WP2 Beyond Standard Neutrino Framework

Conv. A. Palazzo, N. Saviano

Meeting PRIN NAT-NET 6 Luglio 2021

WORKING PACKAGE 2

The TopFlavor scheme in the context of W' searches at LHC

R. Calabrese[1], A. De Iorio[1], D. F. G. Fiorillo[1], A. O. M. Iorio[1], G. Miele[1,2], S. Morisi[1].

[1] Dipartimento di Fisica "Ettore Pancini", Università degli studi di Napoli Federico II, Complesso Univ. Monte S. Angelo, I–80126 Napoli, Italy and INFN – Sezione di Napoli, Complesso Univ. Monte S. Angelo, I–80126 Napoli, Italy

[2] Scuola Superiore Meridionale, Università degli studi di Napoli "Federico II", Largo San Marcellino 10, 80138 Napoli, Italy

Arxiv: 2104.06720

W' SEQUENTIAL STANDARD MODEL?

Altarelli et al , ZPCPF 1989

$$\mathcal{L}_{\mathrm{eff.}} = \frac{V^{f^i f^j}}{2\sqrt{2}} g_w \bar{f}_i \gamma_\mu \left[\alpha_R^{f^i f^j} (1+\gamma^5) + \alpha_L^{f^i f^j} (1-\gamma^5) \right] W'^{\mu} f_j + h.c$$

Effective Lagrangian in analogy with Standard model

It is **not a gauge theory** (Langacker, Rev. Mod. Phys. 81,2009)

Atlas and CMS benchmarks

$$W'_L: \alpha_L^{f_i f_j} = 1 \quad \alpha_R^{f_i f_j} = 0$$

$$W'_R: \alpha_L^{f_i f_j} = 0 \quad \alpha_R^{f_i f_j} = 1$$

→ **Is this all the story?** NO

W' renormalizable **gauge** models:

- **Left-Right** (N. Mohapatra Rabindra. Unification and supersymmetry)
- **331** (F Pisano, Vicente Pleitez, PRD 1992)
- **Little Higgs** (Hock-Seng Goh, Christopher A Krenke, PRD 2007)
- **Twin Higgs** (Zackaria Chacko, Hock-Seng Goh, RoniHarnik, JHEP 2006)
- **Topflavor** (Xiao-yuan Li, Ernest Ma, PRL 1981)
- ...

TOPFLAVOR MODEL

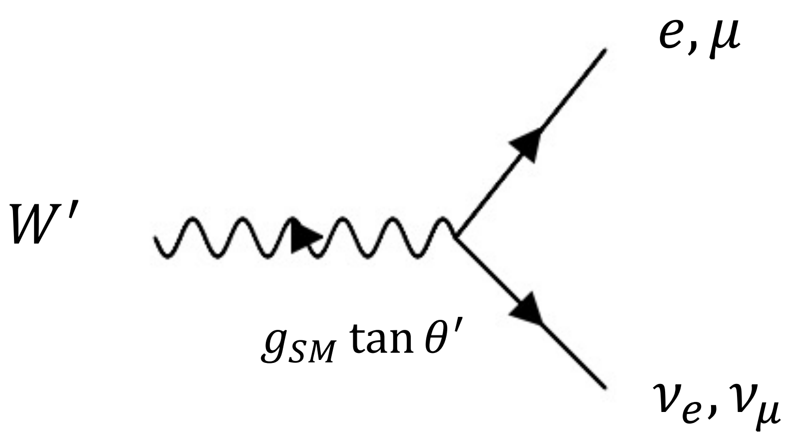
$$\mathrm{SU}(3)_C \times \mathrm{SU}(2)_{12} \times \mathrm{SU}(2)_3 \times \mathrm{U}(1)_Y$$

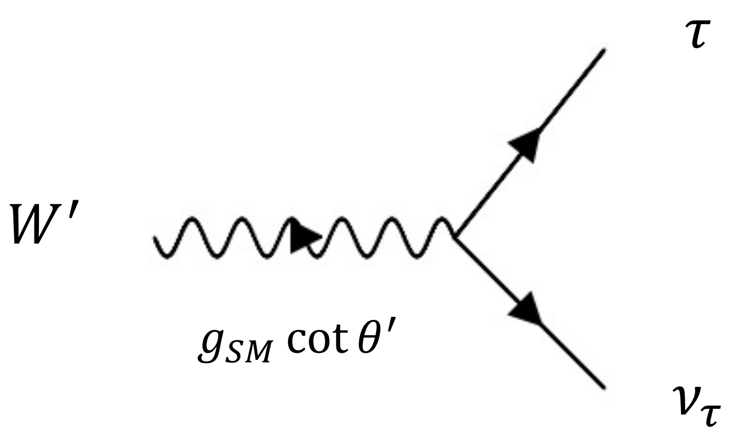
Muller and Nandi, PLB 1996
Muller Nandi NPB 1997
Malkawi et al,PRD 2000
Cao et al NPB 2016

First and second generations

Third generation

Violation of lepton Universality (Li and Ma PRL 1981)

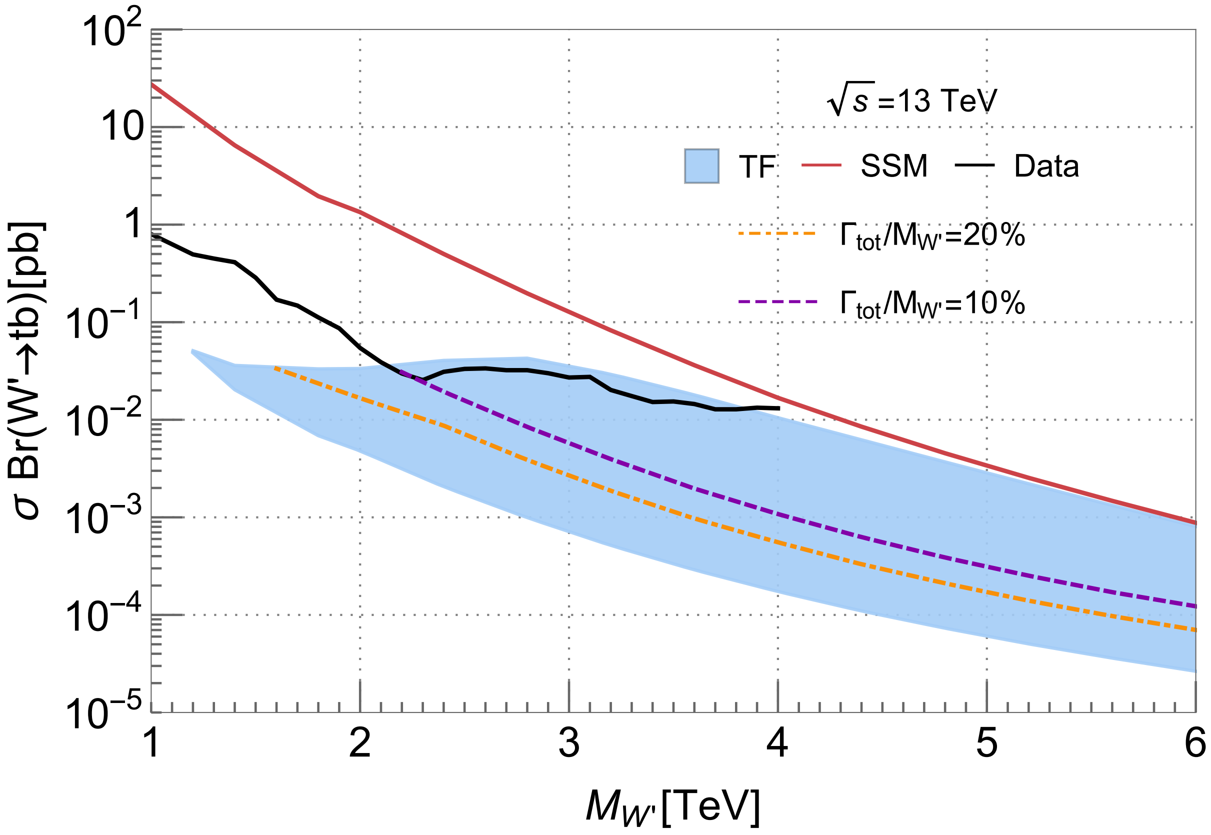


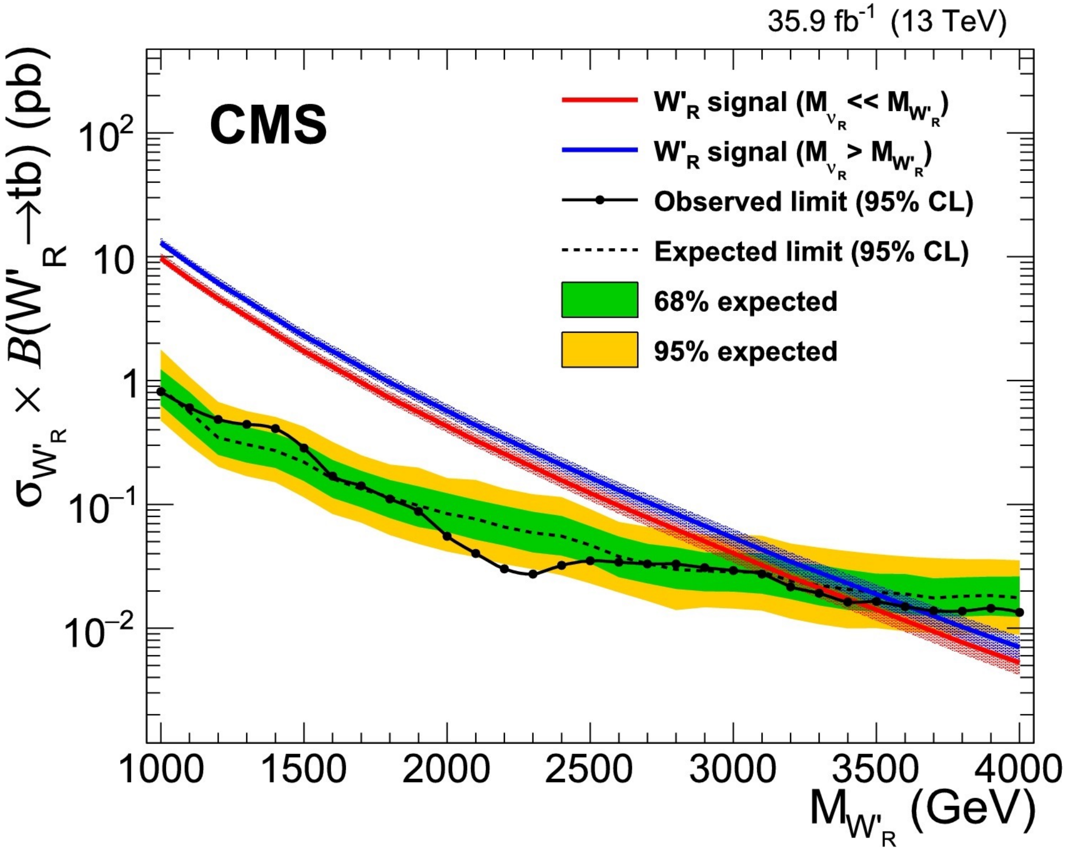


θ': W-W' Mixing angle

Results

$$\sigma(pp \to W')Br(W' \to tb)$$





The Topflavor model requires an improved sensitivity compared to the Sequential Standard Model

THANK YOU FOR THE ATTENTION

IceCube constraints on Violation of Equivalence Principle

Damiano F. G. Fiorillo

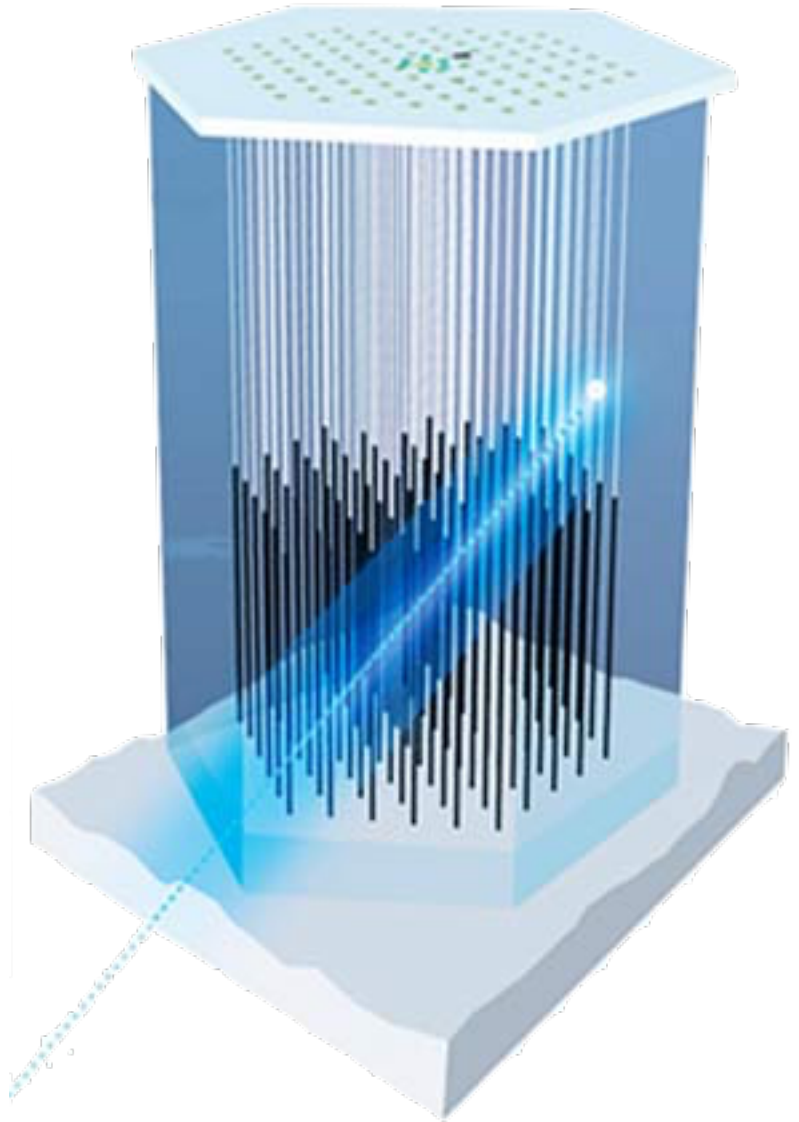
Università degli studi di Napoli "Federico II"
INFN, Napoli

Based on
D. Fiorillo, G. Mangano, S. Morisi, O. Pisanti, arXiv:2012.07867 (*JCAP* 04 (2021) 079)
M. Chianese, D. Fiorillo, G. Mangano, G. Miele, S. Morisi, O. Pisanti, submitted to *Symmetry*

Violation of Equivalence Principle (VEP)

