Systematics of 2+ Excitations

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Collaborators and References

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nucl-th/0611086 Global study of the spectroscopic properties of the first 2+ state in even-even nuclei, Phys. Rev. C, to be published.

nucl-th/0701037 Systematics of the first 2+ excitation with the Gogny interaction, submitted to Phys. Rev. Lett.

Methodologies

CI Shell Model

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Constrained DFT

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Constrained DFT

- Applicable across the mass table
- but how to do spectroscopy?

Constrained DFT

$$E = \int d^3r\, \mathcal{E}(\{\phi_i\}) + \int d^3r\, V(r)\rho(r)$$

Extensions of Constrained DFT

Map to a Bohr Hamiltonian using the GOA (B-l-C,Frankfurt)

- GOA fails for magic nuclei; 518/557 O.K.

Project on J

$$E_J = \frac{\langle q|HP_{JM}|q\rangle}{\langle q|P_{JM}|q\rangle}$$

- All nuclei are deformed in the MAP approximation!

Minimize an “H" in a discrete basis (Brussel/Paris,Madrid)

$$\Psi = \sum_q a_q \Psi_q$$

$$E = \frac{\langle\Psi|H|\Psi\rangle}{\langle\Psi|\Psi\rangle}$$

- only axial deformations at present
- difficult to select a basis q; 359/557 O.K.

Experimental Data Base

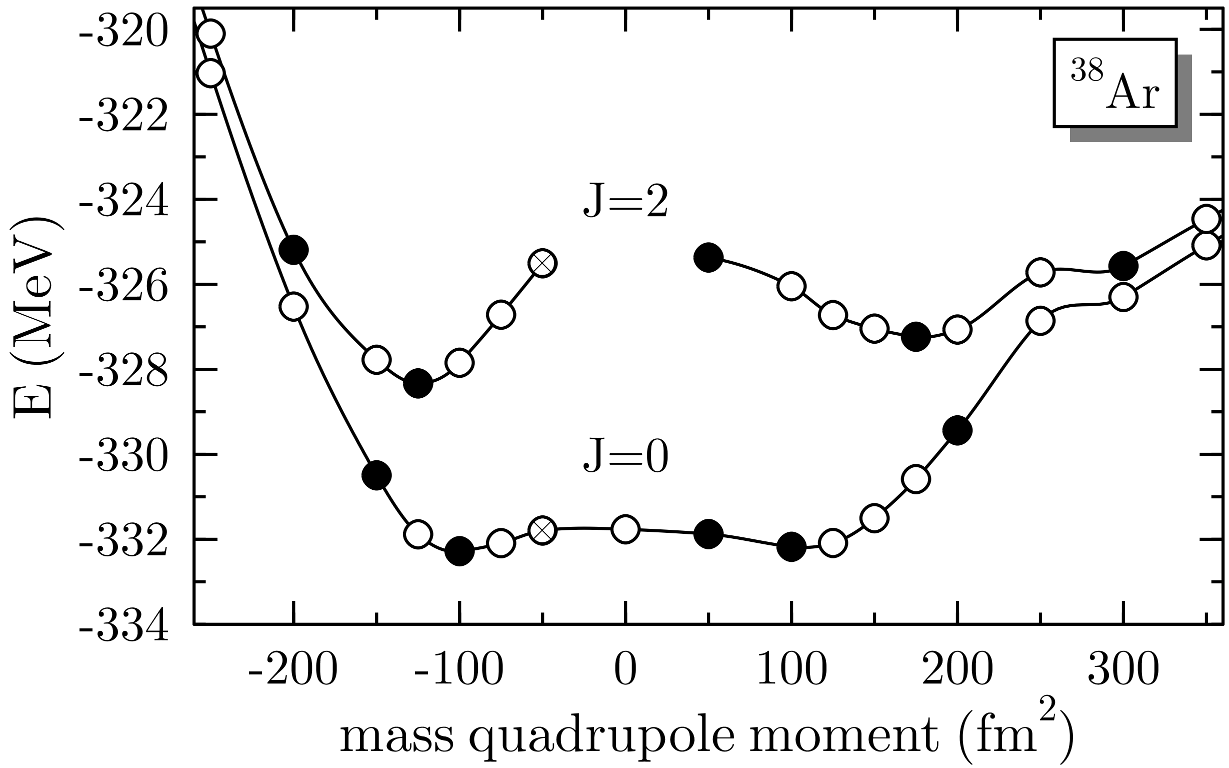
S. Raman, et al. ADNDT **78** 1 (2001)

