Measurement of the sixth-order cumulant of net-charge distributions in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV by the STAR experiment

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Abstract

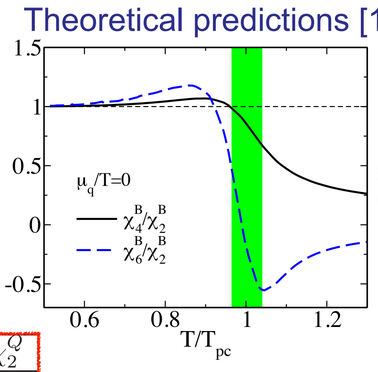
In heavy-ion collision experiments, the study of event-by-event fluctuation is a powerful tool to characterize the thermodynamic properties of the hot and dense QCD matter. According to the Lattice QCD calculations, an analytic cross-over exists at small μ_B regions but there is no experimental evidence for the location of predicted cross-over. Experimentally, it is thought [1] that up to the sixth-order cumulant and the ratio to the variance may provide a signal for the existence of the cross-over. The STAR experiment presented up to the fourth-order cumulant ratios of net-charge and up to the sixth-order of net-proton fluctuations at $\sqrt{s_{NN}}$ = 200 GeV [2, 3]. However, the fifth- and sixth-order cumulant of net-charge have not been presented yet. This poster presents measurements of cumulants from the first- to sixth-order and the ratio to the variance of net-charge using particle species and p_T-dependent efficiency corrections for Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV during Beam Energy Scan in 2010 and 2011.

Introduction

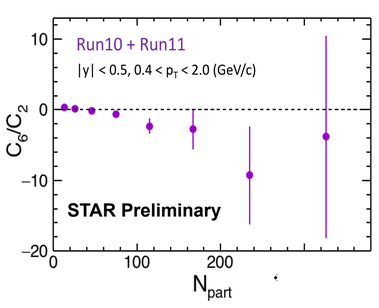
- According to theoretical predictions, the 6th-order cumulants of net-variable may be the signal of cross-over transition [1]. ($\chi_6/\chi_2<0$ near the T_{pc})
- C_6/C_2 of net-proton have already been reported but net-charge is only measured up to 4th-order.

freeze-out conditions	χ_4^B/χ_2^B	χ_6^B/χ_2^B	χ_4^Q/χ_2^Q	χ_6^Q/χ_2^Q
HRG	1	1	~ 2	~ 10
QCD: $T^{freeze}/T_{pc} \lesssim 0.9$	$\gtrsim 1$	$\gtrsim 1$	~ 2	~ 10
QCD: $T^{freeze}/T_{pc} \simeq 1$	~ 0.5	< 0	~ 1	< 0

Theoretical predictions [1]

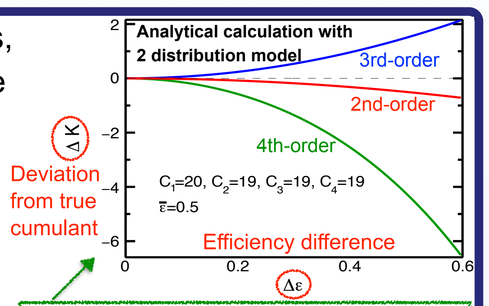


Net-proton fluctuation



First measurement of net-charge fluctuation up to 6th-order.

- In published net-charge results, PID was not done and average efficiencies for each particle species were used.
- However, it is suggested [4] using average efficiencies would give artificial results when distribution doesn't follow the Poisson distribution.



The correction doesn't work well if efficiency is different between 2 phase spaces.

Efficiency corrections should be done separately among different efficiency regions.

The STAR detector

- **TPC and TOF detector are used**

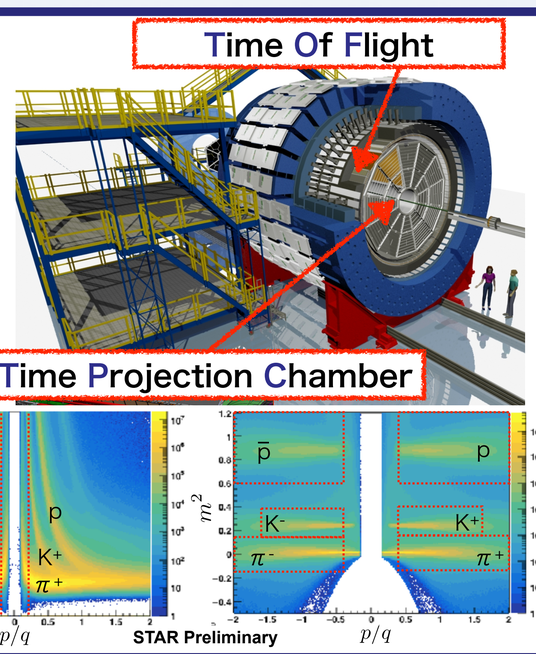
$0.5 < |\eta| < 1$ …used to define centrality (Refmult2)

