Flavors and systematics in CEvNS and CEvNS-related searches

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Interplay of Nuclear, Neutrino and BSM Physics at Low-Energies, INT, Seattle
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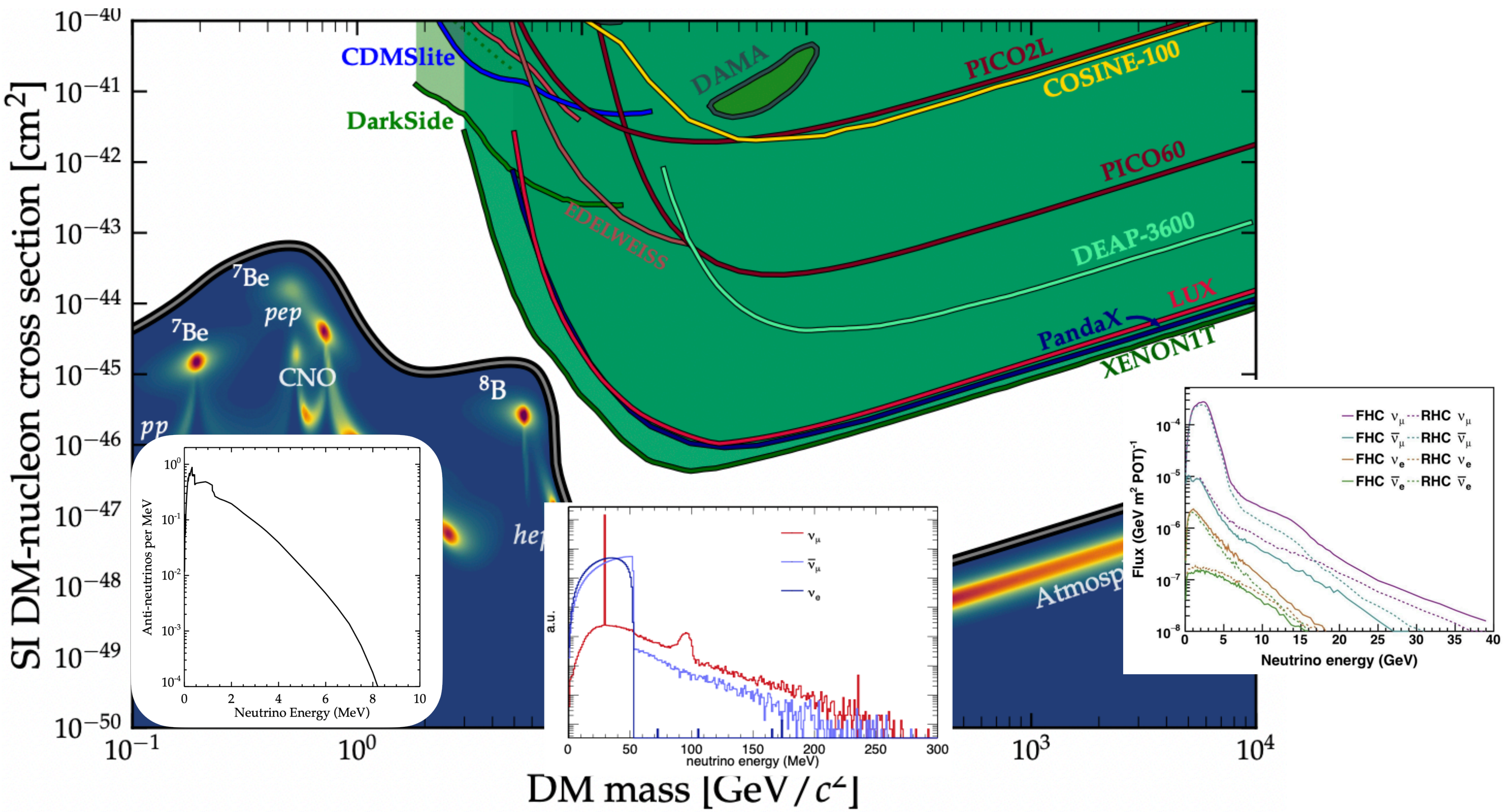
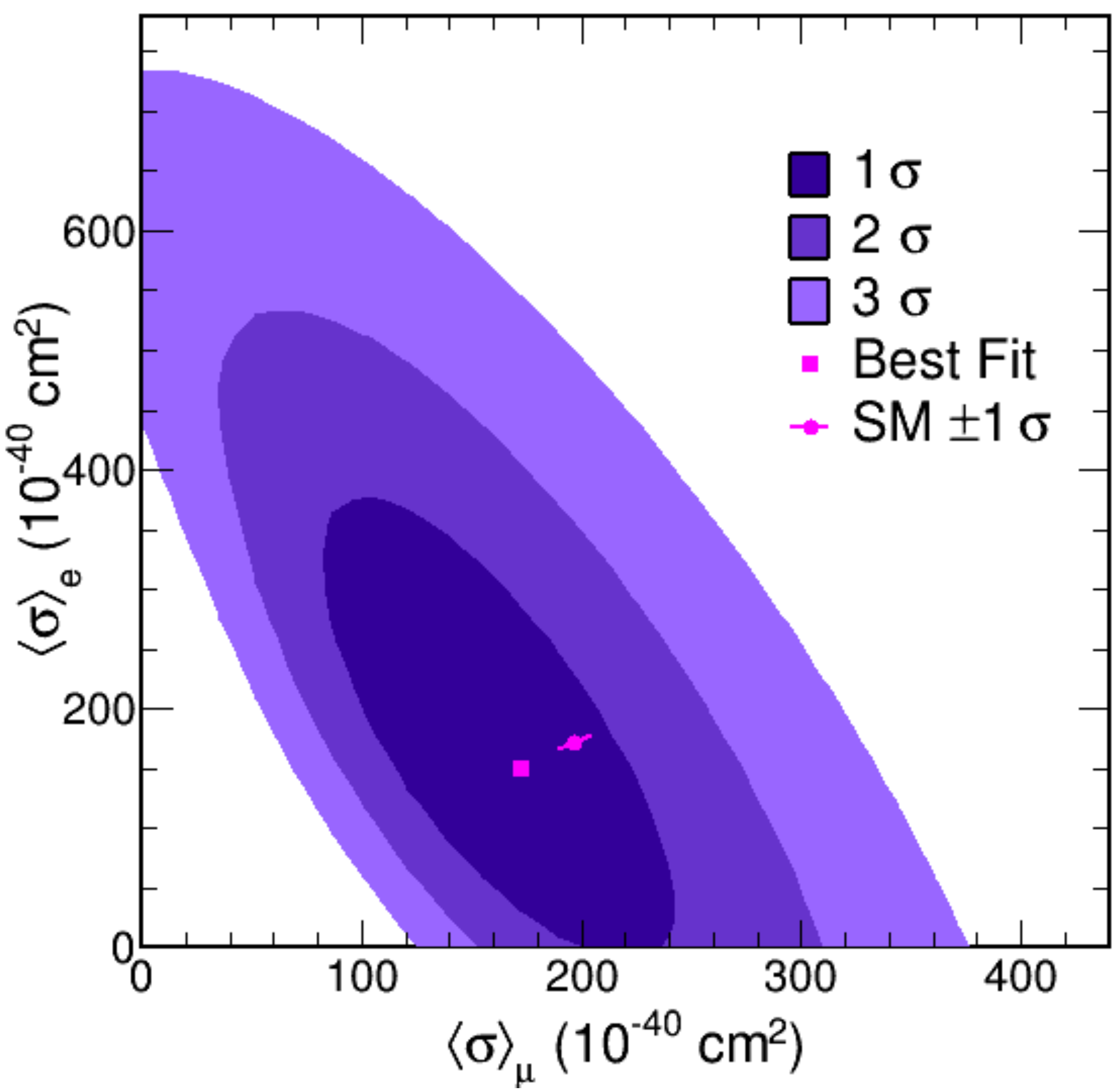
Artwork by Sandbox Studio, Chicago with Ana Kova

Questions for current/future CEvNS and CEvNS-related experiments

- Standard Model physics vs. Beyond-the-Standard Model Physics?
- Standard Model/Beyond Standard Model Physics vs. Systematics/Astrophysics?



