IU/NTC 92–02

January 15, 1992

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IU-NTC-92-02

"Local" EMC Effects and the J/ψ Suppression

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Talk given at the workshop on Gross Properties of Nuclei and Nuclear Excitations, Hirschegg, Austria, January 20-25, 1992.

* research supported in part by the U.S. National Science Foundation under contract NSF-PHY91-08036. Bitnet address: KUMANO@IUCF.

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Abstract

We investigate a dependence of the "old" EMC effect on nuclear structure, namely the dependence on the location of the struck quark within a nucleus ("local" EMC effect). Using the rescaling model and the nuclear binding model, we find that scattering from a central or deeply bound constituent gives a larger EMC effect than scattering from a surface or weakly bound constituent. Central and surface gluon distributions, which are important in the J/ψ suppression, are investigated by using the parton recombination model and the Q^2 rescaling model. We find that such initial condition effects on the J/ψ suppression are of the order of 5−10% and that a calculated p_T slope for the J/ψ is smaller than the observed by NA38.

This talk is based on the research done with F. E. Close.[1,2] At first, we discuss local EMC effect for quarks by using the nuclear binding and the Q^2 rescaling models. Next, local gluonic EMC effect and its contribution to the J/ψ suppression are discussed. Because the gluonic EMC part is still in progress, we simply outline what has been studied. A paper explaining details of our analysis will be written in the near future.[2]

The "old" EMC effect is the experimental finding that the quark momentum distributions in nuclei differ from those in free nucleons. Most discussions have been concentrated on the EMC effect averaged over an entire nucleus (we shall refer to this as the "global" EMC effect), as the EMC data do not identify where in the nucleus the struck quark resided. However, it may be possible to learn this in more refined experiments and measure interesting "central" and "surface" EMC effects which we shall call "local" EMC effects. In nuclear physics, we can investigate the momentum distribution of a nucleon bound in a nucleus by the (e,e'p) experiment. In the same way, it is possible that the EMC effect varies with the initial conditions of the struck nucleon (or quark), depending on how strongly it is bound or where it is located.

We analyze the local EMC effects for the ^{19}F nucleus by two different models, the rescaling model and the nuclear binding model. We do not pass judgment on these models, but take them as defined in the literature and then study their local dependences. In order to evaluate structure functions, we need a reasonable nuclear model for the ^{19}F nucleus, and we choose a density-dependent Hartree-Fock method. In both rescaling and binding models, the results show that the EMC effect is larger for

the scattering from a central constituent (localized mainly in the interior) than that from a surface constituent.[1] In the rescaling model, the local EMC effect could be explained as follows. The 1s nucleon overlap probability with other nucleons is larger than the 1d nucleon overlap and thus gives rise to a larger confinement radius for the 1s nucleon than that for the 1d nucleon. The resulting effective confinement radii are λ_A/λ_N=1.14 (for 1s nucleon), 1.11 (1p), and 1.08 (1d); hence, the confinement radius for a central quark is larger than that for a surface quark by approximately 6%. It is interesting that these differences in the nucleon size could be observed by accurate (e,e'p) experiments.[3] It is obvious that the medium-x region depression is larger for the 1s nucleon because the binding energy is larger, for example, the single-particle energies for neutrons are ε_n=−31.6 MeV (1s), −18.9 (1p), and −5.4 (1d). Another interesting piece of physics is that the nucleon Fermi motion is larger for a surface nucleon, for example, the r.m.s. momenta are $\sqrt{< p^2 >}$=210 MeV (1d), 179 (1p), and 135 (1s).

The E745 collaboration[4] has classified their experimental results into two categories depending on dark tracks they observed. According to their explanation, the events with (without) a dark track came from a neutrino interaction with central (surface) nucleons. However, BEBC experimental data[5] showed that such effects also exist for the hydrogen target. Therefore, the effects observed by E745 are mostly not the local EMC effect.[6] We need more refined experiments for finding the local effect.

