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Non-nucleonic degrees of freedom and the spin structure of the deuteron

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Electro-disintegration of the deuteron at large Q^2 currently represents on of the most promising reactions which allows to probe the bound nuclear state at internal momenta comparable to the rest mass of the nucleon. Large internal momentum in this case makes non-nuncleonic states energetically more feasible and the question that we address is what are the signatures that will indicate the existence of such states in the ground state of the nuclear wave function. To probe such states we developed a light-front formalism for relativistic description of a composite pseudo-vector system in which emerging proton and neutron are observed in electro-disintegration reaction. In leading high energy approximation our calculations show the possibility of the existence of a new “incomplete" P-state-like structure in the deuteron at extremely large internal momenta. The incompleteness of the observed P-state violates the angular condition for the momentum distribution, which can happen only if the deuteron contains non-nucleonic structures, such as $\Delta\Delta$, N^*N or hidden color components. Because such states have distinctive angular momentum ($l = 1$) they significantly modify the polarization properties of the deuteron wave function. As a result in addition to angular anisotropy of the LF momentum distribution of the nucleon in the deuteron one predicts strong modification of the tensor polarization asymmetry of the deuteron beyond the S- and D- wave predictions at large internal momenta in the deuteron.

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1. Introduction

Understanding the dynamics of the transition between hadronic to quark-gluon phases of matter is one of the outstanding issues of strong interaction physics. For cold dense nuclear matter such transitions are relevant for the dynamics of superdense nuclear matter that can exist at the cores of neutron stars and can set the limits for the matter density before it collapses to a black hole. There are few options to investigate such transitions. For example, studying nuclear medium modification of quark-gluon structure of bound nucleons by probing EMC effects [1–3] especially in semi-inclusive processes which allow to control inter-nucleon distances[4]. The other, rather different example is to study implications of the transition of baryonic to quark matter in the cores of neutron stars by searching large mass ($\approx 2.08 M_{\odot}$) neutron stars[5] with radii $R < 10$[6].

In the present work, new approach[7] is suggested in probing baryon-quark transition by exploring deuteron at extremely large internal momenta.

2. Deuteron on the light front (LF)

Non-relativistic picture of the deuteron suggests that the observations of total isospin, $I = 0$, total spin, $J = 1$ and positive parity, P, together with the relation, $P = (-1)^l$, indicate that the deuteron consists of bound proton and neutron in S- and D- partial wave states.

However, for deuteron structure with internal momenta comparable to the nucleon rest mass the nonrelativistic framework is not valid requiring a consistent account for the relativistic effects. There are several theoretical approaches for accounting relativistic effects in the deuteron wave function (see e.g. Refs.[8–12] and the reviews[13–17]). In our approach the relativistic effects are accounted for similar to the one used in QCD (see e.g. [18, 19]) for calculation of quark distribution in hadrons, in which light-front (LF) description of the scattering process allows to suppress vacuum fluctuations that overshadow the composite structure of the hadron. In this approach one needs to identify the process in which the deuteron structure is probed. For this we consider high-momentum transfer electrodisintegration process:

$$e + d \to e' + p + n \tag{1}$$

in which one of the nucleons are struck by the incoming probe and the spectator nucleon is probed with momenta comparable to the nucleon mass. If one can neglect (or remove) the effects related to final state interactions of two outgoing nucleons, then the above reaction at high Q^2, measures the probability of observing a proton and neutron in the deuteron with large relative momenta. In such a formulation the deuteron is not a composite system consisting of a proton and neutron, but it is a composite pseudo - vector ($J = 1$, $P = +$) “particle" from which one extracts a proton and neutron. Thus we formulate the question not as how to describe relativistic motion of proton and neutron in the deuteron, but how such a proton and neutron are produced at such extreme conditions relating it to the dynamical structure of the LF deuteron wave function. In such formulation the latter may include internal elastic $pn \to pn$ as well as inelastic $\Delta\Delta \to pn$, $N^*N \to pn$ or $N_c N_c \to pn$ transitions. Here, Δ and N^* denote Δ-isobar and N^* resonances, while N_c is a color octet baryonic state contributing to the hidden-color component in the deuteron.

