Neutrino physics at dark matter detectors

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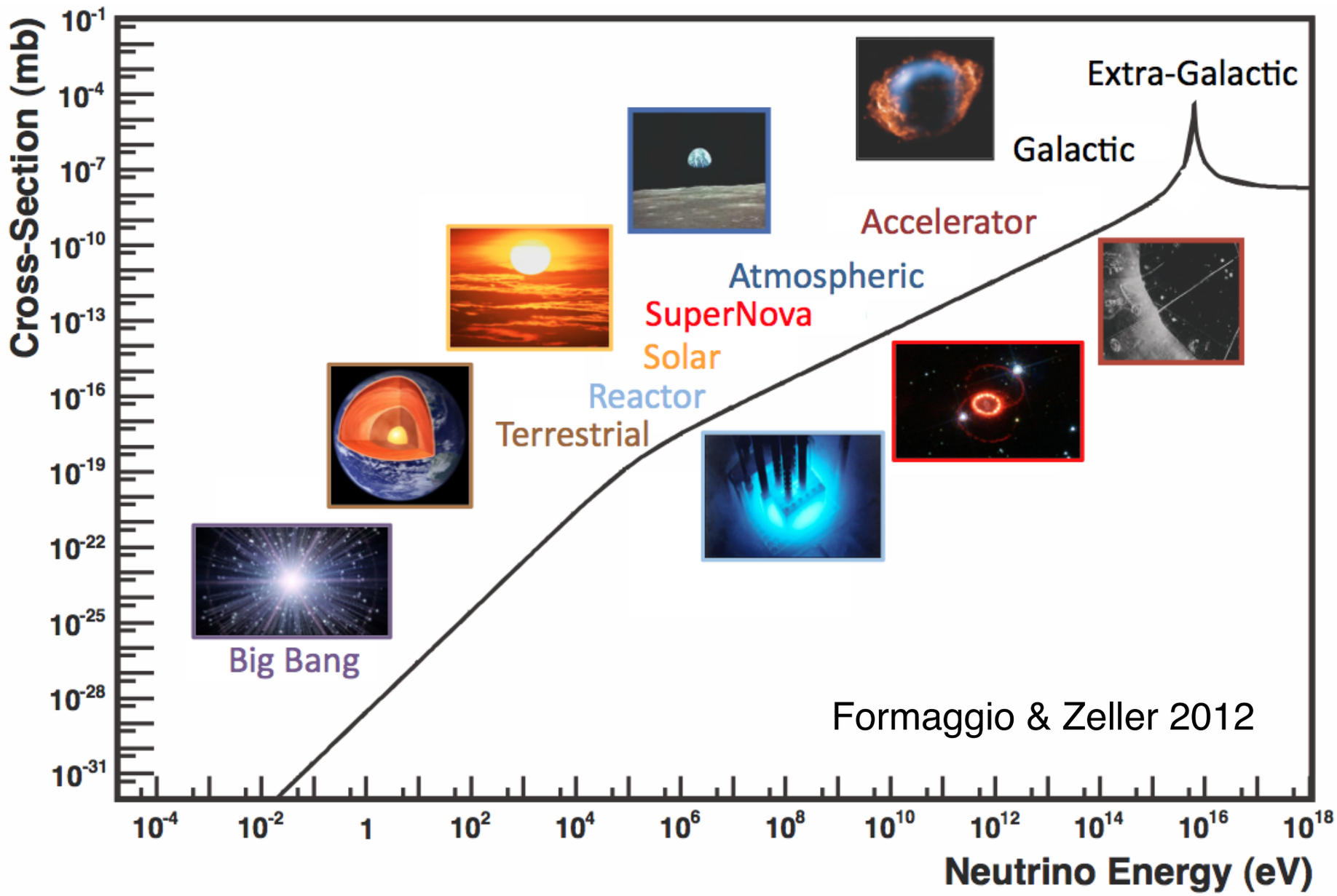
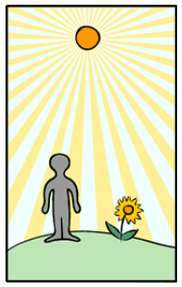
GGI Neutrino Frontiers
July 4, 2024

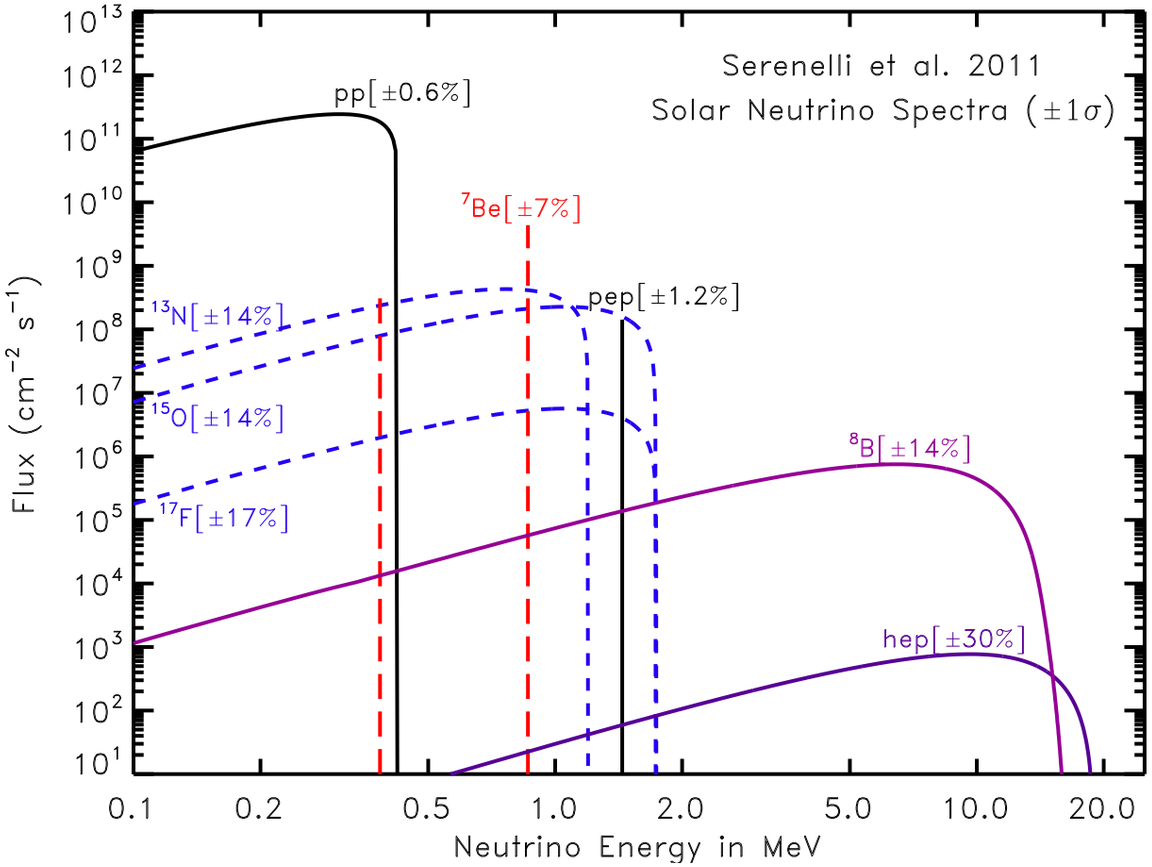
Artwork by Sandbox Studio, Chicago with Ana Kova

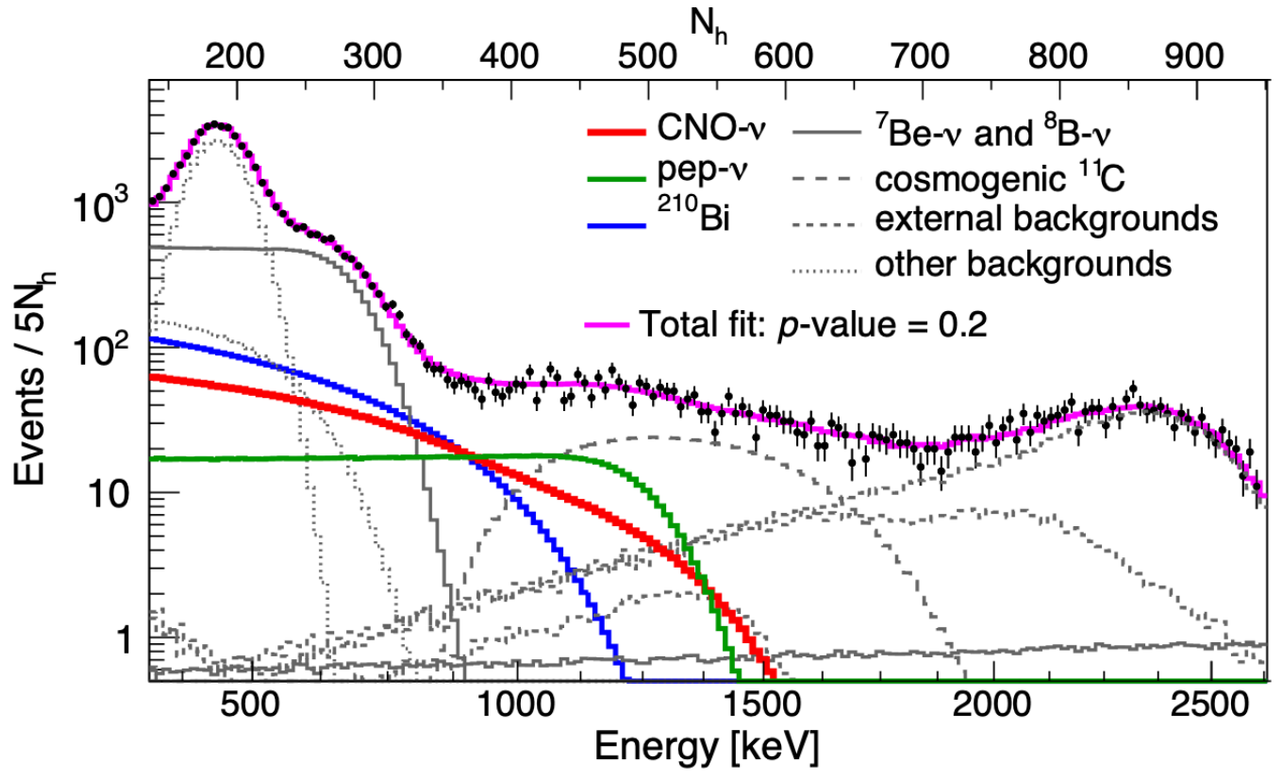
Opportunities for astrophysical and terrestrial neutrino physics



