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The study of neutron-rich nuclei production in the region of the closed shell $N=126$ in the multi-nucleon transfer reaction $^{136}\text{Xe}+^{208}\text{Pb}$

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Abstract. The unexplored area of heavy neutron rich nuclei is extremely important for nuclear astrophysics investigations and, in particular, for the understanding of the r-process of astrophysical nucleogenesis. For the production of heavy neutron rich nuclei located along the neutron closed shell $N=126$ (probably the last "waiting point" in the r-process of nucleosynthesis) the low-energy multi-nucleon transfer reaction $^{136}\text{Xe}+^{208}\text{Pb}$ at $E_{\text{lab}}=870\text{MeV}$ was explored. Due to the stabilizing effect of the closed neutron shells in both nuclei, $N=82$ and $N=126$, and the rather favorable proton transfer from lead to xenon, the light fragments formed in this process are well bound and the Q-value of the reaction is nearly zero.

Measurements were performed with the PRISMA spectrometer in coincidence with an additional time-of-flight (ToF) arm on the +20 beam line of the PIAVE-ALPI accelerator in Legnaro, Italy. The PRISMA spectrometer allows identification of the A, Z and velocity of the projectile-like fragments (PLF), while the second arm gives access to the target-like fragments (TLF). Details on the experimental setup and preliminary results are reported.



1. Introduction

The transfer of many nucleons was suggested as a feasible route to synthesize heavy nuclei on the neutron-rich side of the stability line [1],[2],[3], giving rise to a renewed interest in the study of transfer processes.

Within this work, the low-energy collision of ^{136}Xe with ^{208}Pb was explored. The stabilizing effects of the neutron closed shell $N = 82$ of ^{136}Xe and $N = 126$ of ^{208}Pb , together with the specific trend of the Q -values of all possible mass transfer channels [4], make the chosen system a very good candidate. Protons may experience a higher mobility due to of the neutron closed shell in the projectile and target, and the transfer of several protons from Xe to Pb may lead to very neutron-rich nuclides [3].

2. Experimental Configuration and Data Analysis

The experiment was carried out at the Laboratori Nazionali di Legnaro (LNL) by bombarding a ^{136}Xe beam at $E_{\text{lab}} = 870$ MeV, provided by the Tandem-ALPI complex, onto a $200\text{ }\mu\text{g}/\text{cm}^2$ thick (and 99.9% enriched) ^{208}Pb target, backed on $20\text{ }\mu\text{g}/\text{cm}^2$ Carbon foil. The target was placed at 90° with respect to the beam direction.

PRISMA is a large-acceptance magnetic spectrometer, operating at LNL, designed for identification of reaction products of heavy ion collisions consisting of a Micro Channel Plate detector (MCP), a focusing quadrupole, a dipole magnet, a focal Multiwire Parallel Plate detector (MW-PPAC) and, finally, the ionization chambers (IC) (for ΔE -E measurement). The PRISMA set-up allows identification of the A and Z of the projectile-like fragments (PLF) of reaction within a resolution of $1/220$ and $1/60$, respectively.

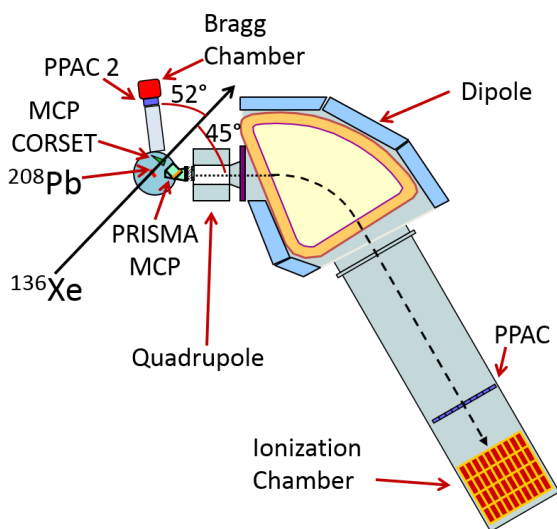


Figure 1. Schematic arrangement of the set-up.

