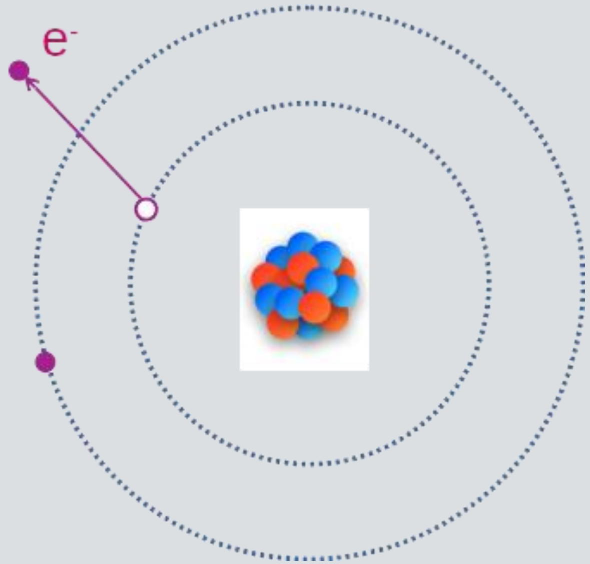
Electric Monopole Transitions in ^{74}Se

Naomi Marchini
University of Florence –
INFN Florence section



E0 Transitions

- E0 transitions are determined by a change in the radial distribution of the electric charge inside the nucleus, and high E0 strength is expected whenever configurations with different mean-square charge radii mix

- Enhanced monopole strength may be considered as a "signature" for shape coexistence

E0 operator

$$T(E0) = \sum_k e_k r_k^2$$

E0 transition strength

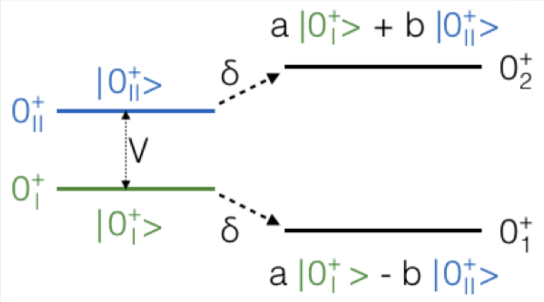
$$\rho^2(E0) = \left| \frac{\langle f | T(E0) | i \rangle}{eR^2} \right|^2$$

Nuclear Observable

$$\rho^2(E0) = C \, \frac{I_K(0_i^+ \rightarrow 0_f^+)}{I_K(0_i^+ \rightarrow 2_k^+)} \, \tau^{-1}$$

C = tabulated and calculated values

- Simple two levels mixing model:



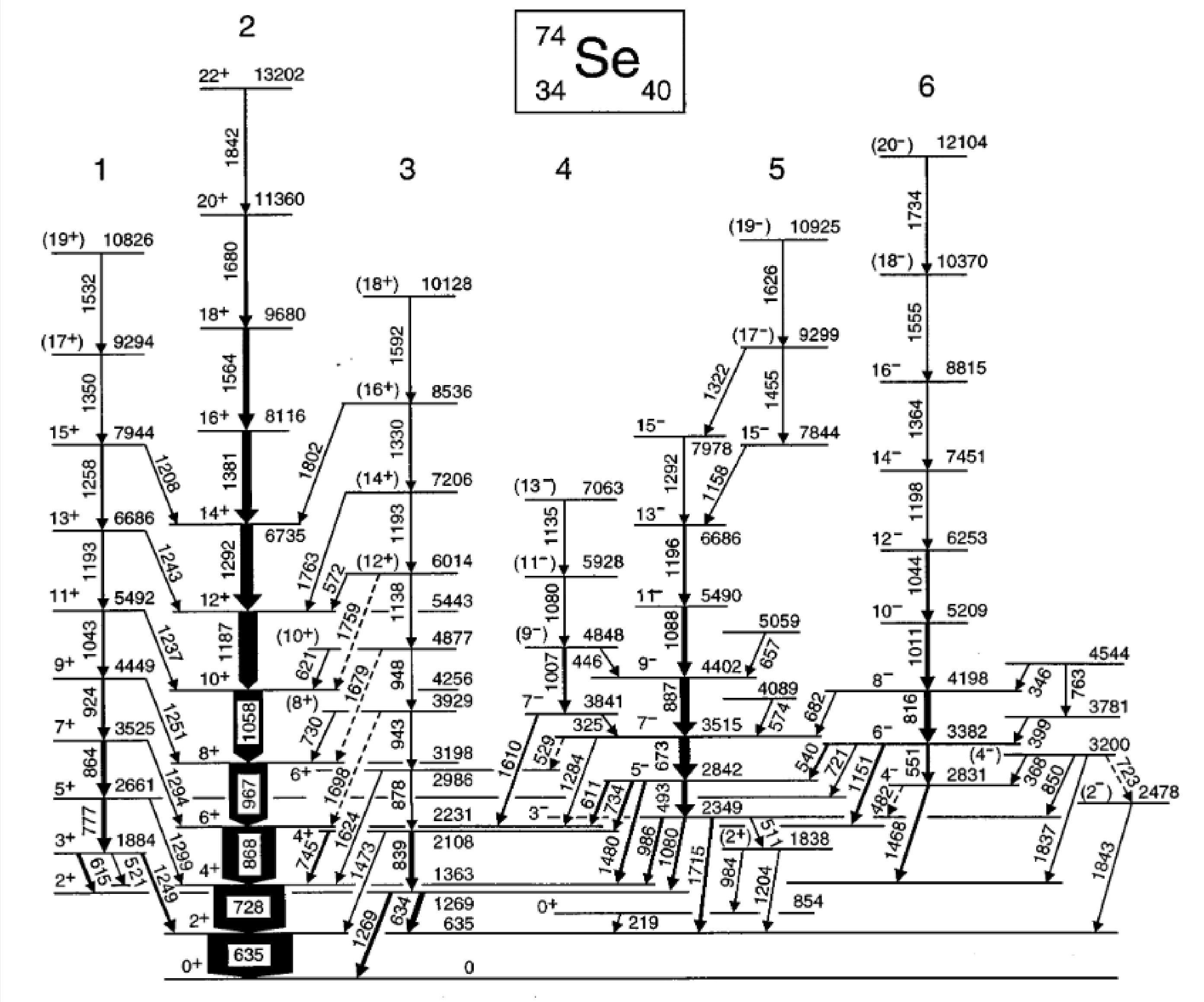
$$\rho^2(E0) = \frac{Z^2}{R^4} a^2 b^2 \left(\Delta \langle r^2 \rangle\right)^2$$

