Local Baryon-Strangeness Correlation from Hypernuclei and Coalescence Volume from Light Nuclei in Relativistic Heavy Ion Collisions

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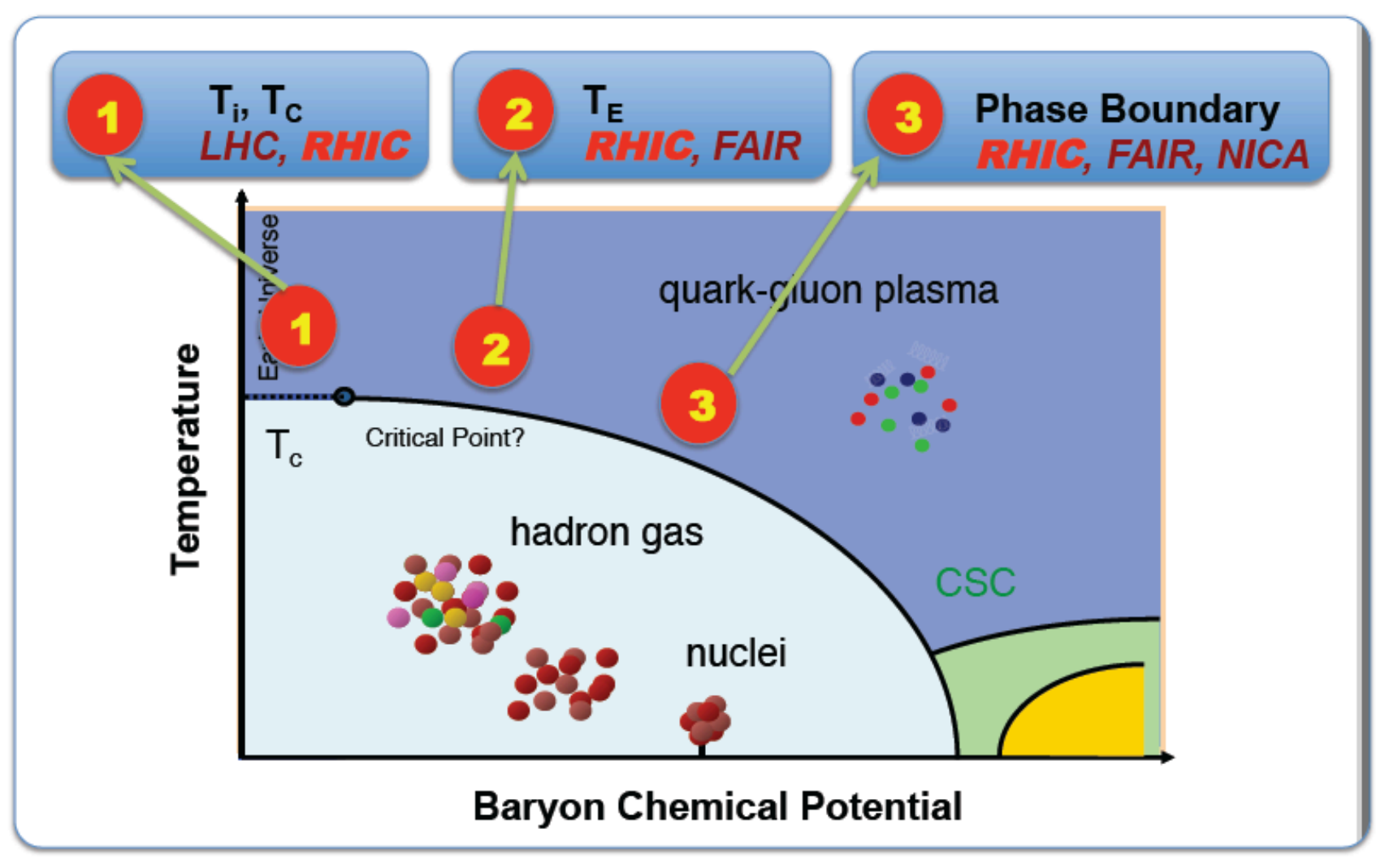
ABSTRACT

