Charged Lepton Flavor Violation in Neutrino Telescopes

arXiv:2605.abcde

Writasree Maitra

m.writasree@wustl.edu

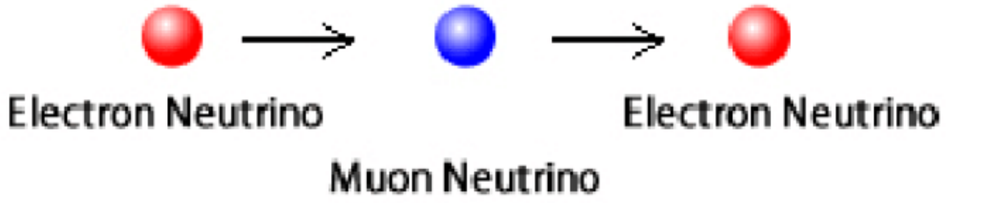
with

Carlos A. Argüelles (Harvard U.), Bhupal Dev (Washington U. in St. Louis),
Ivan Martinez-Soler (Durham U.) and Manibrata Sen (IIT Bombay)

PHENO 2026
University of Pittsburgh
May 12, 2026

Charged Lepton Flavor Violation (CLFV)

Evidence of LFV



From Super-Kamiokande website

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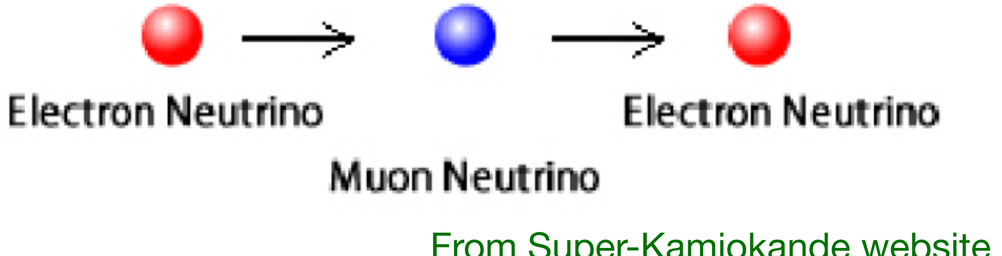

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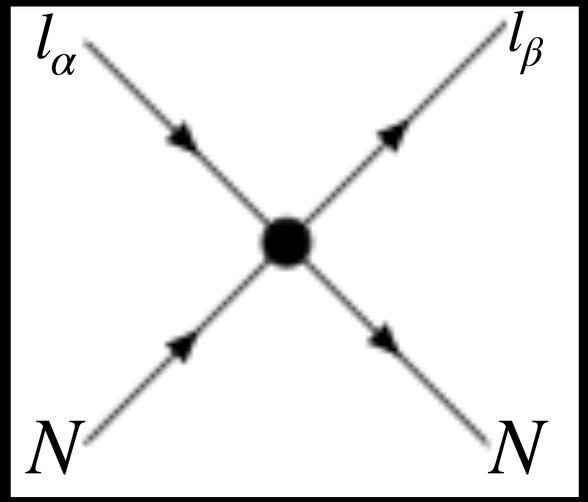
Can we expect the same in the charged lepton sector?



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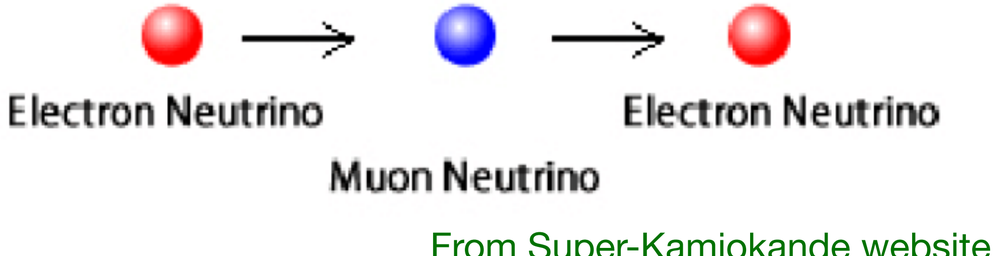

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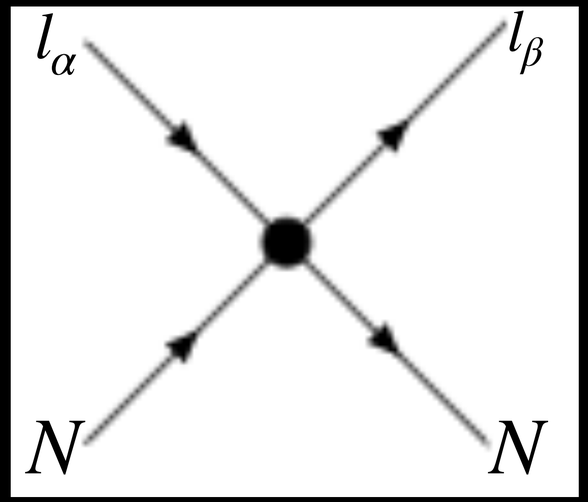

Detecting CLFV will clearly indicate new physics!!

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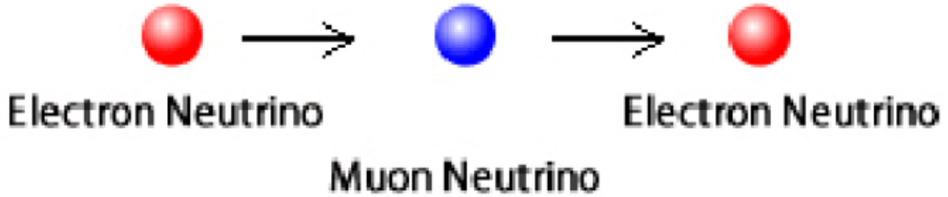

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Case I: 6-dimensional EFT operators

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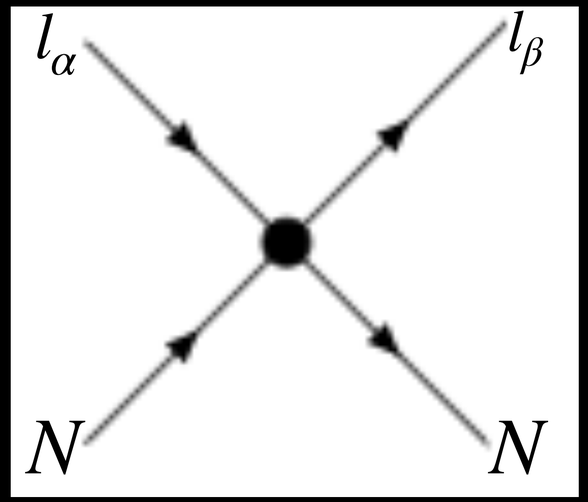

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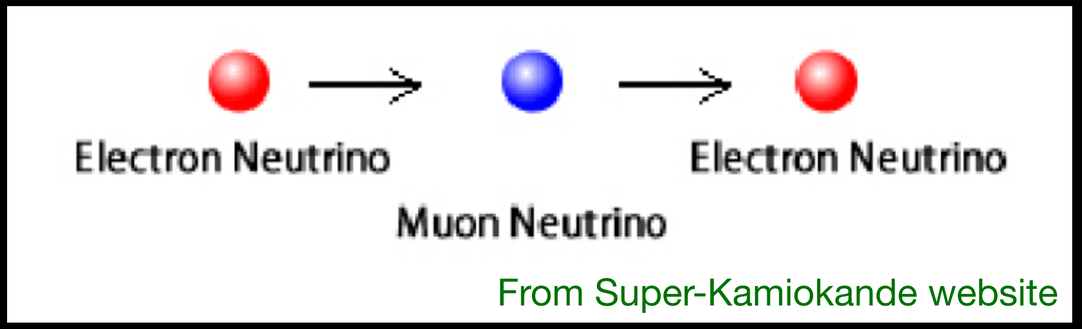

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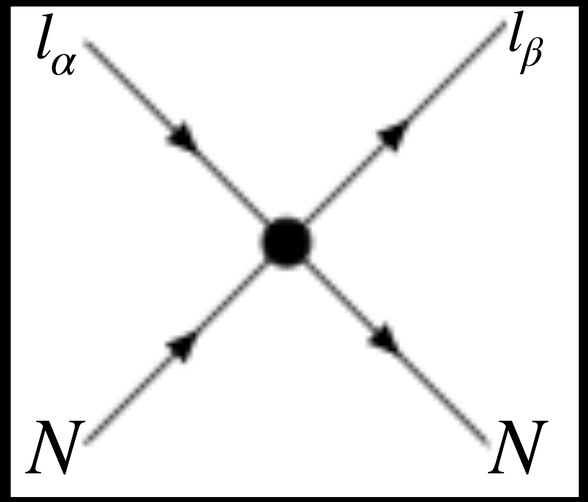

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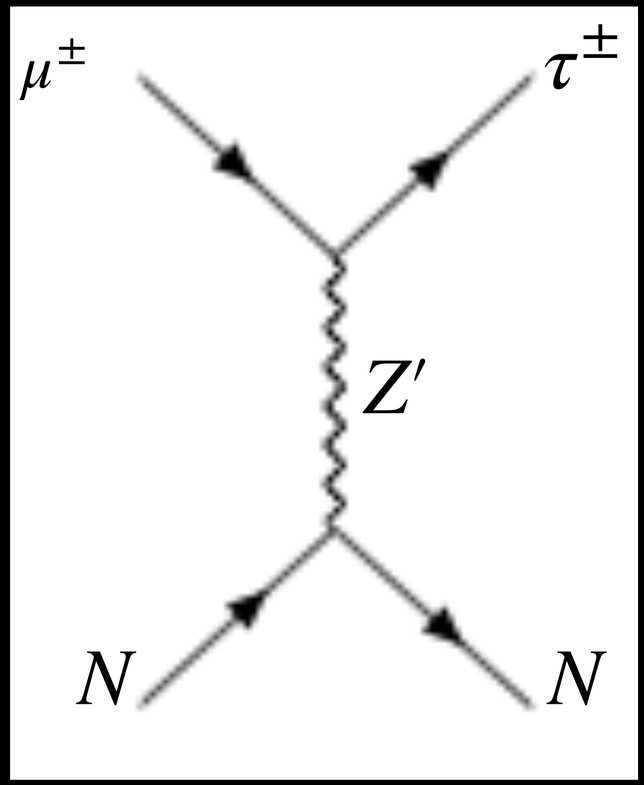

