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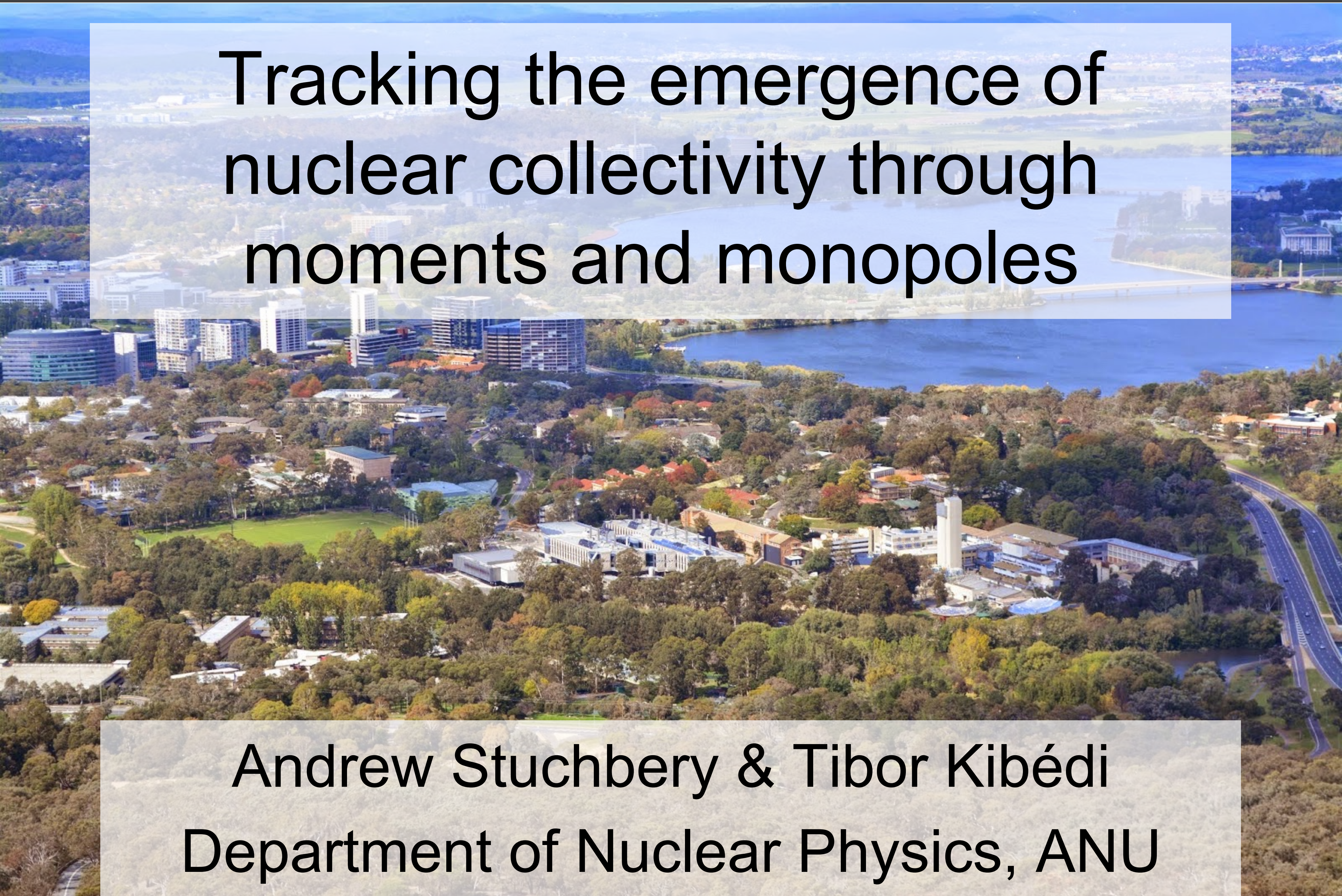


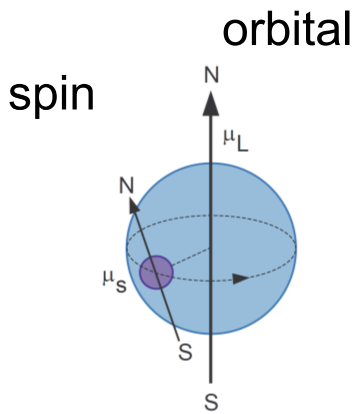
Tracking the emergence of nuclear collectivity through moments and monopoles

Andrew Stuchbery & Tibor Kibédi
Department of Nuclear Physics, ANU

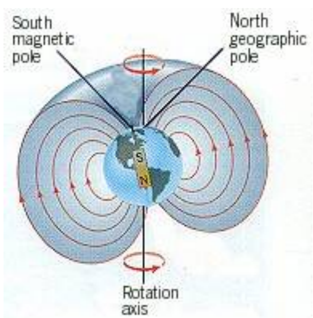
The Message

We must consider magnetic moments and electric monopole transitions along with E2 observables to elucidate the nature and origin of nuclear collectivity

Why magnetic moments:

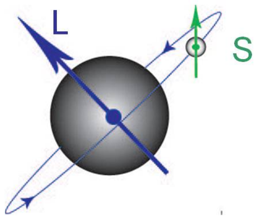


Nucleus ~ 6 × 10^{-15} m



Earth ~ 6 × 10^{6} m

$$\mu = g_l l + g_s s$$



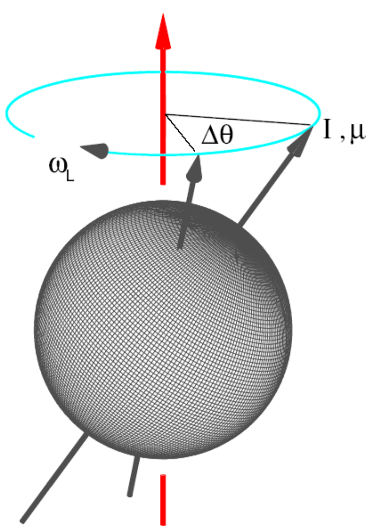
- tell us how the nucleus carries its angular momentum

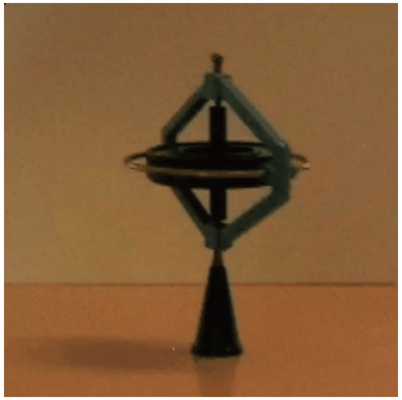
- are sensitive to single-particle aspects of the nuclear wavefunction

- distinguish between proton versus neutron excitations

g factors

$$g = \frac{\mu}{I}$$





We measure spin rotation

i.e. gyromagnetic ratio or “g factor”

g = magnetic moment / angular momentum

Electromagnetic observables

E2 moments & transitions:

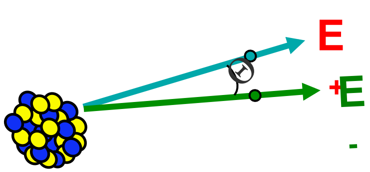
- ✓ Quantify quadrupole collectivity
- ✓ Track evolution of collectivity
- ✓ Distinguish alternative models (possibly)
- ✗ Elucidate nature/origin of collectivity

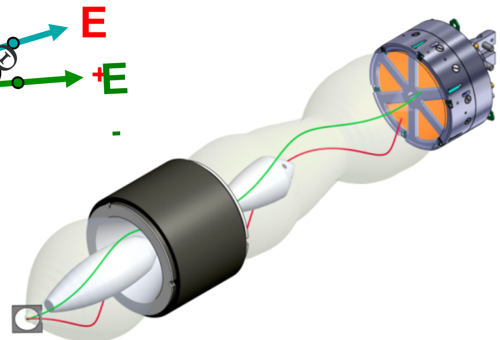
M1 observables (g factors):

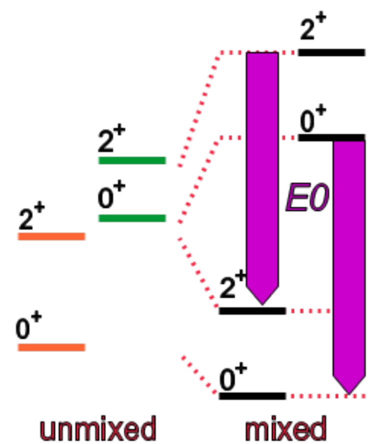
- ✓ Sensitive to microscopic structure
- ✓ Window on drivers of emergent collectivity
- ✓ How the nucleus carries its angular momentum

E0 transitions:

- ✓ Identify and quantify shape co-existence







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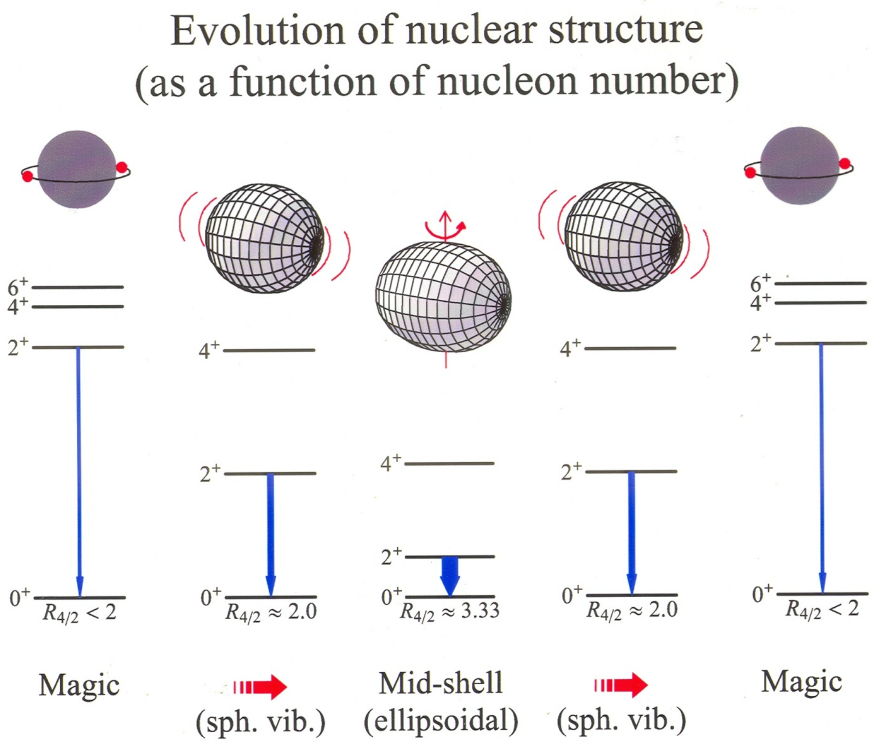
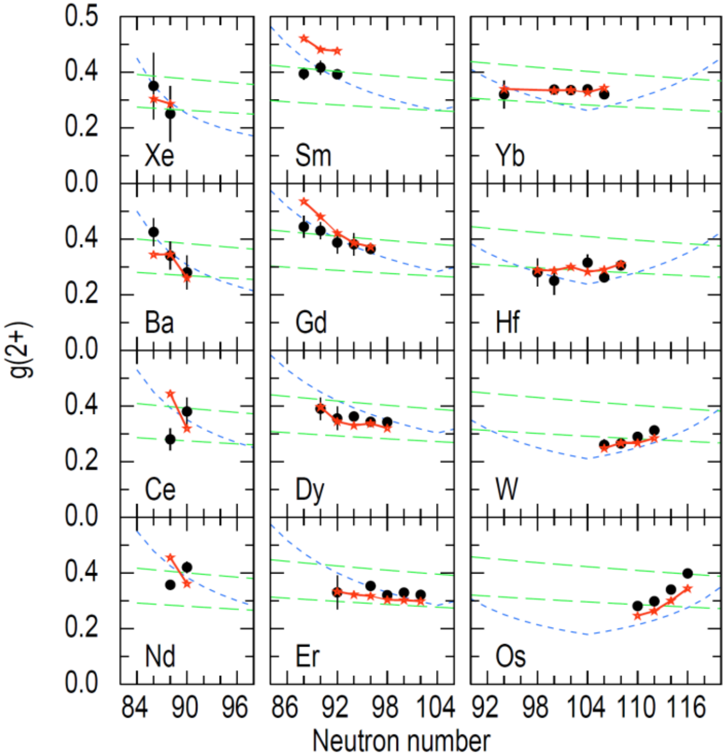
Outline

- Microscopic origins of $g(2^+)$ trends
- **g factors and collectivity in Cd isotopes**
- g factors and collectivity in Te isotopes spanning N=82
- Monopoles: E0 transitions

Nuclear Collectivity



g factor data for first 2+ states

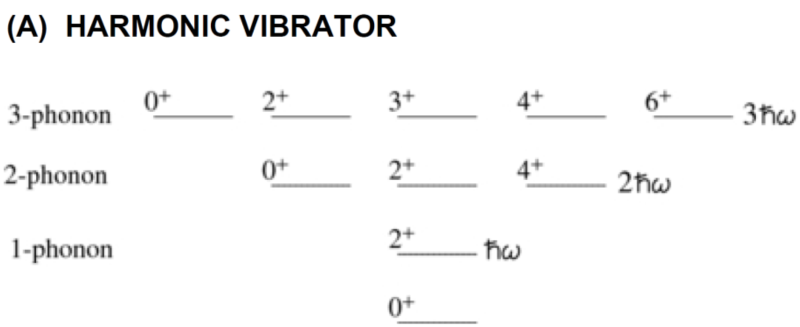


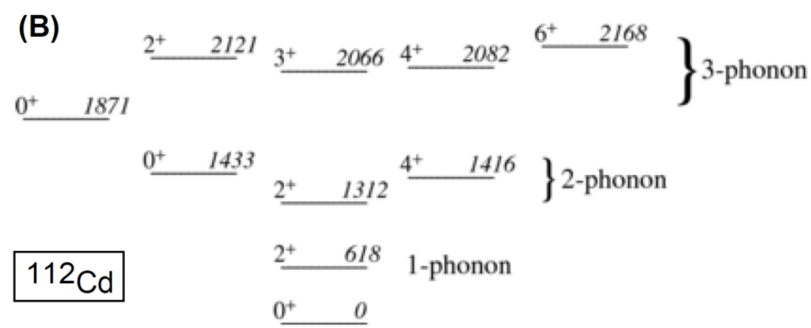
Stefan Frauendorf - Cranking model

Position of high-spin intruder within major shell determines systematics

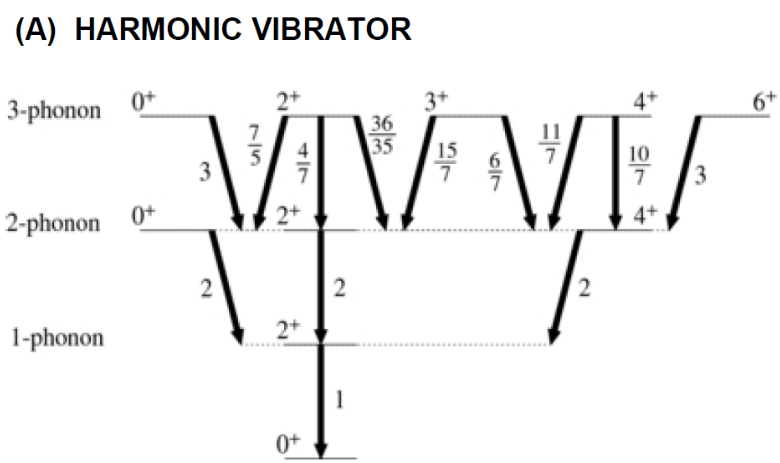
Nature of Cd isotopes

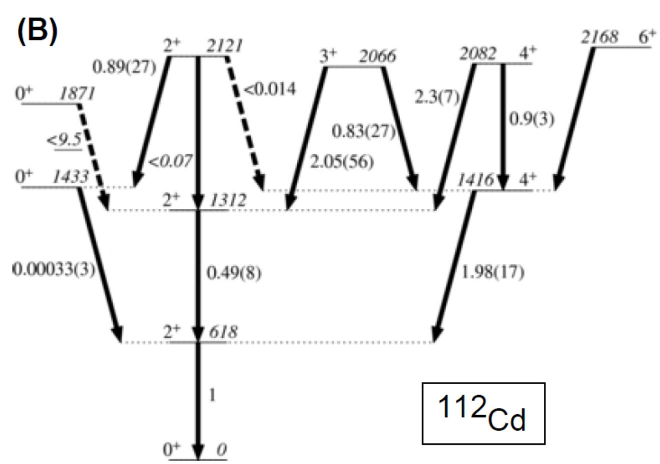
Nature of nuclear collectivity [Garrett & Wood J.Phys.G **37**,064028]





Cd isotopes: energies look vibrational but E2 strengths are not – intruder configurations





1). Do nuclei vibrate? 2). If not vibrators, then what? (γ soft rotor?)

