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Study of Baryon Number Transport via Ω-hadron Correlations

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Abstract

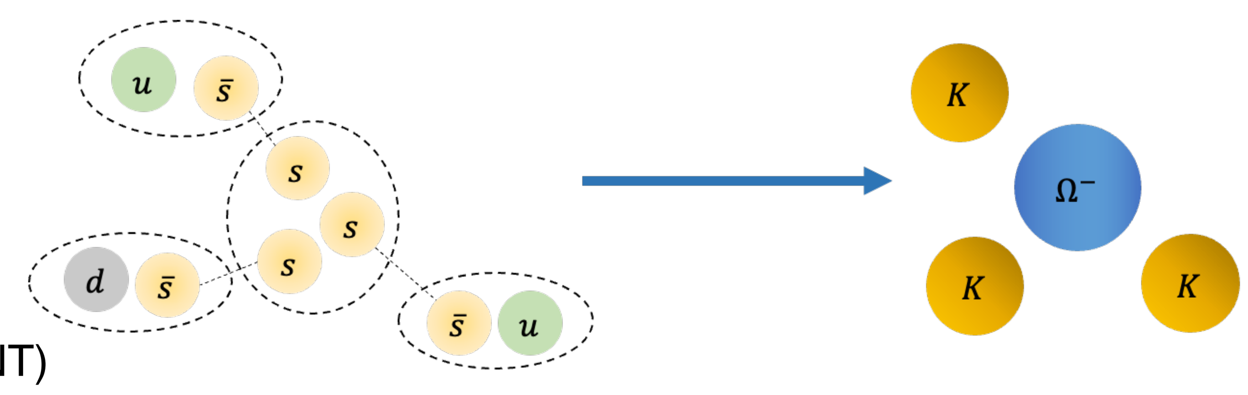
In heavy-ion collisions at lower RHIC BES energies, the $\bar{\Omega}^+$ over Ω^- ratios are significantly below one, suggesting that Ω^- carries net baryon number originated from the colliding nuclei even though s and $\bar{s}$ quarks must be produced in pairs. To investigate the dynamics of possible Ω production scenarios, we propose to measure correlations between Ω and strange hadrons such as K, Λ and Ξ. We will present a novel correlation function based on combinatorial background subtraction that is sensitive to the number of strange hadrons associated with Ω production. Using AMPT simulated events at $\sqrt{s_{NN}} = 7.7$ GeV and 14.6 GeV with both the string-melting (SM) and the default version, the dependence of such correlations on collision energies and harmonization schemes will also be discussed.

Ω^- production in HIC

Scenario 1:

Ω^- carries baryon number from colliding nuclei

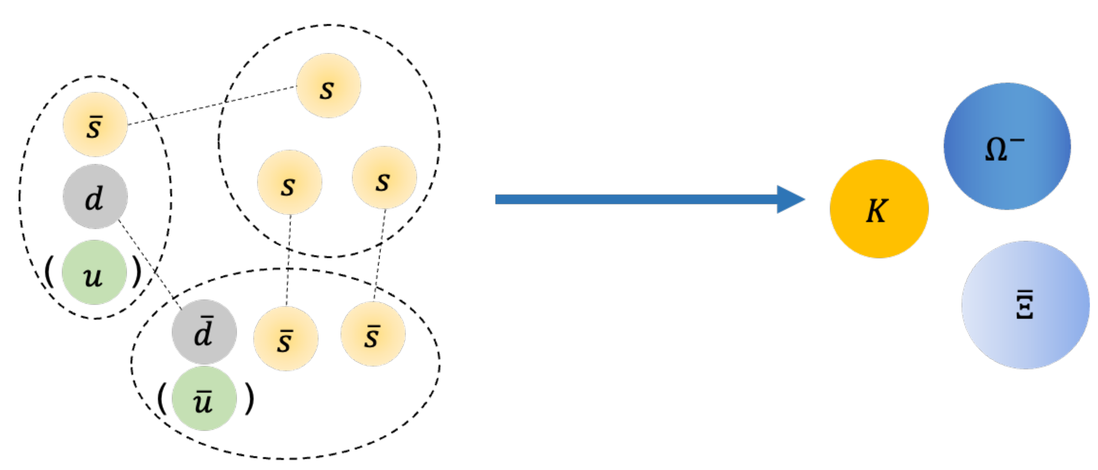
Strangeness Conservation (SC) + Baryon Number Transport (BNT)



