Event-by-event multiplicity fluctuations in charged particle production at the LHC energies with ALICE

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1. Motivation

- As the system approaches critical temperature, the tension between the collective interactions and thermal randomization increases, leading to the formation of clusters.
- Large density fluctuations in the initial stage of collisions transfer into final state collective behaviour as the strongly coupled quark-gluon plasma expands.
- These fluctuations are characterized by the moments of the distribution of particle density in the collision within some phase space.

2. Formalism: Scaling

- A technique of Normalized Factorial Moments (NFM) is used to study the scale invariance over a range of bin sizes.

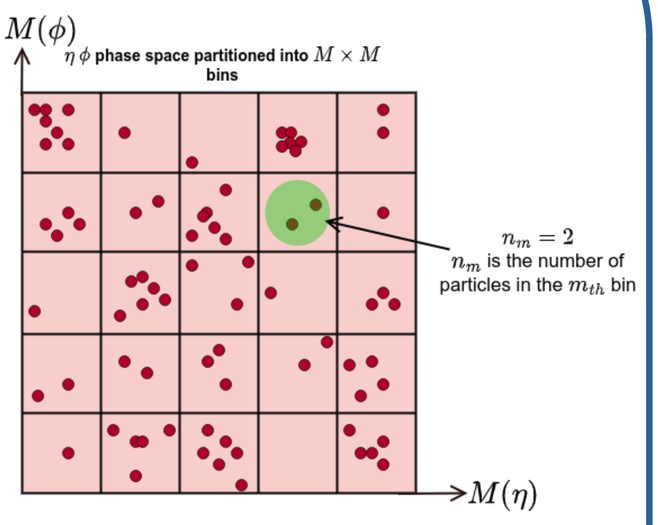
$$F_q(M) = \frac{\frac{1}{N}\sum_{e=1}^{N}\frac{1}{M}\sum_{i=1}^{M} f_q(n_{ie})}{\left(\frac{1}{N}\sum_{e=1}^{N}\frac{1}{M}\sum_{i=1}^{M} f_1(n_{ie})\right)^q}$$

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

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

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

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



- In case of any scale-invariant pattern, NFM are expected to scale with the number of phase space bins, M.
- M-scaling, F-scaling are different because ϕ_q and β_q depend on different critical parameters.
- β_q is independent of the details of the system below critical temperature.
- β_q and the resultant scaling exponent, ν, play a fundamental role in the characterization of the phase transition process.

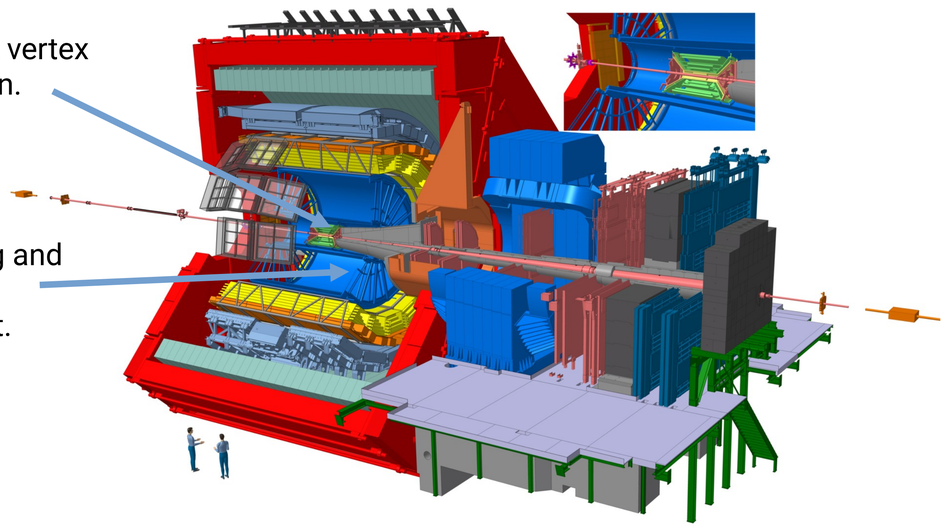
$\nu \cong 1.32$ Ginzburg Landau formalism[1] for the second-order phase transition

$\nu \cong 1.41$ Critical fluctuations, Successive Contraction and Randomization (SCR) Model[2]

3. Data Analysis

ITS: Tracking, vertex reconstruction.

