The extraction of nuclear sea quark distribution and energy loss effect in Drell-Yan experiment

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Abstract

The next-to-leading order and leading order analysis are performed on the differential cross section ratio from Drell-Yan process. It is found that the effect of next-to-leading order corrections can be negligible on the differential cross section ratios as a function of the quark momentum fraction in the beam proton and the target nuclei for the current Fermilab and future lower beam proton energy. The nuclear Drell-Yan reaction is an ideal tool to study the energy loss of the fast quark moving through cold nuclei. In the leading order analysis, the theoretical results with quark energy loss are in good agreement with the Fermilab E866 experimental data on the Drell-Yan differential cross section ratios as a function of the momentum fraction of the target parton. It is shown that the quark energy loss effect has significant impact on the Drell-Yan differential cross section ratios. The nuclear Drell-Yan experiment at current Fermilab and future lower energy proton beam can not provide us with more information on the nuclear sea quark distribution.

Keywords: energy loss, sea quark distribution, nuclear effect, Drell-Yan
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1 Introduction

In 1983, the European Muon Collaboration(EMC) \cite{1} reported that the ratios of nuclear structure functions for the iron and deuteron nuclei is not equal to unity, but a function of the Bjorken scaling variable $x$ in charged lepton-nucleus deep inelastic scattering. It shows that the parton distributions are modified in the nuclear environment because the structure function describes the quark momentum distributions in bound

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nucleons. From then on, the quark and gluon distributions in hadrons and nuclei have been one of the most active frontiers in nuclear physics and particle physics. The nuclear parton distribution directly affects the interpretation of the data collected from the nuclear reactions at high energies\cite{2}. The precise nuclear parton distribution function should be very important in finding the new physics phenomena and determining the electro-weak parameters, neutrino masses and mixing angles in neutrino physics.

In early 1970, S.Drell and T.M.Yan first studied the production of large-mass lepton pairs from hadron-hadron inelastic collisions, which is so-called Drell-Yan process\cite{3}. According to the parton model, the process is induced by the annihilation of a quark-antiquark pair into a virtual photon which subsequently decays into a lepton pair. The nuclear Drell-Yan process of proton-nucleus collisions therefore is closely related to the quark distribution functions in nuclei. It is further natural to expect that the Drell-Yan reaction is a complementary tool to probe the structure of hadron and nuclei.

In 1990, Fermilab Experiment772(E772)\cite{4} made the measurement of the nuclear dependence of the Drell-Yan process by using 800GeV protons bombarding on D, C, Ca, Fe, and W nuclei. Muon pairs were recorded in the range $4\text{GeV} \leq M \leq 9\text{GeV}$ and $M \geq 11\text{GeV}$. The covered kinematical ranges were $0.1 < x < 0.3$, where $x$ is the momentum fraction of the target parton. Their aim is to investigate the modification of the quark structure in nuclei. The theoretical models, which can well describe the EMC effect in the charged lepton-nucleus deep inelastic scattering, were used to fit the observations on the Drell-Yan differential cross section ratios. It is found that some of the theoretical models overestimate the nuclear Drell-Yan ratios from Fermilab E772, such as pion-excess model\cite{5} and quark-cluster model\cite{6}. It indicated that whether there is another nuclear effect apart from the nuclear effects on the parton distributions as in charged lepton-nucleus deep inelastic scattering.

In 1999, Fermilab Experiment866(E866)\cite{7} performed the precise observation of the ratios of the Drell-Yan cross section per nucleon for an 800GeV proton beam
incident on Be, Fe and W target. The Drell-Yan events extend over the ranges $4 \text{GeV} < M < 8.4 \text{GeV}$, $0.01 < x_2 < 0.12$, $0.21 < x_1 < 0.95$ and $0.13 < x_F < 0.93$, where $x_{1(2)}$ and $x_F$ are the momentum fraction of the beam parton (the target nuclear parton) and Feynman scaling variable, respectively. The extended kinematic coverage of E866 significantly increases its sensitivity to the nuclear shadowing effect and the quark energy loss. This is the first experiment on the energy loss of the projectile particle moving through cold nuclei. The E866 compared their experimental data with the results from leading-order Drell-Yan calculations by using the EKRS nuclear parton distributions$^{[8]}$ together with the MRST parton distribution functions$^{[9]}$. It is shown that the energy loss effect can be negligible.

