First direct observation of enhanced octupole collectivity in $^{144,146}$Ba

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Background

- Experimental & theoretical indications that $^{144,146}$Ba are among the most octupole-enhanced isotopes
- Octupole enhancement due to $\Delta J, \Delta \ell = 3$ orbitals near the Fermi surface at $Z \sim 56, N \sim 88$
- How does octupole collectivity evolve with $Z, N$?
  - Improve nuclear models
  - Atomic EDM search

Coulomb Excitation is only unambiguous measure of E3 strength!

E3 quenched or shell occupancy effect?

* Spin-averaged $B(E1)/B(E2)$ multiplied by $B(E2; 2\rightarrow 0)$,
  $^{148}$Ba $B(E2)$ estimated from systematics

Data taken from NNDC

Urban et al., NPA 613:107 (1997)
Production of radioactive barium beams from CARIBU

CAlifornium Rare Ion Breeder Upgrade
- Spontaneous fission $^{252}\text{Cf}$
- Extract $^{144}\text{Ba}$ ($T_{1/2}=11.5$ s), $^{146}\text{Ba}$ ($T_{1/2}=2.2$ s): He gas catcher, isobar separator

650 MeV $^{144,146}\text{Ba}$ Beams
- ECR Ion source: $^{144,146}\text{Ba}^{28+}$
- Accelerated by linac
- 8000 $^{144}\text{Ba}$ per second on target, ~10 days,
  3000 $^{146}\text{Ba}$ per second, ~12 days
- Stable contaminants present from ECR

For experimental details, see Bucher et al., PRL 116: 112503 (2016)
Coulomb Excitation with Chico-II / Gretina

**Compact Heavy-Ion COunter**
- Parallel-plate avalanche counter (20 total)
- Angular coverage is 69% of $4\pi$
- Good intrinsic spatial & temporal resolution ($1\sigma$): $	heta$ (0.66°), $\varphi$ (1.05°), $\Delta t$ (0.51 ns)
- Provides particle ID and Doppler correction for GRETINA

**Gamma-Ray Energy Tracking In-beam Nuclear Array**
- Segmented Ge $\gamma$-ray tracking array
- $1\pi$ angular coverage
- Position resolution 2mm
- 7 clusters each with 4 segmented Ge detectors

(Half of CHICO)

0.9 µm thick Mylar window
$^{146}\text{Ba}$ γ-ray spectrum

- Negative-parity (odd-spin) levels excited by E3
- Decay yields provide measurement of E3 excitation probability!

**Observed A=146 Isobars**
- Ba
- Ce
- La, 2-
- La*, (6-)

Coincident γ-rays (ToF-gated, 40°–75°, no tracking)
Comparison of E3 matrix elements

- Measurement uncertainty dominated by statistics
- Increased octupole collectivity confirmed near N=90
- Theory underpredicts E3 strength, however predicted E1 behavior is validated

Enhanced octupole correlations!


Octupole enhancement from v_{13/2} near Fermi surface around N=90

Data from NNDC
Ground-state $\beta_3$ deformation: atomic EDM search

- Nuclear Schiff moment expected to be largest contribution to atomic EDM for diamagnetic atoms
- Are Schiff moments larger in lanthanide region?

Compare parameters between $^{224}\text{Ra}$ and Ba measurements:
$^{144}\text{Ba}$ is 64% larger, $^{146}\text{Ba}$ 84% larger (numerator only)

$$S \propto \frac{\beta_2 \beta_3^2 Z A^{2/3}}{|E^+ - E^-|}$$

Spevak, Auerbach, & Flambaum, PRC 56: 1357 (1997)

Need more data from reaccelerated RI beam experiments!
Collaborators

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