The effect of short range correlation on the inelastic C4 form factors of ^{18}O nucleus

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Abstract

The effect of short range correlations on the inelastic longitudinal Coulomb form factors for different states of $J^{\pi}=4^{+}, T=1$ with excitation energies 3.553,7.114, 8.960 and 10.310 MeV in ^{18}O is analyzed. This effect (which depends on the correlation parameter β) is inserted into the ground state charge density distribution through the Jastrow type correlation function. The single particle harmonic oscillator wave function is used with an oscillator size parameter b. The parameters β and b are considered as free parameters, adjusted for each excited state separately so as to reproduce the experimental root mean square charge radius of ^{18}O. The model space of ^{18}O does not contribute to the transition charge density. As a result, the inelastic Coulomb form factors of ^{18}O comes absolutely from the core polarization transition charge density. According to the collective modes of nuclei, the core polarization transition charge density is assumed to have the form of Tassie shape. It is found that the introduction of the effect of short range correlations is necessary for obtaining a remarkable modification in the calculated inelastic longitudinal Coulomb form factors and considered as an essential for explanation the data amazingly throughout the whole range of considered momentum transfer.

Key words

Charge density distribution, elastic charge form factors, inelastic longitudinal form factors, short range correlation.

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تاثير دالة ارتباط المدى القصير على عوامل التشكل C4 الغير مرنة لنواة الاوكسجين -18

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الخلاصة

تم دراسة تاثير دالة ارتباط المدى القصير على عوامل التشكل الكولومي غير المرن لحالات مختلفة لـ$(J^{\pi}=4^{+}, T=1)$بطاقات التهيج 3.553, 7.114, 8.960 و10.310 MeV لنواة الاوكسجين -18. لقد تم ادخال هذا التأثير (الذي يعتمد على اعلومة الارتباط β) على توزيع كثافة الشحنة للحالة الأرضية من خلال دالة الارتباط نوع Jastrow. كما تم اعتماد الدالة الموجية للمتذبذب التوافقي للجسيم المنفرد مع معلم حجم المتذبذبb. في هذه الدراسة تم اعتبار β وb كمعلمات حرة تُغَير (لكل حالة متهيجة بصورة منفصلة) للحصول على النتائج العملية للجذر ألتربيعي لمعدل مربع نصف قطر الشحنة. في هذا البحث تم افتراض عدم مساهمة كثافة الشحنة الانتقالية لانموذج فضاء الأوكسجين -18في حسابات عوامل التشكل الكولومي غير المرن والمساهمة تكون فقط من خلال كثافة الشحنة الانتقالية لاستقطاب القلب النووي. وبموجب الصيغة التجميعية للنوى تم حساب كثافة الشحنة الانتقالية لاستقطاب القطب باستخدام (Tassie shape). لقد وُجِدَ ان إدخال تأثير دالة ارتباط المدى القصير يكون ضرورياً للحصول على تعديل ملحوظ في تحسين النتائج النظرية لعوامل التشكل الكولومية الغير المرنة كما ووجد ايضا بانها أساسية لتفسير البيانات بشكل ممتاز خلال مدى الزخم المنتقل المعتمد في هذه الدراسة.

1-Introduction

Electron scattering provides more accurate information about the nuclear structure for example size and charge distribution. It provides important knowledge about the electromagnetic currents inside the nuclei. Electron scattering have been provided a good test for such evaluation since it is sensitive to the spatial dependence on the charge and current densities [1, 2, 3].

The obtained information from the high energy electron scattering by the nuclei depending mainly on the magnitude of the de Broglie wavelength that is associated with the electron compared with the range of the nuclear forces. The de Broglie wave length that compare of the energy of the incident electron is in 100 MeV and more will be in the range of the spatial extension of the target nucleus. The wave length of electron with this energy represents a best probe to study the nuclear structure [4].

Depending on the electron scattering, one can distinguish two types of scattering: in the first type, the nucleus is left in its ground state, that is called "elastic electron scattering" while in the second type, the nucleus is left on its different excited states, this is called "inelastic electron scattering" [5, 6].

In the studies of Massen et al. [7-9], the factor cluster expansion of Clark and co-workers [10-12] was utilized to derive an explicit form of the elastic charge form factor, truncated at the two-body term. This form, which is a sum of one- and two-body terms, depends on the harmonic oscillator parameter and the correlation parameter through a Jastrow-type correlation function [13]. This form is employed for the evaluation of the elastic charge form factors of closed shell nuclei ^{4}He, ^{16}O and ^{40}Ca in an approximate technique (that is, for the expansion of the two-body terms in powers of the correlation parameter, only the leading terms had been kept) for the open $s-p$ and $s-d$ shell nuclei. Subsequently, Massen and Moustakidis [14] performed a systematic study of the effect of the SRC on $s-p$ and $s-d$ shell nuclei with entirely avoiding the approximation made in their earlier works outlined in [7-9] for the open shell nuclei. Explicit forms of elastic charge form factors and densities were found utilizing the factor cluster expansion of Clark and co-workers and Jastrow correlation functions which introduce the SRC. These forms depends on the single particle wave functions and not on the wave functions of the relative motion of two nucleons as was the case of our previous works [15-21] and other works [7,22,23].

