Temperature Fluctuation and the Specific Heat in Au+Au Collisions at $\sqrt{s_{NN}}$ = 7.7 − 200 GeV from AMPT model and STAR

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Abstract

In this poster, we will present the energy dependence of event-by-event temperature fluctuations and specific heat of the QCD matter created in Au+Au collisions at $\sqrt{s_{NN}}$ = 5, 7, 17.3, 39, 62.4, and 200 GeV from the AMPT model calculations and at $\sqrt{s_{NN}}$ = 7.7, 19.6, and 27 GeV from BES-I program of the STAR experiment.

Analysis method

In a system, for a range of p_T within a to b one can estimate $\langle p_T\rangle$ via [1] :

$$\langle p_T\rangle = 2T_{eff} + \frac{a^2 e^{-\frac{a}{T_{eff}}} - b^2 e^{-\frac{b}{T_{eff}}}}{(a+T_{eff})e^{-\frac{a}{T_{eff}}} - (b+T_{eff})e^{-\frac{b}{T_{eff}}}}.$$

This equation links the value of $\langle p_T\rangle$ within a specified range (from a to b) of p_T to the effective temperature, T_{eff} .

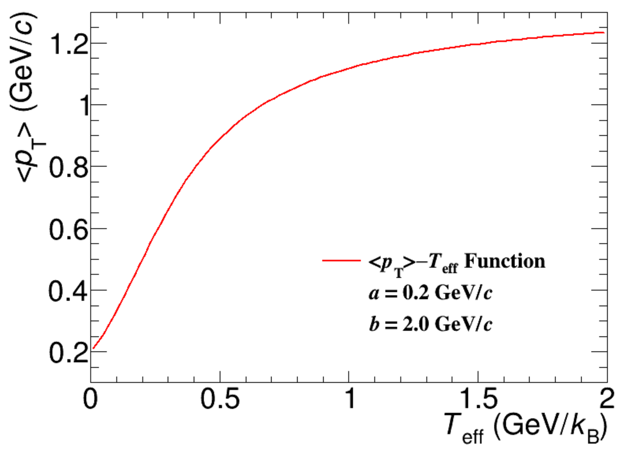
From the temperature distribution[2] $f(T)\sim\exp\left[-\frac{C}{2}\frac{(T-\langle T\rangle)^2}{\langle T\rangle^2}\right]$, heat capacity[3] :

$$C = \frac{\langle T_{kin}\rangle^2}{\left(\Delta T_{eff}^{dyn}\right)^2} = \frac{\langle T_{kin}\rangle^2}{(\Delta T_{eff})^2 - \left(\Delta T_{eff}^{stat}\right)^2},$$

mixed events are used to subtract statistical fluctuations.
The specific heat C_V is obtained as :

$$C_V = \frac{C}{N},$$

where N is the number of particles.



Data Set

- AMPT model :

$\sqrt{s_{NN}}$ (GeV)	5	7	17.3	39	62.4	200
Centrality Selection	impact parameter 0 < B < 3 fm (0-5%)					
Track Selection	$\lvert\eta\rvert < 1$ a = 0.15 GeV/c < p_T < 2 GeV/c = b					

