Institute for Theoretical Physics I

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

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JUSTUS-LIEBIG-
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Preface

The present booklet gives a review of the research program of the Hadron and Nuclear Physics Group of the Institute for Theoretical Physics at the University of Giessen. The program focuses on Hadron and Nuclear Physics in a wide range, with an emphasis on problems at the borderline between nuclear and particle physics. In particular, we try to stress the common physics basis in such seemingly disjunct areas as heavy-ion, photo-nuclear and nuclear structure physics.

All research is done with and by young graduate and postgraduate students, as well as young postdocs and 'Assistant Professors' (Privatdozenten). It is embedded into the *European Graduate School Giessen-Copenhagen "Complex Systems of Hadrons and Nuclei"* which we operate together with colleagues from the Niels-Bohr-Institute and NORDITA. This Graduate School – through its specialized postgraduate course program – provides the ideal complement to our research program: Science and Teaching go together! The group is also an essential part of the newly approved *Marie Curie Training Site for Hadron Physics* which provides access to this postgraduate education also for foreign students from the EU and its associated partners. Internationalization of the university education is for us no longer merely a declaration of intent, but has been the reality for many years.

Our research would not have been possible without considerable and flexible funding from outside sources, all after a thorough and critical evaluation process through the funding agencies. Our particular thanks go to the Bundesministerium für Bildung und Forschung (BMBF) and to GSI Darmstadt, to which we have close, longstanding scientific connections. We are also grateful to the Deutsche Forschungsgemeinschaft (DFG) as well as to the FZ Jülich for continuing support. All this funding is in a period of drastically shrinking basic support for physics not only welcome, but absolutely essential.

Ulrich Mosel

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1 Photonuclear Physics

High-energy photons, real or virtual ones, offer a precise probe for nuclear properties and processes. Reactions initiated by such photons on nuclei are often more sensitive to detailed properties of hadrons in the nuclear medium than heavy-ion reactions, and they proceed closer to the groundstate of nuclear matter. We have, therefore, continued our studies of photo- and electron-induced particle production on nuclei, of properties of hadrons in nuclei, and of total photoabsorption cross sections.

1.1 Meson production

At photon energies of a few hundred MeV, as they are being used in experiments at MAMI, the description of meson production experiments has been at the center of our interest. Here we have used the semiclassical transport codes, originally developed for the description of heavy-ion collisions, to describe the all-important final state interactions of the produced particle on its way out of the nuclear medium. A comparison with photo- and electroproduced pion data has been very successful; the same is true for the 2π and η data obtained by the TAPS collaboration at MAMI. The total cross sections of η-mesons, for example, are described very well. The energy- and angle-differential cross sections, however, do show deviations from the theoretical results; these may be used to infer the in-medium cross sections for interactions between unstable mesons and nucleons.

1.1.1 In-medium Resonances and Photoabsorption

Photoabsorption experiments on nuclei in the Δ resonance region have shown that the total cross sections scale with the nuclear mass number. More recent experiments at higher energies have shown, however, that at higher energies this scaling no longer holds. In particular, the peak in the photoabsorption cross section in the second resonance region, apparently dominated by the $D_{13}\, N(1520)$ resonance of the nucleon, disappears in nuclei. Fits of these data with simple resonance models showed that the width of the resonance would have to at least double in order to make the resonance peak disappear.

This picture is surely oversimplified: the energetic opening of the 2π channel just coincides with the $N(1520)$ region and contributes to the apparent resonance structure. Nevertheless, we have concentrated on an investigation of the origins of a possible broadening of the nucleon resonance. One intriguing possibility is its coupling to the ρN channel, which coupled channel analyses predict to be large, even though the $N(1520)$ resonance lies nominally below threshold. Any coupling of the ρ meson in medium to a $N(1520)-$ *nucleon hole* configuration will thus lead to a lowering of the ρ meson's spectral function and, in a second order effect, to a considerable broadening of the resonance.

In response to a result of the TAPS collaboration that showed no broadening of the resonance structure in the exclusive single pion production on nuclei in the relevant energy range, we have shown that indeed the resonance broadening can only be seen in inclusive photoabsorption data, because any collisional broadening, being proportional to the nuclear density ρ, will suppress the high-density region. On top of that, also the strong absorptive final state interactions will lead to a preference of single pion emission from the surface (low-density) region.

1.2 Shadowing

At higher bombarding energies, from about 1 GeV photon energy on upwards, shadowing becomes important, as experiments at MAMI and ELSA have shown. This shadowing has long since been known to be an effect of quantum mechanical interference of different scattering amplitudes of the 'bare' photon and its hadronic constituents. We have been able to show that a multiple scattering approach (Glauber-Gribov) can indeed explain the early onset of shadowing. Essential here is, in contrast to the situation at higher energies, also the real part of the vector meson scattering amplitude.

We have now combined this description of quantum mechanical coherence in the entrance channel with the incoherent treatment of the final state interactions of the outgoing particle. We do this by calculating first a space- and flavour-dependent 'shadowing function' that gives the probability for the initial electromagnetic process on a given nucleon. The produced particles are then propagated in a coupled channel transport theory that contains baryon, meson and string excitations. The coupled channel treatment here is all-important: the final, observed particles may not only be produced by the initial interaction, but also by secondary processes through a side feeding. Any description that neglects this possibility, like in a Glauber model, may lead to incorrect conclusions about formation times of hadrons in medium and possible colour transparency.

2 Hadron and Quark Physics

The intention of our investigations is to understand the interactions among hadrons and their internal quark structure. The interactions and internal structure mutually influence each other. Therefore one expects that the properties of a hadron changes once it is put in a hadronic medium it can interact with. Similarly one can also investigate the properties of quarks in a quark medium. All these aspects are studied in our group.

