DISSOCIATION OF THE ^{8}He NUCLEUS

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The ^{8}He nucleus is worthy of study because it has the largest neutron-to-proton ratio among the known, bound nuclei. When excited, its most energetic decay channel is ^{6}He+2n, and a large fraction of its decay from low energy excitations is *via* this channel. Its ground state structure, however, is predominantly the less-bound four neutrons and an α-particle core rather than two neutrons and a ^{6}He core [1]. The low-energy decay channels of ^{8}He are illustrated in Fig. 1. Since it takes at least 2.14 MeV to liberate a neutron from ^{8}He, its valence neutrons do not have the long radial tail found in ^{11}Be or ^{11}Li, where the bindings are 0.5 and 0.3 MeV. Tanihata *et al.* [1] have found it more appropriate to call the neutrons a skin rather than a halo. An interesting property of the photo-excitation of some nuclei with neutron haloes is the existence of a low-lying E1 grouping. While most of the E1 strength for stable nuclei is known to be exhausted by the giant dipole resonance, the low-lying strength is indicative of another collective mode, a soft dipole resonance [2].

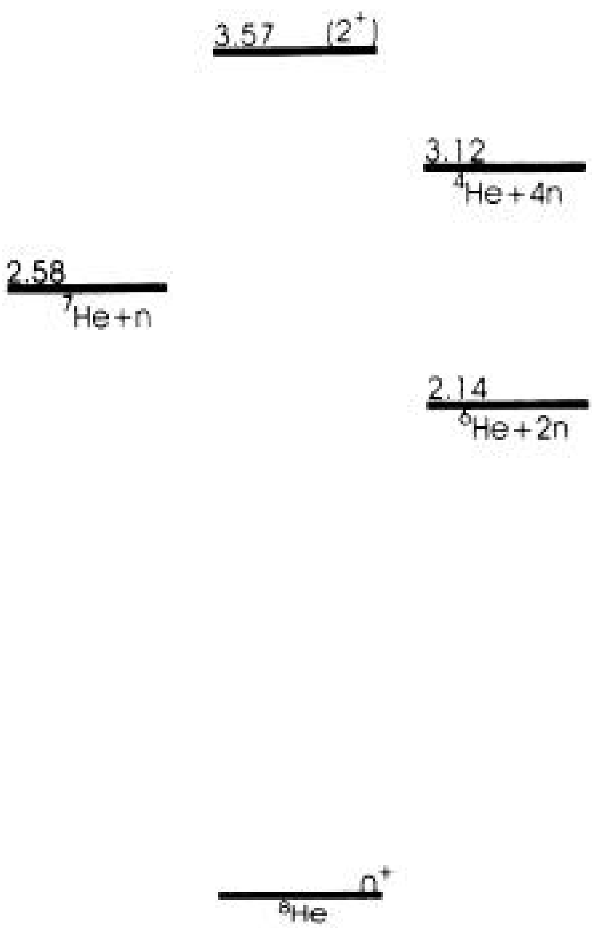

Fig. 1. Energy-level diagram of ^{8}He and decay channels.

In order to clarify the interpretation of the low-lying excitation of ^{8}He, we have studied the dissociation of ^{8}He at E/A = 24 MeV on targets of Al, Sn and Pb. From kinematically complete measurements on dissociation of Pb into ^{6}He+2n we have deduced the low-energy dipole strength function for the first time.

The NSCL standard secondary-beam system was used to bring a beam of ~ 300/sec ^{8}He to our targets. A schematic drawing of the experimental setup is shown in Fig. 2.

Relative energy distributions of the ^{6}He+n system, especially for the Al target, showed a peak around 0.4 MeV, which Fig. 1 shows to be the mass difference ^{7}He-(^{6}He+n), suggesting sequential decay *via* ^{7}He in the ^{8}He dissociation. A mixture of 60% sequential, consistent with [3], and 40% direct decay into ^{6}He+2n via the 2^{+} state of ^{8}He gives a good fit to the distribution function. Further evidence in favor of sequential decay was found in neutron momentum distributions. Transverse and longitudinal components of the neutron momentum distributions for the Al target are displayed in Fig. 3. The momentum distributions are in good agreement with a simulation that assumes 60% sequential.

