COULOMB SUMS FOR ^{7}Li NUCLEUS AT 3-MOMENTUM TRANSFERS $q = 1.250 \ldots 1.625\ fm^{-1}$

A.Yu. Buki [*], ***N.G. Shevchenko, I.S. Timchenko***

National Science Center "Kharkov Institute of Physics and Technology", 61108, Kharkov, Ukraine

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The experimental response functions of ^{7}Li nucleus at effective 3-momentum transfers $q = 1.250$; 1.375; 1.500 and $1.625\ fm^{-1}$ are presented. The longitudinal response functions were used to evaluate the Coulomb sum values. The Coulomb sums for ^{6}Li obtained by us earlier were applied to analyze these data. The Coulomb sums of lithium isotopes were compared with the well-known Coulomb sums values of the other nuclei.

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1. INTRODUCTION

The longitudinal (R_L) and transverse (R_T) response functions represent the spectra of scattered electrons separated into longitudinal and transverse components respectively according to polarization of electromagnetic-interaction field. The relation between the response functions (RF) and the doubly differential electron-scattering cross section ($\mathrm{d}^2\sigma/\mathrm{d}\Omega\mathrm{d}\omega$), according to ref. [1], can be written as

$$\frac{\mathrm{d}^2\sigma}{\mathrm{d}\Omega\mathrm{d}\omega}(\theta, E_0, \omega) \,/\, (\sigma_M(\theta, E_0)) =$$
$$\frac{q_\mu^4}{q^4} \cdot R_L(q,\omega) + \left[\frac{1}{2} \cdot \frac{q_\mu^2}{q^2} + \tan^2\frac{\theta}{2}\right] \cdot R_T(q,\omega), \qquad (1)$$

where E_0 is the initial energy of electron scattered through the angle θ with the transfer of energy ω, effective 3-momentum $q = \xi \cdot \{4E_0[E_0-\omega]\sin^2(\theta/2) + \omega^2\}^{1/2}$ and 4-momentum $q_\mu = (q^2-\omega^2)^{1/2}$ to the nucleus involved; $\sigma_M(\theta, E_0) = Z^2e^4\cos^2(\theta/2)/[4E_0^2\sin^4(\theta/2)]$ is the Mott cross section, e is the electron charge. The correction ξ takes into account the distortion of the electron wave by the electrostatic field of nucleus. According to [2], this correction is written as $\xi = 1 + 1.33Ze^2/(E_0 < r^2 >^{1/2})$, where Z and $< r^2 >$ are, respectively, the charge and r.m.s. radius of the nucleus.

At the present time the theoretical calculations of $R_{T/L}$-functions are rather difficult and exist only for nuclei with $A \leq 4$. Therefore, the experimental data are presented as RF moments, which are compered with calculation by the sum-rule approach. The moment of RF have the following form

$$S_{T/L}^{(n)}(q) = \frac{1}{Z}\int_{\omega_{el}^+}^{\infty} \frac{R_{T/L}(q,\omega)}{\eta \cdot G^2(q_\mu^2)} \cdot \omega^n \mathrm{d}\omega, \qquad (2)$$

where n is the moment number, $G(q_\mu^2)$ is the electric form factor of the proton; $\eta = [1 + q_\mu^2/(4M^2)] \times [1 + q_\mu^2/(2M^2)]^{-1}$ is the correction for the relativistic effect of nucleon motion in the nucleus; M is the proton mass; ω_{el}^+ means that the bottom boundary of the integration domain is the energy transferred that corresponds to elastic scattering of the electron from the nucleus. But the integral does not include the elastic scattering form factor.

Usually the R_L-function moment with $n = 0$ is obtained from the measurements of RF. It is named Coulomb Sum (CS) and denoted as $S_L(q)$.

The investigation of the CS isotopic differences of ^{6}Li and ^{7}Li nuclei was the original aim of our measurements. However, as the result of the processing of only part of the experimental data, the interesting features of ^{7}Li CS values were discovered. The present paper deals with these CS features.

2. EXPERIMENTAL DATA

The spectra of electrons scattered by ^{7}Li nuclei were obtained at the linear accelerator LUE-300 of NSC KIPT at initial energy $E_0 = 129$ to $259\ MeV$ and scattering angles $\theta = 60°30'$ to $94°10'$, $\theta = 160°$. The range of the measurements of the 3-momenta and energies transferred to nuclues are shown in Fig.1.

The experimental equipment and the measurement method have been described in refs. [3, 4]. The data processing and the error analysis were performed as in refs. [4, 5]. In regard to the last we note that this question has been given some consideration in the paper, because the errors of the experimental RF and, consequently, the errors of CS significantly depend on the systematical errors of the absolutization of the measured cross sections. Then, before and after the measuring of each spectrum of electrons scattered by ^{7}Li, the measurements of the ^{12}C ground state form factor were carried out. The absolutization of the measured ^{7}Li(e, e') cross sections was performed

*Corresponding author. E-mail address: abuki@ukr.net.ua

through the comparison of these data and the particularly precise values of ^{12}C form factor from ref. [6]. At the same time the correction obtained in ref. [7] was applied to data of ref. [6]. As additional verification the comparison of the measured during the experiment ^{7}Li ground state form factor and its magnitude from ref. [8] was done.

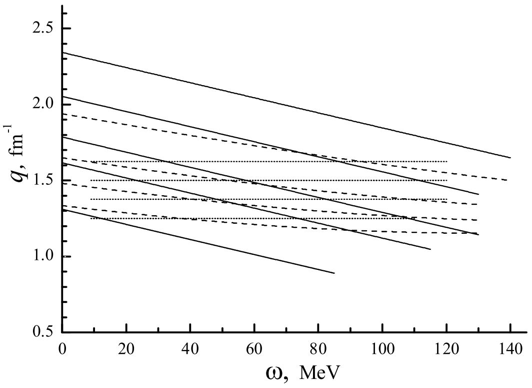


Fig.1. *The transferred 3-momenta and energies of the electron scattered spectra. The solid lines label the measured at $\theta = 160°$ spectra, the dashed lines show the measurements at $\theta = 60°30'$ to $94°10'$, the dotted lines are the constant values of the transferred 3-momenta, at which the RF are obtained*

As a result of the data processing through the usage of eq. 1, the $R_{T/L}$-function values for ^{7}Li nucleus at $q = 1.250 \ldots 1.625\, fm^{-1}$ were obtained. For instance, RF at $q = 1.375\, fm^{-1}$ is present in Fig.2. It is evident from Fig. 2 that to determine experimentally CS, it is essential that RF should be integrated to $\omega = \infty$. For this purpose RF were extrapolated by the function $R \propto \omega^{-\alpha}$ (see refs. [9, 10]) to the region where the measurements are impossible. The value $\alpha = 2.45 \pm 0.15$ of the ^{7}Li longitudinal RF was found by the method of ref. [11]. The obtained in such a way CS values are shown in Fig. 3. The shown in the figure errors are statistical.

First of all the characteristic feature of these data is that the average value of ^{7}Li $S_L(q)$ is equal to $1.018 \pm 0.025 \pm 0.029$ (the first error is statistical, and the second is systematical) at the transferred 3-momenta region $q = 1.375 \ldots 1.625\, fm^{-1}$, while for nuclei with $Z > 1$ $S_L(q)$ it is less than 0.8 at $q = 1.5\, fm^{-1}$ (see, for instance, ref. [12]). To consider this phenomenon it is necessary to make sure of its validity. In this connection we note the following:

- At the same time, when the electron scattered by ^{7}Li spectra were measured, we carried out the measurements of ^{4}He(e, e') spectra. The obtained from these data CS of ^{4}He were in good agrement both with experimental Bates and Saclay data, and with theoretical calculations (see ref. [5]). Consequently it seems to be improbable that the gross error is present in ^{7}Li data.

- Simultaneous with ^{7}Li the measurements of ^{6}Li(e, e') spectra were carried out. From general considerations the CS of lithium isotopes should not differ significantly. In spite of the fact, that not all ^{6}Li data have been processed, some estimations of ^{6}Li CS may be done. At $q = 1.25\, fm^{-1}$ this estimation showed that the CS values of the lithium isotopes are close (see Fig. 4).

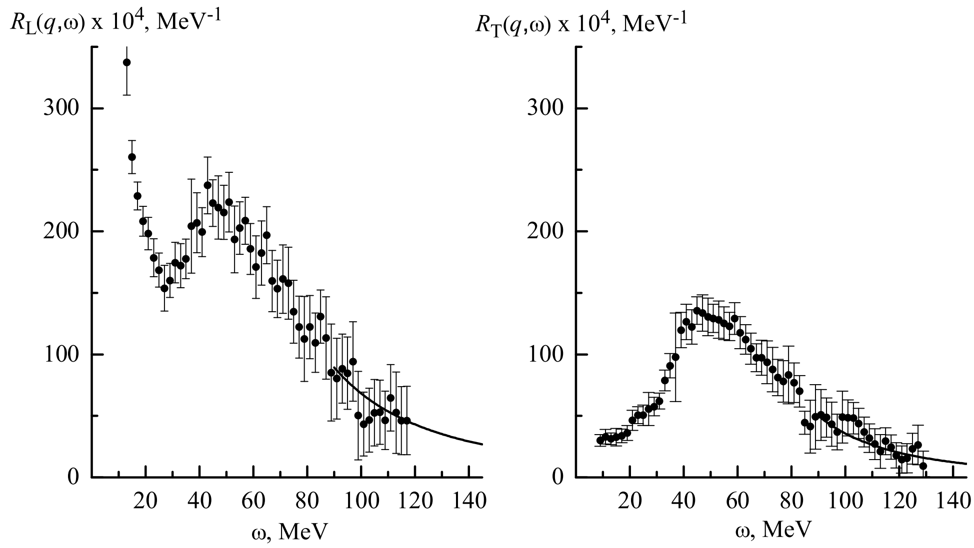
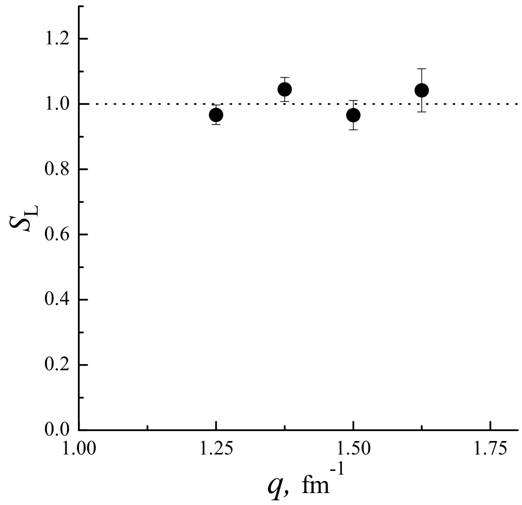


Fig.2. *The longitudinal and transverse ^{7}Li response functions at $q = 1.375\ fm^{-1}$. The solid lines show the extrapolations of RF (see the text)*



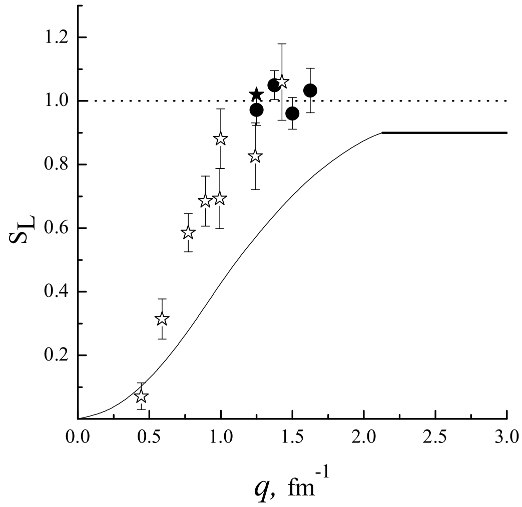


Fig.3. *The ^7Li Coulomb Sums obtained in the present paper*

Fig.4. *The comparison of Coulomb sums of ^7Li, ^6Li and ^4He nuclei. The CS values of ^7Li are labeled as full circles, open stars show ^6Li CS from ref. [13], full star shows the ^6Li CS value which is obtained from the data measured simultaneously with ^7Li data. The solid line shows the ^4He data approximation: at $q < 2\ fm^{-1}$ the calculations of works [14] and [15] are in good agrement with each other; at $q \geq 2\ fm^{-1}$ straight line shows the approximation of the CS values obtained in Bates and Saclay labs [13]*

- Before the measurements with ^{6}Li and ^{7}Li we had carried out the first measurements with ^{6}Li [13]. The ^{6}Li CS from ref. [13] are denoted as $\sigma_l(q)$ and in the term of $\sigma_l(q)$ the modern determination of CS can be written as $S_L(q) = \sigma_l(q)/G^2(q^2)$. ^{6}Li CS values from ref. [13] transformed in the same way are shown in Fig.4[1].

It is evident from Fig. 4 that all available data for lithium isotopes CS data are agree with each other. It is the basis to consider the reliability of the obtained ^{7}Li CS values as sufficiently authorized.

3. DISCUSSION AND CONCLUSIONS

The $S_L(q)$ dependence shapes for $A > 2$ nuclei (with the exception of the lithium isotopes) are similar with each other: at transferred 3-momentum region $q = 0 ... 2\ fm^{-1}$ the smooth rise with the increasing q is observed, and at $q \geq 2\ fm^{-1}$ $S_L(q)$ it is equal to constant value (plateau is obtained). Let us denote $S_L(q)$ in the plateau region as $S_{L,max}$. The value $S_{L,max}$ is equal to 1.0 for $A \leq 3$ nuclei [16, 17]. In the case of all investigated in Bates and Saclay nuclei $A \geq 4$ the $S_{L,max}$ values decrease with the increase of atomic number: from 0.9 ± 0.03 for ^{4}He to $0.5 ... 0.6$ for ^{208}Pb (the effect of the Sum rule quenching)[2]. As an illustration the straight line approximation of the experimental CS values of ^{4}He is showed in Fig. 4.

As it is seen from Fig.4 the $S_L(q)$ dependencies of lithium isotopes and ^{4}He ones differ from each other and, as was mentioned, from other nuclei. Let us discuss the following features of lithium nuclei CS value.

- The $S_L(q)$ dependence is equal to constant value already at $q = 1.25\ fm^{-1}$, but in the case of other nuclei the it is equal to constant value only at $q \approx 2\ fm^{-1}$. This phenomenon is probably explained by the fact that lithium isotopes are very cauterized, while there are investigations of noclustered nuclei only in the systematic of $S_L(q)$.[3]
- Reasoning from the observed tendency of the $S_{L,max}$ decreasing with the growth of atomic number, in the case of lithium isotopes the $S_{L,max} \leq 0.9$ could be expected, but $S_{L,max} = 1.0$ was obtained. On the other hand the sum rule quenching ($S_{L,max} < 1.0$) can be explained by the nucleon modification inside the nuclear matter which have the density bigger than some

[1]It is necessary to say, that the characteristic features of ^{7}Li CS values discussed here may be observed in the ^{6}Li CS values also. However, in 1977, when ref. [13] was published, the obtained ^{6}Li CS values were nothing to compare with. At that time the systematical data of CS values for the various nuclei were absent. The systematics appeared as a result of Bates and Saclay works only after 1979.

[2]Notice, that the attempt to solve the problem of the Sum rule quenching via introduction the corrections into the experimental data was made in ref. [18]. Thus in this work the $S_{L,max}$ values of ^{12}C, ^{40}Ca and ^{56}Fe nuclei were observed to be closed 1, we think that work [18] is mistaken. The same conclusion was made by authors of ref. [19].

[3]Using the results of the measurements of the ^{6}Li $S_L(q)$ the clusterization parameter of this nucleus was obtained in ref. [13] and its value was agreed with the result using the $(e, e'\alpha)$ measurement data from ref. [20]. If in the case of lithium the $S_L(q)$ dependence plateau begins at $q = 2\ fm^{-1}$, the clusterization should be absente, as can be concluded from V.D. Efros calculation [13].

critical value (see, for instance, ref. [21]). Following this hypothesis, let us view the relation between $S_{L,max}$ and the nuclear matter density in the nucleus center (ρ_0). For $A \leq 3$ nuclei $S_{L,max}$ is equaled 1.0 and $\rho_0 < 0.15$ nucleon/fm^3 and for the investigated $A \geq 4$ nuclei (besides ^{6,7}Li nuclei) $S_{L,max}$ is less than 1.0 and $\rho_0 > 0.15$ nucleon/fm^3. In case of ^{6,7}Li $S_{L,max}$ is equal 1.0 and $\rho_0 < 0.15$ nucleon/fm^3 similarly to $A \leq 3$ nuclei (though the atomic numbers of these nuclei are bigger than one of ^{4}He).

Thus the obtained lithium isotope $S_L(q)$ values may be considered as reason of the nucleon modification inside the nucleus matter.

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КУЛОНОВСКИЕ СУММЫ ЯДРА ^{7}Li ПРИ ПЕРЕДАННЫХ 3-ИМПУЛЬСАХ $q = 1,250 - 1,625$ фм$^{-1}$

А.Ю. Буки, Н.Г. Шевченко, И.С. Тимченко

В настоящей работе получены экспериментальные функции отклика ядра ^{7}Li при эффективных переданных 3-импульсах $q = 1,250; 1,375; 1,500$ и $1,625$ фм$^{-1}$. Данные по продольной функции отклика использованы для определения значений кулоновской суммы. Для анализа этих данных были применены значения кулоновской суммы ^{6}Li, полученные нами раннее. Кулоновские суммы изотопов лития сравнивались с известными значениями этой величины других ядер.

КУЛОНІВСЬКІ СУМИ ЯДРА ^{7}Li ПРИ ПЕРЕДАННИХ 3-ІМПУЛЬСАХ $q = 1,250 - 1,625$ фм$^{-1}$

О.Ю. Буки, М.Г. Шевченко, І.С. Тімченко

В роботі отримано експериментальні функції відгуку ядра ^{7}Li при еффективних переданних 3-імпульсах $q = 1,250; 1,375; 1,500$ та $1,625$ фм$^{-1}$. Продольні функції відгуку були використані для обчислення значень кулонівської суми. Для аналізу цих даних залучені значення кулонівських сум ядра ^{6}Li, які були отримані нами раніше. Кулонівські суми ізотопів литію були порівняні з відомими значеннями цієї величини інших ядер.