Mo-100 monopole & quadrupole strength with triaxiality: A time-dependent density functional study

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COMEX 7, Catania, IT

Yue Shi (石跃)[1] and Paul Stevenson[2]

[1]Harbin Institute of Technology, Harbin, CN
[2]University of Surrey, Guildford, UK

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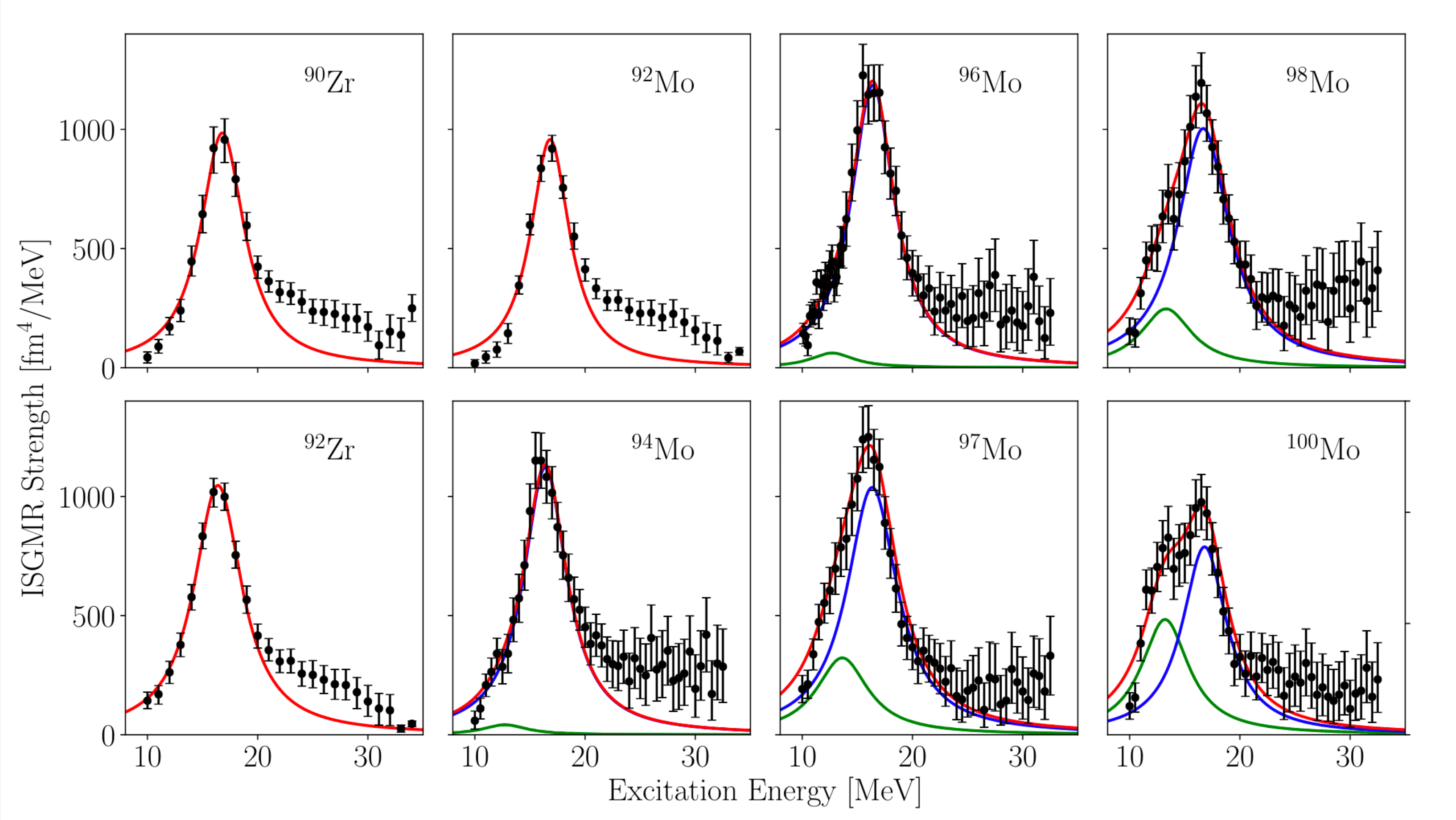
Motivation



