New Pattern of Octupole Collectivity at N = 90

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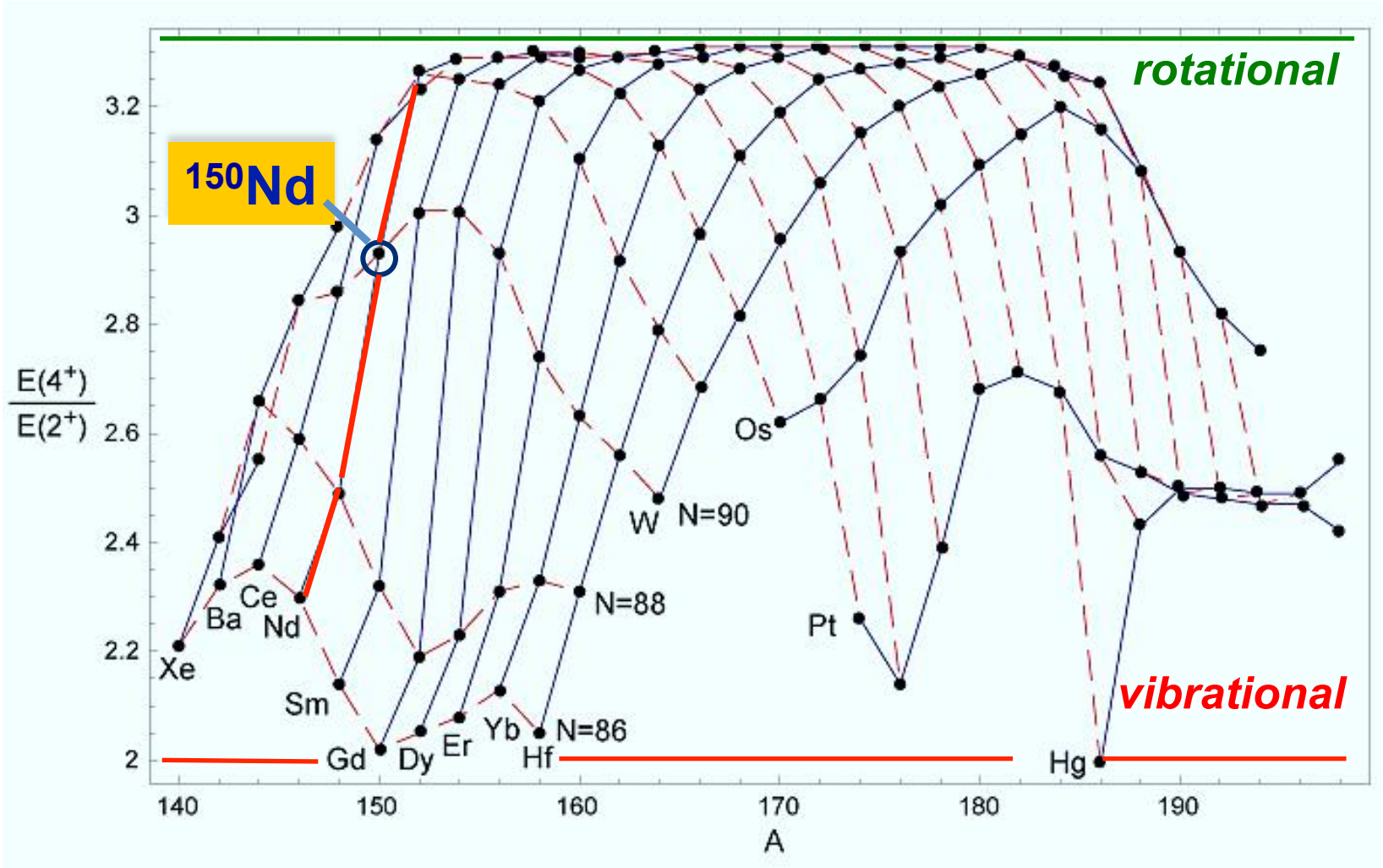
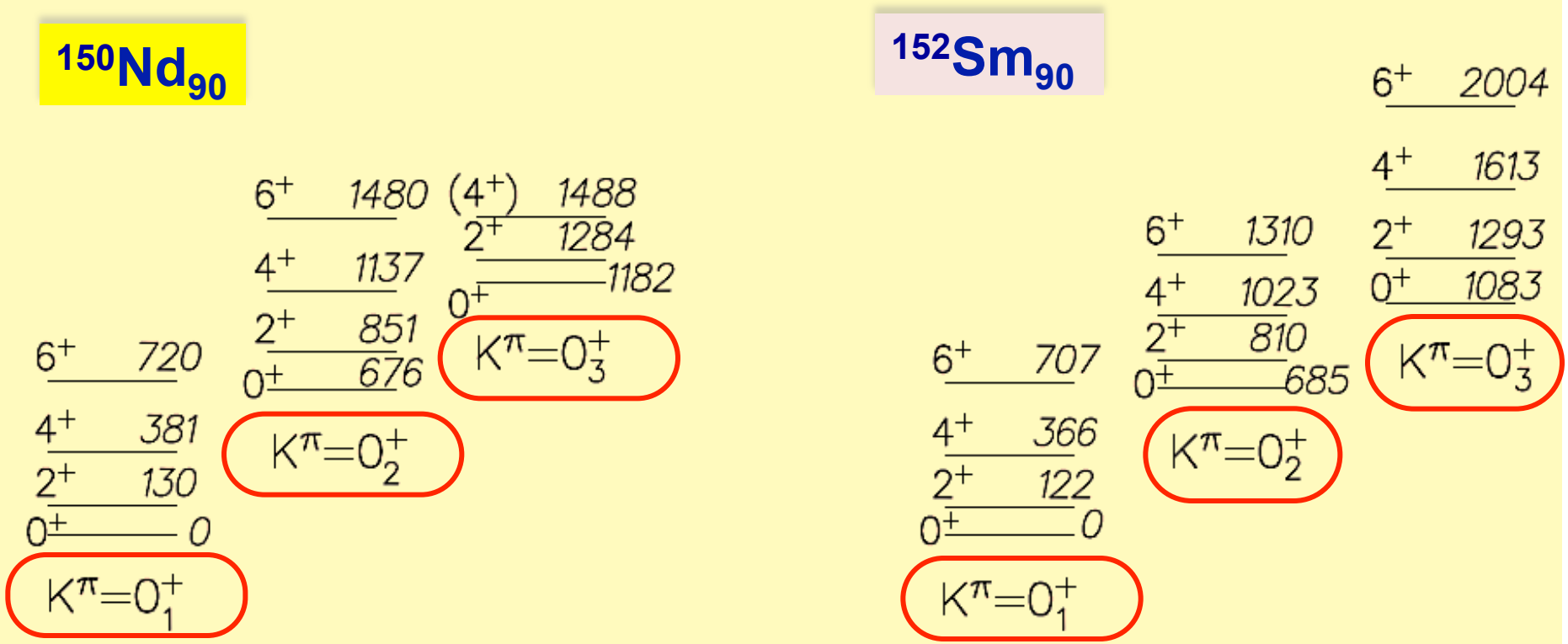
Experimental Evidence for Rapid Change in Structure at N = 90