2.1 Elementary interactions between hadrons

Concerning the interaction among hadrons it has turned out that various hadronic reaction channels cannot be treated separately from each other due to rescattering effects. The coupled-channel K-matrix approach including on equal footing the channels (π, N), (γ, N), (η, N), (K, Λ), (K, Σ) and $(2\pi, N)$ has recently been extended to include also (ω, N) and the $J = 5/2$ nucleon resonances. In this way cross sections can be calculated up to an invariant mass of 2 GeV and the question which resonances couple to the (ω, N) channel could be tackled. This is e.g. interesting for in-medium calculations for vector mesons (see below). In general, the ingredients for the description of meson-nucleon and photon-nucleon interactions are coupling constants and resonance masses. If single reactions were treated separately from each other, one would have a lot of freedom for choosing the input parameters. Hence the predictive power of such an approach and the understanding of the relevant physics would be low. In contrast, our coupled-channel approach allows to highly constrain these input parameters as a lot of channels (i.e. data) have to be explained with the same parameter set. This opens the door for a deeper understanding of the reaction mechanisms and the properties of the relevant degrees of freedom.

2.2 Quark model predictions for hadrons

The influence of spontaneous chiral symmetry breaking on the properties of hadrons is a central question of hadron physics. We used a chiral quark model to calculate specific quantities (pion-pion and pion-photon vertices) which presumably are insensitive to confinement. The vertices were also calculated within a phenomenological hadronic meson exchange model. By matching the expressions for the vertices from the two models one gets quark model predictions for the masses and coupling constants of the mesons. Specifically we considered rho and a_1 meson exchange. The resulting rho and a_1 masses and coupling constants are in reasonable agreement with experiment.

2.3 In-medium spectral functions

2.3.1 Vector Mesons.

Once hadrons are put in a nuclear environment their properties like masses and life times change due to the reactions with the medium. To be detected, however, the hadron has to leave the medium and reach the detector. On this journey the mass, e. g., of the hadron changes from its in-medium to its vacuum value. Thus at least a part of the in-medium information is lost. A promising alternative is to observe not the hadron directly but rather a decay product which does not interact any more. Such a scenario is realized by vector mesons decaying into dileptons which carry information about the in-medium vector meson mass to the detector. This has triggered a lot of theoretical interest in the in-medium properties of vector mesons. In our approach to this problem we study the properties of rho and omega vector mesons put (for simplicity) in infinite nuclear matter. We are aiming at the in-medium mass distributions (spectral function) of the vector mesons. The most important reaction mechanism for nucleon-rho meson collisions is the formation of baryonic resonances in the 1.5 to 2 GeV region. These lead to a significant broadening of the rho spectral function and to interesting new structures. Recently we have extended this approach to a relativistic treatment of the interactions between nucleons, rhos and resonances. We also study the consequences of the fact that in-medium modified vector meson properties in turn change the properties of the baryonic resonances.

2.3.2 Nucleons

Nuclear spectral functions, i.e. the energy-momentum distributions of nucleons in nuclear matter and finite nuclei, have long been studied experimentally in $(e, e'p)$ reactions. Theoretical studies of these functions have been performed in the framework of state-of-the-art, complex and time-consuming many-body calculations. We have now shown that these spectral functions in the hole sector can be surprisingly well described by just one parameter, the average strength of the short-range correlations. This strength determines the interaction rate in a self-consistent treatment of the scattering rates between collision-broadened particles. Thus, hole spectral functions and the connected nucleon momentum distributions in nuclei do not depend on any details of the interaction and the correlation, but offer instead a direct access to the average short-range correlations.

2.3.3 Quarks

Finally we have studied in-medium strong interactions on a more elementary level: While free quarks, if they existed as stable states, would by construction have a delta type spectral function, quarks in a medium experience collisional broadening. The scattering rates which determine the spectral function depend recursively on the spectral functions of the interacting particles. This recursion problem is solved in a self-consistent way for a simple four-point type quark interaction. This enables us to study the properties of quarks in hadronic matter, i. e. in-medium effects on the elementary degrees of freedom.

3 Relativistic Heavy Ion Physics

The microscopic theory of nucleus-nucleus collisions can be based on relativistic transport equations of the various hadronic reactions for either hadrons or quarks/diquarks (‘string-like’ excitations) at higher center of mass energies. Of particular interest are the collective properties of such reactions like the production of strangeness or charm quarks. The prominent aim in the experiments carried out at ultrarelativistic energies is the search for a new state of matter, the quark-gluon plasma (QGP), where the quark and gluon degrees of freedom are deliberated over a macroscopic space-time region.

3.1 Heavy-ion collisions at SIS energies

3.1.1 Particle production

An outstanding problem of relativistic heavy ion collision theory is the correct description of the pion yield in nuclear collisions between heavy reaction partners. Here the calculated yield exceeds the measured pion numbers by up to a factor of 2. We have attacked this problem by studying to which physical processes the observed pion yield is actually sensitive. Since pion production proceeds close to thermal equilibrium, simple changes in the collision rates do not suffice to suppress the calculated pion number. However, by quenching the initial Δ population at high densities we have been able to show that this lowers the calculated pion number significantly.

3.1.2 Dileptons

In continuation of our earlier work on predicting cross sections for HADES and related experiments we have performed calculations of the dilepton yield both for $p + p$ and $p + A$ reactions, which can serve as a basis for the upcoming HADES experiments. With these studies we have complemented our earlier calculations of dileptons produced in $A + A$ and $\pi + A$ reactions. As in these also in $p + A$ there should be an observable consequence of possible in-medium mass shifts of vector mesons.

3.1.3 Off-shell transport of particles

Changing from the reaction of hadrons with infinite nuclear matter to the more realistic albeit more complicated case of the reaction with finite nuclei, one has to switch from in-medium hadron field theory to a quasi-classical kinetic description keeping some of the quantum aspects. Especially resonances with their broad mass distribution constitute an important ingredient in this framework. We have investigated how such resonances can be properly incorporated in a kinetic description.

