# Evidence of nonthermal phase transition in Au-Au collisions at $E_{lab}$ = 10 AGeV for AMPT generated data

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## Introduction

Primary charged particles produced in (ultra)-relativistic nuclear collision exhibits fluctuation in particles number density in different phase-spaces. Analysis of such fluctuations is expected to provide information about particle production mechanism. The fluctuations that occurs in such collisions is mainly divided into two types: (i) statistical and (ii) dynamical or non-statistical. The method of scaled factorial moments (SFM) is considered to be one of the useful mathematical tool that can extract the dynamical part of the fluctuations from the mixture of the two. According to this method, a power-law growth of the scaled factorial moment ($F_q$) with decreasing phase-space bin size, or otherwise, the number of $M$ bins into which the full phase-space is divided, that is $F_q \propto M^{\alpha_q}$, is usually referred as the intermittency. And the exponent of the power-law $\alpha_q$ is known as the intermittency index. Such a power-law behaviour indicates the presence of the dynamical fluctuation in the data sample.

At the critical point, the fluctuations of the order parameters becomes self similar, belonging to the 3D-Ising universality class. And it becomes possible to detect the contribution of such fluctuations via the SFM analysis on proton number density in tranverse momentum space. Therefore, studies of fluctuations in $p_T$ space become significantly important. In this present work, an attempt has been made to analyse the charged particles emission spectra in $\chi(\eta - p_T)$ space for minimum bias Au-Au collisions data at $E_{lab}$ = 10 AGeV, generated with the AMPT.

## Results

In this analysis, the AMPT generated Au-Au collisions data at 10 AGeV with two different modes (default and string-melting (SM)) have been used. The same method of SFM technique as already been described in our earlier published papers [1, 2] has been applied.

The horizontally averaged scaled factorial moment has the limitation of shape dependence on the single particle density distribution spectra. This dependence on the particle density distirbution are eliminated by converting the pseudorapidity ($\eta$) and transverse momentum ($p_T$) distribution to a new cummulative variables called $\chi(\eta)$ and $\chi(p_T)$, respectively. The same defination of cumulative variable as defined in ref [1, 2] has been used.

Mathematically, the horizontally averaged scaled factorial moments $< F_q >$ of order $q$ is defined as [1, 2].

$$< F_q >= \frac{1}{N}\sum_{i=1}^{N} M^{q-1}\sum_{m=1}^{M} n_m(n_m-1)... ..(n_m-q+1)/ < n >^q \quad (1)$$

where, $M$ is the total number of bins, $n_m$ is the number of particles in $m^{th}$ bin, $N$ is the sample size for a particular type of events.

In fig. 1, the horizontally averaged SFM, estimated for the increasing number of phase-space bins $M^2$ for the order of the moments $q$=2-5 in two dimensional $\chi(\eta - p_T)$ space is shown for both sets of AMPT generated data in log-log scale. From the figure, it could be observed that the ln$< F_q >$ increases with the increase of the ln$M^2$ for all the order of the

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TABLE I: Table of intermittency indices for order of moment $q = 2 - 5$.

| AMPT data | $\alpha_2$ | $\alpha_3$ | $\alpha_4$ | $\alpha_5$ |
|---|---|---|---|---|
| Default | 0.054 ± 0.0033 | 0.156 ± 0.0059 | 0.275 ± 0.0095 | 0.390 ± 0.0186 |
| SM | 0.088 ± 0.0050 | 0.285 ± 0.0120 | 0.648 ± 0.0270 | 1.111 ± 0.0404 |

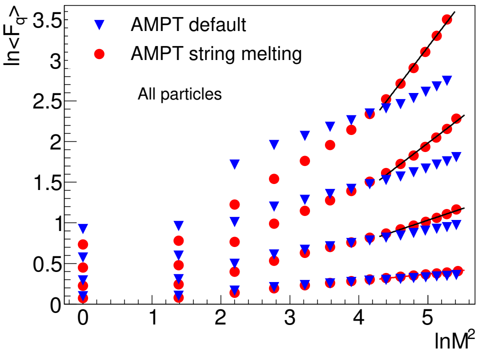


FIG. 1: ln< $F_q$ > vs. ln$M^2$ plot for AMPT (default) and AMPT (SM) data.

moments $q$ confirming the presence of intermittency in the AMPT generated data. The straight lines in the plots shows the best fitted lines with correlation coefficient $R^2 = 0.99$. The values of the slope for the fitted lines or intermittency indices are listed in table.1.

Bialas and Zaleweski [4] reported that the existence of nonthermal phase transition in (ultra)-relativistic nuclear collisions is related to the intermittent behaviour of primary particles produced in nuclear collisions. The presence of the nonthermal phase transition is expected to have a minimum value of coefficient $\lambda_q$ at some value of $q = q_c$. The coefficient $\lambda_q$ is related to the intermittency index $\alpha_q$, through the relation-

$$\lambda_q = \frac{\alpha_q + 1}{q} \tag{2}$$

The region satisfying the condition $q < q_c$ may be dominated by many small fluctuations whereas, the region fulfilling the condition $q > q_c$ contains rarely occurring large fluctuations.

Fig. 2 shows that the values of the coefficient $\lambda_q$ monotonically decreases with the increase of order of moment $q$ for AMPT default data in $\chi(\eta - p_T)$ space. On the other hand, for AMPT (SM) data, a clear minimum value of $\lambda_q$ at $q = q_c \approx 4$ is evident in the same phase-space and is indicative of the occurence of a nonthermal phase transition like behaviour.

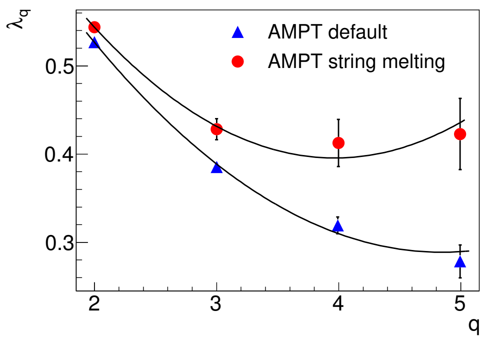


FIG. 2: $\lambda_q$ vs. $q$ plot for AMPT (default) and AMPT (SM) data.

## Acknowledgments

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## References

[1] S. Gope and B. Bhattacharjee, Eur. J. Phys. A (2021) 57:44
[2] P. Sarma and B. Bhattacharjee, Phys. Rev. C 99, 034901 (2019).
[3] Zi-Wei Lin et. al, arXiv:nucl-th/0411110v3 20 Dec 2005.
[4] A. Bialas and K. Zalewski, Phys. Lett. B 238, 413 (1990).