

Valentina De Romeri
(IFIC Valencia - UV/CSIC)

CEvNS: combining results from different sources

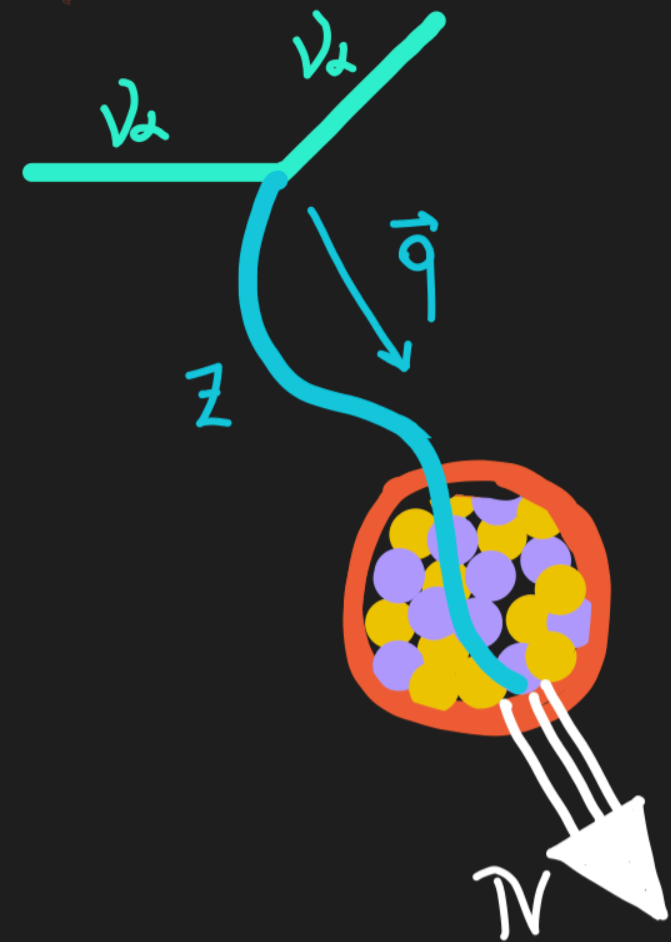
Rencontres de Noirmoutier 2026
island of Noirmoutier (France)
5 June 2026



COHERENT ELASTIC NEUTRINO-NUCLEUS SCATTERING (CEvNS)

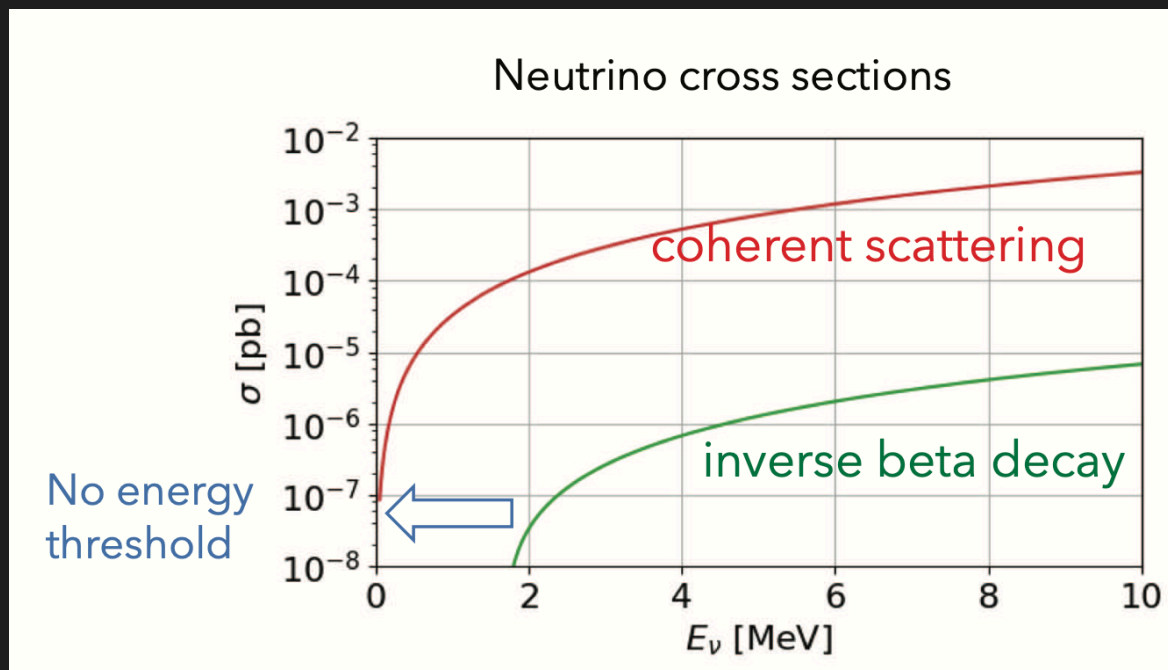
Neutral-current process: $\nu + N(A,Z) \rightarrow \nu + N(A,Z)$

- ▶ The neutrino sees the nucleus as a whole
- ▶ CEvNS occurs when:
 - Wavelength of the mediator $>$ nuclear radiusor
 - $|\vec{q}| \leq 1/R_{\text{nucleus}}$
- ▶ **Coherent**: target nucleon wave functions remain in phase with each other before and after the collision. **Amplitudes** of scattering on individual nucleons **add**.
- ▶ **Elastic**: no new particles are created and nuclear target remains in the same energy state.

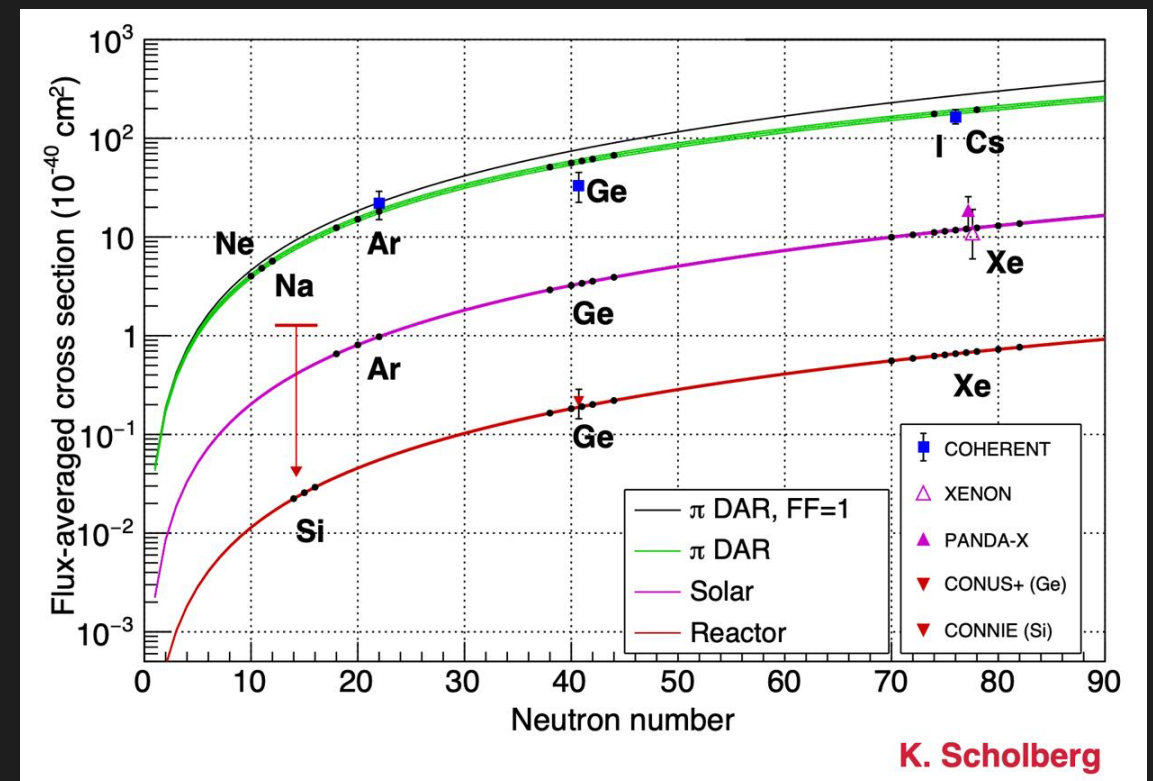


COHERENT ELASTIC NEUTRINO-NUCLEUS SCATTERING (CEvNS)

- ▶ Total cross section scales approximately like N^2 $\frac{d\sigma}{dE_R} \propto N^2$
- ▶ CEvNS cross section is large!
- ▶ Despite its large cross section, not observed for years due to tiny nuclear recoil energies.



Credit: R. Strauss @ Magnificent CEvNS



K. Scholberg

AN ACT OF HUBRIS

First theoretically predicted in 1974

D.Z. Freedman, Phys. Rev. D 9 (1974)

V.B. Kopeliovich and L.L. Frankfurt, JETP Lett. 19 4 236 (1974)

PHYSICAL REVIEW D

VOLUME 9, NUMBER 5

1 MARCH 1974

Coherent effects of a weak neutral current

Daniel Z. Freedman†

National Accelerator Laboratory, Batavia, Illinois 60510

and Institute for Theoretical Physics, State University of New York, Stony Brook, New York 11790

(Received 15 October 1973; revised manuscript received 19 November 1973)

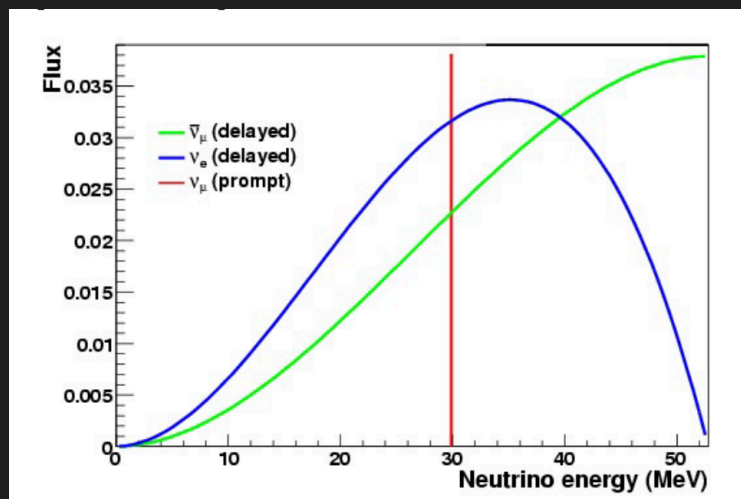
If there is a weak neutral current, then the elastic scattering process $\nu + A \rightarrow \nu + A$ should have a sharp coherent forward peak just as $e + A \rightarrow e + A$ does. Experiments to observe this peak can give important information on the isospin structure of the neutral current. The experiments are very difficult, although the estimated cross sections (about 10^{-38} cm² on carbon) are favorable. The coherent cross sections (in contrast to incoherent) are almost energy-independent. Therefore, energies as low as 100 MeV may be suitable. Quasi-coherent nuclear excitation processes $\nu + A \rightarrow \nu + A^*$ provide possible tests of the conservation of the weak neutral current. Because of strong coherent effects at very low energies, the nuclear elastic scattering process may be important in inhibiting cooling by neutrino emission in stellar collapse and neutron stars.

Our suggestion may be an act of hubris, because the inevitable constraints of interaction rate, resolution, and background pose grave experimental difficulties for elastic neutrino-nucleus scattering. We will discuss these problems at the end of this note, but first we wish to present the theoretical ideas relevant to the experiments.

Experimentally the most conspicuous and most difficult feature of our process is that the only detectable reaction product is a recoil nucleus of low momentum. Ideally the apparatus should have sufficient resolution to identify and determine the momentum of the recoil nucleus and sufficient mass to achieve a reasonable interaction rate. Neutron background is a serious problem

CE ν NS was **observed for the first time ~40 years later**,
in **2017** by the COHERENT experiment at the Oak Ridge Spallation Neutron Source.

LOW-ENERGY NEUTRINO SOURCES



D. Akimov et al. (COHERENT). 2110.07730

Stopped pions
(Decay at rest)

Reactors

Radioactive
source ^{51}Cr

ARTIFICIAL SOURCES

Beam induced
radioactive sources
(IsoDAR)

Next-generation
neutrino beams

Geoneutrinos

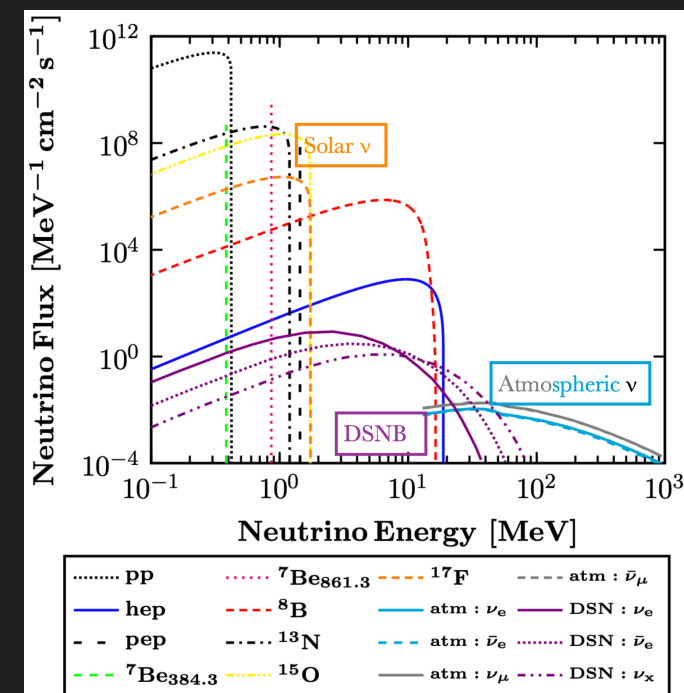
DSNB

Atmospheric
neutrinos

NATURAL SOURCES

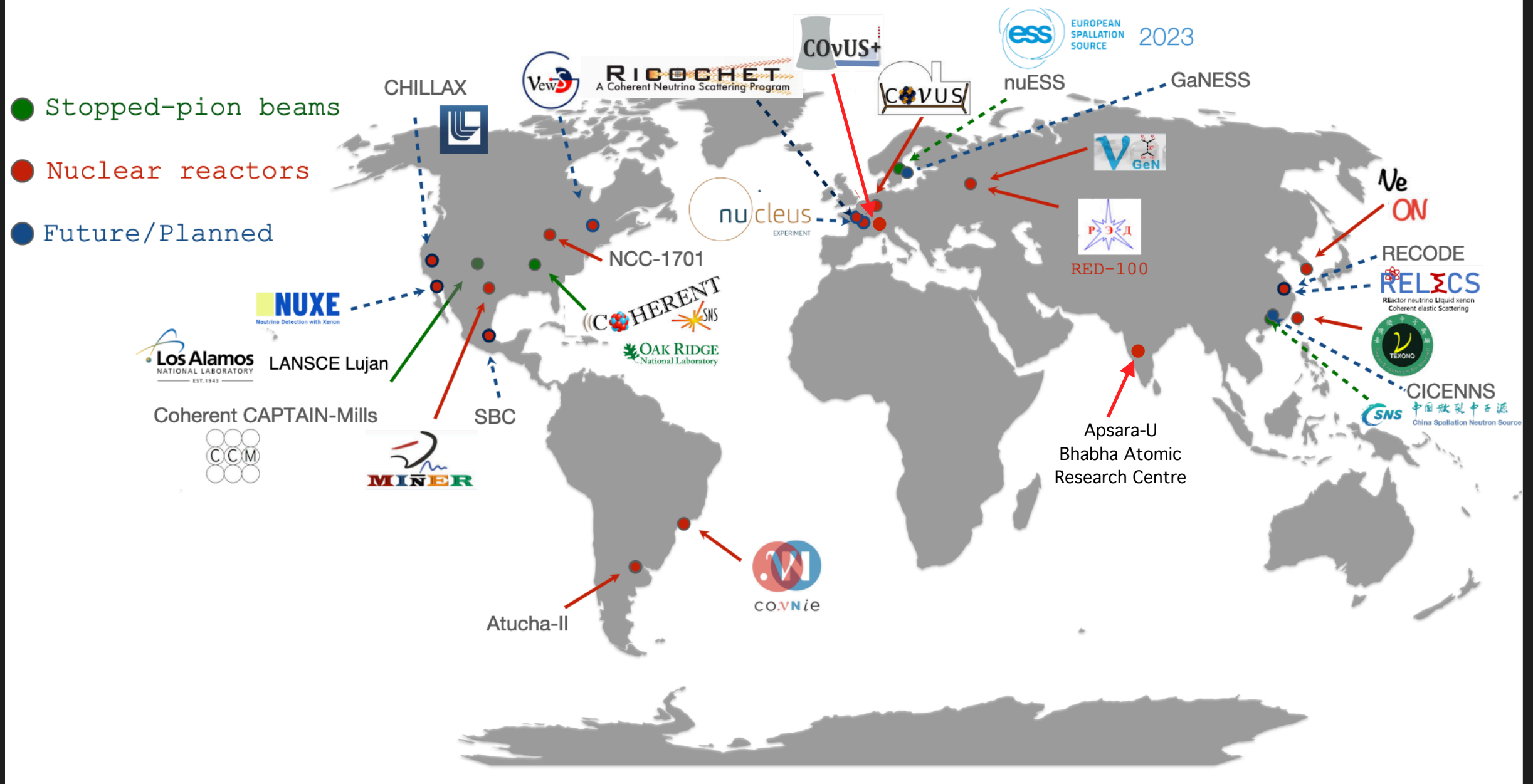
Supernova
bursts neutrinos

Solar neutrinos



Aristizabal, VDR, Flores, Papoulias JCAP 01 (2022) 01, 055

CEvNS EXPERIMENTS WORLDWIDE

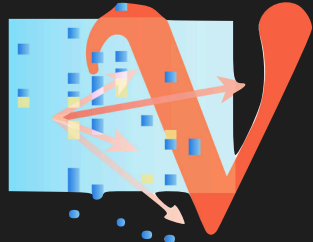


Updated from I. Nasteva @NEUTRINO 2024

+ DM direct detection experiments

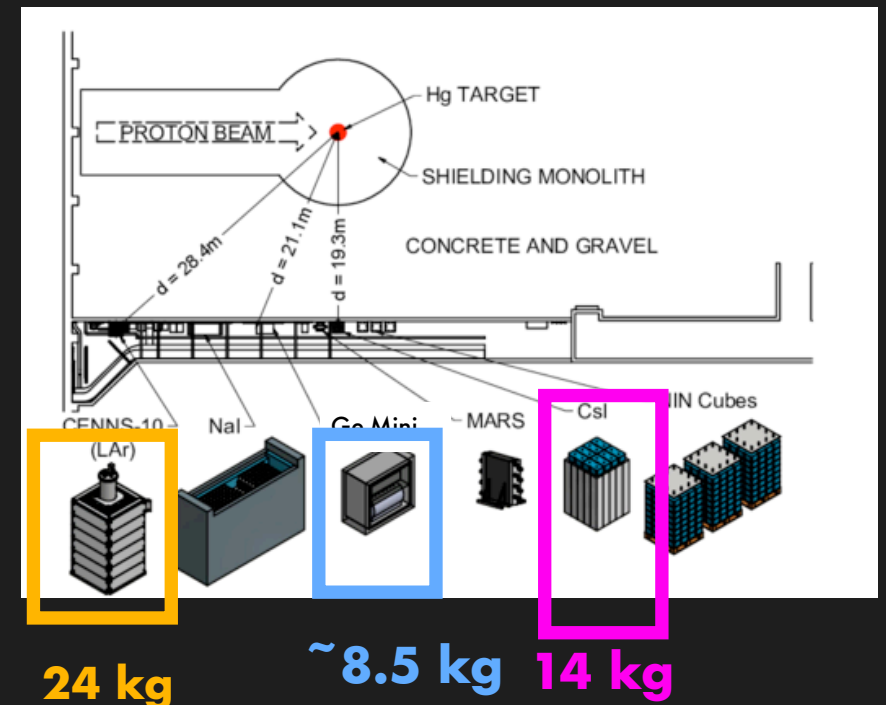
LIST OF CEvNS OBSERVATIONS

Stopped pions
(Decay at rest)



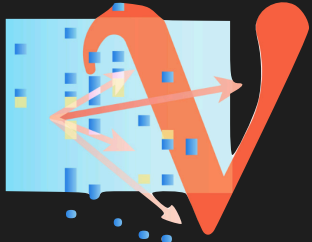
- ▶ 2017(->2021): COHERENT-CsI[Na], 11.6σ CL
- ▶ 2020: COHERENT-LAr, 3.9σ CL
- ▶ 2024 (-> 2026): COHERENT-Ge, $\sim 7\sigma$ CL

D. Akimov et al. (COHERENT) Science 357, 1123–1126 (2017)
 D. Akimov et al. (COHERENT) Phys. Rev. Lett. 129, 081801
 D. Akimov et al. (COHERENT) Phys. Rev. Lett. 126, 012002 (2021)
 S. Adamski et al. (COHERENT) Phys. Rev. Lett. **134**, 231801 (2025)
 Adhikari et al. (COHERENT) 2603.17951



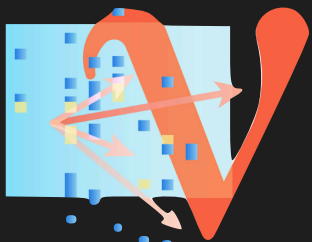
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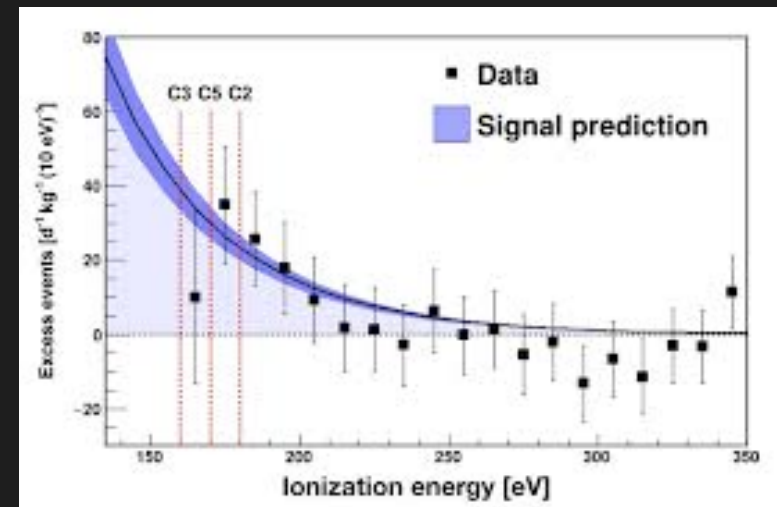