From the underlying quantum-field theory we have derived expressions for the resonance cross sections and resonance life times. Using a numerical implementation of the this new formalism, we have focused in particular on experimentally observable consequences on the Delta resonance. This resonance is formed in pion-nucleon collisions and is important, e.g., for the understanding of pion-nucleus reactions.

Our method how to propagate off-shell, collision-broadened particles so that they retain their correct asymptotic free behavior is general. It can be applied to nucleons and mesons, but also to partons.

3.2 Particle production at SPS and RHIC energies

3.2.1 Antihyperons and antiprotons

We have elaborated on our recent suggestion on antihyperon production in ultrarelativistic heavy ion collisions solely by means of multi-mesonic (fusion-type) reactions.

Strangeness enhancement has been predicted a long time ago as a diagnostic probe to prove for the short-time existence of a QGP. With respect to the high production thresholds in the various binary hadronic reaction channels, especially the antihyperons were then advocated as the appropriate candidates. Indeed the existence of nearly chemically saturated populations of the antihyperons has been experimentally demonstrated with the Pb+Pb experiments at CERN-SPS.

Within the newly proposed mechanism we have shown that the antihyperons are driven towards chemical equilibrium with pions, nucleons and kaons on a timescale of 1–3 fm/c in a still moderately baryon-dense hadronic environment without the need of a temporary QGP state. Explicit rate calculations for a dynamical setup were carried out and detail the proposed picture. For an estimated entropy per baryon of $S/A \approx 30 - 40$ at maximum SPS energies yields of each antihyperon species are obtained which are consistent with chemical saturated populations at $T \approx 150 - 160$ MeV, thus supporting the chemical freeze-out for the antibaryons at such a temperature. The production process should also dominate at AGS energies and at energies of possible future heavy ion facilities at GSI.

We have implemented these 'back-reactions' of the strong baryon-antibaryon annihilation in the present transport code. First results concerning the production of anti-protons at AGS and SPS energies are quite impressive. It is found that the abundances as observed from peripheral to central collisions can approximately be described on the basis of such multiple interactions of formed hadronic states which drive the system to chemical equilibrium by flavor exchange or quark rearrangement reactions.

3.2.2 Open charm

In the last decade the interest in hadronic states with charm flavors $(c, \bar{c})$ has risen continuously in line with the development of new experimental facilities. This relates to the elementary charm production cross section in pN and πN reactions as well as to their interactions with baryons and mesons which determine their properties (spectral functions) in the hadronic medium. The charm quark degrees of freedom play an important role especially in the context of a phase transition to the quark-gluon plasma (QGP) where it was expected that charmonium ($c\bar{c}$) states could no longer be formed due to color screening.

However, the suppression of J/Ψ and Ψ' mesons in the high density phase of nucleus-nucleus collisions seen by the NA50 Collaboration at the SPS might also be attributed to inelastic comover scattering provided that the corresponding J/Ψ-hadron cross sections are in the order of a few mb. Present theoretical estimates here differ by more than an order of magnitude, especially with respect to J/Ψ-meson scattering. On the other hand, the enhancement of 'intermediate-mass dileptons' in $Pb + Pb$ collisions at the SPS has been tentatively attributed to an enhancement of 'open charm' in nucleus-nucleus collisions relative to pA reactions at the same invariant energy by the NA50 Collaboration. Thus charmonium suppression and open charm enhancement are present facets of relativistic heavy-ion collisions, which provide a theoretical and experimental challenge for the future.

In our previous transport studies on $D\bar{D}$ meson production and propagation in nucleus-nucleus collisions from $\sim$ 20 A GeV to 21 A TeV we have found a global scaling of open charm mesons in the transverse mass M_T with pions and kaons and even more surprisingly with J/Ψ and Ψ' mesons. The latter calculations have been based on extrapolations from PYTHIA calculations for the elementary production cross sections down to the individual thresholds that could not be controlled by experimental data. On the basis of the latter cross sections the impact of secondary 'meson-baryon' collisions has been found to be less than 10% at all energies. However, in 'low' energy 'meson-baryon' reactions the dominant $c\bar{c}$ production might be related to the two-body (or quasi two-body) reactions $\pi N \rightarrow \bar{D}(\bar{D}^*)\ \Lambda_c(\Sigma_c)$. Estimates within the framework of the Quark-Gluon String model suggest cross sections of a few μb for $\pi N \rightarrow \bar{D}\Lambda_c$ in the region of about 1 GeV above threshold. This estimated order of magnitude for the open charm cross section is found - within transport calculations - to be compatible with the open charm enhancement claimed by the NA50 Collaboration at the SPS without employing the assumption of thermal and chemical or statistical equilibrium. It should be stressed, however, that experimental investigations on open charm production in πN reactions at invariant energies of $4.2 \leq \sqrt{s} \leq 15$ GeV are mandatory to confirm or disprove this suggestion.

3.3 Energy loss of high p_t hadrons by final hadronic state

When discussing the parton jet quenching phenomena in ultrarelativistic heavy ion collisions typically hadronization is assumed to take place in vacuum outside the reaction zone. On the other hand quantum mechanical estimates give a hadronization time of the order of only a few fm/c for jets materializing into hadrons with transverse momentum of $p_t \leq 10\,\text{GeV}$, which thus should well take place inside the fireball. Typical (in-)elastic collisions of these high p_t particles with the dominant low momentum hadrons of the fireball have a rather low invariant mass and are thus nonperturbative. The mean free path in the late hadronic stage is estimated to be $\lambda \approx 1 - 5\,\text{fm}$, resulting in a few collisions $L/\lambda = 0, 1, 2, \ldots$. We have performed an analysis within this opacity expansion by means of the FRITIOF collisions scheme for various hadrons. This study shows that these collisions can account for the modification of the p_t spectrum observed for central collisions at RHIC. Here the 'initial' spectrum of high-p_t hadrons was generated by PYTHIA, which describes to a large accuracy the peripheral collisions. Any deductions for possible QCD effects of a deconfined QGP phase on the materializing jets have to be disentangled for the here investigated final state interactions, before definite conclusions on the importance of a potential partonic phase can be drawn.

