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QUASIELASTIC DEUTERON KNOCK OUT AND ITS DEPENDENCE ON NUCLEAR ATOMIC NUMBER

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Abstract

The backward quasielastic deuteron knock out has been studied with pion beam in full kinematics on ^{6}Li, ^{7}Li, ^{12}C and ^{16}O . The experiment was performed at the ITEP Proton Synchrotron with the 3-m magnet spectrometer at an incident pion momentum of 0.72 GeV/c. Momentum and angles of forward going deuteron as well as of the beam and backward scattered pions were measured. The excitation energy spectra , the momentum distributions of the internal motion of the quasideuteron clusters and quasideuteron effective numbers were obtained. A-dependence of quasideuteron effective numbers is practically independent of atomic number in contrast with $A^{0.33}$ dependence observed for inclusive deuteron knock out measured with proton beam. Possible reasons for such a difference are discussed.

Quasielastic deuteron knock out from nuclei is an effective way to study cluster structure, nucleon-nucleon correlations and reaction mechanisms of particle-nucleus interactions. To disentangle the effects of nuclear structure and reaction mechanism it is necessary to have measurements for different projectiles.There are data on quasielastic deuteron knock out taken with proton and electron beams. The aim of our experiment is to widen a variety of projectiles and to obtain the data with pion beam. In [1] pions were used for the first time for a study of quasielastic deuteron knock out from ^{6}Li with identification of ground state of the rest nucleus ^{4}He. In the following works [2–4] all spectrum of energy excitation of rest nuclei for ^{6}Li, ^{7}Li, ^{12}C, ^{16}O has been analysed and also the first data for triton knock out has been

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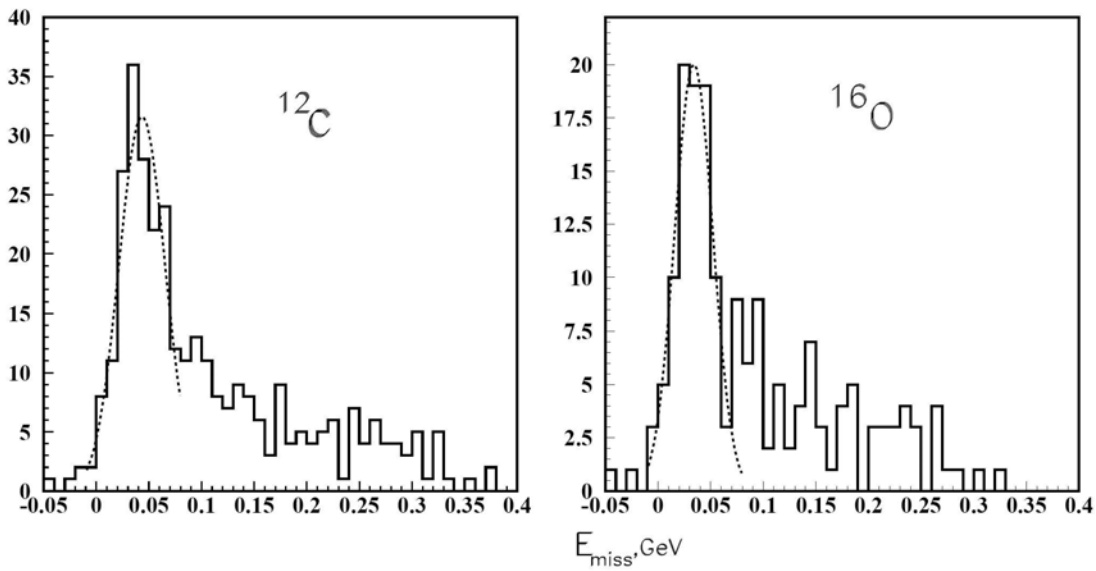

Figure 1: Missing energy distributions for ^{12}C and ^{16}O, fit by gaussian is shown by dotted lines.

obtained. Present work is mainly aimed at an analysis of A-dependence of effective deuteron number in nuclei seen in deuteron knock out.

The experiment has been performed on a negative pion beam of 10 GeV ITEP proton synchrotron at $p_0 = 0.72$ GeV/c. The 3-m magnet spectrometer with spark chambers placed in a magnetic field has been used (see [5] for details). Nuclear targets were placed near the center of a large dipole magnet of $3\times1\times0.5$ m^3 with maximal field 1.66 T. One half of the magnet was used as a forward going deuteron spectrometer. Another half was used as a beam and backward scattered pion spectrometer. An accuracy in an energy excitation of the rest nucleus was $\sim$ 10 MeV. Time-of-flight was used to identify deuterons from the reaction

$$\pi^- + A \to \mathrm{d} + \pi^- + X. \tag{1}$$

A momentum of a quasideuteron intranuclear motion and missing energy (an excitation energy of a rest nucleus) were calculated in plain wave impulse approximation.

