Beta-delayed charged-particle spectroscopy using TexAT

J. Bishop,[1] G.V. Rogachev,[1,2,3] S. Ahn,[1,2] E. Aboud,[1,2] M. Barbui,[1] P. Baron,[4] A. Bosh,[1,2] E. Delagnes,[4] J. Hooker,[1,2] C. Hunt,[1,2] H. Jayatissa,[1,2,*] E. Koshchiy,[1] R. Malecek,[5] S.T. Marley,[5] R. O'Dwyer,[1,2] E.C. Pollacco,[4] C. Pruitt,[6] B.T. Roeder,[1] A. Saastamoinen,[1] L.G. Sobotka,[6] and S. Upadhyayula[1,2,+]

[1]*Cyclotron Institute, Texas A&M University, College Station, Texas 77843,*

[2]*Department of Physics & Astronomy, Texas A&M University, College Station, Texas 77843,*

[3]*Nuclear Solutions Institute, Texas A&M University, College Station, Texas 77843,*

[4]*IRFU, CEA Université Paris-Saclay, F-91191, Gif-sur-Yvette, France*

[5]*Department of Physics and Astronomy, Louisiana State University, Baton Rouge, Louisiana 70803*

[6]*Department of Chemistry, Washington University, St. Louis, Missouri 63130,*

[*] Current address: Physics Division, Argonne National Laboratory, Argonne, Illinois 60439

[+] Current address: Department of Physics and Astronomy, University of Tennessee, Knoxville, Tennessee 37996

The experimental technique for measuring beta-delayed charged-particle spectroscopy in TexAT [1] – in this instance the $^{12}N \rightarrow ^{12}C^{*} \rightarrow 3\alpha$ reaction – has been previously detailed [2,3]. Analyzing data from this experiment, performed in March 2019, the efficacy of this technique has been proven.

To demonstrate the technique works well, a number of previously well-known observables were replicated [3]. Firstly, the '2p-mode' of the GET electronics allowed for a measurement of the time between the implant of the ^{12}N into TexAT and the subsequent decay branch to 3 α-particles. This allowed for a measurement of the ^{12}N half-life, shown in Fig. 1. From these data, a value of $t_{1/2}$ = 10.92 +/- 0.11 (stat.) +/- 0.11 (sys.) ms was obtained which is in good agreement with the literature value of 11.000 +/- 0.016 ms.

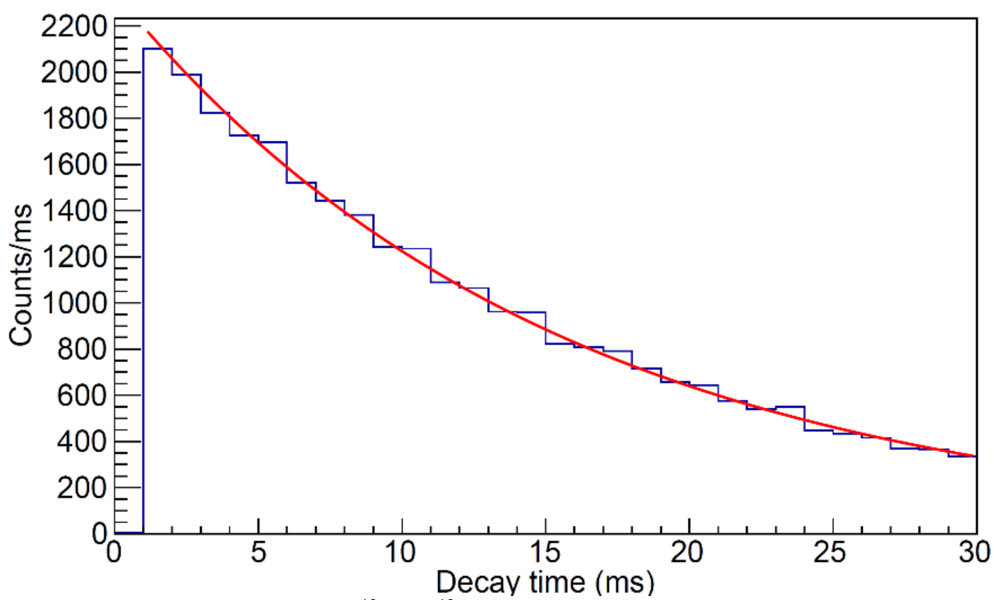

Fig. 1. Decay time spectrum for $^{12}N \rightarrow ^{12}C(0_2^+)$. The fitted value is 10.92 +/- 0.11 (stat.) +/- 0.11 (sys.) ms.

