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A Review on Study Short-Range Correlations and the Isospin Dependence

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مراجعة لدراسة الارتباطات قصيرة المدى واعتماد اللف المتساوي

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ABSTRACT

High-energy electron scattering can be considered a crucial tool for interpreting the function of high-momentum nucleons (and quarks) in nuclei and offers a clean, accurate probing for investigations of hadronic and nuclear organization. The intense repulsion of nuclear contact at small distances is the source of short-range interactions in nuclei and nuclear matter. These connections have been verified in several nuclear tests using hadronic and electroweak probes.

Improved knowledge of the underlying structure of these high-momentum and short-range arrangements in nuclei will be crucial for a variety of high-energy observables. The short-range correlations also appear to be associated with changes in the quark distributions in nuclei. Over the past ten years, there has been a significant concentration on both theoretical and experimental efforts aimed at characterizing short-range correlations, namely their isospin dependence.

In this review, it will employ a theoretical framework rooted in many-body Green's functions theory. Specifically, review focus on the one-body momentum distributions as a fundamental variable. The objective is to provide a concise overview of the latest research findings in the field.

Keywords: Electron scattering; nuclear structure; short range correlation; Isospin; Nuclear structure functions.

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INTRODUCTION

Several models have been developed that accurately describe the microscopic interactions between two nucleons, which successfully explain the nature of the deuteron and the scattering characteristics [1]. While the fundamental physics components of these models vary, they also have some things in common. The common features of these entities encompass a tensor element, which may accurately explain the deuteron quadrupole moment [2] and many aspects of light nuclei [3]. Additionally, they possess a repulsive core at small distances that elucidates the powerful energy reliance observed in single- channel scattering phase-shifts.

The formal definition of Short-Range Correlations (SRCs) is the first issue that arises when thinking about them theoretically or empirically. The majority of theoretical work often defines correlations in regard to a reference state that serves as a starting point and an "uncorrelated state," which presents a condensed picture of the many-body problem. Accordingly, actions that deviate from the reference image1 can be described as correlations". Since there isn't an equivalent of a "reference" baseline condition in trials, the challenge of detecting associated states or areas is significantly more challenging. To find regimes, observables, and analysis approaches that can accurately quantify SRCs, experiments hence require theoretical direction [4, 5].

Since they offer a way to summarize intricate many-body dynamics, correlation functions are an invaluable tool for characterizing interacting many-body systems. The probability density of what is considered a many-body, such as the one derived from a many-body quantum mechanical wave-function, can be represented as a combination of single-particle probability densities that have been anti-symmetrized to account for the absence of correlations. Significant departures from this image are described by the correlation function. In nuclear physics, correlation functions are often employed for recent reviews [6,7].

The nucleus is a high-density, strongly interacting many-body quantum mechanical system with intricate interactions between its constituent nucleons. There must be connections, as there is no fundamental core potential. The correlation functions play an essential part in various recent examples, such as the computations of neutrinoless double beta decay [8], nuclear transparency during quasielastic scattering [9], shadowing in deeply inelastic scattering [20], and parity violations in nuclei [10]. Although correlation functions are widely used, less research has been done on their spin and isospin dependence.

Both spin and isospin dependences of the nucleon–nucleon interaction become highly significant at short ranges, giving rise to phenomena like the strong preference for proton–neutron short-range correlated couples [11]. The impact of fragmentation on the observations of single-particle orbitals in nuclear research can be approximately characterized by the momentum distribution n(k) [10]. Recent scattered electron experiments have focused on understanding the isospin dependency of short-range correlations by studying nucleon knock-out on nuclei with non-zero isospin asymmetry ($\eta \neq 0$).

Significant impacts have been observed in both the minority protons and majority neutrons in neutron-rich nuclear systems, according to data examined by Continuous Electron Beam Accelerator Facility, Large Acceptance Spectrometer (CLAS) collaboration [12]. The numerous static features of nuclei are well described by current mean-field nuclear theories, but they are unable to explain the dynamic impacts of SRCs. Currently, calculations utilizing the ab-initio many-body concept [13] are restricted to light nuclei and/or soft contact that

govern the high-momentum, short-range aspects of nuclear wave function. Effective theories are necessary to identify the fundamental physical process at close distances and to characterizing medium and heavy nuclei. Considerable advancements have been achieved in the characterization of (SRCs) in low-density Fermi systems over the past decade. The system's description can be modelled using a contact theory when the interaction range r_0 is considerably smaller than the mean distance between particles d, and the scattering length as.

Several correlations between several observables and the probability of detecting a nearby pair of particles become evident. For ultracold Fermi gases, the contact theory was thoroughly investigated theoretically and confirmed empirically [14, 15]. It has been demonstrated that numerous other characteristics of the atomic system are connected to a single parameter, known as the contact, which describes the likelihood of finding two atoms near one another. Recently, the contact formalism was extended to nuclear systems.

Following their definition, the nuclear contacts were demonstrated to be connected to a wide range of nuclear quantities, including the Coulomb sum rule, the two-nucleon density [16], high momentum tails, the Levinger constant, and electron scattering experiments. The results of experiments drive the field of SRCs in nuclear physics. Early on in the discipline, electron scattering experiments played a pivotal role in characterizing the development of single-particle strength with mass number [17, 18].

All of nuclear physics is saturated with SRCs. The resulting uncertainties have a direct impact on various fields; hence efforts to characterize the features of SRCs quantitatively are crucial. Furthermore, SRCs are connected to fundamental physics phenomena like the European Muon Collaboration (EMC) effect and have the potential to influence the comprehension of high-energy proton-ion and heavy-ion reactions. Due to their reliance on the chosen scale and computing method that is involved in building theoretical models, it is difficult to separate and analyze their effects in isolation [19].

In the coming years, one of the challenges facing nuclear theory will be to sort through its significance in experimental evidence. We will display some of the result of authors in table (1).

Table 1. A previous literature review of short- range correlation and isospin dependence.

Authors	Technique used	Nuclei	Result
20	The scattering of electrons	^{20}Ne ,^{22}Ne	Over a limited range of momentum transfer the study of 20Ne has been extended to excited states up to 8 MeV. A phase shift code has been used to extract the ground state transition probabilities of the states observed.
21	Used the NN-SRC model	^{12}C	Discovered that when a proton with initial momentum between 275–550 MeV/c is removed from the nucleus, a correlated neutron is emitted with momentum roughly equal and opposite. This suggests

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			that the probabilities of pp or nn short-range correlations in the nucleus are at least six times smaller than that of pn correlations.
22	Utilized a linked and number-conserving cluster expansion method with correlated wave functions	^{40}Ca,^{16} O , ^{12}C	Tensor correlations dominate high-momentum distributions, Proton-neutron pairs are more prevalent than proton-proton pairs at moderate momenta, and the tensor force has a notable impact on the probabilities of correlated proton-neutron and proton-proton pairs in these nuclei.
23	core-polarization transition charge density	^{20}Ne ^{2}4Mg, ^{28}Si, ^{32}S	the core polarization affects which represent the collective modes are essential in obtaining a remarkable agreement between the calculated inelastic longitudinal F(q)'s and those of experimental data.
24	VMC numerical data	^{4}He,^{6}He, ^{8}He, ^{6}Li, ^{10}B, ^{8}Be	It has been established a connection between these two momentum distributions, highlighting the substantial influence of short-range correlations (SRCs) on the high-momentum region of a single nucleon.
25	core-polarization transition charge density	^{19}F and ^{27}Al	the core polarization affects which represent the collective modes are essential in obtaining a remarkable agreement between the calculated inelastic longitudinal F (q)'s and those of experimental data for all considered nuclei.
26	Combination of experimental measurement and simulations to investigate three nucleon short range correlation in light nuclei	^{2}H, ^{3}He, ^{4}He , ^{12}C	The ^{4}He/^{3}He cross section ratio, which includes all particles, is found to be unaffected by both x and Q2 within the range of 1.5 < x < 2. This observation confirms that two-nucleon short-range correlations are the dominant factor. Based on our findings, it is evident that for values of x greater than 2, the hypothesis stating that

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			three-nucleon correlation dominance was a result of poor measurement resolution is supported. Although 3N-SRCs seem to play a substantial role, our data indicate that isolating 3N-SRCs is considerably more complex compared to isolating 2N-SRCs.
27	Straightforward model that incorporates the behavior of both short and long separation distances by utilizing a singular mixing function.	$Ca,^{16}O^{40}$	Presented a method that allows for the prediction of two-body densities and correlation functions for nuclei that are too big to be accurately calculated using ab initio methods was presented
28	Factored asymptotic wave-functions and nuclear contact theory are being discussed.	^{4}He, ^{6}Li, ^{7}Li, ^{8}Be, ^{9}Be, ^{10}B, ^{12}C. ^{16}O, ^{40}Ca	The relationship that links high-momentum with short-range dynamics in nuclear systems is equivalent. The results obtained from the experimental extraction of the contacts are also similar. The contact values provide a thorough examination of the spin-isospin quantum properties of (SRC) pairs, and also demonstrate the absence of a combinatorial relationship between isospin and spin in SRCs.
29	Nuclear contact formalism	He , $^{12}C^{4}$	Good agreement between the theoretical predictions based on the nuclear contact formalism and the experimental data for the ratio of proton-proton pairs to proton-neutron pairs in ^{4}He. However, some discrepancies were observed for in the ratio of proton-proton pairs to the total knocked-out protons in ^{12}C.
30	Glauber- based calculations	^{12}C, ^{27}Al, ^{56}Fe, ^{208}Pb	It has been detected that the prevalence of proton-neutron short-