Cd controversy & g factors

PHYSICAL REVIEW C **86**, 044304 (2012)

Detailed spectroscopy of ^{110}Cd: Evidence for weak mixing and the emergence of γ-soft behavior

P. E. Garrett,[1,2,3] J. Bangay,[1] A. Diaz Varela,[1] G. C. Ball,[2] D. S. Cross,[4] G. A. Demand,[1] P. Finlay,[1,*] A. B. Garnsworthy,[2] K. L. Green,[1] G. Hackman,[2] C. D. Hannant,[5] B. Jigmeddorj,[1] J. Jolie,[6] W. D. Kulp,[7] K. G. Leach,[1] J. N. Orce,[2,8] A. A. Phillips,[1] A. J. Radich,[1,2] E. T. Rand,[1] M. A. Schumaker,[1] C. E. Svensson,[1] C. Sumithrarachchi,[1,†] S. Triambak,[2,‡] N. Warr,[5,§] J. Wong,[1] J. L. Wood,[7] and S. W. Yates[9]

PHYSICAL REVIEW C **92**, 064309 (2015)

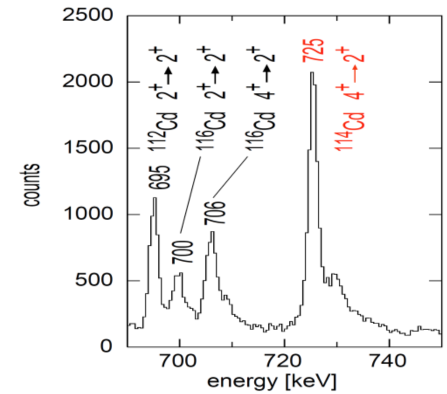
Effective field theory for nuclear vibrations with quantified uncertainties

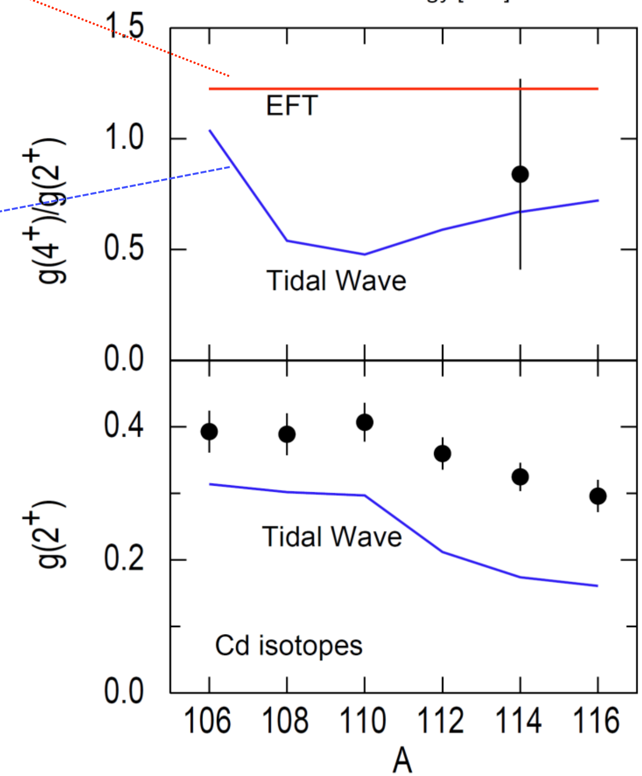
E. A. Coello Pérez[1] and T. Papenbrock[1,2]
[1]*Department of Physics and Astronomy, University of Tennessee, Knoxville, Tennessee 37996, USA*
[2]*Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA*
(Received 9 October 2015; published 14 December 2015)

PHYSICAL REVIEW C **83**, 054318 (2011)

Measured *g* factors and the tidal-wave description of transitional nuclei near *A* = 100

S. K. Chamoli,[1] A. E. Stuchbery,[1] S. Frauendorf,[2] J. Sun,[2] Y. Gu,[2] R. F. Leslie,[1] P. T. Moore,[1] A. Wakhle,[1] M. C. East,[1] T. Kibédi,[1] and A. N. Wilson[1]





Precise g(4⁺)/g(2⁺) a job for the future.

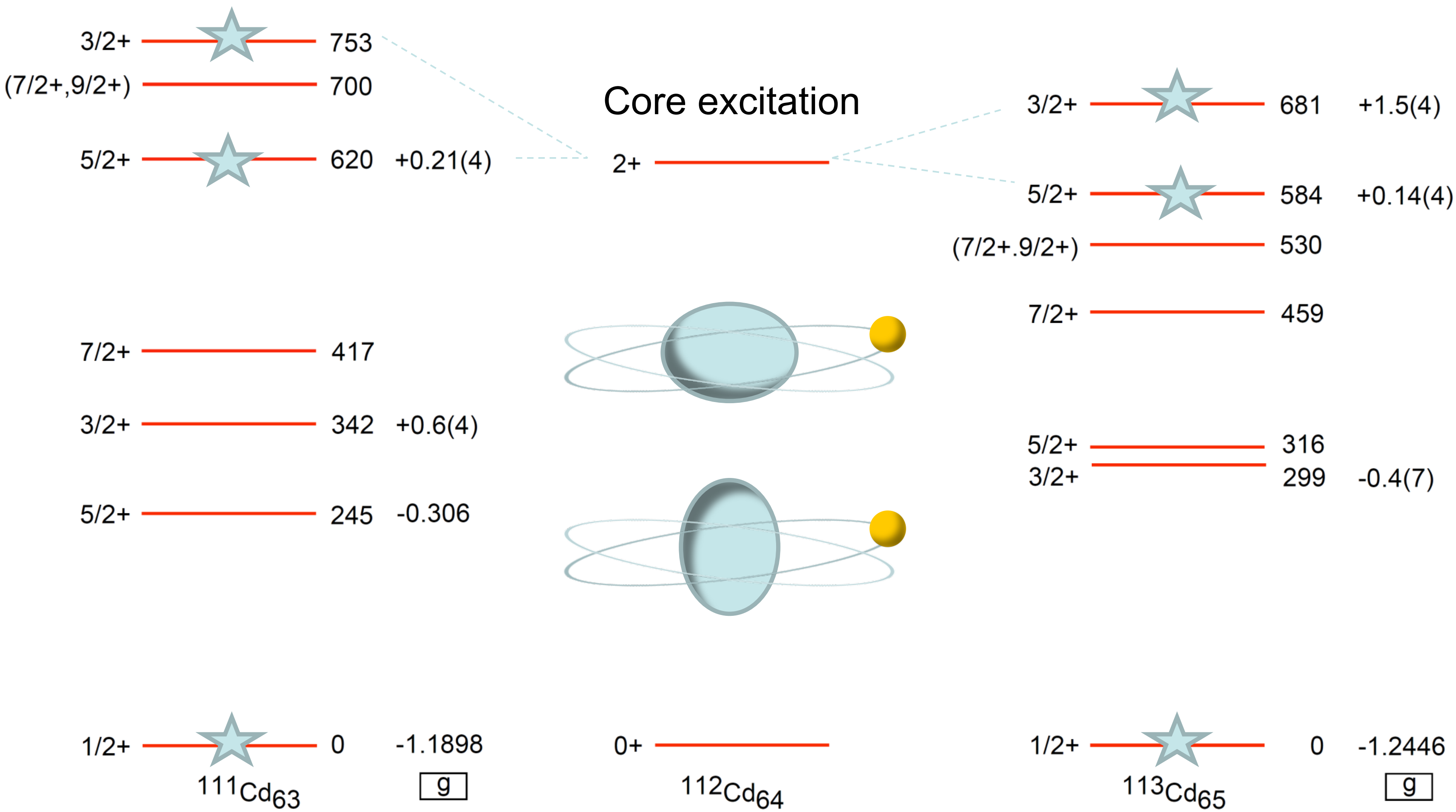
Alternatively look at the odd-A isotopes:

PHYSICAL REVIEW C **93**, 031302(R) (2016)

Particle-rotor versus particle-vibration features in *g* factors of ^{111}Cd and ^{113}Cd

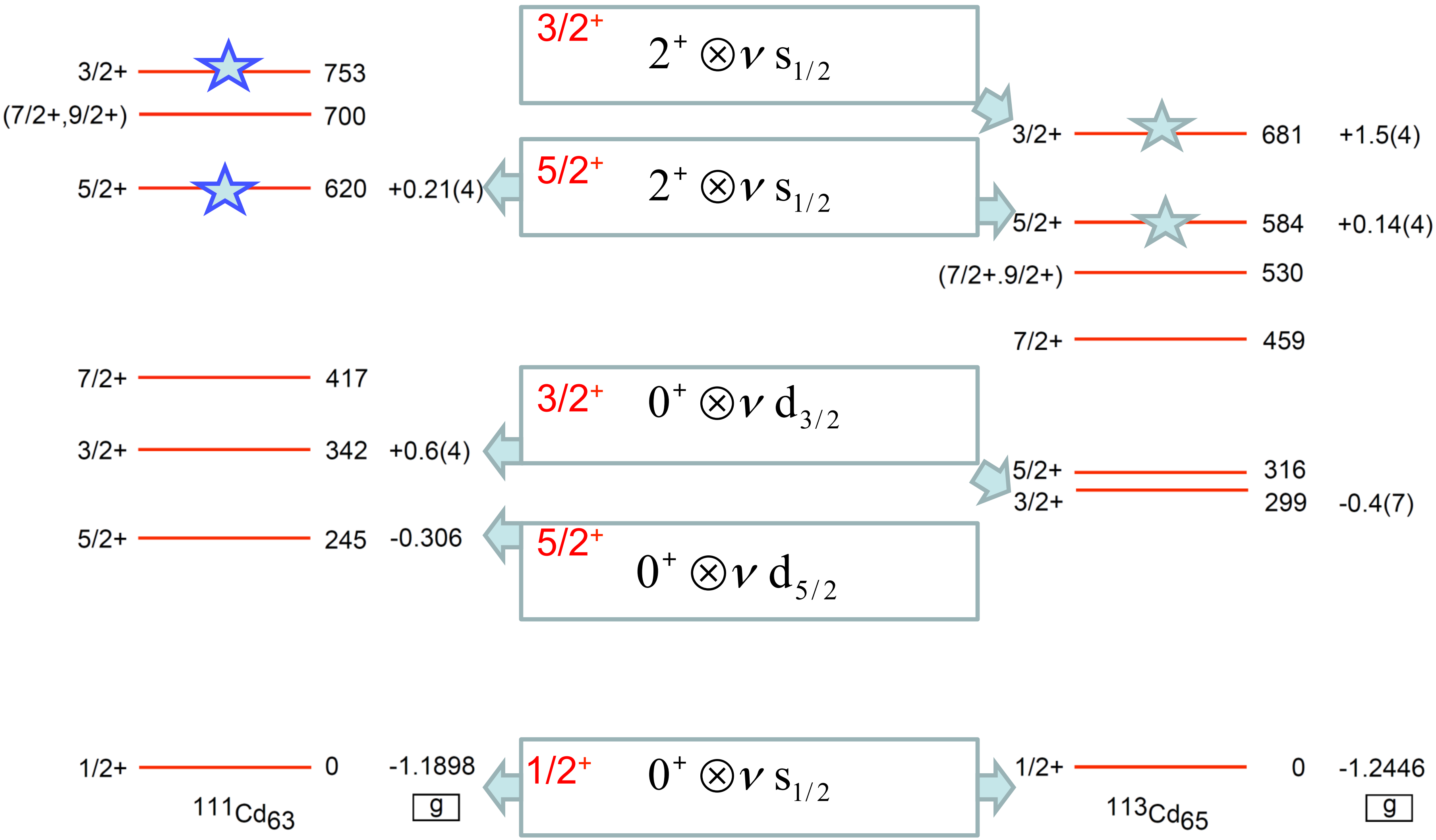
A. E. Stuchbery,[*] S. K. Chamoli,[†] and T. Kibédi

Odd-A Cd isotopes: ^{111,113}Cd

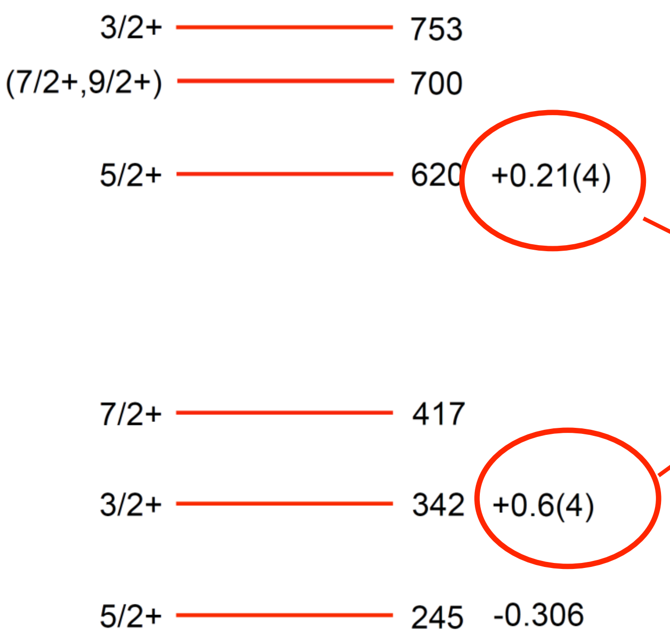


What can the odd-A isotopes tell us about the collectivity of their even cores?

Weak coupling model

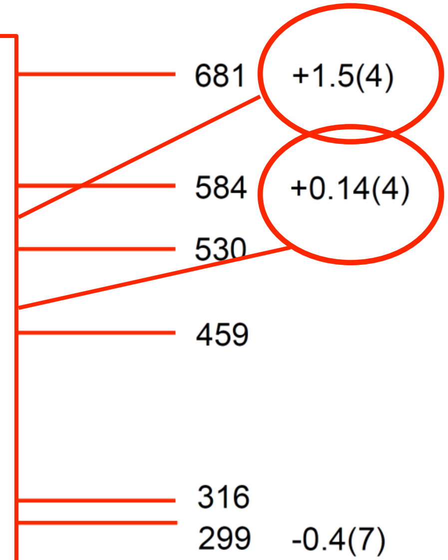


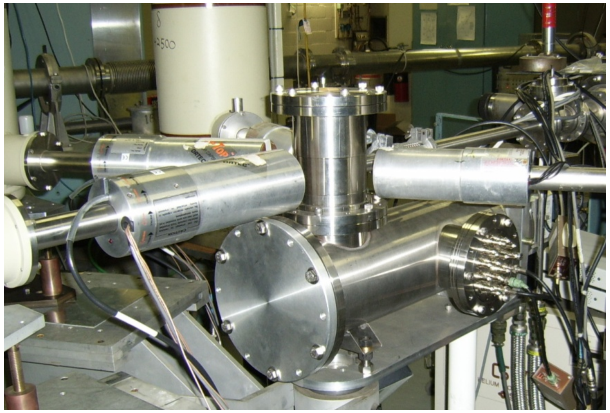
Odd-A Cd isotopes: ^{111,113}Cd

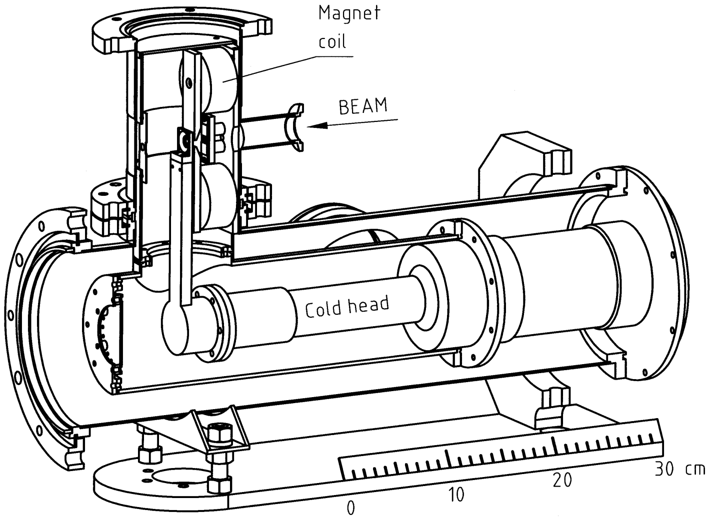


Transient-field g-factor measurements and spectroscopy after Coulomb excitation.