- first excited 2^+ in 557 nuclei
- B(E2) values for 328 nuclei

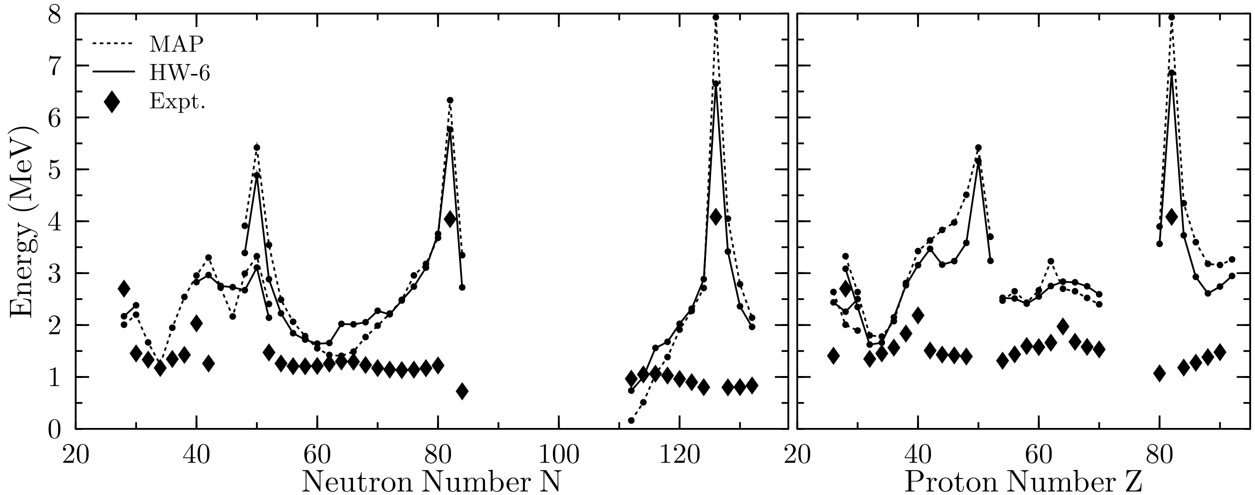
N.J. Stone, ADNDT **90** 75 (2005)

