DE LA RECHERCHE À L'INDUSTRIE

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Introduction of a valence space in QRPA: impact on the vibrational mass parameters and the QRPA spectroscopy

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OUTLINE

I – Theoretical Background

II – Mass parameters

III – QRPA Spectroscopic quantities

IV – Conclusion

THEORETICAL BACKGROUND

THEORETICAL BACKGROUND

- 5-Dimensional Collective Hamiltonian reads

$$H_{5DCH} = V + T_{rot} + T_{vib}$$

- T_{vib} requires 3 *'quadrupolar vibrational mass parameters'* B_{00}, B_{20} & B_{22}

$$B_{\mu\nu} = \frac{\hbar^2}{2} \frac{\mathcal{M}_{-3,\mu\nu}}{\left(\mathcal{M}_{-1,\mu\nu}\right)^2}$$

with

$$\mathcal{M}_{p,\mu\nu} = \sum_n E_n^p \left| \langle \tilde{0} | \hat{Q}_{2\mu} | n \rangle \langle n | \hat{Q}_{2\nu} | \tilde{0} \rangle \right|$$

THEORETICAL BACKGROUND

- HFB (D1M) calculation gives quasiparticle levels

- Excited states are built over HFB GS by solving QRPA equation

$$\begin{pmatrix} A & B \\ -B & -A \end{pmatrix} \begin{pmatrix} X_n \\ Y_n \end{pmatrix} = \omega_n \begin{pmatrix} X_n \\ Y_n \end{pmatrix}$$

- QRPA Quasi-boson creation operator defined by

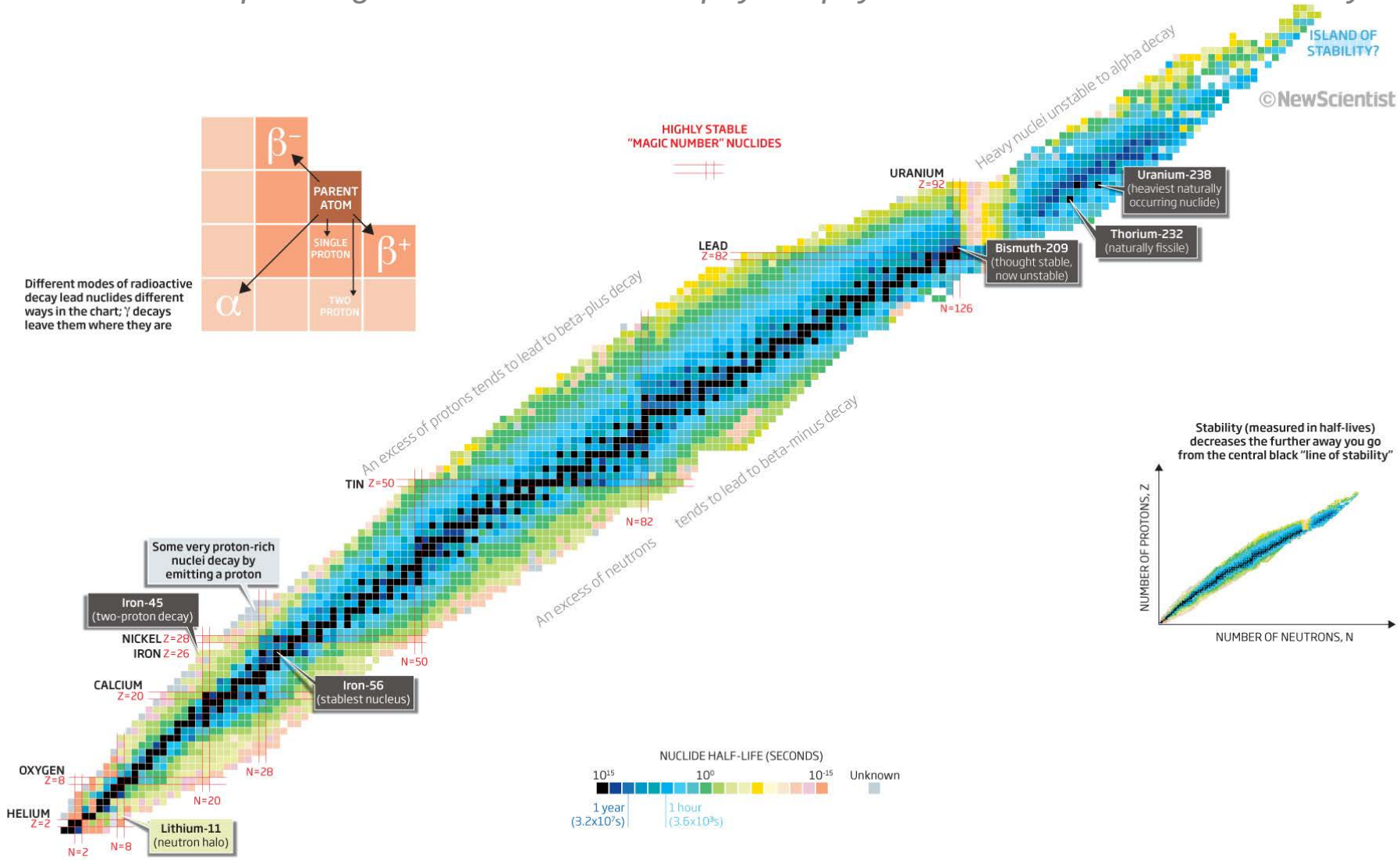
$$\begin{cases} \theta_n^+ = \sum_{i,j} X_n^{i,j} \eta_i^+ \eta_j^+ - Y_n^{i,j} \eta_j \eta_i \\ \theta_n^+ |\tilde{0}\rangle = |n\rangle \end{cases}$$

- Formula of p-th order moment then becomes

$$\mathcal{M}_{p,\mu\nu} = \sum_n \omega_n^p \left| \langle \tilde{0} | \hat{Q}_{2\mu} \theta_n^+ | \tilde{0} \rangle \langle \tilde{0} | \theta_n^+ \hat{Q}_{2\nu} | \tilde{0} \rangle \right|$$

THEORETICAL BACKGROUND

Chart taken from
www.frankswebspace.org.uk/ScienceAndMaths/physics/physicsGCE/nuclearIslandOfStability.htm



