Large variety of nuclear collective motions

surface vibrations (quadrupole, octupole, hexadecupole, …)

rotations

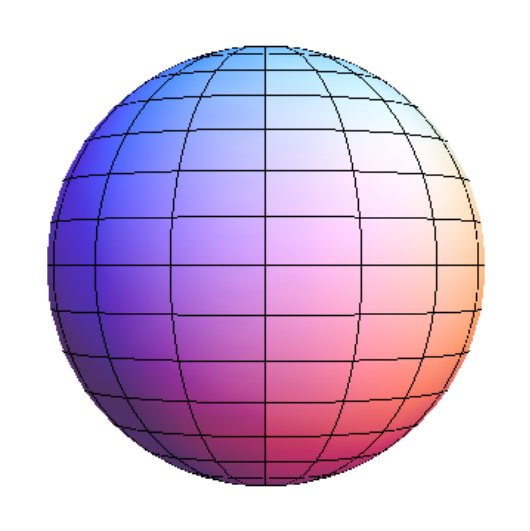
fission (large-amplitude collective motion)

giant resonances (proton-neutron displacements, monopole, dipole, quadrupole, …)

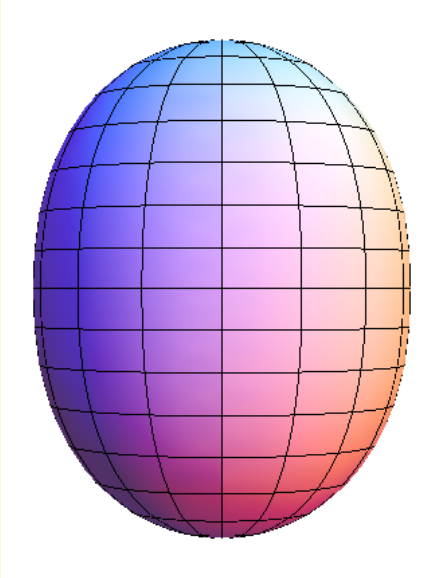
scissors mode (proton-neutron angular displacement)

pygmy resonance (n-rich nuclei, vibration of neutron halo / skin with respect to the core)

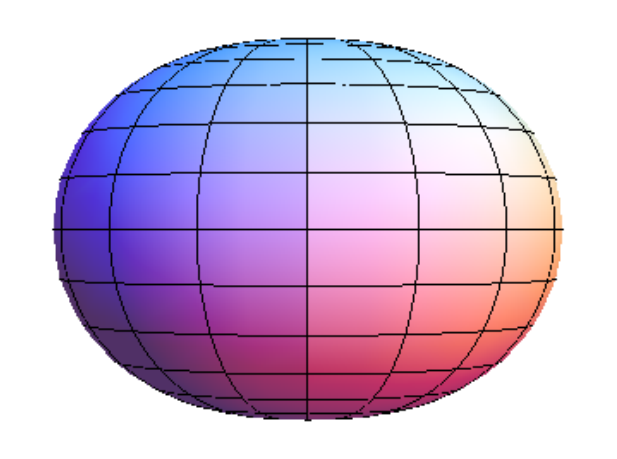
Collective model: surface vibrations



spherical



prolate

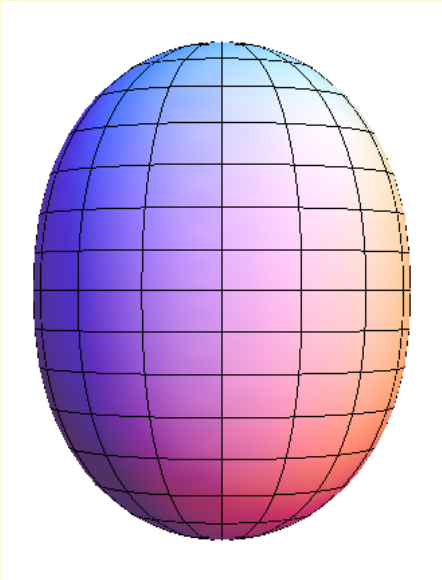


oblate

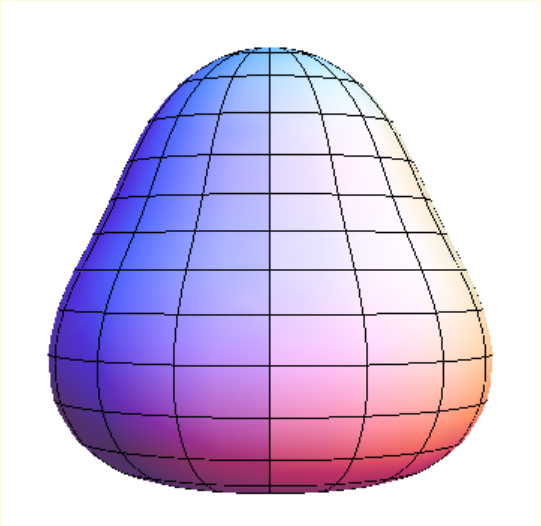
quadrupole deformation

Nuclear collective excitations: surface vibrations

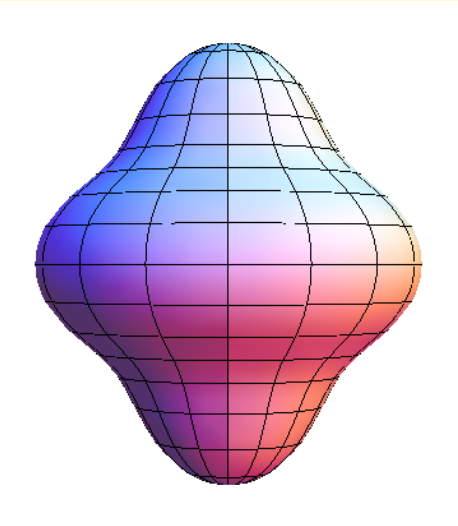
vibr. energy $\hbar\omega \approx 1.5 MeV$ $\longrightarrow$ vibr. frequency $\omega \approx 2 * 10^{21} s^{-1}$



