Physics Letters B 803 (2020) 135357

Contents lists available at ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Comment

Comment on B.O. Kerbikov, "The effect of collisions with the wall on neutron-antineutron transitions", Phys. Lett. B 795 (2019) 362

V.V. Nesvizhevsky [a,*], V. Gudkov [b], K.V. Protasov [c], W.M. Snow [d], A.Yu. Voronin [e]

[a] Institut Max von Laue – Paul Langevin, 71 avenue des Martyrs, Grenoble, 38042, France
[b] Department of Physics and Astronomy, University of South California, Columbia, SC 29208, USA
[c] Laboratoire de Physique Subatomique et de Cosmologie, UGA-CNRS/IN2P3, Grenoble, 38026, France
[d] Department of Physics, Indiana University, 727 E. Third St., Bloomington, IN, 47405, USA
[e] P.N. Lebedev Physical Institute, 53 Leninsky pr., Moscow, 119991, Russia

ARTICLE INFO

Article history:
Received 10 February 2020
Accepted 5 March 2020
Available online 7 March 2020
Editor: M. Doser

We are grateful to Boris Kerbikov for inviting us to comment on the difference between the conclusions in his work [1] and our works [2], [3] on the violation/conservation of coherence during the reflection of a neutron-antineutron superposition $(n/\overline{n})$ from a material surface. Indeed, this is an important issue for experiments on the search for neutron-antineutron oscillations $(n-\overline{n})$. For a comprehensive review of the theoretical status and experimental prospects of these activities, see [4]. The reflection of a coherent $(n/\overline{n})$ superposition from the walls would increase the observation time, and, therefore, the sensitivity of such an experiment.

In fact, the conclusions of all these works [1], [2], [3] are based on the same simple quantum-mechanical formalism for calculations of the amplitude of reflection of a particle from an absorbing potential step, well known from textbooks on quantum mechanics. However, this formalism has been applied for essentially different experimental approaches in the design of $(n-\overline{n})$ experiments.

In ref. [1] and other previous publications on this topic, the formalism for the calculation of the amplitude of $n/\overline{n}$ reflection is correct. However, the experimental design considered in these works is qualitatively different from that discussed in [2], [3]. To profit from the coherent effect of reflection of $(n/\overline{n})$ from the walls, [1] proposed to use the slowest, so-called ultracold neutrons (UCNs). Since UCN fluxes are limited, it was proposed in [1] to use the complete range of transverse velocities of $(n/\overline{n})$ for surface reflection. In this case, the $(n/\overline{n})$ with large transverse velocities penetrate deeper into the wall surface upon reflection, and the effect of any difference between the potentials of the wall material for n and $\overline{n}$ can become quite large. Therefore, the author of [1] concluded that the effect of loss of coherence is large on average, and therefore the reflection of $(n/\overline{n})$ from the walls in experiments to search for $(n-\overline{n})$ oscillations is not useful. We agree with the conclusions of [1] as applied to this experimental design and set of assumptions.

In refs. [2], [3], the assumptions we make about the regime of operation of this experiment are qualitatively different from those chosen in [1], and that is the reason why we can come to a different conclusion while using the same fundamental underlying physics and formulae. We show that there are different experimental conditions under which the correct use of $(n/\overline{n})$ reflection from the walls is very beneficial. In particular, these conditions consist in the appropriate pre-shaping of the initial n spectrum and beam phase space so that the transverse $(n/\overline{n})$ velocities are significantly smaller than the critical velocity of the wall material (both for n and $\overline{n}$). In this case, the dephasing effect is minimal and can be calculated much more reliably. Moreover, a correct choice of wall material allows one to further reduce the effect of dephasing. Thus we have shown that, over a wide range of experimental parameters, the effect of coherence loss is negligible with respect to the $\overline{n}$ annihilation in the surface upon reflection. In combination with the use of large cold neutron fluxes and optimized experiment geometry, the effect of coherent reflection of $(n/\overline{n})$ from the walls can greatly increase the sensitivity of an experiment to search for $(n-\overline{n})$ oscillations, simplify its design, decrease costs and minimize theoretical uncertainties associated with the correction for the effect of loss of coherence when interpreting experimental results.

Acknowledgements. The work of V.V.N. and W.M.S. was supported in part by a grant from Gordon and Betty Moore Foundation. V.G. is grateful for support of the U.S. Department of Energy, Office of Science, Office of Nuclear Physics program under Award

DOI of original article: https://doi.org/10.1016/j.physletb.2019.06.041.
* Corresponding author.
E-mail address: nesvizhevsky@ill.eu (V.V. Nesvizhevsky).

https://doi.org/10.1016/j.physletb.2020.135357

No. DESC0015882. W.M.S. acknowledges support from NSF PHY-1614545 and from the Indiana University Center for Spacetime Symmetries.

References

[1] B.O. Kerbikov, The effect of collisions with the wall on neutron-antineutron transitions, Phys. Lett. B 795 (2019) 362.
[2] V.V. Nesvizhevsky, V. Gudkov, K.V. Protasov, W.M. Snow, A.Y. Voronin, A new operating mode in experiments searching for free neutron-antineutron oscillations based on coherent neutron antineutron mirror reflections, Europ. Phys. J. Web Conf. 191 (2018) 01005.
[3] V.V. Nesvizhevsky, V. Gudkov, K.V. Protasov, W.M. Snow, A.Yu. Voronin, Experimental approach to search for free neutron-antineutron oscillations based on coherent neutron and antineutron mirror reflection, Phys. Rev. Lett. 122 (2019) 221802.
[4] D.G. Phillips, W.M. Snow, K. Babul, S. Banerjee, D.V. Baxter, Z. Berezhiani, M. Bergevin, S. Bhattacharya, G. Brooijmans, L. Castelanos, M.C. Chen, C.E. Coppola, R. Cowsik, J.A. Crabtree, P. Das, E.B. Dees, A. Dolgov, P.D. Ferguson, et al., Neutron-antineutron oscillations: theoretical status and experimental prospects, Phys. Rep. 612 (2016) 1.