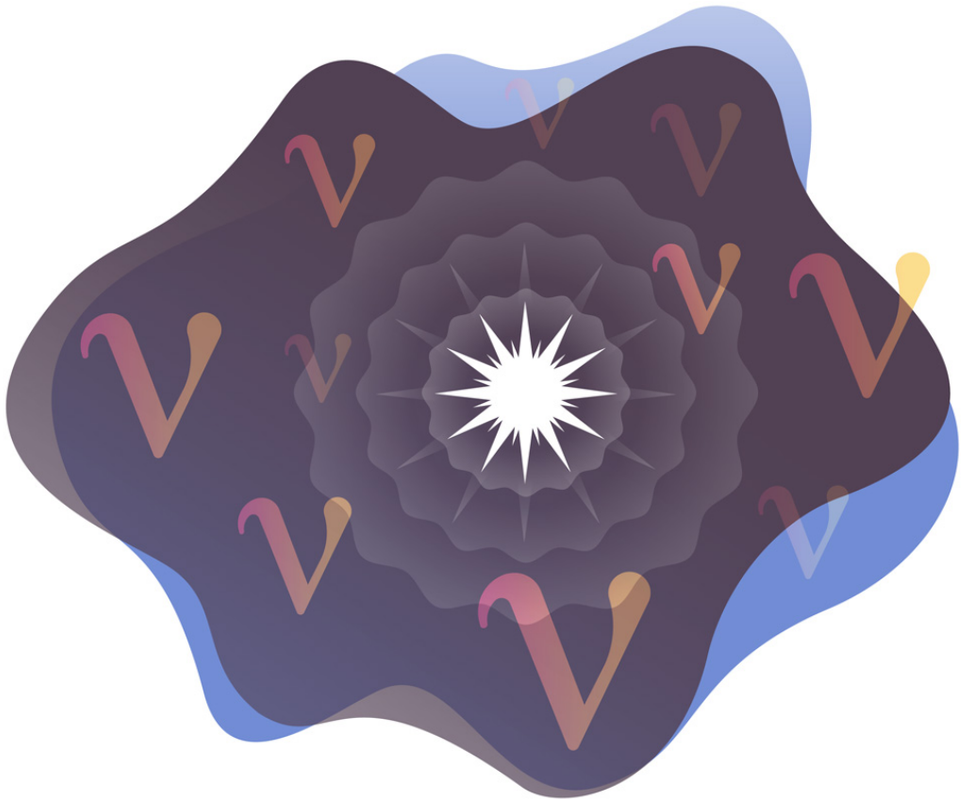

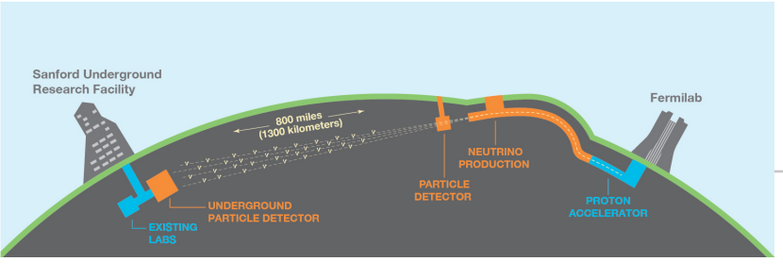

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Ying-Ying Li（李英英）

arXiv: 2302.10965, 2403.09781,
2406.07477, 2502.07024

Heavy neutral lepton searches via the dipole portal

Apr , 2025 @ MEPA 2025

Heavy Neutral Lepton - Mixing Portal

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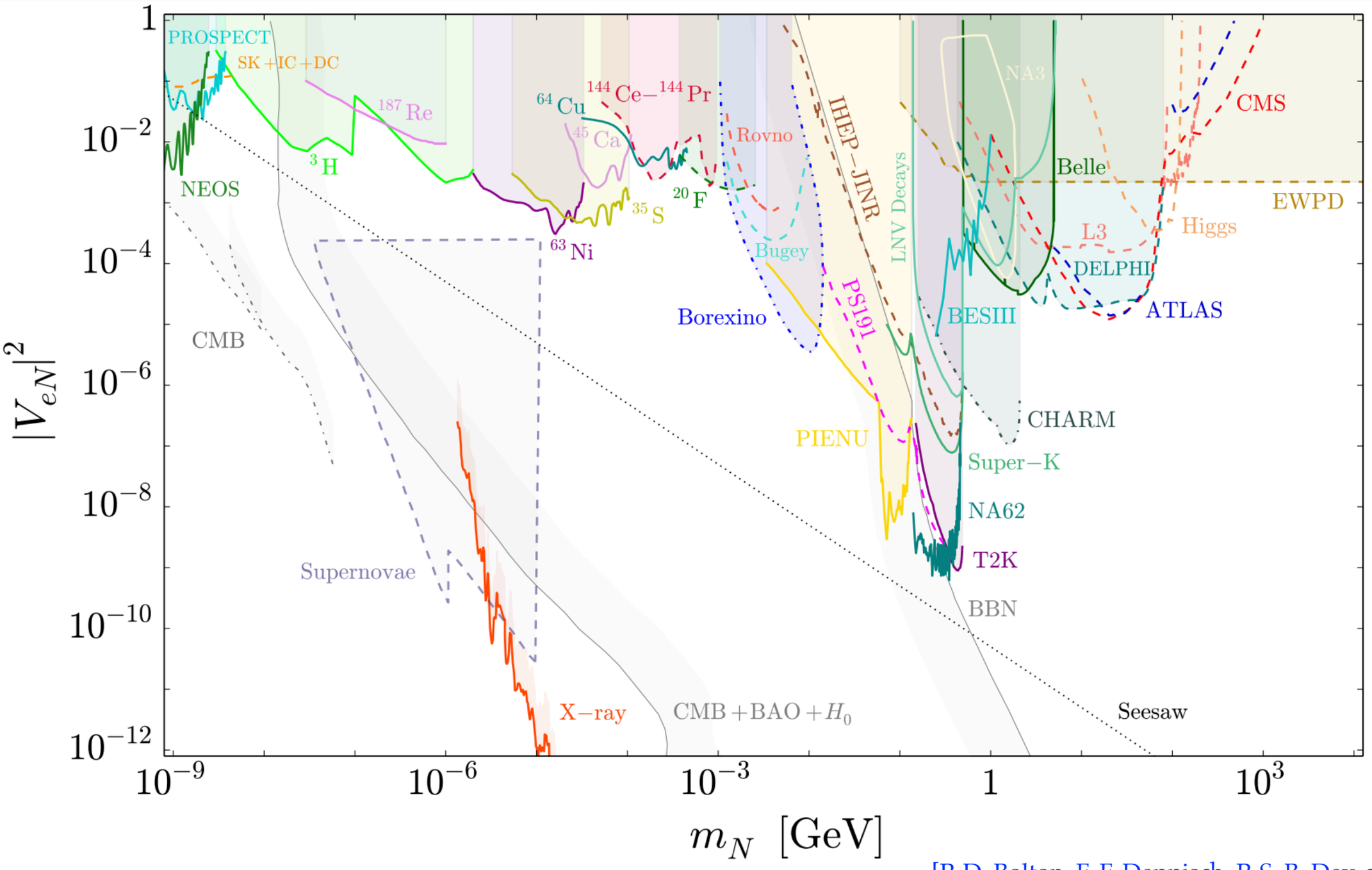
$$\Gamma_{\nu_s \to \nu_a \gamma} = 1.38 \cdot 10^{-29}\ \mathrm{sec}^{-1} \left(\frac{\sin^2 2\theta}{10^{-7}}\right) \left(\frac{m_s}{1\ \mathrm{keV}}\right)^5 .$$



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

Heavy Neutral Lepton - Dipole Portal

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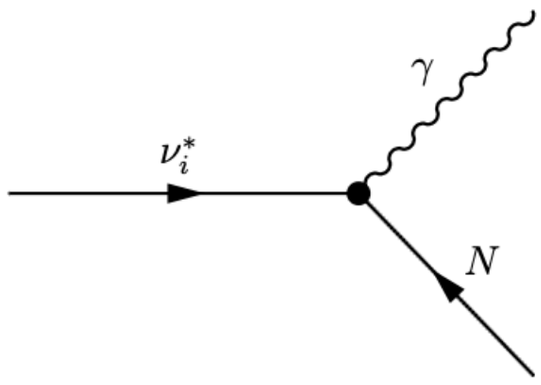
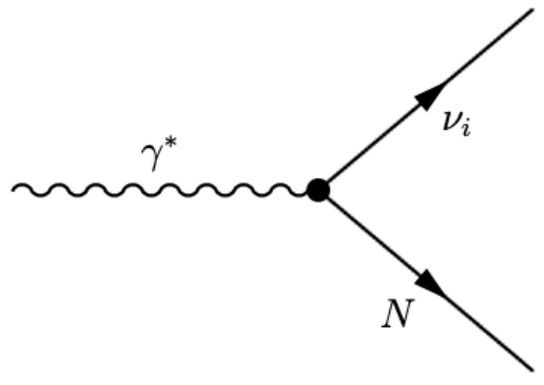
$$\mathcal{L} \supset \frac{1}{2}\mu_\nu \bar{\nu}_L^\alpha \sigma^{\mu\nu} N F_{\mu\nu}$$

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

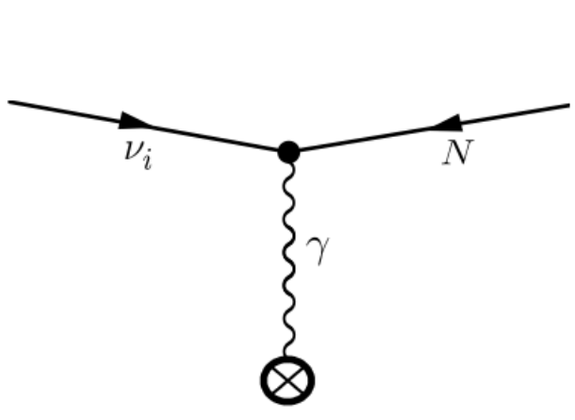


(a) Weak meson decays

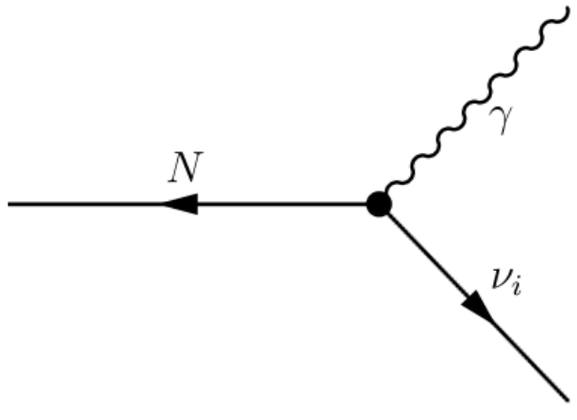


(b) Dalitz-like decay

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



(c) Primakoff upscattering



(d) $N \to \gamma\nu$ (signal)

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

Current Probes: terrestrial experiments

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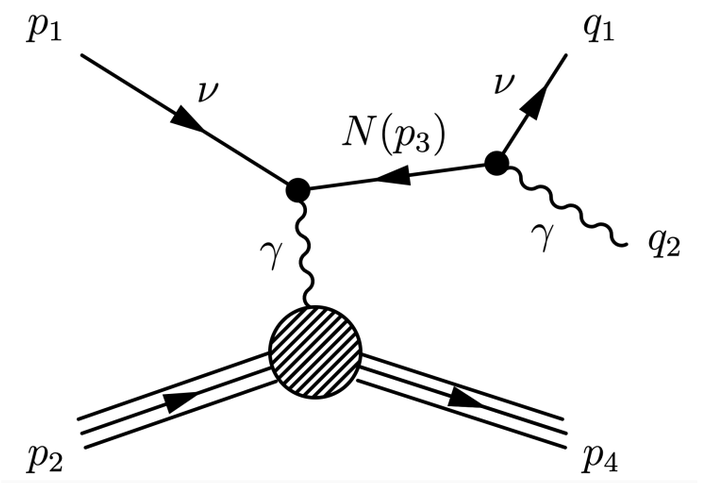
Beam dump experiments:

