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Photodisintegration of ^3H in a three dimensional faddeev approach

S. Bayegan[1,a], M. A. Shalchi[1], and M. R. Hadizadeh[2]

[1] Department of Physics, University of Tehran, P.O.Box 14395-547, Tehran, Iran
[2] Instituto de Física Teórica, Universidade Estadual Paulista, Rua Dr. Bento Teobaldo Ferraz 271, Bl. II, Barra Funda, 01140-070, São Paulo, Brazil

Abstract. An interaction of a photon with ^3H is invstigated based on a three dimensional Faddeev approach. In this approach the three-nucleon Faddeev equations with two-nucleon interactions are formulated with consideration of the magnitude of the vector Jacobi momenta and the angle between them with the inclusion of the spin-isospin quantum numbers, without employing a partial wave decomposition. In this formulation the two body t-matrices and triton wave function are calculated in the three dimensional approach using AV18 potential. In the first step we use the standard single nucleon current in this article.

1 Introduction

Since the early days of the study of the nuclear physics so many efforts have been performed on 3N systems considering real or virtual photon interactions [1]-[2]. Also several studies on the behavior of 3N bound states in real or virtual photon absorbtion have been reported[3]-[4]. Before sixties variational approach was used for these calculations and works using this approach are still continuing. After introducing Faddeev formulation for three body systems [5]-[6], new efforts using this scheme were started. As an example one can point out the early calculations of electrodisintegration [7] and photodisintegration[8] with ^3He and ^3H. An improvement in the photodisintegration calculation of the bound and 3N continuum with the same 3N hamiltonian have been performed [9]. There are also other approaches to calculate electromagnetic interactions with light nuclei such as Green-function-Monte-Carlo method [10], hyperspherical harmonic expansions [11], and Lorentz integral transform (LIT) method [12].There is a very good review of Faddeev calculations on the interaction of real or virtual photon with ^3He [13]. In this work like previous calculations the partial wave decomposition has been used. In PW approach one should sum all PW to maximum angular momentum where the calculation is converged. The problem is that in higher energies this maximum angular momentum increases and we should solve more complicated equations. To avoid this complexity one should use vector momentum as basis states [14]. To this aim in the past decade the main steps have been taken by Ohio-Bochum collaboration (Elster, Glöckle et al.) and Bayegan et al. to implement the 3D approach in few-body bound and scattering calculations (see for examples Refs. [15]-[22]). It should be clear that the building blocks to the few-body calculations without angular momentum decomposition are two-body off-shell t-matrices, which depend on the magnitudes of the initial and final Jacobi momenta and the angle between them. Fachruddin et al. have calculated the NN bound and scattering states in a 3D representation using the Bonn-B and the AV18 potentials [15]-[16]. Recently there has been efforts to do the same calculation using chiral potential [23]. our aim in this work is to formulate photodisintegration of ^3H in a three dimensional Faddeev approach. In the first step we ignore three body forces and we just use the single nucleon current. We will use AV18 potential and triton wave function which has been calculated in our previous work [20].

This manuscript has been organized as follow: in section 2 we explain our basic states and we evaluate all of the matrix elements in these basis. In section 3 we introduce our singularity problem and its solution. We finish in section 4 with a summary and outlook.

2 Integral equation of nuclear matrix elements without partial wave decomposition

To calculate the photodisintegration observable we first need to calculate nuclear matrix elements in the Faddeev scheme. For more details see Ref.[13].

$$N = \frac{1}{2}\langle\phi_0|(1 + tG_0)P|U\rangle \tag{1}$$

$$|U\rangle = (1 + P)J|\psi\rangle + tG_0P|U\rangle \tag{2}$$

In above equations t is NN t-operator which obeys Lipmann-Schwinger equations, G_0 is free propagator, P is permutation operator, $|\psi\rangle$ is three body bound state and $|U\rangle$ is an axillary state. Three body forces have been ignored.