- static Q of first 2^+ state in $\sim$90 nuclei

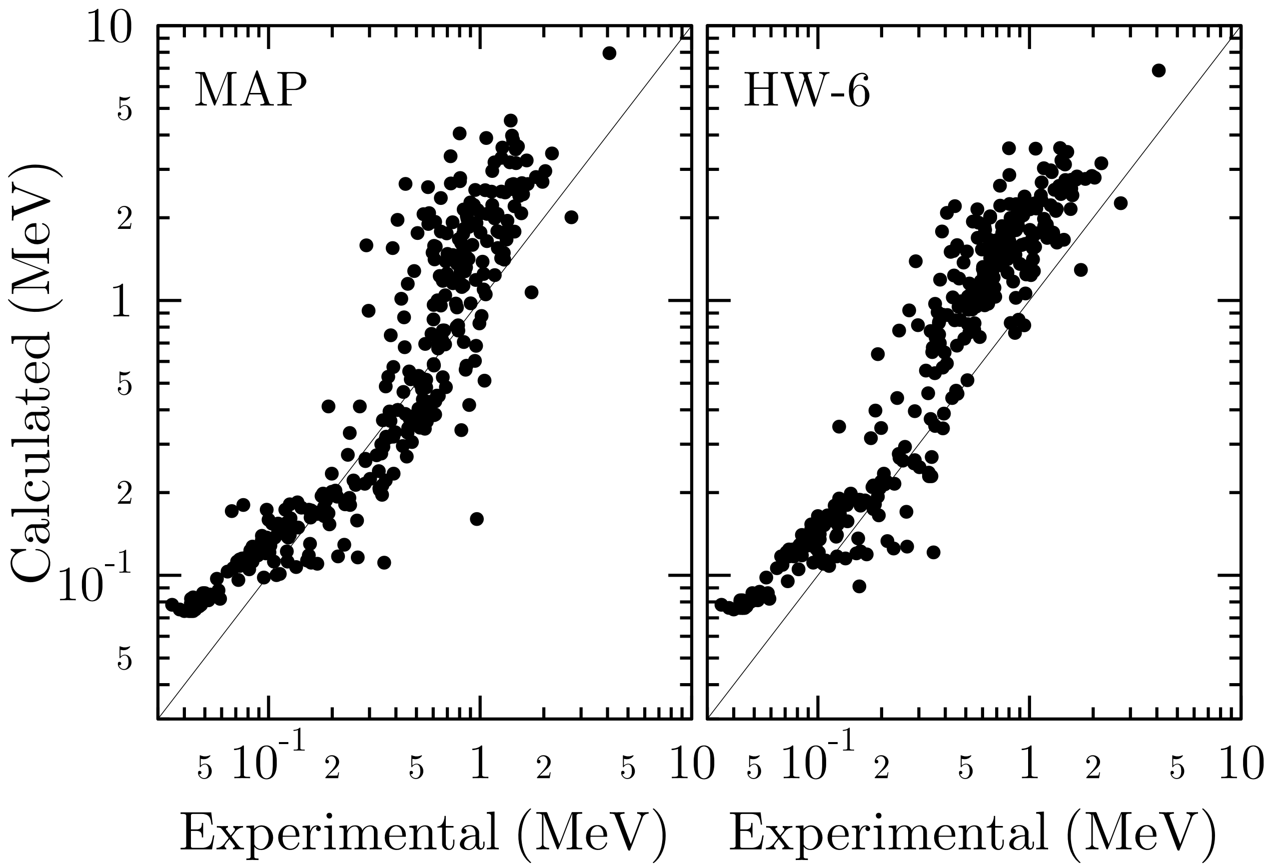
A potential landscape