The production of hypertriton and light nuclei are simulated in a dynamical coalescence model coupled with a multi-phase transport model (AMPT). The beam energy dependence of strangeness population factor, $S_3 = \frac{{}^3_\Lambda H}{{}^3H_e \times (\frac{\Lambda}{p})}$, is calculated to study local baryon-strangeness correlation as a valuable tool to probe the nature of the dense matter created in relativistic heavy ion collisions. We find that AMPT with string melting predicts an increase of S_3 with increasing beam energy, and is consistent with experimental data, while AMPT with only hadronic scattering results in a low S_3 throughout the energy range from AGS to RHIC, and fails to describe the experimental data. And we analyzed coalescence parameters, B_2 and B_3, based on the production of deuteron, helium-3 and proton. The coalescence parameters of B_2 and B_3 decrease with increasing of beam energy or number of participant. The value of B_2 and B_3 in this model are consistent with the measurement by experiment collaboration in nucleus-nucleus collisions at different beam energy or in different centralities. The freeze-out correlation volume, V_f^{A-1} (A is atomic mass number), is calculated in AMPT model. The results of coalescence parameter and the freeze-out correlation volume follow the relation of $B_A \sim V_f^{1-A}$, which is from coalescence mechanism and observed in experiments.

QCD Phase transition

The baryon-strangeness local correlation and evolution of collision zone are sensitive to deconfinement phase transition



Dynamical Coalescence model

The multiplicity of a M-hadron cluster in a heavy ion collision is given by,

$$N_M = G\int d\vec{r}_{i_1}\, d\vec{q}_{i_1} \cdots d\vec{r}_{i_{M-1}}\, d\vec{q}_{i_{M-1}} \times \left\langle \sum_{i_1 > i_2 > \cdots > i_M} \rho_i^W(\vec{r}_{i_1}, \vec{q}_{i_1} \cdots \vec{r}_{i_{M-1}} \vec{q}_{i_{M-1}}) \right\rangle$$

Deuteron: $\rho_d^W(r,\vec{k}) = 8\left(-\frac{r^2}{\sigma_d^2}\right)\exp\left[-\vec{k}^2\sigma_d^2\right]$

3-hadron cluster: $\rho_{3h}^W(\rho,\lambda,\vec{k}_\rho,\vec{k}_\lambda) = 8^2\left(-\frac{\rho^2+\lambda^2}{\sigma_{3h}^2}\right)\exp\left[-(\vec{k}_\rho^2+\vec{k}_\lambda^2)\sigma_{3h}^2\right]$