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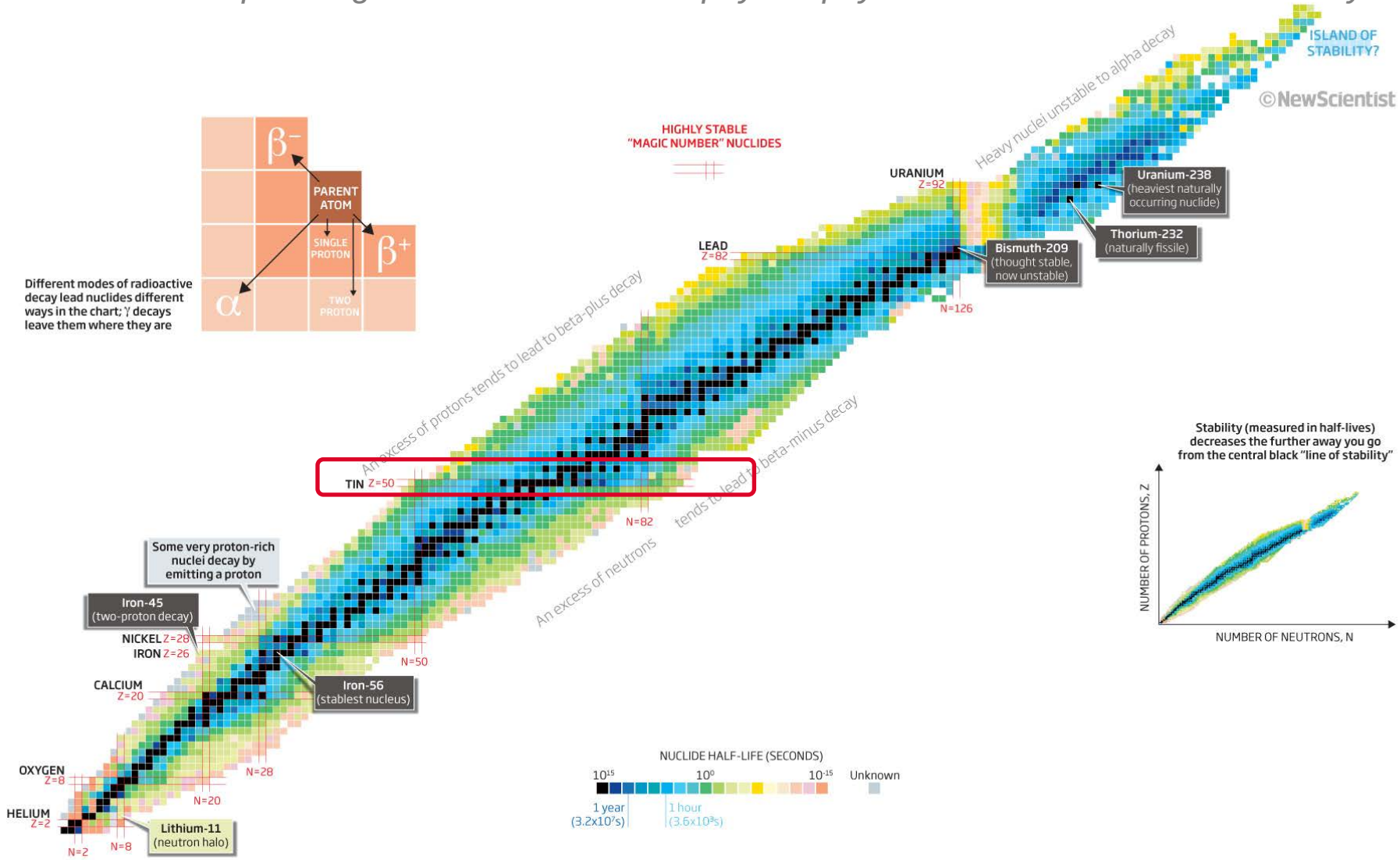
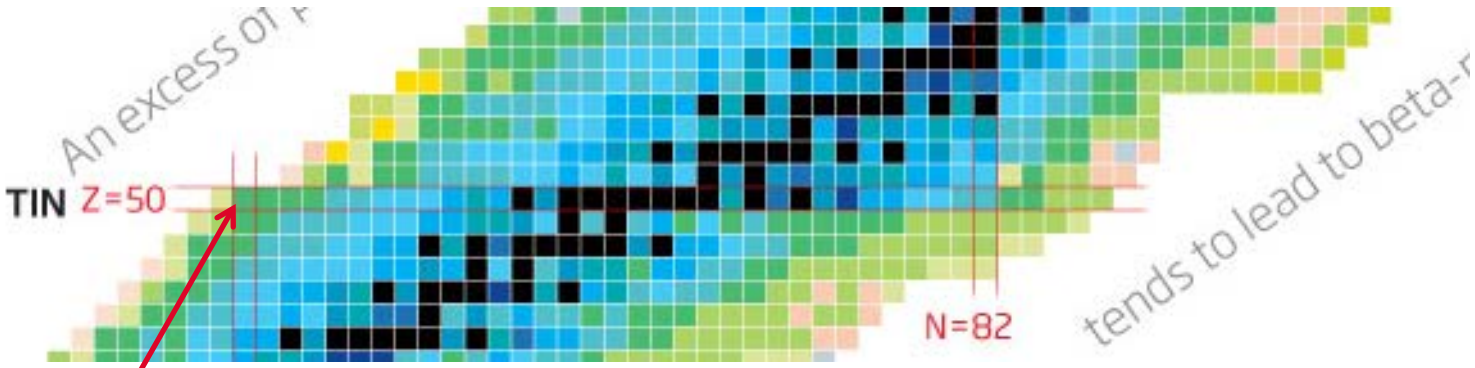
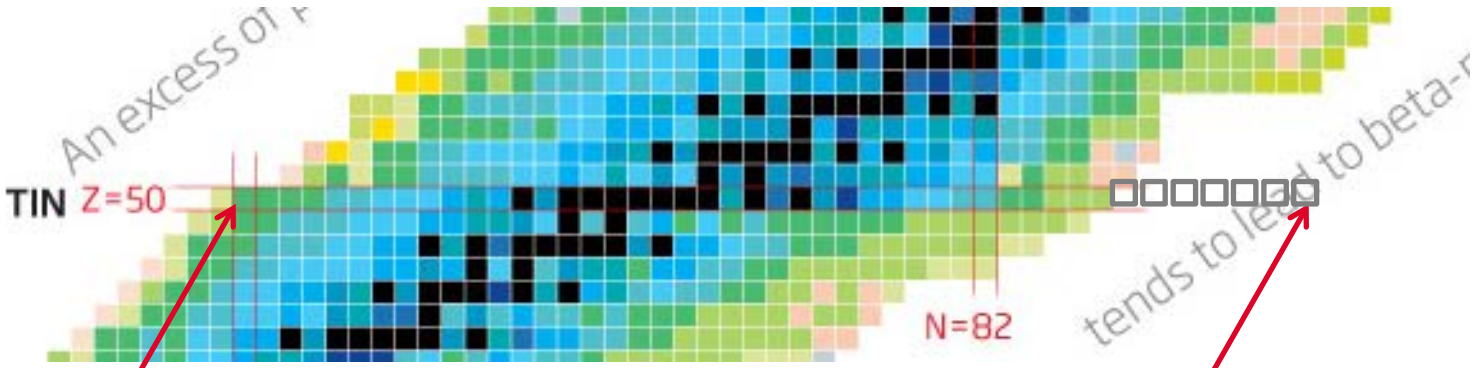


