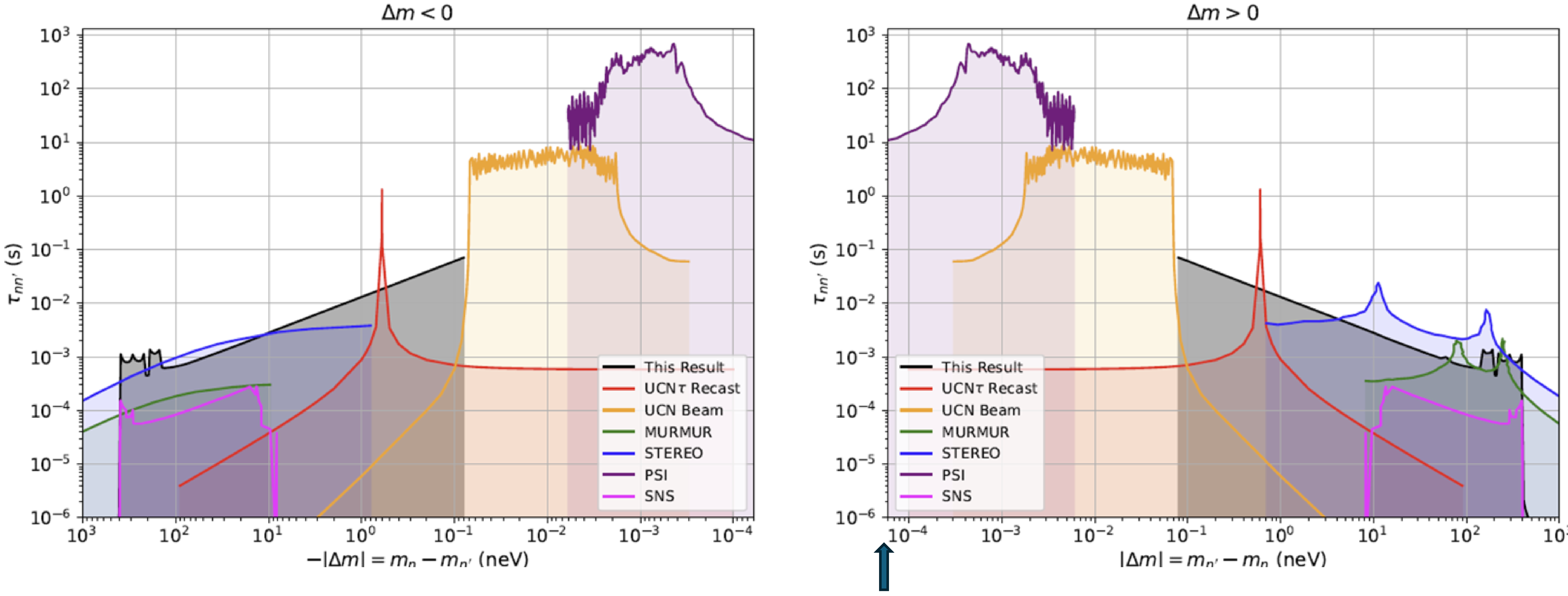
NN’ ORNL-UT-LU Zoom meeting • May 019, 2026

Agenda

1. Yuri - 10' New recent published papers on n-n'
2. Yuri - 10' Calculations to be done for the new PRD paper (was discussed at the last meeting)
3. John, Shaun, Yuri - 15' discussion of the pressure system for nTMM runs in fall 2026
4. AOB

Our new PRD plot for tau(nn') vs Δm (Nathan)



6×10^{-14} eV

Statistical reach of Neutron Electric Dipole Moment Experiments to Neutron to Mirror-Neutron Oscillations

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Baryogenesis requires baryon number violation. Certain extensions to the Standard Model have proposed the existence of an exact, but parity-conjugated, copy of the ordinary elementary particles called *mirror* particles. Several experiments have been conducted to search for $n - n'$ oscillation, a baryon number violating process, and have imposed very strong constrains on its parameters. Recent analyses of some of these experiments have identified anomalies that could suggest the detection of $n - n'$ oscillation. Neutrons, owing to their large magnetic moment, precess upon the application of a magnetic field, and similarly, its mirror counterpart is also affected by the mirror magnetic field. Previous attempts to search for $n - n'$ oscillation have involved (i) disappearance experiments, which isolated the magnetic field dependent loss channel in ultracold neutron storage or transport, (ii) reappearance experiments, which have searched for magnetic field dependent regeneration of neutrons across a barrier, that could only be traversed by a state invisible to the fundamental forces of the standard model, like the mirror neutron, and (iii) by studying the variations in the precession frequency of polarized neutrons upon flipping the direction of the applied magnetic field, which is precisely measured by experiments searching for neutron electric dipole moment. In this work, we have presented the statistical sensitivity increase for neutron electric dipole moment measurement based search for $n - n'$ oscillation by over an order of magnitude compared to [Symmetry 14, 487 (2022)], $\tau_{nn'}^{\text{(stat. sens.)}}/\sqrt{\cos(\beta)} \gtrsim 65$ s ($0.36\ \mu\mathrm{T}' < B' < 1.01\ \mu\mathrm{T}'$), at 95% C.L., where β is a fixed angle between the ambient mirror magnetic field and the applied magnetic field, as would be the case if the ambient mirror magnetic field has terrestrial origins. Furthermore, we have for the first time, also presented the statistical sensitivity for modulations of the difference in the precession frequency, upon flipping the direction of the magnetic field, as a means of accessing $n - n'$ oscillations, in the case of a galactic source of ambient mirror magnetic field. This has allowed us to demonstrate a 95% C.L. sensitivity of $\tau_{nn',\Omega_\oplus}^{\text{(stat. sens.)}} \gtrsim 43$ s ($0.36\ \mu\mathrm{T}' < B' < 1.02\ \mu\mathrm{T}'$) and $\tau_{nn',2\Omega_\oplus}^{\text{(stat. sens.)}} \gtrsim 51$ s ($0.36\ \mu\mathrm{T}' < B' < 1.03\ \mu\mathrm{T}'$), with existing data. These constraints could be further improved with the help of the next generation neutron electric dipole moment experiments.