$|\eta| < 0.5$ && p_T cut …used to calculate net-charge fluctuations

Using different kinematic window to reduce auto-correlation.

	TPC	TPC+TOF
π	0.2 - 0.4 GeV/c	0.4 - 2 GeV/c
K	0.2 - 0.4 GeV/c	0.4 - 1.6 GeV/c
p	0.4 - 0.8 GeV/c	0.8 - 2. GeV/c

TOF is used for PID at high p_T region.



Analysis method

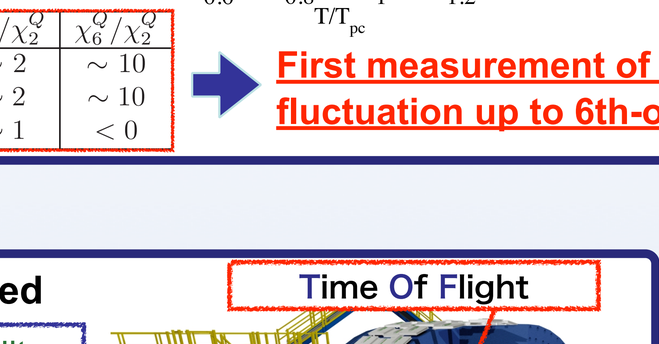
- **Earlier method**

All positive charged particles (high p_T) / All negative charged (low p_T)

N_1, $(w_{\pi^+}\epsilon_{\pi^+}) + (w_{K^+}\epsilon_{K^+}) + (w_p\epsilon_p)$

N_2, $(w_{\pi^-}\epsilon_{\pi^-}) + (w_{K^-}\epsilon_{K^-}) + (w_{\bar{p}}\epsilon_{\bar{p}})$

Net-charge : N_1-N_2 Efficiency : $(\varepsilon_1+\varepsilon_2)/2$



- **New method**

high p_T	π^+	K^+	p	π^-	K^-	$\bar{p}$
	n_1, ε_1	n_2, ε_2	n_3, ε_3	n_4, ε_4	n_5, ε_5	n_6, ε_6
low p_T	n_7, ε_7	n_8, ε_8	n_9, ε_9	n_{10}, ε_{10}	n_{11}, ε_{11}	n_{12}, ε_{12}

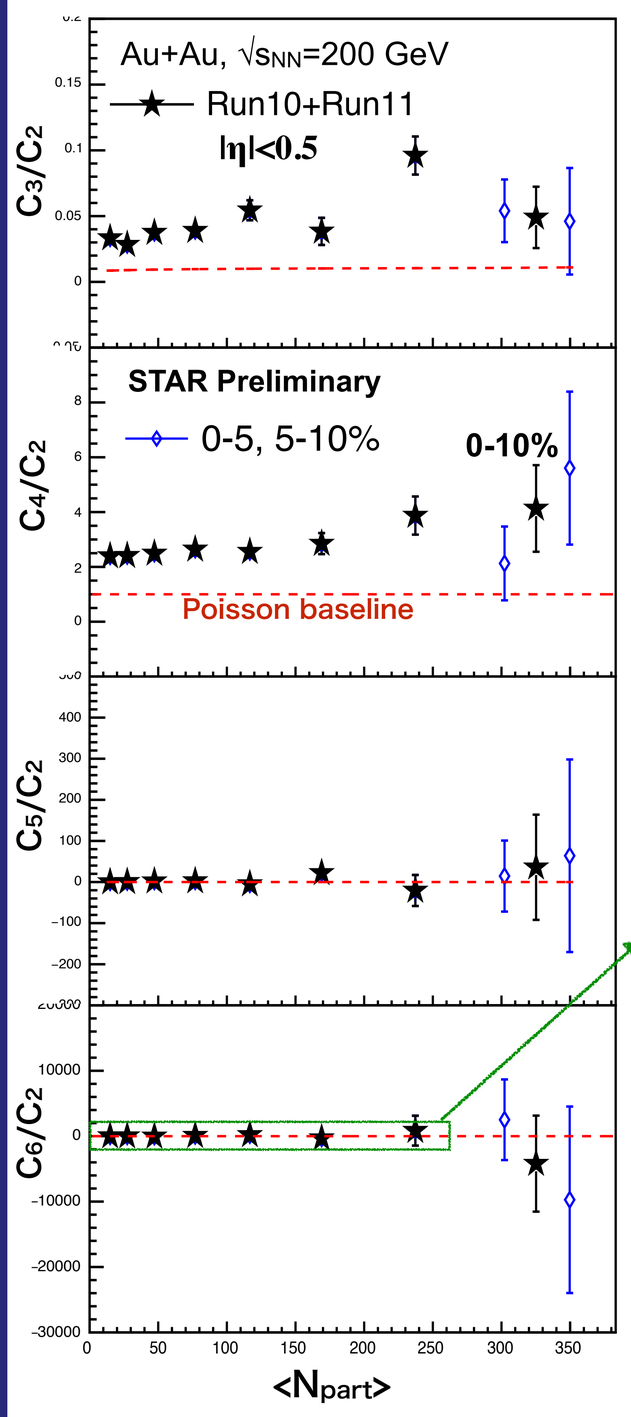
Net-charge : $(n_1 + n_2 + n_3 + n_7 + n_8 + n_9) - (n_4 + n_5 + n_6 + n_{10} + n_{11} + n_{12})$

Efficiency : $\epsilon_1\ \epsilon_2\ \epsilon_3\ \cdots$ 12 efficiency bins

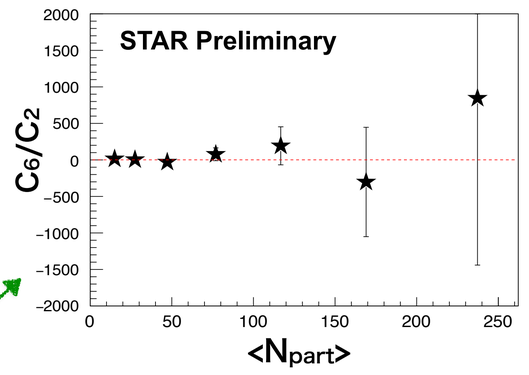
- Efficiencies are different not only among different centrality bins but also different p_T regions and different particle species.

Efficiency corrections are applied for π^+, π^-, K^+, K^-, p, $\bar{p}$ and high and low p_T region for each multiplicity bin separately.

Results



- **Number of Statistics**
  - 180M(0-10%), 580M(10-80%)
- **C_3/C_2 ,C_4/C_2**
  - Larger than Poisson baseline for all centralities.
- **C_5/C_2 ,C_6/C_2**
  - Consistent with Poisson baseline for all centralities.
  - Statistical uncertainty of net-charge C_6/C_2 is 1000 times larger than that of net-proton.



- **Statistical errors**
  - Estimated by Bootstrap (100times)
- **Centrality Bin Width Correction** have been done.
- **Factorial cumulant method [4]** was used.

Summary

- The 1st- to 6th-order cumulants and cumulant ratios of net-charge fluctuation were measured for the first time in Au+Au collisions at $\sqrt{s_{NN}}$=200 GeV.
- Efficiency corrections are applied for π^+, π^-, K^+, K^-, p, $\bar{p}$ and high and low p_T region separately by factorial cumulant method.
- C_3/C_2 and C_4/C_2 are larger than Poisson baseline for all centralities.
- C_6/C_2 is consistent with zero within statistical uncertainty for all centralities so signal of cross-over was not seen in this analysis.

Outlook

- Systematic uncertainty estimation.

Reference

[1] B. Friman, F. Karsch, K. Redlich, V. Skokov, Eur. Phys. J. C, 71:1694(2011).
[2] L.Adamczyk et al.(STAR Collaboration), Phys. Rev. Lett. 113, 092301(2014).
[3] M. M. Aggarwal et al. (STAR Collaboration), Phys. Rev. Lett. 105, 022302(2010).
[4] T.Nonaka, M.Kitazawa and S.Esumi. Phys. Rev. C 95, 064912(2017).