Daniel J. Salvat

The COHERENT physics program

INDIANA UNIVERSITY BLOOMINGTON

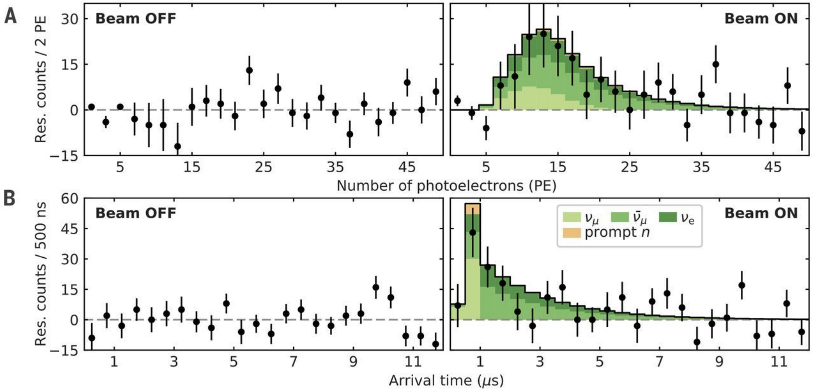
Non-standard interactions

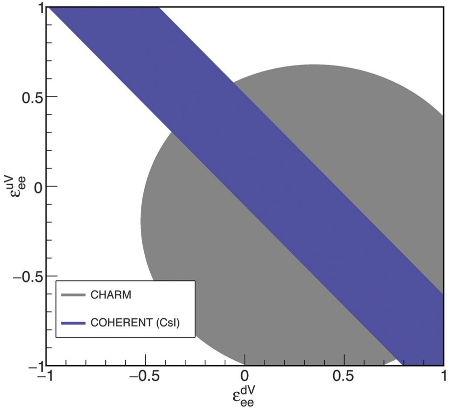
CEvNS, the SM, and beyond

$$\frac{d\sigma}{dT}_{coh} = \frac{G_f^2 M}{2\pi} G_V^2 \left[1 + \left(1 - \frac{T}{E_\nu}\right)^2 - \frac{MT}{E_\nu^2}\right]$$

$$G_V = ((g_V^p + 2\epsilon_{ee}^{uV} + \epsilon_{ee}^{dV})\, Z + (g_V^n + \epsilon_{ee}^{uV} + 2\epsilon_{ee}^{dV})N)\, F_{\mathrm{nucl}}^V(Q^2)$$

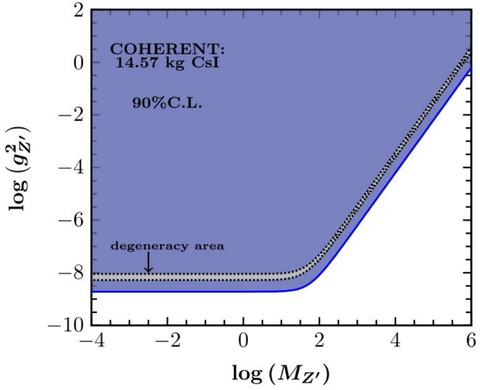
What have we learned?

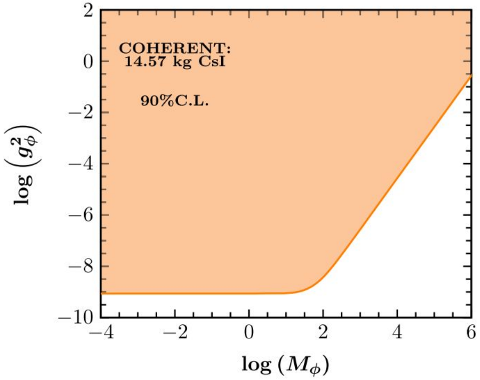


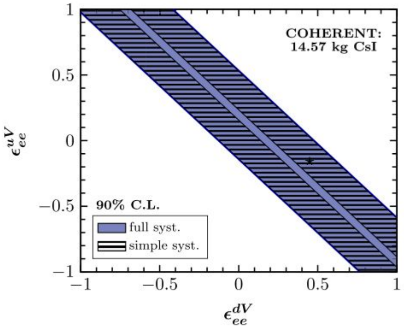


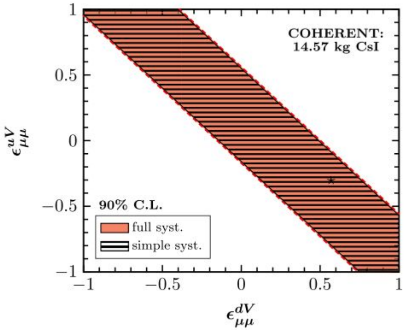
CEvNS, the SM, and beyond

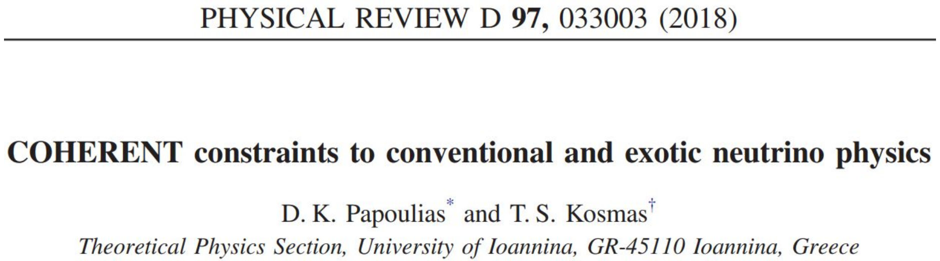
- New constraints on
    - *Z'* (for left-handed neutrinos)
    - scalar mediator
    - flavor-diagonal NSI









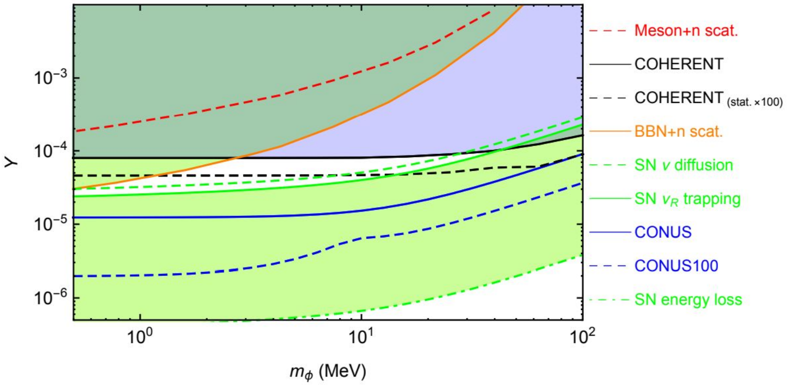

PHYSICAL REVIEW D **97,** 033003 (2018)