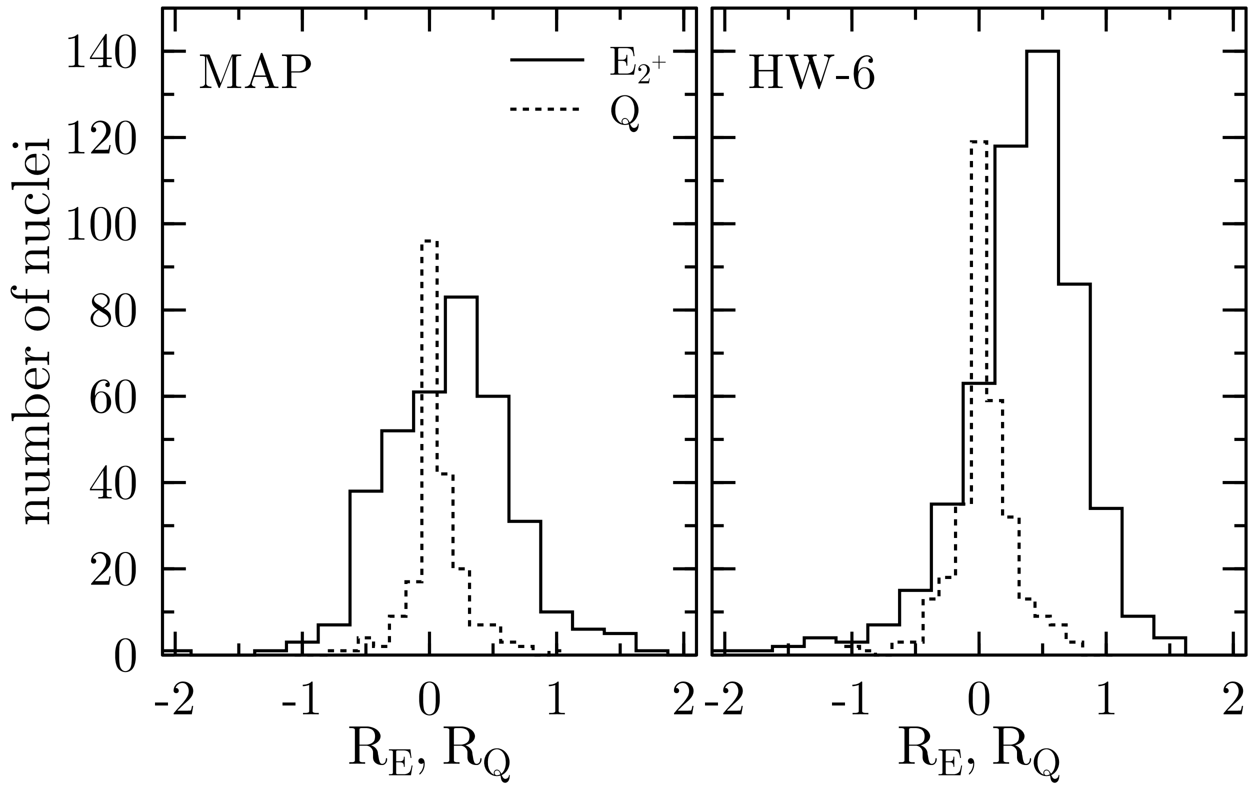
Energy systematics near magic numbers



Energies for MAP and HW

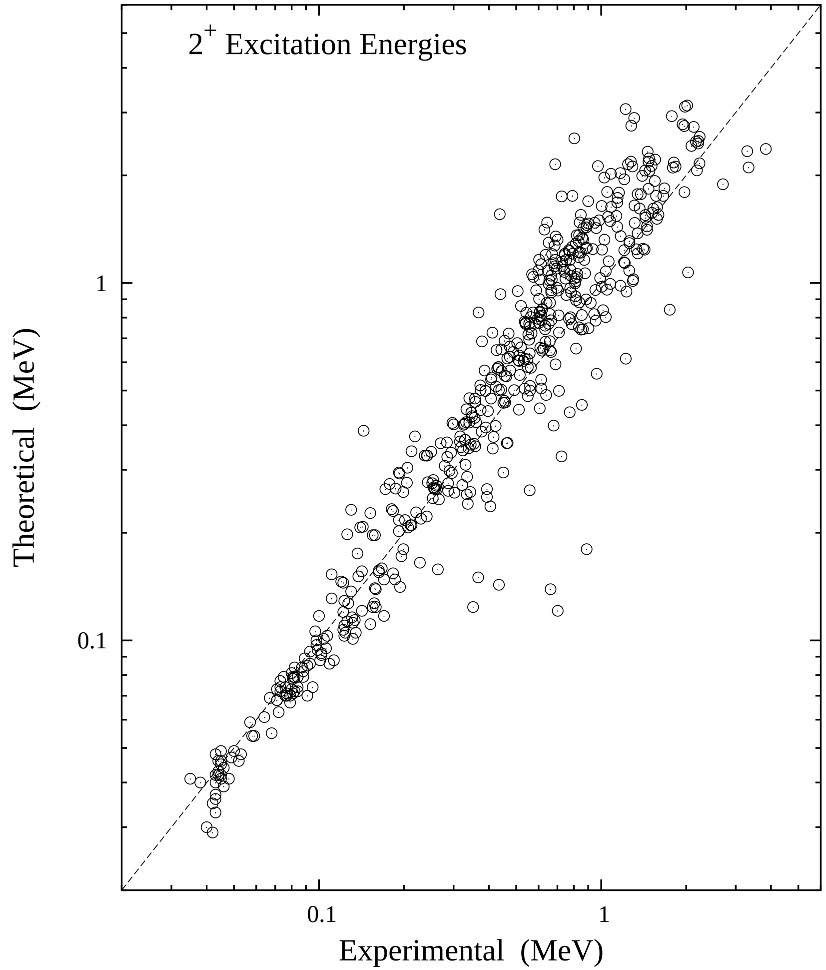


