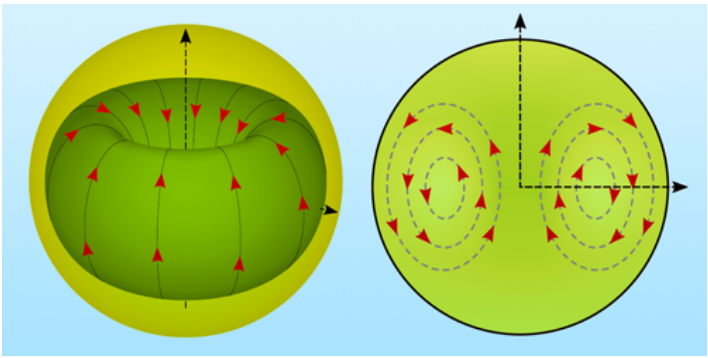
A Toroidal Mode in an Excited Nucleus

Nuclear scattering data suggest the possible observation of a predicted but never-observed nuclear vibration.

By **Charles Day**

If a nucleus gets hit by a particle of the right energy, it can set the nucleus's protons and neutrons sloshing past each other. The dominant vibrational modes are known as giant $E1$ resonances, but many other modes are possible, among them the toroidal dipole resonance (TDR). Predicted 50 years ago, the TDR involves protons and neutrons oscillating along nested loops that form a toroid inside the nucleus. It has yet to be unambiguously detected. But now Peter von Neumann-Cosel of the Technical University of Darmstadt in Germany and his collaborators have developed a theoretical description of the TDR whose predictions match the results of scattering experiments with nickel-58 nuclei [**1**].

In general, the interaction probability (cross section) of charged particles that electromagnetically scatter off nuclei has two components: a "longitudinal" one, which originates in the distribution of charge in the nucleus, and a "transverse" one, which originates in the current distribution. If an electron excites a TDR, the jiggling back and forth of protons causes the electron's scattering cross section to have a transverse component. But such transverse components are not engendered exclusively by TDRs. To be sure of seeing a TDR, Neumann-Cosel and his collaborators realized that their theoretical description had to predict the scattering cross sections not only of electrons but of protons and gamma rays.



Credit: P. von Neumann-Cosel *et al.* [**1**]

The researchers compared predictions made using their theory—a variant of density-functional theory—to electron, proton, and gamma-ray data from three separate experiments. So far, these experiments have examined only one nucleus, nickel-58, with the required resolution and range of scatterers, and the data were consistent with the theory. Measurements of more nuclei—notably, heavy ones—will be needed before declaring that the long-sought TDR has been found.

Charles Day is a Senior Editor for *Physics Magazine*.

REFERENCES

1. P. von Neumann-Cosel *et al.*, "Candidate toroidal electric dipole mode in the spherical nucleus ^{58}Ni," **Phys. Rev. Lett. 133, 232502 (2024).**