Event-by-Event Multiplicity Fluctuations in Pb-Pb Collisions at CERN-LHC Energies

Maitreyee Mukherjee for the ALICE Collaboration

Variable Energy Cyclotron Centre, 1/AF Bidhan Nagar, Kolkata – 700064, India

e-mail : maitreyee.mukherjee@cern.ch

Tapan Kumar Nayak (Presenter)

Abstract

We present a study of event-by-event multiplicity fluctuations of the produced charged particles in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV at the CERN LHC. The multiplicity fluctuations are expressed in terms of scaled variance ω_{ch}. Volume fluctuations play an important role when measuring the multiplicity fluctuations, and thus ω_{ch} is measured in narrow centrality bins. The results are presented as a function of centrality, and compared to calculations from event generators.

Introduction

- Event-by-event fluctuations of thermodynamic quantities are basic tools for understanding particle production mechanisms and for probing the QCD phase transition [1].
- A large number of particles in each Pb-Pb collision at the LHC makes event-by-event fluctuation studies possible.
- Measurements at vanishing μ_B like at LHC energies set the scale of theoretical calculations, i.e, lattice calculations, etc.
- Fluctuations of the multiplicity of produced charged particles is one of the basic fluctuation measurements, which may affect all other fluctuation measurements [2].
- In order to extract the dynamical part of the fluctuations, the statistical part has to be well understood.

Multiplicity fluctuations are usually characterized by the scaled variance of the multiplicity distributions, defined as

$$\omega_{ch} = \frac{\sigma^2}{\mu}$$

where μ and σ² are the mean and variance of the multiplicity distribution, respectively.

Correction for detector efficiency

- Within the p_T range for the analysis, $0.2<p_T<2.0$ GeV/c, the tracking efficiency (ε) is not flat with p_T.
- In order to take care of the local efficiency effects, in each centrality bin, tracks are counted in p_T bins {0.2,0.3,0.4,0.5,0.6,0.8,1.2,1.6,2.0}.
- At the same time, ε has been evaluated in each p_T bin. The corrected factorial moments are evaluated as :

$$F_1 = \sum_{i=1}^{m} < N(x_i) > = \sum_{i=1}^{m} \frac{< n(x_i) >}{\varepsilon(x_i)} \qquad \mu = F_1$$

Corrected mean, where m denotes the number of p_T bins, i denotes each p_T bin.

$$F_2 = \sum_{i=1}^{m}\sum_{j=i}^{m} \frac{< n(x_i)(n(x_j) - \delta_{x_i x_j}) >}{\varepsilon(x_i)\varepsilon(x_j)} \qquad \sigma^2 = F_2 + F_1 - F_1^2$$

Corrected σ, where all the correlation terms between all the p_T bins have been considered to evaluate the second factorial moment F_2.

From the corrected μ and σ, we get the corrected value for the scaled variance.

Summary

- A detailed event-by-event study of fluctuations in the multiplicity of charged particles has been carried out using data from ALICE.
- Volume fluctuations i.e, ω_{Npart} are close to unity.
- Multiplicity fluctuations are presented as a function of centrality. It is seen that ω_{ch} decreases from peripheral to central collisions, with a value significantly larger than unity.
- Results are compared to HIJING and AMPT event generators.

