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ABSTRACT BOOK

PARALLEL SESSION B

Photoprouction of Mesons off Light Nuclei

B. Krusche

Department of Physics, University of Basel, Switzerland

The nuclear excitation scheme has been under intense investigation with meson photoproduction experiments during the last few years world wide. Currently, large efforts are under way at the CLAS experiment at Jlab, the ELSA accelerator in Bonn, and the MAMI accelerator in Mainz to investigate single and double polarization observables for different meson production reactions using longitudinally and transversely polarized targets and linearly and circularly polarized photon beams. These new data sets will provide stringent constraints for partial wave analyses of meson photoproduction off the proton. However, a full classification of the nucleon resonances includes also the iso-spin structure of their electromagnetic excitations which requires the measurement off the neutron as well as coherent photoproduction from light nuclei.

Photoproduction off mesons off nucleons bound in light nuclei, in particular in the deuteron, is so far the only practical method to investigate the electromagnetic excitation spectrum of the neutron. We have studied during the last few years in a series of experiments at the Bonn ELSA accelerator and the Mainz MAMI facility many different final states and investigated in detail systematic effects related to the 'nuclear' environment. The result is, that for many reaction channels reliable results for the elementary cross sections off free nucleons can be extracted.

The detector systems at both accelerators are electromagnetic calorimeters with almost 4p solid angle coverage (Crystal Barrel/TAPS at ELSA, Crystal Ball/TAPS at MAMI). They allow a detailed study of reactions which are not accessible at other facilities, in particular those which have only photons and neutrons in the final state. The obtained results cover e.g. $\pi^0 n$, $2\pi^0 n$, ηn, $\eta\pi^0$n, $\eta' n$ final states.

A very interesting and unexpected finding is a prominent structure in the excitation function of the $n(\gamma,\eta)n$ reaction. This reaction shows a narrow peak around W=1.7 GeV, which has no counter part in the $p(\gamma,\eta)p$ reaction, except perhaps a much less prominent little dip-like structure around the same energy. Fits of the observed width of the peak typically give results in the range from 20 - 50 MeV FHWM, however the experimental resolution is of the same order. This structure has been seen in the experiments at ELSA and MAMI, but also by the GRAAL experiment and at Tohoku-LNS. The statistical significance is beyond any doubts. Very recently, we have also observed it in quasi-free η-photoproduction off neutrons bound in ^{3}He nuclei, indicating that the nuclear environment is not important and the structure is really a feature of the the elementary $n(\gamma,\eta)n$ reaction. It's nature is so far not understood. We will discuss different scenarios.

Currently, measurements off polarization observables for the quasi-free $n(\gamma,\eta)n$ reaction in this energy range are under way at ELSA (observable E from longitudinally polarized target, circularly polarized photon beam) and MAMI (observables T, F from transversely polarized target and circularly polarized beam). First preliminary results will be discussed.

Coupled channel analysis of the $N^*(1520)(3/2^-)$ and $N^*(1700)(3/2^-)$ with ρN (s-wave), πN (d-wave) and $\pi\Delta$ (s-wave and d-wave) channels.

E. J. Garzon, J.J. Xie and E. Oset

Departamento de Física Teórica and IFIC, Centro Mixto Universidad de Valencia-CSIC, Institutos de Investigación de Paterna, Aptdo. 22085, 46071 Valencia, Spain

We carry out calculations of the coupled channels ρN (s-wave), πN (d-wave) and $\pi\Delta$ (s-wave and d-wave) using the lagrangians of the local hidden gauge approach, which coincide with the chiral Lagrangians for pseudoscalar-baryon and extrapolate this interaction to the case of vector-baryon. Then we used a coupled channel unitary approach in the line of the chiral unitary approach when chiral Lagrangians are used. We show the relevance of the coupled channels since the ρN channel helps push up the $N^*(1520)$ resonance, which with only $\pi\Delta$ appears at too low energies [1]. Similarly, the $N^*(1700)$ appears mostly as a ρN state, but the other channels also have an important influence in its mass and properties with respect to what one gets from ρN alone [2]. The model allows us to calculate the decays widths of the two resonances into all these channels and we compare the results with existing experimental data. With only free parameter, a subtraction constant in the loops which we find of natural size, we can obtain reasonable numbers for the eight decay partial decay widths.

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Chiral dynamics in the nonet SS and PP two-point correlation functions, semi-local duality and scalar spectroscopy

Zhi-Hui Guo [a,b], J. A. Oller[b] and J. Ruiz de Elvira[c]

[a] Department of Physics, Hebei Normal University, 050024 Shijiazhuang, P. R. China.
[b] Departamento de Física, Universidad de Murcia, E-30071 Murcia, Spain.
[c] Departamento de Física Teórica II, Universidad Complutense de Madrid, E-28040 Madrid, Spain.

