Discover New Physics with Neutrinos!

outline

1. High-energy, long propagation experiments
2. High-intensity, high-precision experiments
3. Challenges

An Italian-American being forced to watch pineapple added to pizza for the first time (1914 Brooklyn, USA)

My talk is not that bad...

Teppei Katori @teppeikatori
King's College London

Neutrino 2024, Milano, Italy, June 21, 2024

Discover New Physics with Neutrinos?

How to

Where is new physics???

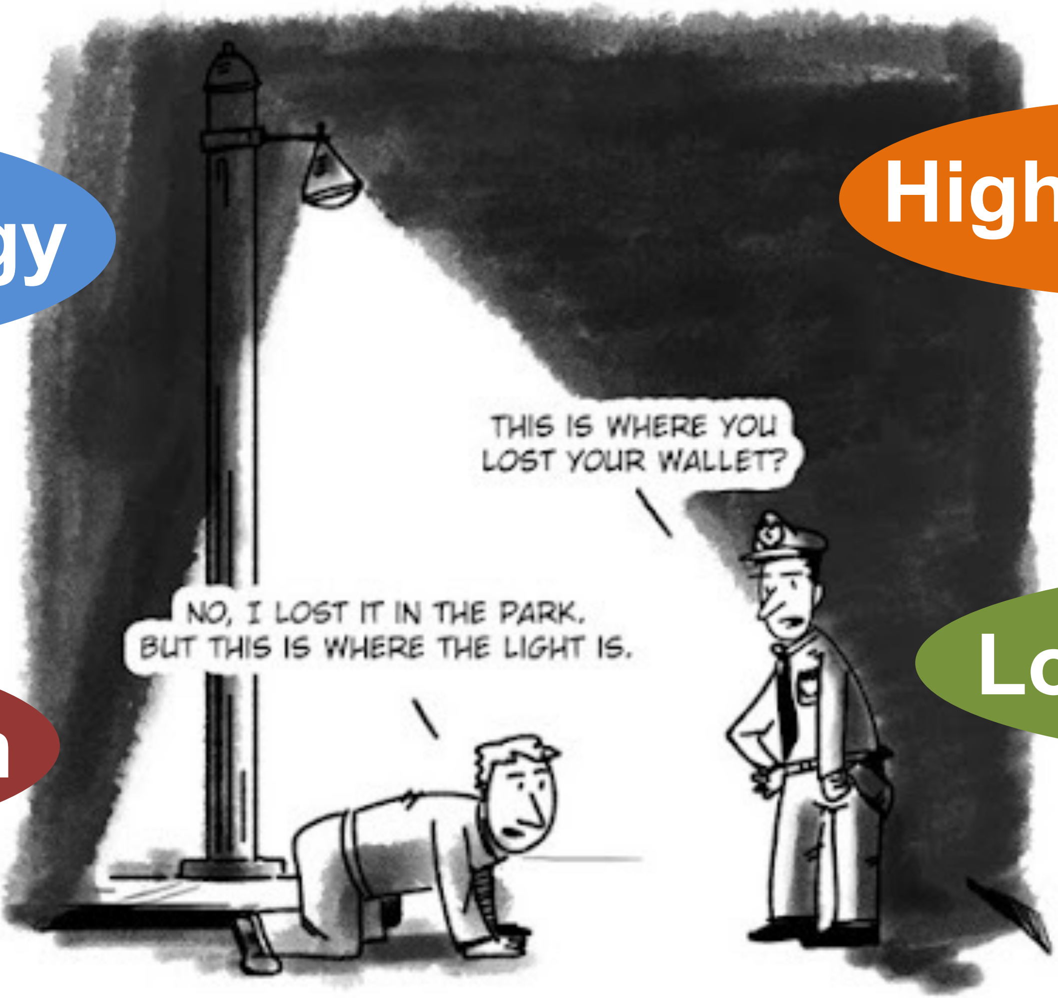
Discover New Physics with Neutrinos?

How to

Where is new physics???

High Energy

High Intensity



Long propagation

High Precision

Paradigm shift from neutrino physics

We continue our investigations of neutrinos...
- Measure neutrino parameters and interactions with higher accuracy
- Study persistent anomalies
- Search rare processes (0nbb, proton decay, etc)

What else can we do? Where is new physics?
- 3-massive active neutrino model (νSM) paradigm is very successful

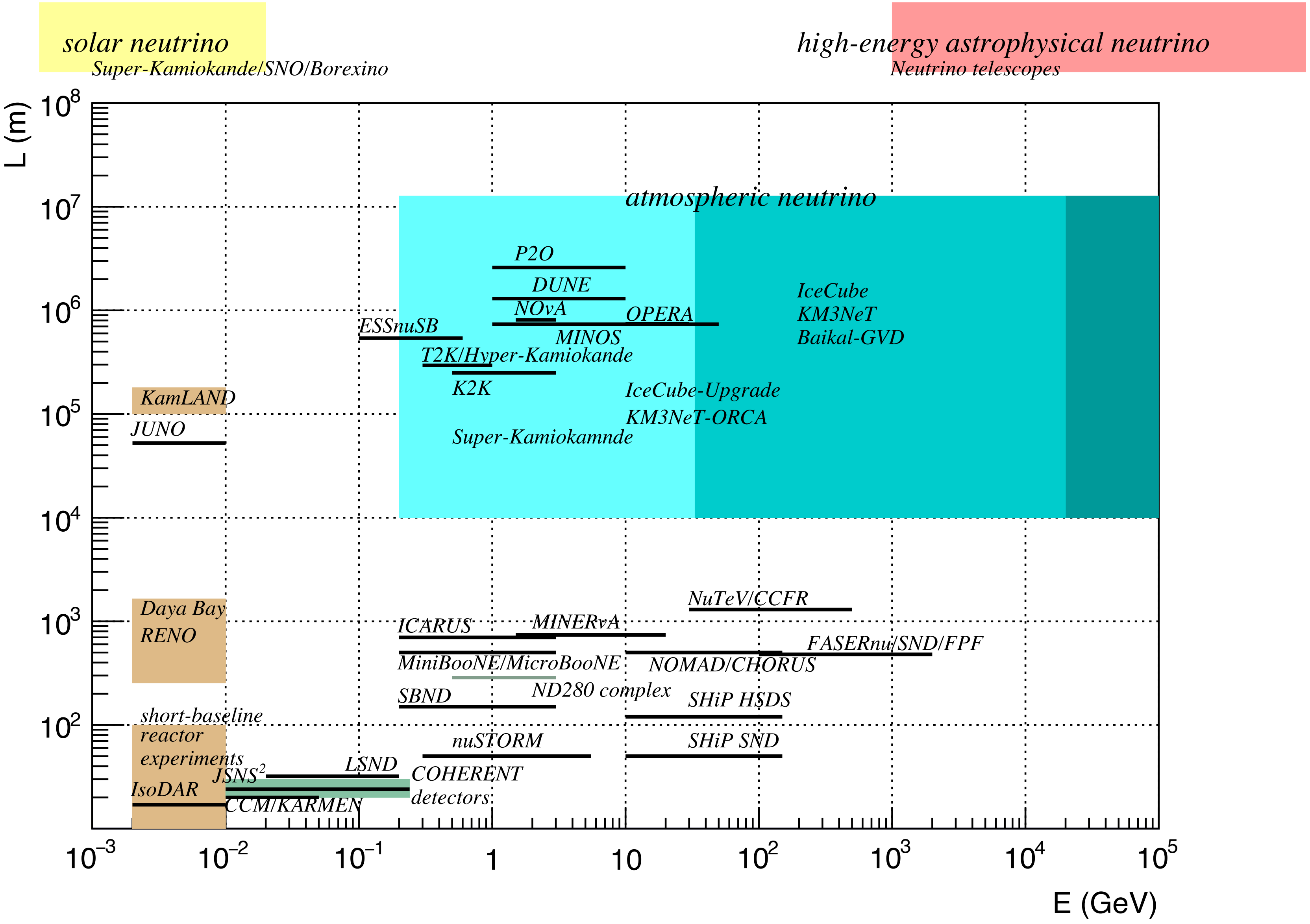
→ New physics effect is small in current experiments

We explore all possible scenarios to look for new physics!
- High energy
- Low energy → high precision measurement
- Long propagation → accumulate new physics effect
- Short propagation → high intensity to find rare process

Every neutrino experiments can be described by **L** and **E**

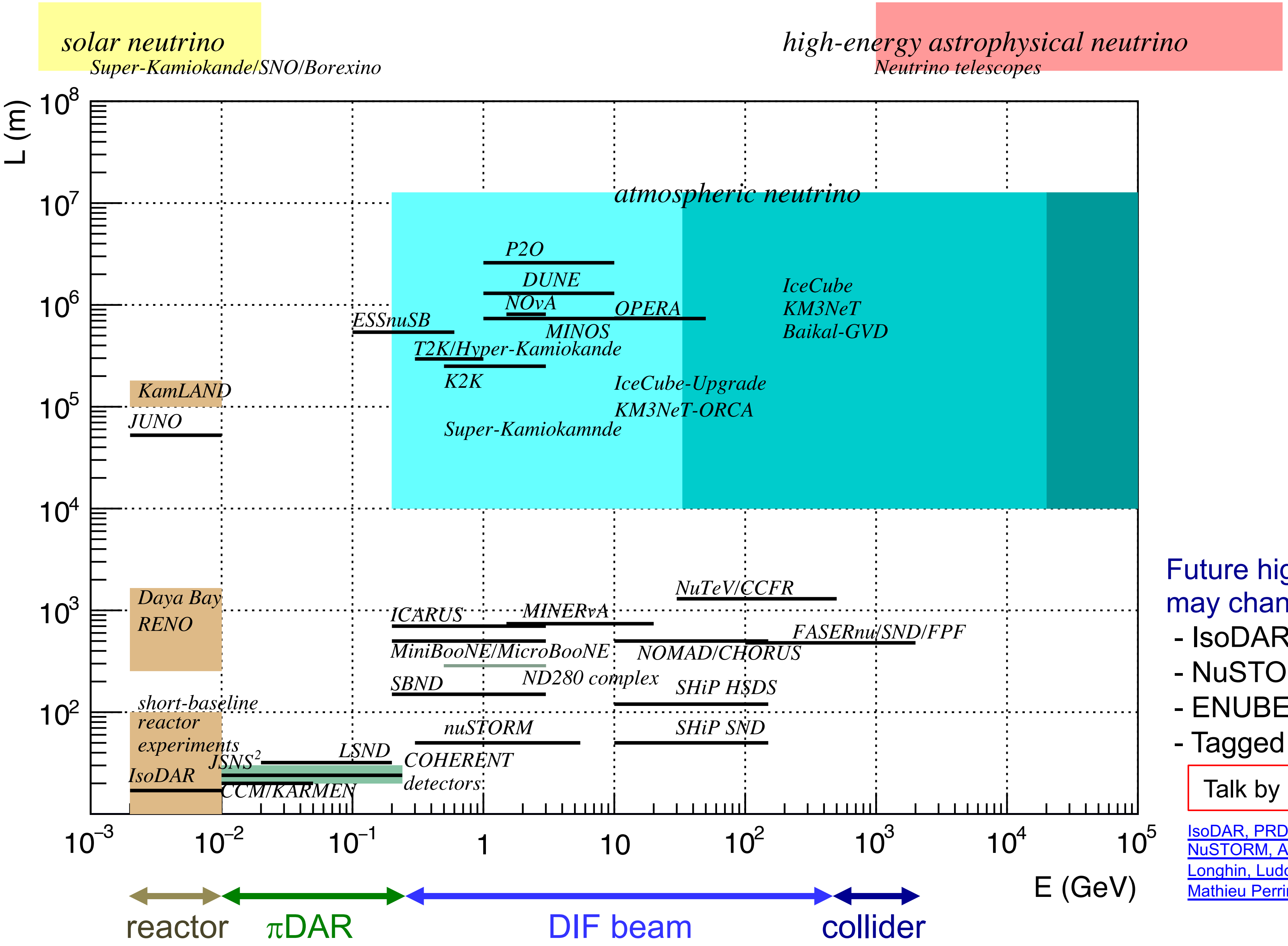
Argüelles, Hostert, TK, in preparation

L-E plot



Argüelles, Hostert, TK, in preparation

L-E plot



Future high-precision beams may change this landscape

- IsoDAR
- NuSTORM
- ENUBET
- Tagged beam, etc

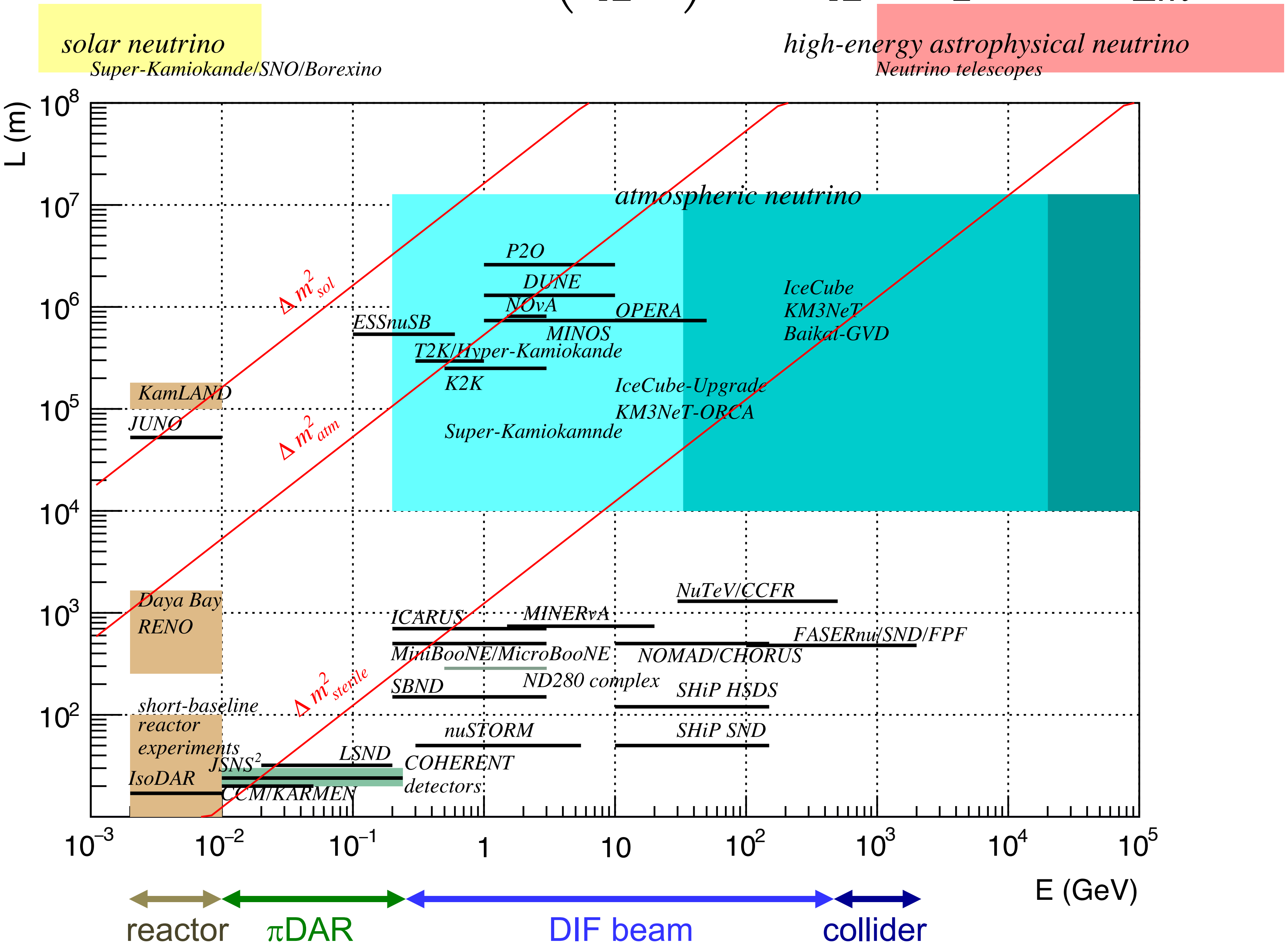
Talk by Giulia Brunetti (Friday)

IsoDAR, PRD105(2022)052009
NuSTORM, ArXiv:2203.07545
Longhin, Ludovici, Terranova, EPJC75(2015)155
Mathieu Perrin-Terrin, EPJC82(2022)465

Argüelles, Hostert, TK, in preparation

L-E plot

$$P(L,E) = sin^2 2\theta sin^2\left(\frac{\Delta m^2}{4E}L\right), \quad \frac{\Delta m^2}{4E}L \sim \frac{\pi}{2}, \quad L \sim \frac{2\pi}{\Delta m^2}E$$

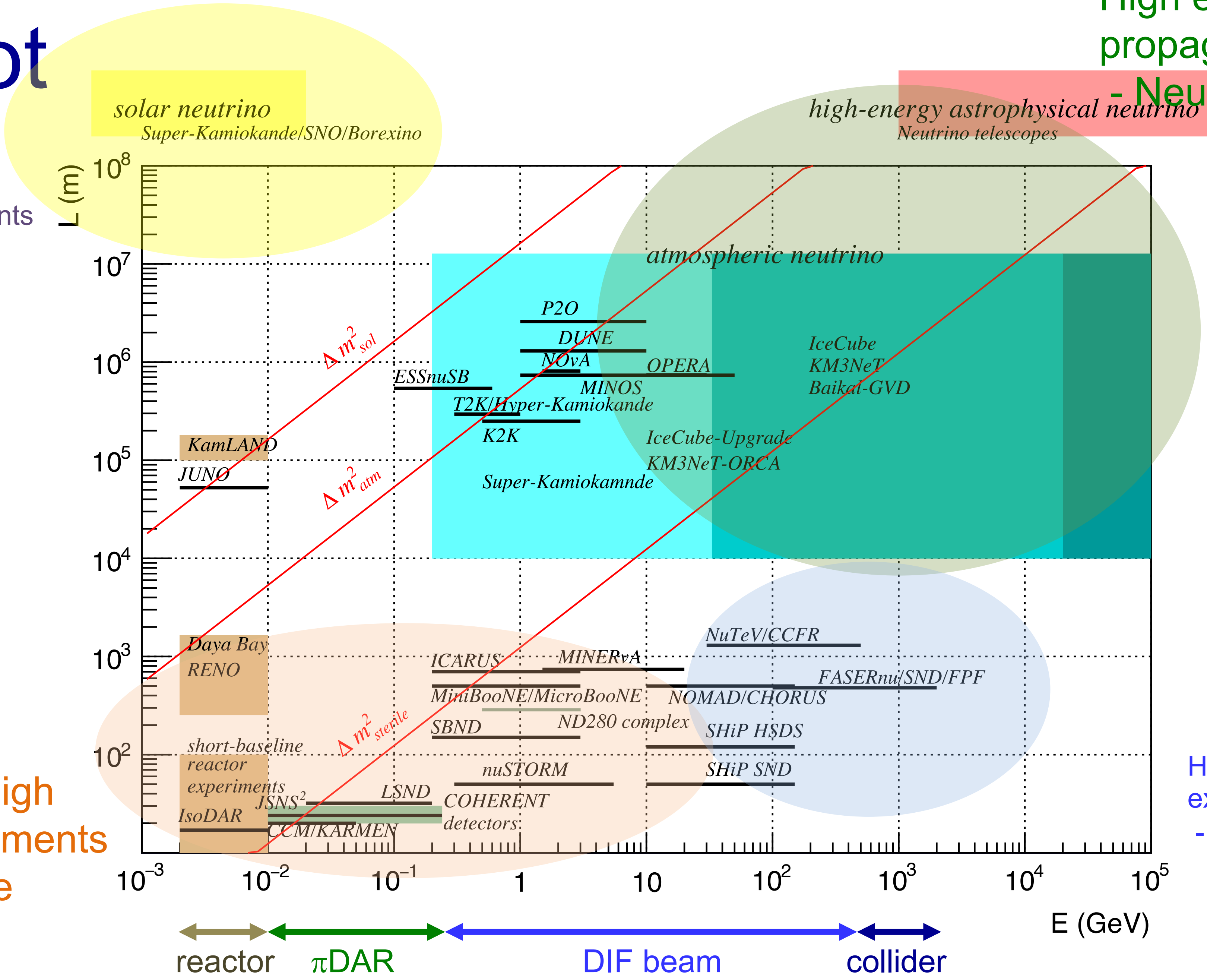


Argüelles, Hostert, TK, in preparation

L-E plot

High energy, long propagation experiments
- Neutrino telescopes

Low energy, long propagation experiments
- Underground low-background detectors



High intensity, high precision experiments
- Short-baseline experiments

High energy, high precision experiments
- Collider neutrino experiments

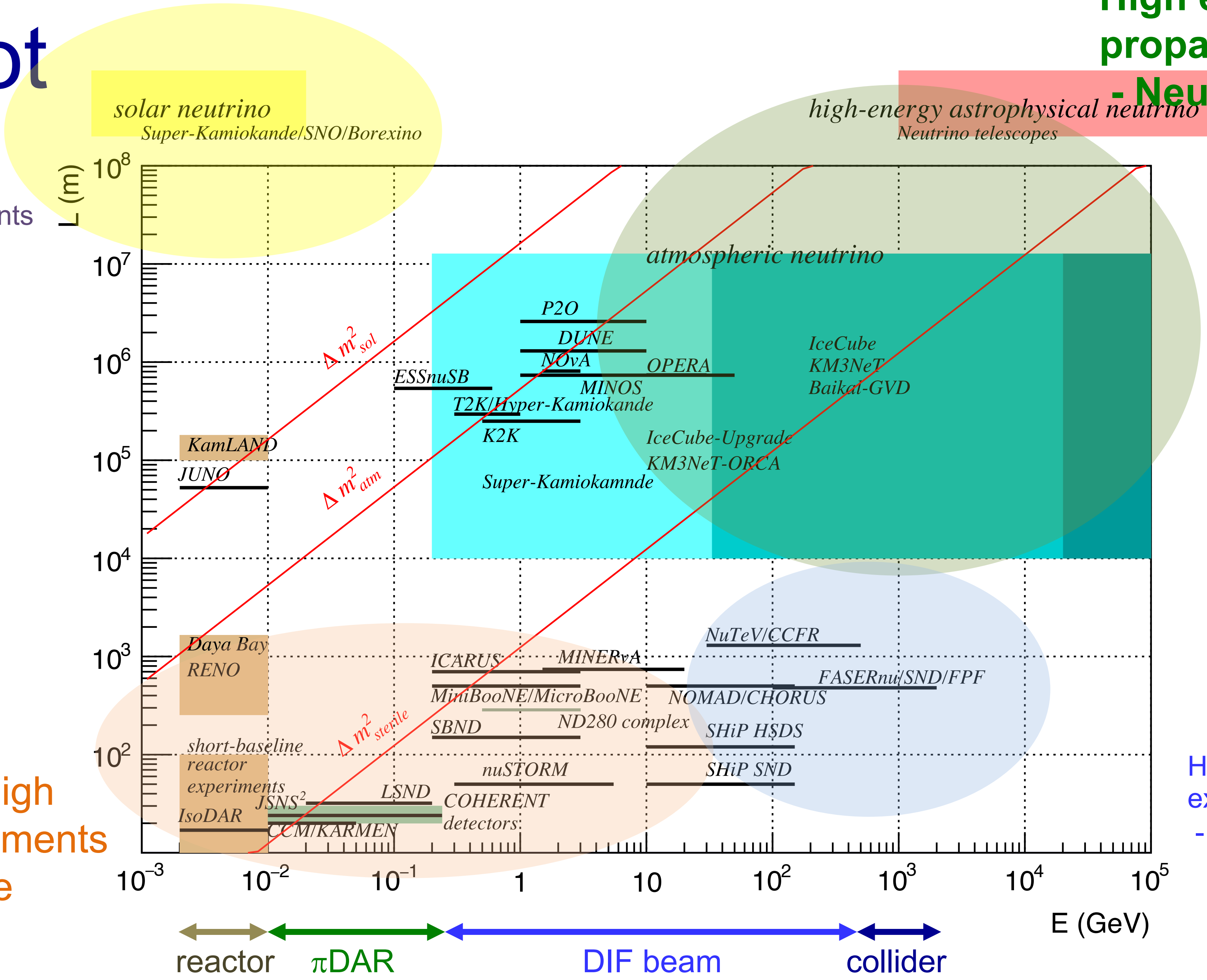
Talk by Albert De Roeck (Friday)

