Probing dissociation of space-like photons at HERA

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In this talk, I briefly summarize some of the experiments my collaborators and myself proposed in a recent paper [1]. We show: By using the characteristic spin-effects observed in high-energy hadron-hadron collisions as indicators, hadronic dissociation of space-like photons can be directly probed by performing measurements in the fragmentation region of transversely polarized and unpolarized proton beams at HERA.

It is known already for a long time that hadronic dissociation of space-like photons may play a significant role in deep-inelastic lepton-hadron scattering — especially in diffractive processes [2,3]. People seem to agree that, viewed from the hadron- or nucleus-target, not only real, but also space-like photons ($Q^2 \equiv -q^2 > 0$, where q is the four-momentum of such a photon) may exhibit hadronic structure. But, as far as the following question is concerned, different theoretical models (see e.g. Refs. 2-5 and the papers cited therein) seem to give different answers. How do such hadronic dissociation processes depend on the standard kinematic variables of deep-inelastic lepton-nucleon scattering, Q^2 and $x_B \equiv -q^2/(2pq)$, where p is the four-momentum of the struck nucleon? In particular, do virtual photons indeed behave like hadrons in the small x_B and large Q^2 region ?

Viewed from the rest frame of the struck nucleon mentioned above, the lifetime τ_γ of the virtual hadronic system is of the order $2\nu/Q^2 = 1/(Mx_B)$, where ν is the photon-energy and M is the proton-mass. This means, the corresponding formation/coherence length is of the order 100 Fermis for $x_B = 10^{-2}$. Furthermore, we note that τ_γ is function of x_B, independent of Q^2. Does it imply that the hadronic dissociation of a photon always takes place — independent of its virtuality Q^2? Is it true that we are practically *always* dealing with hadron-hadron collisions, when x_B is sufficiently small ($x_B \sim 10^{-2}$, say)?

Some of the dynamical models based on such a photon-dissociation picture (See e.g.[4]) have been used to describe the proton structure function $F_2^p(x_B, Q^2)$ in the small x_B region and the obtained results are in reasonable agreement with the existing data [6,7]. Can we, on the basis of this agreement, say: "Experiments show that space-like photons $\gamma^*(Q^2)$ always dissociate into hadronic systems — independent of their virtualities (Q^2-values)" ? Is it correct and/or appropriate to say that the question whether space-like photons dissociate hadronically depends entirely on the choice of reference frames ?

A large number of inelastic lepton-nucleus experiments have been performed in which the hadronic properties of the space-like photons have been studied. But, probably due to the complicated nucleon structure which has to be taken into account, the data can be reproduced by different models based on different physical pictures [4,5]. Can hadronic dissociation of space-like photons be probed without using nuclear targets ?

Having the present and the future experimental possibilities at HERA in mind, we think it would be useful to consider the characteristic spin-effects observed — and only observed — in the fragmentation regions of hadron-hadron collisions at comparable energies and use them as indicators to probe space-like photon $\gamma^*(Q^2, x_B)$ at given values of Q^2 and x_B. To be more precise, we propose to measure the left-right asymmetry A_N of produced charged mesons in the fragmentation region of the transversely polarized proton $p(\uparrow)$, to measure Λ-polarization P_Λ of the unpolarized protons p at HERA in the small-x_B region for different Q^2-values, and to compare the obtained results with those obtained in the corresponding hadron-hadron collisions.

In order to demonstrate in a quantitative manner how the Q^2-dependence of such dissociation processes may manifest itself, we examine the $F_2^p(x_B, Q^2)$-data [6,7] in the small-x_B region. In Fig.1, we separate the well-known vector-dominance contribution (See e.g. [4,5]) from "the rest" which may be identified as "the part due to quark-antiquark continuum" or "the rest of the contributions due to the generalized vector-dominance model", and we consider the following two extreme possibilities which correspond to two very much different physical pictures: (i) The hadronic dissociation of virtual space-like ($Q^2 > 0$) photons take place for all possible Q^2-values. In other words, in this picture $\gamma^*(Q^2)$ should always be considered as a hadronic system — independent of Q^2. (ii) The hadronic dissociation of such photons depends very much on Q^2. In terms of a two-component picture (See e.g.[2-5]) the virtual photon $\gamma^*(Q^2)$ is considered to be either in the "bare photon" state or in a hadronically dissociated state ("hadronic cloud") described by the vector-dominance model. In other words, only the latter can be considered hadronic; and the probability for $\gamma^*(Q^2)$to be in this state is the ratio between the values shown by the dashed and the full lines.

Let us first look at the left-right asymmetry data [8] for $\pi^\pm$-production in $p(\uparrow) + p$ and see what we may obtain by replacing the unpolarized proton-target p by a photon with given Q^2, $\gamma^*(Q^2)$. It is clear that the corresponding asymmetry which we denote by $A_N(x_F|Q^2)$ will have the following properties: If scenario (i) is correct, we shall see no change in $A_N(x_F|Q^2)$ by varying Q^2. If scenario (ii) is true, there will be a significant Q^2-dependence. The results are shown in Fig.2a. Similar effects are expected also for K^+-mesons. In order to emphasize the model-independence of this test the curve which goes through the existing proton-proton data points [8] should be considered as an empirical fit, although such an asymmetry-data can be described by a relativistic quark model [9].