COHERENT constraints to conventional and exotic neutrino physics

D. K. Papoulias* and T. S. Kosmas†

Theoretical Physics Section, University of Ioannina, GR-45110 Ioannina, Greece

Scalar and tensor currents



Probing neutrino coupling to a light scalar with coherent neutrino scattering

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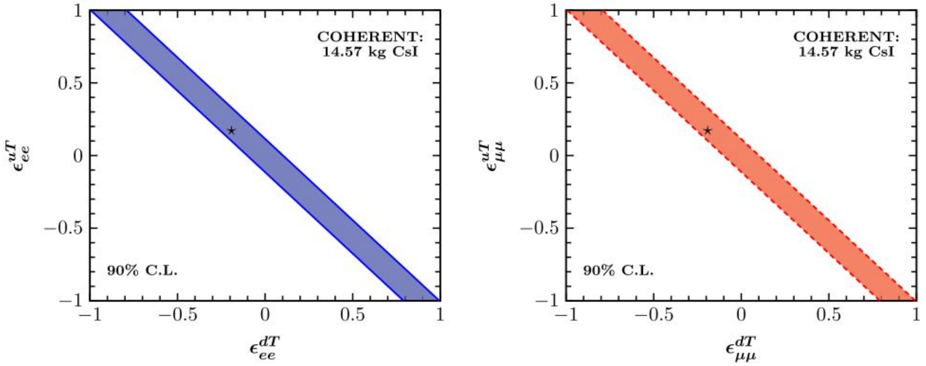
Yasaman Farzan,[a] Manfred Lindner,[b] Werner Rodejohann[b] and Xun-Jie Xu[b]

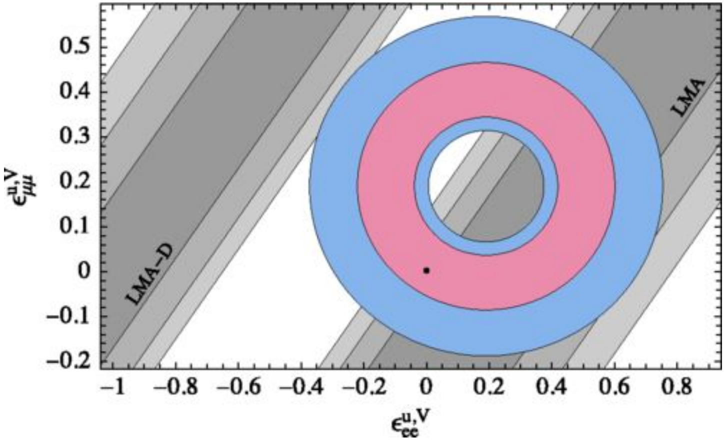


PHYSICAL REVIEW D **97,** 033003 (2018)

COHERENT constraints to conventional and exotic neutrino physics

D. K. Papoulias[*] and T. S. Kosmas[†]
Theoretical Physics Section, University of Ioannina, GR-45110 Ioannina, Greece

The LMA-D solution



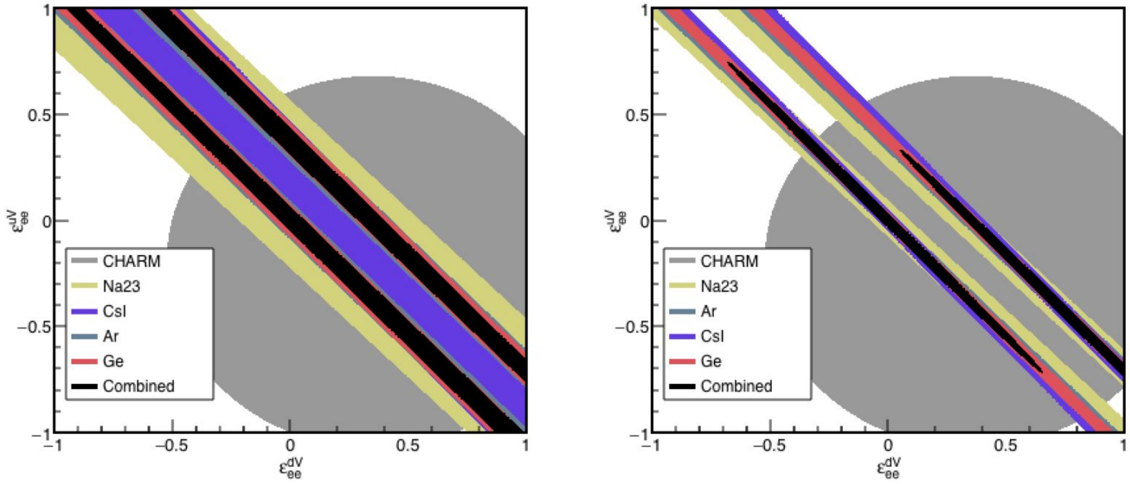
CEvNS compliments oscillation data to break LMA-D degeneracy

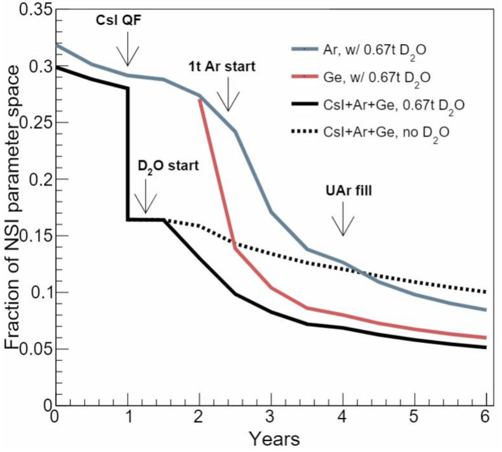
PHYSICAL REVIEW D **96,** 115007 (2017)

