Chiral Dynamics and Nuclear Matter ◇

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We calculate the equation of state of isospin-symmetric nuclear matter in the three-loop approximation of chiral perturbation theory. The contributions to the energy per particle $\bar{E}(k_F)$ from one- and two-pion exchange diagrams are ordered in powers of the Fermi momentum k_F (modulo functions of k_F/M_π). It is demonstrated that, already at order $O(k_F^4)$, two-pion exchange produces realistic nuclear binding. The underlying saturation mechanism is surprisingly simple (in the chiral limit), namely the combination of an attractive k_F^3-term and a repulsive k_F^4-term. The empirical saturation point and the nuclear compressibility $K \cong 250$ MeV are well reproduced at order $O(k_F^5)$ with a momentum cut-off of $\Lambda \cong 0.65$ GeV which parametrizes short-range dynamics. No further short-distance terms are required in our calculation of nuclear matter. In the same framework we calculate the density-dependent asymmetry energy and find $A_0 \cong 34$ Me V at the saturation point, in good agreement with the empirical value. The pure neutron matter equation of state is also in fair qualitative agreement with sophisticated many-body calculations and a resummation result of effective field theory, but only for low neutron densities $\rho_n < 0.25\, fm^{-3}$.

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Isospin Breaking in Neutron β-Decay and $SU(3)$ Violation in Semi-Leptonic Hyperon Decays ◇

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Present precision measurements of the neutron life time lead to a CKM matrix element $|V_{ud}|$ which is three standard deviations off the value inferred from heavy quark decays etc. We investigate the possibility whether isospin-breaking effects in the neutron-to-proton vector current transition matrix element $\langle p|V_0^+|n\rangle = 1+\delta g_V$ could eventually close this gap. For that we calculate in chiral perturbation theory the effect of pion and kaon loops on the matrix element $\langle p|V_0^+|n\rangle$ taking into account the mass differences of the charged and neutral mesons. We find a negligibly small isospin-breaking effect of $\delta g_V \cong -4.10 \cdot 10^{-5}$. The crucial quantity in the analysis of neutron beta-decay precision measurements is thus the radiative correction term Δ_R. Furthermore, we calculate in heavy baryon chiral perturbation theory the $SU(3)$ breaking effects on the vector transition charges of weak semi-leptonic hyperon decays. We find for these quantities channel-dependent relative deviations from the $SU(3)$ limit which range from -10% to $+1\%$.

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Chiral Corrections to Kaon-Nucleon Scattering Lengths ◇

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We calculate the threshold T-matrices of kaon-nucleon and antikaon-nucleon scattering to one loop order in $SU(3)$ heavy baryon chiral perturbation theory. To that order the complex-valued isospin $1\bar{K}N$ threshold T-matrix can be successfully predicted from the isospin 0 and $1KN$ threshold matrices. As expected perturbation theory fails to explain the isospin $0\bar{K}N$ threshold matrix which is completely dominated by the nearby subthreshold $\Lambda(1405)$-resonance. Cancelations of large terms of second and third chiral order are observed as they seem to be typical for $SU(3)$ baryon chiral perturbation theory calculations. We also give the kaon and eta loop corrections to the πN scattering lengths and we investigate $\pi\Lambda$ scattering to one-loop order. The second-order s-wave low-energy constants are all of natural size and do not exceed 1 GeV^{-1} in magnitude.

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