First results on ^{208}Pb + ^{64}Ni collisions studies

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Reactions induced by heavy ions with incident energies close to the Coulomb barrier have been intensly investigated using particle–gamma coincidence and charged particle spectroscopy methods. A different approach to use the γ–γ coincidence technique to study such collisions was recently demonstrated [1,2]. In this paper we describe some initial results obtained from a study of ^{208}Pb + ^{64}Ni system using γ–γ coincidences supplemented with radioactivity measurements.

The 350 MeV beam energy was chosen, which at the surface of the target corresponds to a collision energy 11 % higher than the Coulomb barrier. A thick ^{208}Pb target (98.7 % enriched) was used to stop the reaction products, consequently the data are integrated over the projectile energy range from the initial 350 MeV down to the Coulomb barrier. The ^{64}Ni beam from the VICKSI HMI Berlin accelerator was pulsed with 69 ns burst separation, which allowed to separate the in–beam and off–beam (isomeric and radioactive decay) events. The γ–γ coincidences were measured using the OSIRIS spectrometer (11 Compton suppressed germanium detectors) together with the multiplicity and sum energy from the 48 element BGO ball.

The analysis of the data included spectroscopy studies of nuclei in the lead and nickel regions. Two first, encouraging results to be mentioned here are the study of γ–decay of the particle–hole states with the highest spins in ^{208}Pb [3] and the identification of new high–spin states in the ^{207}Pb nucleus [4].

To study various processes that take place in the ^{208}Pb + ^{64}Ni collision we aimed to determine as complete as possible the distribution of the reaction products. The relative production yields of long–lived radioactive isotopes produced in the reaction were obtained from measurements of the radioactivity collected in the thick target. These measurements started immediatly after the end of the experiment at HMI Berlin with the OSIRIS array. They were continued for 5 months at the INP Kraków (using a single germanium detector). A detailed analysis of the activity spectra led to the identification of about 120 isotopes produced and stopped in the thick target with lifetimes ranging from few hours to 33 years. Most of the identified nuclei are target–like or projectile–like products which suggests a dominant role of binary processes in the investigated reaction. However, several products in the fusion–fisson mass region were also identified. Rates for the production of those isotopes are quite small, of the order of 10^{-3} as compared to the nuclei that were produced at highest production rates (nuclei close to the target or projectile nucleus). This confirms that at our beam energy ($E_{LAB}/A = 5.5$ MeV/u) almost no compound nuclei are formed as has been already established for this system by R.Bock et al. [5]. It has been shown that the fusion followed by fission starts to play a significant role at energies about $E_{LAB}/A = 6.0$ MeV/u.

From the quantitative analysis of the off-beam coincidence data we determined the production yields of short-lived radioactive isotopes with lifetimes in the range of seconds to few hours as well as the population of isomers living longer than few nanoseconds.

The in-beam coincidence data analysis is also in progress and should provide the production yields for stable isotopes. In individual nuclei the known γ-transitions depopulating states of considerably high spins (up to 20 $\hbar$) are seen. Thus, a comparison of the average spin brought into different reaction products should be possible. We observe also the cross-coincidences of γ-rays emitted from two nuclei – the binary reaction partners. As we can identify both nuclei, we should be able to determine the average number of neutrons and protons evaporated from both hot primary products formed in the first stage of the reaction.

A complete distribution of the reaction products with additional hints on the spin population will enable us to study the mass, charge and angular momentum dissipation phenomena that occur in heavy-ion collisons. One of the interesting questions that we would like to investigate is the equilibration of the N/Z ratio in nuclear reactions of different types.

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