Shape coexistence in ^{96,98}Sr

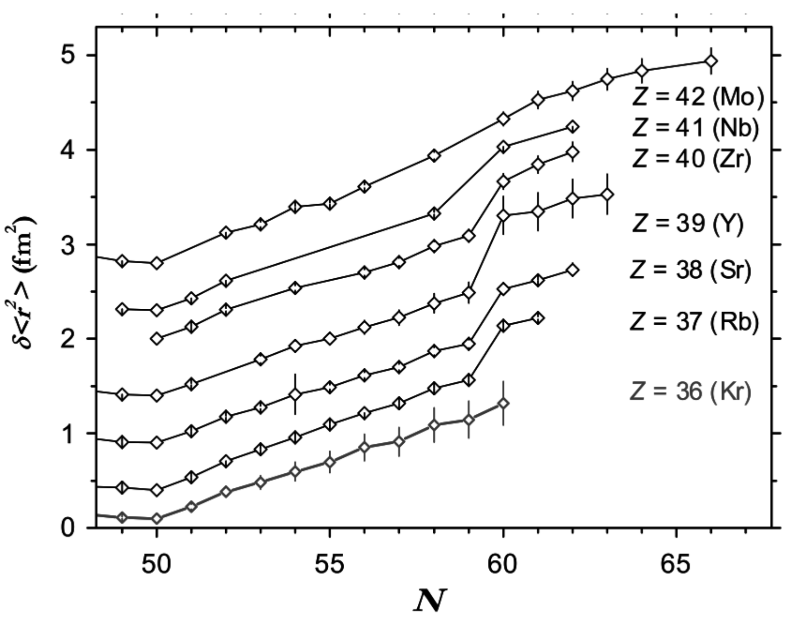
E. Clément[1], M. Zielińska[2], A. Görgen[3], W. Korten[2],
S. Péru[4], J. Libert[4], H. Goutte[2], S. Hilaire[4]

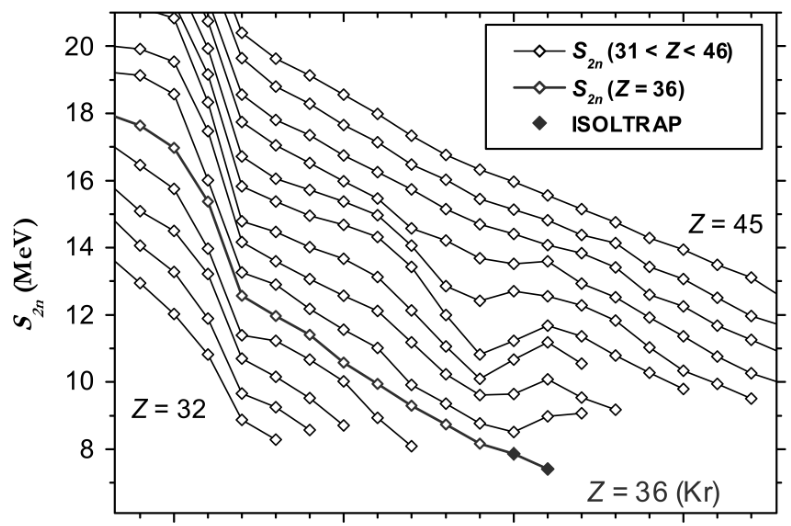
and the IS451 collaboration

[1] GANIL, Caen, France; [2] CEA Saclay, France; [3] University of Oslo, Norway;
[4] CEA/DAM, Bruyères-le-Châtel, France

Shape transition at N=60

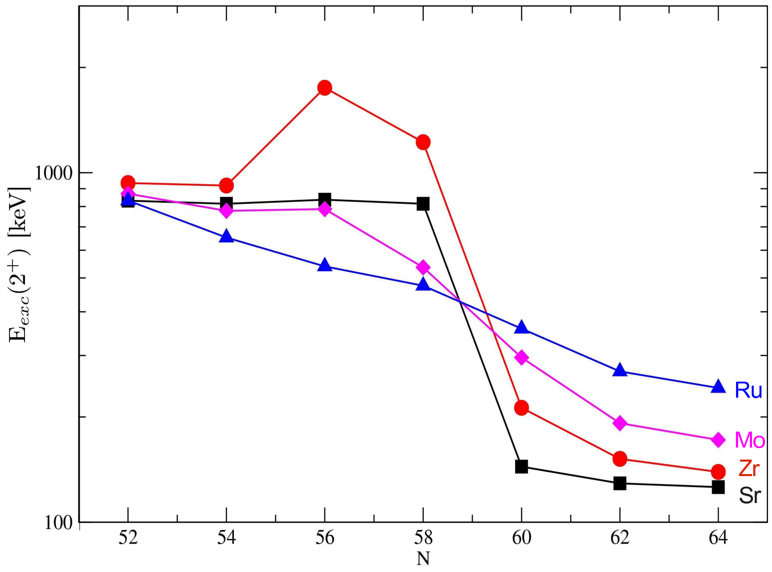
- dramatic change of the ground state structure observed at N = 58, 60 for Rb, Sr, Y, Zr isotopes
- considerable theoretical and experimental effort in this mass region
- onset of deformation at N=60 confirmed by 2^+ energies and transition probabilities in even-even nuclei (Sr, Zr, Mo...)

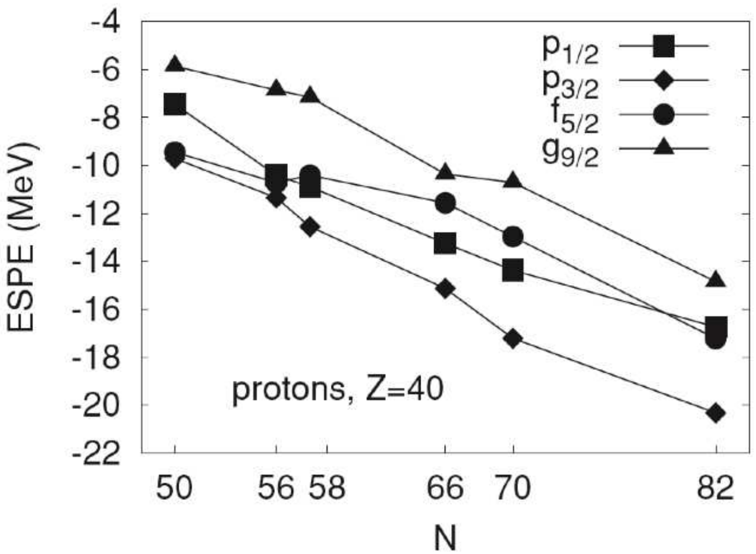




compilation: S. Naimi et al., Phys. Rev. Lett. 105 (2010) 032502

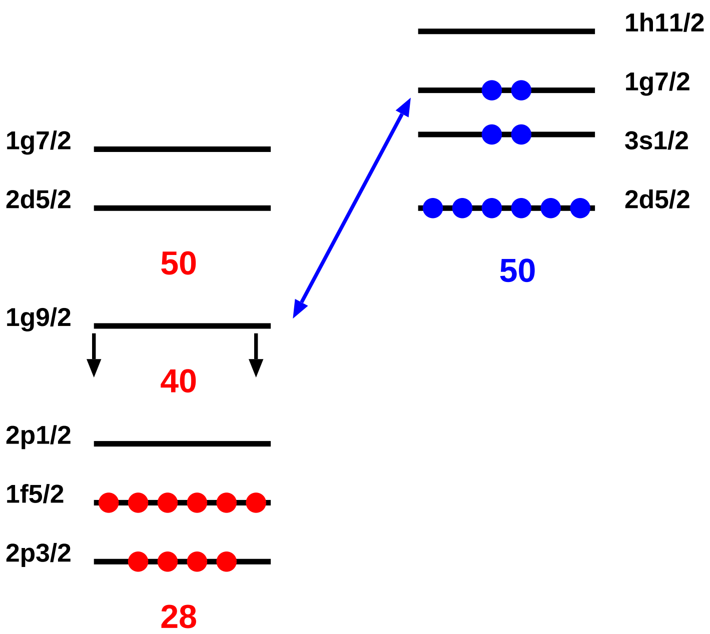
Onset of deformation and shape coexistence at N=60





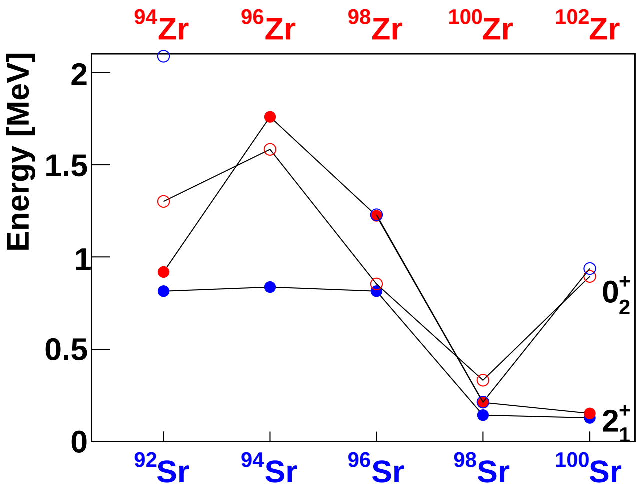
K. Sieja et al PRC 79, 064310 (2009)

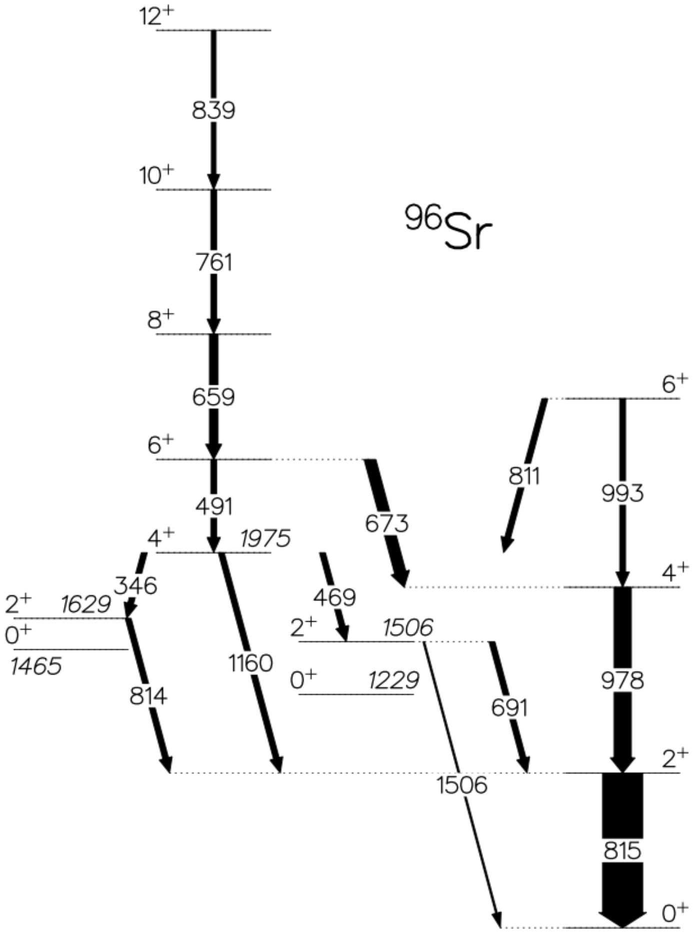
- 0_2^+ state created by 2p-2h excitation across Z=40
- Beyond N=60, the p-n interaction contributes to lowering of the 0_2^+ state and high collectivity of the 2_1^+ state.



Shape transition and coexistence in ^{96,98}Sr

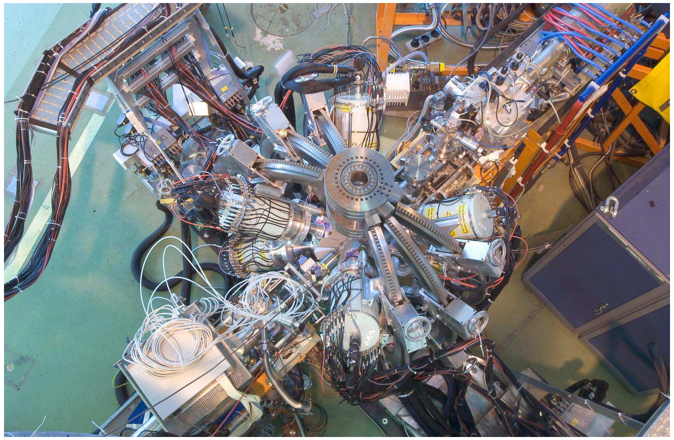
- low-lying 0^+ states observed in N=58,60 Zr, Sr isotopes
- enhanced E0 transition of ρ^2(E0)= 0.053 in ^{98}Sr
- regular rotational band in ^{96}Sr (W. Urban et al., Nucl. Phys. A 689 (2001))

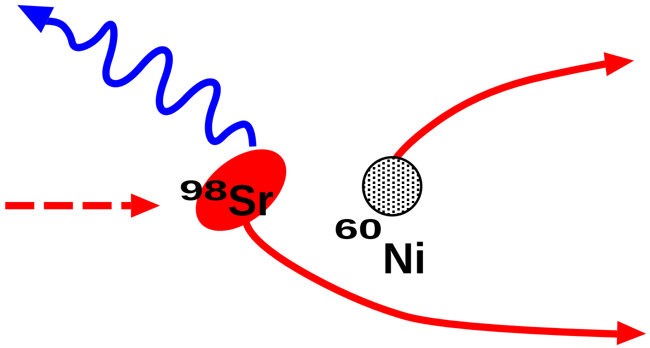




- shape coexistence?
- configuration inversion at N=60?

Coulomb excitation of ^{96,98}Sr at ISOLDE





gamma-ray detection array:
MINIBALL
8 triple clusters, 8% efficiency

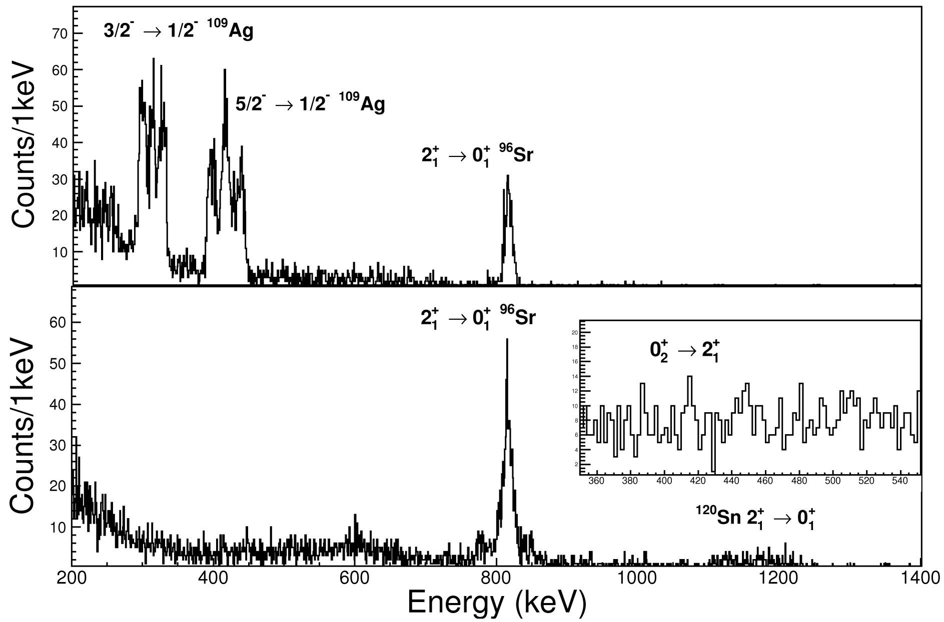
particle detection setup:
annular DSSD detector at forward angles
detection of scattered Sr
and recoiling target nuclei

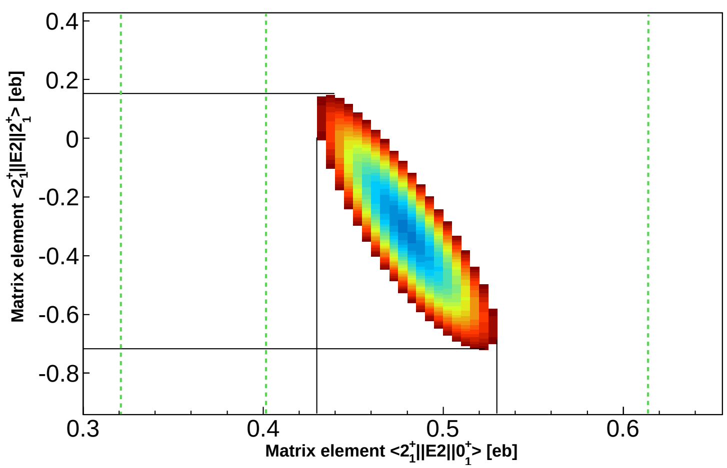
- deexcitation γ rays mesured in coincidence with particles (Sr and target recoils)
- targets: ^{109}Ag, ^{120}Sn (^{96}Sr), ^{60}Ni, ^{208}Pb (^{98}Sr)

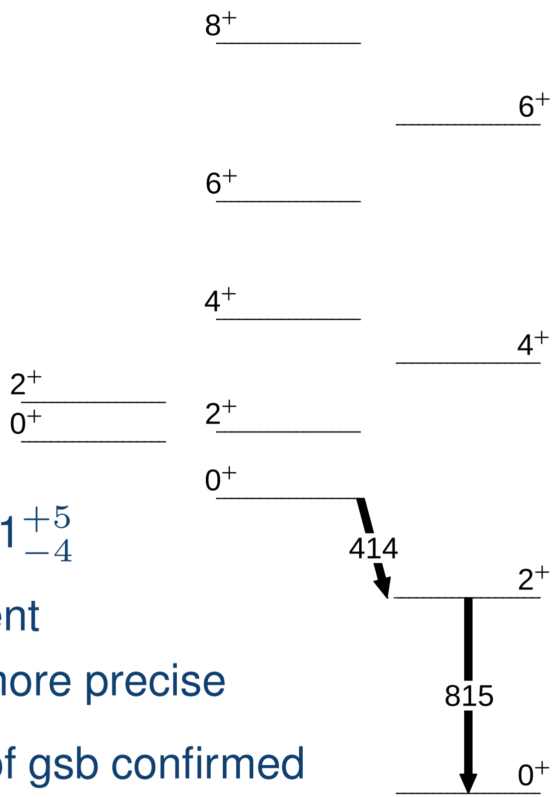
^{96,98}Sr beams

- surface ionisation, strong contamination of Rb expected
- ^{96}Sr:
  - molecular extraction of $^{96}Sr^{18}F^{+}$
  - worked well but beam intensity strongly reduced ($7 \cdot 10^3$ pps) due to REX-TRAP problems
- ^{98}Sr:
  - atomic extraction of ^{98}Sr (only 5% of mass 98, the rest was ^{98}Rb)
  - long trapping and breeding time (> 300ms):
    ^{98}Rb ($T_{1/2}$ 96 ms) decays, ^{98}Sr ($T_{1/2}$ 650 ms) survives
  - 5% ^{98}Rb, 80% ^{98}Sr, 15% ^{98}Y
  - 6 10^4 pps of ^{98}Sr

Shape transition and coexistence in ^{96,98}Sr





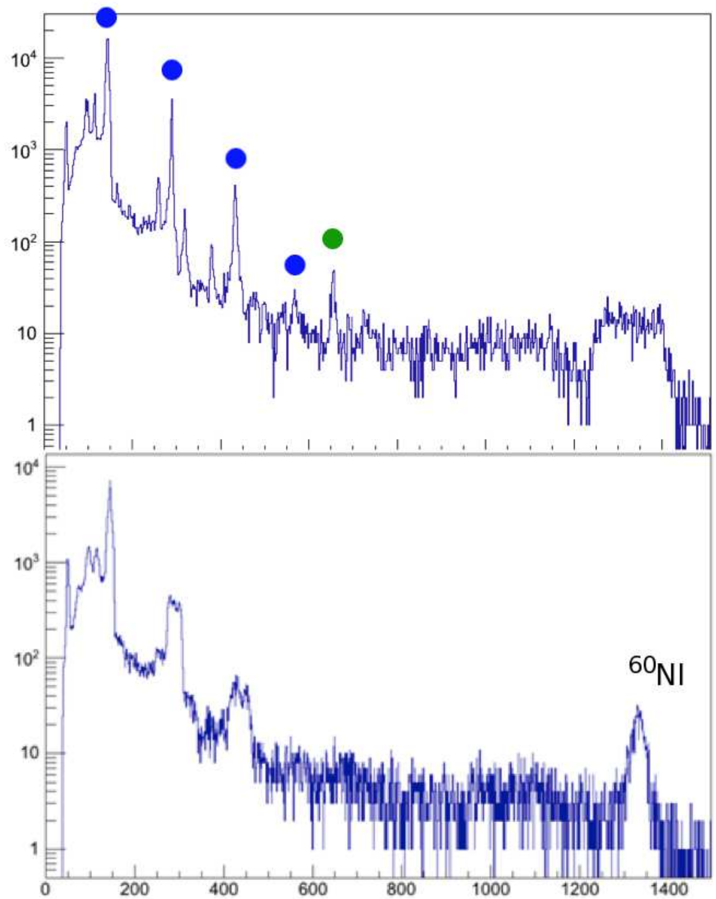


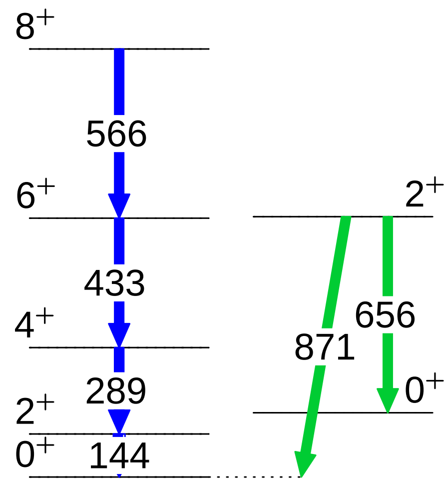
β (from Q_s) = 0.11^{+5}_{-4}

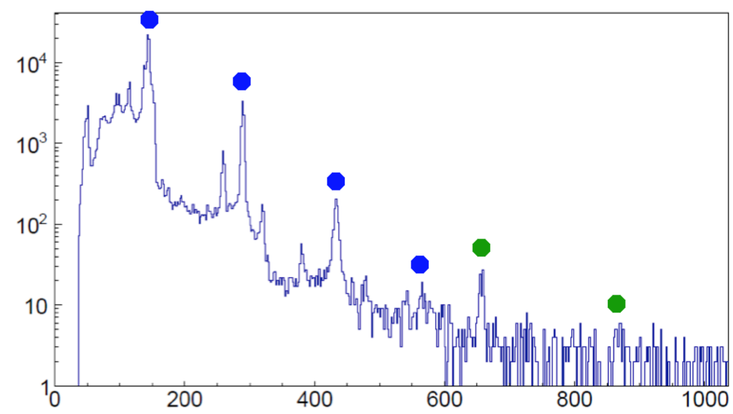
B(E2) in agreement
with lifetime but more precise

low deformation of gsb confirmed

Coulomb excitation of ^{98}Sr

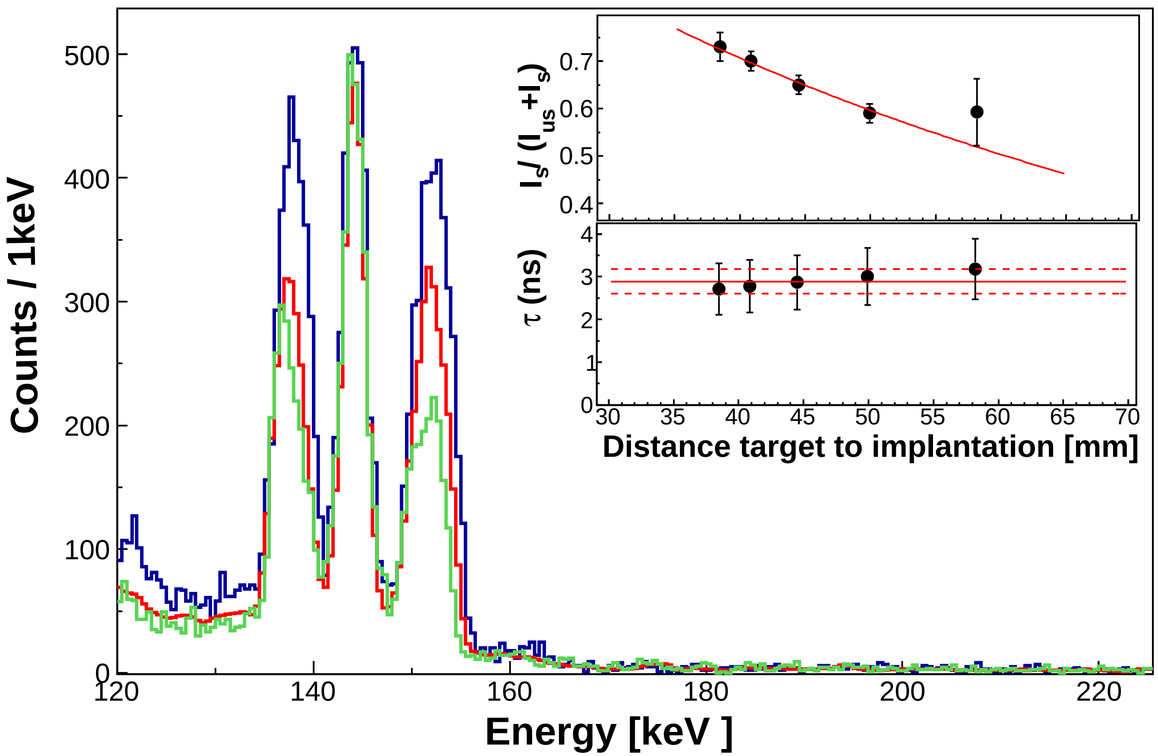






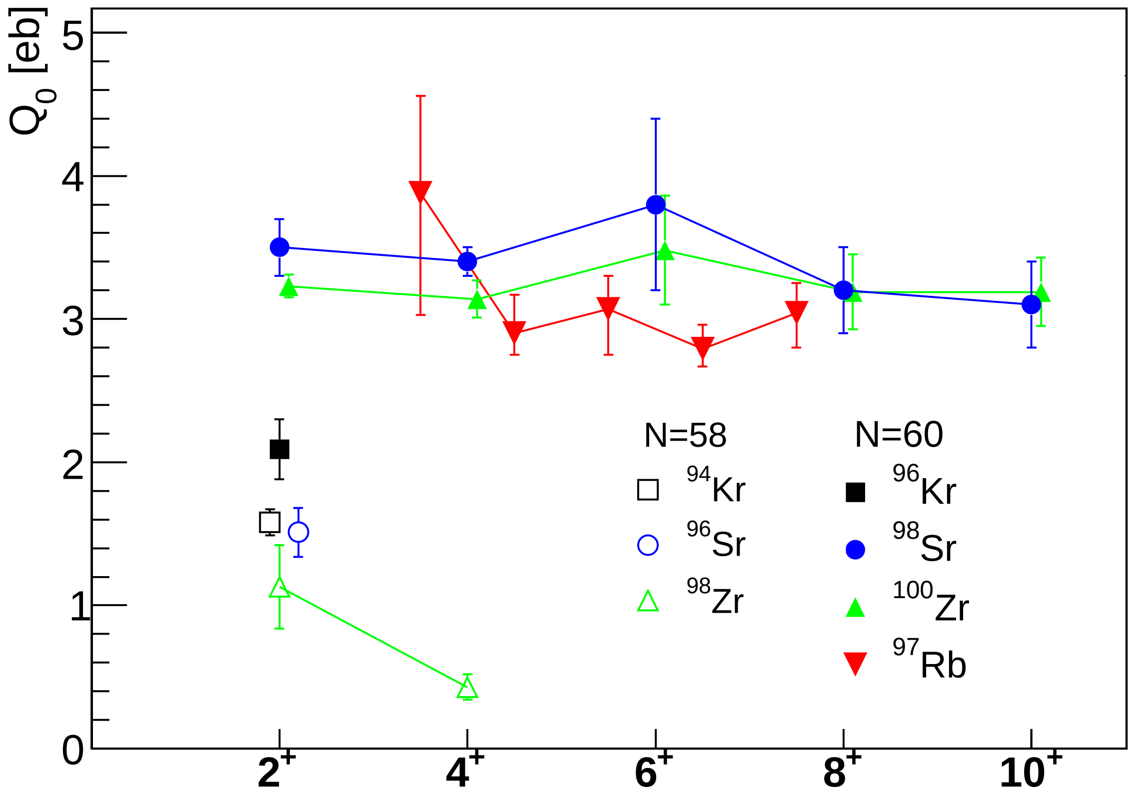
- 2 targets differing in Z: ^{60}Ni and ^{208}Pb
- gsb populated up to 8^+
- good statistics: 4 subdivisions of CM angles for ^{208}Pb, 3 for ^{60}Ni

Plunger-style analysis for ^{98}Sr



- 2_1^+ decays in flight and after implantation in the CD
- small scattering angles: shorter distance at higher velocity; larger scattering angles: longer distance at lower velocity
- obtained lifetime τ=2.9(3) ns shorter than literature value 4.0(1) ns
- effect attributed to the difference in solid angles for both components

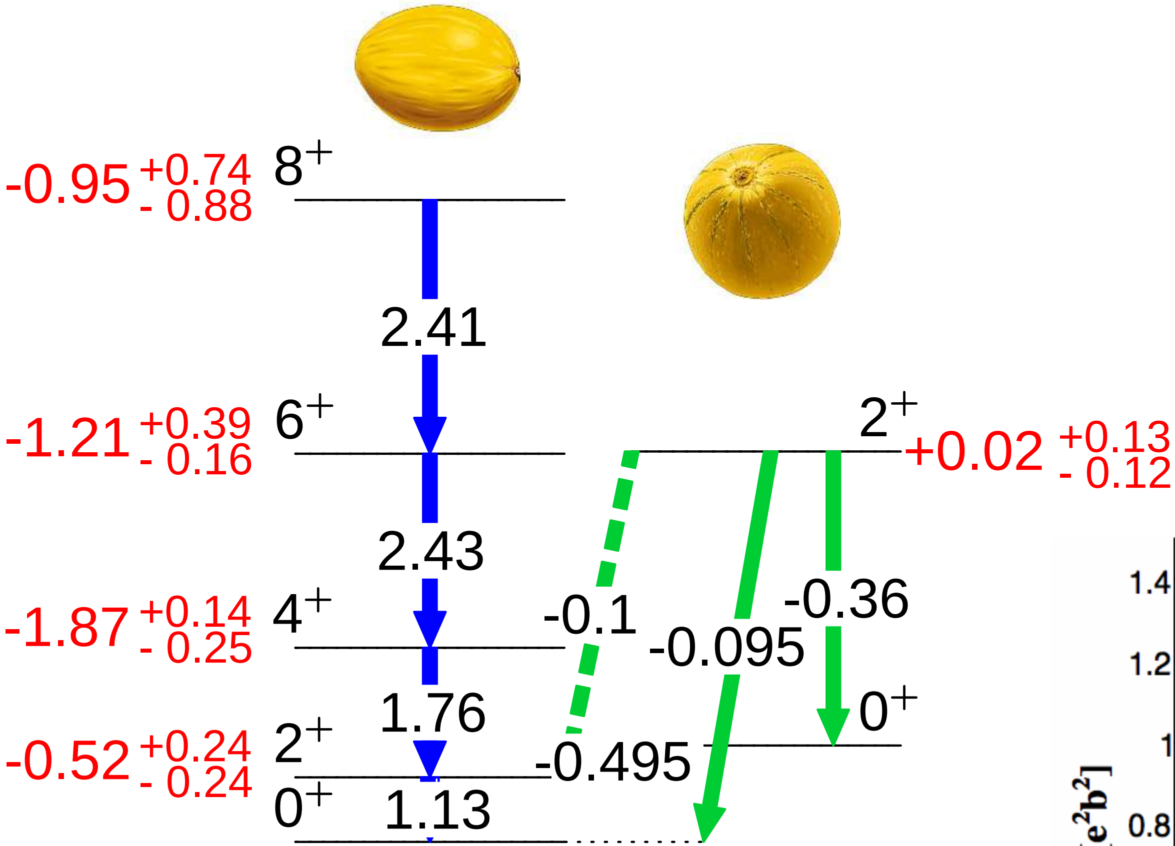
Transition probabilities: comparison with neighbouring nuclei

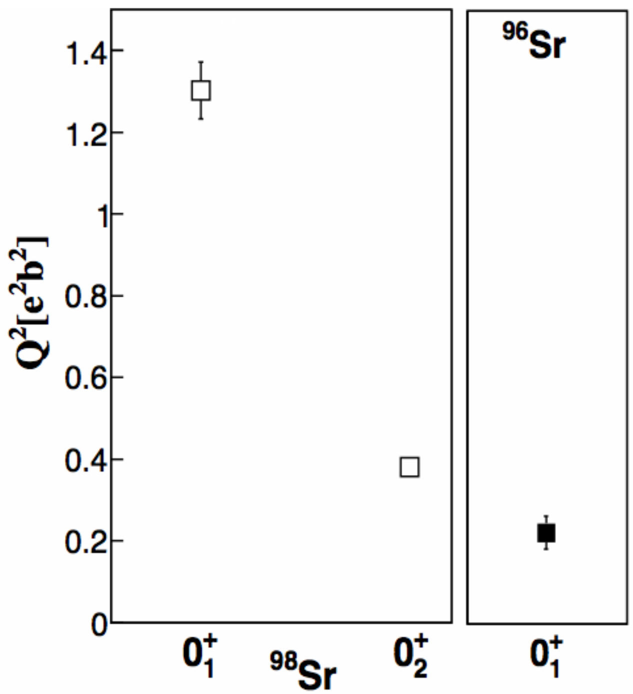


- Q_0 values in ^{98}Sr similar to those in N=60 Zr and Rb nuclei
- visible reduction of Q_0 for N=58 (^{96}Sr, ^{98}Zr) – similar to what is observed for ^{94,96}Kr

See poster of Christophe Sotty for more details on ^{97}Rb!

Shape transition and coexistence in ^{96,98}Sr: quadrupole moments

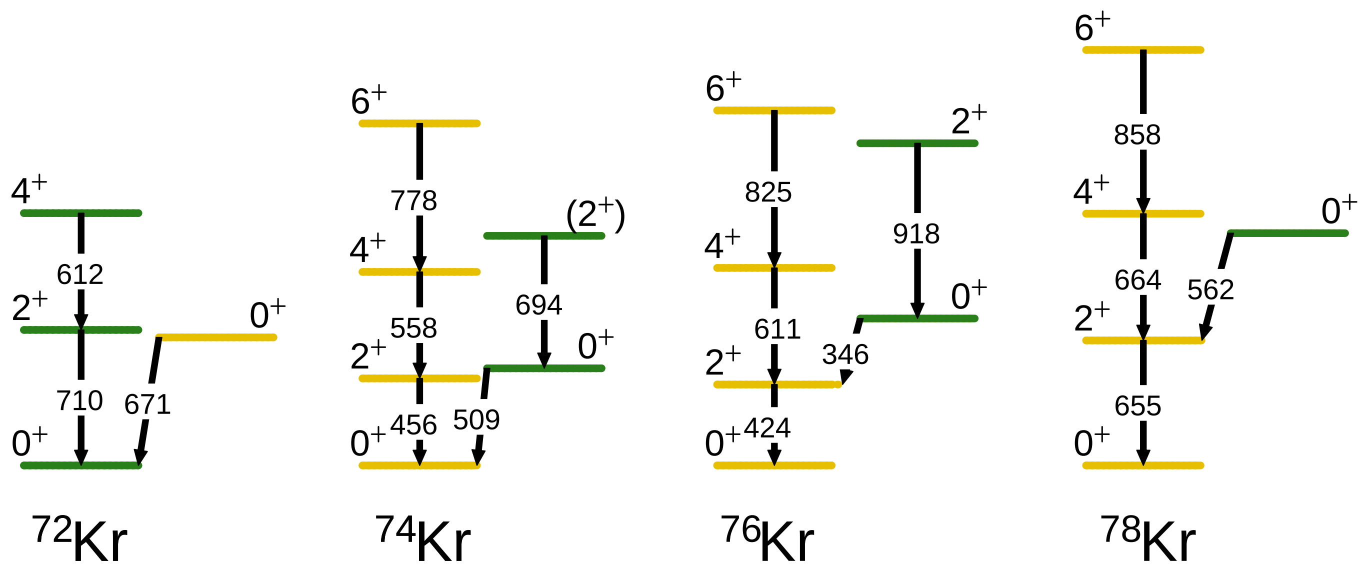


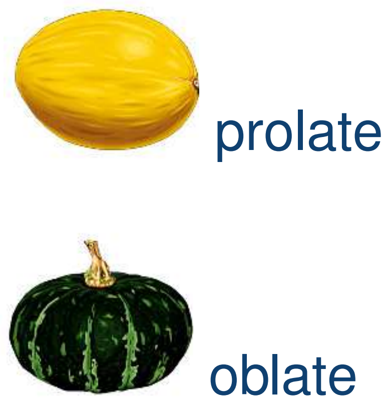


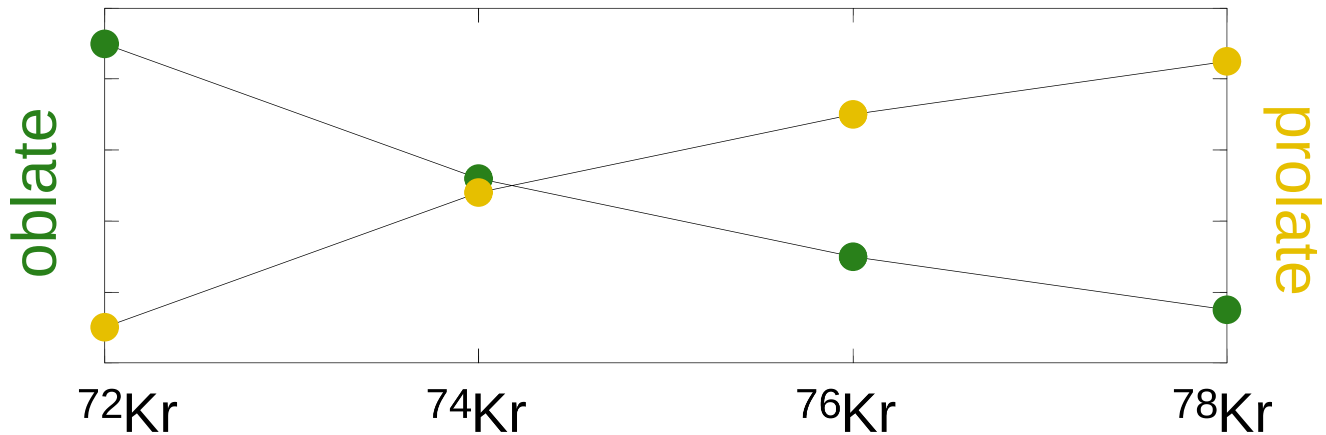
- well deformed prolate band ($\beta \geq 0.3$)
- low deformation of the excited band ($\beta < 0.1$)

Shape coexistence: two-state mixing

Kr: E. Bouchez *et al.* Phys. Rev. Lett. 90, 082502 (2003)



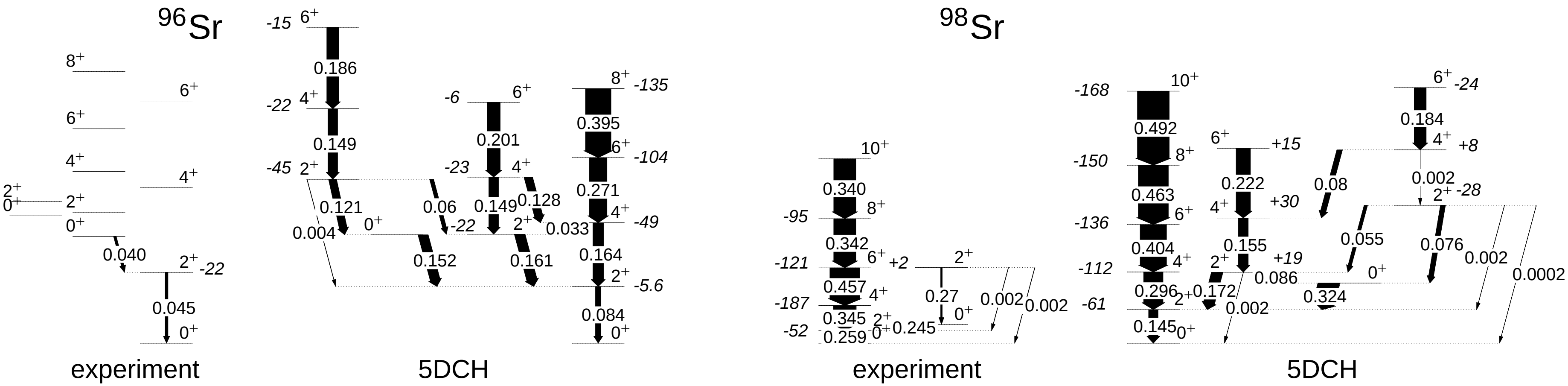




mixing of the g.s.
(from distortion
of rotational bands)

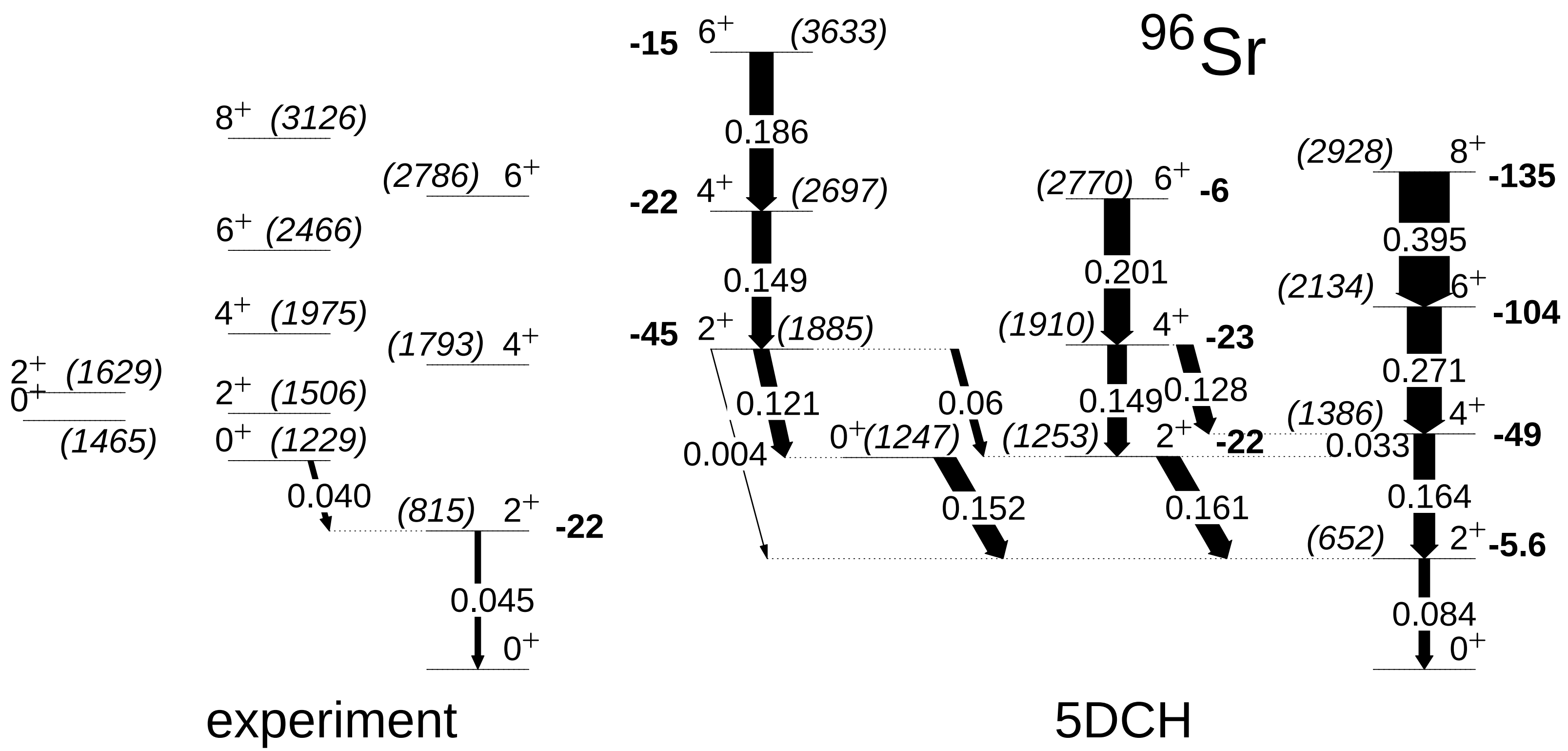
mixing amplitudes for ^{98}Sr (from ME): $\cos^2\theta_0=0.82$, $\cos^2\theta_2=0.99$

Theoretical predictions for Sr isotopes



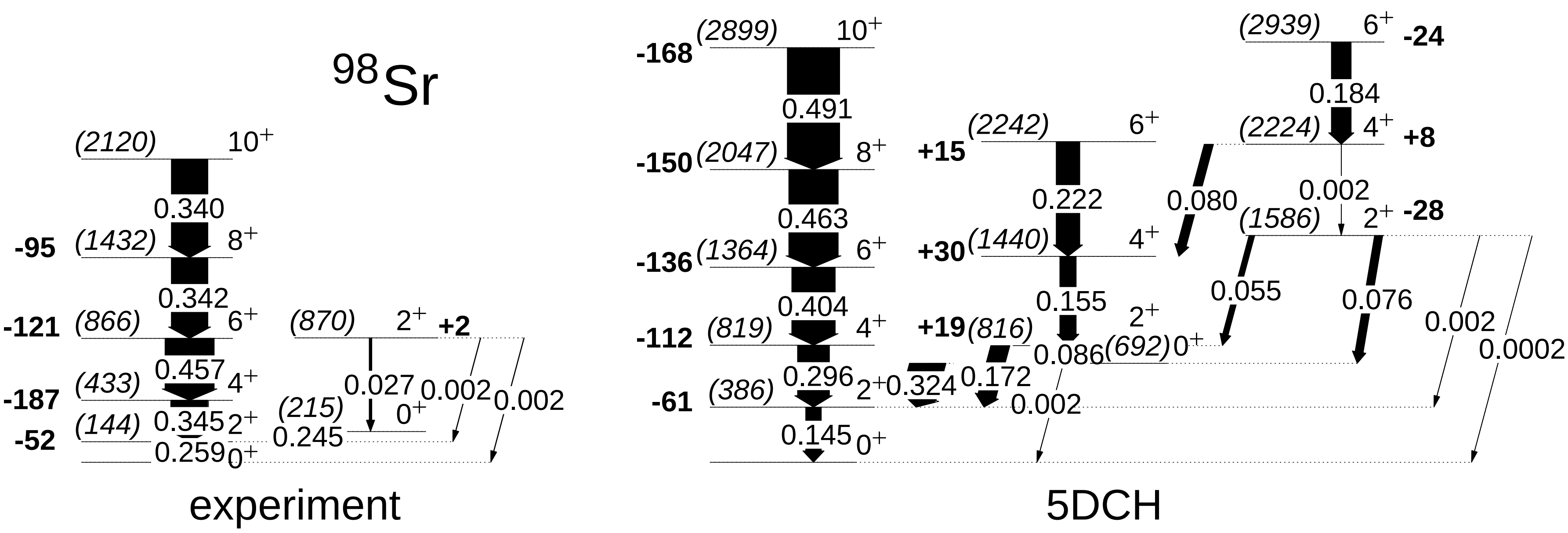
- beyond mean field calculations: GCM (GOA) D1S, (S.Péru, H. Goutte, J. Libert et al)
- first detailed calculation of transition probabilities on both sides of the N=60 shape transition
- shape change at N=60 and shape coexistence reproduced

Theoretical predictions for Sr isotopes



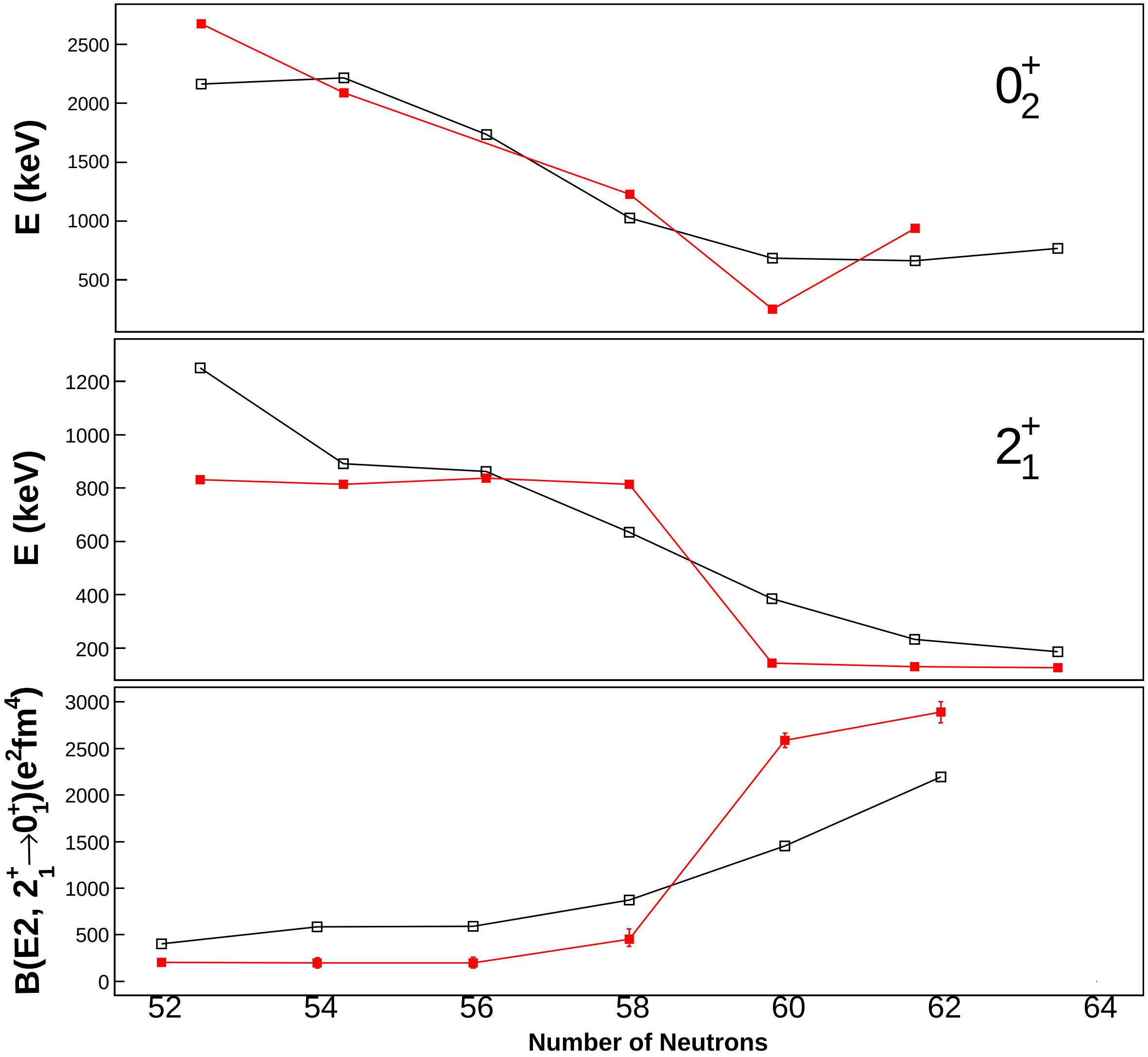
- collectivity in ground-state bands overestimated as well as mixing of the structures

Theoretical predictions for Sr isotopes



- collectivity in ground-state bands overestimated as well as mixing of the structures
- calculated K=2 band in ^{98}Sr has no experimental counterpart

Theoretical predictions for Sr isotopes



GCM(GOA) D1S vs experiment

Summary and outlook

- shape coexistence in ^{98}Sr and similarity of 0_1^+ in ^{96}Sr and 0_2^+ in ^{98}Sr confirmed by measured quadrupole moments and quadrupole invariants
- low mixing of coexistent structures in contrast to Hg and Kr nuclei
- general features well reproduced by beyond mean field calculations

- byproduct: first observation of excited states in ^{98}Rb!
- ^{96}Sr to be revisited (development of deformation in the ground-state band, structures built on $0_{2,3}^+$ states)