Abstract In this work, we pave the way to calculate the productions of $\omega$ and $K_S^0$ mesons with large $p_T$ in p+p and A+A collisions both at RHIC and LHC. The fragmentation functions (FFs) of the $\omega$ meson in vacuum at next-to-leading order (NLO) are obtained by evolving the NLO DGLAP evolution equations with rescaled $\omega$ FFs at initial scale $Q_0^2 = 1.5 \text{ GeV}^2$ from a broken SU(3) model, and the FFs of $K_S^0$ in vacuum are taken from AKK08 parametrization directly. Within the framework of the NLO pQCD improved parton model, we arrive at good descriptions of the experimental data on $\omega$ and $K_S^0$ in p+p both at RHIC and LHC. With the higher-twist approach, to take into account jet quenching effect by medium-modified FFs, nuclear modification factors for $\omega$ meson and $K_S^0$ meson both at RHIC and LHC are presented with different sets of jet transport coefficients $q_0$. Then we make a global extraction of $q_0$ both at RHIC and LHC by confronting our model calculations with all available data on six identified mesons: $\pi^0$, $\eta$, $\rho^0$, $\phi$, $\omega$, and $K_S^0$. The minimum value of total $\chi^2/d.o.f$ for productions of these mesons gives the best value of $q_0 = 0.5 \text{ GeV}^2$/fm for Au+Au collisions with $\sqrt{s_{NN}} = 200 \text{ GeV}$ at RHIC, and $q_0 = 1.2 \text{ GeV}^2$/fm for Pb+Pb collisions with $\sqrt{s_{NN}} = 2.76 \text{ TeV}$ at LHC, respectively, with the QGP spacetime evolution given by the event-by-event viscous hydrodynamics model IEBE-VISHNU. With these global extracted values of $q_0$, nuclear modification factors of $\pi^0$, $\eta$, $\rho^0$, $\phi$, $\omega$, and $K_S^0$ in A+A collisions are presented, and predictions of yield ratios such as $\omega/\pi^0$ and $K_S^0/\pi^0$ at the high-$p_T$ regime in heavy-ion collisions both at RHIC and LHC are provided.

1 Introduction

The jet quenching effect describes energy dissipation of an energetic parton when it traverses through the hot and dense QCD medium, which is produced shortly after high energy nuclear collisions [1]. The single hadron production suppression at the high-$p_T$ regime when compared to scaled p+p data is one of the primary perturbative probes to study the properties of this de-coupled quark and gluon QCD matter [2]. $\pi^0$ is the best measured final-state hadron, and its nuclear modification factor $R_{AA}$ as a function of transverse momentum $p_T$ is interpreted as the consequence of the jet quenching effect and it did help us to constrain the strength of the jet–medium interaction and the properties of the QCD medium [3-9]. In 2013, the Jet Collaboration summarized different jet quenching theoretical frameworks and compared the jet transport parameter extracted by different energy loss models using the same hydro description of QCD medium [10]. Meanwhile, the $R_{AA}$ for different final-state identified hadrons have been measured, and their production suppressions as well as patterns of their yield ratios have been observed [4,5,11-16]. It is of interest and it is a challenge to describe the cross sections of leading hadrons of different types and their yield ratios with each other in heavy-ion collisions (HIC) both at RHIC and LHC with a unified model of jet quenching, which should shed light on the flavor dependence of the parton energy loss and the intrinsic properties of the identified hadron productions in p+p and A+A reactions [17-24].

We have achieved a better understanding of the suppression patterns of different mesons by conducting calculations and by analysis of the $R_{AA}$ and particle ratios for other identified hadron productions [25-27]. We find that understanding of the suppression pattern of the leading hadron requires one to take into account all three factors [25]: the initial hard jet spectrum, the energy loss mechanism and the parton fragmentation functions in vacuum. The flavor dependence of the energy loss will result in a decrease of the fraction of
the strength of the jet–medium interaction characterized by the medium. Due to the changes of the medium description, the spacetime evolution information of the hot and dense viscous hydrodynamics model (IEBE-VISHNU) [33] to give a description of the spacetime evolution of the QGP fireball. In this section, we mainly investigate one of the low-mass vector mesons ($\omega$) and one of the pseudoscalar mesons ($K^0_S$), together with $\pi^0$, $\eta$, $\rho^0$ and $\phi$ to achieve these goals.

