USQCD

Particle Physics

Searching for Physics Beyond the Standard Model:
Strongly-Coupled Field Theories at the Intensity and Energy Frontiers

SciDAC-3 Scientific Computation Application Partnership project

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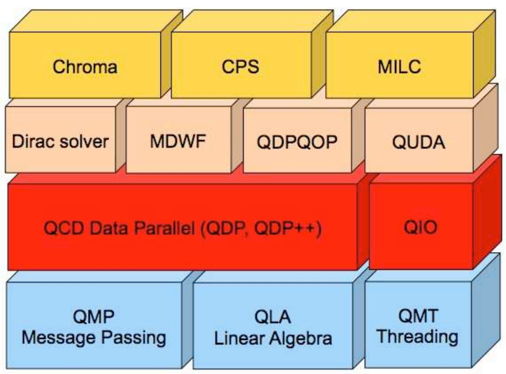
The standard model of particle physics accounts for all known experiments and underlies all physical phenomena. Most particle physicists believe that it is the “low”-energy approximation to a more exact still higher energy theory. The central goals of particle physics today are to test the limits of validity of the standard model and to search for evidence of new physics beyond it. Experimentalists at the LHC in Geneva will spend the rest of the year investigating whether the recently discovered “Higgs-like” particle is in fact the Higgs in its simplest form, the last undiscovered particle of the standard model, or whether it has different properties and is part of some more complicated theory not yet discovered.

Quantum Chromodynamics, or QCD, is the theory of the strong nuclear forces. It explains the properties of the proton, neutron, and the other hadrons in terms of the underlying theory of quarks and gluons. In most cases, QCD cannot be solved by the ordinary analytic techniques of quantum field theory. By formulating QCD on a space-time lattice, large-scale numerical simulations can be used to make predictions numerically.

Lattice QCD plays a crucial role in the central program of particle physics in two ways. The Intensity Frontier experimental program aims to use higher and higher intensity experiments at medium energies to make increasingly precise searches for deviations from the predictions of the standard model. Lattice QCD calculations are essential for relating the fundamental properties of quarks and gluons to the observed decays and mixings of the hadrons. Energy Frontier experiments at the LHC are searching for direct evidence of new particles belonging to new physics beyond the standard model. Models of new physics typically involve new strongly interacting sectors with new gauge groups and new types of matter particles. Lattice gauge theorists are beginning to investigate such theories using lattice gauge theories with gauge groups other than the SU(3) of QCD and with matter particles in new representations of these groups.

The USQCD SciDAC program in particle physics.

The USQCD Intensity Frontier program requires lattice QCD calculations of ever increasing precision to match the increasingly precise experiments. This requires development and deployment of improved algorithms, and the porting and optimizing of USQCD code to the latest and most capable hardware, such as the Blue Gene/Q and GPUs.



The SciDAC Layers and the software module architecture, http://www.usqcd.org/usqcd-software/ .

A fundamental component of the USQCD code base developed under SciDAC-1 and 2 is the QCD-API (left). It contains modules specific to QCD, such as QLA, a library of routines for performing linear algebra operations among the SU(3) matrices of QCD and the complex three-vectors representing quarks. The USQCD Energy Frontier software programs is extending this API to include modules for new gauge groups and representations beyond those found in QCD.

Collaborations and links to SciDAC Institutes

Work on multigrid algorithms is being performed in cooperation with the FastMATH SciDAC institute. The optimization of software for specific compute platforms is being coordinated with development teams of hardware manufactures at IBM, INTEL and NVIDIA. The teams in IBM and NVIDIA include trained lattice gauge theorists.

The software development performed by this project is coordinated with that of the Scidac-3 project "Computing Properties of Hadrons, Nuclei and Nuclear Matter from Quantum Chromodynamics". Both projects are part of the software development effort of the USQCD Collaboration, which consists of nearly all of the high energy and nuclear physicists in the United States working on the numerical study of lattice gauge theories. All software developments will be made publicly available through the USQCD collaboration WEB page (http://www.usqcd.org).