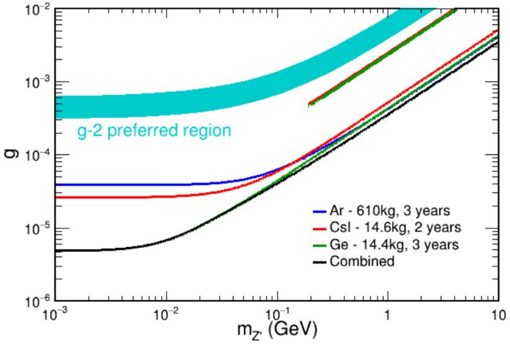
COHERENT enlightenment of the neutrino dark side

Pilar Coloma,[1,*] M. C. Gonzalez-Garcia,[2,3,4,†] Michele Maltoni,[5,‡] and Thomas Schwetz[6,§]

Future COHERENT NSI constraints







- Multiple targets with different *N/Z* eliminates more parameter space
- Considering sensitivity studies that incorporate recoil spectra
- Degeneracy in *Z’* models broken by using multiple nuclear targets

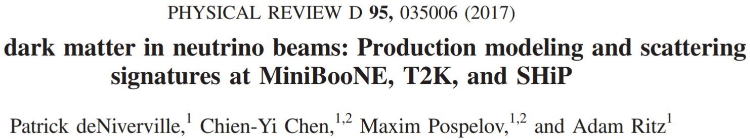
Future COHERENT NSI constraints

- CsI result already strengthens limits on vector-like NSI
- Sensitivity studies underway for modulation of recoil spectra
- Future measurements will constrain π-DAR ν flux

Accelerator-produced dark matter

Vector portal dark matter

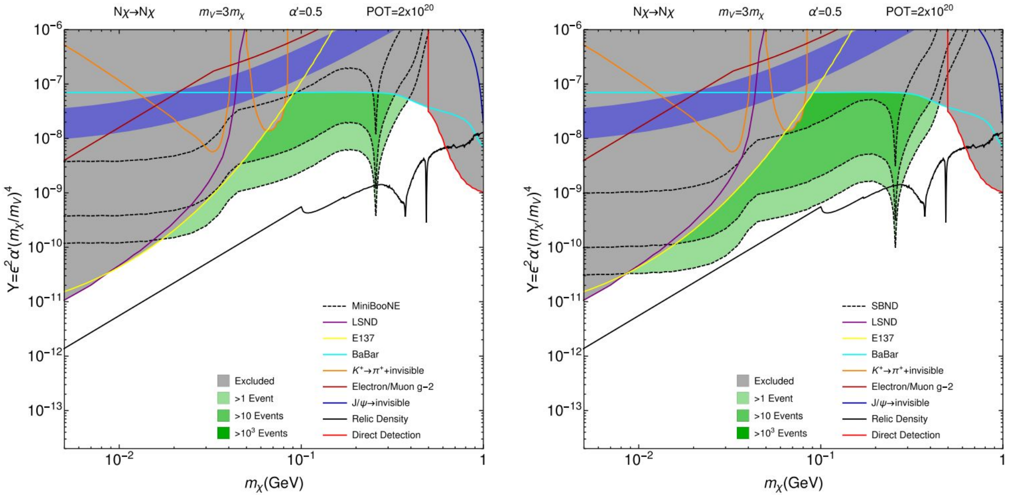
$$\mathcal{L} = \mathcal{L}_\chi - \frac{1}{4}V_{\mu\nu}V^{\mu\nu} + \frac{1}{2}m_V^2 V_\mu V^\mu - \frac{\epsilon}{2}V^{\mu\nu}F_{\mu\nu} + q_B g' V_\mu J_B^\mu + \cdots$$



PHYSICAL REVIEW D **95,** 035006 (2017)

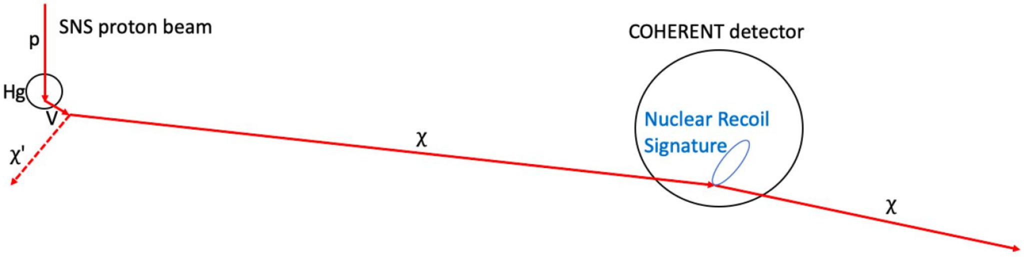
Light dark matter in neutrino beams: Production modeling and scattering signatures at MiniBooNE, T2K, and SHiP

Patrick deNiverville,[1] Chien-Yi Chen,[1,2] Maxim Pospelov,[1,2] and Adam Ritz[1]

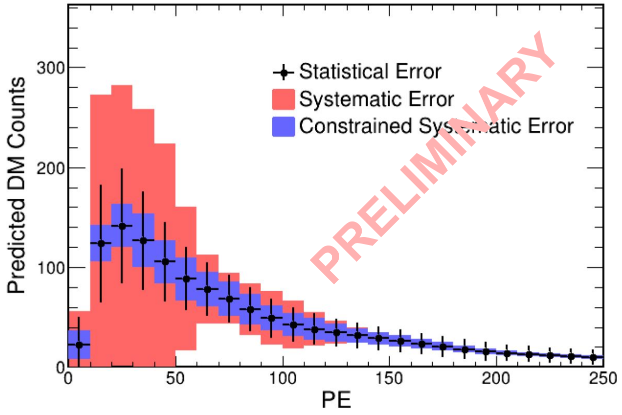


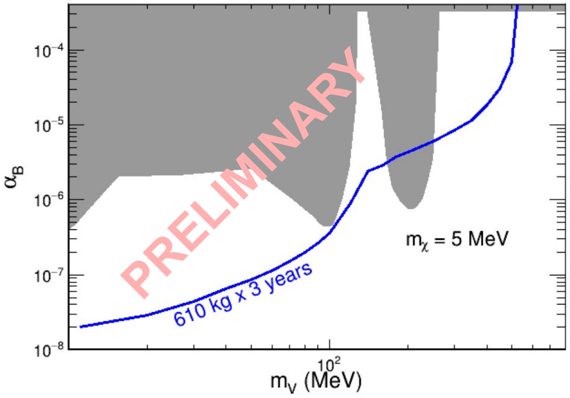
Existing limits from accelerators

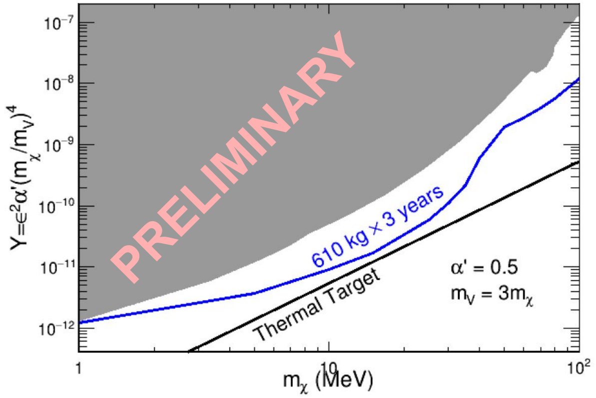
but elastic n.r. offers coherent enhancement!



