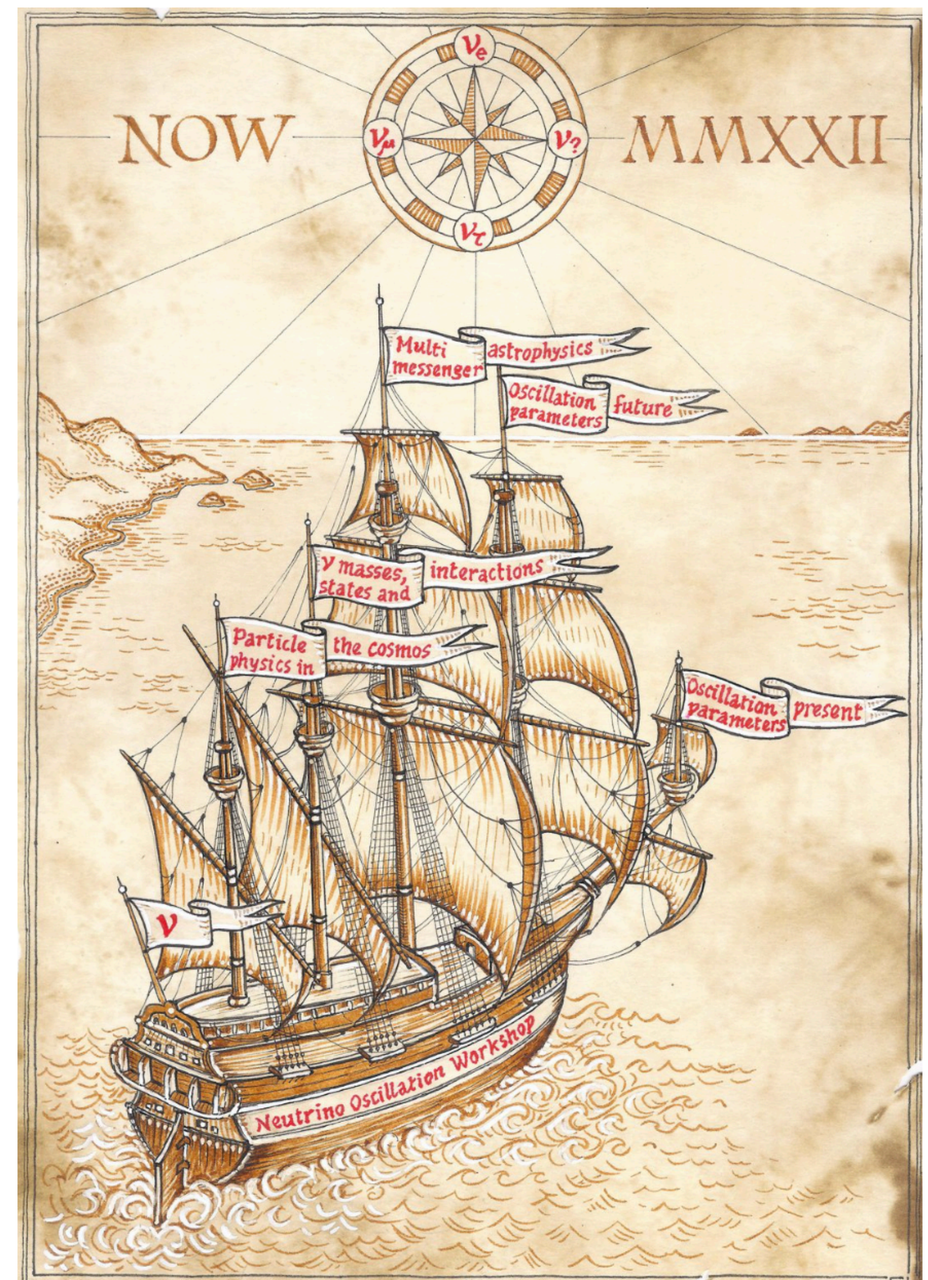
Neutrino signals and/or backgrounds at dark matter detectors

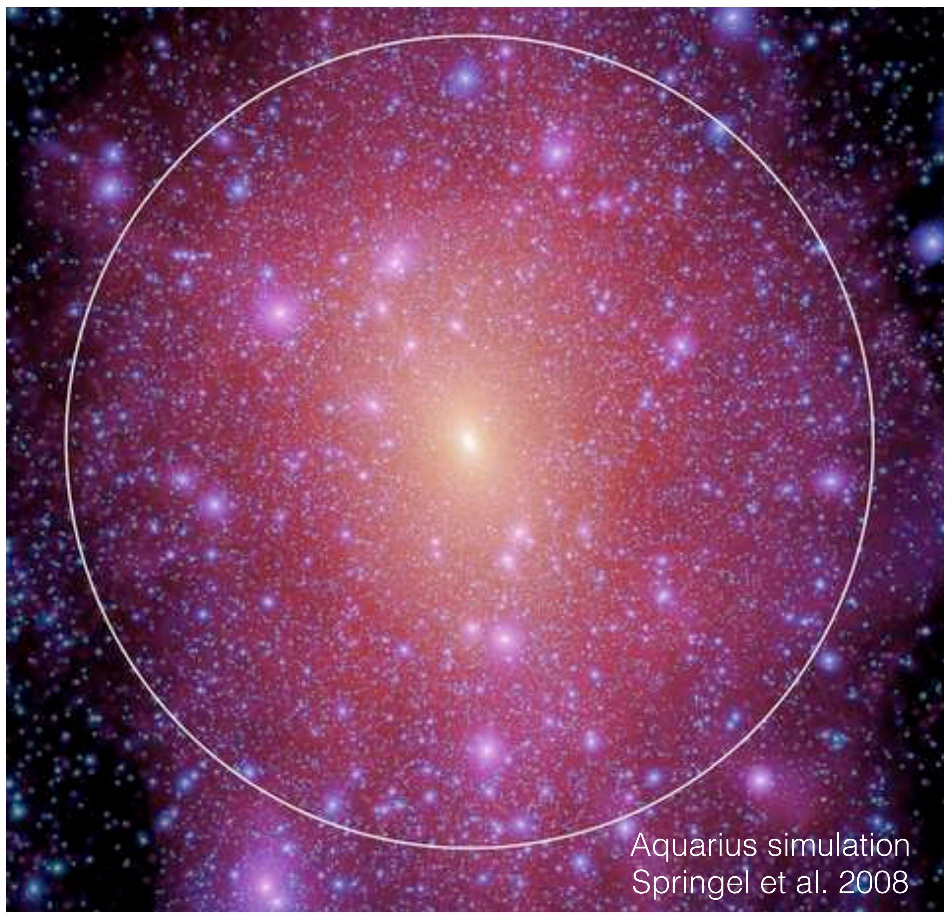
Artwork by Sandbox Studio, Chicago with Ana Kova

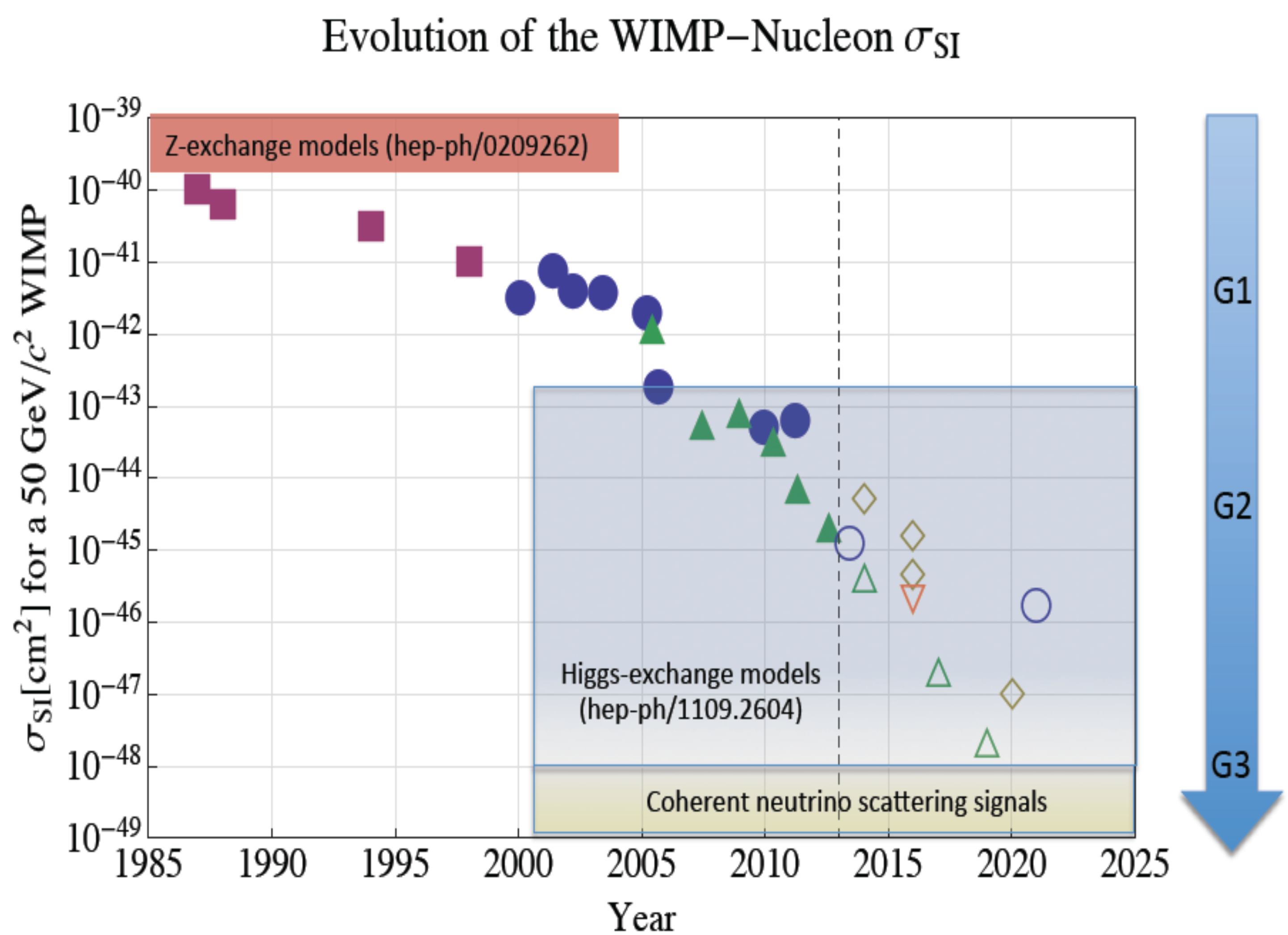


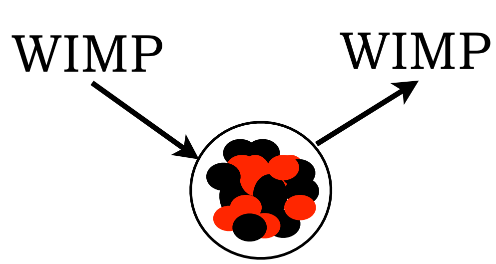
Louis E. Strigari
Texas A&M University
Mitchell Institute for Fundamental Physics and Astronomy

NOW 2022
Sept 10, 2022

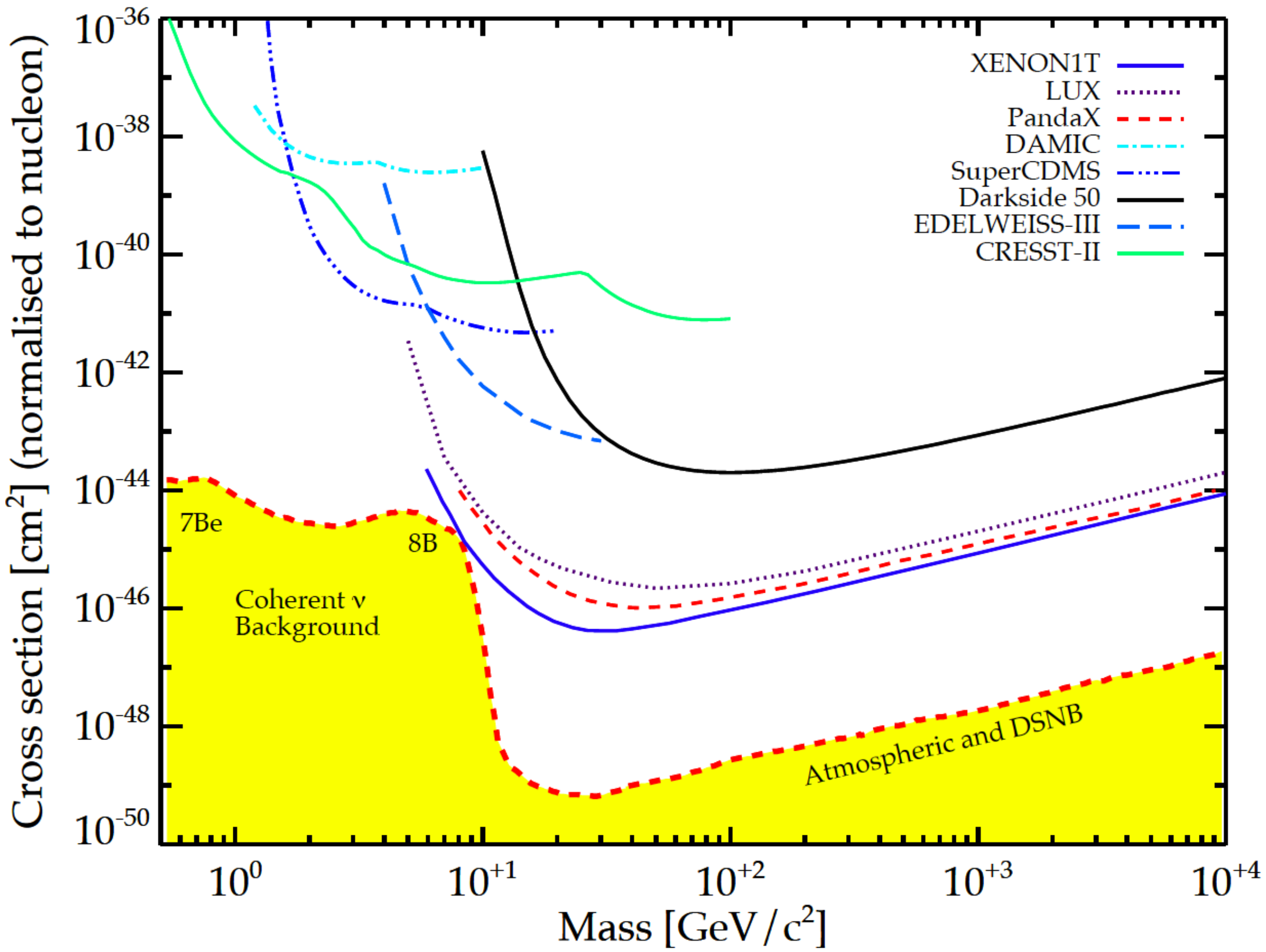
Direct detection of weak-scale dark matter



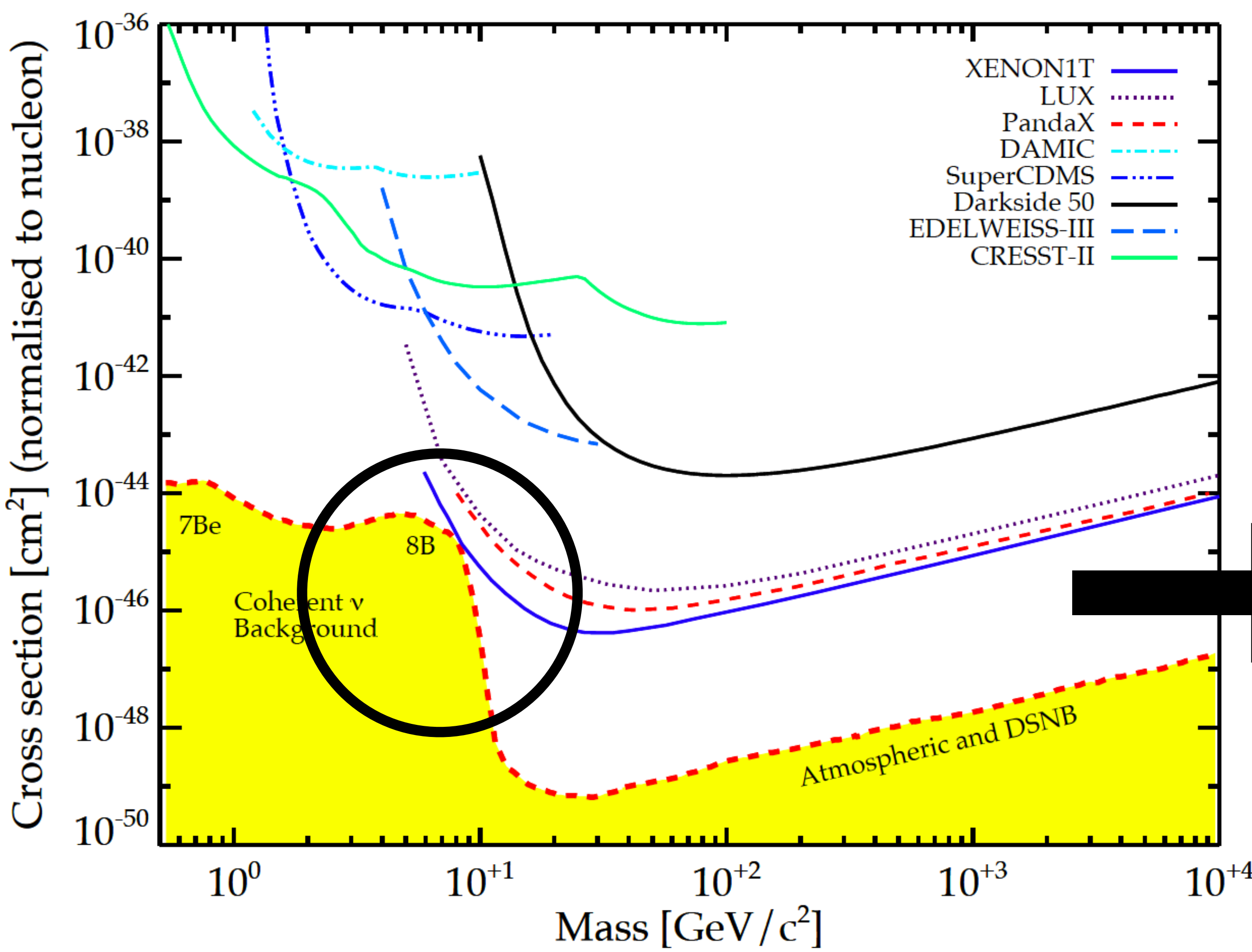


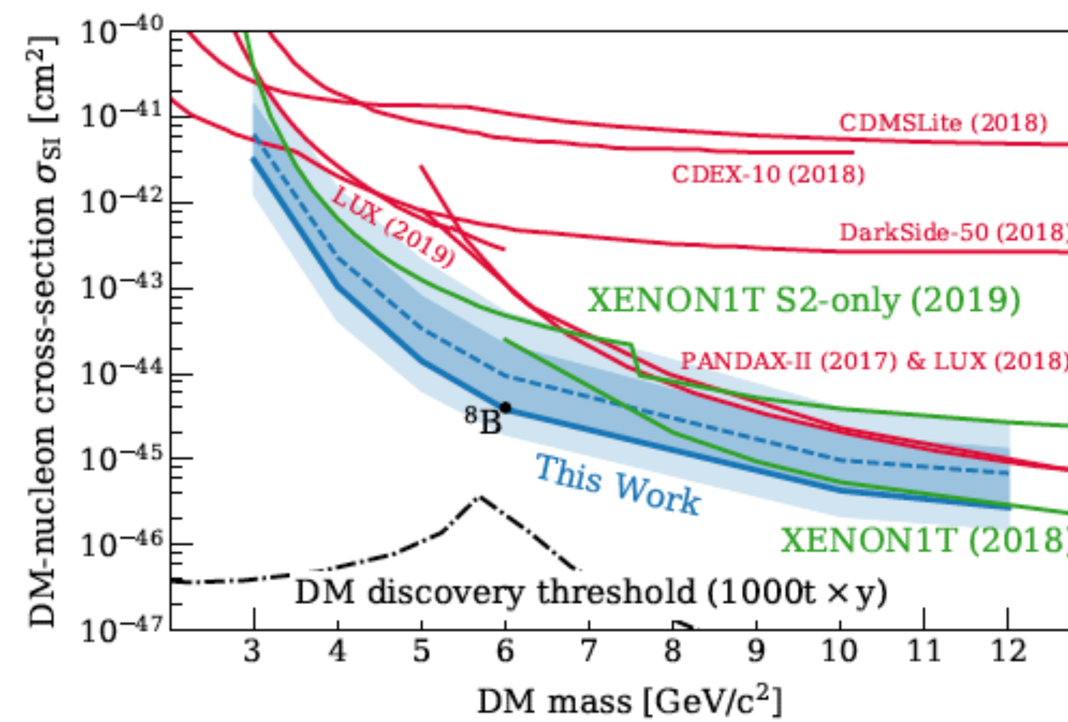


Search for Coherent Elastic Scattering of Solar ^{8}B Neutrinos in the XENON1T Dark Matter Experiment



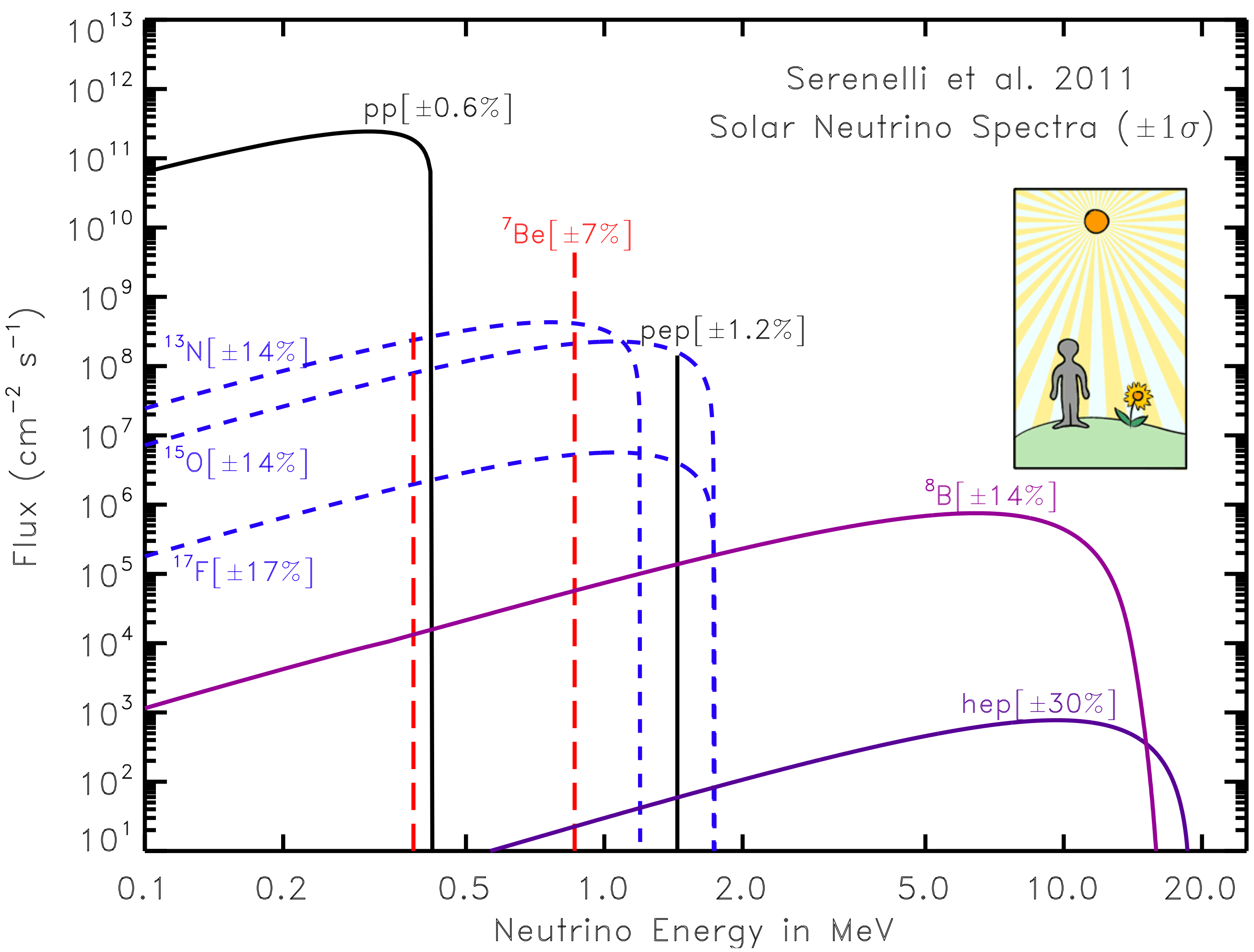
Search for Coherent Elastic Scattering of Solar ^{8}B Neutrinos in the XENON1T Dark Matter Experiment

