# Along the N=126 closed shell: $^{204}$Pt*

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Relativistic energy projectile fragmentation of $^{208}$Pb has been used to produce neutron-rich nuclei with N≈126. The nuclei of interest were studied by detecting delayed gamma rays following the decay of isomeric states. Experimental information on the excited states of the neutron-rich $^{204}$Pt N=126 nucleus, following internal decay of two isomeric states, was obtained for the first time. Raw experiemtnal data and shell-model calculations are presented.

## 1. INTRODUCTION

First results from a new initiative of experiments focusing on the study of the internal structure of nuclei at the extremes of N/Z ratio using isomer spectroscopy are reported. These experiments represent the first of the Stopped Beam section of the *Rare Isotopes Investigations at GSI* (RISING) project. Exotic nuclei were synthesised using relativistic projectile fragmentation of E/A=500–1000 MeV beams of $^{58}$Ni [1], $^{107}$Ag [2] and $^{208}$Pb.

The present paper presents selected highlights of the experimental results, with the focus on N=126 systems populated in the fragmentation of the $^{208}$Pb projectile. Studies of semi-magic nuclei are of special importance since they allow direct test of the purity of the model wave functions. Information on the single-particle energies and two nucleon residual interactions can be derived from the experimental observables such as energies of the excited states and transition probabilities.

## 2. EXPERIMENTAL DETAILS

Heavy nuclear species were populated in relativistic energy projectile fragmentation. A beryllium target of thickness 2.5 g/cm$^2$ was bombarded with an $E/A$=1 GeV $^{208}$Pb beam provided by the SIS accelerator at GSI, Darmstadt, Germany. The nuclei of interest were separated and identified using the FRagment Separator (FRS) [3] operated in standard achromatic mode. The setup is shown in fig. 1. The identification of the fragments (see fig. 2) is based on the determined $A/q$ ($\sim$TOF), the energy loss in the ionisation chambers ($\approx Z$), and the longitudinal position of the nuclei at the intermediate (S2) and final (S4) focal planes of the FRS. For more details about the setup used in the present experiment see ref. [5].

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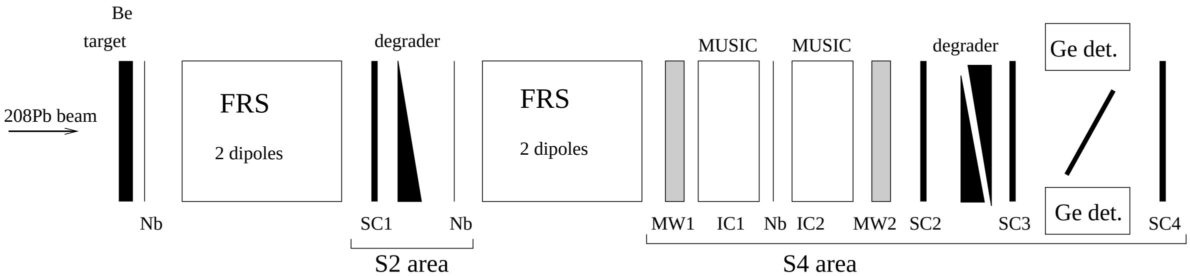


Figure 1. Schematic view of the experimental setup.

The transmitted nuclei were stopped in a cacther surrounded by the high-efficiency, high granularity Stopped RISING $\gamma$-ray spectrometer [4]. Time-correlated gamma de-

