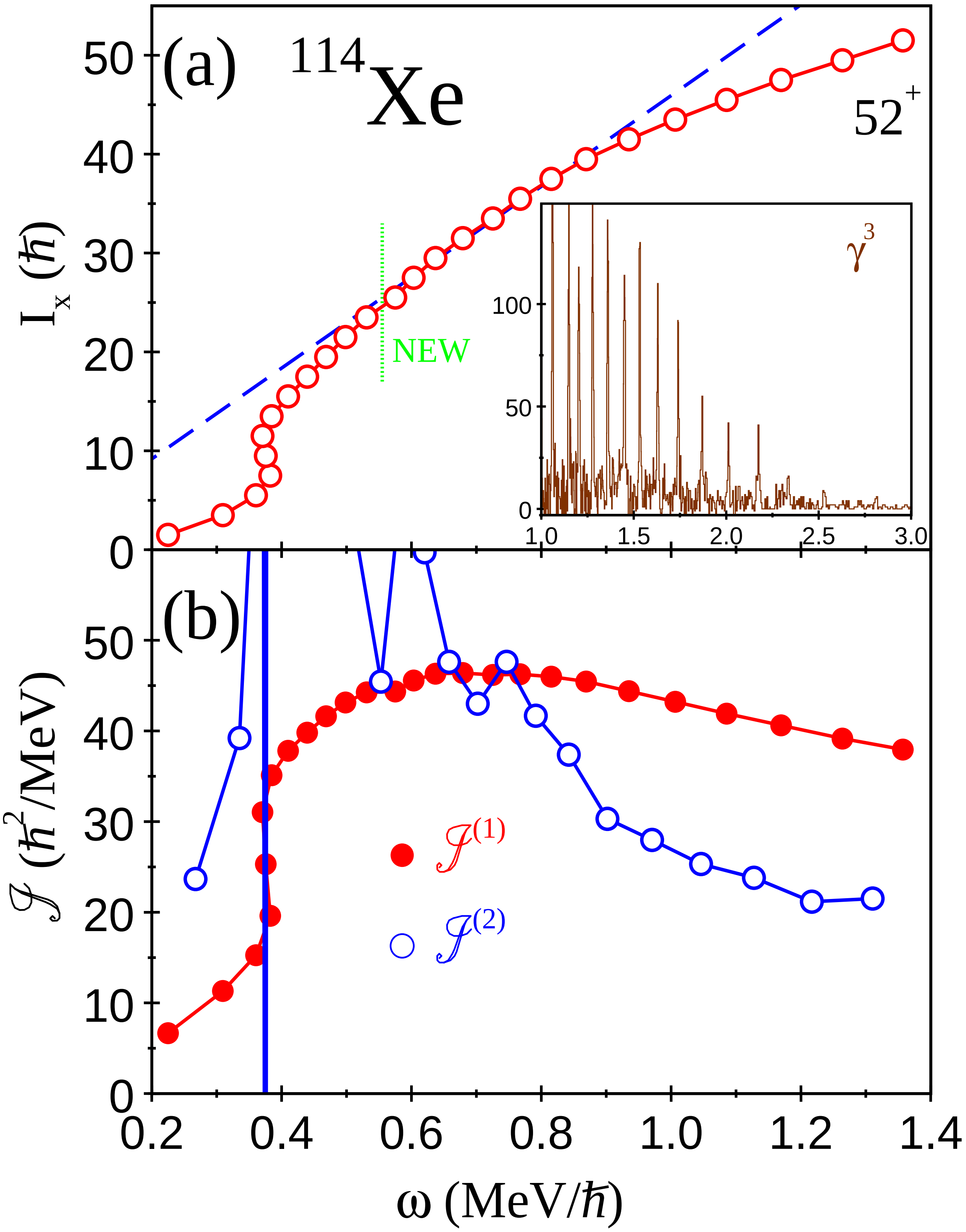
High-Spin States and Band Termination

E.S. Paul

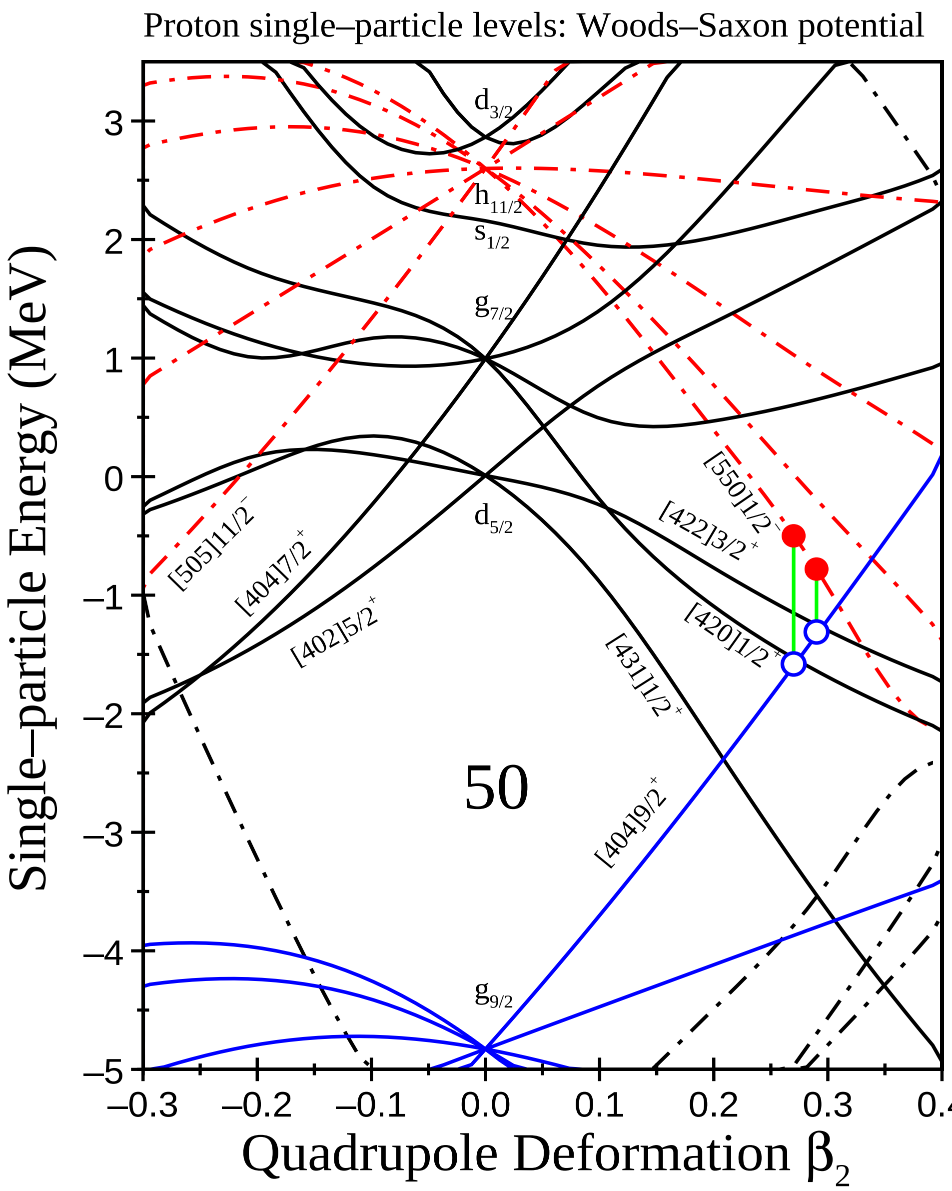
THE UNIVERSITY of LIVERPOOL

- The high-spin behaviour of superdeformed (SD) and normally deformed (ND) bands in $A \sim 130$ nuclei is compared to the smoothly terminating