2 - 18 Research Progress in the Exotic Nuclei Group

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Digital decay spectroscopy of actinide isotopes at the gas filled separator SHANS

All over the chart of nuclides, the region to the "north-east" of ^{208}Pb, with $Z \geq 84$ and $N = 128\sim130$, hosts the shortest-lived α radioactivities, with half-lives in the range of nanoseconds to microseconds. Synthesis and detection of neutron-deficient isotopes above thorium in this region are challenging due to their low production cross sections and short half-lives. Decay spectroscopy of nuclei with $Z > 90$ were performed using the ^{187}Re+^{40}Ar reaction with isotopically enriched ^{187}Re targets. The ^{40}Ar beam was accelerated to 188 MeV by the Sector-Focusing Cyclotron (SFC) of the Heavy Ion Research Facility in Lanzhou (HIRFL). The beam intensity on target, monitored via Faraday Cups upstream and downstream of the target chamber, was around 320 pnA on average during the entire experiment of 110 h.

The N=130 short-lived isotope ^{223}Np was identified through temporal and spatial correlations with subsequent α decays in the decay chain starting from ^{223}Np. The half-life and energy were extracted to be $T_{1/2} = 2.15(100, 52)$μs and $E_\alpha = 9477(44)$ keV from pileup traces by using modern digital pulse processing techniques. The energy of individual α in pileup trace with time difference between overlapping signals down to ~100 ns was extracted, the shortest analyzed so far using this method. The trend in proton separation energy shows no sign of a $Z = 92$ subshell closure. The spin and parity of ^{223}Np are proposed to be $9/2^-$ by combining the reduced α-decay width and large-scale shell-model calculations in truncated model space, negating the presence of a $h_{9/2}$ subshell closure at Z= 92 near $N = 126$. The decay chain of ^{219}Pa, the α-emitter with the shortest half-life measured directly, was established for the first time[1].

New results have been also obtained in the α decays of ^{223}U[2] and ^{220}Pa[3].

In beam γ-spectroscopy of n-rich Mn isotopes with $N \sim 40$

The experiment was performed at the Radioactive Isotope Beam Factory. A ^{238}U primary beam (345 MeV/u) impinged on a ^{9}Be primary target for the production of the secondary RI beams at the entrance of the BigRIPS separator. These isotopes then impinged on a thick liquid hydrogen target (LH_2). The nuclei of interest were created via nucleon removal interaction in the target. The particle identification before and after the LH_2 target were performed by $B\rho$-ΔE-TOF method on an event-by-event basis in the BigRIPS and ZeroDegree spectrometers, respectively.

Based on the analysis of $\gamma-\gamma$ coincidence, level schemes have been established in ^{65,67}Mn for the first time while the result for ^{63}Mn is consistent with a recent experiment. Similar level schemes of this Mn isotopes chain, consisting of a level sequence of $11/2^-$, $9/2^-$, $7/2^-$ and $5/2^-$, connected by I→(I-1) M1/E2 transitions, have been identified. The experimental results of ^{63,65,67}Mn are reproduced remarkably well by large-scale shell model calculations with LNPS-m interactions. The progress in the analysis of the experimental results is presented in Ref. [4].

In beam γ-spectroscopy of the very n-deficient ^{117}Ba using the RDT method

High-spin states in the very neutron deficient ^{117}Ba have been observed for the first time using the recoil-decay tagging technique following the heavy-ion fusion-evaporation reaction ^{64}Zn (^{58}Ni, 2p3n) ^{117}Ba. Prompt γ rays have been assigned to ^{117}Ba through correlations with β-delayed protons following the decay of $A = 117$ recoils. Through the analysis of the $\gamma-\gamma$ coincidence relationships, a high-spin level scheme consisting of two bands has been established in ^{117}Ba. Based on the systematics of the level spacings in the neighboring barium isotopes, the two bands are proposed to have $\nu h_{11/2}[532]5/2^-$ and $\nu d_{5/2}[413]5/2^+$ configurations, respectively. The observed band-crossing properties are interpreted in the framework of cranked shell model. The results have been published and more details can be found in Ref. [5].