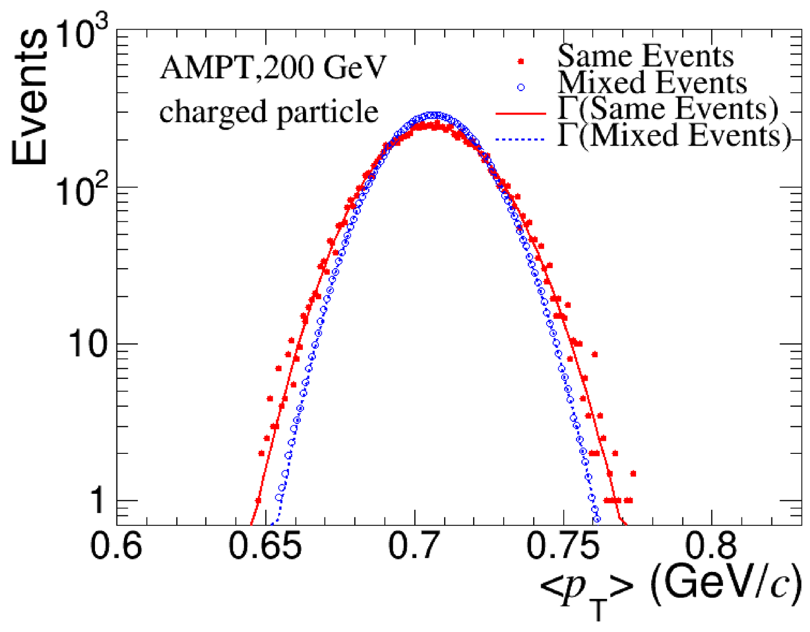
- STAR data :

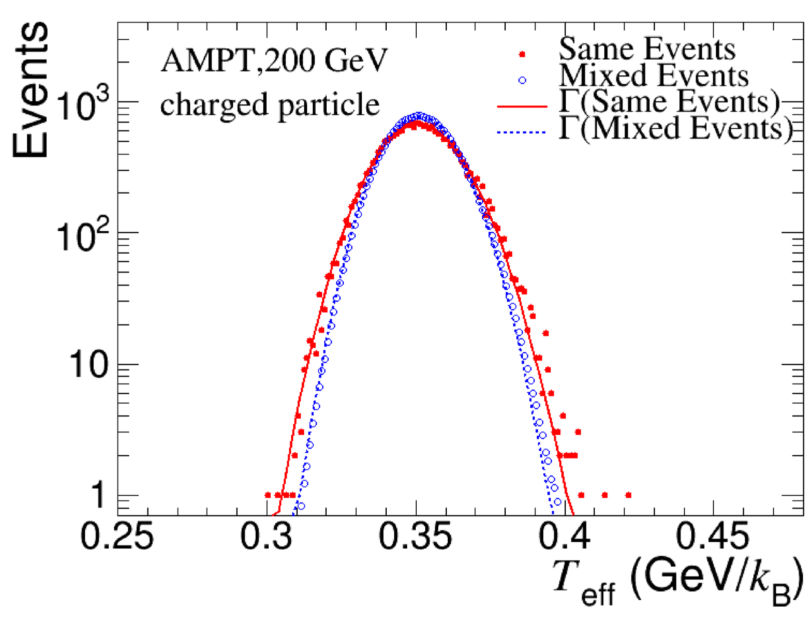
$\sqrt{s_{NN}}$ (GeV)	7.7	19.6	27
Year	2010	2011	2011
Events(10^6)	3	15	32
Centrality Selection	0-5%		
Track Selection	$\lvert\eta\rvert < 1$, a = 0.15 GeV/c < p_T < 2 GeV/c = b		

$\langle p_T\rangle$ and T_{eff} distributions

Curves represent fitted gamma distributions[4] : $Ga(x) = \frac{x^{\alpha-1}e^{-x/\beta}}{\Gamma(\alpha)\beta^{\alpha}}, x > 0\ (\alpha, \beta > 0)$.

The mean (μ) and standard devistion (σ) of the distribution are related to the fit parameters (α and β) by $\mu = \alpha\beta$ and $\sigma^2 = \alpha\beta^2$. The T_{eff} distributions can be nicely described by the gamma distribution. The σ of gamma fitting of T_{eff} distributions are used as ΔT_{eff}.





Temperature high order fluctuations measures

High order cumulants describe the shape of distribution and quantify fluctuations. They are sensitive to the correlation length ξ. We use them to characterize the fluctuations of temperature. The cumulants of event-by-event temperature distributions can be expressed in terms of moments.

