Double Hadron Leptoproduction in the Nuclear Medium

When an electron (or its anti-particle, the positron) of sufficiently high energy is incident on a target, it interacts via the exchange of a virtual photon with one of the constituents of the nucleon: the quarks. After the quark has absorbed the photon, it has high energy, and begins to depart the target nucleon. However, it is an unique feature of the interaction between quarks, the "strong force", that it is not possible for a quark to exist in isolation. We can imagine that as a quark leaves a nucleon, a string is stretched between it and the remaining quarks. When the energy content of the string exceeds a certain threshold, the string breaks, creating a new quark (q) and anti-quark ($\bar{q}$) at the new ends of the string fragments. The quark from the $q\bar{q}$ pair combines with the remaining quarks, while the antiquark combines with the outgoing quark, resulting in the formation of a hadron. This process is also known as hadronization. Experimental information on the hadronization process and its space-time evolution, can be obtained by embedding the formation process in an atomic nucleus, which acts as an ensemble of targets. Specifically, quark propagation in the nuclear environment involves processes like multiple interactions with the surrounding medium resulting in energy loss of the quark. If the final hadron is formed inside the nucleus, the hadron can also interact with the nucleons via the relevant hadron-nucleon interaction cross section.

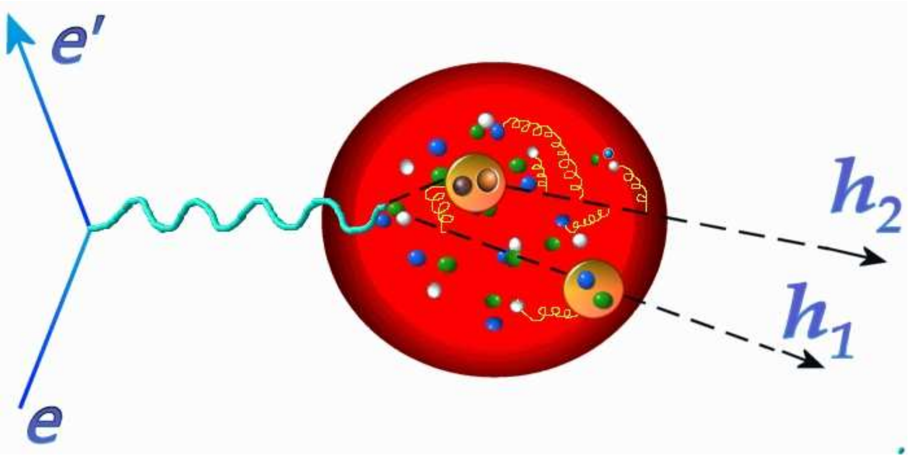

Figure 1: Pictorial view of two hadron production in electron scattering in a nucleus.

Despite recent accurate experimental results from HERMES about quark fragmentation to $\pi^{\pm}$, π^0, $K^{\pm}$, p and $\bar{p}$ in various nuclear targets ranging from deuterium to krypton, theoretical models that attempt to describe hadronization in the nuclear medium disagree on the relative contributions from the different underlying mechanisms. This uncertainty gives doubts for the interpretation of the results from heavy-ion experiments at RHIC (Brookhaven National Laboratory) which are looking for a new status of the matter: the quark-gluon plasma.

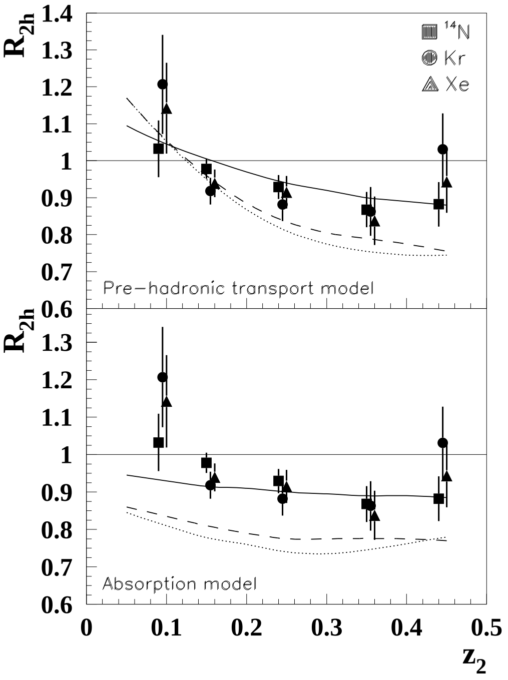

Figure 2: The ratio R_{2h} as a function of z_2, the fractional energy of the subleading hadron with respect to the virtual photon energy for ^{14}N (squares), Kr (circles) and Xe (triangles). The curves (^{14}N: solid; Kr: dashed; Xe: dotted) are from a pre-hadronic transport model (top panel) and for an absorption model (bottom panel).

In this paper a new observables (R_{2h}) has been measured. By the ratio of events with at least two hadrons to the events with at least one hadron, it is possible to study the correlation of the nuclear effects between hadrons produced in the same interaction but at different time and position in the nucleus. If the final hadron absorption (i.e. hadron-nucleon interaction) is the primary mechanism involved, R_{2h} is expected to decrease with the atomic mass number, since the effect on the two hadrons is uncorrelated. In other words, due to the fact that the second (subleading) hadron is formed more inside the nucleus, it must have more hadronic interactions with the nuclear matter than the first (leading) hadron. On the contrary, if the energy loss of the struck quark is the only mechanism involved, R_{2h} is expected to be only slightly dependent on the atomic mass number, since the effect on the two hadrons is correlated, as shown in Fig. 1.

The results obtained show that the nuclear effect in the double hadron process is much smaller than for the already published results on the single hadron suppression, moreover there is no significant difference for the behavior of R_{2h} between Nitrogen, Krypton and Xenon target, indicating a very weak or independence on the atomic mass number of the nuclear medium in which the hadronization is going on, as shown in Fig. 2.

In Fig. 2 also curves from model calculations are drawn. The upper panel shows calculations based on treatment of both energy loss and absorption in the medium. Although the general trend of the data is reproduced, the model predicts an effect twice as large for xenon and krypton as for nitrogen, which is not fully supported by the data. In the bottom panel the same data are compared with a calculation having the unique assumption of hadron interaction in the medium. Data seem to rule out this assumption.

Similarly to the jet correlation measurements in heavy-ion collisions, the double-hadron observables in semi-inclusive deep inelastic scattering provide new information for differentiating between models of hadronization in nuclei that are indistinguishable in single-hadron measurements.