

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

P. MASON^a, L. CORRADI^a, E. FIORETTO^a, B. GUIOT^a, R. SILVESTRI^a
A.M. STEFANINI^a, S. BEGHINI^b, G. MONTAGNOLI^b, F. SCARLASSARA^b
N. MĂRGINEAN^c, S. SZILNER^d, G. POLLAROLO^e, E. FARNEA^b
A. GADEA^a, D. MENGONI^b, D.R. NAPOLI^a, F. RECCHIA^b, E. SAHIN^a
C.A. UR^b, J.J. VALIENTE-DOBÓN^a, R. CHAPMAN^f, S. FREEMAN^h
A. HODSDON^f, G. JONES^g, M. LABICHE^g, D. O'DONNELL^g, J. OLLIER^g
R. ORLANDI^f, J. SMITH^f, K. SPOHR^f, N. THOMPSONⁱ
P. WADY^f, Z. WANG^f

^aINFN, Laboratori Nazionali di Legnaro, Italy

^bINFN and University of Padova, Italy

^cHoria Hulubei National Institute, Bucharest, Romania

^dRuder Boskovic Institute, Zagreb, Croatia

^eINFN and University of Torino, Italy

^fUniversity of West of Scotland, Paisley, UK

^gDaresbury Laboratory, Daresbury, UK

^hUniversity of Manchester, Manchester, UK

ⁱUniversity of Surrey, Guildford, UK

(Received October 30, 2008)

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 $^{96}\text{Zr}+^{124}\text{Sn}$ at $E_{\text{lab}} = 500$ MeV and $^{136}\text{Xe}+^{208}\text{Pb}$ at $E_{\text{lab}} = 930$ 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 .

PACS numbers: 23.20.Lv, 25.70.Hi, 29.30.Aj

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

* Presented at the Zakopane Conference on Nuclear Physics, September 1–7, 2008, Zakopane, Poland.

reactions [1]. This holds in particular in the region of neutron-rich isotopes of elements $Z = 30\text{--}60$, 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 ~ 7 MeV A and intensities up to ~ 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 $^{96}\text{Zr}+^{124}\text{Sn}$ at $E_{\text{lab}} = 500$ MeV and $^{136}\text{Xe} + ^{208}\text{Pb}$ at $E_{\text{lab}}=930$ 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 (~ 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_i, Y_i position signals. After a path of ~ 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_f, Y_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_i, Y_i and X_f, Y_f . In particular, trajectory reconstruction yields the total distance D traveled by the ion (and therefore its scalar velocity $v = D/\text{TOF}$) and the curvature radius R of its trajectory inside the dipole magnet: from v

