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Reaction dynamics and nuclear structure of moderately neutron-rich Ne isotopes by heavy ion reactions

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Abstract. The heavy ion reaction ^{22}Ne+^{208}Pb at 128 MeV of bombarding energy has been studied using the PRISMA-CLARA experimental setup at Legnaro National Laboratories. Elastic, inelastic and one nucleon transfer cross sections have been measured. The experimental results are presented in parallel with the analysis on existing data for the unstable ^{24}Ne nucleus, from the reaction ^{24}Ne+^{208}Pb at 182 MeV (measured at SPIRAL with the VAMOS-EXOGAM setup). The β_2^C charge deformation parameter for both ^{22}Ne and ^{24}Ne has been determined by a DWBA analysis of the experimental angular distributions, showing a strong reduction for ^{24}Ne.

1 Introduction

Heavy ions play an important role in the study of nuclear structure and nuclear reaction mechanisms. In particular, multi-nucleon transfer reactions allow to investigate the properties of exotic systems, moving away from the valley of stability [1, 2]. Information on the deformation and the interplay between collective excitations and single particle motion are essential to understand the evolution of the structure towards the drip-lines. For this purpose many heavy ion reaction experiments have been performed in these years, making use of new technologies such as unstable ions beam accelerators and detectors of high efficiency [3–6]. In this work the heavy ion reaction ^{22}Ne+^{208}Pb at 128 MeV beam energy is presented [7]. The analysis focuses on the study of particle - γ coincidences aiming at the investigation of reaction mechanisms as well as nuclear structure properties of neutron rich Ne isotopes and neighbouring nuclei.

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2 Analysis and discussion

The experiment, performed at Legnaro National Laboratories of INFN using the PRISMA-CLARA experimental setup [8], employed a ^{22}Ne beam at 128 MeV impinging on a ^{208}Pb target 300 μg/cm^2 thick [7]. Each ion detected in the magnetic spectrometer PRISMA, described in Ref. [9], was measured in coincidence with γ-rays detected in the γ-array CLARA. The angular acceptance of the magnetic spectrometer ($\Delta\theta$=13°) allowed to collect data for five different angles around the grazing angle θ_g=70°. Following the method described in Ref. [10] and successfully applied in previous works [3, 6, 10], absolute differential cross sections for elastic, inelastic and one-particle transfer channels has been evaluated. Fig.1 shows the energy integrated angular distribution of the most intense reaction channels.

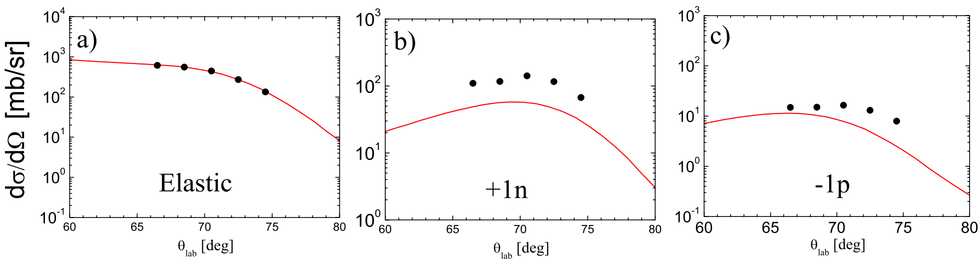

Figure 1. Inclusive (energy integrated) angular distributions for the most intense reaction channels ^{22}Ne, ^{23}Ne and ^{21}F (panels a), b) and c)) compared with theoretical calculations (solid lines) using the semi-classical model GRAZING [11].

Using the same scaling factor determined for the elastic channel [7], a global agreement between experimental data and theoretical calculation performed by the semiclassical GRAZING model [11] can be seen. These results show the validity of such a model for describing heavy-ion direct reactions also in this mass region. Due to particle - γ coincidences, the differential cross section for the inelastic scattering to the 2^+ state of ^{22}Ne has been determined. A similar analysis was performed for the 2^+ state of ^{24}Ne, measured at SPIRAL [6]. Experimental angular distributions have been interpreted using a DWBA model, implemented in the code PTOLEMY [12], employing the same optical parameters used to fit the elastic channel. Information about the structure of ^{22}Ne and ^{24}Ne can be extracted by the DWBA analysis. In particular the β_2^C charge deformation parameter has been determined. It is found that ^{22}Ne has a rather large quadrupole deformation ($\beta_2^C \approx 0.4$). On the other hand a small value for the deformation parameter of ^{24}Ne is observed ($\beta_2^C \approx 0.1$). The results are shown in Fig.2 where the sensitivity to β_2^C and β_2^N is also presented. Our β_2^C values have been compared with the charge deformation parameters derived from experimental B(E2;$0^+ \rightarrow 2^+$) measurements reported in literature. In Fig.3 a) we show by open circles the "adopted" β_2^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 [15–19]. These values are systematically lower than the adopted ones, indicating the difficulty in determining experimentally a firm value for the β_2^C parameter. In Fig.3 b) the predictions for the deformation parameters of the ground state, β_2^{gs}, obtained in three recent theoretical calculations (HF+BCS, Mean Field, relativistic HFB [20–22]) are shown. 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]. A similar trend is suggested by our data.