$R_4 = E(4^+) / E(2^+)$ $R_4 \approx 2.0$ (Vibrator) $R_4 \approx 3.33$ (Rotor)



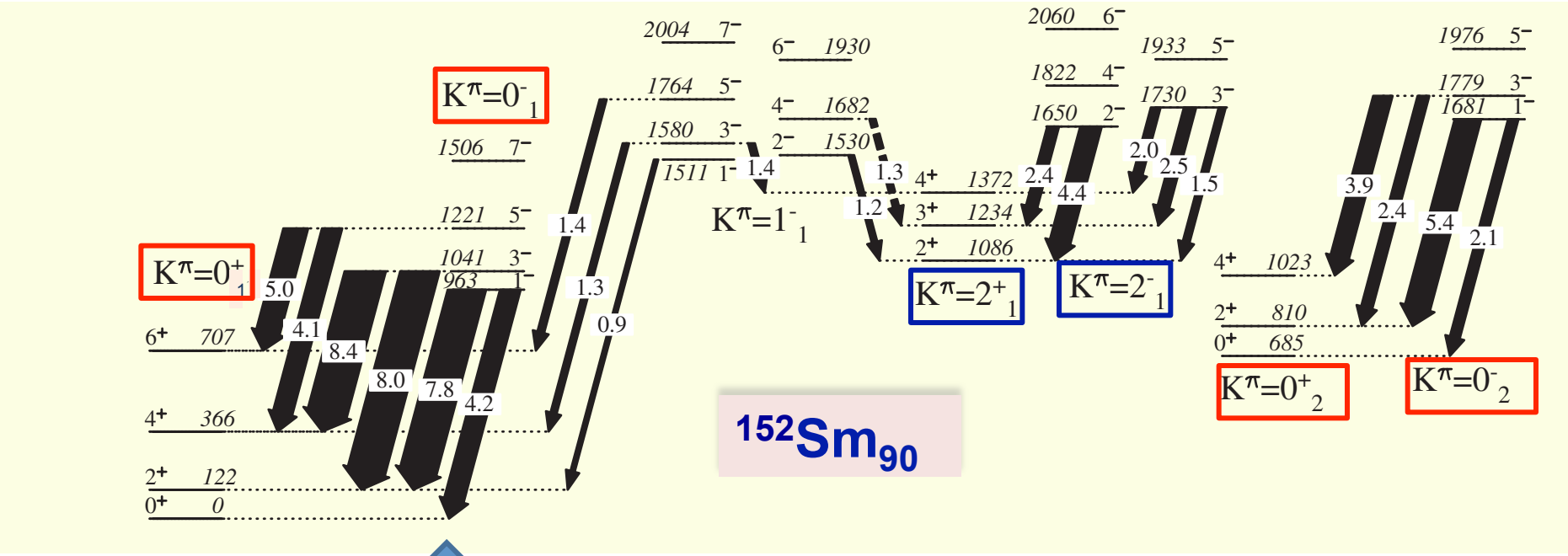
Evidence from R_4 values

Positive Parity 0^+ Bands in $^{150}Nd_{90}$ and $^{152}Sm_{90}$



^{152}Sm Coexisting $K^{\pi}=0^{-}$ bands

P. E. Garrett et al., Phys. Rev. Lett. 103, 062501 (2009)



in mW.u.

Experimental set-up

^{150}Nd(n,n'γ): Singles Measurements

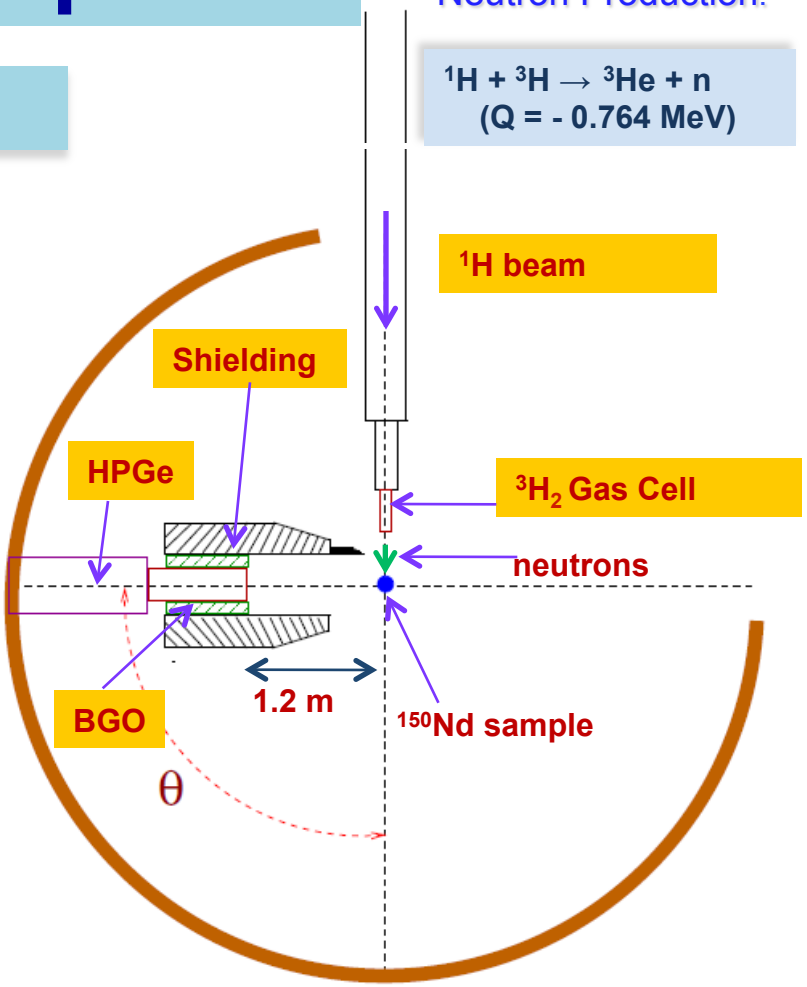
- Target: 31 grams (96% enriched) ^{150}Nd sample (Nd_2O_3)
- 7-MV Van de Graaff accelerator
- Mono-energetic neutrons
- Pulsed beam
- Time-of-flight gating

Excitation Function:
Beam Energy:
from 1.2 to 2.7 MeV in 100-keV steps
(detector at 125°)

Angular Distribution:
5 to 12 Different Angles
(Angles between 40° and 155°)
Beam Energy:
1.2, 1.4, 2.05, and 2.7 MeV

Neutron Production:

$^1H + ^3H \rightarrow ^3He + n$
(Q = - 0.764 MeV)



