Effective Field Theory for Few-Nucleon Systems[1]

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We review the effective field theories (EFTs) developed for few-nucleon systems. These EFTs are controlled expansions in momenta, where certain (leading-order) interactions are summed to all orders. At low energies, an EFT with only contact interactions allows a detailed analysis of renormalization in a non-perturbative context and uncovers novel asymptotic behavior. Manifestly model-independent calculations can be carried out to high orders, leading to high precision. We review the results obtained for a number of interesting processes, like the neutrino-deuteron cross sections (relevant to SNO) and $n+p \to d+\gamma$ (relevant for Big-Bang nucleosynthesis), as well as deuteron properties like electromagnetic form factors and polarizabilities. We also discuss the novel and unique features of the renormalization in the three-nucleon system, and use the power counting that follows from it to perform accurate calculations of neutron-deuteron elastic phase shifts.

At higher energies, an EFT that includes pion fields justifies and extends the traditional framework of phenomenological potentials. Chiral symmetry becomes relevant in this energy regime, and it is the key for a systematic expansion in powers of momenta and quark masses. The correct treatment ofchiral and other QCD symmetries ensures a connection with lattice QCD. We put particular emphasis on the conceptual issues of renormalization arising from the existence of singular potentials. We also discuss the results for a number of reactions, concentrating on those involving a real pion in the initial or final state, since those cannot be approached by the simpler "pionless" EFT. The differences and similarities to potential models are pointed out. Several tests and prospects of these EFTs are discussed.

The applications of the EFT ideas developed for nuclear physics to other fields like Bose-Einstein condensates in atomic traps are briefly described.

[1] Paulo F. Bedaque and U. van Kolck, to appear on Reviews on Nulcear and Particle Science