Wave function mixing

Difference in mean square radii

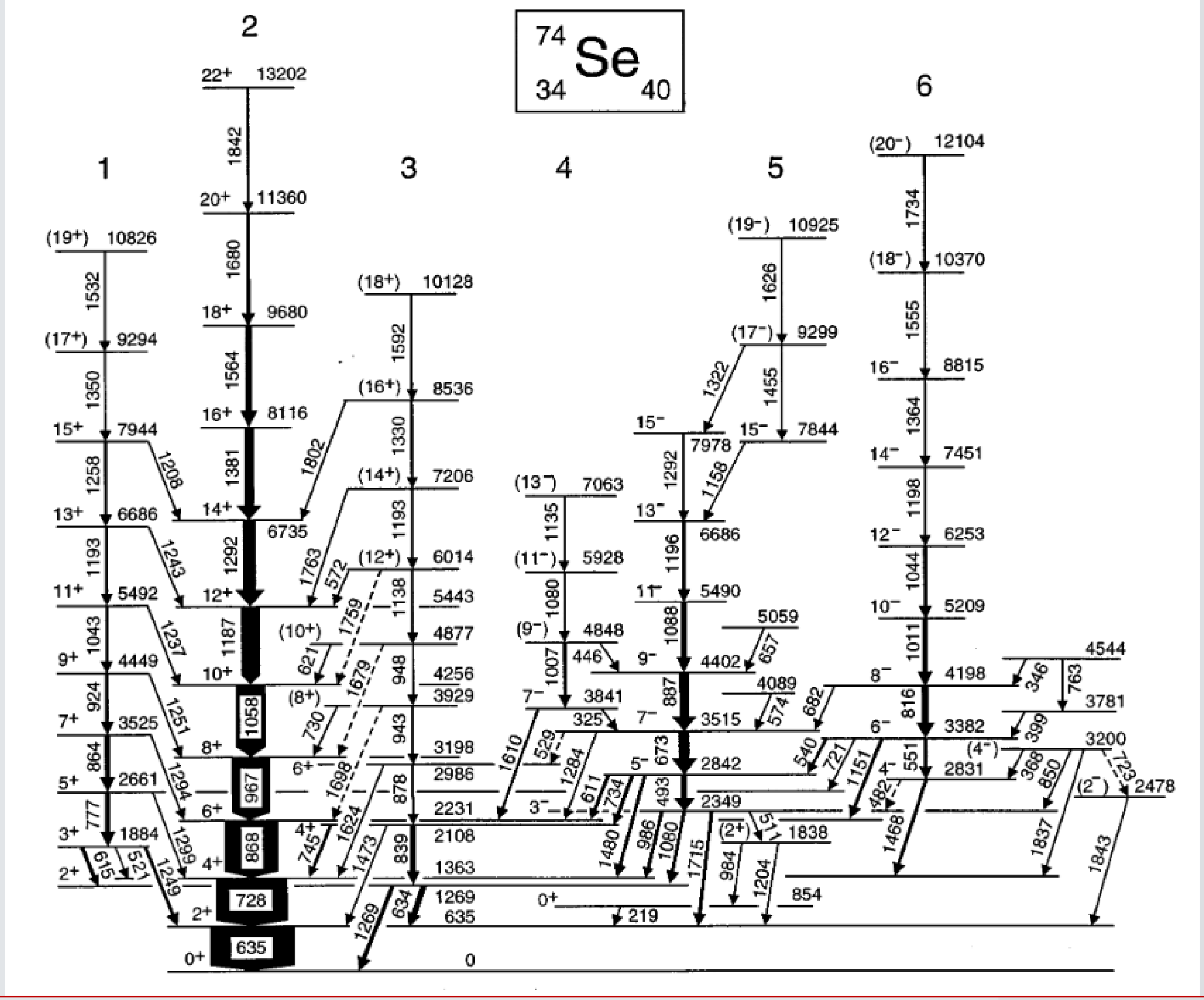
^{74}Se - Physics case

J. Döring *et al* Phys. Rev. C 57, 2912–2923 (1998)

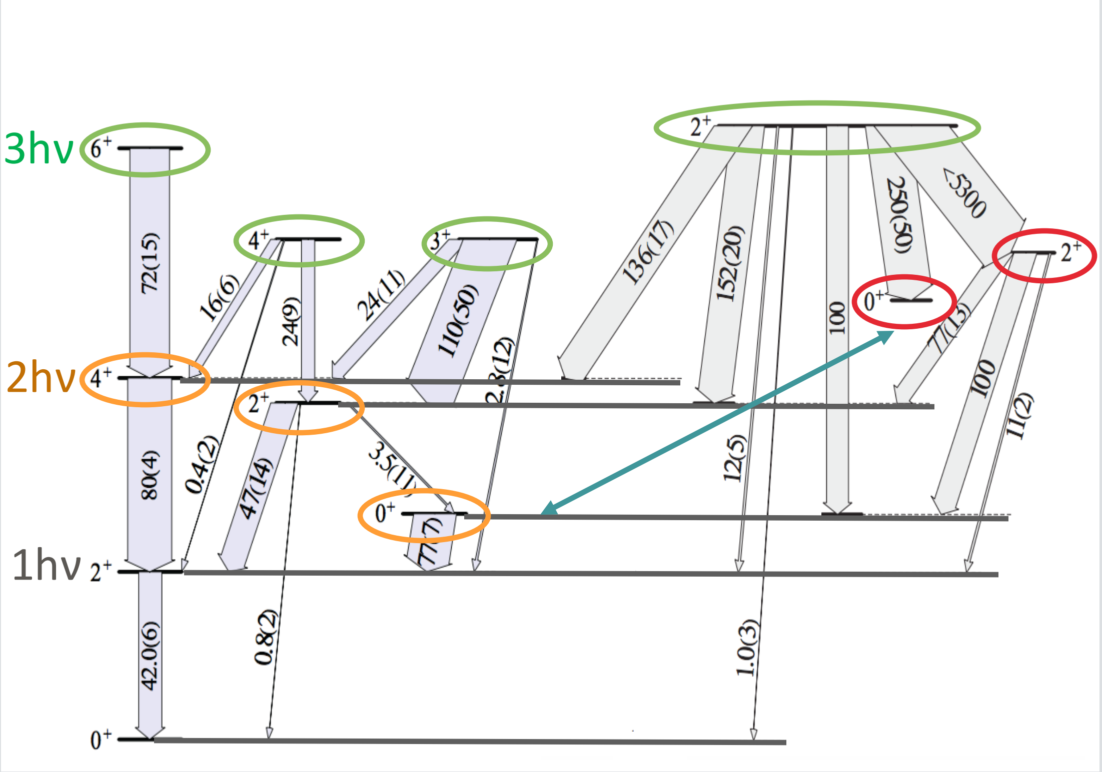


^{74}Se – Physics case

J. Döring *et al* Phys. Rev. C 57, 2912–2923 (1998)

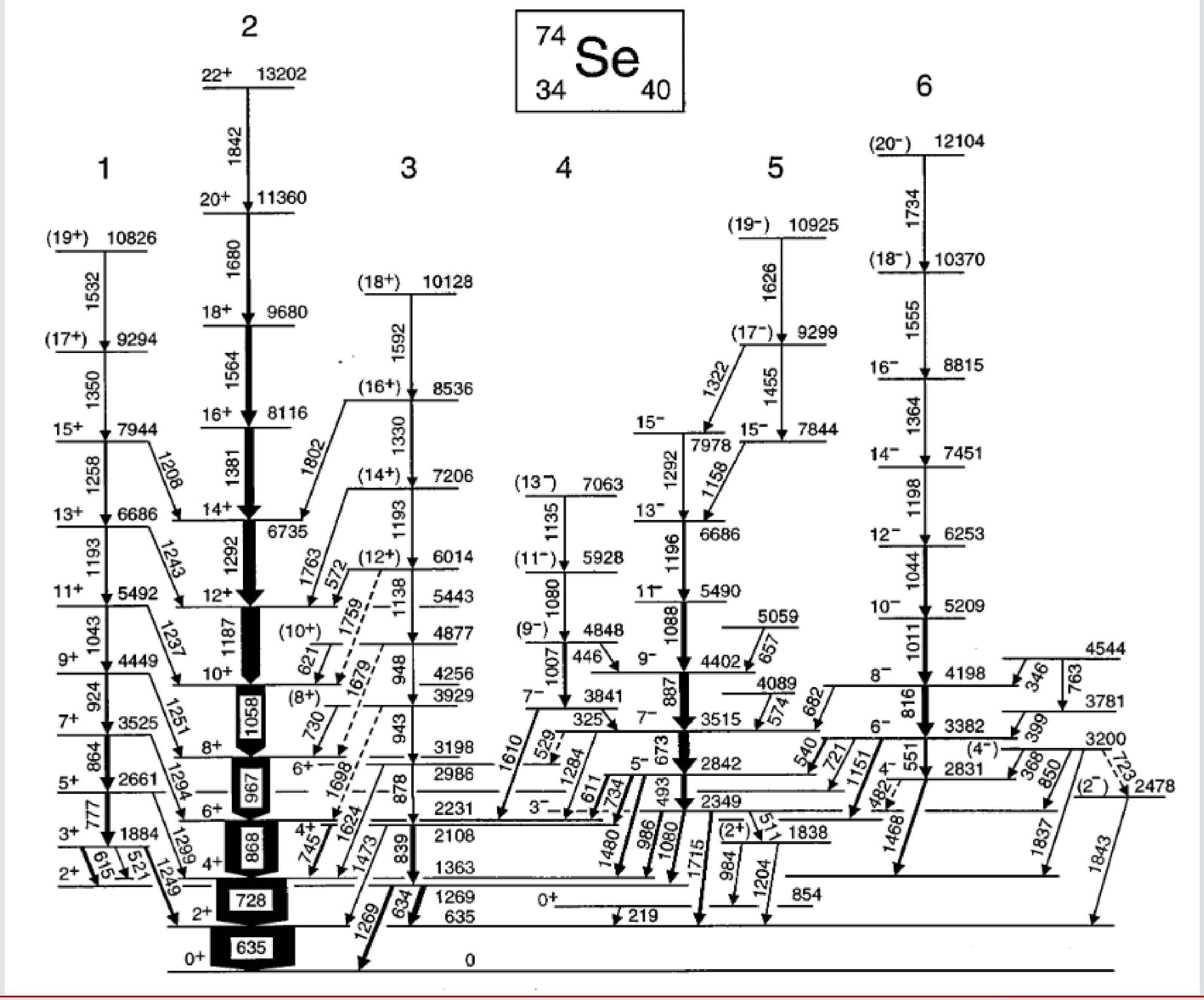


E. A. McCutchan *et al* Phys. Rev. C 87, 014307 (2013)

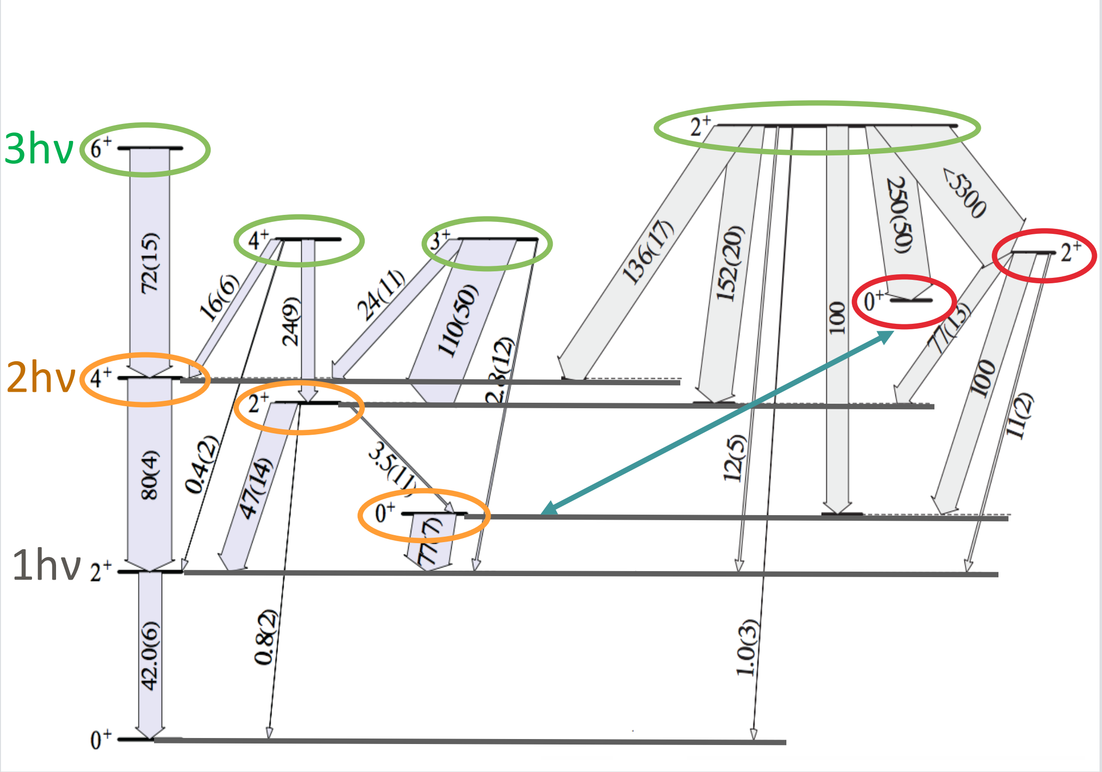


