STUDY OF NUCLEAR SHAPES IN MERCURY ISOTOPES

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REX-ISOLDE

Abstract

- The nucleus is a unique and complex, many-body quantum system consisting of protons and neutrons. The phenomenon of shape coexistence, when two or more differently shaped structures can compete at low excitation energies, occurs in nuclei with near 'magic' numbers of protons and between these 'magic' numbers for neutrons. To confirm (or quash) theoretical predictions one can experimentally determine the electric charge distribution of the excited states and hence assign a shape and deformation, or quadrupole moment, Q_0. Presented is the ongoing study of Coulomb excitation of the radioactive nuclei ^{184,188}Hg.

Physics Motivation

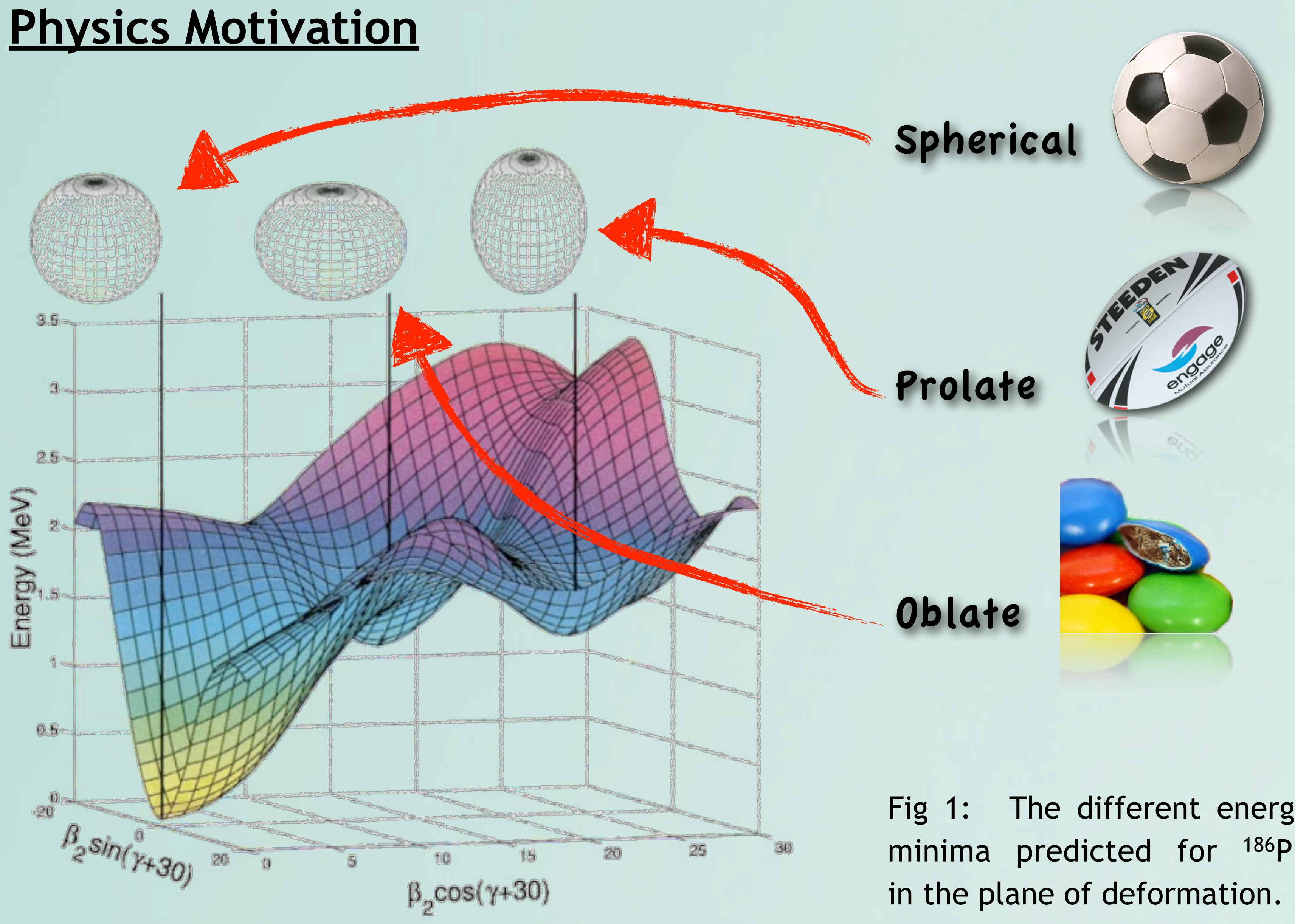


Fig 1: The different energy minima predicted for ^{186}Pb in the plane of deformation.

