Data-based research project: double helix level scheme

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The *Nuclear Data Research program* is a development of the regular *Nuclear Structure and Decay Data Evaluation* work at Cyclotron Institute Evaluation Center. As the names indicate, while the latter is by its goals a production work (while by nature is a basic research activity) the former is rather a pure basic research activity of data evaluation. In fact, *the first benefit of this work is an upgraded concept of Level Scheme*, which is of direct interest for the ENSDF data evaluation community but can also be important for the research community at large.

As input, this is *data research* in the sense that it uses published data of high-spin physics, that through a general property of *Repeatability* evidenced in the data – a certain type of granularity of gamma-ray energies – has astonishing effects. That is, when transferred from gammas to levels, this property leads to the unexpected transformation of a conventional scheme of nuclear levels, into a well-defined geometrically correlated object in the form of a *double helix*. That seems to suggest that the high-spin rotational motion of the nucleus can be represented as a *double helix quantum vortex*. Actually, this is a straightforward generalization of the Bohr-Mottelson quantum *I(I+1)* rotor rule to a topological structure of a *parabolic double helix*.

Figure 1 presents the prototypes of the Double Helix Level Scheme for even-A and odd-A nuclei, respectively, with the counterclockwise rotation of the helices chosen arbitrarily. The real rotational bands are superimposed as decay paths on these structures.

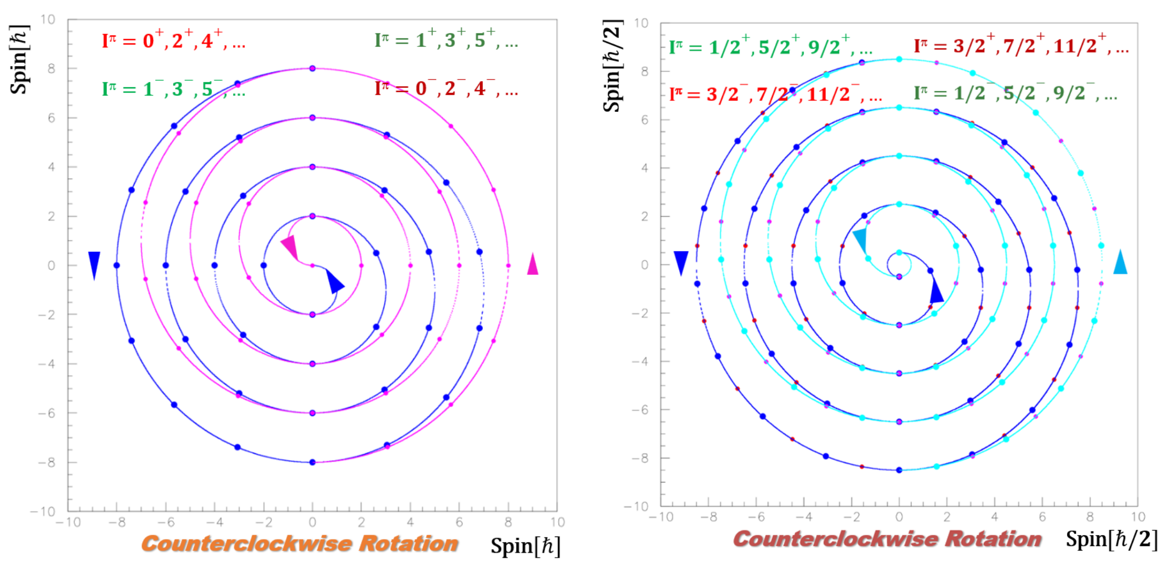

Fig. 1. Double Helix Level Scheme (2D projection view from above of the 3D structure) for even-A nuclei on the left, and for odd-A nuclei on the right part of the figure. The four types of rotational bands shown in the top are represented on the blue (pink) helices for the bands in the left (right) corners for the even-A case, and on the blue (magenta) helices for the odd-A case, respectively.

backbone of the method with the output of several such new double-helix level scheme. Following an intense work started in the last reporting period, in the this one we published an ample article [1] titled "Double Helix Level Scheme of ^{171}Yb Nucleus" (22 pages, 27 figures) with the detailed description of the algorithm for the new type of level scheme.