TPC: Tracking and momentum measurement.



- Pb–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV and $\sqrt{s_{NN}}$ = 2.76 TeV.
- Charged particles in 0–5% centrality class and $|\eta| < 0.8$.

4. Scaling behaviors

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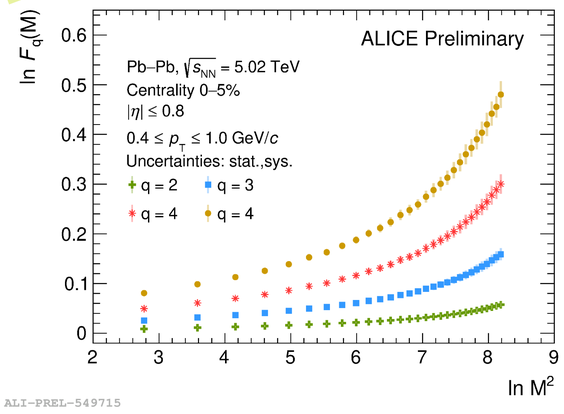
M-scaling



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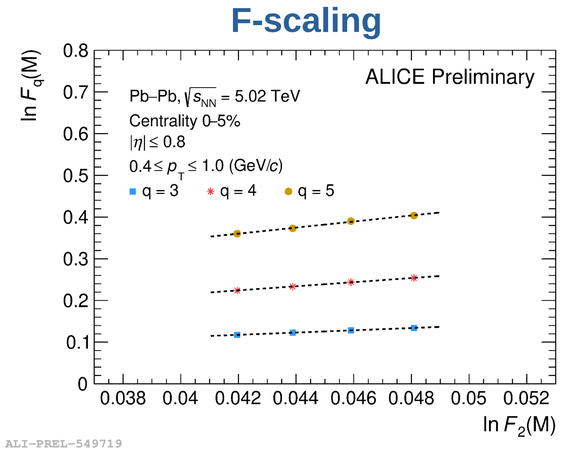
- Power-law growth of the NFM with the increase in the number of bins (M) indicates a scale-invariant pattern.
- F-scaling observed in ALICE data and the corresponding scaling exponent is calculated.

F-scaling



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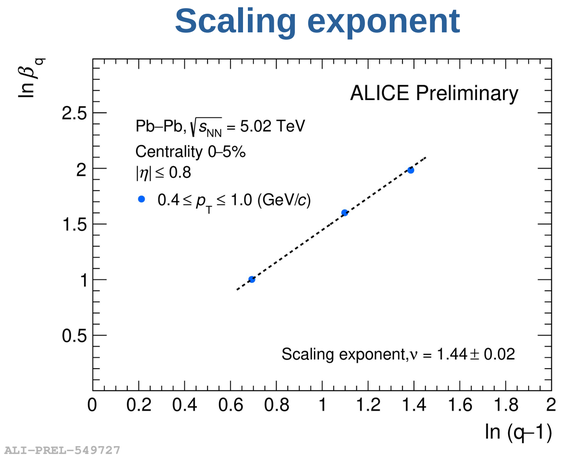
Scaling exponent



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5. M-scaling: Data & Models

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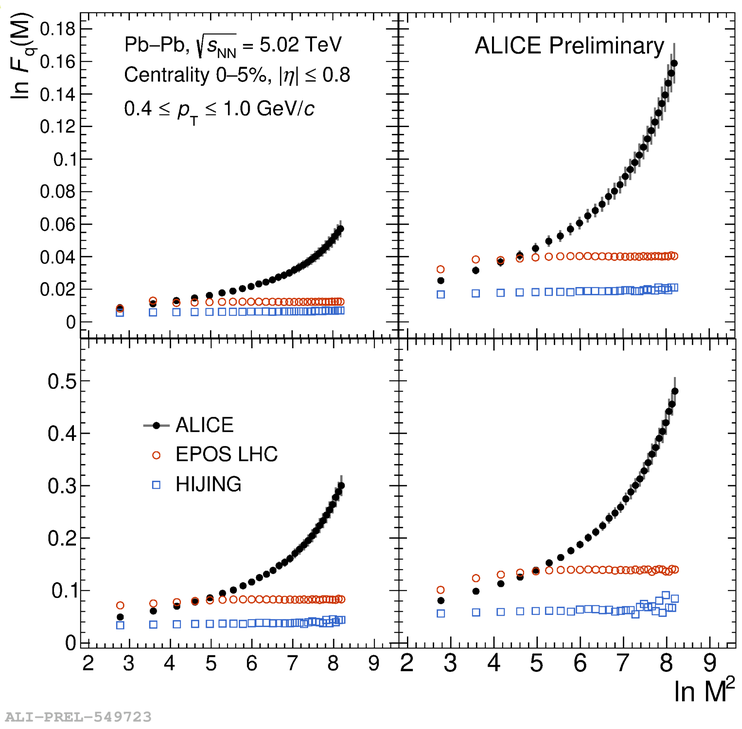