For a distribution of N (here N is T_{eff} , $\delta N = N - \langle N\rangle$), the cumulants be expressed [5]-[7] :

$$C_1 = \mu = \langle N\rangle,$$
$$C_2 = \sigma^2 = \langle(\delta N)^2\rangle,$$
$$C_3 = S\sigma^2 = \langle(\delta N)^3\rangle,$$
$$C_4 = \kappa\sigma^4 = \langle(\delta N)^4\rangle - 3\langle(\delta N)^2\rangle^2,$$

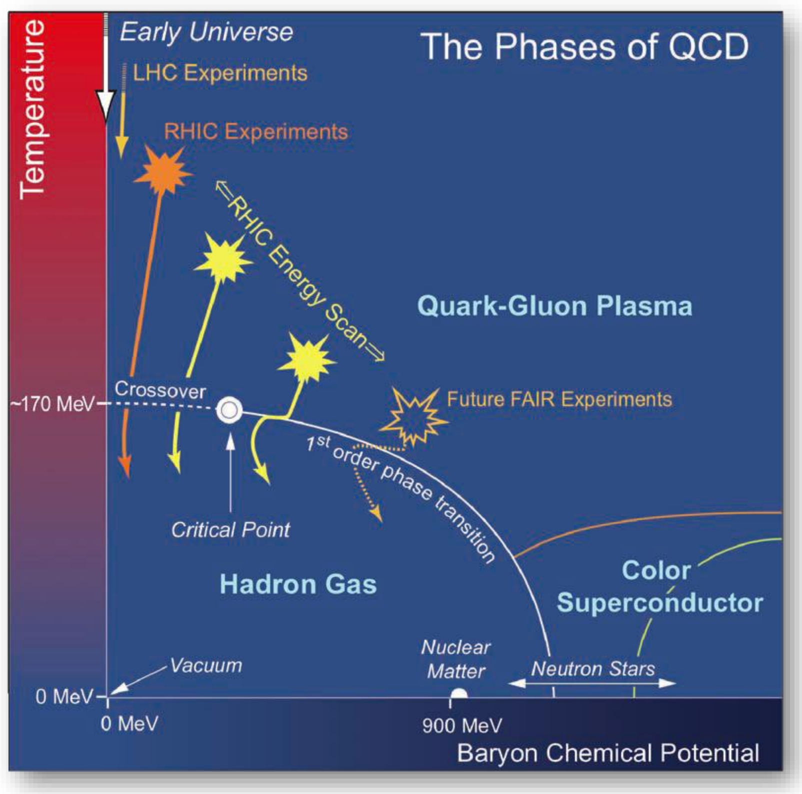
Directly connected to the susceptibility of the system: $S\sigma = \frac{C_3}{C_2}, \kappa\sigma^2 = \frac{C_4}{C_2}$.

For a gamma distribution $S\sigma = 2\beta$ and $\kappa\sigma^2 = 6\beta^2$.