We complete the one-loop calculation of meson-meson scattering, the scalar and pseudoscalar form factors in the framework of $U(3)$ chiral perturbation theory with the explicit tree level exchanges of resonances. The spectral functions of the nonet scalar-scalar (SS) and pseudoscalar-pseudoscalar (PP) correlators are constructed by using the corresponding form factors. After fitting the unknown parameters to the scatting data, we discuss the resonance content of the resulting scattering amplitudes. We also study the second Weinberg-like spectral function sum rules in the $SS - SS$ and $SS - PP$ sectors as well as semi-local duality from scattering. The former relate the scalar and pseudoscalar spectra between themselves while the latter mainly connects the scalar spectrum with the vector one. Finally we investigate these items as a function of N_C for $N_C > 3$. All these results pose strong constraints on the scalar dynamics and spectroscopy which are discussed. They are successfully fulfilled by our meson-meson scattering amplitudes and spectral functions.

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Electroweak Hadron Structure in Point Form Dynamics

María Gómez Rocha [a)], Wolfgang Schweiger [b)].

[a,b)] Institute of Physics, University of Graz. Universitaetsplatz 5, A-8010 Graz, Austria.

We present a formalism that uses the point form of relativistic Hamiltonian dynamics [1] to describe the electroweak structure of heavy-light mesons within constituent quark models. Analytic expressions for both, electromagnetic and weak form factors, are given for mesonic systems of arbitrary constituent flavors. As a particular case we study the heavy quark limit (i.e. $m_Q \to \infty$) and check that the predictions of heavy quark symmetry [2] are satisfied. In addition, cluster separability properties of our approach and its relation to front form calculation will be discussed [3].

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Radiative decay of heavy-light mesons in a relativistic potential model

Koichi Seo [a)], Takayuki Matsuki [b)]

[a)] Gifu City Women's College, Gifu, Japan
[b)] Tokyo Kasei University, Tokyo, Japan

In a relativistic potential model which has succeeded in reproducing the mass spectrum of the heavy-light mesons (charmed or bottom mesons), we have computed the radiative decay widths of the excited heavy-light mesons. In order to take into account the recoil effect of the mesons emitting a photon, we related the wave function of the heavy-light meson in the moving frame to the one in the rest frame (see Ref. [1]). As for the wave function we included the first order correction in $1/m_Q$ expansion. We have evaluated the matrix element of the electro-magnetic current in the Breit frame where the initial and final heavy-light mesons are moving with the velocity V and $-V$ along the z-axis, respectively. In the heavy limit of the quark masses compared to the photon momentum, our formulas reduce to the non-relativistic expressions for the $E1$ or $M1$ transitions. We take small values (86MeV/c^2, 168MeV/c^2) for up, down and strange quark masses, and they are not larger than the photon momentum under consideration. We have obtained the values 11keV and 0.56keV for the radiative decay widths of D^{*0} and D^{*+}, respectively.

Bardeen et al. (Ref. [2]) have assumed the magnetic moments of the constituent quarks to be $e_q/(2m_q^*)$ and $e_{\bar{Q}}/(2m_Q^*)$, where the quark mass with an asterisk stands for the constituent quark mass (not the current quark mass). In the case of $D^{*0}(D^{*+})$, two magnetic moments contribute with the same(opposite) sign. This is the reason for the smallness of the width of the charged D^* meson according to Bardeen et al. The cancellation is much prominent for D_s^{*+} because of the heaviness of the strange quark mass in their case. Due to our relativistic formula, this is not the case, and we have obtained the value 0.72keV for the radiative decay width of D_s^{*+}.

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Recent results on hadron production from ISR and two-photon processes at BABAR

Denis Bernard

On behalf of the BaBar Collaboration.

LLR, CNRS/IN2P3, Ecole Polytechnique, 91218 Palaiseau France

We report on recent results of a variety of BaBar measurements of hadron production involving e^+e^- initial state radiation and two photon fusion reactions. These include the precision measurement of the cross section of several multihadron final states with the initial-state radiation (ISR) method and its implication for the hadronic vacuum polarization correction to $g-2$. We also search for new states and study known states with ISR and $\gamma\gamma$ production.

Precise dispersive determination of the $f_0(600)$ and $f_0(980)$ resonances

J. R. Peláez [a)], R. García-Martín[a], R. Kamiński[b] and J. Ruiz de Elvira[a]

[a)] Dept. de Física Teórica II, Universidad Complutense de Madrid, 28040 Madrid, Spain
[b)] Dept. of Theoretical Physics Henryk Niewodniczański Institute of Nuclear Physics, Polish Academy of Sciences, 31-342, Kraków, Poland.

We review our recent dispersive and model independent determination of the lightest two scalars, in terms of poles and residues [1] – or mass, width and coupling – by means of once and twice subtracted Roy equations, using as input constrained fits to data [2], including the most recent ones from Kl4 decays.

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The nature of $X(3900)$ and recognition of open charm effects

Qian Wang [a)], Gang Li [b)], Xiao-Hai Liu [a)], Qiang Zhao [a,c)]

[a)] Institute of High Energy Physics, Chinese Academy of Sciences, Beijing 100049, P.R. China
[b)] Department of Physics, Qufu Normal University, Qufu, 273165, P.R. China
[c)] Theoretical Physics Center for Science Facilities, CAS, Beijing 100049, P.R. China

We identify open charm effects in a direct production process $e^+e^- \to J/\psi\pi^0$ [1]. A unique feature of this process is that $D\bar{D}^* + c.c.$ is located at a relative isolated energy region, i.e. 3.876 GeV, which is far away from the well-established charmonia $\psi(3770)$ and $\psi(4040)$. Therefore, the cross section line-shape of this reaction provides an opportunity for singling out the open charm effects. A model-independent cusp effect between the threshold of $D^0\bar{D}^{*0} + c.c.$ and $D^+D^{*-} + c.c.$ is predicted. This study can also help us to understand the $X(3900)$ enhancement recently observed by Belle Collaboration in $e^+e^- \to D\bar{D} + c.c.$ We also show that the open charm effects play a crucial role for our understanding of the long-standing "$\rho\pi$ puzzle" [2].

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Radiative decay of the $X(3872)$ into $J/\Psi\gamma$ from the perspective of a $\bar{D}D^* + c.c.$

F. Aceti [a)], R. Molina [a)], E. Oset [a)]

[a)] Departamento de Física Teórica and IFIC, Centro Mixto Universidad de Valencia-CSIC, Institutos de Investigación de Paterna, Aptdo. 22085, 46071 Valencia, Spain

From a picture of the $X(3872)$ where the resonance is a bound state of $\bar{D}D^* + c.c.$, we evaluate the decay width into the $J/\Psi\gamma$ channel, which is sensitive to the internal structure of this state.

For this purpose we evaluate the loops on which the $X(3872)$ decays into its components, and the J/Ψ and the photon are radiated from these components. We use the local hidden gauge approach [1] extrapolated to $SU(4)$ with a particular $SU(4)$ breaking [2]. The radiative decay involves anomalous couplings and we obtain acceptable values which are compared to experiments and results of other calculations.

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Exclusive $c \to s, d$ semileptonic decays of ground-state spin-1/2 doubly charmed baryons

C. Albertus-Torres [a)], E. Hernández [a)], J. Nieves [b)]

[a)] Departamento de Física Fundamental e IUFFyM, Universidad de Salamanca. E-37008 Spain
[b)] Instituto de Física Corpuscular (IFIC), Centro Mixto CSIC-Universidad de Valencia, Institutos de Investigación de Paterna, Aptd. 22085, E-46071 Valencia, Spain

We have evaluated [1] exclusive semileptonic decays of ground state spin-1/2 doubly heavy charmed baryons driven by a $c \to s, d$ transition at the quark level. To our knowledge, this is the first systematic study of these exclusive decay channels. We have also derived for the first time, heavy quark spin symmetry (HQSS) relations among the relevant form factors that govern these decays near zero recoil. Our results for the form factors are consistent with those HQSS constraints with moderate deviations of about 10% induced by the finite charm quark mass. These deviations are larger than those found in $b \to c$ semileptonic transitions of Xi_{bb} and Xi_{bc} baryons [2]. We have checked that these discrepancies tend to disappear at arbitrarially large values for the charm quark mass. Uncertainties in the model calculations are also discussed.

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Resonances of the Systems $\pi^-\eta$ and $\pi^-\eta'$ in the Reactions $\pi^- p \to \pi^-\eta p_{\text{slow}}$ and $\pi^- p \to \pi^-\eta' p_{\text{slow}}$ at COMPASS

Tobias Schlüter, Wolfgang Dünnweber, Martin Faessler for the COMPASS Collaboration

Department für Physik, LMU München, 85748 Garching, Germany

We describe partial-wave analyses of the systems $\pi^-\eta$ and $\pi^-\eta'$ produced in interactions of a π^- beam (190 GeV/c) with a liquid hydrogen target. The data were recorded during the 2008 COMPASS run, where a slow recoiling proton ($|t| > 0.1\,\text{GeV}^2$) was required by the trigger. We compare analyses of the $\pi^-\eta$ and $\pi^-\eta'$ data. Significant contributions can be attributed to the resonances $a_2(1320)$, observed in the D_+-wave, and $a_4(2040)$, observed in the G_+-wave. We investigate the influence of non-resonant production mechanisms. Finally, we discuss the possibility of a resonant interpretation fo the P_+-wave whose neutral isospin partner would have the exotic quantum numbers $J^{PC} = 1^{-+}$.

Nucleon resonance electrocouplings in the non-perturbative regime

Philip Cole [a], Victor Mokeev [b] [c], Ralf Gothe [d], Volker Burkert [b],
and the CLAS Collaboration

[a] Idaho State University; Department of Physics; Pocatello, Idaho 83209-8106; USA
[b] Jefferson Lab; 12000 Jefferson Ave.; Newport News, VA 23606; USA
[c] Skobeltsyn Nuclear Physics Institute; Moscow State University, 119899; Moscow, Russia
[d] University of South Carolina; Department of Physics; Columbia, South Carolina 29208; USA

Studies of nucleon resonance electrocouplings $\gamma_v NN^*$ from data on exclusive meson electroproduction off nucleons represent an important part in the N* Program with the CLAS detector [1]. These data afford us the opportunity to explore the nature of the non-perturbative strong interaction, which is responsible for the formation of the nucleon and, in turn, the excited states of the nucleon [2].

We have extended the data on differential cross sections to $Q^2 = 6.0$ GeV^2 for the Nπ electroproduction channel. These CLAS measurements of the longitudinally polarized beam/beam-target asymmetries have allowed for extracting the electrocouplings of the $P_{11}(1440)$, $D_{13}(1520)$, and $S_{11}(1535)$ resonances, which were determined from analyses within the framework of two conceptually different reaction models [3]. Electroproduction data were also collected on the two-charged-pion channel off protons, which provides nine independent differential $\pi^+\pi^-p$ cross sections at Q^2 up to 1.5 GeV^2. Using a phenomenological approach [4], the $P_{11}(1440)$ and $D_{13}(1520)$ electrocouplings were determined from the $\pi^+\pi^-p$ electroproduction data. The results are consistent with the results of the independent Nπ electroproduction analyses. Electrocouplings of the $S_{31}(1620)$, $S_{11}(1650)$, $D_{33}(1700)$, and $P_{13}(1720)$ states have also become available from this channel [5].

These results have revealed that there exist two major contributions to $\gamma_v NN^*$ electrocouplings: a) an internal quark core, and b) an external meson-baryon cloud. Recent theoretical developments using the Dyson-Schwinger Equations of QCD for the interpretations of $\gamma_v NN^*$ electrocouplings provide guidelines to search for the manifestation of dynamical masses of dressed quarks. Lattice QCD is making progress toward a $\gamma_v NN^*$ electrocoupling description from the QCD Lagrangian. The new data will be discussed in light of these new developments. And further, we will present an extension of the N* Program using the CLAS12 detector, which will take place after completion of the 12 GeV upgrade to JLab.

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Decaying Hadrons Within Constituent-Quark Models

Wolfgang Schweiger and Regina Kleinhappel

Physics Institute, University of Graz, Austria

When calculating hadron spectra within pure constituent-quark models hadron excitations come out as stable bound states and not as resonances with a finite life time. A more realistic description of hadron spectra can be achieved by including explicit mesonic degrees of freedom, which couple directly to the constituent quarks. We will present a coupled-channel formalism that describes such hybrid systems in a relativistically invariant way and allows for the decay of excited hadrons. The formalism is based on the point-form of relativistic Hamiltonian dynamics. If one assumes an instantaneous confining force between the quarks it can be formally shown that the mass-eigenvalue problem for such a system with dynamical quarks and mesons reduces to a hadronic eigenvalue problem in which the eigenstates of the pure confinement potential (bare hadrons) are coupled via meson loops. The only point where the quark substructure enters are form factors at the meson-(bare) hadron vertices. The physical picture that emerges resembles the kind of hadronic resonance model that has been developed by Sato and Lee and is now heavily used at the Excited Baryon Analysis Center (EBAC) to fix N^* properties. Our approach, however, is in a certain sense inverse to the one of Sato and Lee. Whereas they want to undress physical resonances to end up with bare quantities, we rather want to dress the bound-states resulting from a pure constituent quark model to end up with quantities that can be directly compared with experiment. The way how our procedure works will be exemplified by means of a simple toy model.

Sea content of the ground-state octet baryons

C. S. An [1] and B. Saghai [2]

1) Theoretical Center for Science Facilities, CAS, P. O. Box 918-4, Beijing 100049, China
2) Institut de Recherche sur les lois Fondamentales de l'Univers, DSM/Irfu, CEA/Saclay, F-91191 Gif-sur-Yvette, France

We will present our recent results on the sea quark components in the ground-state octet baryons [1], employing a chiral constituent quark model, extended to include five-quark components [2, 3].

All possible five-quark configurations with different flavor, spin, color and orbital states, which may exist in the baryons, are considered.

An operator of $^3P_0$ version is used to calculate the couplings between three- and five-quark components in the baryons. We use the flavor asymmetry data [4] for the proton $\bar{d} - \bar{u} = 0.118 \pm 0.012$ as input value, and predict the $\bar{s}$ content in the proton, as well as all of the flavor contents in the other ground-state of the octet baryons.

Our numerical results on the sea quark components show that the probabilities of the $s\bar{s}$ content in all of the investigated baryons ($N,\ \Lambda,\ \Sigma,\ \Xi$), turn out to be around $6.0\% \pm 0.3\%$, while the probabilities for the light $\bar{q}q$ ($q \equiv u,\ d$) components come out in the range 25% to 31%.

Comparisons with findings by other autors [5, 6, 7, 8] will also be discussed.

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Relativistic Quark-Model Spectroscopy of Light and Heavy Baryons

Joseph P. Day and W. Plessas

Institute of Theoretical Physics, University of Graz, A-8010 Graz, Austria

We report results from a study of light- and heavy-baryon spectra within a relativistic constituent-quark model that relies on a universal dynamics for baryons of all flavor contents, from the nucleons up to Ω_{bbb}. The (linear) confinement is taken according to the QCD string tension and the (flavor-dependent) hyperfine interaction is derived from an effective Lagrangian resulting from chiral-symmetry breaking. In general, the spectra are reproduced in good agreement with known phenomenological values for ground and excited states. In particular, we point to open questions with respect to the lesser known excitation spectra of heavy-flavor baryons, which is an issue for future experiments.

A first prediction of the electromagnetic rare decays $\eta' \to \pi^0\gamma\gamma$ and $\eta' \to \eta\gamma\gamma$

Rafel Escribano [a], Renata Jora [b]

[a] Departament de Física, Universitat Autònoma de Barcelona, 08193 Bellaterra, Spain
[b] National Institute of Physics and Nuclear Engineering, PO Box MG-6, Bucharest-Magurele, Romania

The invariant mass spectra and the branching ratio of the electromagnetic rare decays $\eta \to \pi^0\gamma\gamma$ [1]–[7] and $\eta' \to (\pi^0, \eta)\gamma\gamma$ [8] are analysed in terms of scalar and vector meson exchange contributions [9, 10] using the frameworks of the linear sigma model and vector meson dominance, respectively. The measured $\eta \to \pi^0\gamma\gamma$ process serves as a test of our approach while the non yet measured $\eta' \to (\pi^0, \eta)\gamma\gamma$ reactions are predicted for the first time. Our prediction for the $\eta \to \pi^0\gamma\gamma$ decay agrees with recent experimental reported values [6, 7], thus supporting the validity of our framework. Therefore, our predictions for the $\eta' \to \pi^0\gamma\gamma$ and $\eta' \to \eta\gamma\gamma$ decays should be taken as a first indication of the possible shape of the invariant mass spectra and the values of the branching ratios. We hope these predictions to be interesting and useful for the experimental collaborations such as CLEO, KLOE-2 [11], Crystal Ball, Crystal Barrel, WASA, and BES-III where these processes are expected to be measured in the next future.

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Hadron Physics at KLOE and KLOE-2

Jaroslaw Zdebik [For the KLOE-2 Collaboration]

Jagiellonian University, Krakow, Poland

The KLOE experiment has collected 2.5 fb^{-1} at the peak of the ϕ resonance at the e^+e^- collider DAΦNE in Frascati. A new beam crossing scheme, allowing for a reduced beam size and increased luminosity, is operating at DAΦNE. The upgraded KLOE-2 detector is successfully rolled in inside this new interaction region and is ready to acquire collision data.

Pseudoscalar production at the ϕ-factory associated to internal conversion of the photon into a lepton pair allows the measurement of the form factor $\text{F}(q_1^2 = M_\phi^2, q_2^2 > 0)$ of pseudoscalar mesons in the kinematical region of interest for the VMD model. The only existing data on $\phi \to \eta e^+e^-$ are based on 213 events. At KLOE, with a sample of 1.5 fb^{-1}, a detailed study of this decay has been performed using the $\eta \to \pi^+\pi^-\pi^0$ final state. Simple analysis cuts provide about 14,000 signal events with very small residual background contamination. The e^+e^- invariant mass distribution has been used to set an upper limit on the process $\phi \to \eta U$, where U is a vector gauge boson, mediating dark forces. The resulting exclusion plot covers the mass range $5 < M_U < 470$ MeV, setting an upper limit on the ratio between the U boson coupling and the fine structure constants of $\alpha'/\alpha \leq 2 \times 10^{-5}$ at 90% C.L. for $50 < M_U < 420$ MeV [1].

The γ-γ couplings and partial widths of mesons provide information about their structure and can be measured in the $e^+e^- \to e^+e^-\gamma^*\gamma^* \to e^+e^-X$ processes. In particular, the study of $\gamma^*\gamma^* \to \eta$ and $\gamma^*\gamma^* \to \pi^0\pi^0$ performed at KLOE will be discussed [2]. The data sample consists of an integrated luminosity of 240 pb^{-1} of data taken at the center of mass energy $\sqrt{s} = 1$ GeV - where backgrounds from phi decays are suppressed - without tagging of the e^+e^- in the final state. The preliminary measurement of the cross section for the reaction $\gamma^*\gamma^* \to \eta$ in the two decay channels $\eta \to \pi^+\pi^-\pi^0$ and $\eta \to 3\pi^0$, with independent systematic uncertainties, will be presented. The $e^+e^- \to e^+e^-\pi^0\pi^0$ cross section is studied in the mass region where the contribution of the σ scalar meson is expected. These studies prove the feasibility of γ-γ measurements at DAΦNE in view of the forthcoming data taking campaign, with the KLOE-2 detector equipped with e^+e^- taggers at small angle.

We have also performed the third independent measurement of the $e^+e^- \to \pi^+\pi^-(\gamma)$ cross section below 1 GeV, which is particularly important to test the Standard Model calculation for the (g-2) of the muon, where a long standing 3 σ discrepancy is observed. The previous measurements, with the photon emitted at small and large angle, respectively, were normalized to the DAΦNE luminosity using large angle Bhabha scattering events. In the new analysis the pion form factor is obtained directly from the $\pi^+\pi^-\gamma(\gamma)/\mu^+\mu^-\gamma(\gamma)$ ratio. In the overlap region there is a very good agreement among different KLOE measurements.

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Meson spectroscopy with unitary coupled-channels model for heavy-meson decay into three mesons

Satoshi Nakamura

Excited Baryon Analysis Center (EBAC), Thomas Jefferson National Accelerator Facility
Newport News, VA 23606, USA

I present a unitary coupled-channels model for investigating the decays of heavy mesons and excited meson states into three light pseudoscalar mesons [1]. The model accounts for the three-mesons final state interactions in the decay processes, as required by both the three-body and two-body unitarity conditions. Previous analyses of heavy-meson decays into three mesons have been mostly based on the so-called isobar model, in which two of the three mesons form an excited state, and the third meson is treated as a spectator. Obviously, three-body unitarity is missing. For example, such analyses have been done to search for exotic states in three-mesons production data from $\pi(\gamma)N \to M^*N \to \pi\pi\pi N$ where the intermediate mesons M^* could be exotic. An essential ingredient for respecting the three-body unitarity is the so-called Z-diagrams in which one of two particles from an isobar decay interacts with the third spectator to form another isobar. It is interesting to study how important corrections due to the Z-diagrams are for extracting excited meson properties. We apply our coupled-channels model to the three-pions decays of $a(1260)$, $\pi(1670)$, $\pi(2100)$, and show that the Z-diagram mechanisms can contribute to the calculated Dalitz plot distributions by as much as 30% in magnitudes in the regions where $f_0(600)$, $\rho(770)$ and $f_2(1270)$ dominate the distributions. Also, by fitting the same Dalitz plot distributions with the unitary model and the isobar model, we demonstrate that couplings for M^* decay vertices can be rather different between the two models. These couplings are important information to distinguish a hybrid state from an ordinary $q\bar{q}$ excitation. Our results indicate that the commonly used isobar-model analysis need to be extended to account for the final state interactions required by the three-body unitarity to reanalyze the three-mesons decays of heavy mesons, thereby exploring hybrid and/or exotic mesons.

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Charmed and strange baryon resonances with heavy-quark spin symmetry

O. Romanets [a], L. Tolos [b), a], C. García-Recio[c], J. Nieves[d], L. L. Salcedo[c],
R. G. E. Timmermans[a]

[a] KVI, University of Groningen, Zernikelaan 25, 9747AA Groningen, The Netherlands
[b] Institut de Ciències de l'Espai (IEEC/CSIC), Campus Universitat Autònoma de Barcelona, Facultat de Ciències, Torre C5, E-08193 Bellaterra, Spain
[c] Departamento de Física Atómica, Molecular y Nuclear, and Instituto Carlos I de Física Teórica y Computacional, Universidad de Granada, E-18071 Granada, Spain
[d] Instituto de Física Corpuscular (centro mixto CSIC-UV), Institutos de Investigación de Paterna, Aptdo. 22085, 46071, Valencia, Spain

We study charmed and strange baryon resonances that are generated dynamically by a unitary baryon-meson coupled-channel model which incorporates heavy-quark spin symmetry. This is accomplished by extending the SU(3) Weinberg-Tomozawa chiral Lagrangian to SU(8) spin-flavor symmetry [1, 2] plus a suitable symmetry breaking. The model produces resonances with negative parity from s-wave interaction of pseudoscalar and vector mesons with $1/2^+$ and $3/2^+$ baryons. Resonances in all the isospin, spin, and strange sectors with one, two, and three charm units are studied. Our results are compared with experimental data from several facilities, such as the CLEO, Belle or BaBar Collaborations, as well as with other theoretical models. Some of our dynamically generated states can be readily assigned to resonances found experimentally, while others do not have a straightforward identification and require the compilation of more data and also a refinement of the model. In particular, we identify the $\Xi_c(2790)$ and $\Xi_c(2815)$ resonances as possible candidates for a heavy-quark spin symmetry doublet.

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Enhanced non-quark-antiquark and non-glueball N_c behavior of light scalar mesons.