ISGMR response in ^{94,96,97,98,100}Mo @ RCNP Osaka

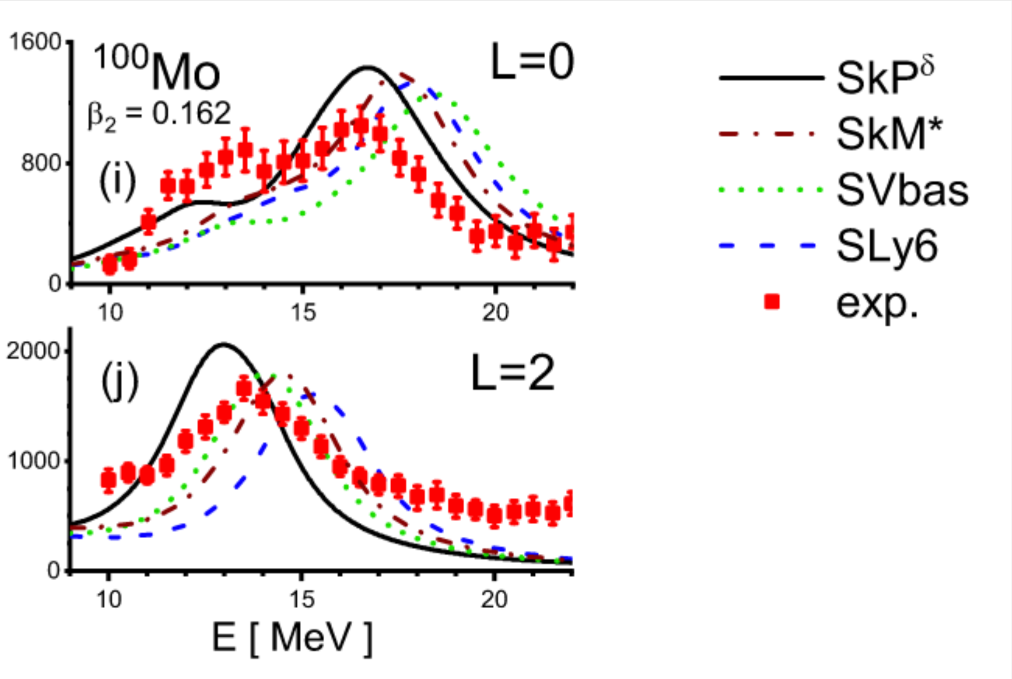
Evidence of increasing structure as one moves away from the ^{90}Zr doubly-closed shell