95 MeV ^{32}S 12.5 pnA
Natural Cd target cooled to 6K

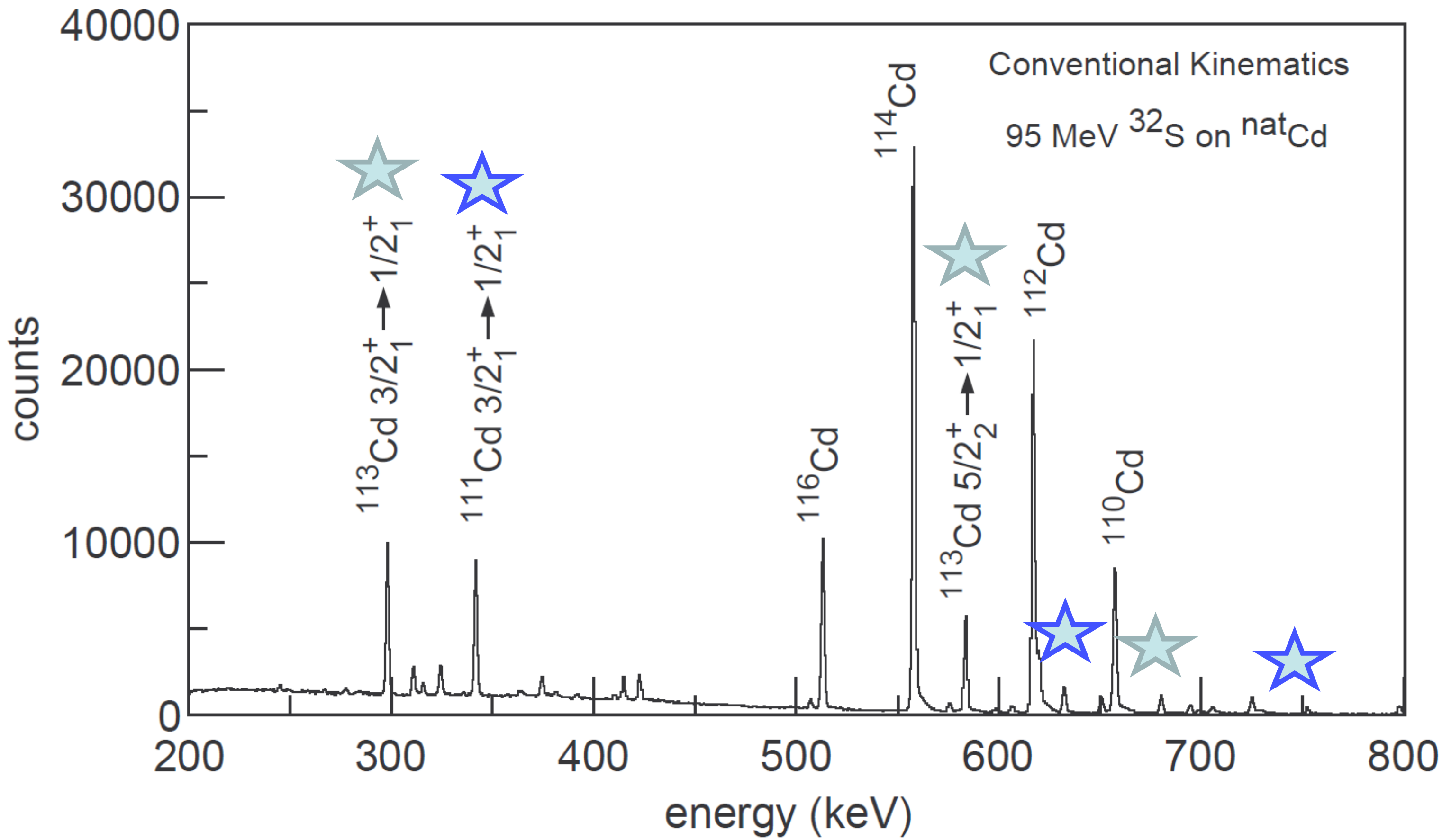






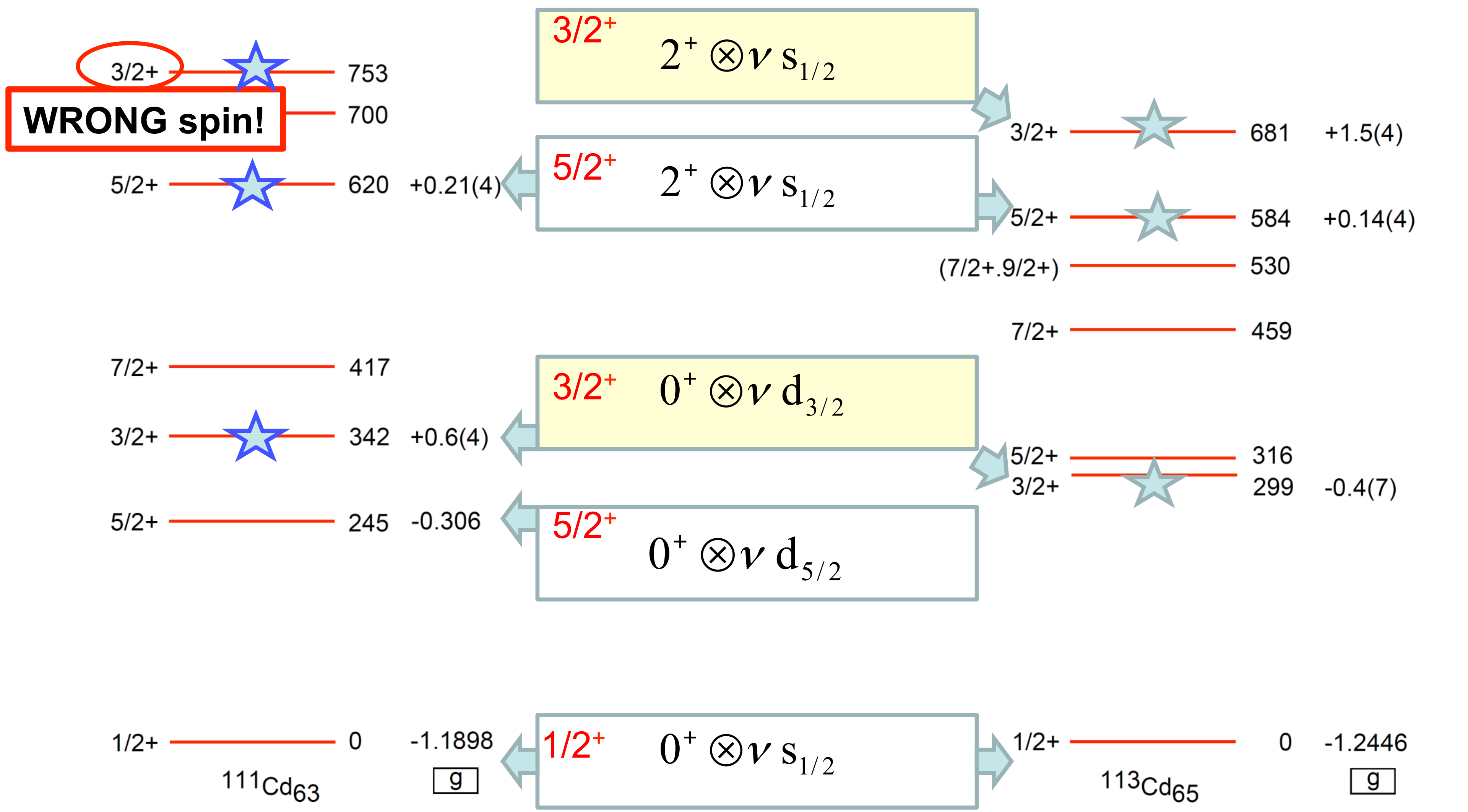
p-γ spectrum after Coulex

Natural Cd target



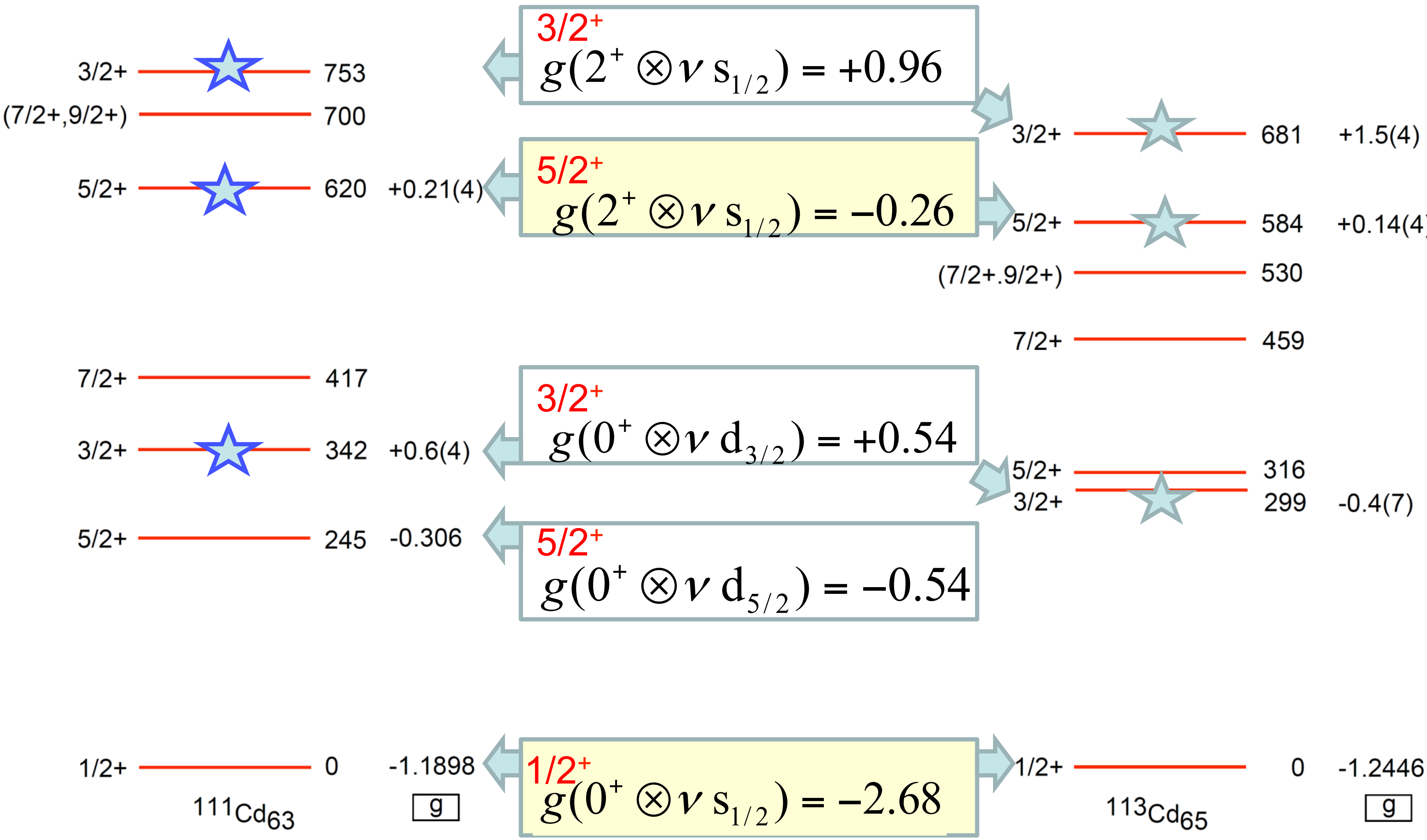
Core-coupled states are most strongly Coulomb excited

Weak coupling model



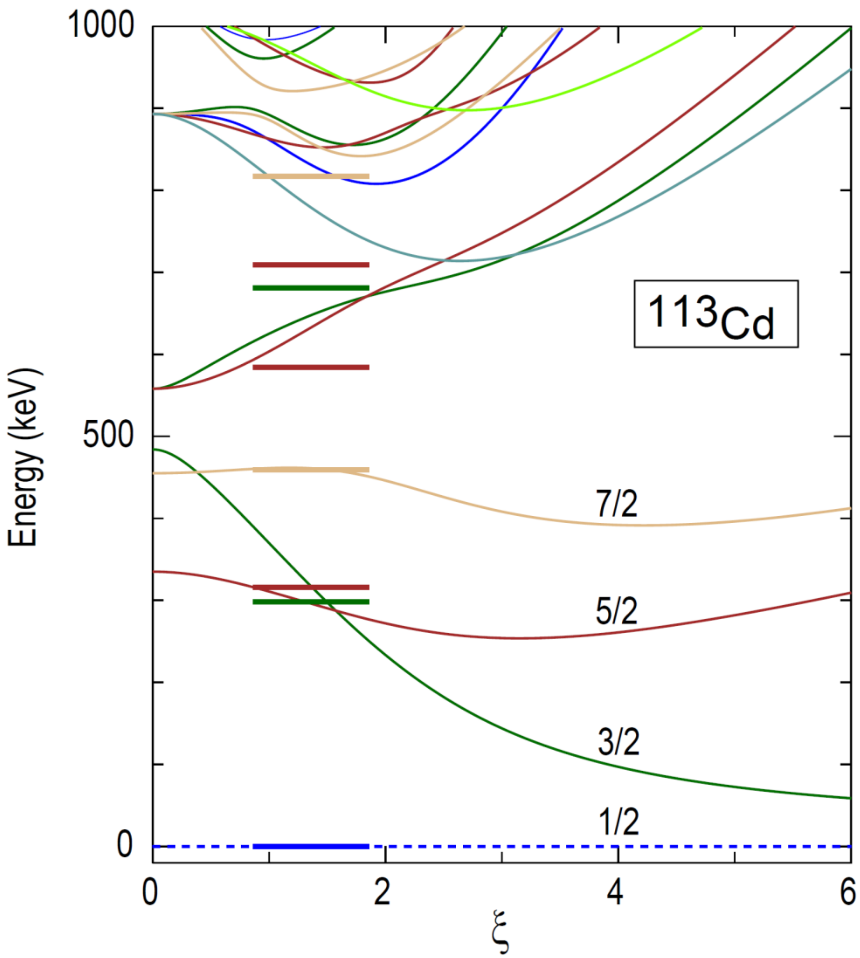
Coulex $\Rightarrow 3/2_1^+$ state must be mixed

Weak coupling model



g factors $\Rightarrow$ $1/2_1^+$ and $5/2_2^+$ states must be mixed

Particle-vibration model



Fit to energy levels in ^{113}Cd

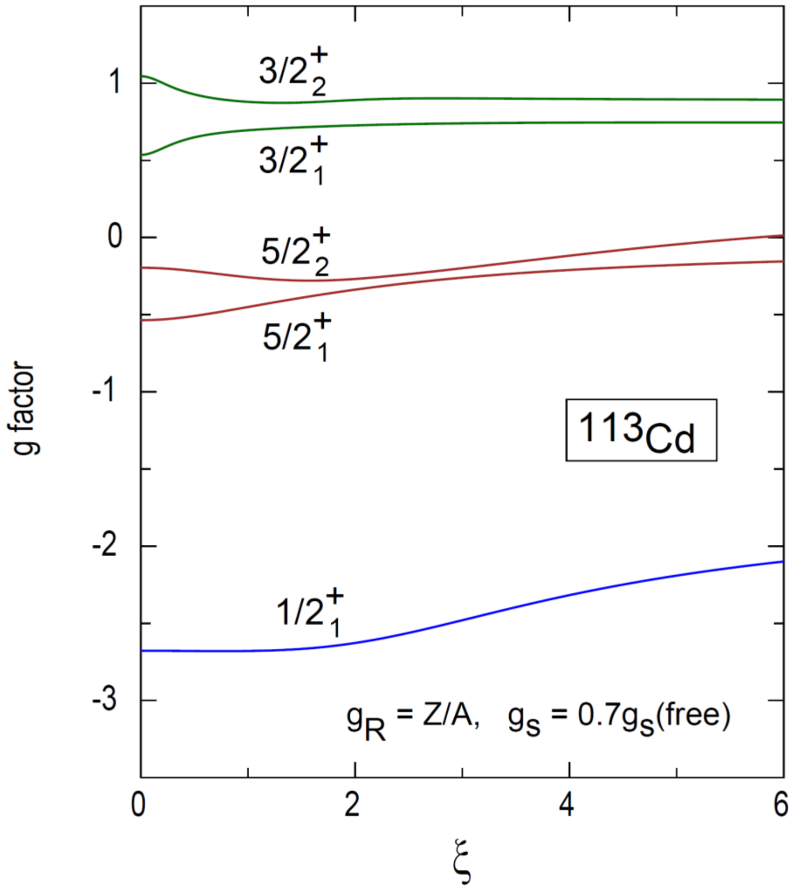
1-3 phonons $\otimes$ ν $s_{1/2}$, $d_{3/2}$, $d_{5/2}$, $g_{7/2}$

$$H = H_{\text{coll}} + H_{\text{s.p.}} + H_{\text{int}}$$

Parameter ξ determines coupling between odd nucleon and core vibration

Heyde & Brussard, NPA 104, 81 (1967)
Purrington, CPC 58, 211 (1990)

g factors & PV coupling

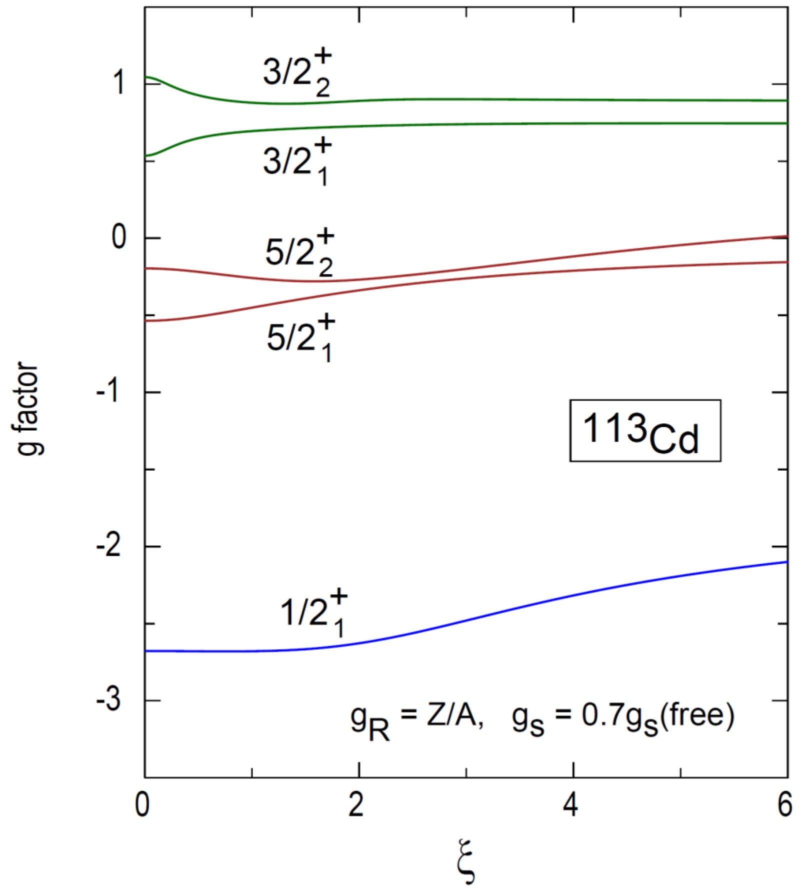


g(5/2⁺) never becomes positive

g(1/2⁺⁾ insensitive to ξ & a factor of 2 too negative

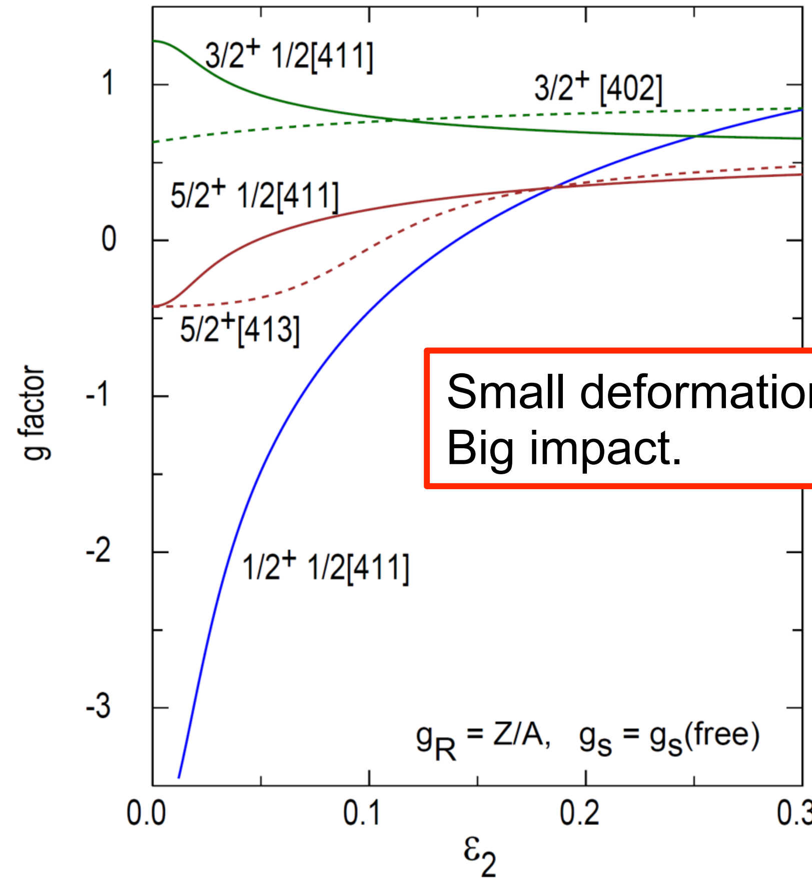
Vibration vs Rotation

Particle + vibration



PV coupling

Particle + rotor

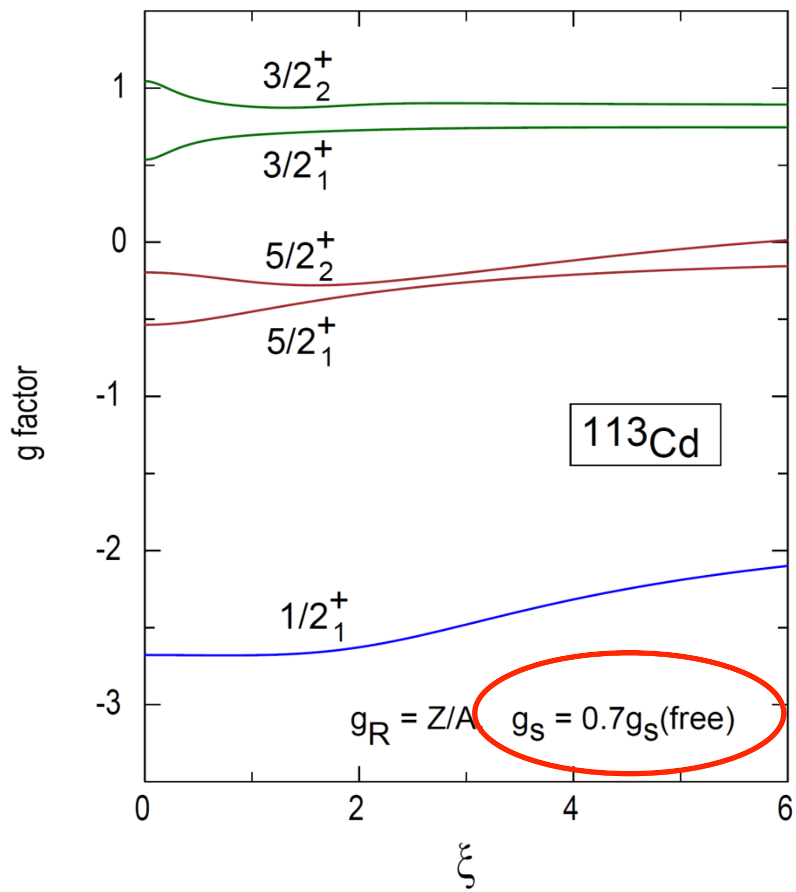


Small deformations
Big impact.