Schematic view

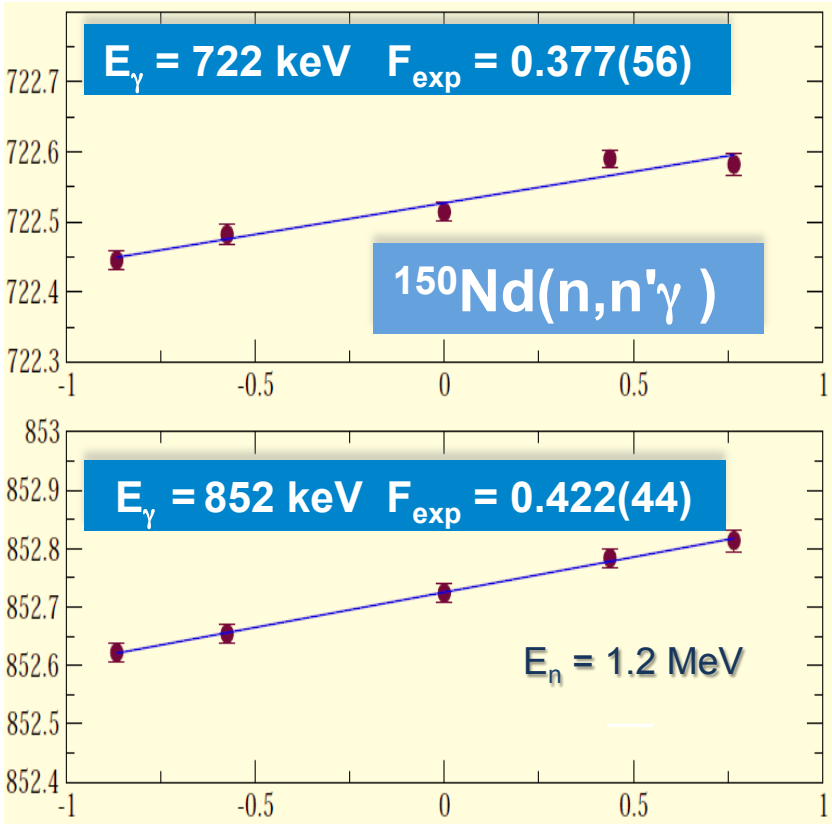
Doppler Shift Attenuation Method (DSAM)

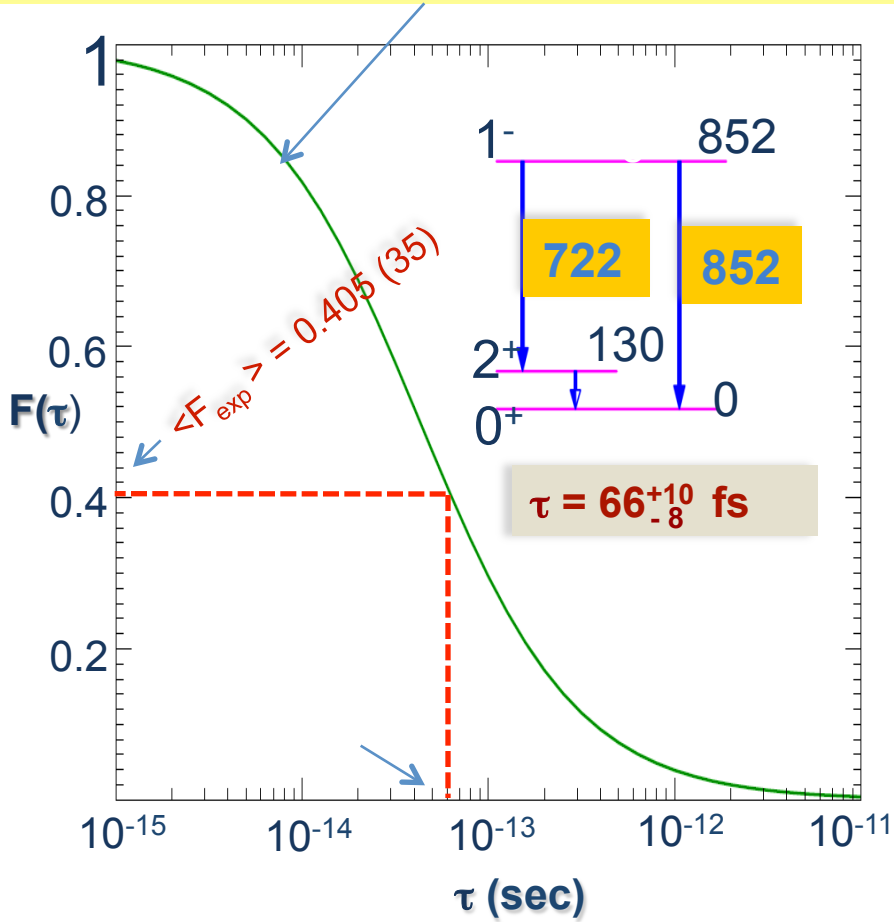
$$E(\theta) = E_0\left(1 + \frac{v_{cm}}{c} F(\tau)\cos\theta\right)$$

