Search for highly excited states in neutron rich nuclei using deep inelastic reactions


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INTRODUCTION

One of the most investigated issues in nuclear physics is the influence of the N/Z ratio on the structure of the atomic nucleus. Strong disagreement between the predictions of various models is found for nuclei far from the valley of stability. To test the validity of those models vibrations and rotations are studied in isotopic chains as a function of the N/Z ratio. Particularly important in such a context are the low-lying electric dipole states (pygmy) since in neutron-rich nuclei they are expected to have a sizeable strength. Up to now systematic of such states exists for stable isotopes based on photon scattering experiments [1]. In a recent experiment, May 2007, we investigated, for the first time, the possibility to populate highly excited states in neutron-rich Ca nuclei by means of deep-inelastic collisions (DIC). Yrast states of the chosen nuclei have been studied with DIC at energies around 1 pnA. The PRISMA magnetic spectrometer [3], placed at the grazing angle for this reaction ($\theta \approx 20^\circ$), allowed the identification in mass and charge of the reaction products on an event by event basis, through the reconstruction of the individual trajectories. These were obtained by combining the measurements of X and Y positions in the MCP entrance detector and in the focal plane MWPPAC detector, of the time of flight (TOF) between the MCP and MWPPAC and of the energy released in the elements of the ionization chamber (IC).

The related Clover array CLARA [4] allows to detect $\gamma$ rays in coincidence with the recoils. Owing to the very forward angular position of PRISMA only 22 Compton suppressed Clover detectors were placed around the scattering chamber covering angles between 98° and 180° with a photopake efficiency of 3% for 1 MeV $\gamma$ rays. The identification of reaction products and the separation between gamma rays emitted from projectile-like and target-like products was achieved with an accurate Doppler correction, thanks to the reconstruction of the trajectory of the ions (TOF and path) in the magnetic spectrometer PRISMA. The count rate on the start MCP detector was quite high as a consequence of the large amount of Rutherford scattering events dominating at the small angle at which PRISMA was located. Therefore, in order to enhance the events of interest, given by DIC reactions, a double coincidence between MCP and $\gamma$ was requested.

EXPERIMENTAL SET-UP

The experiment performed at the Laboratori Nazionali di Legnaro (LNL) consisted of a $^{48}$Ca TANDEM-ALPI beam accelerated onto a 0.98 mg/cm$^2$ thick $^{64}$Ni target, at a beam energy of $E_{lab}=300$ MeV. During the 6 days of data taking the average intensity of the beam was stable around 1 pmA. The PRISMA magnetic spectrometer [3], placed at the grazing angle for this reaction ($\theta \approx 20^\circ$), allowed the identification in mass and charge of the reaction products on an event by event basis, through the reconstruction of the individual trajectories. These were obtained by combining the measurements of X and Y positions in the MCP entrance detector and in the focal plane MWPPAC detector, of the time of flight (TOF) between the MCP and MWPPAC and of the energy released in the elements of the ionization chamber (IC).

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<table>
<thead>
<tr>
<th>Isotope</th>
<th>Channel</th>
<th>Population (%)</th>
</tr>
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<tbody>
<tr>
<td>Ca</td>
<td>0p</td>
<td>83.37</td>
</tr>
<tr>
<td>Sc</td>
<td>+1p</td>
<td>4.49</td>
</tr>
<tr>
<td>K</td>
<td>-1p</td>
<td>4.26</td>
</tr>
<tr>
<td>Ti</td>
<td>+2p</td>
<td>1.35</td>
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<tr>
<td>Ar</td>
<td>-2p</td>
<td>1.17</td>
</tr>
<tr>
<td>Cl</td>
<td>-3p</td>
<td>0.41</td>
</tr>
</tbody>
</table>

TABLE I: Abundances of the most intense species populated in the $^{48}$Ca + $^{64}$Ni reaction described in the current work. The 100 % refers to the integral over the whole E-∆E matrix.
PRELIMINARY RESULTS

The reaction populated nuclei ranging from P to Cr, that correspond to the -5p and +4p channels. In table 1 we report the abundancies of the most intense atomic species populated in the present experiment. The population of each isotope is normalized to the total integral over the E - ∆E matrix, reported in Fig. 1. These abundancies are evaluated with no requirement on γ rays, therefore the elastic scattering dominates the distribution.

In Fig. 1 a E - ∆E bidimensional spectrum is plotted. This matrix is obtained from the energy released in the ionization chamber for the full statistics of the experiment. The E variable is the sum of the total energy released in the IC, while ∆E is the energy released in its first longitudinal sections. The insets of Fig. 1 show the mass spectra for the Ti and K isotopes, obtained gating the E-∆E matrix along the two dotted lines superimposed to the spectrum.

For each isotope we studied the masses produced in the reaction and their distribution as a function of the Total Kinetic Energy Loss (TKEL). In Fig. 2 (top line) the Q-value spectrum (TKEL) and the mass spectrum for Ca isotopes are shown. The TKEL spectrum is clearly divided into two areas, one corresponding to quasi-elastic events and the other one to deep-inelastic processes, showing that highly excited nuclei were populated. In the bottom line of Fig. 2 we plot the measured γ spectra in coincidence with 48Ca and 50Ca. The on-going analysis will concentrate on high energy γ rays that will be enhanced by making use of cuts in the TKEL spectrum. Gamma spectra of all populated nuclear species will be analysed.

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