histogram

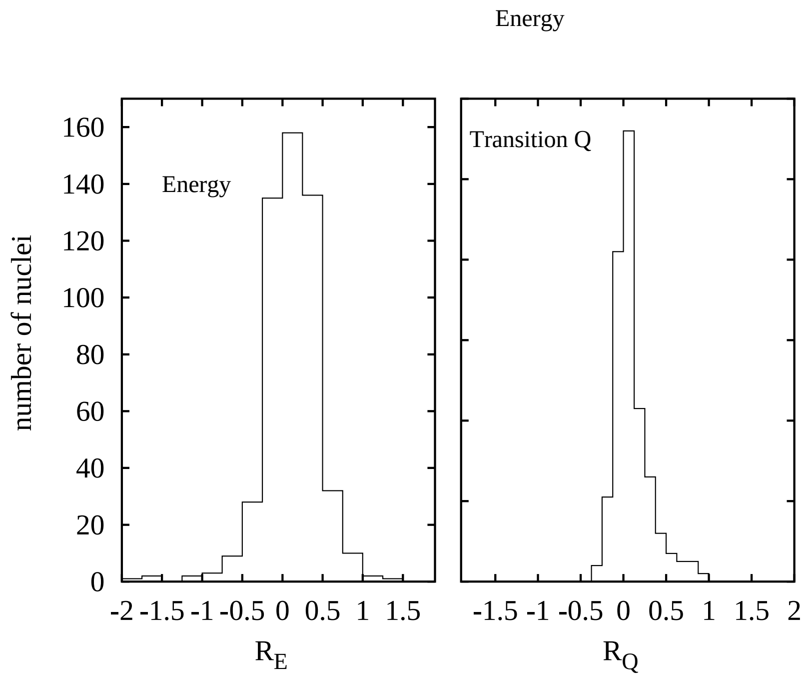


MAP
HW-6
E_{2^+}
Q
number of nuclei
0
20
40
60
80
100
120
140
-2
-1
0
1
2
R_E, R_Q

