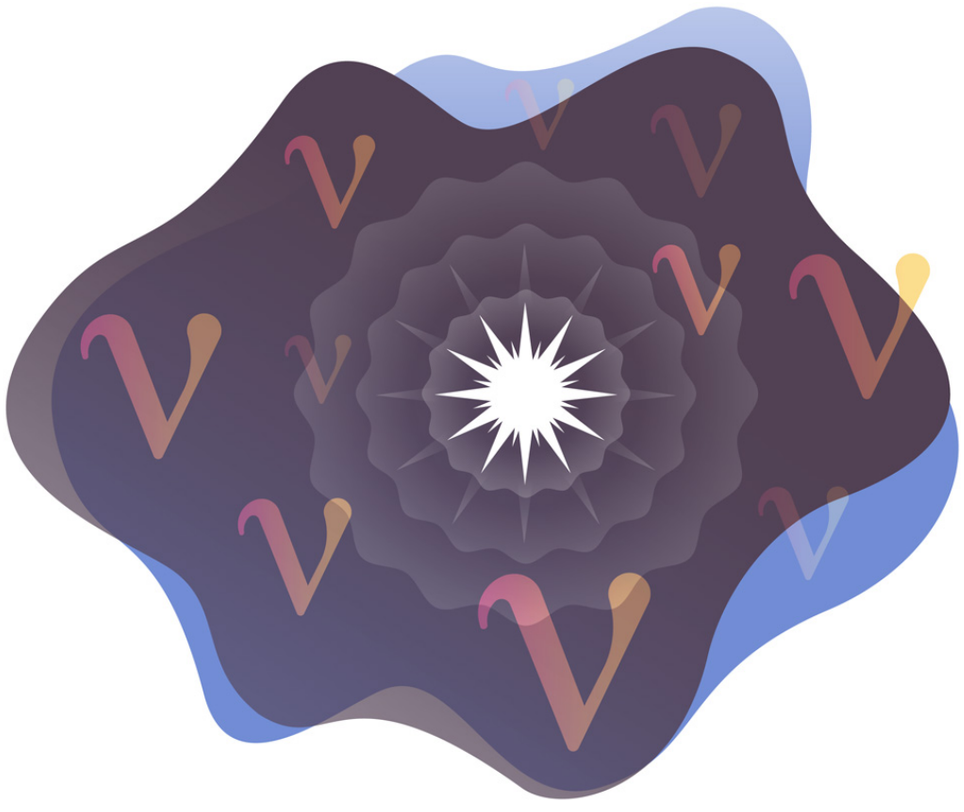
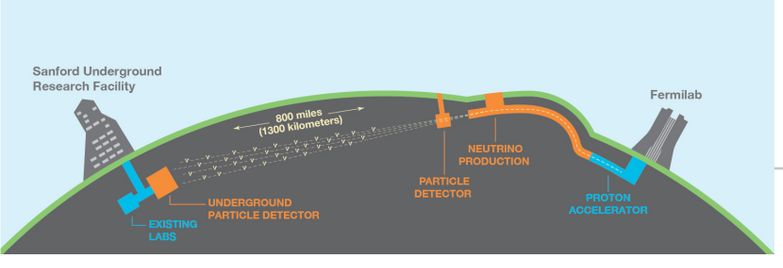




University of Science and Technology of China *Ying-Ying Li* (李英英)

arXiv: 2302.10965

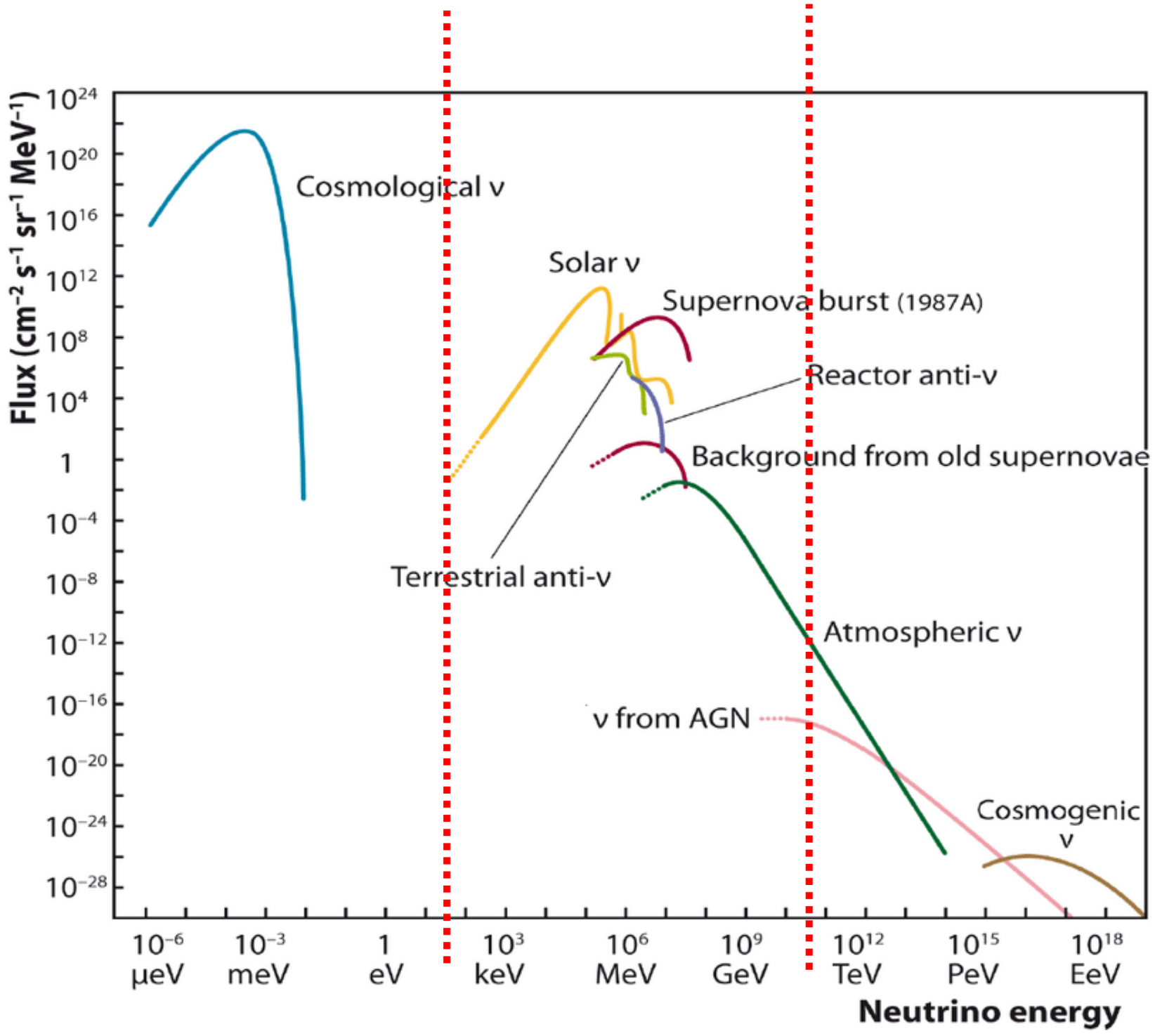
arXiv: 2403.09781

C. A. Argüelles, V. Brdar,
A. D. Gouv^ea, P. A. N. Machado,
J. Lazar

Supernovae Time Profiles as a Probe of New Physics at Neutrino Telescopes

Apr , 2024 @ JUNO*相关的理论和唯象研讨会, *CCAST

- looking to the sky

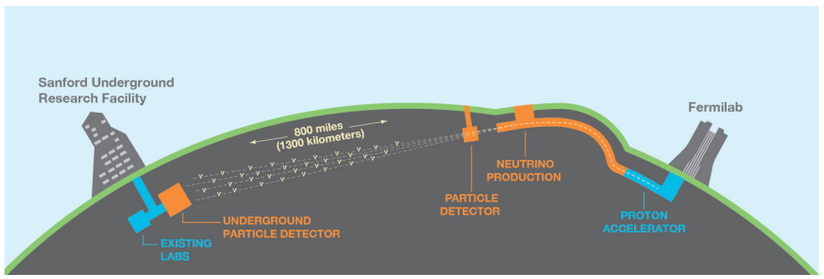


Multimessenger Signals

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

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

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



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

Multimessenger Signals

$$\nu + e^{\pm} \to N + e^{\pm}$$

$$\nu + p \to N + p$$

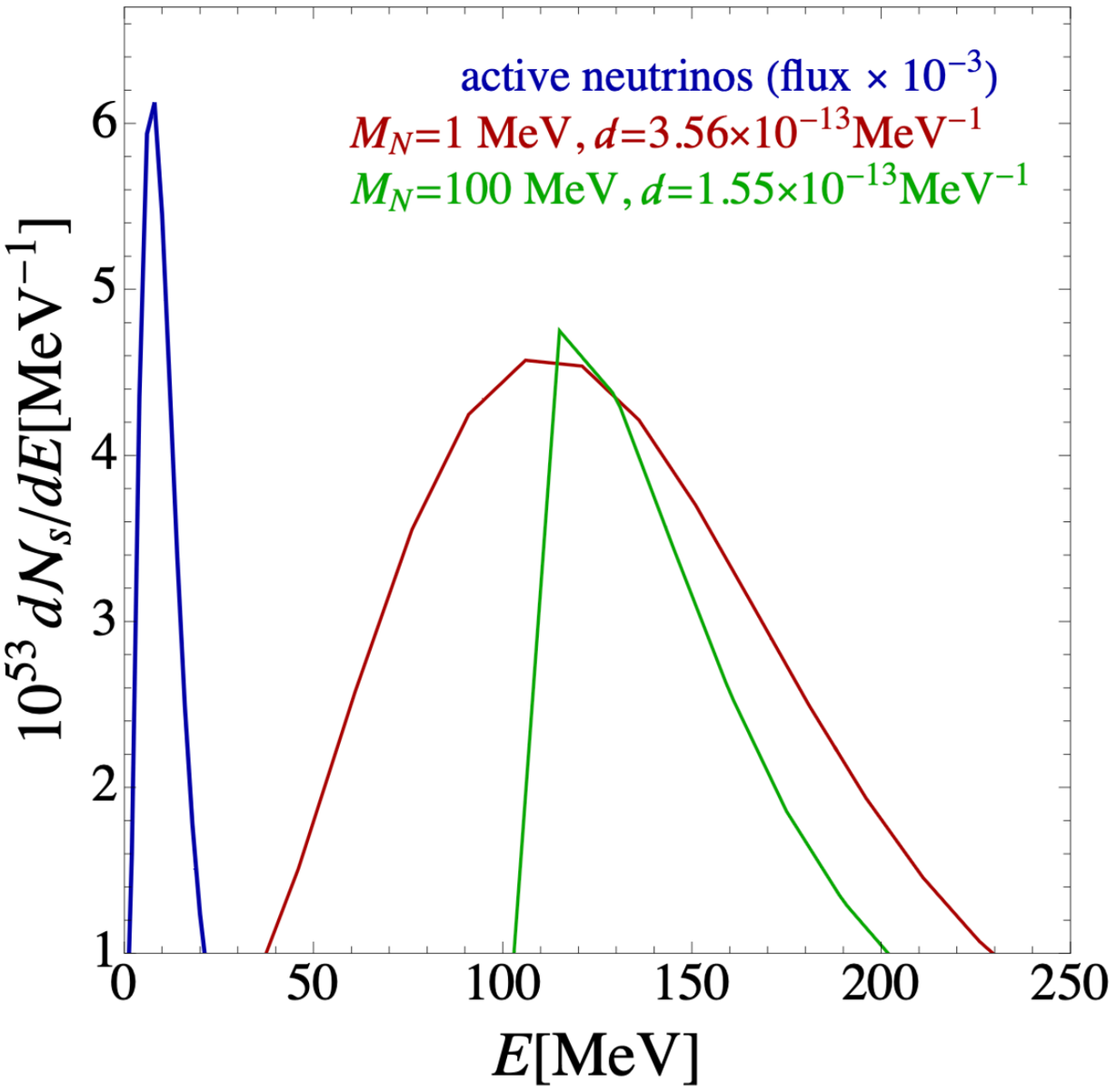
$$e^{+} + e^{-} \to \bar{\nu} + N$$

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

$$\frac{1}{4\pi r^2}\frac{\partial^2}{\partial r \partial t}\left(\frac{d\mathcal{N}_s}{dE_N}\right) = \sigma n_e \frac{dn_\nu}{dE}$$

using data associated to the simulation performed by the Garching group of an 8.8M⊙ progenitor star

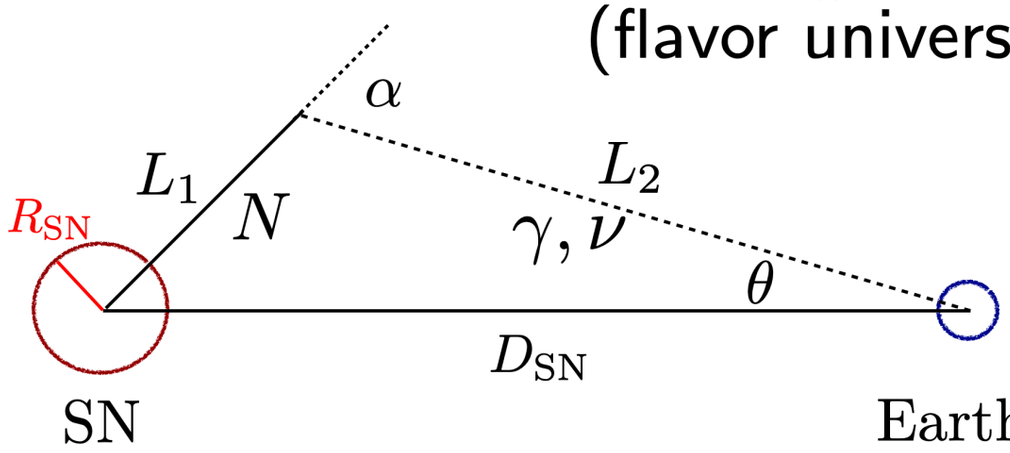
[V. Brdar, A. D. Gouv^ea, YYL, P. A. N. Machado, arXiv:2302.10965]



sterile neutrinos are produced in a dense T ~ 100 MeV core and leave subsequently the star without further interactions

Multimessenger Signals

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



$$\cos\alpha = \frac{2E_N E_{\gamma/\nu} - M_N^2}{2E_{\gamma/\nu}\sqrt{E_N^2 - M_N^2}}$$