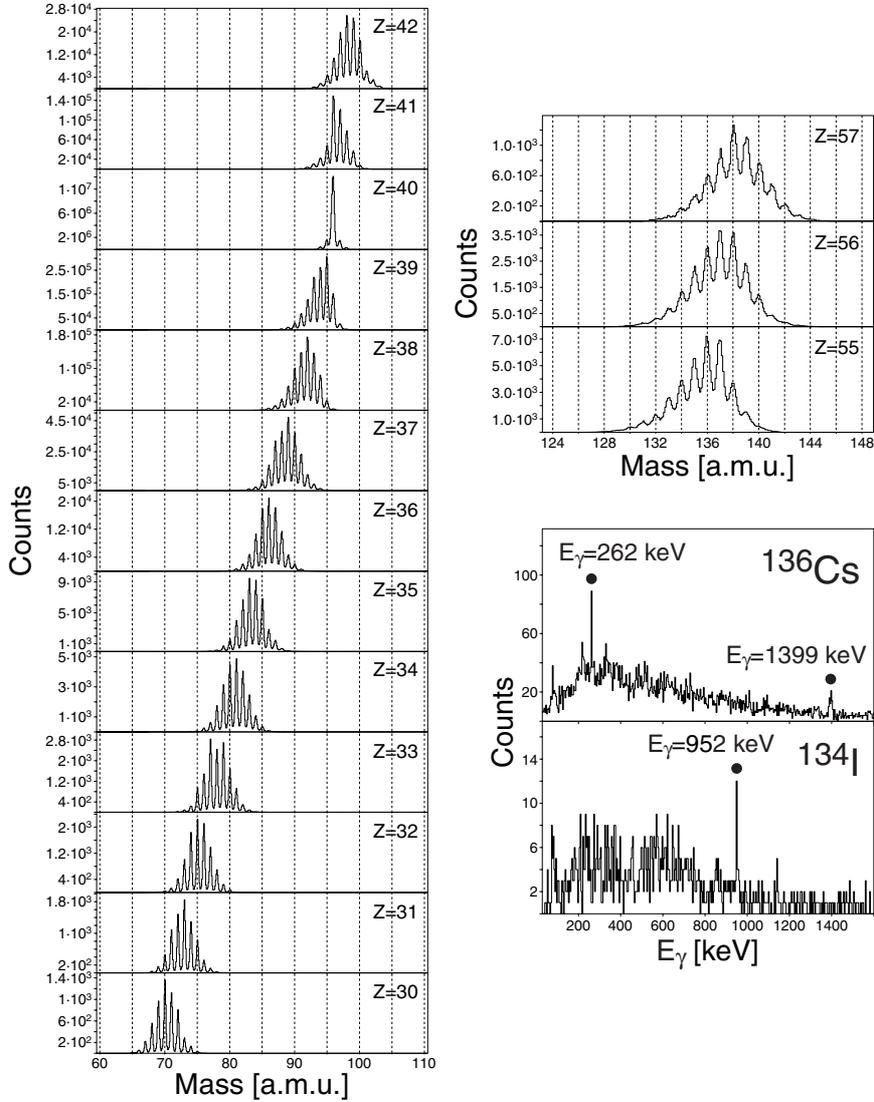


Fig. 1. (Left-hand side) Mass spectra of elements $Z = 30$ – 42 produced in the reaction $^{96}\text{Zr} + ^{124}\text{Sn}$ at $E_{\text{lab}} = 50$ MeV and detected at the angle $\theta_{\text{lab}} = 38^\circ$. (Right-hand side) (Top) Mass spectra of elements $Z = 55$ – 57 produced in the reaction $^{136}\text{Xe} + ^{208}\text{Pb}$ at $E_{\text{lab}} = 930$ MeV and detected at the angle $\theta_{\text{lab}} = 38^\circ$. (Bottom) γ spectra respectively tagged on the detection of the nuclides ^{136}Cs and ^{134}I , produced in the reaction $^{136}\text{Xe} + ^{208}\text{Pb}$. 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 unit, 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 $^{96}\text{Zr}+^{124}\text{Sn}$ at $E_{\text{lab}} = 500$ MeV and $^{136}\text{Xe}+^{208}\text{Pb}$ at $E_{\text{lab}} = 930$ 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 $^{96}\text{Zr}+^{124}\text{Sn}$ at $E_{\text{lab}} = 500$ MeV and $^{136}\text{Xe}+^{208}\text{Pb}$ 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.

REFERENCES

- [1] R. Broda, *J. Phys. G* **32**, R151 (2006).
- [2] A.M. Stefanini *et al.*, *Nucl. Phys.* **A701**, 217c (2002).
- [3] A. Gadea *et al.*, *Eur. Phys. J.* **A20**, 193 (2004).
- [4] G. Montagnoli *et al.*, *Nucl. Instrum. Methods Phys. Res.* **A547**, 455 (2005).
- [5] S. Beghini *et al.*, *Nucl. Instrum. Methods Phys. Res.* **A551**, 364 (2005).
- [6] S. Szilner *et al.*, *Phys. Rev.* **C76**, 024604 (2007).
- [7] P. Mason *et al.*, *Eur. Phys. J.* **ST 150**, 359 (2007).