Intermittency Analysis of charged particles generated in Xe-Xe collisions at $\sqrt{s_{NN}}$ = 5.44 TeV using the AMPT Model

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Outline

- Physics Motivation
- Methodology and Observables
- Observations
- Summary

Physics Motivation

As strongly coupled QGP expands

initial state conditions of the collisions transfer into the final-state collective behaviour

↓

Large density fluctuations (QCD)

↓

Fluctuations in the geometrical configurations (Spatial patterns)

One of the proposed measures

- to characterize QGP
- and hence to add to information about the QCD phase diagram/particle production mechanismm

↓

To study Fluctuations in spatial patterns

To study Fluctuations in spatial patterns

↓

scaling properties of multiplicity fluctuations over wide range of bin sizes

using

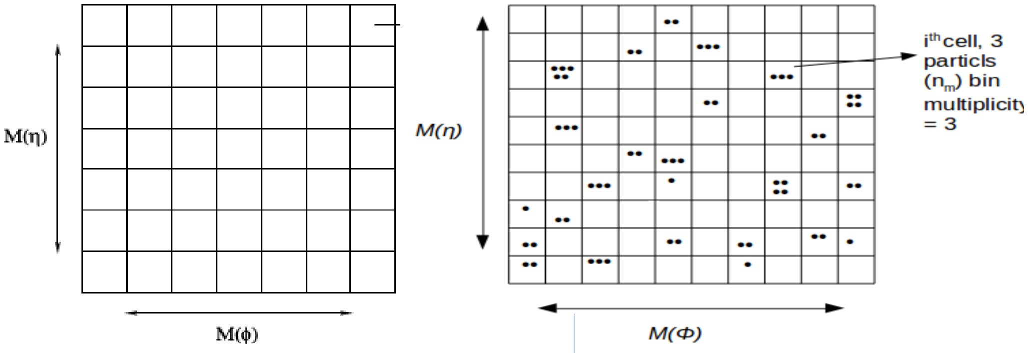
Normalized Factorial Moments (NFM)

Intermittency analysis

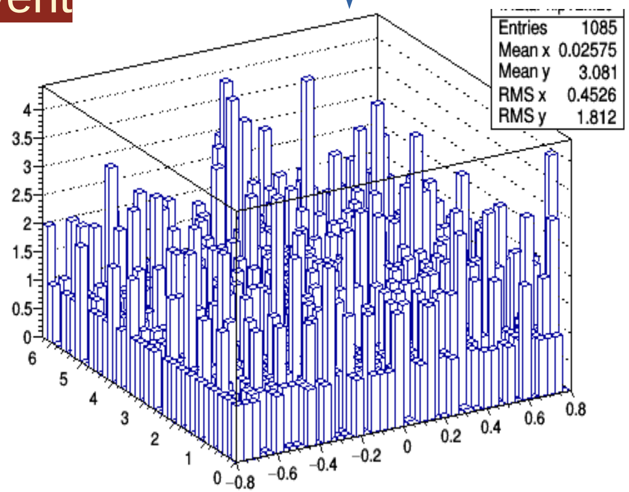
Primary Sources:

- R.C. Hwa and C. B. Yang, Acta Physica Polonica B . Vol. 48 Issue 1 (2017).
- R.C. Hwa & C.B. Yang, PRC 85, 044914 (2012), nucl-ex:1411.6083
- R.C. Hwa and M.T. Nazirov, Phys. Lett. 69, 741 (1992).

Eta-phi phase space of an event is binned into M×M bins



Single event



Phase space (η, Φ) is divided into a square lattice

- M(η) and M(Φ) : Number of bins along eta and phi axis respectively.
- Charged particles are mapped into this 2D matrix
- Number of particles that go in each cell defines the bin multiplicity (n_{ie})

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

- q is the order of the moment (positive integer) $q \geq 2$
- n_{ie} is bin multiplicity, $n_{ie} \geq q$, M is number of bins.

Observables

Normalized factorial Moments

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

where M is number of bins, N is the number of events

M-Scaling → $F_q(M) \propto M^{\varphi_q}$

- ϕ_q is the intermittency index and can be acquired as a quantity characterizing fractality

- F_q filters out statistical fluctuations
- Robust against the uniform efficiency losses

A. Bialas and R. Peschanski, Nucl. Phys. B, 273 (1986).
R.C. Hwa and C. B. Yang, Acta Physica Polonica B . Vol. 48 Issue 1 (2017).