Argüelles, Hostert, TK, in preparation

L-E plot

High energy, long propagation experiments - Neutrino telescopes

Low energy, long propagation experiments
- Underground low-background detectors



High intensity, high precision experiments
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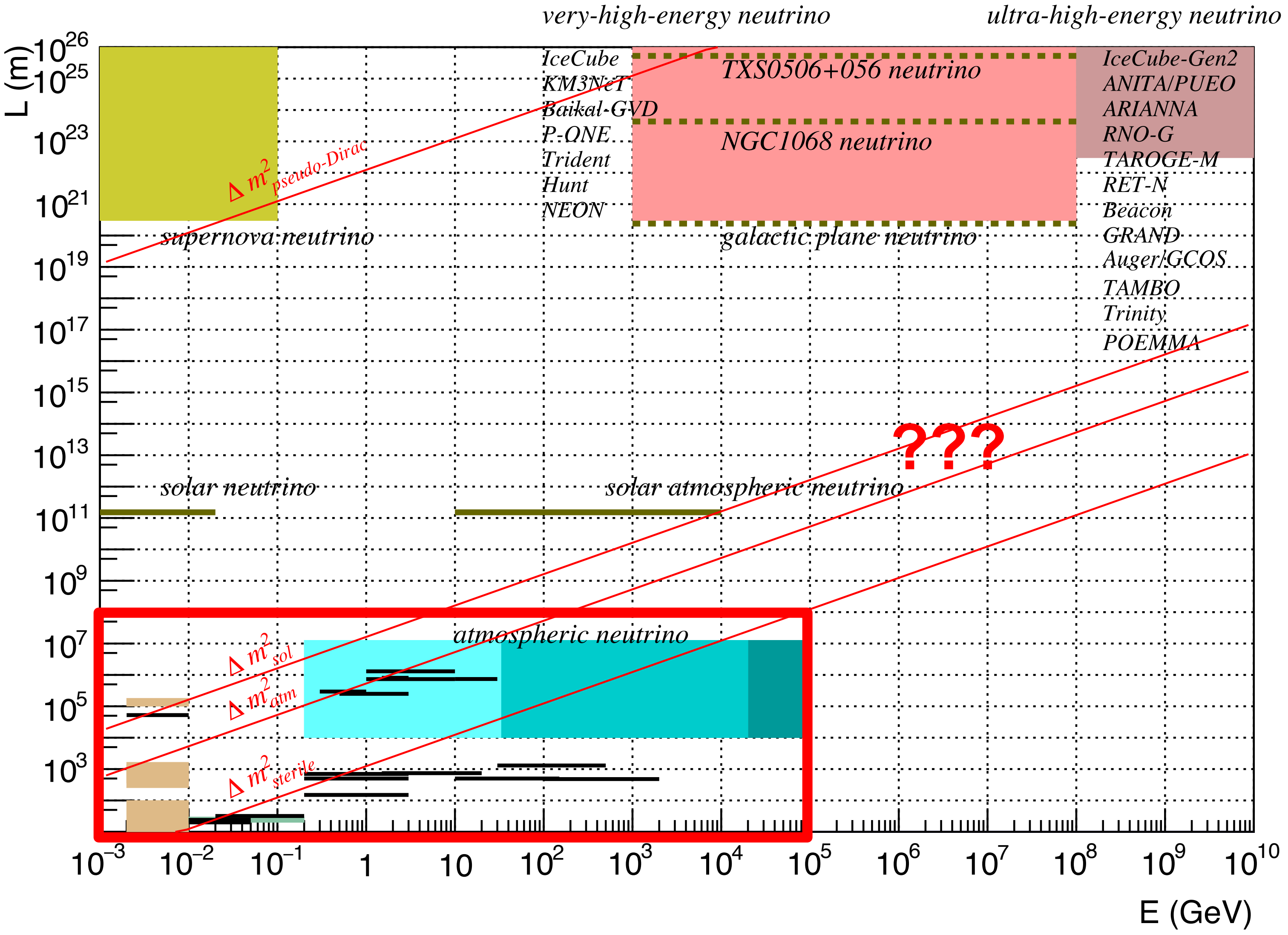
Argüelles, Hostert, TK, in preparation

L-E plot

High energy, long propagation experiments - Neutrino telescopes

Snowmass, JHEA36(2022)55

Low energy, long propagation experiments
- Underground low-background detectors



Argüelles, Hostert, TK, in preparation

L-E plot

High energy, long propagation experiments - Neutrino telescopes

Snowmass, JHEA36(2022)55

Low energy, long propagation experiments
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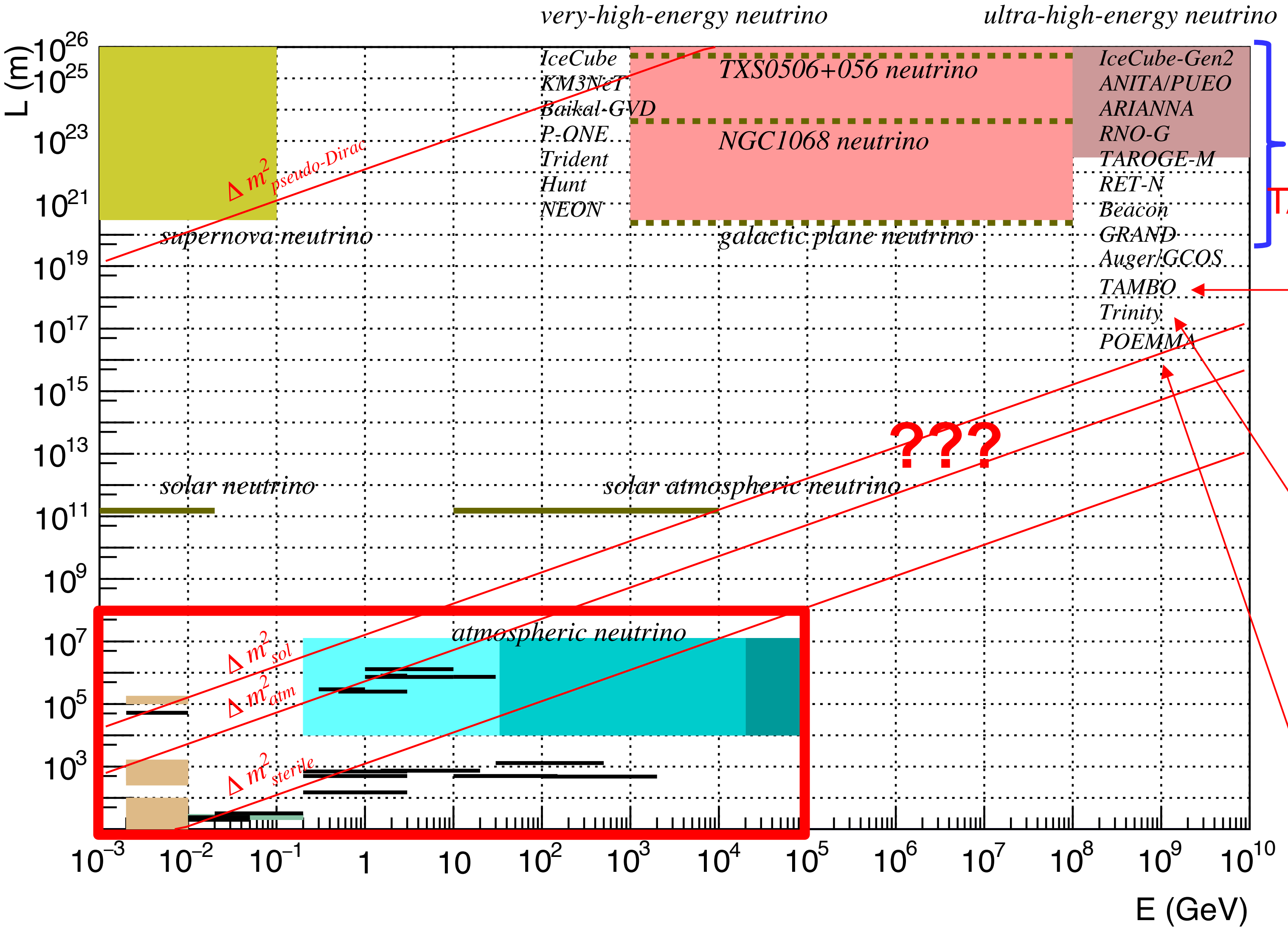
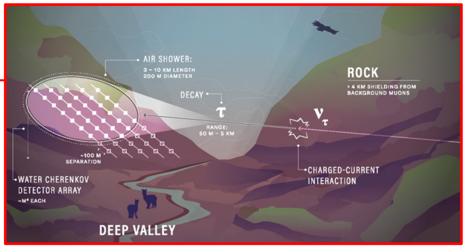
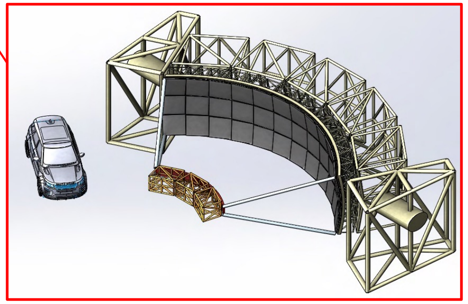


radio

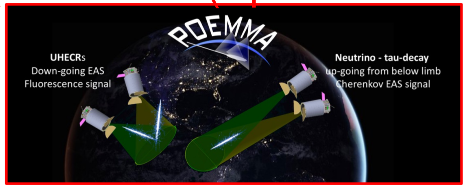
TAMBO (Cherenkov tank array)



Trinity (Air-shower telescope)



POEMMA (Space camera)



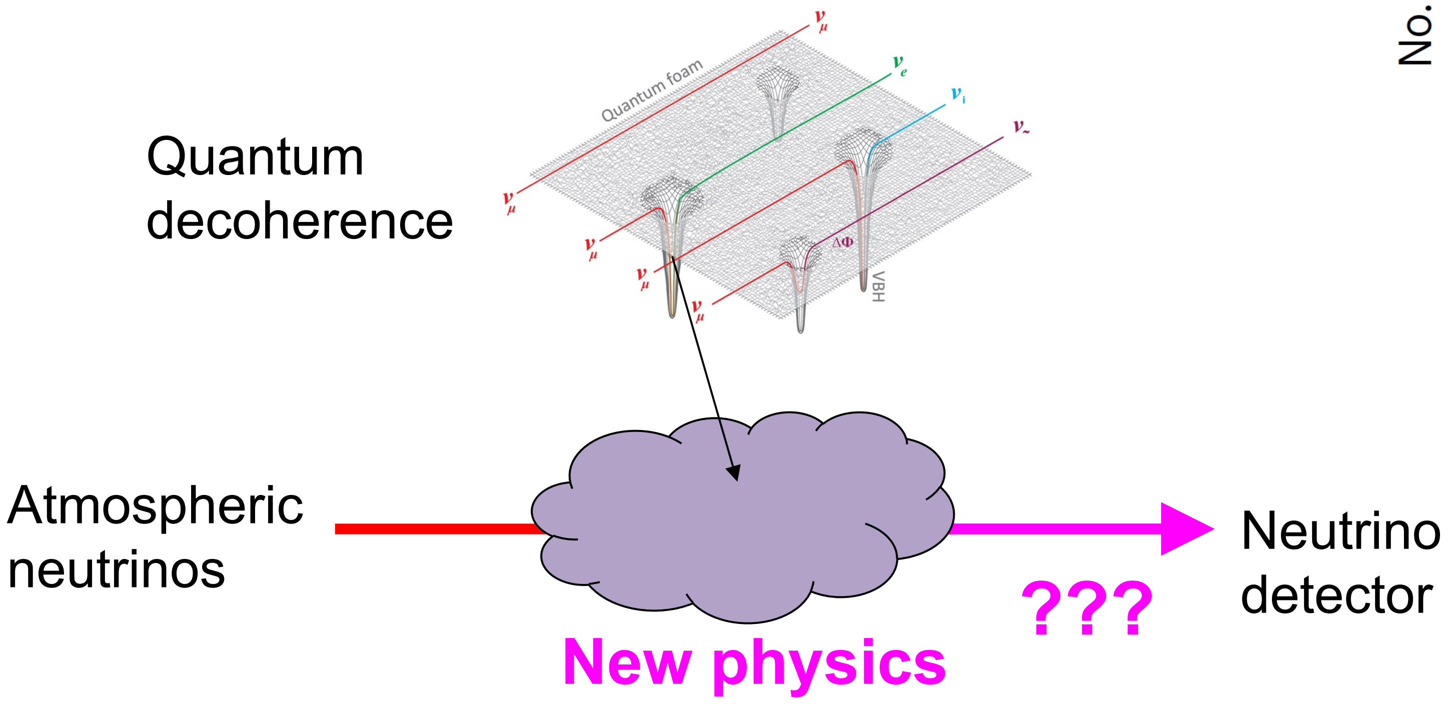
Snowmass21, EPJC83(2023)15, IceCube, Nature Physics 20 (2024) 913, JUNO, JHEP06(2022)062

High-energy, long propagating neutrinos

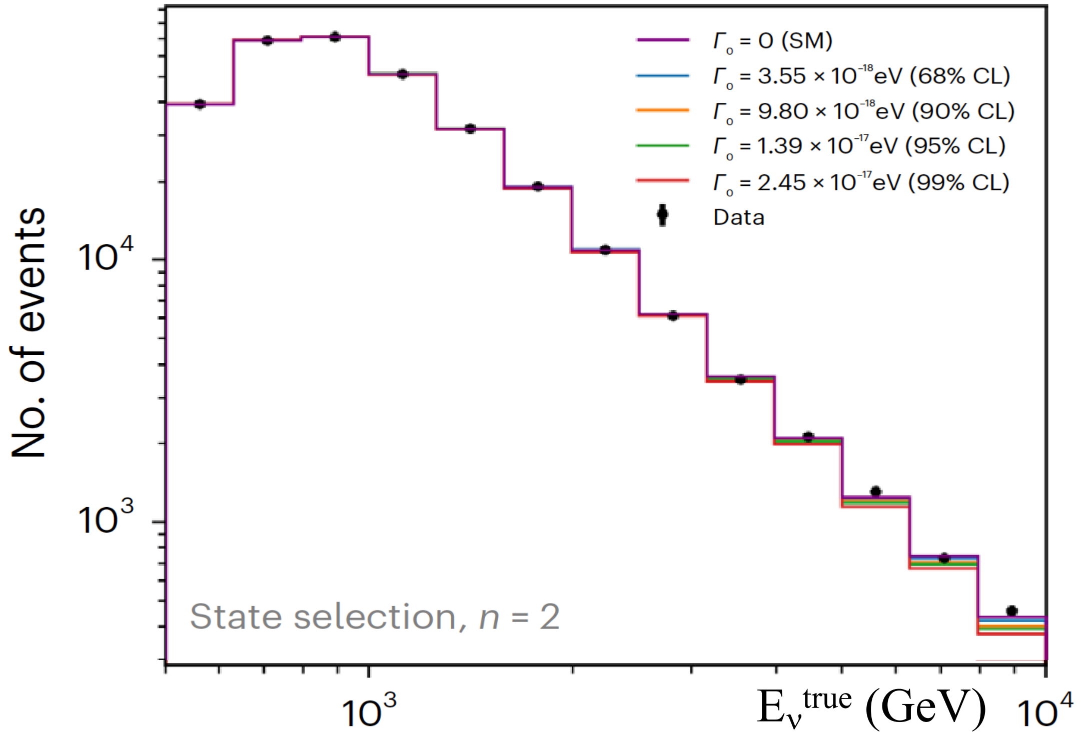
Atmospheric neutrinos

- Long baseline accumulates new physics effect
- High energy enhances new physics effect

$$P \sim exp(-\Gamma \cdot L), \qquad \Gamma \sim \Gamma_0 \left(\frac{E}{E_0}\right)^n$$



Atmospheric neutrino energy spectrum



- Atmospheric neutrinos have higher sensitivity to most of new physics searches than accelerator-based long-baseline experiments

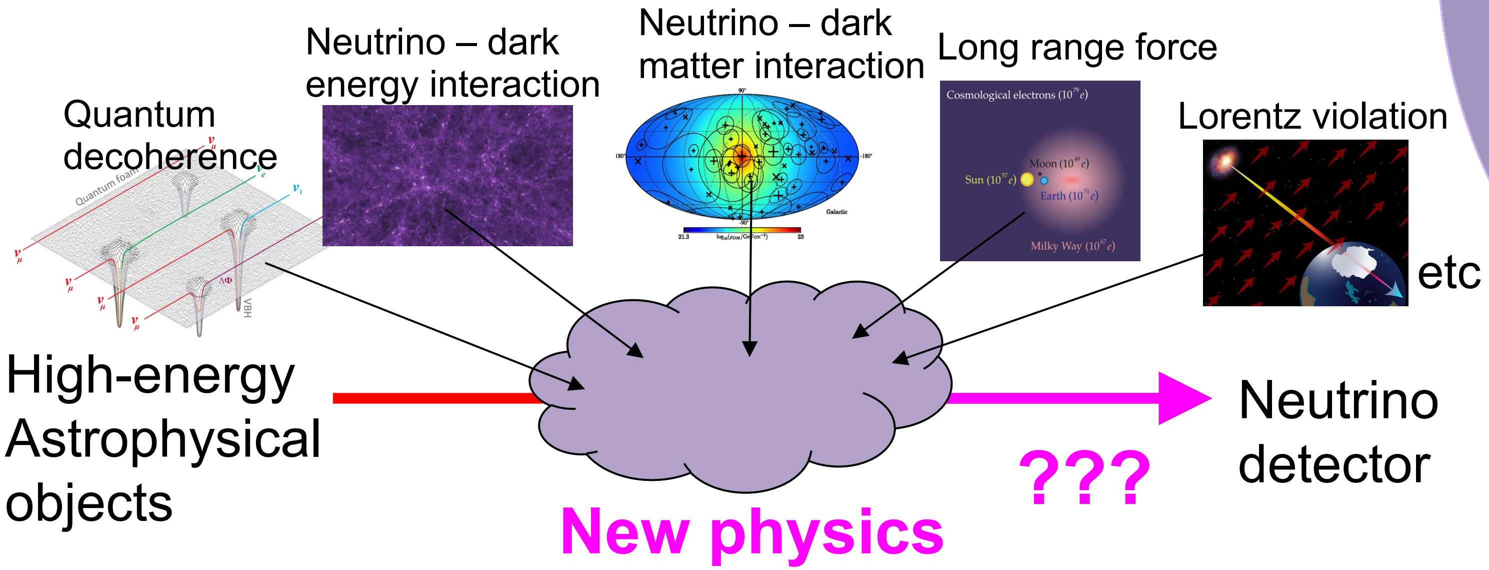
High-energy, long propagating neutrinos

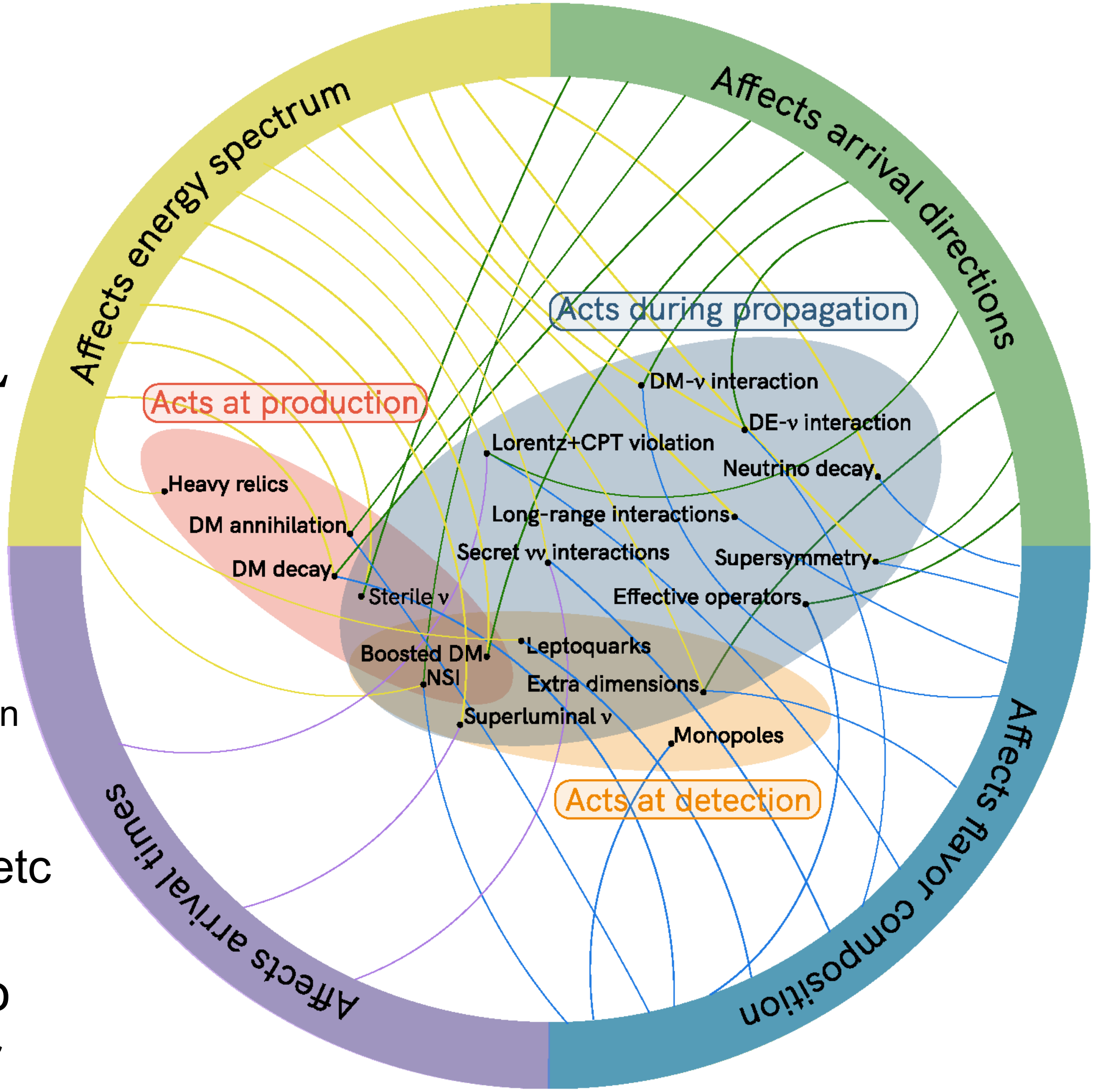
High-energy astrophysical neutrinos

- Long baseline accumulates new physics effect
- High energy enhances new physics effect

$$H \sim \frac{m^2}{2E} + V(new\ physics),\ P \sim V(new\ physics) \cdot L$$

- Energy spectrum, arrival time, flavor are affected by production, propagation, detection of neutrinos



