PARTICLE-OCTUPOLE VIBRATION COUPLING NEAR ^{208}Pb*

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High spin states in nuclei around ^{208}Pb were populated in deep inelastic collisions of ^{136}Xe, and ^{208}Pb projectiles with ^{208}Pb targets at beam energies about 12% above the Coulomb barrier. New states in nuclei in vicinity of ^{208}Pb have been found that are resulting from coupling of one and two valence quasi-particles to the lowest 3^- excitation of ^{208}Pb core. The results are presented and discussed in the frame of the Particle-Octupole Vibration Coupling model.

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The low lying states of the nuclei in the vicinity of ^{208}Pb result from the excitation of very few particles or holes due to the double shell closure of the ^{208}Pb core. The presence of the low lying collective 3^- state of the core nucleus, that is interpreted to be a surface vibration of octupole character, is also very important for the structure of the lowest excited

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states in these nuclei. Many levels in the nuclei close to ^{208}Pb combine this collective octupole excitation with the excitation of single quasi-particles. There is a coupling between the single particle structure and the octupole phonon, that is essential for the properties of these states. This subject has been theoretically treated in detail by Hamamoto [1, 2].

In the present study heavy ion beams of 5.7 A·MeV ^{136}Xe and of 6.5 A·MeV ^{208}Pb were used to bombard a 30 mg/cm^2 ^{208}Pb target (98.7% enriched). Excited states in neutron rich nuclei were populated in deep inelastic collisions. Gamma rays were measured in five EUROBALL HPGe-Cluster detectors [3] of total photo peak efficiency of ~2.2% at 1.33 MeV and in the CRYSTAL BALL array [4] of total photo peak efficiency of ~53% at 1.33 MeV.

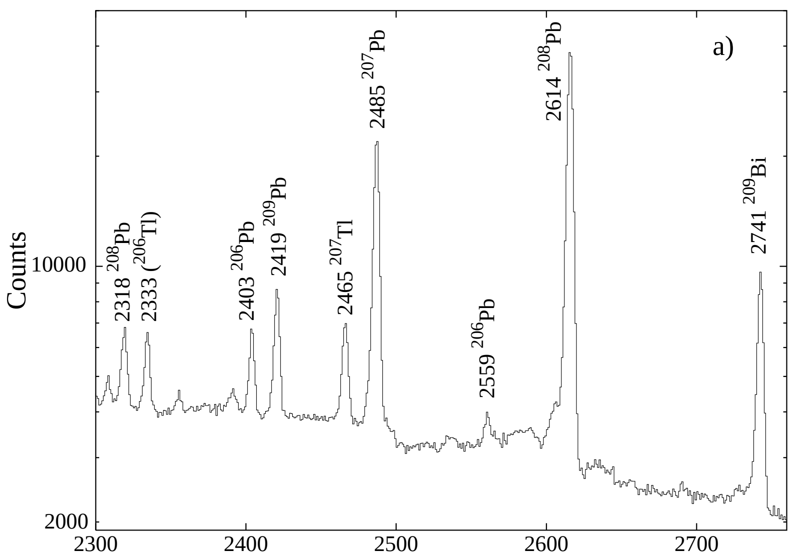

Fig. 1. The high energy part of the total projection of the prompt-prompt E_γ-E_γ coincidence matrix from the experiment with ^{208}Pb beam.

The part of the measured E_γ-E_γ projection around 2615 keV, the energy of the 3^- octupole vibrational state in ^{208}Pb, is shown in Fig. 1. Many strong γ transitions are evident. Most of these γ lines could be identified as is indicated in Fig. 1; the information on these transitions is summarized in Table I. All these transitions are interpreted as deexciting an octupole vibration built on the states of highest spin formed by one or two quasi-particles. The new states are assumed to result from stretched angular momentum coupling. The detailed discussion of these states is described elsewhere [5, 11]. Here we present briefly an example of states observed in ^{209}Pb.