A bit on IceCube

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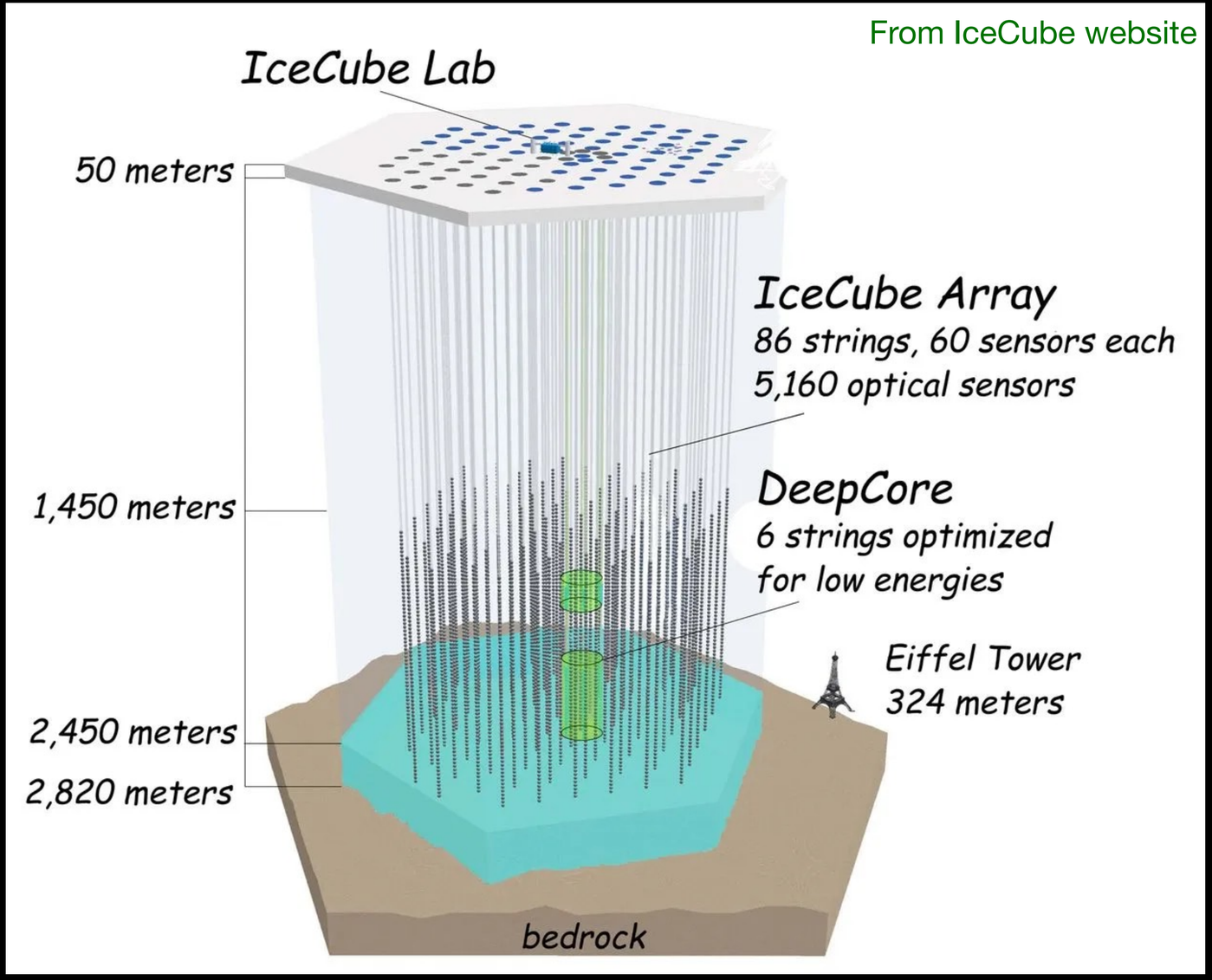

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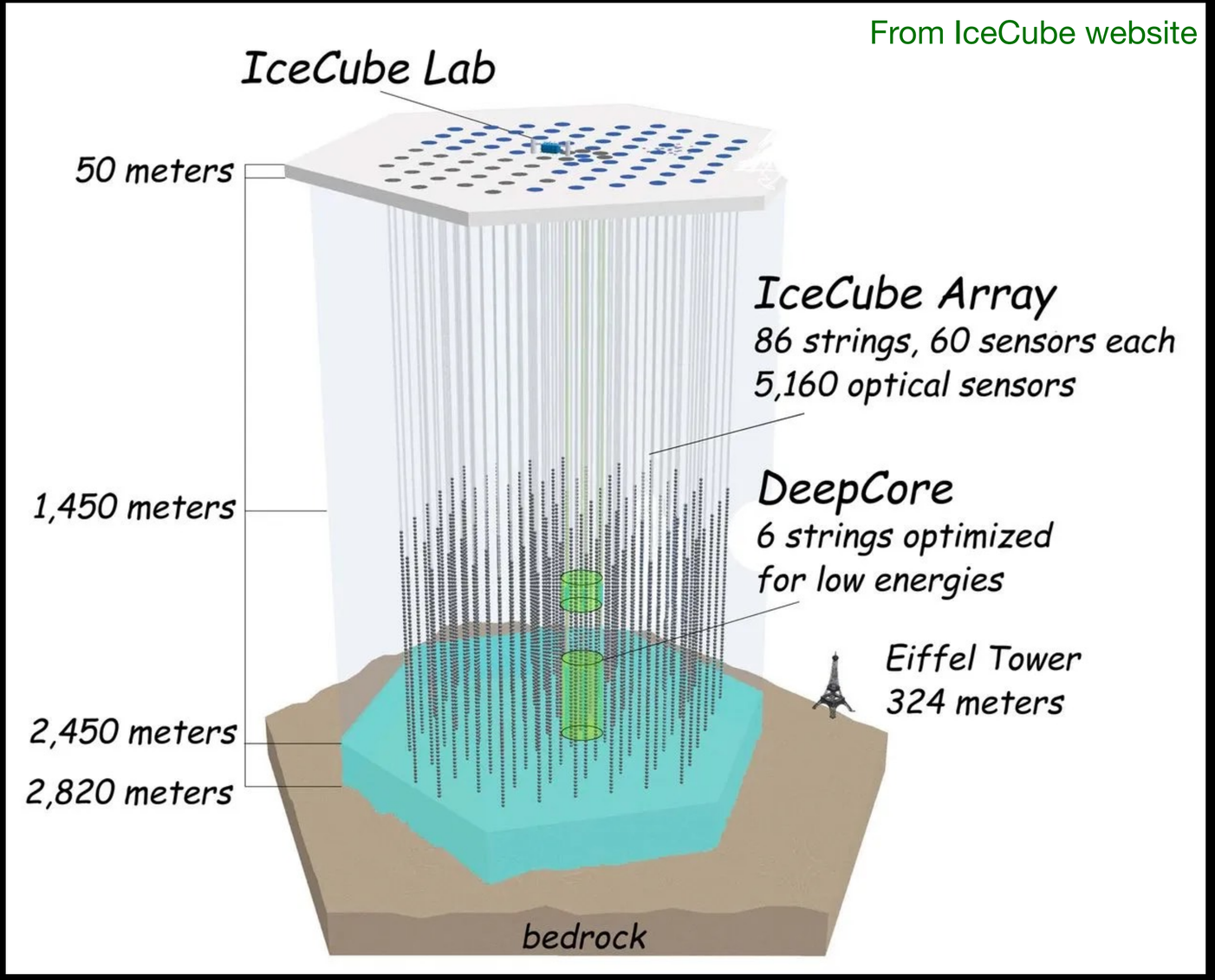

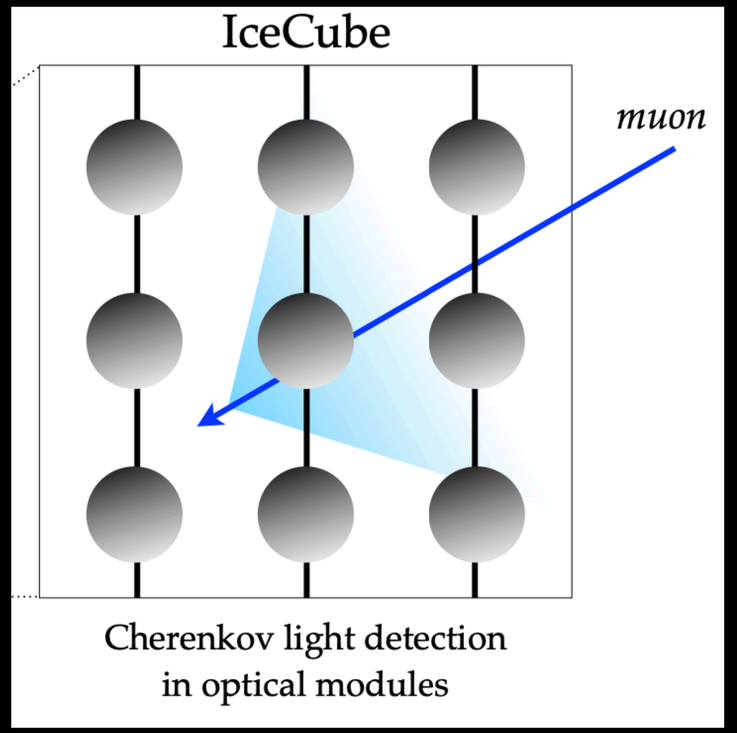

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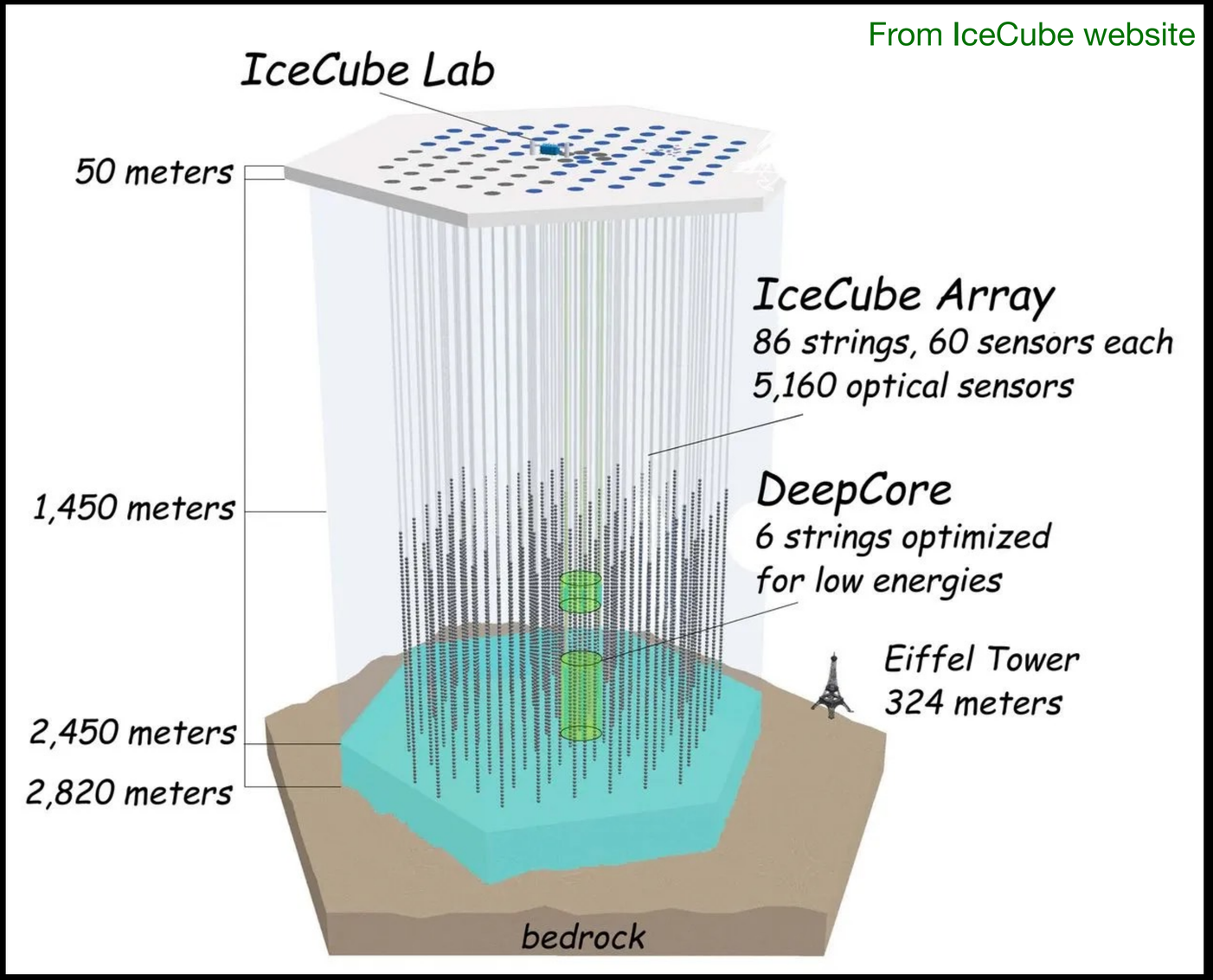