The framework for calculation of reaction (1) in the relativistic domain is the LF approach (e.g.

Ref.[13, 14, 19]) in which one introduces the LF deuteron wave function:

$$\psi_d^{\lambda_d}(\alpha_i, p_\perp, \lambda_1\lambda_2) = -\frac{\bar{u}(p_2,\lambda_2)\bar{u}(p_1,\lambda_1)\Gamma_d^\mu \chi_\mu^{\lambda_d}}{\frac{1}{2}(m_d^2 - 4\frac{m_N^2+p_\perp^2}{\alpha_i(2-\alpha_i)})\sqrt{2(2\pi)^3}} == -\sum_{\lambda_1'} \bar{u}(p_1,\lambda_1)\Gamma_d^\mu \gamma_5 \frac{\epsilon_{\lambda_1,\lambda_1'}}{\sqrt{2}} u(p_1,\lambda_1'), \quad (2)$$

where $\alpha_i = 2\frac{p_{i+}}{p_{d+}}$, $(i = 1, 2)$ are LF momentum fraction of proton and neutron, outgoing from the deuteron with $\alpha_1 + \alpha_2 = 2$ and in the second part we absorbed the propagator into the vertex function and used crossing symmetry. Here $u(p, \lambda)$'s are the LF bi-spinors of the proton and neutron[20] and $\epsilon_{i,j}$ is the two dimensional Levi-Civita tensor, with $i, j = \pm 1$ nucleon helicity. Since the deuteron is a pseudo-vector "particle", due to γ_5 in Eq.(2), the vertex Γ_d^μ is a four-vector which we can construct in a general form that explicitly satisfies time reversal, parity and charge conjugate symmetries. Noticing that at the $d \to pn$ vertex on the light-front the "-" $(p^- = E - p_z)$ components of the four-momenta of the particles are not conserved, in addition to the four-momenta of two nucleons, p_1^μ and p_2^ν, one has the additional four-momentum:

$$\Delta^\mu \equiv p_1^\mu + p_2^\mu - p_d^\mu \equiv (\Delta^-, \Delta^+, \Delta_\perp) = (\Delta^-, 0, 0), \quad (3)$$

where

$$\Delta^- = p_1^- + p_2^- - p_d^- = \frac{4}{p_d^+}\left[m_N^2 - \frac{M_d^2}{4} + k^2\right]; k = \sqrt{\frac{m_N^2 + k_\perp^2}{\alpha_1(2-\alpha_1)} - m_N^2}; \quad \alpha_1 = \frac{E_k + k_z}{E_k}, \quad (4)$$

with $E_k = m^2 + k^2$. With p_1^μ, p_2^μ and Δ^μ 4-vectors the Γ_d^μ is constructed in the form:

$$\Gamma_d^\mu = \Gamma_1\gamma^\mu + \Gamma_2\frac{(p_1-p_2)^\mu}{2m_N} + \Gamma_3\frac{\Delta^\mu}{2m_N} + \Gamma_4\frac{(p_1-p_2)^\mu \not{\Delta}}{4m_N^2}$$
$$+i\Gamma_5\frac{1}{4m_N^3}\gamma_5\epsilon^{\mu\nu\rho\gamma}(p_d)_\nu(p_1-p_2)_\rho(\Delta)_\gamma + \Gamma_6\frac{\Delta^\mu \not{\Delta}}{4m_N^2}, \quad (5)$$

where Γ_i,$(i = 1, 6)$ are scalar functions (see also Refs.[12, 17]).