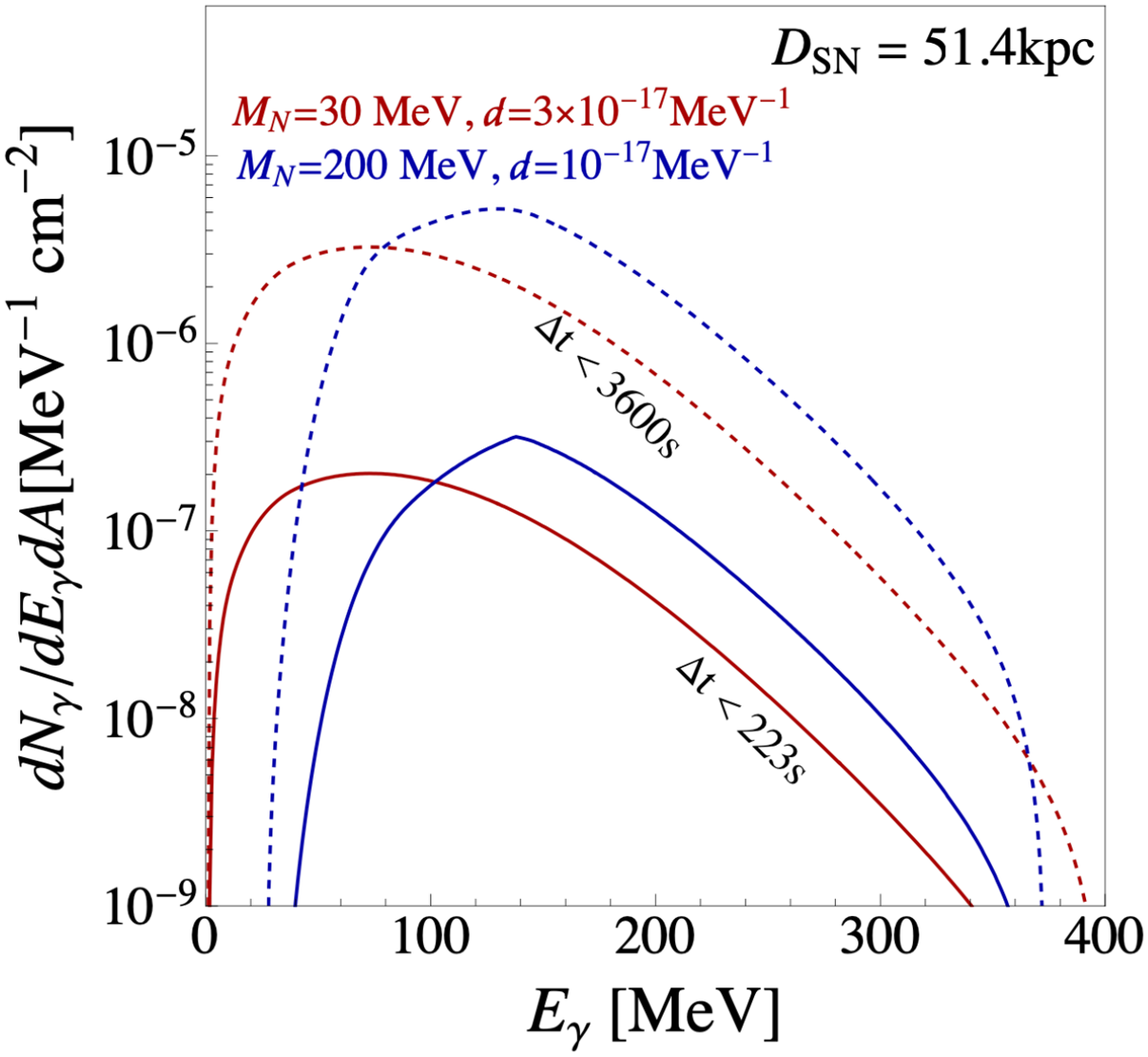
$$\Delta t = L_1/\beta + L_2 - D_{\rm SN}$$

$$\beta = \sqrt{E_N^2 - M_N^2}/E_N$$

$$R_{\rm SN}^{\gamma/\nu} \le L_1 \le L_1^{\rm max}$$

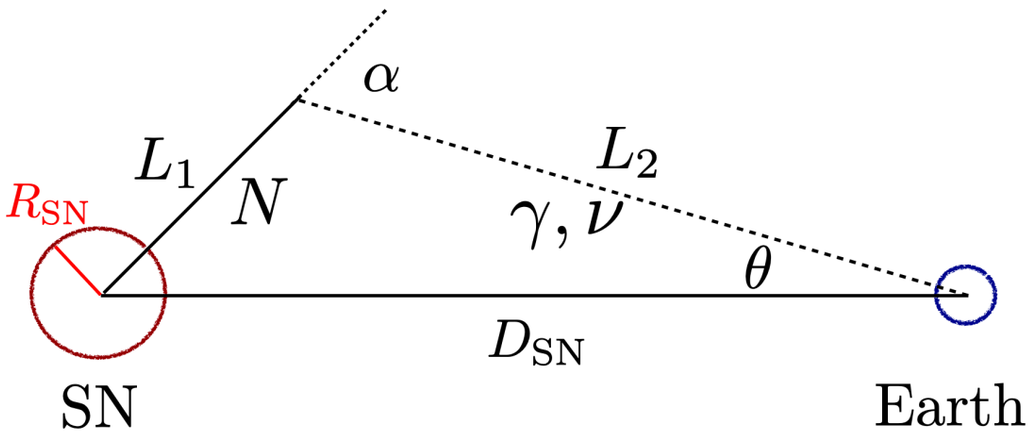
$$R_{\rm SN}^{\gamma} = 3\times 10^{10}\,{\rm m}$$

$$R_{\rm SN}^{\nu} = 30\ {\rm km}$$



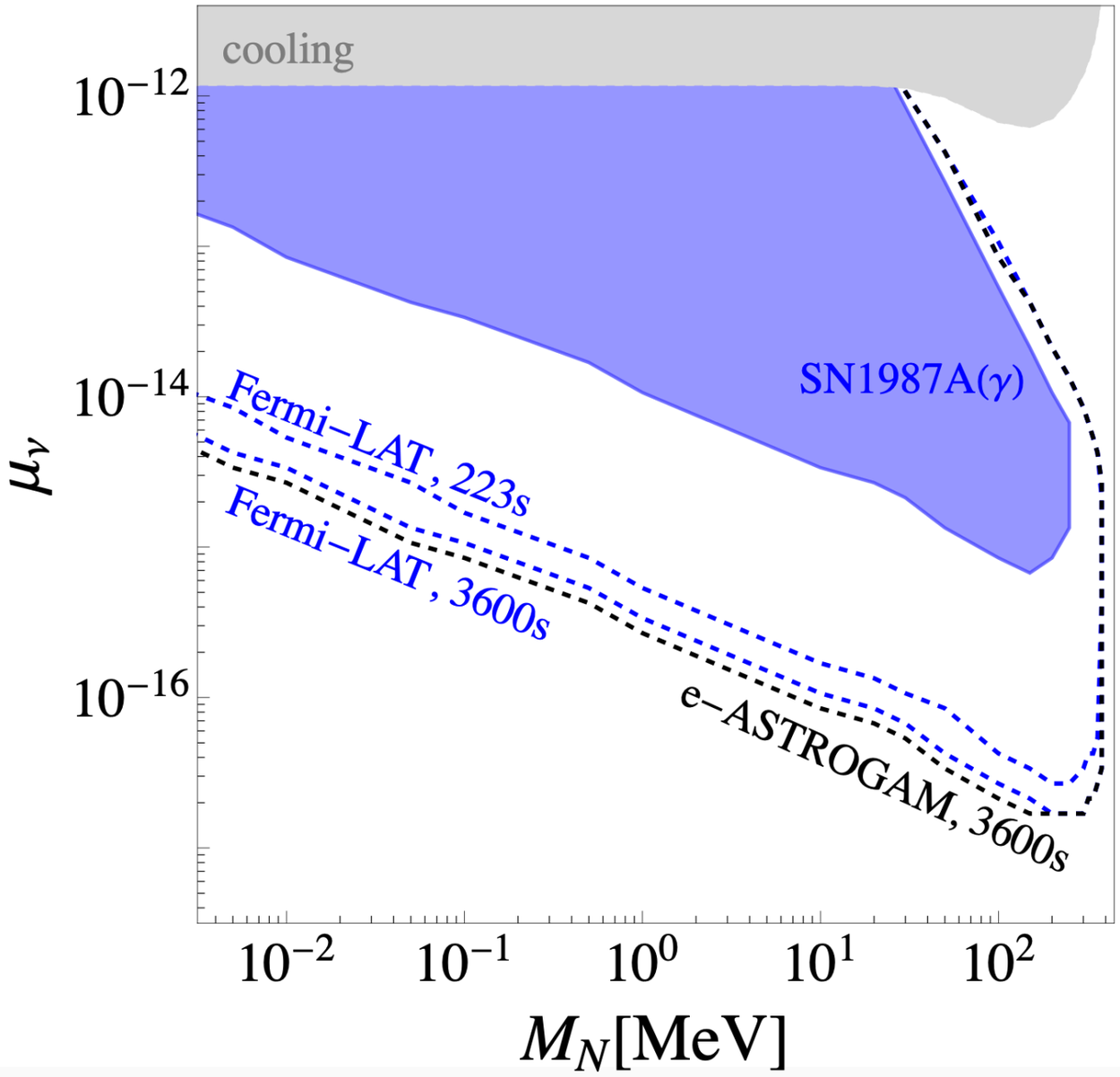
[V. Brdar, A. D. Gouv^ea, YYL, P. A. N. Machado, arXiv:2302.10965]

Multimessenger Signals : γ – ray detection



- 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: $E_\gamma > 1\text{MeV}, \theta < 1.25^\circ$

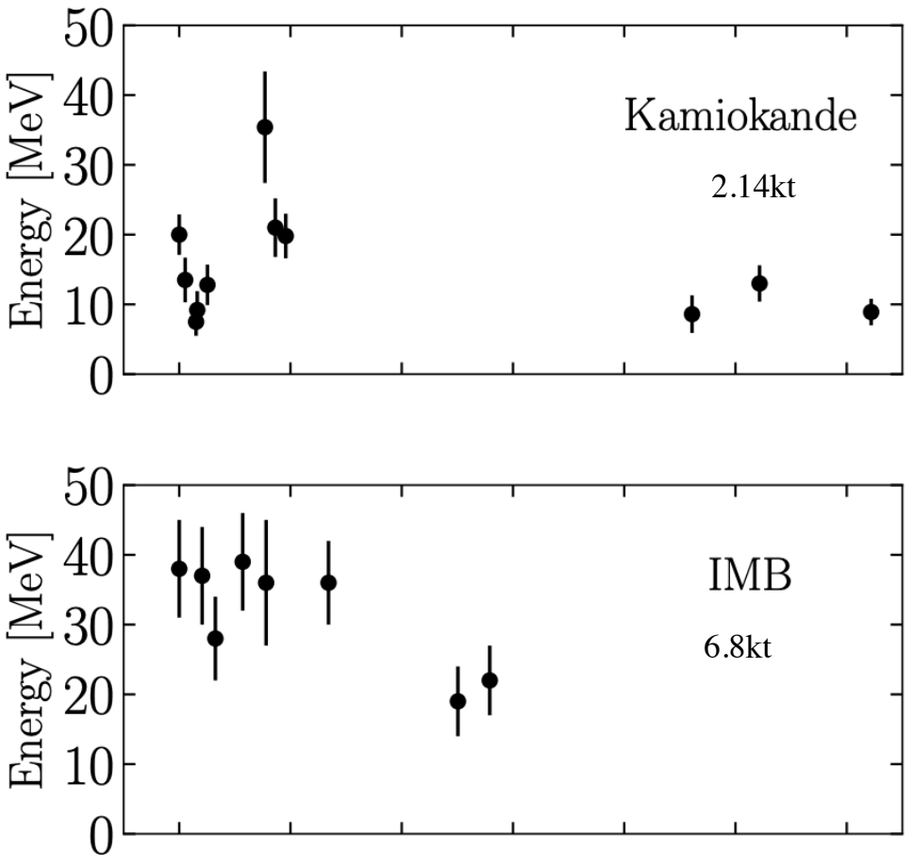


[V. Brdar, A. D. Gouv^ea, YYL, P. A. N. Machado, arXiv:2302.10965]

Multimessenger Signals : neutrino detection

SN1987A, neutrino events

water-Cherenkov detectors

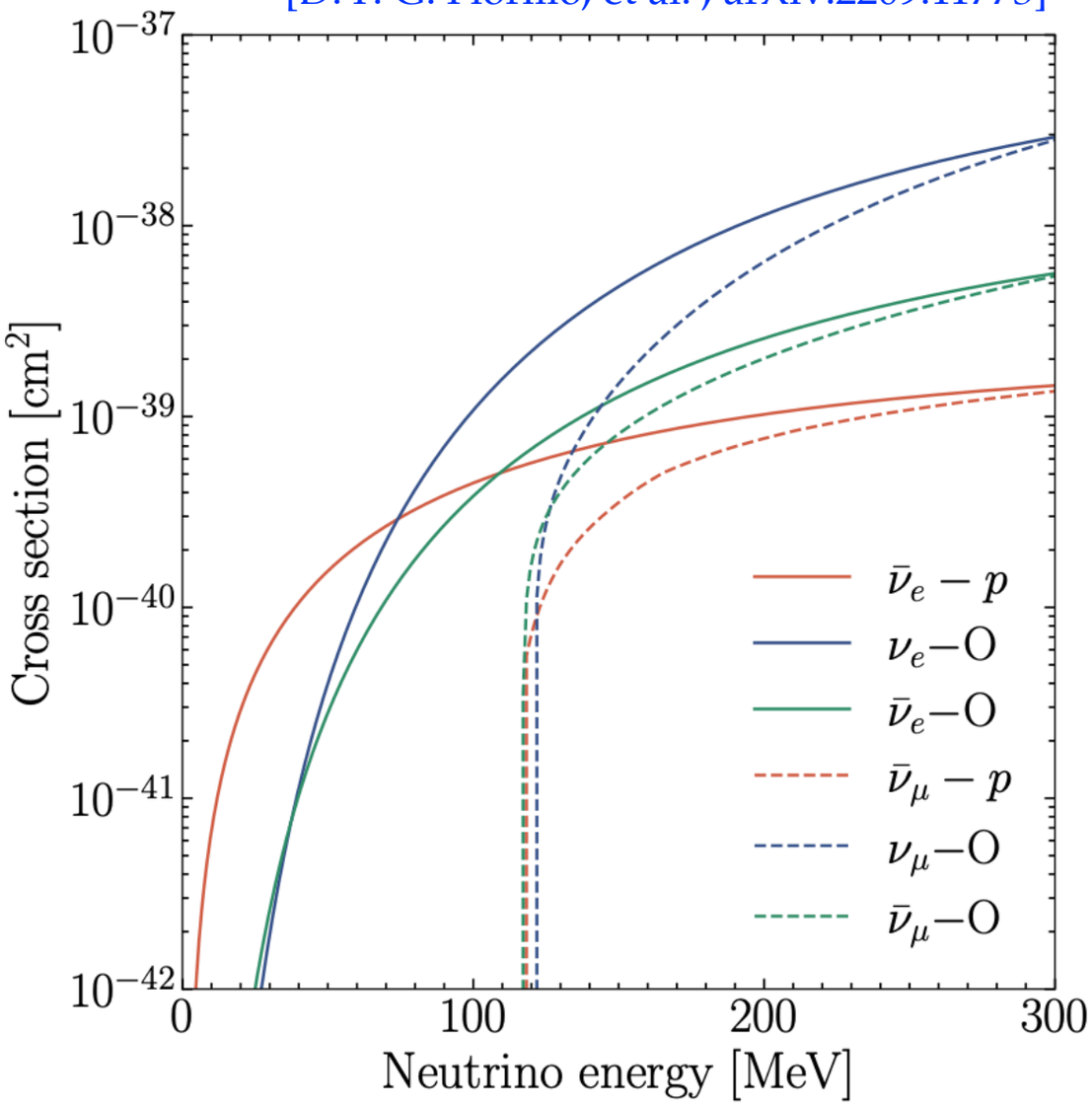


- No significant excess was observed by Kamiokande-II and IMB for

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

$$N_\nu^{\text{BSM}} = N_{\text{tgt}} \int dE_\nu \frac{dN_\nu}{dE_\nu dA}(E_\nu)\, \sigma_{\text{IBD}}(E_\nu)\, \varepsilon(E_\nu)$$