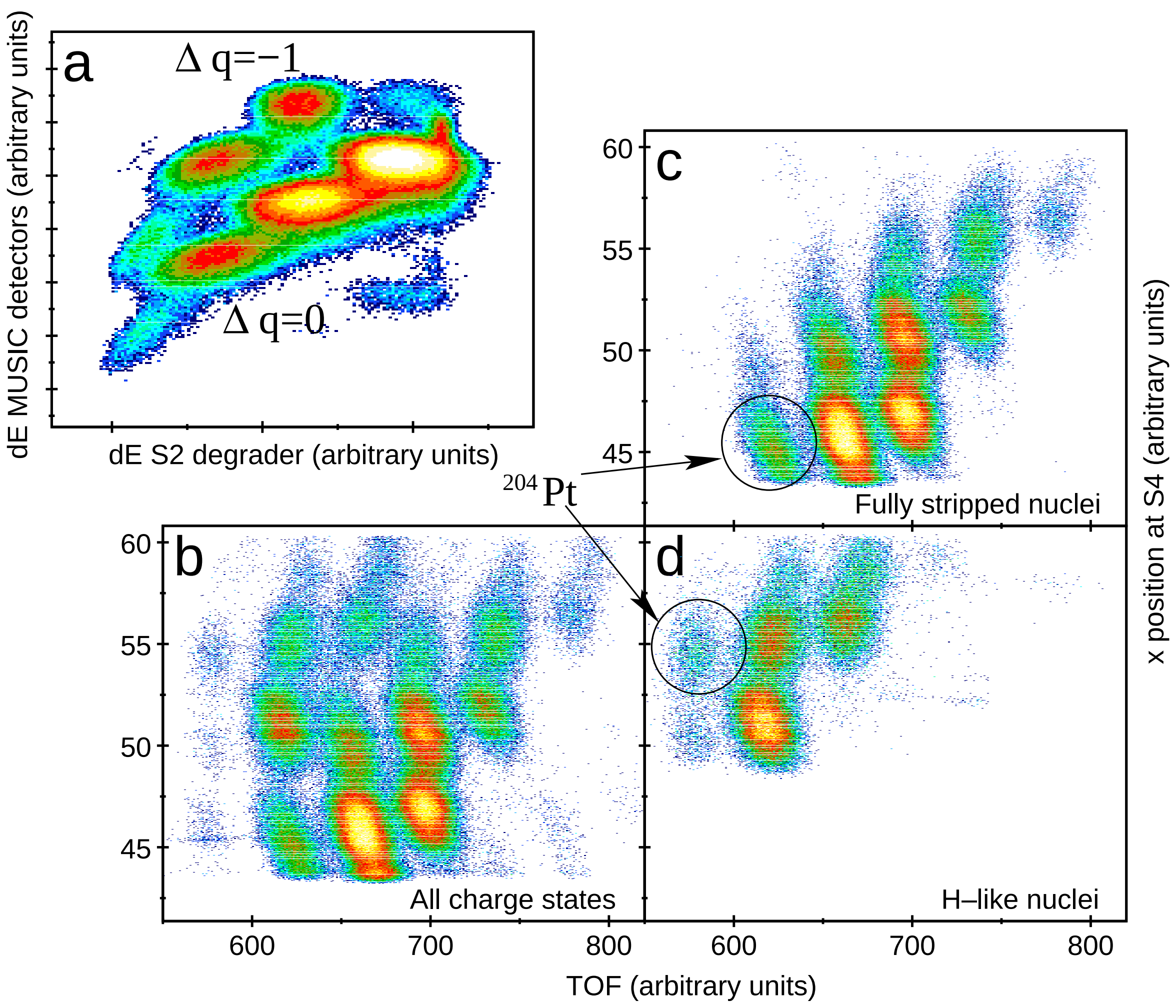


Figure 2. Identification of the fragmentation products. (a) Energy loss at the final focal plane vs. energy loss at the middle focal plane. It distinguishes between nuclei which don't change charge state at S2 from those which do. (b,c,d) energy loss vs. time-of-flight matrices without charge state condition (b), selecting fully-stripped nuclei (c) and H-like nuclei (d), respectively. The circless in (c) and (d) indicate the $^{204}$Pt nuclei.

