Signs of shape coexistence in mid-shell Te isotopes

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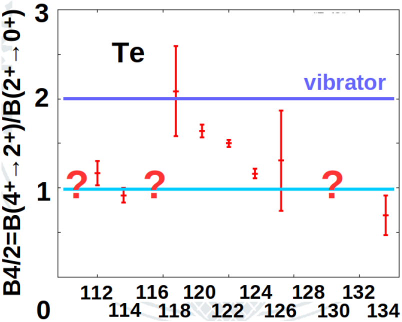
Motivation

- Unclear nuclear structure
- Very low $B_{4/2}$ value measured in ^{114}Te
- Shape coexistence in Te suspected, but scarce data

Rikovska *et al.* Hyperfine Interactions 22 (1985) 405



→ Lifetime measurements in light Te isotopes

Signs of shape coexistence in Cd

- Mirror case of the Te isotopes
- Well studied
- The discovery of shape coexistence has changed the understanding of Cd. Not simple vibrators anymore

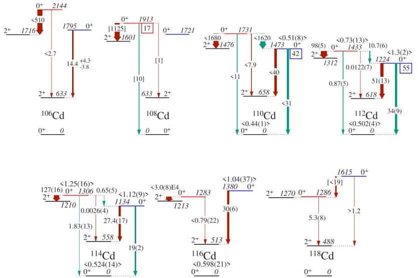
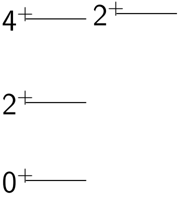


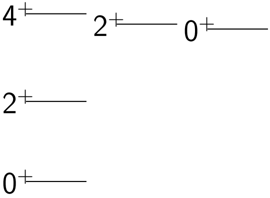
Fig. 36. Properties of the low-lying 0^+ states observed in the mid-neutron-shell Cd isotopes. The widths of the arrows are proportional to the $B(E2)$ values (rust colour) and $10^3 \times \rho^2(E0)$ (green). The transitions are labelled with the absolute $B(E2)$ values in W.u. with uncertainties in parenthesis, or relative $B(E2)$ values in square brackets. The $E0$ transitions are labelled with their $10^3 \times \rho^2(E0)$ values, or the $X(E0/E2)$ value for the 0_3^+ state in ^{108}Cd relative to the $E2$ to the 2_1^+ level. The numbers inside boxes attached to the levels are the ratios (in %) of the (^{3}He, n) transfer cross sections to those of the ground state. Quantities contained within the brackets are the $\langle Q^2 \rangle$ values, expressed in e^2b^2; those for excited states, especially, should be considered as lower limits. Data are taken from the National Nuclear Data Center database [38] and Refs. [87,260–262,337,352,360,362].

Figure taken from
Garrett et al. Progress in Particle and Nuclear Physics 124 103931

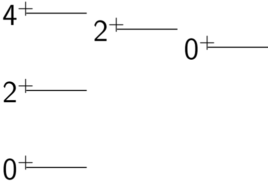
Levelschemes of the Te isotopes



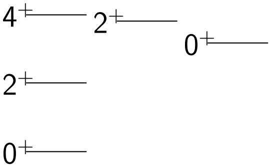
^{112}Te



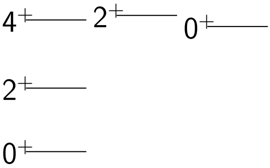
^{114}Te



^{116}Te



^{118}Te



^{120}Te

Signs of shape coexistence in Te

- Few experimental data
- Development of 0+ states could hint on shape coexistence

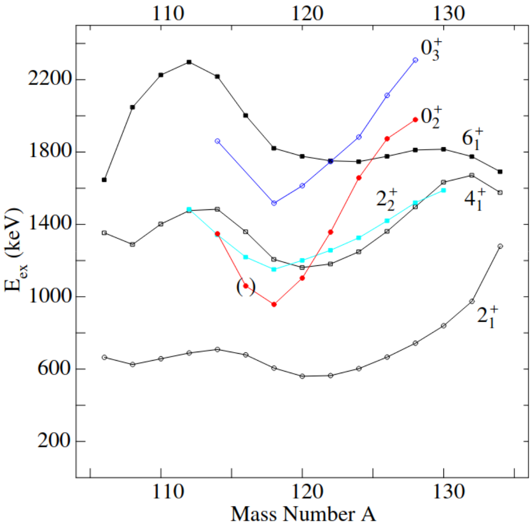
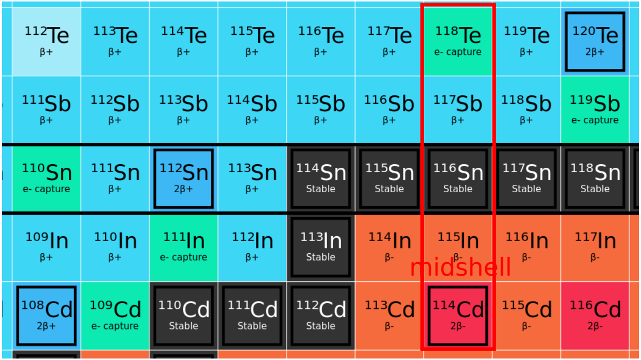