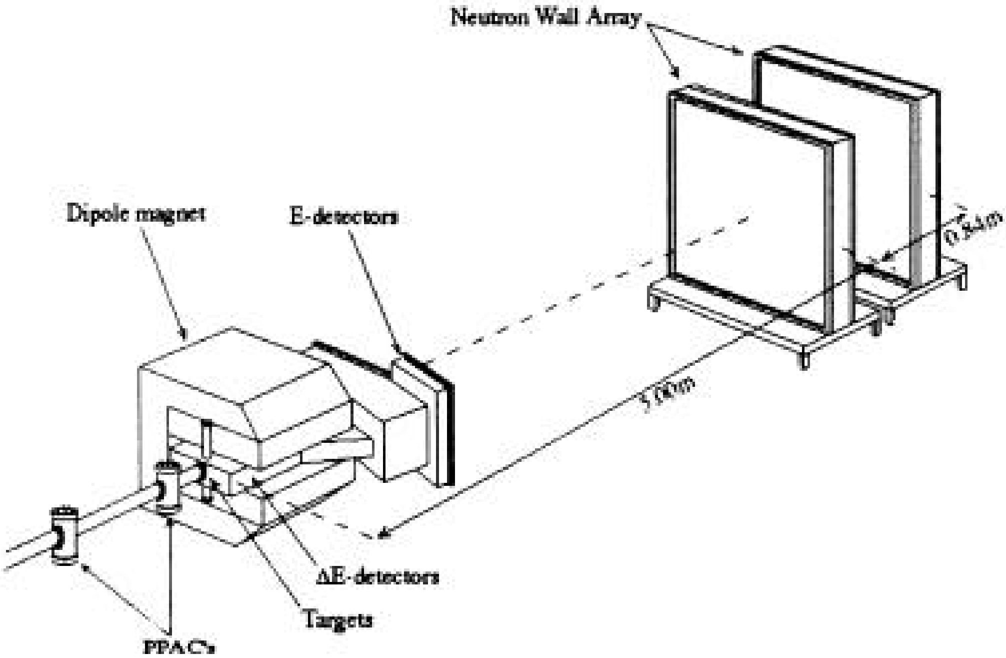

Fig. 2. Schematic of fragment (left) and neutron (right) detectors.