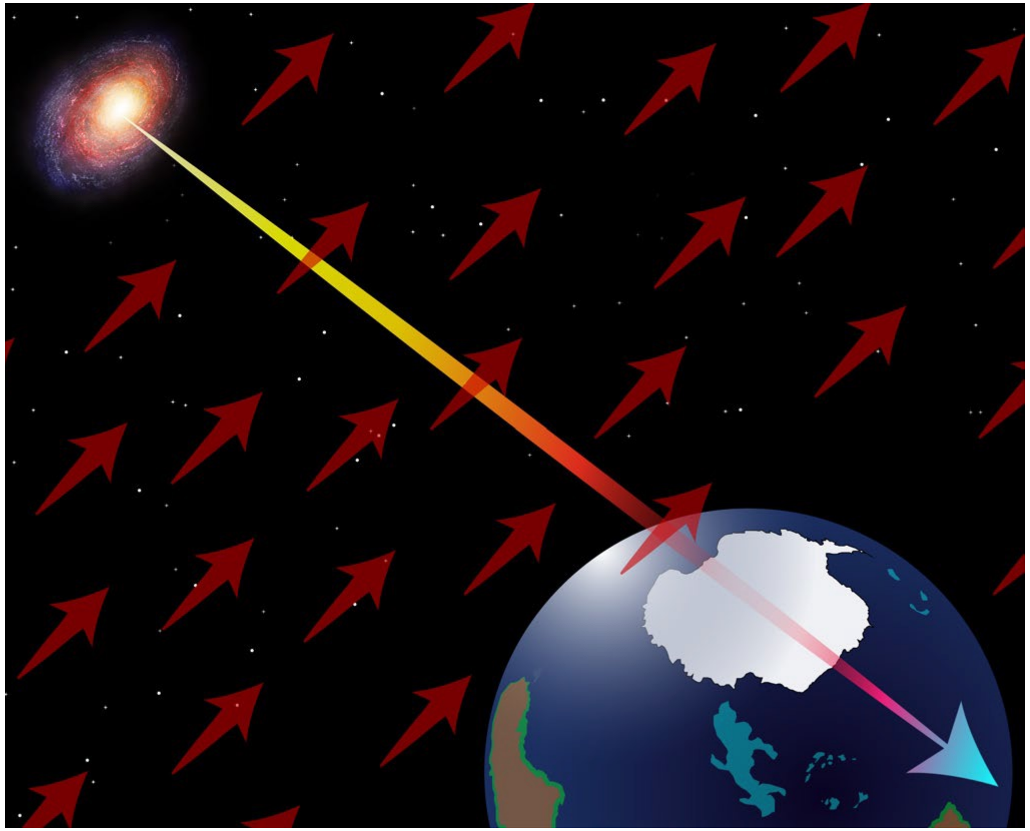


IceCube, Nature Physics(2022), (2024), Klop,Ando, PRD97(2018)063006,Argüelles,Kheirandish,Vincent, PRL119(2017)201801, Bustamante,Agarwalla, PRL122(2019)061103, Amelino-Camelia, ,Di Luca, Gubitosi, Rosati, D'Amico, Nature Astronomy (2023)

High-energy, long propagating neutrinos

Violation of Lorentz invariance

- Theoretically motivated (long list of models)
- Neutrino interacting with new fields in vacuum
- Matter potential in vacuum, but very small
- Energy spectrum, arrival time, flavor are affected
- Astrophysical neutrino flavor physics

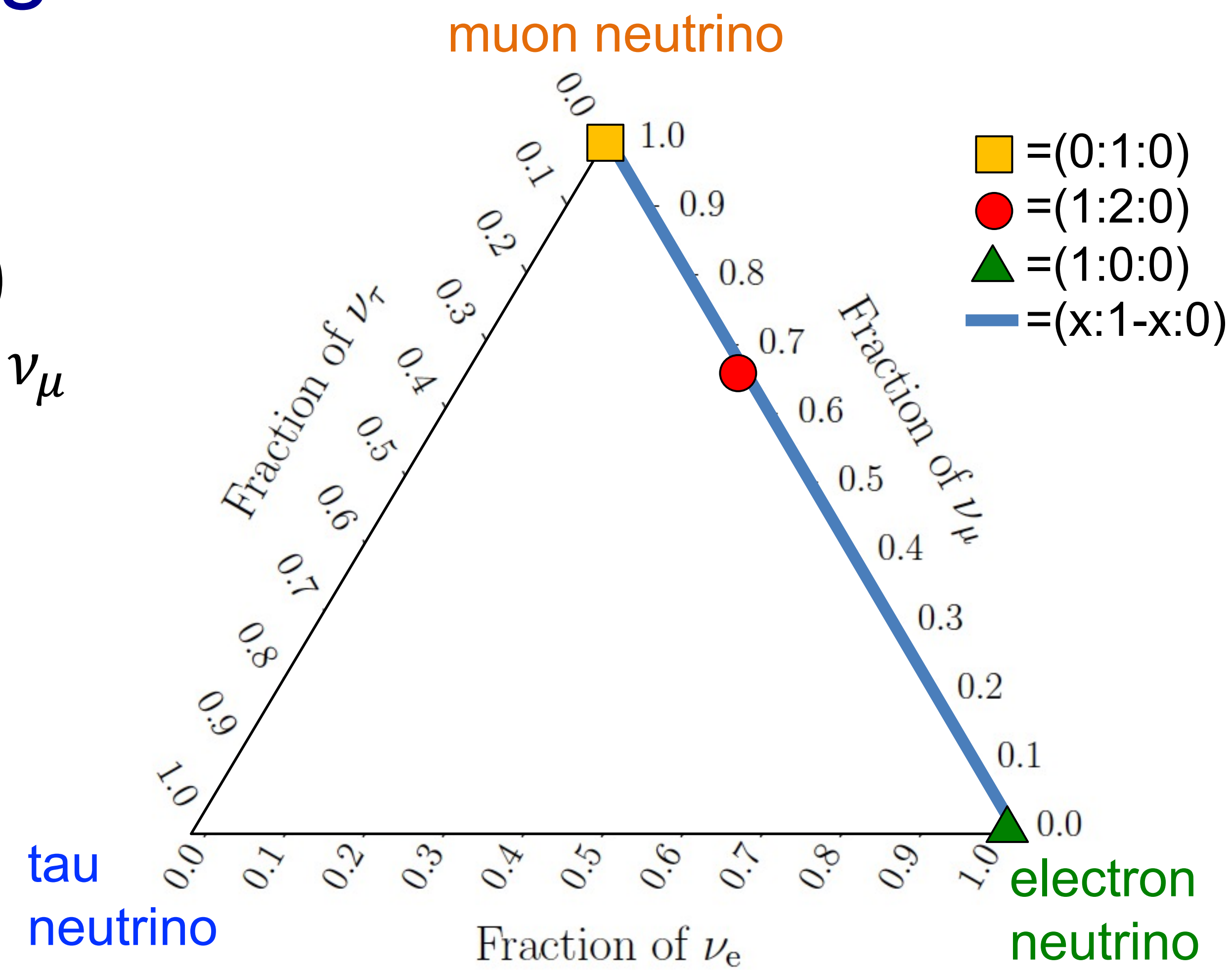


IceCube, Nature Phys. 18, 1287 (2022)

High-energy, long propagating neutrinos

Astrophysical neutrino flavor physics

- Flavor triangle
- Spectrum integrated flavor ratio $(\nu_e : \nu_\mu : \nu_\tau)$
- Standard production models include ν_e and ν_μ



IceCube, Nature Phys. 18, 1287 (2022)

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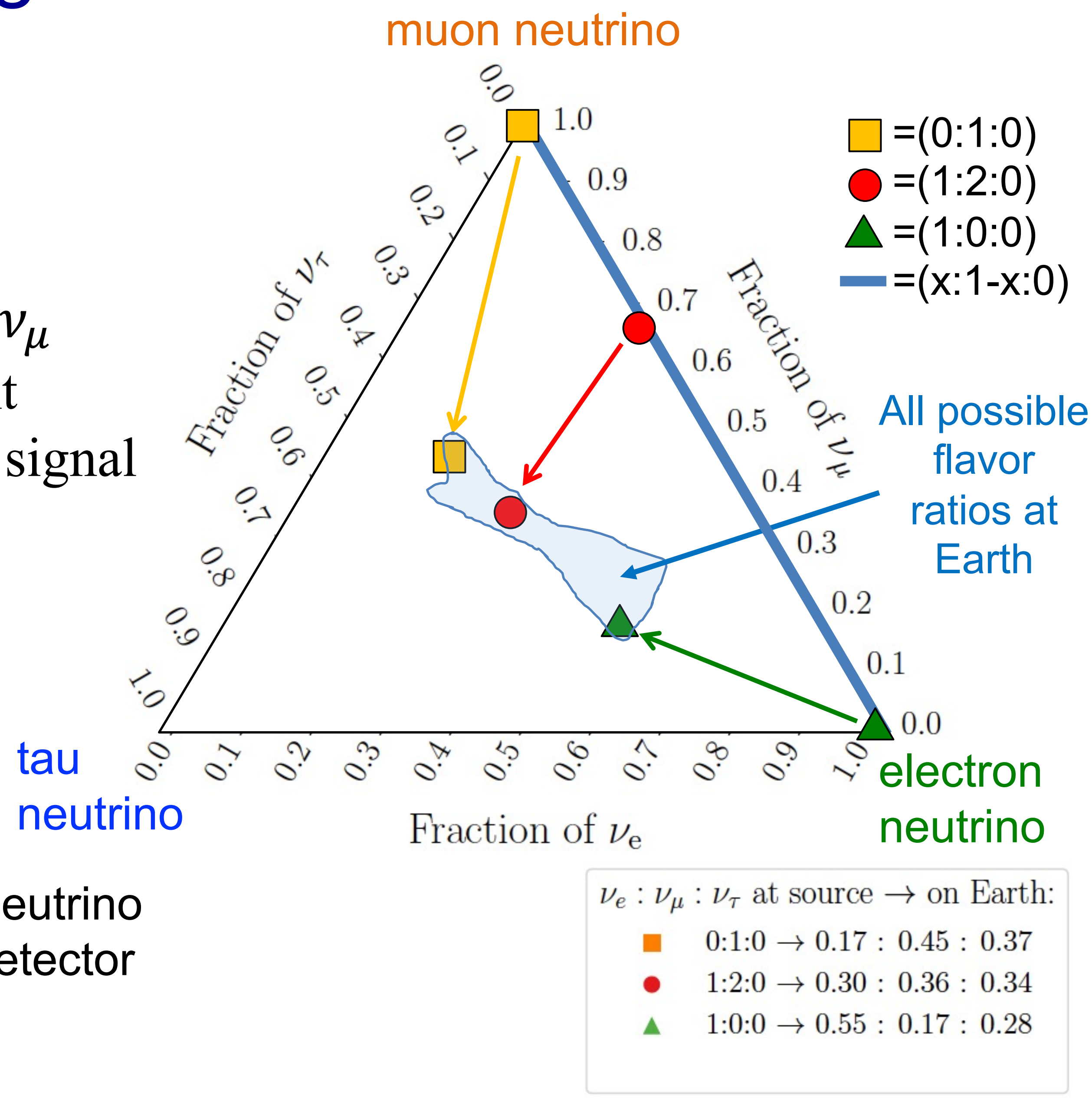
- Flavor ratio observables on Earth is different
- Deviation from this "island" is new physics signal



IceCube, Nature Phys. 18, 1287 (2022), IceCube, PRD104,(2021)022002, EPJC82(2022)1031

High-energy, long propagating neutrinos

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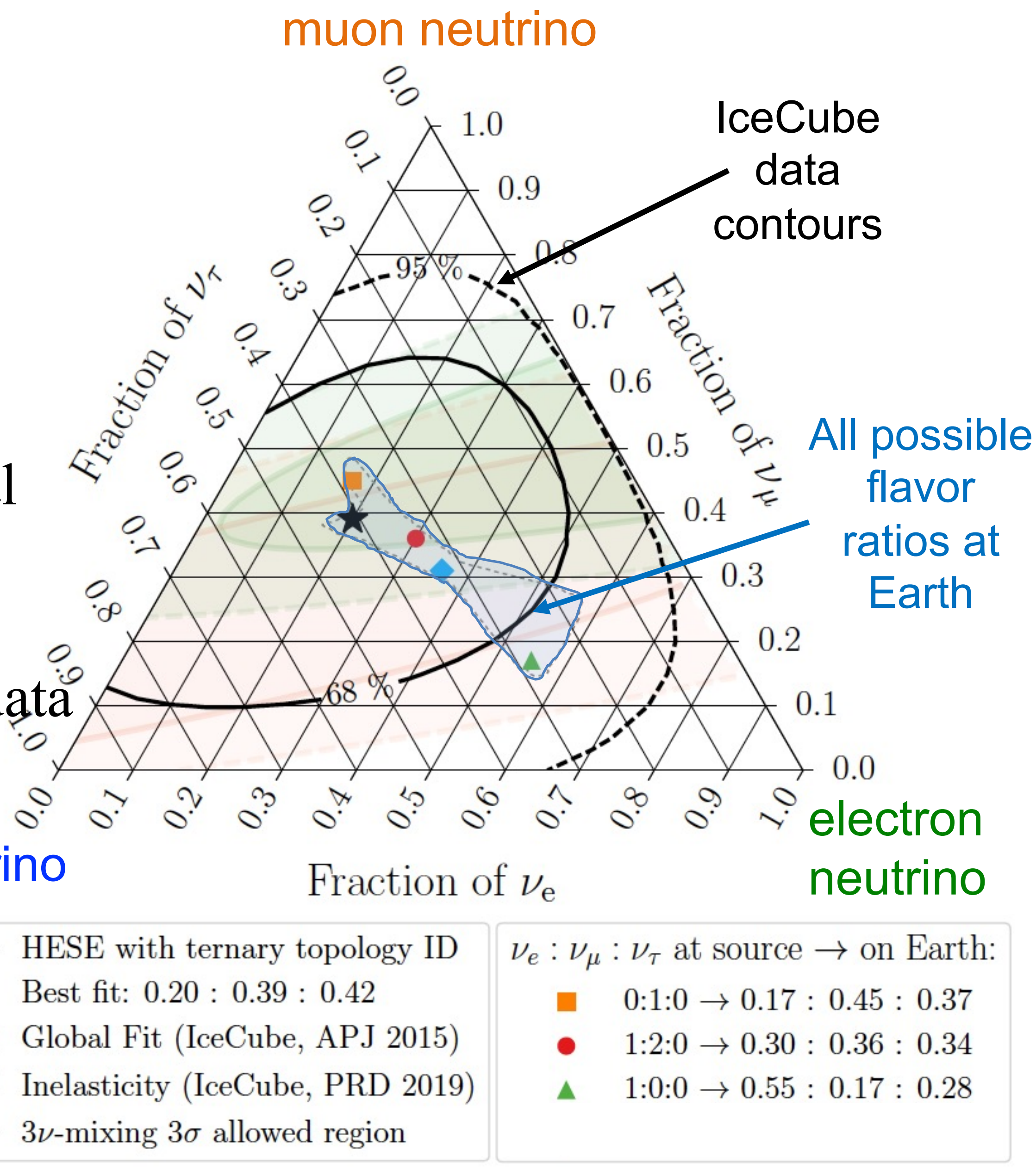
Data contour covers most of flavor triangle

- New physics cannot be discovered from current data
- Limits are set on vacuum operators



High-energy Astrophysical objects

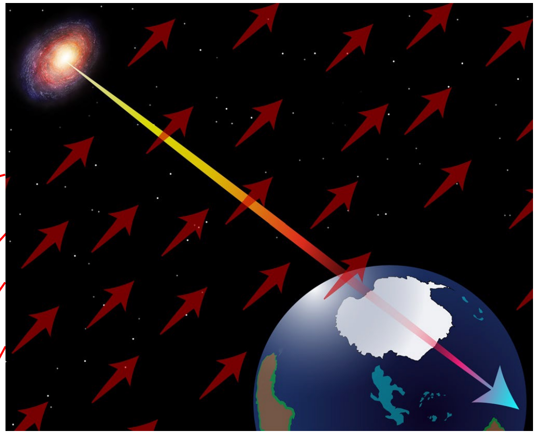
High-energy, long propagating neutrinos

Lorentz violation searches in SME framework

- Lower dimension operators → searches by tabletop experiments
- Higher dimension operators → searches by astrophysical observations

$$H \sim \frac{m^2}{2E} + a^{(3)} - E \cdot c^{(4)} + E^2 \cdot a^{(5)} - E^3 \cdot c^{(6)} \ldots$$

Lorentz violation



dim.	method	type	sector	limits	ref.
$\mathring{a}^{(3)}$	CMB polarization	astrophysical	photon	$\sim 10^{-43}$ GeV	[2]
	He-Xe comagnetometer	tabletop	neutron	$\sim 10^{-34}$ GeV	[3]
	torsion pendulum	tabletop	electron	$\sim 10^{-31}$ GeV	[4]
	muon g-2	accelerator	muon	$\sim 10^{-24}$ GeV	[5]
	neutrino mixing	astrophysical	neutrino	$\sim 10^{-26}$ GeV	[1]
$\mathring{c}^{(4)}$	GRB vacuum birefringence	astrophysical	photon	$\sim 10^{-38}$	[6]
	Laser interferometer	LIGO	photon	$\sim 10^{-22}$	[7]
	Sapphire cavity oscillator	tabletop	photon	$\sim 10^{-18}$	[8]
	Ne-Rb-K comagnetometer	tabletop	neutron	$\sim 10^{-29}$	[9]
	trapped Ca^+ ion	tabletop	electron	$\sim 10^{-19}$	[10]
	neutrino mixing	astrophysical	neutrino	$\sim 10^{-31}$	[1]
$\mathring{a}^{(5)}$	GRB vacuum birefringence	astrophysical	photon	$\sim 10^{-34}$ GeV^{-1}	[6]
	ultra-high-energy cosmic ray	astrophysical	proton	$\sim 10^{-22}$ to 10^{-18} GeV^{-1}	[11]
	neutrino mixing	astrophysical	neutrino	$\sim 10^{-37}$ GeV^{-1}	[1]
$\mathring{c}^{(6)}$	GRB vacuum birefringene	astrophysical	photon	$\sim 10^{-31}$ GeV^{-2}	[6]
	ultra-high-energy cosmic ray	astrophysical	proton	$\sim 10^{-42}$ to 10^{-35} GeV^{-2}	[11]
	gravitational Cherenkov radiation	astrophysical	gravity	$\sim 10^{-31}$ GeV^{-2}	[12]
	neutrino mixing	astrophysical	neutrino	$\sim 10^{-42}$ GeV^{-2}	[1]

[1] IceCube, Nature Phys. 18, 1287 (2022) [2] WMAP, AstrophysJ.180, 330 (2009) [3] Allmendinger et al., PRL112, 110801 (2014) [4] Heckel et al., PRL97, 021603(2006) [5] Muon g-2, PRL100, 091602 (2008) [6] Kostelecký, Mewes,PRL110, 201601 (2013) [7] Kostelecký, Melissinos, Mewes, PLB 761, 1 (2016) [8] Nagel et al.,Nature Comm. 6, 8174(2015) [9] Smiciklas et al., PRL107, 171604 (2011) [10] Pruttivarasin et al., Nature 517, 592 [11] Maccione et al., JCAP 0904, 022 [12] Kostelecký, Tasson, PLB 749, 551

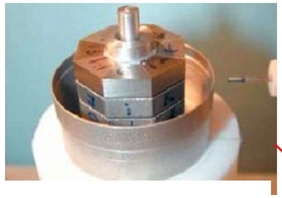
Argüelles, Hostert, TK, in preparation

High-energy, long propagating neutrinos

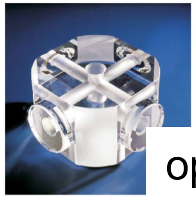
Physics MMA

Lorentz violation searches in SME framework

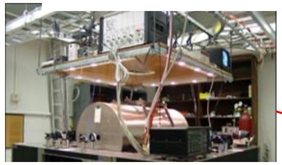
- Lower dimension operators → searches by tabletop experiments
- Higher dimension operators → searches by astrophysical observations



torsion pendulum

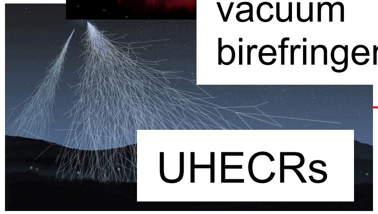


optical resonator



comagnetomator

vacuum birefringence



UHECRs

$$H \sim \frac{m^2}{2E} + a^{(3)} - E \cdot c^{(4)} + E^2 \cdot a^{(5)} - E^3 \cdot c^{(6)} \dots$$

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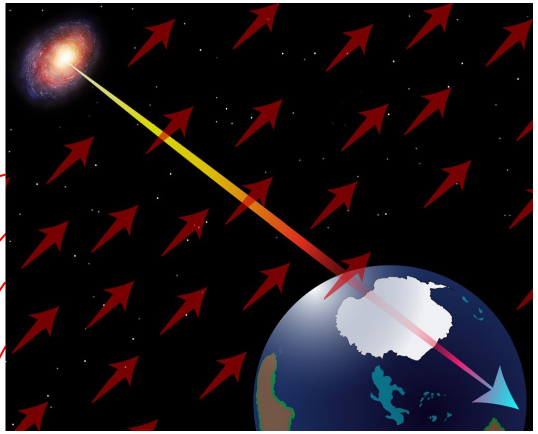
Lorentz violation



Weak interaction + small mass + mixing = macroscopic quantum system you cannot disturb

mystery of neutrinos!

