Gravimagnetic nucleon form-factors in the impact parameter representation.

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Abstract

In the framework of the new $t$-dependence of the General Parton Distributions (GPDs), which reproduce the electromagnetic form factors of the proton and neutron at small and large momentum transfer, the gravitational form factors of the nucleons and a separate contribution of the quarks to them are obtained.

As a basis, it is assumed that the form factor is dominated by a soft mechanism and the Generalized Parton distributions (GPDs)-handbag approach \cite{1} is utilized. GPDs for $\xi = 0$ provide information about the distribution of the parton in impact parameter space \cite{4}. It is connected with $t$-dependence of GPDs.

In \cite{3}, a simple ansatz was proposed which will be good for describing the form factors of the proton and neutron by taking into account a number of new data that have appeared in the last years. We choose the $t$-dependence of GPDs in the form

$$
\mathcal{H}^u(x,t) = u(x) \exp[a_+ \frac{(1-x)^2}{x^m} t]; \quad \mathcal{H}^d(x,t) = d(x) \exp[a_- \frac{(1-x)^2}{x^m} t].
$$

The size of the parameter $m = 0.4$ was determined by the low $t$ experimental data; the free parameters $a_\pm$ ($a_+$ for $\mathcal{H}$ and $a_-$ for $\mathcal{E}$) were chosen to reproduce the experimental data in a wide $t$ region. The $q(x)$ was taken from the MRST2002 global fit \cite{5} with the scale $\mu^2 = 1$ GeV$^2$. In all our calculations we restrict ourselves, as in other works, only to the contributions of $u$ and $d$ quarks and the terms in $\mathcal{H}^q$ and $\mathcal{E}^q$. Correspondingly, for $\mathcal{E}^u(x)$, as for example \cite{2}, we have

$$
\mathcal{E}^u(x) = \frac{k_u}{N_u}(1-x)^{\kappa_1} u(x), \quad \mathcal{E}^d(x) = \frac{k_d}{N_d}(1-x)^{\kappa_2} d(x),
$$

where $\kappa_1 = 1.53$ and $\kappa_2 = 0.31$ \cite{2}. With standard normalization of the form factors, we have $k_u = 1.673$, $k_d = -2.033$, $N_u = 1.53$, $N_d = 0.946$. The parameters $a_+ = 1.1$ and $a_-$ were chosen to obtain two possible forms of the ratio of the Pauli and Dirac form factors.

1 Proton and neutron electromagnetic form factors

The proton Dirac form factor calculated in \cite{3} reproduces sufficiently well the behavior of experimental data not only at high $t$ but also at low $t$. Our description of the ratio of the Pauli to the Dirac proton form factors and the ratio of $G_E^p/G_M^p$ shows that in our model we can obtain the results of both the methods (Rosenbluth and Polarization) by changing the slope of $\mathcal{E}$. Based on the model developed for proton the neutron form factors are calculated.
too. To do this the isotopic invariance can be used to change the proton GPDs to neutron GPDs. Hence, we do not change any parameters and conserve the same \( t \)-dependence of GPDs as in the case of proton. Our calculation of \( G_E^n \) shows that the variant which describes the polarization data is in better agreement with the experimental data. The calculation of \( G_M^n \) more clearly shows that this variant much better describes the experimental data especially at low momentum transfer.

\section{Gravitational form factors}

As was shown in \cite{6}, the gravitational form factor for fermions is determined as

\[
\int_{-1}^{1} dx \ x [H(x, \Delta^2, \xi) + E(x, \Delta^2, \xi)] = A_q(\Delta^2) + B_q(\Delta^2). \tag{3}
\]

Using this representation we can calculate the gravitational form factor for the nucleon. Our result for \( A_q(t) \) is shown in Fig.1a. Separate contributions of the \( u \) and \( d \)- quark distribution are shown in Fig.1b. At \( t = 0 \) these contributions equal \( A_u(t = 0) = 0.35 \) and \( A_d(t = 0) = 0.14 \); and \( B_u(t = 0) = 0.22 \), \( B_d(t = 0) = -0.27 \). The sum of \( B_q \) will be near zero \( B_q(t = 0) = -0.05 \). In accuracy of our approximations this result coincides with zero. In fig.1a we compare gravitational form factors with our calculations of electromagnetic form factors. It can be seen that at large momentum transfer they have the same \( t \)-dependence. Of course, they essentially differ in size.

\section{Conclusion}

We introduced a simple new form of the \( t \)-dependence of GPDs. It satisfies the conditions of the non-factorization, introduced by Radushkin, and the Burkhardt condition on the power of \((1 - x)^n\) in the exponential form of the \( t \)-dependence. With this simple form we
obtained a good description of the proton electromagnetic Sachs form factors. Using the isotopic invariance we obtained good descriptions of the neutron Sachs form factors without changing any parameters.

On the basis of our results we calculated the contribution of the $u$ and $d$ quarks to the gravitational form factor of the nucleons. The cancellation of these contributions at $t = 0$ shows that the gravimagnetic form factor is zero for separate contributions, gluons and quarks, which confirms the result of [8].

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