[a] e-mail: bayegan@khayam.ut.ac.ir

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$|\phi_0\rangle$ is a subsection of the fully antisymmetric free state, $|\Phi_0\rangle$, in which nucleons 2 and 3 are in subsystem.

$$|\Phi_0\rangle = (1+P)|\phi_0\rangle \tag{3}$$

$|\phi_0\rangle$ is also our basic state to solve the integral equation (2) and is antisymmetric under permutation of nucleons 2 and 3.

$$|\phi_0\rangle \equiv |\mathbf{pq}m_1m_2m_3\nu_1\nu_2\nu_3\rangle^a \tag{4}$$

In equation (4) **p** and **q** are jacobi momenta and m's and ν's are the spin and isospin of the individual nucleons respectively.

Orthonormality and completeness relations of these basic states can be considered as bellow:

$$\begin{aligned}&{}^a\langle\mathbf{pq}m_1m_2m_3\nu_1\nu_2\nu_3|\mathbf{p}'\mathbf{q}'m_1'm_2'm_3'\nu_1'\nu_2'\nu_3'\rangle^a\\&=\frac{1}{2}\{\delta(\mathbf{p}-\mathbf{p}')\delta_{m_2m_2'}\delta_{m_3m_3'}\delta_{\nu_2\nu_2'}\delta_{\nu_3\nu_3'}\\&-\delta(\mathbf{p}+\mathbf{p}')\delta_{m_2m_3'}\delta_{m_3m_2'}\delta_{\nu_2\nu_3'}\delta_{\nu_3\nu_2'}\}\delta(\mathbf{q}-\mathbf{q}')\delta_{m_1m_1'}\delta_{\nu_1\nu_1'}\end{aligned} \tag{5}$$

$$\sum_{\substack{m_1\\ \nu_1}}\sum_{\substack{m_2\\ \nu_2}}\sum_{\substack{m_3\\ \nu_3}}\int d^3\mathbf{p}\,d^3\,\mathbf{q}|\mathbf{pq}m_1m_2m_3\nu_1\nu_2\nu_3\rangle^a \times{}^a\langle\mathbf{pq}m_1m_2m_3\nu_1\nu_2\nu_3|\equiv 1 \tag{6}$$

Considering these properties we can rewrite the integral equations (1) and (2) in our basic stats.

$$\begin{aligned}N&=\frac{1}{2}\,{}^a\langle\mathbf{pq}m_1m_2m_3\nu_1\nu_2\nu_3|(1+tG_0)P|U\rangle\\&=\frac{1}{2}\,{}^a\langle\mathbf{pq}m_1m_2m_3\nu_1\nu_2\nu_3|P|U\rangle\\&+\frac{1}{2}\,{}^a\langle\mathbf{pq}m_1m_2m_3\nu_1\nu_2\nu_3|tG_0P|U\rangle\end{aligned} \tag{7}$$

$$\begin{aligned}&{}^a\langle\mathbf{pq}m_1m_2m_3\nu_1\nu_2\nu_3|U\rangle\\&={}^a\langle\mathbf{pq}m_1m_2m_3\nu_1\nu_2\nu_3|(1+P)J|\psi\rangle\\&+{}^a\langle\mathbf{pq}m_1m_2m_3\nu_1\nu_2\nu_3|tG_0P|U\rangle\end{aligned} \tag{8}$$

The effect of permutation operator on our basic states can be considered as follow:

$$\begin{aligned}&\langle\mathbf{pq}m_1m_2m_3\nu_1\nu_2\nu_3|P|\mathbf{p}'\mathbf{q}'m_1'm_2'm_3'\nu_1'\nu_2'\nu_3'\rangle\\&=\delta(\mathbf{p}+\frac{1}{2}\mathbf{p}'+\frac{3}{4}\mathbf{q}')\delta(\mathbf{q}-\mathbf{p}'+\frac{1}{2}\mathbf{q}')\\&\times\delta_{m_1m_2'}\delta_{m_2m_3'}\delta_{m_3m_1'}\delta_{\nu_1\nu_2'}\delta_{\nu_2\nu_3'}\delta_{\nu_3\nu_1'}\\&+\delta(\mathbf{p}+\frac{1}{2}\mathbf{p}'-\frac{3}{4}\mathbf{q}')\delta(\mathbf{q}+\mathbf{p}'+\frac{1}{2}\mathbf{q}')\\&\times\delta_{m_1m_3'}\delta_{m_2m_1'}\delta_{m_3m_2'}\delta_{\nu_1\nu_3'}\delta_{\nu_2\nu_1'}\delta_{\nu_3\nu_2'}\\&=\delta(\mathbf{p}+\pi_2)\delta(\mathbf{p}'-\pi_1)\\&\times\delta_{m_1m_2'}\delta_{m_2m_3'}\delta_{m_3m_1'}\delta_{\nu_1\nu_2'}\delta_{\nu_2\nu_3'}\delta_{\nu_3\nu_1'}\\&+\delta(\mathbf{p}-\pi_2)\delta(\mathbf{p}'+\pi_1)\\&\times\delta_{m_1m_3'}\delta_{m_2m_1'}\delta_{m_3m_2'}\delta_{\nu_1\nu_3'}\delta_{\nu_2\nu_1'}\delta_{\nu_3\nu_2'}\end{aligned} \tag{9}$$

Where:

$$\pi_1=\mathbf{q}+\frac{1}{2}\mathbf{q}' \qquad \pi_2=\frac{1}{2}\mathbf{q}+\mathbf{q}' \tag{10}$$

Now with respect to above relation and symmetry considerations we can evaluate equations (7) and(8) as follow:

$$\begin{aligned}N&=\frac{1}{2}\{\langle-\frac{1}{2}\mathbf{p}-\frac{3}{4}\mathbf{q},\ \mathbf{p}-\frac{1}{2}\mathbf{q}\,m_2m_3m_1\nu_2\nu_3\nu_1|U\rangle\\&\langle-\frac{1}{2}\mathbf{p}+\frac{3}{4}\mathbf{q},\ -\mathbf{p}-\frac{1}{2}\mathbf{q}\,m_3m_1m_2\nu_3\nu_1\nu_2|U\rangle\}\\&+\sum_{\substack{m_2'\\ \nu_2'}}\sum_{\substack{m_3'\\ \nu_3'}}\int d^3\mathbf{q}^a\langle\mathbf{p}\,m_2m_3\nu_2\nu_3|t|\frac{1}{2}\mathbf{q}+\mathbf{q}',m_2'm_3'\nu_2'\nu_3'\rangle^a\\&\frac{1}{E-\frac{\mathbf{q}^2+\mathbf{q}'^2+\mathbf{q}\cdot\mathbf{q}'}{m}}\langle-\frac{1}{2}\mathbf{q}'-\mathbf{q},\ \mathbf{q}'\,m_2'm_3'm_1\nu_2'\nu_3'\nu_1|U\rangle\end{aligned} \tag{11}$$

$$\begin{aligned}&\langle\mathbf{pq},\ m_1m_2m_3\nu_1\nu_2\nu_3|U\rangle\\&=\langle\mathbf{pq},\ m_1m_2m_3\nu_1\nu_2\nu_3|(1+P)J|\psi\rangle\\&+\sum_{\substack{m_2'\\ \nu_2'}}\sum_{\substack{m_3'\\ \nu_3'}}\int d^3\mathbf{q}^a\langle\mathbf{p}\,m_2m_3\nu_2\nu_3|t|\frac{1}{2}\mathbf{q}+\mathbf{q}',m_2'm_3'\nu_2'\nu_3'\rangle^a\\&\frac{1}{E-\frac{\mathbf{q}^2+\mathbf{q}'^2+\mathbf{q}\cdot\mathbf{q}'}{m}}\langle-\frac{1}{2}\mathbf{q}'-\mathbf{q},\ \mathbf{q}'\,m_2'm_3'm_1\nu_2'\nu_3'\nu_1|U\rangle\end{aligned} \tag{12}$$

The firs term in the equation(12) can be evaluated as:

$$\begin{aligned}&{}^a\langle\mathbf{pq},\ m_1m_2m_3\nu_1\nu_2\nu_3|(1+P)J|\psi\rangle\\&=\sum_{m',\nu'}\int d^3\mathbf{p}'d^3\mathbf{q}'\\&{}^a\langle\mathbf{pq},\ m_1m_2m_3\nu_1\nu_2\nu_3|(1+P)J|\mathbf{p}'\mathbf{q}',\ m_1'm_2'm_3'\nu_1'\nu_2'\nu_3'\rangle^a\\&\times{}^a\langle\mathbf{p}'\mathbf{q}',\ m_1'm_2'm_3'\nu_1'\nu_2'\nu_3'|\psi\rangle\end{aligned} \tag{13}$$

Now we concentrate on the elements of these equations i.e. current, two-body t-matrix and triton wave function, more precisely.

2.1 current

Considering the symmetry properties we have:

$$\begin{aligned}&{}^a\langle\mathbf{pq},\ m_1m_2m_3\nu_1\nu_2\nu_3|(1+P)J^{SN}|\psi\rangle\\&=3{}^a\langle\mathbf{pq},\ m_1m_2m_3\nu_1\nu_2\nu_3|(1+P)J^{SN}(1)|\psi\rangle\end{aligned} \tag{14}$$

Matrix elements of single nucleon current can be evaluated as follow:

$$\begin{aligned}&{}^a\langle\mathbf{pq},\ m_1m_2m_3\nu_1\nu_2\nu_3|J(1)|\mathbf{p}'\mathbf{q}',\ m_1'm_2'm_3'\nu_1'\nu_2'\nu_3'\rangle\\&=\delta(\mathbf{q}'-\mathbf{q}+\frac{2}{3}\mathbf{Q})\\&\times\frac{1}{2}[\delta(\mathbf{p}-\mathbf{p}')\delta_{m_2m_2'}\delta_{m_3m_3'}\delta_{\nu_2\nu_2'}\delta_{\nu_3\nu_3'}\\&\quad-\delta(\mathbf{p}+\mathbf{p}')\delta_{m_2m_3'}\delta_{m_3m_2'}\delta_{\nu_2\nu_3'}\delta_{\nu_3\nu_2'}]\times J_{\substack{m_1\\ \nu_1}\ \substack{m_1'\\ \nu_1'}}(\mathbf{Q},\mathbf{q})\end{aligned} \tag{15}$$

In above equation $\mathbf{Q}$ is the momentum of photon. We need to rewrite the single nucleon current operator in a form which is suitable for our basic states. The current operator which we will use is:

$$J = G_E(Q)\frac{\mathbf{k}_1 + \mathbf{k}_1'}{2m_N} + \frac{i}{2m_N}G_M(Q)\sigma \times (\mathbf{k}_1 - \mathbf{k}_1') \quad (16)$$

Which is summation of convection current and spin current. $G_E(Q)$ and $G_M(Q)$ are electric and magnetic form factors respectively. For the convection part we have:

$$\mathbf{q} + \mathbf{Q} + \frac{2}{3}\mathbf{K} \quad (17)$$

As we will show we have to choose coordinate system in which the z axis is along the Q vector and we also need tensor component of current so the second and the third terms of the right hand side of equation(17) will vanish. Thus for the convection current we have:

$$J_{\pm 1}^{convec} = G_E(Q)\frac{q_{\pm 1}}{m_N} \quad (18)$$

And the tensor component of spin part can also be evaluated as:

$$J_{\pm 1}^{S\,pin} = \frac{-\sqrt{2}Q}{2m_N}G_M(Q)S_{\pm} \quad (19)$$

2.2 two-body t- matrix

Two body t-matrices can be related to the one which calculated in helicity basis:

$$\begin{aligned}
&{}^a\langle \mathbf{p}m_1m_2n\nu_1\nu_2|t|\mathbf{p}'m_1m_2\nu_1'\nu_2'\rangle^a = \frac{1}{4}\delta_{(\nu_1+\nu_2),(\nu_1'+\nu_2')}\\
&e^{i(\Lambda_0\phi_p - \Lambda_0'\phi_p')}\sum_{\pi st}(1-\eta_\pi)C(\frac{1}{2}\frac{1}{2}t,\nu_1\nu_2)C(\frac{1}{2}\frac{1}{2}t,\nu_1'\nu_2')\\
&C(\frac{1}{2}\frac{1}{2}S, m_1m_2\Lambda_0)C(\frac{1}{2}\frac{1}{2}S, m_1'm_2'\Lambda_0')\\
&\sum_{\Lambda\Lambda'} d^S_{\Lambda_0\Lambda}(\theta_p)d^S_{\Lambda_0'\Lambda'}(\theta_p')\frac{\sum e^{iN(\phi_p-\phi_p')}d^S_{N\Lambda}(\theta_p)d^S_{N\Lambda'}(\theta_p')}{d^S_{\Lambda'\Lambda}(\theta_{pp'})}\\
&t^{\pi St}_{\Lambda\Lambda'}(p,p',\cos\theta_{pp'},z)
\end{aligned} \quad (20)$$

In the above relation $z = E - \frac{3q^2}{4m}$ is the energy of subsystem. As we know two-body function has a singularity in the energy of deuteron, $z = E_d$. To remove this singularity we should consider t-operator as follow:

$$\begin{aligned}
&{}^a\langle \mathbf{p}m_1m_2n\nu_1\nu_2|t|\mathbf{p}'m_1m_2\nu_1'\nu_2'\rangle^a\\
&= \frac{{}^a\langle \mathbf{p}m_1m_2n\nu_1\nu_2|\hat{t}|\mathbf{p}'m_1m_2\nu_1'\nu_2'\rangle^a}{z - E_d}
\end{aligned} \quad (21)$$

Two body t-matrix in helicity basis has been calculated before[15].

$$\begin{aligned}
&t^{\pi St}_{\Lambda'\Lambda}(p',p,\cos\theta) = V^{\pi St}_{\Lambda'\Lambda}(p',p,\theta)\\
&+\ \frac{1}{2}\int dp''p''^2\int_{-1}^{1}d(\cos\theta'')\,v^{\pi St,\Lambda}_{\Lambda'1}(p',p'',\theta',\theta'')G_0(p'')\\
&t^{\pi St}_{1\Lambda}(p'',p,\theta'')\\
&+\ \frac{1}{2}\int dp''p''^2\int_{-1}^{1}d(\cos\theta'')\,v^{\pi St,\Lambda}_{\Lambda'0}(p',p'',\theta',\theta'')G_0(p'')\\
&t^{\pi St}_{0\Lambda}(p'',p,\theta'')
\end{aligned} \quad (22)$$

Where

$$v^{\pi St,\Lambda}_{\Lambda'\Lambda''}(p',p'',\theta',\theta'') = \int_0^{2\pi} d\phi'' e^{-i\Lambda(\phi'-\phi'')}V^{\pi St}_{\Lambda'\Lambda''}(\mathbf{p}',\mathbf{p}'') \quad (23)$$

2.3 triton wave function

For evaluating the Triton wave function we need to make a relation between this wave function in our basic states to the one which has been calculated in the following basis[20]:

$$\langle \mathbf{pq}(s\frac{1}{2})S\,m_S(t\frac{1}{2})T\,m_T|\psi\rangle = \langle pq, X_{pq}, \alpha|\psi\rangle \quad (24)$$

We can relate these states to our free spin and isospin states with Clebsch-Gordan coefficients.

$$g_{\gamma\alpha} = \langle\gamma|\alpha\rangle \quad (25)$$

Where

$$\begin{aligned}
|\alpha\rangle &= |(s\frac{1}{2})S\,m_S,(t\frac{1}{2})T\,m_T\rangle\\
|\gamma\rangle &= |m_1m_2m_3\nu_1\nu_2\nu_3\rangle
\end{aligned} \quad (26)$$

It is very important to mention that the spin of the nucleons is quantized in the direction of the z axis which in the calculation of wave function it has been chosen to be in the direction of $\mathbf{q}$. But we have to consider the z axis along the direction of incident photon $\mathbf{Q}$. So we should first rotate the spin of the nucleons in our basis to be settled in the direction of $\mathbf{q}$ axis. Then we should use Clebsch-Gordan coefficients to obtain the wave function in the calculated basis mentioned in the equation (24):

$$\begin{aligned}
&\langle \mathbf{pq}m_1m_2m_3\nu_1\nu_2\nu_3|\psi\rangle\\
&= \sum_{m_1'm_2'm_3'}\sum_{\alpha} D_{m_1m_1'}(\theta_q,\phi_q)D_{m_2m_2'}(\theta_q,\phi_q)D_{m_3m_3'}(\theta_q,\phi_q)g_{\gamma\alpha}\\
&\times\langle pq, X_{pq}, \alpha|\psi\rangle
\end{aligned} \quad (27)$$

3 Singularity problem

In order to consider the singularity problem we can rewritten the equation (11) an (12) in a unified form ignoring isospin dependent which is similar to spin dependent.

$$U_{m_1m_2m_3}(\mathbf{p},\mathbf{q},\mathbf{Q}) = U'_{m_1m_2m_3}(\mathbf{p},\mathbf{q},\mathbf{Q}) + \sum_{m'_2m'_3}\int d^3q'' \frac{U_{m'_2m'_3m_1}(\pi_2,\mathbf{q}'',\mathbf{Q})}{E-\frac{q^2+q''^2-\mathbf{q}\cdot\mathbf{q}''}{m}} \frac{\hat{t}^a_{m_2m_3m'_3m'_3}(\mathbf{p},\pi_1,z)}{E+i\epsilon-E_d-\frac{3q^2}{4m}} \tag{28}$$

To solve this integral equation we should evaluate singularity in the denominator of the propagator which is a function of q'' and angle between $q''$and q. So instead of singular point we have a region of singularity in $q-q''$ plane. There is a solution to this moving singularity in Ref.[24]. For using this method we have to put z axis along the $\mathbf{q}$. But because of simplification in current operator and final cross section we should choose the z axis in the direction of the momentum of the photon, $\mathbf{Q}$. So in order to evaluate the singularity we should use another method which is introduced in Ref.[25]. Therefore one should separate angle part of delta functions as follow:

$$\delta(\mathbf{p}'+\pi_1)\delta(\mathbf{p}''-\pi_1) = \frac{\delta(p'-\pi_1)}{p'^2}\frac{\delta(p''-\pi_1)}{p''^2} \delta(\hat{\mathbf{p}}'+\hat{\pi}_1)\delta(\hat{\mathbf{p}}''-\hat{\pi}_1)$$
$$\delta(\mathbf{p}'-\pi_1)\delta(\mathbf{p}''+\pi_1) = \frac{\delta(p'-\pi_1)}{p'^2}\frac{\delta(p''-\pi_1)}{p''^2} \delta(\hat{\mathbf{p}}'-\hat{\pi}_1)\delta(\hat{\mathbf{p}}''+\hat{\pi}_1) \tag{29}$$

And then the integral equation can be rewrite as follow:

$$U_{m_1m_2m_3}(\mathbf{p},\mathbf{q},\mathbf{Q}) = U'_{m_1m_2m_3}(\mathbf{p},\mathbf{q},\mathbf{Q}) + \sum_{m'_2m'_3}\int d^3q''dp'dp'' \frac{U_{m'_2m'_3m_1}(\pi_2,\mathbf{q}'',\mathbf{Q})}{E-\frac{1}{m}(p''^2+\frac{3}{4}q''^2)} \frac{\hat{t}^a_{m_2m_3m'_3m'_3}(\mathbf{p},\pi_1,z)}{E+i\epsilon-E_d-\frac{3q^2}{4m}} \tag{30}$$

After some simplification the integral equation transforms to this equation:

$$U_{m_1m_2m_3}(\mathbf{p},\mathbf{q},\mathbf{Q}) = U'_{m_1m_2m_3}(\mathbf{p},\mathbf{q},\mathbf{Q}) + \frac{2}{q}\sum_{m'_2m'_3}\int_0^\infty dp'p' \frac{1}{E+i\epsilon-\frac{1}{m}(p'^2+\frac{3}{4}q^2)} \int_{|q/2-p'|}^{q/2+p'} dq''q''\bar{G}(q,q'',p')\int d\hat{q}''\delta(x''-x_0) U_{m'_2m'_3m_1}(p''\hat{\pi}_2,\mathbf{q}'',\mathbf{Q})\hat{t}^a_{m_2m_3m'_3m'_3}(\mathbf{p},p'\hat{\pi}_1,z) - \frac{2}{q}\sum_{m'_2m'_3}\int_0^\infty dq''q'' \frac{1}{E+i\epsilon-E_d-\frac{3q^2}{4m}} \int_{|q/2-q''|}^{q/2+q''} dp'p'\bar{G}(q,q'',p')\int d\hat{q}''\delta(x''-x_0) U_{m'_2m'_3m_1}(p''\hat{\pi}_2,\mathbf{q}'',\mathbf{Q})\hat{t}^a_{m_2m_3m'_3m'_3}(\mathbf{p},p'\hat{\pi}_1,z) \tag{31}$$

In the above equation $\bar{G}$ which is always positive is defined as:

$$\bar{G}(q,q'',p') = \frac{1}{-E_d-\frac{3q''^2}{4m}+\frac{1}{m}(p'^2+\frac{3}{4}q^2)} \tag{32}$$

$x'' = \cos\theta''$ indicates the angle between $\mathbf{q}$ and $\mathbf{q}''$ and x_0 is introduced as follow:

$$x_0 = \frac{1}{qq''}(p'^2-\frac{1}{4}q^2-q''^2) = \frac{1}{qq''}(p''^2-\frac{1}{4}q''^2-q^2) \tag{33}$$

4 Summary and outlook

In this paper we have formulated the Faddeev integral equations for calculating the photodisintegration observable of triton in a three dimensional approach. To this aim we introduced our basic states which contains jacobi momenta in vector forms as well as individual spin and isospin of each nucleon. So we have avoided to decompose angle states in terms of angular momentum states (partial wave approach) which is traditionally used to solve these kind of equations. The final integral equations are less complicated than the PW ones and are unique in number of the equations in all energies. We have also explained about overcoming of the moving singularity in our work.

The calculation of this observable using the AV18 potential is underway and the results will be published soon.

Adding two and three body currents as well as three body forces in our calculations are other future major works. The same calculation for radiative capture is also under consideration.

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References

1. E. Wigner, Phys. Rev. **43**, (1993) 252.
2. E. Gerjuoy, J. Schwinger, Phys. Rev.**61** (1942) 138.
3. H. Collard et al., Phys. Rev. Lett. **11**, (1963) 132.
4. L.I. Schiff, H. Collard, R. Hofstadter, A. Johansson, M.R. Yearian, Phys. Rev. Lett **11** (1963) 387.
5. L.D. Faddeev, Zh. Eksp. Theor. Fiz. **39** (1960) 1459
6. E.O. Alt, P. Grassberger, W. Sandhas, Nucl. Phys. **B2** (1967) 167
7. D.R. Lehman, Phys. Rev. Lett. **23** (1969)1339

8. I.R. Barbour, A.C. Phillips, Phys. Rev. Lett. **19** (1967)1388
9. B. F. Gibson and D. R. Lehman, Phys. Rev. **C11** (1975) 29
10. J. Carlson, Phys. Rev. **C36** (1987) 2026
11. M. Viviani, A. Kievsky, L.E. Marcucci, S. Rosati, R. Schiavilla, Phys. Rev. **C61** (2000) 064001.
12. V.D. Efros, W. Leidemann, G. Orlandini, Phys. Lett. **B338**
13. J.Golak et al. , Phys.Rept. **415** (2005) 89
14. R. A. Rice, Y. E. Kim, Few-Body Syst. **14** (1993) 127
15. I. Fachruddin, Ch. Elster, Glöckle, Phys. Rev. **C 62** (2000)044002.
16. I. Fachruddin, Ch. Elster, W. Glöckle, Phys. Rev. **C 63** (2001)054003
17. I. Fachruddin, Ch. Elster, W. Glöckle, Phys. Rev. **C 68**(2003)054003
18. I. Fachruddin, W. Glöckle, Ch. Elster, A. Nogga, Phys. Rev. **C 69** (2004) 064002
19. M. R. Hadizadeh and S. Bayegan, Eur. Phys. J. **A 36** (2008)201
20. S. Bayegan, M. R. Hadizadeh, and M. Harzchi, Phys. Rev. **C 77** (2008) 064005
21. S. Bayegan, M. R. Hadizadeh, and W. Glöckle, Prog. Theor. Phys. **120** (2008)887
22. S. Bayegan, M. Harzchi and M. R. Hadizadeh, Nucl. Phys. **A 814** (2008) 21
23. S. Bayegan, M. A. Shalchi, M. R. Hadizdeh, Phys. Rev. **C79** (2009) 057001
24. H. Liu, Ch. Elster, W. Gloeckle, Phys.Rev. **C72** (2005) 054003
25. Ch. Elster, W. Glöckle, H. Witala, Few Body Syst. **45** (2009) 1