Probing the Coulomb field in relativistic collisions

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Two main questions determine the recent directions of the research in nuclear dynamics. One is the role of the Coulomb field in diluted nuclear matter: in cosmological objects (e.g. neutron stars, supernovae) theoretical studies relate it to the formation of crystalline structures by frustration effects [1]. The Coulomb field can be probed experimentally at the nuclear scale, where it rules the mechanism of disintegration in multifragmentation reactions. Another question is the research of the conditions (density and excitation) that determine the appearing of a bimodal behaviour of the heaviest-residue distribution, which can be related to the order parameter of a liquid-gas phase transition [2].

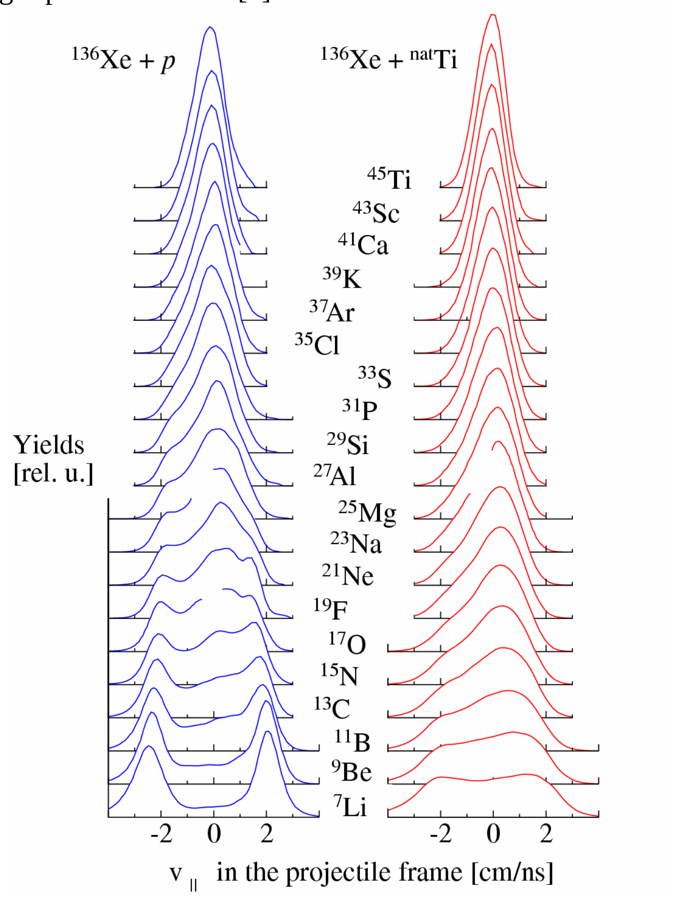

Fig. 1. Normalized experimental velocity spectra, measured for a series of isotopes having $N = Z + 1$ in the systems ^{136}Xe+^{1}H (left) and ^{136}Xe+Ti (right) at 1 *A* GeV.

Among the inclusive measurements, the FRS operated in inverse kinematics provides unique experimental information about the reaction kinematics. The high resolution and absence of energy thresholds in the detection of ejectiles allow for extracting the full longitudinal-velocity spectrum of each nuclide formed as a reaction fragment [3]. Moreover, the possibility of employing liquid-hydrogen and heavy targets allows for studying the largest variation of excitation energy at a given incident energy in relativistic collisions. In Fig. 1, a series of longitudinal-velocity spectra recently measured for the ^{136}Xe+^{1}H, Ti systems [4], is shown for twenty isotopes having N=Z+1. The velocities are shown in the reference frame of the projectile. For both reactions, each spectrum can be decomposed in a double-humped shape and a wide Gaussian-like component. The widths and the relative weights of these components vary as a function of the isotope. Two wide humps are mostly evident in the lightest isotopes produced in ^{136}Xe+^{1}H. Also the system ^{136}Xe+Ti manifests the presence of a two-humped component for isotopes lighter than ^{15}N. As the two humps are largely spaced, the system ^{136}Xe+^{1}H shows clearly the superposition of the Gaussian-like and the two-humped contribution. The high resolution of the spectra even shows that the central Gaussian-like component is shifted in forward directions with respect to the two-humped component.

Multifragmentation reactions are characterised by the simultaneous disintegration of the nuclear system into several fragments. The concept of simultaneity is related to the Coulomb field: the nucleus disassembles so rapidly (10^{-22}-10^{-21}s) that the fragments can exchange mutual interactions while they are accelerated by the Coulomb field of the system. For this reason, the shape of the velocity distributions is directly associated to the multiplicity and size of fragments. Two-humped shapes reflect an asymmetric split: we observe one light fragment repelled by the heavy partner at velocities that even exceed fission velocities [4]. The central component is associated with more complex emission mechanisms such as a volume emission of several light fragments. The forward shift of the central shape with respect to the two-humped component is rather surprising. The central component is related to more violent collisions resulting in volume emission. If we associate more violent collisions only to larger frictional effect, we would expect a shift of the central component in the opposite direction that we observe. The forward peaking of the emission was also measured in ion-ion collisions at the FRS and related to "blast" effects induced on the spectator by the fire-ball [5]. A similar 'highly unusual feature' was observed in proton-induced collisions at high-energy and interpreted as the effect of shock waves [6]. In our experiment such a feature was observed for the first time in proton-induced collisions in the 1 *A* GeV incident-energy range.

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