Super heavy dark matter origin of the PeV neutrino event: KM3-230213A

Kazunori Kohri, Partha Kumar Paul, Narendra Sahu, Phys. Rev. D 112 (2025) 3, L031703
arXiv:2503.04464 [hep-ph]

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Abstract

- KM3-230213A with $E=220^{+570}_{-100}$PeV can be explained by dark matter decaying at the Milkyway galactic halo (DM → ν + Higgs)

  C. Rott, S.-C. Park, K. Kohri, arXiv:1408.4575
  See also, N. Hiroshima, R. Kitano, K. Kohri, K. Murase, arXiv:1705.04419

- However ,we have the tension at 2.9σ with the upper bound on it from IceCube and/or Auger

- High-energy gamma rays can be also emitted, but small, and so non-detections by HESS, LHASSO, CASA-MIA, or Auger

- Dark matter can be related to massive right-haded neutrino (N_R) which was non-thermally produced in the early Universe

$$M_\nu = -M_D^T \frac{1}{M_{\rm M}} M_{\rm D} = -(y\langle\Phi\rangle)^T \frac{1}{M_{\rm M}} (y\langle\Phi\rangle)$$

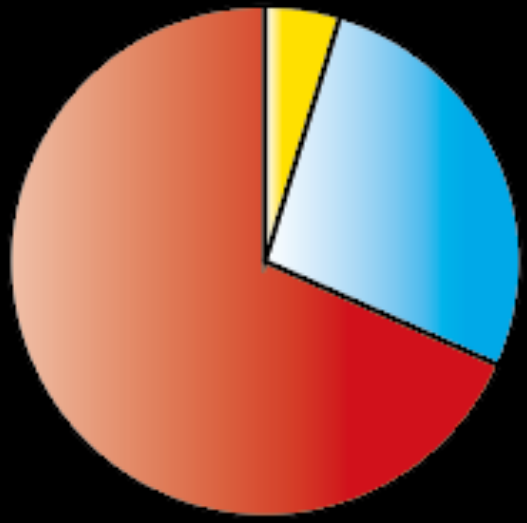
M_ν: 10^{-3}eV; M_D: 10^2GeV; $M_{\rm M}$: 10^{16}GeV; $M_{\rm D}$: $10^{-4}\times 10^2$GeV; $M_{\rm M}$: 10^8GeV; $y\langle\Phi\rangle$: $10^{-4}\times 10^2$GeV

Energy at present

Baryon
4.9%

Dark matter
26.8%

WIMP?
axion
Primordial BHs
Right-handed neutrino



Dark energy
68.3%

no longer even matter
cosmological constant?
axion?