T. Belgya, et al., Nucl. Phys. **A608**, 43 (1996)

Lifetime determination in the range between 10^{-15} s and 10^{-12} s

K. B. Winterbon, Nucl. Phys. **A246**, 293 (1975)



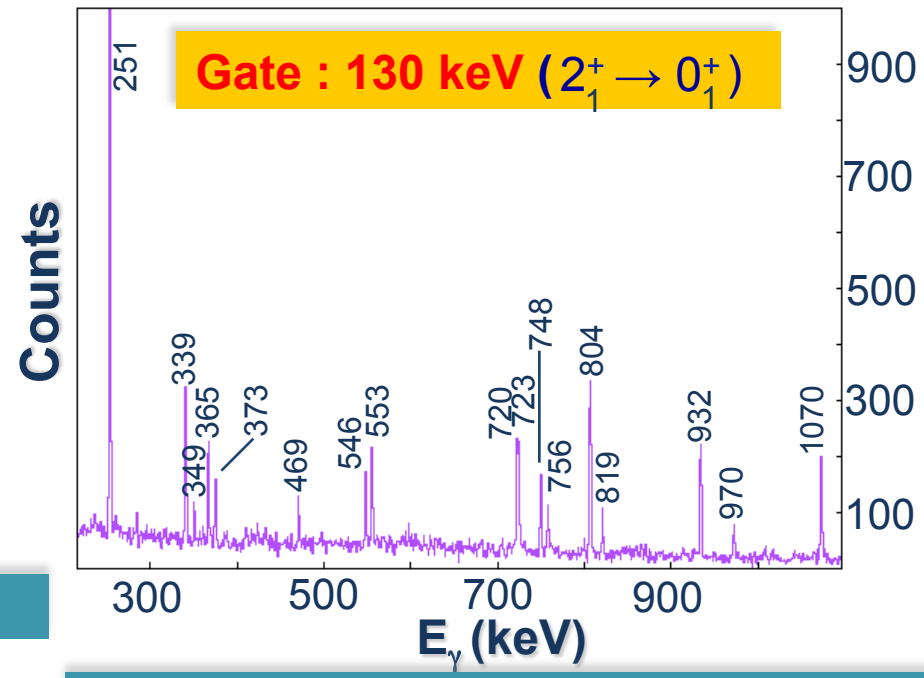


Coincidence Measurements

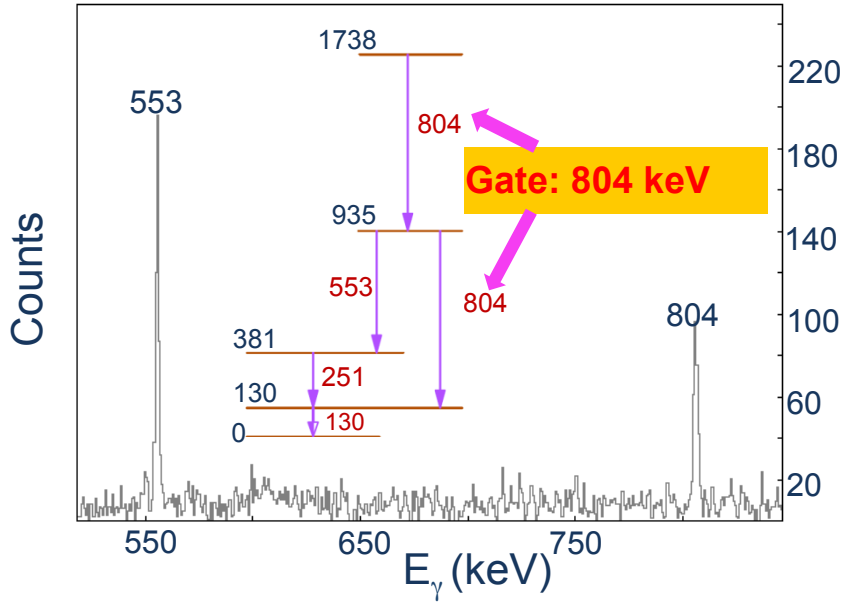
- **Beam energy: 3.2 MeV**
- **4 HPGe detectors**

C.A. McGrath, et al., Nucl. Instrum. Methods Phys. Res. **A421**, 458 (1999)

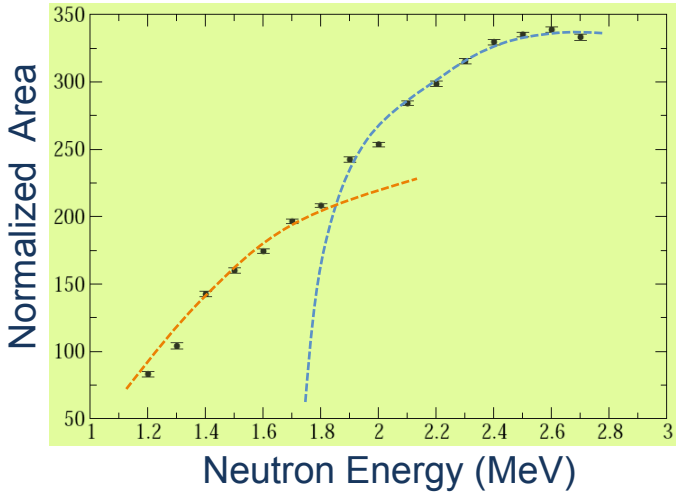
Coincidence spectrum with ground state transition



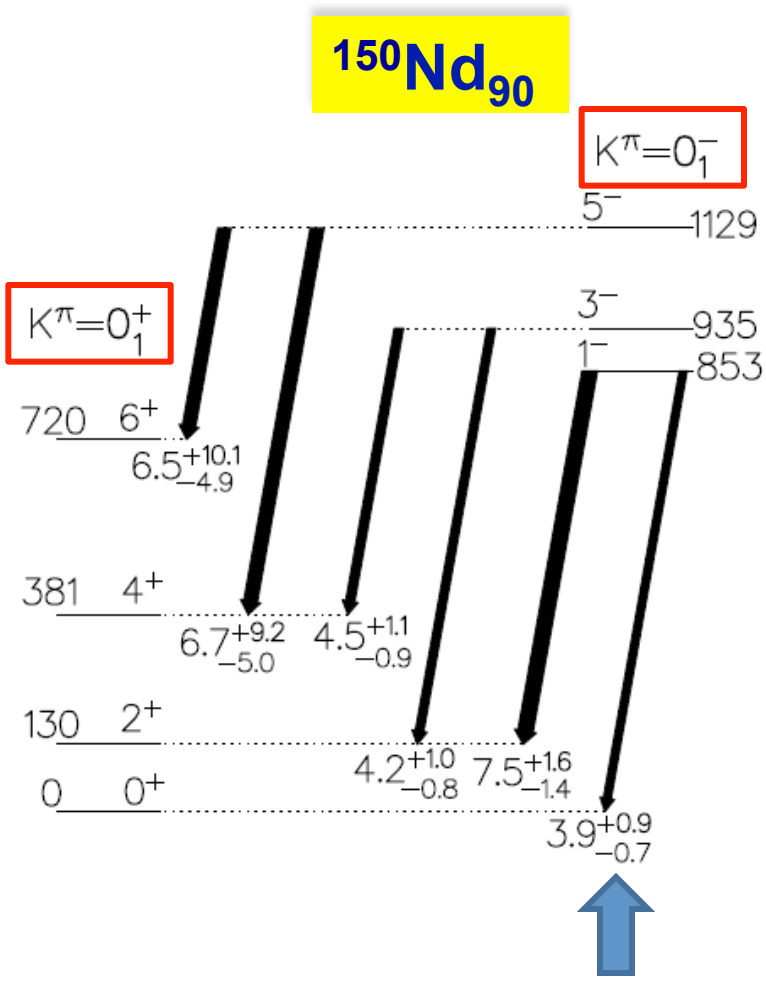
Coincidence spectrum with gate on 804-keV transition