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Reactors

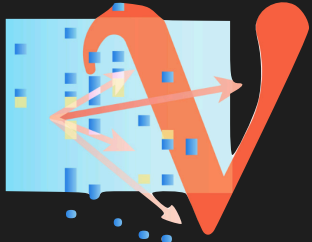


- 2022: Dresden-II, Ge
 Colaresi, Collar et al. Phys. Rev. Lett. 129 (2022) 211802
- 2025: CONUS+, Ge, 3.7σ CL
 Ackermann+ Nature 643 no. 8074, (2025) 1229–1233



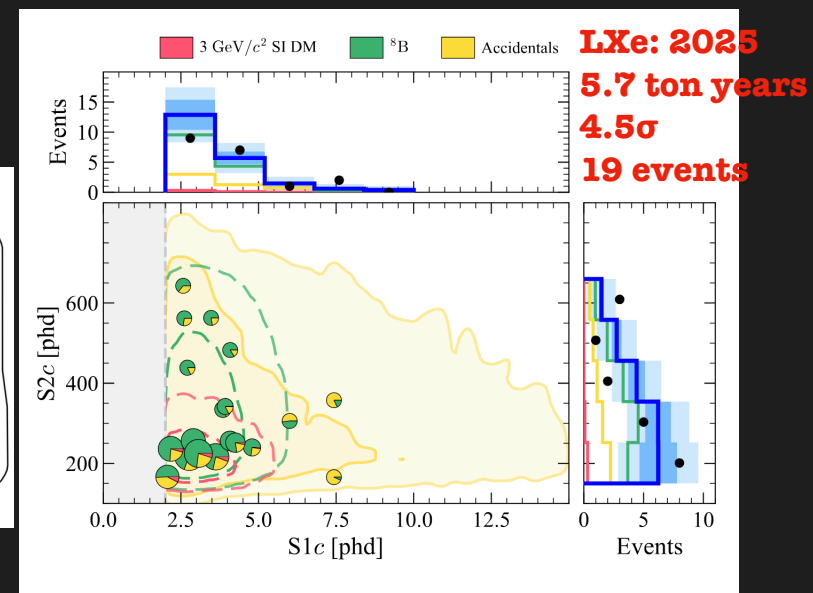
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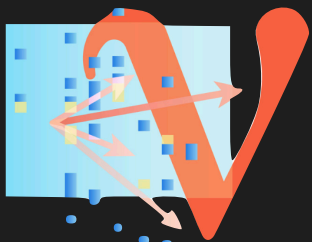


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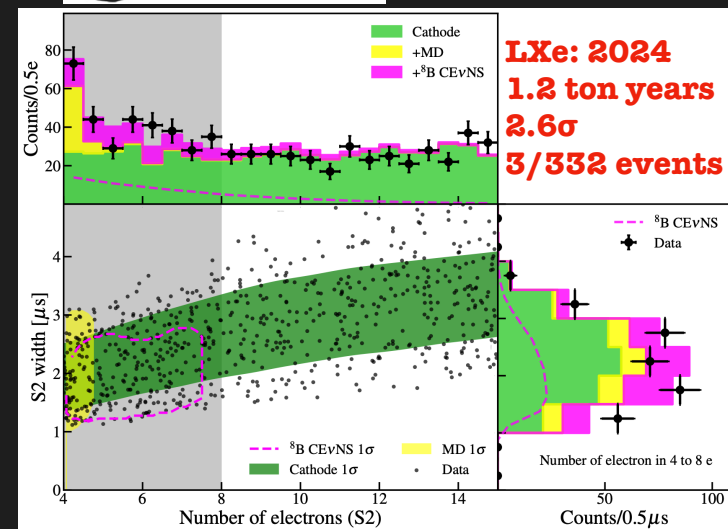


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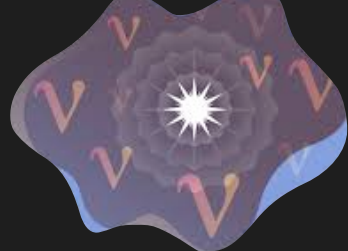
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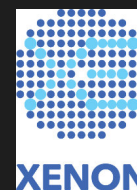


^8B Solar
neutrinos

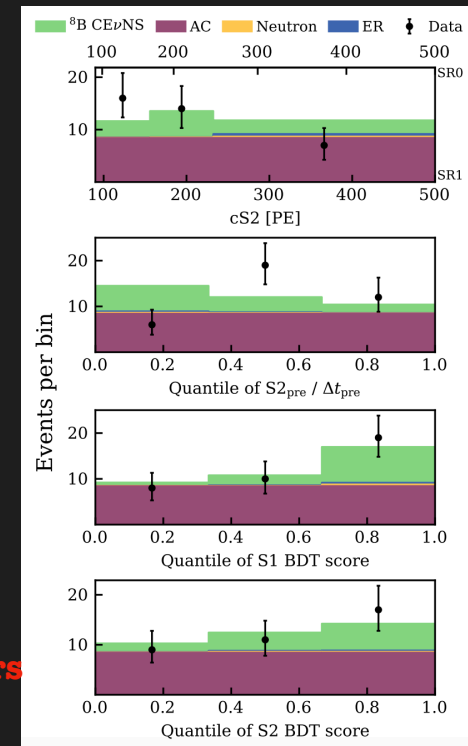


- 2024: XENONnT-Xe, 2.73σ CL
- 2024: PandaX-4T-Xe, 2.64σ CL
- 2025: LZ-Xe, 4.5σ CL

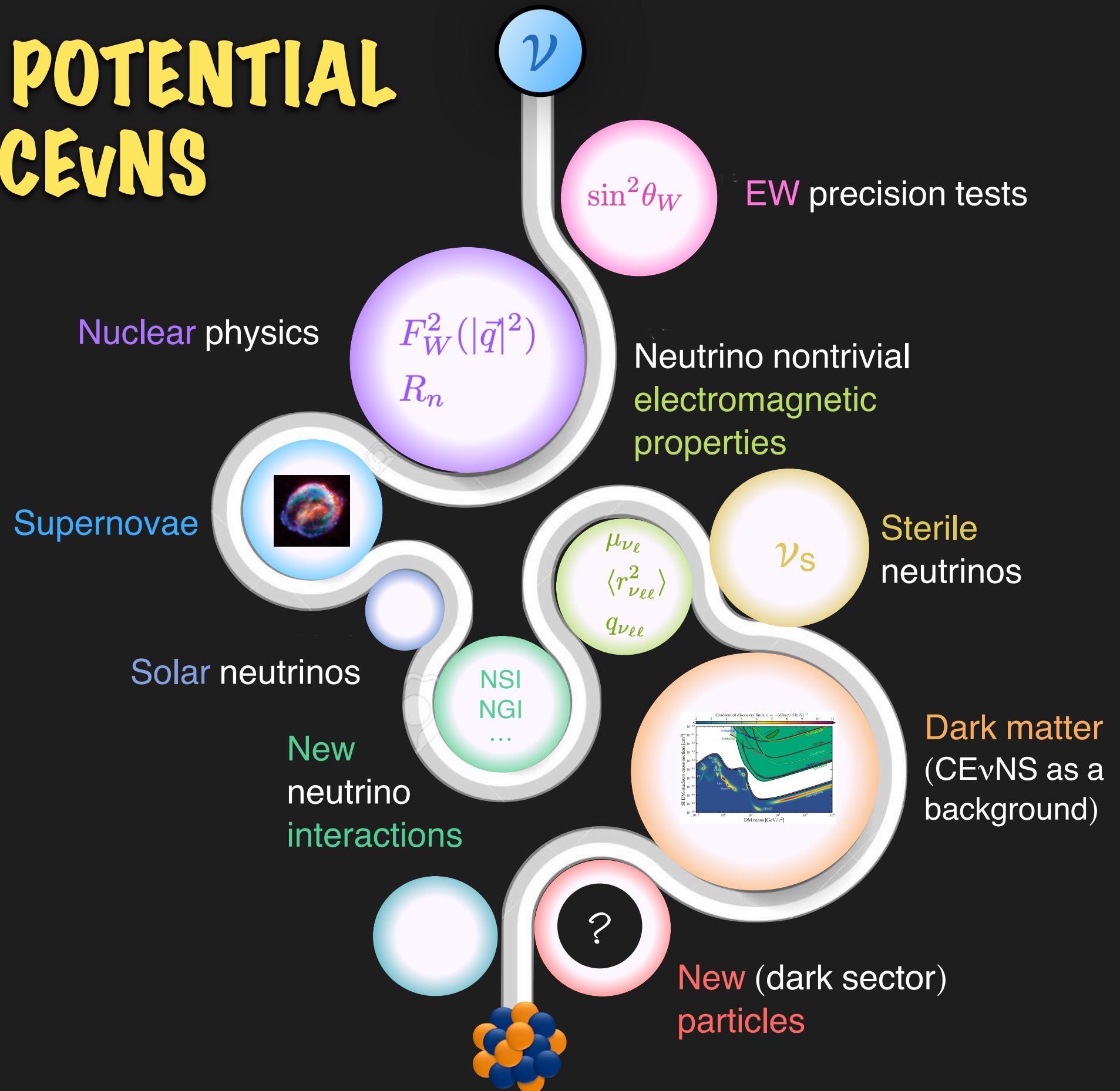
E. Aprile et al. (XENONnT) PRL 133, 191002 (2024)
 Z. Bo et al. (PandaX) PRL 133, 191001
 Akerib et al. LUX-ZEPLIN (LZ), arXiv:2512.08065



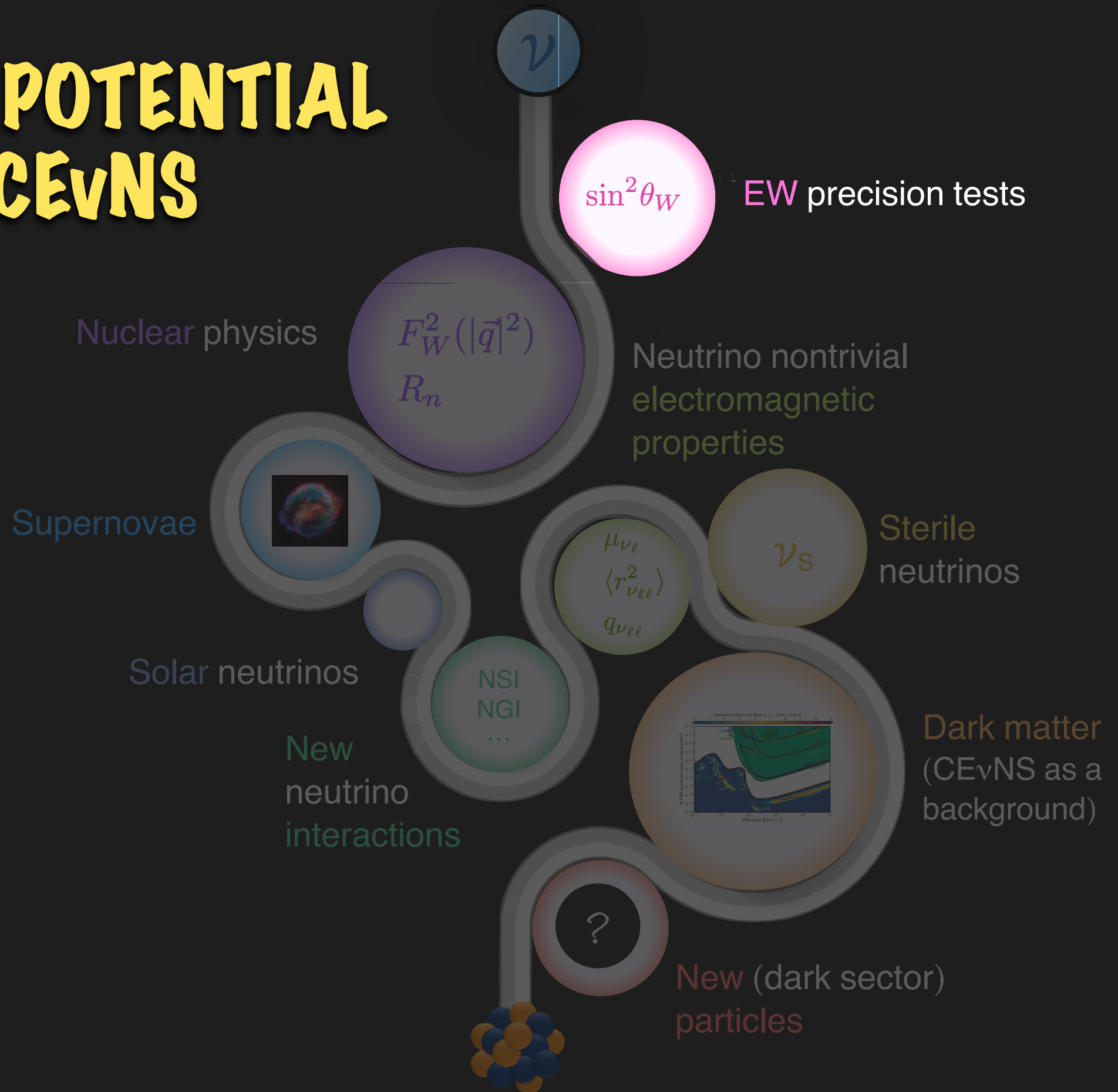
LXe: 2024
3.5 ton years
2.7 σ
37 events



PHYSICS POTENTIAL OF CEvNS



PHYSICS POTENTIAL OF CEvNS



CEvNS CROSS SECTION IN THE SM

CEvNS cross-section in the SM:
(probability of kicking a nucleus with nuclear recoil energy T_N)

Freedman, PRD 9 (1974) 1389; Drukier, Stodolsky, PRD 30 (1984) 2295; Barranco, Miranda, Rashba, hep-ph/0508299

$$\frac{d\sigma}{dT_N} = \frac{G_F^2 m_N}{4\pi} \left(1 - \frac{m_N T_N}{2E_\nu^2} - \frac{T_N}{E_\nu} \right) Q_W^2 F_W^2(|\mathbf{q}|^2) + \frac{G_F^2 m_N}{4\pi} \left(1 + \frac{m_N T_N}{2E_\nu^2} - \frac{T_N}{E_\nu} \right) F_A^2(|\mathbf{q}|^2)$$

CEvNS CROSS SECTION IN THE SM

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(probability of kicking a nucleus with nuclear recoil energy T_N)

$$\frac{d\sigma}{dT_N} = \frac{\overbrace{G_F^2}^{\text{Fermi constant (SM parameter)}} m_N}{4\pi} \left(\underbrace{1 - \frac{m_N T_N}{2E_\nu^2} - \frac{T_N}{E_\nu}}_{\text{Kinematics}} \right) \underbrace{Q_W^2}_{\text{Weak nuclear charge}} \underbrace{F_W^2(|\mathbf{q}|^2)}_{\text{Nuclear Form Factor: } F=1 \text{ full coherence}} + \frac{G_F^2 m_N}{4\pi} \left(1 + \frac{m_N T_N}{2E_\nu^2} - \frac{T_N}{E_\nu} \right) F_A(|\mathbf{q}|^2)$$

$$Q_W = [Z(1 - 4 \sin^2 \theta_W) - \overbrace{N}] \quad \text{sw}^2 = 0.23 \rightarrow \text{protons unimportant}$$

Neutron contribution dominates

- E_ν : is the incident neutrino energy
- M : the nuclear mass of the detector material
- 3-momentum transfer $|\vec{q}|^2 = 2MT$
- (Q_A included in F_A)

STANDARD MODEL PHYSICS

$$\left. \frac{d\sigma_{\nu\mathcal{N}}}{dE_{\text{nr}}} \right|_{\text{CE}\nu\text{NS}}^{\text{SM}} = \frac{G_F^2 m_N}{\pi} F_W^2(\mathbf{q}^2) Q_W^2 \left(1 - \frac{m_N E_{\text{nr}}}{2E_\nu^2} - \frac{E_{\text{nr}}}{E_\nu} + \frac{E_{\text{nr}}^2}{2E_\nu^2} \right)$$

$$Q_W = -N/2 + (1/2 - 2\sin^2\theta_w)Z \quad \text{sw}^2 = 0.23 \rightarrow \text{protons unimportant}$$

Neutron contribution dominates

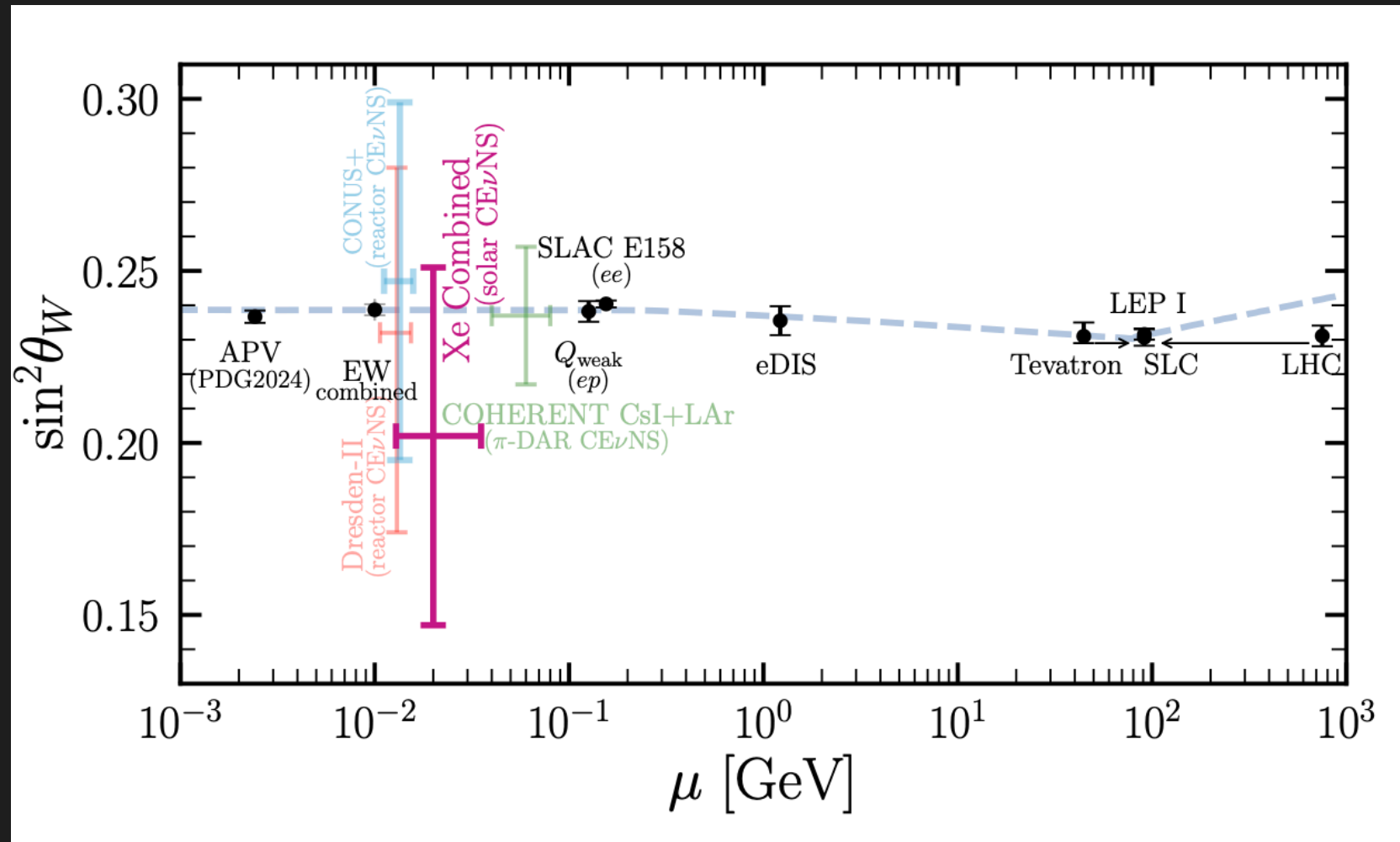
Information on the value of the neutrino neutral-current interaction at low energy:

- Observable: $\sin^2\theta_w$
- poorly measured at low energies
- Affects the normalization of CEvNS spectra



EW PRECISION TESTS: WEAK MIXING ANGLE

PandaX-4T (2024) + XENONnT (2024) + LZ (2025)

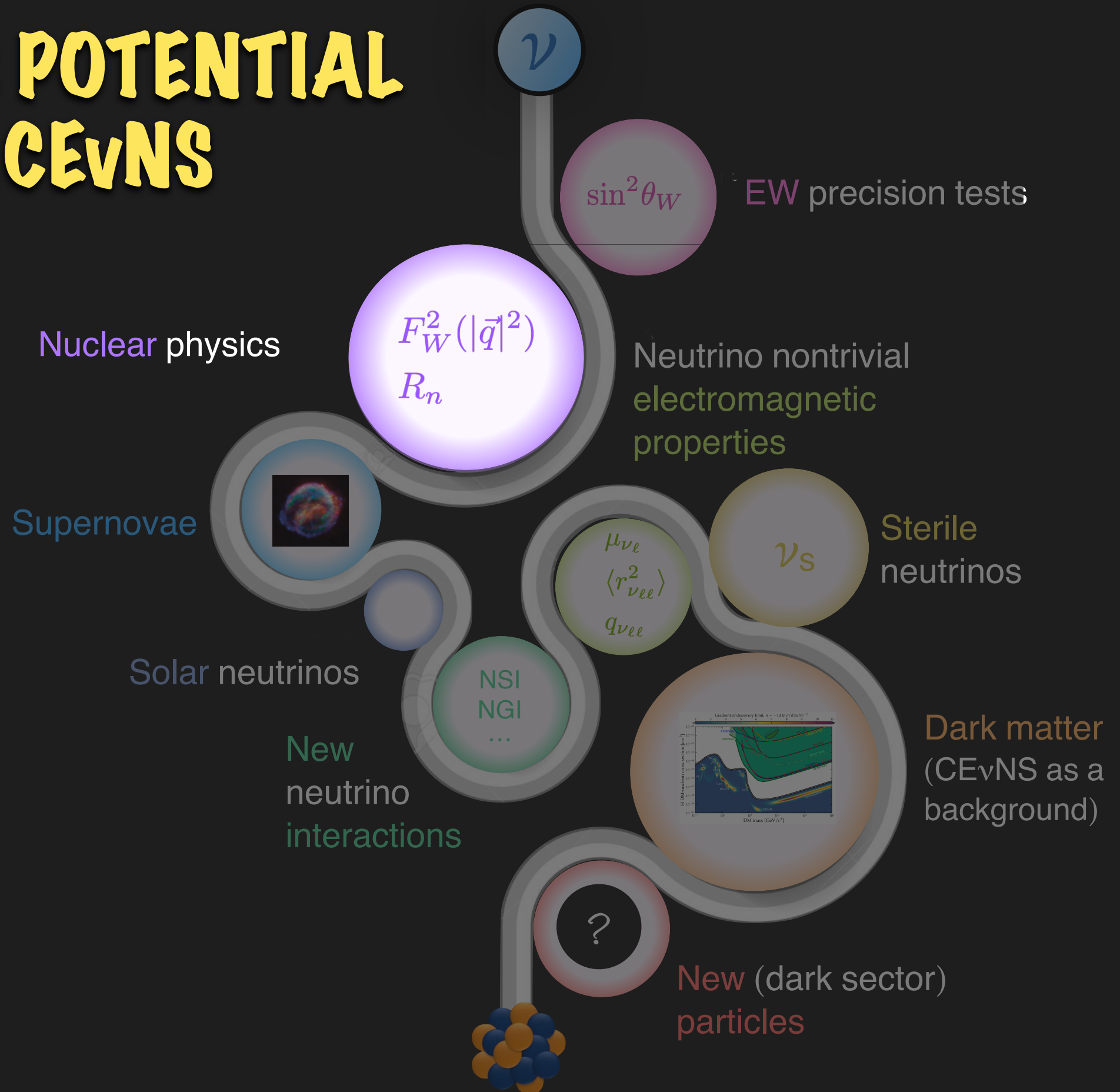


VDR, Papoulias, Pompa, Sanchez Garcia, Ternes, arXiv: 2603.00554

Other (previous) CEvNS analyses:
Miranda et al. JHEP 05 (2020) 130
VDR, Miranda, Papoulias+ JHEP 04 (2023) 035
See also Cadeddu et al. '20,'21,'22,'23,'24...
(Also combination with APV data)

VDR, Papoulias, Sanchez Garcia PRD 111, 075025 (2025)
Alpizar-Vanegas+ 2501.10355, Chattaraj+ 2501.12441
Majumdar+ Phys.Rev.D 106 (2022) 9, 093010
Boehm, Maity PRD 112 no. 5, (2025) 053001
VDR, Papoulias, Ternes JCAP 05 (2025) 012
Akerib et al. LUX-ZEPLIN (LZ), arXiv:2512.08065

PHYSICS POTENTIAL OF CEvNS



NUCLEAR PHYSICS

$$\left. \frac{d\sigma_{\nu\mathcal{N}}}{dE_{\text{nr}}} \right|_{\text{CE}\nu\text{NS}}^{\text{SM}} = \frac{G_F^2 m_N}{\pi} F_W^2(\mathbf{q}^2) Q_W^2 \left(1 - \frac{m_N E_{\text{nr}}}{2E_\nu^2} - \frac{E_{\text{nr}}}{E_\nu} + \frac{E_{\text{nr}}^2}{2E_\nu^2} \right)$$

Nuclear form factor $F_W^2(|\vec{q}|^2) = \int e^{-i\vec{q}\cdot\vec{r}} \rho(r) d^3r$

$\rho(r)$ is the charge density distribution

is the Fourier transform of the neutron distribution in the nucleus

- Observable: **nuclear rms radius**
- Largest theoretical uncertainty
- Affects the shape of CEvNS spectra

Partial coherency gives information on the nuclear neutron form factor.

