High angular momentum states populated in fragmentation reactions

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The main experimental observables to test the theory of peripheral fragmentation, so far, are the production cross sections and the longitudinal momenta of the fragments. It is more difficult to study the angular momenta of the fragments. Experimentally we cannot determine the population of a single state with a given angular momentum, but only the total population of all the states decaying into the level of interest. Therefore, the study of the population at high angular momentum from the tail of the distribution, provides a much more stringent test of the theory than at lower angular momenta. Here we present results obtained for the population of high angular-momentum states produced in peripheral fragmentation. It has immediate consequences for the production of radioactive beams in long-lived states with high angular momentum, where production rates can be a critical factor.

Neutron-rich nuclei close to the N=126 neutron shell-gap were populated in relativistic energy projectile fragmentation. A beryllium target of thickness 1 g/cm^2 was bombarded with an E/A=900 MeV ^{238}U beam provided by the SIS accelerator at GSI, Darmstadt, Germany. The nuclei of interest were separated and identified using the FRagment Separator (FRS) [1] operated in standard achromatic mode. The ions of interest were implanted in a catcher, surrounded by an array of germanium detectors. The γ-rays in prompt and delayed coincidence with the individually identified fragments were recorded.

Several previously known long-lived states were observed in one magnetic rigidity setting of the fragment separator, centred on ^{216}Ac. The population of these metastable states (isomeric ratios) has been determined. Theoretical calculations have been performed using the Monte Carlo code ABRABLA [2]. In this model the angular momentum is generated by the internal angular momenta of the removed nucleons. The new experimental data for high angular momentum states, $I \geq 17\hbar$, contradict the model: the isomeric ratio is larger than the calculated one, and the discrepancy increases with the angular momentum. The discrepancy is more than a factor of 10 at I=43/2$^-$ (the I=43/2$\hbar$ state in ^{215}Ra represents the highest discrete spin state observed following a projectile fragmentation reaction). Therefore, an additional source of angular momentum has to be considered. Experimentally a clear negative correlation between the mean velocity of the projectile-like fragment and the mass loss in very peripheral collision was observed (e.g. [3]). The velocity decreases as more nucleons are removed. This can be interpreted as the consequence of a kind of friction in the nucleus-nucleus collision. Since the nucleons removed from the projectile are at the periphery, the shift in the longitudinal-momentum will also be accompanied by additional angular-momentum. This angular-momentum can be considered as a collective contribution, as opposed to that originating from the angular momentum of the individual nucleons.

The effect of the collective angular momentum contribution has been estimated. The coupling of the angular momenta representing the single-particle and collective motions significantly improves the description of the experimental data.

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