HK 10: Struktur und Dynamik von Kernen

Zeit: Montag 16:30–19:00 Raum: RW 3

Gruppenbericht HK 10.1 Mo 16:30 RW 3

Chiral Fermi liquid description of nuclear matter — •Jeremy Holt, Norbert Kaiser, and Wolfram Weise — Technische Universität München

We employ Landau's theory of normal Fermi liquids to study the bulk properties of nuclear matter with high-precision two- and three-nucleon interactions derived within the framework of chiral effective field theory. The $L = 0, 1$ Landau parameters, characterizing the isotropic and p-wave interaction between two quasiparticles on the Fermi surface, are computed to second order in many-body perturbation theory (MBPT) with chiral and low-momentum two-nucleon forces. Already at this order a number of observables are well described in the theory, including the nuclear isospin asymmetry energy, the quasiparticle effective mass and the spin-isospin response. An adequate description of the nuclear compression modulus (encoded in the Landau parameter F_0) requires the inclusion of the leading-order (N^2LO) chiral three-nucleon force, which we include to first order in MBPT. The remaining $L = 0$ Landau parameters receive only small corrections from the chiral three-nucleon force, and the $L = 1$ parameters are all reduced, resulting in an effective interaction of apparent short range. We then employ renormalization group techniques to study the scale dependence of the quasiparticle interaction, which allows for an estimation of theoretical uncertainties.

Work supported in part by BMBF, GSI and by the DFG cluster of excellence: Origin and Structure of the Universe.

Gruppenbericht HK 10.2 Mo 17:00 RW 3

Ab-Initio Theory of Medium-Mass Nuclei with Normal-Ordered Chiral NN+3N Interactions — •Sven Binder, Joachim Langhammer, Angelo Calci, Klaus Vobig, and Robert Roth — Institut für Kernphysik, Technische Universität Darmstadt

We study the use of truncated normal-ordered three-nucleon interactions in ab initio nuclear structure calculations starting from chiral two- plus three-nucleon Hamiltonians evolved consistently with the similarity renormalization group (SRG). We present three key steps: (i) a rigorous benchmark of the normal-ordering approximation in the importance-truncated no-core shell model (IT-NCSM) for ^{4}He, ^{16}O, and ^{40}Ca; (ii) a direct comparison of the IT-NCSM results with coupled-cluster calculations at the singles and doubles level (CCSD) for ^{16}O; and (iii) first applications of SRG-evolved chiral NN+3N Hamiltonians in CCSD for the medium-mass nuclei ^{16,24}O and ^{40,48}Ca. We show that the normal-ordered two-body approximation works very well beyond the lightest isotopes and opens a path for ab initio studies of medium-mass and heavy nuclei with chiral two- plus three-nucleon interactions. For low-lying excited states and collective excitations we present first applications of the EOM-CCSD method, which is superior to RPA-type approaches.

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HK 10.3 Mo 17:30 RW 3

Resummations and chiral dynamics of nuclear matter — •Sebastian Schultess, Nobert Kaiser, and Wolfram Weise — Physik-Department, Technische Universität München, 85748 Garching, Germany

The equation of state of isospin-symmetric nuclear matter and pure neutron matter is calculated to three-loop order with in-medium chiral perturbation theory, taking into account also two-pion exchange with Δ-isobar excitations. The large empirical S-wave NN-scattering lengths, $a_s = 19\,\mathrm{fm}$ and $a_t = -5.4\,\mathrm{fm}$, require a non-perturbative treatment via a resummation of ladder diagrams to all orders. Our resummation method includes (combined) particle-particle and hole-hole rescatterings in the medium. The remaining short range part of the interaction is described by adjustable (p^2-dependent) NN-contact terms.

In this framework the saturation properties of symmetric nuclear matter can be well reproduced and the nuclear matter compressibility takes on an improved value in comparison to earlier calculations without resummations. The neutron matter equation of state is particularly improved by the resummations. At low densities the energy per particle follows one half of the kinetic energy, which is a feature of the unitary fermi gas. The results of sophisticated neutron matter calculations can be reproduced up to high neutron densities $\rho_n = 0.4\,\mathrm{fm}^3$.

Work supported in part by BMBF, GSI and the DFG Cluster of Excellence "Origin and Structure of the Universe".

HK 10.4 Mo 17:45 RW 3

Topological phases for bound states moving in a finite volume — •Shahin Bour Bour[1], Dean Lee[2], Hans-Werner Hammer[1], Ulf-G. Meissner[1], and Sebastian König[1] — [1]Helmholtz-Institut für Strahlen- und Kernphysik und Bethe-Center for Theoretical Physics, Universität Bonn — [2]Department of Physics, North Carolina State University, Raleigh, NC 27695, USA

We show that bound states moving in a finite periodic volume have an energy correction which is topological in origin and universal in character. The topological volume corrections contain information about the number and mass of the constituents of the bound states. These results have broad applications to lattice calculations involving nucleons, nuclei, hadronic molecules, and cold atoms. We illustrate and verify the analytical results with several numerical lattice calculations.

