Studies of Color Transparency using the (e,e′p) Reaction

R. Ent
Jefferson Lab

The Color Transparency (CT) conjecture by Mueller and Brodsky [1] has stimulated great interest. CT was first discussed in terms of perturbative QCD considerations. However, later work [2] indicates that this phenomenon occurs in a wide variety of model calculations with nonperturbative reaction mechanisms. The existence of CT requires that high momentum transfer scattering should take place via selection of amplitudes in the initial and final state hadrons characterized by a small transverse size. Secondly, this small object should be 'color neutral' outside of this small radius in order not to radiate gluons. Finally, this compact size must be maintained for some distance in traversing the nuclear medium. Unambiguous observation of CT would provide a new means to study the strong interaction in nuclei.

Experimentally, measurements of the transparency of the nuclear medium to high energy protons in quasielastic A(p,2p) and A(e,e'p) and to ρ mesons have been carried out over the last several years. The nuclear transparency measured in A(p,2p) at Brookhaven [3] has shown a rise consistent with CT but decreases at higher momentum transfer. The NE-18 A(e,e'p) measurements at SLAC [4] yield distributions in missing energy and momentum completely consistent with conventional nuclear physics predictions and the extracted transparencies exclude sizable CT effects up to $Q^2 = 7$ (GeV/c)^2. These data, Bates data from Ref. [5], and the recent high-precision data from JLab experiment E91-013 (measured up to $Q^2 = 3.3$ (GeV/c)^2) [6] are shown in Fig. 1. At Fermilab the nuclear transparencies have been measured [7] in exclusive incoherent ρ^0 meson production from nuclei. Increases in the nuclear transparencies have been observed as the virtuality of the photon increases, as expected from CT. At DESY the HERMES collaboration has recently measured exclusive incoherent ρ^0 meson production off ^{3}He and ^{14}N [8].

JLab has several advantages to offer in searching for CT effects in quasielastic A(e,e'p) measurements. Data from experiments NE18 at SLAC

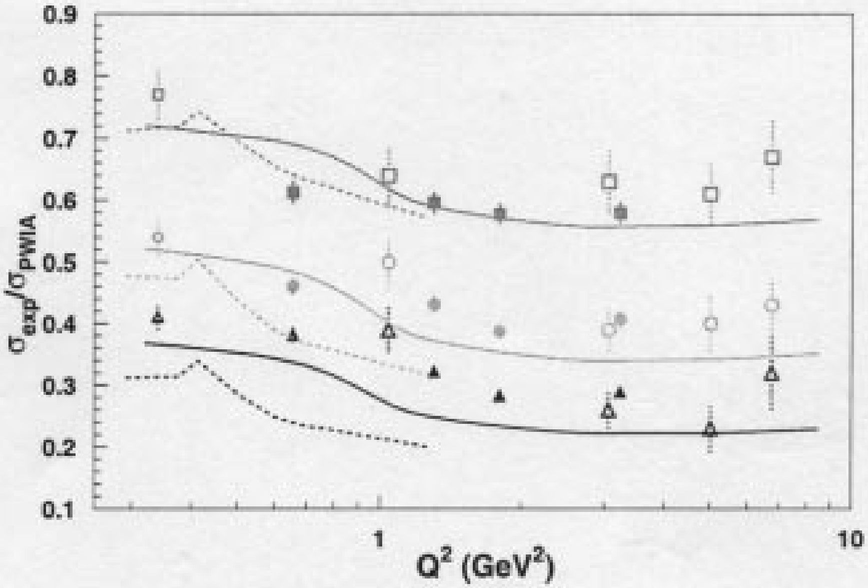

Fig. 1. Nuclear transparencies determined from measurements of quasielastic A(e,e'p) scattering as a function of Q^2 as measured at Bates (small open symbols) [5], SLAC (large open symbols) [4] and JLab (solid symbols) [6]. C (squares), Fe (circles), and Au (triangles) targets were used for the SLAC and JLab experiments, the Bates experiment used Ni and Ta targets instead of Fe and Au targets. The dashed curves are Distorted-Wave Impulse Approximation calculations [9] and the solid curves are Glauber calculations [10].

and E91-013 and E91-007 at JLab will provide a baseline for conventional Glauber calculations; the fundamental electron-proton scattering cross-section is smoothly varying and accurately known in this kinematic range; the high duty factor, the high luminosity, the large solid angle high momentum Hall C spectrometers and the high missing energy resolution all contribute to making high quality, precision measurements feasible. In particular, the high missing energy resolution at high Q^2 will provide an unprecedented opportunity to study the dependence of the nuclear transparency on the initial proton state. As the beam energy at JLab increases the momentum transfer accessible also rises. Presently E91-007 and its extension are on the preliminary Spring 1999 Hall C schedule for running at beam energies up to 5.5 GeV. We intend to per-

