

Experimental study of ${}^9\text{He}$ through the isobaric analog states in ${}^9\text{Li}$

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The unbound neutron-rich ${}^9\text{He}$ isotope has been studied extensively over the past two decades, and many unusual experimental claims have been put forth that stand in contradiction to our understanding of nuclear structure in this mass region. Specifically, several works in the literature have argued for the existence of two narrow low lying states in ${}^9\text{He}$: a $l=0$ virtual state just above the neutron separation energy with a strongly negative scattering length and an $l=1$ state at approximately 1.3 MeV above the neutron separation energy with a width on the order of 100 keV [1-7]. Such narrow widths for these states have not been successfully reconciled with nuclear theory, and in each case the argument for their existence is not supported by a strong statistical significance above background due to the small cross sections involved in the individual techniques.

We have performed a search for low-lying states in ${}^9\text{He}$ by looking for evidence of their $T=5/2$ isobaric analogs in ${}^9\text{Li}$ populated through the elastic scattering of protons from ${}^8\text{He}$. The experiment was performed at the ISAC facility at TRIUMF using a reaccelerated ${}^8\text{He}$ beam produced through the ISOL technique, and excitation functions were measured using the thick target inverse kinematics (TTIK) method [8]. The beam impinged on a scattering chamber filled with 990 Torr of methane gas, and protons from elastic scattering were detected in three quad-segmented forward Si detectors. For particle identification and scattering angle determination, two layers of position-sensitive proportional counter cells were placed just before the Si detectors. Absolute normalization of the data and beam-contaminant identification was provided by an ionization chamber located just after the entrance to the scattering chamber. The excellent quality of the ${}^8\text{He}$ beam produced at TRIUMF allowed for good energy resolution across the excitation energy region of interest.

To verify the experimental setup, technique, and analysis, proton elastic scattering was also measured from incident ${}^{12}\text{C}$ ions in a separate experiment performed at the Cyclotron Institute as well as at TRIUMF just before the main ${}^8\text{He}$ run. Due to varying experimental conditions, these runs provided data over differing energy regions. The combined results can be seen in Fig. 1, and the excellent resolution is clearly visible over the state at 1.6 MeV. Also shown is an R-matrix calculation produced after fitting resonance parameters to the data of Meyer et al. [9].

The ${}^8\text{He}(p,p){}^8\text{He}$ experiment yielded a relatively featureless spectra with an isotropic distribution (see Fig. 2). The only notable feature in the spectra is a low energy rise, detectable at the most forward angles in the lab frame and attributed to the closing of the neutron decay channel to $T=2$ states in ${}^8\text{Li}$. This decay channel is most preferred by $T=5/2$ resonances, and taken

together with the isotropic distribution is strong evidence for a broad $T=5/2$ $l=0$ contribution to the cross section. The solid red curve in Fig. 2 shows the best R-matrix description of the cross section, and includes only a broad $T=5/2$

