Exotic Triaxial Shape and Wobbling Motion in ^{189}Au

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Introduction

While the nuclei of atoms primarily take spherical, oblate and prolate shapes, a strongly deformed asymmetric triaxial shape can be observed in rare cases.

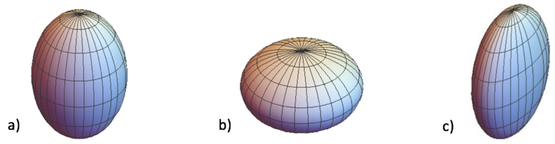

Figure: Nuclear Shapes: a) Prolate, b) Oblate, C) Triaxial

Triaxiality can be identified through the observation of chirality or wobbling. Wobbling is the rotation of one of the principle axes of a triaxial nucleus about the total angular momentum vector J.

Wobbling Energy:

- Quantifies the additional rotational energy present in wobbling spin states relative to the Yrast band.
- $E_{wobb} = E(I, n_w = 1) - [\frac{E(I+1,n_w=0)+E(I-1,n_w=0)}{2}]$

Two Types of Wobbling:

- ***Longitudinal Wobbling***
  1) Medium axis (m) rotates around J
  2) Wobbling energy (E_{wobb}) increases with the spin
- ***Transverse Wobbling***
  1) Short axis (s) rotates around J
  2) Wobbling energy (E_{wobb}) decreases with the spin

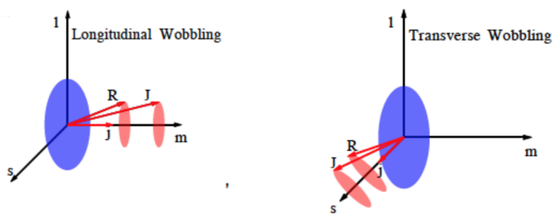

Figure: Schematic of Longitudinal and Transverse Wobbling in a Triaxial Nucleus

Overview of "Wobblers"

- Triaxiality is extremely rare and has only been identified in a handful of nuclei.
- Wobbling has been firmly established in the $A \sim 130$ and $A \sim 160$ mass regions.
- This project on ^{189}Au is aimed to experimentally explore and characterize wobbling in the $A \sim 190$ region.
- Research teams around the world are searching for more wobbling nuclei in order to establish triaxiality as a generalized phenomenon.

Experimental Details

- Gamma Ray spectroscopy for this study was performed over two experiments held at Argonne National Laboratory. Gammasphere, an array of 110 high purity Compton suppressed Ge detectors, was used in both experiments.
- Reaction: ^{174}Yb $+^{19}$F $\rightarrow ^{189}$Au + 4n
- Target: 13 mg/cm^2 thick foil of ^{174}Yb deposited on a 33 mg/cm^2 ^{208}Pb backing.

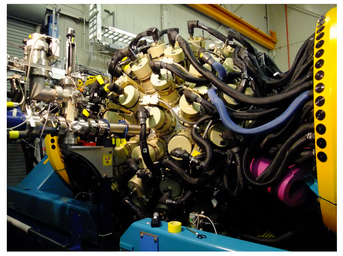

Figure: The Gammasphere array at Argonne National Laboratory

Exp. Number	Beam Energy	Detectors Working	Triple Coincidence Events
1	105 MeV	57	4.2×10^{10}
2	115 MeV	73	6.0×10^{10}

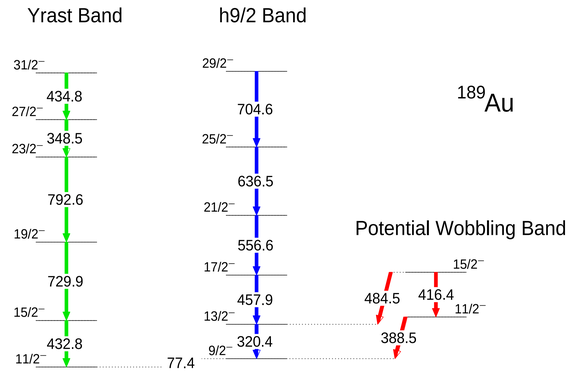

Figure: A partial negative parity level scheme of ^{189}Au generated during this experiment. First level in Yrast band (spin $11/2^-$) has an exitation energy of 681.7 keV.

DCO-Like Ratios

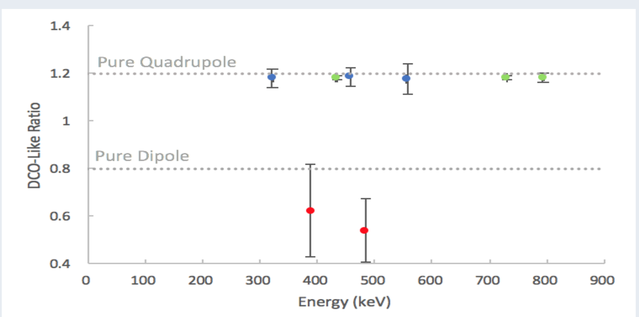

Figure: The DCO-like ratios of key transitions in level scheme provided above. A DCO-like ratio quantifies the coincidence of gamma rays which are detected at the back or front of the detector with those in the middle. This ratio provides information about the multipolarity of the gamma ray based on scattering angle. A pure quadrupole has a DCO-like ratio of 1.2; a pure dipole has a DCO-like ratio of 0.8; a highly mixed transition has a ratio significantly less that 0.8.

Results

Longitudinal Wobbling in ^{189}Au

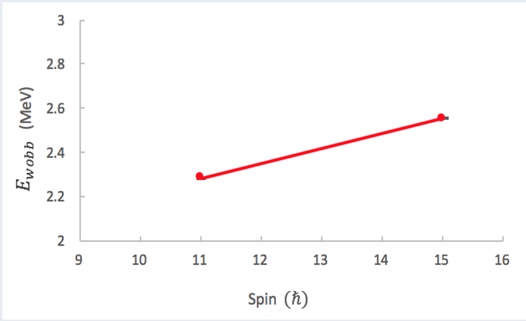

Figure: Plot of Experimental Wobbling Energy versus Spin for the potential Wobbling Band. The positive correlation between wobbling energy and spin state demonstrated suggests longitudinal wobbling.

Conclusion and Future Analysis

The presence of longitudinal wobbling and triaxial shape in ^{189}Au is supported by these findings. Angular distributions and mixing ratios of key transitions will be calculated in order to further confirm the presence of wobbling in ^{189}Au. The identification of triaxiality in ^{189}Au would support the generalization of triaxiality as a phenomenon not limited to certain mass regions.

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