bands seen systematically in $A \sim 110$ nuclei.
- The $\pi g_{9/2}$ orbital, originating below the $Z = 50$ spherical shell gap plays a key role in these structures.

GSFMA92 Results: $^{58}Ni + ^{58}Ni$



Theory

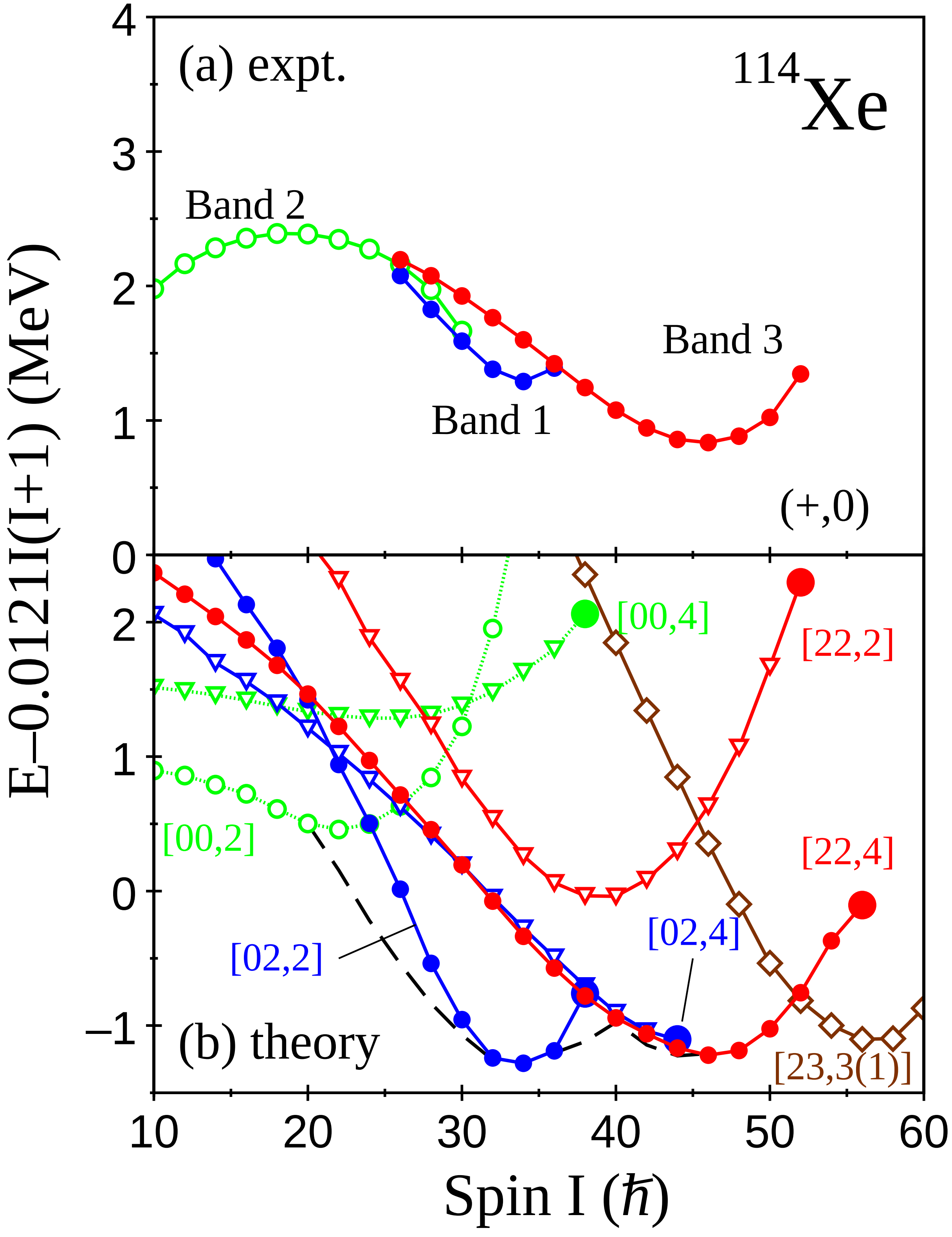


Relative to N=Z=50, configurations classified by:

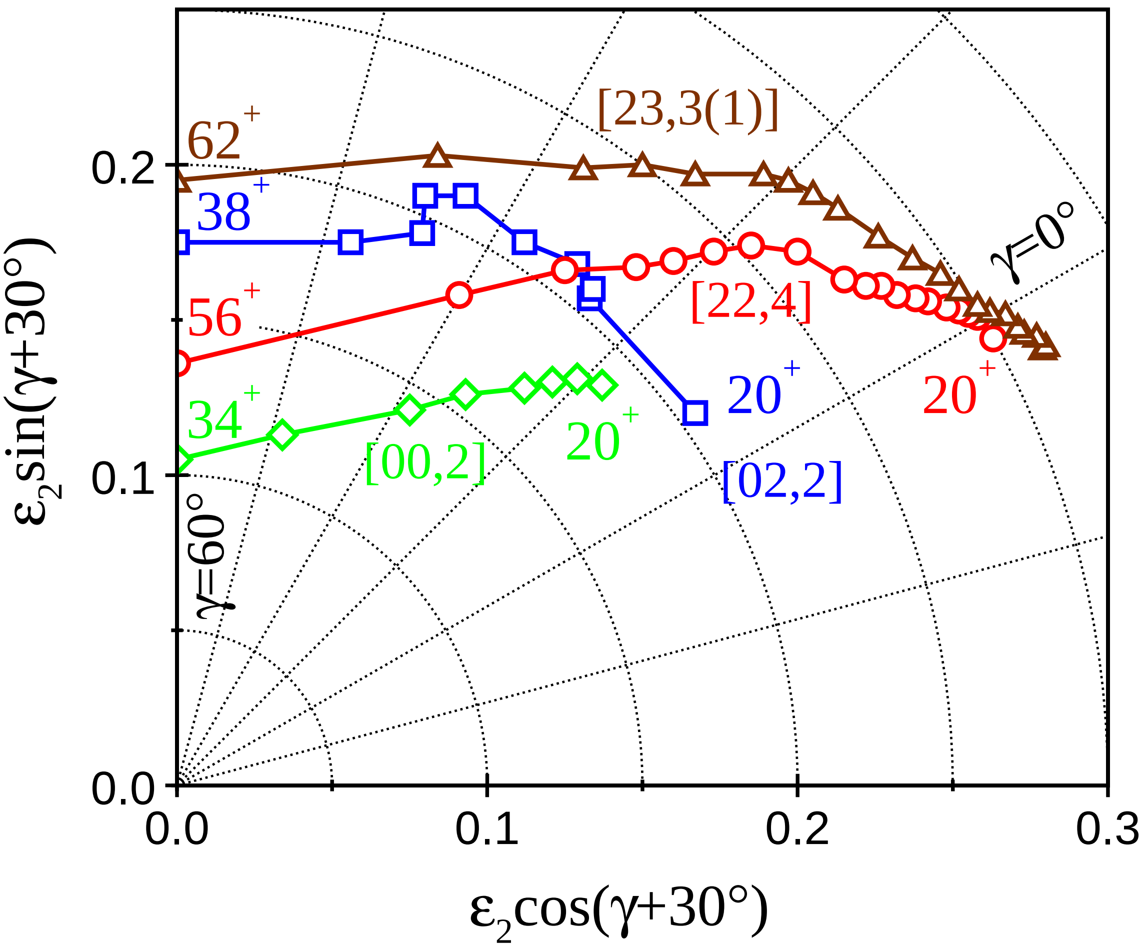
$$[p_1 p_2, n_1 (n_2)] \quad \equiv \quad \pi \left\{ (g_{9/2})^{-p_1} (h_{11/2})^{p_2} \ldots \right\}$$