quadrupole

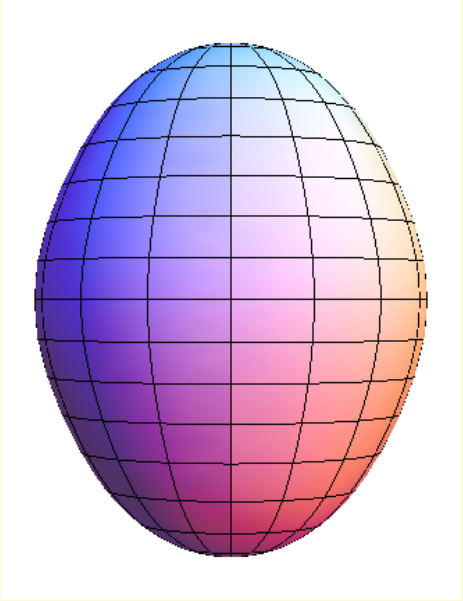


octupole



hexadecapole

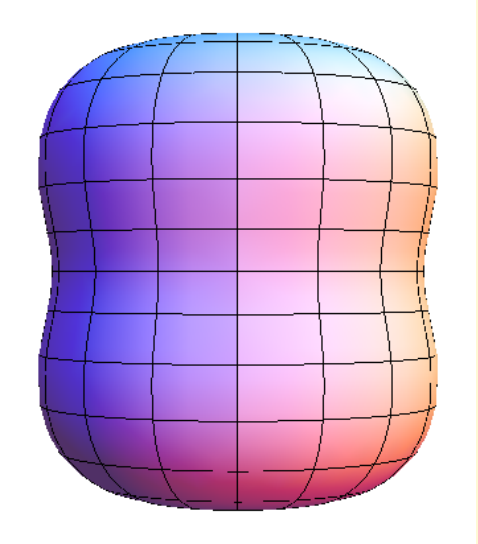
Nuclear ground state shapes based on exp. data



^{238}U

$\beta_2 = 0.2653$
$\beta_3 = 0.0$
$\beta_4 = 0.0672$

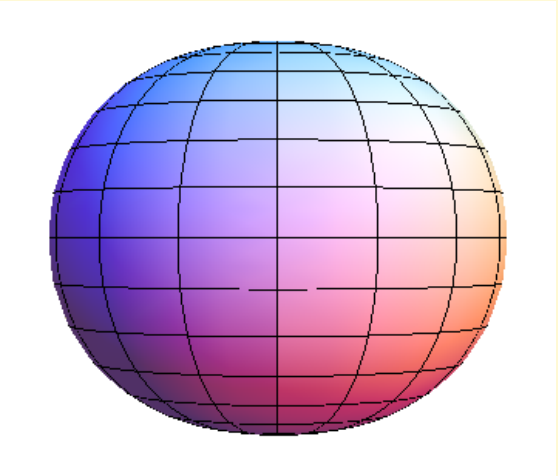
Phys. Rev. Lett. 53, 1889 (1984)



^{180}Hf

$\beta_2 = 0.32$
$\beta_3 = 0.0$
$\beta_4 = -0.22$

Phys. Rev. Lett. 40, 366 (1978)



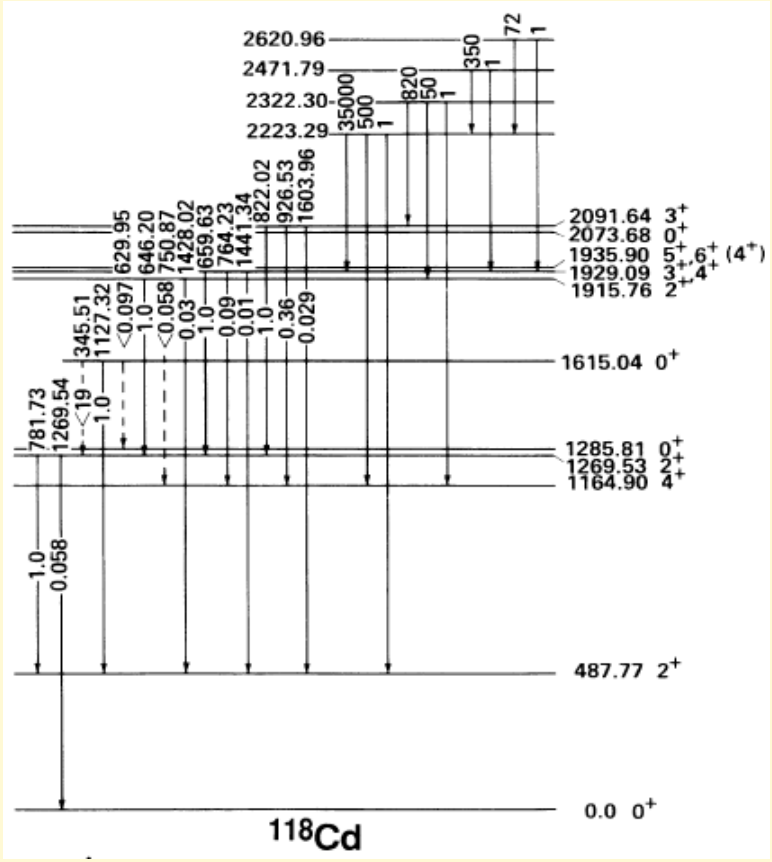
^{182}Os

$\beta_2 = -0.149$
$\beta_3 = 0.0$
$\beta_4 = -0.02$

Nucl. Phys. A512, 73 (1990)

