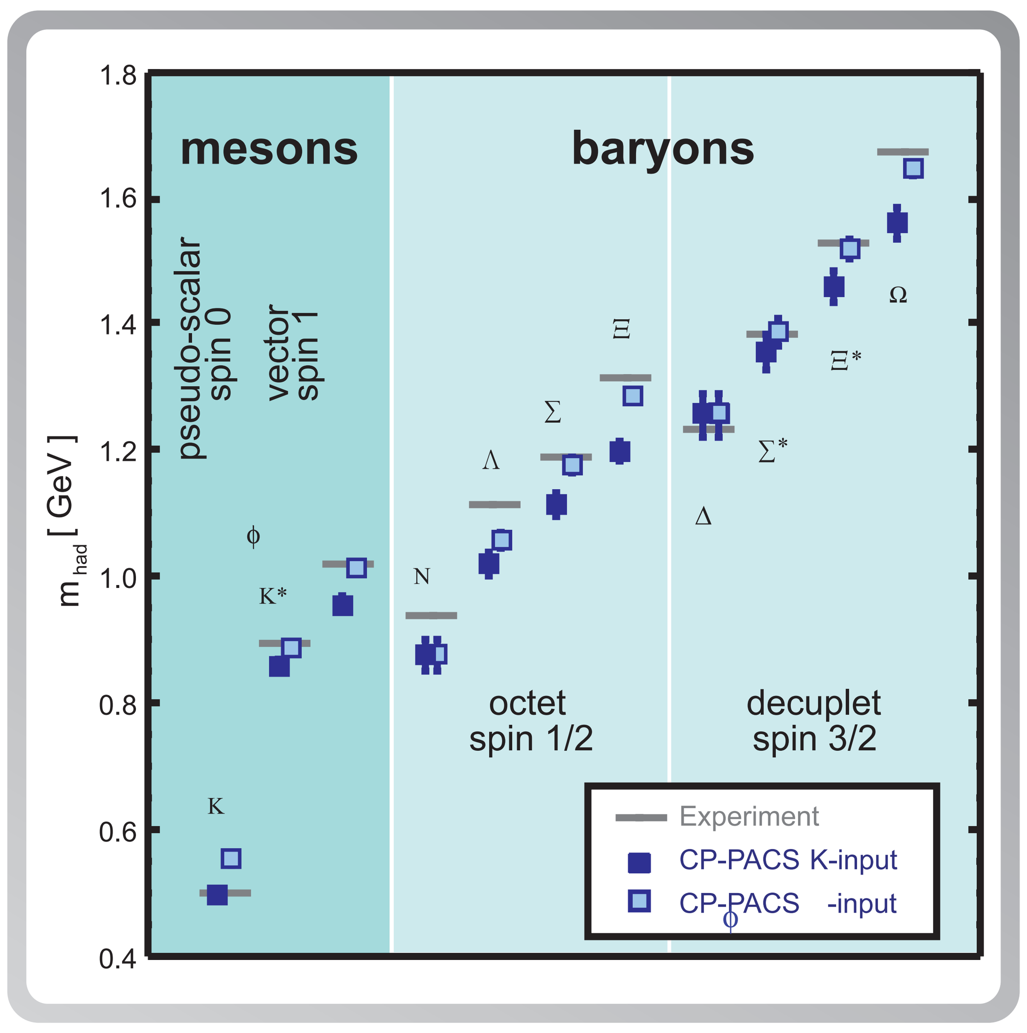
Research in Particle Physics (1)