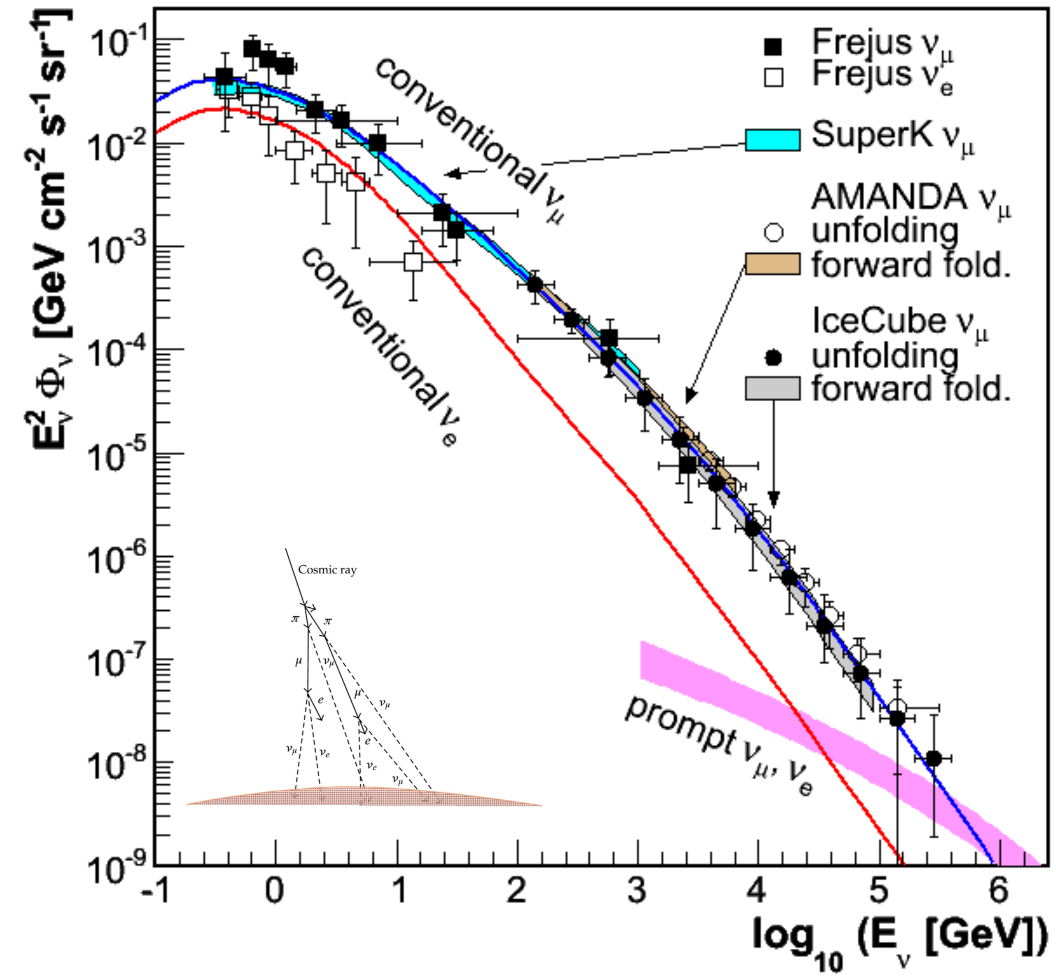


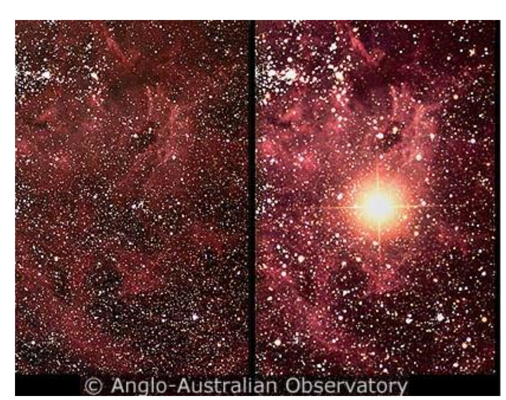


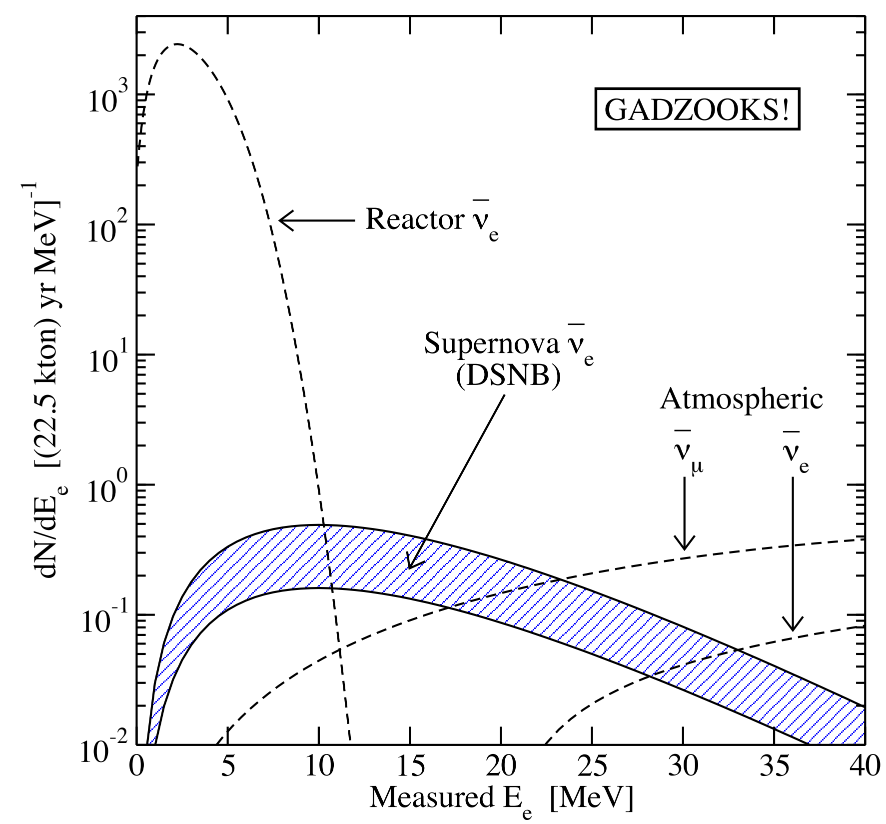
XENON collaboration, PRL 126 (2021) 091301: 2012.02846 [hep-ex]
PandaX-4T collaboration: 2207.048833

Astrophysical neutrinos and dark matter



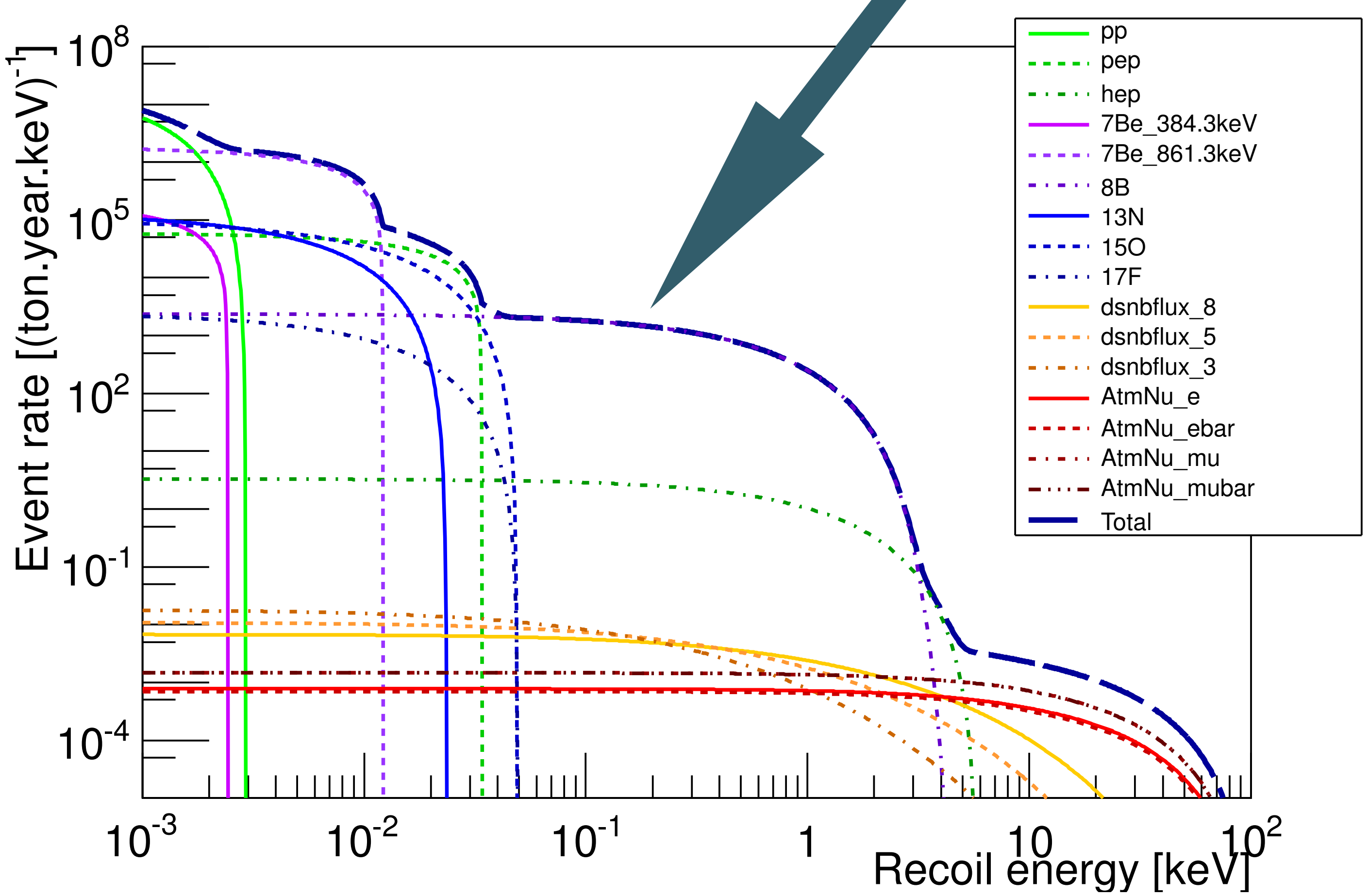


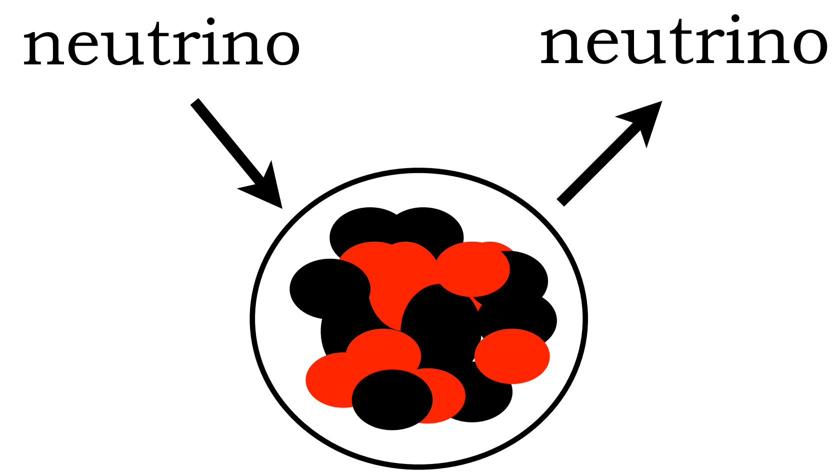


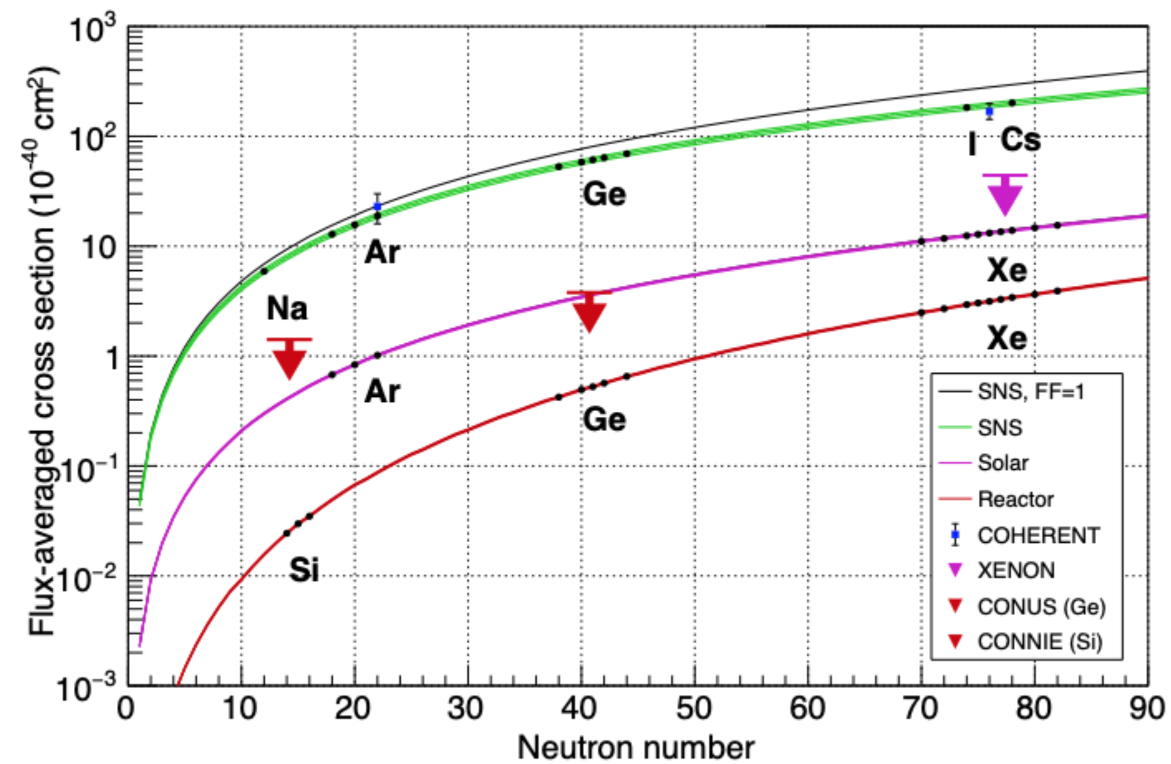


Solar neutrinos & CEvNS detection

Looks like a 6 GeV WIMP

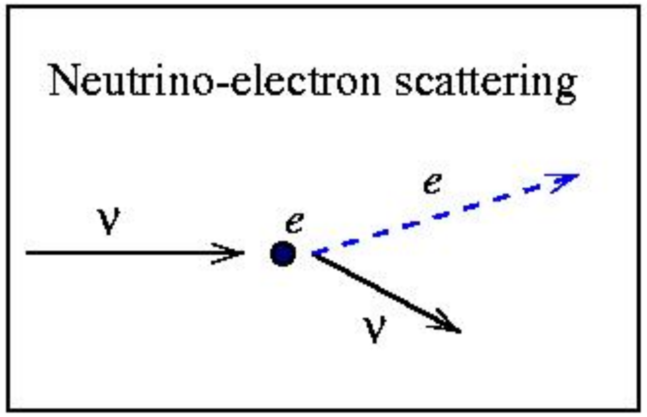


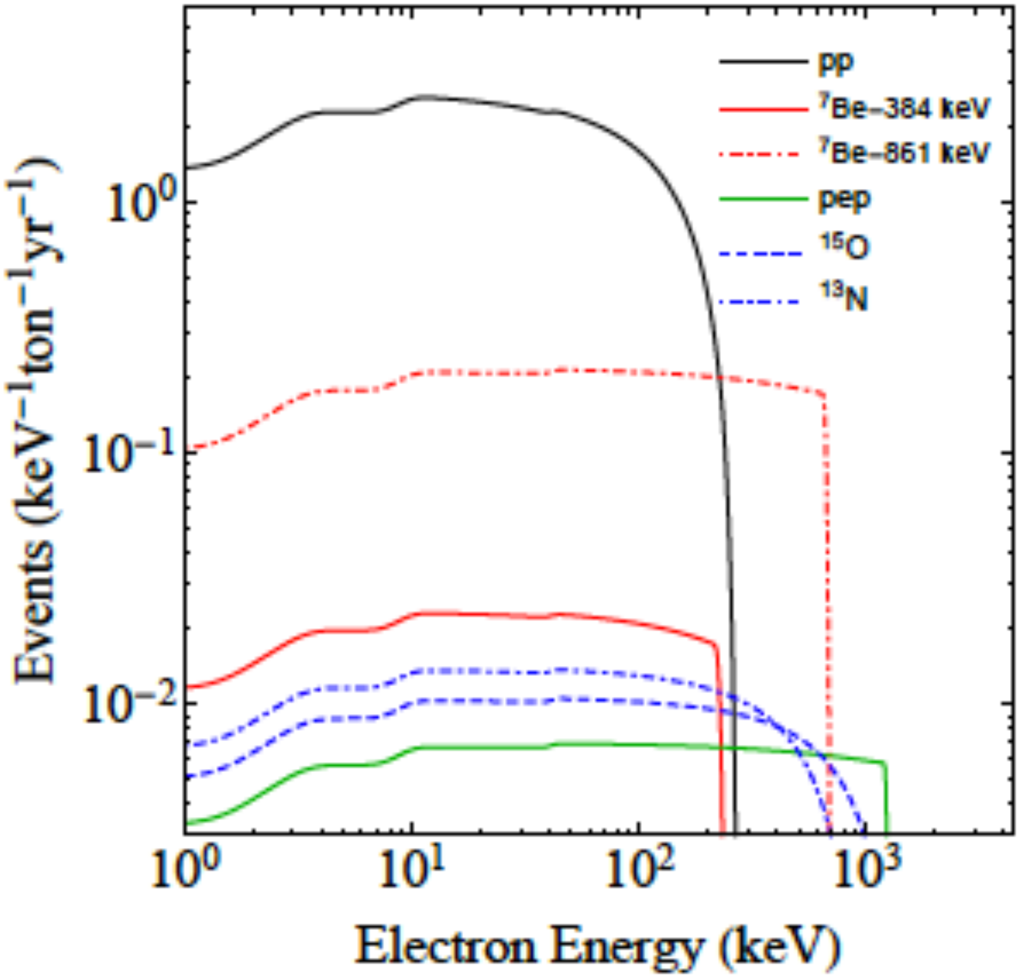


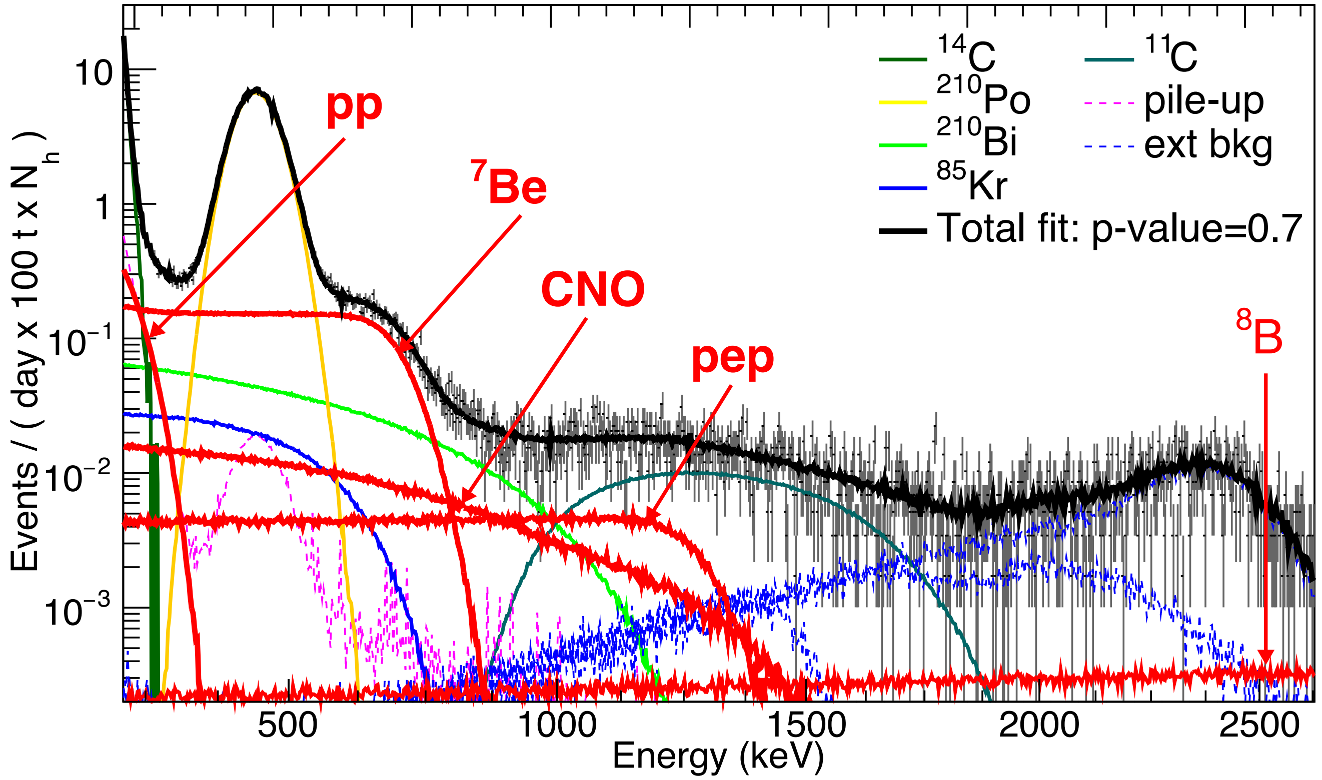


The first detection of CEvNS from astrophysical sources likely from 8B solar neutrinos

