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1. INTRODUCTION.

Nuclei and hadronic systems are thought to be ultimately built of light quarks. However, most of their known properties can be understood in the framework of effective Lagrangian theories, without explicit reference to quark degrees of freedom. We are still left with the two following open questions: i) How do these effective degrees of freedom (baryons and mesons) arise from a more fundamental description of the hadronic matter?; ii) At which scale quarks and gluons start to be the relevant degrees of freedom to describe nuclear matter?.

The answer to these questions requires to disentangle the mechanisms which drive the coupling of the probe to the quark from those which drive its propagation and its interaction in hadronic systems. In order to achieve this goal, both the energy and the momentum transfered to the system should be large enough to allow a perturbative treatment of the coupling between the probe and the quark.

The study of high p_T exclusive reactions, the determination of the various spin observables and the study of the production of different flavors, in reactions induced by real and virtual photons, offer us with three complementary ways to disentangle hard and soft mechanisms and to study the short range behavior of hadronic matter. Since these topics have been already discussed in Ref.1, where many examples and references can be found, only the main arguments are reviewed in this short note.

2. HIGH p_T EXCLUSIVE REACTIONS.

In *inclusive* electron scattering (where only the scattered electron is detected), there are only two independent kinematical variables : the total energy $\sqrt{s}$ transfered to the hadronic system and the exchanged photon four-momentum Q^2. Probing the short distance behavior of the hadronic system requires to work at high Q^2.

In *exclusive* reactions, one or few particles are detected in coincidence with the scattered electron. One more variable governs the size of the volume of interaction : the invariant momentum transfer $\sqrt{t}$, in the t channel, or equivalently the transverse momentum p_T of one of the emitted particles. Short distance processes can therefore be studied for small values of Q^2, and even at the photon point (Q^2=0). Perturbative QCD is therefore expected to be valid at lower energy than in inclusive experiments.

Above E_γ = 1 GeV (above the resonance region) the cross-section of exclusive meson photoproduction reactions exhibits a typical pattern. At forward angles ($t \simeq 0$), the angular distribution of the emitted meson is dominated by the exchange, in the t channel, of the Regge trajectories of the various mesons or of the Pomeron, and falls down very quickly (exponentially) when t increases. At backward angles (t large, $u \simeq 0$), it is dominated by the exchange, in the u channel, of the baryon Regge trajectories, and falls down very quickly when u increases (or t decreases). Around 90°, where both t and u are large (above 1 $(GeV/c)^2$), the angular distribution exhibits a plateau, whose the variation with the squared total energy $\sqrt{s}$ is proportional to s^{-8}. This behavior is a signature of a hard interaction between the photon and the quarks inside the nucleon. It occurs when the energy is large enough ($\sqrt{s} > m$) to be the only mass scale, and when the momentum transfer is also large enough (p_T > 1 $(GeV)^2$) in order that the struck quark escapes quickly the volume of interaction and hadronizes far away. Typical examples are the $\gamma p \to n\pi^+$ reaction which have been studied at SLAC[1] in the energy range $3 \le E_\gamma \le 8$ GeV, or the $\gamma p \to p\omega$ and $\gamma p \to \Delta^{++}\pi^-$ reactions which have been studied at Daresburry[2] in the energy range $3 \le E_\gamma \le 5$ GeV.

The study of short range quark rearrangement mechanisms in nuclei, requires to select kinematics where at least two nucleons are active and where hard scatterings have already been observed in reactions induced on free nucleons. A possible example would be the comparison between the reactions $\gamma D \to \Delta^{++}\pi^- n$ and

$\gamma p \rightarrow \Delta^{++}\pi^-$. The value of the transverse momentum of the emitted Δ^{++} must be large in order to sign a hard scattering and the momentum of the neutron must be large enough in order to suppress the quasi-free mechanism (where the neutron is spectator). Of course many other reactions can be studied as for instance the simplest, the $\gamma D \rightarrow pn$ reaction[3] when the proton is emitted at 90°, or the $\gamma D \rightarrow \Delta^{++}\Delta^-$ and the $\gamma D \rightarrow pn\omega$ reactions for high values of p_T.

A CW electron beam, in the energy range $6 \leq E_\gamma \leq 10$ GeV, is necessary to perform these experiments. The reactions $\gamma p \rightarrow \Delta^{++}\pi^-$ and $\gamma p \rightarrow p\omega$ were studied[2] with a tagged photon beam of 10^6 γ/s (due to the low duty factor, 5%, of the Daresbury machine). A continuous electron beam allows to increase this figure by more than one order of magnitude and to reach a few 10^7 γ/s. The experiments on a free nucleon target can be performed with a higher accuracy and at higher values of p_T. A systematic study of high p_T reactions induced by photons on nuclear targets can be undertaken.