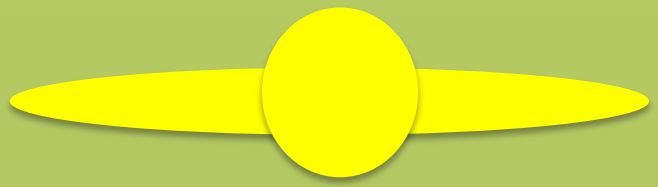
Radiation 0.01%
Antimatter < 0.001%

http://map.gsfc.nasa.gov/

Collapse of density perturbation of dark matter produces galaxies

Formation of galactic halos only by dark matter

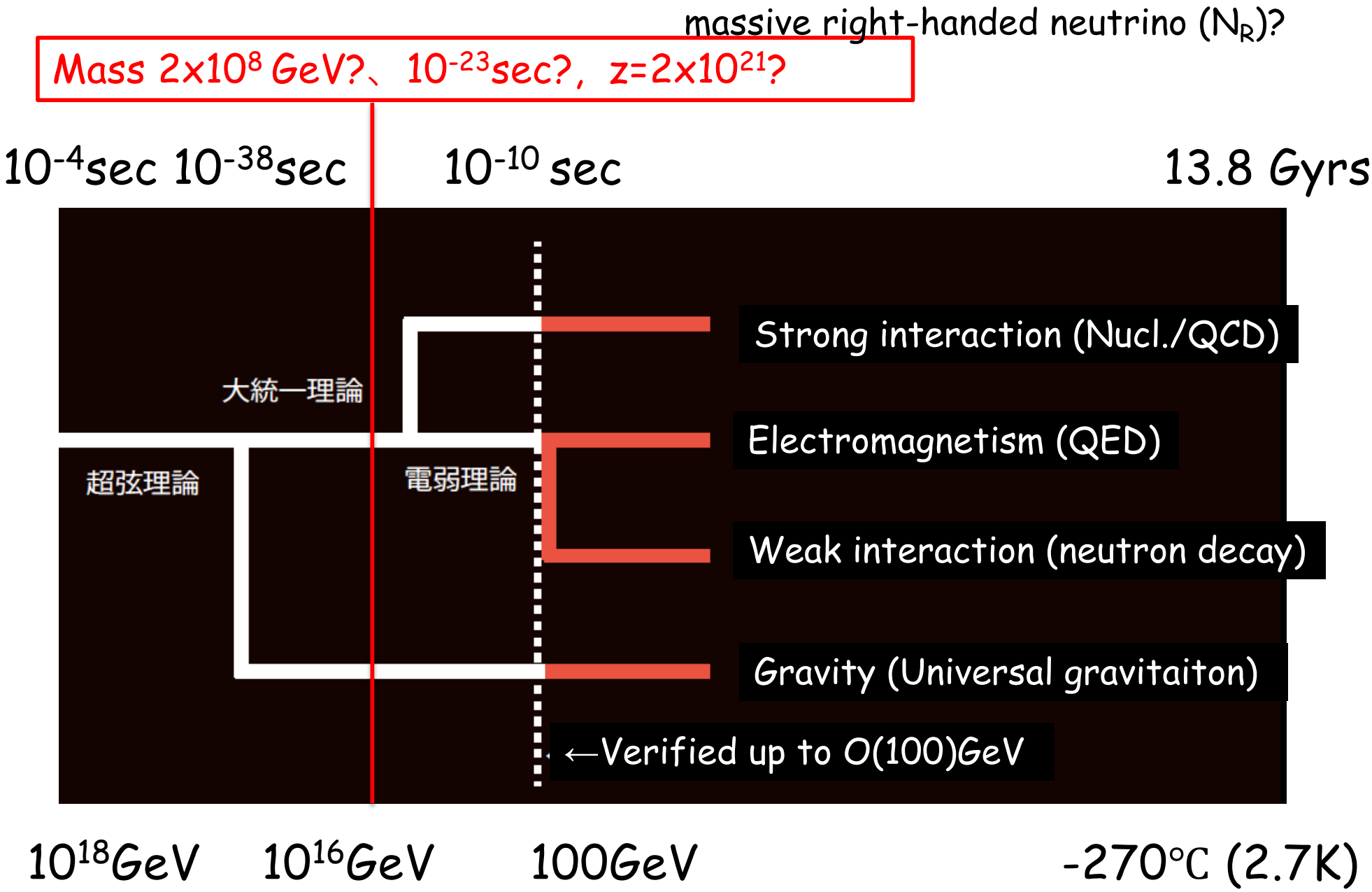
A galaxy was produced gravitationally
inside the dark matter halo



