

Anomalous $B_{4/2}$ in the Osmium isotopic chain



Irene Zanon

Royal Institute of Technology





Nuclear Physics Meeting 2024 - I. Zanon

1

The $B_{4/2}$ anomaly



$$R_{4/2} = \frac{E_X(4^+)}{E_X(2^+)} > 2$$
$$B_{4/2} = \frac{B(E2; 4^+ \to 2^+)}{B(E2; 2^+ \to 0^+)} > 1$$



$$R_{4/2} > 2 \& B_{4/2} > 1$$

for collective nuclei

The $B_{4/2}$ anomaly









$B_{4/2}$ anomaly in Os

Seniority-like scenario;

[B. Cederwall et al., PRL 121 (2018)]

IBM calculation: triaxial rotor;

[Y. Zhang et al., PLB 834 (2022)]

No shape change;

[T. Grahn et al., PRC 94 (2016), A. Goasduff et al., PRC 100 (2019)]





$B_{4/2}$ anomaly in Os

$$B_{4/2} = \frac{B(E2; 21/2^+ \to 17/2^+)}{B(E2; 17/2^+ \to 13/2^+)}$$

- B_{4/2} = 0.79(16) in ¹⁶⁹Os [W. Zhang et al., PLB 820 (2022)]
- Same trend of the even isotopes
- > Role of unpaired neutron?



¹⁶⁷Os study case



FE Reaction: ⁷⁸Kr(⁹²Mo,2pn)¹⁶⁷Os @ 360 MeV





Experimental setup





Recoil-alpha tagging





RDDS method







 $Ratio = \frac{D}{(IF + D)}$

Depends on:

- the speed;
- the distance;
- the lifetime!

01/11/24



The 17/2⁺ state



The 17/2⁺ state



| Ring | τ [ps] | |
|-----------------------------|-------------------------|---------------------|
| Ring O | 20(3) | |
| Ring 1 | 22(2) | |
| | | 0 |
| | | 40 |
| | | |
| Agreement with $\tau = 200$ | previous data: 4) ps | |
| O'Donnel et al., | PRC 79 (2009) | |
| | | 0 1 10 100 |
| | | Time of Flight [ps] |

Nuclear Physics Meeting 2024 - I. Zanon

The 21/2⁺ state





Nuclear Physics Meeting 2024 - I. Zanon

The 21/2⁺ state



| Ring | τ [ps] | |
|----------|-----------|---------------------|
| Ring 0 | 6.4(1.8) | |
| Ring 1 | 5.6(1.4) | 0.2 |
| | | |
| | | 20 - |
| | | |
| Agreemen | t between | |
| the tw | o rings | |
| | | |
| | | 1 10 100 |
| | | Time of Flight [ps] |



The 25/2⁺ and 29/2⁺ state



The B_{4/2} ratio



| Transition | τ [ps] | B(E2) [W.u.] |
|-----------------------------|--------|--------------|
| $17/2^+ \rightarrow 13/2^+$ | 22(1) | 107(10) |
| $21/2^+ \rightarrow 17/2^+$ | 6(1) | 52(9) |



The $B_{4/2}$ ratio

- R_{4/2} constant around 2.5, small staggering effect;
- B(E2; 17/2⁺ → 13/2⁺) constant as a function of neutrons;
- B(E2; 21/2⁺ → 17/2⁺) decreases with the number of neutrons;
- $B_{4/2}$ ratio follows a similar trend as the even equivalent.





Total Routhian Surface calculations



- For even-N isotopes $(\pi, \alpha) = (+, 0)$ configuration corresponding to g.s.
- For odd-N isotopes $(\pi, \alpha) = (+, 1/2)$ configuration corresponding to $i_{13/2}$ yrast band
- Calculation performed at $\hbar\omega$ =0.00 MeV and $\hbar\omega$ =0.12 MeV