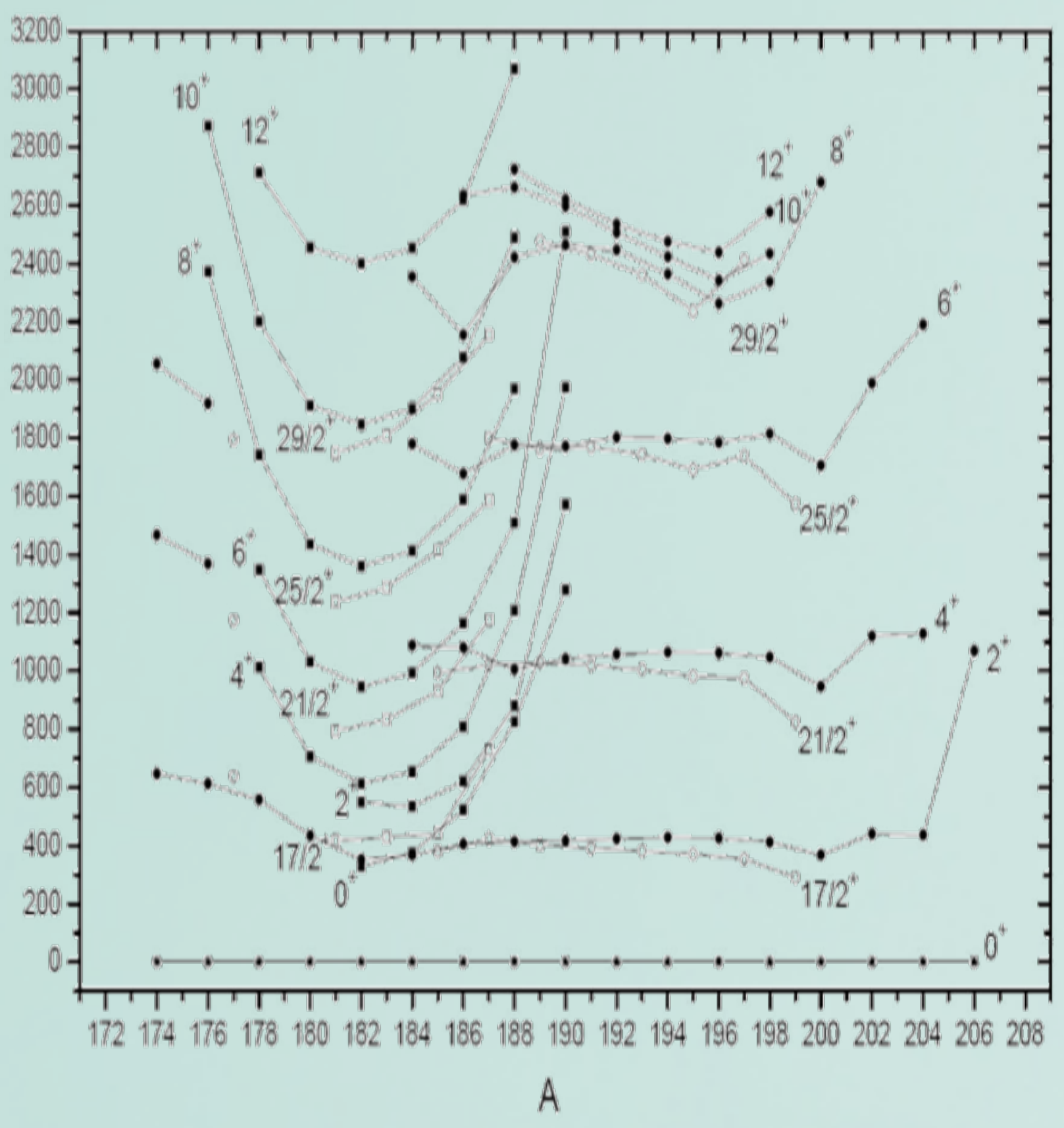