[1] Phys. Rev. D 84, 091503(R) (2011), arXiv:1107.1272v2

HK 10.5 Mo 18:00 RW 3

Consistent SRG transformed chiral two- plus three-body interactions — •Angelo Calci, Joachim Langhammer, Sven Binder, and Robert Roth — Institut für Kernphysik, Technische Universität Darmstadt

Chiral effective field theory provides two- (NN) and three-body (3N) interactions from QCD in a consistent manner. We employ these interactions in ab initio nuclear structure calculations within the importance-truncated no-core shell model (IT-NSCM) using an additional Similarity Renormalization Group (SRG) transformation to improve convergence. Formally, the SRG induces irreducible many-body contributions, which nowadays can be included up to the three-body level. Using a flow-parameter analysis we show that the conventional SRG evolution induces sizeable many-body contributions for nuclei in the mid-p-shell and beyond. We demonstrate that the induced many-body contributions originate from the two-pion exchange terms of the initial 3N interaction. Finally, the suppression of the induced many-body contributions either by an alternative formulation of the SRG or by a modification of the initial chiral interactions is discussed. This opens an opportunity to universal applications of chiral 3N interactions in nuclear structure.

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HK 10.6 Mo 18:15 RW 3

Relativistic Quasi-Particle Interaction in Nuclear Matter — •Andreas Fedoseew, Julian Georg, and Horst Lenske — Institut für Theoretische Physik, Justus-Liebig-Universität Giessen, Heinrich-Buff-Ring 16, D-35392 Giessen

We present a generalized Dirac Fermi-Liquid Theory for nuclear matter. The concept of quasi-particle residual interaction is extended to a fully covariant and thermodynamically consistent field theory. In our calculation we use the ab initio Lagrangian of the Giessen Density Dependent Relativistic Hadron (DDRH) field theory for the NN interaction. With this approach higher order corrections to the common quasi-particle interaction are included. We discuss self-consistent relativistic RPA calculations for response functions of asymmetric nuclear matter and finite nuclei. Applications to quasielastic (e, e') scattering and charge-changing current reactions will be presented.

Supported by HIC for FAIR and GSI.

HK 10.7 Mo 18:30 RW 3

Neutral pion photoproduction on the trinucleon in ChPT — •Mark Lenkewitz[1], Evgeny Epelbaum[2], Hans-Werner Hammer[1], and Ulf-G. Meissner[1] — [1]Helmholtz-Institut für Strahlen- und Kernphysik und Bethe-Center for Theoretical Physics, Universität Bonn — [2]Institut für Theoretische Physik II, Ruhr-Universität Bochum

Threshold pion photoproduction on the trinucleon is investigated in the framework of baryon ChPT at next-to-leading one-loop order in the chiral expansion. To this order in small momenta, the production operator is a sum of one- and two-nucleon terms. We calculate the expectation value of the production operator using chiral wave func-

tions in a manifestly three-dimensional approach without partial wave expansion. The resulting integrals are evaluated using Monte Carlo integration.We obtain results for the threshold production multipoles on 3He and 3H and comment on the sensitivity to the fundamental neutron amplitude.

[1] M. Lenkewitz, E. Epelbaum, H.-W. Hammer, Ulf-G. Meißner, Phys. Lett. B 700 (2011) 365. http://arxiv.org/abs/1103.3400

HK 10.8 Mo 18:45 RW 3

Constraining the in-medium hyperon-nucleon interactionin heavy-ion collisions — •Theodoros Gaitanos, Anika Obermann, and Horst Lenske — Institut für Theoretische Physik, Universität Giessen, Germany

The knowledge of the strangeness sector of strong interactions is important for our understanding of hadron dynamics. It is still a widely debated topic how the hyperon-nucleon interaction is modified inside a dense hadronic environment. From our recent in-medium T-matrix calculations for hyperon-nucleon scattering with strangeness exchange, e.g., $\Sigma^+ n \to \Sigma^0 p, \Lambda p$, we determine the in-medium modifications of cross sections at finite baryon density. The results are used in intermediate energy heavy-ion collisions, which offer an unique opportunity to investigate this issue in the laboratory. Indeed, precise data on $K^{0,+}$ and $\Lambda + \Sigma^0$ production exist and can help us to study the in-medium modifications of the hyperon-nucleon interaction with strangeness exchange. We apply a relativistic Boltzmann-like transport approach, which incorporates a perturbative propagation of particles with finite strangeness (positive and neutral kaons with $S = 1$ and hyperons with $S = -1$) under the influence of chiral potentials for the kaons and hyperons self-energies. Our calculations shows that strangeness production in heavy-ion collisions is a sensitive tool for investigations of in-medium YN- and YY-interactions. We compare transport theoretical results on strangeness yields and their rapidity distributions with data and discuss in particular the high density properties of YN-interactions, entering e.g. also into neutron star calculations.