Other than M-scaling, there exist another scaling which is

$$F_q(M) \propto F_2(M)^{\beta_q}$$ → **F-Scaling**

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

ν: is **scaling exponent** (dimensionless exponent) gives economical summary of the system under study

Aim

- **Scaling @ LHC energies?**
- **ν @ LHC energies?**

Predictions (Theory/Models)

ν =~ **1.32** Ginzburg Landau formalism[1] for the second-order phase transition

=~ **1.41** Critical fluctuations, SCR Model [2]

1. R.C. Hwa and Jicai Pan, PLB 297, 35 (1992).
2. R.C. Hwa and C.B. Yang, PRC 85, 044914 (2012).

Observations: AMPT

- Is a hybrid transport model and is designed to model the heavy-ion collisions available at relativistic energies
- AMPT with string melting version

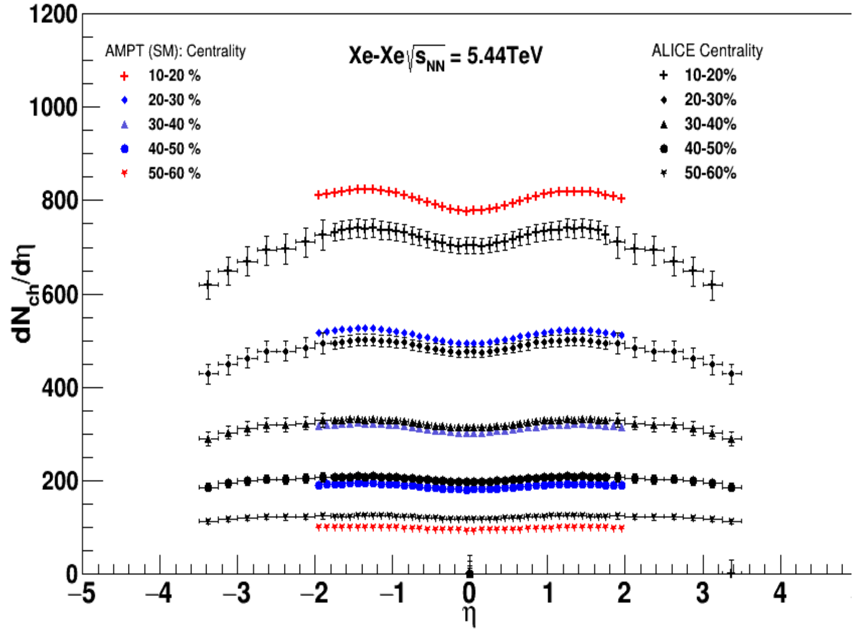


Fig1a.