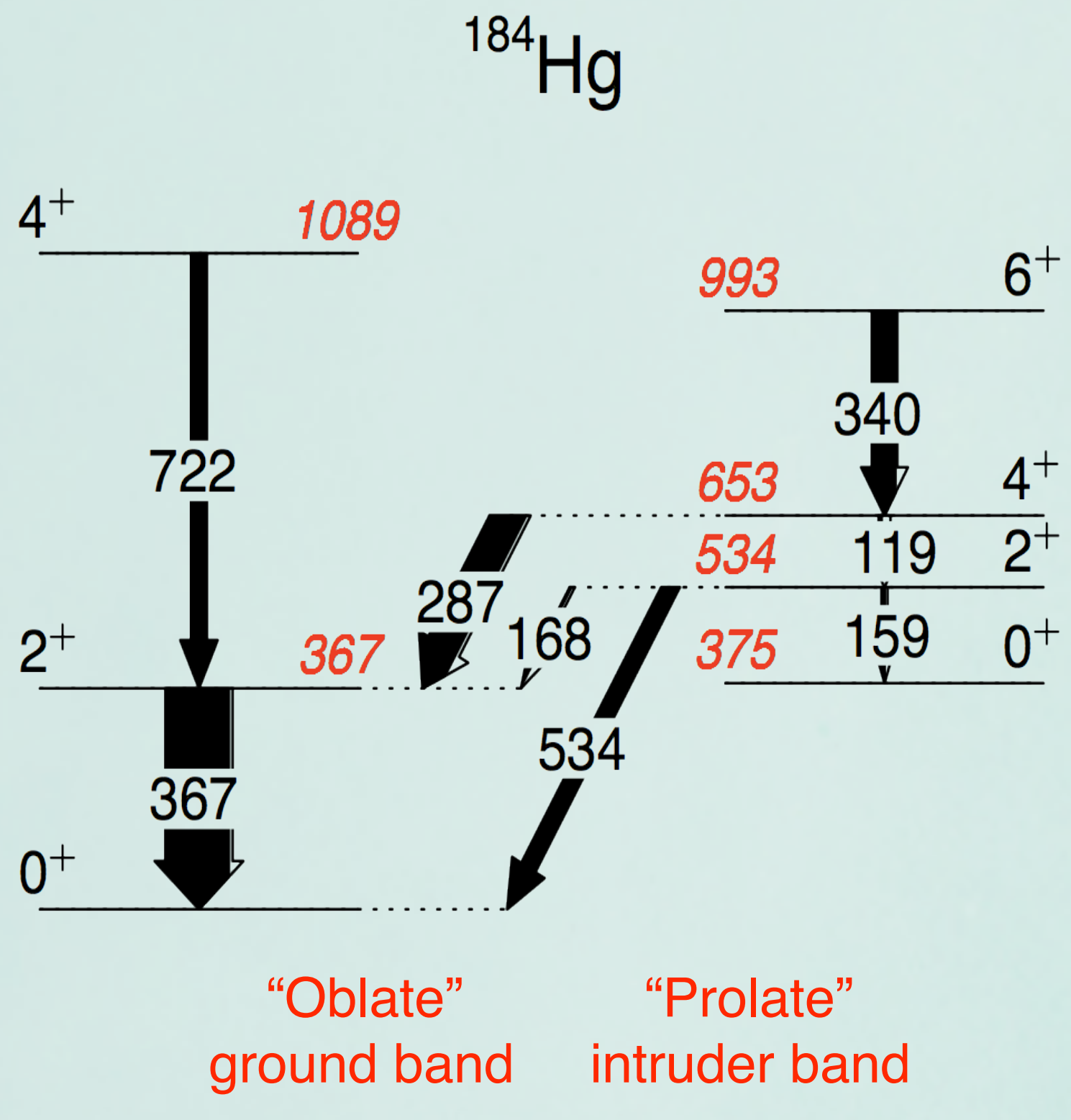


