REACTION DYNAMICS AND γ SPECTROSCOPY OF Ne ISOTOPES BY THE HEAVY ION REACTION ^{22}Ne+^{208}Pb*

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The heavy ion reaction ^{22}Ne+^{208}Pb at 128 MeV beam energy has been studied using the PRISMA-CLARA experimental setup at Legnaro National Laboratories. Aim of the experiment is the measurement of elastic, inelastic and one nucleon transfer cross sections. The data are presented in parallel with similar results for the unstable ^{24}Ne nucleus, using existing data from the reaction ^{24}Ne+^{208}Pb at 182 MeV (measured at SPIRAL with the VAMOS-EXOGAM setup). A comparison with angular distributions obtained by semiclassical and DWBA predictions for the quadrupole deformation parameter is also discussed. In particular, the DWBA analysis allowed to determine the $\beta_2^{\rm C}$ charge deformation parameter both in ^{22}Ne and ^{24}Ne.

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1. Introduction

Heavy ions play an important role in the study of nuclear reaction mechanisms and nuclear structure. In particular, multi-nucleon transfer reactions allow to investigate the properties of exotic systems, moving away from the valley of stability [1, 2]. For this purpose, many heavy ion reaction experiments have been performed in these years, making use of new technologies

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such as unstable ion beam accelerators and detectors of high efficiency [3–6]. In this work [7], the heavy ion reaction ^{22}Ne+^{208}Pb at 128 MeV beam energy is discussed. The analysis focused on the study of particle — γ coincidences aiming at the investigation of reaction mechanisms and nuclear structure properties of neutron rich Ne isotopes and neighbouring nuclei.

2. The analysis

The experiment has been performed at Legnaro National Laboratories of INFN, using the PRISMA-CLARA experimental setup [8] and a ^{22}Ne beam at 128 MeV ($\approx 25\%$ above the Coulomb barrier) impinging on a ^{208}Pb target, 300 μg/cm^2 thick [7]. The magnetic spectrometer PRISMA, described in Ref. [9], was coupled to the γ-array CLARA. This allowed particle-γ coincidence measurements for each ion detected in the magnetic spectrometer. The angular coverage of the PRISMA spectrometer is $\Delta\theta = 13°$ and our data have been collected for 5 different angles around the grazing angle $\theta_{\rm g} = 70°$.

The evaluation of absolute differential cross sections for elastic, inelastic and one-particle transfer channels has been performed following the method described in Ref. [10] and which was successfully applied in previous works [3, 6, 10]. Figure 1 (top) shows the inclusive (energy integrated) angular distribution of the most intense reaction channels.

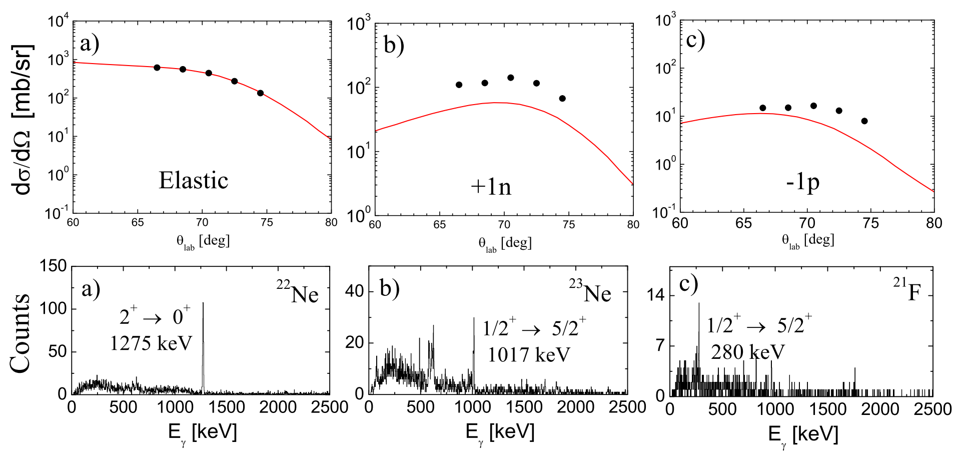

Fig. 1. Top: Inclusive (energy integrated) angular distributions for the most intense reaction channels ^{22}Ne, ^{23}Ne and ^{21}F (panels (a), (b) and (c)) compared with theoretical calculations (solid lines) using the semi-classical model GRAZING [11]. Bottom: γ spectra of ^{22}Ne, ^{23}Ne and ^{21}F (panel (a), (b) and (c), respectively) adapted from Ref. [7].

It is worth to notice that two-neutron pick-up and stripping has been observed but with very few counts not enough to perform an angular distribution. Experimental data are compared with theoretical calculation performed by the semiclassical GRAZING model [11] providing a global agreement between data and theory, which all scale with the same normalization factor determined in the elastic channel [7]. In Fig. 1 (bottom), the γ spectra measured by the CLARA array in coincidence with ^{22}Ne, ^{23}Ne, ^{21}F, the projectile-like fragments of the reaction ^{22}Ne+^{208}Pb, are presented.

In the case of ^{22}Ne, the differential cross section for the inelastic scattering to the 2^+ state has been determined. It has been interpreted using a DWBA model, implemented in the code PTOLEMY [12]. The results are shown in Fig. 2 and compared with a similar analysis performed on the 2^+ state of ^{24}Ne, measured at SPIRAL [6].

