# SEARCH FOR A STATE AT $E_x = 2.6$ MeV IN $^{20}$Na VIA THE $^{20}$Ne(p,n)$^{20}$Na REACTION AND POSSIBLE BREAKOUT FROM THE HOT CNO CYCLE


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At the high temperatures and densities present in supernovae explosions, explosive hydrogen burning proceeds through the hot CNO cycle (HCNO),

$$^{12}\text{C(p},\gamma)^{13}\text{N(p},\gamma)^{14}\text{O}(\beta^+\nu)^{14}\text{N(p},\gamma)^{15}\text{O}(\beta^+\nu)^{15}\text{N(p},\alpha)^{12}\text{C}.$$

At very high temperatures ($T > 3 \times 10^8$ °K), the reactions $^{15}\text{O}(\alpha,\gamma)^{19}\text{Ne}(\text{p},\gamma)^{20}\text{Na}$ may begin a sequence of rapid proton captures and beta decays which can process CNO seed nuclei to form elements up to A = 56 and can increase nuclear energy generation significantly.[1] This branching may also explain over-abundances of Ne, Na, Mg, and Al isotopes in nova ejecta[2] and cosmic rays[3] relative to solar abundances.

The strength of this possible breakout branching is very sensitive to resonances in the $^{19}$Ne+p system, i.e., states in $^{20}$Na near the proton threshold. This threshold is at 2.199 MeV. A state has been observed at 2.6 MeV via the $^{20}$Ne($^3$He,t)$^{20}$Na reaction by three separate groups.[1,4,5] This state would be the first state above threshold; consequently its existence and properties significantly affect the strength of the branching. In an earlier experiment,[6] we saw no evidence for such a state in the $^{20}$Ne(p,n)$^{20}$Na reaction. On the basis of DWBA analyses of the ($^3$He,t) experiments, it was suggested that the $J^\pi$ of the 2.6 MeV state is $0^+$ or $1^+$, i.e., it is $\Delta L = 0$.

We performed a new experiment using the beam-swinger at the IUCF in January 1993 in order to search more carefully for such a state. The new experiment used the "stripper loop" storage ring to achieve ~2 μs between beam bursts. The earlier experiment, performed without the stripper loop, used normal pulse suppression and had ~133 ns between beam bursts. The longer time between beam bursts eliminates overlap background from earlier beam bursts and also greatly reduces backgrounds from cosmic rays (because the system is open for a smaller fraction of the total time). The net result is a much improved signal-to-background ratio (better by more than a factor of 10). Care was taken to obtain as good an energy resolution as possible with the swinger system. The flight paths to the large-volume, mean-timed neutron detectors were 128 m. We obtained an overall time resolution of 750 ps, which translates into an energy resolution of 260 keV.

Our preliminary results at 0.2° are shown in Fig. 1. If there is a $0^+$ or $1^+$ state at 2.6 MeV, we would expect it to peak at 0° ($\Delta L = 0$). As one can see, there is no evidence for a state at 2.6 MeV. The large peak seen at 1.0 MeV is a known $1^+$ state in $^{20}$Na, as is the smaller state observed at 3.0 MeV.[6] The very large peak seen near 3.4 MeV is the $^{12}$C(p,n)$^{12}$N g.s. reaction from the carbon in the Kapton entrance and exit windows of the

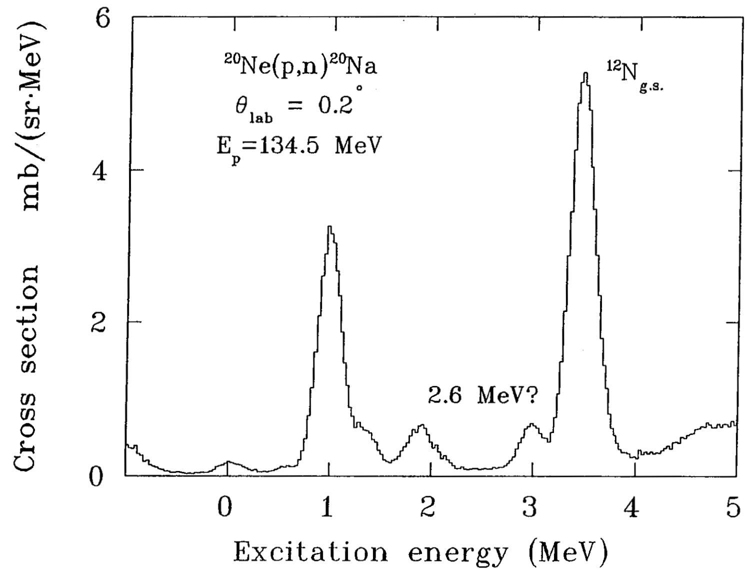


*Figure 1.* Excitation-energy plot for the $^{20}$Ne(p,n)$^{20}$Na reaction at 135 MeV and 0°.

gas cell. The bump observed near 2 MeV is a complex of $2^-$, $3^-$, and $3^+$ states.[1] The region around 2.6 MeV is seen to be quite flat with a very low background (this spectrum has no background subtraction). From these results, we will be able to place an upper limit on the existence of a $0^+$ or $1^+$ state with one-particle one-hole strength. It appears unlikely that such a state exists with simple structure.

These results are consistent with the recent work of Kubona, *et al.*,[7] who looked for the beta decay of $^{20}$Mg and then observed the delayed beta decay to $^{20}$Na. They found that 85% of the decay went to the $1^+$ state at 1.0 MeV, 9% to the $1^+$ state at 3.0 MeV, 5% to the $1^+$ state at 3.9 MeV, 1% to a $0^+$ state at 6.4 MeV and less than 1% to any possible state at 2.6 MeV. More recently, it has been suggested that the 2.6 MeV state might be a $3^+$ state.[8] This possibility will be considered as the data are further analyzed.

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