Solar neutrinos



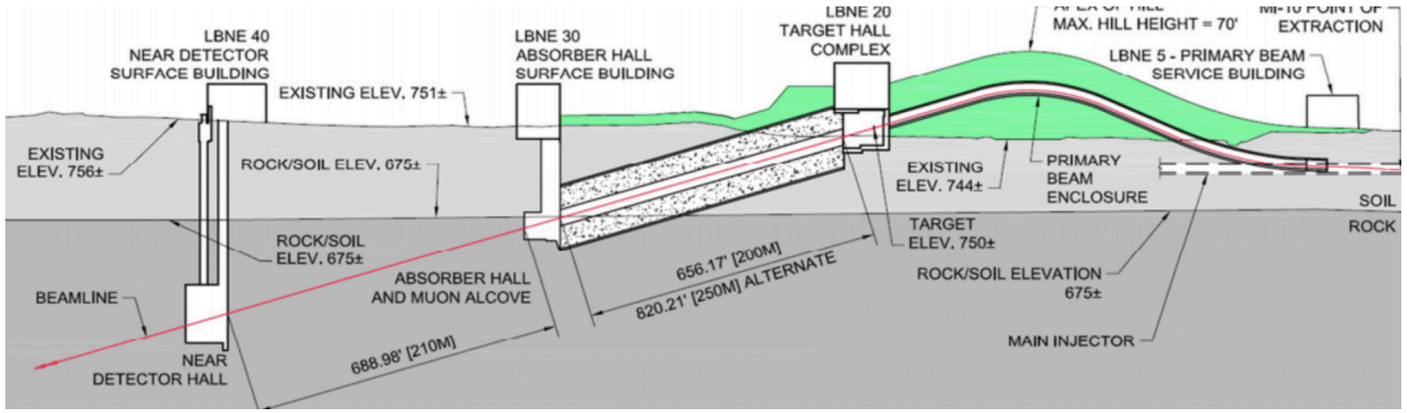




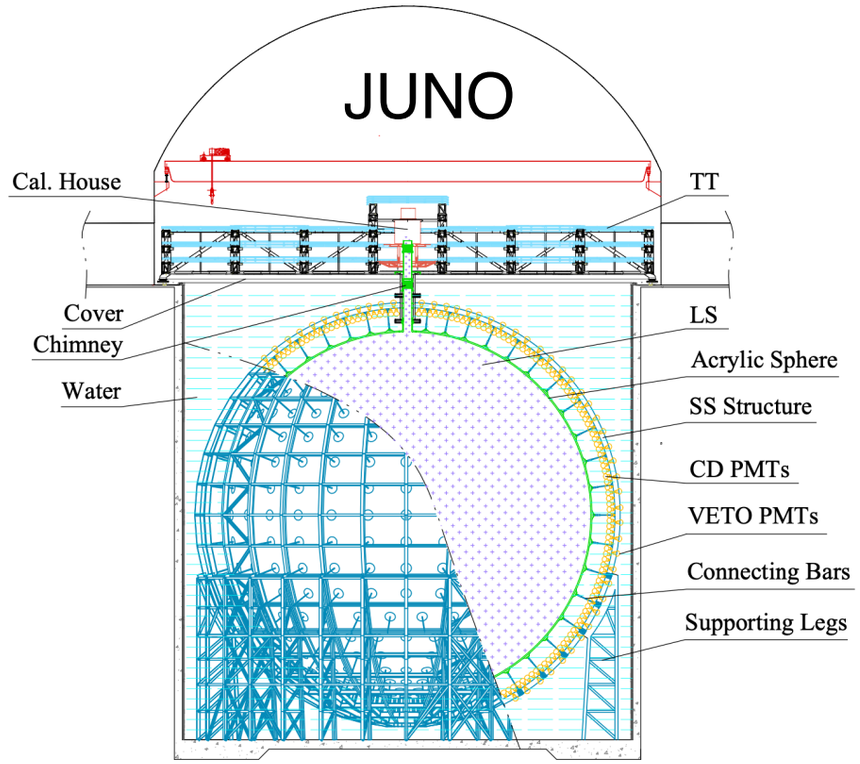
Borexino collaboration 2205.15975

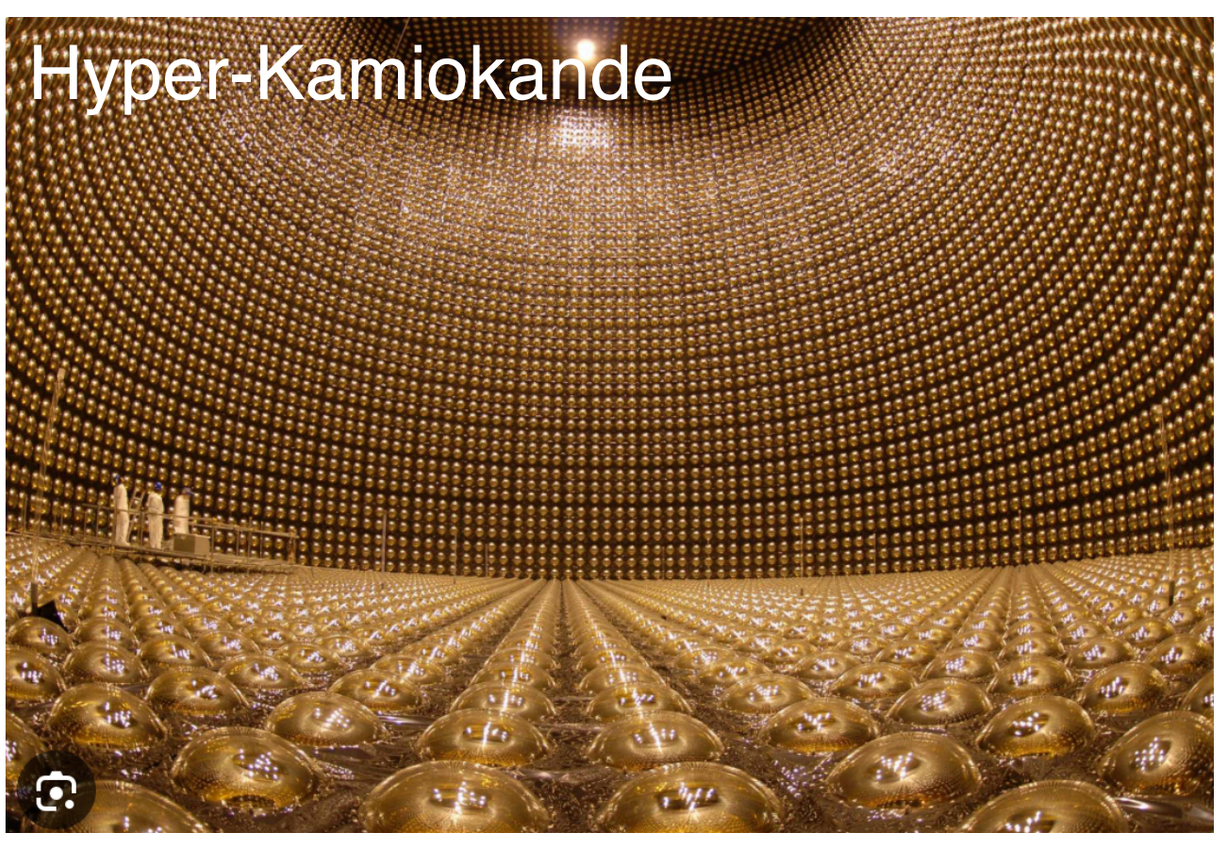
Next generation neutrino detection

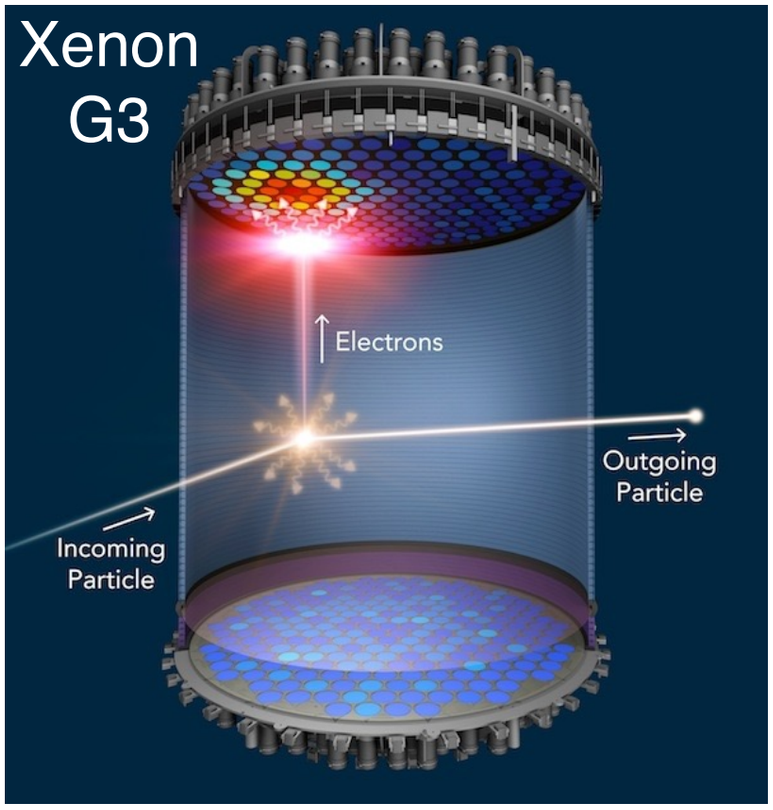
DUNE



JUNO

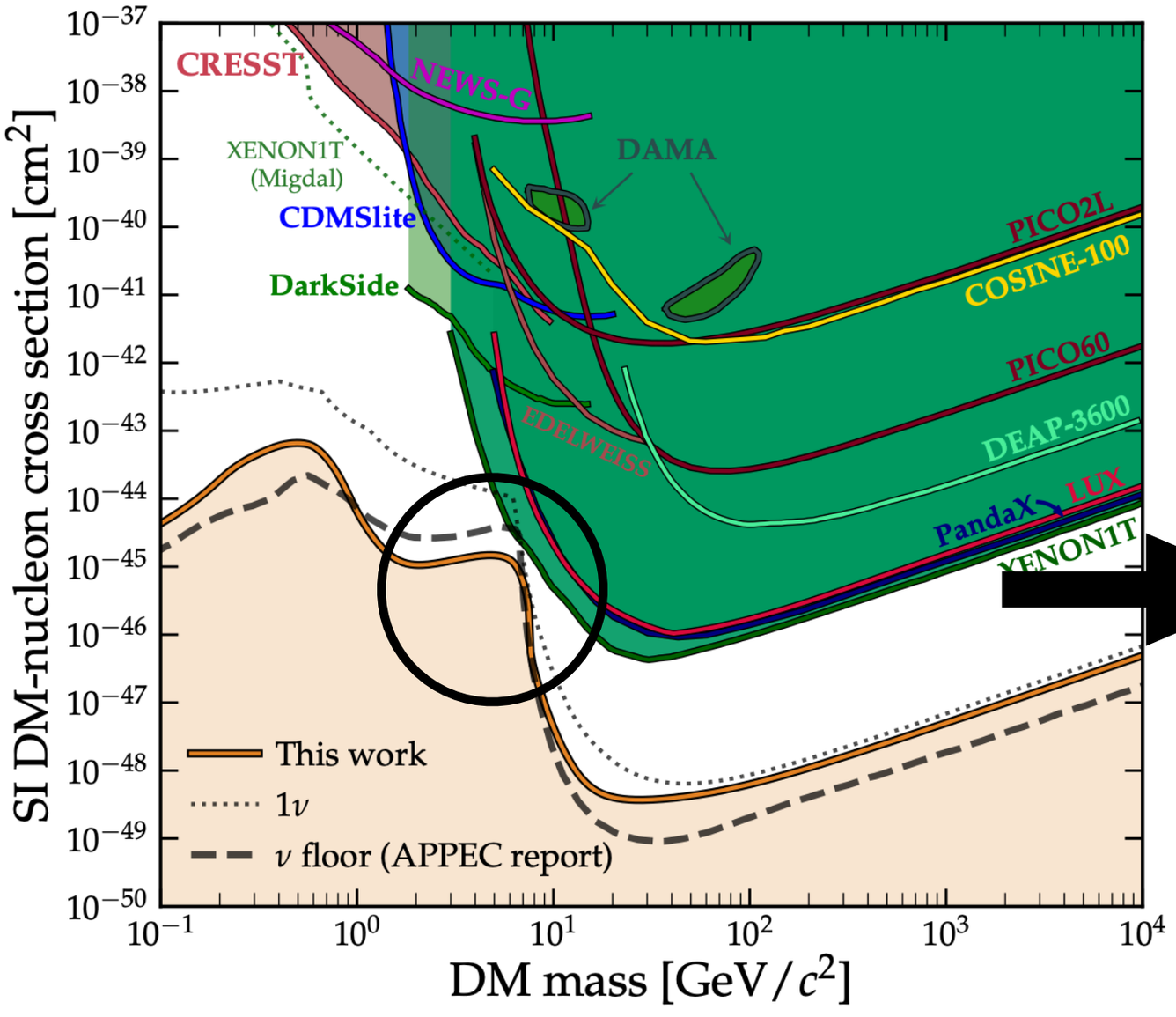


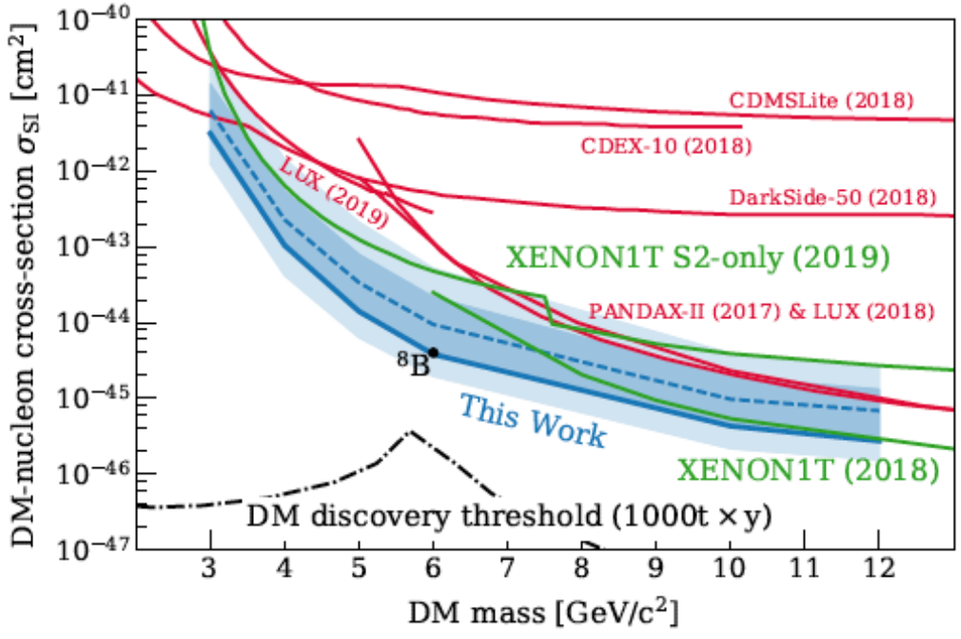




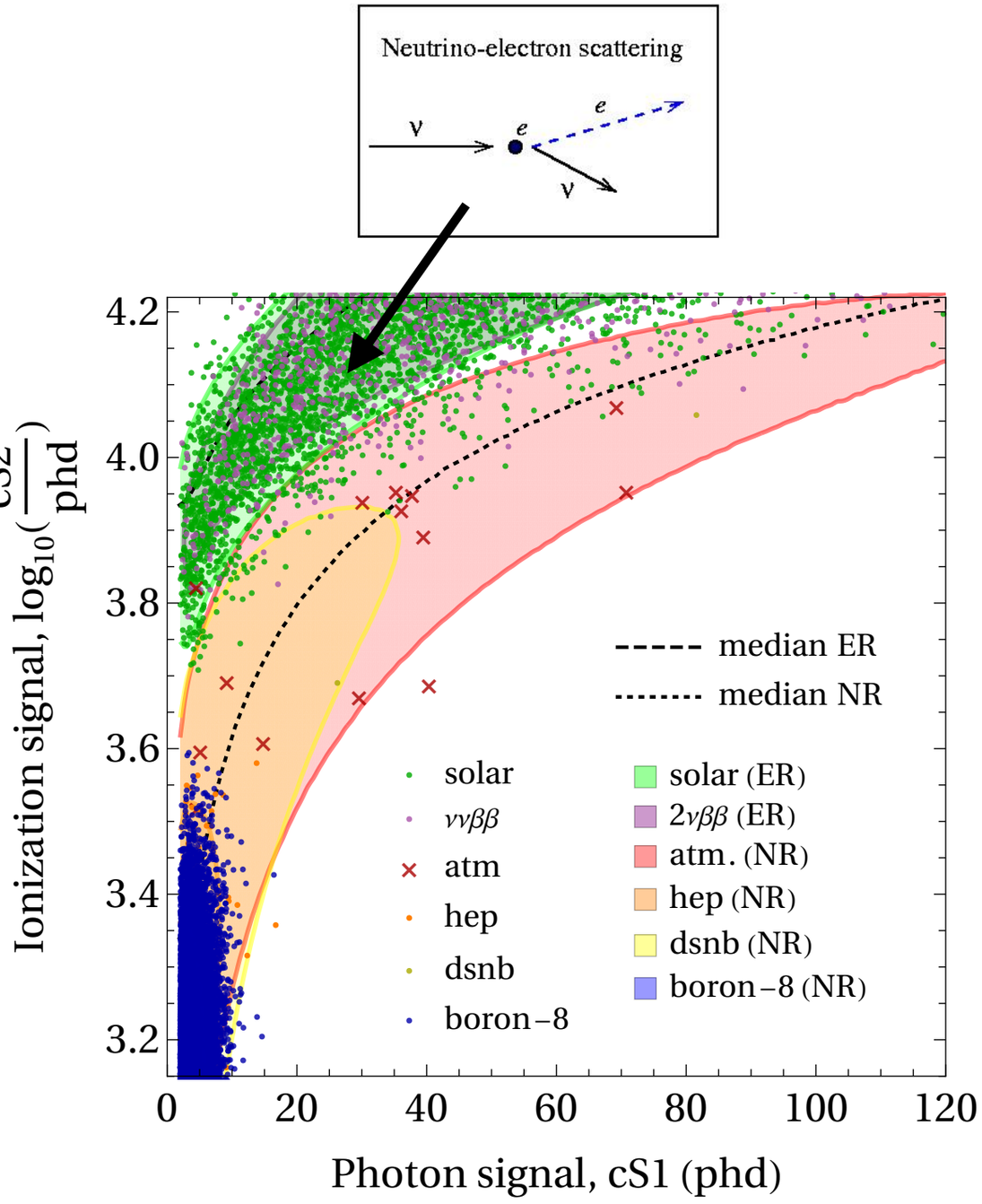
Search for Coherent Elastic Scattering of Solar ^{8}B Neutrinos in the XENON1T Dark Matter Experiment