$$\otimes \quad \nu \left\{ (h_{11/2})^{n_1} (i_{13/2})^{n_2} \ldots \right\}.$$

Smoothly Terminating Bands



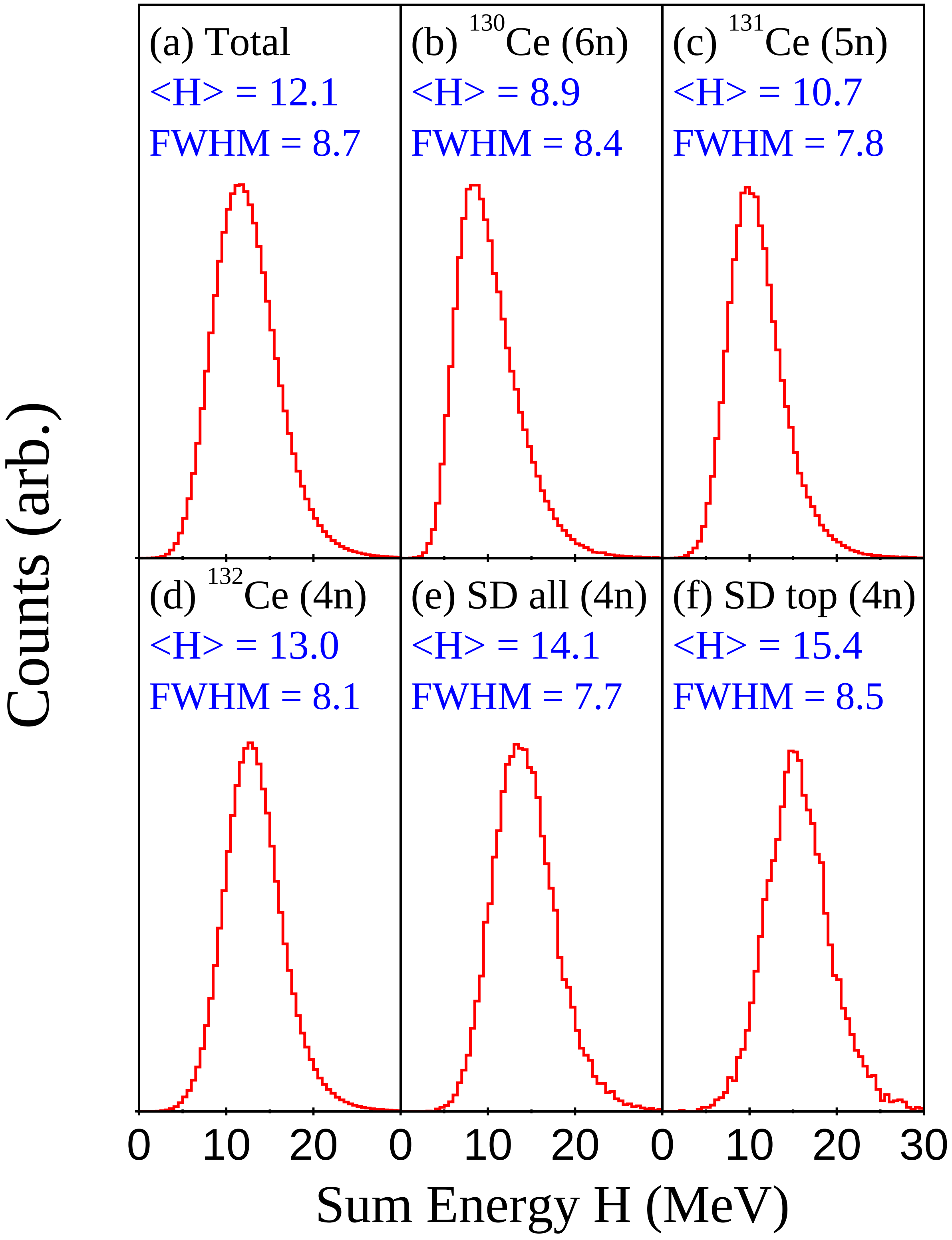
Predicted Shape Evolution



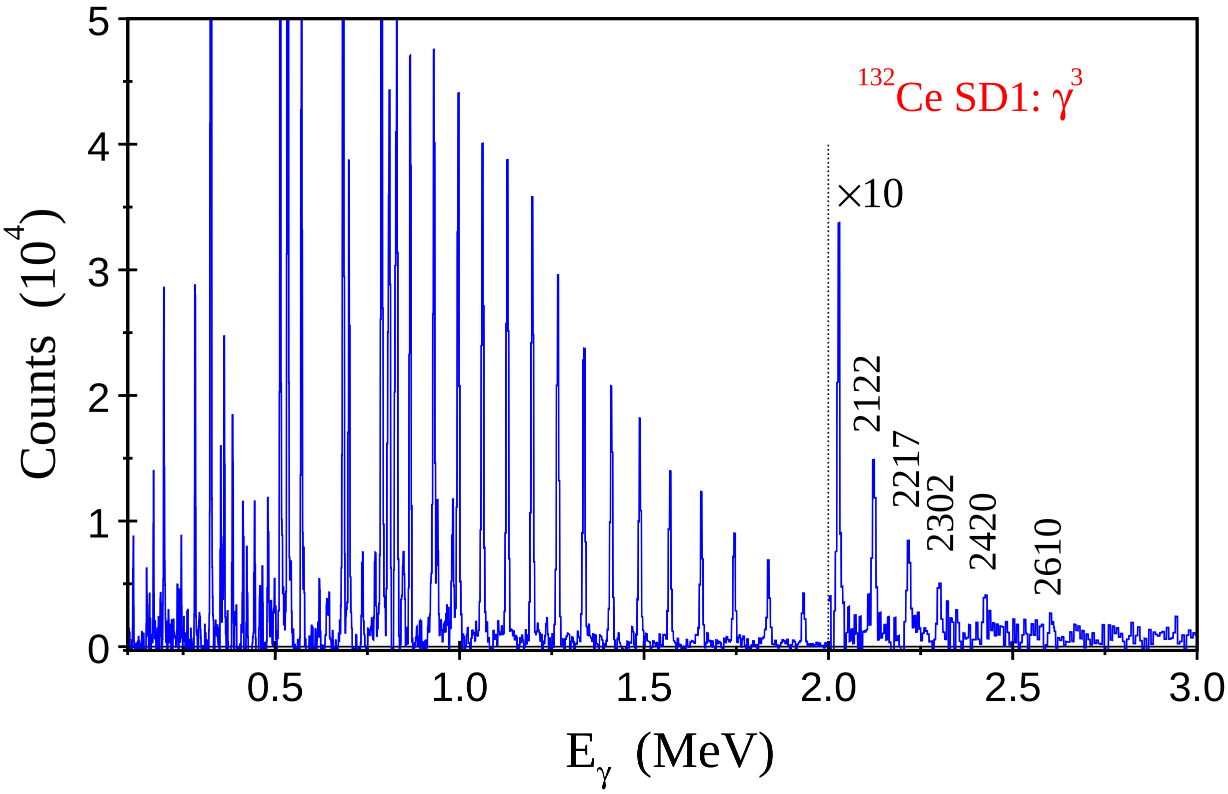
- The $\pi g_{9/2}$ holes stabilise larger deformation.
- More $\pi g_{9/2}$ holes ($\nu i_{13/2}$ particles) increase the spin available before termination.

Evidence for $\nu i_{13/2}$ orbital in $^{113}_{53}\mathrm{I}_{60}$:
K. Starosta et al., PRC **64**, 014304 (2001).
Also bands of large deformation in $^{108}_{48}\mathrm{Cd}_{60}$:
R.M. Clark et al., PRL **87**, 202502 (2001).