↓

$\rho_{DM} / \rho_{baryon} \sim 5$

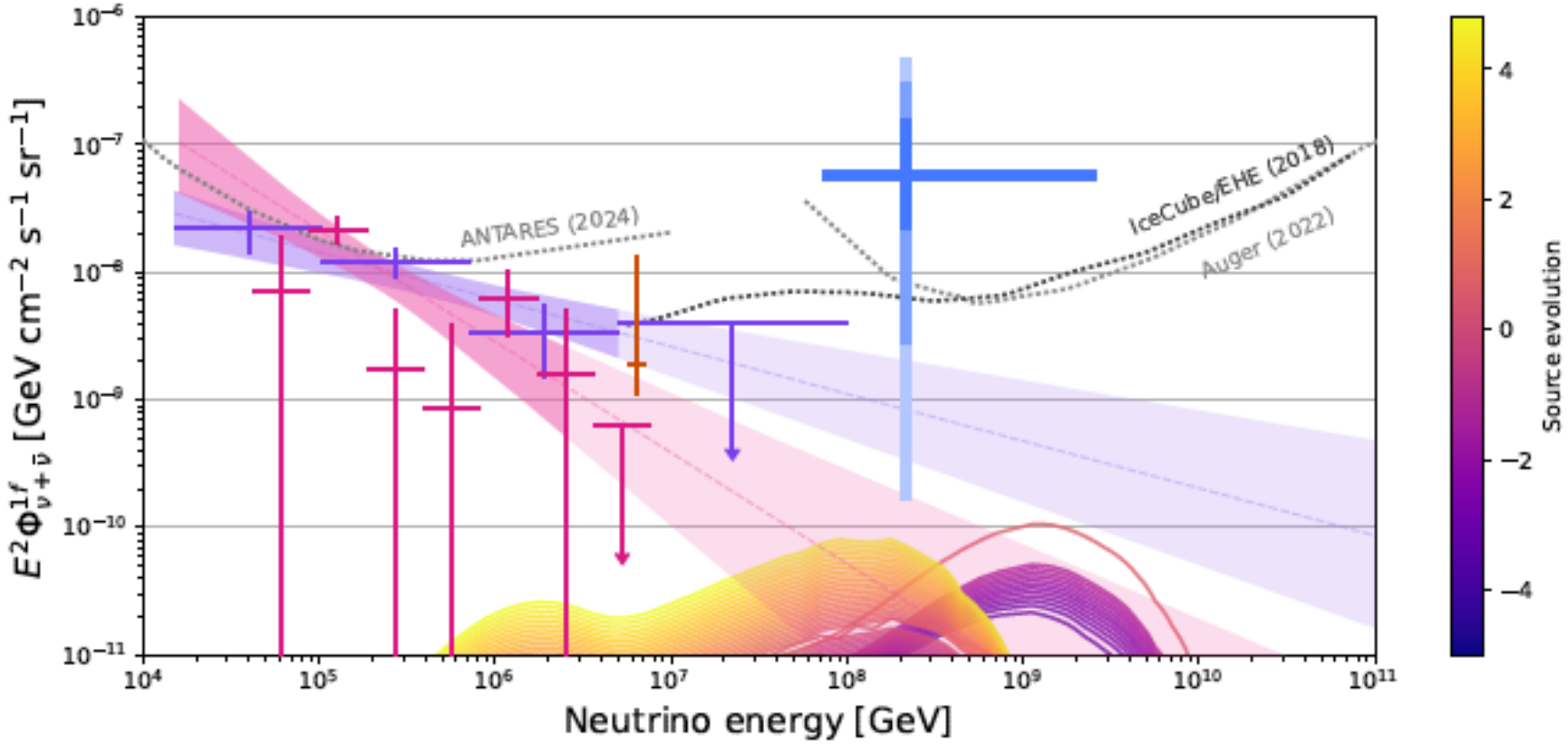
Unification of four forces



On the potential cosmogenic origin of the ultra-high-energy event KM3-230213A

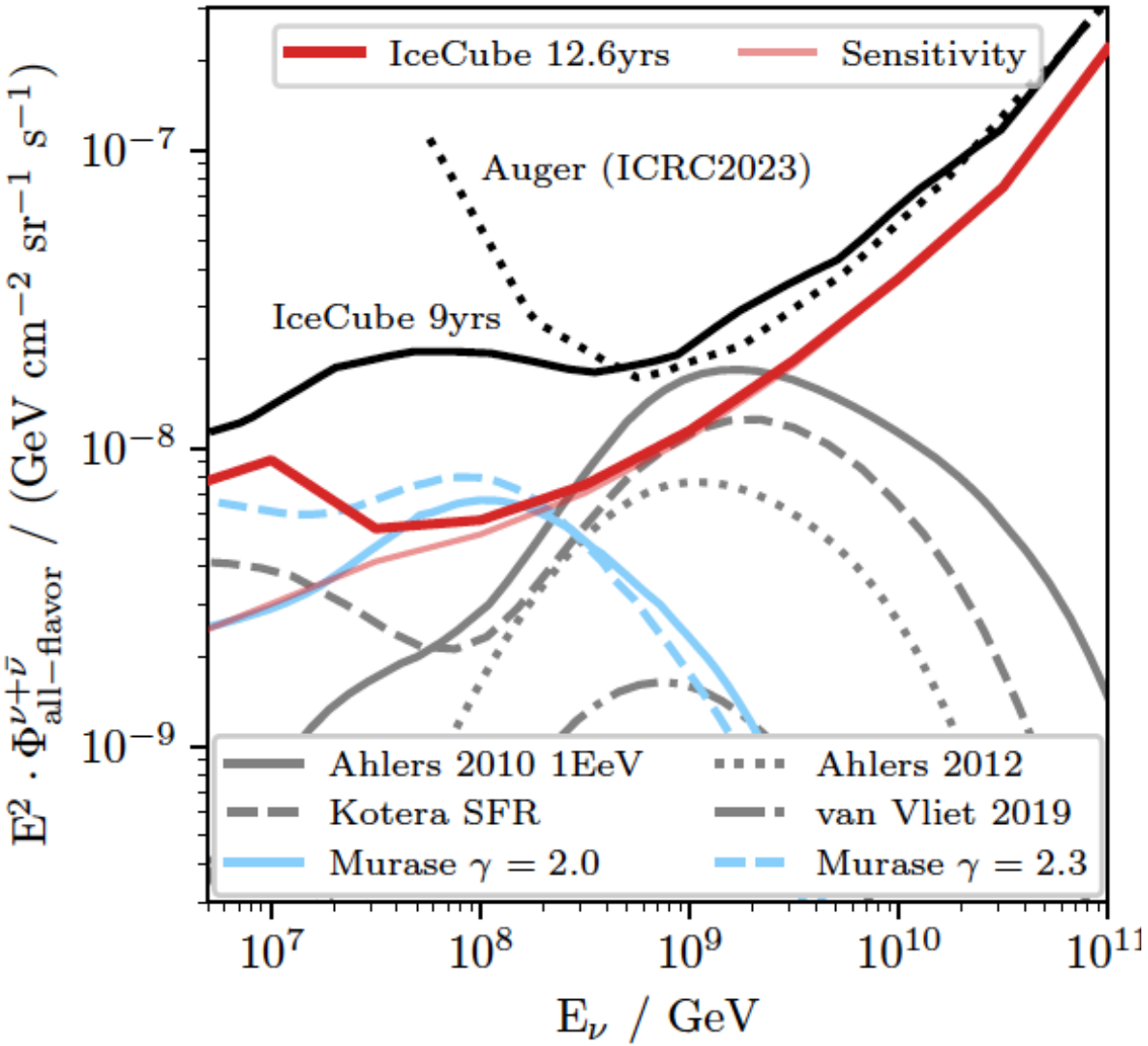
O. Adriani et al, The KM3NeT collaboration, arXiv:2502.08508 [astro-ph.HE]

