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Polarization Transfer in Inelastic Scattering and Pionic Models of the EMC Effect

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It is now well established from deep-inelastic lepton scattering experiments[1,2] that the F_2 quark structure function of nucleons bound in nuclei differs from that of free nucleons. Attempts to understand this result, now termed the EMC (European Muon Collaboration) effect, have inspired numerous theoretical papers in the past two years.[3] These theoretical efforts may be classified roughly in two different categories: those which invoke some new quark-level physics in nuclei, and those which attribute the EMC effect to excess nuclear pions-a "conventional" many-body enhancement employing meson, nucleon, and isobar degrees-of-freedom, and hence not requiring new quark effects in nuclei.[4-7] Models of the first type typically contain parameters which allow one to obtain the EMC effect through quark-level mechanisms --the magnitude of this mechanism usually remains to be explained. The enhanced pion field calculation, on the other hand, can be done with no free parameters.

The aim of the Los Alamos experiment was to make a precise test of the enhanced pion field model in a medium-energy scattering experiment. For energies near 500 MeV, the nuclear distance scale probed actually allows one to explore the distributions of nucleons and pions rather than those of quarks. The quantity probed is the spin-longitudinal ($\vec{\sigma}\cdot\vec{q}$) response function, $R_L(q,\omega)$, a measure of the nuclear pion density which is used explicitly in the pion-excess models of the EMC effect. There are two features which set our experiment apart from others which have used the nucleon as a probe of pionic effects. First, as in the EMC experiment, our point of reference is deuterium. We compare the spin-dependent response functions for heavy targets and ^2H using identical experimental techniques. If the predicted many-body effects are present, even at a very small level, they should be detectable in a precise ratio experiment. Second, we use the technique of complete polarization transfer to separate the spin-longitudinal ($\vec{\sigma}\cdot\vec{q}$) and spin-transverse ($\vec{\sigma}\times\vec{q}$) response in the continuum as a function of ω. The responses are measured at a momentum transfer $q = 1.75\ \mathrm{fm}^{-1}$ which corresponds to the maximum predicted enhancement of $R_L(q,\omega)$.

The experiment consisted of precise determinations of the polarization transfer coefficients D_{LL}, D_{SS}, and D_{NN} for 500 MeV protons inelastically scattered from Pb, Ca, and ^2H at $q = 1.75\ \mathrm{fm}^{-1}$. The experiment utilized longitudinal (L), sideways (S), and normal (N) polarized beams from LAMPF in conjunction with final polarization analysis from the focal-plane polarimeter of the high-resolution spectrometer. The quantities constructed from the above data are the longitudinal and transverse spin-flip probabilities, S_L and S_T respectively. With the assumptions detailed in Refs. 8 and 9 the appropriate combinations of heavy target (H) and deuterium quantities yield

$$(S_L^H/S_L^D)/(S_T^H/S_T^D) = R_L(q,\omega)/R_T(q,\omega) \quad , \tag{1}$$

where the longitudinal response functions on the right are for the heavy target. The results are shown in Fig. 1 along with calculations detailed below.

In order to evaluate the implications of our experiment for the pion-excess model of the EMC effect we have performed calculations of the ratio of eq. (1) and of the EMC effect with the same model. The response functions are generated in infinite nuclear matter using a mixture of π-exchange and g_0' for R_L and ρ-exchange and g_0' for R_T. The EMC effect calculations employ the same R_L using the techniques outlined by Stump, Bertsch and Pumplin.[6] For the (p,p′) experiments surface and isoscalar contributions are taken into account in a manner described in Refs. 8 and 9.

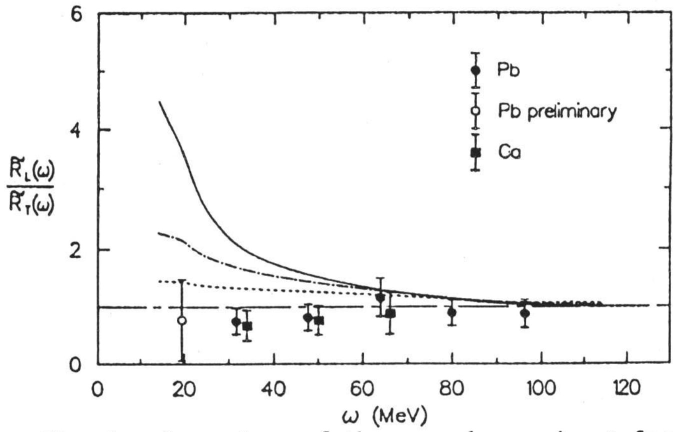

Fig. 1. Comparison of theory and experiment for the ratio R_L/R_T from 500 MeV proton scattering. The calculations are for values of $g_0' = 0.55$ (solid), $g_0' = 0.7$ (dash-dot), and $g_0' = 0.9$ (dotted).

Figures 1 and 2 display the results of these calculations for both experiments. It is clear that the Los Alamos experiment is inconsistent with a value of g_0' which is low enough to provide the ~15% pion excess required to explain the low-x EMC effect. Our experiment, in fact, favors the rather large value of g_0' which results from a consistent treatment of π and ρ exchange in the presence of the repulsion from ω exchange.[10]

In summary we find no evidence for collectivity in the isovector spin-longitudinal response function. On the basis of our best analysis, excess nuclear pions are unlikely to be the dominant source of the low-x EMC effect. This, of course, leaves a variety of quark-level nuclear structure explanations of the EMC experiment--a more exciting prospect if one is after real evidence of quark physics in nuclear structure.

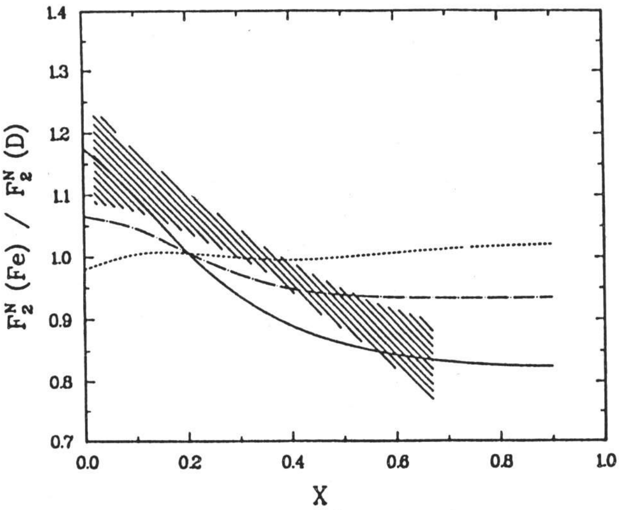

Fig. 2. Calculations of the EMC effect in pion-excess model. The values of g_0' used to calculate $R_L(q,\omega)$ are given in Fig. 1. The shaded region shows the error corridor of the EMC experiment.

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