Universität zu Köln

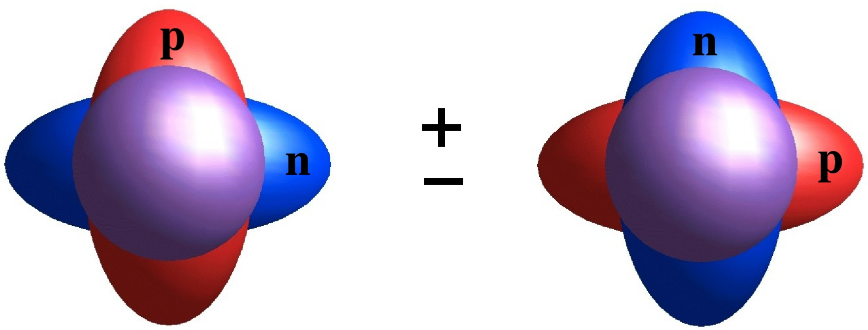
Collectivity in the A=100 mass region: Newest results from Cologne

C. Fransen, L. Bettermann, A. Blazhev,
N. Braun, A. Dewald, J. Jolie,
D. Mücher, T. Pissulla
Institute for Nuclear Physics,
University of Cologne, Germany

- Fundamental collective symmetric and mixed-symmetric excitation
- Recent experiments on nuclei in the A=100 mass region
- Interpretation: Evolution of collectivity

Motivation: fundamental collective excitations in the valence space

Vibrator like nuclei



Isoscalar quadrupole vibration: symmetric

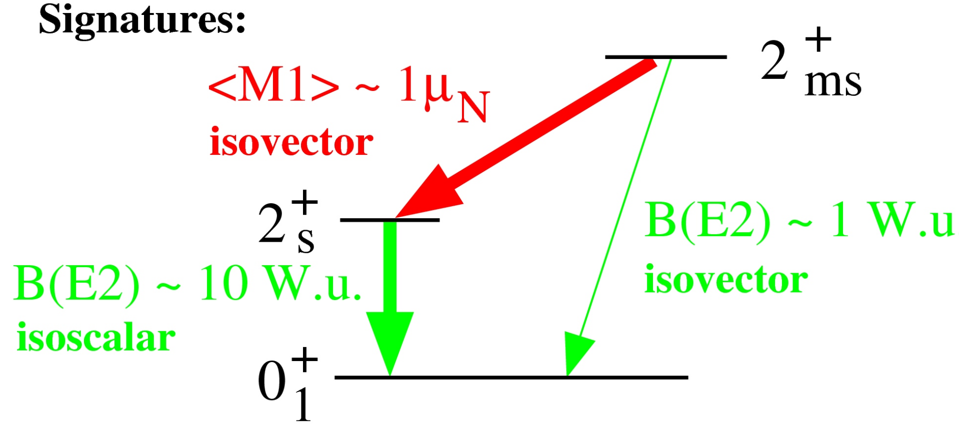
$$|2^+_{\mathrm{s}}\rangle \propto |2^+_{\mathrm{p}}\rangle + |2^+_{\mathrm{n}}\rangle$$

Isovector quadrupole vibration: mixed−symmetric

$$|2^+_{\mathrm{ms}}\rangle \propto a \cdot |2^+_{\mathrm{p}}\rangle - b \cdot |2^+_{\mathrm{n}}\rangle$$

Description: Interacting boson model (sd-IBM-2)
A. Arima, F. Iachello, T. Otsuka

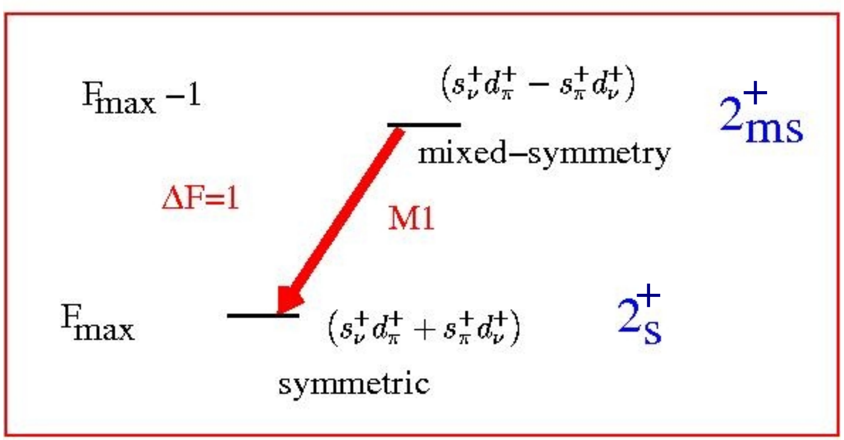
Signatures:



M1: Signature for Mixed−Symmetry

$$T(M1) \propto (g_\pi - g_\nu)\left([d_\pi^\dagger \tilde{d}_\pi]^{(1)} - [d_\nu^\dagger \tilde{d}_\nu]^{(1)}\right) \quad + \mathrm{L_{tot}}$$