Next, we investigate local EMC effect for gluons and its relation to the J/ψ suppression phenomena.[2]

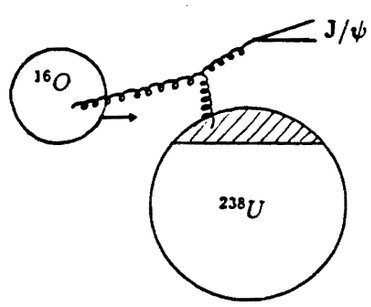

Fig.1a low E_T events (surface gluon).

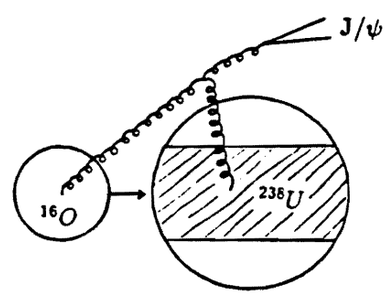

Fig.1b high E_T events (central gluon).

The NA38 Collaboration observed suppressions of the J/ψ production relative to the Drell-Yan continuum in O-U collisions at CERN.[7] These experimental results are important in the sense that the suppression may provide a signature of quark-gluon plasma.[8] Although there are other theoretical models for explaining the suppression, effects of initial conditions on the suppression have not been well investigated.[9] We

should note that the suppression is observed in the high E_T region, which is considered to be events for the central collisions. In a quark-parton picture, this separation of the initial condition by E_T corresponds to a separation of initial gluon distributions into the central and surface gluon distributions (as shown in Figs. 1a and 1b). The gluon distribution has been investigated so far as an averaged distribution in nuclei, and there is no investigation on such "local" gluon distributions as far as the author knows. Because the local gluonic effect could be essential for the J/ψ suppression, we cannot determine whether or not the quark-gluon plasma is formed unless we know the initial gluon distributions. We address this issue in this investigation.

Gluon distribution in the nucleon can be obtained, for example, by scaling violations of the structure function $F_2(x)$ and by analyzing data of direct photon productions in p+p interactions. However, little is known about gluon distributions in nuclei (gluonic EMC effect) and they will be interesting physics in the near future. Due to the lack of experimental data for the gluonic EMC effect, our investigation is inevitably speculative. We simply try to estimate contributions of the local gluonic EMC effect on the J/ψ suppression by using a reasonable model which can explain the EMC effect for quarks. We modify the Q^2 rescaling model by using a parton recombination idea[10] so that the model can explain existing data for $F_2(x)$. The parton recombination model was proposed as a model for explaining $F_2(x)$ in the very small x region (shadowing region), but it also changes the gluon distribution significantly. Comparisons with experimental data, such as those by the NMC, show that the recombination model explains $F_2(x)$ in the small x region reasonably well. The mechanism also produces distributions at $x > 1$; therefore, it could explain the EMC effect at large x region (so called "Fermi motion" part). If the recombination model is combined with the Q^2 rescaling model, quark distributions in nuclei are explained in the whole x range. We use rescaling parameters (ξ_O and ξ_U) obtained by fitting SLAC $F_2(x)$ data (^{12}C and ^{197}Au) for ^{16}O and ^{238}U. We use the Q^2 rescaling model modified by the recombination mechanism for investigating the gluonic EMC effect in ^{238}U.

For investigating central and surface effects in ^{238}U, density distributions obtained by using a simple density-dependent Hartree-Fock method are shown in Fig. 2. Because the 1s (1i) nucleon is located mainly in the central (surface) region of the nucleus, we could study central and surface gluon distributions by using these wave functions. Although this is a very simplified central and surface separation, it is enough for a rough estimate for the J/ψ suppression.

