Charge Fluctuations in Pb + Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV

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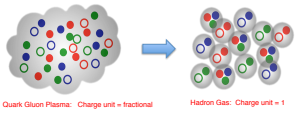
Fluctuations of conserved quantities, such as net-charge, net-baryon number and net-strangeness have been proposed to be the most direct observables for the study of phase transition of hadronic matter to a new form of high density and high temperature matter called Quark Gluon Plasma (QGP). Recently, the ALICE experiment at CERN-LHC has collected data for Pb+Pb collisions at $\sqrt{s_{NN}}$ 2.76 TeV in central detectors of ALICE within the pseudo-rapidity range from -0.8 to +0.8. The study of the fluctuations of charge multiplicity has been carried out using two variables, ν_{dyn} as functions of centrality. The advantages of these quantities are that they are free from the collisional bias, i.e., impact parameter fluctuation and fluctuations coming from the finite number of charged particles within the detector acceptance. The first results of charge fluctuations presented for collision centrality as well as a function of collision energy from CERN-SPS to RHIC and LHC energies.

Motivation

- Physical quantities which describe a macroscopic body in equilibrium are almost always, very nearly equal to their mean values. Nevertheless deviations from mean values, though small do occur – "*quantities are said to fluctuate* ---- *Landau*
- Lattice QCD calculations predict that in an environment characterized by high temperature and energy density a new state of matter can emerge, where the degrees of freedom are given no more by the hadrons but by their constituents, the quarks and the gluons (quark gluon plasma - QGP)



Quark Gluon Plasma: Charge unit = fractional — Hadron Gas: Charge unit = 1

Hadrons Gas: $q = \pm 1 \quad q^2 = 1$

QGP: $q = \pm\frac{1}{3}, \frac{2}{3} \quad q^2 = \frac{1}{9}, \frac{4}{9}$

=> The charge fluctuations in the QGP, with fractionally charged partons, are significantly different from those of hadron gas with unit charges

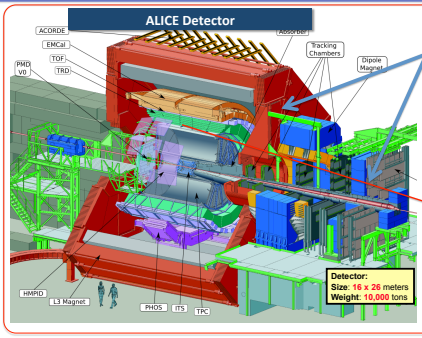
- Prediction: A drastic decrease in the EbyE fluctuations of net charge in local phase space regions in the deconfined QGP phase compared to that of the confined case of hadronic gas

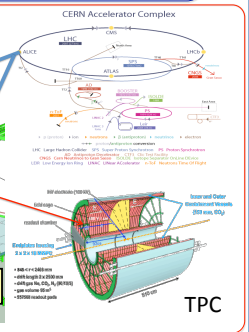
Jeon & Koch: PRL (2000) 2076, Asakawa, Heinz & Muller: PRL (2000) 2072

- Evolution of fluctuations: The transition between the low-temperature hadronic and high-temperature quark–gluon phase occurs in a small temperature interval and leads to a rapid change in entropy and energy density, it is expected that these transitions causes large fluctuations of conserved quantities.

Shuryak & Stephanov: PR C63 (2001) 064903 , 2. Heiselberg & Jackson: PRC 63 (2001) 06490

ALICE Detector





Charge Fluctuation Measures

EOS for Classical Ideal Gas

$\langle(\delta Q)^2\rangle = q^2\langle(N^+) - \langle N^-\rangle = q^2 N \qquad \frac{\langle(\delta Q)^2\rangle}{S} \alpha \; n_\alpha \; q^2$

S is entropy of the system

But we have finite Detector Acceptance; after correcting that with 4π coverage this would be

$D = 4\frac{\langle(\delta Q)^2\rangle}{N_{ch}}$

Predictions

QGP phase	Hadron phase
D ~ 1	D ~ 4

Phys. Rev. Lett. 85, 2076 (2000)

Dynamical Fluctuation =>

$v_{(+-)} = \left\langle \left(\frac{N_+}{\langle N_+\rangle} - \frac{N_-}{\langle N_-\rangle} \right)^2 \right\rangle$

N_+ = Total Negative Charge tracks
N_- = Total Positive Charge tracks

Statistical Fluctuation=>

$v_{(stat)} = \frac{1}{\langle N_+\rangle} + \frac{1}{\langle N_-\rangle}$

$v_{(dyn)} = v_{(+-)} - v_{(stat)}$

Dynamical variable can be define as

$N_{ch} \times \nu_{+-dyn} \approx D - 4$

QGP ~ -3

The evolution in the hadronic stage may diffuse these fluctuations. The diffusion strength can be estimated experimentally by calculating ν_{dyn} different η window.

Analysis Details

Event Selection

Particle Track	TPC/Global
Centrality Estimator	V0M/SPD
Pseudorapidity	-0.8 to 0.8
|Vz|(max)	10 cm

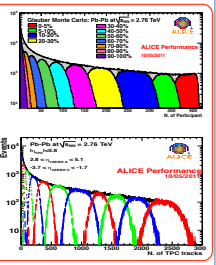
Track Selection – Quality cuts

Number of TPC clusters	80 out of 159
$\chi^2/N_{TPCclusters}$	4
dca_z	3 cm
dca_{xy}	3 cm
Reconstructed Vertex	Yes

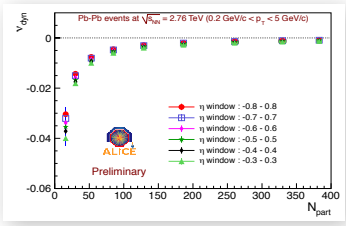
Statistical error is calculated by dividing whole sample of events in to many sub samples . The v is estimated for each sub sample and the dispersion gives the statistical error.