Measurement of CEvNS cross section



COHERENT collaboration 2021

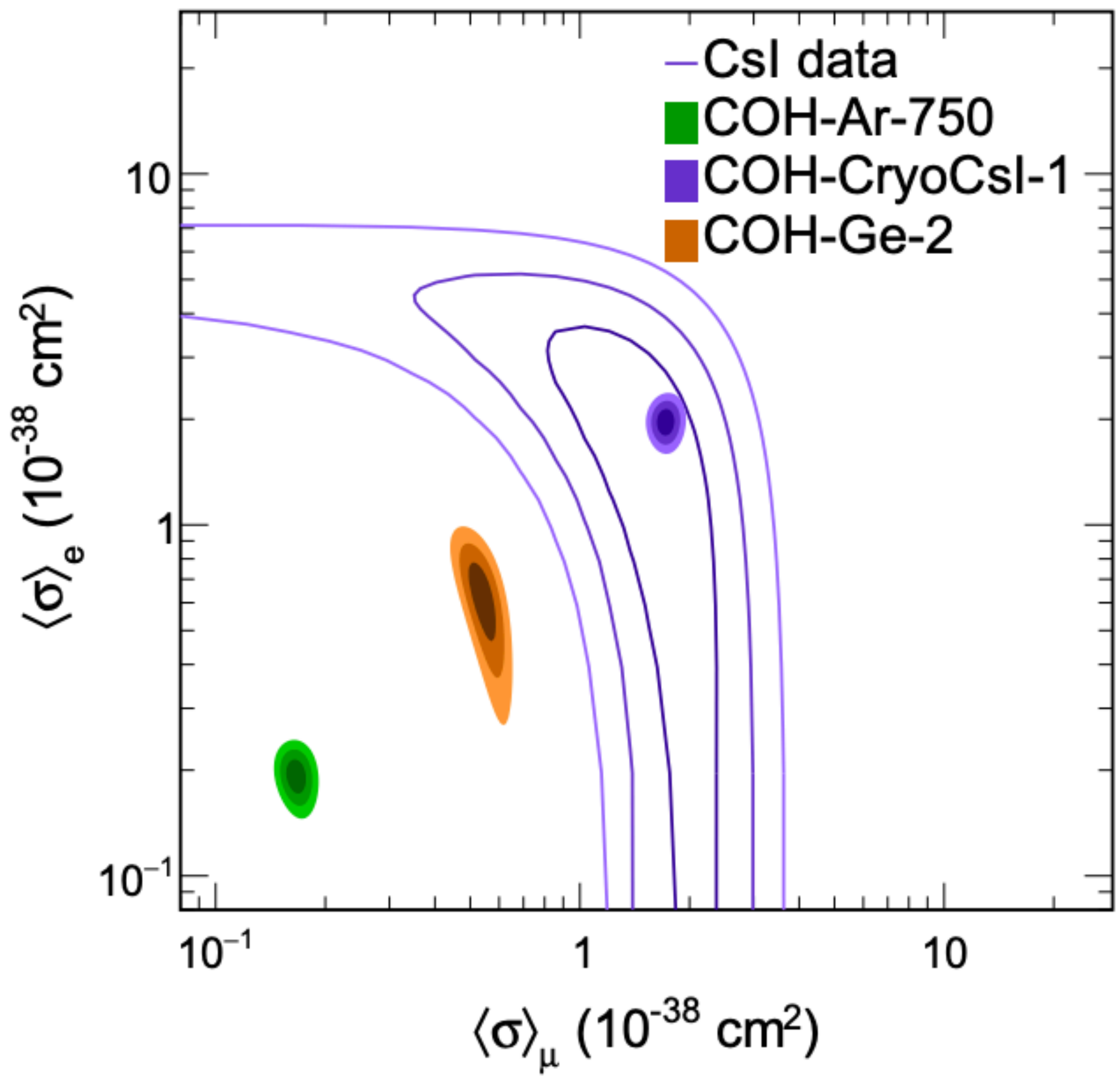
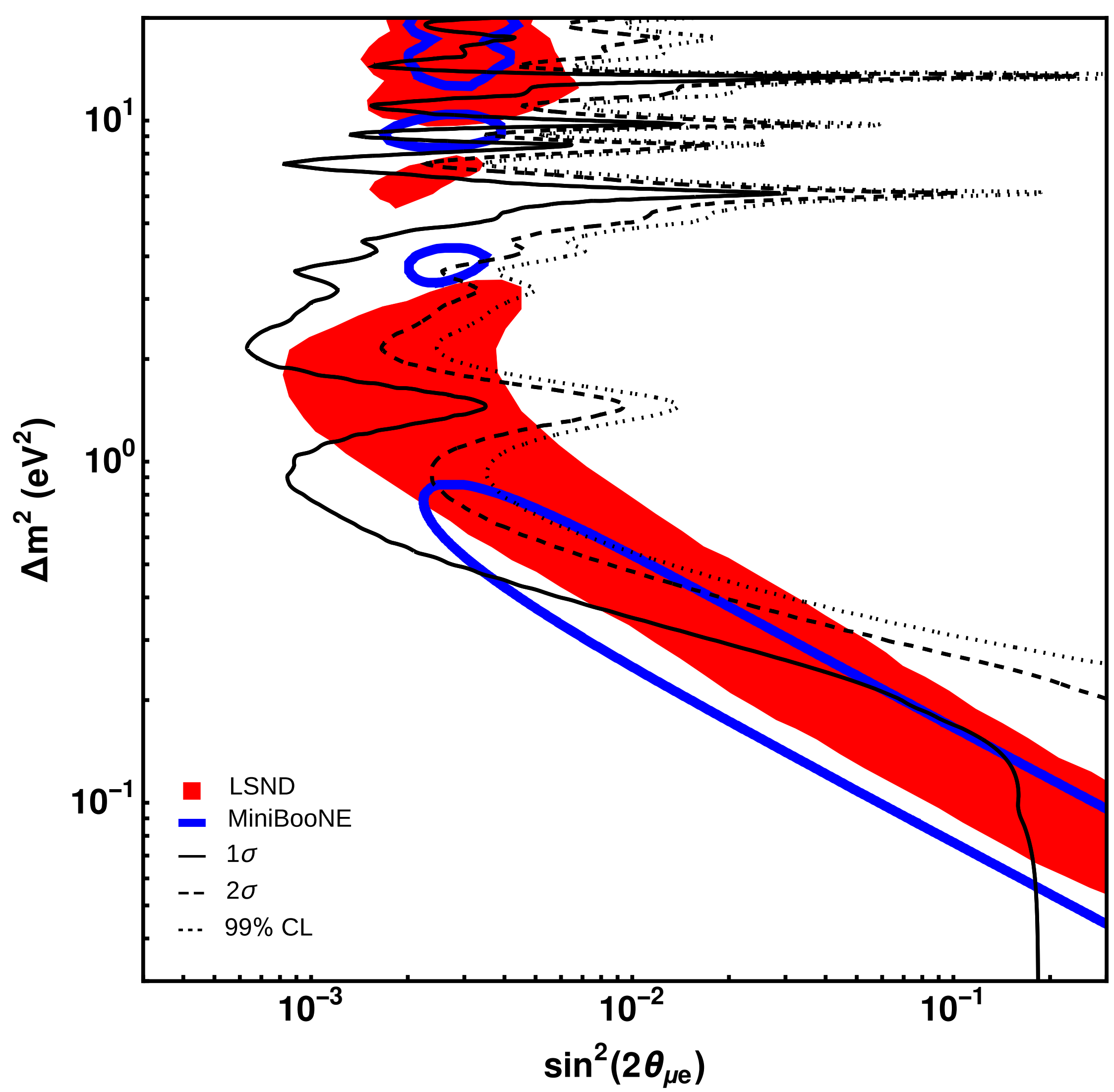
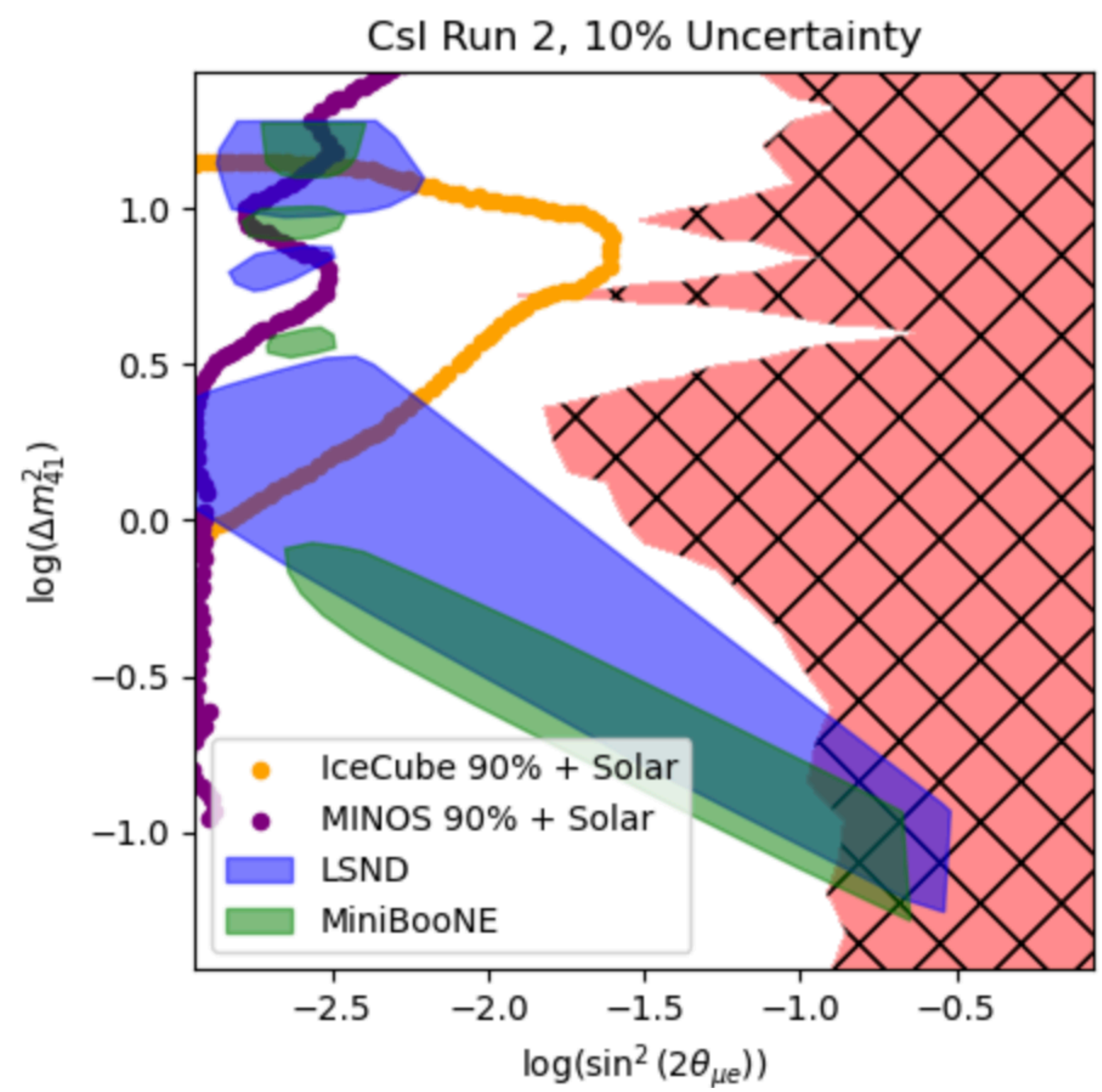