THEORETICAL BACKGROUND



$^{100}_{50}Sn$

THEORETICAL BACKGROUND



$^{100}_{50}Sn$

$^{144}_{50}Sn$

THEORETICAL BACKGROUND

- Isotopic chain of tin isotopes from ${}^{100}_{50}Sn$ to ${}^{144}_{50}Sn$

- Calculations performed at spherical point ($\beta = 0$) to decorrelate deformation from valence space

- For spherical nuclei

$$B_{00} = 2B_{20} = 4B_{22}$$

MASS PARAMETERS

TAMM-DANCOFF APPROXIMATION

- Tamm-Dancoff Approximation: no additional correlations after HFB

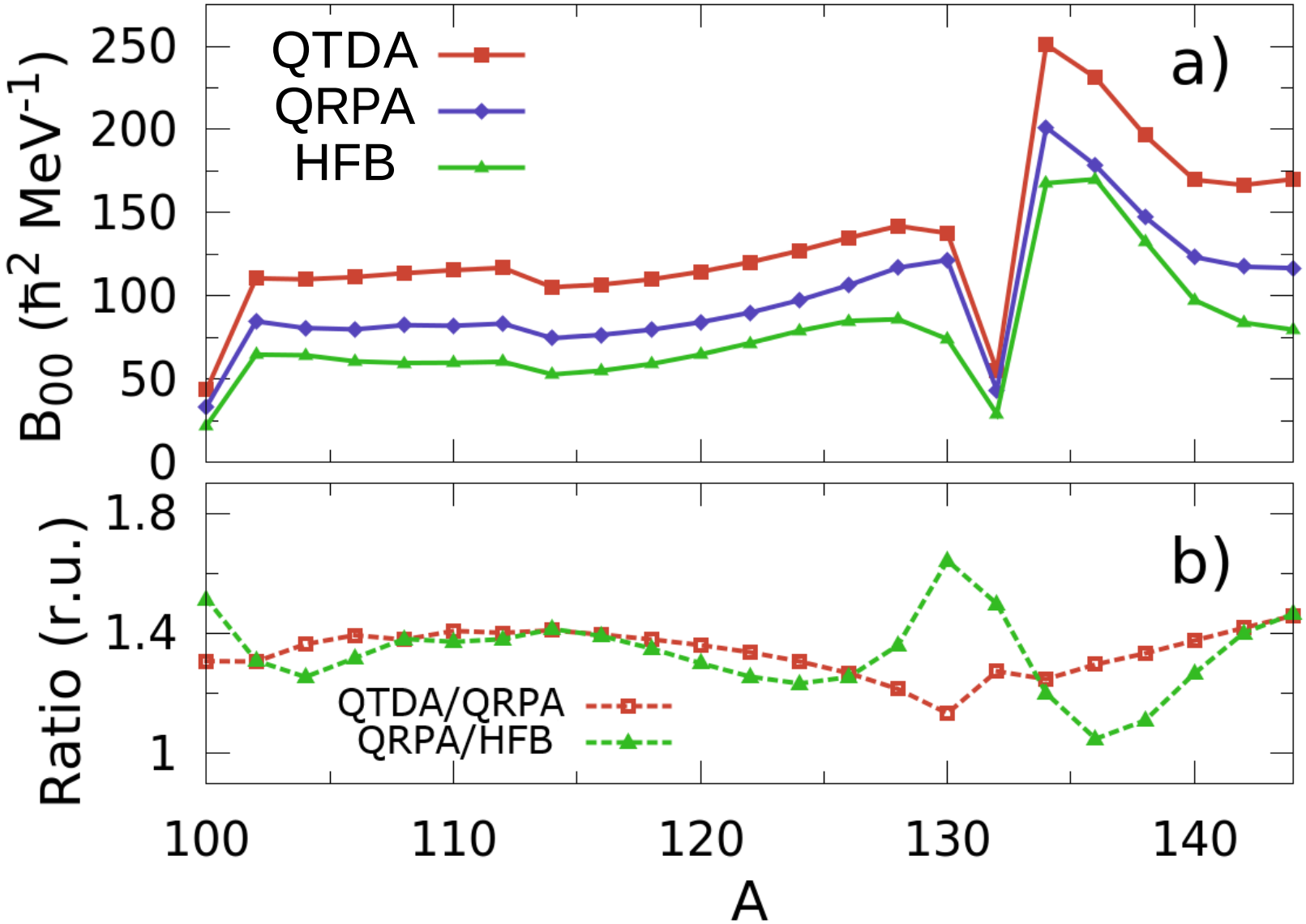
- Reduced QRPA equation

$$AX_n = \omega_n X_n$$

- Calculation time halved !