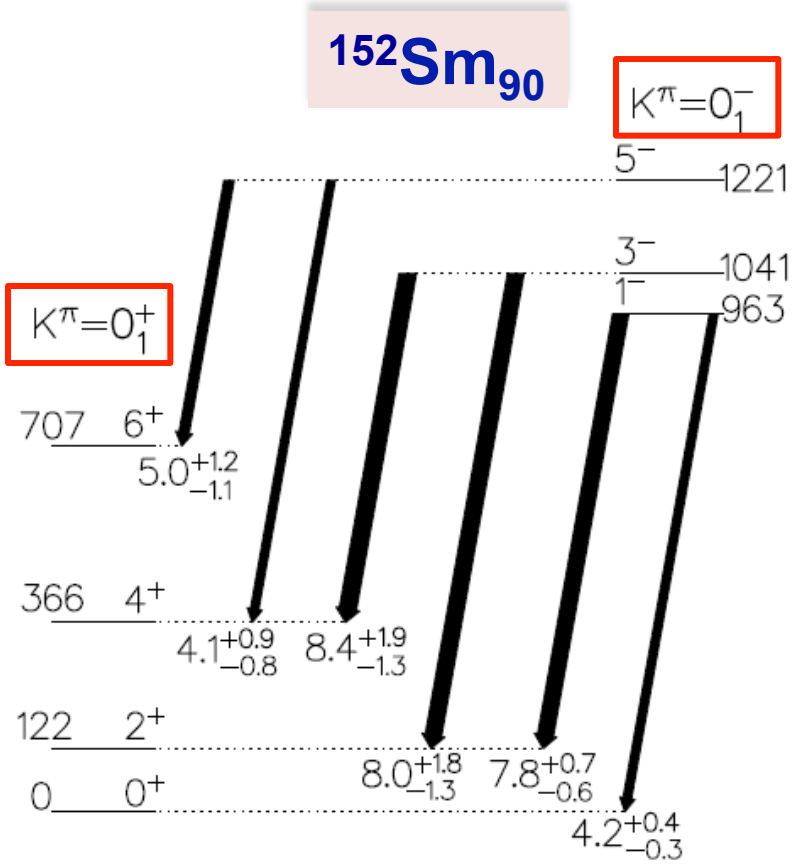


Excitation function plot for 804-keV transition



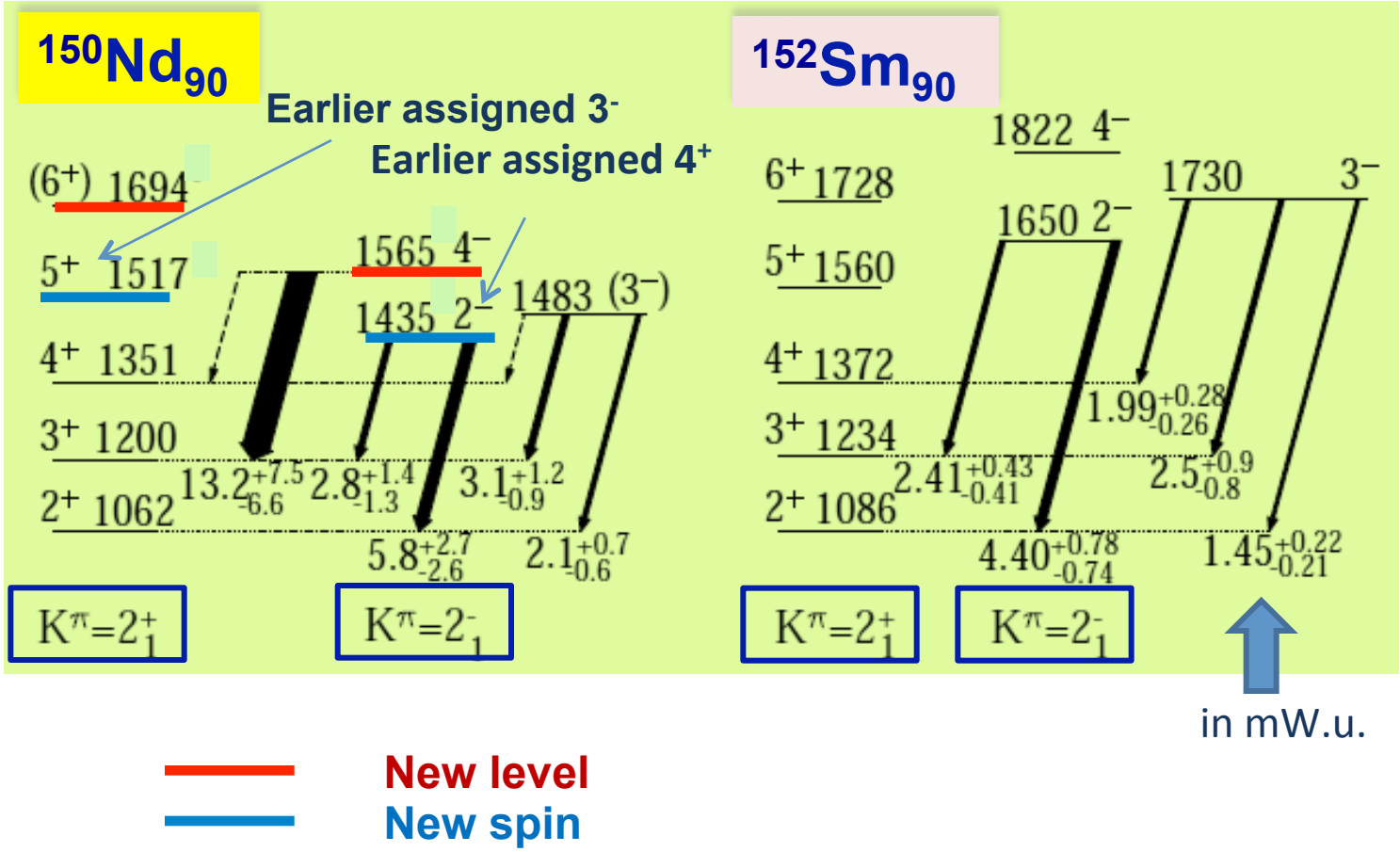
E1 Decay Pattern : Comparison between ^{150}Nd and ^{152}Sm





in mW.u.

