NUCLEAR TRANSPARENCY FROM QUASIELASTIC A(E,E′P) REACTIONS UP TO $Q^2 = 8.1$ (GEV/C)^2.

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The quasielastic (e,e′p) reaction was studied on targets of deuterium, carbon, and iron up to a value of momentum transfer Q^2 of 8.1 (GeV/c)^2. A nuclear transparency was determined by comparing the data to calculations in the Plane-Wave Impulse Approximation. The dependence of the nuclear transparency on Q^2 and the mass number A was investigated in a search for the onset of the Color Transparency phenomenon. We find no evidence for the onset of Color Transparency within our range of Q^2.

Under certain conditions it is possible to select hadrons which consist of their minimal Fock space components. Large four momentum transfer reactions are expected to select these point-like configurations. Mueller and Brodsky [1] conjectured these small transverse size quark configurations would posses a small color dipole moment and thereby interact weakly with the nuclear medium leading to an increase of the nuclear transparency. This effect has become to be known as Color Transparency (CT). A similar phenomenon occurs in QED where an e^+e^- pair of small size has a small cross section determined by its electric dipole moment [2]. In QCD, a $q\bar{q}$ or qqq system can act as an analogous small color dipole moment

Originally the onset of nuclear transparency above that predicted by Glauber calculations, CT, was thought to indicate that one is approaching the asymptotic limit where perturbative QCD calculations become applicable. However it has been demonstrated [3] that a large increase in the pion transparency in nuclei can result from using nonperturbative pion distribution amplitudes. Although the observation of CT can not unambiguously indicate that one is in the perturbative regime it's observation is required as a necessary but not sufficient condition for the applicability of factorization [4]. Factorization theorems are intrinsically related to the access to Generalized Parton Distributions (GPD's), introduced by Ji and Radyushkin [5,6].

The transparency of the nuclear medium to high energy protons in quasielastic A(p,2p) measured at Brookhaven [7,8] has shown a rise consistent with CT for $Q^2 \simeq 3$ - 8 (GeV/c)^2, but decreases at higher momentum transfer. Two explanations for the surprising behavior were given: Ralston and Pire [9] proposed that the interference between short and long distance amplitudes in the free p-p cross section was responsible for these energy oscillations, where the nuclear medium acts as a filter for the long distance amplitudes. Brodsky and De Teramond [10] argued that the unexpected decrease could be related to the crossing of the open-charm threshold.

For the case of the quasielastic A(e,e$'$p) reaction the cross section is given in the non-relativistic plane-wave impulse approximation (PWIA) as

$$\frac{d^6\sigma}{dE_{e'}d\Omega_{e'}dE_{p'}d\Omega_{p'}} = K\sigma_{ep}S(E_m, \vec{p}_m), \tag{1}$$

where $dE_{e'}, d\Omega_{e'}, dE_{p'}$ and $d\Omega_{p'}$ are the phase space factors of the electron and proton, $K = |\vec{p}_{p'}|E_{p'}$ is a known kinematical factor, and σ_{ep} is the off-shell electron-proton cross section. The spectral function $S(E_m, \vec{p}_m)$ is defined as the joint probability of finding a proton of momentum $\vec{p}_m$ and separation energy E_m within the nucleus.

The definition of the transparency ratio is the ratio of the cross section measured in a nuclear target to the cross section for (e,e$'$p) scattering in PWIA. Numerically this ratio can be written as

$$T(Q^2) = \frac{\int_V d^3p_m dE_m Y_{exp}(E_m, \vec{p}_m)}{\int_V d^3p_m dE_m Y_{PWIA}(E_m, \vec{p}_m)}, \tag{2}$$

where the integral is over the phase space V defined by the cuts $E_m < 80$ MeV and $|\vec{p}_m| < 300$ MeV/c, $Y_{exp}(E_m, \vec{p}_m)$ and $Y_{PWIA}(E_m, \vec{p}_m)$ are the corresponding experimental and simulation yields.

The measured transparency $T(Q^2)$ values from this (large solid symbols) and previous work are presented in Fig. 1. The errors shown include statistical and systematic uncertainties, but do not include model-dependent systematic uncertainties in the spectral functions and correlation corrections used in the simulations. This is the same as for the data of Ref. 11 (small solid symbols). Data from previous experiments [12,13,14] (represented by open symbols) include the full uncertainty. The present results for carbon and iron are of similarly high precision as those of Ref. 11, and of substantially higher precision than of Refs. 12,13,14. Clearly the new data for deuterium, carbon and iron, for Q^2 greater then ≈ 2 (GeV/c)^2, show no marked increase in the transparency ratio which could be interpreted as a signal for CT. Excellent constant-value fits can be obtained for the various transparency results above such Q^2. For deuterium, carbon, and iron fit values are obtained of 0.904 ($\pm$ 0.013), 0.570 ($\pm$ 0.008), and 0.403 ($\pm$ 0.008), with χ^2 per degree of freedom of 0.56, 1.29, and 1.17, respectively.

