

Relativistic Description of Two- and Three-body Systems in Nuclear Physics

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Titles & Abstracts

1. A. Arriaga (CFN, Lisbon, Portugal):

A relativistic calculation of the deuteron threshold electrodisintegration at backward angles

The threshold electrodisintegration of the deuteron at backward angles is studied with a relativistic Hamiltonian, including a relativistic one-pion-exchange potential (OPEP) with off-shell terms, as predicted by pseudovector coupling of pions to nucleons. The bound and scattering states are obtained in the center-of-mass frame, and then boosted to the Breit frame, where the matrix elements of the electromagnetic current operator are calculated. The latter includes one-body and two-body terms due to pion exchange obtained, consistently with the OPEP, in pseudovector pion-nucleon coupling theory. Full Lorentz structure of the currents is retained. Cross section results show that, in the calculations using one-body currents, relativistic corrections become significant (larger than 10%) only at high momentum transfer Q ($Q^2 \sim 40 fm^{-2}$ and beyond). Yet, the inclusion of two-body currents makes the relativistic predictions considerably smaller than the corresponding non-relativistic results in the Q^2 region $18 - 40 fm^{-2}$. Calculations also confirm the inadequacy, already known in a non-relativistic context, of the present electromagnetic current model to reproduce accurately the experimental data at intermediate values of momentum transfers.

2. B.L.G. Bakker (Vrije Universiteit, Amsterdam, The Netherlands):

Light-Front Singularities: New developments

Light-front dynamics (LFD) as a Hamiltonian form of quantized field theory has several advantages. One of them is that the Fock-space expansion leads to sensible results, because the light-front vacuum does not allow particle-antiparticle creation from the vacuum. Moreover, in LFD one deals with physical degrees of freedom only, which means that particles are on their mass shell, like in non-relativistic dynamics; there are no ghosts in the light-front gauge. These advantages come with a certain cost, namely the occurrence of singularities that are not present in manifestly covariant approaches. In the talk a taxonomy of these singularities is given and the way they can be related is shown in several examples.

3. N. Barnea (Jerusalem Univ., Israel):

Weak reactions with light nuclei

At the 2-body level, the nuclear axial current contains one free parameter normally calibrated through the ^3H beta-decay. In this talk I will review the different approaches to derive this axial 2-body current, its calibration and prediction regarding the ^6He beta-decay into the ground state of ^6Li which is the only viable test for this current.

4. B.V. Carlson (ITA - CTA S. Josè dos Campos, Brazil)

Static and covariant meson-exchange interactions in nuclear matter

The Bonn A, B and C interactions were determined from a fit of deuteron properties and two-nucleon scattering data up to lab energies of about 300 MeV. The interactions were obtained using a static approximation to meson exchange with the Thompson reduction of the Bethe-Salpeter equation. When used in a Brueckner ladder approximation to the

many-body mean fields and energy, these interactions have the appealing property of furnishing a nuclear matter saturation point near the expected position. We have readjusted the Bonn interaction coupling constants to (more or less) reproduce the deuteron properties and scattering data using the static approximation to meson exchange with the Blankenbecler-Sugar reduction of the Bethe-Salpeter equation, as well as covariant meson exchange interactions with the two reductions of the Bethe-Salpeter equation. The static Blankenbecler-Sugar interaction leads to reasonable values of nuclear saturation, just as the static Bonn interactions do with the Thompson reduction. In contrast, the covariant interactions yield deeply overbound nuclear matter, suggesting the need for repulsive three-body interactions similar to those used in nonrelativistic models.

5. J. Carbonell (LPSC, Grenoble, France):

Bethe-Salpeter solutions in Minkowski space: numerical methods and electromagnetic form factors.

We will present the numerical methods used to obtain the Bethe-Salpeter amplitudes in Minkowski space. Applications to the electromagnetic form factors, in particular the differences existing with respect to the corresponding Euclidean results will be discussed.

