Model-independent calculation of E2 transitions

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Motivation

Geometric and algebraic collective models employ quadrupole degrees of freedom (QDF) to describe:

- Low-energy spectra.
- Strong intra-band transitions.
- Relatively weaker inter-band transitions.

However:

- Absolute B(E2) values for inter-band transitions tend to be overpredicted [1, 2].

Transitions are computed from the quadrupole operator, motivated by Siegert's theorem:

- Derivation based on the gauging of momentum operators.
- Application to models employing QDF is questionable.

We propose the gauging of an effective Hamiltonian:

- Transition operators consistent with the Hamiltonian.
- The power counting allow us to provide theoretical uncertainties.

[1] P. E. Garrett, J. Phys. G: Nucl. Part. Phys. 27, R1 (2001)
[2] M. Caprio, Phys. Lett. B 672, 396 (2009)

Gauging the effective Hamiltonian

Upto NNLO the effective Hamiltonian is [3]:

- $H = H_{\mathrm{LO}} + H_{\mathrm{NLO}} + H_{\mathrm{NNLO}}$ Energy scale
- $H_{\mathrm{LO}} = \frac{p_0^2}{2} + \frac{\omega_0^2}{2}\psi_0^2 + \frac{p_2^2}{4} + \frac{1}{4\psi_2^2}\left(\frac{p_\gamma}{2}\right)^2 + \frac{\omega_2^2}{4}\psi_2^2$ ω
- $H_{\mathrm{NLO}} = \frac{1}{2C_0}\left(\mathbf{I}^2 - p_\gamma^2\right)$ $\omega(\xi/\omega)$
- $H_{\mathrm{NNLO}} = -\frac{1}{2C_0^2}\left(C_1\psi_0\mathbf{I}^2 + C_2\psi_2\left(\mathbf{e}_r \times \mathbf{I}\right)^T\hat{\Gamma}\left(\mathbf{e}_r \times \mathbf{I}\right)\right)$ $\omega(\xi/\omega)^{3/2}$

Gauging [3]:

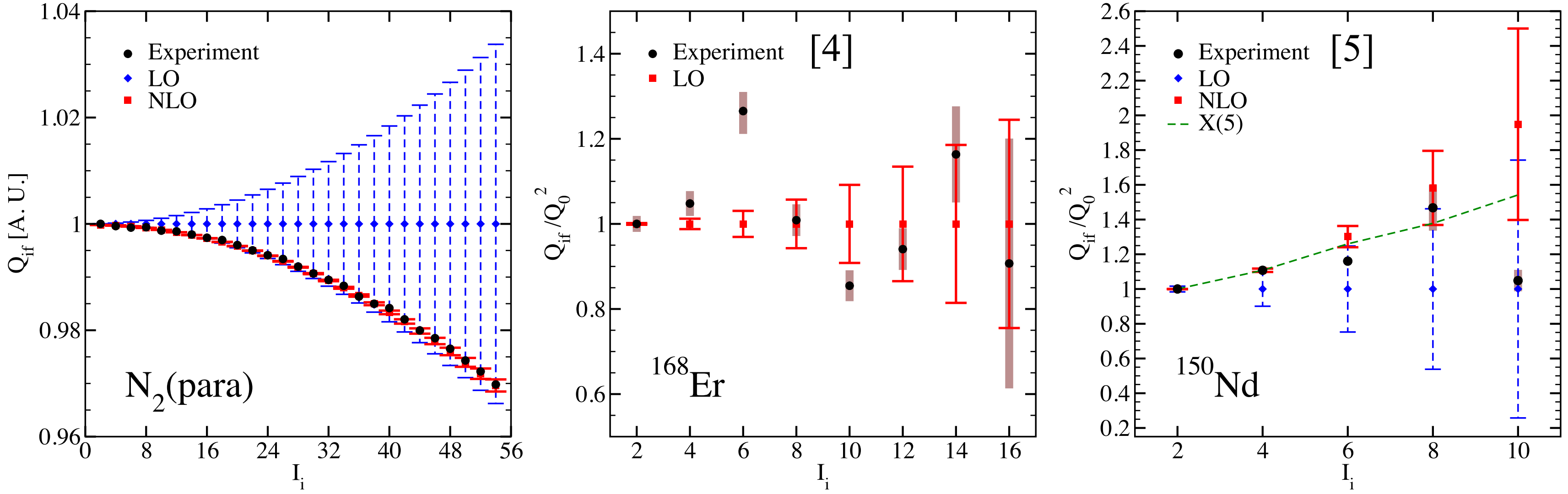
$$\hat{\mathbf{I}} \to \hat{\mathbf{I}} + q\mathbf{e}_r \times \mathbf{A}_\Omega$$

[3] arXiv:1502.04405

Intra-band transitions

$$Q_{if} = Q_0^2 \left[1 + X_1 l_i(l_i - 1)\right]$$

LO **NLO**



[4] C. M. Baglin, NDS 111, 1807 (2010)
[5] Krücken et al. Phys. Rev. Lett. 88, 232501 (2002)

Inter-band transitions

^{154}Sm

$i \to f$	$B(E2)_{\mathrm{exp}}$[6]	$B(E2)_{\mathrm{ET}}$	$B(E2)_{\mathrm{CBS}}$[7]	$B(E2)_{\mathrm{BH}}$
$2_g^+ \to 0_g^+$	0.863(5)	0.863$^{\mathrm{a}}$	0.853	0.863
$4_g^+ \to 2_g^+$	1.201(29)	1.233(41)	1.231	1.234
$6_g^+ \to 4_g^+$	1.417(39)	1.358(101)	1.378	1.355
$8_g^+ \to 6_g^+$	1.564(83)	1.421(189)	1.471	1.424
$2_\gamma^+ \to 0_g^+$	0.0093(10)	0.0110(11)		0.0492
$2_\gamma^+ \to 2_g^+$	0.0157(15)	0.0157$^{\mathrm{a}}$		0.0703
$2_\gamma^+ \to 4_g^+$	0.0018(2)	0.0008(3)		0.0050
$2_\beta^+ \to 0_g^+$	0.0016(2)	0.0025(2)	0.0024	0.0319
$2_\beta^+ \to 2_g^+$	0.0035(4)	0.0035$^{\mathrm{a}}$	0.0069	0.0456
$2_\beta^+ \to 4_g^+$	0.0065(7)	0.0063(6)	0.0348	0.0821

$^{\mathrm{a}}$ Values employed to adjust the LECs of the effective theory.

[6] T. Möller et al. Phys. Rev. C 86, 031305 (2012)
[7] N. Pietrala & O. M. Gorbachenko, Phys. Rev. C 70, 011304 (2004)

Summary

- The electromagnetic structure of deformed nuclei is more complicated than suggested by collective models. Absolute inter-band transitions are correctly described at the expense of additional parameters. This suggest that the naïve usage of the quadrupole operator is not valid beyond intra-band transitions.
- For well-deformed nuclei, the effective theory is meaningful only at LO. Data on B(E2) values for such systems is not sufficiently precise. For transitional nuclei, data and NLO results are consistent within the theoretical uncertainties below the breakdown scale.
- Within the effective theory, rotational bands on top of 0^+ states with B(E2) values to the ground band smaller than those predicted by collective models can still be described as rotational bands on top of a vibrational mode that preserves the axial symmetry of the system.