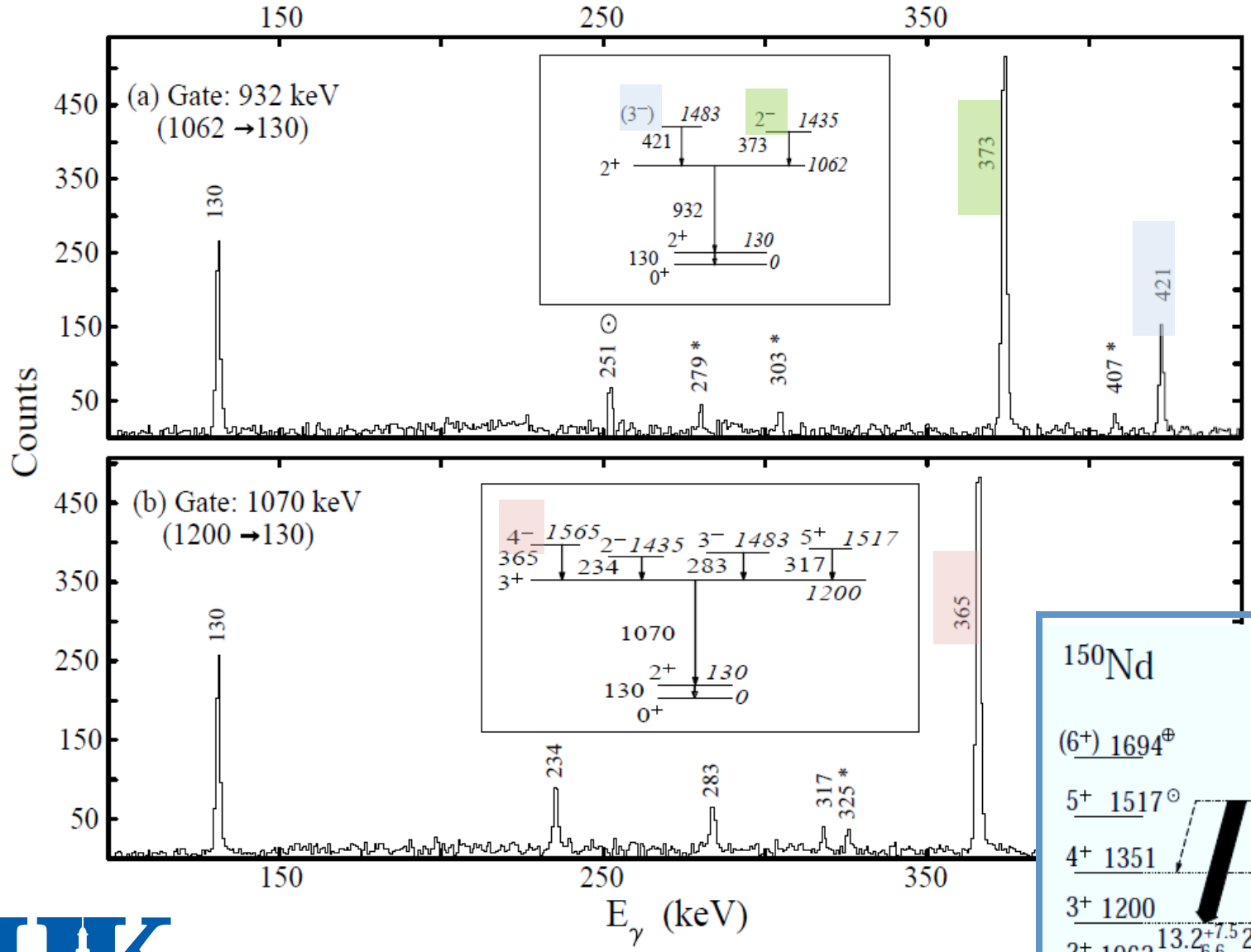
E1 Decay Pattern : Comparison between ^{150}Nd and ^{152}Sm

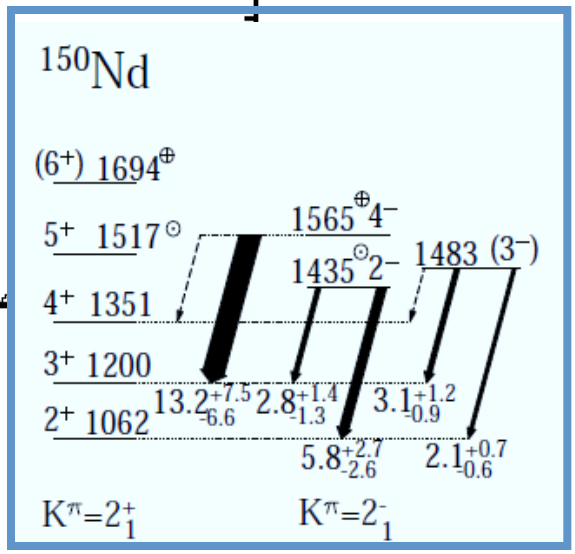


New level

New spin

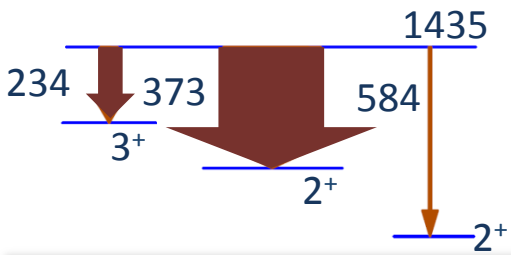
Coincidence Spectra





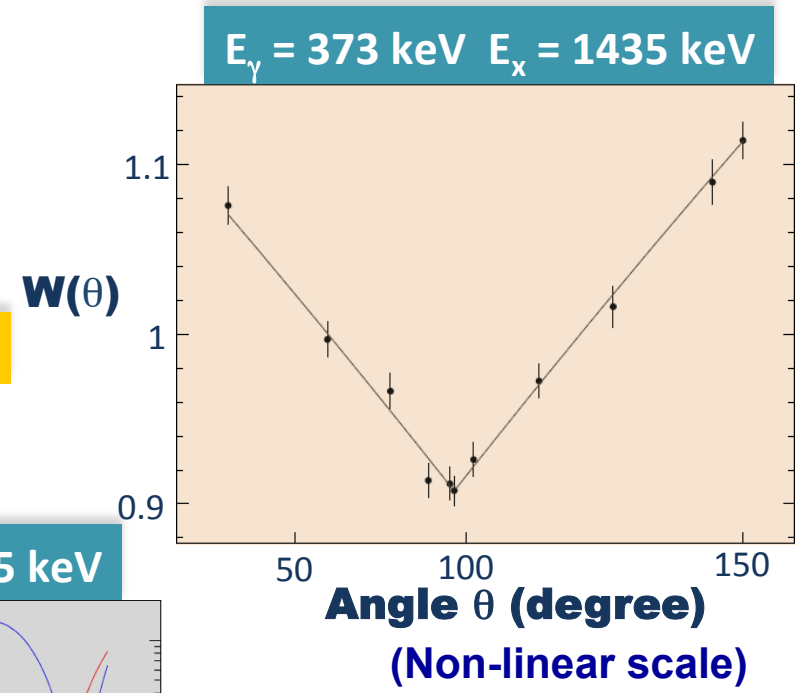
Angular Distribution for 373-keV transition

