# HIGH-SPIN SPECTROSCOPY OF $^{124,125,126}$Xe*

A. Al-Khatib, H. Hübel, P. Bringel, C. Engelhardt
A. Neusser-Neffgen

Helmholtz-Institut für Strahlen- und Kernphysik, Universität Bonn, Germany

G.B. Hagemann, C.R. Hansen, B. Herskind, G. Sletten

Niels Bohr Institute, University of Copenhagen, Denmark

A. Bracco, F. Camera, G. Benzoni

Dipartimento di Fisica, Universitá di Milano and INFN, Italy

P. Fallon, R.M. Clark

Lawrence Berkeley Laboratory, Berkeley, USA

M.P. Carpenter, R.V.F. Janssens, T.L. Khoo, P. Chowdhury

Argonne National Laboratory, Argonne, USA

H. Amro

Yale University, New Haven, USA

*(Received October 31, 2006)*

High-spin states in $^{124,125,126}$Xe have been populated in the reaction $^{82}$Se$(^{48}$Ca$, xn)^{130-x}$Xe and $\gamma$-ray coincidences were measured with the GAMMASPHERE spectrometer. Twelve new bands extending into the spin 50–60 $\hbar$ region are identified in $^{125}$Xe and $^{126}$Xe and previously known rotational bands at low spins are confirmed and extended. Earlier known structures in $^{124}$Xe are confirmed and a new band is observed. Irregular structures are identified at the top of the yrast and a side band in this nucleus. Configuration assignments for the different structures are suggested.

PACS numbers: 21.10.–k, 23.20.Lv, 27.60.+j

* Presented at the Zakopane Conference on Nuclear Physics, September 4–10, 2006, Zakopane, Poland.

## 1. Introduction

The main aim of the investigation of $^{124,125,126}$Xe was to search for hyperdeformed structures at very high spin. Up to date no statistically significant discrete-line hyperdeformed bands have been discovered, but the analysis of the $\gamma$-ray continuum shows ridge structures with small energy spacings which may result from rotational bands with very large moments of inertia [1–3]. In the present paper, we report on an analysis of the normal-deformed level structure of these isotopes. Results on $^{126}$Xe have been reported at a previous conference [2].

## 2. Experimental details

High-spin states in $^{124,125,126}$Xe were populated in the $^{82}$Se($^{48}$Ca, $xn$) reaction. The $^{48}$Ca beam of 205 MeV was provided by the ATLAS accelerator at ANL. The target consisted of a 0.5 mg/cm$^2$ foil of $^{82}$Se evaporated on a 0.5 mg/cm$^2$ Au backing, and the Se was protected by a thin Au layer. Since the Au backing faced the beam, the beam energy at mid-target was about 199 MeV. For heat dissipation, the target was mounted on a rotating wheel and the beam was wobbled horizontally by about 5 mm. With these precautions, a beam current of about 4 $pnA$ could be used. Gamma-ray coincidences were measured with the GAMMASPHERE spectrometer. With a Ge-detector fold selection of $\geq 5$, a total of $2.8 \times 10^9$ events were recorded in a beam time of 7 days.

The $\gamma$-ray coincidence events were sorted into three- and four-dimensional arrays and were analysed using the RADWARE program package [4]. Matrices and $\gamma$-ray-gated matrices were created for an analysis of angular correlation ratios. This work and a complete determination of $\gamma$-ray intensities are in progress.

## 3. Results and discussion

The level structures of $^{124,125,126}$Xe were previously studied up to a spin of about 20 $\hbar$ [5–8]. The present work extends the level schemes of $^{125,126}$Xe into the region of 50–60 $\hbar$. As $^{124}$Xe is populated in the $6n$ reaction channel, its level scheme can only be moderately extended. The level schemes of $^{124}$Xe and $^{125}$Xe are presented in Figs. 1 and 2, respectively. The level scheme of $^{126}$Xe was given in a previous publication [2]. The most prominent features of the level schemes of $^{125,126}$Xe are the long regular cascades extending to high angular momenta. An example of the spectra of one of these bands in $^{125}$Xe is shown in Fig. 3, together with the spectrum of a new band found in $^{124}$Xe.

Due to the short lifetimes of the transitions within the high-spin bands in $^{125,126}$Xe, Doppler shifts could be observed even with the thin target used in the experiment. Following the method suggested by Cederwall [9], spectra

