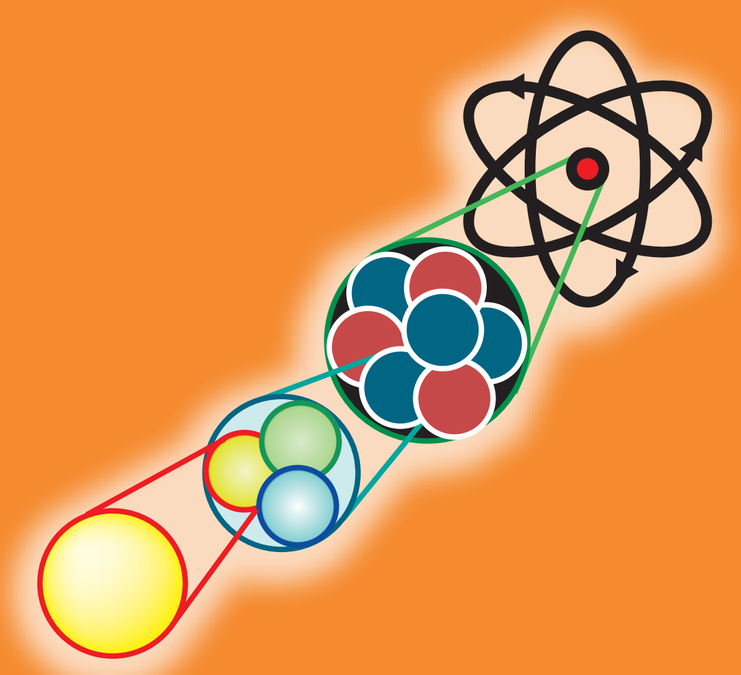
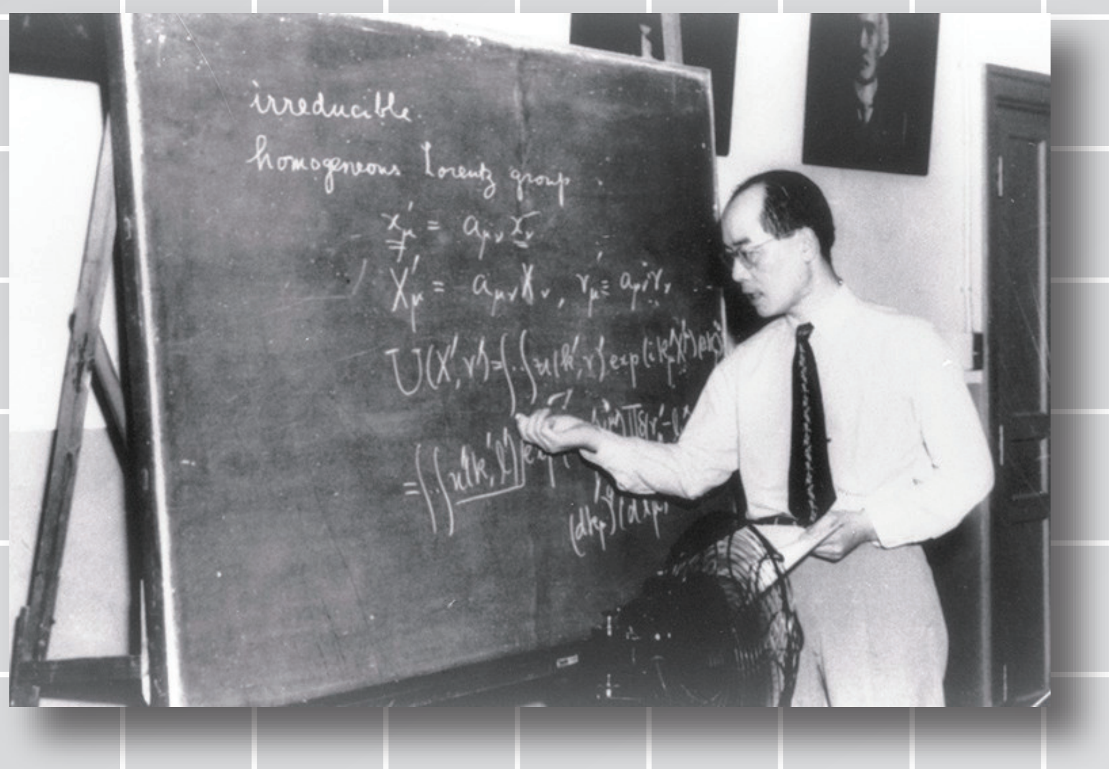
Center for Computational Sciences, University of Tsukuba
www.ccs.tsukuba.ac.jp