In this article, we investigate the production of two other mesons, $\omega$ and $K^0_S$, with large $p_T$ in A+A collisions, which has never been computed so far, to the best of our knowledge. The $\omega$ meson is one of the lightest mesons, carrying strangeness components, $K^0_S(\frac{d+s}{2})$ is one type of kaon, consisting of s-quark, d-quark and their corresponding anti-quarks. The productions of these two mesons have been measured in p+p and A+A collisions both at RHIC and LHC, but a theoretical description is lacking. Within the NLO pQCD improved parton model, we calculate $\omega$ and $K^0_S$ yields at the high-$p_T$ regime in heavy-ion collisions, by employing medium-modification fragmentation functions (FFs) due to gluon radiation in the hot/dense QCD medium in the higher-twist approach of jet quenching [22,23,28–30], the same approach as in our calculations on the productions of $\eta$, $\rho^0$ and $\phi$ mesons in HIC [25–27].

It is noted in the previous studies that, for consistency, we implemented the Hirano hydro description [31,32] to describe the spacetime evolution of the QGP fireball. In this work, we utilize a state-of-the-art, event-by-event (2+1)-D viscous hydrodynamics model (IEBE-VISHNU) [33] to give the spacetime evolution information of the hot and dense medium. Due to the changes of the medium description, the strength of the jet–medium interaction characterized by the jet transport parameter $q_0$ should be re-extracted. Taking advantage of the systematical study of the nuclear modification factors with respect to $p_T$ and the large amount of experimental data of $\pi^0, \eta, \rho^0$ and $\phi$ both at RHIC and LHC, with two more mesons $\omega$ and $K^0_S$ calculated in this article, we can make a global extraction of the jet transport parameter $q_0$ with all the available experimental data of these six identified mesons $R_{AA}$.

The article is organized as follows. We first present the theoretical framework of computing single hadron cross sections in p+p collision in Sect. 2, and we give the p+p baseline in investigating the in-medium modification of these productions. In Sect. 3, we discuss the inclusive hadron production in A+A collisions with the medium-modified FFs, based on the higher-twist approach of parton energy loss, and we present the nuclear modification factors $R_{AA}$ for $\omega$ and $K^0_S$ both at RHIC and LHC. Section 4 shows the global extraction of the jet transport coefficient $q_0$ both at RHIC and LHC by confronting our model calculations with all available data on six identified mesons: $\pi^0$, $\eta$, $\rho^0$, $\phi$, $\omega$, and $K^0_S$. In Sect. 5, we make predictions on the identified hadron yield ratios $\omega/\pi^0$ and $K^0_S/\pi^0$ in p+p and A+A collisions, and we compare them with experimental data if applicable. We give a brief summary in Sect. 6.

2 Large $p_T$ yield of $\omega$ and $K^0_S$ meson in p+p

We start with the productions of $\omega$ and $K^0_S$ mesons at NLO in p+p collisions. In the framework of the pQCD improved parton model, the inclusive hadron production in p+p collisions can be given by the convolution of three parts, the parton distribution functions (PDFs) in a proton, the hard partonic scattering cross section, denoted $d\sigma/dt$ (up to the order of $a_s^2$), and the parton fragmentation functions (FFs) to the final-state hadron $D_{q,g}(z_h, Q^2)$. One may convolute PDFs and partonic cross section $d\sigma/dt$ into the initial hard (parton-) jet spectrum $F_{q,g}(p_T)$, and we have

$$\frac{1}{p_T} \frac{d\sigma_{\omega, K^0_S}}{dp_T} = \int F_q \left( \frac{p_T}{z_h} \right) \cdot D_{q\rightarrow\omega, K^0_S}(z_h, P_T) \frac{dz_h}{z^2_h} + \int F_g \left( \frac{p_T}{z_h} \right) \cdot D_{g\rightarrow\omega, K^0_S}(z_h, P_T) \frac{dz_h}{z^2_h}. \quad (1)$$

