Isospin Symmetry Breaking in Mirror Nuclei $^{23}\text{Mg} - ^{23}\text{Na}$

A. Boso$^{1,2}$, S. M. Lenz$^{1,2}$, F. Recchia$^{1,2}$, S. Aydin$^3$, M. A. Bentley$^8$, B. Cederwall$^9$, E. Clement$^9$, G. de France$^9$, A. Di Nitto$^5$, A. Dijon$^9$, M. Doncel$^6$, F.Ghazii-Moradi$^6$, A. Gottardo$^3$, T. Henry$^9$, T. Huyuk$^7$, G. Jaworski$^{12}$, P.R. John$^{1,2}$, I. Kutl$^3$, B. Melon$^{10}$, D. Mengoni$^{1,2}$, C. Michelagnoli$^{1,2}$, V. Modamio$^7$, D.R. Napoli$^7$, B.M. Nyakò$^4$, J. Nyberg$^{11}$, M. Palacz$^{12}$, J.J. Valiente-Dobon$^9$

1 Dipartimento di Fisica e Astronomia Università degli Studi di Padova, Padova, Italy.
2 INFN, Sezione di Padova, Padova, Italy.
3 INFN, Laboratori Nazionali di Legnaro, Legnaro (Padova) Italy.
4 Institute of Nuclear Research (ATOMKI) of Hung. Acad. Sciences, Debrecen, Hungary
5 Dipartimento di Scienze Fisiche and INFN, Sezione di Napoli, Napoli, Italy
6 Department of Physics, Royal Institute of Technology, Stockholm, Sweden
7 IFIC-CSIC, Valencia, Spain.
8 University of York, York, United Kingdom.
9 GANIL, Caen, France.
10 Dipartimento di Fisica and INFN, Sezione di Firenze, Firenze, Italy
11 Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden
12 Heavy Ion Laboratory, Warsaw University, Warszawa, Poland
13 Aksaray Universitesi, Department of Physics, Aksaray, Turkey

INTRODUCTION

Nuclei located at or close to the N=Z line are the only region in the Chart of Nuclides where it is possible to find answers to some fundamental problems in nuclear physics, such as the isospin symmetry of the nuclear interaction. One of the consequences of this symmetry is that the level schemes of mirror nuclei (obtained interchanging neutrons and protons) should be identical. The differences between the excitation energy of analogue states, called mirror energy differences (MED), are therefore an important signature of isospin symmetry breaking. Although the Coulomb interaction is the main responsible of this asymmetry, it has been pointed out that Isospin Symmetry Breaking (ISB) terms could arise from the residual nuclear interaction[1].

Systematic studies in the $f_{7/2}$ shell have shown that MED constitute a very delicate probe of the nuclear structure, being sensitive to the nucleon alignment, the radius variation with increasing J and the wavefunction configuration[2]. The extension of these investigations to other mass regions is very important to check the limits of validity of the isospin symmetry for different masses, to look for possible isospin non conserving (INC) contributions and to search for other isospin breaking effects. What we have learned from the systematic studies in the $f_{7/2}$ shell relies on the good amount of experimental data and the excellent shell model description of the structure of these nuclei[3].

A mass region where the shell model reproduces with good accuracy the experimental data is the lower sd shell. The experiment presented in this report intended to study the MED in T=1/2 mirror nuclei $^{23}\text{Mg} - ^{23}\text{Na}$ up to high spin.

EXPERIMENTAL METHOD

The experiment presented in this report has been performed with the EXOGAM-DIAMANT-NEUTRON WALL setup and the CIME accelerator at GANIL. High spin states in $^{23}\text{Mg} - ^{23}\text{Na}$ have been populated with the fusion evaporation reactions $^{12}\text{C}(^{16}\text{O},\alpha n)$ and $^{12}\text{C}(^{16}\text{O},\alpha p)$ respectively; the $^{16}\text{O}$ beam at 60 MeV impinged on a selfsupported Carbon target of 500 $\mu\text{g/cm}^2$.

The light charged particles evaporated from the $^{28}\text{Si}$ compound nucleus have been detected by the $4\pi$ DIAMANT detector, composed by 80 CsI(Tl) scintillators, which permits to achieve a very good discrimination between alphas and protons. The NEUTRON WALL array, consisting of 50 closely packed liquid scintillators, was placed at forward angles with respect to the beam direction, covering $\sim 1\pi$ of the total solid angle. These ancillary devices permitted to cleanly select the evaporation channels of interest, $(\alpha p)$ and $(\alpha n)$.

The $\gamma$-rays produced in the reaction have been detected by the $\gamma$-ray array EXOGAM which in this experiment was composed by 10 Compton suppressed clovers of 4 segmented HPGe detectors each, placed at 15 cm from the target to allow a good Doppler correction. Seven clovers were placed at 90$^\circ$, and three clovers at 135$^\circ$ with respect to the beam line.

PRELIMINARY RESULTS

Requiring coincidences with the proper number of charged particles and neutrons, it is possible to obtain the gamma spectra of the nuclei of interest. Since the estimated detection efficiency for one neutron is 25%, while for protons and alphas is 60% and 40% respectively, the spectra can be contaminated by $\gamma$-rays coming from reaction channels which evaporate more particles.

The possibility to determine the emission angle of the alpha particles evaporated in the reaction allows to correct, event-by-event, the mean $\beta$ value and the outgoing direction of the residual nucleus, improving the Doppler correction.

The $\gamma$-ray spectra of the nuclei of interest are reported...
in Fig.1. The $^{23}$Mg spectrum, corresponding to the ($\alpha n$) channel, is weakly contaminated by the more strongly populated ($\alpha p$) channel, as can be seen by the presence of the 627-keV and 1636-keV lines in the lower panel of Fig.1. This suggests a leakage of $\gamma$-rays in the neutron gates performed on NEUTRON WALL spectra.

The known $\gamma$-ray transitions [4] have been observed up to the highest spin states.

**CONCLUSIONS**

High spin states in $T=1/2$ mirror nuclei $^{23}$Mg $\rightarrow$ $^{23}$Na have been studied by means of the fusion evaporation reactions $^{12}$C($^{16}$O,$\alpha n$) and $^{12}$C($^{16}$O,$\alpha p$) respectively. The experimental setup, composed by the $\gamma$-ray array EXOGAM, the light charged particle detector DIAMANT and the neutron detector NEUTRON WALL, permit to select the reaction channel of interest. Preliminary $\gamma$-ray spectra are reported.