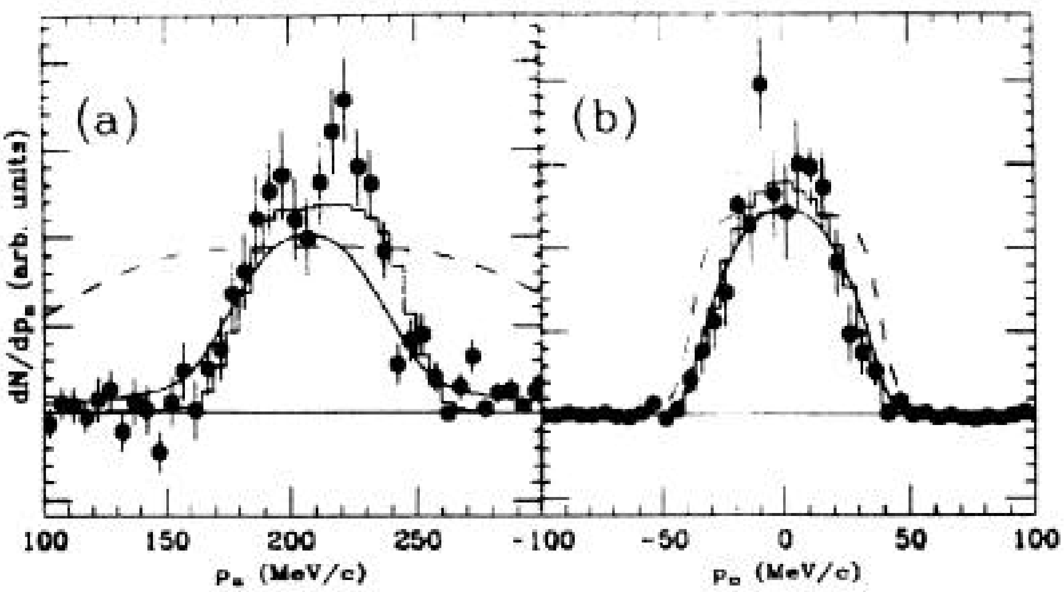

Fig. 3. Longitudinal (a) and transverse (b) components of momentum distributions of neutrons in coincidence with ^{6}He fragments with the Al target. Histogram on each side shows results of a Monte Carlo simulation assuming ^{8}He breakup 60% *via* ^{7}He+n intermediate state and 40% direct. Solid and dashed curves show results of COSMA model with and without correction for ^{7}He resonance, respectively.

A five-body cluster orbital shell model approximation (COSMA) that describes the ^{8}He ground state wave function as α+4n [4-6] fits the momentum distributions of several experiments when sequential decay is included [3-6]. Calculated distributions according to the COSMA wave function with and without considering the final state interaction (FSI) of the ^{7}He resonance are shown in Fig. 3 by the solid and dashed curves, respectively. Especially for the longitudinal distribution, the FSI is clearly required to reproduce the data. We conclude that sequential decay is the leading channel in the dissociation of ^{8}He by Al.

Data from the target with the highest Z, the Pb target, offer the best opportunity to study the Coulomb excitation of ^{8}He, and we focused on the kinematically complete ^{8}He→^{6}He+2n events. The measured decay energy distribution is shown in Fig. 4a. The nuclear contribution was assumed to come from inelastic scattering to the 2^{+} first-excited state. Its integrated magnitude was determined by the factorization method [7] to be 78 mb. To evaluate the E1 strength here, we assumed that ^{8}He is excited into the E1 continuum and then decays with 3-body phase space distributions into ^{6}He and two neutrons. We parameterized the E1 photonuclear cross section $\sigma_{E1}(E_x)$ with a Breit-Wigner function characterized by a resonant energy E_0 and an energy-dependent width σ_0.