Solar neutrinos & electron scattering

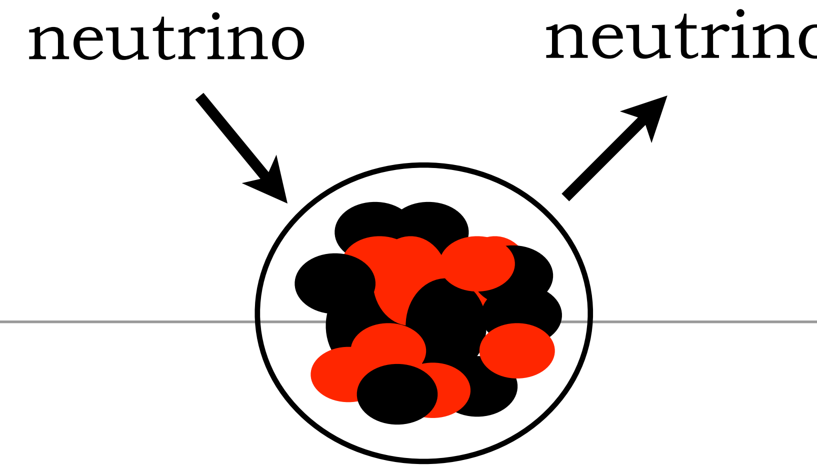


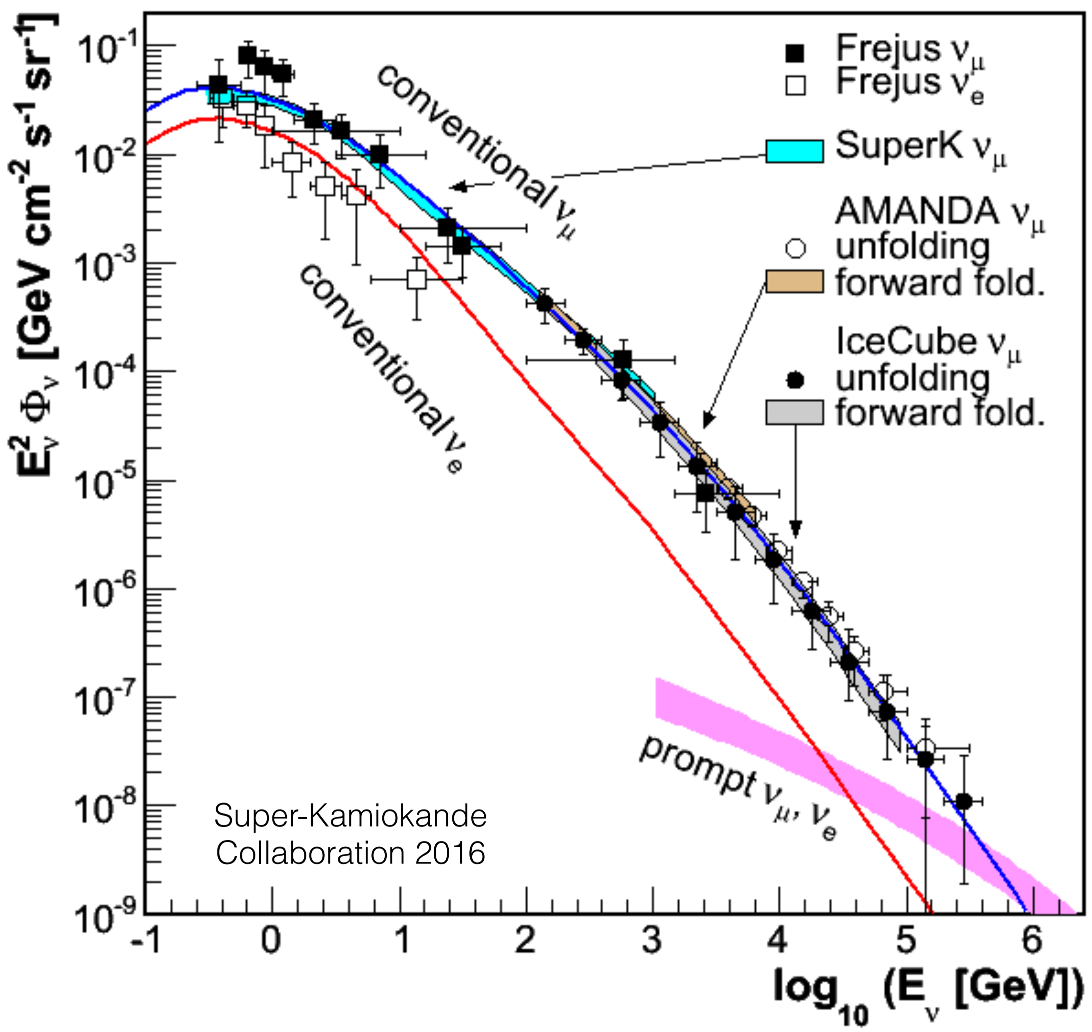


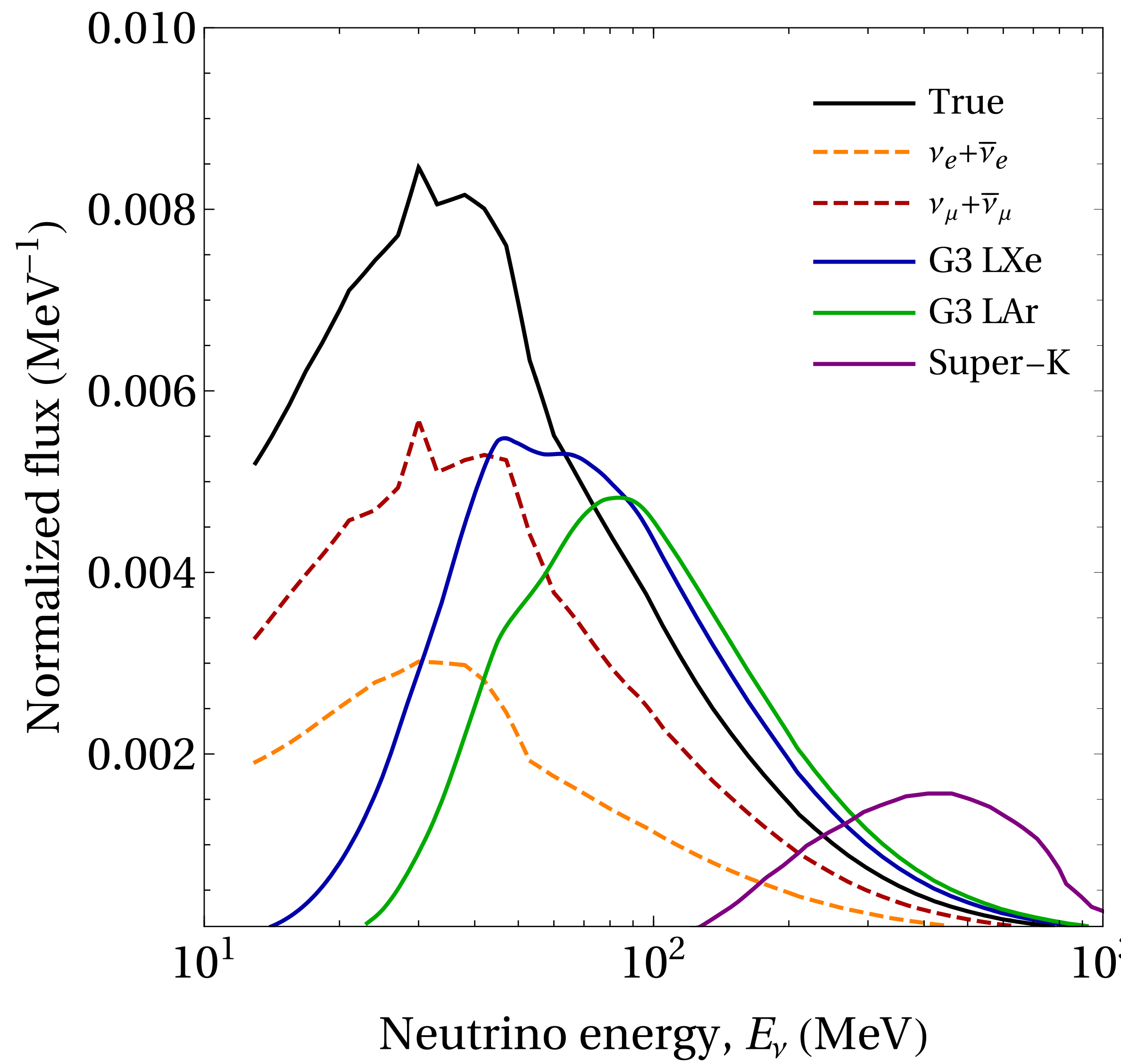


- Borexino multi-component analysis of the Solar neutrino spectrum with ~ 150 keV electron threshold [Borexino Collaboration, Phys.Rev.D 100 (2019) 8, 082004 1707.09279]
- Discovery of the the CNO component of the Solar neutrino flux [Borexino collaboration, Nature 587 (2020) 577-582 2006.15115]; implications for solar metallicity

Low-energy atmospheric neutrinos



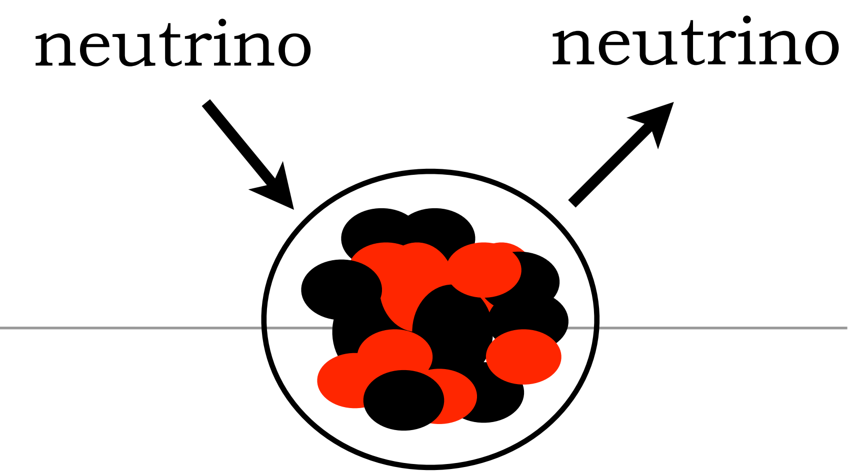


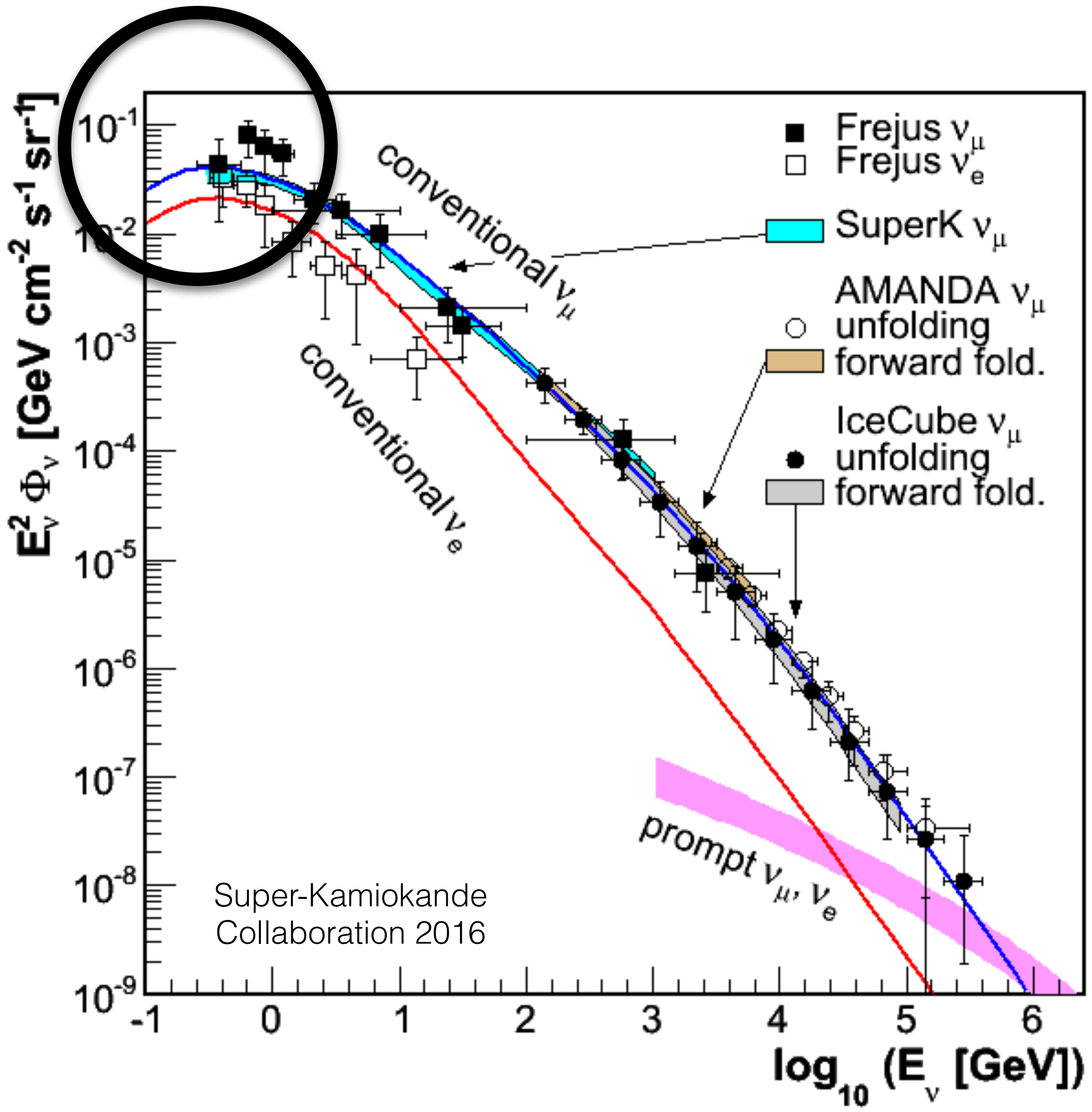


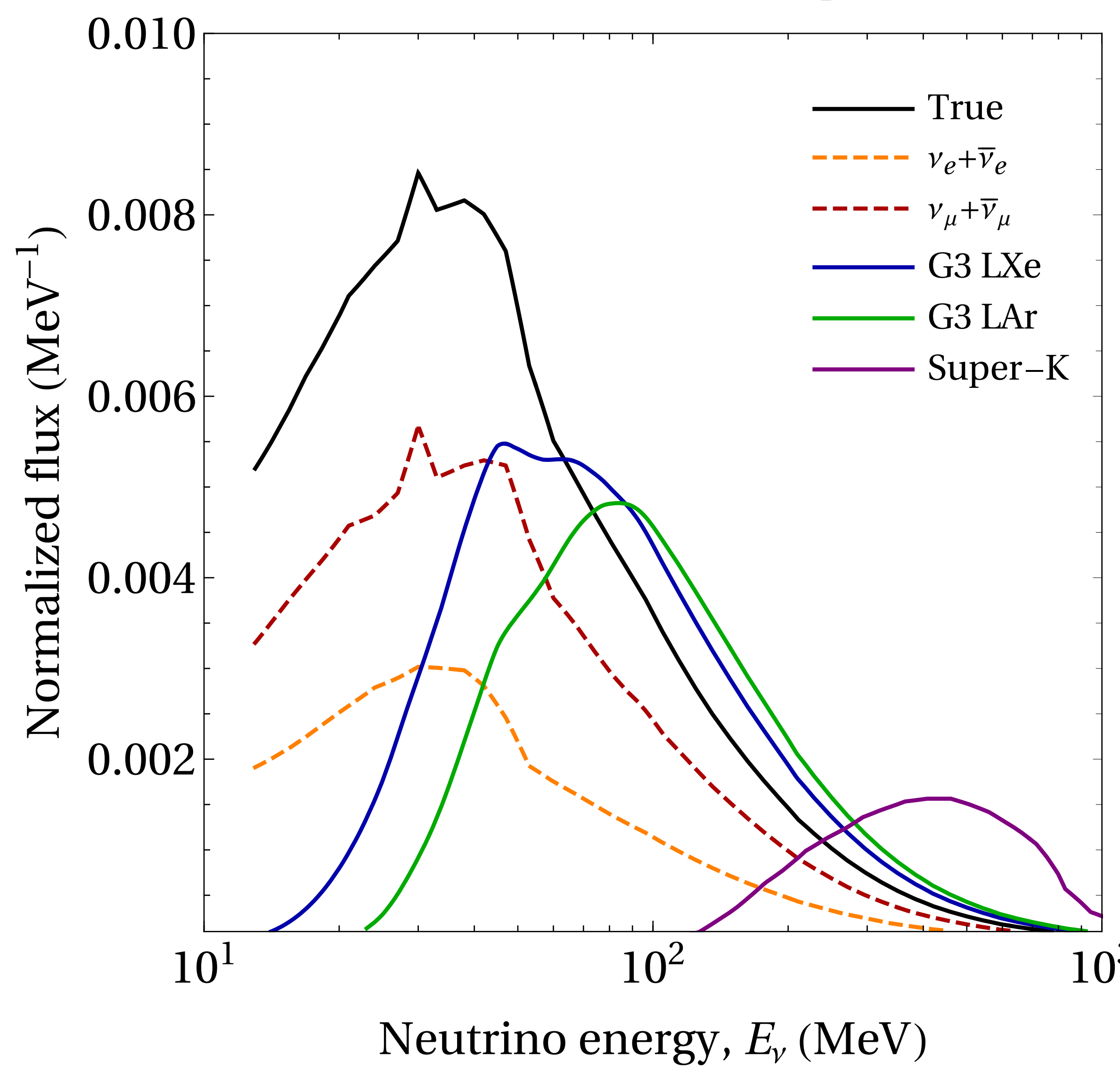
DM detectors sensitive to extremely low-component of the atmospheric neutrino flux

Newstead, Lang, Strigari 2020;
Zhuang, Strigari, Lang 2022

Low-energy atmospheric neutrinos



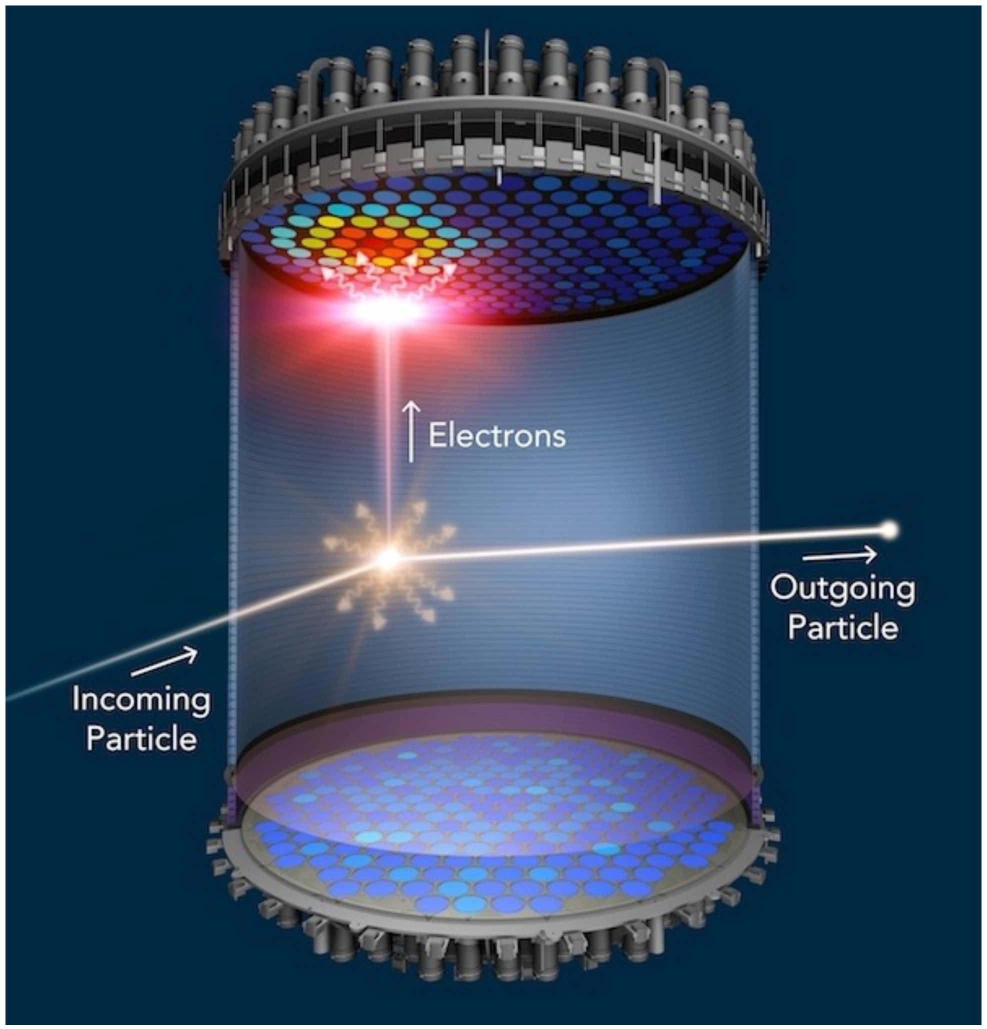


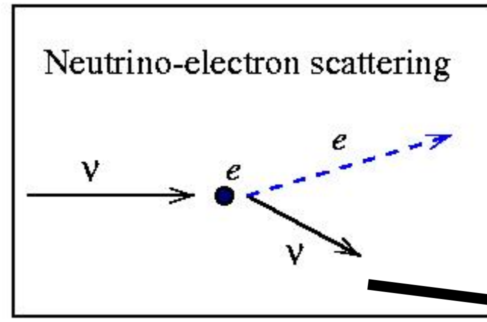


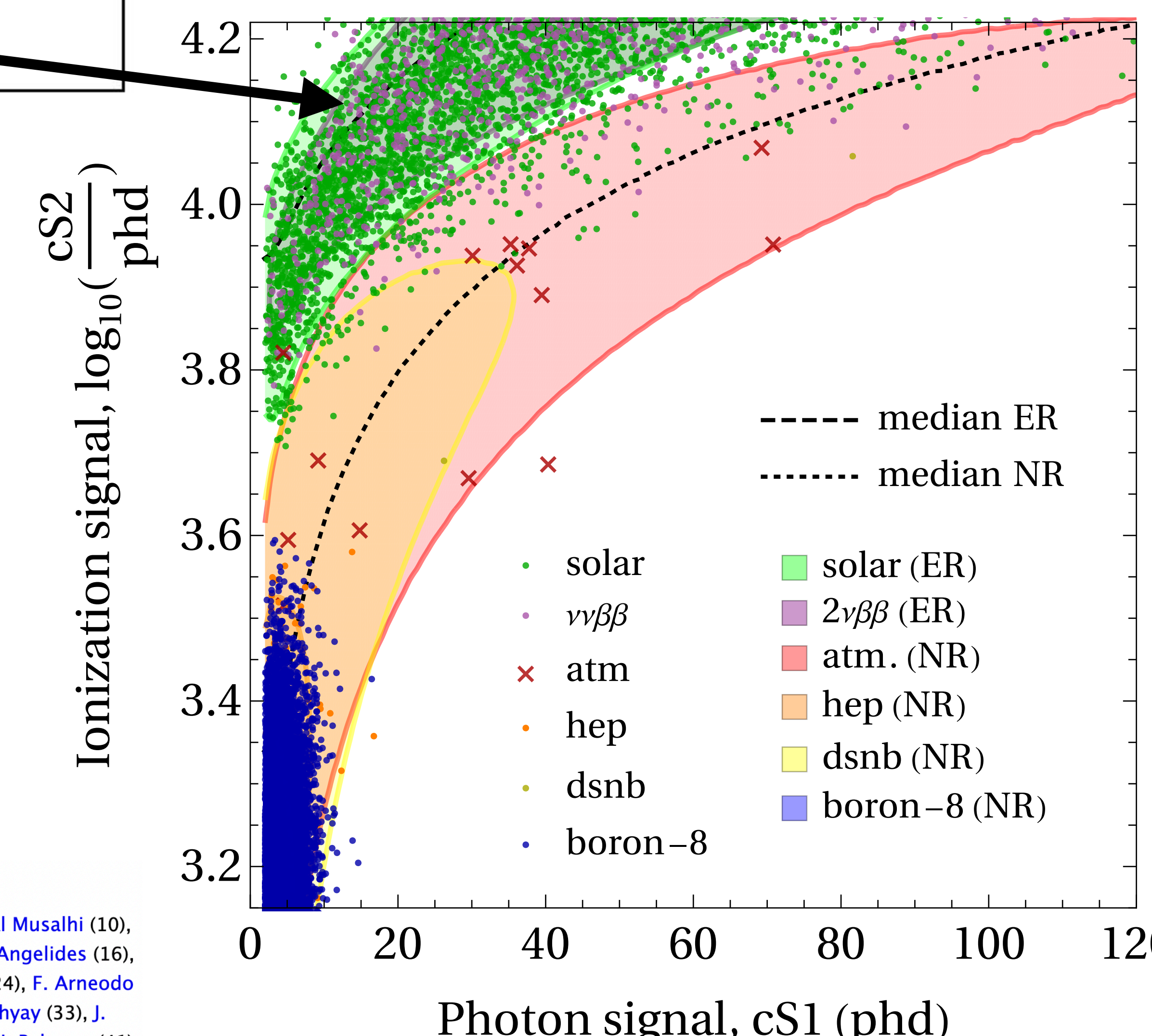
DM detectors sensitive to extremely low-component of the atmospheric neutrino flux