NEUTRON DENSITY DISTRIBUTION

The CEvNS process can be used to provide a model-independent measurement of the root-mean-square (rms) neutron distribution radius, R_n .

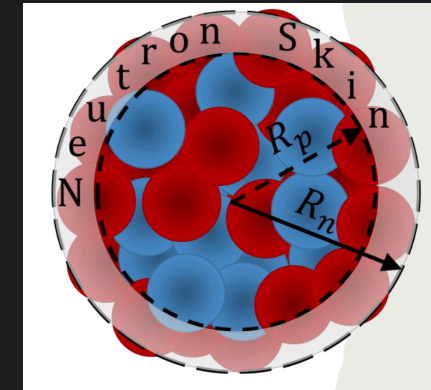
Proton rms radii are fixed

$$R_p(\text{I}) = 4.766 \text{ fm}$$

$$R_p(\text{Cs}) = 4.824 \text{ fm}$$

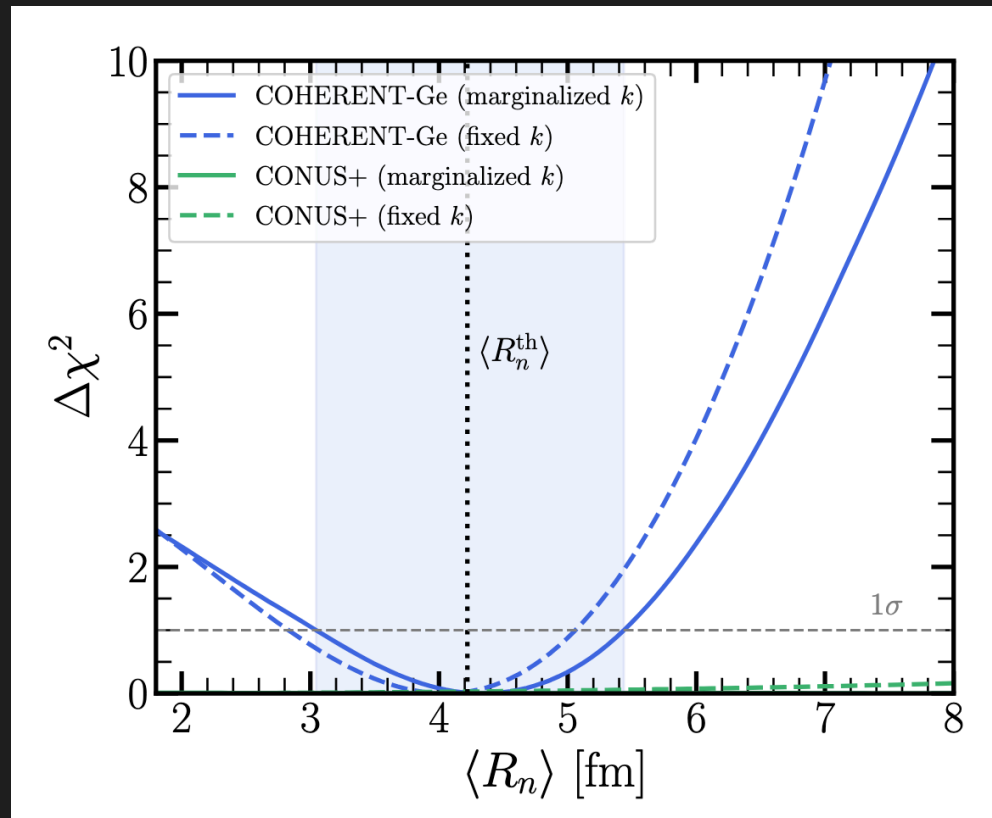
$$R_p(\text{Ar}) = 3.448 \text{ fm}$$

$$R_p(\text{Ge}) = 4.078 \text{ fm}$$



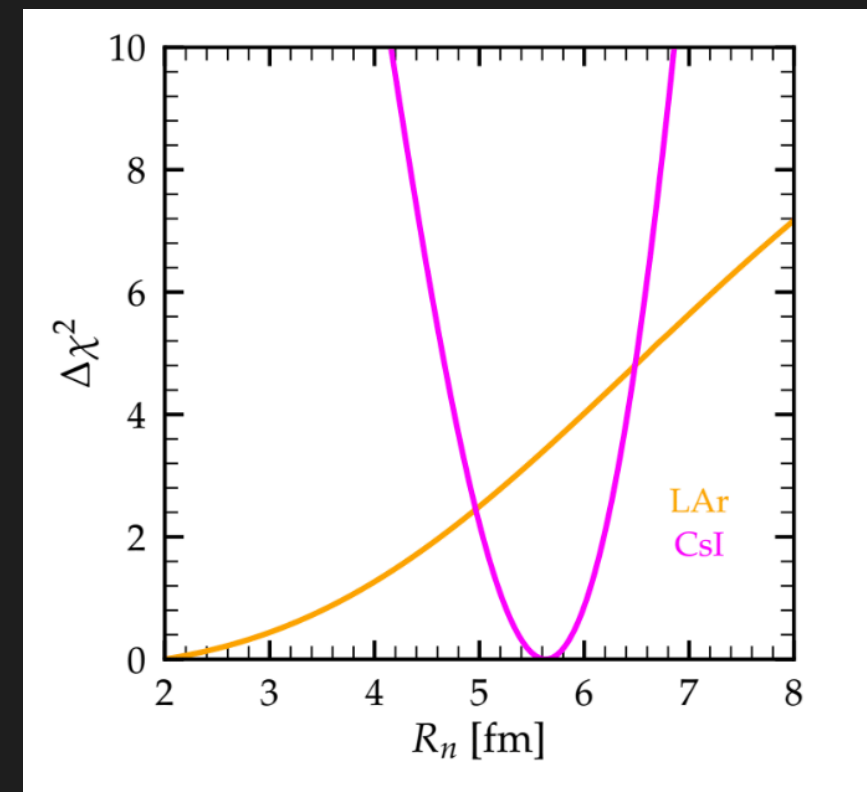
Credit: M. Cadeddu

COHERENT Ge (2026) + CONUS+ (2025)



VDR, Duque, Papoulias, Sanchez-García, Ternes 2605.27121

COHERENT CsI (2021) + LAr



VDR, Miranda, Papoulias, Sanchez-García, Tórtola and Valle, JHEP 04 (2023) 035

See also: Atzori-Corona 2605.07975

Cadeddu + Phys. Rev. D 101, 033004 (2020), Phys. Rev. D 102, 015030 (2020), Phys. Rev. C 104, 065502 (2021), [...] Aristizabal 2301.13249, Cañas+ Phys. Lett. B 784, 159

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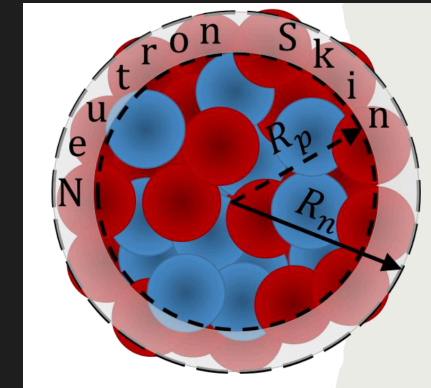
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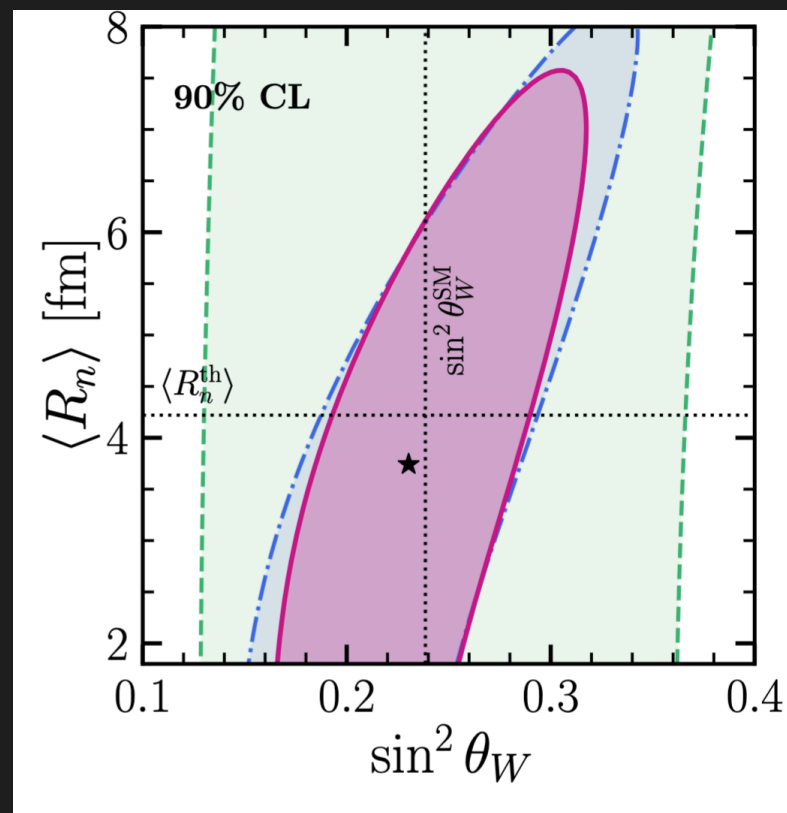
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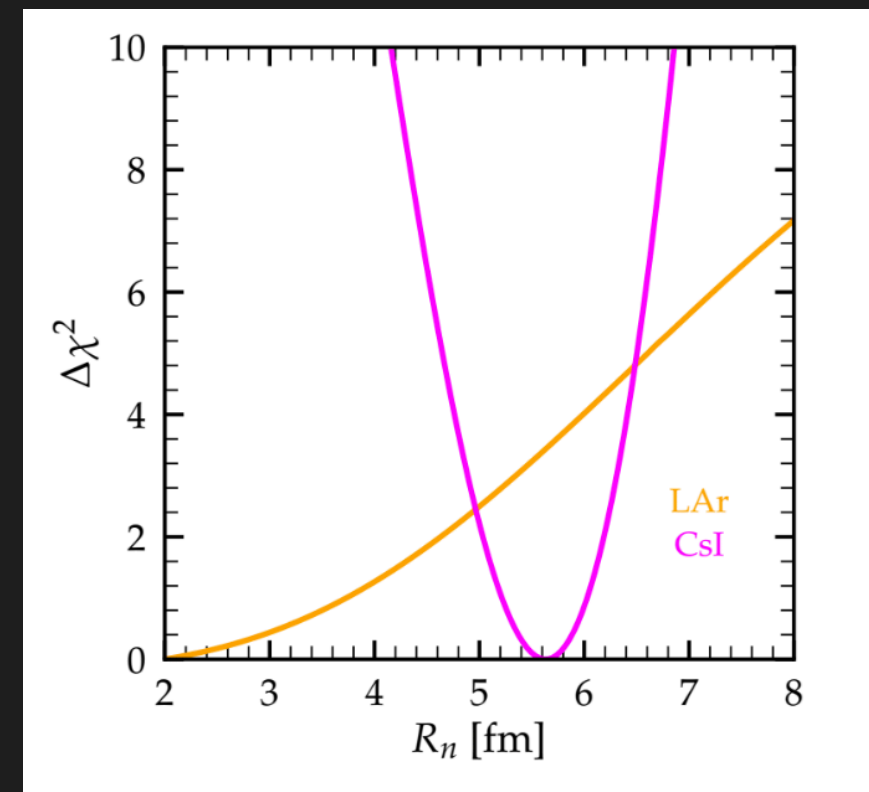
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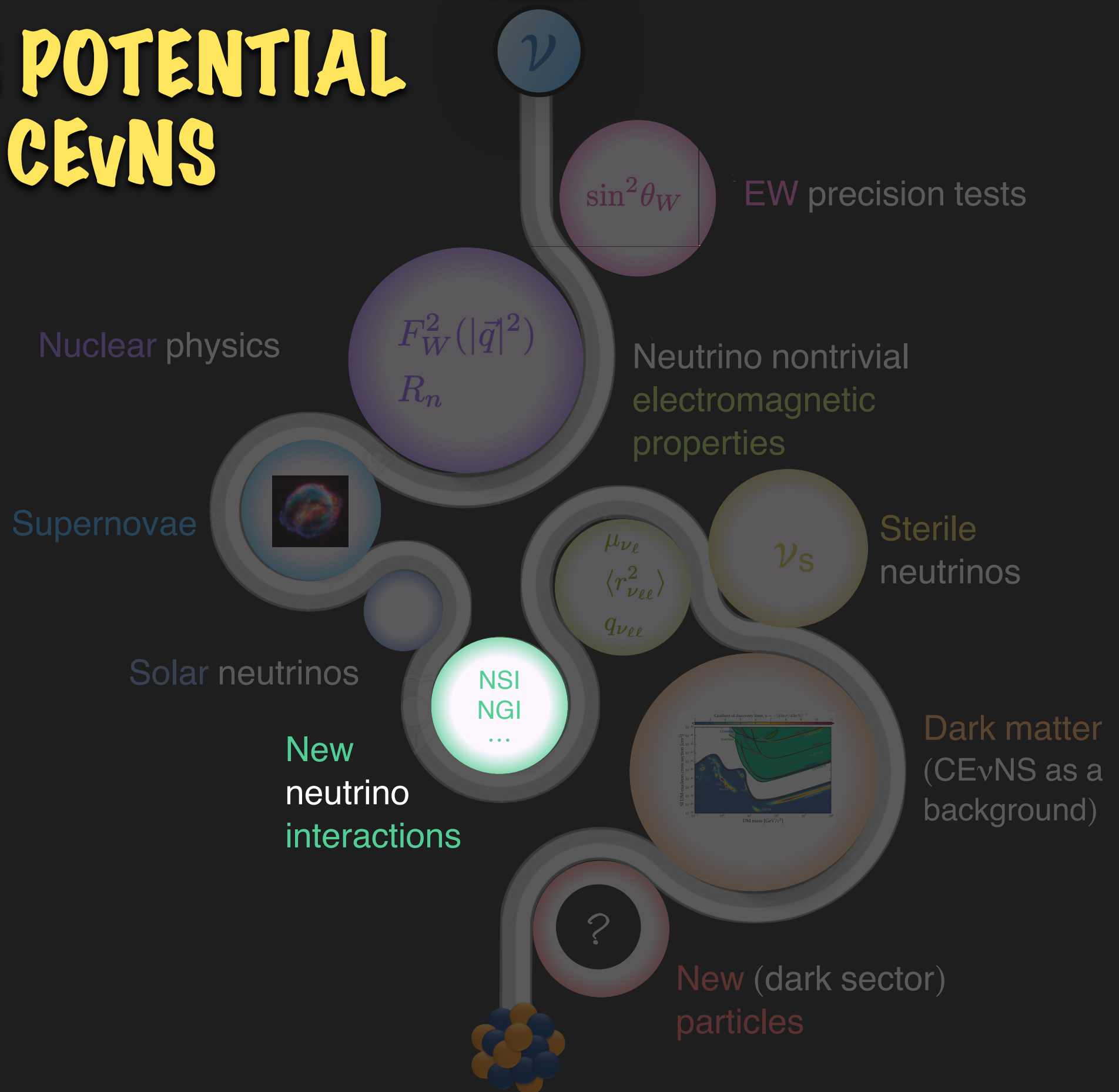


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PHYSICS POTENTIAL OF CEvNS

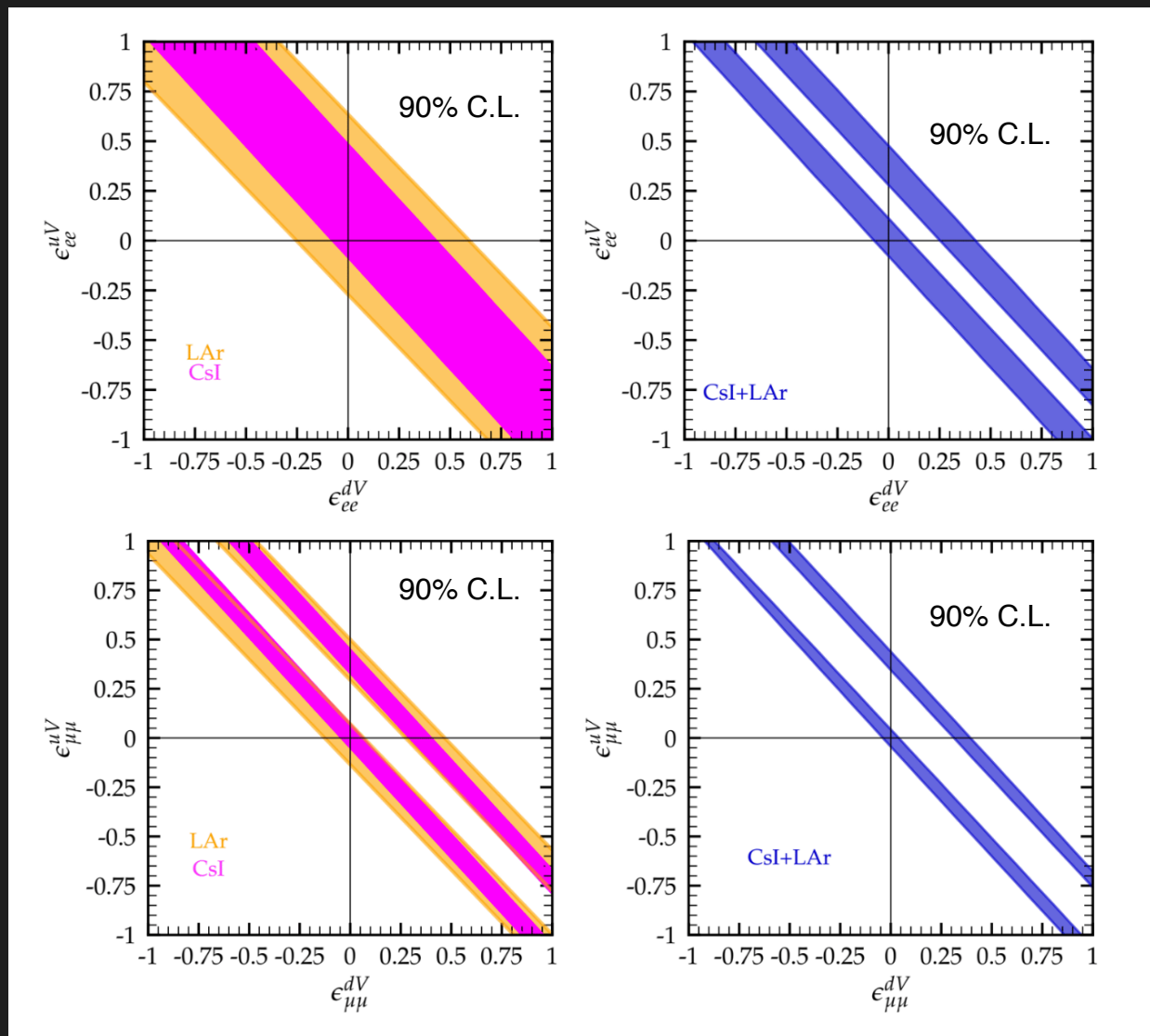


NEW NEUTRINO INTERACTIONS: NSI

Neutrino NSI can be formulated in terms of the effective four-fermion Lagrangian:

$$\mathcal{L}_{\text{NC}}^{\text{NSI}} = -2\sqrt{2}G_F \sum_{q,\ell,\ell'} \epsilon_{\ell\ell'}^{qX} (\bar{\nu}_\ell \gamma^\mu P_L \nu_{\ell'}) (\bar{f} \gamma_\mu P_X f)$$