Boris Kayser (1938-2024)

[1] IceCube, Nature Phys. 18, 1287 (2022) [2] WMAP, AstrophysJ.180, 330 (2009) [3] Allmendinger et al., PRL112, 110801 (2014) [4] Heckel et al., PRL97, 021603(2006) [5] Muon g-2, PRL100, 091602 (2008) [6] Kostelecký, Mewes,PRL110, 201601 (2013) [7] Kostelecký, Melissinos, Mewes, PLB 761, 1 (2016) [8] Nagel et al.,Nature Comm. 6, 8174(2015) [9] Smiciklas et al., PRL107, 171604 (2011) [10] Pruttivarasin et al., Nature 517, 592 [11] Maccione et al., JCAP 0904, 022 [12] Kostelecký, Tasson, PLB 749, 551

Song, Li, Argüelles, Bustamante, Vincent, JCAP04(2021)054

High-energy, long propagating neutrinos - summary

High energy astrophysical neutrinos have amazing new physics sensitivity, and it will increase more

Multi-messenger astronomy

Talk by Maurizio Spurio (Tuesday)
Anna Franckowiak (Friday)

- High-energy astrophysical neutrino model errors will be reduced (spectrum, flavor, direction, time)

New neutrino telescopes

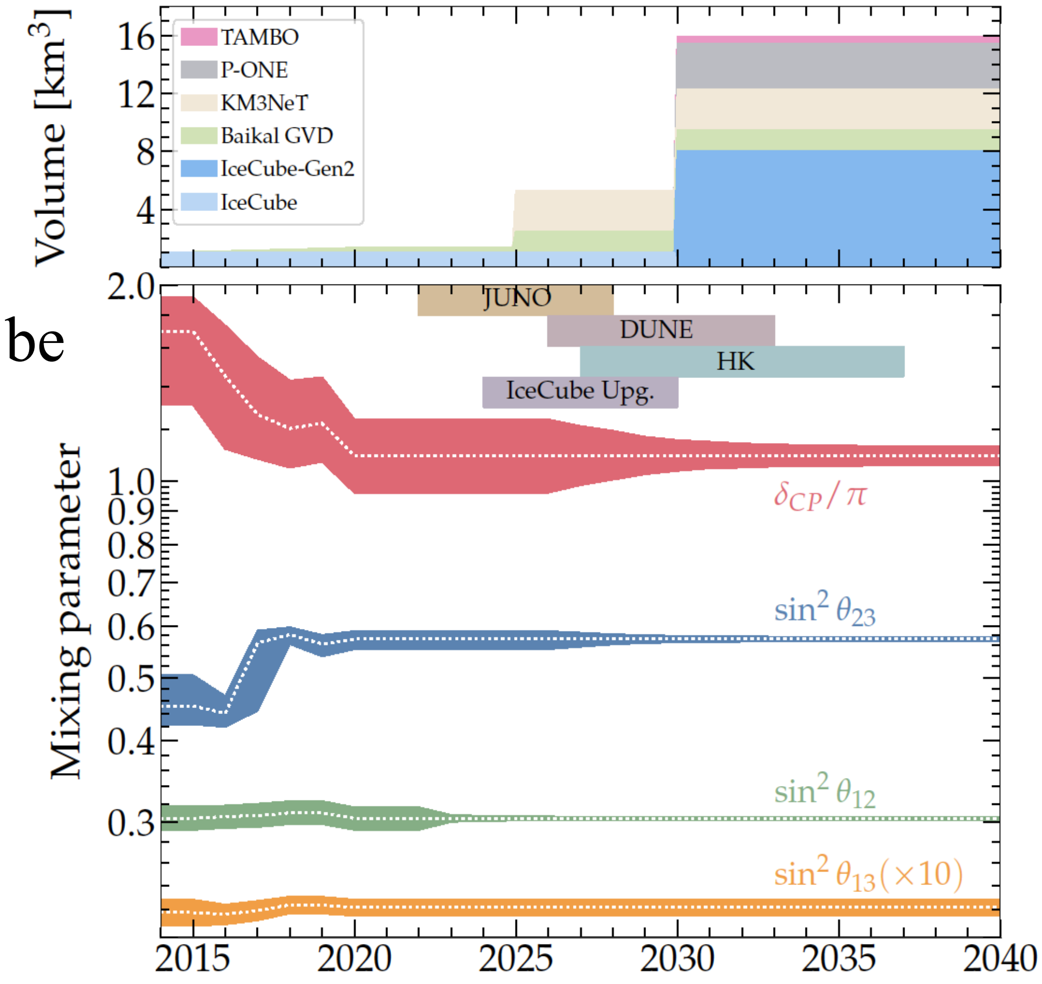
Talk by Kaeli Hughes (Wednesday)
Naoko Kurahashi (Wednesday)

- Higher statistics to reach higher energy events

Neutrino physics

Talk by Mariam Tórtola (Monday)

- Oscillation parameter errors will be reduced



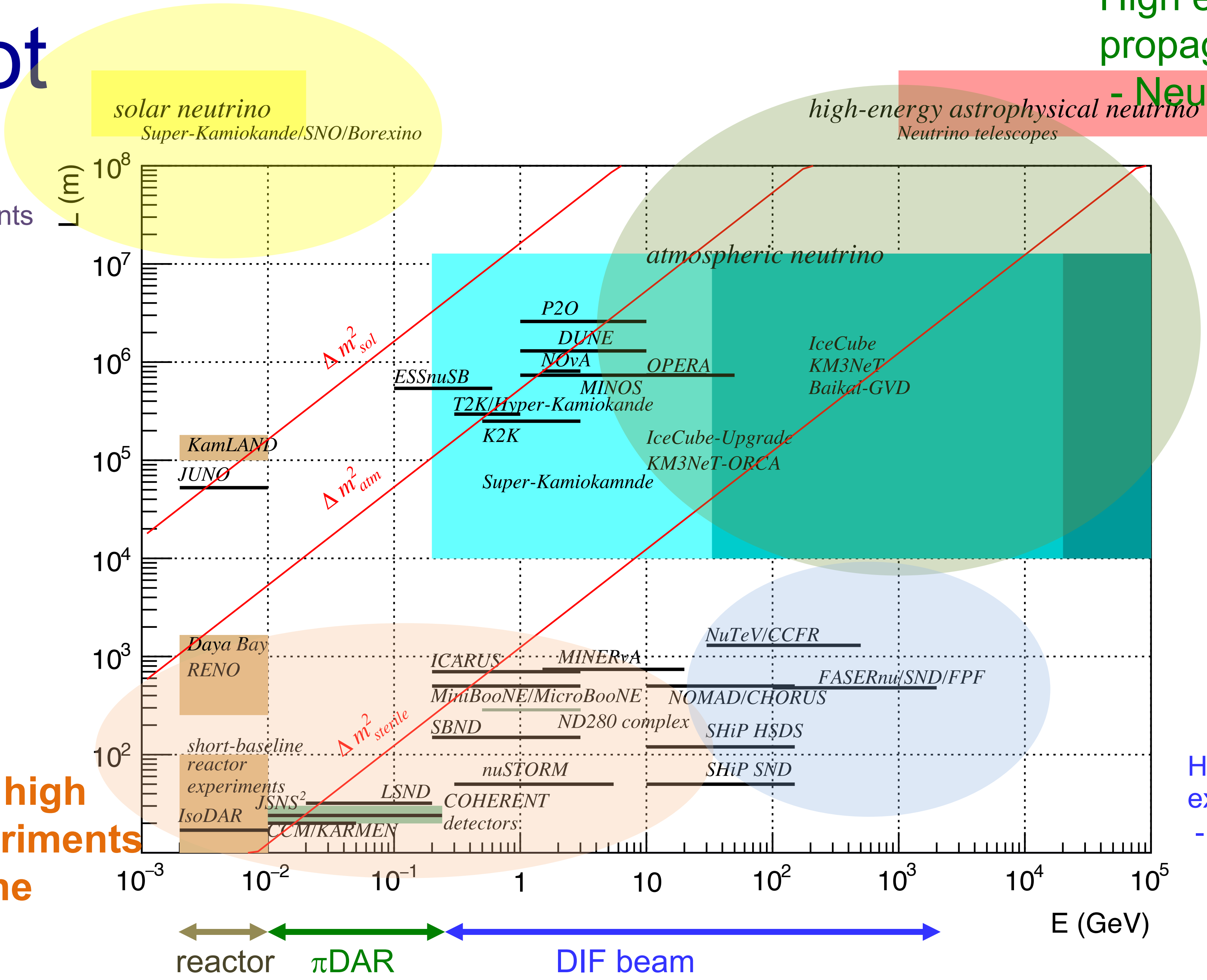
Strong synergy between particle physics and astrophysics!

Argüelles, Hostert, TK, in preparation

L-E plot

High energy, long propagation experiments
 - Neutrino telescopes

Low energy, long propagation experiments
 - Underground low-background detectors



High intensity, high precision experiments
 - Short-baseline experiments

High energy, high precision experiments
 - Collider neutrino experiments

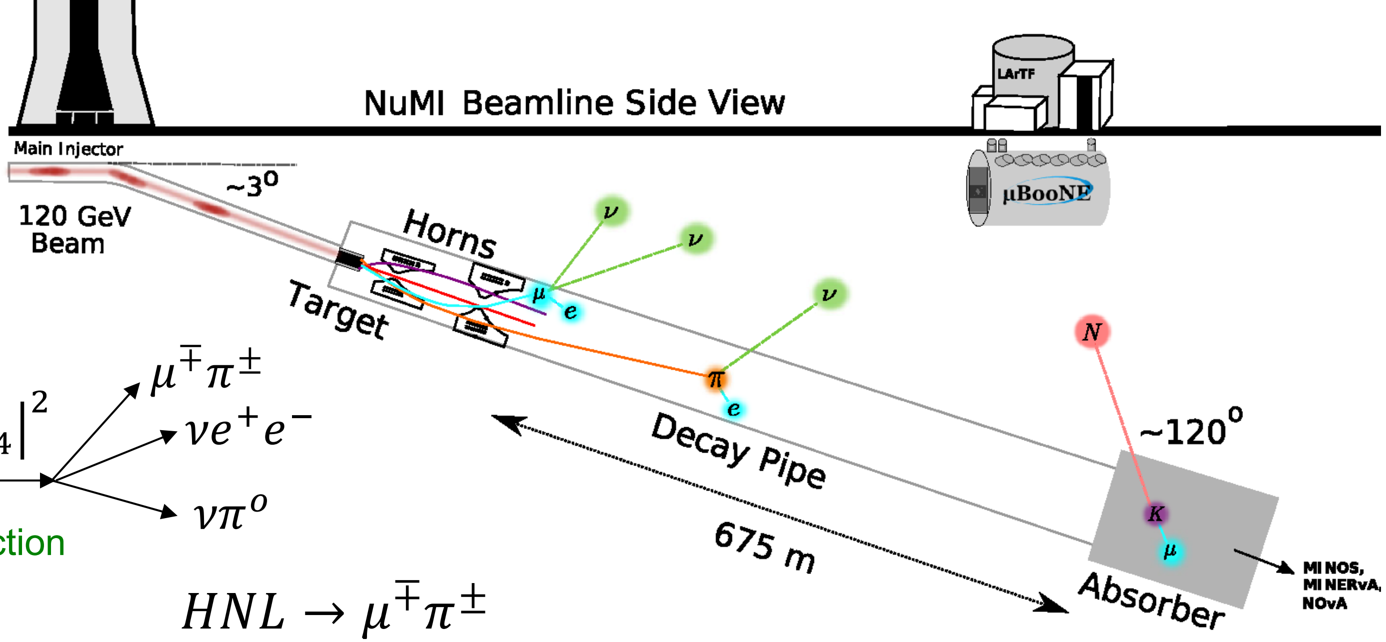
MicroBooNE, PRD106(2022)092006, PRL132(2024)041801, ArXiv:2312.13945, de Gouvêa, Fox, Harnik, Kelly, Zhang, JHEP01(2019)001, T2K, PRD100(2019)052006, Snowmass2021 J.Phys.G50(2023)020501, Batell, Berger, Ismail, PRD100(2019)115039

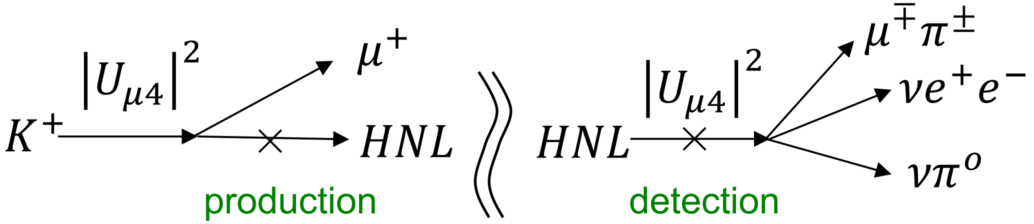
High-intensity, high-precision experiments

New particle searches

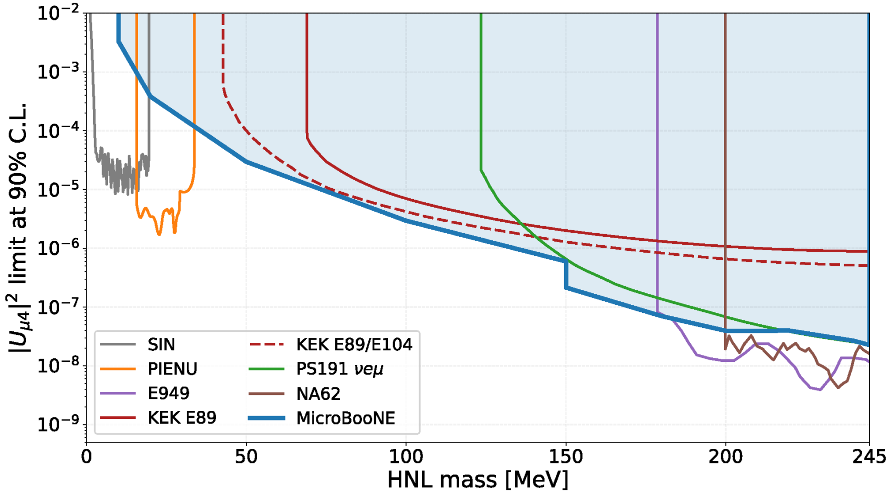
- Heavy neutral leptons
- Long lived particles
- Higgs Portal Scalar
- Dark trident, etc

MicroBooNE new particle search

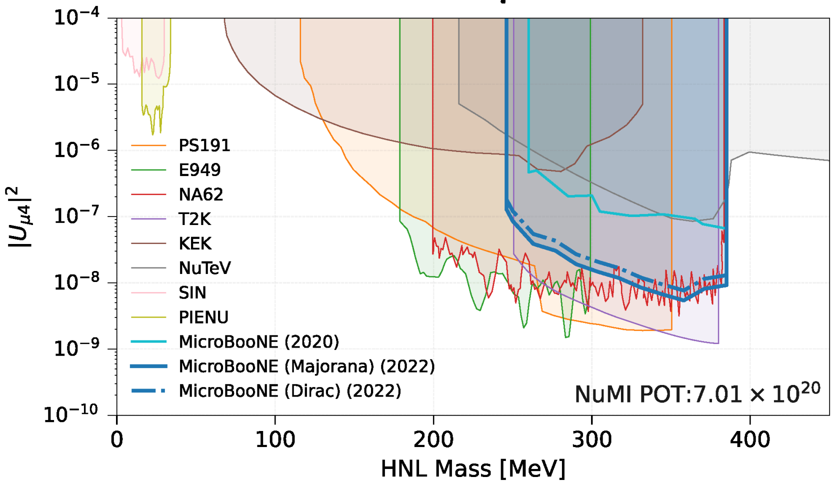


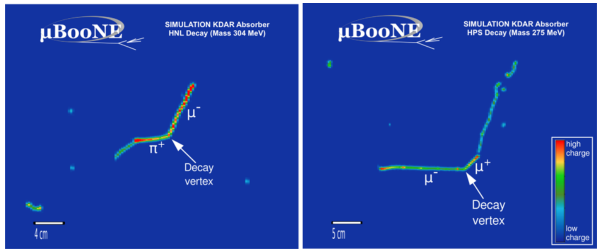


$HNL \rightarrow \nu e^+ e^-, \nu \pi^o$



$HNL \rightarrow \mu^\mp \pi^\pm$





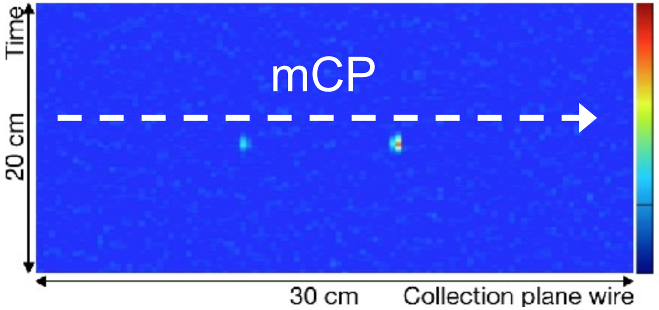
Talk by David Caratelli (Monday)

Magill, Plestid, Pospelov,Tsai, PRL122(2019)071801, ArgoNeuT, PRL124(2020)131801
Waites et al., PRD107(2023) 095010, Hostert, McKeen, Pospelov, Raj, PRD107(2023)075034

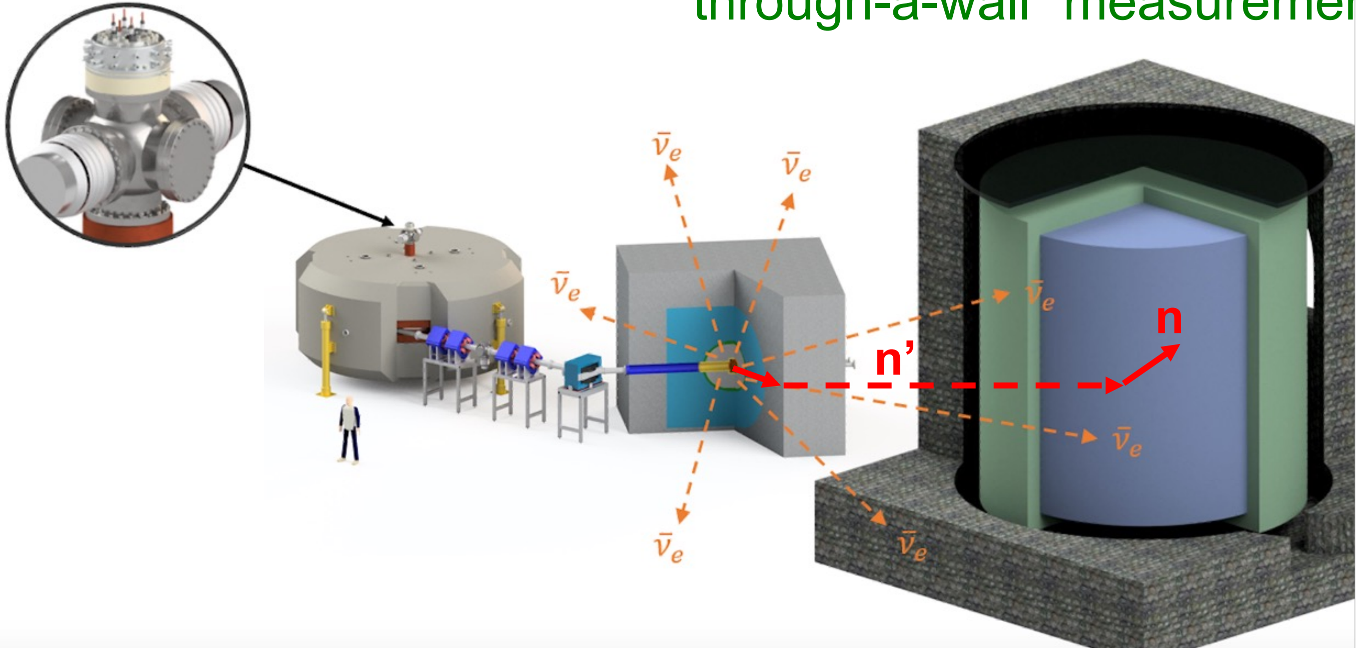
High-intensity, high-precision experiments

New particle searches
- Heavy neutral leptons
- Long lived particles
- Higgs Portal Scalar
- Dark trident
- Millicharged particles
- Dark neutron, etc