EB99.08 Results: $^{36}S+^{100}Mo$



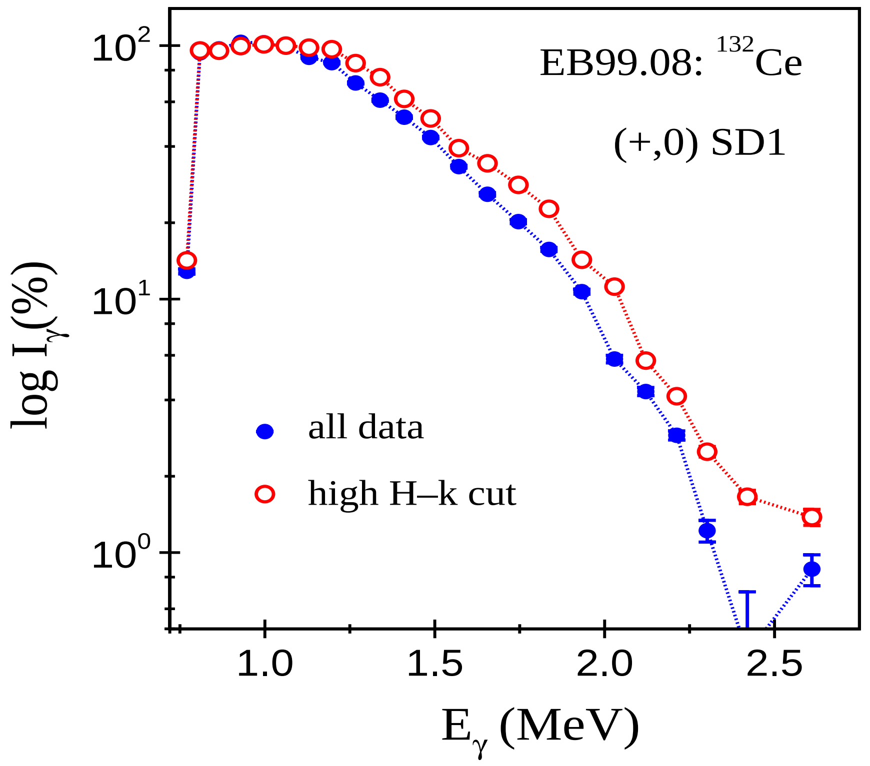
EB99.08 Results: ^{132}Ce Yrast SD Band

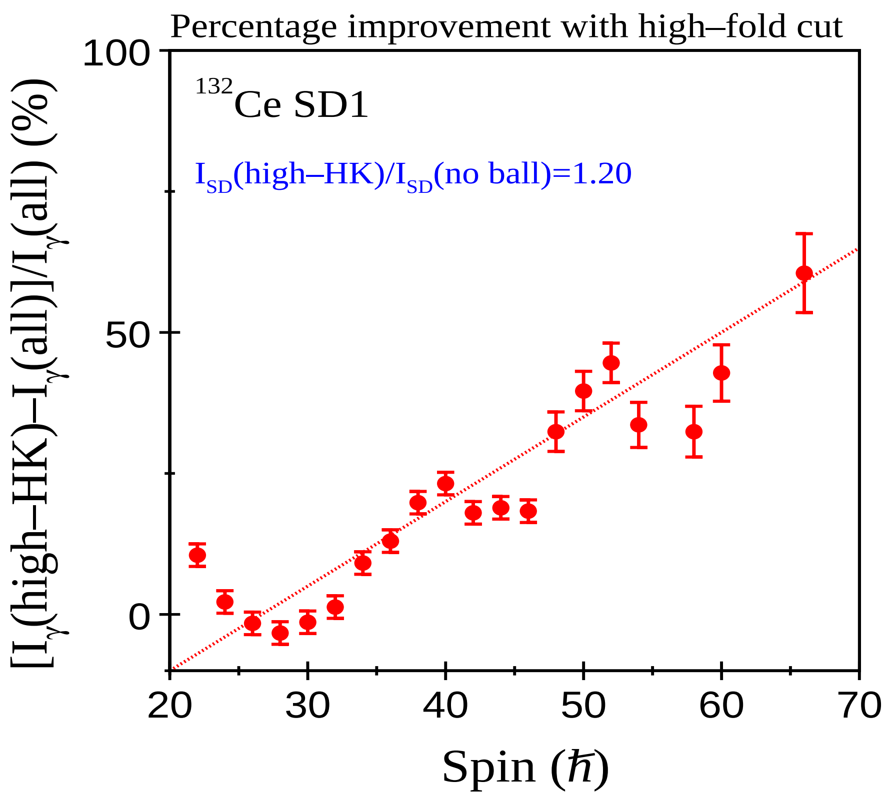


A total of 1.5×10^9 events were recorded with mean γ-ray fold of 4.5. The fold k and sum-energy H of an event were constructed from both the inner ball and the germanium detectors. Events of high fold ($k > 22$) and sum-energy ($H > 13$ MeV) were selected.

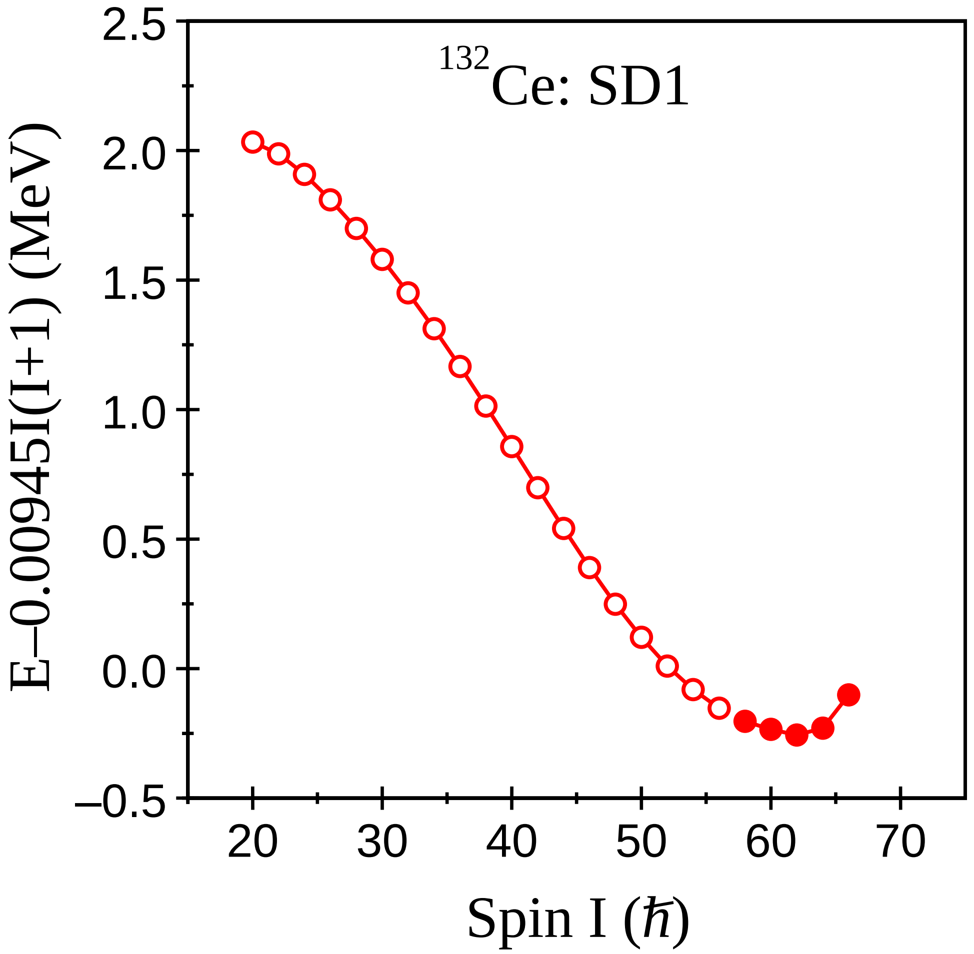
7.3×10^9 γ^4 coincidences were unfolded from the data and sorted into a RADWARE hypercube for analysis.

