Shrinking Hadrons

Protons and rho (ρ^0) mesons are composite particles made of quarks, bound together by a force so strong that individual quarks can never be observed in isolation. These tightly bound states of quarks, collectively referred to as hadrons, are manifestations of the color force mediated by gluons and described by quantum chromodynamics (QCD), the theory of strong interactions. When hadrons pass through a nucleus, they are strongly absorbed due to the interactions between the quarks of the hadron and those of the nucleus. However, QCD predicts the existence of exotic hadron-like configurations, which, under specific conditions, will pass through nuclear matter with dramatically reduced interaction. These configurations are of extremely small size and their interactions with the nucleus are suppressed because of the small spatial extent of their color field. This makes the nucleus appear more transparent and leads to the phenomenon known as color transparency (CT). Our results [1] represent the strongest evidence of CT phenomenon at low energy to date. Because of the simple reaction mechanism and high statistics of the measurements, we were able to observe (11 ± 2.3)% and (12.5 ± 4.1)% decrease in the absorption of the ρ^0 in the iron and carbon nuclei respectively, as the momentum transfer from the electron beam to the ρ^0 increases. This provides a clear signature that small-sized hadron-like states were created and propagate more freely through the nucleus during their extremely short lifetime (~10^{-24} second) before evolving into full-fledged ρ^0 mesons. The properties of the interaction of these exotic states with the nucleus vary as their color fields expand to those of a normal hadron. Establishing color transparency is a major step toward fully understanding the elusive role of the color field in nuclear physics, which is totally hidden in the interaction of ordinary hadrons. We anticipate that our findings will open new venues into studies of special configurations in the hadron wave function and how they dress with time to form its fully complex wave function.

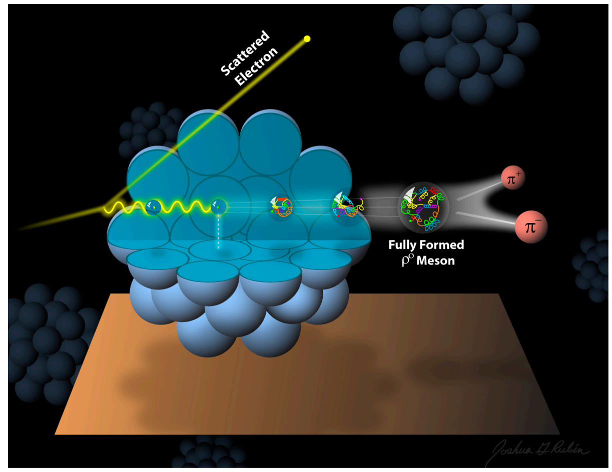

Figure 1: Illustration of the creation of a point-like configuration inside the nucleus and its evolution to a ρ^0 meson and later its decay to an oppositely charged pion pair.

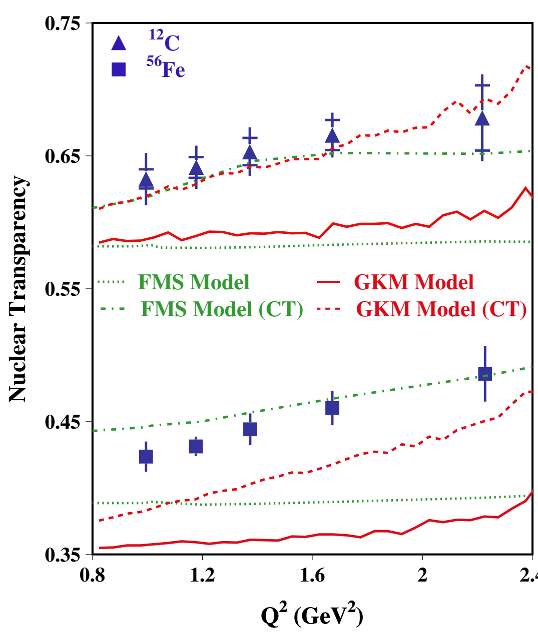

Figure 2: Nuclear transparency as a function of Q^2. The inner error bars are statistic uncertainties and the outer ones are statistic and point-to-point (Q^2 dependent) systematic uncertainties added in quadrature. The curves are predictions of the FMS [2] and GKM [3] models with (dashed-dotted and dashed curves, respectively) and without (dotted and solid curves, respectively) CT.

[1] L. El Fassi, K. Hafidi *et al.*, Phys.Lett. B **712**, 326 (2012).
[2] L. Frankfurt, G.A. Miller, and M. Strikman, Phys. Rev. C **78**:015208 (2008).
[3] K. Gallmeister, M. Kaskulov and U. Mosel, Phys. Rev. C **83**:015201 (2011).