A DM search with COHERENT data



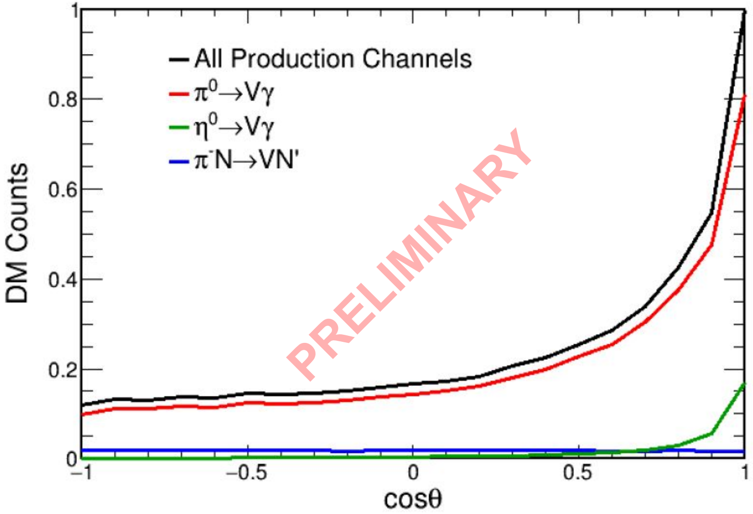


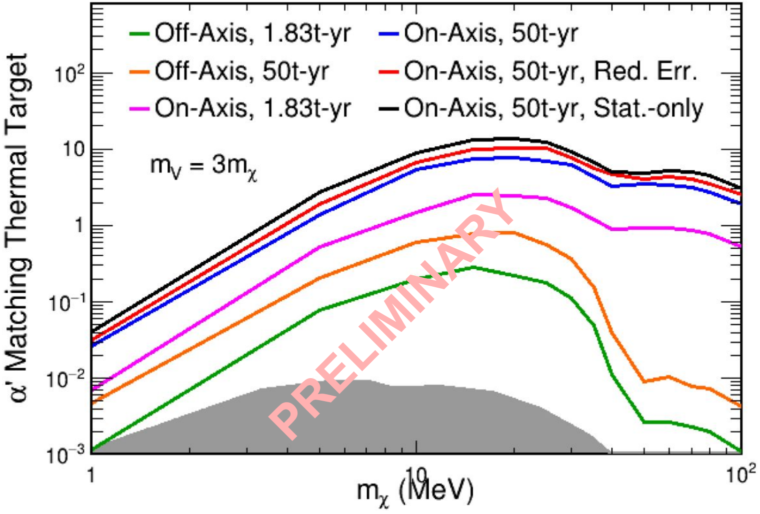


- Coherent cross section enhancement
- DM and CEvNS recoil spectra are different -- *delayed CEvNS provide constraint for prompt DM*
- Competitive constraints for ~10-30 MeV vector portal in neutrino alley
- Strong limits on baryonic portal

STS prospects

- Preliminary results indicate that a ~10 ton scale detector is feasible
- On axis with beam produces largest boosted pion flux
- Can rule out all couplings for $m_\chi>4$ MeV assuming $m_V=3m_\chi$
- Mitigating fast-*n* backgrounds key for leveraging the full power of the pulsed *π*-DAR source



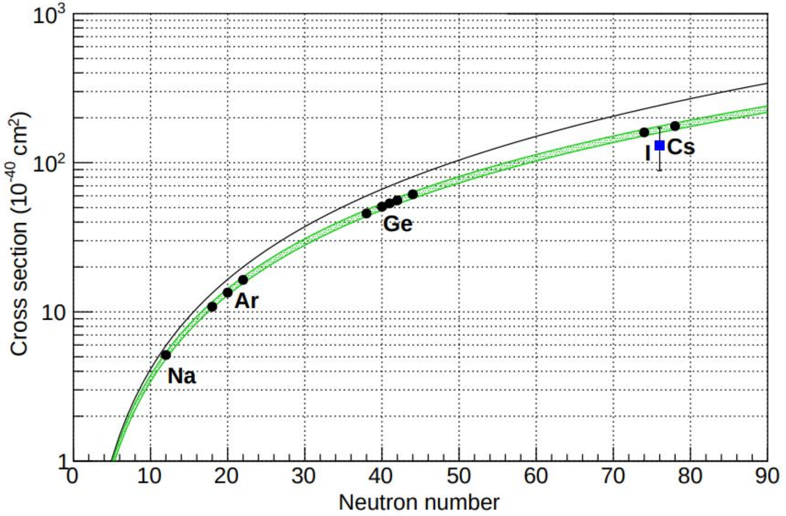


Nuclear form factors

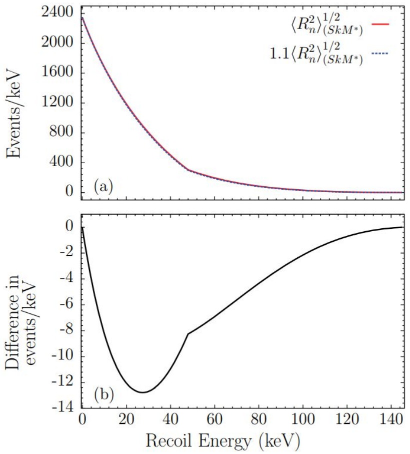
Nuclear targets for COHERENT

$$G_V = (g_V^p Z + g_V^n N) F_{\rm nucl}^V(Q^2)$$

$$G_A = (g_A^p (Z_+ - Z_-) + g_A^n (N_+ - N_-)) F_{\rm nucl}^A(Q^2)$$



$$F_n(Q^2) \approx \frac{1}{N}\int \rho_n(r)\left(1-\frac{Q^2}{3!}r^2+\frac{Q^4}{5!}r^4-\frac{Q^6}{7!}r^6+\cdots\right)r^2dr$$
$$\approx \left(1-\frac{Q^2}{3!}\langle R_n^2\rangle+\frac{Q^4}{5!}\langle R_n^4\rangle-\frac{Q^6}{7!}\langle R_n^6\rangle+\cdots\right), \quad (6)$$