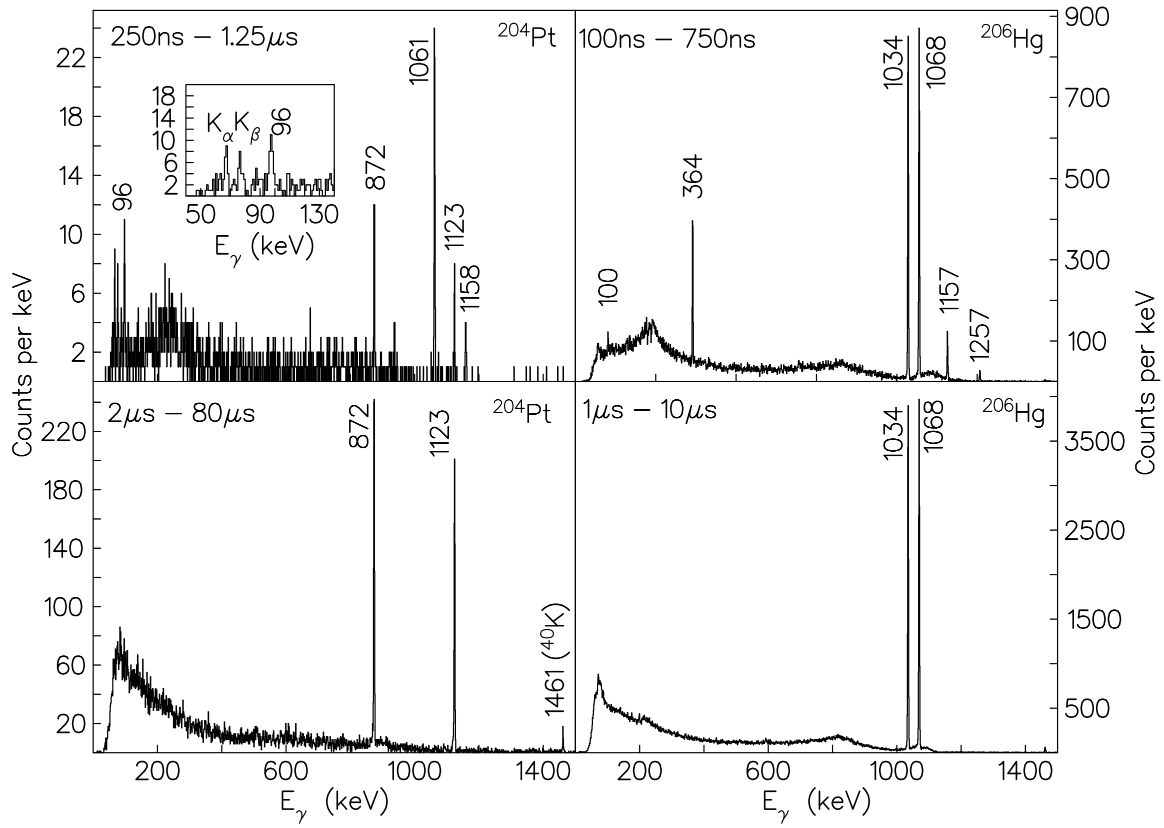


Figure 3. Delayed gamma-ray spectra associated with $^{206}$Hg and $^{204}$Pt. Note that in the upper panels the shape of the background around ∼300 keV is unphysical, and it is due to used data analysis method.

cays from individually identified nuclear species have been measured, allowing the clean identification of isomeric decays.

## 3. RESULTS AND DISCUSSION

Information on the neutron-rich N=126 nuclei is scarce. The lack of information is due to the difficulties in populating these nuclei. Below the doubly magic $^{208}$Pb nucleus there is experimental information on only three isotones: $^{207}$Tl, $^{206}$Hg and $^{205}$Au. While in both $^{207}$Tl [6] and $^{206}$Hg [7] excited states have been observed, in $^{205}$Au only the ground state is known ($I^{\pi}$=(3/2$^{+}$) [8]).

$^{204}$Pt has four protons less than the doubly magic $^{208}$Pb nucleus. Its yrast structure should be dominated by the proton-hole orbitals $\pi d_{3/2}$, $\pi s_{1/2}$, $\pi h_{11/2}$ and possible $\pi d_{5/2}$. Its level scheme is expected to be similar to that of $^{206}$Hg.

Gamma-ray spectra associated with $^{204}$Pt and $^{206}$Hg are presented in fig.3. In $^{204}$Pt two new isomeric decays have been observed, with a longer lifetime associated to the 872 keV and 1123 keV transitions, and a shorter to the 1061 keV, 1158 keV and 96 keV gamma-lines.