Figure taken from
Garrett et al. Progress in Particle and Nuclear Physics 124 103931

Experimental challenges

- The interesting midshell isotopes are not stable
- Many doublets
  e.g. in ^{116}Te: $4_1^+ \rightarrow 2_1^+$ 680.8 keV, $2_1^+ \rightarrow 0_1^+$ 678.9 keV



^{112}Te β+	^{113}Te β+	^{114}Te β+	^{115}Te β+	^{116}Te β+	^{117}Te β+	^{118}Te e- capture	^{119}Te β+	^{120}Te 2β+
^{111}Sb β+	^{112}Sb β+	^{113}Sb β+	^{114}Sb β+	^{115}Sb β+	^{116}Sb β+	^{117}Sb β+	^{118}Sb β+	^{119}Sb e- capture
^{110}Sn e- capture	^{111}Sn β+	^{112}Sn 2β+	^{113}Sn β+	^{114}Sn Stable	^{115}Sn Stable	^{116}Sn Stable	^{117}Sn Stable	^{118}Sn Stable
^{109}In β+	^{110}In β+	^{111}In e- capture	^{112}In β+	^{113}In Stable	^{114}In β-	^{115}In β-	^{116}In β-	^{117}In β-
^{108}Cd 2β+	^{109}Cd e- capture	^{110}Cd Stable	^{111}Cd Stable	^{112}Cd Stable	^{113}Cd β-	^{114}Cd 2β-	^{115}Cd β-	^{116}Cd 2β-

Experimental setup in Cologne

- 10 MV accellerator
- Cologne plunger
- 5 HPGe detectors at 143.2° and 6 HPGe detectos at 45°

Recoil-Distance-Doppler-Shift experiments

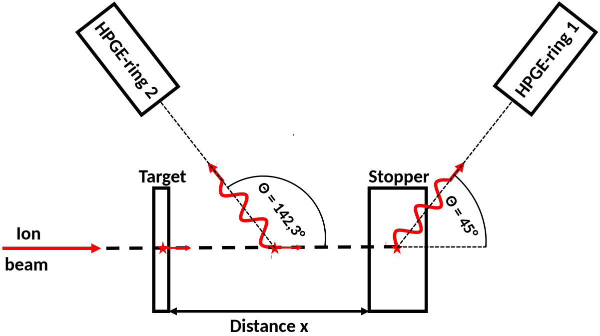


Figure: Exemplary setup of a RDDS experiment.

$$E_\gamma^s(\beta, \Theta) = E_\gamma^u \cdot \frac{\sqrt{1-\beta^2}}{1-\cos\Theta\cdot\beta}$$

Differential Decay Curve Method with γ-γ-coincidences

DDCM:

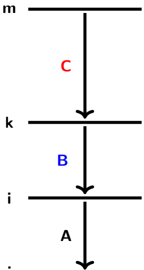
$$\tau_i = \frac{1}{\lambda_i} = \frac{-N_i(t) + \sum_k b_{ki} N_k(t)}{\frac{d}{dt} N_i(t)}$$

Direct gate:

$$\tau_i = \frac{\{B^s, A^u\}}{\frac{d}{dx}\{B^s, A^s\} \cdot v}$$

Indirect gate:

$$\tau_i = \frac{-\{C^s, A^u\} + \alpha^{C}_{B,A}\{C^s, B^u\}}{\frac{d}{dx}\{C^s, A^s\} \cdot v}$$



→ only relative distances needed

→ independent from sidefeeding

Experiments performed in Cologne

Fusion-Evaporation-Experiments:

→ High cross sections
→ Mainly yrast states get populated
→ Ideal for DDCM with γ-γ coincidences

- ^{93}Nb(^{24}Mg,p2n)^{114}Te
  → PRC 71, 0642324 (2005)
- ^{92}Mo(^{23}Na,p2n)^{112}Te
- ^{106}Pd(^{13}C,3n)^{116}Te
- ^{100}Mo(^{23}Na,4np)^{118}Te
- ^{110}Pd(^{13}C,3n)^{120}Te

Exemplary development of shifted and unshifted component: ^{120}Te

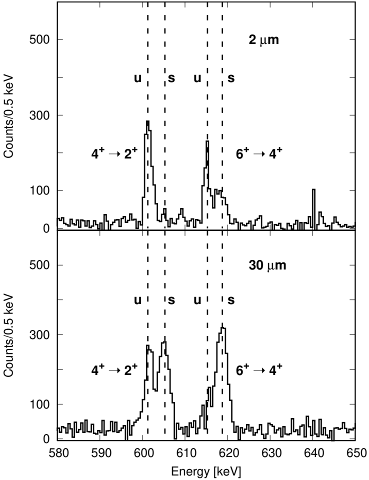


Figure: $4_1^+ \rightarrow 2_1^+$ and $6_1^+ \rightarrow 4_1^+$ transition, gated from above.