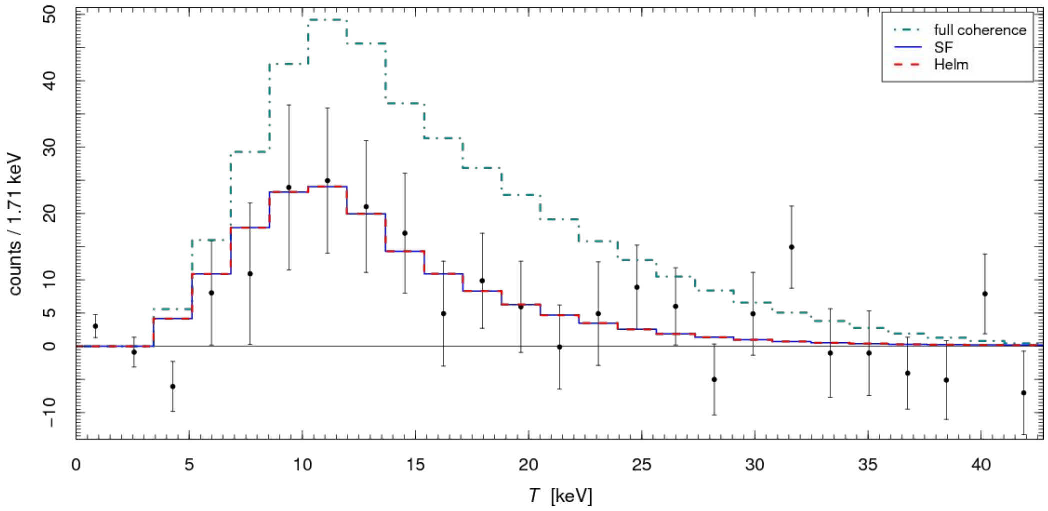
Neutrino-nucleus coherent scattering as a probe of neutron density distributions

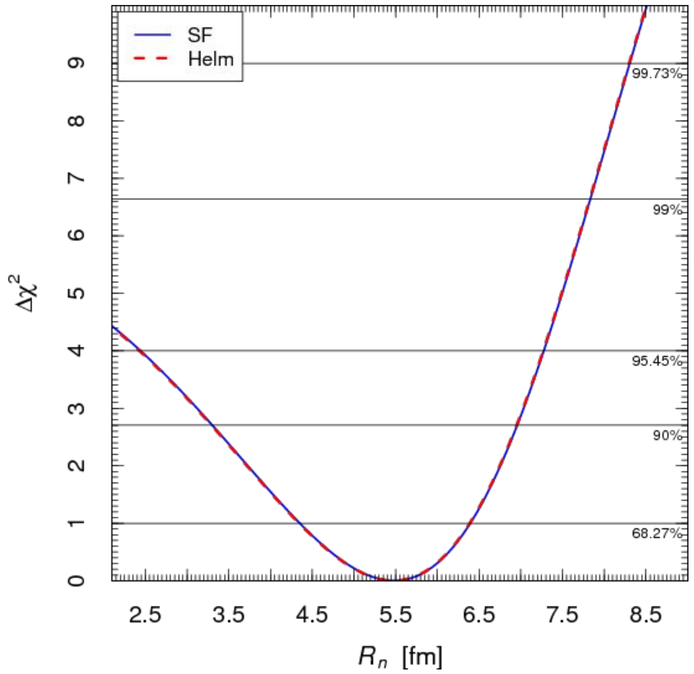
Kelly Patton,[1,*] Jonathan Engel,[2,†] Gail C. McLaughlin,[1,‡] and Nicolas Schunck[3,§]
[1] *Physics Department, North Carolina State University, Raleigh, North Carolina 27695, USA*
[2] *Department of Physics and Astronomy, University of North Carolina, Chapel Hill, North Carolina 27599, USA*
[3] *Physics Division, Lawrence Livermore Laboratory, Livermore, California 94551, USA*

The Cs & I neutron density distribution

PHYSICAL REVIEW LETTERS **120,** 072501 (2018)

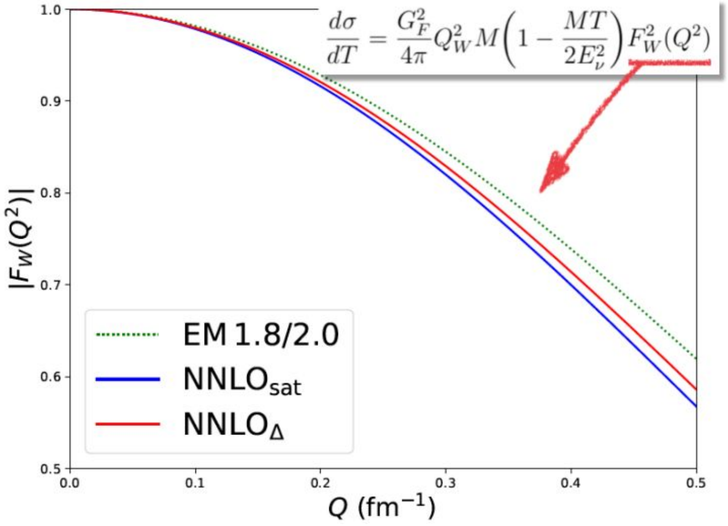
Average CsI Neutron Density Distribution from COHERENT Data





Advances in chiral EFT

from G. Hagen



$$\frac{d\sigma}{dT} = \frac{G_F^2}{4\pi} Q_W^2 M \left(1 - \frac{MT}{2E_\nu^2}\right) F_W^2(Q^2)$$

