Coexistence of Exotic Shapes in Neutron-deficient Nuclei near A$\sim$180

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The coexistence between different shapes in a single nucleus is a general phenomenon of nuclei near closed shell gaps. It is usually associated with the interplay between the occupation of specific intruder orbitals and the stabilizing role played by the shell closures. Experimental investigations of the development of shape coexistence through and beyond the mid-shell, and the interaction between coexisting configurations play an important role in the better understanding of the structure of the nucleus. In particular, such studies put constraints on the general theoretical problem of modeling the structure of heavy and super-heavy nuclei. They also provide opportunities to test the robustness of various theoretical models in predicting the single-particle states near the proton drip line and in elucidating their effect on the formation of new proton and neutron shell gaps.

The Hg and Pb nuclei around Z=82 provide some of the best examples of shape co-existence known so far. The neutron-deficient Pb nuclei ($N > 100$) are observed to form three minima at low spin - a "spherical" minimum consistent with the Z=82 closed shell, an "oblate" minimum associated with an excitation of a proton pair into the down-sloping high-Ω intruder orbitals at oblate deformation, and a third, "prolate" minimum from a more complex combination of four-particle, four-hole excitations at prolate deformation. The Hg isotopes show evidence for co-existence of prolate and oblate minima only. Calculations by Nazarewicz [1] predict that, for neutron number $N < 98$, the *prolate* minimum of the even-even Hg nuclei evolves from $\beta_2\sim0.25$ towards larger deformations of $\beta_2\sim0.56$, but the excitation energy of the latter rises to $E^*\sim3.5$ MeV. Similarly, for neutron deficient Pb isotopes ($N < 102$) a highly deformed *oblate* ($\beta_2\sim-0.35$) and a strongly elongated *prolate* ($\beta_2\sim0.50$) minimum are predicted at $E^*\sim2.5$ MeV and $E^*\approx3.5$ MeV, respectively. The search for structures trapped in a second potential well forms one aim of the present proposal. It is worth mentioning that superdeformed structures have already been observed in the neutron-rich Hg and Pb nuclei [2]. Because of the lower binding energy for the unpaired proton, excited states in neutron-deficient odd-Z nuclei in this region may prefer to decay not only by means of γ rays but also by emission of fast (or delayed) protons. The second aim of the present proposal is to search for such an exotic decay mode.

The spectroscopy of nuclei near the proton drip line is more complex and difficult compared to that for nuclei located near the valley of stability. As one approaches the proton drip line, it becomes increasingly difficult to produce states of high spin and excitation energy in nuclei by using conventional heavy-ion fusion neutron-evaporation reactions because of the severe competition from fission and charged particle emissions. These processes lead to a large fragmentation of the residual fusion-evaporation cross section, resulting in a dramatic reduction of the evaporation residue cross section and the population of residues at high spin.

Based on our previous experience in producing proton-rich nuclei in this mass region, we propose to study excited structures in very neutron deficient Pt, Au, Hg, Tl, Pb and Bi nuclei using fusion reactions of symmetric species near the barrier. The high sensitivity in the proposed measurements will be achieved by employing the so-called recoil-decay tagging technique [3] where the γ rays emited at the target position are correlated with subsequent α decays of residues registered at the focal plane of the FMA following mass selection. We propose to use various beams of neutron deficient Sr, Y, Zr and Mo nuclei with $A = 78 - 84$

on the ^{84}Sr, ^{90}Zr and ^{92}Mo targets. For example, the ^{169}Au nucleus can be studied via the $1p$ channel of the ^{78}Sr + ^{92}Mo reaction. By using the following conditions:

- Beam Intensity: I_{beam}=10^{10} pps
- Reaction Cross-section: σ_{1p}=100 μb
- Target tickness: t=0.5 mg/cm^2
- Gammasphere Efficiency: ε_{GS}=10%
- FMA Efficiency: ε_{FMA}=10%

we would expect for a one day run to detect:

- Residues: 290000
- Residue-FMA coincidences: 29000
- Mass-gated singles γ-rays: 2900
- Mass-gated γ-γ coincidences: 290

¿From these estimates, it is clear that nuclei at the proton drip line can be studied in some detail in a 3-4 days experiment.

[1] W. Nazarewicz, Phys. Lett. **B305**, 195 (1993).
[2] R. V. F. Janssens and T. L. Khoo, Annu. Rev. Nucl. Part. Sci. **41**, 321 (1991).
[3] E. S. Paul *et al.*, Phys. Rev. C**51**, 71 (1995); R. S. Simon *et al.*, Z. Phys. A**325**, 197 (1986).