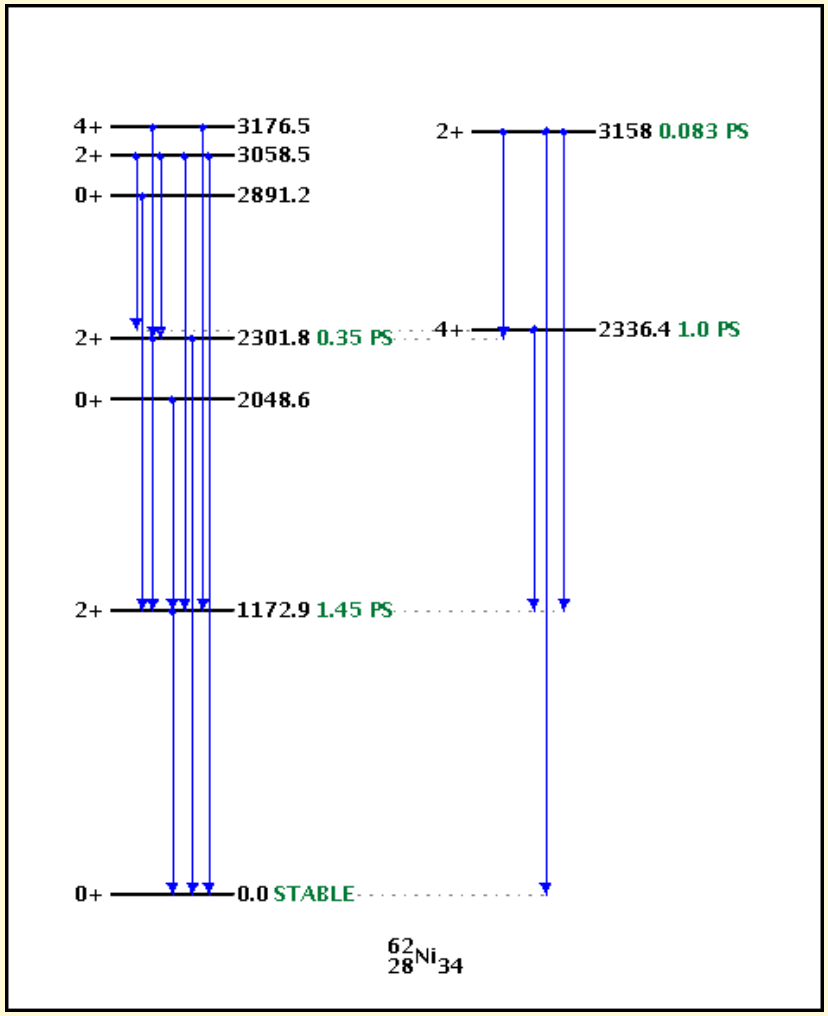
“First observation of a near-harmonic vibrational nucleus”

Ref: Aprahamian, Brenner, Casten, Gill, and Piotrowski
Phys. Rev. Lett. 59, 535 (1987)



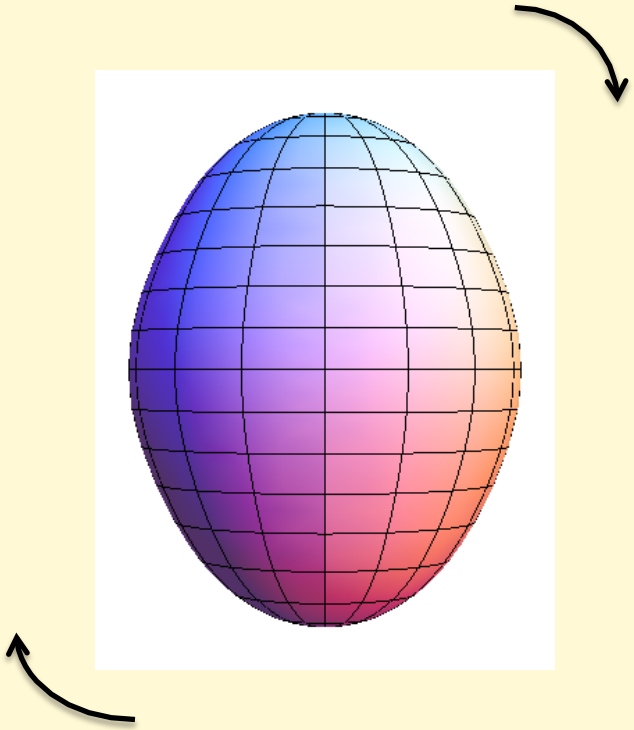
1- and 2-phonon E2 vibrational levels for nickel-62 (magic number Z=28)