6. W. Cosyn (Gent Univ., Belgium):

Modeling final-state interactions with a relativistic multiple-scattering approximation.

A relativistic and quantum mechanical framework used to model pion and nucleon production reactions is presented. The final-state interactions for the ejected pions and nucleons are implemented in a relativistic Glauber eikonal approach. The proposed model can account for the color-transparency (CT) phenomenon and short-range correlations (SRC) in the final-state interactions. Results are presented for kinematics corresponding to completed experiments for a variety of reactions, such as $A(e, e'\pi)$, $A(p, 2p)$ and $A(e, e'p)$. The influence of the CT and SRC mechanisms on the nuclear transparency observable is studied. We show that the two effects can be clearly separated as they exhibit a different dependence on the hard-scale parameter. The similarities in the trends and magnitudes of the computed results compared to semi-classical models indicate that they are not subject to strong model dependencies. The effective nuclear densities probed in the knockout reactions accommodated by the model are also compared to each other.

7. A. Deltuva (Univ. of Lisbon, Portugal) :

Few-Nucleon calculations with Δ degrees of freedom

Three- and four-nucleon systems are described allowing for the excitation of a nucleon to a Delta isobar. The excitation of the Delta isobar remains virtual; the Delta isobar is therefore considered a stable particle with zero width. It yields a two-nucleon dispersion and effective many-nucleon forces. The two-baryon coupled-channel potential CD Bonn + Delta is based on the single exchange of the standard isovector mesons pi and rho and of the isoscalar mesons omega and sigma; the same mesons are contained in the effective many-nucleon forces that are dynamically consistent with each other and with the effective two-nucleon force. The resulting three-nucleon force simulates the two-pion exchange Fujita-Miyazawa force and the three-pion ring part of the Illinois force in a reducible energy-dependent form, but it is much richer with respect to Δ -isobar excitation and also has shorter ranged components than standard irreducible two-pion exchange three-nucleon forces.

The few-particle equations are solved exactly using the momentum-space framework. The

Delta isobar effect on the observables of hadronic and electromagnetic three-nucleon reactions and of low-energy four-nucleon scattering is isolated and discussed.

8. C. Elster (Ohio Univ., USA):

A New Approach to the 3D Faddeev Equation for Three-Body Scattering

9. C. Forssén (Chalmers Univ., Goteborg, Sweden):

The ab-initio No-Core Shell Model and Light Nuclei

The ab initio no-core shell model (NCSM) is a well-established theoretical framework aimed at an exact description of nuclear structure starting from high precision interactions between the nucleons [1,2]. In the NCSM we consider a system of A point-like, non-relativistic nucleons that interact by realistic inter-nucleon interactions. We consider two-nucleon interactions that can fit nucleon-nucleon phase shifts with high precision up to certain energy, typically up to 350 MeV. We can also include NNN interactions with terms related to two-pion exchanges with an intermediate delta excitation. These selections include both semi-phenomenological potentials as well as modern chiral interactions. The performance of the NCSM within nuclear physics will be exemplified by showing results from studies of light nuclei. Major challenges in the future development of the method will be outlined.

10. T. Frederico (ITA, Sao Paulo, Brazil):

Projecting the Bethe-Salpeter equation onto the light-front.

The projection of the four-dimensional two-body Bethe-Salpeter equation to the three-dimensional light-front hypersurface using the quasi-potential formalism will be discussed with relation to the valence component of the wave function. Examples for mass operator equation for two-bosons and two-fermions systems will be given. The conserved electromagnetic current operator acting on the valence component of the light-front wave function will be also shown. The generalization of the formalism to three-particles will be discussed.

11. L. Girlanda (Pisa Univ., Italy)

Relativity constraints on the $O(p^2)$ two-nucleon contact Lagrangian

The two-nucleon contact Lagrangian is an important ingredient for the chiral effective theory description of nuclear forces. Starting with a relativistically invariant Lagrangian density, we will derive its minimal form up to the second order of the derivative expansion in terms of non-relativistic nucleon fields. We argue that three new operators are needed to describe the low-energy interaction of two nucleons away from their center of mass, which could be relevant for the description of three-nucleon systems.