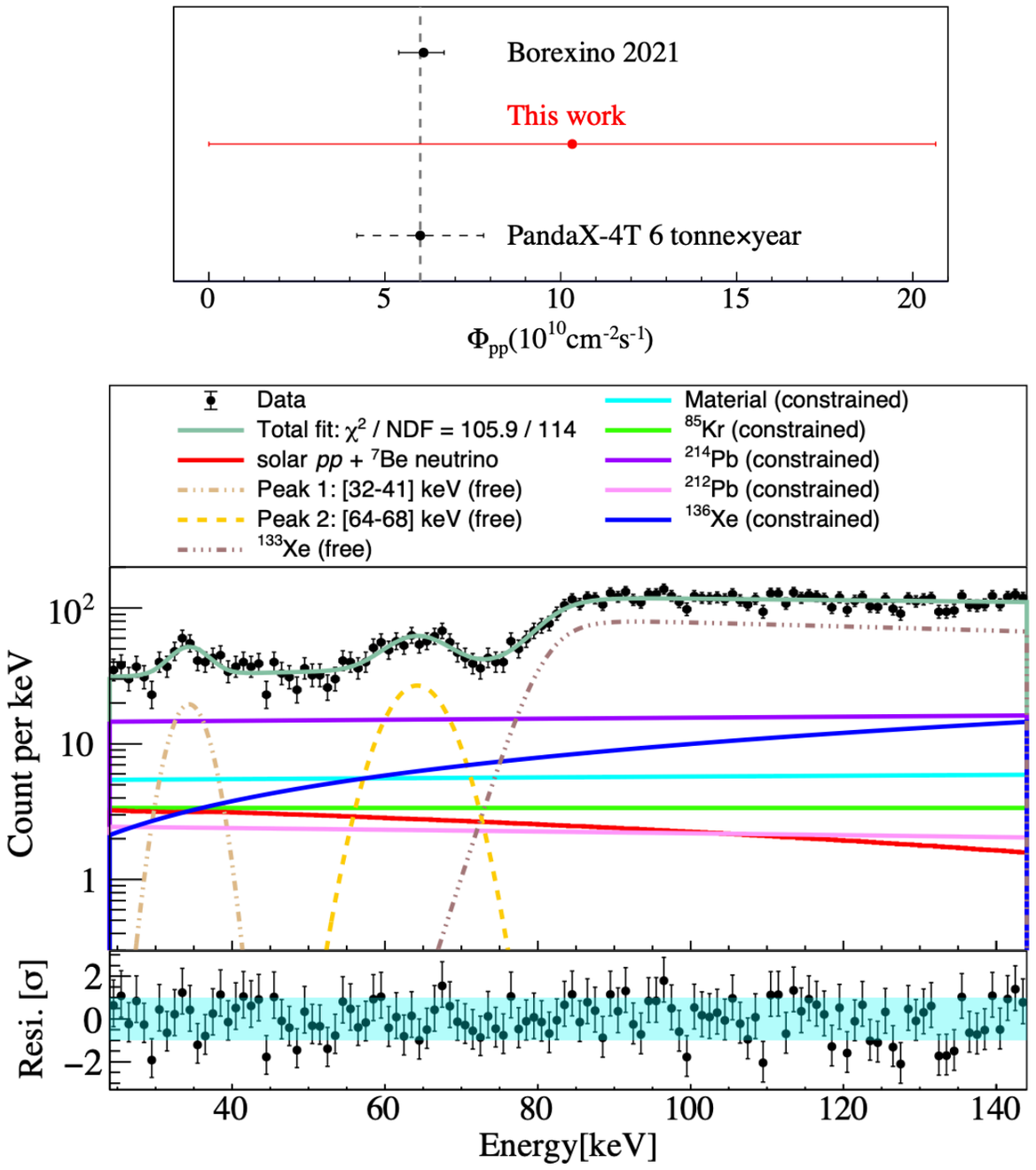
XENON collaboration, PRL 126 (2021) 091301: 2012.02846 [hep-ex]





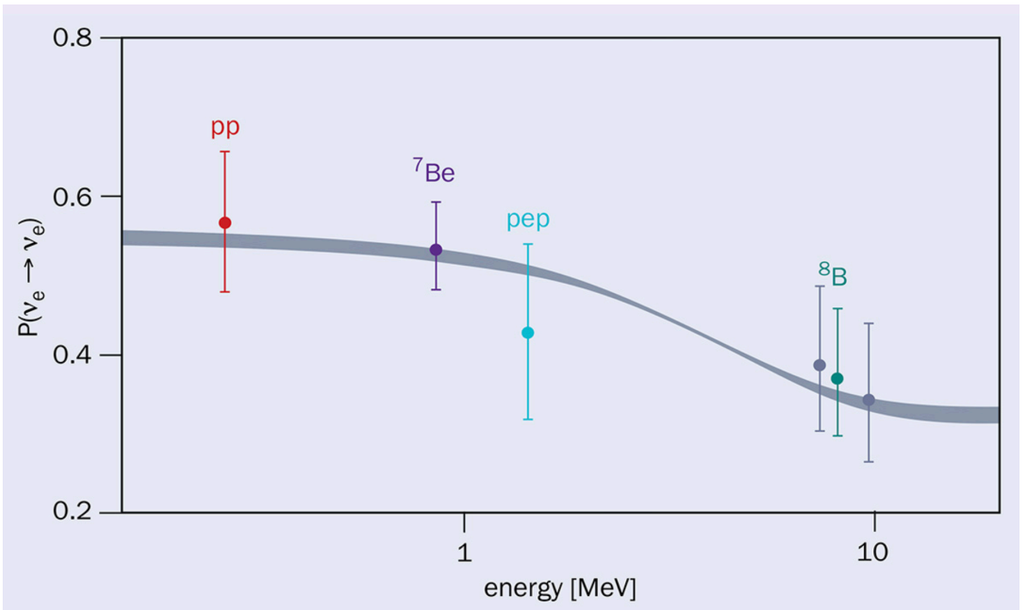
A Measurement of Solar *pp* Neutrino Flux using PandaX-4T Electron Recoil Data