[D. F. G. Fiorillo, et al. , arXiv:2209.11773]



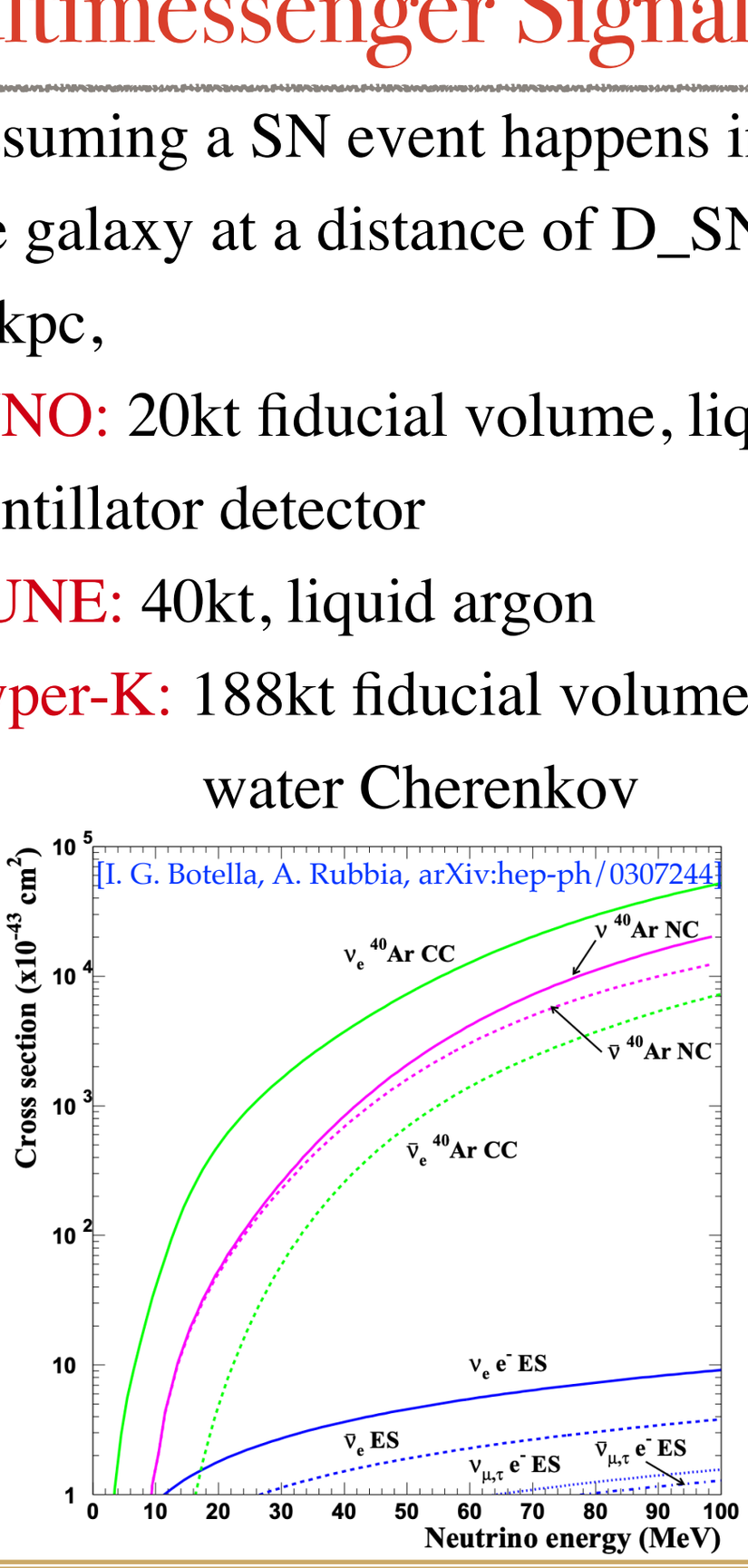
Multimessenger Signals : neutrino detection

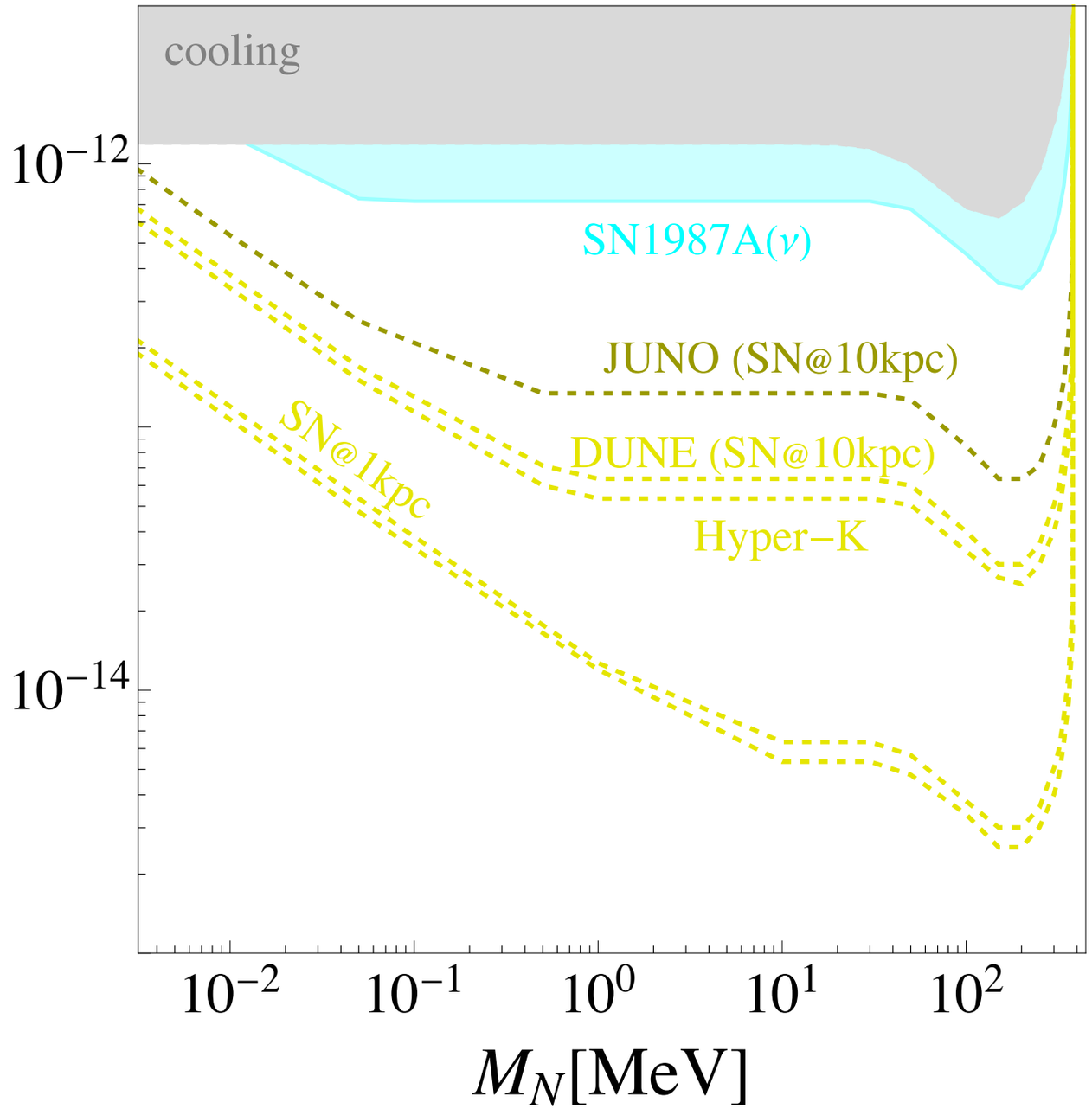
- Assuming a SN event happens in the galaxy at a distance of D_SN = 10kpc,

  JUNO: 20kt fiducial volume, liquid scintillator detector

  DUNE: 40kt, liquid argon

  Hyper-K: 188kt fiducial volume water Cherenkov



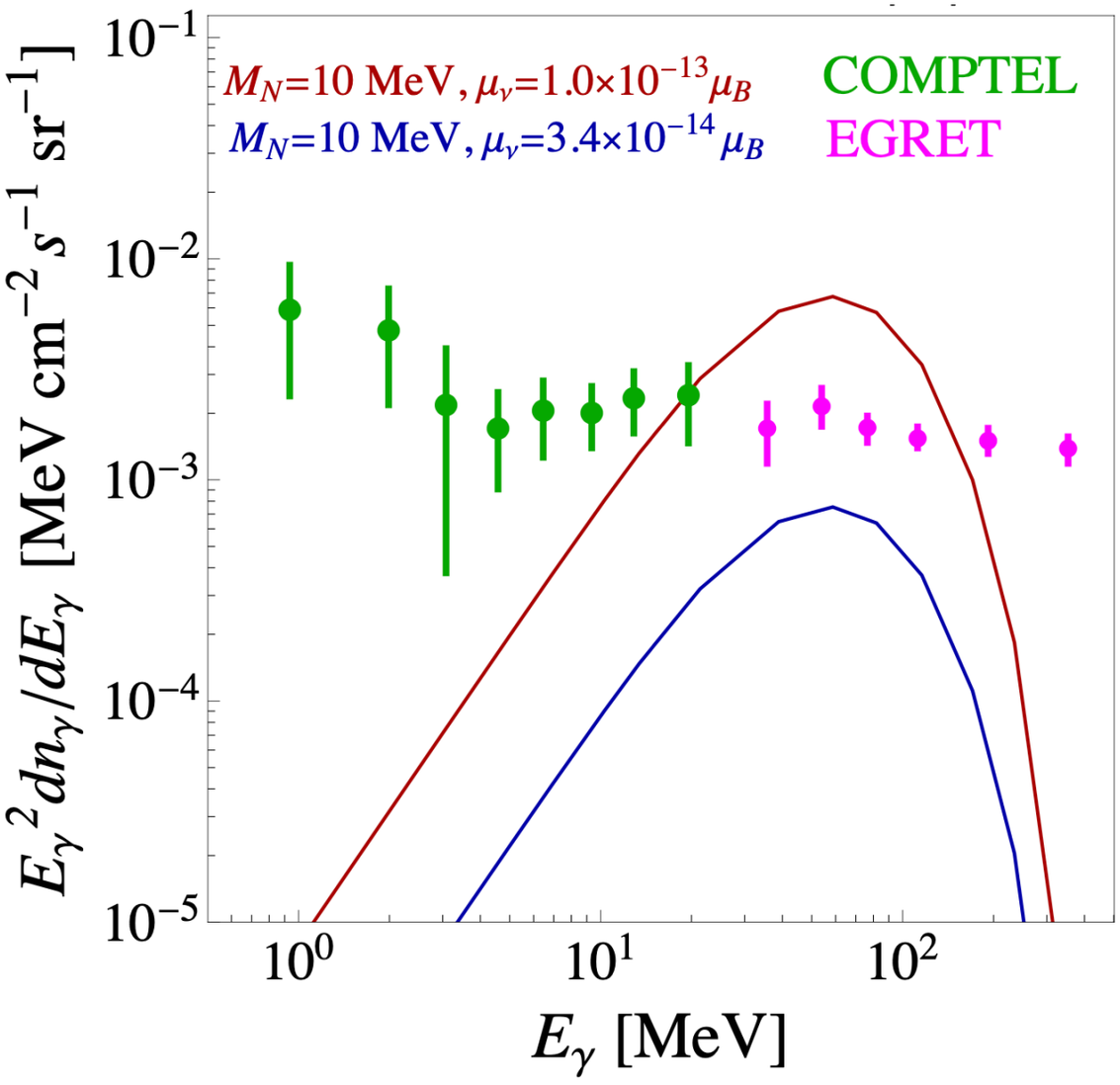


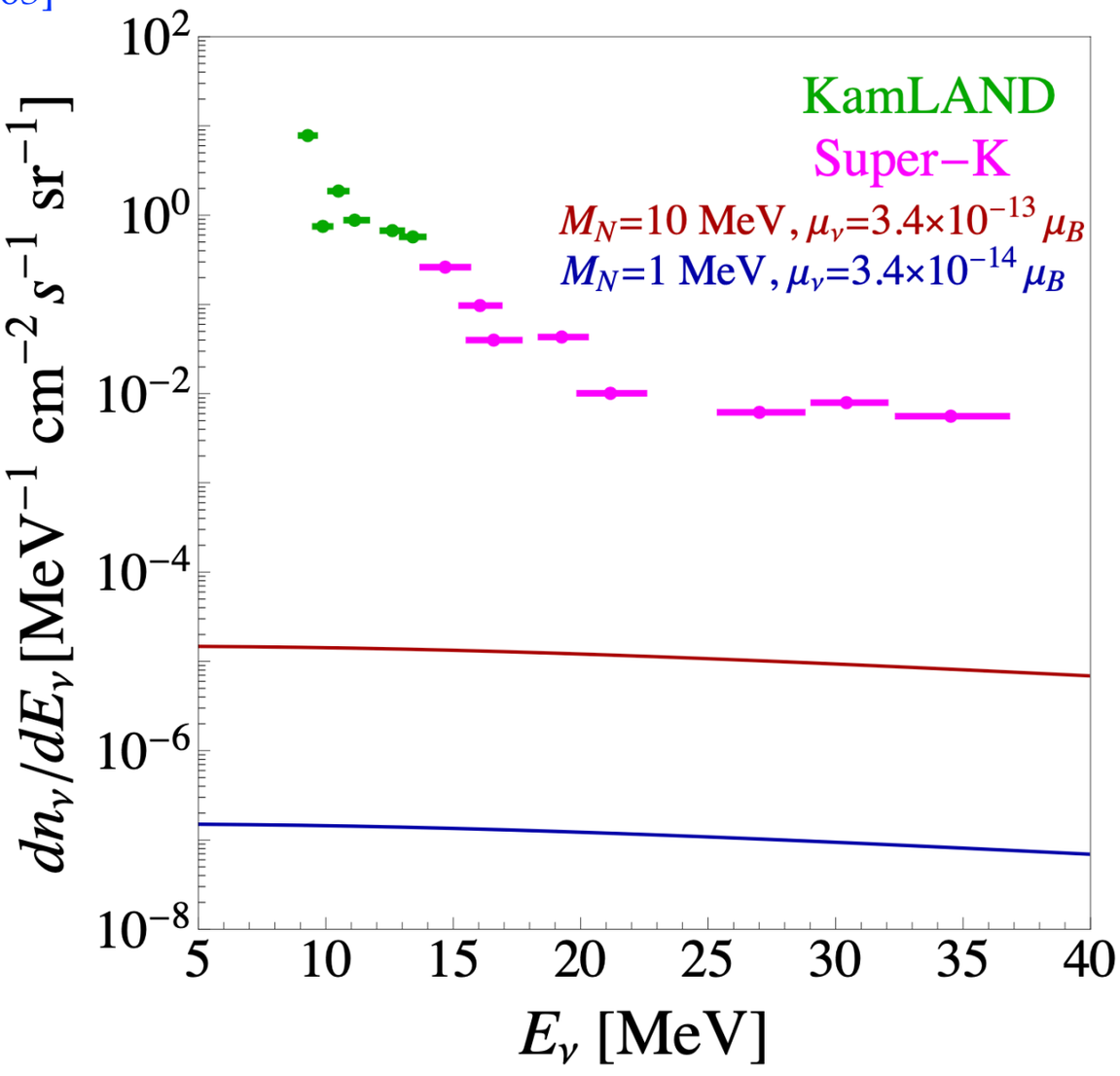
[V. Brdar, A. D. Gouv^ea, YYL, P. A. N. Machado, arXiv:2302.10965]

