Temperature Fluctuation and the Specific Heat in Au+Au Collisions at $\sqrt{s_{NN}}$ = 7 – 200 GeV in AMPT model

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Abstract

Specific heat is a thermodynamic quantity that characterizes the equation of state of the system. For a system undergoing phase transition, the specific heat, C_V, is expected to diverge at the critical point. Temperature fluctuation of the system provides an estimation of C_V. The specific heat 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.

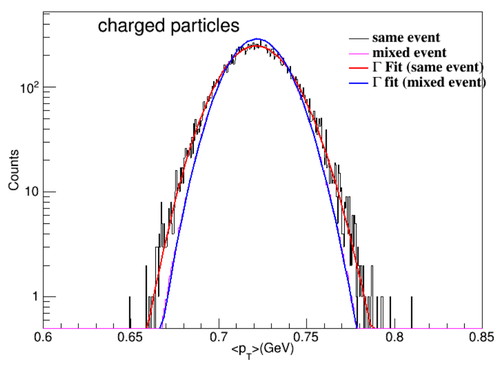
In this poster,we will present the energy dependence of specific heat and temperature fluctuations of the QCD matter created in Au+Au collisions at $\sqrt{s_{NN}} = 5, 7, 17.3, 39, 62.4, 200 GeV$ from AMPT model calculations.

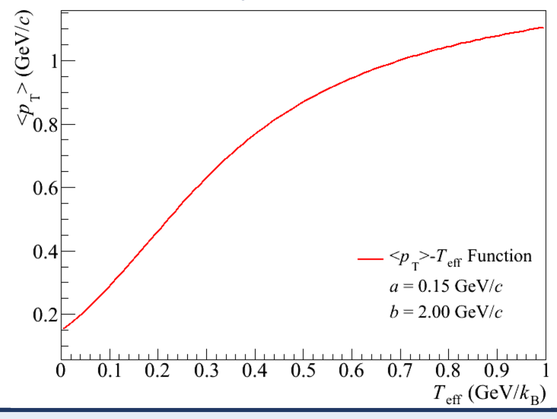
Mean p_T associated effective temperature

For a range of p_T within a to b :

$\langle p_T \rangle = 2T_{eff} + \frac{a^2 e^{-a/T_{eff}} - b^2 e^{-b/T_{eff}}}{(a+T_{eff})e^{-a/T_{eff}} - (b+T_{eff})e^{-b/T_{eff}}}$ [1]

The effective temperature of the system , T_{eff} , is obtained from this equation.





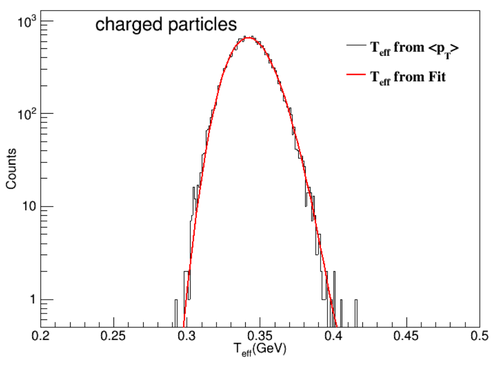
Specific heat capacity

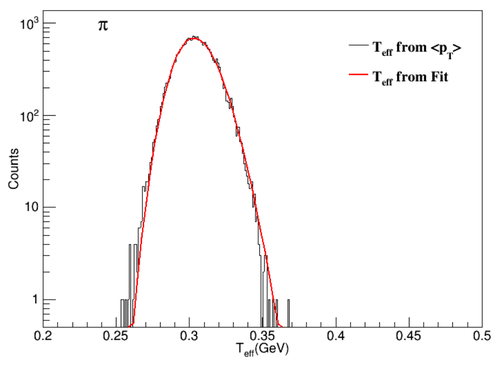
The distribution of temperature is assumed to be:

$P(T) = A\, e^{-C(\Delta T/T)^2}$ [2]

A is the normalization parameter , C is heat capacity.