General Relativity

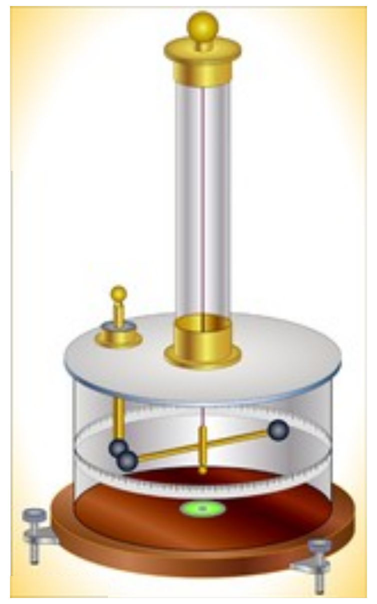
Equivalence Principle
All particles couple equally to the gravitational field



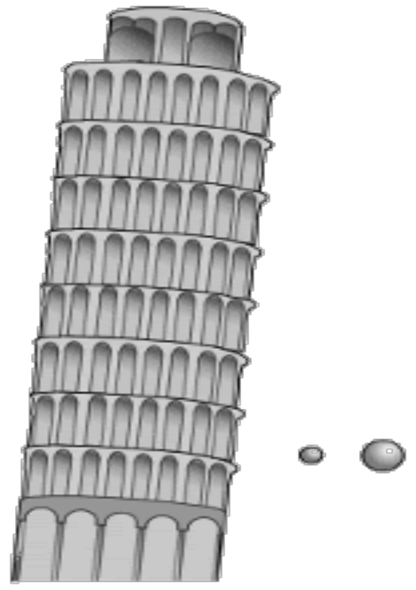
IceCube can constrain at the level of 10^{-22}

Testing the Equivalence Principle can guide toward complete theory

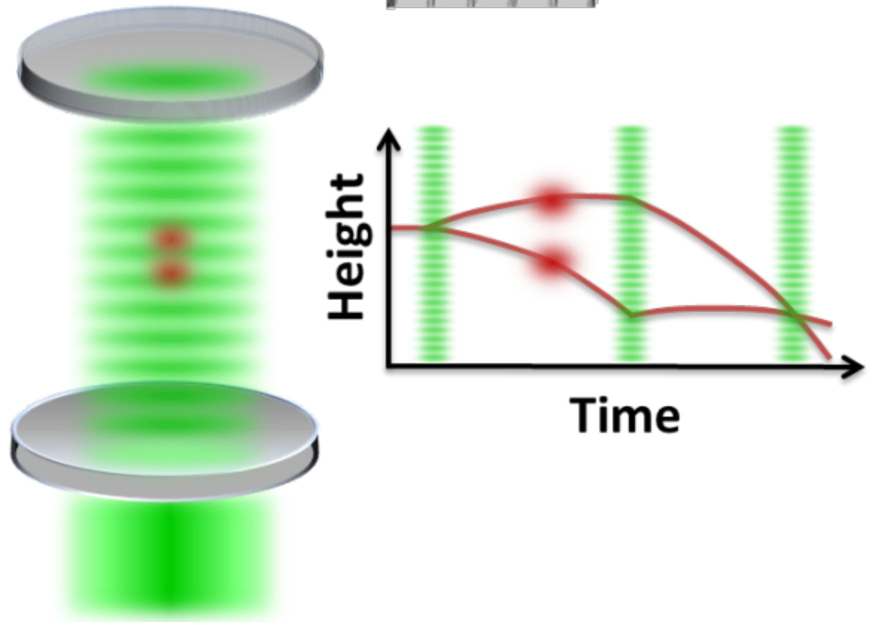
$\delta G/G$



Lab experiments $10^{-13} - 10^{-14}$



Free fall $10^{-10} - 10^{-15}$



Atom interferometry $10^{-9} - 10^{-15}$

Damiano Fiorillo

VEP and high energy neutrinos

Why does VEP influence neutrinos?

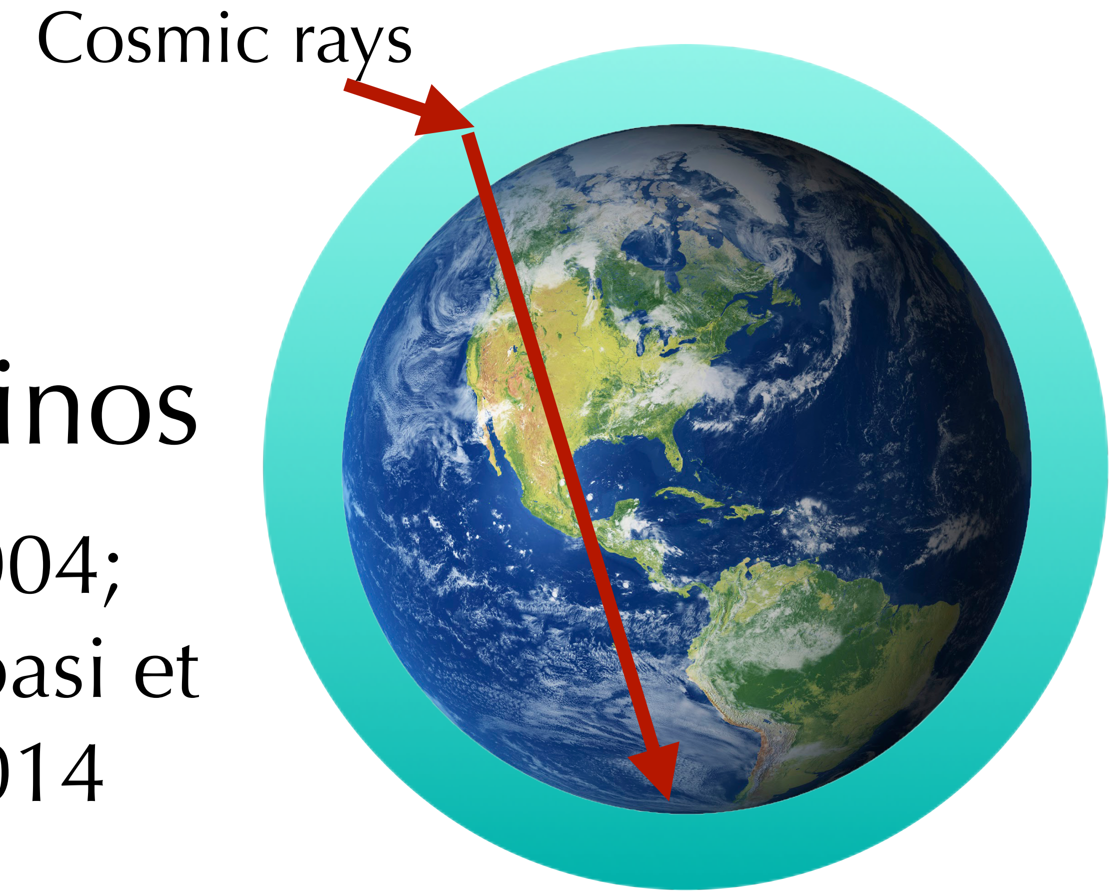
$$\nu \longrightarrow \begin{cases} \xrightarrow{\nu_1} G'_1 = \gamma_1 G \\ \xrightarrow{\nu_2} G'_2 = \gamma_2 G \\ \xrightarrow{\nu_3} G'_3 = \gamma_3 G \end{cases}$$

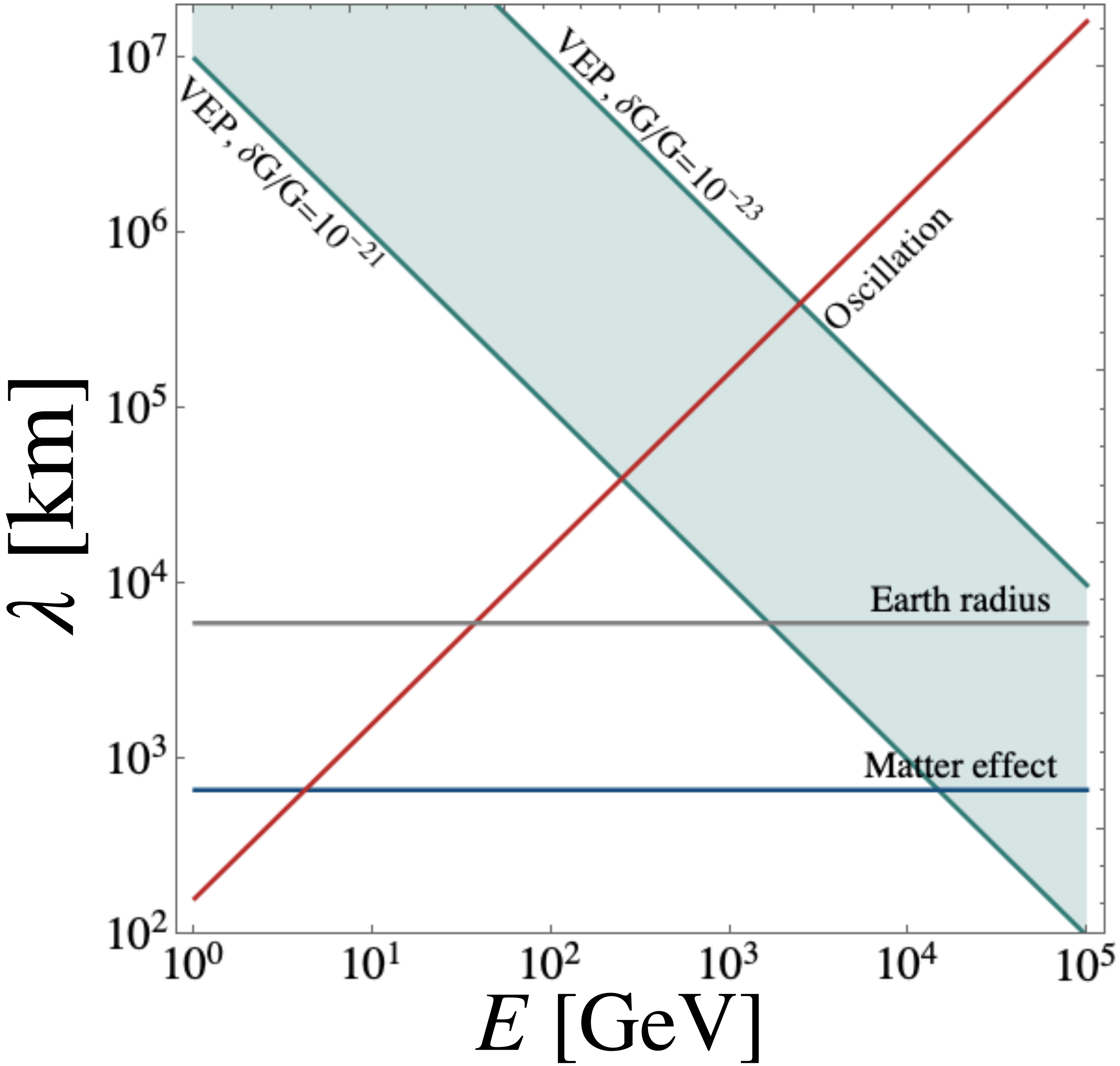
Dephasing leads to oscillations

$E \gtrsim 1$ TeV

Atmospheric neutrinos

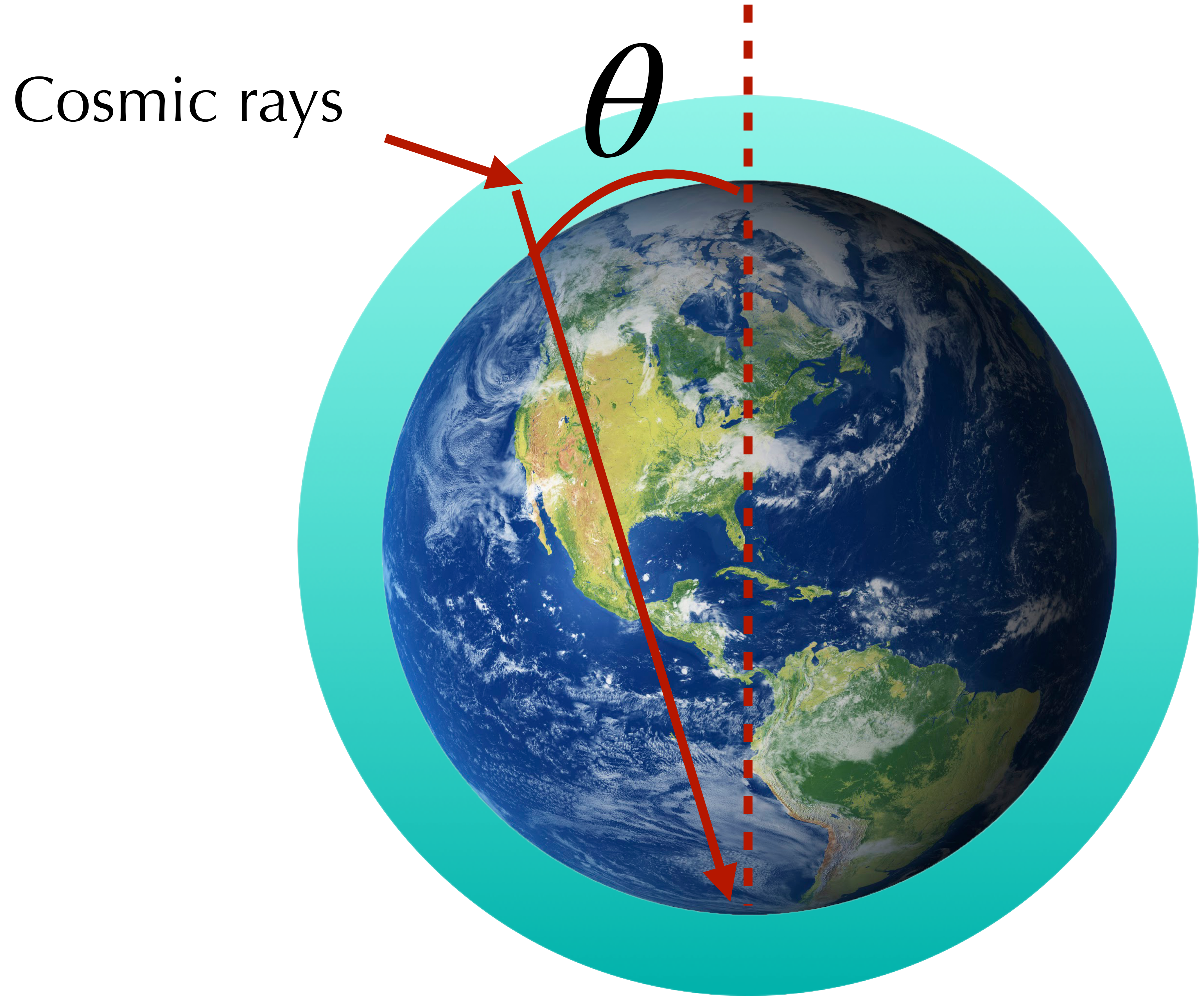
Gonzalez-Garcia et al., 2004; Battistoni et al., 2005; Abbasi et al., 2009; Esmaili et al., 2014