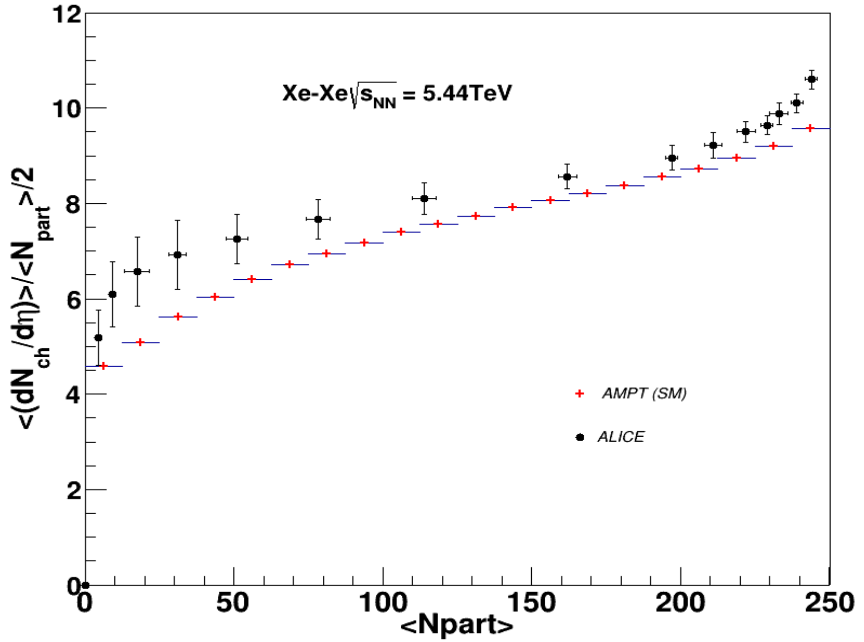
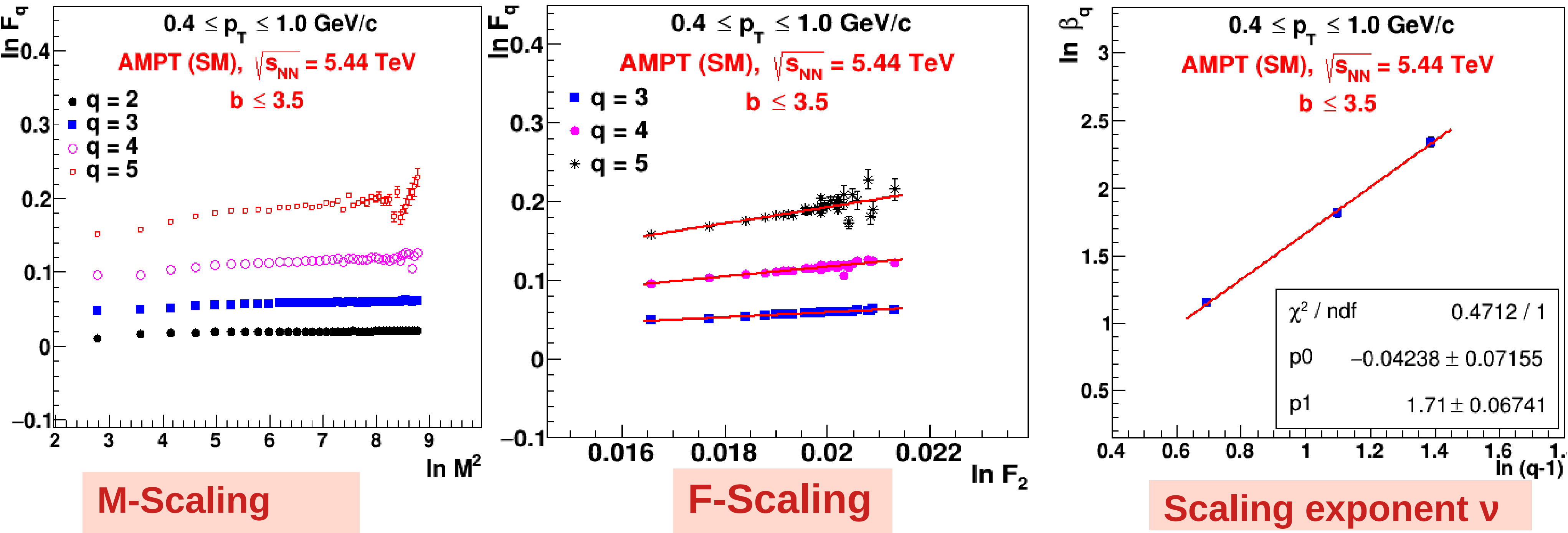


Fig1b.