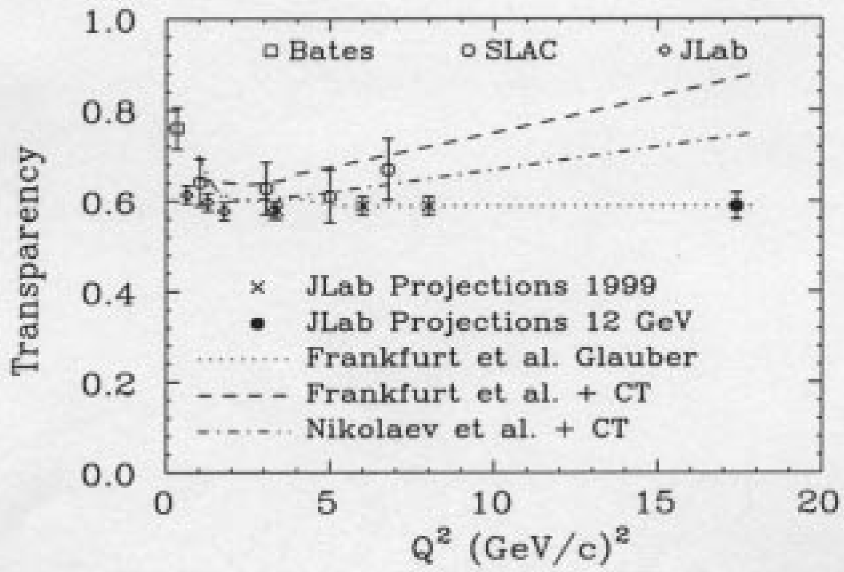

Fig. 2. The projected uncertainty for E91-007 (crosses) and for a 12 GeV experiment (solid circle) in the nuclear transparency measurements of quasielastic $^{12}C(e,e'p)$ scattering at JLab, compared with existing data.

form measurements at Q^2 of 3.4, 6.0 and 8.0 $(GeV/c)^2$. A higher value of Q^2 would preclude measurements at both sides of the momentum transfer vector, with the present Hall C setup. Fig. 1 shows that the Q-dependence of the present transparency data is reasonably described by correlated Glauber calculations [10]. However, both the Glauber calculations [10] and the Distorted-Wave Impulse Approximation calculations [9] have a problem reproducing the A-dependence of the transparencies. This has to be understood before we can draw any definite conclusions on CT from future data.

Upgrade to a 12 GeV beam energy would allow measurements at even higher momentum transfers. Assuming a Super-High Momentum Spectrometer (SHMS) with a maximum momentum of 12 GeV/c, a minimum scattering angle of 5.5°, and a solid angle of about 3 msr, in combination with the HMS spectrometer in Hall C, a momentum transfer of about 20 $(GeV/c)^2$ could be obtained. However, realistically the highest obtainable momentum transfer is limited by statistics. In Fig. 2 we show the projected uncertainties for the E91-007 experiment scheduled to run in 1999, in combination with the projected uncertainty assuming a beam energy of 12 GeV and the HMS-SHMS combination, for the ^{12}C(e,e'p) reaction. The projected uncertainty for the 12 GeV point assumes a data taking period of 80 hours. As shown in Fig. 2 such a precise data set will allow us to distinguish between conventional Glauber calculations and state-of-the-art CT predictions of Nikolaev et al. [11] and Frankfurt et al. [12].

References

[1] A.H.Mueller, in Proceedings of the Seventeenth Recontre de Moriond Conference on Elementary Particel Physics, Les Arcs, France, 1982, edited by J. Tran Thanh Van (Editions Frontieres, Gif-sur-Yvette, France,1982); S.J.Brodsky, in Proceedings of the Thirteenth International Symposium on Multiparticle Dynamics, Volendam, The Netherlands, 1982, edited by W. Kittel et al. (World Scientific, Singapore, 1983).

[2] L. Frankfurt, G.A. Miller, and M. Strikman, Comments Nucl. Part. Phys., **21**, 1 (1992).

[3] A.S. Carroll et al., Phys. Rev. Lett. **61**, 1698 (1988).

[4] N.C.R. Makins et al., Phys. Rev. Lett. **72**, 1986 (1994); T.G. O'Neill et al., Phys. Lett. B **351**, 87 (1995).

[5] G. Garino et al., Phys. Rev. C **45**, 780 (1992).

[6] D. Abbott et al., Phys. Rev. Lett. **80**, 5072 (1998).

[7] M.R. Adams et al., Phys. Rev. Lett. **74**, 1525 (1995).

[8] HERMES collaboration, private communications.

[9] J.J. Kelly, Phys. Rev. C **54**, 2547 (1996).

[10] H. Gao, V.R. Pandharipande and S.C. Pieper, private communication; V.R. Pandharipande and S.C. Pieper, Phys. Rev. C **45**, 791 (1992).

[11] N.N. Nikolaev et al., Phys. Rev. C **50**, R1296 (1994).

[12] L.I. Frankfurt et al., in Workshop on 'CEBAF at Higher Energies', Eds. N. Isgur and P. Stoler, Conf. Proc. p. 499 (1994).