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Discovery of collective states in the heavy ^{208}Pb nucleus by complete spectroscopy

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Complete spectroscopy for a certain nucleus means that up to a given excitation energy for each state, spin and parity is determined by experiment and the composition is described by some theoretical model. Among heavy nuclei the goal to reach complete spectroscopy is approached only for ^{208}Pb.

Knowledge of nuclear states in ^{208}Pb is gained since 1899. Since the 1990s the sensitivity of the Munich Q3D magnetic spectrograph [1] improved and several hundred levels in ^{208}Pb up to 8 MeV were found. The shell model describes the majority of nuclear states in ^{208}Pb with great success [2].

From the very beginning a few low-lying states were recognized to need other model descriptions. The qualities of the 3- yrast state were understood to be peculiar already in the 1950s. Its coupling to 1p-1h configurations revealed a new class of nuclear excitations [3,4]. The description of collective states as tetrahedral rotations and vibrations invented 80 years ago was verified by discovering the 2- member of the predicted 2+- parity doublet in ^{208}Pb at Ex = 4.1 MeV [5,6].

In 2016 a major step of complete spectroscopy was reached with the identification of 151 states below 6.2 MeV with spin, parity, and major composition [3]. Now below 6.2 MeV nearly 160 states are observed - including 5 states predicted but not yet clearly identified [3-6]. The shell model predicts, however, only about 125 states. Sixteen states are described by coupling 1p-1h configurations to the 3- yrast state, four states as pairing vibrations, nine states as tetrahedral rotations and vibrations, and six states wait for some model description.

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[2] R. Broda et al. PRC 95:064308 (2017)
[3] A. Heusler et al. PRC 93:054321 (2016)
[4] A. Heusler et al. PRC submitted
[5] A. Heusler et al. EPJ A 53:215 (2017)
[6] A. Heusler et al. PRC(R) submitted

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