Intermittency and associated issues in p + Au interactions at $\sqrt{s_{NN}}$ = 200 GeV

Tumpa Biswas

DST INSPIRE Fellow

Department of Physics

Cooch Behar Panchanan Barma University

tumpa.biswas@cern.ch

tumpa.dta@gmail.com

Supervisior: Prof. Prabir Kumar Haldar

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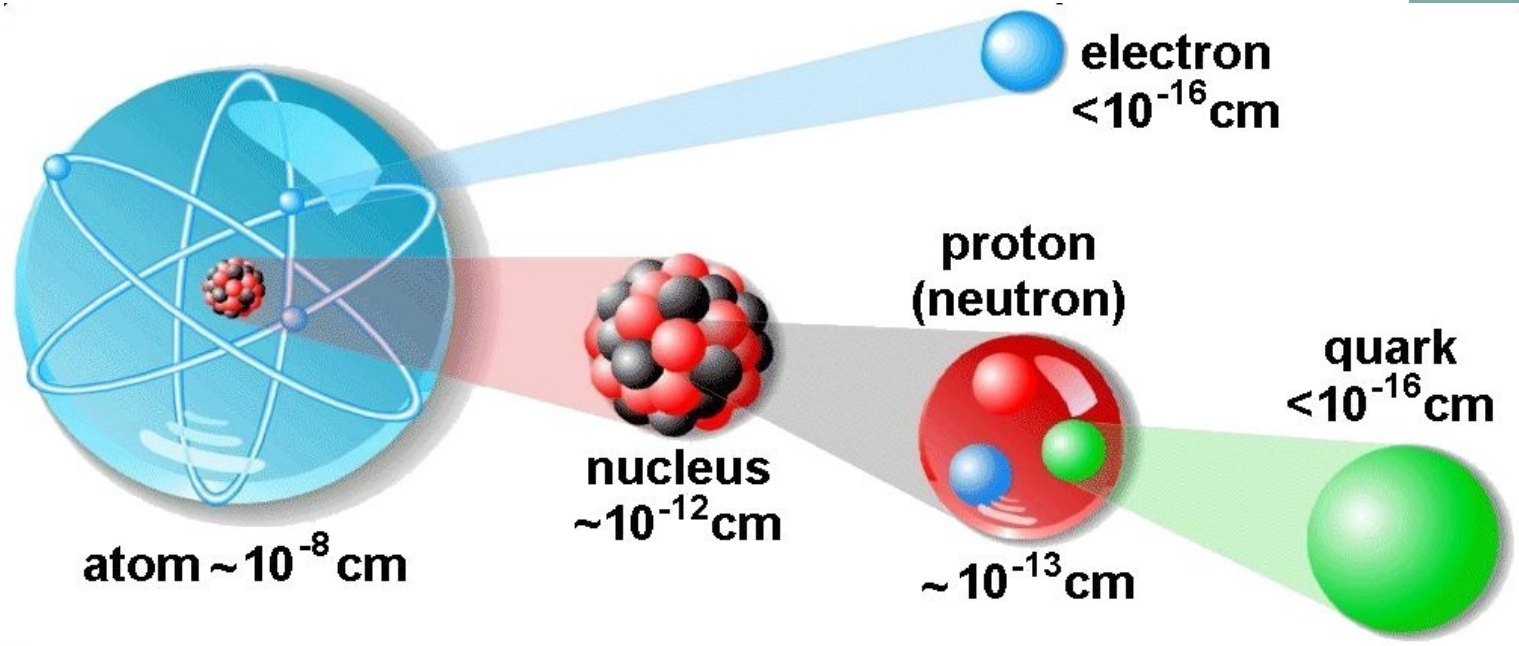
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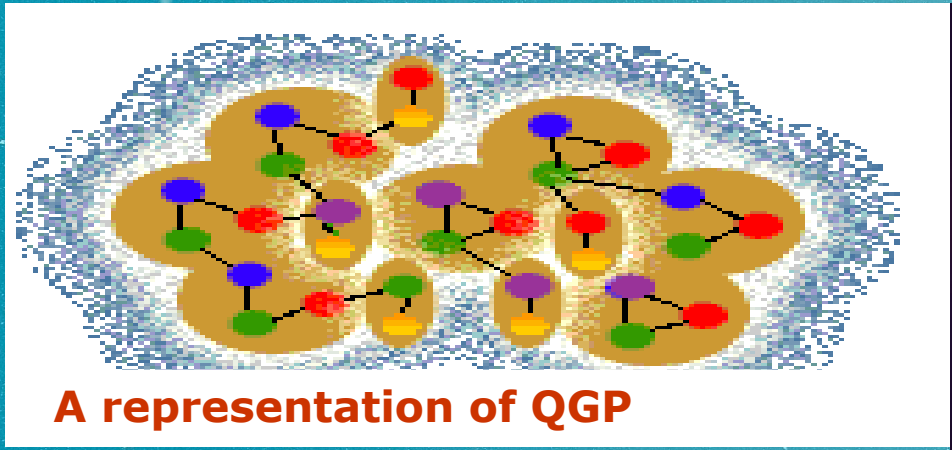
01
Introduction