ArgoNeuT millicharged particle candidate event

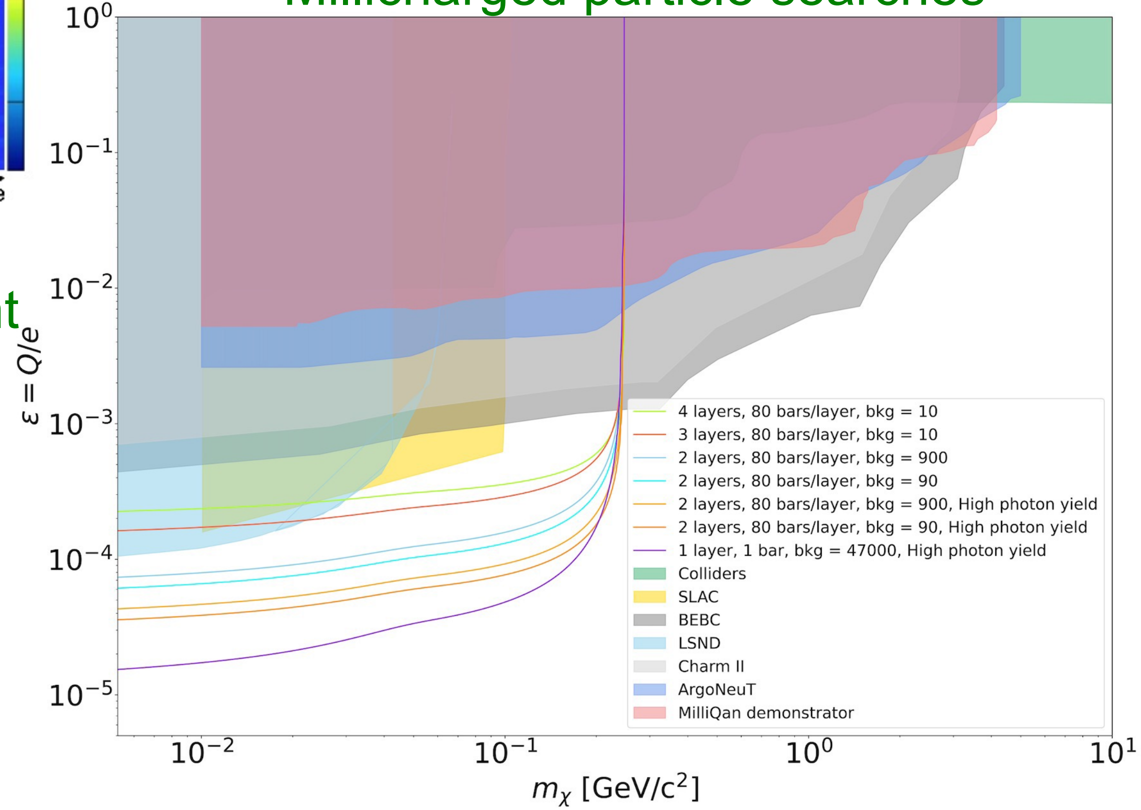


IsoDAR "neutron-shinning-through-a-wall" measurement



$$\frac{d\sigma}{dE} \sim \frac{2\pi\alpha\varepsilon^2}{m_e E_r^2}$$

Millicharged particle searches



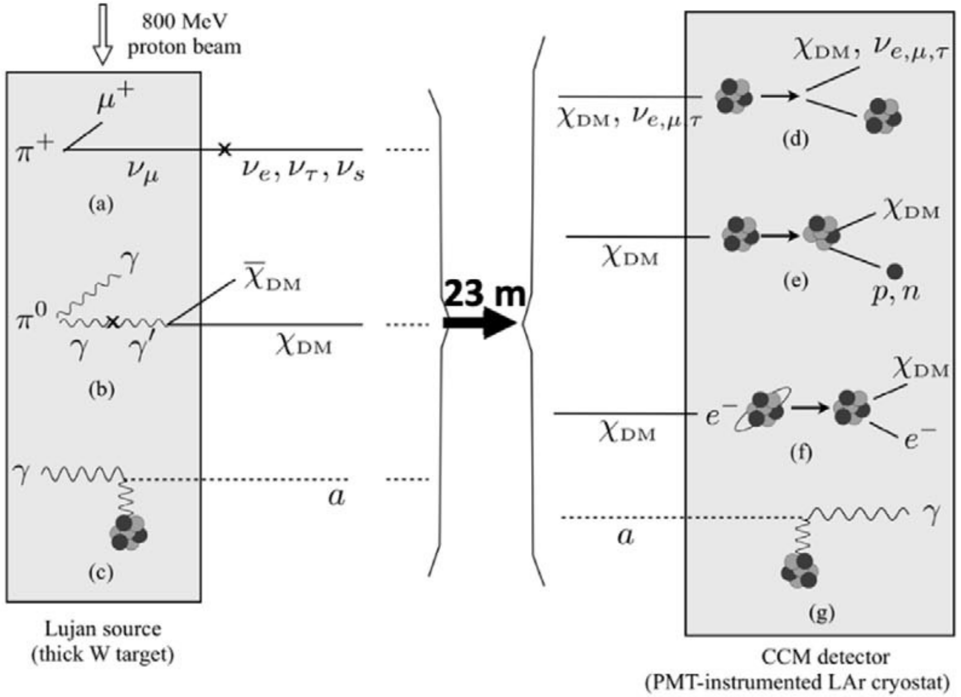
CCM, PRL129(2022)021801, PRD106(2022)012001;107(2023)095036;109(2024)095017,
COHERENT, PRL130(2023)051803, PRD106(2022)052004;109(2024)092005

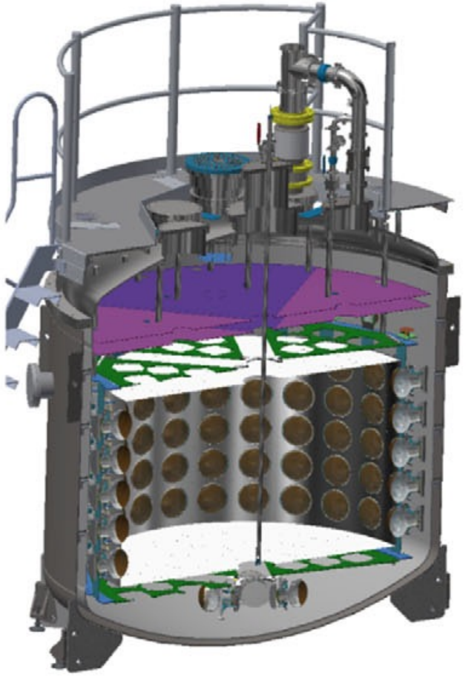
High-intensity, high-precision experiments

New particle searches
- Heavy neutral leptons
- Long lived particles
- Higgs Portal Scalar
- Dark trident
- Millicharged particles
- Dark neutron
- All kinds of dark matter particles
  - scalar, pseudoscalar
  - vector, axion-like particle
  - Dirac, Majorana, pseudo-Dirac
  - Leptophobic, etc

... New particle Zoo!

CCM dark matter searches





Pandey, PPNP134(2023)104078, Van Dessel, Pandey, Ray, Jachowicz, Universe9(2023)207
COHERENT, PRL126(2021)012002: 129(2022)081801, PRD109(2024)092005

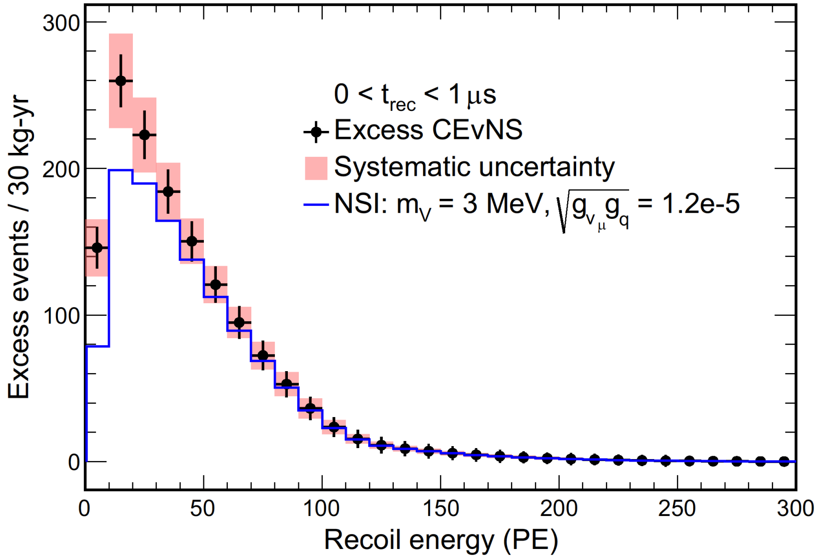
High-intensity, high-precision experiments

High-precision spectrum measurements
- Beta and double-beta decays
- Neutrino-electron scattering
- Coherent elastic neutrino - nucleus scattering (CEvNS)
  - Next generation CEvNS new physics searchers may be affected with nuclear models

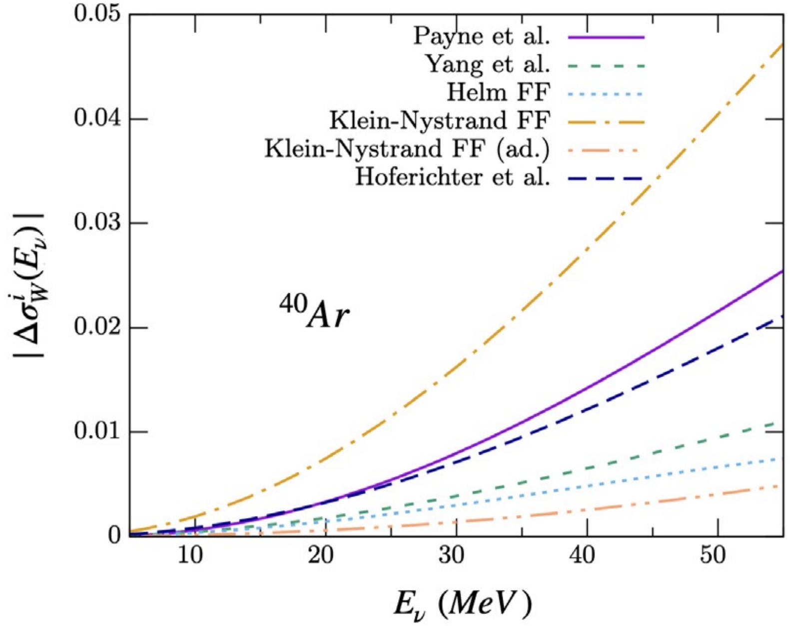
Talk by Alexey Lokhov (Wednesday)

Talk by Irina Nasteva (Friday)
Matt Green (Friday)

COHERENT future NSI model sensitivity



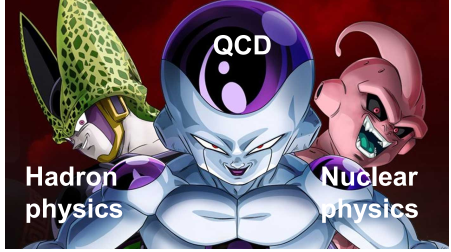
Form factor model differences



Anomalies are (mostly) explained by Strong interaction

CLAS, Nature566(2019)354, Lovato, Carlson, Gandolfi, Rocco, Schiavilla,PRX10(2020)031068, Gysbers, Hagen, Holt et al, Nature Phys. 15(2019)428
Meyer, Walker-Loud, Wilkinson, Annu.Rev.Nucl.Part.Sci.72(2022)205, PNDNE, PRD109(2024)014503, PACS, PRD109(2024)094505

Many anomalies have explanations using Strong interaction (QCD, nuclear physics, hadron physics)



Argonne NATIONAL LABORATORY

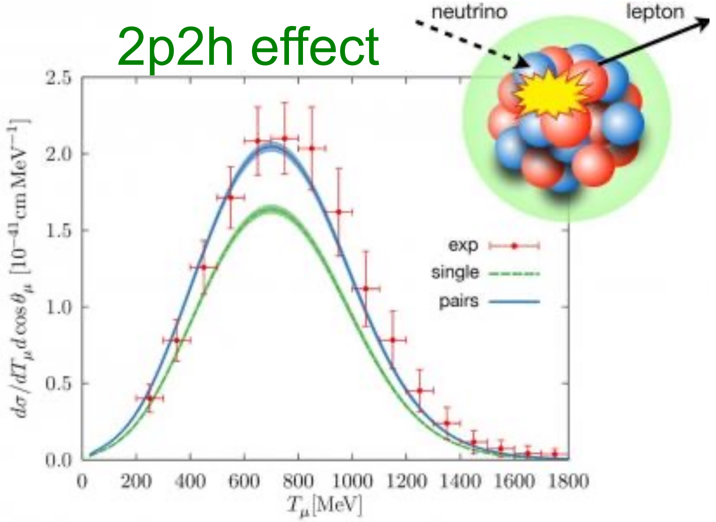
PRESS RELEASE | ARGONNE NATIONAL LABORATORY

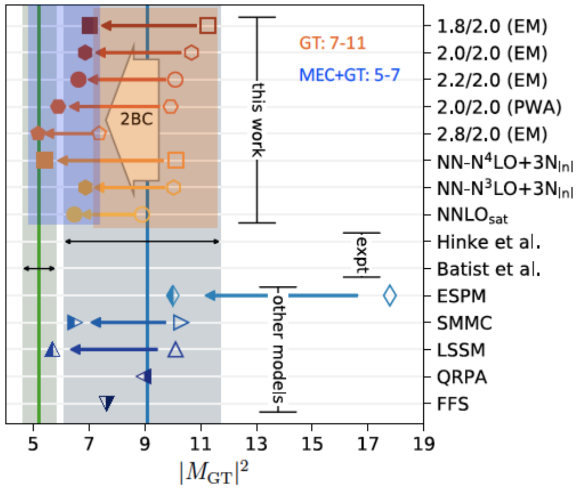
Understanding ghost particle interactions

BY JOSEPH E. HARMON | SEPTEMBER 28, 2020

Team constructs accurate nuclear physics model of neutrino-nuclei interactions.

2p2h effect

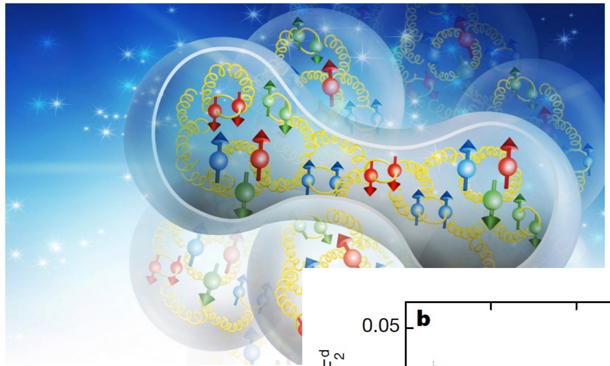


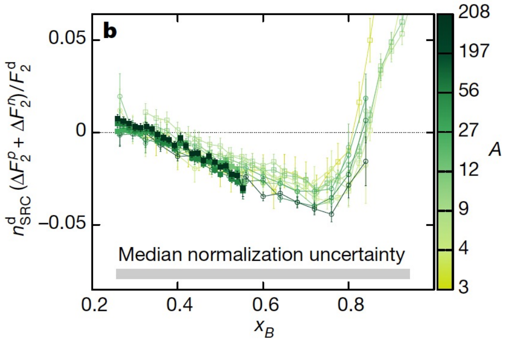


CORRELATED NUCLEONS MAY SOLVE 35-YEAR-OLD MYSTERY

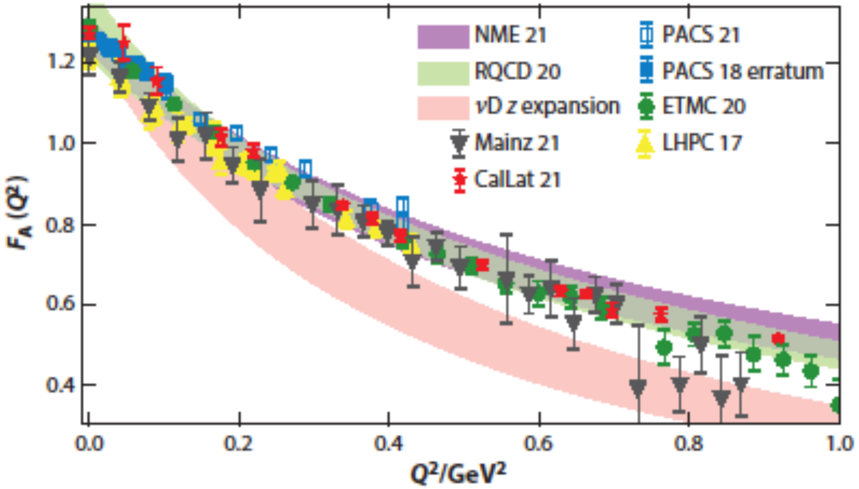
Jefferson Lab

EMC effect





Axial FF anomaly

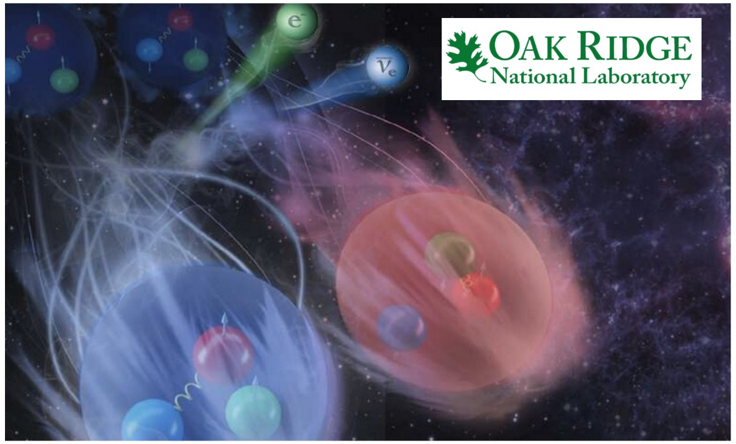


Talk by Luis Alvarez-Ruso (Thursday)

Physicists solve a beta-decay puzzle with advanced nuclear models

by Oak Ridge National Laboratory

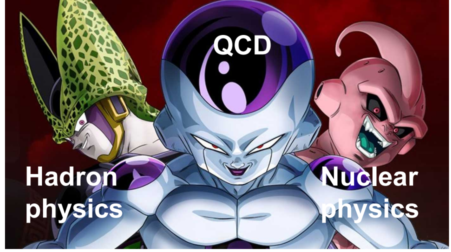
g_A quenching

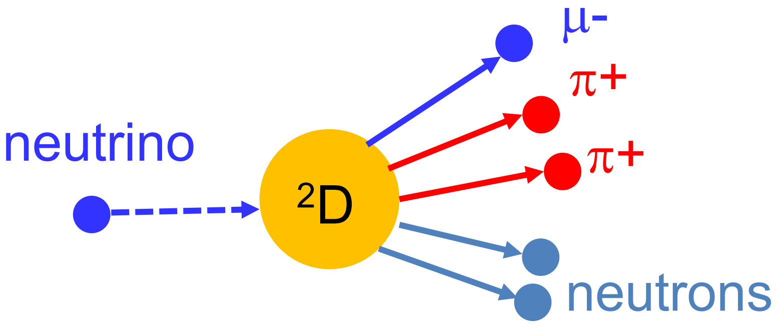


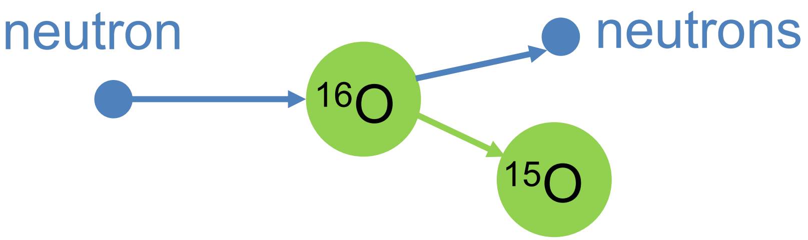
Talk by Javier Menendez (Monday)

Nakamura Kamano, Hayato, Hirai, Horiuchi, Kumano, Murata, Saito, Sakuda, Sato Rep.Prog.Phys.80(2017)056301
https://tendl.web.psi.ch/tendl_2015/tendl2015.html

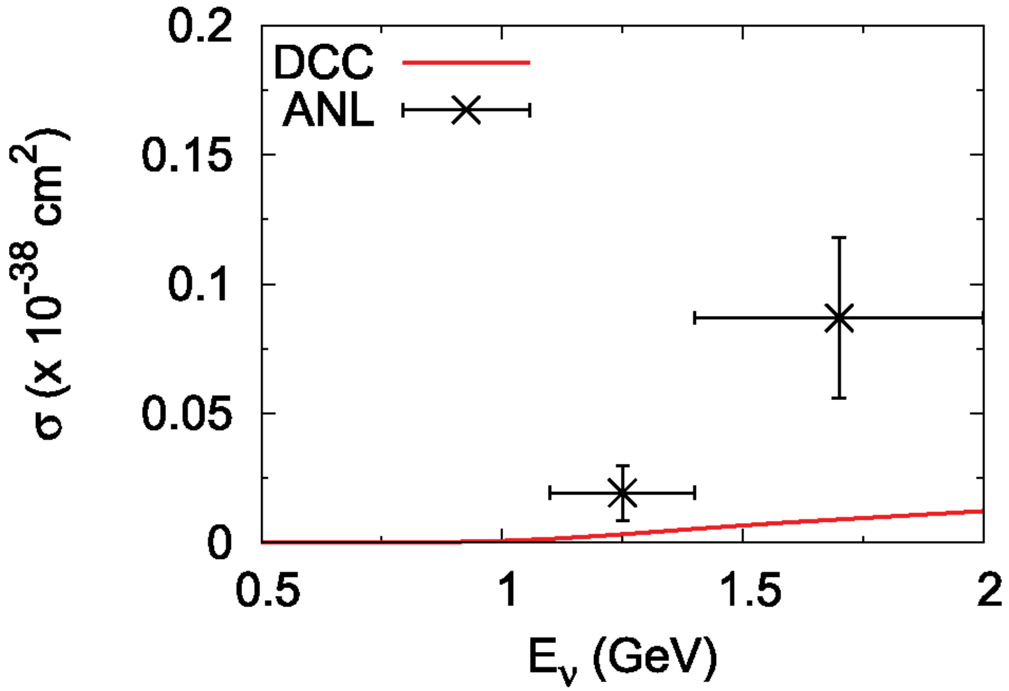
Next generation detectors use hadron final states to exploit neutrino information to look for new physics



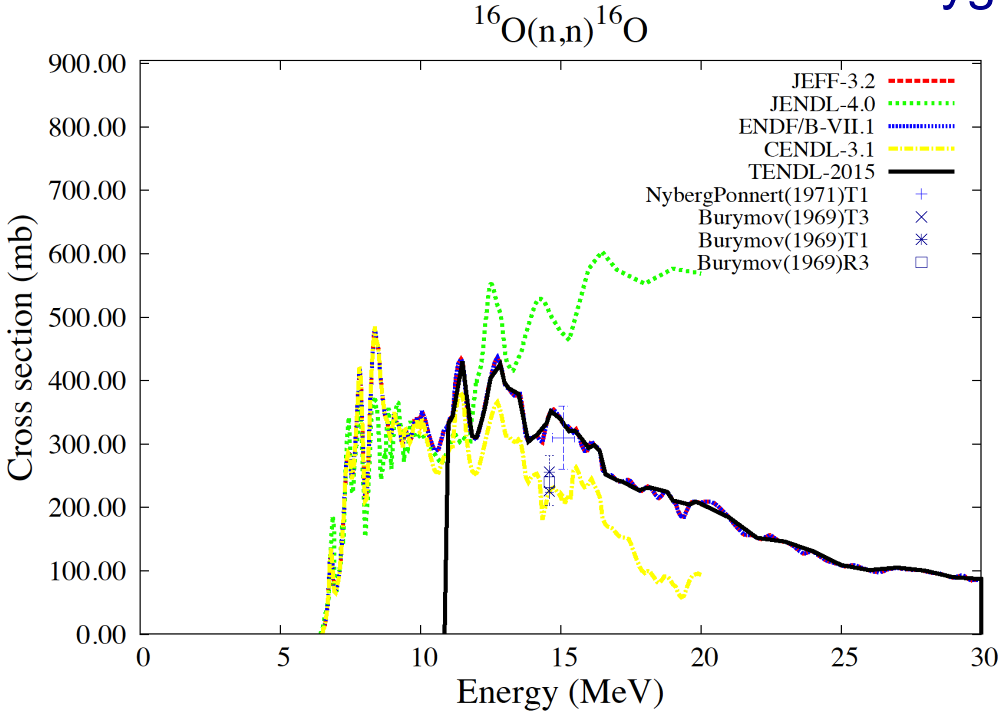




Neutrino induced 2-pion production



Neutron total inelastic cross section on oxygen



High-intensity, high-precision experiments - Summary

Nuclear physics in particle physics

- Current neutrino experiments use state-of-the-art nuclear theories and models
  oscillation physics, CEνNS, 0νββ...
- Neutrino physics is a major topic in nuclear physics communities
  JLab, INT, ECT*, NUSTEC...