Multimessenger Signals : diffused BSM Photon and neutrino background

$$\frac{dn_N}{dE} = \frac{c}{4\pi}\int_0^\infty dz(1+z)\, n'_{\rm cc}(z)\, \frac{d\mathcal{N}_s}{dE}(E_z)$$

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

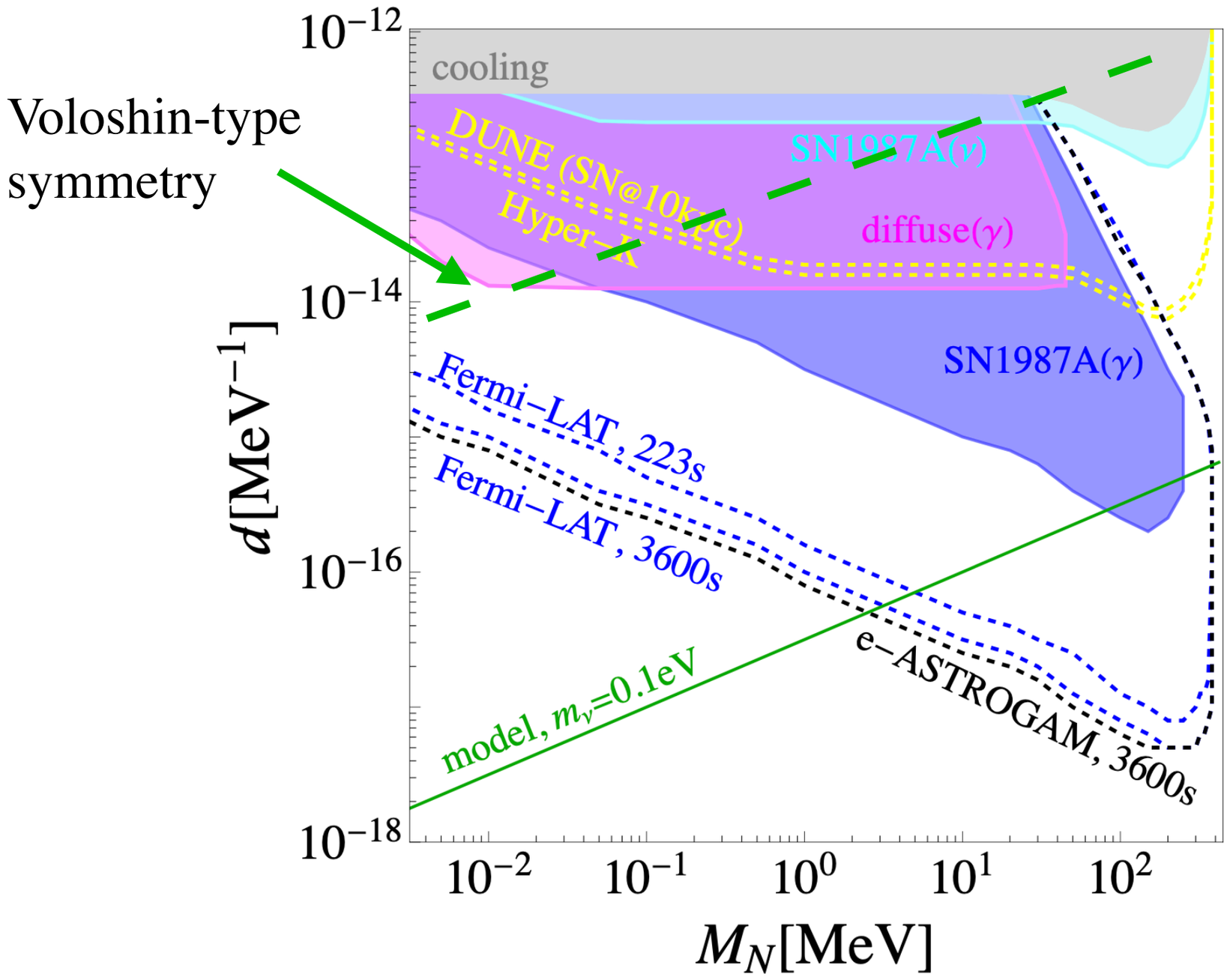




extragalactic background light

Multimessenger Signals : diffused BSM Photon and neutrino background

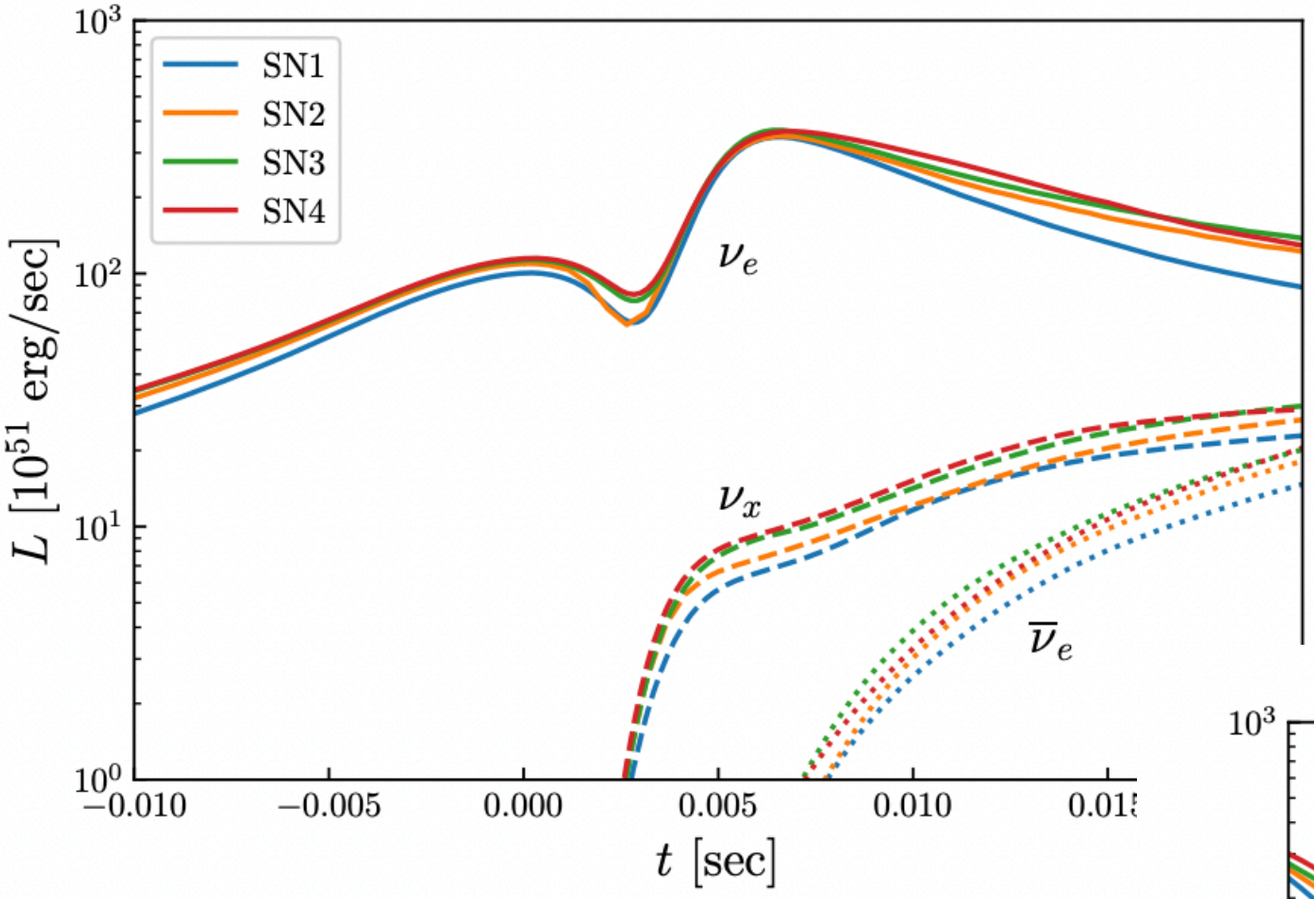
$$\mathcal{L} \supset \frac{1}{2}\mu_\nu \bar{\nu}_L^\alpha \sigma^{\mu\nu} N F_{\mu\nu}$$

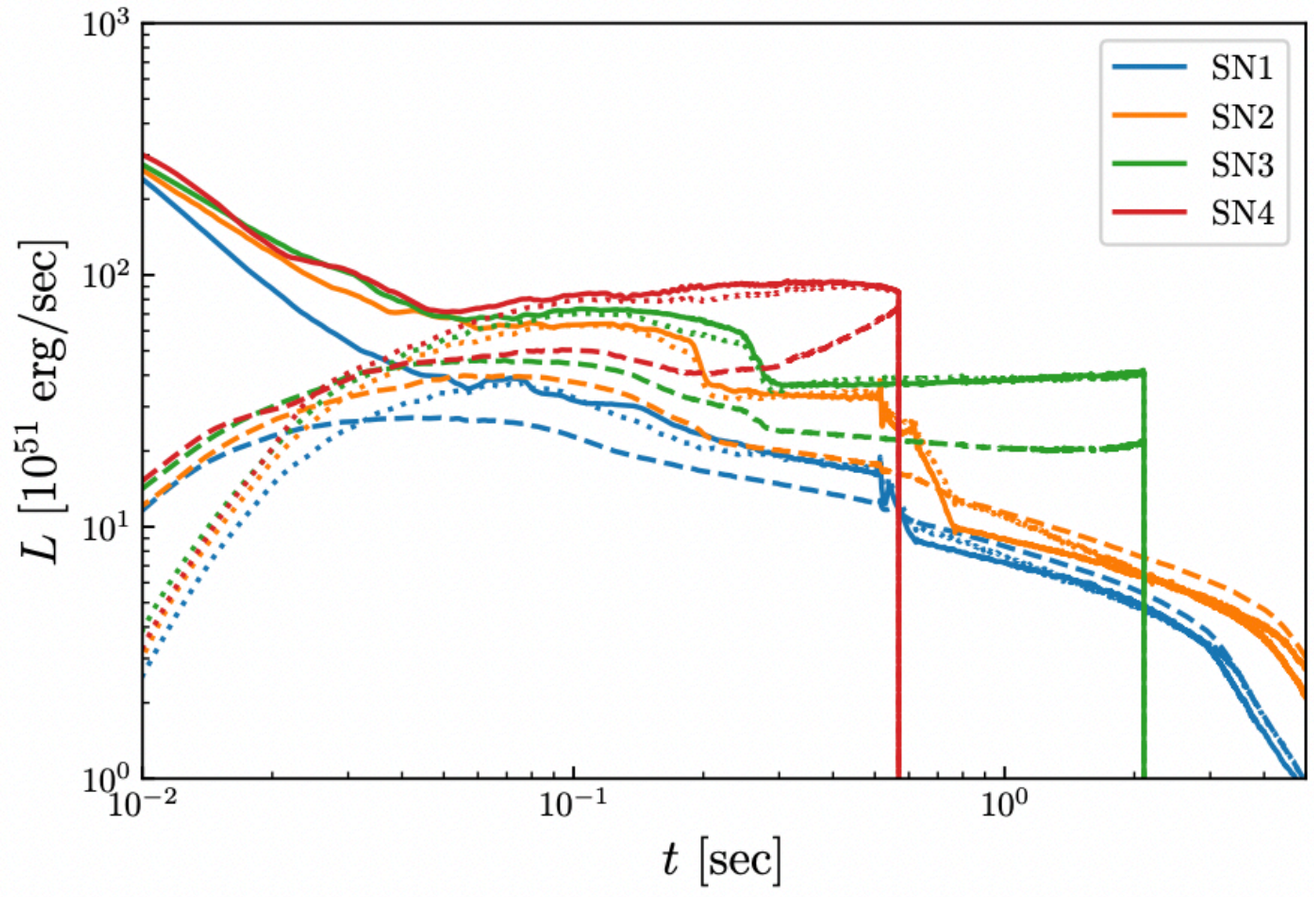


[V. Brdar, A. D. Gouv^ea, YYL, P. A. N. Machado, arXiv:2302.10965]