12. F. Gross (William & Mary, USA):

Paving the Relativistic Way: Past, Present and Future

13. N. Ishii (Tokio Univ., Japan):

Lambda-Nucleon and Nucleon-Nucleon interactions on the Lattice

Recent lattice study of nuclear forces is reviewed. Scattering phase shift is an important experimental observable for two particle system. In lattice QCD, phase shifts are calculated from long distance behavior of Bethe-Salpeter(BS) wave functions by Luscher's finite volume method. For applications to nuclear physics of multi-nucleon system, it is more advantageous to keep the information of phase shifts in the form of potentials. We therefore extend the method to generate the potentials from BS wave functions. These potentials are faithful to scattering phase shift by construction, because they can reproduce the long distance behaviors of BS wave functions. The method was first applied to the central force in NN system. It is now applied to many objects, such as tensor force, hyperon forces, energy dependence of nuclear force, and investigations of the repulsive core at short distance.

14. S. Jeschonnek (OSU):

Exclusive Scattering from Unpolarized and Polarized Deuteron

Currently, several data sets on $D(e, e'p)n$ reactions, taken at Jefferson Lab, are analyzed or have been published recently. A solid theoretical description is necessary in order to understand these data and extract all possible information, both on the reaction mechanism and the nuclear ground state.

We have performed a fully relativistic calculation of the $D(e, e'p)n$ reaction in the impulse approximation. Our most recent calculations have been performed for both vector- and tensor-polarized deuteron targets. We employ the Gross equation to describe the deuteron ground state, and we use the SAID parametrization of the full pn scattering amplitude to describe the final state interactions (FSI's). We include both on-shell and positive-energy off-shell contributions in our FSI calculation. I will show results for momentum distributions and angular distributions of the differential cross section, as well as for various asymmetries that can be accessed only with a polarized target. The sensitivity of various observables to spin-dependent final state interactions will be discussed.

15. H. Kamada (KIT, Kitakyushu, Japan)

Lorentz Boosted Nucleon-Nucleon T-matrix and the Triton Binding Energy

There are two basic approaches to a relativistic formulation of the 3N problem. One is a manifestly covariant scheme linked to a field theoretical approach, the other is based on an exact realization of the symmetry of the Poincare group in three nucleon quantum mechanics. We employ the second approach, where the mass operator (rest energy operator) consists of relativistic kinetic energies together with two- and many-body interactions including their boost corrections. The phase equivalent relativistic NN potential, which is related by a nonlinear equation to the original nonrelativistic potential, is used to construct the mass operator (rest Hamiltonian) of the 3-nucleon system. Using some realistic NN potentials, the solution of the relativistic 3N Faddeev equation for triton shows slightly less binding energy than the corresponding nonrelativistic result. The effect of the Wigner spin rotation on the binding is very small.

16. L. Kaptari (JINR, Dubna, Russia)

Two-Fermion Bound States within the Bethe-Salpeter Approach

Several mathematical and numerical methods to solve the spinor-spinor Bethe-Salpeter (BS) equation in Euclidian space are considered. The BS amplitude is decomposed over different complete sets of 4×4 matrices and the corresponding unitary transformations from one basis to another are found explicitly. Results of concrete calculations of a variety of observables in reactions with the deuteron are presented and relativistic effects discussed.

Particular attention is focused on the problem of finding the energy spectrum of the two-fermion bound states. A mathematical method, based on the Gramm-Schmidt orthogonalisation procedure, is suggested to find numerically the mass-spectrum of the BS equation for scalar particle and a generalization of the method to spinor particles is presented.

