# Particle Production in nucleus-nucleus collisions using HYDJET++

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## Introduction

Multiparticle production in relativistic heavy ion collisions may provide a better insight about the properties of Quantum Chromodynamics (QCD) at finite temperature. There are existing dynamical and semi-dynamical computational models which use theoretical or phenamenological foundation of strong interaction to mimic the space-time evolution of collision experiments. Moreover, most of the existing models either consist of high $p_T$ particle production from jet fragmentation or involve low $p_T$ hadron production using thermal statistical processes. However, HYDJET++ [1, 2] model consistently includes the production of hard as well as soft $p_T$ particles and incorporates most of the effects during the evolution of QCD medium. In HYDJET++ model, PYTHIA type initial condition is used for hard particle production and Glauber type initial condition for soft particle production. In this article, we study charged hadron production in $Au+Au$, $Pb+Pb$ and deformed $U+U$ collisions at $\sqrt{s_{NN}}$ = 200 GeV, 2.76 TeV and 193 GeV, respectively, by modifying the existing HYDJET++ model. Further, we present the modified HYDJET++ model results in terms of pseudorapidity distribution ($dn_{ch}/d\eta$) in non-deformed ($Au+Au, Pb+Pb$) collisions and deformed ($U+U$) collisions, and elliptic flow of charged hadrons in tip-tip and body-body configurations of deformed $U+U$ collisions.

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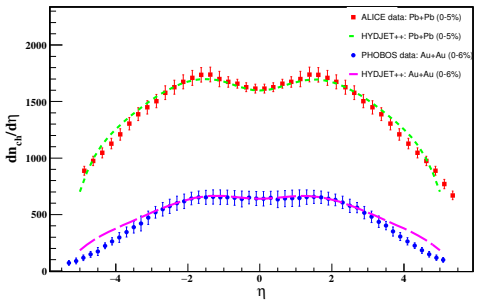


FIG. 1: Taken from Ref. [1]. Variation of $dn_{ch}/d\eta$ with respect to $\eta$ is shown for $Au+Au$ and $Pb+Pb$ collisions in most central events. We have also plotted the corresponding experimental data [3, 4] for comparison.

## HYDJET++ model description

The hard multi-parton production is based on PYQUEN partonic loss model which produces initial parton spectra according to PYTHIA and jet production vertices at given impact parameter. Rescattering of partons along with radiative and collisional energy loss is incorporated according the parton path in dense QCD medium. Final hadronization of hard partons and in-medium emitted gluon takes place according to the Lund string model.

The soft part of HYDJET++ is the thermal production of hadrons generated on chemical and thermal freeze-out hypersurface obtained from the parameterization of relativistic hydrodynamics with given freeze-out conditions. The thermal method provides 4-momentum and spatial positions of hadrons in rest frame of liquid element. Bjorken's longitudinally

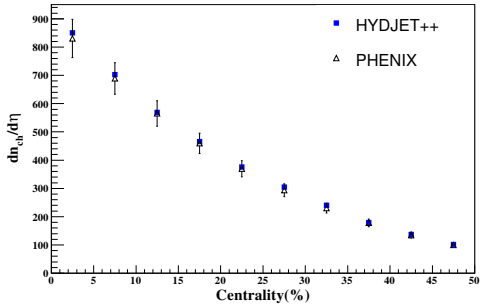


FIG. 2: Taken from Ref. [1]. Variation of $dn_{ch}/d\eta$ at midrapidity with centrality in minimum-bias configuration of $U+U$ collisions. Experimental data from PHENIX experiment [3] is also shown for comparison.

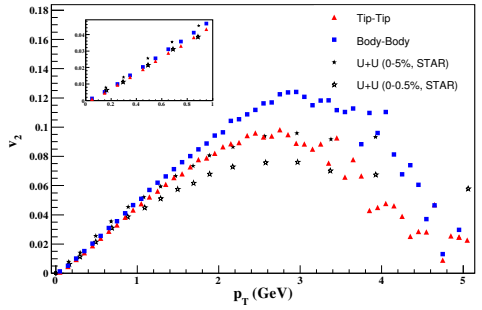


FIG. 3: Taken from Ref. [1]. Comparison of $v_2$ of charrged hadrons with respect to $p_T$ in tip-tip and body-body configurations for most central collision. STAR data is taken from Ref. [5].

boost invariant hydrodynamics is used to generate 4-velocity of liquid element and their dynamical evolution with proper time ($\tau$). Feed down corrections from two and three body decays of the resonances with branching ratios are taken from SHARE particle decay table. To make HYDJET++ work for $U+U$ collisions, one has to transform deformed Woods-Saxon nuclear density profile function from spherical polar $(r,\theta,\phi)$ to cylindrical polar coordinate $(\rho,z,\psi)$ system as HYDJET++ deals in latter system. As shown in Ref. [1], the relations are $\theta = \tan^{-1}(r/z)$ and $\theta = \tan^{-1}(z/r)$ for tip-tip and body-body configurations of $U+U$ collisions, respectively.

## Results and Discussions

Fig. 1 shows the pseudorapidity distribution of charged hadrons produced in Au+Au and Pb+Pb collisions at RHIC and LHC energies for most central events obtained using HYDJET++. We found a good agreement between our model results and published experimental data upto $|\eta| \leq 3$. However, HYDJET++ model slightly overestimates the data at higher rapidities. In Fig. 2, we have shown the variation of $dn_{ch}/d\eta$ at midrapidity with centrality in minimum-bias configuration of deformed U+U collision which is evaluated by taking the average of tip-tip and body-body configurations at midrapidity and a good agreement is found with the experimental data. In Fig. 3, we found that the elliptic flow of body-body configuration is slightly larger than tip-tip configuration and as we move towards larger $p_T$, this difference increases with increasing $p_T$. The STAR data of 0-0.5% centrality class, consisting mainly tip-tip events of $U+U$ collisions, matches with HYDJET++ results when $p_T < 1$ GeV (see inset of Fig. 3). Further, the experimental data from 0-5% centrality matches with the tip-tip results for intermediate and large $p_T$.

## Acknowledgments

AS acknowledges UGC for financial support. PKS acknowledges postdoctoral research grant from IIT Ropar. OSKC is greatful to CSIR, New Delhi for providing research grant.

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