Recent advances on proton-neutron pairing and quartet correlations in nuclei

ESNT-Saclay, 10-14 sept 2018

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Opening

Motivation & Main issues

Proton-neutron pairing in nuclei: the beginning

SOVIET PHYSICS JETP VOLUME 11, NUMBER 3 SEPTEMBER, 1960

SUPERFLUIDITY OF LIGHT NUCLEI

V. B. BELYAEV, B. N. ZAKHAR'EV, and V. G. SOLOV'EV

Joint Institute of Nuclear Research

Submitted to JETP editor October 12, 1959

J. Exptl. Theoret. Phys. (U.S.S.R.) **38**, 952-954 (March, 1960)

The physical ideas and the mathematical methods developed in superconductivity theory are applied to a study of the properties of light nuclei. On the basis of the shell model of the nucleus, it is shown that account of the residual interactions of protons and neutrons located near the Fermi surface leads to the appearance of superfluid states. Data on the binding energy of the last neutron in the $22 \leq A \leq 32$ region indicate the presence of paired (pp), (nn), and (np) correlations with the same quantum numbers s and m connected with the superfluidity of light nuclei.

pioneering papers on pn pairing in the BCS/HFB framework

A. Goswami, NPA 60 (1964): T=1 pn pairing

H. Chen and A. Goswami, PL 24 B (1967): T=1 & T=0 pairing

A. Goodman, NPA 186 (1972): most general T=1 & T=0 pairing.

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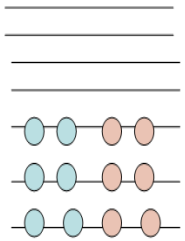
Proton-neutron pairing in nuclei: main issues

S=0, T=1 | **4 types of spin-isospin pn pairs** | **S=1, T=0**

$\nu^+_\uparrow \nu^+_\downarrow$ $\quad$ $\pi^+_\uparrow \pi^+_\downarrow$ $\quad$ $\nu^+_\uparrow \pi^+_\downarrow + \pi^+_\uparrow \nu^+_\downarrow$ $\quad$ $\nu^+_\uparrow \pi^+_\downarrow - \pi^+_\uparrow \nu^+_\downarrow$ $\quad$ $\nu^+_\downarrow \pi^+_\downarrow$ $\quad$ $\nu^+_\uparrow \pi^+_\uparrow$



collective pairs $\quad \Gamma^+_{\pi\nu} = \sum_i x_i (\nu^+_i \pi^+_{\bar{i}} + \pi^+_i \nu^+_{\bar{i}})$ $\quad\quad$ $\Delta^+_0 = \sum_i x_i (\nu^+_i \pi^+_{\bar{i}} - \pi^+_i \nu^+_{\bar{i}})$

"condensates" of pairs $\quad (\Gamma^+_{\nu\pi})^{N_{\pi\nu}/2}$ $\quad\quad$ $(\Delta^+_0)^{N_{\pi\nu}/2}$

Long standing questions

there is a "condensate" of pn pairs in nuclei ?

what is the relation between T=0 and T=0 pn pairing ?

Search for fingerprints of pn pairing

binding energies (e.g., Wigner energy)

excitations (e.g., high-spin, low-lying GT)

proton-neutron transfer reactions

Proton-neutron pairing & alpha-like quartetting

the biginning

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"we must take into consideration the quadruple correlation of alpha-particle-like nucleons in addition to pair correlations; these new correlations evidently play a very important role and somewhat mask the effect of pair correlations"

pioneering studies on pn pairing & alpha correlations

V. G. Soloviev NP18 (1960)

B. Bremond and J. G. Valatin NP41(1963)

B. H. Flowers and M. Vijicic,NPA49(1963)

A. Arima and V. Gillet, Ann. Phys. 66 (1971),

J. Eichler and M. Yamamura, NPA182(1972)

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Volume 34B, number 1 PHYSICS LETTERS 18 January 1971

EVIDENCE FOR QUARTET STRUCTURE IN MEDIUM AND HEAVY NUCLEI

M. DANOS‡ and V. GILLET
Service de Physique Théorique, Centre d Etudes Nucléaires de Saclay, B.P. no 2-91-Gif-sur-Yvette, France

