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# “NUCLEUS-2019”
# ON NUCLEAR SPECTROSCOPY AND NUCLEAR STRUCTURE

## “Fundamental Problems of Nuclear Physics, Nuclei at Borders of Nucleon Stability, High Technologies”

*Dedicated to the International Year of the Periodic Table of Chemical Elements*

Dubna, Russia, 1–5 July 2019

**BOOK OF ABSTRACTS**

Edited by *V. V. Samarin* and *M. A. Naumenko*

**Dubna 2019**

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# MECHANISMS OF FORMATION OF MODULATION EFFECTS IN ELASTIC DIFFRACTION SCATTERING OF CHARGED PARTICLES

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One of the methods of experimental detection of a multi-cluster structure is the decomposition of experimental angular distributions of differential cross sections for elastic diffraction scattering into multi-cluster components. Within the framework of the diffraction theory and under the assumption of total absorption inside the sphere of interaction, the authors obtained a decomposition of the total amplitude into several multi-cluster modes [1], and for the first time measurements of nuclear clustering by two direct methods on medium-energy alpha particle beams [2] were performed.

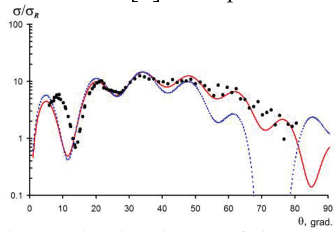


*Fig. 1. The angular distribution of elastic scattering $^{9}Be(\alpha,\alpha)^{9}Be$ $E_{\alpha}=104$ MeV.*

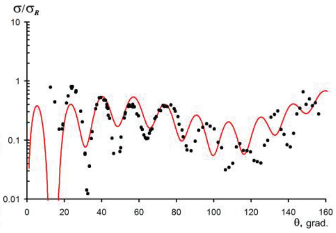


*Fig. 2. The angular distribution of elastic scattering $^{20}Ne(\alpha,\alpha)^{20}Ne$ $E_{\alpha}=33$ MeV.*

This paper describes experimental data in the framework of the theory of diffraction scattering as a superposition of wave functions on an absolutely black core and on absolutely black substructures. Figure 1 shows the fit of the full wave function consisting of two modes (dashed curve) and three modes (solid curve). The first mode is responsible for scattering on the nucleus as a whole, the second on nuclear alpha-clusters, the third on nucleons. It can be seen that for the $^{9}$Be in the forward hemisphere there is a sufficient divergence, since an unpaired neutron makes a significant contribution to the cross section. Figure 2 shows the characteristic lift at the rear angles. The phenomenon of uneven lifting in the angular distributions of differential cross sections and a rise under the rear angles during elastic diffraction scattering of charged particles, obviously, occurs due to the scattering mechanism on cluster configurations without recoil.

1. V.V.Dyachkov, K.S.Dyussebayeva, M.M.Akhmetzhanova Modulation of angular distributions of scattered alpha particles by multicluster nuclei // 68 International Conference "NUCLEUS-2018", Voronezh, 2018. Book of abstracts. P.60.
2. Yu.A.Zaripova, V.V.Dyachkov, A.V.Yushkov, T.K.Zholdybayev, D.K.Gridnev. Direct experimental detection of spatially localized clusters in nuclei on alpha-particle beams // International Journal of Modern Physics E. 2018. V.27 (2). 18500171.

# DEPENDENCE OF DEFORMATION OF EXOTIC NUCLEI FROM THE HALF-LIFE

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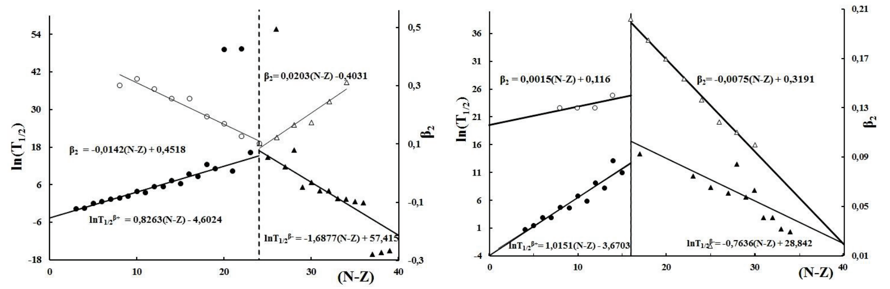
The deformation of nuclei is usually measured by their excitation into lower collective rotational states $2^+$ with the subsequent extraction of nuclear matrix elements. The nuclear quadrupole deformation parameter is uniquely related to these elements $\beta_2$ [1]. However, this method is unsuitable for exotic short-lived nuclei, the inelastic scattering on which is difficult to measure, and for odd nuclei is impossible at all.