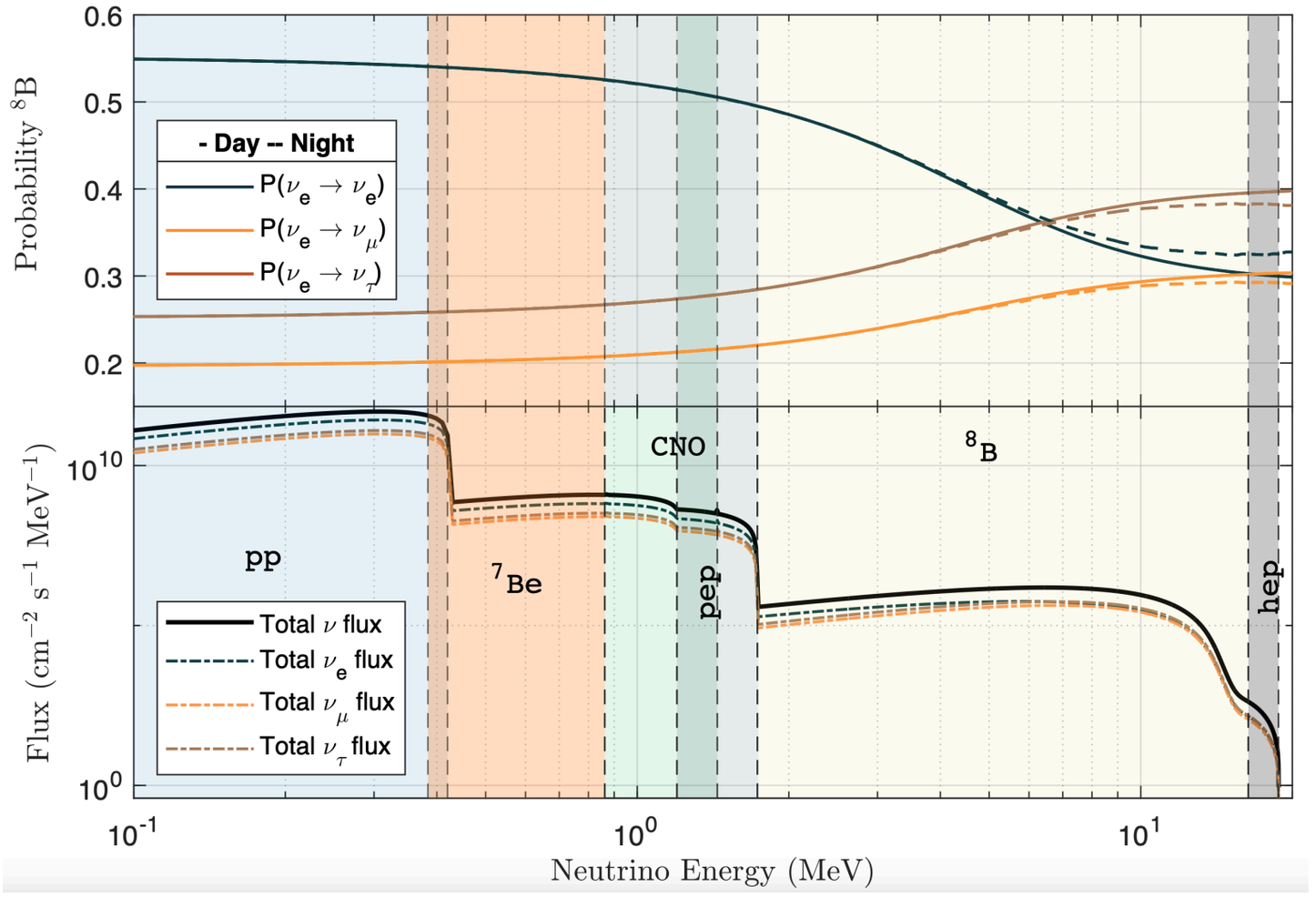




Pandax collaboration, 2401.07045

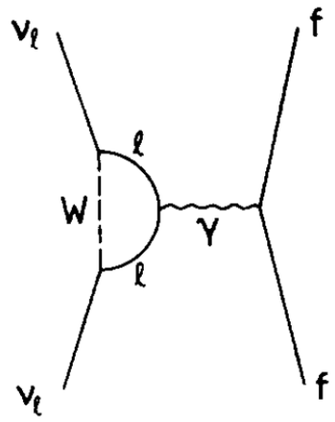
Flavor composition of solar neutrinos

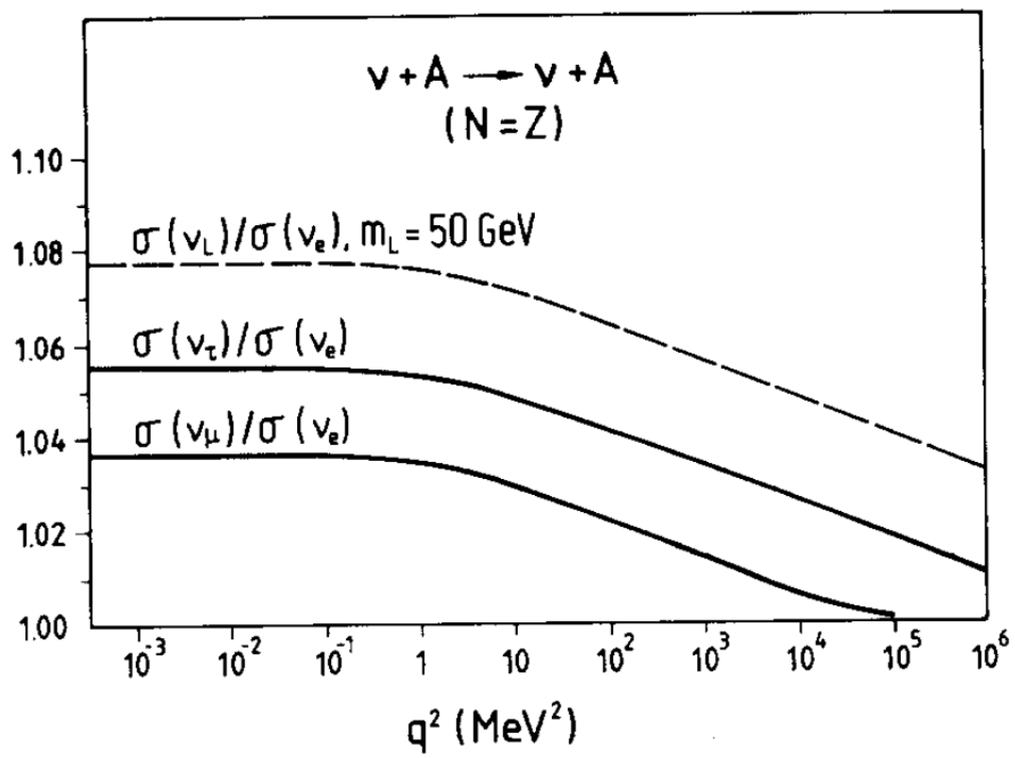


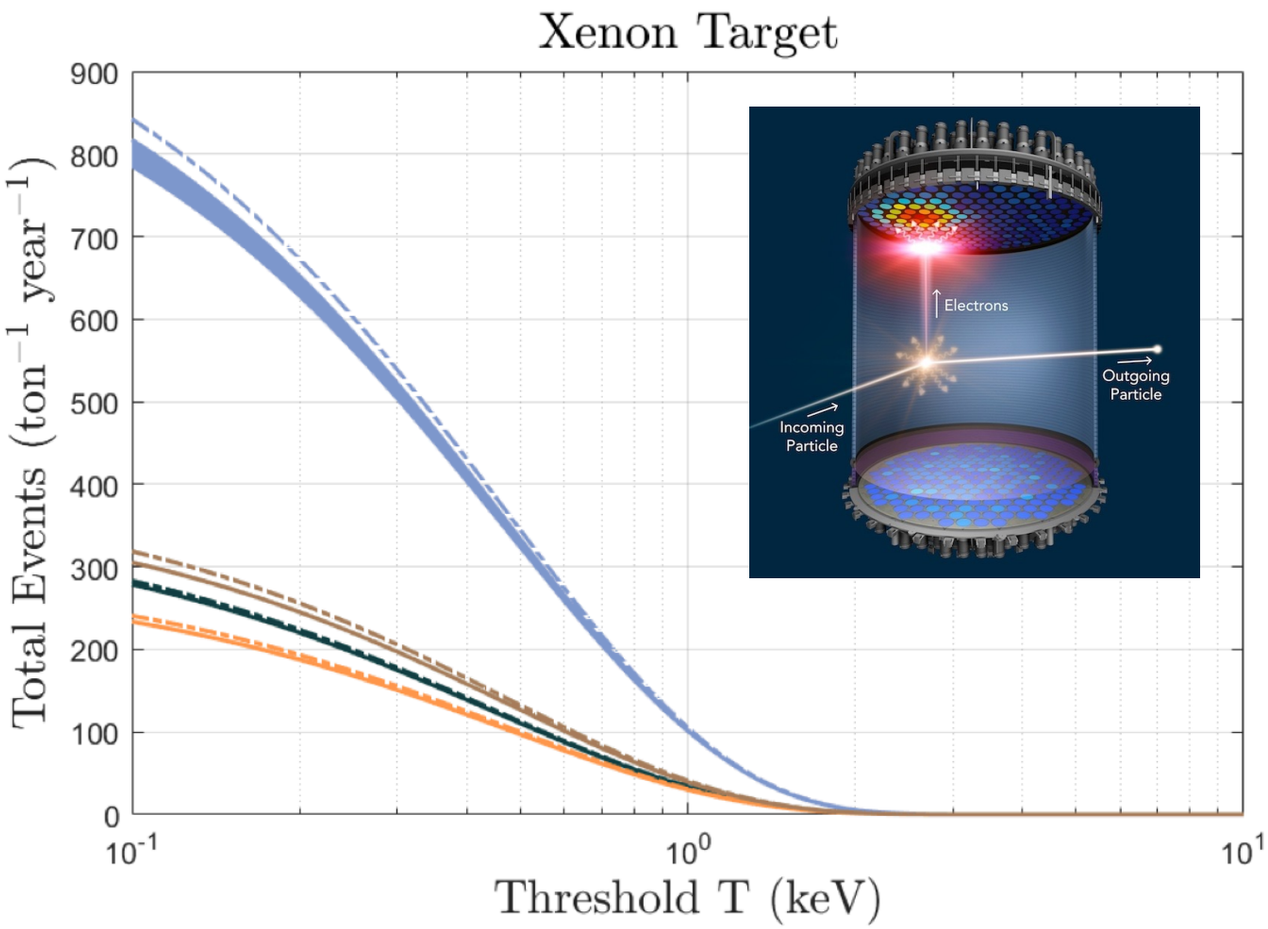


Nityasa Mishra & L. Strigari PRD 2023

Beyond tree level: ^{8}B solar neutrinos



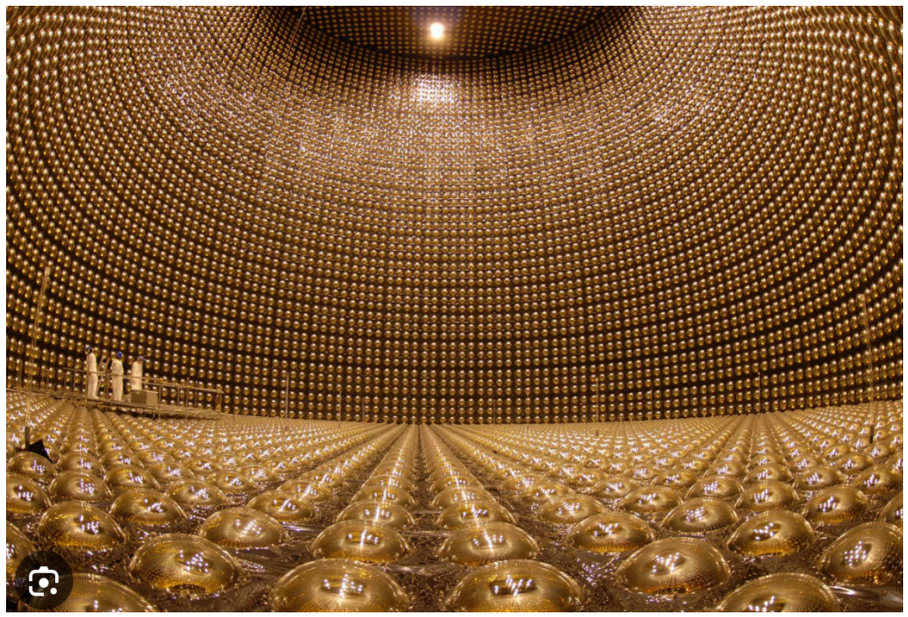


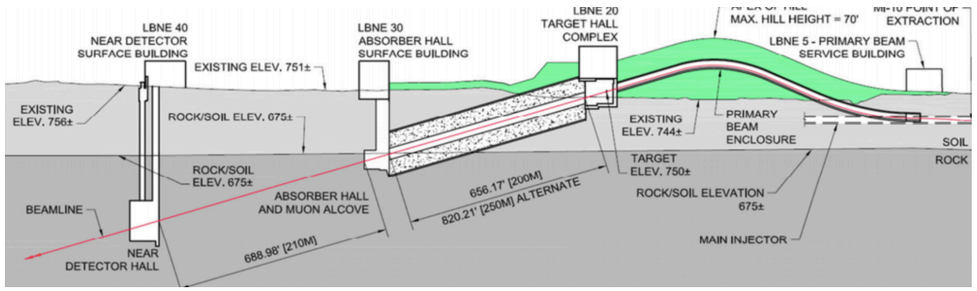


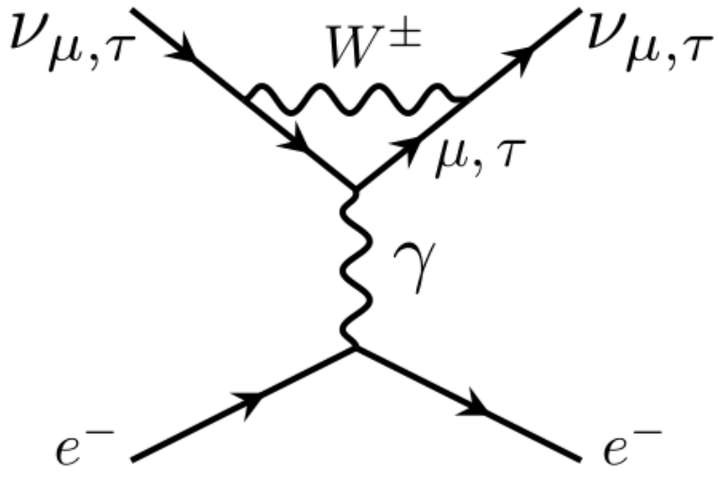
Radiative corrections to the CEvNS cross section induce small flavor dependences [Marciano & Sirlin 1980; Sehgal 1985; Tomalak et al. 2021] ; Charge radius contribution in CEvNS [Cadeddu et al. 2018; de Romeri et al. 2023]

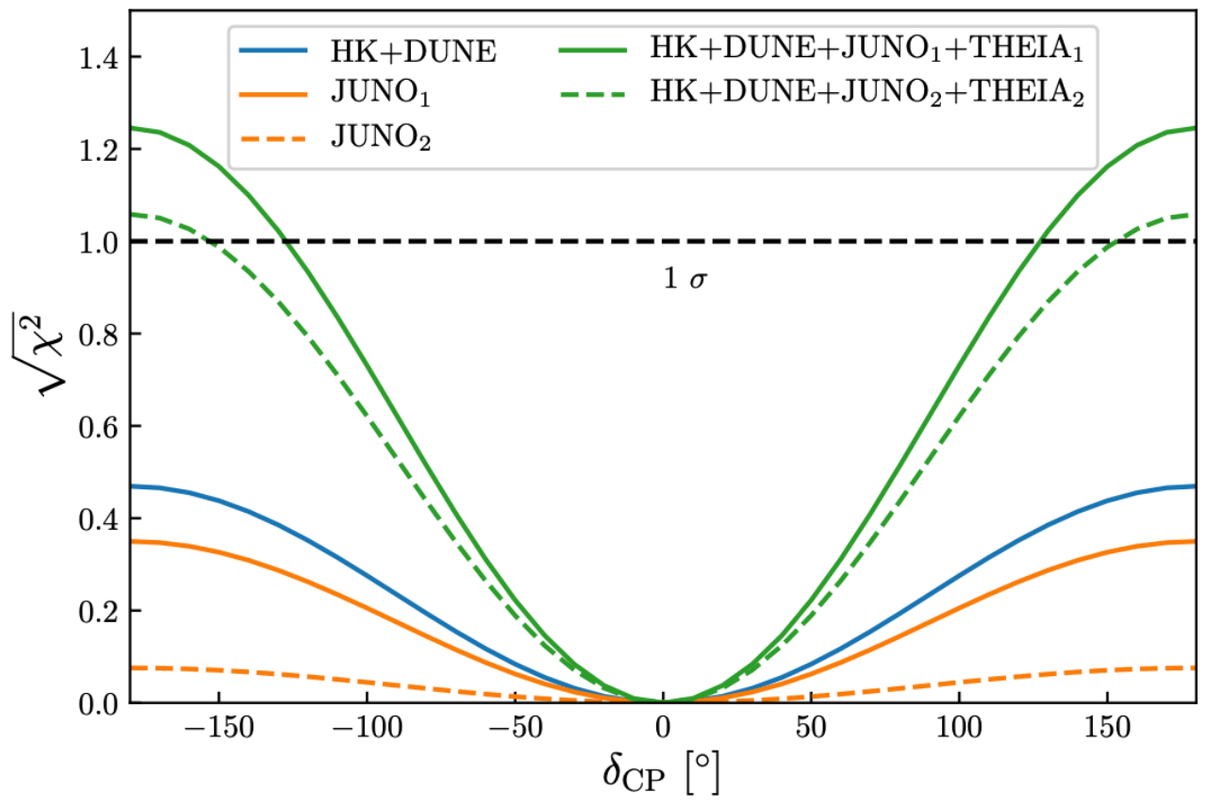
Flavor-dependent corrections introduce a small day/night asymmetry in solar neutrino rate [Nityasa Mishra & L. Strigari PRD 2023]

Beyond tree level: ^{8}B solar neutrinos



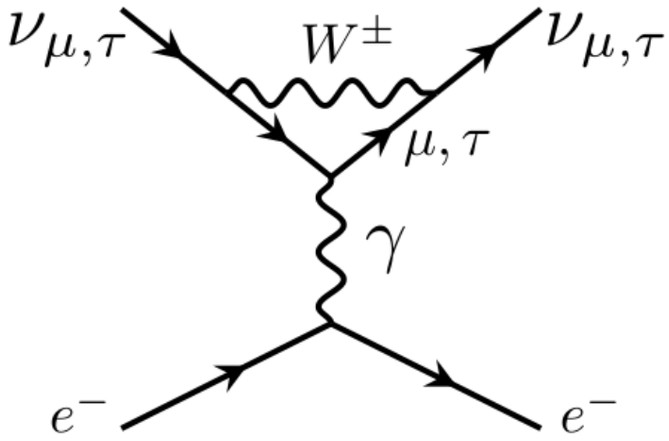


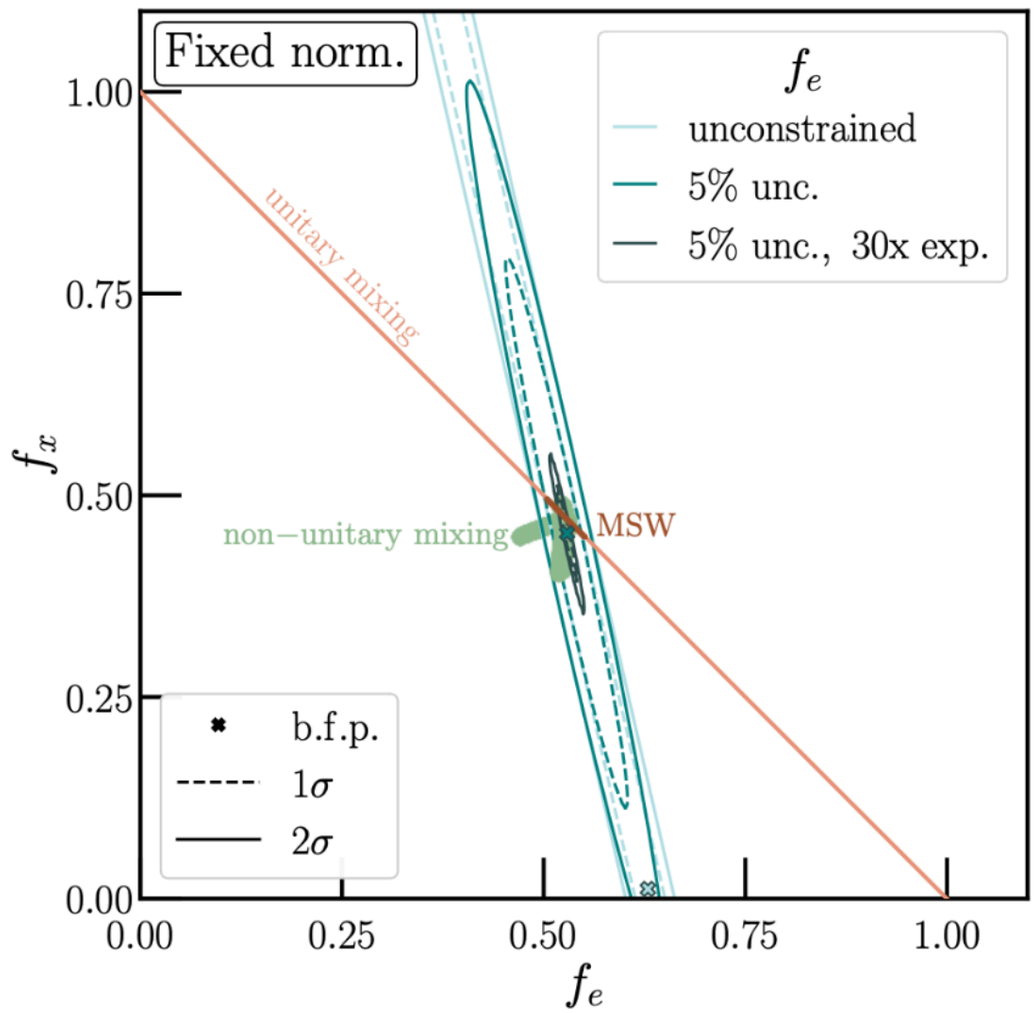


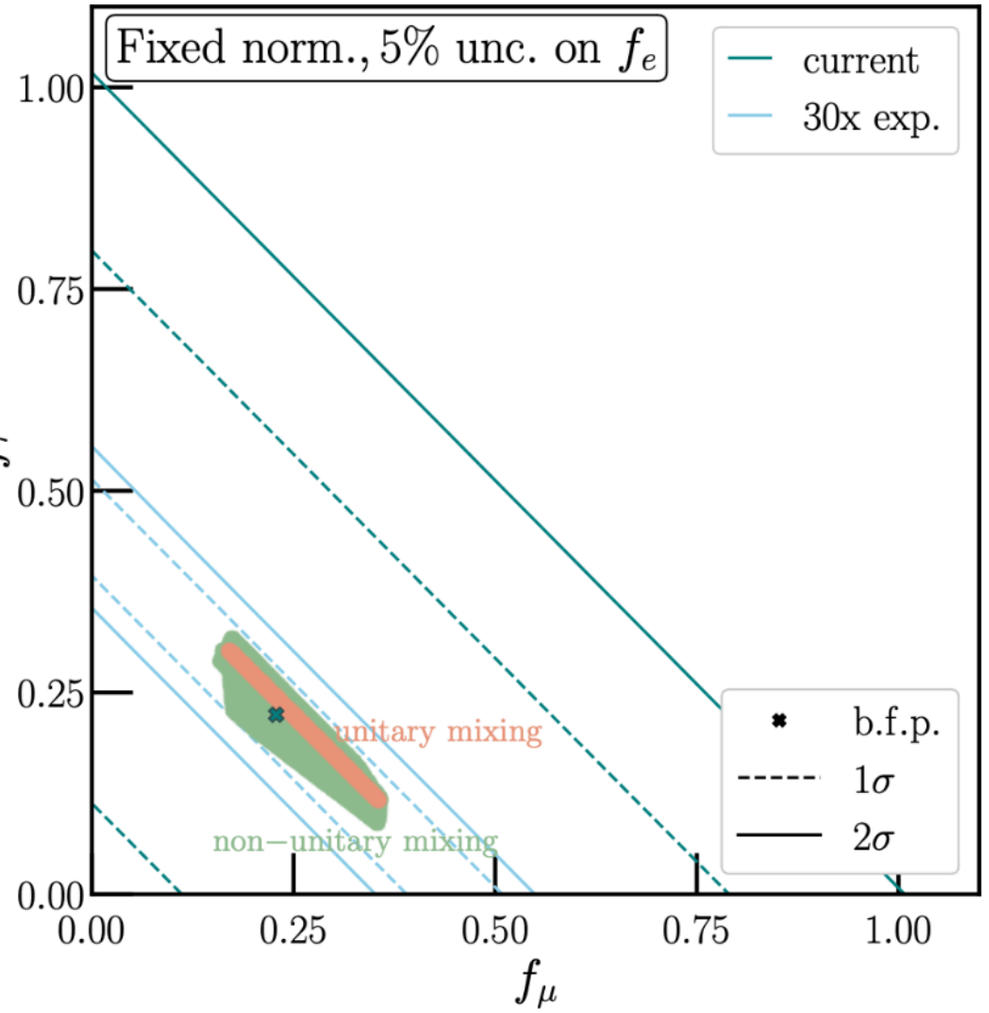


Brdar & Xu PLB 2024

Beyond tree level: ^{7}Be solar neutrinos

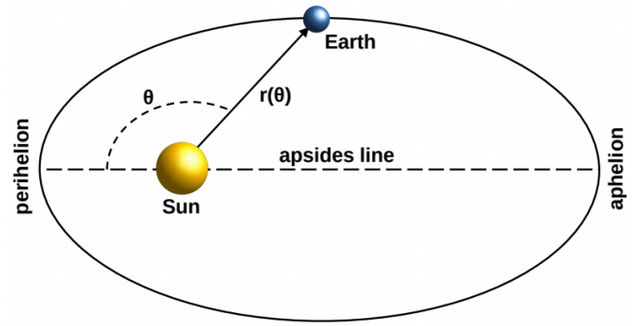


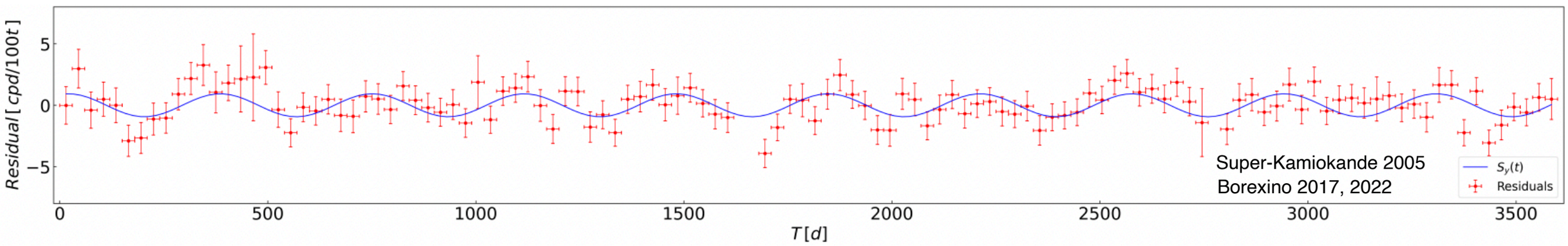




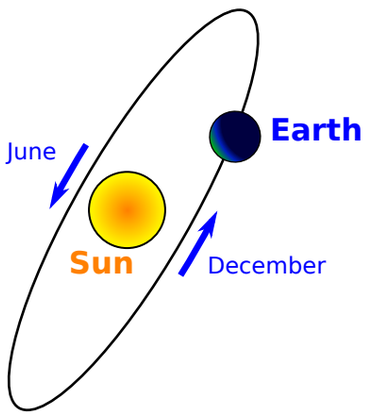
Larger scale experiment similar to Borexino, e.g. JUNO, may be sensitive to non-unitarity in 3-flavor oscillations
[K. Kelly, N. Mishra, M. Rai, LS 2024]