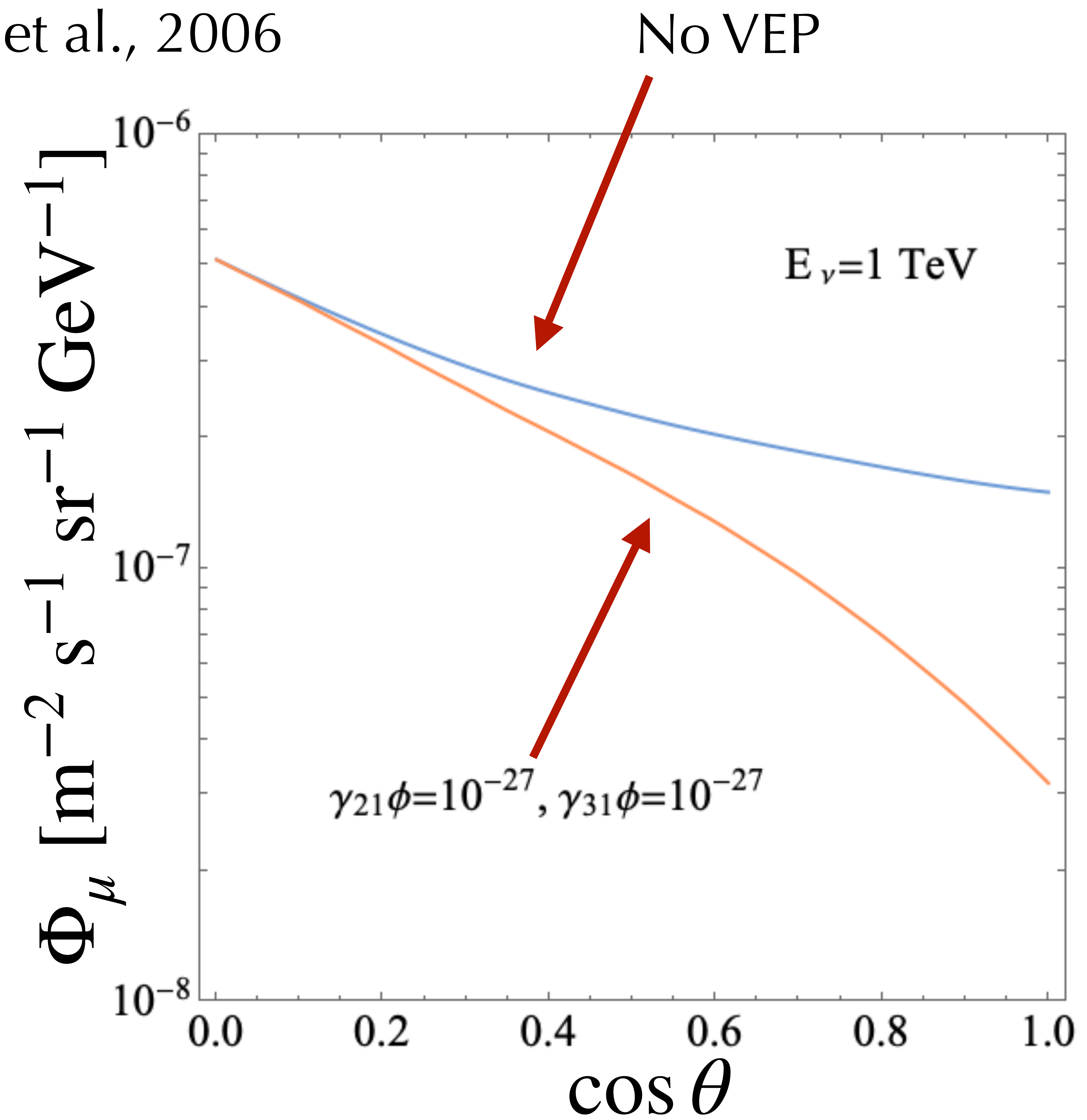




VEP and atmospheric neutrinos

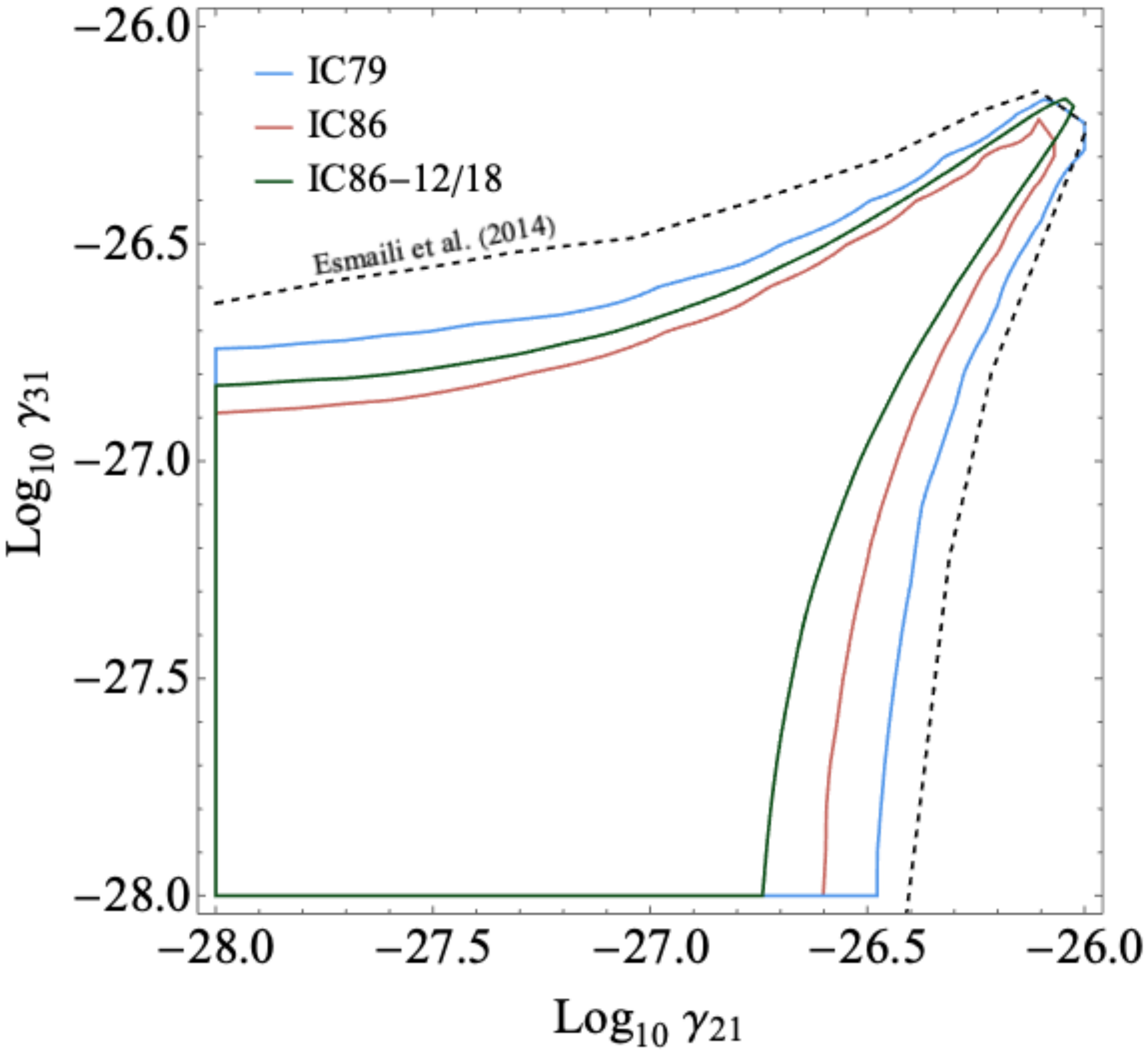
Model of atmospheric fluxes from Honda et al., 2006



