Structure of ^{10}N via ^{9}C+p resonance scattering

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The new capabilities of rare isotope beams allowed the discovery of unusually large matter radii in some exotic nuclei by Tanihata, et al. [1]. The most famous example is ^{11}Li which has a nuclear matter root mean square radius as large as that of ^{208}Pb. This is due to the two- neutron halo of ^{11}Li where the wave function of two valence neutrons extends far beyond the ^{9}Li core. Important role in explaining the halo structure of ^{11}Li was played by three-particle models that describe ^{11}Li as a ^{9}Li-n-n system. These models rely on accurate knowledge of neutron-^{9}Li interaction, that can be established from the known states in ^{10}Li. However, in spite of much effort (see [2-9] and references therein), uncertainty in spin-parity assignments and excitation energies of some low-lying states in ^{10}Li still remains. Even less is known about the mirror nucleus ^{10}N. Only one experiment that claimed observation of the ground state of ^{10}N has been done. A broad resonance at 2.6(4) MeV with a width of 2.3(16) MeV was reported in ^{10}B(^{14}N,^{14}B)^{10}N reaction with rather low statistical significance [10]. The goal of this work is to provide a spin-parity assignment for the ground state and search for the excited states in this exotic, unbound nitrogen isotope - ^{10}N.

States in ^{10}N, including the ground state, were populated in resonance elastic scattering of ^{9}C on protons. The rare isotope beam of ^{9}C was produced by recoil spectrometer MARS using ^{10}B(p,2n) reaction. The TexAT-P1 time projection chamber (TPC) was placed at the end of the MARS beam line. The protons from ^{9}C+p elastic scattering events were identified using energy losses and energies in the TPC and array of Si detectors, assisted by tracking in TPC. A more detailed description of the experimental setup and the analysis procedures can be found in [11,12,13].

The excitation function for ^{9}C+p resonance scattering is shown in Fig. 1 [13]. The scattering angle is a function of excitation energy, the smallest angle (139^{o}) corresponds to the lowest energies. The excitation function has a sharp low energy rise vs. the Rutherford scattering shown as the red dash-dotted line in Fig. 1. This is characteristic for L=0 resonance(s). R-matrix analysis leads to the following conclusions. In order to reproduced the excitation function, it is necessary to add a 2^- L=0 ground state (g.s.) at 2.2 MeV and a 1^- L=0 state at 2.8 MeV. The corresponding fit is shown as the blue dashed line in Fig 1. It is also possible to fit the excitation function with a 1^- L=0 ground state at 1.9 MeV and a 2^- L=0 first excited state at 2.8 MeV (the green solid line in Fig. 1). The two fits are statistically identical. There is no conclusive evidence for any L=1 state(s) in the measured excitation function. However, an L=1 state placed at 3.3 MeV does not contradict the experimental data (the black dash-dotted line in Fig. 1). This location for the first L=1 state in ^{10}N was chosen since the most recent measurement on ^{10}Li observed a p-wave state at 0.45(3) MeV above the neutron threshold and a width of 680(30) keV [9]. This corresponds to 3.3 MeV above the proton threshold in ^{10}N.

The main result of this work is the first conclusive observation of ^{10}N – discovery of a new, most proton rich isotope of Nitrogen. The energy of the 2s shell in ^{10}N was measured to be 2.3 ± 0.2 MeV above the proton threshold in ^{10}N. We used simple potential model to calculate Thomas-Ehrman shift between ^{10}N-^{10}Li mirror pair and determined that the ^{10}Li ground state has to be the 2s shell state

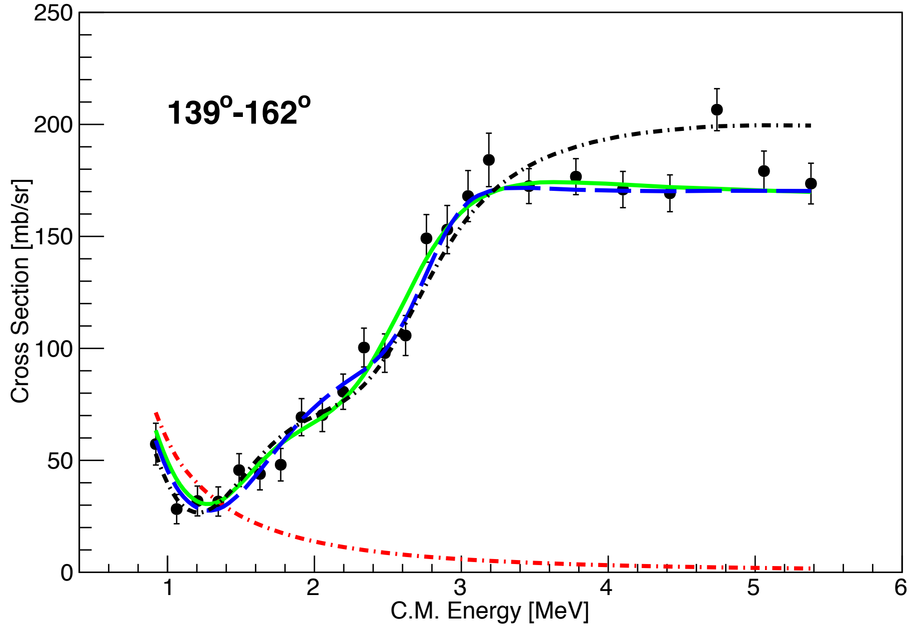

FIG. 1. Spectrum of protons from the ^{9}C+p resonance scatting. The red dash-dotted line is the Rutherford scattering cross-section, the blue dashed line is the best fit with the 2^- as the g.s. and a 1^- state as the 1^{st} excited state. The green solid line is the best fit with a 1^- g.s. and 2^- 1^{st} excited state. The black dash-dotted curve is the fit with a 2^- g.s., a 1^- 1^{st} excited state and a 1^+ state at 3.3. MeV.

somewhere between 0 and 100 keV. This is consistent with breakup measurements [14]. Definitive spin-parity assignment (2^- or 1^-) for the ^{10}N ground state cannot be made solely on the basis of this experimental data. We also see no evidence for any L=1 state(s) in ^{10}N but cannot rule out existence of broad L=1 states at 3.3 MeV and above with respect to the proton decay threshold. We have also shown that the ^{10}Li ground state must be an L=0 state. These results are published in [13]

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