The Building Block of Matter

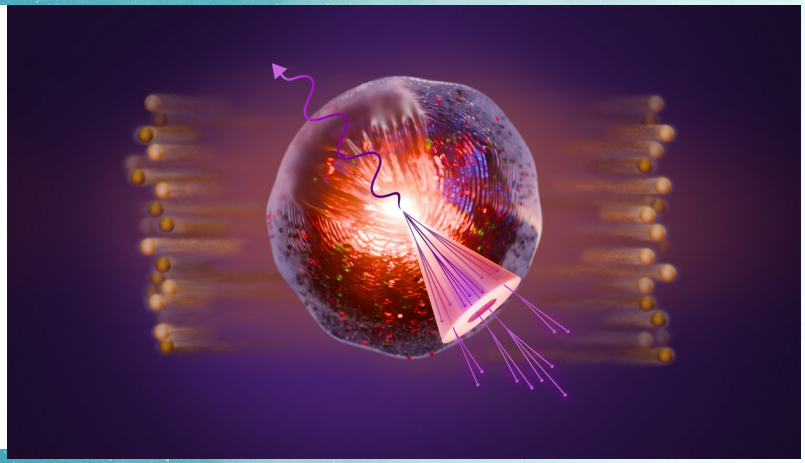


02
Motivation

- Study of **relativistic and ultrarelativistic nuclear collision** is interesting and useful since it may provide basic information about interactions among elementary particles and possible formation of Quark-Gluon Plasma (QGP).



A representation of QGP



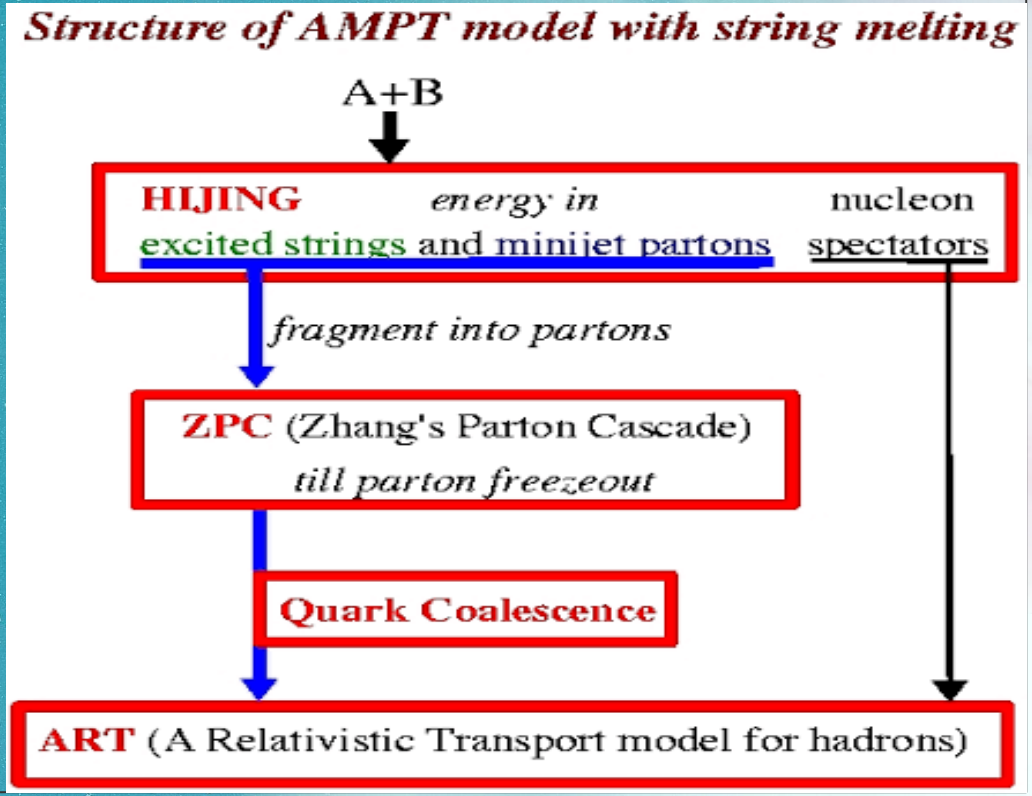
- Study of fluctuation is important for understanding the dynamics of relativistic nuclear interactions in general. It may also provide possible signal of QGP formation. The transition from the quark-gluon plasma to hadronic matter is one of several transitions occurring in the early universe.

