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The Proton in the Nuclear Medium[1]

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Whether the nucleon changes its fundamental properties while embedded in nuclear medium has been a long-standing question in nuclear physics. Nucleons are composite objects of quarks and gluons, the degrees of freedom of the Quantum Chromodynamics (QCD) Lagrangian. Yet, because of the highly non-perturbative nature of the phenomena in the confinement region, there are no available calculations for nuclei within the QCD framework. Conventionally, nuclei are effectively and well described as clusters of nucleons held together by a strong, long-range force mediated by meson exchange. In the effective nuclear field theory, the interaction of an electromagnetic probe with a nucleon inside the nucleus is described by taking into account the presence of the nuclear medium. Conventional nuclear medium effects such as the nucleon being off-shell, meson-exchange currents, isobar configurations, and final-state interactions need to be incorporated as corrections to the impulse approximation picture. In this context, the question arises whether in the nuclear current operator free or nuclear medium modified form factors should be used. What are the effects of the nuclear medium on the sub-nucleon structure? Polarization transfer in quasi-elastic nucleon knockout is sensitive to the properties of the nucleon in the nuclear medium. In our recently completed experiment E03-104 at Jefferson Lab in Hall A we measured the proton recoil polarization in the $^4\mathrm{He}(\vec{e}, e'\vec{p})^3\mathrm{H}$ reaction at a Q^2 of 0.8 $(\mathrm{GeV}/c)^2$ and 1.3 $(\mathrm{GeV}/c)^2$ with unprecedented precision. These data complement earlier data between 0.4 and 2.6 $(\mathrm{GeV}/c)^2$ from both Mainz and Jefferson Lab. The measured ratio of polarization-transfer coefficients differs from a fully relativistic calculation, and is well described by either the inclusion of a medium modification of the proton form factors predicted by a quark-meson coupling model or strong charge-exchange final-state interactions. The measured induced polarizations agree well with the fully relativistic calculation and indicate that these strong final-state interactions may not be applicable.

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