3.4 Parton dynamics and hadronization

At present we develop a fully microscopic Monte-Carlo simulation of real-time parton dynamics starting with early minijet production of (semi-)hard partons followed by a semiclassical kinetic transport description of Boltzmann type. The sampling of the minijets (with $p_t \geq 1 - 2$ GeV) are generated via perturbative QCD, where a Glauber treatment for multiple collisions is utilized. At present we construct the subsequent kinetic transport describing the $2 \rightarrow 2$ collisions, which we will then generalize for $2 \rightarrow n$ processes to incorporate radiation effects, being responsible for a fast generation of entropy. Our major aim will be to study in detail the evolution of strongly interacting, non-equilibrium parton matter and to achieve more realistic calculations for the various signatures like flavor production (strangeness and charm), electromagnetic probes and hard probes. The calculations then will be compared to the soon expected results of the now started experimental undertaking at RHIC.

3.5 A model of confinement

It is a so far unsolved problem which properties of quarks are most relevant for the formation of hadrons. Clearly perturbation theory for quarks and gluons, which works well at high energies, is incapable of describing the low-energy structure of hadrons. The most prominent non-perturbative aspects of quark dynamics are confinement and chiral symmetry breaking. It is expected that these phenomena are crucial for the formation of hadrons. In lack of a derivation of these aspects from the underlying microscopic theory of quarks and gluons (QCD) we develop models which incorporate one or the other aspect on a phenomenological basis and try to calculate hadronic properties from the respective phenomenological model. In the Friedberg-Lee model, confinement is realized by describing the vacuum as a dielectric medium. The formation of hadrons out of quarks is achieved by treating the quarks as the sources of the chromo-electric fields which, in turn, couple to the dielectric field. In this way the dielectric field constrains the chromo-electric field to a narrow space region. Strings are formed by this numerically rather involved mechanism. The approach aims at a dynamical description of hadrons and their transition between confined and deconfined states.

4 Exotic Nuclei and Hypernuclei

Investigations of structure and reaction dynamics of exotic nuclei and hypernuclei have been the central research topics in the last year. For dripline nuclei strong evidence for a gradual transition from mean-field dynamics to a new kind of correlation dynamics was found, being confirmed by recent experiments. The field theoretical methods developed for normal nuclear matter were extended to the full $SU(3)$ flavour sector in studies of interactions in hyper matter and hypernuclear structure calculations.

4.1 Interactions in nuclear matter and hypernuclear matter

An unexpected result of various structure calculations with seemingly well established models is the observation that empirical interactions lead to considerably divergent predictions for asymmetric nuclear matter and exotic nuclei. At first glance, it could be assumed that the problems might be solved by adjusting parameters to more precise and extended data. However, a closer inspection leads to the conclusion that with increasing asymmetry the phenomenological descriptions seem to approach their limits of applicability. An important reason for this is the unresolved diagrammatic structure of phenomenological interaction models, inhibiting systematic extensions of the operator set. For phenomenological non-relativistic and relativistic mean-field models and also for many-body shell model interactions it is observed that the whole parameter set must be readjusted when enlarging the operator set. Close to stability, this problem is of minor importance because there isoscalar mean-field dynamics prevail and interactions are dominated by a rather limited class of diagrams. Off stability, however, nuclear properties change drastically with rapid variations over small mass ranges. On the relativistic mean-field level the scalar-isovector δ meson ($a_0(980)$) is a representative example, being well established in free NN interactions. From our Dirac-Brueckner calculations we find important contribution to the self-energies in asymmetric matter and nuclei with a large neutron excess. Attempts to include the δ meson in relativistic mean-field models, however, have failed, mainly because this interaction channel cannot be separated unambiguously from others.

Generally, our calculation indicate a preference of the microscopic description over the empirical approaches close to the driplines and for extrapolations into regions beyond the experimental limits. This conjecture is confirmed by Dirac-Brueckner calculations for asymmetric nuclear matter, hypermatter and applications to finite nuclei and hypernuclei with the density dependent relativistic hadron field (DDRH) theory. DDRH theory is based on a Lagrangian formulation with meson-baryon vertices given by functionals of the baryon field operators, assuring covariance and thermodynamical consistency. In practice, the density dependence of the vertices is derived from infinite matter Dirac-Brueckner self-energies. Hence, the DDRH interactions are of a well defined diagrammatic structure, given by ladder diagrams. Additional diagrams can easily be incorporated and are presently under investigation. An interesting astrophysical application are calculations for neutron star matter in β equilibrium and neutrons stars, testing the in-medium interactions at high density and a variable strangeness content. The mass-radius relation obtained by solving the Tolman-Volkov-Oppenheimer equation agrees well with the generally accepted values.

The well defined diagrammatic structure of our interactions is also important for extensions of DDRH theory into the strangeness sector. A Dirac-Brueckner scheme for the full baryon octet has been formulated theoretically and implemented numerically. A most transparent interpretation of the results is obtained by replacing the usual decomposition of the Dirac-Brueckner interactions into Lorentz invariants by a physically motivated expansion into meson exchange interactions. At the same time, this method simplifies the numerical calculations considerably, making a solution of the full Bethe-Salpeter equations without a 3-dimensional reduction feasible in the near future.