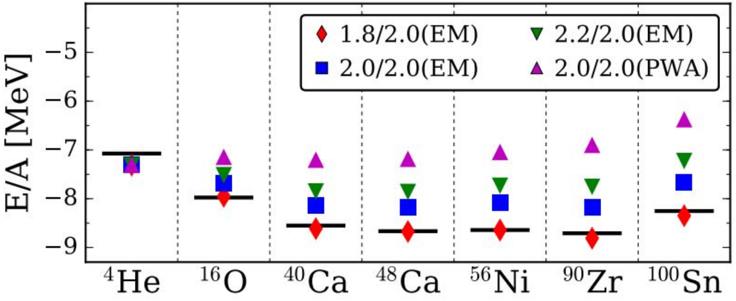
Structure of the lightest tin isotopes

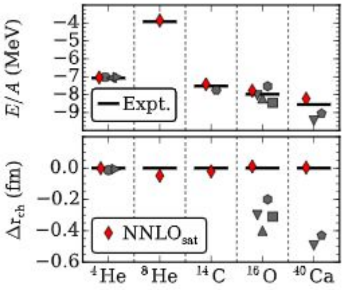
T. D. Morris,[1, 2] J. Simonis,[3, 4] S. R. Stroberg,[5, 6] C. Stumpf,[3] G. Hagen,[2, 1]
J. D. Holt,[5] G. R. Jansen,[7, 2] T. Papenbrock,[1, 2] R. Roth,[3] and A. Schwenk[3, 4, 8]

PHYSICAL REVIEW C **91**, 051301(R) (2015)

Accurate nuclear radii and binding energies from a chiral interaction

A. Ekström,[1,2] G. R. Jansen,[2,1] K. A. Wendt,[1,2] G. Hagen,[2,1] T. Papenbrock,[1,2] B. D. Carlsson,[3] C. Forssén,[3,1,2]
M. Hjorth-Jensen,[4,5] P. Navrátil,[6] and W. Nazarewicz[4,2,7]





Outlook

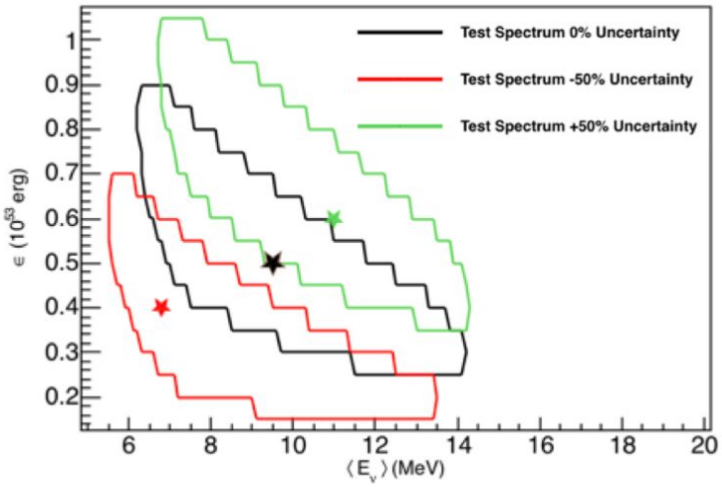
- CEvNS measures weak form factors, complementing PV elastic scattering
- Working to investigate sensitivities for the broad range of potential nuclei for future high precision measurements

CC/NC inelastic scattering

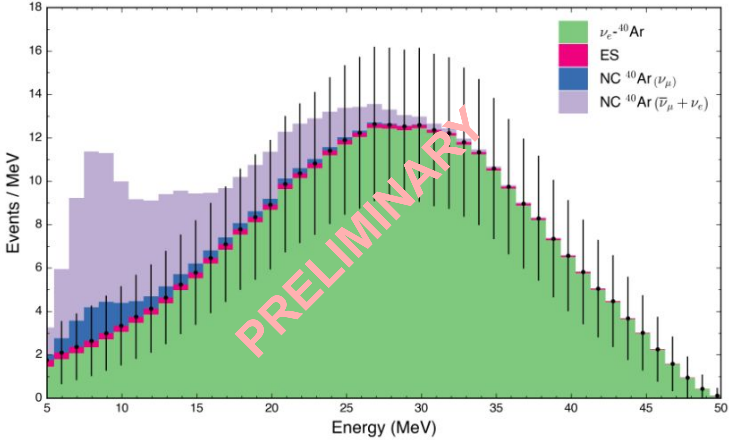
Inelastic interactions in LAr

$$\nu_e + {}^{40}\mathrm{Ar} \rightarrow e^- + {}^{40}\mathrm{K}^*$$

- Predominant reaction expected for DUNE supernova signature
- Future COHERENT LAr detector can inform cross section, event topologies



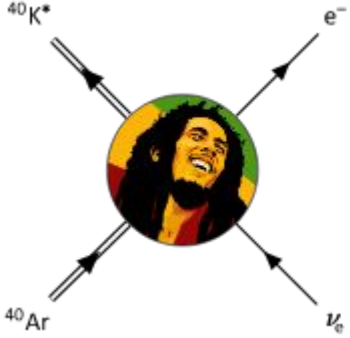
from E Conley & K Scholberg

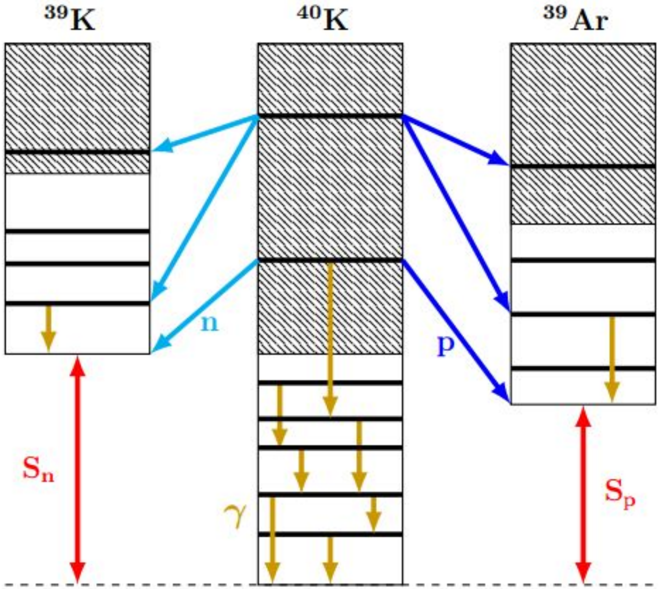


MARLEY sims for next-gen LAr detector

- Model of Argon Reaction Low-Energy Yields
- Comprehensive event generator incorporating optical model for resulting compound nucleus, nuclear level densities…
- Deploying for studies of π-DAR ν_e for next-gen LAr

See S. Gardiner's talk!

