International Journal of New Horizons in Physics

http://dx.doi.org/10.12785/ijnhp/010105

The Effect of The Omega(782)Resonance on The Response Functions For The Incoherent $\pi^{\pm}$ Electroproduction Form The Deuteron

***Mahmoud Tammam*[1], *Zakaria M. M. Mahmoud*[2] *and Mohamed S. I. Koubisy*[1,*]**

[1]Department of Physics , Faculty of Science, Al-Azhar University, Assiut Branch, Egypt.
[2]Department of Physics, Faculty of Science, Assiut University, New valley Branch, Egypt.

Received: 2 April 2014, Revised: 30 May 2014, Accepted: 5 June 2014
Published online: 1 July 2014

Abstract: The effect of the Omega(782) resonance on the response functions for the incoherent charged pion electroproduction form the Deuteron at different values for the four-momentum transfers squared (K^2) and the virtual photon lab energy (k_0^{lab}) are studied. The study is carried out in the impulse approximation (IA) i.e. the final state interactions is neglected. The elementary amplitude for pion electroproduction is taken from the MAID-2007 model.

Keywords: pion electroproduction; the Omega (782) resonance; Invariant Amplitudes; CGLN amplitudes; Structure functions; the impulse approximation (IA)

1 Introduction

The pion is now known to exist in three charge states, π^+,π^- and π^0, with masses of 139.6 MeV for charged pions and 135.0 MeV for the neutral pion .The Pion photo- and electroproduction is presently one of the main sources of our information on the structure of nucleons.
The Photo- and electroproduction of pions on a proton have been studied thoroughly both theoretically and experimentally. Beyond the pion threshold energy almost all reactions on the nucleon, either initiated by photons, pions or other hadrons with energies of a few hundred MeV (in the center-of-mass) are dominated via the formation of the first excited state of the nucleon. The electroproduction of single pions on a nucleon indicates the following reactions.

$$\begin{aligned} e+p &\longrightarrow \quad e^{'}+n+\pi^+ \\ e+n &\longrightarrow \quad e^{'}+p+\pi^- \end{aligned} \tag{1}$$

The elementary amplitude of pion photo- and electroproduction on free nucleons is one of the main ingredients of the analysis of these reactions for nuclei. In order to study pion electroproduction in the resonance region on complex nuclei, one first has to understand the production process on the nucleon. To this end there have been extensive studies, for example, in [1].

The basic interaction in mesons elctoroproduction is as follows: a virtual photon is incident on a target nucleus and interacts with its constituents. As a result, a pseudoscalar meson is produced along with other particles. Two kinds of processes depending on the nature of the other particles produced in this interaction are found: coherent and incoherent processes. In the coherent process [2,3], the meson is produced with the target nucleus maintaining its initial character. Thus, the interaction starts with a a virtual photon and some nucleus, and ends up with a meson and the same nucleus ,i.e. $\gamma^* X_A \longrightarrow \pi X_A$, where A is the mass number of the target nucleus. The process is labeled ”coherent” because all nucleons in the nucleus participate in the process coherently, leading to a coherent sum of the individual nucleon contributions.
In the incoherent process [4], the nucleus ruptures and thus fails to maintain its initial identity. The meson is produced in association with a nucleon (or an excited state of the nucleon) and some new recoil ”daughter” hadronic system. Thus, the interaction starts with a a virtual photon and some nucleus and ends up with a meson, a free nucleon (or an excited state of it) and a new hadronic system, i.e. $\gamma^* X_A \longrightarrow \pi N X_{A-1}$. The process is

* Corresponding author e-mail: M.S.I.koubisy@gmail.com

labeled as ”incoherent” because it occurs in kinematic and physical circumstances similar to those of the process that produces a meson from a free nucleon. The electromagnetic production of pions on the free nucleon, including photoproduction and electroproduction, has long been studied since the pioneering work of Chew, Goldberger, Low and Nambu (CGLN) [4].
In view of the fact that there is a shortage of theoretical studies of pion electroproduction off nuclei, we have started an investigation of incoherent pion electroproduction off the deuteron . Deuteron was chosen since it allows one to study this reaction on a bound nucleon in the simplest nuclear environment, so that one can take into account medium effects in a reliable manner, at least in the nonrelativistic domain. It provides important information on this reaction on the neutron. In view of this latter aspect, the deuteron is often considered as an effective neutron target assuming that binding effects can be neglected to a large extent.
The pion electroproduction on the deuteron near threshold has been studied in the impulse approximation using an approach based on the unitary transformation method both experimentally [5,6] as well as theoretically [7,8,9,10].

Nucleon resonances are excited states of nucleon particles, often corresponding to one of the quarks having a flipped spin state, or with different orbital angular momentum when the particle decays.The symbol format is given as $N(M)L_{2I2J}$, where M is the particle's approximate mass, L is the orbital angular momentum of the Nucleon-meson pair produced when it decays, and I and J are the particle's isospin and total angular momentum respectively. Since nucleons are defined as having $1/2$ isospin, the first number will always be 1, and the second number will always be odd. When discussing nucleon resonances, sometimes the N is omitted and the order is reversed, giving $L_{2I2J}(M)$. For example, a proton can be symbolized as ”$N(939)S_{11}$” or ”$S_{11}(939)$” ,Delta resonances can be symbolized as”$S_{33}(1232)$” and Omega can be symbolized as ”Omega(782)”.
Pion electroproduction from nuclei in the Omega region has been studied in less detail. The relative importance of two-body contributions from hadronic rescattering and electromagnetic meson exchange currents besides the impulse approximation for the incoherent pion meson photoproduction on the deuteron is investigated in [4]. It turned out that in the near threshold region the first-order approximation for the final state interaction is insufficient, i.e. three-body aspects cannot be neglected (see also [11]). photoproduction and electroproduction of mesons via ω exchange has been studied several authors [12], especially in the so -called ”vector meson dominance” models.The Omega has mass 782 *Mev* and is isoscalar field. It has a lifetime of $7.75 \pm 0.07 \times 10^{-23}$ *sec*, It has decay into $\pi^0 + \pi^+ + \pi^-$ or $\pi + \gamma$. The theoretical determination of the $\omega(782)$ properties in the medium has been addressed in numerous studies [13,14].

In this paper the effect of $\omega(782)$(Omega) on the semi-exclusive structure functions of the incoherent $\pi^{\pm}$-meson electroproduction off the deuteron is studied at 0.01, 0.05 and $0.1 GeV^2$ four momentum transfer and different values of the incident virtual photon lab energy k_0^{lab}.

The present paper is organized as follows; the formalism of $\pi^{\pm}$ electroproduction off the deuteron in the IA is briefly given in section (2). The results are summarized and some discussion is presented in section (3). At the end the summary and an outlook are presented in section (4).

2 Formalism

The basic formalism for electromagnetic single pion production on the deuteron has been presented in detail for the case of photoproduction [15]. Therefore, we review here only the most important ingredients with due extensions to electroproduction according to the additional contributions from charge and longitudinal current components.

2.1 Kinematics

The kinematics of the positive and negative pion electroproduction in the one-photon exchange approximation is very similar to photoproduction in replacing the real photon by a virtual one with longitudinal and transverse [16]

$$\begin{aligned} \gamma^*(k) + d(p_d) \longrightarrow \quad & p(p_1) + p(p_2) + \pi^+(q), \\ \longrightarrow \quad & n(p_1) + n(p_2) + \pi^-(q) \end{aligned} \tag{2}$$

where $K = (k_0, \mathbf{k})$, $p_d = (E_d, \mathbf{d})$,$q = (\omega, \mathbf{q})$, and $p_1 = (E_1, \mathbf{p}_1)$, $p_2 = (E_2; \mathbf{p}_2)$ denote the four-momenta of the the incoming virtual photon, initial deuteron, the outgoing pion and the two outgoing nucleons, respectively.

The energies are given by:

$$\begin{aligned} & E_d = \sqrt{M_d^2 + \mathbf{d^2}}\,, \quad E_1 = \sqrt{M^2 + \mathbf{p_1^2}} \\ & E_2 = \sqrt{M^2 + \mathbf{p_2^2}} \quad \text{and} \quad \omega = \sqrt{m_\pi^2 + \mathbf{q^2}} \end{aligned} \tag{3}$$

As coordinate system we choose a right-handed orientation with z-axis along the photon momentum $\mathbf{q}$ and y-axis perpendicular to the scattering plane along $\mathbf{k}_e \times \mathbf{k}_{e'}$. We distinguish in general three planes: (i) the scattering plane spanned by the incoming and scattered electron momenta, (ii) the pion plane, spanned by the photon and pion momenta, which intersects the scattering plane along the z-axis with an angle ϕ_π, and (iii) the nucleon plane spanned by the momenta of the two outgoing nucleons intersecting the pion plane along the total momentum of the two nucleons. This is illustrated in Fig.(1) constant.

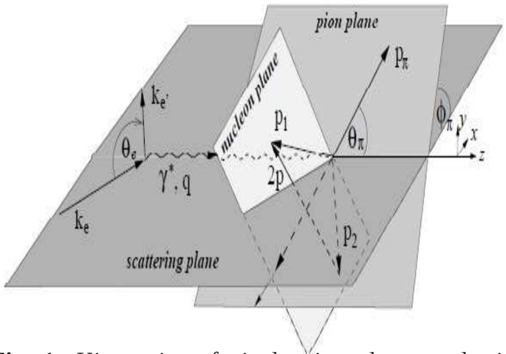

Fig. 1: Kinematics of single pion electroproduction on the deuteron.

2.2 The T-matrix

As in photoproduction, all observables are determined by the T -matrix elements of the electromagnetic pion production current $J_{\gamma\pi}$ between the initial deuteron and the final πNN states

$$T_{sm_s,\mu m_d} = -^{(-)}\langle \mathbf{p}_1\mathbf{p}_2 sm_s, \mathbf{p}_\pi | J_{\gamma\pi,\mu}(0) | \mathbf{p}_d 1m_d\rangle \quad (4)$$

where s and m_s denote the total spin and its projection on the relative momentum $\mathbf{p}$ of the outgoing two nucleons, and md correspondingly the deuteron spin projection on the z-axis as quantization axis. In the expression on the rhs of [17] non-covariant normalization for the initial deuteron and the final πNN-states is adopted. As already mentioned, all kinematic quantities related to the T -matrix refer to the $\gamma^* - d$ c.m. system. Introducing a partial wave decomposition of the final states, one finds

$$\begin{aligned} T_{sm_s,\mu m_d}(W,Q^2,p_\pi,\Omega_\pi,\Omega_p) &= e^{i(\mu+m_d-m_s)\phi_\pi} \\ &\times t_{sm_s,\mu m_d}(W,Q^2,p_\pi,\theta_\pi,\theta_p,\phi_{p\pi}) \end{aligned} \quad (5)$$

where the small t-matrix depends besides W, Q^2 and p_π only on θ_π, θ_p, and the relative azimuthal angle $\phi_{p\pi} = \phi_p - \phi_\pi$.

We had shown in [4] that, if parity is conserved, the following symmetry relation holds for $\mu = \pm 1$

$$\begin{aligned} t_{s-m_s-\mu-m_d}(W,Q^2,p_\pi,\theta_\pi,\theta_p,\phi_{p\pi}) &= (-)^{s+m_s+\mu+m_d} \\ &\times t_{sm_s,\mu m_d}(W,Q^2,p_\pi,\theta_\pi,\theta_p,-\phi_{p\pi}) \end{aligned} \quad (6)$$

In the present work we include as e.m. current the elementary one-body pion production current of MAID-2007 [18] which has been developed for nuclear applications for photon energies up to 2 GeV. It contains Born terms, nucleon resonances $P_{33}(1232)$, $P_{11}(1440)$,$D_{13}(1520)$,$S_{11}(1535)$,$S_{31}(1620)$,$S_{11}(1650)$, $D_{15}(1675)$,$F_{15}(1680)$,$D_{33}(1700)$,$P_{13}(1720)$,$F_{35}(1905)$, $P_{31}(1910)$,$F_{37}(1950)$ and vector meson exchange, see Fig. (2).

The FSI of the rescattering contributions in the final NN- and subsystems. Thus as in [19] we split the T -matrix into the impulse approximation (IA) T^{IA}, where final state interaction effects are neglected, and the rescattering contribution T^{NN} and $T^{\pi N}$ of the two-body NN- and πN-subsystems, respectively.

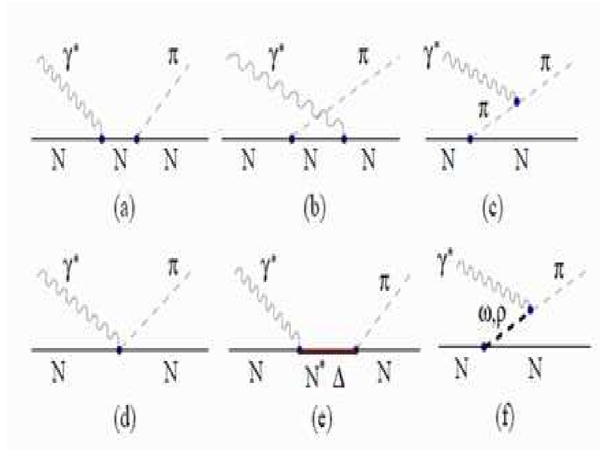

Fig. 2: Diagrammatic representation of the elementary pion electroproduction on the nucleon. Born terms: (a)-(d) nucleon, crossed nucleon, pion poles and Kroll-Rudermann contact term; (e): resonance term; (f): vector meson exchange.

$$T_{sm_s\mu m_d} = T^{IA}_{sm_s\mu m_d} + T^{NN}_{sm_s\mu m_d} + T^{\pi N}_{sm_s\mu m_d} \quad (7)$$

For the IA contribution, where the final state is described by a plane wave, antisymmetrized with respect to the two outgoing nucleons, one has [20].

$$\begin{aligned} T^{IA}_{sm_s\mu m_d} = &\ \langle \mathbf{p} sm_s, \mathbf{p}_\pi | [J_{\gamma\pi,\mu}(1) + J_{\gamma\pi,\mu}(2)] | 1m_d\rangle \\ = &\ \sqrt{2}\textstyle\sum_{m_s'} \boldsymbol{(}\langle sm_s | \langle \mathbf{p}_\pi | J_{\gamma\pi,\mu}(W_{\gamma N_1},Q^2) | \mathbf{p}_d - \mathbf{p}_2\rangle \\ &\times \phi_{m_s' m_d}(\tfrac{1}{2}\mathbf{p}_d - \mathbf{p}_2) | 1m_s'\rangle - (1 \longleftrightarrow 2)\boldsymbol{)} \end{aligned} \quad (8)$$

where $J_{\gamma\pi,\mu} J_{\gamma\pi,\mu}$ denotes the elementary pion photoproduction operator of the MAID-2007 model, $W_{\gamma N_1}$ the invariant energy of the γN_1 system, $\mathbf{p}_{1/2} = (\mathbf{q} + \mathbf{p}_d - \mathbf{p}_\pi)/2 \pm \mathbf{p}$. Furthermore, $\phi_{m_s m_d}$ is related to the internal deuteron wave function in momentum space by.

$$\begin{aligned} \langle \mathbf{p}, 1m_s | 1m_s\rangle^{(d)} &= \phi_{m_s m_d}(\mathbf{p}) \\ &= \textstyle\sum_{L=0,2}\sum_{m_L} i^L (Lm_L 1m_s | 1m_d) \mu_L(p) Y_{Lm_L}\mathbf{p} \end{aligned} \quad (9)$$

The two re-scattering contributions have a similar structure.

$$\begin{aligned} T^{NN}_{sm_s\mu m_d} = \langle \mathbf{p}\, sm_s, \mathbf{p}_\pi | T_{NN} G_{NN} [&J_{\gamma\pi,\mu}(W_{\gamma N_1},Q^2) \\ +&J_{\gamma\pi,\mu}(W_{\gamma N_2},Q^2)] | 1m_d\rangle\,, \end{aligned} \quad (10)$$

$$\begin{aligned} T^{\pi N}_{sm_s\mu m_d} = \langle \mathbf{p}\, sm_s, \mathbf{p}_\pi | T_{\pi N} G_{\pi N} [&J_{\gamma\pi,\mu}(W_{\gamma N_1},Q^2) \\ +&J_{\gamma\pi,\mu}(W_{\gamma N_2},Q^2)] | 1m_d\rangle\,, \end{aligned} \quad (11)$$

where T^{NN} and $T^{\pi N}$ denote respectively the NN- and πN scattering matrices and G^{NN} and $G^{\pi N}$ the corresponding free two-body propagators.

2.3 Cross Section and Structure Functions

The well-known spectator model fig.(1) in which the pion production takes place on a single nucleon inside the deuteron while the other nucleon acts as a pure spectator is used to produce the matrix element of electroproduction off the deuteron.

The general expression for the completely exclusive differential cross section is given by [16]

$$\frac{d^5\sigma}{dE_e^{'}d\Omega_e^{'}dq^{c.m}d\Omega_\pi^{c.m}d\Omega_r^{c.m}} = \frac{\alpha}{(2\pi)^2(K^2)^2}\frac{p_e^{'}}{p_e} \times(\bar{\rho}_T(W_{11}+W_{-1-1})+\bar{\rho}_L W_{00} - \bar{\rho}_{LT}\Re e(W_{10}-W_{-10})-\bar{\rho}_{TT}(W_{1-1}+W_{-11})) \tag{12}$$

where $\Omega_r^{c.m}=(\theta_r^{c.m},\,\phi_r^{c.m})$ are the spherical angles of the relative two-nucleon momentum and α is the fine structure constant.The four independent components of the density matrix of the virtual photon are given by

$$\begin{aligned} &\rho_L=\beta^2Q^2\frac{\xi^2}{2\eta} \qquad \rho_T=\frac{1}{2}Q^2(1+\frac{\xi}{2\eta})\\ &\rho_{LT}=\beta Q^2\frac{\xi}{\eta}\sqrt{\frac{\xi+\eta}{8}} \qquad \rho_{TT}=-Q^2\frac{\xi}{4\eta}\end{aligned} \tag{13}$$

With

$$\begin{aligned} &\beta=\frac{k^{lab}}{k^c} \qquad \xi=\frac{K^2}{(k^2)} \qquad \eta=tan^2(\frac{\theta_e^{lab}}{2})\\ &k^{lab}=p_e-p_e^{'} \qquad Q=\frac{1}{2}(p_e+p_e^{'})\end{aligned} \tag{14}$$

where β expresses the boost from the lab system to the frame in which the hadronic current is evaluated and k^c denotes the momentum transfer in this frame. Here it is the c.m. system, and one has $\mathbf{k}^c=\mathbf{k}$. As a side remark, we would like to mention the simple relation to another often used parametrization of the virtual photon density matrix in terms of the quantities of Ref [17] (for $\beta=1$ for the lab frame, i.e. $\mathbf{k}^c=\mathbf{k}$). The hadronic three-dimensional tensor $W_{\lambda\cdot\lambda}$ $(\lambda=0,\pm1)$ is given by

$$\begin{aligned} &W_{\lambda\cdot\lambda}(K^2,W,q^{c.m},\Omega_\pi^{c.m},\Omega_r^{c.m})=\rho\\ &\times\sum_{m_d s m_s}\langle p_1\,p_2\,sm_s\,q|J_\lambda|d\,m_d\rangle^*\langle p_1\,p_2\,s\,m_s\,q|J_{\lambda'}|d\,m_d\rangle\end{aligned} \tag{15}$$

where m_d the spin projection of the deuteron, s the total spin of the two outgoing nucleons, m_s its spin projection.The hadronic tensor depends on the squared four-momentum transfer K^2, the invariant mass W, the pion momentum $q^{c.m}$, the pion spherical angles $\Omega_\pi^{c.m}=(\theta_\pi^{c.m},\phi_\pi^{c.m})$, and the spherical angles $\Omega_r^{c.m}=(\theta_r^{c.m},\phi_r^{c.m})$ of the relative two-nucleon momentum $p_r^{c.m}$. In the semi-exclusive reaction, one has to integrate over $q^{c.m}$ and $\Omega_r^{c.m}$, then one has,

$$\begin{aligned} &W_{\lambda\cdot\lambda}(K^2,W,\Omega_\pi^{c.m})=\int\Omega_r^{c.m}\int_0^{q_{max}^{c.m}}dq^{c.m}\\ &\times W_{\lambda\cdot\lambda}(K^2,W,q^{c.m},\Omega_\pi^{c.m},\Omega_r^{c.m})\end{aligned} \tag{16}$$

where $q_{max}^{c.m}=\sqrt{\omega^2-m_\pi}=\frac{1}{4W}\sqrt{[(W-2M)^2-m_\pi^2][(W+2M)^2-m_\pi^2]}$. For this tensor, which depends on the invariant mass W, the squared four-momentum transfer K^2, and on the pion angles is $\Omega_\pi^{c.m}$.

The final expression for the semi-exclusive differential cross section

$$\frac{d^3\sigma}{dE_e^{'}d\Omega_e^{'}d\Omega_\pi^{c.m}} = \frac{\alpha}{(2\pi)^2(K^2)^2}\frac{p_e^{'}}{p_e}(\bar{\rho}_T R_T +\frac{1}{2}\bar{\rho}_L R_L-\frac{1}{\sqrt{2}}\bar{\rho}_{LT}R_{LT}cos\phi_\pi^{c.m}-\bar{\rho}_{TT}R_{TT}cos2\phi_\pi^{c.m}) \tag{17}$$

where the structure functions $R_\alpha(\alpha=L,T,LT,TT)$ are given in detail by

$$\begin{aligned} R_L=W_{00}, \qquad R_T=W_{11},\\ R_{LT}=-\sqrt{2}ReW_{10}, \qquad R_{TT}=W_{1-1}.\end{aligned}$$

These structure functions depend on the invariant mass W, the squared four-momentum transfer K^2, and on the pion angle $\theta_\pi^{c.m}$.

3 Results and discussion

In this section we present and discuss our numerical results for the structure functions of positive and negative pion electroproduction from the deuteron with FSI of NN- subsystems.As already mentioned, the realistic MAID-2007 model [18] has been used for the evaluation of the elementary pion electroproduction operator on the free nucleon.

The electromagnetic production amplitude is parametrized in term of CGLN amplitudes given as numerical tables in the pion-nucleon c.m. frame. This amplitude had to be generalized to an arbitrary frame of reference in order to be incorporated into the reaction on the deuteron. This was achieved by constructing from the MAID-2007 model Lorantz invariant amplitudes. This generalized elementary production operator was then used to evaluate pion electroproduction off the deuteron.The numerical evaluation is based on a Gauss integration for the calculation of the matrix element of the MAID operator using for the deuteron wave function an analytical parameterization of the *S*- and *D*-waves of the Bonn potential in momentum space [21].

In Figures.(3-20) the angular distribution for the four structure functions at different values for the four momentum transfer K^2 and the virtual photon lab energy k_0^{lab}. The dotted lines indicate the situation when the Omega(782) resonance contribution is eliminated from the elementary process and the continues ones are when this contribution is considered.

It is clear that the bigger contributions come from the longitudinal (R_L and transferee- transferee (R_{TT} structure functions which reach their maximum values at nearly $\theta_\pi=90^0$ and fall off at backward angles.

In Fig.(3) where the reaction $d(e,e^{'}\pi^+)nn$, the four momentum transfer $K^2=0.01GeV^2$ and the virtual photon lab energy k_0^{lab}=300 MeV, the contribution of Omega(782) is very small for R_T,R_{TT} and R_{LT} where it is small for R_L, resulting in small decrease in the forward

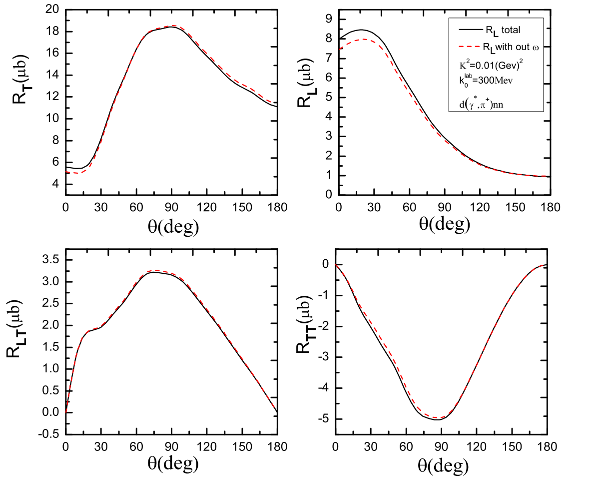

Fig. 3: Angular dependence of the four semi-exclusive structure functions of $d(e,e^{\prime}\pi^{+})nn$ at k_0^{lab} = 300 MeV and squared four-momentum transfer $K^2 = 0.01(GeV)^2$, full lines where the $\omega(782)$ is included and dashed lines where $\omega(782)$ is eliminated.

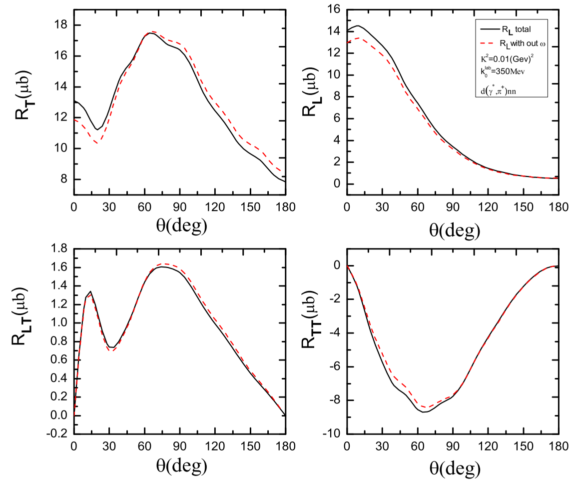

Fig. 4: Notation as in Figure (3) at $k_0^{lab} = 350$ MeV.

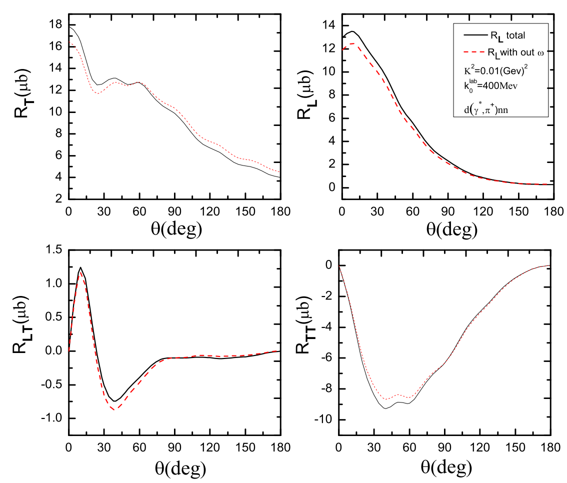

Fig. 5: Notation as in Figure (3) at $k_0^{lab} = 400$ MeV.

angles and small increase in the backward ones.

Increasing virtual photon lab energy to k_0^{lab}= 350 MeV and keeping the four momentum transfer $K^2 = 0.01GeV^2$ (Fig.4), the absolute size of R_T, R_{TT} and R_{LT} decrease and the contributions of Omega(782) are some what bigger than what was found in Fig.(3). For R_{LT} still so very small, R_L resulting in small decrease at the forward angles and small increase at the backward ones, R_T a small increase at the forward angles and small decrease at the backward angles and a small effect was found for R_{TT} at the peak region. This mean, increasing the k_0^{lab} results in increasing the effect of adding Omega (782) resonance.

In Fig.(5) the virtual photon lab energy is increased to k_0^{lab}=400 MeV at the same value of the four momentum transfer $K^2 = 0.01GeV^2$, the absolute size of R_T, R_{TT} and R_{LT} reduced and the contributions of Omega(782) are some what bigger than what was found in Fig.(4) but the effect of adding Omega(782) resonance still so bigger

In Fig.(6) where the four momentum transfer $K^2 = 0.05GeV^2$ and the virtual photon lab energy k_0^{lab}=300 MeV, the contribution of Omega(782) is very small for R_T, R_{TT} and R_{LT} where it is small for R_L, resulting in small decrease in the forward angles and small increase in the backward ones.

Increasing virtual photon lab energy to k_0^{lab}=350 MeV and keeping the four momentum transfer $K^2 = 0.05GeV^2$ (Fig.7), the absolute size of R_T, R_{TT} and R_{LT} decrease and the contributions of Omega(782) are some what bigger than what was found in Fig.(6). For R_{LT} still so very small,R_L resulting in small decrease at the forward angles and small increase at the backward ones, R_T a small increase at the forward angles and small decrease at the backward angles and a very small effect was found for R_{TT} at the peak region. This mean, increasing the k_0^{lab} results in increasing the effect of adding Omega(782) resonance.

In Fig.(8) the virtual photon lab energy is increased to k_0^{lab}=400 MeV at the same value of the four momentum transfer $K^2 = 0.05GeV^2$, the absolute size of R_T and R_{TT} reduced and the contributions of Omega(782) are some what bigger than what was found in Fig.(6) but the effect of adding Omega(782) resonance still so bigger.

In Fig.(9) where the reaction $d(e,e^{\prime}\pi^{+})nn$, the four momentum transfer $K^2 = 0.1GeV^2$ and the virtual photon lab energy k_0^{lab}=300 MeV, the contribution of

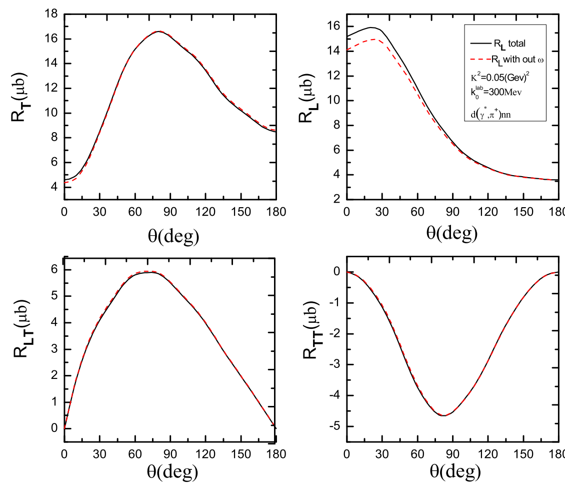

Fig. 6: Angular dependence of the four semi-exclusive structure functions of $d(e,e^{'}\pi^{+})nn$ at k_0^{lab} =300 MeV and squared four-momentum transfer $K^2 = 0.05(GeV)^2$, full lines where the $\omega(782)$ is included and dashed lines where $\omega(782)$ is eliminated.

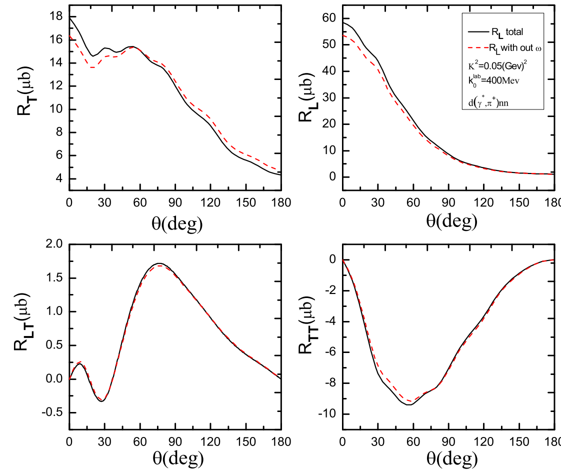

Fig. 8: Notation as in Figure (6) at k_0^{lab} =400 MeV.

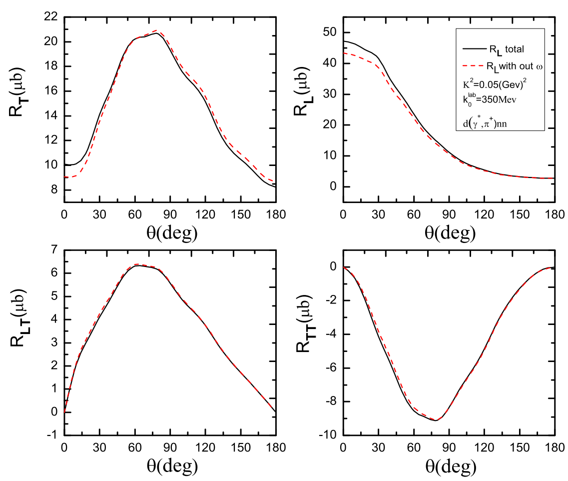

Fig. 7: Notation as in Figure (6) at k_0^{lab} =350 MeV.

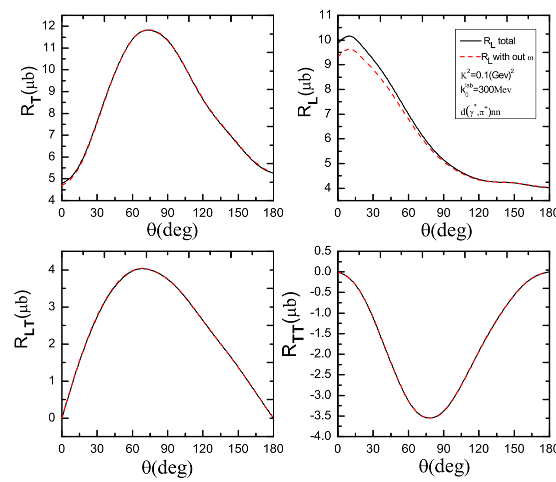

Fig. 9: Angular dependence of the four semi-exclusive structure functions of $d(e,e^{'}\pi^{+})nn$ at k_0^{lab} =300 MeV and squared four-momentum transfer $K^2 = 0.1(GeV)^2$, full lines where the $\omega(782)$ is included and dashed lines where $\omega(782)$ is eliminated.

Omega(782) is mostly neglected of R_T, R_{TT} and R_{LT} where it is small for R_L, resulting in small decrease in the forward angles and small increase in the backward ones.

Increasing virtual photon lab energy to k_0^{lab}=350 MeV and keeping the four momentum transfer $K^2 = 0.1GeV^2$(Fig.9), the absolute size of R_T, R_{TT} and R_{LT} decrease and the contributions of Omega(782) are some what bigger than what was found in Fig.(9). For R_T still so very small,R_L resulting in small decrease at the forward angles and small increase at the backward ones, R_{LT} a very small increase at the forward angles and very small decrease at the backward angles and a small effect was found for R_{TT} at the peak region. This mean, increasing the k_0^{lab} results in increasing the effect of adding Omega(782) resonance.

In Fig.(11) the virtual photon lab energy is increased to k_0^{lab}=400 MeV at the same value of the four momentum transfer $K^2 = 0.1GeV^2$, the absolute size of R_T, R_{TT} and R_{LT} reduced and the contributions of Omega(782) are some what bigger than what was found in Fig.(10) but the effect of adding Omega(782) resonance still so small.

In Fig.(12) where the reaction $d(e,e^{'}\pi^{-})pp$, the four

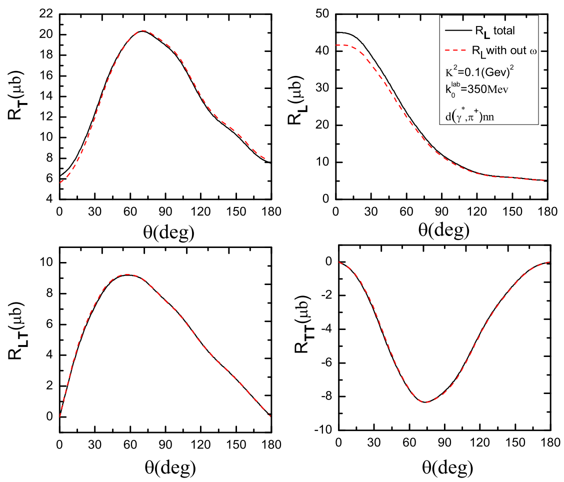

Fig. 10: Notation as in Figure (9) at k_0^{lab}=350 MeV.

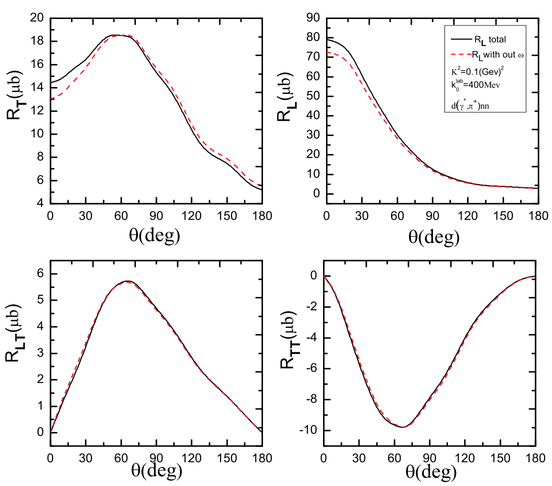

Fig. 11: Notation as in Figure (9) at k_0^{lab}=400 MeV.

momentum transfer $K^2 = 0.01GeV^2$ and the virtual photon lab energy k_0^{lab}=300 MeV, the contribution of Omega(782) is small for R_T,R_{TT} and R_{LT} where it is small for R_L, resulting in small decrease in the forward angles and small increase in the backward ones.

Increasing virtual photon lab energy to k_0^{lab}=350 MeV and keeping the four momentum transfer $K^2 = 0.01GeV^2$ (Fig.13), the absolute size of R_T,R_{TT} and R_{LT} decrease and the contributions of Omega(782) are some what bigger than what was found in Fig.(12). For R_{LT} is small, R_L resulting in small decrease at the forward angles and small increase at the backward ones, R_T a small increase at the forward angles and small decrease at the backward angles and a small effect was

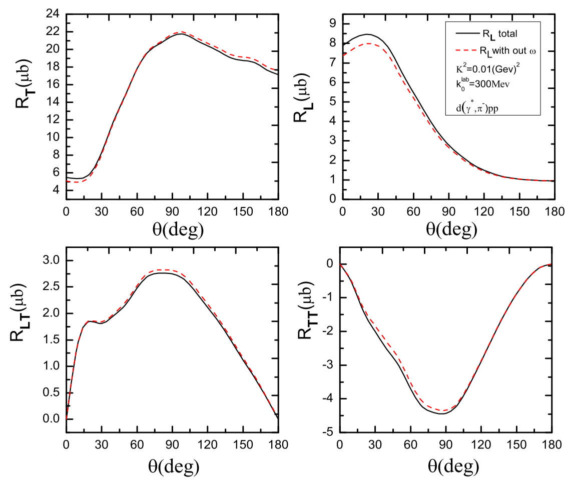

Fig. 12: Angular dependence of the four semi-exclusive structure functions of $d(e,e^{'}\pi^{-})pp$ at k_0^{lab}=300 MeV and squared four-momentum transfer $K^2 = 0.01(GeV)^2$, full lines where the $\omega(782)$ is included and dashed lines where $\omega(782)$ is eliminated.

found for R_{TT} at the peak region. This mean, increasing the k_0^{lab} results in increasing the effect of adding Omega(782) resonance.

In Fig.(14) the virtual photon lab energy is increased

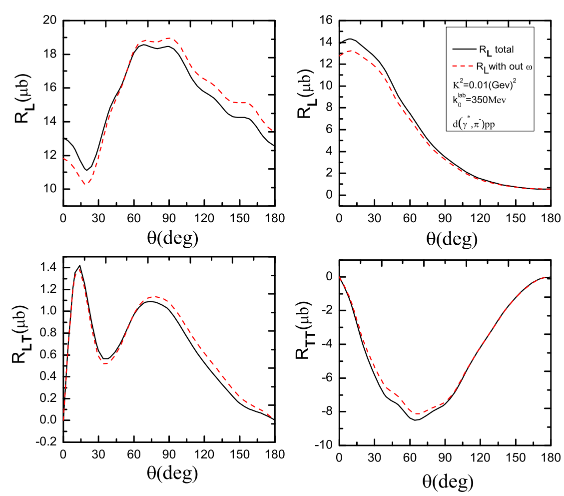

Fig. 13: Notation as in Figure (12) at k_0^{lab}=350 MeV.

to k_0^{lab}=400 MeV at the same value of the four momentum transfer $K^2 = 0.01GeV^2$, the absolute size of R_T,R_{TT} and R_{LT} reduced and the contributions of Omega(782) are some what bigger than what was found in Fig.(12) but the effect of adding Omega(782) resonance still so small

In Fig.(15) where the reaction $d(e,e^{'}\pi^{-})pp$, the four

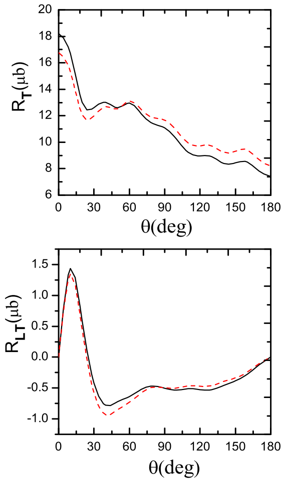

Fig. 14: Notation as in Figure (12) at k_0^{lab}=350 MeV.

momentum transfer $K^2 = 0.05GeV^2$ and the virtual photon lab energy k_0^{lab}=300 MeV, the contribution of Omega(782) is very small for R_T, R_{TT} and R_{LT} where it is small for R_L, resulting in small decrease in the forward angles and small increase in the backward ones.

Increasing virtual photon lab energy to k_0^{lab}=350

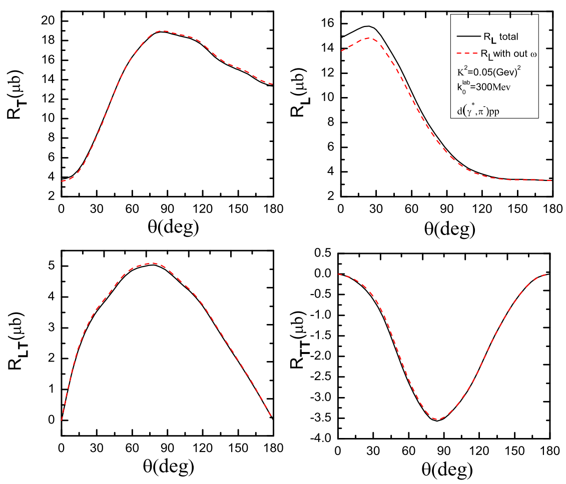

Fig. 15: Angular dependence of the four semi-exclusive structure functions of $d(e,e^{'}\pi^{-})pp$ at k_0^{lab}=300 MeV and squared four-momentum transfer $K^2 = 0.05(GeV)^2$, full lines where the $\omega(782)$ is included and dashed lines where $\omega(782)$ is eliminated.

MeV and keeping the four momentum transfer $K^2 = 0.05GeV^2$ (Fig.16), the absolute size of R_T, R_{TT} and R_{LT} decrease and the contributions of Omega(782) are some what bigger than what was found in Fig.(15). For R_{LT} still so small, R_L resulting in small decrease at the forward angles and small increase at the backward ones, R_T a small increase at the forward angles and small decrease at the backward angles and a very small effect was found for R_{TT} at the peak region. This mean, increasing the k_0^{lab} results in increasing the effect of adding Omega(782) resonance.

In Fig.(17) the virtual photon lab energy is increased

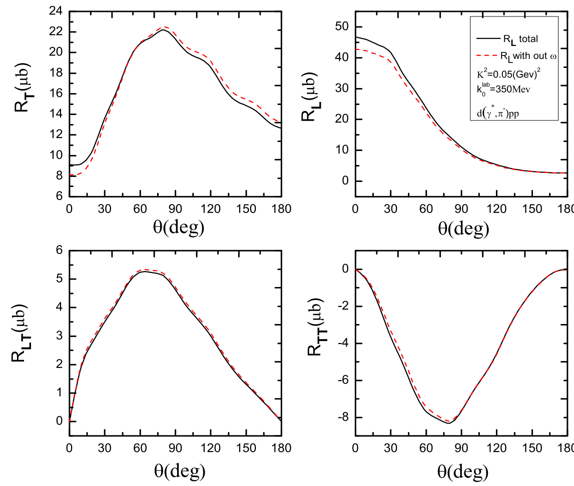

Fig. 16: Notation as in Figure (15) at k_0^{lab}=350 MeV.

to k_0^{lab}=400 MeV at the same value of the four momentum transfer $K^2 = 0.05GeV^2$, the absolute size of R_T, R_{TT} and R_{LT} reduced and the contributions of Omega(782) are some what bigger than what was found in Fig.(15) but the effect of adding Omega(782) resonance still so small

in Fig.(18) where the reaction $d(e,e^{'}\pi^{-})pp$, the four momentum transfer $K^2 = 0.1GeV^2$ and the virtual photon lab energy k_0^{lab}=300 MeV, the contribution of Omega(782) is very small for R_T, R_{TT} and R_{LT} where it is small for R_L, resulting in small decrease in the forward angles and small increase in the backward ones.

Increasing virtual photon lab energy to k_0^{lab}=350 MeV and keeping the four momentum transfer $K^2 = 0.1GeV^2$ (Fig.19), the absolute size of R_T, R_{TT} and R_{LT} decrease and the contributions of Omega(782) are some what bigger than what was found in Fig.(18). For R_{LT} still so small, R_L resulting in small decrease at the forward angles and small increase at the backward ones, R_T a small increase at the forward angles and small decrease at the backward angles and a small effect was found for R_{TT} at the peak region. This mean, increasing the k_0^{lab} results in increasing the effect of adding Omega(782) resonance.

In Fig.(20) the virtual photon lab energy is increased

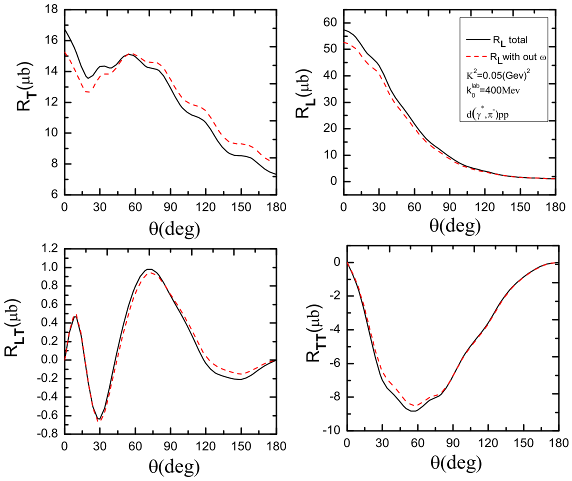

Fig. 17: Notation as in Figure (15) at k_0^{lab}=400 MeV.

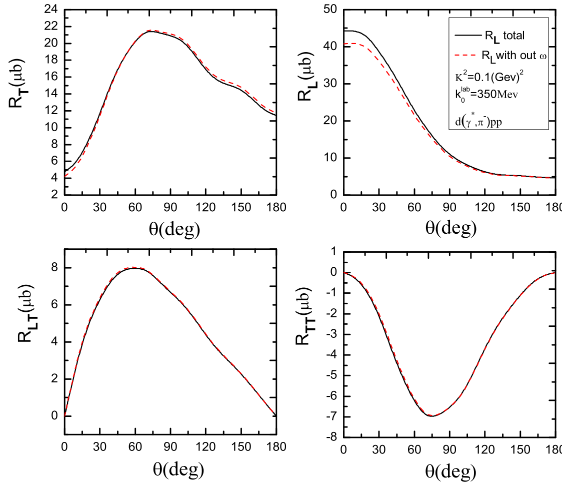

Fig. 19: Notation as in Figure (18) at k_0^{lab}=350 MeV.

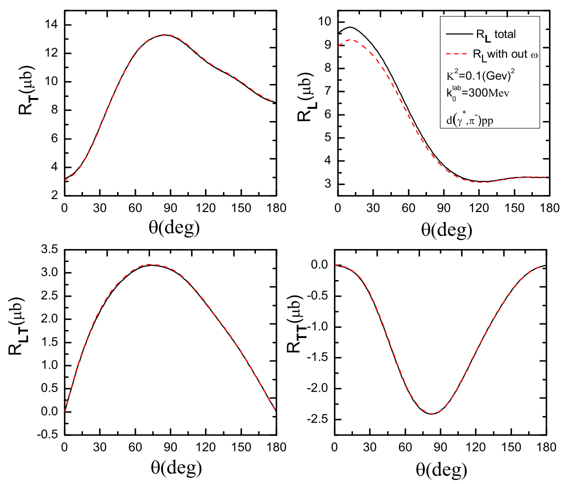

Fig. 18: Angular dependence of the four semi-exclusive structure functions of $d(e,e'\pi^-)pp$ at k_0^{lab}=300 MeV and squared four-momentum transfer $K^2 = 0.1(GeV)^2$, full lines where the $\omega(782)$ is included and dashed lines where $\omega(782)$ is eliminated.

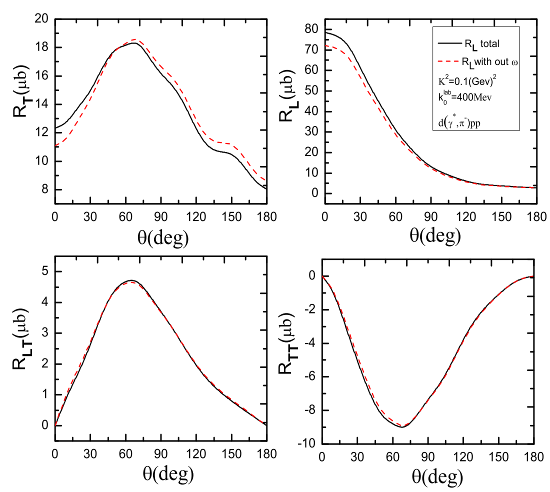

Fig. 20: Notation as in Figure (18) at k_0^{lab}=400 MeV.

to k_0^{lab}=400 MeV at the same value of the four momentum transfer $K^2 = 0.1GeV^2$, the absolute size of R_T, R_{TT} and R_{LT} reduced and the contributions of Omega(782) are some what bigger than what was found in Fig.(18) but the effect of adding Omega(782) resonance still so small.

4 Conclusion

A systematic study for the contribution of Omega(782) resonance on the structure functions of the charged pion electroproduction off the deuteron is made. This study is made in the IA without adding NN final state interactions.

Since the structure functions depend on the squared four momentum transfer K^2, the invariant energy or equivalently the virtual photon laboratory energy and the outgoing pion angle in the final hadronic c.m. system, three values for K^2 and k_0^{lab} have been selected for the presentation of the results. The results show a small effect of Omega(782) resonance on the charged pion electroproduction from the deuteron, this effect decrease by increasing K^2 and increase by increasing .

In future work it will be necessary to study the effect of Omega (782) resonance on the neutral pion electroproduction from the deuteron.

References

[1] X. Li, PhD dissertation, Chinese Academy of Sciences, Institute of Physics (1993).
[2] M. P.Rekalo, E. Tomasi-Gustafsson and J. Arvieux, *Annals of Physics*, **295**, 1-32 (2002).
[3] E. Breitmoser, H. Arenhövel, *Nuclear Physics (A)*, **612**, 321-345 (1997) .
[4] A. Fix, H. Arenhövel, *Physics Letters (B)*, **492**, 32-38 (2000) .
[5] R Gilman, M. Bernheim, M. Brussel, J. Cheminaud, J. Danel, J. Didelez, M. Duval, G. Fournier, R. Frascaria, R. J. Holt, H. E. Jackson, J. Kim, E. Kinney, J. LeGoff, *Physical Review Letters*, **64**, 622-624 (1990).
[6] D. Gaskell et al., *Physical Review Letters*, **87**, 202301 (2001).
[7] R. J. Loucks, V. R. Pandharipande, and R. Schiavilla, *Physical Review (C)*, **49**, 342 (1994).
[8] K. Hafidi and T.-S. H. Lee, *Physical Review (C)*, **64**, 064607 (2001).
[9] L. G. Levchuk and A. V. Shebeko, *Nuclear Physics (A)*, **62**, 228-236 (1999).
[10] L. G.Levchuk, L. Canton, and A. V. Shebeko, European *Physicsal Journal (A)*, **21**, 29-36 (2004).
[11] A. Fix, H. Arenhövel, *Nuclear Physics (A)*, **697**, 277-302 (2002).
[12] F. Bernds, A. Donnachie,and D. Weaver, *Nuclear Physics (B)*, **4**, 103 (1967)
[13] H. C. Jean, J. Piekarewicz and A. G. Williams, *Physical Review (C)*, **49**, 1981 (1994).
[14] S. Ghosh and S. Sarkar, European *Physicsal Journal (A)*, **49**, 97 (2013).
[15] H. Arenhövel and A. Fix, *Physical Review (C)*, **72**, 064004 (2005).
[16] M. Tammam, A. Fix, H. Arenhövel, *Physical Review (C)*, **74**, 044001 (2006) .
[17] T. W. Donnelly and A.S. Raskin, *Annals of Physics (N.Y.)*, **169**, 247 (1986).
[18] D. Drechsel, O. Hanstein, S. Kamlov, L. Tiator, *Nuclear Physics (A)*, **645**, 423-438 (1999).
[19] M. Tammam, *Nuclear Physics (A)*, **829**, 126–135 (2009).
[20] M. Tammam, *Al-Azhar Bull. Sci.*, **6**, 105-114 (2010): .
[21] R. Macleidt, K. Holinde, C. Elster, *Physics Reports*, **149**, 1 (1987).