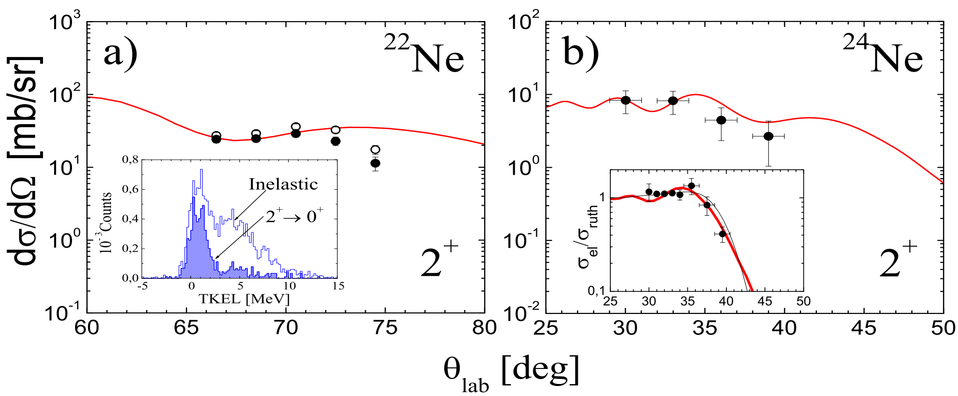

Fig. 2. Panel (a): Angular distribution of ^{22}Ne ions measured in coincidence with the $2^+ \rightarrow 0^+$ γ transition of 1275 keV. Filled (open) symbols refer to the analysis performed on the γ spectrum of ^{22}Ne taking (not taking) into account the feeding from high-lying states around 5 MeV. Inset of panel (a): Inelastic TKEL spectrum of ^{22}Ne and the contribution coming from the $2^+ \rightarrow 0^+$ γ-decay (shaded area). Panel (b): Angular distribution of ^{24}Ne, measured in coincidence with the $2^+ \rightarrow 0^+$ γ transition of 1982 keV. Inset of panel (b) shows the elastic over the Rutherford cross section of ^{24}Ne, as a function of the scattering angle [6]. Experimental data are indicated by symbols, while theoretical calculations performed by the code PTOLEMY [12] (GRAZING [11]) are given by thick (thin) lines. A similar plot for ^{22}Ne can be found in [7].

The DWBA analysis allowed to extract information on the $\beta_2^{\rm C}$ charge deformation parameter. It is found that ^{22}Ne has a rather large quadrupole deformation ($\beta_2^{\rm C} \approx 0.4$). On the contrary, a small value for the deformation parameter of ^{24}Ne is found ($\beta_2^{\rm C} \approx 0.1$). It is interesting to compare our $\beta_2^{\rm C}$

values with the charge deformation parameters derived from experimental $B(E2;0^+ \to 2^+)$ measurements. In Fig. 3 (a), we show by open circles the "adopted" $\beta_2^{\rm C}$ values [13], by open diamonds the results from a similar experiment [14] while filled circles refer to the most recent measurements, derived from Coulomb excitation experiments at MSU, RIKEN and ISOLDE [15–19]. These recent values are systematically lower than the adopted ones, clearly indicating the difficulty in determining experimentally a firm value for the $\beta_2^{\rm C}$ parameter. In Fig. 3 (b), we show the predictions for the deformation parameters of the ground state, $\beta_2^{\rm gs}$, obtained in three recent theoretical calculations (HF+BCS, Mean Field, relativistic HFB [20–22]). The models predict that the deformation decreases close to the middle of the *sd* shell, as a consequence of the closure of the $d_{5/2}$ subshell [23]. Our data may suggest a similar trend.

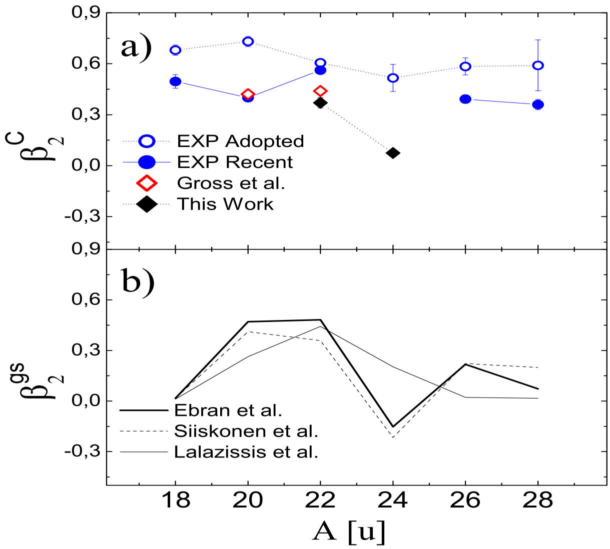

Fig. 3. Panel (a): Quadrupole deformation parameter $\beta_2^{\rm C}$ of the nuclear charge distribution for Ne isotopes compared with adopted values [13] and other experiments [14–19]. Panel (b): Predictions for the ground state deformation parameter $\beta_2^{\rm gs}$ [20–22].

3. Conclusion

In this paper, we have studied the dynamics of the heavy ion reaction ^{22}Ne+^{208}Pb at 128 MeV beam energy [7]. Elastic, inelastic and one nucleon transfer differential cross sections have been measured and compared with semiclassical and DWBA calculations, resulting in a global agreement between data and theory. A comparison with existing data from the

^{24}Ne+^{208}Pb has been done. The analysis provides a very small $\beta_2^{\rm C}$ value for ^{24}Ne. Such a result calls for additional experimental investigation on this nucleus, which is of key importance for the understanding of the evolution of the shell structure along the Ne isotopic chain.

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