^{74}Se – Physics case

J. Döring *et al* Phys. Rev. C 57, 2912–2923 (1998)



E. A. McCutchan *et al* Phys. Rev. C 87, 014307 (2013)



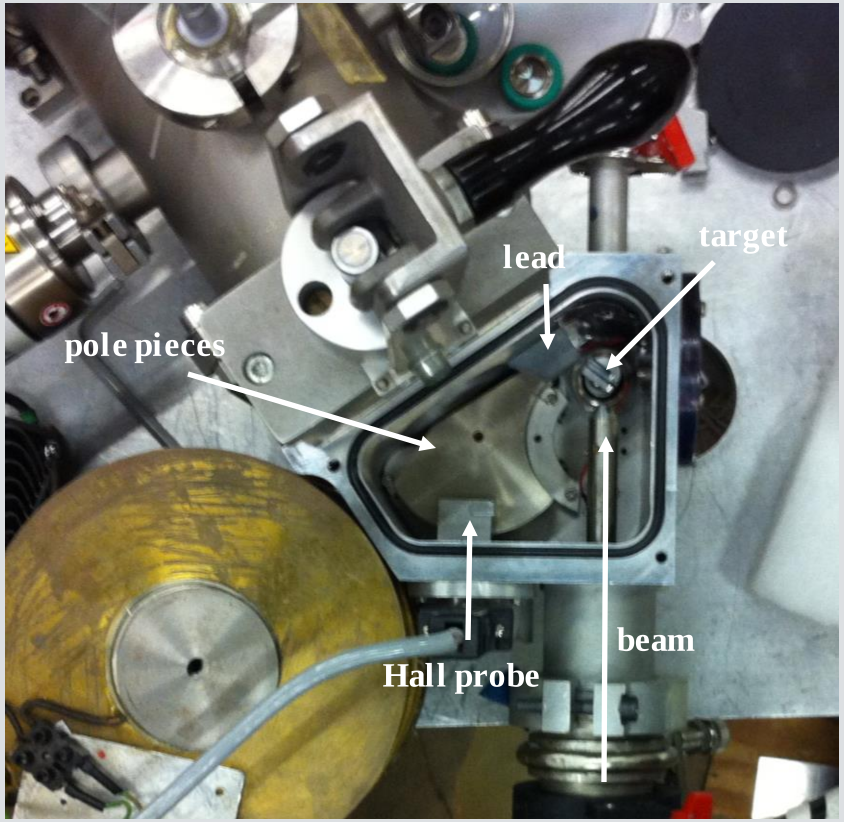
In this interpretation are expected:

- Strong $\rho^2(E0;\, 0_3^+ \rightarrow 0_2^+)$
- Negligible $\rho^2(E0;\, 2_2^+ \rightarrow 2_1^+)$

^{74}Se - Experiments

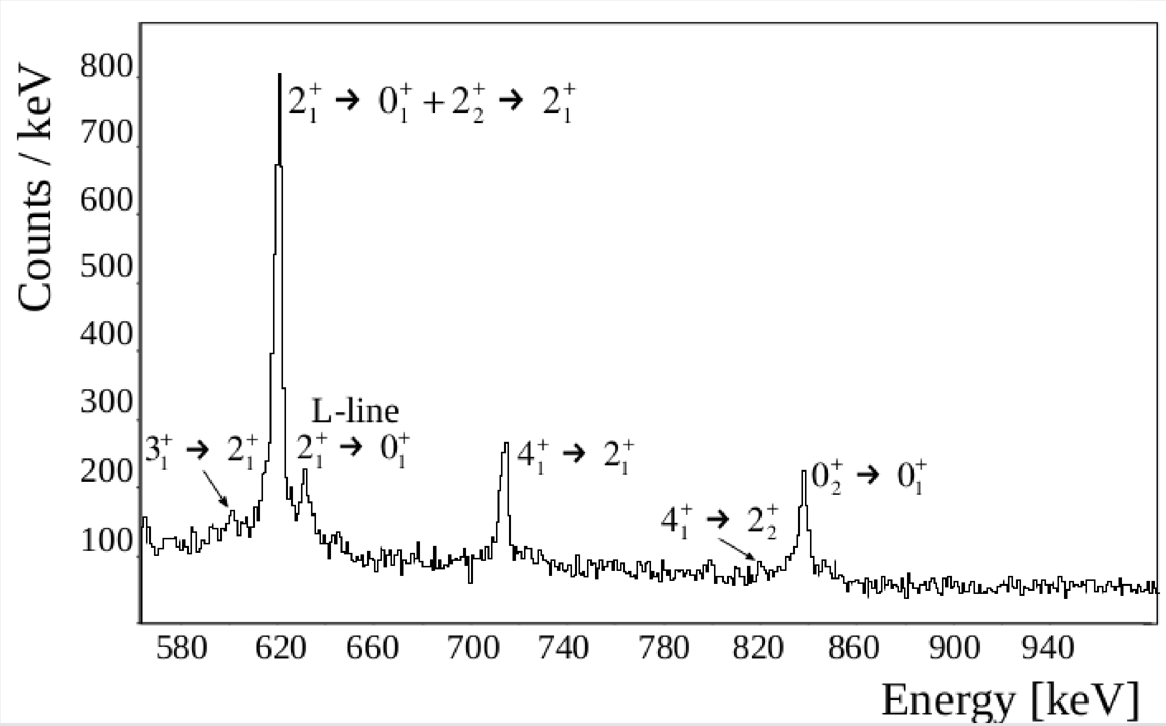
Experimental setup:

- Si(Li) detector (5cm^2 X 6mm) resolution (FWHM) ~2.5 keV for 1 MeV electrons
- Sector shaped uniform field magnetic spectrometer
- different magnetic field settings imply different range of transmitted electron energy
- overall efficiency ~ 1% in the 150-1500 keV energy range
- HPGe Detector



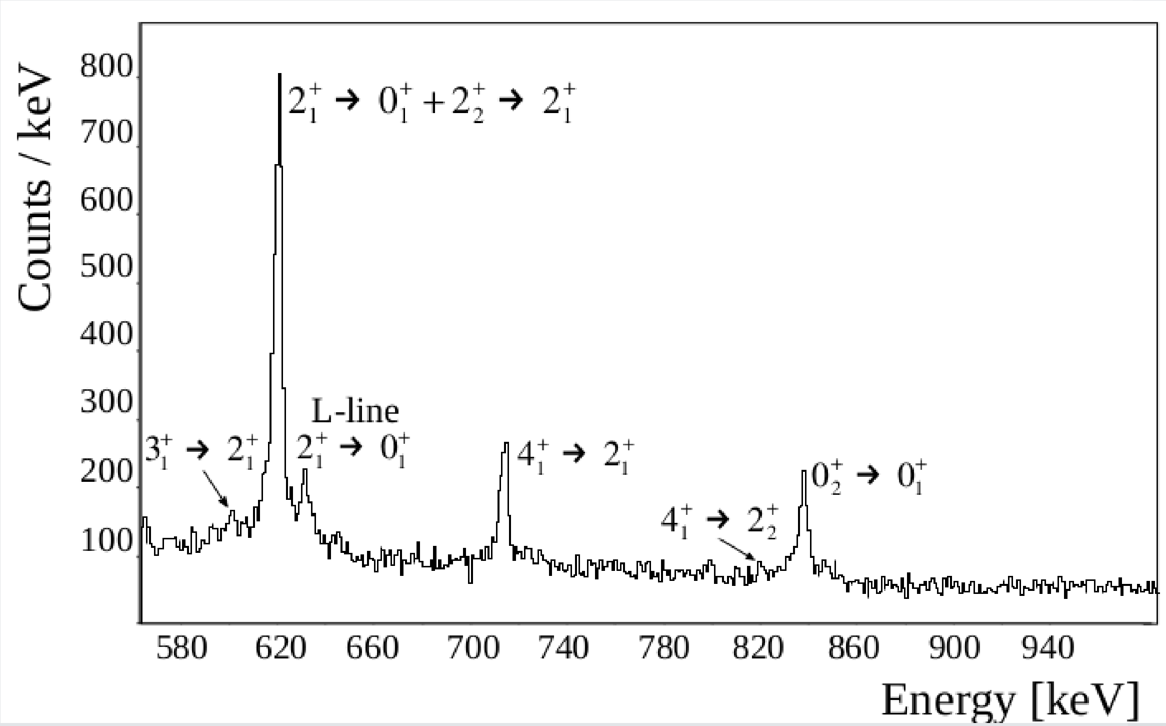
^{74}Se - Experiments

- ^{60}Ni(^{16}O,pn) @ 45 MeV
- ^{74}Br g.s. EC+β^+ decay in ^{74}Se with τ = 35m