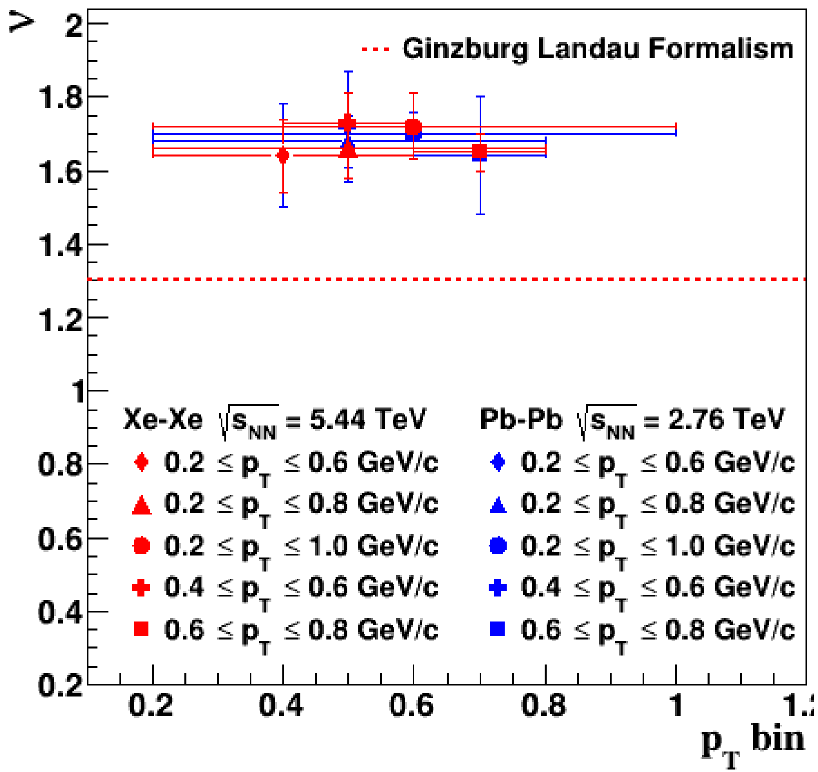
- 500K minimum biased Xe-Xe events at $\sqrt{s_{NN}}$ = 5.44 TeV generated, impact parameter $0 \leq b \leq 3.5$ fm.
- Pseudorapidity density distribution (Fig1a) , particle density vs number of participants (Fig1b)

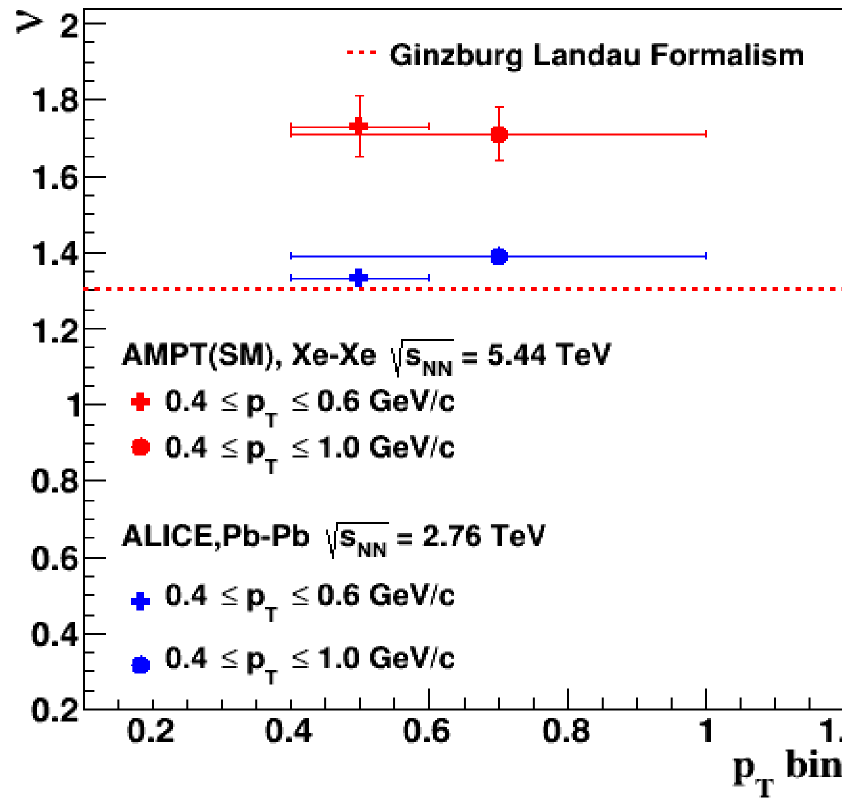
Observations



- The M-scaling (left) and F-scaling (middle) behaviour of the NFM (F_q) are studied for p_T bins [0.4-1.0] and the scaling index (right) value are calculated for the same.

Observations





ALICE Results: Poster Session (today)
Pythia+Angantyr: Flash Talk (2-8-22)

Summary

- Scaling properties of the charged particles generated in the mid rapidity region in Xe-Xe collisions at $\sqrt{s_{NN}}$ = 5.44 TeV have been studied in the framework of intermittency analysis.
- A power-law growth of NFM (ln F_q) with ln M is observed **to be absent at high M** values in all the p_T bins.
- However **F-scaling is observed.**
- With no phase transition physics implemented in (SM) AMPT model

  - Scaling behaviour in line with intermittency is absent.