Methodological calculations within the hyper-spherical harmonic basis have been performed for scalar, pseudo-scalar and vector exchanges and the procedure of numerical inverse Wick rotation back to Minkowsky space is briefly discussed. The possibility of a description of mesons as two-quark bound states within the hyper-spherical basis is considered as well. For this sake the Dyson-Schwinger equation for the quark masses is solved within the rainbow approximation.

17. V. Karmanov (Lebedev Physical Institute, Russia): **The Bethe-Salpeter equation and the Nakanishi representation.**

We present a method of finding the Bethe-Salpeter (BS) amplitude in Minkowski space. The method is based on representation of the BS amplitude (as a function of two variables) via a double integral from other function $g(\gamma, z)$ (Nakanishi representation). This integral incorporates analytically the singularities of the BS amplitude, that simplifies finding $g(\gamma, z)$. We derive an equation for $g(\gamma, z)$ which is well solvable numerically (in contrast to initial BS equation). Then, knowing $g(\gamma, z)$, we restore the BS amplitude both in Minkowski and in Euclidean spaces (and in the complex plane, if needed).

The method, initially developed for spinless particles, after recent modifications and improvements, was applied to two-fermion system. For a test, we compare binding energies, found by our method, with our solution in Euclidean space and with the Euclidean solutions given in literature. For any system (scalars or fermions) these three sets of binding energies coincide with each other with high accuracy.

18. A. Kievsky (INFN -Pisa, Italy):
The three-nucleon force: a comparative study

The inclusion of a three-nucleon force (TNF) in the nuclear Hamiltonian is important to better reproduce some quantities as the ${}^3\text{H}$ and ${}^4\text{He}$ binding energies. Also the doublet $n - d$ scattering length is better reproduced in this case. However the agreement of these three quantities to their corresponding experimental values is not completely satisfactory. We will see that some of the parameters in the old TNF models, as the Tucson-Melbourne or UrbanaIX, need large modifications to better agree with the mentioned observables. More recently a local TNF model, based on chiral effective field theory at next-to-next-to-leading order, has been derived. With this potential it is possible to obtain a good agreement in the three quantities with a small change of the original values. The impact of these modification in other observables, as for example the tensor analyzing powers will be discussed.

19. W.H. Klink (U. Iowa, USA):
Point-form quantum field theory and applications

I present an overview of point form relativistic quantum theory, including both point form quantum field theory and point form relativistic quantum mechanics (for finite degrees of freedom). Interactions in point form quantum field theory are introduced via vertexes; applications include the gluon self interactions and associated vacuum problem, as well as perturbative scattering theory using a point form interaction picture. For point form relativistic quantum mechanics a mass operator is introduced to model the strong and electroweak interactions. A number of applications are discussed including a procedure

for generating electromagnetic currents to calculate form factors as well as a discussion of cluster properties of the S matrix in point form.

20. H. Krebs (Bonn Univ. and Forschungszentrum Jlich, Germany):
Modern Theory of Nuclear Forces

Chiral effective field theory allows for a systematic and model-independent derivation of the forces between nucleons in harmony with the symmetries of Quantum Chromodynamics. In my talk I will review the foundations of this approach and will discuss its application to processes involving few nucleons. In the second part of the talk I will discuss an extension of this approach to many-body systems. In particular I will present a novel lattice effective field theory method developed for systems with larger number of nucleons where explicit methods are hard to apply. Combining Monte Carlo lattice simulations with effective field theory one can calculate properties of light nuclei, neutron and nuclear matter.

21. W. Leidemann (Trento U., Italy):
Relativistic effects in the (e,e') inelastic inclusive response functions of the three-nucleon systems with the LIT method

The longitudinal and transverse inelastic response functions, $R_L(\omega, q)$ and $R_T(\omega, q)$ are calculated up to $q=700$ MeV/c. A realistic nuclear interaction (AV18 NN potential, UIX three-nucleon force) is used. The full final state interaction is considered via the Lorentz integral transform (LIT) method. Meson exchange currents and relativistic corrections to the one-body operator are taken into account. The frame dependence of the results is studied. It is discussed that from a theoretical point of view it is advantageous to perform calculations in the "active nucleon Breit system", where the target nucleus is moving with $P = -3q/2$. In fact, the experimental peak positions are well described up to the highest considered momentum transfer. Up to $q=500$ MeV/c there is also a good agreement for the peak heights, while theory overestimate the experimental peak a bit at even higher q .

