Study of single-nucleon transfer reactions in the $^{18}O+^{48}Ti$ collision at 275 MeV

O. Sgouros[1,*], M. Cutuli[1,2], M. Cavallaro[1], F. Cappuzzello[1,2], D. Carbone[1], C. Agodi[1], A. Gargano[3], G. De Gregorio[3,4], C. Altana[1], G. A. Brischetto[1,2], S. Burrello[5,6], S. Calabrese[1,2], D. Calvo[7], V. Capirossi[7,8], E. R. Chávez Lomelí[9], I. Ciraldo[1,2], F. Delaunay[1,2,10], H. Djapo[11], C. Eke[12], P. Finocchiaro[1], M. Fishichella[1], A. Foti[13], A. Hacisalihoglu[14], F. Iazzi[7,8], L. La Fauci[1,2], R. Linares[15], J. Lubian[15], N. H. Medina[16], M. Moralles[17], J. R. B. Oliveira[16], A. Pakou[18], L. Pandola[1], F. Pinna[7,8], G. Russo[2,13], M. A. Guazzelli[19], V. Soukeras[1], G. Souliotis[20], A. Spatafora[1,2], D. Torresi[1], A. Yildirim[21] and V. A. B. Zagatto[15]
for the NUMEN collaboration

[1] INFN - Laboratori Nazionali del Sud, Catania, Italy, [2] Dipartimento di Fisica e Astronomia "Ettore Majorana", Università di Catania, Catania, Italy, [3] INFN - Sezione di Napoli, Napoli, Italy, [4] Dipartimento di Matematica e Fisica, Università della Campania "Luigi Vanvitelli", Caserta, Italy, [5] Université Paris-Saclay, CNRS/IN2P3, IJCLab, Orsay, France, [6] Technische Universität Darmstadt, Institut für Kernphysik, Darmstadt, Germany, [7] INFN - Sezione di Torino, Torino, Italy, [8] DISAT - Politecnico di Torino, Torino, Italy, [9] Instituto de Física, Universidad Nacional Autónoma de México, Mexico City, México, [10] LPC Caen, Normandie Université, ENSICAEN, UNICAEN, CNRS/IN2P3, Caen, France, [11] Ancara University, Institute of Accelerator Technologies, Turkey, [12] Department of Mathematics and Science Education, Faculty of Education, Akdeniz University, Antalya, Turkey, [13] INFN - Sezione di Catania, Catania, Italy, [14] Institute of Natural Sciences, Karadeniz Teknik Universitesi, Trabzon, Turkey, [15] Instituto de Física, Universidade Federal Fluminense, Niterói Brazil, [16] Instituto de Física, Universidade de São Paulo, São Paulo, Brazil, [17] Instituto de Pesquisas Energeticas e Nucleares IPEN/CNEN, São Paulo, Brazil, [18] Department of Physics, University of Ioannina and Hellenic Institute of Nuclear Physics, Ioannina, Greece, [19] Centro Universitario FEI, São Bernardo do Campo, Brazil, [20] Department of Chemistry, University of Athens and Hellenic Institute of Nuclear Physics, Athens, Greece, [21] Department of Physics, Akdeniz Universitesi, Antalya, Turkey

*e-mail: onoufrios.sgouros@lns.infn.it

Motivation-Introduction

NUclear Matrix Elements for Neutrinoless double beta decay (0νββ)

✓ **NUMEN** [1] is an innovative project aiming at accessing information on the **Nuclear Matrix Elements** (NMEs) of the **0νββ decay** through the study of heavy-ion induced **Double Charge Exchange** (DCE) reactions.

✓DCE reactions and 0νββ decay are mediated by different interactions **BUT** they exhibit some interesting similarities. Among them, both processes probe the same initial and final nuclear wave functions and the operators connecting them have a similar spin – isospin mathematical structure [2,3].

✓Transfer reactions: Competing processes leading to the same final states as DCE reactions. Their study can provide information on the degree of competition between successive nucleon transfer and charge exchange reactions, the latter being of particular interest in the context of single and double beta decay studies [4,5].

✓The $^{18}O+^{48}Ti$ reaction was studied at the energy of 275 MeV for the first time under the NUMEN and NURE [6] experimental campaigns with the aim of investigating the complete net of reaction channels potentially involved in the $^{48}Ti \rightarrow ^{48}Ca$ DCE transition.

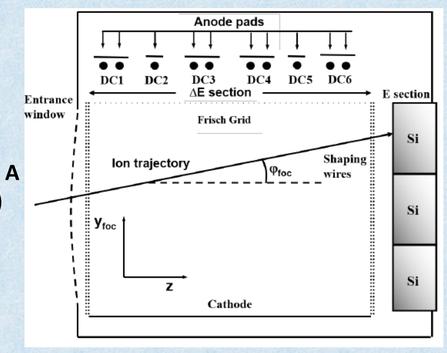
Experimental setup: The MAGNEX facility @ INFN-LNS

- Beam: $^{18}O^{8+}$ accelerated at 275 MeV.
- Target: TiO_2 evaporated on a thin ^{27}Al foil.
- Background estimation: 2 additional runs with a WO_3 and a ^{27}Al target.
- The reaction ejectiles were detected by the MAGNEX Focal Plane Detector (FPD).

