Transition to the Island of Inversion: Study of Excited States in $^{28-30}$Ne

P. Fallon[1] , E. Rodriguez-Vieitez[1,2], D. Bazin[3], C. M. Campbell[3], R. M. Clark[1], J. M. Cook[3], M. Cromaz[1], M. A. Deleplanque[1], M. Descovich[1], D.-C. Dinca[3], A. Gade[3], T. Glasmacher[3], I.-Y. Lee[1], A. O. Macchiavelli[1], W. F. Mueller[3], S. G. Prussin[2], F. S. Stephens[1], D. Ward[1], M. Wiedeking[1], K. Yoneda[3]

[1] *Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720*

[2] *Department of Nuclear Engineering, University of California Berkeley, California 94720*

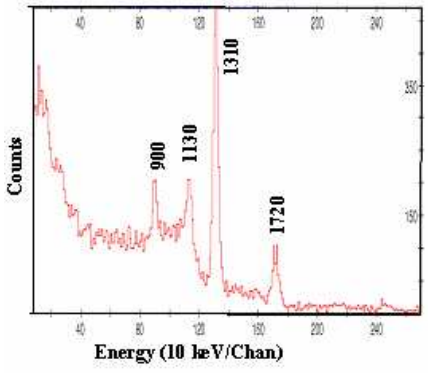
[3] *National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, Michigan 48824*

Neutron rich *sd-pf* nuclei exhibit a rich variety of physics that includes modified shell structure, the onset of large collectivity, and increased binding of drip-line nuclei. One of the most studied phenomena in this region is the "island-of-inversion" – a region of deformed (2p2h) ground states in Ne, Na and Mg at N~20, which corresponds to the promotion of a pair of neutrons across the N=20 shell from the $d_{3/2}$ to $f_{7/2}$ state. This intrusion of 2p2h states below the spherical (0p0h) states suggests a much reduced N=20 shell gap, compared to nuclei near beta-stability. Recently, a Monte Carlo Shell Model (MCSM) [1] that includes mixing between *sd-pf* states and a strong T=0 monopole interaction between valence $d_{3/2}$ neutrons and $d_{5/2}$ protons has been used to predict energy levels in neutron-rich nuclei. In this contribution we present results on the transition to the island of inversion in neutron-rich $^{28-30}$Ne by comparing experimental spectra with MCSM predictions.

The experiment was carried out at the National Superconducting Cyclotron Laboratory, Michigan State University. A 140 MeV/A ^{48}Ca primary beam was used to produce a "cocktail" of secondary beams (^{29}Na/^{30}Mg/^{32}Al and ^{32}Mg/^{33}Al/^{35}Si), which then underwent secondary knockout/fragmentation reactions to produce neutron-rich isotopes of Mg, Na, Ne and F. The segmented germanium detector array, SeGA [2], was used to measure the in-beam gamma-ray decays from excited states populated in the secondary reaction. Both the incoming secondary-beam and the final products were unambiguously identified on an event-by-event basis using the S800 spectrograph [3].

Fig. 1 shows the Doppler-corrected prompt gamma-ray spectrum for ^{28}Ne produced by one-proton knockout from ^{29}Na, with a cross section of ~1.5 mb; the experimental level scheme is shown in comparison with USD [4] (*sd* shell) and MCSM [5] (SDPF-M, both *sd* and *pf* shells with cross-shell mixing) calculations. The high-statistics ^{28}Ne data yielded a cascade (determined from gamma-gamma coincidences) of three consecutive transitions decaying to the ground state (Fig. 1), with energies of 900, 1720, and 1310 keV. These data show no definitive evidence for the predicted 0_2^+ state at ~2.2 MeV, and the location of the intruder 0_2^+ level in ^{28}Ne remains undetermined. Our data rules out the interpretation given in a recent publication [6] in which a ~930 keV transition (parallel to the 1720 keV γ-ray) is assumed to connect the 0_2^+ state to the 2_1^+. ^{28}Ne does, however, contain one additional (and new) strong gamma-ray transition at 1130 keV, which is not in coincidence with any other transition (Fig. 1); one interpretation is that it corresponds to the $2_2^+ \rightarrow 0_2^+$ transition. If the 0_2^+ state is lower than predicted, even by a few hundred keV, it may well be isomeric. It is also possible that the energy of the 0_2^+ level is below the 2_1^+ level.

Two γ-rays at 626 and 472 keV were observed in ^{29}Ne. The measured excitation spectrum is consistent with a strongly deformed 2p2h ground state configuration and a reduced effective N=20 shell gap. In ^{30}Ne, an observed transition at 797 keV provides an important confirmation of a recently reported low-energy 2_1^+ state [7] and is consistent with a large static ground state deformation. Two higher energy transitions are candidates for higher-lying excited states.



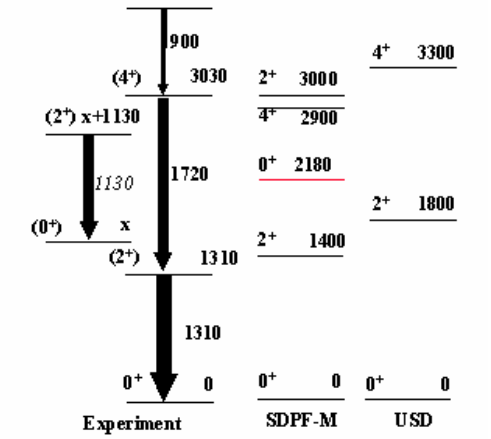


Fig. 1. Gamma-ray spectrum of ^{28}Ne, and experimental and calculated level schemes.

References

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