PROTON SCATTERING FROM THE UNSTABLE ^{8}B NUCLEUS

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The ^{8}B nucleus, which has a proton separation energy of only 137 KeV and its last proton in a *p* state, represents a good proton halo candidate. The experimental evidence for the existence of a proton halo is up to now somewhat contradictory. The measurement of a large quadrupole moment [1] and a large reaction cross section [2] suggested the existence of a proton halo. Studies of the ^{8}B structure through the measurement of the ^{7}Be momentum distributions following the breakup of the ^{8}B on light and heavy target to estimate the extent of the proton spatial distribution were undertaken but the results reported from GSI [4] and from MSU [5] were not conclusive concerning the existence of a proton halo. Quasielastic scattering of ^{8}B on ^{12}C was measured at GANIL [6] at an energy of 320 MeV. The results interpreted in terms of a double folding model and coupled-channels calculations did not support the existence of a substantial proton halo in ^{8}B.

In order to obtain information on the ground state density distribution of ^{8}B as well as to extract the values of the reduced transition probabilities B(E2) towards the 1^{+} and 3^{+} excited states of ^{8}B located respectively at 0.774 and 2.32 MeV, an experiment to study the proton scattering on ^{8}B in inverse kinematics was performed at the NSCL/MSU facility. The secondary 35 MeV/A ^{8}B beam was produced through fragmentation of a primary ^{12}C beam impinging on a ^{9}Be production target. The fragments were analyzed using the A1200 spectrometer whose momentum acceptance was limited to 1% and the velocity filter of the RPMS beam line. Such a setting yielded an average ^{8}B beam intensity of 12000 pps and a beam purity of 65% with ^{7}Be and ^{9}C as main contaminants.

The experimental setup consisted of an array of 4 Si strip telescopes allowing the detection of the energy and angle of recoiling protons, a ΔE-E plastic scintillator placed around zero degree to identify the ^{8}B beam and two PPACs used as tracking detectors. The beam particles were identified event by event in the zero degree plastic scintillator using the combined information of deposited energy and the time of flight measured between an upstream scintillator (BLT) placed at the exit of the A1200 spectrometer and the zero degree detector. This procedure allowed us to identify the ^{8}B beam event by event. Due to the large emittance of the secondary beam two tracking detectors placed upstream at 77cm and 176cm from the target were used to determine event by event the beam trajectory and the calculate the impact point and the incident angle on the target. The ^{8}B projectiles impinged on a thin CH_2 target of 1.63 mg/cm^2 thickness to limit angular straggling of the recoiling protons which were detected in the array of telescopes. Each element of the array, with 5 x 5 cm^2 active area, consisted of a 300 micron thick Si-strip detector with 16 horizontal strips 3.2 mm wide. The vertical position was deduced from the strip number and the horizontal position from charge division, the signal being read out from each end of each strip. The resolution of the horizontal position measurement was 1mm. Each strip detector was backed by two Si-pin diodes, each of 500 μm thickness and a CsI scintillator of 1cm thickness read out through 4 photodiodes . They were placed on both sides of the beam at a distance of 23cm from the CH_2 target and covered an angular range from 59° to 77° in the lab frame. Proton identification was achieved by ΔE-E measurement; this induced a low energy threshold of 6 MeV in the identification due to the protons stopped in the strip detector.

The proton events in the Si-strip telescopes were selected requiring the coincidence with the ^{8}B projectile detected in the zero degree detector. This also encompasses inelastic events where the excited ^{8}B nucleus breaks up into ^{7}Be + p, as such events could not be distinguished from ^{8}B in the zero degree detector. The selected events exhibit clear kinematic lines when plotted in an energy vs. scattering angle correlation matrix. Due to the two body kinematics the recoil proton data give access to the excitation energy spectrum of the ^8B where the excited states 1^+ and 3^+ appear to be populated.

Elastic as well as inelastic scattering events were separated fitting the excitation energy spectrum with three gaussians centered around zero for elastic component and at the known excitation energies of 0.774 and 2.32 MeV as shown in fig.1. A value of the excitation energy resolution of 730 KeV was extracted fitting the elastic component in the excitation energy spectrum and was assumed to be the same for the excited states. The 2.32 MeV energy level has an intrinsic width of 350 KeV and therefore this contribution to the total width of the peak was added. The total excitation energy spectrum was nicely reproduced using the fitting procedure. This allowed us to select the different contributions and to extract elastic as well as inelastic angular distributions for the 1^+ and 3^+ states. In fig.2 are presented the elastic (circles) and inelastic (squares) angular distribution for the 1^+ excited state. The data were first analyzed with a coupled-channel calculation using a phenomenological optical potential. The CH89 parametrization developed by Varner et al. [7] was used to calculate the optical model parameters. A very good agreement was obtained for elastic angular distribution indicating that the parametrization proposed for stable nuclei in a mass range A = 40-209 and for energies between E = 10 and 65 MeV works well also on light exotic nuclei. The analysis of the inelastic cross-section data towards the 1^+ level allowed us to extract a preliminary value for the deformation parameter which was then used to calculate the reduced transition probability B(E2). A B(E2) value of the order of 70 ± 15 e^2fm^4 was obtained.

