# Project Summary

This proposal requests an allocation on the NSF's petascale computing system, Blue Waters, in order to study quantum chromodynamics (QCD), the theory of the strong interactions of subatomic physics. Travel funds and early access to detailed information regarding the architecture of Blue Waters is also requested to assist in the development of efficient code for this computer by the time it is ready for production use. This proposal is submitted on behalf 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 QCD and other strongly coupled field theories of importance to these fields.

**Intellectual Merit:** The long term goals of high energy and nuclear physicists are to identify the fundamental building blocks of matter and to determine the interactions among them that give rise to the physical world we observe. Major progress has been made towards these goals through the development of the Standard Model, which encompasses our current knowledge of the fundamental interactions of physics. The Standard Model has been enormously successful in explaining a wealth of data produced in accelerator and cosmic ray experiments over the past thirty years; however, our knowledge of it is incomplete because it has been difficult to extract many of the most interesting predictions of QCD. To do so requires large scale numerical simulations in the framework of lattice gauge theory. A Target Problem is proposed that will have a transformational impact on the numerical study of QCD by for the first time enabling simulations at the physics masses of the up and down quarks, the two lightest of the six quarks that are the fundamental constituents of strongly interacting matter. Major objectives of the Target Problem are to 1) determine fundamental parameters of the Standard Model, such as the masses of quarks and the values of the weak transition couplings between them (elements of the CKM matrix); 2) make precise tests of the Standard Model and search for new physics beyond it; 3) calculate the masses, internal structure and interactions of strongly interacting particles. This work will provide critical input to major experiments in high energy and nuclear physics.

**Broader Impact:** The USQCD Collaboration has developed the QCD Applications Programming Interface (QCD API), a programming environment that enables lattice gauge theorists to develop highly efficient, portable code. It will be optimized for Blue Waters. The QCD API and community applications codes that are built on it will be used in the Target Problem. Since the QCD API and the community application codes are all publicly available and widely used, the impact of the code development effort will be much broader than the Target Problem. Similarly, it is the policy of the USQCD Collaboration to make all large data sets (gauge configurations and quark propagators) that it generates and save for physics analysis, publicly available. So, these data sets too will have a broader scientific impact than their role in the Target Problem.

Lattice QCD has been a fruitful training ground for doctoral and postdoctoral students. There are approximately seventy-five young scientists in training in this field in the United States at the present time. They will benefit from working on the Target Problem, and from the code and data sets produced by it. Those entering the field must obtain a broad knowledge of computer hardware and software, in addition to a solid background in physics. As a result, scientists trained in this field have a wide range of employment opportunities inside and outside of academia.