In previous works$^{[10]}$, we investigated the Drell-Yan differential cross section ratios as the function of the momentum fraction of the beam parton from E866 data in the framework of Glauber model by means of EKRS and HKM nuclear parton distribution functions$^{[11]}$. We found that the theoretical results with energy loss of the beam proton are in good agreement with the Fermilab E866 experiment by means of HKM nuclear parton distributions. However, the calculated results without energy loss can give good fits by using EKRS nuclear parton distribution functions. Furthermore, we introduced two typical kinds of quark energy loss parametrization, i.e. the linear and quadratic quark energy loss with the average path length of the incident quark in the nucleus $A$. The nuclear dependence of the Drell-Yan production cross sections were calculated by combining the quark energy loss effect with the EKRS, HKM and HKN$^{[12]}$ nuclear parton distribution. The $\chi^2$ global fit to the Drell-Yan differential cross section ratios indicated that the theoretical results without energy loss effects agree very well with the E866 experimental data by taking advantage of the EKRS nuclear parton distribution functions. If employing the HKM nuclear parton distribution function, the results with energy loss effect are in good agreement with the Fermilab E866 data. In addition, the results with HKM are most near to those with HKN. It
is demonstrated that at current Fermilab incident proton energy, we can not distinguish between the linear and quadratic dependence of the quark energy loss. Further experiments are needed about nuclear Drell-Yan reactions with a lower energy incident proton. Using the values of quark energy loss from a fit to E866 experimental data, the prospects are given for the lower energy proton beam bombarding deuteron and tungsten. It is shown that these future experiments can give valuable insight in the energy loss of fast quark propagating through cold nuclei. In the analysis above, we performed the leading order calculations of the Drell-Yan differential cross sections. As is well known, QCD corrections can alter quite significantly the cross sections at a hadronic collider. Thus, these may have serious bearing on the discovery potential of the Drell-Yan reactions, in which the leading order (LO) results may seriously underestimate the cross sections. This has led to the incorporation of the next-to-leading order (NLO) results. As for the nuclear parton distributions, EKRS, HKM and HKN nuclear parton distributions are obtained by Eskola et al.[8], Hirai et al.[11,12] with the global analysis of the relative experimental data, respectively. It is noticeable that HKM use only the charged lepton-nucleus deep inelastic scattering experimental data, HKN and EKRS employ E772 and E866 nuclear Drell-Yan reaction data in order to pin down the nuclear antiquark distribution in the small x region. In this report, we will explore the effect of NLO correction on the Drell-Yan differential cross section ratios, and the influence of quark energy loss on the Drell-Yan differential cross section ratios as a function of the momentum fraction of the target parton.

This paper is organized as follows. In sect.2, a brief formulism for the differential cross section in the Drell-Yan process is presented. The effect of NLO correction is given on the Drell-Yan differential cross section ratios in sect.3. The influence of quark energy loss is given on the Drell-Yan differential cross section ratios as a function of the momentum fraction of the target parton in sect.4, and the summary is given in sect.5.
2 Brief formulism for differential cross section in Drell-Yan reaction

In the Drell-Yan process\[^3\], the perturbative QCD leading order contribution is quark-antiquark annihilation into a lepton pair. The annihilation cross section can be obtained from the \(e^+e^- \rightarrow \mu^+\mu^-\) cross section by including the color factor \(\frac{1}{3}\) with the charge \(e_f^2\) for the quark of flavor \(f\).

\[
\frac{d\sigma}{dM} = \frac{8\pi\alpha^2}{9M} e_f^2 \delta(s - M^2),
\]

