7-19-2019

Single-Neutron States in Titanium Isotopes

Jessica Nebel-Crosson
Ursinus College, jenebelcrosson@ursinus.edu

Single-Neutron States in the Titanium Isotopes

Jessica Nebel-Crosson

July 19, 2019

Abstract

Previous experimental studies of neutron-rich nuclei beyond 48Ca have shown that the theoretical predictions regarding the behavior of collective excited states do not reflect the experimental results. From the data we have collected at the John D. Fox Accelerator Laboratory at Florida State University using ^{48}Ti and ^{50}Ti targets, we will discuss our analysis via the use of the neutron-transfer reaction to study the single-neutron states of neutron-rich titanium isotopes, ^{49}Ti and ^{51}Ti. This analysis will help us to improve our experimental picture of these single-particle states.

1 Introduction

In a recent study of ^{54}Ti and other neutron-rich Ca and Ti isotopes [5], the experimental observations have not reflected the theoretical predictions of the collective behavior of exotic nuclei. The theory systematically over-predicts the probabilities of exciting collective states. There are no adjustable parameters within the theoretical model. However, the inputs into the model are characteristics of single particle states. Therefore, we are attempting to verify the single particle structure in ^{51}Ti through identification of excited states and the determination of their angular momenta using the neutron transfer reaction. Neutron transfer is a reaction in which a single neutron from the projectile nucleus is a reaction in which a single neutron from the projectile nucleus is transferred to the target nucleus. In the present work, the projectile is a deuteron, and the target is ^{50}Ti. We deduce the properties of single-neutron states in ^{51}Ti by detecting the energies and emission angles of the protons produced by the reaction.

2 Experiment

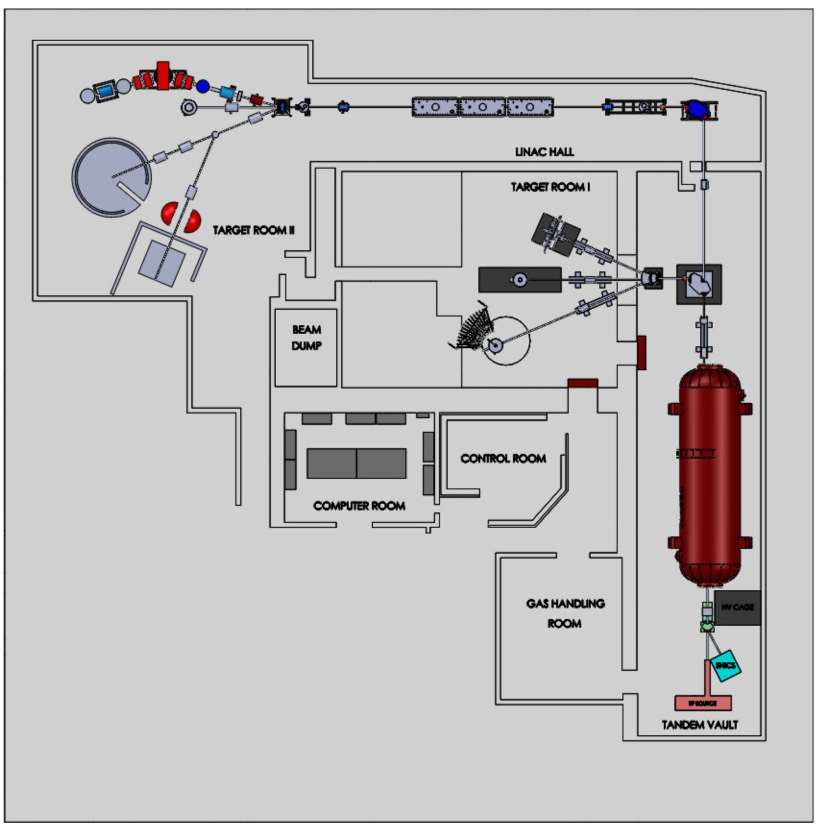

Figure 1: An overhead view of the Fox Laboratory [1]. Beginning in the bottom right corner, the beam travels upwards and to the left to the spectrograph in Target Room II.