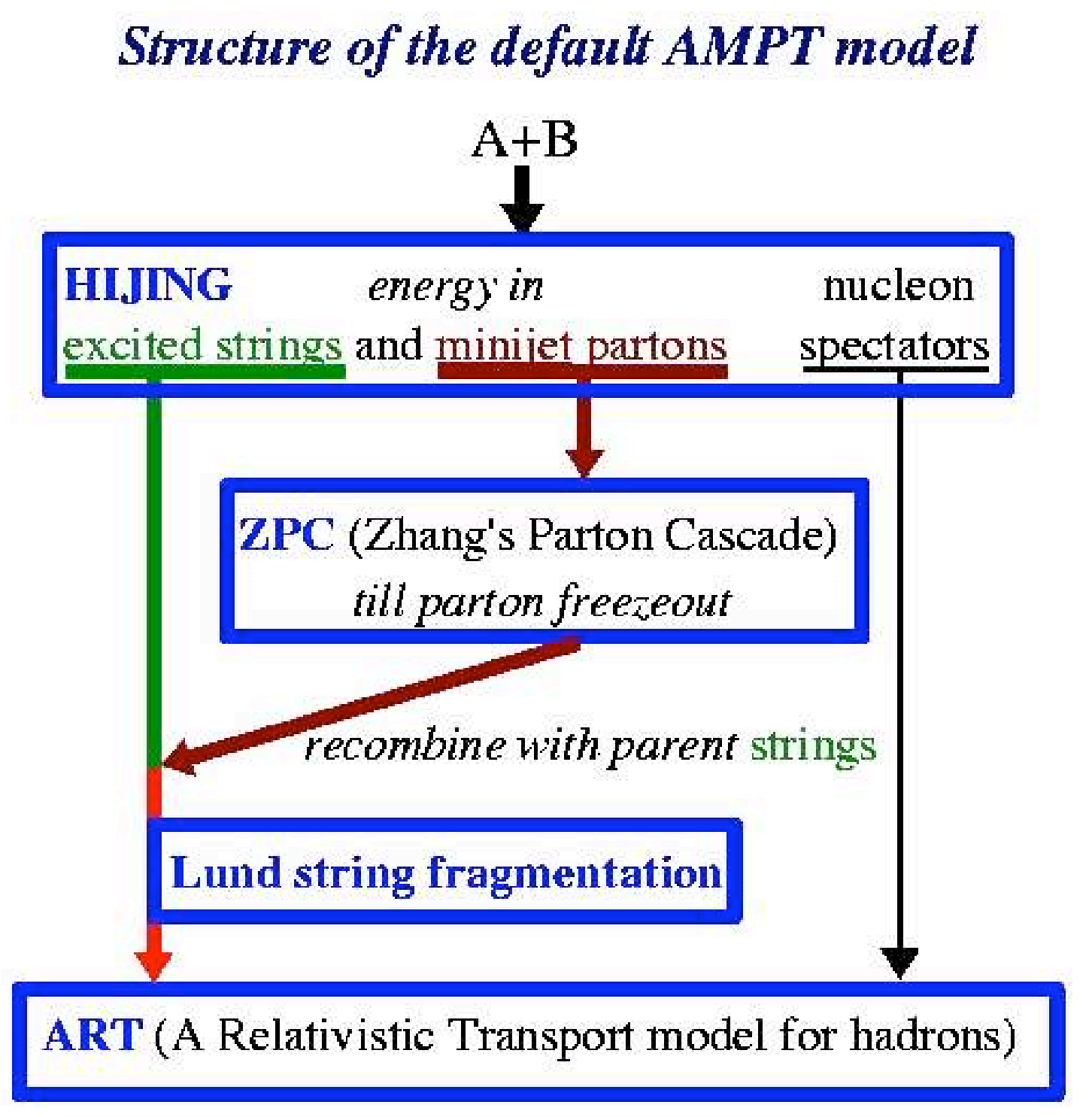
Coalescence picture: d(p,n), t(p,n,n), ${}^3_\Lambda$H(p,n,Λ), ^{3}H$_e$(p,p,n)