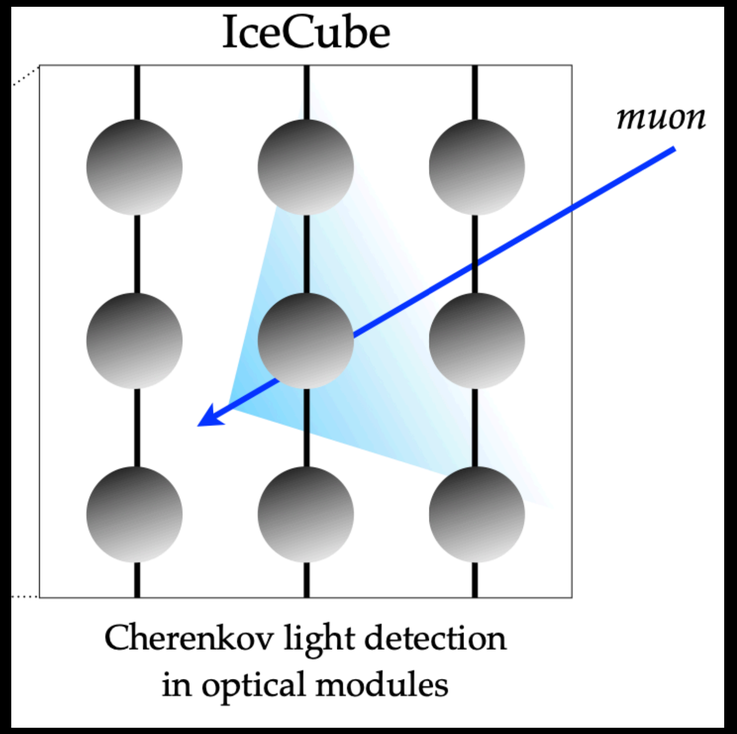

IceCube (or any such neutrino experiment like Gen2 & HUNT) can be a hub of these ν-induced muons & hence can be used to look for CLFV.

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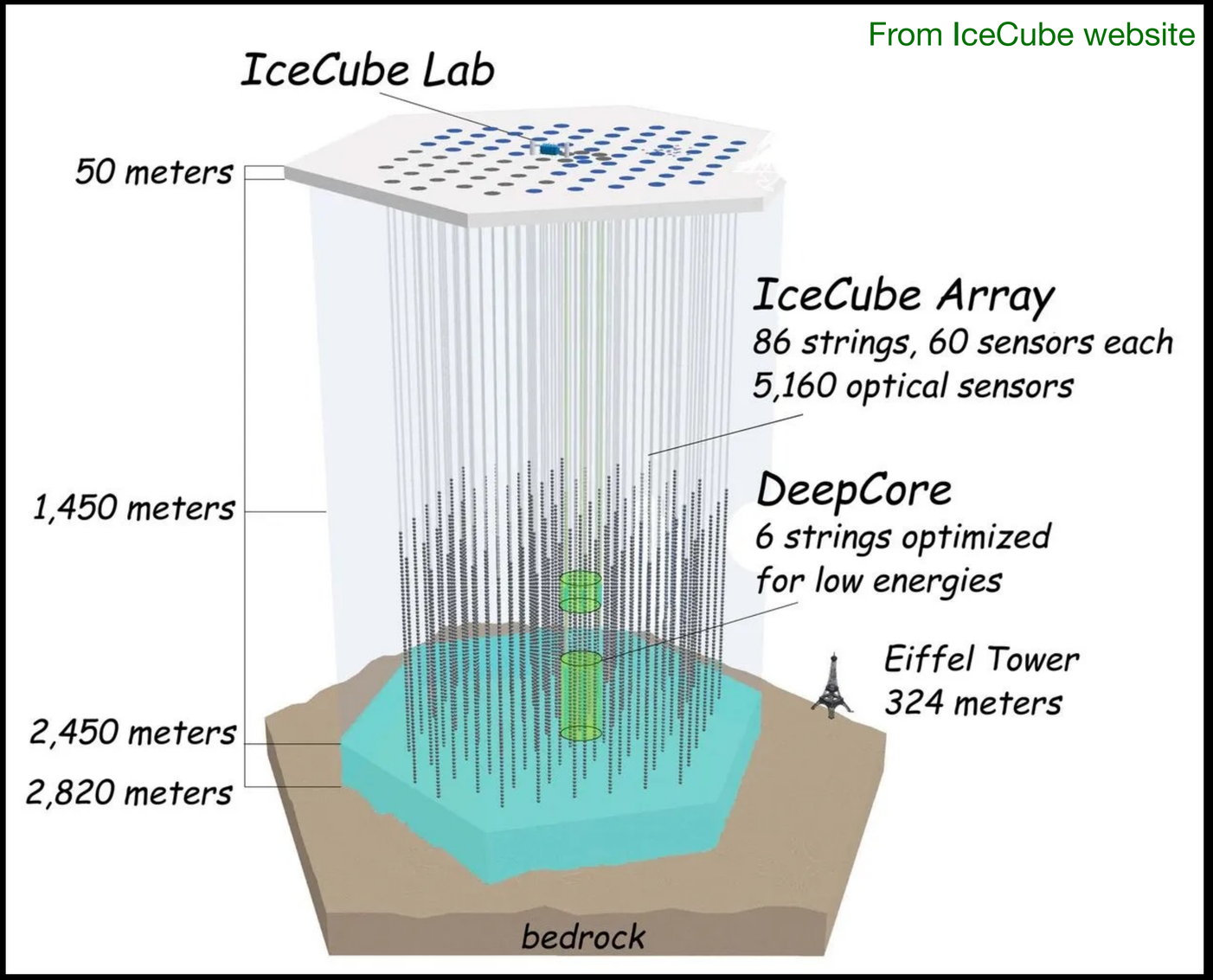

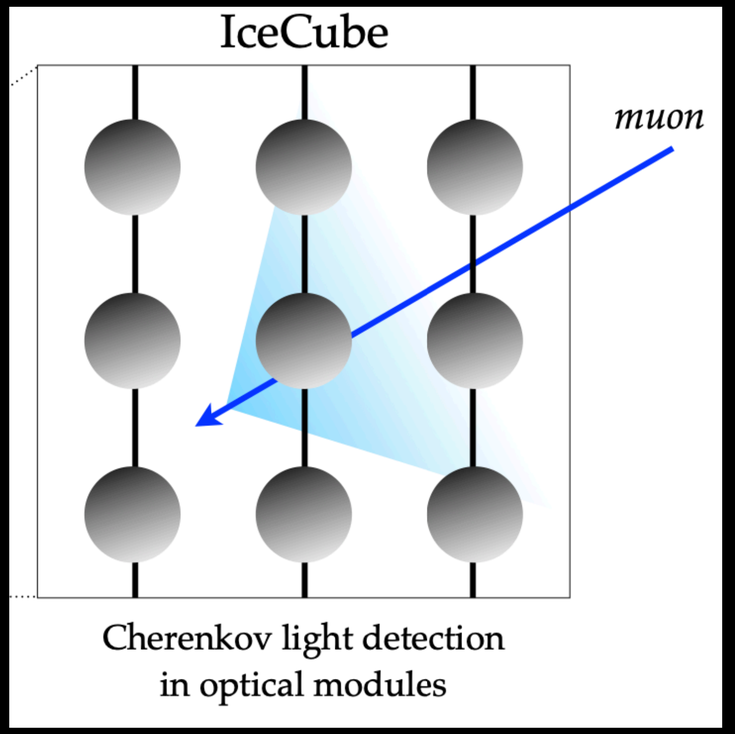

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Motivation!!

IceCube Data Analysis (without CLFV)

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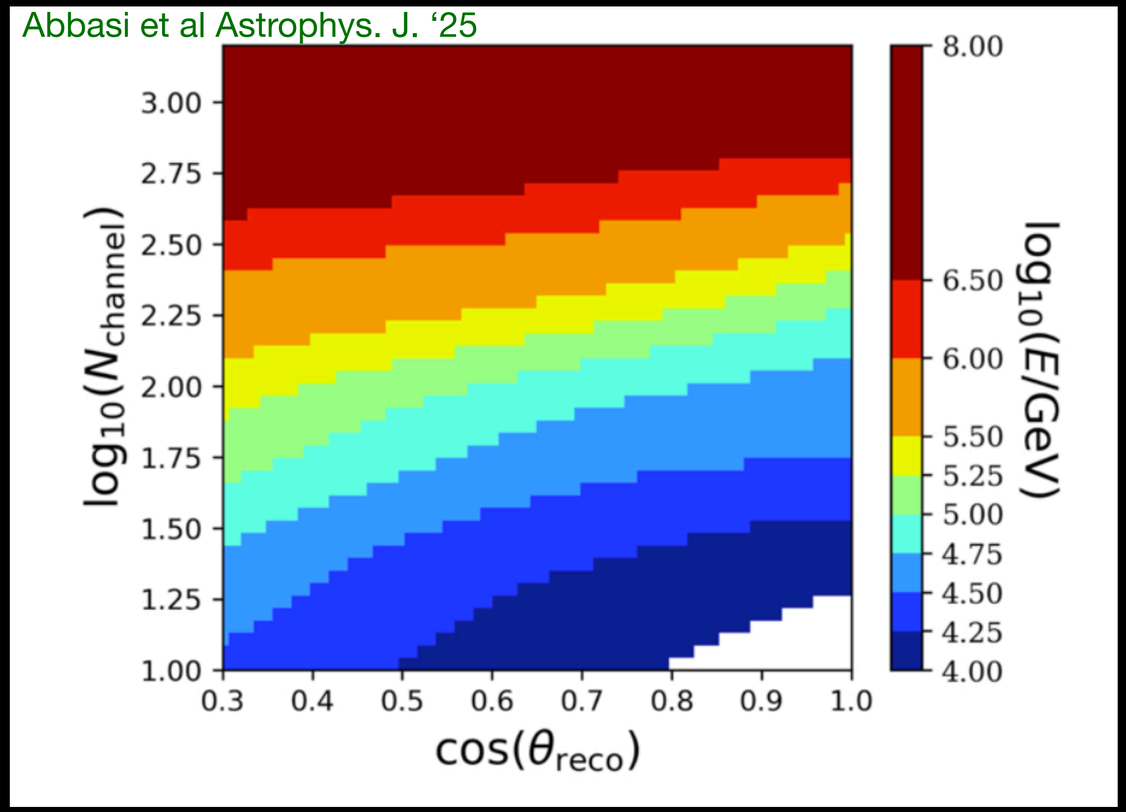
Abbasi et al Astrophys. J. ‘25