mapped Bohr results: energies

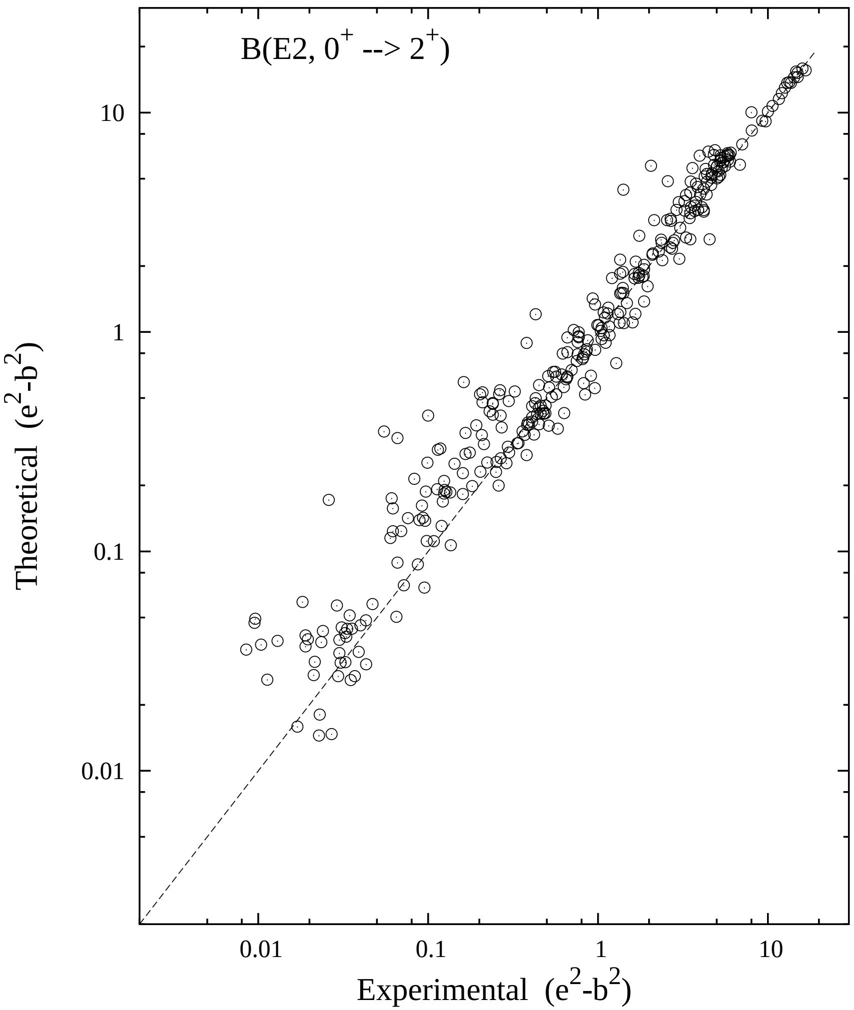


mapped Bohr

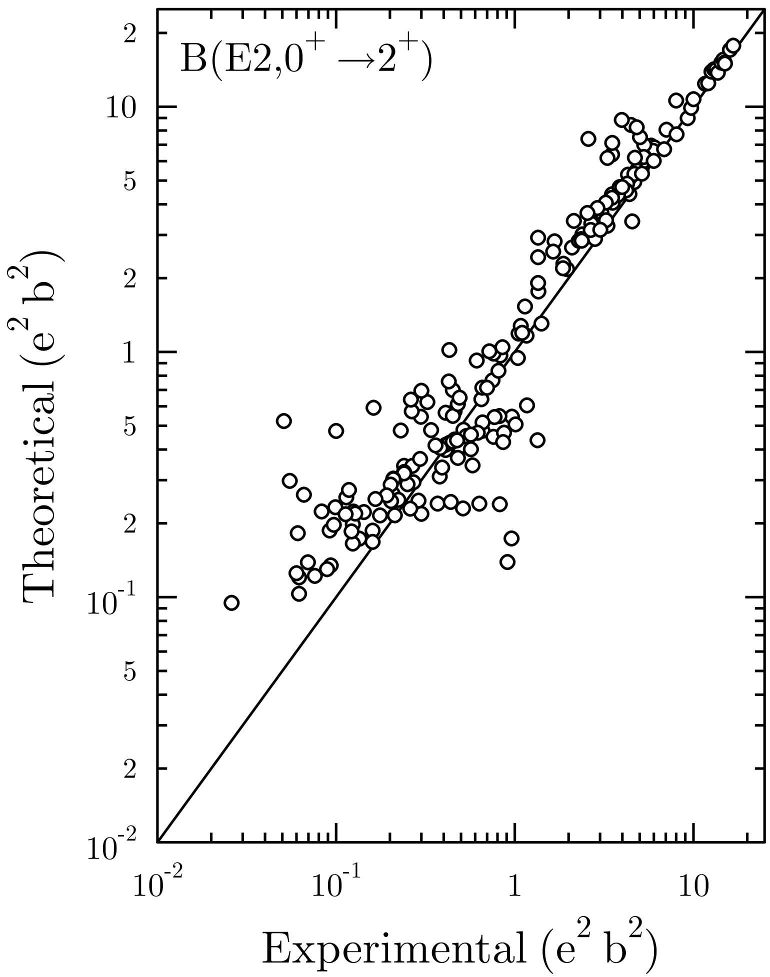

Energy
Energy
Transition Q
number of nuclei
0
20
40
60
80
100
120
140
160
-2 -1.5 -1 -0.5 0 0.5 1 1.5
-1.5 -1 -0.5 0 0.5 1 1.5 2
R_E
R_Q

Performance on B(E2)

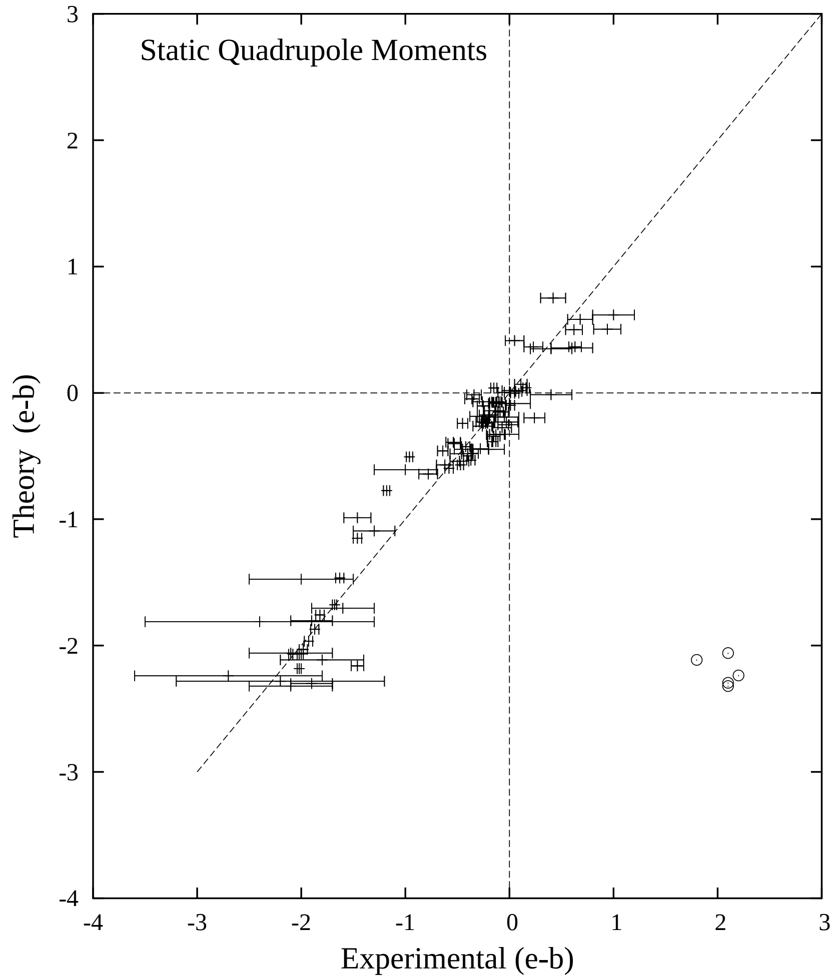
DFT+GCM (SLy4)



DFT mapped to Bohr (Gogny)



mapped Bohr results: static Qs



Metrics for Theory Performance

$$R_E = \log\left(\frac{E_{th}}{E_{exp}}\right)$$

$$\text{average :} \langle R_E \rangle = \sum_i^N R_E^i / N$$

$$\text{variance :} \sigma_E = \left(\sum_i^N (R_E^i - \langle R_E \rangle)^2 / N)^{1/2} \right)$$

Similar definitions for $\langle R_Q \rangle, \sigma_Q$.