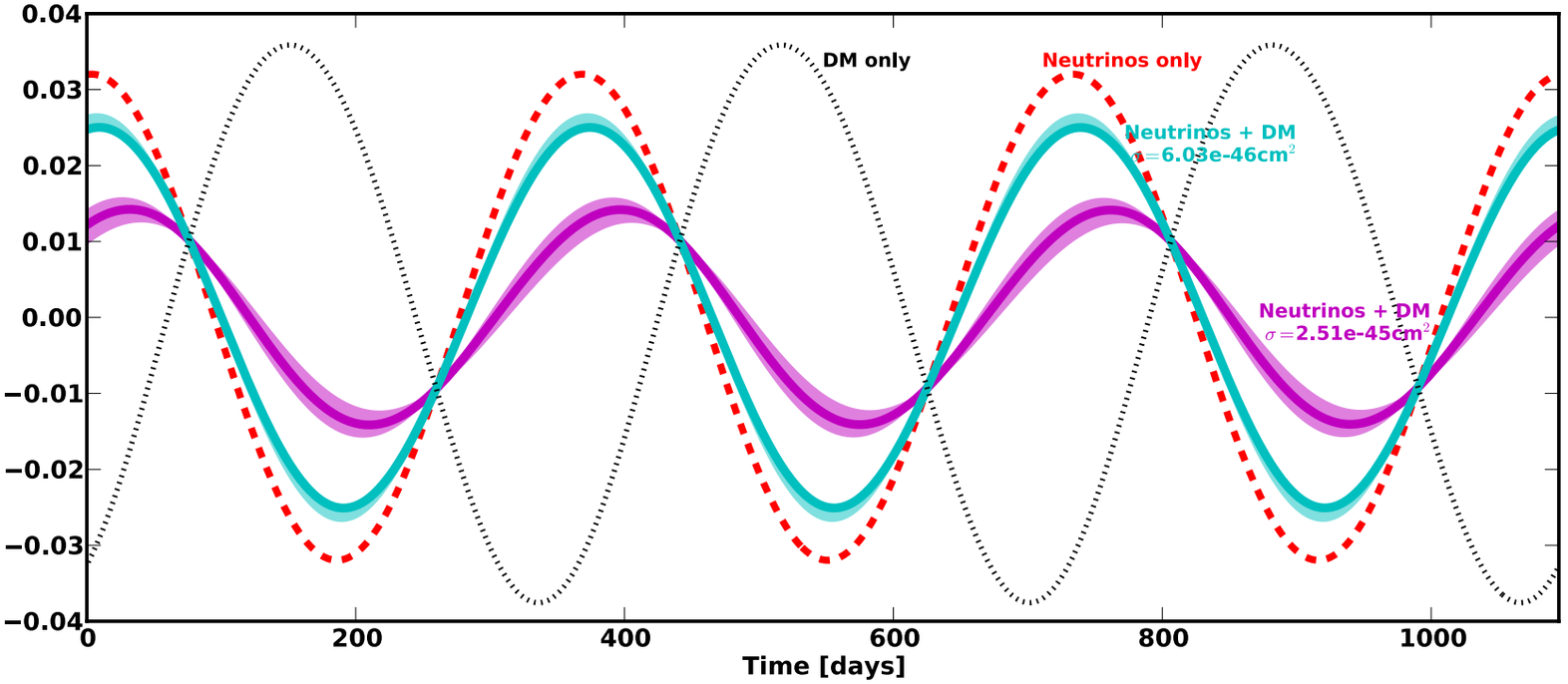
Time variation of solar neutrino flux





WIMP wind

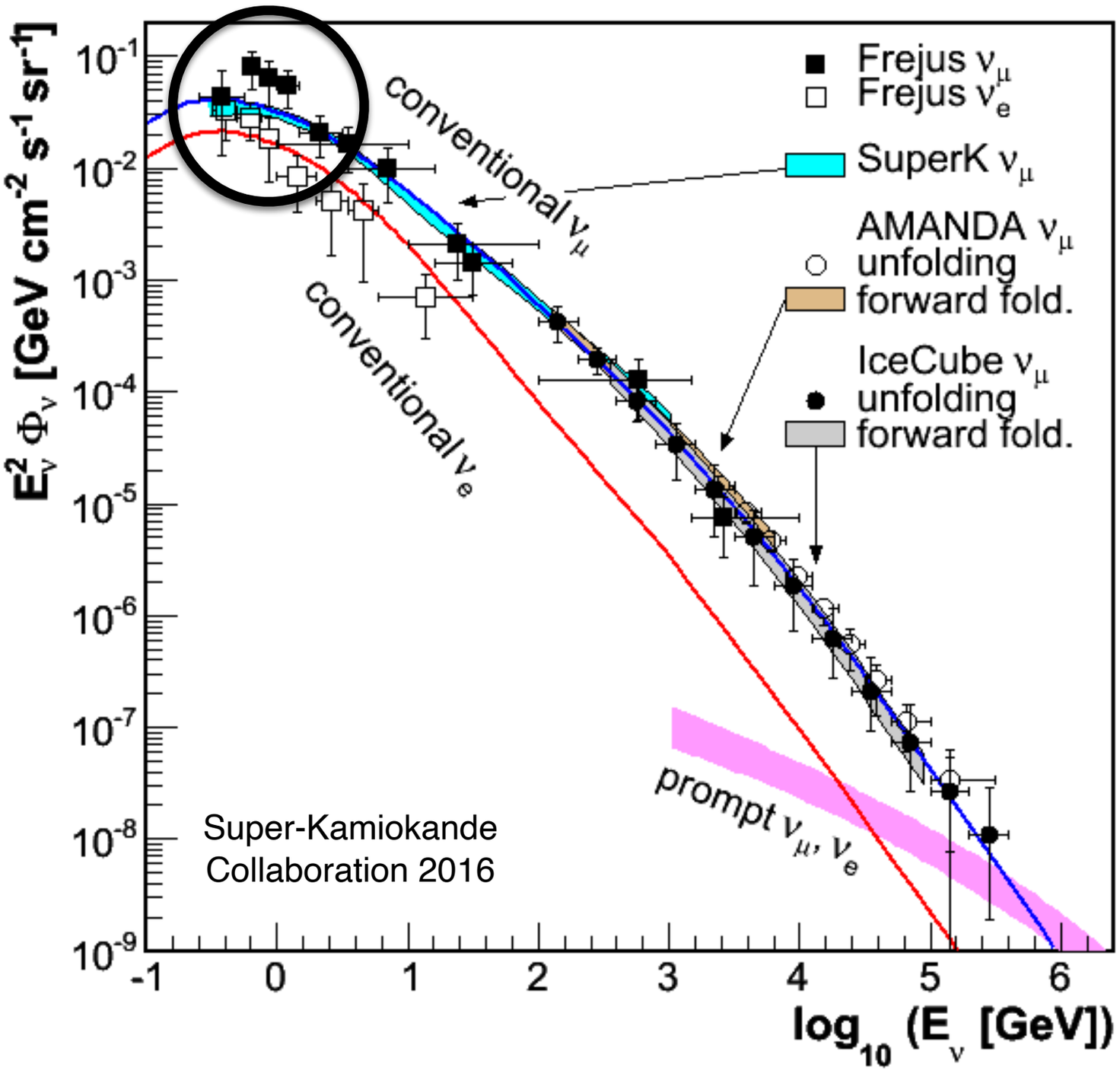




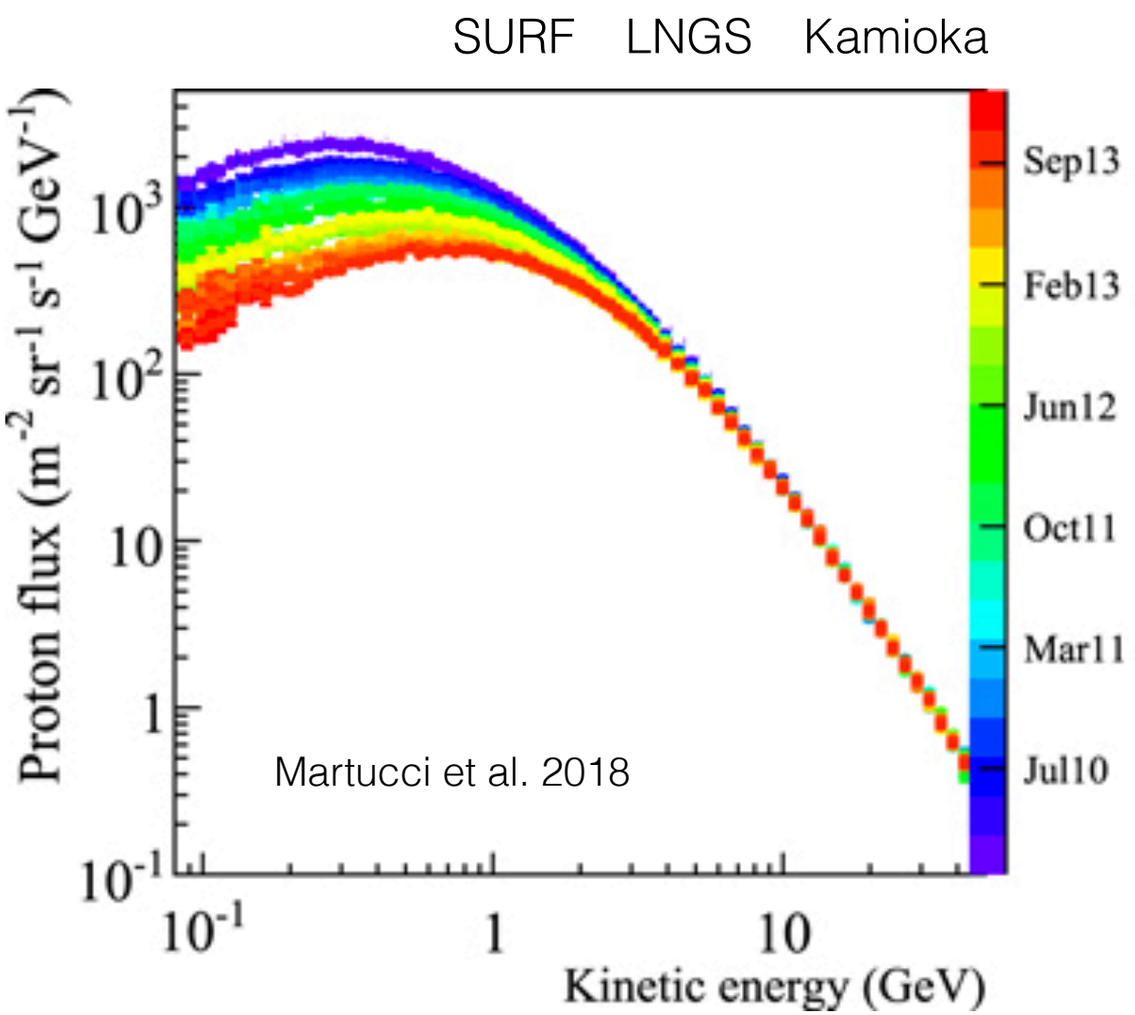
Dark matter modulation should be out of phase with solar neutrino modulation [Davis 2014]

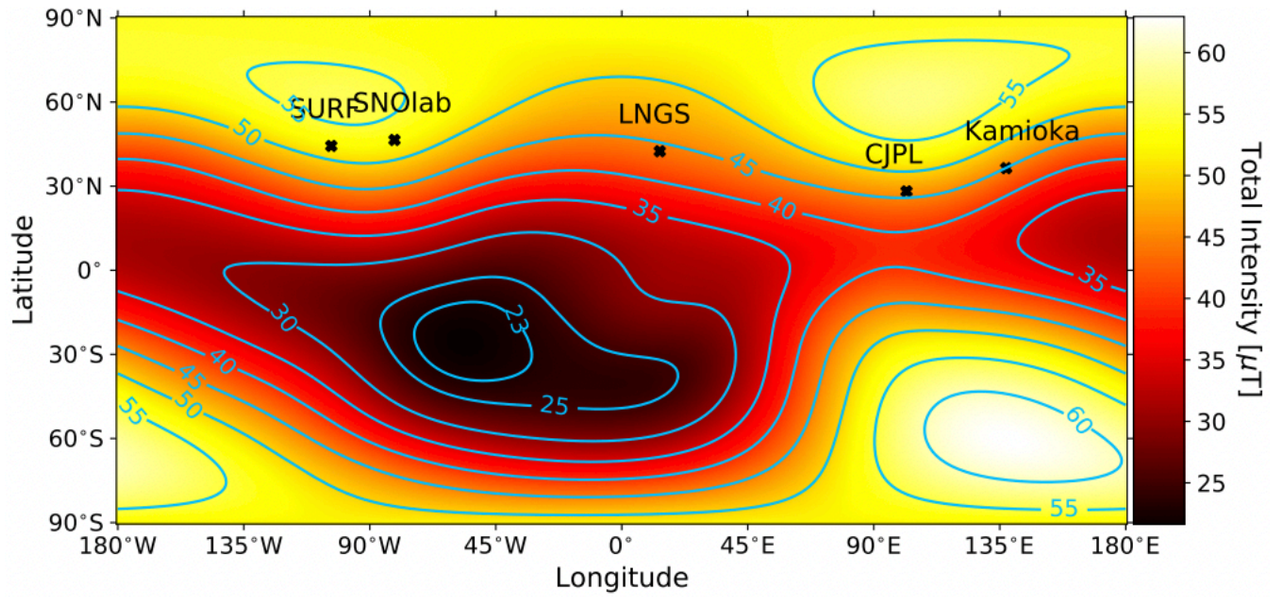
Time variability should be observable in G3 Xenon detector for electron and nuclear recoils [Zhuang, Strigari, Jin, Sinha, 2023, 2024]

