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Transverse single spin asymmetry in elastic electron–proton scattering

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Abstract. We discuss the two-photon exchange contribution to observables which involve lepton helicity flip in elastic lepton-nucleon scattering. This contribution is accessed through the single spin asymmetry for a lepton beam polarized normal to the scattering plane. We estimate this beam normal spin asymmetry at large momentum transfer using a parton model and we express the corresponding amplitude in terms of generalized parton distributions.

PACS. 25.30.Bf Elastic electron scattering – 12.38.Bx Perturbative calculations – 13.40Gp Electromagnetic form factors

1 Introduction

Elastic electron-nucleon scattering in the one-photon exchange approximation gives direct access to the electromagnetic form factors of the nucleon, an essential piece of information about its structure. In recent years, the ratio G_{E_p}/G_{M_p} of the proton's electric to magnetic form factors has been measured up to large momentum transfer Q^2 in precision experiments [1,2] using the polarization transfer method. It came as a surprise that these experiments for Q^2 up to 5.6 GeV^2 extracted a ratio of G_{E_p}/G_{M_p} which is incompatible with unpolarized experiments [3,4,5] using the Rosenbluth separation technique. In [6], it was pointed out that this discrepancy may be resolved by a precise account of the two-photon exchange effects which enter the radiative corrections to elastic form factors.

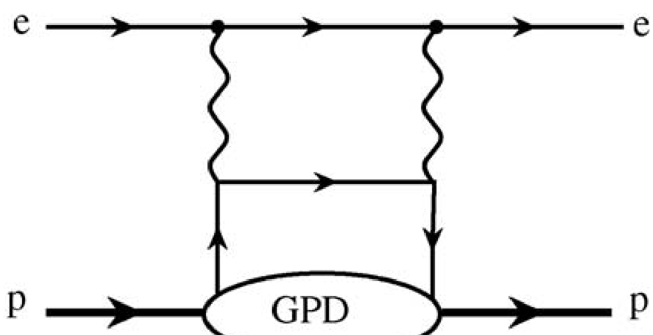

Fig. 1. Handbag contribution to the 2γ-exchange amplitude for elastic ep scattering

2 Elastic lepton-nucleon scattering amplitude beyond the one-photon exchange

In this work, we consider the elastic lepton-nucleon scattering process $l(k)+N(p) \to l(k')+N(p')$. The general amplitude for elastic scattering of two spin-1/2 particles can be parameterized in terms of six independent amplitudes. Three of them describe such scattering without helicity flip on the lepton side [6], and the other three amplitudes do flip the lepton helicity [7]. We note that in the one-photon exchange (Born) approximation, only two of them survive, the well known electromagnetic form factors G_E and G_M which are real functions of the momentum transfer Q^2 only. In this work, we study the single spin asymmetry, $B_n = \frac{\sigma_\uparrow - \sigma_\downarrow}{\sigma_\uparrow + \sigma_\downarrow}$, where $\sigma_{\uparrow(\downarrow)}$ denotes the cross section for an unpolarized target and a lepton beam spin parallel (anti-parallel) to the normal polarization vector defined as $S_n^\mu = (0, \mathbf{S}_n)$, $S_n^2 = -1$ with $\mathbf{S}_n \equiv [\mathbf{k} \times \mathbf{k}']/|[\mathbf{k} \times \mathbf{k}']|$. Its leading non-vanishing contribution is linear in the lepton mass. Furthermore, B_n vanishes in the Born approximation, and is therefore of relative order e^2. Keeping only the leading term in e^2, B_n arises from an interference between the one-photon exchange (Born) amplitude and the imaginary part of the two-photon exchange amplitude [8]. To calculate the latter, we proceed with the model used in [7,9] where the partonic (handbag) model (cf. Fig. 1) has been adopted.

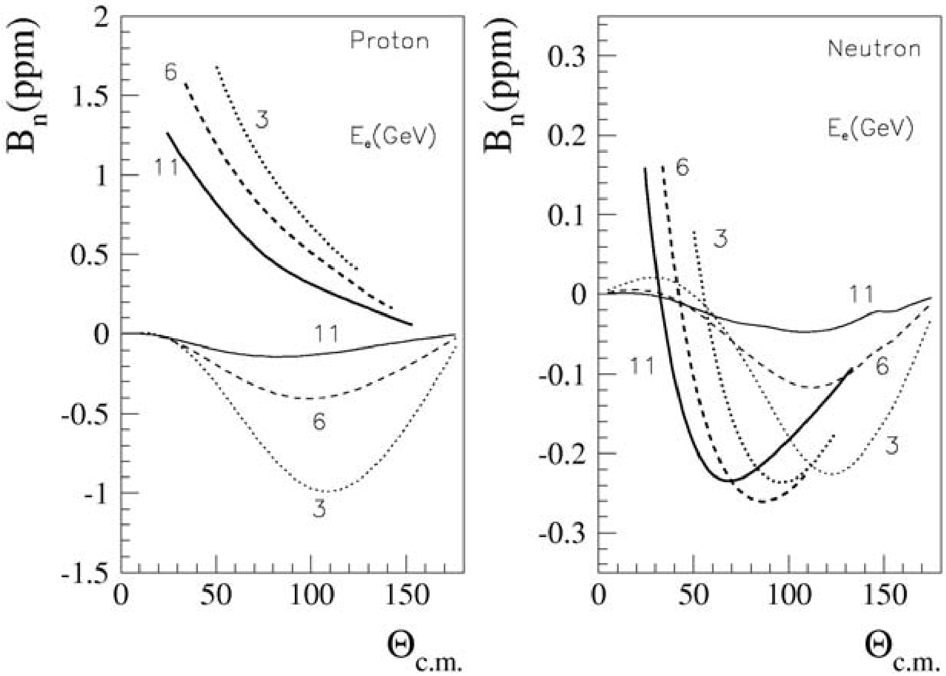

Fig. 2. Beam normal spin asymmetry for elastic $e^- N$ scattering as function of c.m. scattering angle at different values of beam energy as indicated on the figure for the proton target (*left panel*), and the neutron target (*right panel*). The *thick curves* are the GPD calculations for the kinematical range where $s, -u > M^2$. For comparison, the nucleon pole contribution is also displayed (*thin curves*)

3 Results

In this section we present our results for the asymmetry B_n on the proton and neutron targets. In our calculation, we used the most recent parameterizations of the GPDs [10,11] for the evaluation of the lower blob of Fig. 1, while we calculate exactly the loop integral appearing in the upper part of Fig. 1, for details see [7,9]. As one can see from Fig. 2, the handbag mechanism predicts the effect of ~ 1.5 ppm for the proton, and ~ -0.2 ppm for the neutron. For comparison, the contribution of the nucleon intermediate state (instead of the lower blob with GPD in Fig. 1) is shown for the same kinematics. This latter can be calculated exactly since it only contains the on-shell elastic form factors of the nucleon. For the proton, the forward kinematics ($30^\circ < \Theta_{cm} < 90^\circ$) looks promising for disentangling the inelastic contribution from the elastic one on the experiment. For the neutron, the effect is quite small due to partial cancellation of competing contributions. Further investigations of this observable at high momentum transfers is necessary to obtain a valuable cross-check for the real part of the 2γ-exchange amplitude in order to resolve the present experimental situation with the elastic form factors. At present, there exist experimental data on B_n [12,13], while the further several experiments are planned, aiming to measure this beam normal spin asymmetry in different kinematics [14,15,16].

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