HTB

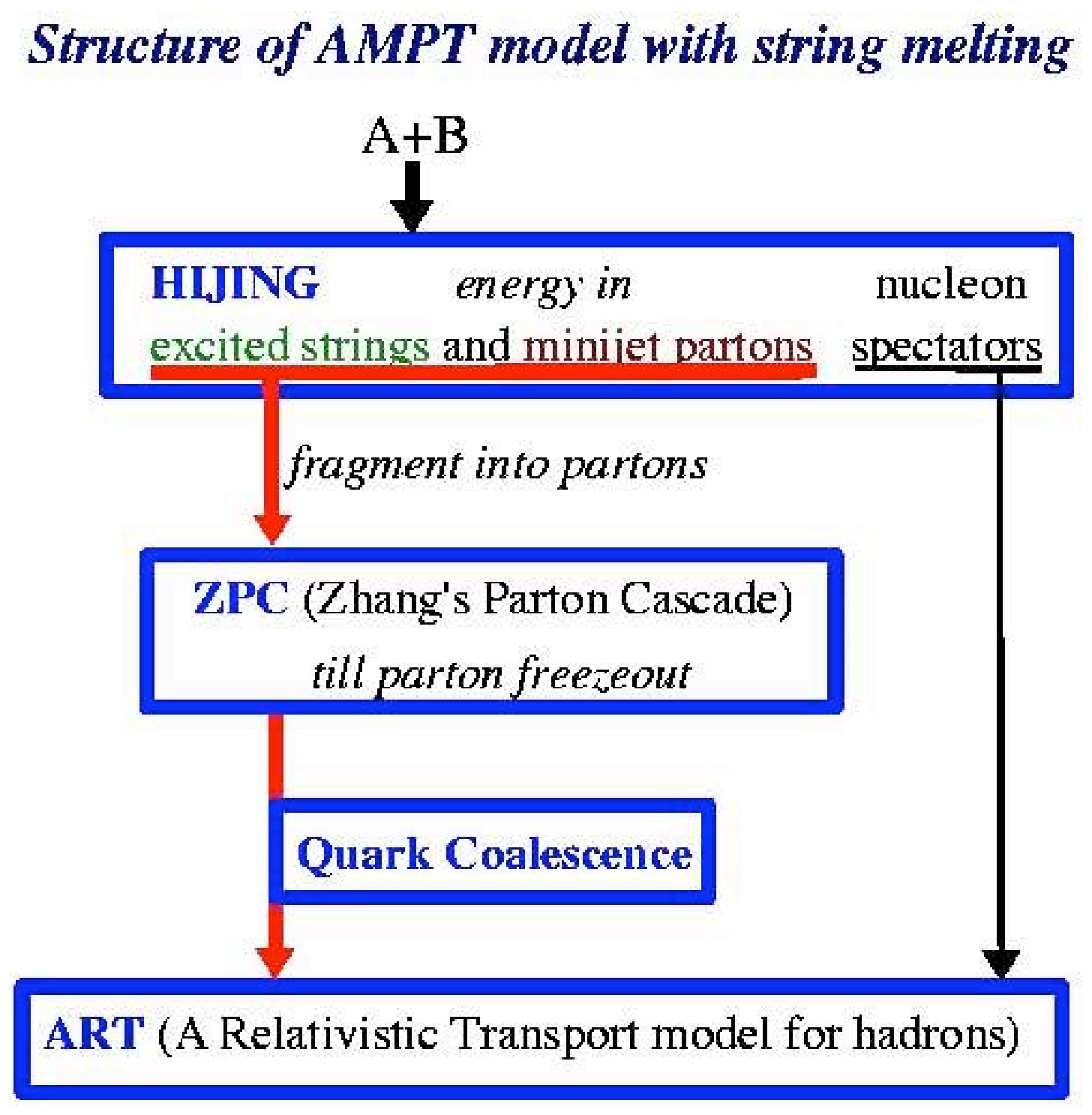
CRAB is based on the formula,

$$C(\vec{P}_{tot},\vec{q}) = 1 + \frac{\int d^4x_1 d^4x_2 S_1(x_1,\vec{p}_1) S_2(x_2,\vec{p}_2) |\phi_{rel}(x_2' - x_1')|^2}{\int d^4x_1 d^4x_2 S_1(x_1,\vec{p}_1) S_2(x_2,\vec{p}_2)}$$

AMPT model


Structure of the default AMPT model

A+B
HIJING energy in excited strings and minijet partons nucleon spectators
ZPC (Zhang's Parton Cascade) till parton freezeout
recombine with parent strings
Lund string fragmentation
ART (A Relativistic Transport model for hadrons)


Structure of AMPT model with string melting

A+B
HIJING energy in excited strings and minijet partons nucleon spectators
fragment into partons
ZPC (Zhang's Parton Cascade) till parton freezeout
Quark Coalescence
ART (A Relativistic Transport model for hadrons)

(1) Initial condition (HIJING); (2) Parton cascade (ZPC);
(3) Hadronizition; (4) Hadronic rescattering (ART)

