Comment on "Fitting the Annual Modulation in DAMA with Neutrons from Muons and Neutrinos"

A Letter [1], proposes a new mechanism to explain the modulation effect apparent in DAMA/LIBRA data. Neutrons induced by ^{8}B solar neutrinos (solar NINs) would add to those produced by muon interactions in the vicinity of the detectors, improving agreement with the observed modulation phase. The modulation amplitude required from this newly considered process is 0.039 counts per kg of NaI [Tl] per day, which for 3.3% annual solar flux modulation implies a large mean rate of $R_\nu \sim 11.5$ NIN interactions per day in the relevant 2–6 keV$_{ee}$ region, for interactions affecting single 9.7 kg DAMA/LIBRA crystals.

In this Comment, we focus on the proposed solar NIN effect and leave aside additional issues (e.g., that the muon-induced neutron contribution is too small to account for either DAMA/LIBRA or CoGeNT modulation [2–4]). Three overoptimistic approximations have been made in Ref. [1]. First, the assumed effective volume of target material $V \sim 1000$ m^3 is much larger than the existing volume of high-NIN-cross-section material near the detector; only ~0.98 m^3 of lead is present in the DAMA/LIBRA shield [5]. Second, the NIN mean free path is taken to be 2.6 m, justifying the large V. While appropriate for $O(100)$ MeV neutrons generated by muon interactions, NINs should carry $O(1)$ MeV energies [6], resulting in a smaller range (a few tens of cm in concrete), and modest V [7]. Third, Ref. [1] neglects the small efficiency for transporting NINs from their originating sites through shielding and then generating single-crystal interactions in the 2–6 keV$_{ee}$ spectral energy region.

Assuming a standard ^{8}B solar neutrino flux [8], ν_e survival probability of ~0.4, and using Ref. [9], which employs cross sections from Ref. [10], we calculate the rate of solar NIN emission in ^{208}Pb to be 0.85 per kiloton of lead per day. We have performed two independent calculations of NIN transport, one based on GEANT 4.10.0.1, the second using MCNP-POLIMI, both in agreement. The geometry (copper, lead, cadmium, polyethylene) follows Ref. [5]. One meter of Gran Sasso concrete and two of rock are included. The geometry uses 10 cm of polyethylene (up to 40 cm are present [5]), to allow a maximum of external NINs reaching the detectors. Quenching factors from Ref. [11] are used to generate ionization energy spectra from NIN interactions in one of the 16 external DAMA/LIBRA detectors. We find that the solar NIN modulation would extend tens of keV$_{ee}$ beyond the 2–6 keV$_{ee}$ range. We find that only ~0.046% of the NINs generated in lead deposit energy in the 2–6 keV$_{ee}$ range of a given single external detector module. This results in 4.3×10^{-6} NIN/day creating relevant signals, which, in turn, implies that the NIN cross section in lead required to produce the necessary R_ν would have to be more than 10^6 greater than in Ref. [10]. A similar factor for NINs in the copper surrounding the detectors would be required. Given the self-shielding, the presence of polyethylene moderator, and additional distance to the detector, the solar NIN cross section in the simulated 114 m^3 of concrete necessary to explain DAMA/LIBRA observations would have to be more than 10^7 larger than expected for lead, for the thesis in Ref. [1] to hold. The contribution from 660 m^3 of rock is negligible after attenuation in the inner concrete.

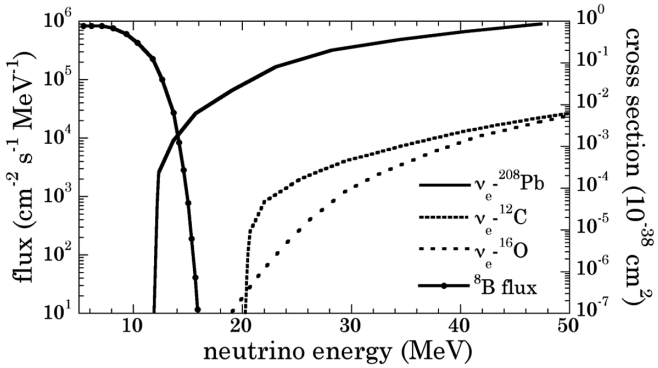

FIG. 1. Example calculated charged-current neutrino cross sections [9,10]. Neutron-generating partial cross sections have higher thresholds and smaller magnitudes (factor of a few). Neutral-current equivalents are smaller by $O(10)$. We considered only lead in our calculations; the ^{8}B flux is not energetic enough to produce NIN reactions in the lighter shielding and most cavern materials.

The pertinent cross sections (Fig. 1) have never been measured. We have recently embarked on an effort to measure them [12,13], although we do not expect a discrepancy with respect to predictions [6,10] even close to sufficient to account for the DAMA/LIBRA modulation.

P. S. Barbeau,[1] J. I. Collar,[2] Y. Efremenko[3] and K. Scholberg[1,*]

[1]Department of Physics, Duke University
Durham, North Carolina 27708, USA
[2]Department of Physics, University of Chicago
Chicago, Illinois 60637, USA
[3]University of Tennessee
Knoxville, Tennessee 37996, USA

Received 10 September 2014; published 26 November 2014
DOI: 10.1103/PhysRevLett.113.229001
PACS numbers: 95.35.+d, 26.65.+t, 96.50.sf

*Corresponding author.
schol@phy.duke.edu

[1] J. H. Davis, Phys. Rev. Lett. **113**, 081302 (2014).
[2] R. Bernabei *et al.* (DAMA Collaboration), Eur. Phys. J. C **72**, 2064 (2012); Int. J. Mod. Phys. A **28**, 1330022 (2013).
[3] C. E. Aalseth *et al.* (CoGeNT Collaboration), Phys. Rev. D **88**, 012002 (2013).
[4] R. Bernabei *et al.*, arXiv:1409.3516.
[5] R. Bernabei *et al.* (DAMA Collaboration), Nucl. Instrum. Methods Phys. Res., Sect. A **592**, 297 (2008).
[6] E. Kolbe and K. Langanke, Phys. Rev. C **63**, 025802 (2001).

[7] V. Tomasello, M. Robinson, and V. A. Kudryavtsev, Astropart. Phys. **34**, 70 (2010).
[8] J. N. Bahcall, E. Lisi, D. Alburger, L. De Braeckeleer, S. Freedman, and J. Napolitano, Phys. Rev. C **54**, 411 (1996).
[9] K. Scholberg *et al.*, http://www.phy.duke.edu/~schol/snowglobes.
[10] J. Engel, G. C. McLaughlin, and C. Volpe, Phys. Rev. D **67**, 013005 (2003).
[11] J. I. Collar, Phys. Rev. C **88**, 035806 (2013).
[12] D. Akimov *et al.* (COHERENT Collaboration), arXiv:1310.0125.
[13] J. I. Collar *et al.*, arXiv:1407.7524.