Recent results on the analysis of the ^{48}Ti(^{18}O,^{20}Ne)^{46}Ca reaction at 275 MeV

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Abstract. The ^{18}O+^{48}Ti reaction was studied at the energy of 275 MeV for the first time under the NUMEN and NURE experimental campaigns with the aim of investigating the complete reaction network potentially involved in the ^{48}Ti→^{48}Ca double charge exchange transition. Understanding the degree of competition between successive nucleon transfer and double charge exchange reactions is crucial for the description of the meson exchange mechanism. Into this context, angular distribution measurements for one- and two-nucleon transfer reactions for the system ^{18}O+^{48}Ti were performed at the MAGNEX facility of INFN-LNS in Catania. An overview of the status of the analysis for the two-proton transfer reaction will be given.

1. Introduction

Over the past decades, the search for the neutrinoless double beta ($0\nu\beta\beta$) decay continues with undiminished interest, since it is the best probe of the neutrino nature. Numerous experimental campaigns from all over the globe are seeking evidence of such a rare process using different candidate nuclei for $0\nu\beta\beta$ decay [1, 2, 3, 4]. Among them, NUMEN (NUclear Matrix Elements for Neutrinoless double beta decay) campaign [5, 6], carried out at INFN-LNS in Catania, proposes for the first time the use of double charge exchange (DCE) reactions induced by heavy ions as a mean to obtain data-driven information on the nuclear matrix elements (NMEs) for various $0\nu\beta\beta$ decay target candidates. Into this context, the ^{48}Ti nucleus is of great interest since it is the daughter nucleus of ^{48}Ca in the $0\nu\beta\beta$ decay process [7].

The one-step DCE reaction is one of the possible pathways of the complete DCE mechanism, since the same final states may be populated through a sequence of multi-nucleon transfer reactions and/or double single charge exchange (DSCE). A theoretical study [8] for the ^{18}O+^{40}Ca collision suggested the combination of single charge exchange (SCE) with sequential one-proton and one-neutron transfer reactions as a possible process in the leading order in the ^{18}O + ^{40}Ca$\rightarrow^{18}$Ne + ^{40}Ar transition. In a recent study [9] it was demonstrated that the sequential multi-nucleon transfer gives a negligible contribution to the total DCE cross-section in the ^{20}Ne + ^{116}Cd$\rightarrow^{20}$O + ^{116}Sn transition at 306 MeV. However, it is very important to quantify the degree of competition between the direct meson exchange mechanism [10, 11] and other competitive processes [12, 13, 14, 15, 16, 17, 18] for a precise determination of the absolute DCE cross-sections, which may be the key for accessing the information of the NMEs of the $0\nu\beta\beta$ decay [19, 20, 21].

Taking into consideration all the above, in the present work which is part of the NURE project [22], the ^{18}O+^{48}Ti reaction was studied by measuring in the same experiment the complete net of the available reaction channels that may be involved in the ^{48}Ti$\rightarrow^{48}$Ca DCE transition, namely, elastic and inelastic scattering, SCE, single- and two-nucleon transfer reactions. The present article provides an overview of the strategy adopted for the data analysis of the ^{48}Ti(^{18}O,^{20}Ne)^{46}Ca two-proton transfer reaction channel. The complete analysis of the ^{48}Ti(^{18}O,^{19}F)^{47}Sc one-proton transfer reaction channel can be found in Ref. [23], while the analyses for the rest of the reaction channels is in progress [24, 25].

2. Experimental details

The experiment was conducted at INFN-LNS in Catania, where an $^{18}O^{8+}$ ion beam at the energy of 275 MeV impinged a TiO_2 target evaporated on a thin ^{27}Al foil. To this purpose, additional measurements with a ^{27}Al target and a WO_3 target with an aluminium backing were performed for estimating the background contributions arising from the different target components.

The various reaction ejectiles were momentum analyzed by the MAGNEX large acceptance magnetic spectrometer [26] and detected by its Focal Plane Detector (FPD) [27]. The FPD is a hybrid detection system composed of two sectors. The first part is a gas detector acting as a proportional drift chamber providing information on the energy of the ions lost inside the gas (ΔE_{tot}) and also as a position-sensitive detector for the measurement of the horizontal and vertical positions and angles of the ions' track. The second part of the FPD comprises a wall of 60 silicon detectors for the measurement of the ions' residual energy (E_{resid}). Using the information provided by the FPD, the particle identification (PID) is performed following the prescription reported in Ref. [28]. An example of the PID procedure is illustrated in Fig. 1 for the case of the ^{48}Ti(^{18}O,^{20}Ne)^{46}Ca reaction.

3. Data reduction

Having identified the $^{20}Ne^{10+}$ events, a high-order software ray reconstruction is applied to the data and the momentum vector of the ions at the target position is determined [29]. Having

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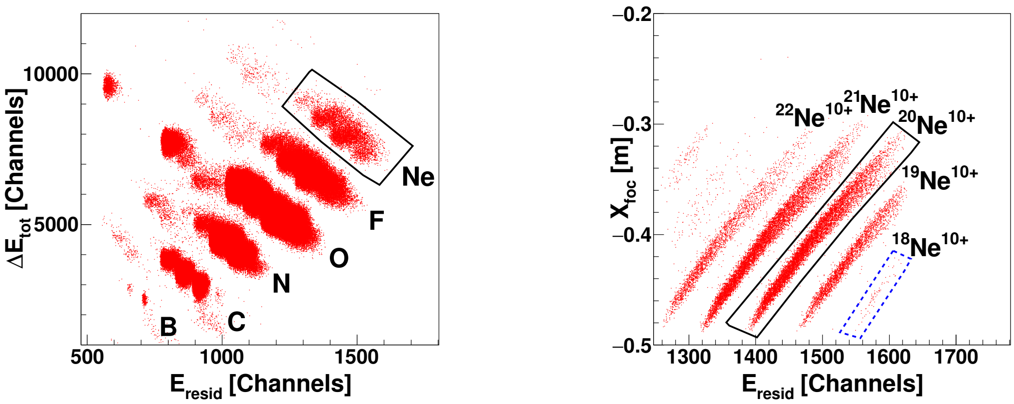