Here, the quark and gluon fragmenting contributions are written separately to facilitate future discussions. A next-to-leading order (NLO) Monte Carlo code has been employed to calculate leading hadron productions in the p+p collision [36], and the CT14 parametrization of PDFs for the free proton [37] has been implemented. In the framework, as long as the parametrization of the specific final-state hadron FFs in vacuum is available, one can predict its production yield at large $p_T$ in elementary p+p collisions in principle.

In order to make the NLO calculation of $\omega$ and $K^0_S$ mesons in p+p, the NLO parton FFs of these two mesons are needed. The parton FFs of the $K^0_S$ meson at NLO can be found in the AKK08 parametrization [38], while there is not such a kind of global parametrization for $\omega$ FFs in vacuum. So we have to rely on theoretical models and utilize $\omega$ parton FFs at a starting scale $Q^2_0 = 1.5$ GeV$^2$ provided by a broken SU(3) model [39,40]. We note that our preceding investigations on leading
\( \rho^0 \) and \( \phi \) production [26, 27] have benefited from this broken SU(3) model. In this model, the independent parton FFs of different flavor are reduced into three independent functions named valence function, \( V(x, Q^2) \), sea function, \( \gamma(x, Q^2) \) and gluon function, \( D_g(x, Q^2) \), by considering the SU(3) flavor symmetry with a symmetry breaking parameter and also addressing the isospin and charge conjugation invariance of the vector mesons. We can write these three functions into a standard polynomial at the starting low energy scale of \( Q_0^2 = 1.5 \text{ GeV}^2 \) as

\[
H_i(x) = a_i x^b (1 - x)^c (1 + d_i x + e_i x^2),
\]

where the full set of parameters \((a, b, c, d, e)\) defined in \( V, \gamma, D_s \) and a few additional parameters defined for each vector meson such as the strangeness suppression factor \( \lambda \), the vector mixing angle \( \theta \), the sea suppression factor \( f_{\text{sea}}(\omega), f_{\gamma}^{\mu}(\omega) \) and \( f_g^\omega \) have been determined in the broken SU(3) model in Refs. [39, 40], and we multiply the parameter \( a_i \) by 3 to make the best fit to the yield of the \( \omega \) meson in p+p collisions. All these parameters for fitting the initial FFs of \( \omega \) meson are listed in Table 1. To obtain a NLO parton FF for \( \omega \) at any energy scale \( Q \), we employ the numerical NLO DGLAP evolution program provided in Ref. [41] with the initial parton FFs starting scale \( Q_0^2 = 1.5 \text{ GeV}^2 \) as input.

We demonstrate in Fig. 1 the NLO DGLAP evolved FFs of the \( \omega \) meson as functions of \( z_h \) at fixed \( Q^2 = 1.5 \text{ GeV}^2 \) and \( Q^2 = 100 \text{ GeV}^2 \) on the left and as functions of \( Q \) at fixed \( z_h = 0.4 \) and \( z_h = 0.6 \) on the right. We find in the typical fraction region \((z_h = 0.4 \rightarrow 0.7)\) \( D_g^\omega > D_s^\omega > D_u(d)^\omega \), unlike the case \( D_g^\omega > D_s^\omega > D_u(d)^\omega \) in the \( \phi \) FFs [27]. Due to the fact that in parton FFs the gluon contribution exceeds the quark contribution, an overwhelming advantage of the gluon fragmenting contribution of the final-state \( \omega \) production in p+p collision is expected in the competition with the quark fragmenting contribution. In Fig. 2, we plot the NLO FFs of \( K_S^0 \) from the AKK08 parametrization in the same manner as the \( \omega \) meson in Fig. 1. We find the strange quark FF \( D_s^{K_S^0} > D_s^{K_S^0} \) in the typical \( z_h = 0.4 \rightarrow 0.7 \) region, therefore competition of the gluon and quark fragmenting contributions is expected in the \( K_S^0 \) production in p+p collisions based on the pattern discovered in the previous study of the \( \pi^0, \eta, \rho^0 \) and \( \phi \) mesons.