In this work, we have presented the statistical sensitivity increase for neutron electric dipole moment measurement-based search for $n - n'$ oscillation by over an order of magnitude compared to [Symmetry **14**, 487 (2022)]

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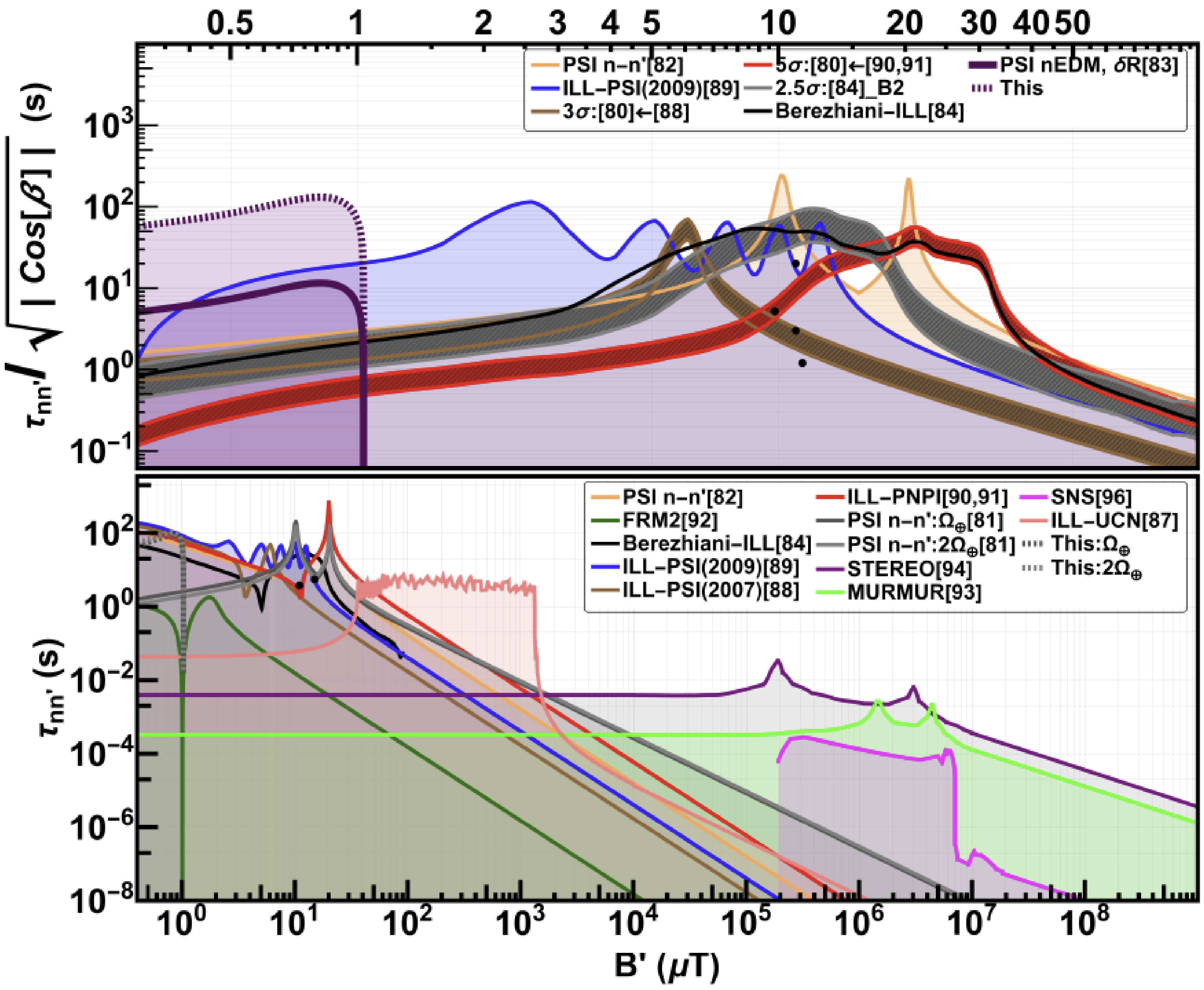
A Search for Neutron to Mirror Neutron Oscillation Using Neutron Electric Dipole Moment Measurements

by Prajwal Mohanmurthy [1,2,*], Albert R. Young [3,4,*], Jeff A. Winger [5] and Geza Zsigmond [6]



Limit for "Δm" ~ $B' < 1\mu T$ ~6×10^{-14} eV

$\tau_{nn'} > 200$ s $\rightarrow$ $\epsilon < 3.3 \times 10^{-18}$ eV

In PDG (Serebrov 2009) at $B' < 0.1\mu T$

$\tau_{nn'} > 448$ s $\rightarrow$ $\epsilon < 1.47 \times 10^{-18}$ eV

Berezhiani claims that $n \rightarrow n'$ role in cosmic rays GZK effect can be essential only if $\tau_{nn'} \lesssim \tau_n = 880\ s$
$\rightarrow$ $\epsilon \gtrsim 7.5 \times 10^{-19}$ eV

2

Neutron portal to ultrahigh-energy neutrinos

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Current data on ultrahigh-energy (UHE) cosmic rays suggest they are predominantly made of heavy nuclei. This indicates that, in the absence of a subdominant proton component, the flux of neutrinos produced from cosmic ray collisions on the cosmic microwave background is small and hard to observe. Motivated by the recent extremely high-energy muon event reported by KM3NeT, we explore the possibility of enhancing the energy-flux of cosmogenic neutrinos through nuclear photodisintegration in the presence of new physics. Specifically, we speculate that UHE neutrons may oscillate into a new state, dark (or mirror) neutron n' that in turn decays injecting large amount of energy to neutrinos, $n \to n' \to \nu_{\mathrm{UHE}}$. While this mechanism does not explain the tension between the KM3NeT event and null results from IceCube, it reconciles the experimental preference for a heavier cosmic ray composition with a large diffuse cosmogenic flux of UHE neutrinos.

