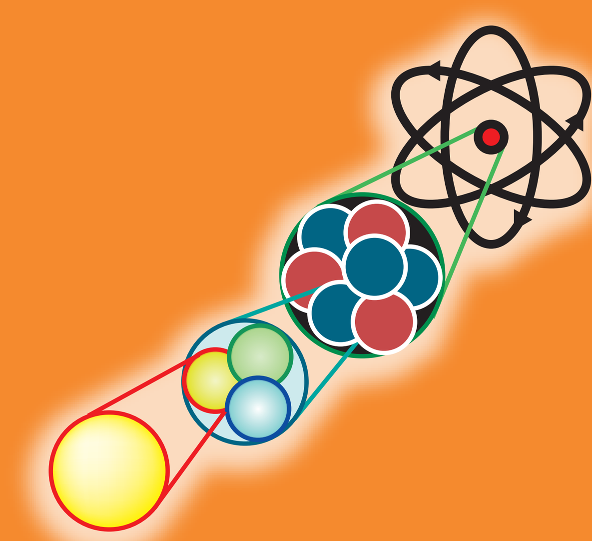
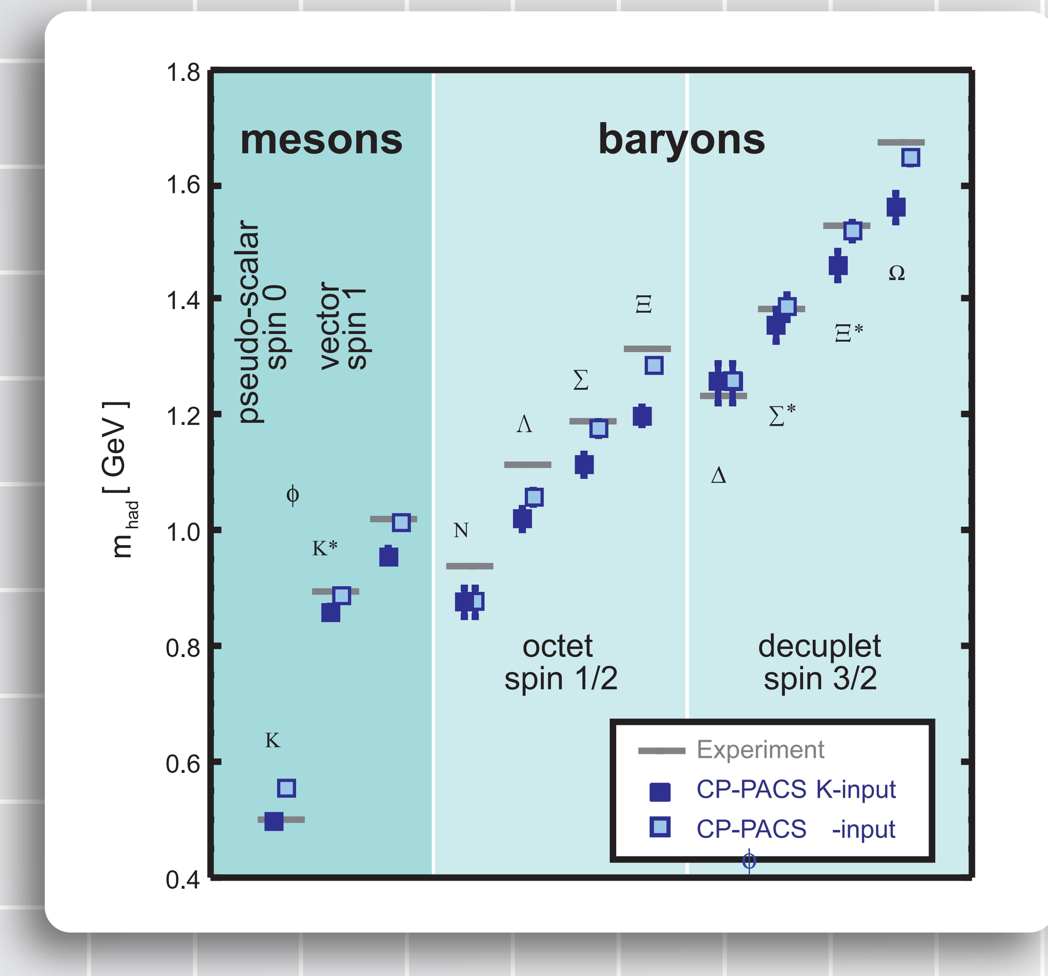


