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Colloquia: COMEX7

Elastic scattering angular distribution for the ^{18}O + ^{48}Ti collision at 275 MeV within the NUMEN project

G. A. Brischetto(1)(2), (*) O. Sgouros(1)(2), D. Carbone(1),
F. Cappuzzello(1)(2), M. Cavallaro(1), J. Lubian(3), G. De Gregorio(4)(5),
C. Agodi(1), D. Calvo(6), E. R. Chávez Lomeli(7), I. Ciraldo(1),
F. Delaunay(1)(2)(8), H. Djapo(9), C. Eke(10), P. Finocchiaro(1),
M. Fisichella(1), A. Gargano(4), M. A. Guazzelli(11), A. Hacisalihoglu(12),
R. Linares(3), N. H. Medina(13), M. Moralles(13), J. R. B. Oliveira(14),
A. Pakou(15), L. Pandola(1), V. Soukeras(1)(2), G. Souliotis(16),
A. Spatafora(1), D. Torresi(1), A. Yildirim(17) and V. A. B. Zagatto(14)
for the NUMEN Collaboration

(1) *Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali del Sud - Catania, Italy*
(2) *Dipartimento di Fisica e Astronomia "Ettore Majorana", Università di Catania - Catania, Italy*
(3) *Instituto de Fisica, Universidade Federal Fluminense - Niteroi, Brazil*
(4) *Istituto Nazionale di Fisica Nucleare, Sezione di Napoli - Napoli, Italy*
(5) *Dipartimento di Matematica e Fisica, Università della Campania "Luigi Vanvitelli" Caserta, Italy*
(6) *Istituto Nazionale di Fisica Nucleare, Sezione di Torino - Torino, Italy*
(7) *Instituto de Física, Universidad Nacional Autónoma de México - Mexico City, Mexico*
(8) *Université de Caen Normandie, ENSICAEN, CNRS/IN2P3, LPC Caen UMR6534 - Caen, France*
(9) *Ankara University, Institute of Accelerator Technologies - Ankara, Turkey*
(10) *Department of Mathematics and Science Education, Faculty of Education, Akdeniz University - Antalya, Turkey*
(11) *Centro Universitario FEI - Sao Bernardo do Campo, Brazil*
(12) *Department of Physics, Recep Tayyip Erdogan University - Rize, Turkey*
(13) *Instituto de Pesquisas Energeticas e Nucleares IPEN/CNEN - Sao Paulo, Brazil*
(14) *Instituto de Fisica, Universidade de Sao Paulo - Sao Paulo, Brazil*
(15) *Department of Physics, University of Ioannina and Hellenic Institute of Nuclear Physics Ioannina, Greece*
(16) *Department of Chemistry, University of Athens and Hellenic Institute of Nuclear Physics Athens, Greece*
(17) *Department of Physics, Akdeniz University - Antalya, Turkey*

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(*) E-mail: `giuseppe.brischetto@lns.infn.it`

Summary. — In the context of the NUMEN project, the ^{18}O + ^{48}Ti collision at 275 MeV incident energy was studied for the first time. In the adopted multichannel approach, the elastic scattering was measured in order to deduce the initial state interaction and the corresponding optical potential. The angular distribution of elastic scattering was determined across a wide range of scattering angles.

1. – Introduction

A renewed interest in double charge exchange (DCE) reactions has been raised in virtue of the close analogies to neutrinoless double beta ($0\nu\beta\beta$) decay [1, 2]. Indeed, the study of DCE could help to probe the nuclear transitions occurring in double beta decay processes. In this scenario, the NUMEN (NUclear Matrix Elements for Neutrinoless double beta decay) [3, 4] and NURE (NUclear REactions for neutrinoless double beta decay) [5] projects were proposed at the Laboratori Nazionali del Sud of the Istituto Nazionale di Fisica Nucleare (INFN-LNS). The objective of these projects is to obtain information on the nuclear matrix elements of $0\nu\beta\beta$ decay through an experimental method that involves the measurement of heavy-ion DCE cross sections [6, 7]. To fully understand the DCE reaction mechanism, it is necessary to analyze a wide set of reaction channels, including elastic and inelastic scattering, one- and two-nucleon transfer [8-14], and single charge exchange reactions. This requires a multichannel approach that involves both experimental measurements and theoretical analysis [1, 15, 16]. A crucial ingredient for the description of the aforementioned nuclear reactions is the initial state interaction, that accounts for the distortion of the incoming wave [17, 18]. To this extent, the determination of the optical potential through the analysis of the elastic scattering channel is central for the NUMEN strategy. In this work, the elastic scattering experimental angular distribution cross section for the ^{18}O + ^{48}Ti collision at 275 MeV incident energy is presented for the first time.