Newstead, Lang, Strigari 2020;
Zhuang, Strigari, Lang 2022

Next generation dark matter and neutrino detection







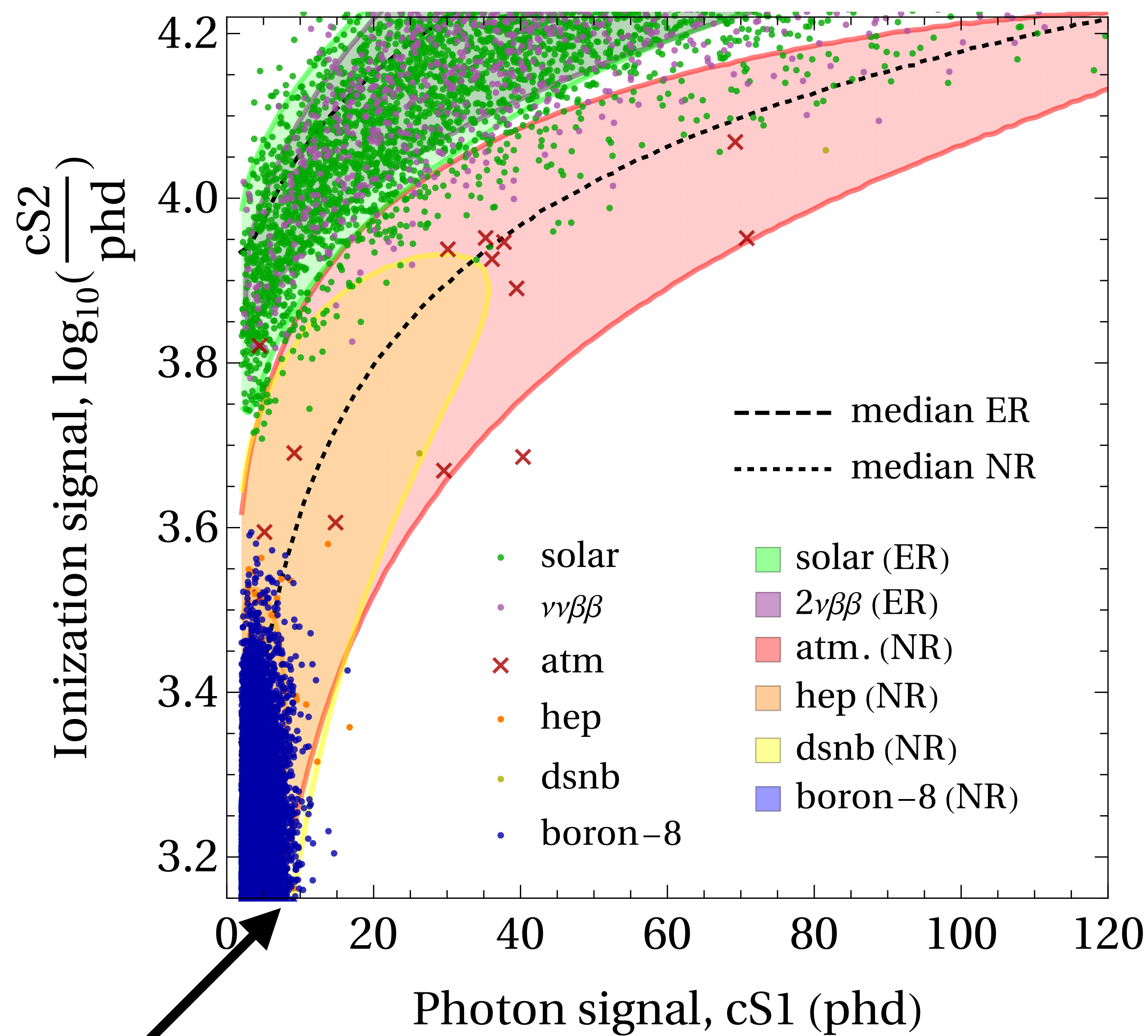
Newstead, Lang, Strigari 2021

A Next-Generation Liquid Xenon Observatory for Dark Matter and Neutrino Physics

J. Aalbers (1 and 2), K. Abe (3 and 4), V. Aerne (5), F. Agostini (6), S. Ahmed Maouloud (7), D.S. Akerib (1 and 2), D.Yu. Akimov (8), J. Akshat (9), A.K. Al Musalhi (10), F. Alder (11), S.K. Alsum (12), L. Althueser (13), C.S. Amarasinghe (14), F.D. Amaro (15), A. Ames (1 and 2), T.J. Anderson (1 and 2), B. Andrieu (7), N. Angelides (16), E. Angelino (17), J. Angevaare (18), V.C. Antochi (19), D. Antón Martin (20), B. Antunovic (21 and 22), E. Aprile (23), H.M. Araújo (16), J.E. Armstrong (24), F. Arneodo (25), M. Arthurs (14), P. Asadi (26), S. Baek (27), X. Bai (28), D. Bajpai (29), A. Baker (16), J. Balajthy (30), S. Balashov (31), M. Balzer (32), A. Bandyopadhyay (33), J. Bang (34), E. Barberio (35), J.W. Bargemann (36), L. Baudis (5), D. Bauer (16), D. Baur (37), A. Baxter (38), A.L. Baxter (9), M. Bazyk (39), K. Beattie (40), J. Behrens (41), N.F. Bell (35), L. Bellagamba (6), P. Beltrame (42), M. Benabderrahmane (25), E.P. Bernard (43 and 40), G.F. Bertone (18), P. Bhattacharjee (44), A. Bhatti (24), A. Biekert (43 and 40), T.P. Biesiadzinski (1 and 2), A.R. Binau (9), R. Biondi (45), Y. Biondi (5), H.J. Birch (14), F. Bishara (46), A. Bismark (5), C. Blanco (47 and 19), G.M. Blockinger (48), E. Bodnia (36), C. Boehm (49), A.I. Bolozdynya (8), P.D. Bolton (11), S. Bottaro (50 and 51), C. Bourgeois (52), B. Boxer (30), P. Brás (53), A. Breskin (54), P.A. Breur (18), C.A.J. Brew (31), J. Brod (55), E. Brookes (18), A. Brown (37), E. Brown (56), S. Bruenner (18), G. Bruno (39), R. Budnik (54), T.K. Bui (4), S. Burdin (38), S. Buse (5), J.K. Busenitz (29), D. Buttazzo (51), M. Buuck (1 and 2), A. Buzulutskov (57 and 58), R. Cabrita (53), C. Cai (59), D. Cai (39), C. Capelli (5), J.M.R. Cardoso (15), M.C. Carmona-Benitez (60), M. Cascella (11), R. Catena (61), S. Chakraborty et al. (497 additional authors not shown)

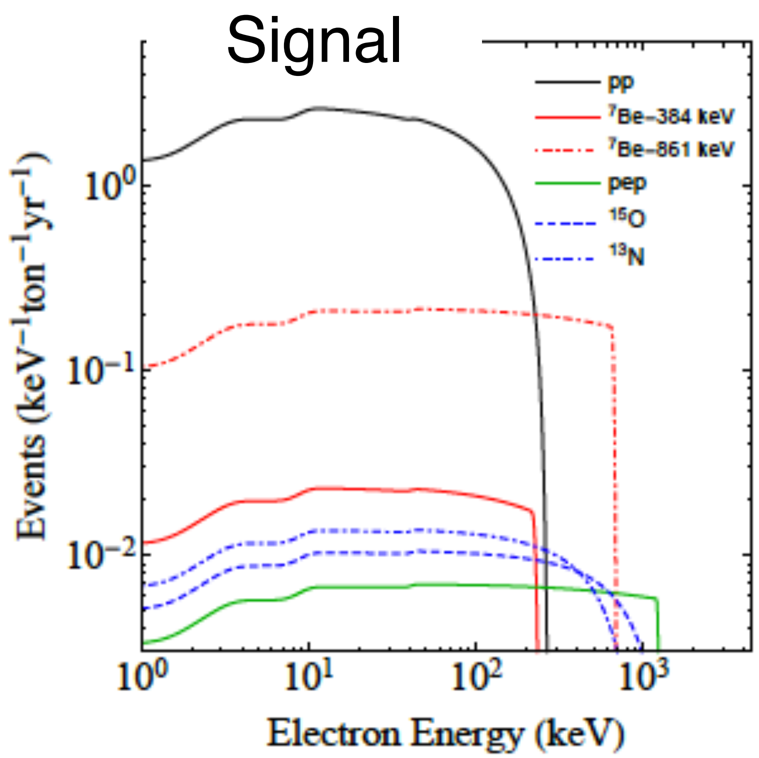
Next generation dark matter and neutrino detection

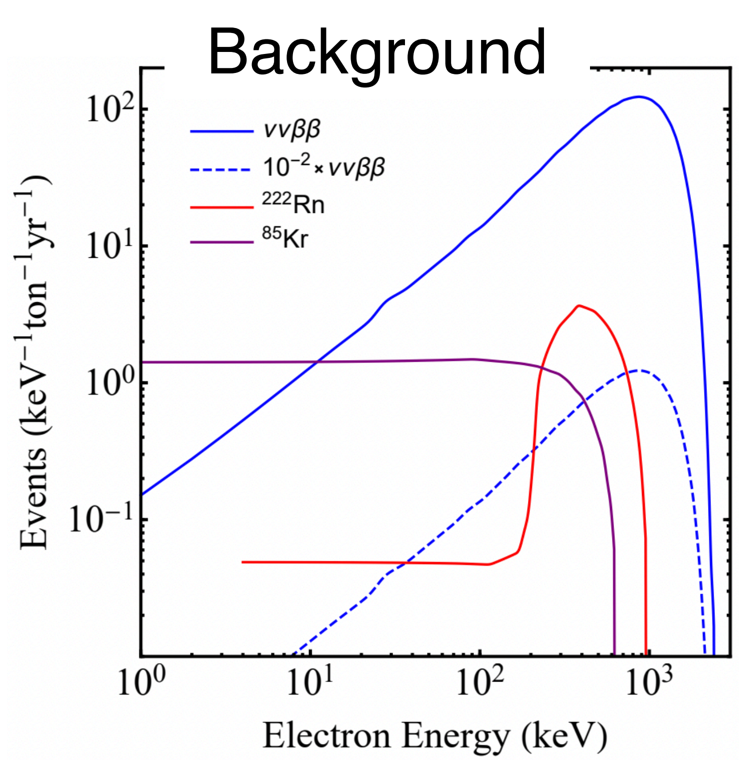
- Independent neutral current channel from SNO
- Large enough exposure improves the 8B flux normalization (Takeuchi, Rossi, Villante talks)
- Measurement of neutrino energy spectrum
- Applications to sterile neutrinos (Billard, LS, Figueroa-Feliciano 2014)



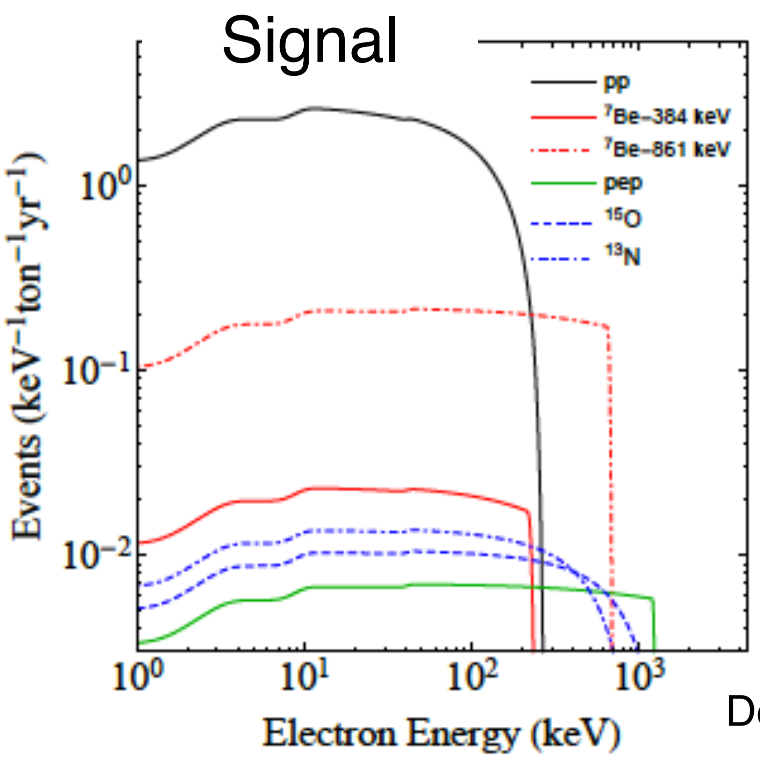
Newstead, Lang, Strigari 2021

Detection of solar neutrinos

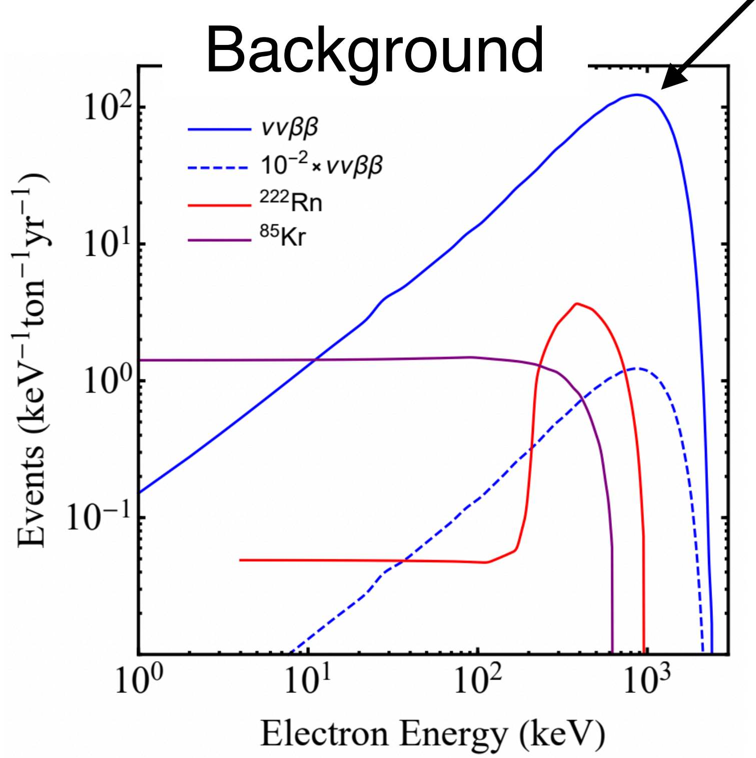


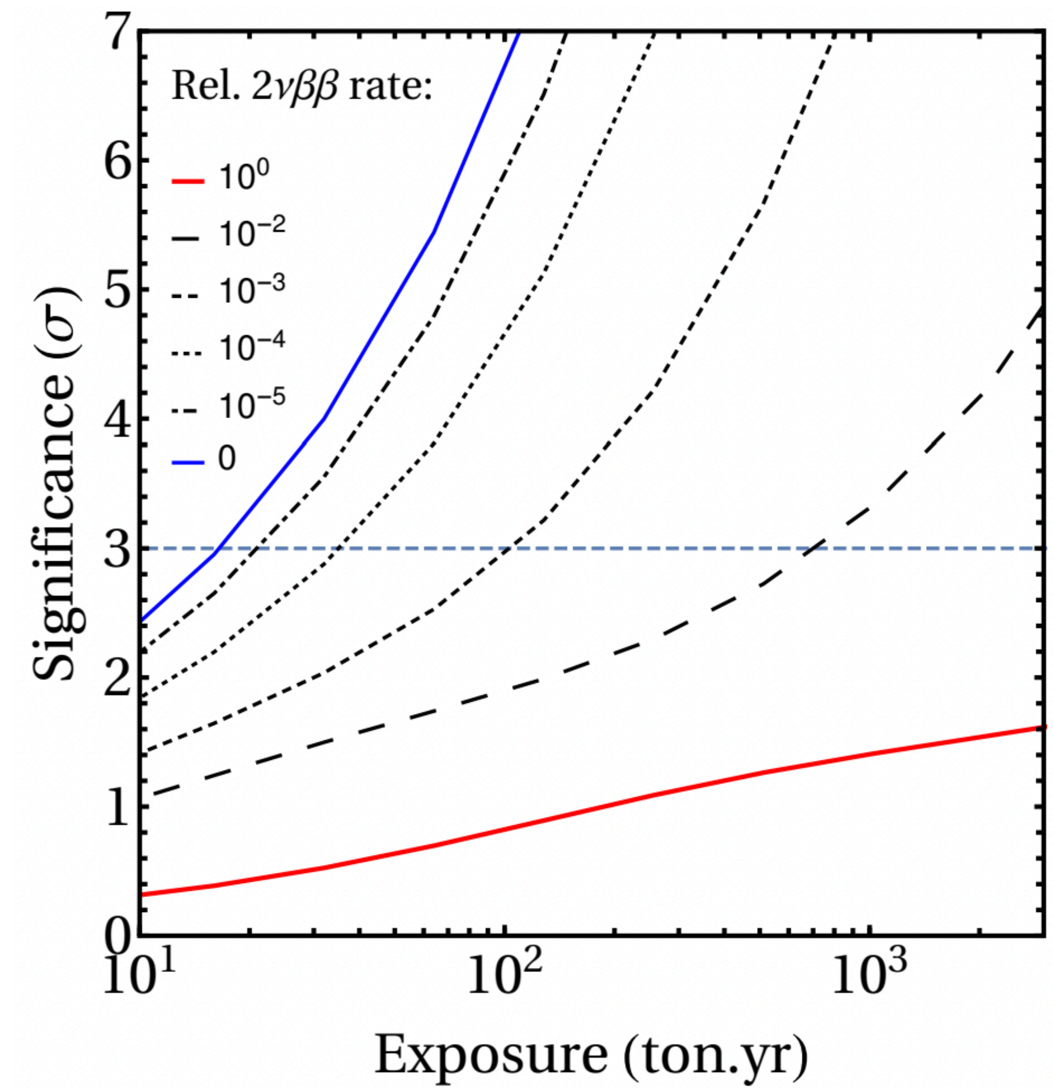


Detection of solar neutrinos



Decay of ^{136}Xe $2\nu\beta\beta$

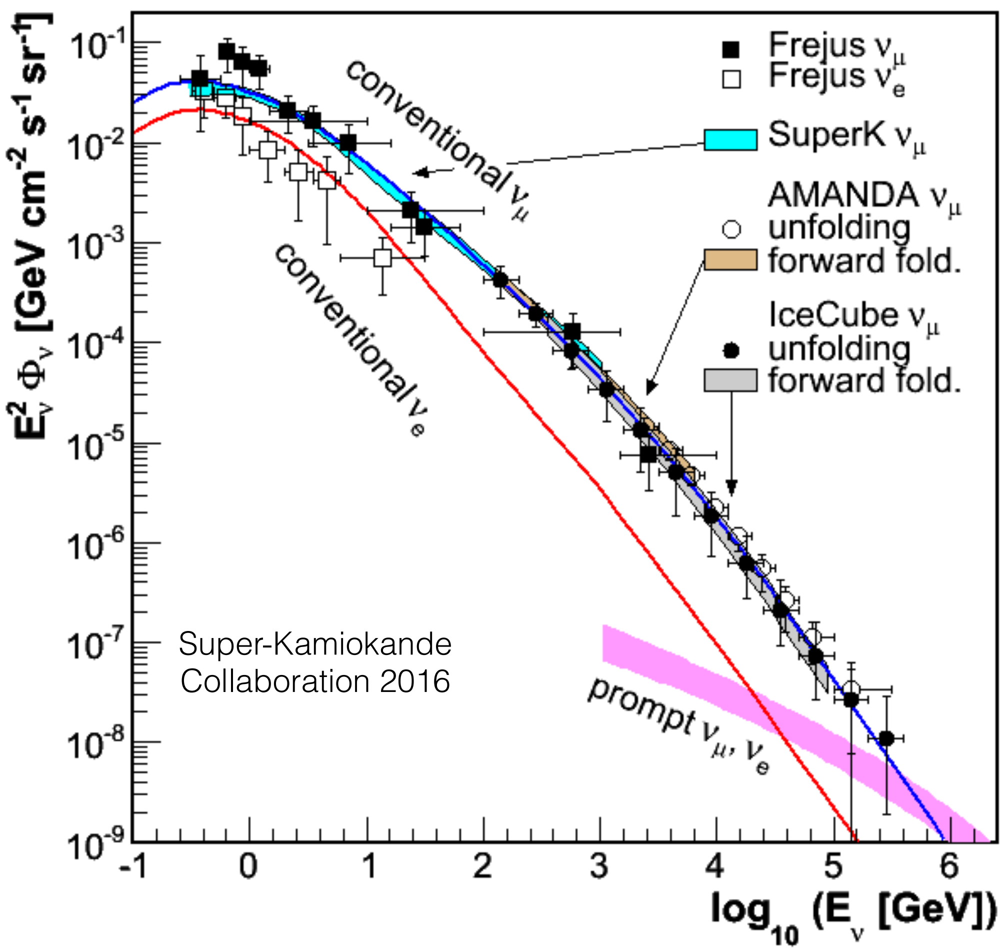


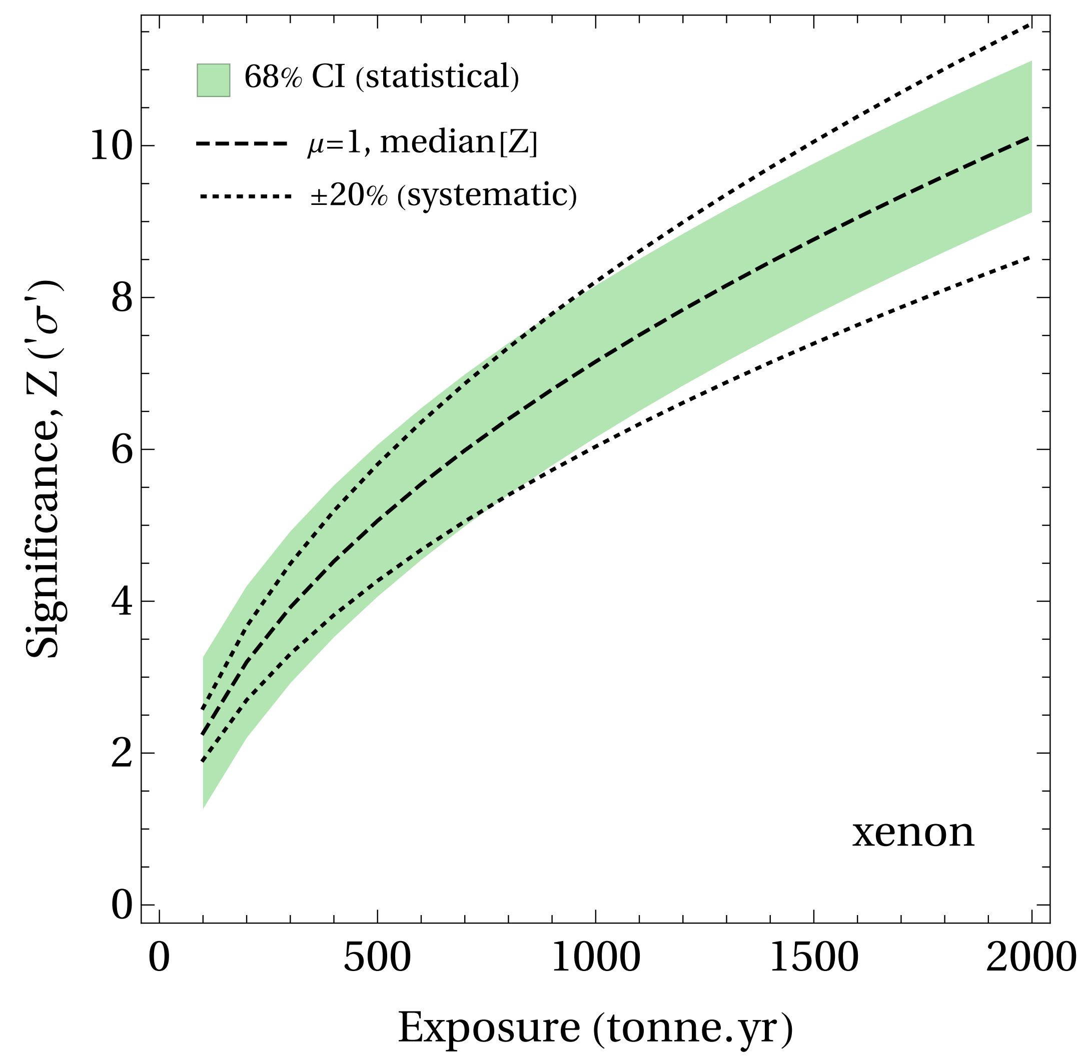


Detection of all components of the solar neutrino flux requires reduction of the 2-neutrino double beta decay background