MiniBoone, NONAD, CHARM

production via:

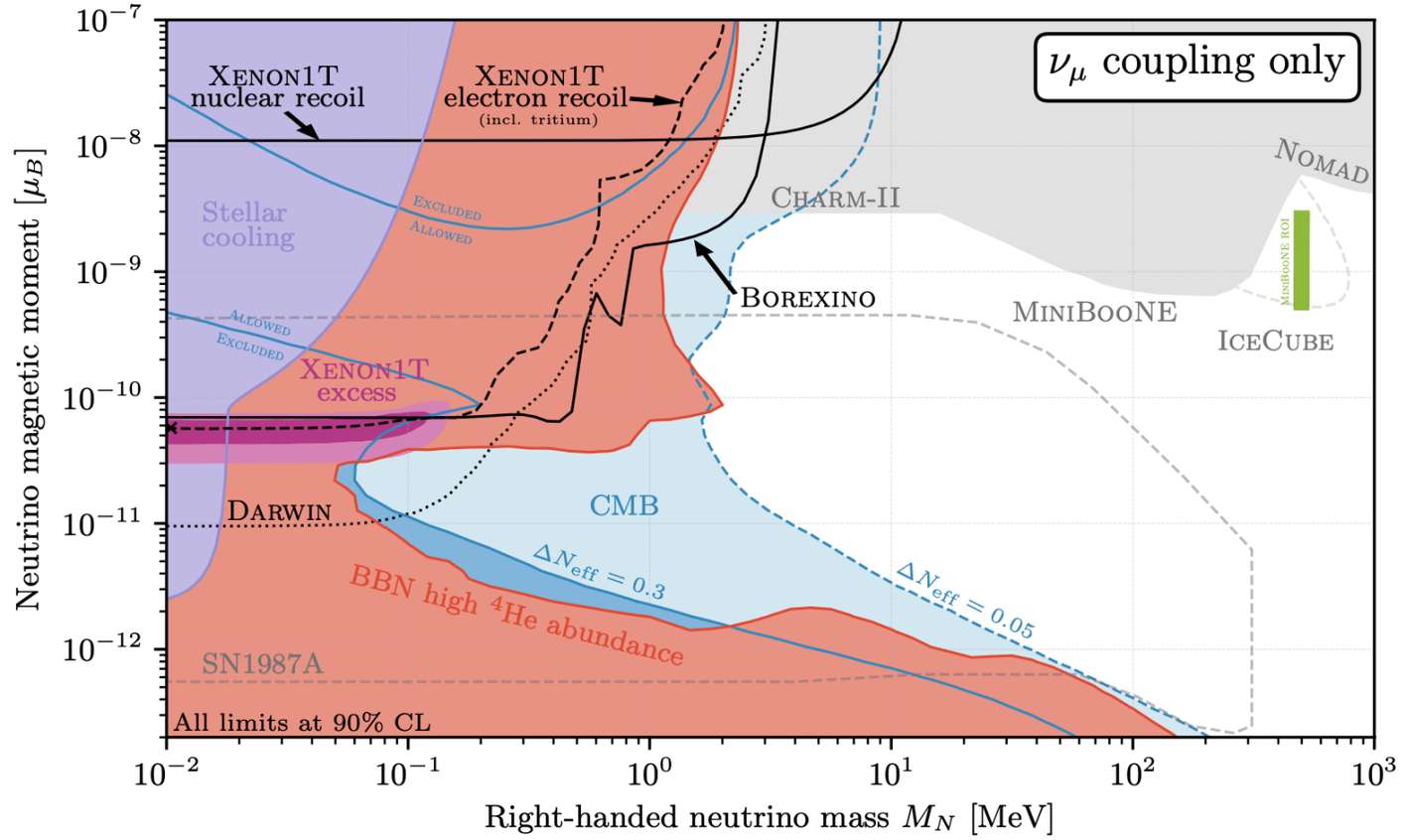


$$\pi^0, \eta \to \gamma(\gamma^* \to \nu_a N)$$

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

relevant for transition magnetic moments between ν_μ and N

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



Current Probes: terrestrial experiments

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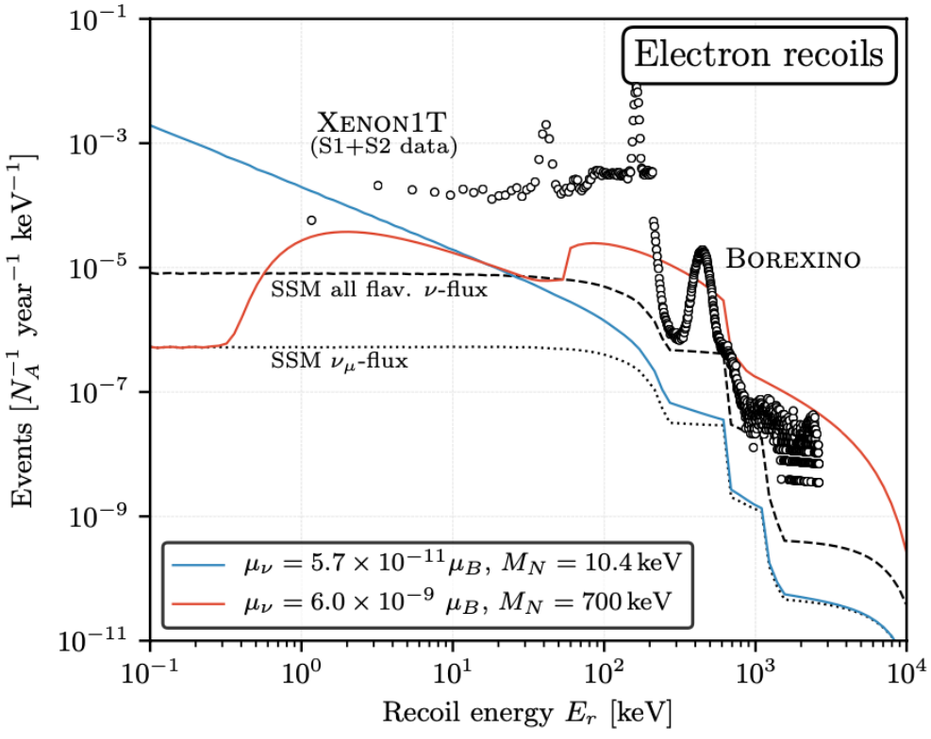
Solar neutrino spectrum:

Xenon1T, Borexino

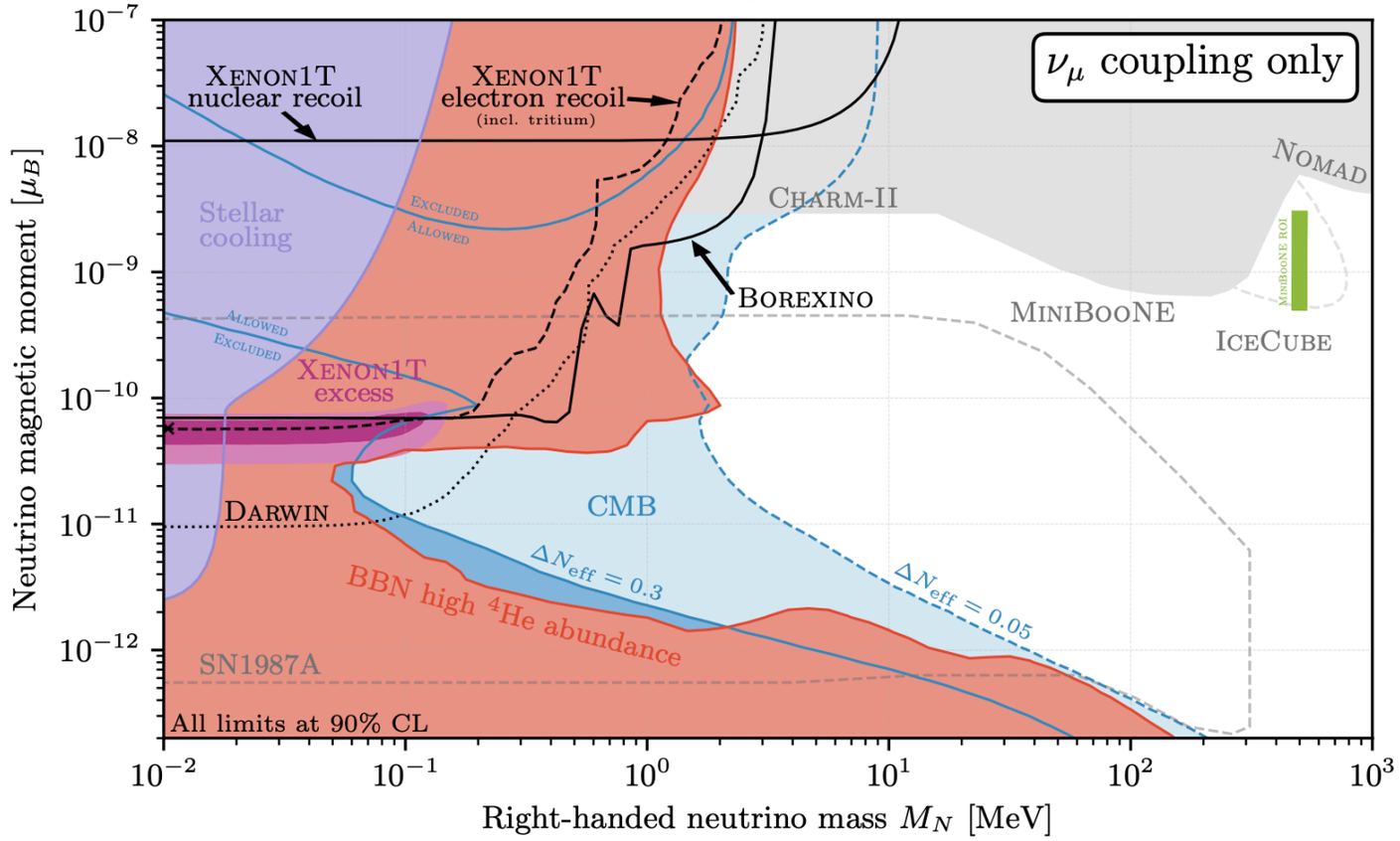
detection via:

$$\nu_L + e^- \to N + e^-$$

$$\nu_L + X_Z^A \to N + X_Z^A$$



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



Current Probes: terrestrial experiments

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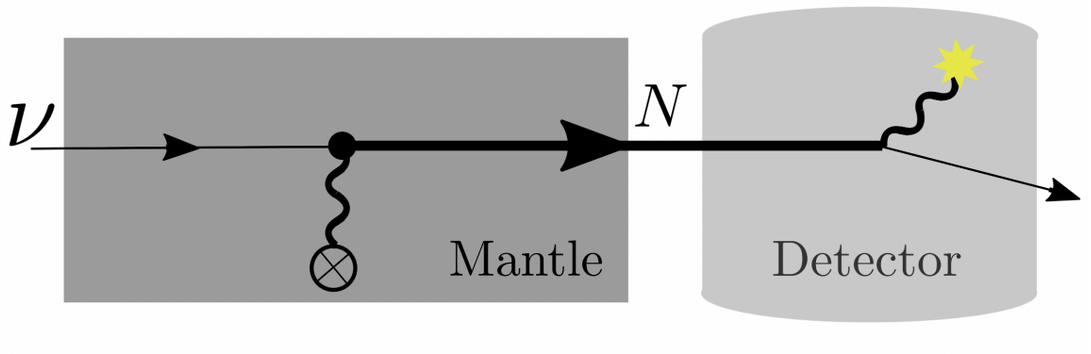
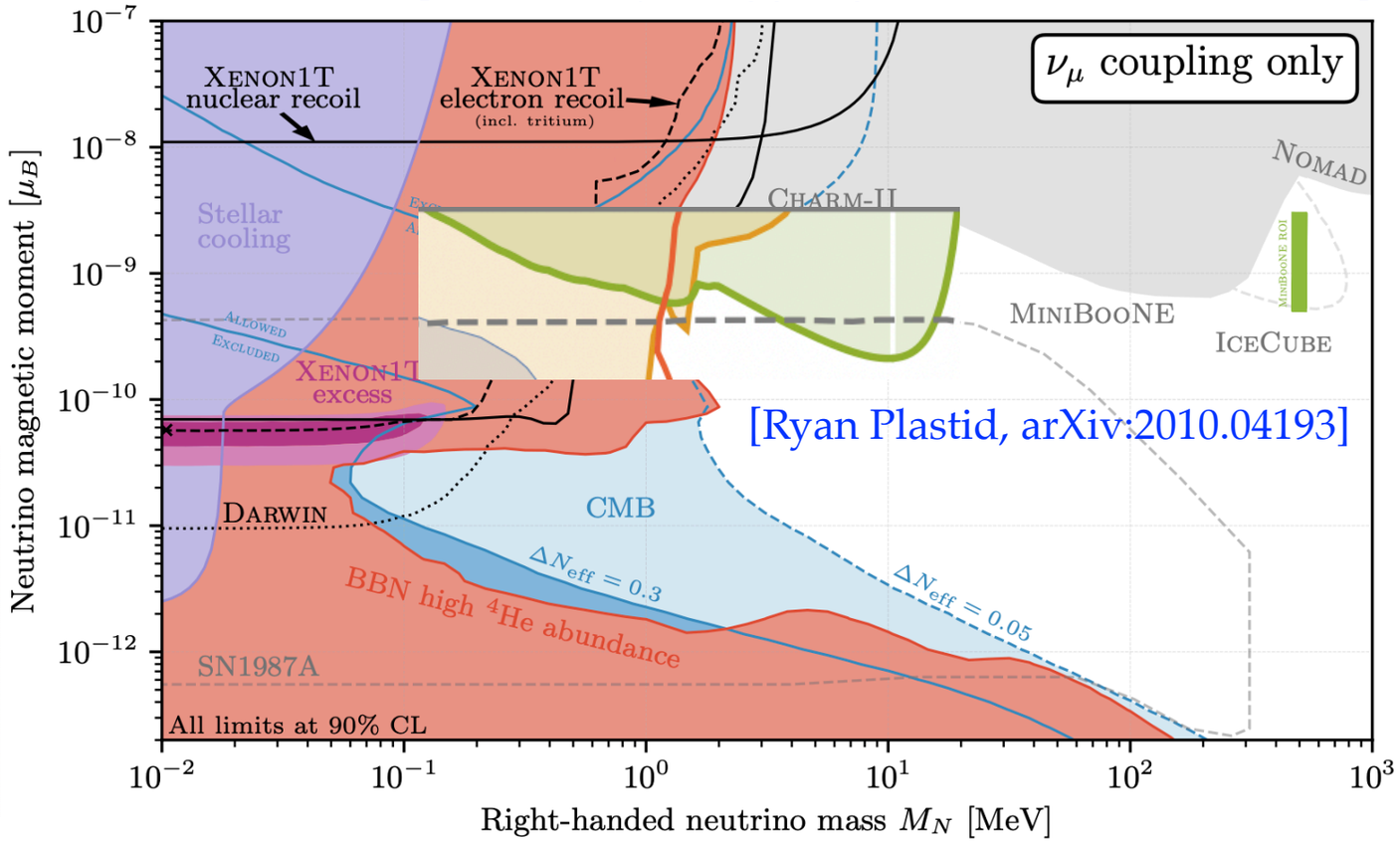
Solar neutrino

up-scattering and decays

production and decay



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



[Ryan Plastid, arXiv:2010.04193]

Borexino, SuperK

Current Probes: terrestrial experiments

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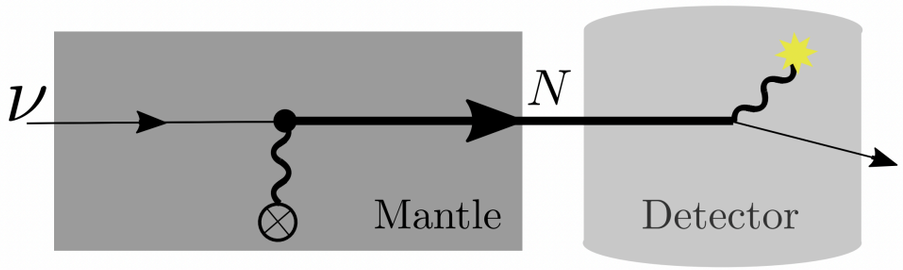
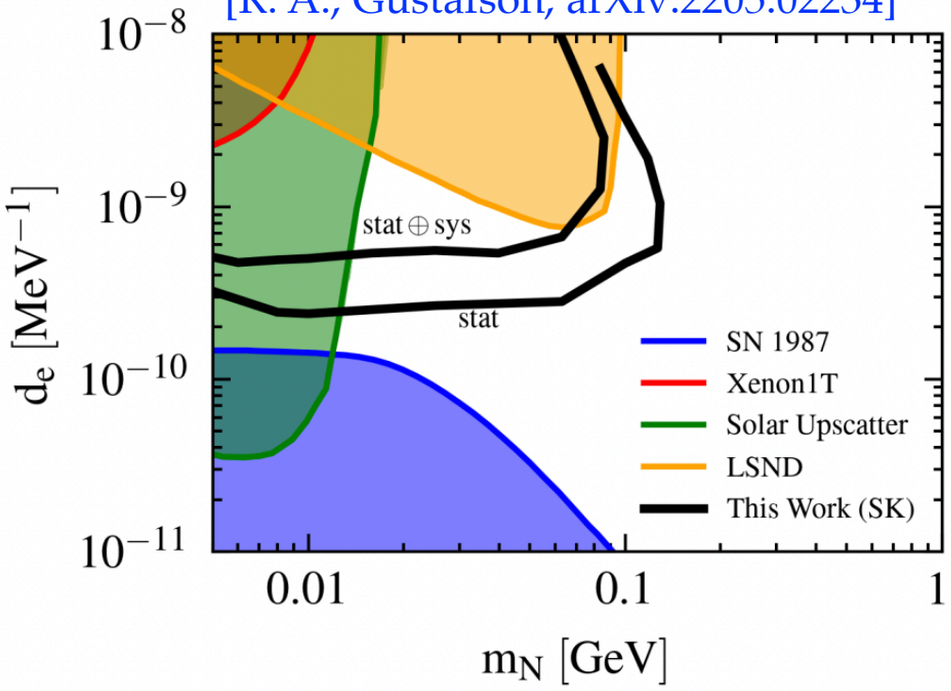
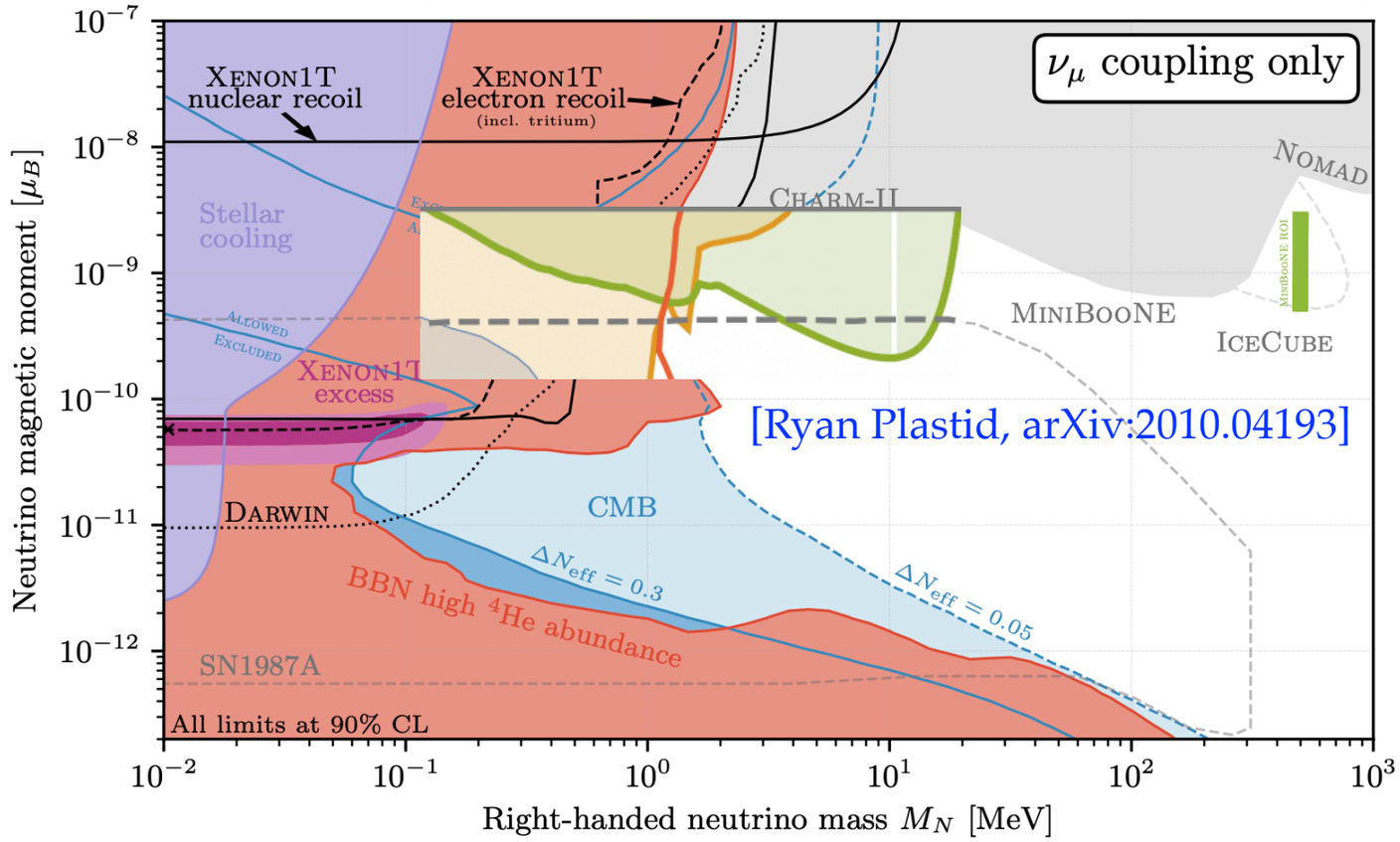
Atmospheric neutrino DUNE, Super-K



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



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



[Ryan Plastid, arXiv:2010.04193]

$$M_N \gtrsim 6\text{GeV}\ (\text{LHC, LEP}):\ e^+e^-(q\bar{q}) \to (N \to \gamma\nu)\bar{\nu} + h.c.$$