3. FROM REAL TO VIRTUAL PHOTONS.

Except for the case of the electroproduction of vector mesons[4,5], the experiments performed with virtual photons are very scarce. However, they open two new axes of research. On the one hand, they allow to go far from the domain of validity of the Vector Meson Dominance (VMD) model and to reach the domain where the photon behaves as a point like object. On the other hand, they allow to determine the coulomb part of the cross section, which vanishes at the photon point.

In the energy range $2 \leq \sqrt{s} \leq 4$ GeV, a virtual photon is more point like than a real photon above $Q^2 = 1$ $(\mathrm{GeV/c})^2$. Furthermore, such a point like coupling of the virtual photon seems to occur for smaller values of its squared mass, provided that the momentum transfer (t or p_T) is high enough. This is suggested[1] by the variation, with the momentum transfer $t = (k_\gamma - k_\pi)^2$ for selected values of Q^2, of the cross section[6] of the $p(e,e'\pi^0)p$ reaction as compared to the variation of the cross section of the $p(\gamma,\pi^0)$ reaction, at the same value of the total c.m. energy $\sqrt{s} = 2.55$ GeV.

Virtual photons allow also to determine the coulomb part of the cross section, where the physics is different than in the transverse part (which looks like the real photon absorption cross section for small values of t). For instance, PQCD predicts a vanishing coulomb inclusive cross section : indeed the measured ratio $R = \sigma_L/\sigma_T$, between the longitudinal and transverse part of the cross section, vanishes[7] for large values of Q^2. However it is significantly different from zero when Q^2 decreases, in the range $Q^2 \leq 5$ $(GeV/c)^2$. This is a signature of higher order corrections to PQCD, as higher twists for instance.

Traditionally the separation between the longitudinal and the transverse parts of the cross section is performed with the Rosenbluth method. It requires a high energy of the incoming electron for the measurement at the most forward angle. Furthermore, to pin down the small contribution of the coulomb amplitude to the cross section, a perfect control of the accuracy, not only stastistical but also systematical, is mandatory.

4. SPIN OBSERVABLES.

An alternative way, to overcome these difficulties, would be to measure the various spin transfer observables which depend on the interference between the coulomb and the transverse amplitudes. The two advantages of this method are: i) such a measurement does not require to be performed at forward angle of the scattered electron : the energy of the incoming electron beam can be lower than in the Rosenbluth method (roughly by a factor two); ii) only relative measurements (in which only the spin of the electron or of the target is flipped) are necessary : the sources of systematical errors are minimized. Besides the determination of the coulomb part of the transition amplitudes, they also provide us with a powerful way to disentangle the various reaction mechanisms and with an useful complement to the study of the spin observables in hadronic reactions (see Ref.1).

This can be achieved in reactions induced by polarised electrons on a target polarised perpendicularly to the direction of the exchanged photon, or when the ejectile is polarized perpendicularly to its direction of motion. Three examples are relevant :

- The sideways asymmetry measured in the *inclusive* scattering of polarized electrons on a spin 1/2 target (nucleon or ^3He for instance) is directly proportional to the higher twist (twist-3) contribution to the response function[8]. It contributes to the longitudinal response function recently mesured at SLAC[7], at the level of 10 % when Q^2 does not exceed 10 $(Gev/c)^2$ and vanishes above. This asymmetry should be measured in this momentum range, since the large transverse response function acts as an amplifier and makes it more sensitive.

- The measurement of the target asymmetries in *exclusive* meson electroproduction or electrodisintegration reactions will open up a completely new field. Out of the plane experiments will be necessary.

- The determination of the spin transfer polarisation of the ejectile in *exclusive* reactions is not only complementary, but the only way left open when the target is difficult or impossible to polarize. In this respect the production of *self-analysing* particles (vector mesons, hyperons, etc...) is particularly appealing.

The analysis of both the polar and azimuthal angular distributions of their decay products (pion or kaon pairs) allows to determine the polarization of the vector mesons emitted in electronuclear reactions. This has already been achieved in the study of the $p(e,e'\rho^0)p$ reaction performed at Cornell[4], in the range $3 \leq \sqrt{s} \leq 4$ GeV and $Q^2 \leq 2$ $(GeV/c)^2$, and at CERN[5], in the range $8 \leq \sqrt{s} \leq 11$ GeV and $1 \leq Q^2 \leq 10$ $(GeV/c)^2$. The incoming electron energy was $E_- = 11$ GeV at Cornell and $100 \leq E_- \leq 200$ GeV at CERN.