- Results: comparison between QRPA, QTDA and HFB

TAMM-DANCOFF APPROXIMATION

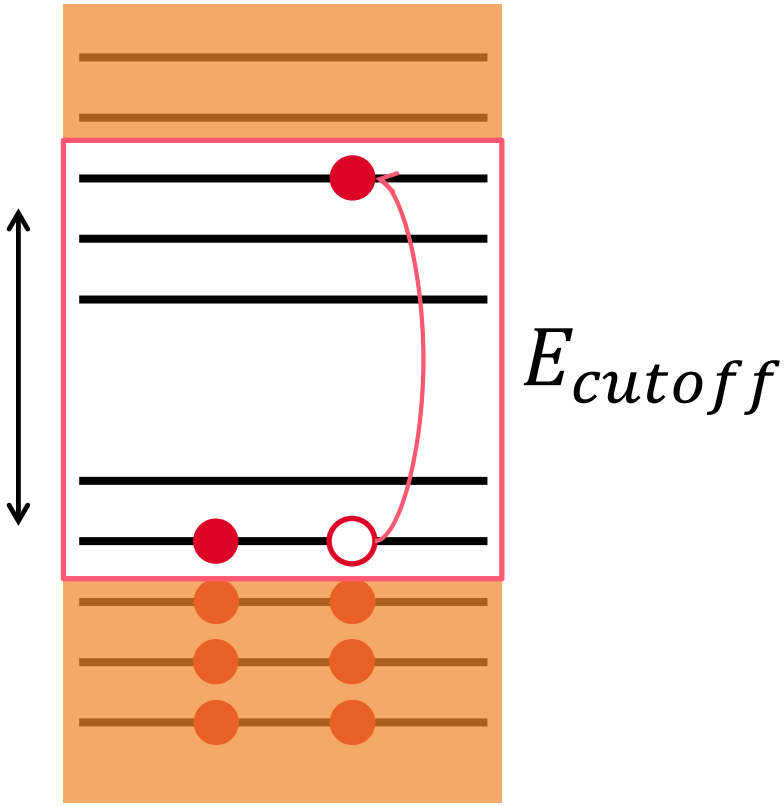


ENERGY CUTOFF

- 2-qp energy cutoff

⇔

limitation of the energy difference of the 2 qp states

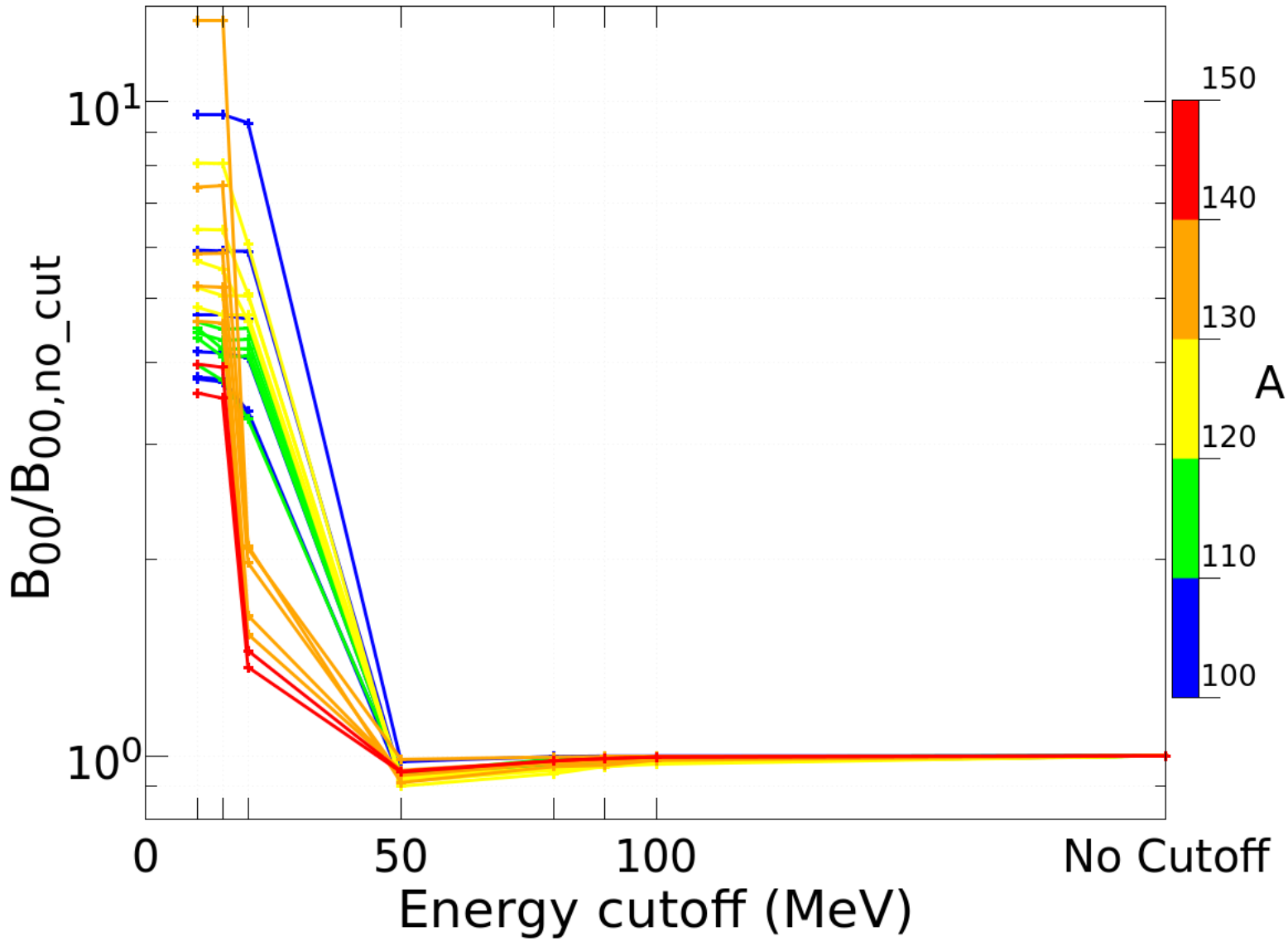


- Insertion of an inert core

⇔

deepest qp frozen