The specific heat is obtained as the heat capacity per number of particles (N) as (C_V= C/N) within the system.





Temperature high order fluctuations

High order cumulants describe the shape of distribution and quantify fluctuations. We use it to characterize the fluctuations of temperature. The cumulants of event-by-event temperature distributions can be expressed in terms of moments with the following relations:[3][4][5]

$C_1 = \mu = \langle N \rangle$,

$C_2 = \mu_2 = \langle (\delta N)^2 \rangle = \sigma^2$,

$C_3 = \mu_3 = \langle (\delta N)^3 \rangle$,

$C_4 = \mu_4 - 3\mu_2^2 = \langle (\delta N)^4 \rangle - 3\langle (\delta N)^2 \rangle^2$,

$S\sigma = \frac{C_3}{C_2}, \kappa\sigma^2 = \frac{C_4}{C_2}$,

where $\mu_r = \langle (\delta N)^r \rangle$.

The T_{eff} distributions are nicely described by using the gamma distribution:

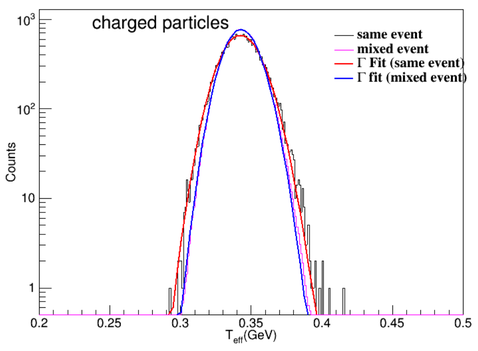
$f(x) = \frac{x^{\alpha-1} e^{-x/\beta}}{\Gamma(\alpha)\beta^\alpha}, x > 0 (\alpha, \beta > 0)$,

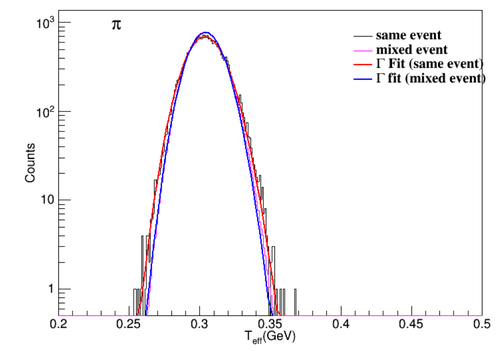
The mean (μ) and standard deviation (σ) of the distribution are related to the fit parameters(α and β) by $\mu = \alpha\beta$ and $\sigma^2 = \alpha\beta^2$.

Then we can obtain that:

$\mu_3 = 2\alpha\beta^2$, $\mu_4 = 6\alpha(\alpha+2)\beta^4$,$\mu_5 = (20\alpha^2 + 24\alpha)\beta^5$,.....

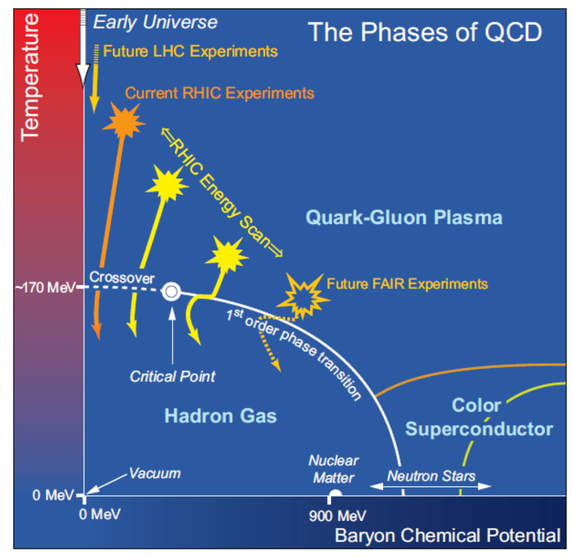
$S\sigma = 2\beta$,$\kappa\sigma^2 = 6\beta^2$.