03
Data Description

- The AMPT (A Multi-Phase Transport) model *v2.26* with string melting mechanism [1,2].

- The Lund string fragmentation parameters "a" and "b", with values of 0.55 and 0.15/GeV^2

- 10^6 events of $p + Au$ interactions at a c.m. energy of $\sqrt{s_{NN}}$ = 200 GeV (RHIC Energy) [3].



04
Methodology

To investigate non-statistical fluctuations and fractality in our simulated data, we have used the following analytical methods:

- **Scaled Factorial Moments (SFMs):**

  (a) Critical Exponent

  (b) Lévy Index

  (c) Multifractal Specific Heat

Intermittency

- According to Bialas and Peschanski [4], in a one-dimensional phase space that is divided into M number of bins, the factorial moment F_q of order q will be given by

$$F_q = M^{q-1} \sum_{m=1}^{M} \frac{\langle n_m(n_m-1)\cdots(n_m-q+1)\rangle}{n_m^q}$$

Here, n_m denotes the total number of charged particles including $\pi^{\pm}$ and $K^{\pm}$ within the m^{th} bin.
q is the order of moment.

- Intermittency manifests itself as the the scaling behavior of the form, $\langle F_q \rangle \propto M^{\alpha_q}$
- α_q values can be obtained by performing a best fit according to linear relation $\ln\langle Fq\rangle = \alpha_q \ln M + A$

Critical Exponent, Lévy Index, Specific Heat

- According to the Ginzburg–Landau (GL) theory [5], the expression for Critical Exponent (ν) is

$$\beta_q = (q - 1)^{\nu}$$

- According to Lévy law [6], the ratio of anomalous dimensions depends on μ and can be expressed through the following relation:

$$\beta_q = (q^{\mu} - q) / (2^{\mu} - 2)$$

- The multifractal specific heat [7] can be derived from the relation given below:

$$D_q = (a - c) + c [\ln q / (q - 1)]$$

05
Results and Discussion

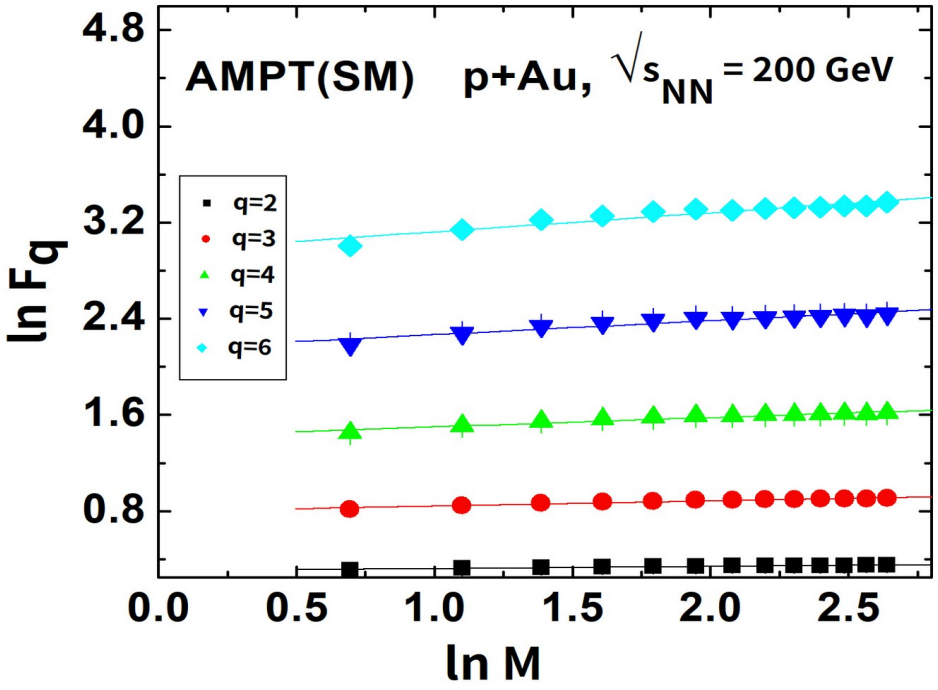


Fig 1: Plot of ln Fq versus ln M in η-space for $\pi^{\pm}$, $K^{\pm}$ at $\sqrt{s_{NN}}$ = 200 GeV.

Order(q)	α_q
2	0.018 ± 0.001
3	0.044 ± 0.003
4	0.077 ± 0.007
5	0.115 ± 0.012
6	0.158 ± 0.017

Table 1: Values of α_q

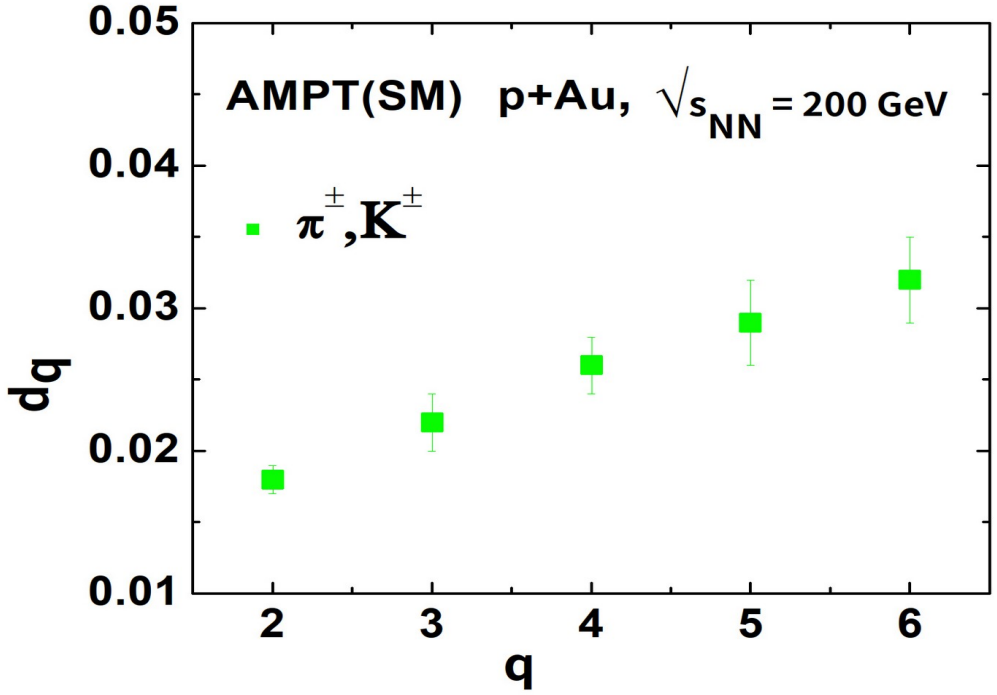
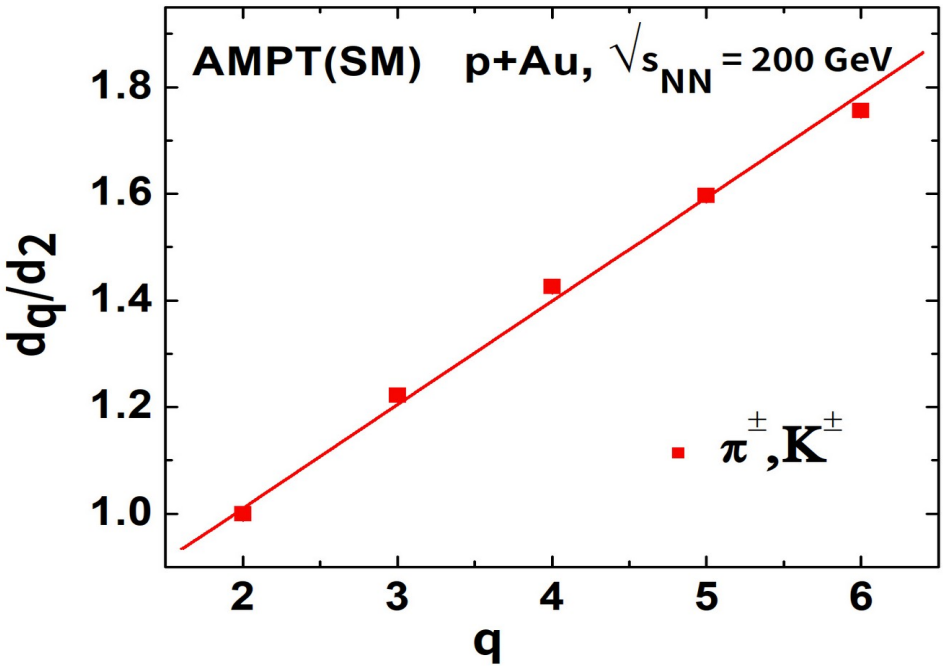


