Observation of Unbound States in $^{16}$Ne / $^{15}$Ne via 1n- / 2n-Knockout on $^{17}$Ne

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In recent years, experiments investigating the driplines have unearthed rich evidence on the peculiarities of the nuclear force, in particular those connected to weak binding and large proton-neutron asymmetry. While for very neutron-rich systems, e.g., various manifestations for 1n and 2n halo systems are found, the existence of the dripline is known only up to $Z = 8$. Quite reversed due to the additional presence of the Coulomb barrier, the proton dripline is sharp and known up to $Z = 91$, whereas halo formation is suppressed and just a few cases exist. In the recent past we have investigated proton-knockout reactions studying the borromean 2p-halo nucleus $^{17}$Ne [1, 2], and here we have used the dataset from the same experiment as a stepping stone to reach beyond the proton dripline and explore yet unknown regions of the nuclear landscape.

This report presents data of 1n- and 2n- knockout reactions on $^{17}$Ne projectiles in light targets (C, CH$_2$), populating states in the unbound nuclei $^{16}$Ne and the yet unobserved $^{15}$Ne. In a simple picture, the respective neutrons were removed from the $^{17}$Ne core, $^{15}$O, thus creating 14+13 fragments coupled to the two remaining $s^2/d^2$ protons, all travelling under forward angles and being detected in coincidence. The data analysis procedure, via 4-momentum reconstruction and invariant-mass technique, is equivalent to the description in [1]. The excitation spectra, in terms of f-2p relative-energy spectra, of the $^{16}$Ne and $^{15}$Ne systems are shown in Fig. 1. The shown data (full dots with errorbars) have been corrected for experimental acceptance, and the peaks have been fitted by Coulomb-Breit-Wigner functions (dashed, dotted lines) folded with the experimental resolution, and in the case of $^{16}$Ne in addition by a non-resonant background (full line). The experimental acceptance and the $E_{rel}$ calibration and resolution have been obtained from R3BROOT-based simulations [2] in combination with the width and position of the known 5/2$^+$ state in the $^{15}$O+2p continuum of $^{17}$Ne as a reference.

For $^{16}$Ne ($^{14}$O+2p) we have extracted the positions and widths of the ground state and the first two excited states as $E_r(\text{g.s.}) = 1.388(15)$ MeV, $\Gamma_r(\text{g.s.}) = 0.082(15)$ MeV; $E_r(1.x.) = 3.22(5)$ MeV, $\Gamma_r(1.x.) \le 0.05$ MeV; $E_r(2.x.) = 7.57(6)$ MeV, $\Gamma_r(2.x.) \le 0.1$ MeV. These values are in good agreement with previous publications on $^{16}$Ne, e.g. [4], and confirm the validity of our technique and calibrations.

For the first time, the unbound isotope $^{15}$Ne has been observed, as coincidences between $^{15}$O and two beam-like protons (see Fig. 1(bottom)). The same type of analysis as for the $^{16}$Ne case has been performed for the $^{15}$Ne ($E_{fpp}$) spectrum. We identified the ground state and the first excited state with parameters of $E_r(\text{g.s.}) = 2.522(66)$ MeV, $\Gamma_r(\text{g.s.}) = 0.59(23)$ MeV; $E_r(1.x.) = 4.42(4)$ MeV, $\Gamma_r(1.x.) \le 0.1$ MeV. The observed position of the $^{15}$Ne ground state at $S_{2p} = -2.522(66)$MeV is in good agreement to a recent model prediction [5].

**References**
