T=3/2 isobaric analog states in ^{9}Be

C. Hunt, G.V. Rogachev, S. Almaraz-Calderon,[1] A. Aprahamian,[1] B. Bucher,[1] W. Tan,[1]
E.D. Johnson,[2] J. P. Mitchell,[2] M. Avila,[2] A. Kuchera,[2] and L.T. Baby[2]
[1]*Nuclear Science Laboratory, University of Notre Dame, Notre Dame, Indiana*
[2]*Department of Physics, Florida State University, Tallahassee, Florida*

The Thick Target and Inverse Kinematics (TTIK) approach [1] has been applied extensively to study the structure of exotic, proton rich nuclei [2,3]. The key advantages of TTIK, such as high efficiency, excellent energy resolution and well developed theoretical tools for analysis (R-matrix formalism) make it very attractive for such studies. It also inspires the application of this approach for neutron rich nuclei. Of course, direct implementation of TTIK for the neutron rich case would require neutron resonance scattering with radioactive beams though this is not possible at present. Instead, it has been suggested [4] to study neutron rich nuclei using TTIK through the corresponding isobaric analog states (IAS) populated in proton resonance scattering. The idea is 20 years old, but only few experiments have been performed. Specifically, structure of ^{9}He [5,6] and ^{13}B [7] have been studied through the corresponding IAS in ^{9}Li and ^{13}C populated in ^{8}He+p and ^{12}B+p resonance scattering. The progress is likely limited by complexities in R-matrix analysis, associated with the high density of T_{low} states. The main goal of this experiment is to benchmark the application of the TTIK technique for studies of neutron rich nuclei. The A=9 T=3/2 isobaric multiplet provides an ideal opportunity. Experimental data on proton resonances in ^{9}C and on structure of low lying states in ^{9}Li are available [8,9]. Therefore, direct comparison between ^{9}C, ^{9}Li and new data on T=3/2 states in ^{9}Be, populated using ^{8}Li+p resonance scattering is possible. The main goal of this experiment was to measure the excitation function for ^{8}Li+p resonance elastic scattering and compare the results to the available data for ^{9}C and ^{9}Li to benchmark the IAS TTIK method. Another goal was to locate the positive parity states (none are known in A=9 T=3/2 isobaric multiplet) to shed light on energy of the sd-shell in these nuclei.

The experiment was carried out at Florida State University using the RESOLUT radioactive beam facility. The ^{8}Li beam was produced using the ^{7}Li(d,p) reaction in a 4-cm long deuterium gas cell. The secondary beam ^{8}Li was momentum selected, bunched and separated from other contaminants by RESOLUT. The typical composition of the beam at the secondary polyethylene (C_2H_4) target was 95% of ^{8}Li and 5% of ^{7}Li. Three different target thicknesses were used, 5.5, 4.1, 2.8 mg/cm^2 with three ^{8}Li beam energies 25.0, 22.0 and 18.0 MeV.

The experimental setup is shown in Fig. 1. Three annular position sensitive detectors (S2, MicronSemiconductors) were used to detect the light and heavy recoils (eg., protons and ^{8}Li for elastic scattering) in coincidence. The kinematically complete measurement allowed for the unambiguous identification of the reaction and also made it possible to use the relatively thick target to simultaneously measure a significant energy region of the excitation function while still having excellent energy resolution (30 keV in c.m.).

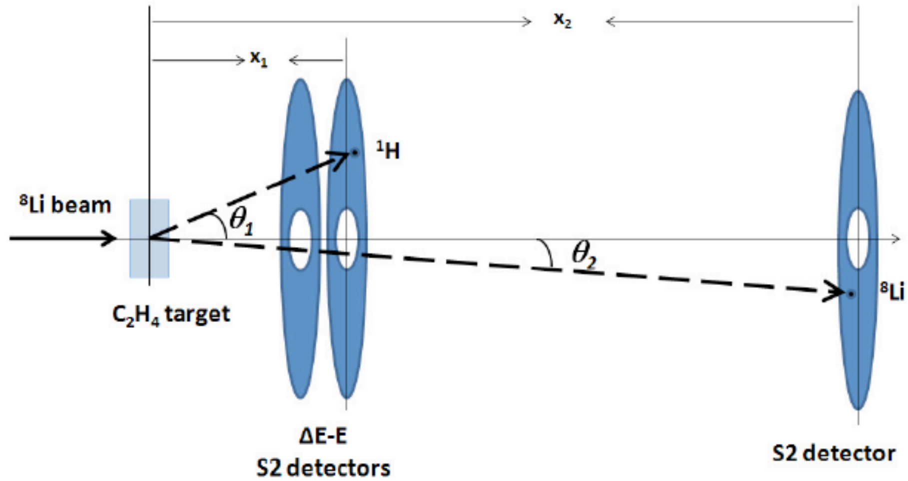

FIG. 1. The experimental set-up that include the thick target, dE detector and the light and heavy recoil detectors. Protons and ^8Li are measured in coincidence.