Newstead, Strigari, Lang 2018

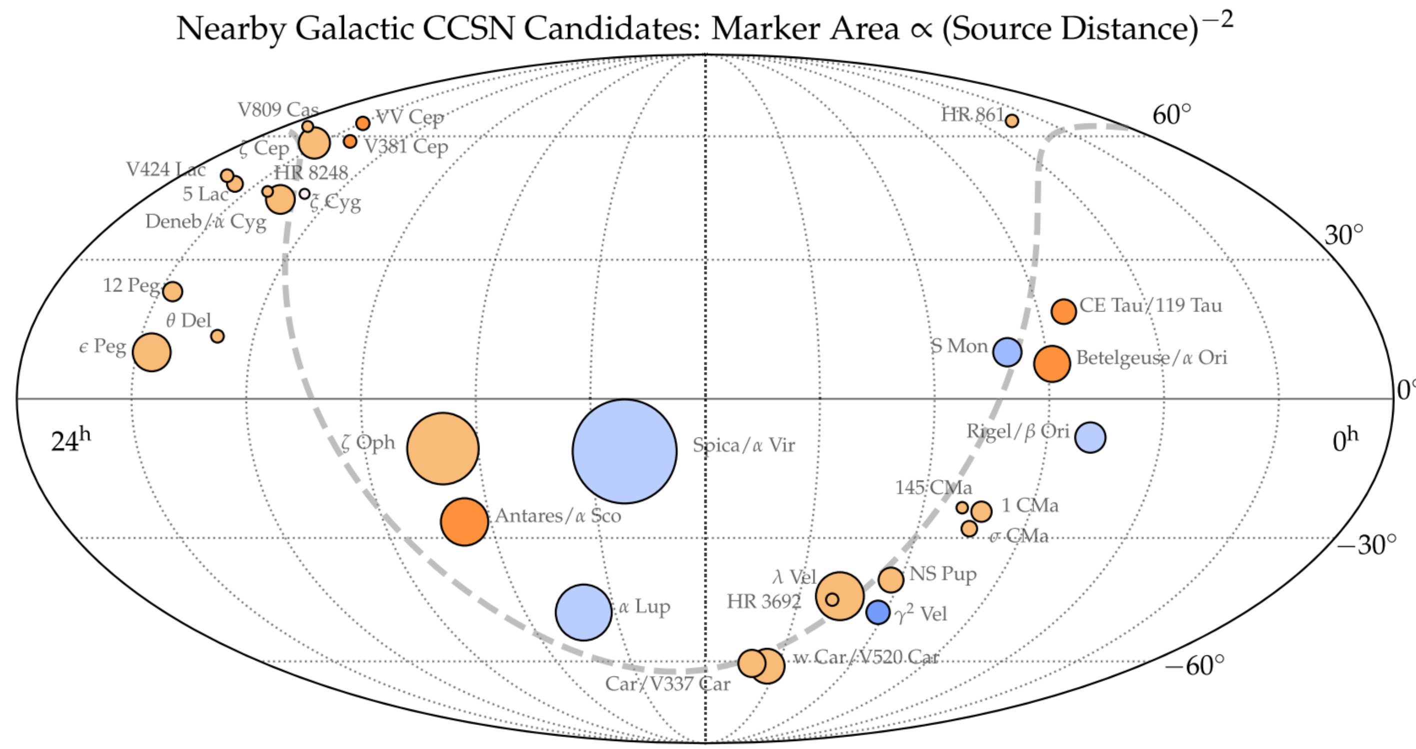
Detection of low-energy atmospheric neutrinos

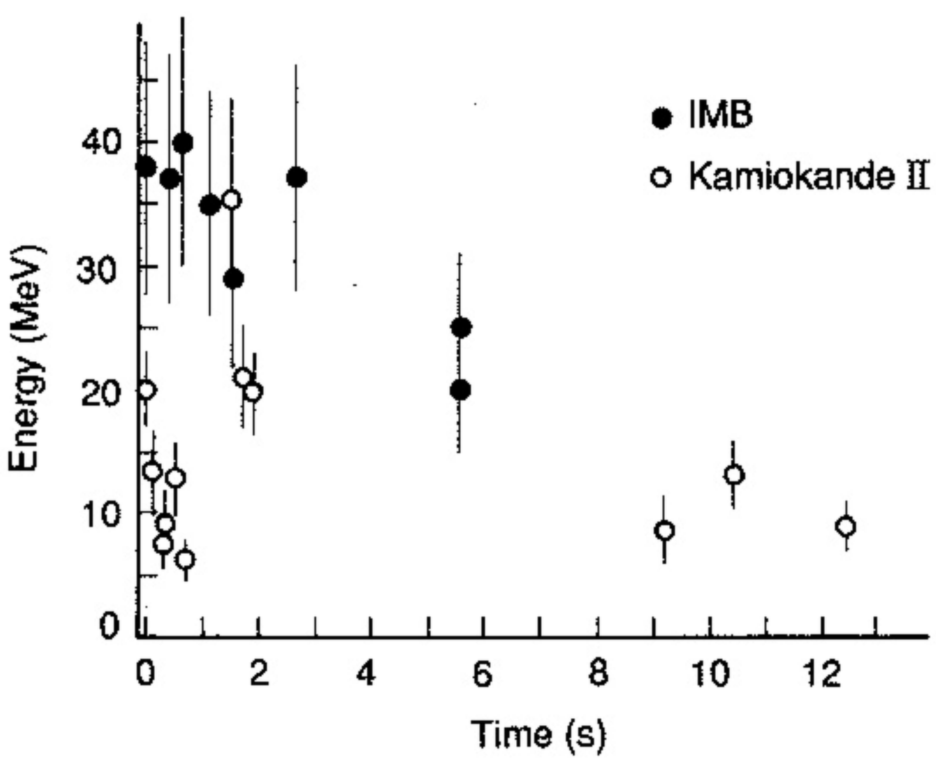




- Identification of atmospheric neutrino flux component depends on systematics in measurements of the atmospheric neutrino flux [Newstead, Lang, Strigari 2021; Zhuang, Strigari, Lang 2022]
- Detection of DSNB likely requires exposure > 10 kton-yr [Strigari 2009; Suliga et al. 2022]

CEvNS & neutrinos from Galactic supernova

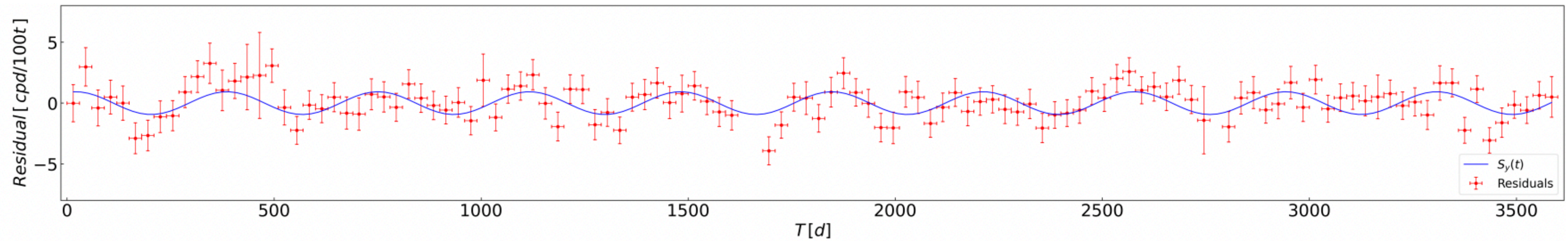




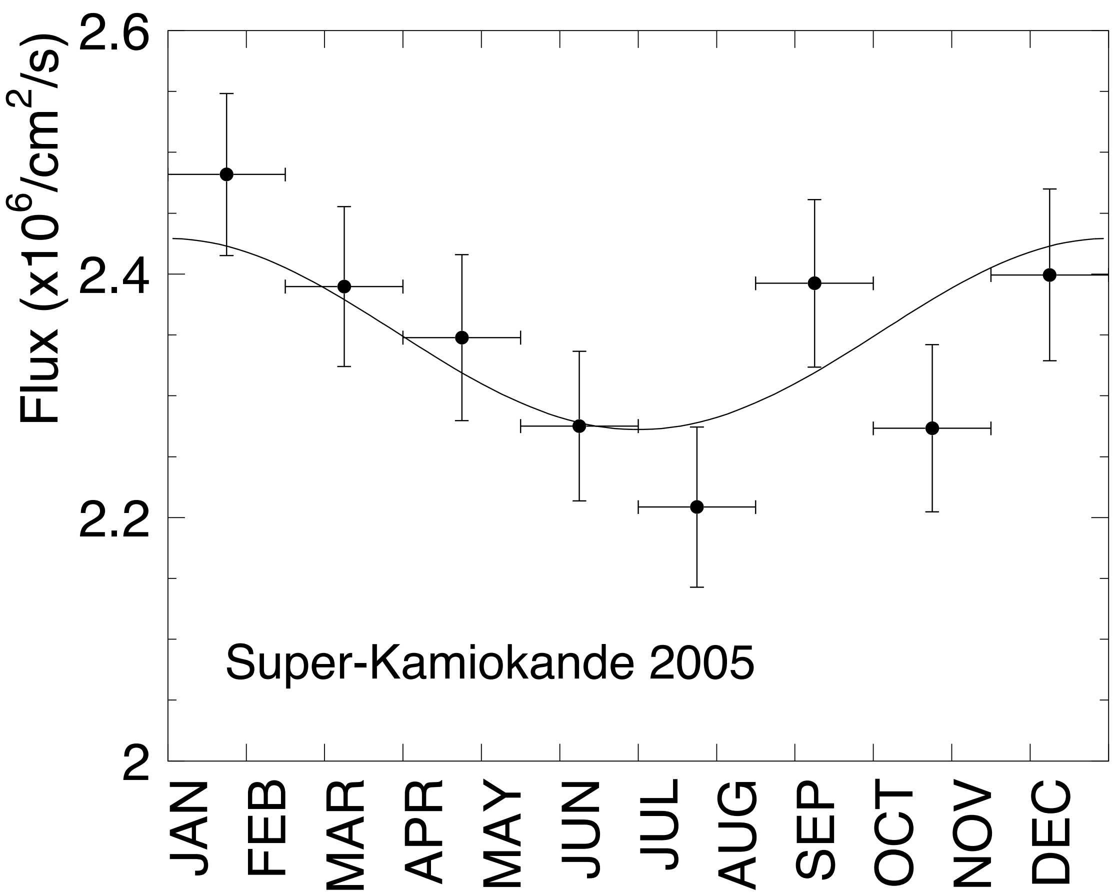
Neutrino signal from 27 Solar mass progenitor within 10 kpc (Lang et al. 2016)

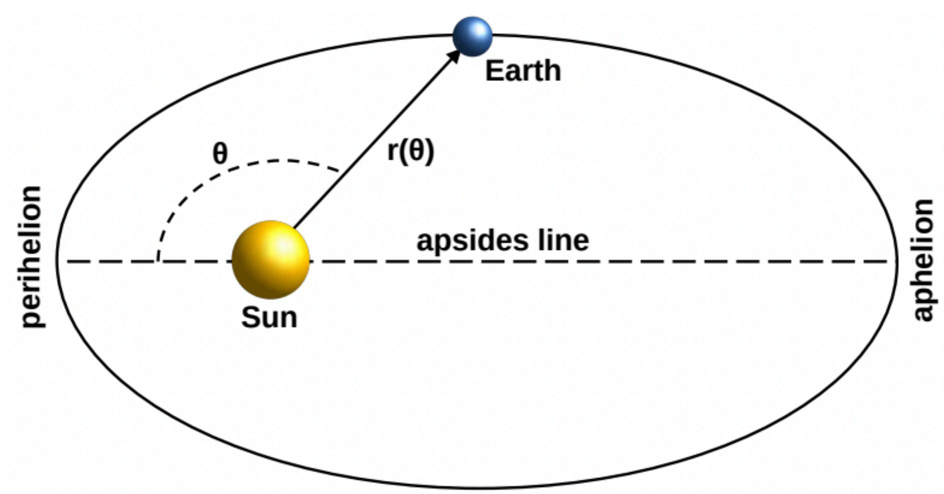
SNEWS network
Khaitan 2018; Mukhopadhyay et al. 2020;
Al Kharusi et al. 2021

Time variation of solar neutrinos



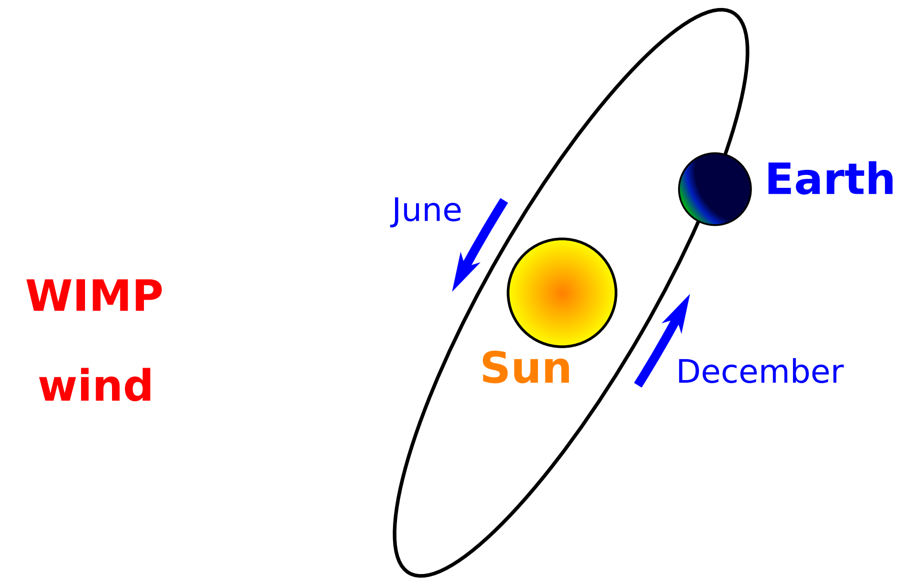
Borexino 2017
Borexino 2022

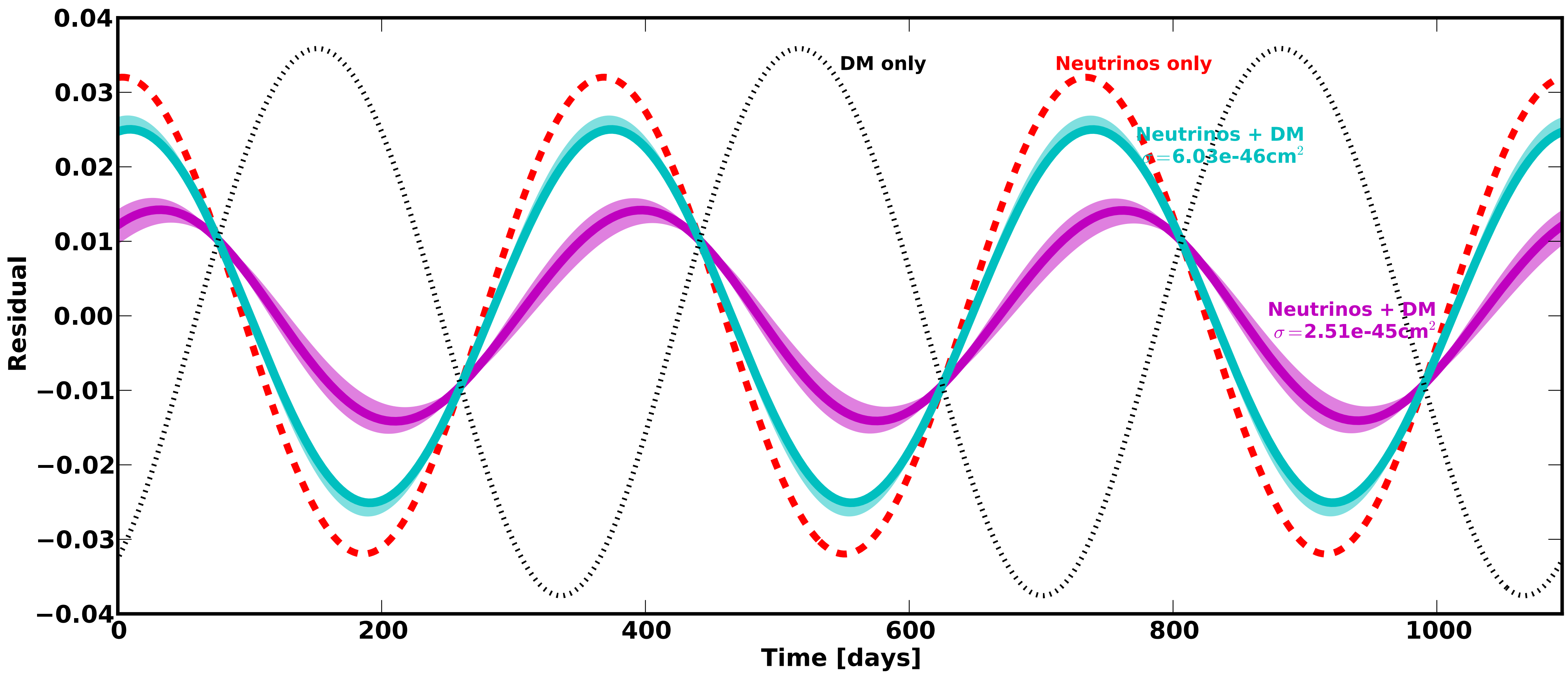




A 50 ton detector would measure the eccentricity in ~5 years [Zhuang+ 2022]

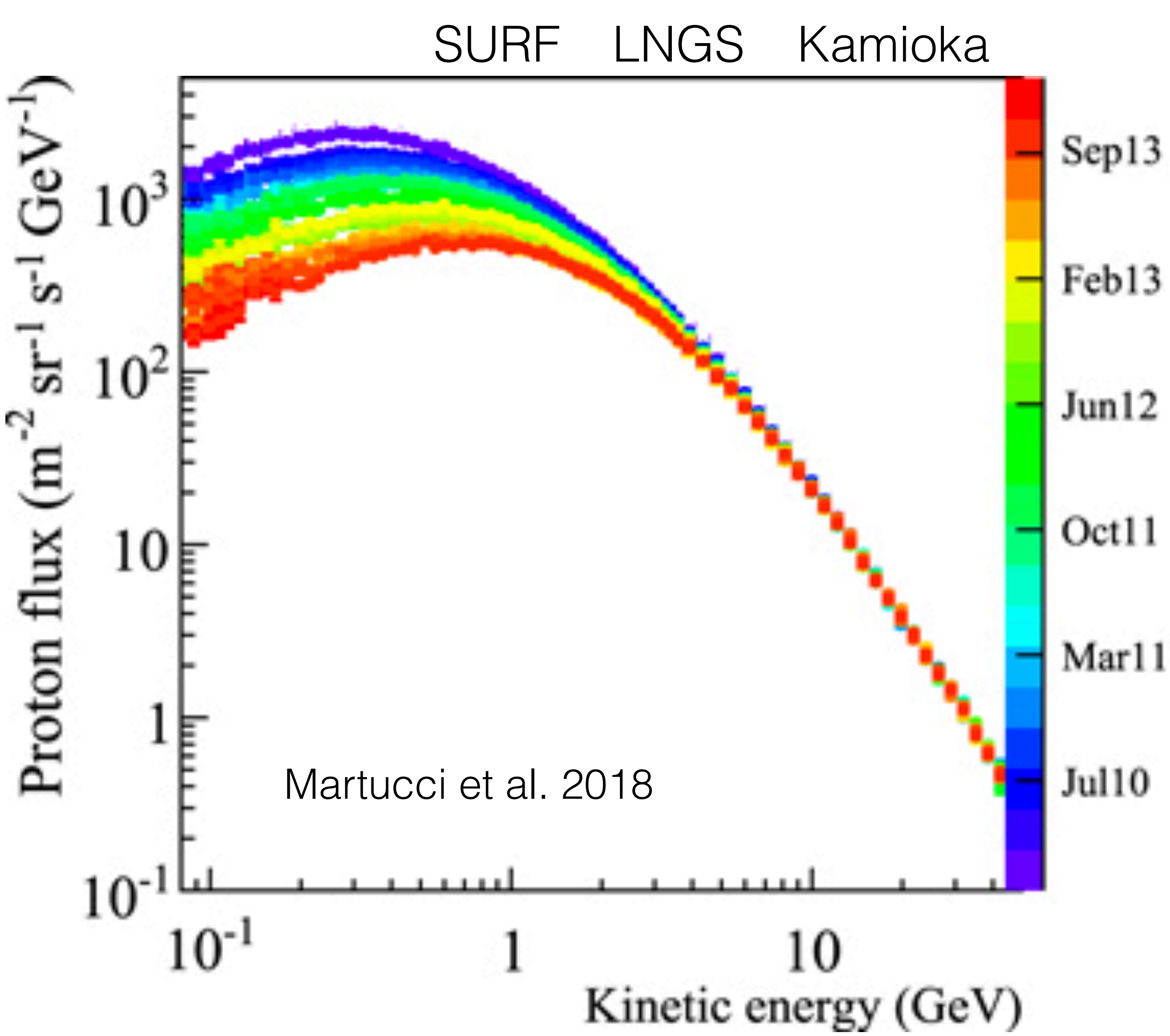
Time variation of solar neutrinos & dark matter detection