$$g_\pi \approx 1\ \mu_N\ , \quad g_\nu \approx 0\ \mu_N$$

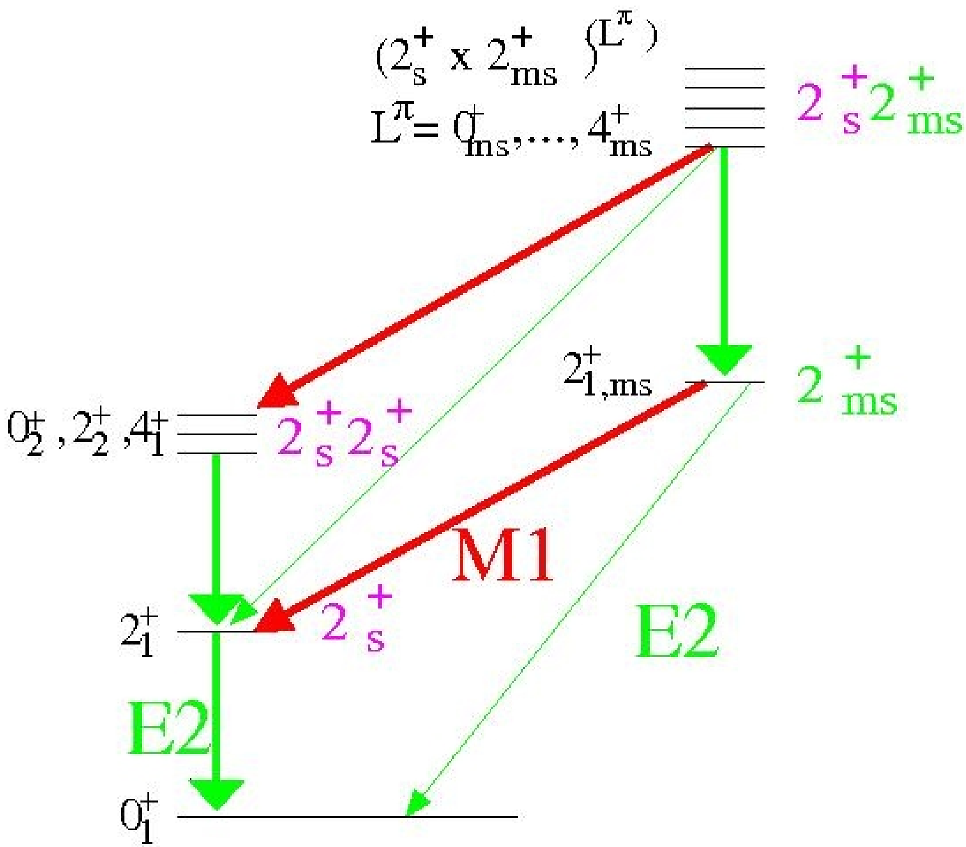


$$\langle F_{\max} \,||\, M1 \,||\, F_{\max} - 1\rangle \approx 1\ \mu_N$$

Mixed-symmetric multiphonon excitations

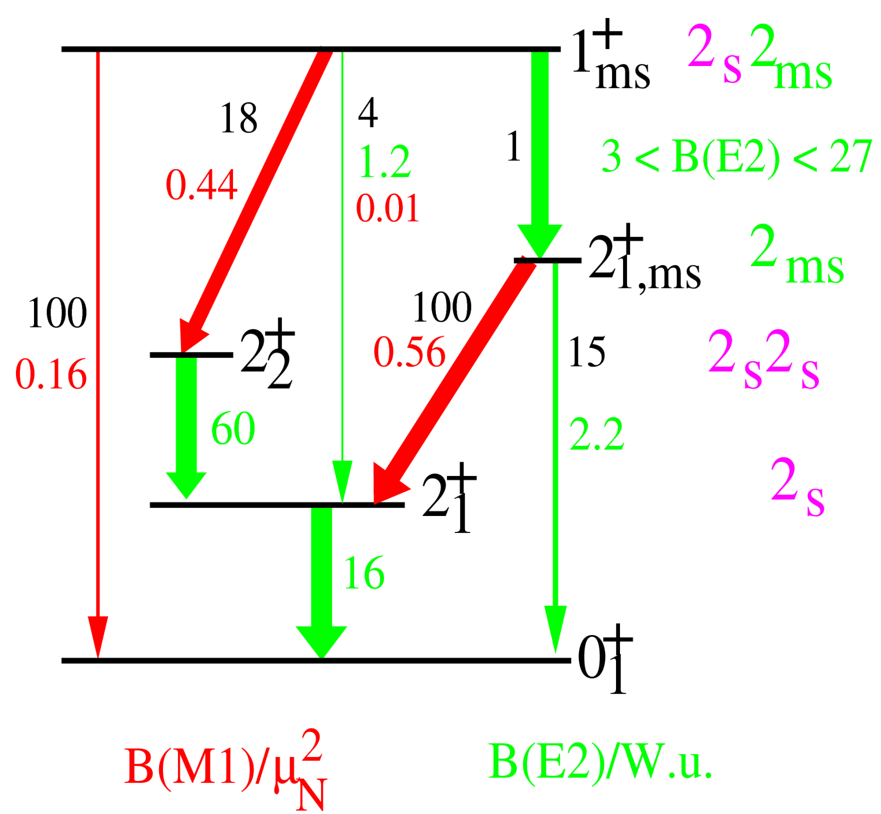
$|2_s^+\rangle \sim |2_p^+\rangle + |2_n^+\rangle$

$|2_{ms}^+\rangle \sim a|2_p^+\rangle - b|2_n^+\rangle$



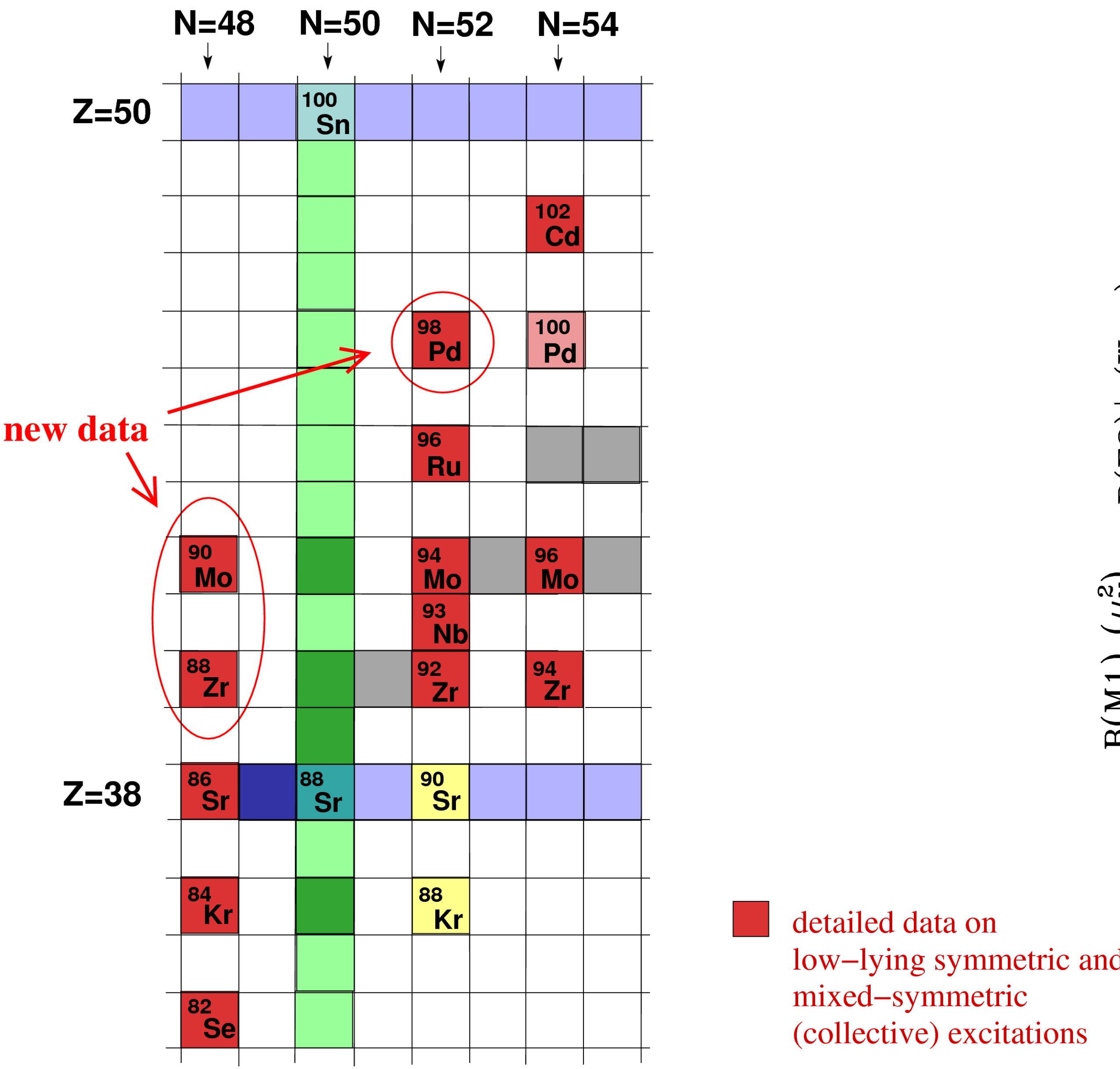
A. Arima et al., Phys. Lett. 66B, 205 (1977).
A. Faessler, Nucl. Phys. 85, 653 (1966).

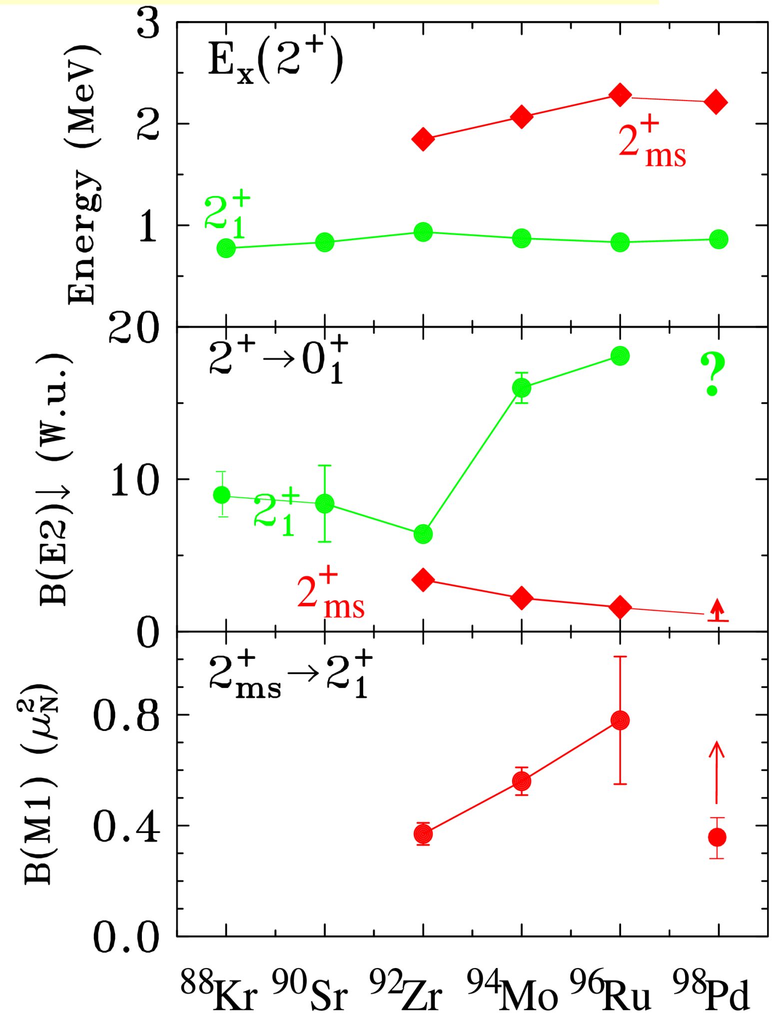
Example:
multiphonon MS states
identified in ^{94}Mo