Scenario 2:

Strange baryon pair production

Strangeness Conservation (SC) + Baryon Number Conservation (BNC)



At lower RHIC BES energies, below-unity $\bar{\Omega}^+/\Omega^-$ ratios can be attributed to production of Ω^- in scenario 1. Due to the unique nature of Ω^-'s quark content (sss), this scenario may be sensitive to exotic baryon number transport mechanism such as the gluon junction[1], where a Ω^- can be viewed as the result of a Y-shaped gluon junction hadronizing by combining with three s quarks in the QGP matter.

Characterizing Ω^- production scenarios

$$\Delta N_A \equiv \langle A \rangle_{\text{w.}\Omega^-} - \langle A \rangle_{\text{w.o.}\Omega^-}$$

Average number of particle A — With or without Ω^-

	ΔN_K	$\Delta N_{\bar{B}}$
Scenario 1 (SC+BNT)	3	0
Scenario 2 (SC)	1, 2, 3	1

We expect a stronger $\Omega^- K$ correlation in scenario 1 and a stronger $\Omega^- \bar{B}$ correlation in scenario 2.

Correlation Function

Event Mixing Technique:

Can describe the strength and shape of the correlation but is insensitive to the number of hadrons associated with Ω production

$$C(k^*) = \mathcal{N}\frac{A(k^*)}{B(k^*)}$$

$A(k^*)$: Same-event distribution; $B(k^*)$: Mixed-event distribution

—>Cannot distinguish between scenario 1 and 2

Combinatorial Background Subtraction Method (CBS)

Use same-strangeness-sign pairs to model combinatorial background. Sensitive to both the shape and the quantitative effects different Ω production scenarios induce.

$$C^{\text{CBS}}_{\Omega^- K^+}(k^*) = \frac{dN_{\Omega^- K^+}/dk^*}{N_{\Omega^-}} - \frac{dN_{\bar{\Omega}^+ K^+}/dk^*}{N_{\bar{\Omega}^+}}$$

Comparison between $C^{\text{CBS}}_{\Omega^- K^+}(k^*)$ and $C^{\text{CBS}}_{\bar{\Omega}^+ K^-}(k^*)$ **—> scenario 1 dynamics**

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Reference:

[1] D. Kharzeev, Phys. Lett. B **378**, 238 (1996)
[2] Z. Lin, et al, Phys. Rev. C **72**, 064901 (2005)
[3] W. Dong, et al, arXiv:2306.15160 **[hep-ph]**