(1)

where \(\sqrt{s} = (x_1x_2s)^{1/2}\) is the center of mass system (c.m. system) energy of \(q\bar{q}\) collision, \(x_1\) (resp. \(x_2\)) is the momentum fraction carried by the projectile (resp. target) parton, \(\sqrt{s}\) is the center of mass energy of the hadronic collision, and \(M\) is the invariant mass of the produced dimuon. The hadronic Drell-Yan differential cross section is then obtained from the convolution of the above partonic cross section with the quark distributions in the beam and target,

\[
\frac{d^2\sigma^{DY}}{dx_1dx_2} = \frac{4\pi\alpha^2}{9sx_1x_2} \sum_f e_f^2 [q_f^p(x_1, Q^2)\bar{q}_f^A(x_2, Q^2) + \bar{q}_f^p(x_1, Q^2)q_f^A(x_2, Q^2)],
\]

(2)

where \(\alpha\) is the fine-structure constant, the sum is carried out over the light flavor \(f = u, d, s\), and \(q_f^{p(A)}(x, Q^2)\) and \(\bar{q}_f^{p(A)}(x, Q^2)\) are the quark and anti-quark distributions in the proton (nucleon in the nucleus A).

In addition to the leading order Drell-Yan term, the contributions are needed from \(q\bar{q}\) annihilation processes\((\bar{q}q \rightarrow \gamma^* + g)\) and gluon Compton scattering\((q + g \rightarrow \gamma^* + q)\)[\(^{13}\)] in the perturbative QCD next-to-leading order, which are denoted as Ann and Comp, respectively. The contribution from the order-\(\alpha_s\) annihilation graphs is

\[
\frac{d^2\sigma^{Ann}}{dx_1dx_2} = \int_{x_1}^1 dt_1 \int_{x_2}^1 dt_2 \frac{d^2\tilde{\sigma}^{Ann}}{dt_1dt_2} \sum_f e_f^2 [q_f^p(t_1, Q^2)\bar{q}_f^A(t_2, Q^2) + \bar{q}_f^p(t_1, Q^2)q_f^A(t_2, Q^2)]
\]

\[+ \frac{d^2\tilde{\sigma}^{Ann}}{dt_1dt_2}(t_1 \leftrightarrow t_2) \sum_f e_f^2 [q_f^p(t_1, Q^2)\bar{q}_f^A(t_2, Q^2) + \bar{q}_f^p(t_1, Q^2)q_f^A(t_2, Q^2)],
\]

(3)

with

\[
\frac{d^2\tilde{\sigma}^{Ann}}{dt_1dt_2} = \sum_f \frac{8\alpha^2\alpha_s(Q^2)}{27Q^2} \delta(t_1 - x_1)\delta(t_2 - x_2)\left[1 + \frac{5}{3}\pi^2 - \frac{3}{2} \ln \frac{x_1x_2}{(1-x_1)(1-x_2)}\right]
\]
can be written as

\[ + 2 \ln \frac{x_1}{1-x_1} \ln \frac{x_2}{1-x_2} \]

\[ + \sum_f 8 \alpha_s^2 (Q^2) \delta(t_2 - x_2) \left[ \frac{t_1^2 + x_1^2}{t_1^2(t_1-x_1)_+} \ln \frac{2x_1(1-x_2)}{x_2(t_1+x_1)} \right] \]

\[ \frac{3}{2(t_1-x_1)_+} - \frac{2}{t_1} - \frac{3x_1}{t_1^2} \] (1 \leftrightarrow 2)

\[ + \sum_f 16 \alpha_s^2 (Q^2) \left[ \frac{(\tau + t_1 t_2)\tau^2 + (t_1 t_2)^2}{(t_1 t_2)^2(t_1+x_1)(t_2+x_2)(t_1-x_1)(t_2-x_2)_+} \right] \]

\[ - \frac{2 \tau (\tau + t_1 t_2)}{t_1 t_2(t_1 x_2 + t_2 x_1)^2}, \] \hspace{1cm} (4)

