Beam energy and centrality dependence of particle production in heavy ion collision at RHIC and LHC

Sanchari Thakur[1], Kustuv Dutta[2], Souvik P. Adhya[1], Tapan K. Nayak[1], and Sumit Basu[1]*
[1] *Variable Energy Cyclotron Centre, 1/AF Bidhannagar, Kolkata 700064, INDIA. and*
[2] *Department of Physics, Reed College, Portland, OR 97202, US A*

Introduction

The primary goal of colliding heavy-ions at ultra- relativistic energies is to study nuclear matter under extreme conditions, in which hadronic matter is expected to undergo a phase transition to a new state of matter, the Quark-Gluon Plasma (QGP). In this paper is to find a function which can predict the charged particle multiplicity at any higher energy at a given centrality.There are two main mechanism for particle production that explain well the multiplicity density:
Glauber:

$$\frac{dN_{ch}}{d\eta}_{AA} = \frac{dN_{ch}}{d\eta}_{pp}[xN_{coll} + (1-x)\frac{N_{part}}{2}] \quad (1)$$

&
CGC:

$$\frac{dN_{ch}}{d\eta} \approx N^{\alpha}_{part}\sqrt{s_{NN}}^{\gamma} \quad (2)$$

Motivation

The charged particle multiplicity depends on the beam energy $\sqrt{S}$ as well as the number of participants nucleon [1] N_{part}.

$$\frac{2}{N_{part}}\frac{dN_{ch}}{d\eta} = f(S) * g(N_{part}) \quad (3)$$

The energy and centrality dependence of multiplicity normalised with the number of participant pair are given by[1],

$$f(S) = 0.0147ln(S)^2 + 0.6 \quad (4)$$

$$g(N_{part}) = 1 + 0.095{N_{part}}^{1/3} \quad (5)$$

for Au+Au collsion. For Cu+Cu, the data are seen to be well fitted by,

$$g(N_{part}) = 1 + 0.129{N_{part}}^{1/3} \quad (6)$$

f(S) is same as previous. The plot is shown in Fig.1 for Au+Au,Cu+Cu and Pb+Pb. It is seen that the Pb+Pb data do not match well with such functional form. As we go towards higher and higher N_{part}, the data deviate from the fit function more and more.

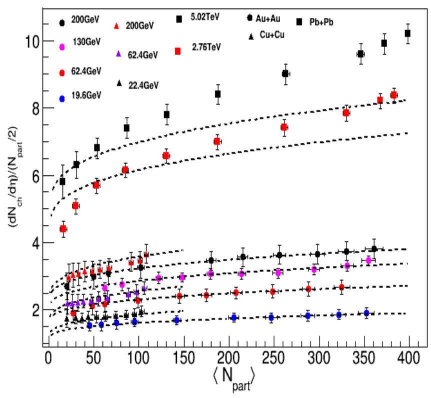

FIG. 1: Particle multiplicity normalised with participant pair as a function of number of participants

Analysis

We have to find a functional form that contains both energy and centrality, that matches with all the energies to a good extent.
The Central Limit Theorem predicts that, Mean multiplicity μ i.e. $\frac{dN_{ch}}{d\eta} \propto N_{part}$

*Electronic address: sumit.basu@cern.ch

Therefore we assume that the mean multiplicity has the form,

$$\frac{dN_{ch}}{d\eta} = \alpha * N_{part} + \beta \tag{7}$$

where, $g(N_{part}) = N_{part}$ and α & β contain the beam energy. Now we have to find the energy dependence of these two coefficients.Particle production mechanism is of two types:soft scattering or thermal part & hard scattering. The thermal part behaves logarithmically with $\sqrt{s}$ and hard scatter part shows power law dependency on $\sqrt{s}$. We have fitted the $dN_{ch}/d\eta$ vs. $< N_{part} >$ with Eqn.1 and plot α & β as a function of beam energies to find their dependency on $\sqrt{s}$.

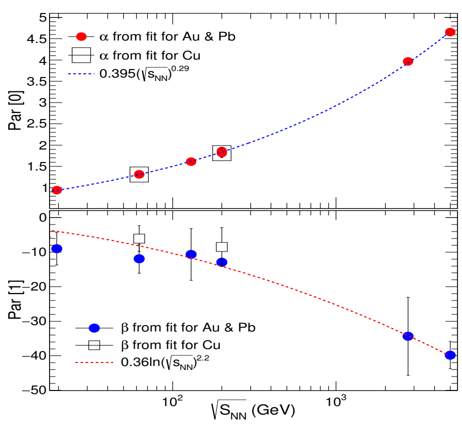

FIG. 2: Energy dependence of the parameters α and β

From the plot, we see that the data can be well described by:

$$\boxed{\alpha = 0.395(\sqrt{S_{NN}})^{0.29}} \tag{8}$$

&

$$\boxed{\beta = -0.36(ln\sqrt{S_{NN}})^{2.2}} \tag{9}$$

Collision system	$\sqrt{S_{NN}}$ (GeV)	a (func)	a (fit)	b (func)	b (fit)
Au+Au	19.6	0.936	0.937	-3.96	-9.12
Au+Au	62.4	1.309	1.310	-8.17	-11.9
Au+Au	130	1.620	1.604	-11.7	-10.67
Au+Au	200	1.836	1.848	-14.10	-12.94
Cu+Cu	62.4	1.309	1.310	-8.17	-6.06
Cu+Cu	200	1.836	1.809	-14.10	-8.50
Pb+Pb	2760	3.931	3.957	-34.18	-34.45
Pb+Pb	5020	4.675	4.652	-40.12	-39.84

Table shows the comparison of the values of the parameters obtained from the function and fit.

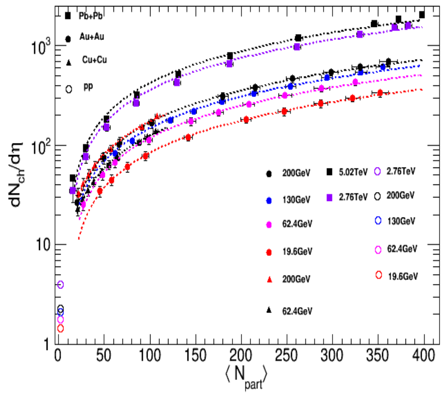

FIG. 3: $dN_{ch}/d\eta$ vs N_{part}

Now we find the parameters for different energy and fit the $dN_{ch}/d\eta$ vs $< N_{part} >$ with eqn.(1).The plot is shown in Fig.3.

Summary

This work could be verified in the d-Au and p-Pb collisions for 200 GeV and 5020 GeV. It could be studied further that eqn [7-9] for finding multiplicity density and Bjorken energy density.

References

[1] B. Alver *et al.* [PHOBOS Collaboration]
[2] A. Adare *et al.* [PHENIX Collaboration], Phys. Rev. C **78** (2008) 044902
[3] S.Basu *et al.* Phys. Rev. C **93** (2016) 064902