Center for Computational Sciences, University of Tsukuba
www.ccs.tsukuba.ac.jp

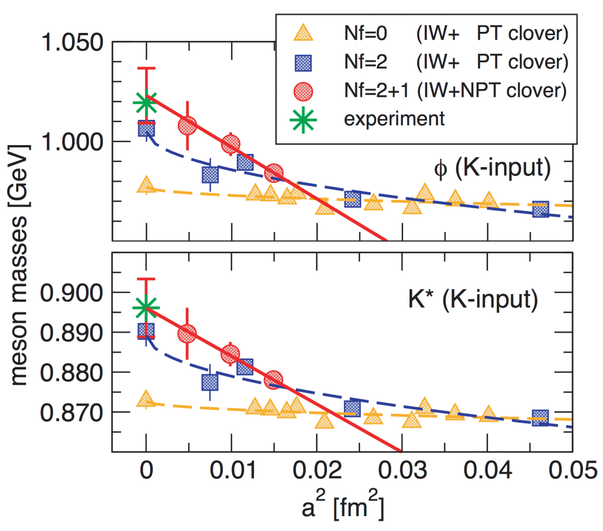
Research in Particle Physics (2)

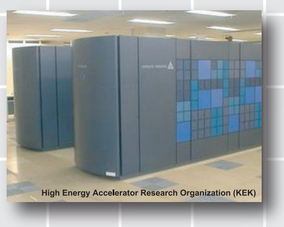
Toward a fully realistic simulation of QCD

The large scale simulations of QCD by the CP-PACS have shown the importance of dynamical quarks. In the two flavor simulations, while the dynamical effects of the light u, d quarks are incorporated, the third quark “s” is still treated in the quenched approximation. As the last step toward a fully realistic simulation of QCD, we are pushing forward 2+1 flavor full QCD simulations taking the dynamical effects of the s quark.

2+1 flavor QCD at intermediate quark masses

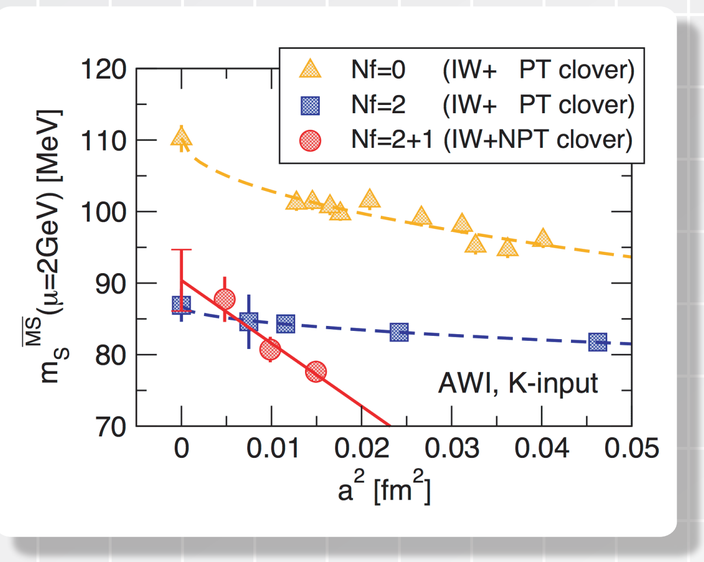
Restricting first ourselves to quark masses heavier than about 60 MeV, we have carried out a systematic study of 2+1 flavor QCD at three lattice spacings a ~ 0.076, 0.01, and 0.122 fm using a highly improved lattice QCD action. The physical point for light u and d quarks are extrapolated, and thar for the s quark is interpolated. For the project we have concentrated the computer power of CP-PACS at CCS, SR-8000 at CCS and KEK, VPP-5000 at ACCC, Univ. of Tsukuba, and the Earth-Simulator at the ES center. The total fraction of peak peformance for QCD was about 2.5 TFLOPS. (*CP-PAC/JLQCD Collaborations, 2006*)





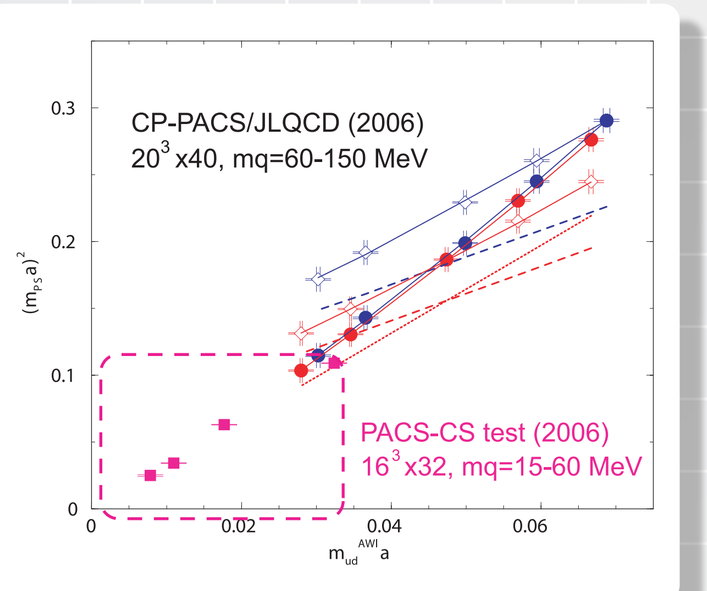
Experimental values of f and K* meson masses shown by stars are correctly reproduced by a continuum extrapolation of 2+1 flavor QCD simulation results (red circles) to the limit of vanishing lattice spacing a. This provides us with one of the most stringent test of QCD as the correct theory of quarks.

Because quarks are confined within hadrons, their fundamental properties such as masses have to be theoretically calculated from QCD. This figure shows the s quark mass determined in quenched QCD, two-flavor QCD, and the 2+1 flavor QCD. The full QCD results are much lower than the previous quenched value. In the continuum limit (a = 0), the s quark mass is about 90 MeV. This indicates the importance of dynamical quarks.



QCD directly at the physical point with the PACS-CS

The physical u and d quark masses are about 4 MeV. With the current method, enormous computer power required prevents us simulating QCD close to the physical point.



The high performance of the PACS-CS computer together with a recent development of new exact simulation algorithm DDHMC enables us to drastically push down the quark masses. The left figure shows the results of our test study down to 15 MeV, extending our previous study at mq > 60 MeV. The new data smoothly extend the previous results and show non-trivial quark mass dependences We are currently simulating at 7 MeV, and planning to study directly at the physical point mq ~ 4 MeV.