# SPECTROSCOPY OF THE $^{10}$Li NUCLEUS

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The nucleus $^{10}$Li has been the subject of much experimental study, primarily due to its importance for the study of $^{11}$Li. It has been speculated that the best model for $^{11}$Li is a three-body system, and attempts to understand $^{11}$Li rely on the nature of the interaction between the two-body subsystems, n-n and n-$^{9}$Li. The n-n interaction is well known, but the n-$^{9}$Li interaction is not well understood. Information about the n-$^{9}$Li interaction is best obtained through experimental study of the unbound nucleus $^{10}$Li. The existing experimental situation is unclear; there is no consensus on $^{10}$Li structure based on experimental work [1,2,3,4,5,6,7] (a summary can be found in Ref. [7]) and the difficulty of studying this nucleus is well documented.

The S800 spectrograph was used to make a spectroscopic measurement of the $^{9}$Be($^{9}$Be,$^{8}$B)$^{10}$Li reaction in order to study states in $^{10}$Li. A beam of 40.1(1) MeV/u $^{9}$Be was used to bombard thin beryllium and carbon targets. The reaction products were transported to the focal plane of the spectrograph, where the two transverse positions, angles, and total energies of the ions were measured. Ray-tracing techniques were used to reconstruct the energy and scattering angle of the ejectile from the target from measured positions and angles in the focal plane [8]. The $^{12}$C($^{9}$Be,$^{8}$B)$^{13}$B and $^{12}$C($^{9}$Be,$^{11}$C)$^{10}$Be reactions were used for energy calibration; these reactions populated several known states in $^{13}$B and two states in $^{10}$Be. Elastic and inelastic scattering of the incident $^{9}$Be beam off the targets provided calibration of the spectrograph bending radius and scattering angle.

Figure 1 (left) shows the reconstructed and kinematically-shifted energy spectra of the $^{8}$B and $^{11}$C particles following the $^{12}$C($^{9}$Be,$^{8}$B)$^{13}$B, $^{9}$Be($^{9}$Be,$^{8}$B)$^{10}$Li, $^{12}$C($^{9}$Be,$^{11}$C)$^{10}$Be, and $^{9}$Be($^{9}$Be,$^{11}$C)$^{7}$He reactions at 40.1(1) MeV/u. The peaks in the $^{11}$C energy spectra come from populating states in both the residual nuclei ($^{10}$Be and $^{7}$He) and the ejectile. Several states in $^{13}$B and the ground and first excited states in $^{10}$Be were used for energy calibration.

The $^{10}$Li energy spectrum was fit using a convolution of the estimated line-shape [4] with the experimental resolution. Figure 1 (right) shows the calibrated energy spectra and the corresponding fits. The fit parameters are summarized in Table 1. No other states in $^{10}$Li were identified in this experiment, either because they weren't populated, or the experimental resolution was insufficient. The 500 keV peak is probably the peak seen by Young *et al.* [4] and Bohlen *et al.* [5]. Statistical errors on the parameters dominate the uncertainties.

Table 1: Different fits to the energy spectrum of $^{10}$Li from the $^{9}$Be($^{9}$Be,$^{8}$B)$^{10}$Li reaction in the present work. The single p-wave fit provided the best fit to the data. See text for details.

| States included in the fit | peak location [keV] | Width [keV] |
|---|---|---|
| one p-wave | 500(60) | 400(60) |
| two p-waves | 100(60), 525(60) | 50(50), 345(60) |
| one s-wave, one p-wave | $\leq$50, 500(60) | $\leq$100, 400(60) |

The energy spectrum is almost identical to that of Young *et al.* [4], except with ≈50% more statistics. There is no evidence for a state at ∼250 keV in the present data. The excess of counts at threshold cannot be attributed to a state given the current experimental resolution and statistics, but the presence of a small enhancement is suggestive of one, as in the Young *et al.* [4] experiment.

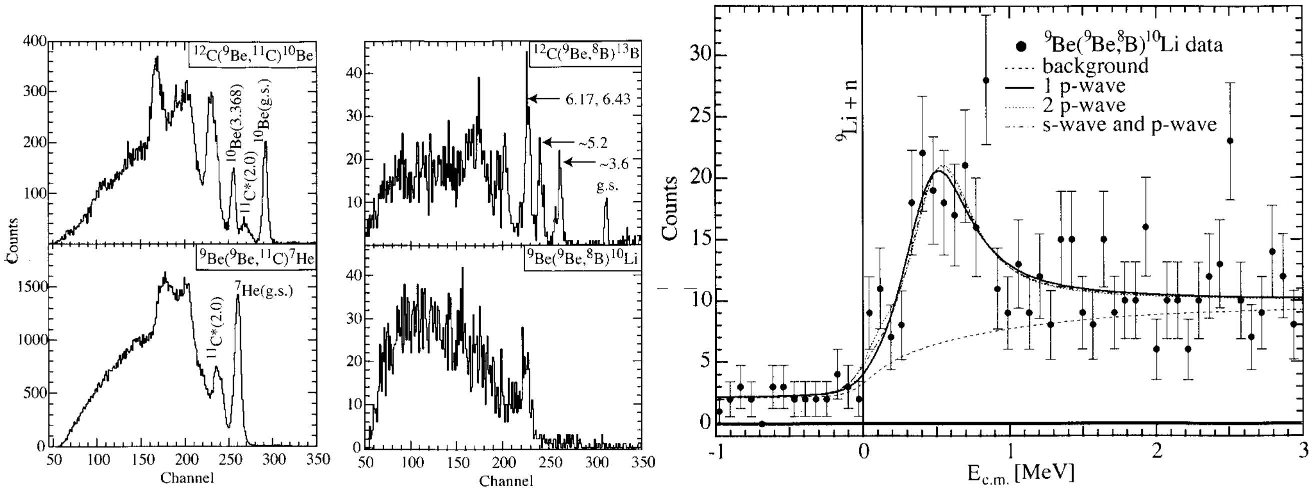


Figure 1: Left: $^{11}$C (left) and $^{8}$B (right) energy spectra for all reactions used in this experiment, at $\Theta_{lab}$=3.5-8.3 degrees, kinematically shifted to 0 degrees, and 40.1(1) MeV/u. The states in $^{13}$B labeled as $\sim$3.6 and $\sim$5.2 MeV correspond to groups of states that were populated at those energies. The $^{11}$C states marked with an asterisk are broadened by in-flight gamma decay. Right: The $^{10}$Li energy spectrum and associated fits. The solid line is the best fit to the data using a single p-wave resonance shape at -$S_n$=500(60) keV with a width of 400(60) keV, including contributions from a constant plus a three-body background. The dashed and dot-dashed lines represent fits with two p-waves and one s-wave and one p-wave, respectively. Both produce fits which are statistically less significant than the single p-wave resonance.


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