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NEUTRON KNOCKOUT AT RELATIVISTIC ENERGIES ACROSS THE psd SHELL*

C. Rodríguez-Tajes[a], D. Cortina-Gil[a], H. Álvarez-Pol[a]
E. Benjamim[a], J. Benlliure[a], M. Caamaño[a], E. Casarejos[a]
K. Eppinger[b], H. Geissel[c], R. Gernhäuser[b], B. Jonson[d]
R. Krücken[b], T. Kurtukian[a], P. Maierbeck[b], T. Nilsson[d]
C. Nociforo[c], D. Pérez[a], A. Prochazka[c], H. Simon[c]
K. Sümmerer[c] H. Weick[c]

for the S245 Collaboration

[a]Universidade de Santiago de Compostela, Spain
[b]Technische Universität München, Germany
[c]Gesellschaft für Schwerionenforschung, Germany
[d]Chalmers Tekniska Högskola, Sweden

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One-neutron knockout reactions have been studied in a systematic way for a set of neutron-rich projectiles. The goal of the experiment, performed at GSI, was to explore the evolution of the nuclear structure close to the neutron drip line, in the region between C and Al. The momentum distributions of the surviving fragments and the cross-sections of the knockout process have been measured and used as physical observables. This report focuses on oxygen and nitrogen isotopes around $N = 14$. In particular, we discuss the case of ^{22}N, for which the mentioned observables have been determined for the first time. We will consider ^{23}O, already studied in earlier experiments, as a reference.

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1. Introduction

The availability of relativistic radioactive beams has stimulated the investigation of nuclear structure far from stability. Meanwhile, the neutron drip line has become accessible to the experimental research for light nuclei. The neutron excess and the low binding energies in this region can lead to important structural changes, as neutron halo configurations [1], that have

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been discovered in the last decades. Halo nuclei are characterized by a sharp increase of their matter radius coming from a low density tail of the valence neutron(s). Other signatures are weak binding energies and narrow momentum distributions of the valence neutron(s), together with an enhancement of the neutron-knockout cross-section.

Moreover, experimental data also show that new magic numbers appear and some others disappear when moving towards exotic nuclei, this is the case of the appearance of new sub-shell closures at $N = 14$ and $N = 16$ for oxygen isotopes [2,3]. In this context, experimental efforts have been dedicated in the past to elucidate the structure of ^{23}O. In the neutron-knockout experiment described in Ref. [4], the authors assigned a ground state spin of $I^\pi = 1/2^+$ for ^{23}O, with a large spectroscopic factor for the $s_{1/2} \otimes {}^{22}$O (0^+) single particle configuration.

The case of ^{23}O can be used as a reference for ^{22}N, for which an spatially extended distribution of the neutron $s_{1/2}$ state has also been suggested [5,6].

2. Experimental setup

The experiment was performed at GSI (Darmstadt, Germany), at the FRS magnetic spectrometer. We used a fully ionized ^{40}Ar primary beam, with an intensity around 10^{10} ions/spill and accelerated in the SIS synchrotron 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.

As shown in Fig. 1, the first half of FRS (F0–F2) was dedicated to identify the neutron-rich projectiles. At the intermediate focal plane, F2, they hit the knockout target (Be, 1720 mg/cm^2 thick). The resulting fragments after the one-neutron knockout reaction were selected and identified in the second half of the FRS.

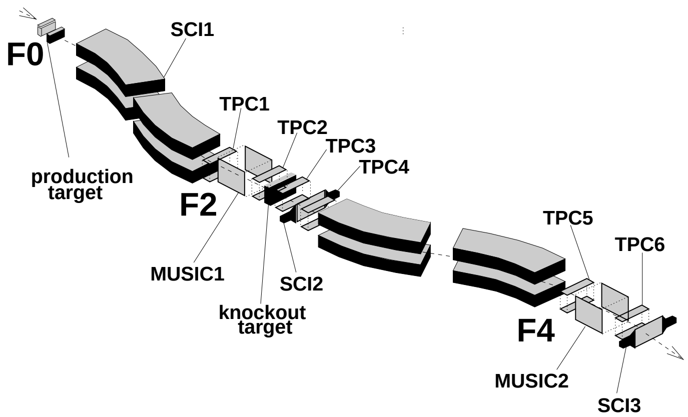

Fig. 1. Scheme of the detector arrangement in the FRS.

