Scaling properties of charged particle multiplicity fluctuations at $\sqrt{s_{NN}}$= 2.76 TeV in ALICE at the LHC

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1. Introduction and motivation

- As the system approaches critical temperature, tension between the collective interactions and thermal randomization increases leading to formation of clusters.
- Multiplicity fluctuations are an important tool for understanding the dynamics of the produced particles and phase transition in the heavy-ion collisions

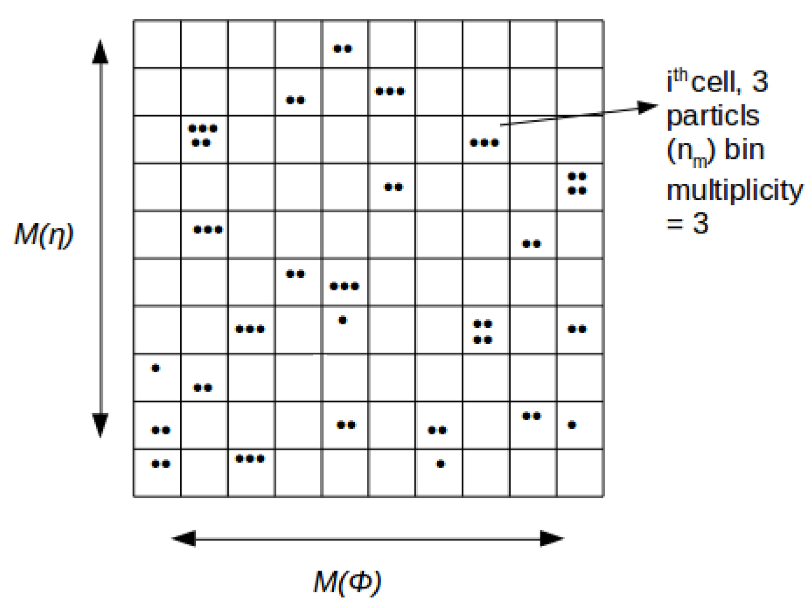
Clustering → **Fluctuations in the geometrical configurations (Spatial patterns)** → ***Criticality and quark-hadron phase transition***

- Large density fluctuations in the initial stage of the collision transfer into final-stage collective behaviour as the strongly coupled quark-gluon (QGP) plasma expands.
- These fluctuations are characterized by the moments of the particle density distribution within a given phase space.

Scaling @ LHC energies? | Scaling exponent @ LHC energies?

2. Formalism

Normalized Factorial Moments (NFM) are used to study the scale-invariance



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

N : Number of events
M : Number of bins
n_{ie} : Bin multiplicity

$$f_q(n_{ie}) = \langle n_{ie}(n_{ie}-1)\ldots(n_{ie}-q+1)\rangle_h$$

Intermittency: In case of any scale-invariant pattern, NFM are expected to scale with the number of phase-space bins, *M*