Fig. 2: The systematics for mercury isotopes show these intruder states for $^{180-188}$Hg. [2]

- A triplet of low-lying 0^+ states in ^{186}Pb have recently been observed [1], each associated with a different shape. Other than the spherical ground state, there are two, deformed minima. These states can be considered as intruder states.



Can we prove the nuclear shape?

- By exciting the nucleus in the electric field of another nucleus (Coulomb excitation or Coulex) one can measure the charge distribution of the state that is populated which, if non-zero, indicates a deformed shape.

  Positive sign -> Prolate shape;
  Negative sign -> Oblate shape.

- As the electro-magnetic force is very well understood, one can fit the experimental data to calculations to determine the deformation.

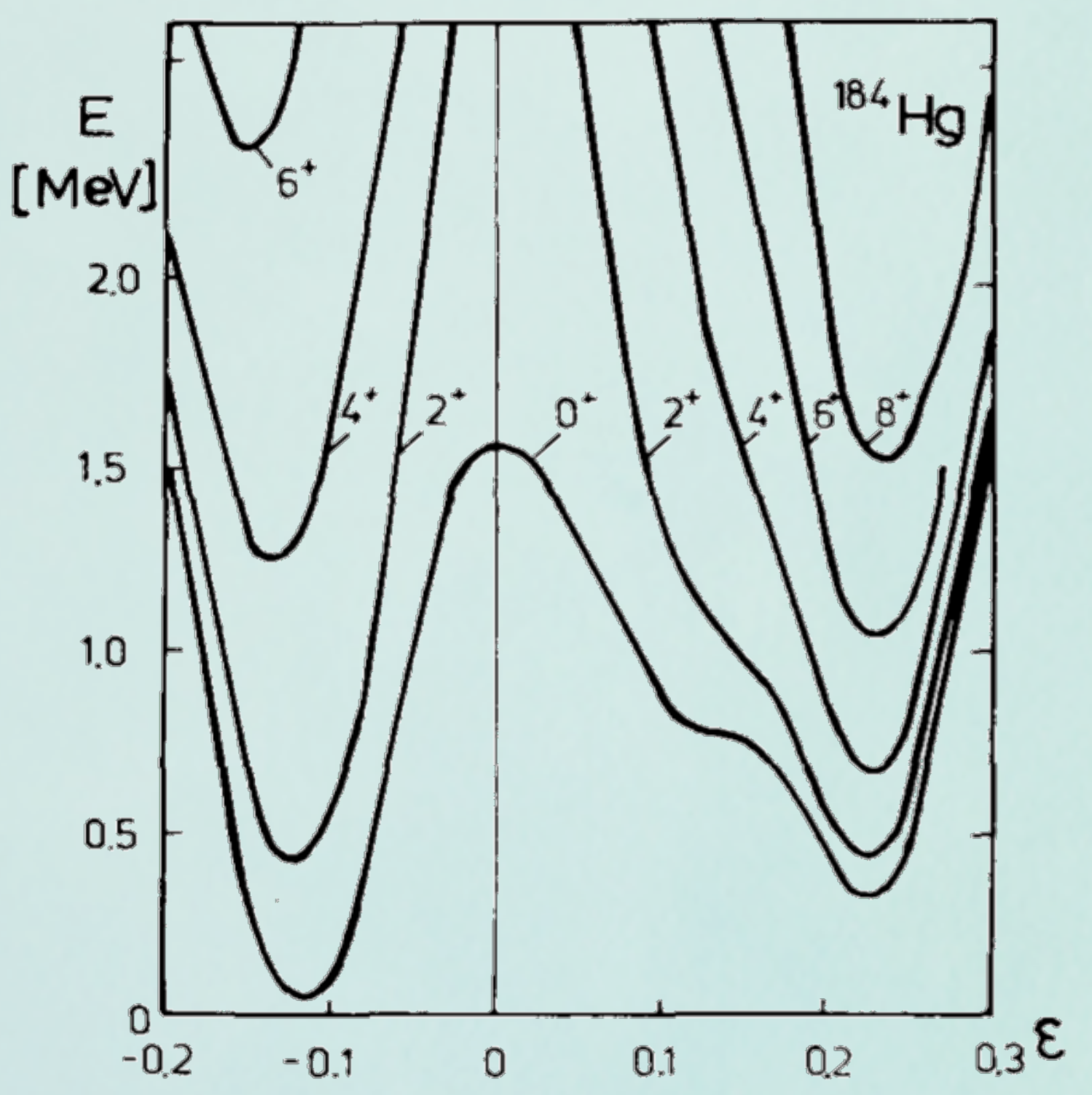
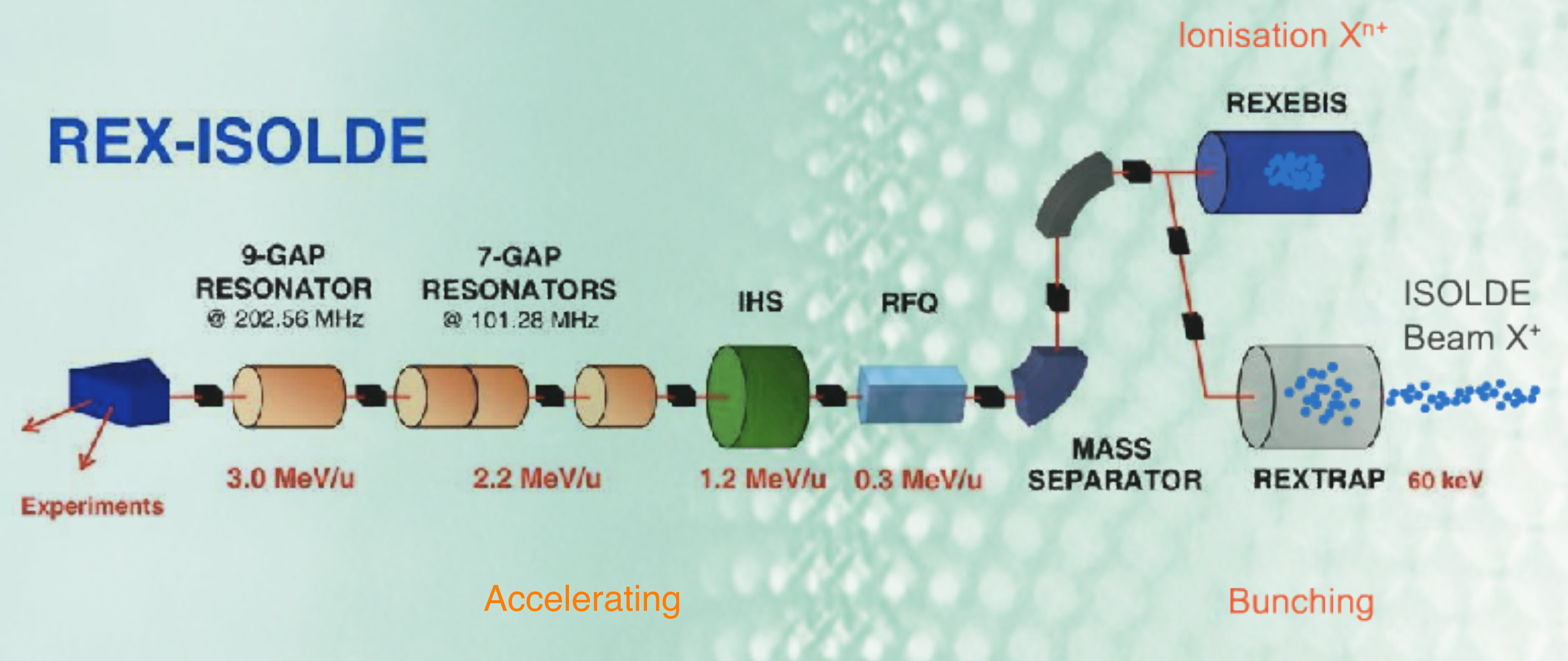


Fig. 3: Theoretical prediction for deformation [3]