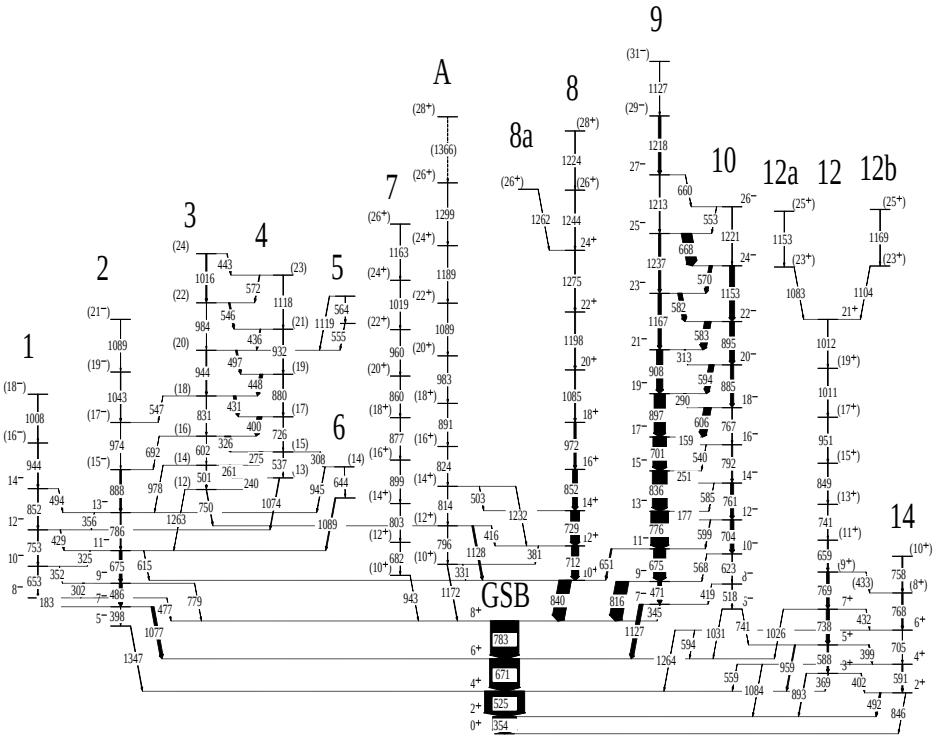


Fig. 1. Level scheme of $^{124}$Xe based on present work and previous results [6].

were sorted for the strongest band in $^{126}$Xe, band **a** [2], for different recoil velocities $v/c$, and the widths of the $\gamma$-ray peaks were determined in each of these spectra. An $F(\tau)$ curve was obtained adopting the $v/c$ values for which the width of a given peak was a minimum. For band L4 in $^{125}$Xe, see Fig. 2, spectra were sorted for different Ge-detector angles relative to the beam direction, from which $v/c$ and $F(\tau)$ values were determined. Due to the thin target, Doppler shifts could be determined for 12 transitions in each band and the change in $F(\tau)$ is about 6%. Therefore, only estimates of the transition quadrupole moments are obtained from fits to the $F(\tau)$ curves, resulting in $Q_{\rm t} \simeq 5.0$–$5.5\,$b for both bands. These quadrupole moments are significantly larger than those for low-spin states in these nuclei [10] and probably correspond to highly deformed prolate minima ($\varepsilon \approx 0.35, \gamma \approx 5^\circ$) in the potential energy calculations using the Ultimate Cranker (UC) code.

To assign configurations to the bands, we compare excitation energies, moments of inertia, quadrupole moments, aligned angular momenta and band-crossing frequencies to UC calculations [11]. In the lower-spin region, where the deformation is small and the shape is fluctuating, the configurations are dominated by $h_{11/2}$ and $g_{7/2}$ neutrons and $h_{11/2}$ and $g_{7/2}$ protons.