These two experiments have revealed the breakdown of the s-channel helicity conservation (SCHC) rule, which works at the real photon point. The virtual photon is mostly absorbed in a transverse helicity state, but the production of longitudinaly polarized ρ^0 is increasing when Q^2 increases above 1 $(GeV/c)^2$. This could be a signature of the onset of perturbative mechanisms (beyond VMD) when Q^2 increases.

These two experiments were performed with a beam of low intensity (typically a few 10^7 electrons /second, i.e a few pA), and only integrated cross-sections were determined. They are dominated by the emission of particles at forward angles (low p_T) and only two independent variables are relevant: $\sqrt{s}$ and Q^2. An intense continuous polarized electron beam (a few tens of μA, allowing a luminosity of the order of 10^{35} to 10^{36}) would allow to perform the separation between the transverse and longitudinal helicities of both the virtual photon and the emitted vector meson, not only at low p_T but also at high p_T, and to map out the transition between the non pertubative diffractive regime and the pertubative regime, in nucleon as well as nuclei.

5. Strangeness.

The production and the propagation of strangèness and heavy flavors in hadronic systems provide us with new tools to study their structure. On the one hand the specific flavor of the corresponding quark is a powerful tag to follow how the transfered energy and momentum are distributed in the system. On the other hand, the corresponding reactions do not involve the valence quarks of the target, and probe its sea quark and gluon distributions.

With respect to heavy flavors, strangeness presents two advantadges. On the one hand, the threshold for strangeness (0.9 Gev for $p(\gamma,k)\Lambda$ or 1.7 GeV for $p(\gamma,\phi)p$, for instance) is much more lower than the threshold for heavier flavors (8.2 GeV for $p(\gamma,J/\psi)p$, for instance). Beams of lower energy allow to reach a perturbative regime sooner. On the other hand, for a comparable excess of energy above threshold, the cross-section of strangeness production is larger (400 nb for the $p(e,e'\phi)p$ reaction in the range $3 \leq E_\gamma \leq 10$ GeV) than the cross-section of charm production (5 nb for the $p(e,e'J/\psi)p$ at 20 GeV). The experiments are more easy.

As in the case of ligth flavors, the same arguments can be repeated. Spin observables should be determined in *exclusive* reactions. In that respect, the emission of self-analysing particles, as ϕ or Λ, is particularly appealing. This is an almost completely virgin field, whose the study will complement the few intriging results concerning spin observables in hadron induced reactions[1]. Furthermore, the variation of the transverse momentum p_T in exclusive reactions should be used as a "knob" to tune diffractive processes or hard scatterings.

6. Conclusion.

The analysis of the scarce reactions induced by electrons, as well as those induced by hadrons[1], indicates that, in the range of momentum transfer $1 \leq p_T \leq 3$ to 4 GeV/c and total c.m. energy $2 \leq \sqrt{s} \leq 4$ to 5 GeV, leading twist pertubative mechanisms dominate the cross section. However, spin observables reveal interferences with smaller contributions due to higher twists or non pertubative mechanisms.

A more systematic study, with a special emphasis on spin observables, of these hard mechanisms in the free nucleon will lead to a better understanding of the interplay between perturbative and non perturbative processes, and lead to strong constraints on the wave functions of hadrons. High p_T reactions provide us with the way of disentangling the hard interaction of the probe with the quarks of the target, which can be treated in a perturbative way, and the soft interactions between the quarks inside the probe or the target, which insure their cohesion and determine their wave functions.

Their study in the nuclear medium enlarges the dynamical domain in two related ways. On the one hand, quark rearrangement mechanisms allow to determine the short range part of the nuclear wave function, and to single out its hidden color component. On the other hand, the nucleus acts as a filter : if the momentum transfer is large enough, the nuclear medium damps the non perturbative mechanisms, which involve the full size of the hadrons, and selects the hard mechanisms, which occur at short distances inside the interacting hadrons.

A continuous beam of polarized electrons of energy around 10 GeV will allow us to cover the light and strange quark sector of this program[1]. The few experiments in that energy range have been performed at Cornell, with an unpolarized electron beam whose intensity was not exceding a few pA. A CW polarized electron beam of intensity around a few tens of μA will allow to gain several orders of magnitude on the luminosity and to cover completely this field. The study of the charmed quark sector near threshold calls for an energy around 15 GeV, but the smallness of the charm production cross section leaves open the problem of the feasibility of this part of the program.

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