Exp. Data: National Nuclear Data Center, Brookhaven



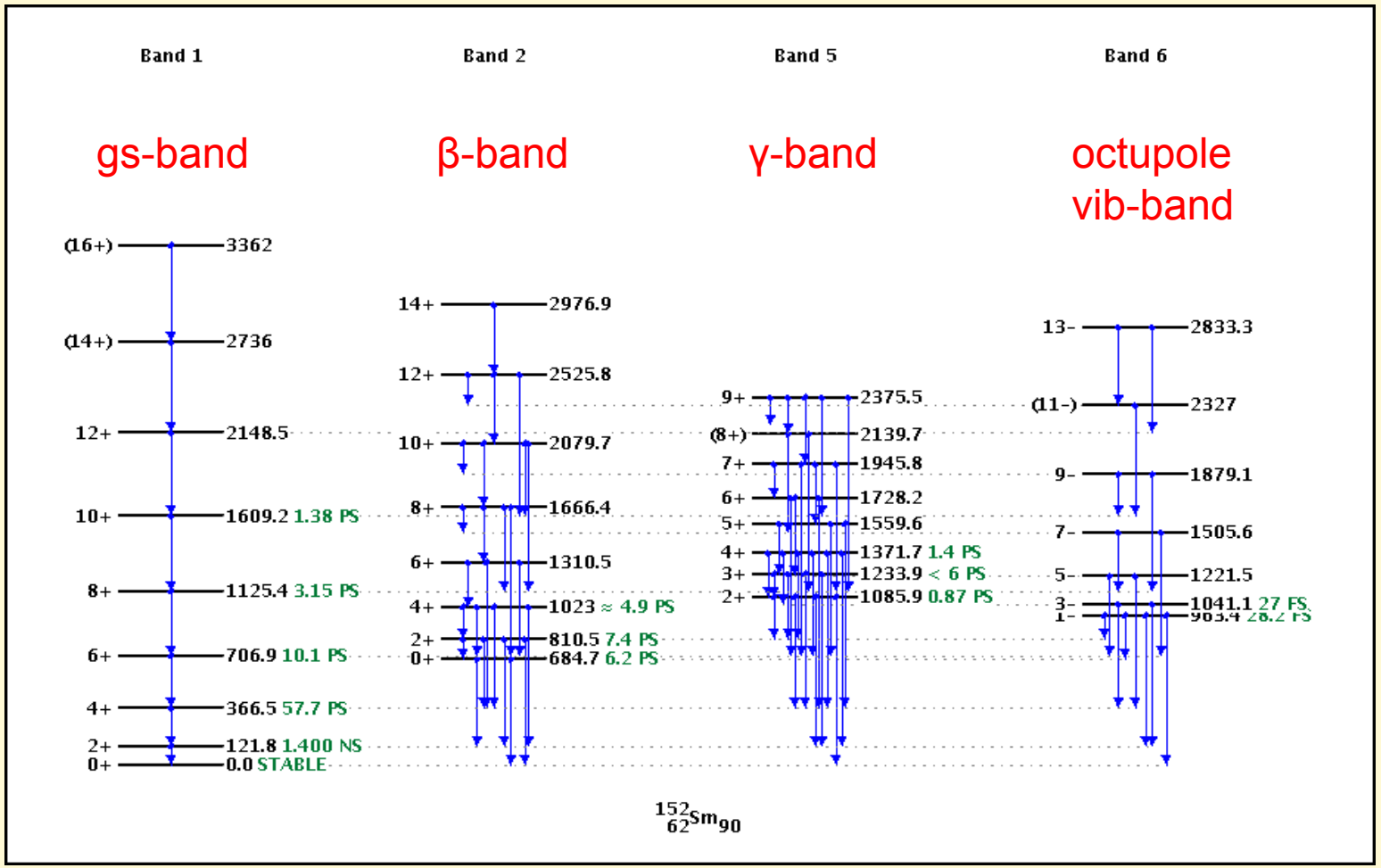
Nuclear collective excitations: rotations

