Event by event strangeness fluctuation in MPD-NICA experiment

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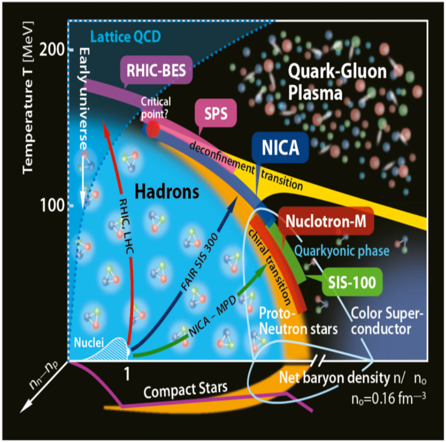
Content

Motivation: QCD Phase diagram

- Some QCD calculations indicate that there exists a critical point in the phase transition from hadron gas to quark-gluon plasma.
- The Critical Point can be explored experimentally by studying Quantum Number Fluctuations.
- The MPD experiment is going to explore the region were the Critical Point can be found.



Cumulants

Let $\Delta N = N - \bar{N}$ be the net multiplicity of a particle, then the standard deviation is $\delta N = \Delta N - \langle \Delta N \rangle$, and the first order cumulants are defined as:

$$C_1 = \langle \Delta N \rangle, \quad C_2 = \langle (\delta N)^2 \rangle, \quad C_3 = \langle (\delta N)^3 \rangle, \tag{1}$$
$$C_4 = \langle (\delta N)^4 \rangle - 3\langle (\delta N)^2 \rangle^2.$$

The cumulants are related with the statistical moments as:

$$M = C_1, \quad \sigma^2 = C_2, \quad S = \frac{C_3}{(C_2)^{3/2}}, \quad \kappa = \frac{C_4}{(C_2)^2} \tag{2}$$

Cumulants from thermodynamic point of view

Modeling the particle system with a partition function for a grand canonical ensemble $Z(z, V, T)$, it can be shown that

$$C_n = \frac{\partial^n \log Z}{\partial(\mu/T)^n}. \tag{3}$$

Using the definition of generalized susceptibilities:

$$\chi_q^{(n)} = \frac{1}{VT^3}\frac{\partial^n \log Z}{\partial(\mu_q/T)^n} \Rightarrow C_n = VT^3\chi_q^{(n)}. \tag{4}$$

where $\chi_q^{(n)}$ can be theoretically calculated. Additionally, the cumulants are also related to the correlation length ξ as:

$$C_2 \sim \xi^2, \quad C_3 \sim \xi^{4,5}, \quad C_4 \sim \xi^7. \tag{5}$$

In the ideal thermodynamic limit, ξ diverges at the critical point.

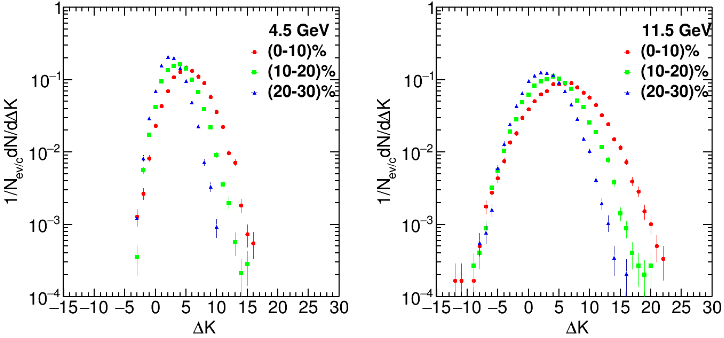
Data Analysis

Data sample

The following events were generated using the model UrQMD.