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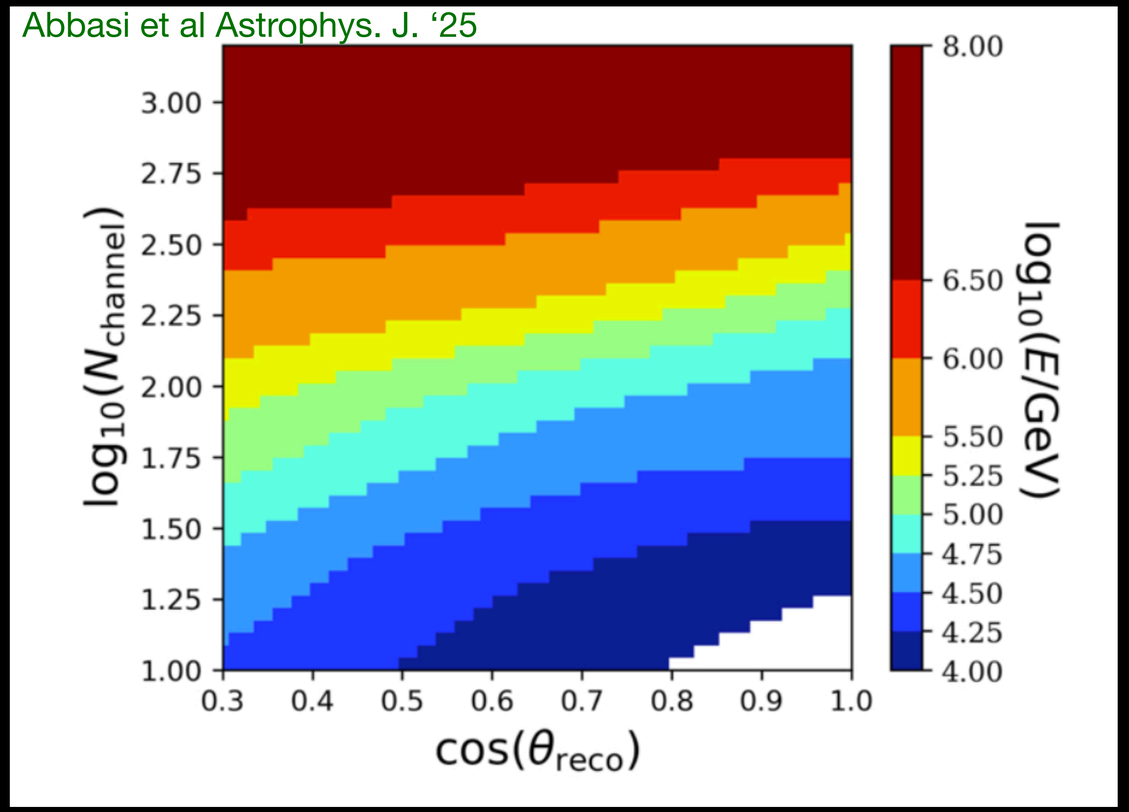

$$N_\mu(E_i) = \int_{E_{\min}}^{E_{\max}} dE \int_{-1}^{1} d\cos\theta \frac{d^2 N_\mu(E)}{dE d\cos\theta}(E, E_i)$$

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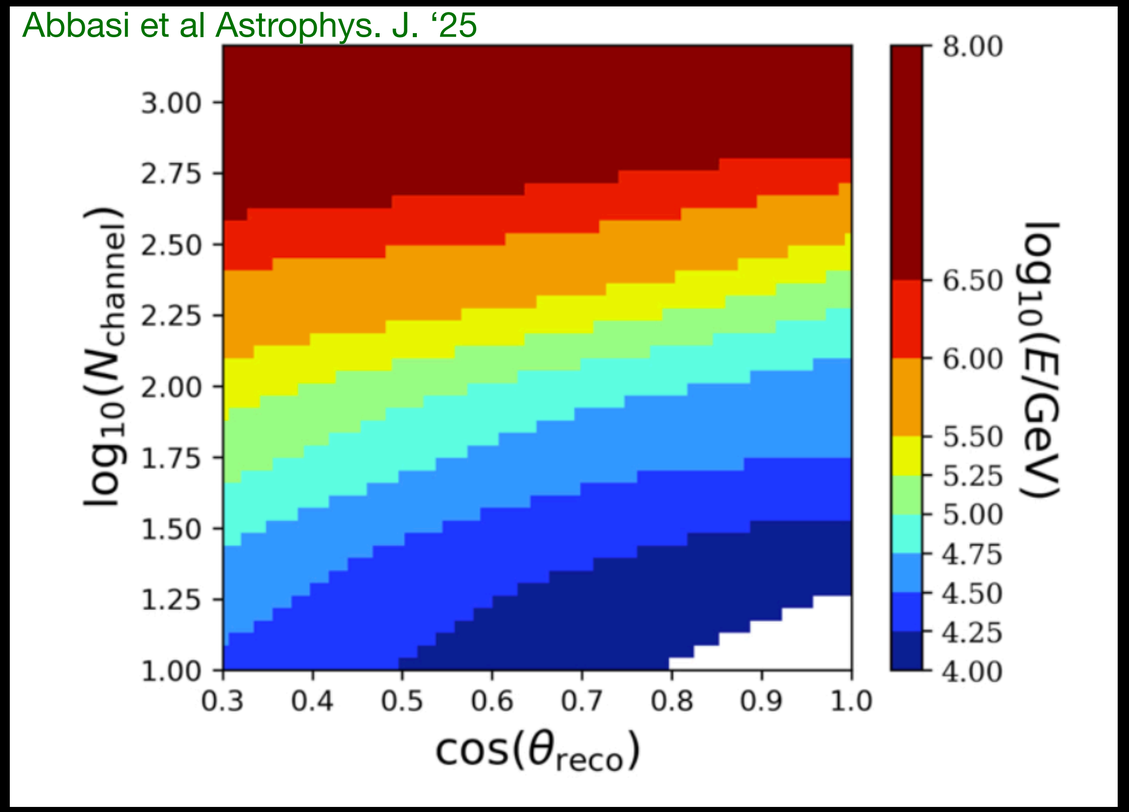

Energy, E_i (TeV)	N_{events} $(\times 10^9)$
13	330.40
24	197.15
42	89.74
67	22.17
130	6.32
240	2.13
470	1.0147
1500	0.1019
5300	0.0128

792 billion events in total

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Mean free path of CLFV interaction

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$$\frac{dE_\mu}{dx} = -a - bE_\mu$$

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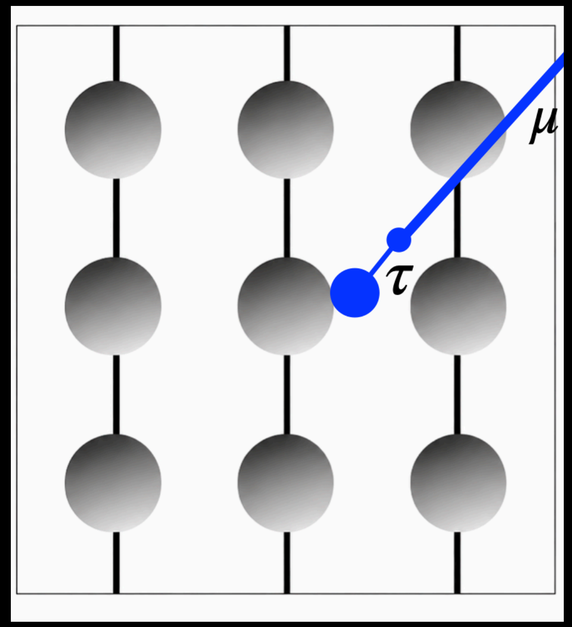

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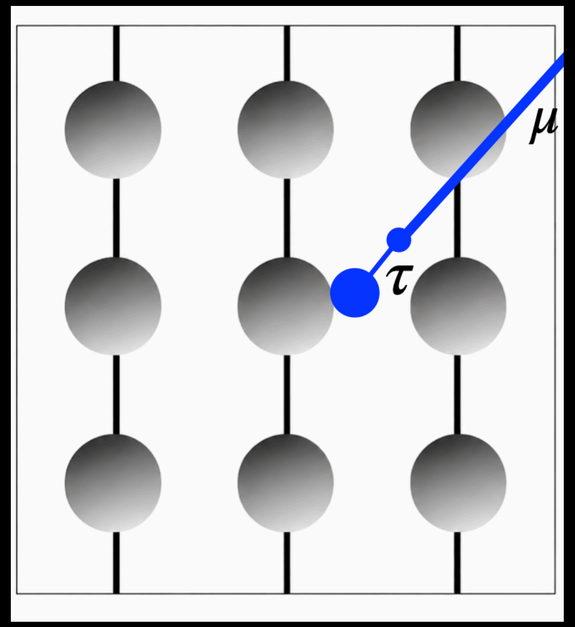

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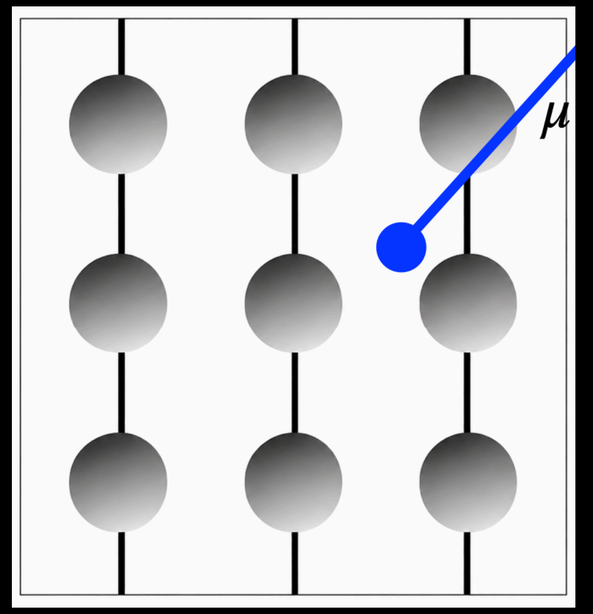