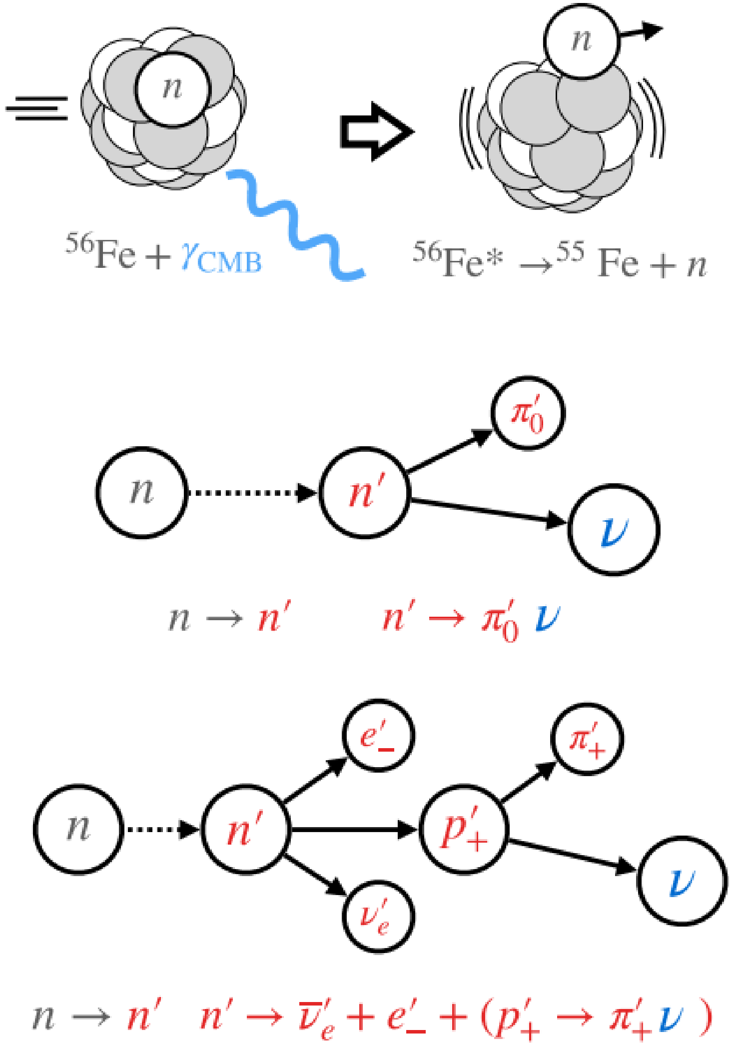


FIG. 1. The photo-disintegration process of an iron UHE cosmic ray (top). We also show the $n \to n'$ oscillation with two options for subsequent mirror-baryon decays: $n' \to \pi_0'\nu$ (middle) or n' beta-decay followed by $p_+' \to \pi_+'\nu$ (bottom).