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Qualitative and quantitative differences are observed between data and MC.

6. ν: p_T & p_T bin width dependence

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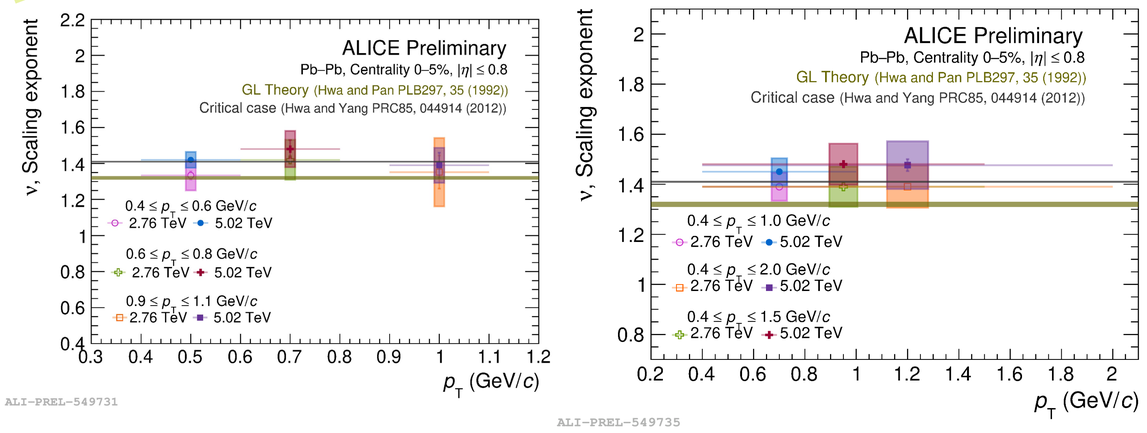

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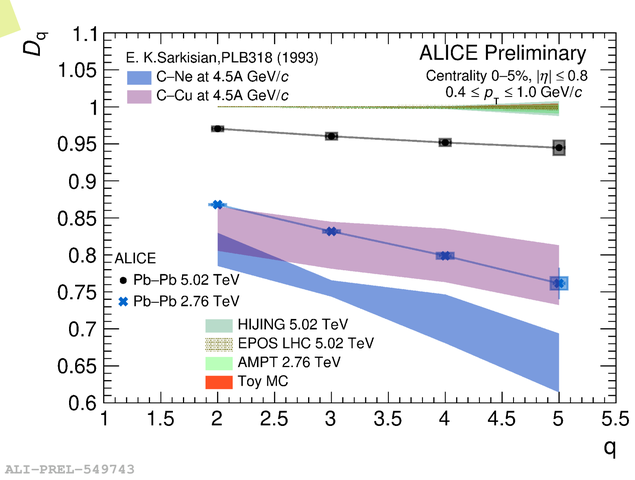
- The scaling exponent is independent of p_T bin and p_T bin width within uncertainties.
- Results agree with the Ginzburg-Landau formalism [1] and the SCR model [2] within the experimental uncertainties.

7. Anomalous fractal dimensions

NEW

$$D_q = 1 - \frac{\phi_q}{1}$$

- It provides information on whether the system is monofractal or multifractal.
- Dependence of D_q on q is observed for both energies, indicating a multifractal system.



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8. Summary

- An intermittency signal has been observed for charged particles produced in Pb–Pb collisions at LHC energies, suggesting scale-invariant fluctuations.
- Results agree with models incorporating critical fluctuations within the experimental uncertainties.
- HIJING and EPOS-LHC models fail to describe the data.
- The multifractal nature of the system created in the Pb–Pb collisions is observed at LHC energies.

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References

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