Figure 2 presents the Double Helix Level Scheme of ^{171}Yb nucleus as a *3D* picture (upper left), and the *2D* projections: *xy* (lower left), *yz* (upper right), and *xz* (lower right). We can observe the precessions (or apparent rotations) of the rotational bands on the double helix structure (the one on the right-hand side of Figure 1) which result from the interplay of macroscopic and microscopic degrees of freedom. The backbending phenomenon is clearly visible as well, as a sudden or more gradual change in the direction of apparent rotations.

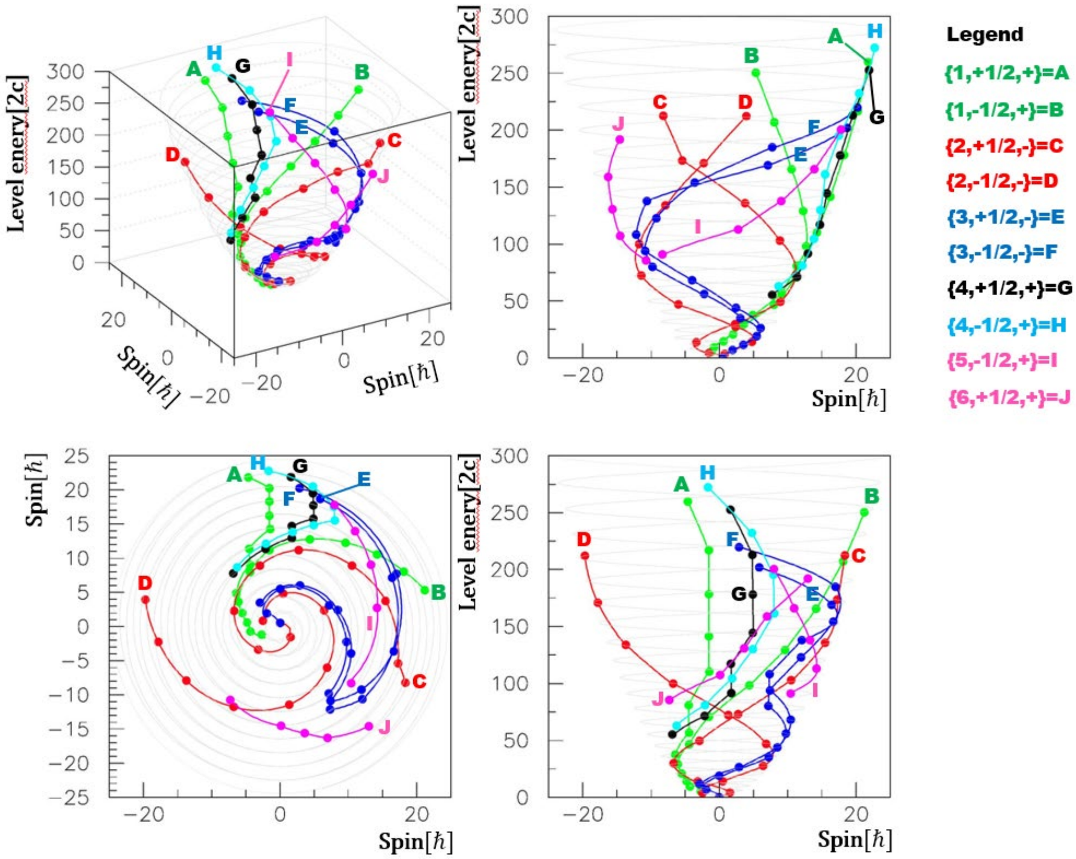

Fig. 2. Double Helix Level Scheme of 171Yb nucleus.

A second article, a proceedings paper [2] retakes this theme shortly, with some extensions on the introduction of *Repeatability*, as well as with the hypothesis that Double Helix could offer an explanation to the ever-intriguing fact of the high spin states populated in the fragments of spontaneous fission. Indeed, the main elongation mechanism of the fissioning nucleus cannot induce by itself the large amounts of angular momentum found experimentally. However, if during the elongation process the double helix structure develops in each fragment, i.e. the preformed fragments not only *translate*, but also *rotate* relative to each other, at scission the fragments would take over the large amounts of accumulated rotation thus explaining the large amounts of angular momentum found experimentally.

Double Helix is a new mesoscopic paradigm of nuclear rotational motion, which is unifying the traditional macroscopic and microscopic ones. We are going to continue investing in this topic at the highest possible pace, planning to allocate all our efforts beyond the ENSDF evaluation work.

[1] N. Nica, At. Data Nucl. Data Tables **160**, 101682 (2024).
[2] N. Nica, Eur. Phys. J. Web Conf. **304**, 04003 (2024).