C. Fransen et al., Phys. Rev. C 67, 024307 (2003)

Data on mixed-symmetry states in the A=100 mass region so far



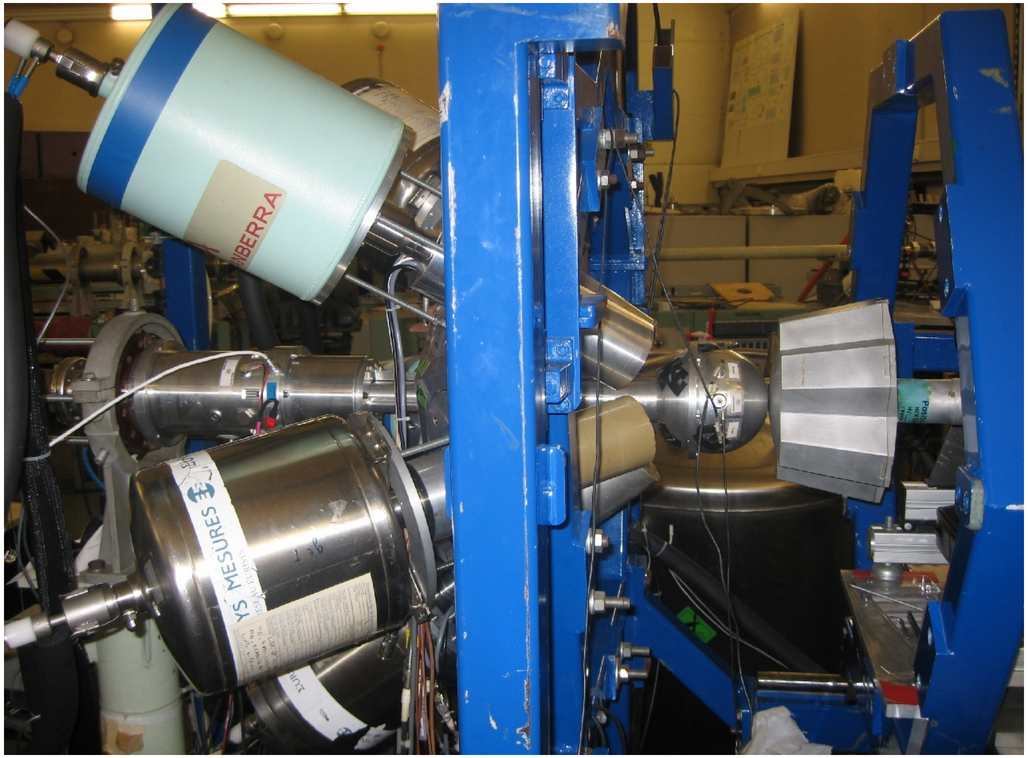


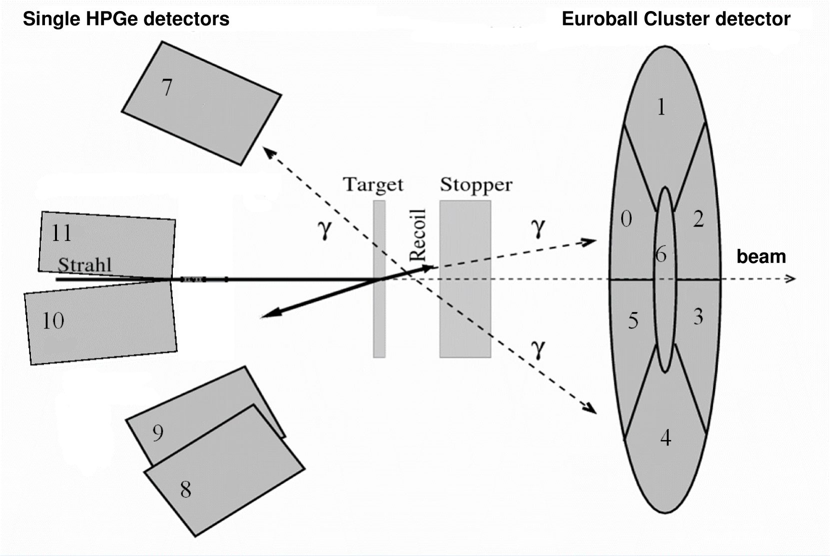
N=52 isotones

Information about collectivity

- ➔Existence and properties of the low-lying symmetric and mixed-symmetric multiphonon excitations.
- ➔Need to know: absolute transition strengths.
- ➔Determine from level lifetimes and decay properties (multipolarities, branching ratios):
- ➔Level lifetimes in the picosecond range: RDDS (plunger), lifetimes in the femtosecond range: DSAM
- ➔Decay properties: angular correlation measurements.

The Cologne Plunger

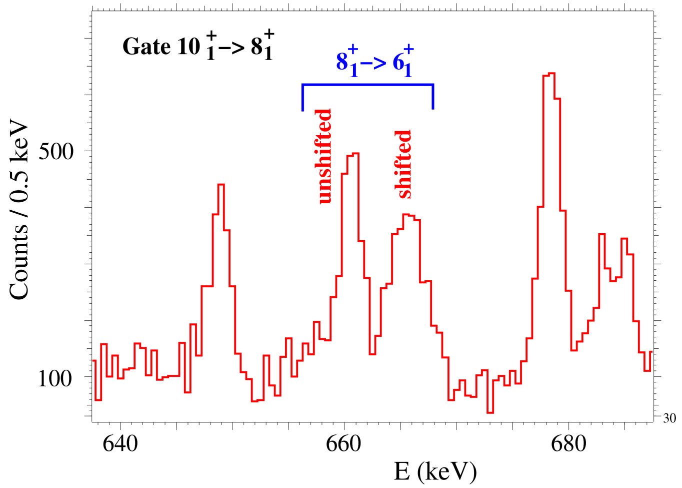




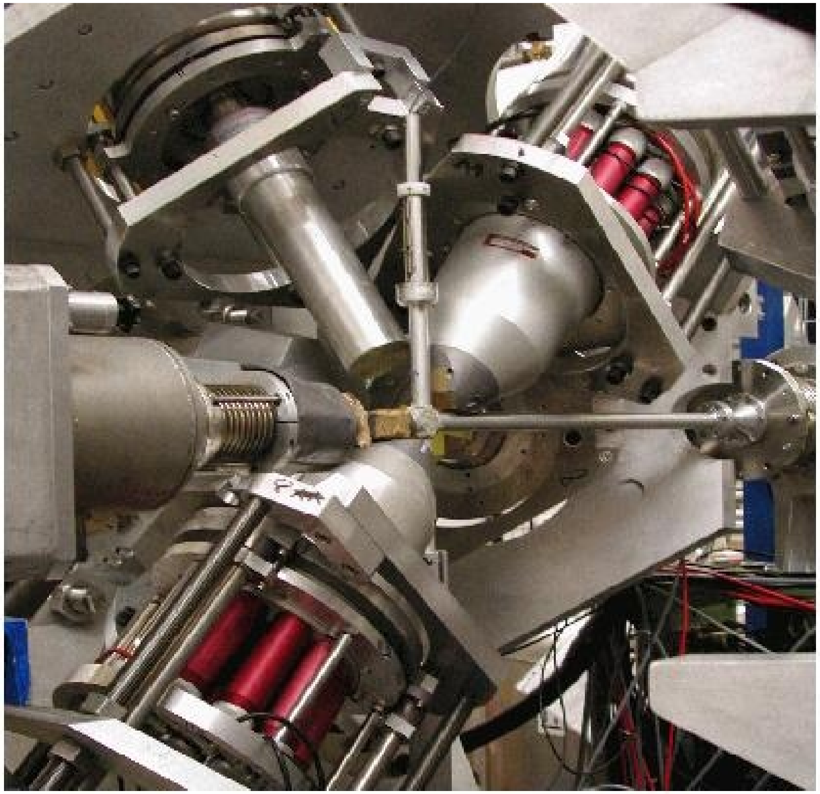
Lifetime determination with RDDS
(recoil distance Doppler shift method)

