COLOR COHERENT PHENOMENA

L. L. Frankfurtm, M. I. Strikman

1. Hard diffractive electroproduction of vector mesons in QCD

In Ref.[1] we extended our perturbative QCD calculation [2] of the hard diffractive electroproduction of longitudinally polarized vector mesons. Cross section is calculated within the leading $\alpha_s \ln \frac{Q^2}{\Lambda^2_{QCD}}$ approximation of QCD using the leading order parton densities within the nucleon. Novel QCD features of the production of excited states and of the restoration of flavor symmetry are analyzed. At the onset of the asymptotic regime, our analysis finds an important role of quark Fermi motion within the diffractively produced vector mesons, and we suggest to use this effect to measure the high momentum tail of the wave function of the vector mesons. We deduce a kinematical boundary for the region of applicability of the decomposition of the hard amplitudes over powers of Q^2 and/or a limit on the increase of the cross sections of hard processes at small x, and briefly analyze its consequences. We also estimate the nuclear attenuation of the diffractive electroproduction of vector mesons and compare with estimates of the shadowing of the longitudinal structure function.

2. Study of Color Fluctuations in Hadrons

Experimental investigation of hard processes has established that at small space - time intervals hadron interactions can be described in terms of quantum chromodynamics - QCD. However soft hadron interactions are not well understood in spite of many brilliant ideas. One of the promising ideas for the expansion of QCD into the nonperturbative domain is to combine well understood methods of the physics of hard processes with the physics of color coherent phenomena to investigate softer ones. The idea is that Lorentz slowing down of the interactions at high energies results in enhancement of the coherent effects due to color distributions in colliding hadrons (color transparent and color opaque fluctuations). The constructive way to incorporate this physics into the dynamics of relativistic collisions is provided by the concept of hadronic cross-section fluctuations (color fluctuations) which was first introduced by E. L. Feinberg and I. Y. Pomeranchuk, and by M. L. Good and W. D. Walker. The key quantity one has to know is the probability, $P(\sigma)$ to find a nucleon in the configuration with cross section σ. $P(\sigma)$ was first introduced by H.Miettinen and J.Pumplin. Therefore we have undertaken a comprehensive analysis of information about $P(\sigma)$. We developed a procedure to extract $P(\sigma)$ from the current data on cross section of the hadron interaction with deuteron suggesting in addition the QCD quark-counting rule constraint on the behavior of $P(\sigma)$ at small σ [3]. In the case of πN scattering we produced an independent check of this procedure. We calculated $P_\pi(\sigma \ll < \sigma >)$ directly from pQCD using the QCD wave functions of the pion in the $q\bar{q}$ configuration [4]. The results of two determinations are reasonably close.

Nontrivial check of this picture has been provided in [5] where we have calculated inelastic diffraction off nuclei through $P(\sigma)$. For the interaction with a black disc this cross section should be proportional to the radius of a nucleus. Experiments performed at FNAL (which measured semi-inclusive channels) found considerably faster increase of cross section with atomic number. The data agrees with our theoretical calculations of the $A-$dependence of

the cross section confirming significant probability of color fluctuations in the wave function of a hadron near its average configuration. In ref. [6] M.Strikman and V.Guzey have extended the analysis of [5] to the case of the lightest nuclei and applied it to calculate the total cross section of inelastic coherent diffractive dissociation off ^{4}He in the process $p + {}^4\mathrm{He} \to X + {}^4\mathrm{He}$ in terms of the relative cumulants of the cross-section distribution $P_N(\sigma)$. The theoretical result for the ratio $r = \left(\frac{d\sigma_{diff}}{dt}\right)^{pHe}_{t=0} \Big/ \left(\frac{d\sigma_{diff}}{dt}\right)^{pp}_{t=0} = 6.8 \div 7.6$ is close to the value $r = 7.1 \pm 0.7$ which we extracted from the FNAL jet target 1981 data. These are the only $A > 2$ data of this kind. The comparison provides the first confirmation of the cross-section fluctuation approach to the description of the absolute value of the inelastic diffraction cross-section off nuclei. It provides also a new constraint on the first 4 cumulants of the cross-section distribution.

3. Color transparency phenomena in quasielastic processes and models of hadrons

For wide angle two body collisions, QCD predicts dominance of small spatial size configurations in the interacting hadrons. If this process takes place within nuclear medium, the produced small configuration propagates within nucleus with small cross section. This CT phenomenon was predicted a long ago by S.Brodsky and A.Mueller. The argument was based on the application of perturbative QCD which is likely to be applicable for such processes for very large Q^2 only. In [7] we performed extensive analysis of current models of nucleon and pion form factors and found that in practically all the models small size configurations determine form factors already for momentum transfers as low as 2-3 GeV^2 which is well below the region where perturbative QCD may be applicable for the calculation of the form factors.

However at energies feasible for experiments it is necessary to take into account space-time evolution of produced small size wave packet, and this tends to suppress CT [8]. Besides at feasible energies it is necessary to take properly nuclear effects. So we have developed mathematical methods to account for these effects.