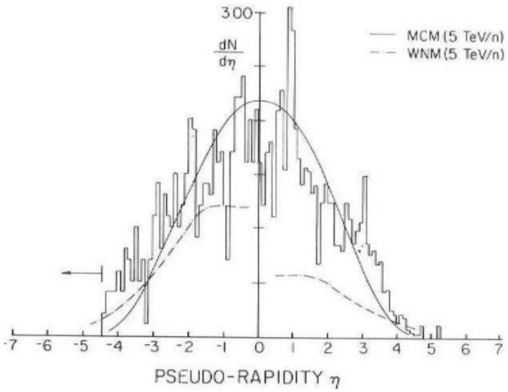
  - Scaling exponent value (ν) is greater than the value predicted by theory for second – order phase transition.

Thanks ....

Back up

Motivation: Fluctuations and Intermittency

- Large local density fluctuations exist in the process of space-time evolution in high-energy collisions
- To decide whether these fluctuations are dynamical, i.e. larger than expected from Poisson noises,
  - Bialas and Peschanski have suggested the use of normalized factorial moments (NFM)
- These dynamical fluctuations in high-energy collisions can be manifested as an abnormal scaling
  - when the corresponding collision system is a fractral



A. Bialas and R. Peschanski, Nucl. Phys. 273, 703 (1986).; 308, 857 (1988)

Scaling properties of multiplicity fluctuations over wide range of bin sizes

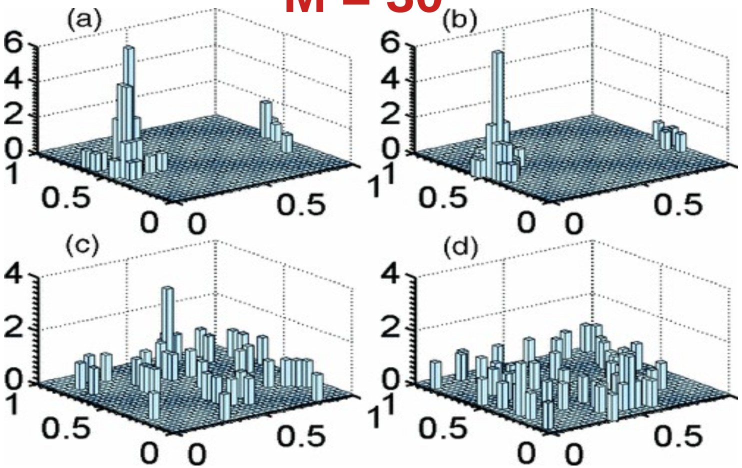
(Intermittency Analysis)