Current Probes: Supernova

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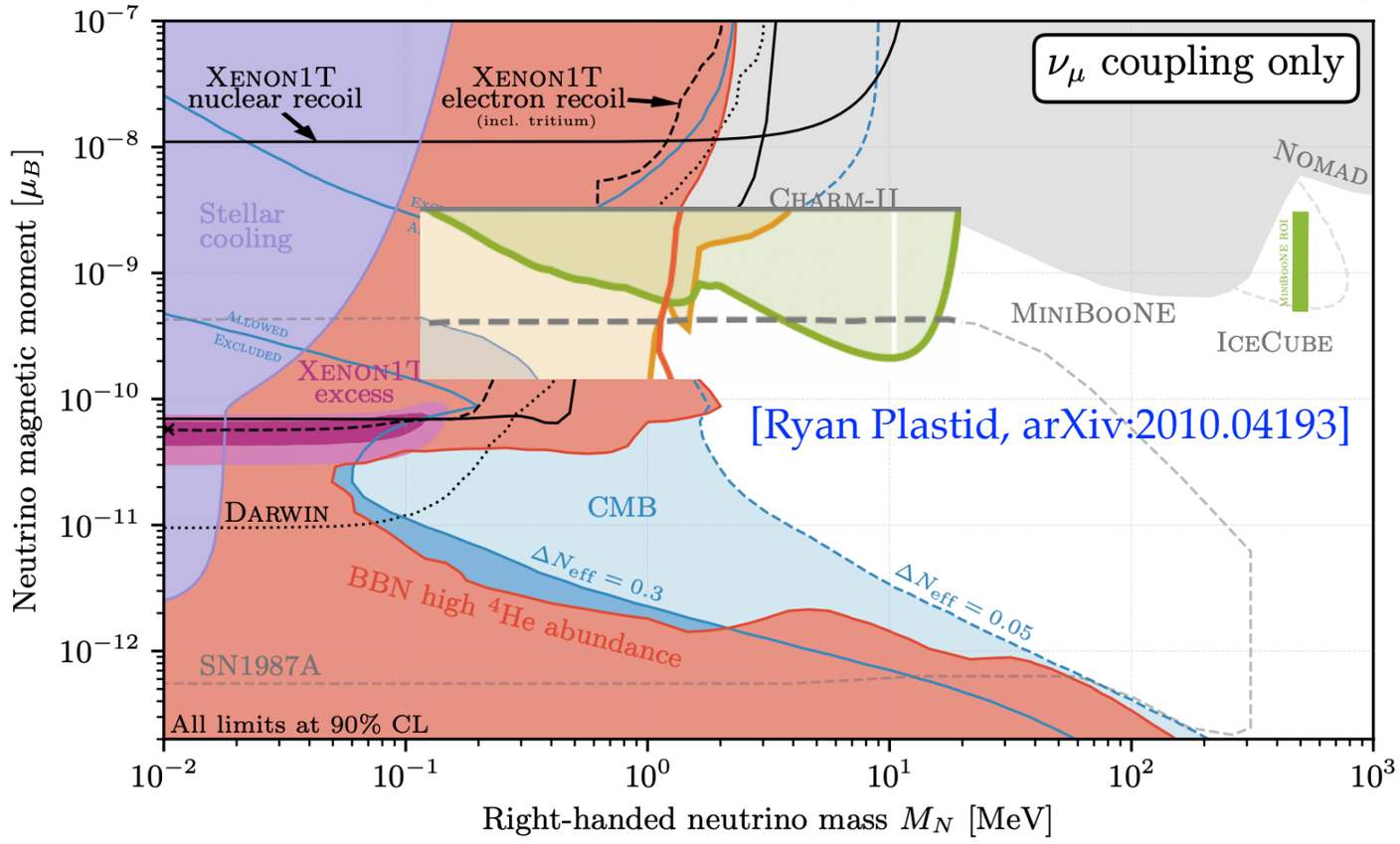
10% of energy loss

to sterile neutrino

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

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



[Ryan Plastid, arXiv:2010.04193]

Multimessenger Signals

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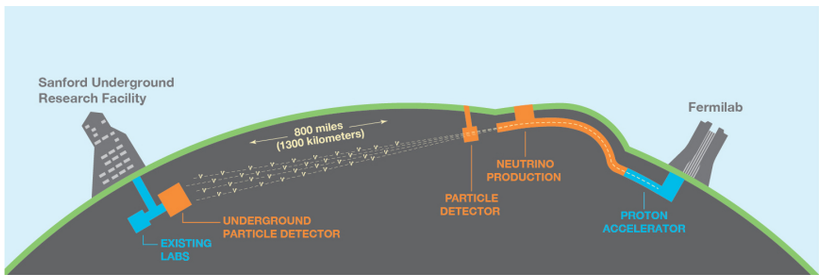
$$\nu + e^{\pm} \to N + e^{\pm}$$
$$\nu + p \to N + p$$
$$e^{+} + e^{-} \to \overline{\nu} + N$$
$$\gamma + \nu \to N$$

$$\mathcal{L} \supset \frac{1}{2}\mu_{\nu}\bar{\nu}_{L}^{\alpha}\sigma^{\mu\nu}NF_{\mu\nu}$$

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



[V. Brdar, A. D. Gouv^ea, YYL, P. A. N. Machado, arXiv:2302.10965]

Multimessenger Signals : γ – ray detection

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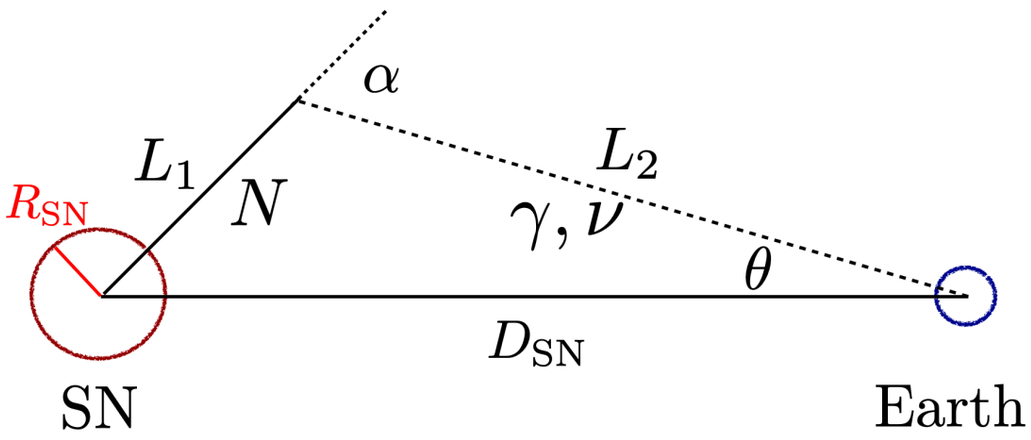
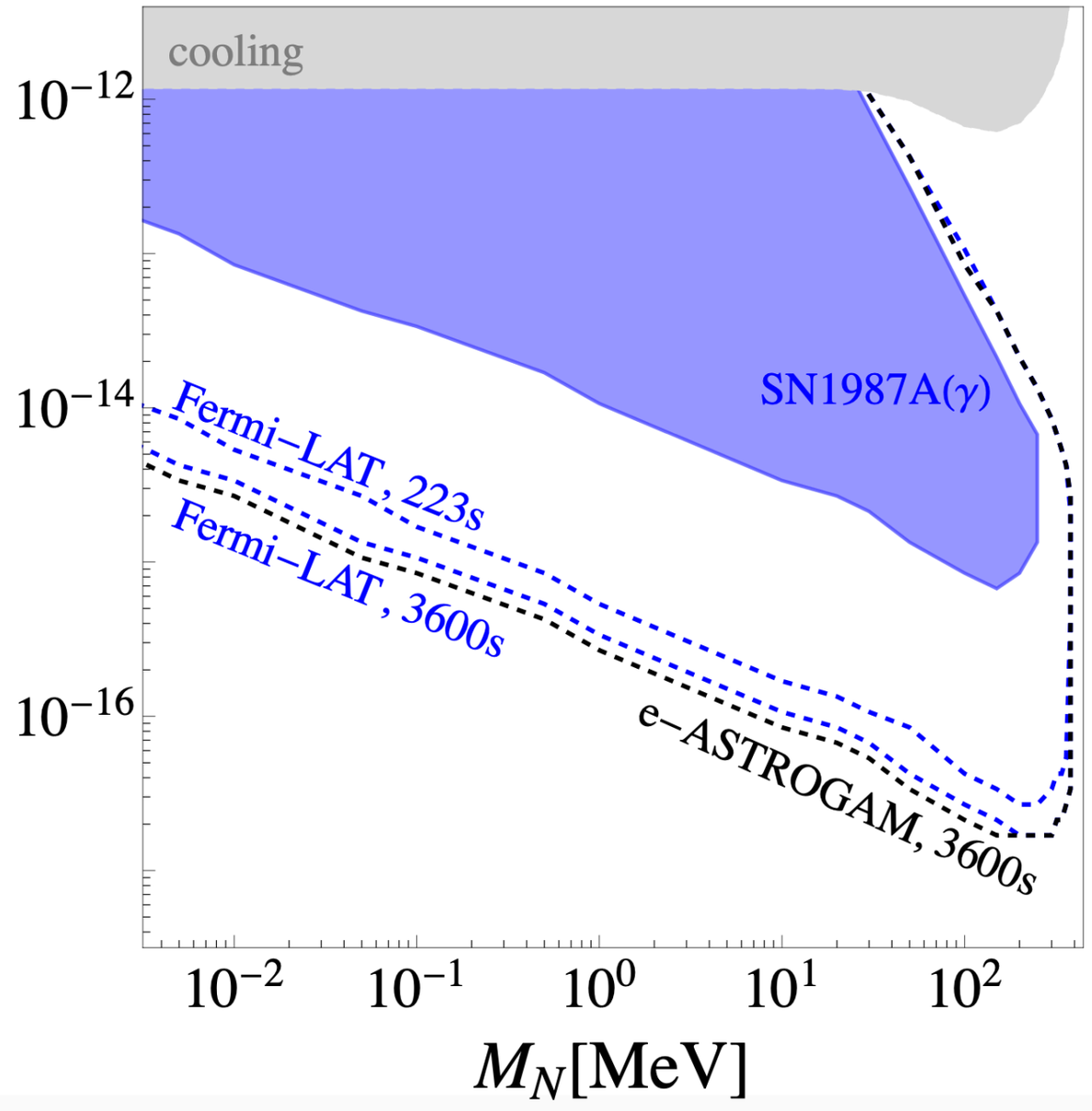


- At the time of SN1987A, the Gamma-Ray Spectrometer (GRS) observed Nobs = 1393 photons with energy 25-100 MeV at $\Delta t < 223s$

- 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, arXiv:2302.10965]