Fig 2: Plot of d_q versus q in η-space for $\pi^{\pm}$, $K^{\pm}$ at $\sqrt{s_{NN}}$ = 200 GeV.

Order(q)	d_q
2	0.018 ± 0.001
3	0.022 ± 0.002
4	0.026 ± 0.002
5	0.029 ± 0.003
6	0.032 ± 0.003

Table 2: Values of d_q

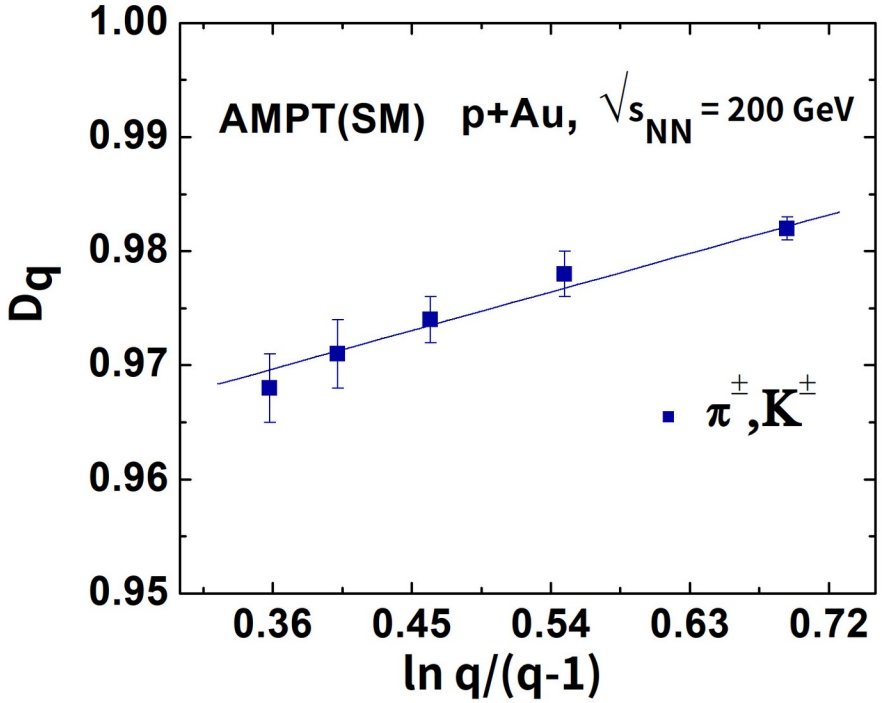


Order(q)	d_q/d_2
2	1.000 ± 0.002
3	1.222 ± 0.003
4	1.426 ± 0.003
5	1.597 ± 0.004
6	1.756 ± 0.004

Fig 3: Plot of d_q/d_2 versus q in η-space for $\pi^{\pm}$, $K^{\pm}$ at $\sqrt{s_{NN}}$ = 200 GeV.

Table 3: Values of d_q/d_2

The value of degree of multifractality (r) is **0.194 ± 0.001**



Order(q)	D_q
2	0.982 ± 0.001
3	0.978 ± 0.002
4	0.974 ± 0.002
5	0.971 ± 0.003
6	0.968 ± 0.003

Fig 4: Plot of D_q versus ln q / (q-1) in η-space for $\pi^{\pm}$, $K^{\pm}$ at $\sqrt{s_{NN}}$ = 200 GeV.