Figure 1. An example of PID spectra for the ^{48}Ti(^{18}O,^{20}Ne)^{46}Ca reaction measured at 275 MeV. Left panel) Typical ΔE_{tot} - E_{resid} plot gated by one silicon detector of the FPD. The neon contour is highlighted with the solid black line. Right panel) Correlation plot between the horizontal position at the focal plane of the spectrometer, X_{foc}, and the E_{resid} for the identified neon ions of the left panel. The various loci represent ions with different ratio $\sqrt{m}$/q. The ^{20}Ne^{10+} and ^{18}Ne^{10+} events are indicated by the solid black and dotted blue lines, respectively.

known the momentum vector, the excitation energy spectrum may be obtained as E_x= Q_0 - Q, where Q_0 is the ground state (g.s.) to g.s. Q-value and Q is the reaction Q-value calculated adopting the missing mass method [26]. A preliminary E_x spectrum is shown in Fig. 2. After $E_x \approx$ 3.0 MeV events coming from the two-proton transfer reaction on ^{27}Al and ^{16}O components of the target are present in the spectrum. However, measurements with an aluminium and oxygen target were repeated in order to estimate and subtract such events. A preliminary E_x spectrum for the two-proton transfer reaction on ^{27}Al is also shown in Fig. 2. The analysis of the data obtained with the oxygen target is still in progress. It can be seen that the yield in the low-lying excitation energy region in both spectra is exhausted by ^{20}Ne states, as observed previously in Ref. [13] for the same reaction on a ^{40}Ca target. Based on that it seems that the (^{18}O,^{20}Ne) reaction favors the population of ^{20}Ne states regardless of transition undertaken from the target. After subtracting the contaminant events, experimental angular distribution cross-sections for the ^{48}Ti(^{18}O,^{20}Ne)^{46}Ca reaction will be extracted and analyzed under the proper reaction frameworks as done previously in Refs. [12, 13], in order to quantify the contribution of simultaneous and sequential nucleon transfer in the measured two-proton transfer cross-sections. To this purpose, data for the (^{18}O,^{19}F) one-proton transfer reaction [23] are crucial in order to constrain the reaction probability of the sequential mechanism (^{18}O$\rightarrow$^{19}F$\rightarrow$^{20}Ne).

4. Summary

A global study of the ^{18}O+^{48}Ti reaction at 275 MeV was performed for the first time as part of the NUMEN and NURE experimental campaigns by measuring the complete net of the available reaction channels. Angular distribution measurements for the various reaction ejectiles were performed by means of the MAGNEX magnetic spectrometer. The present contribution is focused on the analysis of the two-proton transfer reaction, where a preliminary excitation energy spectrum for the low-lying states involved in the ^{48}Ti(^{18}O,^{20}Ne)^{46}Ca reaction was obtained. The background subtraction procedure is in progress and upon its completion we will gain access to the high excitation energy region of the spectrum. The results of this analysis in conjunction with the ones for the two-neutron transfer reaction will provide the appropriate constraints on the DCE mechanism in the ^{48}Ti(^{18}O,^{18}Ne)^{48}Ca transition.

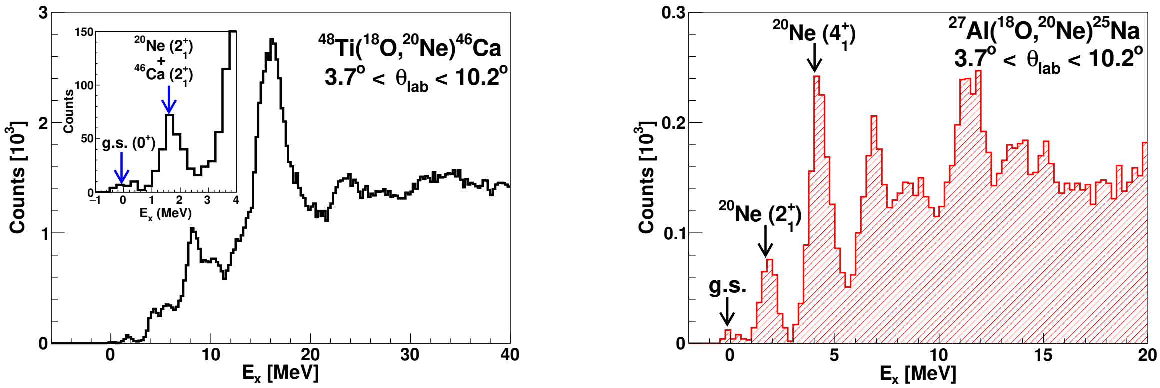

Figure 2. Left panel) Preliminary excitation energy spectrum corresponding to the ^{48}Ti(^{18}O,^{20}Ne)^{46}Ca reaction at 275 MeV. In the inset, the region corresponding to -1<E$_x$<4 MeV is shown. Figure taken from Ref. [24]. Right panel) Same as in figure on the left panel, but for the ^{27}Al(^{18}O,^{20}Ne)^{25}Na reaction.

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