Multimessenger Signals : neutrino detection

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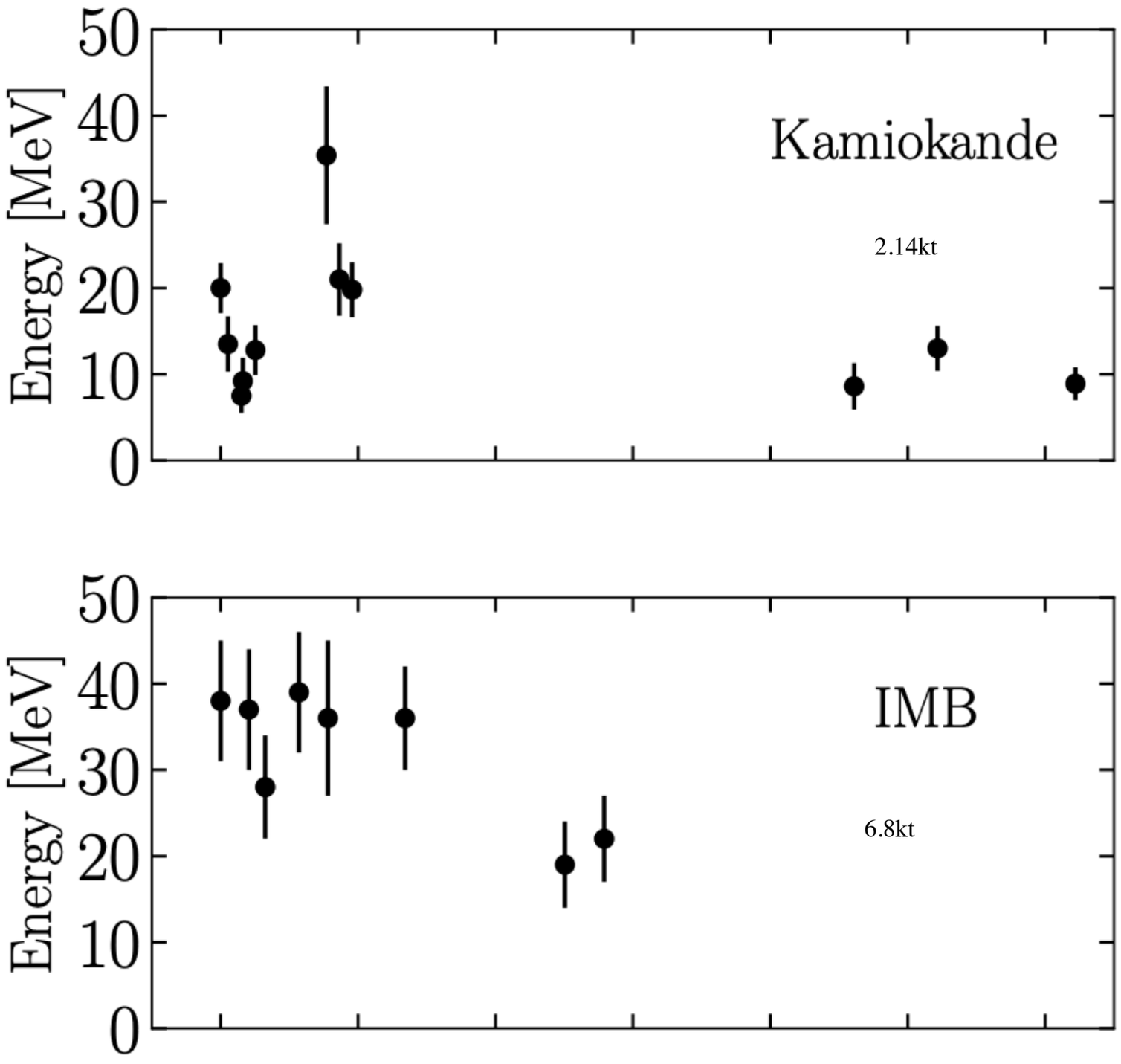

SN1987A, neutrino events

water-Cherenkov detectors

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

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

Multimessenger Signals : neutrino detection

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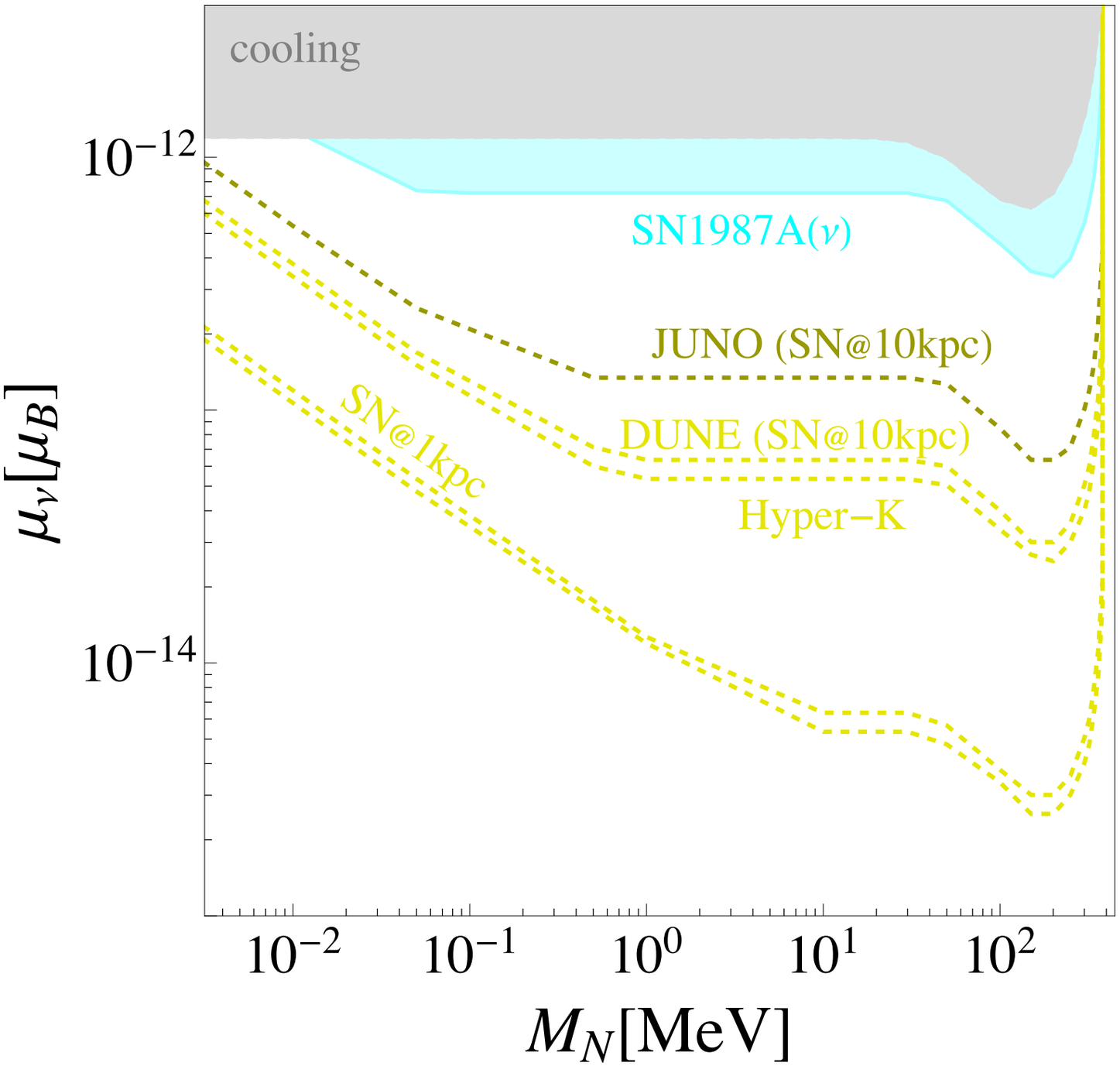
- Assuming a SN event happens in the galaxy at a distance of D_SN = 10kpc,
  JUNO: 20kt fiducial volume, liquid scintillator detector
  DUNE: 40kt, liquid argon
  Hyper-K: 188kt fiducial



[V. Brdar, A. D. Gouv^ea, YYL, P. A. N. Machado, arXiv:2302.10965]

Multimessenger Signals

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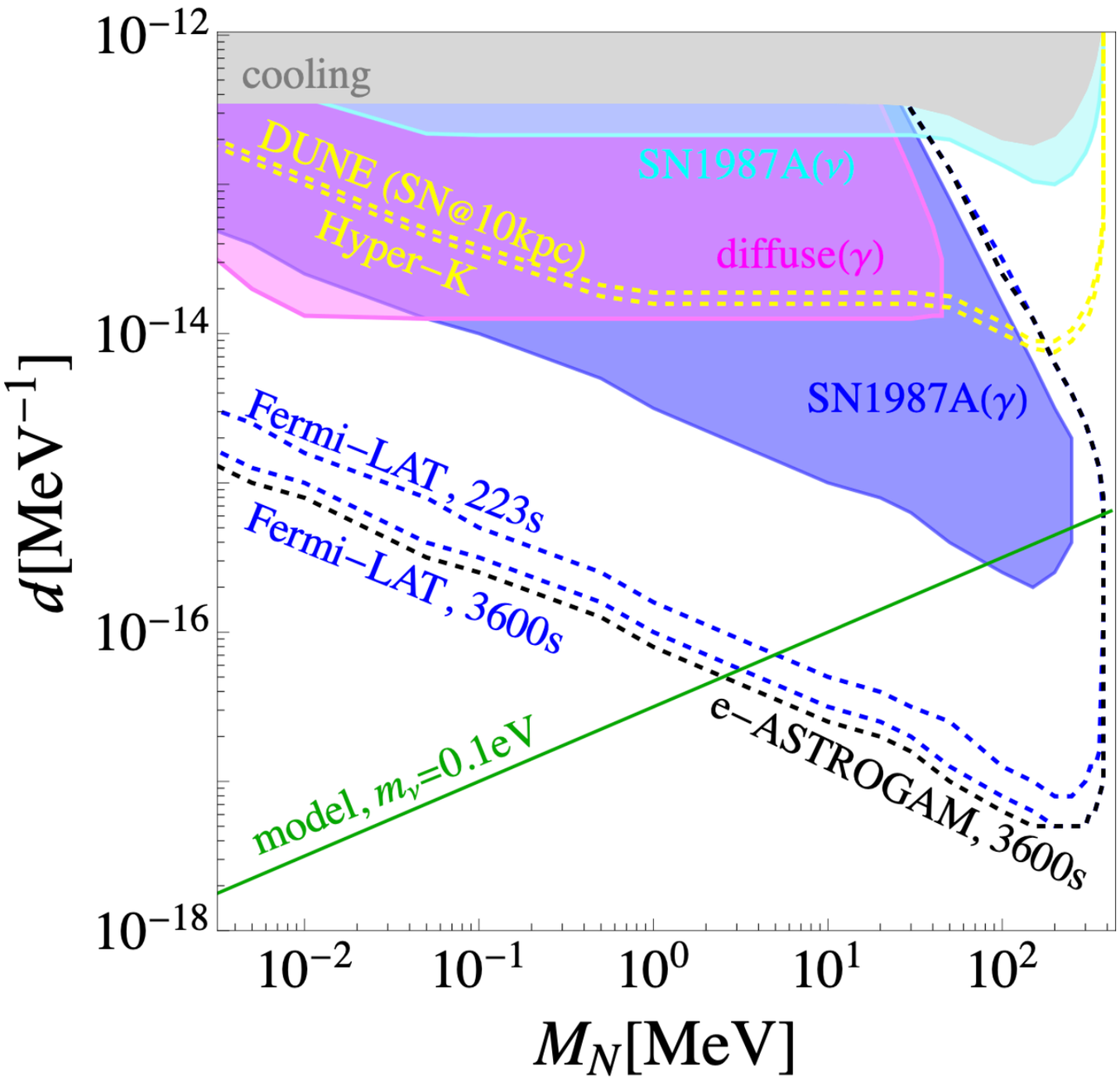
diffused BSM Photon and neutrino background

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



[V. Brdar, A. D. Gouv^ea, YYL, P. A. N. Machado, arXiv:2302.10965]