SD Band Enhancement with Inner Ball



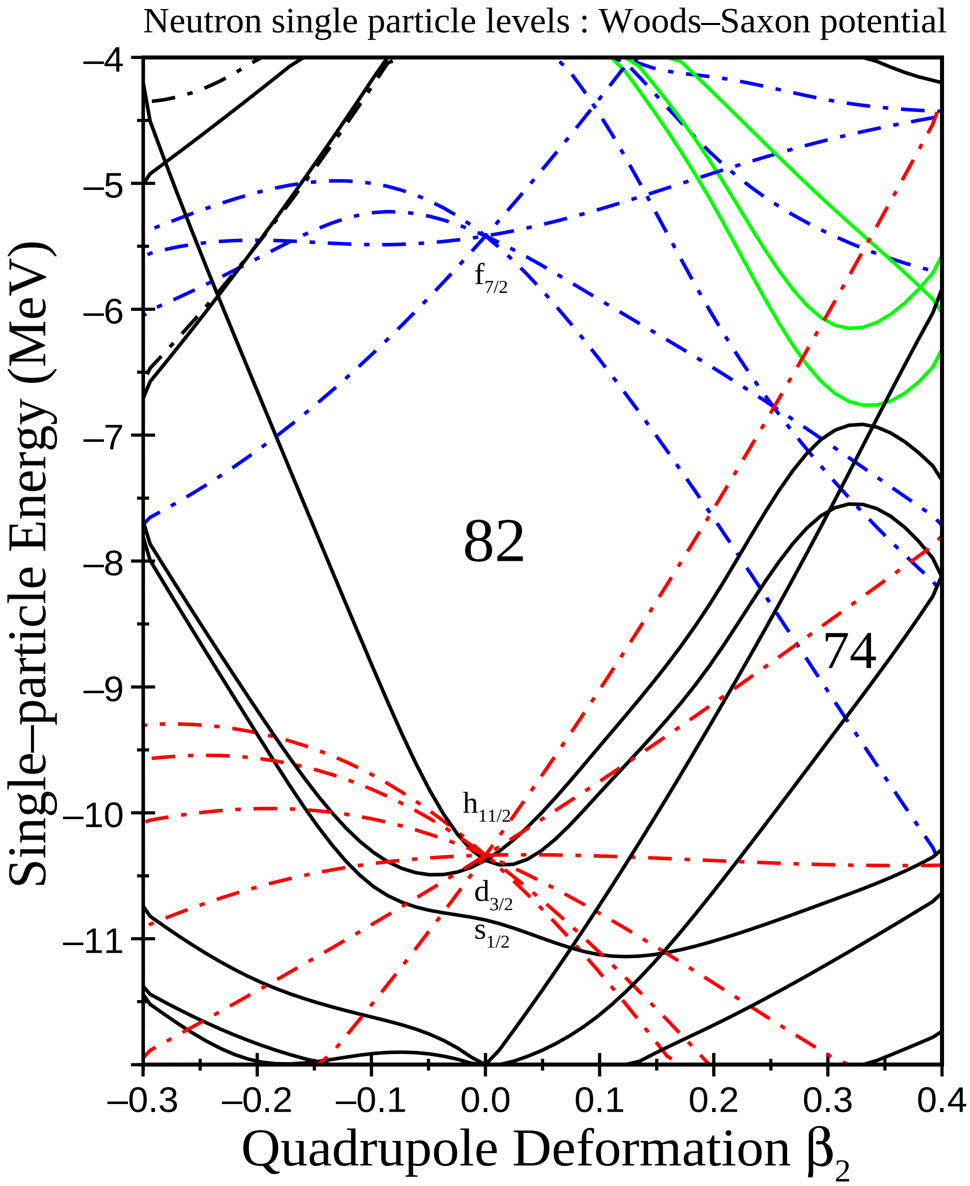


^{132}Ce: Rigid-Rotor Plot



The high-spin behaviour of the yrast SD band in ^{132}Ce is similar to the mass 110 smooth terminating bands! The band must be approaching termination. The maximum spin available for the SD configuration is $78\hbar$. It has two $\pi g_{9/2}$ holes and two $\nu i_{13/2}$ particles.

Theory: ^{132}Ce SD1



$$[p_1 p_2 (p_3), n_1 n_2 n_3] \equiv$$

$$\pi \left\{ (g_{9/2})^{-p_1} (h_{11/2})^{p_2} (i_{13/2})^{p_3} \ldots \right\}$$

$$\otimes \nu \left\{ (h_{11/2})^{n_1} (h_{9/2}/f_{7/2})^{n_2} (i_{13/2})^{n_3} \ldots \right\}.$$

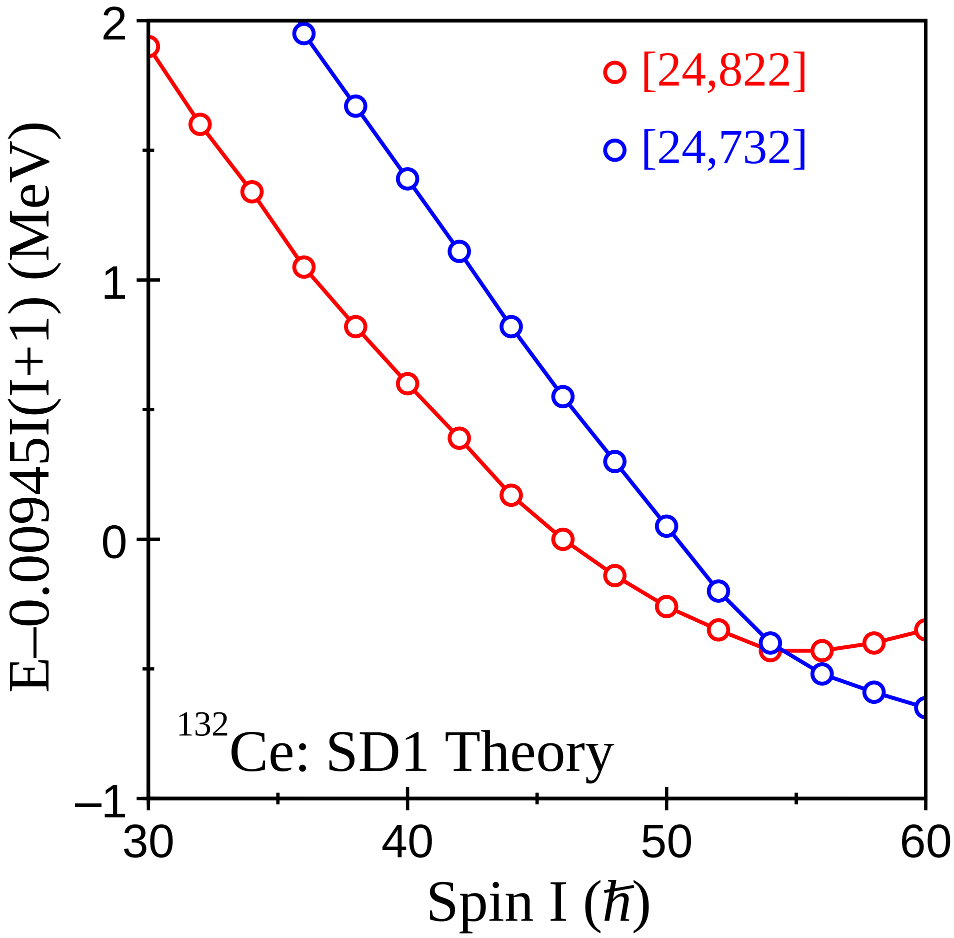
^{132}Ce SD1: Termination

Relative to the ^{100}Sn core, the configuration of the yrast SD band in ^{132}Ce is [24,822] which can accommodate $60\hbar$ of angular momentum. The remaining (unlabelled) 6 protons and 12 neutrons occupy $g_{7/2}/d_{5/2}$ orbitals and can generate a further $12\hbar$ and $6\hbar$, respectively. This configuration should therefore terminate at $78\hbar$.

- At spin $20\hbar$, this configuration has predicted deformation: $\varepsilon_2 = 0.391, \gamma = 0°$
- At spin $60\hbar$, this configuration is predicted to be still near-prolate but with lower quadrupole deformation: $\varepsilon_2 = 0.354, \gamma = 6°$

Configuration constrained cranked Nilsson-Strutinsky method (no pairing):
A. V. Afanasjev and I. Ragnarsson, Nucl. Phys. **A608**, 176 (1996).

