Cross sections for hard exclusive electroproduction of π^+ mesons on a hydrogen target

June 7, 2007

The measurement presented here is aimed at exploring the **Generalized Partons Distributions** (GPDs), the unknown functions, which offer the possibility to construct a three-dimensional picture of the nucleon.

We know that the proton is a composite object made out of point-like partons: quarks and gluons. Presently, much of our knowledge of the quark-gluon structure of the nucleon comes from measurements by scattering lepton beams off nucleon targets. Such interaction is described by the exchange of a virtual photon γ^* between the electrons of the beam and the nucleons of the target (as shown in the top edge of the diagram of Fig. 1). Here, the virtual photon acts as a microscope on the nucleon with a resolution proportional to its four-momentum squared Q^2 (related to its energy): in order to *see* the quark and gluon content of the nucleon, the virtual photon energy has to be high enough (values of Q^2 typically above 1 GeV^2).

Two kinds of experiments provide information on the nucleon structure. From *elastic* scattering experiments, where the virtual photon interacts with the nucleon without alterating its nature, the form factors were measured and provide the information on the localization of the partons in the nucleon. In *deeply inelastic* scattering (*deeply* means that the energy of the virtual photon is high), the nucleon is broken up and many hadronic particles are produced. From such experiments, the parton distribution functions were measured and provide the information on the momentum distribution of the partons in the nucleon.

To learn more about the nucleon structure, a new type of experiment is needed: the *hard exclusive* scattering. In that case, the high energy of the virtual photon corresponds to a *hard* interaction, one or more hadronic particles are produced but the proton remains intact after the interaction of the nucleon with the virtual photon. By selecting a particular final state, all other processes are excluded and the reaction is denoted as *exclusive*. Fig. 1 shows the diagram for the exclusive scattering $ep \to en\pi^+$, in which a π^+ is produced (since the proton and the neutron are closely related to each other by isospin symmetry, the neutron is resulting from the original proton with modified quantum properties from the interaction). In such reaction, the virtual photon interacts with one of the quark of the nucleon which is then reabsorbed by the nucleon with a different momentum. The nucleon structure is parametrized here by the GPDs which describe the dynamical correlations between partons with different momenta. While the form factors and parton distribution functions describe, respectively, the localization and the momentum distribution of the partons in the nucleon, the GPDs describe the correlation between those quantities and provide hence a three-dimensional picture of the nucleon structure. In particular, by measuring exclusive reactions

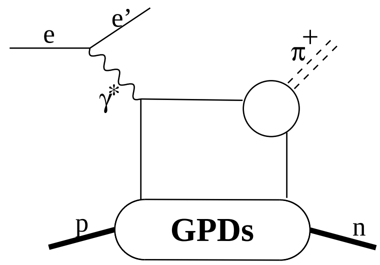

Figure 1: Diagram for the hard exclusive process $ep \to en\pi^+$.

and determining the GPDs, the still unknown orbital angular momentum of quarks and gluons in the proton can be extracted.

For the present analysis, we are interested in the reaction $ep \to en\pi^+$. We measure the probability (the cross section) that the reaction occurs as a function of the kinematic variables Q^2 and t'. The latter variable is related to the momentum transfer to the nucleon target.

The 27.6 GeV electron beam at DESY is scattered off protons. With the HERMES detector, we detect in the final state two particles: the scattered electron and the produced pion. As HERMES is a forward angle spectrometer, we are not able to detect the recoiling nucleon [1]. The exclusive reaction is then signed using the missing mass technique: from the energy-momentum conservation between the initial and final states, we can calculate the missing mass of the undetected particle or group of particles. In case of the reaction $ep \to en\pi^+$, the missing mass is equal to the mass of the neutron. For more particles in the final state, the missing mass is higher than the mass of the neutron. Constraining the missing mass, we can select the exclusive reaction.

To extract our observable, the cross section, we first measure the yield of events that fulfil the conditions described above. Then we correct the yield from different sources: from other processes that can contaminate our sample, from the HERMES spectrometer that is limited in acceptance, from the efficiency of the different detectors that composed the spectrometer, from the constraints applied on the data to select our sample, etc. To estimate the different correction factors, we are using Monte Carlo simulations that reproduce the yield of events observed with the HERMES spectrometer.

In Fig. 2, the cross section is presented as a function of the momentum transfer to the target t' for different values of Q^2. The data are compared to calculations based on a GPD model with different hypothesis. We will focus here on the most complete calculations aimed for describing our data. Those calculations, which are drawn by the solid lines, reproduce the data at low t' for the available Q^2 range. The data support therefore the size of the contributions entering the calculations of the cross section for the GPD model at low t'. At higher t', the GPD model does not describe the data showing that either the dependence in t' is not well described by that model or that another process may occur. Another theoretical model called Regge can also describe the reaction. However, the Regge model does not describe the nucleon in terms of quark and gluons but as a whole and does not provide the same kind of information on the nucleon structure as in the GPD model. This model has

[1] However, since 2006, we installed a new detector around the target in the HERMES experiment and we are now able to detect a recoiling proton.

been tuned to other experimental data measured at different energy in comparison to our data. The calculations based on the Regge model (dashed-lines) nicely reproduce our data with no additional tuning, showing that this model contains the correct description of the various kinematic dependences.

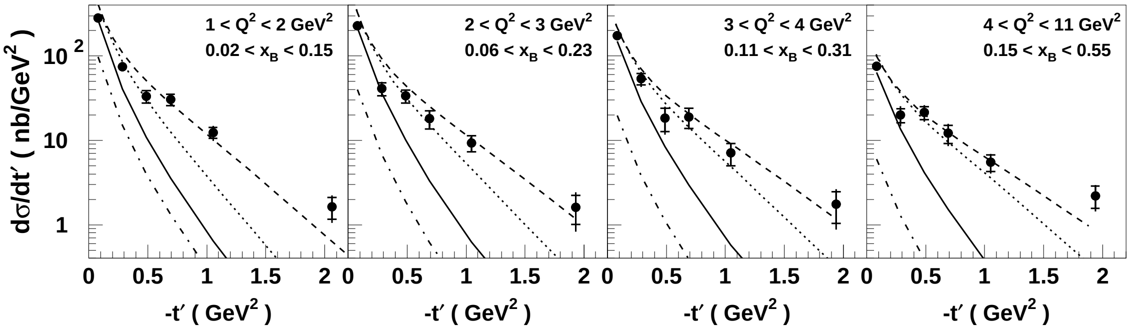

Figure 2: Probability for producing an exclusive π^+ as a function of the transfer energy to the target t'. The curves represent calculations based on a GPD model (solid lines) and a Regge model (dashed lines).