The contribution from the Compton scattering graphs is

\[ \frac{d^2 \sigma^{Comp}}{dx_1 dx_2} = \int_{x_1}^{1} \int_{x_2}^{1} d^2 \sigma^{Comp}_{dt_1 dt_2} \sum_f e_f^2 g^p(t_1, Q^2) [q_f^A(t_2, Q^2) + \bar{q}_f^A(t_2, Q^2)] \]

\[ + \frac{d^2 \sigma^{Comp}_{dt_1 dt_2}(t_1 \leftrightarrow t_2)}{dt_1 dt_2} \sum_f e_f^2 [q_f^p(t_1, Q^2) + \bar{q}_f^p(t_1, Q^2)] g^A(t_2, Q^2), \] \hspace{1cm} (5)

where \( g(t, Q^2) \) is the gluon distribution in the beam proton and target nuclei, and

\[ \frac{d^2 \sigma^{Comp}}{dt_1 dt_2} = \sum_f 2 \alpha_s^2 (Q^2) \left[ \frac{x_2^2 + (t_2 - x_1)^2}{2t_1^2} \ln \frac{2x_1(1-x_2)}{x_2(t_1+x_1)} \right] \]

\[ + \frac{1}{2t_1} - \frac{3x_1(t_1-x_1)}{t_1^3} \]

\[ + \sum_f 2 \alpha_s^2 (Q^2) \left[ \frac{x_2(\tau + t_1 t_2)\tau^2 + (\tau - t_1 t_2)^2}{t_1^2(t_1 x_2 + t_2 x_1)(t_2 + x_2)(t_2 - x_2)_+} \right] \]

\[ + \frac{\tau (\tau + t_1 t_2)\tau(t_1 x_2 + t_2 x_1)}{(t_1 t_2)^2(t_1 x_2 + t_2 x_1)^2}, \] \hspace{1cm} (6)

Therefore, to the next leading order, the differential cross section in Drell-Yan reaction can be written as

\[ \frac{d^2 \sigma^{NLO}}{dx_1 dx_2} = \frac{d^2 \sigma^{DY}}{dx_1 dx_2} + \frac{d^2 \sigma^{Ann}}{dx_1 dx_2} + \frac{d^2 \sigma^{Comp}}{dx_1 dx_2}. \] \hspace{1cm} (7)

With calculating the integral of the differential cross section above in leading order (Eq.2) and next-to-leading order (Eq.7), the Drell-Yan production cross section is given by

\[ \frac{d\sigma}{dx_{1(2)}} = \int dx_{2(1)} \frac{d^2 \sigma}{dx_1 dx_2}. \] \hspace{1cm} (8)

3 The influence of QCD correction on the ratio of Drell-Yan cross section
In the Drell-Yan reaction experiments, the ratios are measured of Drell-Yan cross sections on two different nuclear targets bombarded by proton,

$$R_{A_1/A_2}(x_{1(2)}) = \frac{d\sigma^{p-A_1}}{dx_{1(2)}} / \frac{d\sigma^{p-A_2}}{dx_{1(2)}}. \quad (9)$$

In order to explore the influence of QCD correction, we introduce the ratios,

$$R^{NLO/DY}_{A_1/A_2}(x_{1(2)}) = \frac{R_{A_1/A_2}^{NLO}(x_{1(2)})}{R_{A_1/A_2}^{DY}(x_{1(2)})}, \quad (10)$$

where $R_{A_1/A_2}^{NLO}(x_{1(2)})$ and $R_{A_1/A_2}^{DY}(x_{1(2)})$ are the ratios of Drell-Yan differential cross section with QCD correction and with only leading order contribution, respectively.