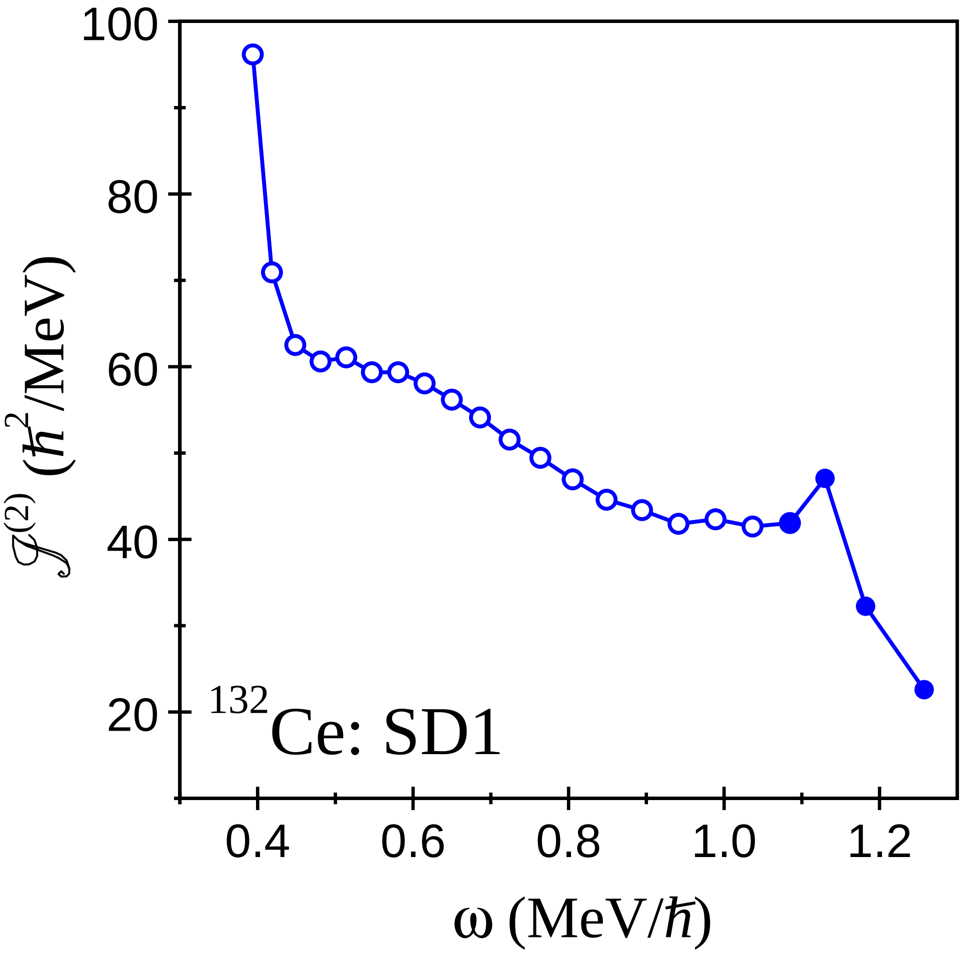
^{132}Ce SD1: Band crossing



The [24,822] configuration is predicted to be crossed at high spin by the [24,732] configuration, obtained by promoting an $h_{11/2}$ (m=–3/2) neutron into an $h_{9/2}/f_{7/2}$ (m=7/2) orbital and can accommodate a maximum spin of $83\hbar$.

Is there evidence for this high-spin band crossing?

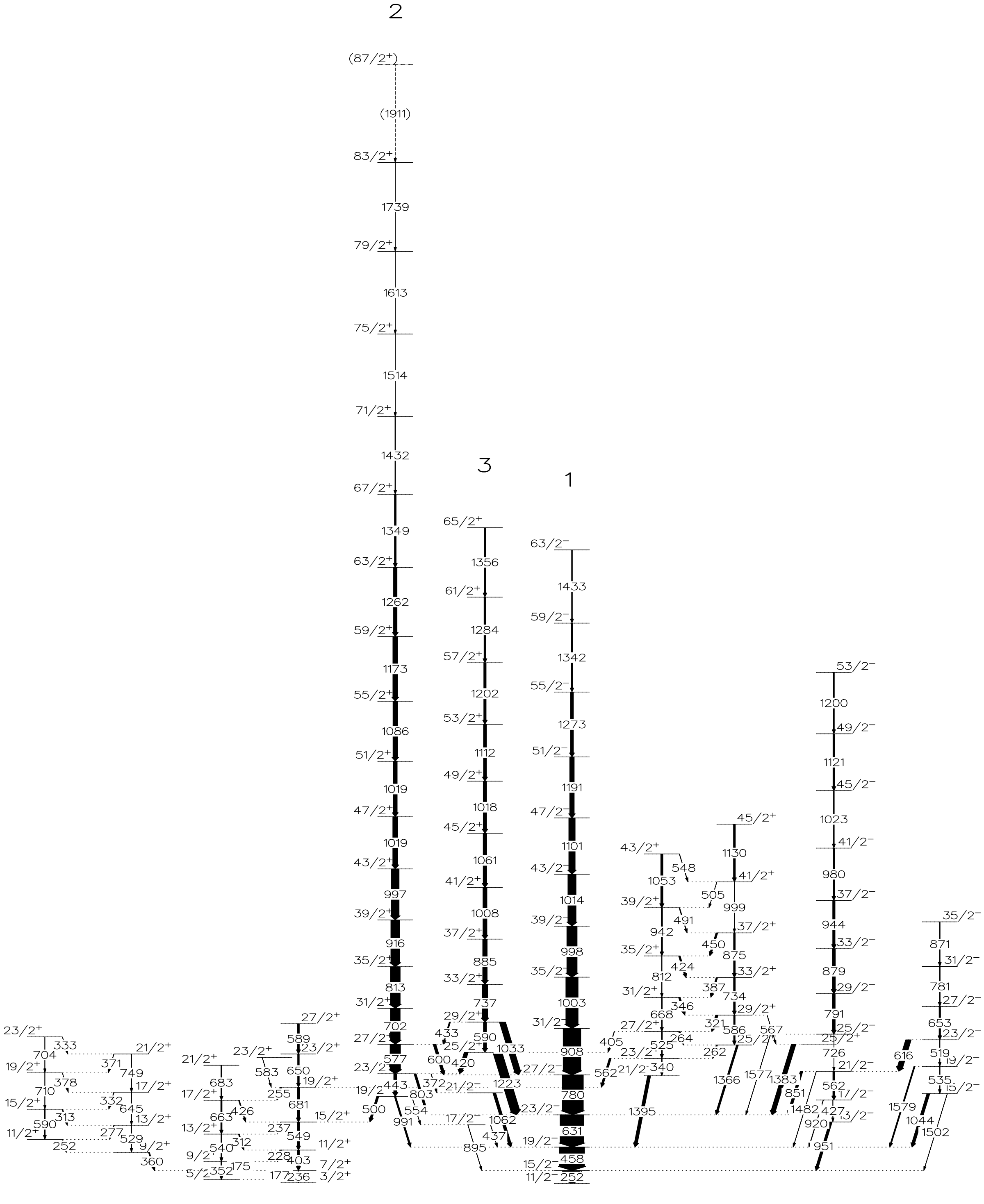
^{132}Ce: Dynamic Moment of Inertia



The behaviour of the dynamic moment of inertia suggests something happens at high spin - a band crossing.