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

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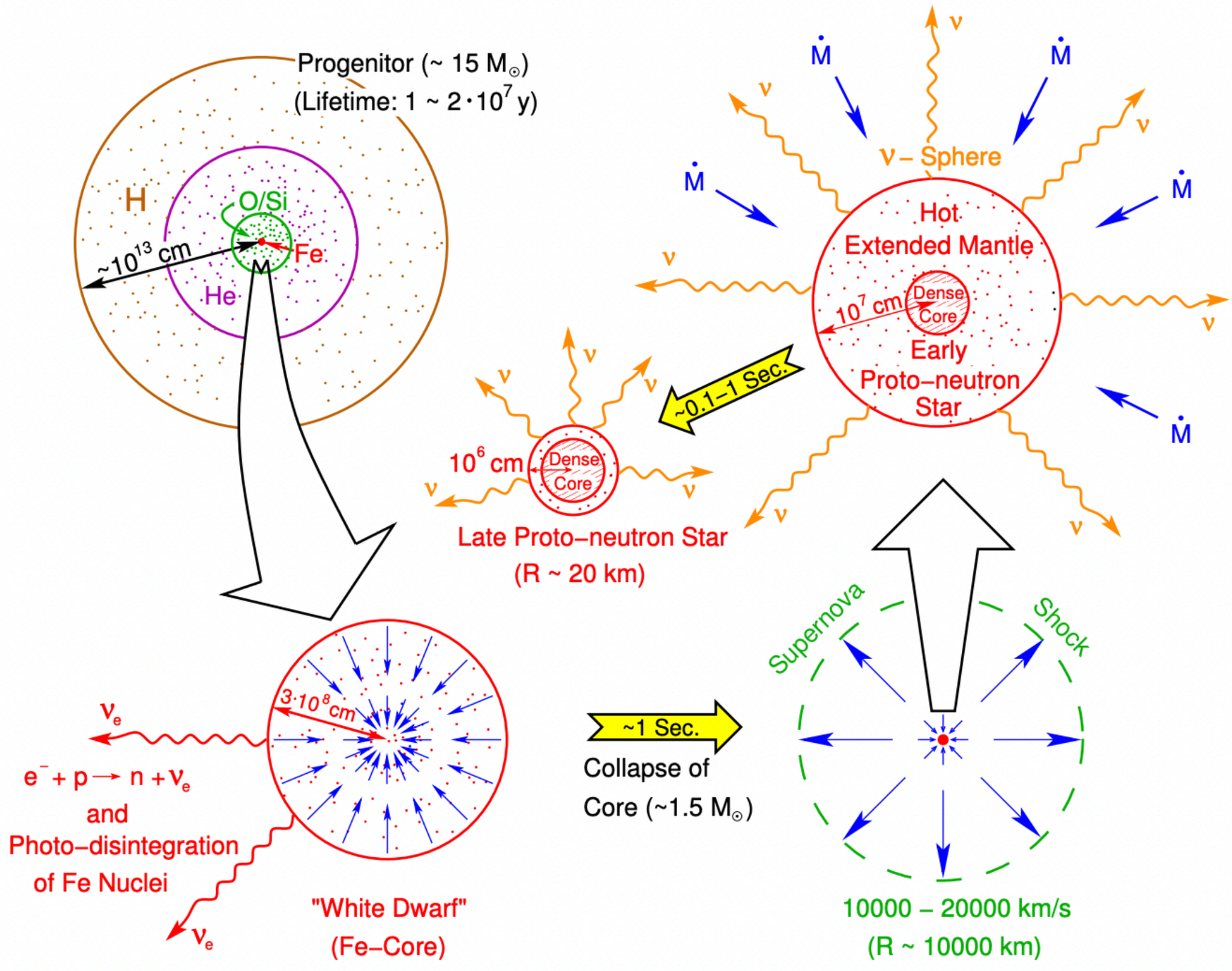

[Hans-Thomas Janka, arXiv:1702.08713]

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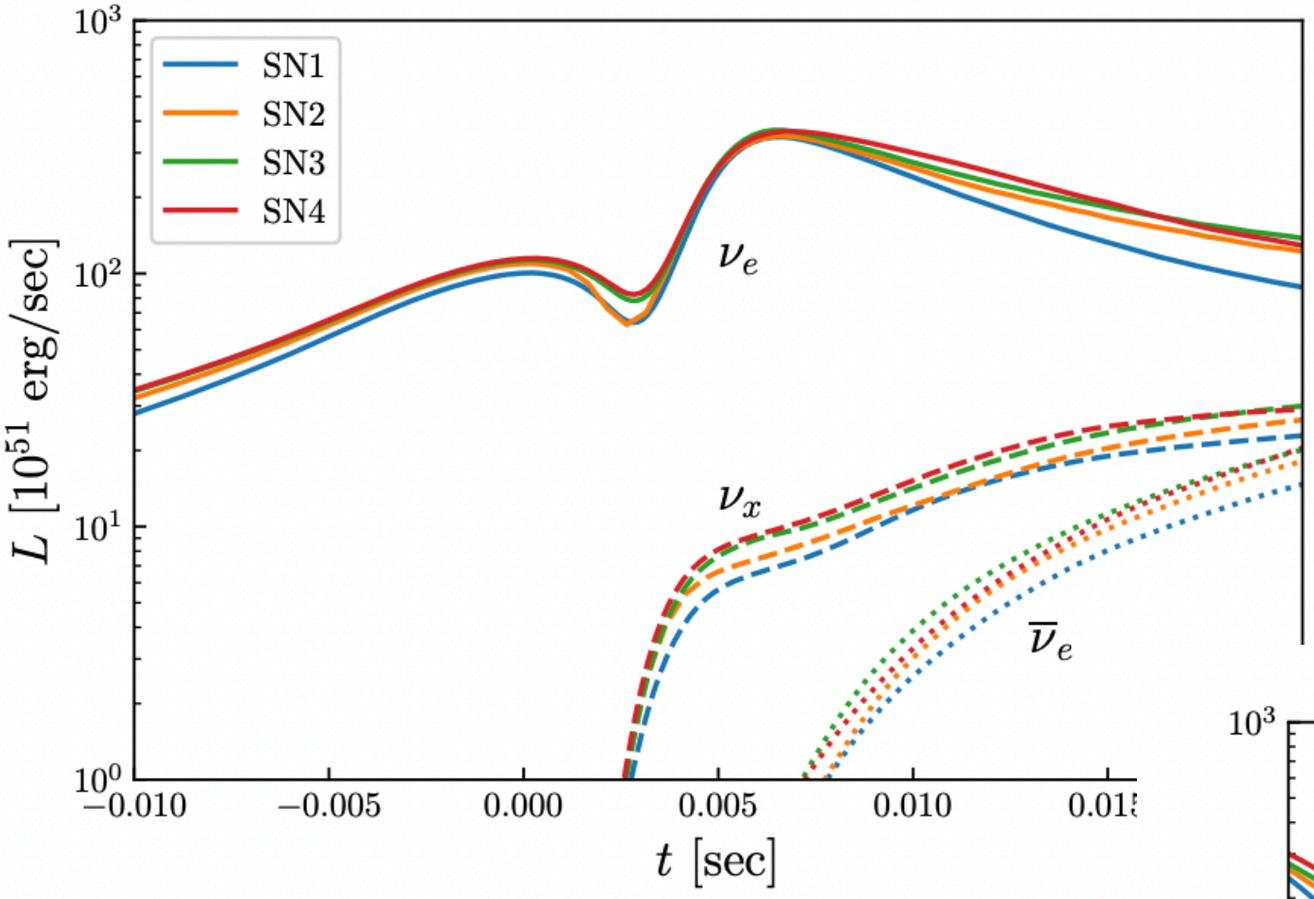
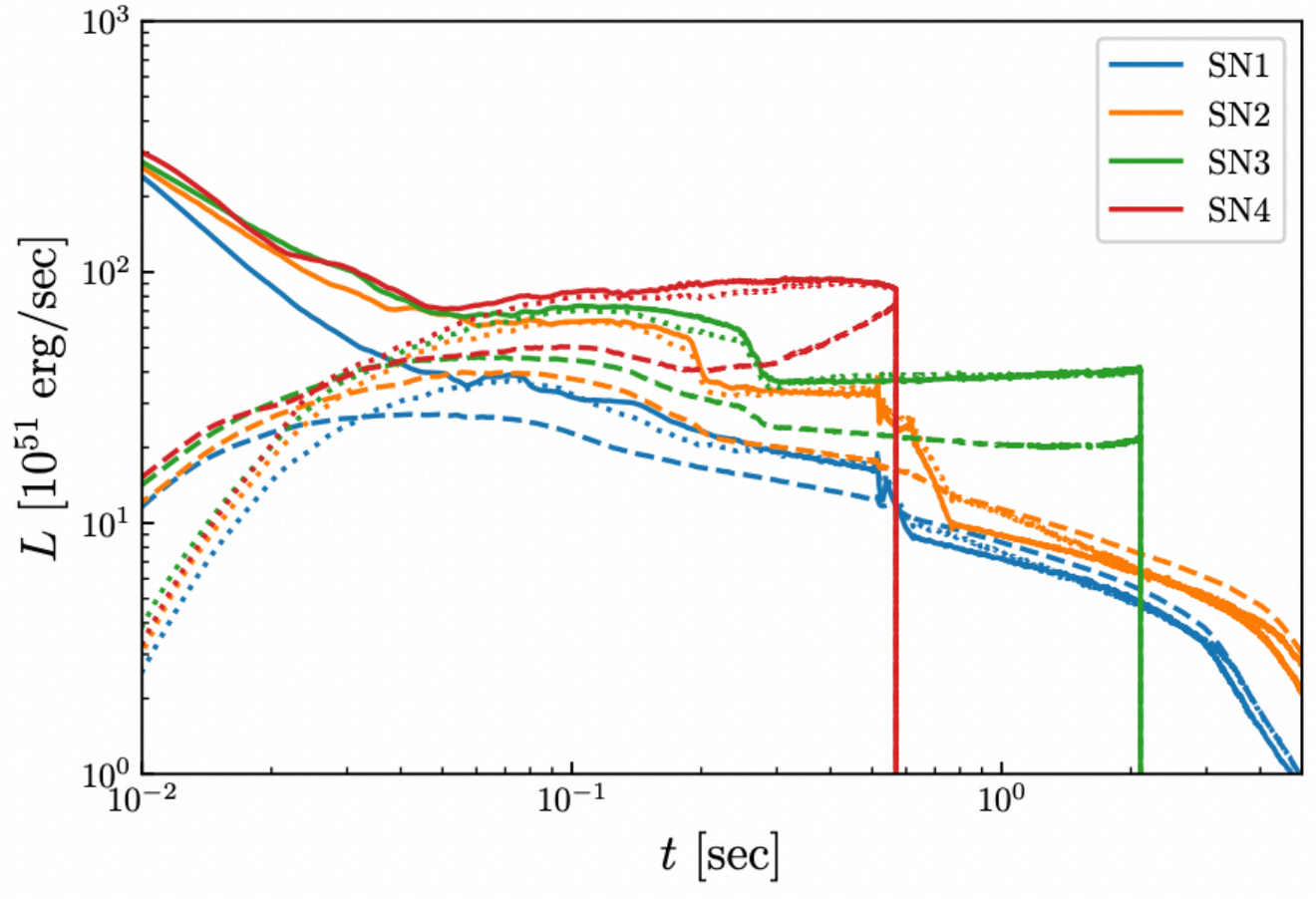
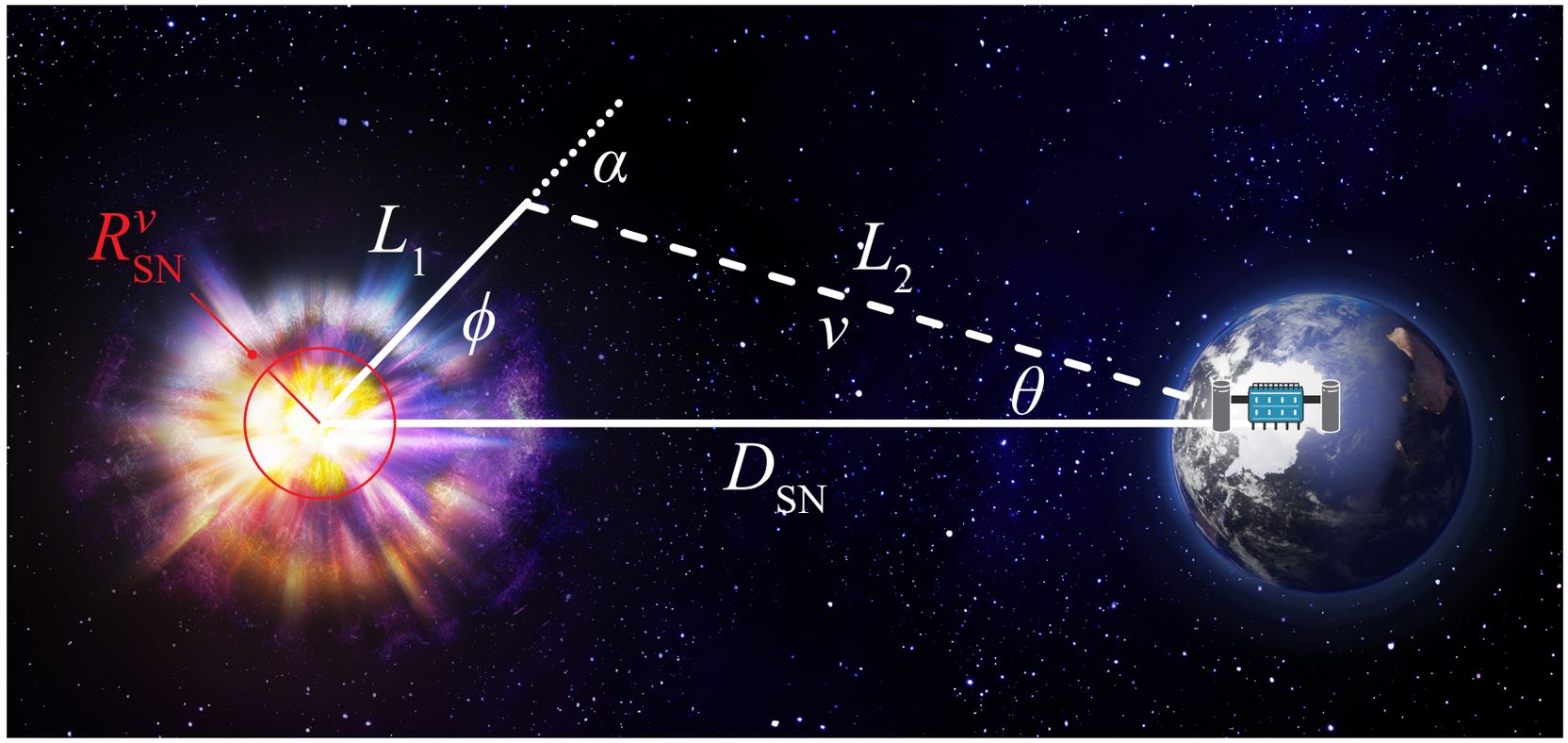
Neutrinos from SN bursts

