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Transverse charge densities of the deuteron in soft-wall AdS/QCD

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Abstract

We investigate the transverse charge densities of the deuteron in a soft-wall AdS/QCD model by considering both the unpolarized and the transversely polarized cases. The deuteron form factors are derived from the soft-wall AdS/QCD model and it is shown that the calculated results agree with the phenomenological parametrization and experimental data. The transverse charge densities of the deuteron are also derived from the soft-wall AdS/QCD model, and we notice slight deviations from those of the phenomenological parametrization.

Keywords: Deuteron; AdS/QCD model; Transverse charge densities; Form factors

1. Introduction

The electromagnetic forms factors contain information about the internal structure of the nucleon and the nucleus. With the Fourier transformation, form factors of nucleons reflect the spatial distributions such as charge densities [1]. There have been considerable efforts to investigate the transverse charge densities of the nucleon [2–5]. The initial and final states for

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calculating form factors are different and the three dimensional Fourier transformation can not be interpreted as densities. But the transverse densities, which defined in fixed light-front time, have density interpretation [6,7]. Transverse charge densities are a new tool for analyzing electromagnetic form factors of systems composed of constituents that move relativistically [8]. It has led to some very interesting findings by use of transverse charge densities. For example, the center of the neutron charge densities have a negative core [9] and the spatial extent of the magnetization density of the proton is greater than that of its charge density [10].

In recent years, anti-de Sitter (AdS) spacetime and quantum chromodynamics (QCD) correspondence, which has emerged as one of the most promising techniques to investigate the structure of hadron, has achieved significant progress in research of non-perturbative QCD. According to the AdS and conformal field theories (CFT) conjecture [11], a weakly coupled gravity theory in AdS_{n+1} can be related to a conformal theory in n-dimensional space–time. To apply AdS/CFT to QCD, which is not a conformal theory, the conformal invariance need to be broken. Usually, there are two methods, referred to as the hard-wall model [12] and the soft-wall model [13], adopted to achieve this goal. In the former method, a sharp cutoff is imposed at large distance, so that the wave functions vanish at the boundary. In the latter method, the conformal invariance is broken by a dilaton background, which provides a smooth cutoff at large distance. Compared to the hard-wall model, soft-wall AdS/QCD can reproduce the Regge trajectory [14] and the massless pion in the chiral limit [15]. So far, AdS/QCD has been successfully applied to describe many hadron properties such as hadron mass spectrum, generalized parton distributions, meson and nucleon form factors, transverse densities, and structure functions etc. [16–26].

The transverse charge densities of the nucleon in a model independent way have been studied in Ref. [9] and the charge densities in the transverse plane for a transversely polarized nucleon are shown in Refs. [1,27]. In Ref. [28], by using the method of dispersion analysis and chiral effective field theory, transverse charge densities have been studied in the chiral periphery of the nucleon. The transverse densities for the quarks of the nucleon are analyzed in a chiral quark–soliton model [8]. Apart from the transverse charge densities of the nucleon, it is also interesting to study the transverse densities of the deuteron. For example, the transverse charge densities of the deuteron have been studied in Ref. [29], by using the parametrization of the deuteron form factor data given as fit II by Abbott et al. [31].

In this work, we give a comparison of the deuteron form factors calculated in the soft-wall model with those from the experimental data and phenomenological parametrization. Then, we give a prediction for the transverse charge densities of the deuteron in the soft-wall AdS/QCD model and compare the results with the parametrization.

The paper is organized as follows. The electromagnetic form factors of the deuteron in the soft-wall AdS/QCD model are given in Sec. 2. In Sec. 3, the transverse charge densities of the deuteron for both unpolarized and transversely polarized cases are discussed. Finally, we provide a brief summary in Sec. 4.

2. Soft-wall ADS/QCD model for deuteron form factors

For the deuteron electromagnetic form factors, we consider the soft-wall model of AdS/QCD proposed by Gutsche et al. [32,33]. The effective action is given by