Contribution ID : **58** Type : **Oral**

Evidence for a toroidal electric dipole mode in nuclei

Friday, 21 July 2023 13:35 (15)

A multipole expansion of electromagnetic fields shows that besides the well-known electric and magnetic terms a toroidal dipole mode must exist, where the electric current is bent on the surface of a torus (1). Such modes appear in a wide variety of fields ranging from solid-state physics, quantum and nonlinear optics, to particle physics and astronomy. A toroidal electric mode should also appear in all nuclei as response to an external dipole field, like the isovector giant dipole resonance or the isoscalar compression resonance due to nuclear density variations. Such a mode was predicted more than 50 years ago, but clear experimental evidence is lacking so far (2). Using a combination of high-resolution inelastic scattering experiments with photons (3), electrons (4) and protons (5), we identify for the first time candidates for toroidal excitations in the nucleus ^{58}Ni and demonstrate that transverse electron scattering form factors represent an unique experimental observable to prove their nature (6). While the present case refers to a nucleus with almost equal proton and neutron number, toroidal excitations might also offer an explanation for the observation of the pygmy dipole resonance at low energies in nuclei with neutron excess (7).

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Supported by DFG under contract SFB 1245 (Project ID No. 79384907)

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Session Classification : Session 16

Track Classification : Fundamental Symmetries and Interactions