Two-Lorentzian fits show increasing second mode contributing as N increases

K. Howard, Ph.D. thesis, Notre Dame University (2020), 10.7274/p2676t08h50

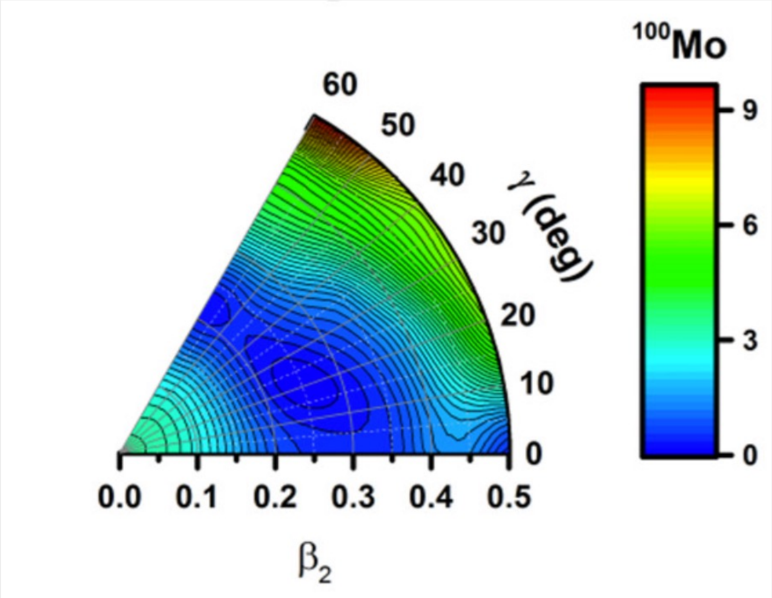
Previous studies

Colò et al. peformed (Q)RPA calculations with axial deformation, interpreting lower bump/peak in Mo-100 as due to quadrupole mode



Some evidence / previous calculations suggesting that Mo-100 could be triaxially deformed in its ground state

e.g. Relativistic mean field DD-PC1 interaction (H. Abusara et al., Phys. Rev. C 95, 054302 (2017))



Our method: triaxial TDHF+BCS

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- New code from Yue Shi: C++ 3D TDHF code, planned publication 2023.
- Benchmarked against Sky3D TDHF code Comput. Phys. Commun. 185, 2195 (2015)

Static HF + BCS + shape constraints

- $Q_{20} = 2z^2 – x^2 – y^2$
- $Q_{22} = x^2 – y^2$

We map out potential energy surface & then use several points on the surface as starting points for giant monopole excitations

Time-dependent calculation: initial boost at t=0

$$\psi_{i,q}(r,\sigma;t=0+) \equiv \exp(-i\,\epsilon\, r^2)\psi_{i,q}(r,\sigma),$$

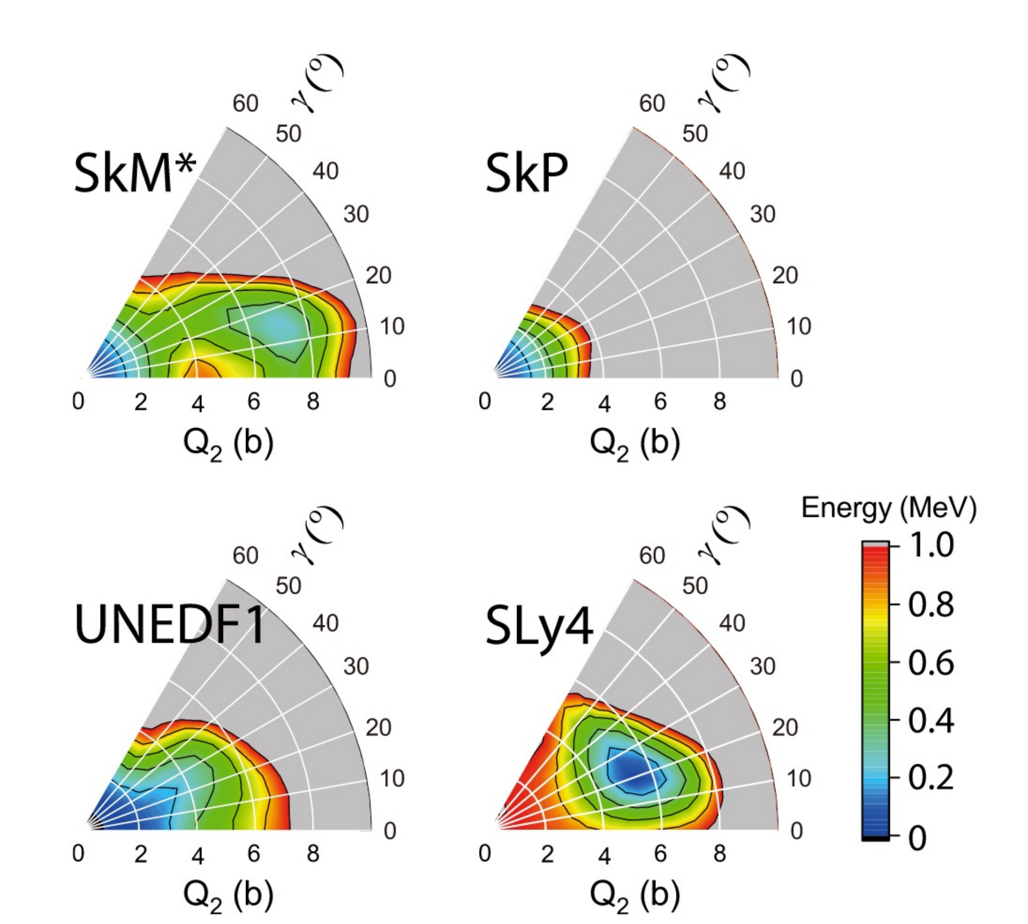
Followed by time-evolution, then measurement of monopole strength = Fourier Transform of time-dependent monopole moment

