Multi-channel study of the $^{12}C(^{18}O,^{18}F)^{12}B$ single charge exchange reaction at 275 MeV

A key theoretical and experimental approach for the NUMEN Project

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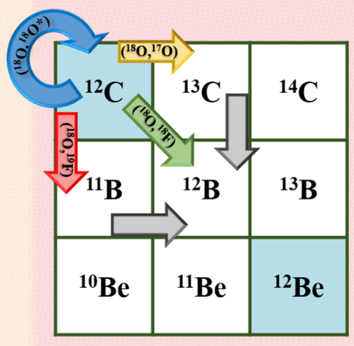
Introduction

The goal of this work is the study of a **network** of nuclear reactions emerging from the $^{18}O + ^{12}C$ collision at 275 MeV of incident energy to test the capability of state-of-art nuclear structure and reaction theories in describing the direct and sequential components involved in the (^{18}O, ^{18}F) **single charge exchange** reaction. The work is part of the more general scientific purpose of **NUMEN**[1] *(Nuclear Matrix Elements for Neutrinoless Double Beta Decay)* project that studies **Double Charge Exchange** (**DCE**) reactions on specific isotopes, in order to extract information about **Nuclear Matrix Elements** (**NME**) of great interest on $0\nu\beta\beta$ decay physics.

The experiment



The experiment was performed by using the **MAGNEX**[2] magnetic spectrometer and the **K800** superconducting cyclotron at the Laboratori Nazionali del Sud of the Istituto Nazionale di Fisica Nucleare (**LNS-INFN**), in Catania. The elastic and inelastic scattering, one-nucleon transfer and single charge exchange reaction channel data have been reduced and analysed.

The NUMEN Project

The NUMEN project intends to extract **data-driven** information on NME for all the systems candidate for $0\nu\beta\beta$ from the **measurement** of DCE reaction cross-sections. In order to study the **theoretical connection** between measured cross sections of DCE nuclear reactions and the $0\nu\beta\beta$ NMEs, the capability of the state of art nuclear theories to describe the DCE and SCE reaction mechanisms needs to be tested.

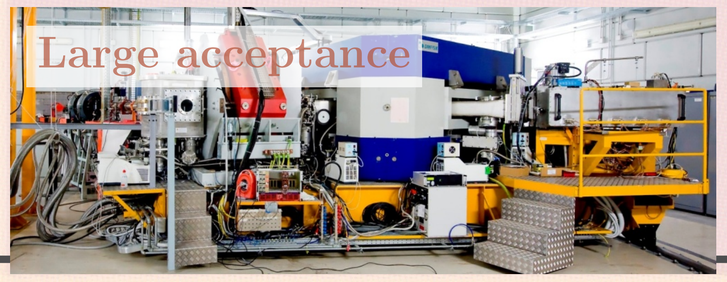
Why ^{12}C?

- Simple **nuclear structure**
- Low **density of levels**
- Well-known and studied system

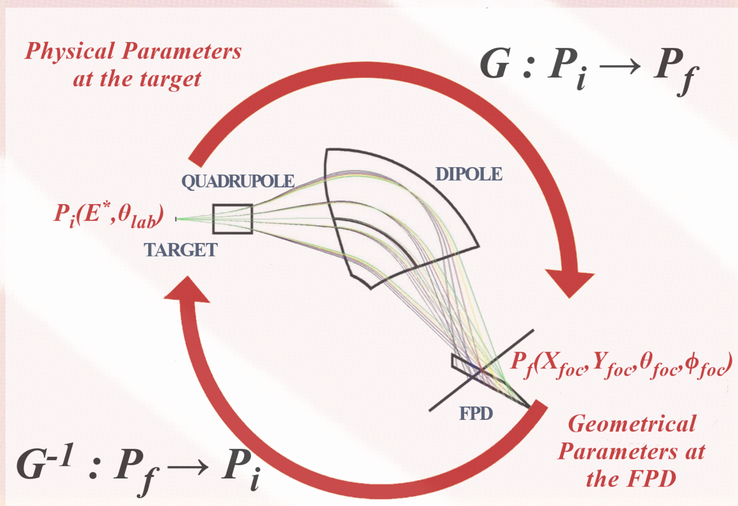
^{12}C is the best candidate to test the full-comprehensive coherent approach applied by the NUMEN collaboration to the experimental and theoretical study of the complete net of nuclear reactions.