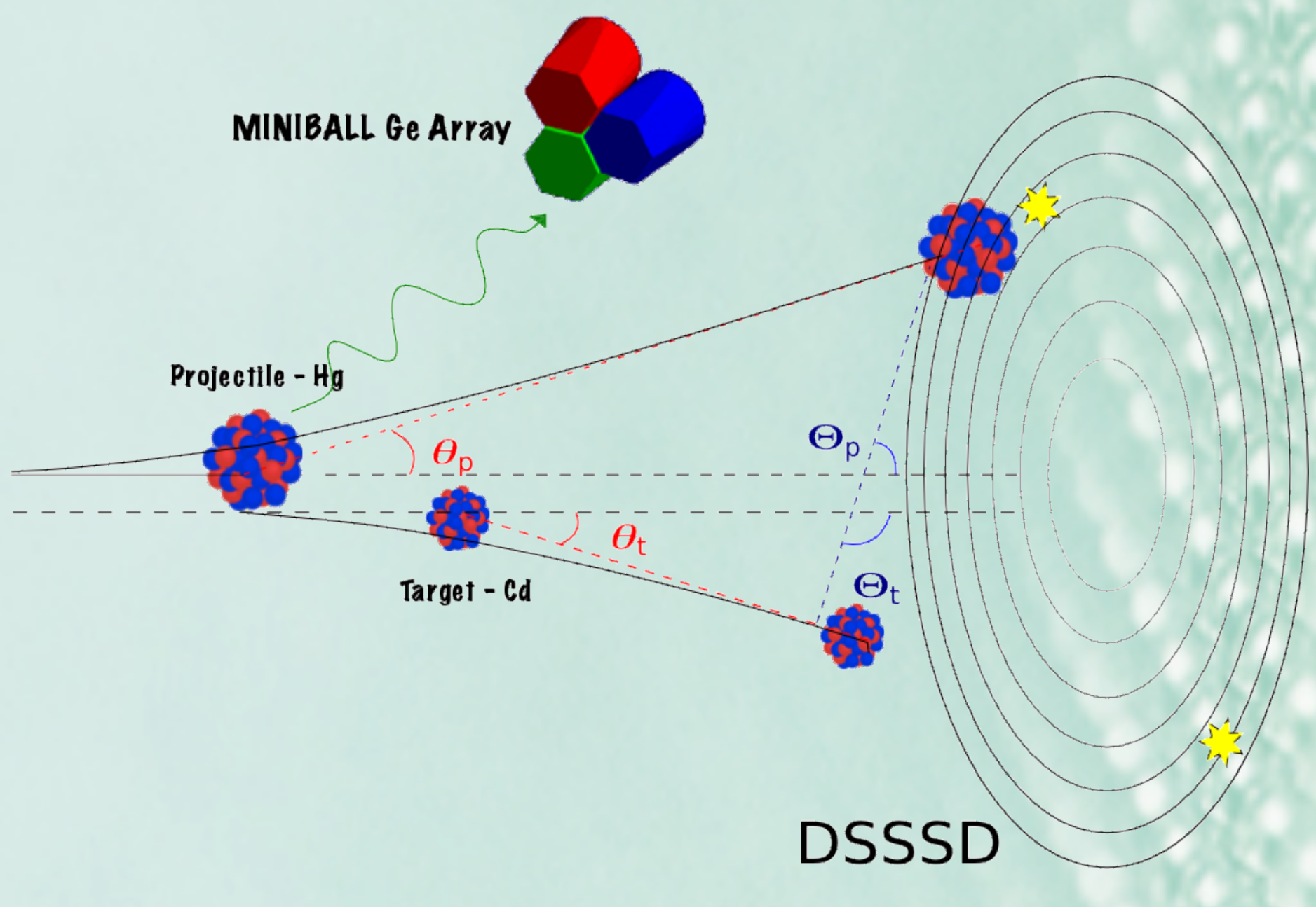
The Experiment : REX-ISOLDE @ CERN



- The nuclei we want to study are unstable and radioactive so we need to synthesise them and transport them quickly. These are so called post-accelerated, Radioactive Ion Beams (RIBs)

- At ISOLDE, CERN (Geneva, Switzerland), 1.4 GeV protons impinge on a Uranium Carbide target to produce a huge number of reaction products. From these the mercury isotopes of interest are extracted as 1^+ ions at very low energy (~60 keV) and feed it into a system of trapping, charge breeding, mass separating and accelerating, to a final energy of ~525 MeV.