3. High energy approximation

For the large Q^2 limit, the LF momenta for reaction (1) are chosen as follows:

$$p_d^\mu \equiv (p_d^-, p_d^+, p_{d\perp}) = \left(\frac{Q^2}{x\sqrt{s}}\left[1 + \frac{x}{\tau} - \sqrt{1+\frac{x^2}{\tau}}\right], \frac{Q^2}{x\sqrt{s}}\left[1 + \frac{x}{\tau} + \sqrt{1+\frac{x^2}{\tau}}\right], 0_\perp\right)$$
$$q^\mu \equiv (q^-, q^+, q_\perp) = \left(\frac{Q^2}{x\sqrt{s}}\left[1 - x + \sqrt{1+\frac{x^2}{\tau}}\right], \frac{Q^2}{x\sqrt{s}}\left[1 - x - \sqrt{1+\frac{x^2}{\tau}}\right], 0_\perp\right), \quad (6)$$

where $s = (q + p_d)^2$, $\tau = \frac{Q^2}{M_d^2}$ and $x = \frac{Q^2}{M_d q_0}$, with q_0 being the virtual photon energy in the deuteron rest frame. The high energy nature of this process results in, $p_d^+ \sim \sqrt{Q^2} \gg m_N$, which makes Δ^- term to be suppressed by the large p_d^+ factor in Eq.(4). As such we treat $\frac{\Delta^-}{2m_N}$ factor as a small parameter in the problem.

Analyzing now the vertex function (5) one observes that Γ_1 and Γ_2 terms are explicitly leading order in $O^0(\frac{\Delta^-}{2m_N})$. The Γ_3 and Γ_4 terms enter with order $O^1(\frac{\Delta^-}{2m_N})$, while the Γ_6 term enters as $O^2(\frac{\Delta^-}{2m_N})$. The situation with the Γ_5 term is, however, different; since the covariant components:

$\Delta_+ = \frac{1}{2}\Delta^-$ and $p_{d,-} = \frac{1}{2}p_d^+$, the term with $\epsilon^{\mu+\perp-}$ is leading order ($O^0(\frac{\Delta^-}{2m_N})$) due to the fact that the large p_d^+ factor is canceled in the $p_{d,-}\Delta_+ = \frac{1}{4}p_d^+\Delta^-$ combination.

Keeping the leading, $O^0(\frac{\Delta^-}{2m_N})$, terms in Eq.(5) and using the boost invariance of the wave function we calculate it in the CM of the deuteron[7] to obtain:

$$\psi_d^{\lambda_d}(\alpha_i, k_\perp) = -\sum_{\lambda_2,\lambda_1,\lambda_1'} \bar{u}(-k,\lambda_2)\left\{\Gamma_1\gamma^\mu + \Gamma_2\frac{\tilde{k}^\mu}{m_N} + \sum_{i=1}^{2} i\Gamma_5\frac{1}{8m_N^3}\epsilon^{\mu+i-}p_d'^{+}k_i\Delta'^{-}\right\}\gamma_5\frac{\epsilon_{\lambda_1,\lambda_i'}}{\sqrt{2}}u(k,\lambda_1')s_\mu^{\lambda_d}, \quad (7)$$

where $\tilde{k}^\mu = (0, k_z, k_\perp)$ with $k_\perp = p_{1\perp}$, $k^2 = k_z^2 + k_\perp^2$ and $E_k = \frac{\sqrt{s_{NN}}}{2}$ and $s_\mu^{\lambda_d} = (0, \mathbf{s_d^\lambda})$, with $s_d^1 = -\frac{1}{\sqrt{2}}(1, i, 0)$, $s_d^1 = \frac{1}{\sqrt{2}}(1, -i, 0)$, $s_d^0 = (0, 0, 1)$ and $p_d'^{+} = \sqrt{s_{NN}}$, $\Delta'^{-} = \frac{1}{\sqrt{s_{NN}}}\left[\frac{4(m_N^2+k_\perp^2)}{\alpha_1(2-\alpha_1)} - M_d^2\right]$. Since the term related to Γ_5 is proportional to $\frac{4(m_N^2+k_\perp^2)}{\alpha_1(2-\alpha_1)} - M_d^2$, which diminishes at small momenta, only the Γ_1 and Γ_2 terms will contribute in the nonrelativistic limit defining the S- and D- components of the deuteron. Thus, the LF wave function in Eq.(7) provides a smooth transition to the non-relativistic deuteron wave function. This can be seen by expressing Eq.(7) through two-component spinors:

$$\psi_d^{\lambda_d}(\alpha_1, k_t, \lambda_1, \lambda_2) = \sum_{\lambda_1'} \phi_{\lambda_2}^\dagger\sqrt{E_k}\left[\frac{U(k)}{\sqrt{4\pi}}\sigma\mathbf{s_d^{\lambda_d}} - - \frac{W(k)}{\sqrt{4\pi}\sqrt{2}}\left(\frac{3(\sigma\mathbf{k})(\mathbf{k}\mathbf{s_d^\lambda})}{k^2} - \sigma\mathbf{s_d^\lambda}\right) + (-1)^{\frac{1+\lambda_d}{2}}P(k)Y_1^{\lambda_d}(\theta,\phi)\delta^{1,|\lambda_d|}\right]\frac{\epsilon_{\lambda_1,\lambda_1'}}{\sqrt{2}}\phi_{\lambda_1'}. \quad (8)$$

Here the first two terms have explicit S- and D- structures where the radial functions are defined as:

$$\begin{aligned} U(k) &= \frac{2\sqrt{4\pi}\sqrt{E_k}}{3}\left[\Gamma_1(2 + \frac{m_N}{E_k}) + \Gamma_2\frac{k^2}{m_N E_k}\right] \\ W(k) &= \frac{2\sqrt{4\pi}\sqrt{2E_k}}{3}\left[\Gamma_1(1 - \frac{m_N}{E_k}) - \Gamma_2\frac{k^2}{m_N E_k}\right]. \end{aligned} \quad (9)$$

This relation is known for pn-component deuteron wave function[12, 13], which allows us to model the LF wave function through known radial S- and D- wave functions evaluated at LF relative momentum k defined in Eq.(4).

The new result is thhat due to the Γ_5 term there is an additional leading contribution, which because of the relation $Y_1^\pm(\theta,\phi) = \mp i\sqrt{\frac{3}{4\pi}}\sum_{i=1}^{2}\frac{(k\times s_d^{\pm 1})_z}{k}$, has a P-wave like structure, where the P-radial function is defined as:

$$P(k) = \sqrt{4\pi}\frac{\Gamma_5(k)\sqrt{E_k}}{\sqrt{3}}\frac{k^3}{m_N^3}. \quad (10)$$

Note that this term is purely relativistic in origin: as it follows from Eq.(10) it has an extra $\frac{k^2}{m_N^2}$ factor in addition to the $\frac{k^{l=1}}{m_N}$ term that characterizes the radial P-wave. Thus our result does not affect the known non-relativistic wave function.

The unusual feature of our result is that the P-wave is "incomplete", that is it contributes only for $\lambda_d = \pm 1$ polarizations of the deuteron.

4. Light front density matrix of the deuteron

One defines the unpolarized deuteron LF momentum distribution $n_d(k, k_\perp)$ and density matrix [2, 13] as follows:

$$n_d(k, k_\perp) = \frac{1}{3} \sum_{\lambda_d=-1}^{1} | \psi_d^{\lambda_d}(\alpha, k_\perp) |^2 \quad \text{and} \quad \rho_d(\alpha, k_\perp) = \frac{n_d(k, k_\perp)}{2 - \alpha}. \tag{11}$$

Using Eq.(8) the LF momentum distribution is expressed through the radial wave functions as follows:

$$n_d(k, k_\perp) = \frac{1}{3} \sum_{\lambda_d=-1}^{1} | \psi_d^{\lambda_d}(\alpha, k_\perp) |^2 == \frac{1}{4\pi} \left(U(k)^2 + W(k)^2 + \frac{k_\perp^2}{k^2} P^2(k) \right) \tag{12}$$

with $\int \rho_d(\alpha, k_\perp) \frac{d\alpha}{\alpha} = 1$, $\int \alpha \rho_d(\alpha, k_\perp) \frac{d\alpha}{\alpha} = 1$ and $\int \left(U(k)^2 + W(k)^2 + \frac{2}{3} P^2(k) \right) k^2 dk = 1$. Due to the incompleteness of the P-wave structure our result predicts that LF momentum distribution for unpolarized deuteron depends explicitly on the transverse component of the relative momentum on the light front. This is highly unusual result, implication of which will be discussed in the next section.

