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Colloquia: COMEX7

Investigation of ^{76}Se(^{18}O, ^{17}O)^{75}Se and ^{76}Se(^{18}O, ^{19}F)^{75}As transfer reactions at 15 MeV/u in a multi-channel approach within the NUMEN project

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Summary. — A full-comprehensive study of heavy-ion induced nuclear reactions is a powerful tool to characterize nuclear mean-field features as well as few-nucleon correlations in low-lying nuclear states. In this context, the investigation of ^{76}Se(^{18}O, ^{17}O)^{75}Se and ^{76}Se(^{18}O, ^{19}F)^{75}As transfer reactions was performed with the NUMEN project, aiming at providing data-driven information to constrain nuclear structure models for the ^{76}Se nucleus. This nucleus is under investigation since it is the daughter nucleus of ^{76}Ge in the neutrinoless double beta decay ($0\nu\beta\beta$) process. The experiment was performed at INFN-LNS where the ^{18}O beam impinged the ^{76}Se target and the reaction ejectiles were momentum analyzed by the MAGNEX magnetic spectrometer.

1. – Introduction

The heavy-ion induced one-nucleon transfer reactions provide a quantitative access to the relevant single particle orbitals and core polarization correlations. This feature is particularly relevant, since it provides data-driven information to constrain nuclear structure models for different nuclei. In this perspective, different systems have been systematically investigated at the Istituto Nazionale di Fisica Nucleare - Laboratori Nazionali del Sud (INFN-LNS) (Italy) by the (^{18}O, ^{17}O) and (^{18}O, ^{19}F) reactions at incident energies ranging from 84 to 275 MeV [1-10]. Thanks to the MAGNEX large acceptance magnetic spectrometer [11-13], used to detect the ejectiles, many nuclear systems were explored obtaining high quality inclusive spectra.

The ^{76}Se(^{18}O,^{17}O)^{77}Se one-neutron stripping and ^{76}Se(^{18}O,^{19}F)^{75}As one-proton pick-up reactions were studied in the frame of the NUMEN (NUclear Matrix Elements for Neutrinoless double beta decay) [14] and NURE (NUclear REactions for neutrinoless double beta decay) [15] projects in 2018. NUMEN was conceived at INFN-LNS in Catania, aiming at accessing information about the nuclear matrix elements (NME) of neutrinoless double beta decay ($0\nu\beta\beta$) [16, 17] through the study of the heavy-ion induced double charge exchange (DCE) reactions on various $0\nu\beta\beta$ decay candidate targets [18,19]. Among these, the ^{76}Se nucleus is under investigation since it is the daughter nucleus of ^{76}Ge in the $0\nu\beta\beta$ decay process. Adopting a multi-channel reaction approach [7, 20, 21], several quasi-elastic processes are simultaneously studied from both the experiment and theory side. This allows to characterize nuclear mean field as well as few-nucleon correlations in low-lying nuclear states.

2. – Experiment and method

A ^{18}O^{8+} beam provided by the Superconducting Cyclotron at 15 MeV/A incident energy was sent to the MAGNEX scattering chamber where it impinged on the ^{76}Se target. This was composed by ^{76}Se (270 μg/cm^2) evaporated on a natural carbon foil (80 μg/cm^2), consequently an interaction of the ^{18}O beam with ^{12}C nuclei was also expected. In order to estimate and subtract the contribution coming from the ^{12}C backing, a supplementary measurement on a natural carbon target (400 μg/cm^2) was performed in the same experimental condition. The reaction ejectiles and residual nuclei were