COHERENT CsI (2021) + LAr



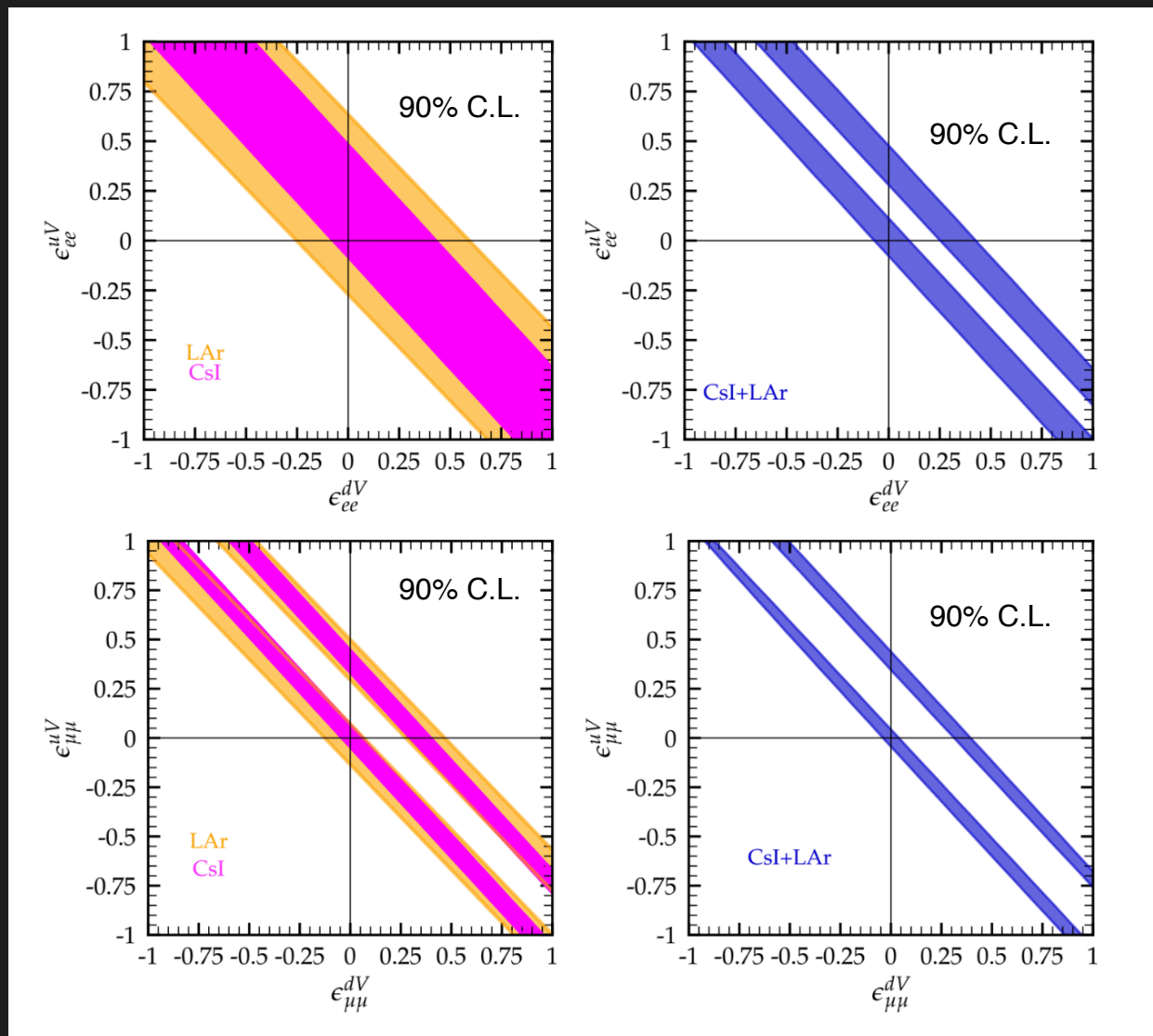
VDR, Miranda, Papoulias, Sanchez-García, Tórtola and Valle, JHEP 04 (2023) 035

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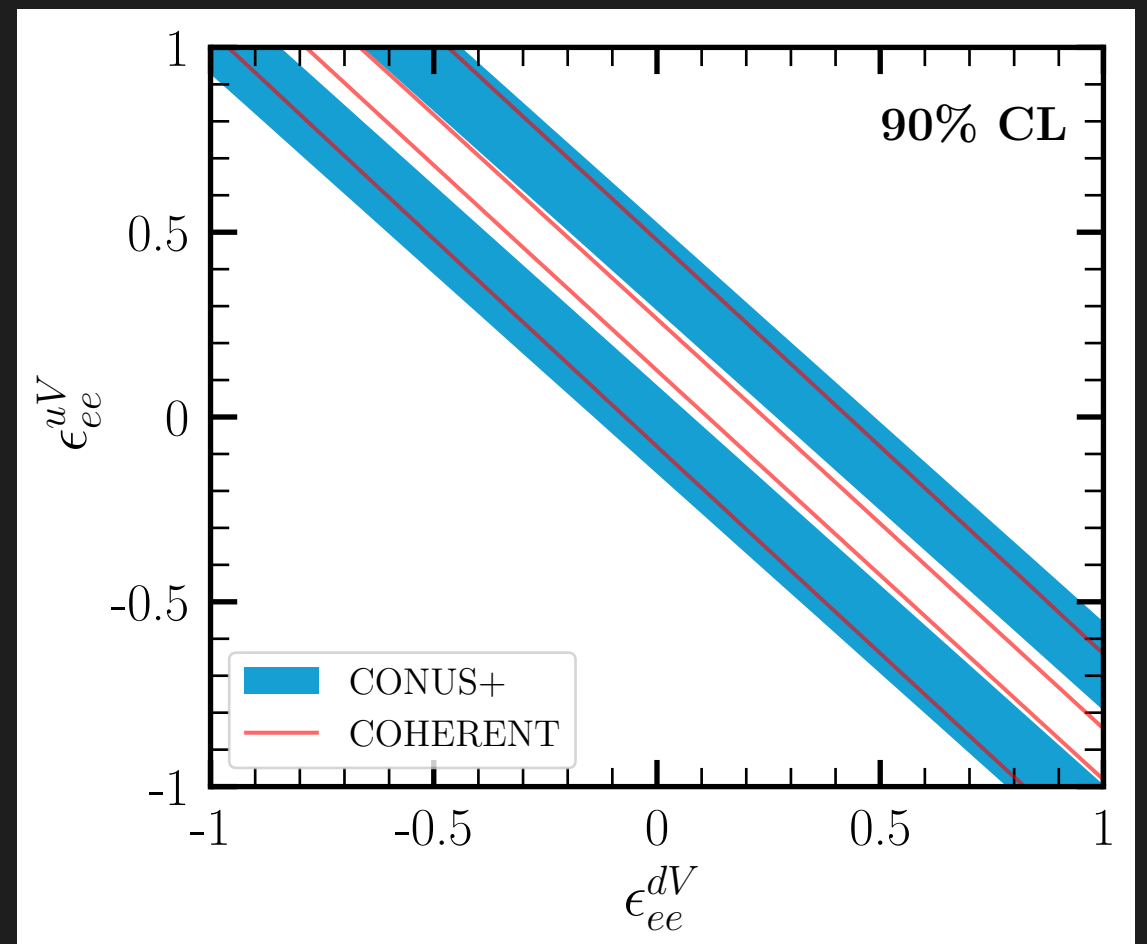
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COHERENT CsI (2021) + LAr



CONUS+ (2025)

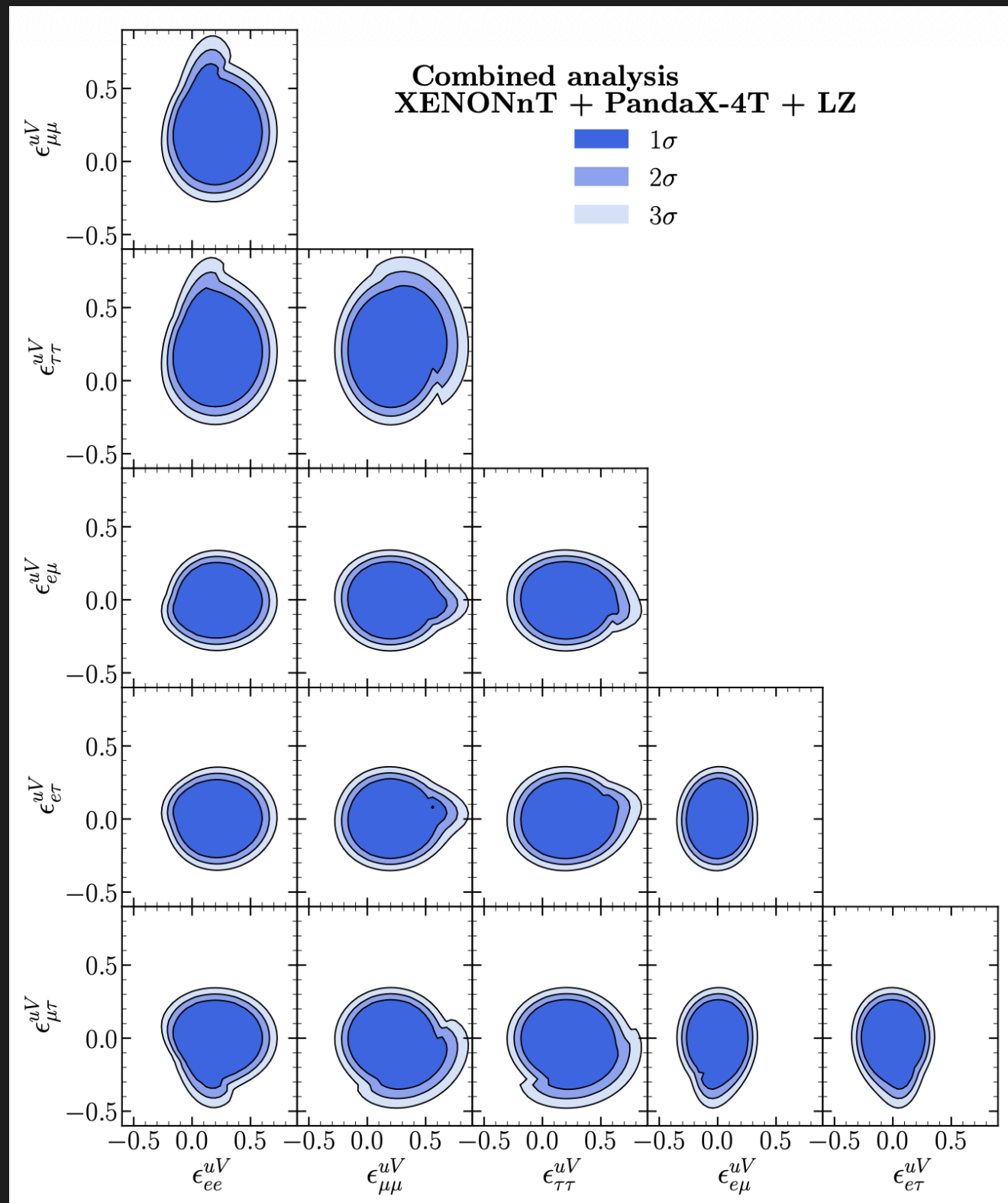


VDR, Papoulias, Sanchez Garcia PRD 111, 075025 (2025)

VDR, Miranda, Papoulias, Sanchez-García, Tórtola and Valle, JHEP 04 (2023) 035

See also Alpízar-Vanegas+ 2501.10355, Chattaraj+ 2501.12441
Li et al 2601.19883

NEW NEUTRINO INTERACTIONS: NSI



- NSI modify the event rates in two ways:
- introduce additional contributions to the matter potential, thus altering neutrino flavor evolution inside the Sun
 - Contribute to the CE ν NS cross section

Direct detection experiments become crucial to constrain neutrino NSI.

They need to be included in global neutrino fits.

Amaral+ JHEP 07 (2023) 071

VDR, Papoulias, Pompa, Sanchez Garcia, Ternes, arXiv: 2603.00554

NEW NEUTRINO INTERACTIONS: LIGHT MEDIATORS

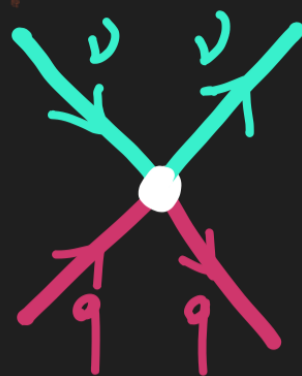
New BSM scenarios might be associated with different types of interactions and mediators. These mediators would contribute to CE ν NS leading to detectable **distortions of the event rates, especially at low-energy recoils.**

Cerdeño+ JHEP 1605 (2016) 118
Bertuzzo+ JHEP 1704 (2017) 073
Farzan+ JHEP 1805 (2018) 066
Denton+ PRD 106 (2022) 015022

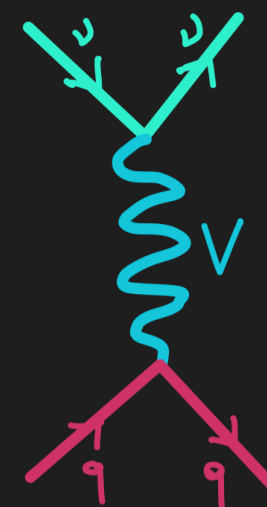
Low-energy neutrino experiments are sensitive to interactions involving light mediators, inducing spectral distortions at low recoil energies.

We may consider **light mediators** with a mass comparable to the typical momentum transfer

$$|\mathbf{q}| \approx \sqrt{2m_{\mathcal{N}}E_{\text{nr}}}$$



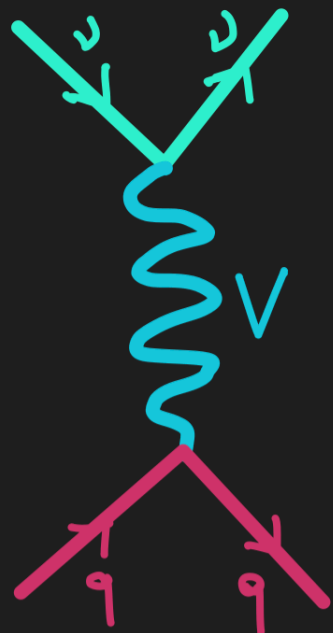
$$G_F^2 |\varepsilon_\ell^X|^2 \rightarrow \frac{2g_X^4}{(m_X^2 + |\mathbf{q}|^2)^2}$$



NEW NEUTRINO INTERACTIONS: LV

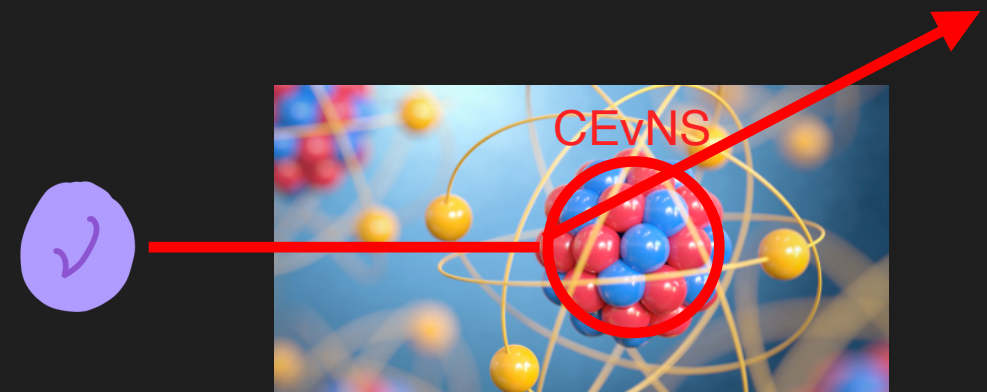
$$\left. \frac{d\sigma}{dE_{\text{nr}}} \right|_{\text{CE}\nu\text{NS}}^{\text{LV}} = \left(1 + \kappa \frac{C_V}{\sqrt{2} G_F Q_W^{\text{SM}} (2m_N E_{\text{nr}} + m_V^2)} \right)^2 \left. \frac{d\sigma}{dE_{\text{nr}}} \right|_{\text{CE}\nu\text{NS}}^{\text{SM}}$$

$$C_V = g_{\nu V} \left[(2g_{uV} + g_{dV}) Z + (g_{uV} + 2g_{dV}) N \right]$$



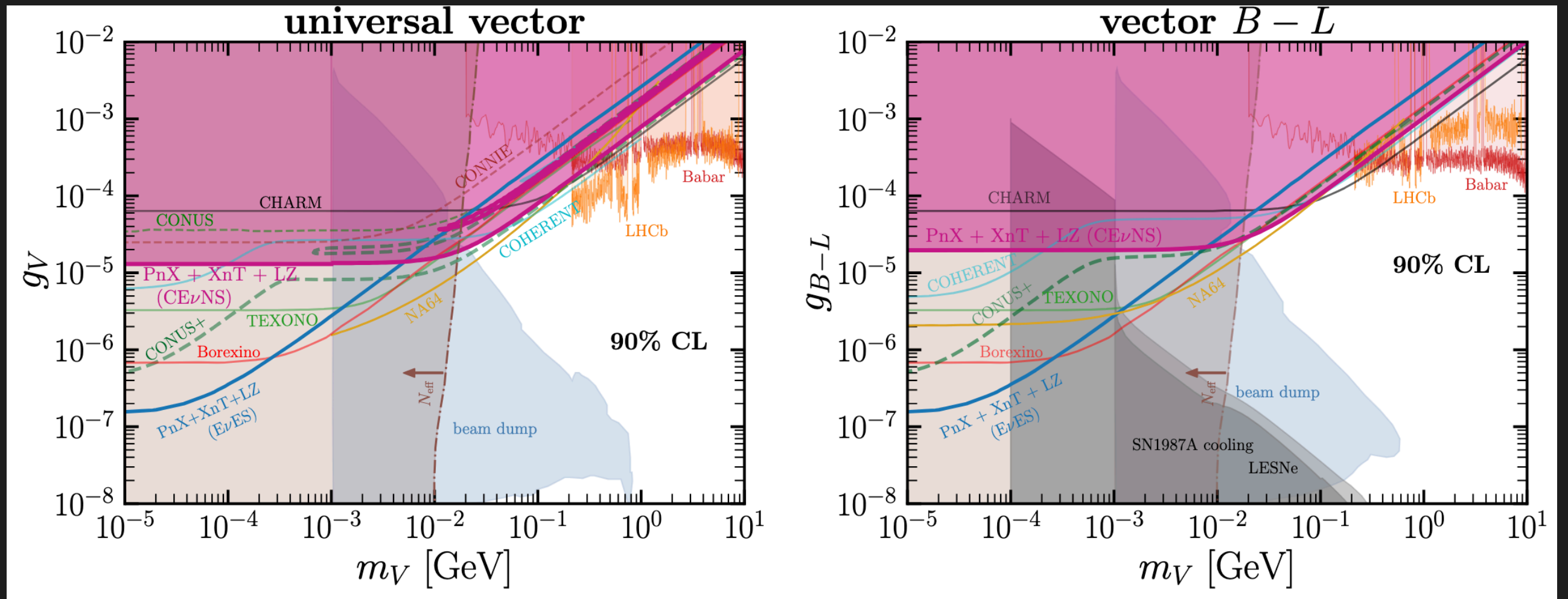
$\kappa = 1$ for universal couplings
 $\kappa = -1/3$ in the B - L model

$$g_V = \sqrt{g_{\nu V} g_{qV}}$$



NEW NEUTRINO INTERACTIONS: LV

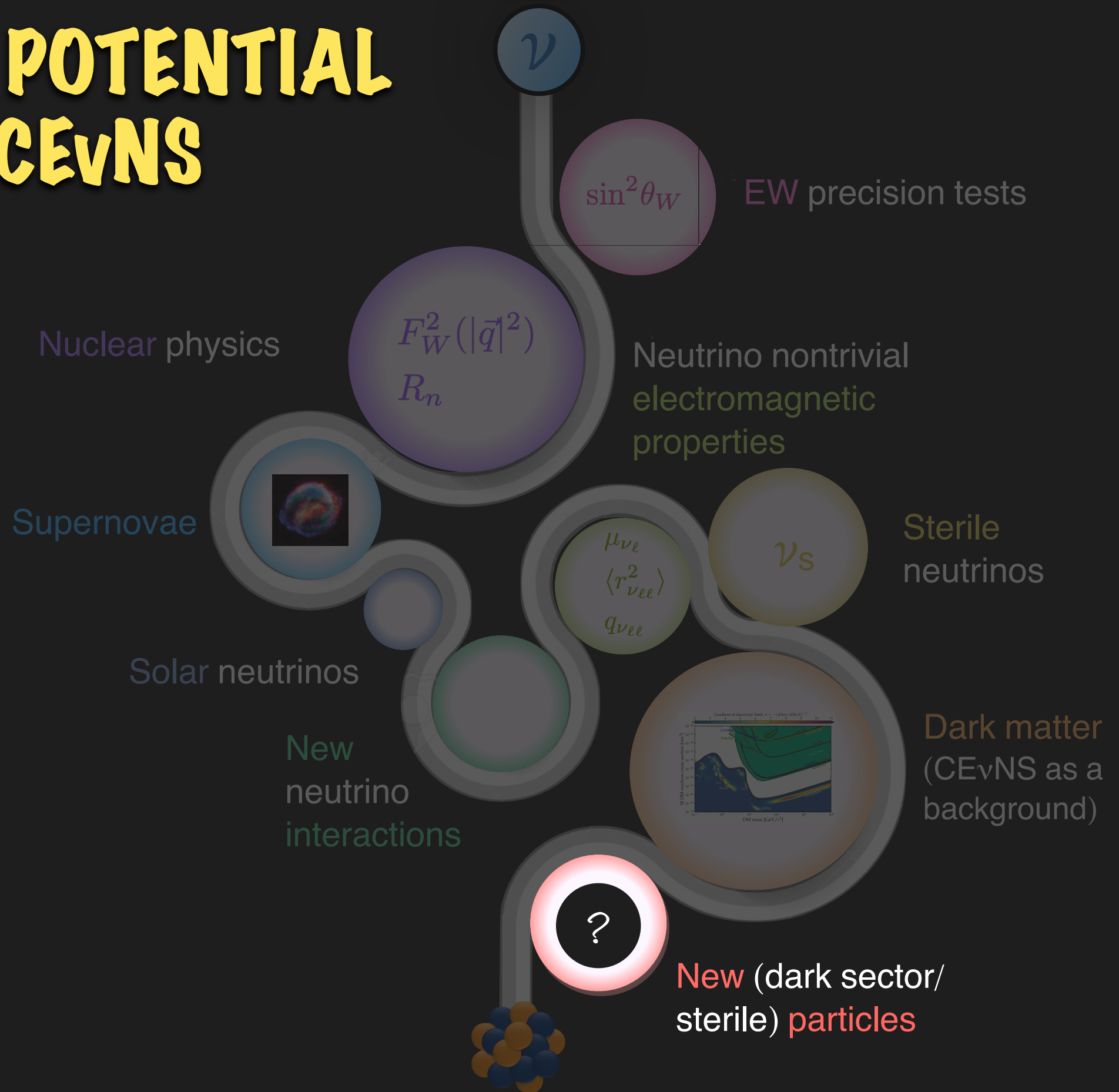
PandaX-4T (2024) + XENONnT (2024) + LZ (2025)