Figure: Dan Pershey

BSM: Sterile neutrinos

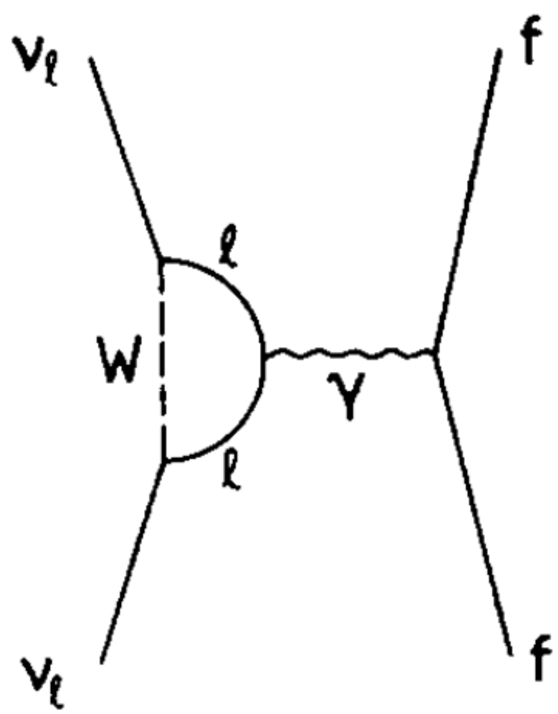


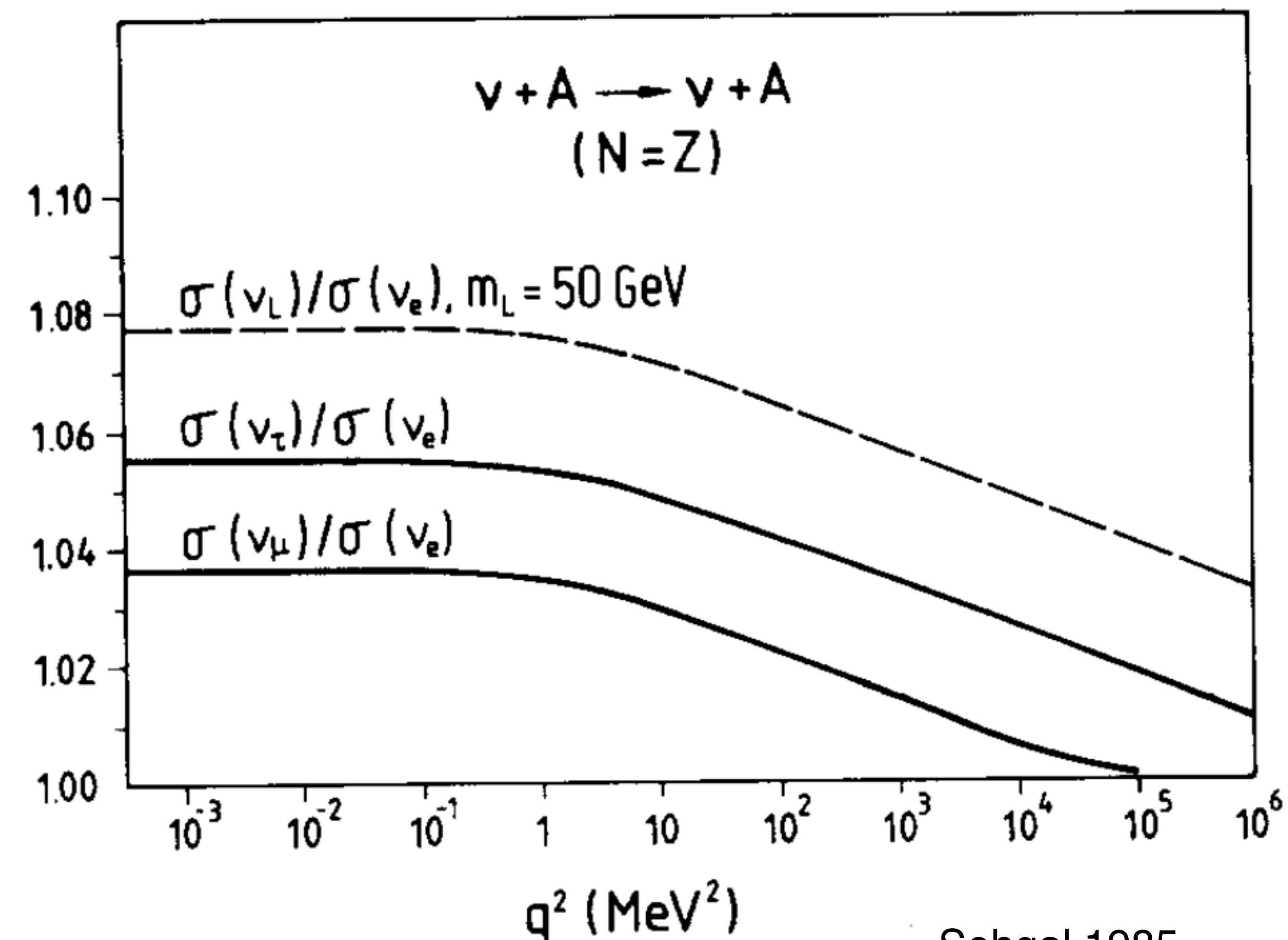


Bisset, Dutta, Huang, LS

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

Standard Model corrections of CEvNS cross section

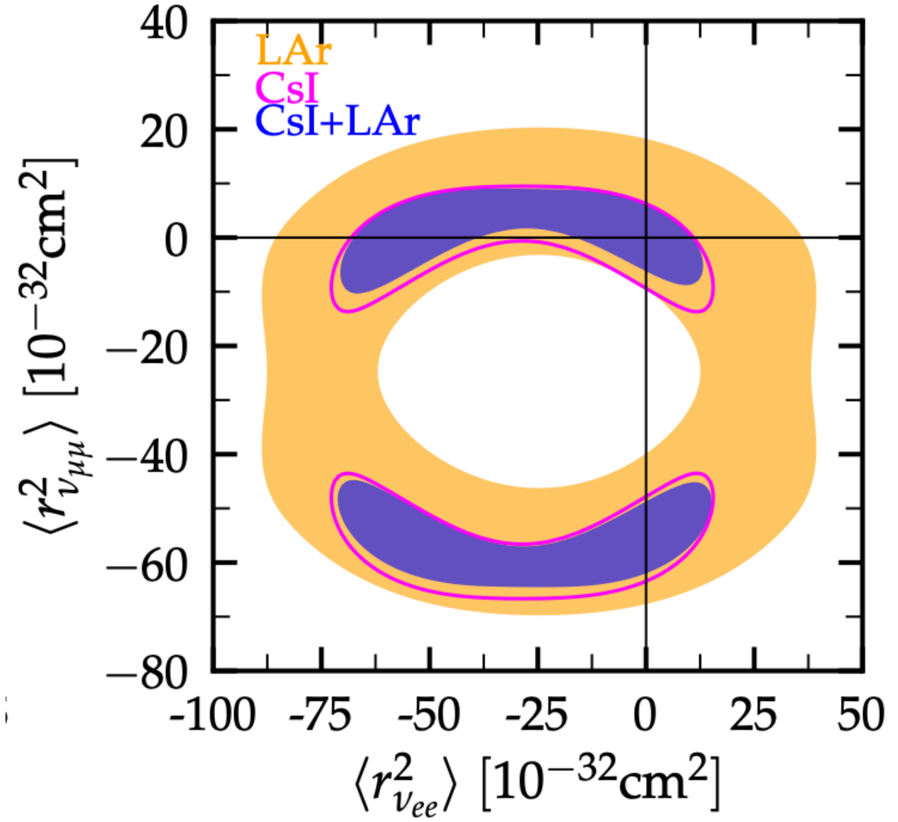




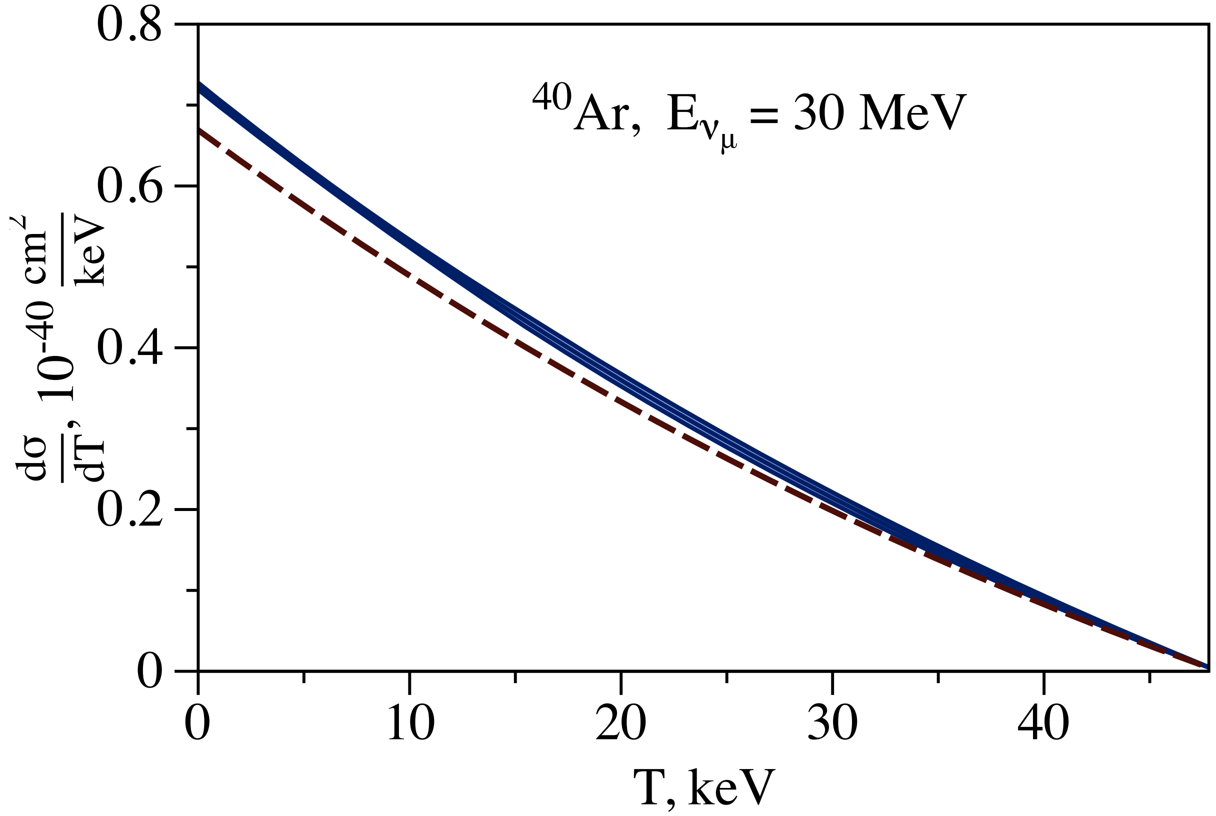
Sehgal 1985

- Radiative corrections to the CEvNS cross section induce small flavor dependences [Marciano & Sirlin 1980; Sehgal 1985; Tomalak et al. 2021]

Standard Model corrections of CEvNS cross section



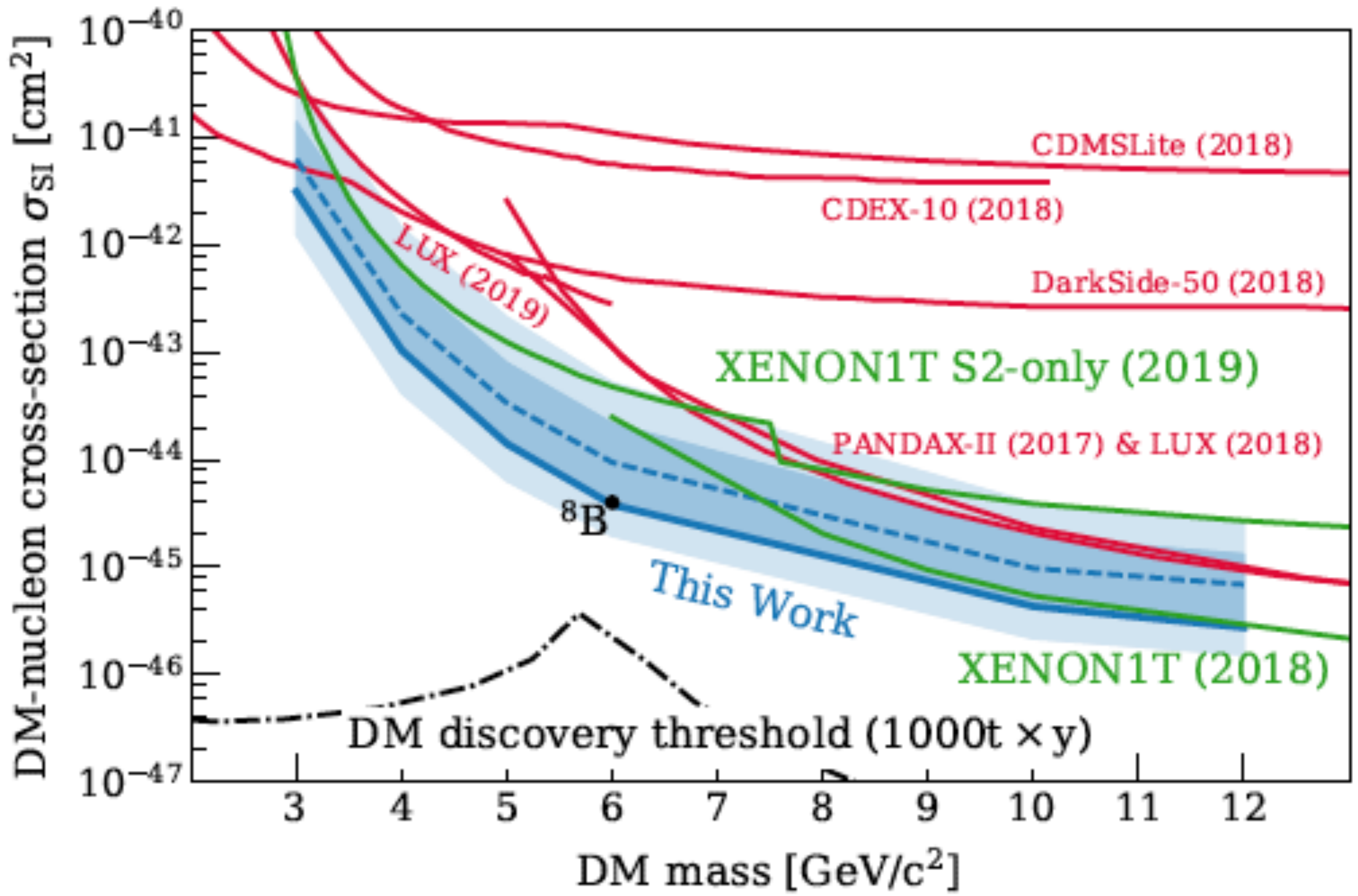
Charge radius contribution: Cadeddu et al. 2018; de Romeri et al. 2023



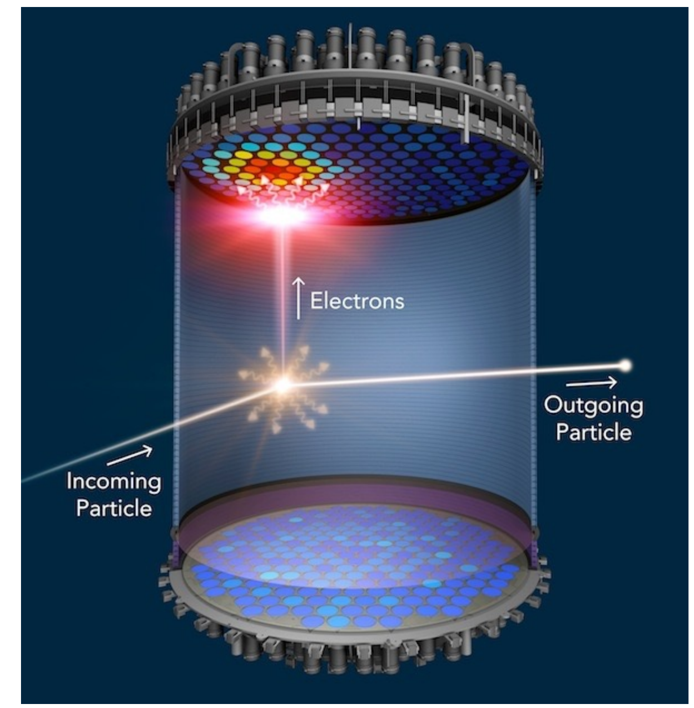
Tomalak et al. 2020

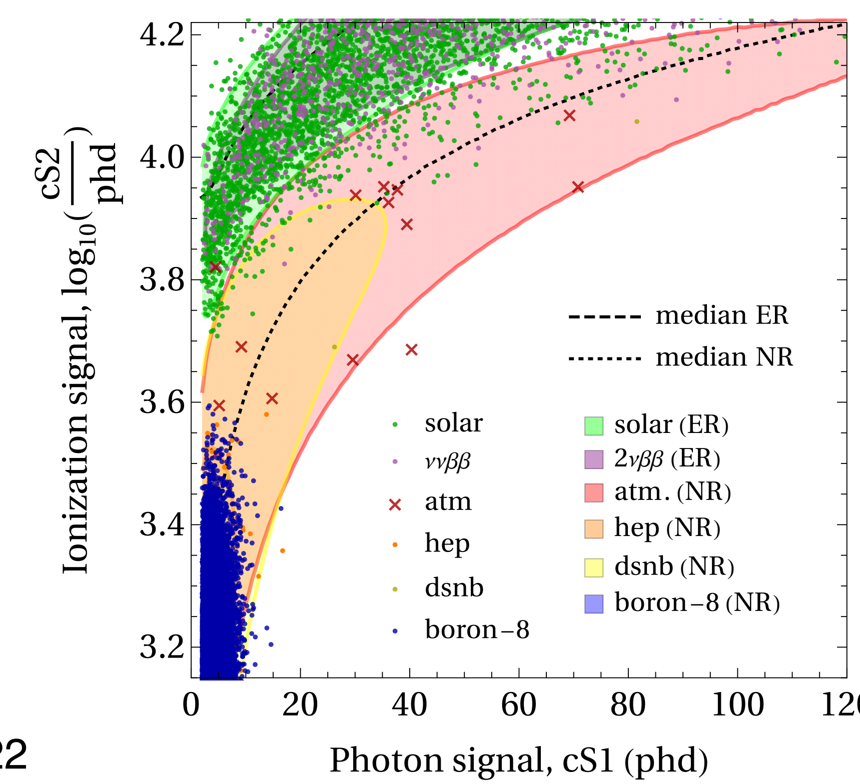
- Separate flavor-independent and flavor-dependent components to the corrections
- Goal: Measure flavor-dependent corrections
- Timing information from stopped-pion source