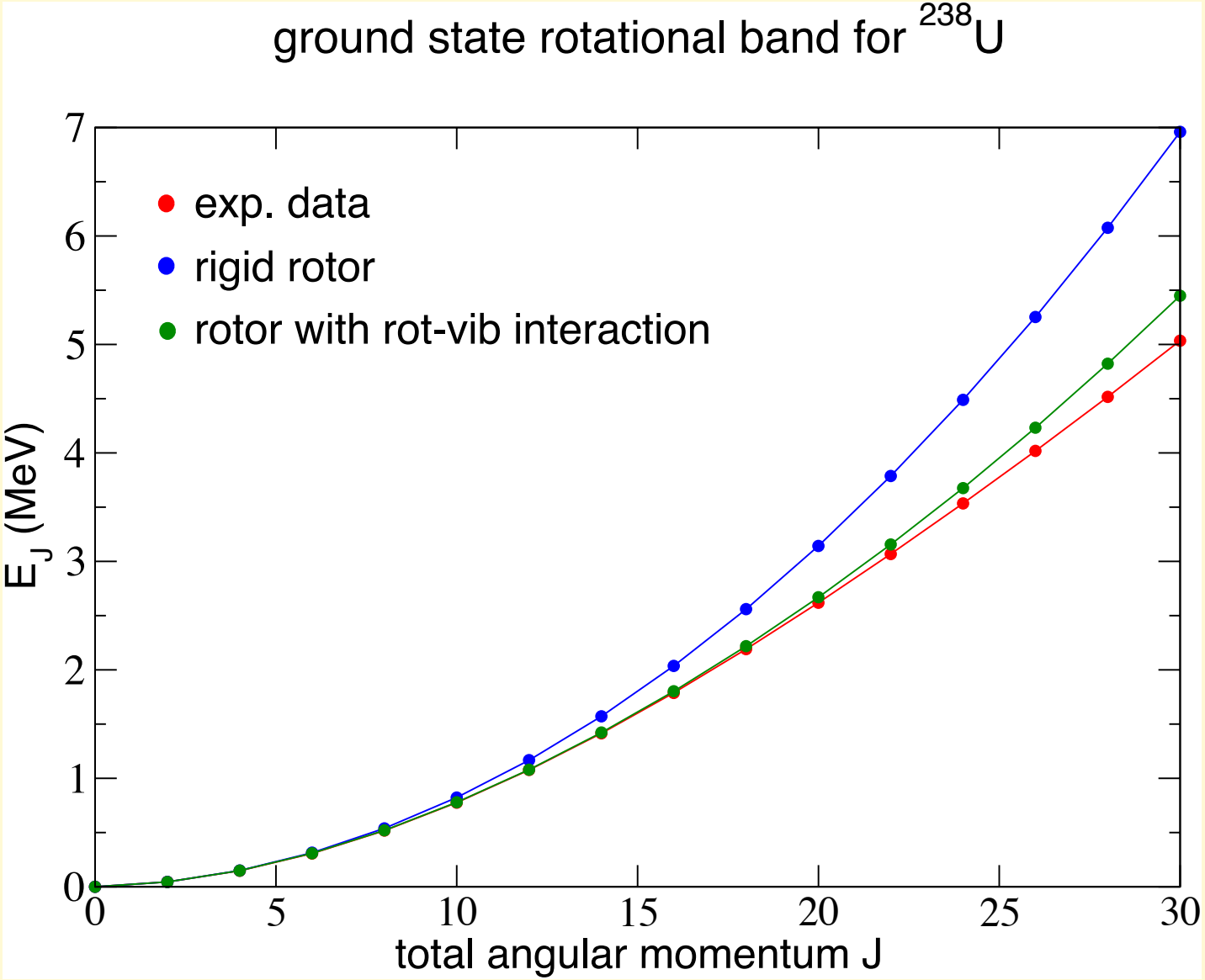
rot. energy $\hbar\omega \approx 100 keV$ ⟶ rot. frequency $\omega \approx 1.5 * 10^{20} s^{-1}$



Rotational bands for ^{152}Sm

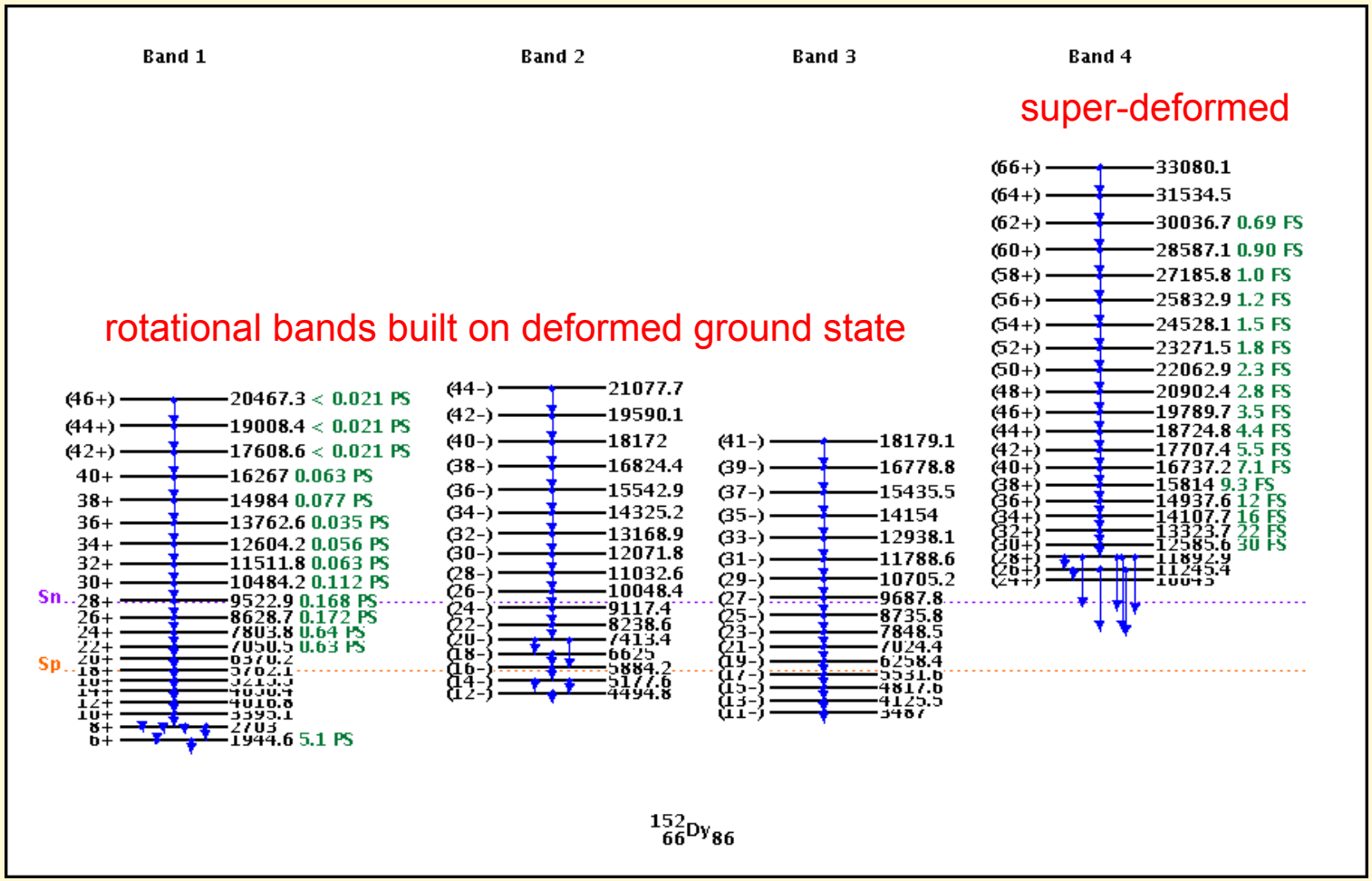
Exp. Data: National Nuclear Data Center, Brookhaven