2. – Experimental set-up and data reduction

The $^{18}O^{8+}$ beam was accelerated at 275 MeV incident energy by the K800 superconducting cyclotron of the INFN-LNS in Catania. The beam impinged on a target composed of a 510 μg/cm^2 thick TiO_2 foil, evaporated on a 216 μg/cm^2 thick aluminum layer. Supplementary measurements with WO_3 + ^{27}Al and ^{27}Al targets were performed in order to evaluate the background produced by the interaction of the ^{18}O beam with the oxygen and the aluminum target components. A copper Faraday cup (FC) was used to stop the beam and collect the total charge in each run. The ^{18}O ejectiles were analysed in momentum by the MAGNEX large acceptance magnetic spectrometer [19] and measured by its focal plane detector (FPD) [20]. The elastic scattering data were collected in three different data sets, where the MAGNEX optical axis (θ_{opt}) was rotated by 9°, 15°, and 21° relative to the beam direction. Therefore, a total angular range extending from 4° to 27° in the laboratory reference frame was explored, which corresponds to the angular region between 6° and 37° in the centre-of-mass (c.m.) one. The MAGNEX angular

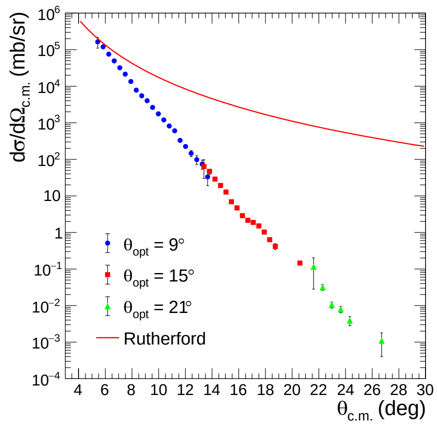

Fig. 1. – Cross-section angular distribution for the ^{18}O + ^{48}Ti elastic scattering at 275 MeV. The three explored angular ranges are highlighted with different colors and markers. The Rutherford differential cross-section is also shown (red line).

acceptance was set to its maximum value (50 msr) for $\theta_{opt} = 15°$ and 21°; instead, for $\theta_{opt} = 9°$, it was reduced in order to have an event rate sustainable by the FPD.

In this study, the data reduction strategy described in refs. [21, 22] was followed. First of all, the calibration of the horizontal and vertical positions measured by the FPD was performed. Then, an unambiguous selection of the $^{18}O^{8+}$ ejectiles was obtained by employing a particle identification procedure based on the combined use of the standard $\Delta E - E$ method and of a technique exploiting the properties of the Lorentz force [23]. For each identified particle, the trajectory was reconstructed by solving the equation of motion to the 10th order, allowing to deduce the momentum vector at the target position for each event [24]. This permits to determine the excitation energy spectrum and the cross section angular distribution.

3. – Results

The experimental cross-section angular distribution of the elastic scattering for the three explored angular settings is shown in fig. 1. As can be noticed, they are in good agreement with each other. The measured elastic angular distribution varies of eight orders of magnitude in the overall angular range covered, which extends from 5° to 27° in the c.m. reference frame. The error bars include contributions from the statistical error, the fitting procedure, and the solid angle evaluation. The systematic error due to uncertainties in the measure of the total charge with the FC and in the evaluation of the target thickness was estimated to be less than 10% and it is not explicitly considered in the error bars, since it is common to all the experimental points. In fig. 1, the Rutherford differential cross-section is also illustrated. The experimental point at very forward angles shows a good overlap with the Rutherford cross section without the use of any normalization factor. This indicates a small systematic error in the absolute cross section measurement, as found in heavier systems [25, 26]. The elastic scattering cross section is expected to closely follow the Rutherford formula in the region below the grazing angle ($\theta^g_{c.m.} \approx 7.6°$), where the Coulomb field is more important. Above the grazing, deviation from Rutherford scattering is due to nuclear absorption phenomena.

4. – Conclusions

The ^{18}O + ^{48}Ti elastic scattering at 275 MeV incident energy was studied for the first time within the NUMEN project. The ^{18}O ejectiles were momentum analyzed by the MAGNEX magnetic spectrometer and detected by its focal plane detector. The elastic scattering angular distribution was measured. A broad range of scattering angles was explored in only three angular settings thanks to the large acceptance of MAGNEX. At very forward angles, the agreement between the experimental angular distribution and the Rutherford one indicates that the experimental cross section was extracted with a negligible systematic error. Theoretical calculations within the distorted wave Born approximation and the coupled channels frameworks will be performed to study the optical potential and to access the initial state interaction of the system [25-29].

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