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



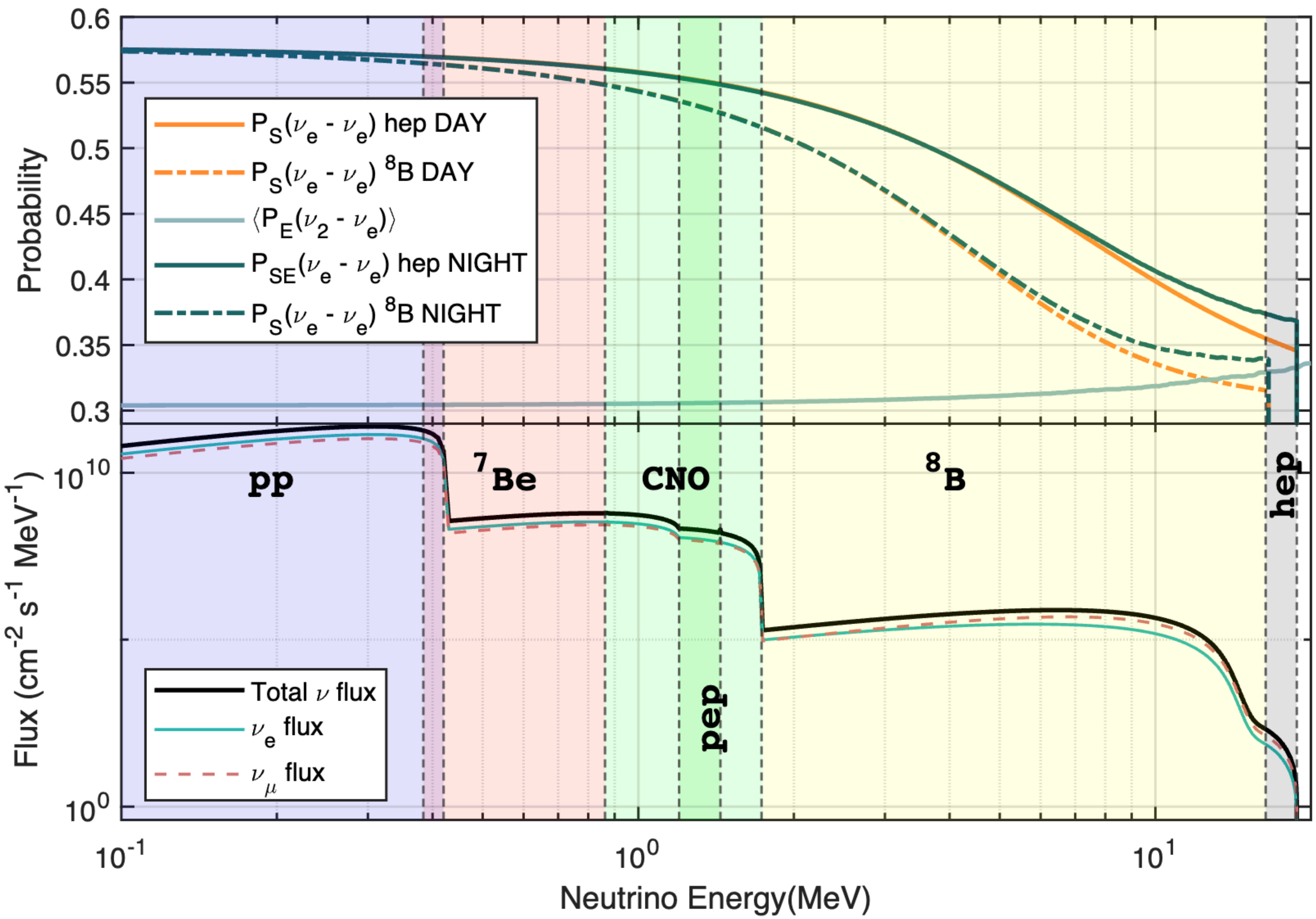
XENON collaboration, PRL 126 (2021) 091301: 2012.02846 [hep-ex]



