LNF–89/066

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Estratto da: Nuovo Cimento 101A, n. 6(1989)

IL NUOVO CIMENTO VOL. 101 A, N. 6 Giugno 1989
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A Simple Description of Nucleon High-Momentum Components Due to Short-Range Correlations in Nuclei.

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(ricevuto il 29 Marzo 1989)

Summary. — Effects of short-range correlations are included in nuclear momentum distribution also using a simple method suitable for high mass number nuclei.

PACS 21.10 – General and average properties of nuclei; properties of nuclei; properties of nuclear energy levels.
PACS 21.30 – Nuclear forces.
PACS 13.75.Cs – Nucleon-nucleon interactions, including antinucleon, deuteron, etc. (energy ≤ 10 GeV).

Many nuclear reactions (*e.g.*, pion absorption, quasi-elastic electron scattering, nuclear photo-effect (1)) are very sensitive to high-momentum components of the nucleon momentum distribution. The high-momentum tail results from the short-range part of the nucleon-nucleon interaction which introduces short-range correlations (SRC) in the motion of nucleons and raises nucleons above the Fermi sea. Several methods have been developed to include

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(1) A. N. ANTONOV, P. E. HODGSON and I. ZH. PETKOV: in *Nucleon Momentum and Density Distributions in Nuclei* (Oxford University Press, Oxford, 1988).

the effects of SRC in momentum distribution (2-5). However these methods turn out to be prohibitively complicated for all but the lightest nuclei. It would be therefore very desirable to have a procedure which enables the momentum distribution, with proper high-momentum components, to be easily calculated for all nuclei.

In a recent study (6) of nuclear momentum distribution $n(k)$ we have considered its integral representation

$$n(k) = (2\pi)^{-3} \int_0^{\alpha/k} \mathrm{d}x\, W_n(x)(4/3)\pi x^3 , \tag{1}$$

$W_n(x)$ being a weighting function of uniform momentum distributions in spheres of radii x.

From the normalization condition

$$\int_0^\infty \mathrm{d}x\, W_n(x) = 4\pi \int_0^\infty \mathrm{d}k\, k^2 n(k) , \tag{2}$$

one finds $\alpha = (9\pi/2)^{1/3}$.

The numerical analysis of the weighting functions $W_n(x)$ for various nuclear models (6) has revealed a clear-cut effect of short-range correlations. The function $W_n(x)$ shows two peaks if the nucleon are correlated but only one if they are not correlated. In the former case, one broad peak is associated with the Fermi momentum and does not vary from one nucleus to another. The other narrow peak, at a smaller value of x, is attributable to the correlations which produce high-momentum components in the nucleon momentum distribution. Motivated by these results we investigate here a possible additivity of weighting factors $W_n(x)$ corresponding to long- and short-range correlations in nuclei:

$$W_n(x) = (1 - \varepsilon_\mathrm{S}) W_\mathrm{L}(x) + \varepsilon_\mathrm{S} W_\mathrm{S}(x) , \tag{3}$$

proposing $W_\mathrm{S}(x)$ in the Gaussian form:

$$W_\mathrm{S}(x) = \pi^{-1/2} \gamma_\mathrm{S}^{-1} \exp\left[-\left(\frac{x - x_\mathrm{S}}{\gamma_\mathrm{S}}\right)^2\right], \tag{4}$$

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(2) A. MAŁECKI and P. PICCHI: *Riv. Nuovo Cimento*, 2, 119 (1969); *Lett. Nuovo Cimento*, 8, 16 (1973).
(3) O. BOHIGAS and S. STRINGARI: *Phys. Lett. B*, **95**, 9 (1980).
(4) J. G. ZABOLITZKY and W. EY: *Phys. Lett. B*, **76**, 527 (1978).
(5) J. W. VAN ORDEN, W. TRUEX and M. K. BANERJEE: *Phys. Rev. C*, **21**, 2628 (1980).
(6) A. MAŁECKI, A. N. ANTONOV, I. ZH. PETKOV and P. E. HODGSON: *Z. Phys. A*, 328, 393 (1987).

with the parameters x_S and γ_S describing the position and width of the peak associated with SRC. The parameter ε_S measures the relative presence of short-range correlations in the nucleus. We do not need to specify $W_L(x)$ since the long-range part of the momentum distribution, corresponding to the first term in (3), may be taken from the single-particle model:

$$n_L(k) = (4\pi)^{-1} \sum_{nlj} (2j+1) N_{nlj} |R_{nlj}(k)|^2 , \tag{5}$$

$R_{nlj}(k)$ being the radial wave functions in the momentum space and N_{nlj} appropriate occupation numbers of single-particle states.