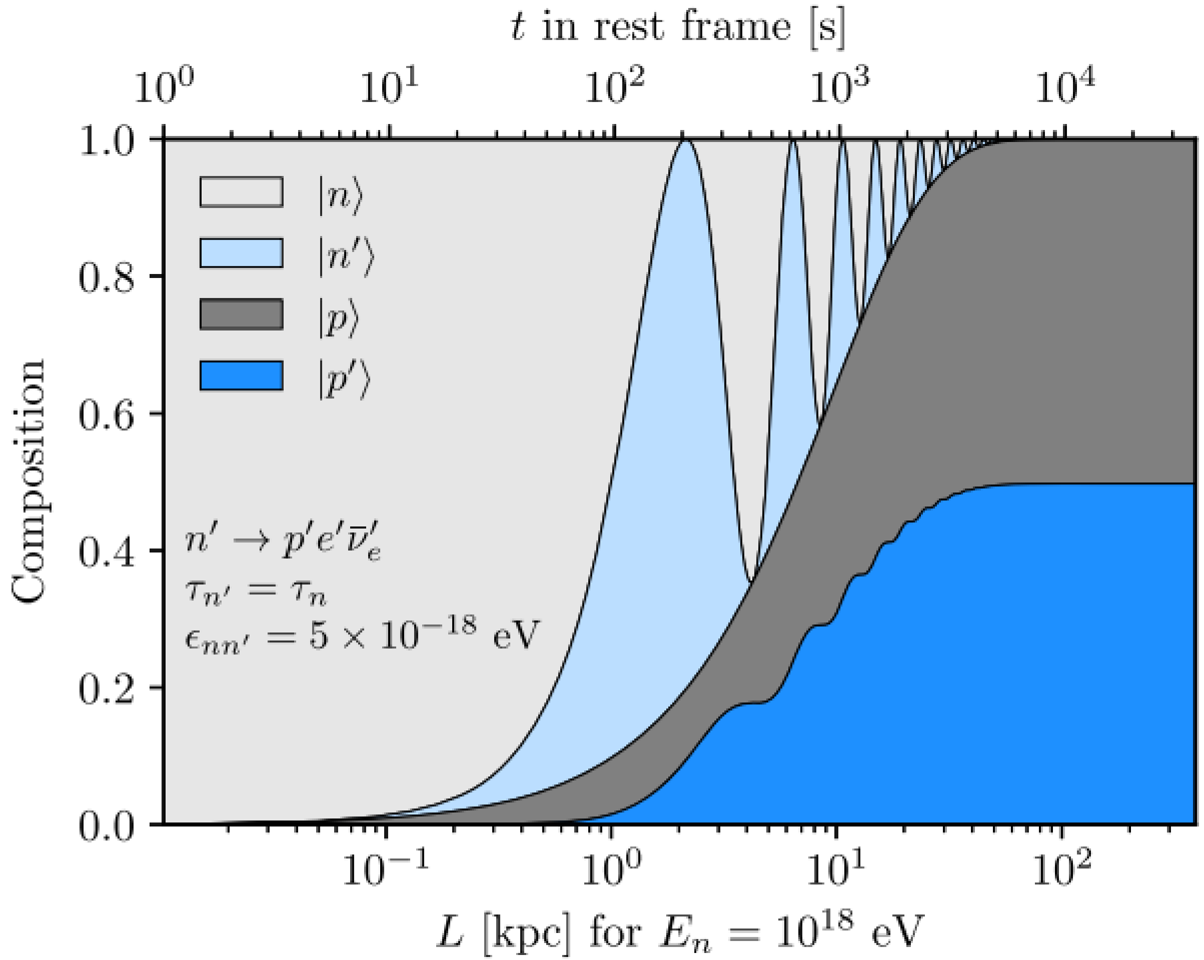
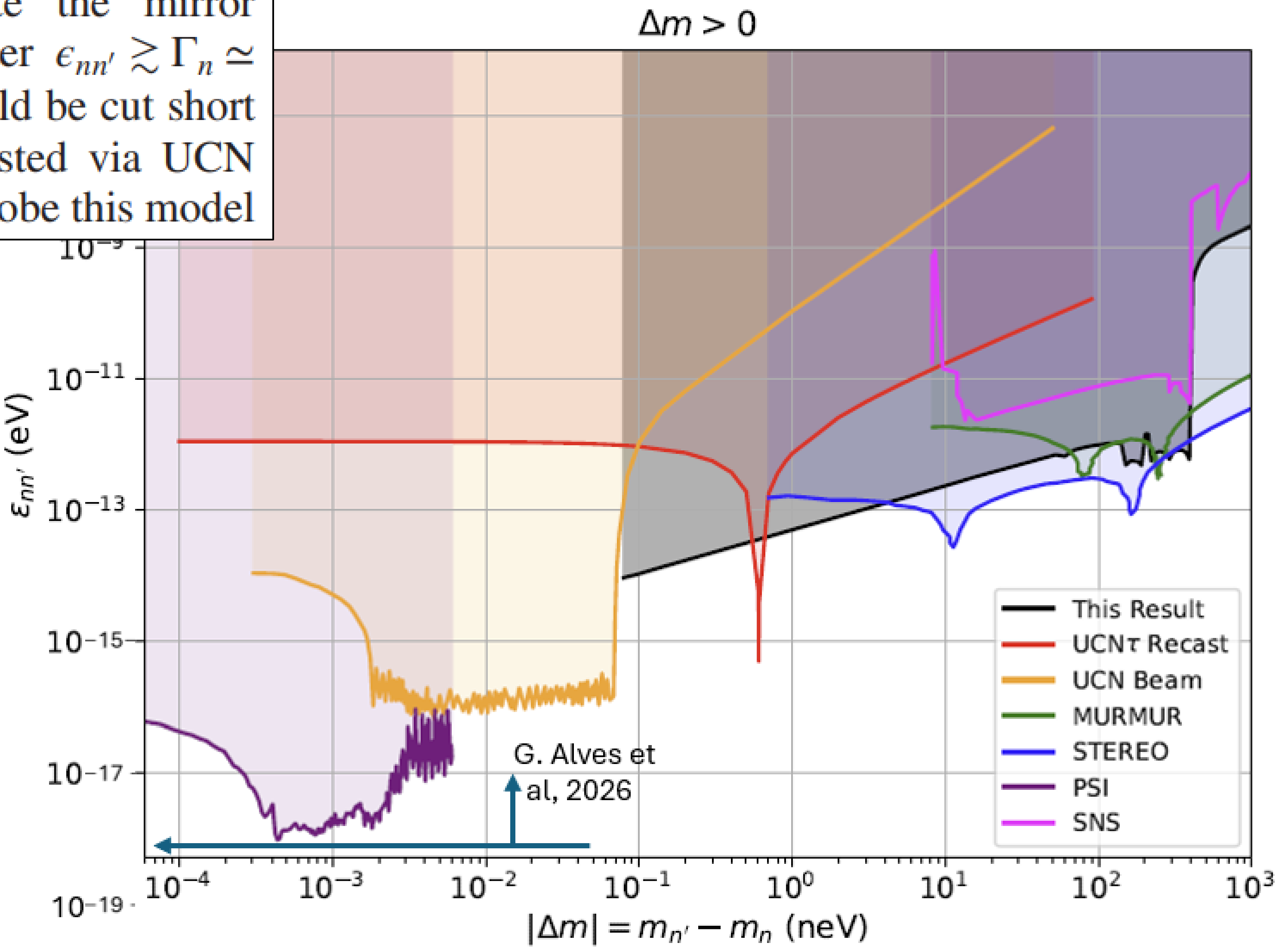


FIG. 2. The time dependence of a system initialized as a neutron with $E = 10^{18}$ eV in terms of its fractional composition (stacked). Here, $|p'\rangle = |\pi_0'\nu\rangle$ or $|p'\rangle = |p'e'\bar{\nu}_e'\rangle$ is the daughter state produced by n' decays.

