Jan Orlinski

# Study of transverse flow of lambda baryons and other strange hadrons in relativistic heavy ion collisions

Subatomic physics, which deals with the smallest building blocks of the Universe, has been developing dynamically for over a century. It has provided us with numerous groundbreaking discoveries and continually pushes the boundaries of human knowledge, building some of the largest experiments in the history of physics — particle accelerators and colliders. Several decades ago, the existence of quarks was experimentally confirmed, and simultaneously, a theory describing their interactions — quantum chromodynamics (QCD) — was developed. The effect of this interaction is the combination of quarks into bound systems called hadrons. A system of three quarks is called a baryon, and a quark-antiquark pair forms a meson. The best known baryons — protons and neutrons — are made of up quarks (u) and down quarks (d), although we know of a total of six, including the strange quark (s).

The protons and neutrons thus formed are held together by residual interactions between quarks, forming atomic nuclei. Additionally, protons interact electrostatically, repelling each other. Therefore, the forces binding quarks must be significantly stronger than this repulsion to overcome it. These forces are called the strong interaction. It is not difficult to see that the question of the nature of these interactions essentially touches on the causes and mechanisms of the formation of matter in the Universe as we know it — built from atoms with nuclei at their centers. The interaction between the proton and neutron is also responsible for the formation of neutron stars.

It is believed that hadrons containing strange quarks (strange hadrons) emitted from collisions of atomic nuclei at energies of several gigaelectronvolts per nucleon can provide us with answers to many questions about the nature of this interaction. Strange particles are not produced in large quantities at these energies. A single particle emitted in a collision travels through nuclear matter and has relatively ample time to interact with it. In their resultant momentum, these particles carry information about the nature of this interaction, making them excellent probe particles.

For particles emitted from the collision, the azimuthal angle can be determined relative to the original plane, similar to the geographic longitude relative to the prime meridian. Inhomogeneities (anisotropies) in the distribution of particle emission in this variable are called the transverse flow phenomenon. It is predicted that the transverse flow effect is sensitive to several interesting phenomena occurring in nuclear matter, including its equation of state (the dependence of potential energy on the density of matter) and the change in the effective mass of the particles within it. Measurements of the transverse flow of strange hadrons and comparisons of distributions with model predictions have the potential to bring us closer to understanding the nature of nuclear matter under the extreme conditions of a collision.

One of the unresolved problems in hadron physics is the so-called "hyperon puzzle," which arises from the discrepancy between the observed masses of neutron stars in the Universe and the current theoretical predictions. The core of the problem lies with hyperons — baryons containing, in addition to up and down quarks, strange quarks. Their presence is predicted in neutron stars, which would allow for the formation of neutron stars with correspondingly larger masses or smaller radii, which has not yet been observed. A precise understanding of the nature of nuclear matter and its interaction with strange hadrons may solve this puzzle and reconcile the observed masses of neutron stars with model predictions.