Alternatively one can analyze the A-dependence of the transparency ratio. Figure 2 shows T as a function of A. The curves represent empirical fits of the form $T = cA^{\alpha(Q^2)}$, using the deuterium, carbon, and iron data. We find,

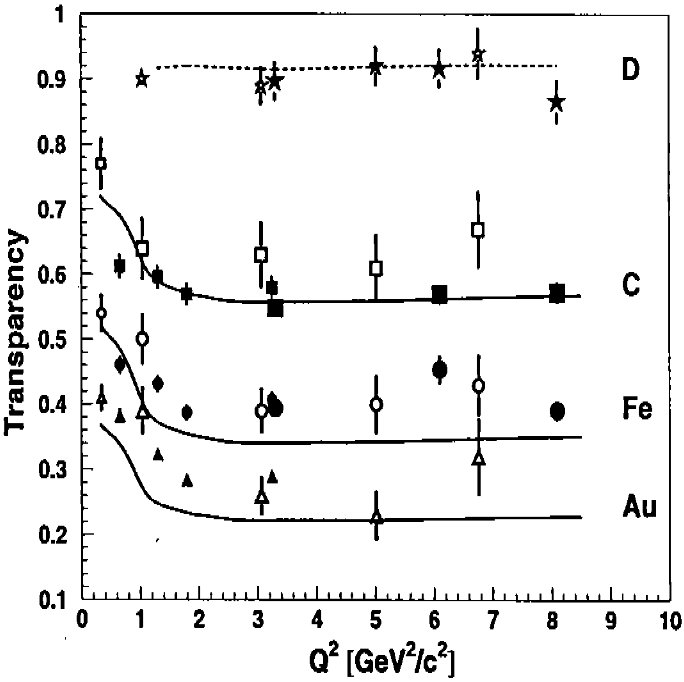

Figure 1. Transparency for (e,e′p) quasielastic scattering from D (stars), C (squares), Fe (circles), and Au (triangles). Data from the present work are the large solid stars, squares, and circles, respectively. Previous JLab data (small solid squares, circles, and triangles) are from Ref. 11 . Previous SLAC data (large open symbols) are from Refs. 12,13. Previous Bates data (small open symbols) at the lowest Q^2 on C, Ni, and Ta targets, respectively, are from Ref. 14. The errors shown include statistical and systematic ($\pm$ 2.3%) uncertainties, but do not include model-dependent systematic uncertainties on the simulations. The solid curves shown from $0.2 < Q^2 < 8.5$ $(\mathrm{GeV/c})^2$ are Glauber calculations from Ref. 15. In the case of D, the dashed curve is a Glauber calculation from Ref. 16.

within uncertainties, the constant c to be consistent with unity as expected and the constant α to exhibit no Q^2 dependence up to $Q^2 = 8.1$ $(\mathrm{GeV/c})^2$.

Clearly a discrepancy exist between the A(p,2p) and A(e,e′p) measurements. The proposed explanation of Ralston and Pire [9], that the nuclear medium A eliminates the long distance amplitudes in the A(p,2p) case, might resolve the apparent discrepancy between the A(e,e′p) and A(p,2p) results. In light of the ambiguity in the existing proton data it is hoped that an upcoming pion transparency [17] measurement will help our understanding of the transparency of hadrons in nuclei.

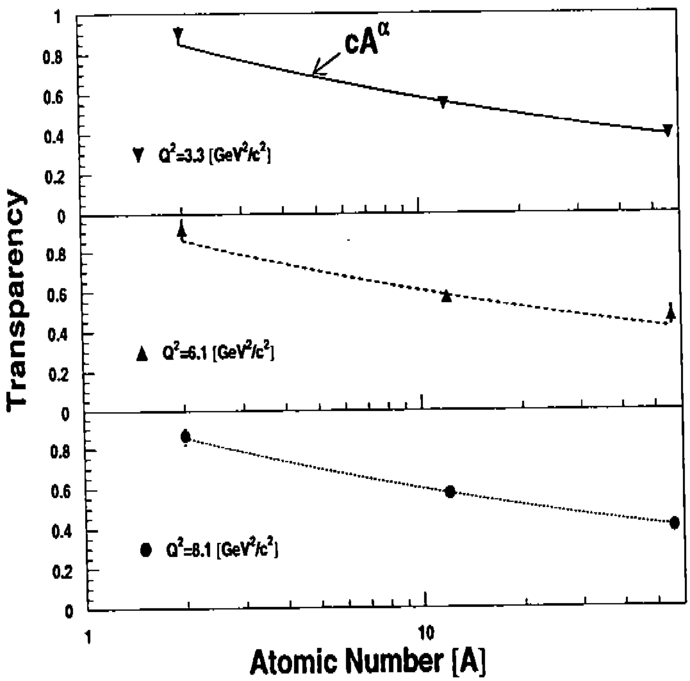

Figure 2. Nuclear Transparency as a function of A at $Q^2 = 3.3$, 6.1, and 8.1 $(\text{GeV/c})^2$ (top to bottom). The curves are fits to the D, C, and Fe data using $T = cA^{\alpha}$.

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