By taking advantage of the HKM cubic type of nuclear parton distribution functions \[11\], the ratios $R^{NLO/DY}_{Fe/Be}(x_{1(2)})$ and $R^{NLO/DY}_{W/Be}(x_{1(2)})$ for proton incident on Be, Fe, W targets are calculated at the Fermilab 800GeV proton beam energy in the range $4 < M < 8\text{GeV}$. It is found that the differential cross section ratios in the next-to-leading order are almost identical to those in the leading order. The similar results are given for the lower energy proton bombarding deuterium and tungsten at the Fermilab Main Injector(FMI,120GeV proton beam)\[14\] and the Japan Hadron Facility(JHF,50GeV proton beam)\[15\]. Therefore, it can be concluded that the QCD correction is negligible in the nuclear Drell-Yan reactions for the current Fermilab and lower energy proton beam. The production of lepton pairs in proton-nucleus collisions, the nuclear Drell-Yan process, is one of most powerful tools to probe the propagating of quark through cold nuclei. The experimental study of the relatively low energy nuclear Drell-Yan process can give valuable insight in the quark energy loss dependence on the medium size. Furthermore, the influence of quark energy loss can be investigated on the Drell-Yan differential cross section ratios as a function of the momentum fraction of the target parton in the leading order.

4 The impact of quark energy loss on the Drell-Yan differential cross section ratios as a function of the momentum fraction of the target parton.
The Fermilab E866 collaboration reported their measurement of the differential cross section ratios \( R_{Fe/Be}(x_2) \) and \( R_{W/Be}(x_2) \) for an 800GeV proton beam bombarding Be, Fe and W nuclei\(^7\). By combining HKM cubic type of nuclear parton distribution\(^1\) with the quark energy loss, the global \( \chi^2 \) analysis to the E866 experimental data are performed in the perturbative QCD leading order. We introduce two typical kinds of quark energy loss expressions. One is rewritten as

\[
\Delta x_1 = \alpha \frac{< L >_A}{E_p},
\]

(11)

where \( \alpha \) denote the incident quark energy loss per unit length in nuclear matter, \( < L >_A \) is the average path length of the incident quark in the nucleus A, \( E_p \) is the energy of the incident proton. The average path length is employed using the conventional value, \( < L >_A = 3/4(1.2A^{1/3}) \text{fm} \). In addition to the linear quark energy loss rate, another one is expressed as

\[
\Delta x_1 = \beta \frac{< L >^2_A}{E_p},
\]

(12)

i.e., the quark energy loss is quadratic with the path length. With considering the quark energy loss in nuclei, the incident quark momentum fraction can be shifted from \( x'_1 = x_1 + \Delta x_1 \) to \( x_1 \) at the point of fusion.

If the quark energy loss do not put in, the obtained \( \chi^2 \) value is \( \chi^2 = 48.06 \) for the 16 total data points. The \( \chi^2 \) per degrees of freedom is given by \( \chi^2/d.o.f. = 3.00 \). It is apparent that theoretical results without energy loss effects do not significantly agree with the E866 experimental data on the ratios \( R_{A_1/A_2}(x_2) \). After adding the fast quark energy loss, the \( \chi^2 \) per degrees of freedom is \( \chi^2/d.o.f. = 1.12 \) for the linear quark energy loss formula with \( \alpha = 1.27 \), and the \( \chi^2 \) per degrees of freedom is given by \( \chi^2/d.o.f. = 1.13 \) for the quadratic quark energy loss expression with \( \beta = 0.19 \). By using the parameter values in the linear and quadratic expressions obtained by fitting the E866 experimental data on the ratios \( R_{A_1/A_2}(x_1) \), the \( \chi^2 \) per degrees of freedom are \( \chi^2/d.o.f. = 1.69 \) with \( \alpha = 1.99 \) and \( \chi^2/d.o.f. = 1.65 \) with \( \beta = 0.29 \), respectively. The
calculated results with the linear and quadratic energy loss expression are shown in Fig.1 and Fig.2, which is the Drell-Yan cross section ratios for Fe to Be and W to Be as functions of $x_2$, respectively. The solid curves are the ratios with only the nuclear effect on the parton distribution as in deep inelastic scattering, the dotted and dash curves respectively correspond to the linear energy loss with $\alpha = 1.27$ and $\alpha = 1.99$ in Fig.1, and the quadratic energy loss with $\beta = 0.19$ and $\beta = 0.29$ in Fig.2. From comparison with the experimental data, it is shown that our theoretical results with energy loss effect are in good agreement with the Fermilab E866. Meanwhile, It is noticeable that the values of the parameter $\alpha$ (or $\beta$) are different by means of the global $\chi^2$ analysis to the E866 experimental data on the ratios $R_{A_1/A_2}(x_1)$ and $R_{A_1/A_2}(x_2)$. The results may be originated from the experimental precision. If the experimental data are sufficiently precise, the values of the parameter $\alpha$ (or $\beta$) in the quark energy loss expression should be the same for fitting the ratios $R_{A_1/A_2}(x_1)$ or $R_{A_1/A_2}(x_2)$ from the nuclear Drell-Yan experiment.