Talk by Julia Tena Vidal (Friday)

- Good communication to remove misunderstanding
  language, tools, approximations...

Particle physics will be better with the help from nuclear physicists and others!

High-intensity, high-precision experiments - Summary

Theorists and experimentalists

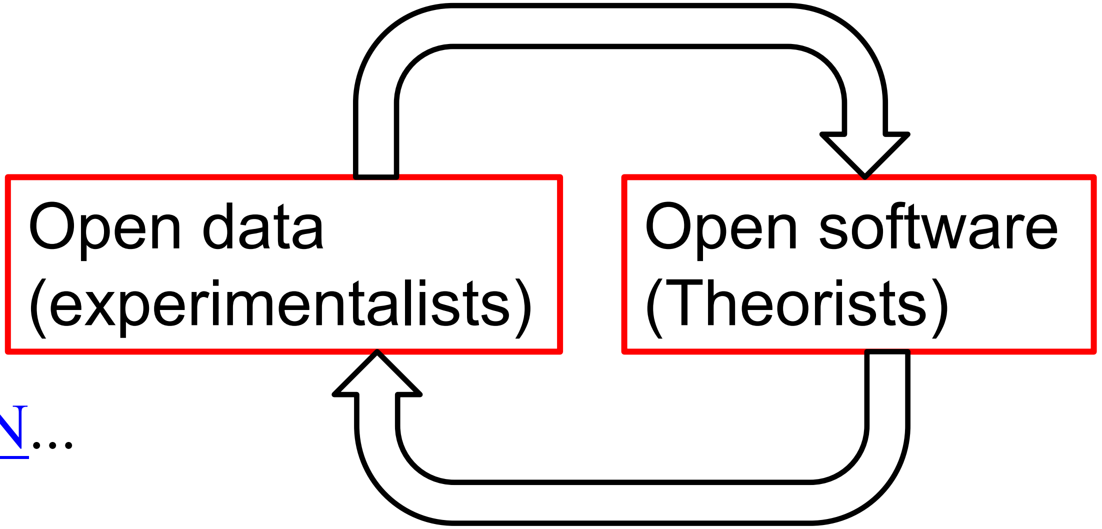
- Theory-Experiment joint workshop

  Magnificent CEvNS, Short-baseline...

  Correct understanding of data and theory

- Open data, open software for efficient work

  nuSQUID, Prometheus, DarkNews, SIREN...



Theorists and experimentalists can work together to make particle physics better!

Conclusion: We must discover new physics with neutrinos!

Effective communication is the key for the new physics discovery

Cross-disciplinary effort is important
- Particle physics, astrophysics, nuclear physics, and more

Healthy Theory-Experiment relationship is important
- Open data, open software
- Joint Theory-Experiment workshop

Enjoy the conference!

Thank you for listening!

Acknowledgements: Carlos Argüelles, Matheus Hostert, Malcolm Fairbairn, Chris McCabe, Stephen Dolan, Kajetan Niewczas, Stefan Söldner-Rembold, David Caratelli, Vishvas Pandey, Yu-Dai Tsai, Livia Ludhova, Rex Tayloe, Javier Menendez, Josh Spitz, Tatsuya Kikawa, Akitaka Ariga, Kevin McFarland, Matt Green, Julia Tena Vidal, Yota Hino, Beda Roskovec, Luis Alvarez Ruso, JP Athayde Marcondes de Andréand King's College London Experimental Particle and Astroparticle Physics group.

Backup

Snowmass21, EPJC83(2023)15, Abdullahi, Denton, PRD102(2020)023018

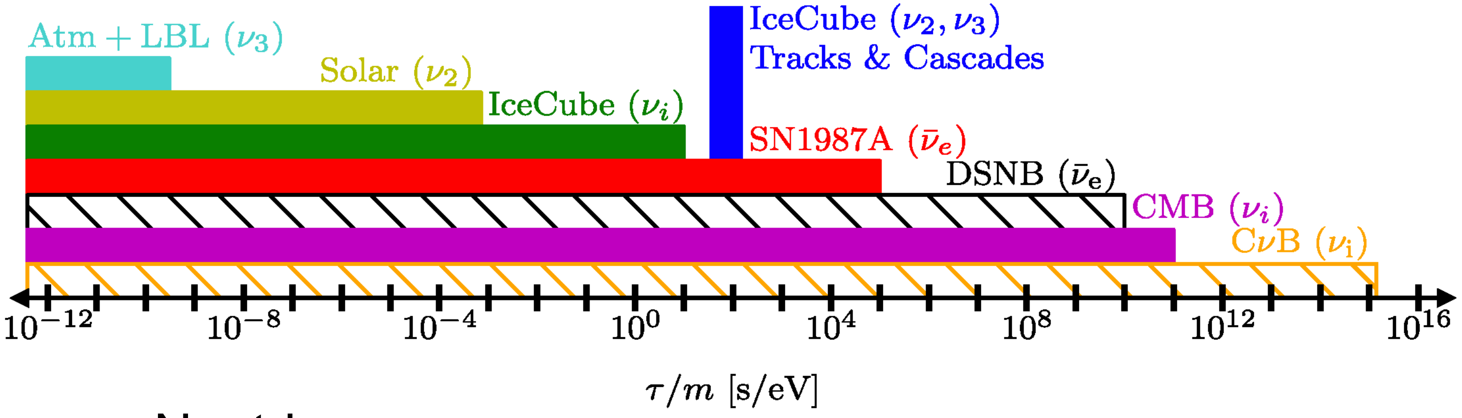
Low-energy, long propagation neutrinos

Supernova neutrinos

- Long baseline accumulates new physics effect

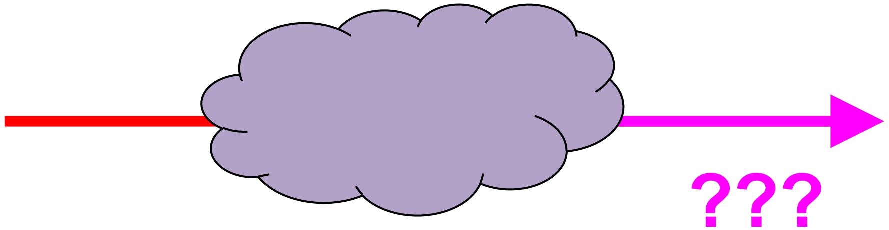
$$P \sim exp(-\Gamma \cdot L), \qquad \Gamma \sim \frac{g^2 m^2}{E}$$

- Core collapse supernova neutrinos and DSNB will be the great test to look for neutrino decays and other neutrino properties



Neutrino decay limits and a hint

Supernova neutrinos



Neutrino detector

???

Neutrino decay

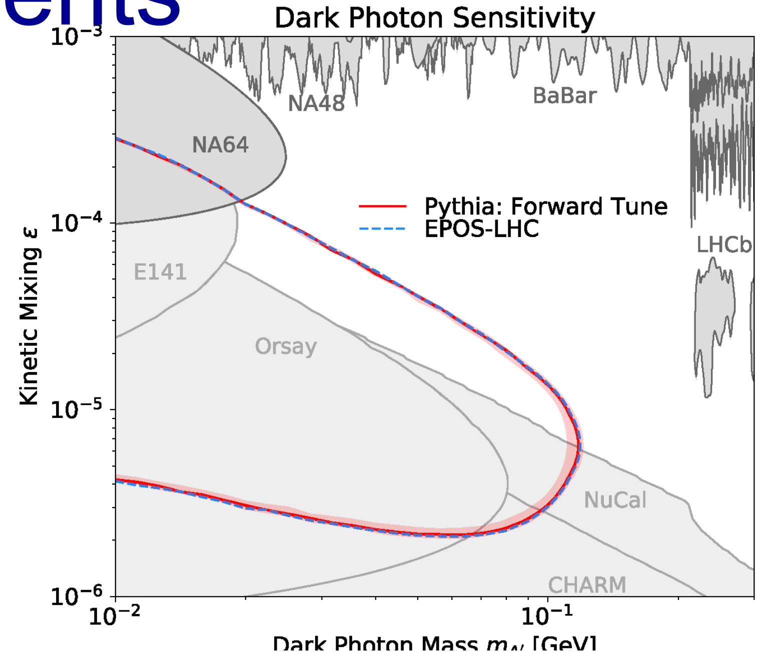
FASERnu, J. Phys. G, 50(2023)030501, ArXiv:2403.12520, Fieg,Kling,Schulz,Sjöstrand, PRD109(2024)016010
Falkowski,González-Alonso,Kopp,Soreq,Tabrizi, JHEP10(2021)086

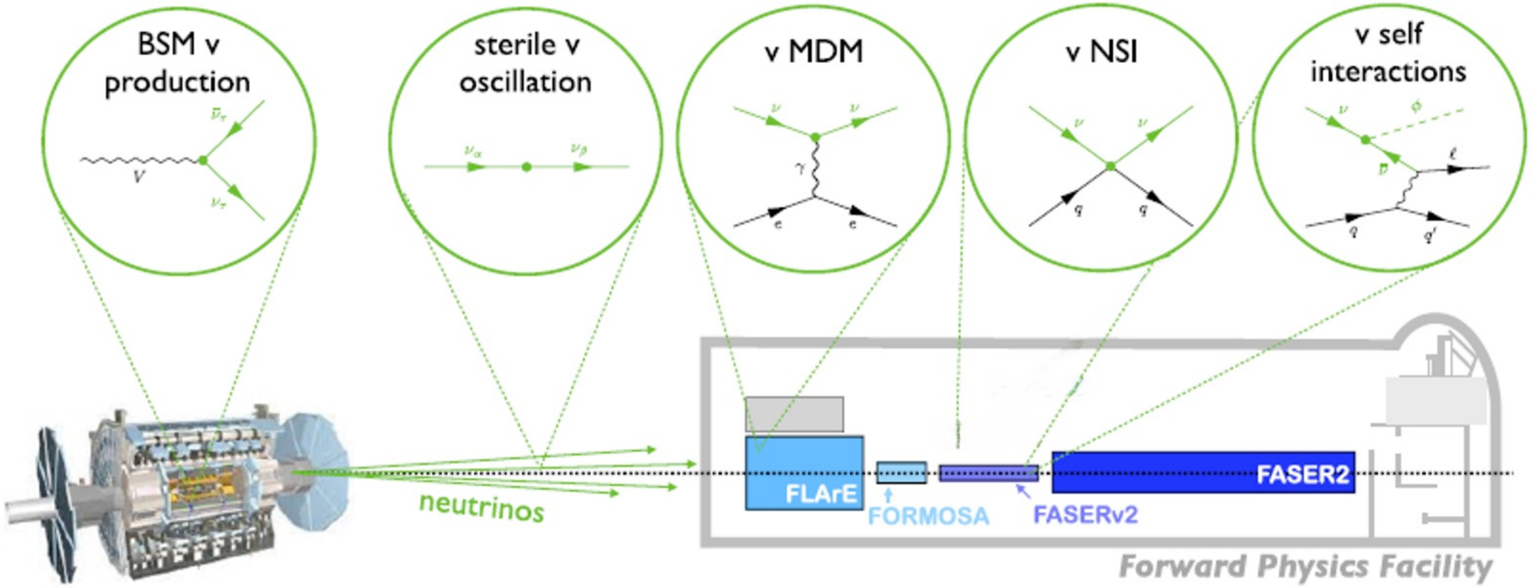
Talk by Albert De Roeck (Friday)

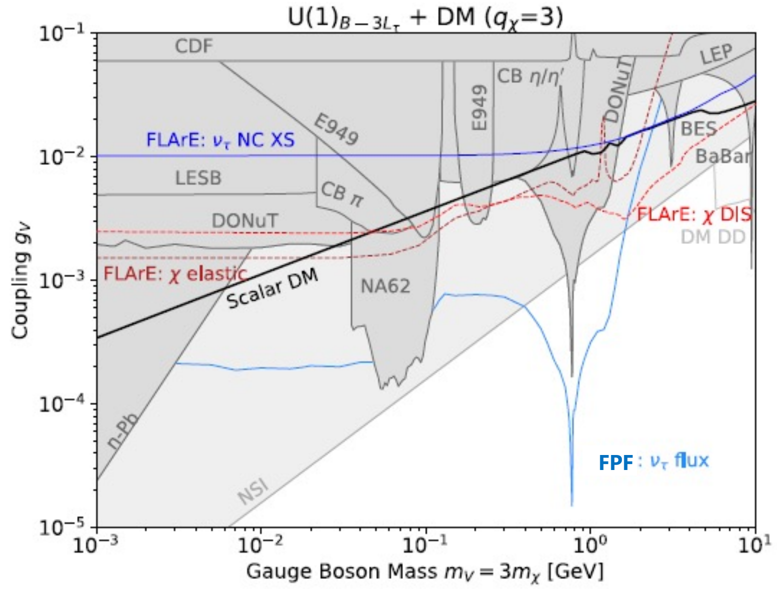
High-energy, high-precision experiments

Collider neutrinos

- High energy beam dump experiments
- Forward production
- Searches of neutrinophillic mediators and particles
- Weak EFT framework







Snowmass21, EPJC83(2023)15, Snowmass, JHEA36(2022)55, COST Action CA18108 PPNP125(2022)103948
IceCube, Nature Phys. 18, 1287 (2022), Stecker,Scully,Liberati,Mattingly,PRD91(2015)045009, Amelino-Camelia, ,Di Luca, Gubitosi, Rosati, D'Amico, Nature Astronomy (2023)

High-energy, long propagating neutrinos

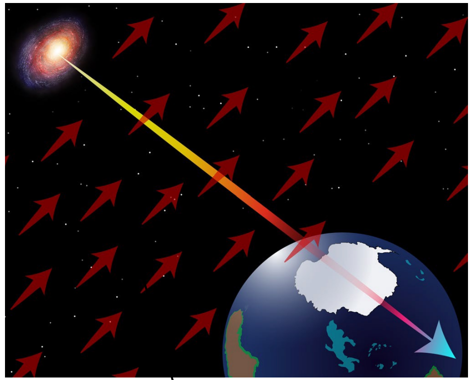
Violation of Lorentz invariance

- Neutrino interacting with vector fields in vacuum
- Matter potential in vacuum, but very small
  $New\ physics < M_{Planck}^{-1}(GeV^{-1}), M_{Planck}^{-2}(GeV^{-2})\cdots$
- Energy spectrum, arrival time, flavor are affected

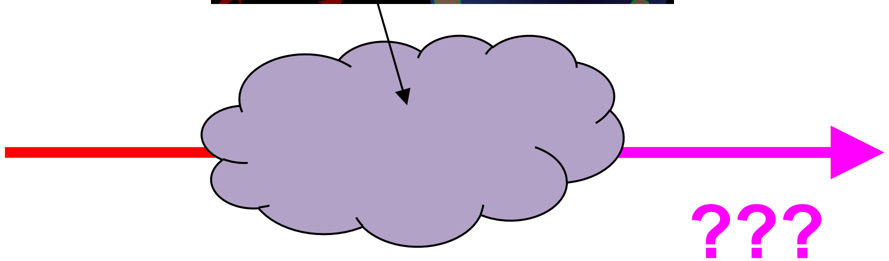
Motivation
- String theory
- Loop quantum gravity
- Horava-Lifshitz gravity
- Lee-Wick theory
- Non-commutative field theory
- Supersymmetry

etc

Lorentz violation



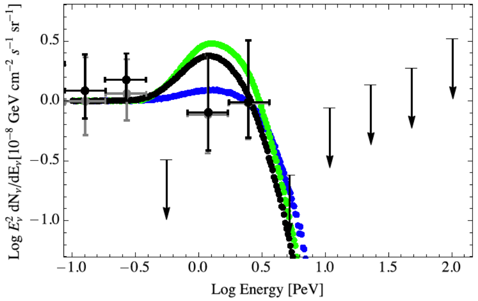
High-energy Astrophysical objects

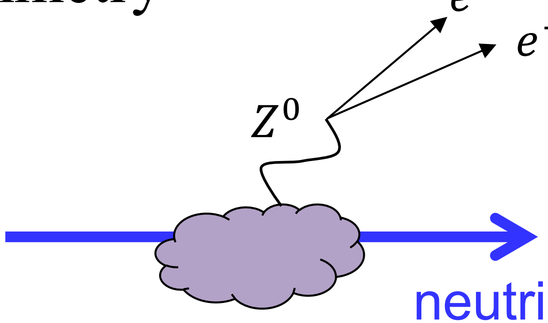


???

Neutrino detector

Flavour mixing



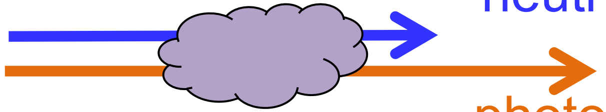


Z^0 e^- e^+

neutrino

Spectrum distortion

GRB



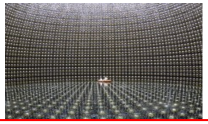
neutrino

photon

Time delay

Test of Lorentz violation with neutrinos

Spectral distortion

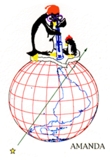


Super-Kamiokande

PRD91(2015)052003

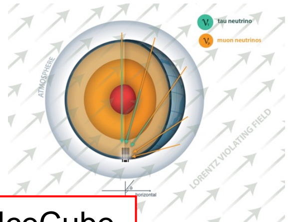
Daya Bay

PRD98(2018)092013



AMANDA

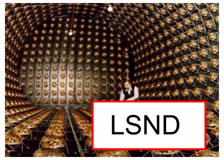
PRD79(2009)102005



IceCube

Nature Physics 14(2018)961

Sidereal variation



LSND

PRD72(2005)076004

MiniBooNE

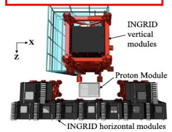
PLB718(2013)1303

MINOS ND

PRL101(2008)151601

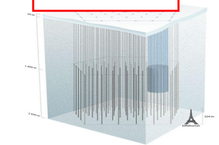
MINOS FD

PRL105(2010)151601



T2K ND

PRD95(2017)111101



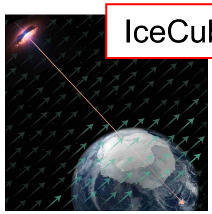
IceCube

PRD82(2010)112003

Double Chooz

PRD86(2013)112009

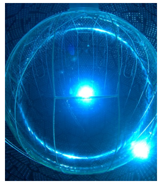
Flavor ratio



IceCube

Nature Physics 18(2022)1287

Seasonal variation



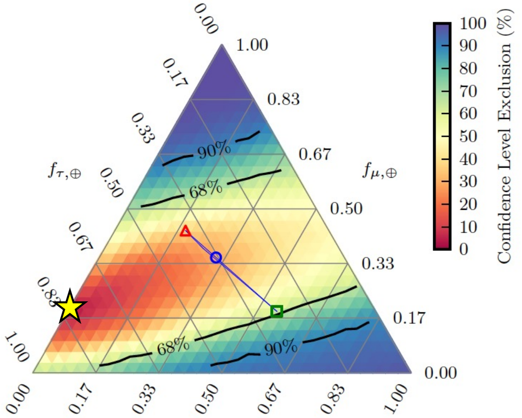
SNO

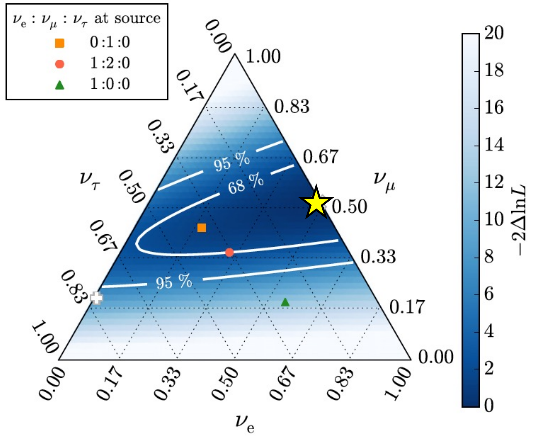
PRD98(2018)112013

IceCube, PRL114(2015)171102, Astro.J.809:98(2015), PRD99(2019)032004, PRD104(2021)022001

IceCube flavor ratio measurements

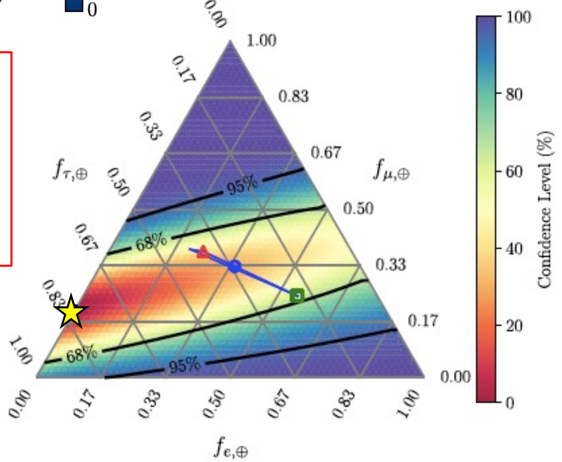
IceCube
1st flavour ratio result
(0.0:0.2:0.8)

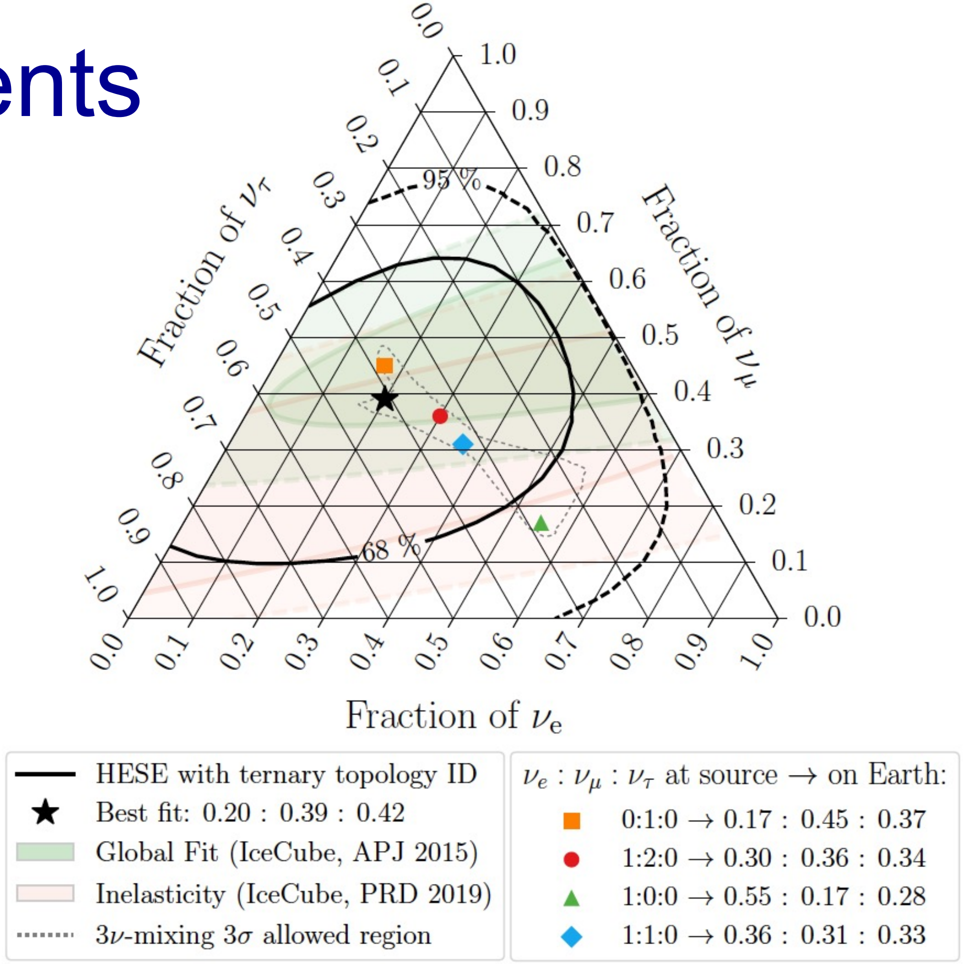




IceCube
2nd flavour ratio result
(0.5:0.5:0.0)

