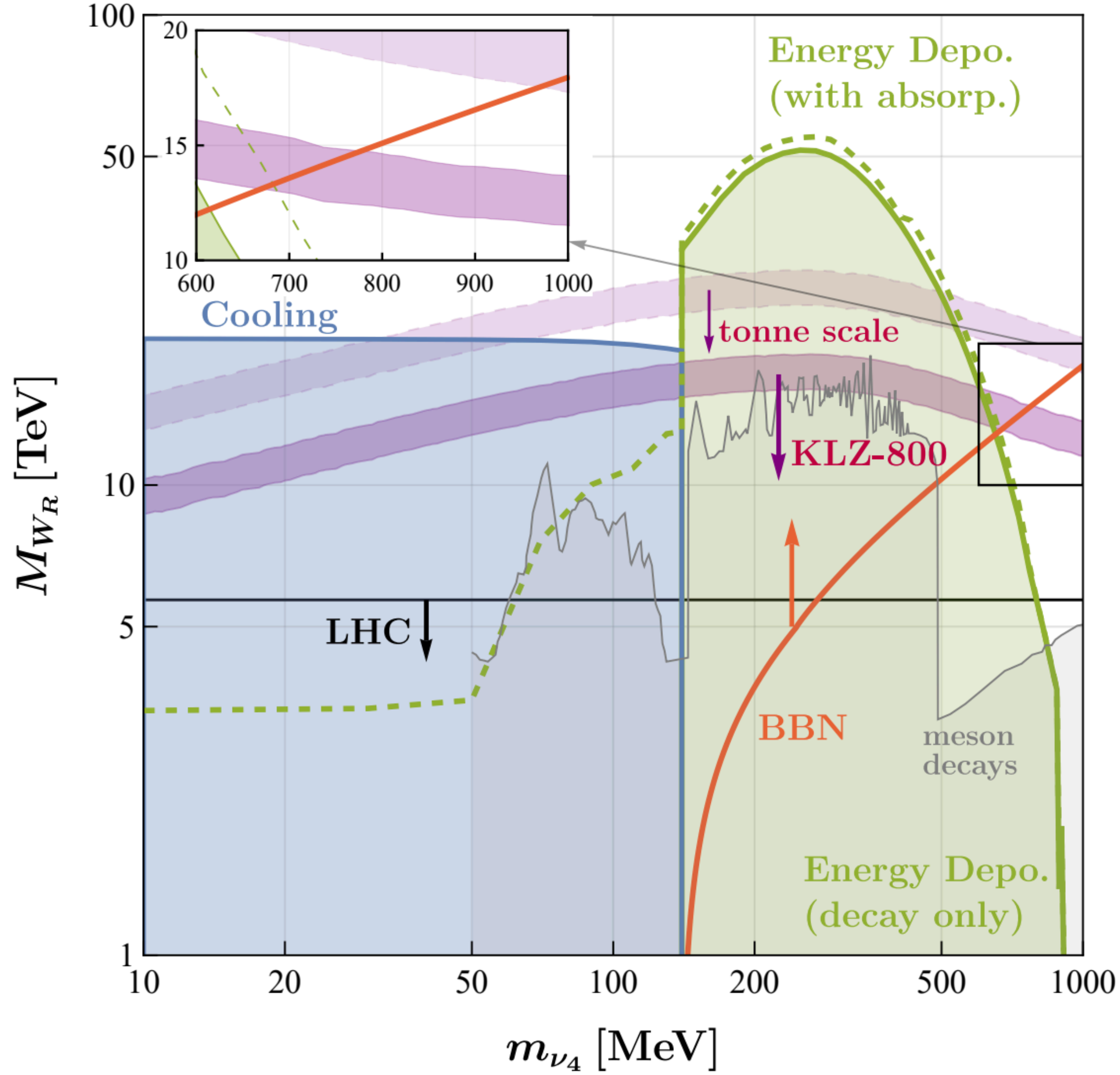
Majorana Case



next generation of 0νββ decay searches with ton-scale detectors

[G. Li et al., arXiv:2009.01257]

without left-right mixing



[Gang Li, YYL, Sida Lu, Ye-Ling Zhou, arXiv:2508.15609]

Thank you