$$S(E;E0) = -\frac{1}{\pi\hbar\epsilon}\mathrm{Im}\int \delta D(t)\,\mathrm{e}^{(\mathrm{i}E-\Gamma/2)t/\hbar}\,\mathrm{d}t,$$

Yue Shi and P. D. Stevenson Chin. Phys. C 47 034105 (2023) – this work

Y. Shi, N. Hinohara, and B. Schuetrumpf, Phys. Rev. C 102, 044325 (2020) for methodological details

Ground state structure

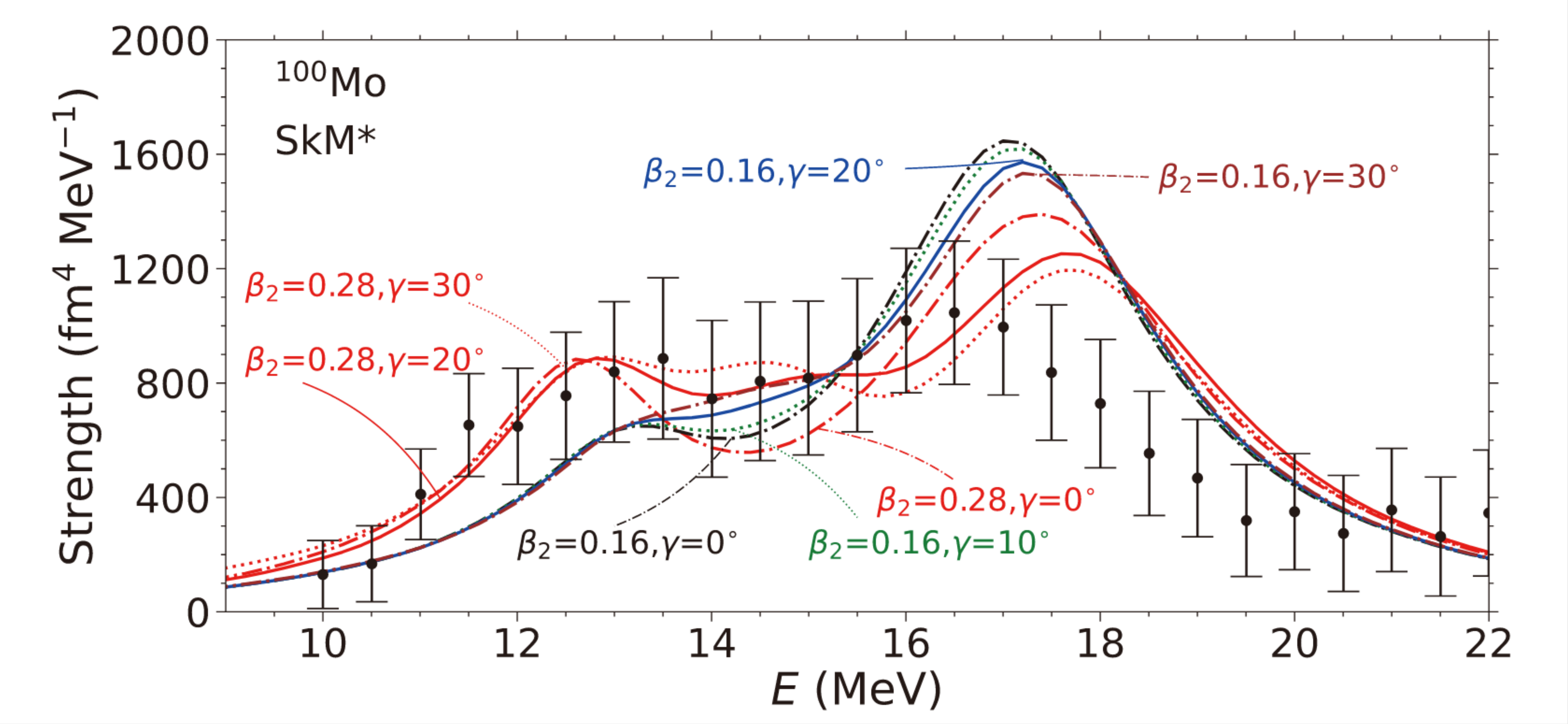