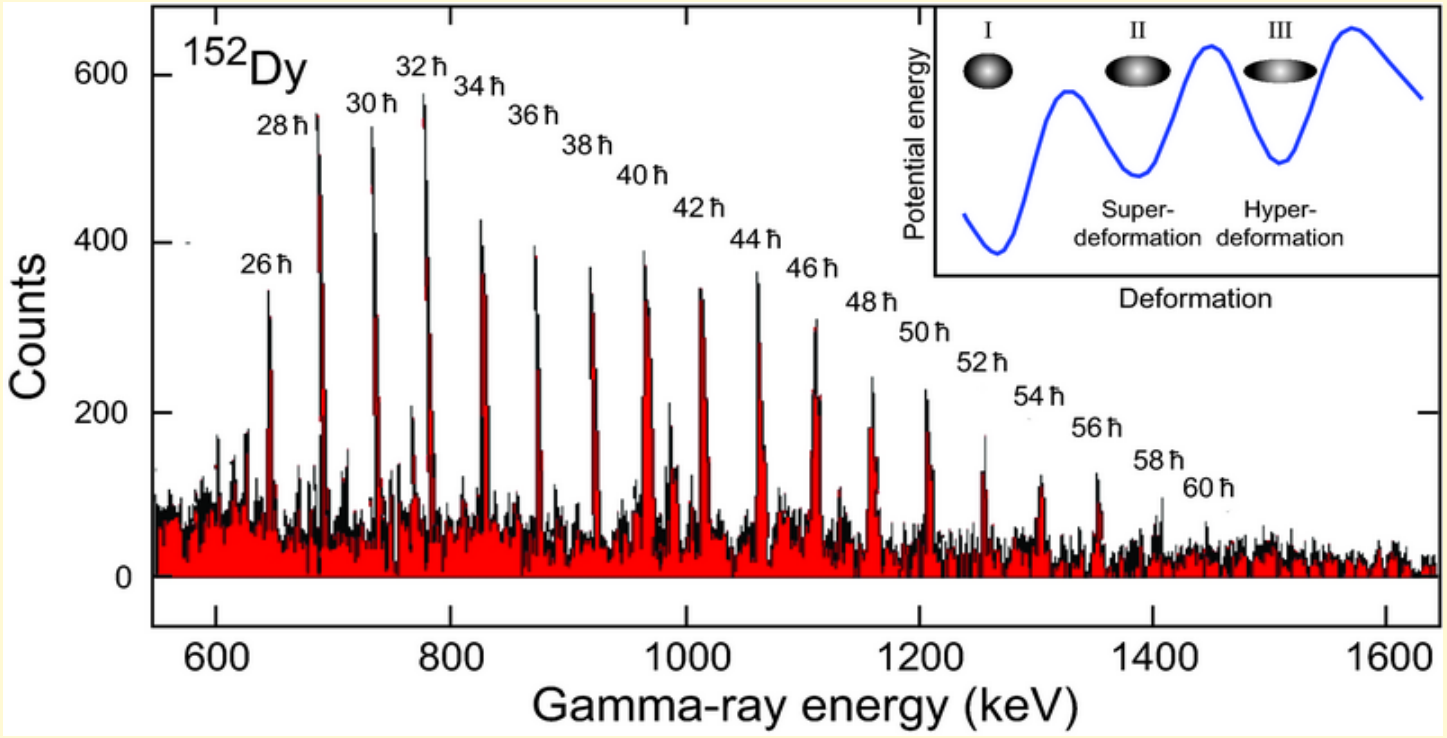

ground state rotational band for ^{238}U
exp. data
rigid rotor
rotor with rot-vib interaction
E_J (MeV)
total angular momentum J
0
1
2
3
4
5
6
7
0
5
10
15
20
25
30

rotational bands for ^{152}Dy (up to J=66)