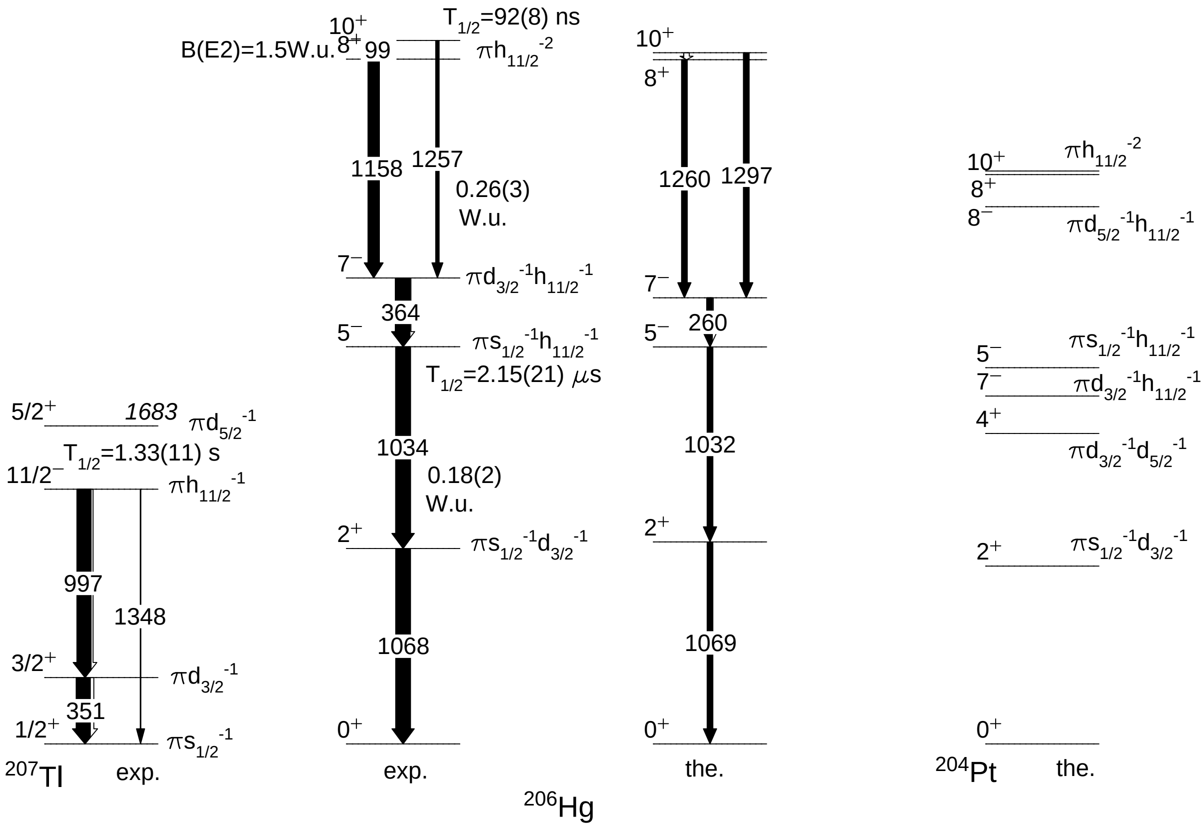


Figure 4. Partial level schemes of $^{207}$Tl [6] and $^{206}$Hg [7]. The results of the shell model calculation for $^{206}$Hg and $^{204}$Pt are shown on the right hand side.

Shell-model calculations are being performed using the OXBASH code [9]. The empirical interaction matrix elements are from [10] and are based on those of Kuo and Herling [11]. The experimental proton-hole energies were taken from the experimental level scheme of $^{207}$Tl. The results of the calculations for $^{206}$Hg and $^{204}$Pt are presented in fig. 4. There is a rather good agreement between theory and experiment for $^{206}$Hg (note that the interaction matrix elements were obtained by fitting on a range of nuclei, including the $2^+$ and $5^-$ states of $^{206}$Hg [10]). In $^{204}$Pt, these calculations predict a $4^+$ state at rather low energy, below both the $5^-$ and $7^-$ states, with a dominant configuration of $\pi d^{-1}_{5/2} d^{-1}_{3/2}$. The existence of a $4^+$ state below the $5^-$ and $7^-$ states is in contradiction with the experimental findings: none of these states would be isomeric with microseconds lifetime. Since in the configuration of the $4^+$ state a $d_{5/2}$ proton-hole is involved, further calculations were performed for nuclei where such states are known experimentally. The comparison between the OXBASH calculation and experiment for $^{203}$Au are shown in figure 5. Here spectroscopic factor measurements [12] indicate that the second $5/2^+$ state

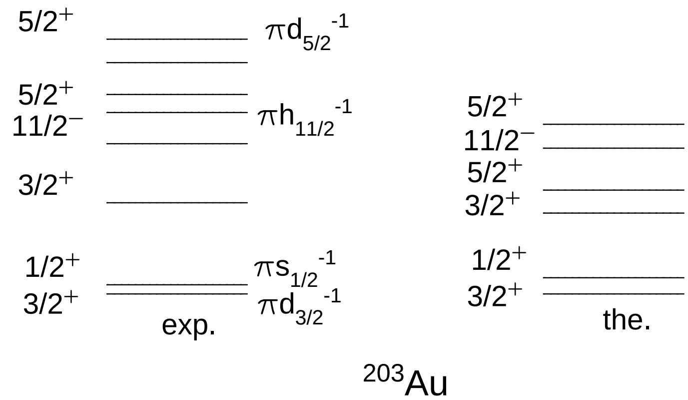


Figure 5. Comparison between experiments [12] and shell model calculation for $^{203}$Au.

has the largest $\pi d^{-1}_{5/2}$ component. The calculations foresee this state at much lower energy. This might indicate that states involving the $\pi d^{-1}_{5/2}$ proton-hole lie at considerably higher energies that the present calculations predict. The interpretation of the experimental results for $^{204}$Pt is in progress.

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