Deformation

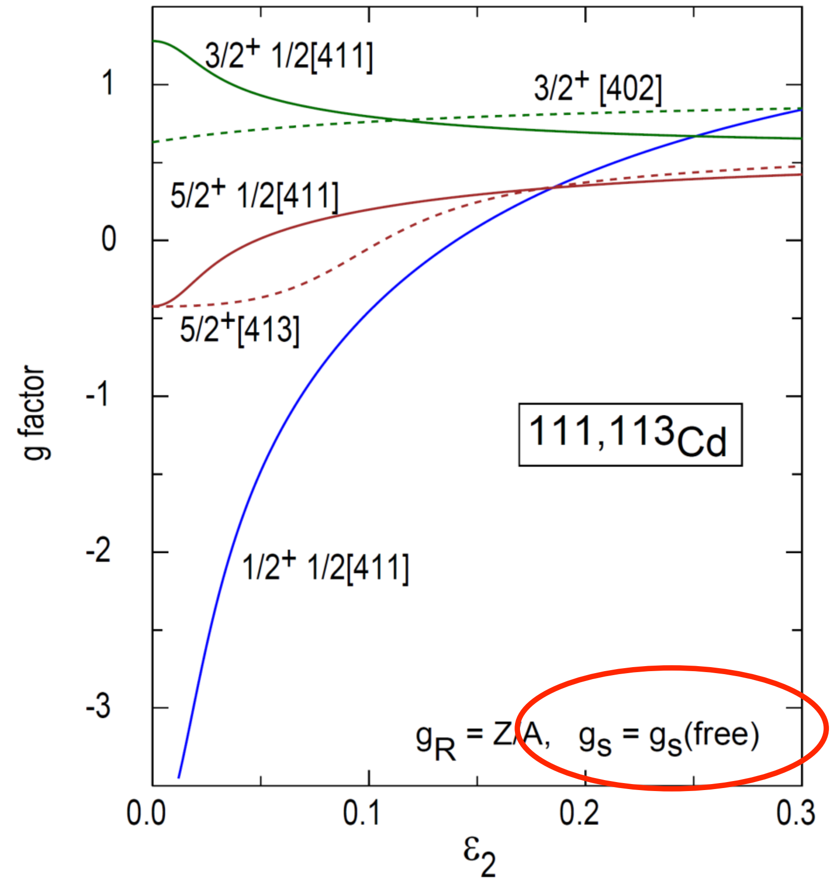
Vibration vs Rotation

Particle + vibration



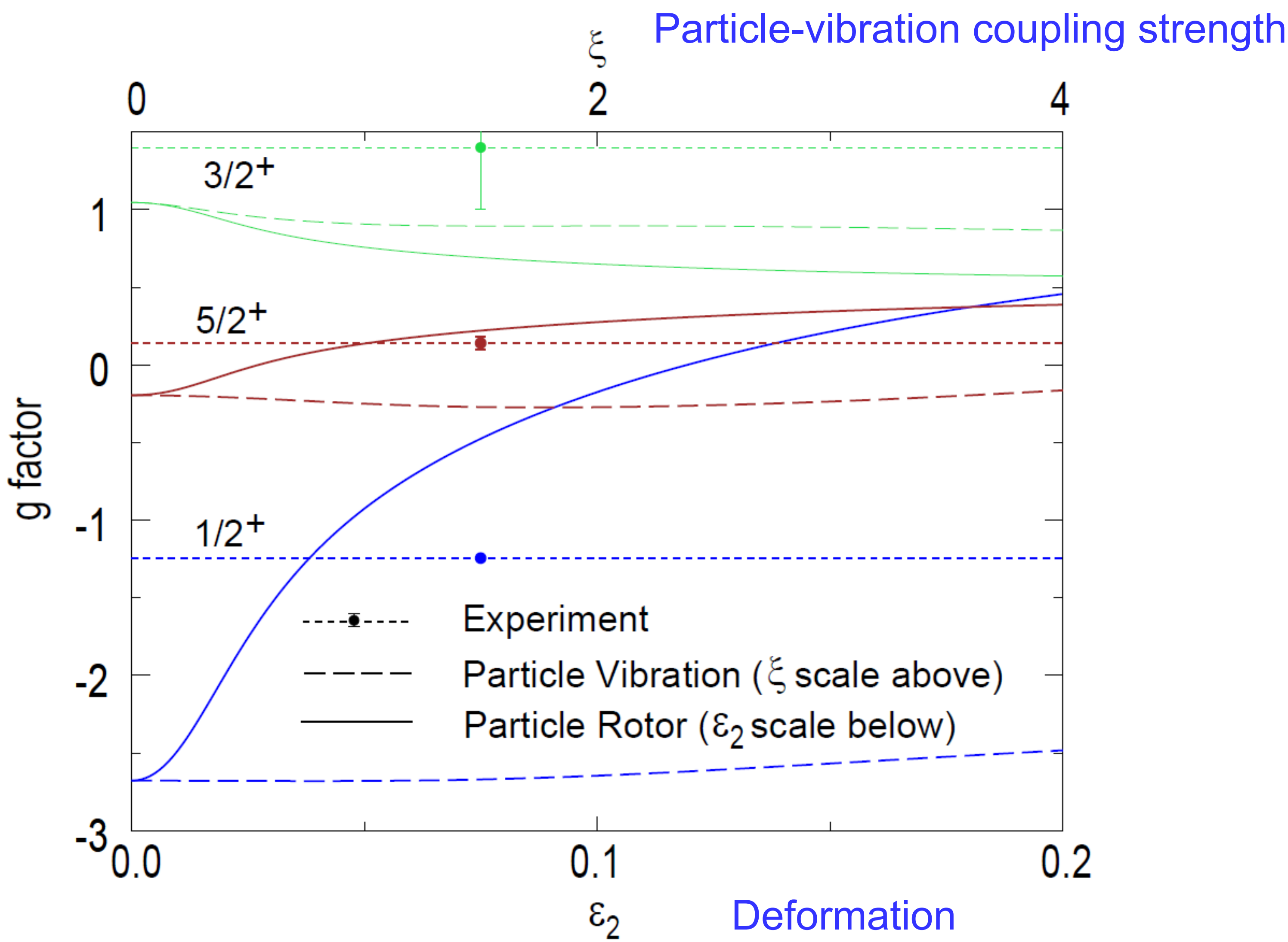
PV coupling

Particle + rotor

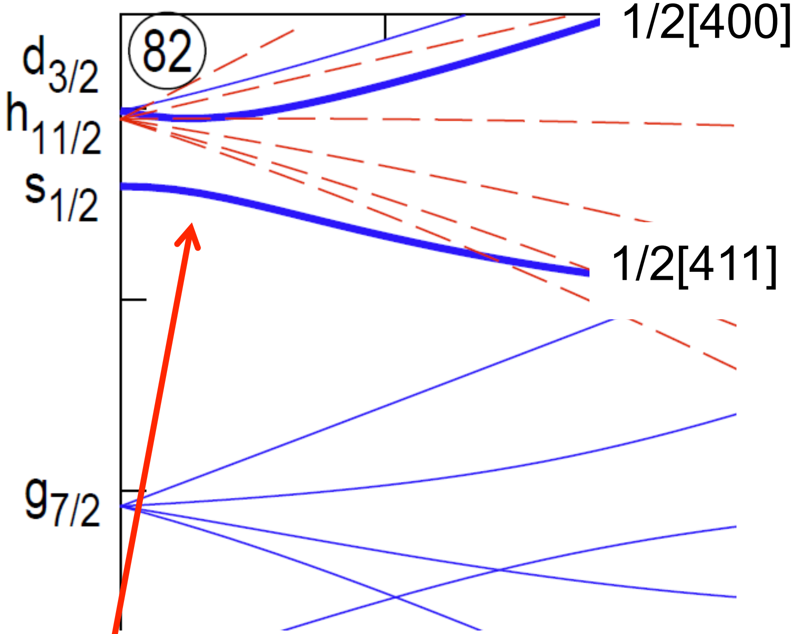


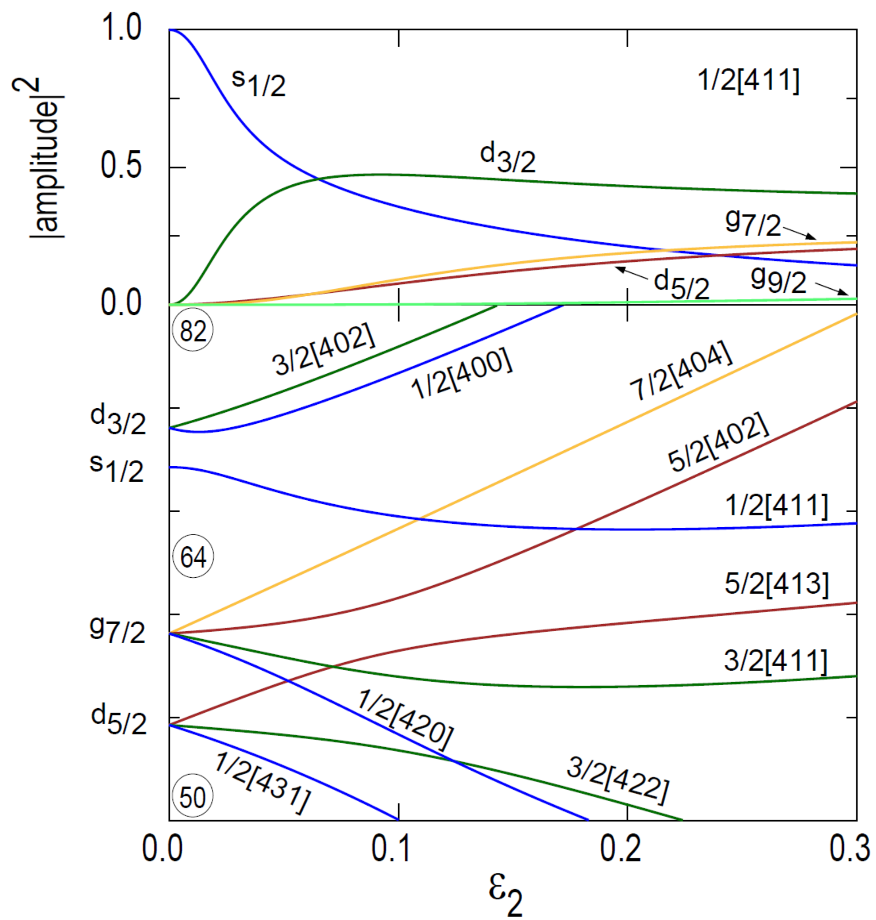
Deformation

PV & PR "start the same"!



Deformation: correct mixing





Quadrupole deformation mixes $s_{1/2}$ and $d_{3/2}$ orbits:
brings g factors into better agreement with experiment.

Further spectroscopy ^{111}Cd

5/2+	752.81	336.16 *10*	14 *3*		E_γ,I_γ: from (n,n'γ).
		410.77 *10*	37 *9*	M1+E2 -0.05 *3*	
		507.6 *3*	100 *5*		
		752.85 *10*	44 *9*	E2	
3/2+	754.9	413.0	40		I_γ: unweighted av of Iγ/Iγ(755γ) from 1968Mc04 and 1975AnYZ in Coul ex.
		509.4 *5*	50		I_γ: from β⁻ decay. Others: Iγ(509γ)/Iγ(755γ)=10 6 (^{3}He,2nγ), 1.8 (1968Mc04 in Coul ex.), and 0.98 (1975AnYZ) in Coul ex. these values are strongly affected by γ±.
		754.9 *5*	100		I_γ: see comment for Iγ(509.4γ).

This is the Coulomb excited state

Wrong energy

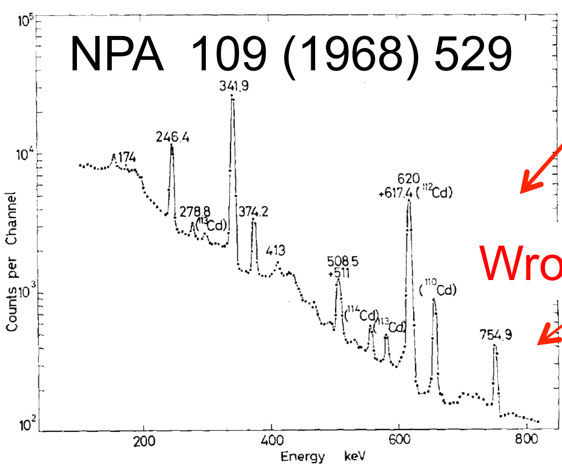
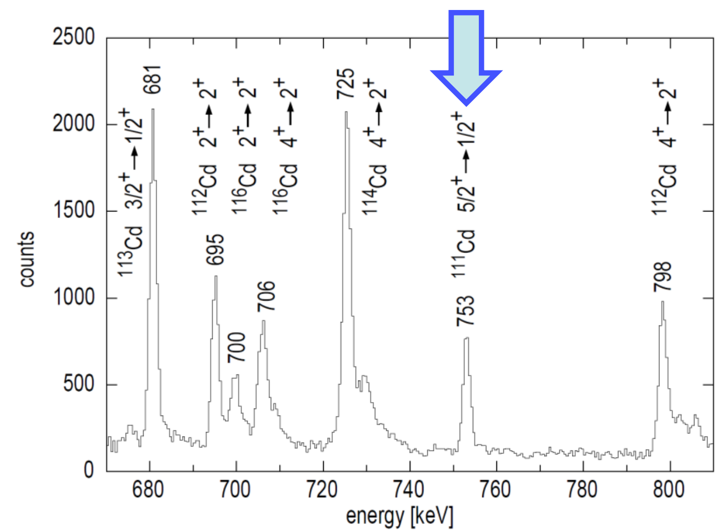
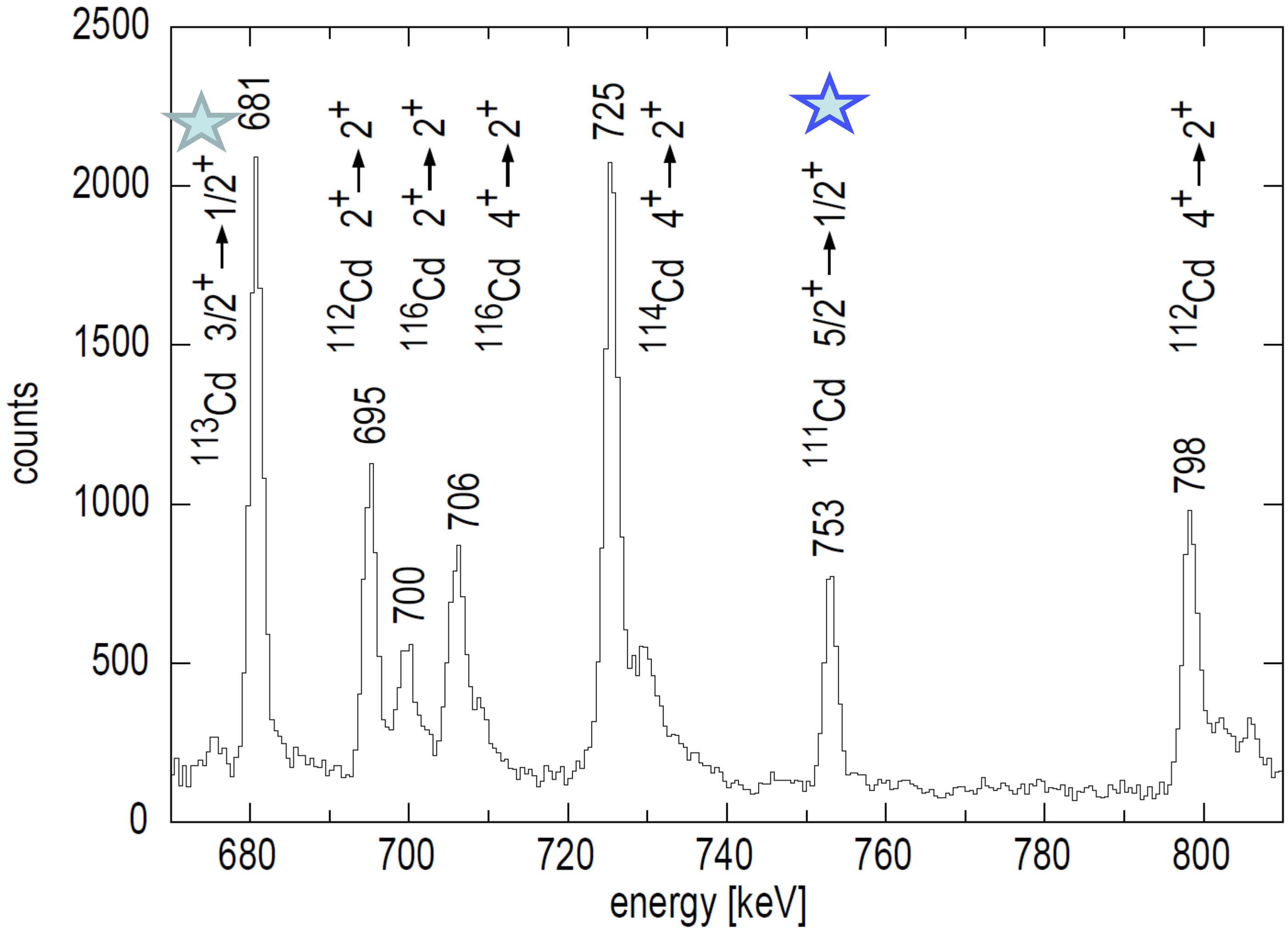


Fig. 3. Energy spectrum of gamma rays in the 24 cm³ Ge(Li) detector following Coulomb excitation of ^{111}Cd with 8 MeV α-particles.