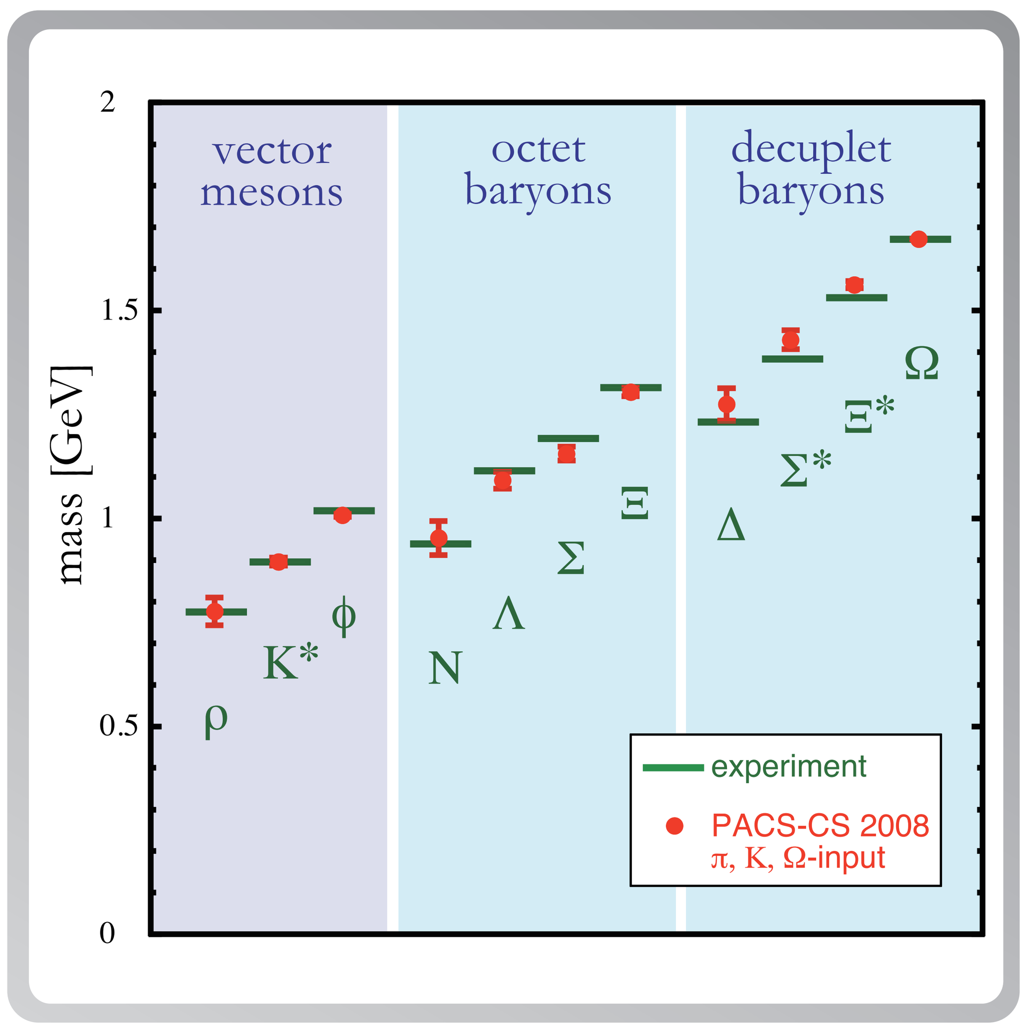
Prediction of Hadron Spectrum from QCD

Hadrons are the constituents of atomic nuclei. The computation of their mass spectrum from the quantum chromodynamics (QCD), the fundamental theory of quarks and gluons, has been a principal subject in particle physics. In this figure, our results are compared with experiment. Experimental results are reproduced within about 5-10%, critically proving the validity of QCD. At the same time, with the precision first achieved by the CP-PACS, a limitation of the widely accepted "quenched" approximation, in which dynamical quarks are neglected, was made clear, answering a question since 1981 about the effects of quenching.



2+1 Flavor QCD at the Physical Pont with PACS-CS and T2K

The deviation of quenched hadron spectrum from experiment was diminished in a succeeding 2 flavor QCD simulation with dynamical up and down quarks by the CP-PACS, thus proving the importance of dynamical quarks. The study was extended to 2+1 flavor QCD by incorporating the dynamical strange quark, though the degenerate up-down quark mass was more than 60 MeV, much heavier than the expected physical value of 3 MeV.



On the PACS-CS and T2K computers, we have succeeded in reducing the up-down quark mass down to less than 6 MeV. The left figure compares the light hadron spectrum extrapolated to the physical quark masses (physical point) with the experiment. Three physical inputs of the pion, the kaon and the omega baryon masses are employed to determine the physical up-down and strange quark masses and the lattice cutoff. Our results show good agreement with the experiment albeit errors are still not quite small for some of the hadrons.

So far our calculations have been carried out assuming an artificial isospin symmetry with degenerate up and down quark masses due to simlicities of simulation algorithm. In nature, however, the isospin symmetry is broken because of the up-down quark mass difference and their electric charge difference. Their effects are observed in mass splittings among isospin multiplets of light hadrons, e.g., $m_{K^0} - m_{K^\pm}$, $m_n - m_p$. The magnitude of splittings is very tiny yet important since, e.g., the inequality $(m_n - m_p)/m_p = 0.001378 > 0$ guarantees the stability of proton. Thus, we have embarked on 1+1+1 QCD+QED lattice simulation at the physical point incorporating the isospin breaking effects.The right figure plots the ratio of K^0 to K^+ propagators to detect their mass difference. Our results (black symbol) show a good consistency with the expected slope from the experimental value of $m_{K^0} - m_{K^\pm}$ (red line).