			range correlations in heavy atomic nuclei by directly measuring the ratios of short-range correlated pairs between protons (pp) and between neutrons and protons (np). The results demonstrated a decreased ratio of pp to np pairs in comparison to prior measurements. The discoveries offer vital insights into the nuclear structure and interactions within heavy nuclei.
31	Low-Order Correlation Operator Approximation (LCA)	^{4}He,^{12}C,^{16}O, ^{27}Al,^{40}Ar,^{40}Ca,^{48}Ca,^{56}Fe,^{84}Kr ^{106}Ag,^{124}Xe,^{142}Nd,^{184}W,^{208}Pb	Evidence demonstrates that the the lowest-order correlation operator approximation (LCA) can accurately explain the patterns observed in the data. For instance, it accounts for the phenomenon where in nuclei with an excess of neutrons, the protons contribute significantly to the presence of high-momentum components, contrary to expectations. .
32	Utilizing the nuclear contact formalism to establish a direct relation between the charge density of nuclei and the properties of nuclear (SRCs)	Ca^{40}	The study effectively established a direct connection between the charge density of nuclei and the characteristics of nuclear Short-Range Correlations (SRCs) through the utilization of nuclear contact formalism.
33	Real Photon Beams at GlueX	^{12}C, ^{27}Al, ^{63}Cu and ^{197}Au, ^{4}He, ^{12}C, ^{27}Al, ^{56}Fe , ^{208}Pb	The proposed experiment will thoroughly investigate the phenomenon of np dominance, the short-distance N-N interaction, and reaction theory. Furthermore, it will provide novel insights into the structure of bound nucleons and the beginning of color transparency.
34	The lowest-order correlation operator	^{12}C, ^{40}Ca , ^{48}Ca	It would be interesting to investigate whether a model that

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	approximation (LCA) to include SRC		well captures both long-range and short-range correlations leads to substantial modifications in the nuclear radii. .
35	The impact of isospin symmetric in nuclear systems on two-body distributions.	Li,^{6} Be,^{6}He,^{7}B,^{7} Be,^{10}Be^{6}	Isospin symmetry enables the extraction of information regarding the spectator nucleons during the development of a short-range correlated pair.
36	Two-body functions and corresponding contact parameters.	H^{2}	It provides a systematic framework for the analysis of large momentum transfer electron scattering experiments, focused on SRC physics, and connects them to low-energy nuclear physics studies.
37	Auxiliary-_eld diusion Monte Carlo method.	^{3}He, ^{4}He, ^{6}Li , ^{16}O	The results are examined using the Generalized Contact Formalism, which has been expanded to incorporate three-body correlations. This analysis uncovers the universal characteristics of nucleon triplets at close proximity.

CONCLUSION

Theoretical and experimental techniques play a complementary position inside the look at short-range correlations (SRCs) within the nucleus. Theoretical tactics, consisting of numerical and atomic shape modeling, provide a framework for information on the underlying physics concepts governing SRC. These theoretical techniques help to signify SRC conduct, their isospin kinetic shape and the importance of atoms in communique.

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Conflict of interests.

There is no conflict interest

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خلاصة

يمكن اعتبار تشتت الإلكترونات عالية الطاقة أداة حاسمة لتفسير وظيفة النيوكليونات عالية الزخم (والكواركات) في النوى، ويوفر اختبارًا نظيفًا ودقيقًا للتحقيقات في التنظيم الهادروني والنووي. إن التنافر الشديد للتلامس النووي على مسافات صغيرة هو مصدر التفاعلات قصيرة المدى في النوى والمادة النووية. وقد تم التحقق من هذه الروابط في العديد من التجارب النووية باستخدام مجسات الهادرونات والكهروضعيفة.

إن تحسين المعرفة بالبنية الأساسية لهذه الترتيبات ذات الزخم العالي والقصيرة المدى في النوى سيكون أمرًا بالغ الأهمية لمجموعة متنوعة من العناصر القابلة للرصد عالية الطاقة. يبدو أيضًا أن الارتباطات قصيرة المدى مرتبطة بالتغيرات في توزيعات الكواركات في النوى. على مدى السنوات العشر الماضية، كان هناك تركيز كبير على كل من الجهود النظرية والتجريبية الرامية إلى توصيف الارتباطات قصيرة المدى، أي اعتمادها على اللف المتساوي. في هذه المراجعة، سيتم استخدام إطار نظري متجذر في نظرية وظائف الجسم المتعدد لجرين. على وجه التحديد، تركز المراجعة على توزيعات الزخم لجسم واحد كمتغير أساسي. الهدف هو تقديم لمحة موجزة عن أحدث نتائج البحوث في هذا المجال.

الكلمات الرئيسية: تشتت الإلكترون. البنية النووية الارتباط قصير المدى؛ إيسوسبين. وظائف البنية النووية.

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