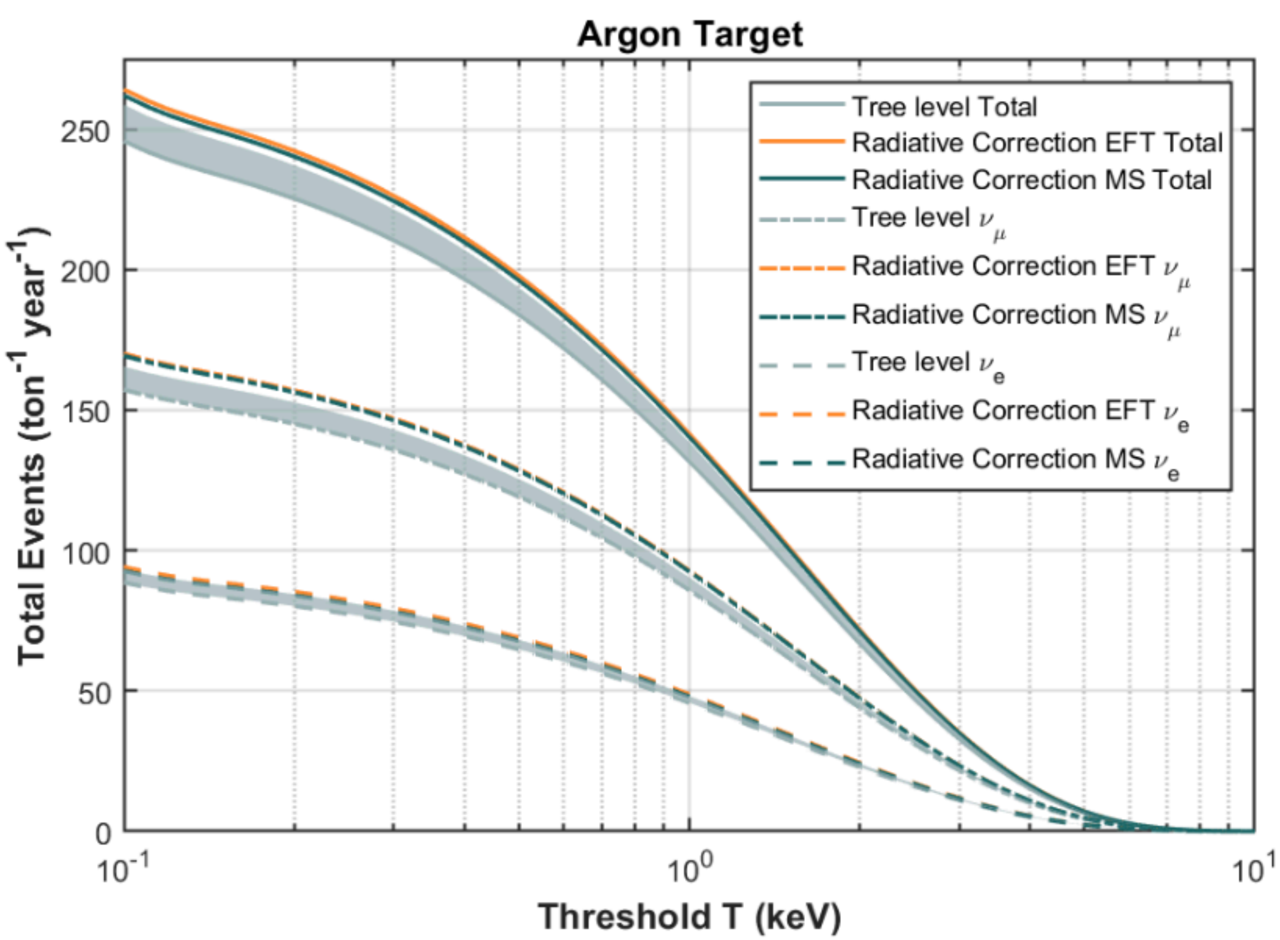


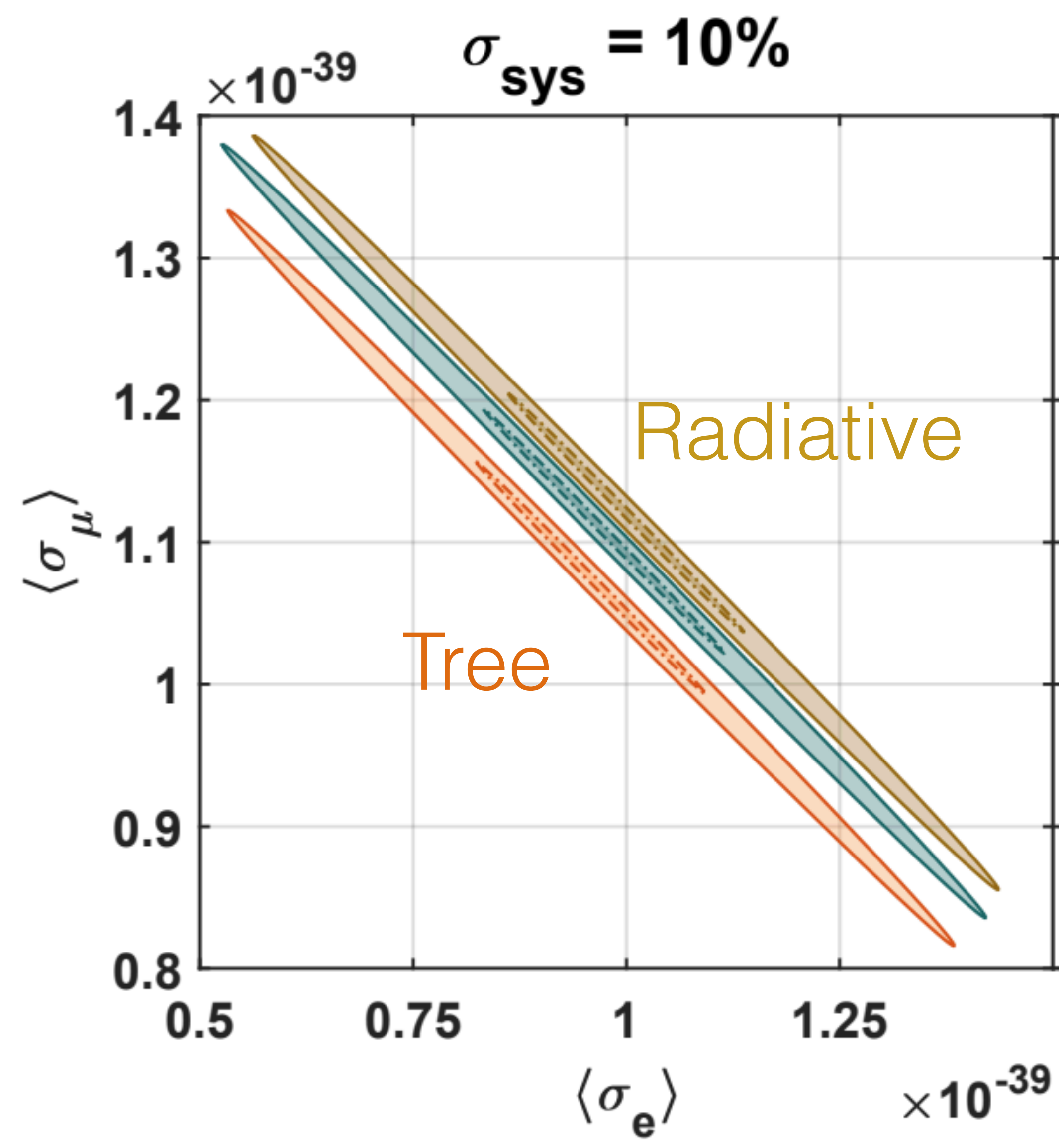
Newstead, Lang, LS 2022

Flavor composition of solar neutrinos



Solar neutrinos with radiative corrections

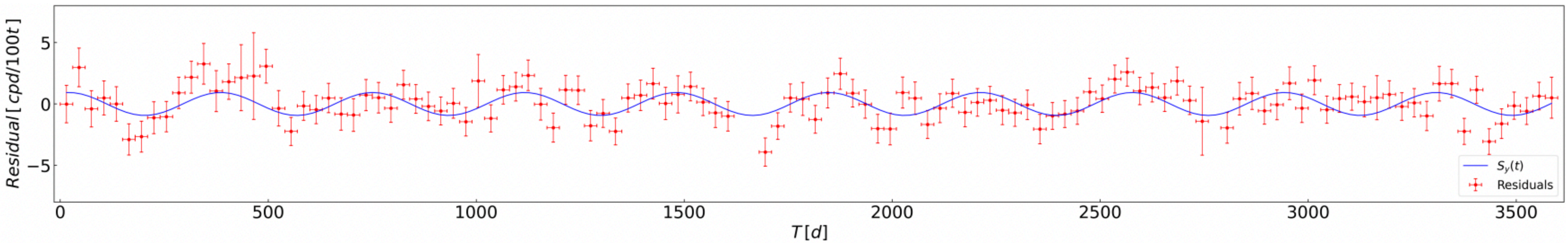




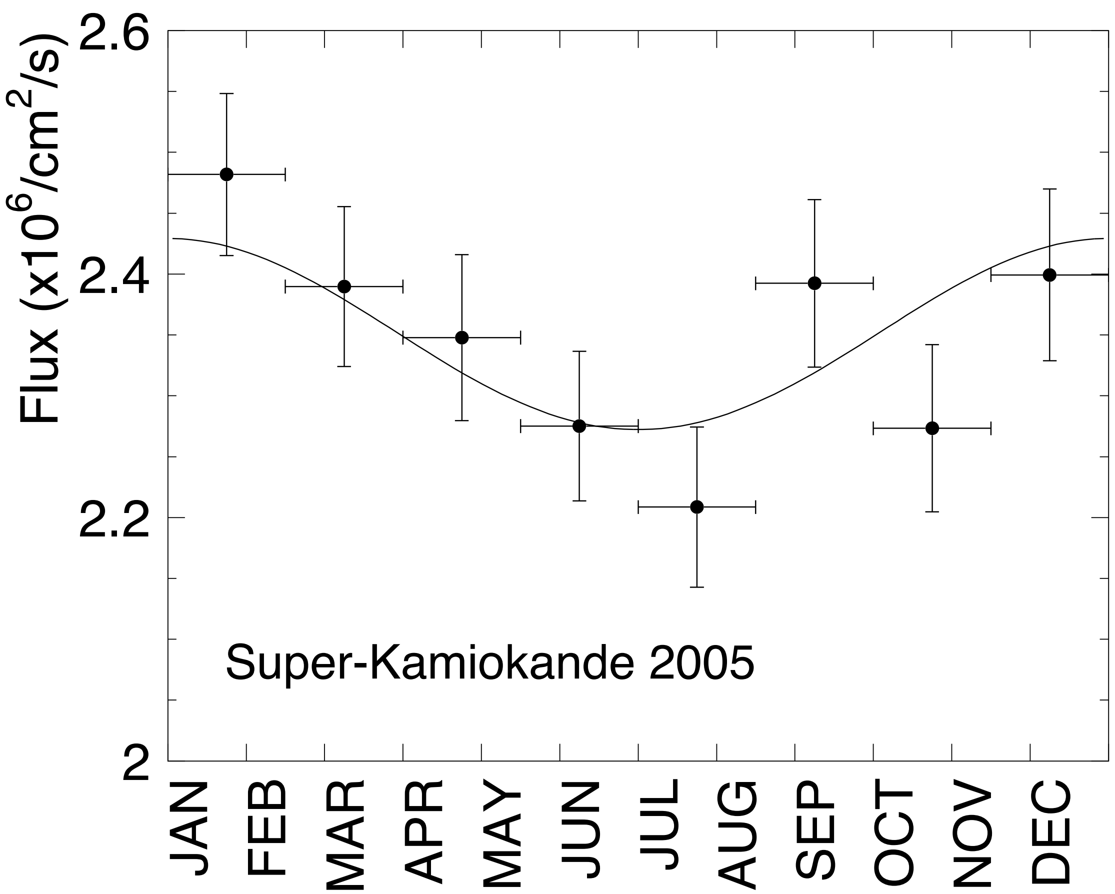
In addition, flavor-dependent corrections introduce a small day/night asymmetry in solar neutrino rate

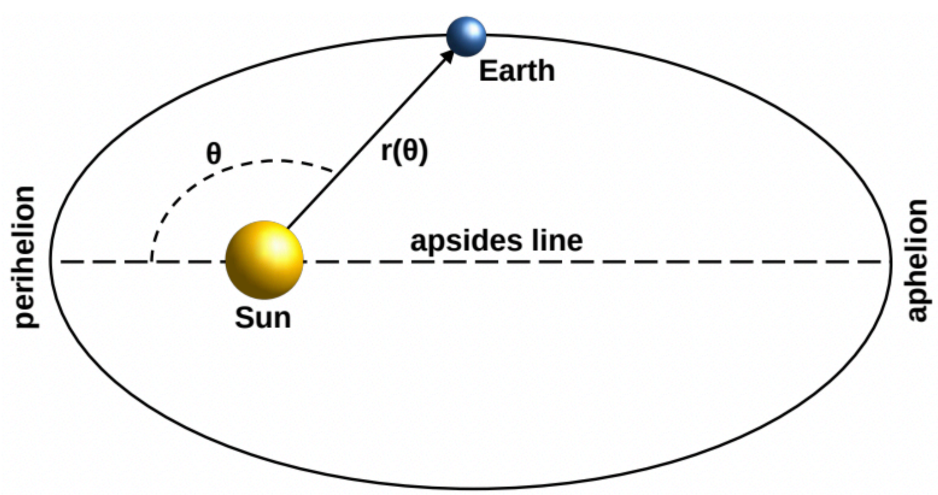
Nityasa Mishra & LS to appear

Time variation of solar neutrino flux



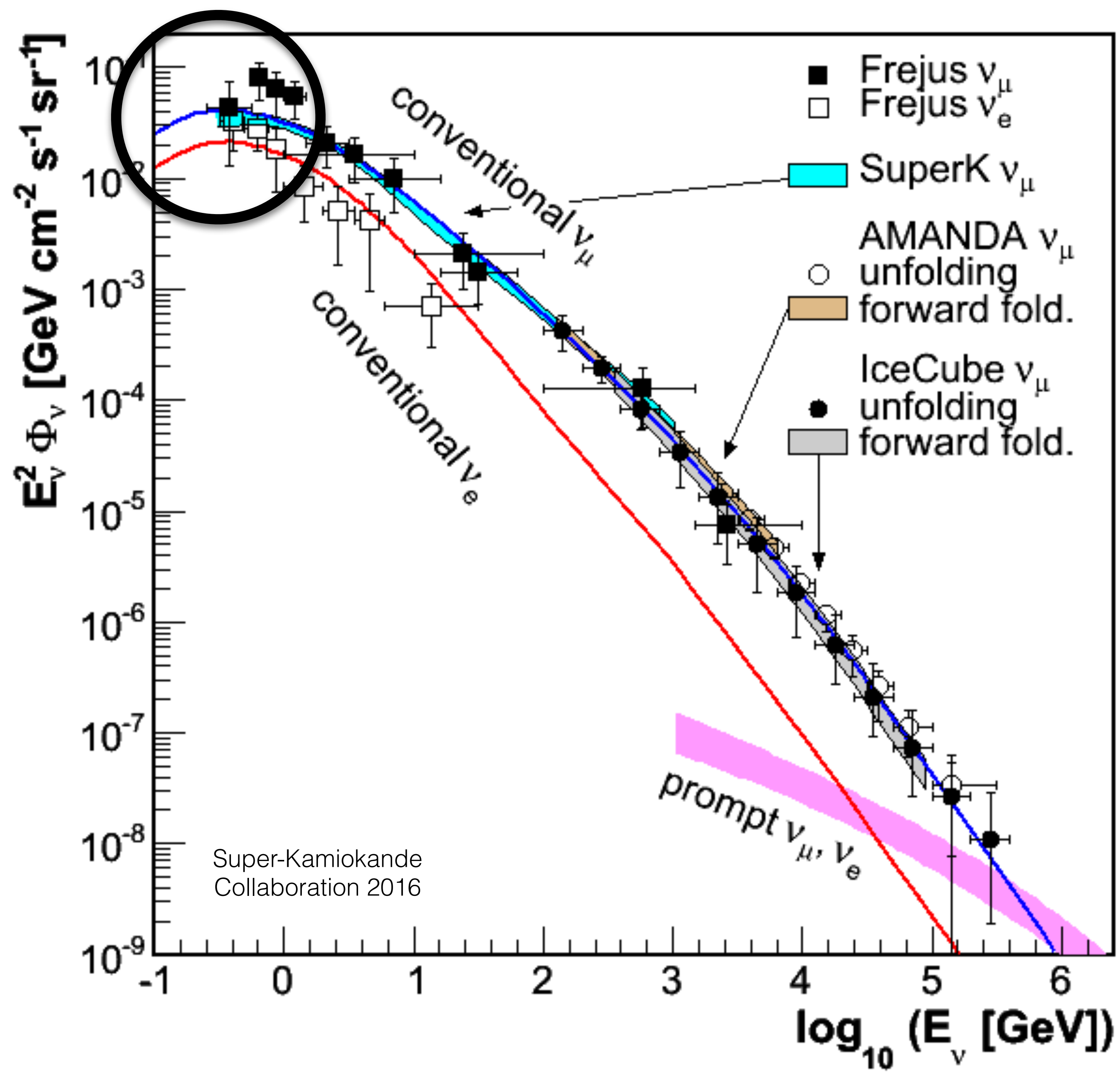
Borexino 2017
Borexino 2022





A 50 ton detector would measure the eccentricity in ~5-10 years in electron and nuclear recoil channels