Accuracy of the theories

All nuclei

statistic	5DCH	MAP	HW6
$\langle R_E \rangle$	0.12	0.28	0.51
σ_E	0.33	0.49	0.38
$\langle R_Q \rangle$	0.10	0.12	0.09
σ_Q	0.21	0.22	0.23

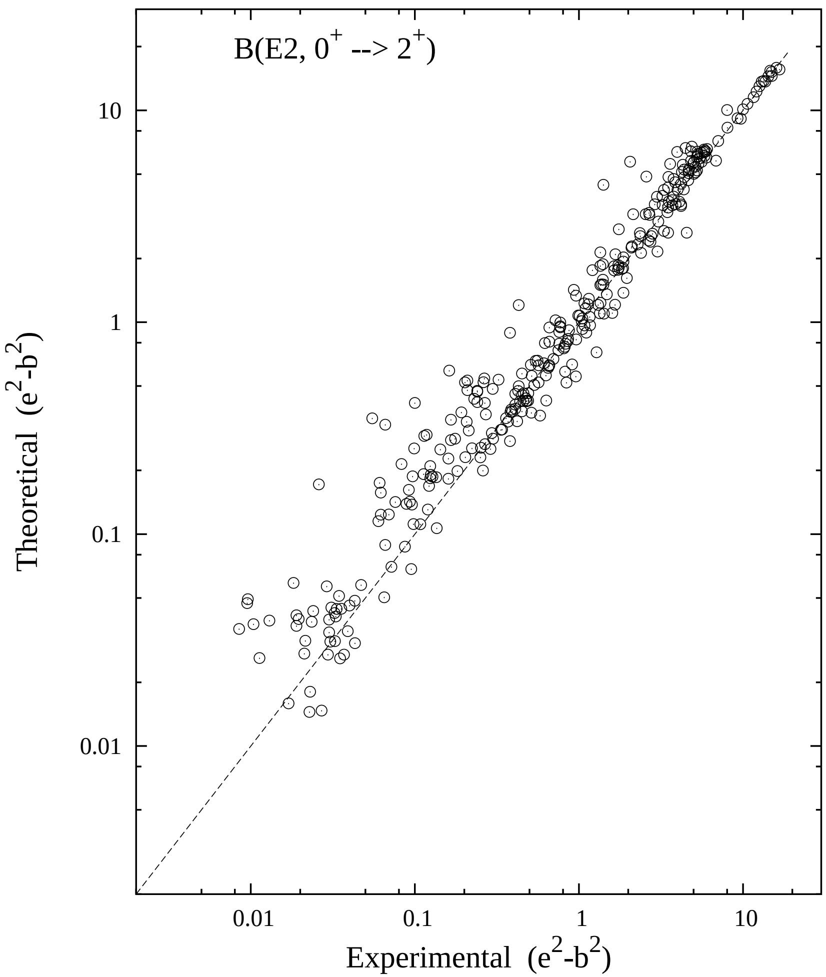
Deformed nuclei

statistic	5DCH	MAP	HW6
$\langle R_E \rangle$	-0.05	0.20	0.27
σ_E	0.19	0.36	0.33
$\langle R_Q \rangle$	0.04	0.10	0.10
σ_Q	0.09	0.10	0.11

Conclusion and outlook

- Present DFT is robust for nuclear shapes
- Quadrupolar GCM is inadequate for spherical nuclei
- Differences between the excitation energies of the two extensions is not understood.
- Importance of number projection is unclear
- Dynamic pairing?

mapped Bohr results: B(E2)s



Constrained DFT-B

$$E = \int d^3r\, \mathcal{E}(\{\phi_i\}) + \int d^3r\, V(r)\rho(r) + \int d^3r\, \kappa(r)\Delta_{ext}(r)$$