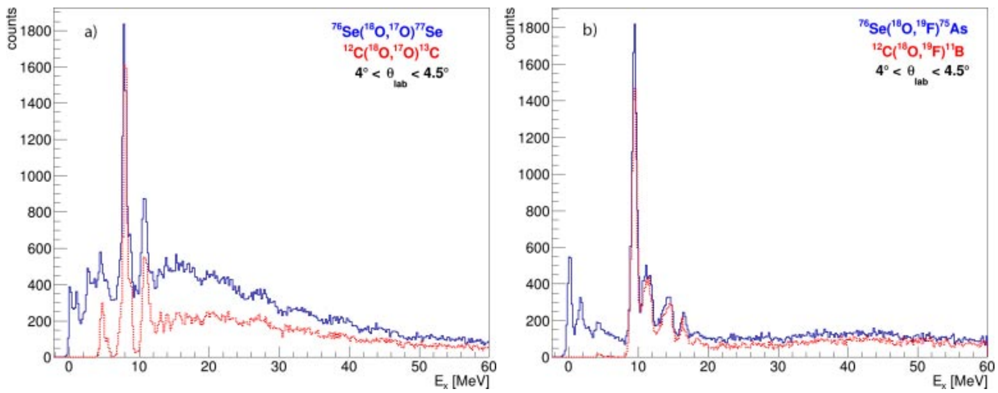

Fig. 1. – (a) Excitation energy spectrum for the ^{76}Se(^{18}O,^{17}O)^{77}Se (in blue) and ^{12}C(^{18}O,^{17}O)^{13}C (in red) reactions. (b) Excitation energy spectrum for the ^{76}Se(^{18}O,^{19}F)^{75}As (in blue) and ^{12}C(^{18}O,^{19}F)^{11}B (in red) reactions.

analyzed by the MAGNEX magnetic spectrometer. The focal plane detector [22] measured the incident angles, the vertical and horizontal positions and provided the particle identification. The detected particle were identified and their trajectories reconstructed through specific techniques [23-26]. In particular, the ^{17}O ejectiles were identified in the ^{76}Se(^{18}O,^{17}O)^{77}Se and ^{12}C(^{18}O,^{17}O)^{13}C reactions whereas the ^{19}F ejectiles in the ^{76}Se(^{18}O,^{19}F)^{75}As and ^{12}C(^{18}O,^{19}F)^{11}B ones. The ray reconstruction technique was performed using the same transport map of the reactions with ^{76}Se target and the same kinematics [26]. This last point is fundamental to subtract the ^{12}C as a background in the energy spectra of ^{76}Se.

For ^{76}Se(^{18}O,^{17}O)^{77}Se and ^{76}Se(^{18}O,^{19}F)^{75}As transfer reactions the excitation energy E_x and the Q-value were extracted by missing mass calculations based on momentum conservation and relativistic energy laws: $E_x = Q_0 - Q$ (where Q_0 is the ground-to-ground state reaction Q-value). The excitation energy spectra for the studied reactions on ^{76}Se target are plotted in fig. 1 together with the events due to the ^{12}C target. The background contribution is not negligible and it must be subtracted using a normalization factor properly determined. The peaks related to the reaction on ^{12}C are integrated in each spectra (blue and red) and then the ratio between the two integrated values gives the normalization factor. After the subtraction of the background, the absolute differential cross section spectra and the related angular distribution have been extracted [5, 10].

3. – Theoretical study

From the theory side, the angular distribution data were analyzed within the Distorted-Wave Born Approximation (DWBA) framework [5, 8, 10]. Different reaction models were adopted: Distorted Wave Born Approximation (DWBA), Coupled Channel Born Approximation (CCBA) and Coupled Reaction Channel (CRC). The good description of the experimental data without adopting any scaling factor suggested that the reaction mechanism is under control. The optical potential for the system ^{18}O + ^{76}Se is calculated according to the elastic and inelastic scattering analysis, showing that the inclusion of the excited states of projectile and target in the coupling scheme is relevant [27]. Moreover, the spectroscopic amplitudes for target overlaps were derived by two different nuclear structure models, the large-scale shell model and the interacting boson-fermion model. Adopting the same model space and reaction mechanism, the one-nucleon transfer reaction data were found to be sensitive to different nuclear structure models [5, 8, 10]. Therefore, this study is envisaged also for single and double charge exchange reactions.

4. – Conclusions

The study of one-nucleon transfer reactions populated in the collision ^{18}O + ^{76}Se was performed in a multi-channel approach. The achieved results suggest that the experimental and theoretical analysis is envisaged for accurate description of the complete network of nuclear reaction data, including charge-exchange reactions.

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