22. L. Marcucci (Pisa Univ., Italy)
Muon capture on light nuclei

In this talk I will review the current theoretical and experimental status for the muon capture processes on light nuclei, i.e. deuteron, ^3He and ^4He . In particular, I will focus on the latest developments for the $A=2$ and 3 reactions.

23. P. Maris (Iowa Univ., USA):
Relativistic three-body bound state calculations in Bethe-Salpeter and light-front formalism

Three-body bound states can be described by a homogeneous integral equation for the bound state amplitudes, analogous to the two-body Bethe-Salpeter equation. In ladder truncation, one can solve these covariant three-body bound state equations numerically, without any further approximations. Similarly, one can solve the ladder truncation of the three-body bound state equation in light-front dynamics. The results show significantly stronger binding for the three-body Bethe-Salpeter equation than for the corresponding light-front bound state equation. This difference can largely be attributed to relativistic 3-body force effects due to two intermediate exchange particles, which are automatically included in the explicitly covariant BS framework, but absent in the ladder truncation in light-front dynamics. I also present new results for three-body bound state calculations with intrinsic three-body forces.

24. J.-F. Mathiot (LPC, Université Blaise Pascal, Clermont-Ferrand, France)
Non-perturbative renormalization scheme in Light Front Dynamics

The calculation of relativistic bound state systems in hadronic physics demand a double non-perturbative approach. One first needs an eigenvalue equation to calculate the bound state properties, like its mass or wave function, which enables to sum to all orders the contribution from an irreducible kernel. Secondly, this irreducible kernel involves elementary couplings which are not small. It should therefore be calculated in a non-perturbative approach. Moreover, the procedure should incorporate a well defined strategy in order to improve, in a systematic way, the necessary approximations which one should do to calculate the bound state properties.

We would like to advocate, in this presentation, the use of light-front dynamics in order to deal with the requirements mentioned above. We will show how one can control three important aspects of the calculation i) the violation of rotational invariance by using an explicitly covariant formulation of light-front dynamics. ii) the regularisation procedure, which should be systematic and preserve all symmetries. We shall present a new scheme, the Taylor-Lagrange renormalization scheme, based on the properties of quantum fields as distributions acting on test functions with specific mathematical properties. iii) the renormalization scheme which should be non-perturbative, and consistent with the truncation of the Fock space.

Results will be presented on the non-perturbative calculation of the anomalous magnetic moment of a fermion in the Yukawa model, in the three-body truncation.

25. G. A. Miller (Washington U., USA):
Electromagnetic Form Factors and Charge Densities From Hadrons to Nuclei

A simple exact covariant model in which a scalar particle is modeled as a bound state of two different particles is used to elucidate relativistic aspects of electromagnetic form factors. The model form factor is computed using an exact covariant calculation of the lowest-order triangle diagram and shown to be the same as that obtained using light-front techniques. The meaning of transverse density is explained using coordinate space variables, allowing us to identify a true mean-square transverse size directly related to the form factor. We show that the rest-frame charge distribution is generally not observable because of the failure to uphold current conservation. Neutral systems of two charged constituents are shown to obey the lore that the heavier one is generally closer to the transverse origin than the lighter one. It is argued that the negative central charge density of the neutron arises, in pion-cloud models, from pions of high longitudinal momentum. The non-relativistic limit is defined precisely and the ratio of the binding energy to that of the mass of the lightest constituent is shown to govern the influence of relativistic effects. The exact relativistic formula for the form factor reduces to the familiar one of the three-dimensional Fourier transform of a square of a wave function for a very limited range of parameters. For masses that mimic the quark-di-quark model of the nucleon we find substantial relativistic corrections for any value of Q^2 . A schematic model of the lowest s-states of nuclei is used to find that relativistic effects decrease the form factor for light nuclei but increase the form factor for heavy nuclei. Furthermore, these states are strongly influenced by relativity.

26. D. Nicmorus (Karl-Franzens-Universitt Graz, Austria)
The Rainbow-ladder truncation of Dyson-Schwinger equations

The rainbow-ladder truncation of Dyson-Schwinger equations enables a simultaneous study of meson and nucleon properties from an effective quark-gluon interaction. In analogy to

sophisticated meson studies, herein I will present the calculation of nucleon and Delta-baryon masses in a Poincare-covariant quark-diquark model. A consistent setup for the dressed quark, quark-quark and quark-diquark interactions is used, where all the ingredients are solutions of their respective Dyson-Schwinger or Bethe-Salpeter equations in rainbow-ladder truncation. The rainbow-ladder results are identified with the hadron's quark core via estimating all the corrections that are expected beyond rainbow-ladder, and subsequently tuning the rainbow-ladder contribution such that the corrected result would describe the experimental data.

27. M.T. Pena (CFTP, Lisbon, Portugal):

Electromagnetic form factors of the Nucleon and the Delta in the Spectator formalism

The four electromagnetic form factors of the Delta baryon are predicted within the framework of the covariant Spectator formalism. Estimates of the charge and magnetic radii, not accessed experimentally, are presented. Comparison to other theoretical calculations and to recently available lattice-QCD data is provided.

The quark model underlying our calculations describes the nucleon form factor data, as well as the nucleon to delta electromagnetic transition. Both S and D states are included in the Delta wave function. The role of the lattice data for the nucleon to delta transition in constraining the model is discussed.

28. W. Polyzou (Iowa U., USA):

From field theory to the Poincaré invariant three-body problem

I show how one arrives at Poincaré invariant quantum mechanical models of the three-nucleon system by starting from a quantum field theory and suitably restricting the number of degrees of freedom. I discuss general properties of the resulting models and discuss recent applications.

29. E.P. Rogochaya (JINR, Dubna, Russia)

The covariant relativistic separable kernel approach

Modern approaches used for the description of few-body systems can be divided into two groups. The first one is the so-called relativistic quantum mechanics which differ by the way how the state vectors are constructed. The second group includes approaches based on the Bethe-Salpeter (BS) equation or its modifications, propagator dynamics. We work within this approach. The BS equation is the quantum field theory QFT equation describing two-particle bound systems. As for the most of the QFT equations there is no exact solution for it because the interaction kernel and the propagator in it are unknown quantities. Therefore there are many approaches for the BS equation (reductions) which allow to get a solution. However instead of the reduction of the equation its kernel can be presented in a separable form. In that case the initial integral equation is transformed into a system of linear homogeneous equations which can be solved easily. Parameters of the separable presentation are fitted by the description of phase shifts of elastic neutron-proton (np) scattering, deuteron characteristics etc. The constructed kernel can then be used in calculations of various reactions with the deuteron or scattered np states. The elastic (deep inelastic) electron-deuteron scattering, deuteron photo- and electrodisintegration and many other processes were calculated in this way. The presented report is devoted to a review of current status and future prospect of models based on a separable approximations.

30. R. Rosenfelder (PSI, Villigen, Switzerland):

Exact path integral representations for the T -matrix in nonrelativistic potential scattering

Here I describe recent path-integral representations of the T -matrix for non-relativistic scattering which offer new insights and possibilities for approximate and numerical evaluation. In this approach the functional integration is over velocities and the eikonal approximation is obtained when all velocity fluctuations are suppressed. Numerically this can be achieved by giving the particle a complex mass so that a Monte-Carlo evaluation of the velocity path integral can be performed for different values of the imaginary part (width) with a subsequent extrapolation to zero width. I will present some preliminary results and discuss possible extensions to many-body and relativistic physics.