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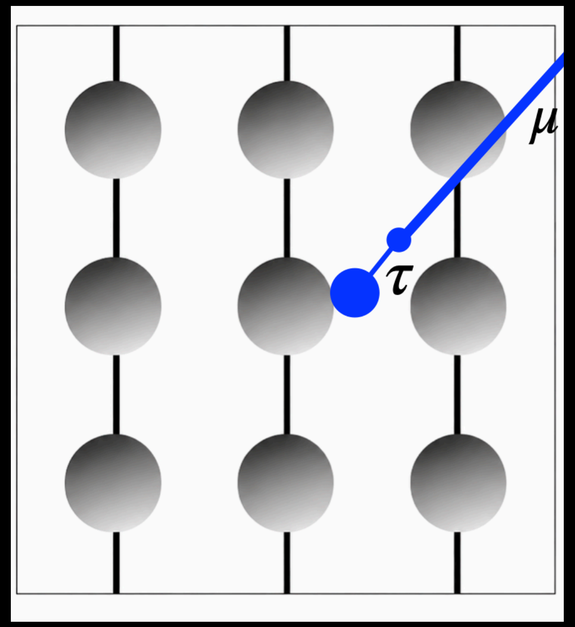

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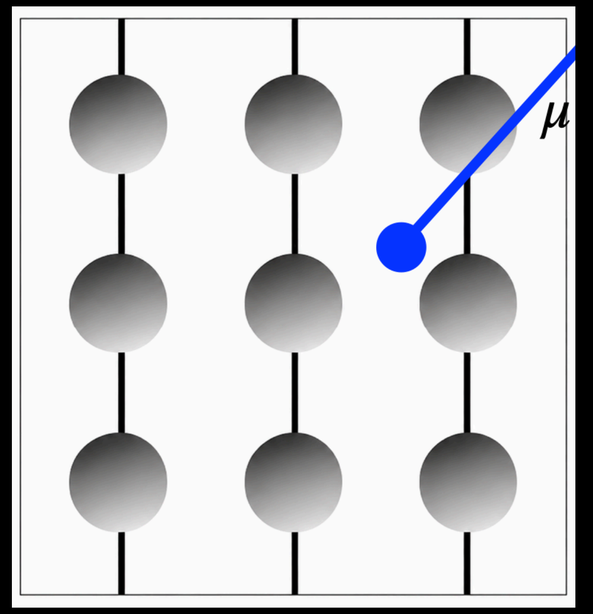

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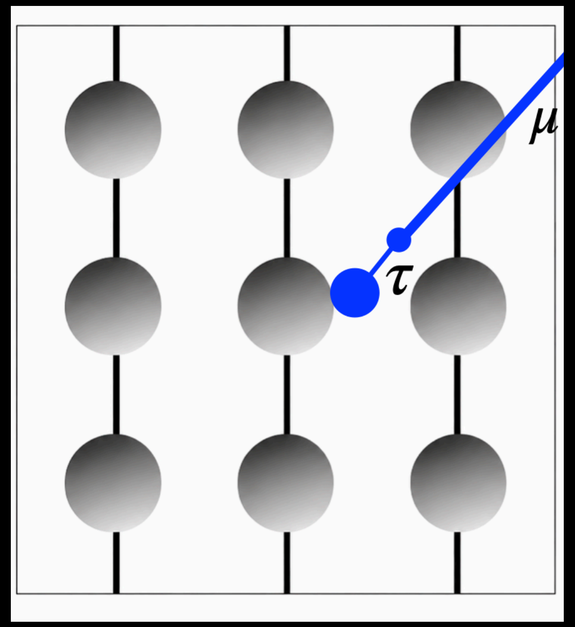

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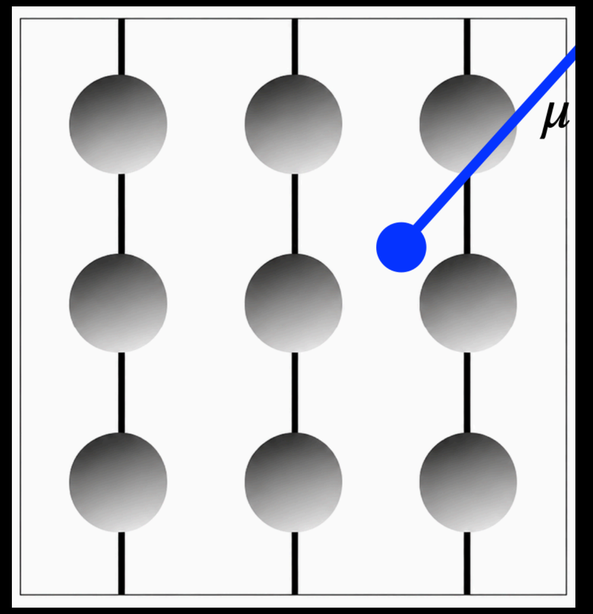

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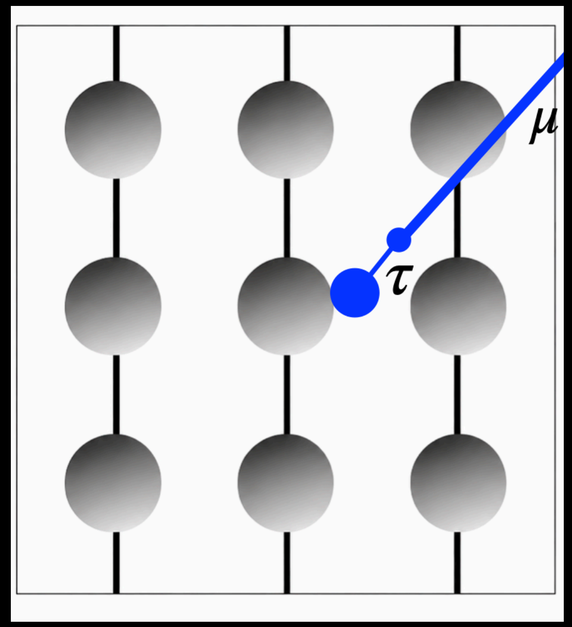

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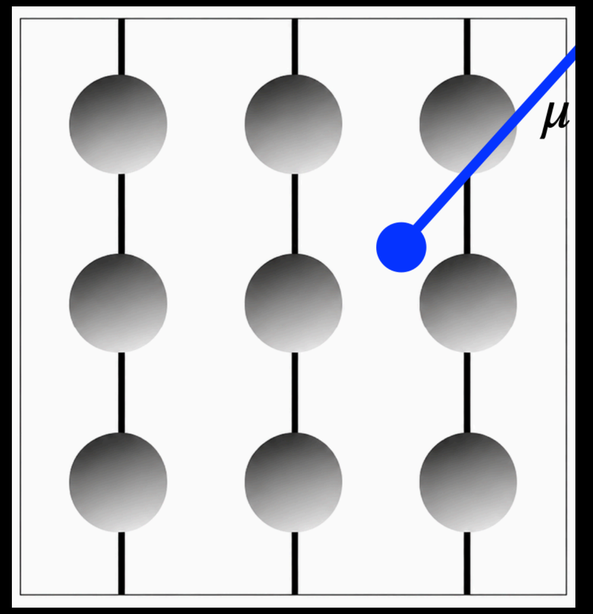

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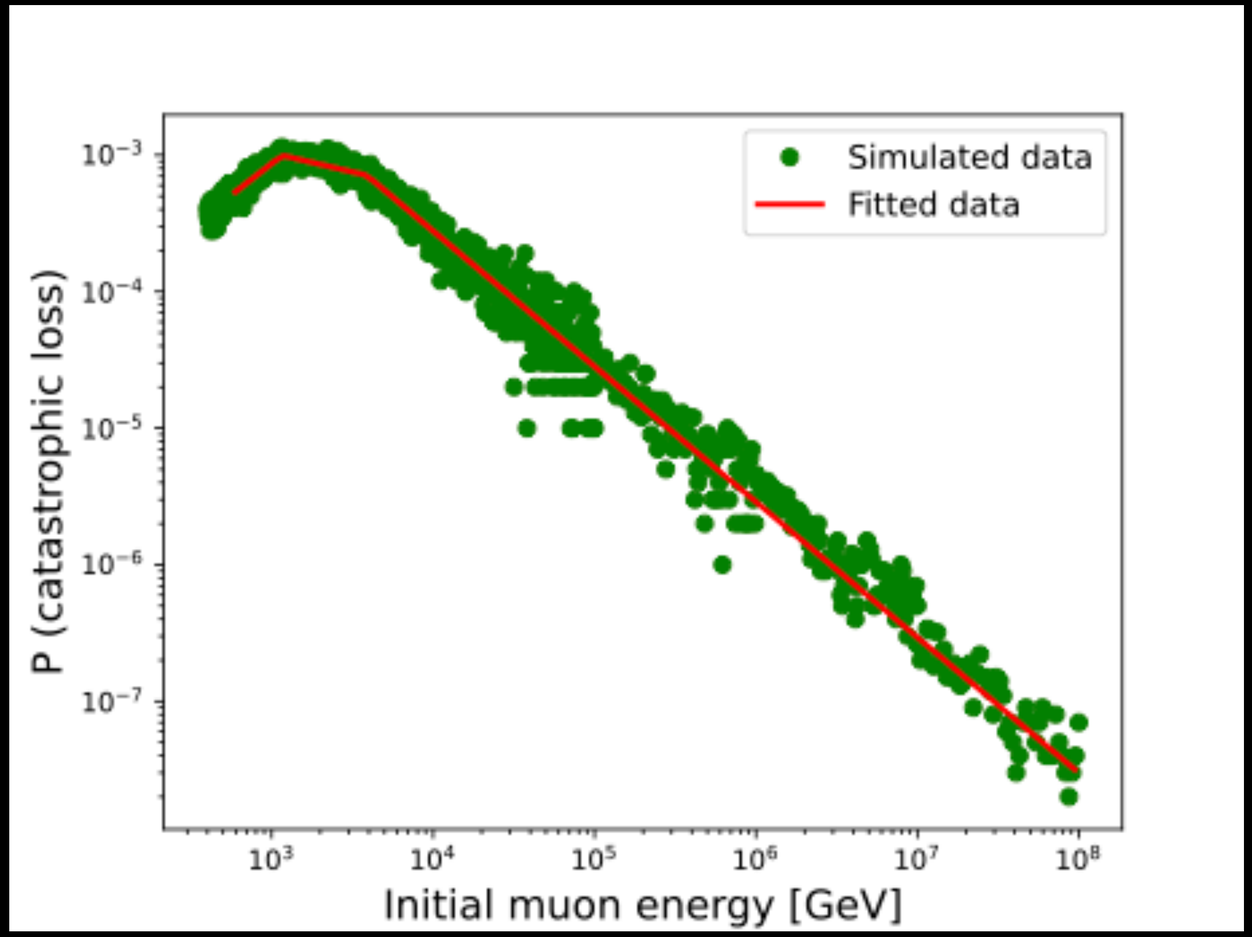