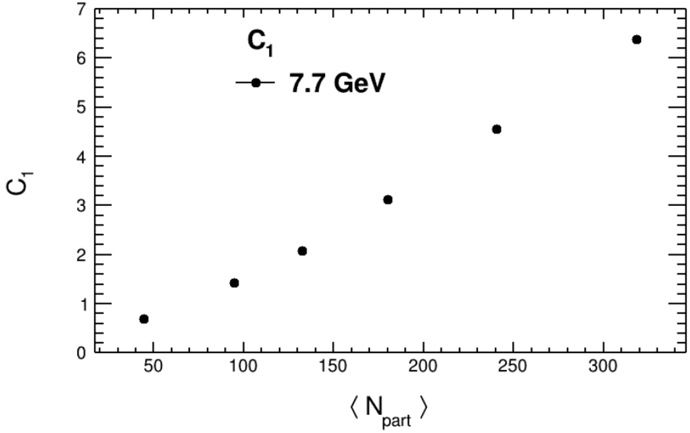
Collision Type	$\sqrt{S_{NN}}$	Events	Analysis
Au+Au	4.5 GeV	190,000	Monte Carlo
Au+Au	7.7 GeV	190,000	Monte Carlo
Au+Au	9.2 GeV	190,000	Monte Carlo
Au+Au	11.5 GeV	190,000	Monte Carlo
Bi+Bi	9.2 GeV	300,000	Reconstructed

MC: Kaon net number at different energy



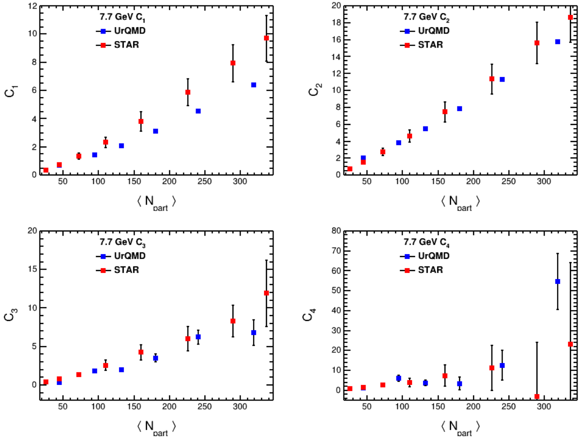
ΔK Distributions. Distributions from most central collisions are wider. As centrality decreases, the peak shifts towards zero. The distributions are not symmetrical. $0{,}2 \leq p_T \leq 1{,}2$ GeV/c. $|y| \leq 0{,}5$.

MC: Net kaon C_1 as a function of participants for Au+Au



The volume dependency is observed.

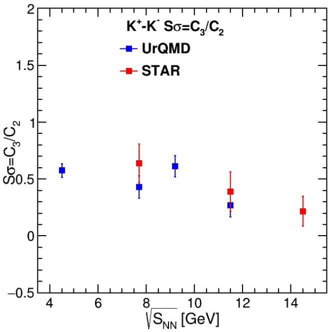
MC: Comparison with STAR data. ΔK, $\sqrt{s_{NN}} = 7{,}7$ GeV



The first cumulant does not match the experimental data; however, the agreement with the other cumulants is very good.

MC: Ratio of Cumulants and its comparison with STAR data

Comparison with STAR data for central Au+Au collisions at different energies.

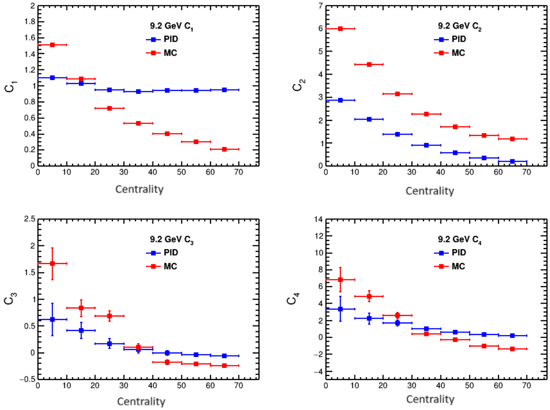


A prediction is shown for energies of 4.5 GeV and 9.7 GeV; however, it is necessary to test different models.

Possible measurements in the MPD experiment

UrQMD generated Bi+Bi events. $\sqrt{s_{NN}} = 9{,}2$ GeV. Reconstructed Data

Calculation of cumulants (uncorrected)



Statistical cumulants (uncorrected) compared with Monte Carlo. It is not possible to perform the physical analysis without correction.