The Experiment : Coulex



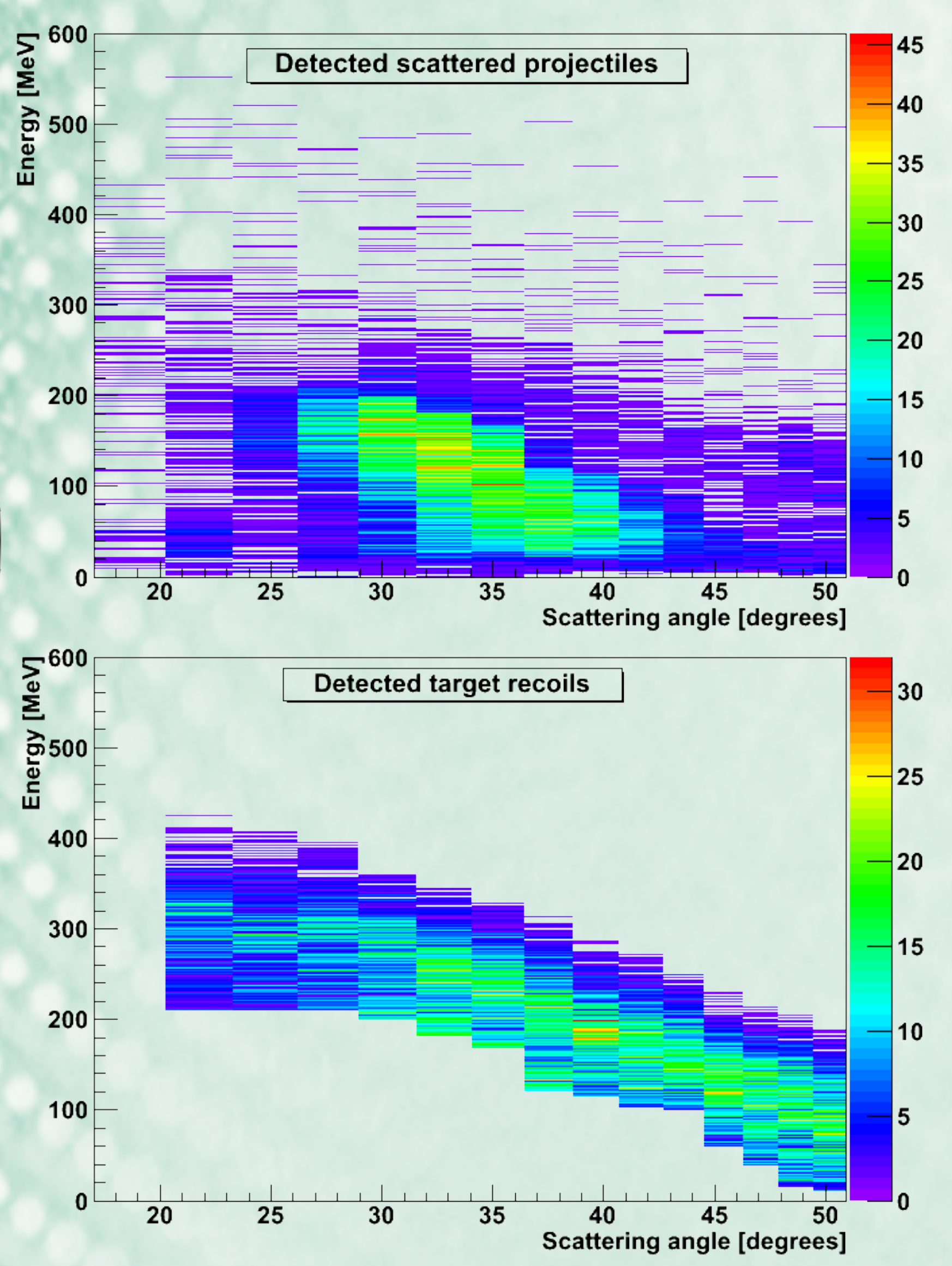


Fig 3: Energy and angle of particles scattered into the CD detector. Mercury on top, cadmium bottom.

