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Nuclear modification of the flavor asymmetry $\bar{u} - \bar{d}$

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NUCLEAR MODIFICATION OF THE FLAVOR ASYMMETRY $\overline{u}-\overline{d}$

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In order to test the NMC finding of flavor asymmetry $\overline{u}-\overline{d}$ in the nucleon, existing Drell-Yan data for the tungsten target are often used. However, we have to be careful in comparing nuclear data with the nucleon ones. We investigate whether there exists significant nuclear modification of the $\overline{u}-\overline{d}$ distribution in a parton-recombination model. It should be noted that a finite $\overline{u}-\overline{d}$ distribution is theoretically possible in nuclei even if the sea is symmetric in the nucleon. In neutron-excess nuclei such as the tungsten, there exist more d-valence quarks than u-valence quarks, so that more $\overline{d}$-quarks are lost than $\overline{u}$-quarks due to parton recombinations. Our results suggest that the nuclear modification in the tungsten is a 2–10 % effect on the NMC $\overline{u}-\overline{d}$ distribution. The nuclear modification of the flavor asymmetry should be an interesting topic in connection with ongoing Drell-Yan experiments.

The New Muon Collaboration (NMC) suggested that the Gottfried sum rule should be violated in 1991. It indicates $\bar{d}$ excess over $\bar{u}$ in the nucleon. Since then, there have been efforts to investigate mechanisms of creating a flavor asymmetric distribution $\bar{u}-\bar{d}$ in the nucleon.[1] In order to test the NMC finding, Drell-Yan experiments are in progress at Fermilab. On the other hand, there exist Drell-Yan data for various nuclear targets, so that some people use, for example, tungsten data in investigating the flavor asymmetry. However, we have to be careful in comparing the NMC result with the tungsten data because of possible nuclear medium effects. In order to find whether such a comparison makes sense, we estimate a nuclear modification effect.[2] It in turn could be found experimentally by analyzing accurate Drell-Yan data in the near future.

We investigate the $\bar{u}-\bar{d}$ distribution in the tungsten nucleus. If isospin symmetry could be applied to parton distributions in the proton and the neutron, the distribution per nucleon becomes $x[\bar{u}(x)-\bar{d}(x)]_A = -\varepsilon x[\bar{u}(x)-\bar{d}(x)]_{proton}$ without considering nuclear modification. It is just the summation of proton and neutron contributions. The neutron-excess parameter ε is defined by $\varepsilon=(N-Z)/(N+Z)$, and it is 0.196 for the tungsten ${}^{184}_{74}W_{110}$. According to the above equation, the flavor distribution should be symmetric ($[\bar{u}-\bar{d}]_W=0$) if it is symmetric in the nucleon. However, it is not the case in a parton-recombination model.

It is well known that shadowing phenomena occur in nuclear structure functions at small x. One of the ideas for explaining the shadowing is the recombination model.[3] In an infinite momentum frame, the longitudinal localization size of a parton with momentum $xp_{_N}$ exceeds the average longitudinal nucleon separation in a Lorentz contracted nucleus $[(2\ \mathrm{fm})M_A/P_A{=}(2\ \mathrm{fm})m_{_N}/p_{_N}]$ in the small x region ($x<0.1$). Therefore, partons from different nucleons could interact, and the interaction is called parton recombination. We apply studies of this model in the structure function F_2 to the asymmetry $\bar{u}-\bar{d}$ in nuclei.

The flavor asymmetry could be created in the recombination model in the following way. In a neutron-excess nucleus ($\varepsilon>0$) such as the tungsten, more $\bar{d}$ quarks are lost than

$\bar{u}$ quarks in the parton recombination process $\bar{q}q \to G$ because of the d quark excess over u in the nucleus. The $\bar{q}q \to G$ type recombination processes produce positive contributions at small x. In the $(\bar{u}-\bar{d})_N \neq 0$ case, the $\bar{q}(x)G \to \bar{q}$ process is the dominant one kinematically at small x. Its contribution to $\bar{u}(x) - \bar{d}(x)$ becomes negative due to the neutron excess. In the medium x region, the $\bar{q}G \to \bar{q}(x)$ process becomes kinematically favorable. Because it produces $\bar{q}$ with momentum fraction x, its contribution becomes opposite to the one at small x. These results are shown in Fig. 1.

We evaluate the recombination effects on the $\bar{u} - \bar{d}$ distribution at Q^2=4 GeV^2 in the tungsten nucleus $^{184}_{74}W_{110}$ (ε = 0.196).[2] Input parton distributions are those of the MRS-D0 (1993). In the $(\bar{u} - \bar{d})_N = 0$ case, $\Delta = 0$ is taken in the MRS-D0 distributions. Obtained results are shown in Fig. 1, where the solid curve shows recombination contributions to $\bar{u} - \bar{d}$ (per nucleon) in the tungsten nucleus, and the dashed curve shows the result in the $(\bar{u}-\bar{d})_N \neq 0$ case.

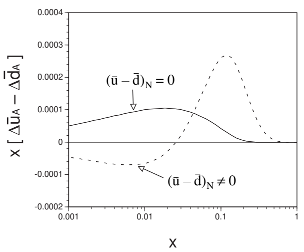

Figure 1: Recombination contributions to $\bar{u} - \bar{d}$ in the tungsten nucleus.

We briefly comment on Q^2 dependence of our calculation. Because the recombinations are higher-twist effects, there is a Q^2 dependent factor $\alpha_s(Q^2)/Q^2$ in the contributions. It may seem to be very large at small Q^2; however, parton distributions $p(x, Q^2)$ are also modified. As a consequence, the overall Q^2 dependence is not so significant. According to our estimate, there are merely factor-of-two differences between the asymmetric distribution at Q^2=4 GeV^2 and the one at $Q^2 \approx 1$ GeV^2. Considering this factor of two, we find that the nuclear modification is of the order of 2%–10% compared with the asymmetry suggested by the NMC.

Although our estimate is based on a special model, the results indicate roughly several % nuclear modification in the $\bar{u} - \bar{d}$ distribution of the tungsten nucleus. Therefore, the existing tungsten Drell-Yan data should not be compared with the NMC flavor asymmetry within several % magnitude. On the other hand, the modification itself is an interesting topic for future theoretical and experimental studies.

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