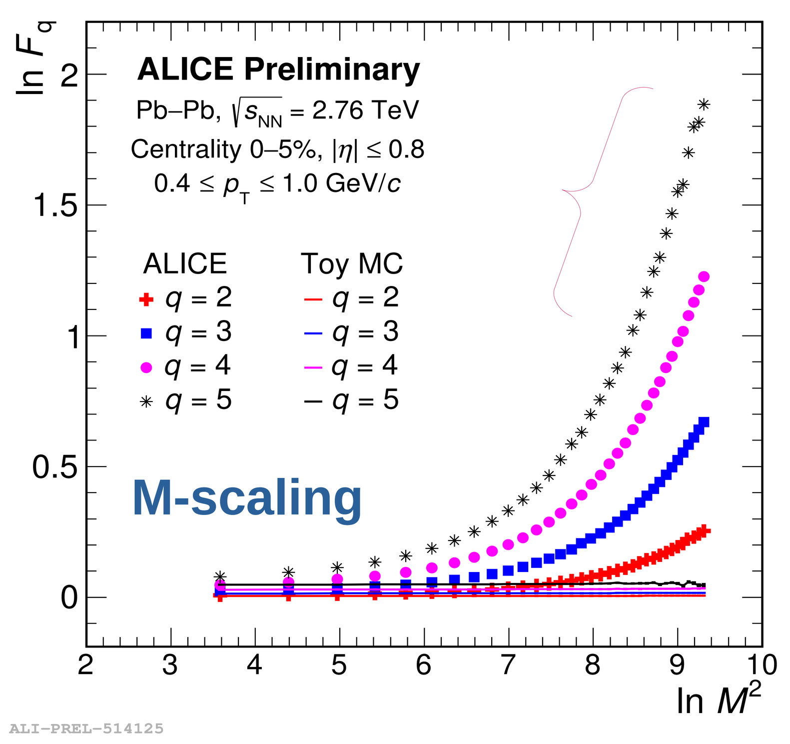
M-scaling $F_q \propto M^{\phi_q}$

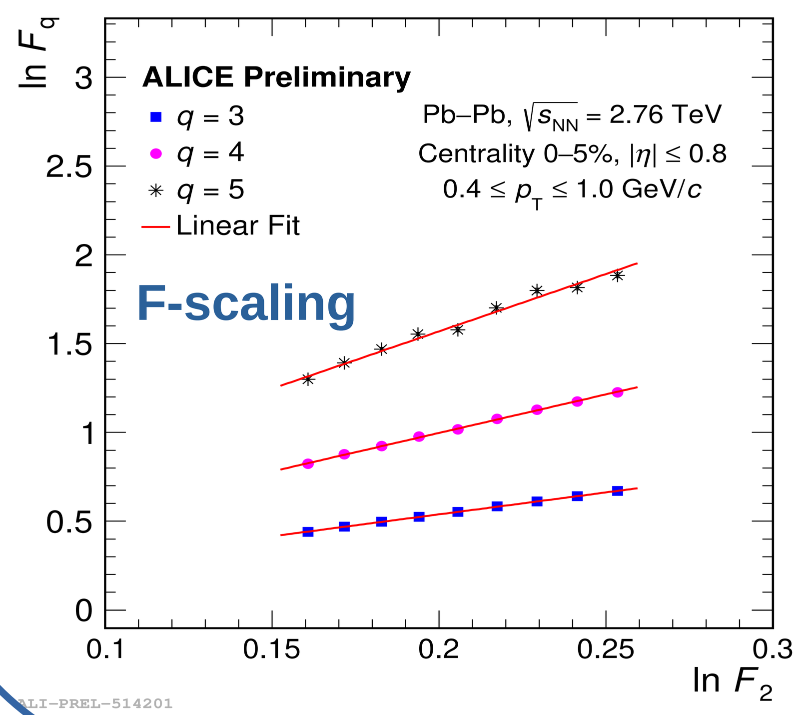
F-scaling $F_q \propto F_2(M)^{\beta_q}$