Low-energy atmospheric neutrinos



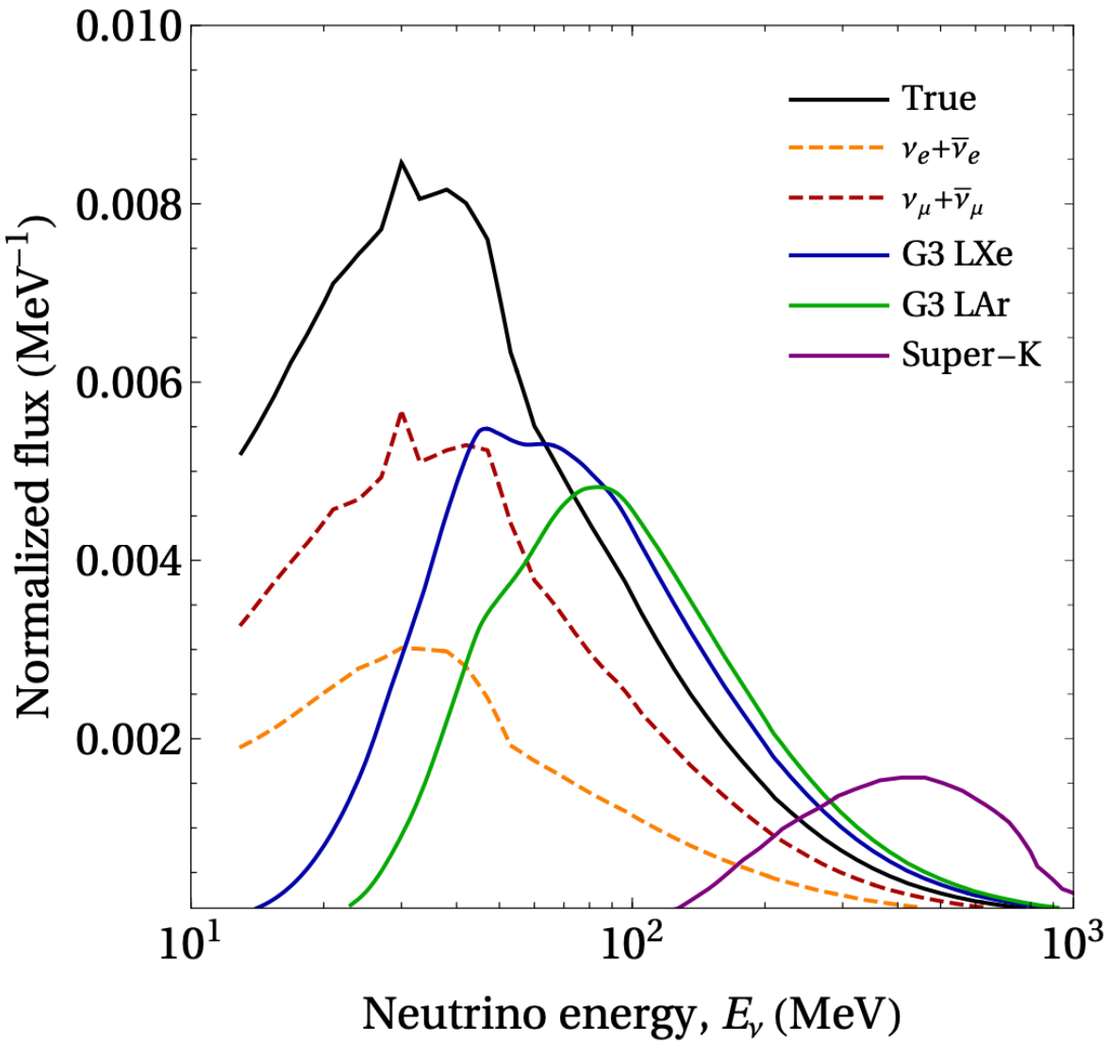
Solar and geomagnetic effects



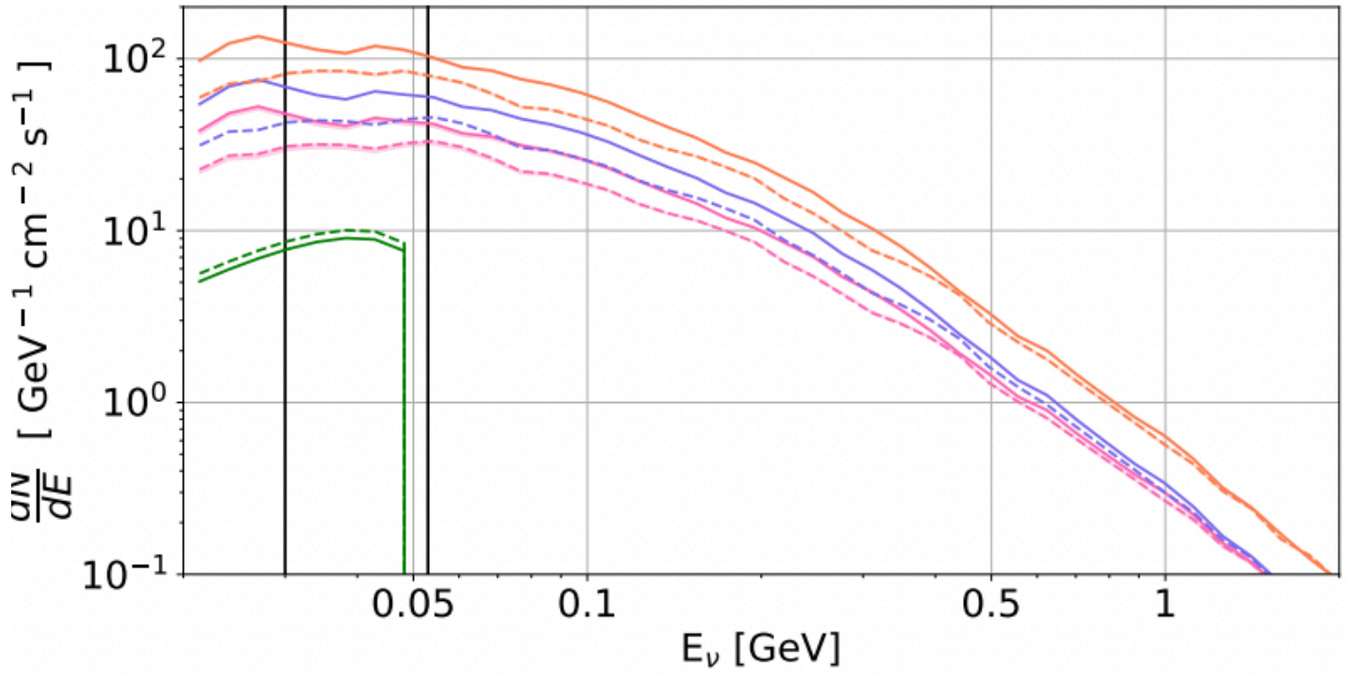


Time variation and geomagnetic effects depend on detector location [Zhuang, Strigari, Lang PRD 2021]

Low energy atmospheric neutrino fluxes

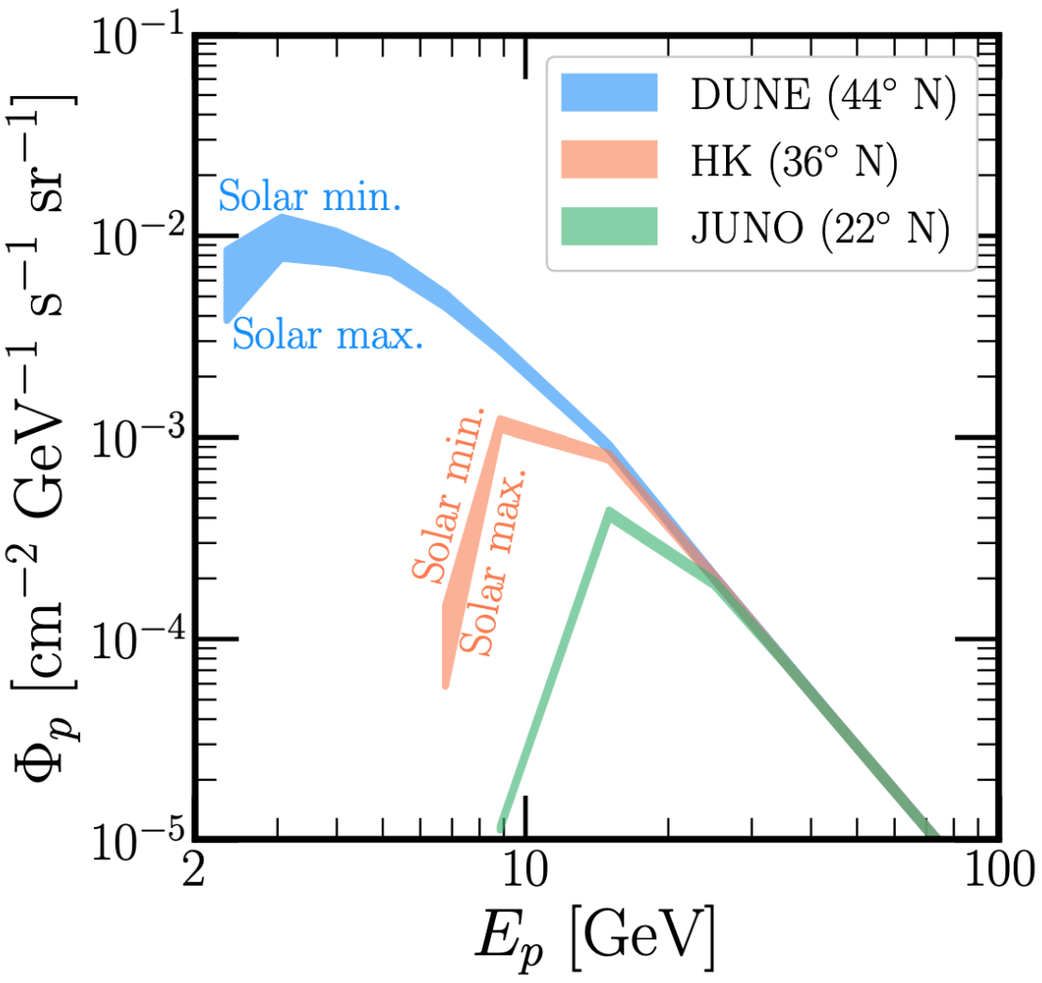


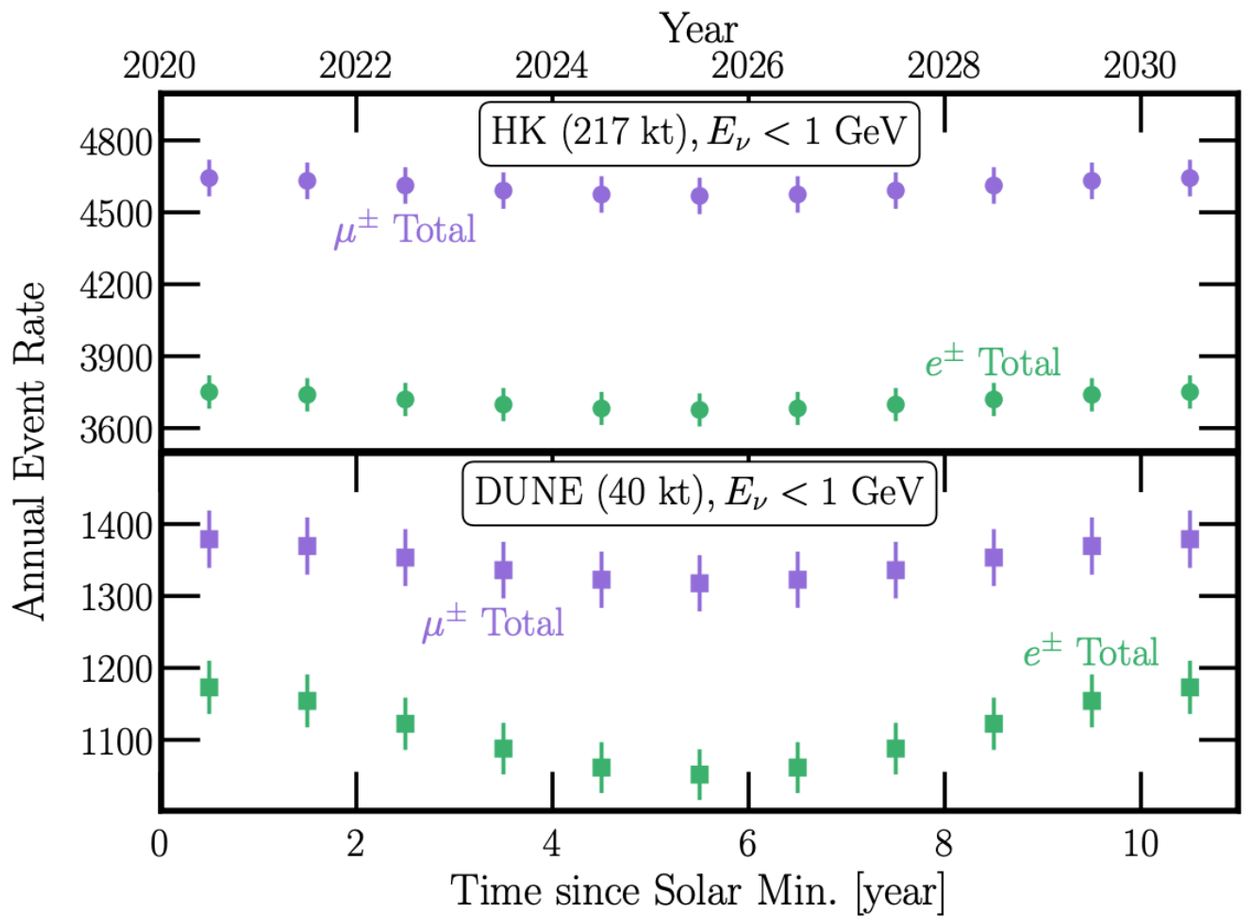
Newstead, Lang, LS PRD 2020



Honda et al. 2015, Zhuang, LS, Lang PRD 2021

Solar and geomagnetic effects at DUNE and Hyper-Kamiokande

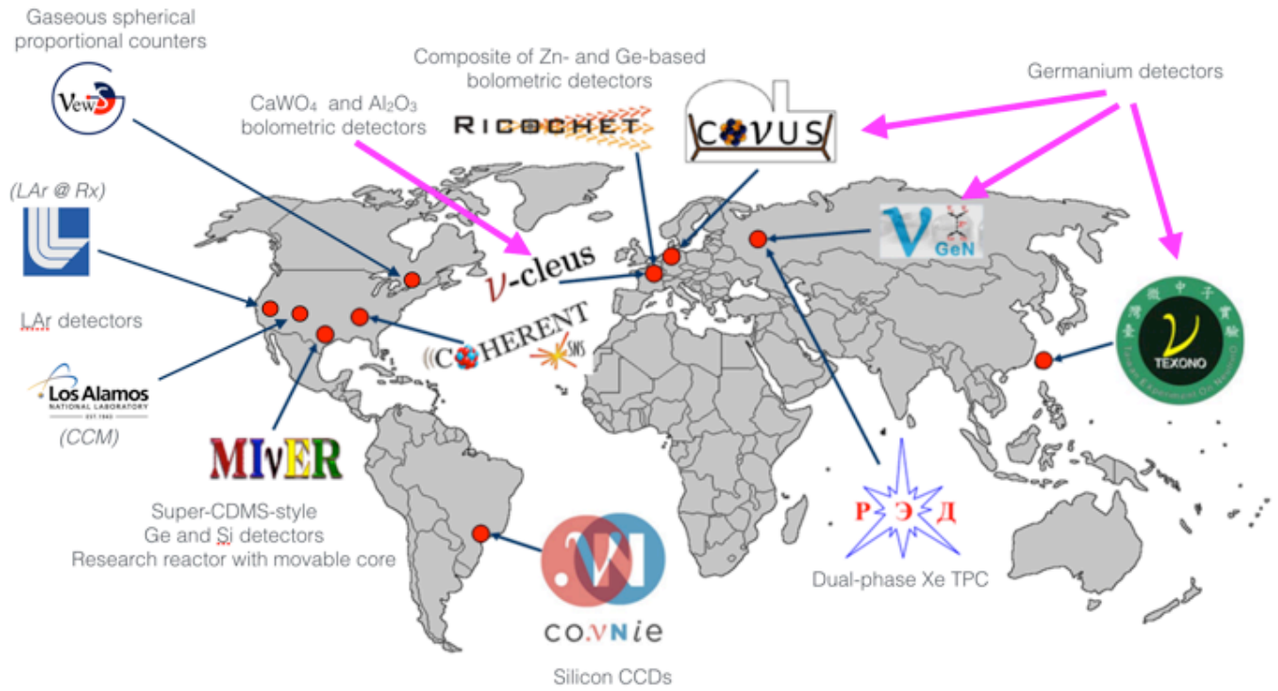




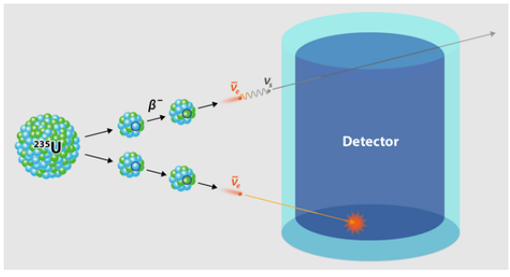
- Over 11-year solar cycle, statistical significance for observing time modulation of atmospheric neutrinos is 4.8σ for DUNE and 2.0σ for HK.
- Flux measurements at both DUNE and HK important for understanding systematics and oscillations in low-energy atmospheric neutrinos.