ENERGY CUTOFF



INERT CORE

- 2-qp energy cutoff

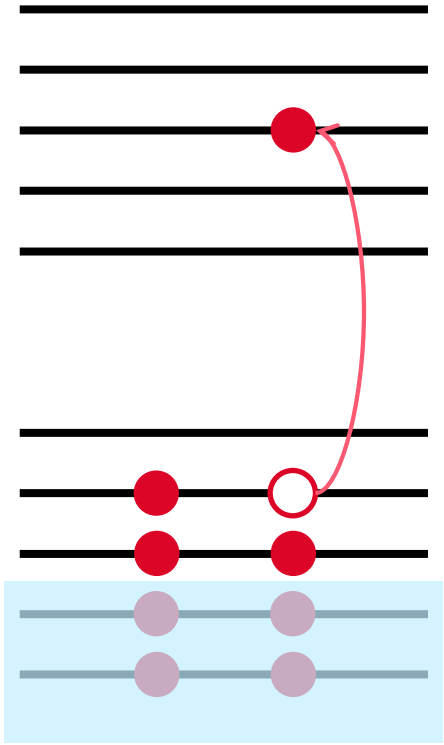
⇔

limitation of the energy difference of the 2 qp states

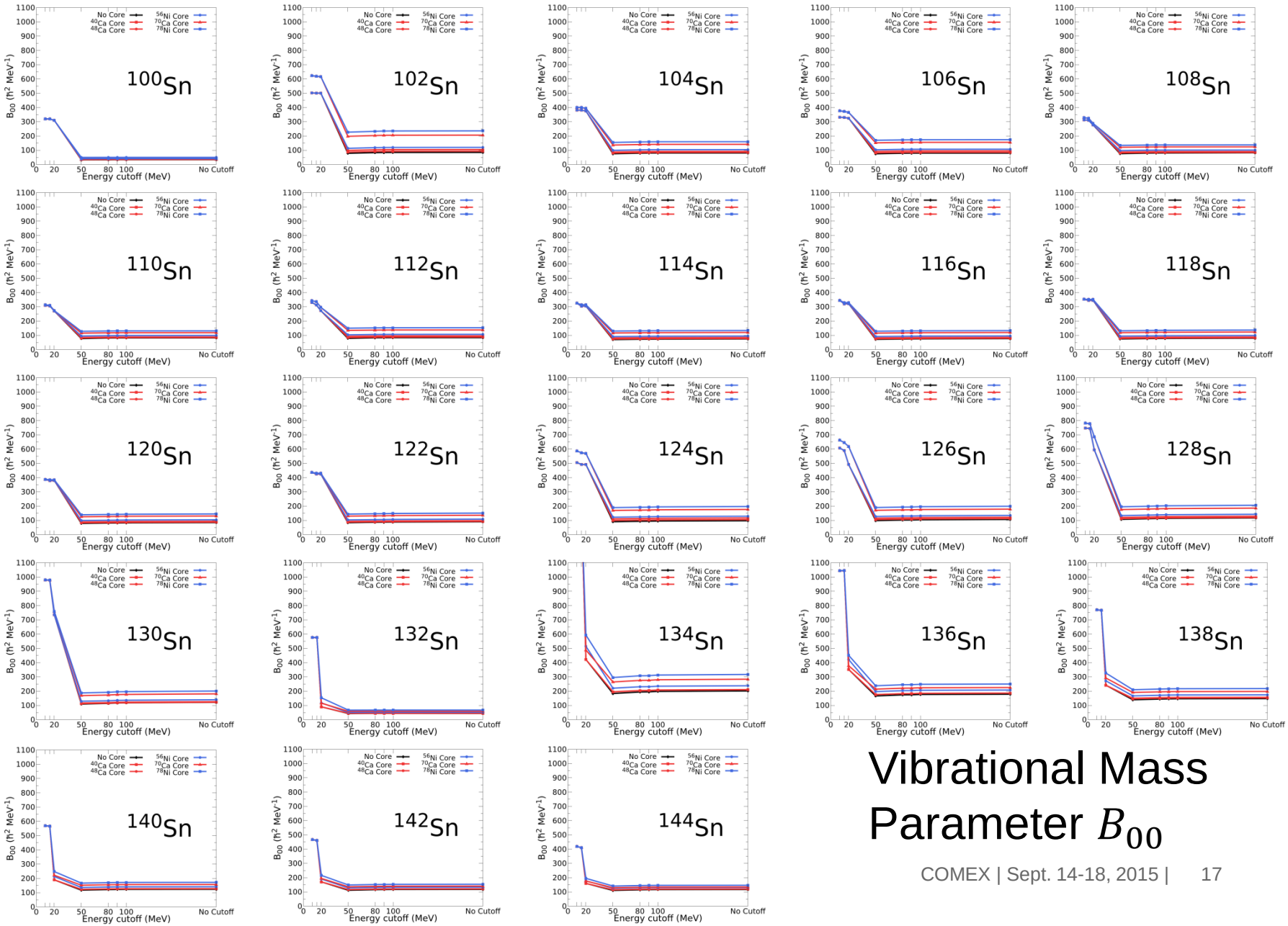
- Insertion of an inert core

⇔

deepest qp frozen

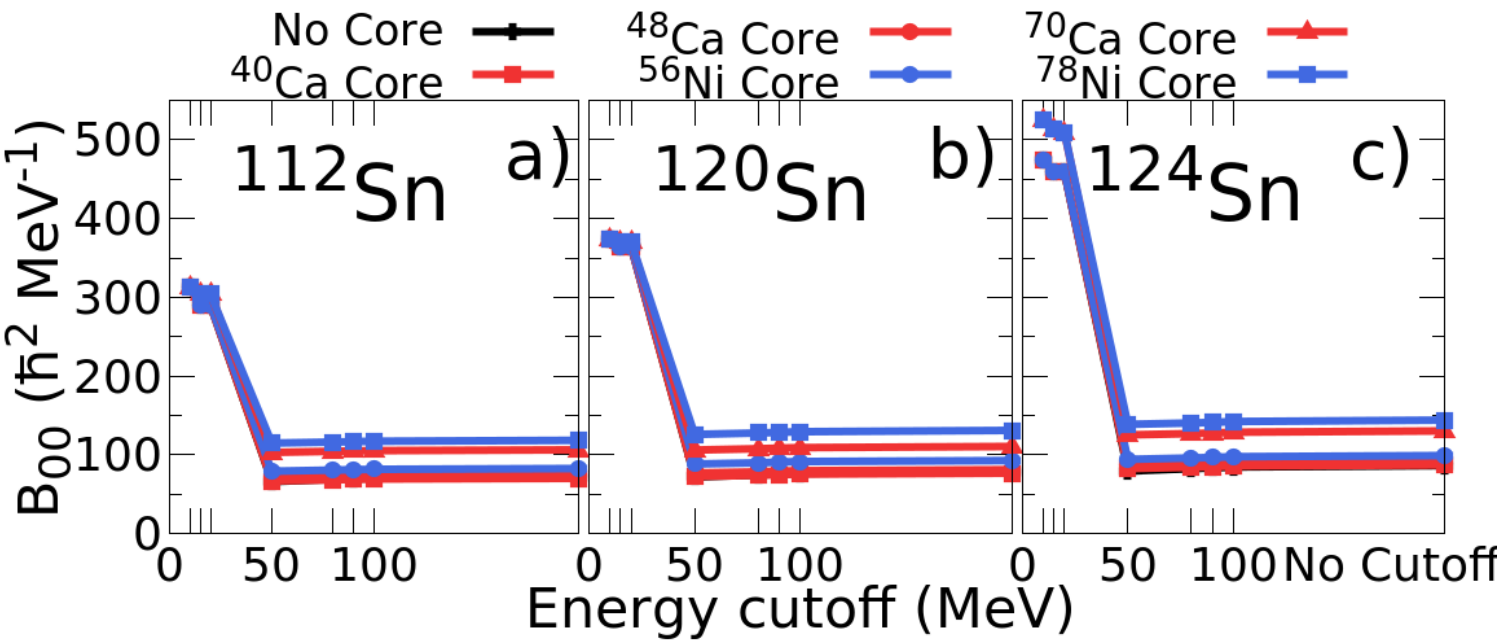


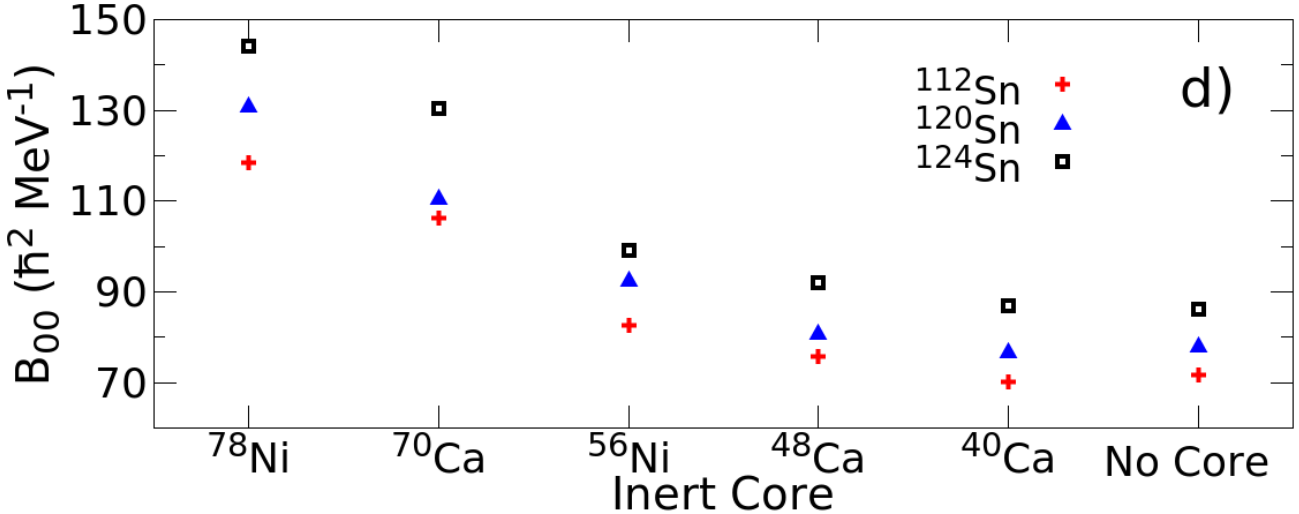