Table 4: Values of D_q

The value of Multifractal specific heat (c) is **0.375±0.006**

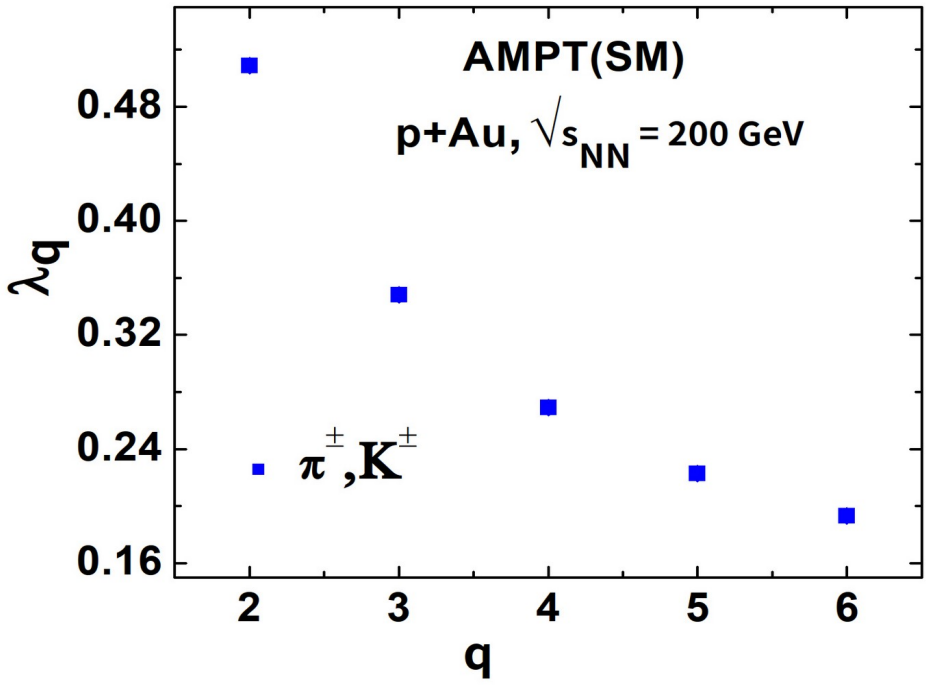


Fig 5: Plot of λ_q versus q in η-space for $\pi^{\pm}$, $K^{\pm}$ at $\sqrt{s_{NN}}$ = 200 GeV.

Order(q)	λ_q
2	0.509 ± 0.001
3	0.348 ± 0.001
4	0.269 ± 0.002
5	0.223 ± 0.002
6	0.193 ± 0.003

