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Precise determination of the n-17B scattering length

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The s-wave neutron-nucleus scattering length a_s characterizes the low-energy neutron scattering off nuclei. In the effective-range approximation, the neutron-nucleus scattering cross-section at very low energies tends to $4a_s^2$, giving to the scattering length a sense of nuclear apparent size experienced by a neutron approaching at low energy. Its specific value is the result of a complex balance between the attractive individual neutron-nucleon potential and the repulsion generated by the Pauli principle with respect to the other neutrons in the nucleus. As such, it oscillates between positive and negative values (respectively for bound and virtual states) with increasing nuclear mass, with absolute values ranging from the about 20 fm of the n-N systems to the few fm for light nuclei.

However, in ^{18}B the peculiar balance between attraction and repulsion leads to a spectacular increase in absolute value, with an upper limit of a_s<-50 fm provided by the only existing measurement [1]. Letting aside the anomalous value in itself, the fact that adding an extra neutron to the system leads to the weakly-bound two-neutron halo nucleus ^{19}B may have strong physics implications. The three-body system ^{17}B+n+n would be thus built from two scattering lengths, a large one of about 20 fm and a potentially huge one of tens, hundreds or even thousands of fm, opening the debate about possible Efimov states in ^{19}B and the description of nuclei at the unitary limit [2].

We have determined this essential observable by using a series of nuclear reactions leading to the ^{17}B+n final state. The experiments were performed at the RIKEN Nishina Center as part of the SAMURAI Day1 campaign (for experimental details see for example [3]). A series of secondary beams (^{19}B, ^{18,19,20}C, ^{20,21,22}N) at about 250 MeV/N were tracked onto a carbon target. The reaction products of interest, ^{17}B and neutrons, were detected respectively by the SAMURAI spectrometer and the NEBULA array, and the energy of the ^{17}B+n system was reconstructed by invariant mass. With respect to the previous measurement [1], the large acceptance of the SAMURAI+NEBULA setup has allowed for a complete observation of the virtual state, and the better resolution coupled to the high intensity of the secondary beams has led to a precise characterization of its line shape.

The (^{19}C,^{17}B+n) reaction is found to populate exclusively the virtual state, as expected by the s-wave neutron halo character of ^{19}C, and has been used for the determination of a n-^{17}B scattering length of the order of a thousand fm, taking into account the structure of the initial state. Moreover, the high acceptance and resolution has allowed for the first measurement of the n-^{17}B effective range, governing the second term of the effective-range expansion, and for an exploration of the next term, related to the shape of the potential. The (^{19}B,^{17}B+n) reaction populates the virtual state but also two additional resonances. While the latter represents the first spectroscopy of ^{18}B, the line shape of the former is found to be very sensitive to the neutron separation energy S_n of ^{19}B. We will discuss how these results constrain the value of S_n(^{19}B), and as a consequence S_{2n} and the mass of ^{19}B.

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