Wrong energy

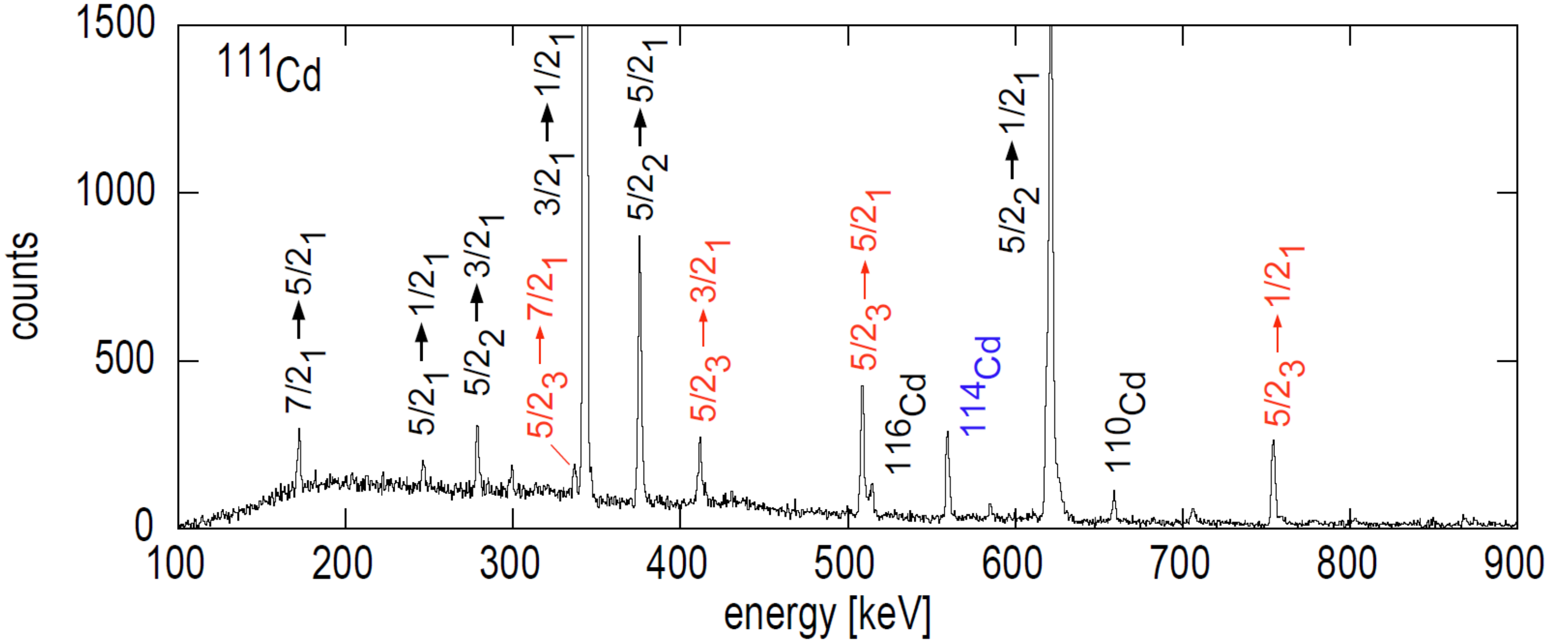


p-γ spectrum after Coulex



Further spectroscopy ^{111}Cd

NEW Transient-field g factor and angular correlation measurements ^{111}Cd target

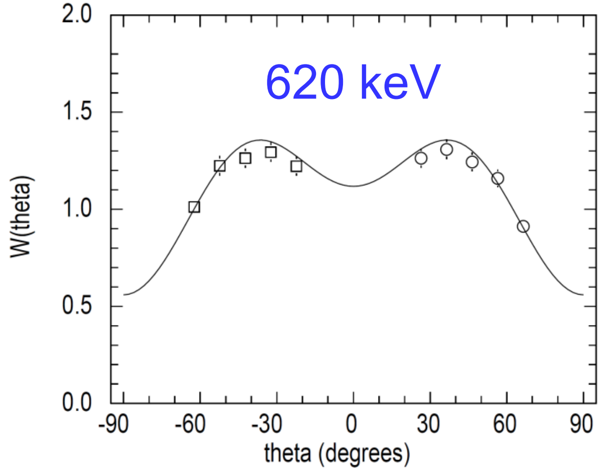


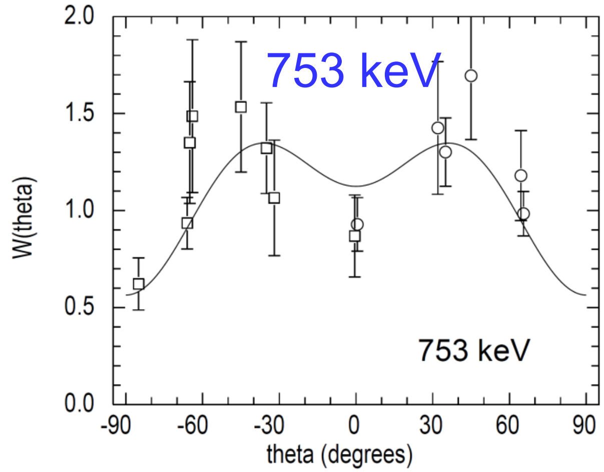
Ben Coombes (ANU Honours Project). Experiment done June 2016.

Australian National University

Further spectroscopy ^{111}Cd

$5/2^+ \rightarrow 1/2^+$ E2

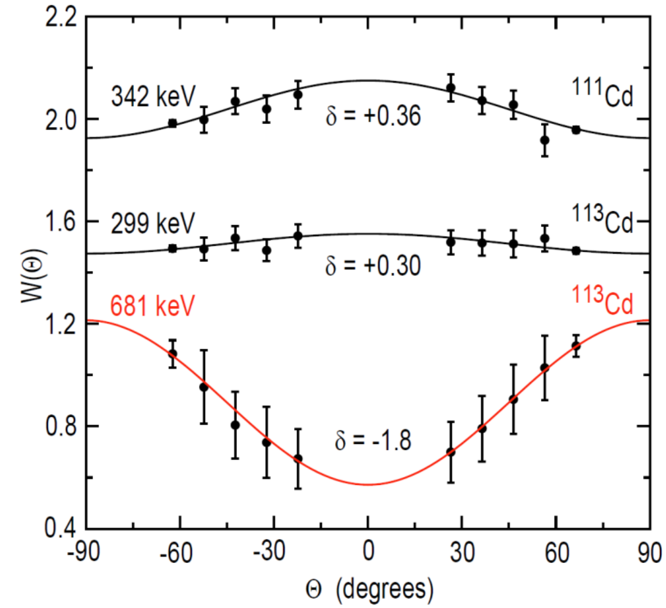




Online analysis
(Small Fraction of Data)

CONTRAST

$3/2^+ \rightarrow 1/2^+$ mixed M1/E2



The 753 keV level is $5/2^+$

ENSDF:

752.81	336.16 *10*	14 *3*		
	410.77 *10*	37 *9*	M1+E2	-0.05 *3*
	507.6 *3*	100 *5*		
	752.85 *10*	44 *9*	E2	

^{111}Cd: $5/2_{1,2,3}{}^{+}$ states

Number of basis states for Jt = 5/2 is 13:

Nc, Jc, Jp, Lp, (sp id), Jt >	Ex(keV):	205.02	588.41	784.08
	g factor:	-0.502	-0.217	-0.221

Predicted negative g factors

Nc	Jc	Jp	Lp	(sp id)	Jt				
1	2	7/2	4	(# 4)	5/2	0.055412	-0.022356	-0.005479	-0.193541
2	2	7/2	4	(# 4)	5/2	-0.001520	0.000216	-0.036944	0.170422
2	4	7/2	4	(# 4)	5/2	-0.014572	0.008535	0.055239	0.209400
2	0	5/2	2	(# 3)	5/2	0.027491	0.064907	-0.106497	-0.070984
2	2	5/2	2	(# 3)	5/2	0.020536	0.153249	0.068694	-0.047313
2	4	5/2	2	(# 3)	5/2	0.031646	0.122353	-0.116468	0.160426
0	0	5/2	2	(# 3)	5/2	0.942679	-0.252305	0.196564	0.066962
1	2	5/2	2	(# 3)	5/2	-0.177872	0.084888	0.917382	-0.087685
2	2	3/2	2	(# 2)	5/2	0.015032	0.054609	-0.026840	0.085343
1	2	3/2	2	(# 2)	5/2	-0.064757	0.024468	0.018026	0.884982
2	4	3/2	2	(# 2)	5/2	0.034944	0.135788	-0.025110	-0.112697
1	2	1/2	0	(# 1)	5/2	0.260520	0.929222	-0.021240	-0.005131
2	2	1/2	0	(# 1)	5/2	-0.027270	0.020546	0.289091	0.203123

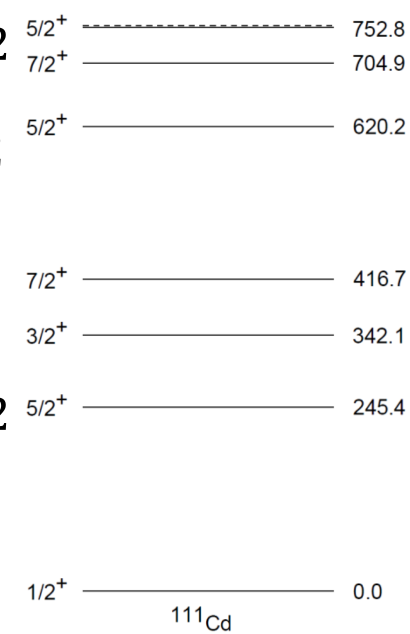
13 states of spin 5/2:

Ex (keV)	Number	g	mu (N.M.)	Q (e.b.)
1690.299	20	0.401	1.001	0.045
1675.229	21	0.387	0.968	-0.043
1620.016	22	0.346	0.864	0.051
1578.792	23	0.318	0.795	0.032
1437.218	24	0.327	0.817	0.109
1418.983	25	-0.200	-0.500	0.144
1405.683	26	-0.251	-0.627	0.002
1244.327	27	-0.207	-0.517	-0.047
979.681	28	0.303	0.759	-0.046
971.438	29	0.484	1.211	-0.037
784.082	30	-0.221	-0.553	0.008
588.405	31	-0.217	-0.542	0.011
205.023	32	-0.502	-1.255	-0.230

Mainly $2\uparrow+ \otimes d\downarrow 5/2$

Mainly $2\uparrow+ \otimes s\downarrow 1/2$

Mainly $0\uparrow+ \otimes d\downarrow 5/2$



Particle-vibration model calculations

- **Can explain 3 Coulomb-excited $5/2^+$ states**

^{111}Cd: $5/2_{1,2,3}^{+}$ states

Number of basis states for Jt = 5/2 is 13:

Nc,	Jc,	Jp,	Lp,	(sp id),	Jt >				
						Ex(keV):	205.02	588.41	784.08
						g factor:	-0.502	-0.217	-0.221
1	2	7/2	4	(# 4)	5/2		0.055412	-0.022356	-0.005479
2	2	7/2	4	(# 4)	5/2		-0.001520	0.000216	-0.036944
2	4	7/2	4	(# 4)	5/2		-0.014572	0.008535	0.055239
2	0	5/2	2	(# 3)	5/2		0.027491	0.064907	-0.106497
2	2	5/2	2	(# 3)	5/2		0.020536	0.153249	0.068694
2	4	5/2	2	(# 3)	5/2		0.031646	0.122353	-0.116468
0	0	5/2	2	(# 3)	5/2		0.942679	-0.252305	0.196564
1	2	5/2	2	(# 3)	5/2		-0.177872	0.084888	0.917382
2	2	3/2	2	(# 2)	5/2		0.015032	0.054609	-0.026840	0.085343
1	2	3/2	2	(# 2)	5/2		-0.064757	0.024468	0.018026	0.884982
2	4	3/2	2	(# 2)	5/2		0.034944	0.135788	-0.025110	-0.112697
1	2	1/2	0	(# 1)	5/2		0.260520	0.929222	-0.021240	-0.005131
2	2	1/2	0	(# 1)	5/2		-0.027270	0.020546	0.289091	0.203123

Predicted negative g factors

Preliminary result:

$g(5/2^{+}_{3}) > 0$ [≈ +0.46(16)]

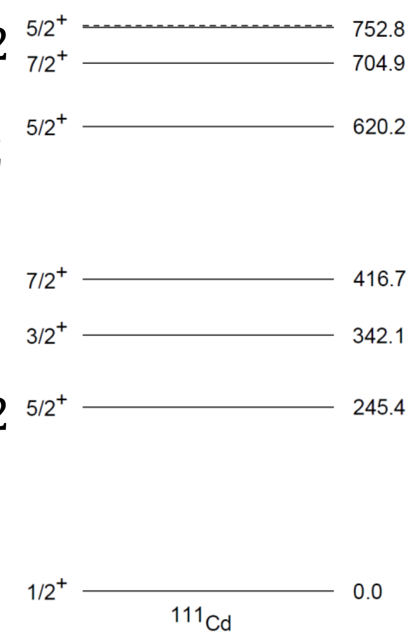
13 states of spin 5/2:

Ex (keV)	Number	g	mu (N.M.)	Q (e.b.)
1690.299	20	0.401	1.001	0.045
1675.229	21	0.387	0.968	-0.043
1620.016	22	0.346	0.864	0.051
1578.792	23	0.318	0.795	0.032
1437.218	24	0.327	0.817	0.109
1418.983	25	-0.200	-0.500	0.144
1405.683	26	-0.251	-0.627	0.002
1244.327	27	-0.207	-0.517	-0.047
979.681	28	0.303	0.759	-0.046
971.438	29	0.484	1.211	-0.037
784.082	30	-0.221	-0.553	0.008
588.405	31	-0.217	-0.542	0.011
205.023	32	-0.502	-1.255	-0.230

Mainly $2{\uparrow}+ \otimes d{\downarrow}5/2$

Mainly $2{\uparrow}+ \otimes s{\downarrow}1/2$

Mainly $0{\uparrow}+ \otimes d{\downarrow}5/2$



Particle-vibration model calculations

- **Can explain 3 Coulomb-excited $5/2^{+}$ states**

^{111}Cd: $3/2_1^+$ state

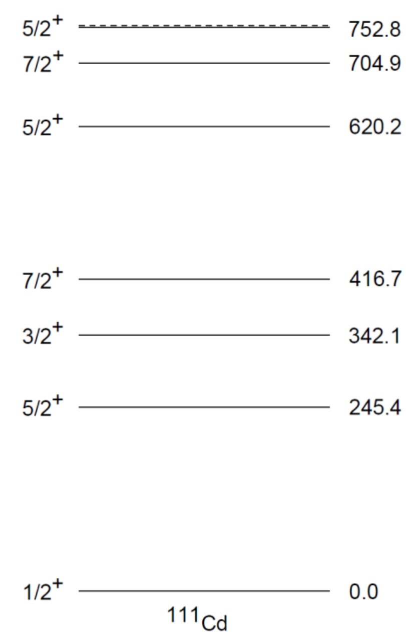
Number of basis states for Jt = 3/2 is 12:

| Nc,	Jc,	Jp,	Lp,	(sp id),	Jt >					
						Ex(keV):	371.42	609.92	808.08	953.59	1006.44
						g factor:	0.635	0.935	-0.302	0.393	
1	2	7/2	4	(# 4)	3/2		0.235577	0.152159	-0.105608	0.142747	0.903242
2	2	7/2	4	(# 4)	3/2		-0.034806	-0.028848	-0.028451	0.040324	-0.202877
2	4	7/2	4	(# 4)	3/2		-0.023430	-0.018154	0.046439	0.251317	-0.061923
1	2	5/2	2	(# 3)	3/2		0.138675	0.110605	0.951678	0.109582	0.026423
2	2	5/2	2	(# 3)	3/2		-0.041503	0.078101	-0.074904	-0.130463	-0.079203
2	4	5/2	2	(# 3)	3/2		-0.097703	0.196817	-0.065241	0.096741	-0.019460
2	2	3/2	2	(# 2)	3/2		0.046713	-0.097513	-0.068574	0.001926	0.077458
0	0	3/2	2	(# 2)	3/2		0.826741	0.415732	-0.159808	0.122910	-0.308607
1	2	3/2	2	(# 2)	3/2		-0.144424	-0.093591	-0.007772	0.843800	-0.061222
2	0	3/2	2	(# 2)	3/2		0.053885	-0.027618	0.037286	-0.051304	0.155931
2	2	1/2	0	(# 1)	3/2		0.034296	0.034055	0.195523	-0.383010	0.049816
1	2	1/2	0	(# 1)	3/2		-0.449024	0.851817	-0.020056	0.003197	-0.005386

12 states of spin 3/2:

Ex (keV)	Number	g	mu (N.M.)	Q (e.b.)
1703.500	8	0.487	0.731	0.230
1655.871	9	0.519	0.779	0.014
1628.182	10	0.427	0.641	-0.109
1591.724	11	0.232	0.348	0.002
1450.704	12	1.077	1.615	0.051
1410.800	13	-0.186	-0.280	-0.024
1255.009	14	0.985	1.478	-0.045
1006.442	15	0.248	0.372	-0.104
953.594	16	0.393	0.590	0.129
808.077	17	-0.302	-0.454	0.001
609.920	18	0.935	1.403	0.003
371.417	19	0.635	0.952	-0.148

Mainly $0^{+} \otimes d_{3/2}$



Particle-vibration model calculations

- **Predict 2 Coulomb-excited $3/2^+$ states**

^{111}Cd: No $3/2_2^+$ state?