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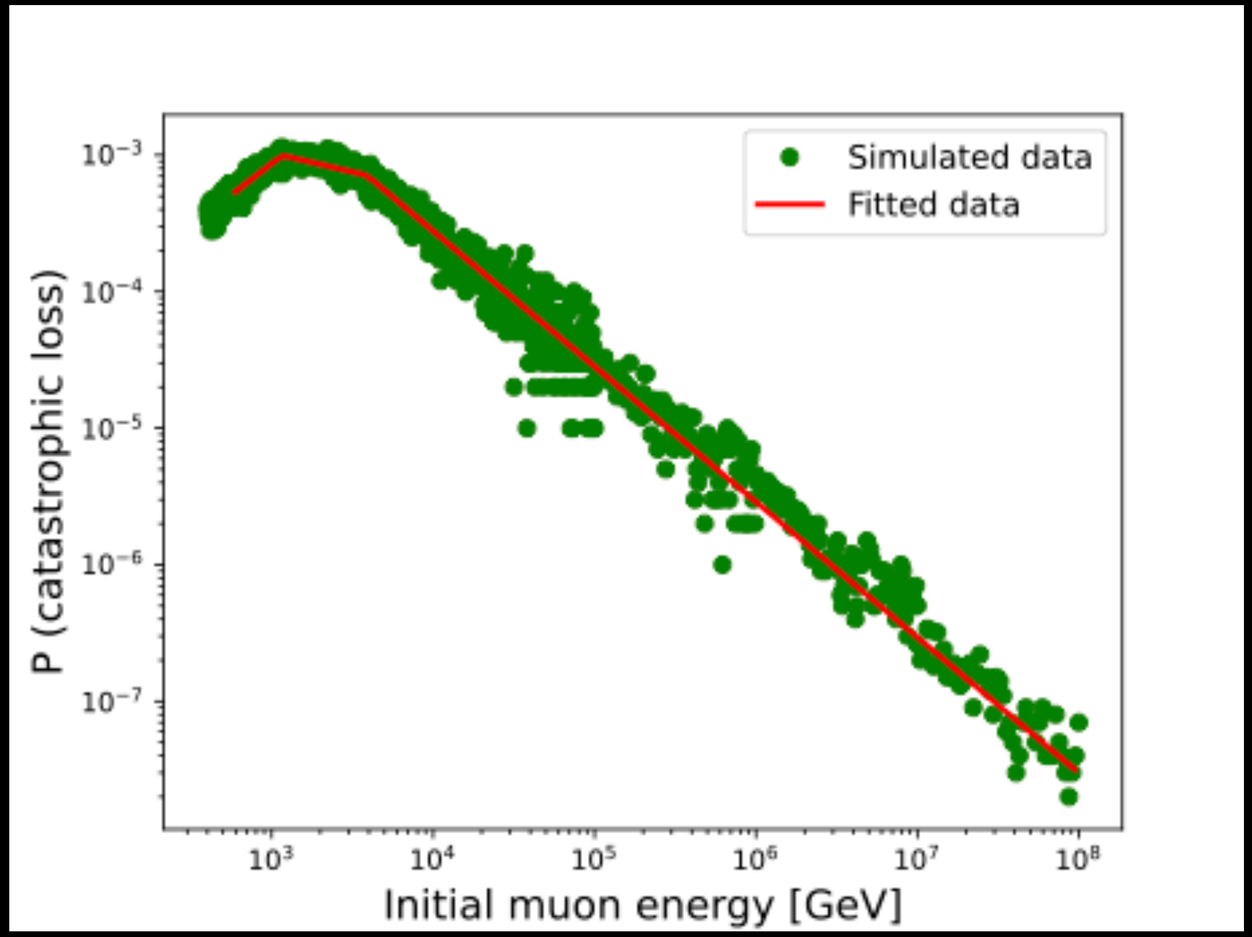

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[Alameddine et al Comput. Phys. Commun. ’24]

Fitted with a broken power law

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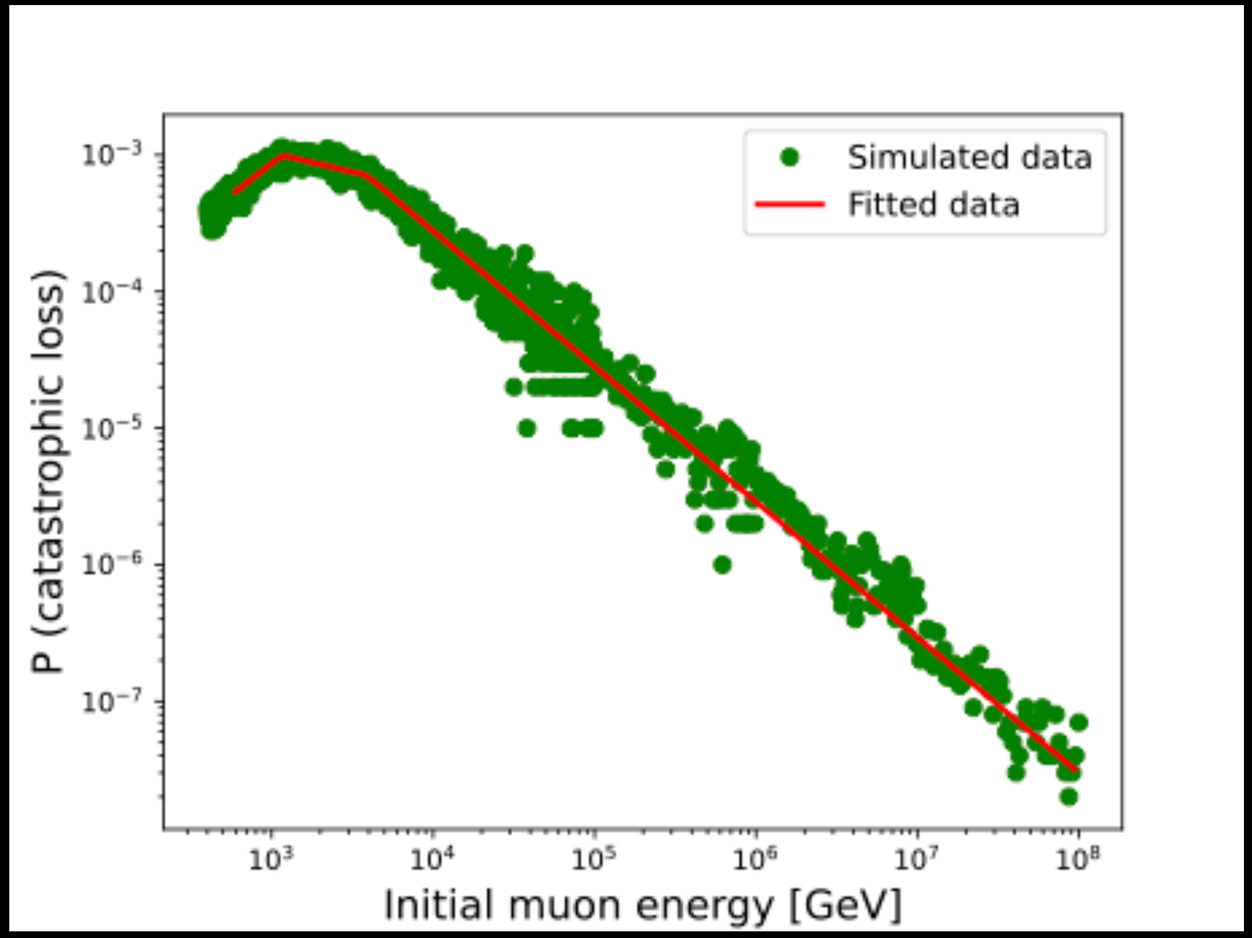

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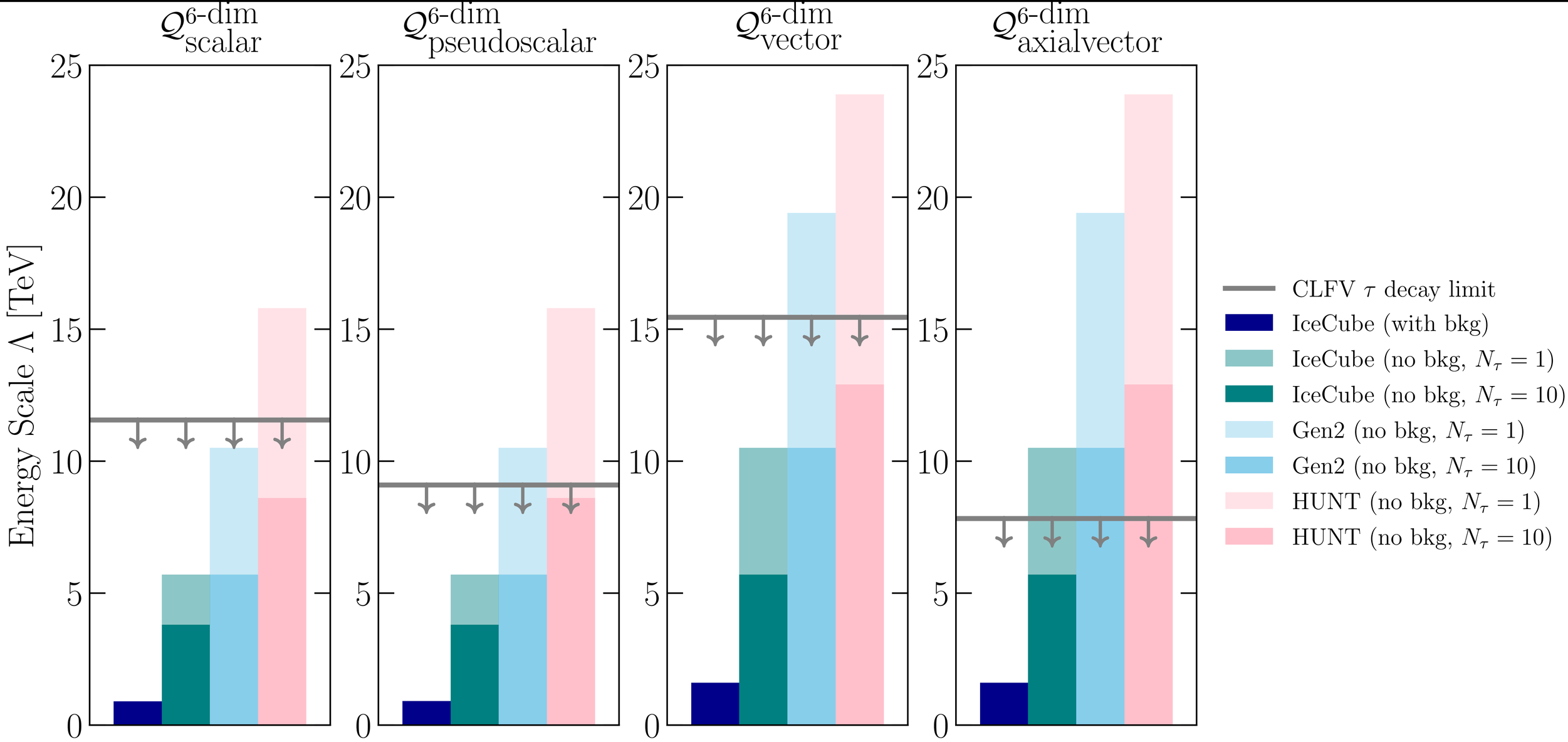

