STUDY OF LIGHT NEUTRON-RICH NUCLEI VIA ONE-NEUTRON KNOCKOUT REACTIONS

C. Rodríguez-Tajes[1,*], H. Álvarez-Pol[1], T. Aumann[2], E. Benjamim[1], J. Benlliure[1], M.J.G. Borge[3], M. Caamaño[1], E. Casarejos[1], D. Cortina-Gil[1], A. Chatillon[2], K. Eppinger[4], T. Faestermann[4], M. Gascón[1], H. Geissel[2], R. Gernhäuser[4], B. Jonson[5,6], R. Kanungo[7], R. Krücken[4], T. Kurtukian[1], K. Larsson[5], P. Maierbeck[4], T. Nilsson[5], C. Nociforo[2], C. Pascual-Izarra[3], A. Perea[3], D. Pérez-Loureiro[1], A. Prochazka[2], H. Simon[2], K. Sümmerer[2], O. Tengblad[3], H. Weick[2] M. Winkler[2] and M. Zhukov[5].

[1] Departamento de Física de Partículas, Universidade de Santiago de Compostela, 15782 Santiago de Compostela, Spain.

[2] GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany.

[3] Instituto de Estructura de la Materia, CSIC, 28006 Madrid, Spain.

[4] Physik Department E12, Technische Universität München, 85748 Garching, Germany.

[5] Experimental Fysik, Chalmers Tekniska Högskola och Göteborgs Universitet, 412 96 Göteborg, Sweden.

[6] PH Department, CERN, 1211 Geneve 23, Switzerland.

[7] Astronomy and Physics Detartment, Saint Mary´s University, Halifax, NS B3H 3C3, Canada.

[*] Present address: Centro de Láseres Pulsados Ultracortos Ultraintensos, 37008 Salamanca, Spain. Phone: +34 923 294 500. Mail: carme.rodriguez@usal.es

Topic: Nuclear Structure.

One-neutron knockout reactions have been used in this work to explore the evolution of the nuclear structure close to the neutron drip-line, where the neutron excess and the low binding energies can lead to important structural changes. One example is the appearance of neutron halo configurations, which are characterized by a sharp increase of the nuclear radius due to a low-density tail in the wave function of the valence neutron(s) [1]. Moreover, experimental data show that new magic numbers appear and some others disappear when moving towards exotic nuclei. This is the case of the disappearence of the N = 8 closed shell in ^{11}Li or ^{12}Be and the appearence of new sub-shell closures at N = 14 and 16 for oxygen isotopes [2,3]. The N ~ 20 region is also of great interest, since indications of new structural phenomena such as the vanishing of the N = 20 magicity, established for stable nuclei, have been found. This area is commonly known as the island of inversion because the ground state is believed to consist of intruder configurations with neutrons excited from the *sd* to the *pf* shell [4].

The experiment was performed at GSI (Darmstadt, Germany), at the FRS magnetic spectrometer [5]. Thirty-eight different isotopes, ranging from C to Al, were studied and the region between N = 8 and 22 was closely examined.

A fully ionized ^{40}Ar primary beam, with an intensity around 10^{10} ions/spill, was accelerated in the SIS synchrotron up to 700 MeV/nucleon. Neutron-rich projectiles were produced by fragmentation in a 4 g/cm^2 Be target, placed at the entrance of the FRS. The first half of the FRS (up to the intermediate focus) was used to separate and identify the projectiles. The one-neutron knockout target (Be, 1720 mg/cm^2 thick) was placed at the intermediate focal plane, where a set of Ge detectors, MINIBALL, was included in order to measure the gamma rays emitted in coincidence with the reaction and disentangle the populated states of A-1 fragments, which were studied in the second half of the FRS.

Two inclusive observables were determined in this work, the one-neutron knockout cross-sections and the longitudinal-momentum distributions of the A-1 fragments, which are especially appropiate for the study of halo configurations and, in general, can be used to identify the orbital angular momentum of the neutron removed in the reaction [6]. Exclusive measurements were also carried with the help of MINIBALL and, for a number of cases, branching ratios to the populated fragments states and exclusive cross-sections have been determined.

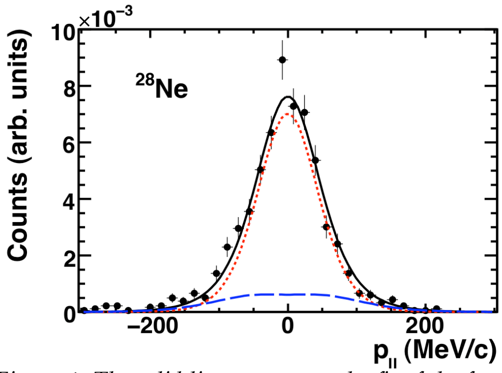

Figura 1. The solid line represents the fit of the fragment momentum distribution measured in the one-neutron knockout of ^{28}Ne. The dashed and dotted lines correspond to the calculated l=2 and l=1 contributions, corresponding to ^{27}Ne(3/2$^+$,g.s.)x$d_{3/2}$ and ^{27}Ne(1/2$^+$,885 keV)x$s_{1/2}$ configurations, respectively.

In general, the experimental results obtained in this work are in good agreement with previous experiments and provide new structural information in the vecinity of the neutron drip-line. The results for ^{22}N, ^{23}O, and ^{24}F one-neutron knockout reflect without any doubt the change from $0d_{5/2}$ to $1s_{1/2}$ configurations expected at N = 14. This work provided the first one-neutron knockout data for ^{22}N, which has been proposed as a one-neutron halo candidate [2,7], and probed a significant $1s_{1/2}$ admixture in its ground state.

Special attention was dedicated to the $^{24\text{-}28}$Ne isotopic chain because of their proximity to the island of inversion. Ne isotopes also exhibit significant $1s_{1/2}$ contributions at N = 14. However, ^{27,28}Ne do not behave as expected, the valence neutron occupies a $s_{1/2}$ level rather than $d_{3/2}$ and is coupled to an excited state of the core. To study the structure of $^{24\text{-}28}$Ne isotopes more fully, the experimental momentum distributions were analyzed on the basis of a simple theoretical model. The calculations included the orbital angular momentum of the removed neutron, its separation energy and a lower cutoff on the impact parameter which ensured the core survival [8]. The results, which are shown in Fig. 1 for ^{28}Ne, are in agreement with the previous work of Ref. [9], where exclusive one-neutron knockout measurements were carried out for ^{27,28}Ne.

[1] P. G. Hansen et al., Europhys. Lett. 4, 409 (1987).
[2] A. Ozawa et al., Phys. Rev. Lett. 84, 5493 (2000).
[3] T. Otsuka et al., Phys. Rev. Lett. 87, 082502 (20001).
[4] H. Geissel et al., Nucl. Instr. Meth. B 70, 286 (1992).
[5] Y. Utsuno et al., Phys. Rev. C 60 (1999) 054315.
[6] P. G. Hansen, Phys. Rev. Lett. 77, 1016 (1996).
[7] D. Sohler et al., Phys. Rev. C 77, 044303 (2008).
[8] C. Rodríguez-Tajes et al., Phys. Lett. B 687, 26 (2010)
[9] J.R. Terry et al., Phys. Lett. B 640. 86 (2006)