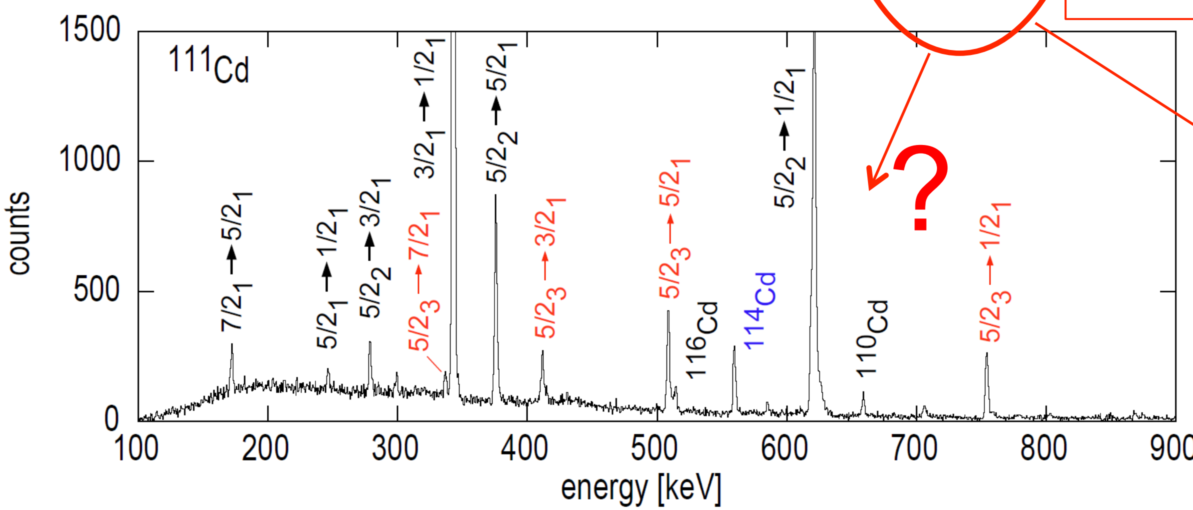
Number of basis states for Jt = 3/2 is 12:

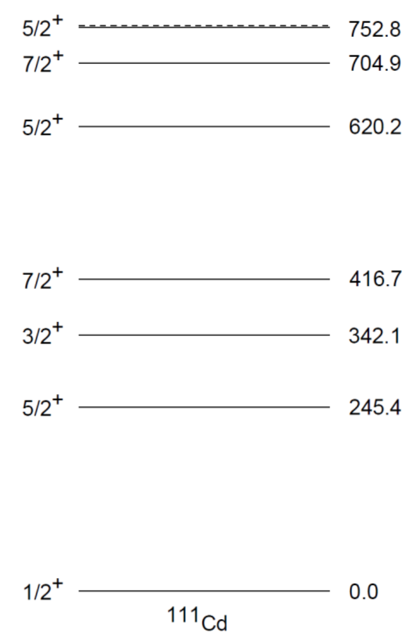
Nc	Jc	Jp	Lp	(sp id)	Jt					
					Ex(keV):	371.42	609.92	808.08	953.59	1006.44
					g factor:	0.635	0.935	-0.302	0.393	
1	2	7/2	4	(# 4)	3/2	0.235577	0.152159	-0.105608	0.142747	0.903242
2	2	7/2	4	(# 4)	3/2	-0.034806	-0.028848	-0.028451	0.040324	-0.202877
2	4	7/2	4	(# 4)	3/2	-0.023430	-0.018154	0.046439	0.251317	-0.061923
1	2	5/2	2	(# 3)	3/2	0.138675	0.110605	0.951678	0.109582	0.026423
2	2	5/2	2	(# 3)	3/2	-0.041503	0.078101	-0.074904	-0.130463	-0.079203
2	4	5/2	2	(# 3)	3/2	-0.097703	0.196817	-0.065241	0.096741	-0.019460
2	2	3/2	2	(# 2)	3/2	0.046713	-0.097513	-0.068574	0.001926	0.077458
0	0	3/2	2	(# 2)	3/2	0.826741	0.415732	-0.159808	0.122910	-0.308607
1	2	3/2	2	(# 2)	3/2	-0.144424	-0.093591	-0.007772	0.843800	-0.061222
2	0	3/2	2	(# 2)	3/2	0.053885	-0.027618	0.037286	-0.051304	0.155931
2	2	1/2	0	(# 1)	3/2	0.034296	0.034055	[illegible]	[illegible]	[illegible]9816
1	2	1/2	0	(# 1)	3/2	-0.449024	0.851817	[illegible]	[illegible]	[illegible]386

Mainly $2_1^+ \otimes s_{1/2}$

?

?





Particle-vibration model calculations

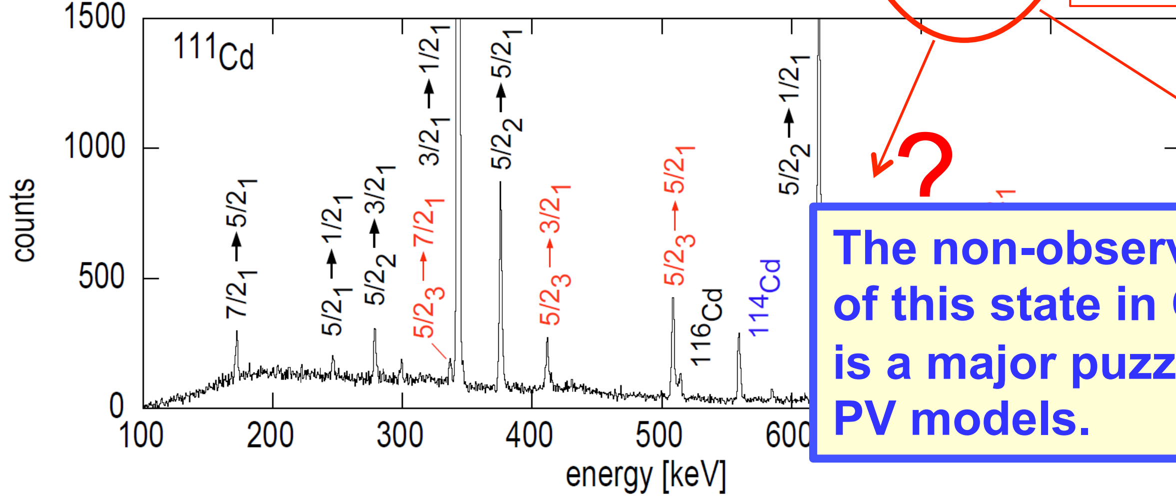
- **Where is the second $3/2^+$ state?**

^{111}Cd: No $3/2_2^+$ state?

Number of basis states for Jt = 3/2 is 12:

| Nc,	Jc,	Jp,	Lp,	(sp id),	Jt >					
						Ex(keV):	371.42	609.92	808.08	953.59	1006.44
						g factor:	0.635	0.935	-0.302	0.393	
1	2	7/2	4	(# 4)	3/2		0.235577	0.152159	-0.105608	0.142747	0.903242
2	2	7/2	4	(# 4)	3/2		-0.034805	-0.028848	-0.028451	0.040324	-0.202877
2	4	7/2	4	(# 4)	3/2		-0.023430	-0.018154	0.046439	0.251317	-0.061923
1	2	5/2	2	(# 3)	3/2		0.138675	0.110605	0.951678	0.109582	0.026423
2	2	5/2	2	(# 3)	3/2		-0.041503	0.078101	-0.074904	-0.130463	-0.079203
2	4	5/2	2	(# 3)	3/2		-0.097703	0.196817	-0.065241	0.096741	-0.019460
2	2	3/2	2	(# 2)	3/2		0.046713	-0.097513	-0.068574	0.001926	0.077458
0	0	3/2	2	(# 2)	3/2		0.826741	0.415732	-0.159808	0.122910	-0.308607
1	2	3/2	2	(# 2)	3/2		-0.144424	-0.093591	-0.007772	0.843800	-0.061222
2	0	3/2	2	(# 2)	3/2		0.053885	-0.027618	0.037286	-0.051304	0.155931
2	2	1/2	0	(# 1)	3/2		0.034296	0.034055	[illegible]	[illegible]	[illegible]9816
1	2	1/2	0	(# 1)	3/2		-0.449024	0.851817	[illegible]	[illegible]	[illegible]386

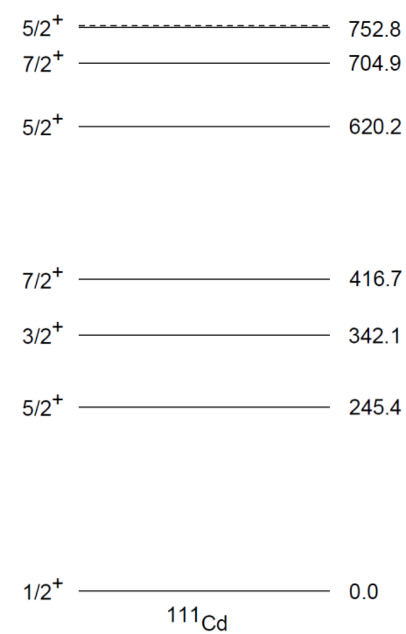
Mainly $2^{+}_{\uparrow} \otimes s_{\downarrow 1/2}$



?

?

The non-observation of this state in Coulex is a major puzzle for PV models.



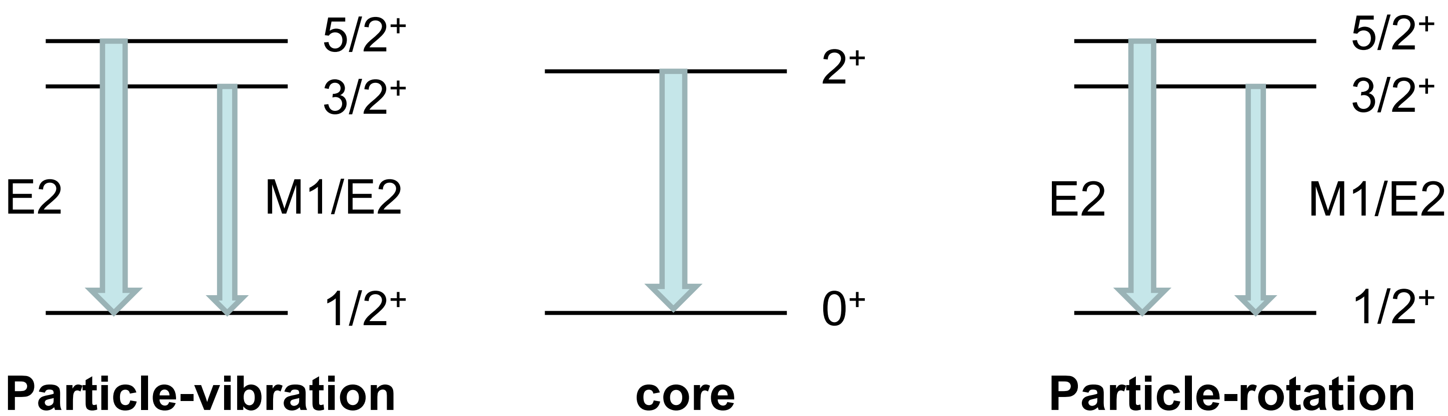
Particle-vibration model calculations

- Where is the second $3/2^+$ state?

Odd-A Cd & Collectivity

g factors and the core collectivity:

- ✓ Sensitive to the nature of the core collectivity in ways E2 rates are not



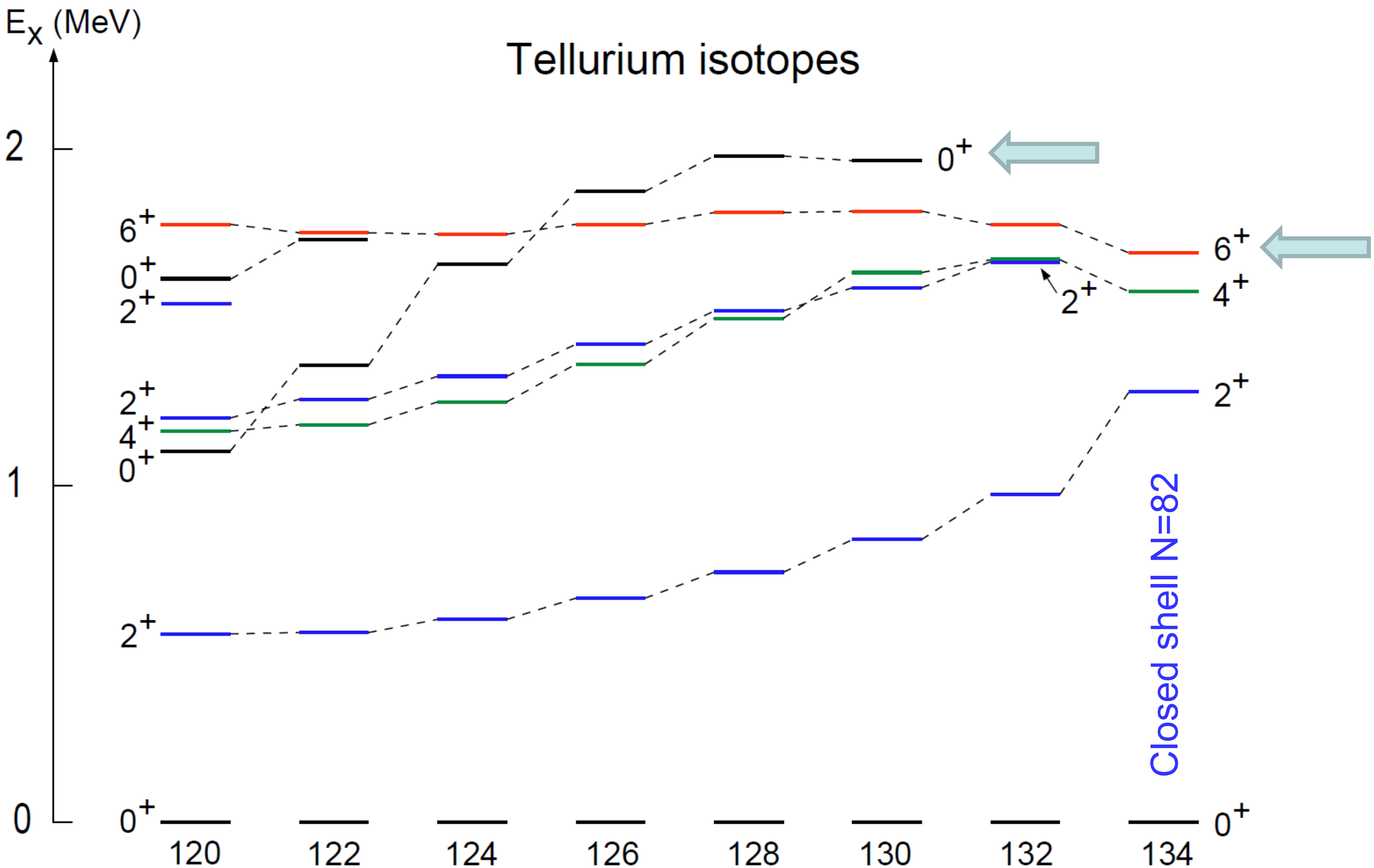
$B(E2: 3/2\rightarrow 1/2)\ / B(E2: 5/2\rightarrow 1/2)$ Same for PV and PR cases

Odd-A Cd & Collectivity

g factors and the core collectivity:

- ✓ Sensitive to the nature of the core collectivity in ways E2 rates are not
- ✓ Particle-vibration and particle-rotor models reduce to same limit for j=1/2 orbits
- ✓ Deformation mixes $s_{1/2}$ with $d_{3/2}$, particle-vibration coupling mixes $d_{5/2}$
- ✓ Must consider M1 observables along with E2 in mapping the path to collectivity

Emerging nuclear collectivity



Shape coexistence in the even-Hg isotopes:

NOTE characteristic *parabolic energy* trend

Slide from John Wood

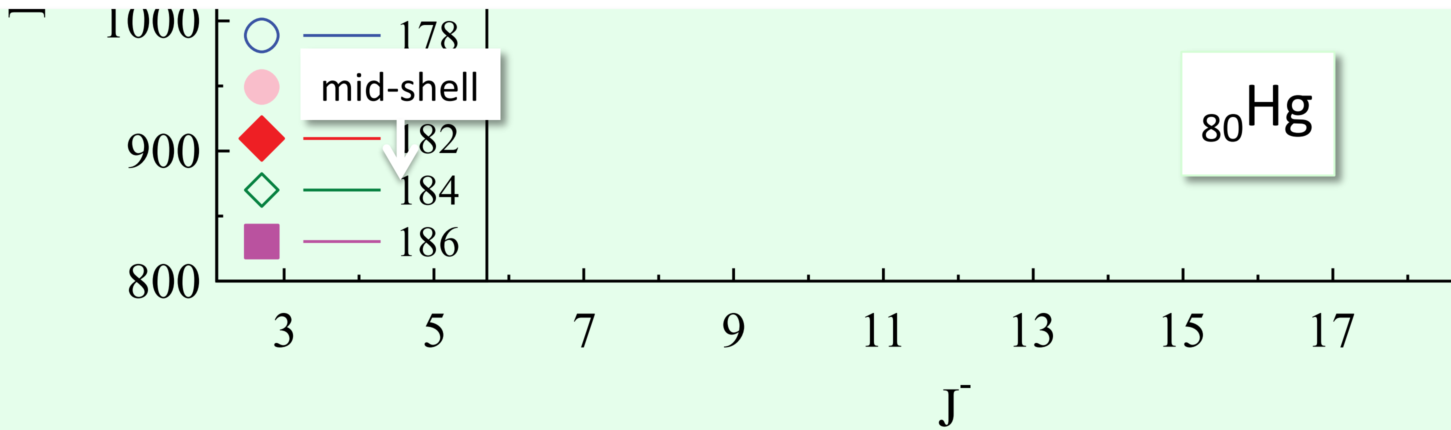
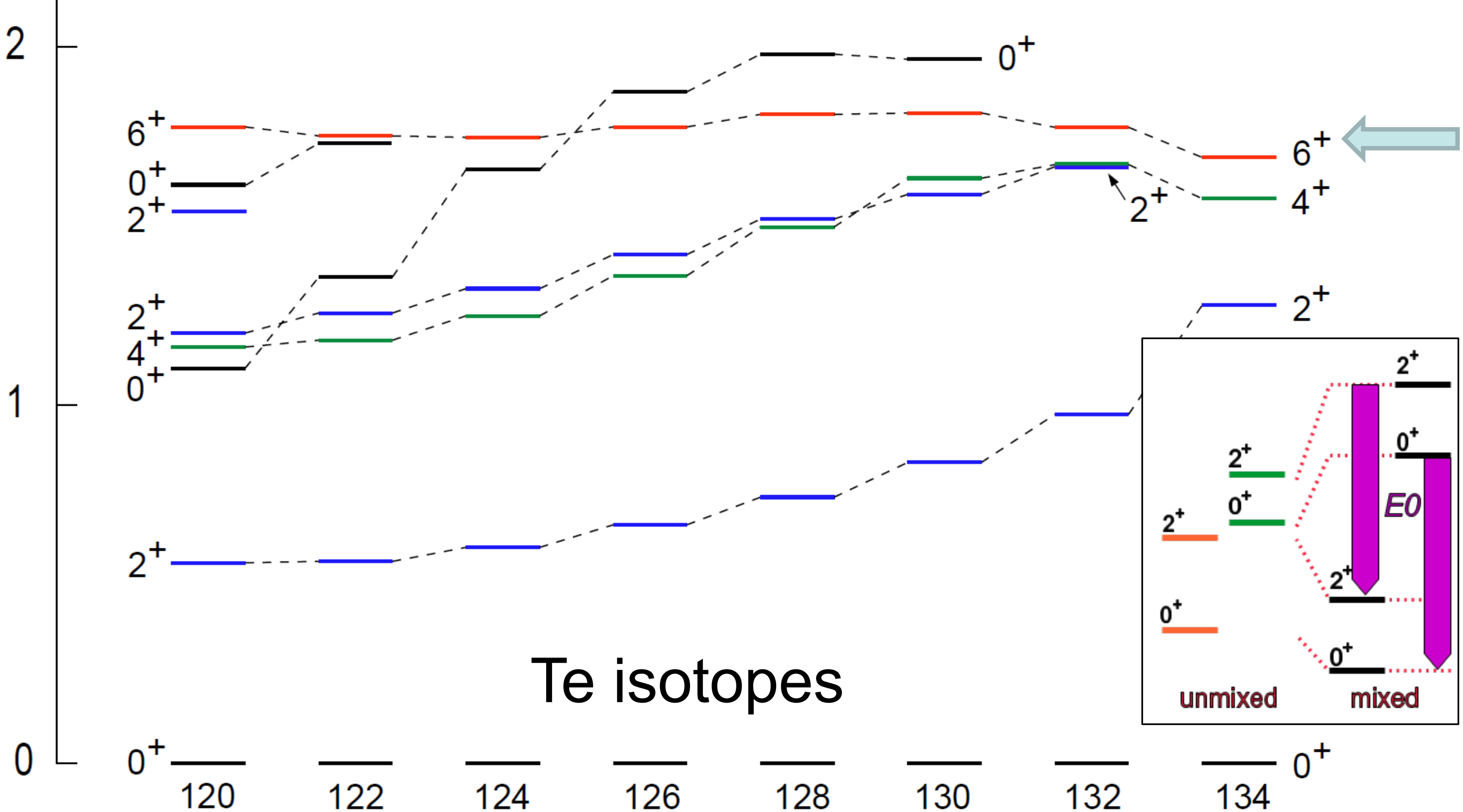


FIG. 2. (Color online) Energy differences for states of spin band and the even-spin yrast states with a differenc units of angular momentum.

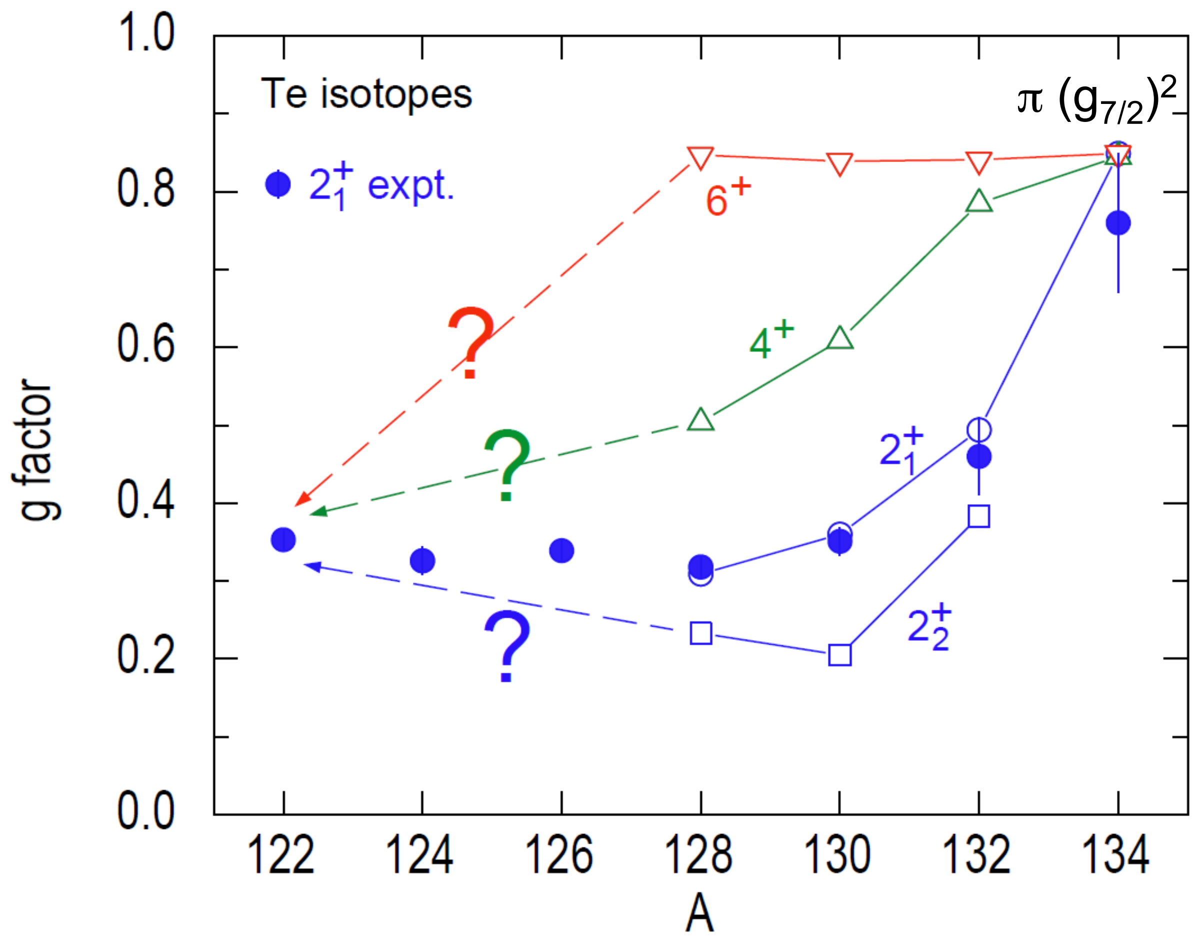
Figure from J. Elseviers et al.
PR C84 034307 2011

Incomplete EM data

A:	120	122	124	126	128	130	132	134
$T_{1/2}(6+)$:	?	?	?	68 ps	0.45 ns	9.8 ns	145 ns	164 ns



g factors & collectivity



Questions

Need data!

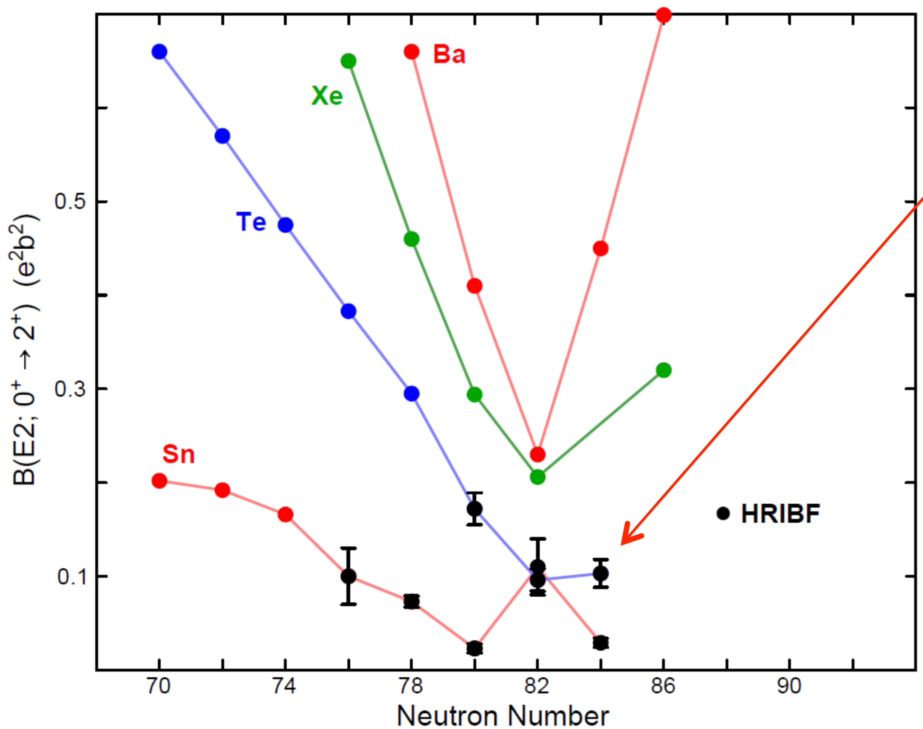
E0, M1, E2

e.g. 6^+ g factors

Nushellx with interactions from Alex Brown – PRC **71**, 044317 (2005)
Data: ANU & ORNL: PRL **94,** 192501 (2005); PRC **76**, 034306 (2007); PRC **76**, 034307 (2007); PRC **88**, 051304(R) (2013)

Emerging nuclear collectivity

B(E2) Results



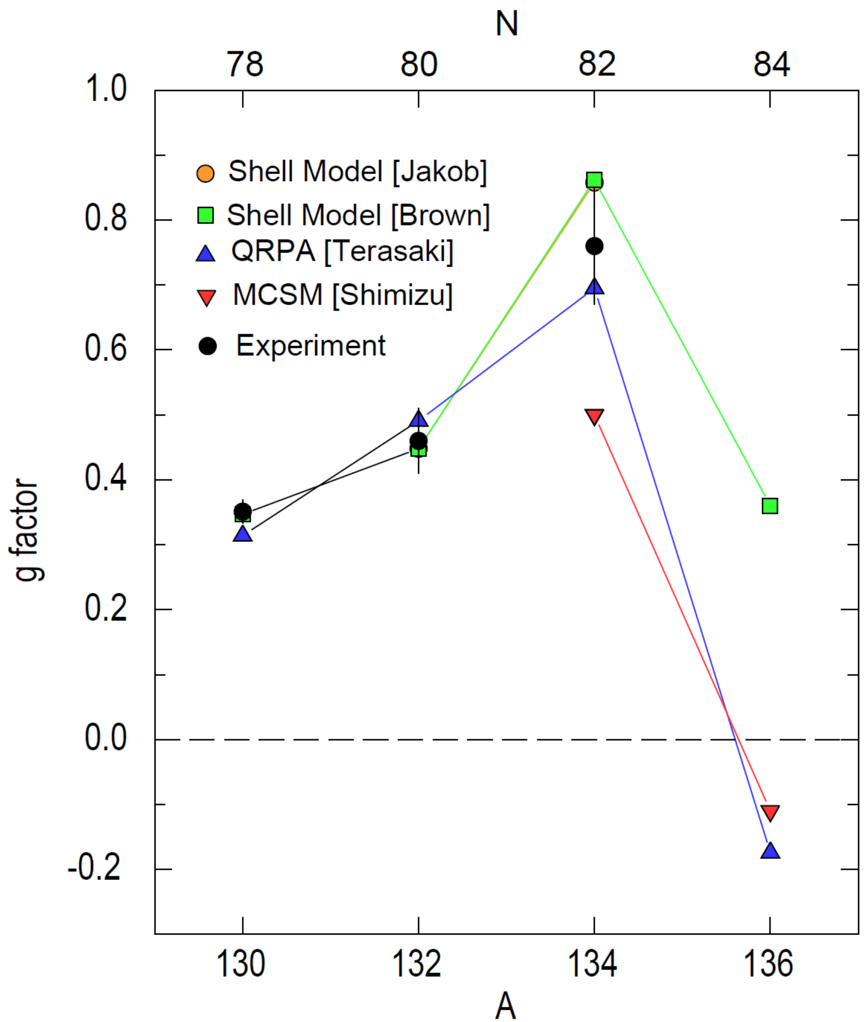
"Low" B(E2) in ^{136}Te

Z=50 + 2 protons
N=82 + 2 neutrons

2_1^+ state: predominantly a neutron excitation?

Radford et al.
PRL 88, 222501 (2002)

Emerging nuclear collectivity



Conflicting theoretical predictions for ^{134,136}Te

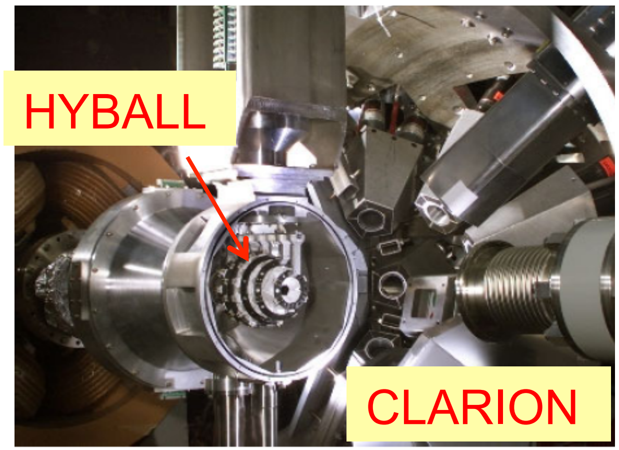
Differences stem from:

- proton-neutron interactions
- effective nucleon g factors: g_l and g_s

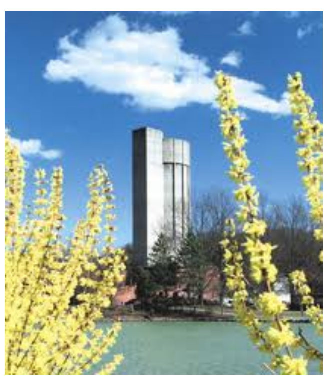
[SM] G. Jakob et al. PRC 65, 024316 (2002);
[SM] B. A. Brown et al., PRC 71, 044317 (2005)
[QRPA] J. Terasaki, et al., PRC 66, 054313 (2002) ;
[MCSM] N. Shimizu et al., PRC 70, 054313 (2004).