References

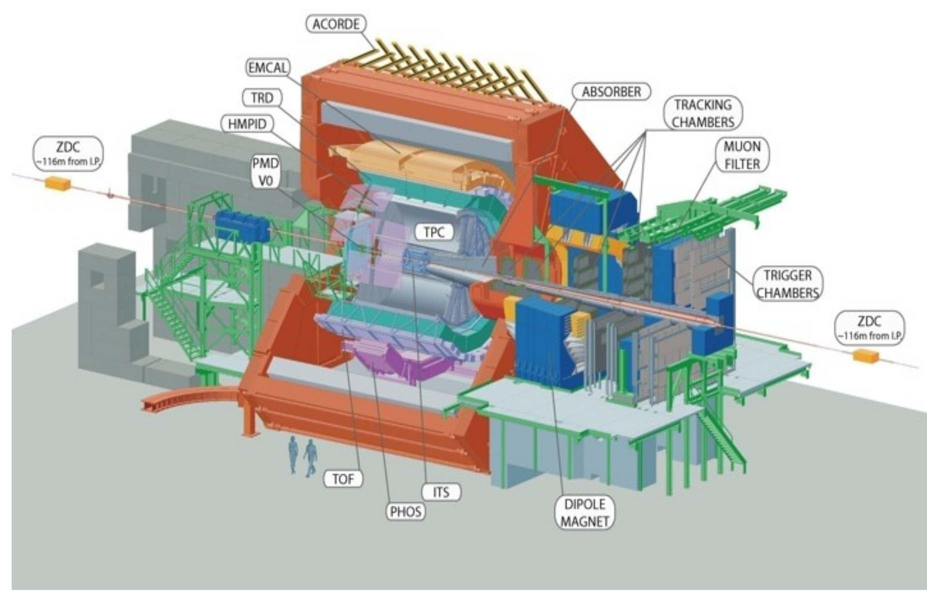
[1] A. Adare et al., Phys. Rev. C 78, 044902 (2008).

[2] M.A. Stephanov, K. Rajagopal, and E.V. Shuryak, Phys. Rev. D 60, 114028 (1999)

[3] M. M. Aggarwal et al.,Phys. Rev. C 65, 054912 (2002).

[4] X. Luo, J. Phys. G : Nucl. Part. Phys.39, 025008 (2012).

ALICE Detector



The detectors used for this analysis are :

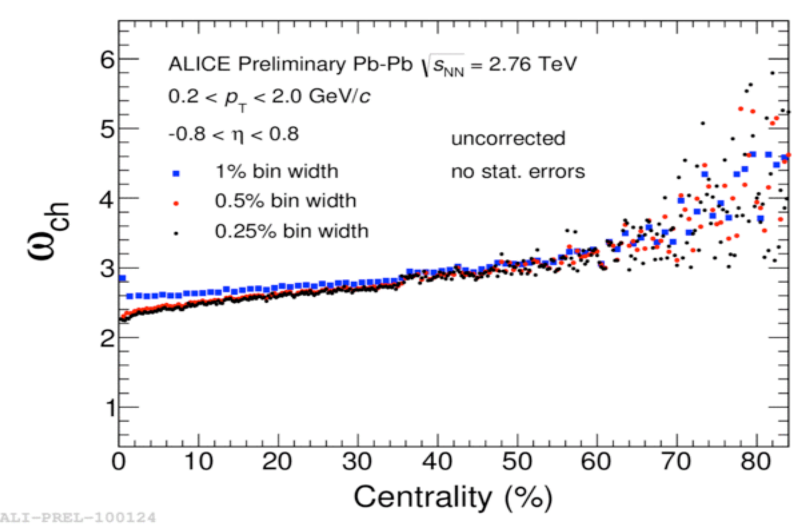
- ITS (Inner Tracking System) : for vertex selection and tracking.
- TPC (Time Projection Chamber) : for tracking (within $-0.8<\eta<0.8$), for $0.2<p_T<2.0$ GeV/c.
- V0 : for centrality selection; located at $2.8<\eta<5.1$ and $-3.7<\eta<-1.7$

Analysis strategy: Minimization of statistical components of multiplicity fluctuations

- **Centrality selection** : Narrow centrality bins are important for fluctuation studies.
- **Centrality bin-width correction**: The centrality bin-width effect is caused by non-uniformity of charged-particle distributions. This needs to be corrected by:

$$X = \frac{\sum_i n_i X_i}{\sum_i n_i}$$

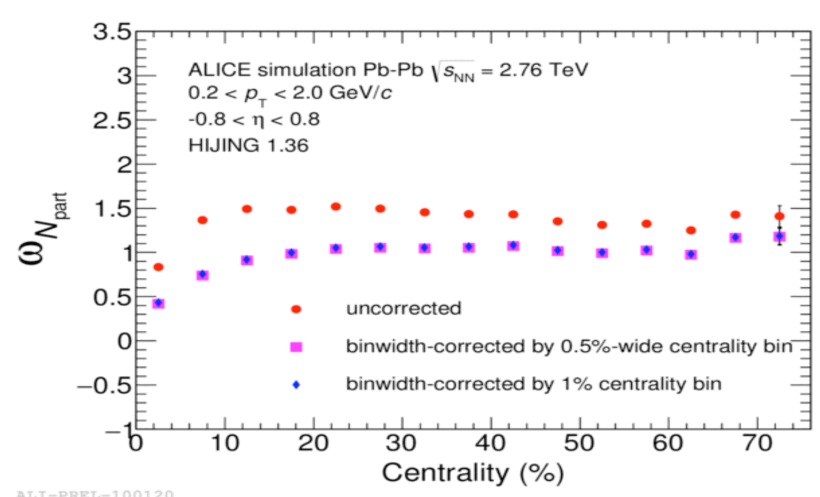
where the index i runs over each multiplicity bin, X_i are various moments for the i-th bin, and n_i is the number of events in the i-th multiplicity bin.



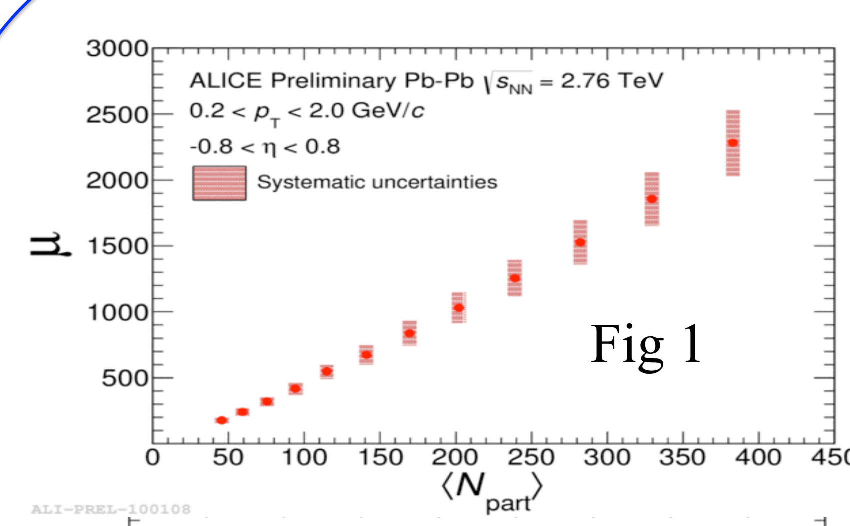
ω_{ch} as a function of centrality, using three different bin sizes, is shown. The results are not bin-width corrected, this is to show the bin-width effect on the observable. The final results (Figs 1-4) are bin-width corrected with 0.5%-wide bins in 0-40% central collisions and 1%-wide bins for more peripheral events.

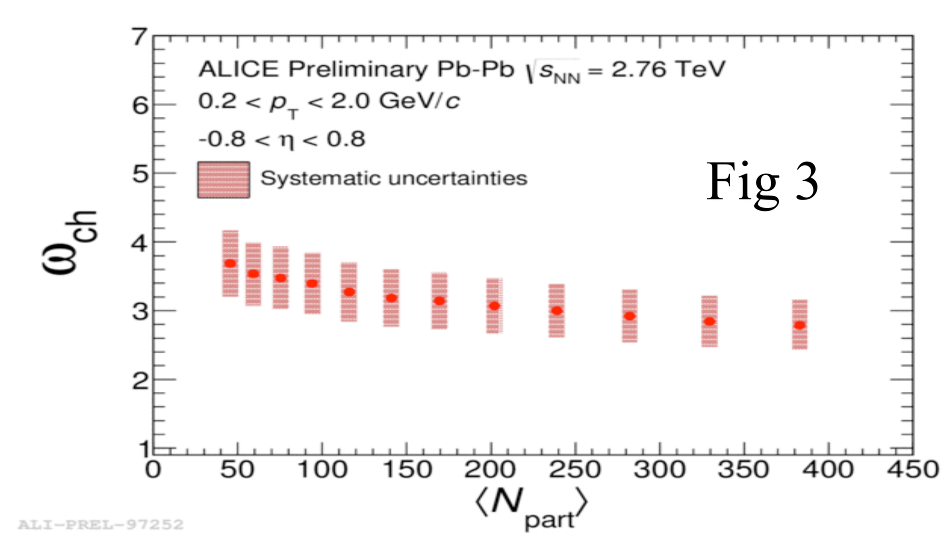
- **Volume fluctuations** :