Exp. Data: National Nuclear Data Center, Brookhaven

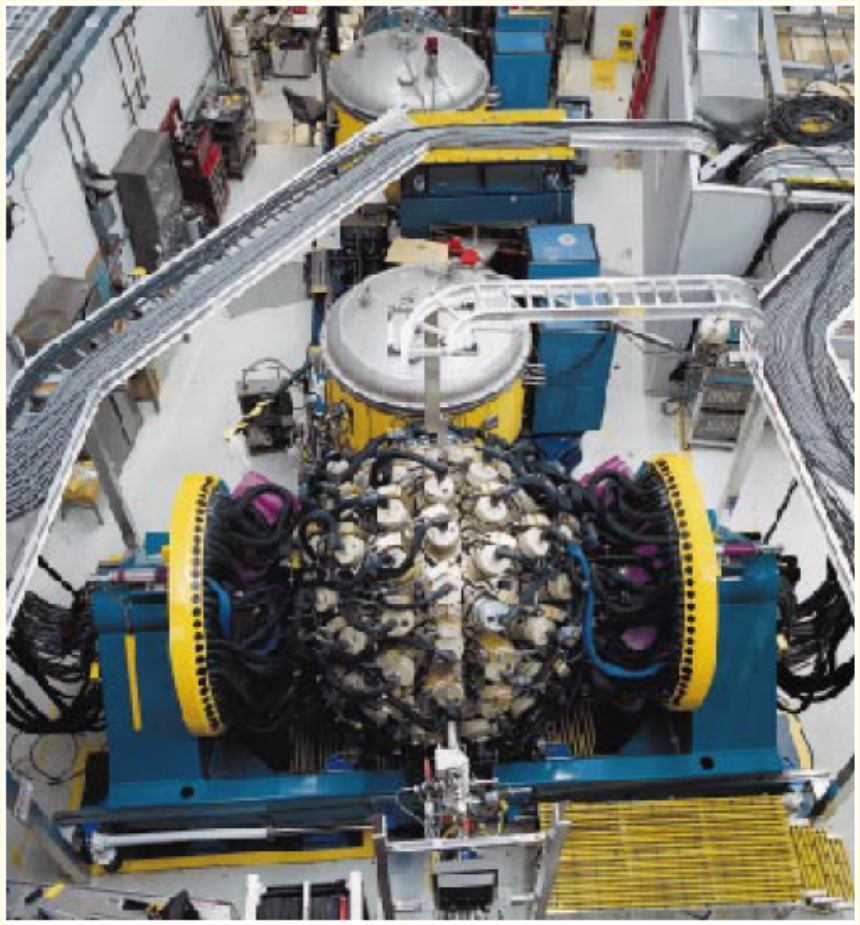


Gamma ray transitions within rotational band: "picket fence" structure



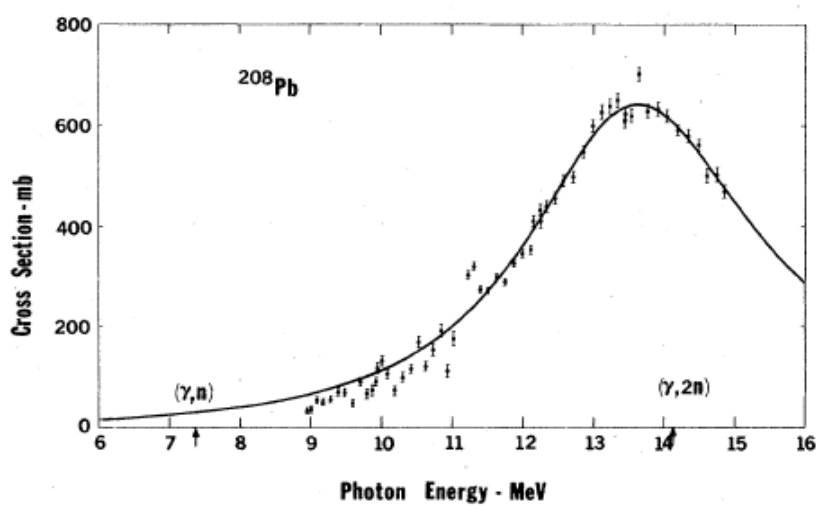
Gammasphere: currently the most powerful γ-ray detector

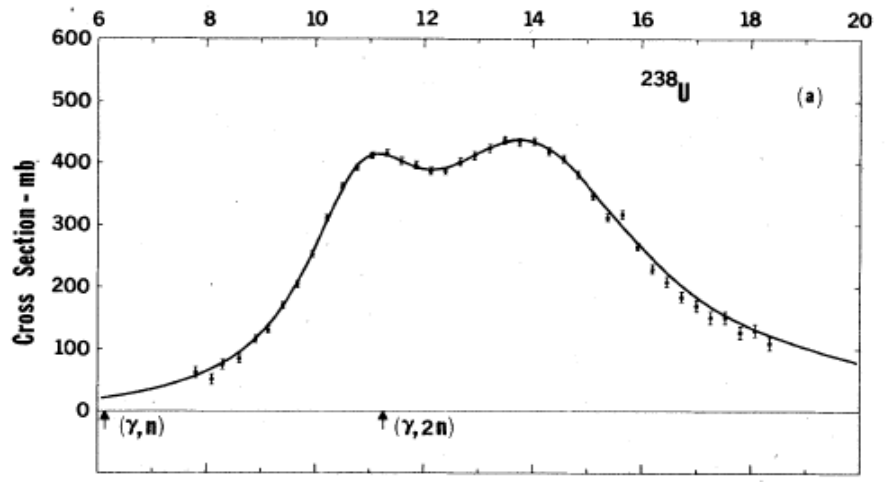
110 high-purity germanium detectors



Giant dipole resonance in spherical and deformed nuclei

Ref: Berman and Fultz, Rev. Mod. Phys. 47 (1975) 713





1-phonon and 2-phonon giant resonances (E1, E2) in xenon

Ref: DOE / NSF Long-Range Plan (1996)

