Tracking the baryon quantum number with heavy-ion collisions

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Abstract

The baryon number is a conserved quantity in quantum chromodynamics (QCD), which is typically divided equally among the valence quarks in baryonic matter. There is an alternative theory suggesting that the baryon number is carried by a non-perturbative, Y-shaped topology of gluons called the baryon junction, which connects all three valence quarks. Neither theory has been experimentally verified yet. Preliminary results from semi-inclusive photonuclear collisions identified using Au+Au collisions at $\sqrt{s_{NN}} = 54.4$ GeV have shown significant baryon stopping (an excess of baryons compared to anti-baryons) and rapidity asymmetry at low transverse momentum, which is consistent with the baryon junction picture.

We now present additional studies to differentiate between the two pictures. Our finding, based on data from isobar collisions ($^{96}_{44}\mathrm{Ru} + ^{96}_{44}\mathrm{Ru}$ and $^{96}_{40}\mathrm{Zr} + ^{96}_{40}\mathrm{Zr}$) at $\sqrt{s_{NN}} = 200$ GeV recorded by the STAR experiment, shows that at mid-rapidity ($|y| < 0.5$), the ratio of baryon stopping (B_{net}) to net charge difference between the two systems (ΔC_{net}) is roughy twice the ratio of mass number to atomic number differences (i.e. 96/4) in central events. ΔC_{net} is measured with great precision thanks to the almost identical running conditions for the isobar collisions, resulting in a cancellation of the systematic uncertainties. If both charge and baryon numbers are carried by the valence quarks, $B_{\mathrm{net}}/\Delta C_{\mathrm{net}}$ should be close to 96/4, which is supported by calculations from Ultra-relativistic Quantum Molecular Dynamics model that does not include baryon junction. The observed enhancement in baryon stopping favors the baryon junction hypothesis, as the baryon junction would have different interaction cross section and distribution function compared to quarks. Additionally, a centrality dependence of $B_{\mathrm{net}}/\Delta C_{\mathrm{net}}$ is observed, the shape of which is consistent with the effect of different neutron skins in the two isobar species.