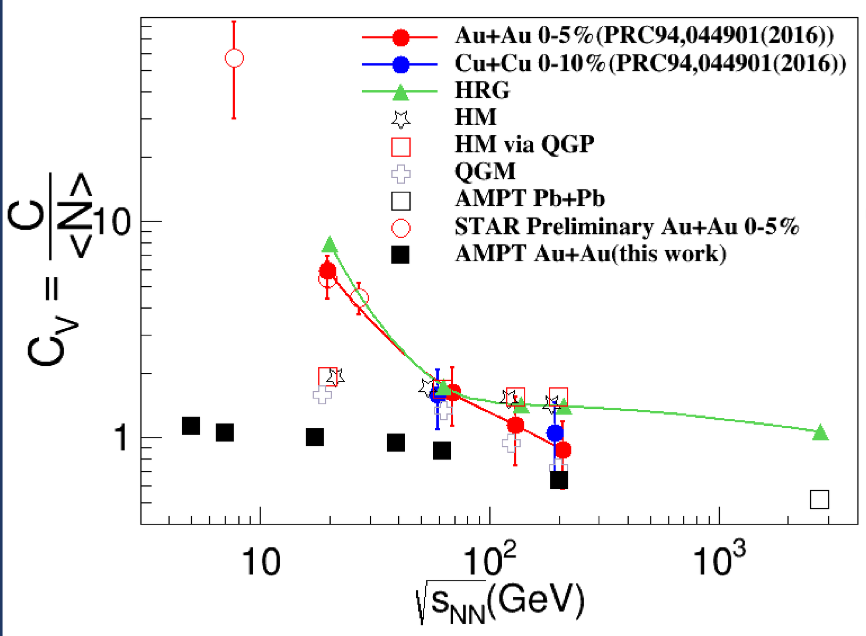
Motivation

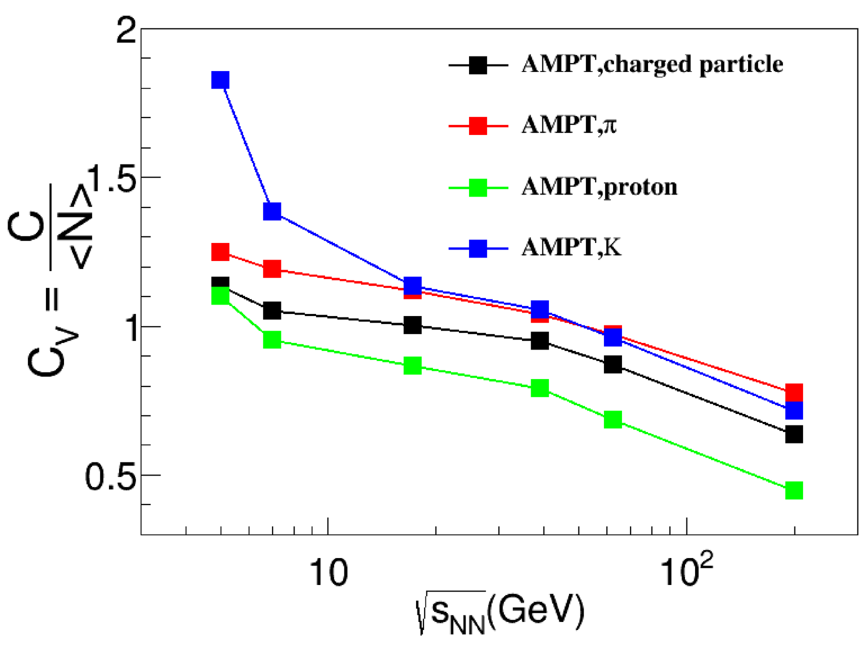
The transition to QGP changes from a crossover to the 1st order phase transition results in the existence of a critical point (circle) in the QCD phase diagram. Lattice QCD estimates indicated that the critical point exists in the range 250 < μ_B < 450 MeV [8] .

The specific heat, C_V, is a thermodynamic quantity that characterizes the equation of state of the system. For a system undergoing phase transition, C_V is expected to diverge at the critical point, which can be extracted from event-by-event temperature fluctuation. Thus the variation of thermal fluctuations with temperature can be effectively used to probe the QCD phase transition and QCD critical point.