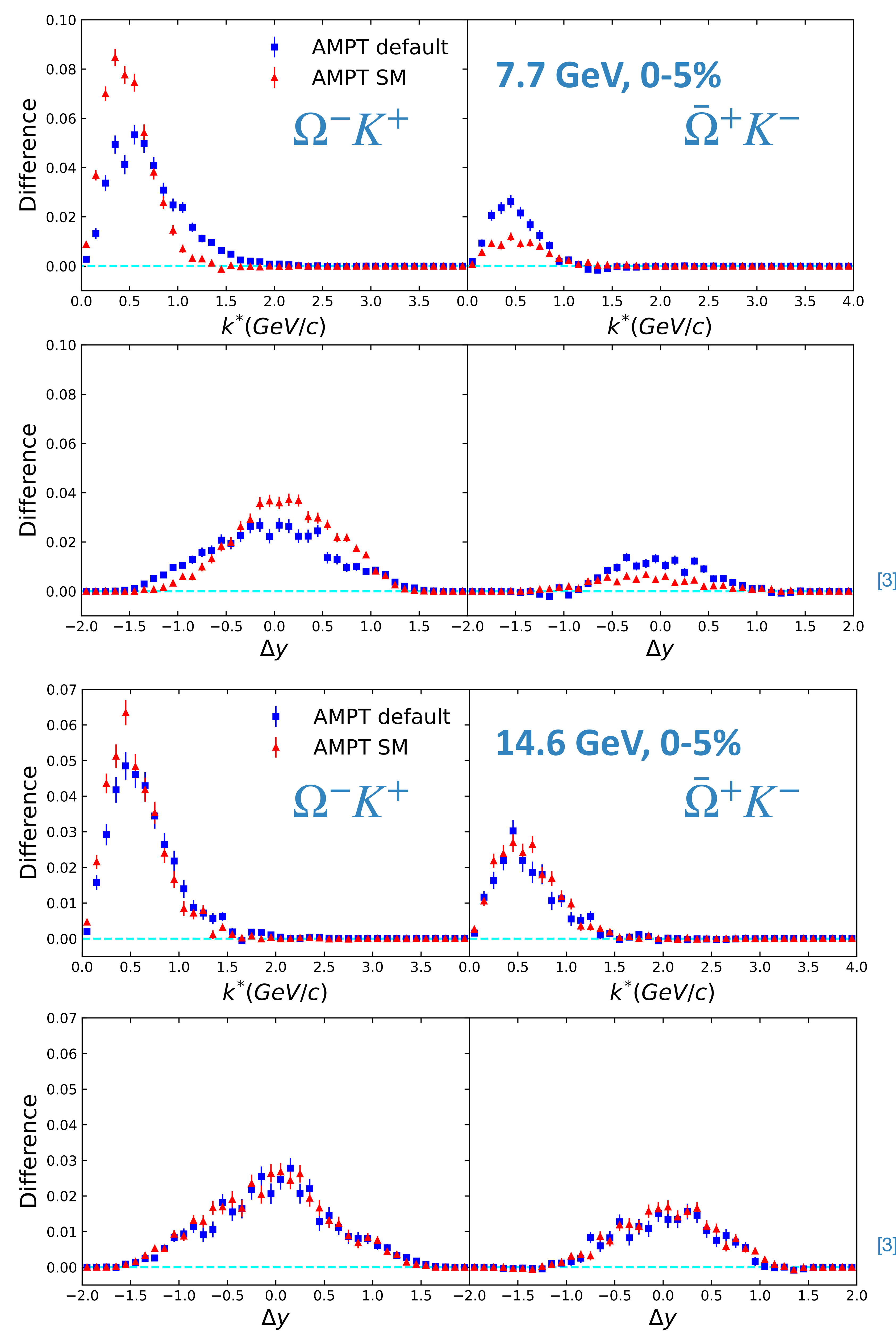
AMPT[2] Simulation

More than 50 million min-bias events with both the string-melting (SM) and default versions at 7.7 GeV and 14.6 GeV.

	Hadronization	7.7 GeV ΔN_K	7.7 GeV $\Delta N_{\bar{B}}$	14.6 GeV ΔN_K	14.6 GeV $\Delta N_{\bar{B}}$
SM	Coalescence	2.46	0.017	2.44	0.119
Default	String fragmentation	1.74	0.078	1.76	0.28

Scenario 1 Ω^- production is more prominent in SM version at both 7.7 GeV and 14.6 GeV

CBS $\Omega^- K^+$ and $\bar{\Omega}^+ K^-$ Correlations



Summary

We introduce the novel CBS approach, which is sensitive to dynamics of different Ω^- production scenarios. Both AMPT-SM and AMPT-Default show excess $\Omega^- K^+$ correlation over $\bar{\Omega}^+ K^-$ correlation at 7.7 GeV and 14.6 GeV, confirming the existence of scenario 1. AMPT-SM exhibits more significant scenario 1 contribution at 7.7 GeV. Comparison of these results with experimental measurement may reveal dynamical signatures of exotic BNT mechanism such as the gluon junction.