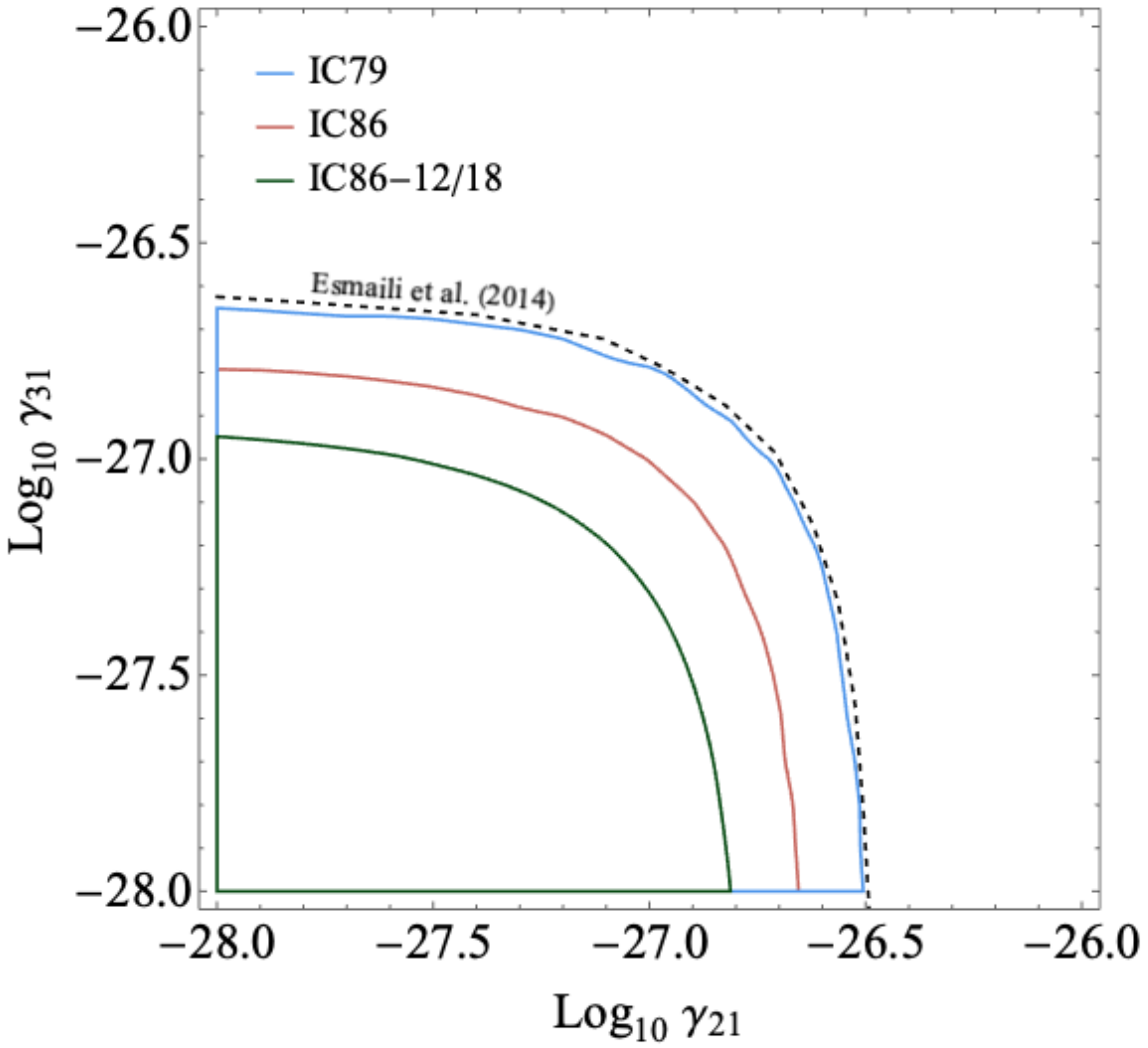


Constraints from atmospheric neutrinos

γ_{21}, γ_{31} have same signs

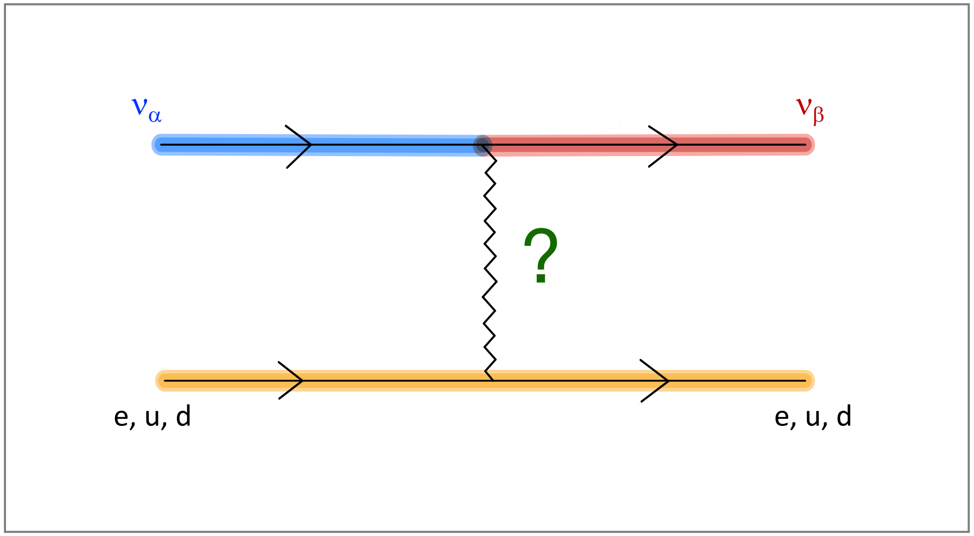


γ_{21}, γ_{31} have opposite signs



Hint of nonstandard ν interactions from NOνA & T2K

Mostly based on S.S. Chatterjee & A.P.,
PRL 126 051802 (2021) arXiv: 2008.04161

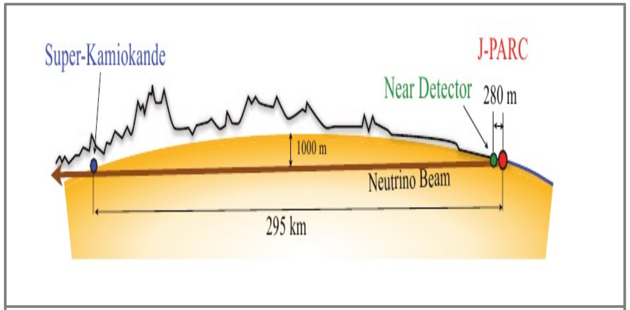


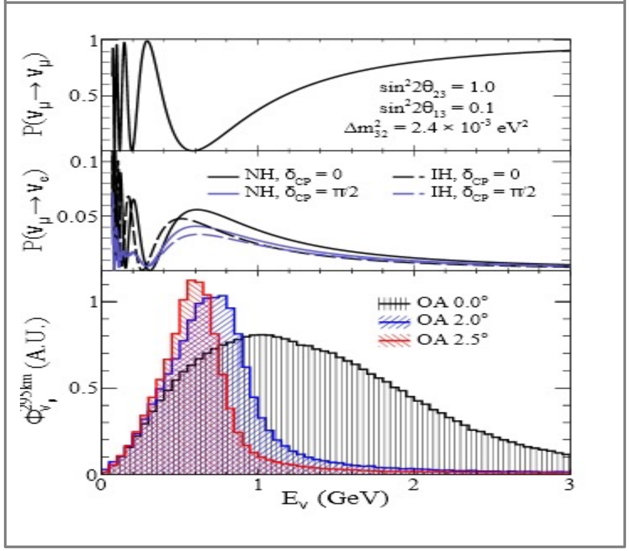
UNIBA press-release

INFN-BA press-release

Antonio Palazzo
University of Bari & INFN

T2K & NOνA at the forefront of CPV searches

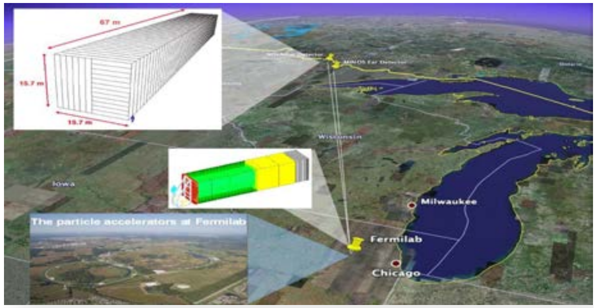


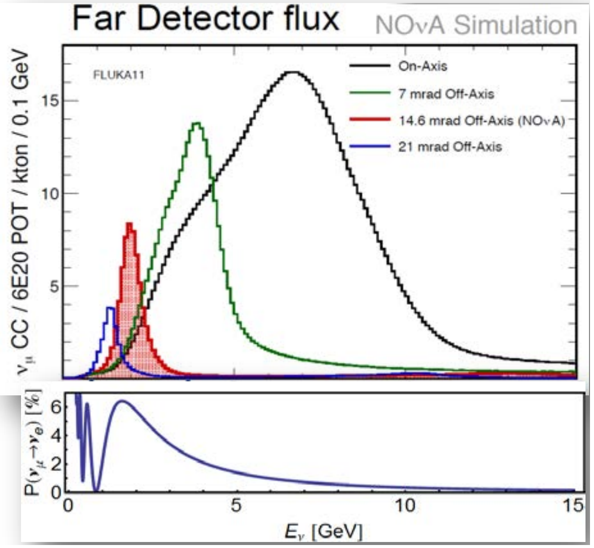


off-axis beam

$$\Delta = \frac{\Delta m^2_{13} L}{4E} \simeq \frac{\pi}{2}$$

First oscillation maximum





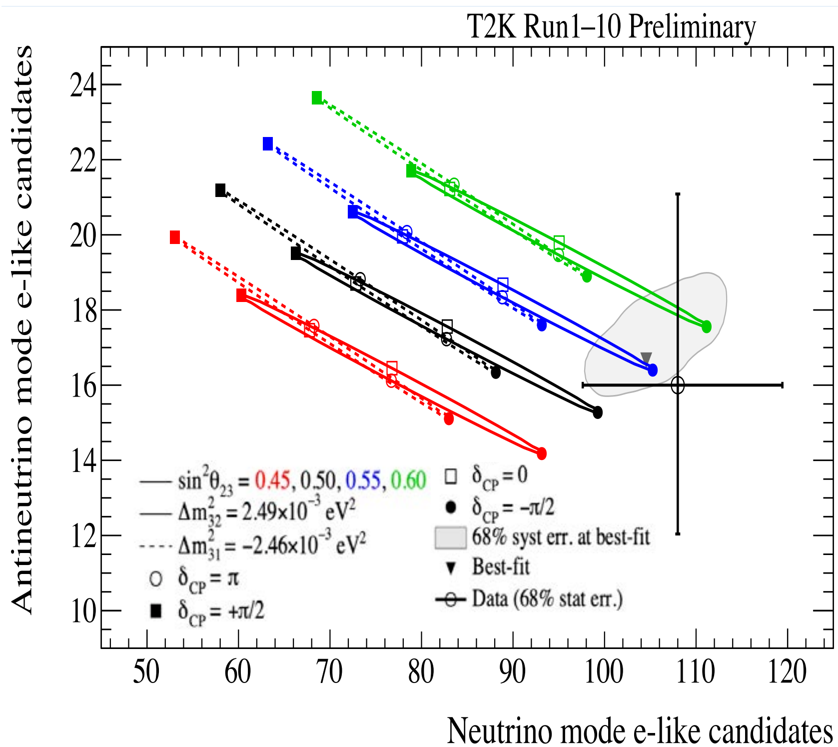
E = 0.6 GeV

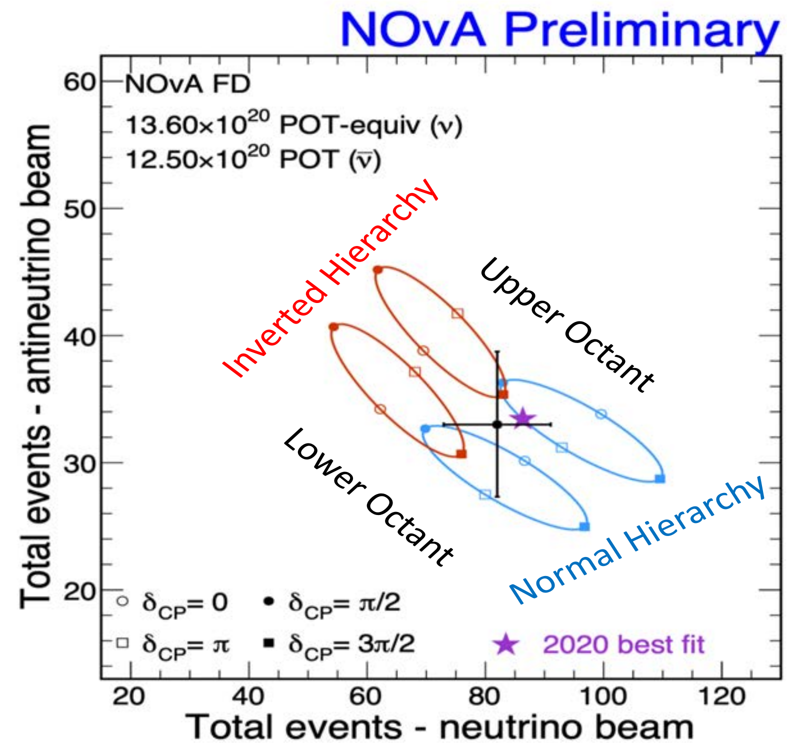
L = 295 km

E = 2 GeV

L = 810 km

Discrepancy visible in bievents plots





for Normal Ordering:

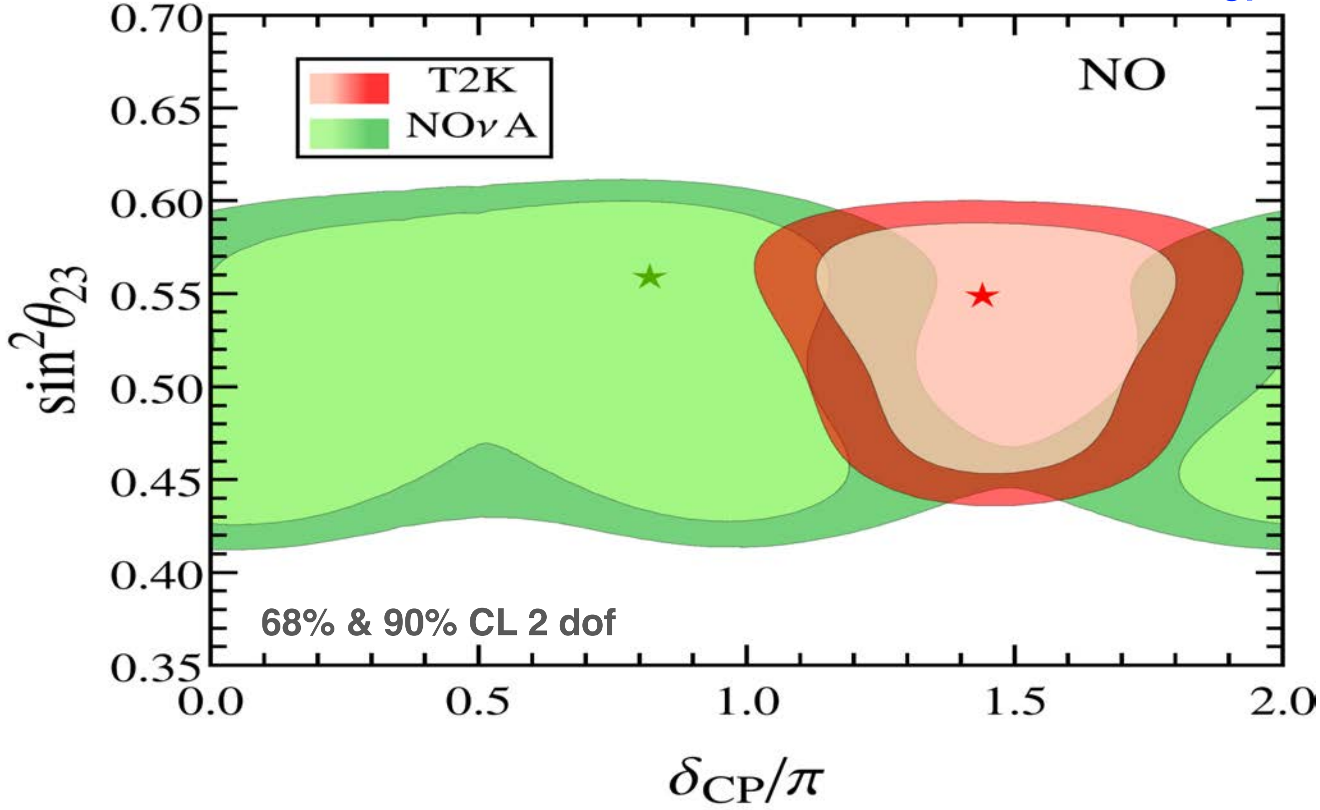
<u>IO disfavored from Global Analysis</u>

T2K prefers $\delta_{CP} \sim 1.5\pi$

NOνA prefers $\delta_{CP} \sim 0.8\pi$

Our analysis of ν 2020 preliminary data

In NO, tension in the determination of δ_{CP}



Maybe a statistical fluctuation or a systematic error

But interesting to consider alternative explanations…

Why to consider non-standard interactions

T2K and NOvA have **different baselines** and **peak energies** (L/E = costant)

Matter effects depend on the ratio $v = \frac{2V_{\rm CC}E}{\Delta m^2_{31}} = 0.18\left[\frac{E}{2.0\,{\rm GeV}}\right]$ **T2K** $v \sim 0.05$ **NOvA** $v \sim 0.17$

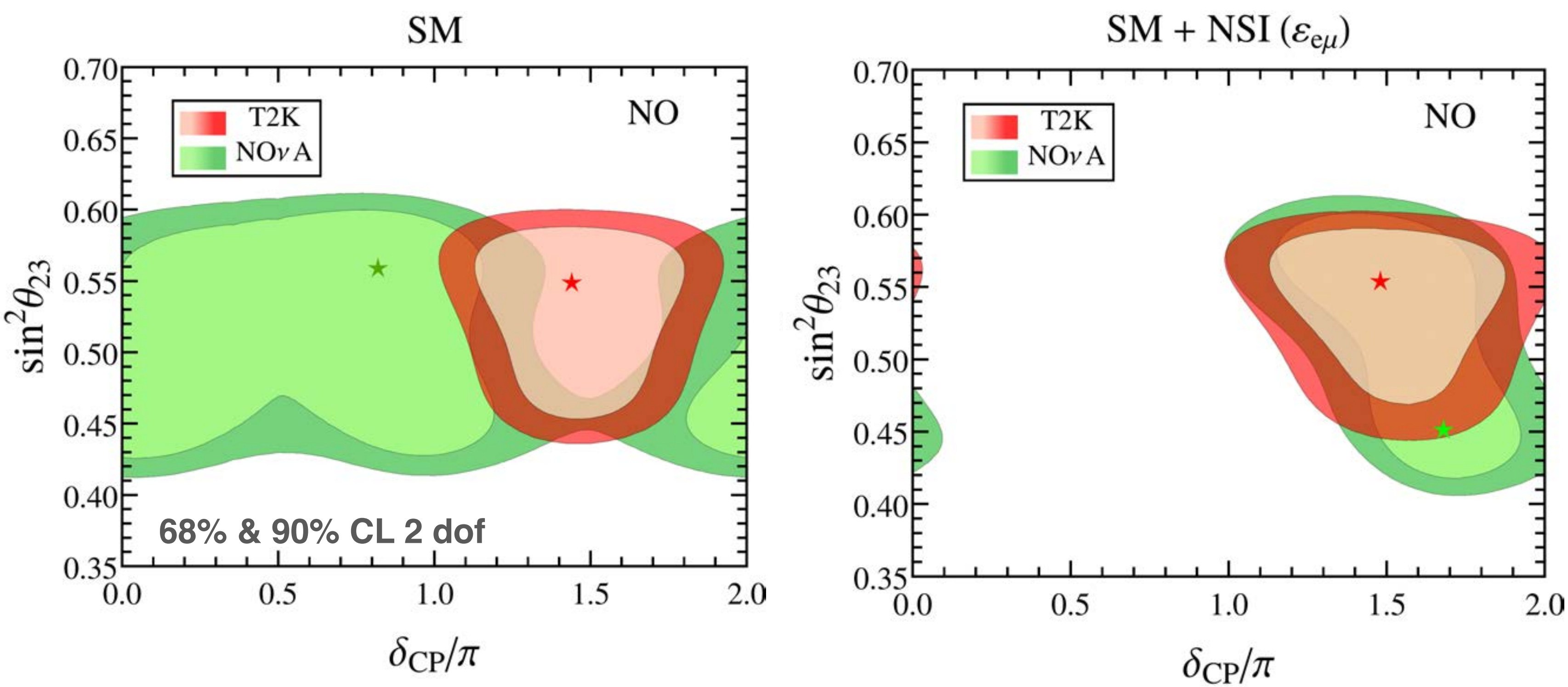
New matter effects encoded by NSI are also proportional to v

Basic Idea: suppose NSI exist, then:

T2K is a "**quasivacuum**" experiment. Its estimate of δ_{CP} is **independent** of NSI.

NOvA is a "**matter dominated**" experiment. The extracted value of δ_{CP} is **affected** by NSI. If NSI are taken into account, the estimate of δ_{CP} should return in agreement with that of T2K.

