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Intermittency analysis to understand multiparticle production in heavy-ion collisions

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Intermittency

- Large local density fluctuations exist in the process of space-time evolution in high-energy collisions
- Fluctuations in the geometerical configurations (spatial patterns) of the produced particles in multiparticle production
  - ✓ is one of the signatures of criticality
  - ✓ helps to understand the particle production mechanism

- Fluctuations of dynamical nature, i.e. larger than expected from Poisson noises are manifested in the multiplicity distributions
  - ✓ Normalized factorial moments (NFM)[1] of mulitplicity distributions as a promising tool to investigate fluctuations are suggested in [1,2]
  - ✓ These dynamical fluctuations in high-energy collisions can be manifested as an abnormal scaling property of NFM [3,4]

A power law behaviour of the normalized factorial moments as function of number of bins is termed as intermittency

Observables

Phase space (η, ϕ) is divided into a square lattice : Bin multiplicity (n_{ie}) - used to calculate the Normalized factorial Moments(NFM)

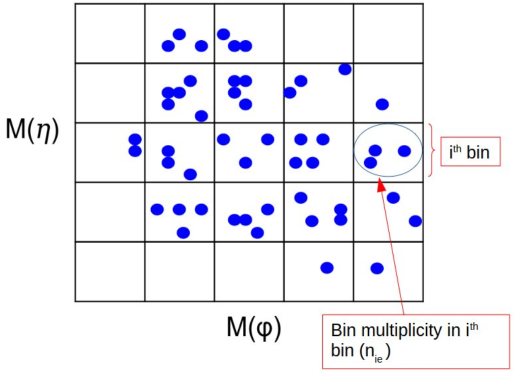


Fig. 1. Graphic illustration of two dimensional (η, ϕ) phase space partitioned in M × M bins

$$f_q(n_{ie}) = n_{ie}(n_{ie}-1)(n_{ie}-2)........(n_{ie}-q+1)$$

- q - order of the moment; $q \geq 2$, $n_{ie} \geq q$

$$F_q(M) = \frac{\frac{1}{N}\sum_{e=1}^{N}\frac{1}{M}\sum_{i=1}^{M} f_q(n_{ie})}{\left(\frac{1}{N}\sum_{e=1}^{N}\frac{1}{M}\sum_{i=1}^{M} f_1(n_{ie})\right)^q}$$

Intermittency: If F_q shows power law dependence on number of phase space bins, M [3,4]

1. M-Scaling ⟶ $F_q(M) \propto M^{\varphi_q}$

➔ ϕ_q is the intermittency index

2. F-Scaling ⟶ $F_q(M) \propto F_2(M)^{\beta_q}$

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

➔ **ν: is scaling exponent** characterizes the dynamics of the system under study

ν ≅ **1.32** Ginzburg Landau formalism[5] for the second- order phase transition

≅ **1.41** Critical fluctuations, SCR Model

Scaling in Toy Monte Carlo events

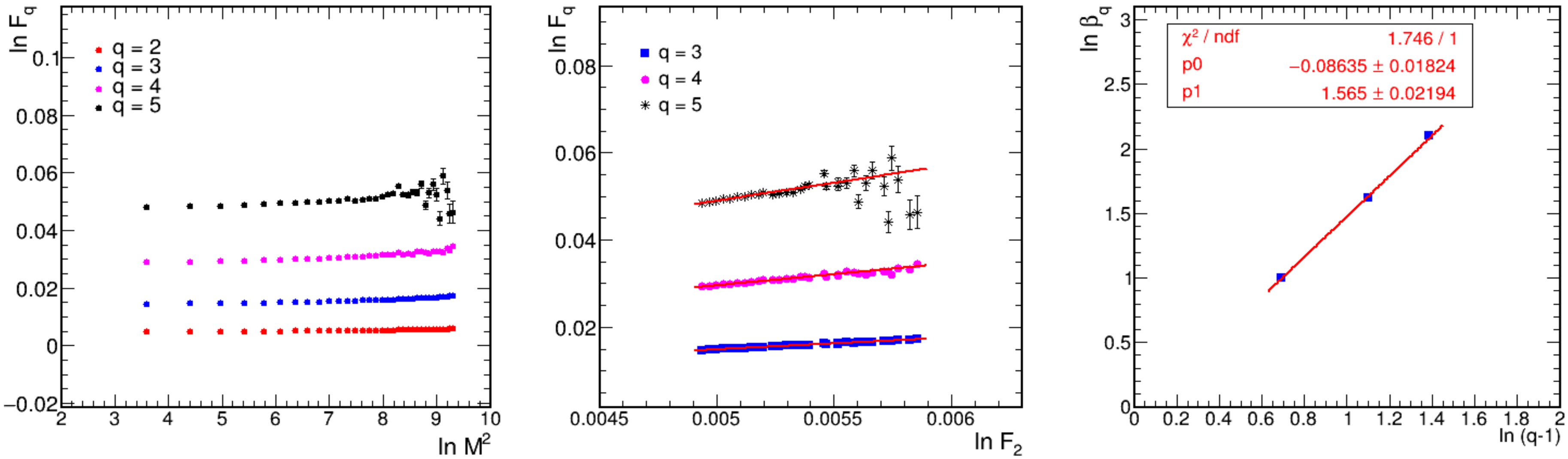


Fig. 6 (left) log-log plot of F_q vs M^2 (M-scaling)
(middle) log-log plot of F_q vs F_2 (F-scaling)
(right)) Scaling exponent obtained from lnβ_q vs ln (q-1)

$\nu = 1.565 \pm 0.022$

Observations:

M-scaling independent of M. No significant power-law growth.

