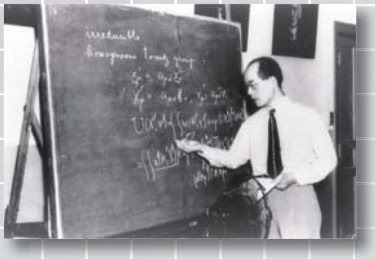
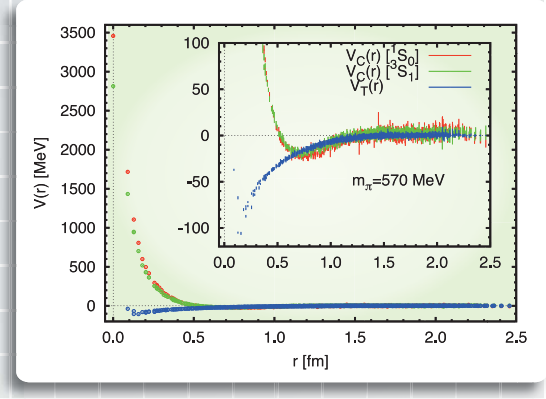
Research in Particle Physics (2)

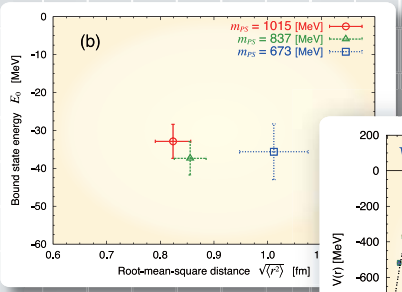
Nuclear Force Directly from Quarks

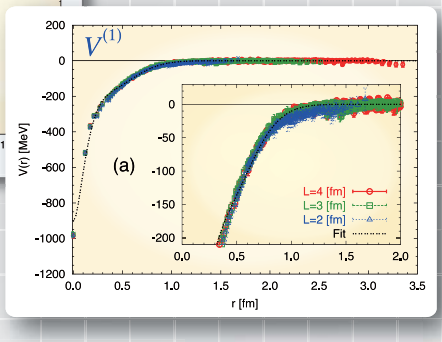


In 1935, Hideki Yukawa theoretically introduced π mesons to account for the nuclear force among protons and neutrons inside nuclei. Later it was found that the proton, the neutron and the π meson are all composed of more fundamental quarks. Due to high complexities of QCD, which governs the dynamics of quarks, however, it has been difficult to reproduce the nuclear force from quarks.

We have succeeded, for the first time, in unraveling the the nuclear force directly from lattice QCD. Extending our first study in 2007 using the quenched approximation, we studied the 2+1 flavor QCD and reproduced not only the Yukawa's force at long distances but also the strong repulsive core at short distances, as shown in the right figure [red: central force potential for spin 0 states, green: central force potential for spin 1 states, blue: tensor potential for spin 1 states]. Our calculation predicts absence of the repulsive core in the tensor potetial.







As an application of our method, the flavor-singlet 6 quark states, called H-dibaryon, is studied in flavor SU(3) limit of lattice QCD. The left figure shows that the flavor-singlet potential is insensitive to the spatial lattice extension L.
This potential leads to a bound H-dibaryon with the binding energy of 30-40 MeV, as shown in the rightfigure, where its size and binding energy are plotted at three different values of the pseudo-scalar meson mass.

Rho Meson Decay Width

Clarification of the decay of ρ mesons is a significant step for understanding the dynamical aspect of hadron reactions with lattice QCD.

The ρ meson decay width can be calculated from the scattering phase shift for the iso-triplet $(I = 1)$ two-pion system. The right figures show our results of the the scattering phase shift $(k^3/\tan\delta(k))/\sqrt{s}$ obtained at $m_\pi = 410$ MeV and at $m_\pi = 300$ MeV. Our result $\Gamma = 141 \pm 25$ MeV is consistent with the experimental value, 146.2 ± 0.7 MeV.