For polarized deuteron the quantity that can be probed in the reaction1 is tensor asymmetry which we defined as:

$$A_T = \frac{n_d^{\lambda_d=1}(k, k_\perp) + n_d^{\lambda_d=-1}(k, k_\perp) - 2n_d^{\lambda_d=0}(k, k_\perp)}{n_d(k, k_\perp)}. \tag{13}$$

Here because of the same incompleteness of the "$P - wave$" structure one may expect more sensitivity that for unpolarized momentum distribution.

5. The new term and the non-nucleonic components in the deuteron:

One of our main prediction that LF momentum distribution Eq.(12) will explicitly depend on the transverse component of the deuteron internal momentum on the light front. Such a dependence is impossible for non-relativistic quantum mechanics of the deuteron since in this case the potential of the interaction is real (no inelasticities) and the solution of Lippmann-Schwinger equation for partial S- and D-waves satisfies the “angular condition", according to which the momentum distribution in the unpolarized deuteron depends on the magnitude of the relative momentum only. As we mentioned earlier, our result does not contradict the properties of non-relativistic deuteron wave function since, according to Eq.(10) the P-wave is purely relativistic in nature.

In the relativistic domain the definition of the interaction potential is not straightforward to allow the use of quantum-mechanical arguments in claiming that the momentum distribution in Eq.(12) should satisfy the angular condition also in the relativistic case. (i.e. to be dependent only on the magnitude of k).

To check the situation in relativistic case one considers Weinberg type equation[21] on the light-front for NN scattering amplitudes, in which only nucleonic degrees are considered, in the CM of the NN system. One obtains[22]:

$$T_{NN}(\alpha_i, k_{i\perp}, \alpha_f, k_{f,\perp}) \equiv T_{NN}(k_{i,z}, k_{i\perp}, k_{f,z}, k_{f,\perp}) = V(k_{i,z}, k_{i\perp}, k_{f,z}, k_{f,\perp})$$
$$+ \int V(k_{i,z}, k_{i\perp}, k_{m,z}, k_{m,\perp}) \frac{d^3 k_m}{(2\pi)^3 \sqrt{m^2 + k_m^2}} \frac{T_{NN}(k_{m,z}, k_{m\perp}, k_{f,z}, k_{f,\perp})}{4(k_m^2 - k_f^2)}, \tag{14}$$

where “i", “m" and “f" subscripts correspond to initial, intermediate and final NN states, respectively, and momenta $k_{i,m,f}$ are defined similar to Eq.(4).

The realization of the angular condition for the relativistic case will require that the light-front potential in general to satisfy the condition:

$$V(k_{i,z}, k_{i\perp}, k_{m,z}, k_{m,\perp}) = V(\vec{k}_i^2, (\vec{k}_m - \vec{k}_i)^2). \tag{15}$$

Such a conditions for the on-shell limit follows from the Lorentz invariance of the T_{NN} amplitude:

$$T_{NN}^{on\ shell}(k_{i,z}, k_{i\perp}, k_{m,z}, k_{m,\perp}) = T_{NN}^{on\ shell}(\vec{k}_i^2, (\vec{k}_m - \vec{k}_i)^2) \tag{16}$$

and the existence of the Born term in Eq.(14) indicates that the potential V satisfies the same condition in the on-shell limit.

