Simulations of charged hadron and charmed meson production in Pb+Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV with HYDJET++ generator

J. Bielčík, L. Bravina, G. Eyyubova, V. Korotkikh, I. Lokhtin, S. Petrushanko, A. Snigirev, J. Štorek and E. Zabrodin

Faculty of Nuclear Sciences and Nuclear Engineering, Czech Technical University in Prague, Břehová 7, Prague, Czech Republic

Department of Physics, University of Oslo, PB 1048 Blindern, N-0316 Oslo, Norway

Skobeltsyn Institute of Nuclear Physics, M. V. Lomonosov Moscow State University, Leninskie gory, Moscow 119991, Russian Federation

E-mail: jaroslav.bielcik@fjfi.cvut.cz, larissa.bravina@fys.uio.no, Gyulnara.Eyyubova@cern.ch, Vladimir.Korotkikh@cern.ch, igor.lokhtin@cern.ch, Serguei.Petrouchanko@cern.ch, Alexandre.Snigirev@cern.ch, storejar@fjfi.cvut.cz, zabrodin@fys.uio.no

HYDJET++ is a Monte Carlo event generator merging parametrized soft part inspired by hydrodynamics with hard part containing jets. It has been successful to describe particle production in Pb+Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV energies. In this contribution, particle spectra and collective flow for the top LHC energy $\sqrt{s_{NN}} = 5.02$ TeV Pb+Pb collisions are presented for the first time. Specifically, the HYDJET++ model version 2.4 has been used to simulate spectra of charged particles, $D^0$ and $J/\psi$ mesons and related $v_2$ and $v_3$ azimuthal flow harmonics. The particle spectra and flow harmonics are studied in different centrality bins ranging from 0–10% up to 30–40% centrality in midrapidity region for charged particles and $D^0$ mesons and in forward rapidity in case of $J/\psi$ mesons. The simulated results have been compared with the LHC data to tune HYDJET++ parameters.
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J. Štorek

1. Introduction

In central ultra-relativistic heavy ion collisions, extreme energy densities are reached such that quark-gluon plasma (QGP), a novel phase of matter where quarks and gluons are deconfined, can be observed [1]. Different effects, e.g. modified yields of particle species with regards to a proton-proton collision, collective behavior of particles produced in the collision or jet quenching\(^1\), can be recognized as phenomena of the QGP. Different physical models are used to predict the outcome of an experiment and correctly understand the main physical processes.

2. HYDJET++

HYDJET++ is a Monte Carlo (MC) generator for simulation of relativistic heavy ion collisions and merges hydro-inspired blast wave parameterization (soft) with jet quenching (hard) [2, 3]. In the soft part, hadrons are generated at chemical freeze-out hypersurface and thermal equilibrium is assumed during the thermal emission. The hard part is based on PYQUEN (PYthia QUENched) partonic energy loss model [4] which employs jet quenching in PYTHIA [5] generated jet events.

In former studies, production of charged hadrons and charmed mesons was successfully described in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV [2, 6] and in Pb+Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV [7]. It has been found that different simulation parameters need to be used for a correct description of different particle species at different collisions energies. The temperature at thermal freeze-out $T_{th}$ needs to be the same for charged hadrons and $D$ mesons ($T_{th} = 105$ MeV) and different for $J/\psi$ meson ($T_{th} = 165$ MeV) at $\sqrt{s_{NN}} = 2.76$ TeV energy [7]. The values of $T_{th}$ at $\sqrt{s_{NN}} = 5.02$ TeV energy are studied in this proceedings using the most recent version 2.4 of the HYDJET++.

![Figure 1: Left: Comparison of the HYDJET++ simulated elliptic and triangular flow coefficients of all charged hadrons $h^\pm$ with the ATLAS experimental data [8] in 20–30% centrality bin. Right: Comparison of the HYDJET++ simulated $p_T$ distribution histogram of the $J/\psi$ meson yield to the ALICE experimental data [9].](image)

\(^1\)Jet quenching is the modification of a jet caused by the QGP medium.
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J. Štorek

3. Charged hadrons $h^\pm$

The transverse momentum, $p_T$, and pseudorapidity $\eta$ distributions of charged hadrons can be described well by HYDJET++ in 0–40% centrality range. HYDJET++ also correctly reproduces elliptic and triangular flow distributions $v_2, v_3$ calculated by experiment adapted scalar product method in 10–30% semi-central events in $0 < p_T < 4$ GeV/c region, however, it underestimates the data in $4 < p_T < 10$ GeV/c region as shown in left graph in Fig. 1. Thermal freeze-out temperature $T_{th} = 105$ MeV has been set for the simulation.

4. $J/\psi$ meson

In the right graph in Fig. 1, HYDJET++ $J/\psi$ transverse momentum $p_T$ distribution is compared to the ALICE experimental data in 0–10% centrality bin. Parameter $\gamma_c$, which accounts for deviations of charm multiplicity from the complete thermal equilibrium value, has been set to $\gamma_c = 15$ for a correct description. One can see an underestimation of the experimental data in the $4 < p_T < 6$ GeV/c region. The mismatch can be slightly eliminated by tuning the maximal fluid flow transverse rapidity at thermal freeze-out $\rho_{max}$ parameter. Nevertheless, no significant impact on elliptic flow of the $J/\psi$ is observed in central collisions and $v_2^{J/\psi}$ is well described in the left graph in Fig. 2 up to $p_T < 6$ GeV/c. Thermal freeze-out temperature $T_{th} = 165$ MeV has been used for the $J/\psi$ simulations.

5. $D^0$ mesons

Charm production enhancement parameter $\gamma_c$ obtained from $J/\psi$ simulations has been also used for the $D^0$ $p_T$ distribution resulting in a very good match between the HYDJET++ simulation and ALICE experimental data in $3 < p_T < 14$ GeV/c region. Elliptic flow of the $D^0$ meson has been also studied in 10–30% centrality as can be seen in the right graph in Fig. 2. HYDJET++

\begin{itemize}
  \item Inclusive charged hadrons $h^\pm$ are $\pi^\pm$, $K^\pm$, protons $p$ and antiprotons $\bar{p}$.
\end{itemize}
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J. Štorek

generally follows the trend of the experimental data but overestimation in $4 < p_T < 6$ GeV/c region is observed.

The same thermal freeze-out temperature $T_{th} = 105$ MeV as for the charged hadrons has been used for HYDJET++ $D^0$ simulations.

6. Conclusion

For all the studied distributions, a good description of the LHC data has been achieved by the HYDJET++ model. It appears that raising Pb+Pb collision energy from $\sqrt{s_{NN}} = 2.76$ TeV to $\sqrt{s_{NN}} = 5.02$ TeV does not have a significant impact on the thermal freeze-out temperature $T_{th}$ which is the same value for $h^+$ and $D^0$ meson and different value for $J/\psi$. Correct description of charm meson spectra has been achieved by tuning charm enhancement parameter $\gamma_c = 15$ and the maximal fluid flow transverse rapidity at thermal freeze-out $\rho_{max}$ parameter is found to have only a small impact on the $J/\psi$ elliptic flow in central events.

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