Smallness of CT effects expected in the NE-18 type experiments combined with expectation of dominance of rather small configurations in the form factors already at $Q^2 \geq 4$ (GeV/c)^2 leads to a challenging situation - it is necessary to find processes which are less affected by the quantum diffusion in order to check whether at the momentum transfer accessible for CEBAF, and CEBAF II ($Q^2 \leq 6 - 8$ (GeV/c)^2) small size configurations are produced.

One idea was to study transitions to the well defined nuclear levels [9]. This strategy is persuaded now in the CEBAF experiment E-91-007. Together with E.Moniz and M.Sargsyan we deduced eikonal formulae for the final state interaction in (e,e'p) processes taking into account in a consistent way short-range correlations in nuclei [10]. We found that uncertainties in the theoretical calculations of the excitation of the low nuclear levels in $A(e,e'p)$ reactions are sufficiently small and the final result is close to the results of the optical model calculation [9]. This result indicates that in spite of a small value of CT effects expected in the forthcoming CEBAF experiments the high energy resolution of these experiments would allow one to obtain data for which eikonal predictions can be calculated with accuracy of

few percent. Thus there is a chance to observe and to interpret reliably $\sim$ 10% effects of CT expected in these experiments.

Together with G.Miller, W.Greenberg , K.Egiyan and M.Sargsyan we suggested *a novel class of reactions* with the lightest nuclei which is more sensitive to CT effects than conventional $(e, e'p)$ processes [11]:

$$l(h) + A \to l(h) + p + p + (A-2)$$

where the second nucleon is selected in the kinematics corresponding to rescattering of knocked out nucleon. The idea is that at intermediate energies CT is suppressed by evolution of small configurations with time. However if instead of determining probability for ejected nucleon *not to interact* one would measure probability *to interact* one can use the lightest nuclei. As a result one can explore in the discussed reactions, interaction of ejected system at small distances from the production point $\sim$ 1 fm there expansion of the wave packet is suppressed. Our first results of theoretical calculations seem to indicate that one can look for CT effects at much smaller Q^2 than in the more traditional processes like $A(e, e'p)$. So there is a chance to observe this physics at CEBAF energies. We are now in the process of building more detailed models for double scattering processes, including effects of short-range correlations. With experimentalists of CEBAF we wrote a proposal to search for such effects at CEBAF (Virginia): "Measurement of nuclear transparency in double rescattering processes"; Spokespersons:K.Egiyan, Y.Sharabian, M.Strikman.[12] It was accepted at the recent PAC meeting of CEBAF.

Together with W.Greenberg, G.Miller and M.Sargsyan we studied high momentum transfer electro-disintegration of polarized and unpolarized deuterium targets, $d(e, e'p)n$ [13,14]. We have shown that the importance of final state interactions FSI, occurring when a knocked out nucleon interacts with the other nucleon, depends strongly on the momentum $\vec{p}_n$ of the spectator nucleon. In particular, these FSI occur when the essential contributions to the scattering amplitude arise from internucleon distances $\leq 1.5\ fm$. If the point like configuration is still small after propagating about 1.5 fm, the FSI are suppressed. The result is that significant color transparency effects, which can either enhance or suppress computed cross sections, are predicted to occur for $10(GeV/c)^2 \geq Q^2 \geq 4\ (GeV/c)^2$. Evident advantage of such reactions is that nuclear effects are under very good control since the wave function of the deuteron is well known for these momenta from other experiments. Measurements seem feasible both at CEBAF and with HERMES.

4. Probing short range nucleon correlations in high energy hard quasielastic *pd* reactions

We performed together with E.Piasetsky (Tel Aviv University) and M.Sargsyan a detailed analysis of hard $p + d \to ppn$ reaction [15]. We found that the strong dependence of the amplitude for NN hard scattering on the collision energy and the exclusive nature of the reaction can be used to magnify the effects of short range nucleon correlations. The initial and final state interactions are calculated for the discussed exclusive processes. We find that for spectator momenta $\leq$ 350 MeV/c and $p_t \sim 0$ the effect of initial and final state interactions can be accounted for by rescaling the cross section calculated within the plane wave impulse approximation. The feasibility to investigate in this kinematics the role of relativistic effects in the deuteron wave function is demonstrated by comparing the pre-

dictions of different relativistic formalisms. It is demonstrated also that in this kinematics the final and initial state interactions reduce sensitivity of the cross section to uncertainties in the high momentum component of the deuteron wave function. We also find that for $p_z \sim 0$, 150 MeV/c$\geq p_t \geq$ 50 MeV/c initial and final state interaction strongly reduce the cross section while relativistic effects are very small. This kinematic is optimal for color transparency studies. We also analysed binding effects due to short range correlations in deuteron. EVA (E-850) experiment (Brookhaven) has included such a measurement in their plans. First results are expected next year.

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