F-scaling observed and scaling exponent > 1.3, the characteristic value for second order phase transition

Toy Monte Carlo events

- Toy Model : Events are generated for a random multiplicity distribution using random event generator for flat distributions in the chosen phase space

Uniform Efficiency Maps (x%) Tracks are removed randomly from each event so as to maintain x% track efficiency.

Non-Uniform Efficiency Maps Tracks are removed non uniformly from sample of events and tracking efficiency maps are obtained for all values of M.

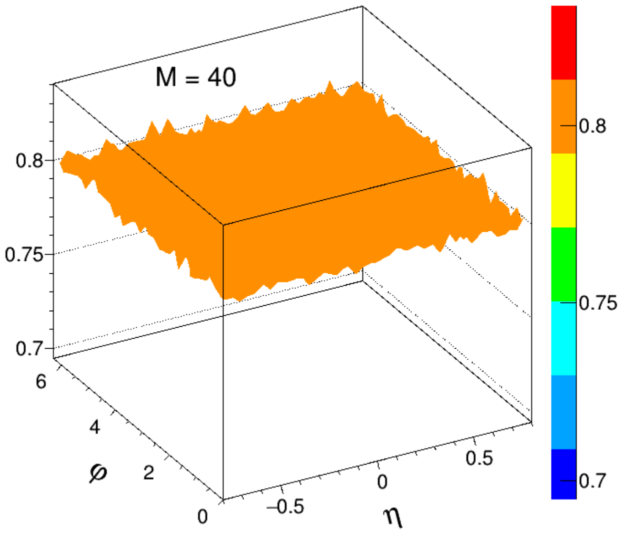


Fig. 2 Efficiency map in (η, ϕ) space for M = 40 with uniform removal of tracks.

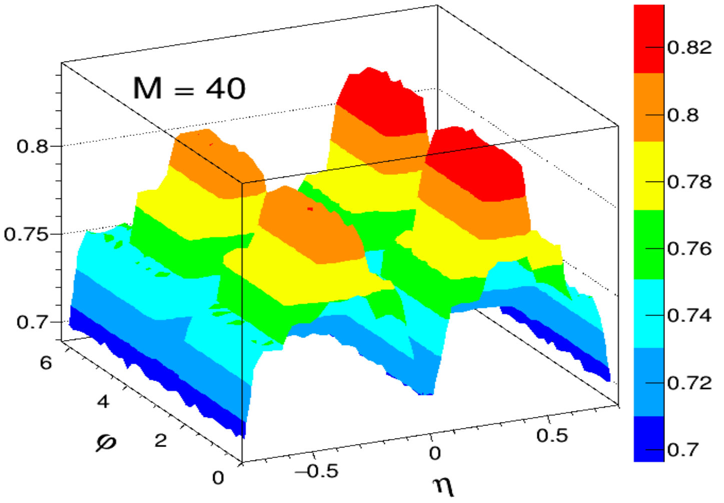


Fig. 3 Efficiency map in (η, ϕ) space for M = 40 with non-uniform removal of tracks.

Closure Test

Efficiency Corrections: Efficiency maps in the two phase space variables are obtained for each "M".

$$\epsilon = \frac{\text{Number of tracks after removal of some tracks}}{\text{Number of tracks within acceptance}}$$

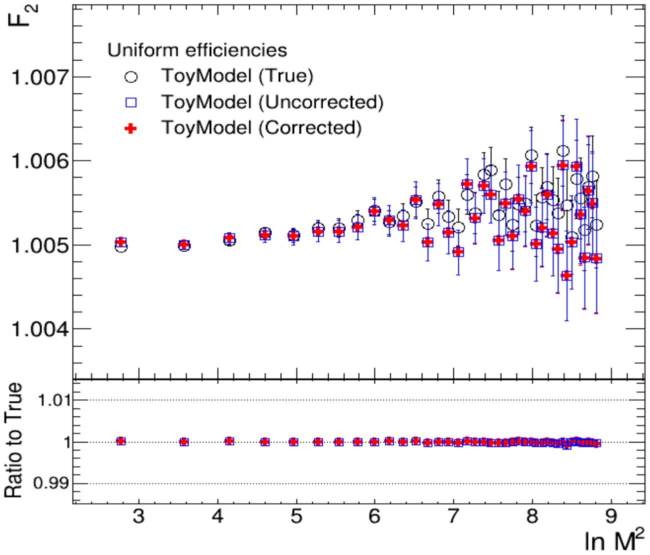


Fig. 4 F_2 vs M^2 plot in case of uniform type efficiencies

Corrected factorial moment is defined as

$$F_q(M) = \frac{\frac{1}{N}\sum_{e=1}^{N}\left\langle \frac{f_{qi}^{rec}(n_{ie})}{\epsilon_i^q} \right\rangle_h}{\left(\frac{1}{N}\sum_{e=1}^{N}\left\langle \frac{n_i^{rec}}{\epsilon_i} \right\rangle_h\right)^q}$$

