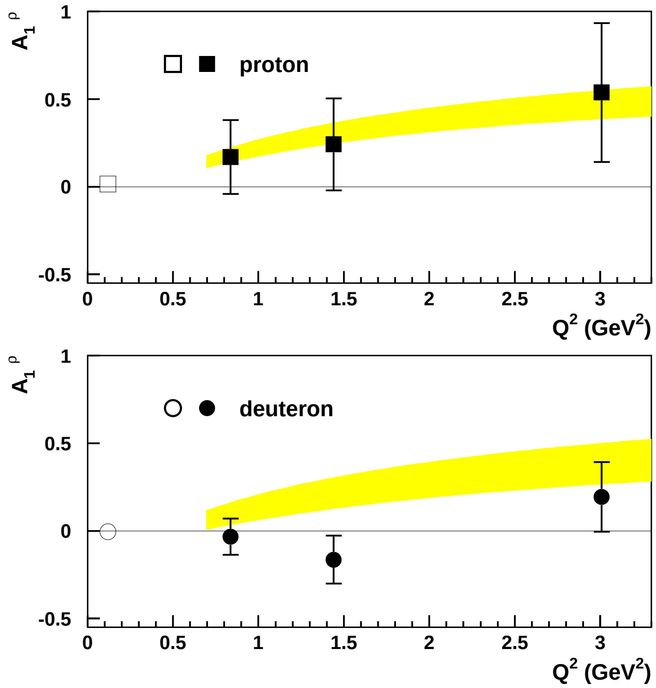
Indication for a Double-Spin Asymmetry in ρ^0 Meson Electroproduction on the Proton at Intermediate Virtual Photon Energies

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 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 or ϕ 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 having the same quantum numbers as the incoming photon, in particular also spin 1, and hence called *vector meson*. At HERMES, vector mesons are detected through their decays, e.g. $\rho^0 \rightarrow \pi^+\pi^-$ or $\phi \rightarrow K^+K^-$. Measuring the momenta and the scattering angles of the outgoing particles allows the reconstruction of the respective values for the produced 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 vector 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 gas target of sufficiently high density constitutes a strong technological challenge that has been met at HERMES for the first time. The measured double-spin asymmetry is nothing more than the (normalised) difference between the numbers of detected vector 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.



In the data taken with a polarised Hydrogen target, the HERMES collaboration observed an average double-spin asymmetry of 23% with a (mainly statistical) uncertainty of 13%. In the context of the above sketched picture of dissociative diffraction, such a behaviour of the asymmetry was qualitatively predicted already 25 years ago, while the experimentalist's tools to measure it became available only recently. In the figure, filled squares (circles) describe the Q^2-dependence of the double-spin asymmetries in ρ^0 meson production, as measured on the proton (deuteron). Here Q^2 represents the square of the mass of the virtual photon which – unlike for real photons that have no mass – describes the spatial resolution of this special light. The error bars describe the statistical uncertainty of the measurement, while the systematic one can be neglected. In addition, zero asymmetry results of precise measurements at very low Q^2 are shown as open square and circle, respectively.

In the framework of the present theory of strong interactions – Quantum Chromodynamics – a precise explanation of the observed phenomenon has not yet been accomplished. In the context of the so-called Regge approach – a very successful phenomenological model to describe gentle interactions, invented 30 years ago – a new calculation has been performed very recently for ρ^0 production. The predicted range, representing some theoretical uncertainty, is shown as a shaded band in the figure. Agreement between data and phenomenological calculations is found for scattering on the proton, but not for the deuteron. For ϕ meson production all asymmetries were found to be compatible with zero; there are no model predictions available that can be directly applied to the HERMES kinematics. Seen altogether, more accurate data as well as more firm theoretical predictions are required to reach a final conclusion.