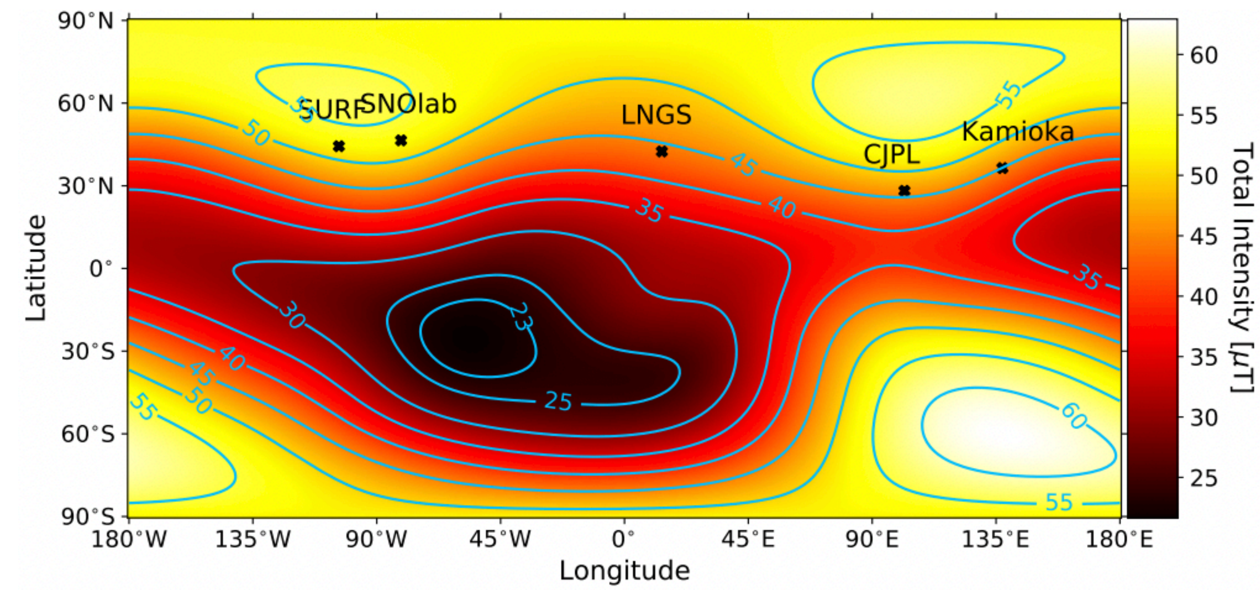


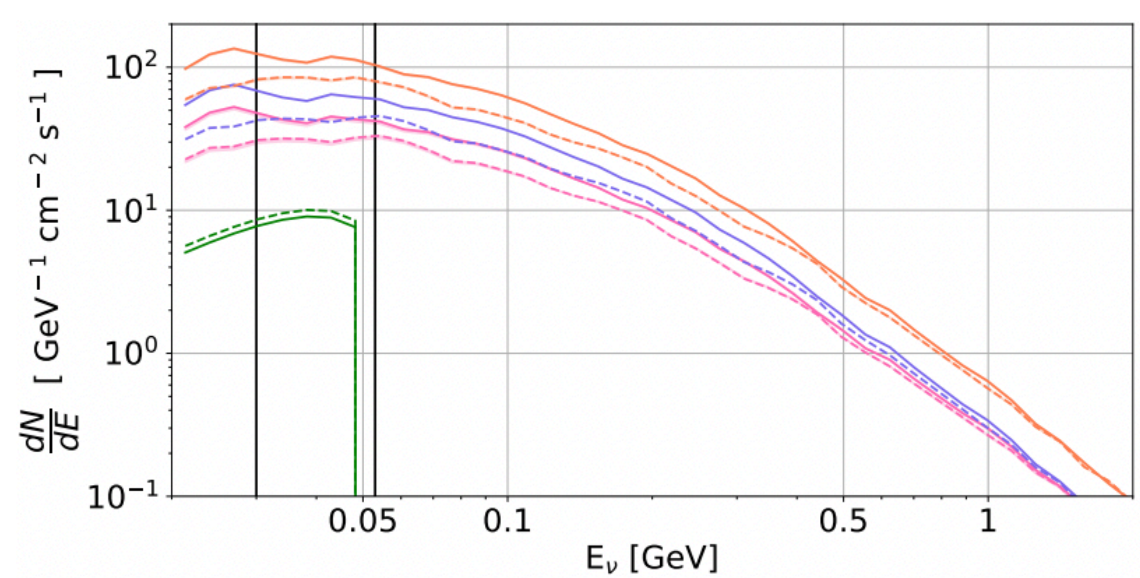


J. Davis 2014

Location and time dependence of atmospheric neutrinos

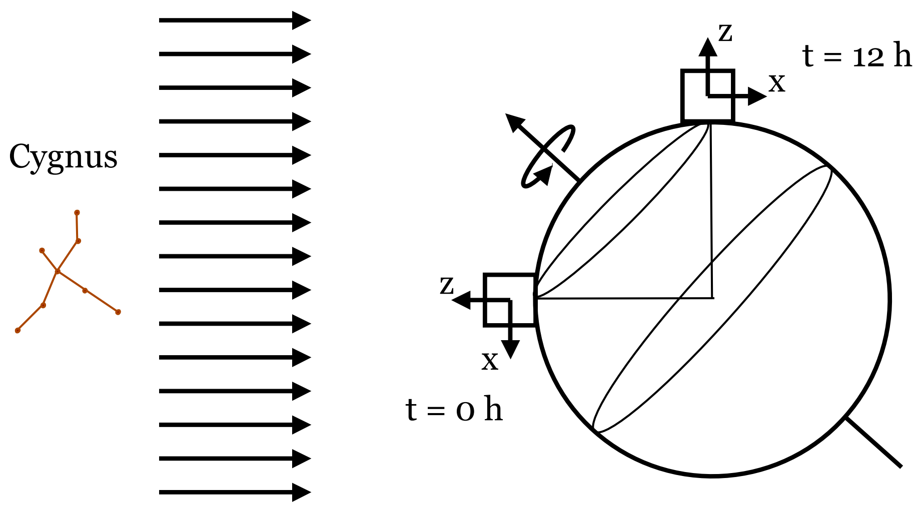




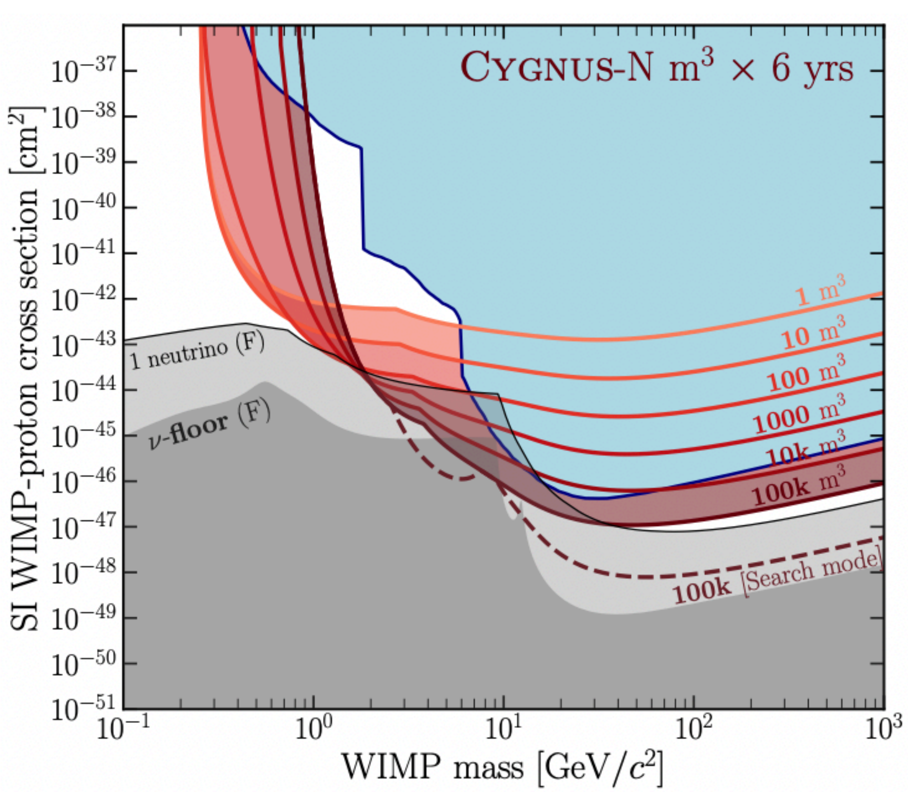


Time variation and geomagnetic effects depend on detector location [**Zhuang**, Strigari, Lang 2021]

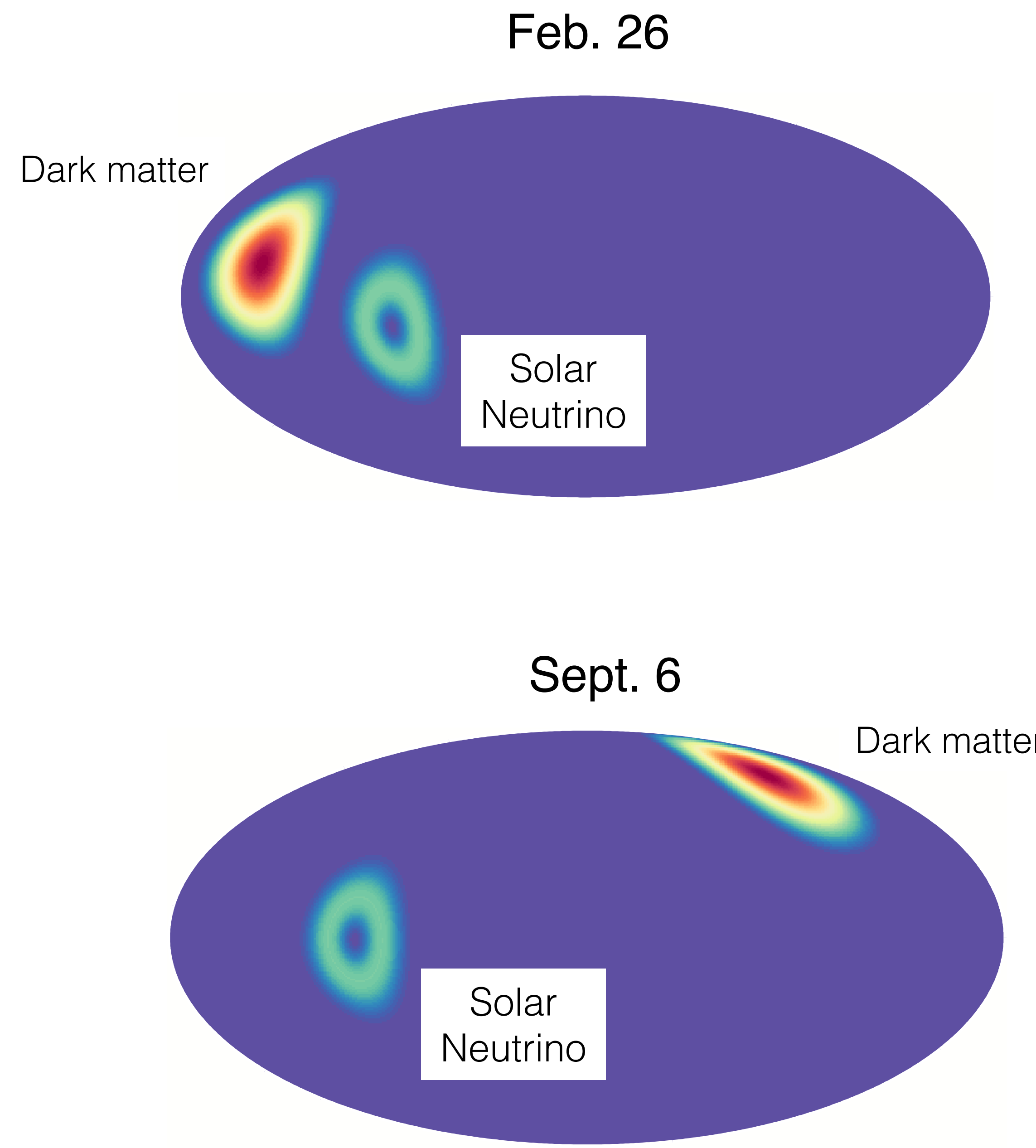
Dark matter and solar neutrinos with directional detectors



Mayet et al. Phys. Reports 2016

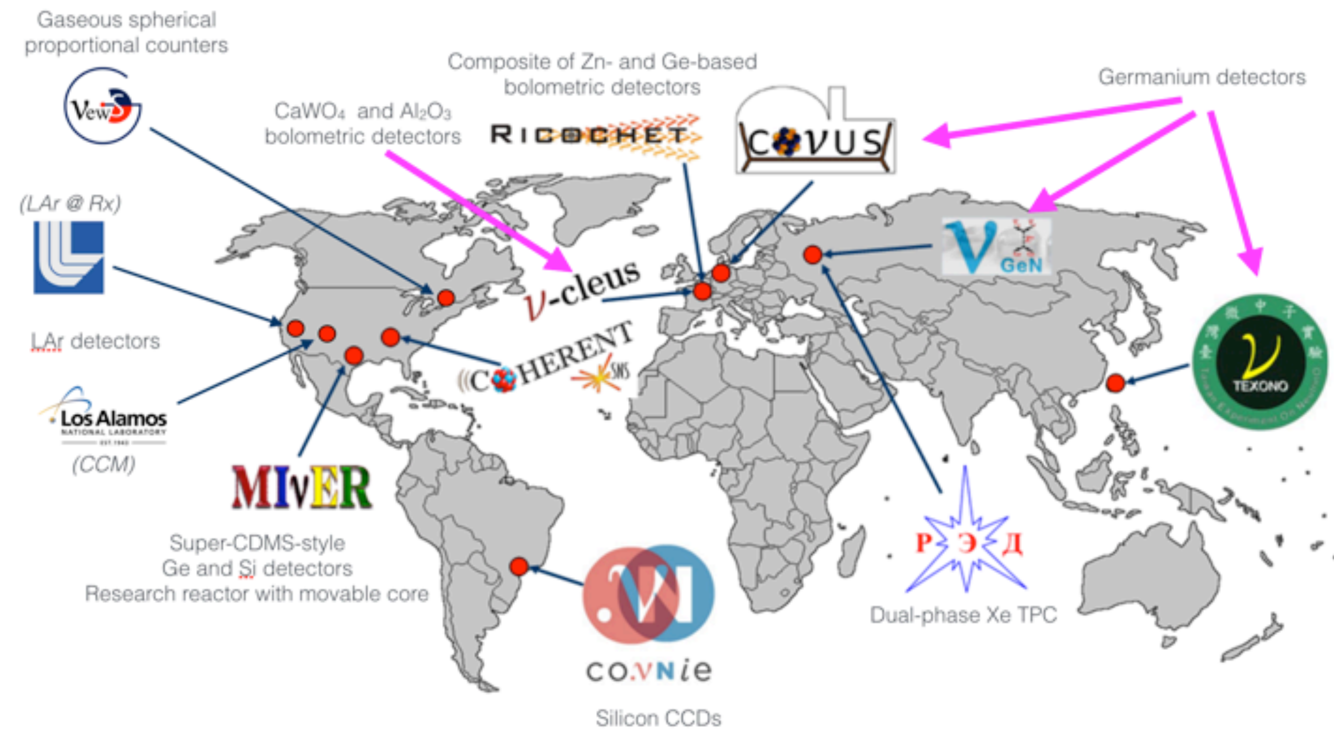


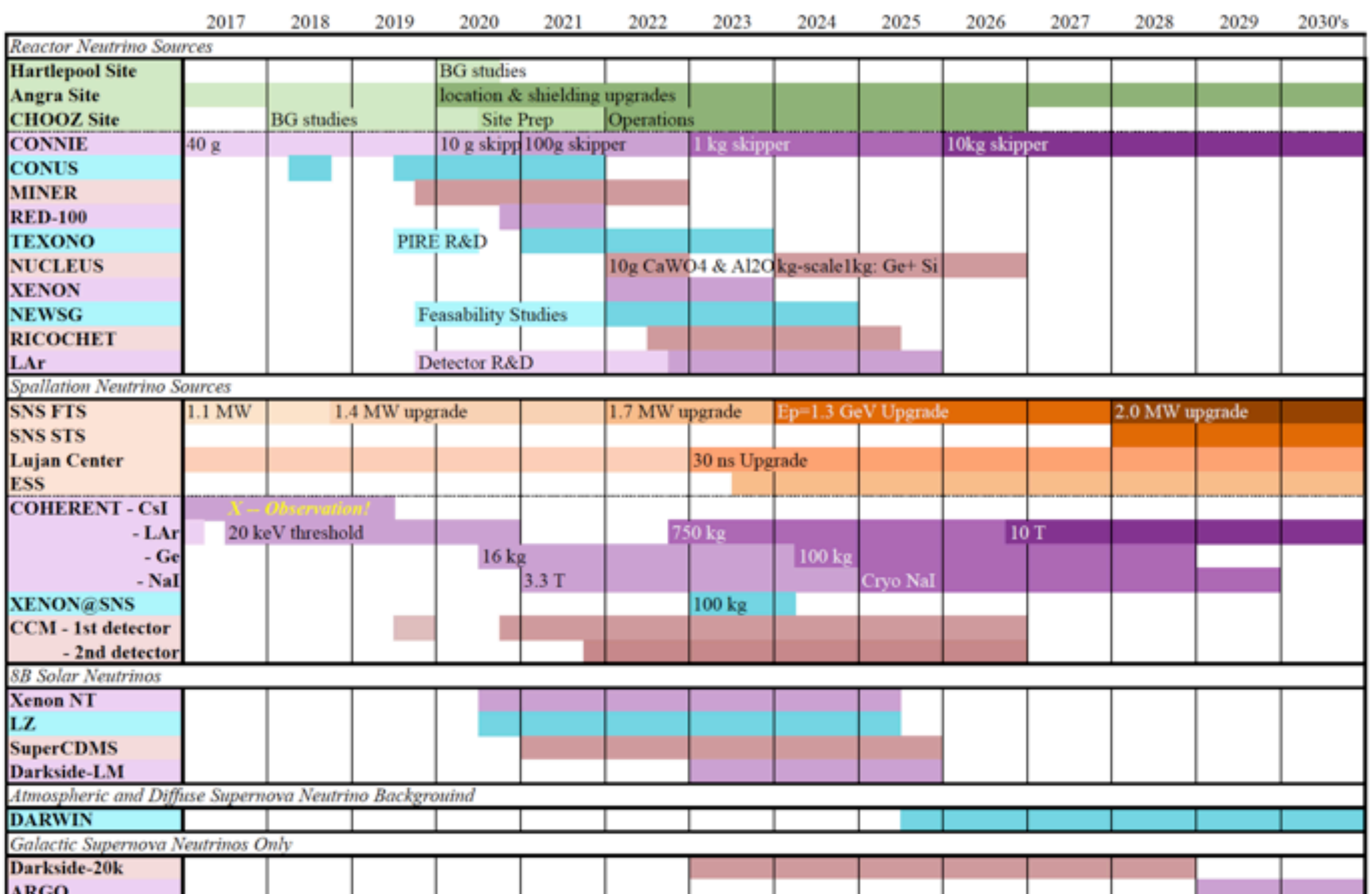
O'Hare et al., 2022 Snowmass whitepaper

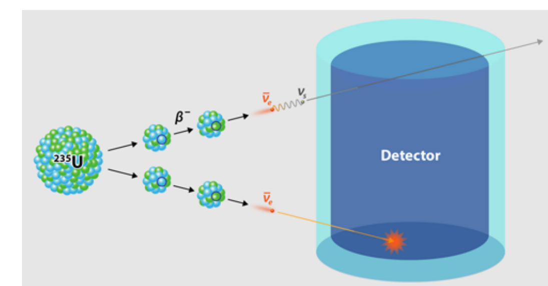


Grothaus, Fairbairn, Monroe, PRD 2014;
O'Hare et al. PRD 92 (2015) 6, 063518 1505.08061

