Evidence for a Double-Spin Asymmetry in ρ^0 Meson Electroproduction from Hydrogen at Intermediate Virtual Photon Energies

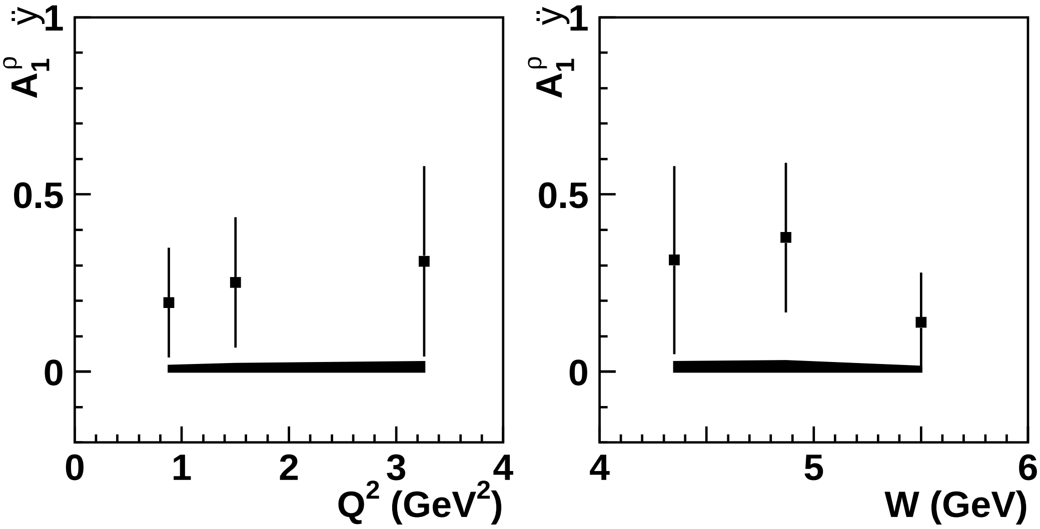
Does the ‘image’ of a proton produced in a femtometer (= 10^{-15} m) ‘microscope’ change if the light polarisation is reversed ? Probably yes, under certain conditions. This could be a possible interpretation of recent results from the HERMES experiment at HERA.

In this experiment the ‘objects’ – protons, as nuclei of gaseous atomic hydrogen – were irradiated by 27.5 GeV positrons, circulating with nearly the speed of light in the HERA storage ring. The positron-proton interaction is mediated by (virtual) photons that act as ‘probes’ to study the protons. Selected facets of the photon-proton interaction can be distinguished by detecting various types of outgoing radiation.

In this paper it is described how the HERMES apparatus was used to detect outgoing ‘heavy light’ in the form of ρ^0 mesons which have been produced in a process called *dissociative diffraction*. This analogy to classical optics has been chosen many years ago to describe a very gentle interaction where the inspected proton does not break up. The photon however, beyond any analogy to classical processes, may quantum-mechanically fluctuate into a (virtual) quark-antiquark pair which may in turn interact with the proton. As a result of this interaction, the virtual quark-antiquark pair materializes into a massive short-living particle, like a ρ^0 meson, having the same quantum numbers as the incoming photon. At HERMES, a ρ^0 meson is detected through its decay into a $\pi^+\pi^-$ pair. Measuring the momenta and the scattering angles of the outgoing particles allows the reconstruction of the respective values for the produced ρ^0 meson, which can be interpreted as the ‘image’ of the proton, i.e. the result of the ‘microscopic’ study.

An important ingredient of the study is the polarisation of the incoming ‘light’ that can be controlled through the magnetic field orientation in the so-called spin rotators of the HERA storage ring. The main question is, does a reversal of this beam polarisation change the number of outgoing ρ^0 mesons per incoming positron ? If yes, an asymmetry should show up between the two cases. It is crucial to note here that a sensitivity to this reversal exists only if also the protons are kept in a well-defined state of nuclear polarisation. Such a requirement to operate in a high-energy storage ring a polarised atomic hydrogen target of sufficiently high density constitutes a strong technological challenge that has been met at HERMES for the first time. The expected double-spin asymmetry is nothing more than the (normalised) difference between the numbers of detected ρ^0 mesons for parallel and anti-parallel spin orientation of beam and target, respectively; the result depends only on the relative orientation of the two spin directions.

The HERMES collaboration, in their data sample collected in 1996-97, observed an average double-spin asymmetry of 24 % with a (mainly statistical) uncertainty of 11 %. The latter will be considerably reduced once the data taken in 1998-2000 will have been analysed. In the context of the above sketched picture of dissociative diffraction, such an asymmetry was qualitatively predicted already 25 years ago, while the experimentalist's tools to measure it became available only recently.



In the figure the dependence of the measured double-spin asymmetry A_1^ρ on two important kinematic variables is shown: On the left hand side, Q^2, the square of the mass of the virtual photon – unlike for real photons that have no mass –, describes the spatial resolution of this special light. On the right hand side, W, the invariant mass of the photon-proton system, describes – for the considered process of dissociative diffraction – mainly the energy given to the produced ρ^0 meson. In the figure, the error bars and the dark bands at the bottom describe the statistical and the systematic uncertainty of the measurement, respectively. Clearly, more accurate data is required to discern any kinematical dependence of the measured asymmetry.

In the context of the present theory of strong interactions – Quantum Chromodynamics (QCD) – a precise explanation of the observed phenomenon has not yet been accomplished. To reach that point, progress is required in both theory and experiment. On the theory side, dramatic new progress would be needed to precisely describe all the relevant facets of the photon-proton scattering process in terms of an interaction between the photon and the partons (quarks and gluons), i.e. the *constituents* of the proton. This may possibly be accomplished within the very modern concept of the so-called 'Skewed Parton Distributions (SPDs)' that constitutes a promising generalization of the hitherto used concept of ordinary parton distributions. On the experiment's side, high precision measurements may become possible in a HERMES-like experiment that is presently being discussed as part of the envisaged new facility TESLA at DESY in the not too far future.