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



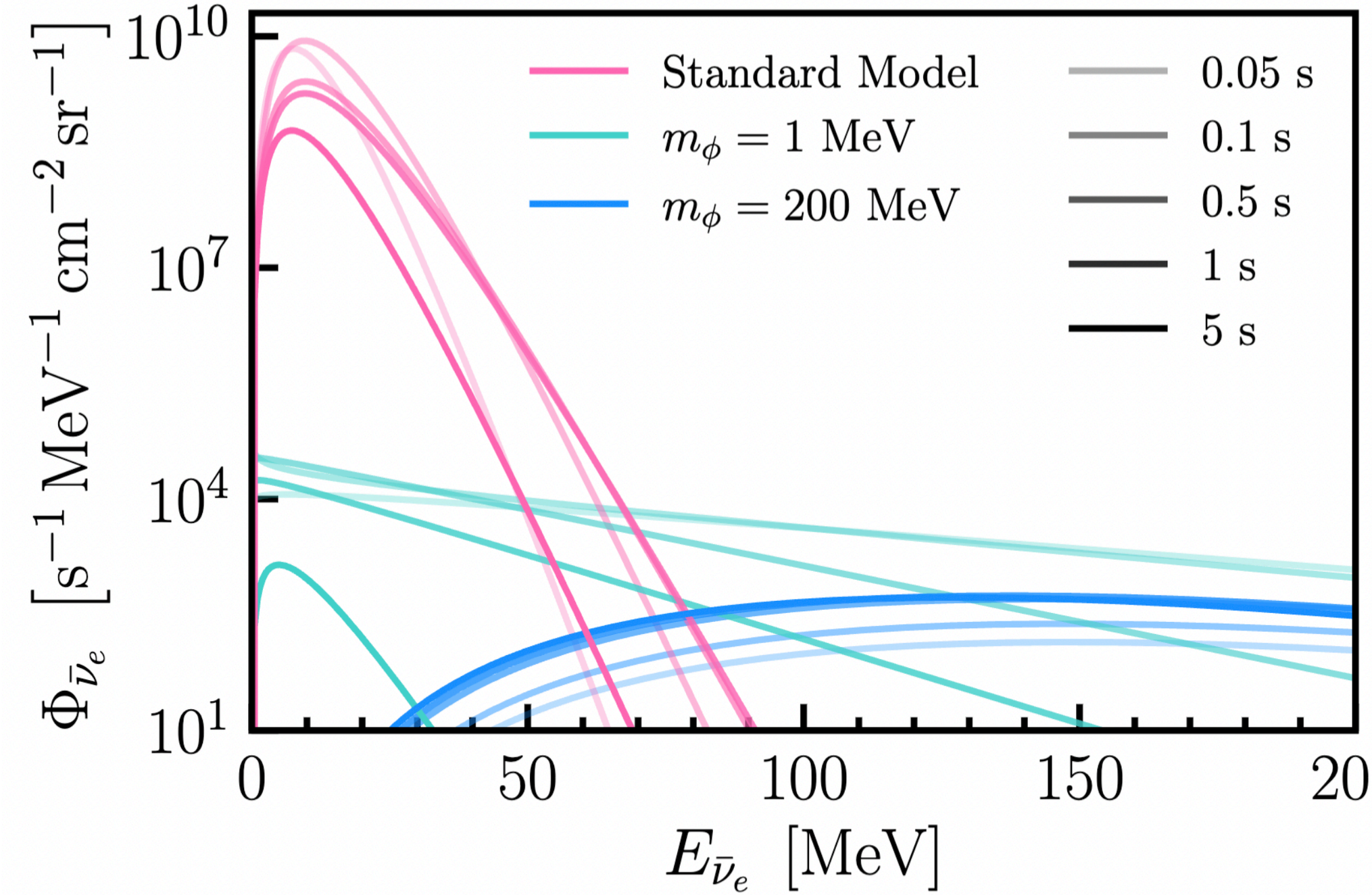


$$\mathcal{L} \supset -g_{\alpha\beta}\nu_\alpha\nu_\beta\phi + \text{h.c.} - m_\phi\phi\phi^*$$

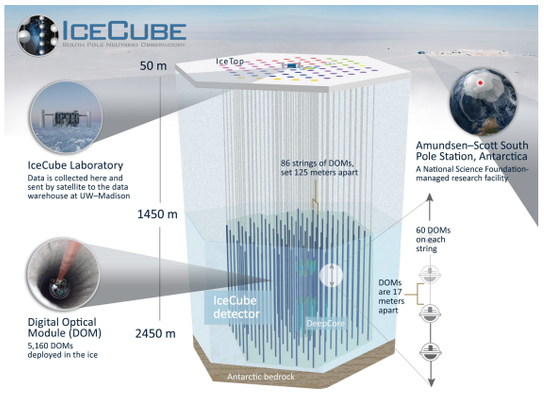


$$\delta t = \left(\frac{L_1}{\beta} - L_1\right) + (L_1 + L_2 - D_{\rm SN})$$

[C. A. Argüelles, V. Brdar, J. Lazar, **YYL**, arXiv:2403.09781]



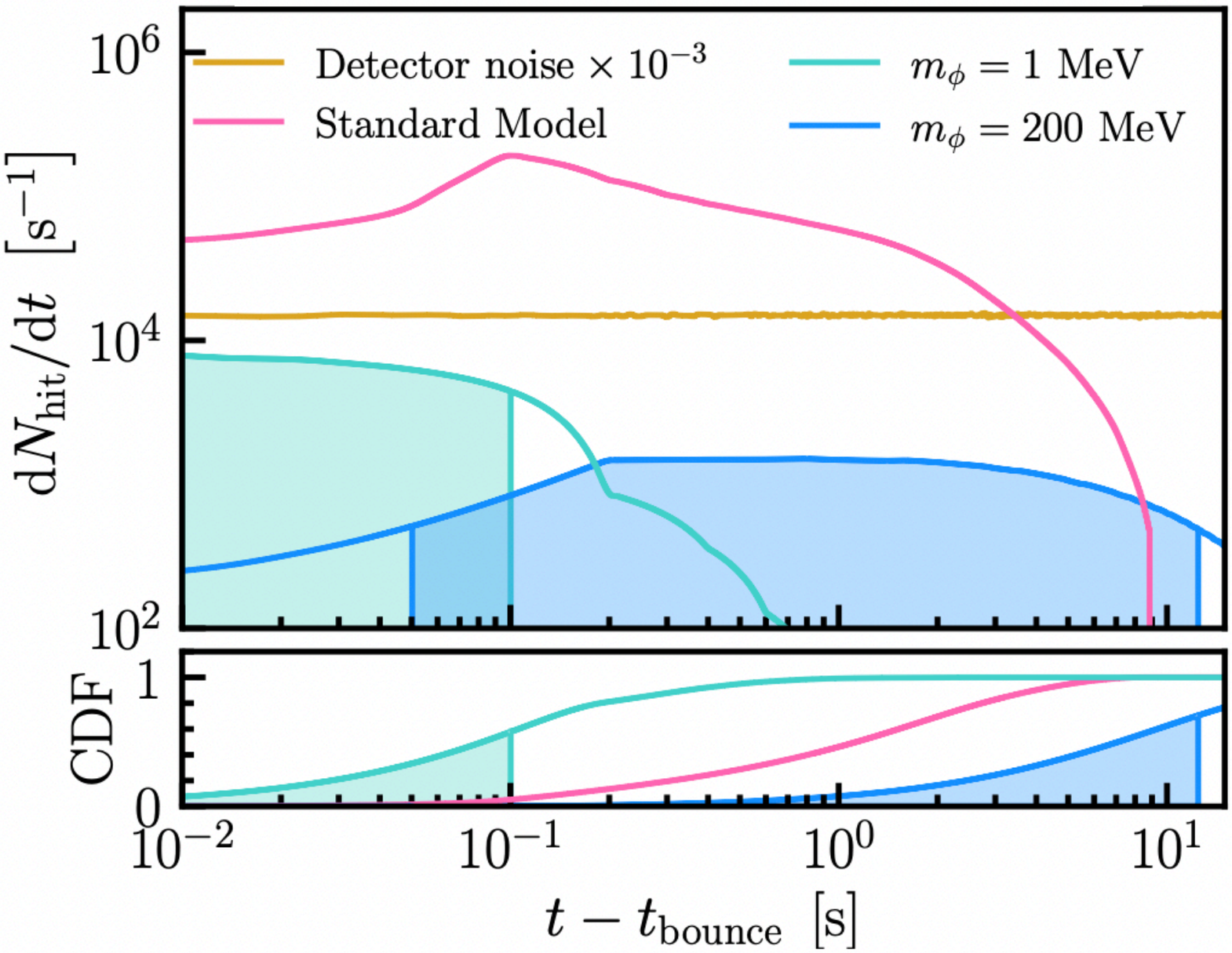
[C. A. Argüelles, V. Brdar, J. Lazar, **YYL**, arXiv:2403.09781]



High energy (TeV): muon neutrino

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

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



[C. A. Argüelles, V. Brdar, J. Lazar, **YYL**, arXiv:2403.09781]