IceCube
3rd flavour ratio result
(0.0:0.2:0.8)





2018 flavour ratio measurement

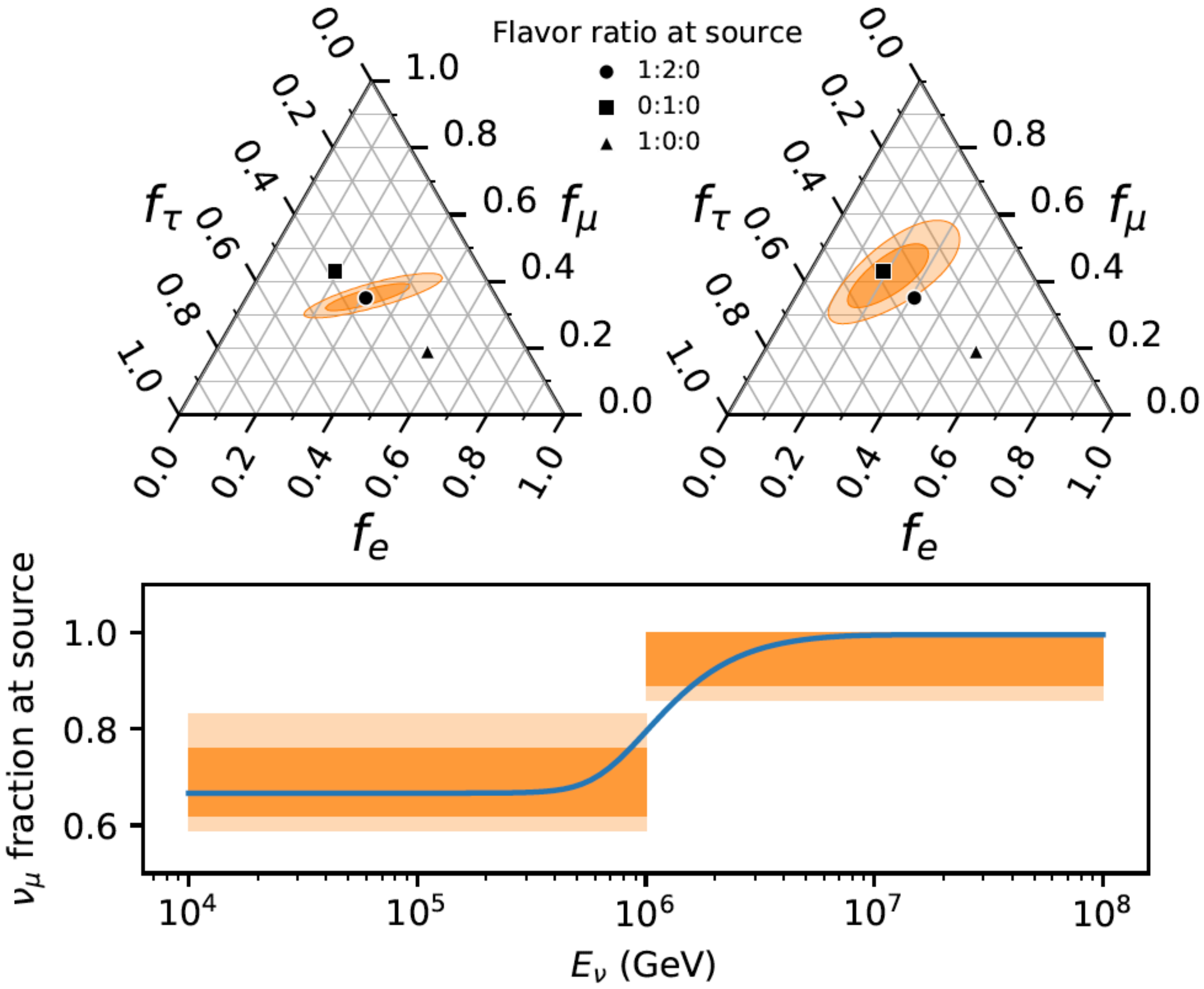
- Likelihood is very shallow and fit often confuses between ν_e and ν_τ
- Flavour ratio result has some power to distinguish ν_e and ν_τ

IceCube-Gen2, J.Phys.G48(2021)060501

Energy dependence of flavor ratio

Muon neutrino increases at higher energy

Future higher-statistics flavor measurement

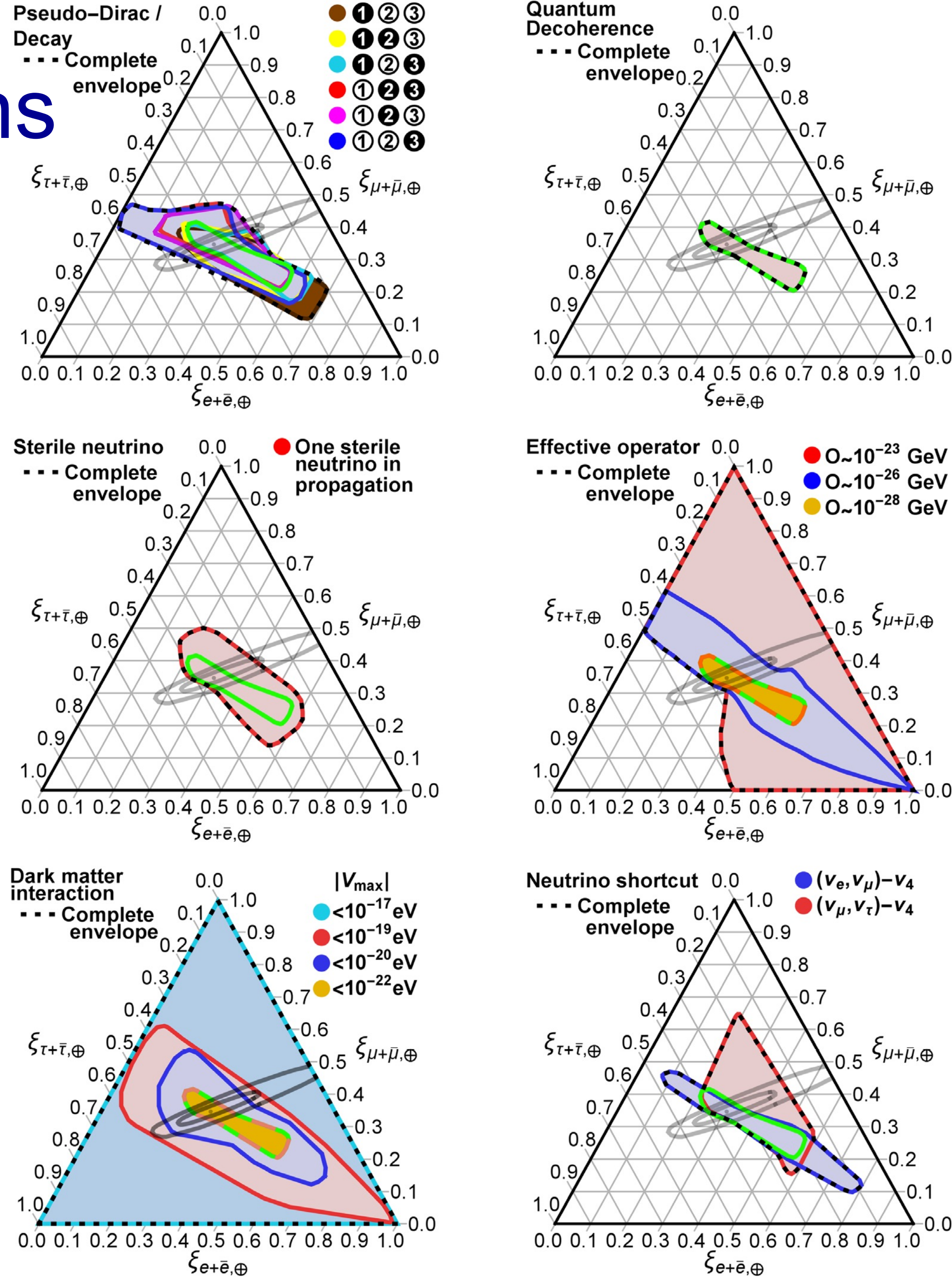


Rasmussen, Lechner, Ackermann, Kowalski, Winter, PRD96(2017)083018

New physics flavor ratio predictions

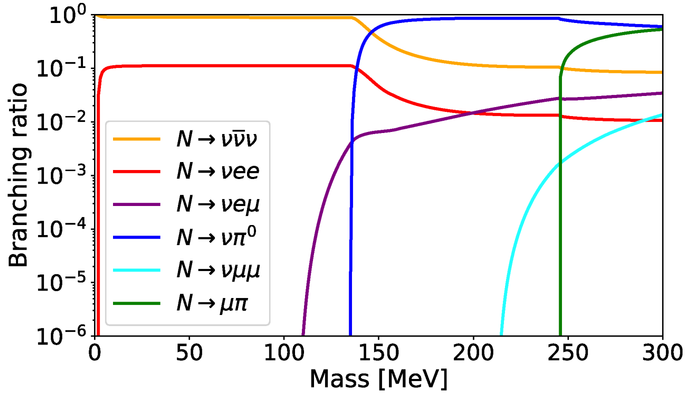
New physics models have different flavor ratios

Effective operator
- It includes Lorentz violation
- Assuming all possible standard production models, (ν_e:ν_μ:ν_τ) = (x:1-x:0), it covers 2/3 of the phase space.



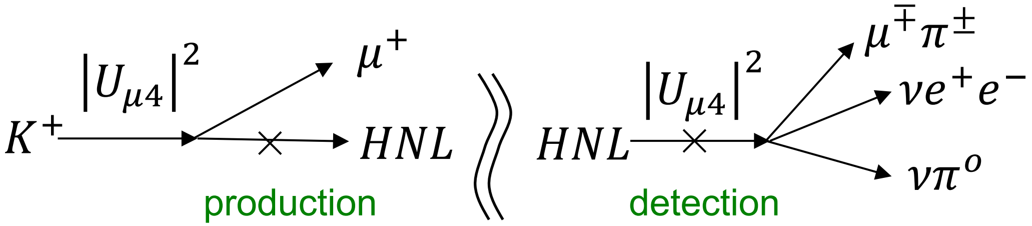
MicroBooNE, PRD106(2022)092006, PRL132(2024)041801, ArXiv:2312.13945, de Gouvêa, Fox, Harnik, Kelly, Zhang, JHEP01(2019)001, T2K, PRD100(2019)052006, Snowmass2021 J.Phys.G50(2023)020501, Batell, Berger, Ismail, PRD100(2019)115039

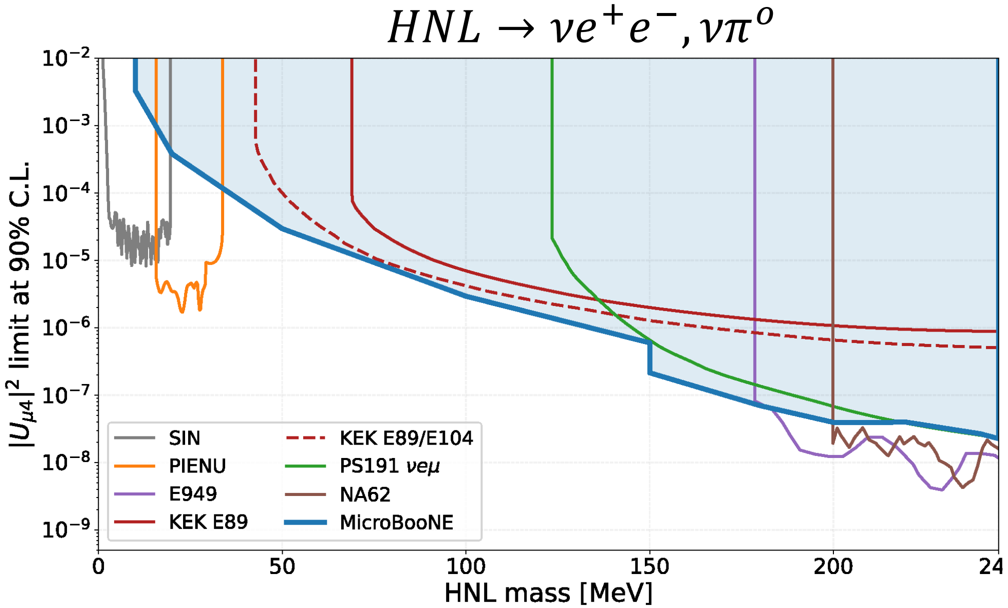
High-intensity, high-precision experiments

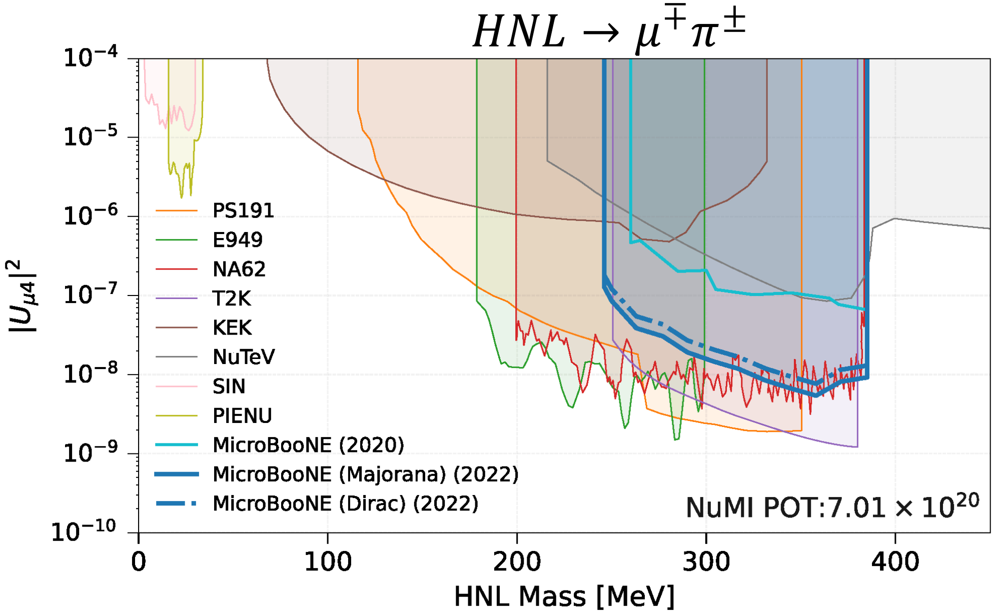


Heavy neutral leptons (HNLs)

- Produced at the NuMI beam dumps
- Delayed from neutrino spill
- Weaker limit for Dirac ($\mathrm{HNL} \to \mu^-\pi^+$ only)
- $m_\pi + m_\mu < m_{HNS} < m_K - m_\mu$





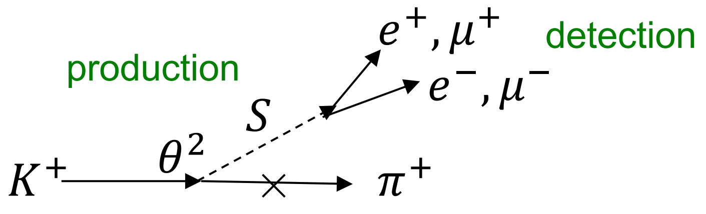


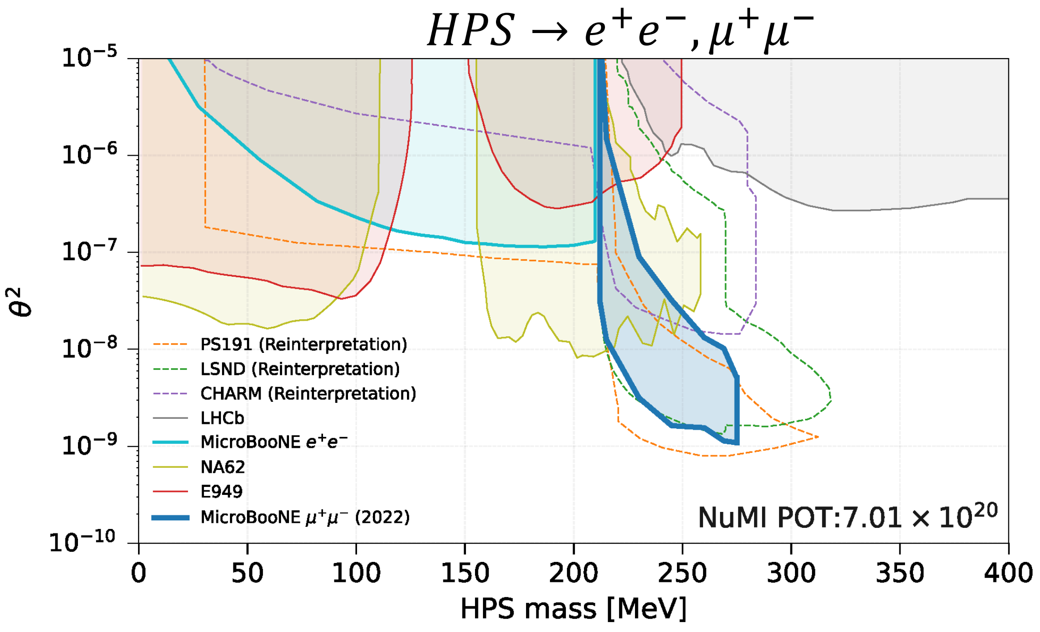
MicroBooNE, PRD106(2022)092006, PRL127(2021)151803, Bhanderi, PhD thesis (Manchester)
Batell, Berger, Ismail, PRD100(2019)115039

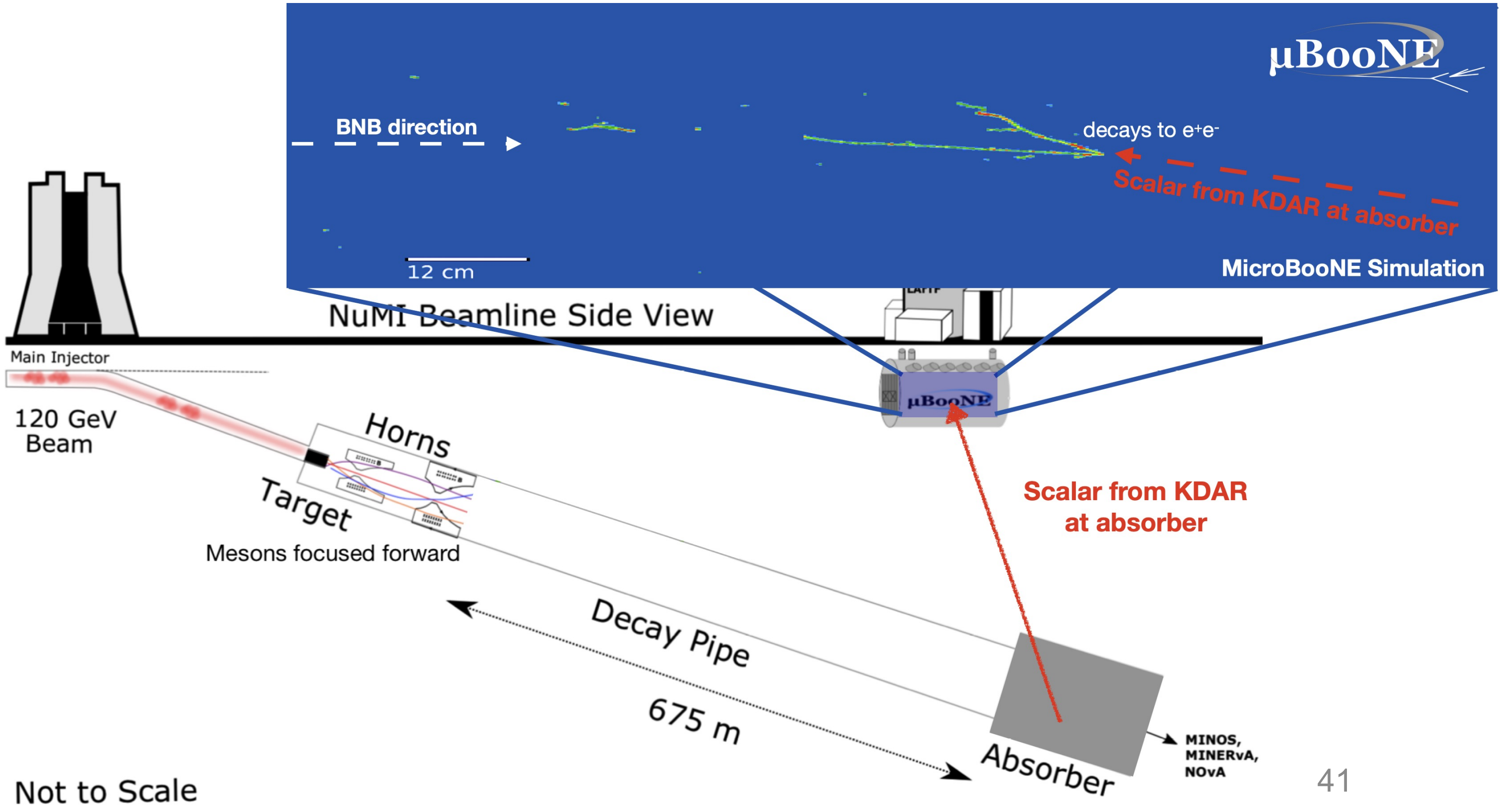
High-intensity, high-precision experiments

Higgs Portal Scalars (HPSs)

