Structure of $N \geq 126$ nuclei produced in fragmentation of ^{238}U

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Abstract. The nuclear structure of neutron-rich $N \geq 126$ nuclei have been investigated following their production via relativistic projectile fragmentation of a $E/A=1$ GeV ^{238}U beam on a Be target. The cocktail of secondary beam products were separated and identified using the GSI FRagment Separator (FRS). The nuclei of interest were implanted in a high-granularity active stopper detector set-up consisting of 6 double sided silicon strip detectors. The associated gamma-ray transitions were detected with the RISING array, consisting of 15 Euroball cluster Ge-detectors. Time-correlated gamma decays from individually identified nuclear species have been recorded, allowing the clean identification of isomeric decays.

Keywords: Nuclear structure, metastable states and fragmentation

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1. INTRODUCTION

The understanding of how shell structure arises and develops is a major goal in nuclear physics. Below the doubly magic ^{208}Pb nucleus there is experimental information on only four isotones: ^{207}Tl , ^{206}Hg , ^{205}Au and ^{204}Pt . While in both ^{207}Tl [1] and ^{206}Hg [2] excited states have been known for some time, excited states in ^{204}Pt [3] and ^{205}Au [4] have been observed for the first time in our Rare ISotope INvestigations at GSI (RISING) experiment performed in March 2006 using a ^{208}Pb beam. In the case of $N > 126$ the situation is even worse, i.e. for $N = 128$ excited states below $Z = 82$ are known only for ^{209}Tl [5]. This lack of information on $N \sim 126$ nuclei with $Z < 82$ is due to the difficulties in populating these neutron-rich nuclei. However, projectile fragmentation has proved to be an efficient tool to produce such exotic nuclear species. When projectile fragmentation is combined with high sensitivity gamma detection arrays, structural information can be gained for otherwise inaccessible nuclei. The aim of the present work is important for both our understanding of the possible shell evolution at $N = 126$ and to provide better theoretical predictions for the properties of the r-process path at $N \sim 126$.

2. EXPERIMENTAL DETAILS

A 1 GeV/nucleon ^{238}U beam was incident on a 2.5 g/cm^2 Be target. The primary beam intensity was $\leq 10^9$ ion/spill (spill length $\simeq 5$ s). The fragmentation products of interest were separated and identified using GSI FRagment Separator (FRS) operated in both achromatic and monochromatic mode with a wedge shaped degrader at the intermediate focal plane [6]. Identification was based on the standard magnetic rigidity, time of flight, energy loss and position measurements (details of the particle identification procedure can be found in refs. [7,8]).

FIGURE 1. Schematic of the detector configuration at the final focus of the GSI Fragment Separator used in the present work.

Compared to our previous experiments [3,4], there were some improvements in the FRS detectors setup: (i) Time Projection Chambers (TPC) were used to track the ions by measuring X and Y in two different position along the beam line both in the intermediate focal plane (S2) and the final focal plane (S4). Our previous standard setup used slow Multiwire (MW) proportional chambers for tracking at S4, and a single scintillator

detector to get position at S2. The high rate acceptance of TPCs allowed tracking even at S2, which was previously not standard. (ii) An automatic correction for pressure change of the Multi Sampling Ionization Chambers (MUSIC) was used.

The ions of interest were stopped in the active stopper. The stopper was surrounded by the RISING germanium array, which detected the delayed γ radiation following internal conversion or β -decay.

The RISING gamma-ray array [9] consists of fifteen, high efficiency seven-element germanium cluster detectors. The RISING detectors are placed in three rings of 5 cluster-detectors. The measured photopeak γ -ray efficiency for the array in this geometry for sources placed in the centre of the focal plane was $\sim 15\%$ at 661 keV [8]. The RISING active stopper [10] consisted of six 5×5 cm Double Sided Silicon Detectors (DSSSDs), each with 16 horizontal and vertical strips. The DSSSDs were used to determine the position of the implanted secondary fragments.

FIGURE 2. Charge state selection (left) and particle identification spectra for no change in charge state (i.e. $\Delta q=0$) between the first and second halves of the FRS (right).

3. EXPERIMENTAL RESULTS

The secondary products of interest were transmitted through the FRS and particle identification was made on an event-by-event basis [11–14]. The information from the energy loss of the ions as measured at the final focal stage using MUSIC detectors together with the inferred energy loss at the intermediate degrader allows charge state discrimination to be made for the transmitted ions. Charge state selection is of particular importance in cases of heavy neutron-rich nuclei [15]. Figure 2 (left) shows the effect of plotting the energy loss of the ions as measured through a pair of MUSIC at the final focus of the FRS (see figure 1) versus the derived energy loss of the ions from their difference in magnetic rigidity through the first and second halves of the FRS. Figure 2 (right) shows a particle identification matrix from the current experimental work for the setting centred on $^{205}\text{Pt}_{127}$. The particle identification is confirmed by the identification of the

FIGURE 3. Gamma-ray spectrum from the current work showing transitions from the previously reported isomeric decays in ^{206}Hg [2].

previously reported isomeric decays in ^{206}Hg [2] (see figure 3). The preliminary analysis of the current data indicates the presence of previously unreported isomeric states in the $N=128$ isotones ^{208}Hg and ^{209}Tl .

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