The experiment took place at the John D. Fox Accelerator Laboratory at Florida State University. The Super-Enge Split-Pole Spectrograph (SPS), located within the lab, was utilized to collect the measurements necessary for data acquisition which then is analyzed and made into readable histograms. Before entering the spectrograph, a deuteron source is injected into the 9 Megavolt Super-FN Tandem Van de Graaff accelerator where the beam is accelerated through the tandem. At various points along the beam-line path are quadrupole magnets which acts as "lenses" to focus the beam particles into a point and dipole magnets to steer the beam towards its destination into the spectrograph. The target is composed of enriched ^{50}Ti, with some contamination of ^{48}Ti, with a thickness of 0.425 mg/cm^3. Protons from the (d,p) reaction were detected in the focal plane of the instrument. An overhead view of the lab can be seen in Figure 1.

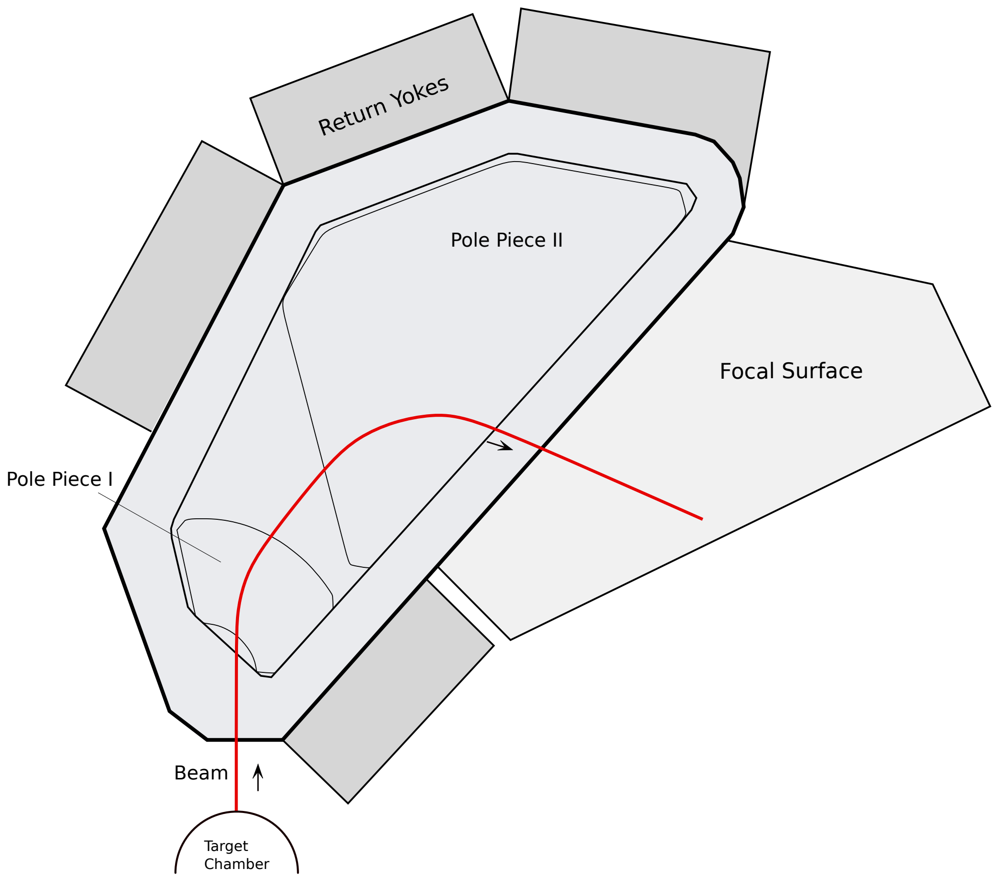

Figure 2: Overhead and inside view of the split-pole spectrograph. The protons from the (d,p) reaction inside the target chamber are steered by the magnetic field towards the focal plane detector.