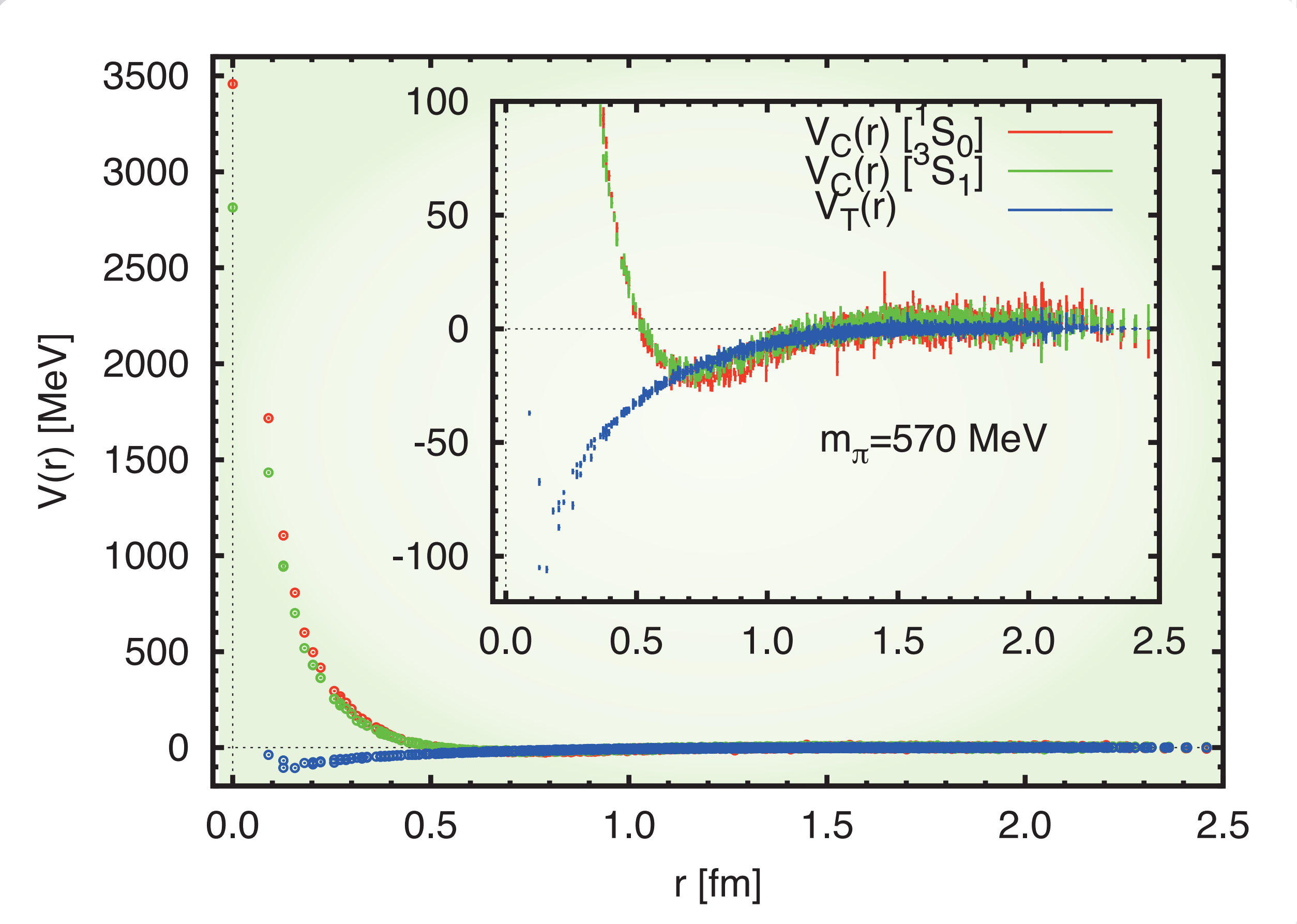
Research in Particle Physics (2)