Research in Particle Physics (1)

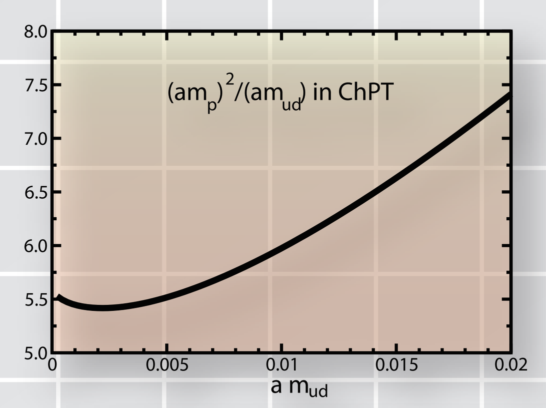
Prediction of hadron spectrum from QCD

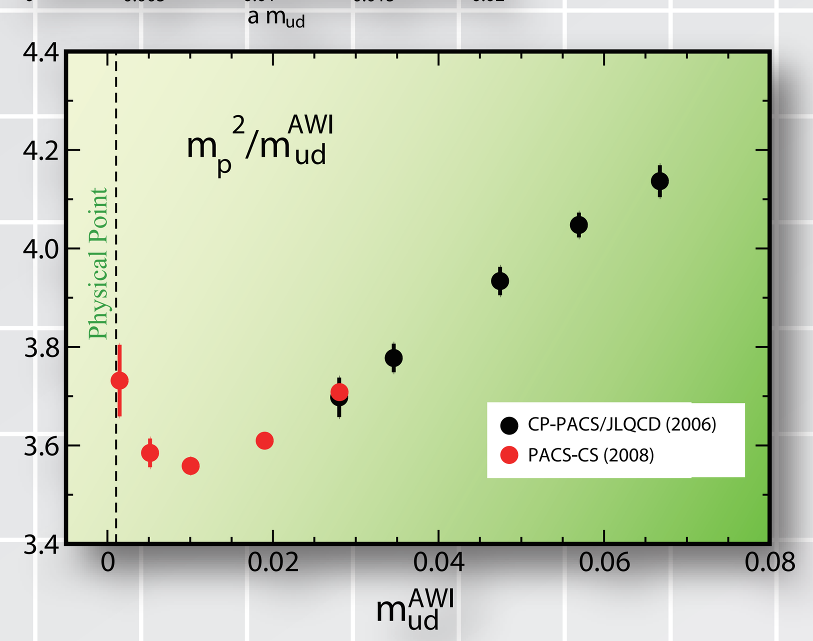
Hadrons are the constituents of atomic nuclei. The computation of their mass spectrum from the quantum chromodynamics (QCD), the fundamental theory of quarks and gluons, has been a principal subject in particle physics. In this figure, our results are compared with experiment. Experimental results are reproduced within about 5-10%, critically proving the validity of QCD. At the same time, with the precision first acheved 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 point 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 suceeded to reduce the up-down quark mass down to less than 6 MeV. The left figures compare the quark mass dependence of the pion mass and the pseudoscalar meson decay constants to the predictions from the chiral perturbation theory (ChPT), an effective theory of light hadrons. An important observation is that, while the previous results (black cirles) show almost linear quark mass dependence, we find clear curvatures at small up-down quark masses (red circles), which is qualitatively consistent with the chiral logarithm predicted by the ChPT (the upper panel).

The right 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.

We are now carrying out a simulation just on the physical point. A systematic study varing the lattice spacing is planned to remove remaining cutoff errors. We are also introducing the mass difference between up and down quarks, thus removing the last approximation.