Probing initial baryon stopping and equation of state with $v_1(y)$ of identified particles

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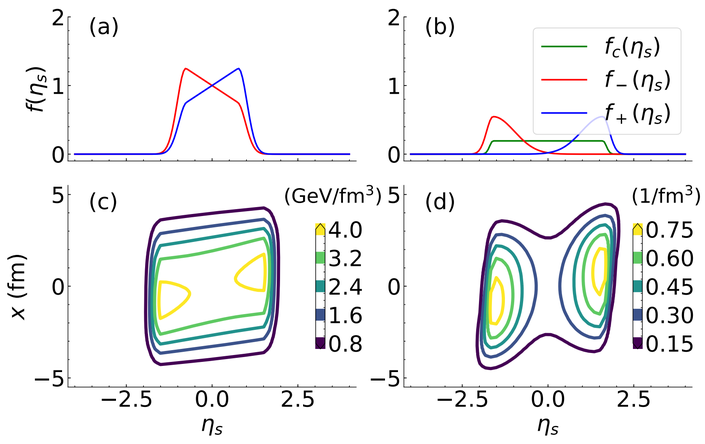
Introduction

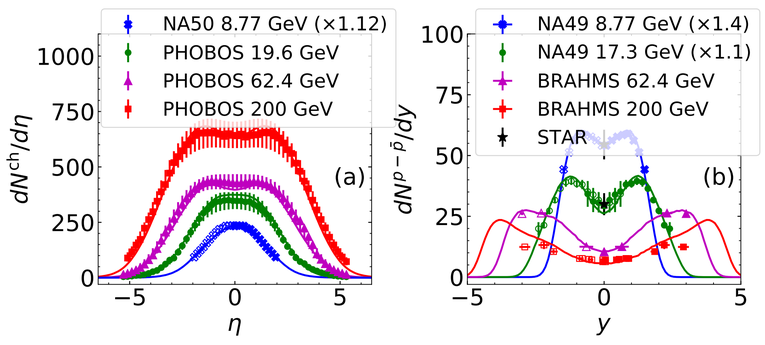
- At RHIC energies and intermediate impact parameters, $dv_1/dy|_{y=0}$ for protons changes sign from positive to negative between 7.7 and 11.5 GeV, with a minimum between 11.5 and 19.6 GeV, while for pion it is negative at all measured energies.
- Although various models have been used to calculate $v_1(y)$ from AGS to top RHIC energies, the results vary widely over the span of the available beam energies and collision systems. We demonstrate why explaining the measured $v_1(y)$ of baryons while also reproducing the rapidity distribution of net protons $dN^{p-\bar{p}}/dy$, which has two peaks is extremely challenging.
- In this work, we explain the $v_1(y)$ for mesons and baryons, using a (3+1)-dimensional hybrid framework with parametric initial conditions, and show how they can constrain the initial baryon stopping and equation of state (EoS) of dense nuclear matter at finite chemical potentials.

Model and Setup

- This work uses a (3+1)-dimensional hybrid framework with parametric initial conditions constructed by extending the nucleus thickness with parametrized longitudinal profiles.
- In the initial baryon profile, we introduce a rapidity-independent plateau component for the first time in a phenomenological study.