^{74}Se – Experiments

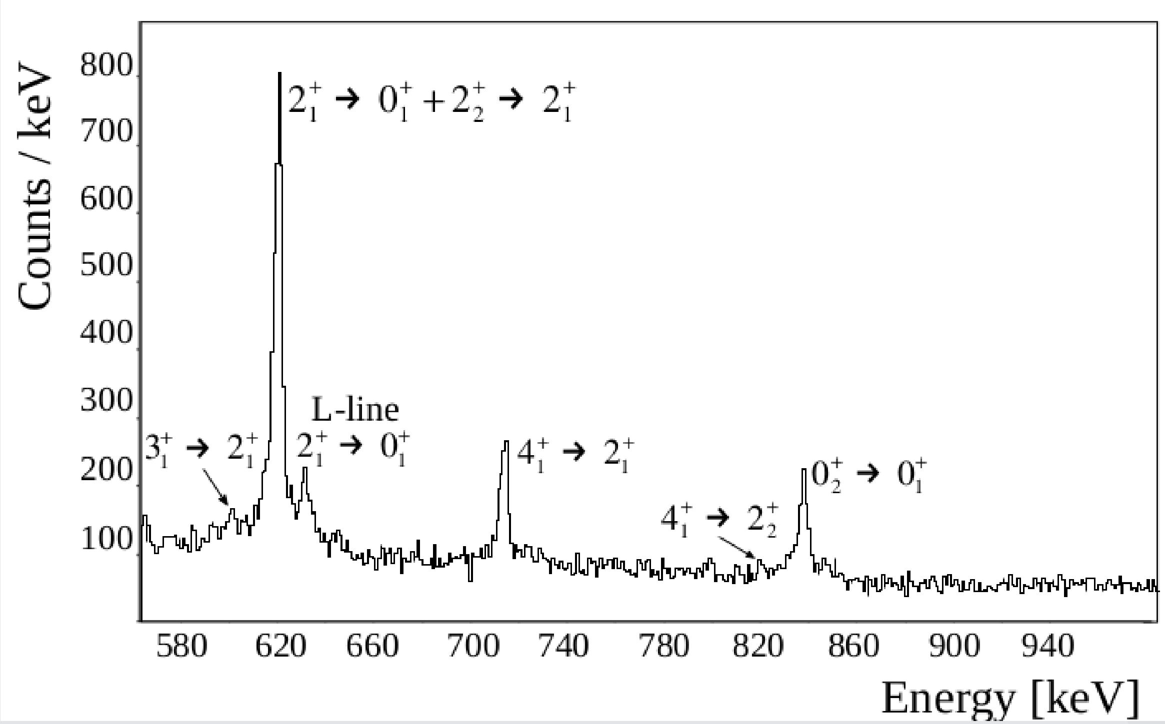
- ^{60}Ni(^{16}O,pn) @ 45 MeV
- ^{74}Br g.s. EC+β^+ decay in ^{74}Se with τ = 35m



$J_i^\pi \rightarrow J_f^\pi$	E_γ [keV]	$q^2(E0/E2)$		$\rho^2(E0)\cdot 10^3$	
		Present	Previous	Present	Previous
$0_2^+ \rightarrow 0_1^+$	854	0.210(14)	0.202(14)	25(3)	22.9(25)
$0_3^+ \rightarrow 0_2^+$	804	< 15			
$2_2^+ \rightarrow 2_1^+$	634	0.39(22)		210(130)	

^{74}Se - Experiments

- ^{60}Ni(^{16}O,pn) @ 45 MeV
- ^{74}Br g.s. EC+β^+ decay in ^{74}Se with τ = 35m



$J_i^\pi \to J_f^\pi$	E_γ [keV]	$q^2(E0/E2)$ Present	Previous	$\rho^2(E0)\cdot 10^3$ Present	Previous
$0_2^+ \to 0_1^+$	854	0.210(14)	0.202(14)	25(3)	22.9(25)
$0_3^+ \to 0_2^+$	804	< 15			
$2_2^+ \to 2_1^+$	634	0.39(22)		210(130)	

- Small limit for the $q^2(E0; 0_3^+ \to 0_2^+)$

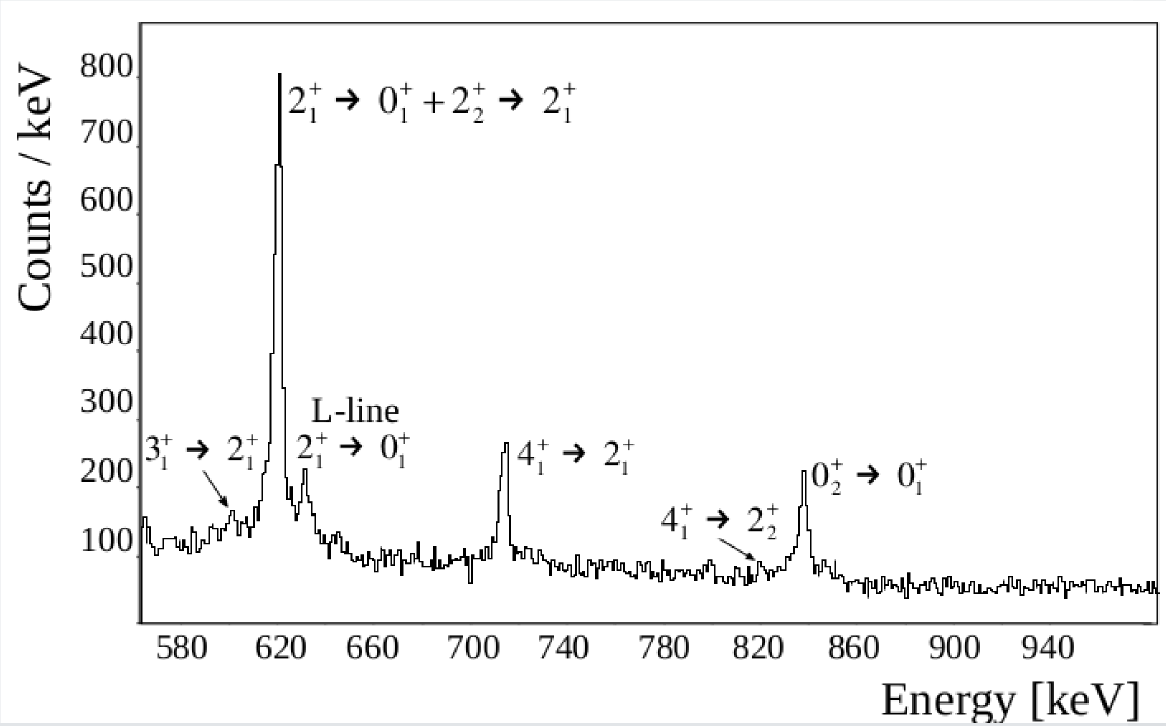
$$\rho^2(E0;0_3^+ \to 0_2^+)\cdot 10^3 = 3.28\cdot 10^{-3} q^2(E0/E2)\cdot \cdot B(E2;0_3^+ \to 2_1^+)$$

$\underline{\leq 5}$
(with B(E2) =100W.u.)