NSI bring the estimates of δ_{CP} in agreement

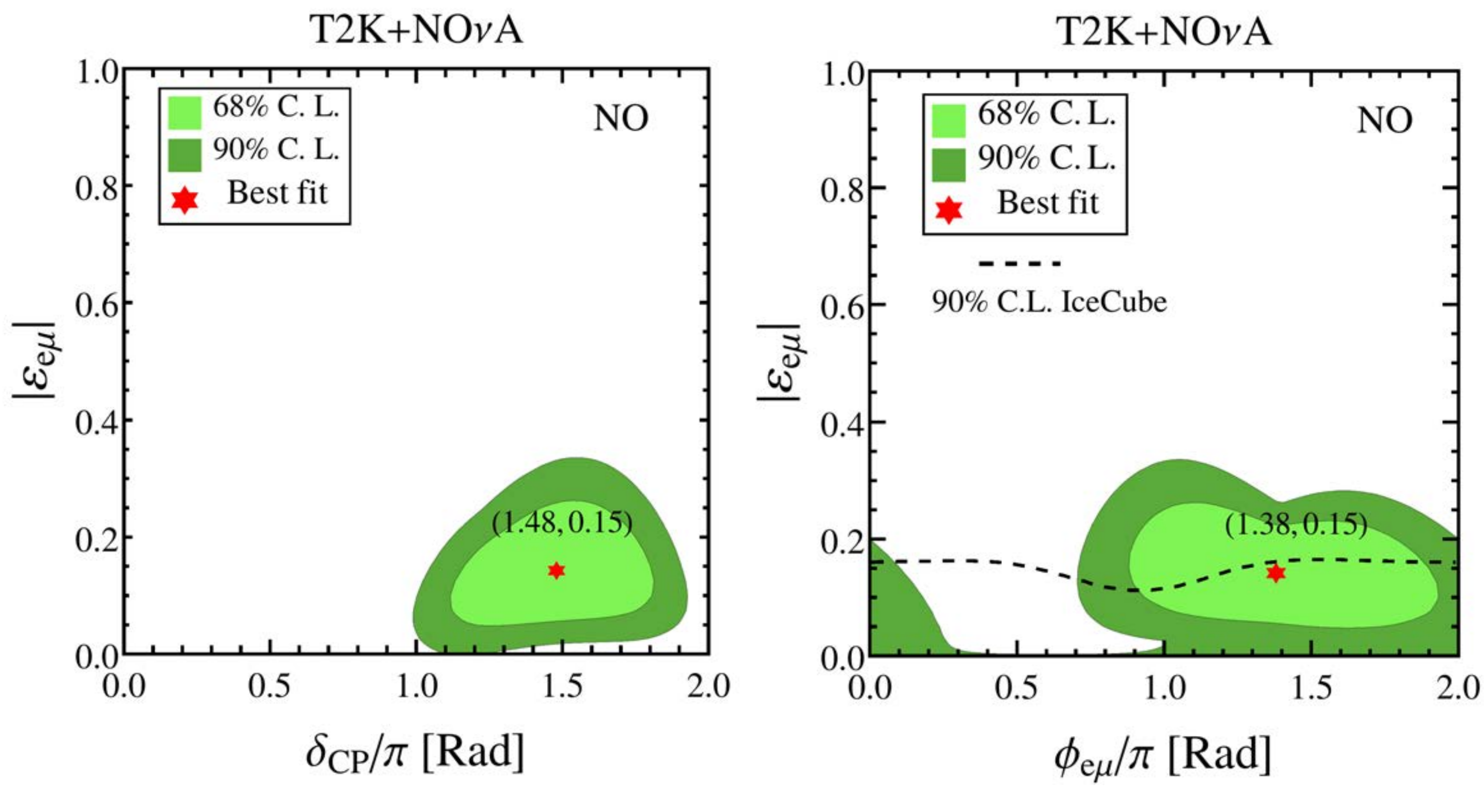


Contours obtained for the best fit of T2K + NOνA: $[\varepsilon_{e\mu} = 0.15,\ \phi_{e\mu} = 1.38\pi]$

T2K region almost unaltered

NOνA region strongly modified

Indication of non-zero $\varepsilon_{e\mu}$ from T2K + NOνA



~2 sigma preference for NSI

Conclusions

T2K and NOνA display a tension at ~2 sigma level

Complex flavor-changing NSI can solve the tension for $\varepsilon \sim 0.2$

New IceCube data with higher statistics should be able to probe these couplings

If the NSI indication persists, T2HK and DUNE will definitely confirm/disconfirm it.

Back up

Theoretical Framework

$$\mathcal{L}^{eff} = \mathcal{L}_{SM} + \frac{c^{d=5}}{\Lambda}\mathcal{O}^{d=5} + \frac{c^{d=6}}{\Lambda^2}\mathcal{O}^{d=6} + \dots$$

← **NSI**

$$\delta\mathcal{L}_{\rm NSI} = -2\sqrt{2}\,G_F \sum_{f,P} \epsilon^{fP}_{\alpha\beta}\,(\overline{\nu_\alpha}\gamma^\mu P_L \nu_\beta)\,(\bar{f}\gamma_\mu P f)$$

$$f = e, u, d$$

$$P = (P_L, P_R)$$

Only vectorial couplings are relevant for matter effects

$$\varepsilon^f_{\alpha\beta} = \varepsilon^{f,L}_{\alpha\beta} + \varepsilon^{f,R}_{\alpha\beta}$$

Effective couplings in the Earth's crust ($N_n \cong N_p$)

$$\varepsilon_{\alpha\beta} \simeq \varepsilon^e_{\alpha\beta} + 3\varepsilon^u_{\alpha\beta} + 3\varepsilon^d_{\alpha\beta}$$

$$H = U \begin{bmatrix} 0 & 0 & 0 \\ 0 & k_{21} & 0 \\ 0 & 0 & k_{31} \end{bmatrix} U^\dagger + V_{\rm CC} \begin{bmatrix} 1+\varepsilon_{ee} & \varepsilon_{e\mu} & \varepsilon_{e\tau} \\ \varepsilon^*_{e\mu} & \varepsilon_{\mu\mu} & \varepsilon_{\mu\tau} \\ \varepsilon^*_{e\tau} & \varepsilon^*_{\mu\tau} & \varepsilon_{\tau\tau} \end{bmatrix}$$

$$k_{ij} = \frac{\Delta m^2_{ij}}{2E}$$

$$V_{\rm CC} = \sqrt{2} G_F N_e$$

Off-diagonal $\varepsilon_{\alpha\beta}$ are complex and bring a CP phase

$$\varepsilon_{\alpha\beta} = |\varepsilon_{\alpha\beta}| e^{i\phi_{\alpha\beta}}$$

We focus on $\varepsilon_{e\mu}$ and $\varepsilon_{e\tau}$ ($\varepsilon_{\mu\tau}$: small effect on ν_e apperance and strong bounds)

Analytical expectations

$P_{\mu e}$ involves 4 small quantities

$s_{13} = 0.15$	ϵ	$v = \frac{2 V_{CC} E}{\Delta m^2_{31}} = 0.18 \left[\frac{E}{2.0\,\mathrm{GeV}} \right]$	ϵ
$\alpha = 0.03$	ϵ^2	$\lvert \varepsilon_{\alpha\beta} \rvert \sim 0.2$	ϵ

$P_{\mu e}$ is the sum of three terms

$$P_{\mu e} \simeq \underbrace{P_0 + P_1}_{\text{SM}} + \underbrace{P_2}_{\text{NSI}}$$

T2K	$v \sim 0.05$
NOvA	$v \sim 0.18$

$$P_0 \simeq 4 s^2_{13} s^2_{23} f^2 \qquad \epsilon^2$$

$$P_1 \simeq 8 s_{13} s_{12} c_{12} s_{23} c_{23} \alpha f g \cos(\Delta + \delta_{CP}) \qquad \epsilon^3$$

$$P_2 \simeq 8 s_{13} s_{23} v \lvert \varepsilon_{\alpha\beta} \rvert [a f^2 \cos(\delta_{CP} + \phi_{\alpha\beta}) + b f g \cos(\Delta + \delta_{CP} + \phi_{\alpha\beta})] \qquad \epsilon^3$$

$$f \equiv \frac{\sin[(1-v)\Delta]}{1-v}, \qquad g \equiv \frac{\sin v\Delta}{v}$$

$$a = s^2_{23}, \quad b = c^2_{23} \quad \text{if} \quad \alpha\beta = e\mu$$

$$a = s_{23} c_{23}, \quad b = -s_{23} c_{23} \quad \text{if} \quad \alpha\beta = e\tau$$

$$\nu \to \bar{\nu} \quad [v, \delta_{CP}, \phi_{\alpha\beta}] \to [-v, -\delta_{CP}, -\phi_{\alpha\beta}]$$

P_2 brings one additional CP-phase $\phi_{\alpha\beta}$

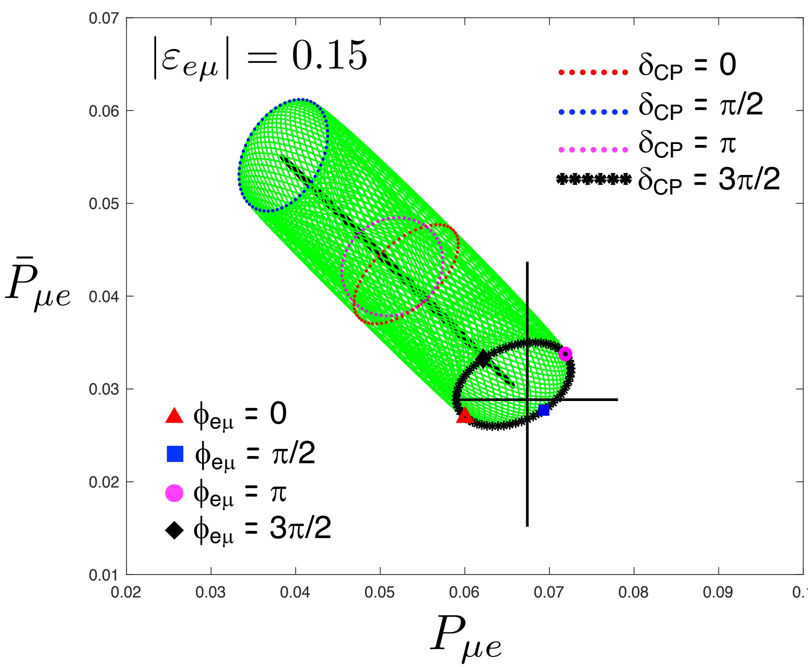
Parametric curve in biprobability plot:

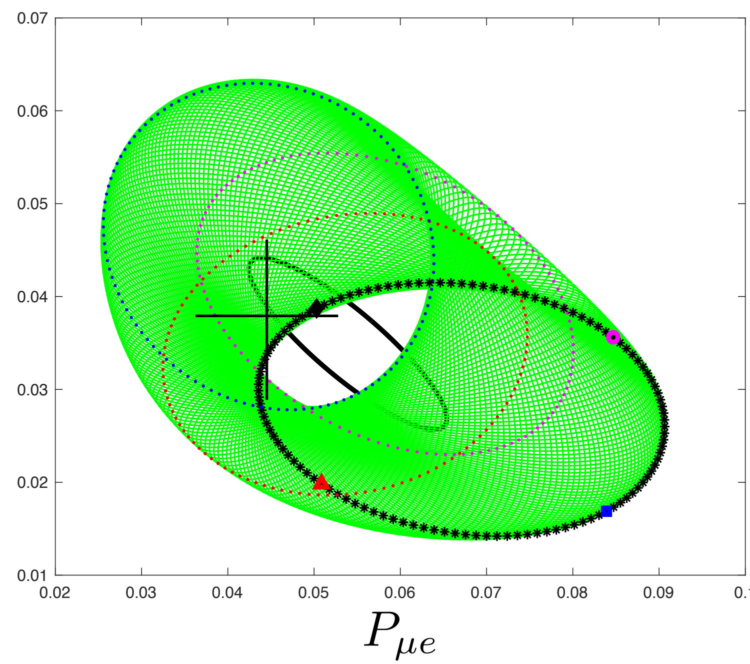
$[x, y] = [P_{\mu e}, \bar{P}_{\mu e}]$

- **For fixed $\phi_{\alpha\beta}$ → ellipse for varying δ_{CP}**
- **For fixed δ_{CP} → ellipse for varying $\phi_{\alpha\beta}$**

Biprobability plots in the presence of NSI

T2K	**NOνA**
Strongly favors $\delta_{CP} \sim 3\pi/2$ ellipse (almost no sensitivity to $\phi_{e\mu}$)	In agreement with $\delta_{CP} \sim 3\pi/2$ ellipse. On this ellipse it pins down $\phi_{e\mu} \sim 3\pi/2$





PRIN NAT-NET
6th Jul 2021

Massive sterile neutrinos in the Early Universe: from thermal decoupling to cosmological constraints

Based on L. Mastrototaro, P. D. Serpico, A. Mirizzi, N. Saviano ArXiv:2104.11752

MASSIVE STERILE NEUTRINO IN THE EARLY UNIVERSE

- The aim of the work is to obtain:
  - a precise calculation of the sterile neutrino evolution in the Early Universe;
  - bounds on the sterile neutrino parameters from the BBN and CMB measurement.
- Already studied in:
  - Dolgov et al, ArXiv:*hep-ph/*0002223 → analytical treatment
  - Ruchayskiy and Ivashko, ArXiv:1202.2841 } Numerical treatment focused on Y_p
  - Nashwan et al, ArXiv:2006.07387 } Numerical treatment focused on Y_p
- We solved exactly and numerically the Boltzmann equation for sterile neutrinos with $m_s < m_\pi \sim 135\ \mathrm{MeV}$ and for active neutrinos after their decoupling.

$$x = m_0 a(t) \qquad y = m_0 p$$

$$\partial_x f = \frac{I}{xH}$$

$$I = \frac{(2\pi)^4}{2E_1} \int d^3\widehat{p_2} d^3\widehat{p_3}\, d^3\widehat{p_4} \mathrm{F}(f_1, f_2, f_3, f_4) S |M|^2 \delta^4(p_1 + p_2 - p_3 - p_4)$$

$|M|^2$ sum of scattering and decay processes for ν_s and

$$F(f_1, f_2, f_3, f_4) = -\prod_i f_i \prod_f (1 \pm f_f) + \prod_i (1 \pm f_i) \prod_f f_f$$

I is a 9-dimensional integral that we reduce to a 3-dimensional integral to solve numerically using the technique developed by [*Hannestad et al, arXiv:astro-ph/9506015*]

For active neutrinos, we include the neutrino oscillation:

$$I_\alpha \to \sum_\beta P_{\beta\alpha} I_\beta$$

$P_{\beta\alpha}$ is the time-average transition probability from flavour β to α

STERILE NEUTRINO DECOUPLING

The temperature evolution is taken into account using

$$\frac{d}{dx}\bar{\rho}(x) = \frac{1}{x}(\bar{\rho}(x) - 3P),$$

$$\bar{\rho}_a = \frac{1}{\pi^2}\int dy y^2 \sqrt{\frac{m_a^2 x^2}{m^2} + y^2} f_a(x,y) \qquad P_a = \frac{1}{3\pi^2}\int \frac{dy y^4}{\sqrt{\frac{m_a^2 x^2}{m^2} + y^2}} f_a(x,y)$$

We define $z = Ta(t)$ and consider two main situations:

- Sterile neutrino decoupled (active-EM in equilibrium);
- Sterile neutrino and active neutrino decoupled (at x_d).

