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IDENTIFICATION OF PARITY-DOUBLET BANDS IN ODD-Z²²³Pa

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Octupole Deformation

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- > Requires pairs of $\Delta I = \Delta j = 3$ shells near Fermi level.
- > Octupole magic numbers:
 - > 34 (g_{9/2}⊗p_{3/2})
 - ➣ 56 (h_{11/2}⊗d_{5/2})
 - > 88 (i_{13/2}⊗f_{7/2})
 - > 134 ($j_{15/2} \otimes g_{9/2}$)
- Regions centred around doubly magic nuclei:
 - ¹¹²Ba (Z=56, N=56)
 - ¹⁴⁴Ba (Z=56, N=88)
 - ²²²Ra (Z=88, N=134)



[1] P. A. Butler and W. Nazarewicz, Rev. Mod. Phys. 68, 349 (1996).

Octupole Deformation



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[1] P. A. Butler and W. Nazarewicz, Rev. Mod. Phys. 68, 349 (1996).

Region of Deformation



																Vol	ume 197	, numb	er 4			PHYSICS LE	ETTERS B		51	November 1987
Table Grou botto solid	Table 1 Ground state spin and parities of the odd-A nuclei beyond ²⁰⁸ Pb. The appropriate parity mixed neutro sottom and at the right of the table respectively. The region of the nuclear periodic table in which quadrisolid or dotted lines.															DEI OF	FINIT	ION OF IC QUA	THE	ACTIN OLE-O	IDE REGION CTUPOLE DEF	ORMATIC	DN			
	126	i 127	128	+ 129	Neu 130	tron No. 131	132	133	134	135	136	137	138	139	14	Raymond K. SHELINE Florida State University, Tallahassee, FL 32306, USA and The University of Kinshasa, Kinshasa XI, Zaire										
82 83 ⁱ 84 85 ⁱ 86 ⁱ 87	Pb 3i 9/2 Po At 9/2 An Fr 9/2	9/2 ⁺ (9/2 [*]) 9/2 [*]	(9/2) ⁻ 9/2 ⁻ 9/2 ⁻	9/2* 9/2* (9/2*)	9/2" 9/2" 9/2"	(9/2)* 9/2*	9/2 ⁻ (9/2) ⁻	5/2*	5/2 ⁻	7/2	3/2 ⁽⁻⁾		3/2(-)		1/2							1/2(-0.1:-0.5:-2)	Quadrupole=Octupo			
* 89 ⁴ Proton % 90 ¹ % 91	Ra No 9/2 Th Pa	9/2 ⁺	9/2	9/2* (9/2 [*])	9/2-	not 9/2* not 9/2*		5/2* (5/2*)	3/2 ¹ 5/2 ⁻ 3/2 ¹	3/2* 3/2*	3/2"	1/2* 1/2*	3/2 ⁻ (5/2 ⁺)	3/2+ 5/2+	2 ⁺ (3/2 ⁺ 2 ⁺ 3/2 ⁻ K=1/;	5/2 (1/2* 5/2* 3/2 K=1/2	(1/2*) 3/2 ⁻ K=1/2	2*) 1/2* - /2 ⁻	(3/2 ⁻) (K=1/2 ⁻)		(1/2*)	3/2(0.1;0) Ole Deformed (F(g. 1) P 5/2(0.2;0.4) P)le Deformed (Fig. 1) Pr			
, 92 ¹ 93 ¹	łþ I										6 1	3/2*	(5/2)	(5/2)	(5/2*)	5/2*	5/2*	7/2*	5/2+	1/2*	5/2+	1/2(0.2;-0.1;2)	oton Orbita			
				3/2(0.2;0.2)		1/2(-0.1;0.5;-2)		5/2(0.2;0.2)		3/2(-0.1;0.6)		1/2(0.2;-0.1;3)		3/2(0.3;0.3)		5/2(-0.2:0.7)							18			
				Quadrupole-Octupole Deformed (Fig. 1) Neutron Orbitals																						

[2] R. Sheline, Phys. Lett. B. 197, 500 (1987).