INCOMPATIBLE WITH THE INTEPRETATION OF THE SHAPE COEXISTENCE AND STRONG MIXING BETWEEN 0_2^+ AND THE 0_3^+ STATES

^{74}Se - Experiments

- ^{60}Ni(^{16}O,pn) @ 45 MeV
- ^{74}Br g.s. EC+β^+ decay in ^{74}Se with τ = 35m



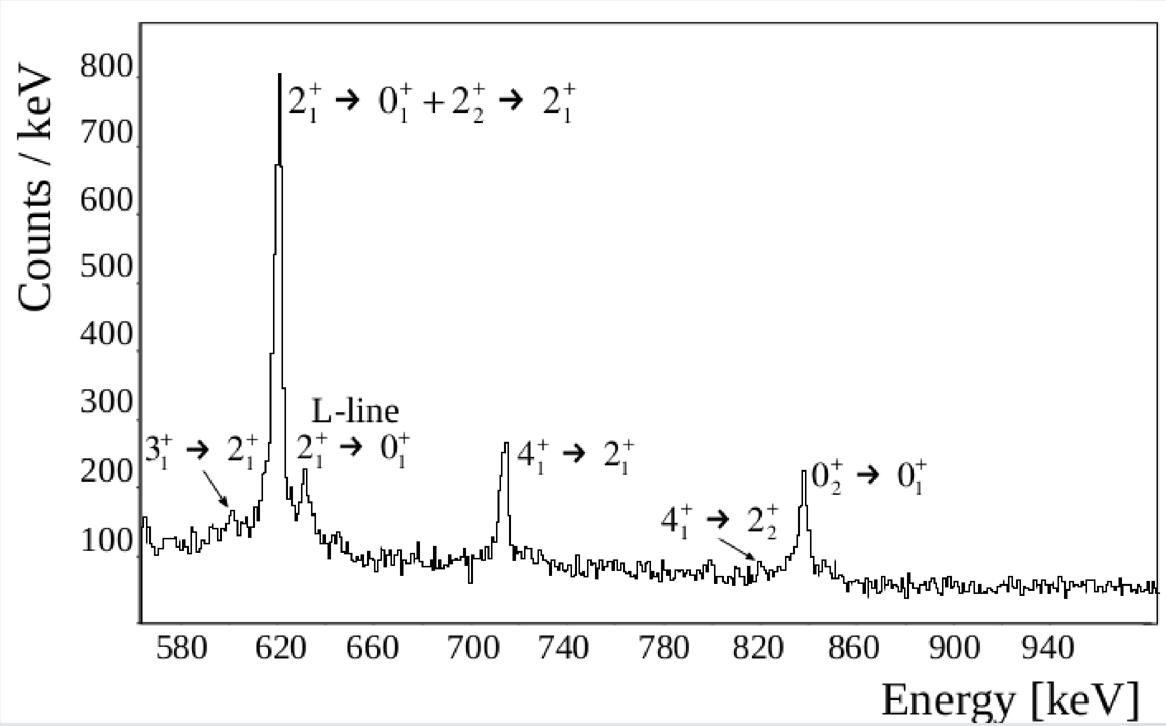
$J_i^\pi \rightarrow J_f^\pi$	E_γ [keV]	$q^2(E0/E2)$ Present	Previous	$\rho^2(E0) \cdot 10^3$ Present	Previous
$0_2^+ \rightarrow 0_1^+$	854	0.210(14)	0.202(14)	25(3)	22.9(25)
$0_3^+ \rightarrow 0_2^+$	804	< 15			
$2_2^+ \rightarrow 2_1^+$	634	0.39(22)		210(130)	

$$\alpha_K = \frac{\alpha_K^{th}(M1) + (1 + q_j{}^2_{if}) \cdot \delta^2 \cdot \alpha_K^{th}(E2)}{(1+\delta^2)}$$

$$\rho^2(\mathrm{E0}) = q_K^2(\mathrm{E0/E2}) \times \frac{\alpha_K(\mathrm{E2})}{\Omega_K(\mathrm{E0})} \times W_\gamma(\mathrm{E2})$$

^{74}Se - Experiments

- ^{60}Ni(^{16}O,pn) @ 45 MeV
- ^{74}Br g.s. EC+β^+ decay in ^{74}Se with τ = 35m



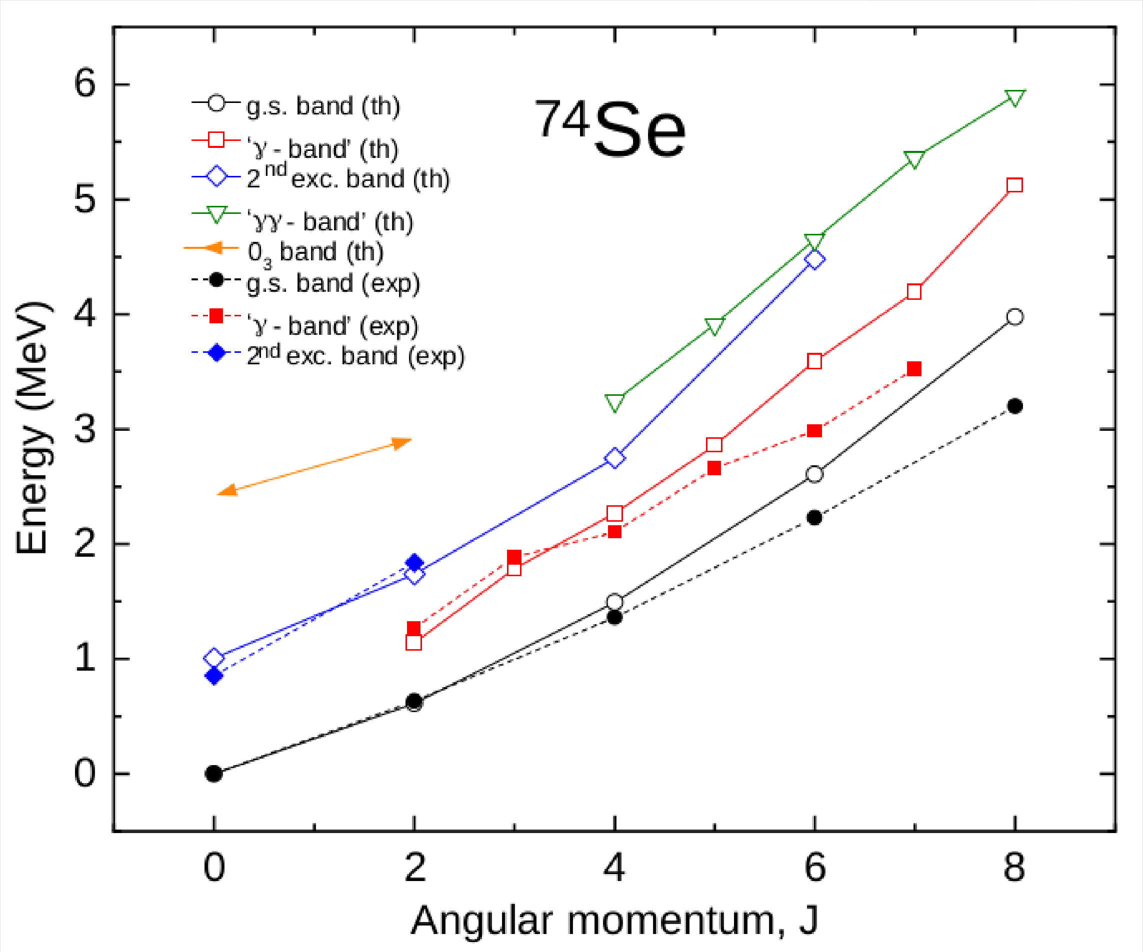
$J_i^\pi \rightarrow J_f^\pi$	E_γ [keV]	$q^2(E0/E2)$ Present	Previous	$\rho^2(E0)\cdot 10^3$ Present	Previous
$0_2^+ \rightarrow 0_1^+$	854	0.210(14)	0.202(14)	25(3)	22.9(25)
$0_3^+ \rightarrow 0_2^+$	804	< 15			
$2_2^+ \rightarrow 2_1^+$	634	0.39(22)		210(130)	

