Constructing probability density function of net-proton multiplicity distributions using Pearson curve method[1]

Nirbhay Kumar Behera
Inha University, Incheon, South Korea

1. Motivation

- Goal: to map the QCD phase diagram.
- Tool: Event-by-event measurements of fluctuations of conserved charges distributions.
- Cumulants of net-particle distributions are sensitive to the critical behaviors. Higher the order, more the sensitivity.
- Lattice QCD: C_6/C_2, C_8/C_2 will provide constraints to determine the freeze-out temperature relative to the chiral phase transition temperature [2].
- Knowing the probability distribution will help to study the O(4) criticality [3,4].
- Construct the probability distributions of net-proton using the experimental results up to 4th order using Pearson curve method

2. Methodology

- Pearson cuve method (PCM): Probability distribution function (PDF) of a frequency data can be obtained which satisfy the following equation.

$$\frac{1}{f(x)}\frac{df(x)}{dx} = -\frac{a+x}{b_0+b_1x+b_2x^2}$$

$$a = \frac{\sqrt{m_2}\sqrt{\beta_1}(\beta_2+3)}{10\beta_2-12\beta_1-18} \quad b_0 = \frac{m_2(4\beta_2-3\beta_1)}{10\beta_2-12\beta_1-18} \quad b_1 = a \quad b_2 = \frac{2\beta_2-3\beta_1-6}{10\beta_2-12\beta_1-18}$$

- m_2, m_3, m_4 are the 2nd, 3rd and 4th moments of the frequency data.
- $\beta_1 = m_3^2/m_2^3$ and $\beta_2 = m_4/m_2^2$.
- 7 types Pearson family of curves (PDF).
- Pearson criterion (k) defines the type of PDF. k = $\frac{b_1^2}{4b_0b_2}$ with a pre-condition of β_2 - β_1 - 1 > 0

3. Results-1

- PDFs of net-proton multiplicity are constructed using PCM at different collision energies.
- The STAR net-proton BES data are used as input to the PCM.
- Au-Au collisions at 19.6 GeV:

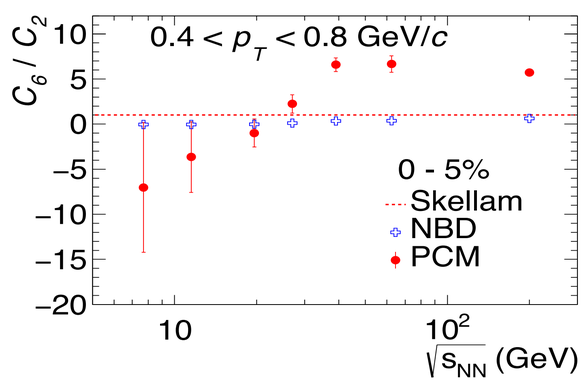
$$f(x) = A(147.71-x)^{282.362} \times (27.1265+x)^{51.0384}$$

- Au-Au collisions at 39 GeV $f(x) = A\frac{e^{59.9249\tan^{-1}[0.0158119(2x+31.0066)]}}{(x^2+31.0066x+1240.29)^{62.1139}}$

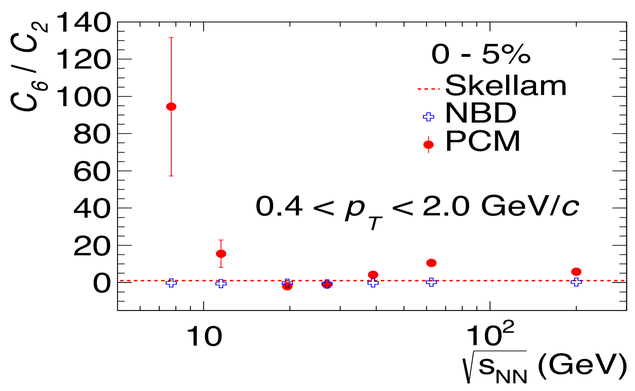
- Au-Au collisions at 200 GeV:

$$f(x) = A\frac{e^{6.93233\tan^{-1}[0.0196186(2x+5.0788)]}}{(x^2+5.0788x+655.983)^{35.7871}},$$

4. Results-2

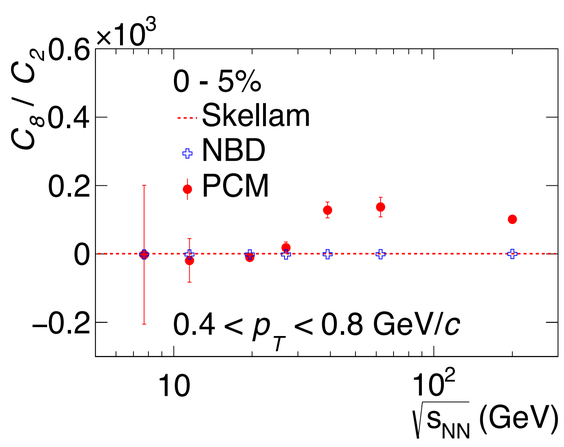


- For $0.4 < p_T < 0.8$ GeV/c, C_6/C_2 changes sign at $\sqrt{s_{NN}} \geq 27$ GeV.

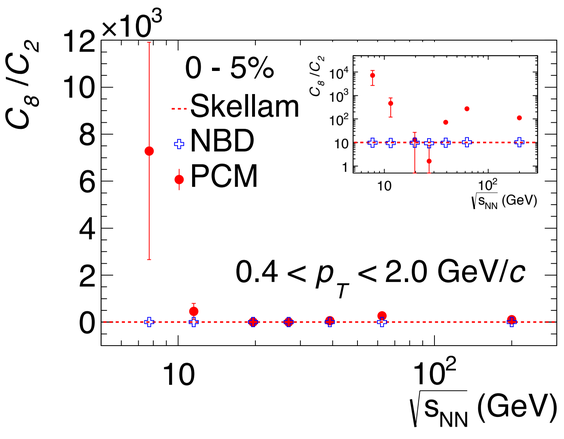


- For $0.4 < p_T < 2.0$ GeV/c, C_6/C_2 is negative only at $\sqrt{s_{NN}} = 19.6$ GeV.

5. Results-3



- For $0.4 < p_T < 0.8$ GeV/c, C_8/C_2 changes sign at $\sqrt{s_{NN}} \geq 27$ GeV.



- For $0.4 < p_T < 2.0$ GeV/c, C_8/C_2 is negative at $\sqrt{s_{NN}} =$ 19.6 and 27 GeV.
- A deep structure is observed at this two energies.

6. Summary

- The PDFs of net-proton distributions are obtained using PCM.
- The C_6/C_2 and C_8/C_2 results are sensitive to the kinematic cuts used for the measurement.
- The C_6/C_2 and C_8/C_2 results deviate from Skellam and larger than unity at $\sqrt{s_{NN}} \geq 39$ GeV.
- Upcoming RHIC BES-II result will help to understand the higher order cumulant results.
- The PDFs can be used for model study.

7. References

[1] N. K. Behera, arXiv:1706.06558
[2] B. Friman, F. Karsch, K. Redlich and V. Skokov, Eur. Phys. J. C 71, 1694 (2011)
[3] M. Cheng et al., Phys. Rev. D 79, 074505 (2009)
[4] K. Morita, B. Friman and K. Redlich, Phys. Lett. B 741, 178 (2015)

The work was sup-ported by National Research Foundation of Korea (NRF), Basic Science Research Program (Grant number: NRF-2014R1A1A1008246)