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Strong Interactions and the Emergence of Mass

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Having uncovered the explicit source for <2% of the mass of visible matter, attention is now shifting to searches for the origin and the explanation of the remaining >98%. That emergent mass is contained within atomic nuclei, which lie at the core of everything we can see. At the first level of approximation, the atomic weight of a nucleus is simply the sum of the masses of all the neutrons and protons (nucleons) it contains. Each nucleon has a mass mN ≈ 1 GeV, i.e. approximately 2000-times the electron mass. The Higgs boson produces the latter, but what produces the masses of the neutron and proton? This is the pivotal question: the vast bulk of the mass of a nucleon is lodged with the energy needed to hold quarks together inside it; and that is supposed to be explained by quantum chromodynamics (QCD), the strong-interaction piece within the Standard Model.

QCD is unique. It is the only known fundamental theory with the capacity to sustain massless elementary degrees-of-freedom, viz. gluons and quarks. Yet gluons and quarks are predicted to acquire mass dynamically, and nucleons and almost all other hadrons likewise, so that the only massless systems in QCD are Nature's composite Nambu-Goldstone (NG) bosons, the pions and kaons. Simultaneously reconciling the emergence of mass in the bulk of hadron systems and the screening of mass generation in the pion and kaon is one of the greatest challenges in modern physics.

This presentation will canvass the potential for a coherent effort in QCD phenomenology and theory, coupled with experiments at existing and planned facilities worldwide, to reveal the origin and distribution of mass and expose and explain its manifold expressions in hadrons and nuclei. This international programme addresses a diverse range of issues, e.g. How do hadron masses and radii emerge for light-quark systems from QCD; What is the interplay of the strong-mass and Higgs-mass generation mechanisms; What are the basic processes that determine the distribution of mass, momentum, charge, spin, etc., within hadrons, and how are these things expressed in observable deformations of the basic building blocks of nuclei?

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