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

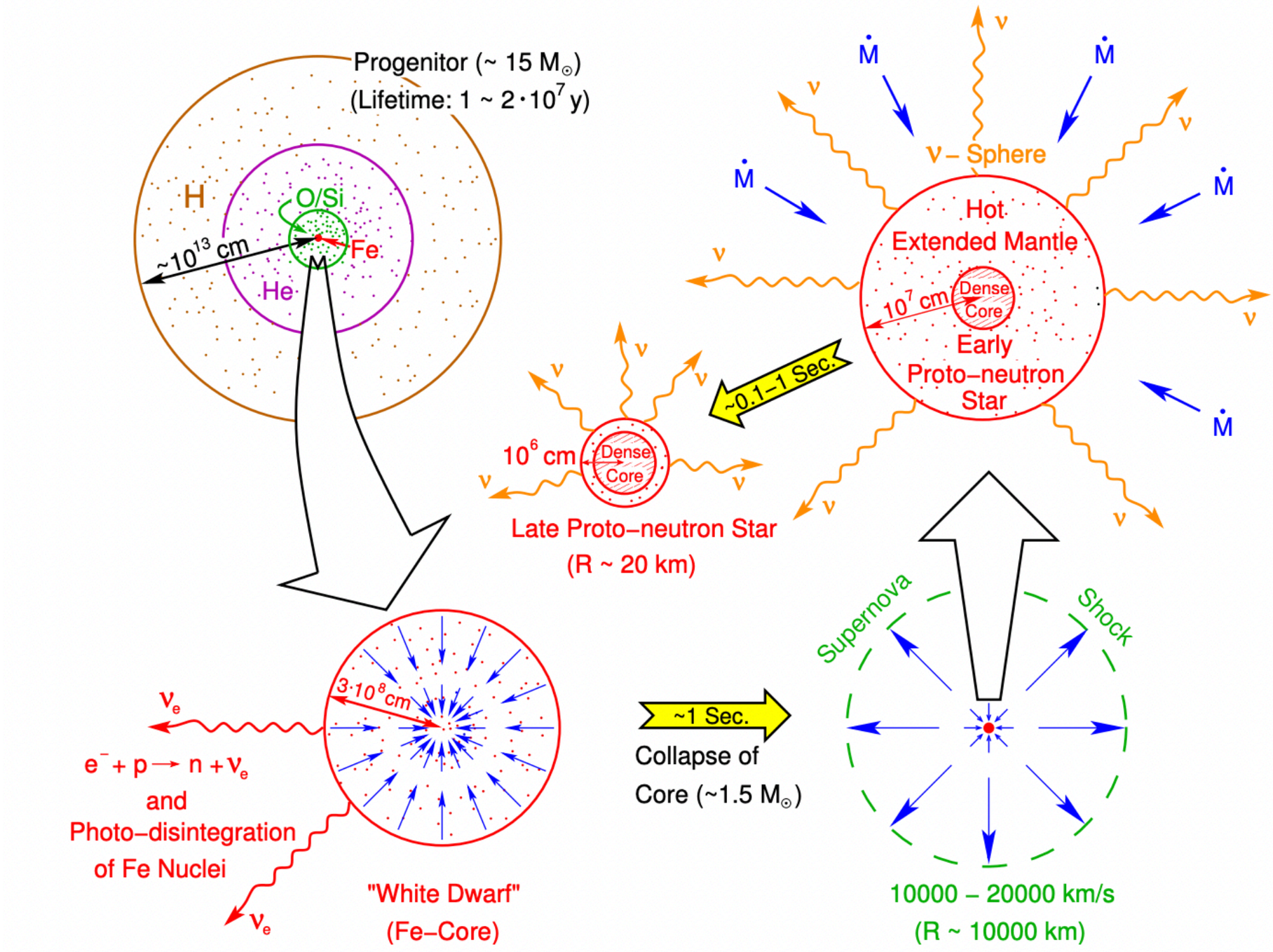
Neutrinos from SN bursts



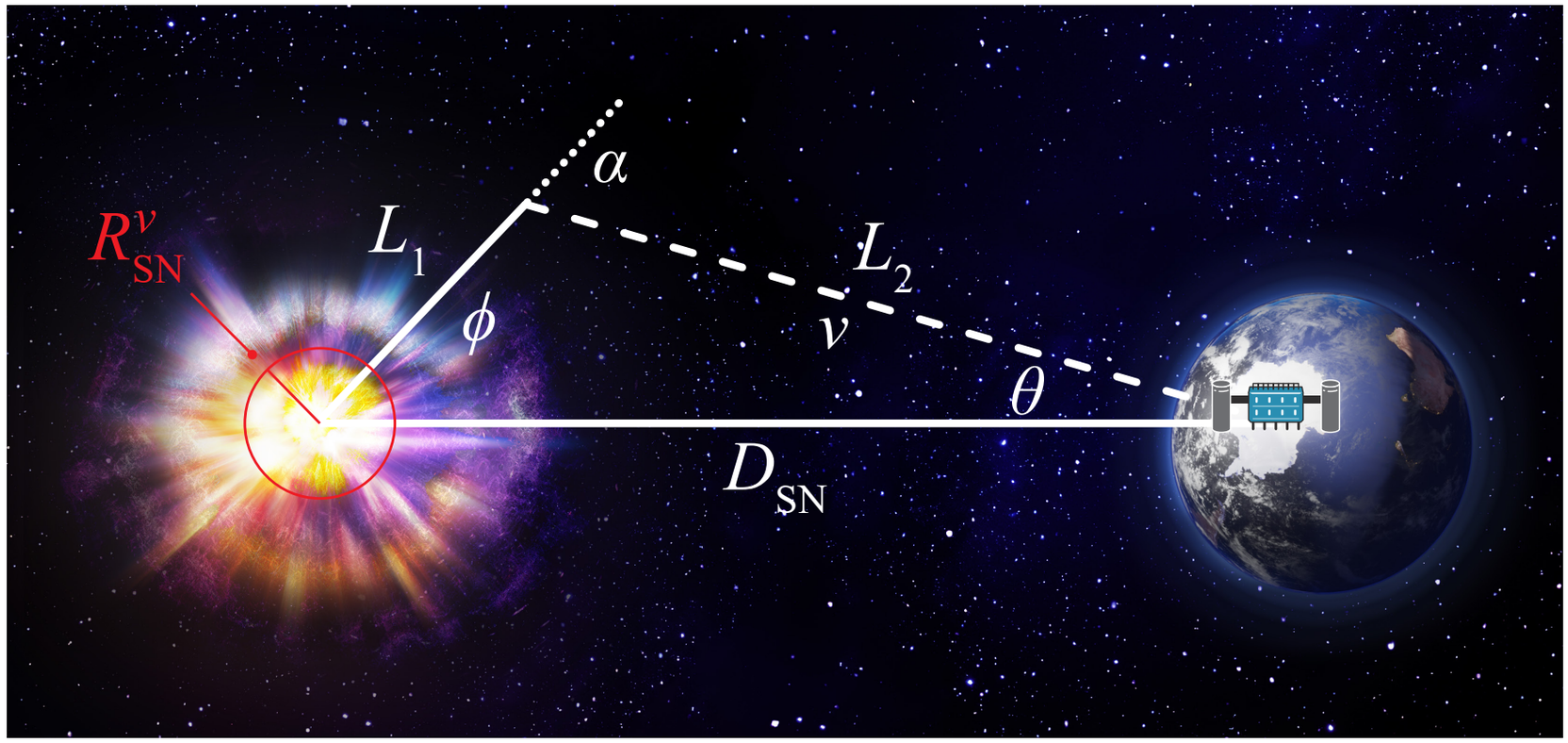


Evolution of a massive star from the onset of iron-core collapse to a neutron star

[Hans-Thomas Janka, arXiv:1702.08713]

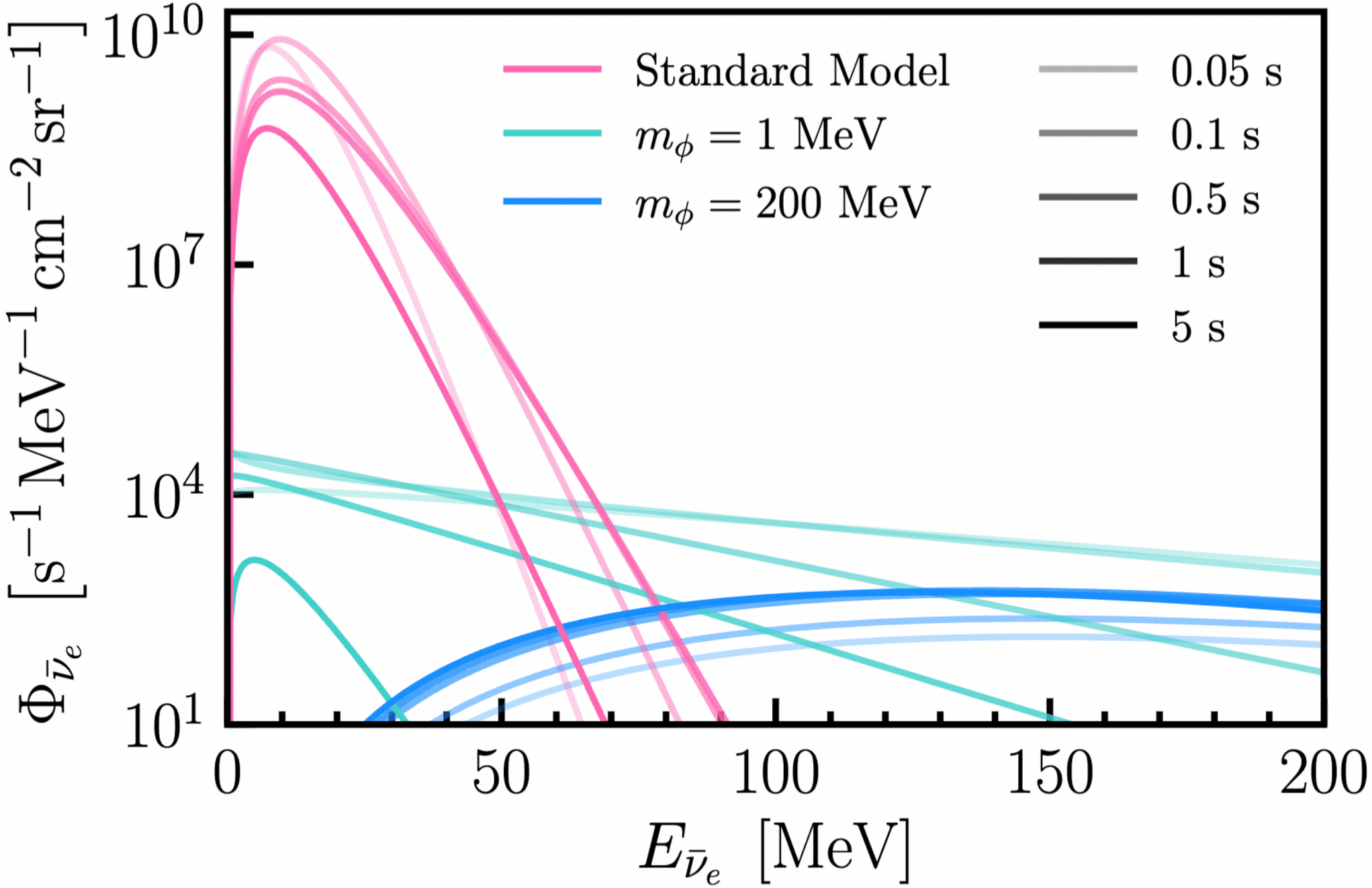


$$\mathcal{L} \supset -g_{\alpha\beta}\nu_\alpha\nu_\beta\phi + \text{h.c.} - m_\phi\phi\phi^*$$

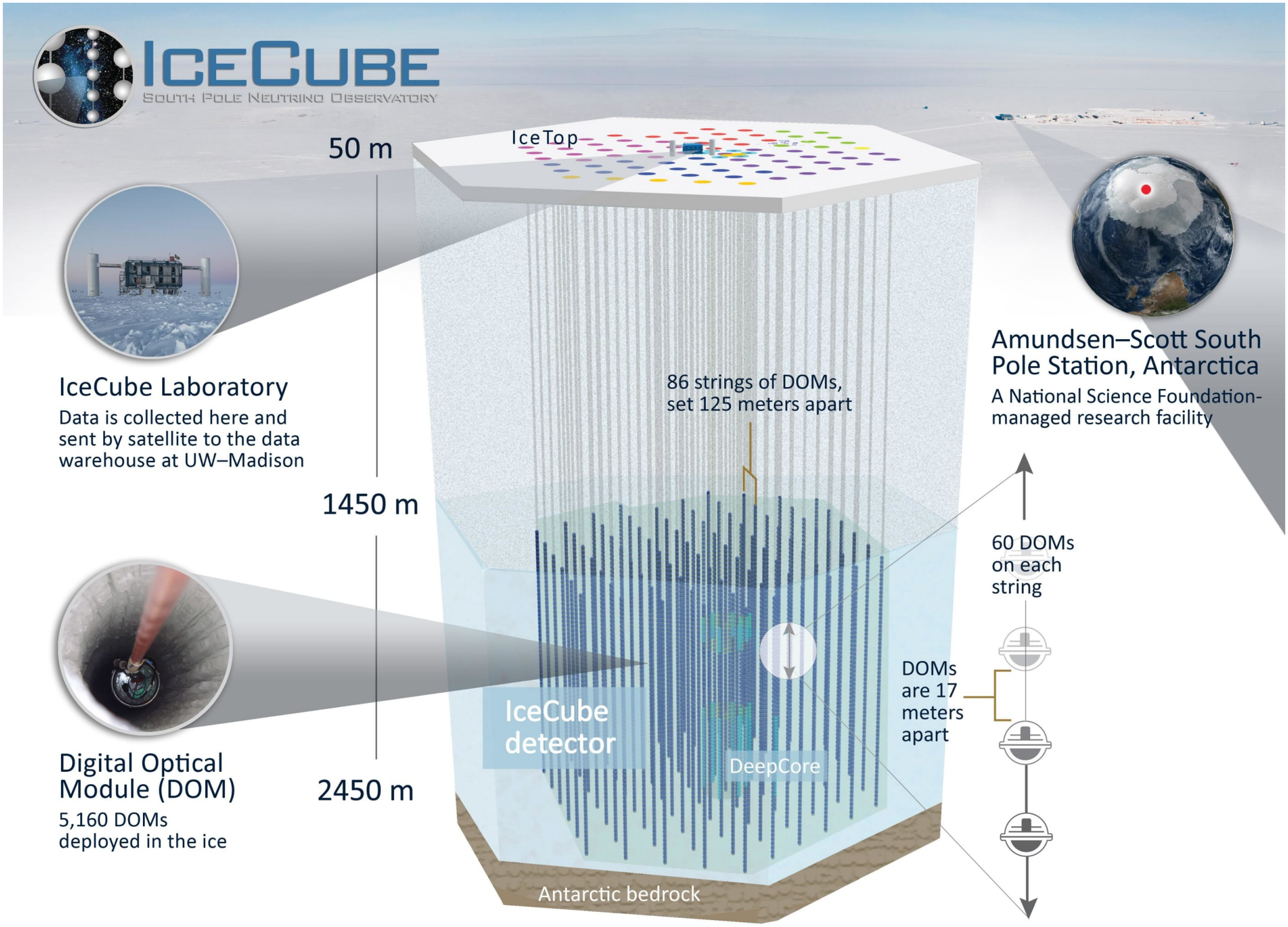


$$\delta t = \left(\frac{L_1}{\beta} - L_1\right) + (L_1 + L_2 - D_{\rm SN})$$

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

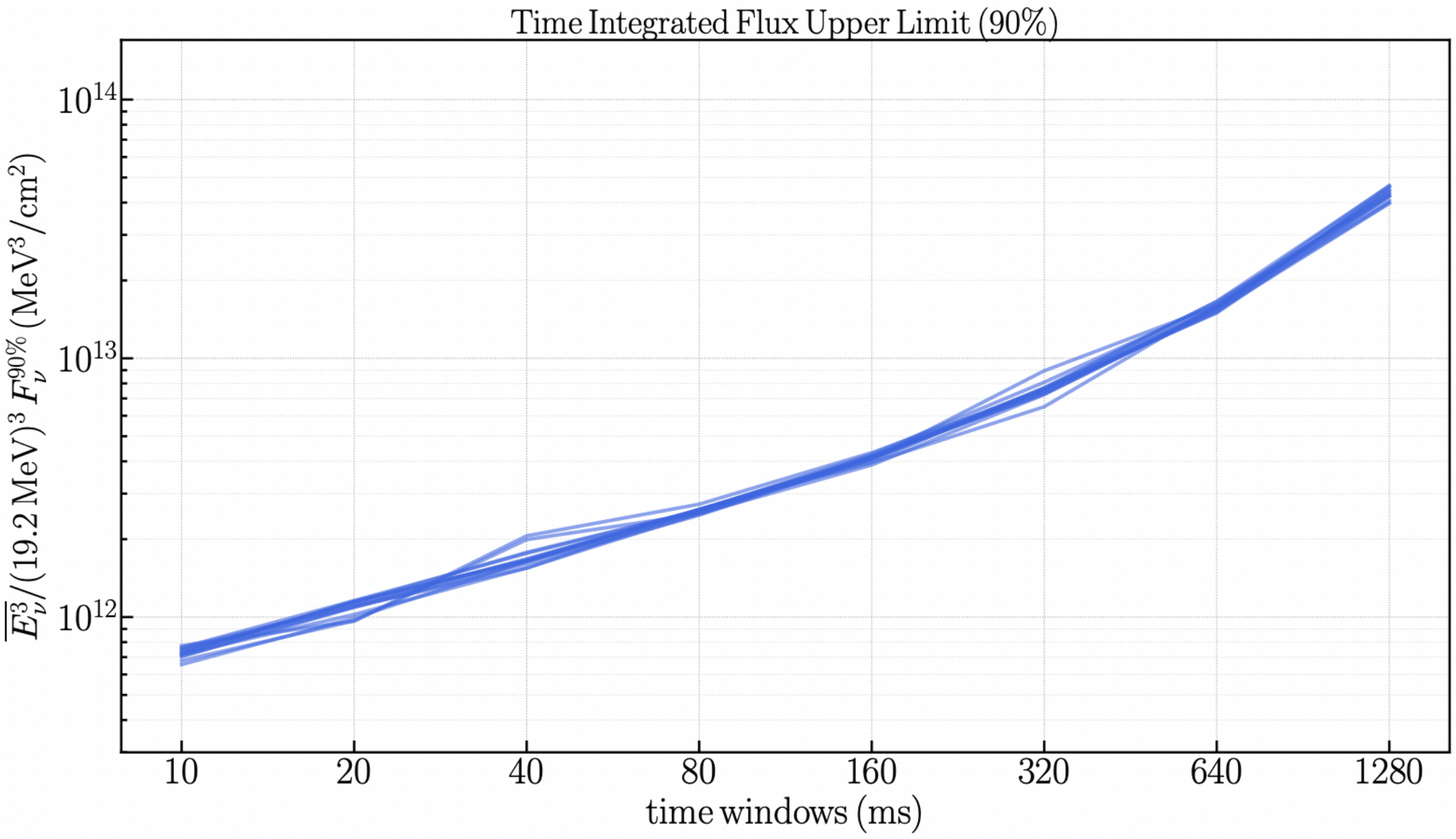


[C. A. Argüelles, V. Brdar, J. Lazar, **YYL**, arXiv:2403.09781]