With the NLO FFs in vacuum of both the \( \omega \) and the \( K_S^0 \) mesons, we are able to confront the numerical results of the \( \omega \) and \( K_S^0 \) meson productions in p+p collisions up to NLO with the available experimental data both at RHIC and LHC shown in Figs. 3 and 4. Note that, in our simulations, the hard scales such as factorization scale, renormalization scale and fragmentation scale are chosen to be the same and proportional to the \( p_T \) of the final-state hadron. We see that the numerical results match well with the experimental data on \( \omega \) meson spectra both at RHIC, \( \sqrt{s_{\text{NN}}} = 200 \text{ GeV} \), and LHC, \( \sqrt{s_{\text{NN}}} = 7 \text{ TeV} \), and the hard scales, \( \mu = 0.5 \ p_T \), as shown in Fig. 3. We also demonstrate in Fig. 4 the good agreement of the theoretical calculations of the leading \( K_S^0 \) meson with the STAR data and the ALICE data, where the hard scales are fixed to be \( \mu = 1.0 \ p_T \) to give the best fit.

### 3 Large \( p_T \) yield of \( \omega \) and \( K_S^0 \) meson in A+A

To calculate the \( \omega \) and \( K_S^0 \) productions in A+A collisions, the jet quenching effect should be included. In this article we utilize the higher-twist approach of parton energy loss, which relates the parton energy loss due to its multiple scattering in QCD medium and medium-induced gluon radiation to twist-four processes, and this shows that these processes give rise to additional terms in QCD evolution equations and lead to the effectively medium-modified fragmentation functions; thus the partonic energy loss effect can be taken into account by replacing the FFs in vacuum with the effec-
is totally carried away by the radiative gluons, then the convolution of these energy loss kernels $\Delta \gamma_{q \to gq}(\Delta \gamma_{q \to gq})$ with the (DGLAP) evolved vacuum FFs at any scale $D^h_{q,g}(z, Q^2)$ implies the assumption that the fast parton first loses its energy in the medium and then fragments into final-state hadrons in vacuum.

The medium-modified splitting functions depend on the properties of the local medium, which cannot be determined directly by the theoretical calculation itself. The jet transport parameter $\hat{q}$, which is defined as the average squared transverse momentum broadening per unit length, is therefore introduced to profile the dependency of the local medium properties in these energy loss kernels [10]. The jet transport parameter $\hat{q}$ can be phenomenologically assumed to be proportional to the local parton density in the hot/dense medium to adopt a further medium description:

$$\hat{q}(\tau, r) = \hat{q}_0 \frac{\rho_{\text{med}}(\tau, r)}{\rho_{\text{med}}(\tau_0, 0)},$$

where $\rho_{\text{med}}$ is the parton (quark and gluon) density in the medium at a given temperature, $\hat{q}_0$ is the initial jet transport parameter at the center of the bulk medium at initial time $\tau_0$, $p^\mu$ is the four-momentum of the jet and $u^\mu$ is the four-flow velocity of the probed local medium in the collision frame. In this article we employ the state-of-art, event-by-event viscous hydrodynamics description IEBE-VISHNU [33] to give the spacetime evolution information of the hot/dense medium, such as temperature, energy density, four-velocity of the local medium at any evolution time and position, and the formation time of QGP, $\tau_0 = 0.6$ fm. Therefore the only undetermined parameter in the calculation is $\hat{q}_0$, representing the strength of the jet–medium interaction, which can be fixed by fitting the data of leading hadrons (usually $\pi$ meson) suppression in A+A collisions [10,25–27].