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

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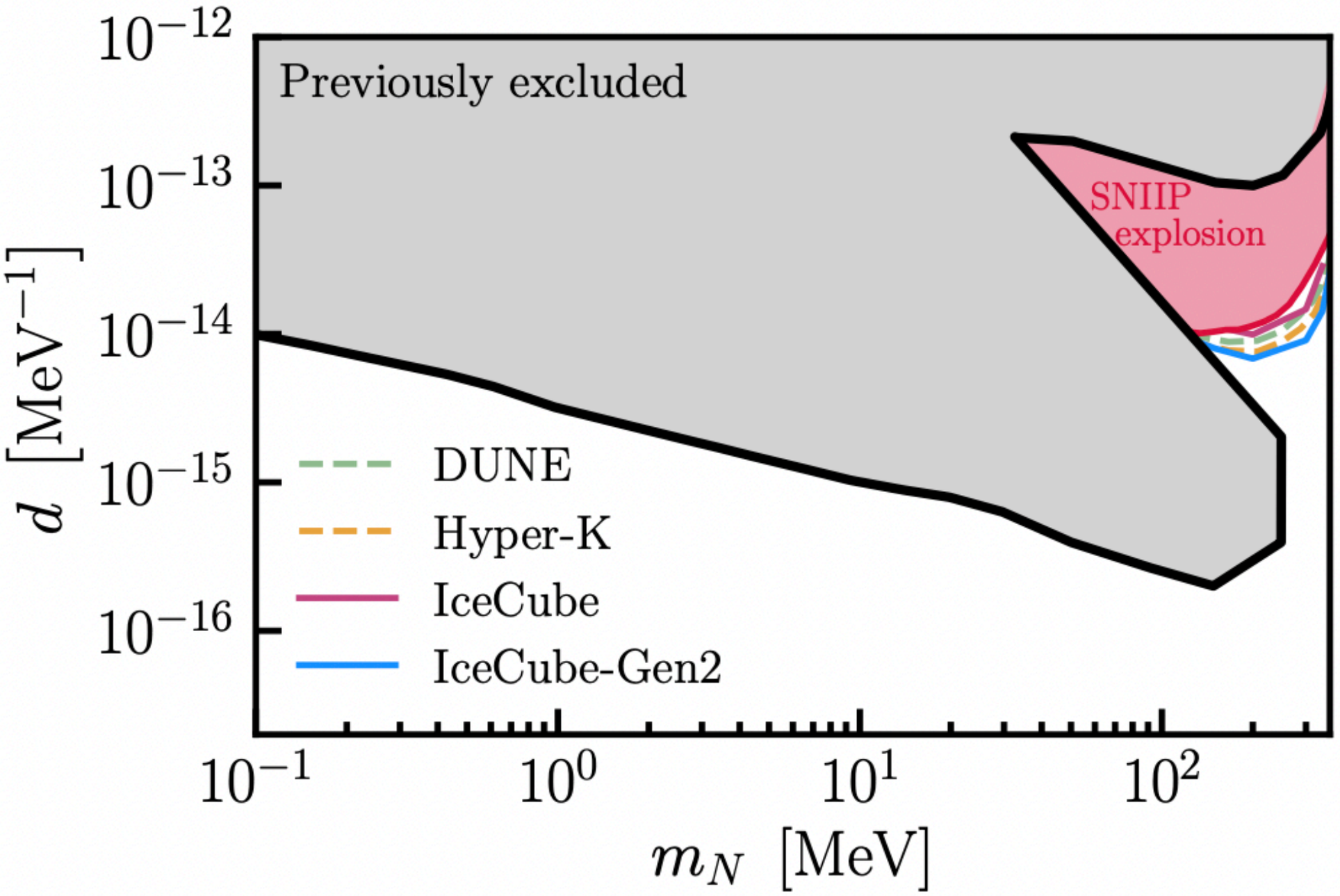

[C. A. Argüelles, V. Brdar, J. Lazar, **YYL**, arXiv:2403.09781]

Spallation Neutron Source (SNS)

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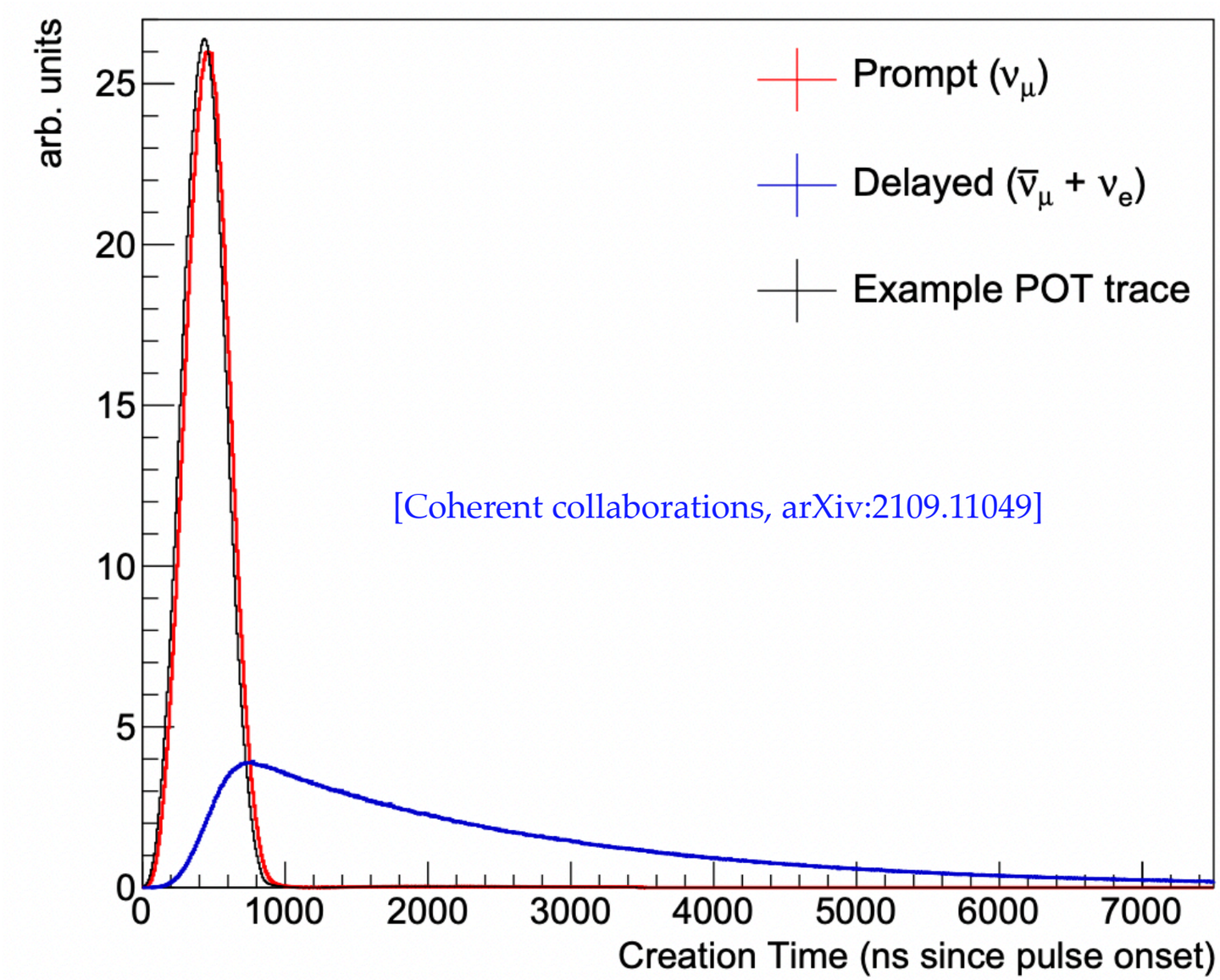
$$\pi^+ \to \mu^+ + \nu_\mu$$

$$\mu^+ \to e^+ + \bar{\nu}_\mu + \nu_e$$



Spallation Neutron Source (SNS)

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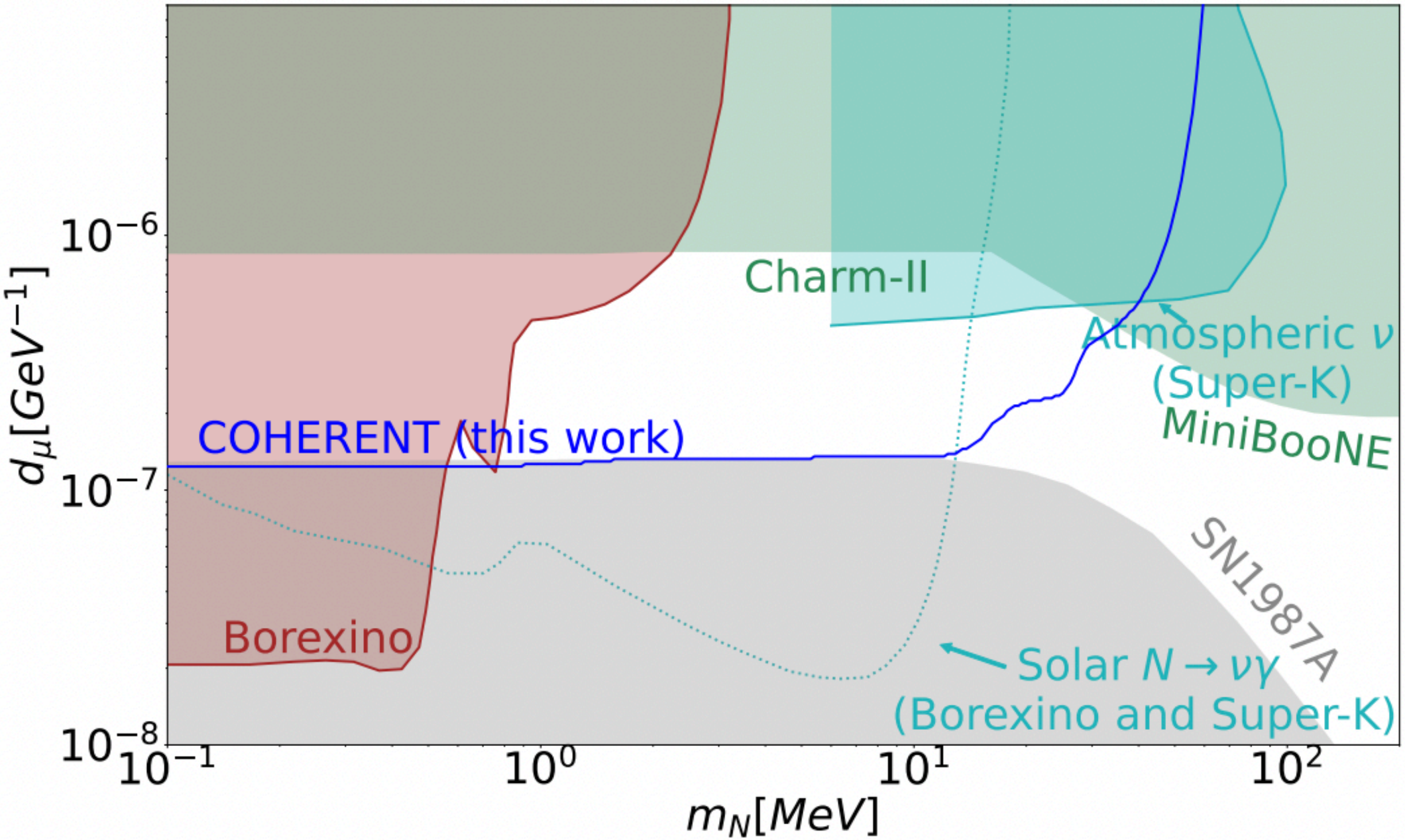
Flavor specific $\mathcal{L} \supset \frac{1}{2}\mu_\nu \bar{\nu}_L^\alpha \sigma^{\mu\nu} N F_{\mu\nu}$



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

Thank you