Cumulants Corrections

To perform the correction, we assume that the difference between the real distribution P and the measured distribution p can be modeled as a binomial distribution, so defining the factorial moments of p and P as

$$f_{ik} = \left\langle \frac{n_1!}{(n_1 - i)!} \frac{n_2!}{(n_2 - k)!} \right\rangle, \quad F_{ik} = \left\langle \frac{N_1!}{(N_1 - i)!} \frac{N_2!}{(N_2 - k)!} \right\rangle \tag{6}$$

we can get the relation

$$F_{ik} = \frac{1}{p_+^i p_-^k} f_{ik}. \tag{7}$$

p_+ and p_- the acceptance of the identification. With this relation, is possible to obtain the real value of the cumulants.

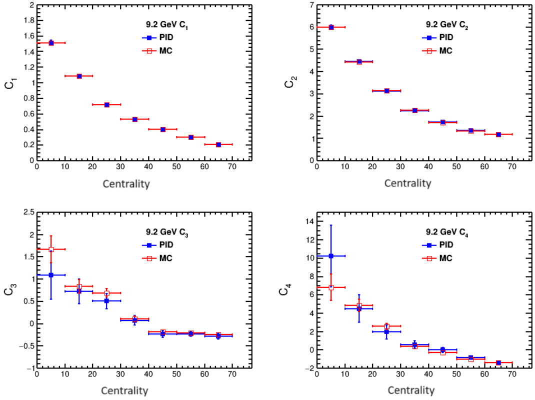
Cumulants Corrections

Using the previous relationship and by the definition of statistical cumulants, the following equalities are obtained:

$$
\begin{aligned}
C_1 &= F_{10} - F_{01}, \\
C_2 &= N - C_1^2 + F_{02} - 2F_{11} + F_{20}, \\
C_3 &= C_1 + 2C_1^3 - F_{03} - 3F_{02} + 3F_{12} + 3F_{20} - 3F_{21} + F_{30} \\
&- 3C_1(N + F_{02} - 2F_{11} + F_{20}), \\
C_4 &= N - 6C_1^4 + F_{04} + 6F_{03} + 7F_{02} - 2F_{11} - 6F_{12} - 4F_{13} \\
&+ 7F_{20} - 6F_{21} + 6F_{22} + 6F_{30} - 4F_{31} + F_{40} \\
&+ 12C_1^2(N + F_{02} - 2F_{11} + F_{20}) - 3(N + F_{02} - 2F_{11} + F_{20})^2 \\
&- 4C_1(C_1 - F_{03} - 3F_{02} + 3F_{12} + 3F_{20} - 3F_{21} + F_{30}).
\end{aligned}
$$

C_n are the cumulants of the real distribution.

Calculation of cumulants (corrected)



Statistical cumulants with correction. Higher order cumulants have more discrepancy in central collisions.

Summary and perspectives

The study of strangeness number fluctuations and the calculation of the first 4 cumulants were presented both at the MC simulation and at the reconstruction level in the MPD experiment.

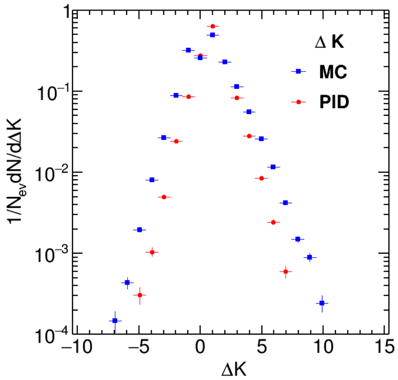
- UrQMD produce a reasonable description of the strangeness.
- The cumulants (C_1, C_2, C_3, and C_4) for strangeness were calculated and corrected using factorial moments. Results from cumulants at the most central collision indicate that I need to increase the statistic sample.

I need to try different models and perform the analysis using the net number of protons.

Thank you for your attention.

Back up

Net Kaon Distribution



Net kaon distribution from Bi+Bi collisions at 9.2 GeV. Monte Carlo and PID uncorrected distribution.