When averaging the medium-modified FFs over the initial production position and the jet propagation direction, we are able to directly replace the vacuum FFs in the p+p formalism with these averaged medium-modified FFs<br>($\bar{D}^h_{q,g}(z, Q^2, E, b)$); therefore the formalism of the calculated cross section of the single hadron productions in HIC would take the form of

$$\frac{1}{\langle N_{\text{coll}}(b) \rangle} \frac{d\sigma^h_{AB}}{d^2y^2 d\tau} = \sum_{abcd} \int d\tau d\rho \frac{f_{a/A}(x_a,\mu^2) f_{b/B}(x_b,\mu^2)}{\pi z_c} \times \frac{d\sigma}{d\tau}(ab \to cd) \frac{\langle \bar{D}^h_{q,g}(z, Q^2, E, b) \rangle}{\pi z_c} + O(\alpha_s^3).
$$

Here, $\langle N_{\text{coll}}(b) \rangle = \int d^2r I_A(r) I_B(|b - r|)$ is the number of binary nucleon–nucleon collisions at a certain impact parameter $b$ in A+B collisions; it can be calculated by using the Glauber model [44]. $f_{a/A}(x_a,\mu^2)$ represents the effective

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**Fig. 3** The theoretical results of the $\omega$ meson production in p+p collisions at $\sqrt{s} = 200$ GeV confronted with the PHENIX data [15] and confronted with the ALICE data [34] at $\sqrt{s} = 7$ TeV.

**Fig. 4** The theoretical results of the $K^0_s$ meson production in p+p collisions at $\sqrt{s} = 200$ GeV RHIC compared with STAR data [35] and at $\sqrt{s} = 2.76$ TeV LHC compared with ALICE data [16].

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The contribution of the medium-induced gluon radiation is attributed to the medium-modified splitting functions represented by $\Delta \gamma_{q \to gq}$ and $\Delta \gamma_{q \to gq}$. In this formula, we assume that the energy loss of the jet propagating through the medium
PDFs inside a nucleus. In our calculations, we employed EPPS16 NLO nuclear PDFs [45] to include the initial-state cold nuclear matter effects on single hadron productions [46].

The nuclear modification factor $R_{AA}$ as a function of $p_T$ is calculated as cross sections in $A+A$ collisions divided by the ones in $p+p$ collision, scaled by the averaged number of binary nucleon–nucleon collisions with the chosen impact parameter $b$ [3]:

$$R_{AB}^b(p_T, y) = \frac{d\sigma_{AB}^b/dy d^2p_T}{\langle N_{coll}(b) \rangle d\sigma_{pp}^b/dy d^2p_T}.$$  \hspace{1cm} (6)

The theoretical results of $R_{AA}$ at various values of $\hat{q}_0 = 0.4 – 0.7 \text{ GeV}^2/\text{fm}$ for both $\omega$ and $K_S$ mesons are presented in Figs. 5 and 6.

When obtaining a suitable value of $\hat{q}_0$ by comparing the theoretical calculations of $R_{AA}$ for $\omega$ and $K_S$ with the corresponding data, there are two caveats. First, since the data of $\omega$ and $K_S$ meson at large $p_T$ in $A+A$ collisions are rather limited and come with a large uncertainty, it is difficult to make a good constraint on $\hat{q}_0$ with these data. Second, there is the caveat that we employ the IEBE-VISHNU hydrodynamics model to describe the spacetime evolution of the fireball, which gives different information of physics quantities, such as temperature and density, from those provided by other hydro models, such as the Hirano hydro description [31,32]. Therefore, we could not take advantage of the extracted value of $\hat{q}_0$ in Refs. [10,22,23,25–27], where the Hirano hydro description has been utilized.

**4 Global extraction of $\hat{q}_0$ with $R_{AA}$ for six identified mesons**

We perform a systematic calculation of the $R_{AA}$ of 6 identified mesons ($\pi^0$, $\eta^0$, $\phi$, $\omega$, $K_S$, and $\omega$) to compare with all their available experimental data both at RHIC and LHC in Figs. 7 and 8.