Optical characteristics of MAGNEX

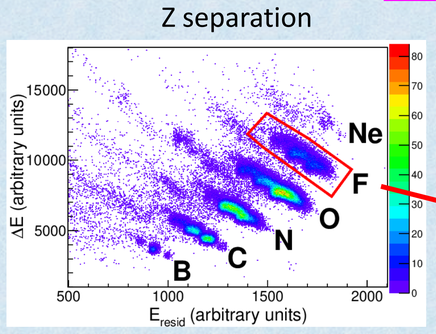
Max. magnetic rigidity (Tm)	1.8
Solid angle (msr)	50
Momentum acceptance	-14%, +10%
Energy resolution (ΔE/E)	~1/1000
Angular resolution	~ 0.3°
Mass resolution	~ 1/160

Lateral view of the MAGNEX FPD
D. Torresi et al., NIM A 989, 164918 (2021)

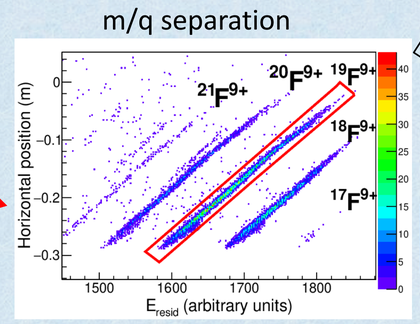


Particle identification (PID)

Z separation



m/q separation

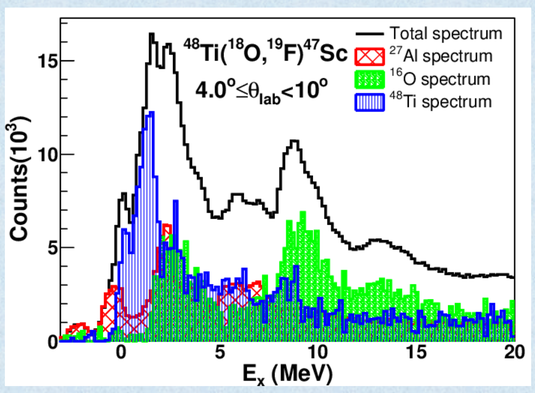


Further details for PID in Ref. [7]

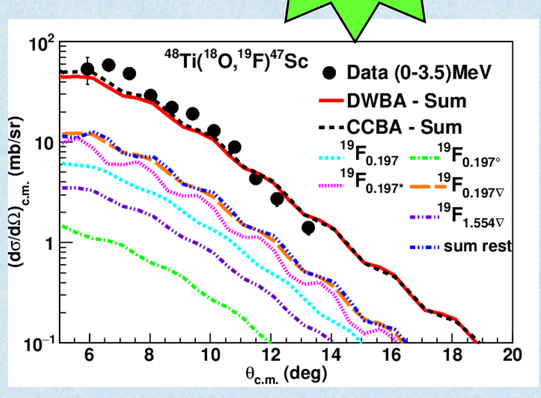
$$B\rho = \frac{p}{q} \Rightarrow x_{foc}^2 \propto \frac{m}{q^2} E_{resid}$$

Results - $^{48}Ti(^{18}O,^{19}F)^{47}Sc$ reaction

Results accepted for publication in PRC



Decomposition of the excitation energy spectrum obtained with the $TiO_2+^{27}Al$ target for the one-proton transfer reaction.



Present angular distribution cross-section data for the excitation energy range (0-3.5)MeV are compared to the results of a DWBA and a CCBA calculation.

DWBA framework

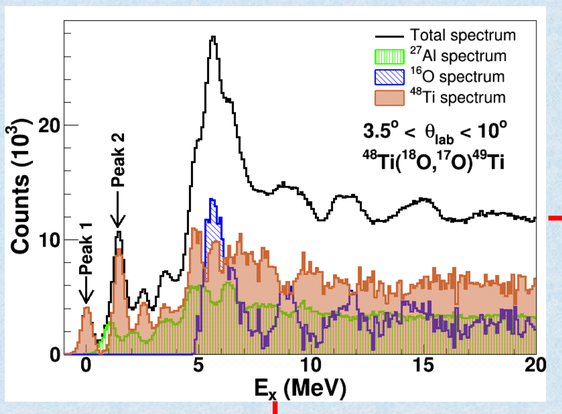
The main ingredients of the DWBA calculation are:
➢The distorted waves at the entrance and exit channels → Calculated adopting the São Paulo Potential (SPP) [8].
➢The overlap functions: Single particle solutions of a Woods-Saxon potential weighted by the corresponding spectroscopic amplitudes provided by many body shell-model calculations.