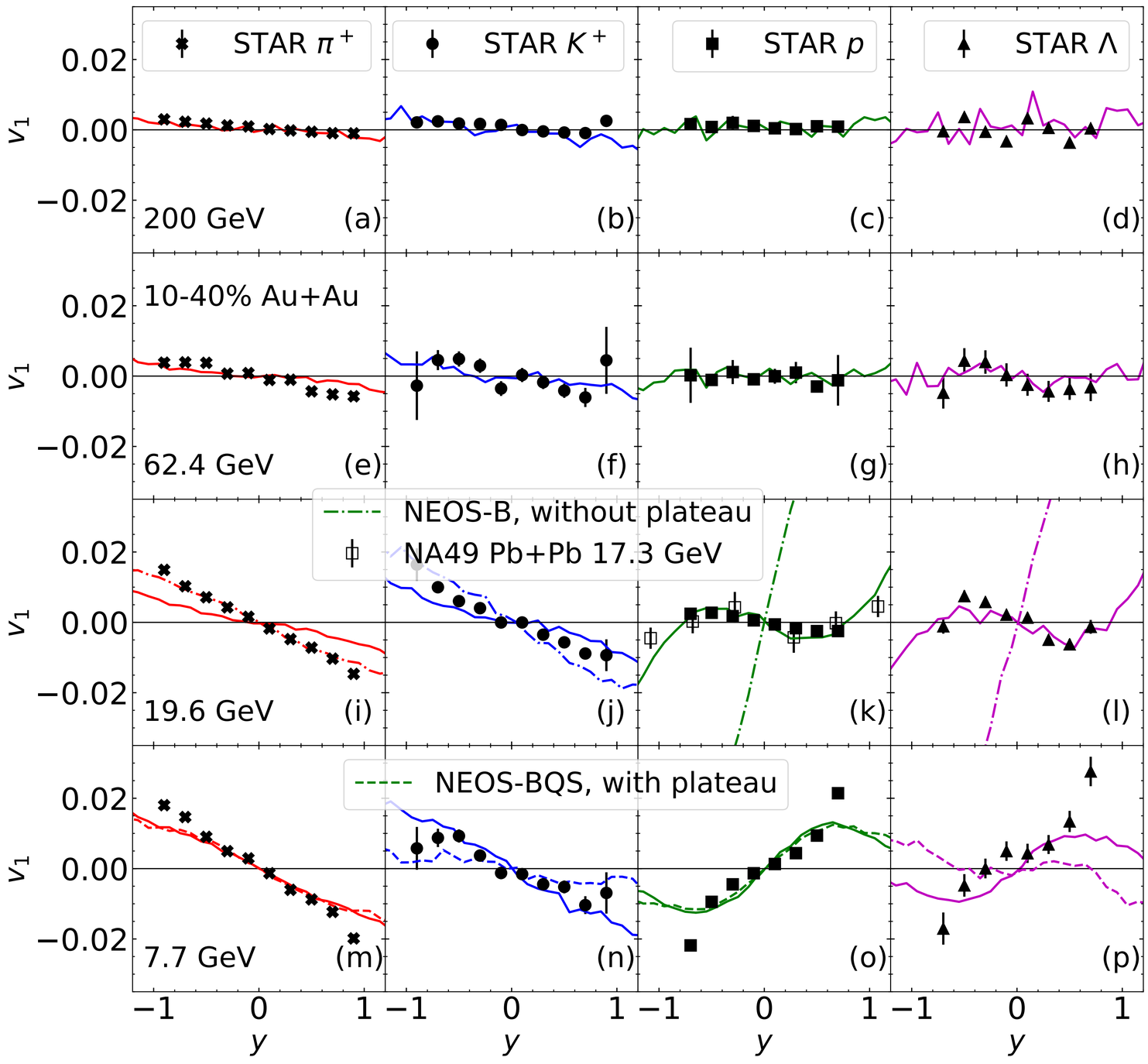


- Within this framework, the directed flow of mesons is driven by the sideward pressure gradient from the tilted source, and that of baryons mainly due to the initial asymmetric baryon distribution with respect to the beam axis driven by the transverse expansion.



- Because the plateau component symmetrically contributes to the baryon density with respect to the beam axis, the $v_1(y)$ of baryons can be strongly suppressed overall, while enough net proton yields can still be achieved around midrapidity since the plateau can contribute a flat net proton yield in rapidity.

Results and Discussion



- At 62.4 and 200 GeV, the plateau component of the net baryon density dominates the mid-rapidity region, resulting in a flat and almost zero $v_1(y)$ of baryons within $|y| \lesssim 1$.
- The $v_1(y)$ of baryons with double sign change in $dv_1(y)/dy$ at 19.6 GeV is nicely reproduced, and that with a positive $dv_1(y)/dy$ around midrapidity at 7.7 GeV is naturally generated.
- Requiring strangeness neutrality $n_S = 0$ (NEOS-BQS) destroys the similarity indicated by the measurements in v_1 of π^+ and K^+, and that in p and Λ at 7.7 GeV. This suggests that to properly describe the dynamical evolution around 10 GeV and lower center-of-mass energies, the simulations propagating multiple charges with EoS at finite $\mu_{B,Q,S}$ without those constraints would be necessary.

Conclusions

- We demonstrate that the $v_1(y)$ of identified hadrons and $dN^{p-\bar{p}}/dy$ together can strongly constrain the initial baryon stopping and that a rapidity-independent plateau component is essential in the initial baryon profile to explain them simultaneously.
- Our study indicates that the rapidity-dependent directed flow measurements of identify strangeness particles around 10 GeV and lower center-of-mass energies can probe the EoS at finite chemical potentials.

References

[1] L. Du, C. Shen, S. Jeon, C. Gale, Probing initial baryon stopping and equation of state with rapidity-dependent directed flow of identified particles, arXiv:2211.16408.

Acknowledgements

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