Decoupling condition: $\Gamma = \int d^3\widehat{p_1} I = H$

m_s [MeV]	$\sin^2\theta_{\tau 4}$	τ [s]	T_D^n [MeV]
20.0	2.6×10^{-2}	3.0×10^{-1}	4.35
40.0	2.8×10^{-3}	8.8×10^{-2}	9.24
60.0	5.5×10^{-4}	6.0×10^{-2}	16.83
80.0	1.5×10^{-4}	5.0×10^{-2}	26.53
100.0	5.8×10^{-5}	4.4×10^{-2}	37.10
130.0	1.6×10^{-5}	4.2×10^{-2}	59.13

COMPARISON WITH COSMOLOGICAL OBSERVATION

Planck results: $N_{eff} = 2.99 \pm 0.17$ and $Y_p = 0.245 \pm 0.003$ [Aghanimet al, arXiv:1807.06209]

Sterile neutrinos affect N_{eff} and Y_p that are both relevant for CMB. We used a likehood analysis

$$\chi^2_{CMB} = (\Theta - \Theta_{obs})\Sigma^{-1}_{CMB}(\Theta - \Theta_{obs})^T$$

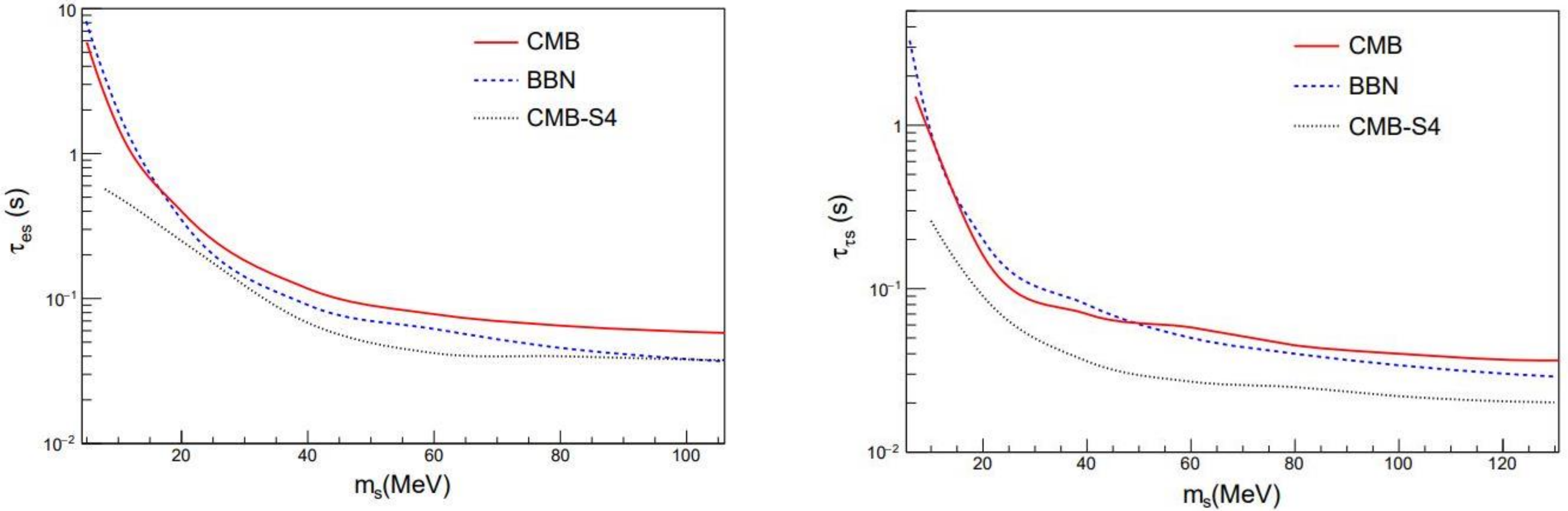
$$\Theta = \left(N_{eff}, Y_p\right) \qquad \Theta_{obs}(2.97, 0.246)$$

$$\Sigma_{CMB} = \begin{pmatrix} \sigma_1^2 & \sigma_1\sigma_2\rho \\ \sigma_1\sigma_2\rho & \sigma_2^2 \end{pmatrix}$$

$$\sigma_1 = 0.2650 \qquad \sigma_2 = 0.0177 \qquad \rho = -0.845$$

Considered a value of $\chi^2 = 6.18$ corresponding to 95.45% CL.

CMB and Y_p CONSTRAINTS



Bounds in the plane $(m_s,\ \tau_s)$ obtained from CMB (red curve) and BBN-Yp (blue curve), as well as forecast sensitivity of CMB-S4 (black curve), for a sterile neutrino mixed with ν_τ (or ν_μ) and ν_e. The 2σ excluded region is the one above the curves.

For Y_p and N_{eff} we have used the Planck data while for the CMB-S4 the expected sensitivity is $\sigma_1 = 0.062$ and $\sigma_2 = 0.0053$ [*Baumann et al, arXiv:*1508.06342]

Heavy decaying dark matter at future neutrino radio telescopes

6 July 2021
PRIN Working Package 2

M. Chianese[1], D. F. G. Fiorillo[1,2], R. Hajjar[3], G. Miele[1,2,3], S. Morisi[1,2], N. Saviano[2,3]

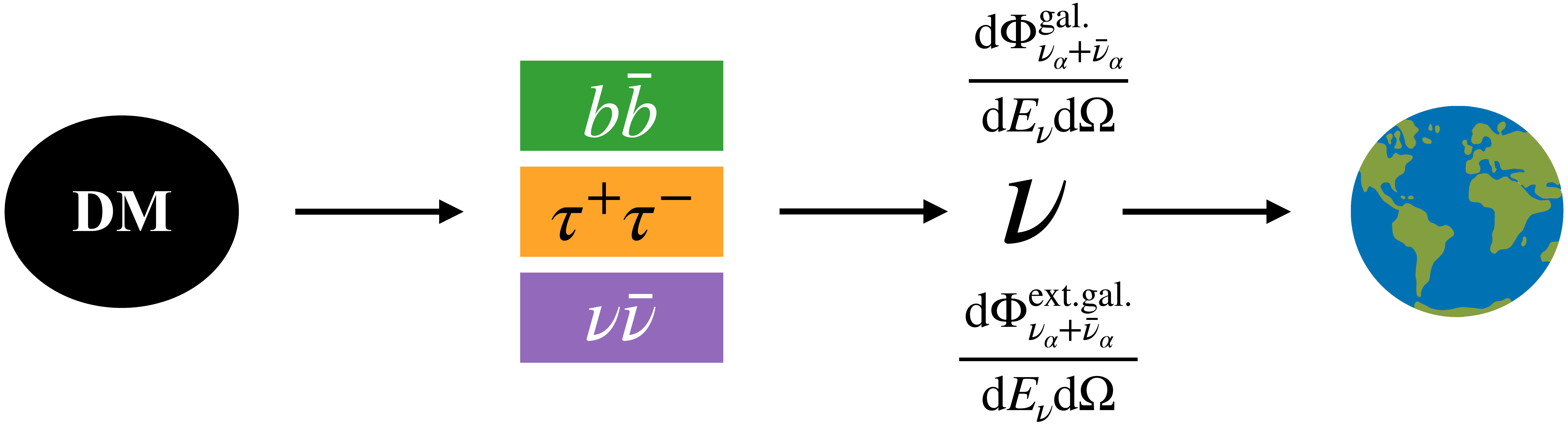
1 2 INFN
3 SSM Scuola Superiore Meridionale
NAP THEORY

JCAP05(2021)074 arXiv: [2103.03254]

Main goal of this work

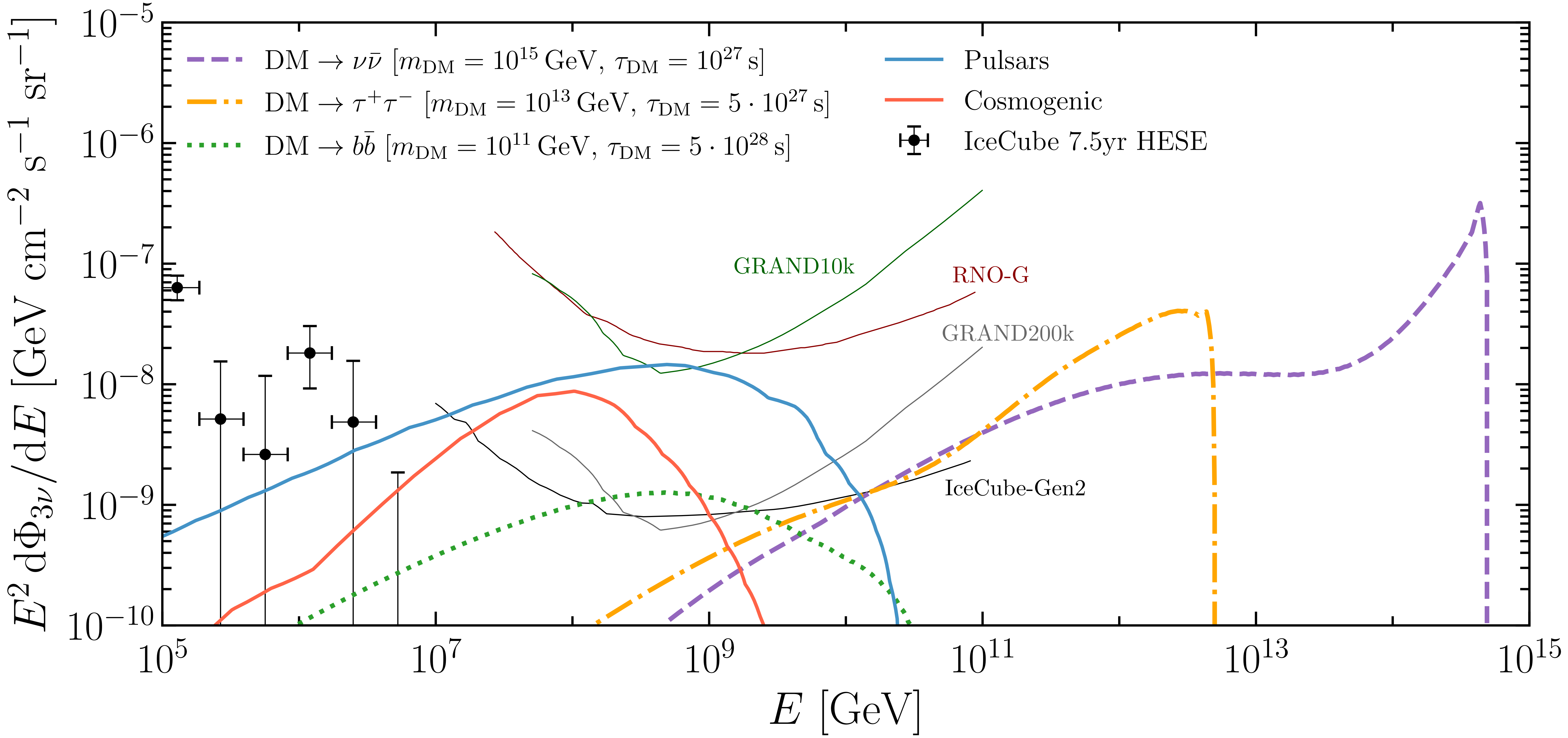
- The main goal of this work is to forecast the limits that we can place on the lifetime of Heavy Dark Matter (HDM) particles using future neutrino radio telescopes.

- We assume that the DM particles decay to a pair of SM particles and the minimal decaying DM scenario with only two parameters: $(m_{\mathrm{DM}}\,,\,\tau_{\mathrm{DM}})$



Methodology

- HDMSpectra to generate DM fluxes: *C. W. Bauer et. al. [2007.15001]*
- Astrophysical neutrinos act as a background.
- **Conservative choice:** highest theoretical astro fluxes.



Cosmogenic

guaranteed but uncertain magnitude, come from CRs interacting with CMB

Newborn Pulsars

higher expected astrophysical contribution in literature for neutrino radio telescopes

New limits on HDDM

$$p\left(N_{\rm obs}\,|\,N_{\rm astro}\right) = \frac{\left(N_{\rm astro}\right)^{N_{\rm obs}} e^{-N_{\rm astro}}}{N_{\rm obs}\,!}$$

N_{obs} stochastic random variable
N_{astro} expected astrophysical events

Conservative choice:

$N_{\rm events}$ of DM > $N_{\rm events}$ observed

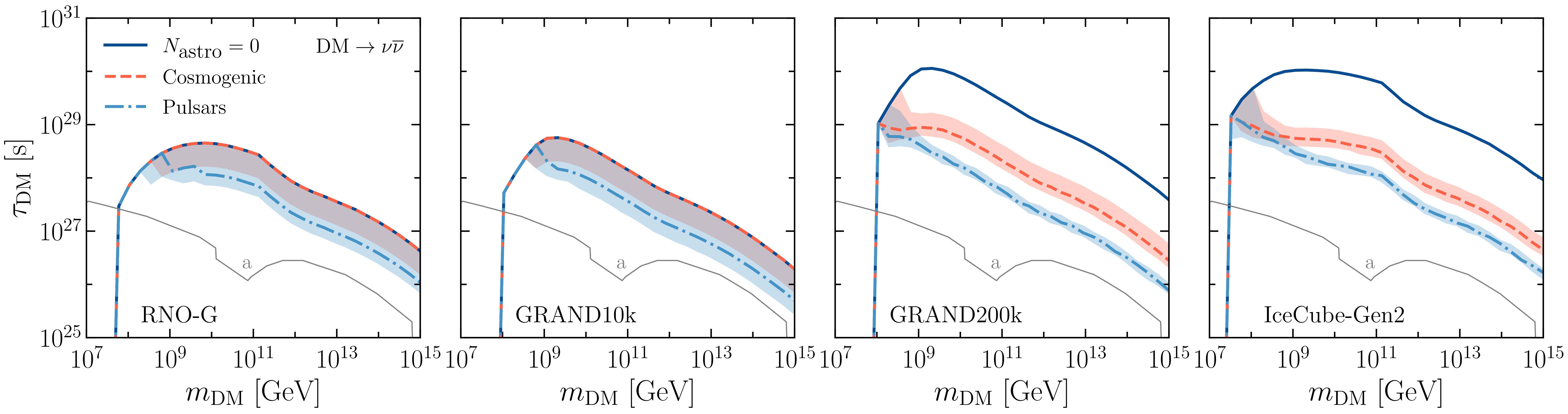
$$\mathrm{TS}(m_{\rm DM}, \tau_{\rm DM}) = \begin{cases} 0 & \text{for} \quad n_{\rm DM} < N_{\rm obs} \\ -2\ln\left(\frac{\mathscr{L}(N_{\rm obs}\,|\,n_{\rm DM})}{\mathscr{L}(N_{\rm obs}\,|\,N_{\rm obs})}\right) & \text{for} \quad n_{\rm DM} \geq N_{\rm obs} \end{cases}$$

$N_{\rm astro} = 0$
Cosmogenic
Pulsars

$$\mathrm{DM} \to \nu\overline{\nu}$$

a) IceCube + PAO + ANITA
A. Esmaili et. al. [1205.5281]