Table 5: Values of λ_q

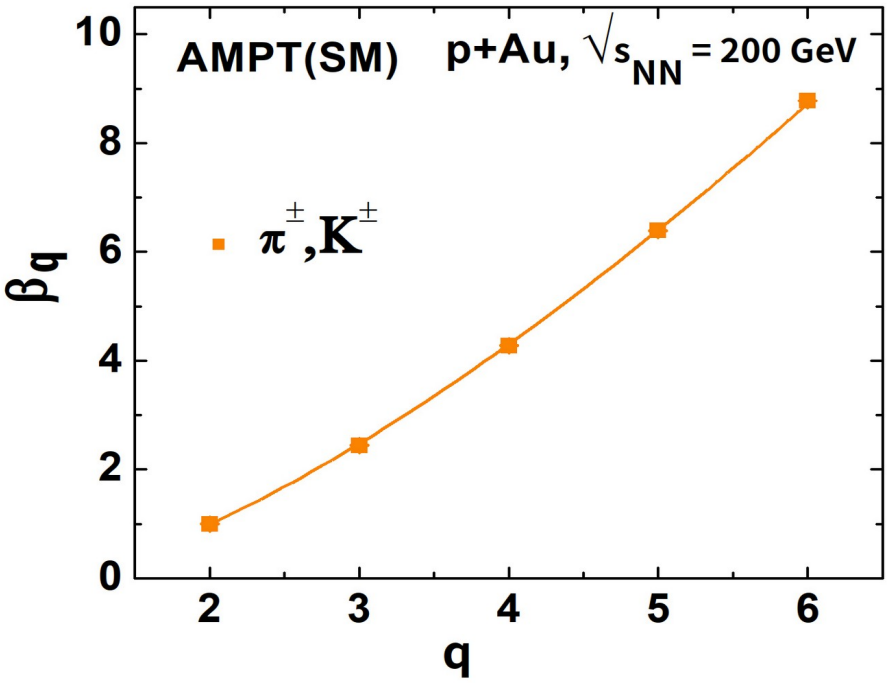
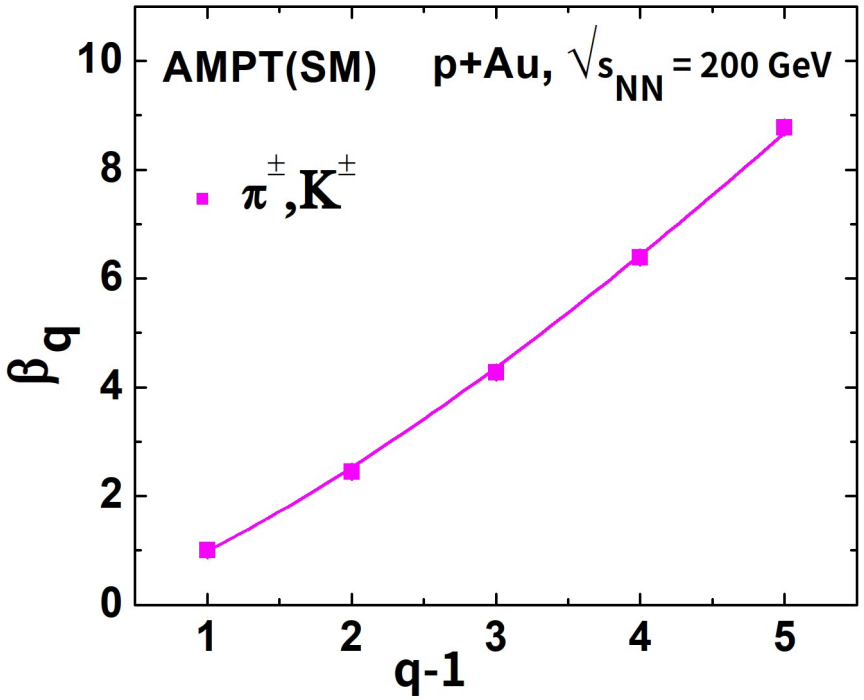


Fig 6: Plot of β_q versus q in η-space for $\pi^{\pm}$, $K^{\pm}$ at $\sqrt{s_{NN}}$ = 200 GeV.

Order(q)	β_q
2	1.000 ± 0.002
3	2.444 ± 0.003
4	4.278 ± 0.003
5	6.389 ± 0.004
6	8.778 ± 0.004

Table 6: Values of β_q

The value of Lévy index (μ) is **1.210±0.005**



Parameters	$\pi^{\pm}$, $K^{\pm}$
r	0.194 ± 0.001
c	0.375 ± 0.006
μ	1.210 ± 0.005
ν	1.343 ± 0.005

FIG 7: Plot of β_q versus q-1 in η-space for $\pi^{\pm}$, $K^{\pm}$ at $\sqrt{s_{NN}}$ = 200 GeV.

The value of Critical Exponent (ν) is **1.343±0.005**

Table 7: Values of the various parameters associated with SFM generated by the AMPT(SM) model at $\sqrt{s_{NN}}$ = 200 GeV

06
Conclusions

- We have investigated the Scaled Factorial Moments (SFMs) to analyze fractality and phase transitions in η space of the AMPT (SM) model-simulated datasets of $\pi^{\pm}$, $K^{\pm}$ in p + Au collisions at $\sqrt{s_{NN}}$ = 200 GeV.

The key findings can be summarised as follows:

— It has been observed that for the AMPT(SM) generated events, the values of v are almost identical with the GL theory predicted value, which suggests the apparent existence of the hadron–quark phase transition in p+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV.

— It has also been observed that for the AMPT(SM) generated events, the value of the Lévy index (μ) for $\pi^{\pm}$, $K^{\pm}$, is greater than unity in the case of 1-dimensional η-space which indicates the signature of non-thermal phase transition and corresponds to "wild" singularities.

— In 1-dimensional η-space, the value of c for $\pi^{\pm}$, $K^{\pm}$ is greater than zero for the AMPT(SM) generated events which indicate multifractality in p+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV.