QCD phase diagram

The transition to QGP changes from a crossover to a first order results in the existence of a critical point (circle) in the QCD phase diagram. Calculation expects that the critical point exists in the range 250 < μ_B < 450 MeV .



Cut Set

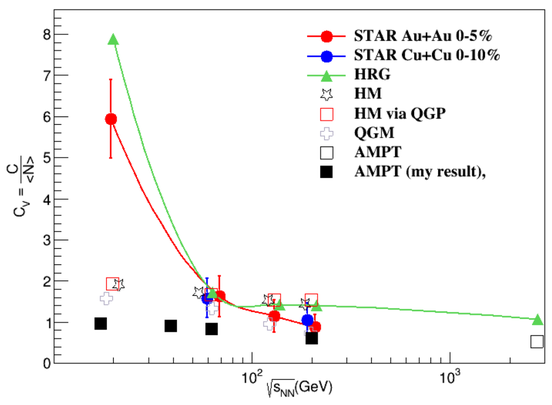
1.Top Centrality (0-5%) : impact parameter 0 < B < 3fm

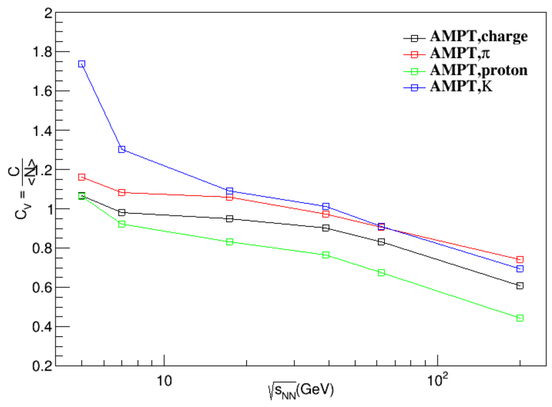
2.|η| < 1

3.a = 0.15GeV/c < p_T< 2GeV/c = b

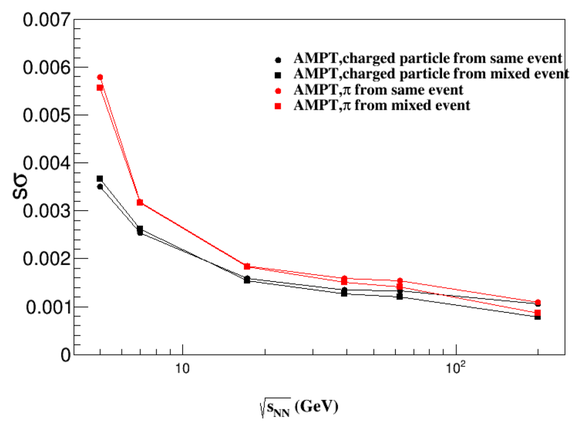
Results

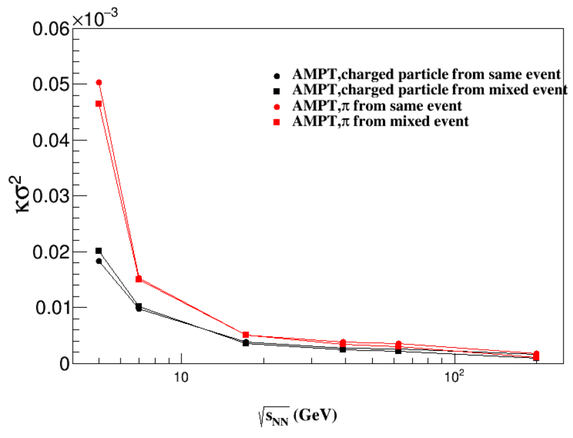
The energy dependence of specific heat：





Temperature fluctuation calculations：





Summary

We studied temperature fluctuations and the specific heat capacity in Au+Au collisions at $\sqrt{s_{NN}}$ = 7 - 200 GeV in AMPT model. C_V result shows good agreement with data at high energy but much lower than data at low energy. 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 in the QCD phase diagram.

References

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[3] Shu He ,Xiaofeng Luo ,2017 arXiv: nucl-ex/1704.00423v3

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