4.2 Structure and reactions of exotic nuclei and hypernuclei

In previous calculations we found strong evidence for a drastic change in nuclear dynamics at the driplines, evolving from mean-field dominance to a new kind of correlation dynamics. The most important consequences of this transition are that the single particle shell model and the quasi particle picture - being the basis for the traditional understanding of nuclei - loose their validity in the correlation dynamical regime. Both of them rely on the existence of a dominating static mean-field which is no longer true at extreme isospin. The transition into a new dynamical regime is well illustrated for the single-nucleon halo systems ^{8}B, ^{11}Be and ^{19}C where a valence nucleon is coupled to a core nucleus which by itself is already far off stability. While former experimental and theoretical studies seemed to indicated a weak coupling of the outer particle to the core, recent experiments have given clear evidence for an intimate interplay of core and valence degrees of freedom. From a many-body theoretical point of view this had to be expected (and was predicted) because the core nuclei are easily polarizable. Our calculations show that the halo particles are bound mainly by dynamical self-energies. The most dramatic change is that the halo particles are found in wavepacket like configurations, being distributed equally over a large number of mean-field orbits. Recent FRS/GSI data, measuring breakup momentum distributions for halo nuclei in conjunction with γ rays from core excitations, confirm on a quantitative level the theoretical predictions. Moreover, corresponding FRS measurements for the neutron-rich oxygen isotopes $^{20-24}$O show that also these nuclei are correlation dynamical systems, thus establishing the effect over a wide mass range. Nuclear structure and relativistic eikonal breakup calculations for these cases are in progress.

For heavier nuclei the evolution of dynamics with increasing isospin has been investigated with DDRH-HFB calculations. As far as data are available a good agreement for binding and separation energies and nuclear radii is obtained in the medium mass ($^{48-82}$Ni) and the heavy mass ($^{100-160}$Sn) region. A common feature in the neutron-rich Ni and Sn isotopes is the appearance of a neutron skin with increasing thickness, approaching values up to 1 fm at extreme neutron excess.

Results of comparable quality are also found in DDRH-calculations for hypernuclei. The separation energies in single Λ nuclei are overall well described considering the experimental uncertainties. The $\Lambda\Lambda$ correlation energies derived from recent KEK experiments producing for the first time $^4\mathrm{He}_{\Lambda\Lambda}$ are not reproduced. This had to be expected because at present the calculations do not yet include the exchange of strangeness-carrying mesons $(K, K^*\phi)$, hence underlining the necessity for a full $SU(3)$ description of interactions. In preparation of a proposed experiment at JLAB, DDRH calculations for the production of Λ hyper nuclei by emission of Auger neutrons have been performed. The results show an interesting dependence of the Auger spectra on the Λ spin-orbit interaction but their observation relies on a suitable tagging procedure.

Publications 2001

M. Avrigeanu, A. Antonov, H. Lenske, I. Stetcu
Full-Folding Optical Potentials for Pre-Equilibrium Nucleon Scattering at Low Energies
Nucl. Phys. A (2001), in press

M. Avrigeanu, A.N. Antonov, H. Lenske, I. Stetcu
Effective Interactions for Multistep Processes
Nucl. Phys. A (2001), in press

S. Barsov, W. Cassing, H. Ströher et al.
ANKE, a New Facility for Medium Energy Hadron Physics at COSY-Jülich
Nucl. Inst. & Meth. A462 (2001) 364

C. Bennhold, A. Waluyo, H. Haberzettl, F.X. Lee, G. Penner, U. Mosel
Nucleon Resonance Properties in Multichannel Approaches
Proc. Workshop on the Physics of Excited Nucleons (N* 2001), Mainz, Germany, 7.-10. March 2001, World Scientific, in press

E.L. Bratkovskaya, W. Cassing, C. Greiner, M. Effenberger, U. Mosel, A. Sibirtsev
Thermal and Chemical Equilibration of Hadronic Matter
Nucl. Phys. A681 (2001) 84c

E.L. Bratkovskaya, W. Cassing, U. Mosel
Perspectives of e^+e^- Production in pp, pd and pBe Reactions at SIS Energies
Nucl. Phys. A686 (2001) 568

E.L. Bratkovskaya
e^+e^- Production in pA Reactions at SIS Energies
Nucl. Phys. A696 (2001) 309

E.L. Bratkovskaya, V.Yu. Grishina, L.A. Kondratyuk, M. Büscher, W. Cassing
Production of a_0-Mesons in pp and pn Reactions
submitted to EPJA

F. Cappuzzello, A. Cunsolo, S. Fortier, A. Foti, M. Khaled, H. Laurent, H. Lenske, J.M. Maison, A.L. Melita, C. Nociforo, L. Rosier, C. Stephan, L. Tassan-Got, J.S. Winfield, H.H. Wolter
Excited States of ^{11}Be
Phys. Lett. B516 (2001) 21

W. Cassing, E.L. Bratkovskaya, A. Sibirtsev
Open Charm Production in Relativistic Nucleus-Nucleus Collisions
Nucl. Phys. A691 (2001) 745

W. Cassing, L.A. Kondratyuk, G.I. Lykasov, M.V. Rzjanin
Open Charm Enhancement by Secondary Interactions in Relativistic Nucleus-Nucleus Collisions?
Phys. Lett. B513 (2001) 1

W. Cassing
Antibaryon Production in Hot and Dense Nuclear Matter
Nucl. Phys. A700 (2002) 618

D. Cortina-Gil, T. Baumann, H. Geissel, K. S"ummerer, L. Axelsson, U. Bergmann, M.J.G. Borge, L. Fraile, M. Hellström, M. Ivanov, N. Iwasa, R.Janik, B. Jonson, H. Lenske, K. Markenroth, G. Münzenberg, F. Nickel, T. Nilsson, A. Ozawa, K. Riisager,G. Schrieder, W. Schwab, H. Simon, C. Scheidenberger, B. Sitar, M. Smedberg, P. Strmen, T. Suzuki, M. Winkler
One-Nucleon Removal Cross-Sections for $^{17,19}C$ and $^{8,10}B$
Eur. Phys. Jour. A 10 (2001) 49