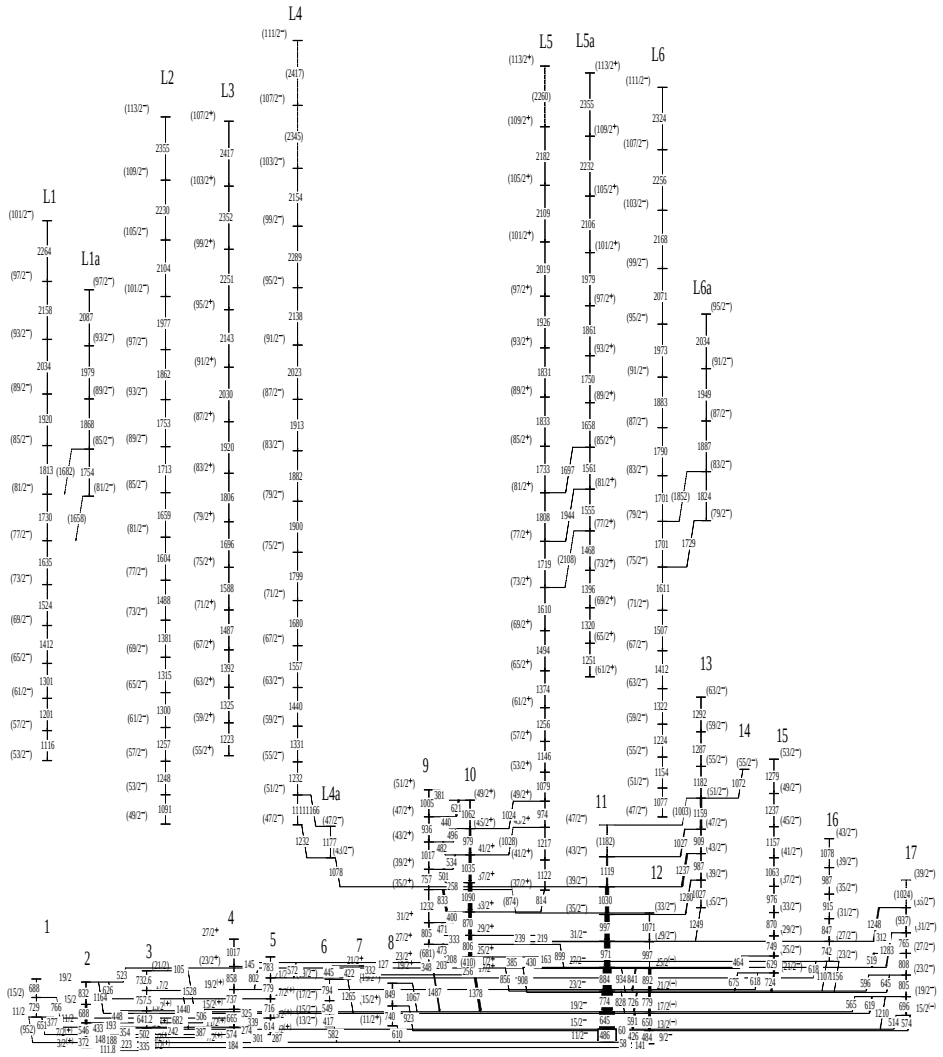

Fig. 2. Partial level scheme of $^{125}$Xe deduced from this work. The low-spin part is taken from [5].

According to the calculations, strongly prolate-driving intruder configurations are responsible for the observed properties of the new high-spin bands. They are of neutron-$i_{13/2}$ origin, but also further $h_{11/2}$ and $g_{7/2}$ proton orbitals play a role.

A sharp crossing and strong alignment gain is observed at a frequency of 1.15 MeV in several of the high-spin bands in $^{125,126}$Xe. The calculations suggest that it is caused by the strongly shape-driving $j_{15/2}$ neutron orbital. As pairing is probably quenched for multi-particle excitations at such high

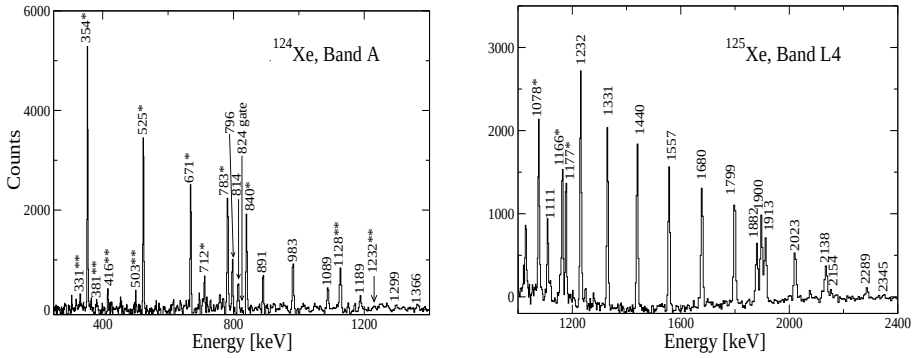


Fig. 3. Examples of $\gamma$-ray coincidence spectra in $^{124}$Xe and $^{125}$Xe. The peaks marked by a single asterisk belong to the ground and yrast bands and those marked by two asterisks are decay-out transitions.

frequencies, crossings with unpaired bands may also occur. It should be pointed out, however, that several of the high-spin bands are still not linked to low-spin states and final configuration assignments have to await firm spin determinations. This work is in progress.

This work was supported by BMBF Germany (contract 06BN109), the Danish Natural Science Research Council FNU and by the US Department of Energy, Office of Nuclear Physics (contract W31-109-ENG-38). The authors are grateful to the staff of the ATLAS accelerator for providing a high-quality $^{48}$Ca beam.

## REFERENCES

[1] H. Hübel, *Acta Phys. Pol. B* **36**, 1015 (2005).
[2] C.R. Hansen *et al., AIP Conf. Proc.* **764**, 64 (2005).
[3] B. Herskind, *Acta Phys. Pol. B* **38**, 1421 (2007), these proceedings.
[4] D.C. Radford, *Nucl. Instrum. Methods* **A361**, 297 (1995).
[5] I. Schneider *et al., Phys. Rev.* **C60**, 014312 (1999).
[6] I. Wiedenhöver *et al., Nucl. Phys.* **A582**, 77 (1995).
[7] V. Werner *et al., Nucl. Phys.* **A692**, 451 (2001).
[8] F. Seiffer *et al., Nucl. Phys.* **A554**, 287 (1993).
[9] B. Cederwall *et al., Nucl. Instrum. Methods* **A354**, 591 (1995).
[10] S. Raman *et al., Atomic Data Nucl. Data Tab.* **36**, 1 (1987).
[11] R. Bengtsson, `www.matfys.lth.se/~ragnar/ultimate.html`