Probing longitudinal distributions and correlations of net charges in the early-stage of heavy ion collisions

Sangwook Ryu and Chun Shen
Introduction and motivation

- Conserved charges (net baryon, strangeness, etc.) have non-trivial longitudinal distributions in heavy-ion collisions at intermediate and low energies.

Particle production mechanisms

- resonance excitations and decays for low collision energies
- string excitations and fragmentations for high collision energies
- (anisotropic) elastic collisions

Results: net baryon transport in early stage spacetime-momentum rapidity correlation

Early-time momentum-space distribution of net baryon is similar to that from nucleon-nucleon collisions.

\[ \tau = 0.2 \text{ fm} \]

Results: net baryon transport in early stage spacetime-momentum rapidity correlation

Rapid baryon transport toward mid-rapidity occurs by secondary collisions in the first fm/c.

$\tau = 0.4 \text{ fm}$
Results: net baryon transport in early stage spacetime-momentum rapidity correlation

Rapid baryon transport toward mid-rapidity occurs by secondary collisions in the first fm/c.

\[ \tau = 0.8 \text{ fm} \]
Results: net baryon transport in early stage spacetime-momentum rapidity correlation

Rapid baryon transport toward mid-rapidity occurs by secondary collisions in the first fm/c.

\[ \tau = 1.2 \text{ fm} \]

\[ \begin{align*}
\text{Pb+Pb} & \begin{array}{c}
20 \text{ GeV} \\
0 & -3 & -2 & -1 & 0 & 1 & 2 & 3
\end{array} \\
\text{η}_s
\end{align*} \]

\[ \begin{align*}
Pb+Pb & \begin{array}{c}
20 \text{ GeV} \\
0 & -3 & -2 & -1 & 0 & 1 & 2 & 3
\end{array} \\
\text{η}_s
\end{align*} \]

w/ secondary collisions

w/o secondary collisions
Results: net baryon transport in early stage spacetime-momentum rapidity correlation

Rapid baryon transport toward mid-rapidity occurs by secondary collisions in the first fm/c.

\[ \tau = 1.6 \text{ fm} \]

**Au+Au 19.6 GeV 0-20%**

- **w/ secondary collisions**
- **w/o secondary collisions**
Results: net baryon transport in early stage spacetime-momentum rapidity correlation

Rapid baryon transport toward mid-rapidity occurs by secondary collisions in the first fm/c.

\[ \tau = 2.0 \text{ fm} \]

\begin{align*}
\text{w/ secondary collisions} & & \text{w/o secondary collisions}
\end{align*}
**Results**: net baryon transport in early stage spacetime-momentum rapidity correlation

Rapid baryon transport toward mid-rapidity occurs by secondary collisions in the first fm/c.

\[ \tau = 2.4 \text{ fm} \]

- **w/ secondary collisions**
- **w/o secondary collisions**
**Results**: net baryon transport in early stage spacetime-momentum rapidity correlation

Rapid baryon transport toward mid-rapidity occurs by secondary collisions in the first fm/c.

\[ \tau = 2.8 \text{ fm} \]

- **w/ secondary collisions**
- **w/o secondary collisions**
Results: net baryon transport in early stage momentum rapidity distribution

Rapid baryon transport toward mid-rapidity occurs by secondary collisions in the first fm/c.

Au+Au 19.6 GeV

\( \tau = 0.4 \text{ fm} \)
\( \tau = 0.8 \text{ fm} \)
\( \tau = 1.2 \text{ fm} \)
\( \tau = 1.6 \text{ fm} \)
\( \tau = 2.0 \text{ fm} \)

w/ secondary coll.
w/o secondary coll.
Conclusions

• We study early-time longitudinal dynamics of net baryon number with the microscopic transport SMASH, in which particles are produced through resonance excitations and string fragmentations.

• Secondary collisions play crucial roles to efficiently transport net baryon number from forward to mid-rapidity in the first fm/c.
Even more story
Results: net baryon transport in early stage spacetime rapidity distribution

Rapid baryon transport toward mid-rapidity occurs by secondary collisions in the first fm/c.

Au+Au
19.6 GeV

\( \frac{dB}{d\eta_s} \)

\( \tau = 0.4 \text{ fm} \)
\( \tau = 0.8 \text{ fm} \)
\( \tau = 1.2 \text{ fm} \)
\( \tau = 1.6 \text{ fm} \)
\( \tau = 2.0 \text{ fm} \)
w/ secondary coll.
w/o secondary coll.
**Results** : net strangeness in early stage spacetime-momentum rapidity correlation

Secondary collisions does not make as big difference as net baryon.

\[ \tau = 0.4 \text{ fm} \]
Results: net strangeness in early stage spacetime-momentum rapidity correlation

Secondary collisions does not make as big difference as net baryon.

$\tau = 0.8$ fm

w/ secondary collisions  
w/o secondary collisions
Results: net strangeness in early stage spacetime-momentum rapidity correlation

Secondary collisions does not make as big difference as net baryon.

\[ \tau = 1.2 \text{ fm} \]
**Results**: net strangeness in early stage spacetime-momentum rapidity correlation

Secondary collisions do not make as big a difference as net baryon.

$$\tau = 1.6 \text{ fm}$$
Results: net strangeness in early stage spacetime-momentum rapidity correlation

Secondary collisions does not make as big difference as net baryon.

\[ \tau = 2.0 \, \text{fm} \]
Results: net strangeness in early stage spacetime-momentum rapidity correlation
Secondary collisions does not make as big difference as net baryon.

$\tau = 2.4 \text{ fm}$

w/ secondary collisions

w/o secondary collisions
Results: net strangeness in early stage spacetime-momentum rapidity correlation

Secondary collisions does not make as big difference as net baryon.

$\tau = 2.8 \text{ fm}$
Results: system size dependence of net baryon spacetime-momentum rapidity correlation

Secondary collisions are crucial in net baryon transport.

\[ \tau = 2.8 \text{ fm} \]