T. Falter, S. Leupold, U. Mosel
Nuclear Shadowing at Low Photon Energies
Phys. Rev. C64 (2001) 024608

F. Frömel, S. Leupold, U. Mosel
Spectral Function of Quarks in Quark Matter
submitted to Phys. Rec. C (2001)

Ye.S. Golubeva, L.A. Kondratyuk, M. Büscher, W. Cassing, V. Hejny, H. Ströher
Medium Effects in the Production and $\pi^0\gamma$ Decay of ω-Mesons in pA Collisions in the GeV Region
Eur. Phys. J. A11 (2001) 237

C. Greiner, S. Leupold
Antihyperon-Production in Relativistic Heavy-Ion Collisions
J. Phys. G27 (2001) L95

C. Greiner
Signatures of the Quark-Gluon Plasma: A Personal Overview
Proc. to ‘Lüderitz 2000: Fundamental and Applied Aspects of Modern Physics’, World Scientific (2001)

C. Greiner
A Novel Scenario for the Production of Antihyperons in Relativistic Heavy-Ion Collisions
submitted to Nucl. Phys. A (2001)

C. Greiner
Die Suche nach dem Quark-Gluon Plasma: Der kleine Urknall im Labor
27 Seiten, Akademievortr"age junger Wissenschaftler: Colloquia Academica, Akademie der Wissenschaften und der Literatur, Mainz (2001)

C. Greiner
Strangeness in Strongly Interacting Matter
submitted to Journal of Physics G

V.Yu. Grishina, L.A. Kondratyuk, W. Cassing, A.B. Kaidalov, E. De Sanctis, P. Rossi
Deuteron Photodisintegration within the Quark-Gluon Strings Model and QCD Motivated Nonlinear Regge Trajectories
Eur. Phys. J. A10 (2001) 355

V.Yu. Grishina, L.A. Kondratyuk, M. Büscher, W. Cassing, H. Ströher
$a_0(980) - f_0(980)$ Mixing and Isospin Violation in the Reactions $pN \to a_o d$, $pd \to a_o + {}^3He/{}^3H$ and $dd \to a_0{}^4He$
Phys. Lett. B521 (2001) 217

C. Gund, H. Bauer, J. Cub, A. Dietrich, T. Härtlein, H. Lenske, D. Pansegrau, A. Richter, H. Scheit, G. Schrieder, D. Schwalm
Potentials and Limitations of Transfer Experiments with Radioactive Beams at REX-ISOLDE
Eur. Phys. Jour. A10 (2001) 85

S.J. Hardy, M.H. Thoma
Neutrino-Electron Processes in a Strongly Magnetized Thermal Plasma
Phys. Rev. D63 (2001) 025014

F. Hofmann, C. Keil, H. Lenske
Density Dependent Hadron Field Theory for Asymmetric Nuclear Matter and Exotic Nuclei
Phys.Rev. C64 (2001) 034314

F. Hofmann, C. Keil, H. Lenske
Application of the Density Dependent Hadron Field Theory to Neutron Star Matter
Phys.Rev. C64 (2001) 025804

B. Kamys, P. Kulessa, H. Ohm, K. Pysz, Z. Rudy, H. Ströher, W. Cassing
Non-mesonic Decay of the Λ hyperon in Hypernuclei produced by p + Au Collisions
Eur. Phys. J. A11 (2001) 1

C.M. Keil, Frank Hofmann, Horst Lenske
The Structure of Λ Hypernuclei
Contributed to HYP2000: 7th International Conference on Hypernuclear and Strange Particle Physics, Torino, Italy, 23-27 Oct 2000, nucl-th/0011046

C.M. Keil, H. Lenske
Threshold Suppression of Λ Spin-Orbit Splitting
nucl.-th/0103035

C.M. Keil, H. Lenske
Single Particle Properties of Λ Hypernuclei in the Density Dependent Relativistic Hadron Field Theory
Proceedings of 8th Meeting on Mesons and Light Nuclei, Prague, Czech Republic, 2.-6. July 2001, AIPMelville, New York, 2001, p. 433

C.M. Keil, H. Lenske, C. Greiner
In-medium Baryon Interactions and Hypernuclear Structure
To appear in the Proceedings at the 6th Int. Conf. on Strange Quarks in Matter 2001, Frankfurt, Germany, 25.-29.09.2002, Journ. of Phys. G, nucl-th/0112047

M.T. Keil, G. Penner, U. Mosel
Anti-Kaon Induced Reactions on the Nucleon
Phys. Rev. C63 (2001) 045202

V. Koptev, W. Cassing, H. Ströher et al.
Forward K^+-Production in Subthreshold pA Collisions at 1.0 GeV
Phys. Rev. Lett. 87 (2001) 022301

P. Kulessa, W. Cassing, L. Jarczyk, B. Kamys, H. Ohm, K. Pysz, Z. Rudy, H. Ströher
The Lifetime of the Λ Hyperon Bound in Hypernuclei produced by $p+U$ Collisions
Acta Phys. Po. B (2001), in press

A.B. Larionov, W. Cassing, S. Leupold, U. Mosel
Quenching of Resonance Production in Heavy-Ion Collisions at 1-2 A GeV
Nucl. Phys. A (2001), in press

A.B. Larionov, M. Effenberger, S. Leupold, U. Mosel
Resonance Lifetime in BUU: Observable Consequences
submitted to Phys. Lett. B (2001), nucl.-th./0107031

J. Lehr, U. Mosel
In-medium Broadening of Nucleon Resonances
Phys. Rev. C64 (2001) 042202

J. Lehr, U. Mosel
Photon and Electron induced Particle Production on Nuclei
Proc. ICTP 3rd Int. Conf. on Perspectives in Hadronic Physics, Trieste, Italy, 7.-11. May 2001, Nucl. Phys. A699 (2002) 324