Low-energy atmospheric neutrinos



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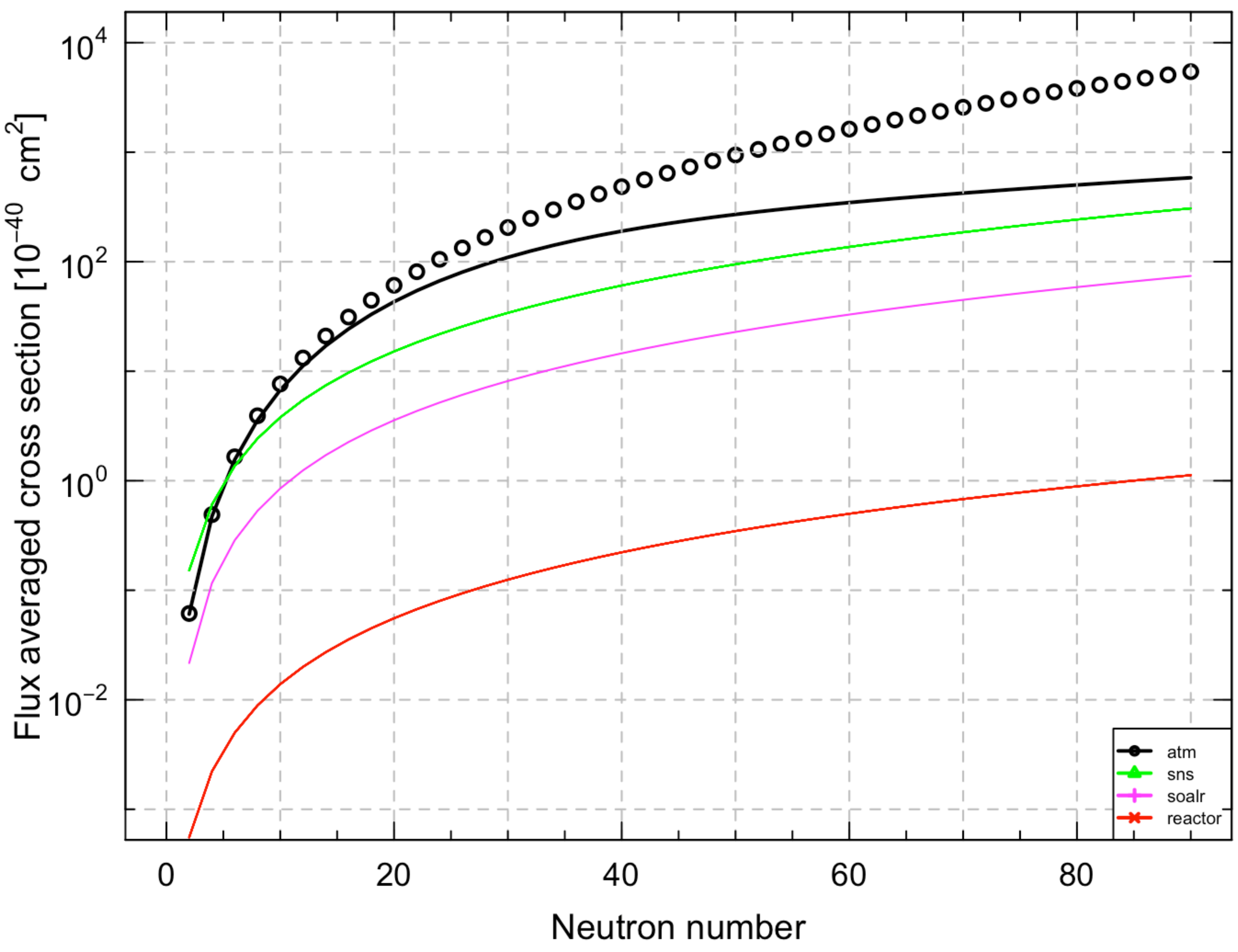
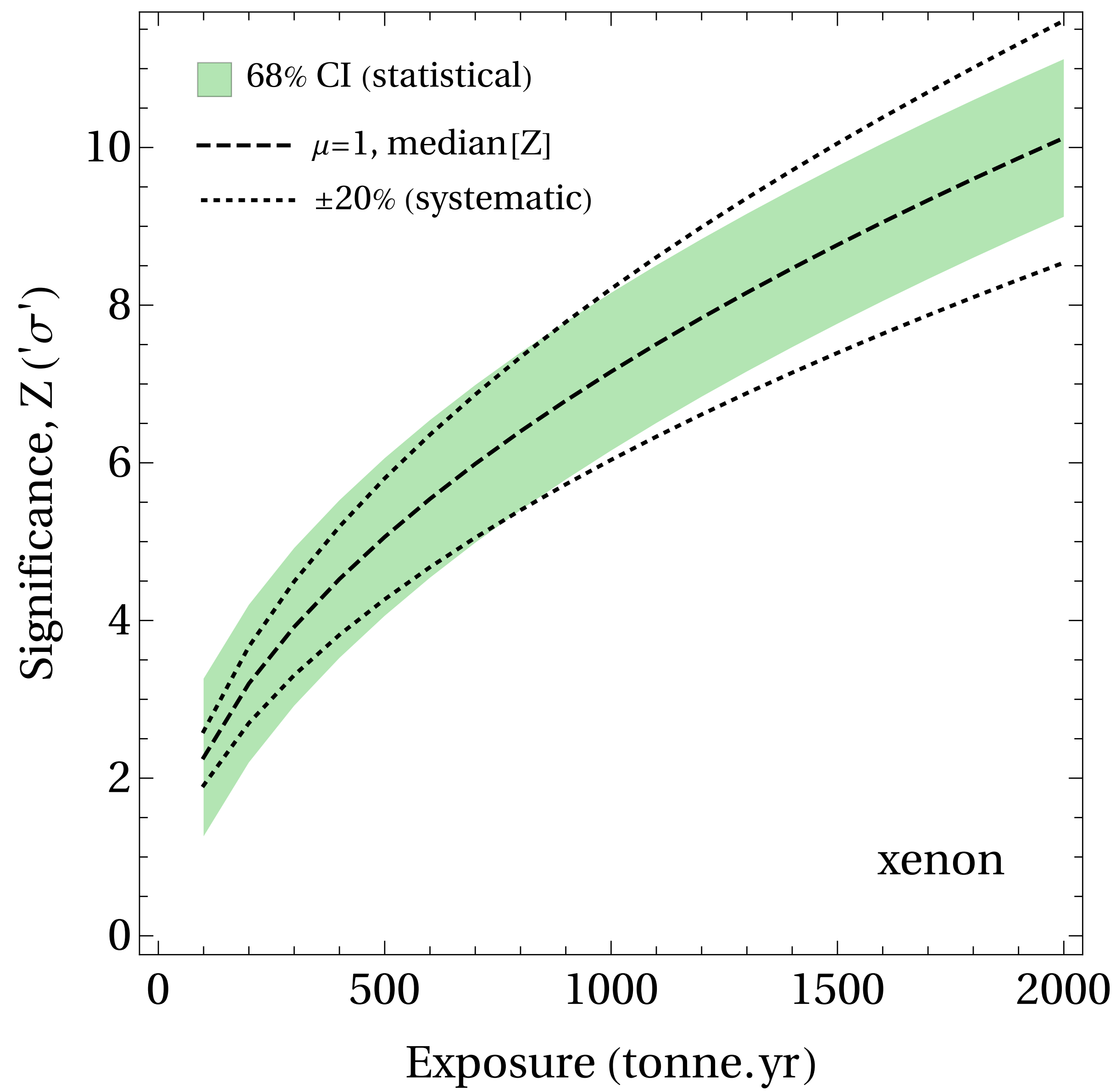
Atmospheric neutrinos for CEvNS

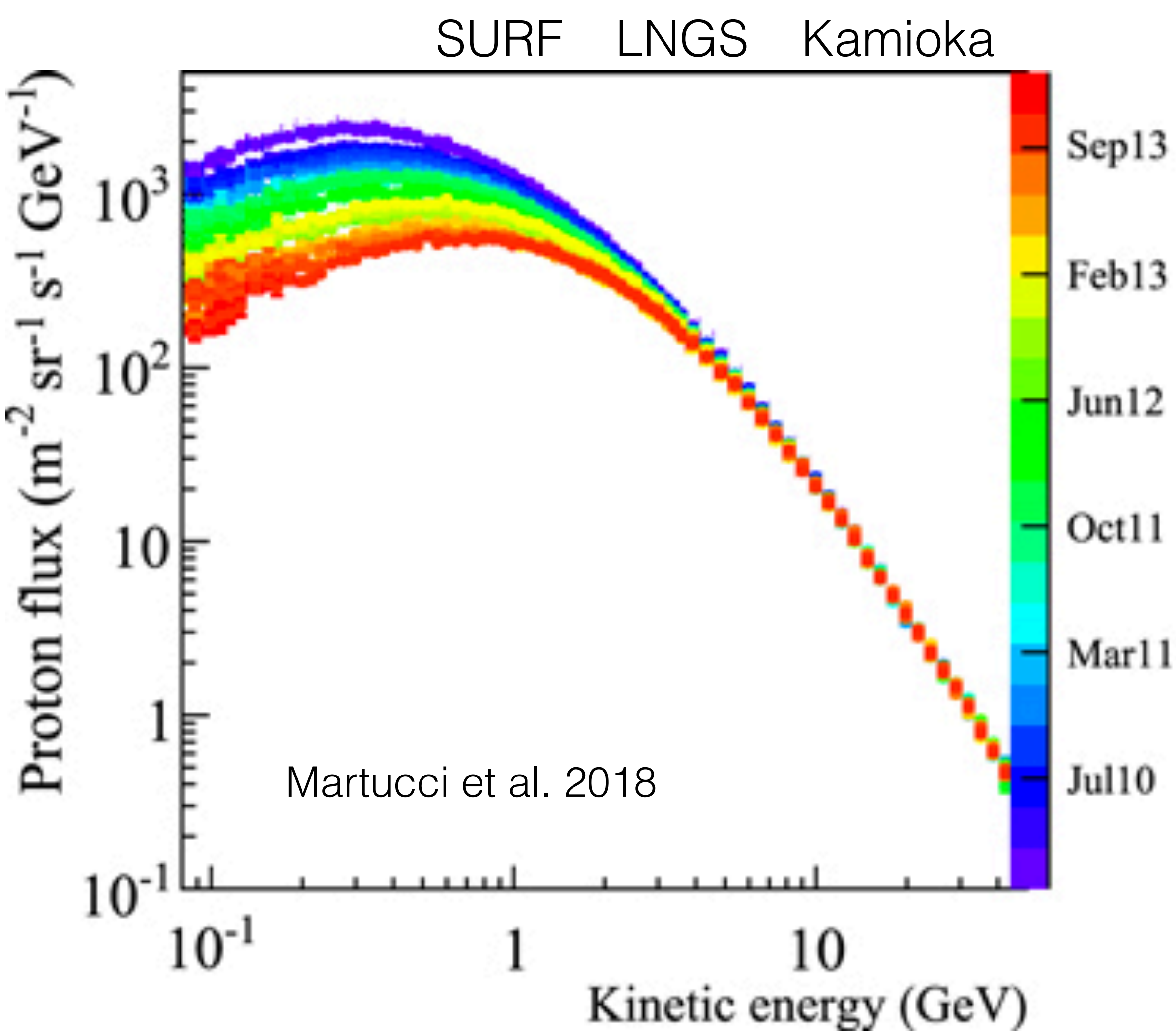


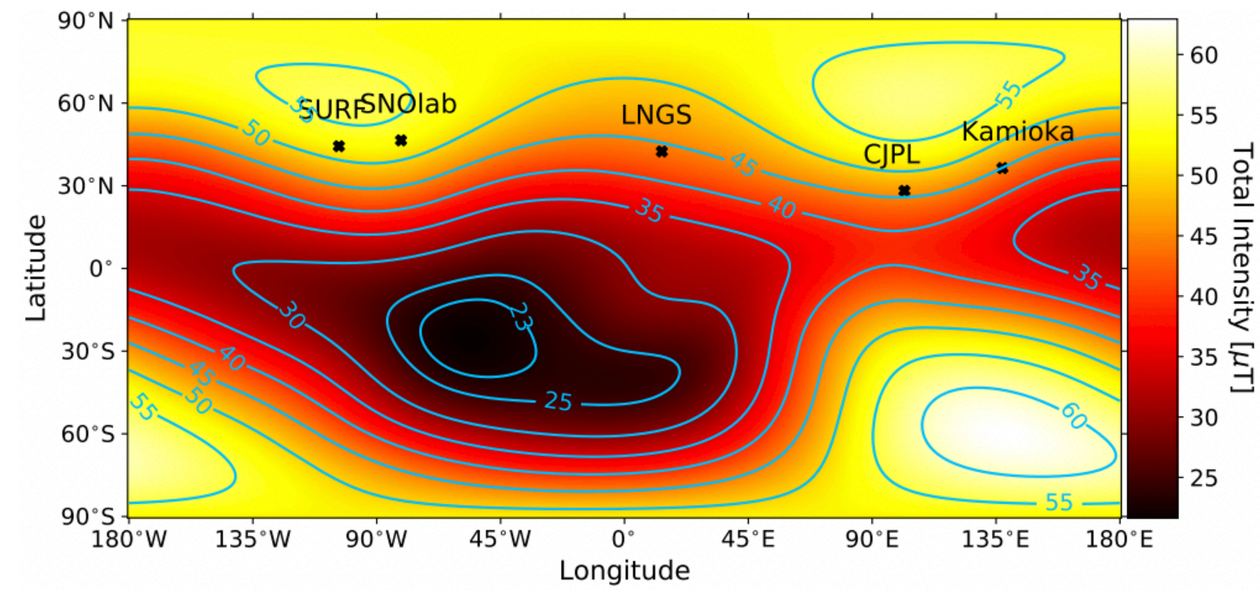
Detection of low-energy atmospheric neutrinos