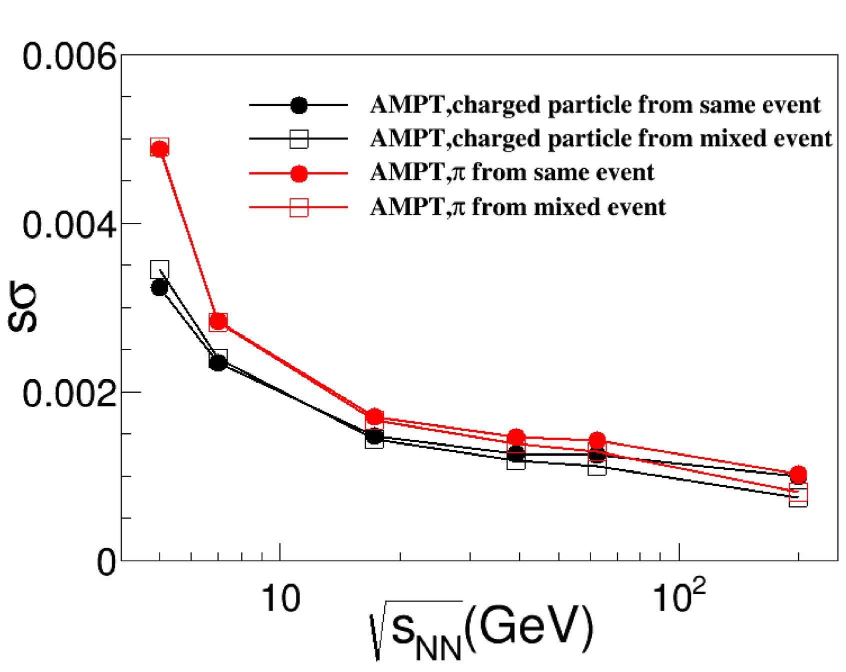


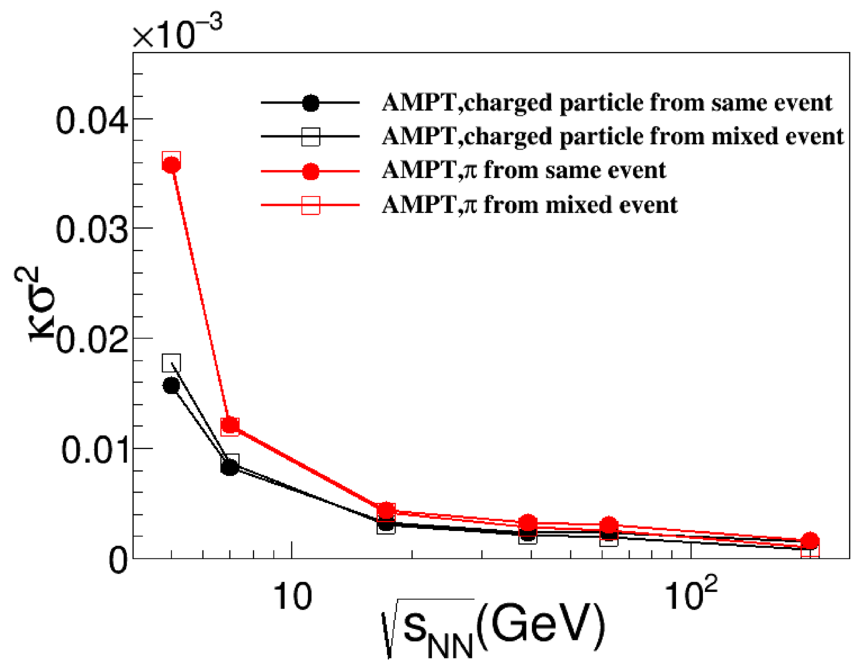
Results





- The specific heat, C_V, as a function of collision energy at 0.2GeV <p_T< 2GeV in 0-5% centrality interval. Left panel: compares the charged particle C_V with published results. Right panel: shows the C_V from AMPT model .





- The 3rd and 4th order fluctuations of temperature as a function of from AMPT model.

Summary

Both C_V and higher order cumulants of the temperature fluctuations show monotonic distributions, which is expected that there is no phase transition critical point in the AMPT model. This provides a good reference for comparison with experimental data to search for the signal of critical point.

At low energies, a sharp drop of C_V from the STAR data is observed and it deviates from the AMPT results. Results will be further improved with more coming data at different energies.

References

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