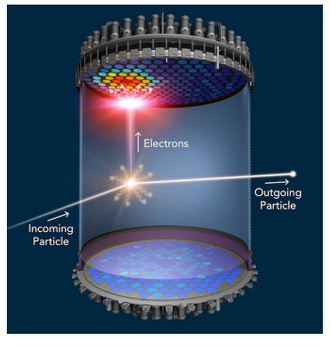
Kelly, Machado, Mishra, LS, Zhuang PRD2023

Terrestrial CEvNS Experiments



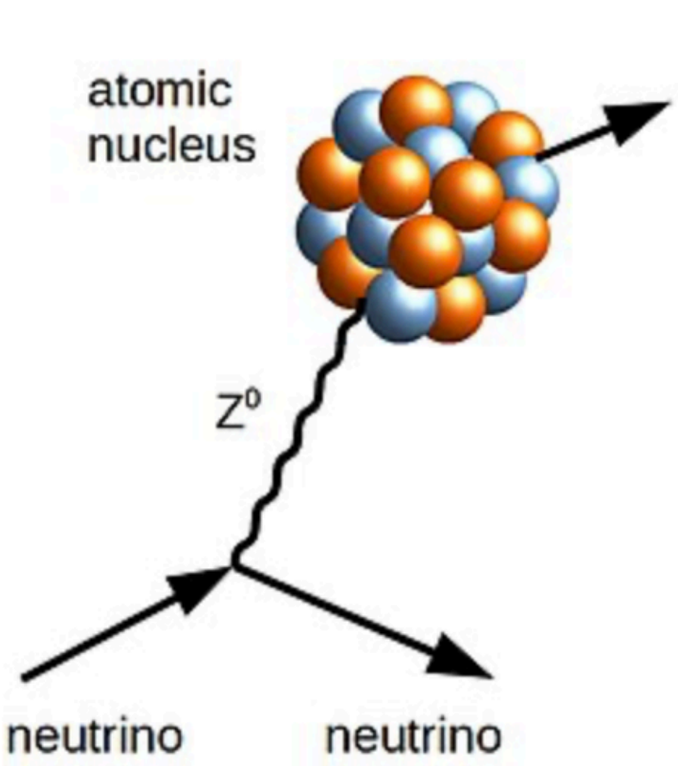
	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030's
Reactor Neutrino Sources														
Hartlepool Site				BG studies										
Angra Site				location & shielding upgrades										
CHOOZ Site		BG studies		Site Prep		Operations								
CONNIE	40 g			10 g skipp	100g skipper		1 kg skipper			10kg skipper				
CONUS														
MINER														
RED-100														
TEXONO			PIRE R&D											
NUCLEUS						10g CaWO4 & Al2O		kg-scale	1kg: Ge+ Si					
XENON														
NEWSG				Feasability Studies										
RICOCHET														
LAr				Detector R&D										
Spallation Neutrino Sources														
SNS FTS	1.1 MW	1.4 MW upgrade				1.7 MW upgrade		Ep=1.3 GeV Upgrade				2.0 MW upgrade		
SNS STS														
Lujan Center							30 ns Upgrade							
ESS														
COHERENT - CsI	*X -- Observation!*													
- LAr	20 keV threshold						750 kg			10 T				
- Ge					16 kg			100 kg						
- NaI					3.3 T				Cryo NaI					
XENON@SNS							100 kg							
CCM - 1st detector														
- 2nd detector														
8B Solar Neutrinos														
Xenon NT														
LZ														
SuperCDMS														
Darkside-LM														
Atmospheric and Diffuse Supernova Neutrino Backgrouind														
DARWIN														
Galactic Supernova Neutrinos Only														
Darkside-20k														
ARGO														

