Charged Hadron Multiplicity: Wounded Quark Scenario

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Introduction

Quantum chromodynamics (QCD), the baisc theory which describes the interactions of quarks and gluons is a well established theory and governs the production of charged hadrons in high energy collisions. The ultimate goal of heavy-ion collision experiments is to test the predictions of quantum chromodynamics (QCD) because these can reveal the nature of hadronic interactions at extreme temperature and/or density and throw light on the role played by the quarks and gluons in multiparticle production mechanism. Due to the inapplicability of perturbative QCD (pQCD) in soft regime where major fraction of charged hadrons are produced, phenomenological models are proven to be an alternative tool in explaning the production mechanism involved in these nuclear collisions. Hadronic multiplicities and their correlations can reveal enough information on the nature, composition and size of the fireball formed in the collider experiments. The evolution of the measured global observables in such experiments varies with the size and mass of the colliding nuclei and it emphasizes that rescatterings or multiple scatterings occur and contribute to the evolution of the energy deposition in the fireball. Thus, our main motive is to search a universal mechanism for charged hadron production common to hadron-hadron, hadron-nucleus and nucleus-nucleus intercations.

Description of Wounded Quark Model

The main ingredients of model are taken from the paper by Singh et. al. [1–3]. Charged hadrons produced from nucleus-nucleus ($A-A$) collisions are assumed to have a somewhat unified production mechanism related to proton-proton ($p-p$) collisions at various energies. Feynman was first to point out that the multiplicity spectrum from proton-proton collisions becomes independent of the centre-of-mass energy ($\sqrt{s}$) as $\sqrt{s} \rightarrow \infty$. This naturally implies that the total multiplicity after integration over rapidity involves $ln\sqrt{s}$ behaviour. Later on, it was realized that the gluons arising from gluon-bremsstrahlung processes give QCD - radiative corrections and hence total multiplicity involves $ln^2\sqrt{s}$ behaviour. Recently, it was noticed by PHOBOS collaboration from the $p-p$ and/or $p-\bar{p}$ data that the central plateau height i.e. $(\frac{dn}{d\eta})_{\eta=0}$ grows as $ln^2\sqrt{s}$ which will give $ln^3\sqrt{s}$ type behaviour to total multiplicity distribution.

Thus we propose here a new parameterization involving a cubic logarithmic term so that the entire $p-p$ experimental data starting from low energies (i.e. from 6.15 GeV) upto the highest LHC energy (i.e. 7 TeV) can suitably be described:

$$\langle n_{ch}\rangle_{hp} = (a' + b'ln\sqrt{s_a} + c'ln^2\sqrt{s_a} + d'ln^3\sqrt{s_a}) - \alpha. \quad (1)$$

where α is the leading particle effect and $\sqrt{s_a}$ is the available center-of-mass energy. a', b', c' and d' are the chosen constants derived from the best fit to the data [4].

The validity of this parametrization for the produced charged particles in hadron-nucleus interactions can be extrapolated by considering multiple collisions suffered by the quarks of hadrons in the nucleus. Thus, the expression for average charged hadron multiplicity in h-A collisions is [4]:

$$\langle n_{ch}\rangle_{hA} = N_q^{hA}\left[a' + b'ln\left(\frac{\sqrt{s_{hA}}}{N_q^{hA}}\right) + c'ln^2\left(\frac{\sqrt{s_{hA}}}{N_q^{hA}}\right) + d'ln^3\left(\frac{\sqrt{s_{hA}}}{N_q^{hA}}\right)\right] - \alpha. \quad (2)$$

In Eq. (2), N_q^{hA} is the average number of constituent quarks interacting inelastically in

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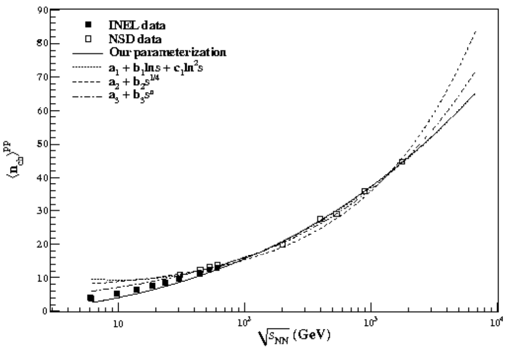

FIG. 1: Variations of total mean multiplicities of charged hadrons in $p-p$ collisions with $\sqrt{s_{NN}}$. Figure is taken from Ref. [4].

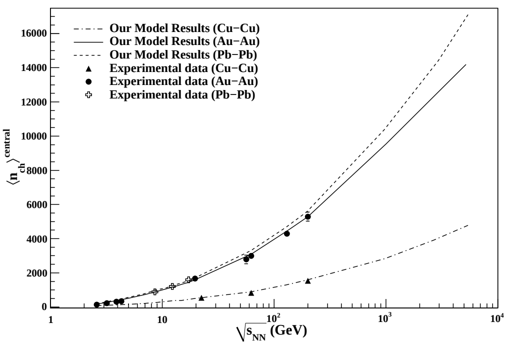

FIG. 2: Variations of total mean multiplicities of charged hadrons in central collisions for different colliding nuclei with $\sqrt{s_{NN}}$. Figure is taken from Ref. [4].

$h-A$ collisions and $\sqrt{s_{hA}}$ is the total available center-of-mass energy in $h-A$ collisions [4].

The generalization of the above picture for the nucleus-nucleus collisions can be achieved as follows [4]:

$$\langle n_{ch}\rangle_{AB} = N_q^{AB}\Big[a' + b' ln\left(\frac{\sqrt{s_{AB}}}{N_q^{AB}}\right) + c' ln^2\left(\frac{\sqrt{s_{AB}}}{N_q^{AB}}\right) + d' ln^3\left(\frac{\sqrt{s_{AB}}}{N_q^{AB}}\right)\Big]. \quad (3)$$

Results and Discussions

Using quark-quark interaction picture, we have given a parametrization which interrelates the multiplicity in p-p, p-A and A-A collisions from low energy (a few GeV) upto the highest LHC energies. It involves the interactions of the constituent quarks of the colliding objects and the mean number of collisions suffered by them. This picture describes consistently the 'soft' hadron production in $p-p$, $p-\bar{p}$, $p-A$ and $A-A$ collisions. We find that our parametrization gives a reasonably good fit to the $p-p$ data in the entire energy range. We also find that a suitable extension of this description works very well for the nucleus-nucleus ($A-A$) collisions in the entire available energy range and describes the available experimental data for nucleus of varying sizes such as $Cu-Cu$, $Au-Au$ and $Pb-Pb$. Thus, successs of wounded quark model in describing the nucleus-nucleus collisions with nuclei of different sizes endorses our view point in considering the superposition of basic quark-quark collisions.

Acknowledgments

Authors are grateful to the Council of Scientific and Industrial Research (CSIR), New Delhi and University Grants Comission (UGC), New Delhi for providing a research grant.

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