G. Ríos [a,b], J. Nebreda [b], J. R. Peláez [b]

[a] Departamento de Física, Universidad de Murcia, E-30071 Murcia, Spain
[b] Departamento de Física Teórica II, Universidad Complutense de Madrid, 28040 Madrid, Spain

We show in [1] that the latest and very precise dispersive $\pi\pi$ and πK data analyses [2, 3] require a large and very unnatural fine-tuning of the $1/N_c$ expansion at $N_c = 3$ if the $f_0(600)$ and $K(800)$ light scalar mesons are to be considered predominantly $\bar{q}q$ states, which is not needed for light vector mesons. For this, in the lines of [4], we use scattering observables whose $1/N_c$ corrections are suppressed further than one power of $1/N_c$ for $\bar{q}q$ or glueball states, thus enhancing contributions of other nature. This is achieved without using unitarized ChPT, but if it is used we can also show that it is not just that the coefficients of the $1/N_c$ expansion are unnatural, but that the expansion itself does not even follow the expected $1/N_c$ scaling of a glueball or a $\bar{q}q$ meson.

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A theory of baryon resonances at large N_c

Dmitri Diakonov [a,b], Victor Petrov [a] and Alexey A. Vladimirov [c]

[a] Petersburg Nuclear Physics Institute, Gatchina 188300, St. Petersburg, Russia
[b] St. Petersburg Academic University, 194021, St. Petersburg, Russia
[c] Institut für Theoretische Physik, Ruhr-Universität Bochum, D-44780 Bochum, Germany

At large number of colours, N_c quarks in baryons are in a mean field of definite space and flavour symmetry. We write down the general Lorentz and flavour structure of the mean field, and derive the Dirac equation for quarks in that field. The resulting baryon resonances exhibit an hierarchy of scales: The crude mass is $\mathcal{O}(N_c)$, the intrinsic quark excitations are $\mathcal{O}(1)$, and each intrinsic quark state entails a finite band of collective excitations that are split as $\mathcal{O}(1/N_c)$. We build a new theory of those collective excitations, where full dynamics is represented by only a few constants. In a limiting (but unrealistic) case when the mean field is spherically-and flavour-symmetric, our classification of resonances reduces to the $SU(6)$ classification of the old non-relativistic quark model. Although in the real world N_c is only three, we obtain a good accordance with the observed resonance spectrum up to 2 GeV [1].

Charmed and bottom baryons also fit nicely in this large-N_c classification scheme. New exotic $cuud\bar{s}$ and $cudd\bar{s}$ pentaquarks are predicted that are probably stable under strong decays [2].

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Prospects on spectroscopy at SuperB

Elisa Manoni [on behalf of the SuperB collaboration].

I.N.F.N. Sezione di Perugia, via A. Pascoli, 06123 Perugia (Italy)

In the past few years, the B Factories and the Tevatron have provided evidence for states that do not admit the conventional mesonic interpretation and that instead could be made of a larger number of constituents. While this possibility has been considered since the beginning of the quark model, the actual identification of such states would represent a major revolution in our understanding of elementary particles. It would also imply the existence of a large number of additional states that have not yet been observed. This talk reviews the steps needed towards the understanding of this picture and discusses the role of the future SuperB project in it.

Exotic gifts of nature

T.F. Caramés [a], A. Valcarce [a], J. Vijande [b]

[a] Dpto. de Física Fundamental, University of Salamanca, Salamanca, Spain
[b] Dpto. de Física Atómica, Molecular y Nuclear, University of Valencia an d IFIC, Valencia, Spain

We perform a systematic analysis of doubly charmed exotic states as meson-meson molecules [1]. We compare our results with those previously obtained within the hyperspherical harmonic formalism [2]. Several relevant conclusions have to be emphasized. First of all, the conclusive existence of a stable isoscalar doubly charmed meson with quantum numbers $(I)J^P = (0)1^+$. This state could be considered as a gift of nature, because there is compelling evidence that such large mass exotic states could be efficiently produced via gluon-gluon fusion at LHC [3] with unique signatures in the detectors and also at RHIC [4]. Second, we revise hadron-hadron scattering calculations within the quark model showing that they have to be done in a complete Hilbert space. The effects coming from the inclusion of the relevant vectors of the Hilbert space could be hidden in the parameters of the model, but this would make that the calculations were not predictive because the parameters have to be different for each quantum number sector. Such a procedure would drive to spurious conclusions. Third, the discovery of these states will undoubtedly give an important push in our understanding of the meson spectroscopy above the threshold for the production of two mesons. Finally, our study highlights the difficulty to generate deeply bound states within the quark model framework when dealing with the threshold and the many-quark system on the same footing. An experimental effort in this direction will confirm or rule out the theoretical expectations. If the scenario presented here turns out to be correct, it will open a new interesting spectroscopic era.