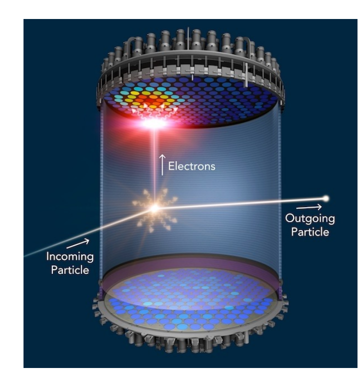
Dark matter & CEvNS



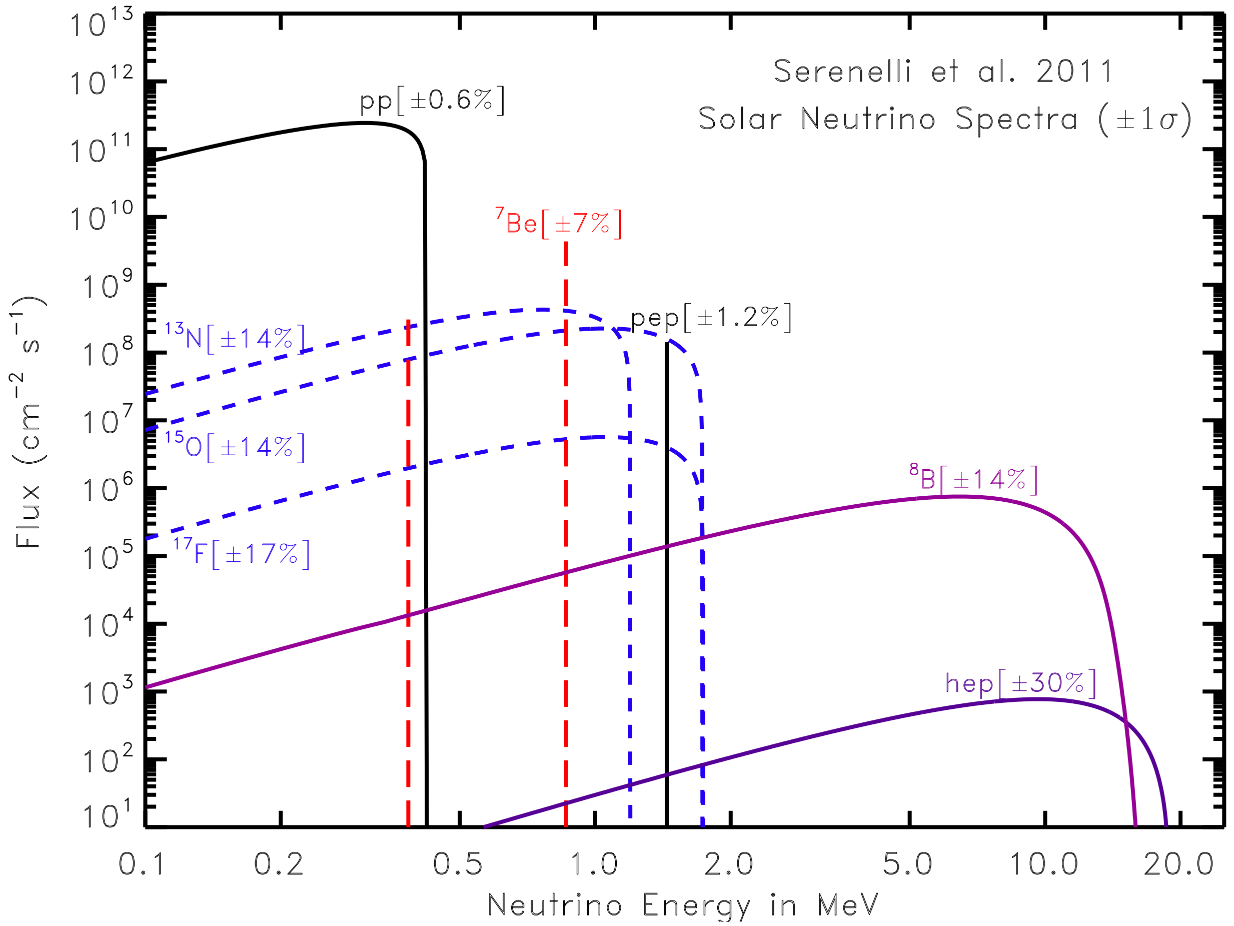


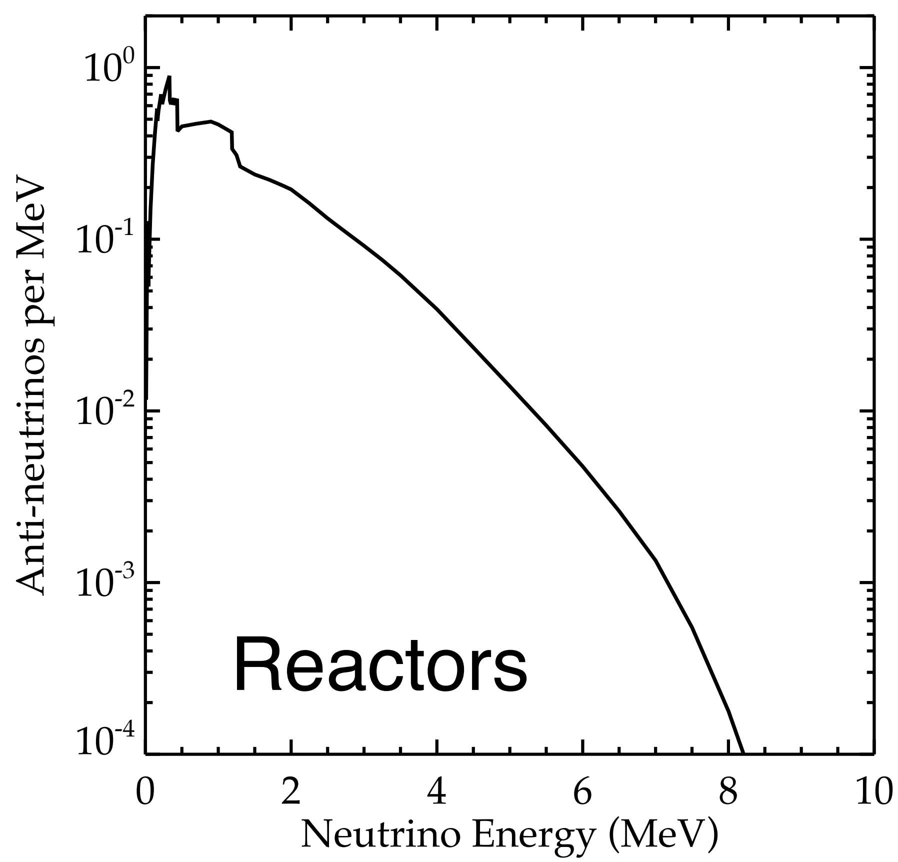


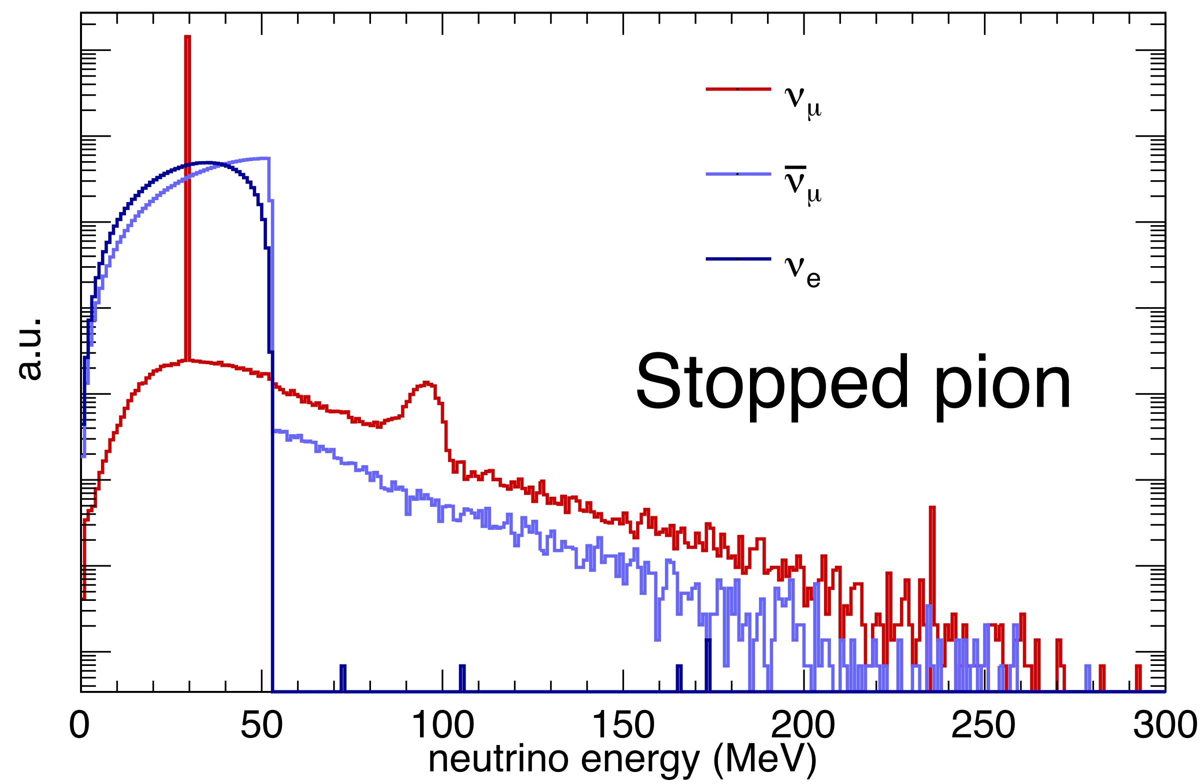
Bernardi talk



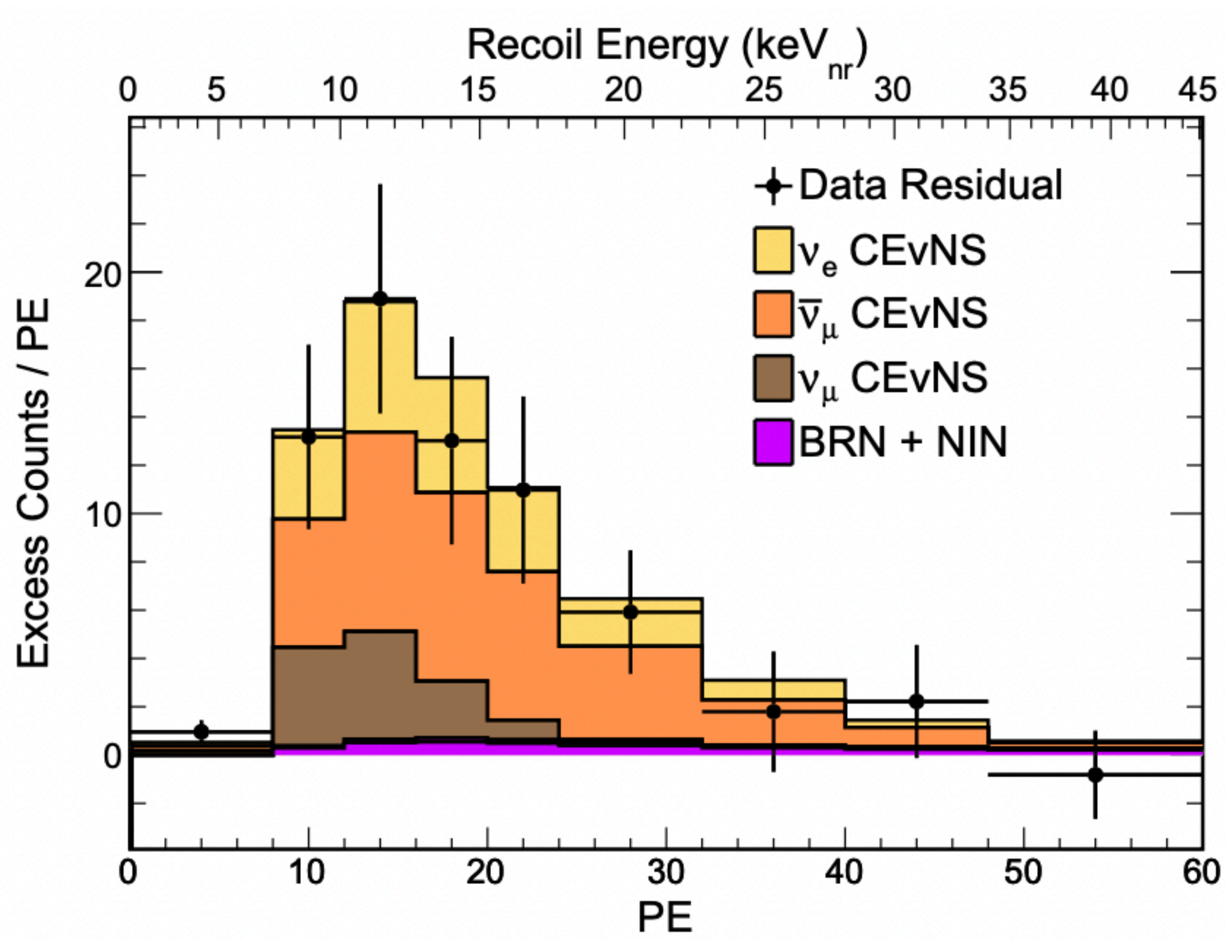
Dark mater & CEvNS

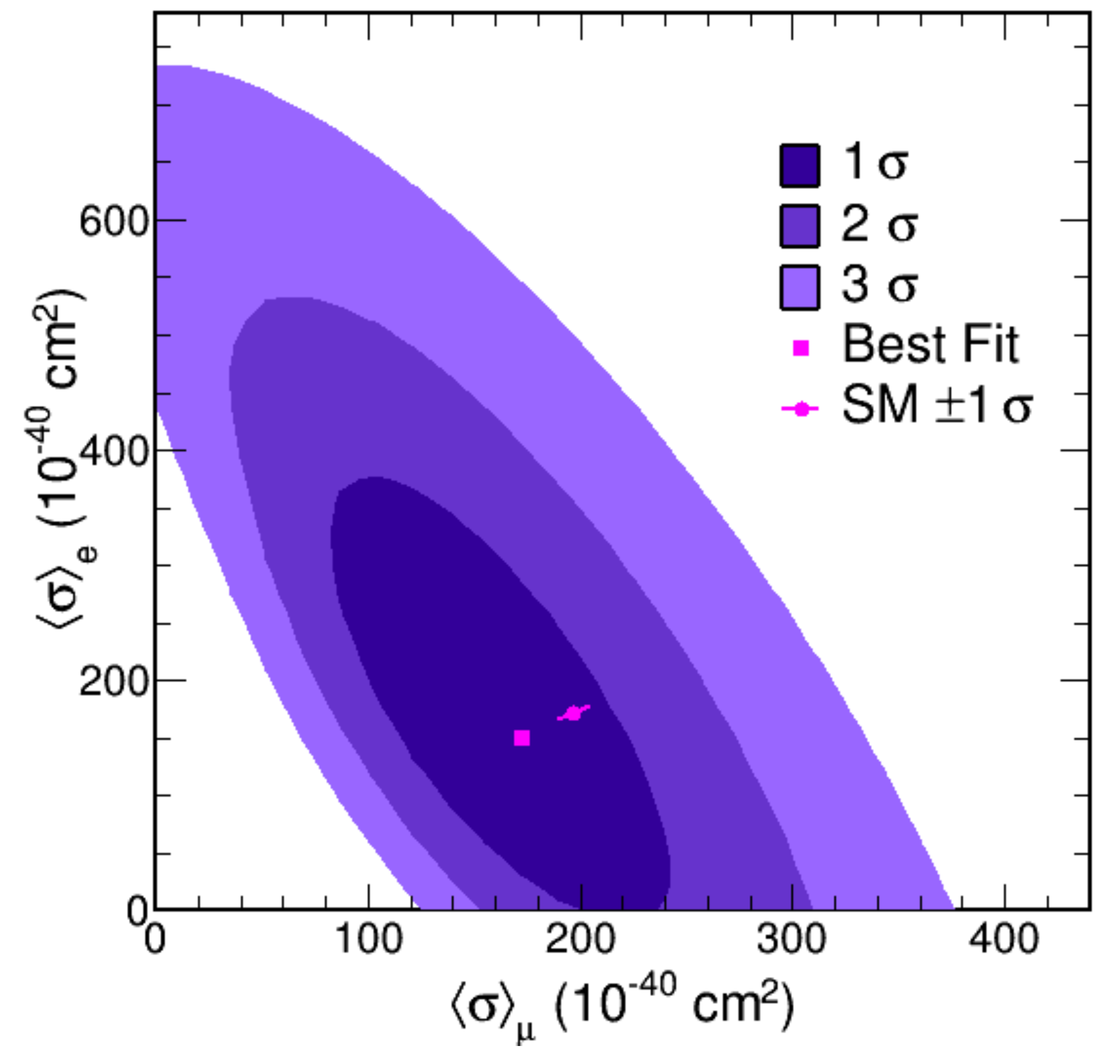






Measurement of CEvNS cross section

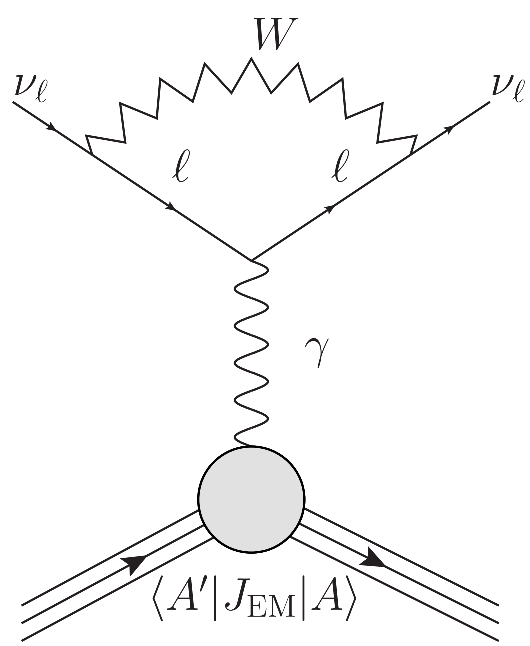


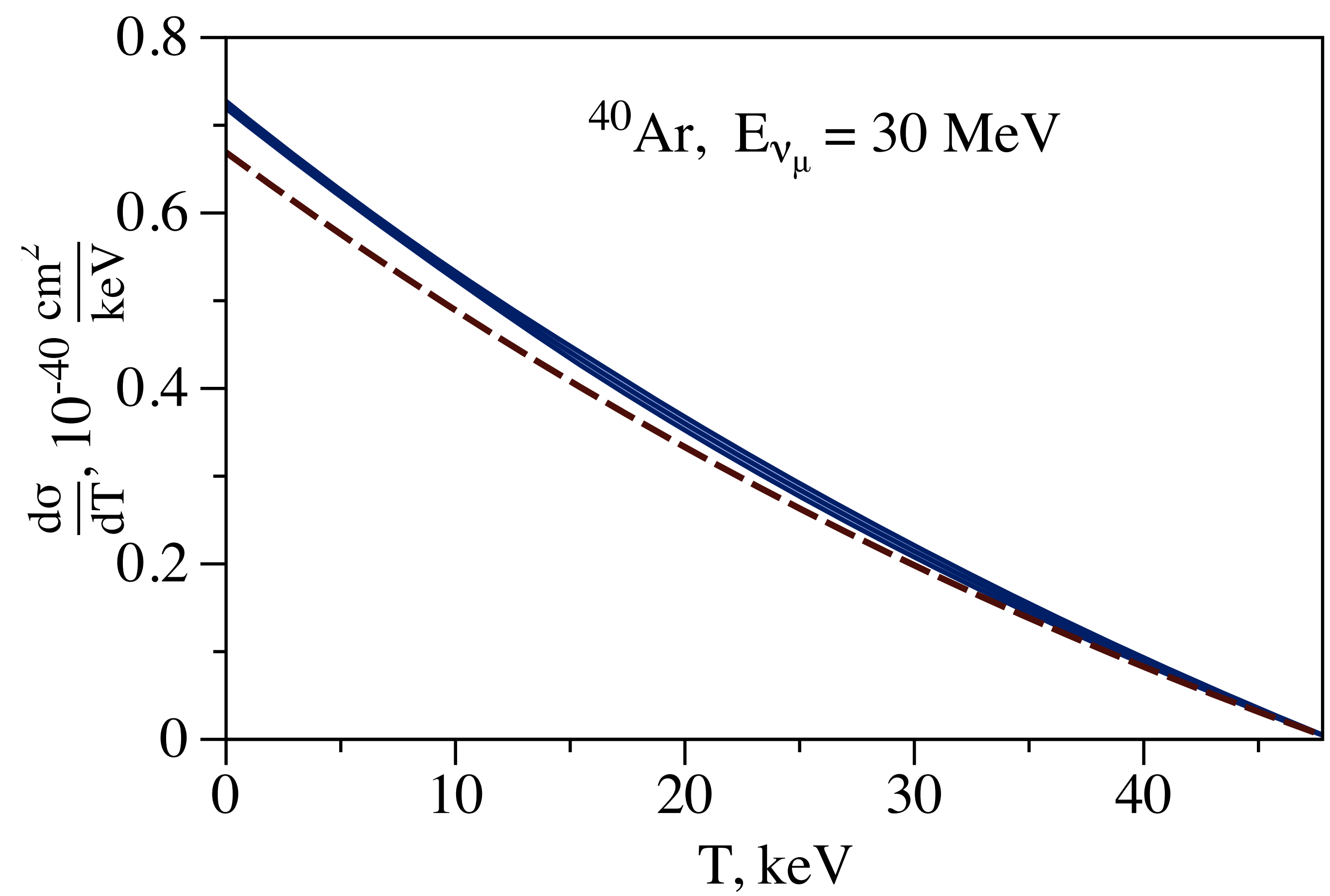


- COHERENT energy and timing data not yet sensitive to flavor separation
- Cross section precision may be reduced to few percent (Snowmass WP, 2204.04575)

COHERENT collaboration 2021

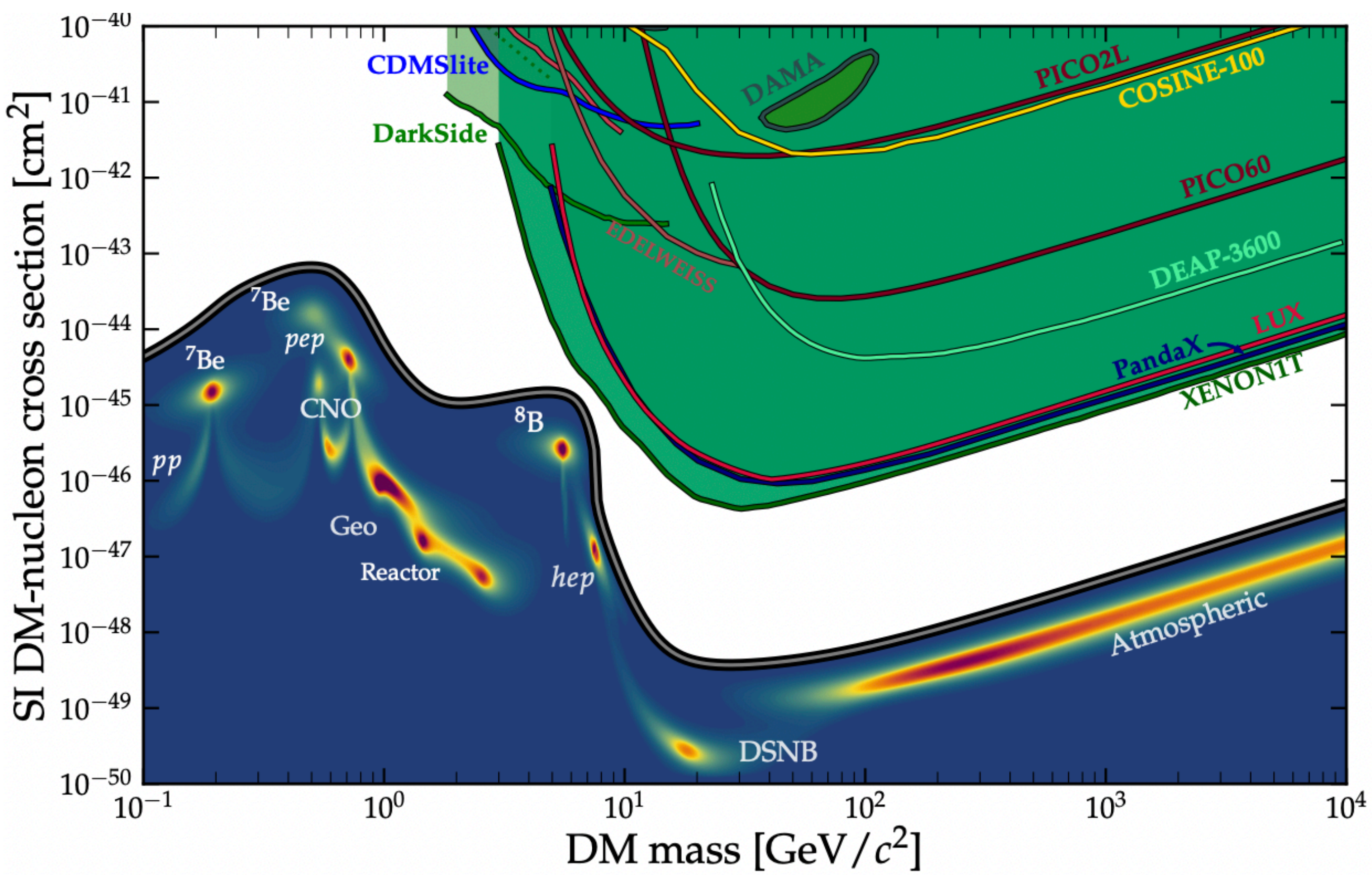
Precision measurement of CEvNS cross section



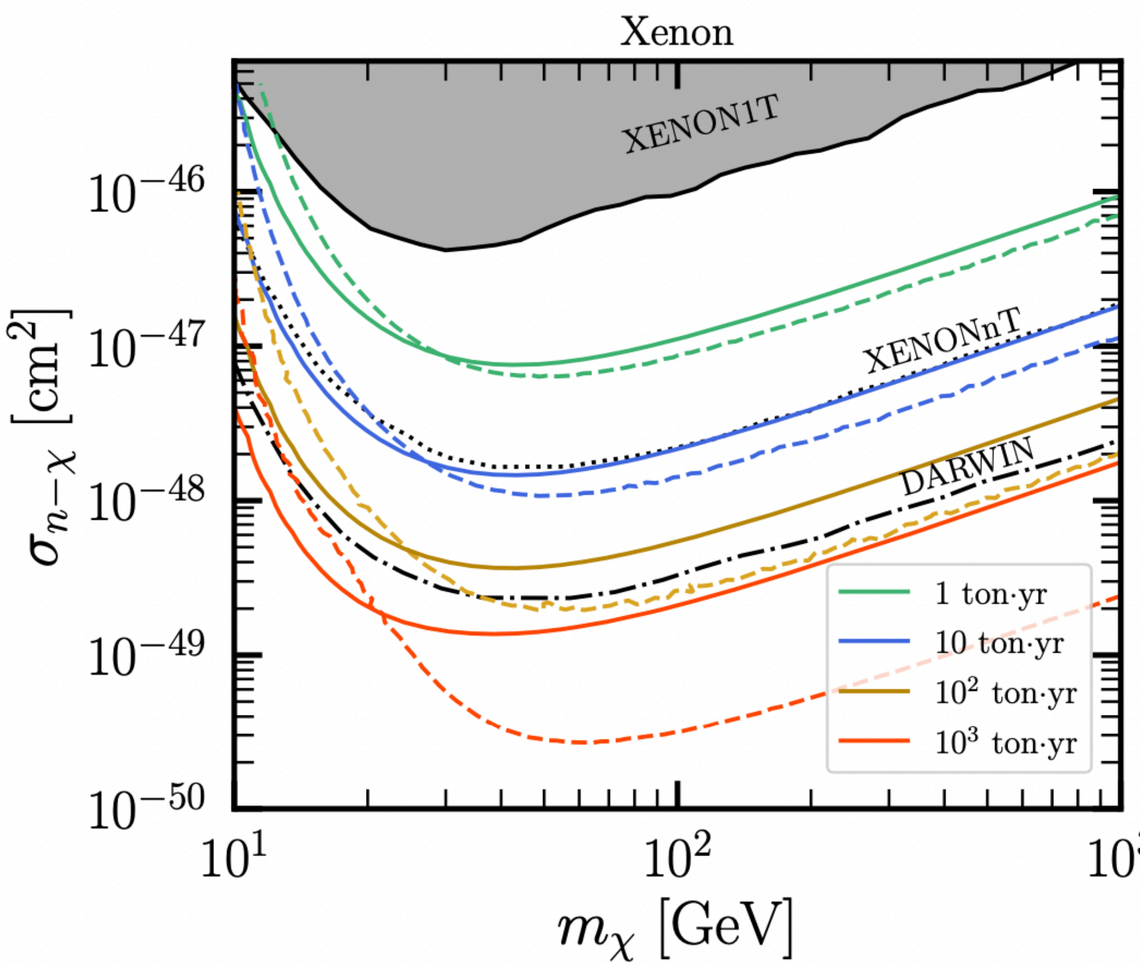


- Radiative corrections to the CEvNS cross section induce flavor dependences [Sehgal 1985; Cadeddu et al. 2019; Tomalak et al. 2021]
- Percent-level measurements of the cross section would be sensitive to these processes
- Terrestrial and astrophysical sources still affected by systematic uncertainties