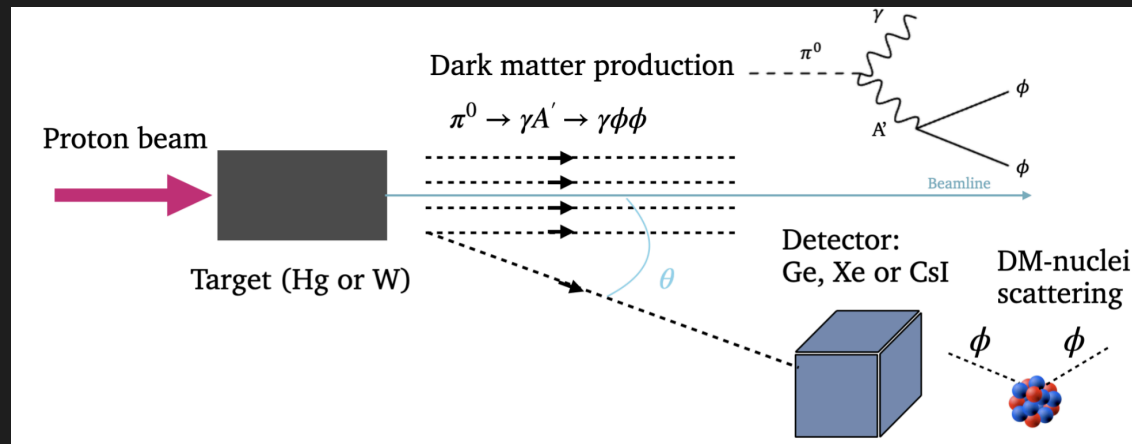
VDR, Papoulias, Pompa, Sanchez Garcia, Ternes, arXiv: 2603.00554

- Complementary analyses in: Blanco-Mas+ JHEP 08 (2025) 043 and ShivaSankar K. A., Phys.Lett.B 839 (2023) 137742 for E ν ES data
VDR, Papoulias, Ternes JCAP 05 (2025) 012

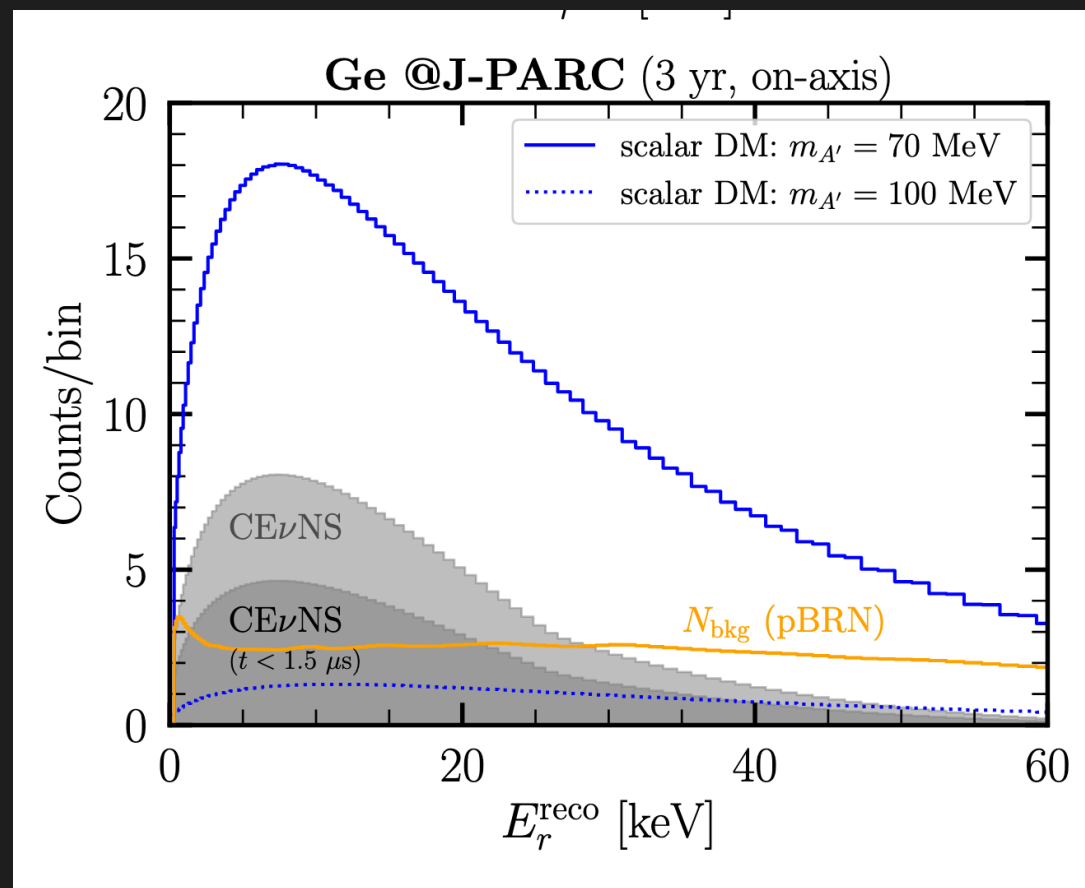
PHYSICS POTENTIAL OF CEvNS



LIGHT DARK MATTER AT SPALLATION SOURCES

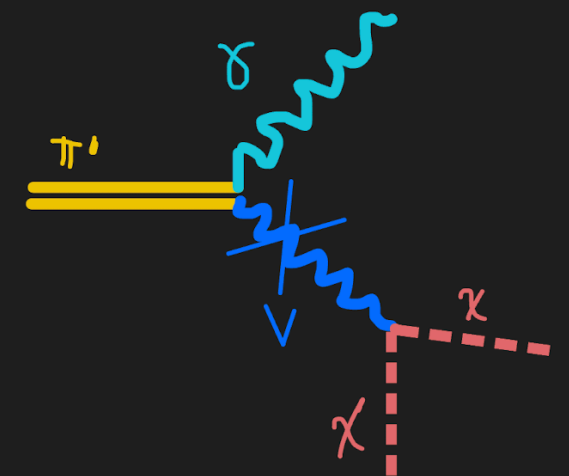


COHERENT Phys.Rev.Lett. 130 (2023) 5, 051803
 deNiverville+ Phys. Rev. D 95, 035006 (2017)
 Dutta+ Phys. Rev. Lett. 124, 121802 (2020)
 COHERENT Phys. Rev. D 102, 052007 (2020)
 COHERENT Phys.Rev.Lett. 130 (2023) 5, 051803
 CCM Phys. Rev. D 106, 012001 (2022)
 Dutta+ JHEP 01 (2022) 144
 CCM Phys. Rev. Lett. 129, 021801 (2022)

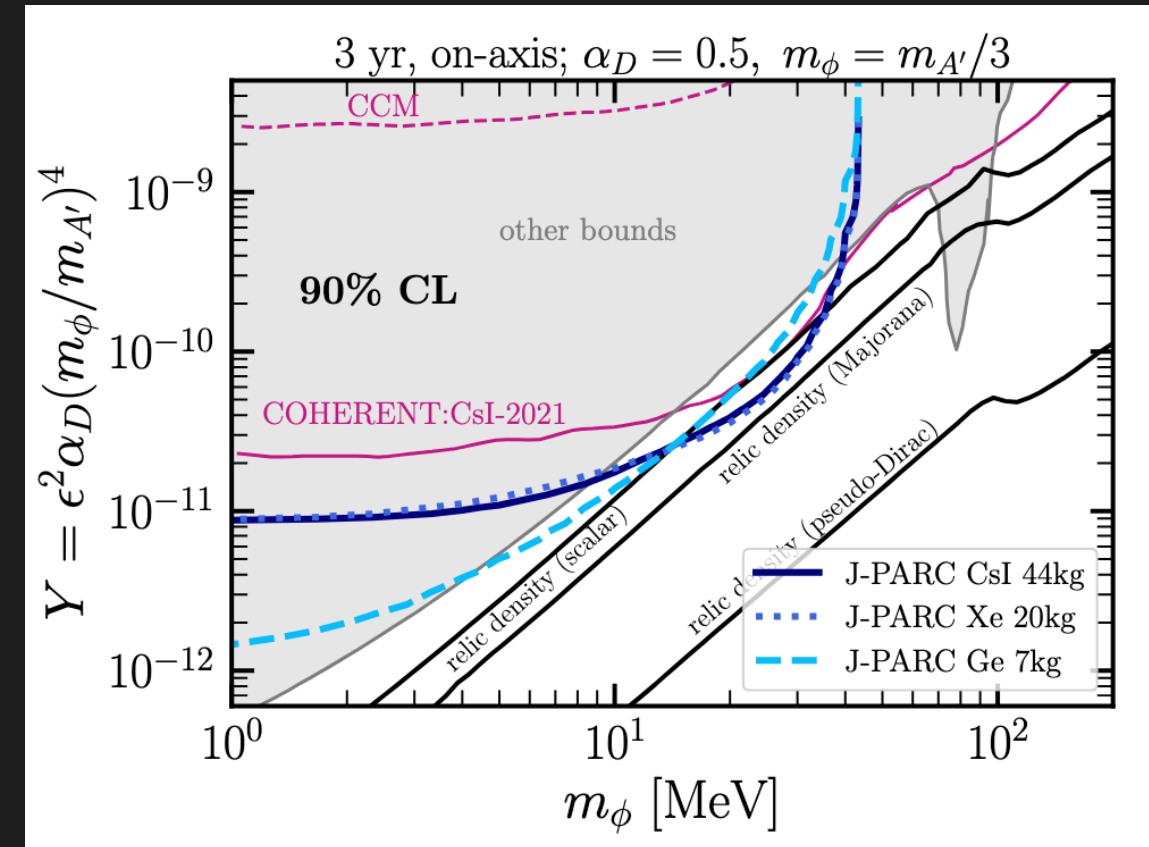
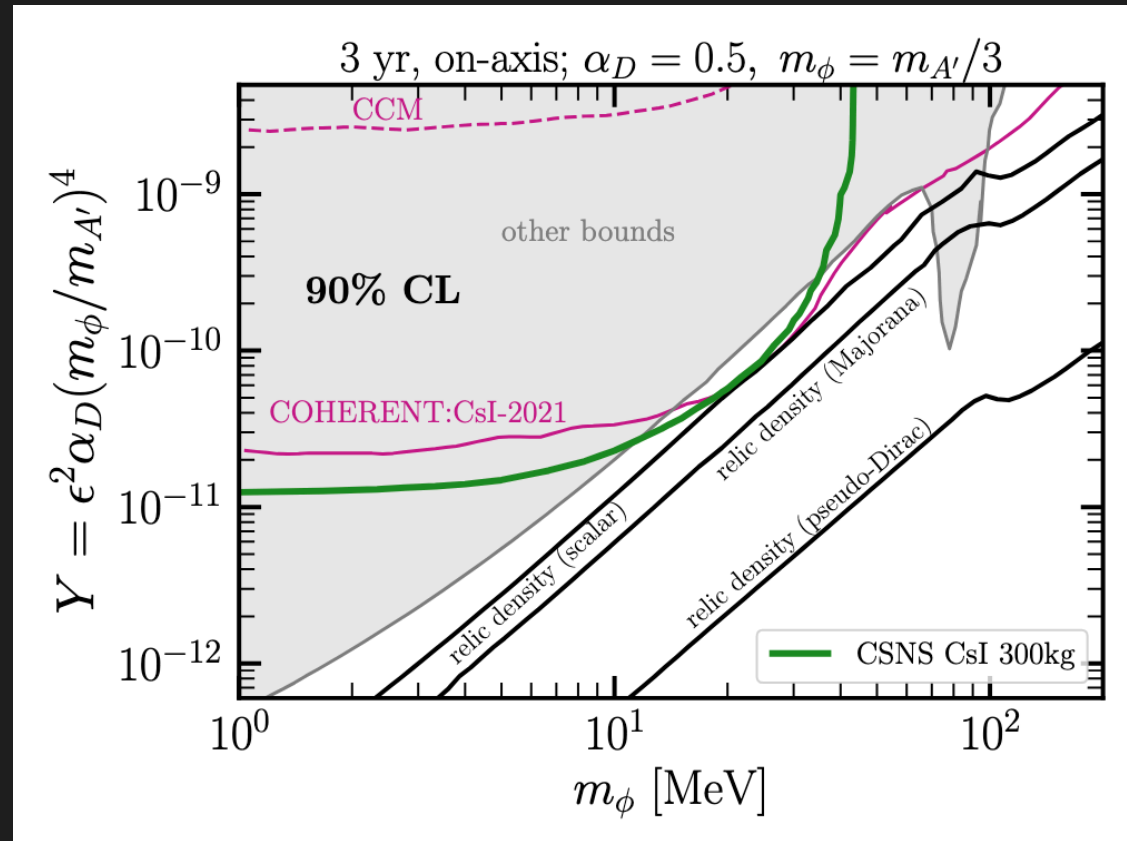


Aristizabal, VDR, Papoulias, Sanchez García, 2603.02132

- Dark photon mediator
- Kinetic mixing with SM photon
- Production through π^0 (or η) decay
- Elastic or inelastic scattering off the target nuclei



LIGHT DARK MATTER AT SPALLATION SOURCES



Aristizabal, VDR, Papoulias, Sanchez García, 2603.02132

Facility	Target	T_p [GeV]	P [MW]	B [m]	Detector	a [cm]	Pulse Timing
ESS [38]	W	2	5	20	Xe (20 kg), Ge (7 kg) CsI (22.5 kg)	50, 11 17	14 Hz of 2.8-ms pulses
J-PARC [39]	Hg	3	1 → 1.3	20	Xe (20 kg), Ge (7 kg) CsI (44 kg)	50, 11 21.4	25 Hz of 0.1- μ s double pulses
CSNS [79]	W	1.6	0.14 → 0.5	10.5	CsI (300 kg)	40.5	25 Hz of 0.5- μ s pulses

Summary

- ▶ **CE ν NS process:**
 - coherency condition (sources: spallation source, nuclear reactors,...)
 - neutrinos scatter on a nucleus which act as a single particle
 - enhancement of the cross section ($\propto N^2$)
- ▶ **CE ν NS experiments and data rapidly expanding:**
 - COHERENT (CsI, LAr, Ge)
 - Reactor experiments (Dresden-II and CONUS+)
 - Now also DM direct detection experiments (XENONnT, PandaX-4T and LZ)!
- ▶ **CE ν NS extended physics potential:**
 - SM physics (weak mixing angle, nuclear physics)
 - Neutrino electromagnetic properties
 - BSM scenarios: NSI, new light mediators, production of dark matter, ALPs, sterile neutrinos...
 - Impact on the neutrino floor/fog
- ▶ Wealth of information from forthcoming data: **Accurate theoretical predictions**, including subleading corrections and **detector effects** such as quenching, together with the **complementarity of multiple sources and targets**, will be essential to fully exploit the potential of future CE ν NS data.

Summary

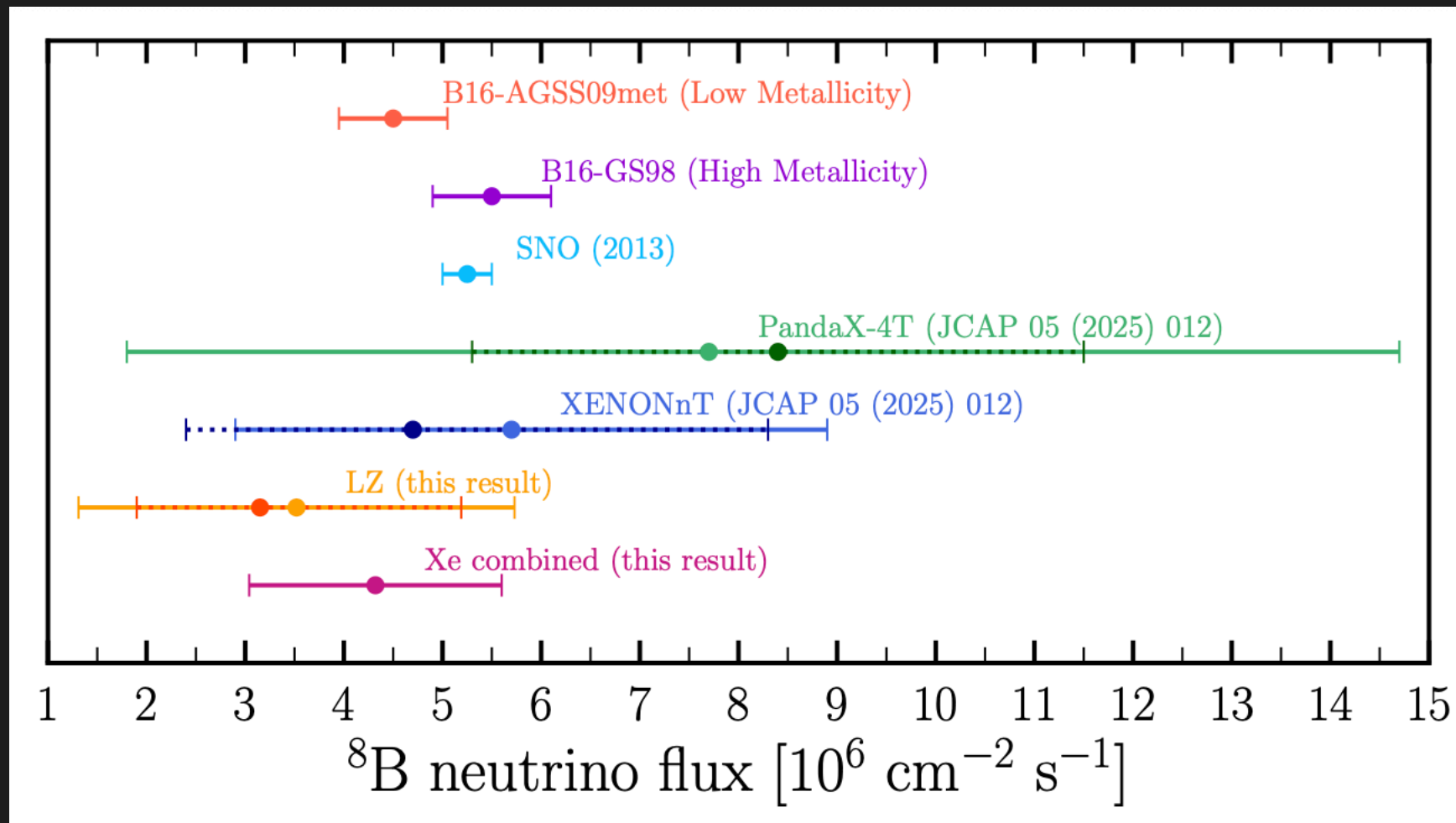
- ▶ **CE ν NS process:**
 - coherency condition (sources: spallation source, nuclear reactors,...)
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- ▶ **Wealth of information from forthcoming data. Accurate theoretical predictions, including subleading corrections and detector effects such as quenching, together with the complementarity of multiple sources and targets, will be essential to fully exploit the potential of future CE ν NS data.**

► **Acknowledgments:**

- CIDEXG/2022/20 (Generalitat Valenciana)
- CNS2023-144124 (MCIN/AEI/ 10.13039/501100011033 and “Next Generation EU”/PRTR)
- PID2023-147306NB-I00 (MCIN/AEI/ 10.13039/501100011033)
- Severo Ochoa (CEX2023-001292-S)

SM PHYSICS: ^8B SOLAR NEUTRINO FLUX

PandaX-4T (2024) + XENONnT (2024) + LZ (2025)



VDR, Papoulias, Pompa, Sanchez Garcia, Ternes, arXiv: 2603.00554

VDR, Papoulias, Ternes JCAP 05 (2025) 012
E. Aprile et al. (XENONnT) PRL 133, 191002 (2024)
Z. Bo et al. (PandaX) PRL 133, 191001
Akerib et al. LUX-ZEPLIN (LZ), arXiv:2512.08065

LIST OF CEvNS OBSERVATIONS

Hard to reconcile different measurements with the same choice of quenching factor.

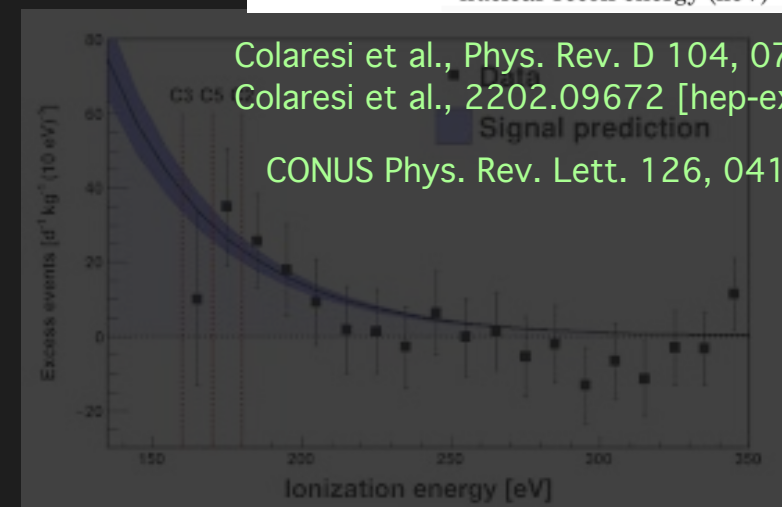
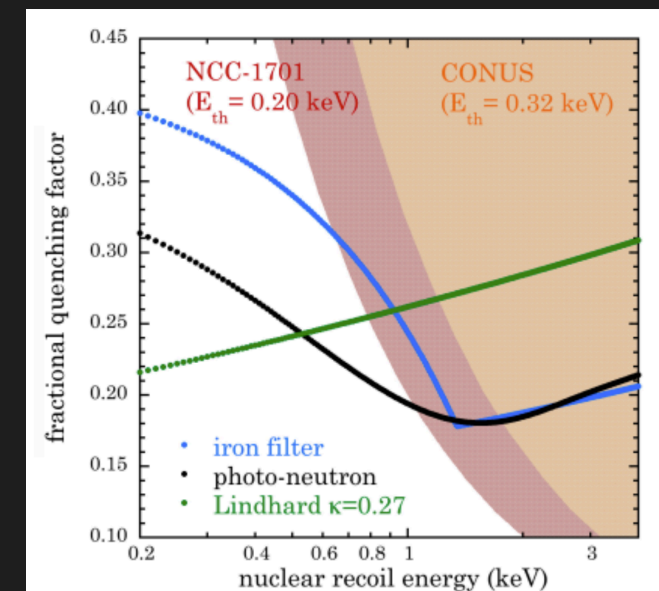
Y. Li+, 2502.12308

New results from vGEN and more (e.g., Ricochet) expected soon.

