Measurement of the β-delayed proton emission of ^{20}Mg and the breakout from the hot CNO cycles

J. P. Wallace,[1] G. Lotay,[1] P. J. Woods,[1] A. A. Alharbi, A. Banu, H. M. David,[1] T. Davinson,[1] M. McCleskey, B. Roeder, E. Simmons, A. Spiridon, L. Trache and R. E. Tribble
[1]*School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom*

In explosive astrophysical environments, such as X-ray bursters and supernovae, sufficiently high temperatures and densities are reached that it is possible to breakout from the hot CNO cycle into the rp process. The main breakout sequence is thought to be ^{15}O(α,γ)^{19}Ne(p,γ)^{20}Na. Both reactions are important and have been investigated through many different experiments, using radioactive beams and indirect methods. It is the second reaction, ^{19}Ne(p,γ)^{20}Na, that will be discussed here.

It has been shown that this reaction rate is dominated by a single resonance at 450 keV above the proton threshold, corresponding to an excitation energy of 2.643 MeV. Over two decades of work has gone into finding the properties of this state through many different experiments. There have been direct measurements of the ^{19}Ne(p,γ)^{20}Na reaction, resulting in an upper limit being put on the resonance strength [1], as well as studies of the charge exchange reactions ^{20}Ne(^{3}He,t)^{20}Na and ^{20}Ne(p,n)^{20}Na, mirror nuclei analysis and a measurement of the β-p emission of ^{20}Mg [2]. However, despite all these experiments there is still a question mark concerning the spin-parity of the key resonant state. The uncertainty comes down to whether the state has a $J^{\pi}=1^{+}$ or 3^{+} assignment. It is widely believed to be a 1^{+} assignment, however the non-observation of the β-p branch from the decay of ^{20}Mg is strong evidence against this [2].

In [2] an experiment was performed where a total of $4.5*10^{6}$ ^{20}Mg ions were selected by the LISE3 spectrometer at GANIL and implanted into a 300 micron position sensitive silicon detector, surrounded by β and Ge detectors. Many strong proton emissions were observed down to a resonance energy of 806 keV, however, below this, intense low energy beta's caused a high background decreasing the sensitivity at low energies. An estimate on the upper limit of the branching ratio was deduced to be 0.1%, corresponding to a lower limit on the log*ft* value of 6.24 [2]. However, these results don't rule out a 1^{+} assignment as the analog mirror state, 3.173 MeV, in ^{20}F has not been observed to be fed by the β emission of ^{20}O, with a logft limit of 5.08 being set. It has been suggested that this 1^{+} state in ^{20}O is an intruder state with only a weak $(sd)^4$ admixture. There are also at least 3 cases where β emission is allowed with a logft value over 6, namely ^{17}N, ^{17}Ne, ^{18}N, associated with small *sd*-shell components [2].

As was previously mentioned the main source of background in the most recent study of the β-p emission from ^{20}Mg was the intense low energy beta's. Due to the method now available at TAMU [3] using thin segmented double sided silicon strip detectors (DSSSD) at the focal plane of MARS, it was possible to repeat this experiment with a 45 micron DSSSD. By using a thinner detector the low energy beta's were eliminated down to energies of about 200 keV. This can clearly be seen in Fig. 1 which shows a lack of the low energy beta background. The background at low energy is now predominately from escaping protons which was not visible in [2]. The K500 cyclotron was used to produce a primary beam of ^{20}Ne which impinged on a cryogenic ^{3}He target, producing a secondary beam of ^{20}Mg which was separated from the contaminants also produced through the use of MARS. The ^{20}Mg ions were implanted into the 45 micron DSSSD, which was sandwiched between two thicker silicon detectors, a 140 micron detector in front and a 1000 micron silicon detector behind. As the half life of ^{20}Mg is 94 ms the beam was pulsed, with 200 ms of beam of 200 ms of acquisition, therefore reducing background further. Fig. 1 shows a preliminary spectrum of a subset of the data collected, showing the strong proton and alpha decay peaks from the decay of ^{20}Na. What is remarkable is that the measurement was done with a very low ^{20}Mg production rate of about 20 pps. This shows that the method itself is very sensitive and selective. Analysis is currently underway.

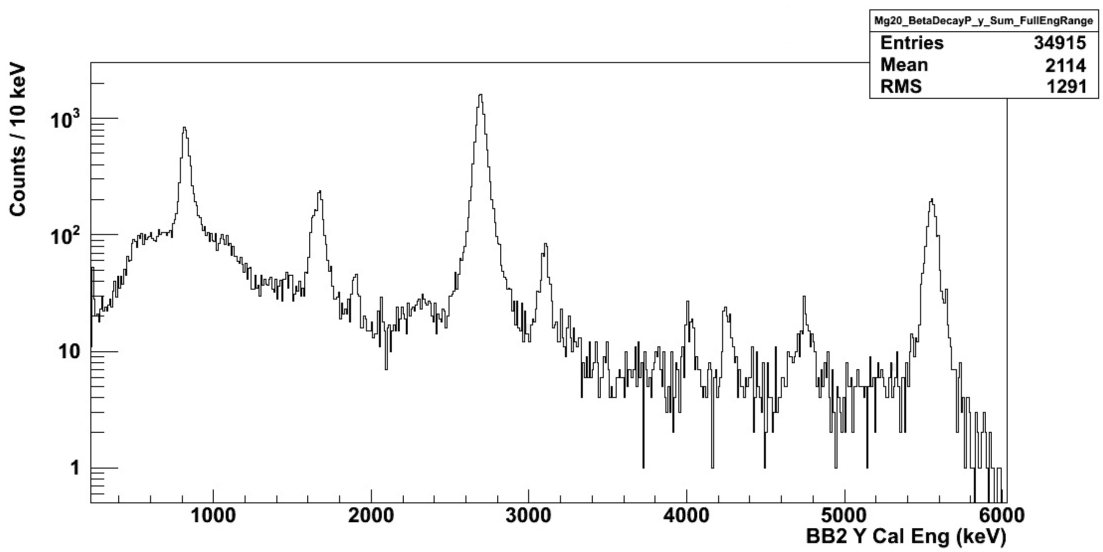

FIG. 1. Spectrum of a subset of the data, showing the strong beta delayed proton and alpha decay peaks from ^{20}Na.

[1] R.D. Page *et al.*, Phys. Rev. Lett. **23**, 3066 (1994).

[2] A. Piechaczek *et al.*, Nucl. Phys. **A584**, 509 (1995).

[3] L. Trache *et al.*, Proceedings of Nuclei in the Cosmos (2008).