- Production at the NuMI beam dump
- Life time $\propto 1/\theta^2$
- $2m_\mu < m_{HPS} < 2m_{\pi^o}$





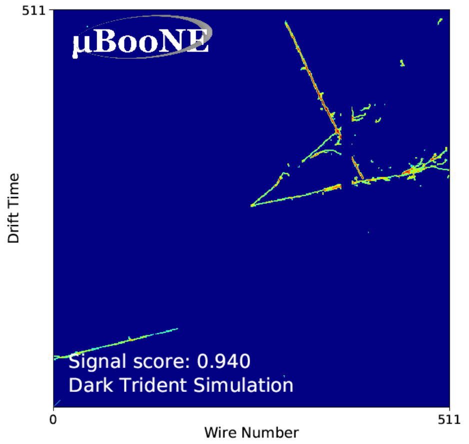


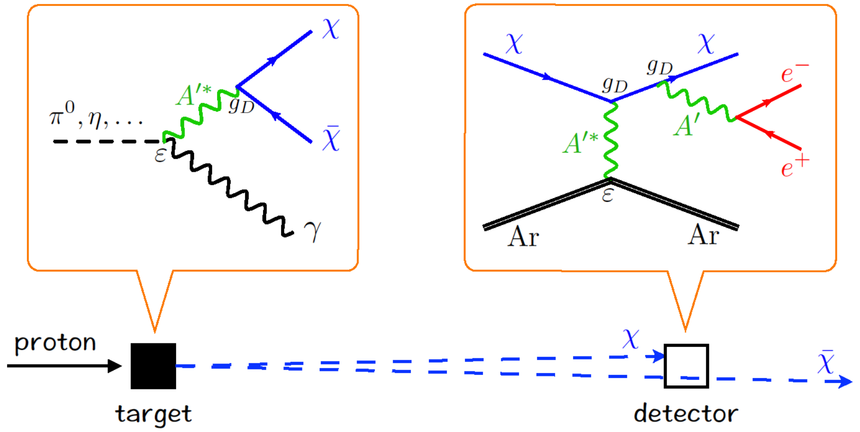
MicroBooNE, ArXiv:2312.13945, de Gouvêa, Fox, Harnik, Kelly, Zhang, JHEP01(2019)001

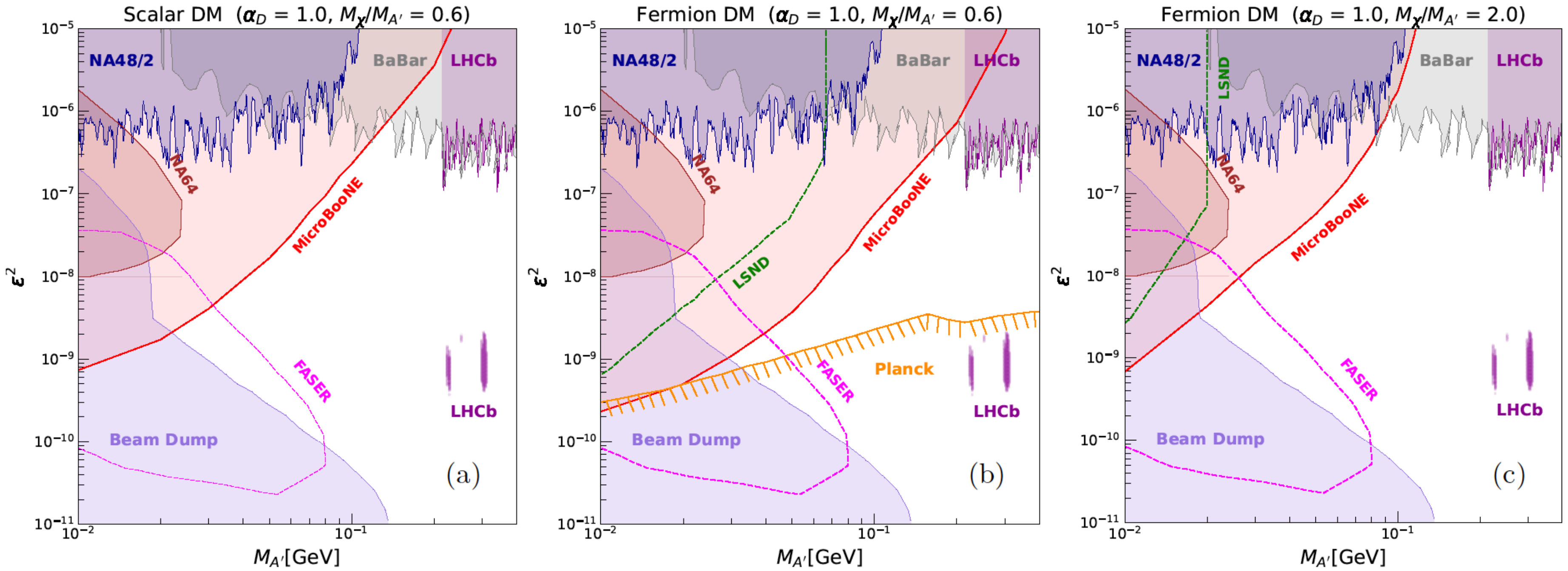
High-intensity, high-precision experiments

Dark trident

- Dark matter pairs produced at the NuMI beam dump
- Dark matter particle scatter off a dark photon, then it decays (dark trident event)





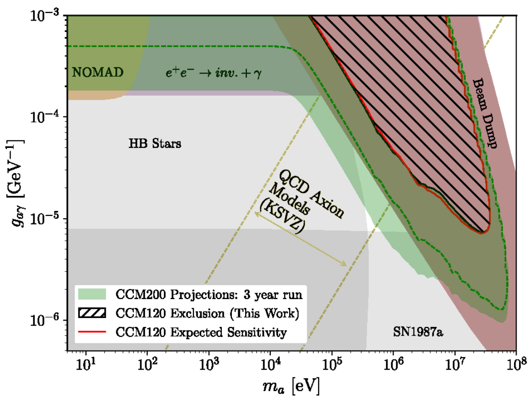


CCM, PRL129(2022)021801, PRD106(2022)012001:107(2023)095036:109(2024)095017

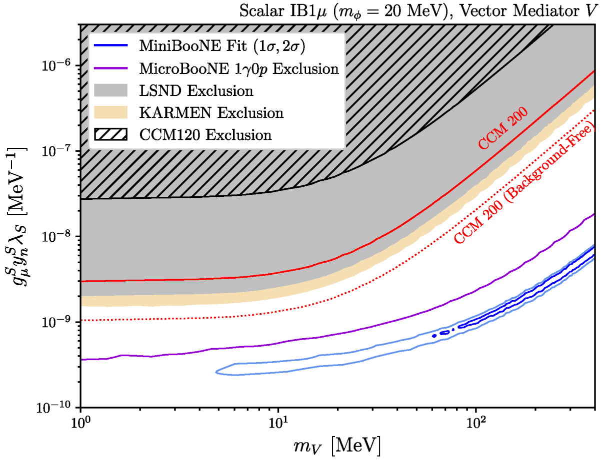
High-intensity, high-precision experiments

CCM (Coherent Captain Mills)

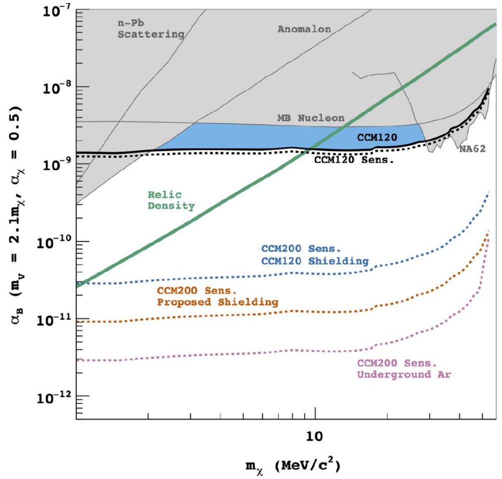
Axion-like particle search



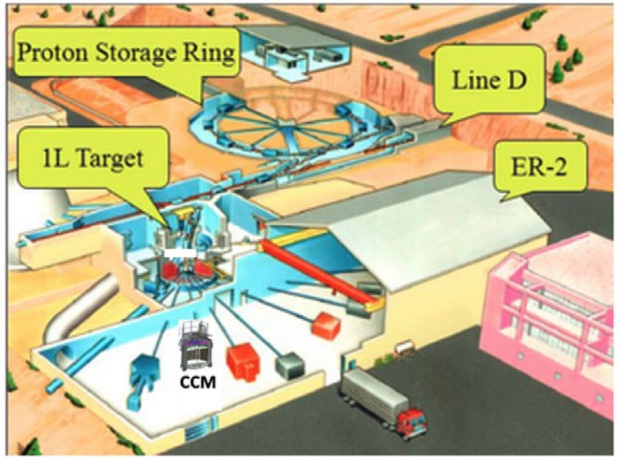
Scalar dark matter search

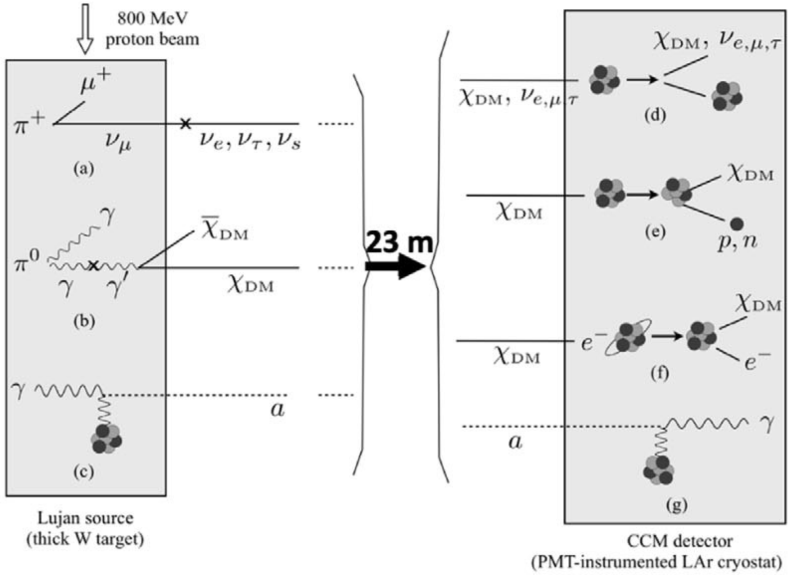


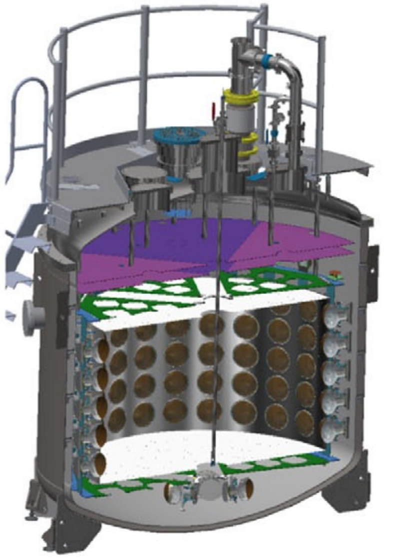
Leptophobic dark matter search



800 MeV protons, 100kW, 290 nsec pulsed beam



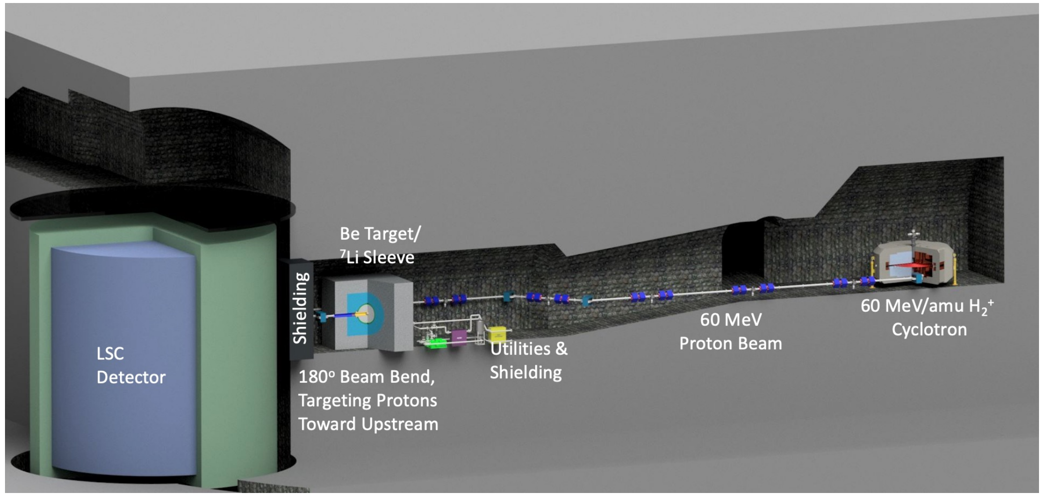




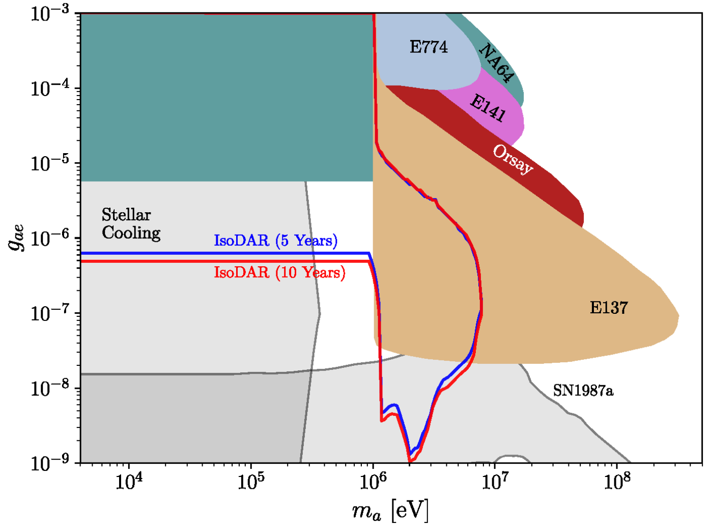
Waites et al., PRD107(2023) 095010, Hostert, McKeen, Pospelov, Raj, PRD107(2023)075034

High-intensity, high-precision experiments

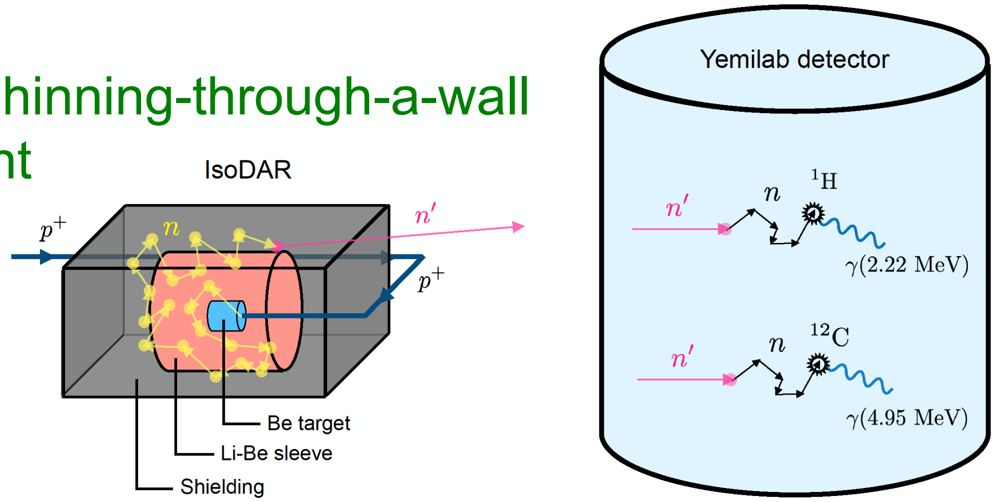
IsoDAR

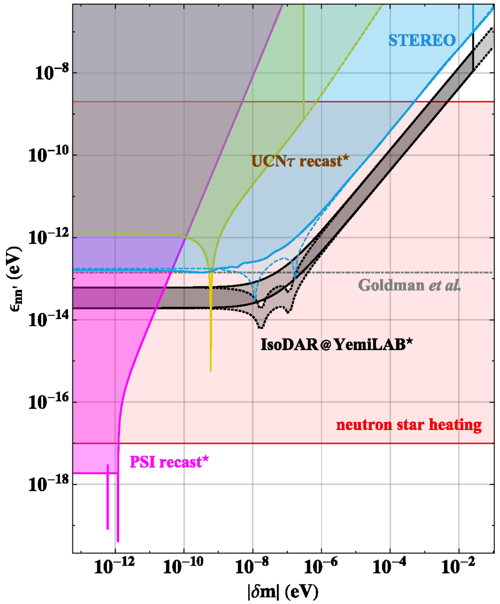


IsoDAR axion-like particle sensibility



Neutron-shinning-through-a-wall experiment

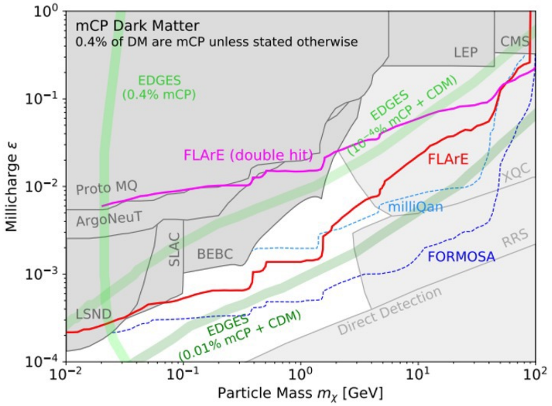




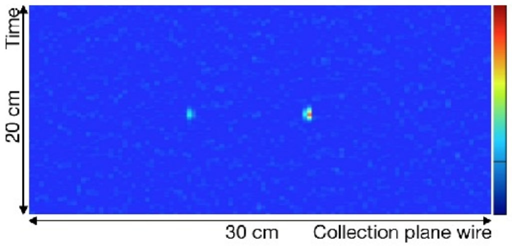
Magill, Plestid, Pospelov,Tsai, PRL122(2019)071801, ArgoNeuT, PRL124(2020)131801
Gan,Tsai, ArXiv:2308.07951, CONNIE and Atucha-II collaborations, arXiv:2405.16316

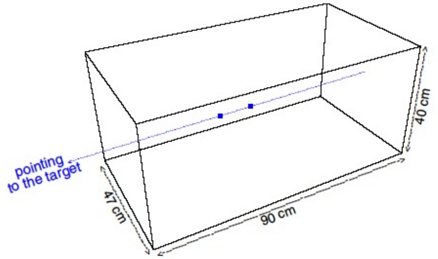
High-intensity, high-precision experiments

Millicharged particles (mCP)
- Theoretically motivated
- Important in cosmic evolution

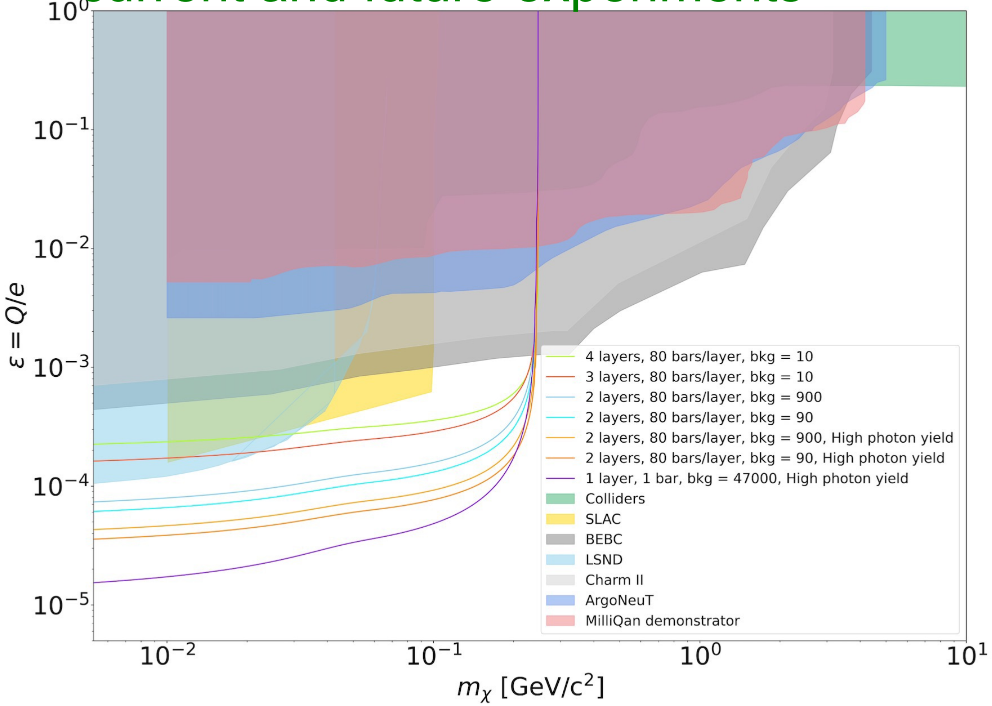


ArgoNeuT millicharged particle candidate event

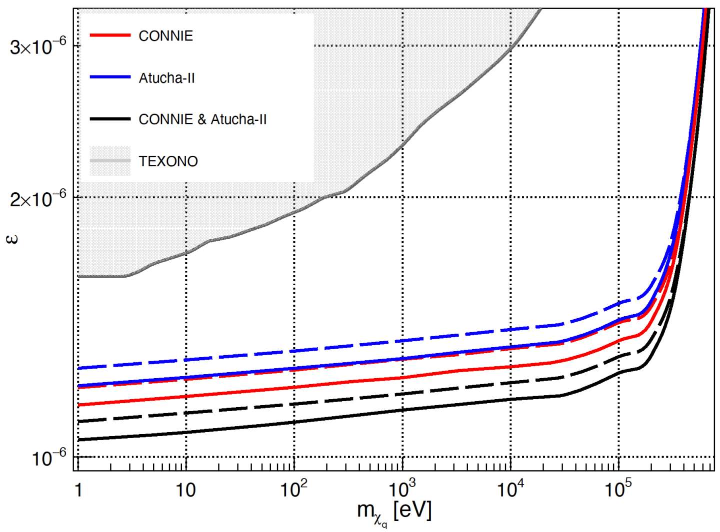




Millicharged particle searches by current and future experiments



CONNIE/Atucha-II mCP search



Nature Physics 11(2015)791

perspective

A century of physics

Roberta Sinatra, Pierre Deville, Michael Szell, Dashun Wang and Albert-László Barabási

An analysis of Web of Science data spanning more than 100 years reveals the rapid growth and increasing multidisciplinarity of physics — as well its internal map of subdisciplines.

"Nuclear and particle physics are not only the most self-referential subfields, but are also separated by significant citation barriers from most other subfields. This isolation brings significant impact penalties: papers in those areas burn out very fast and have much lower ultimate impact than other subdisciplines"