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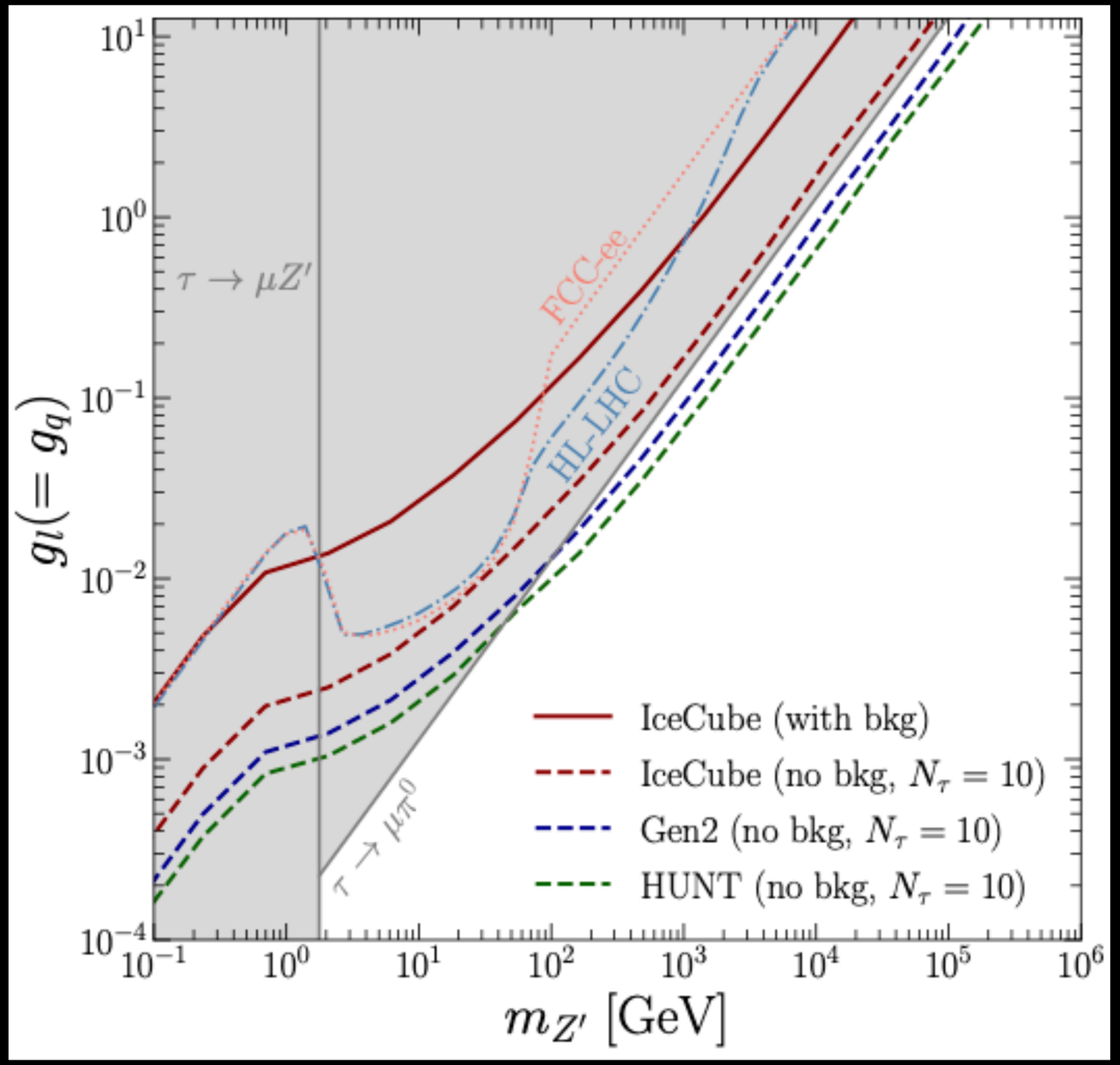

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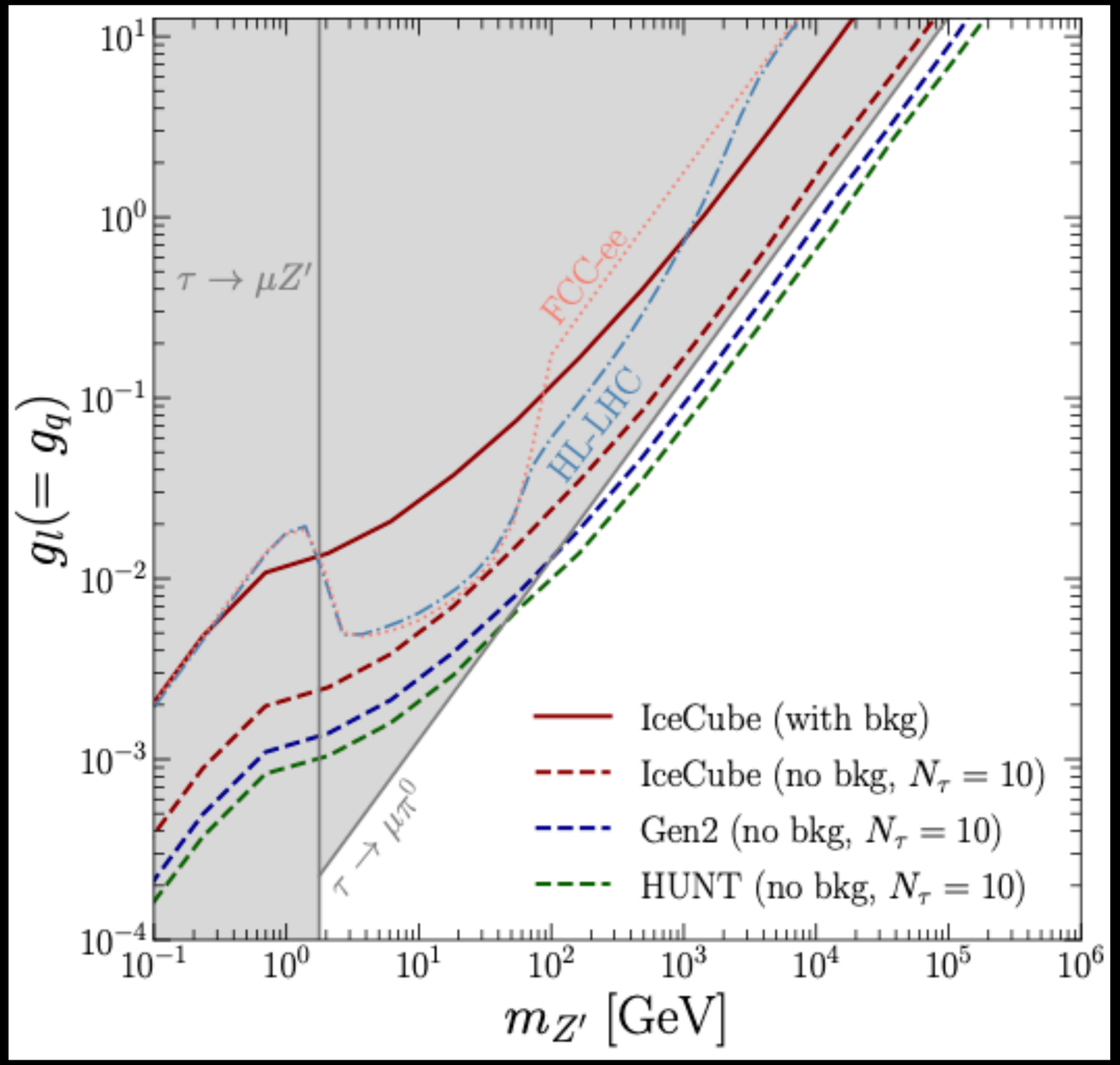