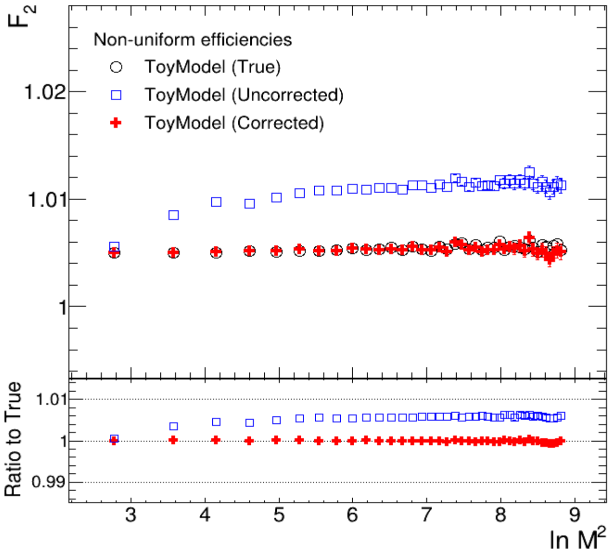


Fig. 5. F_2 vs M^2 plot in case of non-uniform type efficiencies

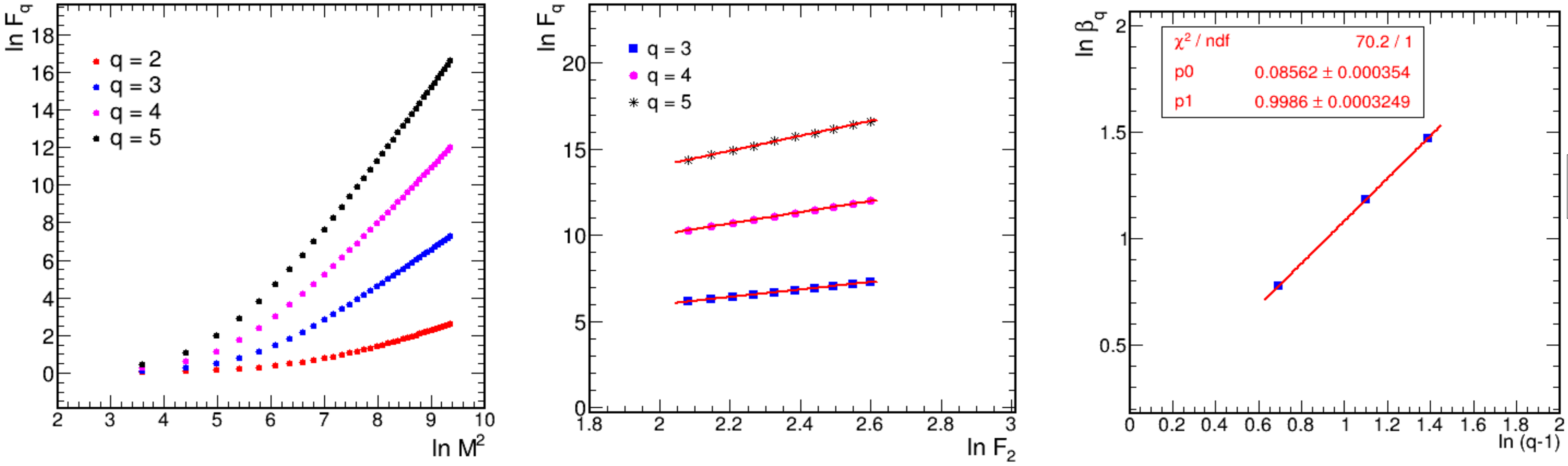
Observations:

NFM are robust against the uniform efficiences in the data

Methodolgy is efficient to recover correct values of NFM in case of non-uniform efficiencies

Fluctuations and scaling in Toy MC

Fluctuations introduced: Fluctuations are added with hand into the Toy Monte Carlo event sample to check the sensitivity of the observable to measure fluctuations in spatial distributions. Tracks equal to 1% of multiplicity per event are are added randomly in some phase space bins and an equal number of tracks are removed from rest of the region so that there is no change in the multiplicity distribution.



ν = 0.99 ± 0.00

Fig. 7 (left) log-log plot of F_q vs M^2 (M-scaling), (middle) log-log plot of F_q vs F_2 (F-scaling) ,(right)) Scaling exponent obtained from lnβ_q vs ln (q-1)

Observations:

NFM good observable to measure fluctuations. Significant power-law growth of NFM with increasing M. F-scaling observed and scaling exponent < 1.3

References

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