Single-spin azimuthal asymmetries in electroproduction of neutral pions in semi-inclusive deep-inelastic scattering

Just like atoms are composed of electrons and nuclei, and nuclei of protons and neutrons, also protons and neutrons are composite objects: they consist of quarks and gluons, which are supposed to combine their own properties - like the electrical charge - to the observed properties of the proton (and neutron).

At leading order the structure of the proton is described by two gluon distribution functions, the number density distribution G and the spin distribution ΔG, and by three quark distribution functions, the number density distribution q and the longitudinal and transverse spin distributions Δq and δq, respectively, for each quark flavour. The quark number density distribution q, which gives the probability to find inside a proton a quark with a given fraction of the total momentum of the proton, has been studied for decades. The gluon number density distribution G, which gives the probability to find inside a proton a gluon with a given fraction of the total momentum of the proton, was measured more accurately over the last 10 years. The same is true for the quark longitudinal spin distribution Δq, which now gives the probability to find a quark with its spin aligned with the proton spin when the proton is longitudinally polarised, i.e. along its direction of motion. On the contrary only a first glimpse was gotten of the gluon spin distribution ΔG, which gives the probability to find a gluon with its spin aligned with the proton spin. The last distribution, the quark *transversity* distribution δq remains unmeasured. It is related to the probability to find a quark with its spin aligned to the proton spin for a transversely polarised proton, i.e. perpendicular to its direction of motion.

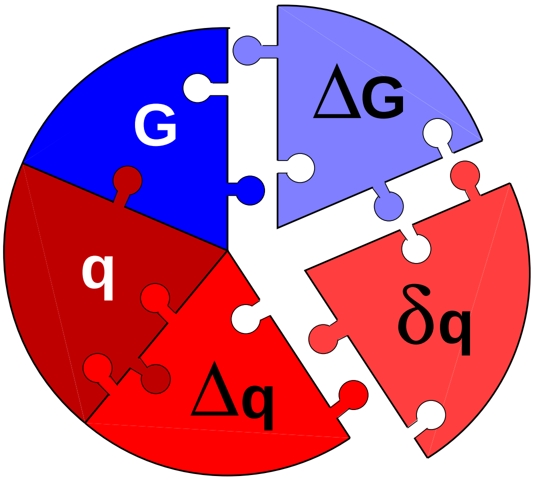

Figure 1: Picture illustrating the current knowledge of the proton structure with the missing pieces ΔG and δq.

Quarks carry an approximate quantum number called chirality which determines the 'handedness' (from the Greek word *chir* for hand) of a particle. Chirality is conserved in all hard QCD and electroweak processes. A particular property of the transversity distribution functions is that they have a chiral-odd nature because they couple quarks with opposite chirality. They are thus very difficult to measure, because they decouple from inclusive deep-inelastic scattering (DIS) and from most other familiar deep-inelastic processes, except from those involving another chiral-odd structure. This is in contrast to the chiral-even number density and helicity distribution functions which are directly accessible in inclusive lepton DIS.

The most promising way to measure the transversity distribution functions is supposed to be semi-inclusive DIS with a transversely polarised target. In this process a chiral-odd quark distribution function appears in combination with a chiral-odd fragmentation function that describes the fragmentation of a transversely polarised quark into an unpolarised hadron.

HERMES has measured single-spin azimuthal asymmetries, where only the target is polarised, for neutral and charged pion production in semi-inclusive deep-inelastic lepton scattering off a *longitudinally* polarised proton target. Here the azimuthal angle ϕ of the pion is defined relative to the lepton scattering plane. The observed single-spin asymmetries, shown in Fig. 2, can be interpreted as the effect of terms in the cross section involving chiral-odd distribution functions with a chiral-odd fragmentation function that is sensitive to the transverse polarisation of the fragmenting quark. The fact that the asymmetries are different from zero for π^0 and π^+ shows that these functions are non-zero. The results provide thus evidence in support of the existence of a non-zero transversity distribution function δq and implies a substantial magnitude for a chiral-odd fragmentation function necessary to measure it. A direct measurement of δq will need experiments on a transversely polarised proton target, something which HERMES will try in the near future.

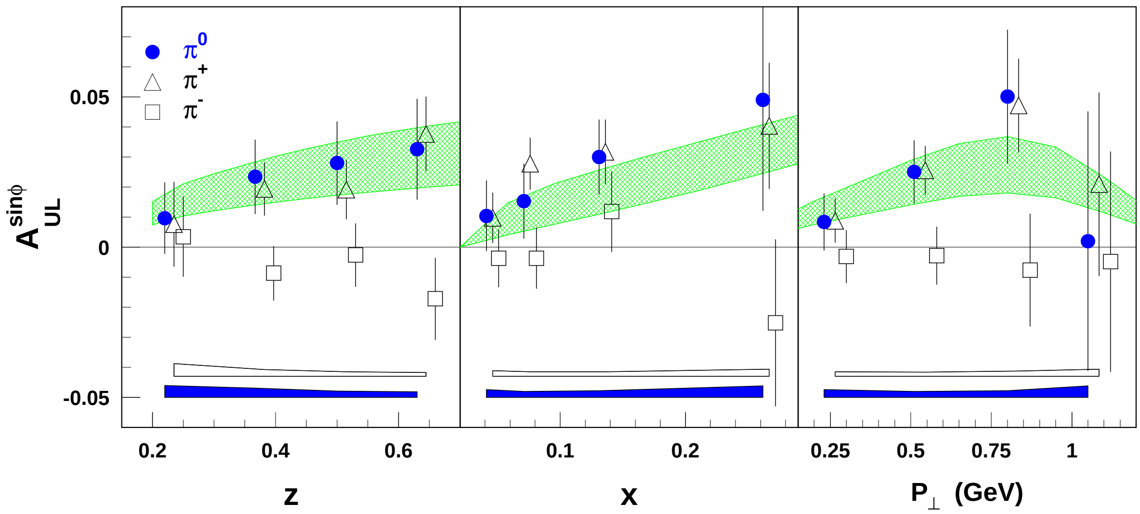

Figure 2: Single-spin asymmetries $A_{UL}^{\sin\phi}$ for π^0 (circles), π^+ (triangles) and π^- (squares) as a function of the pion fractional energy z, the Bjorken variable x and of the pion transverse momentum $P_\perp$. Here x is the fraction of the proton momentum carried by the quark. No sizeable asymmetry is expected for π^- (squares) as the π^- production is suppressed in this measurement using a proton target.
The shaded areas show a range of predictions of a model calculation based on a transversity distribution function coupled with a chiral-odd fragmentation function.