Missing energy distributions for the reaction (1) are given for ^{12}C, ^{16}O in Fig.1 as an example. The peaks of quasielastic deuteron knock out are clearly seen. These peaks were fitted by simple gaussians. The mean (r.m.s) is 43±2(22±2)MeV for ^{12}C and 34±2(18±2)MeV for ^{16}O. The quasideuteron momentum distributions are given in [3, 4]. An effective number N_d of

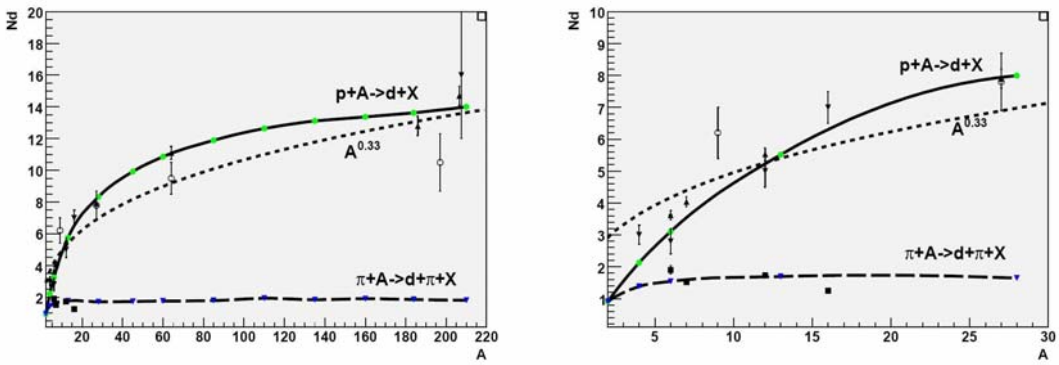

Figure 2: A-dependence of deuteron knock out. Measurements of this experiment - full squares, other data are for inclusive deuteron knock out by protons from compilation [7].

quasideuterons in nucleus participated in the reaction (1) was calculated by integration over the peak area and normalization to backward pion deuteron elastic scattering on free deuteron. These N_d values are shown in Fig.2 by full squares. There is only one measurement of N_d with proton beam in full kinematics on ^{6}Li made at Dubna [6]. It gives N_d=1.73±0.1. Our result N_d=1.90±0.1 for ^{6}Li is in good agreement with it. Our measurements of N_d are practically independent from atomic number A of a target nucleus. Such a dependence is different from observed in inclusive deuteron knock out measured with proton beam (see compilation of all existing measurements with proton beam in [7]) where A-dependence approximated by $A^{0.33}$ was observed. In contrast to measurement in full kinematics in the inclusive deuteron knock out momentum of backward scattered projectile is not measured. So absorption of the backward scattered projectile in the target nucleus result in smaller N_d value for measurements in full kinematics and possibly in different A-dependence. To try to understand if additional absorption could change an A-dependence so drastically we performed calculations in a simple classic model described below. Our calculation can be treated only as an estimation. In our approach N_d for spherical nucleus is given by

$$N_d = Ck \int_0^{+\infty} bdb \int_{-\infty}^{+\infty} \frac{\rho^2(b,x)}{\rho^2(0)} exp(-\int_{-\infty}^{x} (L_b^{-1} + L_s^{-1})dx) exp(-\int_{x}^{+\infty} L_d^{-1} dx) dx$$

where b - impact parameter, x - coordinate along projectile motion, b and x are equal to zero in the center of a nucleus. It is supposed that projectile, scattered particle and knock out deuteron trajectories are straight lines

parallel to x-direction. It is reasonable for geometry of backward scattering. $\rho(r = \sqrt{b^2 + x^2})$ is Fermi distribution of nuclear density with standard parameters $R_A = r_0 A^{0.33}$, $r_0 = 1.1Fm$, $t = 0.5Fm$ normalized to atomic number A, $\int_0^{+\infty} \rho(r)\mathbf{dr} = A$. L_{i0} is absorption length where i=b,s,d for beam, scattered projectile and knock out deuteron respectively. $L_i^{-1} = L_i^{-1}(b,x) = L_{i0}^{-1}(1-2/A)\rho(b,x)/\rho(0)$. Multiplier $(1-2/A)$ effectively corrects the absorption length in such a way that L_i^{-1}=0 for deuteron target. $k = 1 + (A-1)/A$ is of minor importance. It helps to give $N_d = 1$ for free deuteron and it is essential for $A < 5$ only. For inclusive deuteron knock out (where $L_s^{-1} = 0$) we adjusted L_{b0} and L_{d0} to have reasonable description of available experimental data. The result is shown in Fig.2 by full line where L_{b0}= 0.6 Fm and L_{d0} =0.2 Fm. Qualitatively it gives much better description of the data on inclusive deuteron knock out by protons than $A^{0.33}$-dependence drawn dy dotted line. For the measurements of N_d in full kinematics we have to introduce non zero L_s^{-1}. An increase of L_s^{-1} results in smaller values of N_d and changes A-dependence from rising to falling one. To have a reasonable description of our measurements (dashed line in Fig.2) we have to take L_{s0}= 0.1 Fm. At a first glance it seems unrealistically small compared to absorption length for projectile. But two arguments make it more realistic. At first the backward scatted pion has a momentum near Δ-resonance that decrease absorption length. And secondly a small angle elastic scattering of all participants on target nucleons are less important for inclusive deuteron knock out than for measurement in full kinematics. This also effectively increases absorption length. Performed estimation shows that larger absorption effects for full kinematics measurements can result in flat A-dependence of deuteron knock out.

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