Ch. Phys. C 49 053004 (2025)



Quenching factor dependence!



Colaesi et al., Phys. Rev. D 104, 072003 (2021)

Colaesi et al., 2202.09672 [hep-ex]

CONUS Phys. Rev. Lett. 126, 041804

Reactors

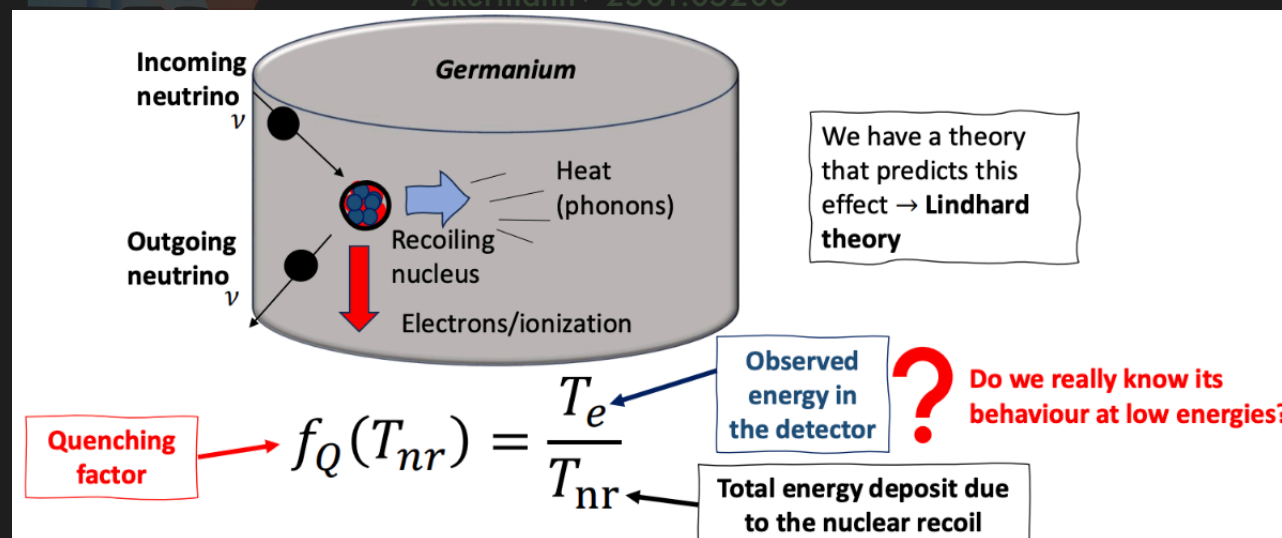


► 2022: Dresden-II, Ge

Colaesi, Collar et al. Phys. Rev. Lett. 129 (2022) 211802

► 2025: CONUS+, Ge, 3.7σ CL

Ackermann+ 2501.05206



Credit: Atzori Corona Magnificent CEvNS 2024

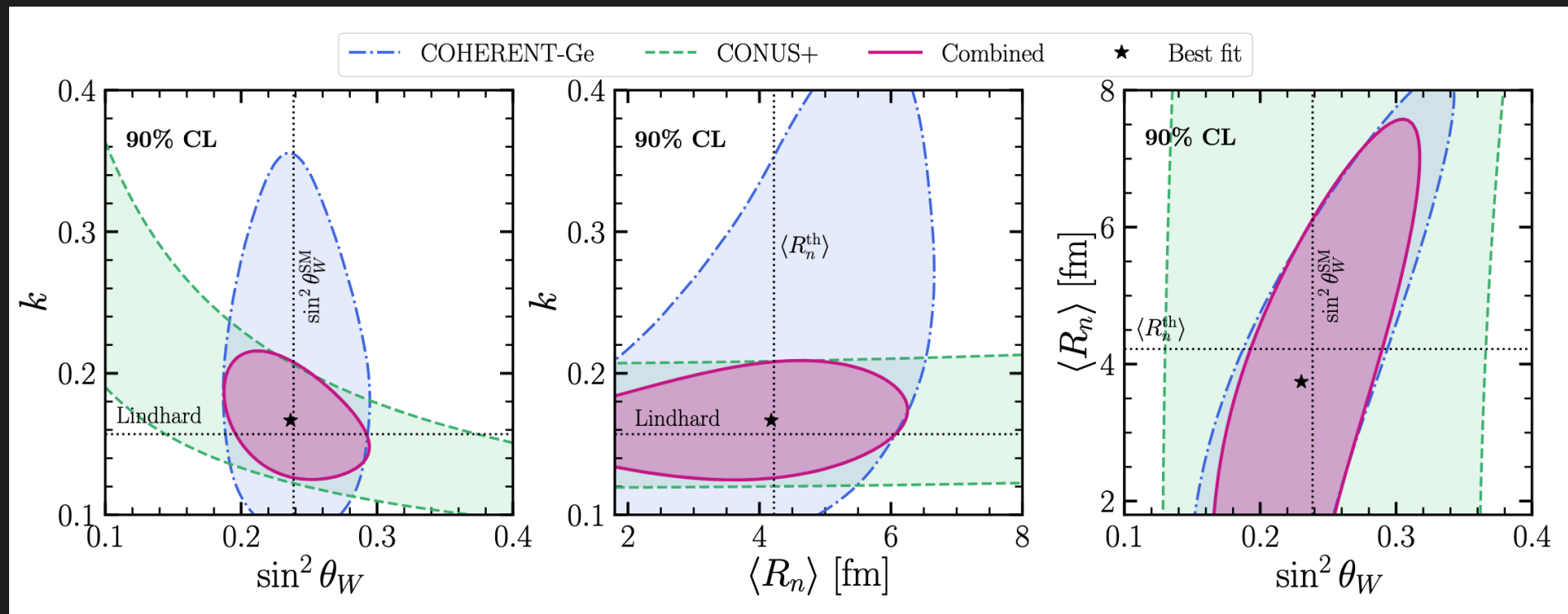
NEUTRON DENSITY DISTRIBUTION

A large R_n has implications for:

- Nuclear physics → a larger pressure of neutrons, stability of nuclei
- Astrophysics → a larger size of neutron stars

$$E_{\text{er}} = Q_{\text{F}}(T_{\mathcal{N}}) \times T_{\mathcal{N}} = \frac{k g(\epsilon)}{1 + k g(\epsilon)} T_{\mathcal{N}} \quad \epsilon = 11.5 Z^{-7/3} T_{\mathcal{N}} \\ g(\epsilon) = 3\epsilon^{0.15} + 0.7\epsilon^{0.6} + \epsilon$$

We assume the Lindhard model and variations of the parameter k



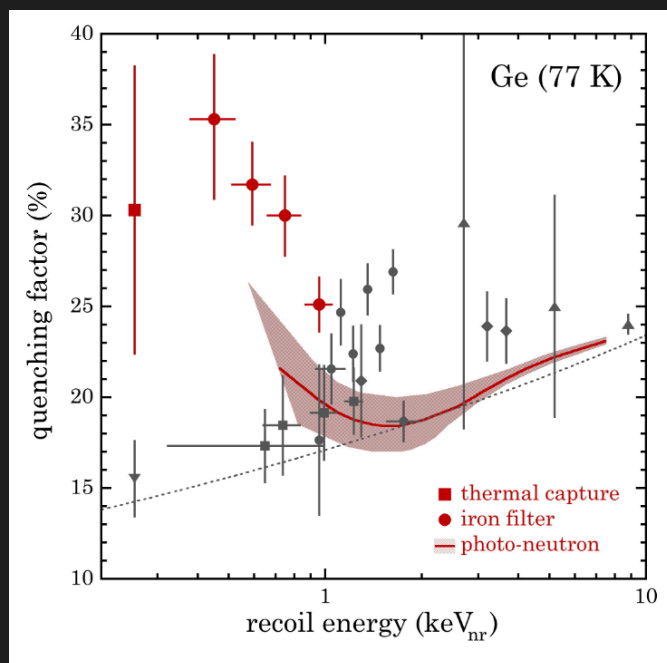
VDR, Duque, Papoulias, Sanchez-García, Ternes 2605.27121

EVIDENCE OF CE ν NS ?

AT NCC-1701 (DRESDEN-II REACTOR)

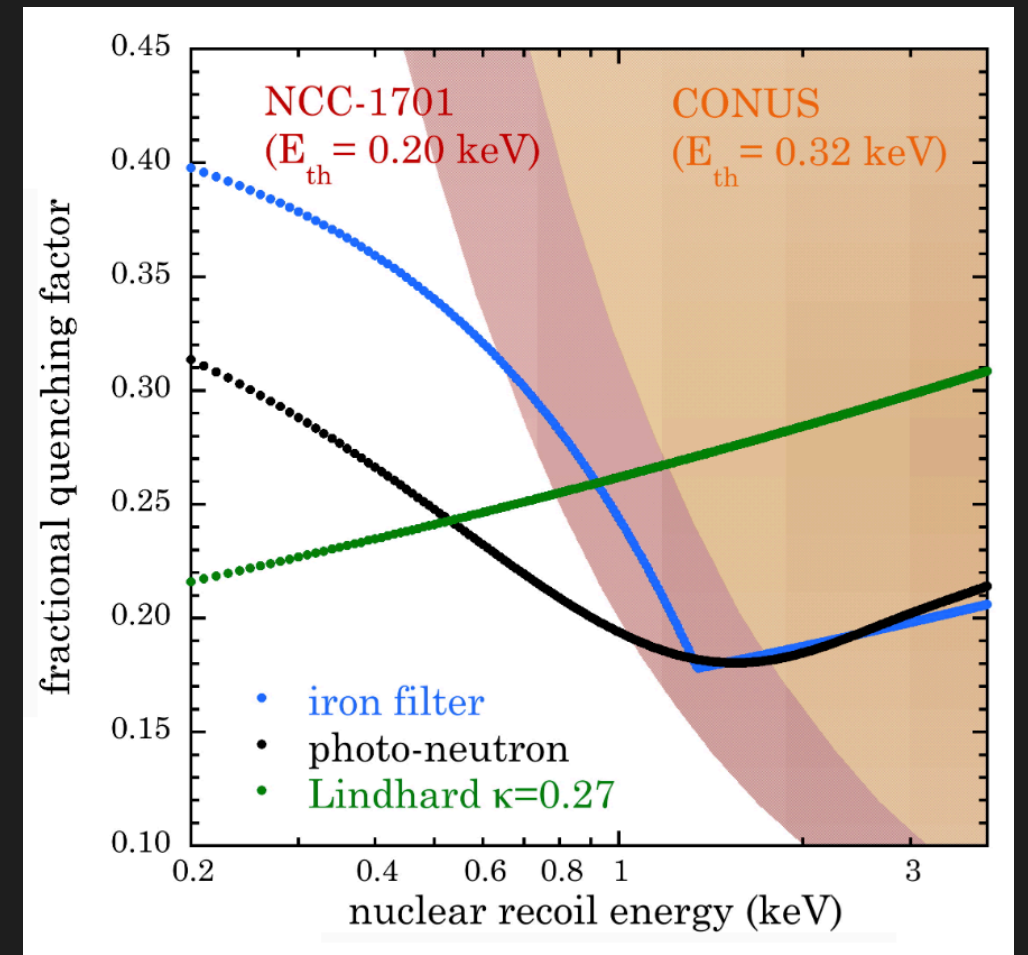
The quenching factor (QF) describes the observed reduction in ionization yield produced by a nuclear recoil when compared to an electron recoil of same energy

- often not (yet) well known at low recoil energies for CE ν NS
- major uncertainty!



J.I. Collar et al, Phys. Rev. D 103, 122003

$$QF = E_{\text{meas}}/E_{\text{nuclear recoil}}$$



Colaresi et al., Phys. Rev. D 104, 072003 (2021)

Colaresi et al., 2202.09672 [hep-ex]

CONUS: Direct measurement of ionization quenching factor: $k=0.162 \pm 0.004$ (compatible with Lindhard)

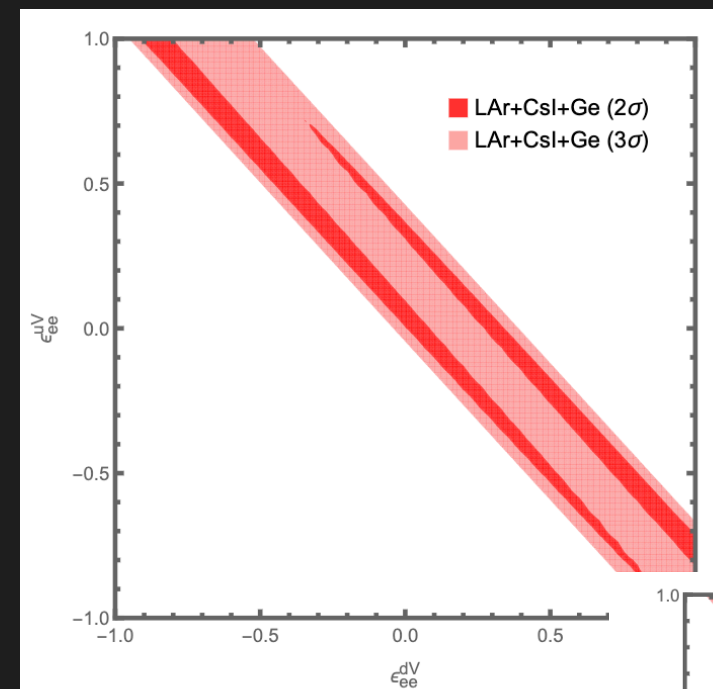
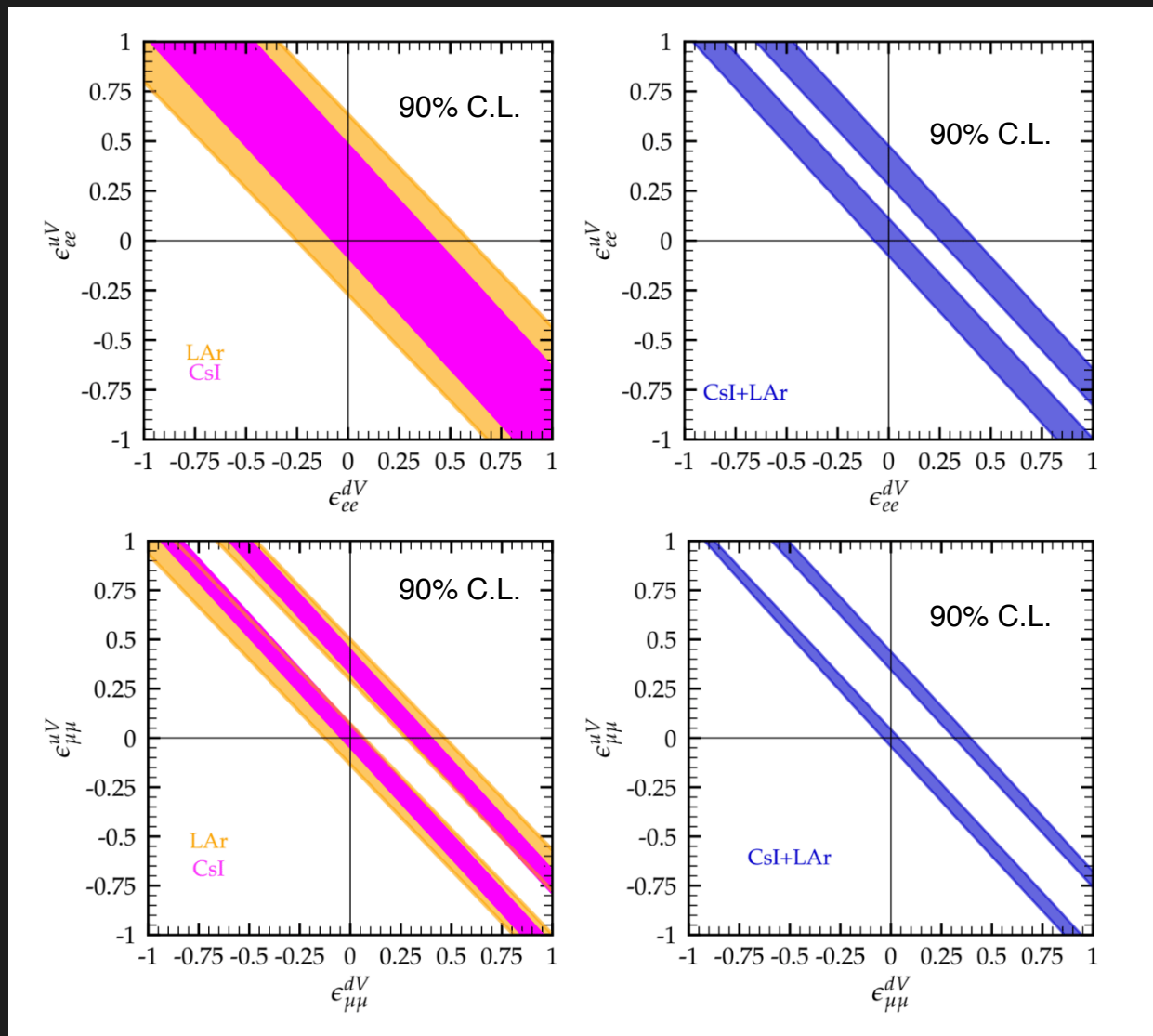
CONUS Phys. Rev. Lett. 126, 041804

NEW NEUTRINO INTERACTIONS: NSI

Neutrino NSI can be formulated in terms of the effective four-fermion Lagrangian:

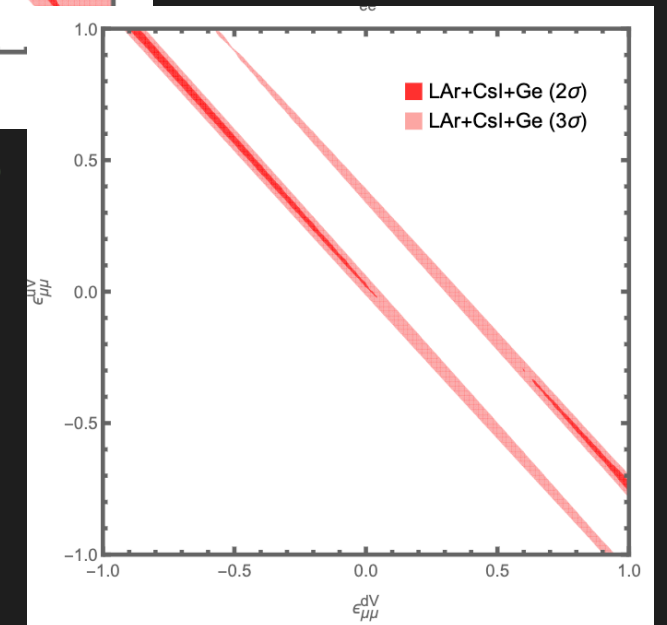
$$\mathcal{L}_{\text{NC}}^{\text{NSI}} = -2\sqrt{2}G_F \sum_{q,\ell,\ell'} \epsilon_{\ell\ell'}^{qX} (\bar{\nu}_\ell \gamma^\mu P_L \nu_{\ell'}) (\bar{f} \gamma_\mu P_X f)$$

COHERENT CsI (2021) + LAr



COHERENT CsI
(2021) + LAr + Ge

Liao+ PRD 110 (2024) 5, 055040

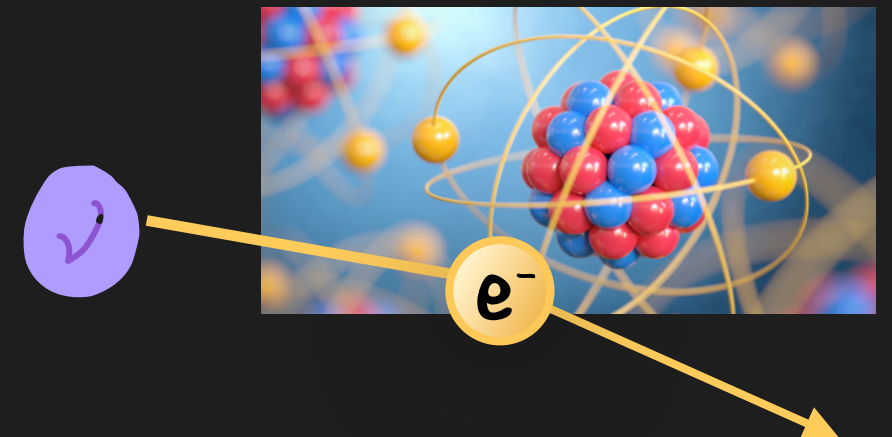
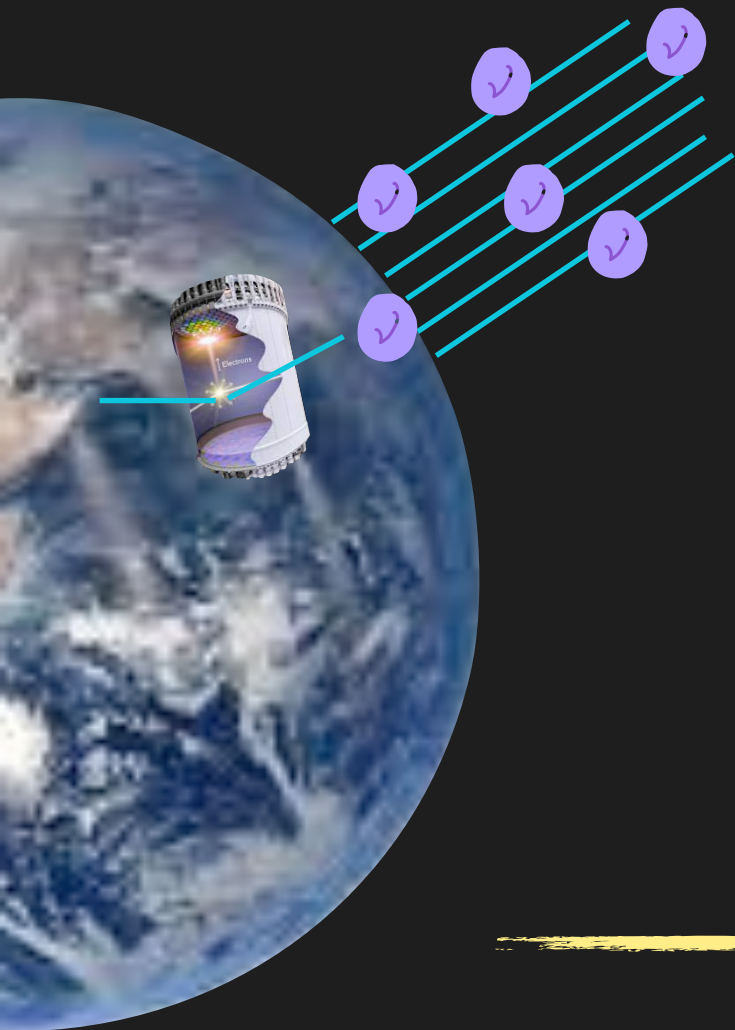