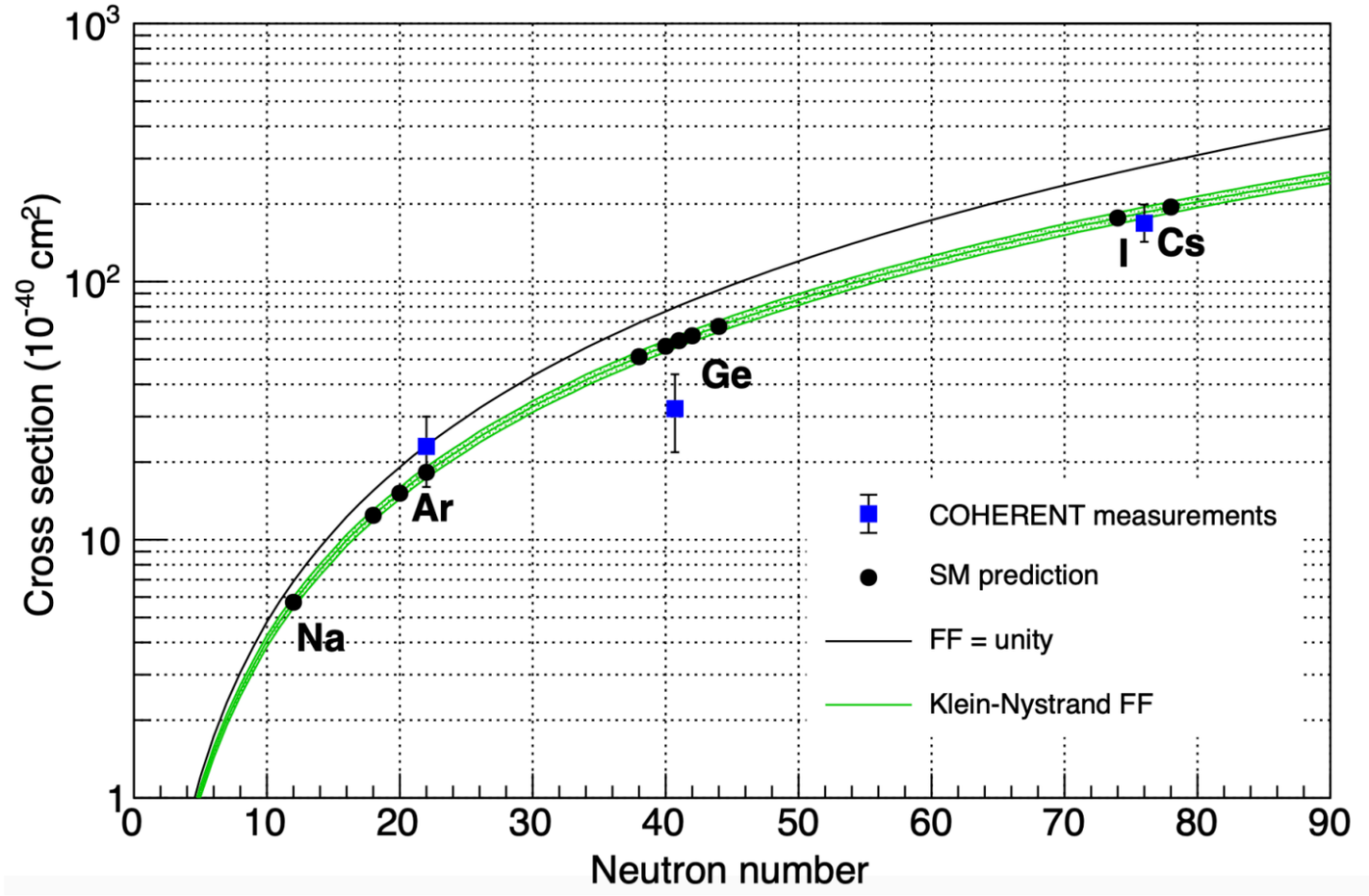




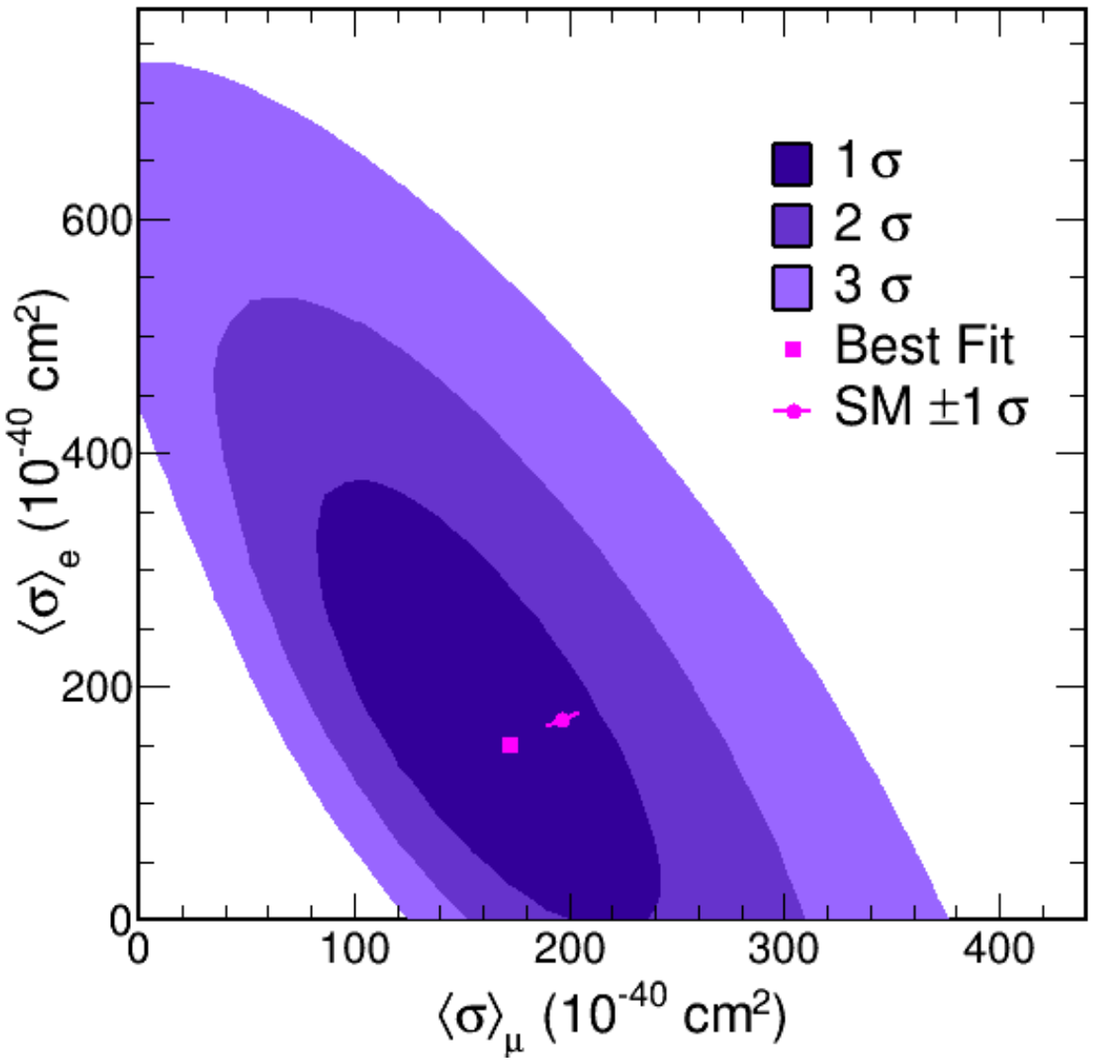
CEvNS cross section measurements

First detection of coherent elastic neutrino-nucleus scattering on germanium





Flavor separation of CEvNS



COHERENT collaboration 2021

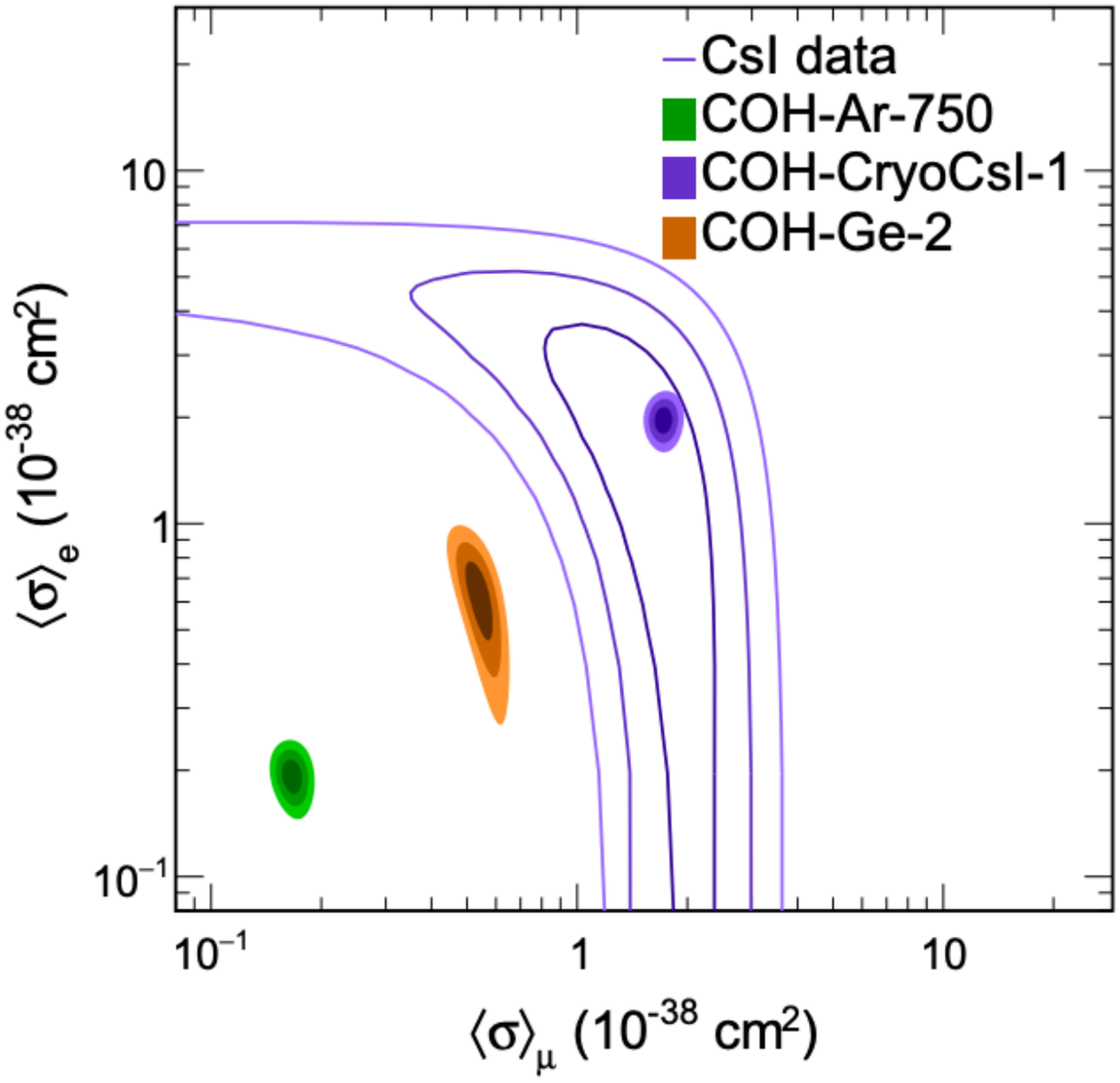
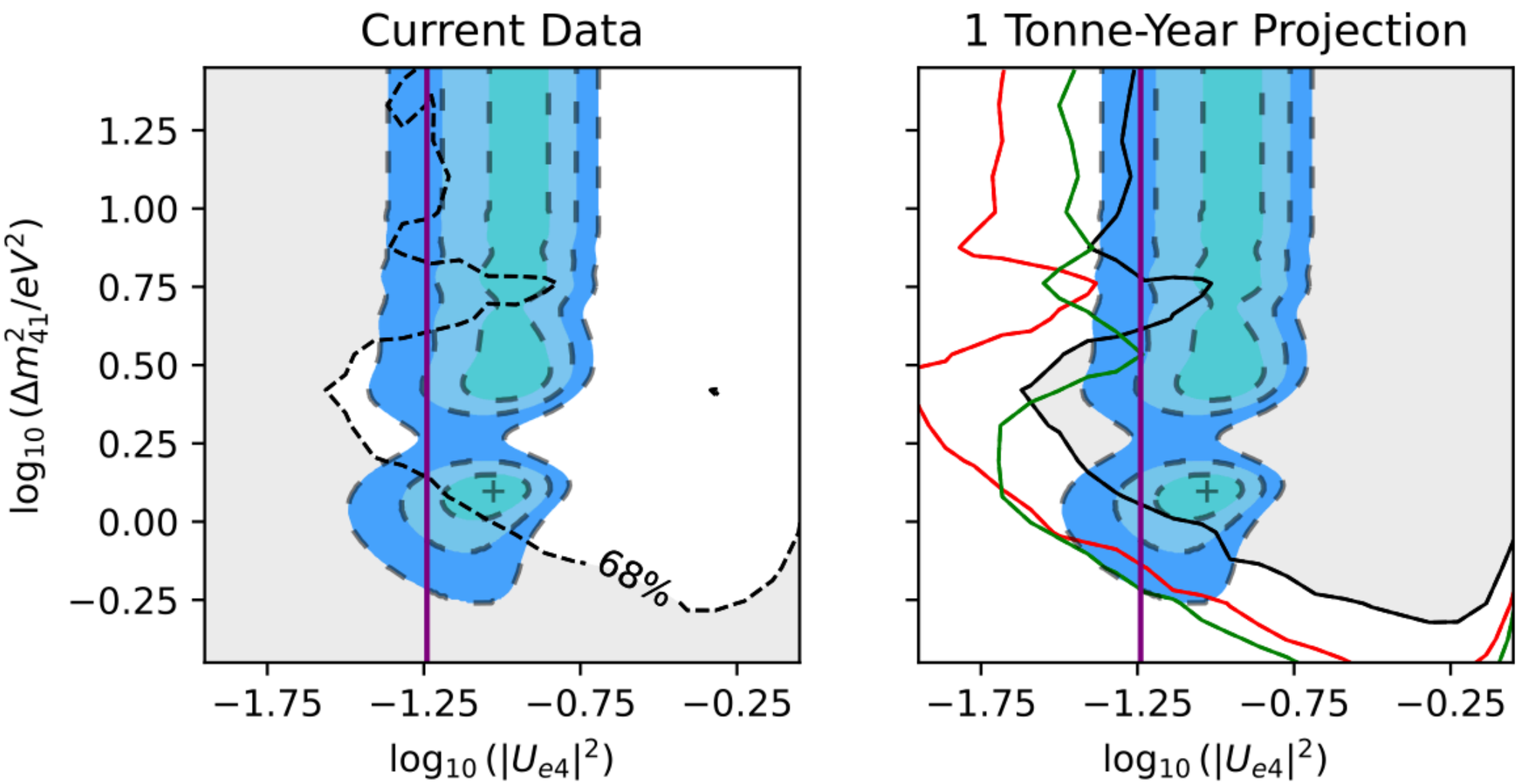


Figure: Dan Pershey

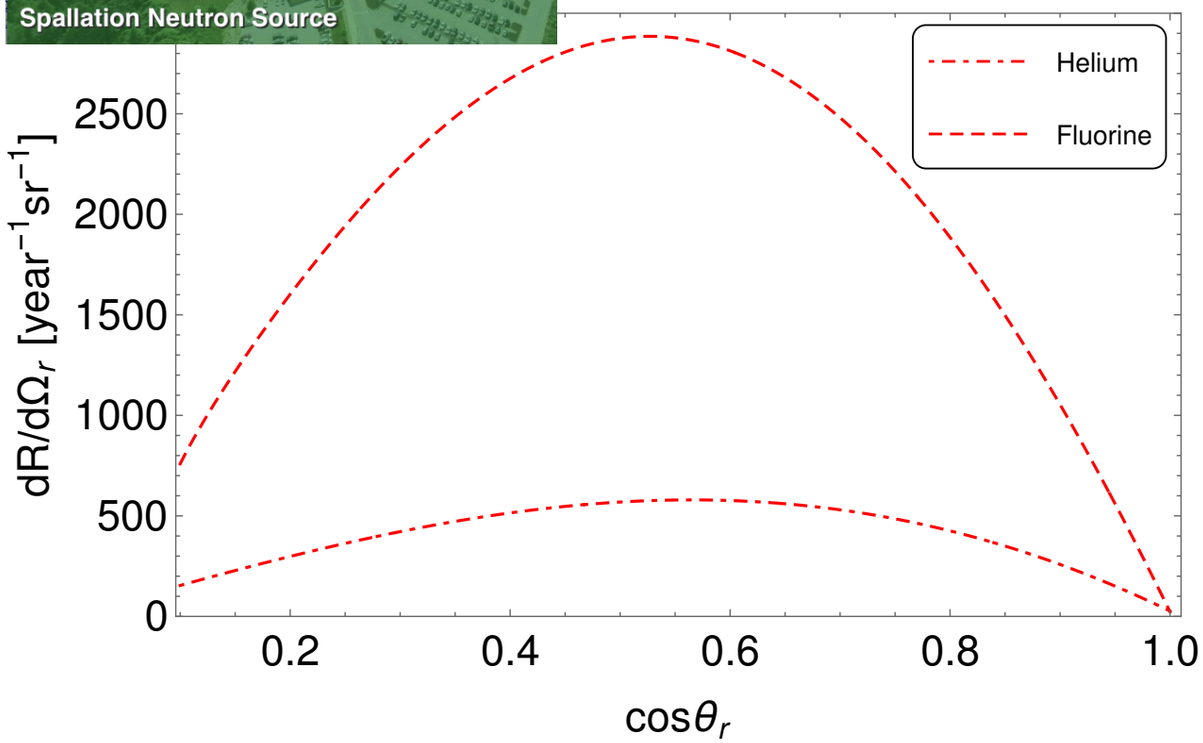
Sterile neutrinos and CEvNS

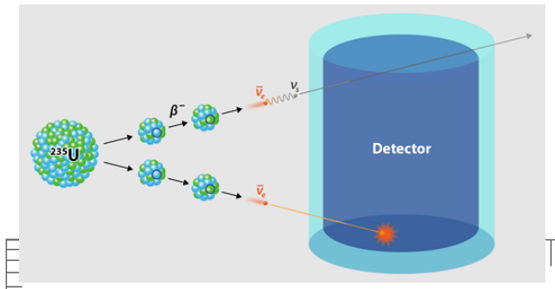


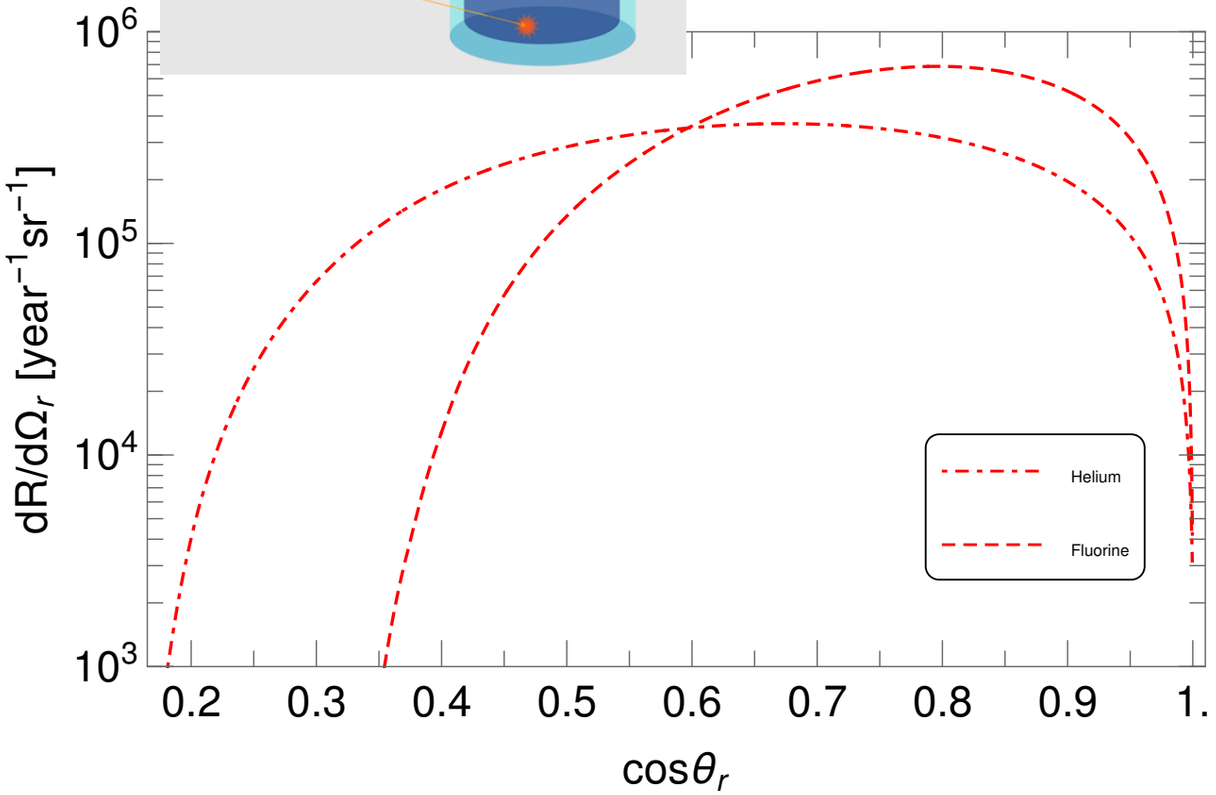
Sterile neutrinos: Anderson et al. 2012; Dutta et al. 2016; Blanco, Machado, Hooper 2019; Miranda et al. 2020

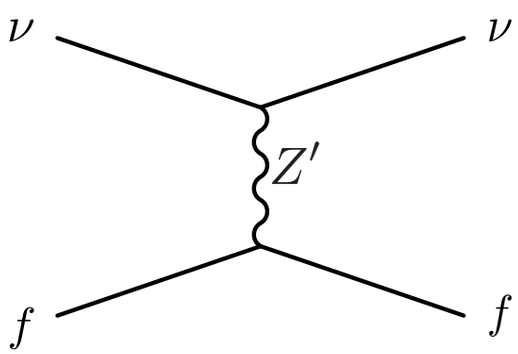
Bisset, Dutta, Huang, LS, arXiv: 2310.13194

CEvNS with directional detectors





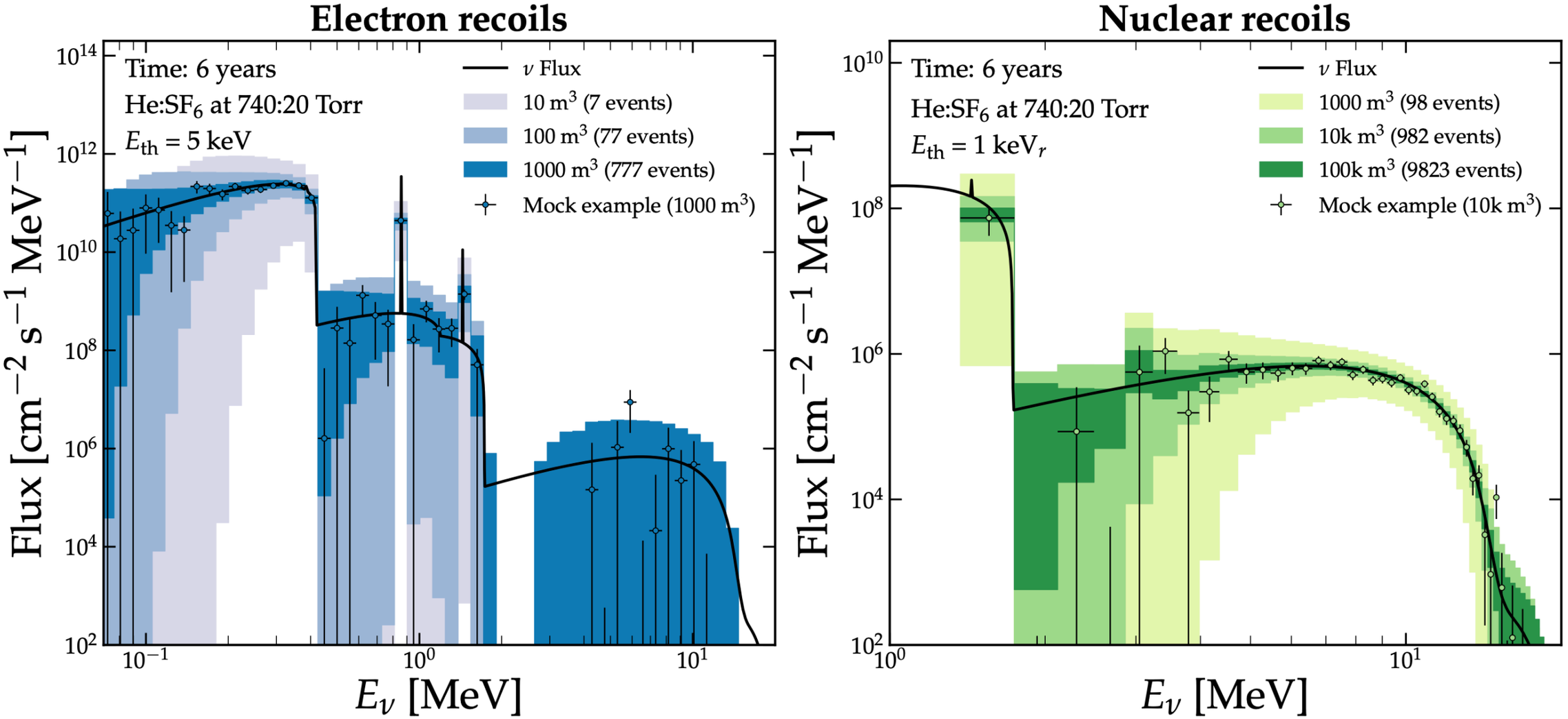




Light mediators alter the shape of angular distribution

Abdullah, Aristizabal-Sierra, Dutta, Strigari
Phys.Rev.D 102 (2020) 1, 015009 2003.11510

Neutrino energy reconstruction



Lisotti et al, 2404.03690

Neutrino physics opportunities with dark matter detectors

- 8B solar neutrinos likely to be the first astrophysical measurement of CEvNS
- Opportunities for atmospheric neutrinos at dark matter detectors
- Flavor dependencies in CEvNS, and future precision measurements
- Opportunities with CEvNS and terrestrial detectors
- CEvNS experiments using decay in-flight