Re-visiting the neutrino floor/fog



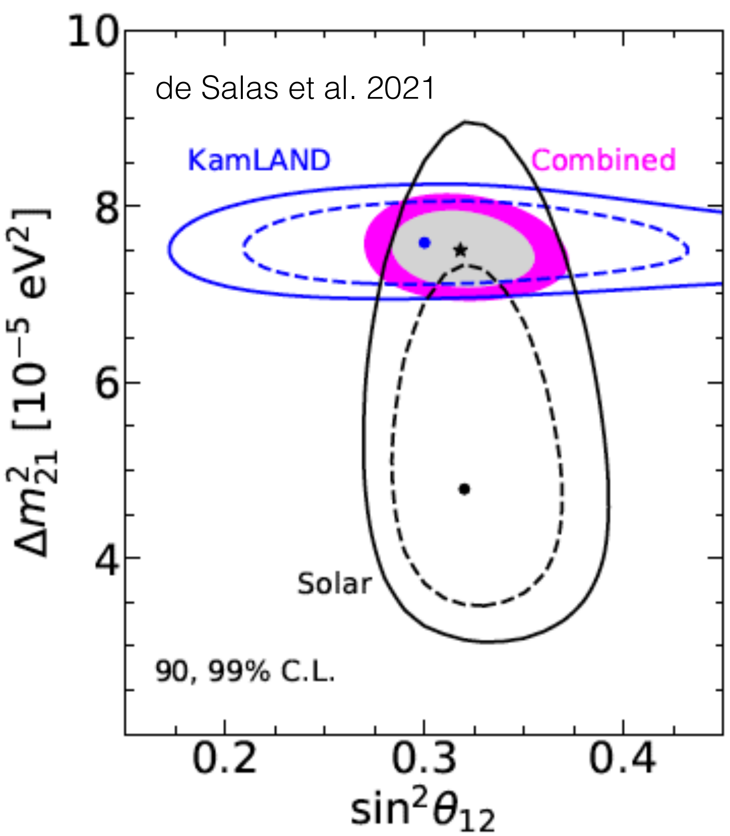
O'Hare PRL 2021

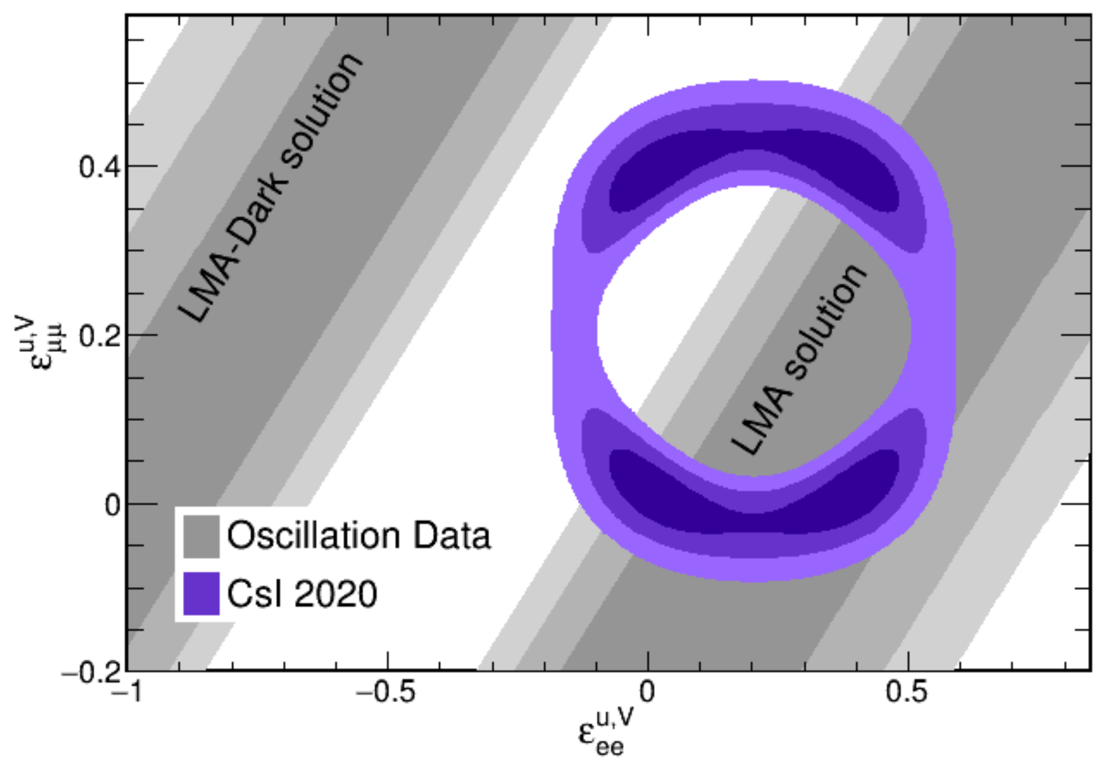


Aristizabel Sierra, De Romeri, Flores, Papoulis 2022

Measurement of CEvNS cross section in terrestrial experiments calibrate location of neutrino background

New physics neutrino interactions





Oscillation data still allow for large NSI couplings and MSW LMA *dark side* solution [Miranda, Valle, Tortola, 2006]

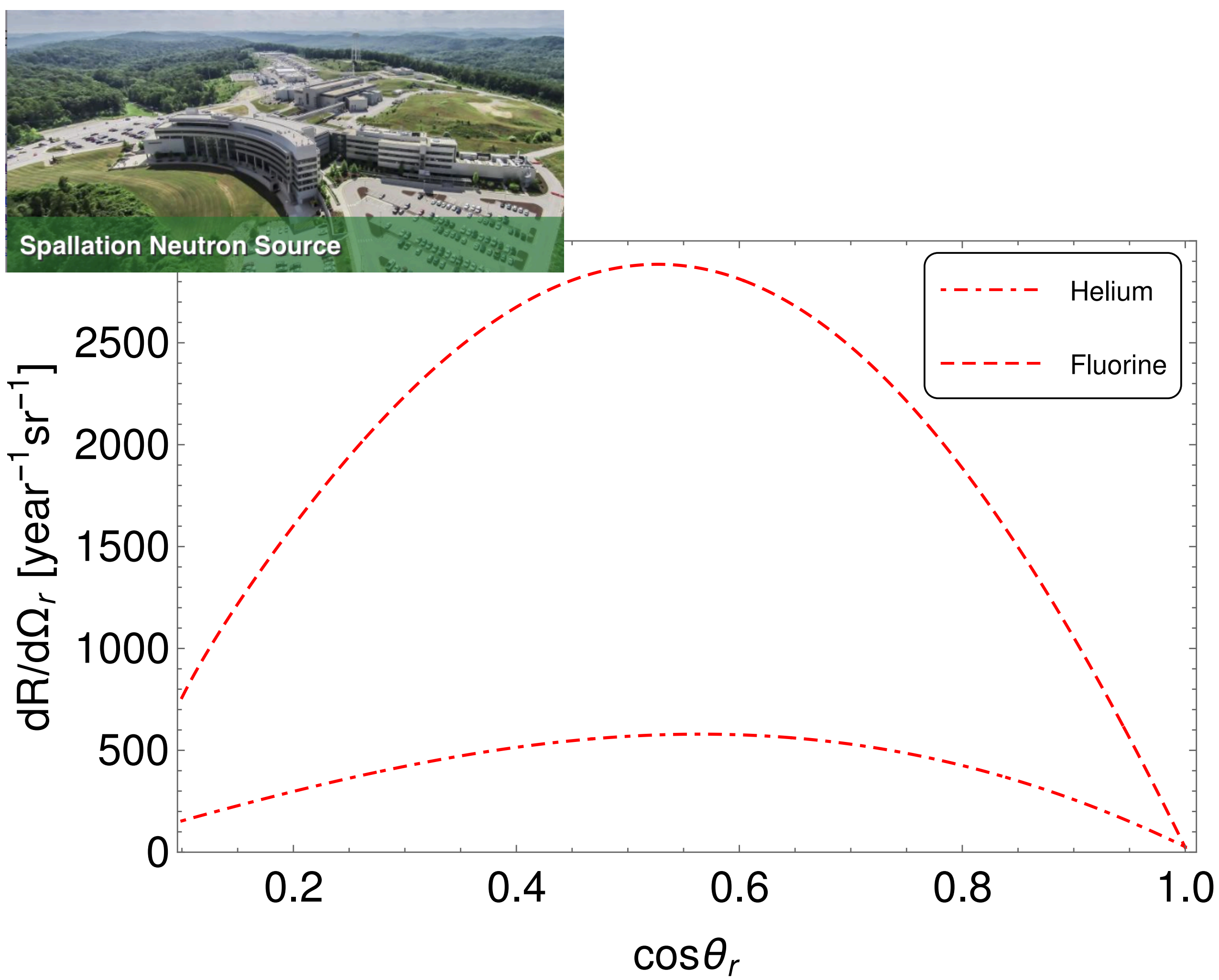
Changes octant of solar angle and sign of mass ordering

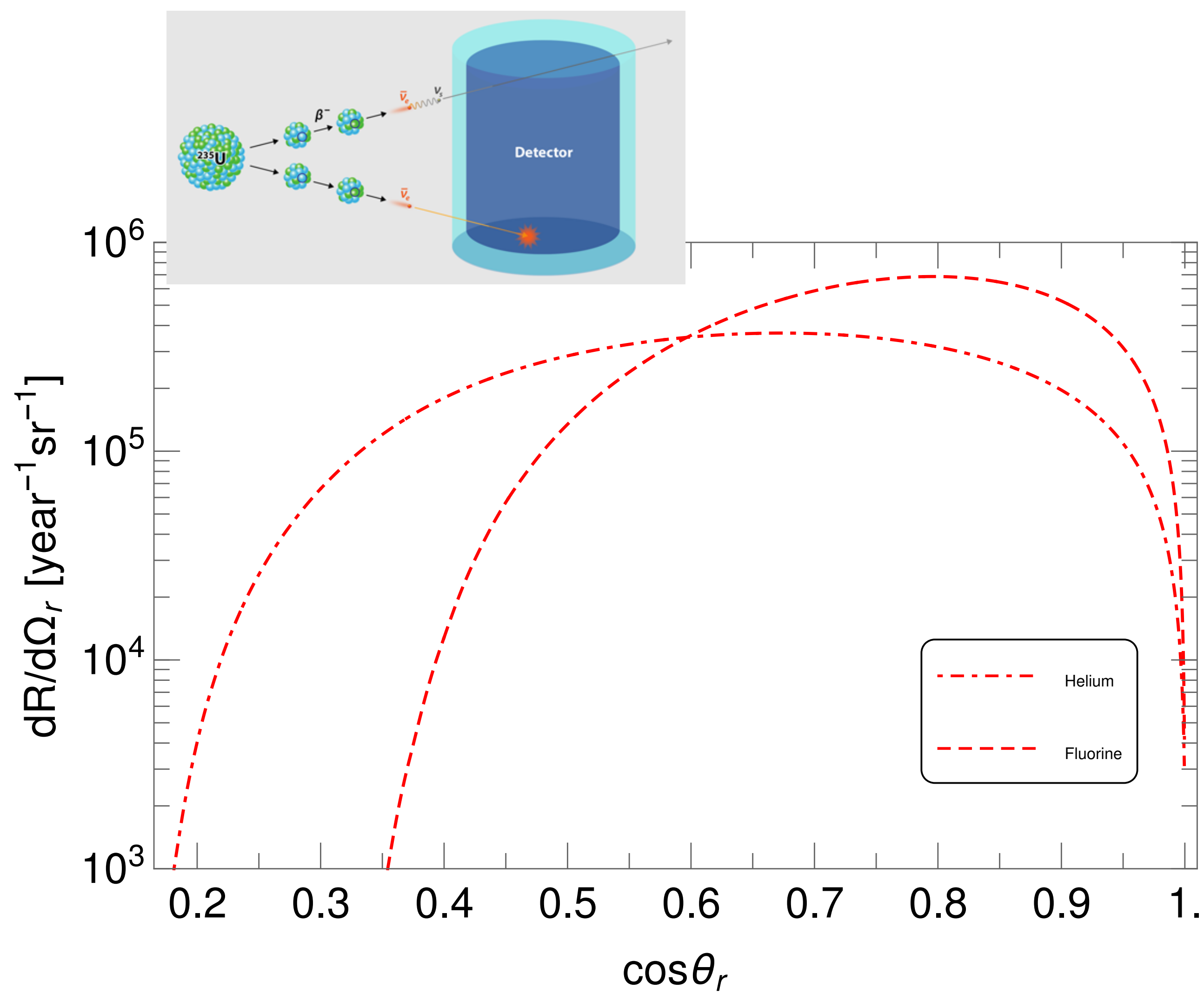
Non-oscillation experiments (e.g. coherent scattering) required to lift existing degeneracy

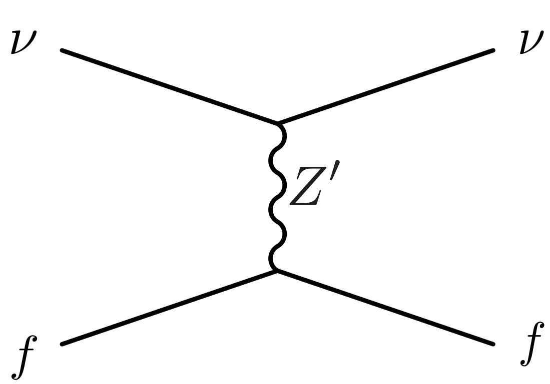
COHERENT collaboration 2020

Coloma, Denton, Gonzalez-Garcia, Maltoni 2017; Denton, Farzan, Shoemaker 2018; Denton & Gehrlein 2020

CEvNS with directional detectors



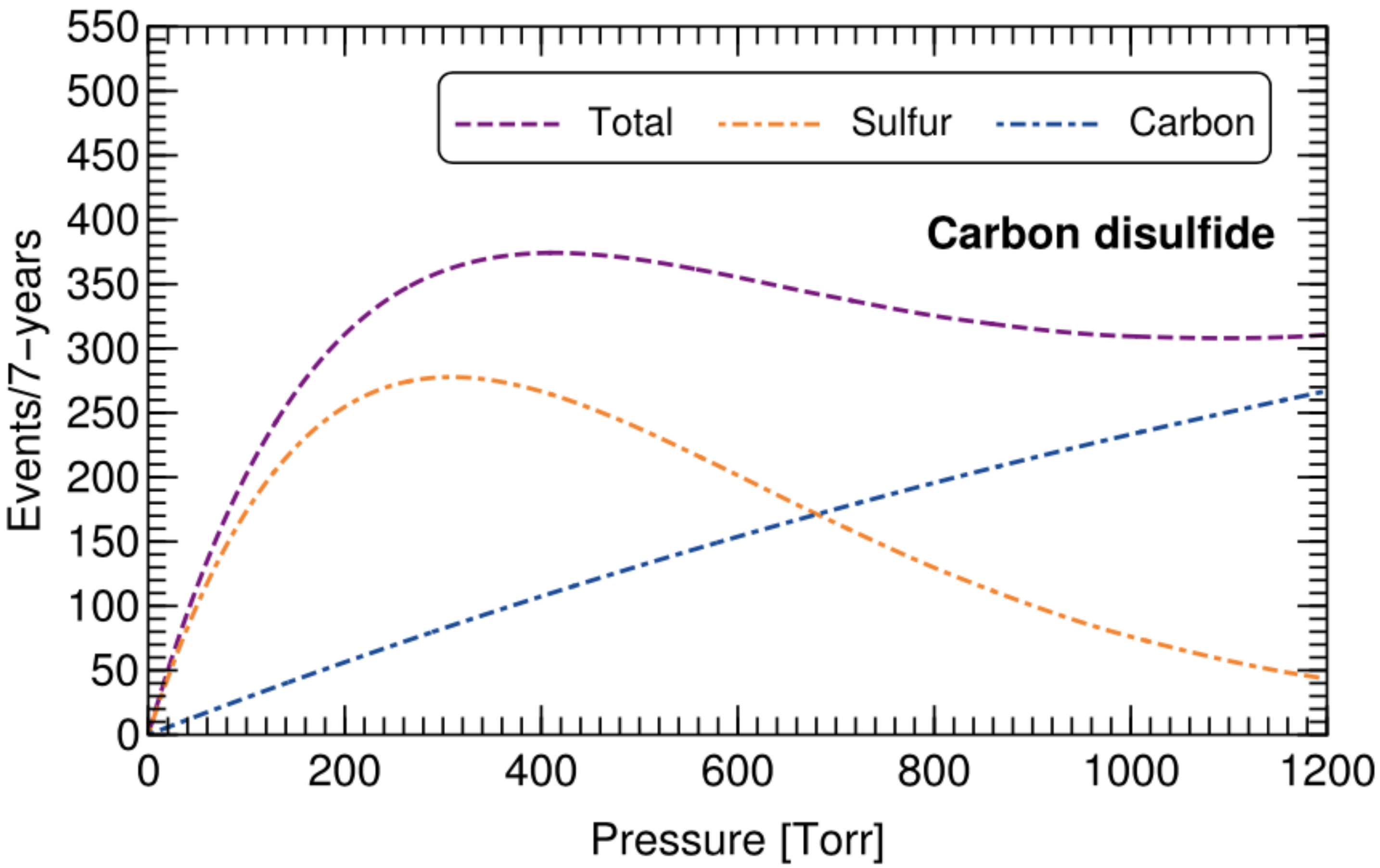


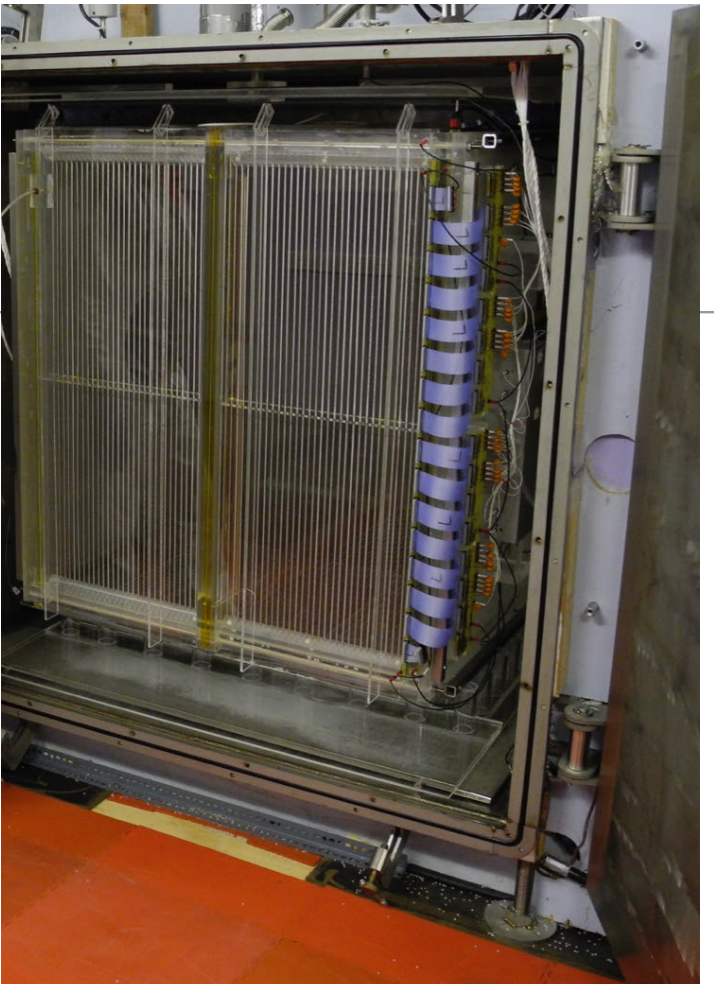


Light mediators alter the shape of angular distribution

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

CEvNS with DRIFT detector





Coherent elastic neutrino-nucleus scattering with the νBDX-DRIFT directional detector at next generation neutrino facilities

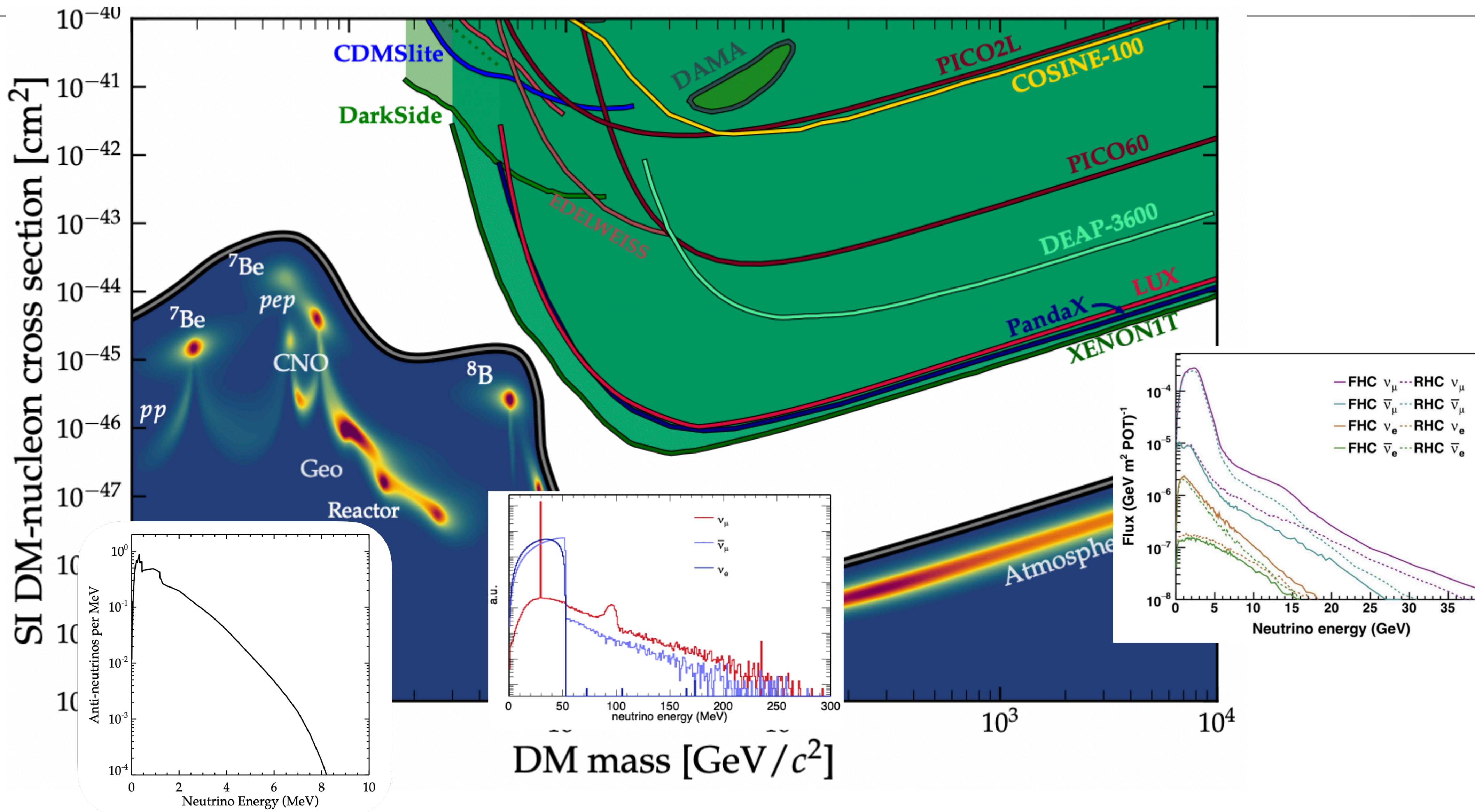
D. Aristizabal Sierra,[1,2,*] Bhaskar Dutta,[3,†] Doojin Kim,[3,‡] Daniel Snowden-Ifft,[4,§] and Louis E. Strigari[3,¶]

Rock Neutron Backgrounds from Fermilab Neutrino Beamlines in the νBDX-DRIFT Detector

To appear

- Recoil energy threshold proportional to pressure
- Max rate @ 400 Torr CS_2
- Significant detection, ~400 events for 7 yrs with 10 cubic m

Dark matter & CEvNS physics with terrestrial and astrophysical sources



Many snowmass white papers on CEvNS, dark matter

Coherent elastic neutrino-nucleus scattering: Terrestrial and astrophysical applications

Physics Opportunities in the ORNL Spallation Neutron Source Second Target Station Era

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