Received 1 November 1970

The second differences of the nuclear masses keeping T constant are discussed for even-even nuclei throughout the mass table. They are shown to be consistent with the quartet picture of weakly interacting tight two-proton two-neutron structures

VOLUME 57, NUMBER 2 PHYSICAL REVIEW LETTERS 14 JULY 1986

Quartet Effects in Rare-Earth Nuclei

H. J. Daley, M. A. Nagarajan, and N. Rowley
Science and Engineering Research Council Daresbury Laboratory, Daresbury, Warrington WA4 4AD, England

D. Morrison
University of Liverpool, Liverpool, England

and

A. D. May
University of Sheffield, Sheffield, England
(Received 5 March 1986)

Quartet effects in deformed rare-earth nuclei are confronted from a phenomenological point of view. Some very simple systematic trends are evident in the experimental data when plotted as a function of a quartet number. The interacting-boson model has been modified to include quartet effects explicitly and it is able to reproduce accurately the experimental trends with fixed parameters.

PACS numbers: 21.10.Re, 21.60.Fw, 23.20.Lv

Proton-neutron pairing and quartet correlations: main issues

- What is the relation between alpha-like quartetting and pn pairing ?

  is quartetting "masking" the pn pairing ?

- How one can disentangle between pn pairing and quartetting ?
- How one can probe the quartet correlations & condensation ?
- Unified treatment of alpha-like correlations and alpha clustering ?

Spin-aligned pairs in nuclei: the beginning

PHYSICAL REVIEW VOLUME 161, NUMBER 4 20 SEPTEMBER 1967

Stretch Scheme, a Shell-Model Description of Deformed Nuclei

MICHAEL DANOS AND VINCENT GILLET
Service de Physique Théorique, Centre d'Etudes Nucléaires de Saclay, Gif-sur-Yvett, Seine et Oise, France
and
National Bureau of Standards, Washington, D. C.
(Received 23 March 1967)

A good angular-momentum wave function containing the maximum possible intrinsic angular momenta leads to a microscopic description of the nuclear rotational spectra in terms of spherical shell-model states. The rotational excitation energies arise from the residual two-body force. In the actual model calculations, the only approximation was a partial violation of the exclusion principle. The computed departures from the $I(I+1)$ law are consistent with experiment. Reasons are given for the preference of positive over negative intrinsic deformations.

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B. Cederwall et al, " Evidence for a spin-aligned neutron-proton paired phase from the level structure of 92Pd", Nature 469 (2011)

Spin-aligned pairs in nuclei : open questions

- How universal they are and what could be their fingerprints ?
- Ground and/or excited states composed mainly by spin-aligned pairs ?

what is the simplest coupling scheme ?

- Competition of spin-aligned pairs with standard J=0 and J=1 pairs ?

can we speak about pairing-type correlations based on J=jmax ?

Monday 10th	Tuesday 11th	Wednesday 12	Thursday 13
*9h30-**10h-10h15*** *Welcome Coffee-**Opening***	10h-10h45 **Sambatoro**	10h-11h **Assié**	10h-11h **Wyss**
10h15-11h15 **Frauendorf**	10h45-11h30 **Cseh**	*11h-11h15* *Coffee Break*	*11h-11h15* *Coffee Break*
11h15-11h30 *Coffee Break*	*11h30-11h45* *Coffee Break*	11h15-12h15 **Vitturi**	11h15-12h15 **Isacker**
11h30-12h30 **Sagawa**	11h45-12h45 **Itagaki**	*12h15-12h45* *Discussions*	*12h15-12h45* *Discussions*
12h30-14h *Lunch break*	*12h45-14h30* *Lunch break*	*12h45-14h30* *Lunch break*	*12h45-14h30* *Lunch break*
14h-14h45 **Sandulescu**	14h30-15h30 **Khan**	14h30-15h15 **Negrea**	14h30-15h15 **Qi**
14h45-15h *Coffee break*	*15h30-15h45* *Coffee break*	*15h15-15h30* *Coffee break*	*15h15-15h30* *Coffee break*
15h-16h ***Discussions***	15h45-16h30 ***Discussions***	15h30-16h15 **Lasseri**	15h30-16h30 ***Summary & Closing***

Talks: we recommend 10-15 minutes to be left for questions & discussions