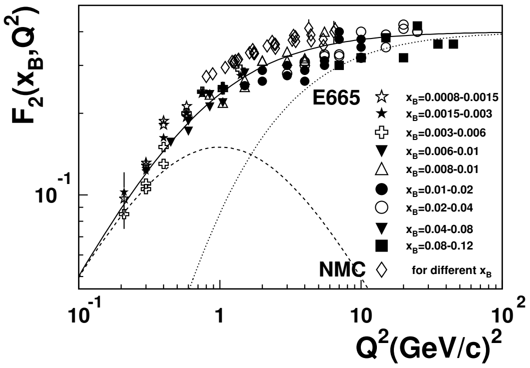

Fig.1: *Structure function $F_2^p(x_B, Q^2)$ as a function of Q^2. The data-points are taken from [6,7]; and they are parametrized (shown as solid line) in order to carry out the quantitative calculation mentioned in the text. The dashed line is the contribution from the vector meson dominance. The difference, which is called "the rest", is shown as dotted line.*

We next consider the Λ-polarization $P_\Lambda(x_F, Q^2)$ in the process $p + \gamma^*(Q^2) \to \Lambda + X$ in which unpolarized proton beam is used [10]. Also here, we expect to see *no Q^2-dependence for scenario (i) but a significant Q^2-dependence for scenario (ii).* This is shown in Fig.2b.

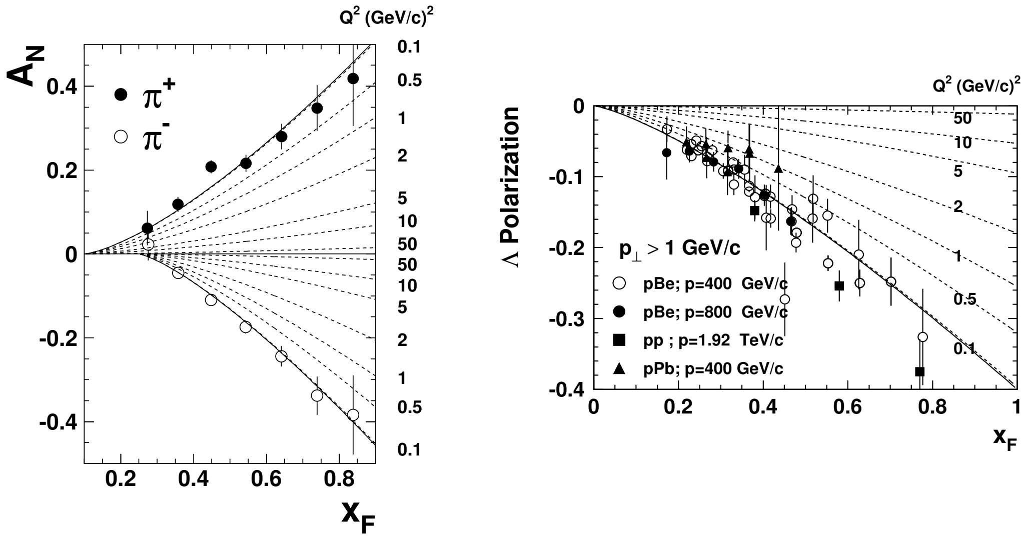

Fig.2: *(a) Left-right asymmetry for pion-production in $p(\uparrow)+\gamma^* \rightarrow \pi^\pm + X$ as function of x_F at different values of Q^2. The data are for $p(\uparrow)+p \rightarrow \pi^\pm + X$ and are from [8]. (b) Polarization for Λ-production in $p+\gamma^* \rightarrow \Lambda + X$ as function of x_F at different Q^2. The data are from [10].*

References

[1] C. Boros, Z. Liang and T. Meng, preprint FUB-HEP/95-21 (revised version).

[2] H.T. Nieh, Phys. Rev. D1, 3161 (1970); Phys. Rev. D7, 3401 (1973).

[3] T.H. Bauer, R.D. Spital, D.R. Yennie and F.M. Pipkin, Rev. Mod. Phys. **50**, 261 (1978).

[4] See e.g. G. Piller, W. Ratzka and W. Weise, Z. f. Phys. **A352**, 427 (1995).

[5] See e.g. M. Arneodo, Phys. Rep. **240**, 301 (1994).

[6] NMC Collaboration, P. Amaudruz et al., Phys. Lett. **295B**, 3 (1992).

[7] Fermilab E665 Collaboration, Ashutosh V. Kotwal, in Proc. of the Eighth Meeting of the Division of Particles and Fields of the American Physical Society (DPF'94), Albuquerque, NM, August 2-6, 1994; Fermilab Conf-94/251-E (1994).

[8] FNAL E581/704 Collaboration, D.L. Adams et al., Phys. Lett. **B261**, 201 (1991); FNAL E704 Collaboration, D.L. Adams et al., Phys. Lett. **B264**, 461 (1991); and **B276**, 531 (1992); Z. Phys. **C56**, 181 (1992); A. Yokosawa, In Frontiers of High Energy Spin Physics, Proc. of the 10th Int. Symp., Nagoya, Japan 1992, edited by T. Hasegawa et al. (Universal Academy, Tokyo, 1993); A. Bravar et al., Phys. Rev. Lett. **75**, 3073 (1995).

[9] C. Boros, Z. Liang and T. Meng, Phys. Rev. Lett. **70**, 1751 (1993), Z. Liang and T. Meng, Phys. Rev. **D49**, 3759 (1994); C. Boros, Z. Liang and T. Meng, (to appear in Phys.Rev.D).

[10] K. Heller, in High Energy Spin Physics, Proceedings of the 9th International Symposium, Bonn, Germany, 1990, edited by K.H. Althoff, W. Meyer (Springer-Verlag, 1991); and the references given therein; A.M. Smith et al., Phys. Lett. **185B**, 209 (1987); B. Lundberg et al, Phys. Rev. **D40**, 3557 (1989); E.J. Ramberg et al., Phys. Lett. **338B**, 403 (1994).