R. C. Hwa et al, PRL 69, 741 (1992); R. C. Hwa et al, PRC 85, 044914 (2012).

Model Predictions

R. C. Hwa et al, PRC 85, 044914 (2012)

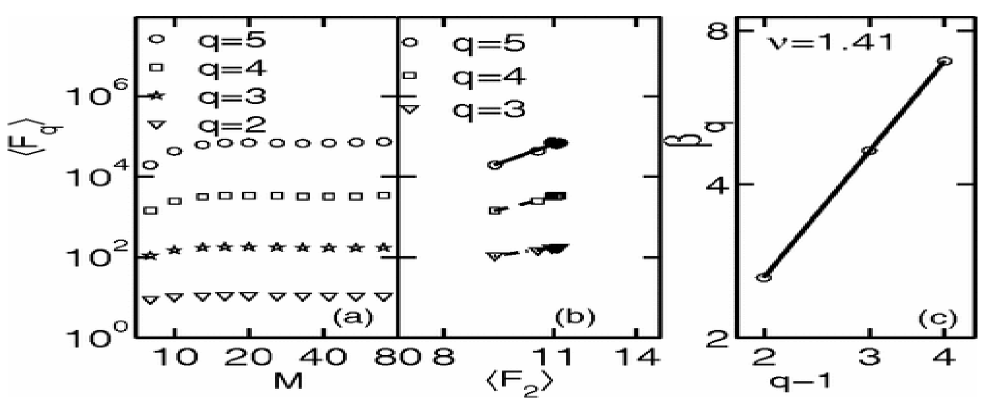
M = 30



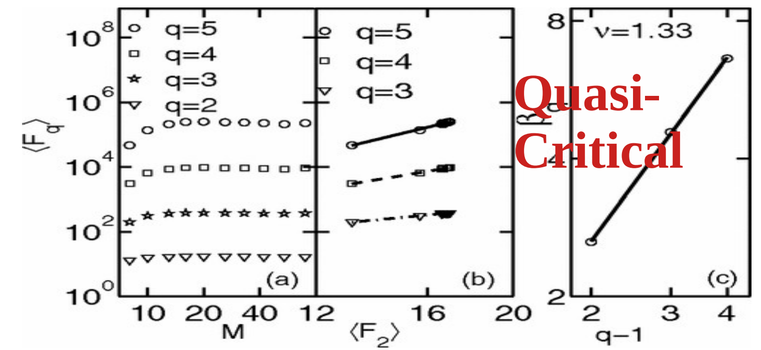
Model: ***Contracting clusters due to color confinement***

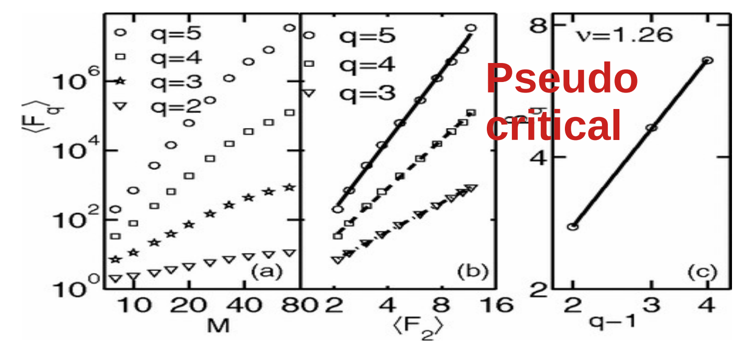
- M= 8 to 70
- Δp_T= 0.04, 0.07, 0.1 GeV/c around p_T = 1 GeV/c
- Quar-hadron phase transition