The excitation functions for ^8Li+p elastic scattering at different angles were reconstructed from measurements at the three beam energies. The 171^o excitation function is shown in Fig. 2. An interesting feature of the measured excitation function is that it can be described very well by a single well known 5/2- T=3/2 state at 18.6 MeV in ^9Be (solid curve). The total width, and excitation energy for this state are taken from [10] and the ratio of the partial neutron to proton widths are determined using isospin Clebsch-Gordon coefficients and the corresponding penetrability factors. The best fit in Fig. 2 is achieved by varying the parameters of the optical model that is incorporated into the R-matrix formalism in the same way as suggested in [11] and is used to describe the statistical contribution of the T=1/2 states. The 5/2-

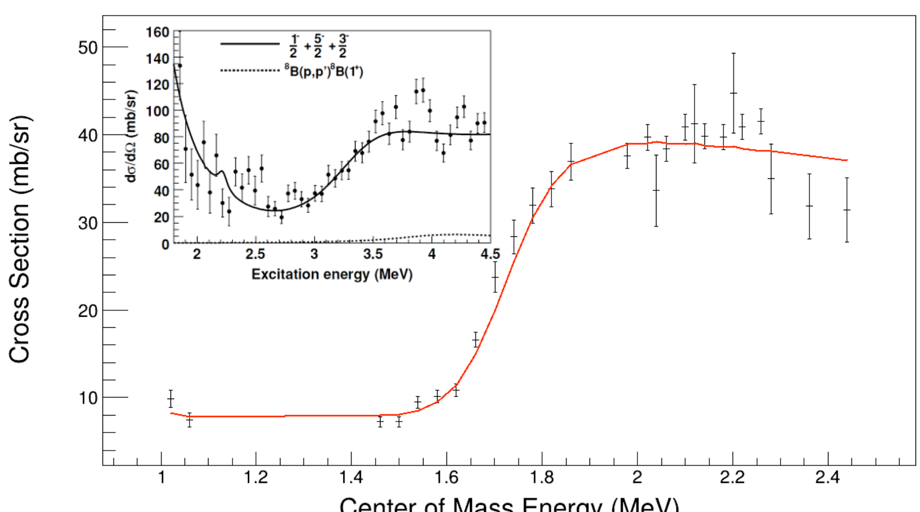

FIG. 2. The excitation function for $^8Li(p,p)$. Solid curve is an R-matrix fit with the known T=3/2 18.65 MeV, 5/2- excited state. Inset is the excitation function of $^8B(p,p)$ from [2].

state is also known to dominate the ^{8}B+p excitation function for resonance elastic scattering [8] which also has almost identical shape to the ^{8}Li+p excitation function (see inset in Fig. 2). This almost one-to-one correspondence provides a strong support for the IAS TTIK approach. It has to be noted, however, that the fit has strong dependence on the parameters of the optical potential and finding reliable and reproducible ways of constraining that potential is of paramount importance for future applications of this experimental technique.

[1] K.P. Artemov *et al.*, Sov. J. Nucl. Phys. **52**, 634 (1990).
[2] L. Axelson *et al.*, Phys. Rev. C **54**, R1511 (1996).
[3] J. Hooker *et al.*, Phys. Lett. B **769**, 62 (2017).
[4] V.Z. Goldberg, AIP Conference Proceedings **455**, 319 (1998).
[5] G.V. Rogachev *et al.*, Phys. Rev. C **67**, 041603 (2003).
[6] E. Uberseder *et al.*, Phys. Lett. B **754**, 323 (2016).
[7] B.B. Skorodumov *et al.*, Phys. Rev. C **78**, 044603 (2008).
[8] G.V. Rogachev *et al.*, Phys. Rev. C **75**, 014603 (2007).
[9] A.H. Wuosmaa *et al.*, Phys. Rev. Lett. **94**, 082502 (2005).
[10] D.R. Tilley *et. al.*, Nucl. Phys. **A745**, 155 (2004).
[11] D. Robson, Phys. Rev. **137**, 535 (1965).