T_{obs} = 3 years



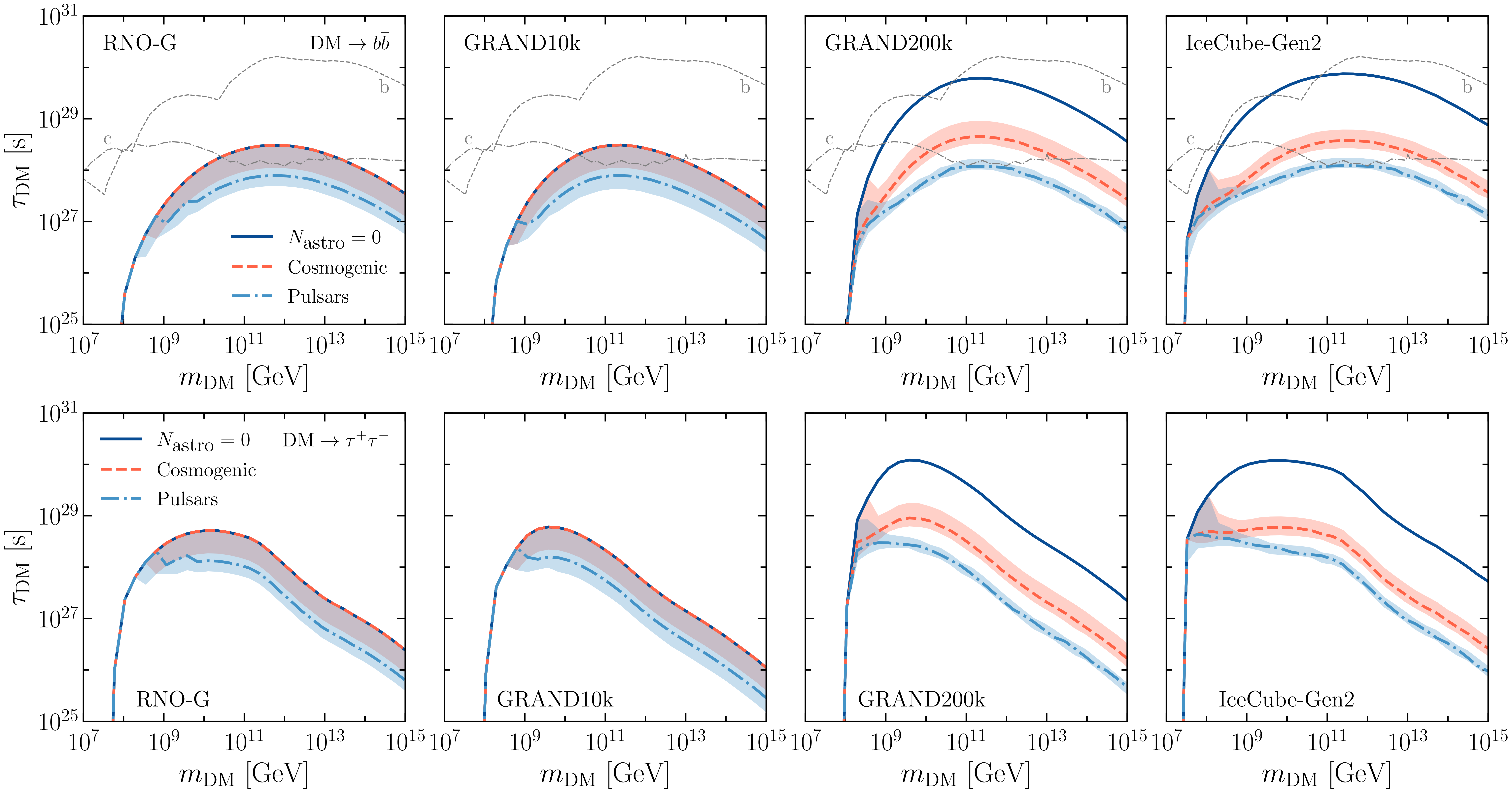
New limits on HDDM

T_{obs} = 3 years

$$\mathrm{DM} \to b\bar{b}$$

b) galactic Multi-Messenger K. Ishiwata et. al. [1907.11671]
c) extragalactic Multi-Messenger K. Ishiwata et. al. [1907.11671]

$$\mathrm{DM} \to \tau^+\tau^-$$



Conclusions

- Radio neutrino telescopes will have potential to detect a contribution coming from DM.
- Forecast analysis in order to set conservative bounds on the lifetime of HDM particles with $m_{DM} = 10^7 - 10^{15}$ GeV.
- 3 channels, 4 experiments and 2 different astrophysical signals.
- Future work: obtain limits using the current gamma-ray measurements for all channels.

Thank you for your attention

Thanks for the attention

HE Neutrinos beyond Standard Model: steriles and secret interactions

Istituto Nazionale di Fisica Nucleare
Sezione di Napoli

Ninetta Saviano

In collaboration with D. Fiorillo, G. Miele, S. Morisi

Based on: *Fiorillo, Miele, Morisi,* ***Saviano*** *2020,* ***PRD 101,083024****, arXiv:2002.10125,*

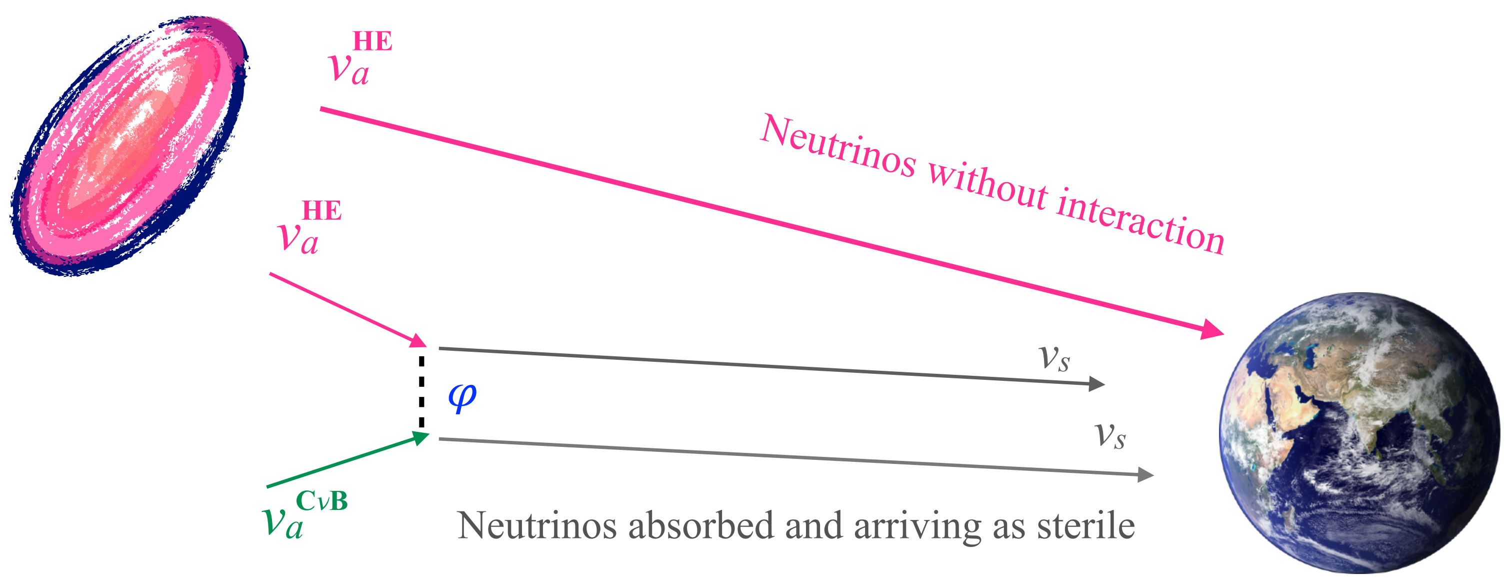
Fiorillo, Miele, Morisi, ***Saviano*** *2020,* ***PhysRevD 102.083014****, arXiv:2007.07866*

Our model

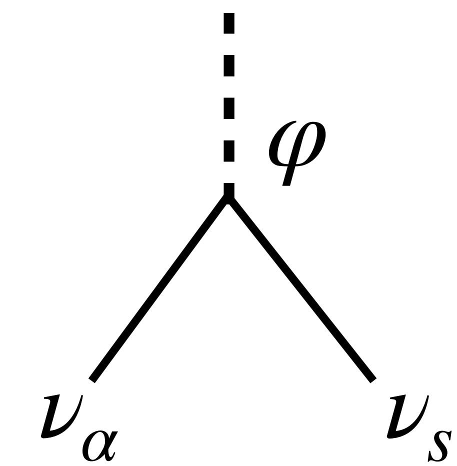
We consider a scheme of SI where the new interaction, mediated by a new pseudoscalar mediator, involves both active and sterile neutrinos:

$$\mathcal{L}_{\rm SI} = \sum_{\alpha} \lambda_\alpha \, \overline{\nu}_\alpha \gamma_5 \nu_s \varphi$$

$$\alpha = e, \mu, \tau$$



λ_α dimensionless free couplings



Parameter space:

$M_\varphi, m_s, \lambda_\alpha$

We study the modifications on the expected (ultra-)high neutrino fluxes at Earth implied by the new coupling, estimating the possibility to measure this effect in present and future apparatus, depending on the neutrino energies.

*Fiorillo, Miele, Morisi, **Saviano** 2020, **PRD 101,083024**, arXiv:2002.10125*

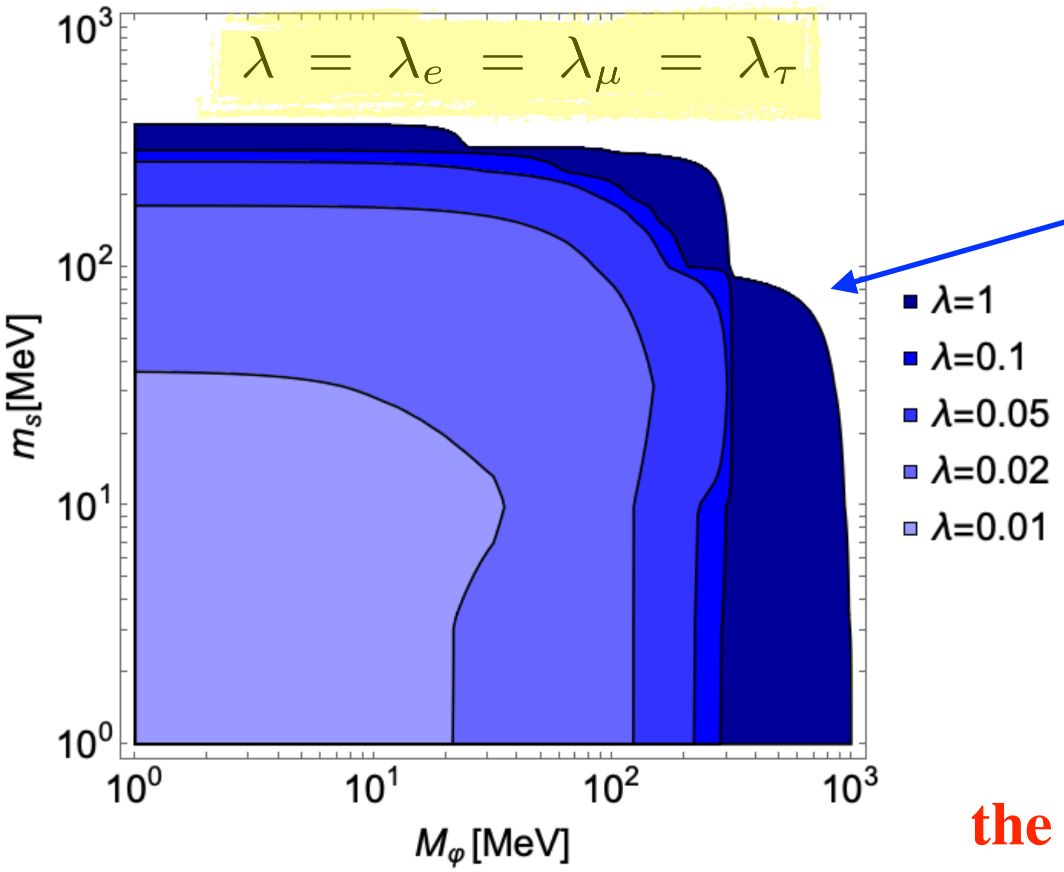
*Fiorillo, Miele, Morisi, **Saviano** 2020, **PhysRevD 102.083014**, arXiv:2007.07866*

Allowed parameter space (1)

- Laboratory constraints

Examples: $K^+ \to \mu\varphi\nu_s$ and $K^+ \to \mu\nu_s\nu_s\overline{\nu}'_\ell$ should be observed as $K \to \mu +$ missing energy

In the standard sector the closer Kaon decay process is $K \to \mu\nu\overline{\nu}\nu$ with BR= 2.4×10^{-6}



We impose $\mathrm{BR}\left(\begin{smallmatrix} K^+ \to \mu\varphi\nu_s \\ K^+ \to \mu\nu_s\nu_s\overline{\nu}'_\ell \end{smallmatrix}\right) < 2.4 \times 10^{-6}$

Bump produced by the four-body decay

the region below the contours is excluded

For $\lambda \geq 0.01$ and $(m_s \text{ or } M_\varphi) \gtrsim 30\, MeV$

the correction to Kaon decay is within the experimental bound

The choice of only $\lambda_\tau \neq 0$ (which involves the D decay) is practically unconstrained from meson physics and even for value of λτ~ O(1), the only relevant bound in the $M_\varphi - m_s$ plane comes from BBN

Allowed parameter space (2)

- Cosmological constraints

BBN requirement: no extra relativistic d.o.f. at the BBN-time (~1 MeV)

CMB requirement: free-streaming active ν at the CMB-time (~1 eV)

Both satisfied for **Mϕ and ms >10 MeV**

- Supernovae constraints

Supernovae neutrinos with energy of 10-100 MeV can produce non relativistic sterile neutrinos via secret interactions.