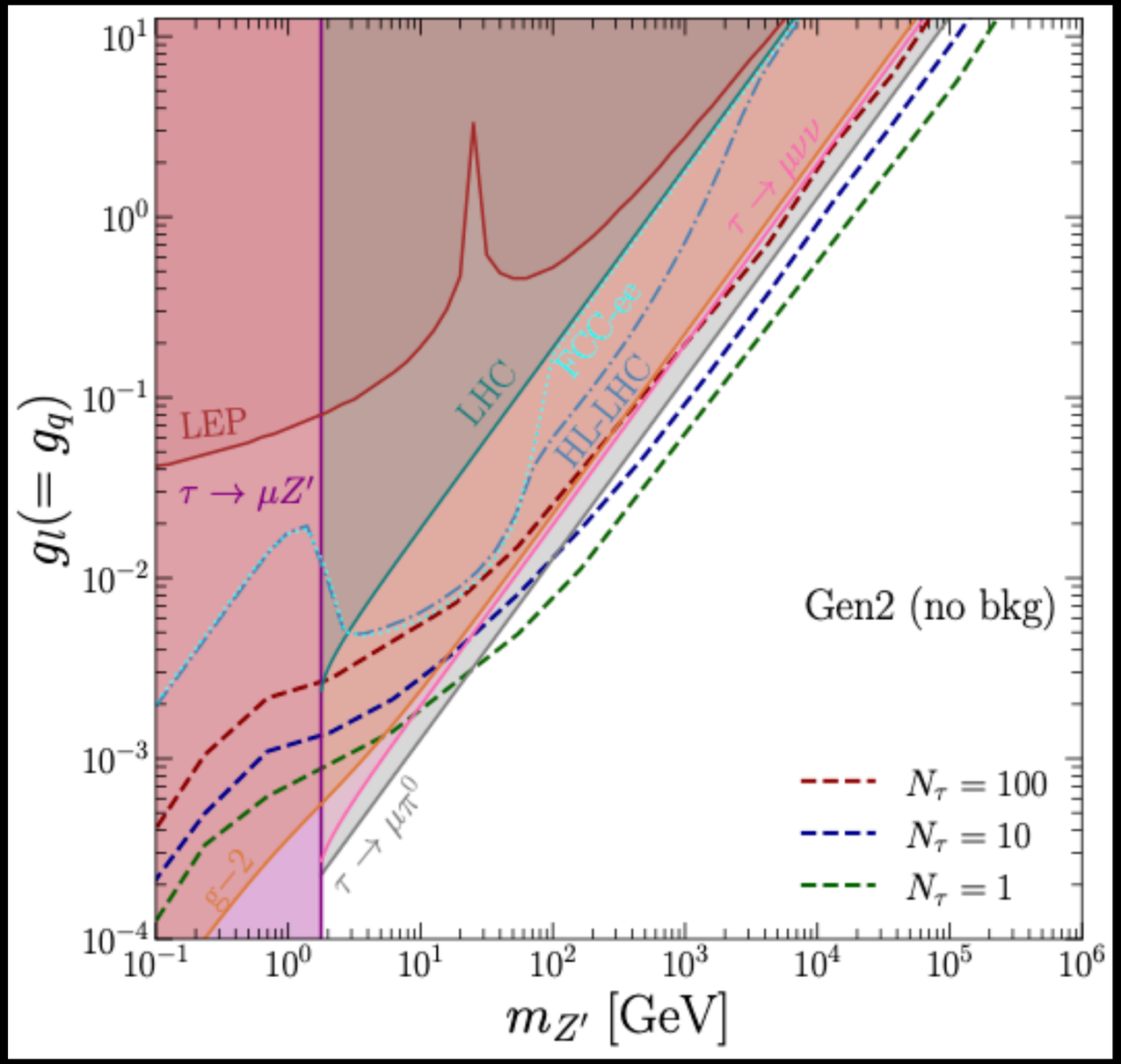

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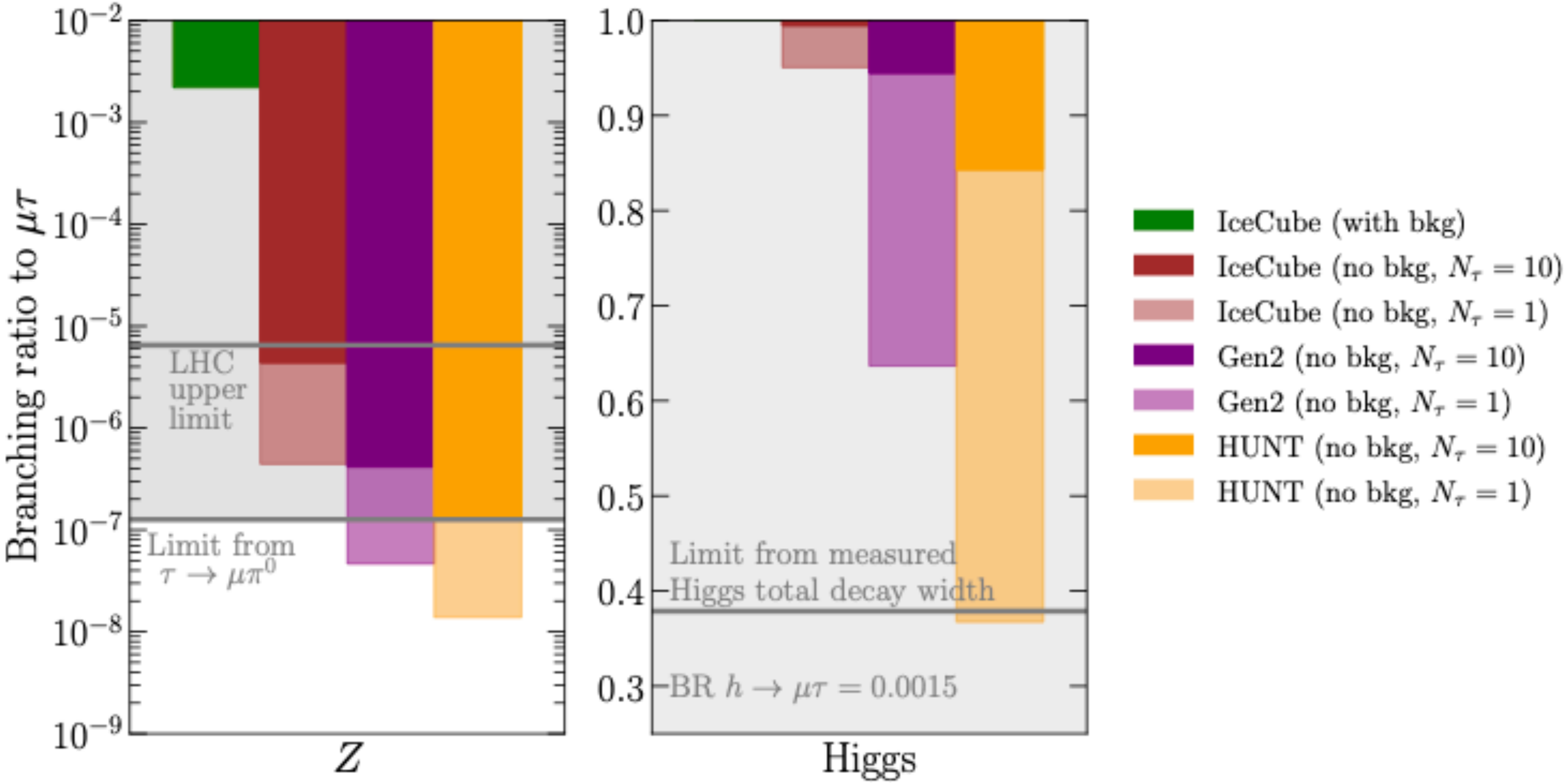

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    - Λ for scalar, pseudoscalar, vector and axial vector six-dimensional EFT operators.
    - Z' mass-coupling parameter space.
    - $Z \to \mu\tau$ and $h \to \mu\tau$ branching ratio.
- We have also projected above-mentioned constraints from future experiments (Gen2 and HUNT).

Summary

- Charged Lepton Flavor Violation (CLFV) can be a telltale signature of BSM physics.
- IceCube and other similar future neutrino experiments like Gen2 and HUNT can be an ideal place to look for CLFV.
- We have analyzed existing IceCube data to set a constraint on
    - Λ for scalar, pseudoscalar, vector and axial vector six-dimensional EFT operators.
    - Z' mass-coupling parameter space.
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- We have also projected above-mentioned constraints from future experiments (Gen2 and HUNT).

Thank you!

References for Experimental Inputs

- Uno et al. (JHEP ’25) [https://arxiv.org/abs/2503.22195]
- Adachi et al. (JHEP ’24) [https://arxiv.org/abs/2405.14625]
- Aad et al. (PLB ’24) [https://arxiv.org/abs/2403.12902]
- Aguillard et al. (PRD ’24) [https://arxiv.org/abs/2402.15410]
- Aad et al. (PRL ’22) [https://arxiv.org/abs/2105.12491]
- Sirunyan et al. (PRD ’21) [https://arxiv.org/abs/2105.03007]
- Hayrapetyan et al. [https://arxiv.org/abs/2601.05168]

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	1	γ^5	γ^α	$\gamma^\alpha\gamma^5$
Dominant CLFV process	$\tau \to \mu\pi^+\pi^-$	$\tau \to \mu\pi^0$	$\tau \to \mu\rho$	$\tau \to \mu\pi^0$
Upper Limit on Branching Ratio	2.1×10^{-8}	1.1×10^{-7}	1.7×10^{-8}	1.1×10^{-7}
Lower limit on Λ	11.56 TeV	9.6 TeV	11.57 TeV	7.85 TeV

Upper limits on branching ratio taken from PDG’24

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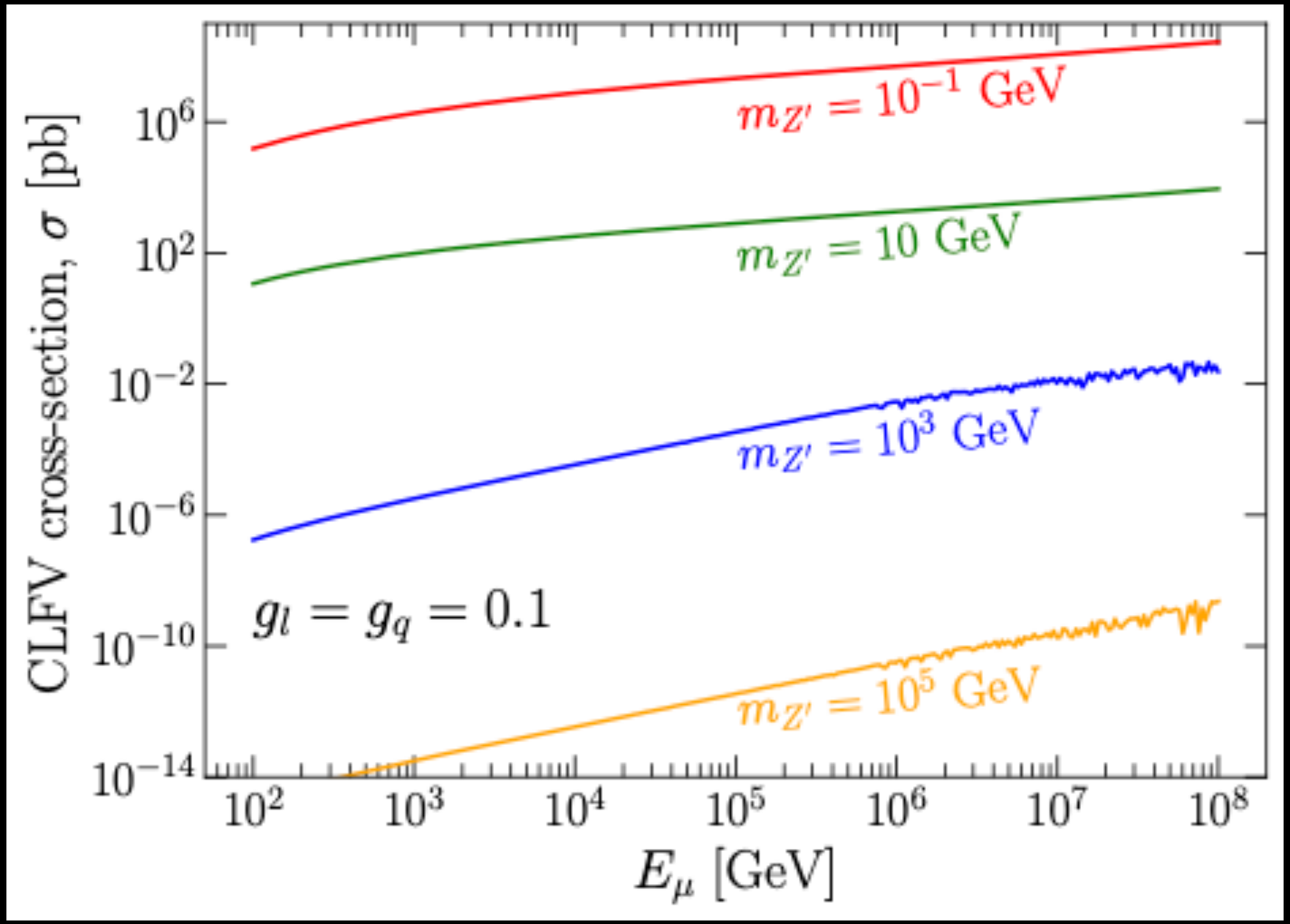

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