Scaling exponent, ν $\beta_q \propto (q-1)^{\nu}$

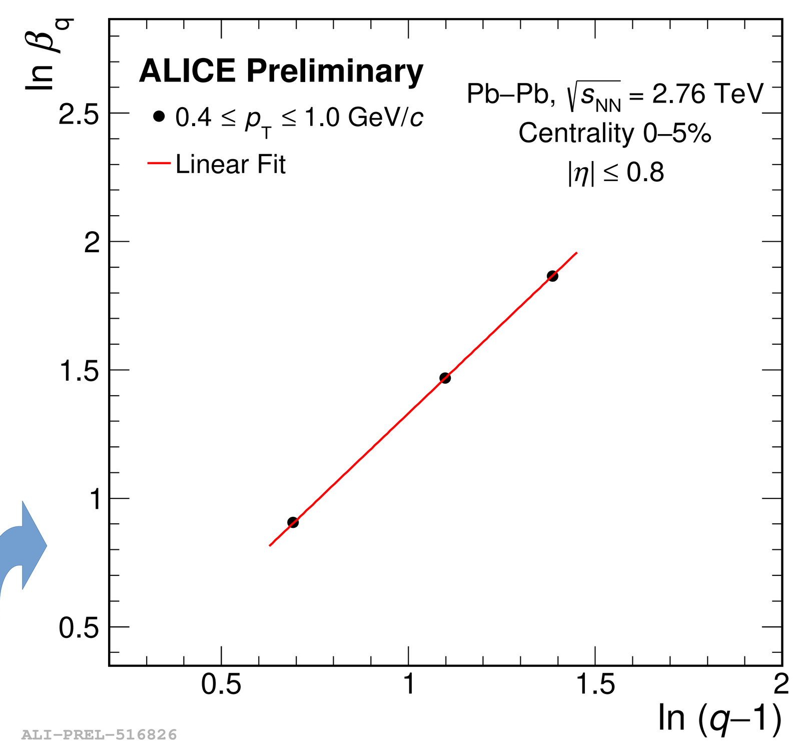
ν ≅ **1.32** Ginzburg Landau formalism[1] for the second-order phase transition
≅ **1.41** Critical fluctuations in case of Successive Contraction and Randomization (SCR) Model [2]

3. Observations





Power-law growth of the NFM with increase in the number of bins (M) indicates scale-invariant pattern in the distribution of particles

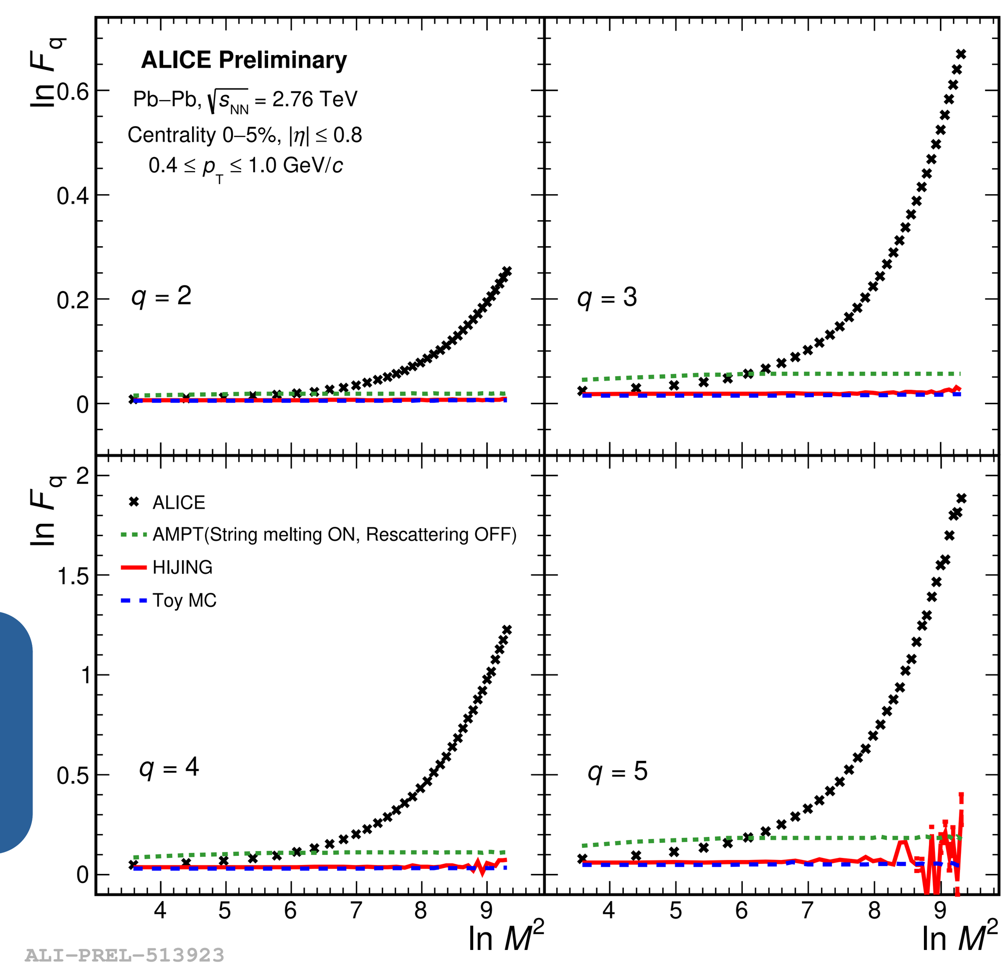


- F-scaling observed in ALICE data
- Toy MC results have monotonic dependence on ln M^2 and does not describe data