The projectiles and fragments were unambiguously identified with the help of ionization chambers (MUSIC), that determined their nuclear charges, Z. The final separation of the different isotopes was achieved by measuring their time of flight between scintillators, SCI1–SCI2 and SCI2–SCI3, and by determining their magnetic rigidity ($B\rho = \frac{\gamma m_0 \beta c}{Q}$) from the positions registered in the time projection chambers, TPCs. Both quantities yielded the corresponding mass-to-charge ratios, A/Z.

2.1. Determination of the physical observables

A plot of Z *vs.* A/Z allowed a clean selection of the one-neutron knockout channel and the determination of the corresponding cross-section. Two different corrections were, however, required: *(i)* the limited transmission of the reaction products through the FRS was accounted for with the help of MOCADI simulations, and *(ii)* the detection efficiency at the final focal plane was evaluated.

The momentum distributions were calculated in the laboratory reference frame from the positions measured by the TPCs and, then, converted to the projectile co-moving frame. An accurate theoretical description of the momentum distributions will be applied in the future to determine the angular momentum of the knocked-out neutron. The widths of the distributions were evaluated by means of Gaussian fits. The additional broadening introduced by the interaction with several layers of matter in the target region was measured in separate settings for non-reacting projectiles reaching the final focal plane.

3. Experimental results

We will here focus on the momentum distributions measured for the oxygen and the nitrogen isotopes around $N = 14$. As it can be observed in Fig. 2, the fragment momentum distributions after one-neutron knockout become significantly narrower when we move from $N = 14$ to $N = 15$. This fact, already observed in previous measurements for ^{23}O [4], was understood in terms of a high purity of the $(d_{5/2})^6(s_{1/2})^1$ configuration. The results obtained for ^{22}N point out in the same direction. Even though the analysis of the experimental data has been completed, it needs to be complemented by theoretical calculations in order to draw up a precise interpretation.

Our results show an increase of the ^{22}N neutron-knockout cross-section and a very narrow momentum distribution, indicative of a neutron halo as already suggested in Refs. [5,6].

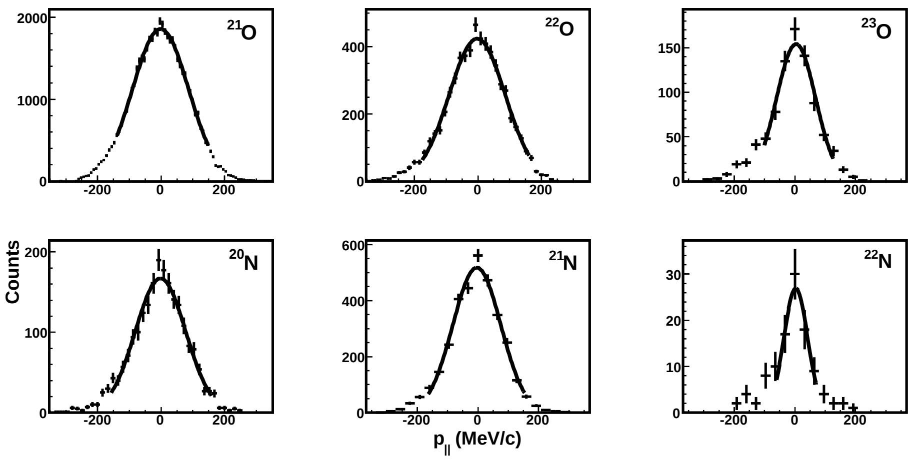

Fig. 2. Longitudinal momentum distributions for $N = 13$–15 isotones in the projectile co-moving frame. The full curves denote Gaussian fits to the central parts of the distributions.

4. Summary and conclusions

A neutron-knockout experiment has been performed at GSI in order to study the nuclear structure of light neutron-rich nuclei. The region around $N = 14$ is particularly interesting because $N = 14$ has been established as a new sub-shell closure. Within this context, we have studied oxygen and nitrogen isotopes up to ^{23}O and ^{22}N. For $N = 15$, we have found a narrow momentum distribution and larger knockout cross-sections compared to the $N = 14$ isotones. Our results are in excellent agreement with previous measurements of ^{23}O and indicate a similar structure for ^{22}N. Theoretical calculations will be performed to understand the structure of this latter nucleus and to explore the possibility of a one-neutron halo configuration.

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