Total Routhian Surface calculations





Total Routhian Surface calculations

| | ħω [MeV] | β ₂ | γ | B(E2) _{th} [W.u.] | B(E2) _{exp} [W.u.] |
|-------------------|----------|----------------|-------|----------------------------|-----------------------------|
| ¹⁶⁷ Os | 0.00 | 0.155 | 3.1° | 95 | 107(10) |
| | 0.12 | 0.155 | 8.1° | 96 | 52(9) |
| ¹⁶⁸ Os | 0.00 | 0.157 | 0.6° | 60 | 74(13) |
| | 0.12 | 0.158 | -3.1° | 86 | 25(13) |
| ¹⁶⁹ Os | 0.00 | 0.168 | 2.2° | 112 | 104(15) |
| | 0.12 | 0.168 | 2.3° | 116 | 82(12) |
| ¹⁷⁰ Os | 0.00 | 0.173 | 0.8° | 73 | 97(9) |
| | 0.12 | 0.174 | -3.6 | 105 | 38 ⁺¹³ -7 |



The B_{4/2} ratio anomaly

| 58 - | | | | | | | | | | | | | 1 | | | | | | | | | | | | |
|------------|---|--------|-------|-------|-------|----------|------------------|----------|-------|-------|-------|-------|-------|-------|------------------|-------|-------|----------|--------------|---------|-------|-------|-------|---------|-------|
| | | | | | | 116La | 117La | 118La | 119La | 120La | 121La | 122La | 123La | - | ¹⁰⁸ S | n: (|).86 | 6(10 |) | 114 | Te: | 0.8 | 4(1 | 2) | |
| | | | 112Ba | 113Ba | 114Ba | 115Ba | 116Ba | 117Ba | 118Ba | 119Ba | 120Ba | 121Ba | 122Ba | | ¹¹² S | n: C |).39 | (6) | | 112 | Xe: | 0.3 | 5(7 | ') | |
| 56 — | | | 4445- | 4426- | 4426- | 4445- | 445.5- | 4465- | 4476- | 4405- | 4405- | 4205- | 1216- | | ¹¹⁴ S | n: (|).52 | 2(7) | | 114 | Xe: | 0.7 | 1(7 | , ') | |
| | | | 11105 | 11205 | 113CS | 114CS | 115CS | 116CS | 117Cs | 118Cs | 119Cs | 12005 | 12105 | | | | | , | | | | ••• | -(' | / | |
| # (7) 54 - | 108Xe | 109Xe | 110Xe | 111Xe | 112Xe | 113Xe | 114Xe | 115Xe | 116Xe | 117Xe | 118Xe | 119Xe | 120Xe | | | | | | | | | | | | |
| Prot | 1071 | 1081 | 109I | 110I | 111I | 1121 | 113I | 114I | 115I | 1161 | 1171 | 118I | 1191 | | | | | | | 178Pb | 179Pb | 180Pb | 181Pb | 182Pb | 183Pb |
| 50 | 106Te | 107Te | 108Te | 109Te | 110Te | 111Te | 112Te | 113Te | 114Te | 115Te | 116Te | 117Te | 118Te | | | | | | 176TI | 177TI | 178TI | 179TI | 180TI | 181TI | 182TI |
| 52 | 4055h | ADCCH | 10755 | 4005h | 10055 | 1405h | 44456 | 44256 | 44264 | 4445h | 44556 | 44654 | 44765 | | | | | | | | | | | | |
| | 10550 | 10650 | 10750 | 10820 | 10920 | 11050 | 11150 | 11250 | 11350 | 11450 | 11550 | 11650 | 11750 |)Hg | 171Hg | 172Hg | 173Hg | 174Hg | 175Hg | 176Hg | 177Hg | 178Hg | 179Hg | 180Hg | 181Hg |
| 50 — | 104Sn | 105Sn | 106Sn | 107Sn | 108Sn | 109Sn | 1105n | 111Sn | 112Sn | 113Sn | 114Sn | 115Sn | 116Sn | Au | 170Au | 171Au | 172Au | 173Au | 174Au | 175Au | 176Au | 177Au | 178Au | 179Au | 180Au |
| - | 54 | 55 | 56 | 57 | 58 | 59 Ne | 60 eutron (N) | 61)# | 62 | 63 | 64 | 65 | 66 | BPt | 169Pt | 170Pt | 171Pt | 172Pt | 173Pt | 174Pt | 175Pt | 176Pt | 177Pt | 178Pt | 179Pt |
| | | | | | | | | | Рк | 166Ir | 167Ir | 168Ir | 169Ir | 170Ir | 171Ir | 172Ir | 173Ir | 174Ir | 175Ir | 176Ir | 177Ir | 178Ir | | | |
| Γ | 166144 0 22451 1600 0 724461 | | | | | | |] | | | | | | | | | | | | | | | | | |
| | 100 VV: 0.33(5) $100 US: 0.79(16)$ | | | | | | | 76 - | 165Os | 166Os | 167Os | 168Os | 169Os | 170Os | 171Os | 172Os | 173Os | 174Os | 175Os | 176Os | 177Os | | | | |
| | ¹⁶ Os: 0.49(10) ¹⁷⁰ Os: 0.39(10) | | | | | | | | 164Re | 165Re | 166Re | 167Re | 168Re | 169Re | 170Re | 171Re | 172Re | 173Re | 174Re | 175Re | 176Re | | | | |
| | ¹⁶⁸ Os: 0.34(19) ¹⁷² Pt: 0.55(19) | | | | | | | 163W | 164W | 165W | 166W | 167W | 168W | 169W | 170W | 171W | 172W | 173W | 174W | 175W | | | | | |
| L | | | | | | | | | | | | | 89 | 90 | 91 | 92 | 93 | 94 Ne | 95 95 (N) | 96 # | 97 | 98 | 99 | 100 | 101 |

