First Measurement of the Tensor Structure Function b_1 of the Deuteron.

The HERMES Collaboration, May 1, 2005

If somebody entering a dark room cannot perceive anything he will switch on the light which then reflects from the chair or from the cat and thereby delivers information about the location and velocity of these objects. A scientist who wants to draw conclusions about the world surrounding us acts exactly the same way: he sheds light on the object and examines the reflection.
By applying this principle of induced interaction and observation, physicists have in the last hundred years penetrated deeper and deeper into matter: to ordered accumulations of atoms (crystals), to the single atom, to its nucleus and the electrons surrounding it, to the building blocks of the atomic nucleus, the protons and neutrons, and finally to their subunits, the quarks and the gluons, the glue particles holding together the proton. Instead of light, other kinds of little particles were employed as a probe, and from their reflected pattern, the spatial structure of the investigated objects could be deduced: imagine you throw a ball against a wall; it will recoil in a different way depending on wether it hits a hard or a soft surface, and it will possibly not return at all in case you hit an open window. The smaller the substructures are that one wants to resolve, the more momentum the used probe has to possess. This leads to high energy physics for very small structures. A special case occurs as soon as one begins to approach the quarks: they first pretend to form a loose compound. The more one gets them at a peel, however, the more they stick together. They give up the relationship to the other quarks in the proton only by entering into a new bond (a new particle) at the same time: you will never find an isolated quark. The investigation of this level of matter has not been completed yet.

The HERMES experiment at DESY in Hamburg has been built to do research in this field. The detector is located more than 20 meters below the ground in a huge hall. A high-energetic beam of electrons is directed to this place, the same particles that surround the atomic nucleus. The co-workers at HERMES, gathering in Hamburg from all over the world, have built an obstacle in the path of the particle current. In the year 2000, for example, nuclei of heavy hydrogen were used: deuterons. The electrons collide with these nuclei and partially destroy them, while the quarks find new partners and fly away embedded in new particles from the collision point. One can imagine the HERMES apparatus to be a huge pair of glasses or a microscope of eight meters length, recording these reactions which are invisible for the human eye.

The deuteron is a very interesting object consisting of a proton and its electrically neutral brother, the neutron. Altough the two are not tied together very tightly, the deuteron is still more than the sum of its single parts in the compound of the two. The HERMES collaboration is especially interested in how a certain feature inherent in the investigated particles comes about: the so-called spin or intrinsic angular momentum. See Figure 1.1 to get an impression about it. One assigns to every particle a symbolic arrow $\longrightarrow\!\!\triangleright$, the spin, which defines an axis in space and which can be tilted only in certain directions. The crucial point is that the deuteron appears to the incoming electron in one shape when the deuteron's spin

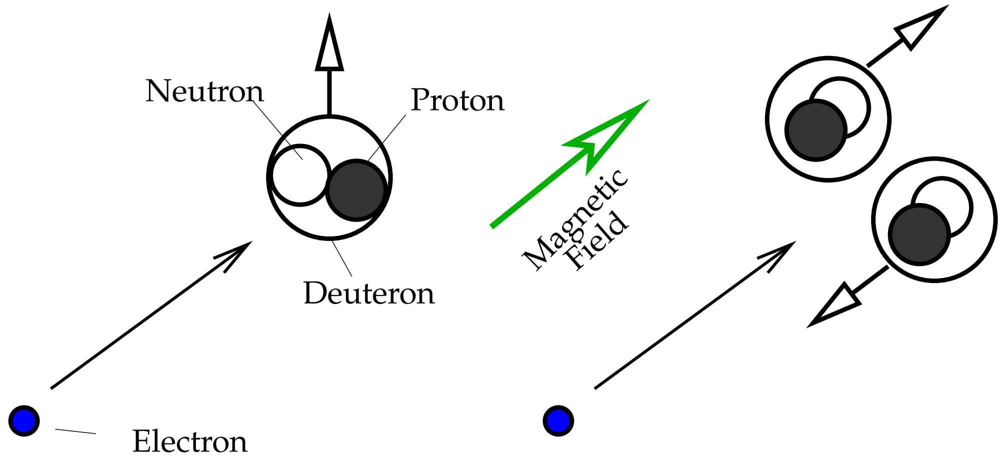

Figure 1.1: The deuteron can align its spin only to the top (left picture) or to the front/back (right picture) with respect to the magnetic holding field; the scattering electron finds the constituents in different spatial arrangements, respectively.

is tilted to the back or to the front (then the proton covers part of the neutron, or vice versa), and in another shape, when its spin is aligned to the top (then the two partners reside beside each other in the deuteron). This is manifested in a different reflection pattern, respectively. To make all deuterons tilt their spin in the same direction (then one obtains what is called polarization), one builds a strong magnetic field around them.

The HERMES group was the first in the world to determine this difference in the reflection pattern between "spin to the front or to the back" and "spin to the top" at energies at which the quark pattern is probed. For this purpose, a well-contrived division of labor between the hard- and software subgroups as well as post-processing of the measured data has been necessary in order to guarantee the result to be free from any disturbing effects. This result, the so-called tensor structure function of the deuteron, is displayed in the figure on the right hand side in dependence on the momentum fraction of the deuteron (x) which is carried by the struck quark. Theorists explain the steep rise of this structure function for small values of x with the picture that the scattering particle can then take the chance to first scatter off the proton and afterwards off the neutron, being then sensitive to the spatial alignment of the two.