From a representative selection of Skyrme force parameterisations

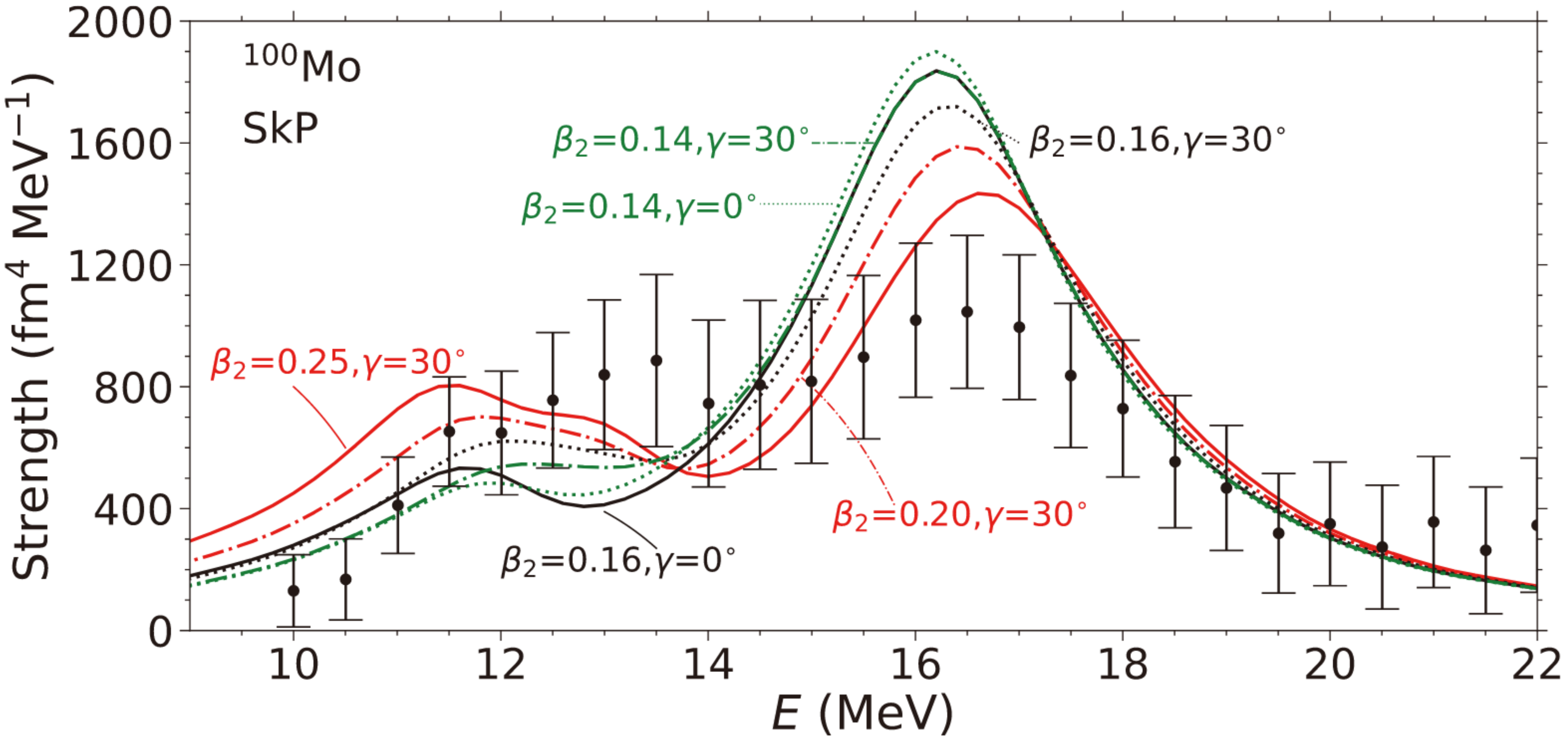
- SkM* designed to reproduce large deformation fission isomers
- SkP with m*/m=1 and good single particle spectra
- UNEDF1 a large scale fit with high deformation included
- SLy4 with special attention to neutron rich matter and neutron star properties.