31. V. Sauli (NPI, Rez near Prague, Czech Republic)

Solving the Bethe-Salpeter equation with an integral representation in Minkowski space

The issue of solving relativistic bound state problems via Minkowski space integral representation for Bethe Salpeter vertex function is discussed. Using integral representation techniques, the bound states solutions are presented in various quantum field models. These include renormalizable 3+1 scalar models with well defined vacua (i.e. the models with quartic and cubic interactions) and the quantum field models with fermionic degrees of freedom as well.

32. R. Schiavilla (JLAB, Newport News and ODU, Norfolk, USA)

Nuclear Electromagnetic Currents in chiEFT with Applications

Nuclear electromagnetic currents have recently been derived in chiral effective field theory (chiEFT) up to order $e Q$ (or N3LO), where Q generically denotes the low-momentum scale and e is the electric charge. The N3LO contributions consist of i) two-pion exchange terms at one loop, and ii) currents generated by minimal substitution in the contact interactions involving gradients of the nucleons' fields, as well as by non-minimal couplings. In order to determine some of the low-energy constants (LEC's) entering the contact currents, we have constructed a potential at order Q^2 (or N2LO) by fitting the np S- and P-wave phase shifts up to 100 MeV lab energies. We have also derived a simple expression for the N3LO magnetic moment (M1) operator consisting of two terms, one of which is determined, uniquely, by the contact and isospin-dependent two-pion-exchange parts of the N2LO potential. These M1 operators are used in calculations of static properties and low-energy radiative capture processes of few-body nuclei. The present talk discusses our approach and summarizes our results, comparing them to those obtained in the conventional (meson-exchange) framework as well as in chiEFT approaches, as implemented by other groups.

33. W. Schweiger (Graz Un., Austria):

A relativistic coupled-channel approach to the electromagnetic hadron structure

Point-form relativistic quantum mechanics is used to derive electromagnetic form factors of hadrons consisting of confined quarks. To this aim the elastic scattering of an electron by a confined constituent-quark system is treated as a relativistic two-channel problem which couples electron-multi-quark states with electron-multi-quark-photon states. With the approximation that the total velocity of the system is conserved at (electromagnetic) interaction vertices this simplifies to an eigenvalue problem for a Bakamjian-Thomas type

mass operator. After elimination of the electron-multi-quark-photon channel the electromagnetic current and form factor can be directly read off from the one-photon-exchange optical potential. An equivalence with the usual front-form expression, resulting from a spectator current in the $q^+ = 0$ reference frame, can then be established. The generalization of this multichannel approach to electroweak form factors for arbitrary bound few-body systems is quite obvious. By an appropriate extension of the Hilbert space this approach is also able to accommodate exchange-current effects.

34. A.V. Smirnov (Lebedev Physical Institute, Moscow, Russia)

Application of Nonperturbative Renormalization Scheme in Light-Front Dynamics to a Scalar Model

Recently we have developed, within the covariant formulation of light-front dynamics, a nonperturbative renormalization scheme based on the Fock decomposition of the state vector, with the subsequent Fock space truncation. The latter implies that a finite number of important Fock sectors (i.e. states with fixed number of particles) in the state vector are taken into account. At the same time no restrictions on the interaction coupling constant magnitude are imposed. In the present talk, this renormalization scheme is applied to a toy model of interacting massive scalar bosons B and b , with the initial "bare" interaction Lagrangian of the form $g_0 B^2(x)b(x)$. We formulate and explicitly solve eigenstate equations for the boson B state vector in different approximations, taking into account the mass and coupling constant renormalization. In the lowest order approximation the state vector contains only two Fock sectors: $|B\rangle$ (a single "bare" boson B) and $|Bb\rangle$ (two "bare" bosons B and b). In the next order approximation we add to the state vector the three-body sectors $|Bbb\rangle$ and $|B\bar{B}B\rangle$, where \bar{B} denotes anti-boson. For both approximations we find dependence of the light-front wave function of each Fock sector on particle momenta and establish relations between the "bare" (non-renormalized) and physical (renormalized) parameters. The wave functions are then used to calculate the electromagnetic form factor of the boson B . We analyze how the extension of Fock space affects the value of the form factor and study its dependence on the physical coupling constant magnitude. The results obtained within the nonperturbative approach are compared with those from perturbation theory. Verifying our general renormalization scheme in the framework of simple models allows to apply it, on the same physical grounds, to realistic cases, e. g. effective nucleon-meson interactions, QED and QCD, which are more complicated technically. In case of rapid convergence of Fock sector decompositions, the approach discussed may become an alternative to lattice calculations.