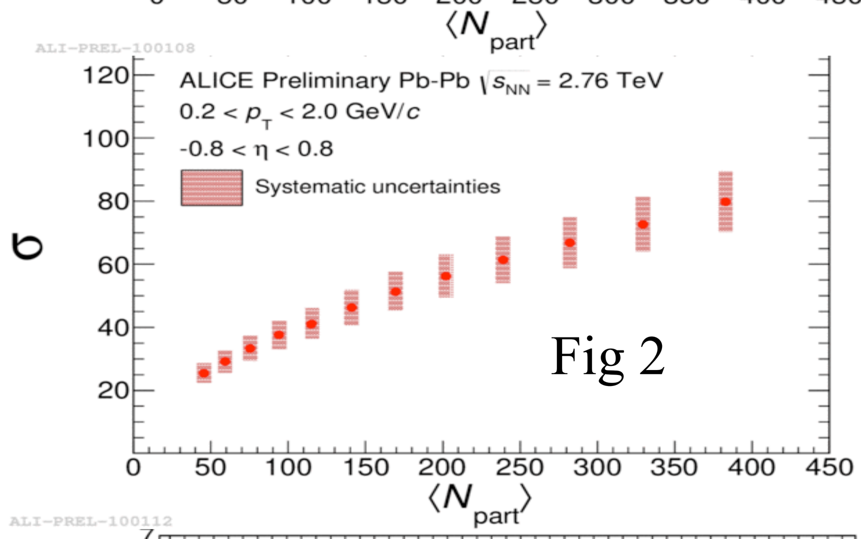
ω_{ch} is strongly dependent on fluctuations in N_{part}. Event generator (HIJING) results are presented here, using 1% and 0.5% -wide bins. Fluctuations in N_{part} are smaller than the total fluctuations.



Results







Figs 1-3 show the μ, σ and ω_{ch} as a function of N_{part}. (Statistical uncertainties are calculated with the Delta theorem [4] and are within the data points.). μ and σ increase with increasing centrality. We observe a weakly decreasing trend for ω_{ch} from peripheral to central collisions.

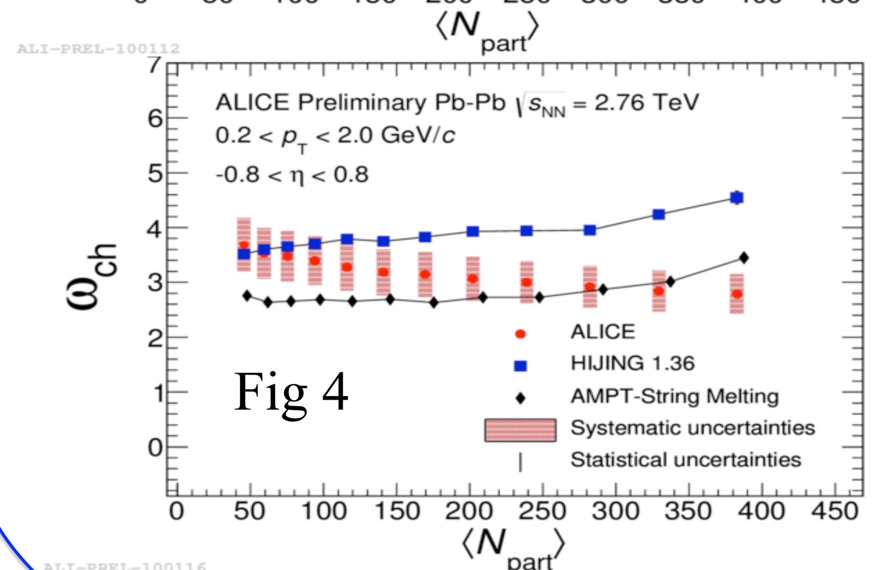


Fig 4 shows the comparison of data with results from HIJING and AMPT string melting models. Whereas the ω_{ch} values from data decrease from peripheral to central collisions, the trend observed in the models is different.