VDR, Miranda, Papoulias, Sanchez-García, Tórtola and Valle, JHEP 04 (2023) 035

ELASTIC NEUTRINO-ELECTRON SCATTERING (EVES)

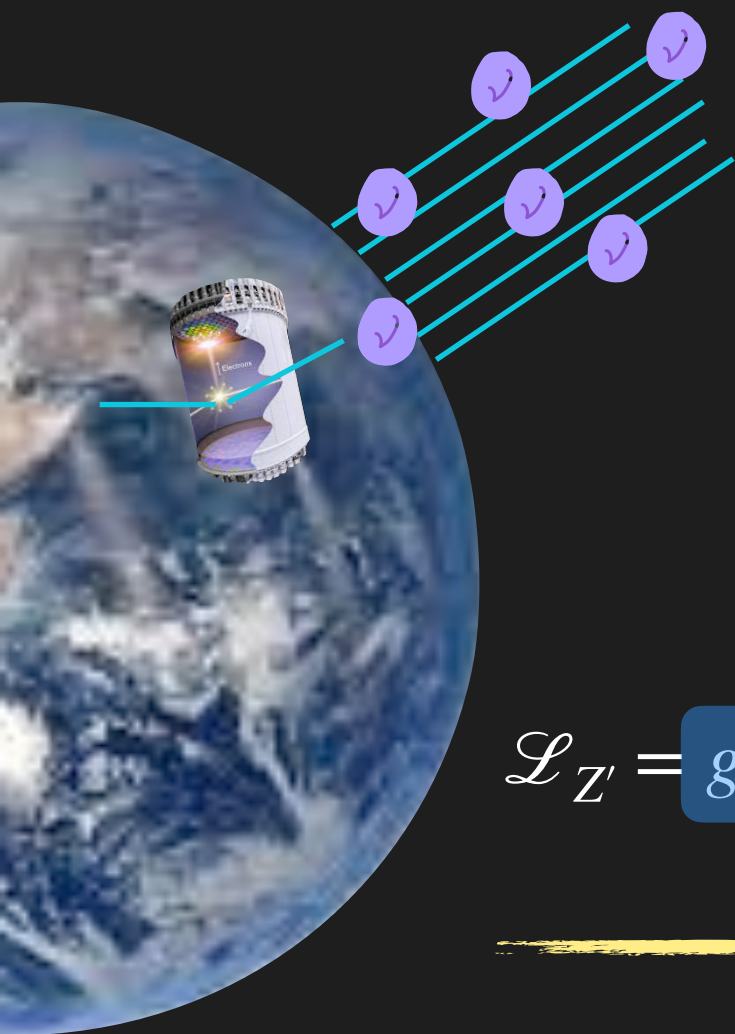
$$\left. \frac{d\sigma_{\nu\ell\mathcal{A}}}{dE_{\text{er}}} \right|_{\text{E}\nu\text{ES}}^{\text{SM}} = Z_{\text{eff}}^{\mathcal{A}}(E_{\text{er}}) \frac{G_F^2 m_e}{2\pi} \left[(g_V^{\nu\ell} + g_A^{\nu\ell})^2 + (g_V^{\nu\ell} - g_A^{\nu\ell})^2 \left(1 - \frac{E_{\text{er}}}{E_\nu} \right)^2 - \left((g_V^{\nu\ell})^2 - (g_A^{\nu\ell})^2 \right) \frac{m_e E_{\text{er}}}{E_\nu^2} \right]$$

effective number of electrons
that can be ionized
with an energy deposition E_{er}

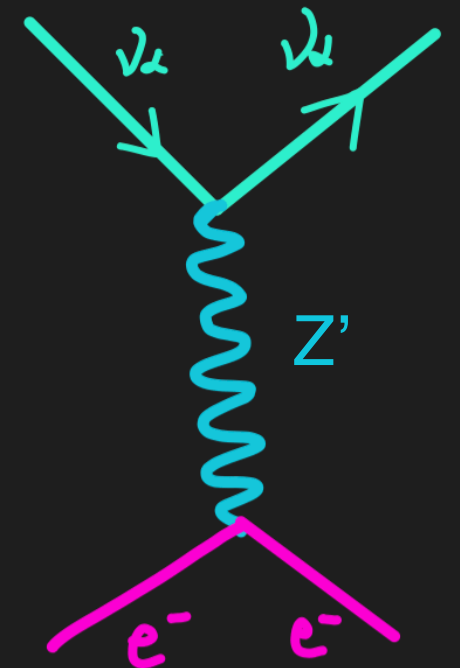


ELASTIC NEUTRINO-ELECTRON SCATTERING (EVES)

$$\left. \frac{d\sigma_{\nu_e \mathcal{A}}}{dE_{\text{er}}} \right|_{\text{E}\nu\text{ES}}^{\text{SM}} = Z_{\text{eff}}^{\mathcal{A}}(E_{\text{er}}) \frac{G_F^2 m_e}{2\pi} \left[(g_V^{\nu_e} + g_A^{\nu_e})^2 + (g_V^{\nu_e} - g_A^{\nu_e})^2 \left(1 - \frac{E_{\text{er}}}{E_\nu}\right)^2 - \left((g_V^{\nu_e})^2 - (g_A^{\nu_e})^2 \right) \frac{m_e E_{\text{er}}}{E_\nu^2} \right]$$



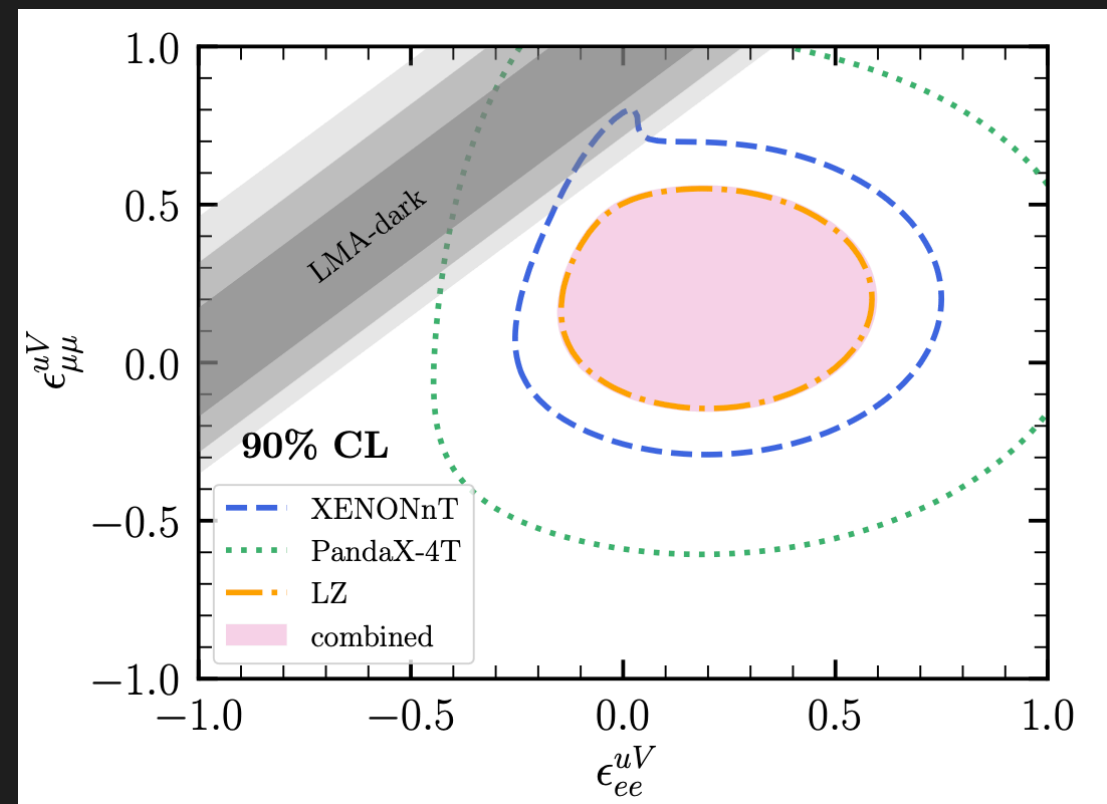
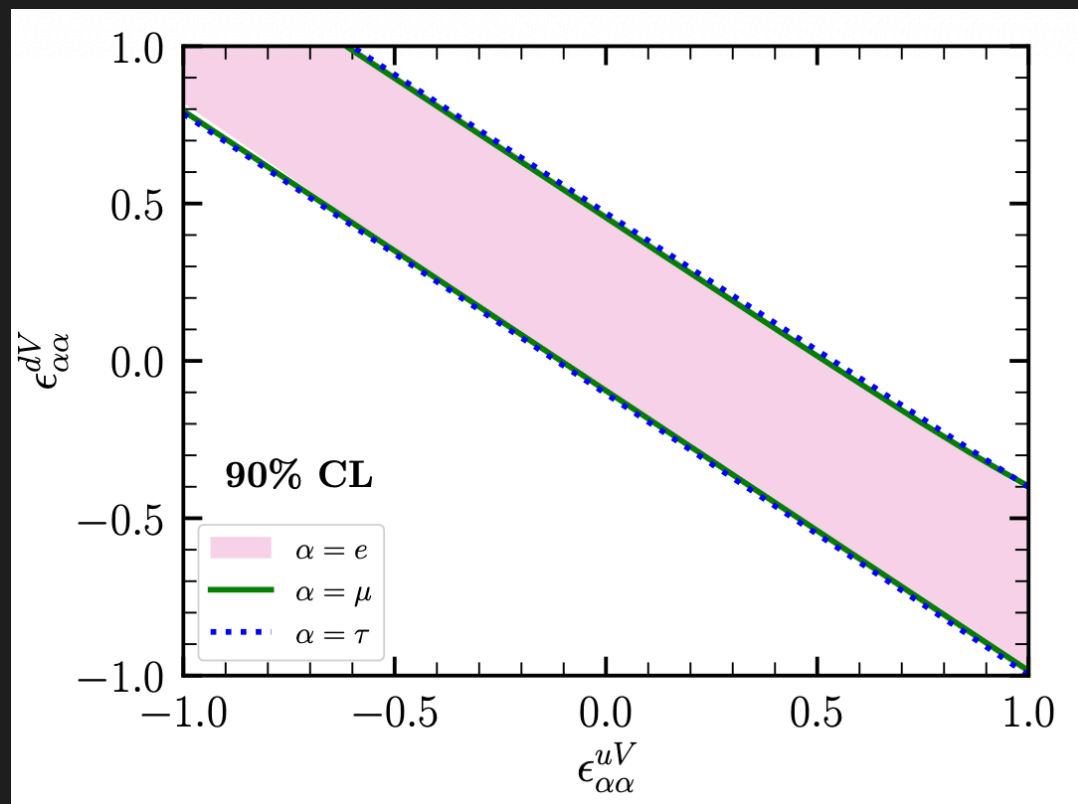
$$g_V \rightarrow g_V^{\text{SM}} + \frac{(g_{Z'})^2 Q_{Z'}^e Q_{Z'}^{\nu_\alpha}}{\sqrt{2} G_F (2m_e T_e + m_{Z'}^2)}$$



$$\mathcal{L}_{Z'} = g_{Z'} Z'_\mu \left(Q_{Z'}^f \bar{f} \gamma^\mu f + \sum_\alpha Q_{Z'}^{\nu_\alpha} \bar{\nu}_{\alpha,L} \gamma^\mu \nu_{\alpha,L} \right) + \frac{1}{2} m_{Z'}^2 Z'^\mu Z'_\mu$$

NEW NEUTRINO INTERACTIONS: NSI

PandaX-4T (2024) + XENONnT (2024) + LZ (2025)



VDR, Papoulias, Pompa, Sanchez Garcia, Ternes, arXiv: 2603.00554

LMA-dark solution: $\sin^2 \theta_{12} > 0.5$ and sizeable NSI contributions.

In the presence of sufficiently large NSI, the symmetry of the effective Hamiltonian under a simultaneous flip of the mass ordering and the θ_{12} octant can be restored through an appropriate sign change in the matter potential.

Miranda+ JHEP 10 (2006) 008

See also:

Coloma+ Phys. Rev. D 96 no. 11, (2017) 115007

Chaves + Schwetz JHEP 05 (2021) 042

Solar CEvNS:

Aristizabal+ PRD 111 (2025) 5, 055007

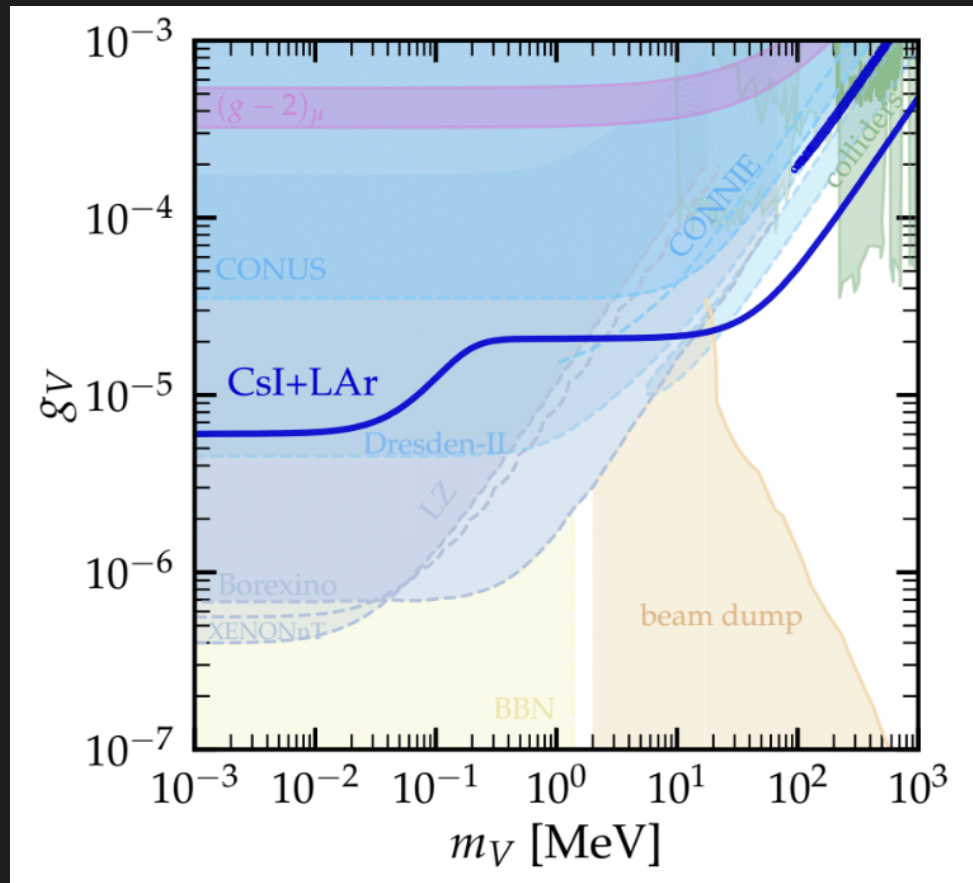
Li+ PRD 111 (2025) 3, 035002

Gehrlein, Kushwaha, PRD 112 (2025) 9, 095032

Li+ 2601.19883

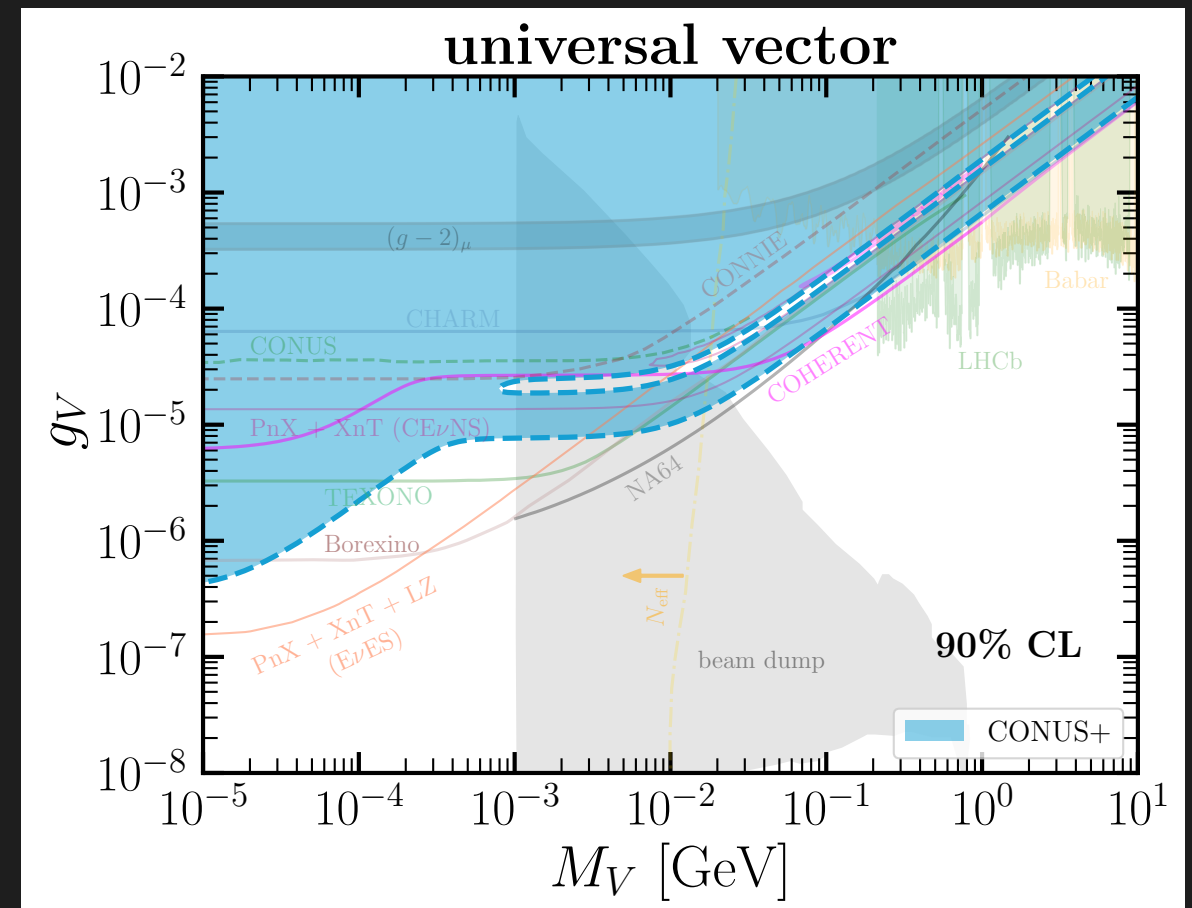
NEW NEUTRINO INTERACTIONS: LV

COHERENT CsI (2021) + LAr



VDR, Miranda, Papoulias, Sanchez-García, Tórtola and Valle, JHEP 04 (2023) 035

CONUS+ (2025)



VDR, Papoulias, Sanchez Garcia PRD 111, 075025 (2025)

See also Chattaraj+ PLB 864 (2025) 139438

- Complementary analyses in: J. Liao, H. Liu, and D. Marfatia, 2202.10622, Coloma et al. 2202.10829, Atzori-Corona et al. 2205.09484, A. Khan 2203.08892, Majumdar+ 2208.13262

CEvNS CROSS SECTION IN THE SM

CEvNS cross-section in the SM:

(probability of kicking a nucleus with nuclear recoil energy T)

$$\frac{d\sigma}{dT_{\mathcal{N}}} = \frac{G_F^2 m_{\mathcal{N}}}{4\pi} \left(1 - \frac{m_{\mathcal{N}} T_{\mathcal{N}}}{2E_{\nu}^2} - \frac{T_{\mathcal{N}}}{E_{\nu}} \right) Q_W^2 F_W^2(|\mathbf{q}|^2) + \frac{G_F^2 m_{\mathcal{N}}}{4\pi} \left(1 + \frac{m_{\mathcal{N}} T_{\mathcal{N}}}{2E_{\nu}^2} - \frac{T_{\mathcal{N}}}{E_{\nu}} \right) F_A(|\mathbf{q}|^2)$$

Axial contribution is small for most nuclei, spin-dependent.

It vanishes for nuclei with even number of protons and neutrons

AXIAL CONTRIBUTION

CEvNS cross-section in the SM:

(probability of kicking a nucleus with nuclear recoil energy T)

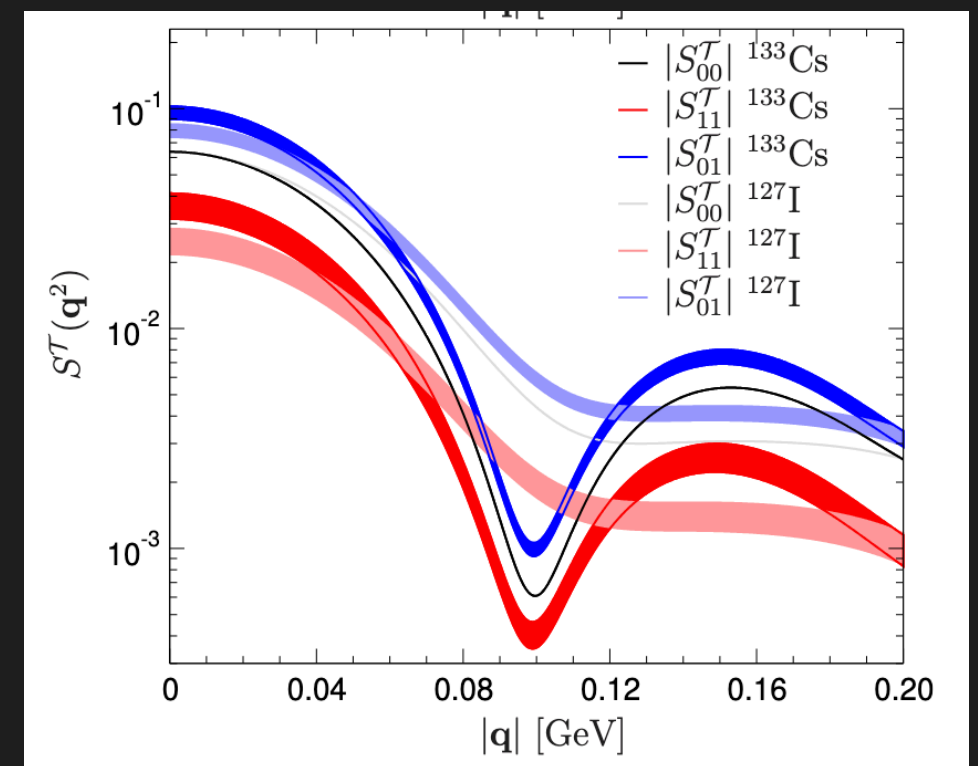
$$\frac{d\sigma}{dT_{\mathcal{N}}} = \frac{G_F^2 m_{\mathcal{N}}}{4\pi} \left(1 - \frac{m_{\mathcal{N}} T_{\mathcal{N}}}{2E_{\nu}^2} - \frac{T_{\mathcal{N}}}{E_{\nu}} \right) Q_W^2 F_W^2(|\mathbf{q}|^2) + \frac{G_F^2 m_{\mathcal{N}}}{4\pi} \left(1 + \frac{m_{\mathcal{N}} T_{\mathcal{N}}}{2E_{\nu}^2} - \frac{T_{\mathcal{N}}}{E_{\nu}} \right) F_A(|\mathbf{q}|^2)$$

$$F_A = \frac{8\pi}{2J+1} \left[(g_A^s)^2 S_{00}^{\mathcal{T}} - g_A g_A^s S_{01}^{\mathcal{T}} + g_A^2 S_{11}^{\mathcal{T}} \right]$$

The different nuclear responses arise from a multipole decomposition of the hadronic current operator.

