1 Hadronization in Cold Nuclear Matter at HERMES

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The effects of the cold nuclear matter on the hadron production in semi-inclusive deep-inelastic scattering have been extensively studied by the HERMES experiment at DESY using a 27.6 GeV positron beam on internal gaseous targets of deuterium, helium, neon, krypton or xenon [1]. By using the very efficient particle identification of the HERMES spectrometer over the whole kinematic range of the interactions, the measurements have been performed for charged and neutral pions, for charged kaons and for protons and anti-protons. The available experimental data are usually presented as a function of one variable, integrating over the others within the experimental acceptance, in order to keep the statistical uncertainties at a reasonable level. Only in the case the multiplicity ratio for charged pions, positively charged kaons and proton, it was possible to perform a detailed binning over one variable and three slices in another one. Here we only show a few examples that highlights the observed effects. The dependence of the multiplicity ratio A/D, indicated as R_A^h, as a function of the virtual photon energy (ν) for three slices of the fractional virtual photon energy (z) carried by the produced hadron is shown in Fig. 1.

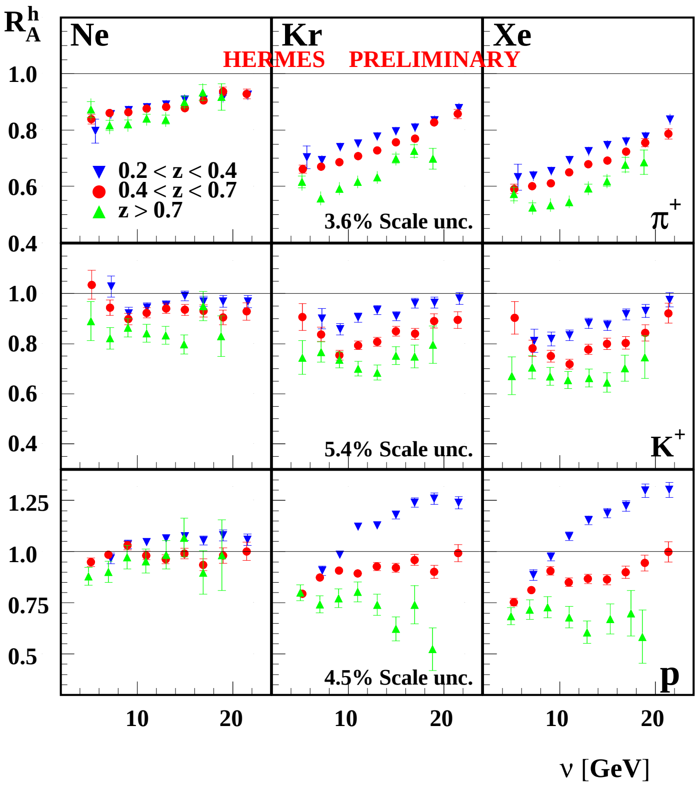

Figure 1: Dependence of R_A^h on ν for positively charged hadrons for three slices in z.

A very striking observation is the behaviour of R_A^h as a function of ν which indicates a clear attenuation at low ν values where the ratio is smaller than one and constantly increases indicating smaller nuclear effects for high energy transferred by the virtual photon. The results are similar for pions and kaons while they are very different for protons where knock-out processes from the target remnant might contribute in the proton yield.

A complementary measurement to the hadron attenuation ratio, which is even more sensible to the partonic stage of the hadronization process, is the hadron transverse momentum broadening $\Delta < p_t^2 >=< p_t^2 >_A^h - < p_t^2 >_D^h$. The first direct measurement has been performed by HERMES [2] and is reported in Fig. 2.