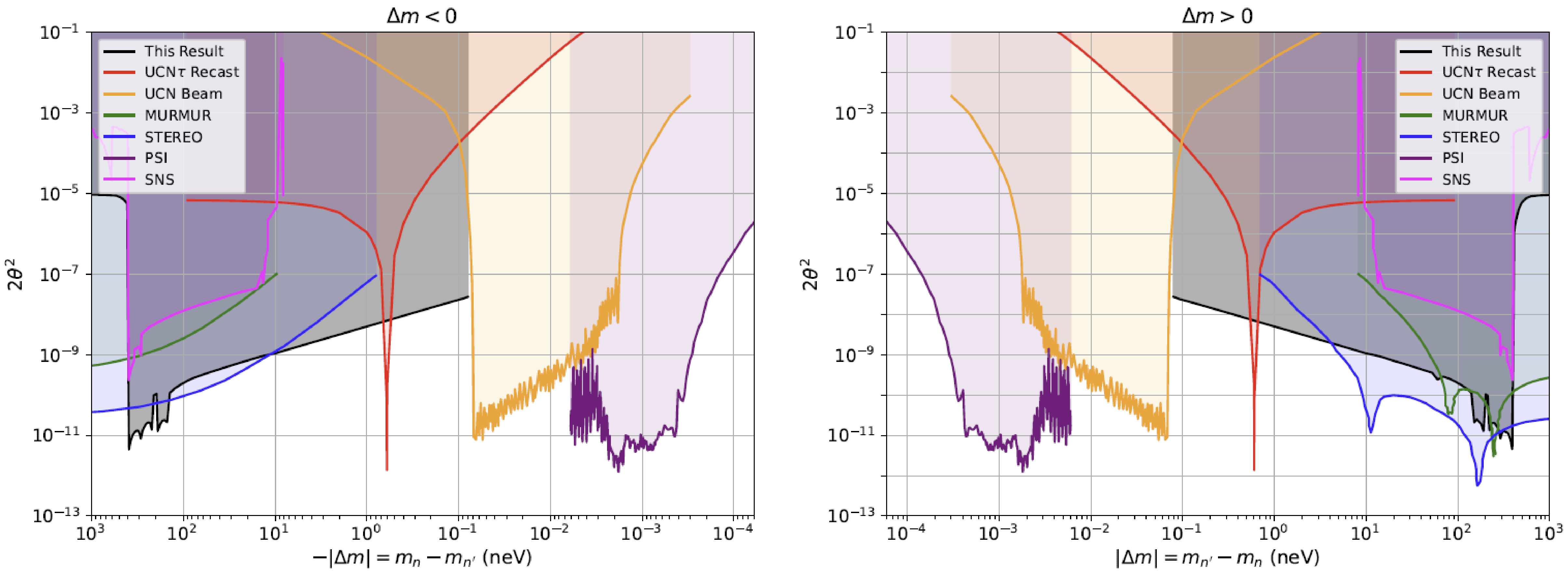
In conclusion

For oscillations to efficiently populate the mirror sector, the $n - n'$ mixing must be of order $\epsilon_{nn'} \gtrsim \Gamma_n \simeq 7.5 \times 10^{-19}$ eV, otherwise, oscillations would be cut short by neutron decay. This can be directly tested via UCN disappearance searches, offering a way to probe this model

Nathan' recent plot



Nathan' recent plots



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Agenda

1. GP-SANS beam time in the second half of 2026 approved

2. Yuri - Discussion of preparation of paper for publication

nTMM Run 2026

Proposal #: IPTS-37490.1
Title: Search with GP-SANS for the Neutron Transition Magnetic Moment
Days Awarded: Up to 4 day(s)
Instrument: CG-2 GP-SANS

We are pleased to inform you that the above proposal has been approved for beam time in the 2026-B cycle at the HFIR, contingent upon scheduling. The anticipated scheduling period for this award is July - December 2026...

In the new paper for PRD in Figure 8 dashed lines correspond to measured excluded probability