Isomerism around ^{132}Sn and a predicted neutron-decaying isomer in ^{129}Pd

Excited states in neutron-rich nuclei located south-east of ^{132}Sn are investigated by shell-model calculations. A new shell-model Hamiltonian is constructed for the present study. The proton–proton and neutron–neutron interactions of the Hamiltonian are obtained through the existing CD-Bonn Gmatrix results, while the proton–neutron interaction across two major shells is derived from the monopole based universal interaction plus the M3Y spin–orbit force. The present Hamiltonian can reproduce well the experimental data available in this region, including one-neutron separation energies, level energies and the experimental B(E2) values of isomers in ^{134,136,138}Sn, ^{130}Cd, and ^{128}Pd. New isomers are predicted in this region, *e.g.* in ^{135}Sn, ^{131}Cd, ^{129}Pd, ^{132,134}In and ^{130}Ag, in which almost no excited states are known experimentally yet. In the odd–odd ^{132,134}In and ^{130}Ag, the predicted very long E2 life-times of the low-lying 5- states are discussed, demanding more information on the related proton–neutron interaction. The low-lying states of ^{132}In are discussed in connection with the recently observed γ rays.

The predicted $19/2^-$isomer in ^{129}Pd could decay by both electromagnetic transitions and neutron emission with comparable partial life-times, making it a good candidate for neutron radioactivity, a decay mode which is yet to be discovered. More details of this study can be found in the publication[6].

Study of the octupole deformation properties in ^{224}U using the RDT method

The strongest octupole correlations are predicted by the HFB calculation to be in the uranium isotopes with N ~134. Improved total Routhian surface calculations show that the ground states of ^{222,224,226}U have static octupole deformations and the most favorable case for stable octupole deformation appears to be ^{224}U which is consistent with previous predictions. An experiment studying the octupole properties of ^{224}U at Argonne National Laboratory was carried out via the ^{20}Ne(^{208}Pb,4n) reaction at 109 MeV using the digital GAMMASHERE + FMA + MCP +DSSD setup. The progress of the data analysis is reported in the annual report[7].

References

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2 - 19 First Identification of the $\nu h_{11/2}$ band in ^{117}Ba*

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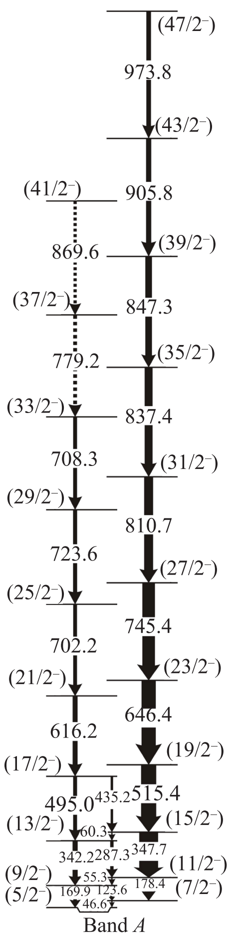

Fig. 1 The $\nu h_{11/2}$ band in ^{117}Ba deduced in this work.

Taking advantage of the large γ-detector array Gammasphere and the recoil mass separator FMA, high-spin states in ^{117}Ba were investigated through the recoil-β-delayed proton decay tagging technique via the heavy-ion induced fusion-evaporation reaction ^{64}Zn (^{58}Ni, 2p3n) ^{117}Ba, at a beam energy of 305 MeV. Prompt γ rays belonging to ^{117}Ba have been identified furthermore, a rotational band has been identified for the first time and presented as band A in Fig. 1.

In ^{117}Ba (N = 61), the neutron Fermi surface lies between the $\nu g_{7/2}/d_{5/2}$ orbitals and the lower part of the $\nu h_{11/2}$ subshell. Collective bands based on these orbitals have been observed at low excitation energy in most nuclei in this region. Due to the high-j nature of the $\nu h_{11/2}$ orbital, bands built on them are strongly populated and become yrast in these nuclei. The relative excitation energies of the $\nu h_{11/2}$ bands in odd-A $^{119-129}$Ba are plotted together with band A in Fig. 2 from which we can see that band A follows the systematic trend of the $\nu h_{11/2}$ bands so well that it most likely has the same origin. We note that that the lowest states in the $\nu \mathrm{h}_{11/2}$ bands of ^{117,119,121}Ba are all characterized by a $I^\pi = 5/2^-$gvalue, suggesting that they are all associated with the same $\nu h_{11/2}[532]5/2^-$ configuration as proposed in Refs. [1,2] for ^{119,121}Ba.

To investigate further the rotational properties of band A in ^{117}Ba, the experimental aligned angular momenta i_x and Routhians e' were extracted. The unfavored $\alpha = +1/2$ sequence experiences a band crossing at $\hbar\omega$ = 0.35 MeV while the favored $\alpha = -1/2$ one