$$220^{+570}_{-100}\ \mathrm{PeV}$$



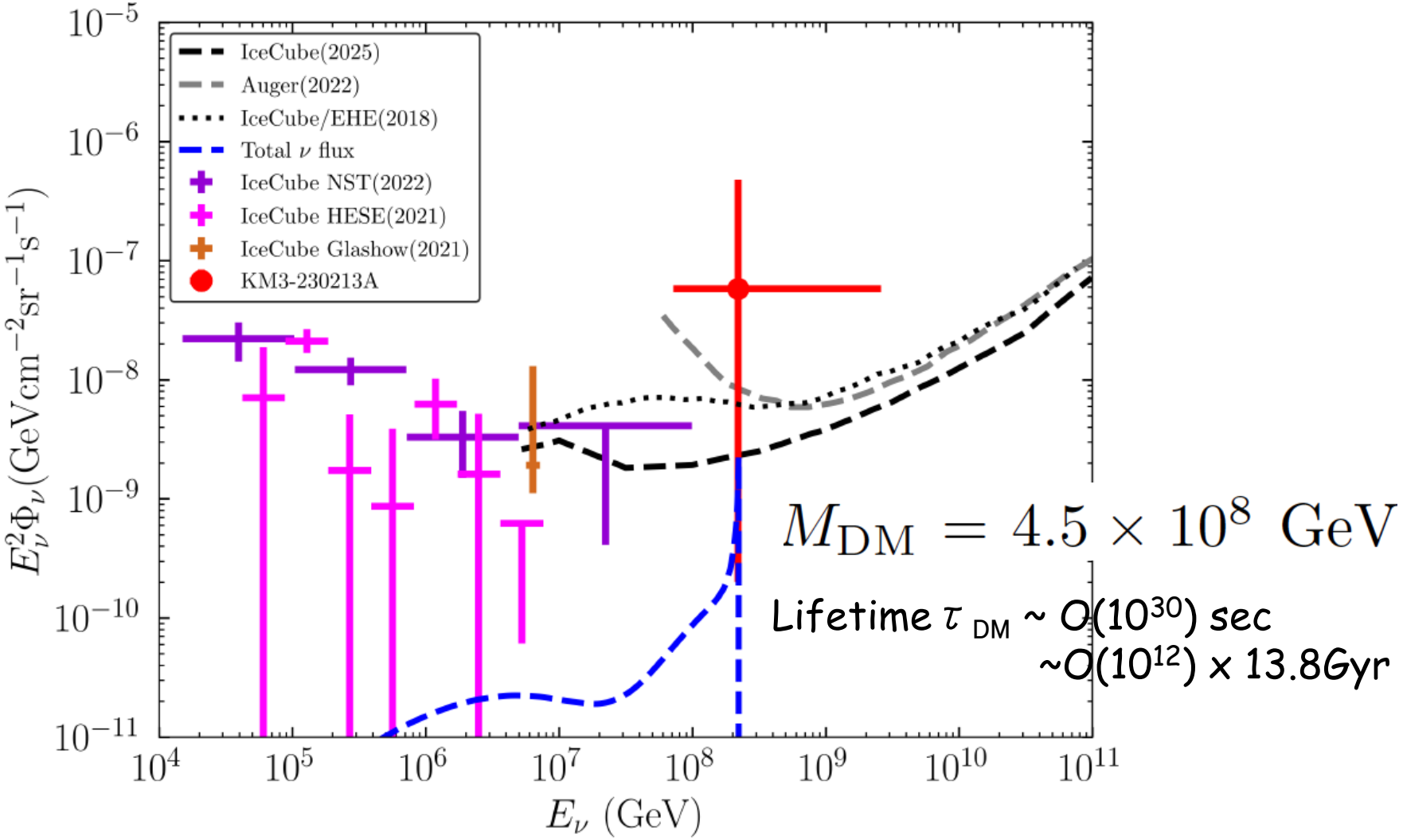
IceCube upper bound on neutrino flux

IceCube Collaboration: R. Abbasi, et al, arXiv:2502.01963 [astro-ph.HE]