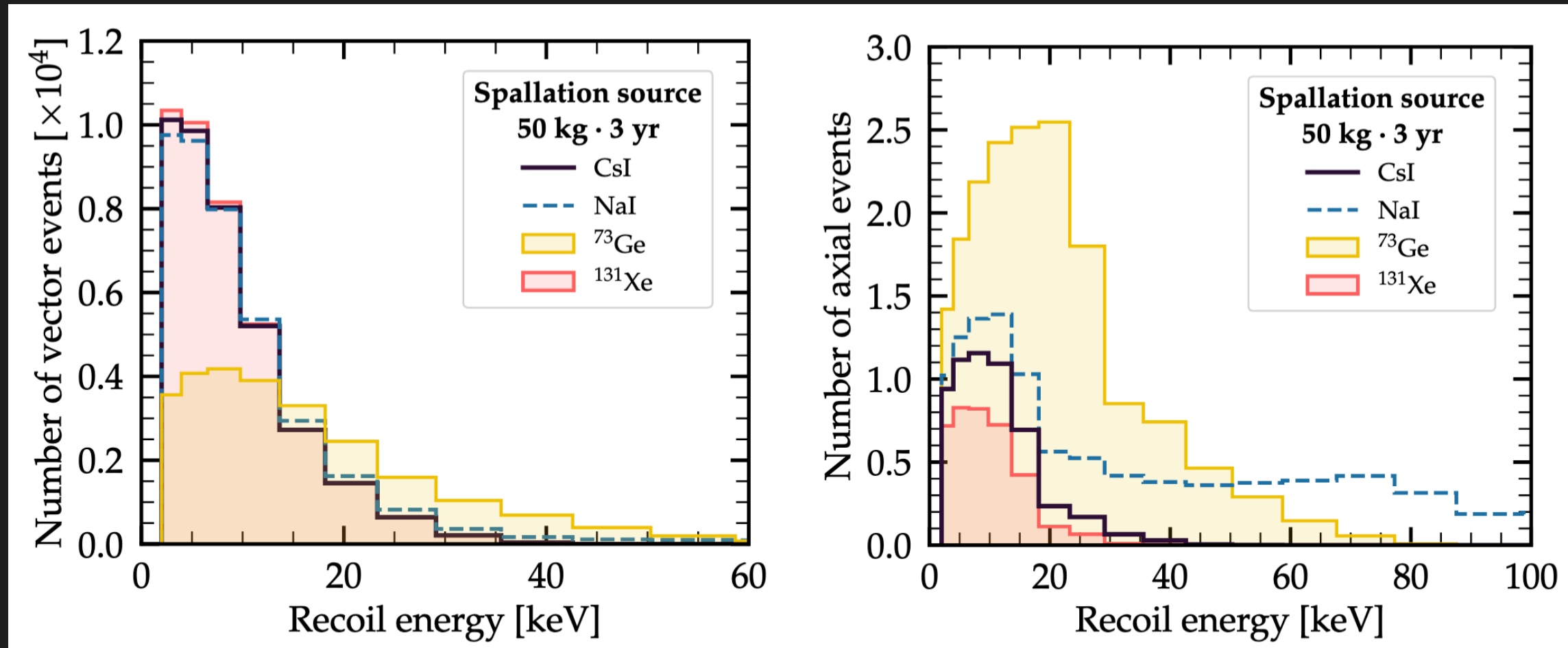
(strong suppression of the longitudinal multipoles)

Transverse SD structure factors for CEvNS



Hofericter+ Phys. Rev. D 102 no. 7, (2020) 074018
Klos+ Phys. Rev. D 88 no. 8, (2013) 083516

AXIAL CONTRIBUTION



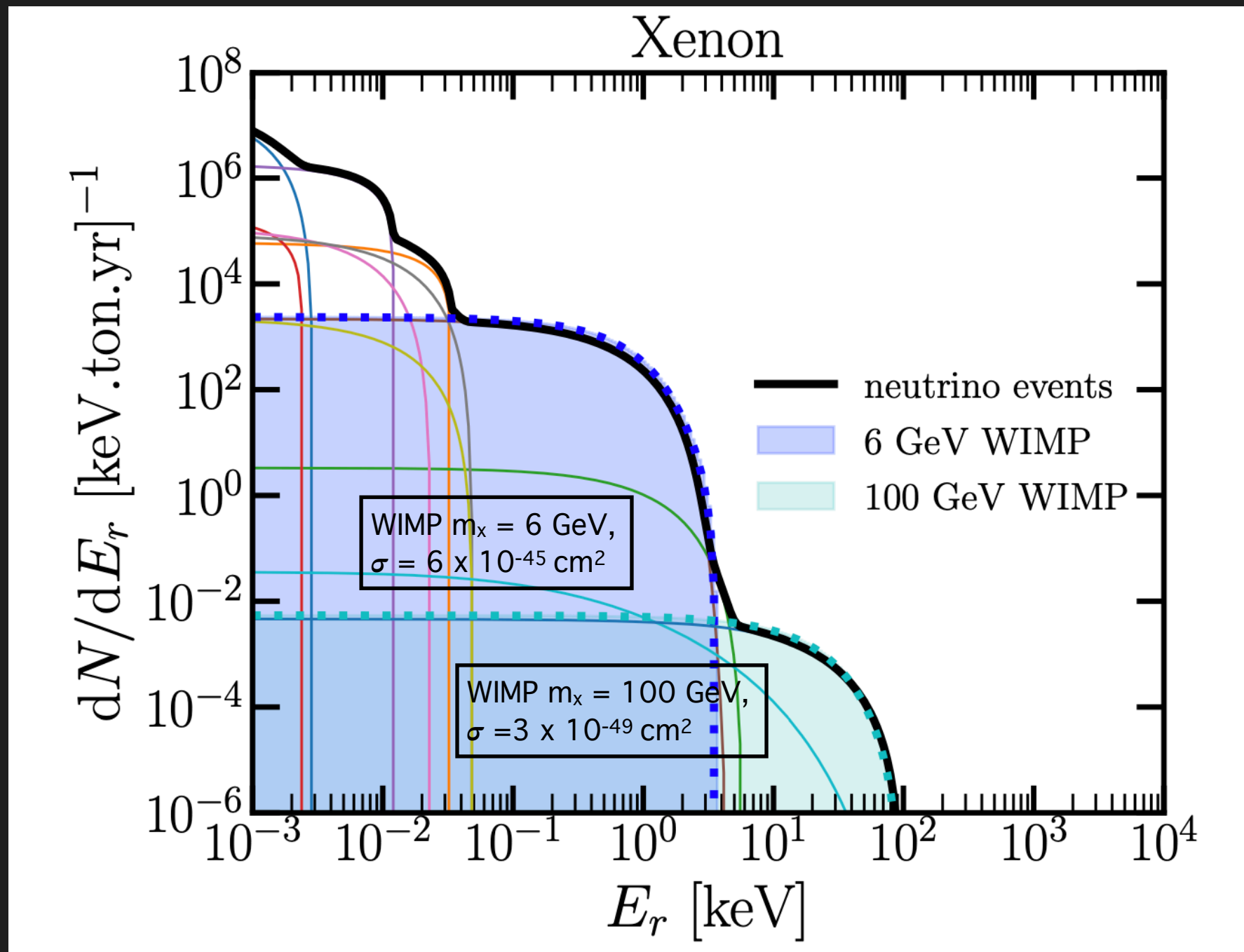
Aristizabal-Sierra, Candela, VDR, Papoulias, Trincado 2603.05281

Component (J^P)	CsI $\left(\frac{7}{2}\right)^+ \left(\frac{5}{2}\right)^+$	NaI $\left(\frac{3}{2}\right)^+$	^{131}Xe $\left(\frac{3}{2}\right)^+$	Xe	^{73}Ge $\left(\frac{9}{2}\right)^+$	Ge
Vector	39176	33944	39773	40018	25967	25752
Axial	5	9	4	4	17	1

We assume a 50 kg fiducial mass detector with a 2 keV recoil threshold and a flat 80% acceptance. Neutrinos are produced via π^+ decay-at-rest.

ASTROPHYSICAL NEUTRINOS

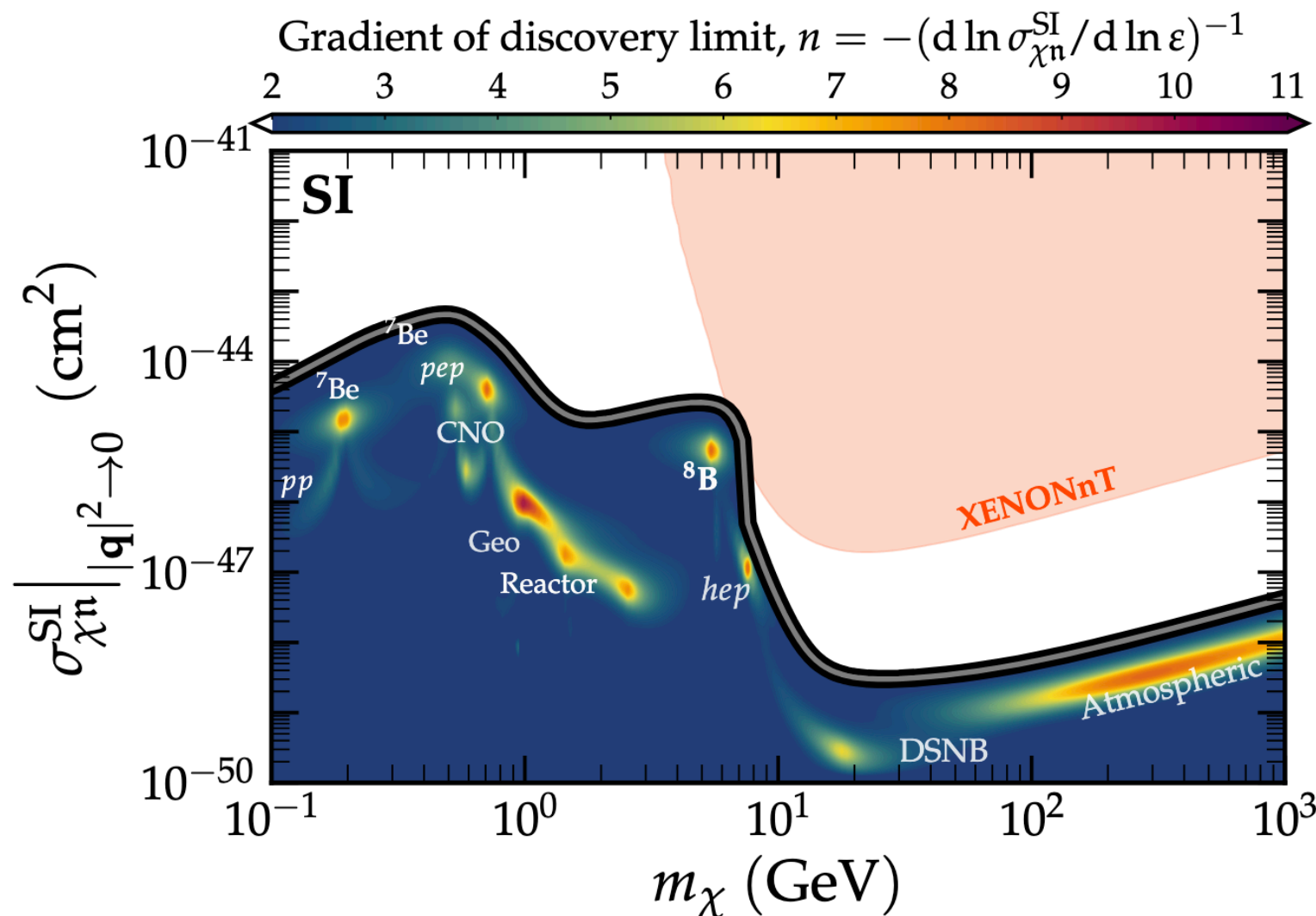
Expected recoil rates from coherent neutrino-nucleus scattering on Xenon:



NEUTRINO FOG (Xe target)

Neutrino “fog” can be quantified by looking at the scaling of sensitivity. Defines how badly the CEvNS background slows progress through DM parameter space.

O’Hare Phys. Rev. Lett. 127, 251802 (2021)



VDR, Anirban Majumdar, D. K. Papoulias, R. Srivastava, 2512.08853

Neutrino fog opacity:

$$n = - \left(\frac{d \ln \sigma_{\chi n}}{d \ln \epsilon} \right)$$

n=2 Poissonian bckg subtraction

n>2 worse than Poissonian

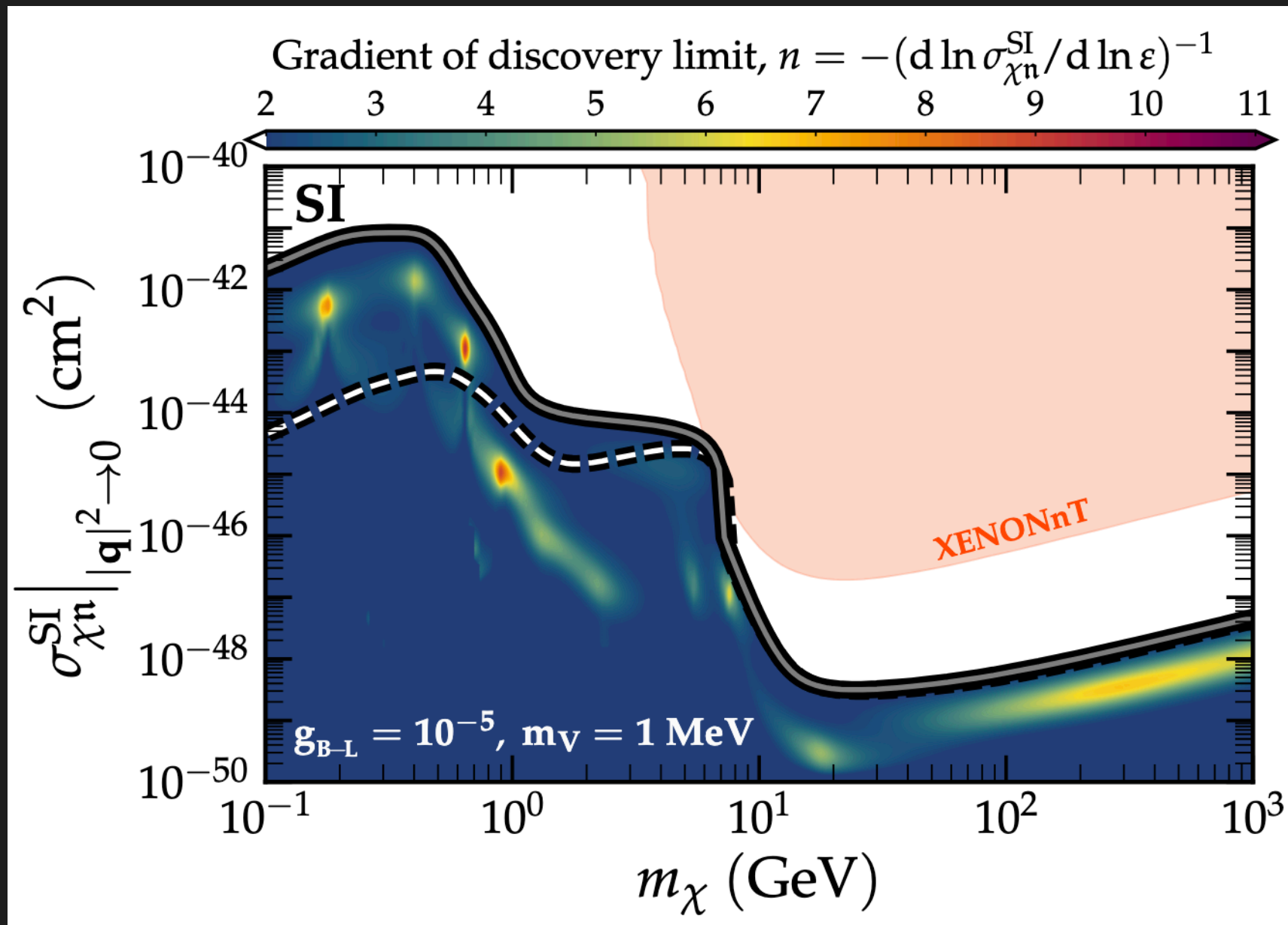
Index n: how fast we can improve upon background

Obtaining a 10 times lower cross section sensitivity requires at least 10^n more exposure.

NEUTRINO FOG: LIGHT MEDIATORS

Orange exclusion area in light of XENONnT 2024 data

E. Aprile et al. (XENONnT)
PRL 133, 191002 (2024)
PRL 134 no. 11, (2025) 111802

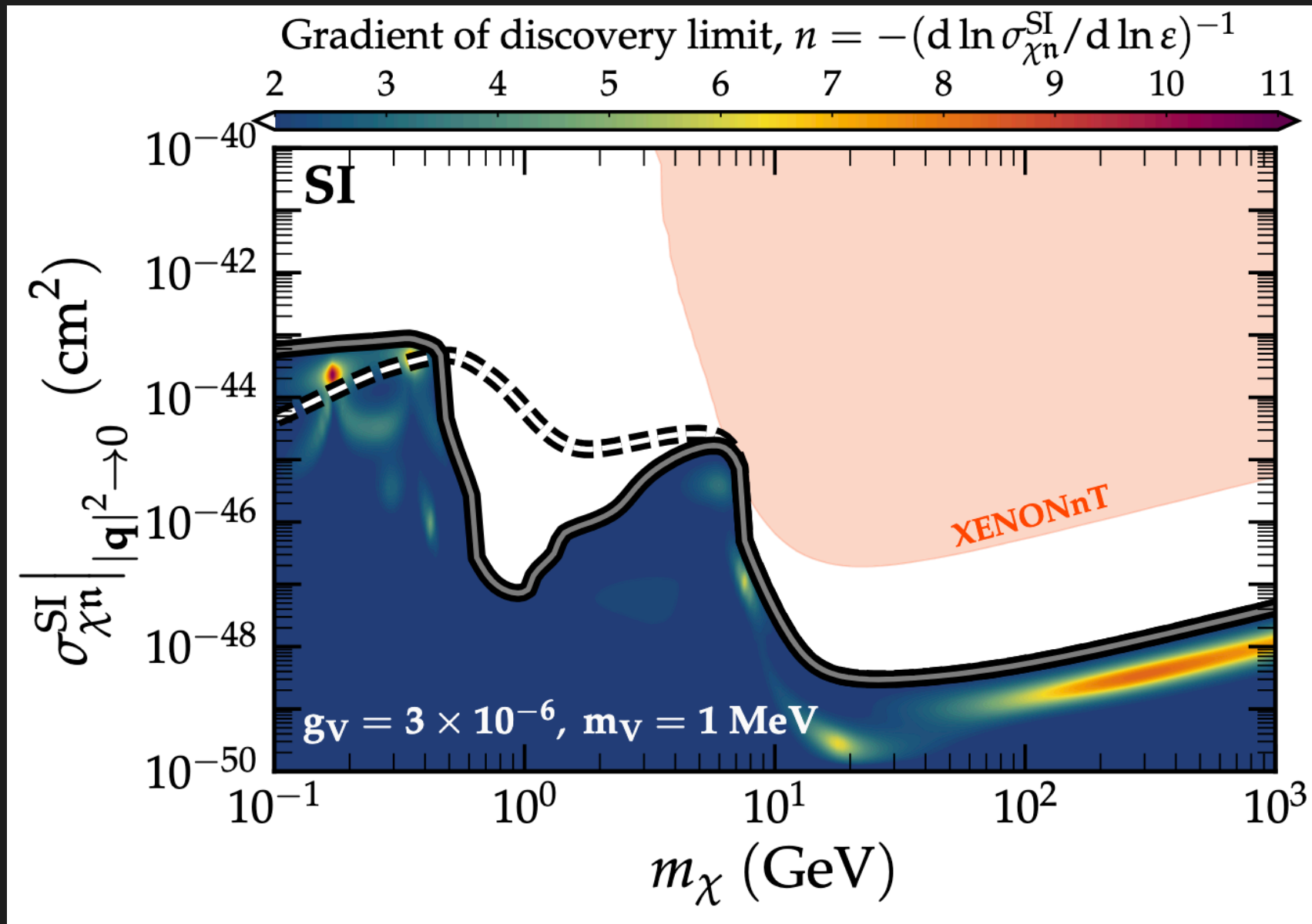


A light vector mediator with B-L couplings in the CEvNS interaction worsen the discovery reach of a Xe detector at low DM masses.

Previous similar studies:
Aristizabal-Sierra+ JHEP 03 (2018) 197
Bertuzzo+ JHEP 04 (2017) 073
Aristizabal-Sierra, VDR+ JCAP 01, (2022) 055
...

VDR, Anirban Majumdar, D. K. Papoulias, R. Srivastava, 2512.08853

NEUTRINO FOG: LIGHT MEDIATORS



VDR, Anirban Majumdar, D. K. Papoulias, R. Srivastava, 2512.08853

A light vector mediator with **universal couplings** in the CEvNS interaction also worsen the discovery reach of a Xe detector at low DM masses; at intermediate masses, **destructive interference** with the SM contribution is possible.