- Large value ρ^2 (E0; $2_2^+ \rightarrow 2_1^+$) compatible with those found for the Ni isotopes in L.J. Evitts *et al.* Phys. Lett. B 779 396 (2018)

INCOMPATIBLE WITH BOTH THE INTEPRETATIONS OF THE 2_2^+ STATE AS MEMBER OF THE TWO PHONON MULTIPLET AND AS THE BANDHEAD OF γ-BAND

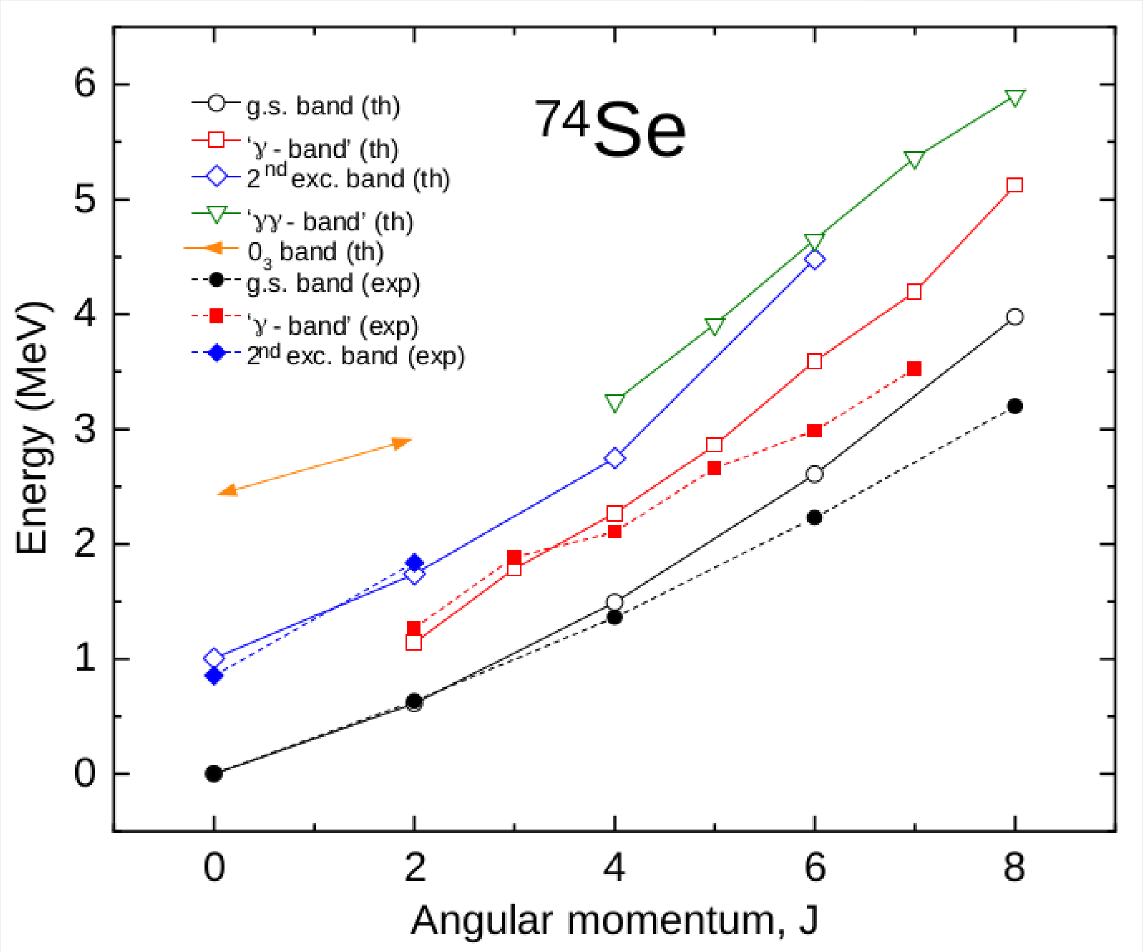
^{74}Se - Theoretical Interpretation

First BMF calculations for the ^{74}Se isotope



^{74}Se - Theoretical Interpretation

First BMF calculations for the ^{74}Se isotope



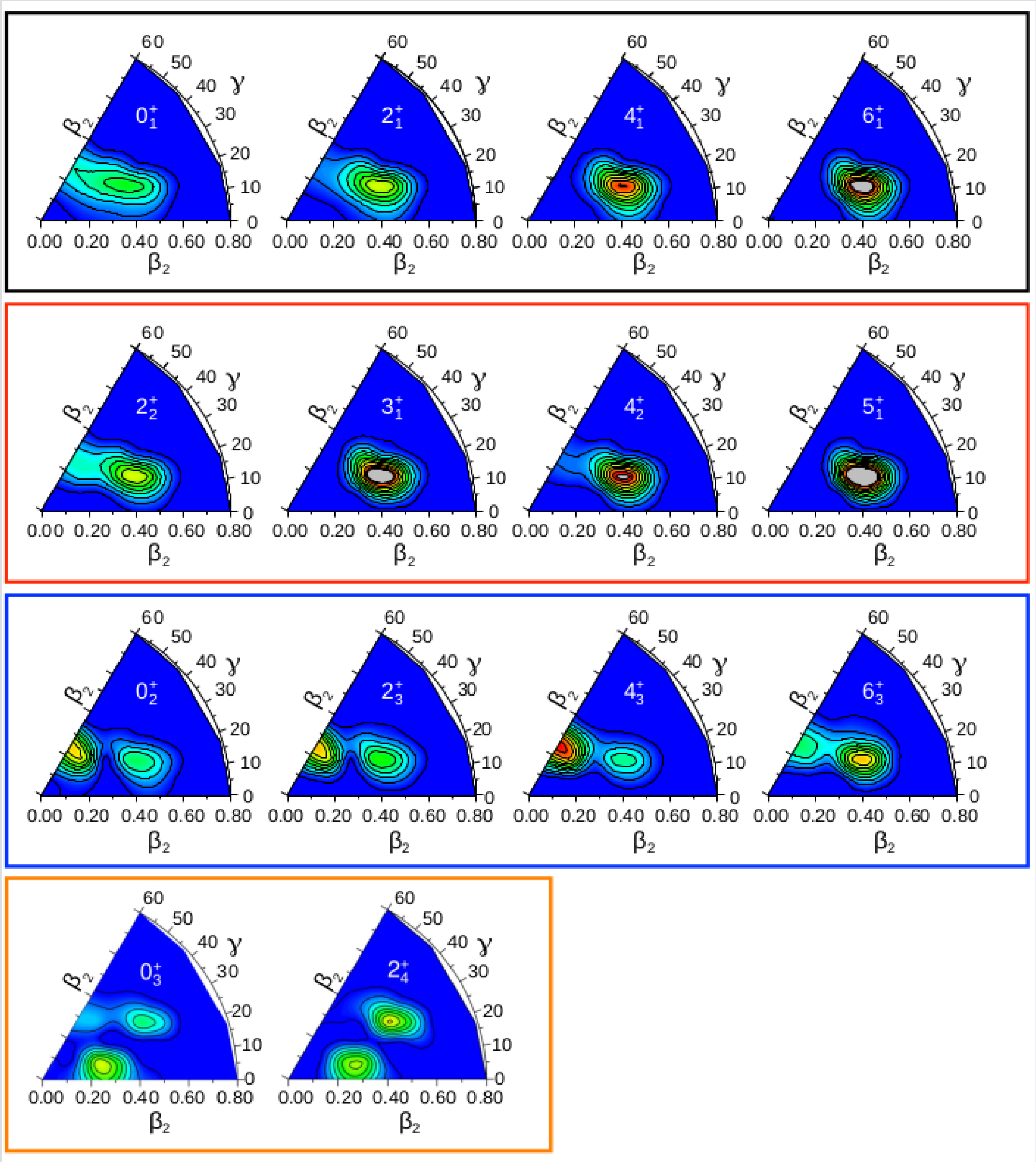
Observable	Exp.	Vibr.	BMF	Nomura *et al.*
$B(E2;2_1^+ \to 0_1^+)$ [W.u.]	42.0(6)		68	42
$B_{rel}(E2;4_1^+ \to 2_1^+)$	1.90(2)	2	1.69	1.88
$B_{rel}(E2;0_2^+ \to 2_1^+)$	1.83(2)	2	0.94	1.50
$B_{rel}(E2;2_2^+ \to 2_1^+)$	1.12(10)	2	1.47	0.16
$B_{rel}(E2;2_2^+ \to 0_2^+)$	0.08(11)	0	0.19	0.52
$B_{rel}(E2;6_1^+ \to 4_1^+)$	1.71(6)	3	2.27	2.14
$\rho^2(E0;0_2^+ \to 0_1^+)\cdot 10^3$	25(3)	0	154	23
$\rho^2(E0;2_2^+ \to 2_1^+)\cdot 10^3$	210(130)	0	26	4.9

K. Nomura et al., Phys. Rev. C 106 (2022) 024330

^{74}Se - Theoretical Interpretation - BMF

<u>First BMF calculations for the ^{74}Se isotope:</u>

- the ground-state band built on top of the triaxial minimum, characterized by mixing with an oblate configuration in the ground state
- the band built on top of the triaxial 2_2^+ state associated with the ground-state band
- the band built on the 0_2^+ state with strong mixing of the oblate and triaxial configurations
- the band built on the 0_3^+ state with strong mixing of the prolate and triaxial configurations



Conclusions

Electric monopole transition strengths in the ^{74}Se isotope has been deduced:

• The obtained $\rho^2(E0;2_2^+ \rightarrow 2_1^+)$ value points out enhanced electric monopole transition between the 2_1 and 2_2 states as for the Ni isotopic chain

• The upper limit deduced for the electron intensity of the $0_3^+ \rightarrow 0_2^+$ transition is not in agreement with the explanation of the 0_2^+ state strongly mixed with the 0_3^+ state.

• The BMF calculations generally reproduce the experimental quantities, except for the $\rho^2(E0)$ values.

• The 0_2^+ state is interpreted as a shape coexisting state in the calculations, and the 2_2^+ state is the head of another band at low excitation energy.

Conclusions

Electric monopole transition strengths in the ^{74}Se isotope has been deduced:

- The obtained $\rho^2(E0;2_2^+ \rightarrow 2_1^+)$ value points out enhanced electric monopole transition between the 2_1 and 2_2 states as for the Ni isotopic chain
- The upper limit deduced for the electron intensity of the $0_3^+ \rightarrow 0_2^+$ transition is not in agreement with the explanation of the 0_2^+ state strongly mixed with the 0_3^+ state.
- The BMF calculations generally reproduce the experimental quantities, except for the $\rho^2(E0)$ values.
- The 0_2^+ state is interpreted as a shape coexisting state in the calculations, and the 2_2^+ state is the head of another band at low excitation energy.
- <u>A more complex shape coexistence and mixing scenario is pictured for ^{74}Se at low-excitation energy</u>
- Further measurements of B(E2) and ultimately the determination of quadrupole invariants via low-energy Coulomb excitation are needed

Thank you for the Attention

Contents lists available at ScienceDirect

Physics Letters B

journal homepage: www.elsevier.com/locate/physletb

Emergence of triaxiality in ^{74}Se from electric monopole transition strengths

N. Marchini [a,b,c,*], A. Nannini [a], M. Rocchini [a], T.R. Rodríguez [d], M. Ottanelli [a], N. Gelli [a], A. Perego [a,b], G. Benzoni [e], N. Blasi [e], G. Bocchi [e], D. Brugnara [f], A. Buccola [a,b], G. Carozzi [f,g], A. Goasduff [f], E.T. Gregor [f,1], P.R. John [g,h], M. Komorowska [i], D. Mengoni [g,h], F. Recchia [g,h], S. Riccetto [j,k,2], D. Rosso [f], A. Saltarelli [c,j], M. Siciliano [f,g,3], J.J. Valiente-Dobón [f], I. Zanon [f,g]

[a] INFN Sezione di Firenze, Firenze, IT-50019, Italy
[b] Università degli Studi di Firenze, Dipartimento di Fisica, Firenze, IT-50121, Italy
[c] Università degli Studi di Camerino, Dipartimento di Fisica, Camerino, IT-62032, Italy
[d] Departamento de Estructura de la Materia Fisica Termica y Electronica and IPARCOS, Universidad Complutense de Madrid, Madrid, E-28040, Spain
[e] INFN Sezione di Milano, Milano, IT-20133, Italy
[f] INFN Laboratori Nazionali di Legnaro, Padova, IT-35020, Italy
[g] Università degli Studi di Padova, Dipartimento di Fisica, Padova, IT-35122, Italy
[h] INFN Sezione di Padova, Padova, IT-35122, Italy
[i] Heavy Ion Laboratory, University of Warsaw, Warszawa, PL-02-093, Poland
[j] INFN Sezione di Perugia, Perugia, IT-06123, Italy
[k] Università degli Studi di Perugia, Dipartimento di Fisica e Geologia, Perugia, IT-06123, Italy