J. Lehr, H. Lenske, S. Leupold, U. Mosel
Nuclear Matter Spectral Functions by Transport Theory
Nucl. Phys. A (2001), in press, nucl.-th/0108008

H. Lenske, C.M. Keil, F. Hofmann
Many Body Theory at Extreme Isospin
Proceedings of the Int. Conf. on Nuclear Physics at Border Lines, Lipari, Messina, Italy, 21.-24.03.2001, World Scientific Publ. Company

H. Lenske, F. Hofmann, C.M. Keil
Exploring the Dripline by Many-Body Theory
Proc. Int. Conf. Bologna 2000 - Nuclear Structure at the Dawn of the Century, Bologna, Italy, May 28 - June 1, 2001, World Scientific, Singapore 2001

H. Lenske, H.H. Wolter, A. Weigel
Statistical Multistep Reaction Approach for Pre-Equilibrium Processes
Nucl. Phys. A690 (2001) 267

S. Leupold
Life time of Resonances in Transport Simulations
Nucl. Phys. A695 (2001) 377

S. Leupold
QCD Sum Rules for Vector and Axial-Vector Mesons in a Nuclear Medium
Nucl. Phys. A684 (2001) 437

S. Leupold
Vector Meson Properties from Matching Resonance Saturation to a Constituent Quark Model
submitted to Phys. Rev. D (2001), hep-ph/0111204

J.G. Meschendorp, A. Sibirtsev, W. Cassing, V. Metag, S. Schadmand
Studying the ω-Mass in-medium in $\gamma + A \to \pi^0\gamma + X$ Reactions
Eur. Phys. Jour. A11 (2001) 95

U. Mosel, M. Post
Vector Meson Decay of Baryon Resonances
Proc. Workshop on the Physics of Excited Nucleons (N* 2001), Mainz, Germany, 7.-10. March 2001, World Scientific, p. 389

G. Penner, U. Mosel
The Giessen Model: Vector Meson Production on the Nucleon in a Coupled Channel Approach
Proc. Workshop on the Physics of Excited Nucleons (N* 2001), Mainz, Germany, 7.-10. March 2001, World Scientific, p. 193

G. Penner, U. Mosel
$\pi N \to \omega N$ in a Coupled Channel Approach
submitted to Phys. Rev. C (2001), nucl.-th/0111023

G. Penner, U. Mosel
What is the Correct $\pi^- p \to \omega n$ Cross Section at Threshold?
nucl-th/0111024

M. Post, S. Leupold, U. Mosel
The ρ Spectral Function in a Relativistic Resonance Model
Nucl. Phys A689 (2001) 753

M. Post, U. Mosel
Coupling of Baryon Resonances to the ωN channel
Nucl. Phys. A688 (2001) 808

M. Post, U. Mosel
Vector Mesons and Baryon Resonances in Nuclear Matter
Proc ICTP 3rd Int. Conf. on Perspectives in Hadronic Physics, Trieste, Italy, 7.-11. May 2001, in press, nucl-th/0108017

R. Shyam, G. Penner, U. Mosel
Role of N*(1650) in the Near Threshold $pp \to p\Lambda K^+$ and $pp \to p\Sigma^0 K^+$ Reactions
Phys. Rev. C63 (2001) 022202

A. Sibirtsev, W. Cassing, U. Mosel
Low Energy Kaon Photoproduction from Nuclei
Nucl. Phys. A679 (2001) 497

A. Sibirtsev, K. Tsushima, A.W. Thomas
Charmonium Absorption by Nucleons
Phys. Rev. C63 (2001) 044906

A. Waluyo, C. Bennhold, G. Penner, U. Mosel
Eta Photoproduction in a Coupled-Channels Approach
Proc. Workshop on the Physics of Excited Nucleons (N* 2001), Mainz, Germany, 7.-10. March 2001, World Scientific, p. 207

Conference Contributions 2001

Stony Brook, NY, USA: Quark Matter 2001 - 15th. Int. Conf. on Ultra-Relativistic Nucleus-Nucleus Collisions
15.01.-20.01.2001

C. Greiner
Antihyperon Production in Relativistic Heavy-Ion Collisions

Schleching, Germany: XXXII. Arbeitstreffen Kernphysik Schleching
01.03.-08.03.2001

Z. Xu
Anfangsverteilung von semiharten Partonen in ultrarelativistischen Schwerionenkollisionen

Mainz, Germany: N*2001
07.03.-10.03.2001

U. Mosel
Vector Meson Decay of Nucleon Resonances

G. Penner
The Giessen Model - Vector Meson Production on the Nucleon in a Coupled Channel Approach

Trento, Italy: Collaboration Meeting on “Dynamical Aspects of the QCD Phase Transition
12.03.-15.03.2001

S. Leupold
Off-Shell Transport Theory and Life-Time of Resonances

Erlangen, Germany: 64. Fr”uhjahrstagung der DPG
19.03.-23.03.2001

T. Falter
Abschattung in nuklearer Photonabsorption bei niedrigen Energien

F. Frömel
Selbstkonsistente Berechnung von relativistischen Quark-Spektralfunktionen

C. Greiner
Produktion von Anti-Hyperonen in ultrarelativistischen Schwerionenkollisionen

C. Keil
Von Hyperkernen zu Neutronensternen

G. Penner
Vektormesonen-Produktion am Nukleon in der K-Matrix-Näherung

M. Post
Spektralfunktionen von Vektormesonen in einem relativistischen Resonanzmodell

S. Leupold
Vektormesonen in kalter Kernmaterie und QCD-Summenregeln

Z. Xu
Anfangsverteilung von semiharten Partonen in ultrarelativistischen Schwerionenkollisionen

Univ. Heidelberg, Germany: RNM Workshop
15.02.2001

W. Cassing
Open Charm and Charmonium Dynamics at SPS and RHIC

INT. Seattle, USA: CEBAF, Int. Workshop Correlations in Nucleons and Nuclei
12.03.-16.03.2001