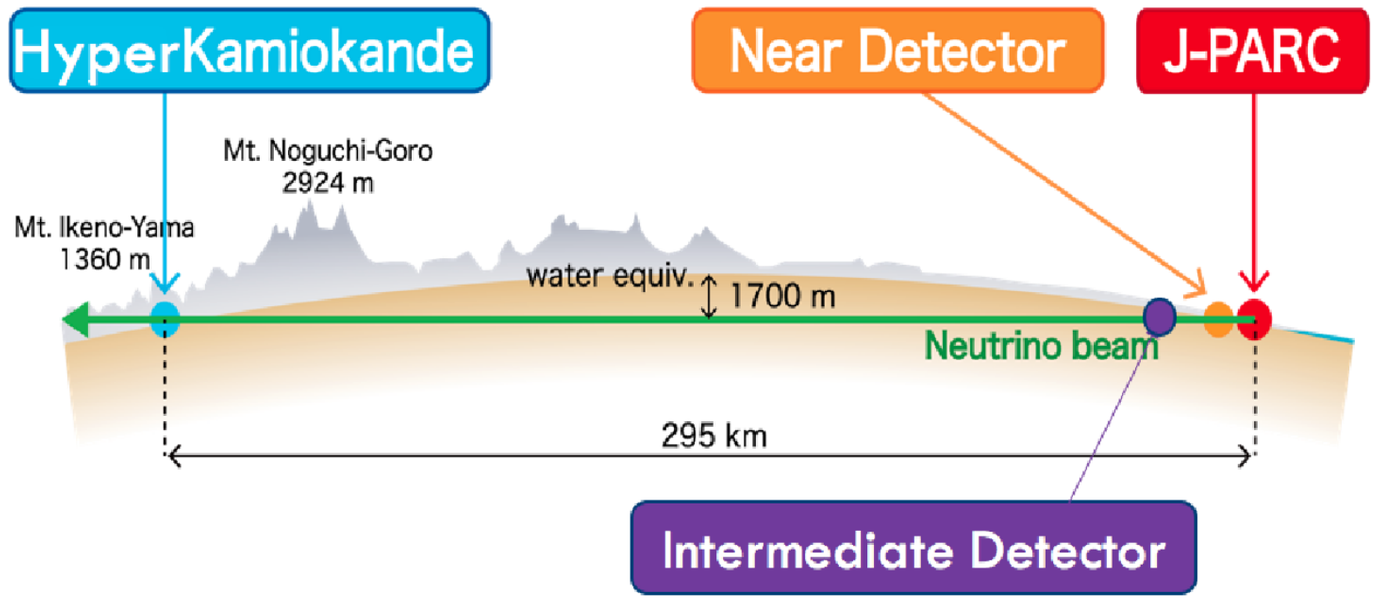
High energy (TeV): muon neutrino Low energy (MeV): $\bar{\nu}_e + p \rightarrow e^+ + n$

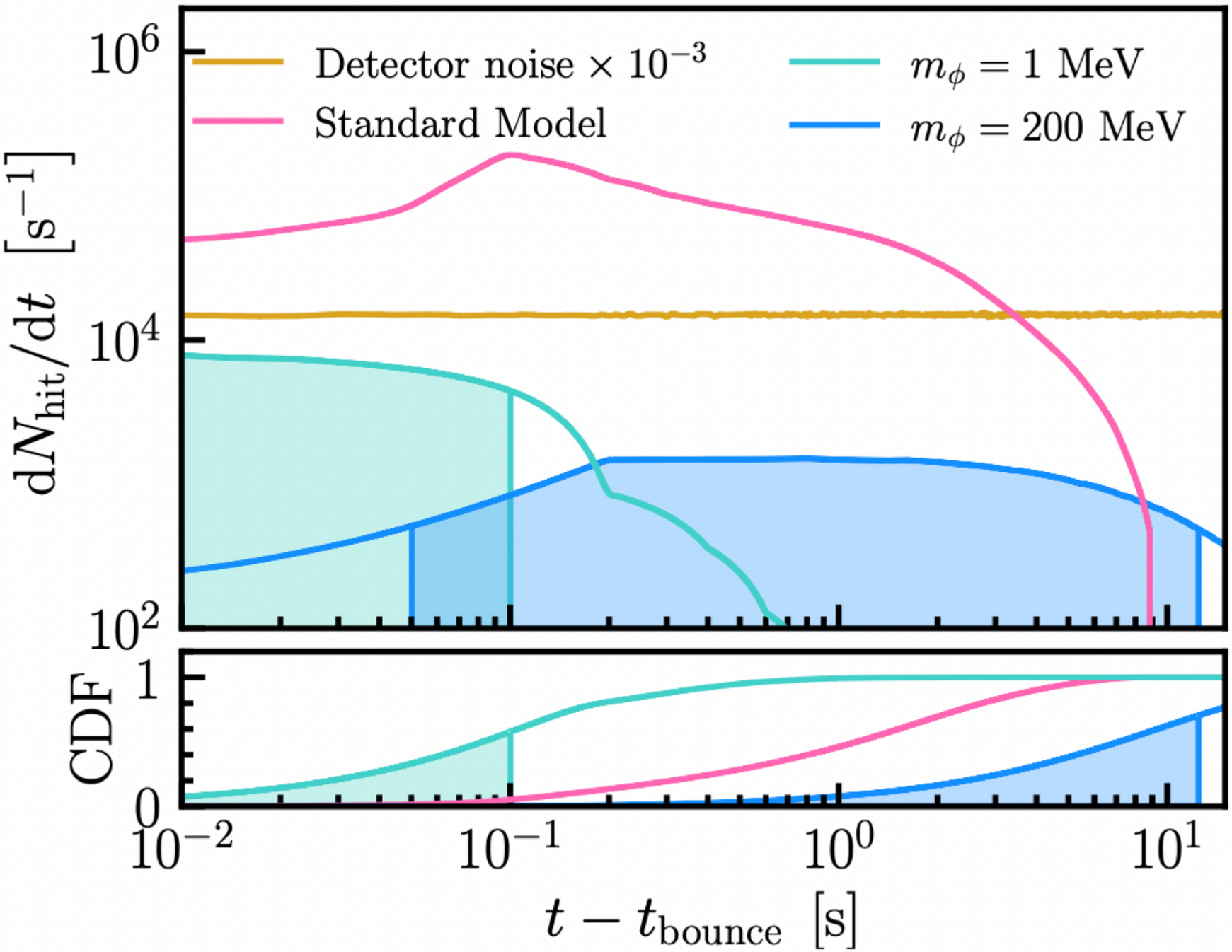
Search for MeV Neutrinos from Fast Radio Bursts with IceCube



[IceCube Collaboration, arXiv: 1108.0171, arXiv:1908.09997]

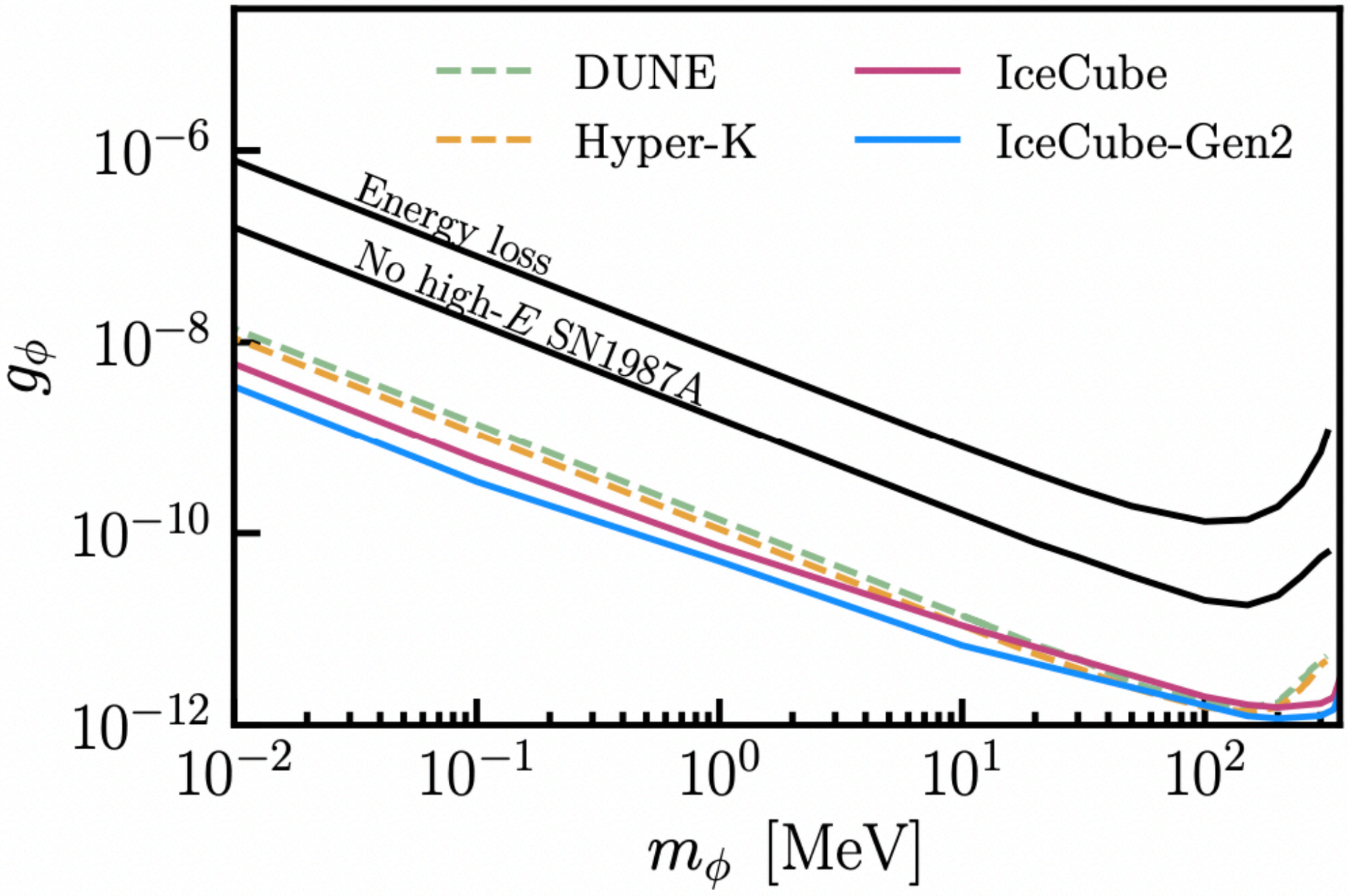
$$\bar{\nu}_e + p \rightarrow e^+ + n$$





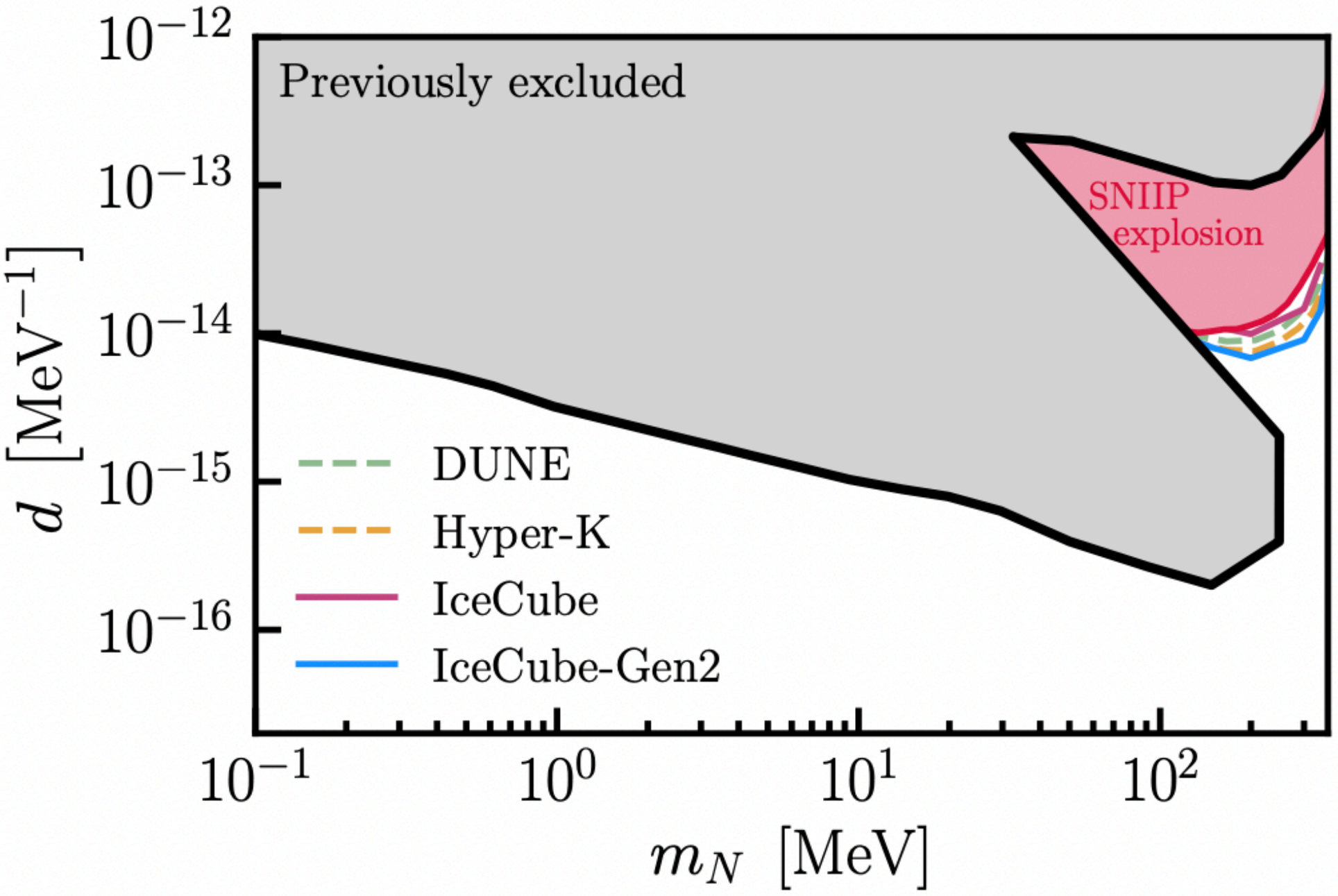
[C. A. Argüelles, V. Brdar, J. Lazar, **YYL**, arXiv:2403.09781]