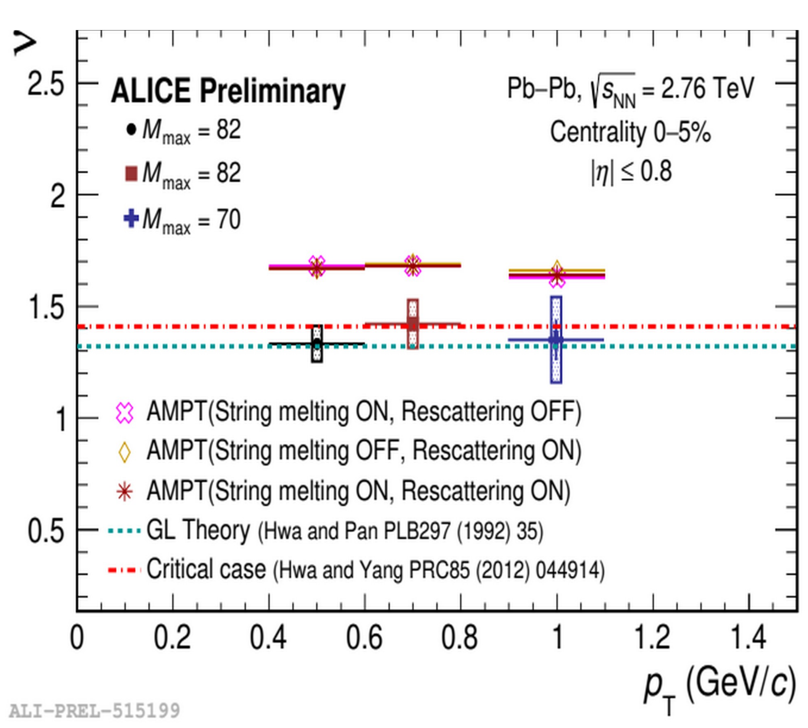
4. M-scaling: comparison with models

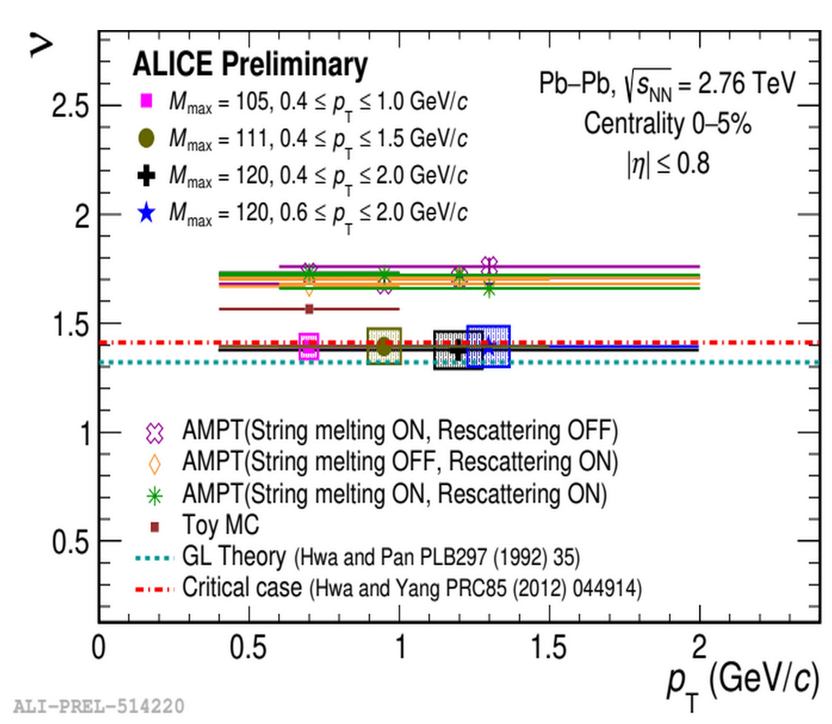
- Qualitative and quantitative difference observed between data and MC
- Difference in the scaling properties of charged particle multiplicity distributions as the binning resolution increases