It is important to point out that all the above studies were concerned with the analysis of the effect of the SRC on the elastic electron scattering charge form factors of nuclei.

There has been no detailed investigation for the effect of the SRC on the inelastic electron scattering form factors of nuclei. We thus, in the present work, perform calculations with inclusion this effect on the inelastic Coulomb (longitudinal) form factors for isotopes of closed shell nuclei. As a test case, the isotope of ^{18}O is considered in this study. In ^{18}O, the model space does not contribute to the transition charge density, since there are only two neutrons distributed over the orbits $1d5/2, 2s1/2$ and $1d3/2$ outside the core of ^{16}O. Thus, the Coulomb form factors of this isotope comes totally from the core polarization transition charge density. According to the collective modes of nuclei, the core polarization transition charge density (which depends on the ground state charge density distribution) is assumed to have the form of Tassie shape [24]. To study the effect of SRC (which depends on the correlation parameter β) on the inelastic electron scattering charge form factors of considered nucleus, we insert this effect on the ground state charge density distribution through the Jastrow type correlation function [13]. The single particle harmonic oscillator wave function is used in the present calculations with an oscillator size parameter *b*. The effect of SRC's on the inelastic Coloumb form factors for the lowest four excited 4^+ states in ^{18}O isotope is analyzed.

Theory

Inelastic electron scattering longitudinal (Coulomb) form factor involves angular momentum J and momentum transfer q, and is given by [25]

$$\left| F_J^L(q) \right|^2 = \frac{4\pi}{Z^2(2J_i+1)} \left| \left\langle f \left\| \hat{T}_J^L(q) \right\| i \right\rangle \right|^2 \left|F_{cm}(q)\right|^2 \left|F_{fs}(q)\right|^2, \qquad (1)$$

where $\left|i\right\rangle = \left|J_i T_i\right\rangle$ and $\left|f\right\rangle = \left|J_f T_f\right\rangle$ are the initial and final nuclear states (described by the shell model states of spin $J_{i/f}$ and isospin $T_{i/f}$), $\hat{T}_J^L(q)$ is the longitudinal electron scattering operator, $F_{cm}(q) = e^{q^2b^2/4A}$ is the center of mass correction (which removes the spurious states arising from the motion of the center of mass when shell model wave function is used), $F_{fs}(q) = e^{-0.43q^2/4}$ is the nucleon finite size correction and assumed to be the same for protons and neutrons, A is the nuclear mass number, Z is the atomic number and b is the harmonic oscillator size parameter.

The form factor of Eq.(1) is expressed via the matrix elements reduced in both angular momentum and isospin [26]

$$\left| F_J^L(q) \right|^2 = \frac{4\pi}{Z^2(2J_i+1)} \left| \sum_{T=0,1} (-1)^{T_f - T_{z_f}} \begin{pmatrix} T_f & T & T_i \\ -T_{z_f} & 0 & T_{z_i} \end{pmatrix} \left\langle J_f T_f \left\| \hat{T}_{JT}^L(q) \right\| J_i T_i \right\rangle \right|^2 \times \left|F_{cm}(q)\right|^2 \left|F_{fs}(q)\right|^2, \qquad (2)$$

where in Eq. (2), the bracket ( ) is the three-J symbol, where J and T are restricted by the following selection rule:

$$\left|J_f - J_i\right| \le T \le J_f + J_i$$
$$\left|T_f - T_i\right| \le T \le T_f + T_i, \qquad (3)$$

and T_z is given by $T_z = \frac{Z-N}{2}$.

The reduced matrix elements in spin and isospin space of the longitudinal operator between the final and initial many particles states of the system including configuration mixing are given in terms of the one-body density matrix (OBDM) elements times the single particle matrix elements of the longitudinal operator [27]

$$\left\langle f \left\| \hat{T}_{JT}^L \right\| i \right\rangle = \sum_{a,b} OBDM^{JT}(i,f,J,a,b) \left\langle b \left\| \hat{T}_{JT}^L \right\| a \right\rangle, \qquad (4)$$

where a and b label single particle states (isospin included) for the shell model space. The $OBDM$ in Eq. (4) is

$$OBDM(\tau_z) = (-1)^{T_f - T_z} \begin{pmatrix} T_f & 0 & T_i \\ -T_z & 0 & T_z \end{pmatrix} \sqrt{2}\, \frac{OBDM(\Delta T = 0)}{2} + \tau_z (-1)^{T_f - T_z} \begin{pmatrix} T_f & 1 & T_i \\ -T_z & 0 & T_z \end{pmatrix} \sqrt{6}\, \frac{OBDM(\Delta T = 1)}{2}, \quad (5)$$

where τ_z is the isospin operator of the single particle.

The model space matrix elements are not adequat to describe the absolute strength of the observed gamma-ray transition probabilities, because of the polarization in nature of the core protons by the model space protons and neutrons. Therfore the many particle reduced matrix elements of the longitudinal electron scattering operator $\hat{T}_J^L(q)$ is expressed as the sum of the model space (ms) contribution and the core polarization (cp) contribution [28], i.e.

calculated in terms of the isospin-reduced matrix elements as [28]

$$\left\langle f \left\| \hat{T}_J^L(\tau_Z, q) \right\| i \right\rangle = \left\langle f \left\| \overset{ms}{\hat{T}_J^L}(\tau_Z, q) \right\| i \right\rangle + \left\langle f \left\| \overset{cp}{\hat{T}_J^L}(\tau_Z, q) \right\| i \right\rangle. \quad (6)$$

The model space matrix element, in Eq. (6), is given by

$$\left\langle f \left\| \overset{ms}{\hat{T}_J^L}(\tau_Z, q) \right\| i \right\rangle = \int_0^\infty dr\, r^2 j_J(qr)\, \rho_{J,\tau_Z}^{ms}(i, f, r), \quad (7)$$

where $j_J(qr)$ is the spherical Bessel function and $\rho_{J,\tau_Z}^{ms}(i, f, r)$ is the model space transition charge density, expressed as the sum of the product of the $OBDM$ times the single particle matrix elements, given by [28].

$$\rho_{J,\tau_Z}^{ms}(i, f, r) = \sum_{jj'(ms)}^{ms} OBDM(i, f, J, j, j', \tau_z) \left\langle j \| Y_J \| j' \right\rangle R_{nl}(r)\, R_{n'l'}(r). \quad (8)$$

Here, $R_{nl}(r)$ is the radial part of the harmonic oscillator wave function and Y_J is the spherical harmonic wave function.

The core-polarization matrix element, in eq. (6), is given by

$$\left\langle f \left\| \overset{cp}{\hat{T}_J^L}(\tau_Z, q) \right\| i \right\rangle = \int_0^\infty dr\, r^2 j_J(qr)\, \rho_{J,\tau_Z}^{cp}(i, f, r), \quad (9)$$

where $\rho_{J\tau_Z}^{cp}(i, f, r)$ is the core-polarization transition charge density which depends on the model used for core polarization. To take the core-polarization effects into consideration, the model space transition charge density is added to the core-polarization transition charge density that describes the collective modes of nuclei. The total transition charge density becomes

$$\rho_{J\tau_Z}(i, f, r) = \rho_{J\tau_Z}^{ms}(i, f, r) + \rho_{J\tau_Z}^{cp}(i, f, r) \quad (10)$$

According to the collective modes of nuclei, the core polarization transition charge density is assumed to have the form of Tassie shape [24]

$$\rho_{Jt_Z}^{cp}(i, f, r) = N_T \frac{1}{2}(1 + \tau_z) r^{J-1} \frac{d\rho_{ch}^{gs}(i, f, r)}{dr}, \quad (11)$$

where N_T is the proportionality constant given by [15]

$$N_T = \frac{\int_0^\infty dr\, r^{J+2} \rho_{t_z}^{ms}(i, f, r) - \sqrt{(2J_i + 1) B(CJ)}}{(2J+1) \int_0^\infty dr\, r^{2J} \rho_{ch}^{gs}(i, f, r)}, \quad (12)$$

which can be determind by adusting the reduced transition probability $B(CJ)$ to the experimental value, and

$\rho_{ch}^{gs}(i, f, r)$ is the ground state charge density distribution of considered nuclei.

For $N = Z$, the ground state charge densites $\rho_{ch}^{gs}(r)$ of closed shell nuclei may be related to the ground state point nucleon densities $\rho_{p}^{gs}(r)$ by [29, 30]

$$\rho_{ch}^{gs}(r) = \frac{1}{2}\rho_{p}^{gs}(r), \qquad (13)$$

in unit of electronic charge per unit volume (e.fm^{-3}).

An expression of the correlated density $\rho_{p}^{gs}(r)$ (where the effect of the SRC's is included), consists of one- and two-body terms, is given by [31]

$$\begin{aligned}\rho_{p}^{gs}(r) &\approx N_D\left[\left\langle \hat{O}_r \right\rangle_1 + \left\langle \hat{O}_r \right\rangle_2\right] \\ &\approx N_D\left[\left\langle \hat{O}_r \right\rangle_1 - 2O_{22}(r,\beta) + O_{22}(r,2\beta)\right],\end{aligned} \qquad (14)$$

where N_D is the normalization factor and $\hat{O}_r$ is the one body density operator given by

$$\hat{O}_r = \sum_{i=1}^{A}\hat{o}_r(i) = \sum_{i=1}^{A}\delta(\vec{r} - \vec{r}_i). \qquad (15)$$

The correlated density $\rho_{p}^{gs}(r)$ of Eq. (14), which is truncated at the two-body term and originated by the factor cluster expansion of Clark and co-workers [10-12], depends on the correlation parameter β through the Jastrow-type correlation

$$f(r_{ij}) = 1 - \exp[-\beta(\vec{r}_i - \vec{r}_j)^2], \qquad (16)$$

where $f(r_{ij})$ is a state-independent correlation function, which has the following properties: $f(r_{ij}) \to 1$ for large values of $\vec{r}_{ij} = \left|\vec{r}_i - \vec{r}_j\right|$ and $f(r_{ij}) \to 0$ for $\vec{r}_{ij} \to 0$. It is so clear that the effect of SRC's, inserted by the function $f(r_{ij})$, becomes large for small values of SRC parameter β and vice versa.

The one-body term, in Eq. (14), is well known and given by

$$\begin{aligned}\left\langle \hat{O}_r \right\rangle_1 &= \sum_{i=1}^{A}\left\langle i\left|\hat{o}_r(1)\right|i\right\rangle \\ &= 4\sum_{nl}\eta_{nl}(2l+1)\frac{1}{4\pi}\phi_{nl}^{*}(r)\phi_{nl}(r),\end{aligned} \qquad (17)$$

where η_{nl} is the occupation probability of the state nl and $\phi_{nl}(r)$ is the radial part of the single particle harmonic oscillator wave function.

The two-body term, in Eq. (14), is given by [31]

$$O_{22}(r,z) = 2\sum_{i<j}^{A}\left\langle ij\left|\hat{o}_r(1)g(r_1,r_2,z)\right|ij\right\rangle_a, \quad (z = \beta, 2\beta) \qquad (18)$$

where

$$g(r_1,r_2,z) = \exp(-zr_1^2)\exp(-zr_2^2)\exp(2zr_1r_2\cos w_{12}), \qquad (19)$$

The form of the two-body term $O_{22}(r,z)$ is then originated by expanding the factor $\exp(2zr_1r_2\cos w_{12})$ in the spherical harmonics and expressed as [31]

$$\begin{aligned}O_{22}(r,z) &= 4\sum_{n_il_i,n_jl_j}\eta_{n_il_i}\eta_{n_jl_j}(2l_i+1)(2l_j+1) \\ &\times\left\{4A_{n_il_in_jl_j}^{n_jl_jn_il_i0}(r,z) - \sum_{k=0}^{l_i+l_j}\left\langle l_i0l_j0\middle|k0\right\rangle^2 A_{n_il_in_jl_j}^{n_jl_jn_il_ik}(r,z)\right\}, \quad (z = \beta, 2\beta)\end{aligned} \qquad (20)$$

where

$$A_{n_1l_1n_2l_2}^{n_3l_3n_4l_4k}(r,z)=\frac{1}{4\pi}\phi_{n_1l_1}^{*}(r)\phi_{n_3l_3}(r)\exp(-zr^2) \times\int_0^\infty \phi_{n_2l_2}^{*}(r_2)\phi_{n_4l_4}(r_2)\exp(-zr_2^2)\; i_k(2zrr_2)r_2^2dr_2 \tag{21}$$

and $\langle l_i 0 l_j 0 | k0\rangle$ is the Clebsch-Gordan coefficients.

It is important to point out that the expressions of Eqs. (17) and (20) are originated for closed shell nuclei with $N=Z$, where the occupation probability η_{nl} is 0 or 1. To extend the calculations for isotopes of closed shell nuclei, the correlated charge densities of these isotopes are characterized by the same expressions of Eqs. (17) and (20) (this is because all isotopic chain nuclei have the same atomic number Z) but this time different values for the parameters b and β are utilized.

The mean square charge radii of nuclei are defined by

$$\langle r^2\rangle=\frac{4\pi}{Z}\int_0^\infty \rho_{ch}^{gs}(r)r^4dr, \tag{22}$$

where the normalzation of the charge density distribution $\rho_{ch}^{gs}(r)$ is given by

$$Z=4\pi\int_0^\infty \rho_{ch}^{gs}(r)r^2dr \tag{23}$$

Results and discussion

The effect of the SRC on inelastic Coulomb (longitudinal) C4 form factors for ^{18}O nucleus is studied. The charge density distribution (based on using the single particle harmonic oscillator wave functions with oscilator size parameter b and occupation probabilities $\eta_{1s}=1$ and $\eta_{1p}=1$) is calculated by eq.(13) together with Eqs. (14), (17) and (20). The calculated CDD without the effect of the SRC (i.e., when the correlation parameter $\beta=0$) is obtained by adjusting the oscillator size parameter b so as to reproduce the experimental root mean square (rms) charge radius $(<r^2>_{\exp}^{2}=2.727\pm 0.02\,fm)$ of ^{18}O. While the calculated CDD with the effect of the SRC (i.e., when $\beta\neq 0$) is obtained by adjusting both parameters b and β so as to reproduce the experimental rms charge radius of ^{18}O.

The SRC effect on the inelastic Coulomb (longitudinal) C4 form factors for different states of $J^{\pi}=4^{+}, T=1$ with excitation energies 3.553,7.114, 8.960 and 10.310 MeV in ^{18}O are studied. The Coulomb form factor in ^{18}O comes totally from the core-polarization transition charge density because the two active neutrons, which move in the model space of this nucleus, give no contribution [i.e., $\rho_{J,\tau_Z}^{ms}(i,f,r)=0$] to the total transition charge density of eq. (10). The SRC effect is introduced into the ground state CDD through the Jastrow type correlation function. According to the collective modes of nuclei, the core polarization transition charge density is evaluated by adopting the Tassie model [Eq. (11)], where this model depends on the ground state charge density distribution. The proportionality constant N_T [Eq. (12)] is estimated by adjusting the reduced transition probability $B(CJ)$ to the experimental value. The single particle harmonic oscillator wave function is employed with an oscillator size parameter b. The CDD calculated without the effect of the SRC depends only on one free parameter (namely the parameter b), where b is fixed with a value of $b = 1.82$ fm so as to reproduce the experimental rms charge radius of ^{18}O. While the CDD calculated with the effect of the SRC depends on two free parameters (namely the harmonic oscillator size parameter b and the correlation parameter β), where these parameters are chosen for each excited state separately so as to reproduce the experimental rms charge radius of ^{18}O.

In Table 1, we display the experimental excitation energies E_x (MeV), experimental reduced transition probabilities $B(C4;\ 0_1^+ \to 4^+)$ (e^2 fm^8) and the chosen values for the parameters b and β for each excited state. The root mean square (rms) charge radius calculated with the effect of the SRC is also displayed in this table and compared with that of experimental result. It is evident from this table that the values of the parameter b employed for calculations with the effect of the SRC are smaller than those of without the SRC ($b = 1.82$ fm). This is attributed to the fact that the introduction of the SRC leads to enlarge the relative distance of the nucleons (i.e., to enlarge the size of the nucleus) whereas the parameter b (which is proportional to the radius of the nucleus) should become smaller so as to reproduce the experimental rms charge radius of the considered nucleus.

Table 1: The experimental excitation energies and reduced transition probabilities, the chosen values for b and β as well as the rms charge radius calculated with the effect of the SRC of ^{18}O.

State	Ex (MeV)	$B(C4)$ (e^2 fm^8)	b (fm)	β (fm^{-2})	$<r^2>^{1/2}_{cal.}$ (fm)	$<r^2>^{1/2}_{exp.}$ (fm)
4^+	3.553 [32]	$(9.04 \pm 0.90)\times 10^2$ [32]	1.57	1.41	2.711	2.727 (20) [34]
4^+	7.114 [32]	$(1.31 \pm 0.06)\times 10^4$ [32]	1.73	3.18	2.653	
4^+	8.96 [33]	$9.3(41)\times 10^2$ [33]	1.73	2.47	2.725	
4^+	10.31 [33]	$< 4\times 10^2$ [33]	1.55	1.8	2.539	

The inelastic Coulomb $C4$ form factors for different transitions ($J^{\pi}_{gs}T_{gs} \to J^{\pi}_{f}T_{f}$) in ^{18}O are displayed in Figs. 1-4. It is obvious that all transitions considered in these figures are of an isovector character. Besides, the parity of them does not change. Here, the calculated inelastic $C4$ form factors are plotted versus the momentum transfer q and compared with those of experimental data. The dashed and solid curves are the calculated inelastic Coloumb $C4$ form factors without and with the inclusion of the effect of SRC, respectively. The open circles, open squares, closed circles and rhomb are those of experimental data taken from [32] and [33].

In Fig.1, we display the inelastic Coulomb $C4$ form factors for the transition $0^+1 \to 4^+1$ ($E_x = 3.553$ MeV and $B(C4) = (9.04 \pm 0.90)\times 10^2\ e^2.\mathrm{fm}^8$ [32]). The calculated $C4$ form factors(displayed by the solid curve) are obtained by adopting the values of $b = 1.57$ fm and $\beta = 1.41$ fm^{-2}. It is clear from this figure that the calculated C4 form factors without the effect of the SRC (the dashed curve) under predicts the experimental data throughout all range of considered momentum transfer. Incorporating the effect of SRC improves the calculated C4 form factors appreciably and describes the experimental data extremely well for q<2.1fm^{-1}. However, the high momentum transfer(2.1≤q≤2.5 fm^{-1}) C4 form factors, which are not in agreement with the experimental data, seem to need some more investigations. The rms charge radius calculated with the above values of b and β is 2.711 fm, which is in good agreement with the experimental value.

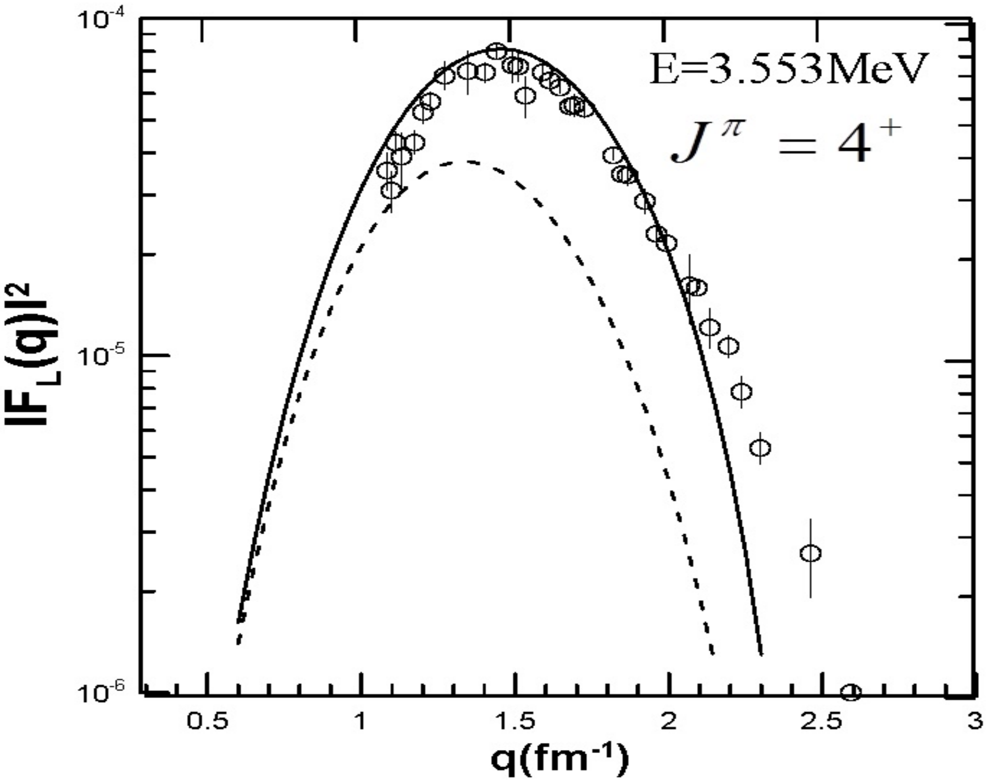

Fig. 1: Inelastic Coulomb $C4$ form factors for the transition to the $4^{+}1$ (3.553 MeV) state. The long-dashed and solid curves are the calculated $C4$ form factors without and with the inclusion of the effect of the SRC, respectively. The open circle symbols are those of the experimental data taken from ref. [32].

In Fig. 2, we exhibit the inelastic Coulomb $C4$ form factors for the transition $0^{+}1 \rightarrow 4^{+}1$ ($E_x = 7.114$ MeV and $B(C4) = (1.31 \pm 0.06) \times 10^4$ $e^2 . \mathrm{fm}^8$ [32]). The calculated inelastic $C4$ form factors revealed by the solid curve (with the effect of the SRC) are obtained with applying the values of $b = 1.73$ fm and $\beta = 3.18$ fm^{-2}. The dashed curve under predicts the experimental data at q>1.2fm^{-1}. Taking into account the effect of the SRC leads to enhance the calculated form factors as seen by the solid curve. Accordingly, the $C4$ form factors exhibited by the solid curve are in a satisfactory description with the experimental data throughout the whole range of considered q. The rms charge radius calculated by applying the above values of b and β is 2.653fm, which is less than the experimental value by 0.074fm, which corresponds to a decrease of nearly 2.7 % of the experimental value.

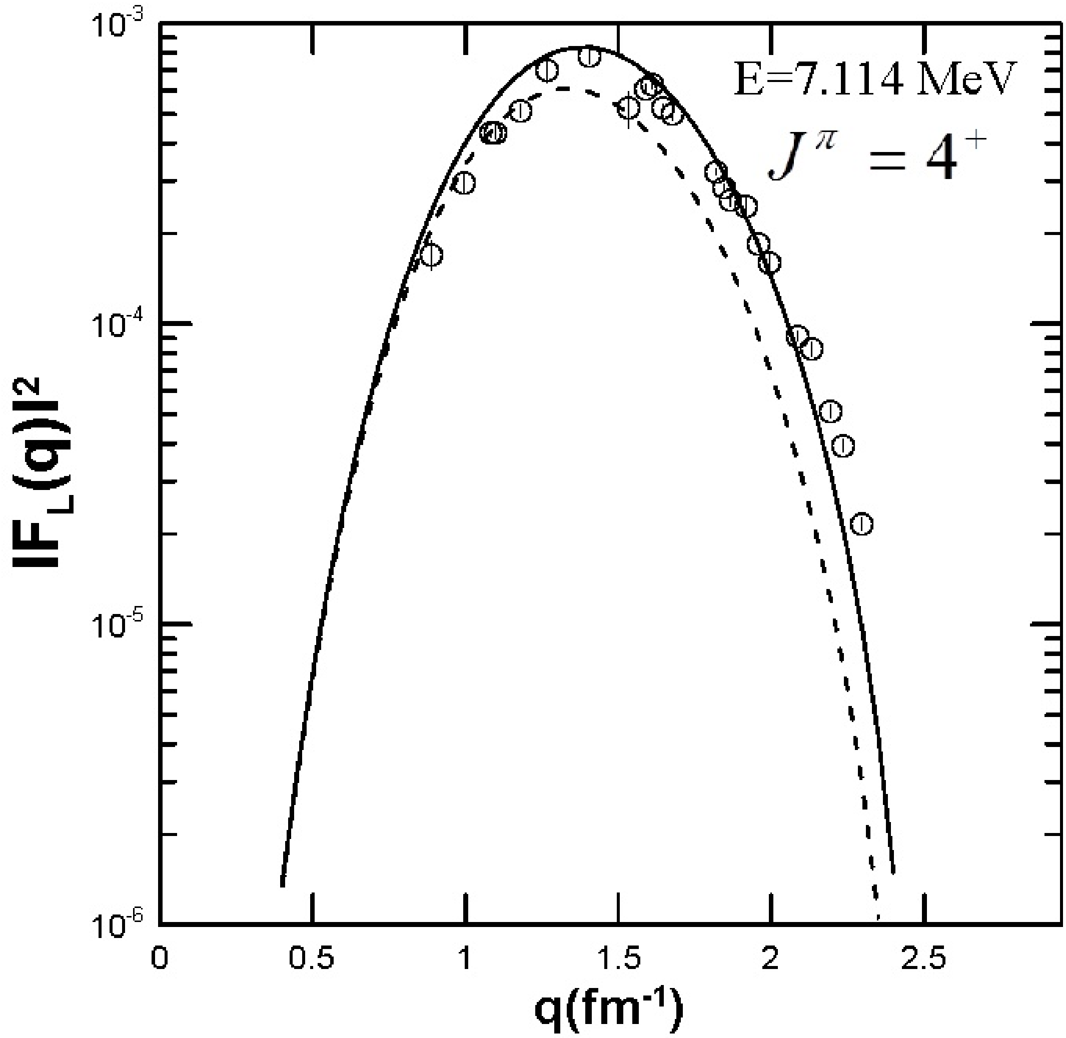

Fig. 2: Inelastic Coulomb $C4$ form factors for the transition to the $4^{+}1$ (7.114 MeV) state. The long-dashed and solid curves are the calculated $C4$ form factors without and with the inclusion of the effect of the SRC, respectively. The open circle symbols are those of the experimental data taken from ref. [32].

In Fig.3, we demonstrate the inelastic Coulomb $C4$ form factors for the transition $0^{+}1 \rightarrow 4^{+}1$ ($E_x = 8.96$ MeV and $B(C4) = 9.3(41) \times 10^{2}\ e^{2}.\,\text{fm}^{8}$ [33]). The calculated $C4$ form factors (the solid curve) are obtained via utilizing the values of $b = 1.73$ fm and $\beta = 2.47$ fm^{-2}. It is apparent from this figure that the calculated form factors without the effect of the SRC (the dashed curve) do not describe the experimental data very well. Incorporating the effect of the SRC leads to give a remarkable improvement in the calculated form factors (the solid curve) and then leads to describe the data astonishingly. The rms charge radius evaluated by utilizing the above values of b and β is 2.725fm, which is in good agreement with the experimental value.

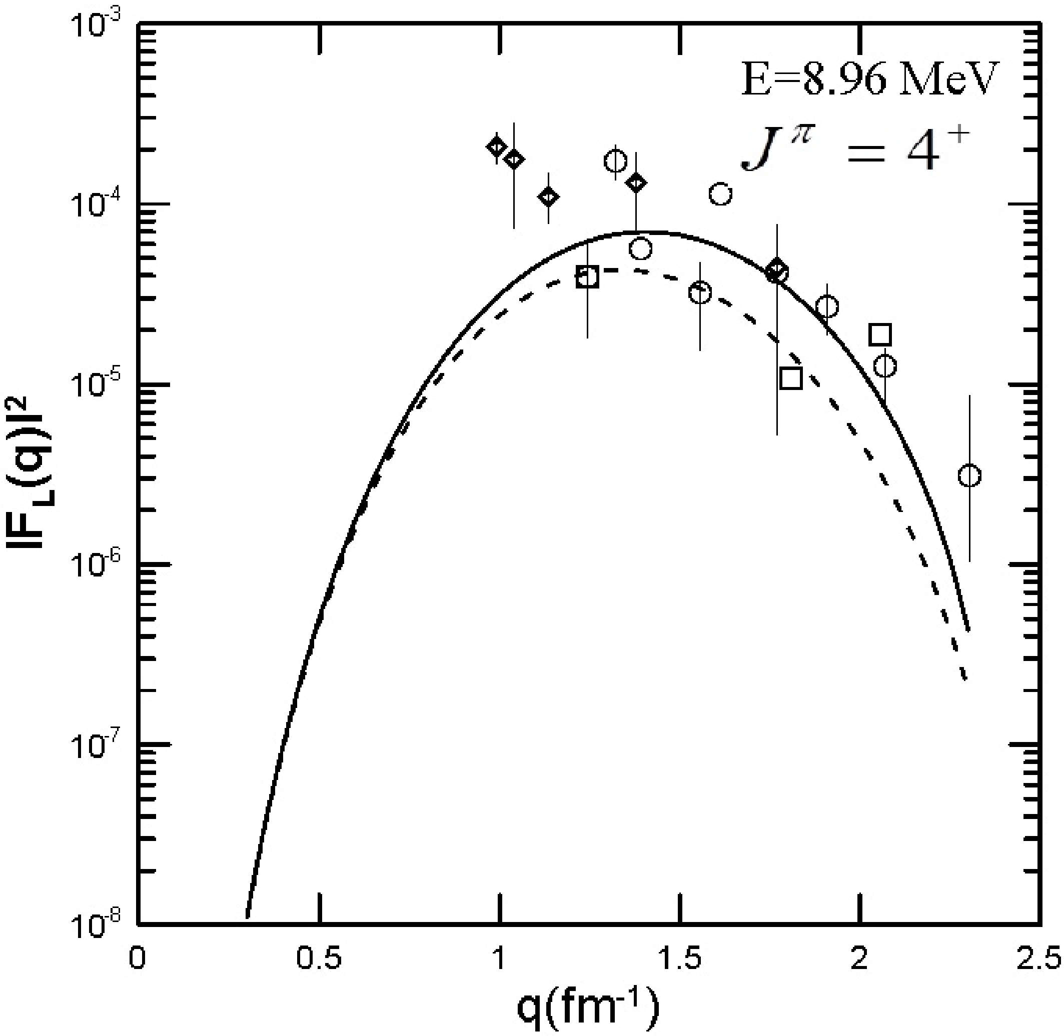

Fig. 3: Inelastic Coulomb $C4$ form factors for the transition to the $4^{+}1$ (8.96 MeV) state. The dashed and solid curves are the calculated $C4$ form factors without and with the inclusion of the effect of the SRC, respectively. The open circle, open square and rhomb symbols are those of the experimental data taken from ref. [33].

In Fig. 4, we present the inelastic Coulomb $C4$ form factors for the transition $0^{+}1 \rightarrow 4^{+}1$ ($E_x = 10.31$ MeV and $B(C4) =< 4\times10^{2}\ e^{2}.\mathrm{fm}^{8}$ [33]). The calculated $C4$ form factors (the solid curve) are obtained by employing the values of $b = 1.55$ fm and $\beta = 1.8$ fm^{-2}. This figure illustrates that the calculated result displayed by the dashed curve (without the effect of the SRC) does not predict correctly the experimental data. Introducing the effect of the SRC leads to provide a notable modification in the calculated $C4$ form factors displayed by the solid curve and subsequently predicts the data amazingly throughout the whole range of considered momentum transfer. The rms charge radius estimated by using the above values of b and β is 2.539fm, which is less than the experimental value by 0.188 fm, which corresponds to a decrease of nearly 6.8%of the experimental value.

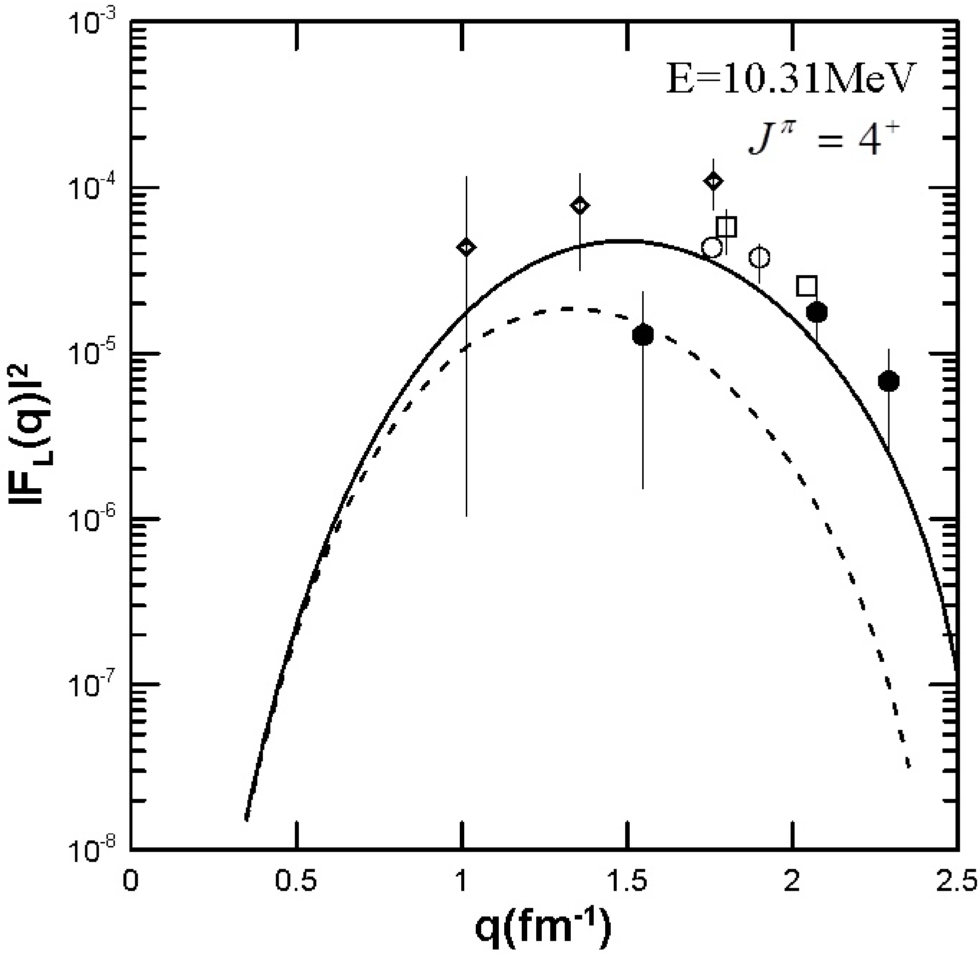

Fig. 4: Inelastic Coulomb $C4$ form factors for the transition to the $4^{+}1$ (10.31 MeV) state. The dashed and solid curves are the calculated $C4$ form factors without and with the inclusion of the effect of the SRC, respectively. The open circle, closed circle, open square and rhomb symbols are those of the experimental data taken from ref. [33].

Conclusions

The effect of the SRC on the inelastic Coulomb $C4$ form factors for different excited 4^{+} states is analyzed. This effect is included in the present calculations through the Jastrow type correlation function. As the model space of ^{18}O does not contribute to the transition charge density, the inelastic Coulomb form factor of ^{18}O comes completely from the core polarization transition charge density. According to the collective modes of nuclei, the core transition charge density is assumed to have the form of Tassie shape. It is concluded that the introduction of the effect of the SRC is necessary for obtaining a notable modification in the calculated inelastic Coulomb C4 form factors and also essential for explanation the data astonishingly throughout the whole range of considered momentum transfer.

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