In order to extract the best value of the initial jet transport parameter $\hat{q}_0$, we perform a $\chi^2$ fit to compare the theoretical results with different $\hat{q}_0$ and the available experimental data of all the different final hadrons. We have

$$\chi^2(a) = \sum_i \frac{(D_i - T_i(a))^2}{\sigma_i^2}.$$  \hspace{1cm} (7)

In the above equations, $D_i$ represents the experimental grids and $T_i$ is our theoretical prediction at input parameter $a$. $\sigma_i^2$ means the $i$th systematic and statistical experimental errors. We show in the top panel of Fig. 9 the derived $\chi^2$ averaged by the number of the compared data points for dif-
different final-state mesons at various $\hat{q}_0 = 0.4$–0.7 GeV$^2$/fm at RHIC with $\sqrt{s_{NN}} = 200$ GeV. In the bottom panel of Fig. 9 we plot the curve $\chi^2/d.o.f$ as a function of $\hat{q}_0$ both at RHIC and LHC, where the minimum of the curve $\chi^2/d.o.f$ with respect to $\hat{q}_0$ presents the best fit of theory with data. We then observe that at RHIC the minimum point of $\chi^2/d.o.f$ of all six identified mesons gives the best value of $\hat{q}_0 = 0.5 (+0.15/-0.05)$ GeV$^2$/fm. It is noted that the production of $\pi^0$ will carry the largest weight due to its more abundant data with relatively smaller error bars. We also derive the best value of $\hat{q}_0$ in the Pb+Pb collisions at LHC $\sqrt{s_{NN}} = 2.76$ TeV to be $\hat{q}_0 = 1.2 (+0.25/-0.15)$ GeV$^2$/fm, though the curve $\chi^2/d.o.f$ at LHC is much flatter that at the RHIC. So theoretical results with $\hat{q}_0 = 1.1 - 1.4$ GeV$^2$/fm should all give decent descriptions as regards the data at LHC.

It is noted that in our current model the extracted values of jet transport coefficient $\hat{q}_0$ both at RHIC and LHC are smaller than that by the JET Collaboration in Ref. [10] and the ones in our preceding calculations [25–27]. These differences come mainly from the different hydro models utilized in the studies. We have checked [47] that if we employ the Hirano hydro description in the calculation, the extracted values of $\hat{q}_0$ from our global fitting will be consistent with those in Refs. [10,25–27], though the model in this article has the potential to give more precise extraction of the jet transport coefficients when more data of identified hadrons in A+A collisions become available in the near future.

5 Particle ratios of $\omega/\pi^0$ and $K^0_s/\pi^0$ in A+A

With the global extracted value of $\hat{q}_0$ discussed in Sect. 4, we are able to further investigate the particle ratio of $\omega$ and $K^0_s$ both at RHIC and LHC. We first calculate $\omega/\pi^0$ ratio as a function of $p_T$ and show the results in p+p and Au+Au at RHIC in the left panel of Fig. 10, where the PHENIX experimental data on the $\omega/\pi^0$ ratio in p+p are also illustrated. An enhancement of the ratio in A+A relative to that in p+p is found in the small-$p_T$ region, whereas we have a small suppression in the high-$p_T$ regime. We also predict the $\omega/\pi^0$ ratio as a function of $p_T$ in p+p and Pb+Pb collisions with $\sqrt{s_{NN}} = 2.76$ TeV at LHC. In Fig. 10 we do not see the overlapping of the curves $\omega/\pi^0$ in p+p and A+A at the high-$p_T$ regime, as we have observed for the ratios $\eta/\pi^0$ [25] and $\rho^0/\pi^0$ [26] in p+p and A+A.

To understand this feature deeper, we plot the gluon and quark (fragmentation) contribution fractions to $\omega$ (and $\pi^0$) in p+p and Au+Au at RHIC in Fig. 11. One sees in the p+p collision at RHIC that the production of $\omega$ is dominated by gluon fragmentation. In the A+A collisions, the gluon suffers more energy loss than the light quark due to its larger color factor, which decreases the gluon contribution fraction and increases the light quark contribution fraction, but the
Fig. 10  Left: the yield ratios of $\omega/\pi^0$ as functions of $p_T$ in p+p and Au+Au collisions with 200 GeV at RHIC, and PHENIX data in p+p [15]. Right: predictions of the yield ratios of $\omega/\pi^0$ as functions of $p_T$ in p+p and Pb+Pb collisions with 2.76 TeV at LHC.