35. A. Stadler (Univ. of Evora and CFN, Univ. of Lisbon, Portugal):

Covariant spectator theory of np scattering

The Covariant Spectator Theory (CST) is a manifestly covariant framework for the description of few-hadron systems. It is based on relativistic quantum field theory, and can be viewed as a reorganization of the complete Bethe-Salpeter series. Its defining feature is that, in intermediate states, all but one particles are placed on their mass shells, which leads to a significant simplification of loop integrations in the calculation of scattering amplitudes or bound state vertex functions. The first reasonably realistic two-nucleon potentials in CST, based on one-boson exchange (OBE), were published in 1992. Since then, the CST potentials have been further improved, and in 2007 we concluded the development of two OBE models for np scattering that rival the best available nonrelativistic potentials in their ability to fit the data, while using a significantly smaller number of adjustable parameters. I will review the properties of these models and of their predecessors, and discuss some recent applications in the two- and three-nucleon systems.

36. N. Tsirova (Samara S. U., Samara, Russia):

Baryon structure in chiral effective field theory on the light front

We propose a new approach to treat baryon structure in terms of an effective chiral Lagrangian. The state vector of the baryon is defined on the light front plane and it is decomposed in the Fock components. An adequate Fock sector dependent renormalization scheme is applied. We present our first results of the calculation of baryon properties in a two-body Fock truncation.

37. A. Vairo (Phys. Dept., Technische Universität München, Garching, Germany)

Non-relativistic bound states: the long way back from the Bethe-Salpeter to the Schrodinger equation

I review, in a personal perspective, the path that has led us from the Bethe-Salpeter equation to the construction of effective field theories in order to describe non-relativistic bound states in QED and QCD.

38. H. Witala (Jagiellonian University, Krakow, Poland)

Relativity and the low energy A_y puzzle

We solved the three-nucleon Faddeev equation including some relativistic features. Those features are relativistic kinematics and boost effects. As dynamical input a relativistic nucleon-nucleon interactions exactly on-shell equivalent to the AV18 or CD Bonn nucleon-nucleon potentials have been used. The boost effects turns out to be significant for the elastic scattering cross section mostly at higher energies. They diminish the transition matrix elements at higher energies and lead, in spite of the increased relativistic phase-space factor as compared to the nonrelativistic one, to rather small effects in the cross section, mostly restricted to the backward angles. At energies below about 20 MeV boost lowers the maximum of A_y by about 3 % increasing slightly the discrepancy between theory and data.

Each exclusive breakup configuration is specified completely by momenta of the outgoing nucleons in the final state. Thus the breakup reaction provides a unique possibility to access the matrix elements of the breakup transition operator in a pointwise manner at specific values of relative 3N momenta. This is entirely different from the elastic scattering where, due to continuum momentum distribution of nucleons inside the deuteron a broad range of relative momenta values contributes to the elastic scattering transition matrix element. That particular selectivity of the breakup singles out this reaction as a tool to look for localized effects which when averaged are difficult to see in elastic scattering. At higher energies this selectivity of breakup allows to find the configurations with large relativistic effects. Some of them seem to be supported by the existing data. A characteristic pattern according to which relativity changes the higher energy exclusive breakup cross section should be testified by future complete measurements.