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Probing initial baryon stopping and equation of state with rapidity-dependent directed flow of identified particles

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Using a (3+1)D hybrid hydrodynamic + hadronic transport framework with parametric initial conditions, we study the rapidity-dependent directed flow $v_1(y)$ of identified particles, including pions, kaons, protons, and lambdas, from 7.7 GeV to 200 GeV. The dynamics in the beam direction is first constrained using the measured pseudo-rapidity distribution of charged particles and the net proton rapidity distribution. Within this framework, the directed flow of mesons is driven by the sideward pressure gradient from the tilted source, and that of baryons mainly by the asymmetric baryon distribution with respect to the beam axis on top of the transverse expansion. Our framework successfully explains the rapidity and beam energy dependences of v_1 for both mesons and baryons. We find that the $v_1(y)$ of baryons has strong constraining power on the initial baryon stopping, and together with that of mesons, the directed flow probes the equation of state for the dense nuclear matter at finite chemical potentials. We also provide predictions for the upcoming STAR Beam Energy Scan II measurements of the pseudo-rapidity dependent v_1 for charged particles at 27 GeV.

Primary authors: DU, Lipei (McGill University); SHEN, Chun (Wayne State University); JEON, Sangyong; Prof. GALE, Charles

Presenter: DU, Lipei (McGill University)

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