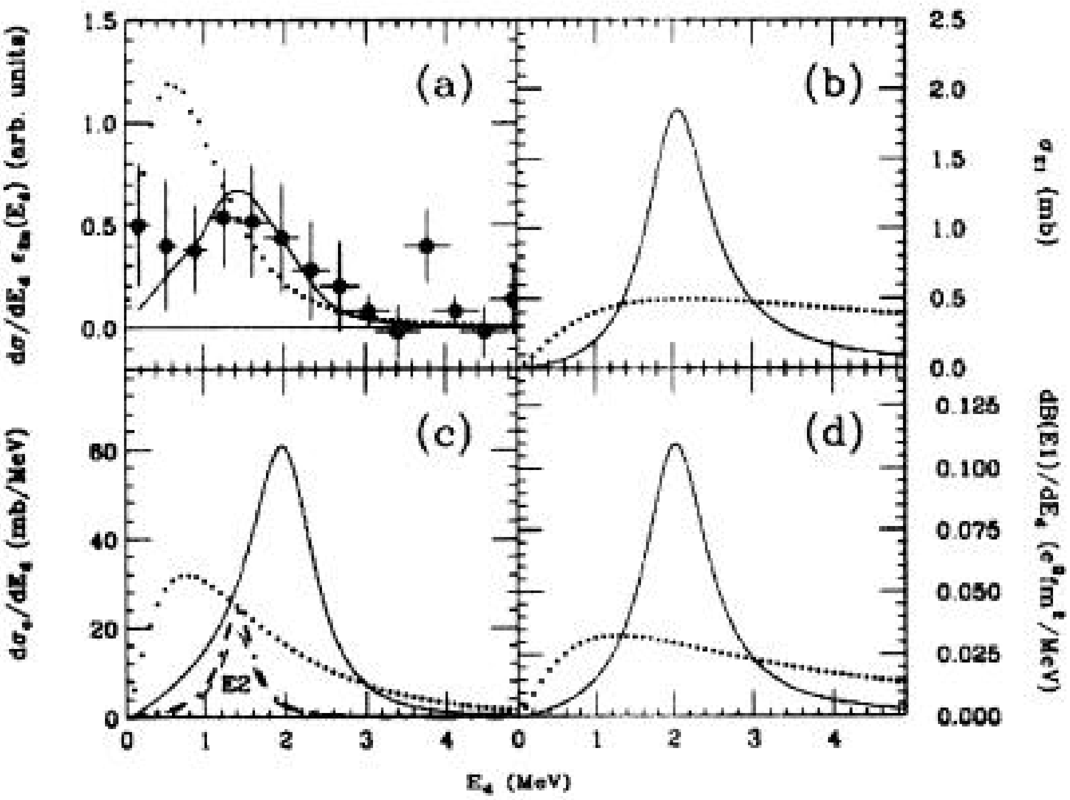

Fig. 4. Energy distribution functions with Pb target for ^{8}He→^{6}He+2n. (a) Points are data. $\varepsilon_{2n}(E_d)$ is acceptance times efficiency of detection system. Solid curve is fit to data with σ_{E1} function of (b), a nuclear contribution and detector response function. (b) Photonuclear cross section function used for fit in (a). (c) E1 Coulomb dissociation cross section derived from (b) and Eq. 1. Dashed (÷1,000) and dot-dashed (÷10) curves are estimates of negligible E2 cross section. (d) E1 strength function.

The Coulomb dissociation cross section $d\sigma_C/dE_x$ is related to the photonuclear cross section $\sigma_{E1}(E_x)$ by

$$d\sigma_C/dE_x = n_{E1}(E_x)\cdot\sigma_{E1}(E_x)/E_x \qquad (1)$$

where the function $n_{E1}(E_x)$ is the virtual photon density for an electric dipole. With this relation, the Coulomb dissociation cross section for the electric dipole contribution can be calculated once E_0 and Γ_0 are selected. Monte Carlo simulations with variation of these two parameters were performed. The fixed nuclear contribution and the detector response function were included. The fit is shown by the solid curve in Fig. 4a, and $\sigma_{E1}(E_x)$ *vs* E_d is in Fig. 4b. Having included the detector response in the fit, we use Eq. 1 to determine the function $d\sigma_C/dE_x$ *vs*. E_d, and that is given in Fig. 4c. Finally, the dipole strength function is calculated with the relation

$$dB(E1)/dE_x = (9\hbar c/16\pi^3)(1/ n_{E1}(E_x))(d\sigma_C/dE_x) \qquad (2)$$

and that function is shown in Fig. 4d. The integral gives a total E1 strength B(E1) = $0.091\pm0.026\ e^2fm^2$, considerably lower than 1.00 ± 0.11 obtained for ^{11}Li [8,9].

A good indication of a core+dineutron structure is afforded by comparison between the cluster, or molecular, model [10, 11] and experiment of the energy-weighted sum of $dB(E1)/dE_x$. The model predicts a sum equal to 2.7 e^2fm^2MeV for the structure $^9Li+n^2$ for ^{11}Li, and the data [8, 12] are consistent with this value. For our ^8He data, however, the experimental sum is only ~20% of the model value for a $^6He+n^2$ structure of ^8He. This comparison supports the idea [1] that ^8He does not have a ^6He core. Agreement of our measured neutron momentum distributions with the 5-particle COSMA model, is in support of the structure α-particle core+4n.

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