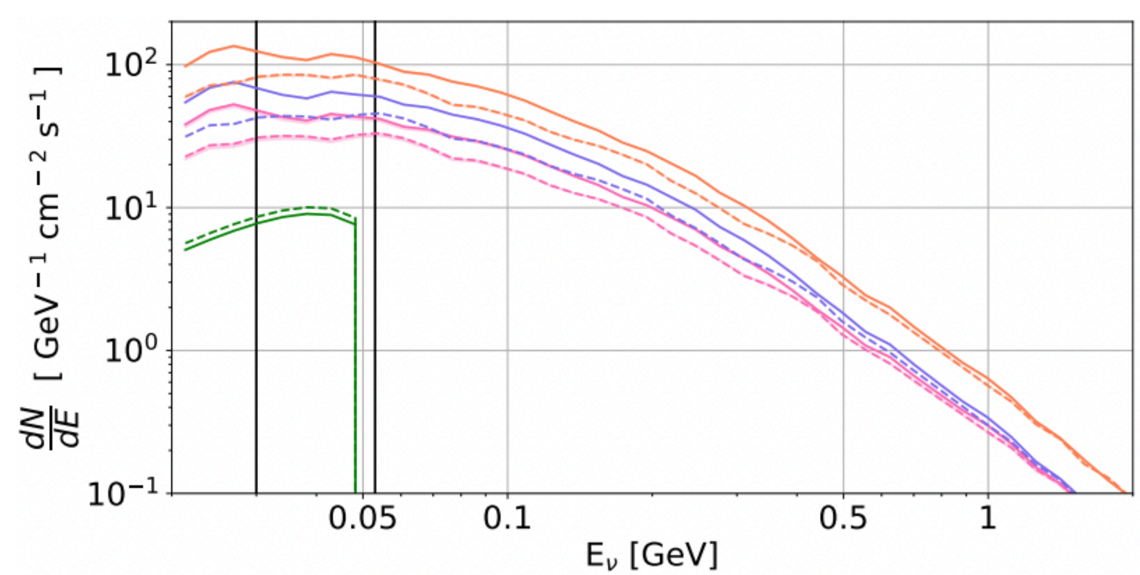


Identification of atmospheric neutrino flux component depends on systematics in measurements of the atmospheric neutrino flux [Newstead, Lang, Strigari 2021; Zhuang, Strigari, Lang 2022]

Location and time dependence of atmospheric neutrinos

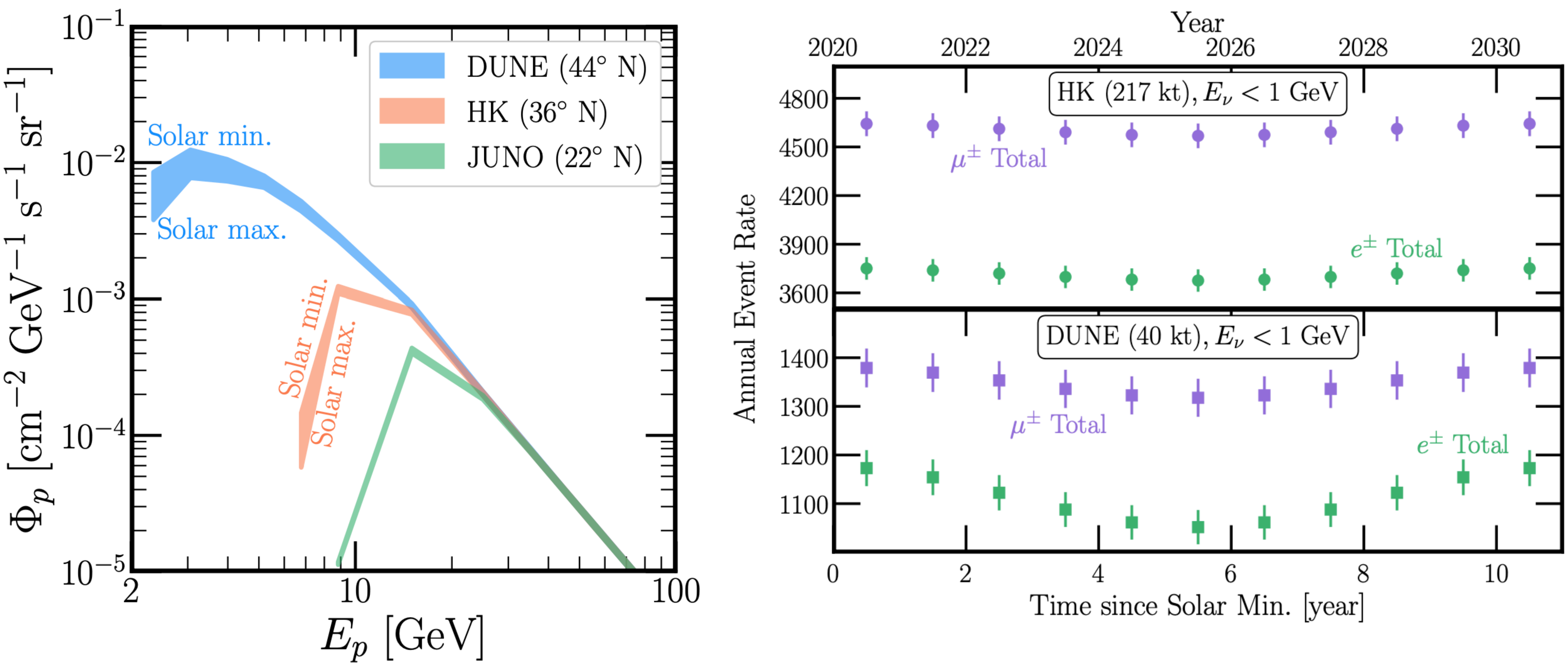






Time variation and geomagnetic effects depend on detector location [**Zhuang**, Strigari, Lang 2021]

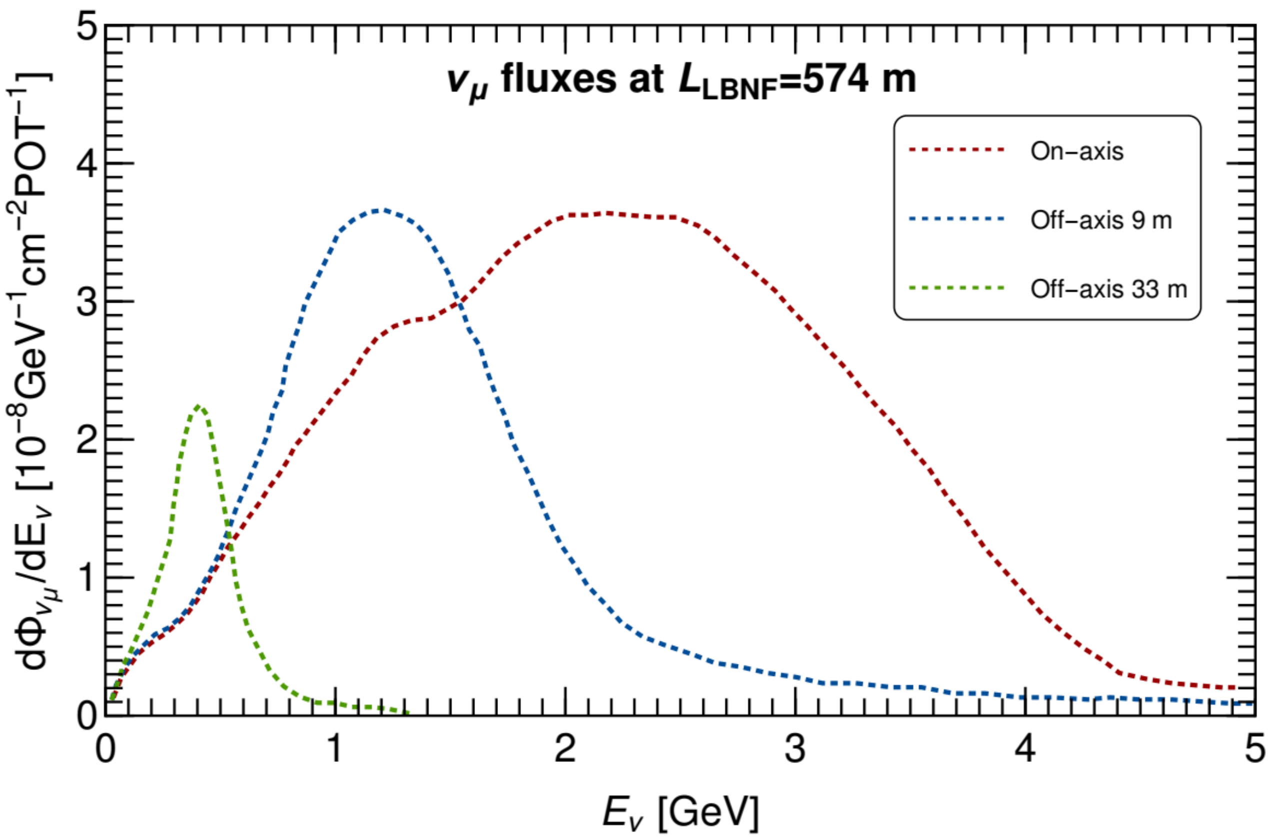
DUNE and Hyper-Kamiokande

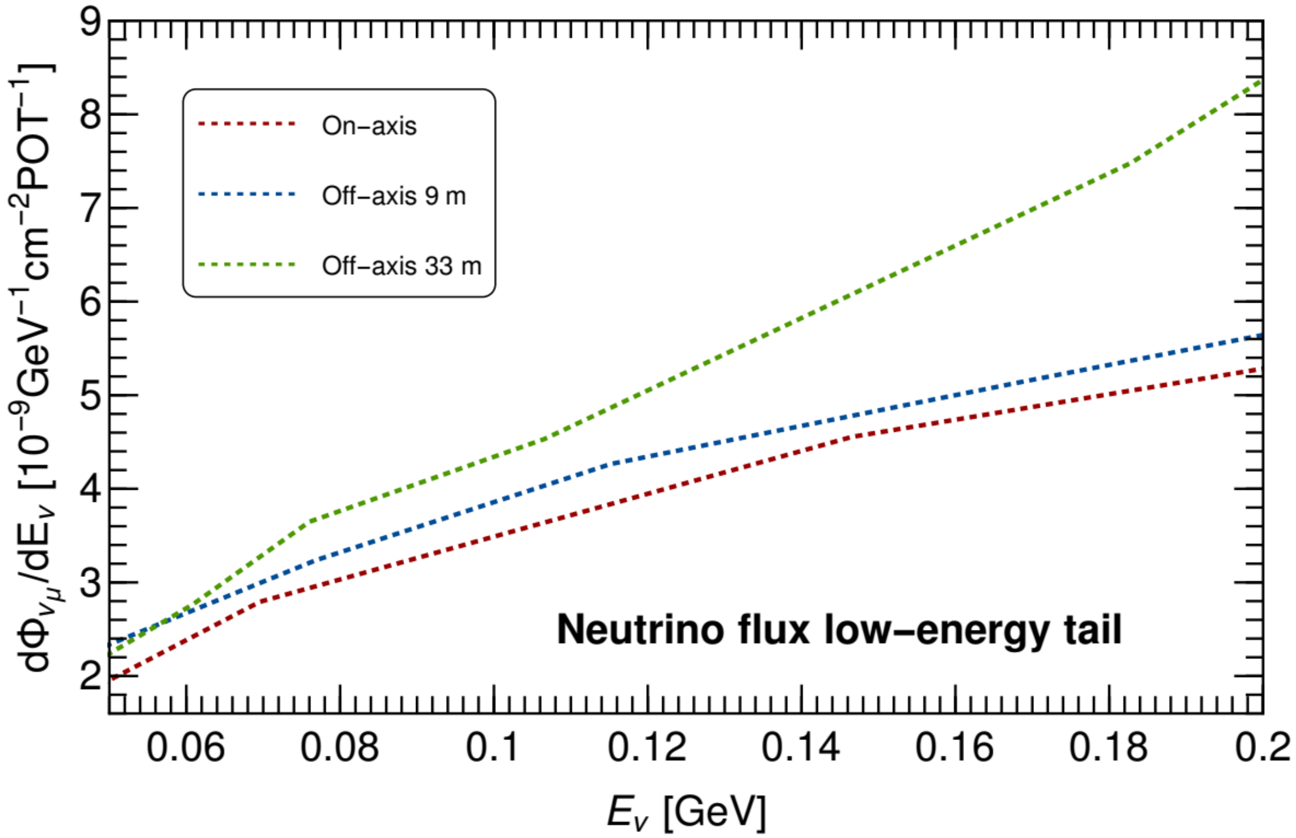


- Over 11-year solar cycle, statistical significance for observing time modulation of atmospheric neutrinos is 4.8σ for DUNE and 2.0σ for HK.
- Flux measurements at both DUNE and HK important for understanding systematics and oscillations in low-energy atmospheric neutrinos.

