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EXPLORING THE PERFORMANCE OF THE SPECTROMETER PRISMA IN HEAVY ZIRCONIUM AND XENON MASS REGIONS*

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We present results from two recent runs which illustrate the performance of the PRISMA spectrometer in the proximity of the upper limit of its operational interval, namely ^{96}Zr+^{124}Sn at $E_{\rm lab}$ = 500 MeV and ^{136}Xe+^{208}Pb at $E_{\rm lab}$ = 930 MeV. In the latter run, the γ array CLARA also allowed us to identify previously unknown γ transitions in the nuclides ^{136}Cs and ^{134}I.

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1. Introduction

Multinucleon transfer processes in the proximity of the Coulomb barrier represent an efficient means to populate nuclei moderately far from stability and non-yrast states that may be hardly reached through fusion–evaporation

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reactions [1]. This holds in particular in the region of neutron-rich isotopes of elements $Z = 30$–60, which can be accessed basically only through peripheral collisions between heavy ions or actinide fission. In either case, direct identification of the reaction products represents a challenging issue, because of the huge number of nuclear species populated in the process and the needed Z- and A-resolutions. In fact, nuclear-structure and reaction-dynamics studies that use peripheral collisions in the proximity of the Coulomb barrier, were recently boosted by the coupling of efficient γ arrays to large solid-angle magnetic spectrometers. The high efficiency and selectivity of the PRISMA–CLARA set-up [2, 3], along with the availability of such beams as ^{96}Zr and ^{136}Xe delivered by the TANDEM–ALPI and PIAVE–ALPI accelerator complexes at LNL at energies up to $\sim$7 MeV A and intensities up to $\sim$5 $pn\,A$, allowed us over the last years to perform several experiments aimed at the exploration of nuclear structure and reaction dynamics in a region ranging from $Z \simeq 8$ to $Z \simeq 60$. We here focus on two runs which well illustrate PRISMA's performance in the proximity of the upper limit of its operational interval, namely ^{96}Zr+^{124}Sn at $E_{\rm lab} = 500$ MeV and ^{136}Xe + ^{208}Pb at $E_{\rm lab}$=930 MeV.

2. Experimental setup and experimental results

The spectrometer has been described in Refs. [2, 4–7], its foremost features being the large solid-angle and momentum acceptance ($\sim$ 80 msr and $\Delta p/p = \pm 10\%$, respectively). At its entrance is placed a two-dimensional position-sensitive micro-channel plate detector providing a start signal for time-of-flight (TOF) measurement and $X_{\rm i}$, $Y_{\rm i}$ position signals. After a path of $\sim$ 6.5 m, ions hit the focal-plane detector, which consists of a ten-section multiwire-type parallel plate providing timing (TOF stop) signals and $X_{\rm f}$,$Y_{\rm f}$ coordinates; this detector is followed by a transverse-field four-stage ionization chamber (IC), which gives the total energy (E) of the ion and its nuclear charge. The γ-ray array CLARA consisted of 24 HPGe clover-type detectors in a 2π configuration at the target point. The total photopeak efficiency of this array was $\sim 3\%$ for $E_\gamma = 1.33$ MeV; its energy resolution was $\sim 0.8\%$ after Doppler correction.

The identification of ejectiles in nuclear charge and mass performed by PRISMA is respectively based on the measurement of energy loss in the IC and the reconstruction of trajectory of the ejectile through the spectrometer, which is in turn based on the measurement of the space coordinates $X_{\rm i}$,$Y_{\rm i}$ and $X_{\rm f}$,$Y_{\rm f}$. In particular, trajectory reconstruction yields the total distance D traveled by the ion (and therefore its scalar velocity $v = D/{\rm TOF}$) and the curvature radius R of its trajectory inside the dipole magnet: from v

