Statistical model approach for EMC effect at low Q^2

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Introduction

The quarks momentum distributions are evaluated in nuclear medium Gold as a function of Nachtmann variable 'ξ' in the resonance region $1.2 < W^2 < 3\text{GeV}^2$ and also $Q^2 < 5\text{GeV}^2$ using the phenomenological model of statistical distribution known as the Thermodynamical Bag Model (TBM). The results of Gold from our measurements are compared with J Lab E89-008 data taken in the above resonance region.

DIS and Resonance regions

In general in the Deep Inelastic Region (DIS) region, where the final square of the invariant hadronic mass W is given by $W^2 > 3\text{GeV}^2$, the Q^2 dependence of the structure functions is predicted by pQCD. The additional scaling violations, target mass corrections and also higher twist effects are said to occur at lower Q^2 and W^2 values. Hence data initially in the resonance region would not innocently be expected to have the same EMC effect as that of the DIS region. As the resonance involves instant excited states, the effect of nuclear medium on these immediate nuclear excitations becomes significant compared to DIS region. Inside the nuclear environment though the resonance production shows different effects, a deeper connection between DIS and resonance regions cannot be ruled out. But EMC effect [1-2] still remains a fascinating and mysterious one. In this study, we concentrate on EMC effect in resonance region to compare with the series of electron scattering experiments in Hall C at J Lab.

Thermodynamical Bag Model [TBM]

TBM as a modified form of MIT Bag model treats the quarks and gluons as fermions and bosons respectively. By treating the thermodynamical bag as an unpolarized nucleon and restricting the consideration to u and d valence quarks, the equation [3-5] defining quarks is

$$q(x) = \left(\frac{6V}{4\pi^2}\right)M^2 Tx.\ln[1 + \exp\{(\frac{1}{T})(\mu_q - \frac{Mx}{2})\}] \quad (1)$$

and the antiquark distribution isobtained by changing μ_q to $-\mu_q$ where V is the volume of the bag, B the bag constant, M the mass of the nucleon and ν the energy transfer, and μ_q is the chemical potential. In the parton model, the distribution function of the quark momenta is denoted by $q_i(x)$ and that of antiquarks by $\bar{q}_i(x)$. Instead of parameterized structure function F_2, we use the sum of the momentum distributions weighted by x and z_i^2 and hence

$$F_2(x) = x\sum_i z_i^2[q_i(x) + \bar{q}_i(x)] \quad (2)$$

In the convolution model, the calculation of the nuclear structure function $F_2^A(x)$ which describes the influence of the nucleon binding energy and Fermi motion is provided by

$$F_2^A(x) = \int f^A(z)F_2^N(x/z)dz \quad (3)$$

where $f^A(z)$ describes the momentum and energy distribution of nucleons and F_2^N is for single nucleon structure function. For the description of $F_2^D(x/z)$ in terms of quark degrees of freedom, the distance scale x is modified to the rescaling variable x/z, which increases with mass number A. In order to calculate the effect of nuclear binding on the structure function, the momentum spectrum of the target nucleons has to be evaluated. In the simple Fermi gas model, the momentum distribution ($3/4\pi k_f$) is constant up to the maximum Fermi momentum k_f and is zero above k_f. The momentum distribution inside the nucleus within the Fermi momentum can be written as

$$f^A(z) = (3/4)(M/k_f)^3[(k_f/M)^2 - (z-\eta)^2] \quad \text{for } -k_f < z < +k_f \tag{4}$$

and $f^A(z) = 0$ otherwise. Also $f^A(z)$ is maximum at $z = x/\eta$ and this leads to the observed depletion at medium x as observed by the EMC effect. Using (3), (4) and (5) the structure function ratio of gold to deuterium is obtained for the resonance region $1.2 < W^2 < 3.0\ GeV^2$ and $Q^2 < 5GeV^2$ as

$$\frac{F_2^A}{F_2^D} = \frac{\int f^A(z) F_2^N(x/z)dz}{F_2^D(x)} \tag{5}$$

The EMC ratio of nuclear medium to Deuterium is evaluated as a function of Nachtmann variable ξ defined by

$\xi = 2x/(1+\sqrt{1+4M^2x^2/Q^2})$.

Results and Discussion

The structure function ratio measurements in the cases of Gold to Deuterium as a function of Nachtmann variable ξ especially in the resonance region $1.2 < W^2 < 3.0\ GeV^2$ where $W^2 > 1.2GeV^2$ exclude quasielastic peak region and $Q^2 < 5GeV^2$ is studied using TBM and the results are compared with J Lab data [6-7] and are shown in Fig. 1. The available Hall C at J Lab data are from lower invariant mass W, and therefore higher x. The difference between ξ and x is often ignored at low x, but cannot be ignored at large x or low Q^2. At finite Q^2 the use of ξ reduces scaling violations related to target mass corrections. Coulomb corrections were applied in the J Lab data. The agreement of our measurements with J Lab data is observed. The extraction of nuclear dependence of structure functions and hence EMC effect in the resonance region is theoretically verified. The crossover point, where the structure function ratios become larger than unity, occurs at larger ξ for Gold. At large ξ the EMC effect is dominated by Fermi motion. This is consistent with J Lab and DIS SLAC data. Slight deviation in Au may be attributed to the deviation from isoscalar configuration.

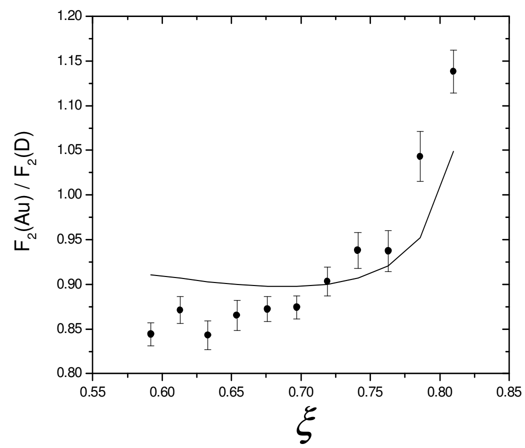

Fig. 1 Structure function ratio measurements compared to J Lab data.

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