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

Nicolae Sandulescu*
National Institute of Nuclear Physics and Engineering, Bucharest

Marlene Assie† and Elias Khan‡
IPN Orsay

Michelangelo Sambataro§
INFN Catania

Workshop at *Espace de Structure et de réactions Nucléaires Théorique* (http ://esnt.cea.fr)
CEA Saclay, SPhN, Orme des Merisiers, b. 703, room 135, F-91191 Gif-sur-Yvette

Date : 10 - 14 September 2018

SCIENTIFIC ISSUES

One of the most debated topic in nuclear structure, stimulated by the opportunities offered by the new radioactive beams facilities, is the competition between the isoscalar (T=0) and the isovector (T=1) proton-neutron pairing correlations in nuclei with neutrons and protons in the same open shell. Fingerprints of isoscalar proton-neutron superfluidity are currently investigated in the ground state of self-conjugate nuclei, in the response of nuclei to the rotation and in the proton-neutron transfer reactions (for a recent review, see [1]). On theoretical side, the most common formalism to treat the competition between T=1 and T=0 pairing is the generalized Hartree-Fock-Bogoliubov (HFB) approach (e.g., see [2, 3]). HFB presents the advantage of a simple and unified treatment of both types of pairing correlations. Its main drawback, which can affect significantly its predictions, is the fact that it does not conserve exactly the particle number and the isospin. One solution to this problem is to describe the pairing correlations in terms of bipairs of two neutrons and two protons coupled to total isospin T=0. This 4-body structure is commonly called alpha-like quartet. Various studies have shown that alpha-like quartets are relevant degrees of freedom for treating the T=1 and T=0 pairing forces [5, 6] as well as more general two-body interactions [4, 7, 8].

The aim of this workshop is to address the issues mentioned above from the perspective of the most recent theoretical and experimental studies. Thus, we shall discuss the latest many-body techniques dedicated to proton-neutron pairing and quartetting, focusing on the accuracy of their predictions, tested against exactly solvable models. In addition, we shall discuss the relevance of various methods for analyzing the long range correlations induced by pairing and quartetting, such as Yang criterion [10] based on density matrices. On experimental side, we shall discuss the recent attempts to find the evidence of proton-neutron pairing correlations from proton-neutron transfer reactions [11], from excited spectra of N=Z nuclei and other observables.

Another purpose of the workshop is to discuss the recent studies dedicated to the emergence of alpha-like quartet correlations [7, 8] and clustering [9] in nuclei. In particular, we shall discuss how the alpha-like correlations predicted by recent studies could be probed by alpha-particle transfer reactions.

In summary, the goals of the workshop are :

1. To review the most recent studies dedicated to proton-neutron pairing and quarteting.
2. To analyze the recent experimental results related to proton-neutron pairing.
3. To discuss possible future experiments which can probe the relevance of alpha-like degrees of freedom in nuclei.

*Electronic address: sandulescu@theory.nipne.ro
†Electronic address: assie@ipno.in2p3.fr
‡Electronic address: khan@ipno.in2p3.fr
§Electronic address: michelangelo.sambataro@ct.infn.it

[1] S. Frauendorf and A. O. Macchiavelli, Prog. Part. Nucl. Phys. **78**, 24 (2014).
[2] A. L. Goodman, Phys. Rev. C **60**, 014311 (1999).
[3] A. Gezerlis, G. F. Bertsch, Y. L. Luo, Phys. Rev. Lett. **106**, 252502 (2011).
[4] M. Hasegawa, S. Tazaki, and R. Okamoto, Nucl. Phys. A **592**, 45 (1995).
[5] J. Dobes and S. Pittel, Phys. Rev. C **57**, 688 (1998).
[6] N. Sandulescu, D. Negrea, D. Gambacurta, Phys. Lett. B **751**, 348 (2015).
[7] M. Sambataro and N. Sandulescu, Phys. Rev. Lett. **115**, 112501 (2015).
[8] M. Sambataro and N. Sandulescu, Eur. Phys. J. A **53**, 47 (2017).
[9] J. P. Ebran, E. Khan,T. Niksic, D.Vretenar, Nature **487**, 341 (2012).
[10] C. N. Yang, Rev. Mod. Phys., **34**, 694 (1962).
[11] Y. Ayyad et al, Phys. Rev. C **96**, 021303 (R) (2017).