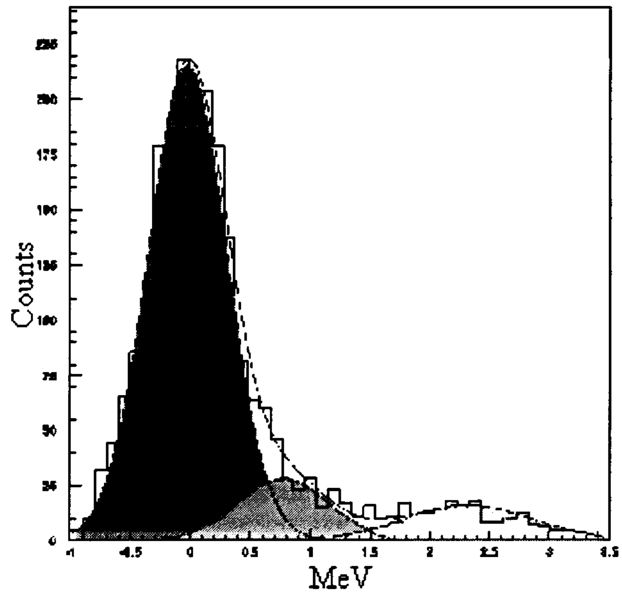

Fig.1. ^8B excitation energy spectrum. Contributions due to elastic and inelastic components centered respectively at 0, 0.774 and 2.32 MeV are shown in different shades of gray.

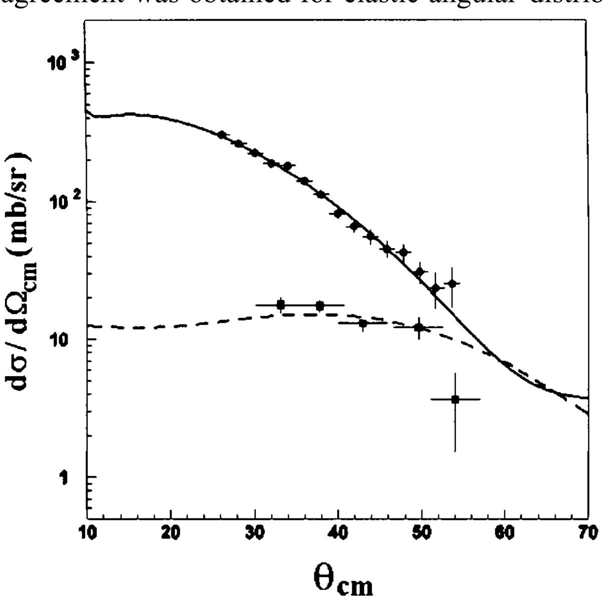

Fig. 2. Elastic (circles) and inelastic (squares) to the 1^+ state data obtained in the present work. Full line indicate the JLM calculation for elastic component while dashed line the calculation for inelastic. Tassie transition densities were adopted to calculate the inelastic cross section.

A microscopic approach to the scattering process attempting to understand the scattering in terms of the motion of the individual nucleons and their mutual interaction was also pursued. A folded microscopic optical potential was derived folding an effective nucleon-nucleon interaction with the proton and neutron ^8B densities. The proton and neutron densities were simulated assuming, following a commonly used description, that the ^8B is formed by a core of ^7Be and a proton in $1p_{3/2}$ state. The ^7Be proton and neutron densities were simulated by two gaussian distributions having square mean radii values of 2.34 fm for protons and 2.11 fm for neutrons [6].

The density of the proton in the $1p_{3/2}$ state was added to the ^{7}Be proton density yielding an extended spatial proton distribution with a root mean square radius of 2.79 fm. The densities were folded with the JLM interaction [8] and the calculated elastic angular distribution using the standard values of normalization parameters of the optical model potential ($\lambda_r = 1.0$, $\lambda_w = 0.8$) is shown in the figure as a full line. A remarkable agreement is observed in both shape and magnitude.

Inelastic angular distribution were also analyzed using a folded optical potential calculated using the JLM interaction and Tassie transition densities deduced from ground state densities. Proton transition densities were normalized using a $B(E2, 2^+ \rightarrow 1^+) = 70\ e^2fm^4$ while neutron transition densities were normalized assuming $M_n/M_p = N/Z = 0.6$. The result of the calculation is shown in the figure as dashed line; a fair agreement with the data is observed confirming the result of the phenomenological analysis.

The extracted B(E2) value was compared to the predictions of the cluster model where the ^{8}B is described assuming a coupling between a proton and a core of ^{7}Be with an internal structure composed by a ^{4}He and a ^{3}He [9]. The value of $B(E2) = 9\ e^2fm^4$ for the transition $2^+ \rightarrow 1^+$ obtained by cluster model is low compared to the experimental value. The same marked difference is observed when comparing the B(E2) prediction of cluster model for the ^{8}Li $B(E2, 2^+ \rightarrow 1^+) = 2.6\ e^2fm^4$ which is the mirror nucleus of ^{8}B with the experimental findings $B(E2)_{8Li} = 55 \pm 15\ e^2fm^4$ [10]. Further constraints to the prediction of the models will be given by the results obtained from the analysis of the inelastic scattering data towards the 3^+ excited state which is still in progress.

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