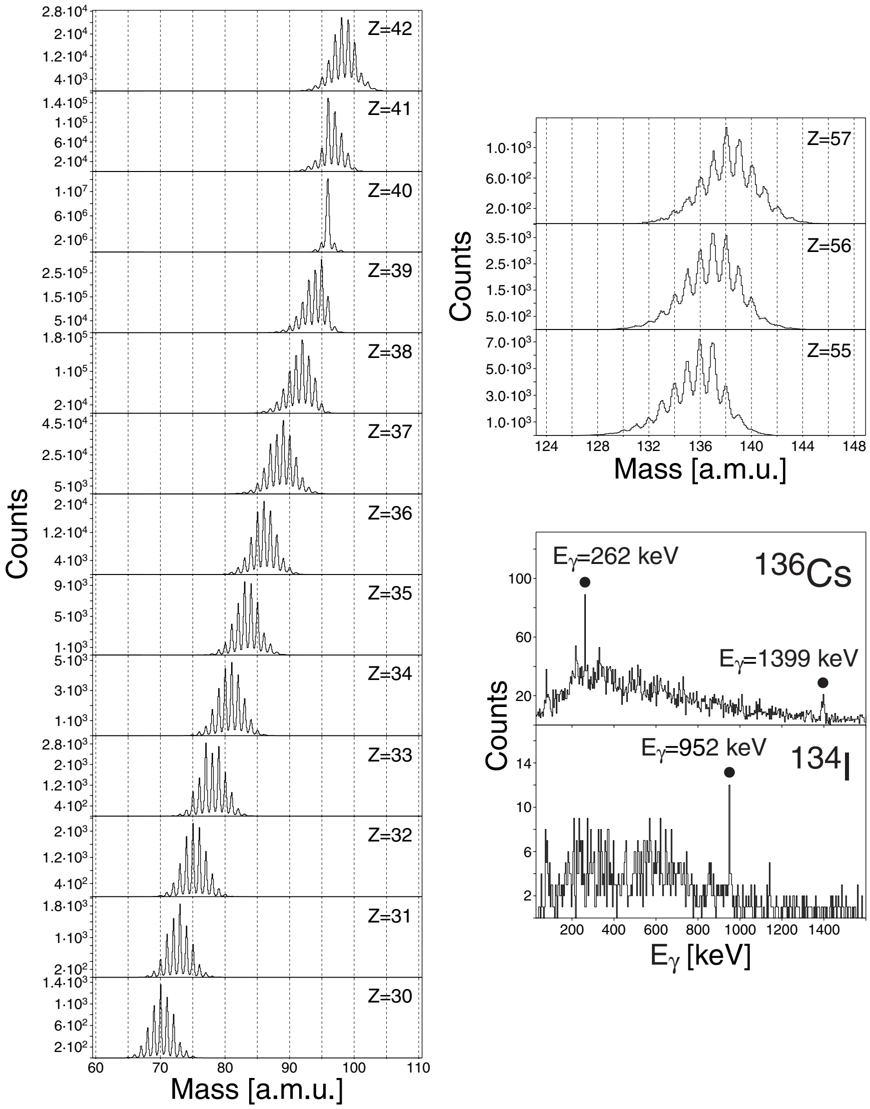

Fig. 1. (Left-hand side) Mass spectra of elements $Z = 30$–42 produced in the reaction ^{96}Zr+^{124}Sn at $E_{\mathrm{lab}} = 50$ MeV and detected at the angle θ_{lab}=38°. (Right-hand side) (Top) Mass spectra of elements $Z = 55$–57 produced in the reaction ^{136}Xe+^{208}Pb at $E_{\mathrm{lab}} = 930$ MeV and detected at the angle θ_{lab}=38°. (Bottom) γ spectra respectively tagged on the detection of the nuclides ^{136}Cs and ^{134}I, produced in the reaction ^{136}Xe+^{208}Pb. The Doppler correction is applied on the basis of the vector velocity of the ejectile. Previously unknown transitions are identified.

and R, the ratio A/q is determined as

$$\frac{A}{q} = \frac{e}{m_n c} \frac{B_d R}{\beta} \sqrt{1-\beta^2}\,,$$

where q is the atomic charge state of the ejectile, m_n is the atomic-mass unity, B_{d} is the magnetic field in the dipole and $\beta = v/c$. The separation of atomic charge states is achieved by plotting a matrix of the quantity $Rv\sqrt{1-\beta^2}$ *versus* the total energy E ($\simeq Av^2/2$) measured by the IC. The mass spectra of the nuclides produced in the reactions ^{96}Zr+^{124}Sn at $E_{\mathrm{lab}} =$ 500 MeV and ^{136}Xe+^{208}Pb at $E_{\mathrm{lab}} = 930$ MeV are plotted in Fig. 1, along with γ spectra tagged on specific nuclides produced in the latter reaction. The resolutions are respectively $\Delta A/A \simeq 1/190$ and $1/200$, allowing a good isotopic separation.

3. Outlook

Numerous neutron-rich nuclides in the proximity of ^{96}Zr and ^{136}Xe were populated in the reactions ^{96}Zr+^{124}Sn at $E_{\mathrm{lab}} = 500$ MeV and ^{136}Xe+^{208}Pb at $E = 930$ MeV. The good beam stability and high intrinsic efficiency of PRISMA's detectors for zirconium- and xenon-like ions ($\sim$ 80%) allowed the collection of high-statistics data-sets that look very promising both on the side of nuclear structure (the analysis of γ–γ coincidences from previous thick-target experiments performed with large γ arrays may benefit from the unambiguous attribution of new transitions to specific nuclides) and on the side of reaction dynamics (the high number of collected PRISMA–γ and PRISMA–γ–γ coincidences may make possible a quantitative study of the impact of neutron evaporation on the final mass yields and/or a quantitative study of mutual excitation of the reaction partners). The interpretation of experimental results is under way.

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