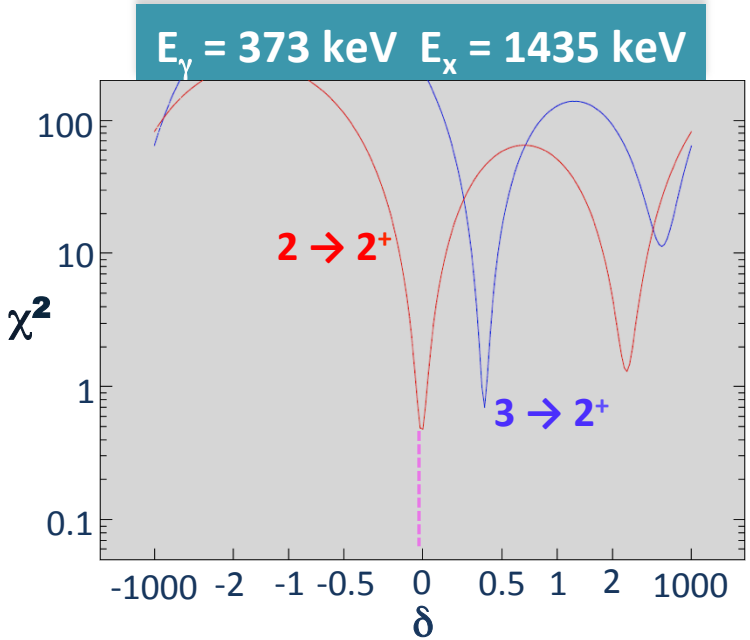
NNDC : 4^+ | **Present : 2^-**



$$W(\theta) = A_0[1 + a_2P_2(\cos\theta) + a_4P_4(\cos\theta)]$$

$$a_2 = 0.18(1) \quad a_4 = 0.00(1)$$

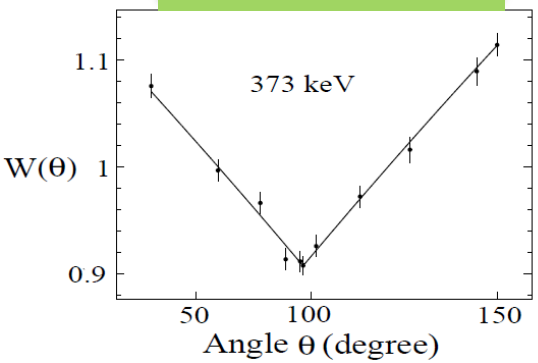




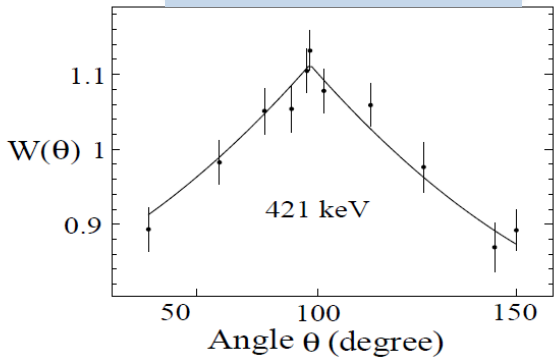
Pure M1? unlikely @ 1400 keV

Angular distribution

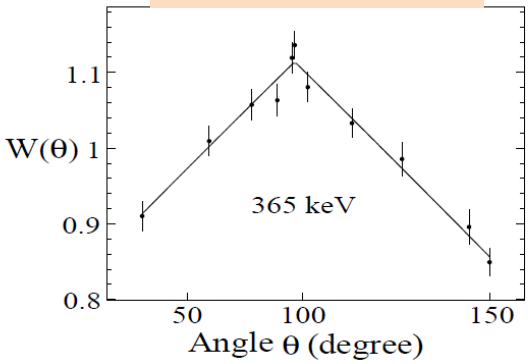
1435 keV 2⁻

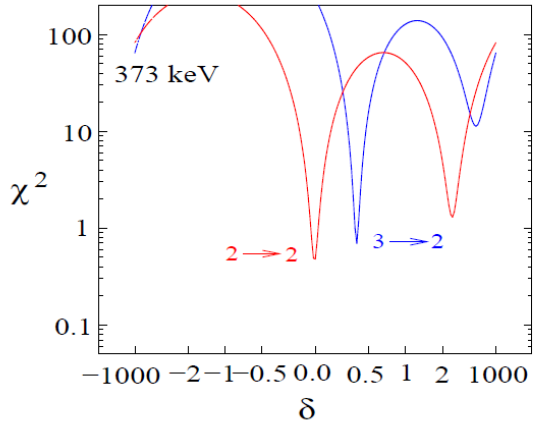


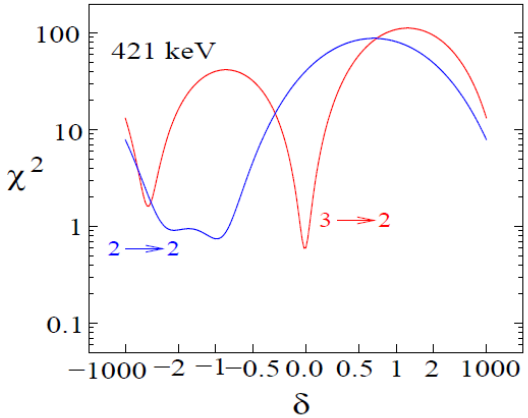
1483 keV (3⁻)