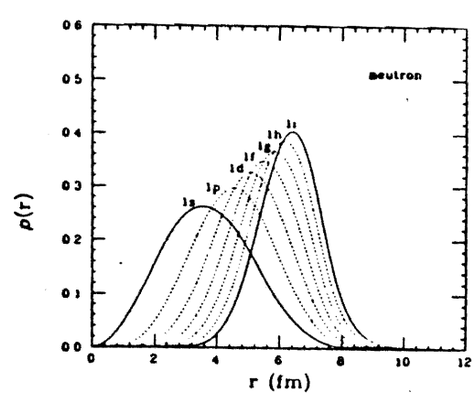

Fig. 2 Density distributions in ^{238}U.

We investigate two possible mechanisms for producing local gluonic EMC effects in ^{238}U. The first one is the local Q^2 rescaling effect, which was discussed in this paper. The other is to modify the recombination strength K. Because the two-nucleon overlap probability (V_A) is large in the central region, the parton recombination probability is also expected to be large. We calculate the overlap probability of the 1s (1i) nucleon with surrounding nucleons, then modify the recombination constant to $K \cdot V_A(1s \ or \ 1p)/ < V_A >$. The overlap probability for the 1s (1i) nucleon is 24% larger (12% smaller) than the averaged one over all nucleons in the nucleus. Using these models, we obtain central and surface gluon distributions in ^{238}U as shown in Figs. 3a and 3b. We find that the gluonic EMC effect obtained by the local Q^2 rescaling is larger in the central region; however, the local recombination mechanism produces opposite results.

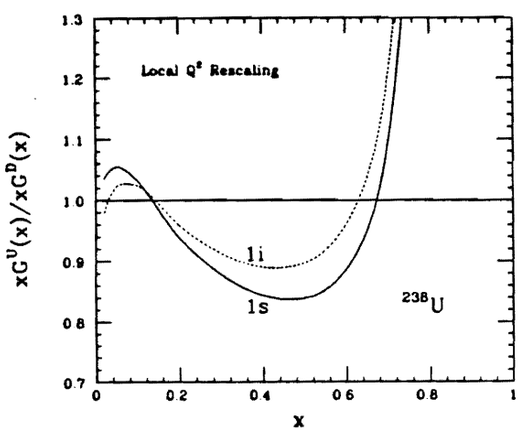

Fig.3a "Local" Q^2 rescaling.

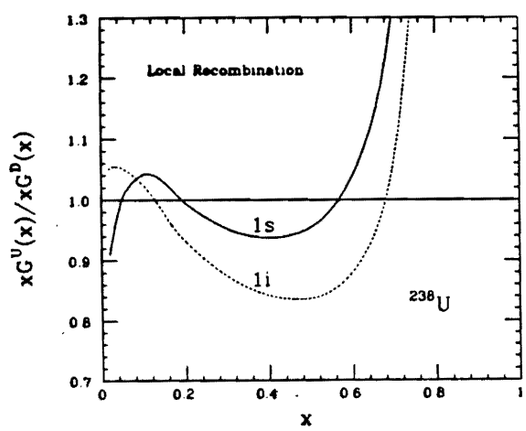

Fig.3b "Local" parton recombination.

P_T distributions of J/ψ are calculated by using the above two local mechanisms. By taking a ratio $d\sigma(high \ E_T : O + U \rightarrow J/\psi + X)/d\sigma(low \ E_T : O + U \rightarrow J/\psi + X)$, we find that the local Q^2 rescaling mechanism produces a very small negative p_T slope, which is different from the observed slope by NA38. On the other hand, the local recombination mechanism produces a positive p_T slope. However, the slope is smaller than the observed one. Comparisons of the J/ψ cross sections with the $\mu^+\mu^-$ indicate that contributions of the local gluonic EMC effect to the J/ψ suppression are of the order of 5−10%.

This research was supported by NSF under Contract No. NSF-PHY91-08036. The author thanks organizers for financial support for attending this workshop. The author acknowledges Drs. R. K. Ellis, R. G. Roberts, and A. S. Umar for providing their computer codes.

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