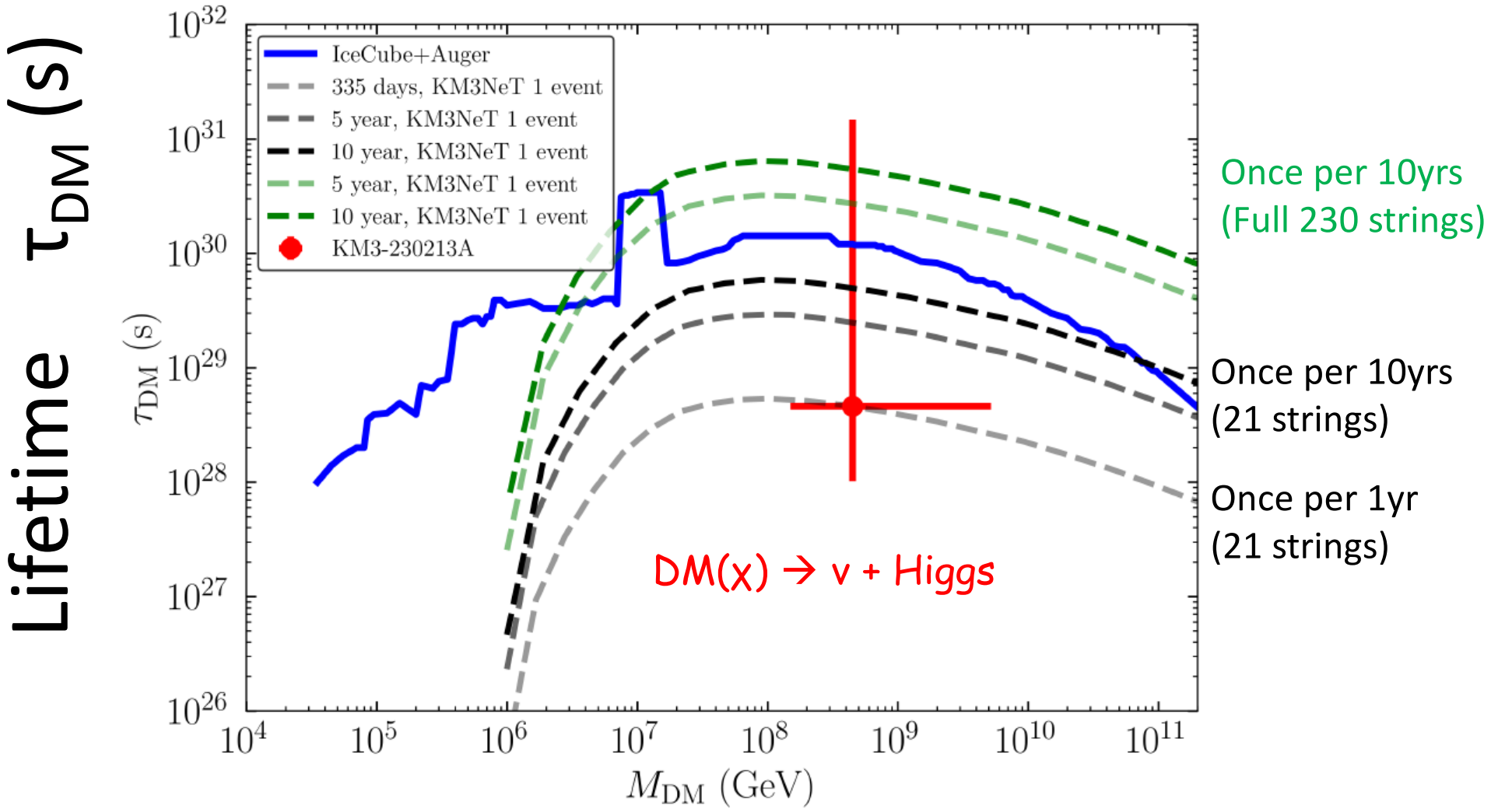
KM3-230213A and dark matter decay (DM → ν + Higgs)

Kazunori Kohri, Partha Kumar Paul, Narendra Sahu, arXiv:2503.04464 [hep-ph]



Lower bound on lifetime of decaying dark matter by IceCube and KM3-230213A

Kazunori Kohri, Partha Kumar Paul, Narendra Sahu, arXiv:2503.04464 [hep-ph]



Models in particle physics

dark matter χ and massive right-handed neutrino N are mixing each other

Kazunori Kohri, Partha Kumar Paul, Narendra Sahu, arXiv:2503.04464 [hep-ph]

$$\mathcal{L}_{\rm seesaw+DM} = -\frac{M_N}{2}\overline{N^c}N - y_{NL}\bar{L}\tilde{H}N - \frac{M_\chi}{2}\overline{\chi^c}\chi$$
$$-y_{N\chi}\bar{N}S\chi + \text{h.c},$$

$$\chi_1 = N\cos\theta + \chi\sin\theta, \quad \chi_2 = -N\sin\theta + \chi\cos\theta$$

$$M_{\rm DM} = 4.5\times 10^8\ \text{GeV}$$

$$\sin\theta \simeq \frac{y_{N\chi}v_S}{\sqrt{2}(M_N - M_\chi)} \sim O(10^{-37})$$

Yukawa coupling y_N is small ($\sim O(10^{-31})$),

↓

lifetime ~$1/(y_N^2 M_{DM})$ ~ $O(10^{30})$sec ~ $O(10^{12})$x13.8Gyr

Gamma-ray (γ) signal by decaying dark matter

(DM → ν + Higgs

Higgs→ bb/ττ→ π,π,π+…→ γ γ+ γ+ ν+ν+ …)

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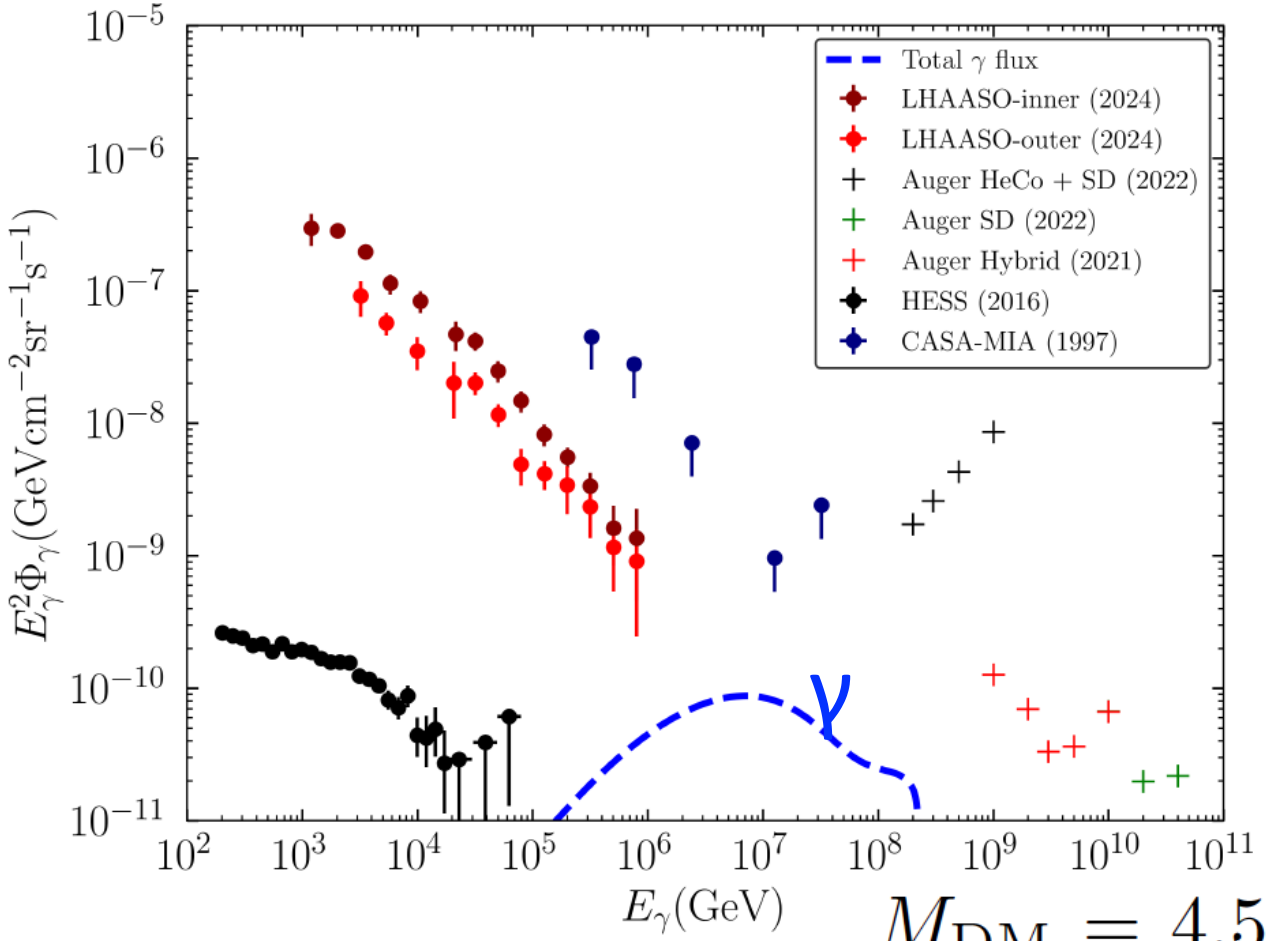
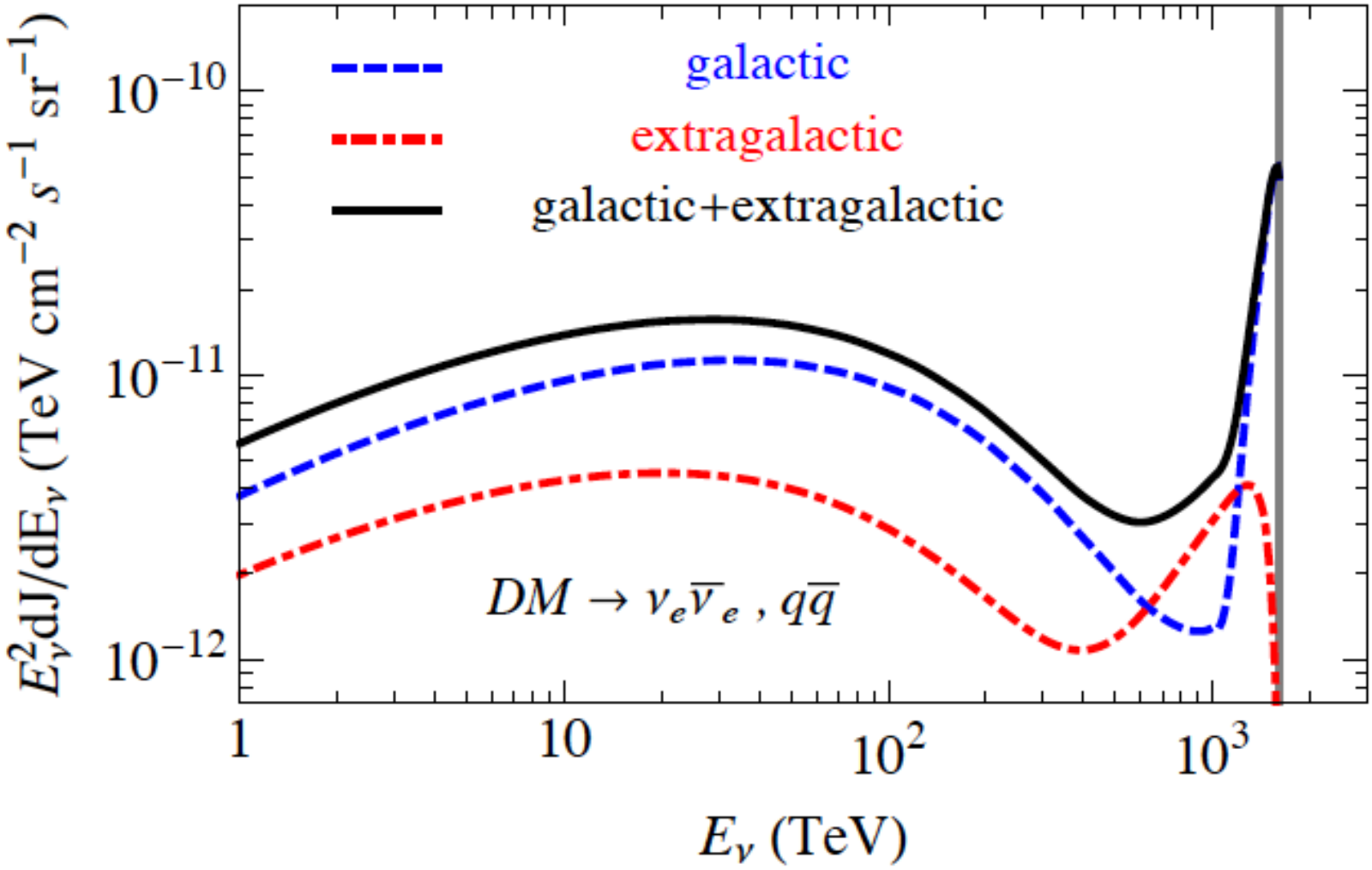


$M_{\mathrm{DM}} = 4.5 \times 10^8\ \mathrm{GeV}$

Extragalactic component?

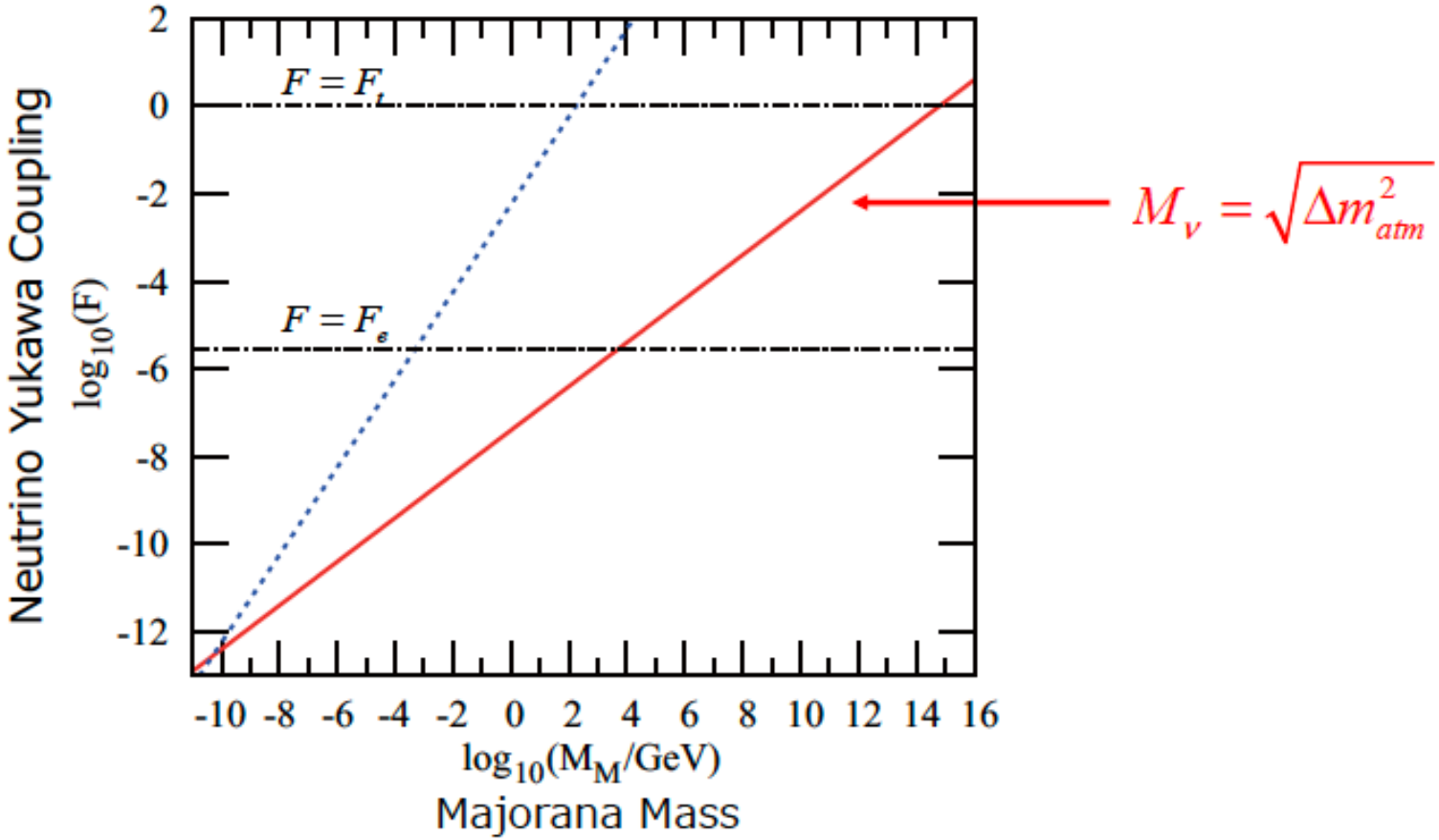
Esmaili and Serpico, arXiv:1308.1105



Majorana mass and Dirac mass for the Seesaw and/or leptogenesis

- The simplest case: one pair of ν_L and ν_R

$$M_\nu = -M_D^T \frac{1}{M_M} M_D \quad \Rightarrow F^2 = M_M M_\nu / \langle \Phi \rangle^2$$



Takehiko Asaka's presentation at KEK in 2013

Conclusion

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