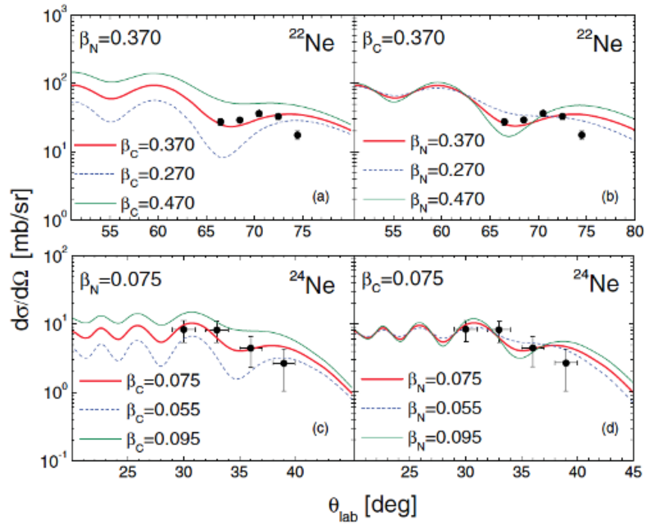

Figure 2. Angular distribution of [22]Ne and [24]Ne measured in coincidence with the correspondent $2^+ \rightarrow 0^+$ transitions. The sensitivity to β_2^C and β_2^N is investigated. Since the variation of β_2^N slightly affects the fit, the final assumption $\beta_2^C = \beta_2^N$ is made.

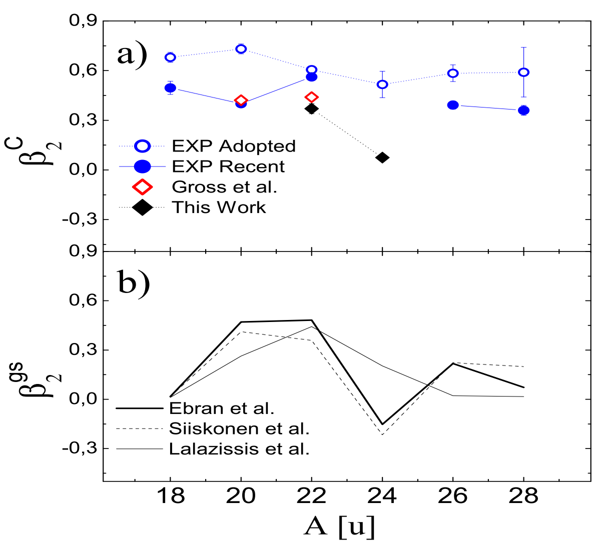

Figure 3. Panel a): Quadrupole deformation parameter β_2^C of the nuclear charge distribution for Ne isotopes compared with adopted values represented as open circles [13] and other more recent experiments [14–19]. Panel b): Predictions for the ground state deformation parameter β_2^{gs} [20–22], suggesting a minimum for [24]Ne in the evolution of Ne isotopic chain as we observed for the analysis of β_2^C (top panel)

3 Conclusion

In this work we have studied the dynamics of the heavy ion reaction ^{22}Ne+^{208}Pb at 128 MeV beam energy [7]. The measurement of elastic, inelastic and one nucleon transfer differential cross sections has been performed and the results have been compared with semiclassical and DWBA calculations, resulting in a global agreement. A similar analysis with existing data from the ^{24}Ne+^{208}Pb reaction has been also done. The results provide a very small β_2^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 and towards the neutron drip-line. The work shows the importance of heavy-ion direct reactions in connection with neutron-rich nuclei. Similar techniques can be used in the future to explore more and more exotic regions.

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