Net-proton fluctuations influenced by baryon stopping and quark deconfinement

Oleh Savchuk

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[OS, arXiv:2407.17670]
WPCF 2024 - 17th Workshop on Particle Correlations and Femtoscopy

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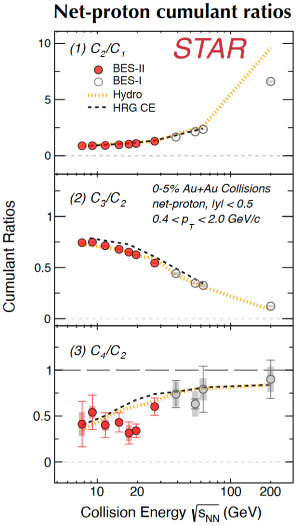
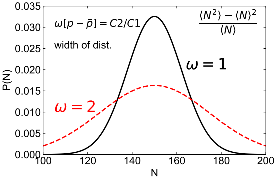
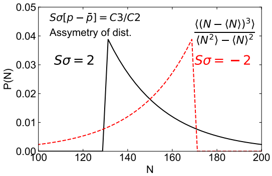
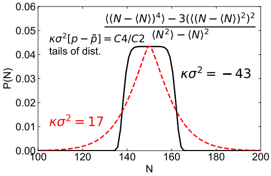
STAR and Onset of deconfinement



HRG CE: P. B Munzinger et al, NPA 1008, 122141 (2021)
Hydro: V. Vovchenko et al, PRC 105, 014904 (2022)





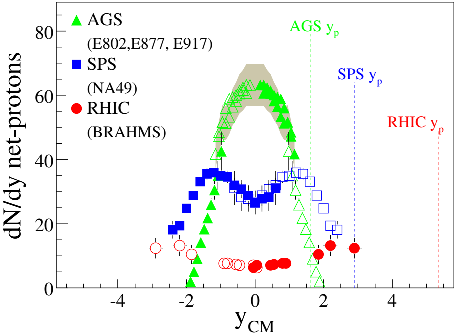


Baryon stopping and pair creation

The creation of pairs and the charge stoping effects in fluctuations can be studied separately:

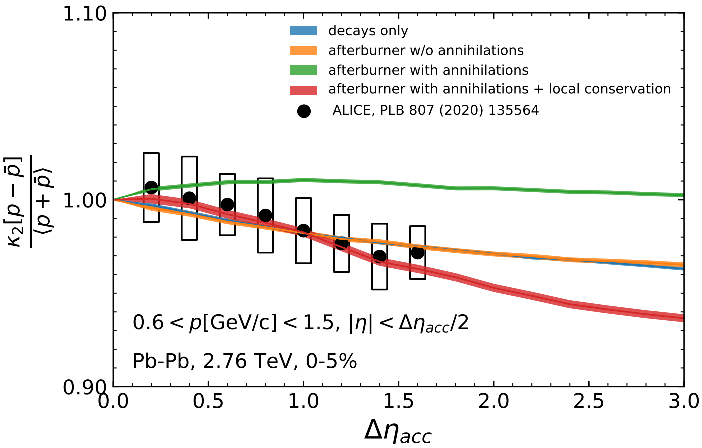
$$\kappa_n = \kappa_n^{\text{stopping}} + \kappa_n^{\text{pair}}.$$

One can expect that net-proton charge is a proxy of stopped charge, while antiprotons are proxies of pairs.