Two minima: spherical and triaxial, though disagreement about which is ground state

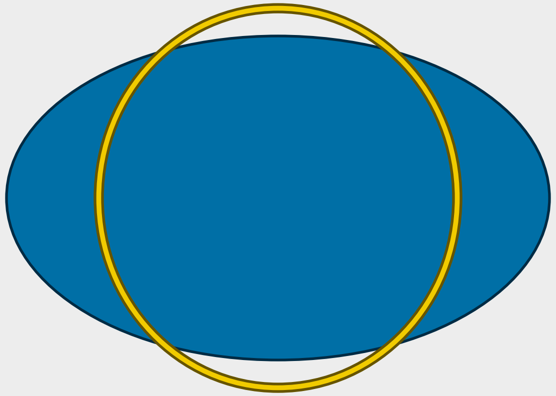
Monopole response (SkM*)



Monopole Response (SkP)



Monopole-Octupole Coupling



A spherically-symmetric excitation of a deformed nucleus acts with different strength on different sides of the nucleus, and induces quadrupole modes

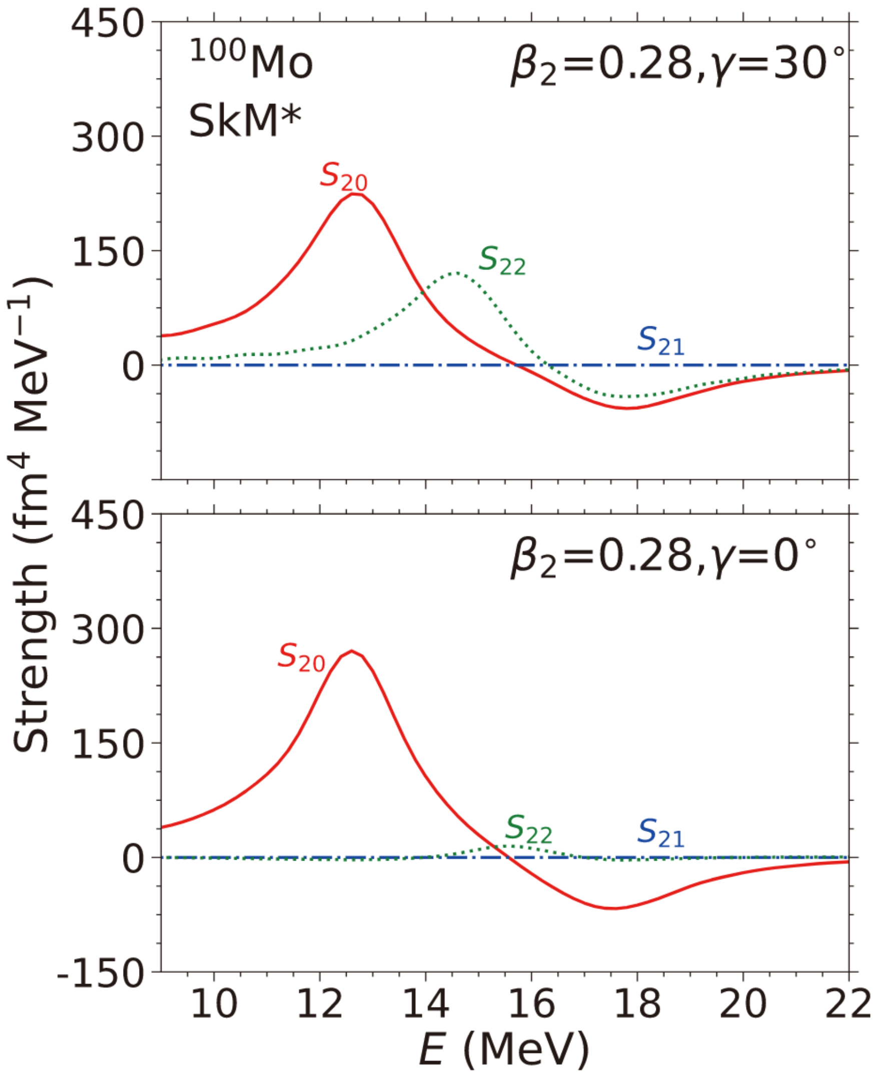
