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

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I – Theoretical Background

II – Mass parameters

III – QRPA Spectroscopic quantities

IV – Conclusion
THEORETICAL BACKGROUND
5-Dimensional Collective Hamiltonian reads

\[ H_{5DCH} = V + T_{rot} + T_{vib} \]

\( T_{vib} \) requires 3 ‘quadrupolar vibrational mass parameters’ \( B_{00}, B_{20} \) & \( B_{22} \)

\[ B_{\mu\nu} = \frac{\hbar^2}{2} \frac{M_{-3,\mu\nu}}{(M_{-1,\mu\nu})^2} \]

with

\[ M_{p,\mu\nu} = \sum_{n} E_{n}^{p} |\tilde{Q}_{2\mu}|n\rangle \langle n|\tilde{Q}_{2\nu}|\tilde{0}\rangle |
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

\[
\begin{cases}
\theta_n^+ = \sum_{i,j} X_{n;i}^{i,j} \eta_i^+ \eta_j^+ - Y_{n;i}^{i,j} \eta_j \eta_i \\
\theta_n^+ |\bar{0}\rangle = |n\rangle
\end{cases}
\]

Formula of p-th order moment then becomes

\[
\mathcal{M}_{p,\mu\nu} = \sum_n \omega_n^p |\bar{0}\rangle \hat{Q}_{2\mu} \theta_n^+ |\bar{0}\rangle \langle \bar{0}| \theta_n^+ \hat{Q}_{2\nu} |\bar{0}\rangle |
\]
THEORETICAL BACKGROUND

$^{100}_{50}Sn$
THEORETICAL BACKGROUND

100\_{\text{50}}Sn \quad 144\_{\text{50}}Sn
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

$$B_{00} = 2B_{20} = 4B_{22}$$
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
2-qp energy cutoff

\[ \iff \]

limitation of the energy
difference of the 2 qp states

\[ E_{cutoff} \]

Insertion of an inert core

\[ \iff \]
deepest qp frozen
2-qp energy cutoff ⇔ limitation of the energy difference of the 2 qp states

Insertion of an inert core ⇔ deepest qp frozen

\[ E_{cutoff} \]
INERT CORE

Vibrational Mass Parameter $B_{00}$

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INERT CORE

No Core
40Ca Core
48Ca Core
56Ni Core
70Ca Core
78Ni Core

$B_0 (h^2 \text{ MeV}^{-1})$

Energy cutoff (MeV)

$112\text{Sn}$ a)
$120\text{Sn}$ b)
$124\text{Sn}$ c)

$B_0 (h^2 \text{ MeV}^{-1})$

78Ni 70Ca 56Ni Inert Core 48Ca 40Ca No Core

$112\text{Sn}$ $120\text{Sn}$ $124\text{Sn}$
INERT CORE

Energy of $\frac{2}{1}^+$

2 MeV shift

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