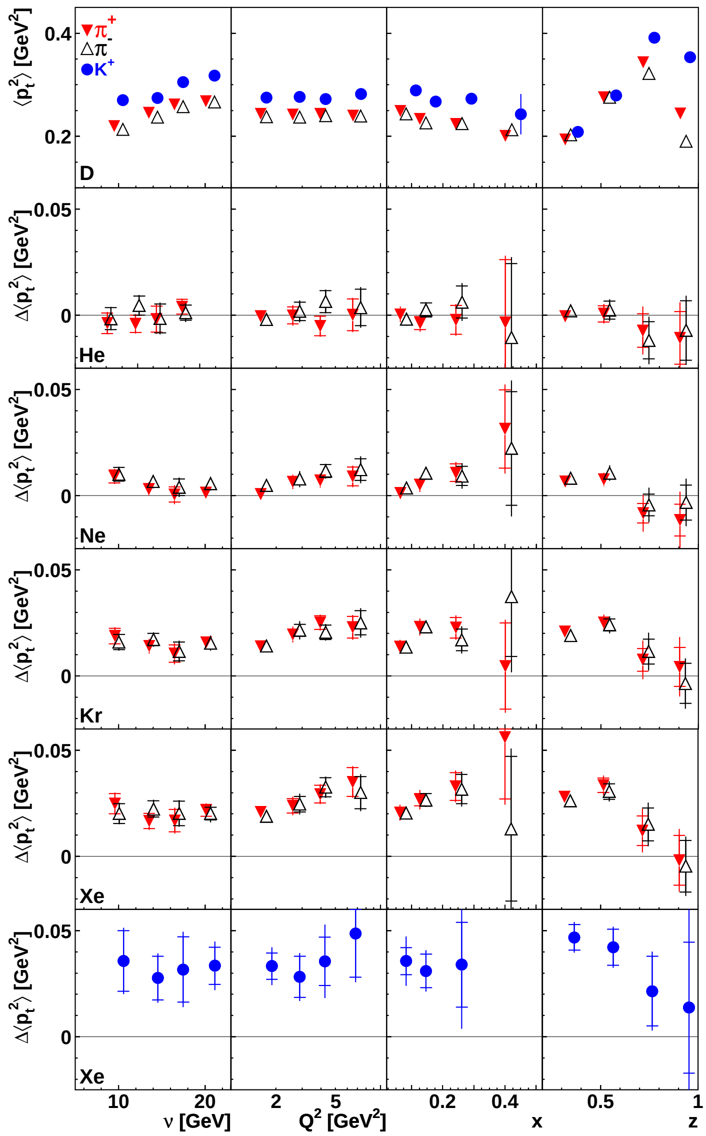

Figure 2: From left to right, the ν, Q^2, x and z dependence of $\Delta < p_t^2 >$ for D (top row) and p_t-broadening (remaining rows) for π^+ and π^- produced on He, Ne, Kr, and Xe targets and for K^+ produced on a Xe target (bottom row).

The panels shows $< p_t^2 >$ for D (top row) and the broadening (remaining rows) as a function of either ν, Q^2, x and z for π^+ or π^- for the various nuclear targets. The data do not reveal a significant dependence on ν while for x and Q^2 the effect slightly increases. On the contrary, the effect on z shows a clear broadening vanishing as z approaches unity. This indicates both that there is no or little dependence of the primordial transverse momentum on the size of the nucleus and that the p_t-broadening is not due to elastic scattering of pre-hadron or hadrons already produced within the nuclear volume.

The evolution of a fast-moving quark into hadrons is a non-perturbative, dynamic phenomenon and its space-time evolution is a basic issue of physics. The lepto-production of hadrons has the virtue that the energy and momentum transferred to the hit parton are well determined, as it is "tagged" by the scattered lepton and the nucleus is basically used as a probe at the fermi scale with increasing size or density. The experimental results achieved in these years showed the enormous potentialities of the nuclear deep-inelastic scattering. However, the existence and relative importance of the various stages like the propagation and the interaction of the partons, color-neutralization state and final hadron to the observed nuclear attenuation have been difficult to determine unambiguously. In this panorama, only a facility like the EIC for eA collisions with its high luminosity could access to the complete disentangle of all the five variables entering in the formulation of the hadronic cross section. For instance, by a multi-dimensional study of the p_t-broadening, it could be possible to access to the effects due to the primordial transverse momentum, the gluon radiation of the struck quark, the formation and soft multiple interactions of the "pre-hadron" and the interaction of the formed hadrons with the surrounding hadronic medium. Data at small $Bjorken\ x_B$ will allow to study the hadron production at increasing gluon density, up to a possible saturation which is strongly connected to effects in the partonic stage. For energies much higher than the HERMES ones, all the attenuation effects will be reduced, so an energy ranging between $\sqrt{s}$=5-10 GeV would be well suitable for accessing all these effects. On the contrary, high energy would favore the p_t-broadening and new measurements as gluon saturation effects.

References

[1] A.Airapetian et al., HERMES Coll., Nucl. Phys. B **780**, 1 (2007);

[2] A.Airapetian et al., HERMES Coll., Phys. Lett. B **684**, 114 (2010).