Reference

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[2] V. L. Kolesnikov (for NA59 Collaboration), J. Phys. Conf. Ser. 110, 032010 (2008) and references therein.
[3] B. I. Abelev et~al. (STAR Collaboration), arXiv:0909.0566.
[4] H. H. Gutbrod et~al., Phys. Rev. Lett. 37, 667 (1976).
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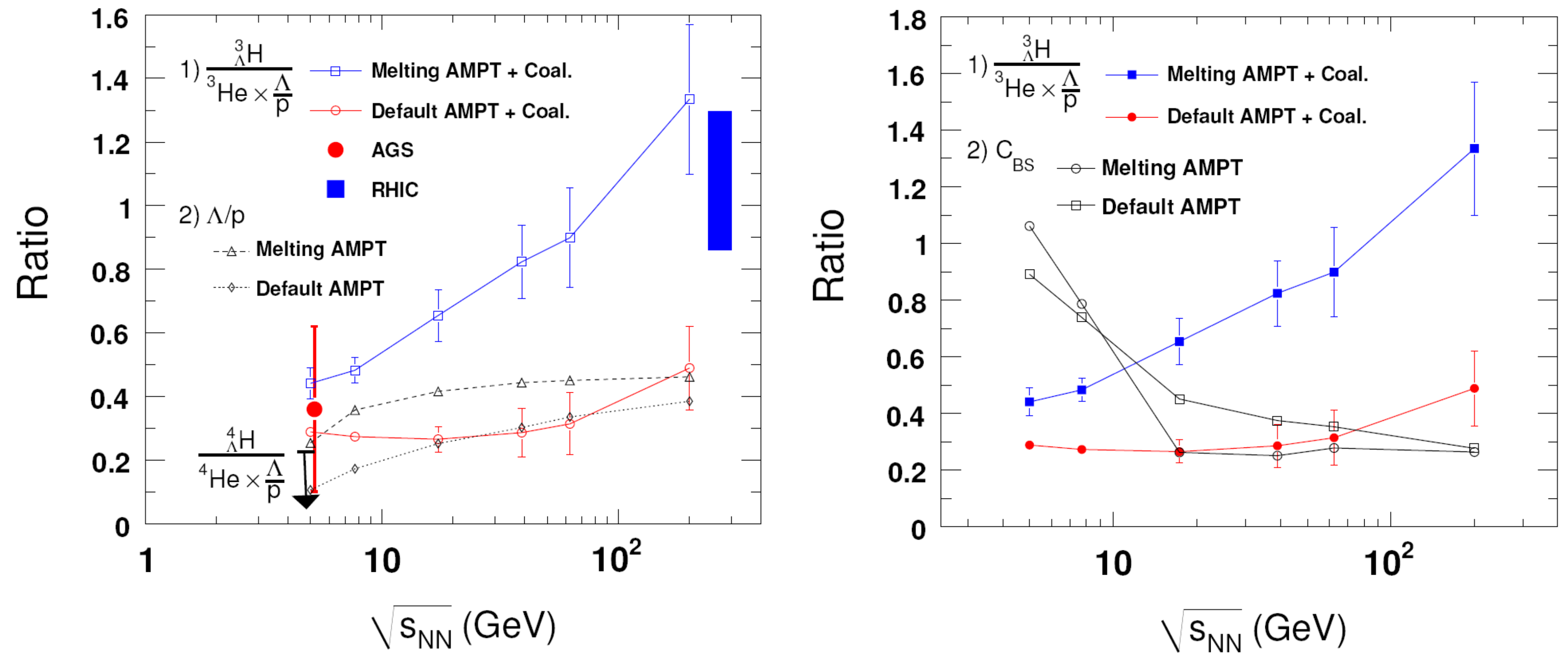
Strangeness population Factor, $S_3 = \frac{{}^3_\Lambda H}{{}^3H_e \times (\frac{\Lambda}{p})}$

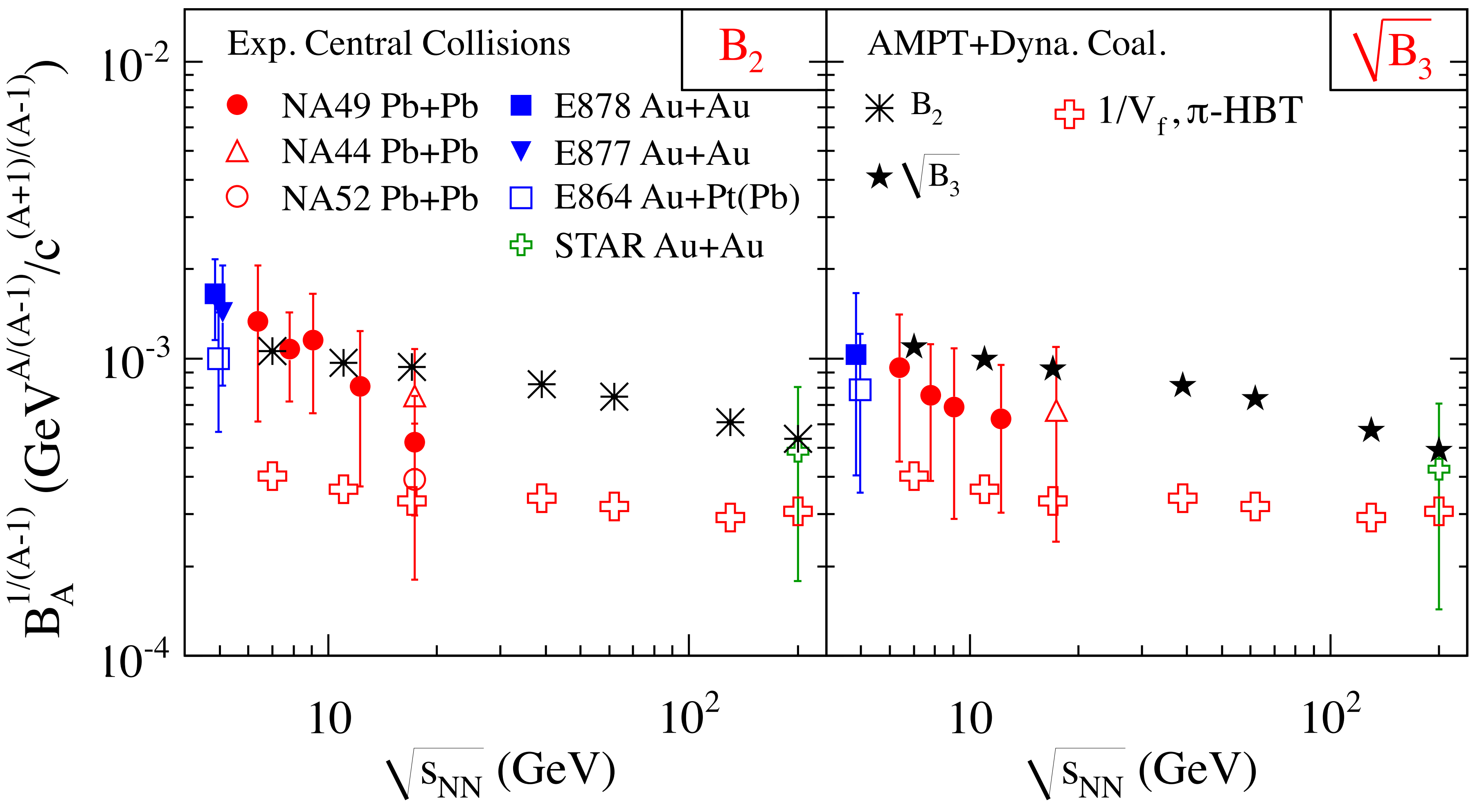


✦Strangeness population factor is sensitive to the freedom degree of the dense medium created in HIC, namely sensitive to the deconfinement;
✦A valuable tool to probe the nature of the dense matter created in HIC

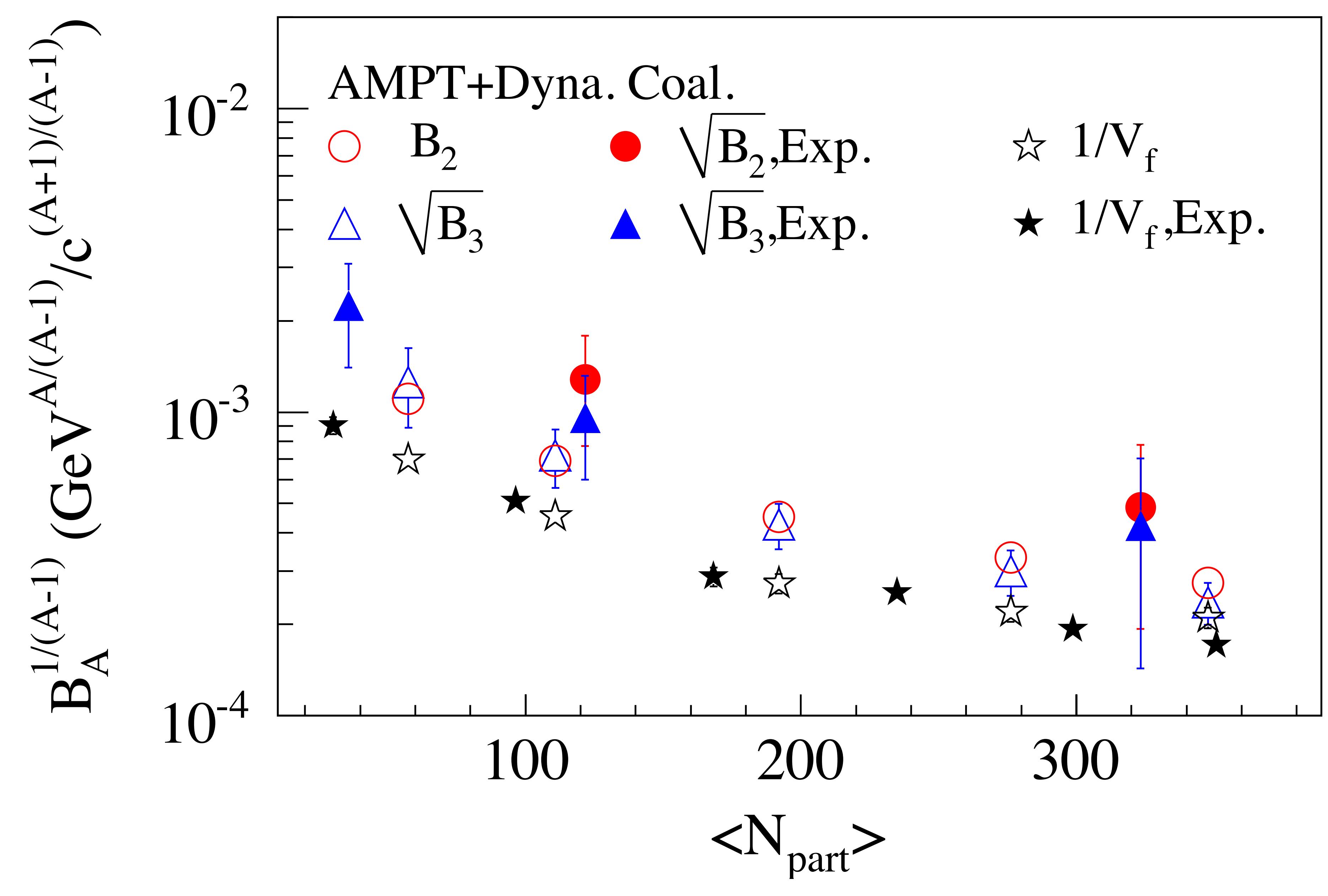
Coalescence parameter and freeze-out correlation volume

Coalescence parameter: $B_A = \frac{d^3N_A / d^3p_A}{(d^3N_p / d^3p_p)^A}$, assuming neutrons have the same distribution of protons

Freeze-out correlation volume: $V_f = (2\pi)^{3/2} R_{side}^2 R_{long}$, R_{side} and R_{long} are the sideward and longitudinal radii from HBT.



✦ The coalescence parameters and reverse of freeze-out volume decrease with increasing of beam energy
✦ The evolution of collisions zone can reach a larger system volume at more high energy collisions



✦ The coalescence parameters and reverse of freeze-out volume decrease with increasing of number of participant

Summary

This beam energy and system size dependences indicate the increase of source size in more high energy collisions and in more central collisions.