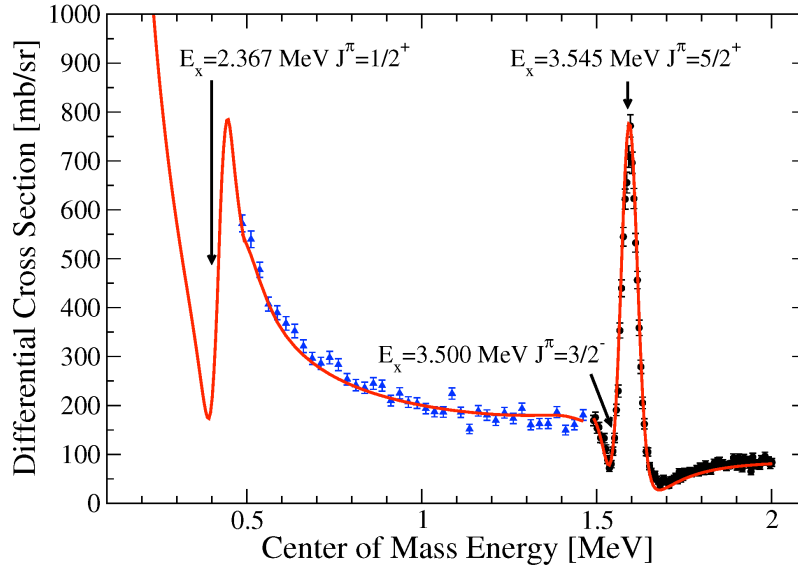
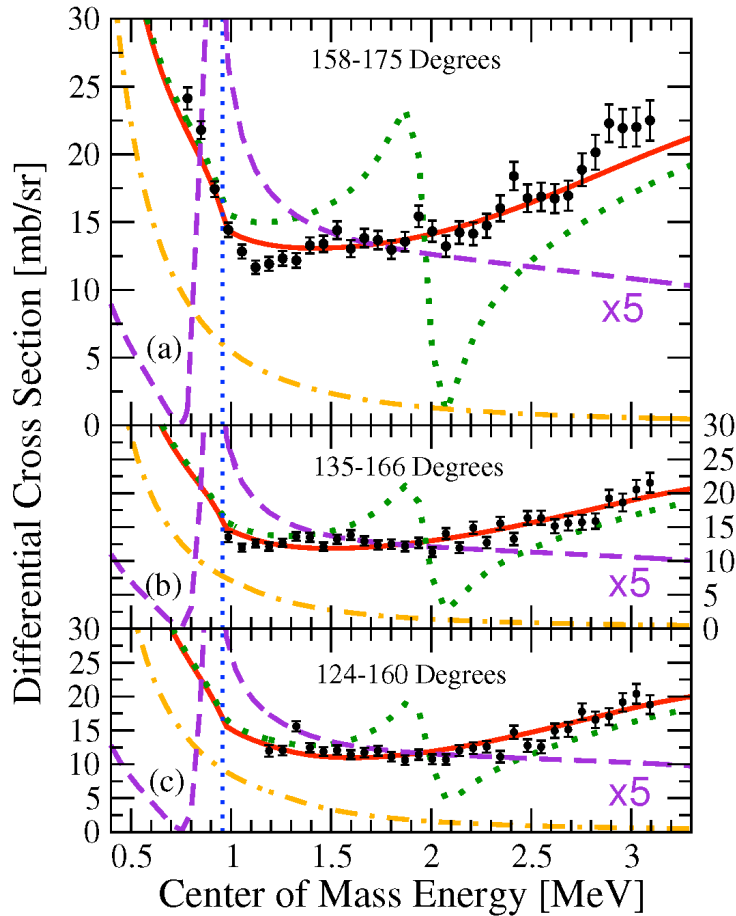


FIG. 1. Present measurement of the $^{12}\text{C}(p,p)^{12}\text{C}$ reaction. The blue points were taken at the Cyclotron Insitute while the black points were measured at TRIUMF. The red line is a calculation based on a fit to Meyer.

s-wave resonance at approximately 3 MeV combined with a $T=3/2$ s-wave background



contribution arising from a potential model calculation. Most striking in the present spectrum is the absence of any evidence for either a narrow $l=0$ state near the neutron decay threshold to the first $T=2$ state in ${}^8\text{Li}$ or a narrow $l=1$ state approximately 1.3 MeV above this threshold. The calculated effect of these states is shown by the dotted green and dashed purple lines, respectively. The orange dash dotted line in Fig. 2 show the contribution to the cross section arising from Coulomb scattering only.

We have performed a high resolution study with low statistical uncertainty searching for $T=5/2$ isobaric analogs of the low-lying states in ${}^9\text{He}$. We find no evidence of any narrow structures, instead observing only a broad, isotropic $T=5/2$ s-wave contribution to the elastic scattering cross section at an energy of approximately 3 MeV. Results of the present experiment have been submitted to Physical Review Letters for publication and are currently under review [10].

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