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Region of Deformation



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^[3] Y. Cao et al., Phys. Rev. C 102, 024311 (2020).

Region of Interest

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Lots of studies on $_{86}$ Rn, $_{88}$ Ra, and $_{90}$ Th. ≻ Z > 90 difficult to access experimentally. ≻ Odd Z lacking. 223Np 224Np 225Np 227Np 231Np 232Np 226Np 228Np 229Np 230Np 233Np 234Np 222U 223U 225U 226U 227U 228U 229U 230U 231U 233U 2340 221Pa 222Pa 223Pa 224Pa 225Pa 226Pa 227Pa 228Pa 229Pa 230Pa 231Pa 232Pa 233Pa 229Th 230Th 231Th 232Th 220Th 224Th 225Th 219Ac 223Ac 224Ac 228Ac 229Ac 230Ac 231Ac 220Ac 221Ac 222Ac 226Ac 226Ra 229Ra 218Ra 219Ra 220Ra 222Ra 227Ra 230Ra 218Fr 219Fr 220Fr 221Fr 222Fr 223Fr 224Fr 225Fr 226Fr 227Fr 228Fr 229Fr 217Fr 217Rn 218Rn 219Rn 220Rn 221Rn 224Rn 225Rn 226Rn 227Rn 228Rn 216Rn 22.3Rn 215At 216At 217At. 218At. 219At 220At 221At 222At 223At 224At 225At 226At 227At

[2] R. Sheline, Phys. Lett. B. 197, 500 (1987).

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Previous Studies-²²³Pa

PHYSICAL REVIEW C, VOLUME 60, 057301
Electromagnetic transitions and α decay of the ²²³Pa nucleus
F. Hoellinger, B. J. P. Gall, and N. Schulz
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- Performed at JYFL with JUROSPHERE (13 EUROGAM & 10 TESSA) and RITU.
- > Measuring RDT coincidences.
- > 208 Pb(19 F,4n) 223 Pa, E = 99 MeV.
- > 500 μ g/cm² target.
- 9 γ rays identified, but no level scheme possible.

[4] F. Hoellinger et al., Phys. Rev. C 60, 057301 (1999).



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Experiment Details





- > JUROGAM-3, RITU, & FP array.
- ¹⁹F beam, E = 99 MeV, 45 pnA.
- ~250 μg/cm^{2 208}Pb target,
 40 μg/cm² C backing.
- > 99% fission, ~100 μb.
- > ²²³Pa RDT γ -ray spectra.



[5] J. Pakarinen *et al.*, Eur. Phys. J. A 56, 149 (2020).
[6] J. Uusitalo *et al.*, NIM B 204, 638 (2003).

Recoil Decay Tagging



FP DSSD used for RDT. \triangleright ²²³Pa, ~600k identified using Δt (recoil – α) and E_{α} . \geq 5000 Log₁₀(t [µs]) 4000 6 3000 5 4 2000 3 1000 2 ₽...P 0 6500 8000 8500 9500 7500 9000 7000

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Energy [keV]

Half-Life Measurement



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[7] J. Borggreen et al., Phys. Rev. C 2, 1841 (1970).
[4] F. Hoellinger *et al.*, Phys. Rev. C 60, 057301 (1999).

Gamma-Ray Spectra



11 ~600k ²²³Pa-γ events. ~60 y rays observed. \triangleright \geq ~225k 223 Pa- γ - γ events. ~25x data as F. Hoelinger et al. \geq \geq Counts [0.5 keV/ch] 2000x10 15001000500 $\dot{0}\dot{0}$ 50100150200250300 350400 450500

Acknowledgements & Summary

Summary:

- There is a lack of experimental evidence for octupole deformation for Z>90.
- Performed ²⁰⁸Pb(¹⁹F,4n)²²³Pa experiment at JYFL with JUROGAM3 & RITU.
- First excited states in ²²³Pa observed, shows parity doublet octupole bands.
- Collectivity appears comparable to ²²²Th, analysis is still ongoing.

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Collaborators:

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