In TDHF, the vibrating nucleus will vibrate with all available multipoles if they can be coupled to the *kick* excitation through single-body dynamics

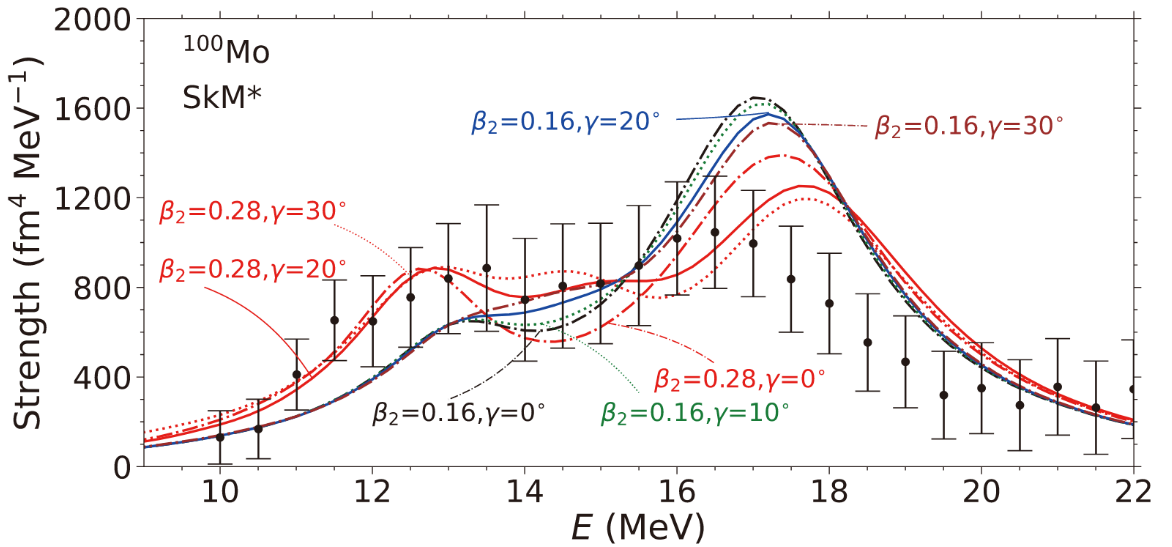
If we *kick* with one operator, M, and *measure* with another operator, Q, our Fourier Transform is

$$S(E) = \Sigma_\nu \langle 0|M|\nu\rangle\langle\nu|Q|0\rangle\delta(E - E_\nu).$$

Thus we can see where both monopole (M) and quadrupole (Q) strength overlap.