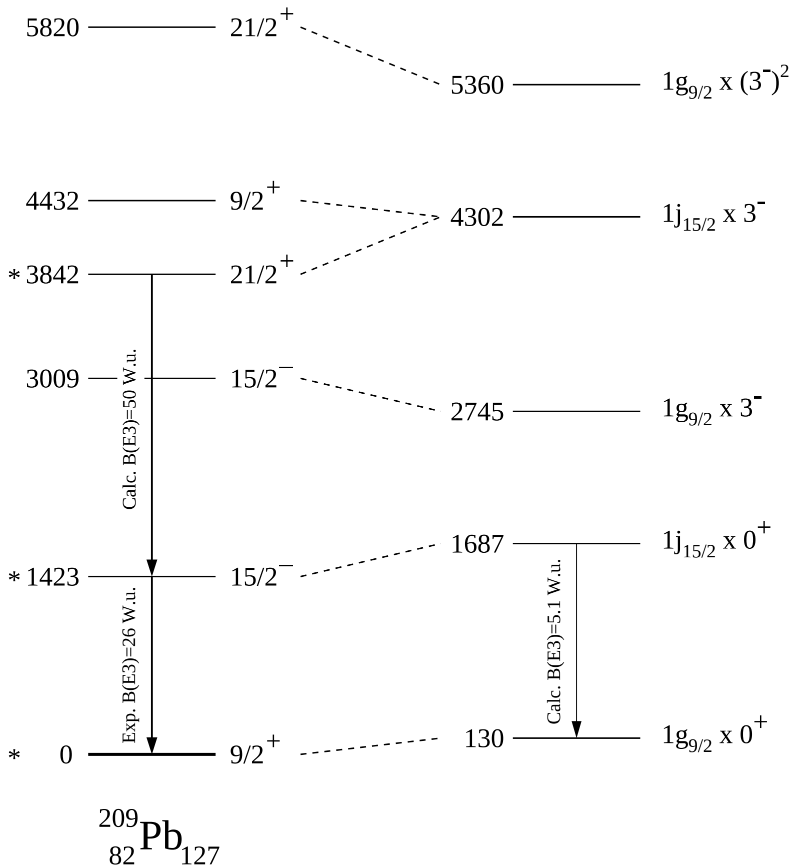

Fig. 2. The partial level scheme of ^{209}Pb nucleus resulting from the particle-octupole vibration coupling calculation (left). The energies of the uncoupled states are presented for comparison on the right. All energies are given in keV relative to the ground state of ^{209}Pb. Energies of levels marked with (*) are taken from experiment and have been used for the calculation.

We find that yrast $9/2^+$, $15/2^-$ and $21/2^+$ states in ^{209}Pb can be described by $g_{9/2} \times 0^+$, $j_{15/2} \times 0^+$ and $j_{15/2} \times 3^-$ configurations with some admixture of $j_{15/2} \times 3^-$, $g_{9/2} \times 3^-$ and $g_{9/2} \times (3^-)^2$ configurations, respectively. The partial level scheme of ^{209}Pb is shown in Fig. 2 (left). Using the Particle-Octupole Vibration Coupling model we derive the unperturbed single particle energies (Fig. 2 (right)) from the experimental energies of levels marked by (*) in the figure. Also the coupling strength $h(\nu j_{15/2}, \nu g_{9/2} \times 3^-) = -0.591$ keV and the wave functions of the coupled states could be deduced.

TABLE I

High energy transitions observed in nuclei around ^{208}Pb. These transitions are interpreted as E3-transitions depopulating octupole excitations on top of high spin few particle states as presented. $|\Phi_f\rangle$ is the leading configuration of final state and $|\Phi_i\rangle \equiv |\Phi_f \times 3^-\rangle$ is that of initial state.

Nucleus	E_γ [keV]	E_i [keV]	I_i^π [$\hbar$]	E_f [keV]	I_f^π [$\hbar$]	$\|\Phi_f\rangle$	Ref
^{206}Tl	2333	4976	(15^+)	2643	(12^-)	$\pi 1h_{11/2}^{-1} \nu 1i_{13/2}^{-1}$	[5]
^{207}Tl	2465	3813	$(17/2^+)$	1348	$11/2^-$	$\nu 1h_{11/2}^{-1}$	[5]
^{206}Pb	2559	5218	12^+	2658	9^-	$\nu 1i_{13/2}^{-1} 2f_{5/2}^{-1}$	[5]
^{206}Pb	2403	6430	15^-	4027	12^+	$\nu 1i_{13/2}^{-2}$	[6]
^{207}Pb	2485	4118	$(19/2^-)$	1633	$13/2^+$	$\nu 1i_{13/2}^{-1}$	[7,8]
^{208}Pb	2318	9062	(17^+)	6744	14^-	$\nu 1j_{15/2} 1i_{13/2}^{-1}$	[8]
^{209}Pb	2419	3842	$(21/2^+)$	1423	$15/2^-$	$\nu 1j_{15/2}$	[5,9]
^{209}Bi	2741	2741	$15/2^+$	0	$9/2^-$	$\pi 1h_{9/2}$	[10]

The presented case shows the great importance of this coupling for low lying excitations in nuclei in the ^{208}Pb region; which is due to the large coupling strength. The relevant states are on or close to the yrast line, where the level density is low, and are especially well suited to explore the particle-octupole vibration coupling phenomenon.

REFERENCES

[1] I. Hamamoto, *Nucl. Phys.* **A126**, 545 (1969).

[2] I. Hamamoto, *Nucl. Phys.* **A141**, 1 (1970).

[3] J. Eberth, Proc. Conf. on Physics from Large γ-ray Detector Arrays, August 2-6, 1994, Berkeley, Ca., USA, vol. II, LBL-35687, p. 160.

[4] V. Metag, *et al.*, *Lecture Notes in Physics* **178**, ISBN 3-540-12001-7 Springer-Verlag Berlin Heidelberg New York Tokyo, 163 (1983).

[5] M. Rejmund, PhD thesis, GSI DISS. 99-03, 1999.

[6] J. Blomqvist, *et al.*, *Nucl. Phys.* **A554**, 45, (1993).

[7] M. Schramm, *et al.*, *Z. Phys.* **A344**, 121 (1992).

[8] R. Broda, *et al.*, Proceedings of the Conference on Nuclear Structure at the Limits, Argonne, Illinois, July 1996, ANL/PHY-97/1 p. 276

[9] M. Rejmund, *et al.*, *Eur. Phys. J.* **A1**, 261 (1998).

[10] K.H. Maier, *et al.*, *Phys. Rev.* **C27**, 1431 (1983).

[11] M. Rejmund, *et al.*, to be published.