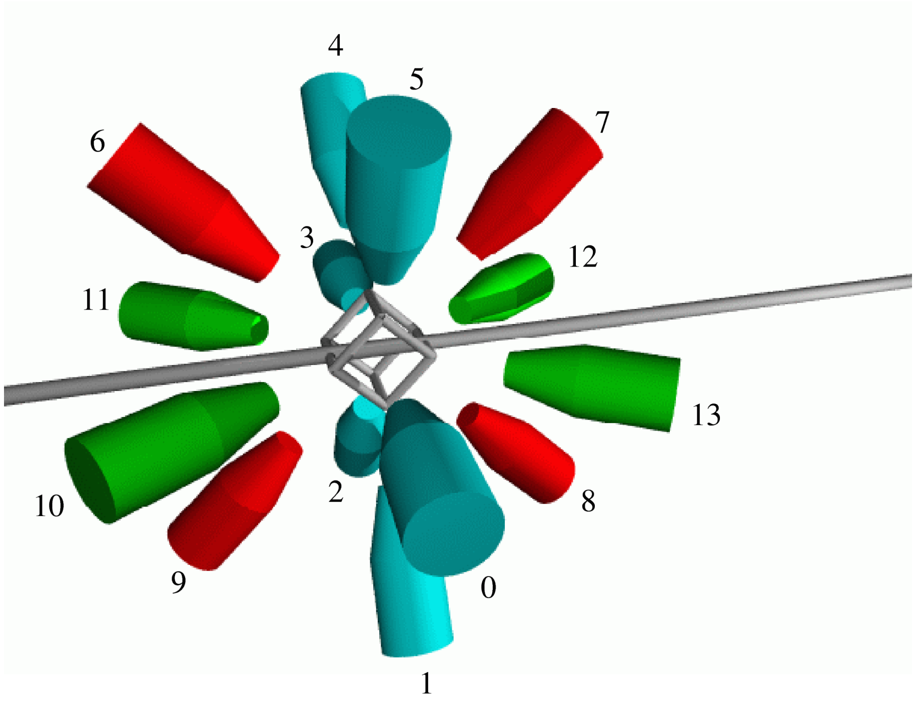
$$\tau(t_k) = \frac{I^{\rm us}(t_k)}{\frac{d}{dt} I^{\rm sh}(t_k)}$$

$I^{\rm us}$ = intensity of the unshifted γ-ray line
$I^{\rm sh}$ = intensity of the Doppler-shifted component



The Cologne HORUS spectrometer





·14 positions for HPGe detectors
·Photopeak efficiency: ~2 % @ 1.3 MeV
·measurements on ^{88}Zr, ^{90}Mo:
9 single HPGe detectors, 1 Euroball cluster
6 BGO shields

cube-like geometry of the HORUS spectrometer: analyze gamma-gamma angular correlations:

spins, multipolarities, (parities)

Performed experiments

Lifetime measurements with the Cologne plunger

^{98}Pd

- Reaction: ^{92}Mo(^{10}B,3np)^{98}Pd, E_{10B}=54 MeV
- Target: 0.3 mg/cm^2 ^{92}Mo, stopper 4.9 mg/cm^2
- 16 target to stopper distances between 0.002 and 2.000 mm

Gamma-gamma angular correlation measurements (HORUS):

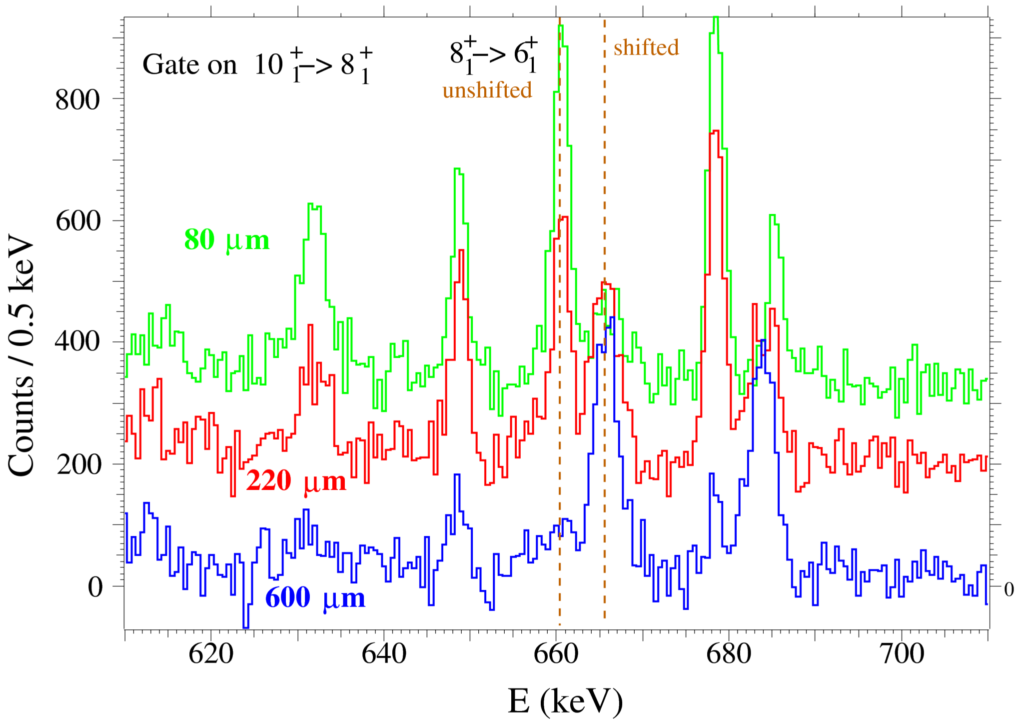
^{88}Zr

- Reaction: ^{89}Y(p,2n)^{88}Zr
- cross section for 2n channel to ^{88}Zr for E_p=17 MeV: ~600 mbarn
- total number of gamma-gamma coincidences: 2.4*10^9
- 2 new excited low-spin states, 7 new decay transitions

^{90}Mo

- Reaction: ^{90}Zr(^{3}He,3n)^{90}Mo
- cross section for 3n channel to ^{90}Mo for E_{3He}=27 MeV: ~150 mbarn
- total number of gamma-gamma coincidences: 2*10^9
- 5 new decay transitions investigated

Results for ^{98}Pd



First determination of lifetimes and E2 transition strengths of Yrast states in ^{98}Pd

J^π	τ (ps)	$B(E2; J^\pi \to [J-2]^\pi)$ (W.u.)
2^+_1	$< 15(1)$	$> 4.2(3)$
4^+_1	$16.9(30)$	$12.6^{+2.7}_{-1.9}$
6^+_1	$27.8(20)$	$18^{+1.4}_{-1.2}$
8^+_1	$95.6(20)$	$2.54(5)$

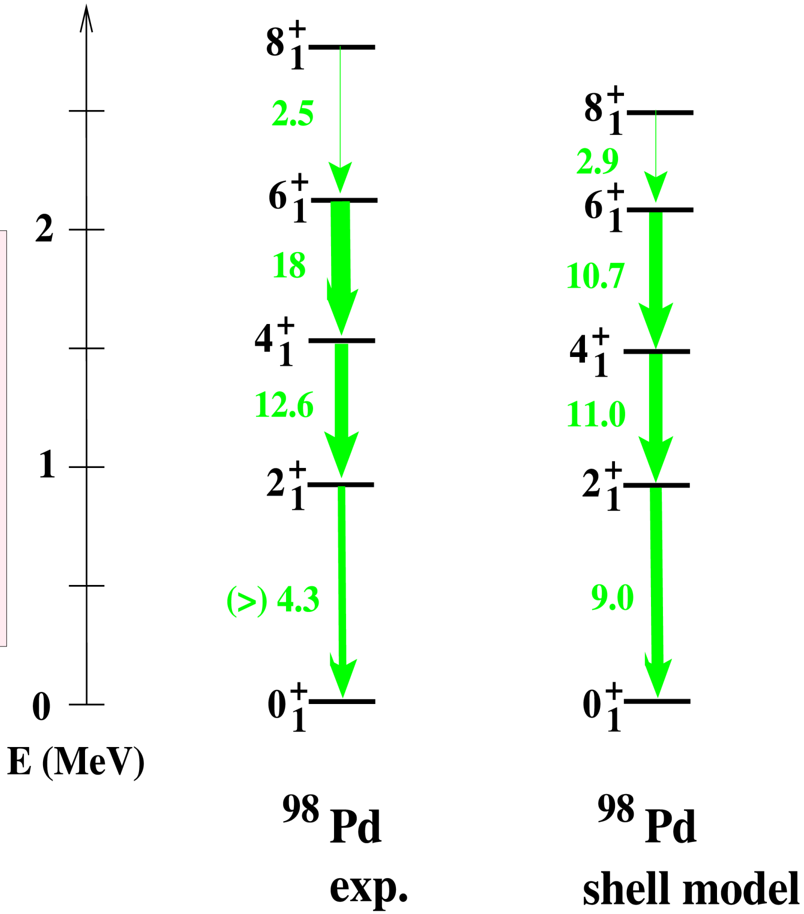
^{98}Pd: comparison to shell model calculations

Code OXBASH (B.A. Brown, et al., MSU-NSCL report 1289 (2004)

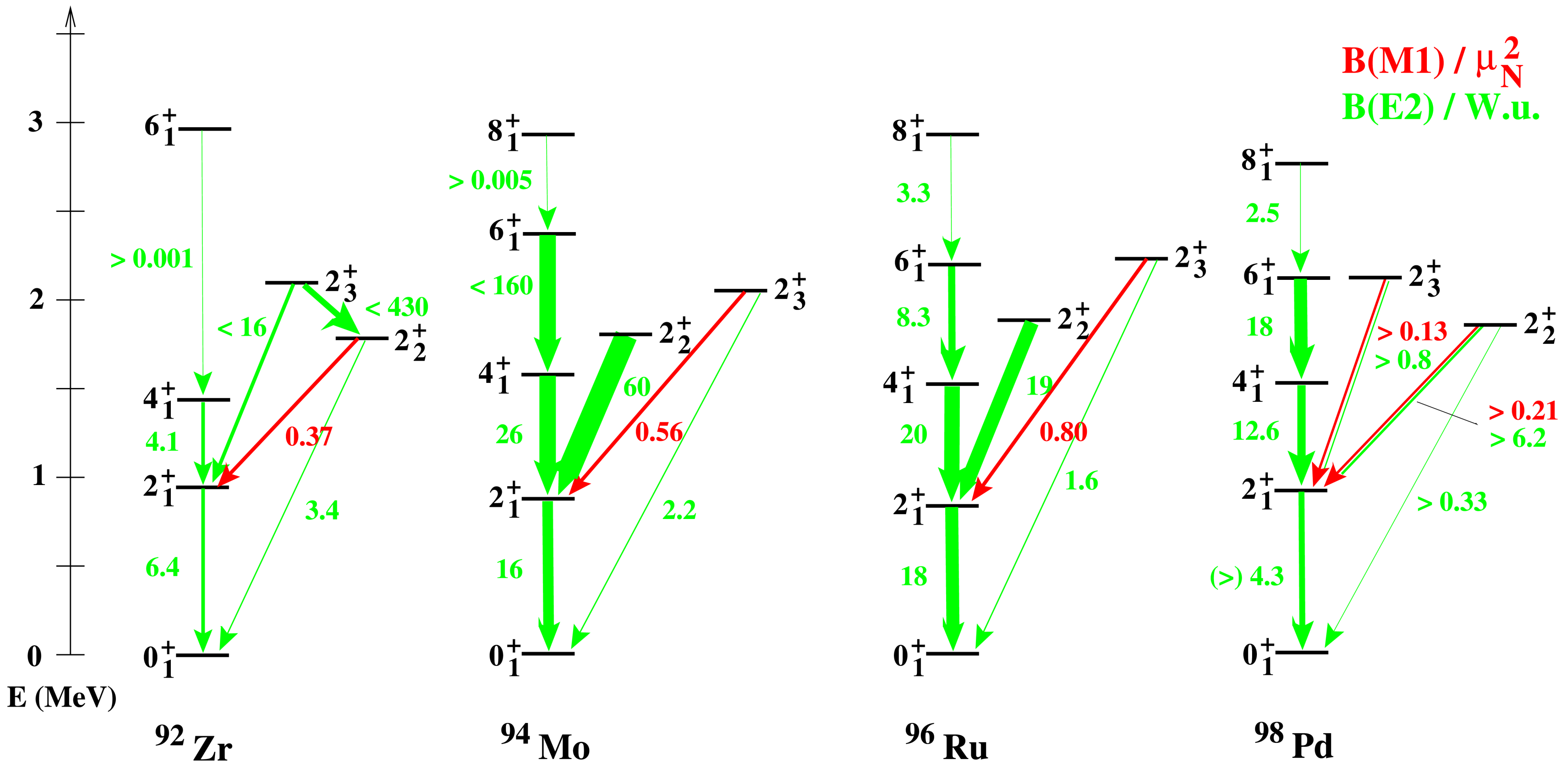
core ^{88}Sr
model space for valence protons: $0g_{1/2}$, $1p_{1/2}$,
neutron single particle orbits: : $1d_{5/2}$, $0g_{7/2}$, $2s_{1/2}$, $1d_{3/2}$, $0h_{11/2}$

Effective charges:
$e_\pi = 1.5$
$e_\nu = 0.5$

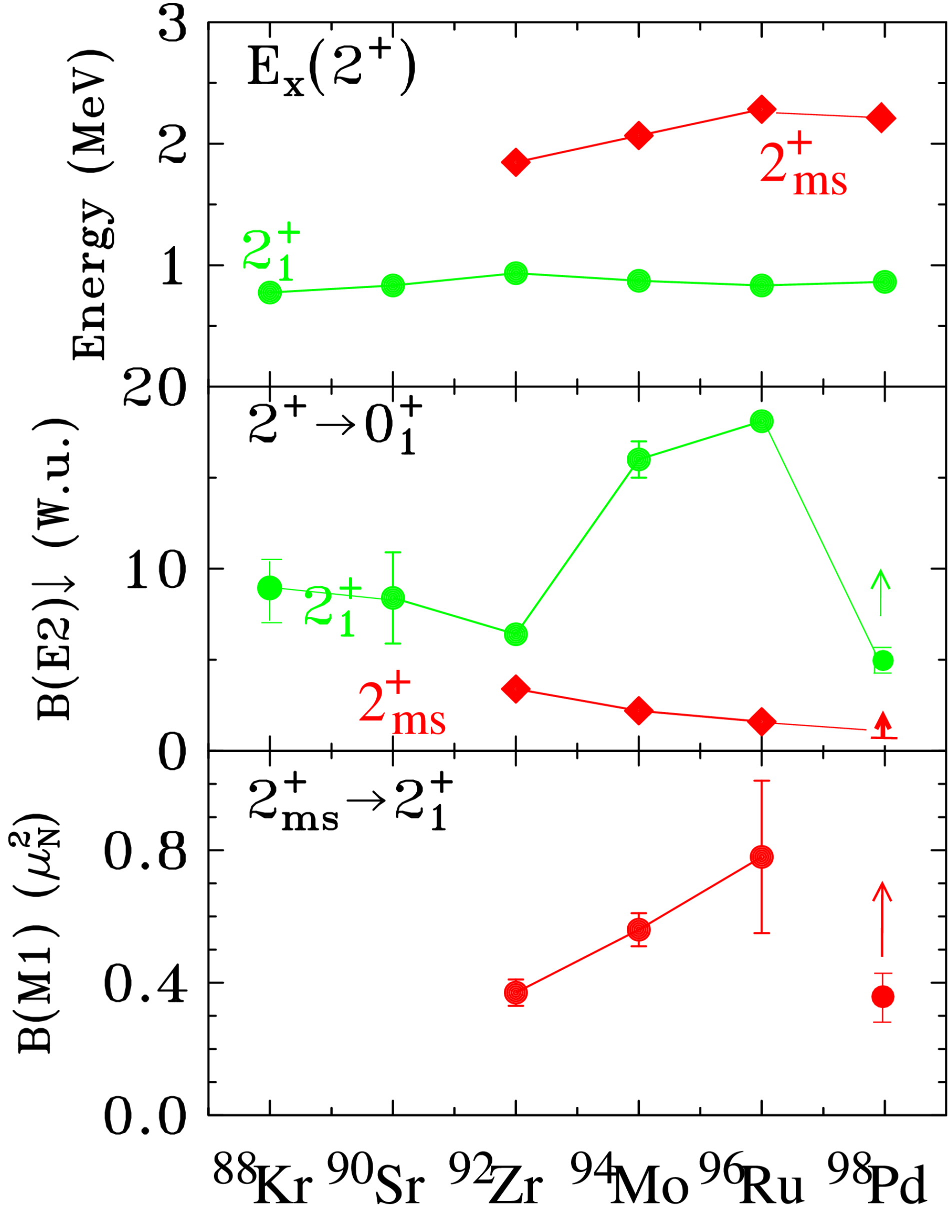
J^π	Exp. E_{level} (keV)	shell model E_{level} (keV)	Exp. $B(E2)\downarrow$ (W.u.)	shell model $B(E2)\downarrow$ (W.u.)
2_1^+	862.9(1)	867	$> 4.2(3)$	9.0
4_1^+	1541.4(1)	1492	$12.6^{+2.7}_{-1.9}$	11.0
6_1^+	2112.5(1)	2062	$18^{+1.4}_{-1.2}$	10.7
8_1^+	2773.3(1)	2439	2.54(5)	2.9



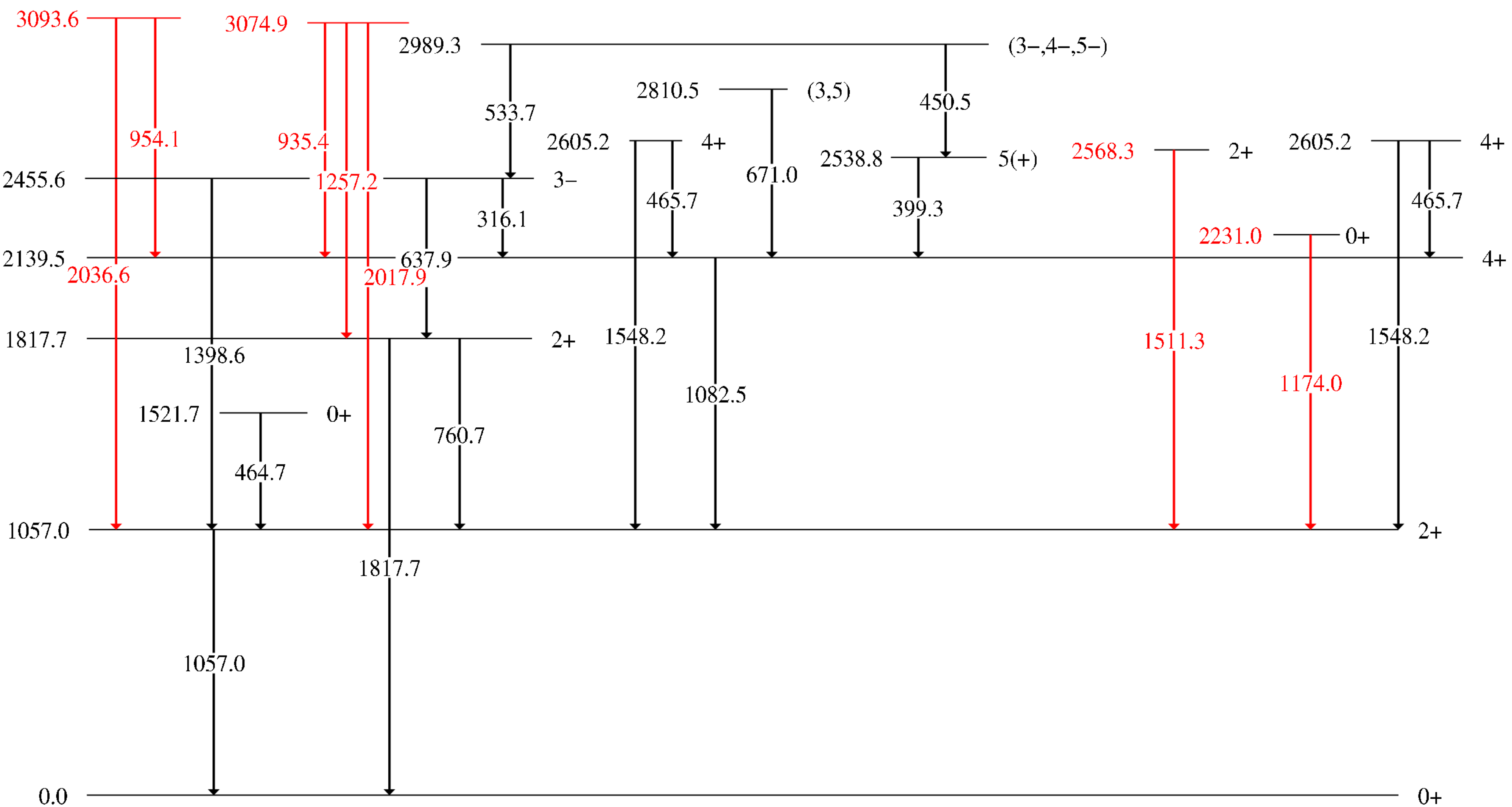
Systematics for N=52 isotones (I)



Systematics for N=52 isotones (II)



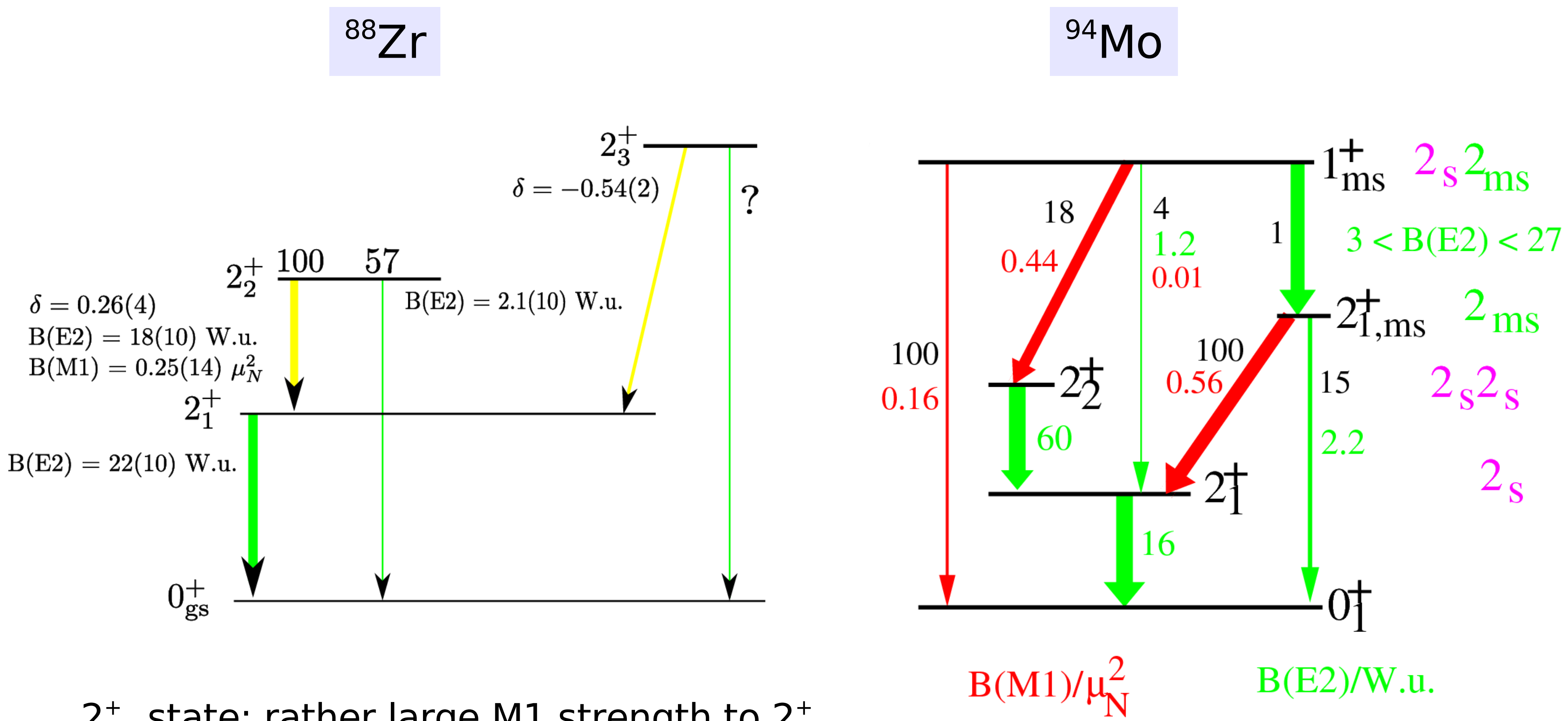
Results for ^{88}Zr



newly observed gamma-rays and levels

N. Braun, Diploma thesis, Univ. zu Köln 2008

Mixed-symmetry states in ^{88}Zr?



2^+_2 state: rather large M1 strength to 2^+_1

But: Also strong E2 transition to 2^+_1

2^+_3 state: no lifetime information, decay to 2^+_1 has large E2 component

→ no description in IBM, need shell model calculations for ^{88}Zr

N. Braun, Diploma thesis

Results for ^{90}Mo

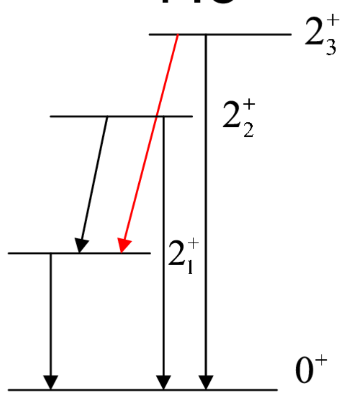
New in ^{90}Mo: 5 gamma-transitions, especially:

- $2^+_2 \rightarrow 0^+_1$ decay
- 2^+_3 state for the first time observed in gamma spectroscopy

L. Bettermann, Diploma thesis, Univ. zu Köln 2008

C. Fransen et. al. Phys.Rev. C 67, 024307 (2003)

^{90}Mo

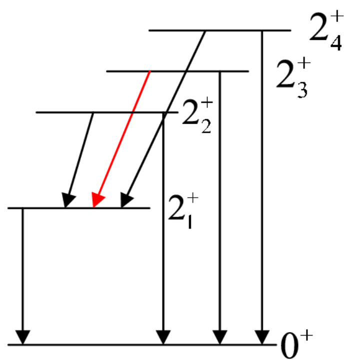


$2^+_3 \rightarrow 2^+_1$ $\delta = 0.13\ (22)$

$$\frac{E_4}{E_2} = 2.11$$

$$\left[\frac{B\left(E2;2_2^+ \rightarrow 2_1^+\right)}{B\left(E2;2_2^+ \rightarrow 0_1^+\right)}\right]_{rel} = \frac{100}{0.19}$$

^{94}Mo



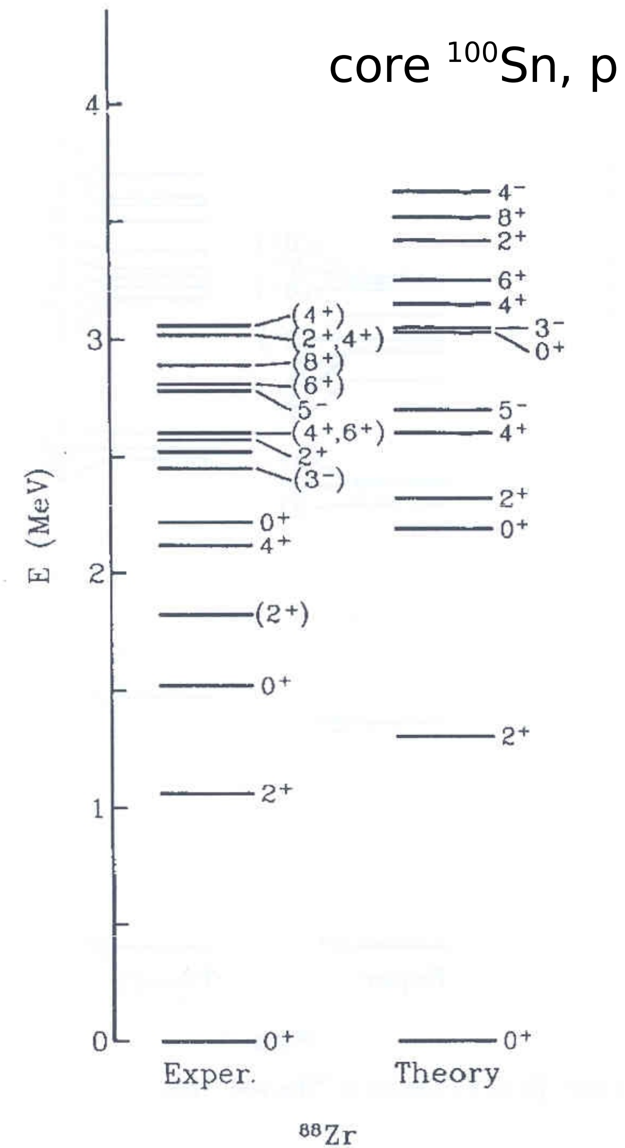
$2^+_3 \rightarrow 2^+_1$ $\delta = 0.15\ (4)$

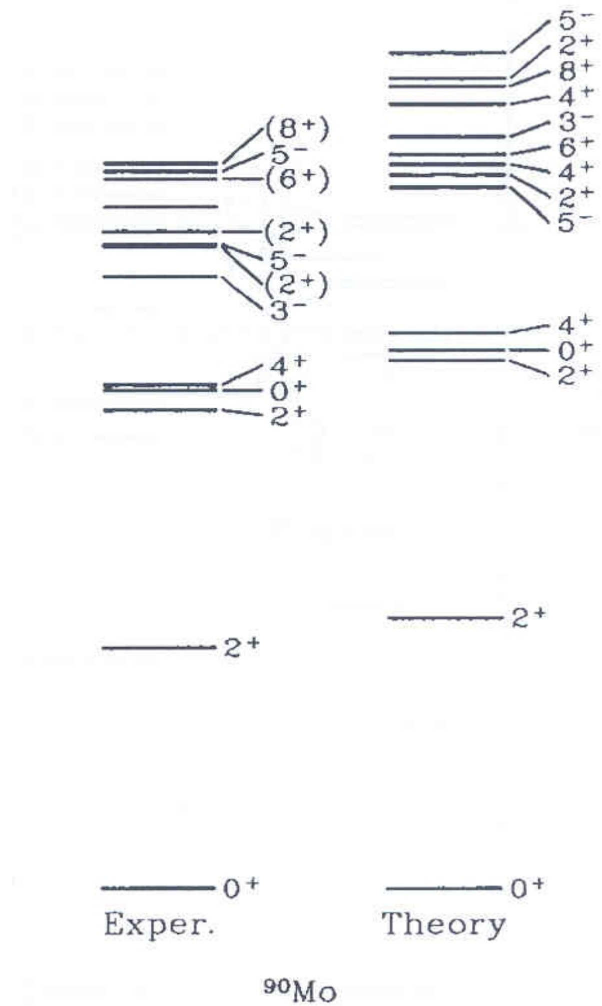
$$\frac{E_4}{E_2} = 1.81$$

$$\left[\frac{B\left(E2;2_2^+ \rightarrow 2_1^+\right)}{B\left(E2;2_2^+ \rightarrow 0_1^+\right)}\right]_{rel} = \frac{100}{0.47}$$

