Studies of pion and kaon Electroproduction in semi-inclusive DIS with Transversely Polarized Hydrogen and Deuterium Targets

A CLAS collaboration proposal

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Abstract

We propose to study the azimuthal spin asymmetries in semi-inclusive DIS (SIDIS) with the CLAS12 spectrometer completed with a RICH detector, using the upgraded JLab 11 GeV polarized electron beam with transversely polarized proton and deuteron targets. The Fourier decomposition of the transverse-polarization-dependent cross-section term of the reaction $ep^{\uparrow} \rightarrow ehX$ (with h=π, K) provides access to a variety of fundamental quark correlation functions probing the parton dynamics within the nucleon and in the fragmentation process. Among them is the poorly known transversity function, whose precise measurement represents the missing piece for the full comprehension of the collinear structure of the nucleon at leading-twist. It differs from the helicity distribution due to the relativistic effects of the quark motion within the nucleon. Other prominent examples are the Sivers and Pretzelosity transverse-momentum-dependent (TMD) quark distributions. The Sivers function is related to the quark orbital motion in a transversely polarized nucleon and, being naive-T-odd, undergoes peculiar universality properties whose experimental verification is considered a key validation of the TMDs formalism. The Pretzelosity distribution function is sensitive to the D-wave component and probes any non-spherical shape of the nucleon. The measurable azimuthal asymmetries, interpreted as transverse-momentum-convolutions of parton distribution and fragmentation functions in the TMDs formalism, are expected to be in the range 2-10% from leading order calculations, depending on the kinematics and on the model used for the predictions. Chirally-odd distribution functions can be studied in conjunction with the Collins fragmentation function, which describes spin-orbit effects in the fragmentation of transversely polarized quarks. Alternatively, the transversity distribution can be studied in a collinear approach in conjunction with a di-hadron interference fragmentation function.

Flavor sensitivity is achieved by the identification of the final-state hadron, in particular kaon mesons, and the use of hydrogen and deuteron nucleon targets. This will help to clarify the "kaon puzzle" for, e.g., asymmetries related to transversity in conjunction with the Collins fragmentation function. HERMES results indicate that the single-spin asymmetries for pions and kaons may be very different. The asymmetries for K^+ are found of the same sign of those of π^+, which is expected if the valence

quarks provide the dominant contribution, but significantly larger in magnitude. The naive interpretation based on valence quark dominance is challenged also by the peculiar signal of K^-, compatible with zero with a hint of opposite sign with respect the large signal of π^-.

Thanks to the large detector acceptance, the x, z, P_T and Q^2 dependences of the asymmetries will be studied in a wide kinematic range to probe the underlying distribution and fragmentation functions. The investigation of the transition from current to target fragmentation region will be possible. A multi-dimensional analysis is planned in order to best decouple the nucleon intrinsic properties from the fragmentation features. In particular a scan over Q^2, to isolate sub-leading contributions, and over P_T, to explore the perturbative to non-perturbative regime transition and the match between the TMD (at $P_T << Q$) and collinear (at $P_T >> M$) factorization formalisms, will be performed. By exploiting novel event-weighing techniques, it will be possible to solve the transverse-momentum-convolution and access parton distributions in a model independent way.

Thanks to the polarized beam, double spin asymmetries for $\vec{e}p^{\uparrow} \rightarrow ehX$, giving access to distribution of longitudinally polarized quarks in the transversely polarized nucleon, will be measured simultaneously. In addition, important information on the sub-leading order parton distributions will be accessible, i.e. a significantly extended (x, Q^2) range of precision measurements of g_2 will be achieved.

A total of 100 days of running of the upgraded CLAS12 detector with 11 GeV highly polarized electron beam on transversely polarized HD-Ice (or possibly NH_3 and ND_3 or ^{6}LiD) target is requested for this experiment including about 20% overhead for target replacements, polarization reversal, and auxiliary measurements.