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



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

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



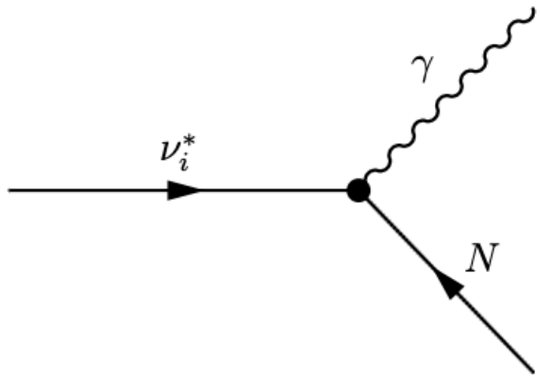
[C. A. Argüelles, V. Brdar, J. Lazar, **YYL**, arXiv:2403.09781]

Thank you

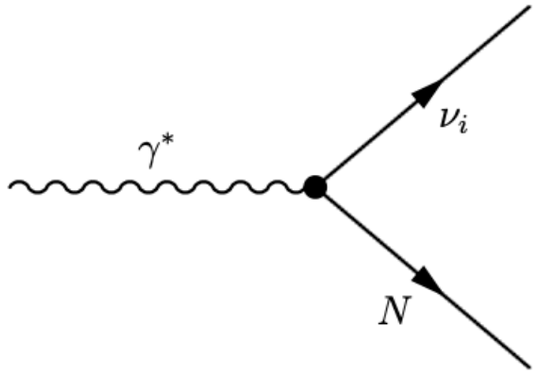
Heavy Neutral Lepton - Dipole Portal

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

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

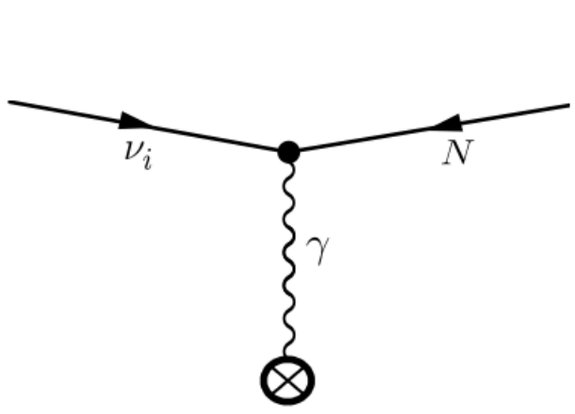


(a) Weak meson decays

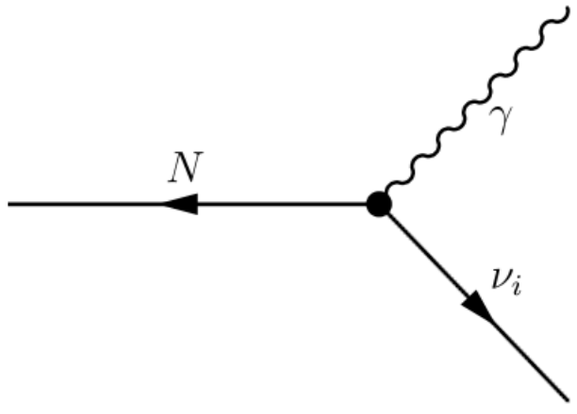


(b) Dalitz-like decay

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



(c) Primakoff upscattering



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

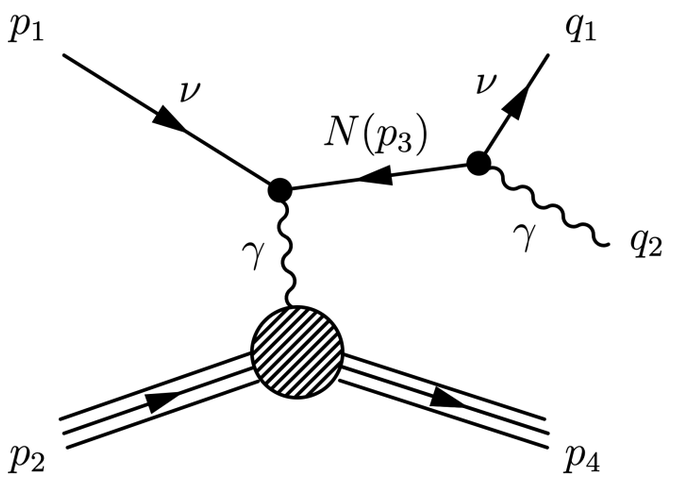
$$\Gamma_N = \frac{6}{4\pi}\,\mu_\nu^2 M_N^3$$
(flavor universal)

Current Probes: terrestrial experiments

Beam dump experiments:

MiniBoone, NONAD, CHARM

production via:

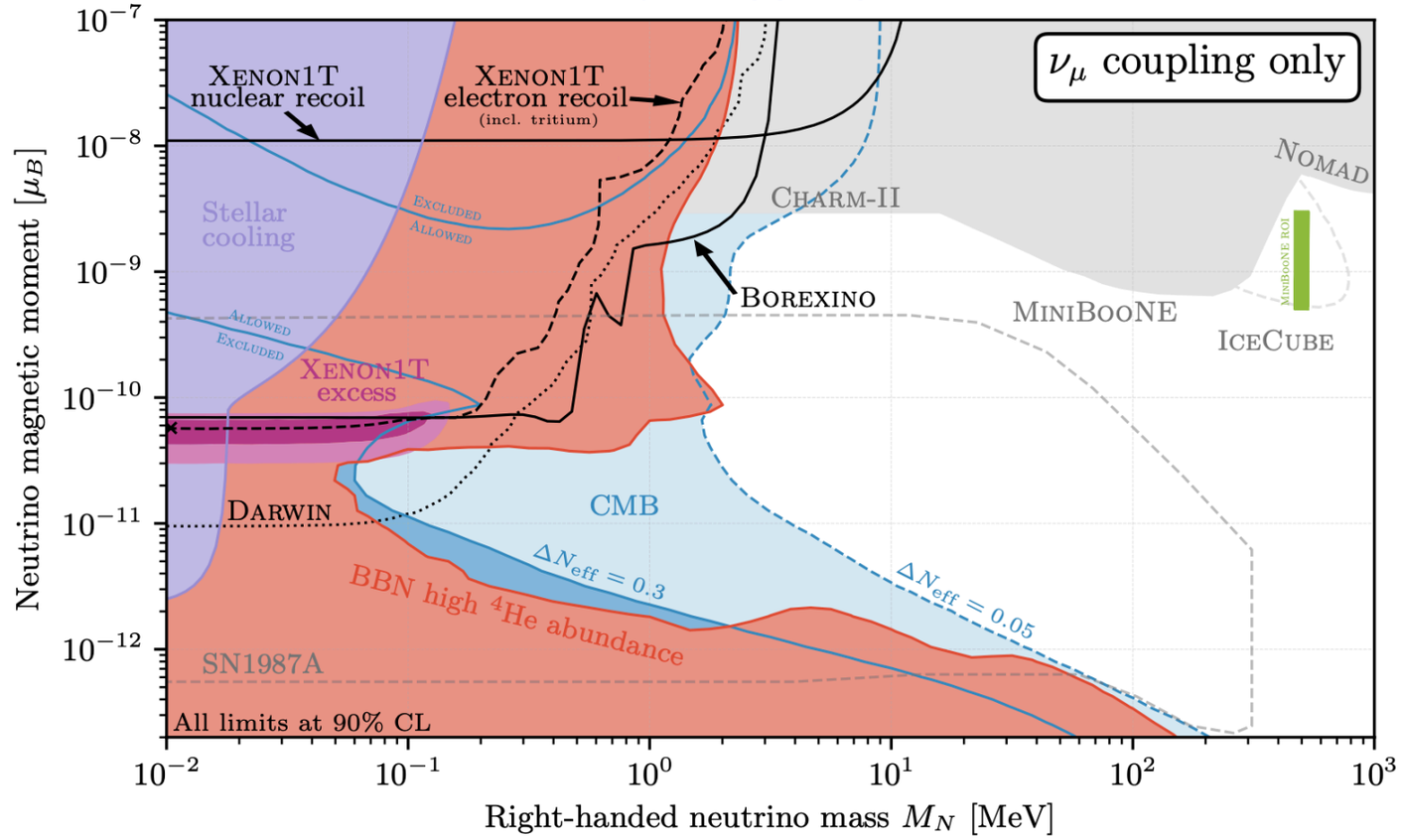


$$\pi^0, \eta \to \gamma(\gamma^* \to \nu_a N)$$

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

relevant for transition magnetic moments between ν_μ and N

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



Current Probes: terrestrial experiments

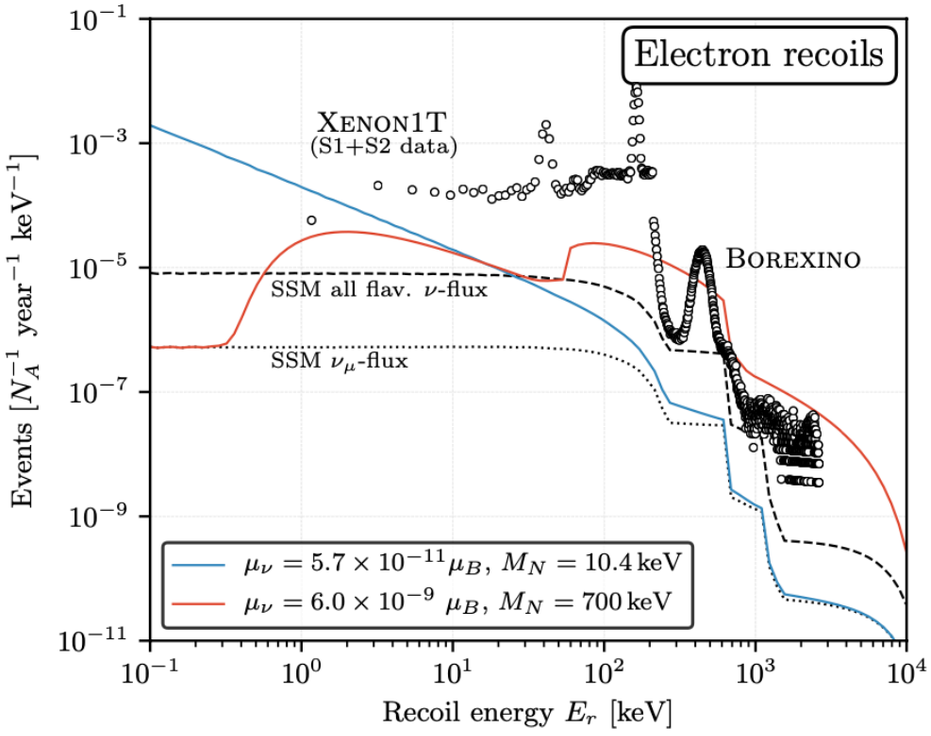
Solar neutrino spectrum:

Xenon1T, Borexino

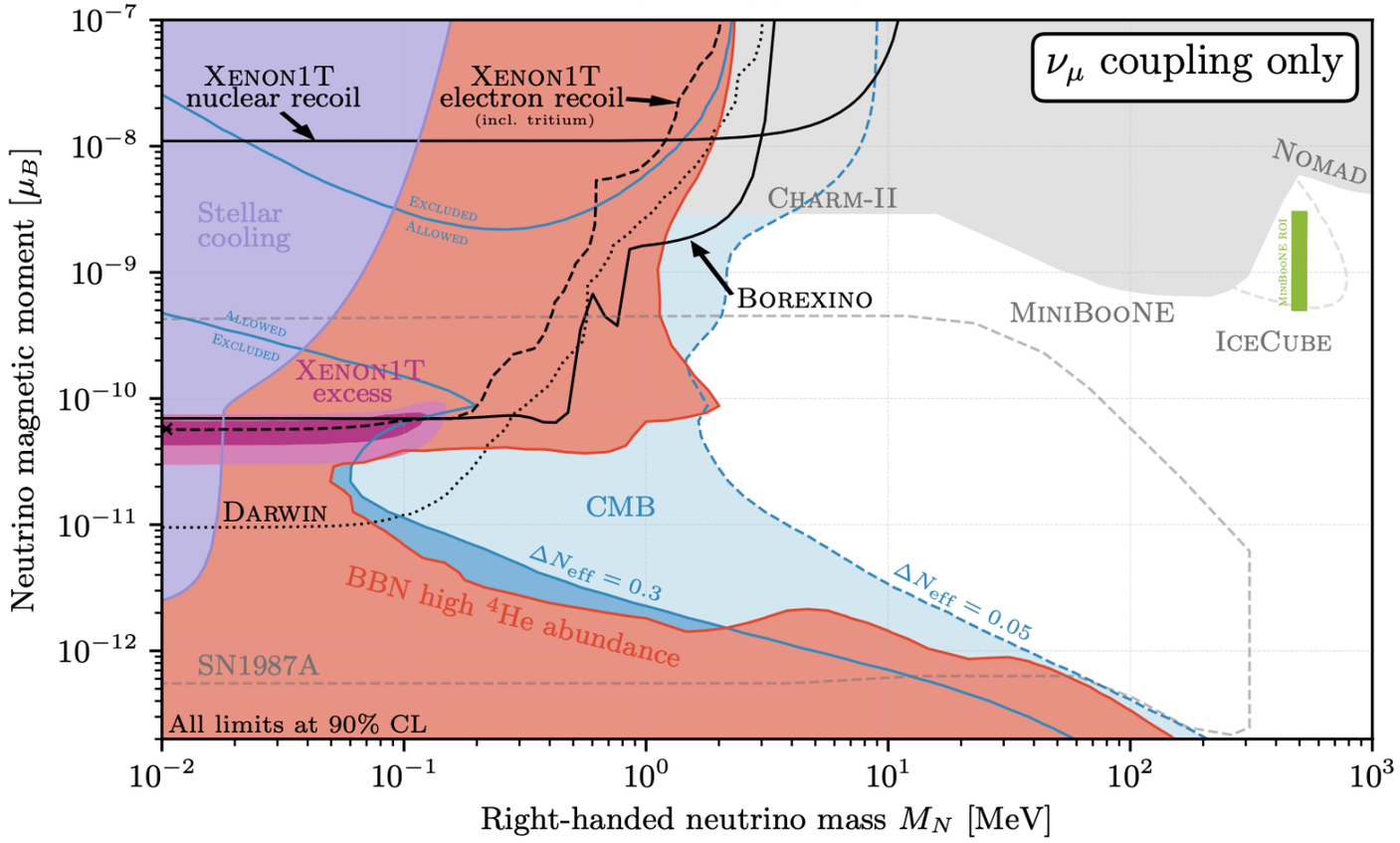
detection via:

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

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



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

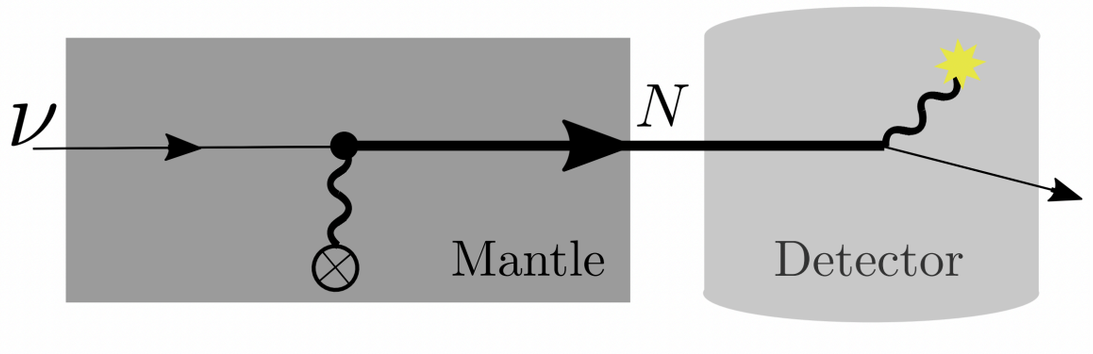


Current Probes: terrestrial experiments

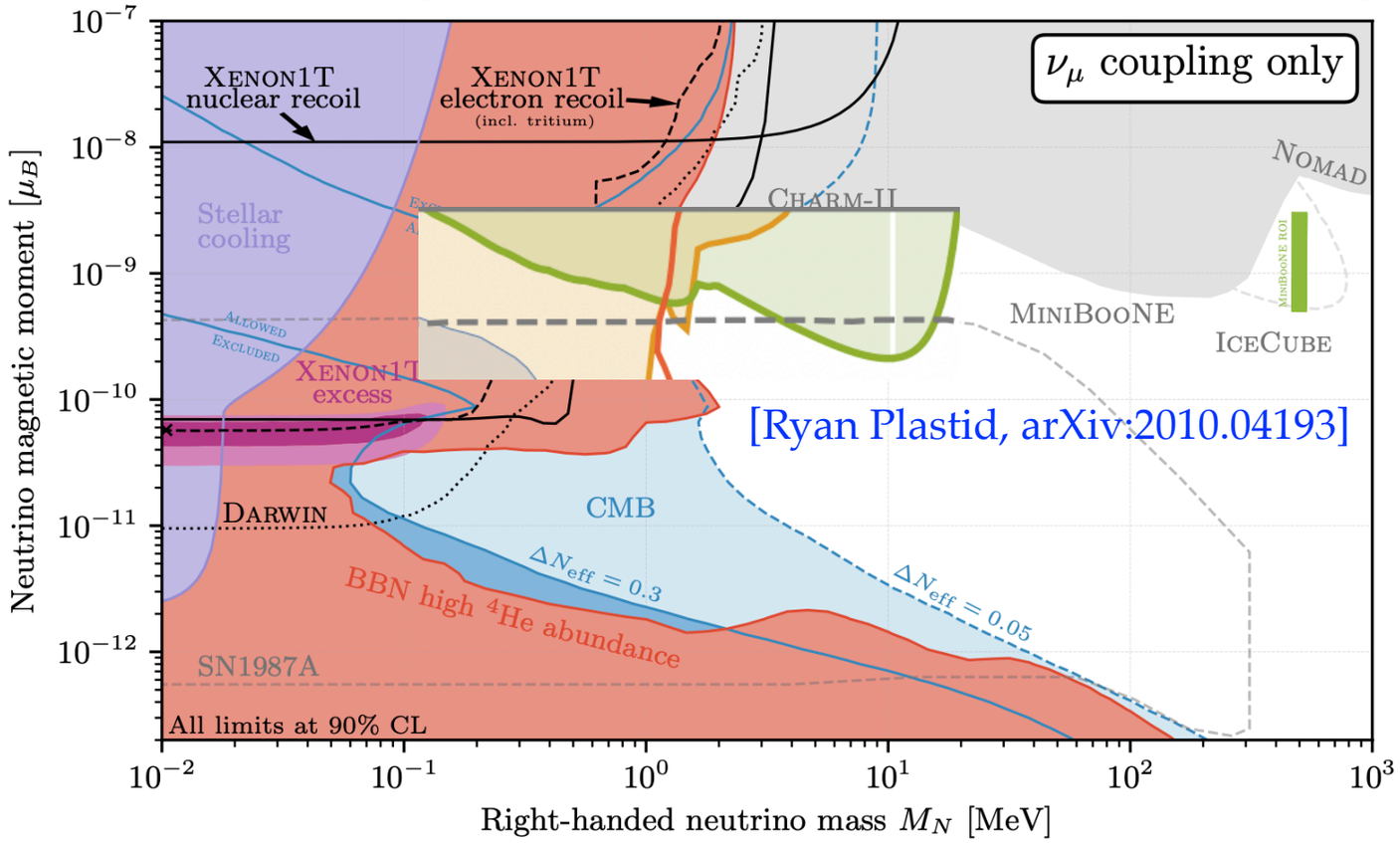
Solar neutrino

up-scattering and decays

production and decay



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

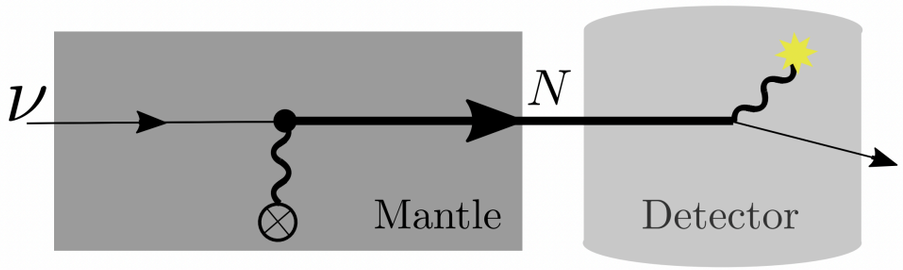


[Ryan Plastid, arXiv:2010.04193]

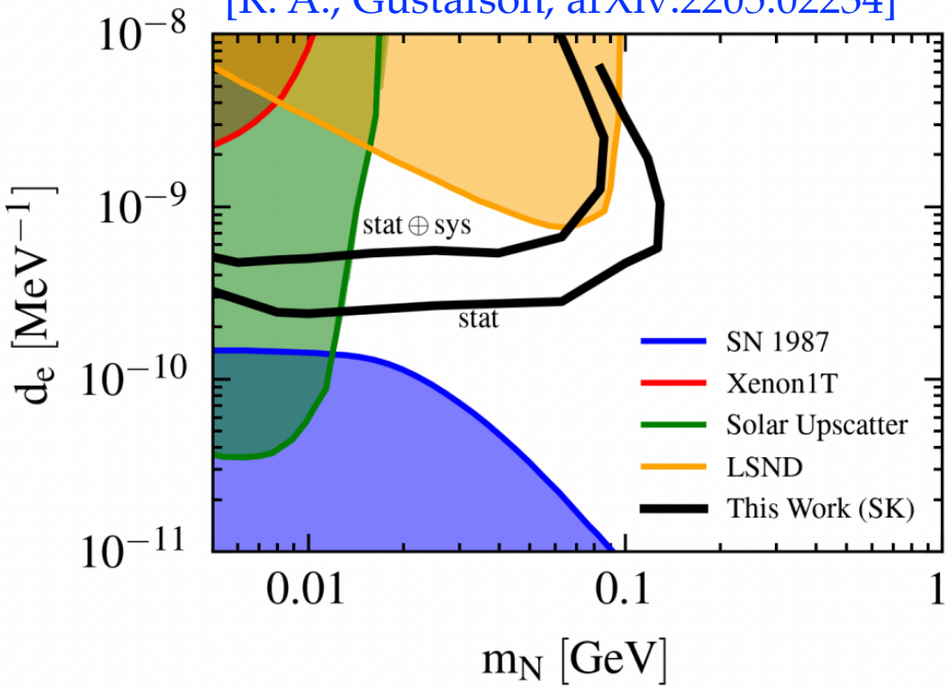
Borexino, SuperK

Current Probes: terrestrial experiments

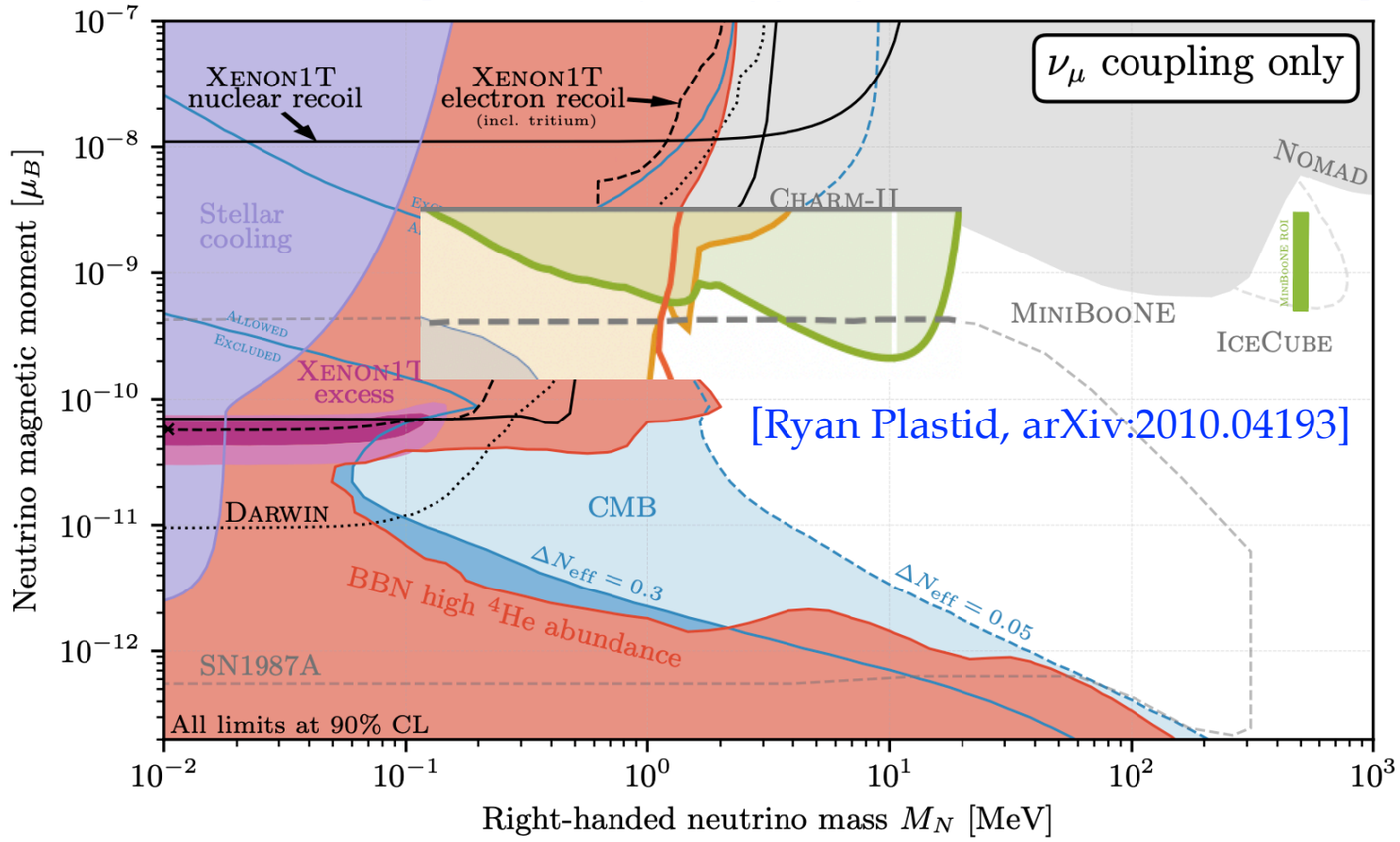
Atmospheric neutrino DUNE, Super-K



[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

10% of energy loss

to sterile neutrino

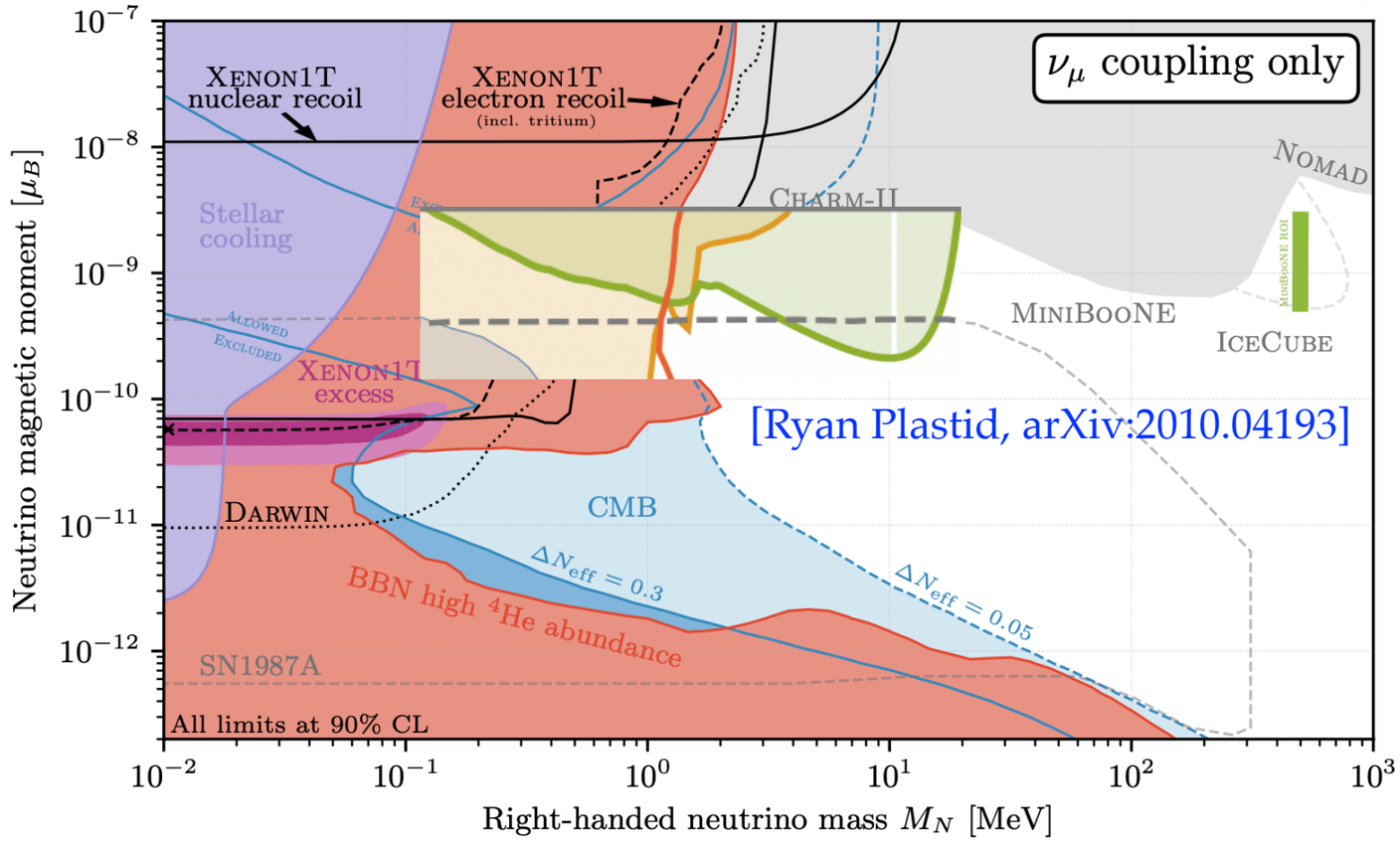
$$\nu + e^{\pm} \to N + e^{\pm}$$

$$\nu + p \to N + p$$

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

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

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



[Ryan Plastid, arXiv:2010.04193]