Study of quadrupole-collective isovector valence-shell excitations of exotic nuclei at SPES

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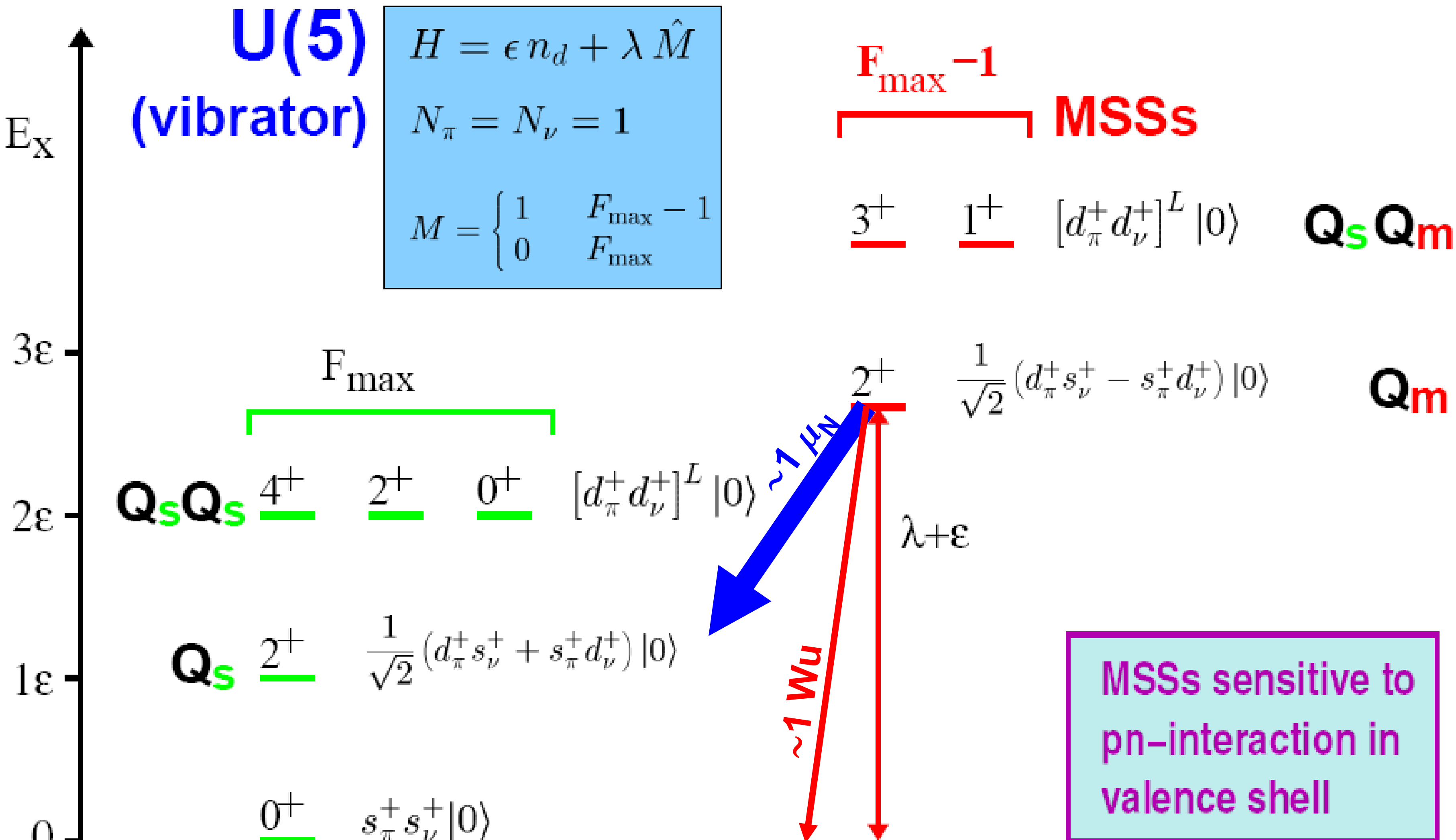
What are the MSSs?

The one-phonon $2^+_{1,ms}$ is the fundamental quadrupole-collective isovector excitations in the valence shell for spherical vibrational nuclei

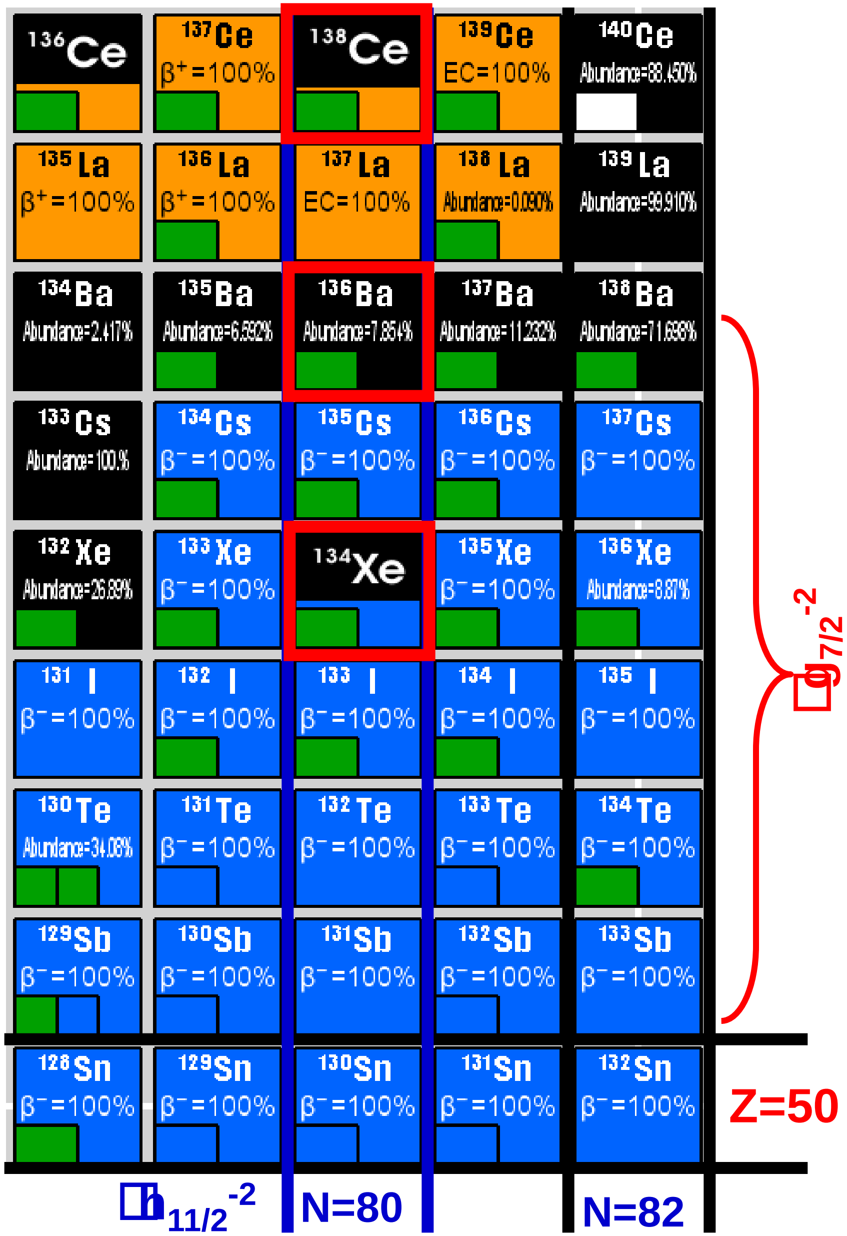
Simple Example: Harmonic Oscillator, N=2

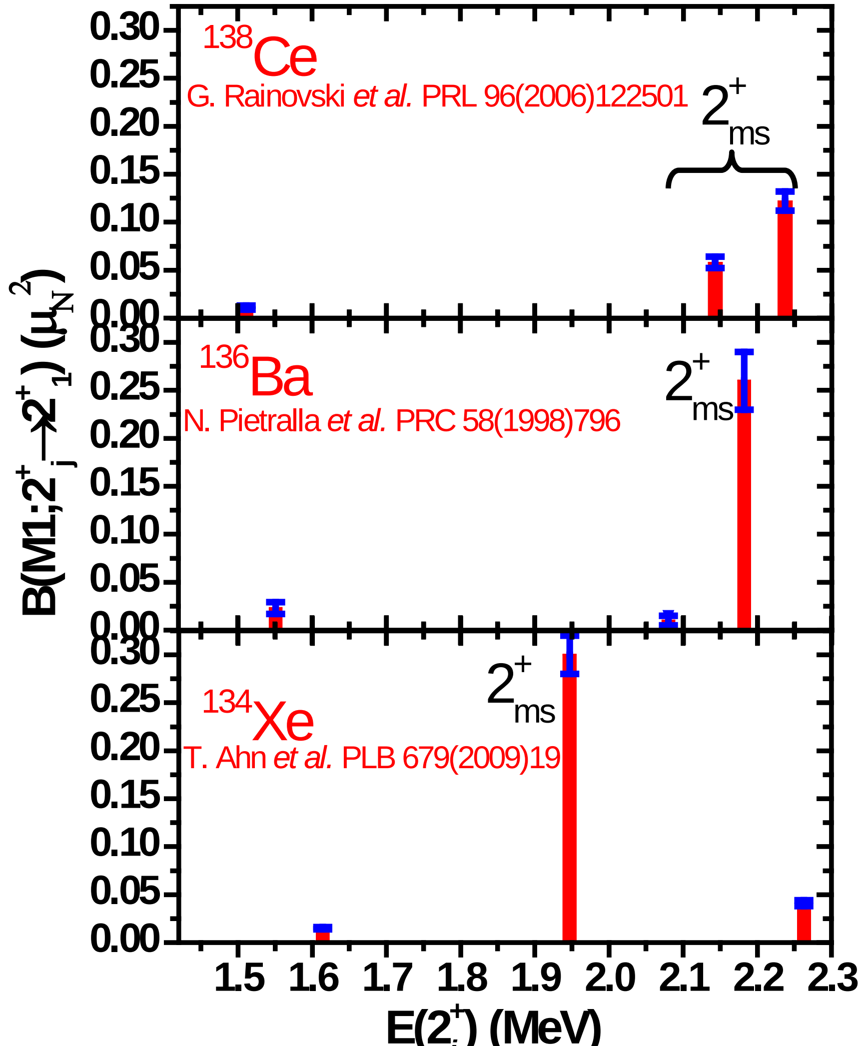


IBM-2 A. Arima, F. Iachello

MSSs in the N=80 isotones

ANL program – Coulomb excitations reactions in inverse kinematics with stable beams and GAMASPHERE



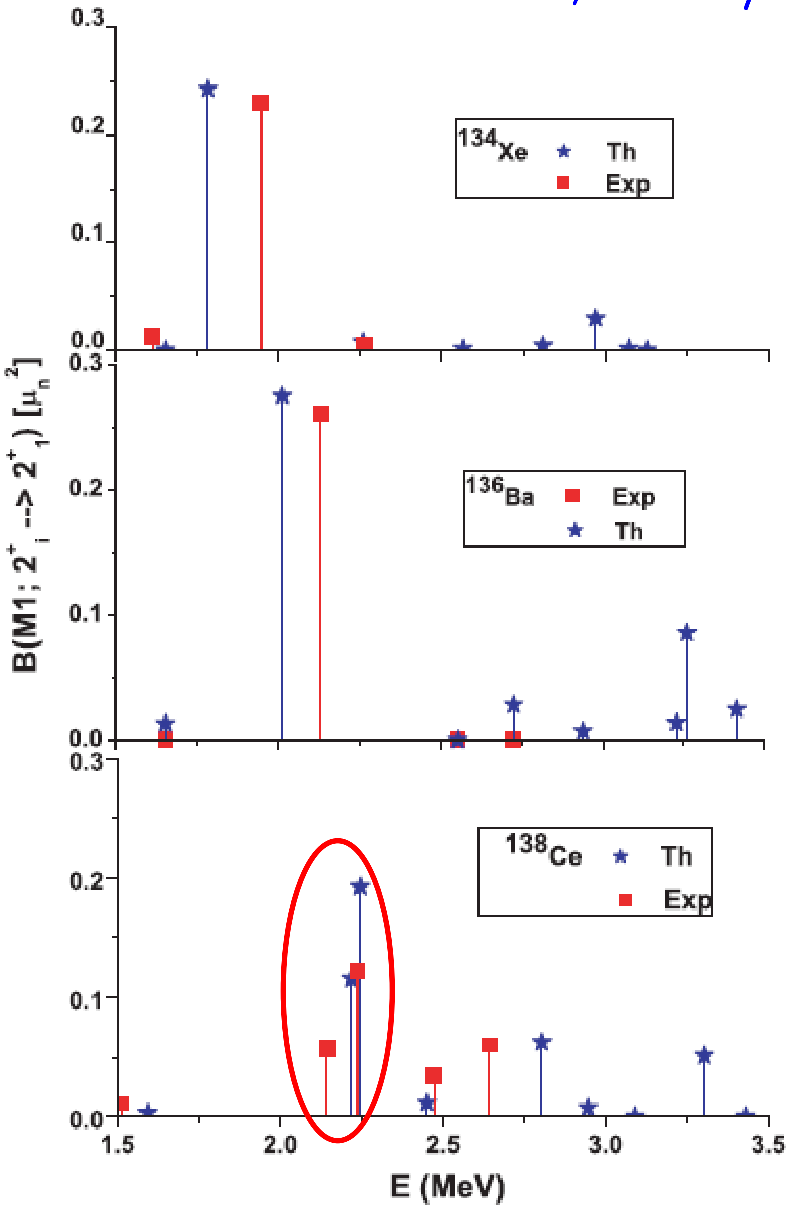


The properties of MSSs are sensitive to the sub-shell structure

Theoretical confirmation

Microscopic description in the framework of the Quasiparticle-phonon model

N. Lo Iudice, Ch. Stoyanov, D. Tarpanov PRC 77, (2008) 044310



Consistent description of the MSSs of ^{134}Xe, ^{136}Ba and ^{138}Ce, including the fragmentation in latter one, can be achieved by a slight (□300 keV) increase of the energy gap between $\pi g_{7/2}$ and $\pi d_{5/2}$ orbitals $\Rightarrow$

weaken the paring correlations

The splitting of the M1 strength in ^{138}Ce is a genuine shell effect caused by the specific shell structure and the pairing correlations!

Theoretical confirmation

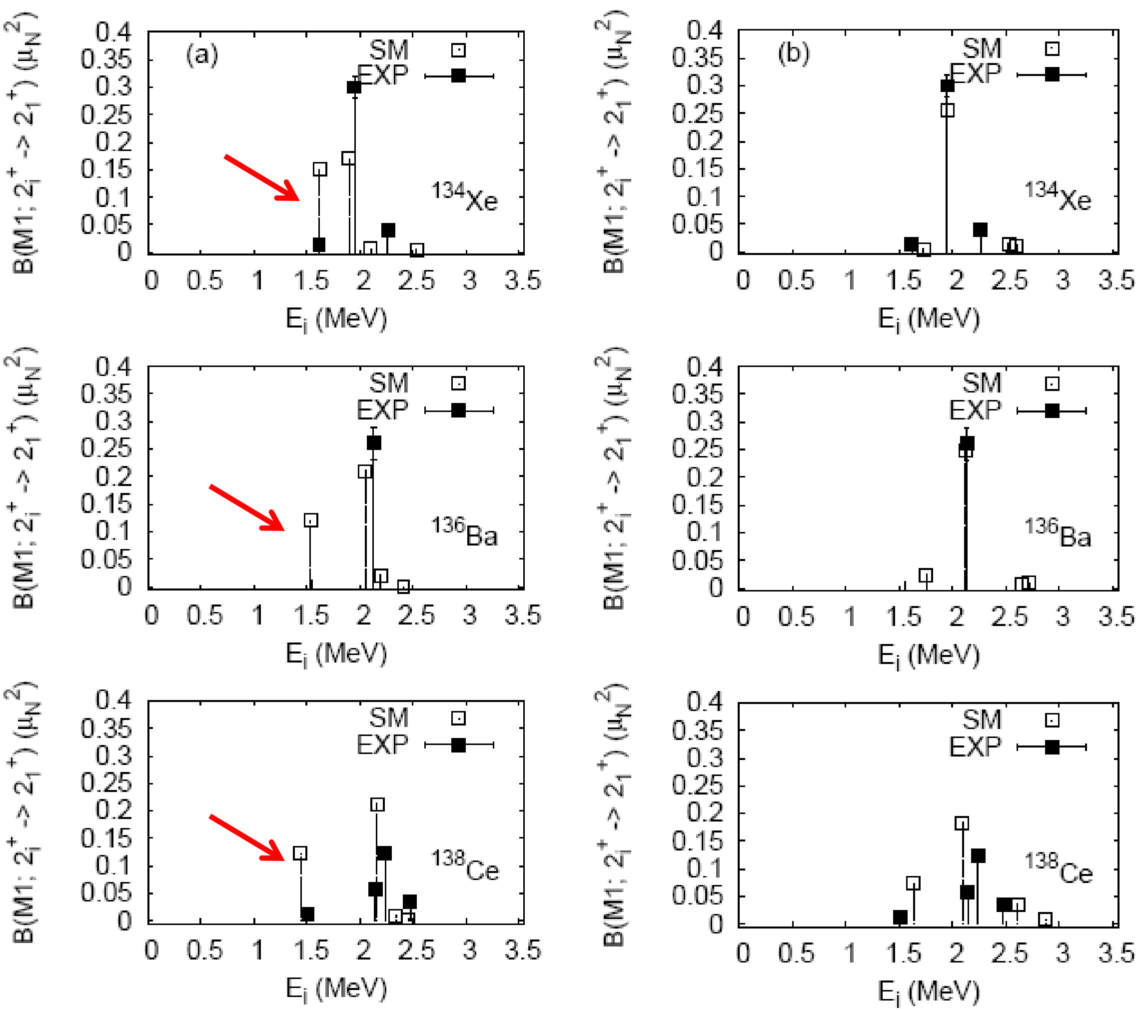
Microscopic description in the framework of the Large Scale Shell Model

K. Sieja, G. Martínez-Pinedo, L. Coquard, N. Pietralla (PRC 80, 054311 (2009))

Interaction: GCN5082 – realistic Bonn-C potential + empirical correction to the monopol part

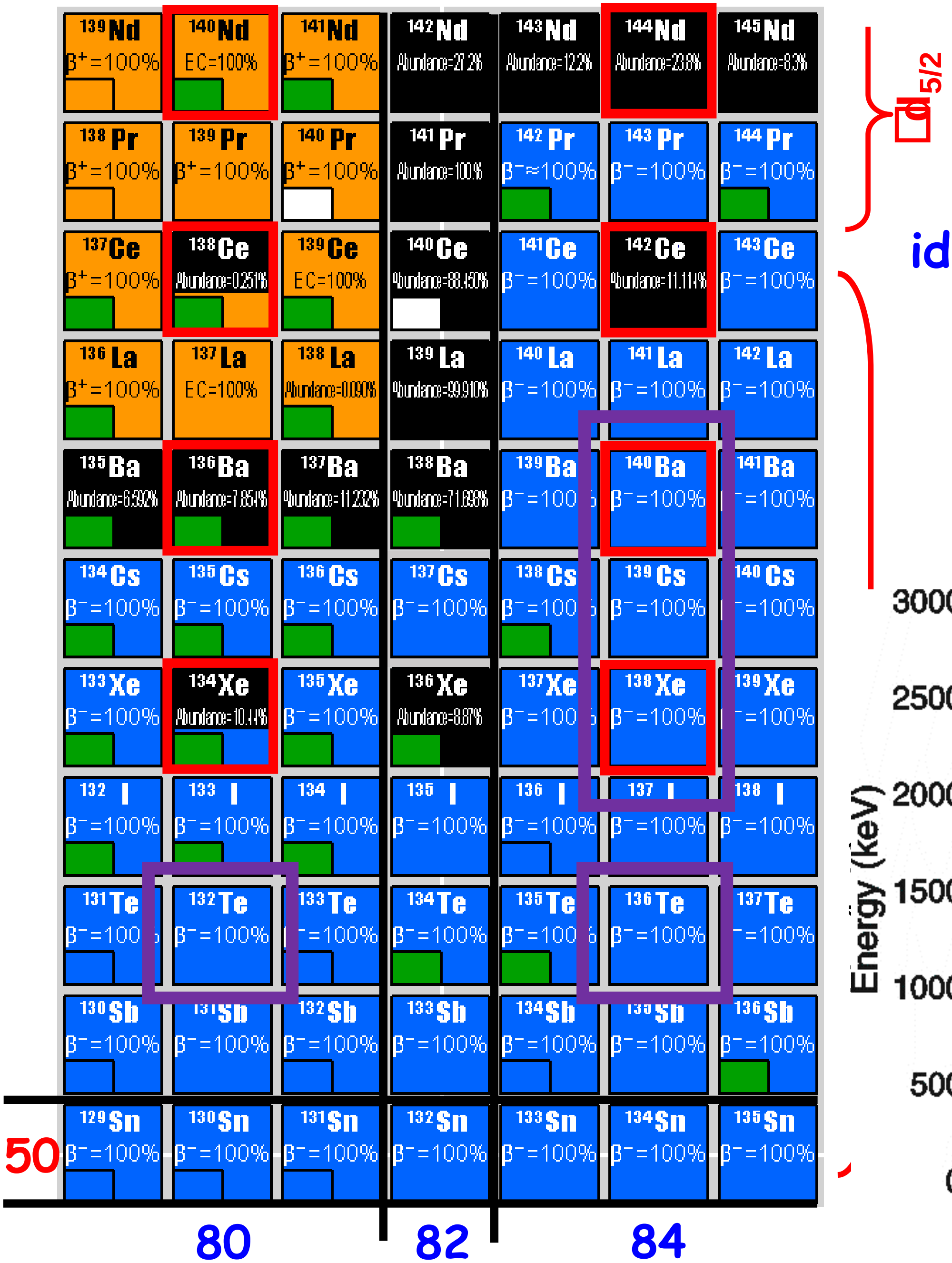
Space: $\{0g_{7/2}, 1d_{5/2}, 1d_{3/2}, 2s_{1/2}, 0h_{11/2}\}$ for both protons and neutrons – NATHAN and ANTOINE

Original interaction | Modified pairing



- realistic SM calculations reproduce correctly the energy spacing between the 2^+_1 and the $2^+_{1,mss}$ in known cases ⇒ prediction for the neighboring isotones.
- information on MSSs provides a tool to determine the pairing matrix elements of realistic interactions as they depend very sensitively on the treatment of core polarization corrections.
- experimental information on MSSs of ^{132}Te and ^{140}Nd is needed.

Is the shell stabilization a generic mechanism?

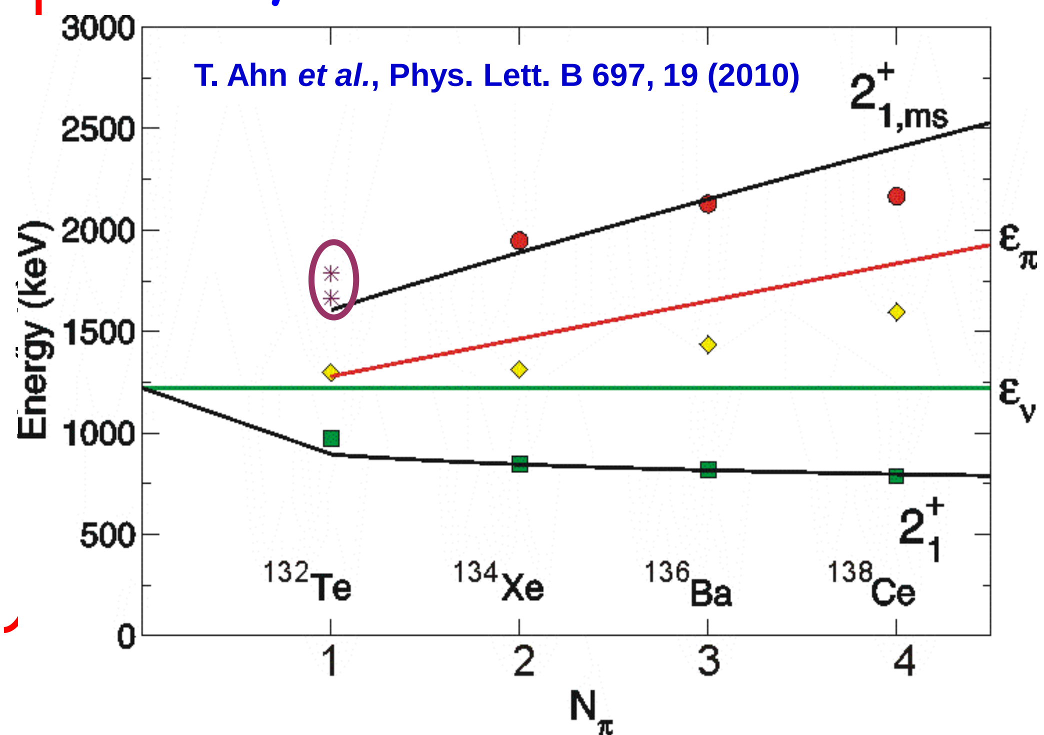


- is the shell stabilization present when the proton excitations are formed in different sub-shell? - $\pi d_{5/2}$

identify the MSSs in ^{140}Nd and ^{142}Sm

- how the shell stabilization depends on relative contributions of protons and neutrons to the collective wave function?

study the MSSs in N=84 isotones



Conclusions

Identifications of one-phonon $2^+_{1,ms}$ of radioactive nuclei seem possible in Coulomb excitation reactions on a carbon target with beam energy ~85 % CB $\Rightarrow$ 3.8 ÷ 4.5 MeV/u and beam intensities of ~$10^6 \div 10^7$ pps $\Rightarrow$

SPES offers ideal conditions!

Beams of interest:

^{138}Xe, ^{140}Ba, ^{132}Te, ^{136}Te

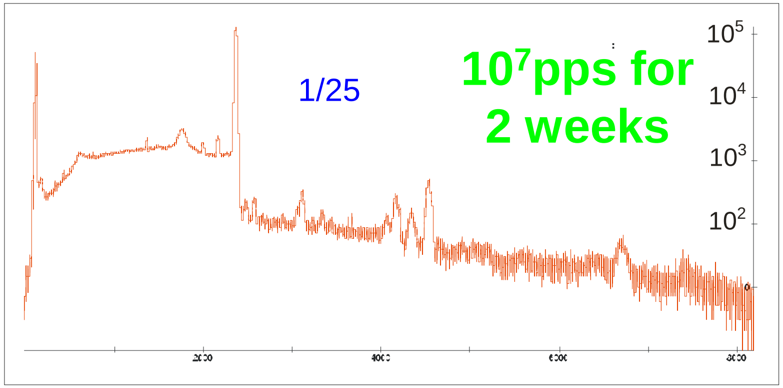
and (if possible)

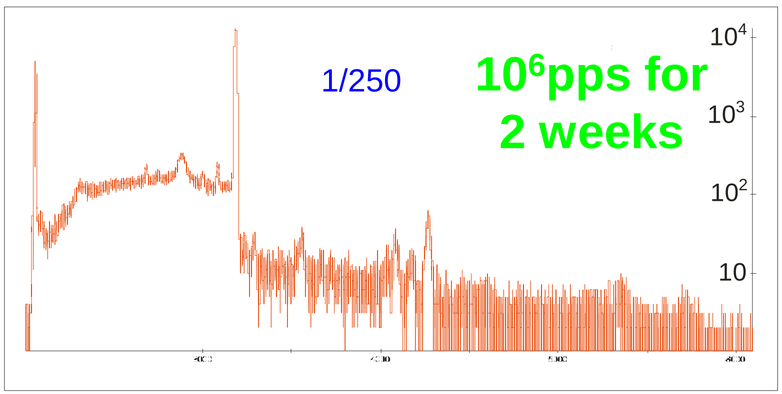
$^{128,132}Cd$.

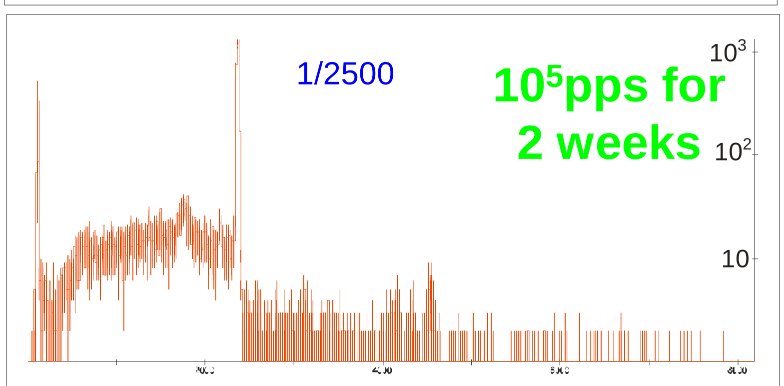
Experimental approach

Coulomb excitations in inverse kinematics on C target

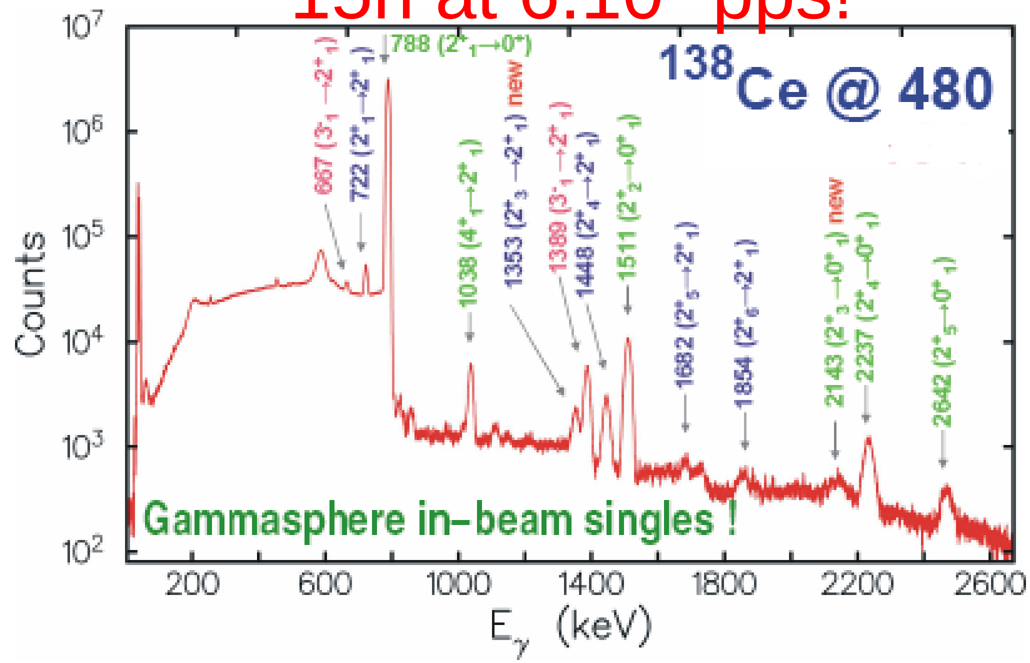
predominantly one-step processes and clean γ-spectrum (no target excitations)







15h at 6.10^9 pps!



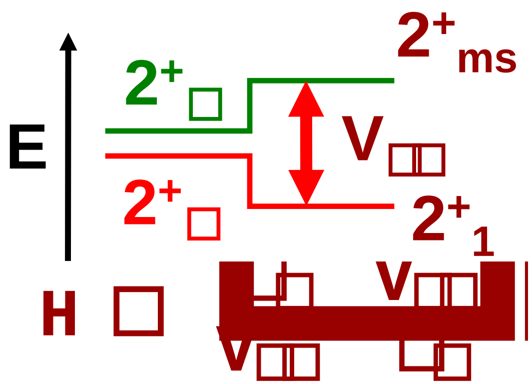
To identify excited 2^+ states (beyond the 2^+_1) in vibrational nucleus (B(E2)~1Wu) with a 10% array for 2 weeks beam time we need 10^5pps. For complete spectroscopy 10^6-10^7 pps will be needed!

Feasible, but requires beam energy ~85% CB (3.5-4 MeV/n)

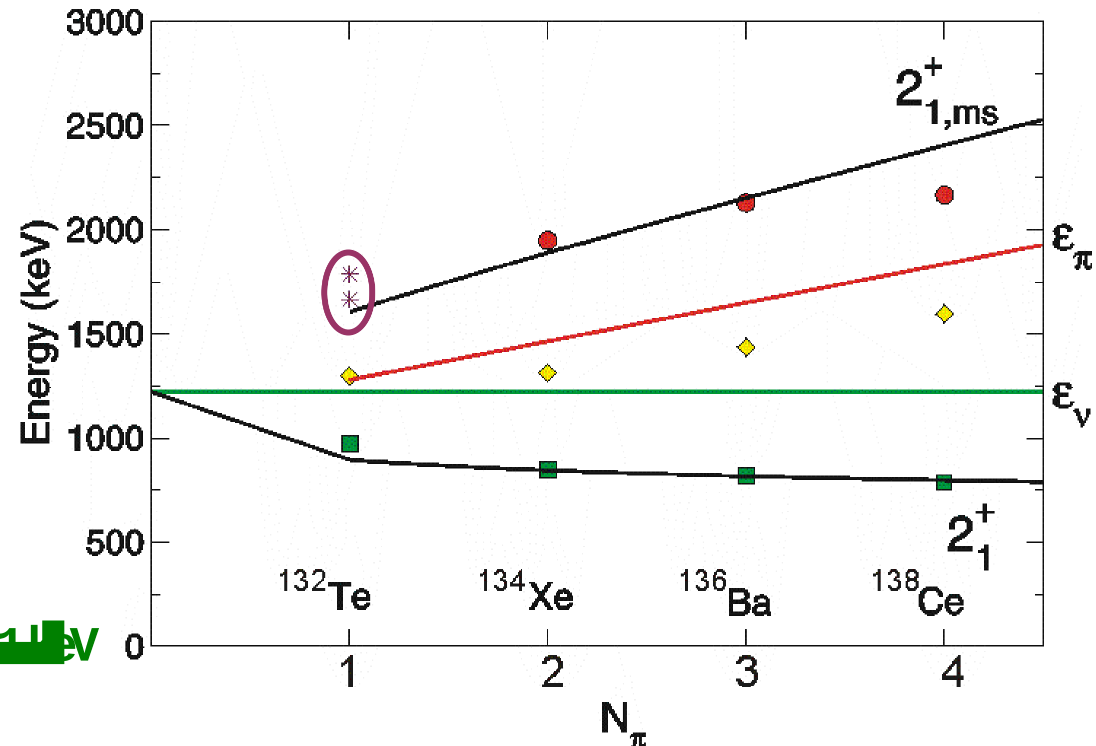
well within the capability of SPES

Evolution of the one-phonon $2^+_{1,ms}$ in N=80 isotones

The one-phonon FSS and MSS can be considered as a result of mixing between the elementary 2^+ proton and neutron excitations caused by the proton-neutron quadrupole interaction



K. Heyde and J. Sau
Phys. Rev. C, 33, 1050(1986)



β = 0.35(1)MeV b = 0.23(4) MeV

= 0.15(1) MeV

T. Ahn *et al.*, Phys. Lett. B 697, 19 (2010)