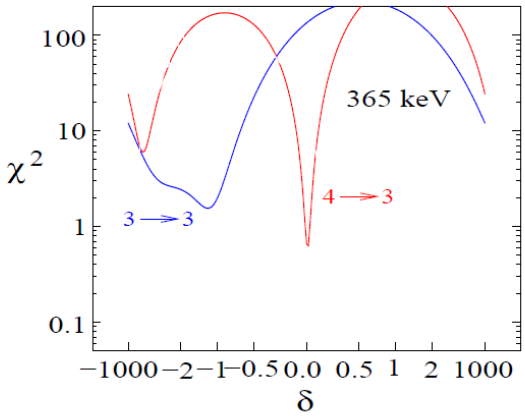


1565 keV 4⁻







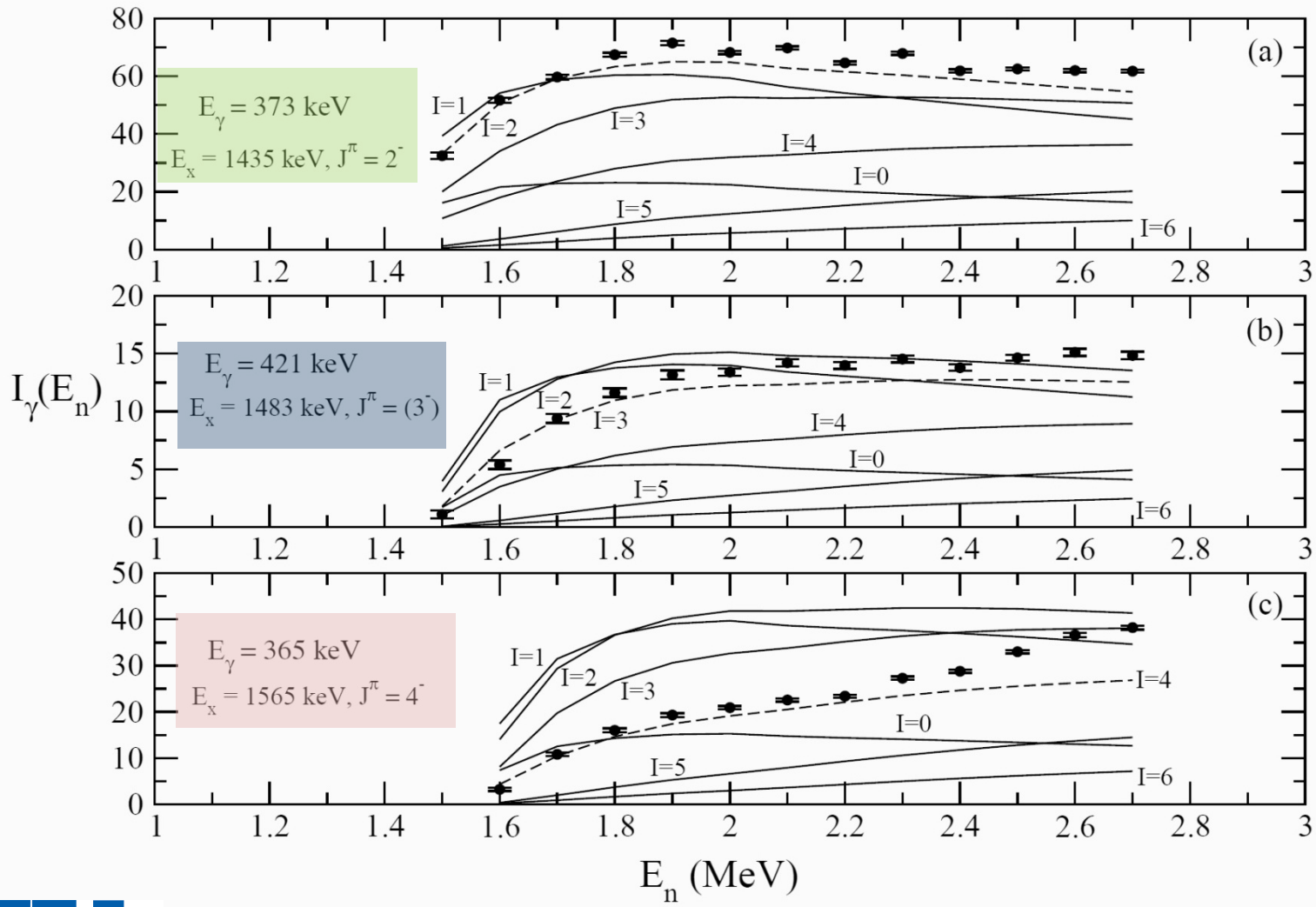


$a_2 = 0.18(1)$ $a_4 = 0.00(1)$

$a_2 = -0.20(3)$ $a_4 = 0.03(4)$

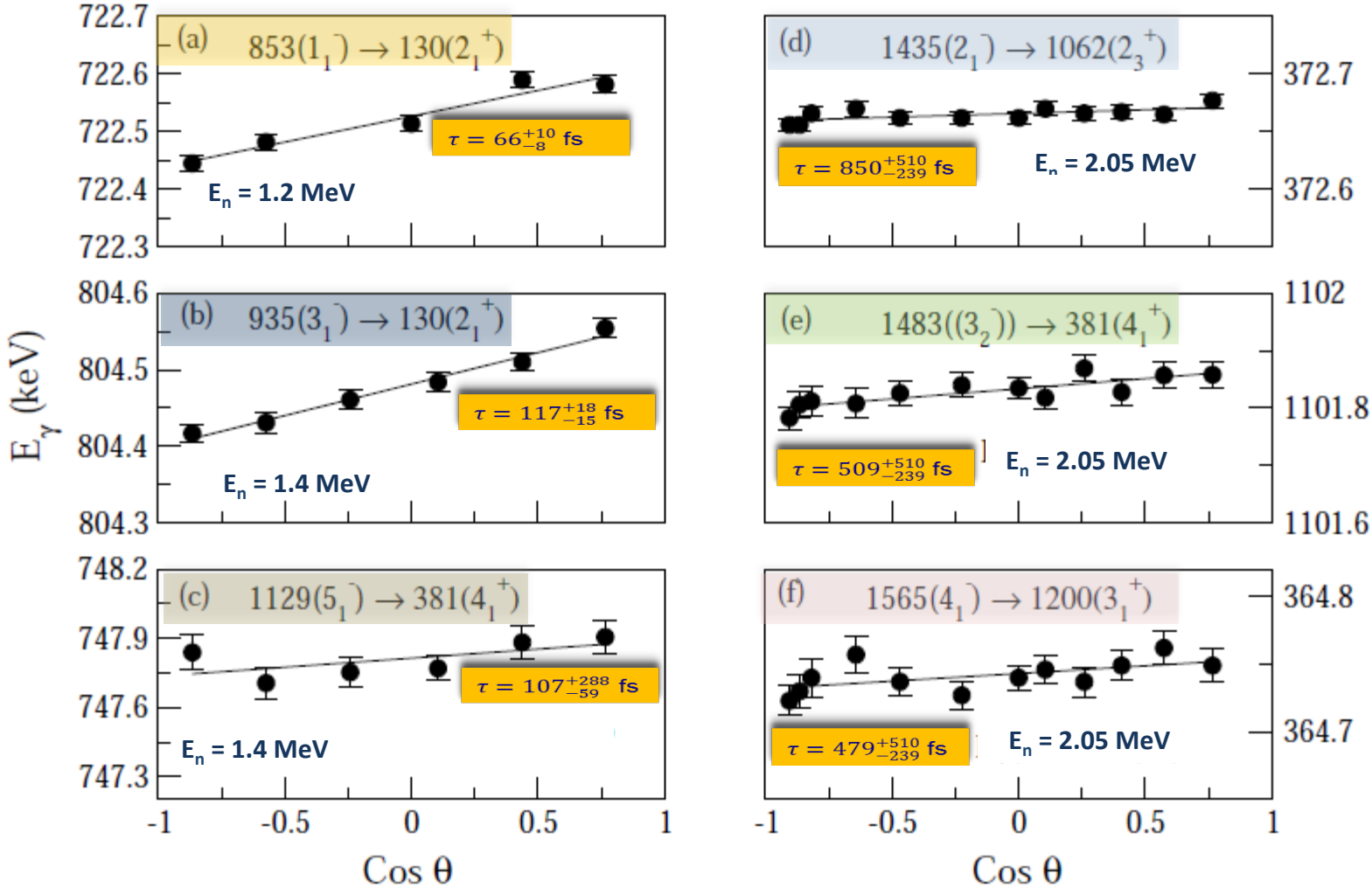
$a_2 = -0.23(2)$ $a_4 = 0.00(3)$

Comparison of Experimental Excitation Function with a Statistical Model (CINDY)



E. Sheldon and V. C. Rogers , Comput. Phys. Commun. **6**, 99 (1973)

Lifetime Results



Theoretical predictions

There is no explanation for the large E1 transitions seen between a $K^{\pi}= 2^-$ band and the lowest $K^{\pi}= 2^+$ in ^{150}Nd and ^{152}Sm.

A simple coupling of an octupole degree of freedom ($K^{\pi}= 0^-$ 2^- or 3^-) to a γ vibration ($K^{\pi} = 2^+$) would result in a range of possible K-bands between K= 0 and K= 5. The operation of the K = 0, ±1 selection rule for E1 transitions would favor the decay pattern $K^{\pi} = 2^- \rightarrow K^{\pi} = 2^+$ observed ·

Summary

- Excited states in ^{150}Nd have been investigated with the ^{150}Nd(n,n'γ) reaction.
- A $K^{\pi} = 0^{-}$ band and new $K^{\pi} = 2^{-}$ band are established.
- Level lifetimes have been determined.
- New spin assignments have been made.
- Lifetime data reveal a strongly enhanced pattern of E1 transition strengths, similar to that observed in ^{152}Sm.
- A new pattern of octupole collectivity has been observed at N=90.

THANK YOU!

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