Conclusions



<u>Results:</u>

- ¹⁶⁷Os successfully populated in the FE reaction;
- Lifetimes of 17/2⁺, 21/2⁺, 25/2⁺ measured;
- B_{4/2} < 1 observed;
- Comparison with TRS calculations.

Future perspective:

- Ground-state band of ¹⁶⁷Os
- Lifetime measurements in ¹⁶⁶Os



Thank you for your attention

I. Zanon^a, M. Doncel^a, B. Cederwall^b, T. Grahn^c, A. Illana^d, G. Appagere^a, K. Auranen^c, T. Bäck^b, V. Bogdanoff^c, A.D. Briscoe^{c,e}, E.A. Cederlöf^{b,f}, G. González Briz^g, P.T. Greenlees^c, R. Jashbhai Makwana^g, H. Joukainen^c, R. Julin^c, H. Jutila^c, D. Knežević^{h,i}, J. Louko^c, M. Luoma^c, A. McCarter^e, B.S. Nara Singh^j, J. Pakarinen^c, A. M. Plaza^{c,e}, P. Rahkila^c, P. Ruotsalainen^c, J. Sarén^c, C.M. Sullivan^e, P.-E. Tegnér^a, E. Uusikylä^c, J. Uusitalo^c, G. Zimba^c

> ^aDepartment of Physics, Stockholm University, Roslagstullsbacken 21, 10691 Stockholm, Sweden ^bDepartment of Physics, KTH Royal Institute of Technology, Roslagstullsbacken 21, 10691 Stockholm, Sweden ^cAccelerator Laboratory, Department of Physics, University of Jyväskylä, P.O. Box 35, FI-40014 University of Jyväskylä, Finland. ^dGrupo de Física Nuclear and IPARCOS, Universidad Complutense de Madrid, CEI Moncloa, E-28040 Madrid, Spain ^eDepartment of Physics, Oliver Lodge Laboratory, University of Liverpool, Liverpool L69 7ZE, United Kingdom ^fDepartment of Physics and Astronomy, Uppsala University, 751 20 Box 516, Uppsala, Sweden ^gDepartamento de Física Fundamental, Universidad de Salamanca, Salamanca, Spain ^hInstitute of Physics Belgrade, Pregrevica 118, 11080 Zemun, Serbia ⁱHeinz Maier-Leibnitz Zentrum (MLZ), Technical University of Munich, Lichtenbergstr. 1, 85748 Garching, Germany. ^jSchool of Computing Engineering and Physical Sciences, University of the West of Scotland, Paisley PA1 2BE, UK