WOUNDED SOURCE MODELS VERSUS EXPERIMENTAL RESULTS FROM RHIC*

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The wounded source emission functions, $F(\eta)$, based on the wounded nucleon, quark, and quark–diquark models, are extracted from PHOBOS data on d+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. Based on these functions, we calculate $\mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta$ distributions in p+Al, p+Au, ^{3}He+Au and Au+Au collisions at the same energy and compare them with the experimental results.

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1. Introduction

We investigate three wounded source models commonly used to describe particle production in the ultra-relativistic nuclei collisions [1–14]. We consider the wounded nucleon model (WNM) [1], the wounded quark model (WQM) [2] and the wounded quark–diquark model (WQDM) [5], which differ by the composition of nuclei.

These models combined with the PHOBOS data on d+Au collisions at $\sqrt{s_{NN}} = 200$ GeV [15] are used to calculate three different wounded source emission functions, $F(\eta)$, being the pseudorapidity distribution of particles from a single wounded source. Using $F(\eta)$ and the Monte Carlo Glauber simulations, we calculate charged particle multiplicity distributions $\mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta$ at $\sqrt{s_{NN}} = 200$ GeV for various colliding systems measured by the PHOBOS and the PHENIX collaborations at RHIC.

For symmetric collisions, such as ^{197}Au+^{197}Au, there are significant differences between the studied models and only the WQDM and WQM are in good agreement with the RHIC data on $\mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta$ [16]. In the case of asymmetric collisions with one light nucleus ($p, d, {}^3$He), all three models give almost the same results [17, 18].

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2. The emission functions

The WNM assumes that nucleons have no internal structure. In the WQDM and WQM, nucleons consist of constituent quark–diquark pairs and three quarks, respectively. By definition, a wounded constituent collides inelastically at least once and produces charged particles regardless of the number of collisions [1]. The pseudorapidity distribution of charged particles is given by [3]

$$\frac{\mathrm{d}N_{\mathrm{ch}}}{\mathrm{d}\eta} = w_{\mathrm{L}} F(\eta) + w_{\mathrm{R}} F(-\eta) \,, \tag{1}$$

where $F(\pm\eta)$ is the emission function of one constituent and w_{L}, w_{R} are the mean numbers of the left- and the right-going wounded constituents. If $w_{\mathrm{L}} \neq w_{\mathrm{R}}$, we have

$$F(\eta) = \frac{1}{2}\left[\frac{N(\eta)+N(-\eta)}{w_{\mathrm{L}}+w_{\mathrm{R}}} + \frac{N(\eta)-N(-\eta)}{w_{\mathrm{L}}-w_{\mathrm{R}}}\right] , \tag{2}$$

where $N(\pm\eta) = \mathrm{d}N_{\mathrm{ch}}(\pm\eta)/\mathrm{d}\eta$.

The mean numbers of wounded sources are calculated using the Monte Carlo Glauber simulations with parameters listed in Ref. [19]. First, one generates positions of nucleons in a nucleus from the adequate distribution (deuteron — Hulthen formula [19, 20], helium-3 — data from [21], aluminium and gold — Woods–Saxon distribution [19, 22]). In the WQM, around the position of every nucleon, we generate quarks from $\rho(\vec{r}) = \rho_0 \exp\left(-Cr/a\right)$, where $a = r_p/\sqrt{12}$ with $r_p = 0.81$ fm (proton's radius) [6, 23] and the coefficient $C = 0.82$[1]. In the WQDM, $C = 0.79$ and for every quark at r, a diquark is in the opposite direction at $r/2$.

We take the inelastic nucleon–nucleon cross section to be $\sigma_{nn} = 41$ mb [19] and by using the trial and error method [18], we determined $\sigma_{qq} = 6.65$ mb for the WQM. In the WQDM, there are three possible interactions: quark–quark, quark–diquark and diquark–diquark. Following [5], we took $\sigma'_{qq} : \sigma_{qd} : \sigma_{dd} = 1 : 2 : 4$. Again, using the trial and error method, we obtained $\sigma'_{qq} = 5.75$ mb.

In our simulation, in the WNM, each wounded source populates particles according to a negative binomial distribution with parameters $\langle n\rangle = 5$ and $k = 1$. For WQDM and WQM, these parameters should be divided by the mean number of wounded constituents per nucleon in the given model (1.14 and 1.27 for the WQDM and WQM, respectively) [18, 24].

Using min-bias $\mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta$ from the PHOBOS data on $d+{}^{197}$Au collision at $\sqrt{s_{NN}} = 200$ GeV [15] and equation (2), we calculated the wounded nucleon, quark, quark–diquark emission functions, $F(\eta)$, presented in Fig. 1 (see also Ref. [25]).

[1] This parameter is chosen to reproduce $\langle r^2\rangle = r_p^2$ for quarks shifted to the center of mass.

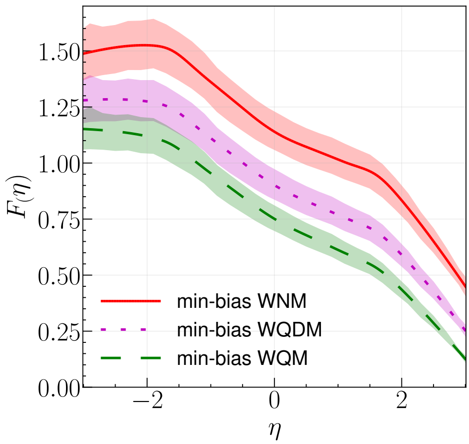

Fig. 1. The min-bias wounded source emission functions at $\sqrt{s_{NN}} = 200$ GeV in the WNM, WQDM and WQM. Shaded areas represent our uncertainties.