U. Mosel
Nuclear Spectral Functions in a Transport-Theoretical Model

Schladming, Austria: 40. Int. Universitätswochen für Theoretische Physik, Dense Matter
04.03.-10.03.2001

G. Martens
Confinement in the Chromo-Dielectric Model

Darmstadt, Germany: Nuclear Astrophysics 2001
03.05.-04.05.2001

C. Keil, H. Lenske
A Density Dependent Field Theory for Exotic Nuclear Matter

Trieste, Italy: 3rd. Int. Conference on Perspectives in Hadronic Physics
07.05.-11.05.2001

J. Lehr
Photon and Electron induced Reactions on Nuclei in a Transport Theoretical Model

M. Post
Vector Mesons and Baryon Resonances in Nuclear Matter

Lipari, Italy: Nuclear Physics at the Border Lines 2001
20.05.-25.05.2001

H. Lenske
Many-Body Theory at Extreme Isospin

Univ. Frankfurt, Germany: RNM Workshop
17.05.2001

W. Cassing
J/ψ, Open Charm and Strangenesss in Compressed Baryonic Matter

Trento, Italy: Int. Workshop on Strangeness Production in Nuclear Collisions from 1 to 200 GeV
11.06.2001-15.06.2001

W. Cassing
Dynamics of Strange and Charm Quarks in Relativistic Nuclear Collisions

C. Greiner
Antihyperon Production by Multimesonic Processes

Gatchina, Russia: Workshop on Experiments on Strangeness Production in pp and pA Interactions at ANKE
19.06.-22.06.2001

W. Cassing
Summary of Theoretical Approaches

Prague, Czech Republic: Int. Conference on Mesons and Light Nuclei 2001
02.07.-06.07.2001

C. Keil
Single Particle Properties of Λ Hypernuclei in the Density Dependent Hadron Field Theory

GSI Darmstadt, Germany: Tagung Komitee Hadronen- und Kernphysik
16.07.2001

H. Lenske
Nuclear Theory far off Stability: Status and Perspectives

Berkeley, USA: Int. Nucl. Physics Conf. INDC 2001
30.07.-03.08.2001

H. Lenske
Nuclear Structure and Reactions at the Driplines

Tübingen, Germany: Workshop on "Quarks and Hadrons in Continuum strong QCD
08.09.-06.09.2001

W. Cassing
Transport Analysis of the Parton-Hadron Phase Transition in Ultra-relativistic Nucleus-Nucleus Collisions

Berlin, Germany: DFG-Schwerpunkttreffen: Untersuchung der hadronischen Struktur
von Nukleonen und Kernen
13.09.-14.09.2001

T. Falter
Photo- und Elektroproduktion von Mesonen am Kern: Stand der Theorie

Frankfurt, Germany: Strange Quarks in Matter 2001
24.09.-29.09.2001

C. Greiner
Strangeness in Strongly Interacting Matter

C. Keil
In-medium Hyperon Interactions and Hypernuclear Structure

Copenhagen, Denmark: Lecture Week 'Complex Systems of Hadrons and Nuclei
24.09.-28.09.2001

T. Falter
Nuclear Shadowing and In-medium Properties of the ρ^0

St. Tecla, Sizilien: European Summer School on Experimenteal Nuclear Astrophysics
30.09.-07.10.2001

C. Keil
From Hypernuclei to Neutron Stars

Santorini, Greece: European Research Conf. on Electromagnetic Interactions with Nucleons and Nuclei
02.10.-09.10.2001

U. Mosel
Hadrons in Nuclei

Trento, Italy: ECT-Workshop "The Physics of Halo-Nuclei
04.10.-12.10.2001

H. Lenske
Nuclear Interactions at Extreme Isospin

GSI Darmstadt, Germany: Workshop Komitee Hadronen- und Kernphysik
19.10.2001

W. Cassing
Perspectives of Hadron Physics

KVI Groningen, The Netherlands: Workshop "Strangeness
01.11.-02.11.2001

G. Penner
Strangeness Production in Pion and Photon induced Reactions on the Proton

Giessen, Germany: Workshop on Strong Non-Equilibrium Matter
08.11.-10.11.2001

W. Cassing
Recent Developments in Quantum Transport

A. Larionov
Off-shell Pions in BUU Transport Theory

J. Lehr
Nuclear Matter spectral Functions by Transport Theory

Z. Xu
Stochastic Behaviour of DCCs

Seminars 2001

W. Cassing
Dynamics of Strange and Charmed Hadrons in Relativistic Nuclear Collisions
NBI, Copenhagen, Denmark, 24.01.2001

C. Greiner
Die Suche nach dem Quark-Gluon Plasma: Der kleine Urknall im Labor
Akademie der Wissenschaften, Mainz, Germany, 20.04.2001

C. Greiner
Strange Matter Ideas in Relativistic Heavy-Ion Physics
CERN, Switzerland, 04.05.2001

C. Greiner
Antihyperon Production in Relativistic Heavy-Ion Collisions by Multimesonic Processes
Nantes, France, 29.08.2001

H. Lenske
Field Theoretical Approach to Hyperon Interactions and Hypernuclei
FZ Jülich, IKP, Germany, 27.08.2001

S. Leupold
Transport Theory for Broad Resonances
Univ. Heidelberg, 19.12.2001

U. Mosel
In-medium Hadrons - Properties and Observables
Texas A& M Univ., College Station, USA, 27.03.2001

U. Mosel
High-Energy Photoproduction of Mesons on Nuclei and Nuclear Shadowing
George Wash. Univ., Washington, USA, 30.03.2001