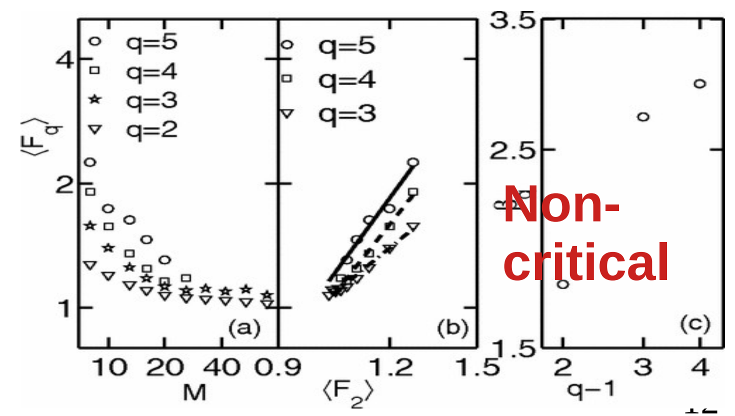
M-Scaling F-Scaling ν



Critical

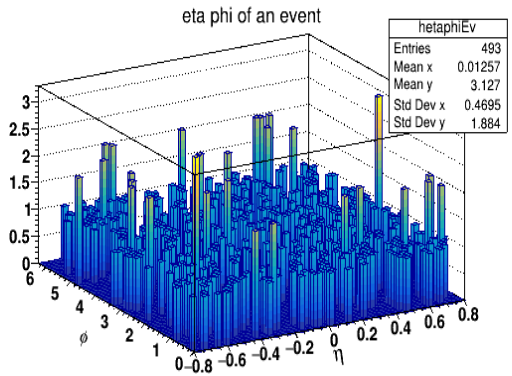


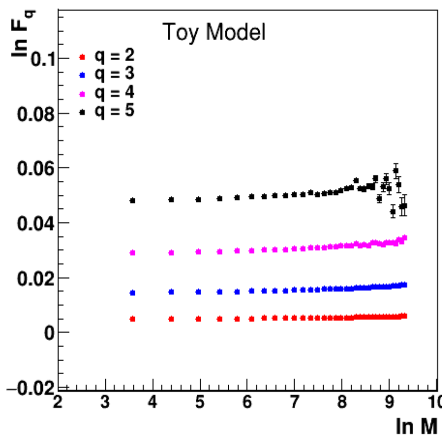


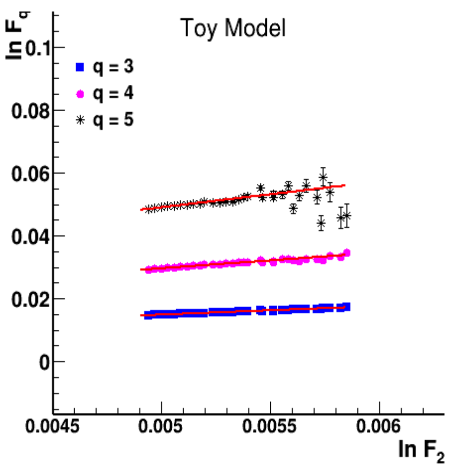


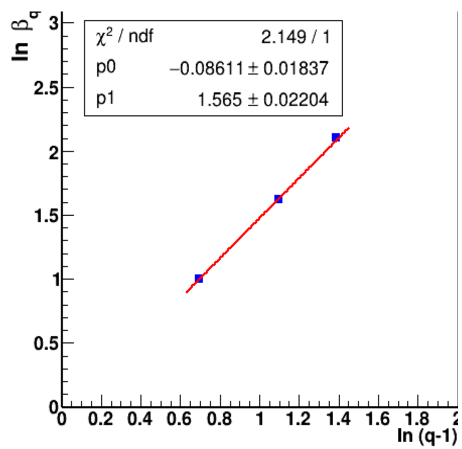
Toy MC: Baseline value of exponent

Toy MC





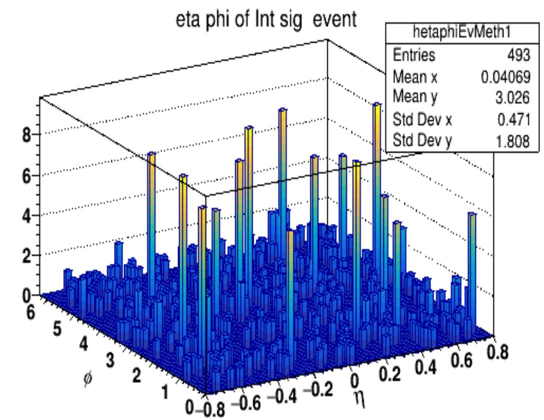


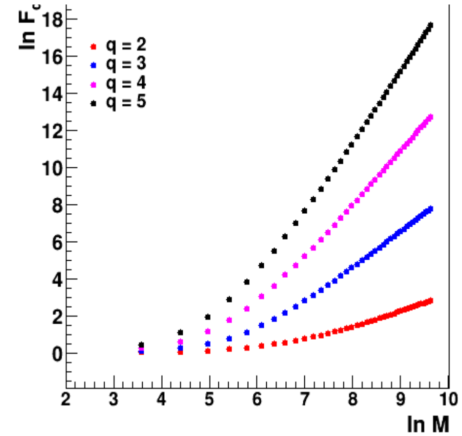


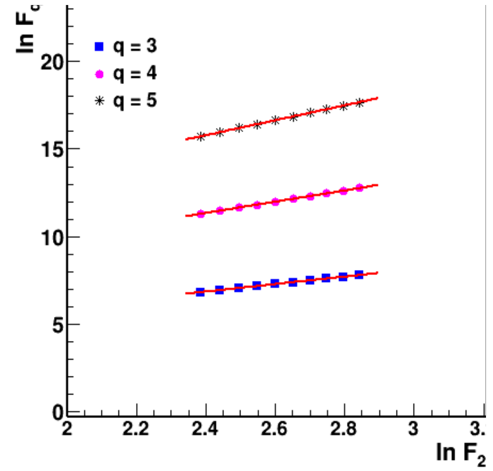
No/least fluctuations

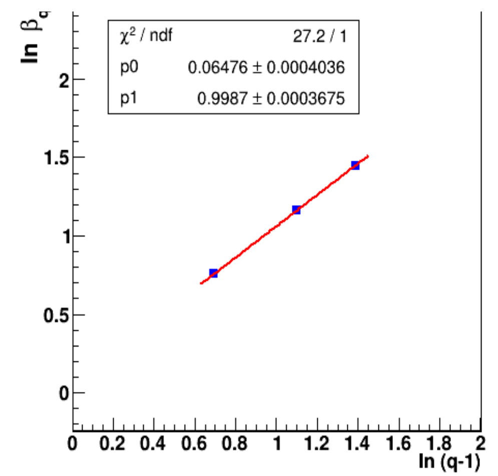
$\nu = 1.565 \pm 0.022$

Toy MC: 1% fluctuations in each events









Increased fluctuations:
Scaling exponent decreases

$\nu = 0.99 \pm 0.00$

Scaling exponent (ν): Data vs Theory and model predictions

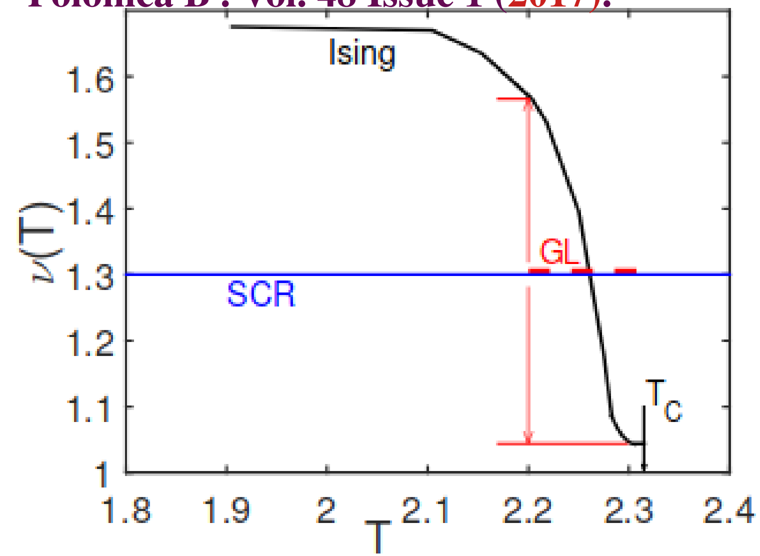
ν	Different Models
1.304	**Without kinetic term in GL potential** **GL Formalism:** R.C. Hwa, M.T. Nazirov, Phys. Rev. Lett. 69, 741 **(1992)**
1.316 ± 0.012	**With kinetic term** in GL potential PLB 297, 35-58 (**1992**)
1.41	SCR Model : R. C. Hwa and C. B. Yang, Phys. Rev. C 85, 044914(**2012**) **Ising Model and SCR Model :** R. C. Hwa and C. B. Yang, Acta Physica Polonica B 48, **(2016)**