- The beam of mercury nuclei is incident on a thin cadmium foil and scatters in the electro-magnetic (Coulomb) field and one of both nuclei can be excited.

- The excited nuclei decay within pico-seconds (10^{-12} seconds), losing angular momentum by emitting a gamma-ray with a characteristic energy. Scattered projectiles and recoiling target nuclei are detected in a silicon detector, Fig.3.

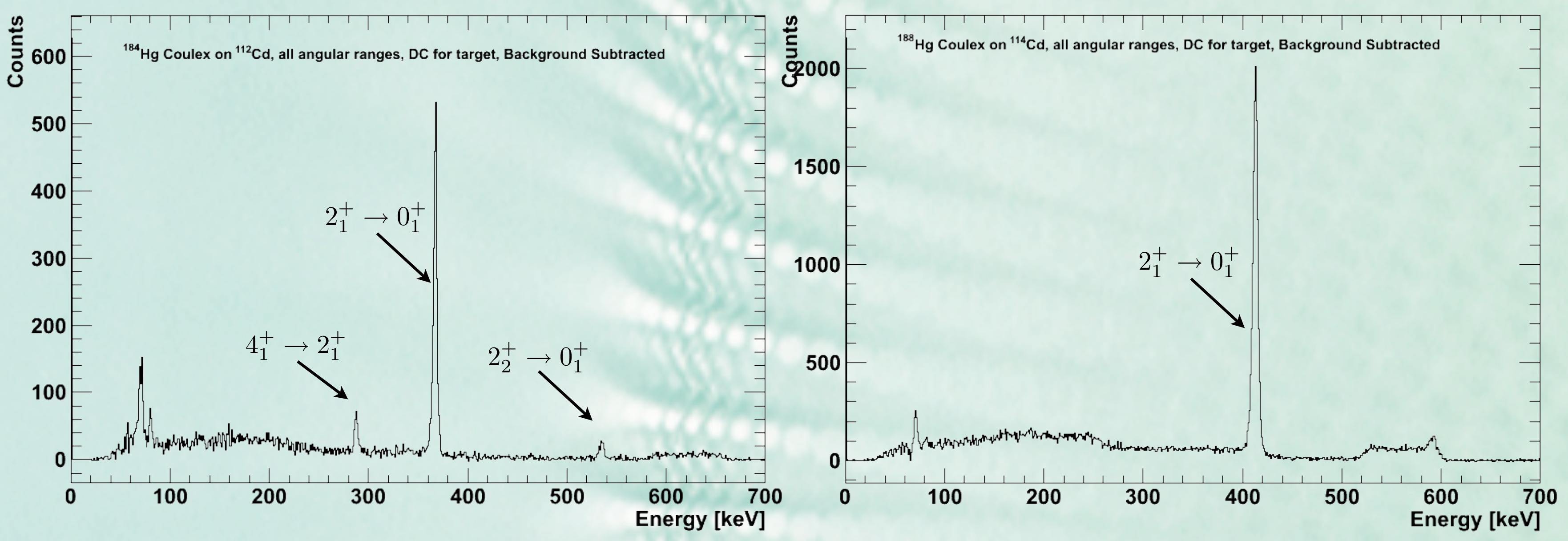


Fig 4: Gamma-ray spectrum for ^{184}Hg and ^{188}Hg after Coulomb excitation, coincident with target and projectile

- The de-excitation gamma-rays are detected in the Miniball array of Hyper-Pure Germanium detectors. The acquired spectra (Fig. 4) along with a knowledge of the excitation process will now allow a quantitative understanding of the underlying structure in the nuclei. This process is ongoing.

References: [1] A N Andreyev *et al.* Nature 405 (2000) [2] Julin R, Helariotta K and Muikku M 2001 *J. Phys. G.* **27** R109 [3] S. Frauendorf and V. V. Pashkevich, *Phys. Lett. B* **55**, 203 (1975)

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