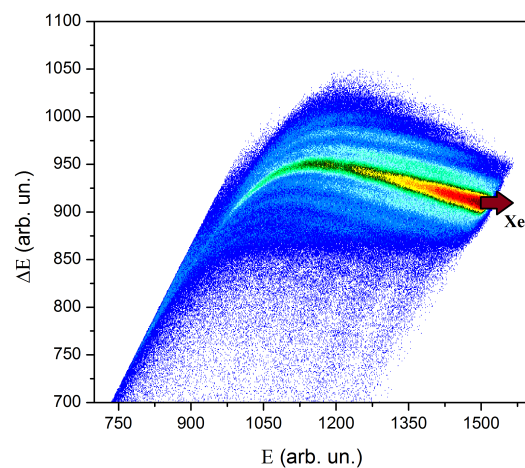


Figure 2. E vs ΔE matrix for the reaction $^{136}\text{Xe} + ^{208}\text{Pb}$, as measured by the ionization chamber of PRISMA. The most intense track corresponds to the Xe beam, while the region of interest corresponds to $Z(\text{Xe})+6$.

For our present case study, the PRISMA setup had in its implementation a second arm, composed of a CORSET [5] compact Micro Channel Plate (MCP) start detector followed by a position-sensitive stop detector and, finally, a Bragg ionization chamber. A schematic view of the setup is shown in figure 1.

The experimental setup provides several methods of separating between good events with different properties. Firstly, the identification of the nuclear charge, Z , is performed within the energy and energy losses measured in the ionization chamber. Figure 2 displays the ΔE vs E matrix for the $^{136}\text{Xe}+^{208}\text{Pb}$ system where the Z separation is clearly visible. Secondly, once the ions' trajectories are uniquely reconstructed on an event-by-event basis, for each selected track in the previously mentioned matrix, one can disentangle different charge states. Because the magnetic fields are known, one may calculate the radius of curvature, R , of the ions inside the dipole and their velocities v . Figure 4 shows the $R \cdot v$ vs E matrix for the enclosed band of $Z = 54$.

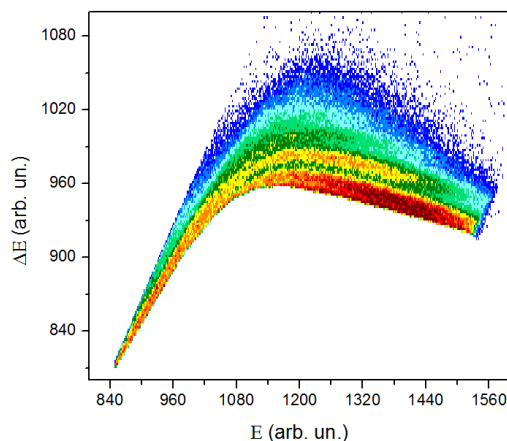


Figure 3. Same matrix as in Figure 2, displaying only events corresponding to $Z > Z(\text{Xe})$.

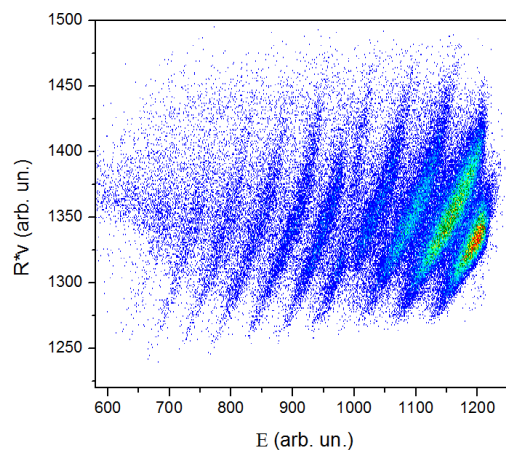


Figure 4. E vs $R \cdot v$ matrix for the Xe ions. The most intense band corresponds to the most probable charge state $q = 40^+$.

3. Conclusions

We report the current status on the production of heavy neutron-rich nuclei located along the neutron closed shell $N=126$ illustrated in the low-energy multi-nucleon transfer reaction $^{136}\text{Xe}+^{208}\text{Pb}$, performed at $E_{\text{lab}}=870\text{MeV}$.

The probability of light particle emission for this type of reaction is negligible, thus the cross section for production of the neutron-rich heavy nuclei, such as Pt, is within experimental reach by using multiple coincident gating. In order to estimate experimentally the cross section for production of new neutron rich heavy nuclei, the mass distribution (with a $\approx \pm 1 - 2$ u resolution) will be obtained by using the time of flight between the PRISMA MCP and PPAC and the fully reconstructed trajectory of ions inside the spectrometer. The analysis is in progress.

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