The authors of this work managed to find a correlation between the parameter $\beta_2$ and half-life $T_{1/2}$ for oblate nuclei with sign$\beta_2 < 0$ and anti-correlation for elongated nuclei sign$\beta_2 > 0$. As a result analytical expressions for the function $\beta_2(T_{1/2})$ have been obtained. For example, for elongated spheroids

$$\beta_2\left(T_{1/2}^{\beta^+}\right) = -0{,}0109 \cdot lnT_{\frac{1}{2}}{}^{\beta^+} + 0{,}3444, \qquad at \text{ sign}\beta_2 > 0,$$

$$\beta_2\left(T_{1/2}^{\beta^-}\right) = -0{,}008 \cdot lnT_{\frac{1}{2}}{}^{\beta^-} + 0{,}2823, \qquad at \text{ sign}\beta_2 > 0.$$

These relations make it possible to calculate with a high accuracy (from 5 to 10%) the parameters of the shape of the nuclei $\beta_2$, knowing the half-lives $T_{1/2}$ for the exotic nuclei for which this quantity is most accurately measured. Figure 1 shows such calculations for isotopic cerium (Fig. 1a) and tellurium (Fig. 1b) series in comparison with experimental half-life values [2, 3].




a) b)

*Fig. 1. The phenomenon of $\beta_2$ anti-correlation with $T_{1/2}$ for oblate nuclei (a) and $\beta_2$ correlation with $T_{1/2}$ elongated nuclei (b).*

1. A.V.Yushkov // Physics of Elementary particles and Atomic Nuclei. 1993. V.24(2). P.348.
2. N.N.Pavlova *et al.* // IZVESTIYA AKADEMII NAUK SSSR SERIYA FIZICHESKAYA. 1979. V.43. P.2317.
3. Nuclear Structure and decay Data: https://www.nndc.bnl.gov/nudat2/

# NEW METHOD OF EXPERIMENTAL DETECTION AND STUDY OF MULTI-NEUTRONS

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Multi-neutron systems (quasi-nuclei) in a bound state still cannot be found (despite numerous targeted searches) [1]. Meanwhile, by analogy with a biological cell, searches for multi-neutrons packed in original nucleon "membranes" are possible. This idea is also promoted by the well-known EMC effect and, recently discovered by us, the phenomenon of a reduction in the size of clusters relative to their size in the free state (in the light nuclei) [2]. Such a compression is expected to bring the neutron matter into a different phase state, similar to the fact that the neutron in the free state is radioactive, and stable in the volume of the nucleus.

The kinematic effects in the $^4n$, $^4$H, $^4$He, $^4$Li nuclei are experimentally quite detectable (Fig. 1) due to the significant difference in their binding energies ε and masses $m$. Experiments at the U-150m accelerator (Almaty) made it possible to detect clusters with masses $m \leq 4$, but to distinguish, for example, α-clusters from 4$n$-nuclei and heavier multiclusters, heavy ion beams are needed. The kinematics of $^{16}$O + $^4n$, $^{16}$O + $^4$H, $^{16}$O + $^4$Li nuclear reactions (Fig. 1) differs from the usual kinematics by its "loop" character – each reaction in the spectrum is represented not by one, but by two peaks, which is an unequivocal identification feature. Requirements for the angular resolution of a heavy ion spectrometer $\delta\theta = \pm 0.1°$; angle step requirements for measuring the angular distributions of differential cross sections $\Delta\theta = 0.1°$.

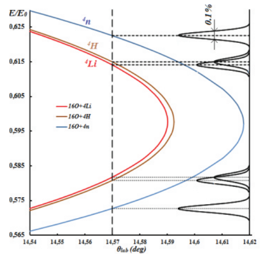


*Fig. 1. Kinematics for the detection of multi-neutron membrane clusters on a beam of heavy $^{16}$O ions.*

From Fig. 1 it is clear that multiclusters with a mass greater than 4 will be experimentally distinguishable from charged clusters.

Such measurements are unique, but quite feasible [3]. Similar to Fig. 1, the calculations performed for isobaric chains $^2n$, $^2$H and $^3n$, $^3$H, $^3$He, $^3$Li also show the feasibility of these experiments in a loop technique [2] on beams of heavy ions.

1. Yu.E.Penionzhkevich, R.G.Kalpakchieva. *Light nuclei at the neutron stability boundary*. – Dubna: JINR, 2016. – 383 p.
2. V.V.Dyachkov *et al.* // International Journal of Modern Physics E. 2018. V.27(2). P.1850017.
3. A.V.Yushkov, N.N.Pavlova // IZVESTIYA AKADEMII NAUK SSSR SERIYA FIZICHESKAYA. 1976. V.40. P.826.

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