EXPERIMENTAL PHYSICS DIVISION SEMINAR

INSTITUTE OF HIGH ENERGY PHYSICS, CAS

Flavour Physics, the Higgs Boson, and Emergent Hadron Mass

Speaker: Prof. Craig D. Roberts (NJU)

Time: 10:00 Tue 10th Oct 2023

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Abstract:

The Higgs boson (HB) is commonly regarded as the origin of mass within the Standard Model of particle physics (SM). The Higgs produces the electron mass, m_e = 0.511 MeV, and the quark current masses, amongst them the light up and down quarks: $m_u \approx 4m_e \approx 2.2$ MeV, $m_d \approx 2m_u$. These particles combine to form the hydrogen atom, the most abundant element in the Universe, whose mass is 939 MeV. Somehow one electron, two u quarks and one d quark, with a total Higgs-generated mass of $\sim 13m_e \approx 6.6$ MeV, combine to form an object whose mass is 140-times greater. Plainly, Nature must have another, very effective mass generating mechanism, responsible for 99% of the visible mass in the Universe.

Contemporary theory explains this emergent hadron mass (EHM) as the consequence of the dynamical generation of a gluon mass in quantum chromodynamics (QCD). The existence of such a mass entails that the QCD running coupling has a stable infrared completion, remaining finite at all energy scales, from the deep ultraviolet into the far infrared. Together, these phenomena explain the character of mass in the matter sector of strong interactions. Such extraordinary predictions require empirical verification.

This presentation will explain the EHM paradigm for the origin of almost all visible mass in the Universe and indicate how the study of semileptonic weak-interaction transitions between heavy and light hadrons may contribute toward its validation. Such cases are of heightened interest because the transitions have long been used to place constraints on the values of the elements of the CKM matrix, which parametrizes quark flavour mixing in the SM. Furthermore, confronting measurements of transitions with different leptons in the final state with sound theoretical predictions can shine bright light onto the question of lepton flavor universality.

Searches for violations of CKM matrix unitarity and/or lepton flavour universality are principal tools in the hunt for physics beyond the SM. Studying the evolution of hadron properties with quark current mass, i.e., the strength of HB couplings into QCD, provides a clear window onto constructive interference between Nature's two sources of mass. This is a new feature of flavour physics, which adds enormously to its role in searching for physics beyond the SM.

About the speaker:

Craig D. Roberts, International Distinguished Professor and Head of Institute for Nonperturbative Physics at Nanjing University since 2019. Before that he was Leader of the Theory Group in the Physics Division at Argonne National Laboratory from 2001 to 2017. Prof. Roberts conducts a broad-ranging research program in modern nuclear and particle theory, pursuing the development and refinement of novel theoretical approaches to hadro-particle physics and strong-coupling quantum field theory.