MAGNEX Spectrometer

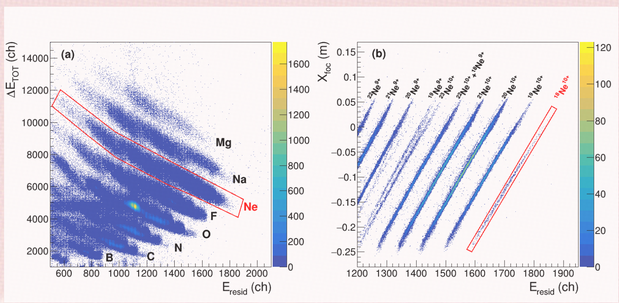
Optical Properties	Actual Value
Magnetic Rigidity	1.8 Tm
Covered Solid Angle	50 msr
Horizontal angular acceptance	−90, +110 mrad
Vertical angular acceptance	−123, +123 mrad
Momentum acceptance	−0.14%, +0.1%
Momentum dispersion	3.68 cm/%



Ray-Reconstruction Technique



Identification[3] of ejectiles



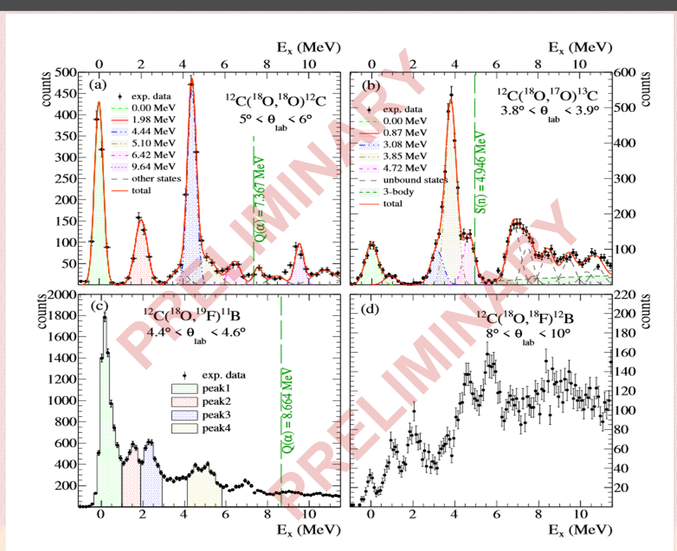
Z identification

$$\Delta E \propto \frac{AZ^2}{E}$$

$\sqrt{m}/q$ identification

$$x_{foc} \propto \frac{\sqrt{m}}{q}\sqrt{E_{Resid}}$$

Energy spectra



Theoretical analysis

Reaction calculations:

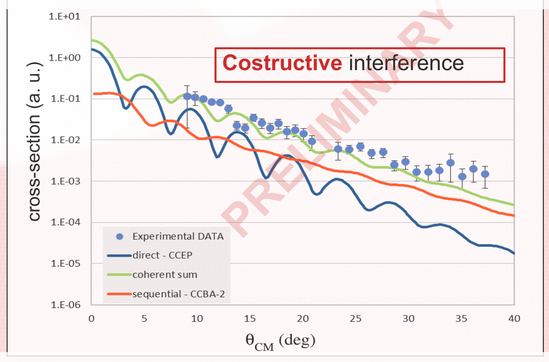
- Optical model/DWBA
- CC/CCBA
- CRC

Nuclear **structure**:

- large scale shell-model[4]
- QRPA[5]

Direct vs sequential SCE

$^{12}C(^{18}O, ^{18}F_{g.s.})^{12}B_{g.s.}$ @275 MeV



Both direct and sequential components contribute to the complete SCE reaction mechanism.

References

[1] F. Cappuzzello, *et al.*, EPJ A **54**, 72 (2018).
[2] F. Cappuzzello, *et al.*, EPJ A **52**, 167 (2016).
[3] D. Torresi, *et al.*, NIM A **989**, 164918 (2021).
[4] N. Shimizu, *et al.*, Comp. Phys. comm **244**, 372 (2019).
[5] H. Lenske, *et al.*, Prog. in part and Nucl. Phys. **109**, 103716 (2019).

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