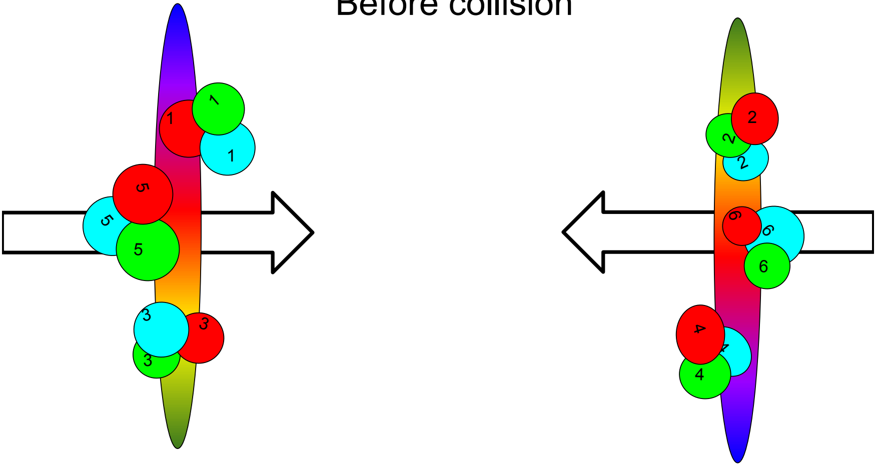
I. G. Bearden et al. (BRAHMS Collaboration), "Nuclear stopping in Au + Au collisions at $\sqrt{s_{NN}} = 200$ GeV", Phys. Rev. Lett. **93**, 102301 (2004)

At high energies all particles produced in pairs. In this case local charge conservation has strongest effect on fluctuation observables:

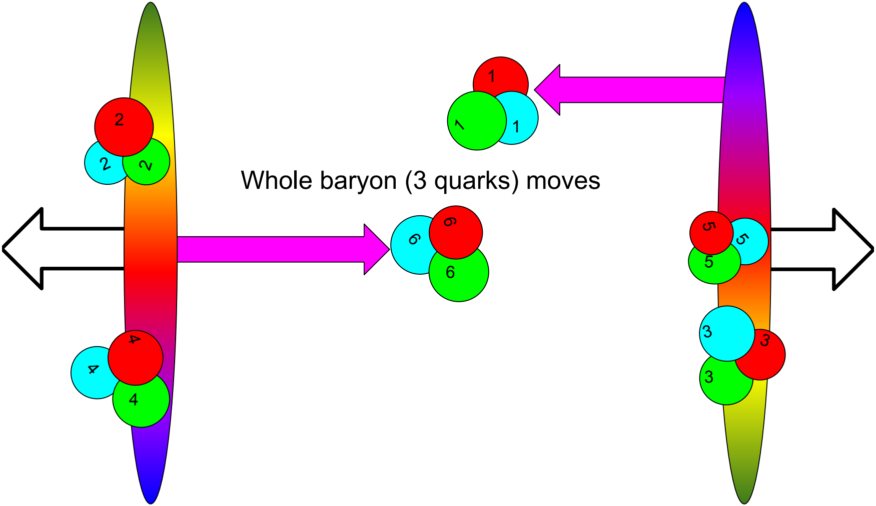


O. Savchuk, V. Vovchenko, V. Koch, J. Steinheimer, and H. Stoecker, "Constraining baryon annihilation in the hadronic phase of heavy-ion collisions via event-by-event fluctuations", Phys. Lett. B **827**, 136983 (2022), arXiv:2106.08239 [hep-ph]