Exemplary lifetime analysis: ^{120}Te

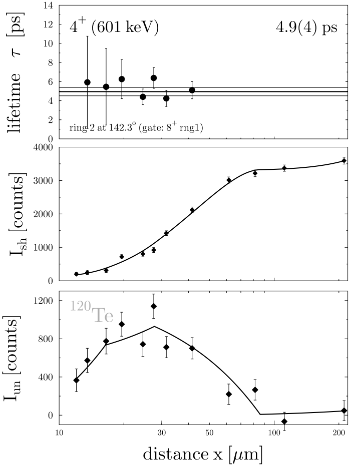


Figure: Exemplary τ-plot for the 4_1^+ state. Gate: $8_1^+ \rightarrow 6_1^+$.

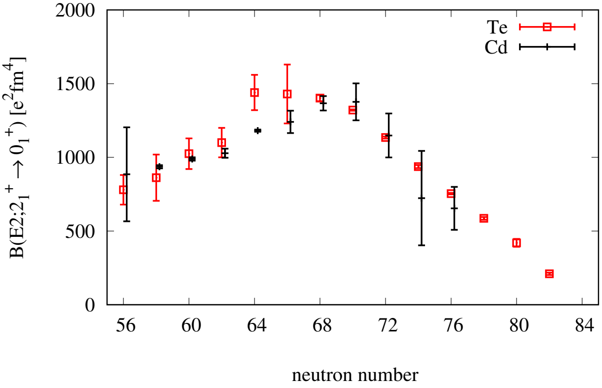
Results

Nucleus	State	Lifetime [ps]*	B(E2) [W.u.]*
^{112}Te	2^+	4.6(1)	36(1)
	4^+	1.8(1)	48(2)
^{114}Te	2^+	4.1(3)	34(3)
	4^+	3.1(3)	29(3)
^{116}Te	2^+	3.9(3)	43(4)
	4^+	3.0(1)	55(3)
^{118}Te	2^+	7.0(4)	42(3)
	4^+	4.0(5)	74(9)
^{120}Te	2^+	10.1(4)	42(2)
	4^+	4.8(3)	62(4)

*With the exception of ^{114}Te, these are preliminary results

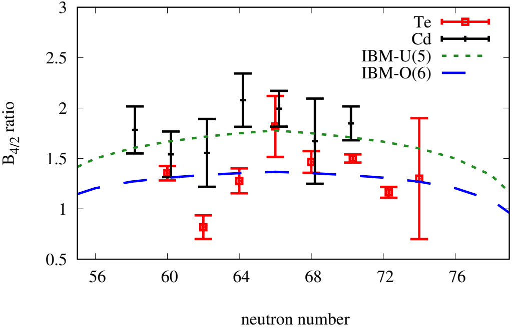
B(E2,$2_1^+ \rightarrow 0_1^+$) systematics

- B(E2,$2_1^+ \rightarrow 0_1^+$) systematics show a clear collective behavior
- Comparison with Cd isotopes shows agreement with Valence Proton Symmetry
- No dip at midshell, like in Sn



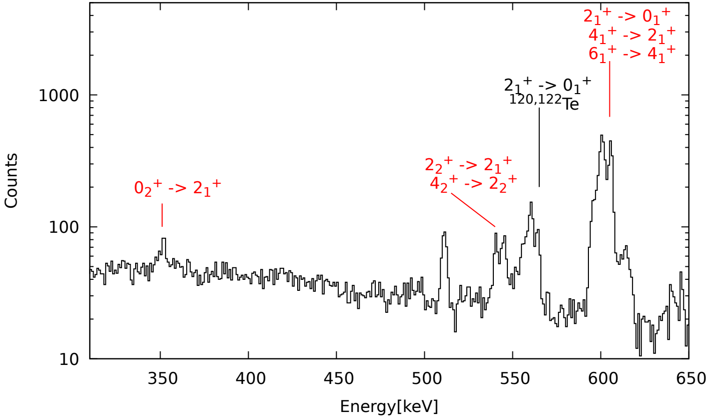
$B_{4/2}$ systematics

- $B_{4/2}$ ratios show that the midshell Te isotopes cannot be viewed as vibrational, but rather have to be seen as more γ-soft nuclei.
- Not yet a hint on shape coexistence
- For further information we need data on off-yrast states



Lifetime measurements for off-yrast states

Tested reaction $^{114}\text{Sn}(^{12}\text{C},^{8}\text{Be})^{118}\text{Te}$



→ off-yrast states, including the 0_2^+ are populated!

Outlook: Measurement of off-yrast lifetimes

- The Te isotopes in question can be reached by direct reactions from Sn isotopes
- Direct reactions can populate off-yrast states → Lifetime measurements with RDDS seems feasible
- 3He,n reactions populate 4p-2h states

Conclusion

- Lifetimes for four even-even Te isotopes were measured
- $B(E2, 2^+ \rightarrow 0^+)$ show no sign of shape coexistence
- $B_{4/2}$ ratios place the structure of Te isotopes closer to O(6) than U(5)

Remaining questions:

- $B_{4/2}$ ratio in ^{114}Te
- Nature of the 0_2^+ states in Te isotopes

Thank you for your attention!