In order to clarify the impact of quark energy loss on the Drell-Yan differential cross section ratios as a function of the momentum fraction of the target parton, the ratios on $R_{A_1/A_2}(x_2)$ without quark energy loss to those with linear quark energy loss are calculated and tabulated in Table 1, for the kinematic ranges covered by the E866 experiment. The similar results can be obtained for the quadratic quark energy loss. It is shown that the quark energy loss effect has obvious influence on the Drell-Yan differential cross section ratios $R_{A_1/A_2}(x_2)$. As for the ratios $R_{Fe/Be}(x_2)$, the variation is approximately 2% to 4%. The extent to which the ratios $R_{W/Be}(x_2)$ vary is roughly 4% to 8%. It can be deduced that the ratios of Drell-Yan differential cross section for nuclei A versus deuterium, $R_{A/D}(x_2)$, are affected largely because of the quark energy loss effect. In the global analysis of nuclear parton distribution functions, the Drell-Yan data are taken mainly to determine the sea quark modification in the small $x$ region. It is obvious that, considering the existence of quark energy loss, the application of
TABLE 1: the ratios of $R_{A_1/A_2}(x_2)$ without quark energy loss to those with linear quark energy loss.

| $x_2$ | 0.03 | 0.05 | 0.07 | 0.09 | 0.12 |
|-------|------|------|------|------|------|
| $\alpha(1.27)$ | $Fe/Be$ | 1.018 | 1.017 | 1.019 | 1.022 | 1.027 |
|       | $W/Be$ | 1.038 | 1.036 | 1.040 | 1.045 | 1.055 |
| $\alpha(1.99)$ | $Fe/Be$ | 1.029 | 1.027 | 1.030 | 1.035 | 1.042 |
|       | $W/Be$ | 1.061 | 1.058 | 1.064 | 1.072 | 1.088 |

nuclear Drell-Yan data is remarkably subject to difficulty in the constraints of the nuclear antiquark distribution.

The ratios of Drell-Yan differential cross section for tungsten versus deuterium, $R_{W/D}(x_2)$, are also calculated at 50GeV and 120GeV proton beam by means of the HKM cubic type of nuclear parton distribution functions \(^{[11]}\) and two kind of quark energy loss expressions. It is indicated that the theoretical results with quark energy loss effect deviate significantly those with only the nuclear effects on the structure function. As an example, Figure 3 shows the ratios $R_{W/D}(x_2)$ with and without linear quark energy loss at 50GeV and 120GeV proton beam, respectively. The kinematic ranges cover $4 < M < 8 GeV$ in order to avoid contamination from charmonium decays. In these calculation, the energy loss per unit length $\alpha$ equal $1.27 GeV/fm$ and $1.99 GeV/fm$ from a good fit to E866 data. Therefore, the Drell-Yan experiment at a lower energy proton beam do not provide us with more information on the nuclear sea quark distribution, especially for large-$x$ region.