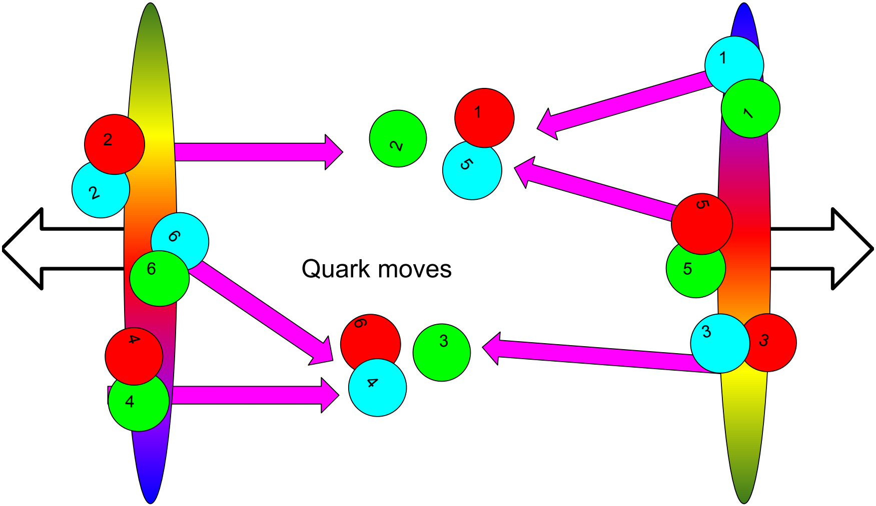
Before collision



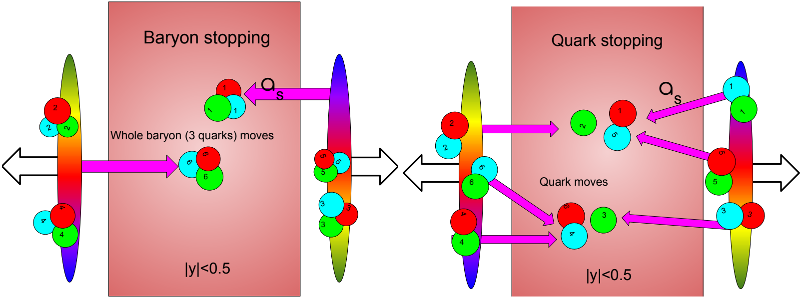
Baryon stopping



Quark stopping



Stopping



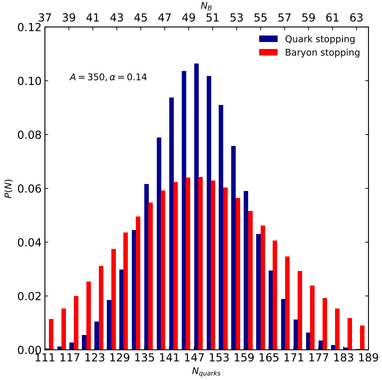
$$\kappa_1^{\text{stopping}} = \alpha_s B_s,$$
$$\kappa_2^{\text{stopping}} = B_s \alpha_s (1-\alpha_s),$$
$$\kappa_3^{\text{stopping}} = B_s \alpha_s (1-\alpha_s)(1-2\alpha_s),$$
$$\kappa_4^{\text{stopping}} = B_s \alpha_s (1-\alpha_s)(1-6\alpha_s(1-\alpha_s)).$$

$$\kappa_1^{\text{stopping}} = \alpha_s B_s,$$
$$\kappa_2^{\text{stopping}} = \frac{1}{3} B_s \alpha_s (1-\alpha_s),$$
$$\kappa_3^{\text{stopping}} = \frac{1}{9} B_s \alpha_s (1-\alpha_s)(1-2\alpha_s),$$
$$\kappa_4^{\text{stopping}} = \frac{1}{27} B_s \alpha_s (1-\alpha_s)(1-6\alpha_s(1-\alpha_s)).$$

Huge suppresion of fluctuations in quarks compared to baryons!

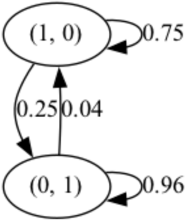
Recombination

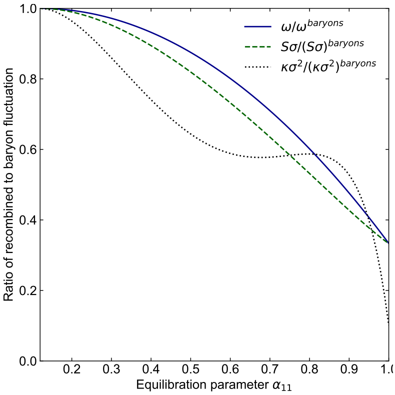
Quarks undergo coalescence into baryons and move in groups of three:



Recombination

- a_{11} - start and finish within acceptance;
- a_{12} - start inside but finish outside;
- a_{21} - start outside and finish inside;
- a_{22} - star and finish outside acceptance;





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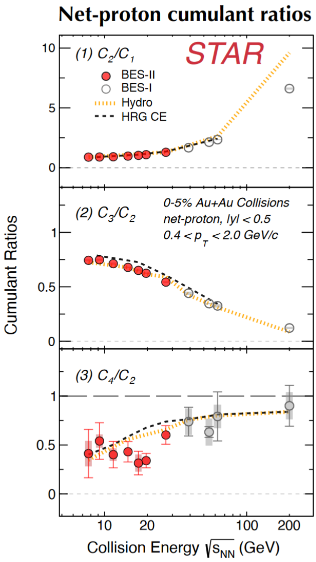
STAR



HRG CE: P. B Munzinger et al, NPA 1008, 122141 (2021)
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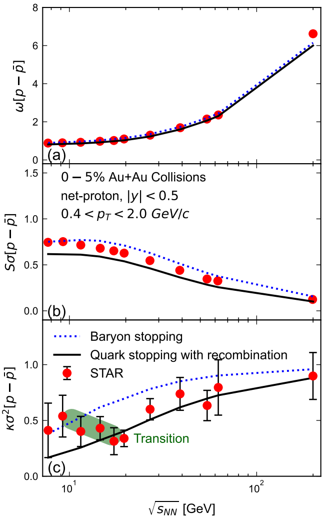
- The baryon stopping baseline reproduces data for scaled variance and skewness.
- Kurtosis notable has a dip in the data when compared to the models.
- Can one "fix" scaled variance and skewness in the quark model?

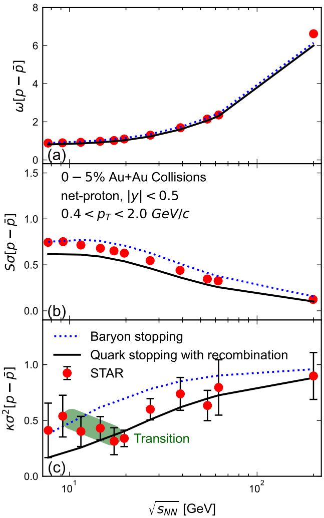
Quark vs. baryon stopping



[OS, arXiv:2407.17670]

- Scaled variance and skewness match the STAR data.
- The suppression in kurtosis successfully captured by the quark stopping.
- Transition from baryon to quark stopping should happen in $\sqrt{s_{NN}} = 7.7 - 17.3\ GeV$ range.

Quark vs. baryon stopping



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- Scaled variance and skewness match the STAR data.
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Thank you for attention!

Extracting proton fluctuations

If the total number of baryons B fluctuates:

$$\omega_\alpha[p] \equiv \frac{\kappa_2[p|\alpha]}{\kappa_1[p|\alpha]} = 1-\alpha+\alpha\omega[B] \;, \tag{1}$$

$$S\sigma_\alpha[p] = \frac{\kappa_3[p|\alpha]}{\kappa_2[p|\alpha]} = \frac{\omega[B]}{\omega_\alpha[p]}\left\{\alpha^2 S\sigma[B] + 3\alpha(1-\alpha)\right\} + \frac{1-\alpha}{\omega_\alpha[p]}(1-2\alpha) \;, \tag{2}$$

$$\kappa\sigma^2_\alpha[p] = \frac{\kappa_4[p|\alpha]}{\kappa_2[p|\alpha]} = \frac{\omega[B]}{\omega_\alpha[p]}\left\{\alpha^3 \kappa\sigma^2[B]\right\} + \frac{\omega[B]}{\omega_\alpha[p]}(1-\alpha)\left\{6\alpha^2 S\sigma[B] + \alpha(7-11\alpha)\right\} + \frac{1-\alpha}{\omega_\alpha[p]}\left\{1-6\alpha(1-\alpha)\right\} \;, \tag{3}$$

[O.S,R.Poberezhnyuk,V.Vovchenko,M.Gorenstein, PRC, 2020]

[O.S,R.Poberezhnyuk,M.Gorenstein, Physics Letters B 835, 137540 (2022)]

Fluctuations of protons can be obtained from fluctuations of baryons if binomial model works.