Would we have background-less detector
this plot could be used with dashed lines

PRL (2022) 1.2×10^{-2}
PRD (2024) 3×10^{-3}
NOW(2026) 2×10^{-3}

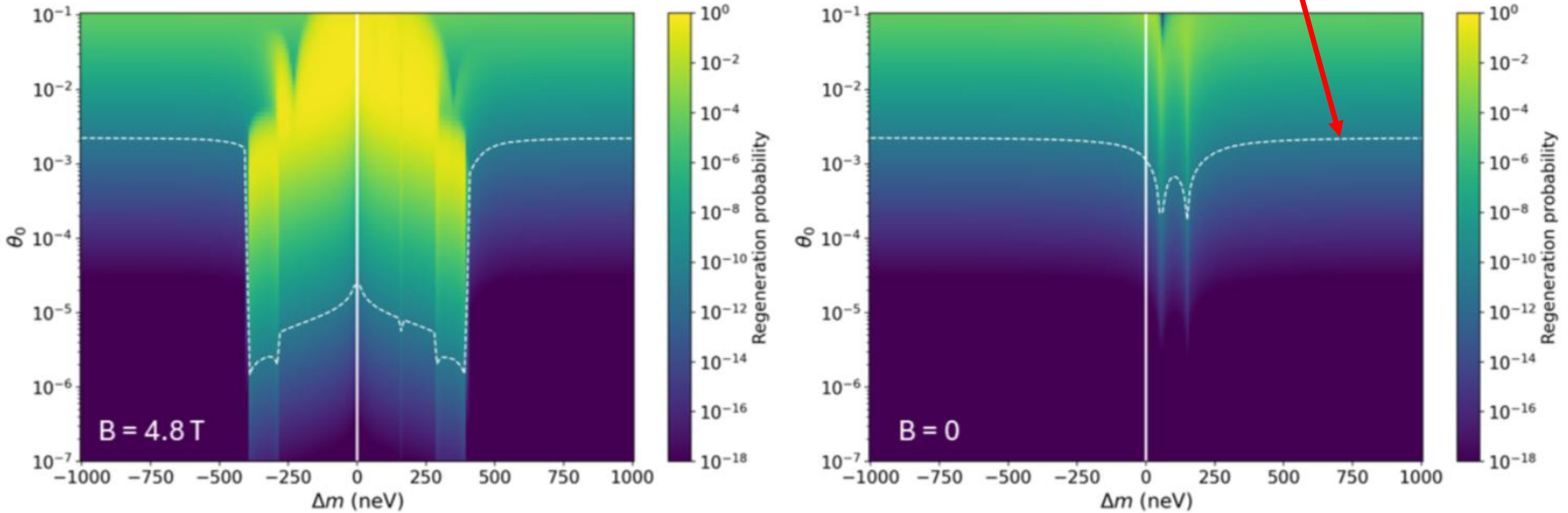
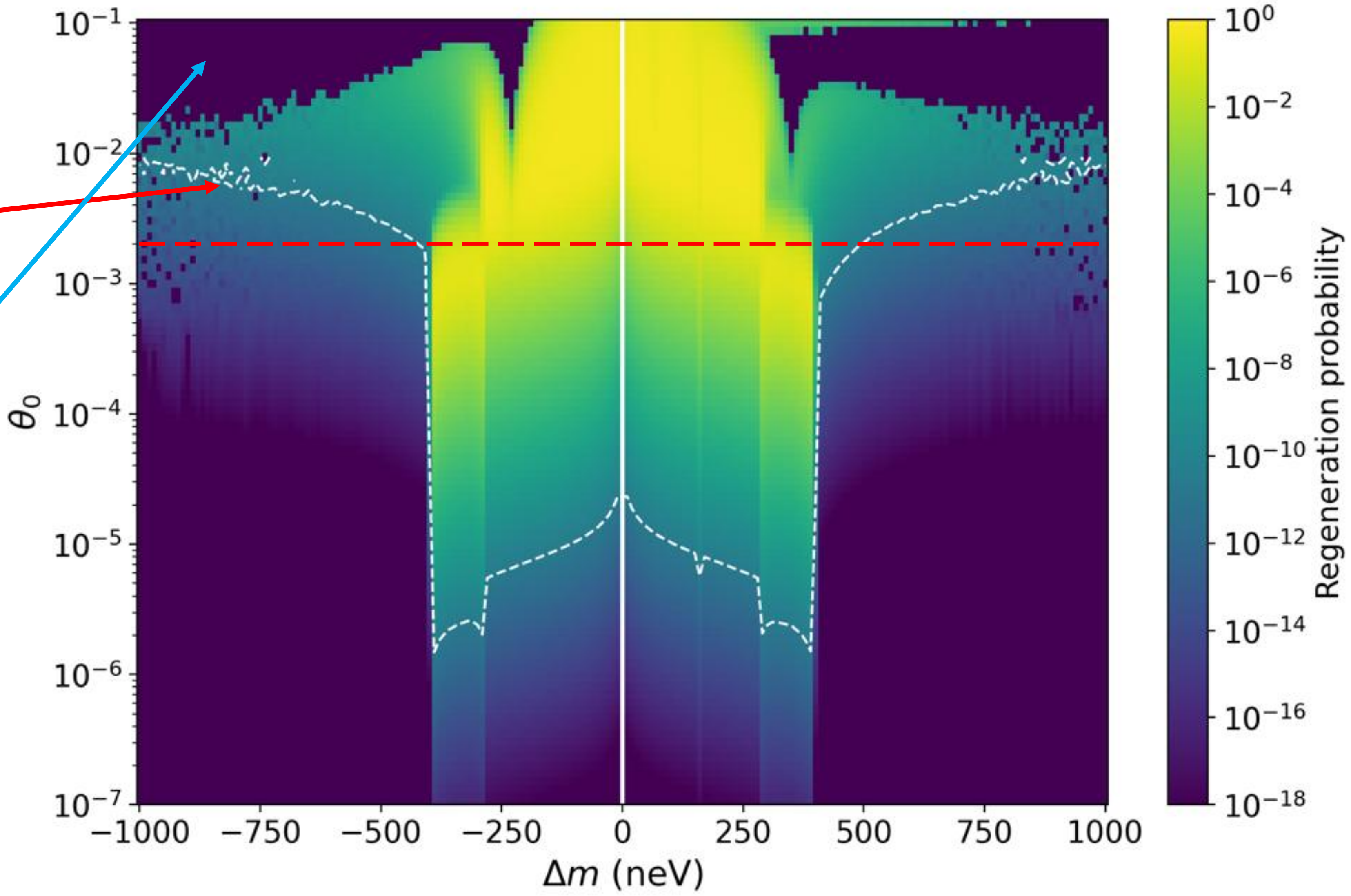


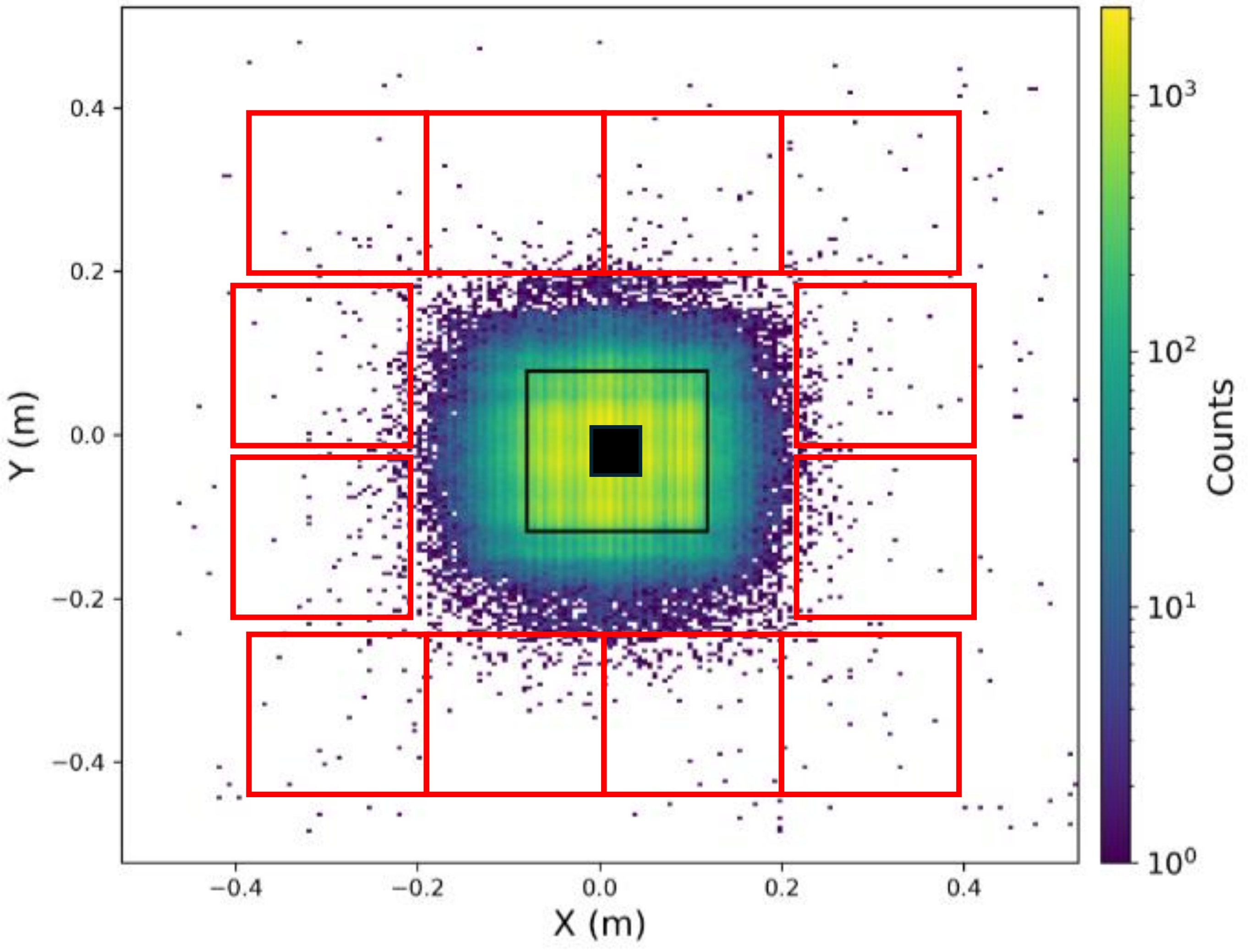
FIG. 8. Calculated regeneration probability ($n \to n' \to n$) as a function of the Δm mass difference and the mixing angle θ_0. Central vertical lines separate two regions in from 10 neV to 1000 neV for negative and positive Δm. Left panel shows the map of probability for 4.8 T magnetic field configuration. Right panel is for "zero" magnetic filed. See discussion in the text. [No dashed lines should be here!] (color online).

- Experimentally we subtract runs with B=0 as a background
- If we do that in simulation as "B=4.8 T" – "B=0" then
  (a) large $\Delta m > 400\ neV$ limits are weaker
  (b) The origin of the dark zones where "B=0" > "B=4.8T" need to be understood, it is not an error, but an effect. The Understanding of this effect is outside the scope of this paper.
- we can restore the limits at large $\Delta m > 400\ neV$ (and may even improve that) by adding analysis of B=0 runs
- No simulation re-running will be needed.



What can we do to improve large Δm limits?

- in 2024 data we have 37 B=0 runs
- central region of peak in ROI to be removed
- for each run we can define 12 aux. ROIs
- the background of 12 ROIs can be averaged and rescaled by area to central ROI (- peak)
- # 12 is for study background consistency. Also, 12 can allow interpolation of bkgr if it will be non uniform
- Subtraction of 12 backgrounds should statistically produce small subtraction errors
- 37 measurements of filtered (ROI – bkgr) should have statistically significant better limit for adiabatic $n \to n'$



NW-Fig-9-relative_limits.png

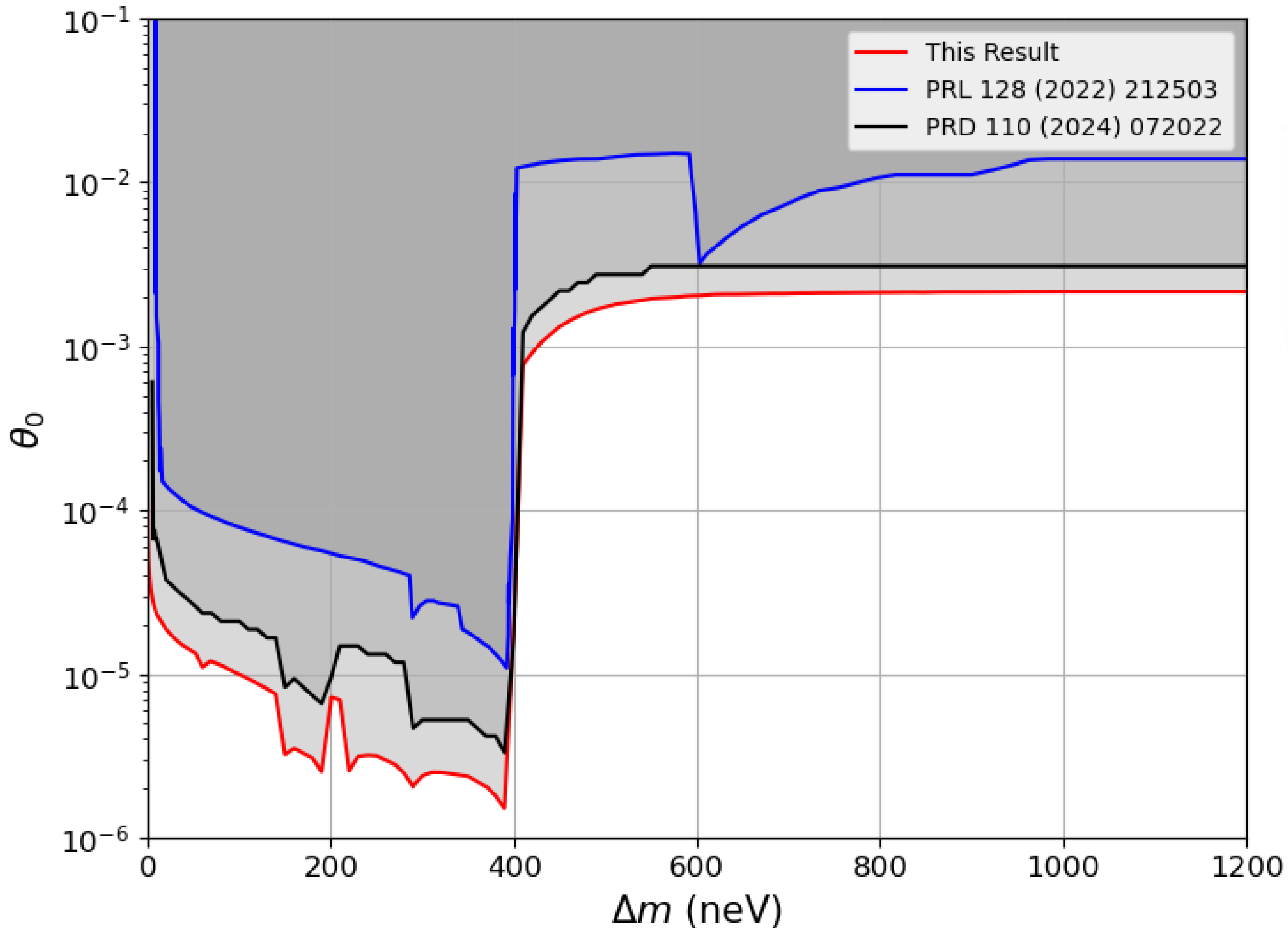


FIG. 9. Comparison of the probability limits of 2 SNS and current HFIR experiments (color online).