Kelly, Machado, Mishra, LS, Zhuang 2023

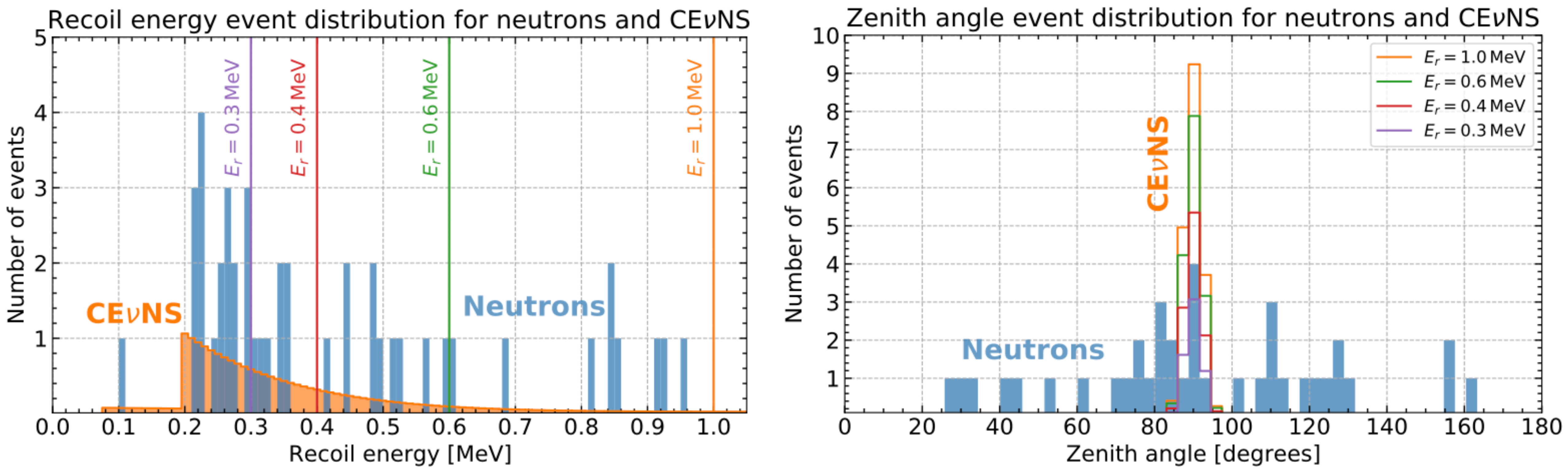
CEvNS with decay-in-flight neutrino beam





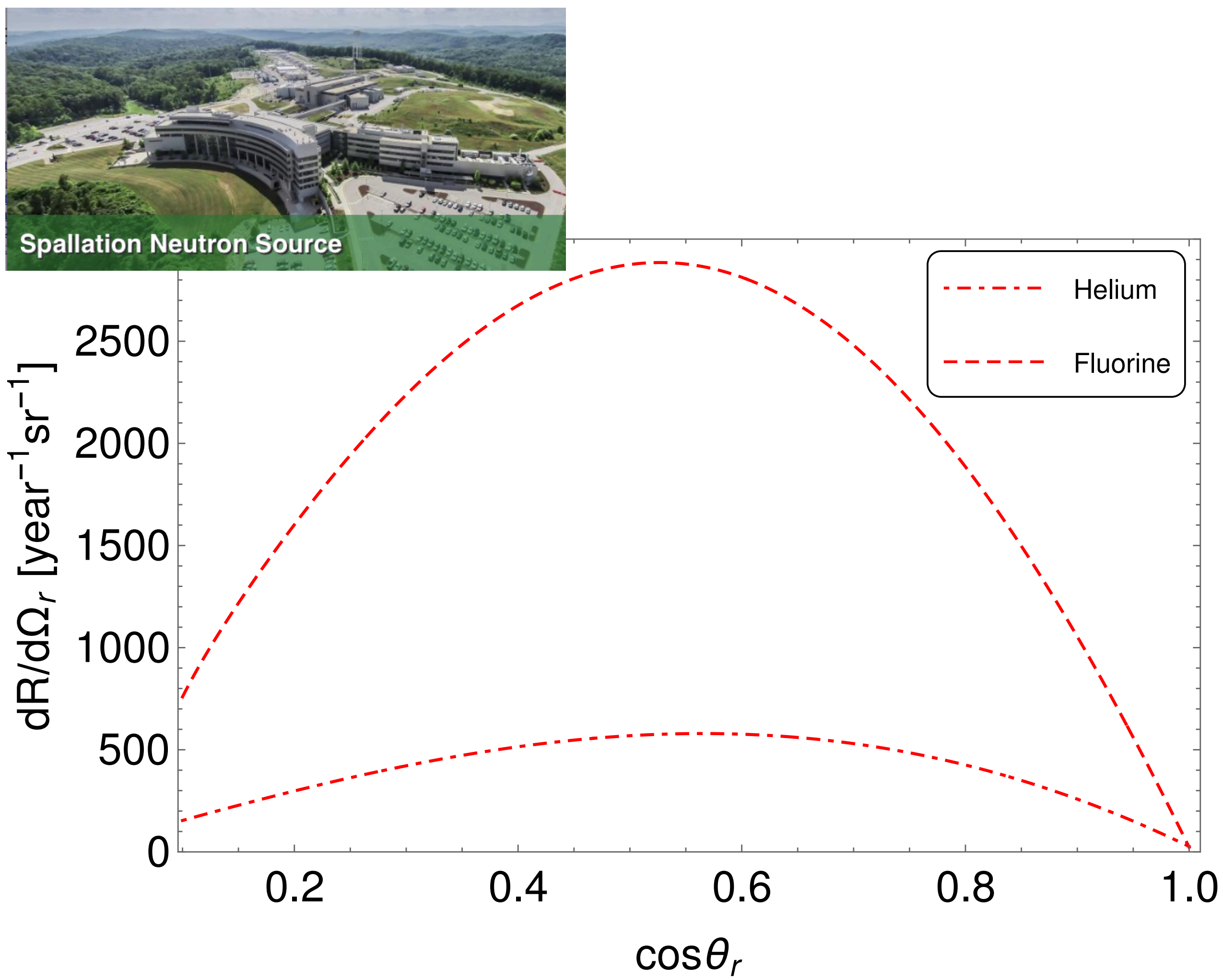
- LBNF beam line provides potential 3rd energy scale for terrestrial CEvNS experiments
- Decay-in-flight spectrum similar to that of atmospheric neutrinos

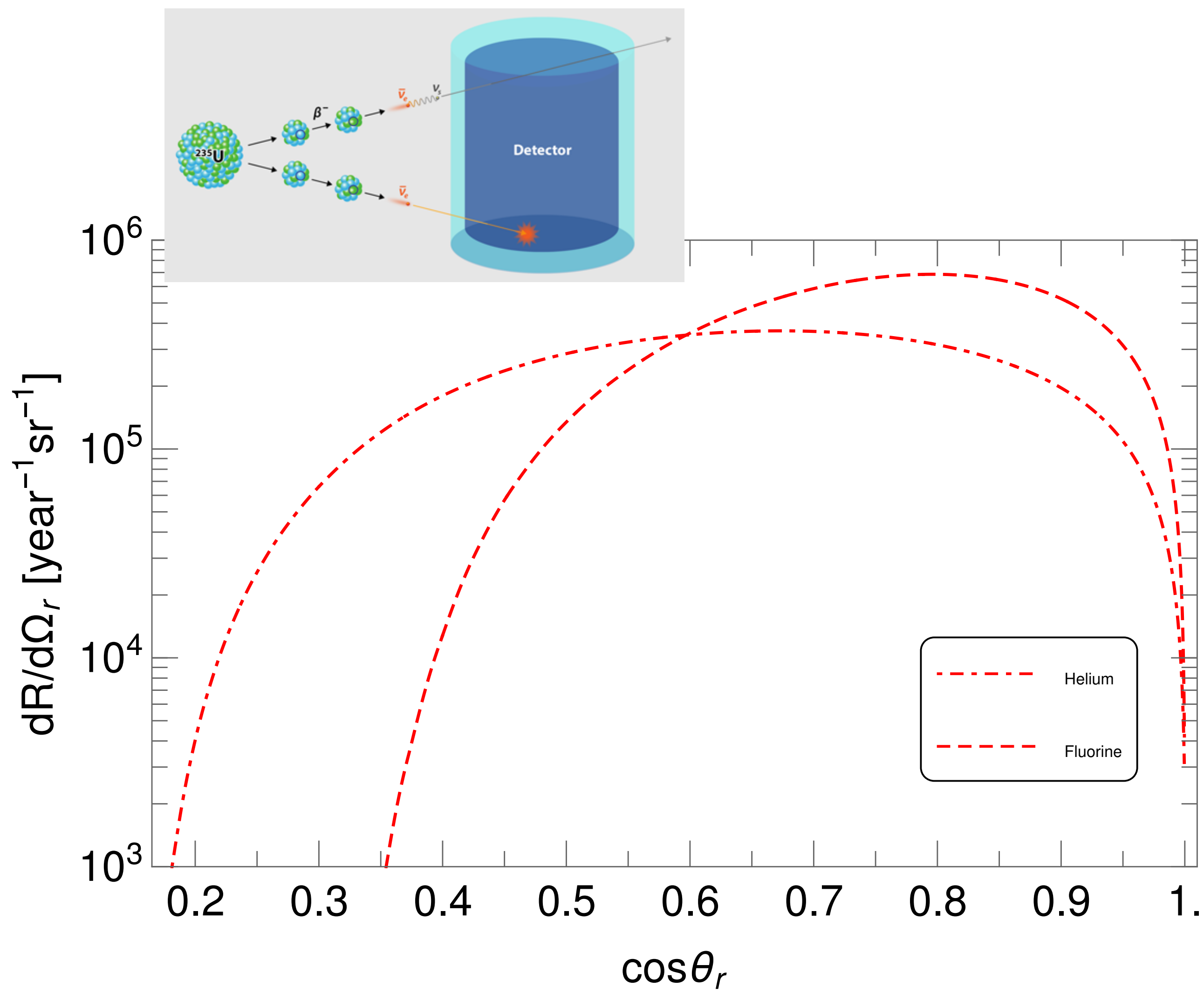
CEvNS with decay-in-flight neutrino beam

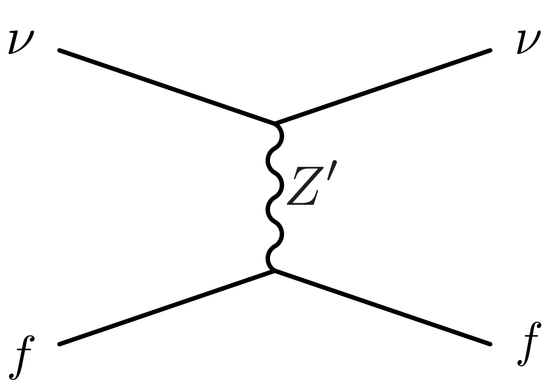


- For decay-in-flight beam, recoils nearly perpendicular to beam direction
- 10 $m^3 \cdot yr$ exposure to the NuMI Low Energy (LE) beam configuration shows a CEvNS signal-to-noise ratio of ~ 2.5.

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

Summary

- Flavor dependencies in future CEvNS searches are a sign of either SM corrections or BSM physics
- Terrestrial and astrophysical beams may be used to separate flavors
- Residual systematics in the (astrophysical and terrestrial) fluxes must be controlled
- Adding new observables such as directionality reduce background and also probe BSM physics