The spectrograph can be rotated to varying angles run to capture outgoing protons at different angles in the laboratory frame. From there, the magnetic fields from the pole pieces guide the particles to the detector in the focal surface, as labelled in Figure 2. When the particles enter the focal-plane and pass through the position-sensitive focal plane detector, they ionize the gas inside. This resulting ionization of the passing particles increases the number of electrons which ultimately amplifies the signals created from the triggered electronics within the detector. The position of the proton trajectory in the focal-plane detector is directly proportional to the momentum of the proton.

Measurements of elastic scattering were also taken as this enables us to place the individual measurements at each angle on a common absolute scale. These angular distribution measurements will enable is to determine the angular momentum of the single-neutron states of ^{51}Ti.

3 Analysis and Results

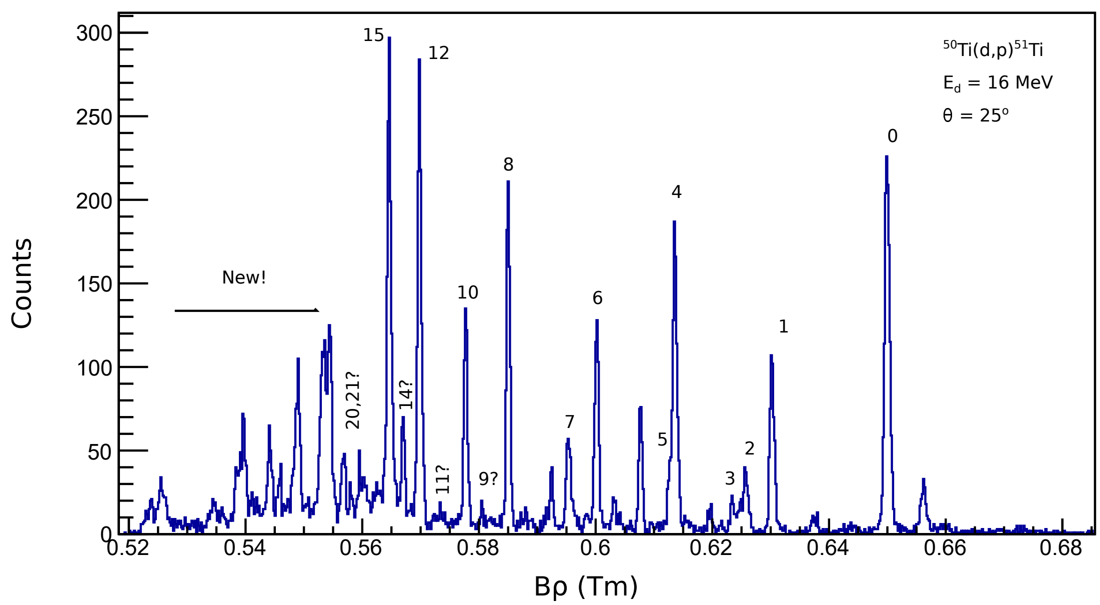

Figure 3: Spectrum of ^{51}Ti excited states at 25° from the present work. Large contaminant peaks concentrated in the higher momentum section in Barnes et al.'s [2] spectrum are not present.