Systematic errors are estimated from the following sources:

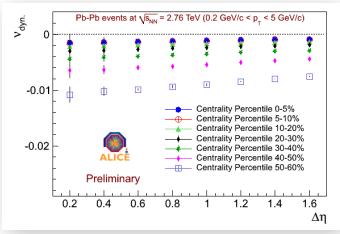
1. Beam Vertex
2. Magnetic Polarity
3. Centrality Estimators
4. Number of TPC clusters
5. DCA cuts
6. Different Analysis Modes
7. Different p_T windows



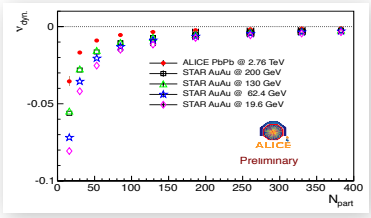
Charge Fluctuations: Dynamical variables



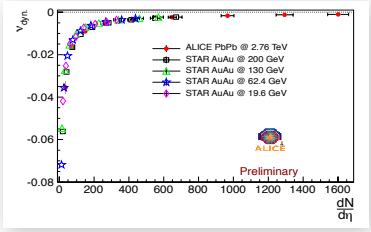
The Dynamical variable ν_{dyn} as function of Number of participants in different η windows



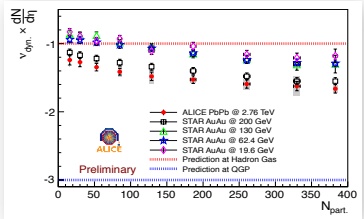
The Dynamical variable ν_{dyn} as function of η windows in centralities



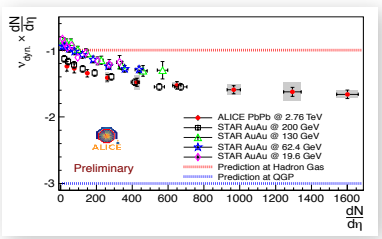
Dynamic fluctuation, ν_{dyn} for Δη = 1 of charged particles for Pb-Pb collisions at LHC and Au-Au collisions at STAR energies, plotted as a function of number of participating nucleons



Dynamic fluctuation, ν_{dyn} for Pb-Pb collisions at LHC and Au-Au collisions at STAR energies, plotted as a function of number of for dN/dη of charged particles

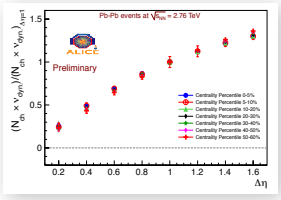


Scaled dynamic fluctuation, $\nu_{dyn} \times dN/d\eta$ for Pb-Pb collisions at LHC and Au-Au collisions at STAR energies, plotted as a function of number of participating nucleons.



Scaled dynamic fluctuation, $\nu_{dyn} \times dN/d\eta$ for Pb-Pb collisions at LHC and Au-Au collisions at STAR energies, plotted as a function of dN/dη of charged particles

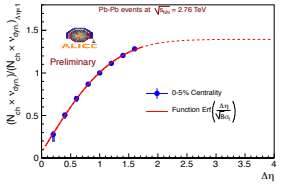
Normalized Dynamical variable



The quantity $N_{ch} \times \nu_{dyn}$ normalized to their values for $\Delta\eta = 1$, as function of the η window. The errors are taken from ν_{dyn} added to the syst calculated from two different p_T window. The syst error is 7%. statistical error 4.5%

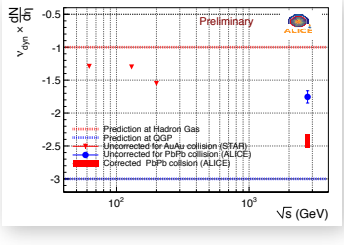
Diffusion Strength

- The diffusion strength is estimated by measuring dynamical variable in increasing Δη up to 1.6 unit in ALICE



The data points are fitted with a functional form $erf(\Delta\eta/\sqrt{8}\sigma_f)$, where σ_f gives the dissipation of fluctuation at freeze-out compared to σ_0 at the hadronisation time.

M. A. Aziz and S. Gavin, Phys. Rev. C70 (2004) 034905



- Figure shows $\nu_{dyn} \times dN/d\eta$ at $\Delta\eta = 1$ as a function of center of mass energy.
- ALICE point shown in red band (PbPb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV) is corrected for diffusion with measured value of σ_f and theoretical value of σ_0 (between 0.25 to 0.5).

STAR Data Points are taken from J. Adams et al. STAR, Phys. Rev. C79, 24906 (2009)

Conclusion

- Dynamical charge fluctuations are extracted for Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV in the ALICE experiment at LHC.
- Diffusion in the fluctuation is extracted from the experimental data by the measurement of dynamical fluctuation over a wide range in rapidity
- After the diffusion correction, the value of charge fluctuation is close to what has been theoretically estimated for the Quark Gluon Plasma.

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