Fig. 11  Gluon and quark contribution fractions of the total yields of $\omega$ and $\pi^0$ mesons in p+p and Au+Au collisions with $\sqrt{s_{NN}} = 200$ GeV at RHIC.

We also compute the $K_S^0/\pi^0$ ratio as a function of $p_T$ both at RHIC and LHC in Fig. 12. We find the curves in A+A and in p+p are approaching to each other with $p_T$ increasing, and an obvious coincidence of these two curves is seen at LHC. We show the gluon and quark contribution fractions to the $K_S^0$ meson (and the $\pi^0$ meson) as functions of $p_T$ in Fig. 13. We find in p+p collisions that the productions of both $K_S^0$ and $\pi^0$ at very large transverse momenta are dominated by quark fragmentation. In A+A collisions, the gluon contribution shall be further suppressed because the gluon generally loses more energy. Thus, both in p+p and A+A collisions, the ratio $K_S^0/\pi^0$ should be largely determined by the ratio of quark FFs for $K_S^0$ ($D_{q/g}^{K_S^0}(z_h, Q^2)$) to quark FFs for $\pi^0$ ($D_{q/g}^{\pi^0}(z_h, Q^2)$) at very high $p_T$, where these FFs vary slowly with the momentum fraction $z_h$. This is very similar to the case of $\eta_0/\pi^0$ at high $p_T$ [25]. Even though in A+A collisions the jet quenching effect can shift $z_h$ of quark FFs, if the quark FFs have a rather weak dependence on $z_h$ and $p_T$, we can see that at the very high-$p_T$ regime the curves for $K_S^0/\pi^0$ in A+A and p+p come close to each other, and they even coincide at LHC.

6 Summary

In summary, we obtain the NLO FFs of the $\omega$ meson in vacuum by evolving the rescaled $\omega$ FFs from a broken SU(3) model at a starting scale $Q^2_0 = 1.5$ GeV$^2$, and we directly employ NLO $K_S^0$ FFs in vacuum from the AKK08 parameterizations; the numerical simulation of productions of both $\omega$ and $K_S^0$ matches well with the experimental data in p+p reactions. With the IEBE-VISHNU hydro profile of the QCD
medium, we calculate the nuclear modification factors of the \( \omega \) and \( K_0^0 \) mesons as well as \( \pi^0, \eta, \phi, \rho^0 \) in A+A collisions both at RHIC and LHC, including the jet quenching effect in a higher-twist approach. The global extraction of the jet transport parameter \( \hat{q}_0 \) is made, with comparison of the theoretical calculation and the experimental data of all six identified mesons: \( \pi^0, \rho^0, \eta, \phi, \omega, K_0^0 \). Furthermore, we predict the yield ratios of \( \omega/\pi^0 \) both at RHIC and LHC, and a fairly good agreement of the theoretical results and experimental data is found at RHIC. Theoretical predictions of \( K_0^0/\pi^0 \) ratios as functions of \( p_T \) at RHIC and LHC are also presented.

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A: Input parameters for $\omega$ in broken SU(3) model

See Table 1

| $\nu$ | $a$ | $b$ | $c$ | $d$ | $e$ | $\gamma$ | $D_8$ | $\lambda$ | $\delta$ | $f^u_8$ | $f_{\text{sea}}$ | $f_8^u$ | $f_8^d$ |
|------|-----|-----|-----|-----|-----|---------|------|--------|-------|-------|----------|--------|--------|
| $V$  | 2.16| 0.52| 1.24| 0.27| -0.16| 2.97    | 11.67| 0.07   | 40.49 | 1.00  | 0.99     | 0.05   | 0        |

Table 1 The parameters for the input fragmentation functions of $\omega$ at the initial scale

$Q^2 = 1.5 \text{ GeV}^2$ based on broken SU(3) model in our calculation

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