— For the AMPT(SM) generated events, the value of the degree of multifractality (r) is nonzero for $\pi^{\pm}$, $K^{\pm}$, i.e., reflects the signature of multifractal behaviour.

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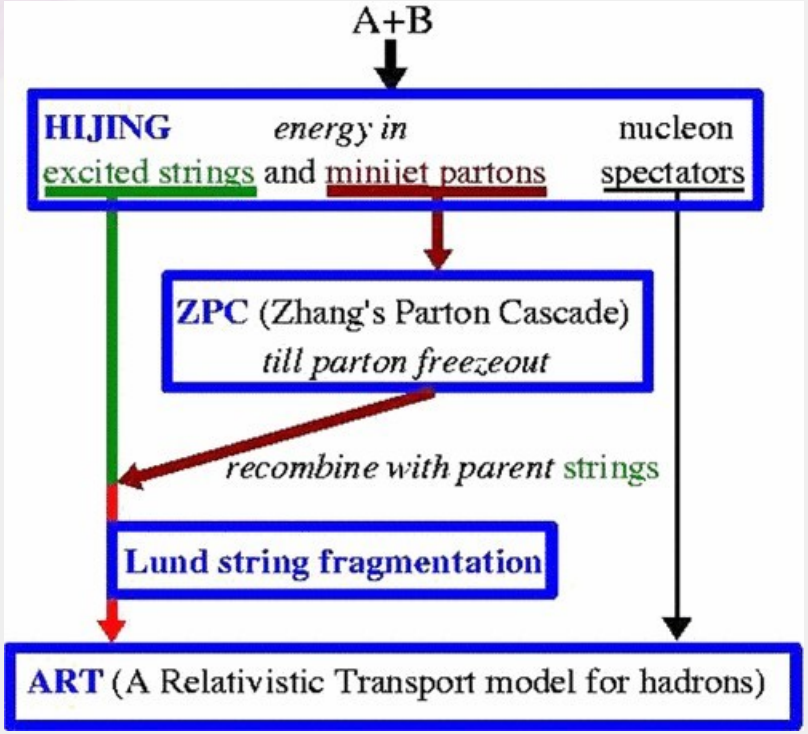
Acknowledgements

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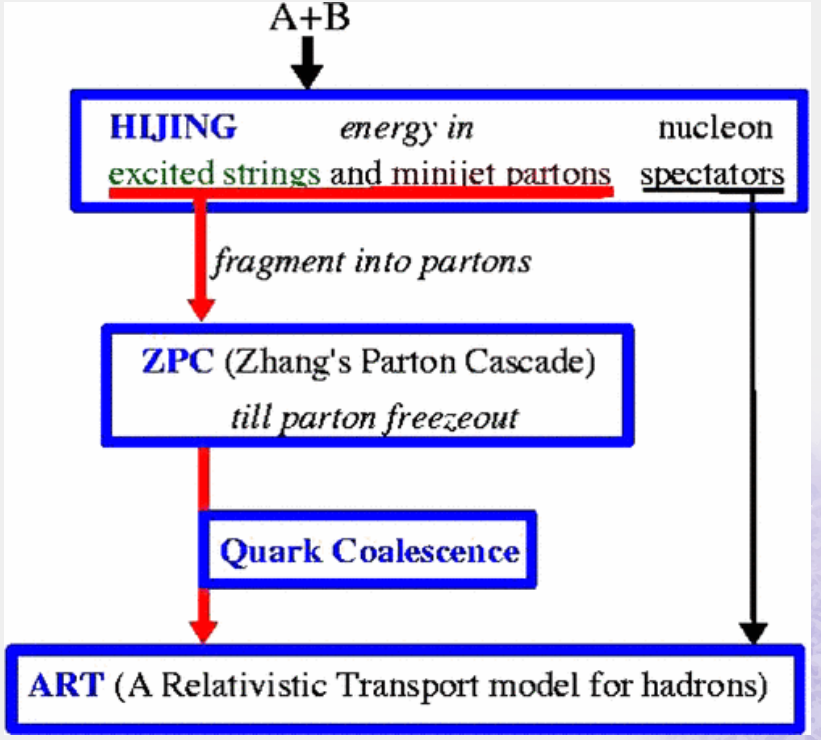
Thank You

Backup

Structure of Default AMPT



Structure of AMPT string melting



Phys. Rev. C 72, 064901 (2005)