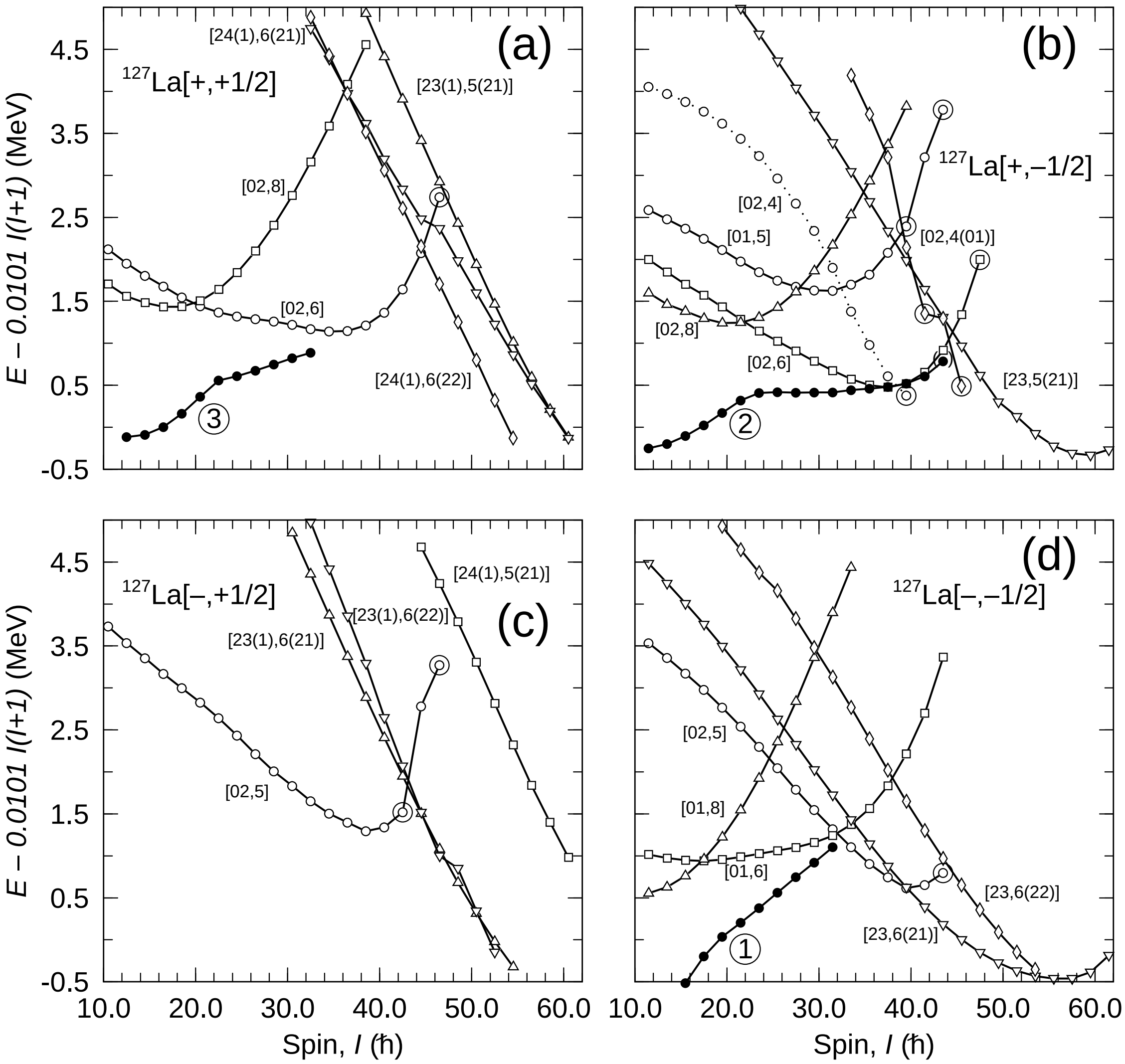
- Is this the [24,822] → [24,732] crossing?

Smoothly Terminating Bands in odd-A La



EUROBALL: $^{100}Mo(^{32}S,p4n)^{127}La$ @ 160 MeV

^{127}La: Rigid-Rotor Plots



$$[p_1 p_2 (p_3), n_1 (n_2 n_3)] \equiv$$

$$\pi \left\{ (g_{9/2})^{-p_1} (h_{11/2})^{p_2} (i_{13/2})^{p_3} \ldots \right\}$$

$$\otimes \nu \left\{ (h_{11/2})^{n_1} (h_{9/2}/f_{7/2})^{n_2} (i_{13/2})^{n_3} \ldots \right\}.$$

$^{127}_{57}$La Configurations

The crossing seen in the positive-parity sidebands 2 and 3 could be explained by the crossing of [02,8] (low-spin) and [02,6] (high-spin) configurations. These latter configurations can accommodate $\sim 95/2\hbar$ before termination.

The crossing in negative-parity band 1 could be explained by the crossing of [01,8] (low-spin) and [01,6] configurations.

C.M. Parry et al., PRC **61**, 021303 (2000).
R. Wadsworth et al., PRC **62**, 034315 (2000).

These are valence-space configurations with no particle-hole excitations across the $Z = 50$ core. Similar structures have been seen in light xenon isotopes.

Similar positive-parity sidebands have been observed in ^{129}La (Eurogam) and ^{131}La (Euroball).

Conclusions

- There is a similarity between the mass 110 terminating bands and the superdeformed bands in mass 130 nuclei.
- Holes in strongly upsloping ($\partial E/\partial\beta > 0$) $\pi g_{9/2}$ orbitals induce large quadrupole deformation.
- The holes augment the amount of spin that configurations can hold. Termination occurs at $\sim$50$\hbar$ for mass 110 nuclei and $\sim$80$\hbar$ for the mass 130 SD configurations.
- The $\nu i_{13/2}$ intruder orbital has now been identified in both mass regions.
- There is evidence that the yrast SD band of ^{132}Ce is not far from termination. Experimentally, the band reaches $\sim$70$\hbar$.
- Smoothly terminating bands containing neither $\pi g_{9/2}$ holes nor $\nu i_{13/2}$ particles have been identified in odd-A lanthanum isotopes.

Experiments

GAMMASPHERE+MICROBALL

- Manchester, UK
  Liverpool, UK
  York, UK
  Stony Brook, USA
  Washington, St. Loius, USA
  Argonne, USA

EUROBALL III, EUROBALL IV

- Liverpool, UK
  York, UK
  Stony Brook, USA
  Debrecen, Hungary
  Padova, Italy
  Legnaro, Italy
  Grenoble, France
  Lyon, France
  IReS, France