In addition, we calculate the ratios $R_{W/D}(x_2)$ with the linear and quadratic energy loss formula in the 50GeV and 120GeV proton beam bombarding deuterium and tungsten target. It is presented that the results with linear quark energy loss are almost identical to those with quadratic energy loss. The ratios $R_{W/D}(x_2)$ do not determine whether the energy loss is linear or quadratic with the path length. However, The ratios $R_{W/D}(x_1)$ can easily distinguish between $L$ and $L^2$ dependence of quark energy loss\(^{[10]}\). As an example, the Fig.4 shows the ratios $R_{W/D}(x_2)$ of the
Drell-Yan cross section per nucleon for an 120GeV proton beam incident on D and W target, where the solid and dotted lines correspond to a quadratic energy loss of $\beta = 0.19 GeV/fm^2$ and to a linear energy loss of $\alpha = 1.27 GeV/fm$, respectively.

5 Concluding remarks

As a summary, the next-to-leading order and leading order analysis are performed on the differential cross section ratios from nuclear Drell-Yan process. The calculated results indicated that the QCD correction can be ignored in the nuclear Drell-Yan reactions for the current Fermilab and lower energy proton beam. Based on this view, the nuclear Drell-Yan process is one of most powerful tools to probe the propagating of quark through cold nuclei. The experimental study in the relatively low energy nuclear Drell-Yan process can give valuable insight in the quark energy loss dependence on the medium size. Furthermore, we have made a leading-order analysis of E866 data on the Drell-Yan differential cross section ratios as a function of the momentum fraction of the target parton by taking into account of the energy loss effect of fast quarks. It is found that the theoretical results with quark energy loss are in good agreement with the Fermilab E866 experiment. The quark energy loss effect has obvious impact on the Drell-Yan differential cross section ratios $R_{A_1/A_2}(x_2)$. The nuclear Drell-Yan experiment at current Fermilab and future lower energy proton beam can not provide us with more information on the extraction of nuclear sea quark distribution. In fact, by means of the structure function $xF_3(x, Q^2)$ in neutrino deep inelastic scattering only, the nuclear modifications to the valence quark distribution can very precisely be determined in the medium and large $x$ regions. With the structure functions $F_2(x, Q^2)$ from the neutrino and charged-leptons deep inelastic scattering off nuclei, the nuclear modifications to the sea quark distribution in the medium and large $x$ regions would be pinned down[16]. The nuclear sea quark distribution in the small-$x$ regions can be relatively determined from the constraints of momentum conservation.
and the structure function in small-\(x\) range. We desire to operate precise measurements of the experimental study in the relatively low energy nuclear Drell-Yan process. These new experimental data can shed light on the energy loss of fast quark propagating in a cold nuclei.

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Figure caption

Fig.1 The nuclear Drell-Yan cross section ratios $R_{A_1/A_2}(x_2)$ on Fe to Be(left) and W to Be(right). Solid curves correspond to nuclear effects on structure function. Dotted and dash curves show the combination of HKM cubic type of nuclear parton distributions with the linear energy loss $\alpha = 1.27$ and 1.99, respectively. The experimental data are taken from the E866[7].

Fig.2 The nuclear Drell-Yan cross section ratios $R_{A_1/A_2}(x_2)$ on Fe to Be(left) and W to Be(right). Solid curves correspond to nuclear effects on structure function. Dotted and dash curves show the combination of HKM cubic type of nuclear parton distributions with the quadratic energy loss $\beta = 0.19$ and 0.29, respectively. The experimental data are taken from the E866[7].

Fig.3 The nuclear Drell-Yan cross section ratios $R_{A_1/A_2}(x_2)$ on W to D at 120GeV and 50GeV incident proton beam with the linear energy loss $\alpha = 1.27GeV/fm$ (dash curves) and $\alpha = 1.99GeV/fm$ (dotted curves). Solid curves correspond to nuclear effects on the structure function.

Fig.4 The nuclear Drell-Yan cross section ratios $R_{A_1/A_2}(x_2)$ on W to D at 120GeV incident proton beam with the quadratic energy loss $\beta = 0.19GeV/fm^2$ (solid curve) and the linear energy loss $\alpha = 1.27GeV/fm$ (dotted curve).
FIG. 1:

FIG. 2:
Fig. 3:
FIG. 4: