Shell evolution of neutron-deficient Xe_{54} isotopes: A correlations laboratory above ^{100}Sn

- *Octupole correlations*
- *Quadrupole correlation vs pairing*
- *Shape coexistence*
- *… almost no cable will be shown but few technical considerations*

E.Clément,
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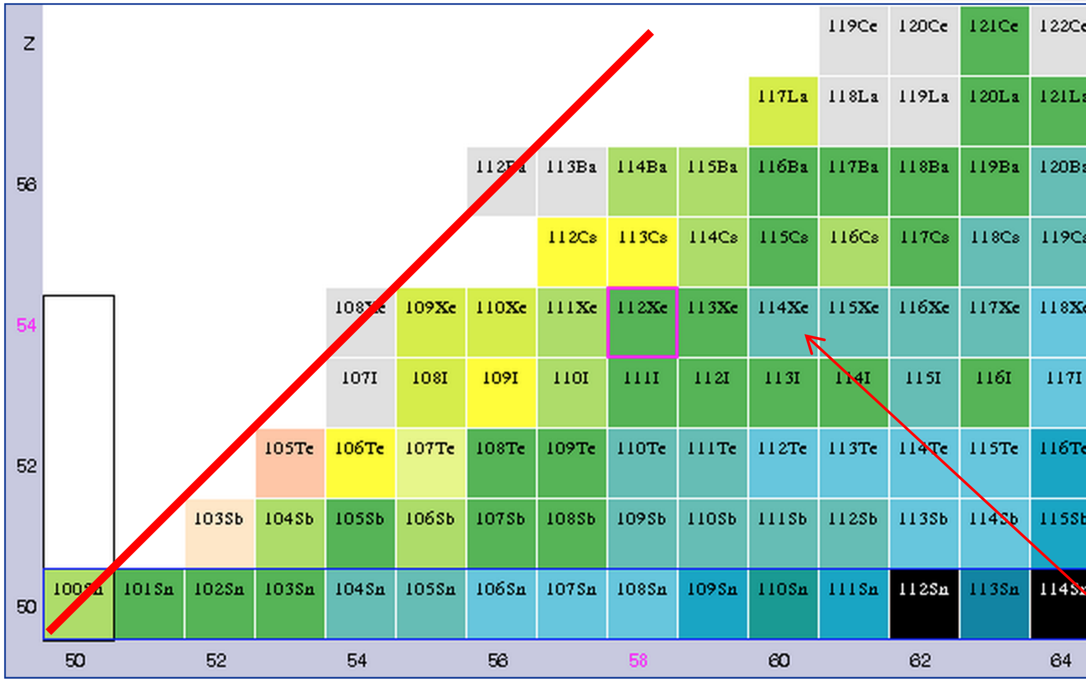
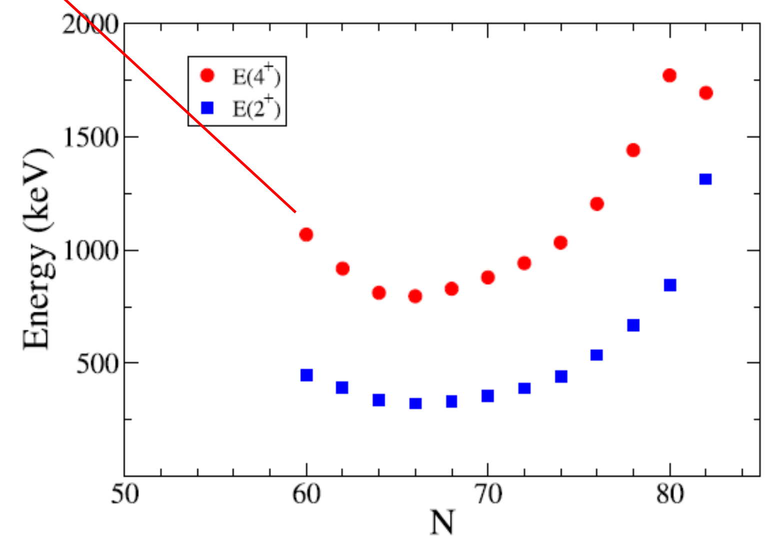
Shell evolution and collectivity development toward ^{100}Sn

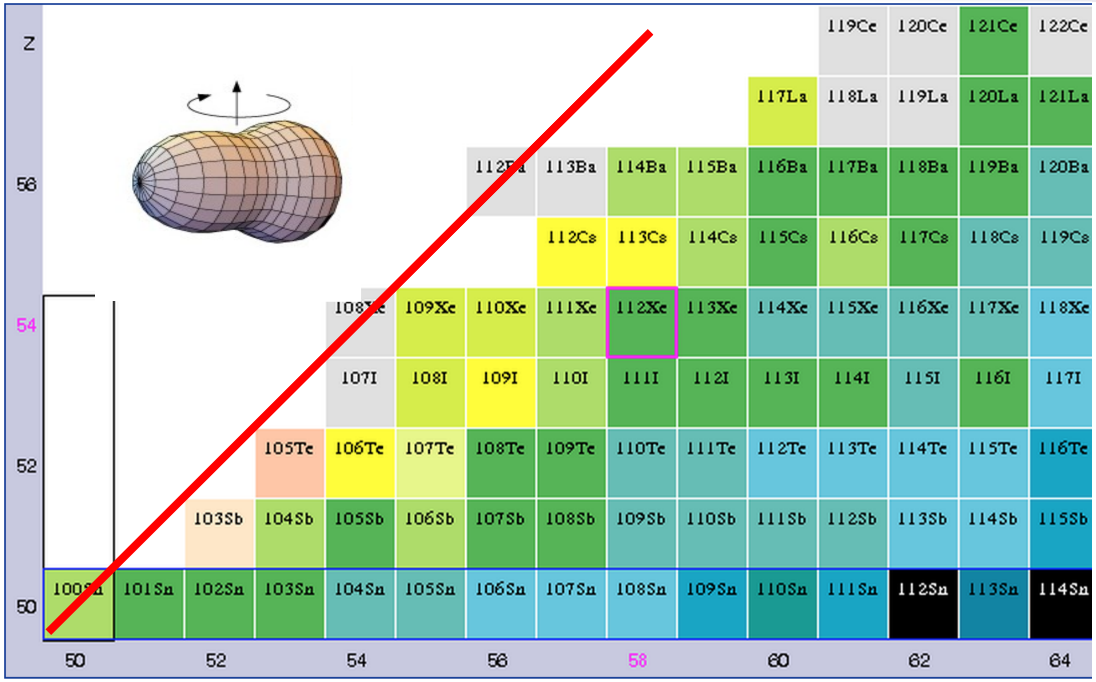


- ❑Maximum of 2^{+} and 4^{+} excitation energies at N=82
- ❑Increase of collectivity



Shell evolution and collectivity development toward ^{100}Sn

Dipole moment and breaking parity



- ❑ ^{112}Ba will correspond to the best octupole N=Z=56 for p and n

→ Enhanced octupole due to the interaction of $d_{5/2}$ and $h_{11/2}$
$\Delta L=3$, $\Delta J=3$, inverse parity

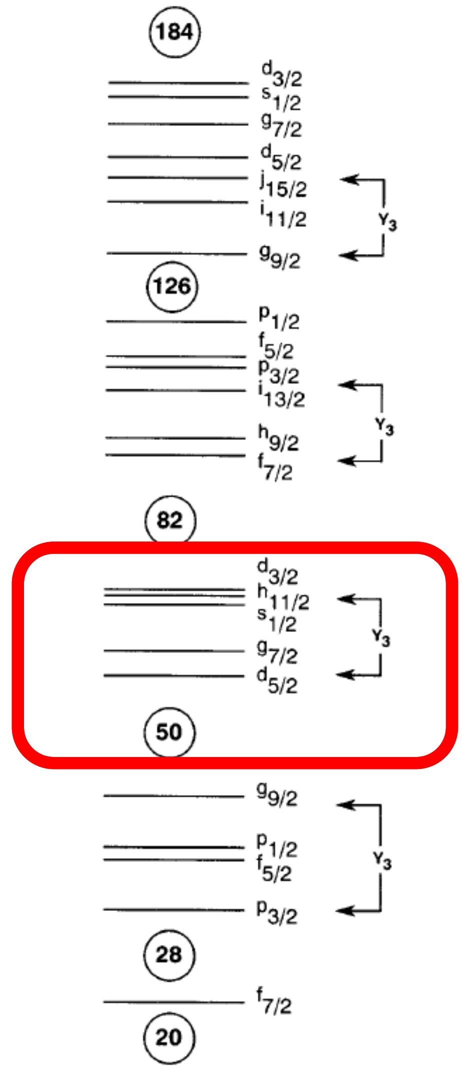


FIG. 4. Nuclear spherical single-particle levels. The most important octupole couplings are indicated.

Odd negative parity state in Xe

3^- states dominate by $\pi d_{5/2} \times \nu h_{11/2}$ orbital configuration

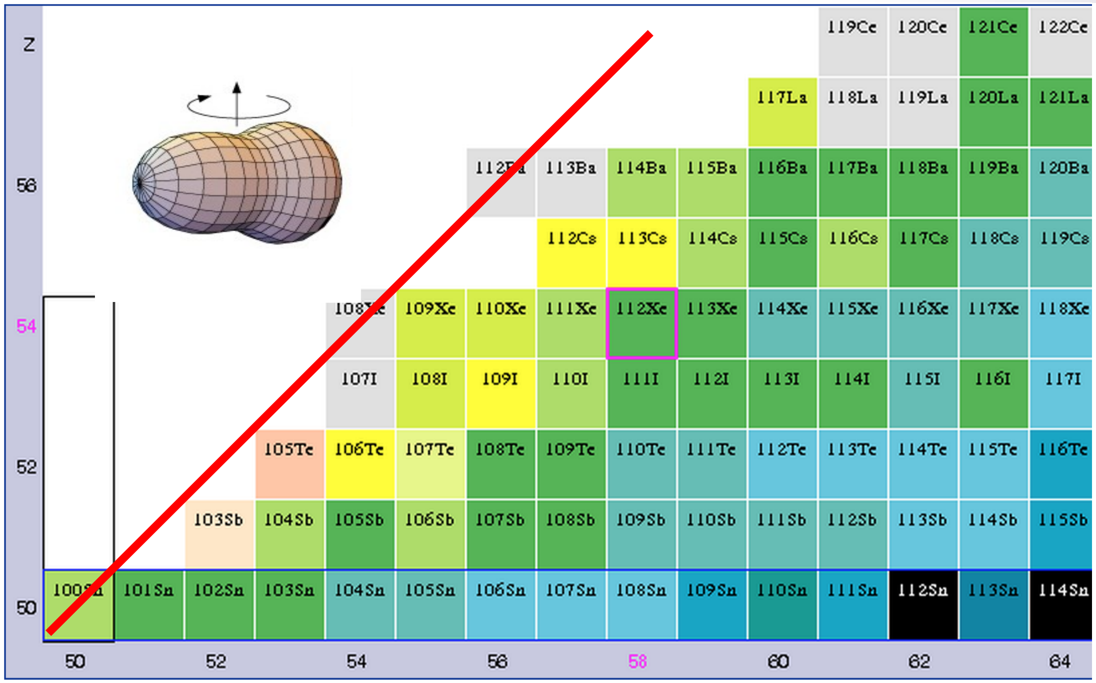
Removing neutron from the $h_{11/2}$ orbital gradually decreases the 3^- excitation energy and enhances the B(E3) value

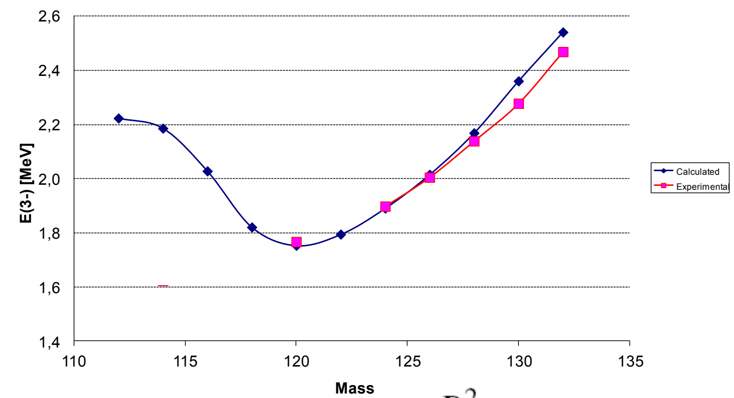
Collective octupole motion in such nuclei is strongly influenced by quadrupole softness
*[M. P. Metlay Phys. Rev. C **52**, 1801 (1995)]*

$$E(3^-) = E_0 - \frac{B^2}{E(2_1^+)}.$$

Shell evolution and collectivity development toward ^{100}Sn

So far a good harmonic octupole vibrator





$$E(3^-) = E_0 - \frac{B^2}{E(2_1^+)}.$$

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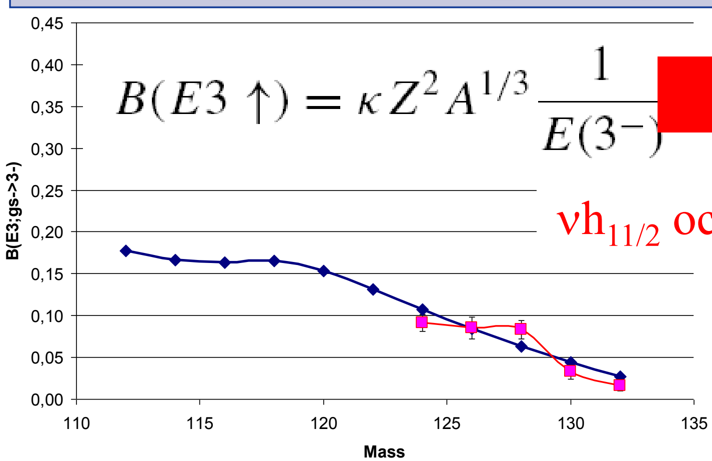
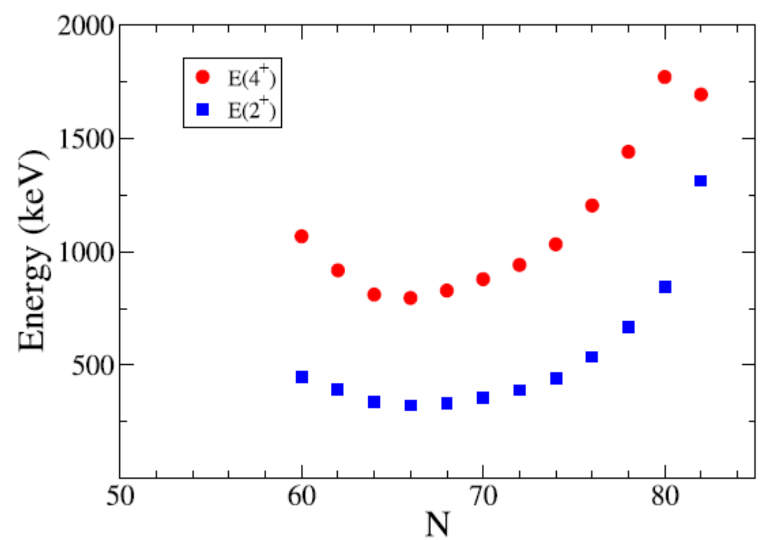
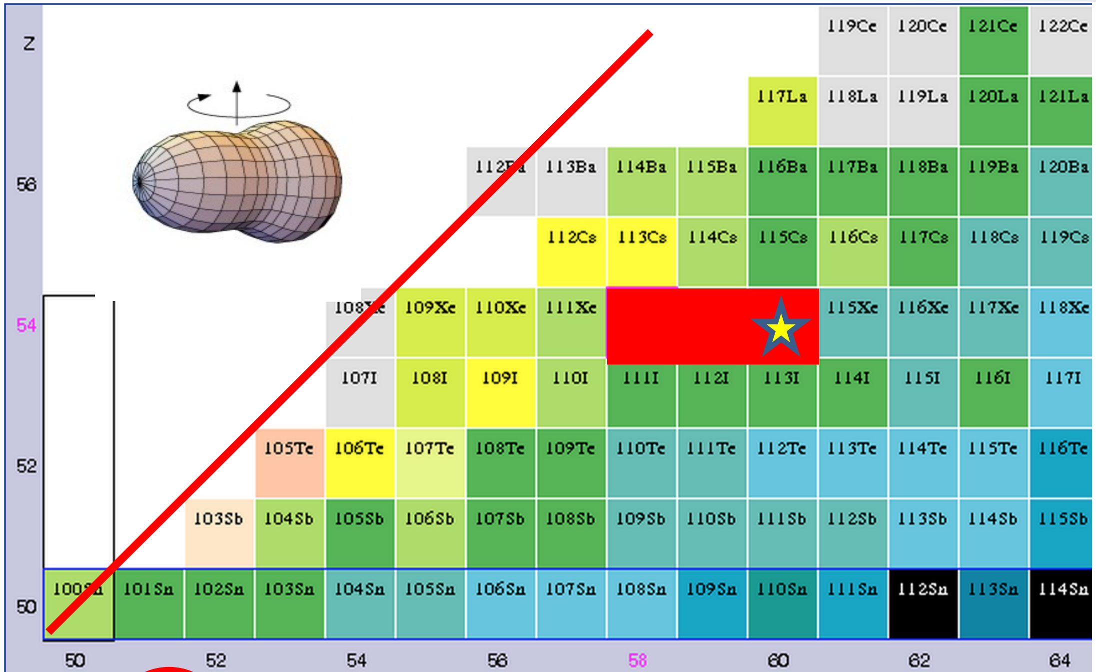


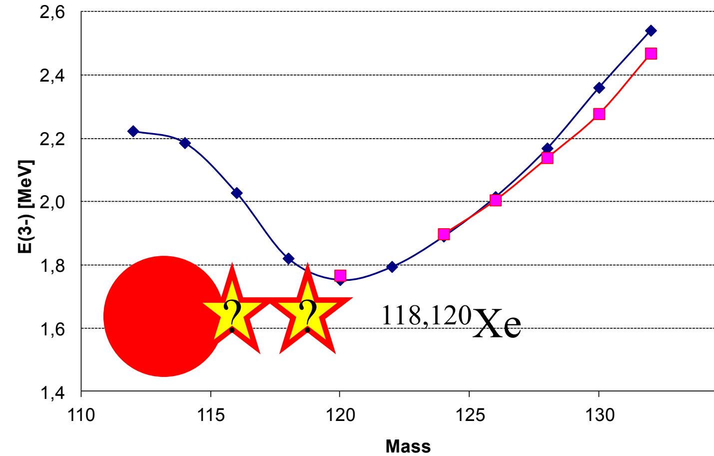
$$B(E3\uparrow) = \kappa Z^2 A^{1/3} \frac{1}{E(3^-)}$$

$\nu h_{11/2}$ occupancy

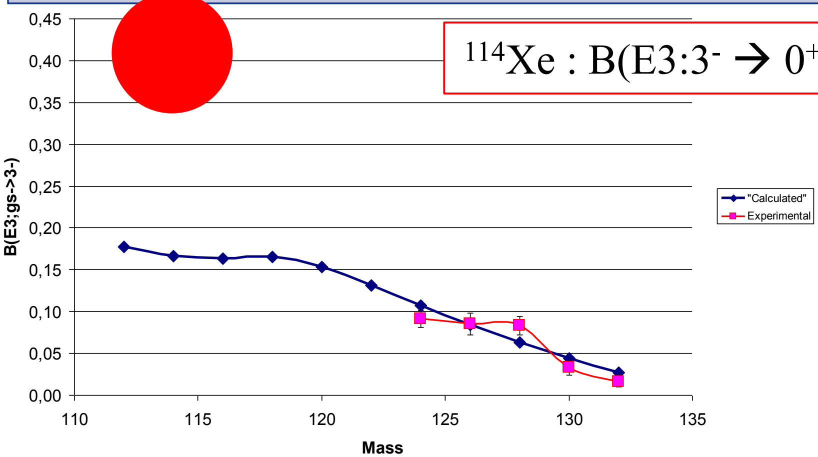


Proton-neutron Octupole correlations

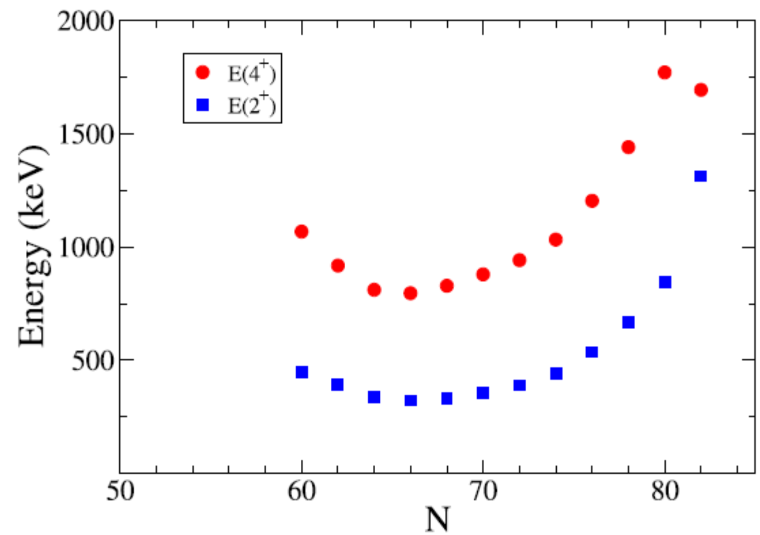




G. de Angelis et al., Phys. Lett. B 535 (2002) 93
J.F. Smith et al., Phys. Lett. B 523 (2001) 13.



^{114}Xe : B(E3:3$^-$ → 0$^+$) = 77 W.u !!



Microscopic calculations Xe-Ba

	^{114}Xe	^{112}Xe	^{118}Ba
E $(3-)_{theo}$ (MeV) / Exp	1.84 /1.62	1.99/1.65	2.11
B(E3: 3- → $0+)_{theo}$ W.u.	17.5	19.2	18.7
B(E3: 3- → $0+)_{exp}$ W.u.	77	-	-

Factor 4.5

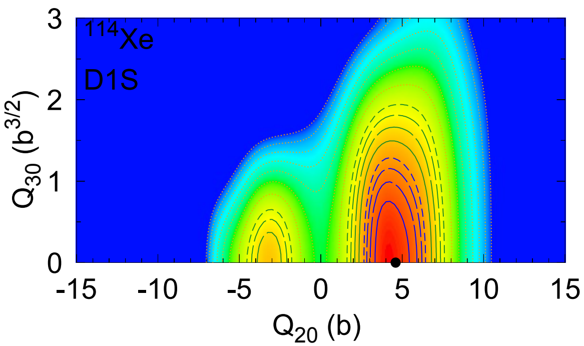
The puzzle in the known case ^{114}Xe is that:

- Q2-Q3 does not change at all the B(E3) value even if shape coexistance is observed from the calculations

The large B(E3) might be understood in terms of dynamical coupling of the proton-neutron type $\pi(\nu)\ d_{5/2} - \nu\ (\pi)\ h_{11/2}$

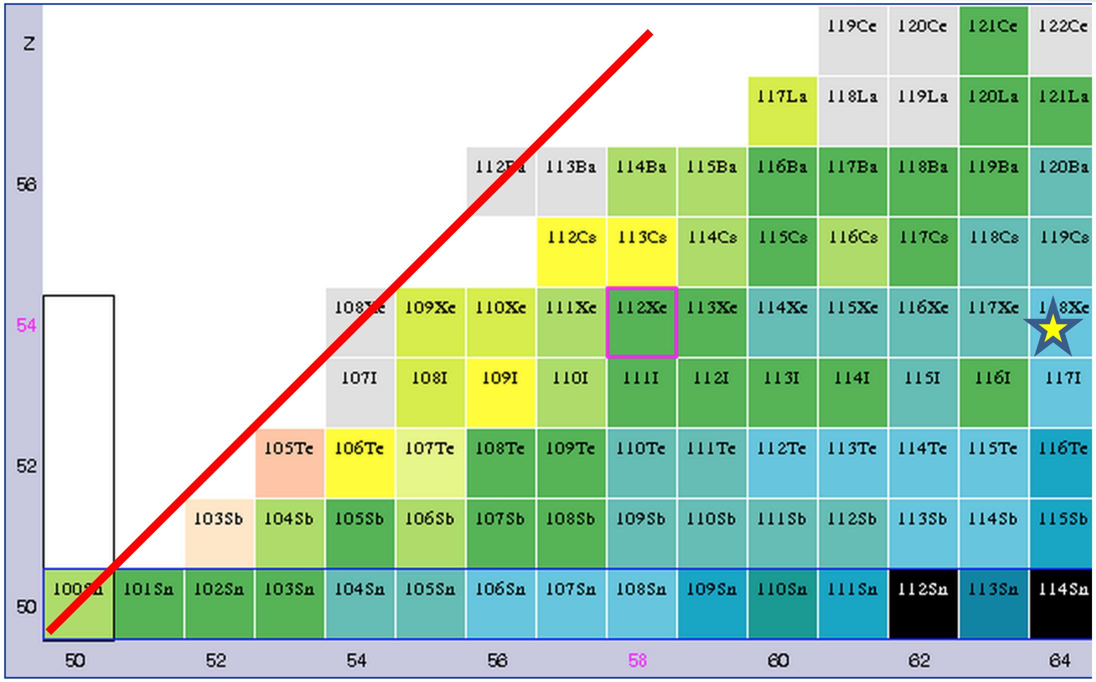
^{112}Xe : B(E3:3^- → 0^+) = ??

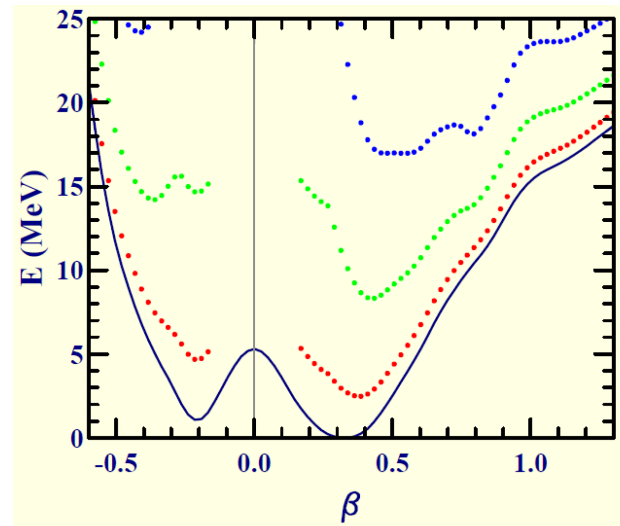
L.M. Robledo private communication



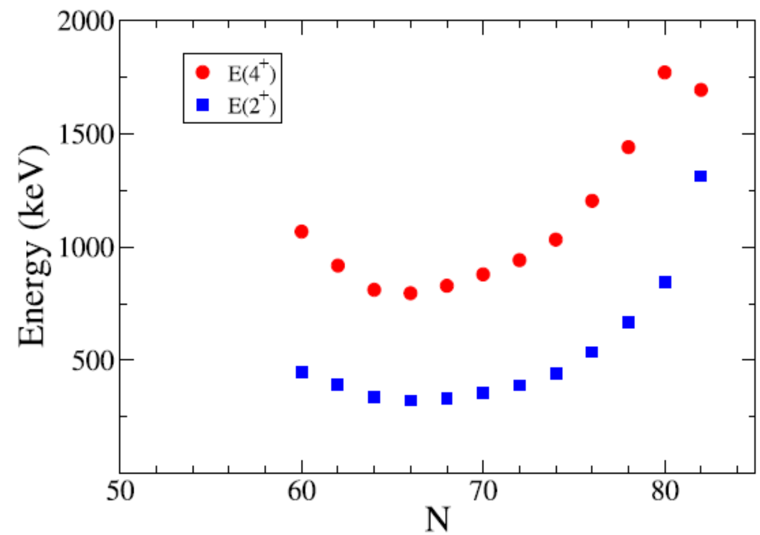
Let's remember that the $h_{11/2}$-$d_{5/2}$ octupole in ^{146}Gd for protons is ~ 30 W.u. nicely reproduced by the GCM HFB calculations!

Shape coexistence beyond ^{100}Sn

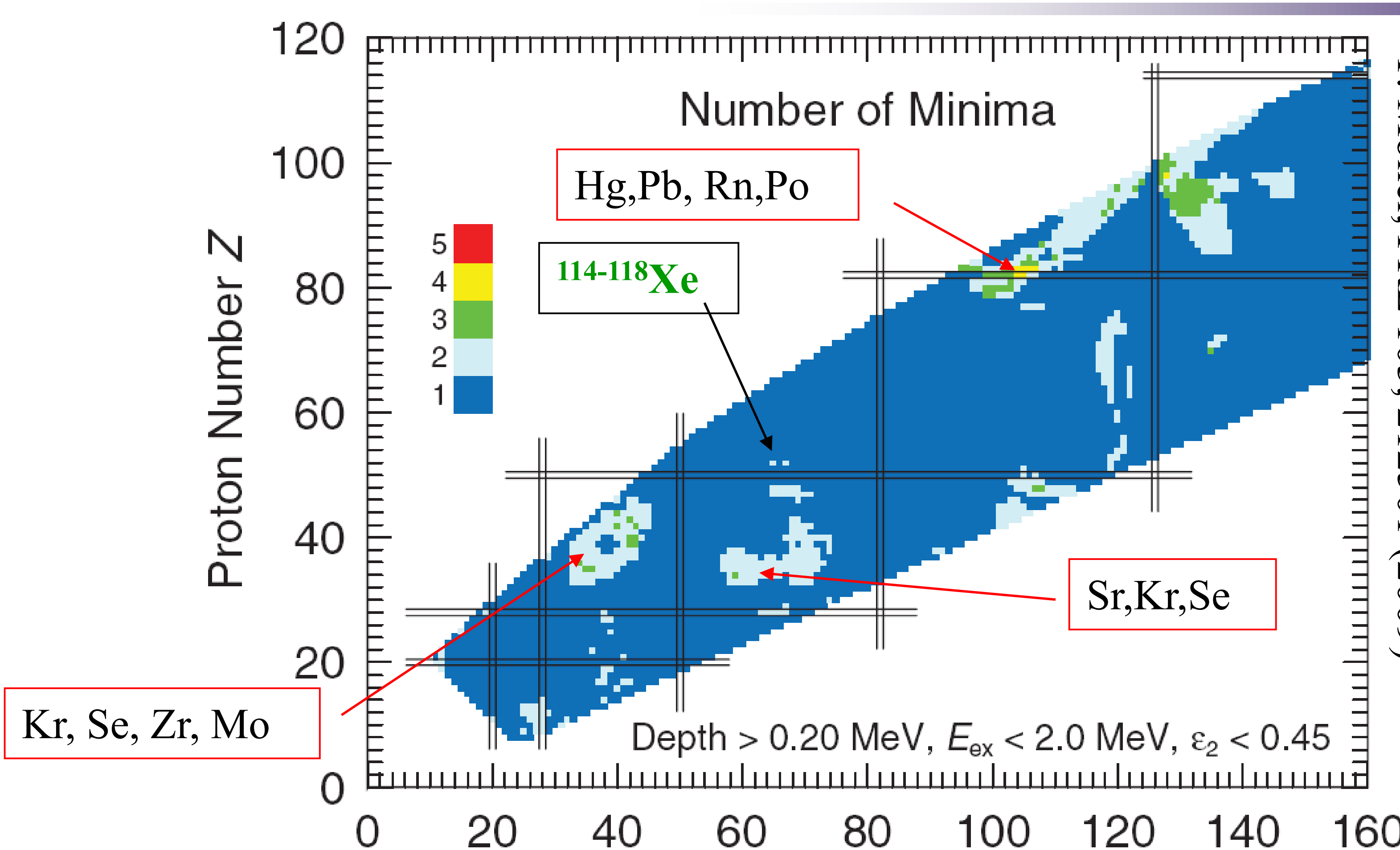




^{118}Xe HFB-D1S Bruyère-le-châtel



Shape coexistence beyond ^{100}Sn

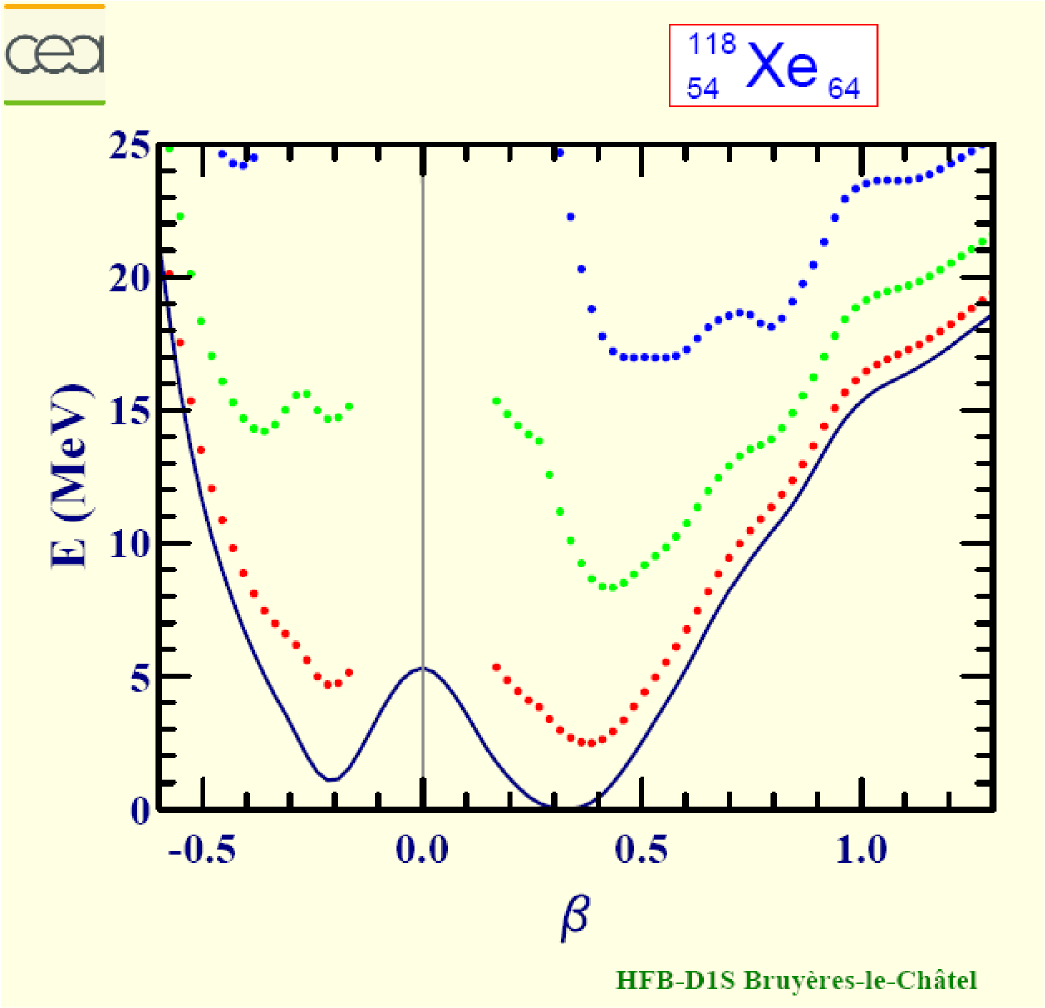


P. Möller, PRL 103, 212501 (2009)

- ❑ Beyond Sn most of the nuclei are γ-soft
- ❑ Separated minima in Xe

→ good candidates to study the shape coexistence just beyond ^{100}Sn

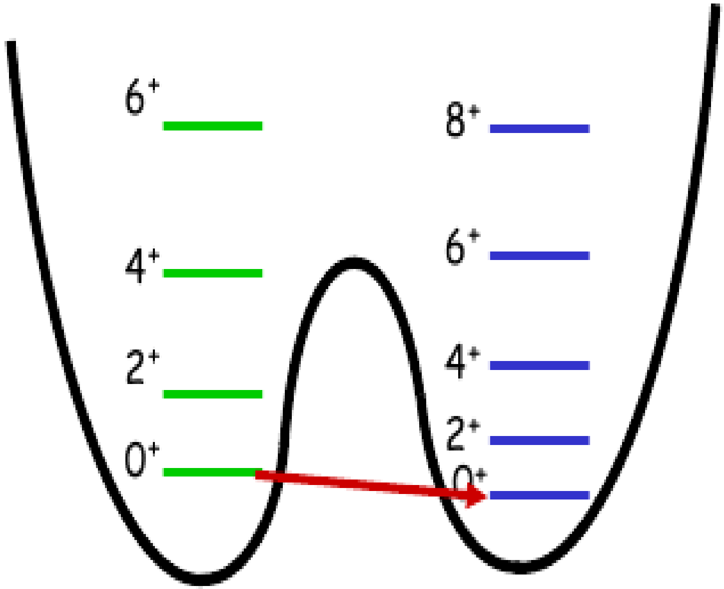
Shape coexistence beyond ^{100}Sn

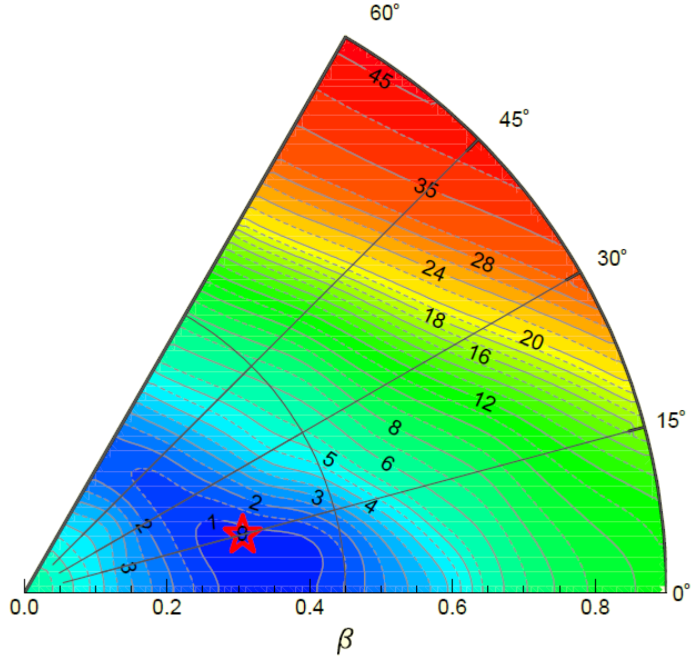


Shape competition between prolate and oblate minima

- *Different shells, new degree of freedom*
- *Can we describe the nuclei above Sn as well as below ?*
- *B(E2) connecting these structure*
- *Spectroscopic quadrupole moment Qs*
- *Mixing of wave function*

Since RIB facilities offers post accelerated beams at 3-5 MeV/A an intensive experimental work is performed on the study of shape coexistence by safe coulomb excitation



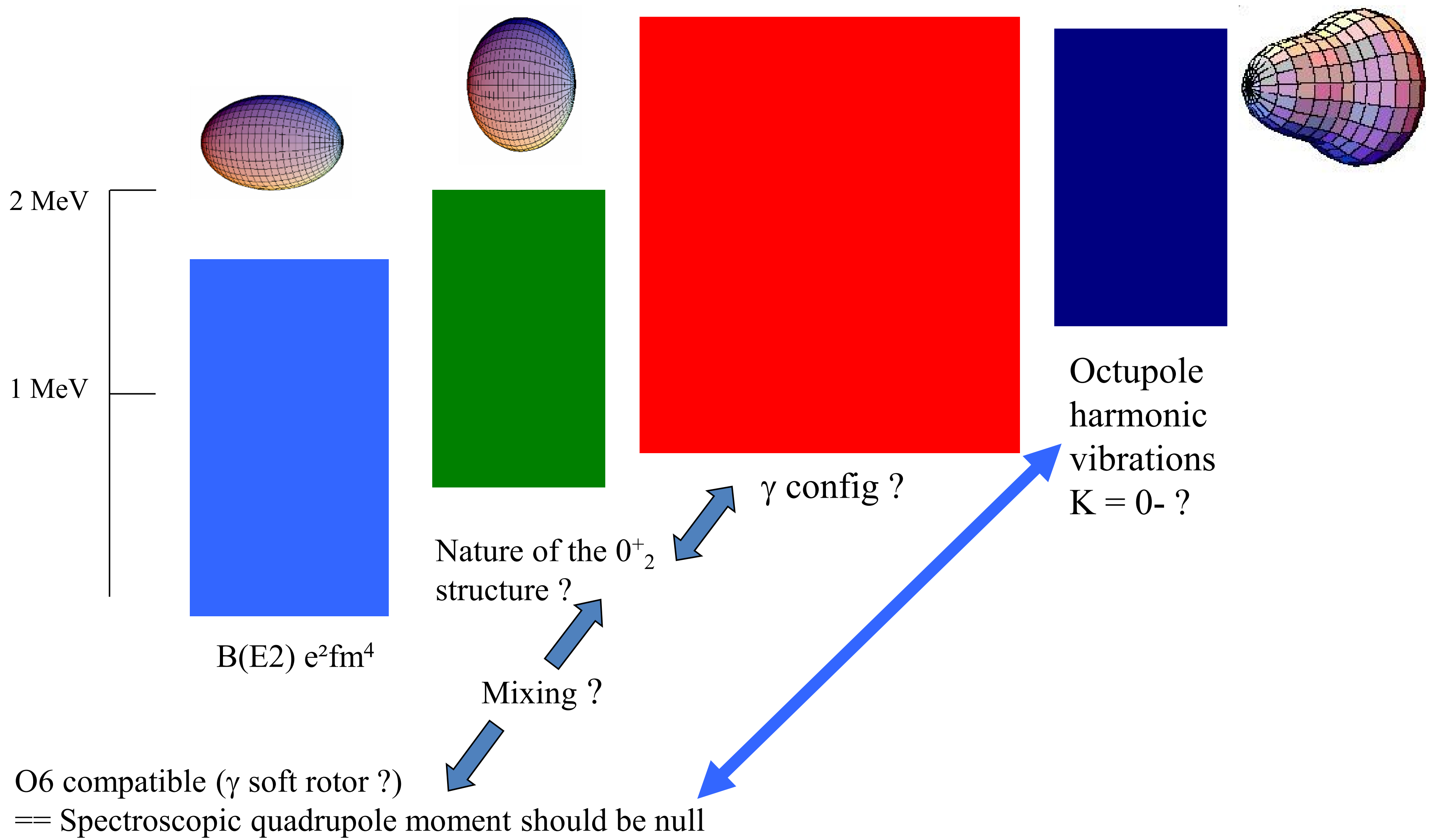


- ❑ Output experimental values are B(E2), algebric Qs (prolate, oblate), mixing angle, deformation parameter

- ❑ « Scanning » the potential energy surface of complex nuclei (that you can not measure) by precisely studying the low lying excited states

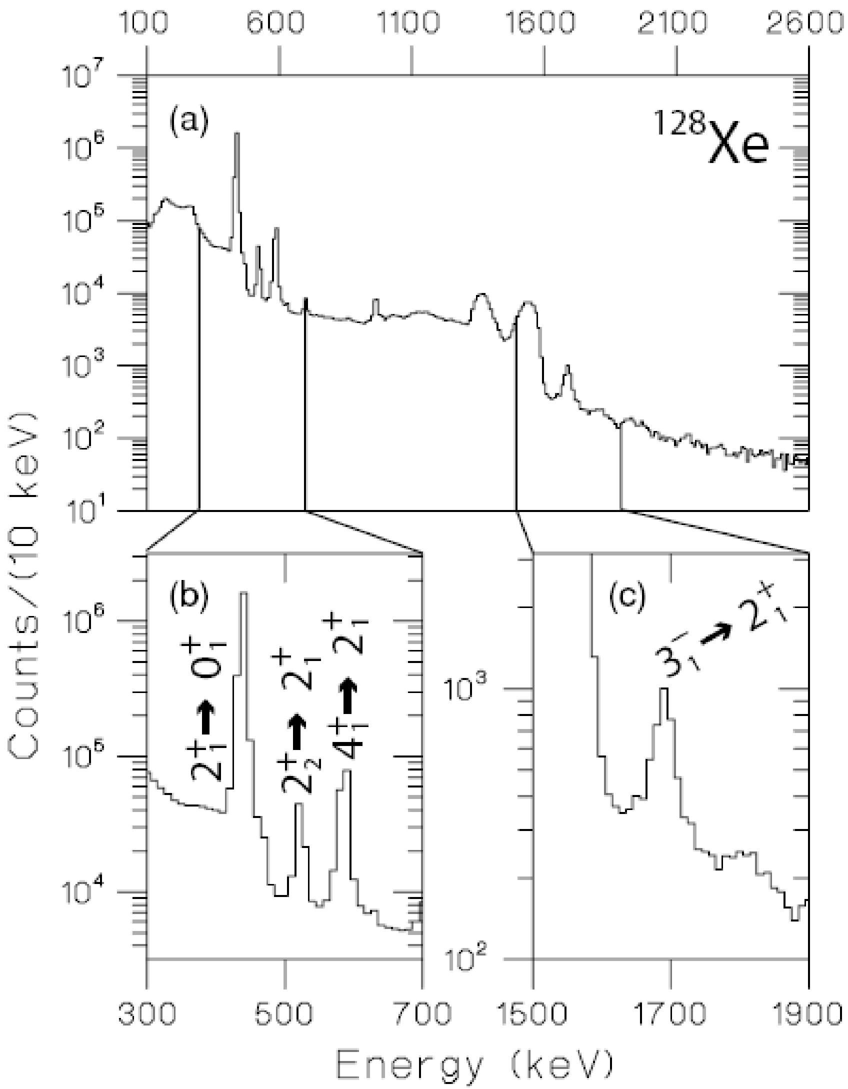
- ❑ The GCM method is the good approach to reproduce such nuclei

Shape coexistence in Xe isotopes (^{118}Xe case)



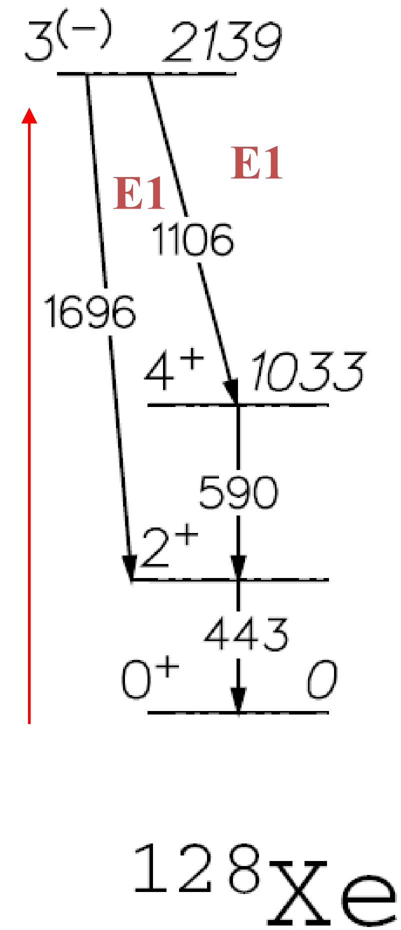
Odd negative parity state in Xe --

W. F. Mueller PHYSICAL REVIEW C 73, 014316 (2006)



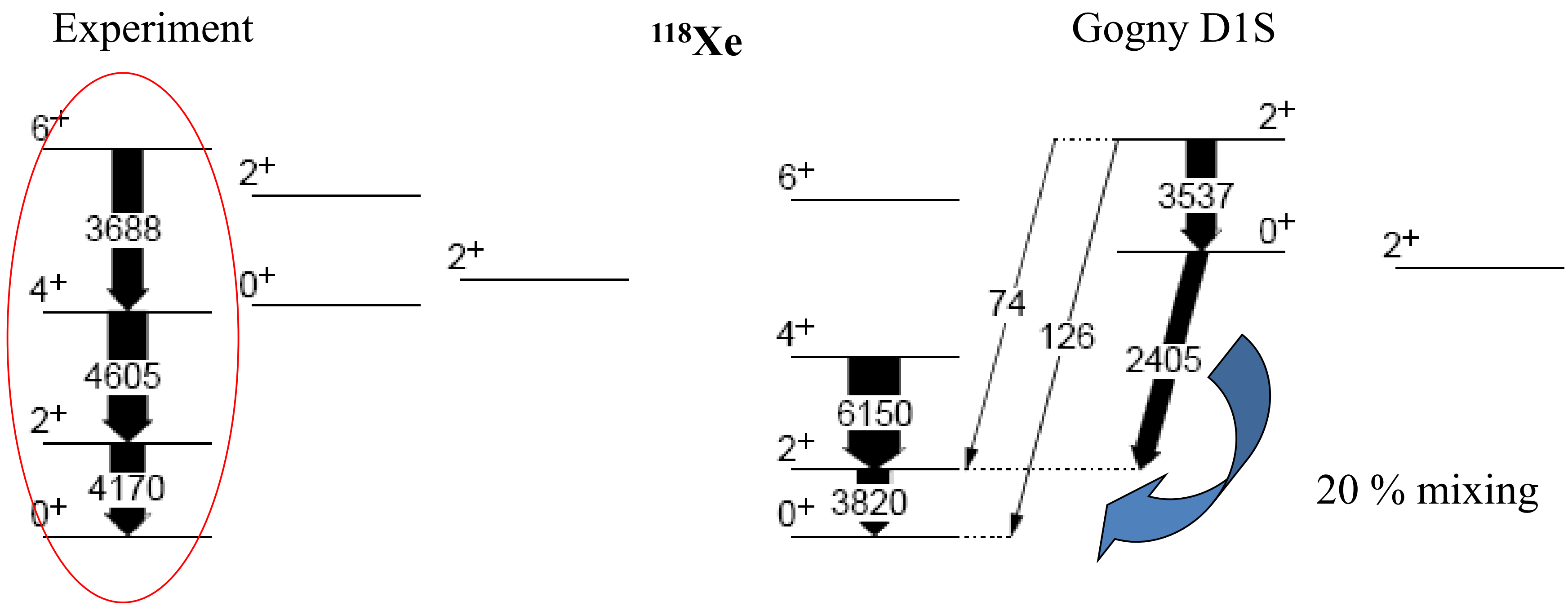
Safe coulex of stable Xe at Argonne has populated these exotic state for coulex technic

B(E3, $0^+ \rightarrow 3^-$)

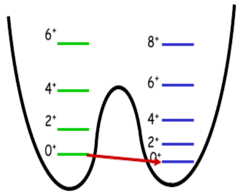


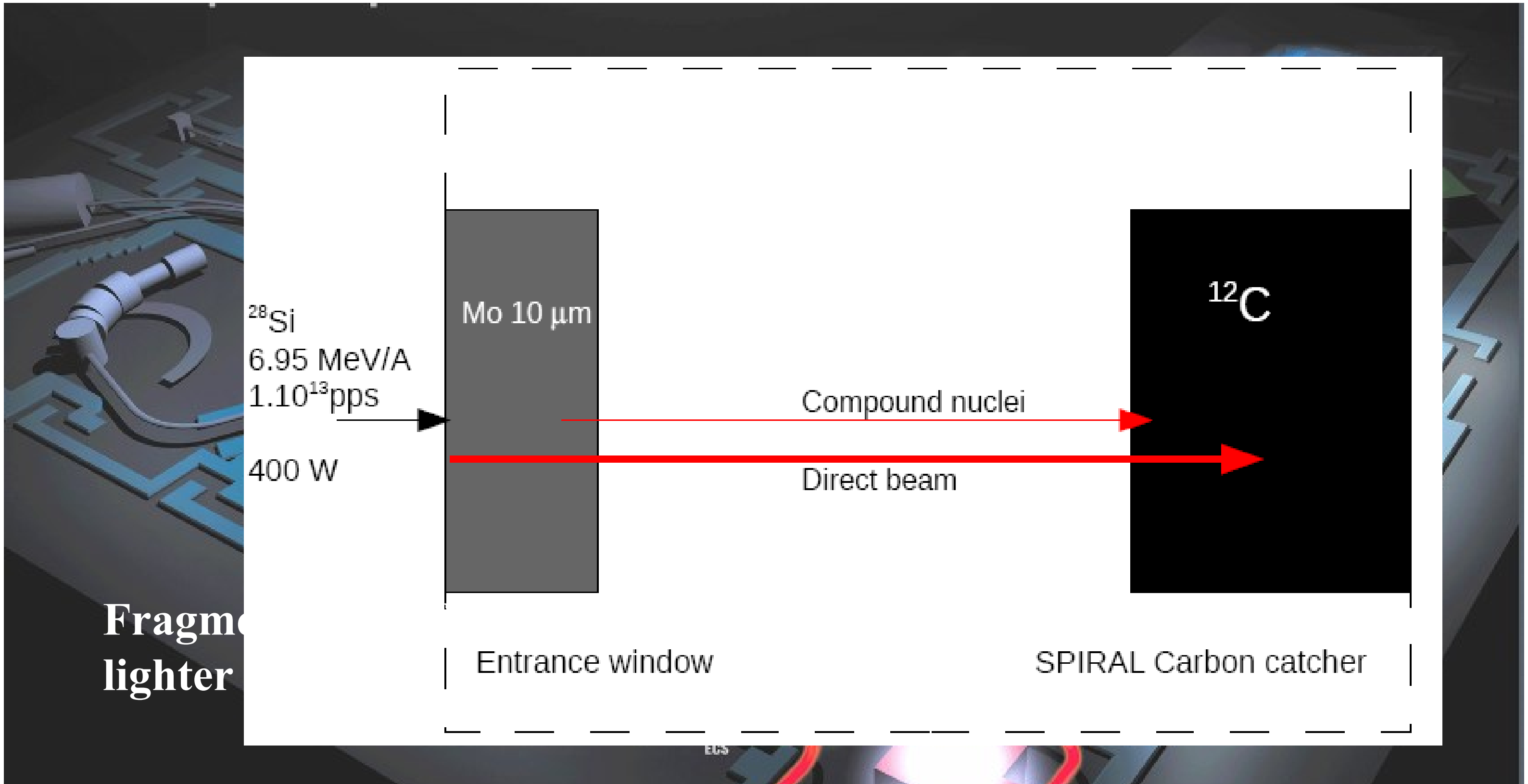
Challenging analysis … but may help to establish 3^- states

Shape coexistence in Xe isotopes (^{118}Xe case)



Can we produce them ?

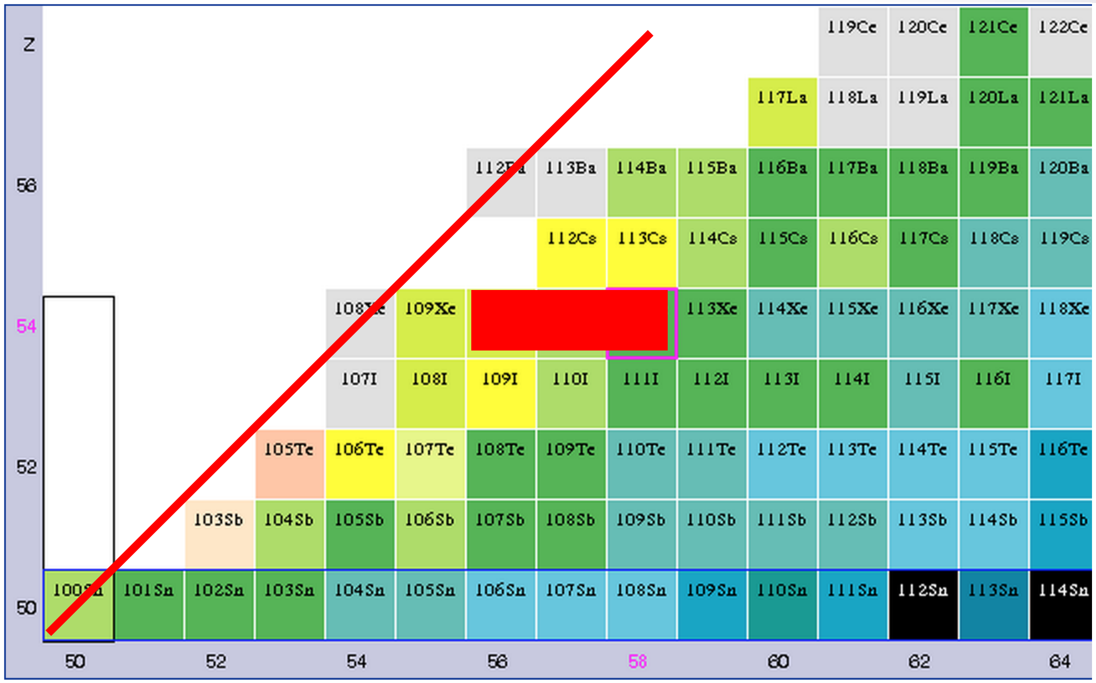




❖Few 10^4 pps at the coulomb barrier for the Xe+Pt system

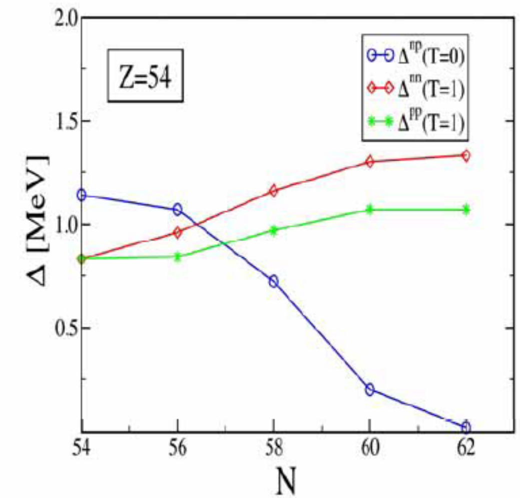
❖As coulex cross section are Z_p*Z_t; probabilities are very high and difficult state (3^-) can be populated

Approaching ^{108}Xe ?



Calculations for Xe

W. Satula, R. Wyss Phys. Rev. Lett. Vol. 86, 4488 (2001)

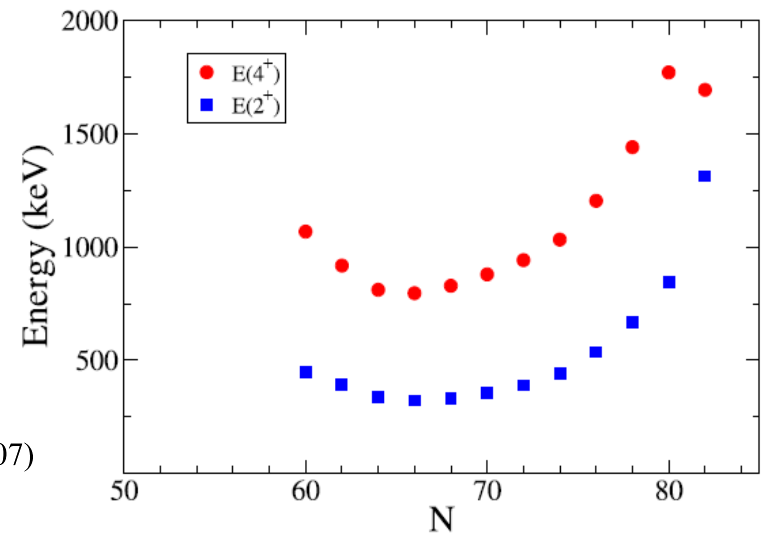


The isoscalar (np) pair gap is predicted to increase as N~Z

- ❑Direct evidence are difficult to find experimentally
 → comparison between state-of-the art calculation and spectroscopic data
- ❑ Call naturally for more data

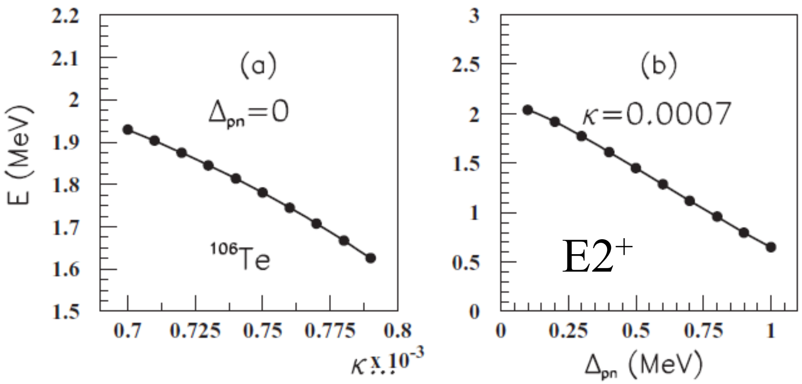
J.F. Smith et al, Phys. Lett. B 523, 13 (2001)

M. Sandzelius et al Phys. Rev. Lett 99, 022501 (2007)



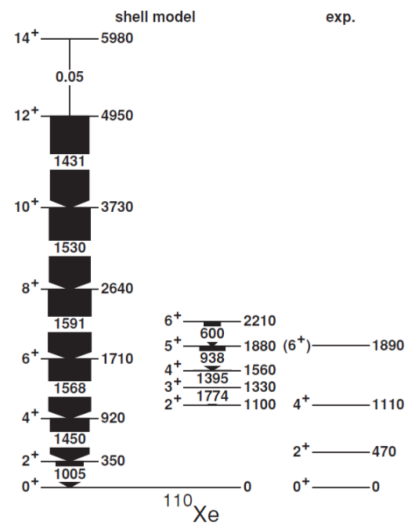
QRPA (Pairing + Quadrupole Hamiltonian)

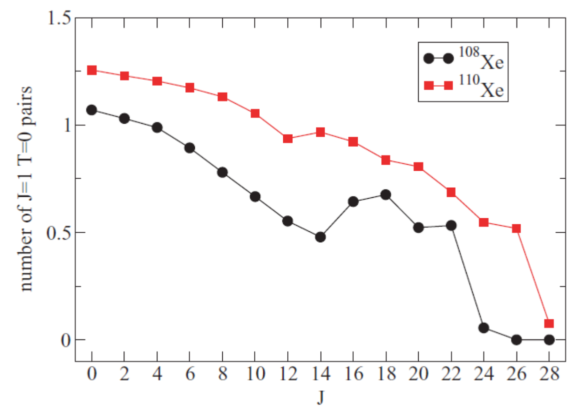
Delion et al, Phys. Rev. C 82, 024307 (2010)



Large Scale Shell Model Calculations

Caurier et al PRC 82, 064304 (2010).





- ❑Q driven : Decrease 2$^+$ and increase B(E2)
- ❑Δ_{pn} driven : Decrease 2$^+$ and B(E2)

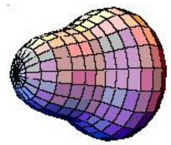
- ❑No need for strong np isoscalar pairing & depletion of the ^{100}Sn core.
- ❑Calculated J=0 T=1 and J=1 T=0 pairs are small
- ❑20% increase of quadrupole collectivity when including a 1p-1h excitation for ^{112}Xe.
- ❑ Low B(E2, 2$^+$→0$^+$) predicted for ^{112}Xe

^{100}Sn core breaking or confirmations of the contribution of the pairing are based on theoretical calculations supported by known spectroscopic experimental data: in the present situation, only excitation energies.

→ B(E2) that will be experimental challenge relialable ?

Experimental details

- ^{58}Ni(^{58}Ni,2p2n)^{112}Xe at 250 MeV

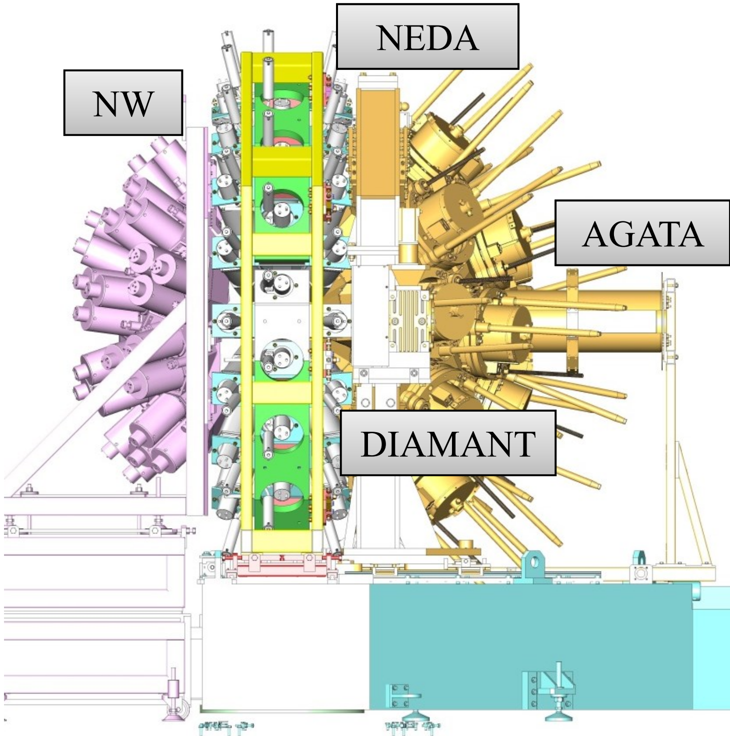


- ^{112}Te(4p), ^{109}Sb(a3p), ^{113}I(3p) and ^{110}Te(a2p) which constitute respectively 46%,16%,12% and 10% of the reaction products → selection by the NWALL

- Plunger measurement using a Stopper foil and γ–γ–ν coincidences ; Ni Target and Au Stopper

- Reference paper : J.F. Smith et al, Phys. Lett. B 523, 13 (2001)

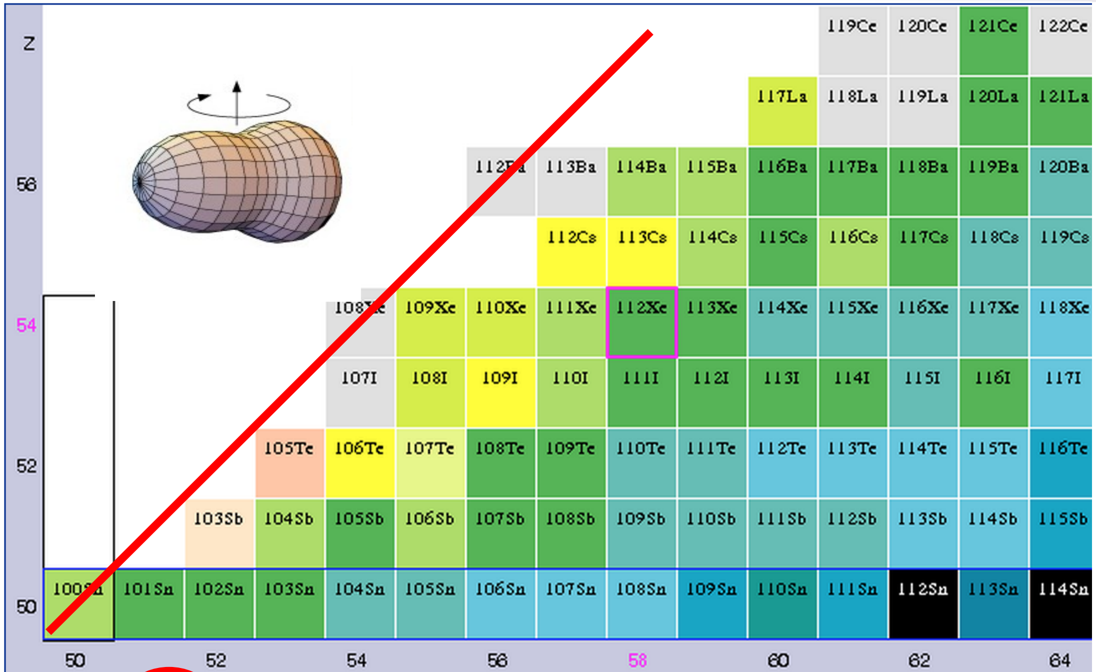
- NWALL+DIAMANT AGATA + 10 days experiment (20pnA) = 300× GS- NE213 (safely) in γ^2

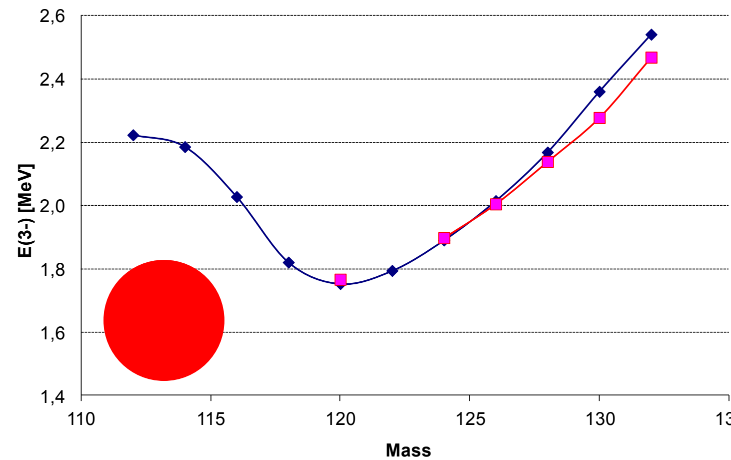


- According to the SM, the 2+ should have a T1/2 of [20- 70 ps]
- The 4^+ should have a T1/2 in the range of 3ps.

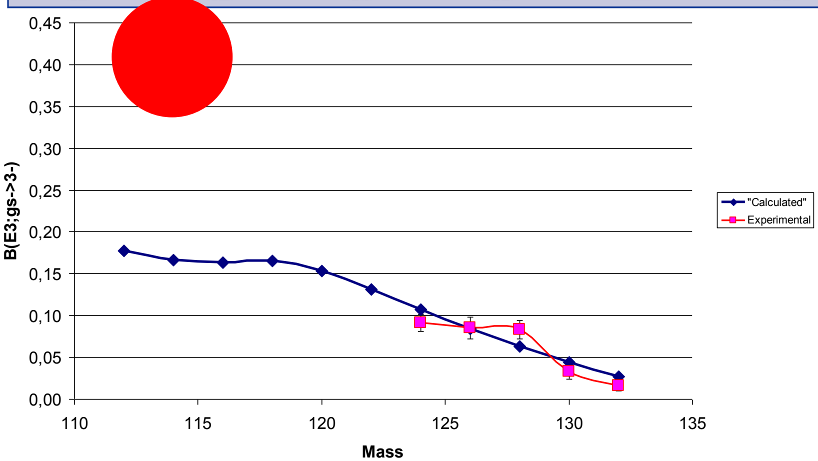
- Extend to g-factor ? → Theory inputs ?

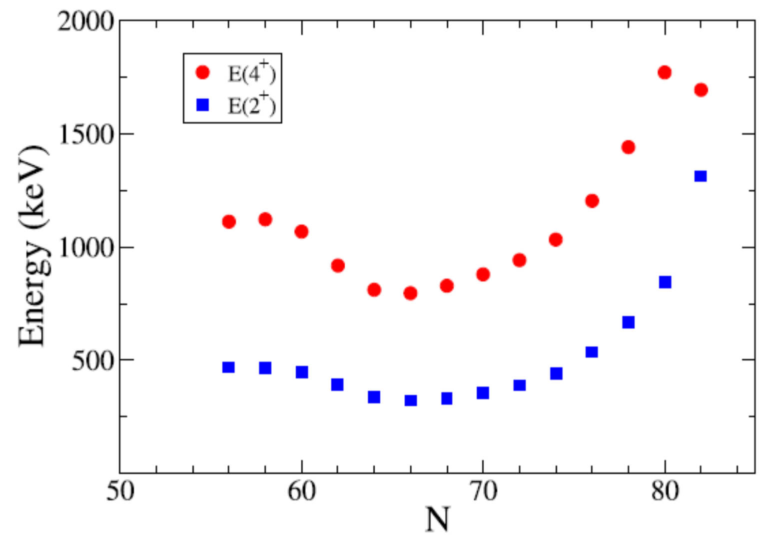
Why to go to 110Xe ?
Enhancement of the pairing, octupole correlations?





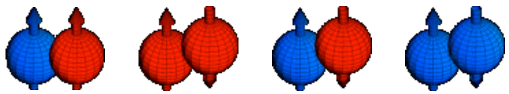
G. de Angelis et al., Phys. Lett. B 535 (2002) 93
J.F. Smith et al., Phys. Lett. B 523 (2001) 13.





E.Clément

Spectroscopy of ^{110}Xe

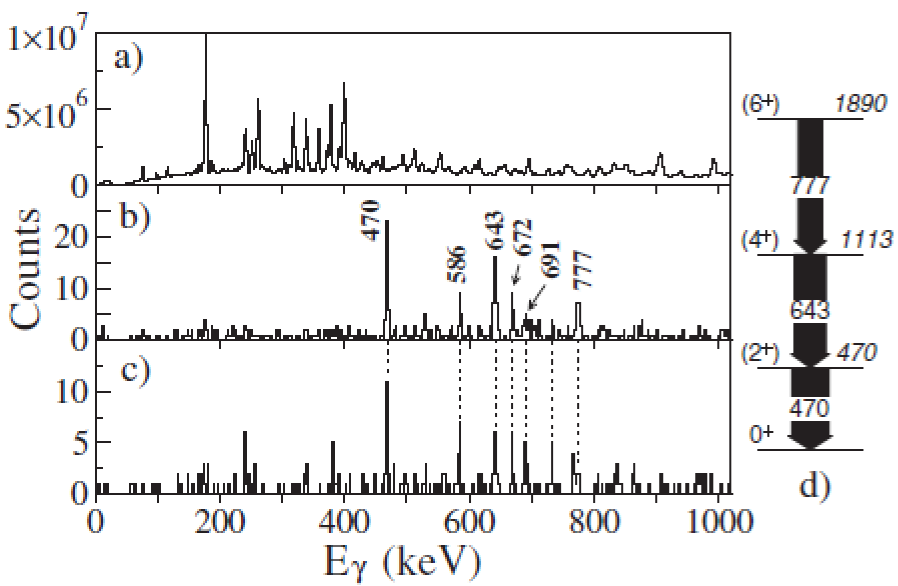


- ❑ ^{58}Ni(^{54}Fe,2n)^{110}Xe channel with a beam energy of 195 MeV.
- ❑ α-emitter, selection by the VAMOS gas-filled, selection of α–α-mother decay
- ❑ trying to improve the spectroscopy applying γγ coincidences using the AGATA array placed in the backward angle coupled to EXOGAM2 detectors at 90°. In this configuration angular distribution and polarization measurements could be performed
- ❑ VAMOS ≈ RITU in that case
- ❑ Total fusion cross section ~250 mb + 5pnA (RITU run) + VAMOS acceptance = 8.10^4 pps in MUSETT !!

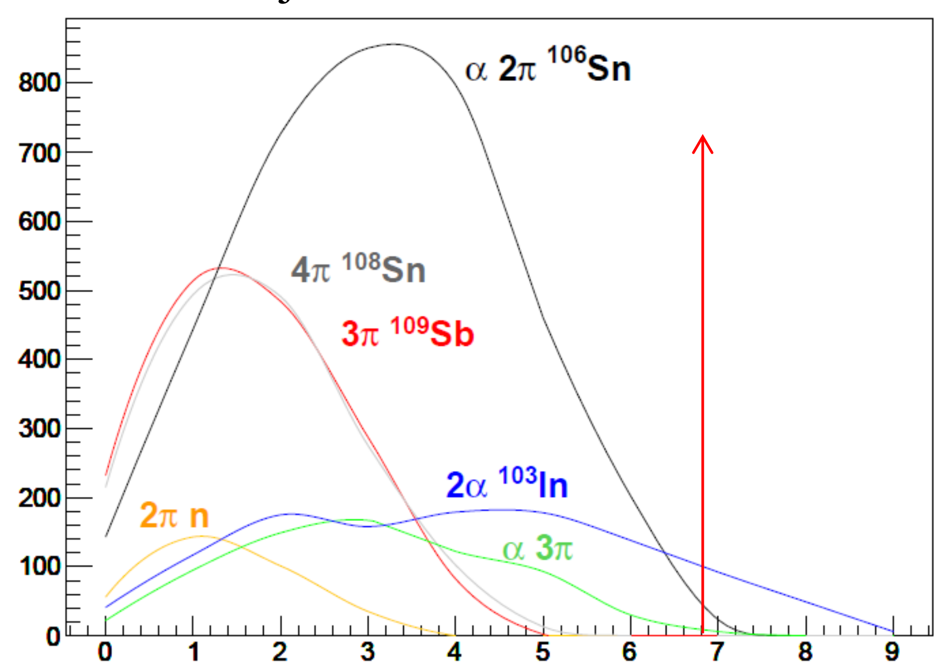
→ limited by the VAMOS angular acceptance ?

Ω = 10 mstrad (RITU) vs 60 mstrad (VAMOS)

Vamos rejection 10^{10}

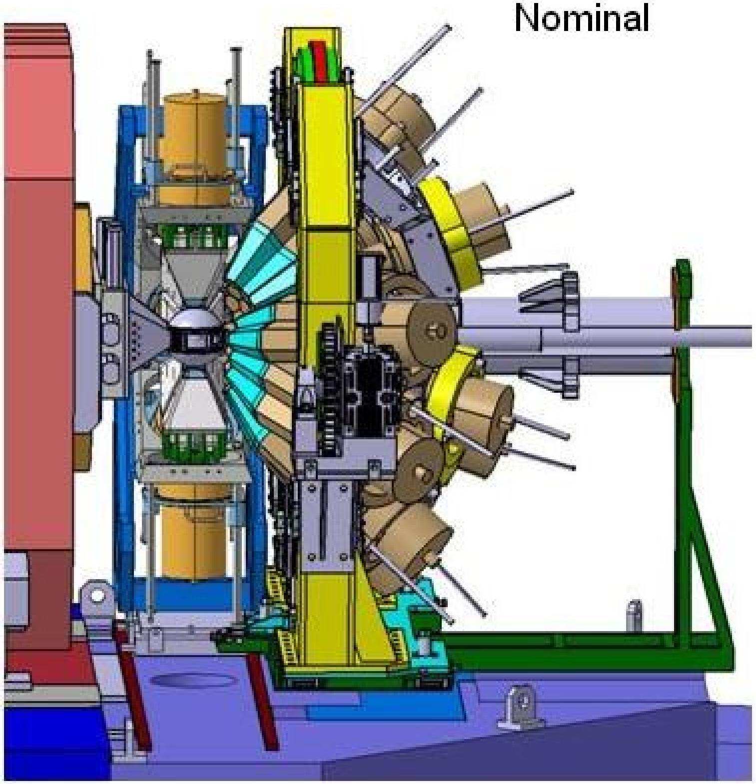


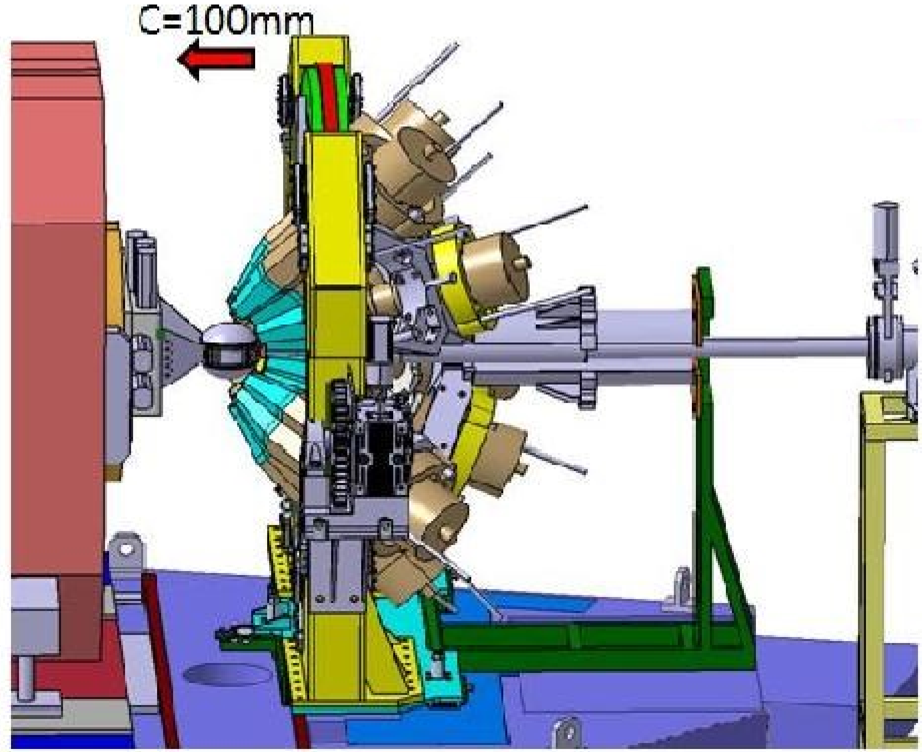
M. Sandzelius et al Phys. Rev. Lett 99, 022501 (2007)



Technical considerations

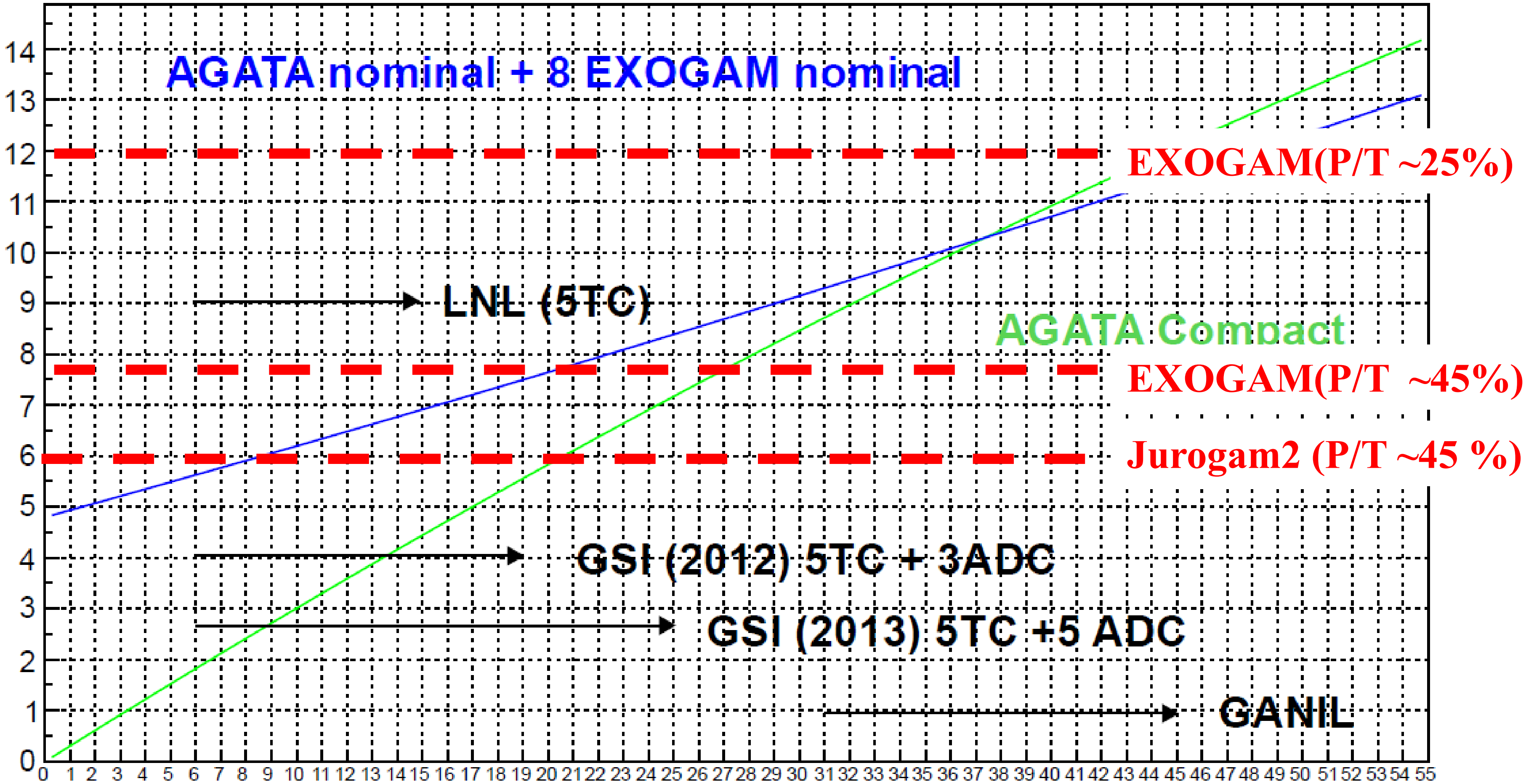
Nominal





Technical considerations

AGATA P/T ~45% Higher fold resolving power to be carefully investigated



Technical considerations

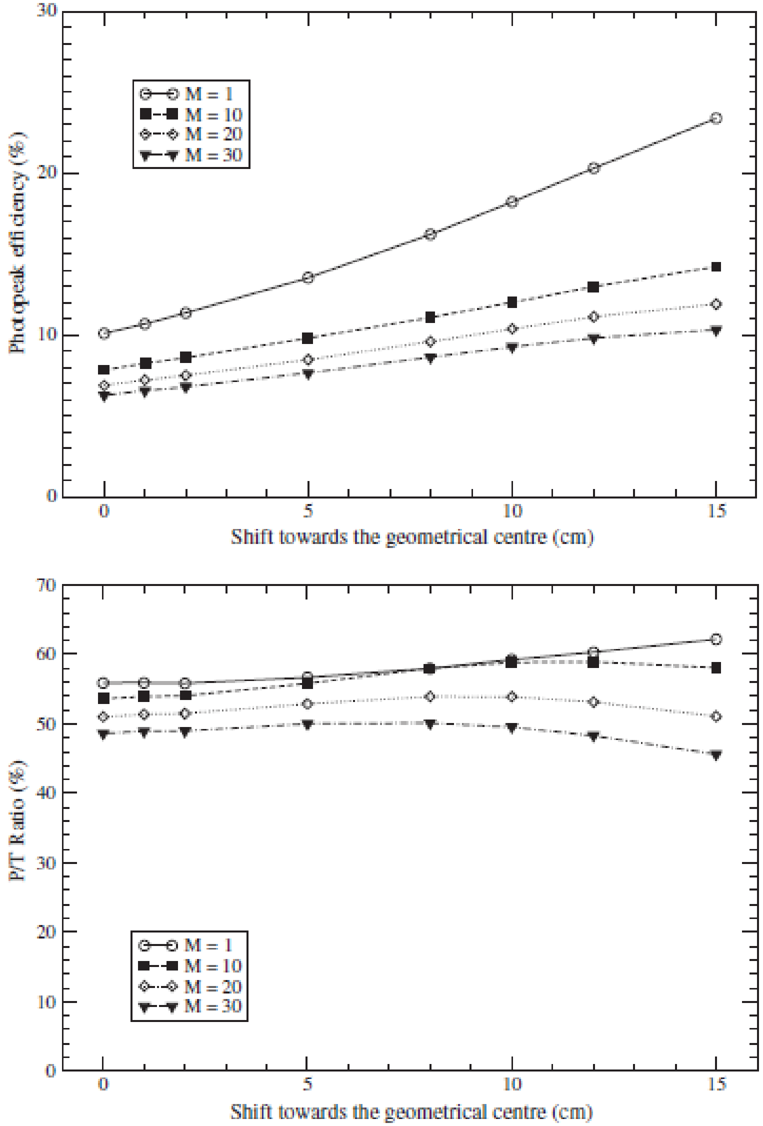
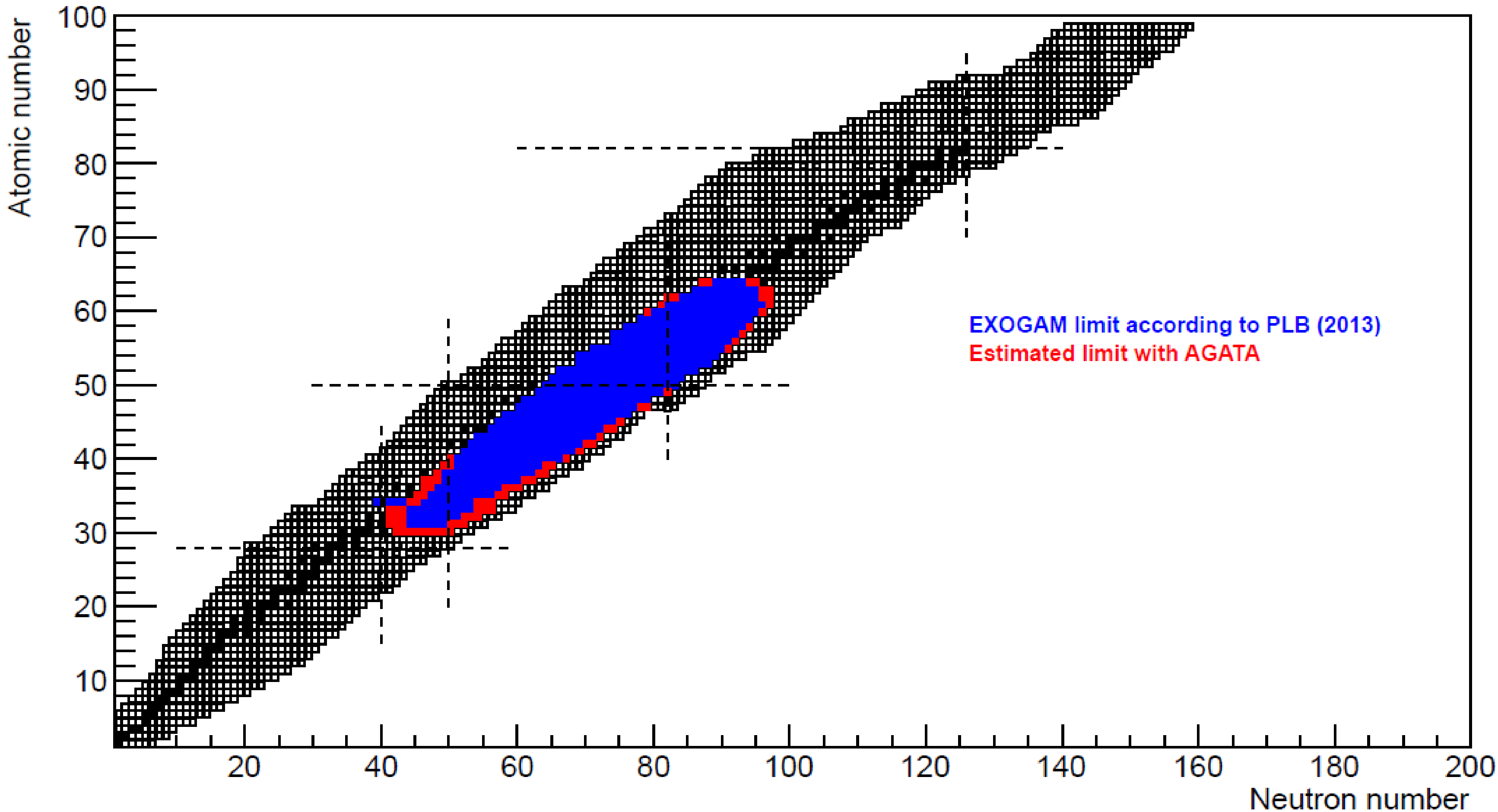


Fig. 10. Photopeak efficiency (top) and peak-to-total ratio (bottom) of the AGATA 1π Array for 1 MeV photons emitted from a point source at rest.

E. Farnea et al. Nuclear Instruments and Methods in Physics Research A 621 (2010) 331–343

Technical considerations

AGATA@GANIL is a lifetime measurement factory !



Technical considerations

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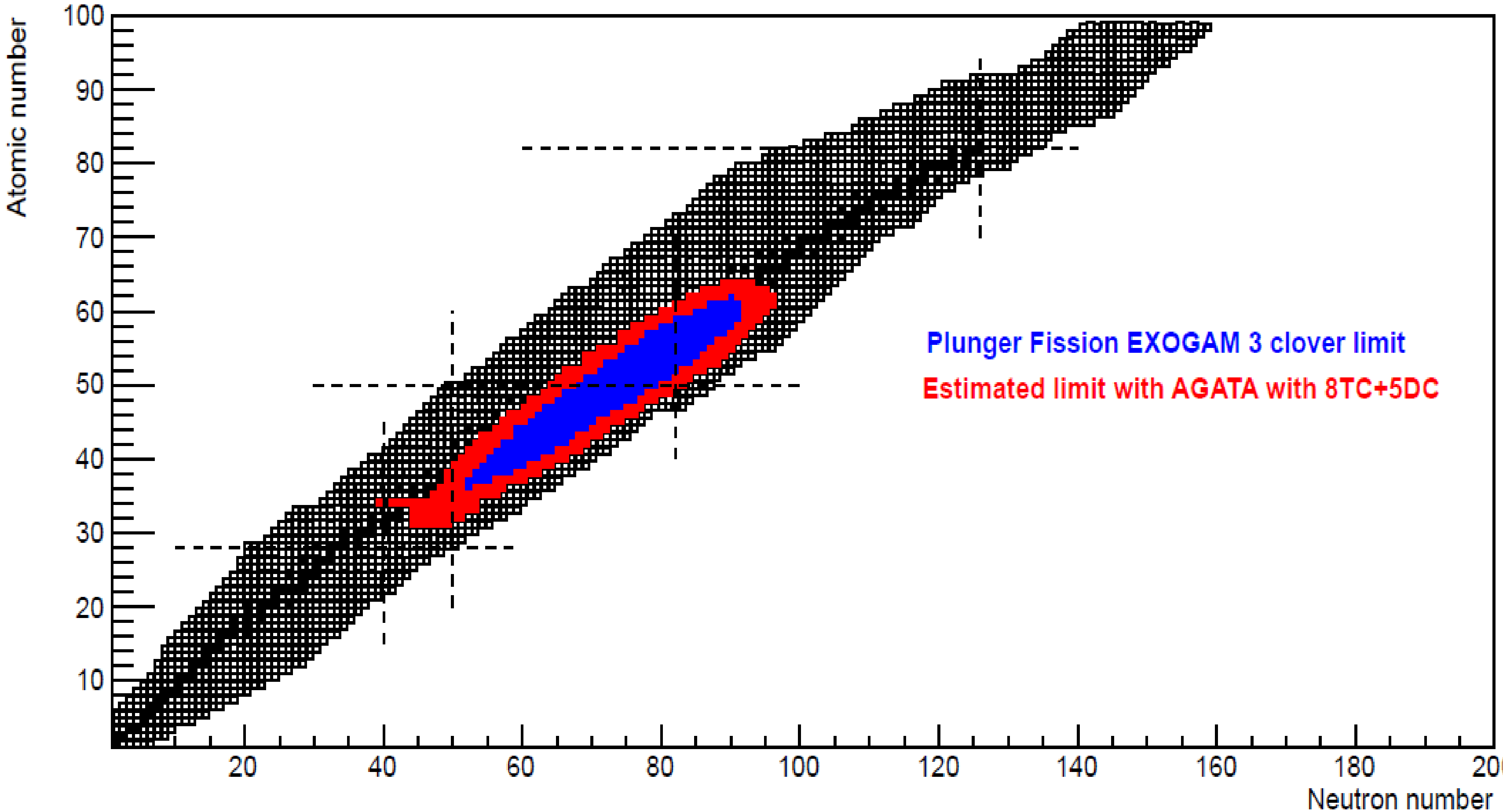

Summary

- The Xe isotopic chain structure evolution includes at low excitation energy

    Octupole correlations
    Shape coexistence
    pn pairing

- Experimental data exist but theories do not reproduce some featuring

    What's going on with the octupole correlation ?

    Can we say something about the T=0 pairing ? From which observable ?
    direct experimental prove looks difficult; we rely on calculations

- Next experimental improvements are major steps : we need to be careful in proposed numbers