Additionally, the beta-decay branching ratios to the excited-states in ^{12}C were also measured. As every implant was counted and the efficiency for measurement of α-unbound states was 100%, this allowed for a simple counting method to determine the branching ratio that doesn't rely on beta-particle or gamma-ray efficiencies as previous measurements have. The results in the current work are detailed in Table I below and can be seen to agree reasonably well with previously-measured values from KVI [4].

Table I. Branching ratios for ^{12}C states populated in ^{12}N β^+-decay from the present work and from KVI [4].

State	**KVI(%)**	**Current work(%)**
g.s.	96.17 ± 0.05	-
4.44 MeV – 2_1^+	1.90 ± 0.04	-
7.65 MeV – 0_2^+	1.44 ± 0.03	1.58 ± 0.01 (stat.) ± 0.11 (sys.)
7.3-16.3 MeV – 3α	2.11 ± 0.03	2.54 ± 0.01 (stat.) ± 0.18 (sys.)
0_2^+/3α	68 ± 2	62.1 ± 0.4 (stat.) ± 0.2 (sys.)

Finally, by reconstructing the events inside of TexAT and analyzing the energy partitions of the decays which proceed via the Hoyle state at 7.65 MeV in ^{12}C, the 'direct-decay mode' was measured whereby the $^{12}C^*$ system decays directly into 3 α-particles without proceeding via the intermittent ^8Be ground state.

A GEANT4 simulation to model the direct-decay and sequential-decay modes was created and analyzed to generate a Dalitz plot which can differentiate the decay modes. The experimental results, in comparison for the GEANT4 simulations for both decay modes can be seen in Fig. 2 and the equivalency of the experimental data to the sequential decay mode is immediately visually apparent. A small

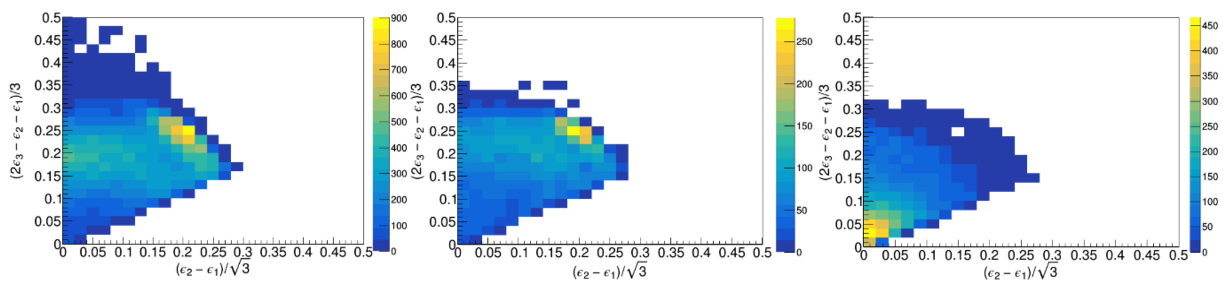

Fig. 2. Dalitz plots for the experimental data (left) against the GEANT4 simulated data for sequential-decay (middle) and direct-decay (right).

branching ratio for the direct decay mode has been obtained and will be published in a soon-to-be-submitted article. This value allows for a benchmarking of the sensitivity available for future beta-delayed charged-particle spectroscopy studies with TexAT such as the planned ^{13}O experiment looking at 3α+p from ^{13}N.

Additionally, this data set (in parallel with a previously-obtained Gammasphere data set [5] and an astrophysical argument) have been used to provide extremely strict limits on the existence of a potential Efimov state in ^{12}C at 7.458 MeV. These results will also be published soon.

In conclusion, the work performed this year demonstrated:

- The capability of TexAT to reconstruct 3 α-particle events at low gas pressure which allowed for the progression of an experiment to study $^{12}C(n,n_2)3\alpha$ with TexAT at Ohio University (partially completed in March 2020).
- The possibility of using the beta-delayed charged-particle spectroscopy technique to study few-body systems in light nuclei – published in NIM [3].
- A measurement of the direct-decay Hoyle branching ratio and a prohibitive limit on the existence of an Efimov state in ^{12}C – to be published soon.

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