3. Results

In Figs. 2 and 3, we present our calculations and the latest PHENIX data [17] on $\mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta$ for asymmetric collisions at $\sqrt{s_{NN}} = 200$ GeV. One can see that the differences between the models are negligible for asymmetric collisions. All results are in quite good agreement with the data from

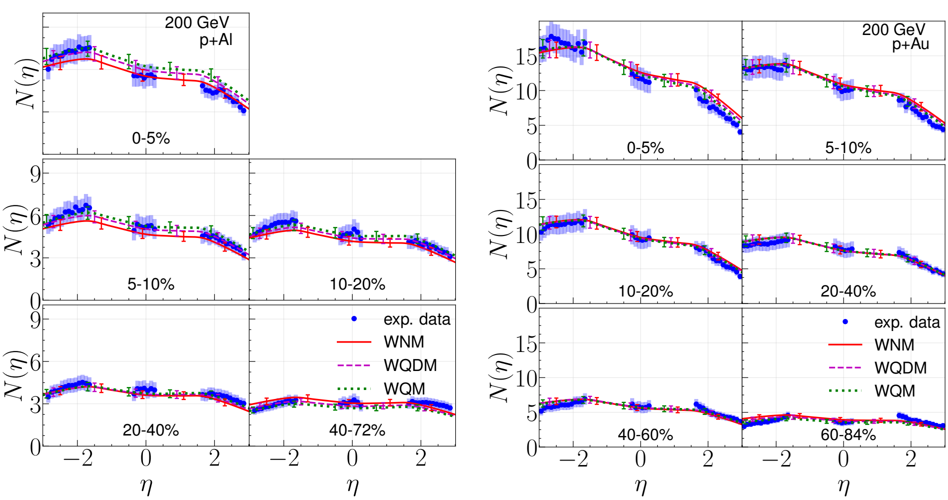

Fig. 2. $N(\eta)$ in the WNM, WQDM and WQM for $p+{}^{27}$Al and $p+{}^{197}$Au collisions at $\sqrt{s_{NN}} = 200$ GeV. Dots represent the PHENIX data [17]. The uncertainties are represented by bars for our simulation and shaded areas for experiment.

PHENIX [17]. We note that the results based on the WQM were presented in Ref. [18] before the PHENIX data were available to us. In Fig. 3 (right panel), we also present our simulation for symmetric Au+Au collisions and compare to the PHOBOS [16] results. This comparison shows that both the WQDM and WQM are in acceptable agreement with the data.

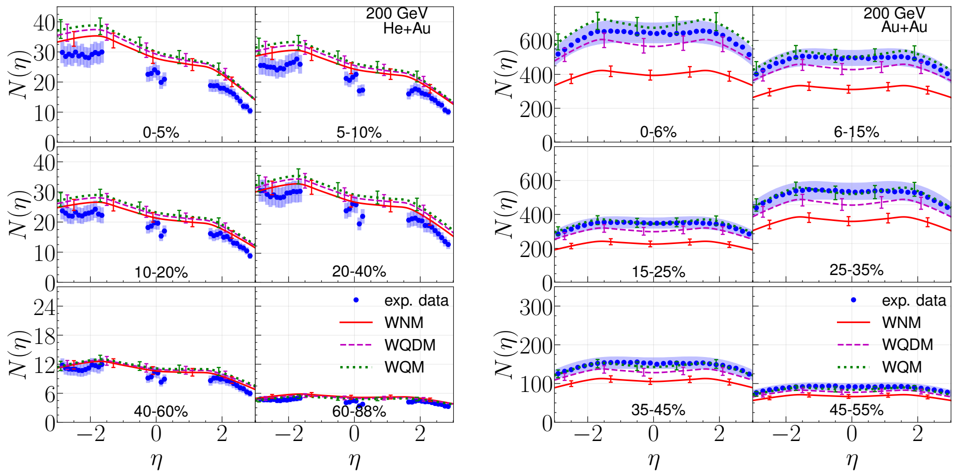

Fig. 3. The same as Fig. 2 but for ^{3}He+^{197}Au and ^{197}Au+^{197}Au. Dots represent the PHENIX and PHOBOS data [16, 17], respectively.

We emphasize that $F(\eta)$ is extracted from the min-bias PHOBOS data on d+^{197}Au collision and all calculations are basically parameter-free. In the upcoming publication, we will discuss all available collisions at $\sqrt{s_{NN}} =$ 200 GeV namely p+p, p+Al, p+Au, d+Au, ^{3}He+Au, Cu+Cu, Cu+Au, Au+Au, and U+U.

To summarize, we calculated three different min-bias emission functions and used them to obtain $\mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta$ distributions in symmetric and asymmetric collisions. All the models are in good agreement with the PHENIX data for asymmetric collisions. However, only the wounded quark and quark–diquark models are in acceptable agreement with the PHOBOS Au+Au data.

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