CCBA framework

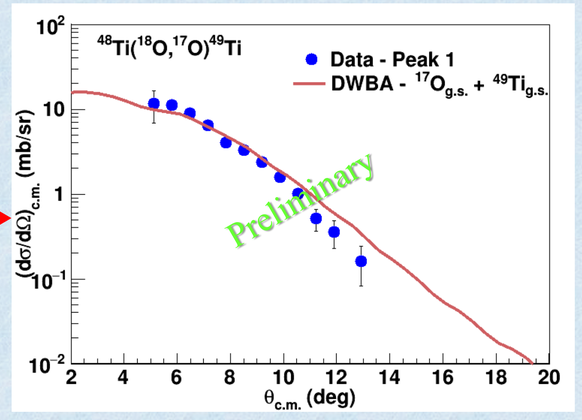
A CCBA calculation is performed in the same way as the DWBA one considering also the following additions:
➢Coulomb deformations: Introduced in terms of the reduced transition probabilities B(Eλ).
➢Nuclear couplings: The nuclear coupling potentials were treated in the first-order approximation as described in Ref. [9].

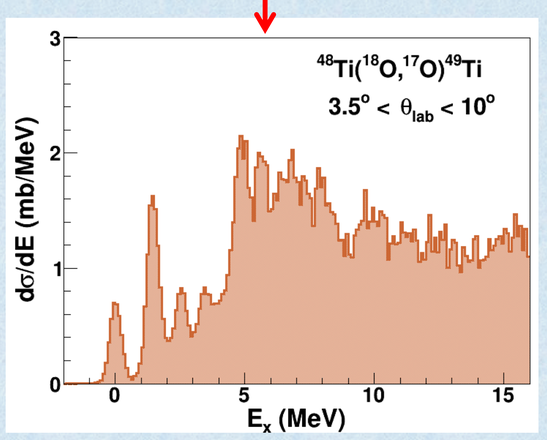
Results - $^{48}Ti(^{18}O,^{17}O)^{49}Ti$ reaction

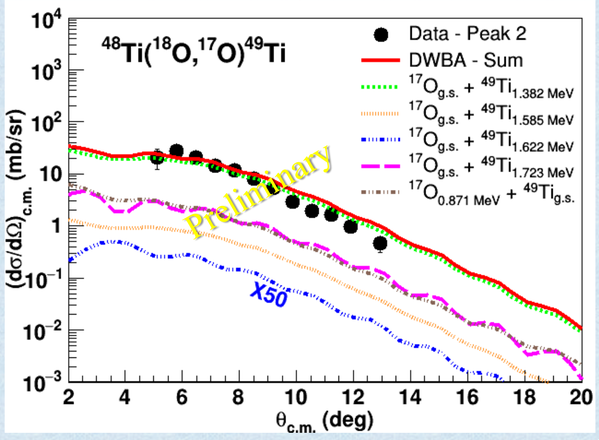
Energy spectra



Angular distributions







Concluding Remarks and perspectives

✓ The theoretical cross-sections are found to be in very good agreement with the experimental data suggesting the validity of the adopted optical potentials and the shell-model description of the involved nuclear states within the adopted model space.
✓The same technique will be also tested through the data set of the two-proton transfer channel.
✓The results of the present analysis in the $^{18}O+^{48}Ti$ reaction will clarify the degree of competition between the direct SCE mechanism (^{18}O,^{18}F) and the sequential nucleon transfer.

References

[1] F. Cappuzzello, C. Agodi, M. Cavallaro et al., Eur. Phys. J. A **54**, 72 (2018).
[2] E. Santopinto, H. Garcia-Tecocoatzi, R. I. Magana Vsevolodovna et al., Phys. Rev. C **98**, 061601(R) (2018).
[3] H. Lenske, F. Cappuzzello, M. Cavallaro et al., Prog. Part. Nucl. Phys. **109**, 103716 (2019).
[4] M. Cavallaro, J. I. Bellone, S. Calabrese et al., Front. Astron. Space Sci. **8**: 659815 (2021).
[5] V. Soukeras, F. Cappuzzello, D. Carbone et al., Res. in Physics **28**, 104691 (2021).
[6] M. Cavallaro, E. Aciksoz, L. Acosta et al., POS **302**, (BORMIO2017) 015 (2017).
[7] F. Cappuzzello, M. Cavallaro, A. Cunsolo et al., Nucl. Instrum. Meth. A **621**, 419 (2010).
[8] D. Pereira, J. Lubian, J. R. B. Oliveira et al., Phys. Lett. B **670**, 330 (2009).
[9] G. R. Satchler, Direct Nuclear Reactions, International Series of Monographs on Physics Vol. 68 (Clarendon Press, Oxford, UK, 1983).

Acknowledgments

We warmly acknowledge the operators of INFN-LNS Accelerator for the production and delivery of the beam and their support throughout the experiment. The research leading to these results was partially funded by the European Research Council (ERC) under the European Unions Horizon 2020 Research and Innovation Programme (Grant Agreement No 714625).