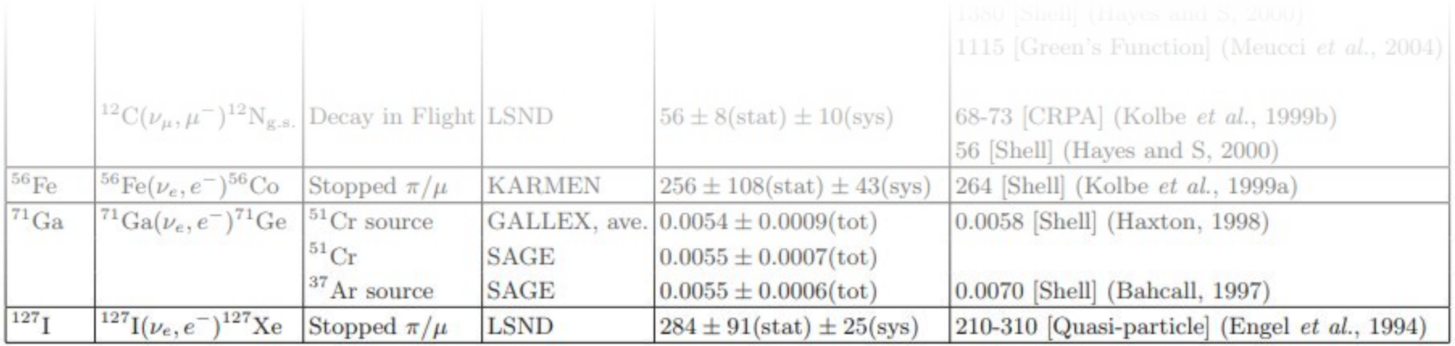




The ^{127}I charged-current cross section

- Exclusive reaction measured in radiochemical measurement
- Test of nuclear models/g_A quenching
- Accessible in COHERENT NaI detector arrays

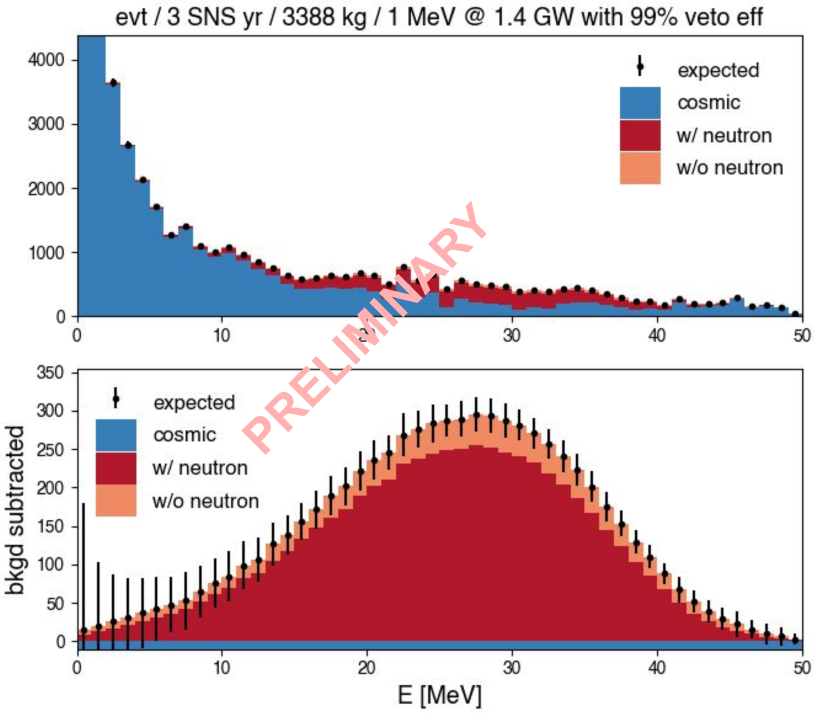
$$\nu_e + {}^{127}\mathrm{I} \rightarrow e^- + {}^{127}\mathrm{Xe}^*$$



	^{12}C$(\nu_\mu, \mu^-)^{12}$N$_{\mathrm{g.s.}}$	Decay in Flight	LSND	56 ± 8(stat) ± 10(sys)	1380 [Shell] (Hayes and S, 2000) 1115 [Green's Function] (Meucci *et al.*, 2004) 68-73 [CRPA] (Kolbe *et al.*, 1999b) 56 [Shell] (Hayes and S, 2000)
^{56}Fe	^{56}Fe$(\nu_e, e^-)^{56}$Co	Stopped π/μ	KARMEN	256 ± 108(stat) ± 43(sys)	264 [Shell] (Kolbe *et al.*, 1999a)
^{71}Ga	^{71}Ga$(\nu_e, e^-)^{71}$Ge	^{51}Cr source	GALLEX, ave.	0.0054 ± 0.0009(tot)	0.0058 [Shell] (Haxton, 1998)
		^{51}Cr	SAGE	0.0055 ± 0.0007(tot)	
		^{37}Ar source	SAGE	0.0055 ± 0.0006(tot)	0.0070 [Shell] (Bahcall, 1997)
^{127}I	^{127}I$(\nu_e, e^-)^{127}$Xe	Stopped π/μ	LSND	284 ± 91(stat) ± 25(sys)	210-310 [Quasi-particle] (Engel *et al.*, 1994)