Scale-invariant density fluctuations observed in ALICE data but absent in MC (HIJING, AMPT, Toy MC)



5. p_T bin width dependence of ν

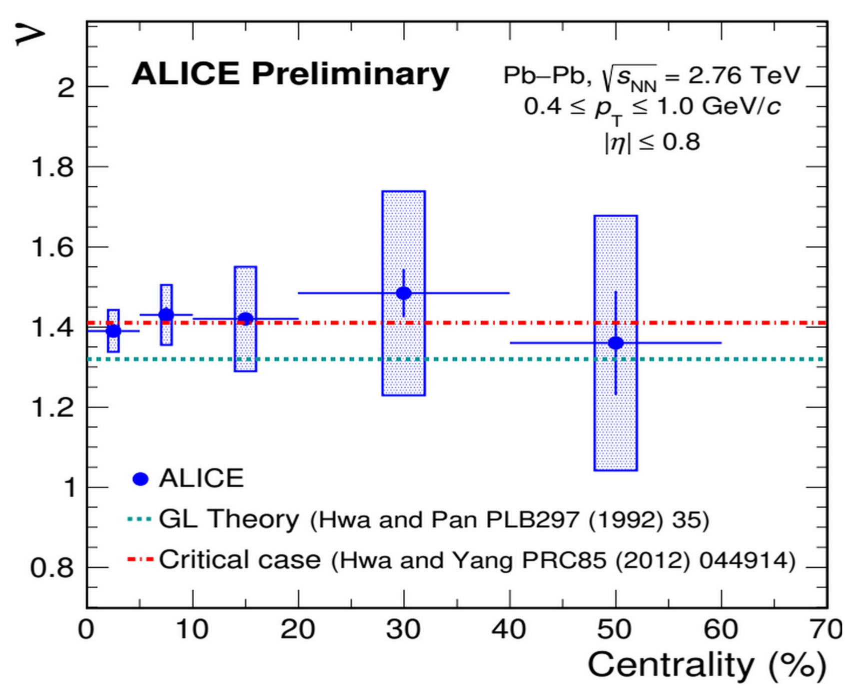




- The scaling exponent (ν) is independent of p_T bin and p_T bin width within uncertainties
- Scaling exponent values obtained for ALICE data are close to the predicted value for critical fluctuations in Refs. [1, 2]

6. Centrality dependence of scaling exponent

- The scaling exponent is independent of centrality within experimental uncertainties
- Uncertainties are large in semi-central and peripheral events due to small event multiplicity



7. Summary

- Intermittency signal i.e. linear behaviour between ln F_q and ln M^2 observed at higher bin resolution (M^2)
- First observation of F-scaling at LHC energies
- The scaling exponent results show no dependence on the p_T bin width and centrality and agree with the models with critical fluctuations within the experimental uncertainties
- HIJING and AMPT models do not describe the data

8. References

1)R.C. Hwa and Jicai Pan, Physics Letters B 297, 35 (**1992**).
2)R.C. Hwa and C.B. Yang, Physical Review C 85, 044914 (**2012**).
3)R.C. Hwa, M.T. Nazirov, Physical Review C 69, 741 (**1992**).

51st International Symposium on Multiparticle Dynamics ISMD2022
Atholl Palace Hotel, Pitlochry, Scottish Highlands, 31 July – 5 Aug, 2022

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