Shell model calculations for ^{88}Zr and ^{90}Mo

core ^{100}Sn, p and n holes in $0g_{9/2}$, $1p_{1/2}$, $1p_{3/2}$, $0f_{5/2}$





„not satisfactory“

„good agreement“

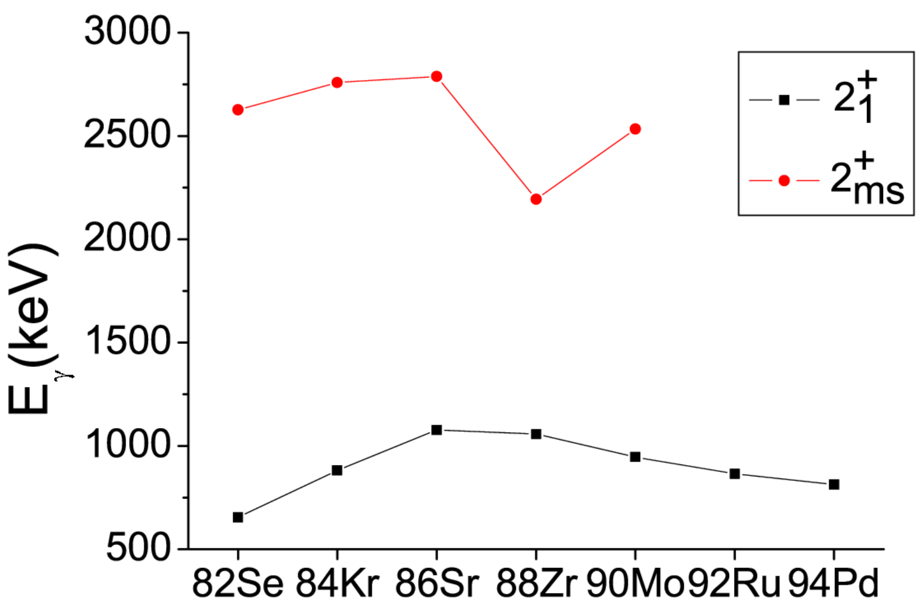
J. Sinatkas et al., J. Phys. G 18, 1401 (1992)

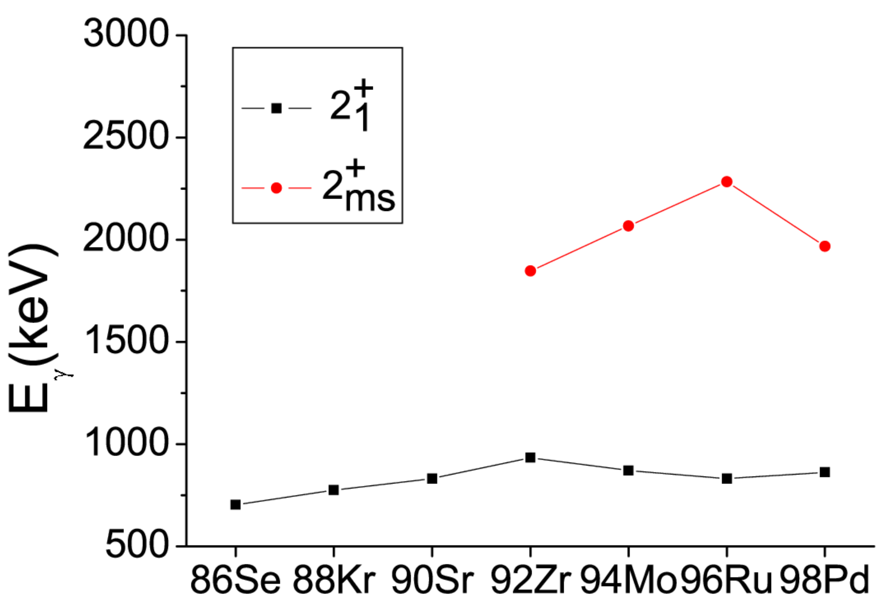
Systematics for N=48 isotones

Energy systematics of the 2^+_1 and (candidates for) the 2^+_{ms} states

N=48

N=52





Conclusion

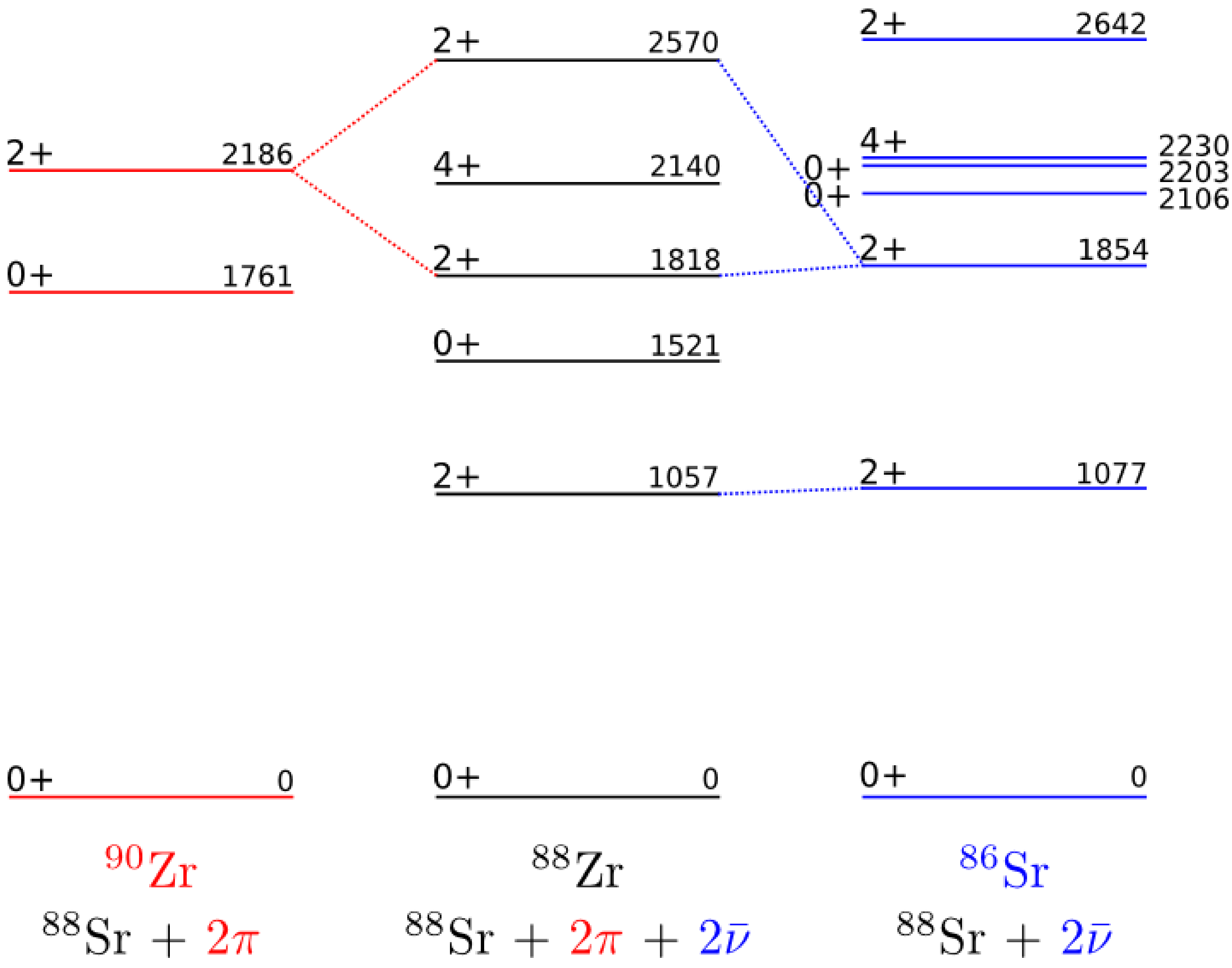
- Gamma-ray experiments on nuclei in the A=100 mass region at the Cologne FN-Tandem accelerator.

- First measurement of lifetimes of Yrast states in ^{98}Pd with the Cologne plunger: Determination of E2 strengths.

- gamma-gamma angular correlation measurements on ^{88}Zr, ^{90}Mo with the Cologne HORUS spectrometer: candidates for mixed-symmetry states.

- Needed: detailed shell model calculations for N=48 isotones to clearly interprete the structure of ^{88}Zr, ^{90}Mo, ...

Proton-neutron structure of ^{88}Zr



N. Braun, Diploma thesis