For the off-shell potential, it was shown[2, 22, 23] that requirements for the potential V to satisfy angular condition in the on-shell limit and that it can be constructed through the series of elastic pn scatterings result in a potential which is an analytic function of angular momentum. With the assumption that the potential, analytically continued to the complex angular momentum space, does not diverge exponentially, it was shown that the V and T_{NN} functions satisfy the angular condition (Eqs.(15,16)) in general. Using the same potential to calculate the LF deuteron wave function will result in a momentum distribution dependent only on the magnitude of the relative pn momentum. This observation requires a consideration of the pn component only in the deuteron.

Inclusion of the inelastic transitions will completely change the LF equation for the pn scattering. For example, the contribution of N^*N transition to the elastic NN scattering:

$$T_{NN}(k_{i,z}, k_{i\perp}, k_{f,z}, k_{f,\perp}) = \int V_{NN^*}(k_{i,z}, k_{i\perp}, k_{m,z}, k_{m,\perp}) \times \frac{d^3k_m}{(2\pi)^3\sqrt{m^2 + k_m^2}} \frac{T_{N^*N}(k_{m,z}, k_{m\perp}, k_{f,z}, k_{f,\perp})}{4(k_m^2 - k_f^2 + m_{N*}^2 - m_N^2)}, \tag{17}$$

will not require the condition of Eq.(15) with the transition potential having also an imaginary component. Eq.(17) can not be described with any combination of elastic NN interaction potentials that satisfies the angular condition. The same will be true also for $\Delta\Delta \to NN$ and $N_c, N_c \to NN$ transitions.

Thus one concludes that if the Γ_5 term is not zero and results in a $k_\perp$ dependence of LF momentum distribution then it should originate from a non-nucleonic component in the deuteron.

6. Predictions and estimate of the possible effects

Our calculations predict three new effects that in probing deuteron structure at very large internal momenta ($\geq m_N$) in reaction (1):

- the LF momentum distribution should be enhanced compared to S- and D- wave contributions only;
- there should be angular anisotropy in the LF momentum distribution;
- the tensor asymmetry should be significantly different as expected from S- and D- wave contributions only.

Observation of all above effects will indicate presence of non-nucleonic components in the deuteron wave function at large internal momenta.

To give quantitative estimates of the possible effects we evaluate the Γ_5 vertex function assuming two color-octet baryon transition to the pn system ($N_c N_c \to pn$) through the one-gluon exchange, parameterizing it in the dipole form $\frac{A}{(1+\frac{k^2}{0.71})^2}$. The parameter A is estimated by assuming 1% contribution to the total normalization from the P wave. The latter is consistent with the experimental estimation in Ref.[24] of 0.7%. In Fig.1 we consider the dependence of the momentum distribution of Eq.(12) as a function of $\cos\theta = \frac{(\alpha-1)E_k}{k}$ for different values of k. Notice that if the momentum distribution is generated by pn component only, the angular condition is satisfied, and no dependence should be observed.

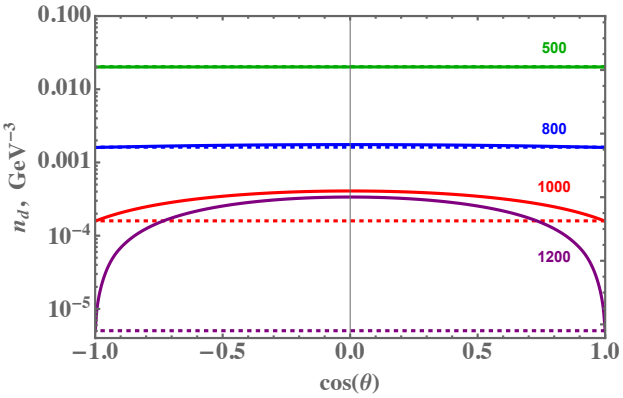

Figure 1: LF momentum distribution of the deuteron as a function of $\cos\theta$, for different values of k. Dashed lines - deuteron with pn component only, solid lines - with P-wave like component included.