INERT CORE



Vibrational Mass Parameter B_{00}

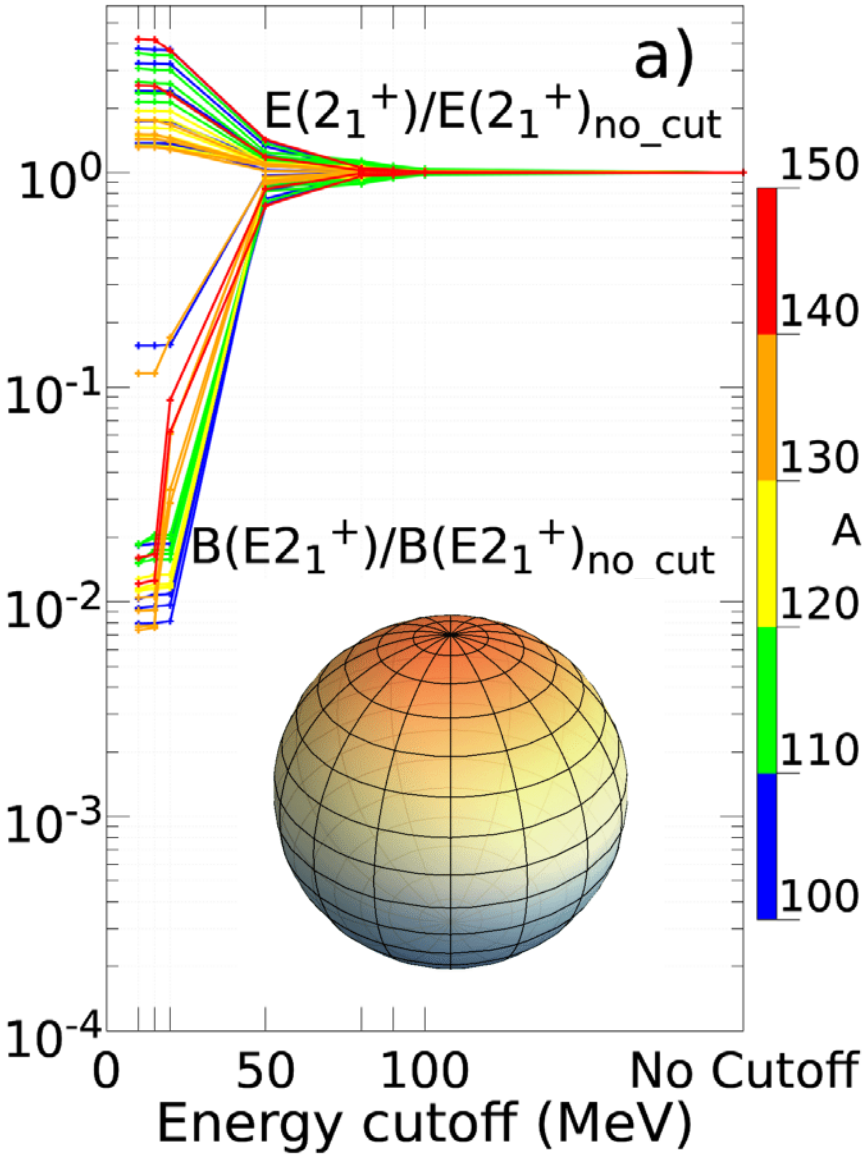
INERT CORE

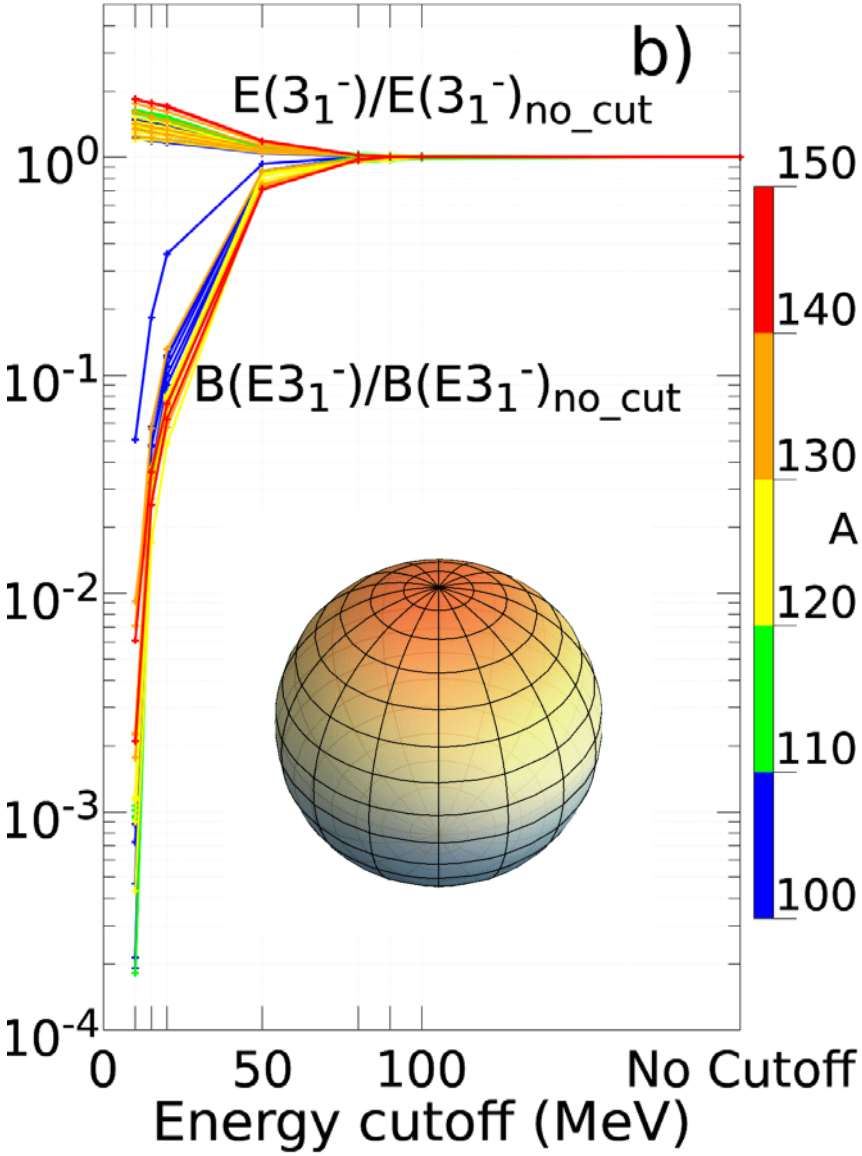

No Core
40Ca Core
48Ca Core
56Ni Core
70Ca Core
78Ni Core
112Sn
a)
120Sn
b)
124Sn
c)
B00 (ħ2 MeV-1)
0
100
200
300
400
500
0
50
100
No Cutoff
Energy cutoff (MeV)