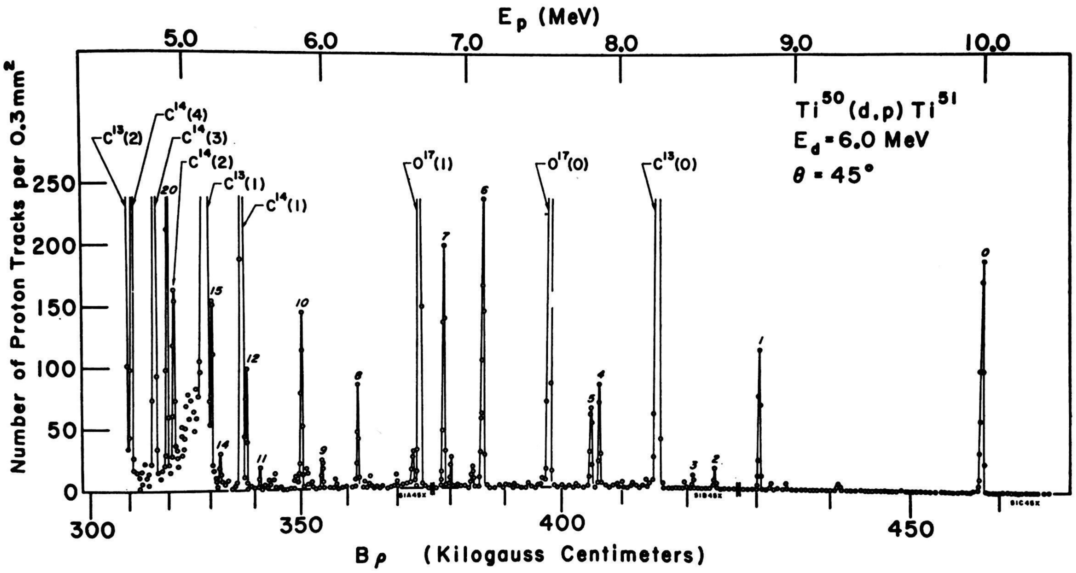

Figure 4: Barnes et al.'s spectrum of ^{51}Ti at 45° [2].

For the analysis of this data, the identification of known energy states across various angles of spectra for ^{51}Ti and any possible contaminants present in the proton spectrum collected at an angle of 25° is shown in Figure 3, and the spectrum from Ref.[2] collected at 45° is shown for comparison in Figure 4. These angles are comparable due to the difference in deuteron energy used in the two measurements.

4 Discussion

Current progress of the analysis is at the identification of excited states and contaminants within the data collected. An interesting early observation is that the peak, labelled 20 in Figures 3 and 4, identified by Barnes et al. does not appear to be present in our spectrum.

The next step in the analysis is to produce angular distribution graphs for the excited states. These will be compared with reaction theory calculations that will enable us to identify the angular momentum values of the states.

References

[1] FSU fox-laboratory|Laboratory and Facilities http://fsunuc.physics.fsu.edu/nrb$_m$$odel/nrb_model.html$.

[2] P. D. Barnes, C. K. Bockelman, Ole Hansen, and A. Sperduto. Inelastic deuteron scattering and (d, p) reactions from isotopes of ti. i. Ti$^{50}(d, p)$Ti^{51}. 136(2):B438–B446.

[3] R. N. Glover, A. Denning, and G. Brown. The influence of 2p - 1h configurations on the low-lying states of ^{51}Ti. 27(7):434–435.

[4] D. C. Kocher and W. Haeberli. Vector analysing power and cross section for (d, p) reactions on ^{40}Ca, ^{46}Ti, ^{48}Ti, ^{50}Ti, ^{52}Cr, and ^{54}Fe. 196(2):225–268.

[5] L. A. Riley, M. L. Agiorgousis, T. R. Baugher, D. Bazin, R. L. Blanchard, M. Bowry, P. D. Cottle, F. G. DeVone, A. Gade, M. T. Glowacki, K. W. Kemper, J. S. Kustina, E. Lunderberg, D. M. McPherson, S. Noji, J. Piekarewicz, F. Recchia, B. V. Sadler, M. Scott, D. Weisshaar, and R. G. T. Zegers. Spectroscopy of ^{54}Ti and the systematic behavior of low-energy octupole states in Ca and Ti isotopes. 96(6):064315.

[6] J. E. Spencer and H. A. Enge. Split-pole magnetic spectrograph for precision nuclear spectroscopy. 49(2):181–193.