PRL (2022) 1.2×10^{-2}
PRD (2024) 3×10^{-3}
NOW(2026) 2×10^{-3}

Table 1

B-Field (T)	Counts, h^{-1}	Signal ($\times 10^{-12}$)	95% CL
2.40	-9 ± 21	-6.34 ± 14.7	2.28×10^{-11}
3.60	13 ± 20	9.1 ± 14.0	3.65×10^{-11}
4.80	-3 ± 20	-2.1 ± 14.0	2.55×10^{-11}
All fields	0.63 ± 12	0.42 ± 8.4	1.69×10^{-11}

at $\Delta m > 600$ neV θ_o is **constant** 2×10^{-3}

$$P_{nn'} = sin^2 2\theta_o \cdot sin^2\,\omega t/\hbar$$

$4\theta_0^2$ $\quad$ $1/2$

Regeneration =

$$=P_{nn'}^2 = 4\theta_0^4 = 6.4\times 10^{-11}$$

compare with

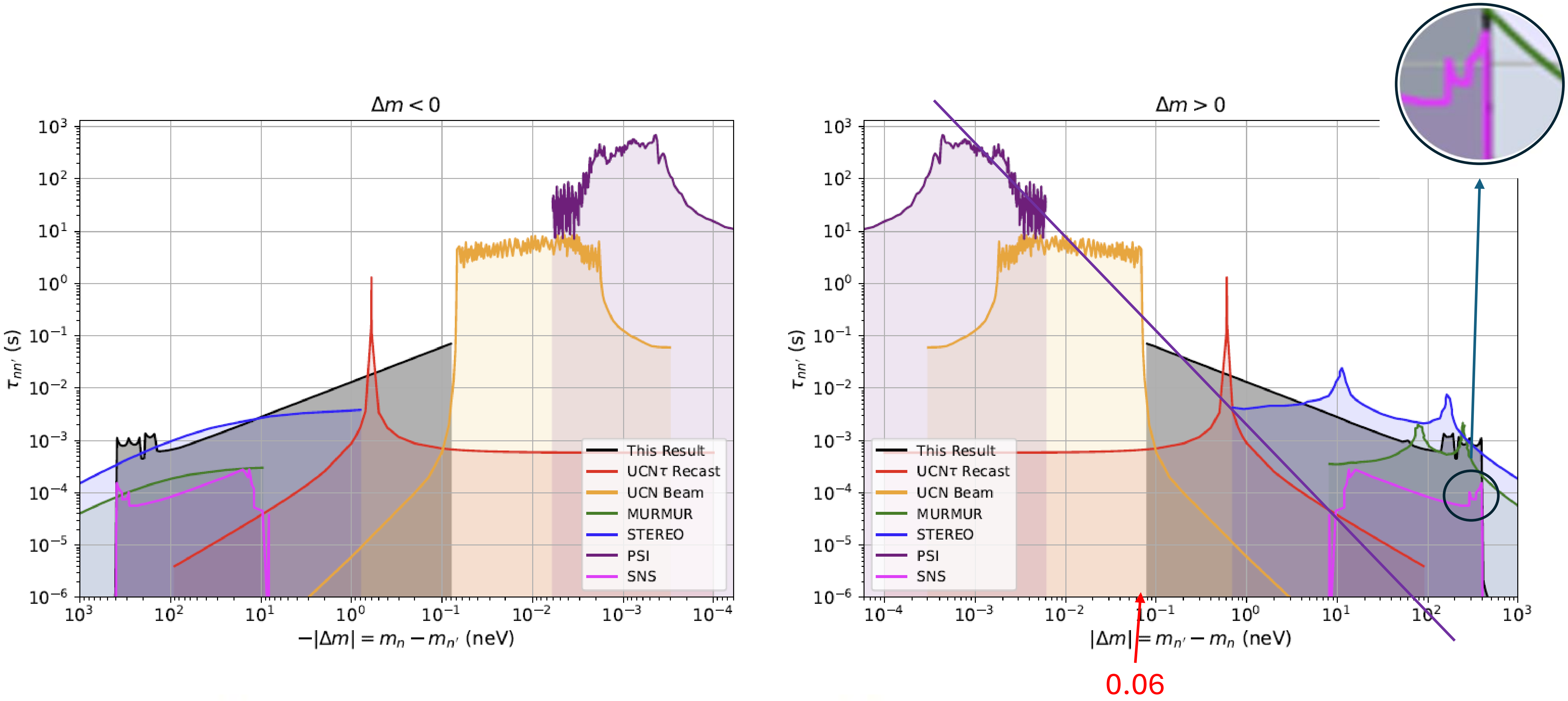


FIG. 10. Summary of most recent $\tau_{nn'}$ limits vs positive and negative Δm range from 6×10^{-5} to 1000 neV. Limits reported in this paper (gray area), overlaid with other searches for sterile neutrons, assuming a unified framework as proposed in [23]. Our previous SNS limits are taken from [4]. Results from UCN storage at PSI [24] have been recast from searches using searches for a nonzero B'. The limit from UCNτ comes from the non-observation of anomalous losses, as calculated in [23]. UCN beam results use disappearance in the GADGET detector [25]. The STEREO and MURMUR reactor results below Δm are also presented from [26, 27]. The UCN $n \to n'$ limits [28] from neutron EDM search apparatus are not shown on this plot.