112Sn
120Sn
124Sn
d)
B00 (ħ2 MeV-1)
70
90
110
130
150
78Ni
70Ca
56Ni
48Ca
40Ca
No Core
Inert Core

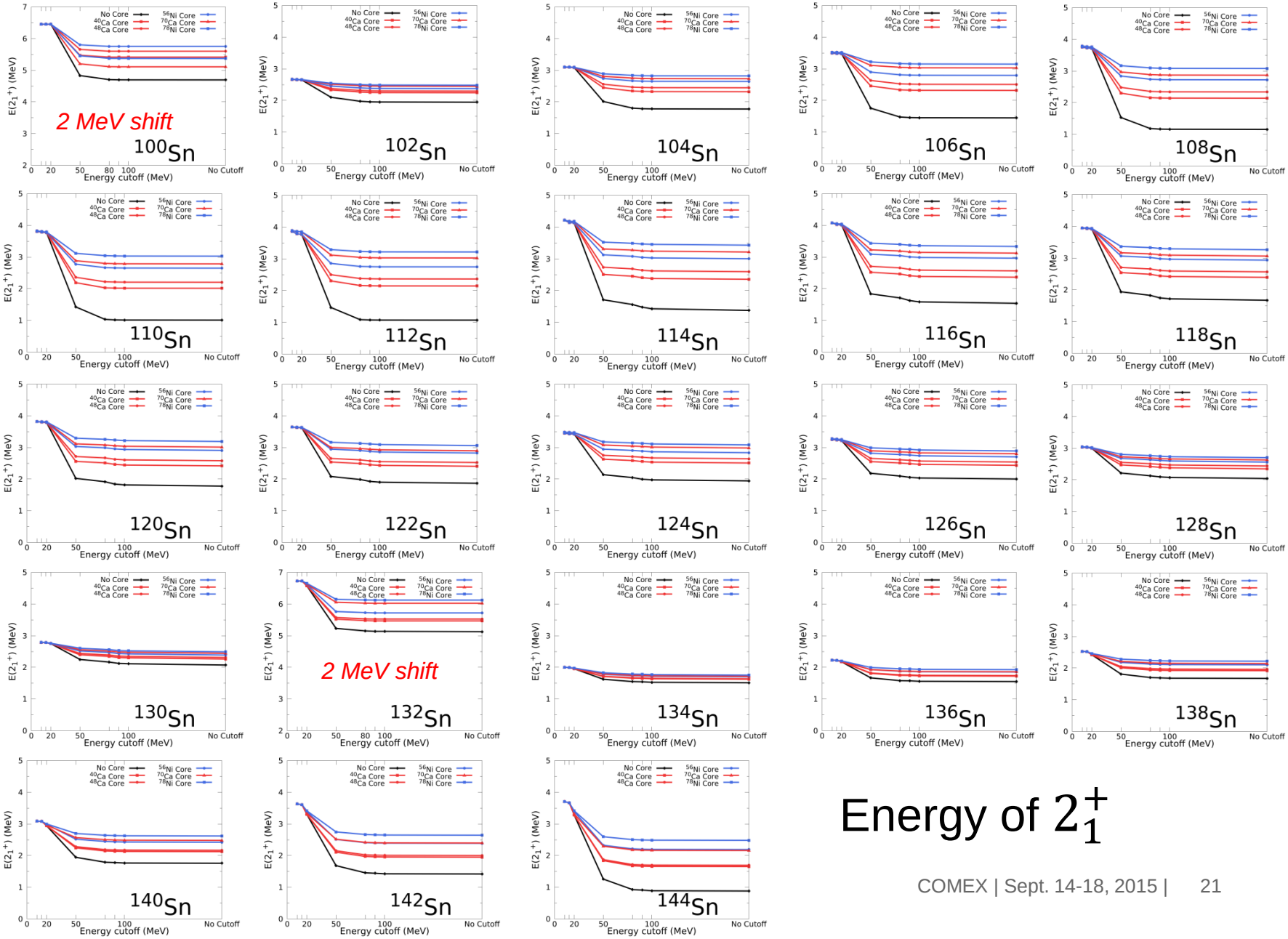
QRPA
SPECTROSOPIC QUANTITIES

ENERGY CUTOFF



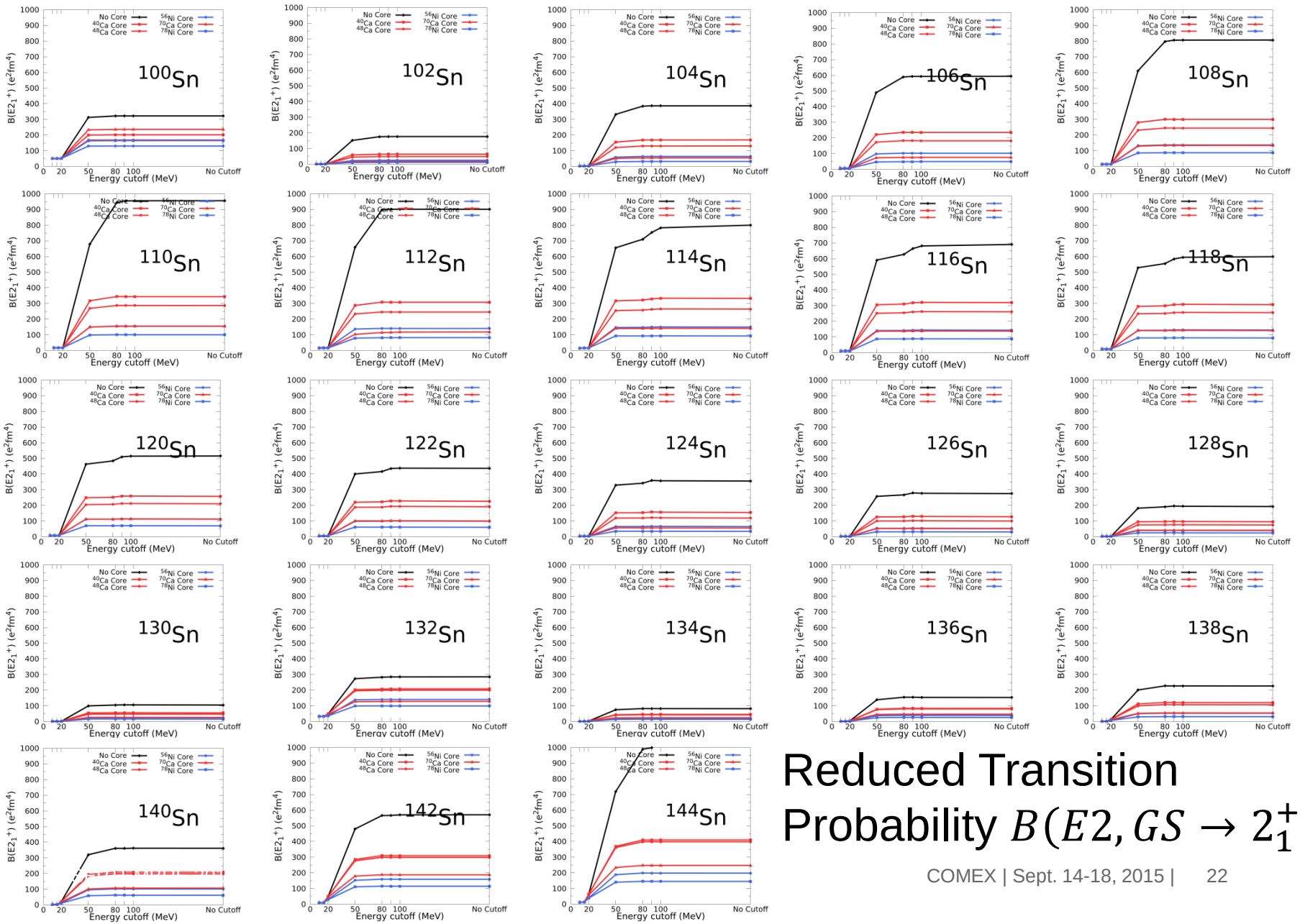


INERT CORE



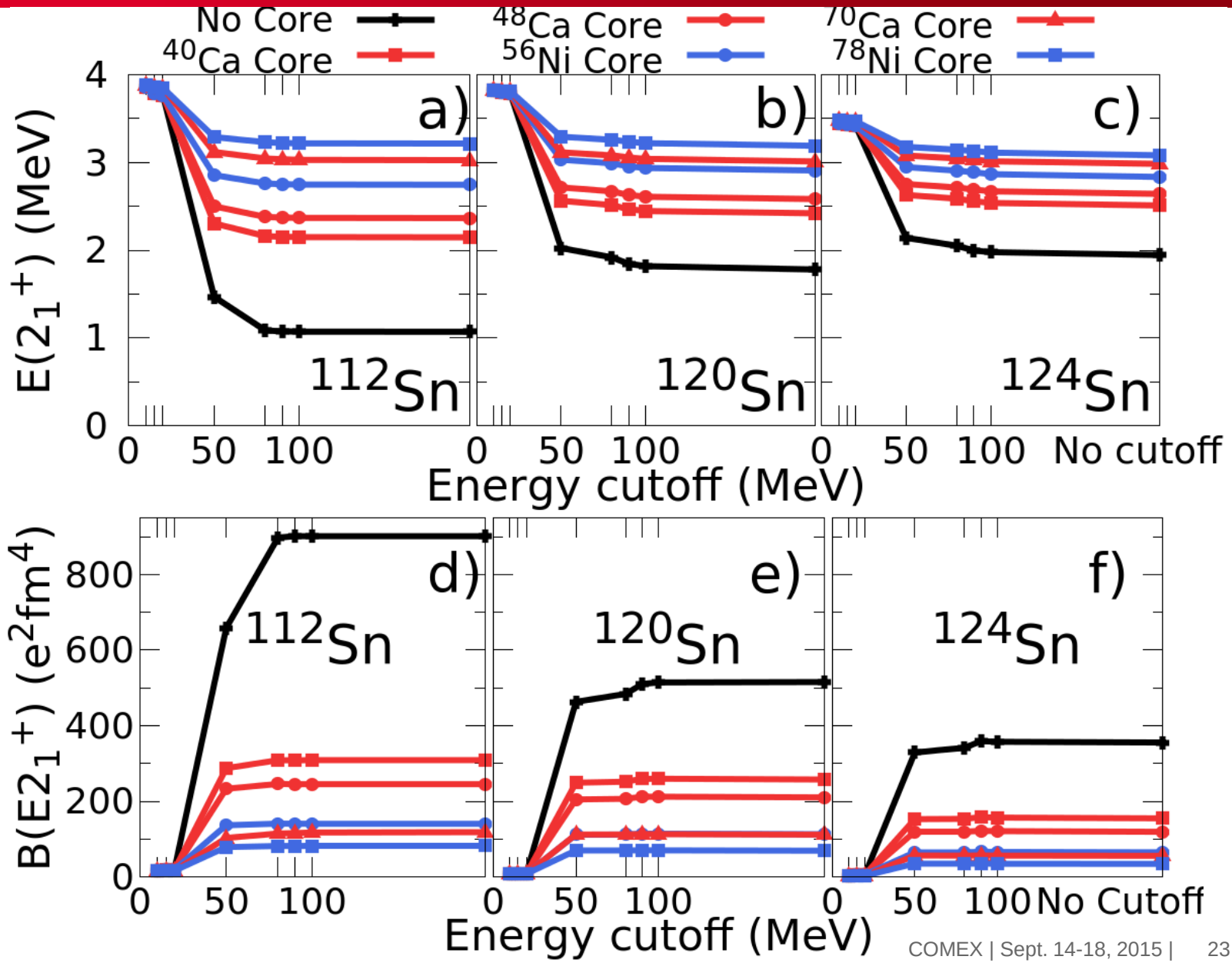
Energy of 2_1^+

INERT CORE



Reduced Transition Probability $B(E2, GS \rightarrow 2_1^+)$

INERT CORE


No Core
40Ca Core
48Ca Core
56Ni Core
70Ca Core
78Ni Core
a)
b)
c)
112Sn
120Sn
124Sn
E(2₁+) (MeV)
0
1
2
3
4
0
50
100
No cutoff
Energy cutoff (MeV)
d)
e)
f)
B(E2₁+) (e²fm⁴)
0
200
400
600
800
No Cutoff

CONCLUSION

CONCLUSION

- TDA rejected
- Small core and 50-MeV cutoff sufficient for B_{00}
- Calculation of mass parameters through QRPA up to 30x faster !

  → Full (β, γ) mapping now handable
- Full valence space and high cutoff for $E(2_1^+)$ and $B(E2)$
- Correction of oversized core possible by refitting interaction ?
- Could seeming convergence be misleading ?

THANK YOU
FOR YOUR ATTENTION

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