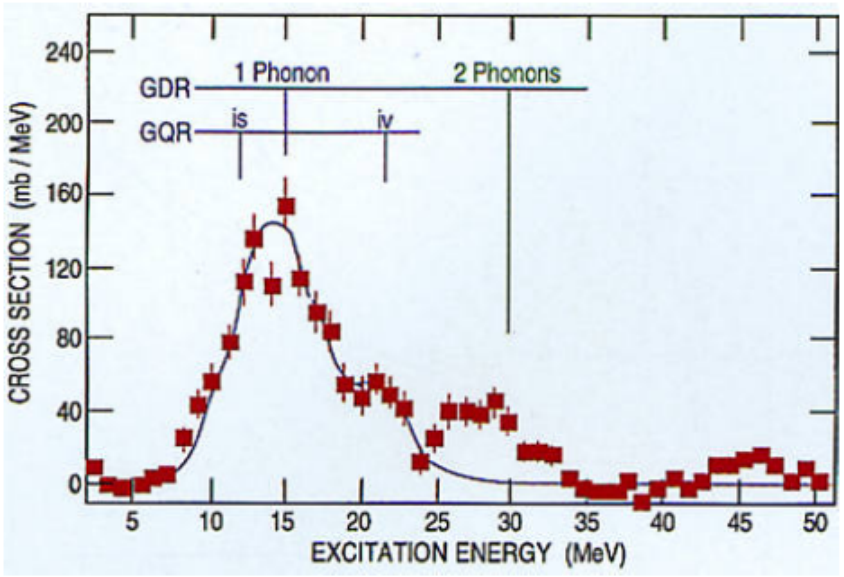
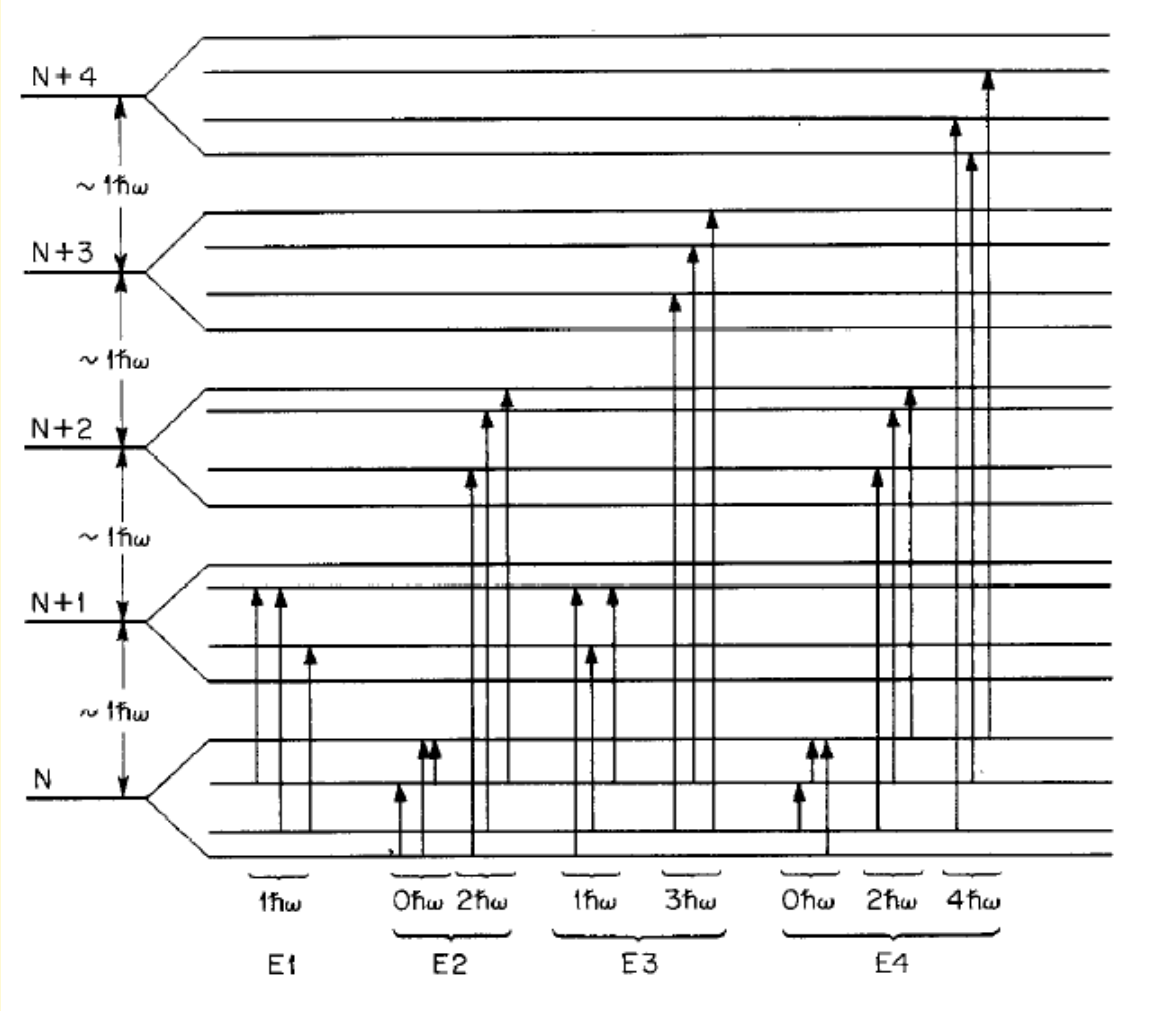


Figure I.11: Excitation energy spectrum of a xenon nucleus excited in collisions with a lead nucleus at near-relativistic energies. Intense fields of virtual photons generated in such collisions provide for the absorption of multiple quanta and excitation of the double giant dipole resonance. Evidence for this new type of excitation is seen, in the expected energy region, in the excess of data over the solid curve, which represents the contributions from the known (isoscalar and isovector) one-phonon giant resonances.

Giant EL resonances: qualitative shell-model interpretation

Ref: F.E. Bertrand, Nucl. Phys. A354, 129c (1981)



Exotic collective modes (neutron-halo and neutron-skin nuclei)
"pygmy" resonance and "scissors" mode