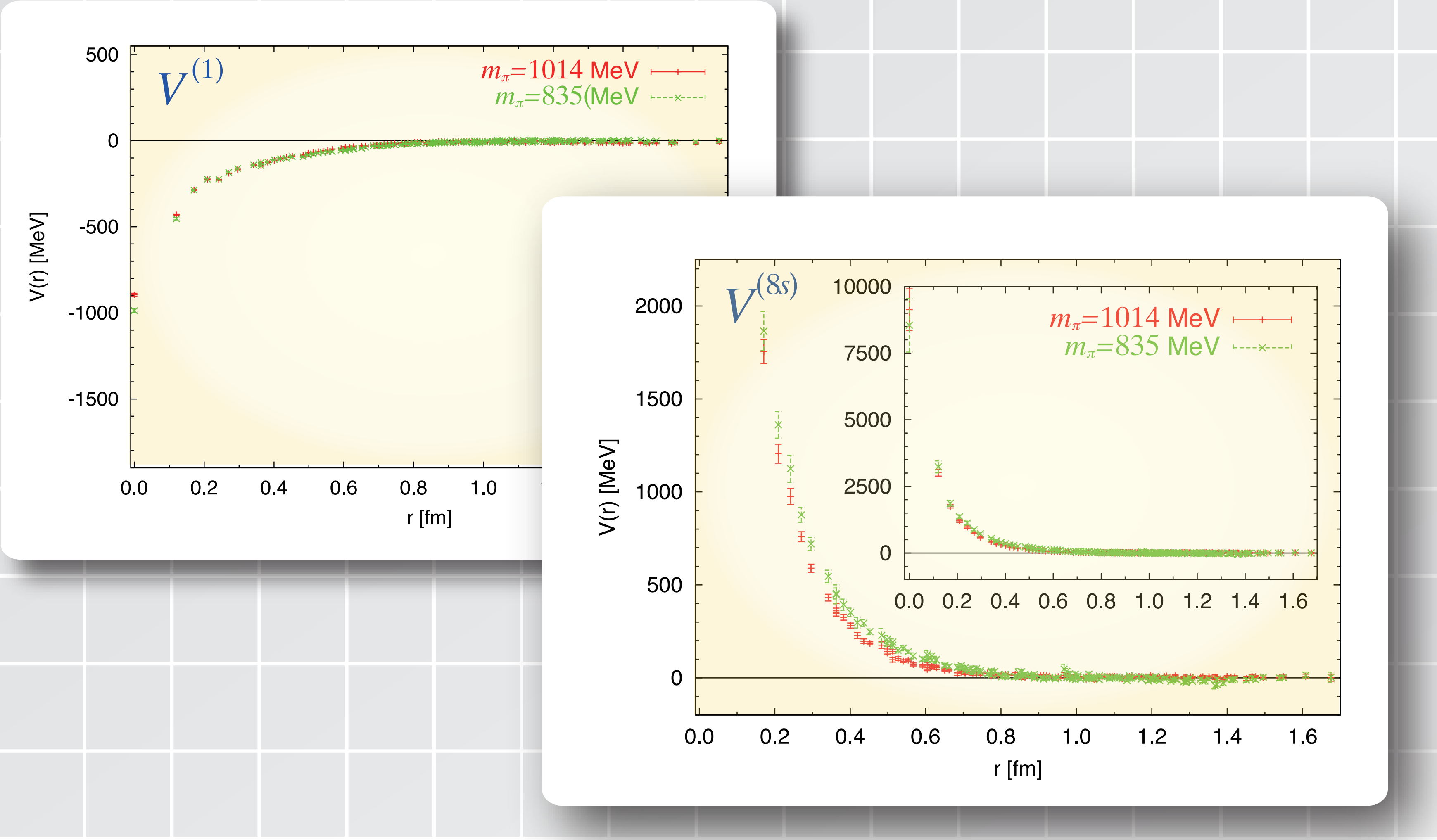
Nuclear force directly from quarks



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.





In order to explore the origin of the repulsive core, we further investigate general baryon-baryon (BB) interactions in three flavor QCD in which the masses for u, d and s quarks are set equal. We observe a strong flavor-dependence of BB potentials at short distances: In the left figures, a strong repulsive core appears in the flavor-octet potential $V^{(8s)}$, while an attractive core is formed in the flavor-singlet potential $V^{(1)}$.

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 Γ can be calculated from the scattering phase shift for the iso-triplet ($I = 1$) two-pion system. The right figure shows our result of the scattering phase shift $k^3/\tan\delta(k)$ obtained at $m_\pi = 410$ MeV. The ρ meson decay width is estimated from this data assuming a quark mass dependence of the phase shift. Our result $\Gamma = 110 \pm 22$ MeV is slightly smaller than the experimental value, 150 MeV. We are now carrying out simulations at $m_\pi = 300$ MeV which is closer to the physical point, to investigate a reason of the discrepancy.