# Search for a Two-Photon Exchange Contribution to Inclusive Deep-Inelastic Scattering

The HERMES Collaboration

The HERMES experiment at DESY investigates Deep-Inelastic Scattering, in which a highly energetic lepton (an electron or its antiparticle, the positron) interacts with a proton, breaking it up into parts, which reassemble themselves into new particles that we then detect in the spectrometer. Usually one assumes that this interaction happens in the simplest possible way, i.e. with the exchange of one single boson, e.g. a photon, between the lepton and the proton, and all our studies and results are based on this assumption.

As our experiments become more and more precise we start to become sensitive to other possible interactions. In this paper we study the possibility that not one but two photons are exchanged between the lepton and the nucleon.

In order to investigate two-photon exchange contributions to the cross section it is necessary to find observables that allow their isolation. Two suitable candidates are beam-charge and transverse single-spin asymmetries, both of which arise from the interference of one-photon and two-photon exchange amplitudes (see Fig. 1), and can be observed in *inclusive* scattering, i.e. by looking just at the scattered lepton.

In the first case, since the interference cross section is directly proportional to the beam charge, one can look at differences between the measured cross section when e.g. electrons and positrons beams are employed.

In the second case, one uses a proton target polarized transversely (perpendicularly) to the beam direction, and looks at the leptons scattered at various angles $\phi_S$, where $\phi_S$ is the azimuthal angle about the beam direction between the lepton scattering plane and the target spin direction. The total cross section is the sum of the cross section for one- and for two-photon ex-

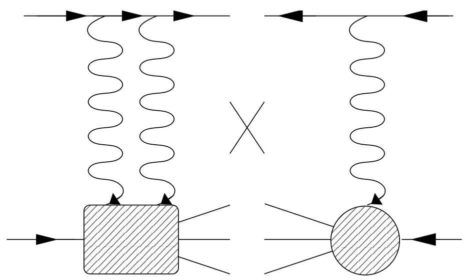

**Figure 1:** A signal from two-photon exchange comes from the interference between the amplitudes for one and two-photon exchange.

change, plus that of their interference. It turns out that the interference term is maximum when the lepton scattering plane is perpendicular to the target spin ($\phi_S = \pm 90^0$), and zero when it is parallel or anti-parallel to it ($\phi_S = 0, \pm 180^0$), while the other contributions to the cross section are independent of $\phi_S$. Additionally, it has opposite sign for the two cases $0 < \phi_S < 180^0$ and $-180^0 < \phi_S < 0$. We can then isolate the two-photon exchange contribution to the cross section by searching for an asymmetric distribution in the azimuthal angle $\phi_S$ of the scattered lepton. The strength of such an asymmetry we denote by $A_{UT}^{\sin\phi_S}$, which can take values between +1 and -1, depending on the preference of the lepton going to positive or negative $\phi_S$.

Our experiment took data with a transversely polarized proton target and a positron beam in 2002 and 2004, while in 2005 we had an electron beam. Our results for the amplitudes $A_{UT}^{\sin\phi_S}$ are shown in Fig. 2. All asymmetry amplitudes are consistent with zero within their uncertainties, which are of the order of $10^{-3}$ for the overall asymmetries. Also, no hint of a sign change of the asymmetry between electron and positron beams is observed, which would be mandatory for a signal for the interference of one- and two-photon exchange contributions.

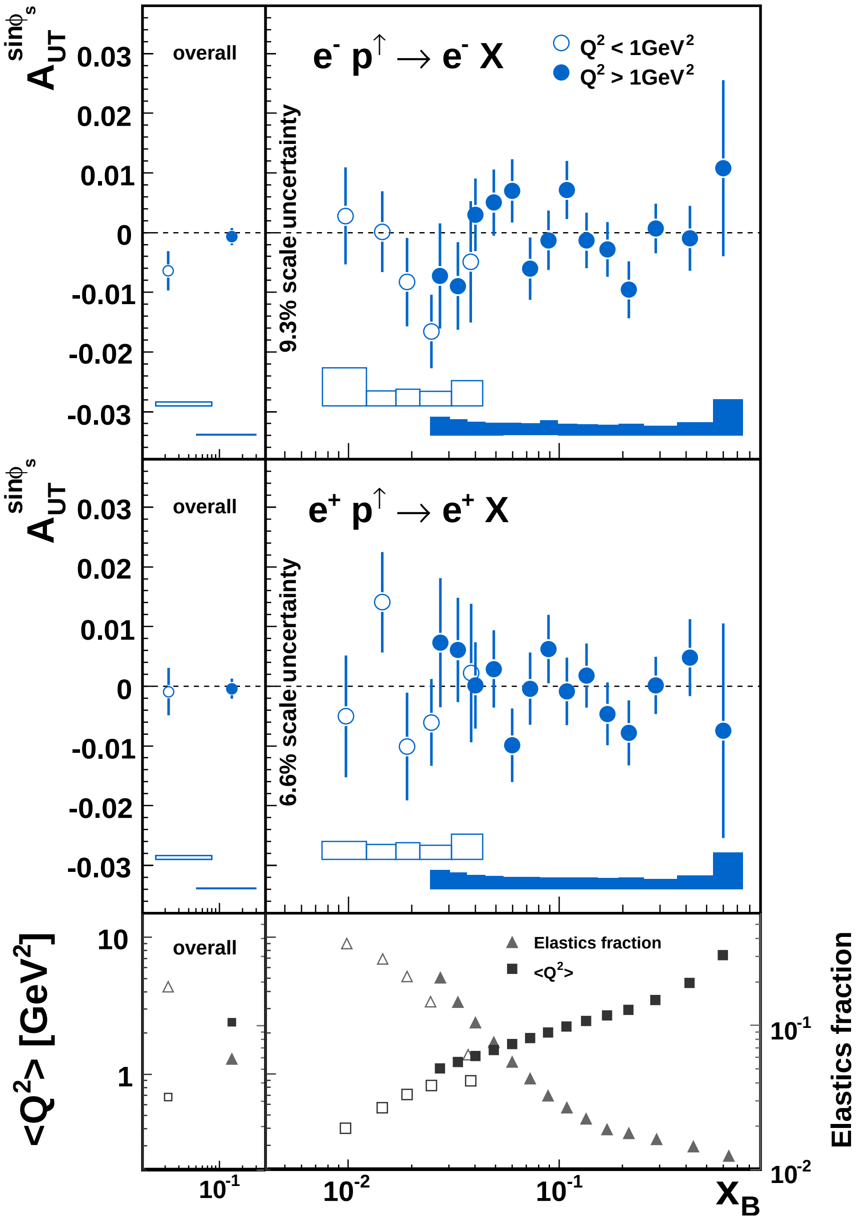


**Figure 2:** Asymmetry amplitudes as a function of $x_B$, which can be interpreted as the fraction of nucleon's four-momentum carried by the struck parton. The top panel is for an electron beam while the central panel is for the positron beam. The overall values are meant as the values over the whole $x_B$ range covered by the experiment. The results are separated into two ranges of $Q^2$, which is the negative squared momentum transferred in the reaction from the lepton to the nucleon. In the bottom panel, the variation of the average $Q^2$ with $x_B$ is shown (squared symbols), as well as the expected contribution of elastic background events to the total sample, obtained from a Monte Carlo simulation, for every $x_B$ bin.