^{136}Te

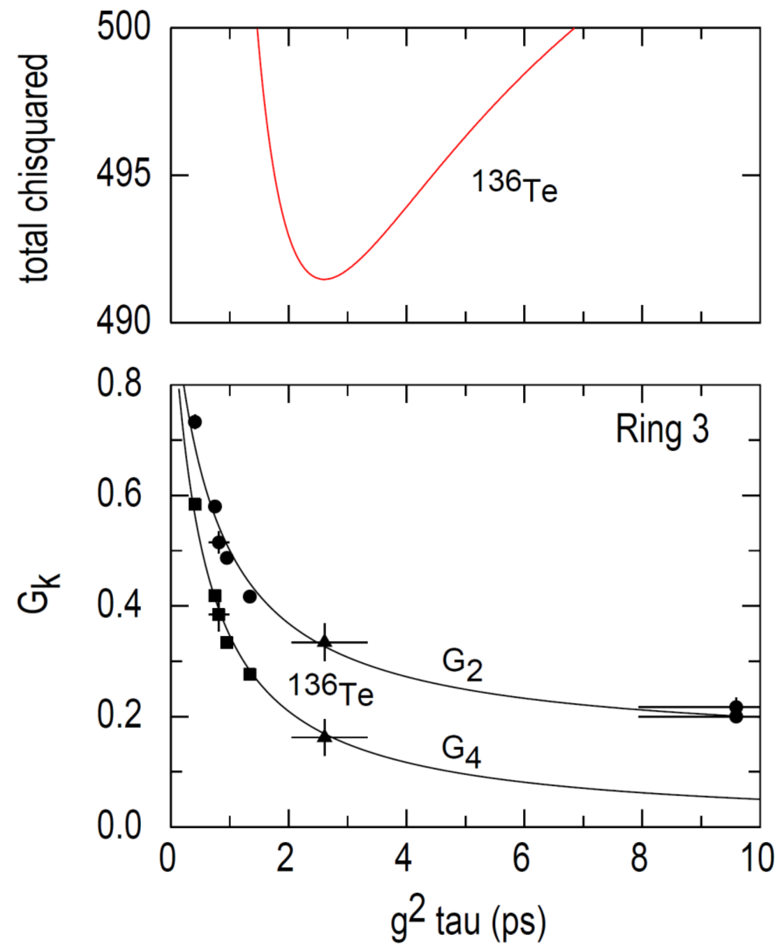
New B(E2) and g (2^+) data for ^{136}Te



J.M. Allmond, A.E. Stuchbery, M. Danchev, C. Baktash, et al

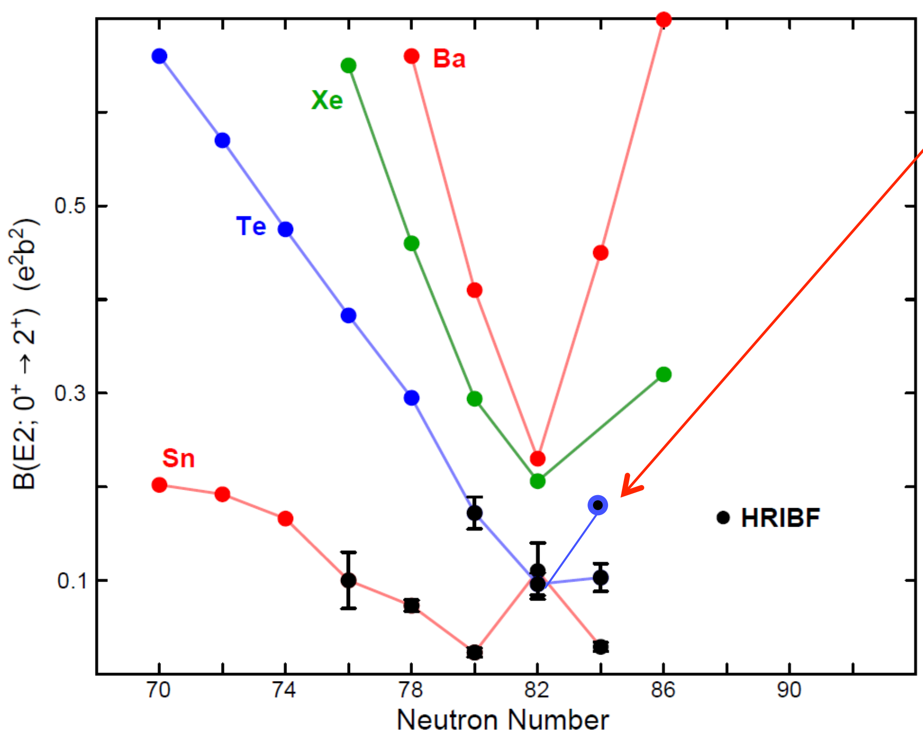


HRIBF Oak Ridge



Results

B(E2) Results



New B(E2) in ^{136}Te

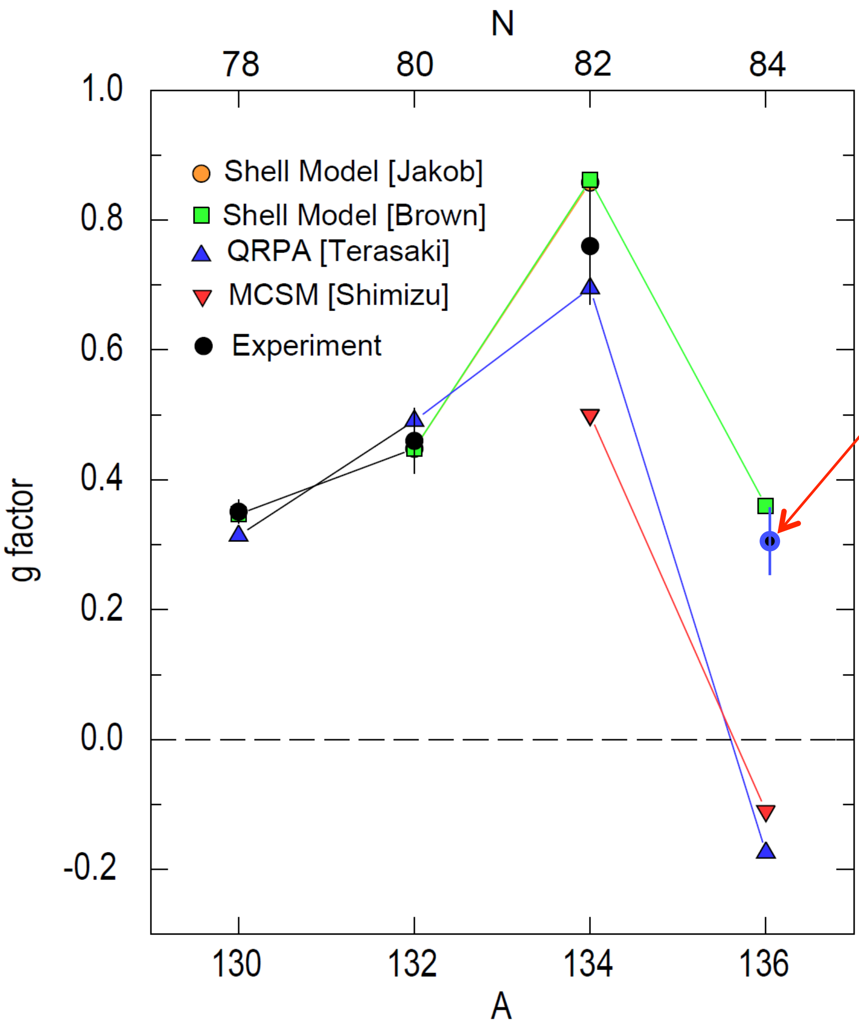
Z=50 + 2 protons
N=82 + 2 neutrons

2_1^+ state: predominantly a neutron excitation?

Shell Model: Qualified 'Yes'

Radford et al.
PRL 88, 222501 (2002)

Emerging nuclear collectivity



First g factor result in ^{136}Te

Z=50 + 2 protons
N=82 + 2 neutrons

2_1^+ state: predominantly a neutron excitation?

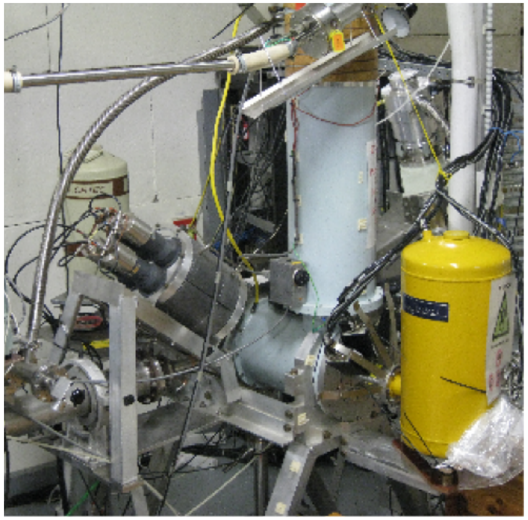
Shell Model: Qualified 'Yes'

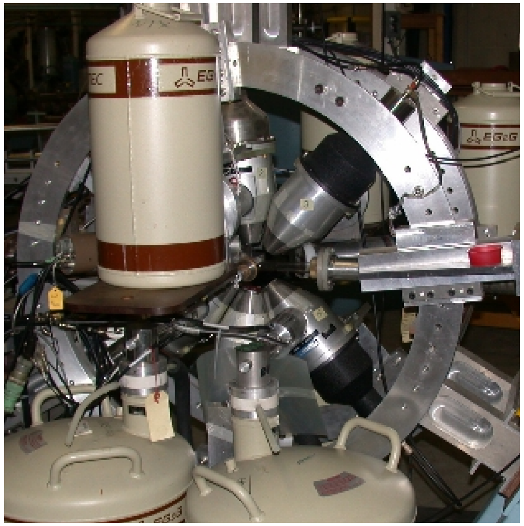
But collective features emerging

Electron and γ spectroscopy

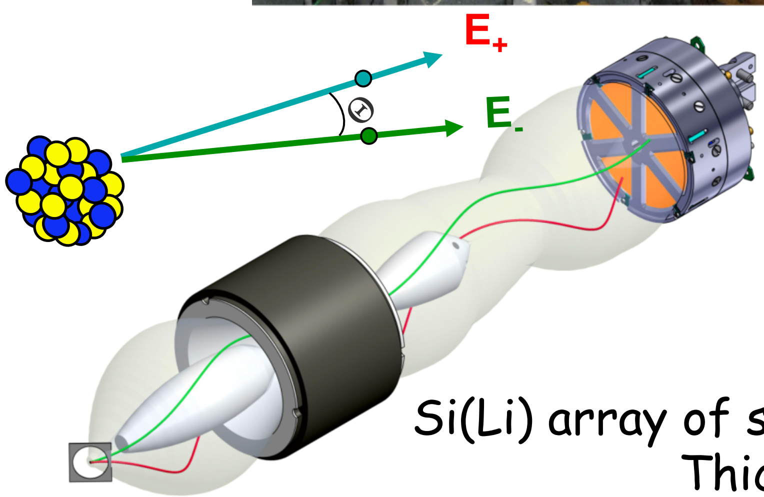
Super-e

- CE
- e^+e^-



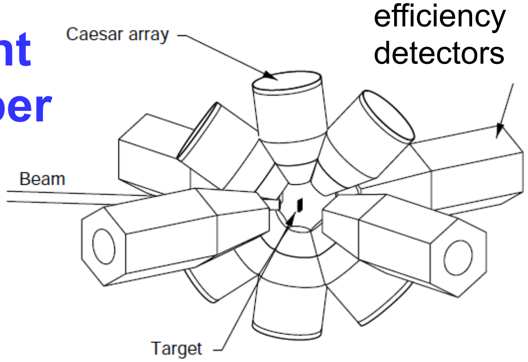


CAESAR array



Si(Li) array of six detectors
Thickness: 9 mm
Area: 236 mm^2
FWHM ≈ 2.5 keV
Semikon GmBh

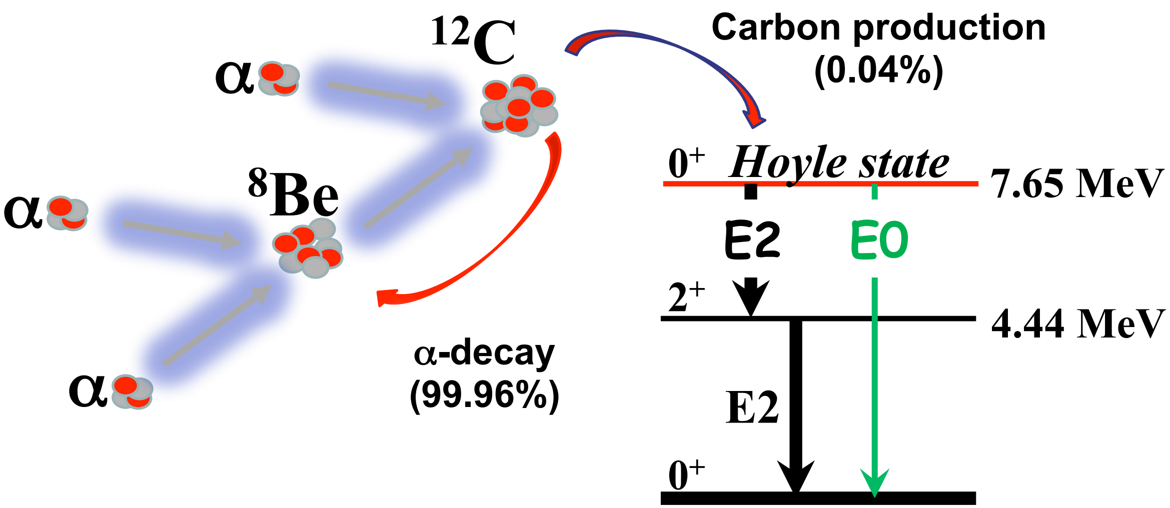
LaBr3 enhancement
Poster – Aqeel Akber

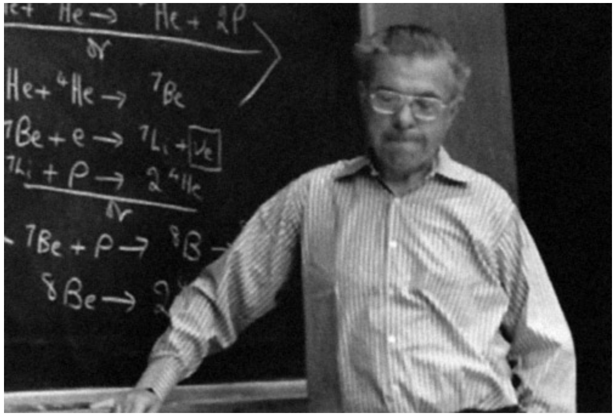


Also SolenoGam
Poster – Matt Gerathy

Pair spectroscopy of the Hoyle State

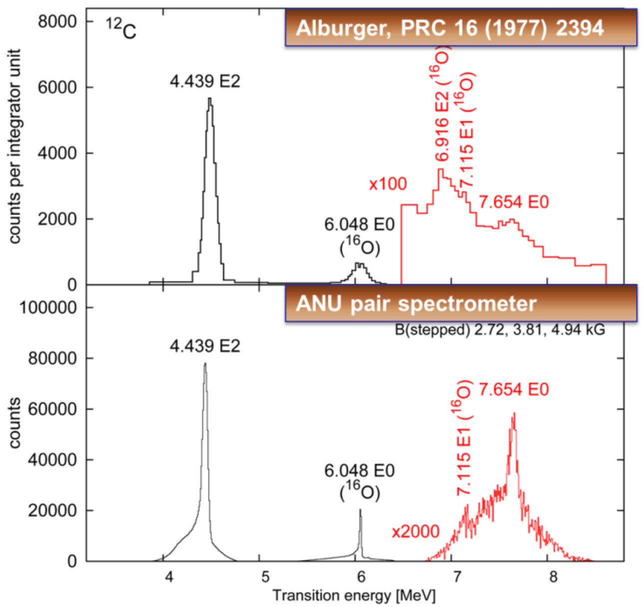
Triple-α reaction in helium burning stars produces carbon in the universe





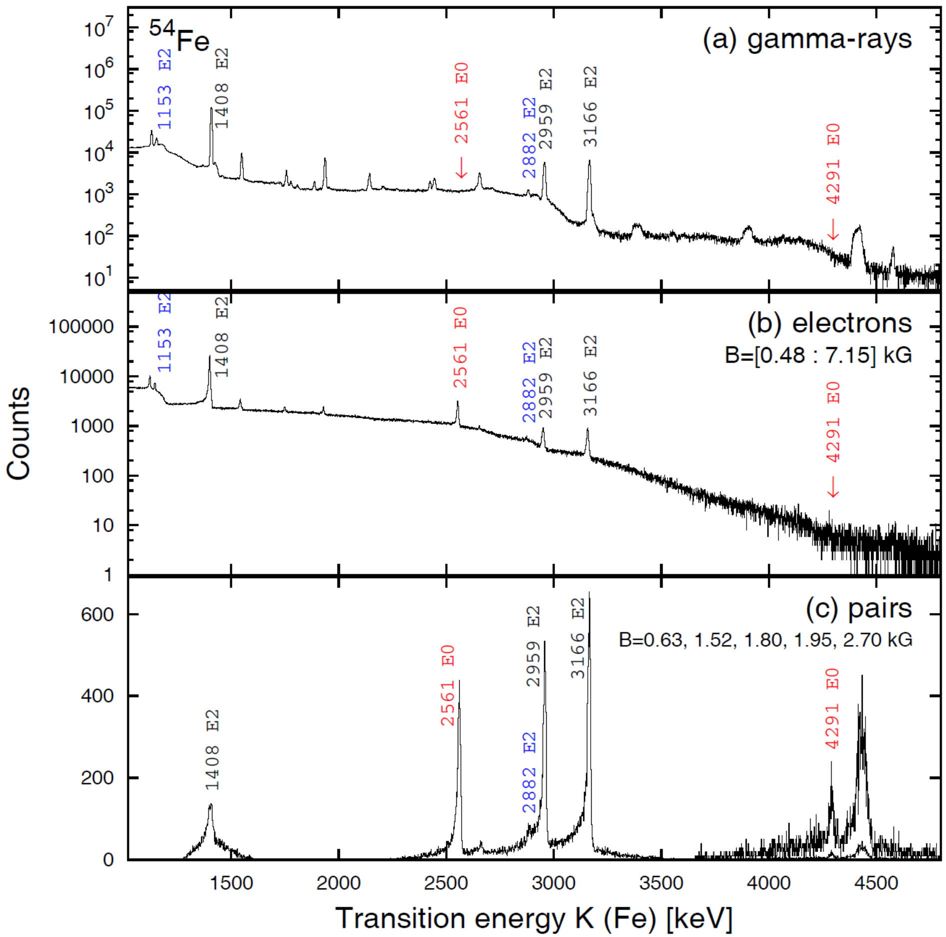
Sir Fred Hoyle (1915-2001)

Our first ^{12}C pair spectrum from the Hoyle state:



Tibor Kibédi : Talk Nuclear Structure A Friday

0⁺ states and E0 in Fe, Ni



- Tibor Kibedi, Adam Garnsworthy (TRIUMF)

$\Rightarrow$ Tomas Erikson this session

- Electron spectroscopy with Super-e: CE and pairs
- Gamma spectroscopy with CAESAR (δ and $\gamma\gamma$)
- (p,p') reaction
- Note: Can do angular distributions with (p,p') - there is alignment! (s-wave scattering?)

E0 Workshop

11-12 September 2015

- ➢ new instruments/facilities/results
- ➢ physics opportunities/exotic beams
- ➢ shape co-existence & E0 transitions
- ➢ Auger electrons - the “forgotten” child of IC

- **Ongoing: E0 working group (Tibor Kibedi, John Wood)**
- Wiki: https://en.wikiversity.org/wiki/Monopole

E0 transition rate

$$T(E0) = \Omega |\rho(E0)|^2$$

Measure T(E0):

- I_{ce} or I_{π} (e/π spectroscopy)
- $T_{1/2}$ (e or γ timing spectroscopy)
- δ(E2/M1) (γ-ray angular correlations)

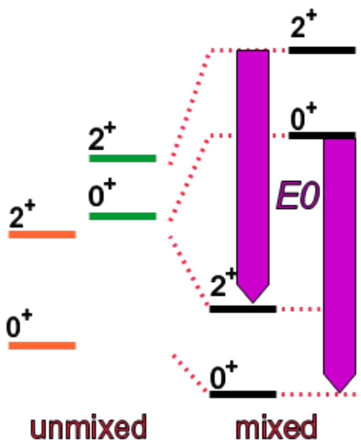
Monopole transition rate:

$$\rho^2(E0) \propto \alpha^2\beta^2[\langle r^2\rangle_1 - \langle r^2\rangle_2]^2$$

Electronic factor $\Omega(\kappa)$:

- Atomic physics
- Resurrected CATAR program (HC Pauli)
- Make $\Omega(\kappa)$ available with BrIcc soon

http://bricc.anu.edu.au/



The Message

We must consider magnetic moments and electric monopole transitions along with E2 observables to elucidate the nature and origin of nuclear collectivity

HIAS

HEAVY ION ACCELERATOR SYMPOSIUM

End