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The mixing of $D_{s1}(2460)$ and $D_{s1}(2536)$

Xiao-Gang Wu [a)], Qiang Zhao [a,b)]

[a)] Institute of High Energy Physics, Chinese Academy of Sciences, Beijing 100049, P.R. China
[b)] Theoretical Physics Center for Science Facilities, CAS, Beijing 100049, P.R. China

We report our recent study [1] of the mixing mechanism of axial-vectors $D_{s1}(2460)$ and $D_{s1}(2536)$ via intermediate hadron loops, e.g. D^*K. By constructing the two-state mixing propagator matrix that respects the unitarity constraint and calculating the vertex coupling form factors in a chiral quark model, we can extract the masses, widths and mixing angles of the physical states. Two poles can be identified in the propagator matrix. One is at $\sqrt{s} = 2454.5$ MeV corresponding to $D_{s1}(2460)$ and the other at $\sqrt{s} = (2544.9 - 1.0i)$ MeV corresponding to $D_{s1}(2536)$. For $D_{s1}(2460)$, a large mixing angle $\theta = 47.5^\circ$ between $^3P_1$ and $^1P_1$ is obtained. It is driven by the real part of the mixing matrix element and corresponds to $\theta' = 12.3^\circ$ between the $j = 1/2$ and $j = 3/2$ state mixing in the heavy quark limit. For $D_{s1}(2536)$, a mixing angle $\theta = 39.7^\circ$ which corresponds to $\theta' = 4.4^\circ$ in the heavy quark limit is found. An additional phase angle $\phi = -6.9^\circ \sim 6.9^\circ$ is needed at the pole mass of $D_{s1}(2536)$ since the mixing matrix elements are complex numbers. Both the real and imaginary part are found important for the large mixing angle. We show that the new experimental data from BaBar [2] provide a strong constraint on the mixing angle at the mass of $D_{s1}(2536)$, from which two values can be extracted, i.e. $\theta_1 = 32.1^\circ$ or $\theta_2 = 38.4^\circ$. Our study agrees well with the latter one. Detailed analysis of the mass shift procedure due to the coupled channel effects is also presented.

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The $D_{s_1}(2460)$ as a molecular state in a constituent quark model

D. R. Entem [a,b], P. García-Ortega [a,b], F. Fernández [a,b].

[a] Grupo de Física Nuclear, Universidad de Salamanca
[b] Instituto Universitario de Física Fundamental y Matemáticas (IUFFyM), Universidad de Salamanca

The D_s P-wave mesons have been revealed as an excellent system to test low momentum QCD. From a theoretical point of view, the combination of a heavy and a light quark allows to make predictions based on the assumption of heavy quark symmetry (HQS). More relevant are, however, the unexpected properties shown by the experiments. In particular the low masses of the $D^*_{s0}(2317)$ and $D_{s_1}(2460)$ states [1, 2] represents a challenge for phenomenological models.

Recently new data related with the $D_{s_1}(2536)$ meson has appeared. BaBar collaboration has performed a high precision measurement of the $D_{s_1}(2536)$ decay width obtaining a value of $1.03 \pm 0.05 \pm 0.12\, MeV$ [3]. The decays of this state into D^*K have been study in a recent work [4] in the framework of a constituent quark model in which $c\bar{s}$ components were coupled phenomenologically to tetraquark components. Also some weak decays have been successfully described recently [5] within the same model. All the observables are consistent with a $c\bar{s}$ state in a dominant $j_q = 3/2^+$ state in the heavy quark basis.

In the present work we couple the $c\bar{s}$ 1^+ components with D^*K, $D^*_s\eta$, $D_s\omega$ and DK^* molecular components microscopically with the same $^3P_0$ model used to study strong decays. We obtain a state below the D^*K threshold explaining the low mass of the $D_{s_1}(2460)$. A state above threshold is also found which could be identified with the $D_{s_1}(2536)$. This is state gets dressed by the two meson states but its $c\bar{s}$ component is almost a pure $j_q = 3/2^+$ state consistent with the data.

In the 0^+ sector we perform a similar calculation coupling $c\bar{s}$ components with DK molecular components. In this case no molecular bound state is found, so other explanation, as the contribution of gluon loop diagrams [6], are necessary to understand this state.

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On the role of one pion exchange and heavy quark spin symmetry in heavy meson molecules

J.M. Nieves, M. Pavón Valderrama

Instituto de Física Corpuscular (IFIC), Centro Mixto CSIC-Universidad de Valencia, Institutos de Investigación de Paterna, Aptd. 22085, E-46071 Valencia, Spain

In this contribution we want to discuss the role of the one pion exchange potential and heavy quark symmetry in heavy meson molecules such as the $X(3872)$ [1] or the recently discovered $Z_b(10610)$ and $Z_b(10650)$ [2]. By using techniques developed in atomic physics for handling power-law singular potentials [3, 4], which have been also successfully employed in nuclear physics [5], we determine the range of center-of-mass momenta for which the one pion exchange potential is perturbative [6]. In this momentum range, the one pion exchange potential can be considered a subleading order correction, leaving at lowest order a very simple effective field theory consisting only on contact-range interactions (basically X-EFT [7] in the case of the charm sector). In this regard, non-perturbative one pion exchange is only required in the bottom isoscalar sector, a case for which the resulting effective field theory has been analyzed at lowest order for $\mathrm{B}\bar{\mathrm{B}}^*/\mathrm{B}^*\bar{\mathrm{B}}$ molecules in Ref. [8]. We also explore the consequences of heavy quark spin symmetry within the previous effective field theory approaches in different scenarios [9].

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