We have checked our conjecture (3), (4) in the case of ^{4}He and ^{16}O nuclei using the single-particle model with harmonic-oscillator wave functions. The short-range part of momentum distribution, corresponding to the second term in (3), has been fitted to the results of Małecki and Picchi (2) obtained in the Jastrow correlation model. The parameter ε_S was allowed to change from one nucleus to another. In such a way we have obtained the parameters of the short-range peak $W_S(x)$: $x_S = 0.69$ fm, $\gamma_S = 0.15$ fm. The strength of SRC is $\varepsilon_S = 0.070$ for ^{4}He and $\varepsilon_S = 0.095$ for ^{16}O. The fit for ^{16}O is presented in fig. 1, where we compare the momentum distributions obtained from the Jastrow correlation model (2) with that resulting from eqs. (1)-(4).

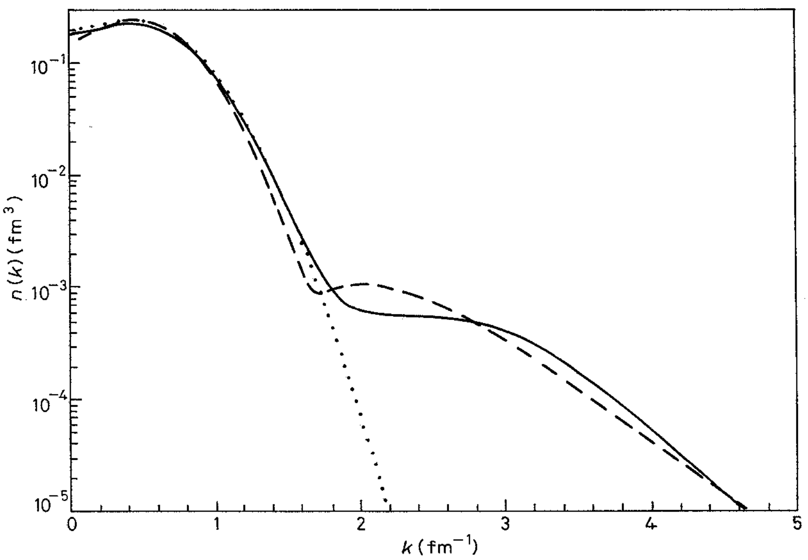

Fig. 1. – Momentum distribution of ^{16}O calculated with the present method (solid line) and from the Jastrow correlation model on Małecki and Picchi (2) (dashed line). The dotted line corresponds to the single-particle model with the harmonic-oscillator energy spacing 118.8 MeV (2).

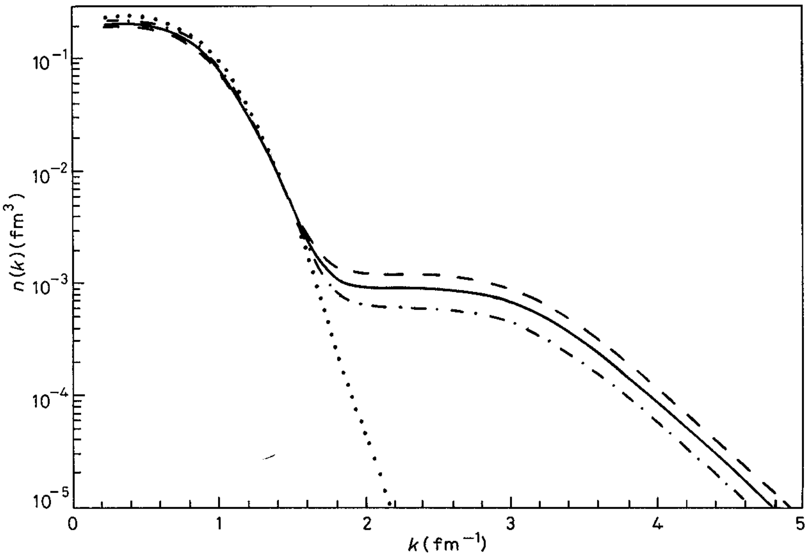

Fig. 2. – Momentum distribution of ^{40}Ca calculated with the present method for three values of the correlation strength: $\varepsilon_S = 0.10$ (dot-dashed line), 0.15 (solid line), 0.20 (dashed line). The dotted line corresponds to the single-particle potential method (7).

Encouraged by the success of our simple parametrization (3), (4) in the case of light nuclei we have also calculated the momentum distribution for ^{40}Ca nucleus using the single-particle potential method (7) for the long-range part and the parametrization (3), (4) to account for short-range correlations. The results are presented in fig. 2 for three values of the correlation strength ε_S. It is evident that the high-momentum tail is reproduced very reasonably.

At present we do not know how the parameter ε_S varies with the mass number A. We expect it should grow with A because of increasing number correlated pairs. Alternatively one may treat ε_S as a convenient parameter measuring the relative effect of short-range correlations in a given nucleus. It could be determined by calculating observables like (e, e′, p) cross-sections and then fitting them to experimental results.

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One of us (AM) would like to thank Prof. L. Satta for the hospitality extended to him at the Laboratori Nazionali di Frascati dell'INFN.

(7) F. MALAGUTI, A. UGUZZONI, E. VERONDINI and P. E. HODGSON: *Nuovo Cimento*, **49**, 412 (1979); *Riv. Nuovo Cimento*, **5**, 1 (1982).

INDICI DEL VOLUME 101 A - SERIE 11 - 1989