Fusion reaction of halo nuclei: 
A real-time wave-packet method for three-body tunneling dynamics

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There has been a long standing controversy on the role of halo nucleon in the fusion process. To obtain deep and reliable understanding on the reaction mechanism, we have been developing a time-dependent wave-packet approach [3]. We describe the reaction as a three-body problem, and the three-body Schrödinger equation is solved accurately with the time-dependent method. The wave-packet approach has several favorable aspects. First we can obtain intuitive picture for the reaction dynamics by visualizing the wave-packet dynamics. Indeed the significance of the Coulomb breakup effect is clearly seen in the wave-packet animation which we show in Fig. 1. Second, it is not necessary to consider the complicated boundary condition for the three-body breakup channels. Third, very high partial waves in the projectile can be incorporated which we found are important to obtain convergent fusion probability.

We previously reported fusion probabilities of halo nuclei mostly for the case of the head-on collision [3]. We now include a full range of impact parameter, for 0 ≤ J ≤ 30, then, for the first time, present results of fusion cross sections calculated with the time-dependent wave-packet method. Calculations are performed for fusion cross sections of $^{11}$Be - $^{209}$Bi and $^6$He - $^{238}$U for which recent measurements are available [1, 2]. We show results for $^{11}$Be reaction in Fig. 2. Recent experiments suggest that the halo neutron does not enhance fusion cross section [1, 2]. Our calculation suggests even slight suppression of the fusion cross section by adding a halo neutron.

![Figure 1: Time evolution of the density distribution of the halo neutron in the rest frame of the projectile. From top-left to bottom-right. A significant breakup and transfer components are seen toward the target (right direction).](image1)

![Figure 2: Calculated fusion cross section of $^{11}$Be and $^{10}$Be on $^{209}$Bi, in comparison with measurement [1, 2].](image2)

References