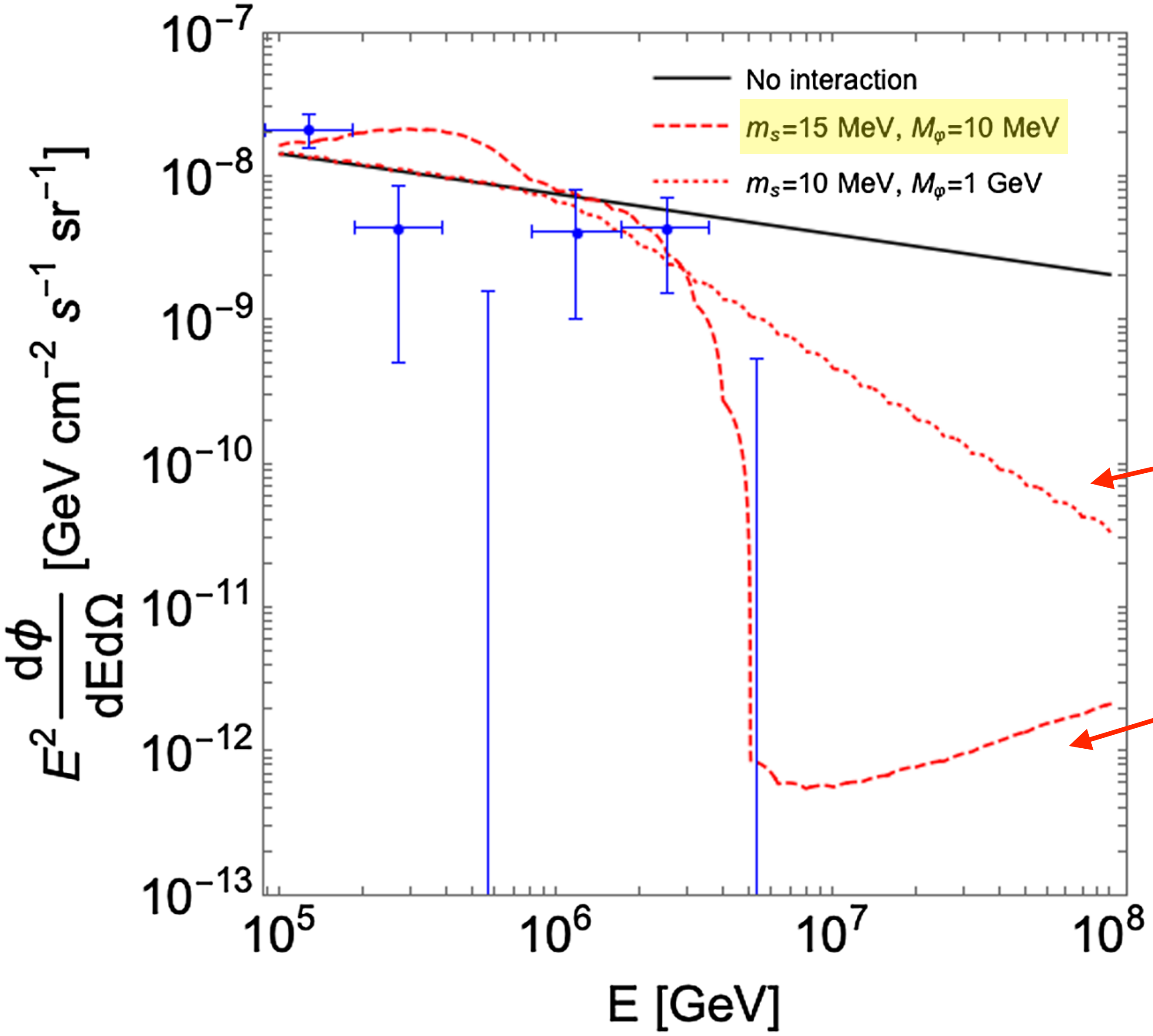
These sterile neutrinos might, depending on their interaction, escape the SN giving rise to an observable energy loss.

For **Mϕ and ms >10 MeV, this situation is never verified and so our model is not subjected to SN constrains**

Results and detection chances for PL Spectrum (1)

Cutoff-like feature in the spectrum:

Energy range roughly below 100 PeV



$\lambda_e = \lambda_\mu = \lambda_\tau = \lambda_{af}$ (where af denotes all flavors)

$\lambda_{af} = 1$

small sterile masses, large scalar masses

m_s=10 MeV, M_φ=1 GeV

$\lambda_e = \lambda_\mu = 0$ and $\lambda_\tau \neq 0$ =1

m_s=15 MeV, M_φ=10 MeV

the constraints from mesons decay are irrelevant

⇨ also lower masses for Mφ

IceCube HESE data

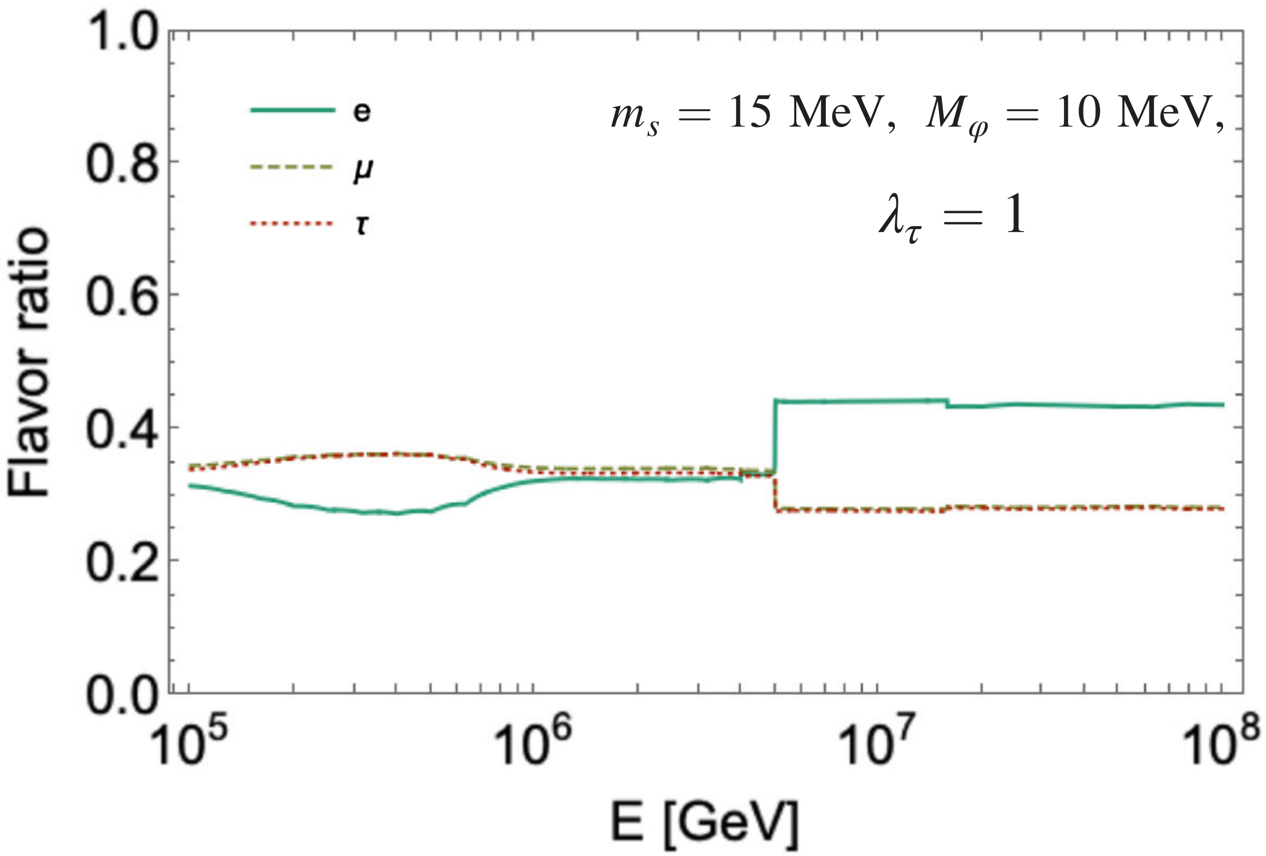
The new interaction causes a cutoff-like feature in the spectrum in the range between 1 PeV and 10 PeV

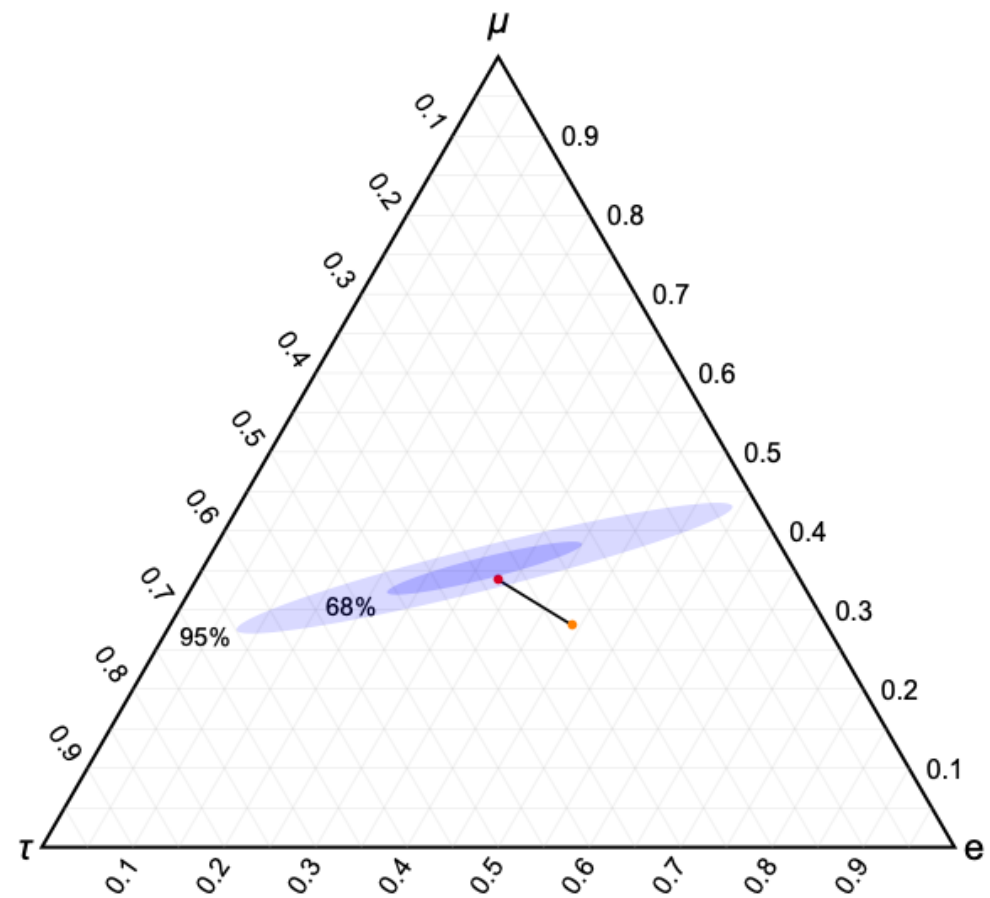
*Fiorillo, Miele, Morisi, **Saviano** 2020, **PhysRevD 102.083014**, arXiv:2007.07866*

Results and detection chances for PL Spectrum (2)

Changing in the flavour ratio:

the depletion is energy dependent ⇨ energy dependent flavor ratio at Earth





flavor ratio at the source (1 : 2 : 0)

Expected flavor ratio at Earth (1 : 1 : 1)

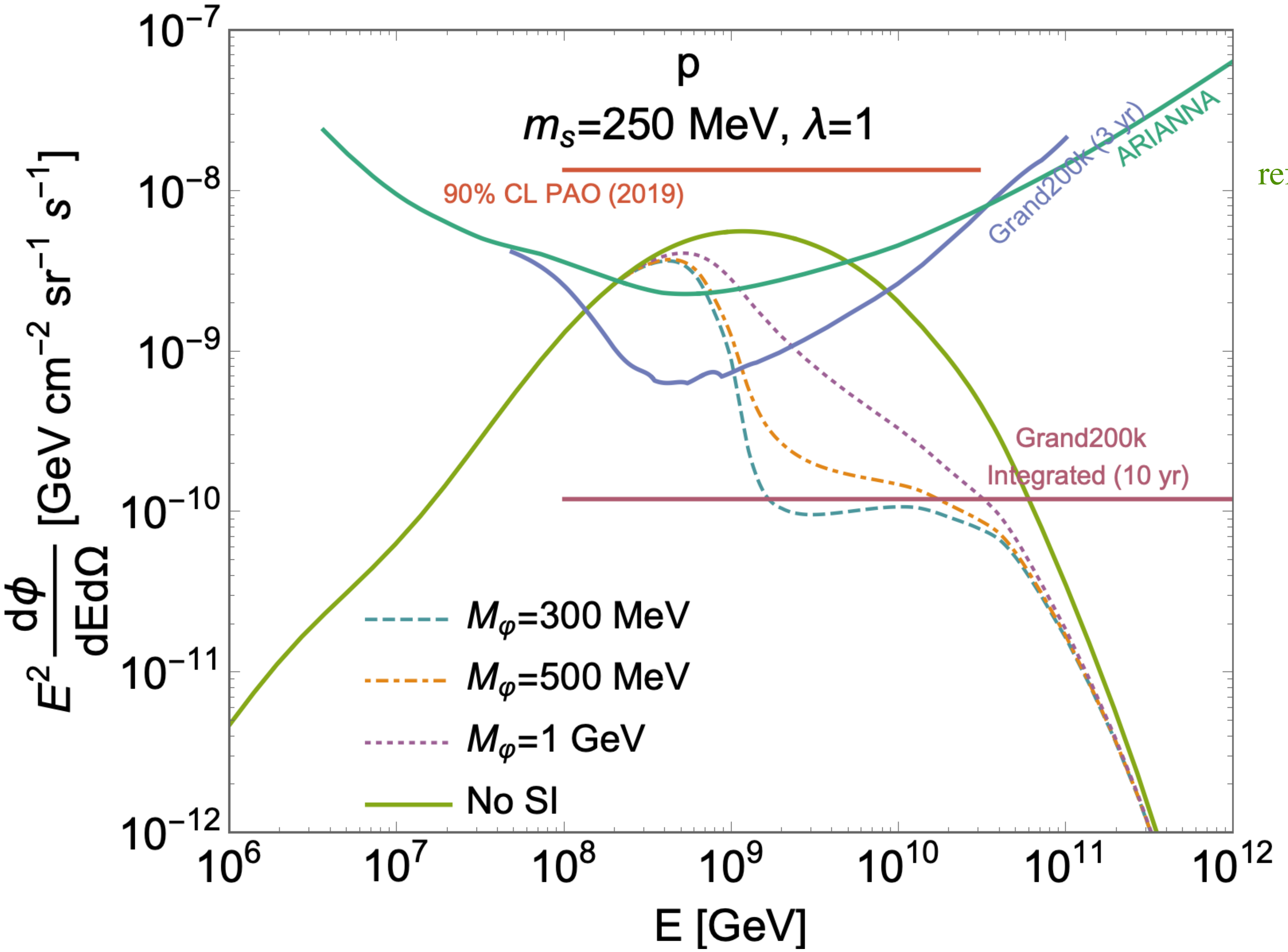
Flavor at 10^5 GeV

Flavor at 10^8 GeV

forecasted sensitivity of IceCube-Gen2

*Fiorillo, Miele, Morisi, **Saviano** 2020, **PhysRevD 102.083014**, arXiv:2007.07866*

Results and detection chance for Cosmogenic Spectrum



proton cosmic rays

reference spectrum given in *Ahlers & Halzen 2012*

The effect is maximal around $10^{9 \div 10}$ GeV

Fiorillo, Miele, Morisi, ***Saviano*** *2020,* ***PRD 101,083024****, arXiv:2002.10125*

Thank you