As the figure shows one may expect measurable angular dependence at $k \gtrsim 1$ GeV/c, which is consistent with the expectation that the inelastic transition in the deuteron corresponding to the non-nucleonic components takes place at $k \gtrsim 800$ MeV/c.

For tensor polarized deuteron we estimated the effect using Eq.13. The results are presented in Fig.2. As the figure shows the presence of a non-nucleonic component will be visible already at $k \approx 800$ MeV/c, resulting in a qualitative difference in asymmetry at larger momenta as compared with the asymmetry predicted by the deuteron wave function with a pn-component only.

The reason why small, 1% effect in overall normalization gives large measurable effect in LF momentum distribution and asymmetry at $k \geq 1$GeV/c is due to the fact that the observed "incomplete P-wave" structure enters with the $\frac{p^2}{m_N^2}$ prefactor (see Eq.(10)), which significantly amplifies the effect at very large internal momenta.

7. Outlook on experimental verification of the predicted effects

The predictions discussed in the previous section that are related to the existence of non-nucleonic component in the deuteron wave function can be be verified at CM momenta $k \gtrsim 1$ GeV/c. These seem an incredibly large momenta to be measured in experiment. However, the first such measurement at high Q^2 disintegration of the deuteron has already been performed at Jefferson Lab[25] reaching $k \sim 1$ GeV/c. It is intriguing that the results of this measurement qualitatively

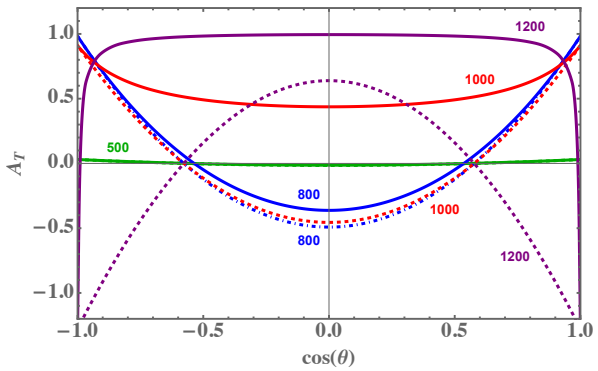

Figure 2: Tensor asymmetry as a function of $\cos\theta$ for different k. Dashed lines - deuteron with pn component only, solid lines - with P component included.

disagree with predictions based on conventional deuteron wave functions once $k \gtrsim 800$ MeV/c. Moreover the data seems to indicate the enhancement of momentum distribution as predicted in our calculations.

The planned new measurements [26] will significantly improve the quality of the data allowing possible verification of the second prediction, that is the existence of angular asymmetry for LF momentum distribution.

What concerns to the tensor asymmetry, currently there is a significant efforts in performing a high Q^2 deuteron electro-disintegration processes at Jefferson Lab employing polarized deuteron target[27]. The possibility of caring out such measurements will significantly improve the validity of any observation that will suggest the existence of non-nucleonic component in the deuteron wave function at very large internal momenta.

It is worth mentioning that the analysis of exclusive deuteron disintegration experiments will require a careful account for competing nuclear effects such as final state interactions, (FSI) for which there has been significant theoretical and experimental progress during the last decade[28–31]. The advantage of high energy scattering is that the eikonal regime is established which makes FSI to be strongly isolated in transverse kinematics and be suppressed in near colinear directions. Additionally the comparison with the first high Q^2 experimental data[31] indicates that the accuracy of FSI calculations increases with Q^2 which will allow a meaningful analysis of new high Q^2 data.

If the experiments will not find the discussed signatures of non-nucleonic components then they will set a new limit on the dominance of the pn component at instantaneous high nuclear densities that corresponds to $\sim$ 1 GeV/c internal momentum in the deuteron. However if predictions are confirmed, they will motivate theoretical modeling of non-nucleonic components in the deuteron, such as $\Delta\Delta$, N^*N or hidden-color N_cN_c that can reproduce the observed results. In both cases the results of such studies will advance the understanding of the dynamics of high density nuclear matter and the relevance of the quark-hadron transition.

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