Study of breakup mechanism of a loosely bound projectile in a region of Coulomb-breakup dominance

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Studies of Coulomb-breakup of composite nuclei have been of constant interest in nuclear physics. The recent discovery of very extended halo nuclei has generated renewed interest in methods for the calculation of Coulomb-breakup. It also has attracted attention in relation to the astrophysical interest. While an exciting application is in the study of such exotic nuclei, the low intensity currently available of secondary beams of these new nuclear species means that present data carry significant experimental uncertainty and are still very limited. Such data inevitably do not challenge sufficiently between different theoretical descriptions.

In the previous study [1, 2], we proposed to pursue the problem by using a light-ion primary beam. The deuteron can be considered as the simplest example of an "exotic" nucleus, because of its small breakup-energy and the dominance of the S-wave in the ground state having no ambiguity in the wave-function. The (d, pn) elastic breakup was measured at $\theta_p = \theta_n = 0°$ and at $E_d = 56$, 140, and 270 MeV on various targets ranging from $Z = 6$ to 82. The data were expected to provide a ground for critical tests of proposed various models. However, the angular resolution was found to be insufficient for the data to be directly compared with theoretical calculations, which predict steep and complicated angular distributions at $\theta \simeq 0°$. Calculations also suggest a need to measure the angular correlation up to fairly large angles. Due to the use of quadrupole-dipole-type magnetic spectrometer, the proton angular resolution was seriously deteriorated and the neutron angle was fixed only at $0°$. In the present experiment, a new beam-line has been constructed in the E experimental

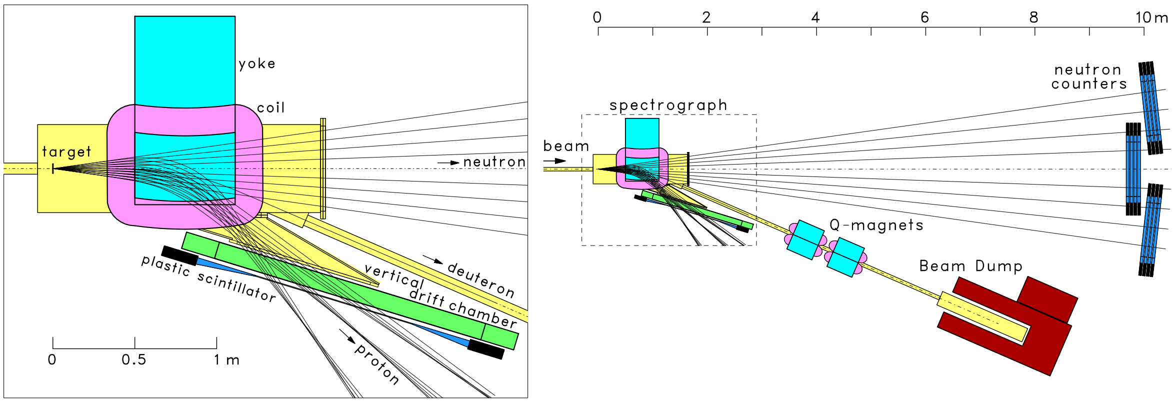

Figure 1: Schematic layout of the experimental setup.

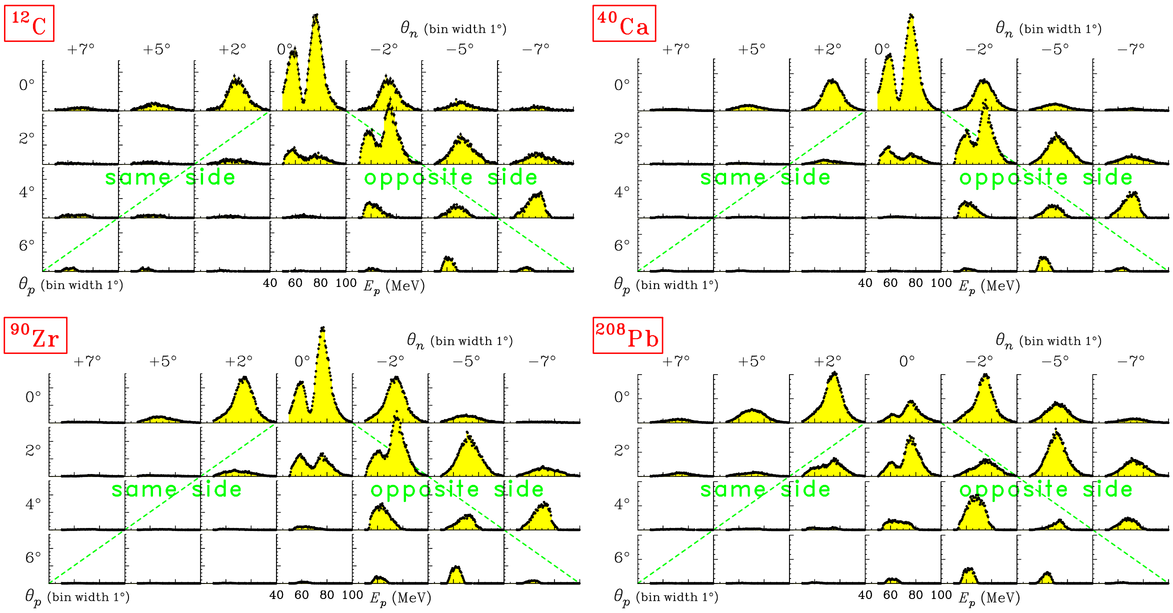

Figure 2: Proton energy spectra of the (d, pn) elastic breakup reaction at $E_d = 140$ MeV on ^{12}C, ^{40}Ca, ^{90}Zr, and ^{208}Pb targets. The ordinate is presented in arbitrary units.

area at RCNP (Fig. 1) with a simple spectrometer system consisting of a bending magnet, previously used at the WN course, and the vertical drift chamber. Both protons and neutrons can be measured up to 8° with a resolution of 0.5° (FWHM) or better. The data have been re-measured only at $E_d = 140$ MeV because the proton energy range is limitted to 50–110 MeV by the spectrometer.

Figure 2 shows the coplanar angular correlations of the proton energy spectra obtained for the (d, pn) elastic breakup reaction on ^{12}C, ^{40}Ca, ^{90}Zr, and ^{208}Pb. It is remarkable that the spectra are well scaled among lighter targets; the shapes are almost identical between ^{12}C and ^{40}Ca and very similar for ^{90}Zr, but the distribution drastically changes for ^{208}Pb. The double-peak structure at $\theta_p = \theta_n = 0°$ indicates a large contribution from P-wave breakup, presumably resulting from the Coulomb breakup dominance, while the asymmetric shape suggests contributions from higher partial waves, post-acceleration effects, and the nuclear breakup. A pure-Coulomb calculation in the framework of adiabatic approximation [3], for example, roughly accounts for the tendency of data but does not reproduce the distinctive difference between ^{208}Pb and other targets. This time the data should be truly useful to establish a theoretical treatment of Coulomb-breakup of loosely bound projectiles.

References

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[3] J.A. Tostevin *et al.*, Phys. Rev. C **57** (1998) 3225; and references therein.