Adapting the MARLEY framework

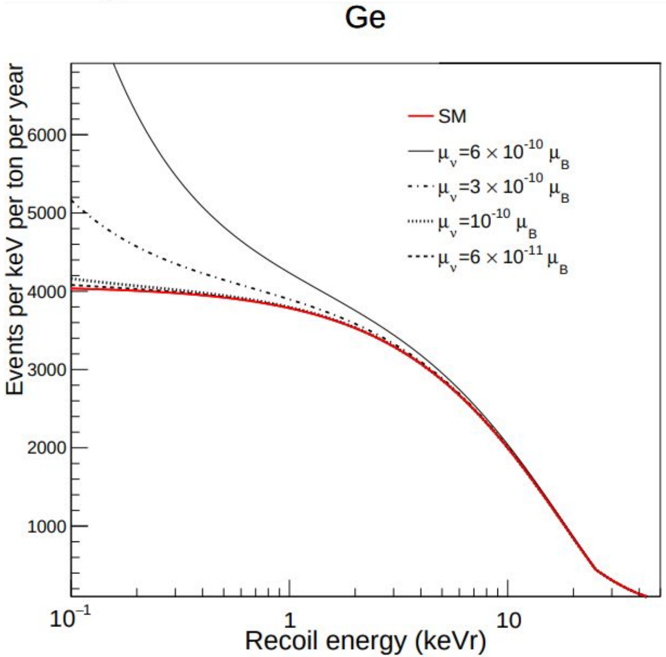
- Incorporating calculations and charge-exchange measurements of B(GT) for ^{127}I into MARLEY
- Use preliminary NaI data to assess backgrounds
- NaI array highly segmented -- studying potentially complex event topologies to optimize S/B and potentially study final states

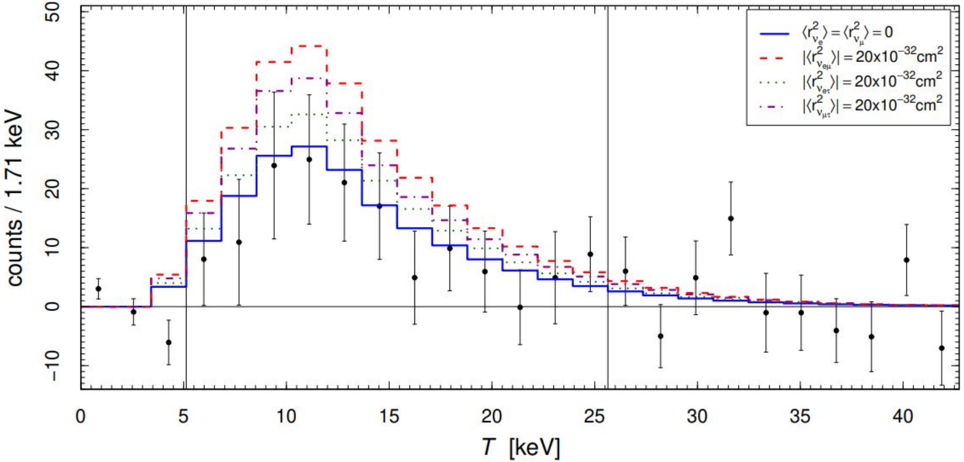


Neutrino properties

Electromagnetic properties

$$\left(\frac{d\sigma}{dT}\right)_{\mathrm{m}} = \frac{\pi\alpha^2\mu_\nu^2 Z^2}{m_e^2}\left(\frac{1-T/E_\nu}{T}+\frac{T}{4E_\nu^2}\right)$$





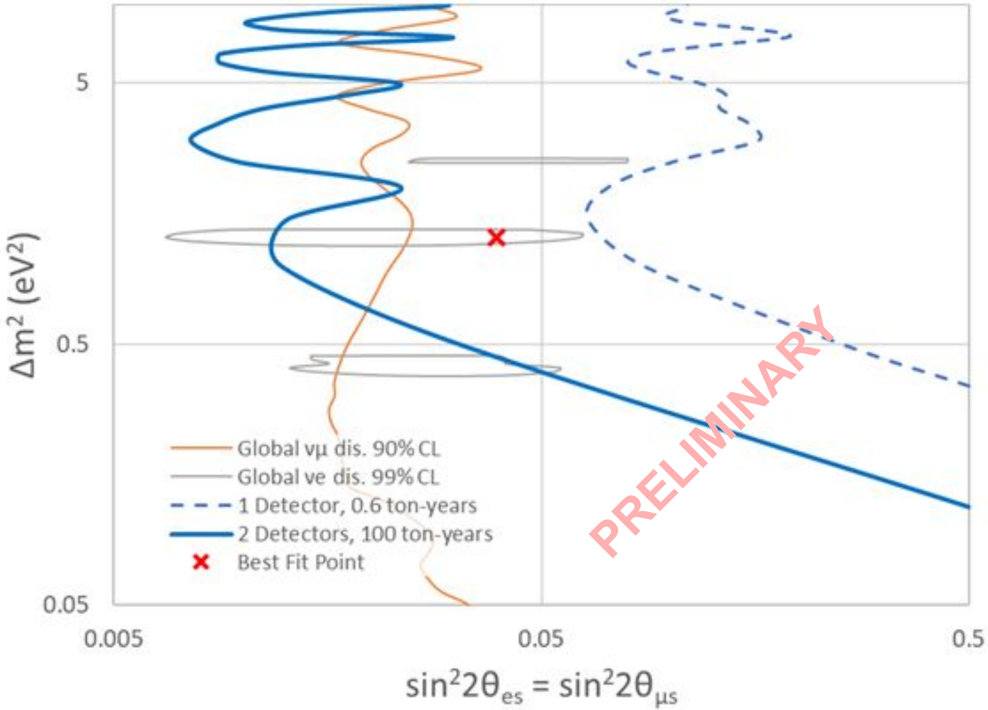
$$\left(|\langle r^2_{\nu_{e\mu}}\rangle|, |\langle r^2_{\nu_{e\tau}}\rangle|, |\langle r^2_{\nu_{\mu\tau}}\rangle|\right) < (22, 38, 27)\times 10^{-32}\,\mathrm{cm}^2$$

Neutrino Charge Radii from COHERENT Elastic Neutrino-Nucleus Scattering

M. Cadeddu,[1,*] C. Giunti,[2,†] K.A. Kouzakov,[3,‡] Y.F. Li,[4,5,§] A.I. Studenikin,[6,7,¶] and Y.Y. Zhang[4,5,**]

Sterile neutrino oscillations

- Potential for flavor-blind disappearance measurement
- A future large-scale, dedicated measurement at STS would be needed to improve bounds



Outlook

The COHERENT physics program

- Already several applications of our CsI data for NSI, neutron distributions
- Multiple nuclear targets at one source mitigates some systematic uncertainties, breaks degeneracies in NSI and *Z’* models
- Ongoing efforts to refine QF and understanding of recoil spectra
    - Many aspects of physics program will benefit from *precision measurements of recoil spectra*
- An on-axis, large scale detector could provide optimal sensitivity to accelerator-produced DM