Quadrupole response to monopole kick





- Strong quadrupole response at low energy ~12 MeV region
- Second quadrupole mode appears for finite gamma
- Similar response for 20 and 22 modes for "monopole" peak

- $Q_{20} = 2z^2 - x^2 - y^2$
- $Q_{21} = xz$
- $Q_{22} = x^2 - y^2$

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… and the dipole mode

We only looked at the monopole mode, but since our paper was published (early 2023), a dipole mode calculation of Mo-100 was made (A. Ait Ben Mennana and M. Oulne NPA1034, 122644 (2023)).

They started from axial and triaxial minima and see better agreement in triaxial case

This was a TDHF+BCS calculation with Sky3D code & Skyrme force SLy6

A. Ait Ben Mennana and M. Oulne *Nuclear Physics A 1034 (2023) 122644*

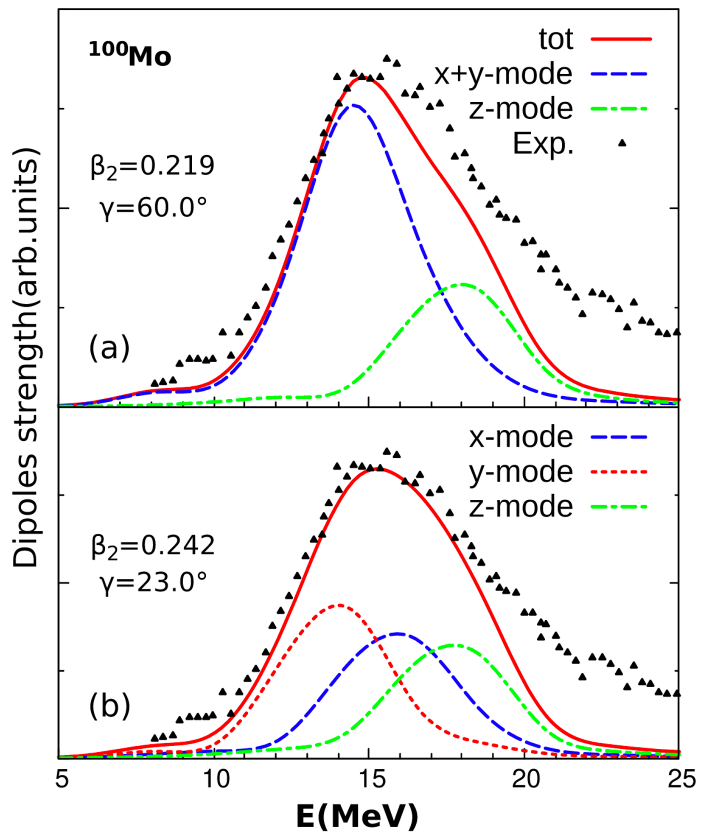

Fig. 4. (Color online.) The calculated GDR spectra for ^{100}Mo with the Skyrme force SLy6: oblate (a) and triaxial (b). The experimental data are extracted from [15].

Conclusions

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TDHF built on HF+BCS shape-constrained states can demonstrate effect of shape on (monopole) response

Mo-100 monopole response suggests triaxial ground state; dipole calculations reinforce this conclusion

Explicit coupling between monopole and quadrupole modes show mixed nature of lower energy peak, confirming Colò et al.'s inference

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