1.55 ± 0.12	EMU01 and KLM Collaboration **EMU01:** M.I. Adamovic PRL, 65,412 **(1990)** **KLM:** PRL, 62, 733 (**1889**); PRC 40, 2449 (**1989**)
1.79±0.10 AMPT	R. Sharma and R. Gupta, AHEP, Article ID 6283801 **(2018)** (small $p_T$bin ~0.2, 0.4 to 0.6 GeV/c, M: 5 to 30) |η| < 0.8 , full azimuthal coverage
1.75 ±0.12 EPOS3	R. Gupta and Salman Khurshid Malik, AHEP, Article ID |η| < 0.8 , full azimuthal coverage

RHIC energies

ν = 1.743 from UrQMD model. S. Bhattacharyya, EPJP 136, 471 (2021).

ν = 1.94 from AMPT model. X. Y. Long et al, NPA 920, 33-34 (2013).

R.C. Hwa and C. B. Yang, Acta Physica Polonica B , Vol. 48 Issue 1 (2017).



The curve ν(T) provides a model-dependent interpretation of the value of ν in terms of temperature

- T_c (=2.315 J/k_B) is the transition temperature in Ising system
- Dashed red line is the GL value (average of the Ising values between T = 2.2 and T_c)
- **<u>However in real system transition occurs at lower temperature (=2.21 J/k_B)</u>**