Quarks, Hadrons and Dense Nuclear Matter

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These lectures introduce and summarize aspects of modern strong interaction physics relevant to some of the current trends in modern nuclear physics. In the first part, chiral dynamics is developed as a framework representing QCD with up-, down- and strange quarks at low energy. Recent progress in the application of chiral effective field theory to hadronic processes is summarized. The second part focusses on hadrons in dense baryonic matter, a topic of interest in high-energy heavy-ion physics and in the astrophysics of compact stellar objects. We summarize our present knowledge on issues such as the chiral (quark) condensate in dense and hot matter and possible in-medium changes of pseudoscalar and vector meson masses. Contact is made with present experiments and future projects.

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Peripheral Nucleon-Nucleon Phase Shifts and Chiral Symmetry ◇

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Within the one-loop approximation of baryon chiral perturbation theory we calculate all one-pion and two-pion exchange contributions to the nucleon-nucleon interaction. In fact we construct the elastic NN-scattering amplitude up to and including third order in small momenta. The phase shifts with orbital angular momentum $L \geq 2$ and the mixing angles with $J \geq 2$ are given parameterfree and thus allow for a detailed test of chiral symmetry in the two-nucleon system. We find that for the D-waves the 2π-exchange corrections are too large as compared with empirical phase shifts, signaling the increasing importance of shorter range effects in lower partial waves. For higher partial waves, especially for G-waves, the model independent 2π-exchange corrections bring the chiral prediction close to empirical NN phase shifts. We propose to use the chiral NN phase shifts with $L \geq 3$ as input in a future phase shift analysis. Furthermore, we compute the irreducible two-pion exchange NN-potentials in coordinate space. They turn out to be of van-der-Waals type, with exponential screening of two-pion mass range.

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The Reaction $\pi N \rightarrow \pi\pi N$ Above Threshold in Chiral Perturbation Theory

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Single pion production off nucleons is studied in the framework of relativistic baryon chiral perturbation theory at tree level with the inclusion of the terms from the dimension two effective pion-nucleon Lagrangian. The five appearing low-energy constants are fixed from pion-nucleon scattering data. Despite the simplicity of the approach, most of the existing data for total and differential cross sections as well as for the angular correlation functions for incoming pion kinetic energies up to 400 MeV can well be described.

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